ANNUAL REPORT | 2015

CRISP

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 AS; the Egersund Group AS; Nergård Havfiske AS), four research partners (the Institute of Marine Research; Nofima AS; the University of Bergen; the University of Tromsø), and two sponsors (Norges Råfisklag; Norges Sildesalgslag).

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

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 fifth 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.

Both the fishing industry and research institutes need more accurate density and abundance measurements of schooling fish species than what is possible with current instrumentation. Simrad is collaborating with IMR for developing new and improved fishery sonars which can quantify the size of a school prior to shooting the purse seine, and high definition echo sounders which may accurately measure the fish size. Most of the problems anticipated in the calibration of both systems are now solved and was published in 2015. Simrad has recently released the wideband echo sounder EK80 as a new product, and is working on finalizing a new sonar which is meant to work inside the purse seine with one to three inspection beams for sizing of fish.

The purse seine fleet may increase their income by choosing harvest strategies that optimize the value of their limited vessel quota, and for this the skipper needs tools for better control of the catch and the gear. Three main topics have been the focus in 2015: 1) Studying how an integrated suite of instruments could be used to investigate the welfare status of schooling fish, and assessing which combination of measurement techniques can best describe the welfare status of fish contained in a purse seine; 2) Further testing of Simrad's "In-seine" sonar technology for catch control of fish inside a purse seine; and 3) Monitoring the geometry and performance of the seine by using transponders developed by Simrad, which transmits an acoustic signal that is received and displayed in the SN90 sonar picture.

Unwanted catches often occur in mixed trawl fisheries regulated by quotas on 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 constant stereo images of all objects passing through a trawl. These 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. Kongsberg Simrad has developed a trawl camera and Ethernet hub system for streaming live information to the vessel bridge via net sonar cable. They also continue to work on new trawl geometry and acoustic observation systems.

The current trawling practice may be harmful to the seabed, have high bycatch rates and high fuel consumption that can affect the environment. High populations of Atlantic cod in the Barents Sea are currently leading to excessively large trawl catches which leads to reduced quality and safety concern. The future of trawling will thus largely depend on the development of trawling techniques that significantly reduce these negative impacts. Egersund Group in cooperation with Simrad and IMR addresses the design, rigging and operation of trawl gears that might achieve such objectives. The two main focus areas in 2015 have been testing of manoeuvrable trawl-doors for semi-pelagic trawling that reduces bottom impact, and catch reduction systems for gentle release of excess catches.

The Norwegian fleet of ocean trawlers has gone through large changes since the turn of the millennium. Based on the encouraging results from the previous CRISP-experiments on quality improvement both in field and in laboratory, Nergård Havfiske AS has decided to develop their new trawler for the future which will be implementing results from recent research regarding fishing efficiency, optimal product quality and improved welfare for the fish as well as for the crew. Studies of the effects of different stressors on fish during capture and handling are carried out aboard fishing vessels as well as in controlled experimental studies in the CRISP large scale swim tunnel/trawl simulator.

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. 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 has been made. According to Nergård, the most important quality parameters regarding the fish are redness and gaping. A model has made based on frequency of good to poor quality of cod subjected to difference in recuperation time after commercial and experimental trawling. The lowest value per kg was found for traditional production. The findings suggest that there are economic benefits from live storage for a minimum of six hours onboard commercial trawlers.

CRISP staff has taken part in a 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 several meetings, seminars and fishing exhibitions arranged by various hosts.

In 2015 Crisp hosted two Post doctorial positions, three PhD position and six Master students. Close to half of the recruitment candidates were females, which is an important step towards increasing gender equality in a formerly male dominant industry.

During the first half year of 2015 the CRISP Centre went through a midway evaluation organized by the Research Council of Norway. The centre was evaluated by a panel of four international experts.

A meeting between CRISP and the evaluation panel was held in Bergen March 26, 2015. Based on the recommendations from the panel, the executive Board of the Norwegian Research Council granted CRISP continuation until 2018 without requirements for major changes. The evaluation panel did, however, give a list of recommendations and suggestions for improvement of the Centre. One important consequence of the midway evaluation is the formation of an International Scientific Advisory Committee as recommended by the panel.

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 the partners in several of the work packages over the coming years.

4 ORGANIZATION

4.1 Organizational structure

IMR in Bergen is the host institution and is responsible for the administration of CRISP. Within IMR, the centre is organized as a project in the Barents and Polar Sea research program. Most IMR personnel working in CRISP projects belong to the Marine Ecosystem Acoustics and Fish Capture research groups. Scientists working in CRISP projects are therefore 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 formal education for PhD and MSc students who are funded by and associated with the Centre.

John Willy Valdemarsen of IMR was appointed director of the Centre from its starting date on April 1, 2011, but was succeeded by Aud Vold, also IMR, from September 1, 2015 (Figure 4.1).

The board of the Centre in 2014 was as follows:

- Olav Vittersø, Kongsberg Maritime AS, Simrad (Chair)
- Helge Hammersland, Scantrol AS
- Vidar Knotten, Egersund Group AS
- Kjell Larsen, Nergård Havfiske AS
- Geir Lasse Taranger, Institute of Marine Research
- Heidi Nilsen, Nofima AS
- Arne Johannessen, University of Bergen
- Jonny Caspersen, Norges Råfisklag
- 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 Norges Råfisklag and Norges Sildesalgslag, alternate as board members every second year.

4.2 Partners

In 2015, the CRISP consortium comprised 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).

Figure 4.1: New (Aud Vold) and old leader (John Willy Valdemarsen) at the midway evaluation meeting in March.

IMR has relevant R&D competence in fisheries acoustic, fish behaviour, fishing gear design and operation, capture of live cod for storage in net pens, 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.

The University of Bergen has relevant scientific and supervision expertise in general fish biology, experimental biology, fish behaviour, fisheries acoustics and fish capture. 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), has particular responsibility for the development of expertise within all areas of fisheries and aquaculture research in Norway. Teaching and research focus is 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 monitors. 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 purpose. 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 our 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. Cooperation with the other industry partners will be helpful in adapting DeepVision to different trawl designs and benefitting from the development of a new signal cable between the vessel and its trawl gear.

The Egersund Group AS is a leading producer of pelagic trawls and trawl doors and a significant producer of purse seines for the Norwegian and Nordic markets. The company provides extensive practical experience to the Centre in 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 The Egersund Group to develop trawl and purse seine technologies that will satisfy future requirements for green harvesting, which will be an advantage in the Norwegian and international markets.

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

Figure 4.2: The consortium gathered at the Annual Science Meeting in Årsgårdsstrand in September 2015.

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 involve 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. A major challenge for the centre is therefore to create an environment for the development of instrumentation and fishing systems where complementary competence can be utilized efficiently to create completely new products. During this fourth year the various partners have continued to spend time on identifying areas of common interest and on launching cooperative efforts.

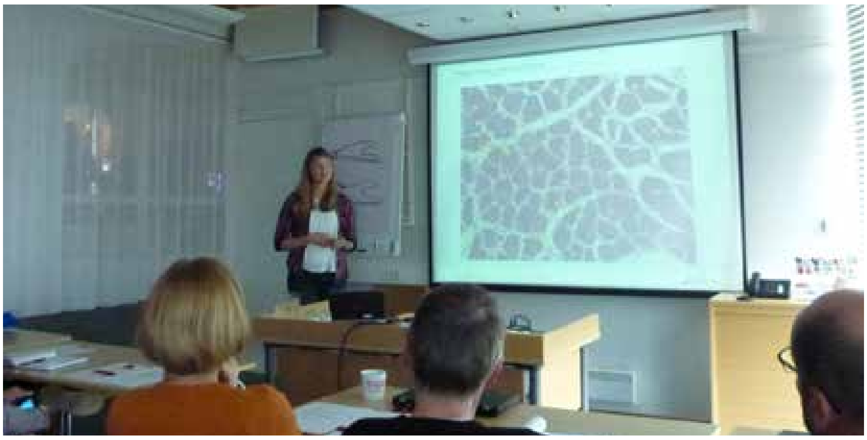

Figure 4.3:
PhD Ragnhild Svalheim giving a presentation about her ongoing project on fish quality at the Annual Science Meeting in Åsgårdstand.

The Centre uses various arenas and methods to encourage mutual trust and to form joint projects involving CRISP's partners. 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 onboard 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 the all partners participates in planning and execution of the research cruises followed by evaluation and reporting of the results. Industry partners, with the assistance from the Centre's management, have arranged meetings to discuss and plan joint development work. All of the CRISP partners participated in a two-days science meeting in Åsgårdstrand in September where matters of common interest were discussed (Figure 4.2 and 4.3). The main focus this year was how the CRISP center should adjust its course according to the recommendations from the midway evaluation committee.

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 with 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 3.3 Catch regulation in trawls	IMR, Scantrol Deep Vision , KM, UiB
WP 4. Low impact trawl	4.1 Manoeuvrable trawl doors 4.2 Semipelagic trawl design and rigging	IMR, Egersund Group, KM, UiB
WP 5. Quality improvement	5.1 Current quality conditions onboard bottom trawlers 5.2 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 measurements of schooling fish species than what is possible with current instrumentation. In this respect, research and industry has a common long term challenge.

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 "poor" sets where 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, instruments that can reduce this risk are needed for future sustainable harvesting of pelagic schooling fish with purse seine gears.

Figure 5.1: The TS probe, used to measure individual target strength of single mackerel in dorsal (echo sounder mode) and lateral (sonar mode).

Activities
Simrad is collaborating with IMR for developing new and improved fishery sonar which can quantify the size of a school prior to shooting the purse seine, and high definition echo sounders which

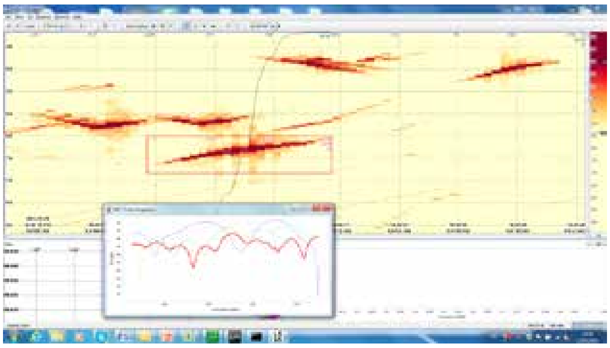

Figure 5.2:
Wideband, EK80, target strength measurements from the probe. TS and TS spectra from 150-270 kHz shown from 3 successive pings in the selected track. About 10000 TS measurements of mean backscattering amplitudes are needed in order to compute a stable mean value.

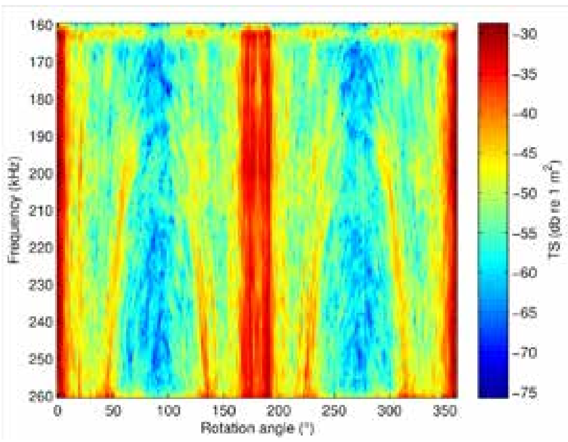

Figure 5.3:
Fig. 1.3 Lateral (side aspect) directivity pattern of a herring, measured while rotated 360 degrees, measured with the EK80 wideband echo sounder, 160 – 270 kHz. Note that the directivity is gradually changing with frequency, which is the basis for identification and sizing with acoustic systems.

may accurately measure the fish size. This includes development and testing of new sonar raw data output formats, and also the development of a standard calibration procedure for multibeam fishery sonars. New data formats and improved software have been delivered by the industry partner in 2013 and tested with participation by Simrad personnel in the trial surveys on herring in 2012 and 2013, and on Atlantic mackerel in October 2014 and 2015. The next years the survey will be targeting capelin.

A CRISP PhD student has successfully used the raw element data of the sonar transducer to create split beam positioning of the calibration target under sonar beam calibrations. The sonar calibration method is now under publishing, and may be implemented directly in the sonar itself. In 2016, a refinement of the calibration rig for holding the reference target will be made, and simplification of the software. On fish, more validations both for larger schools of herring and large schools of mackerel will be made. Publication of the algorithms for biomass measurements is prioritized.

In order to estimate fish size and species composition inside schools, the main activities this year have been to finalize calibration methods of wide-band echo sounders and trials with the new narrow beam transducer. The wideband echo sounder has been modified and improved by the industrial partner, both with respect to the hardware, but also significant effort is now being made on the new echo sounder software. Software and setup was tried with good results in the October 2015 mackerel survey, and a demonstration movie for the systems was made. We now regard the first version of the DABGRAF method to be finished, and ready for commercial use. New mountings of the transducer on fishing vessels will be tried in 2016 if a commercialization project is started. Also a new, light drop-sonde system has been tried inside herring schools in 2016, and shows promising results for real time sizing. This system could be used as a basis both free-floating, transmitting the data to the vessel or inside the purse seine.

Results
This project element is now in its fifth year, and the work with respect to calibration protocols for fishery sonar and wideband echo sounders is now mostly solved and was published in 2015 in Nantes. The calibration accuracy of fishery sonar may be slightly lower than for single beam echo sounders, and an overall accuracy of 0.5 dB (±10%) seems to be a good goal. The environmental effects on the transmitted and reflected signals are also larger for sonars than for vertical echo sounding, and so is also the backscatter variability due to target orientation relative to the sonar beam. For the broadband echo sounders, the accuracy over the entire band of frequencies is comparable to the accuracy of narrowband systems, typically 0.1 to 0.2 dB, or 2%, while the calibration accuracy of fisheries sonars is about ± 10%, mainly due to environmental factors as temperature variations over the cross section of the beam, and temporal variation in this profile during field calibration. The total uncertainty in biomass estimates of from schools however lies mainly in the fish backscattering due to aspect, and the calibration uncertainty is therefore hidden in the total uncertainty.

Analysis of the target spectrum from single fish has continued, and has this year mainly focused on mackerel. Using the new transducer mounting, natural layers in the normal fishing ground for mackerel were well resolved for single target analysis and sizing both horizontally and vertically (Figures 5.1 and 5.2 and 5.3). Algorithms for fish sizing are tried out in new software from the DABGRAF project, which reads and process the wideband echo sounder data directly.

These algorithms now seem to do a much better job than the split beam target strength procedures, when using the information from each track, spectrum nulls and pulse stretching. New algoritmes for sizing mackerel based upon acoustically measuring special acoustic interference phenomena inside the mackerel body are also very promising. The sizing algorithms was published in the Nantes symposium, and a new NFR project will pursue the new findings in body part backscattering with the goal to implement this in future sizing software.

Simrad has now released the wideband echo sounder EK80 as a new product, and is working on finalizing the sonar which is meant to work inside the purse seine with one to three inspection beam for sizing. The prototype SN90 was tried on FV “Kings Bay” in November 2014 and FV “Eros” in 2015 with promising results and a new work package is defined for starting working with this sonar in 2015. This sonar will be the main focus for the WP 1.1 in 2016, both with respect to biomass, density and sizing. Measuring absolute density, i.e number of fish/m^3, in schools and layers seems to be a strong need from many skippers. We will try to implement correct measuring tools for these parameters in 2016, and show them to the skipper in a clear display.

Figure 5.4:
Schooling mackerel in the cage experiment at Austevoll. Various instruments were used to describe the behaviour of these fish under potentially stressful conditions, including crowding and hypoxia.

5.2 Gear and catch monitoring systems in purse seine

Background
In the analysis of the economic status of the purse seine fleet carried out in WP6 "Value adding" it was shown that the purse seine fleet may increase their income by choosing harvest strategies that optimize the value of their limited vessel quota. This can only be done if the skipper is given tools for better control of catch and gear. New instrumentation is also important in order to ensure responsible slipping practices when there is a need to release unwanted catches. These instruments should monitor gear shape and performance during fishing; identify species, size or quality of a catch; and monitor fish welfare parameters, to determine whether it is still safe to release fish.

In 2015, this Work Package has focused on three topics: 1) Assessing how an integrated suite of instruments could be used to investigate the welfare status of schooling fish; 2) Further testing of the "In-seine" sonar technology for catch control; and 3) Monitoring seine geometry and performance using sonar and transponder technology.

Assessing welfare status in schooling fish
In September and October 2015, in collaboration with Project RedSlip (NFR 243885), an integrated suite of instruments was used to measure various behavioural and environmental metrics in a school of mackerel, under simulated capture conditions at the IMR field station at Austevoll. This integrated instrument package contained a high resolution sonar (ARIS); a horizontally oriented stereo-camera; a CTD to monitor depth, temperature and salinity; a GoPro Hero III camera; an oxygen sensor; and tilt-loggers to monitor the orientation of the instruments (Figure 5.5).

The mackerel schools were held in 5x5x5m cages (Figure 5.4) and subjected to different conditions, simulating the

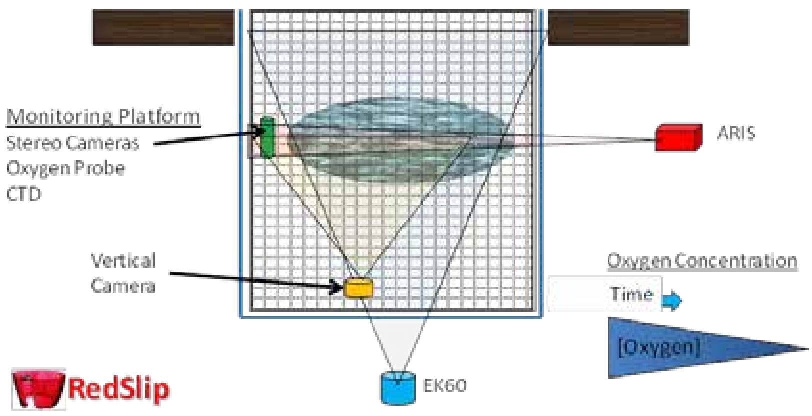

Figure 5.5
The experimental cage setup up at Austevoll. A suite of instruments were used to take integrated measurements of behaviour during different stressor treatments: crowding and hypoxia.

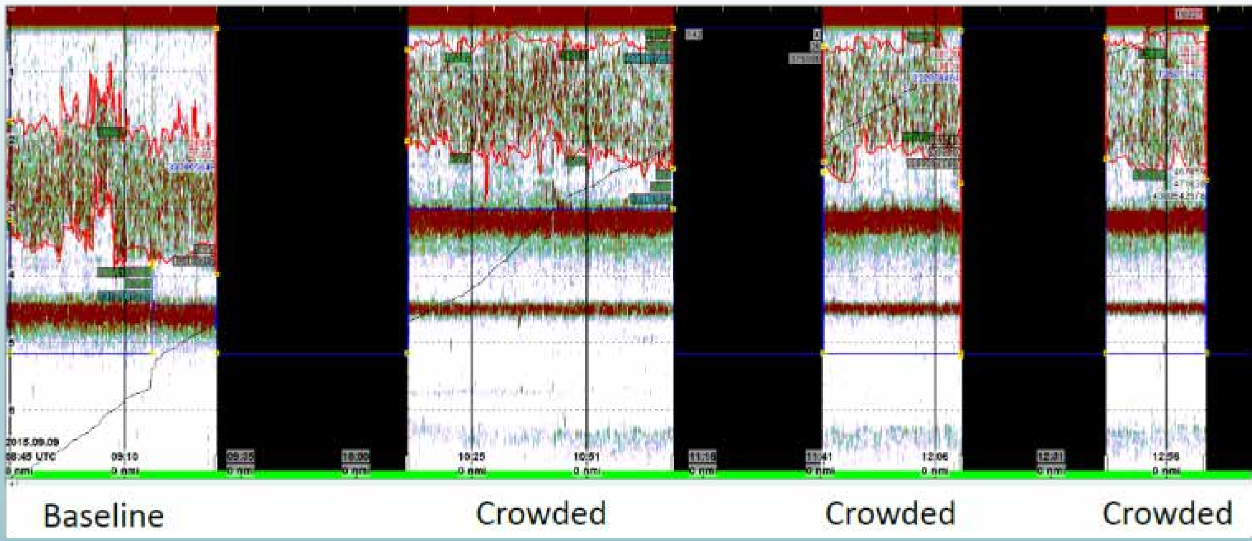

Figure 5.6:
An echogram from an EK60 before (Baseline) and during a crowding treatment. Reducing the volume of the cage forced the school to swim at shallower depths in comparison to the baseline and control treatments. In addition, the signal strength (SV) data suggests the density of the school increased more than expected from the volume reduction during the "crowding" treatments.

effects of capture related stressors (crowding & hypoxia) on the behaviour and welfare of the fish. The purpose was to attempt to initiate behavioural responses, without injuring or killing any of the fish. The first school was crowded by reducing the volume (depth) of the cage for approximately 1 hour. The second school was exposed to the same crowding, but also the cage was surrounded by a large plastic bag, to isolate the fish from fresh water and an oxygen supply (hypoxia). Finally, a third school was not subjected to any of these treatments, but observed in the same way as the other two schools to determine what effect captivity and the observation techniques were having on the fishes' behaviour. The different instruments were used to describe the behavioural responses of the mackerel under the treatment conditions. Images from vertically orientated cameras gave measures of activity (i.e. tail beat frequency), while stereo-cameras were used to describe inter-fish distances and relative orientations, as well give an absolute measure of density (i.e. number of fish per m^3). These results will be compared against the echo-sounder (Simrad EK60) and high resolution sonar (ARIS) to compare their different measures of density.

Preliminary results from this work indicate that measurable behavioural responses can be induced in schooling mackerel at relatively low, non-fatal, levels of capture related stressors: crowding and hypoxia. This suggests that monitoring behaviour of mackerel caught in a purse seine could be used to provide early warning indications of when the captive conditions are becoming potentially dangerous for the fish, and thus provide measurable limits of when any unwanted catch could safely be released.

Reducing the volume of the containing net forced the school to swim at shallower depths in comparison to the baseline and control treatments (figure 5.4). In addition, data from the echo-sounder indicates that the density of the school (i.e. fish per cubic metre) increased more than expected from the reduced volume during the "crowding" treatments. Although, interestingly, the additional hypoxia stressor appears to reduce the tendency to crowd (figure 5.7). This will be confirmed by stereo-camera measurements, when completed.

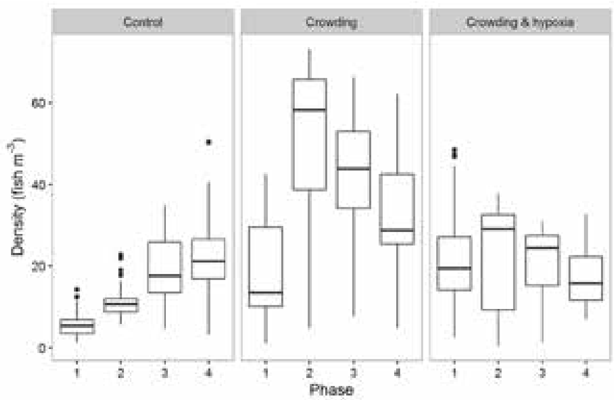

Figure 5.7:
Fish density (no. m^{-3}) varied during different, as well as at different phases during the treatments. Phase 1 refers to the pre-treatment monitoring, and Phases 2 to 4 are during-treatment observations at approximately 20, 40 and 60 minutes into the treatment.

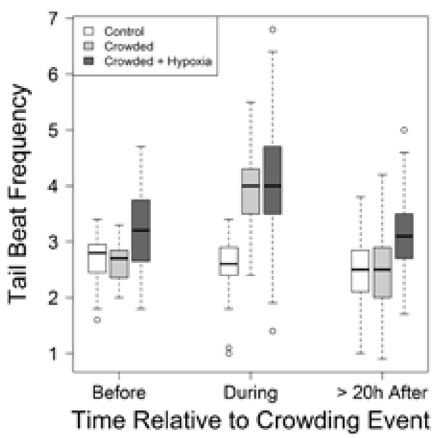

Figure 5.8:
The activity of schooling mackerel, as measured by tail beat frequency, was shown to increase significantly during potentially stressful treatments; i.e. when crowded and when crowded and hypoxic.

In addition, the activity of schooling mackerel, as measured by tail beat frequency, also appeared to show a significant increase during crowding and hypoxia treatments. The activity levels returned to baseline levels after approximately 20 hours (figure 5.8).

Work is ongoing to further analyse the remaining data, after which it will be assessed which combination of metrics and measurement techniques will be most informative and practical for describing the welfare status of mackerel contained in a purse seine.

"In-seine" sonar technology for catch control

In the CRISP survey in November 2015, where the purse seiner FV "Eros" was hired for running experiments simultaneously with RV "G.O. Sars", Simrad's new SN90 sonar was used to monitor mackerel schools and the performance of the seine during six purse seine sets. Two of the sets contained no catches while the remaining four contained between 75 and 203 tonnes of mackerel. During the survey valuable experience was obtained on the operation of the new sonar, but remaining challenges were also identified, e.g. storing raw data for scientific purposes, which is a process that is not part of the normal sonar operation during commercial fishing.

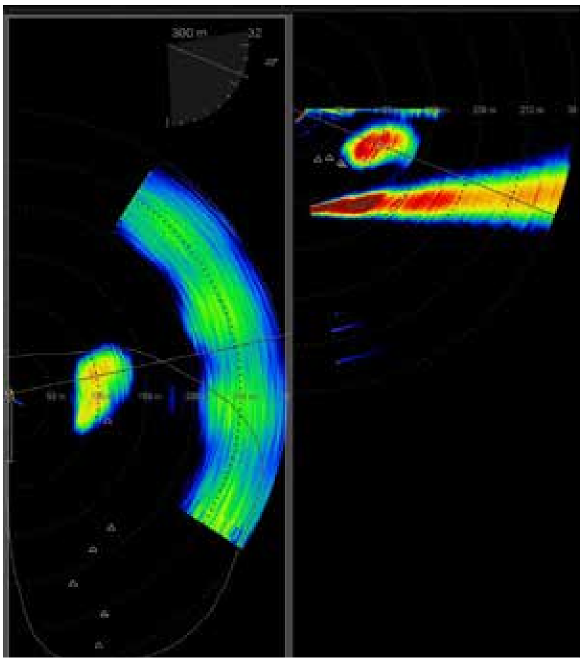

Figure 5.9:
SN90 sonar screen picture of a mackerel school in an early catch stage displayed as a green-yellow circular shape at 100 m range on the starboard side of the vessel in the horizontal section (left panel). In the vertical section (right panel), the school is showed with higher strength (red-yellow). The bottom echoes are displayed along the outer edges of the sections.

In some of the sets the school and the gear could be clearly identified and monitored during capture (Figure 5.9). However, the data quality varied between catches, likely due to different school behaviours (e.g. density and swimming patterns) and environmental conditions. Under strong wind and current conditions waves, vessel pitch and roll and a more intensive use of side thrusters create air bubbles in the water column that disturb and block the acoustic beams. The quality of the data further varied between different fishing stages depending on the use of side thrusters and other seining machinery, suggesting that biomass estimates inside the seine may only be possible during some parts of a purse seine set.

During the survey, the first trials of calibrating the SN90 sonar were carried out, using the experience and knowledge learned from the omni-sonar calibration (WP1). The software

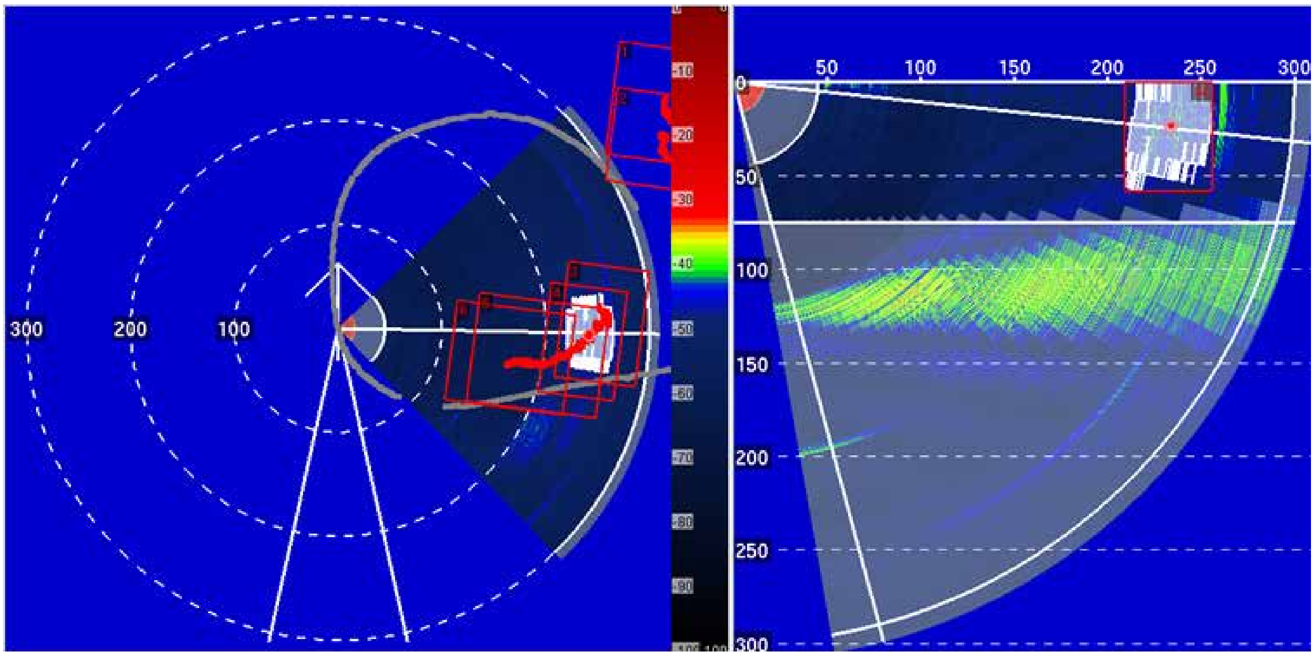

Figure 5.10:
A mackerel school displayed in PROFOS software in horizontal section (left panel) marked with a white overlay and surrounded by a red box. In the vertical section (right panel), school is also surrounded by a red box, with a vertical extension from 0 to 50 m, with bottom echoes displayed as light green at a depth of about 100m. Data from the Simrad SN90 sonar during the CRISP survey in November 2015 onboard F/V "Eros".

module Processing system for omnidirectional fisheries sonars (PROFOS) has been modified to enable the replay and processing of the raw data from the SN90 sonar, as showed in Figure 5.10.

Monitoring seine geometry and performance

At present, there are no efficient monitoring tools that provide the skipper with information of the location of the net relative to the vessel during deployment and pursing of a seine. A new transponder that transmits an acoustic signal which is received and displayed in the SN90 sonar has been developed in cooperation with Simrad with the aim of improving the monitoring of the gear. During the CRISP survey in October, a special version of the sonar software enabling reception of the transponder signals was used, and two transponders were attached to different sections of the purse seine. Empty sets (without fish) were performed for testing the transponders, which were mounted in the bottom line of the net; one in the middle of the net and one about ¼ from the bunt end of the net. The transponders were displayed as strong echoes on the sonar screen, both in horizontal and vertical sections (Figure 5.11). When the conditions were optimal, the transponders clearly visualized the position of the net's bottom line on the sonar screen as it changed depth and range from the vessel.

In the coming years the focus will be on computing single school biomass based on the methodology established in WP1. In addition, school and gear dynamics during purse seining will be analysed. The development of transponder technology for gear monitoring will include improved strength of the transponder signal and interference, and integration of the transponder signal into the fishing sonar mode.

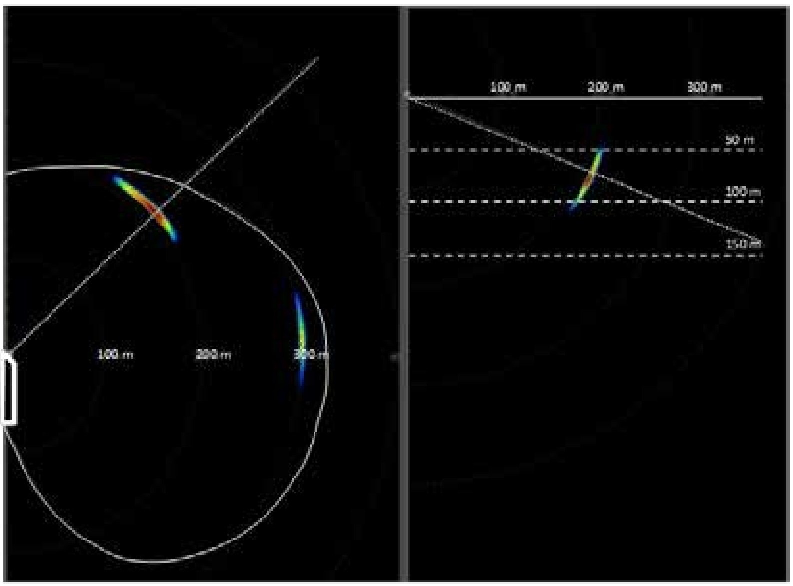

Figure 5.11:
SN90 sonar display of two transponders mounted on the bottom line of the purse seine of F/V "Eros". Horizontal section (left panel) shows the two transponders as coloured elongated shapes between 200 to 300 from the vessel, represented as a white shape in the middle-left end. The vessel track is displayed during the set of the purse seine, as a circular white line. In the vertical section (right panel) one of the transponders is displayed at a depth of about 80 m, 200 m away from the vessel.

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 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 constant stereo images of all objects passing through a trawl. These 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 carried out under CRISP activities in 2015 has largely followed the plans and goals for the year, with focus on refining the system for use by researchers including image collection and analysis for species and size measurement. Major progress has been made in tuning the deployment frame and making improvements to the software used to initiate data collection and analyse the images. Development of a mechanism to take a directed sample for biological analysis was not carried out in 2015, but this is a focus for 2016.

Kongsberg Maritime AS, Simrad, has developed an integrated information system for underwater video, trawl sonar and echo sounder information sent through a standard net-sounder cable from the trawl to the bridge. They have also developed a new Trawleye wireless echosounder for placement on a fishing trawl with live data transfer to the vessel bridge via an acoustic link. These instruments give in situ information about fish species entering the trawl, the behaviour of fish within the trawl as well as monitoring the performance of the trawl. In addition, the company has developed trawl door sensors (Simrad PX MultiSensor) giving information about the distance between the doors, distance from the doors to the seabed and roll and pitch of the doors. This enables precise positioning of the doors in relation to the seabed. These instruments have been further developed and tested during fishing trials on-board research and commercial vessels in 2015.

Figure 5.12:
DeepVision being deployed from a vessel with a stern ramp (left) and using a crane on a vessel without a stern ramp (right).

Visual fish classification

▶ Deployment frame:

The Deep Vision frame, which houses the cameras, lights and channel (Figure 5.12) which fish pass through in order to be imaged, was initially delivered in December 2014. It was completed and minor modifications were made to improve its handling during deployment and retrieval during 2015. Integrated buoyancy and improved

Figure 5.13: DeepVision during deployment on CRISP cruise in March, 2015. DeepVision frame at centre, 3 m long leading sections are the dark mesh panels before (right) and after (left) the DeepVision frame.

Figure 5.14:
New Deep Vision analysis software provides a simplified user interface but faster, more powerful tools for analysis and data export.

low-friction skids were installed and the Deep Vision system was deployed on four Institute of Marine Research Institute research cruises in 2015 (Two CRISP equipment development cruises as well as the coastal survey and swept-area mackerel assessment survey). The 495 kg frame was deployed from three different vessels, both with and without stern trawl ramps, and deck handling procedures were developed to make its launch and recovery a standard part of trawl deployment.

▶ Mounting the frame inside the trawl:
Three-metre long mesh sections were designed and constructed for mounting the Deep Vision between the extension and codend of the trawl (Figure 5.13). Three materials were tested for the tapered panel leading fish into the Deep Vision (50 mm knotted diamond polyethylene mesh, 36 mm knotless square Kevlar mesh and 50 mm knotless square polyethylene mesh). Only the final material (knotless square polyethylene mesh) maintained the required dimensional stability to keep the panel taught and free of pockets where fish can accumulate during trawling. In addition, two funnel-shaped panels of 8 mm knotless nylon mesh were constructed and inserted inside the tapered panel leading into the Deep Vision frame. These panels are attached only at their leading edge, leading them to flutter with the water-flow and preventing small organisms such as krill from becoming enmeshed.

▶ Software:
Significant improvements have been made both to the control software used to communicate with the Deep Vision subsea unit when it is on deck and to the analysis software used to identify and measure lengths of fish in the images (Figure 5.14). Data collection of both images and GPS data used to establish position is now started and stopped with a single button over a wireless network. Furthermore, the time required to transfer images from the Deep Vision unit after it comes on deck after a deployment has been reduced by a factor of ten. When using an Ethernet cable connection, two hours' worth of data (72 000 images) can be downloaded in approximately five minutes.

Figure 5.15:
Deep Vision data being transferred through the Simrad FX trawl mounted communication network.

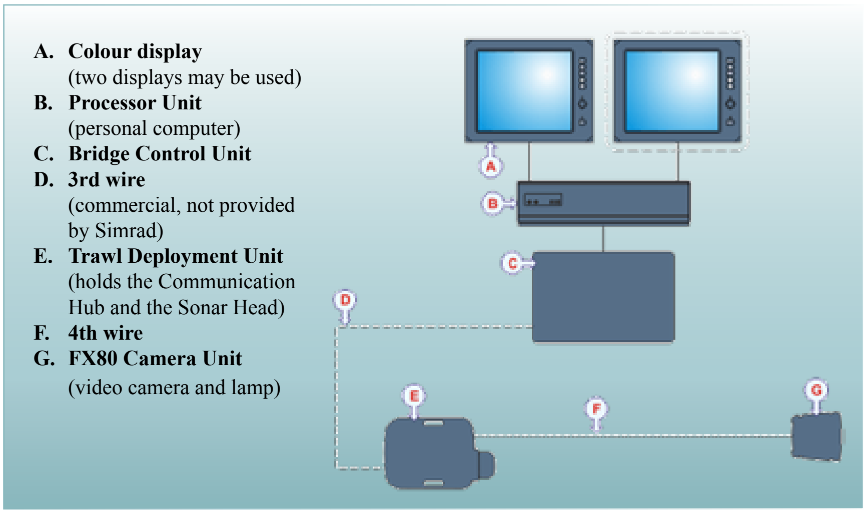

Figure 5.16:
System diagram FX80.

Figure 5.17:
The live Simrad FX80 trawl camera was used to document the escape of fish through the catch limitation device (CRISP WP4).

The Deep Vision analysis software has been redesigned with a simplified user interface while at the same time adding more powerful tools for sorting through large image datasets quickly, including automatic detection and "deactivation" of empty images. Data export has also been improved with a report feature that creates a list of species and lengths in .csv format for uploading to a database or further analysis using spreadsheet or statistical analysis software.

▶ **Live data transfer:**
Data were successfully transferred across the Simrad trawl-mounted hub during the CRISP cruise in March 2015 under the direction of engineers from Scantrol Deep Vision, Simrad USA, and Kongsberg Mesotech, Canada. This test demonstrated that it is technically feasible to interface the Deep Vision system with Simrad's trawl mounted communication network to enable data transfer the third wire to the vessel (Figure 5.15). It is unclear whether this transfer method will be pursued in the future or if focus will be placed a direct acoustic link from Deep Vision to the vessel. An acoustic link would be unable to provide the bandwidth necessary to transfer image data, but could send text and numeric data on count; species; and fish sizes. The primary advantage of an acoustic link is that it would not require the vessel to have a net sonar cable or for a second cable to be attached along the length of the trawl (linking the hub at the trawl opening to the Deep Vision unit near the codend).

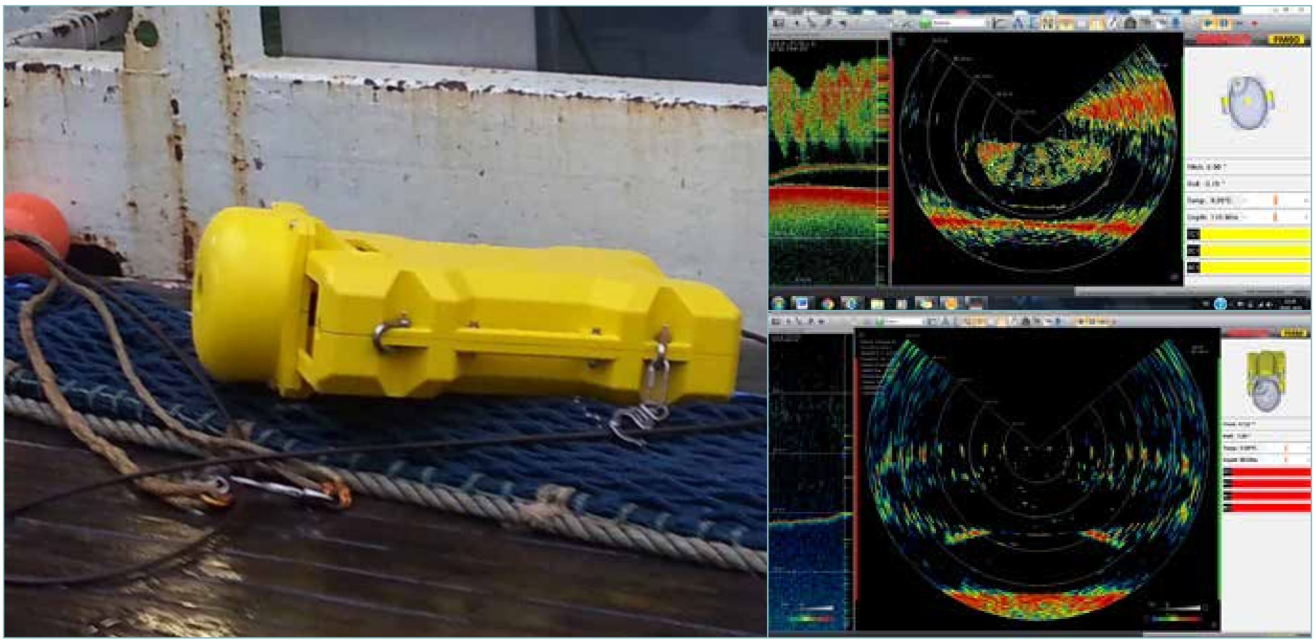

Figure 5.18: Omnidirectional digital sonar unit (left) and examples of a large school of Atlantic mackerel (upper right) and single Alaska Pollock (lower right) entering the trawl.

Figure 5.19:
Simrad trawl-eye mounted on the under panel of a trawl. A school of Atlantic mackerel can be seen passing over.

▶ **Use as a research tool:**
Data collected using the Deep Vision system in June 2015 has formed the cornerstone of a MSc thesis evaluating the trawling technique used to quantify Atlantic mackerel in the Northeast Atlantic. It is being used to quantify the effective sampling time of the trawl and to measure whether there is a difference between towing in a straight line or in a gentle curve, which is believed to reduce the problem of vessel avoidance affecting catch rates.

trawl hub for camera and acoustic systems
Kongsberg Maritime AS, Simrad has developed a trawl camera and communication HUB with Ethernet interface, called FX80 for streaming live information to the bridge via net sonar cable (Figure 5.16). They also continue to work on new trawl geometry and acoustic observation systems (both wired and wireless echo sounders placed on the trawl). The trawl camera is at a level of development where it is used as a routine piece of monitoring equipment and was used extensively to observe other gears tested during CRISP sponsored cruises. For example, it was used to monitor the entrance to the Deep Vision section as different netting solutions were tested (WP3) and the performance of the catch limitation device placed into the codend of the trawl (WP4, Figure 5.17).

The Pollock fleet in Alaska uses the FX80 camera system on a daily basis to detect when unwanted salmon enter the trawl. The skipper then reduces the towing speed to allow the salmon to escape through an escape hole in the net roof.

An omnidirectional digital trawl sonar which interfaces to the Simrad communication hub mounted on the head-rope of the trawl was first tested during a CRISP sponsored cruise in March 2014. This instrument provides much higher resolution and faster sampling rate than the previous analogue scanning sonar system. Equipment tested during 2015 CRISP cruises (Figure 5.18) represented further improvement due to enhanced signal processing algorithms for a clearer representation of the trawl opening and passing fish.

The display software for the wireless sensors, TV80, shows information from all wireless sensors including the Trawleye (Figure 5.19 and 5.20).

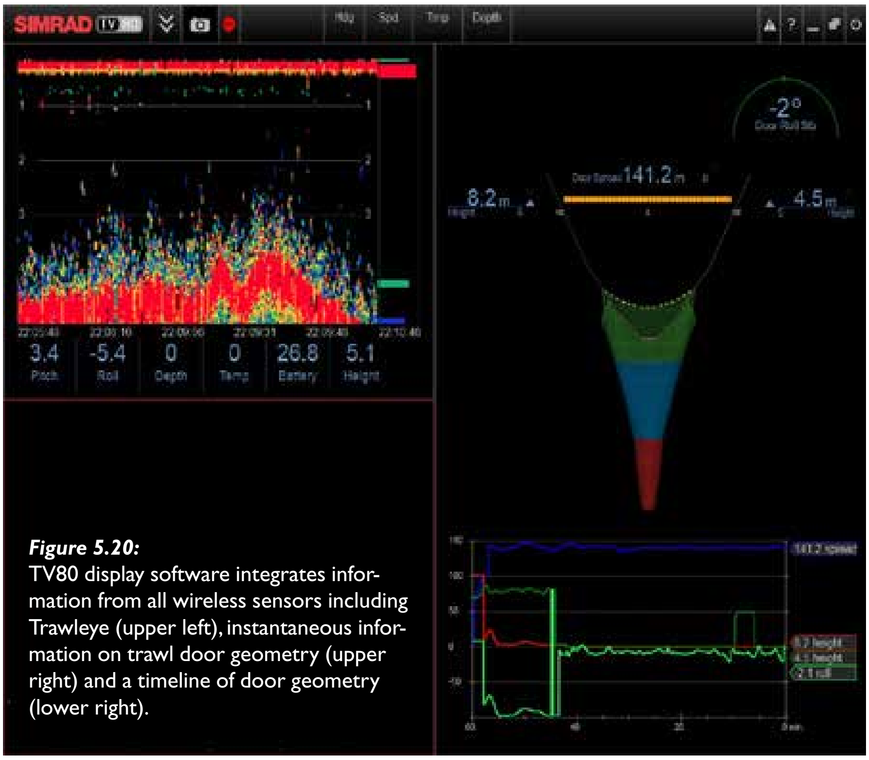

Figure 5.20:
TV80 display software integrates information from all wireless sensors including Trawleye (upper left), instantaneous information on trawl door geometry (upper right) and a timeline of door geometry (lower right).

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 workpackage addresses the design, rigging and operation of trawl gears that might achieve such objectives.

High populations of Atlantic cod in the Barents Sea are currently leading 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 system, the Excess Fish Exclusion Device (ExFED), has been developed and tested by the industry. The ExFED consist of a fish lock just behind an opening in the upper panel covered by a rubber mat attached only at its leading edge (Figure 5.21). The opening was originally kept open by a metal frame. 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, the 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.

After the first introduction of the system to the trawler fleet, the industry reported that the metal frame mounted around the ExFED opening was damaged due to tension when taking in the trawl. In addition, there was a request to test different types of covers above the opening and to verify if the distance behind the grid section and the ExFED could affect its performance. Therefore, the improvement and testing of the ExFED was continued in 2015.

Figure 5.21:
The ExFED system mounted in a trawl.

Figure 5.22:
The original square release opening in exfed was replaced by a triangular one pointing backwards. the brown cover mat to the right.

Adjustable trawl doors and semi-pelagic trawling
Positioning of the two trawl doors in equal heights above the bottom is important to maintain the correct geometry of the trawl system and thus also maintain the catchability when fishing with semi-pelagic trawling techniques, i.e. with the doors off and the trawl on the seabed. This cannot be done by adjusting the warp lengths.

In 2015 development of a robust acoustic communication between the trawler vessel and the motors adjusting the hatch openings on the Seaflex trawl doors continued. Based on previous test results control of the upper hatch in one of the trawl doors was identified to be sufficient to maintain equal height from the bottom of both trawl doors. Testing of this arrangement was conducted during a research cruise with RV "G.O. Sars" off the coast of Finnmark and Troms in March 2015.

The manoeuvrable trawl doors were used with a bottom trawl equipped with a roller ground gear intended to reduce the impact on the bottom habitat. Towing was conducted with both trawl doors above the bottom, classified as semi-pelagic trawling. Video observations and the Deep Vision system (see chapter 5.3) was used to compare the catch rates with the acoustic observations at different door heights. In addition, comparisons between the acoustic density and the capture rates of the pelagic sampling trawl, the Multpelt 832, were conducted for cod during the fishing process. The Seaflex doors were also tested during pelagic trawling on other RV "G.O. Sars" research cruises and with chartered vessels.

Acoustic communication with one motor regulating the opening of the upper hatch was partly successful. However, the prototype cNODE acoustic system is currently too unreliable to be applied commercially for this function. Camera observations showed the hatches opening and closing after communication, but the lack of acoustic confirmation that a command has been received by the doors is a weakness. The vertical adjustment of one trawl door to position the two trawl doors at equal heights above the sea bottom during semipelagic trawling seems achievable and was documented during the cruise. But in order to commercialize this trawl door function further development of a cost effective and robust acoustic communication system is required.

Without manoeuvrable trawl doors, there was a 10 m difference between the trawl door's heights above the bottom during semi-pelagic towing in areas with a transverse slope and side current. The capture efficiency was found to be low when one door was positioned 5 m from the seabed while the other was 15 m. The difference in door height may be eliminated by acoustically adjusting the trawl doors and therefore the CRISP industry partners should prioritize the development of a robust acoustic communication system that can be used to achieve this goal. An advanced control of trawl door performance during semi-pelagic trawling will also include warp length adjustment based on detailed depth information in the fishing area. Therefore, a joint initiative from all the CRISP industry partners have the potential to develop an integrated robust semipelagic trawling system.

Figure 5.23:
The demersal seine system: a slot cut in the upper panel, kept closed during towing with a rope or a thick twine.

Figure 5.24:
The trawl with the ExFED system is taken on board.

Catch regulation in trawls

Based on feedback from the industry and new legislation allowing four panel grid sections to be used in trawls, trials with a modified ExFED were carried out onboard RV "G.O. Sars" and the commercial vessel FV "Atlantic Viking".

During the trials on-board RV "G.O. Sars", a four panel trawl with a sorting grid (Flexi-grid) was used. The rubber mat was replaced with a net panel trimmed with lead ropes in such a way that the net panel was laying firmly towards the top panel of the trawl. In addition, the rectangular opening with a metal frame was replaced with an escape opening made as a backward pointing triangle without a metal frame (Figure 5.22). Video observations showed that the system worked as intended. Fish were observed to calmly swim out through the escape opening at the fishing depth once the cod-end was filled to the desired catch size.

During the trails on-board FV "Atlantic Viking", the ExFED was mounted in a large two panel trawl, with and without a Flexi-grid. The main objective was to test the performance of the ExFED system when removing the steel frame. In addition, a catch regulation system used by the Norwegian demersal seine fleet was tested. This system consists of approximately two-metre long slots, cut in the codend's longitudinal direction, just in front of a fish lock (Figure 5.23). The slots are kept closed by threading a rope along its edges. The rope is slightly shorter than the edges of the net, keeping the slots closed during towing, but when catches build up, the codend expands, the splits open and excess fish is released. Both systems were tested using a twin trawl rigging, with the catch regulation system mounted in one of the trawls.

Removing the metal frame used on the ExFED system did not result in catch losses before the desired catch volume were reached, except for two hauls where the sorting grid was removed. In these hauls, the codend extension was partly twisted, resulting in catch losses due to the negative buoyant rubber mat failing to cover the fish outlet.

The few hauls taken with the demersal seine system did not result in catch losses, but the catch rates were too low to evaluate the performance of the system for effective catch release. During the cruise, low visibility due to sand- and mud clouds stirred up by trawl gears, limited the possibility to properly document the performance of the catch regulation systems.

Because of the problems with low visibility at the fishing depth, the functionality of the catch regulation systems was not fully documented in 2015. The development and testing will therefore continue in 2016. This applies to both the ExFED system without a steel frame, as well as splits cut in the codend for catch regulation.

5.5 Quality improvement

Figure 5.25:
Nergård's new vessel may look like this; 80 meters long, 17 meters wide.

Figure 5.26:
From left to right at the bridge looking into the future of trawling : Kjell Larssen, CEO Nergård Havfiske Ltd, Captain Torgeir Mannvik at FV "J. Bergvoll", PhD-student Ragnhild Aven Svalheim Nofima AS and Stein Harris Olsen, senior scientist, Nofima AS.

Background

The Norwegian fleet of ocean trawlers has gone through large changes since the turn of the millennium. The number of vessels has dropped from around 95 to around 35, but at the same time the yearly quotas of the most important demersal species has increased from 200.000 tons to 250.000 tons. This has led to a restructured fleet that has become both more efficient (fuel consumption per kilo capture reduced with 50%) and more profitable (financial margins increased from 5% to 15%). Several new vessels were introduced in this period and the vessel designers has shown great innovation in the areas of hull design, factory and process as well as robotized freezers and storage. However, innovation and development in the methods for first handling of the catch has been poor. The majority of the new trawlers apply direct gutting and no bleeding in water prior to freezing. Catches up to 20-30 tons are still put directly into the receiving bins without water or chilling, and most of the fish is dead when gutted. These methods and handling practices have hardly changed during the last 60 years, and do not give optimal quality.

The trawler of the future

Based on the encouraging results from the previous CRISP-experiments on quality improvement both in field and in laboratory, Nergård Havfiske Ltd. has decided to develop their new trawler for the future (Figure 5.25). The development is done in close collaboration with Norwegian subcontractors as Rolls Royce, OptimarStette, Cflow and Nofima, and was supported by FHF (The Norwegian Seafood Research Fund) and Innovation Norway. The future trawler will be implementing results from recent research regarding fishing efficiency, optimal product quality, improved welfare for the fish as well as for the crew (health, safety and environment - HSE) (Figure 5.26). In addition to the headed and gutted fish product (H/G), a total utilization of the fish, including by-products of the highest quality possible, is important. Central issue and the key in all designs is the fact that more than 90 % of the catch can be kept alive on board after capture, provided the capture process is done lenient enough and that six hours live holding may turn otherwise pale-pink cod muscle, pure white. The vessel will have special designed receiving bins that can hold up to 30 tons of live fish. In the tanks, the fish are given pure, oxygen-rich water. The transport from the trawl to the bins is crucial, and it can be done by emptying the cod-end directly after pulling a special designed bag up to the trawl deck. Pumping has proved to be more lenient than on-board hauling. However, this will require reinforcement of tanks in case of low-pressure pumping and handling, and HSE-challenges in case of over-under pressure pumping (vacuum). As soon as the beam is shot again, the fish is gently pressured through grading related to species, size and potential quality challenges (subcutaneous bleeding and bruises). The final process includes stunning, bleeding and gutting before freezing.

Quality assessment - instrumental blood analysis

Nofima has designed and implemented an instrumental online instrumental online sys-

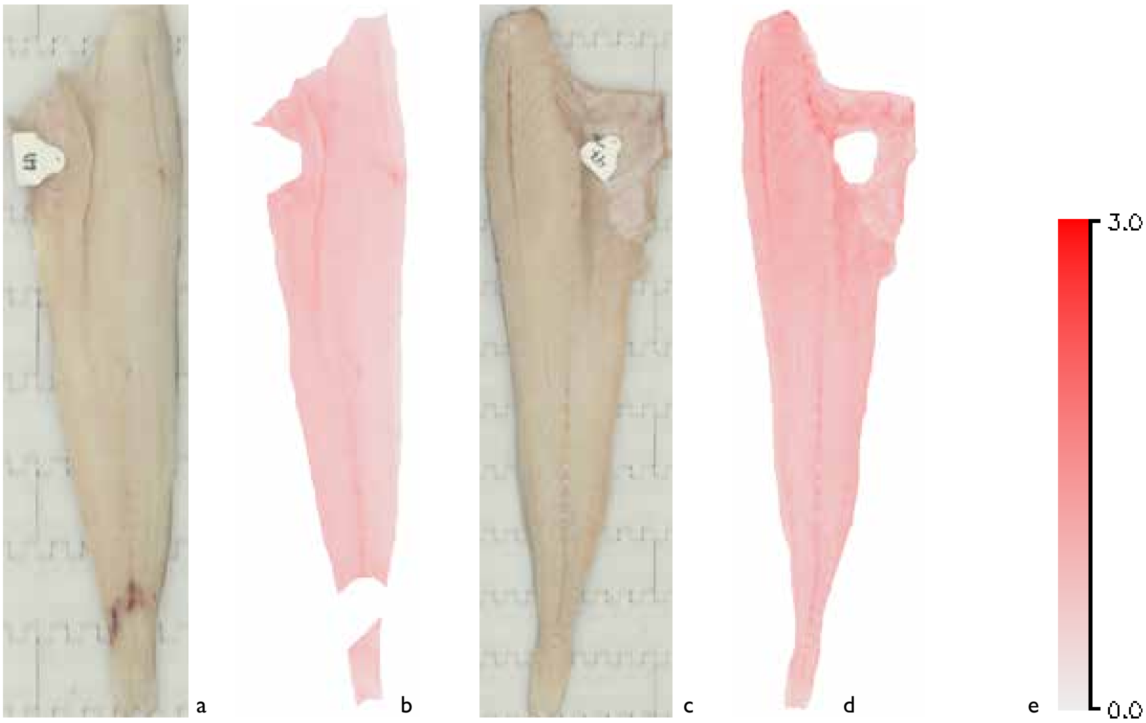

Figure 5.27:
a) and c) shows color images of two cod fillets, and b) and d) shows corresponding blood response for those fillets. e) shows color coding for blood response values between 0.0 and 3.0.

tem for diffuse reflectance measurement, based on imaging spectroscopy. This high-resolution online instrument, which uses hyperspectral imaging at visible and NIR wavelengths, can do measurements at the speed of a conventional conveyer belts (0.5 m/s). This system can measure many chemical components in the sample at the same time. This online system was developed to find potential quality defects in fish fillets, like capture damages, nematodes, black lining, melanin and blood residuals. Thus, this system is a powerful and objective tool to study the effect of stress, associated with commercial trawling of Atlantic cod, on the flesh quality (damages, residual blood, haemorrhages and colour). The technology is also under development to address measuring whole fish (H/G).

Samples of block frozen H/G cod, which was caught at Thor Iversen-Banken (N 73.00, E 033.00) in May 2014 by FV "J. Bergvoll" (Nergård Havfiske), was delivered from Nergård's processing plants in Gryllefjord (Senja) to Nofima (Tromsø) in Mai 2015. The frozen H/G cod was thawed in running water (4°C) until the temperature in the fish muscle had reached a temperature of -1.0 °C. During thawing the fish was gently separated from each other. After thawing the fish was kept on ice until manual filleting and instrumental measurements. A hyperspectral image in diffuse reflectance mode was obtained for each fillet, in which each point (pixel) in the image is presented as a light spectrum. However, the colour and blood volume varies, especially within the fillet, due to differences in muscle thickness and positions.

The average blood response found in the loin part of the fillet showed in Figure 5.27a was 0.6, while the average loin blood response of the fillet in Figure5.27c was 0.9. This corresponds well with the observed difference in redness/yellowness between the two fillets.

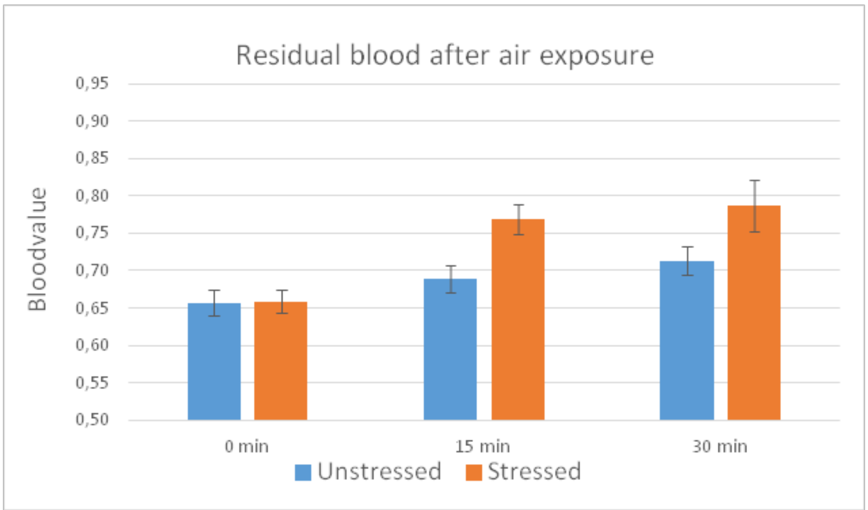

Figure 5.28:
Residual blood in filets from unstressed (taken directly from holding pen) and stressed fish (crowded in net pen for 4 hrs.) that were exposed to air for 0, 15 and 30 minutes. The fish was bled for 30 minutes in running sea water and fillets were assessed for residual blood using diffuse reflectance spectroscopy. Blood value indicates the amount of residual blood in the fillets, higher value indicates a more residual blood in the muscle. N = 10 in each group.

Swim tunnel and experimental trials
Activities in 2015 include two main experiments on wild cod. The first experiment used the experimental swim tunnel as a trawl simulator. The second experiment was an investigation of the effect of stress and air exposure on quality of cod.

The swim tunnel experiment was conducted in February 2015. The swim tunnel was

equipped with a small-scale cod-end to test the effect of swimming, crowding and subsequent recuperation on the flesh quality of wild commercially sized cod. The main purpose of the study was to investigate what effect crowding time has on mortality and residual blood in fillets. A total of 218 fish were used in the experiment. Initially, the experimental set-up included two crowding regimes, of one and five hours respectively, which represent extremes of tow-time for commercial trawlers and three schemes of recuperation time (0, 3 and 6 hours). However, after the first trial, the mortality for the five-hour crowding group came close to 80 %, and we therefore reduced this extreme to three hours.

The air exposure experiment was done in November 2015. The main objective of this study was to investigate what effect of death by asphyxia has on the residual blood in final product (fillet) and to see if there is a difference between stressed and unstressed fish. We considered this question highly relevant for trawl fisheries as death by asphyxia currently is the most common methods of euthanasia. Unstressed (taken directly from holding pen) and stressed fish (crowded in net pen for 4 hrs.) were exposed to air for 0, 15 and 30 minutes. The fish were bled for 30 minutes in running sea water and fillets were assessed for residual blood using diffuse reflectance spectroscopy.

The results from the simulated trawling showed that exhaustive swimming followed by crowding for three hours resulted in 14 % mortality, whereas there was no mortality for the fish crowded for one hour. Crowded fish also had more residual blood than rested, or only swum fish (Figure 5.28). Both rested and swum fish had more than 80 % perfectly white loins with no visible residual blood, crowding for one and three hours reduced this number to 38 and 14 % respectively. Recuperation for three hours, increased the amount of residual blood in fillets, and after six hours of recuperation, visible residual blood was the same as directly after crowding. This experimental study implies that towing times should be kept as short as possible to secure high survival and quality of cod. The results from the swim tunnel are in line with those of trawl caught fish. We are now confident to call the CRISP swim tunnel, the CRISP trawl simulator.

Results from the air exposure trial showed that air exposure has a severe effect on the quality of cod and that this effect is stronger in stressed fish, than unstressed fish. To secure a higher quality fish product from trawler, new methods of stunning or euthanasia should be considered.

5.6 Value adding

Background

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

Activities

A framework for cost-benefit analysis is developed in CRISP (Figure 5.29), 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 5.29, 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.

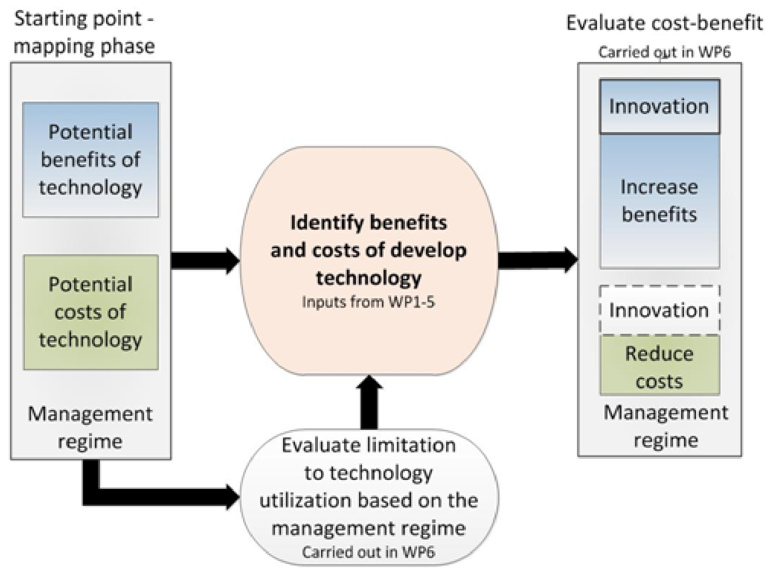

FIGURE 5.29:
Framework for cost-benefit analysis for evaluating the impact of developed technology in crisp.

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 was made. Previous analysis suggests that value adding due to improved product quality alone is in the 100-150 million NOK range for the largest group of trawlers. Thus, value adding from quality of fish landed from the trawler fleet was studied. This activity was coordinated with WP5 and Nergård Ltd.

Changes in the management regime of the Norwegian cod trawler fleet has also been studied. The management regime may influence on the ability to utilize the technology developed, and it is assumed to have a significant impact to the implementation and reduction of environmental foot prints. Both the improved technology and the changes in the management regime may reduce the environmental impacts from the trawlers. Therefore, the number of allowed licenses on each vessel and also fuel consumption within the Norwegian cod trawler fleet from 2002 to 2014, was included in our study.

Technology developed - overview

By December 2015, 15 different technologies have been modified/developed in CRISP. The below listed technologies are at different stages, and some of the technologies are for scientific use, whereas other 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), decreasing the amount of bycatch and lowering the 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.
2 Calibration of the fisheries sonars: Development of equipment and procedures to calibrate the fisheries sonars with an accuracy of 2-3 %.
3 Echo sounder system: Development of a new echo sounder system and methods to measure the size of individual fish inside a school.

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 for use inside a seine.

Wp3 - methods for capture monitoring and catch control during trawling

6 Operationalized Deep Vision in-trawl camera system: Development of in-trawl camera system for species identification and sizing of fish.
7 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.
8 Simrad PX MultiSensor trawl door sensor and TVI topside interface.

Wp4 - low impact trawl

9 Trawl doors: Developed trawl doors which can adjust the spread and position in the water column.
10 Flexible trawl: Developed a flexible trawl and rigging for both semi-pelagic and demersal fishing.
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 technologies 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 vessels.

Value adding and quality

Value adding by improving the quality of the fish has been studied. In this experiment, cod caught by the commercial trawler FV "J. Bergvoll", Nergård Havfiske, was used. According to Nergård, the most important quality parameters for fish filets are redness and gaping. To be able to evaluate the economic value of live storage of cod, a theoretical model was developed. In the suggested model, it was chosen to focus on the redness only, as data of this quality parameter from WP5 is more plentiful (Figure 5.30). The model is based on frequency of good to poor quality of cod subjected to difference in recuperation time after commercial and experimental trawling. In addition, we have included data from traditional production on board a commercial trawler. This model will be developed further in future CRISP activities. According to the model, trawled caught cod has the highest value per kg immediately after capture (0 hours' recuperation). However, this is not realistic during commercial trawl fisheries as the trawlers currently do not have the facilities to stun or slaughter large amounts of fish immediately after capture. Three hours of live storage reduces the value of the fish (increased redness), but after six hours of recuperation the quality and value increases to almost equal to that of immediate slaughter. The lowest value per kg was found for traditional production. These findings suggest that there are economic benefits from live storage for a minimum of six hours onboard commercial trawlers.

Impact of management changes

A mapping of the Norwegian cod trawler fleet has been conducted. The Norwegian cod trawler fleet has undergone a vast reduction in number, from 86 active vessels in 2002 to 36 vessels in 2014. This reduction is triggered by management changes allowing for more licenses on each vessel if old vessels are scrapped. However, the reduction in numbers does not lead to a corresponding reduction in capacity. Exit vessels are old and small, and a wave of eight new large vessels entered the fleet in 2013/2014. Hence, at the end of the period (2014) the fleet capacity reduction was only 16 % when measured in total Gross Tonnage, or 20 % when engine power is measured. Hence, the average vessel in 2014 was 10 meters longer, 3 meters wider, and had doubled its size in tonnage and engine power as compared with 2002. Moreover, a favorable quota development combined with the reduced number of vessels, have led to considerably higher utilization of capacity.

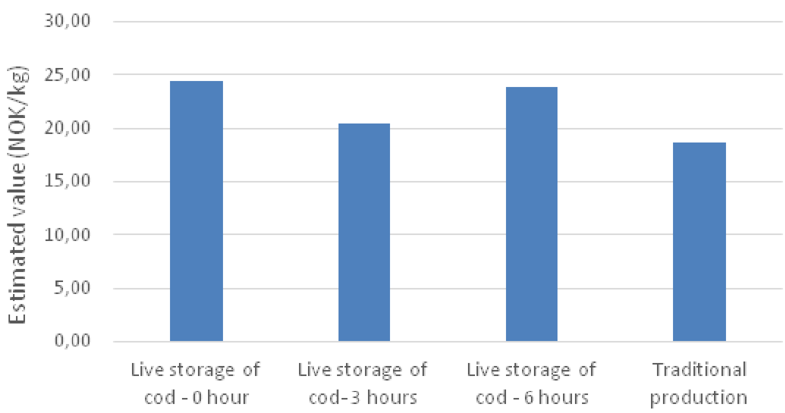

FIGURE 5.30:
Theoretical estimation of value per kg for different groups of cod. based on assessment of residual blood in fillets, under the assumption that there is no fillet gaping.

On average, the number of operating days per vessel has increased from 244 days a year in 2002 to 308 in 2014, and the number of active vessels have decreased by 58%, leading to an overall 47 % reduction in total number of operational days in the fleet. In the same period, the average catch per vessel has increased by 188 % (from 2,560 tons in 2002 to 7,400 tons in 2014). These findings reveal several challenges related to how to adjust the fishing capacity within the frames of the Norwegian fishery management regime.

In this work package, fuel consumption within the Norwegian cod trawler fleet from 2002 to 2014 has also been studied. In the cod trawler fleet, approximately 166 mill liters of fuel was combusted during the fishing operations of the 86 vessels in 2002, which constituted the use of 0,72 liters of fuel per kg of fish landed. 12 years later, 36 vessels combusted 109 mill liters of fuel, correspondingly 0,41 liters per kg of fish. Hence, the total fuel consumption in this fleet is reduced by 1/3, while total catch has increased by 20 %. The reduction in fuel use per kg fish in the period is not only rendered possible due to increased availability of fish. Also, the cod trawlers have over the years omitted the possibility to trawl for shrimp – a highly energy intensive fishery – which has contributed considerably to the fuel cut. As the shrimp fishery has increased, especially in 2015, we suspect the per kg fuel consumption to rise, also due to lower cod abundancy.

6 MIDWAY EVALUATION OF CRISP

During the first half of 2015 the CRISP center, together with the six other SFIs starting in 2011, went through a midway evaluation organized by the Research Council of Norway. Each center was evaluated by a panel of four international experts; two scientific experts with competence to evaluate the research activities of the centre, and two "generalists" with experience from similar programs for university-industry research collaboration. The evaluation committee for CRISP consisted of Professor Alison McKay, University of Leeds (generalist, leader); Dr. Mattias Lundberg, Swedish Foundation for Strategic Research (generalist); Dr. Stephen Walsh, Scientist Emeritus, Fisheries and Oceans Canada (scientific expert); Dr. Petri Suuronen, FAO Rome (scientific expert). The evaluation summed up their view in a written report that filled two main purposes:

Figure 6.1:
The leader of CRISP, John Willy Valdemarsen informs the evaluation committee about the organization of crisp.

1. To form the basis for a decision about whether to continue the center for the remainder of the overall eight-year term, or to wind it up after five years. The decision on continuation was taken by the Executive Board of the research Council of Norway based on recommendations made by the evaluation group and the Research Board for the Division for Innovation.

2. The evaluation should give advice to the centers on aspects of their activity that should be improved.

A meeting between CRISP and the evaluation panel was held in Bergen March 26 2015. In advance the panel had received a range of reports and self-evaluation forms from the center administration and the consortium. The meeting was held in a tone of mutual confidence, and opinions and experiences were exchanged in a positive environment.

The evaluation report was presented for the consortium as draft in May 2015, but the formal decision on continuation of the CRISP Centre was not taken by the executive Board of the Norwegian Research Council until September 30th. CRISP was granted continuation until 2018 without requirements of major changes in the scientific work or administrative matters. The evaluation panel did, however, give a list of recommendations and suggestions for improvement of the Centre. These suggestions have been dealt with in two Board meetings (June and September), and was also the main topic at the annual science conference in Åsgårdstrand in September. A plan of action was submitted to the Research Council in November. One important result of the midway evaluation was the formation of an International Scientific Advisory Committee as recommended by the panel. This Committee is now constituted, and consists of Dr. Stephen Walsh, Scientist Emeritus, Fisheries and Oceans Canada (leader), Dr. Petri Suuronen, FAO Rome, and Dr. Sveinn Margeirsson, MATIS, Iceland. The CRISP center looks forward to a fruitful cooperation with the new advisory committee. The first meeting between CRISP consortium and the advisory committee will be at the annual science conference 2016.

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.

Introduction of new fishing technology and marketing of products developed within CRISP by the industry partners have to be legalized by fishing management authorities in the countries where any new technologies should be implemented. Among CRISP's focus areas is environmentally friendly trawl technology for cod fisheries in the Barents Sea. These resources are managed jointly by Norway and Russia, and therefore involvement of scientific experts from Russia with CRISP activities has been given priority by the centre management.

Deep Vision technology is included in the EU Horizons 2020 project Science, technology and society initiative to minimize unwanted catches in European fisheries (MINOUW). This project, which began in 2015, will use Deep Vision to characterize catch composition in trawl fisheries in Mediterranean Spain and Greece in order to address the discard ban that was included in the most recent European Common Fisheries Policy. Shale Rosen (Postdoctoral researcher under the CRISP centre) took part in a fact finding trip in July 2015 to determine how best to deploy the Deep Vision system in a small-scale trawl fishery in north-eastern Spain, with full-scale tests scheduled for April and July 2016 in Spain and Greece. Also methods developed in CRISP to avoid discarding from purse seine fisheries will be tested in European seine fisheries in the same project.

Deep Vision and the CRISP centre were featured as one of five talks at the Fisheries session at the Transatlantic Science Week 2015- "Blue Futures" conference held in Boston, USA in November, 2015. Transatlantic Science Week is sponsored by the Royal Norwegian Embassy to promote innovation and research based business development between Norway, the USA and Canada.

In the development of acoustic instruments there has been an international cooperation with Dr. Chu Dezhang, National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), USA, for several years concerning calibration of broad band echo sounders and absorption of high frequencies. While in previous years this cooperation has partly been done by common participation on sea cruises, it was limited to correspondence related to co-authorship of scientific publications in 2015.

8 RECRUITMENT

In 2015 the CRISP center hosted three PhD students: Ragnhild Svalheim is employed by Nofima (2013-2016). Her study focus on how muscles of captured fish restore during the post capture phase (WP5). Melanie Underwood is employed by UiB (2012-2016) and has IMR as her working place. Her project deals with behavior of demersal fish during trawl capture (WP3 and 4). Sindre Vatnehol is employed as a PhD student at IMR (2012-2016), and his focus area is sonar technology (WP1). He will submit his synthesis during late winter 2016. Three new PhD students will start up their project in 2016. The first (starting January 2016) will focus on the influence of fish welfare during purse seine fishing and its consequences for fish survival if released or meat quality if taken on board (WP2 and 5). The second will start spring 2016 working the consequences of different trawl innovations on catch quality (WP 4 and 5). The last will focus on value adding caused by CRISP innovations (WP6).

CRISP also employs two Postdoctoral researchers: Anders Karlsson at UiT, working with fish physiology (WP5) and Shale Rosen, with main objective to help adapting the Deep Vision system for visual fish classification to fish assessment purposes (WP3).

Six students conducted their research for their Master Degree under the CRISP umbrella in 2015. Bård Årbakke, Kirsten Howarth and Eugene Kitsios were master students at University of Bergen. The first two were conducting studies related to fish behavior during trawl and purse seine fishing processes (WP 2, 3 and 4), while the last focused on fish welfare during purse seine fishing (WP2). Three master students have been attached to University of Tromsø and Nofima: Jakub Tichy, Tonje Kristin Jensen and Helene Jensen. The first two were looking into problems related to fish quality and physiology (WP5,) while the last focused on value adding (WP6).

Figure 8.1:
Three of CRISP's recruits in 2015. Ragnhild Aven Svalheim (PhD in WP5), Shale Rosen (PostDoc in WP3) and Sindre Vatnehol (PhD in WP1).

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
Marianne SVORKEN	Nofima	Value adding	F
John Willy VALDEMARSEN	IMR	Low impact trawling, Centre management	M 1)
Arill ENGÅS	IMR	Low impact trawling/Instrumentation	M
Olafur A. INGOLFSSON	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 2)
Mike BREEN	IMR	Purse seine technology	M
Helge JOHNSEN	UiT	Quality improvement	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

Asbjørn AASEN	IMR	Trawl technology	M
Jan Tore ØVREDAL	IMR	Engineering, instrument development	M
Kjartan MÆSTAD	IMR	Information logistics	M
Turid LODDENGAARD	IMR	Centre management - economy	F
Atle TOTLAND	IMR	Sonar Technology and Fisheries Instrumentation	M
Bjørn TOTLAND	IMR	Engineering, instrument development	M
Ronald PEDERSEN	IMR	Sonar Technology and Fisheries Instrumentation	M
Tor H. EVENSEN	Nofima	Quality improvement	M

Key personell, industry partners

Ole Bernt GAMMELSÆTER	Kongsberg Group	Sonar technology and fisheries instrumentation	M
Lars N. ANDERSEN	Kongsberg Group	Sonar technology and fisheries instrumentation	M
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
Bowei DONG	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 LARSEN	Nergård Havfiske	Quality improvement and value adding	M
Torgeir MANNVIK	Nergård Havfiske	Fish quality/skipper	M
Morten HERMANSEN	Nergård Havfiske	Quality improvement and value adding	M
Øyvind BERG	Nergård Havfiske	Quality improvement and value adding	M

1) Centre Management until 30/8/2015
2) Centre Management from 1/9/2015

Postdoctoral researchers with financial support from the Centre budget

Name	*Institution*	*Research area*	*Sex M/F*	*Period*	*Nationality*
Anders KARLSSON	UiT	Fish physiology	M	3 years	Norwegian
Shale ROSEN	CRISP	Visual fish classification, fish behavior	M	3 years	USA

PhD students with financial support from the Centre budget

Name	*Nationality*	*Period*	*Sex M/F*	*Topic*
Melanie UNDERWOOD	Australian	07.05.2012-06.05.2016	F	Capture behaviour
Sindre VATNEHOL	Norwegian	01.09.2012-03.03.2016	M	Sonar technnology
Ragnhild SVALHEIM	Norwegian	01.04.2013-31.12.2016	F	Fish quality

Master Students

Name	*Nationality*	*Period*	*Sex M/F*	*Topic*
Bård AARBAKKE	Norwegian	2015-2016	M	Fish behaviour
Kirsten HOWARTH	Great Britain	2015-2016	F	Fish behaviour
Eugene KITSIOS	Dutch	2015-2016	F	Fish welfare
Jakub TICHY	Slovakian	2014-2015	M	Fish quality
Tone K.JENSEN	Norwegian	2014-2015	F	Fish quality
Helene JENSEN	Norwegian	2015-2016	F	Value adding

APPENDIX: 2

Funding

Statement of Accounts 2015

All figures in 1 000 NOK

Funding		**Budget**	**Account**
The Research Council		10 000	10 000
The Host Institution	Havforskningsinstituttet	8 124	11 911
Research Partners	Nofima	1 229	820
	University of Bergen	250	121
	University of Tromsø	1 200	468
Enterprise partners	Kongsberg Maritime AS	2 880	5 699
	Egersund Group AS	1 050	703
	Scantrol AS	1 102	819
	Nergård Havfiske AS	1 000	214
Public partners	Sildesalgslaget	100	100
	Råfisklaget	100	100
		27 035	30 955

Costs

		Budget	**Account**
The Host Institution	Havforskningsinstituttet	14 625	18 561
Research Partners	Nofima	3 478	3 170
	University of Bergen	850	471
	University of Tromsø	2 050	1 318
Enterprise partners	Kongsberg Maritime AS	2 880	5 699
	Egersund Group AS	1 050	703
	Scantrol AS	1 102	819
	Nergård Havfiske AS	1 000	214
Public partners	Sildesalgslaget	0	0
	Råfisklaget	0	0
		27 035	30 955

ATTACHMENT 3

Publications

Journal papers

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Tenningen, M., Pena, H., Macaulay, G. (2015). Estimates of net volume available for fish shoals during commercial mackerel (*Scomber scombrus*) purse seining. Fisheries Research, 161, pp 244-251.

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Valdemarsen, J. W. (2015). New technology for sustainable fisheries. Pan European Networks: Science & Technology 2015 (15) pp 172-173.

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Contributions to workshops and meetings

Isaksen, J. R., Dreyer, B. (2015). Struktur og kapasitet i torsketrålerflåten: Utvikling og drifkrefter. Ombordfryst torskefisk – fra produksjon til marked. Seminar arrangert av Sjømatrådet, Nordea og Fiskebåt; Ålesund, 2015-01-12.

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Karlsen, K.M. (2015). Arbeidspakke 6 – Value adding. Foredrag på CRISP-møte, midtveisevaluering; Bergen, 2015-03-26.

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