ANNUAL REPORT 2018

1. Summary

CRISP, the Centre for Research-based Innovation in Sustainable fish capture and Processing technology, started its research activities in April 2011 and will be finalized by 30 Mars 2019. Since its launch, the consortium has consisted of the same four industry partners (Kongsberg Maritime AS, Simrad; Scantrol Deep Vision AS; the Egersund Group AS; Nergård Havfiske AS), four research partners (the Institute of Marine Research; Nofima AS; the University of Bergen; the University of Tromsø), and two sponsors (Norges Råfisklag; Norges Sildesalgslag).

The research of the Centre is organized in six scientific work packages (WPs):

1. Development of instrumentation for fish identification prior to capture
2. Gear and catch monitoring systems in purse seine
3. Methods for capture monitoring and catch control during trawling
4. Development of low-impact trawls
5. Adaptation of capture and handling practices to optimize catch quality and value
6. Analysis and documentation of the economic benefits to the fishing industry of converting to more sustainable capture techniques.

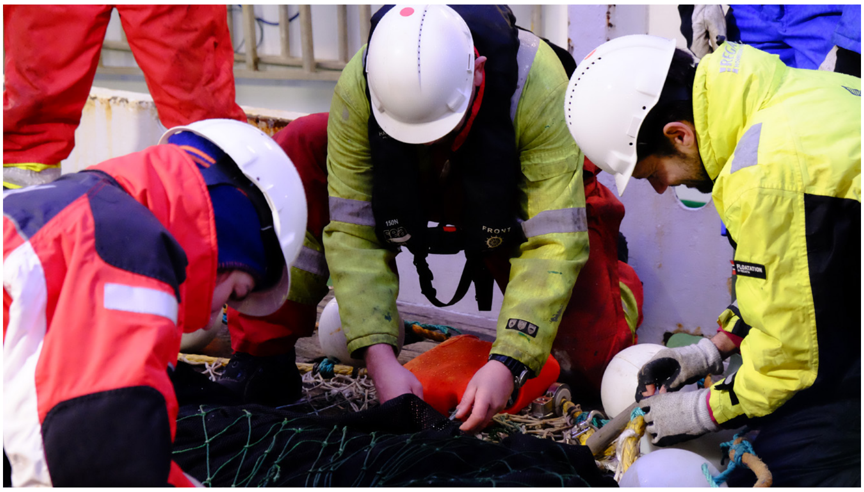
During the lifetime of CRISP, the process of developing new knowledge, new fishing gears and instruments for the fishing fleet as important tools for making the trawl and purse seine fisheries more sustainable has continued. These achievements have only been possible because of extensive cooperation between the centre's industry partners and research institutes. In 2018 CRISP was in its final phase, and much of our focus has been to summarize and report results

WP1: Both the fishing industry and research institutes need more accurate density and abundance measurements of schooling fish species than what is possible with current instrumentation. Simrad collaborates with IMR to develop new and improved fishery sonars which can quantify the volume of a school prior to shooting the purse seine, and high definition echo sounders which may accurately measure the fish size. This year Simrad has mainly been working with the new matrix sonar (SN90) for studying the school and the purse seine net during setting and retrieval. For estimating fish size and species composition inside schools and layers, the main activities in 2018 have been to correct and finalize calibration methods of broadband echo sounders and further trials with measuring single targets in situ with wideband transducers.

WP2: Purse seine fishermen need tools to improve their control over the capture process, including better characterisation of the catch before they shoot their nets, as well as being able to monitor the geometry of the purse seine and the behaviour of the catch during the capture process. Improved catch characterisation will enable fishermen to optimise harvesting strategies to maximise the value of limited vessel quotas, while improving the sustainability of the fishery by helping to avoid taking unwanted catches. In 2018, this work package focused on three topics: 1) further testing of the "In-seine" sonar technology for catch control; 2) monitoring purse seine geometry and performance using sonar and transponder technology; and 3) monitoring the behavior and welfare status of purse seine catches.

WP3: Unwanted catches often occur in mixed trawl fisheries regulated by quotas for individual species. A major topic for CRISP is therefore to develop interactive methods capable of actively releasing unwanted catch from trawls based on early identification of size and species inside these gears. The Deep Vision system, developed by Scantrol Deep Vision AS, takes stereo images of all objects passing through the trawl. The images can be used to identify and measure fish inside a trawl, opening opportunities to improve fisheries surveys by employing new techniques or providing evaluation of the trawling methods presently used. Primary developments in 2018 for the Deep Vision system included delivery of the production version deployment frame, upgrading of the cameras and lights, further development of software for analysis of the stereo images, and new camera calibration techniques for improved image quality and accuracy in length estimates. A control system and underwater motor for actuating an underwater selection mechanism was also tested.

WP4: The current trawling practice is regarded as unsustainable. It may be harmful to the seabed, have high bycatch rates and high fuel consumption that can affect the environment. The future of trawling will thus largely depend on the development of trawling techniques that significantly reduce these negative impacts. WP4 addresses the design, rigging and operation of trawl gears that might achieve such objectives. In 2018 fishing trials have continued to study possible catch reduction effects of lifting the trawl doors above bottom (semi-pelagic trawling). Also, research has started to investigate the efficiency of the MultPelt trawl used to obtain trawl indices for mackerel in the Norwegian Sea. One PhD student successfully defended her thesis this year.



WP5: The Norwegian fleet of ocean trawlers has gone through substantial changes since the turn of the millennium. In CRISP we have studied several quality issues during bottom trawling since the project started. One has been to investigate how prolonged buffer towing, which is commonly used by the Norwegian trawler fleet, influences filet quality. The experiments indicate that such practice has a negative effect on the catch quality. Another issue has been to investigate if a new coded segment constructed by Egersund Trawl has a positive effect on catch quality. The entrance of this codend segment was kept closed during towing, but opened at a predefined depth during haul-back applying a catch releaser. The results show that the catch related damages were significantly reduced. One PhD student linked to this WP successfully defended her thesis this year.

WP6: The last work package in CRISP focuses on how the technological improvements developed in the other work packages will contribute to value adding and environmental friendliness among trawlers and purse seiners. An overview of the modified and developed technologies that have been achieved in CRISP has been made and updated. A framework for cost-benefit analysis is developed, which is relevant when estimating the potential economic premium of the technological improvements achieved. The framework is based on analysis of the economic performance of the trawlers and purse seiners.

CRISP staff has taken part in a wide range of dissemination activities during the last year, including lectures about CRISP activities in national and international scientific meetings. Nationally, CRISP staff has promoted their results at a variety of meetings, seminars and fishing exhibitions arranged by various hosts.

In 2018 Crisp hosted six PhD positions. Four of the recruitment candidates were females, which is a key step towards increasing gender equality in a formerly male dominant industry. Two of our PhD students (Melanie Underwood and Ragnhild Aven Svalheim) delivered their thesis and held their public defence during 2018.

2. Vision/objectives

2.1 Vision

The Centre for Research-based Innovation in Sustainable fish capture and Processing technology aims to enhance the position of Norwegian fisheries-related companies as leading suppliers of equipment and seafood through the development of sustainable trawl and purse seine technology.

2.2 Objectives

To develop and implement instrumentation to identify species and sizes prior to the catching process.

To develop and implement instrumentation for commercial fishing to monitor fish behavior and gear performance during fishing operations.

To develop methods and instrumentation to actively release unwanted bycatch unharmed during trawl and purse seine fishing.

To develop new trawl designs that minimize the environmental impact on bottom habitats and reduce air pollution.

To develop capture and handling practices to optimize quality and thus value of captured fish.

To analyze and document the economic benefits to the fishing industry resulting from implementation of the new technologies developed by the project

3. Research Plan/Strategy

The research plan of the centre includes six research and one management work package, each of which comprises several sub-projects.

WP 1. Pre-catch identification of quantity, size distribution and species composition

WP 2. Gear and catch monitoring systems in purse seine

WP 3. Methods for capture monitoring and catch control during trawling

WP 4. Low-environmental impact trawl

WP 5. Quality improvement

WP 6. Value adding

WP 7. Management activities

Each work package is led by one of the two research partners along with a counterpart leader from one of the four industry partners. Most of the work packages involve one of the research institutes and one of the industry partners. Some work packages involve more than two partners, and it is a priority to increase cooperation among more partners in several of the work packages.

4. Organisation

4.1 Organisational structure

IMR in Bergen is the host institution for CRISP and is responsible for the administration of the centre. CRISP is presently organized as a project in the Biological Mechanisms Program. Most IMR personnel working in CRISP projects belong to the Marine Ecosystem Acoustics and Fish Capture research groups. Scientists working in CRISP projects are also involved in projects outside CRISP. A similar organizational structure also applies to Nofima in Tromsø, the other major research partner in CRISP, where scientists from the research groups Seafood industry and Economy take part in CRISP activities.

The Universities of Bergen and Tromsø are also research partners in the CRISP consortium. Their main function is to secure a formal education environment for PhD and MSc students funded by and associated with the Centre.

Senior scientist Aud Vold at IMR has been appointed director of the Centre since September 1, 2015.

The centre is led by a board, which in 2018 consisted of the following persons:

- Olav Vittersø, Managing Director, Kongsberg Maritime AS, Simrad (Chair)
- Helge Hammersland, Managing Director, Scantrol AS
- Bjørn Havsø, General Manager, Egersund Group AS
- Kjell Larsen, General Manager, Nergård Havfiske AS
- Geir Huse, Research Director, Institute of Marine Research
- Heidi Nilsen, Research Director, Nofima AS
- Helge K. Johnsen, Professor, The Norwegian College of Fishery Science, University of Tromsø
- Jonny Garvik, Chair of board, Norwegian Fishermen's Sales Association for Pelagic Fish
- Liv Jorunn Jensen (replacing Turid Hiller who retired in 2018), Special Advisor, Research Council of Norway (Observer)

The director of the Centre acts as secretary to the board.

Representatives of the University of Bergen and University of Tromsø, as well as Norwegian Fishermen's Sales Organization (Norges Råfisklag) and Norwegian Fishermen's Sales Association for Pelagic Fish (Norges Sildesalgslag), alternate as board members every second year.

4.2 Partners

From its start in 2011, the CRISP consortium has comprised four research partners (the Institute of Marine Research (IMR); Nofima AS; the University of Bergen (UiB); the University of Tromsø (UiT)), four industry partners (Kongsberg Maritime AS, Simrad; Scantrol Deep Vision AS; Egersund Group AS; Nergård Havfiske AS) and two sponsors (Norges Råfisklag (The Norwegian Fishermen's Sales Organization) and Norges Sildesalgslag (Norwegian Fishermen's Sales Association for Pelagic Fish)).

IMR has relevant R&D competence in fisheries acoustic, fish behaviour, fishing gear design and operation, capture based aquaculture, fish welfare and

Figure 4.1. Staff from Scantrol Deep Vision, The National Institute of Fisheries Science, Korea, and IMR working together with the crew at cruise in November on board RV "G.O.Sars" (Photo Tim Petter Hansen).

fishing gear selectivity. IMR also maintains infrastructure for ex situ and in situ experiments at its research stations in Austevoll and Matre and on board its three large research vessels.

Nofima AS possesses competence in handling, storage and feeding of live cod, fish welfare and restitution, sensory, processing and technological quality of fish and fish products, the assessment of quality aspects of fish captured by various fishing methods, and economic competence to evaluate the socio-economic consequences of changes in fishing patterns.

The University of Bergen (UiB) has relevant scientific and supervision expertise in general fish biology, experimental biology, fish behaviour, fisheries acoustics and fish capture. UiB has excellent experimental marine research facilities and a Marine Biological Station in addition to the research vessels operated jointly with IMR.

The Arctic University of Norway, Tromsø, Faculty of Biosciences, Fisheries and Economics (BFE), with it's Norwegian College of Fishery Science, is responsible for education within all areas of fisheries and aquaculture research. Teaching and research focus are primarily on biological oceanography, fishery biology, assessment and management. CRISP will particularly benefit from the University's multidisciplinary expertise and approach.

Simrad is part of Kongsberg Maritime AS (KM). Simrad has been developing tools for fishery research and commercial fisheries for more than 60 years. Simrad is a leading provider of acoustic systems for fish finding, pre-catch evaluation and catch monitoring. The company has a strong tradition of innovation and a history of developing acoustic instruments in cooperation with IMR; for example, instruments for fish size detection and species identification with echo sounders. Other KM subsidiaries manufacture underwater cameras, bottom profilers, underwater telemetry links, underwater positioning systems and subsea transponders for various monitoring and regulating purposes. The company's largest contribution to the Centre will be their leading-edge expertise in acoustics, electronics and instrumentation. The company also operates an experimental acoustic tank, calibration and test facilities on its own vessel and prototypes for full-scale testing.

Scantrol Deep Vision AS has developed a unique technology for taking high-quality stereo photos of fish inside a trawl (DeepVision technology), which can be used to identify species and measure their length through computerized image analysis. DeepVision may be combined with a mechanism that can subsequently retain or release organisms captured during fishing. The present status of DeepVision has partly resulted from cooperation with IMR scientists, including prototype testing on board research vessels. The development of an instrument that can be used in commercial fisheries requires the documentation of benefits compared to traditional selectivity methods, and the optimization of design and performance under practical conditions.

The Egersund Group AS is a leading producer of pelagic trawls and trawl doors and a significant producer of purse seines for the Norwegian and Nordic markets. The company provides extensive practical experience to the Centre in design of trawls, trawl doors and purse seines. The company in turn benefits from close cooperation with producers of gear instrumentation and technologists who have wide-ranging knowledge of fish behaviour and methods to evaluate gear performance, including access to modern research vessels. This cooperation helps The Egersund Group to develop trawl and purse seine technologies that will satisfy future requirements for green harvesting, which will be an advantage in the Norwegian and international markets.

The Nergård Group AS is one of the largest Norwegian exporters of seafood. The company focuses on maintaining local traditions and communities while sharing the sea's valuable assets with the rest of the world. Nergård has made major investments in white-fish vessels and quotas. Throughout the entire production chain, the focus is on taking care of quality requirements on board, during landing, production, processing and transport - all the way to the customer. Nergård plays an important role both in herring (human consumption), whitefish and shrimp production in Norway.

Norges Sildesalgslag (Norwegian Fishermen's Sales Association for Pelagic Fish) is Europe's largest marketplace for first-hand sales of pelagic species. The marketplace is owned and operated by Norwegian fishermen. Approximately 2 million tonnes of pelagic fish are sold every year through this organization, which is equivalent to 2 – 2.5 % of global wild fish catches. The main interest of Norges Sildesalgslag in CRISP is the development of sustainable purse seine fisheries, particularly in relation to eco-labelling and certification.

Norges Råfisklag (The Norwegian Fishermen's Sales Organization) handles important national functions in the seafood trade, together with five other fish sales organisations in Norway. The organisation also plays a national role in resource management. Norges Råfisklag organises and arranges the sales of whitefish, shellfish and molluscs landed on the coast from Nordmøre in the southwest of Norway to Finnmark in the north-east. The most important species are cod, saithe, haddock and shrimps/prawns.

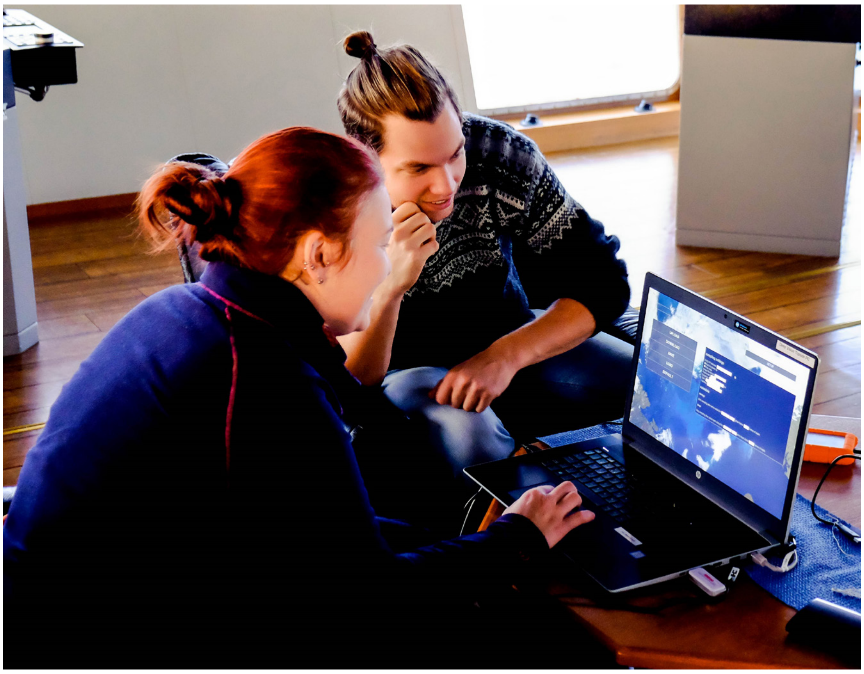


Figure 4.2. Cooperation between Scantrol Deep Vision engineer Kristoffer Løvall and IMR gear technologist Liz Kvalvik at RV "G.O.Sars" at a research cruise in November (Photo Tim Petter Hansen).

4.3 Cooperation between centre's partners

The six research work packages are organized under the leadership of a representative from one of the research partners, and with a counterpart assistant leader from one of the industry partners with a main interest in that work package. The work packages often involve more than two partners, especially those involving MSc and PhD students, where the universities are natural third partners. The four industry partners have complementary competence with minor or no overlapping business interests.

The Centre uses various arenas and methods to encourage mutual trust and to form joint projects involving CRISP's partners. Every second month a regular contact meeting is held between the research partners over video link where matters of mutual interest are being discussed. Most projects within CRISP are conducted jointly by staff from a research institute and one or two of the industry partners. Field studies are normally done on-board research or fishing vessels. The key role of the researchers is to evaluate the efficiency and environmental benefits of the developed tools. The staff from all partners participates in planning and execution of the research cruises followed by evaluation and reporting of the results.

An Annual Science meeting has normally been arranged September each year, but in 2018 it was decided to merge it with the final symposium which will be held in Bergen, May 2019. This will be the final meeting point for the CRISP consortium, where we will come together to sum up the main achievements throughout the lifetime of CRISP and set the course forward after its termination.

5. Scientific activities and results

The scientific activities in CRISP are organized in the form of six work packages, including several sub-projects; the partners involved are shown in Table 5.1.

Table 5.1 Work packages with sub-projects and partners involved

Work package	Sub projects	Partners
WP 1. Pre-catch identification of quantity, size distribution and species composition	Biomass estimation using digital fishery sonars Pre-catch identification and sizing of fish with broadband split-beam echo sounders	IMR, KM and UiB
WP 2. Gear and catch monitoring systems in purse seine	2.3 "In-seine" sonar technology for catch control 2.4 Catch monitoring system in purse seine 2.5 Monitoring seine geometry and performance	IMR, KM and UiB
WP 3. Methods for capture monitoring and catch control during trawling	3.1 Visual fish classification 3.2 Trawl HUB for camera and acoustic systems	IMR, Scantrol Deep Vision , KM, UiB
WP 4. Low impact trawl	4.2 Semi-pelagic trawl design and rigging 4.3 Catch regulation in trawls 4.5 Improving the quality of the pelagic trawl survey for NE Atlantic mackerel	IMR, Egersund Group, KM, UiB
WP 5. Quality improvement	Current quality conditions onboard bottom trawlers Facility and methods for experimental investigation of fish quality	Nofima, IMR, UiT and Nergård
WP 6. Value adding	Vessel operation How renewal and harvest strategies impact fleet performance	Nofima, Nergård and UiT

5.1 Pre-catch identification of quantity, size distribution and species composition

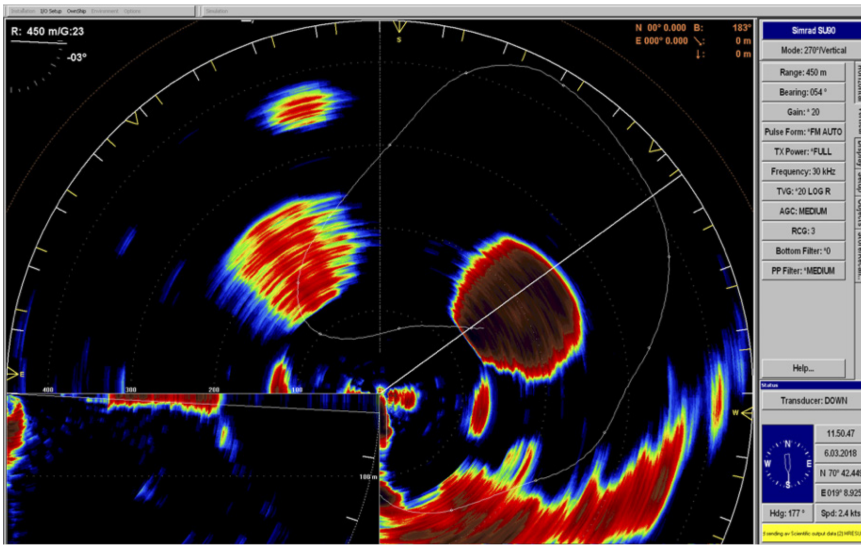


Figure 5.1.1. Dense capelin school where acoustic extinction occur, but not clearly shown in the sonar display. The catch was three times as large as first estimated.

Background

Both the fishing industry and research institutes need more accurate density and abundance measurement methods of schooling fish species than what is possible with currently available instrumentation used for detecting and observing fish horizontally, so-called multibeam sonar systems. In this respect, research and industry has a common long-term challenge. This includes both robust calibration methods but also better understanding of the backscattering of fish in lateral aspects.

There is also a definite need for more precise estimates of size and species composition of fish schools prior to shooting a purse seine. This will reduce the number of unwanted sets where the catch is of the wrong species, wrong size composition or exceeds the amount that can be handled by the fishing vessel and therefore may have to be partly released. As this practice often result in unintended mortality of captured fish, instrument development which can reduce this risk is needed for future sustainable harvesting of pelagic schooling fish with purse seine gears. Similar challenges are also present in commercial trawl fisheries, where pre-catch species identification and sizing will be important in the future. We believe that the instrumentation and methods developed under this work package may now and in the future deliver important information to help the skipper in his decisions both during purse seining and trawling.

Activities

Kongsberg Maritime, Simrad, collaborates with IMR to develop new and improved omnidirectional fishery sonars which can quantify the size of a school prior to shooting the purse seine, and high definition echo sounders which may accurately measure the fish size. This includes development and testing of new sonar raw data output formats, and the development of standard calibration procedures for modern multibeam fishery sonars. Simrad has delivered new data formats and improved software which have been tested in surveys on herring in 2012, 2013, and 2017 and on Atlantic mackerel in 2014, 2015 and 2016. In 2018 similar verification catches were made on capelin, where a new, important acoustic effect was demonstrated. During the survey the acoustic extinction or "acoustic shadowing" in dense capelin schools were so strong

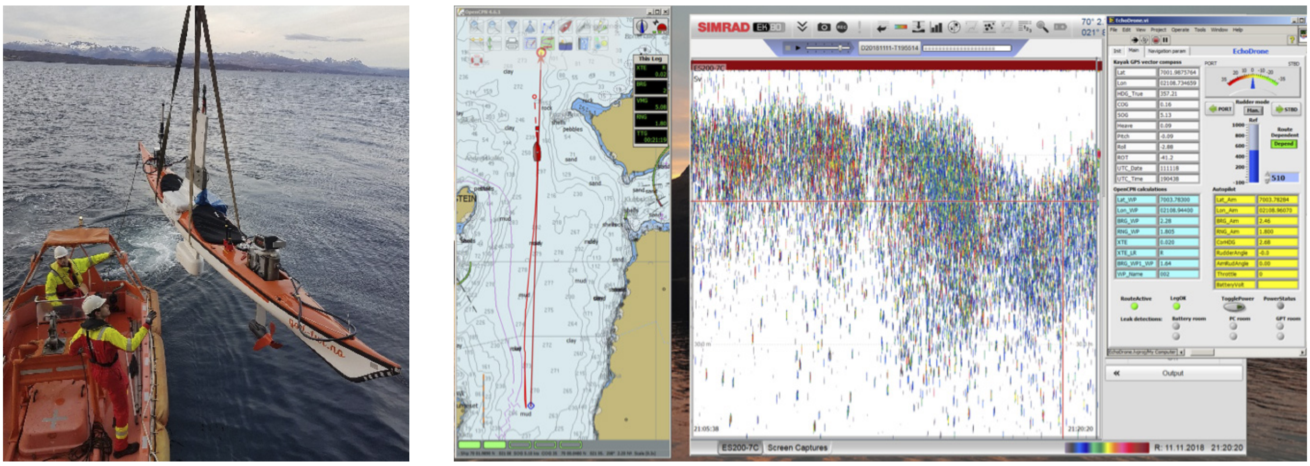


Figure 5.1.2. KayakDrone used on herring layers in Kvænangen, showing the echogram recorded onboard the Drone while passed by RV "G.O.Sars". The herring reaction to the research vessel was obvious as they started diving 100 meters in front of the vessel. Comparisons between densities measured from the vessel, from a drifting buoy, from the Drone and from the side-looking MS70 system will be made on this dataset.

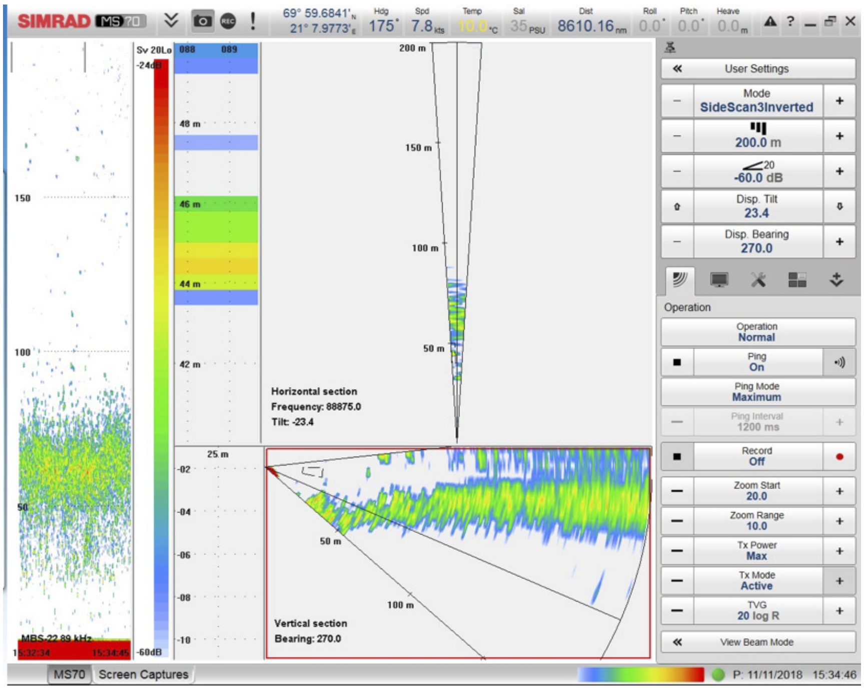


Figure 5.1.3. Measuring herring close to the sea surface with the MS70 sonar.

that the school biomass was severely underestimated by standard procedures (Figure 5.1.1). It was decided to increase the number of observations on capelin 2019. It was also decided to collect data on dense herring schools to evaluate if extinction is a severe problem also in herring schools. Research has started to compensate school biomass estimates for possible acoustic extinction.

This year Kongsberg Maritime, Simrad has mainly been working with the new matrix sonar (SN90) for studying the school and the purse seine net during setting and retrieval. Calibration protocols for the matrix sonar are also being made, and one successful calibration has been made on FV “Eros”. Existing sonar processing software has also been adjusted to read data from SN90 sonar. It has been noted that air bubbles from the side thrusters disturb the sonar signals when using the normal hull blister mounting of the SN90 transducer. Therefore, it was moved to the side of the drop keel on FV “Eros” in 2017. This improved the quality of the received sonar signals, and the catch process could now be properly monitored.

As previously reported, the calibration protocol for the SU90 is now in place and published. Significant improvements are expected with a new software for the sonar, expected to be released in 2019, a bit delayed from the manufacturer. In late 2019 it is also expected that the calibration part of the software is implemented in the sonar software, using split beam to position the calibration sphere. As mentioned in previous reports, more than 10 vessels have been calibrated once and 3 vessels several times using this method. The main results from verification catches of herring and mackerel shown in the previous annual reports are now being published, and further work with additional correction for sound extinction will be conducted towards the end of the project period. The implementation of the new algorithms in the sonar will be made by Kongsberg Maritime, Simrad, hopefully to be finished for testing before CRISP is finalized in 2019.

Fish sizing

For estimating fish size and species composition inside schools and layers the main activities in 2018 have been to correct and finalize calibration methods of broadband echo sounders and further trials with measuring single targets in situ with wideband transducers. The broadband echo sounder has been modified and improved by Kongsberg Maritime, Simrad, both with respect to the hardware, but also significant effort is now being made on new software. The echo sounder is now commercially available both in scientific and fishery versions. Software and setup were tested with good results in the October 2015 and 2016 mackerel surveys and finally for the 2017 and 2018 herring surveys. Full broadband echo sounder setup was also run during an international training course for scientists which were conducted on-board RV “G.O.Sars” in December 2017, with 20 participants from 4 countries. The training course this year was run as an IMR Academy course with 15 national and 5 international participants.

In the Crisp 2018 herring survey new instrumentation from Kongsberg Maritime, Simrad was tested during the first week of the survey, with 5 participants from Kongsberg Maritime. The results from these trials are still confidential.

We now regard the first version of the DABGRAF acoustic fish sizing system to be finished from research, and ready for commercial testing. New mountings arrangements for the transducer on fishing vessels must be made if a commercialization project is desired. It is not yet clear if the narrow beam, broadband transducer beam should be mechanically or electronically tilted. This must be decided by the industry partner, as an electronic tilting would greatly simplify the mounting arrangements on board fishing vessels.

A new acoustic Kayak Drone was also tested during the Crisp 2018 herring survey. The Drone was sent from the mother vessel RV “G.O.Sars” and measured herring close to the sea surface in Kvænangen, Troms. (Figure 5.1.2). Measurements of herring in the vessel acoustic blind zone was the purpose of these tests, as well as evaluation of vessel avoidance from RV “G.O.Sars”, when herring is distributed in a shallow layer close to the sea surface. The autonomous drone worked well under the sea conditions inside Kvænangen but must be ruggedized for full ocean use.

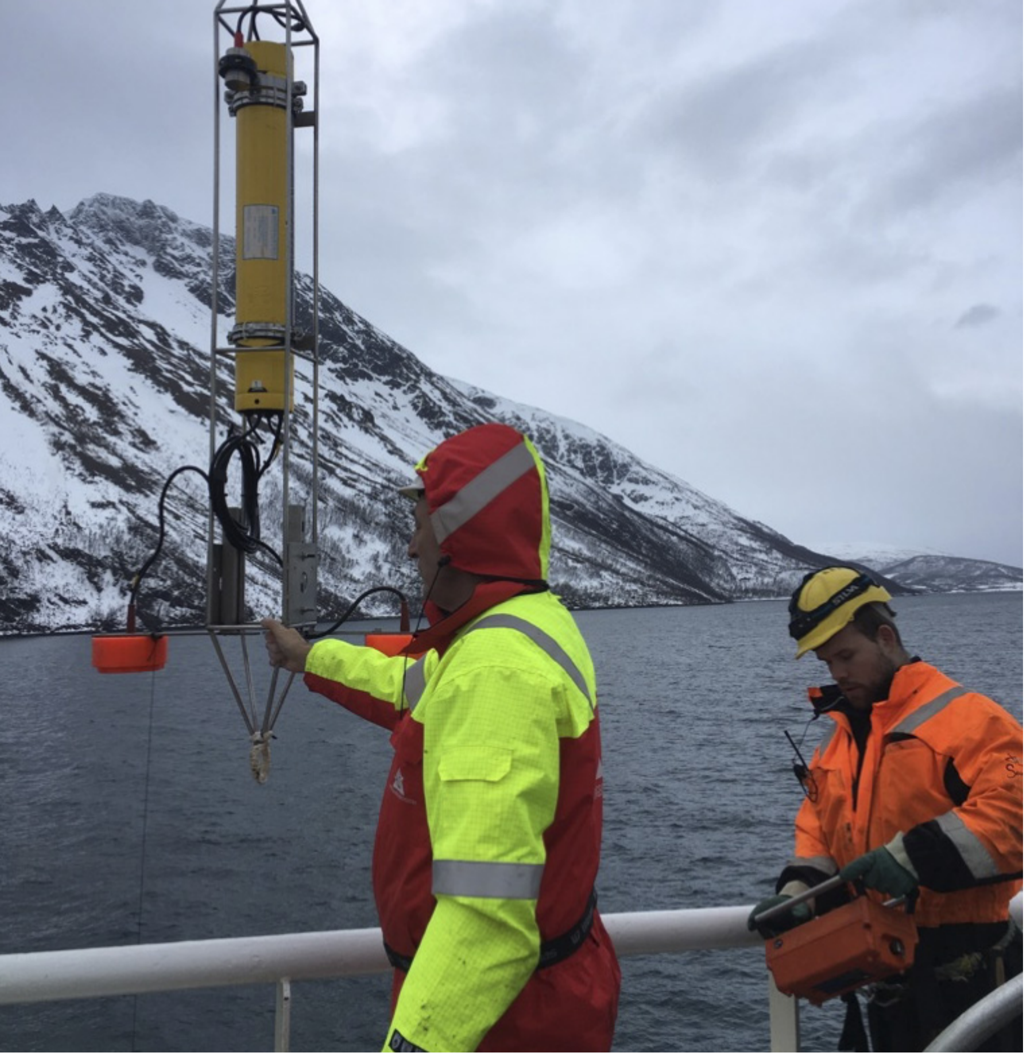


Figure 5.1.4. Setting out the WBAT system for target strength measurements.

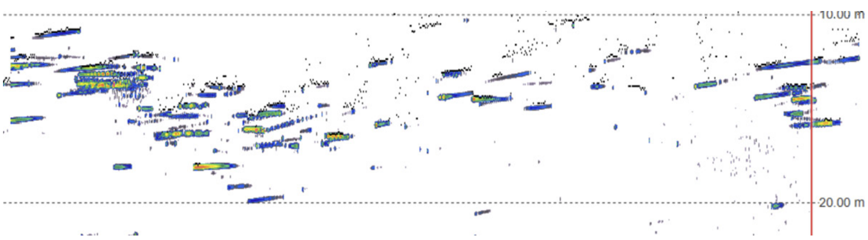


Figure 5.1.5. Lateral TS measurements of herring at 160 m depth at 38 kHz.

Parallel measurements with a modified version of the scientific MS70 sonar, with inverted beam fans relative to a normal setup, was tried, and with only one acoustic fan, positively tilted towards the sea surface for evaluating the possibility to measure herring close to the sea surface (Figure 5.1.3).

A light drop-sonde system with a Simrad WBAT, broadband echo sounder has been tried inside mackerel and herring schools in 2016, 2017 and 2018, and shows promising results for real time sizing (Figure 5.1.4). This system now delivers important information on lateral aspect TS for adult mackerel, herring and capelin, data needed for more exact biomass estimation of schools measured by the sonar.

In the future this system may also be considered used both free-floating, transmitting the data to the vessel from a free drop in layers, or inside the purse seine. If this is considered an interesting product for the fishing fleet, the industry partner must add the data transmit facility on the buoy, a simple, off shelf solution.

Results

Calibration protocols for fishery sonar and methods for correct volume estimation are now finalized, and the largest uncertainty factors in the biomass computation can be further studied. The main uncertainty is the extremely variable backscattering of fish when observed in the lateral aspect, as described in the last year's report. Large deviations from the present simplified method presently used in the sonar software are observed, especially on small to medium sized schools at long range, and at small schools at short range. A recommended range-belt for pre-catch biomass evaluation is suggested to be part of the new software. In 2018, the effect of acoustic extinction was closely studied on 30 selected large herring schools, and data was collected from two different sonars for supporting the theoretical work on this subject. The theory for correcting for acoustic extinction was established in the 1990ies, but the ability of herring and capelin to absorb sound, the so-called extinction cross section for fish in the lateral view, has not yet been established. In vertical echo sounding, the echo from a flat bottom was used when establishing the herring extinction ability, but in lateral observing sonars there is no reference target behind the school, making the theory more complicated. Still we hope to develop the theory during 2019, so that the final biomass algorithms may also include this factor.

During the CRISP research vessel survey in 2018, further target strength data collection with broad band echo sounders have been made on two size categories of herring, 5 years old, 330 g herring in Kvænangen, Northern Norway (Figure 5.1.5) and 390 g adult herring outside the island of Røst, both on the main fishing grounds in November 2018. During these measurements, a new 38 kHz transducer have been tested on the WBAT system, enabling TS measurements closer to the sonar frequency 30 kHz than the ones used before. This is the first pressure stabilized broad band transducer working at 38 kHz. Processing and publication of the TS data in lateral mode on mackerel, herring and capelin will be prioritized in 2019.

5.2 GEAR AND CATCH MONITORING SYSTEMS IN PURSE SEINE

Background

Purse seine fishermen need tools to improve their control over the capture process, including better characterisation of the catch before they shoot their nets, as well as being able to monitor the geometry of the purse seine and the behaviour of the catch during the capture process. Improved catch characterisation will enable fishermen to optimise harvesting strategies to maximise the value of limited vessel quotas, while improving the sustainability of the fishery by helping to avoid taking unwanted catches. Avoiding unwanted or too much catch may not always be possible, so it may sometimes be necessary to release or "slip" some of the catch. At these times, having tools to describe the geometry and volume of the net, as well as monitoring the stress experienced by fish in the catch, through observing changes in behaviour and environmental parameters, will enable the development of responsible slipping practices that ensure the survival of any released catch.

In 2018, this work package focused on three topics: 1) further testing of the "In-seine" sonar technology for catch control; 2) monitoring purse seine geometry and performance using sonar and transponder technology; and 3) monitoring the behaviour and welfare status of purse seine catches. In addition, funding was directed towards an innovative project to determine the possible effects of slipping related mortality on the stock biomass of both herring and mackerel.

"In-seine" sonar technology for catch control

SN90 (developed by Kongsberg Maritime, Simrad) for school and net monitoring was used during the Crisp survey on the Capelin fishing grounds in March 2018. In this survey, schools were often found close to the sea surface and the SN90 with high resolution and inspection beams provided good estimates of fish density. The clear decrease in the acoustic backscattering from the distant part of the school, indicates that the density is so high that an attenuation of the returned echoes occurs. The attenuation is not observed as clear in the omni sonar because of the lower beam resolution. Acoustic attenuation, if not accounted for, may lead to underestimation of school biomass. As an example, one of the schools captured by purse seine was evaluated to 200 tonnes before catch but resulted in a catch of 640 ton (Figure 5.2.1). These results will be used to develop a correction factor for school biomass estimation in cases when attenuation occurs, which will avoid unwanted large catches that could lead to fish slipping or gear damage.

The development of calibration algorithms for the SN90 sonar presented a higher level of complexity than the omni sonar, because of a different data format. The availability of inspection beams with narrow split beams (6 deg opening) highlights the advantage of beam mapping when using a calibration sphere. Beams from the horizontal and vertical fans were calibrated using the inspection beam for an on-axis calibration. However, not enough capacity was available to complete the analysis of the data and generate the required algorithms at the same level accomplished for the omni sonars.

Monitoring seine geometry and performance

The monitoring of the bottom line of the purse seine using transponders was done using a special module in

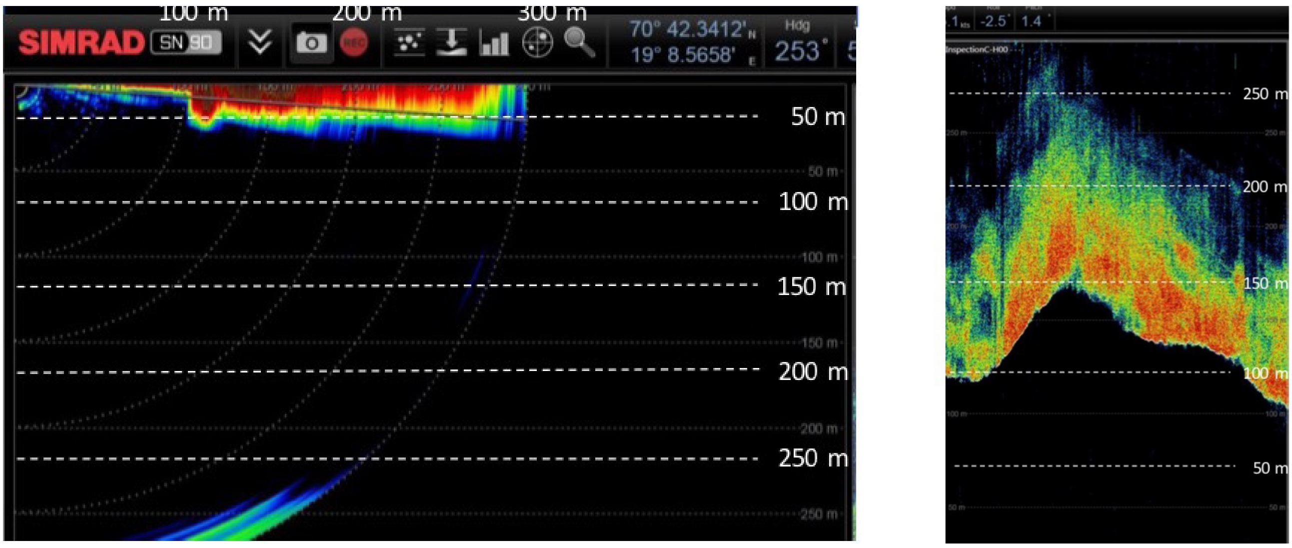


Figure 5.2.1. Vertical section of a capelin school using SN90 sonar with the closer edge of the school at 100 m at a depth of 20 m (left panel). An inspection beam oriented perpendicular to the school, show the decrease (from red to light green colour) in the acoustic backscattering from the closer part of the school at about 100 m towards the distant border about 170 m from the vessel. The range indicates, horizontal distance from the vessel (right panel).

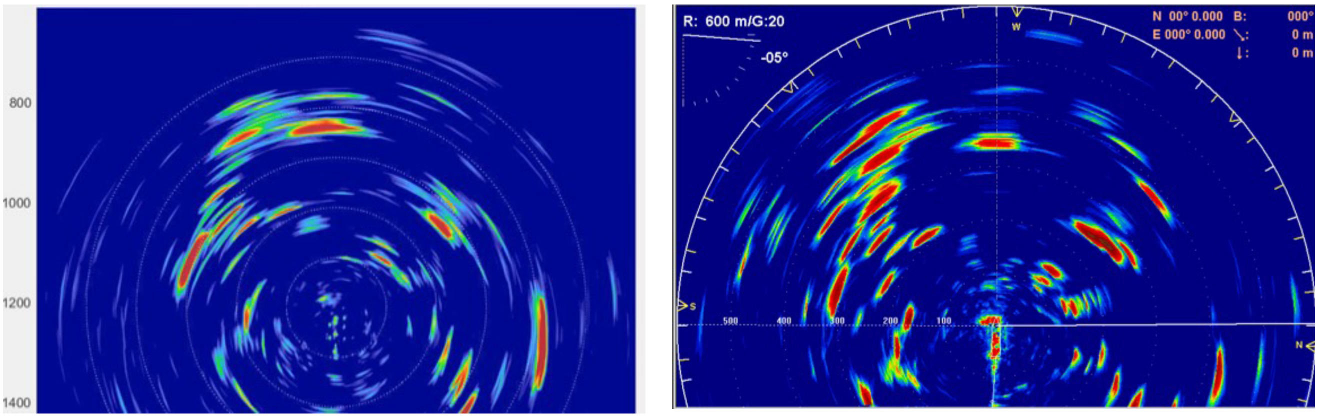


Figure 5.2.2. Display of sonar raw data processed with new developed algorithms (left panel) and screen dump from the sonar display from Simrad SU90 for the same second (right panel).

the SN90 developed by Kongsberg Maritime, Simrad during 2017. Results from testing during the Crisp cruise and opportunistic fishing trips concluded at end of 2017 that to further progress with the development there is a need for changes in the SN90 software. These changes require an automatic and independent monitoring of transponders position and depth when using the sonar to evaluate school dynamics and biomass. The development of the software was not possible by Kongsberg Maritime and the activities related to the gear monitoring were minimal during 2018.

Due to the reduced progress in the proposed activities, an additional task was formulated and executed. One of the main challenges when processing sonar data is the capacity to identify fish schools in the surface layers from other scatters related to surface reflection and air bubbles generated by waves. The algorithms used in modern sonars are very efficient at removing unwanted noise and enhancing schools, but they are the property of the sonar developers and so not available for public use. Therefore, the additional task was to develop suitable algorithms to replicate what the commercial sonars are doing and use improved display of the sonar data to facilitate the analysis for scientific purposes. The work started late in 2018, and current results indicates a good agreement between the new algorithms and the sonar display (Figure 5.2.2). Further tuning of the algorithm parameters will be performed and once the best results are obtained, the final algorithm will be implemented in the post-processing software PROFOS.

Monitoring the behaviour and welfare status of purse seine catches

Over the lifetime of CRISP, IMR has been developing a catch monitoring platform (CMP) to monitor and characterise the catch (with respect to species composition, individual size distribution and behaviour), as well as describe environmental conditions in the net (i.e. temperature and dissolved oxygen concentrations), during the capture process in the purse seine. In collaboration with other projects [Project RedSlip (NFR 243885), Slipping: Best Practice (FHF 900999) and, latterly, Catch Control in Purse Seines (FHF 901350)] several variants of the CMP have evolved to monitor different positions and phases of the later catch process:

1. In net during hauling: a Sony 360 camera provides omni-directional recordings of fish behaviour and density, and a RINKO III logger records oxygen, temperature and depth
2. During pumping: a Go-Pro 5 camera and a RINKO III.
3. Inside the Refrigerated Seawater (RSW) tank: a Go-Pro 5 camera and a RINKO III.
4. During slipping: Go-Pro 5 cameras at the discharge opening to observe behaviour and density of fish as they are released; and
5. Outside the discharge opening: Go-Pro 5 cameras to observe behaviour and density of fish after they are released and a SAIV CTDO probe to measure ambient temperature, salinity and dissolved oxygen.

One variant of the CMP that has been under development incorporates a stereo-camera to provide accurate estimates of the size distribution in a catch before they become too crowded to safely release, if they are undersized. In 2018, tests were conducted using the Weeview SID camera stereo-camera. This camera has several useful features for the CMP, including: it is a commercially available product; is light-weight; and outputs a single synchronised video stream of paired images (thus avoiding image synchronisation issues, particularly during live feed transmissions). Although the image quality was very good (figure 5.2.3) and the camera proved to be sufficiently robust in the challenging conditions in the net, the precision of the length measurements from the camera were not good enough for accurate length estimation. This was primarily because the paired lenses were too close together (50 mm) and unfortunately the manufacturer was not prepared to collaborate on developing a camera with a greater lens separation. Work is already planned to continue the development of the stereo-camera system in Catch Control in Purse Seines (FHF 901350), along with Norwegian and international collaborators.

Figure 5.2.3. Paired stereoscopic images from different stages of the capture process.

As described in earlier CRISP reports, using the CMP we have observed how the catch becomes progressively crowded in the net, which drives ordered schooling behaviour to become disordered, and how at high crowding densities dissolved oxygen concentrations quickly decline. In 2018, observations during pumping in herring and mackerel catches demonstrated the catch could become very crowded and oxygen concentrations as low as 12.1 % saturation (1.32 mg/l) were observed (figure 5.2.4). As part of the Catch Control in Purse Seines project, a method for assessing the welfare of the catch is being developed, by monitoring different behavioural responses and reflexes, e.g. swimming activity and breathing rates. From these a simple score was devised which shows how alive, or "vital", a fish is, where a healthy fish should score ~7 or higher out of 10. In the example below, this showed that mackerel started to show very low vitality (i.e. were dying) quite early in the pumping process, but interestingly vitality started to recover later in the process. These changes appear to be associated with a period when oxygen saturation in the net dropped below a "safe threshold" of 40% (see figure 5.4.4). The vitality of fish taken from the RSW tank (open circles), where oxygen levels were also low and temperature was ~1.5°C, was zero in most fish.

As CRISP comes to end, it is gratifying to know that the catch monitoring technology developed in this work package will be contributing to other projects and promoting more sustainable and welfare conscious fishing practices.

For example, in an exciting innovation in Catch Control in Purse Seines (FHF 901350), IMR and SINTEF are integrating several data-streams from the CMPs, in addition to engineering, navigation and environmental data from the vessel (compiled and logged by SINTEF's Ratatosk system) (figure 5.2.5). Once compiled and time synched, NOLDUS's Observer XT will be used to conduct an integrated analysis of the time dependent data and behavioural responses. By integrating data in this

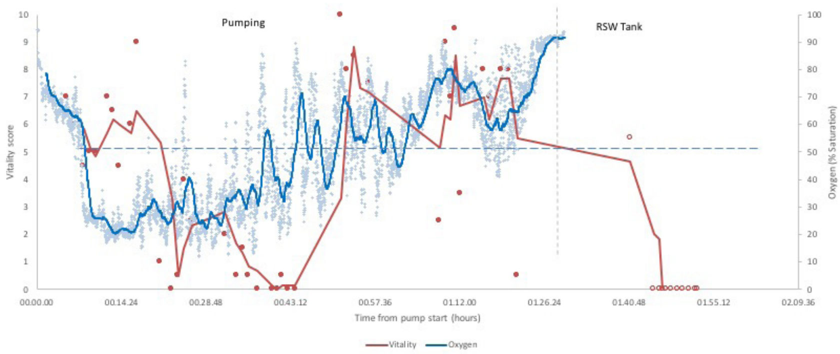


Figure 5.2.4. oxygen concentrations can become very low in the catch during pumping because of high crowding densities, which can significantly affect the "vitality" of the fish as they are pumped on board.

way, we will be able to demonstrate how changes in conditions during the capture process can affect the welfare of fish in the retained catch, as well as those released from the net.

The effect of unaccounted mortality in mackerel and herring purse seine fisheries on stock assessment

The stock estimates in the assessments of the Northeast Atlantic (NEA) mackerel and Norwegian Spring Spawning (NSS) herring are determined by catch and survey data that inform about the cohort sizes and trends in the stock abundance. Fish escaping from burst nets and unwanted catches released from the net have been shown to result in potentially high levels of unaccounted fish mortality and can bias stock assessment. However, very little quantitative data on slipping and net bursts are available and the effect on stock assessment are unknown.

In 2018, preliminary studies were made to investigate the effect of different levels of unaccounted mortality on stock biomass (SSB) of NSS herring and NEA mackerel (Figure 5.2.6 and 5.2.7). Preliminary test runs illustrate how even relatively small changes can cause large deviations in the SSB estimates. For instance, in NSS herring a 50% increased mortality corresponds to an increase in the mortality rate of only 0.075 but causes an average increase in estimated SSB of 1.75 million tons. Furthermore, the quantitative effects are determined by the stock-specific design of the assessment models, notably the number of age classes and assumed natural mortality (e.g., NSS herring is longer lived and has higher natural mortality than mackerel for the first age classes, resulting in stronger cumulative effects of increases in mortality). We are currently working on developing more realistic unaccounted mortality scenarios using the available information on slipping and net burst frequencies, quantities and mortality rates. We hope this exercise will encourage fisheries managers and fishermen to report and register unaccounted mortality in the fisheries more effectively in the future.

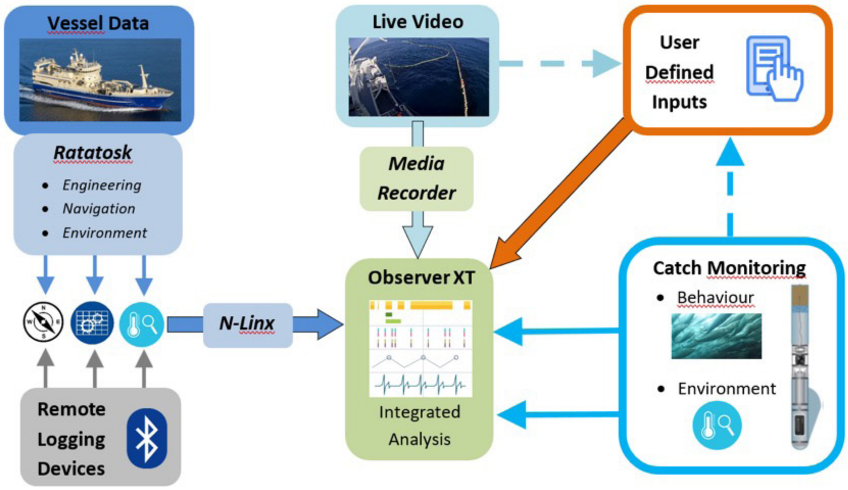


Figure 5.2.5. An overview of the compilation and integration of data (behavioural, engineering, environmental, and navigational) from several sources (vessel, live video, remote logging devices, catch monitoring devices and user defined inputs) via the Ratatosk, N-Linx, Media Recorder and Observer XT systems (Source: Catch Control in Purse Seine - https://www.sintef.no/projectweb/fangstkontroll/).

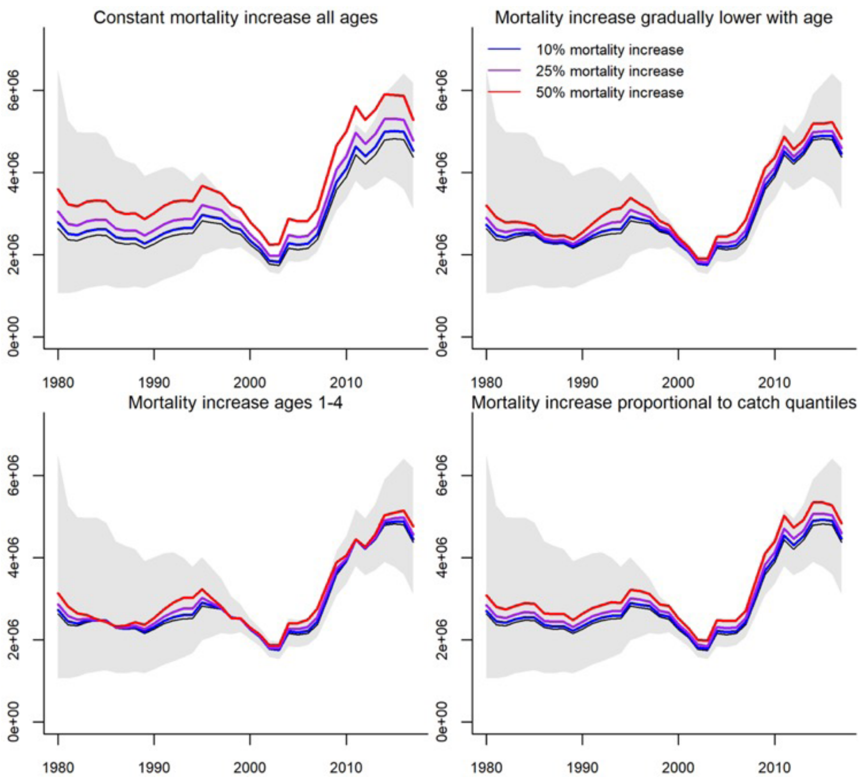


Figure 5.2.6. *Test runs on Norwegian spring spawning herring SSB (1000 t) from 1988 to 2017 using the XSAM model where the natural mortality is increased by 10, 25 and 50% as a proxy for unaccounted mortality. The scenarios are: 1) constant mortality over age classes, 2) percentage mortality decrease linearly with age, 3) mortality is increased only for constant mortality for 3 to 6-year-old herring and 4) constant mortality over ages but the rate is increased proportional to annual catches quantiles (e.g. 10% increase in years with high catches (in the top quartile of all catches), 5% increase in years with intermediate catches (25-75% quartiles) and no increase in years with low catches (lowest quartile). The grey area represents the confidence intervals for the baseline model, i.e. with no unaccounted mortality (95%).*

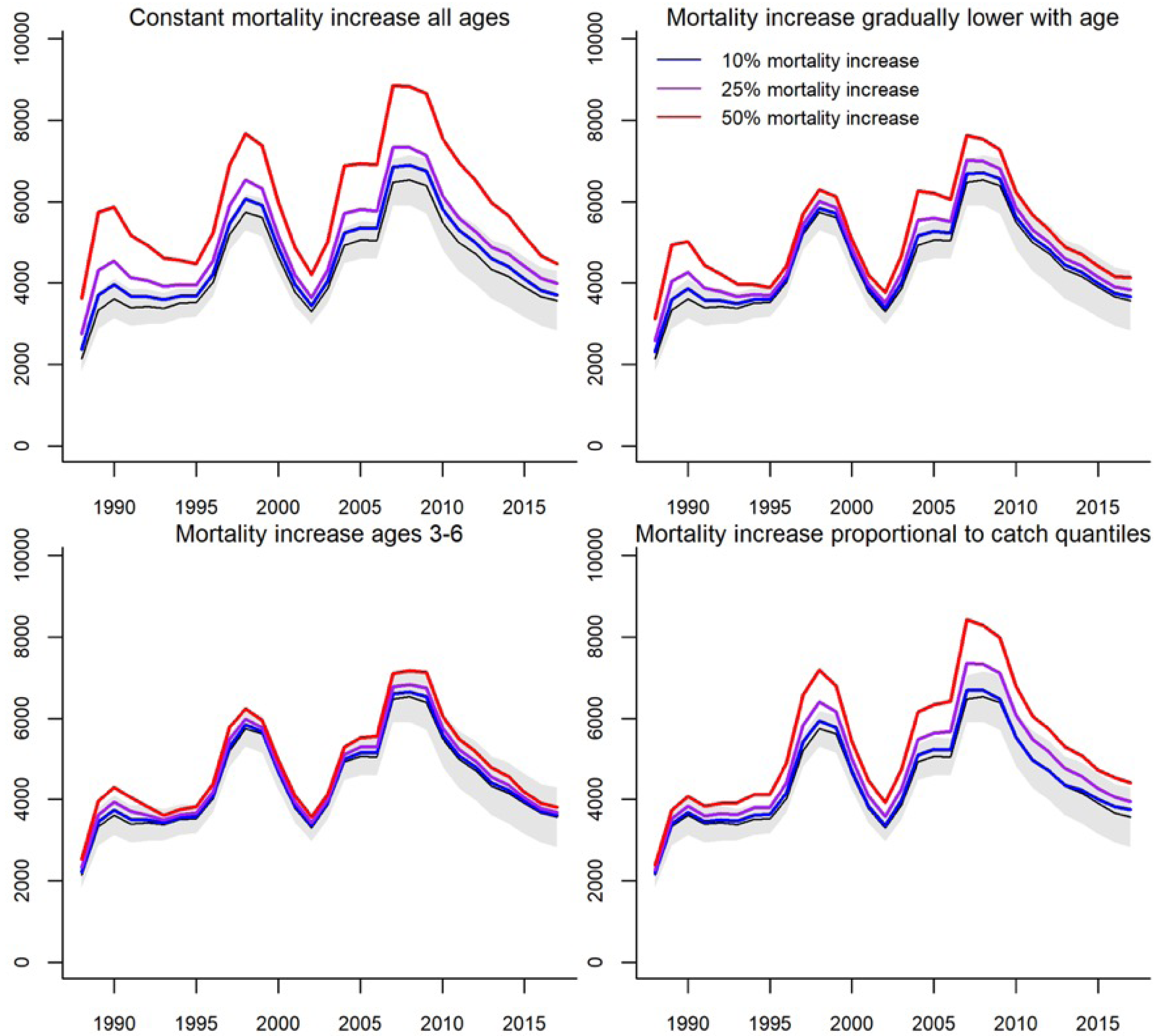


Figure 5.2.7. *Test runs on Northeast Atlantic mackerel SSB (1000 t) from 1988 to 2017 using the XSAM model where the natural mortality is increased by 10, 25 and 50% as a proxy for unaccounted mortality. The scenarios are: 1) constant mortality over age classes, 2) percentage mortality decrease linearly with age, 3) mortality is increased only for constant mortality for 1 to 4-year-old mackerel and 4) constant mortality over ages but the rate is proportional to catch quantiles. mortality is increased proportional annual catches (e.g., 10% increase in years with high catches (in the top quartile of all catches), 5% increase in years with intermediate catches (25-75% quartiles) and no increase in years with low catches (lowest quartile). The grey area represents the confidence intervals for the baseline model, i.e. with no unaccounted mortality (95%).*

5.3 Methods for capture monitoring and catch control during trawling

Primary developments in 2018 for the Deep Vision system developed by CRISP partner Scantrol Deep Vision (https://www.deepvision.no/deep-vision/deep-vision) included delivery of the production version deployment frame, upgrading of the cameras and lights, further development of software for analysis of the stereo images, and new camera calibration techniques for improved image quality and accuracy in length estimates. A control system and underwater motor for actuating an underwater selection mechanism was also tested.

The new deployment frame, moulded from fiberglass with a middle layer of syntactic foam for buoyancy, is both stiffer and lighter than the previous frame constructed of stainless steel and HDPE panels with separate buoyancy elements. The frame's height has also been reduced through the removal of the external buoyancy element and the overall centre of buoyancy has been moved closer to the centre of the frame so that if the frame rolls over it is more likely to roll back again. Also, all electronics have been moved to one side to assist in servicing the system when on deck and to reduce the length of cables and potential for damage.

Upgrades to the cameras and lights include the use of cameras with higher resolution and greater dynamic range (sensitive over a greater range of lighting) and lights which output approximately 50 % more light than the previous model and are designed for use to 2000 m depth. All system components are now designed for deployment to 2000 m.

Significant advances have been made in the Deep Vision Analysis software, including automatic selection of an outline of a fish (segmentation), matching this outline in left and right images and generation of a midline along which length is calculated automatically.

The use of a new calibration tank, designed specifically for calibrating the Deep Vision camera and sized to hold the entire imaging chamber portion of the Deep Vision frame, results in much better control of focus adjustment than previously possible (leading to sharper images) and length measurements were measured with sub-millimeter accuracy after stereo calibration.

Deep Vision technology was further tested and refined during three CRISP cruises in 2018. The first two cruises were conducted as day trips from Bergen on board FV "Fangst" with the goal of training operators for Deep Vision on other IMR cruises and testing and development of the frame and prototype sorting mechanism. The third cruise was conducted on board RV "G.O. Sars" in the Barents Sea and included tests of Deep Vision

CRISP cruise April 2018, Bergen

During the April 2018 CRISP cruise in Bergen, the primary focus was on testing the new lights and cameras and training IMR researchers to operate the Deep Vision system during the annual three-week long Norwegian Sea ecosystem survey. After calibration, distance measurements of a plastic model fish with

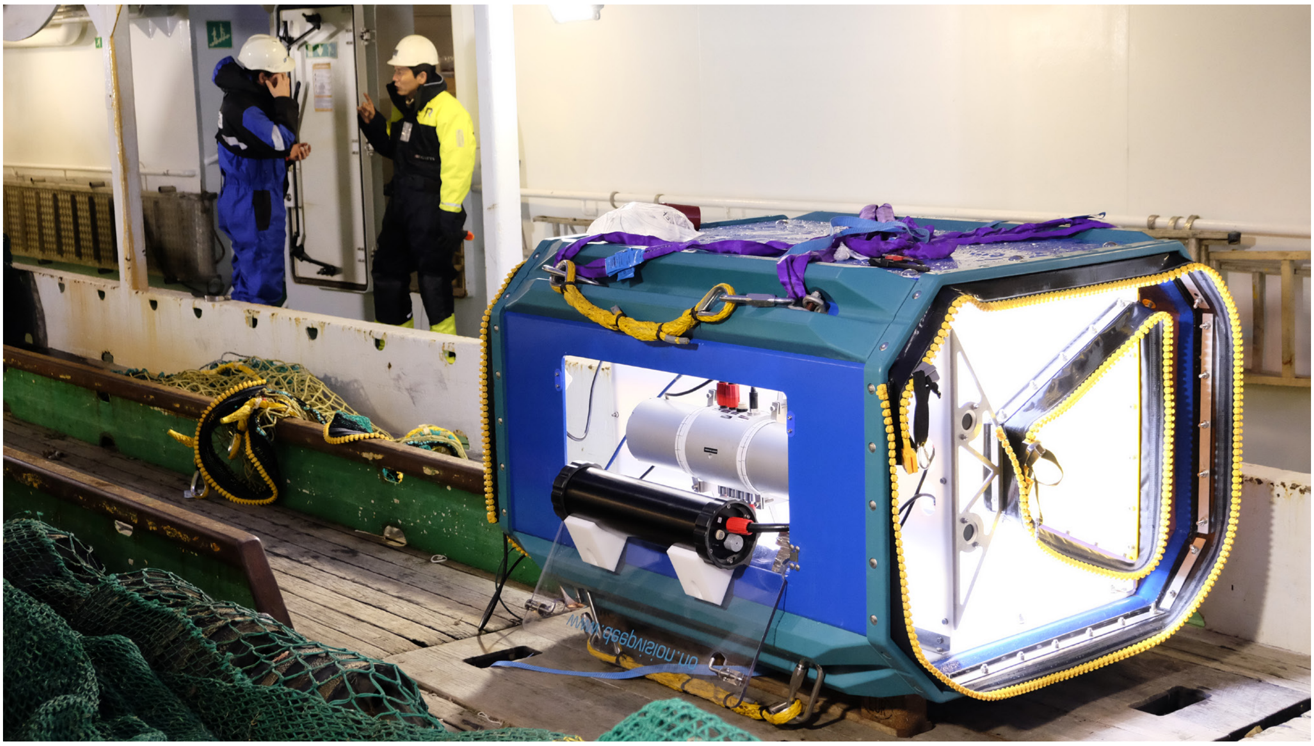


Figure 5.3.1. Deep Vision electronics and new deployment frame. Photo Tim Petter Hansen, UiB.

a series of 45 distance intervals ranging from 22-201 mm revealed a maximum error of 4.5 mm when calculating the distances from images, with 51% of Deep Vision images within 1 mm of the actual distances.

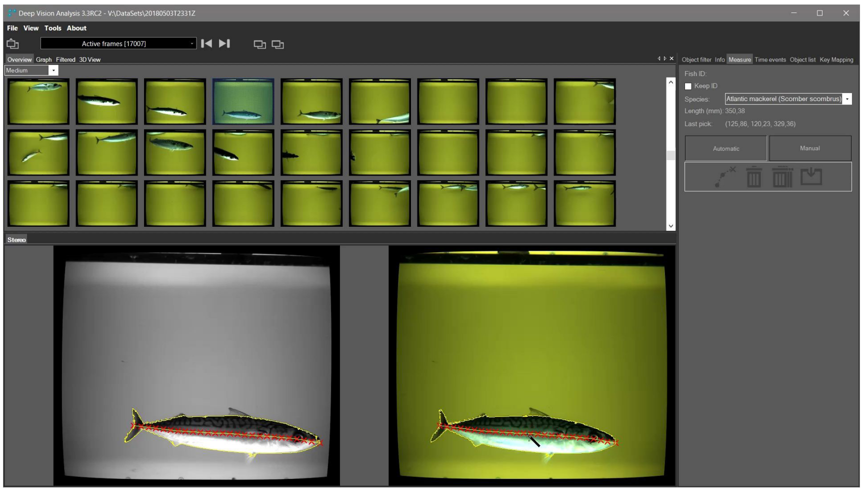


Figure 5.3.2. Example of automatic segmentation, object matching in left and right images, and calculation of length. In this example, the midline of the selected Atlantic mackerel (Scomber scombrus) is generated as a series of 25 segments, with a total length of 350 mm. Image courtesy Girona Vision Research SL.

CRISP cruise June 2018, Bergen

The second Deep Vision-focused CRISP cruise concentrated on rigging and testing the new Deep Vision frame and testing a motor and control system for an active sorting mechanism. The motor raised and lowered a large steel grid which partially closed off the codend behind the Deep Vision frame.

While the actual sorting mechanism tested is unlikely to be the solution ultimately implemented, it provided a setup for testing the motor inside a trawl and demonstrated that the motor was capable of generating several hundred kg of force during operation.

Figure 5.3.3. Kristoffer Løvall and Håkon Valland (Scantrol Deep Vision) adjust camera focus during calibration of the Deep Vision system in a new purpose-built calibration tank. Photo Shale Rosen

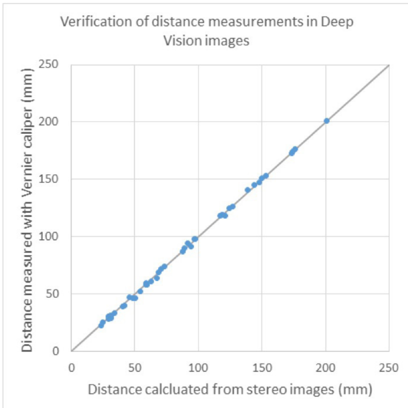


Figure 5.3.4. Distances measured from Deep Vision images (x-axis) match well with physical measurements made using Vernier caliper. Grey line is expected 1:1 relationship. Fifty-one percent of values were accurate within 1 mm, maximum error was an underestimate by 4.5 mm over a 50 mm interval.

CRISP cruise October 2018

During a CRISP-sponsored cruise in the Barents Sea (RV "G.O. Sars"), the Deep Vision frame system was tested in full-scale in both pelagic and demersal trawls. Small adjustments were made to the attachment between the Deep Vision frame and leading panels in order to ensure tension was transferred through the laces, buoyancy was adjusted to keep the frame level and minor modifications were made to the access hatch to the electronics compartment to ensure it remained latched during trawling in open seas. Tests of the acoustic communication system were unsuccessful, due to incorrect internal wiring in the Deep Vision Camera Unit which could not be repaired at sea. Deep Vision trials in the demersal trawl were disappointing, with poor visibility and the accumulation of several hundred kg of cobbles, gravel and mud ahead of the Deep Vision system. This despite the addition of a "stone release" system ahead of the Deep Vision. As visibility was insufficient to use Deep Vision data for species identification and length measurement, Deep Vision was removed from

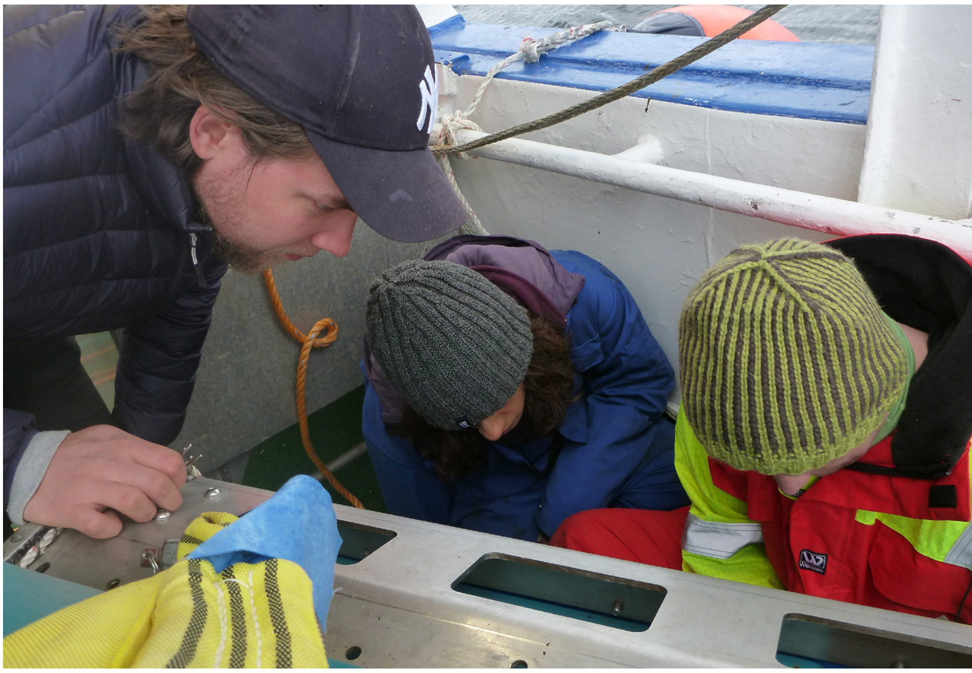
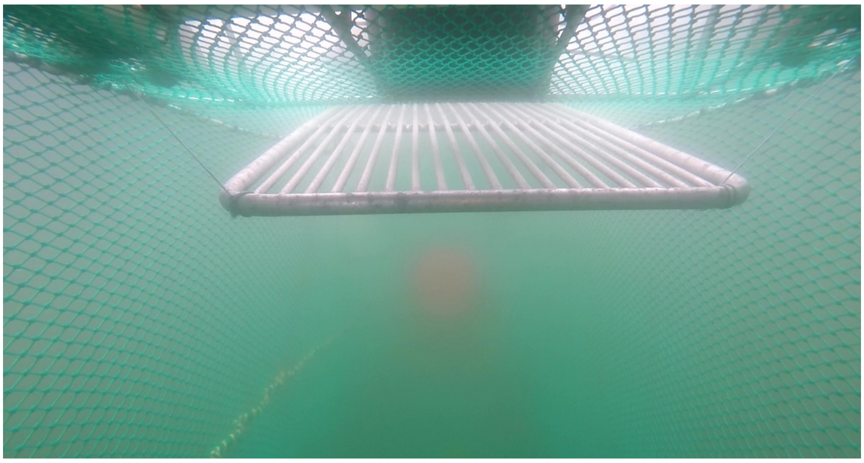


Figure 5.3.5. Preparations for April 2018 Deep Vision CRISP cruise. Guest researcher Monika Szynaka (Universidade do Algarve, Portugal) assists with rigging the Deep Vision (left). Kristoffer Løvall (Scantrol Deep Vision) instructs IMR researchers Vaneeda Allken and Sindre Vatnehol in operation of the Deep Vision camera system. Photos Shale Rosen



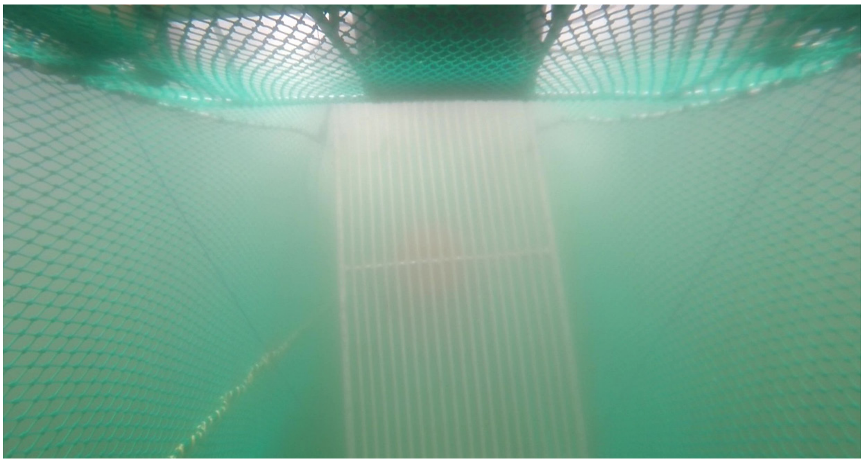


Figure 5.3.6. Prototype sorting mechanism. Håvard Vagstøl (Scantrol Deep Vision) adjusts motor before system is loaded on board FV "Fangst" for testing (left). Opening to release fish is visible in lower right corner of image. Sorting mechanism in "capture" position (upper right) and "release" position (lower right). Photos Liz Kvalvik.

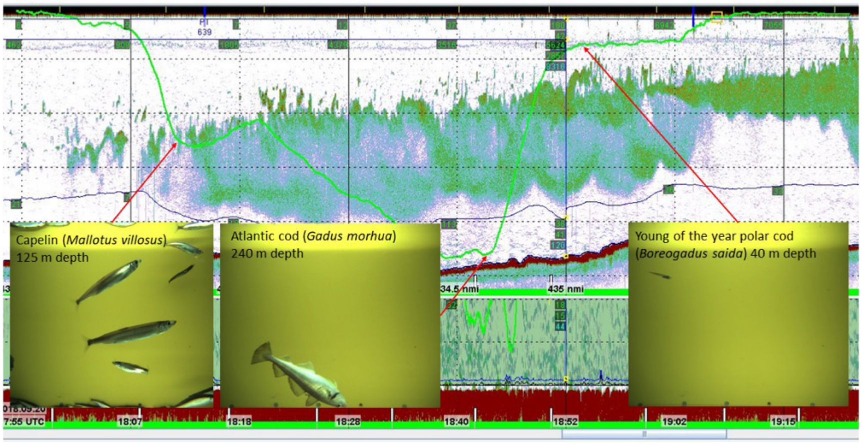


Figure 5.3.7. Composite image showing Deep Vision data (fish images) integrated with acoustic data in LSSS (Large Scale Survey System) software used to analyze acoustic data from the annual Barents Sea ecosystem survey. Deep Vision images confirm that capelin were present in a layer below young-of-the-year polar cod and above adult cod. Image Shale Rosen

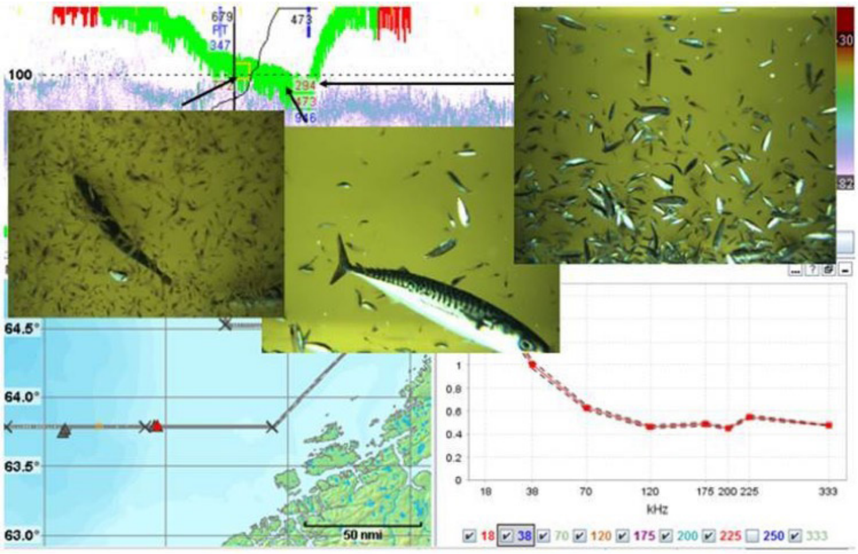


Figure 5.3.8. Composite image showing Deep Vision data (fish images) integrated with acoustic from the annual Norwegian Sea ecosystem survey. Leftmost Deep Vision image shows two Atlantic mackerel and one pearlside, Maurolicus muelleri, in a dense concentration of krill. Center image is mackerel and pearlsides, right image dense concentrations of pearlsides. Image Shale Rosen

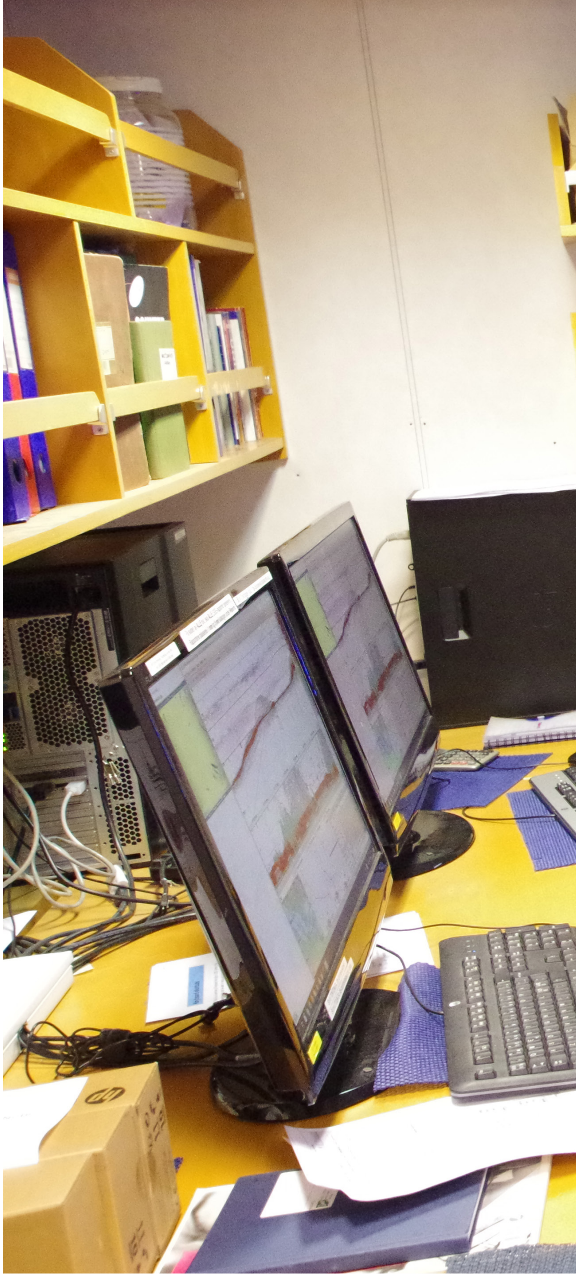


Figure 5.3.10. Students and researchers from the University of Bergen, University of Western Cape (South Africa) and Department of Agriculture, Forestry and Fisheries (South Africa) receive training in the use of Deep Vision technology during acoustic surveys onboard IMR's research vessel "Kristine Bonnevie" in March 2019. Photo Shale Rosen

the demersal trawl after three hauls. It should be noted that the trawling conditions were extremely poor during the demersal trawling portion of the cruise, with the two demersal trawls used sustaining such significant damage that they had to be sent to a net loft for repairs (one trawl used for 5 hauls, the other 25 hauls).

In addition to three CRISP cruises focused on equipment development, Deep Vision was used on four «Standard» Institute of Marine Research cruises in 2018 as well as a training course in Acoustics and advanced sampling techniques for students and researchers from South Africa in March 2019. The IMR cruises covered a variety of species and topics ranging from mesopelagic species to the annual ecosystem survey of the Norwegian sea focused on herring and mackerel and a survey in the north Barents Sea focused on capelin and whether schools aggregate according to size and age.

For both the Norwegian Sea and Barents Sea ecosystem surveys, Deep Vision was operated by researchers trained in use of the system but no one from CRISP or directly involved

in development of Deep Vision was on board for the cruises. The primary use of Deep Vision in these cruises was to provide positive species identification for different scattering layers observed acoustically.

The two IMR research cruises focused on mesopelagic species provided a test of the system at depths exceeding 1000 m and confirmed that images quality was sufficient to differentiate between small mesopelagic species.

During the Acoustics and advanced sampling techniques training course, Students from the University of Bergen (Norway), University of Western Cape (South Africa) and researchers from the Department of Agriculture, Forestry and Fisheries (South Africa) received training in how to collect data with the Deep Vision system and use the images while interpreting acoustic data.

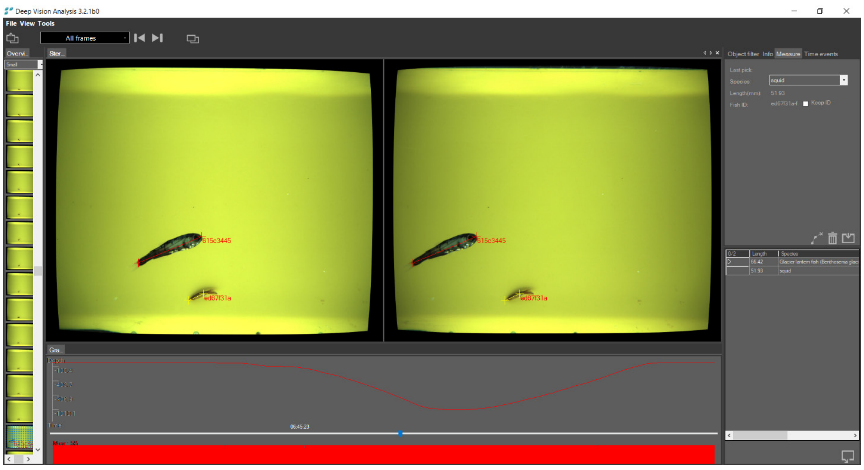


Figure 5.3.9. Example Deep Vision image from 800 m depth during an IMR mesopelagic cruise. Upper object is a glacier lantern fish (Benthosema glaciale), with length of 66 mm, lower object is a squid measured at 52 mm mantle length. Image Shale Rosen

5.4 LOW-IMPACT TRAWLING

BACKGROUND

The current trawling practice is regarded as unsustainable. It may be harmful to the seabed, have high bycatch rates and high fuel consumption that can affect the environment. The future of trawling will thus largely depend on the development of trawling techniques that significantly reduce these nega-tive impacts. Part of this this work-package addresses the design, rigging and ope-ration of trawl gears that might achieve such objectives.

Semi-pelagic trawling, i.e. towing with the doors off and the trawl on the seabed, has the potential for reducing bottom impact. Positioning of the two trawl doors in equal heights above the bottom is to maintain geometry of the trawl system and thus the catchability when fishing with a semi-pelagic tra-wling technique. Trawl doors where the horizontal and vertical spread forces can be adjusted by opening and closing hat-ches in the doors was developed during the first years of CRISP, but because a robust system for communication from the bridge to the regulation unit on the doors is still lacking, the system has not been commercialized.

Semi-pelagic trawling will only be econ-omically viable if the catching efficiency is close to traditional bottom trawling. It has been commonly believed that the sand clouds from the doors while towed at bottom are important stimuli for her-ding the fish towards the trawl opening and therefor important in order to main-tain catch rates. However, the difference in fishing efficiency with doors on and off bot-tom has yet to be fully docu-mented. Therefore, comparative fishing trials were conducted in 2017 and 2018.

The stock assessment estimates for mackerel in the Norwegian sea is partly based on swept-area estimates from tra-wling with the MultPelt trawl during the annual mackerel/ ecosystem survey in July and August each year. The MultPelt trawl is a pelagic trawl with an opening height of about 30 m, which is towed with the headline in the surface, thus covering in the upper 30 m of the water column. It is assumed that all mackerel are distributed in this upper layer. However, the fishing industry claims that this is not always the case. In 2018, CRISP (Egersund Group and IMR) in cooperation with the responsible for the mackerel stock assessment at IMR started an investigation to find possible methods suita-ble for documenting the distribution of mackerel relative to the MultPelt trawl during the surveys.

ACTIVITIES AND RESULTS

SEMI-PELAGIC TRAWLING

Comparative fishing trials with a Cam-pelen 1800 trawl (the standard survey trawl at the IMR) fished with bottom and semi-pelagic rigging (trawl and part of the sweeps on the bottom, doors off) was carried out in November 2018 on board the RV «G. O. Sars». The fishing experiments were made off the coast of Finnmark, at the Nysleppen and Nygrunnen fishing banks. The two alternate hauls of each pair were taken along the same trajectory and in the same towing direction. The vessel's Thyborøn semi-pelagic trawl doors were used. When trawl doors are lifted off

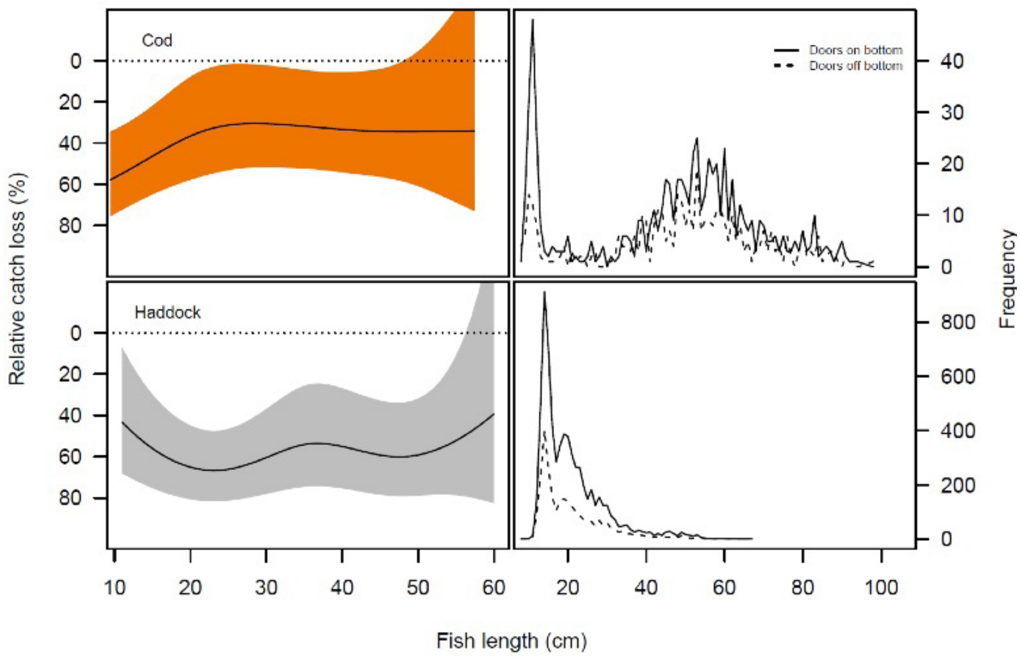


Figure 5.4.1. Left panel: Modelled relative catch loss by fish length for cod (upper) and haddock (lower) when fishing with semi-pelagic rigging as compared to bottom rigging. Right panel: Length frequency distribution for the pooled catch in the eight valid haul pairs.

bottom during semi-pelagic trawling, the foremost part of the sweeps are also lifted. In addition, the door-spread is reduced. This makes it difficult to separate the effects of changed sweep angle, reduced bottom contact for the sweeps and door bottom contact. The present study therefore aimed at keeping sweep angles and the length of the sweeps in contact with the bottom the same for the bottom and semi-pelagic hauls.

The length of the sweeps that had bottom contact was verified by the use of chain and tape which indicated seabed contact through wear while a new type of geometry sensor developed by Simrad as part of activities in WP 3.2 was used to monitor sweep angle. It was concluded that comparable sweep geometry and contact was achieved when using a sweep length of 100 m when bottom trawling and 160 m when trawling semi-pelagically. In addition, a 12 m long constraining rope was used on the warps 200 m in front of the doors. Simrad sensors were used to monitor door height as well as pitch and roll. Previous studies had shown it difficult to maintain the doors in a stable position close to the seabed (i.e. < 5 m) with no other means to control the door height than the towing speed and warp length. The targeted door height above sea bottom during semi-pelagic trawling was therefore set at 10 m.

Catch rates of commercial sized fish was generally low during the experiment, particularly for haddock (Figure 5.4.1, bottom right panel). Analysis of the catch data shows reduced catches of both cod and haddock for the semipelagic compared to standard demersal rigging. For cod the catch loss was 35-40% with no significant relation to fish size (Figure 5.4.1, top left panel). For haddock, the relative catch loss was estimated at approximately 60%. Also, for haddock, the effect of fish size on catch loss was insignificant (Figure 5.4.1, bottom left panel).

As the sweep angles and length of the sweeps that had bottom contact were identical for the bottom and semipelagic rigging, the horizontal sweep-distance at the point of foremost bottom contact was the same with the doors on (= door spread) and off bottom. The present study thus suggests that the herding stimuli generated by trawl doors at (or possibly close to) the bottom are essential for the catching cod and haddock.

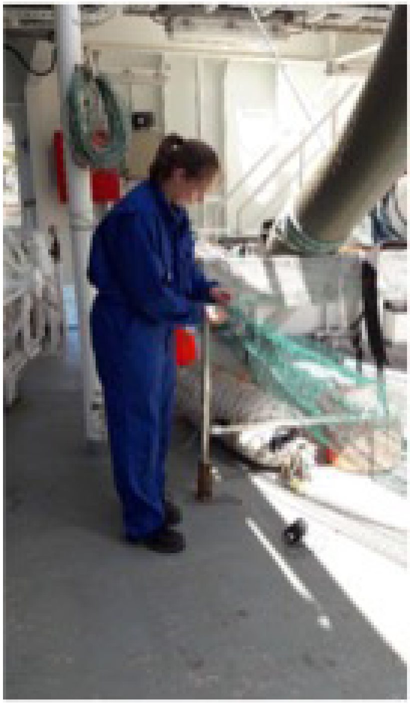


Figure 5.4.2. Wenche Vigrestad and Arvid Sæstad from Egersund Group AS working with the trawl on board FV "Vendla" in June 2018 (Photo IMR).

IMPROVING THE QUALITY OF THE PELAGIC TRAWL SURVEY FOR NE ATLANTIC MACKEREL

In the end of June 2018, one week prior to the annual mackerel/ ecosystem survey, one of the pelagic vessels hired for the survey (FV "Vendla") was dedicated to test different methods to map the mackerel distribution relative to the MultPelt trawl off the coast of western Norway. The mackerel distribution was attempted observed using the Simrad WBAT and WBT Tube with CS200-7DK echo sounders. In addition, acoustic data of mackerel distribution was also collected continually with Simrad EK60 and with Simrad SN90 multibeam sonar onboard the vessel. Attempts were also made with FOCUS equipped with WBT Tube with transducer to map mackerel distribution before trawling. The data are not yet fully analysed. However, it is doubtful whether the WBAT with a transducer with such a narrow beam is well suited for detecting mackerel under the trawl. Probably there will be a need for instruments with faster ping rate and wider beam / many rays to get better records of mackerel distributed in thin shoals and to cover a wider area.

In addition, different aspects of the functionality of the MultPelt trawl was tested and adjusted in preparation for the assessment work. This included observation of trawl geometry relative to rigging of warp length, door spread, opening height etc; functionality of the fish lock and kites; comparison of the standard codend with a codend constructed of netting with T90 meshes; and shortening of the trawl extension. Also a few trawl hauls were carried out at two different depths (0-30 m and 30-60 m) in order get an indication of mackerel presence deeper than 30 m, but the data is too limited to draw any firm conclusion.

These experiments must be considered as a preliminary search for possible future methods to improve the accuracy of the trawl indices for mackerel in the Norwegian Sea.

5.5 Quality improvement

Background

The quality of the catch from trawlers are influenced by various abiotic factors such as fishing depth, water temperature and season and biotic factors such as fish species and fish condition. In addition will catching methods and processing practices strongly influence the final quality of the catch.

During trawling, fish become stressed through exercise, interactions with fishing gear and crowding in the cod-end. As catches are dropped on deck and exposed to air, light and temperature differences, fish are exposed to cumulative stress as well as potential bruising and death by asphyxiation. There is increasing evidence suggesting that pre-mortem stress is of great importance to muscle quality of fish, and this may explain why the catches from trawl fisheries have variable quality.

Cod and other gadoids have a physoclist swim bladder, resulting in its expansion during haul-back until the critical limit where the swim bladder ruptures. Theoretically, this is achieved at approximately 70 % reduction in the ambient pressure. Due to the lack of space, the expansion of the swim bladder is believed to increase the frequency of pressure related injuries, with subsequent negative impact on the catch quality, especially during "buffer towing".

WP 5 aims to improve catch control and quality of trawled fish by documenting the effect various trawl components, such as codend and excessive fish exclusion devices (ExFED-system), have on the fish and by altering these components to optimise the method for bringing the catch on board.

Activities and results

In WP 5.1 a dual sequential codend was tested on a cruise onboard FV "Bergvoll" (Nergård AS), demonstrated a significant improved in the catch quality. The catches in the sequential codend contained significant fewer and less severe damages such as poor exsanguination, ecchymosis, gear damages and skin abrasion. Compared to the conventional codend, the new codend had five times higher probability of retaining cod with no catch damages at all. Due to the design of the sequential codend it was possible that the design would retain more undersized cod compared to the conventional codend. This concern was investigated on a cruise in March 2018 onboard the University of Tromsø's RV "Helmer Hanssen". The results demonstrated that considering the difference in relative size selectivity the sequential codend retained significantly more undersized cod. However, investigating the catch patterns and the total size selectivity between the trawls with the sequential codend and the conventional codend demonstrated no significant difference. The results from the two cruises are published in a scientific paper in Canadian Journal of Fisheries and Aquatic Sciences and PlosOne.

Currently (March 2019) a new idea based on the results with the sequential codend is tested onboard the RV "Helmer Hanssen". The quality improving codend was towed open during the entire rowing phase with a large meshed (155 mm) codend with 30 % shrunk lastridges in front. The shrunk lastridges results in open meshes and would possibly be sufficient for the release of undersized fish so that no sorting grid is needed. The idea was to

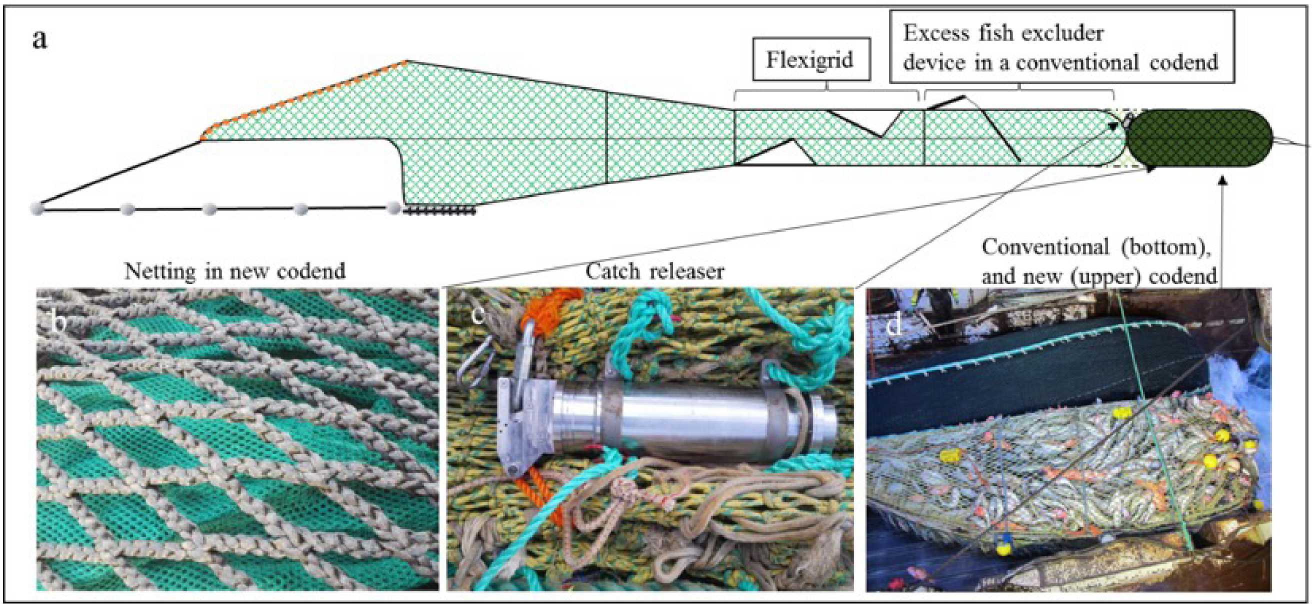


Figure 5.5.1. The setup of the trawls (a), the aft part shows the section with a Flexigrid, followed by an excess fish excluder device in the first codend segment, equivalent to a conventional codend. A second codend segment with quality-improving attributes was attached after the size-selective codend segment and kept closed during fishing with the catch releaser. (b) The netting in the quality-conserving codend segment. (c) The catch release mechanism. (d) The conventional codend trawl beside the trawl with the quality-conserving codend.

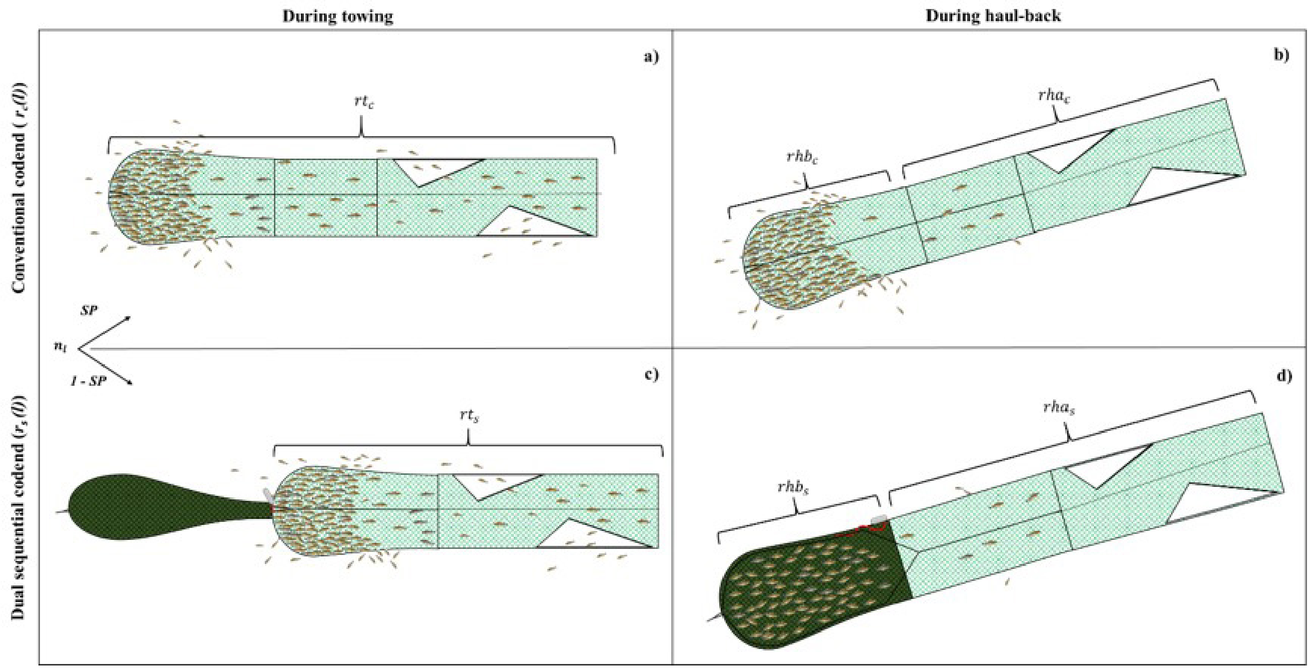


Figure 5.5.2. Schematics showing the size selectivity that occurs with the conventional codend (rc(l)) during (a) towing and (b) haul-back. (c) Size selection in the anterior codend segment of the dual sequential codend during towing, which, due to the codend design, (d) should cease during haul-back when the fish enter the posterior quality-improving codend segment. (The sections are not scaled according to each other).

cause a "bucket effect" due to the small mesh size in the improving codend segment, which would cause the fish to stop in the codend with the large mesh size and shrunk lastridges. After a while the fish would fall back into the second codend segment ensuring improved catch quality. The experiments are currently conducted, and the data has not yet been analyzed.

In WP 5.2 the work related to the experimental swim tunnel (trawl simulator) was finished in December 2018. Two of the studies done using the swim tunnel looked into how the herding of fish in front of the trawl mouth potentially affected the level of stressors and quality of cod and haddock; the first involved exhaustive swimming of cod and the

Figure 5.5.3. The conventional codend with the excessive fish excluder device and a flexi-grid section in front (left), and the dual sequential codend (right).

Figure 5.5.4. A catch in the dual sequential codend (left), and in the conventional codend (right).

second focused on critical swimming speed of haddock. These studies showed that exhaustive swimming causes a moderate stress response, recovery takes longer than 6 hours and that exercise has a short-lasting effect on muscle texture, with little or no effect on muscle coloration. It was concluded that other stages of trawl capture have a higher impact on fillet quality. The results from these two studies are published in Fisheries Research. As a follow up to the results from the swimming trials, a third study was done to investigate how extreme crowding for 1 or 3 hours in the codend, following exhaustive swimming, would affect the physiology and muscle quality of cod. Findings from this study showed that crowding caused a severe stress response and that fish probably suffered from hypoxia due to a significantly reduced ability to move their opercula. In addition, fillet quality was significantly reduced due to increased amount of residual blood in the muscles. Moreover, the detrimental effects of crowding are not fully reversed after 6 hours of recuperation.

The final work from WP 5.2. aimed to study the last stage of trawl capture process, i.e. simulating the effect of air exposure on deck. Fish were stressed by mild crowding and then exposed to air for 15 or 30 minutes, or directly euthanized by terminal blow to the head and then left in air for 0, 15 or 30 minutes before exsanguination. We found that stress/crowding triggered a stronger response to the air exposure by faster increase in residual blood in the muscles, resulting in lower fillet quality. However, direct euthanasia stopped blood flow to the muscle and quality was significantly improved. The results from this study is published in Food Bioscience.

The work shows that there is a strong connection between the type of stress inflicted on the fish during capture and the quality of the fish product (fillets). Measures that may secure top quality fish from trawlers, include reducing crowding time in the cod-end and implementing direct euthanasia or live recuperation for more than 6 hours. Results from the experiment trials are published in the PhD-thesis of Ragnhild Svalheim, who defended her dissertation in December 2018, , and also in the thesis of Jesse Brinkhof who delivered his work late 2018 and will defend his work in February 2019.

5.6 Value adding

Background

Harvesting wild fish resources depends on several factors, like migration pattern of the target species and the harvesting technology chosen. This work package focuses on how the technological improvements developed in CRISP will contribute to value adding and environmental friendliness among trawlers and purse seiners.

Activities

A framework for cost-benefit analysis is developed in CRISP (Figure 5.6.1), which is relevant when estimating the potential economic premium of the technological improvements achieved. The framework is based on analysis of the economic performance of the trawlers and purse seiners, in addition to work on quality as carried out in WP1-5. As illustrated in Figure 5.6.1, the mapping phase was the starting point, where the potential costs and benefits were studied, in addition to the management regime. Some of the costs and benefits are easy to quantify. However, to quantify the further costs and benefits of new technology developed is a more complicated issue.

In order to study how the technological improvements developed in CRISP will contribute to value adding, an overview of the modified and developed technologies in the project is updated during the program.

STRUCTURAL CHANGES

During the program we analyse the structural development, catches, financial performance and fuel consumption among the trawlers and purse seiners. Several new vessels are introduced in both vessel groups during the program. We address how the new vessels perform, in terms of both value adding and environmental friendliness.

Changes in the governance tools for both vessel groups are addressed. The management regime may influence the ability to utilize the technology developed, and to have a significant impact on such implementation and the reduction of environmental footprints. Both improved technology and changes in the management regime may reduce the environmental impacts from the fleet. Therefore, the number of allowed licenses on each vessel and fuel consumption within the fleet are studied.

The illustrations show a substantial reduction in the number of vessels in both vessel groups during the period. The structuring of the cod trawler fleet is, however, more prominent than in the purse seiner fleet, where the reduction in number of trawlers is 62 percent and 22 percent for the purse seiners. This is reflected by the share of structural quotas in the vessel groups' total quotas, which in the case of cod trawlers' cod quota is 62 percent, while for purse seiners' quota for spring spawning herring is 20 percent.

The middle graphs show the development in average age of the vessels in the two vessel groups. It shows, for the cod trawlers that the vast reduction in number of vessels from 2002-2010 was

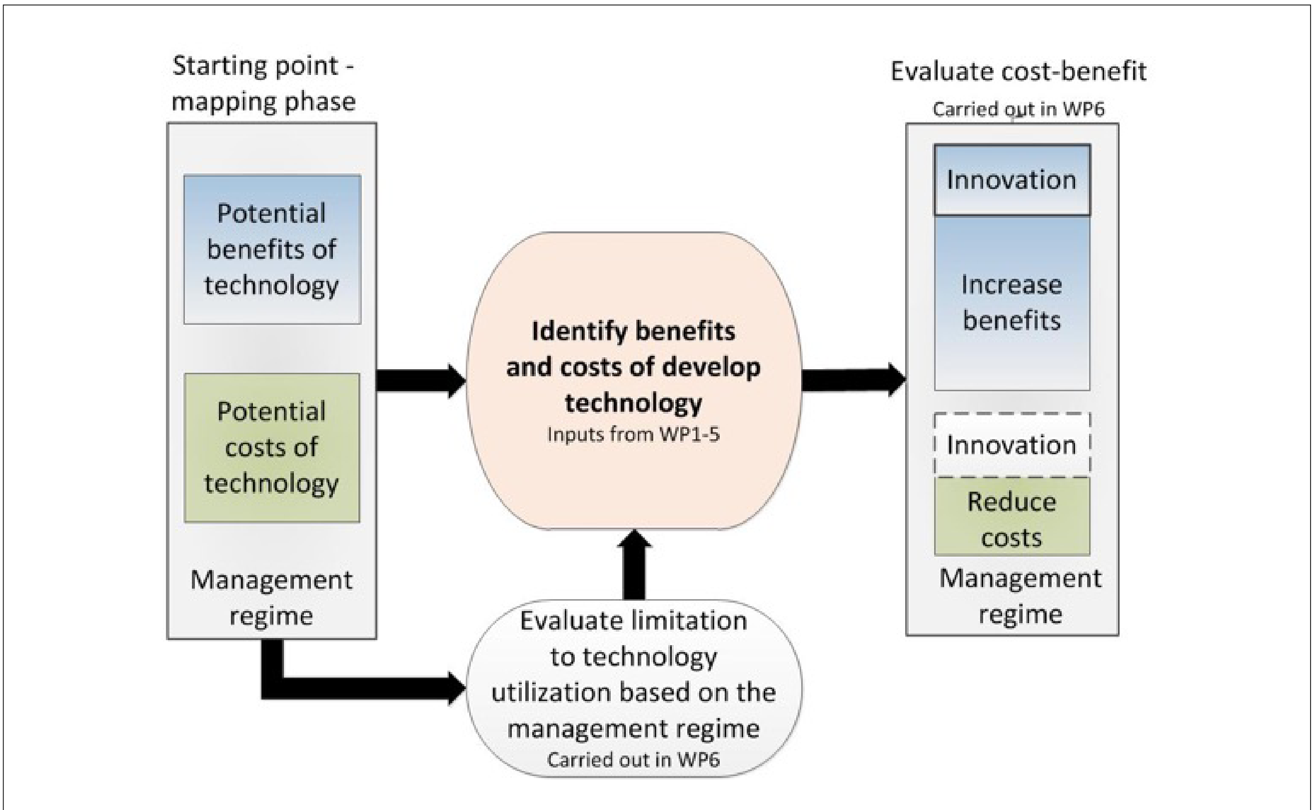


Figure 5.6.1. Framework for cost-benefit analysis for evaluating the impact of developed technology in CRISP.

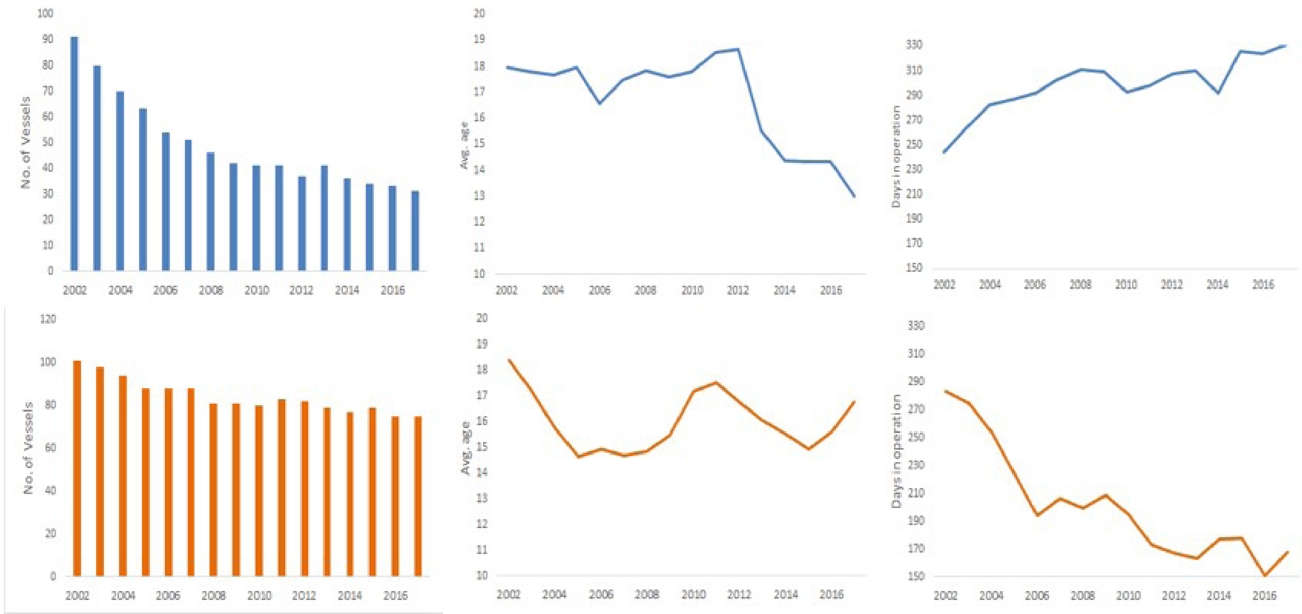


Figure 5.6.2. development in number of vessels, average age and days in operation for cod trawlers (in blue – upper) and purse seiners (in orange – lower) for the period 2002–2017

not enough for reducing the age of the fleet. As several new vessels where introduced to the fleet in 2013-2014, replacing older vessels, the average age fell substantially. It should be noted that without entries or exits in the groups, the age would increase linearly over the period adding 12 years to the average age. In 2016-2017 we observe an increase the average age, heavily influenced by an exit of one of the new vessels introduced in 2014. Moreover, the average age can serve as a proxy to technological development and reflects the profitability of the fleet. For the purse seiner fleet, we see that the average age of the fleet decreases considerably after 2010.

The illustrations to the right show the development in average operative days in the vessel groups. While the cod trawlers have become busier over the years – increasing their activity from 240 to 330 days a year – the opposite is the case for the purse seiners, who are active less than half of the year. The explanations behind these figures are partly the level of structuring within these groups, the development in quotas, and renewal of the fleet. Newer vessels are in general more effective, structuring implies larger quotas per vessel, while larger quotas demand higher activity.

Below the Norwegian catches of cod, saithe and haddock are portrayed together with the catches of herring, blue whiting, mackerel and capelin in the period.

The species portrayed in the figures to the left are those most important for the cod trawlers, whereas those to the right are the most important for the purse seiners, and they are allotted substantial shares of the national TAC's.

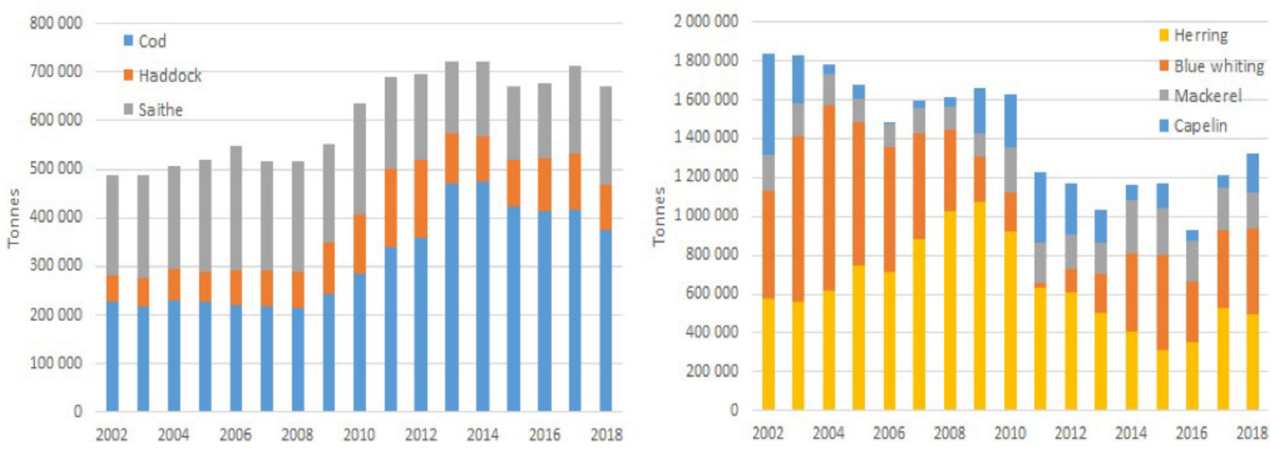


Figure 5.6.3. Annual Norwegian catches of cod, saithe and haddock (left) and herring, blue whiting, mackerel and capelin (right) in the period 2002-2017

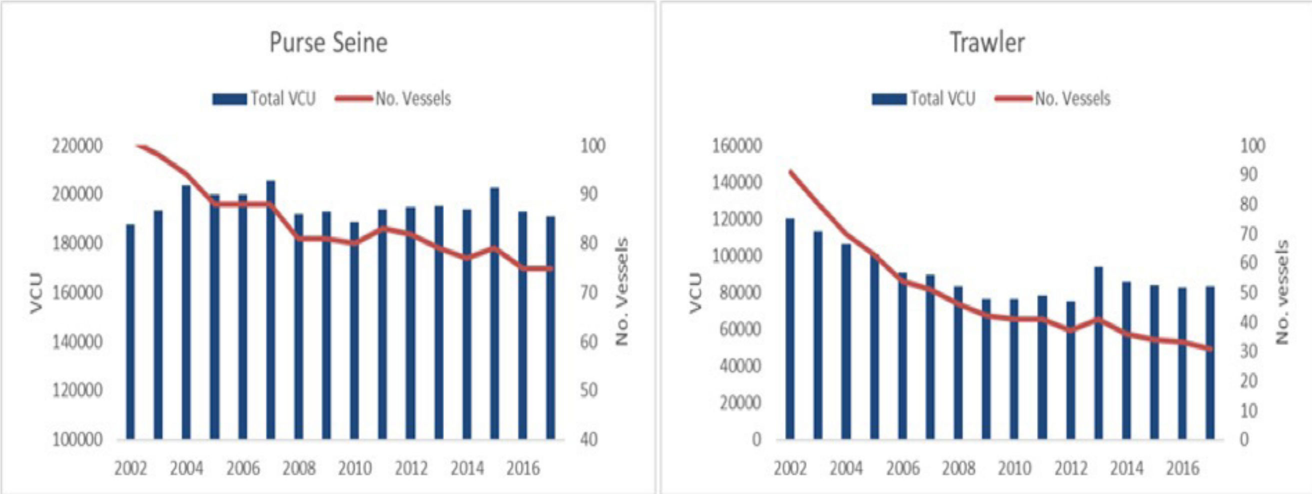


Figure 5.6.4 changes in VCU and Number of vessels in the trawl and purse seine fleet from 2002 to 2017

Capacity and structural differences in trawl and purse seine

The last decade has brought changes in both the Norwegian trawl fleet and purse seine fleet, due to new managerial regimes aiming to achieve improved sustainability in the fisheries, i.e. environmental, economic, social and institutional dimensions of sustainability. As shown in figure 5.6.2, the recent development in number of vessels in the two groups in question is quite different. Whilst the number of trawlers has steadily decreased over the last fifteen years, the change in number of purse seiners are almost negligible. However, several new vessels have been introduced in both groups, as illustrated by the average age (se figure 5.6.2). Indicating that both new technology and increased onboard capacity have been included to the fleet. It is striking that number of days of operation in the two groups show a remarkable difference. Whereas the purse seiners are operative less than half the year, the trawlers capacity are almost fully exploited.

In figure 5.6.3, the total amount of the most important species for both vessel groups are accounted for, indicating that development of days at sea cannot be explained by increase in quotas. In figure 5.6.4 we demonstrate that, although a significant drop in number of vessels, vessel capacity unit (VCU) have not dropped. Accordingly, the new vessels entering have far greater VCU than the ones exiting. In the purse seine fleet, this structural change has led to more efficiency in terms of days at sea, i.e. higher volumes landed. This has also been the case for the trawlers. However, the days at sea indicate that they are at sea for a longer period in order to fill the vessel. Having in mind the development of number of vessels, VCU and days at sea among the trawlers indicate a drop in CPUE from 2015 and onward. CRISP, and other studies, have revealed a relationship between CPUE and fuel consumption. Indicating increased fuel consumption among trawlers in this period. For the purse seiners, however, CPUE seems to have increased in the same period, indicating drop in fuel consumption.

Crisp and quality-Based waste

In order to develop a sustainable fishery, the authorities have given priority to create an economical (non-substituted) and environmentally friendly (sustainable stocks and lower CO2 emissions) fleet. This has been very successful. Today Norway is maintaining some of the most ecofriendly fisheries, with species thriving at a beneficial level and the actors involved are profitable. Lately, reducing quality-based waste has become an important aim. Results from studies indicate a strong relationship between large haul and quality-based waste among both trawlers and purse seiners.

To reduce such waste in the two vessels groups, new technology that helps reducing large quality damaging hauls is essential and have been given priority in CRISP. A closer look at the overview of technology developed in CRISP (see list below) reveals this in all work packages. In WP1, we find new technology that helps in pre-catch identification of quantity, size distribution and specie composition that is essential in avoiding too large haul. Looking closer into the technology developed in WP2 and WP3, we see instruments that improve the knowledge on catch volumes and the welfare of the fish in the catch operation. Even technology that helps to release the fish before it is lethally damage in situations with too much fish in trawl and seine has been developed in CRISP. To reduce quality-based waste, sonars that are more accurate can help skippers to make better judgements about where to fish and avoid too large hauls. With video and live footage, it is possible in the future to accurate asses the size of the single fish below and release them even before they are in the net. The list also indicates that knowledge developed in CRISP has also led to instruments, and process lines onboard that will help reducing quality-based waste both onboard trawlers and seiners (see WP5). In WP 5 development and implementation of sequential codend and hydrostatic catch releaser/ codend opener have proven to reduce quality problems reported on large hauls.

6. Technology developed - overview

During the program, several technologies have been developed/modified in CRISP. The below listed technologies are at various stages of development. Some of the technologies are for scientific use, whereas others have potential commercial value. It is assumed that these technologies will contribute to value adding in different ways, e.g. by improving quality of the fish, lower costs (reduction of fuel consumption), increasing catch efficiency, decreasing amount of bycatch and reducing environmental impact of fishing.

WP1 - PRE-CATCH IDENTIFICATION OF QUANTITY, SIZE DISTRIBUTION AND SPECIES COMPOSITION

1. Acoustic methods: Development of sonars and echo sounders for measuring quantity, species and size of a school prior to catching. Verification catches on three species: herring, mackerel and capelin.

2. Calibration of the fisheries sonars: Development of equipment and procedures to calibrate the fisheries sonars with an accuracy of 2-3 % for the Simrad SU90 and Simrad SN90 sonars.

3. Echo sounder system: Development of a new broad band echo sounder system and methods to measure the size of individual fish inside a school (Simrad EK80 and Dabgraf projects)

4. Development of methods for measuring Target strength of single targets in situ in lateral aspect for converting backscattering measured by sonar to biomass. (Probe and WBAT measurements).

5. Development of methods to correct for acoustic extinction (shadowing) in large herring and capelin schools.

WP2 - GEAR AND CATCH MONITORING SYSTEMS IN PURSE SEINE

6. Transponders: Development of transponders that may be attached to the seine during fishing, which may be used to visualize the net geometry of the seine on the sonar screen in the wheelhouse.

7. Sonar: Development of a new sonar, Simrad SN90, for use inside a seine

8. Catch Monitoring Probe: development of technology and protocols for monitoring the behaviour and welfare of fish during capture in purse-seines, incorporating 360 camera, stereo-camera and oxygen/temperature sensors.

WP3 - METHODS FOR CAPTURE MONITORING AND CATCH CONTROL DURING TRAWLING

9. Operationalized Deep Vision in-trawl camera system: Development of in-trawl camera system for species identification and sizing of fish

10. Simrad FX Integrated information system: Development of information system to stream live video, trawl sonar and echo sounder information from the trawl to the bridge

11. Simrad PX MultiSensor trawl door sensor and TVI topside interface

WP4 - LOW IMPACT TRAWL

12. Trawl doors: Developed trawl doors, which can adjust the spread and position in the water column.

13. Catch regulation device: Developed and implemented a catch regulation device for trawls that releases excess fish at fishing depth

WP5 - QUALITY IMPROVEMENT

14. CRISP trawl simulator: Developed as a scientific tool to simulate trawling conditions in small scale, which `produce trawl-caught fish in the laboratory`.

15. Live fish technology: Development of knowledge and a prototype tank for live storage of cod on board trawlers

16. Vacuum pumping from cod-end: Test vacuum pumping onboard a commercial trawler to improve the landing of fish from the cod-end

17. Stunning and bleeding machines: Tested a modified stunning and bleeding machine (Baader- SI7) on a commercial fishing vessel

18. Sequential codend: Development of a new codend concept, designed to improve the quality of fish without compromising size selectivity.

19. Hydrostatic catch releaser: Development of a hydrostatic catch releaser, which opens the entrance of the quality improving codend segment of the sequential codend during haul-back. Also tested/applied in demersal seines.

7. International cooperation

CRISP has cooperated with international research institutions when such cooperation has been beneficial for joint development and introduction of sustainable fishing technology outside Norway. The industry partners in CRISP are all Norwegian owned, and all have their production activities based in Norway. They are therefore reluctant to involve foreign partners that can share knowledge of product development with foreign potential industry competitors.

It is, however, important to disseminate the main CRISP philosophy (profitable fisheries and supply industries through development of technology for responsible fishing) and CRISP technology to the world community. This has been done by CRISP staff participating in scientific meetings and symposia, but also through the wide international network of the members of our Scientific Advisory Committee.

There is a great international interest in sonar technology developed in CRISP. As in 2017, researchers from a range of nations participated in a training course onboard the RV "G.O.Sars" in acoustic volume measurement with broadband sonars developed under the auspices of CRISP. Also, scientist Hector Pena was invited to give courses in use of sonar technology developed in CRISP at INIDEP, Argentine and NOAA, San Diego, USA (Figure 7.1).

Several researchers connected to CRISP have had key roles in the Horizon 2020 project MINOUW: Science, Technology, and Society Initiative to Minimize Unwanted Catches (Grant Agreement number: 634495 - MINOUW - H2020-SFS-2014-2015). This project aims at gradually eliminating discards in European fisheries. Equipment and instruments developed under the CRISP umbrella, including Deep Vision and gentle-release purse seine technology, are used as methods to reach the goal of reducing bycatch and discards in European fisheries. In 2018 a simplified version of Deep Vision was tested on board a Greek trawler under the auspices of the MINOUW project.

The Deep Vision technology has aroused great interest worldwide. Scantrol Deep Vision AS has had an extensive cooperation with University of Girona, which resulted in the generation of a common software-company with one person employed. The National Institute of Fisheries Science, Korea, has purchased the Deep Vision system for use in stock assessment. Therefore, scientist Pyungkwan Kim from The National Institute of Fisheries Science, Korea, participated in a 14-days CRISP-cruise on board RV

Figure 7.1. Hector Pena giving a training course in use of sonar technology in San Diego, California (Photo Hector Pena).

Figure 7.2. Scientist Pyungkwan Kim from The National Institute of Fisheries Science, Korea, studying the Deep Vision underwater monitoring system at RV "G.O.Sars" late autumn 2018 (Photo Tim Petter Hansen).

"G.O.Sars" in October/November in order gain experience with the use of the Deep Vision technology (Figure 7.2).

CRISP participates in the INTPART project PRIMA LEARNING ("Connecting hands-on-practice and innovative marine Ecological sampling methods and analysis tools for enhancing student learning of ocean science"), led by the University of Bergen, Institute of Biology. The objective of the project is to train South-African students to highly qualified fisheries and marine biologists. CRISP staff particularly participate in the work package "Methods for capture monitoring and catch control during trawling" and contribute with theoretical and practical information on responsible harvesting and stock assessment methods. Of special interest is the use of the Deep Vision technology for stock surveillance. A course will be given in March 2019 on board RV "G.O.Sars".

CRISP researcher Shale Rosen from IMR also contributes to the Nansen Program and has participated in research cruises onboard the research vessel RV "Dr. Fridtjof Nansen". The research vessel is run by the United Nations Food and Agriculture Organization (FAO) and sails under the UN flag. The most important activity has been to implement Deep Vision technology in stock assessment, particularly for mesopelagic fish.

8. Recruitment

IN 2018 THE CRISP CENTER HOSTED SIX PHD STUDENTS:

Melanie Underwood has been employed by UiB in the period 2012-2017 and has IMR as her working place. Her project dealt with behavior of demersal fish during trawl capture (WP3 and 4). Melanie delivered her thesis in January 2018 and defended her PhD degree with success 10th of April 2018 (Figure 8.1). Melanie is now employed as PostDoc at Institute of Marine Research, Fish Capture research group, where her focus area is fishing technology for capture of mesopelagic fish species.

Figure 8.1. PhD student Melanie Underwood (right) at the defense of her thesis at University of Bergen in April 2018.

Ragnhild Aven Svalheim (Figure 8.2) has been employed as PhD student by UiT and Nofima from 2013. Her PhD project focused on how muscles of captured fish restore during the post capture phase (WP5). She finalized her project and delivered her thesis autumn

Figure 8.2. Scientist Stein Harris Olsen, Nofima, and PhD student Ragnhild Aven Svalheim investigates the quality of fish with and without restitution after simulated trawl capture. Foto: Lidunn Boge / Nofima

Figure 8.4. PhD student Neil Anders, IMR and UiB.

Figure 8.3. Ragnhild A. Svalheim celebrates successful completion of her public defense in December 2018, together with first opponent Dr. Petri Suuronen. Petri Suuronen is also a member of CRISP's Scientific Advisory Board (Photo Mike Breen).

Figure 8.5. Phd student Jesse Brinkhof, UiT.

2018 and successfully held her defense in December 12th 2018 (Figure 8.3). Ragnhild is now employed as researcher at Nofima.

Three PhD students started up their projects in 2016. The first, Neil Anders (Figure 8.4), focuses on how handling of the catch during purse seining influence the welfare and thus fish survival (if the fish is released) or meat quality (if taken on board) of mackerel. His project is a cooperation between WP2 and 5, and his team of supervisors comprises scientists both from IMR and Nofima. He aims at delivering his thesis before the end of 2019.

The second, Jesse Brinkhof (Figure 8.5), studied the consequences of different trawl innovations on catch quality (WP 4 and 5) of whitefish. Jesse is supported financially by University of Tromsø, and has supervisors from UiT, Nofima and IMR to assure successful progress in his multidisciplinary study. Jesse delivered his thesis late fall 2018 and will defend his work February 14th 2019.

The third PhD, Helene Jensen, focused on value adding caused by CRISP innovations (WP6), but unfortunately, she decided to terminate her PhD work for personal reasons.

A last PhD, Tonje K. Bjørvig, started up in 2017, is linked to CRISP thematically, working on the consequences of trawl gear innovations on fish quality, but her project is economically funded by the UiT, and not by CRISP. Her supervisors are from UiT and CRISP.

CRISP has added considerably to the recruitment of new scientists working with fishing technology. One positive aspect is that more than 50% of our recruits are females, which is a high proportion in a traditionally masculine field of science.

The former Postdoctoral researcher funded by CRISP, Shale Rosen, who was mainly working to adapt the Deep Vision system for visual fish classification for fish assessment purposes (WP3), is now employed in a permanent position as scientist at IMR, Fish Capture research group.

In 2018 one Norwegian MSc student, Kjetil G. Thorvaldsen, finished his master's degree. His project was acoustic identification of mesopelagic registrations. Also, two new international MSc students, Alexandre Jacky David Greve and Thomas Riedinger, were taken up under the CRISP umbrella in 2018, both working with fish behavior and welfare during fishing with purse seine and pelagic trawl. Their costs were covered by EU grants.

9. Communication and dissemination activities

CRISP staff has participated in several meetings and symposia in 2018, were the scientific output of the centre has been presented for international audiences, among which we will mention North Atlantic Seafood Conference, Bergen 6-9 March; ICES Working group on Fisheries, Acoustics, Science and Technology (WGFAST) in Seattle 20-23 March 2018; ICES Working group on Fishing Technology and Fish Behaviour (WGFTFB) in Hirtshals, Denmark, 4-8 June 2018; and International Institute for Fisheries Economics and Trade (IIFET) Seattle, July 2018.

Figure 9.1. Post Doc Melanie Underwood handling underwater cameras onboard RV "G.O.Sars" in November (Photo Tim Petter Hansen).

Our activities and innovations have also been promoted in several national meetings, seminars and fishing exhibitions arranged by various Norwegian hosts, including Annual Meeting of Pelagic fishermen's association and Nor-Fishing 2018, where a number of CRISP activities were presented at mini seminars arranged at the new "research square", where 8 research and innovation institutions successfully joined forces to promote research and innovation. CRISP innovations were also presented at the seminar "The best in the world – is it good enough?" hosted by Nofima at Nor-fishing 21 August 2018.

CRISP innovations were presented for a public committee looking at means for future fisheries control at The Ministry of Trade, Industry and Fisheries in November.

IMR staff publish most of their work as technical reports in the series "Nytt fra Havforskningen" ("News from IMR"), while Nofima staff publish their work in Nofima Report Series. Many CRISP highlights have been published in short communication brochures in like "Marine Research News" ("Havforskningsnytt"). A selection of scientific results was published in reviewed scientific journals. CRISP achievements have also been presented in radio and on TV news (Norwegian Broadcasting Corporation) both locally and nation-wide, as well as in newspapers and magazines like "Fiskeribladet Fiskaren" (the fisheries magazine of Norway) and internet magazines like "Intrafish", "Tekfisk" and "Forskning.no" (the news magazine of the Norwegian Research Council). Videos taken with underwater cameras to illustrate fish behaviour and performance of various devices developed in CRIPS are published on the web for viewing on YouTube.

APPENDIX 1. PERSONELL

KEY RESEARCHERS			
Name	**Institution**	**Main research area**	**Sex**
Torbjørn TOBIASSEN	Nofima	Quality improvement	M
Heidi NILSEN	Nofima	Quality improvement	F
Stein Harris OLSEN	Nofima	Quality improvement	M
Karsten HEIA	Nofima	Quality improvement	M
Bent DREYER	Nofima	Value adding	M
Kine KARLSEN	Nofima	Value adding	F
John R. ISAKSEN	Nofima	Value adding	M
Marianne SVORKEN	Nofima	Value adding	F
Arill ENGÅS	IMR	Low impact trawling/Instrumentation M	
Shale ROSEN	IMR	Low impact trawling/Instrumentation	M
Olafur A. INGOLFSSON	IMR	Low impact trawling/Instrumentation	M
Terje JØRGENSEN	IMR	Low impact trawling/Instrumentation	M
Egil ONA	IMR	Sonar technology and fisheries instrumentation	M
Hector PENA	IMR	Sonar technology and fisheries instrumentation	M
Aud VOLD	IMR	Purse seine technology, Centre management	F
Maria TENNINGEN	IMR	Purse seine technology	F
Mike BREEN	IMR	Purse seine technology	M
Roger LARSEN	UIT	Quality improvement	M
Arne JOHANNESSEN	UiB	Researcher training, recruitment	M
KEY TECHNICIANS, RESEARCH INSTITUTES			
Jan Tore ØVREDAL	IMR	Engineering, instrument development	M
Kjartan MÆSTAD	IMR	Information logistics	M
Turid LODDENGAARD	IMR	Centre management - Finance	F
Atle TOTLAND	IMR	Sonar Technology and Fisheries Instrumentation	M
Jostein SALTSKÅR	IMR	Engineering, instrument development	M
Liz B.K. KVALVIK	IMR	Engineering, instrument development	F
Bjørn TOTLAND	IMR	Engineering, instrument development	M
Ronald PEDERSEN	IMR	Sonar Technology and Fisheries Instrumentation	M
Tor H. EVENSEN	Nofima	Quality improvement	M

KEY PERSONELL, INDUSTRY PARTNERS

Ole Bernt GAMMELSÆTER	Kongsberg Group	Sonar technology and fisheries instrumentation	M
Lars N. ANDERSEN	Kongsberg Group	Sonar technology and fisheries instrumentation	M
Ivar WANGEN	Kongsberg Group	Sonar technology and fisheries instrumentation	M
Olav VITTERSØ	Kongsberg Group	Management, Board leader	M
Thor BÆRHAUGEN	Kongsberg Group	Monitoring fish and gear	M
Roger KOTENG	Kongsberg Group	Sonar technology and fisheries instrumentation	M
Øivind HANTHO	Kongsberg Group	Sonar technology and fisheries instrumentation	M
Anita P VIK	Kongsberg Group	Sonar technology and fisheries instrumentation	F
Toan Thanh PHAM	Kongsberg Group	Sonar technology and fisheries instrumentation	M
Helge HAMMERSLAND	Scantrol Deep Vision AS	Visual fish classification/Management	M
Kristoffer LØVALL	Scantrol Deep Vision AS	Visual fish classification	M
Håvard VÅGSTØL	Scantrol Deep Vision AS	Visual fish classification	M
Hege HAMMERSLAND-WHITE	Scantrol Deep Vision AS	Visual fish classification/Marketing	F

POSTDOCTORAL RESEARCHERS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET

Name	Funding	Research area	Sex	Duration	Nationality
Anders KARLSSON	Universitetet i Tromsø	Fish physiology	M	3 years	Norwegian
Shale ROSEN	CRISP	Visual fish classification, fish behavior	M	3 years	USA

PHD STUDENTS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET

Name	Nationality	Period	Sex	Topic
Melanie UNDERWOOD	Australian	07.05.2012-10.04.2018	F	Capture behaviour
Sindre VATNEHOL	Norwegian	01.09.2012-03.03.2016	M	Sonar Technology
Ragnhild A. SVALHEIM	Norwegian	15.04.2013-31.03.2018	F	Fish Quality
Jesse BRINKHOF	Norwegian	14.03.2016-13.03.2019	M	Fish Quality/Capture behaviour
Helene JENSEN	Norwegian	01.09.2016-31.08.2018	F	Value adding
Neil R. ANDERS	Great Britain	01.01.2016-31.12.2019	M	Fish Welfare and Quality in Purse seine
Tonje K. BJØRVIG	Norwegian	31.03.2017-31.03.2021	F	Fish Quality in Trawl (funded by UIT)

MASTER STUDENTS

Name	Nationality	Period	Sex	Topic
Alexandre J D GREVE	French	2018-19	M	Fish behavior and welfare
Thomas RIEDINGER	German	2018-19	M	Fish behavior and welfare
Kjetil G THORVALDSEN	Norwegian	2017-18	M	Acoustic id of mesopelagic registrations

APPENDIX 2

Statement of Accounts 2018

Funding

Funding		**Budget**	**Account**
The Research Council		10 000	10 000
The Host Institution	Havforskningsinstituttet	6 559	16 667
Research partners	Nofima	1 100	901
	University of Bergen	580	235
	University of Tromsø	1 556	1 004
Enterprise partners	Kongsberg Maritime AS	2 350	1 401
	Egersund Group AS	980	406
	Scantrol AS	200	70
	Nergård Havfiske AS	800	305
Public partners	Sildesalgslaget	100	100
	Råfisklaget	100	100
		24 325	31 189

Costs		Budget	Account
The Host Institution	Havforskningsinstituttet	14 159	24 517
Research partners	Nofima	3 450	3 251
	University of Bergen	830	235
	University of Tromsø	1 556	1 004
Enterprise partners	Kongsberg Maritime AS	2 350	1 401
	Egersund Group AS	980	406
	Scantrol AS	200	70
	Nergård Havfiske AS	800	305
Public partners	Sildesalgslaget	0	0
	Råfisklaget	0	0
		24 325	31 189

APPENDIX 3

PUBLICATIONS

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Allken, Vaneeda; Handegard, Nils Olav; Rosen, Shale; Schreyeck, Tiffanie; Mahiout, Thomas; Malde, Ketil. 2018. Fish species identification using a convolutional neural network trained on synthetic data. ICES Journal of Marine Science, doi 10.1093/icesjms/fsy147.

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Brinkhof, Jesse; Larsen, Roger B.; Herrmann, Bent; Olsen, Stein Harris. 2018. Assessing the impact of buffer towing on the quality of Northeast Atlantic cod (*Gadus morhua*) caught with a bottom trawl. Fisheries Research 206: 209-219.

Brinkhof, Jesse; Olsen, Stein Harris; Ingólfsson, Ólafur Arnar; Herrmann, Bent; Larsen, Roger B. 2018. Sequential codend improves quality of trawlcaught cod. PLoS ONE 13:e0204328.(10): 1-14.

Karlsson-Drangsholt, Anders; Svalheim, Ragnhild Aven; Aas-Hansen, Øyvind; Olsen, Stein Harris; Midling, Kjell Øivind; Breen, Michael; Grimsbø, Endre; Johnsen, Helge K. 2018. Recovery from exhaustive swimming and its effect on fillet quality in haddock (*Melanogrammus aeglefinus*). Fisheries Research 197: 96-104.

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Svalheim, Ragnhild Aven; Aas-Hansen, Øyvind; Heia, Karsten; Drangsholt-Karlsson, Anders; Olsen, Stein Harris; Johnsen, Helge K. 2019. Simulated trawling: Exhaustive swimming followed by extreme crowding as contributing reasons to variable fillet quality in trawl-caught Atlantic cod (*Gadus morhua*). PLoS ONE doi 10.1101/372581.

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Salvanes, Anne Gro Vea; Glenner, Henrik; Aksnes, Dag Lorents; Asplin, Lars; Dahl, Martin; Devine, Jennifer Ann; Engås, Arill; Erga, Svein Rune; Falkenhaug, Tone; Ferter, Keno; Hestetun, Jon Thomassen; Jensen, Knut Helge; Ona, Egil; Rosen, Shale; Sjøtun, Kjersti. Sampling gears and equipment. I: Marine Ecological Field Methods - A guide for marine biologists and fisheries scientists. John Wiley & Sons 2018 ISBN 9781119184300: 75-120.

PHD THESIS

Svalheim, Ragnhild Aven. 2018. Stress responses influencing fillet quality of trawled Atlantic cod and haddock. A dissertation for the degree of Philosophiae Doctor. Tromsø: UiT the Arctic University of Norway, Faculty of Biosciences and Economics, The Norwegian College of Fishery Science 2018 (ISBN 978-82-8266-162- 1), 116 p. PhD thesis.

Underwood, Melanie. 2018. Understanding interactions between fish and trawl gear in order to improve catching efficiency and scientific sampling, with focus on methodological challenges. A dissertation for the degree of Philosophiae Doctor. University of Bergen 2018 (ISBN 978-82-308-3793-1). PhD thesis.

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