ANNUAL REPORT 2017

CRISP

sfi Centre for Research-based Innovation

1. SUMMARY

CRISP, the Centre for Research-based Innovation in Sustainable fish capture and Processing technology, started its research activities in April 2011. Since its launch, the consortium has consisted of four industry partners (Kongsberg Maritime AS, Simrad; Scantrol Deep Vision AS; Egersund Group AS; Nergård Havfiske AS), four research partners (Institute of Marine Research (IMR); Nofima AS; University of Bergen; 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.

In this seventh CRISP year, 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.

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. Kongsberg Maritime AS, 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. Calibration protocols for fishery sonars and methods for correct volume estimation are now finalized. In 2017, the major work has been to continue studying the extremely variable backscattering of fish when observed from the side aspect, which has been shown to be a major source of uncertainty in biomass estimation of schooling fish. A new, light drop-probe system equipped with a Simrad WBAT broadband echo sounder has been tested inside mackerel and herring schools, showing promising results for real-time sizing.

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 capture. 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 2017, we focused on four topics: 1) using integrated instruments to better describe the behaviour of mackerel in response to capture related stressors; 2) developing a platform for deploying instruments to monitor the behaviour of the catch in relation to key environmental parameters; 3) further testing of the "In-seine" sonar technology for catch control; and 4) monitoring purse seine geometry and performance using sonar and transponder technology.

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. Development work in 2017 has largely followed the plans and goals for the year, with focuser on automating image analysis, upgrading hardware components, and developing a market-ready product.

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. Development of adjustable trawl doors have been one focus area. Experiments have shown that the doors can be maneuvered both vertically and horizontally, but so far the acoustic communication system between the vessel and the trawl doors is too unreliable to be applied to commercial fisheries. In 2017 fishing trials have been conducted to study possible catch reduction effects of lifting the trawl doors above bottom (semi-pelagic trawling). Another focus area has been to refine techniques for catch regulation to avoid excessively large cod catches.

WP5: The Norwegian fleet of ocean trawlers has gone through substantial changes since the turn of the millennium. This year several quality issues during bottom trawling have been studied. 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 Group AS 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.

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 CRSIP 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 2017 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.

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

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

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

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

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

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

6. 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 and is responsible for the administration of CRISP. CRISP is presently organized as a project in the Biological Mechanisms Program at IMR. Most IMR personnel working in CRISP projects belong to the Marine Ecosystem Acoustic 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, the other major research partner in CRISP.

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

Aud Vold of IMR has been appointed director of the Centre from September 1, 2015.

The board of the Centre in 2017 was as follows:

- Olav Vittersø, Kongsberg Maritime AS, Simrad (Chair)
- Helge Hammersland, Scantrol Deep Vision AS
- Bjørn Havsø, Egersund Group AS
- Kjell Larssen, Nergård Havfiske AS
- Geir Huse, Institute of Marine Research
- Heidi Nilsen, Nofima AS
- Arne Johannessen, University of Bergen
- Johnny Caspersen, Norwegian Fishermen's Sales Organization
- Turid Hiller, 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, and from 2018 the Chair of the Board of the Norwegian Fishermen's Sales Association for Pelagic Fish, Jonny Garvik, and professor Helge K. Johnsen from UiT will take over for Jonny Caspersen and Arne Johannessen.

Figure 4.1. Board member Johnny Caspersen from Norwegian Fishermen's Sales Organization taking part in discussions at the CRISP Annual Science Meeting in September 2017.

4.2 PARTNERS

The CRISP consortium comprises four research partners (the Institute of Marine Research (IMR); Nofima AS; the University of Bergen; the University of Tromsø), four industry partners (Kongsberg Maritime AS, Simrad; Scantrol Deep Vision AS; Egersund Group AS; Nergård Havfiske AS) and two sponsors (Norges Råfisklag and Norges Sildesalgslag).

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

University of Bergen has relevant scientific and supervision expertise in general fish biology, experimental biology, fish behaviour, fisheries acoustics and

Figure 4.2. Steven Walsh, leader of CRISP's Scientific Advisory Committee (left), and scientist Shale P. Rosen (right) from IMR at the Annual Science Conference 2017 (Photo Petri Suuronen).

fish capture. For the past six years, the Department of Biology (BIO) has led a Nordic Research School in Fisheries and Marine Biology, NMA (Nordic Marine Academy). UiB also has excellent experimental marine research facilities and a Marine Biological Station in addition to the research vessels operated jointly with IMR.

University of Tromsø, Faculty of Biosciences, Fisheries and Economics (BFE), 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. BFE has systematically developed competence, facilities and equipment closely related to marine and fishery biology and processing, including gear technology.

Simrad, which is part of Kongsberg Maritime AS (KM), 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.

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 the 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 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.

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. In 2008, the Nergård processing industry accounted for 30% of herring (human consumption) production, 18% of whitefish production and 40% of frozen 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 NSS, which is equivalent to 2 – 2.5 % of global wild fish catches. The main interest of NSS 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 south-west of Norway to Finnmark in the north-east. The most important species are cod, saithe, haddock and shrimps/prawns.

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 who include MSc and PhD students, where the universities are a natural third partner. The four industry partners have complementary competence with minor or no overlapping business interests.

An Annual Science meeting is arranged each September. This is the main meeting point for the whole CRISP consortium. All scientists and industry partners involved in CRISP meet up for a two-day meeting where the scientific progress and other matters of importance for all partners are being discussed. In 2017 the Annual Science meeting was held in Bergen at Scandic Flesland Airport Hotel. The programme focused around the theme "Interactions between fisheries management and CRISP".

Figure 4.3. Hege Hammersland-White and Kristoffer Løvall presenting recent development of Deep Vision to the CRISP community at the Annual Science Meeting in Bergen 2017 (Photo Petri Suuronen).

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 a research or a fishing vessel. The key role of the researchers is to evaluate the efficiency and environmental benefits of the developed tools. The staff from all the partners participates in planning and execution of the research cruises followed by evaluation and reporting of the results.

Figure 4.4. Senior scientist Bent Dreyer, Nofima, telling the audience about capacity reducing instruments and fleet structure at the Annual Science Meeting 2017 (Photo Petri Suuronen).

In addition to CRISP staff members, representatives from the fishermen's sales organizations, the Fishing boat-owner's association and the Directorate of Fisheries joined the meeting with presentations and participation in discussions.

5. SCIENTIFIC ACTIVITIES AND RESULTS

The scientific activities in CRISP are organized in the form of six work packages, including several subprojects; 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	1.1 Biomass estimation using digital fishery sonars 1.2 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 Semipelagic trawl design and rigging 4.3 Catch regulation in trawls	IMR, Egersund Group, KM, UiB
WP 5. Quality improvement	1.1 Current quality conditions onboard bottom trawlers 1.2 Facility and methods for experimental investigation of fish quality	Nofima, IMR, UiT and Nergård
WP 6. Value adding	1.1 Nergård operation 1.2 Status of Norwegian trawlers	Nofima, Nergård and UiT

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

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 have 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.

Activities
Kongsberg Maritime AS, Simrad, is collaborating with IMR to develop new and improved omnidirectional fishery sonars which can quantify the size of a school prior to shooting the fishing gear 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 a standard calibration procedure for modern multibeam fishery sonars. Simrad has delivered new data formats and improved software, which have been tested in trial surveys on herring in 2012, 2013 and 2017, and further on Atlantic mackerel in October 2014, 2015 and 2016. Simrad has this year mainly been working with the new matrix sonar (SN90) for studying the fish school and the purse seine net itself during setting and retrieval. Calibration protocols for the matrix sonar are also being made, and one successful calibration was made onboard FV "Eros". Sonar processing software has been adjusted to read data from SN90. Due to the first experiences with air bubble disturbances from the side thrusters on the original mounting of the transducer (a normal hull blister), the transducer on FV "Eros" was in 2017 moved to the side of the drop keel. This improved the data and image output from the SN90 sonar and enabled a proper monitoring of the catch process.

The calibration protocol for the SU90 sonar is now in place, and the method published in scientific journals. However, significant improvement of the performance of the sonar is expected with a new sonar software which is scheduled to be released at end of 2018. During the programme more than 10 vessels have been calibrated once and 3 vessels several times using the calibration protocol developed in CRISP. Sonar measurements of single-schools have been done (Figure 5.1.1), immediately followed by a complete purse seine catch of the same school. In these so-called validation measurements, the expected catch of a school was estimated using the recently developed algorithms, and the estimates compared directly to the actual catch. Such validation experiments were still ongoing for mackerel in 2016, and new validation points was derived for herring in 2017 (Figure 5.1.2. and 5.1.3). Figure 5.1.4 shows a simultaneous measurement with the two sonars SU90 and SN90. Similar validation measurements are planned for capelin in March 2018.

Publication of the algorithms for biomass measurements will be prio-

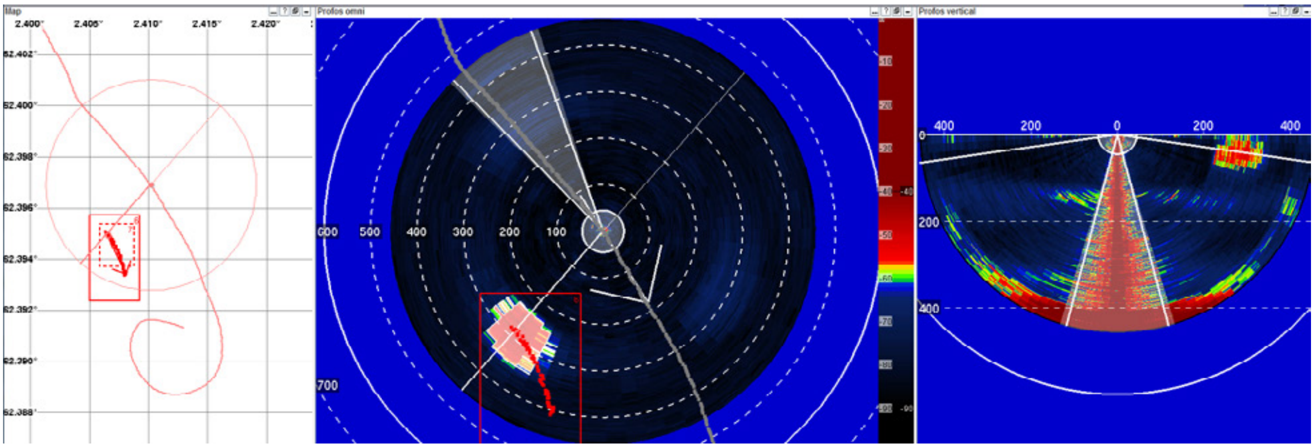

Figure 5.1.1. Detailed skipper inspection of school before catch using the omni sonar SU90. The direction and swimming speed of the school is plotted in the map together with the vessel track (left panel); the horizontal (middle panel) and vertical beams (right panel) are manually adjusted to ensonify the centre of the school for later biomass estimation.

ritized in 2018. We also plan to test machine learning procedures for school biomass estimation in order to give the skipper opportunity to add new schools in his own learning "library". The implementation of the new algorithms in the sonars will be made by Simrad, hopefully to be ready 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 2017 have been to finalize the development of calibration methods for broadband echo sounders as well as further trials with the new narrow-beam transducer. The hardware of the broadband echo sounder has been modified and improved by Simrad, and significant effort has been put into developing the new echo sounder software. The echo sounder is now commercially available, both in scientific and fishery versions. Software and setup were tested with promising results in the October 2015 and 2016 mackerel surveys and finally in the 2017 herring survey. (See example of a herring layer in Figure 5.1.5). Full broadband echo sounder setup was also run during an international training course on-board RV "G.O. Sars" in December 2017, where 20 scientists from 13 countries participated. The training course was run as an ICES training course, and several of the methods and results developed in CRISP surveys were demonstrated for the international experts.

We now regard the first version of the DABGRAF fish sizing system to be finished and ready for commercial testing. New ways of mounting the transducer on fishing vessels must be developed to obtain a successful commercialization of the product. It is presently not decided if the narrow broadband transducer-beam should be mechanically or electronically tilted. This is a decision that must be taken by the industry partner, but an electronic tilting would greatly simplify the mounting arrangements onboard fishing vessels.

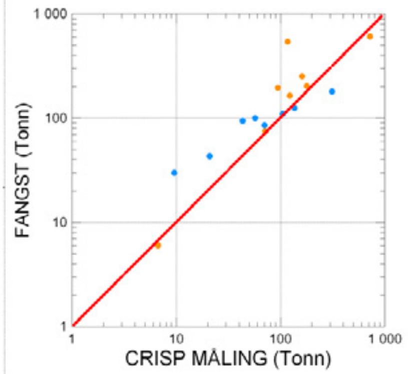

Figure 5.1.2. Preliminary summary of verification catches for mackerel and herring schools, using the Simrad SU90 sonar. CRISP Måling (CRISP measurements (tons)), compared with FANGST (CATCH (tons)). The main reason for the more systematic deviation may be incorrect target strength in lateral mode, while larger deviations are either uncertainty (Fig 5.1.3) or error in either catch or measurement.

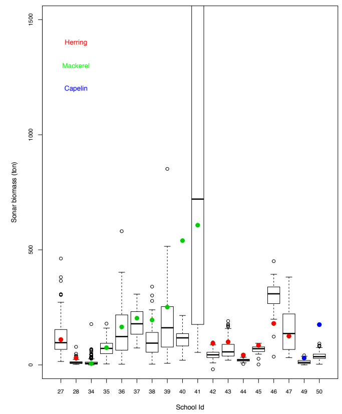

Figure 5.1.3. Biomass estimates of mackerel and herring schools derived from sonar measurements with total uncertainty (boxplot indicates median, first and third quartile). Dots represent the verified purse seine catches landed for each school. Notice that last 6 schools (Id 42 to 47) were collected during the 2017 CRISP survey.

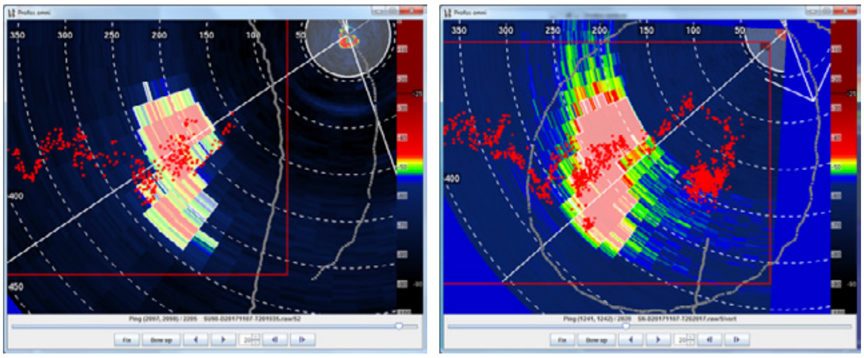

Figure 5.1.4. Herring school measured before catch, overserved with the omni sonar SU90 (left panel) and with the in-seine sonar SN90 (right panel). The figures show one simultaneous ping for both sonars. Note the higher number of beams and the higher resolution along each beam in the SN90 sonar.

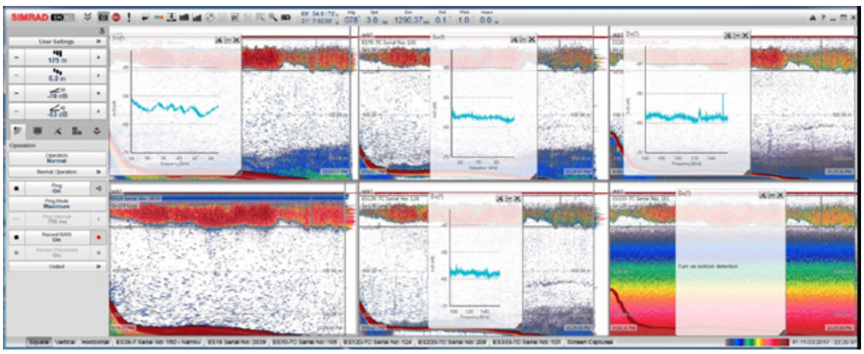

Figure 5.1.5. Herring measured by broad-band echo sounder at 18, 38, 70, 120, 200 and 333 kHz. The herring was young fish of the 2013 year-class measured in Kvænangen, Northern Norway in November/December 2017.

A new, light drop-probe system equipped with a Simrad WBAT broadband echo sounder has been tested inside mackerel and herring schools in 2016 and 2017,

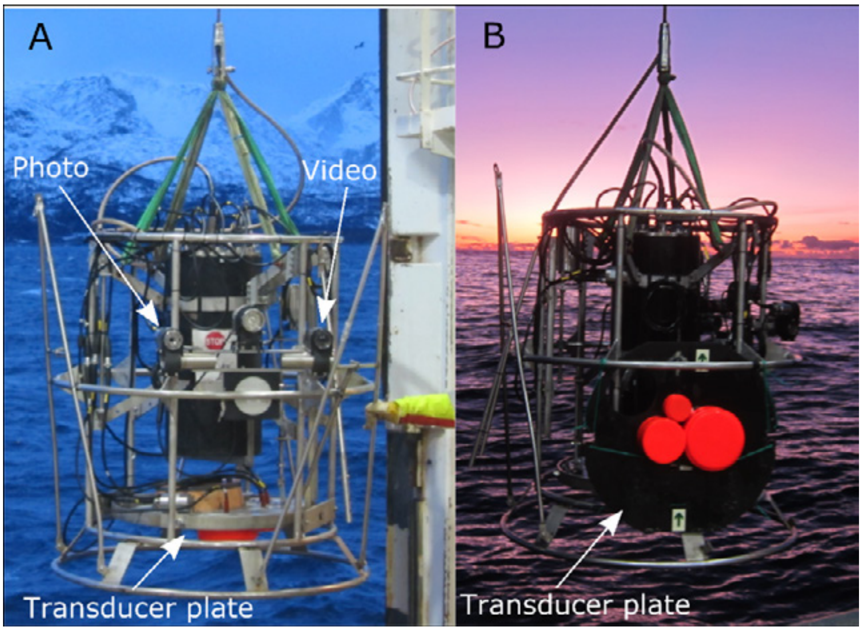

Figure 5.1.6. The TS-probe with transducers mounted for dorsal TS measurements (A) and for lateral aspect TS measurements.

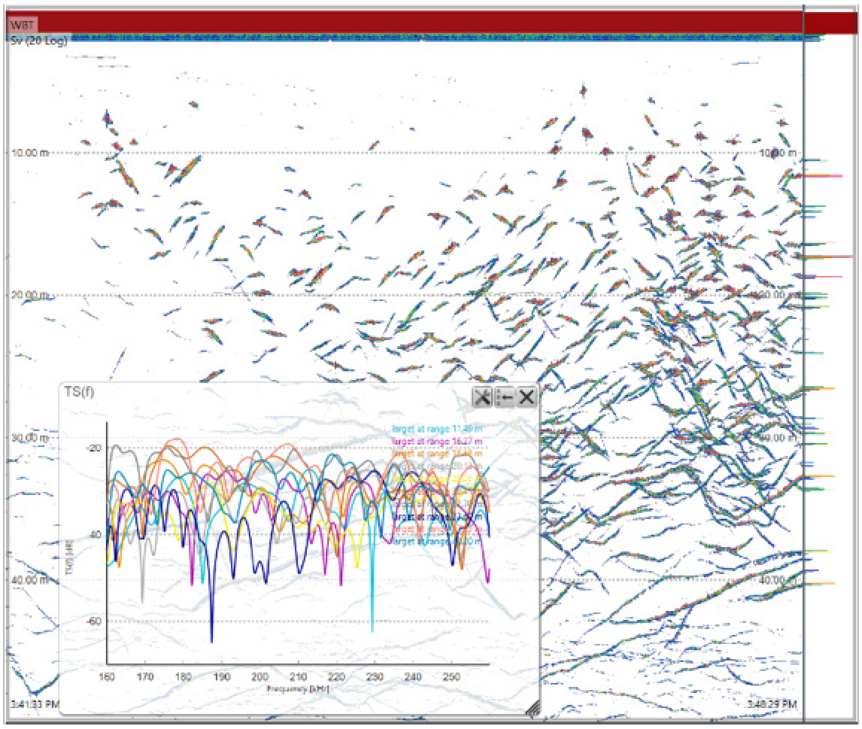

Figure 5.1.7. Example of observations of herring using the probe and WBAT system lowered into a herring layer in Kvænangen in 2017. Note the spectrum of individual targets.

showing promising results for real-time sizing (Fig 5.1.6 and 5.1.7). This system is now able to deliver valuable information on lateral aspect target strength (TS) for adult mackerel, herring and capelin, which is data needed for more exact biomass estimation of schools measured by the sonar. This system may also be evaluated as basis for both free-floating instruments or from instruments dropped in a catch inside a purse seine in the future, transmitting the data to the vessel from a free drop inside fish layers,.

Results

This project element is now in its seventh year. Calibration protocols for fishery sonars and methods for correct volume estimation are finalized, and the largest uncertainty factors in the biomass computation procedures have been further studied. The main uncertainty is the extremely variable backscattering of fish when observed in the lateral aspect. Large deviations from the simplified method presently used in the sonar software have been observed, particularly 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 will be part of the new software that is developed.

During a CRISP research vessel survey in 2017, further target strength data collection with broad-band echo sounders was made on two size categories of herring: 4 years old 220 g herring in Kvænangen, Northern Norway (Figure 5.1.5), and 370 g adult herring on the main fishing grounds outside the island of Røst in November 2017. During these measurements, a new 38 kHz transducer was tested on the WBAT system, enabling target strength measurements closer to the sonar frequency 30 kHz than the ones used before. This is the first prototype pressure stabilized broad band transducer working at 38 kHz, and the data collected so far shows promising results. Further TS measurements with the EK80 mounted on the probe was also successfully done during the young-herring measurements (Figure 5.1.7). Processing and publication of the TS data in lateral mode on mackerel, herring and capelin will be prioritized in 2018.

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 2017, 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 welfare status of purse seine catches

"In-seine" sonar technology for catch control

In 2017, Kongsberg Maritime, Simrad, installed a SN90 system in the scientific keel of FV "Eros", aiming for improved fish and gear monitoring by avoiding or reducing the effect of the bubble layers from main propeller (Figure 5.2.1).

Figure 5.2.1. Illustration showing the location of the SN90 transducer in the standard position between the bow and the bow thruster, and the new location in the starboard face of the scientific keel. The sources of air bubbles affecting the performance of the hull mounted transducer are indicated by the red arrows.

The performance of the SN90 sonar has not been as good as expected during purse seining in the previous two year's surveys. The poor data quality is likely caused by air bubbles that block the hull mounted transducer. The air bubbles have different sources; i) swept down from the bow with the vessel heave, ii) from the bow thruster and iii) from the main propeller. Good quality data during the catch process is only available from a few purse seine sets during the CRISP surveys collected in calm sea and low wind conditions, when the level of air bubbles was low. Not all vessels are equipped with a drop keel and some risk is involved in keeping the drop keel down during purse seining, but the aim was to investigate whether the data can be improved by lowering the transducer.

The results from the CRISP survey in 2017 showed a clear improvement in the quality of the sonar data (Figure 5.2.2). The skipper on board FV "Eros" pointed out that it was the first time the visualization of the school and net was so clear when using the SN90 sonar.

Having the transducer located in the scientific keel, about 8 m below the surface, facilitated continuous monitoring of the school and the net during most of the capture process. It was possible to observe the school dynamics as the net volume was reduced until about the time when the white float (a marker used for regulating slipping placed at 7/8 retrieval of the net) was taken onboard (Figure 5.2.3).

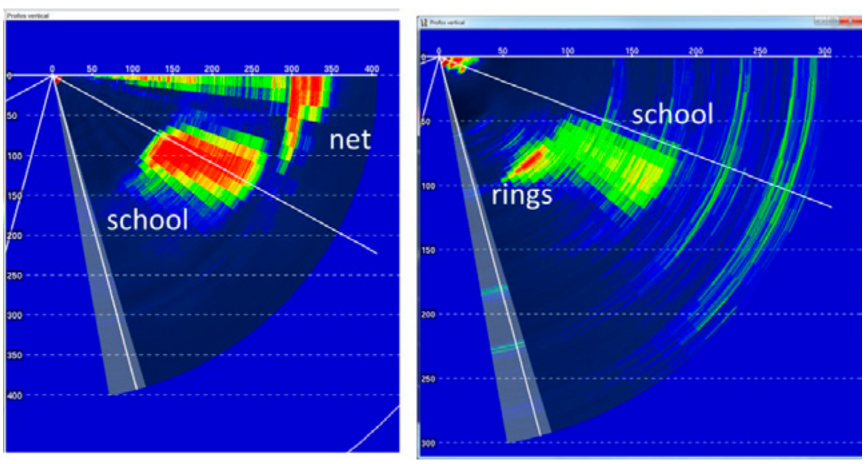

Figure 5.2.2. Vertical beams of the SN90 sonar during purse seine deployment (left panel) and during pursing (right panel). In the left panel the school can be observed and the net sinking at ca. 300 m range. In the right panel the school can be identified together with the rings from the bottom line, as they approach to the vessel during pursing.

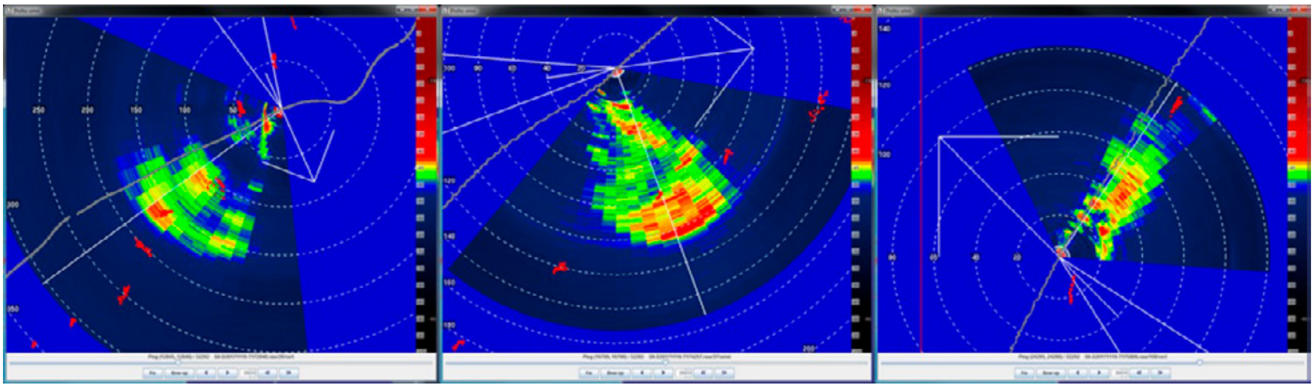

Figure 5.2.3. Sonar images of the school of herring and the net during the hauling phase, 45' before the white float (left panel), 30' before (center panel) and 10' before (right panel).

Calibration results for the SN90 sonar in 2016 were not adequate because the reference sphere could not be accurately positioned in the calibrated horizontal fan beams. In 2017 Kongsberg Maritime, Simrad, implemented a new functionality in the software that allowed for independent movement of the inspection and horizontal fan beams. This functionality made accurate sampling of one whole fan beam by overlapping the inspection beam with split beam capabilities. The SN90 sonar was calibrated with the new software before the CRISP cruise in 2017. Once the calibration equations are finalized, biomass estimations from the school data collected will be computed.

Monitoring seine geometry and performance

A new SN90 sonar software version was produced by Kongsberg Maritime, Simrad, with an integrated mode for combining the fish and transponder modes. In the 2016 version, two separated modes where used and it was not possible to visualize transponder positions and the fish school at the same time. The updated 2017 software version included an option for selecting the number of pings for sampling fish and the number of pings for sampling the transponder signal, displayed in the same mode but not overlapped. The software was stable and easy to use. It was tested in two purse seine sets using 3 transponders attached to the bottom line of the seine, and in a controlled experiment with the transponders at different depths attached to separated buoys inside a fjord.

Despite the improvements, the current solution was found to be inconvenient during commercial fishing operations.

ID	Vessel	Date	Location			Catch		Mean fish
			Generic	Latitude	Longitude	Fate	Size	Weight (g)
A2	Brennholm	22.09.2016	Norwegian Sea	62° 11.65 N	001° 15.14 E	Landed	195t	348g
A6	Brennholm	01.10.2016	Norwegian Sea	63° 36.30 N	000° 54.80 E	Landed	251t	382g
B1	Fiskebas	07.10.2016	Norwegian Sea	62° 04.00 N	002° 57.15 E	Slipped	*~<10t*	?
B2	Fiskebas	07.10.2016	Norwegian Sea	61° 55.65 N	002° 49.64 E	Slipped	*~300t*	?
B4	Fiskebas	08.10.2016	Norwegian Sea	61° 38.51 N	002° 12.69 E	Slipped	*~1200t*	?
B6	Fiskebas	09.10.2016	Norwegian Sea	60° 28.13 N	002° 14.17 E	~10t Slipped; Rest landed.	225t	424g

ID	Cast		Slipping		Pumping		Probe		Oxygen Minimum		Catch
	Start	End	Start	End	Start	End	Start	End	% Sat.	mg/l	Size
A2	09:16	10:23	NA	NA	10:23	11:03	09:50:24	10:19:40	57.31	5.167	195t
A6	16:41	~17:45	NA	NA	~17:45	~18:35	17:13:11	17:46:43	61.39	5.486	251t
B1	08:10	09:20	09:13	09:20	NA	NA	08:41:25	09:20:24	92.77	9.844	*~<10t*
B2	11:42	13:01	12:53	13:01	NA	NA	12:17:24	13:00:10	83.4	8.897	*~300t*
B4	10:39	11:56	11:49	11:56	NA	NA	11:25:11	11:56:13	82.83	8.983	*~1200t*
B6	14:20	13:11	13:02	13:11	13:11	13:30	12:41:19	13:09:45	51.74	5.525	225t

Table 5.2.1. Six deployments of the catch monitoring probe in landed and slipped catches.

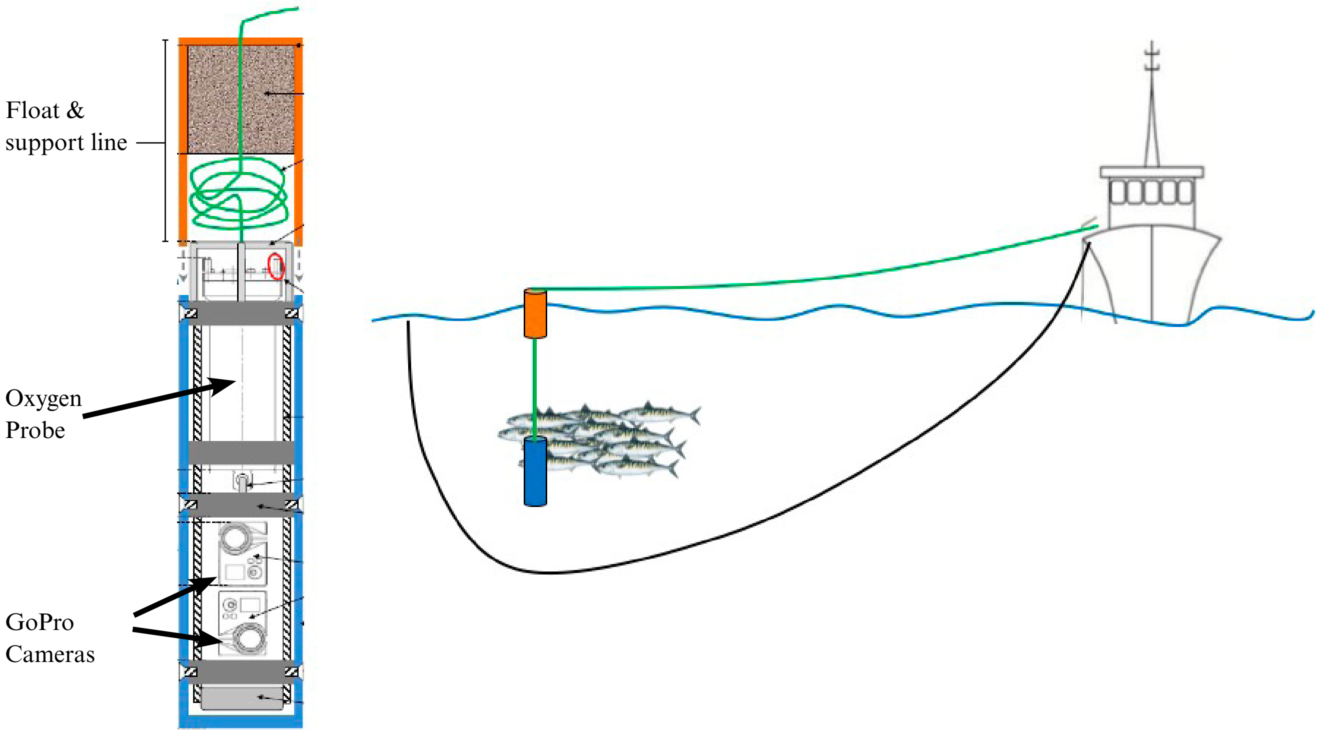

Figure 5.2.4. The catch monitoring probe deployed into a purse seine catch.

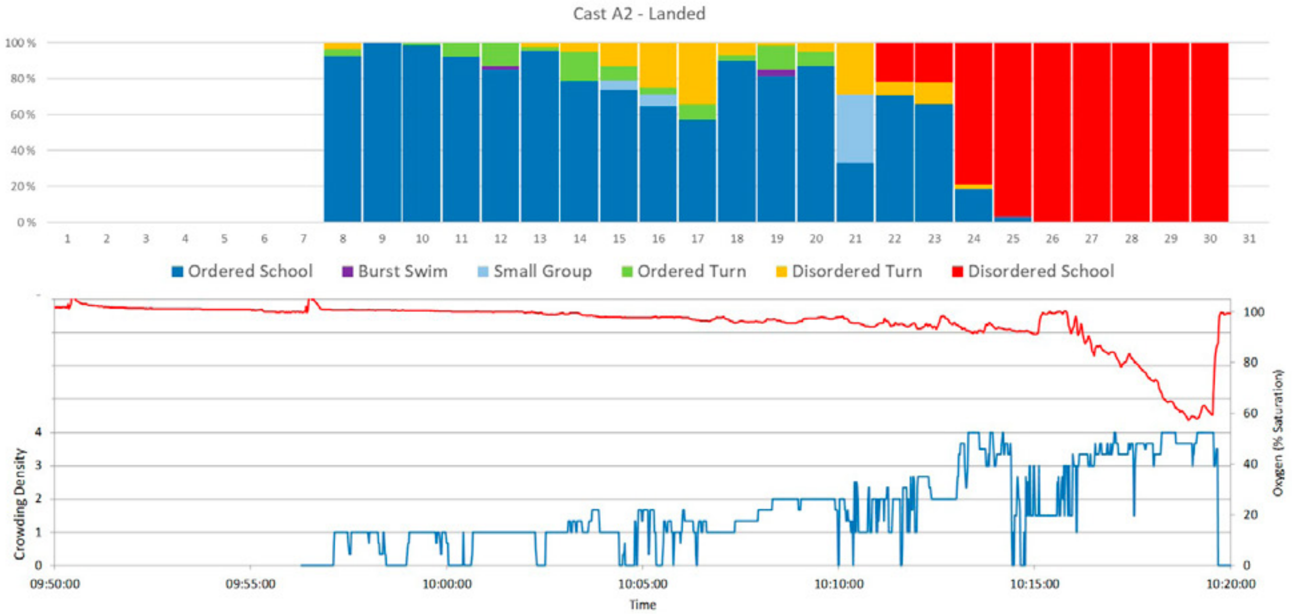

Figure 5.2.5. An example of data from the catch monitoring probe, including crowding density, oxygen concentration and behaviour.

During school monitoring, the horizontal tilt and vertical bearing are actively used to obtain the best school sampling. Locating the transponders also requires active adjustments of tilt and bearing in order to point the centre beam in the direction of the transponders. Different configurations of number of transponder and fish pings were tested. However, it was considered that an effective monitoring of the transponder positions will require an omni-directional reception of the signal, that will not require changes in tilt or beam bearing. Ideally, the bearing, depth and range of each transponder should be computed and represented graphically in the fish mode display. An alternative solution, is to use a separate system for underwater positioning, i.e. Kongsberg Maritime HiPAP, which have dedicated hull mounted transducers to communicate with multiple transponders and can provide accurate transponder positioning information that can be displayed in the sonar display.

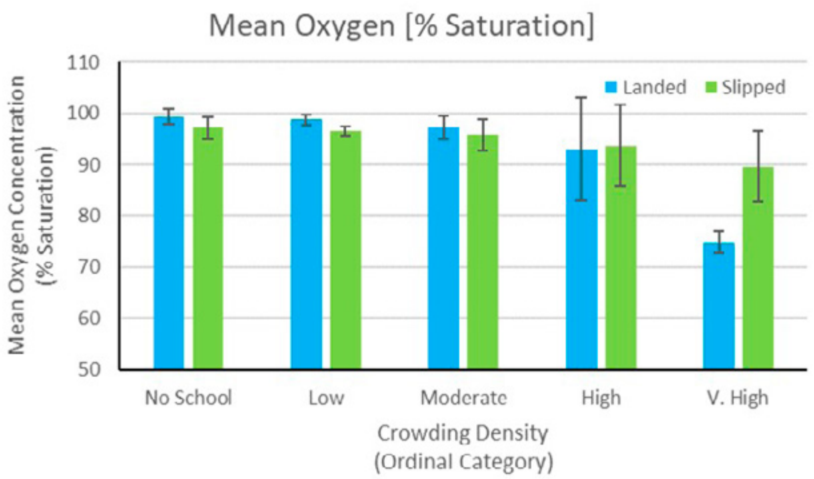

Figure 5.2.6. Mean oxygen concentration, at different crowding densities, in landed and slipped purse seine catches.

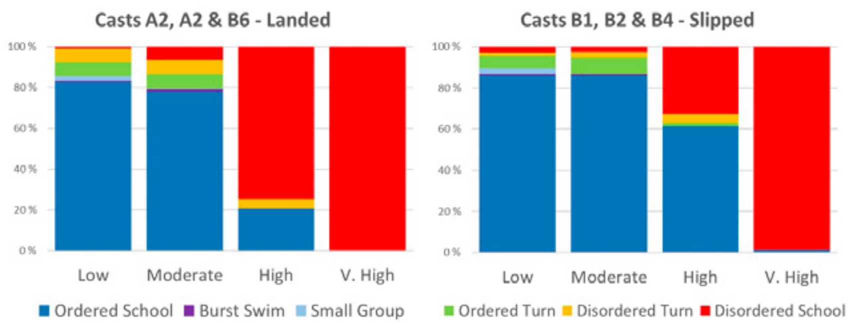

Figure 5.2.7. A summary of behaviours, at different crowding densities, in landed and slipped purse seine catches.

Monitoring welfare status of purse seine catches

In 2017, in collaboration Project RedSlip (NFR 243885) and Project "Catch control in Purse seines" (FHF 901350), work continued on the development of a prototype probe for monitoring fish behaviour and oxygen concentrations in purse seine catches. The first version of the probe (Mk I) contained just a RINKO III probe to measure oxygen, temperature and depth and a GoPro Camera, which was deployed into the catch using a pneumatic cannon. The probe consists of two main parts: a surface float and the instrument package (Figure 5.2.4). When fired from the cannon, the two halves are linked together as a single cylinder. As the cylinder enters the water, the weight of the instrument package separates it from the surface float, and it sinks to a pre-determined depth (typically 5-15m).

The depth, temperature, salinity and oxygen content of the water is recorded every second, while the camera provides visual information to put those data in context; i.e. the proximity of the probe to the catch and/or net (Figure 5.2.5). A new proto-type (Mk II), incorporating a stereo-camera, was tested at sea, aboard FV "Fiskebas" in June 2017, but was not strong enough to withstand the substantial forces needed to launch the now heavier probe into the net, and survived only four deployments. So work continued with the MK I probe, incorporating a new 360° camera, and data was successfully collected on a further three deployments in October 2017 on FV "Fiskebas".

Analysis of data from the 2016 deployments of the monitoring probe has demonstrated the potential value of this tool for describing the welfare status of the catch. This analysis examined data from six deployments in mackerel catches, three that were landed (ranging from 195 to 225 tonnes) and three slipped catches (slipped biomass estimated between <10 tonnes to ~1200 tonnes) (see table 5.2.1). The crowding density was observed to progressively increase during the haul-back phase of the fishing operation (Figure 5.2.5). This increase in crowding also appears to drive changes in the behaviour of the fish, as well as reducing dissolved oxygen concentrations. Behaviour typically progressed from highly polarised and ordered schools (at low crowding densities) to dis-ordered aggregations, lacking any schooling structure (at higher crowding densities). Interestingly, the severity of these behavioural changes and reduced oxygen concentrations, at higher crowding densities, was less for the slipped catches (Figures 5.2.6 & 5.2.7).

In 2018, work will continue, in collaboration with Project Catch Control in Purse Seines (FHF 901350), on the development of the probe to upgrade the instrument package to include a lighter and more compact stereo-camera system for improved description of behaviour and estimation of fish size; as well as the inclusion instrumentation for describing the position and orientation of the probe.

5.3 METHODS FOR CAPTURE MONITORING AND CATCH CONTROL DURING TRAWLING

BACKGROUND

Unwanted catches often occur in mixed trawl fisheries regulated by quotas on individual species. In some fisheries, high grading, meaning that the most valuable fish are preferred leading to a risk of discarding low-value fish, has been identified as a non-sustainable fishing practice. The large catches sometimes taken by trawls may result in burst nets and loss of catch, as well as reduced fish quality when on-board production time is too long. A major topic for CRISP is therefore to develop technologies for early identification of size and species inside trawls, combined with interactive methods capable of actively releasing unwanted catch.

VISUAL FISH CLASSIFICATION (SIMRAD FX80 AND DEEP VISION)

The FX80 live in-trawl camera system **(https://www.simrad.com/fx80)** developed by Kongsberg Maritime AS, Simrad, in the earlier years of CRISP has been a commercially available product for several years. No significant tests or further developments were undertaken in 2017, however Simrad has been in discussions with a major international fishing company about using the system in combination with an active release system to open the codend if significant amounts of non-target species are seen entering the trawl.

The Deep Vision system **(https://www.deepvision.no/deep-vision/deep-vision)**, developed by Scantrol Deep Vision AS, is similarly an in-trawl camera system but collects colour still stereo images of all objects passing through a trawl. These images can be used to positively 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. Eventually, it is hoped that the system can be made smaller and linked to a gate that will open and shut the trawl in real-time according to what species and sizes are passing. Development work carried out under CRISP activities in 2017 has largely followed the plans and goals for the year, with focus on automating image analysis, upgrading hardware components, and developing a market-ready product. In addition, the system was successfully used on several non-CRISP cruises. Notably, the first system has been ordered for commercial purchase and will be delivered in the second quarter of 2018.

WORK ON AUTOMATION OF IMAGE ANALYSIS

Scantrol Deep Vision has worked over the past year with the Underwater Vision and Robotics Research Centre at the University of Girona, Spain on development of techniques to automate analysis of images collected by the Deep Vision system. This includes methods for identifying and tracking objects (fish) in sequential images so that they are counted just once. As reported in the 2016 annual report, the camera hardware and software were upgraded to double the image frame rate from 5 to 10 images per second per camera and to save images in "Raw" and lossless compressed formats to preserve image quality. These new camera settings were tested during cruises in September and October 2017 to collect images for further development and testing of the software algorithms.

The Institute of Marine Research has a separate machine learning project and during summer 2017 two students from the University of Nice, France, applied a machine learning technique called convolutional neural network for automatically recognizing the species of a selection of three species of fish from Deep Vision images. by use of machine learning. Images from a recent cruise with IMR were used to train the software to identify three different species – herring, mackerel and blue whiting.

Using 150 real images Atlantic herring; Atlantic mackerel and blue whiting taken with the Deep Vision system, the students created a training set of 7000 images containing the three different species. Since generating a sufficiently large library of training images is often a challenge for machine learning techniques, this represents a significant advance in applying machine learning techniques to Deep Vision images. Subsequent work indicates that using this training technique, the

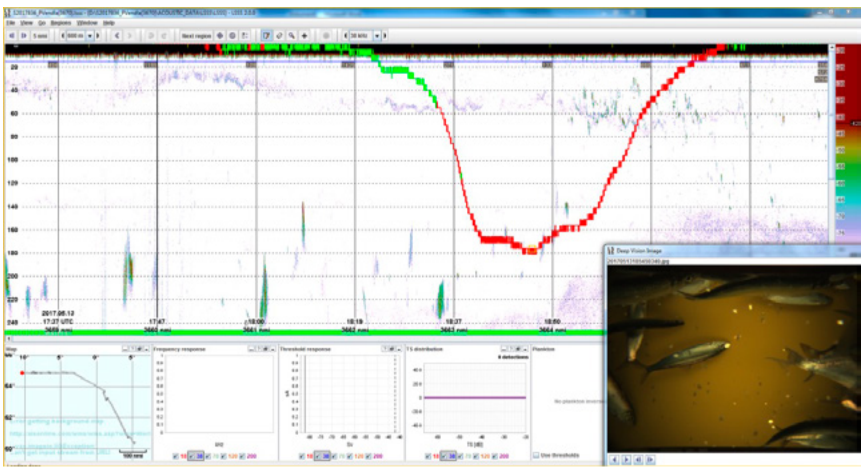

Figure 5.3.1. Integration of Deep Vision images with LSSS software for analysis of acoustic data. Green and red line traces the trawl's path through the water column (vertical axis = water column depth, horizontal axis = time). The image at lower right is from the position indicated by the small orang box (180 m depth) and provides confirmation that the schools observed are Atlantic herring.

convolutional neural network achieves an accuracy of 90-95 % in discriminating between Atlantic herring; Atlantic mackerel and blue whiting.

INTEGRATION OF DEEP VISION IMAGES WITH LSSS SOFTWARE FOR ANALYSIS OF ACOUSTIC DATA

Support for Deep Vision images as added to the LSSS (Large Scale Survey System) software package used to analyse acoustic data from scientific echo sounders. The interface displays both the trawl's track in the echogram and a stream of Deep Vision images, with the position they were taken indicated. This provides the person analysing the acoustic data with confirmation of the species present.

Figure 5.3.2. Deep Vision system being set out from the commercial trawler / purse seiner MS "Vendla" between Norway and Iceland. The system was successfully deployed on 20 trawl hauls, a total of more than 48 hours of active trawling and image collection.

AT-SEA DEVELOPMENT AND APPLICATION OF DEEP VISION

The Deep Vision system was used on three research cruises in 2017. Two additional cruises planned for the Norwegian Agency for Developement Cooperation (Norad) RV "Dr. Fritjof Nansen" off the west coast of Africa were hampered by equipment not arriving in time and sustaining damage under transport. Key results from the successful cruises are detailed below:

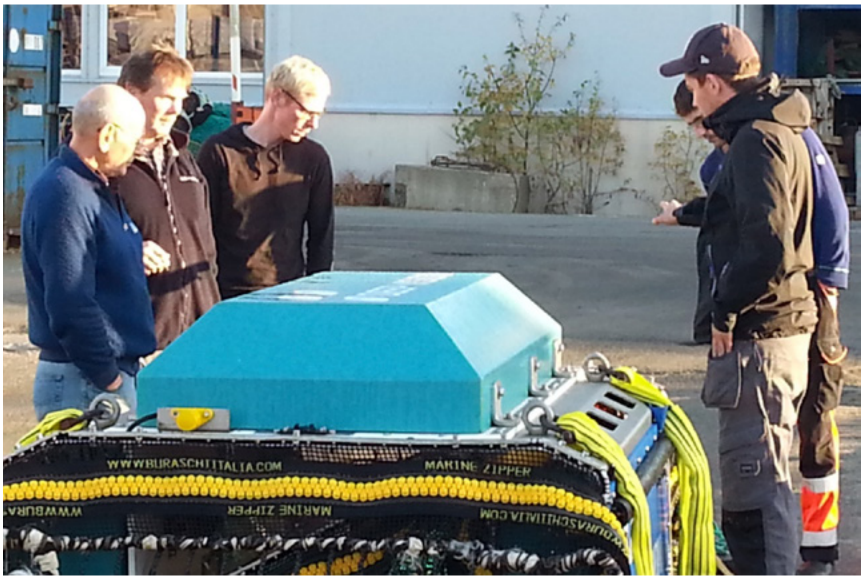

Figure 5.3.3. Kristoffer Løvall of Scantrol Deep Vision AS explains the Deep Vision system to the crew of Nergård Havfiske's trawler "Kasfjord" which was docked at the same pier. The yellow SIMRAD transducer used for acoustic transfer is visible in front of the blue floatation block. The yellow zippers were also tested to provide ready access to clean and adjust components inside the frame.

REDUS cruise May 2017:

This cruise was sponsored by the REDUS project at the Institute of Marine Research, which aims to investigate and reduce sources of error in stock assessment http://redus.no/. Deep Vision was used to document the vertical distribution of pelagic fish species (primarily Atlantic herring, Atlantic mackerel and blue whiting) and made it possible to trawl for very long duration and fully sample the water column and surface layers by leaving the codend open and using deep vision images to measure and identify the fish which then swam out the end of the trawl at the same depth where they were captured.

The new batteries (nickel-metal chemistry) store less energy than the lithium ones used to date, but have the advantage of being able to be transported as standard goods while the lithium batteries must be sent as dangerous goods and are prohibited from being sent onboard passenger air flights. Results from the cruise indicated that even with their reduced storage, the new batteries can operate the system for more than 10 hours in actual sampling conditions at sea. Acoustic transfer, developed in cooperation with CRISP industrial partner Kongsberg Maritime AS, Simrad, was generally successful but had a maximum range of approximately 400 m. Future work in 2018 will focus on improving the range. The zipper attachment to the trawl worked very well and

Figure 5.3.4. Kristoffer Løvall of Scantrol Deep Vision AS monitors Deep Vision system status from the wheelhouse via acoustic link.

Figure 5.3.5. Simrad transducer mounted to Deep Vision frame for acoustic transfer of system status. Development of the acoustic transfer protocol is being done in cooperation with Kongsberg Simrad.

Figure 5.3.6. Example Deep Vision image from the Aegean sea. At least 5 different species are present.

will be the preferred attachment for all future Deep Vision deployments. Data collection at 10 frames per second and in uncompressed format was successful, but greatly increased data transfer time and will require a new downloading solution for routine use.

MINOUW cruise October 2017:

As reported in the 2016 CRISP annual report, tests of Deep Vision in north-eastern Spain under the EU Horizon 2020 project "MINOUW" (http://minouw-project.eu/) proved to be a very challenging deployment, due both to poor water clarity and difficulties shipping the frame and batteries and rigging the trawl onboard an oceanographic vessel not designed to deploy trawl gear. Further MINOUW project work in the Aegean Sea, Greece, were delayed until further trials with alternative solutions for mounting Deep Vision inside the trawl could be tested (these trials in Scotland and Troms were reported in the 2016 annual report).

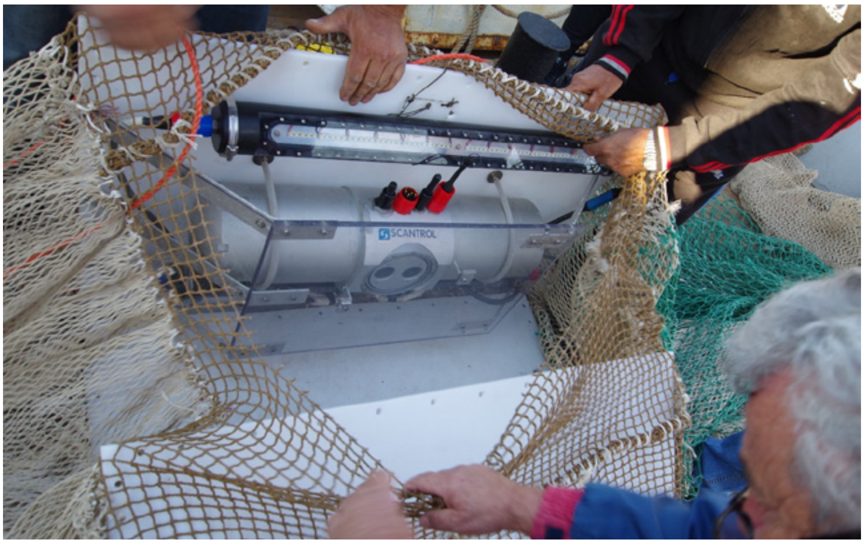

Figure 5.3.7. Simplified deployment frame used in Greece. The standard Deep Vision camera and lights were mounted inside a frame built on-site using 10 mm thick sheets of high density polyethylene (HDPE).

Figure 5.3.8. Rendering of new Deep Vision deployment frame to be delivered to the Institute of Marine Research in April 2018. The new frame incorporates floatation into the fiberglass frame and will be approximately half the weight of the previous frame.

Trials in Greece were ultimately conducted in October 2017 in the northern Aegean Sea just south of Athens and were highly successful. No significant difficulties were encountered in 10 trawl hauls conducted in depths ranging from 60 to 400 m. Suspended sediments sometimes obscured the images, a condition which was highly correlated with seabed type. The physical catch was measured from all hauls. Analysis of Deep Vision data is ongoing for comparison. This will include comparisons of counts by numbers and length frequencies. One important difference between these trials and data collected previously in northern Europe is the much greater species diversity. As many as 100 species were captured during a single trawl haul, as compared to fewer than 10 in most previous deployments of Deep Vision.

Sale of Deep Vision system to Insititute of Marine Research:
Scantrol Deep Vision and the Institute of Marine Research signed a contract for purchase of one complete Deep Vision system plus one extra deployment frame for use by the Institute of Marine Research and Nansen Program (RV "Dr Fritjof Nansen"). This system will be delivered in the second quarter of 2018 and will include both upgraded electronics components and a new deployment frame based generally on the frame used since 2015 but designed to be half the weight and provide improved lighting and handling on deck and in the sea.

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 negative impacts. Part of this this work-package addresses the design, rigging and operation of trawl gears that might achieve such objectives.

Figure 5.4.1. The four panel codend with the ExFed system. The picture is taken onboard the trawler "J. Bergvoll".

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 important to maintain geometry of the trawl system and thus the catchability when fishing with a semi-pelagic trawling technique. Trawl doors where the horizontal and vertical spread forces can be adjusted by opening and closing hatches in the doors was

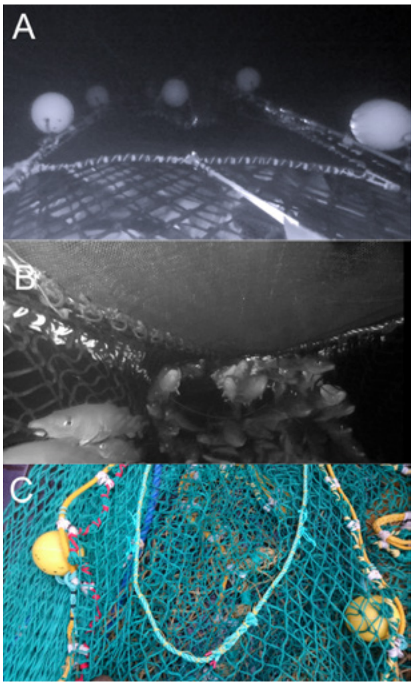

Figure 5.4.2. A: Underwater photo of the ExFed system, showing the rubber mat. B: Underwater film from the inside of the ExFed system: The smooth inner-lining of the rubber mat can be seen. C: The rear part of the ExFed opening was cut round in a "U" shape.

Figure 5.4.3: Snapshot from underwater video, showing the four panel codend during towing.

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 economically 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 herding the fish towards the trawl opening and therefor important in order to maintain catch rates. However, the difference in fishing efficiency with doors on and off bottom has yet to be fully documented. Therefore, comparative fishing trials were conducted in 2017, and will continue 2018.

Recent years high populations of Atlantic cod in the Barents Sea have led to excessively large trawl catches. This leads to reduced quality when the catch exceeds the vessel's production capacity, increasing risk of damage and safety concern. Therefore, at request from the industry and management authorities, a passive catch reduction device, the Excess Fish Exclusion Device (ExFed), has been developed and tested by the industry. The ExFed consist of a fish lock just behind a rectangular opening in the upper panel covered by a rubber mat attached only at its leading edge. The fish lock prevents the target quantity of fish from escaping during haul back. Initially, the mat lies against the top panel of the trawl sealing the escape opening. As fish accumulate and fill up to the fish lock, water flow is diverted out the escape opening, lifting the mat and allowing excess fish to escape at the fishing depth. The system is mounted at a distance from the cod line selected to achieve the target size catch for the vessel. An alternative catch control system is used by the Norwegian Danish seine fleet. It consists of two splits foremost in the codend, just in front of a fish lock. The slots are kept closed by threading a rope along its edges. The rope is slightly shorter than the edges of the net, initially keeping the slots closed during towing, but when catches build up, the codend expands and the openings expand laterally, releasing excess fish. This year further experiments have been conducted to optimize the systems.

ACTIVITIES AND RESULTS

Catch regulation in trawls

A trial was carried out on board the trawler FV "J. Bergvoll" (Nergård Havfiske AS) in April 2017, testing a dynamic catch control system simultaneously on two trawls with different size-selection devices: one with a Flexigrid and the other with a four panel codend with short lastridge ropes. In earlier experiments, the ExFed catch regulation device had been simplified by removing the steel frame surrounding the escape opening. In combination with the mandatory selection grids, however, some fish is inevitably washed out at the surface. The grid inhibits fish passage to the codend, resulting in

Figure 5.4.4. Fitting sensors to the trawl at the RV "Johan Hjort"-survey in December 2017 (Photo Thor Bærhaugen).

fish residues passing the codend extension during haul-back, floating out the ExFed opening at the surface. Removing the grid would solve the problem. For management acceptance, however, an alternative selective solution must be provided.

A size selective codend was therefore designed, with four netting panels and lastridge ropes 30% shorter than the netting of the codend. For maximizing the probability of fish escapes, the four ropes maintain a full square-mesh opening all along the codend. This design ensures open passage from the front parts of the trawl to the codend throughout the duration of the trawl haul.

Comparative fishing trials were performed, towing with two identical trawls simultaneously, one with a Flexi-grid and a conventional 130 mm two-panel codend and the other without a grid, but with a four panel 152 mm codend with short lastridge ropes. The ExFed system used on the four panel codend had a frameless opening cut in a round "U" shape and the rubber mat lined with a small-meshed, knotless netting, to avoid skin abrasion. Ten hauls were carried out, from which haddock, cod and saithe were length measured and all fish counted.

The four panel codend was more size selective, i.e. caught significantly less undersized fish than the Flexi-grid codend combination. It is easy to handle, and no obvious negative effects were experienced. In comparison with previously published selectivity data for cod, the results seem close to what would be expected for the Sort-V grid. Our findings suggest that a four panel codend with short lastridge rope could replace rigid grids in the Barents Sea trawl fishery. To verify the selectivity properties of the codend, a follow-up study should be carried out.

Semi-pelagic trawling

Comparative fishing trials with a small commercial bottom trawl fished with bottom and semi-pelagic rigging was carried out in December 2017 on board the RV «Johan Hjort». The two 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. A constrictor rope was used on the warps to keep similar door distance (approximately 110 m) during bottom and semi-pelagic trawling. Simrad sensors were used to monitor door height as well as pitch and roll. The targeted door height above sea bottom during semi-pelagic trawling was 1-2 m.

It proved difficult to maintain the doors in a stable position close to the seabed with no other means to control the door height than the towing speed and warp length. In several hauls the doors frequently lifted 5 m or more above the sea floor. The catches, which consisted mainly of cod, ranged between 300 and 600 kg for a towed distance of three nautical miles. For the nine pair-wise hauls taken, there was an overall catch reduction in the semi-pelagic hauls of about 15% compared to the bottom trawl hauls. But the results also indicated that the reduction in catches was lower when the doors were kept close to the seabed than when they lifted higher. In hauls where one succeeded in keeping the doors stable at a height of 1-2 m, the catches were similar to those taken by bottom trawling. These experiments will be continued onboard a commercial trawler in 2018.

5.5 QUALITY IMPROVEMENT

Many factors can influence the quality of a catch, such as season, fish-species and - condition, as well as fishing depth, catching methods and processing practices. Both catch size and haul duration, as well as hauling the catch over the stern, are all variables that are likely to affect the quality of the catch. When the catch is hauled onboard, the majority of trawlers drop their 20–30 ton catches directly into the receiving bin, similar to what was done 60 years ago. Thus, fish caught with bottom trawl can have incurred visually detectable gear marks, scale loss, skin abrasion, internal and external ecchymosis and reduced ability of sufficient bleeding.

The high densities of cod encountered in the Barents Sea and at the spawning areas along the coast of Norway, have led to increased frequency of excessive catches onboard trawlers and Danish seines. If the trawl has caught the desired amount of fish, while still producing the catch from the previous haul, the skippers may choose to lift the trawl off the seabed and continue towing at low speed until the production from the previous haul is finished, a process termed buffer towing. During November 2016, there was conducted a cruise onboard RV "Helmer Hanssen" to study the effect of buffer towing. The results, submitted to a scientific journal (Fisheries Research) in November 2017, show that this practice have a negative impact on the catch quality, as well as size selectivity (published in ICES Journal of Marine Science).

Different catch control devices have been tested and introduced to the demersal trawl fisheries. The excess fish excluder (ExFed) comprises a guiding long panel, termed a fish lock, which is obliquely sewn to the section with an opening between the aft part of the panel and the lower trawl panel. The fish lock prevents fish that have entered the codend from swimming forwards and out of the codend. A rectangular hole in the upper panel of the trawl, covered with a rubber mat, in front of the fish lock is lifted upwards when the codend is filled, thus releasing any excess fish caught. Although the ExFed-system allows controlling and limiting the catch sizes, which is important for maintaining superior quality, it implies one drawback that is believed to negatively influence the catch quality. The fish-lock limiting the catch size causes the fish to be crowded too densely. Cod and other gadoids have a physoclist swim bladder, resulting in expansion of the catch volume during haul-back until the critical limit where the swim bladder ruptures is achieved, at ~ 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.

During April 2017, a cruise onboard FV "J. Bergvoll" (Nergård Havfiske AS) aimed to study the amount and severity of catch damage on cod caught with conventional codends and compare these results with those achieved using a newly developed sequential codend concept. The sequential codend was designed to improve the catch quality by reducing catch damages frequently observed on trawl caught fish. The new quality improving codend segment (built by Egersund Group AS) was attached to the aft part of the conventional codend segment. The entrance of this codend segment was kept closed during towing, not allowing fish to fall back in to the new codend. The quality improving codend segment was opened at a predefined depth during haul-

Figure 5.5.1. Live-storage of fish for six hours, then bled by cutting the throat prior to filleting. This contributed to a whiter colour (right fillet) of the fish muscle, as compared to traditional trawl quality (left fillet), which is directly gutted and filleted one hour post-harvest (Photo: Nofima AS).

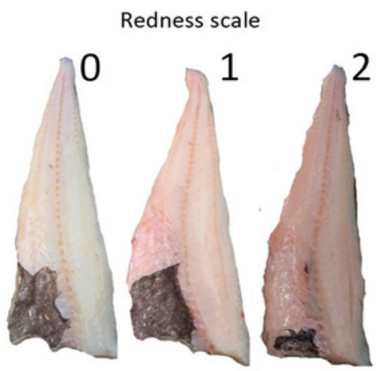

Figure 5.5.2. The fillet colour were evaluated according to three different score; Score 0: natural white. Score 1: slightly reddish: Score 2: moderately red and bruised (Photo: Nofima AS).

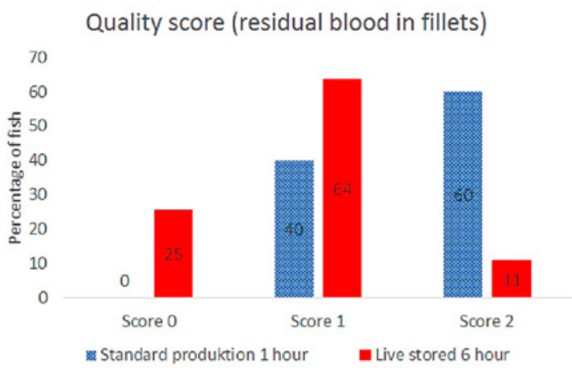

Figure 5.5.3. A larger percentage (25%; score 0 and 64%; score 1) of the fish that was live stored for 6 hours before slaughter, has a lighter base color on the fillets, compared to traditional trawl quality (40%; score 1 and 60%; score 2), which were directly gutted and filleted one hour post-harvest (Figure: Nofima AS).

Figure 5.5.4. The new live storage tank installed at the trawl deck onboard FV "J. Bergvoll", Nergård Havfiske AS (Photo: Nofima AS).

Figure 5.5.5. Due to lack of buoyancy, Atlantic cod is spread throughout the bottom area of the tank during live storage (Photo: Nofima AS).

back applying a catch releaser (built by FossTech AS). The results from this trial, which is submitted to a scientific journal in February 2018, show that the catch related damages (gear marks, poor exsanguination, ecchymosis and skin abrasions) was significantly reduced, when using the dual sequential codend. Specifically, the probability of having no type of catch damage proved to be five times higher for cod retained in the sequential codend, as compared to the conventional codend. The results also demonstrated a significant reduction in the frequency and severity of gear marks, poor exsanguination, ecchymosis and skin abrasions, i.e. improved quality with the sequential codend.

Figure 5.5.6. Testing a new 4-panels codend segment, which is designed in order to improve catch quality. Egersund Group AS, in cooperation with the Institute of Marine Research have designed and built the new codend. The codend segment entrance is closed during towing, not allowing fish to enter, until it reached a predefined depth during haul-back (Photo: Nofima AS).

To produce new high-quality products, it is essential to thoroughly implement the various mechanisms that govern quality. A commercial white fish trawler was refurbished in 2016. The trawler receiving bins and the processing line was modified, in order to keep the catch

Blood-pH start	Blood-pH 6 hour	Blood-lact. start	Blood-lact. 6 hour	Blood-gluc. start	Blood-gluc. 6 hour	Survival (%)
7,2 ± 0,1	7,6 ± 0,1	3,0 ± 0,3	1,7 ± 0,4	5,0 ± 0,6	10,2 ± 1,2	89,3 ± 5,1

Table 5.5.1. Changes in blood pH, blood lactate (mmol/L) and blood glucose (mmol/L) as a response to 6-hour live storage in a new prototype live storing tank. The value is mean ± std. (n=50). The survival (%) after 6 hours live storage is presented as mean ± std. from 10 trawl hauls.

Figure 5.5.7. A standard two panel conventional codend, having the legislated mesh size, and required selective attributes (Photo: Nofima AS).

alive until slaughtering. Several other ship-owners are considering installing short time live storage facilities onboard, when building new boats. However, implementing new technologies on vessels is often connected with financial and technical risks. Nevertheless, before this can be implemented onboard new trawlers today, it is of immense importance to gain new knowledge to understand the fish tolerance, fatigue, recovery, blood flow, and where and why blood is located in the body and fish muscle at any given time.

During November 2017, we conducted a cruise onboard at FV "J. Bergvoll" (Nergård Havfiske AS). The aim of activity was to determine the effect of stress associated with commercial trawling for Atlantic cod, and survival during live storage in a new prototype live storage tank. In 2016, The Norwegian Seafood Research Fund (FHF) financed a project (FHF project no. 901274) to build and test a new prototype of live-storage fish tank (4,5 m3). This tank has capacity to hold 2000 kilos of live fish. The tests show that the dispersion of water in the tank was optimal and gave good results regarding survival of the catch. Out of 10 trawl hauls, an average of 90 percent of the cod survived, after 6 hour in the live-storage tank. Live-storage of fish for six hours contributed to a whiter colour of the fish muscle, as compared to traditional trawl quality. The fish from the North Atlantic and the Barents-sea is adapted to a cold environment with high levels of oxygen in the water. Thus, to obtain good survival and recovery during live storage, the oxygen level in the drain must never fall below 7 mg O2/l. The same technology may also be used in a receiving bin of a trawler. However, during haul-back operation of the trawl, the swim bladder in Atlantic cod and haddock often punctures on its way up to the surface resulting in lack of buoyancy. Thus, it is often seen a 40-50 cm thick layer of fish spread throughout the bottom area of the tank. The Atlantic cod can restore the swim bladder function after rupture. However, it take time to refill their swim bladder after rapture. It is therefore outmost important to have an up-stream water supply, whit plenty supply of fresh seawater, to maintain god survival during live storage. Most of the fish can then be kept alive until stunning and bleeding onboard trawlers.

However, it must be take into consideration that fish increase the quantity of muscle blood during the first 2–3 hours of live-storage. If the fish is slaughtered too early during live storage, this will not contribute to a substantial improvement of the fish muscle quality, as compared regular trawl quality.

Figure 5.5.8. A hydrostatic codend releaser (FossTech AS) is mounted on top of the commercial trawl codend and releases the fish back into the new codend segment at a given depth (Photo: Nofima AS).

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.

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 analyses 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 in this WP.

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.

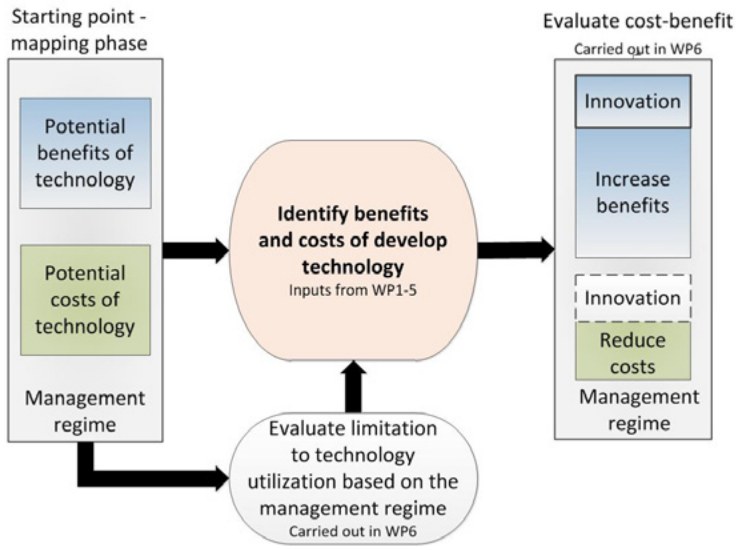

Figure 5.6.1. Framework for cost-benefit analysis for evaluating the impact of developed technology in CRISP.

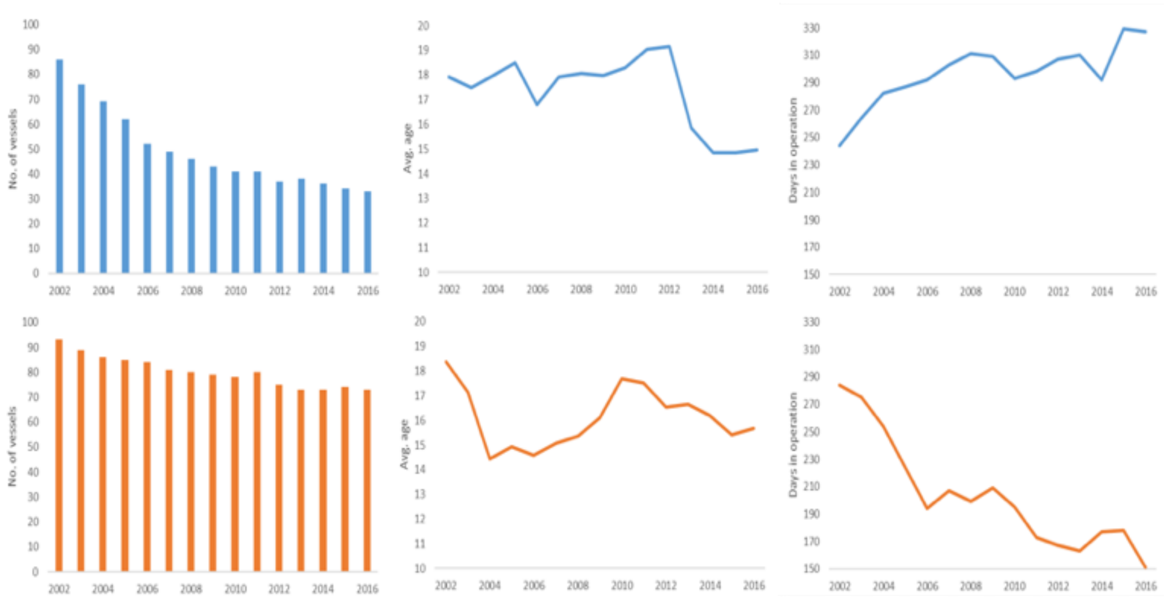

Figure 5.6.2. Development in number of vessels, average age and days in operation for cod trawlers (in blue – upper) and purse seiners (in orange – lower) for the period 2002–2016.

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 substantially reduction in the number of vessels in both vessel groups in 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 is. 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 not sufficient 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. 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.

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 as 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

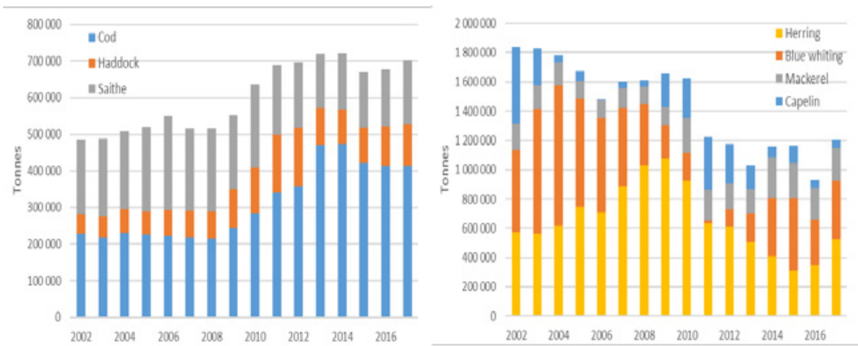

Figure 5.6.3. Annual Norwegian catches of cod, saithe and haddock (left) and herring, blue whiting, mackerel and capelin (right) in the period 2002-2017

Figure 5.6.4. Annual Norwegian catches of cod, saithe and haddock (left) and herring, blue whiting, mackerel and capelin (right) in the period 2002-2017

5.6.4 we demonstrate that, although a significant drop in number of vessels fleets, 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 in both 2015 and 2016. CRISP, and other studies, have revealed a relationship between CPUE and fuel consumption. Indicating increased fuel consumption among trawlers in 2015 and 2016. 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 environmental 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 are essential and have been given priority in CRISP. A closer look at the overview of technology developed in CRISP (see Chapter 6) 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 are 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. Chapter 6 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).

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 echo sounder system and methods to measure the size of individual fish inside a school (Simrad EK80 and Dabgraf projects)

WP2 - GEAR AND CATCH MONITORING SYSTEMS IN PURSE SEINE

4. 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.

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

6. 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

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

8. 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

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

WP4 - LOW IMPACT TRAWL

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

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

WP5 - QUALITY IMPROVEMENT

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

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

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

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

7. INTERNATIONAL COOPERATION

CRISP intends to cooperate with international research institutions when such cooperation is beneficial for joint development and introduction of sustainable fishing technology outside Norway. The industry partners in CRISP are all Norwegian owned, and they 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. Also, researchers from 15 nations participated in a training course in acoustic volume measurement with broadband sonars developed under the auspices of CRISP. This course was held onboard the RV "G.O.Sars".

There is a great international interest in sonar technology developed within CRISP, as demonstrated by the requests to CRISP researcher Hector Pena from IMR to assist AZTI Technology Center in Spain to develop and test methods for quantity estimation of bluefin tuna using Simrad SN90 sonar. Similar transfer of knowledge is planned to researchers in Argentina in 2018, and probably also Peru and Chile.

Figure 7.1. Senior scientist Hector Pena, IMR, teaching sonar technology to international scientists.

Figure 7.2. Masters students Thomas Mahiout and Tiffanie Schreyeck from the University of Nice, France applied convolutional neural network techniques to distinguish between Atlantic herring, Atlantic mackerel and blue whiting in Deep Vision images.

Senior Scientist Bent Dreyer from Nofima had a stay at FAO, Rome as visiting expert in spring 2017, where he worked on "Socio-economic dimensions of sustainability." Several researchers connected to CRISP have 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 in CRISP, 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 2017, a simplified version of Deep Vision was tested on board a Greek trawler under the auspices of the MINOUW project. Also as part of MINOUW, CRISP researchers Mike Breen and Shale Rosen held lectures at the advanced course for fisheries professionals Technological solutions for reduction of discards in fisheries at the International Centre for Advanced Mediterranean Agronomic Studies in Zaragoza, Spain in February 2017.

Scantrol Deep Vision AS has had extensive cooperation with the University of Girona, Spain, which has resulted in the founding of a joint software company in where one person was employed in 2017. In an unrelated project, two Masters students from the University of Nice, France spent the summer 2017 at the Institute of Marine Research where they applied advanced machine learning techniques to species recognition in Deep Vision images.

CRISP researcher Shale Rosen from IMR also contributed to the Nansen Program and has participated in two research cruises onboard the research vessel RV "Dr. Fridtjof Nansen" this year. 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. The two mentioned cruises support the fisheries management in Morocco and Namibia.

CRISP participated in the INTPART successful proposal 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 will 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.

8. RECRUITMENT

In 2017 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 deals with behavior of demersal fish during trawl capture (WP3 and 4). Melanie delivered her thesis in January 2018, and will have her dissertation spring 2018. *Ragnhild Svalheim* has been employed by Nofima from 2013 to 2017. Her study focuses on how muscles of captured fish restore during the post capture phase (WP5). She is also in the final stage of her project, and are expected to deliver her thesis and have her dissertation during 2018.

Three PhD students started up their projects in 2016 and are now well into their research activities. The first, *Neil Anders*, focuses on how handling of the catch during purse seining influence fish welfare and thus fish survival (if the fish is released) or meat quality (if taken on board). His project is a cooperation between WP2 and 5, and his team of supervisors comprises scientists both from IMR and Nofima. The second, *Jesse Brinkhof*, studies 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. The third PhD, *Helene Jensen*, started in September 2016. She focuses on value adding caused by CRISP innovations (WP6), and works at Nofima.

Figure 8.1. PhD student Jesse Brinkhof onboard FV "J. Bergvoll" together with one of his supervisors, Olafur Ingolfsson (Photo: Nofima).

Figure 8.2. The CRISP leader, Aud Vold, communicates with the PhD students Helene Jensen (left) and Tonje K. Bjørvig (right) at the Annual Science meeting (Photo: IMR).

A last PhD, Tonje K. Bjørvig, starting up in 2017, is linked to CRISP thematically, working with the consequences of trawl gear innovations on fish quality, but her project is economically funded by UiT, and not by CRISP. Her supervisors are from UiT and CRISP. CRISP is truly adding to the recruitment of new scientist within the field of 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 as scientist at IMR. In 2017 no new Master students were, unfortunately, taken up in CRISP.

9. COMMUNICATION AND DISSEMINATION ACTIVITIES

CRISP staff have participated in several meetings and symposia in 2017, were the scientific output of the centre has been presented for international audiences, among which we will mention:

- Working group on fisheries, acoustics, science and technology (WGFAST). Nelson, New Zealand, 4-7 April 2017.
- The 3rd Norwegian Food Market Research Conference (NoFoMarc). 2-3 March
- Havforskningsdagene 4-5 Jan 2017
- Technological solutions for reduction of discards in fisheries. The International Centre for Advanced Mediterranean Agronomi, Zaragoza, Spain, 20-24 Feb 2017.

Our activities and innovations have also been promoted at several national meetings, seminars and fishing exhibitions arranged by various Norwegian hosts.

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") and on CRISP's and the institutes' web pages. A selection of scientific results was published in reviewed scientific journals. CRISP achievements, particularly news on the Deep Vision technology and on fish quality, have 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" 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 I

Personell

KEY RESEARCHERS

Name	Institution	Main research area	Sex
Torbjørn TOBIASSEN	Nofima	Quality improvement	M
Kjell MIDLING	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
Geir Sogn GRUNDVÅG	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
Anders FERNØ	UIB	Researcher training, recruitment	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

Personell

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
Jon Even CORNELIUSSEN	Kongsberg Group	Monitoring fish and gear	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
Arvid SÆSTAD	Egersund Group	Low impact trawling	M
Trond NEDREBØ	Egersund Group	Low impact trawling	M
Roy SKULEVOLD	Egersund Group	Low impact trawling	M
Vidar KNOTTEN	Egersund Group	Low impact trawling	M
Bjørn HAVSØ	Egersund Group	Low impact trawling/Management	M
Kjell LARSSEN	Nergård Havfiske	Quality improvement and value adding	M
Torgeir MANNVIK	Nergård Havfiske	Quality improvement and value adding	M
Morten HERMANSEN	Nergård	Quality improvement and value adding	M
Øyvind BERG	Nergård	Quality improvement and value adding	M

POSTDOCTORAL RESEARCHERS WITH FINANCIAL SUPPORT FROM THE CENTRE BUDGET

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

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	Value adding
Helene JENSEN	Norwegian	01.09.2016-31.08.2019	M	Value adding Purse seine
Neil R. ANDERS	Great Britain	01.01.2016-31.12.2019		Purse seine
Tonje K. BJØRVIG	Norwegian	31.03.2017-31.03.2021	F	Fish Quality (funded by UIT)

BACHELOR STUDENTS

Name	Nationality	Period	Sex	Topic
Karoline INGEBRIGTSEN	Norwegian	2017	F	Value adding

APPENDIX 2

Statement of Accounts 2017

All figures in 1 000 NOK

Funding

		Budget	Account
The Research Council		10 000	10 000
The Host Institution	Havforskningsinstituttet	6 050	12 324
Research partners	Nofima	1 676	959
	University of Bergen	350	315
	University of Tromsø	1 200	571
Enterprise partners	Kongsberg Maritime AS	2 300	5 891
	Egersund Group AS	420	334
	Scantrol AS	200	332
	Nergård Havfiske AS	1 000	1 926
Public partners	Sildesalgslaget	100	100
	Råfisklaget	100	100
		23 396	32 852

Costs

		Budget	Account
The Host Institution	Havforskningsinstituttet	12 570	18 844
Research partners	Nofima	4 026	3 309
	University of Bergen	830	795
	University of Tromsø	2 050	1 421
Enterprise partners	Kongsberg Maritime AS	2 300	5 891
	Egersund Group AS	420	334
	Scantrol AS	200	332
	Nergård Havfiske AS	1 000	1 926
Public partners	Sildesalgslaget	0	0
	Råfisklaget	0	0
		23 396	32 852

APPENDIX 3

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