D6.1 Report from test and demonstration activities in Norwegian Sea and Barents Sea fisheries

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SMARTFISH H2020

Innovation for sustainable fisheries

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Report from test and demonstration activities in Norwegian Sea and Barents Sea fisheries

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Abstract

The goal of SMARTFISH H2020 is to develop, test and promote a suite of high-tech systems for the EU fishing sector, thereby optimizing resource efficiency, improving automatic data collection for fish stock assessment, provide evidence of compliance with fishery regulations and reduce the ecological impact of the industry.

This deliverable describes the testing, results, and demonstration of CatchScanner, including a description of different versions of the prototype.

Dissemination level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission services)	
CI	Classified information as referred to in Commission Decision 2001/844/EC)	

Deliverable type		
R	Document, report	X
DEM	Demonstrator, pilot, prototype	
DEC	Web sites, patent fillings, videos, etc.	
OTHER	Software, technical diagram, etc.	

Authorship information	
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Version history

<table>
<tr><th>Version number</th><th>Date</th><th>Description of changes</th></tr>
<tr><td>1</td><td>2022-12-15</td><td>Initial version</td></tr>
<tr><td>2</td><td>2023-05-05</td><td>
Revised version based on the following comments received (verbatim) from the expert reviewers assigned by the European Commission, via email from project manager Rachel Tiller.
<blockquote> D6.1 == The report covers tests of Catch Scanner and Fish Data for whitefish and shrimps and investigations on user acceptance for Fish Data. Catch Scanner turned out to show very good results. The Catch Scanner systems has been customized for gutted fish. The report describes the test settings and appliances, the results and the stakeholder feedback.
Report needs quite significant revision. The executive summary is limited and does not provide an overview of the work carried out or the results. The description of the methodology of the tests completed, as well as a clear presentation of the results and conclusions is also largely missing. From the report provided it is hard to establish whether the trials were a success or not. </blockquote>
The first paragraph relates to the summarized observations of the expert reviewers.
The second paragraph contains suggestions for improvements to this deliverable We will address each point in this paragraph to the best of our ability, with our response to these points below.
"Report needs quite significant revision."
This is a general statement, and it is not clear specifically what needs revision from this statement alone. We will therefore respond to the other comments.
"The executive summary is limited and does not provide an overview of the work carried out or the results."
It is not clear from this statement what specifically is missing in the overview of the work carried out or the results. The executive summary as written provides a brief overview of Tasks 6.1, 6.2, 6.3, and 6.4, which are the tasks relevant for this document. The executive summary also provides a bullet point list of the results of Task 6.2, for CatchScanner on whitefish. We modified the sentence before the bullet point list to more clearly reflect this. Page 9.
"The description of the methodology of the tests completed, as well as a clear presentation of the results and conclusions is also largely missing."
It is not clear from this statement what specifically is missing. As written, Chapter 2 described Task 6.1 fully, since this was reported in WP1. As written, Chapter 3 describes the work done in Task 6.2. Specifically, 3.2 describes the prototype used on board, and shows images of the other prototypes built for operational stability tests. Specifically, 3.3 describes the testing of CatchScanner, FishData and Catch simulator. Specifically, 3.4. describes the training data collected for testing the CatchScanner algorithms, and the results are presented in 3.7. As written, Chapter 4 describes the testing of CatchScanner and FishData in Task 6.3. Section 4.2 was lacking in detail and has been updated for clarity. Page 31.
A conclusion chapter was missing and has been added. Page 35.
"From the report provided it is hard to establish whether the trials were a success or not."
It is not clear from this statement which trials are being referred to, and which product is being referred to. As written, section 3.8 clearly states that the results from trials of CatchScanner are good enough for the fishermen. As written, Chapter 5 describes end-user tests, with feedback, of FishData. The end-users were overall positive in their feedback.
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SMARTFISH H2020 consortium

SMARTFISH H2020 (773521) is an Innovation Action within Horizon 2020, the European Union's framework programme for research and innovation, Call H2020-SFS-2017-1, Topic SFS-22-2017.

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Executive summary

This document describes the testing and demonstration from the tasks in WP6.

Testing of SeinePrecog in Task 6.1 was stopped and finalized based on results from initial tests carried out in the Oceanarium in Hirtshals in connection with WP1.

Testing of CatchScanner and FishData in whitefish and shrimp trawl fisheries was carried out in Task 6.2 and Task 6.3, respectively.

The CatchScanner was tested onboard the trawler "Kågtind 2" on whitefish in Task 6.2, providing the following results for CatchScanner on whitefish:

- **Species recognition:** Approximately 100% correct for cod, saithe, haddock, halibut, redfish and wolffish
- **Weight estimation (pr. individual):** Less than 8% absolute average error
- **Results for weight estimation for batch pr. species:**
  - **Cod:** 0,6% absolute average error, 0,8% standard deviation
  - **Haddock:** 1,6% absolute average error, 1,6% standard deviation
  - **Halibut:** 0,6% absolute average error, 0,8% standard deviation
  - **Redfish:** 0,8% absolute average error, 1,0% standard deviation
  - **Saithe:** 11,0% absolute average error, 25,7% standard deviation
  - **Wolffish:** 1,3% absolute average error, 1,6% standard deviation

Regarding Task 6.3, the CatchScanner hardware and system is most suitable for large demersal fish species, due to the combination of large field of view, modest resolution, and high conveyor speed used. The software is also designed for large fish, and the deep learning algorithms are trained for this purpose. Custom versions suitable for shrimp fisheries, including small-species bycatch, may be possible, but were not built for this test.

FishData

In conclusion, we were able to fulfil all purposes of FishData testing in Task 6.2 and Task 6.3.

In Task 6.4 (End-user tests) there was agreement among the fishers that it would be very useful to link information about catches to information about environmental factors such as seawater temperatures and weather.

Promotion

The promotion (Task 6.5) is reported in Deliverable D6.2 Promotion report and material WP6.

1. SMARTFISH H2020 motivation and background

With an increasing pressure on marine resource extraction mounting with resultant calls for sustainability in the sector, SMARTFISH H2020 will develop, test and promote a suite of high-tech systems that will optimize resource efficiency, improve automatic data collection, provide evidence of compliance with fishery regulations and reduce the ecological impact of the sector on the marine environment (Figure 1).

SMARTFISH H2020 will exploit and further develop existing technological innovations in machine vision, camera technology, data processing, machine learning, artificial intelligence, big data analysis, smartphones/tablets, LED technology, acoustics and ROV technology. The developments will assist commercial fishers throughout Europe in making informed decisions during pre-catch, catch, and post-catch phases of the harvesting process.

SMARTFISH H2020 will also provide new data for stock assessment from commercial fishing and improve the quality and quantity of data that comes from traditional assessment surveys. This provides the potential for more accurate assessment of fish stocks and allows for the assessment of stocks that are currently data-poor and therefore difficult to manage. In addition, the project will access automatically collected catch data from the fisheries which will also allow for management regulations to gain higher compliance rates.

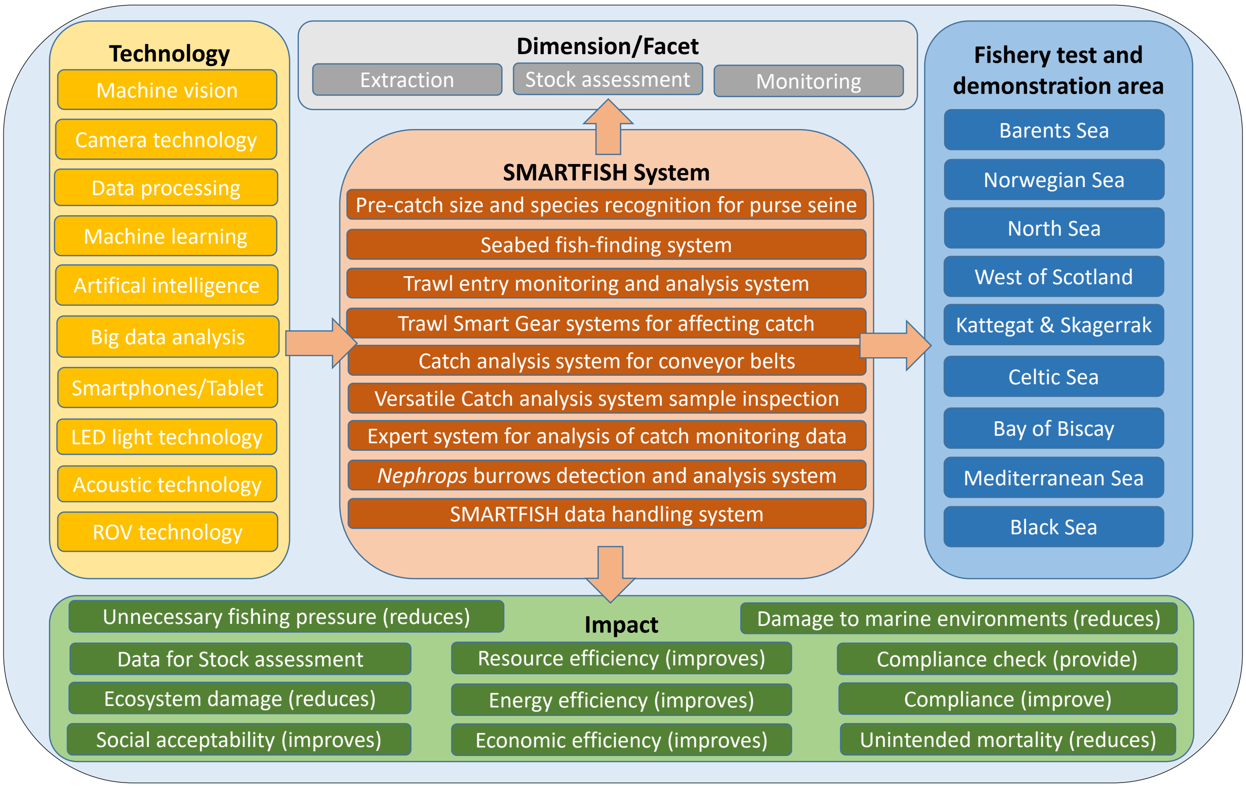

Figure 1: Conceptual structure of SMARTFISH H2020

1.1. Role of the deliverable

The role of this deliverable is to describe the testing and demonstration from the tasks in WP6. This deliverable will describe the tests and results from the different tasks. The description of the testing and demonstration will be presented with text and photos.

1.2. Relationship with other deliverables

The testing and demonstration of CatchScanner and FishData is presented in this document is related to the following deliverables:

- Deliverable D4.2 – Prototype of CatchScanner: The initial version of CatchScanner was developed in this deliverable. Subsequently to D4.2 the CatchScanner has been further developed. D6.1 contains results from functional and operational tests.
- Deliverable D5.3 – FishData analysis
- Deliverable D8.1 – Test and demonstration report WP8: The CatchScanner was also tested in WP8 onboard a research vessel in west of Scotland and northern North Sea fisheries. The testing and results from this deliverable are an addition to the results in D6.1. Since the testing in Task 8.3 the CatchScanner has been further developed and tested, hence more recent results in D6.1.

1.3. Contributors

The following partners have contributed to this deliverable:

- Melbu Systems AS
- SINTEF Ocean AS
- Nergård Haviske

2. Task 6.1: Test SeinePrecog in Norwegian purse seine fisheries

Task 6.1 was stopped and finalized based on results from initial tests carried out in the Oceanarium in Hirtshals in connection with WP1 including Deliverable D1.1, D1.2 and D1.3.

3. Task 6.2: Test CatchScanner and FishData in Norwegian whitefish trawl fisheries

3.1. Developments to prototype since D4.2

The software, use of electrical components and physical design for CatchScanner has continuously been developed and debugged during SMARTFISH H2020. The tests have been the most important factor for the development, but also inputs from stakeholders have been considered, especially for the software part.

The developments to the prototype since D4.2 are listed below:

- **Software** – The software runs in several Docker containers instead of a virtual Python environment. Some settings have been changed to user input for more flexibility. The scanning results are presented in the software. In addition to this, Melbu Systems has developed a local web interface to show and filter scanned and saved data from thefish. The local web interface was developed to make custom changes for different customers. The software that runs CatchScanner is protected this way when there is a need for these kinds of changes. The local web interface is *read-only*.
- **Algorithms** – Improved for better segmentation when multiple fish are sent through the scanner. The improvements make the CatchScanner better at detecting all fish. The time from a fish has been scanned to the result of the scan is ready has been reduced for practical reasons.
- **Physical design** – The appearance of CatchScanner has been improved to look more presentable as commercial product. CatchScanner is made of stainless steel AISI304 to meet the demands from the harsh environments it can be exposed to, and the cabinets are original products from a subcontractor. The stainless steel and cabinets constrain the possible physical design. In addition, there is a fixed height from the laser to the conveyor belt. From the latest version of CatchScanner to the next version there may be only small cosmetic changes. The cabinets have been used to guarantee the needed IP code on equipment for this use. A two cabinet design is used, so as to separate the laser and camera from the industrial computer. The reason for this was to reduce thermal load on the laser. The latest version of the CatchScanner is shown in Figure 2 (3D). Figure 3, Figure 4 and Figure 6 shows the cabinets of the scanner and Figure 5 shows the realistic photo of the assembly.
- **Touchscreen and mirroring the computer screen** – The prototype from D4.2 had a regular and external monitor and keyboard/mouse to control the software of CatchScanner. This was not a good solution when testing and collecting data. To improve this part there are two choices: *1. Integrated touchscreen* and *2. Mirror the screen of the industrial computer over a local network*. Using one of these two solutions makes it possible to control the CatchScanner and see results from the scanning. The integrated touchscreen can be seen in Figure 5.
- **Laser module** – To make the laser module last longer and produce less heat it is controlled by the camera's duty-cycle. The heating is also reduced by lowering the power of the RGB-laser modules. To control and get errors from the RGB-laser modules a RS-232 communication has been established. Also, Melbu Systems AS has created a circuit board that can communicate with all three laser modules instead of each one individually. This makes the module easier and more flexible to use, and the number of cables has been reduced.
- **Thermoelectric cooler** – To control the heat inside the cabinets a thermoelectric cooler has been installed (see Figure 6). Because of the harsh environment onboard vessels and trawlers, a normal inlet/outlet with fan is useless over time. The thermoelectric cooler works as a Peltier element and has the needed IP code and no open connection to the outside air.

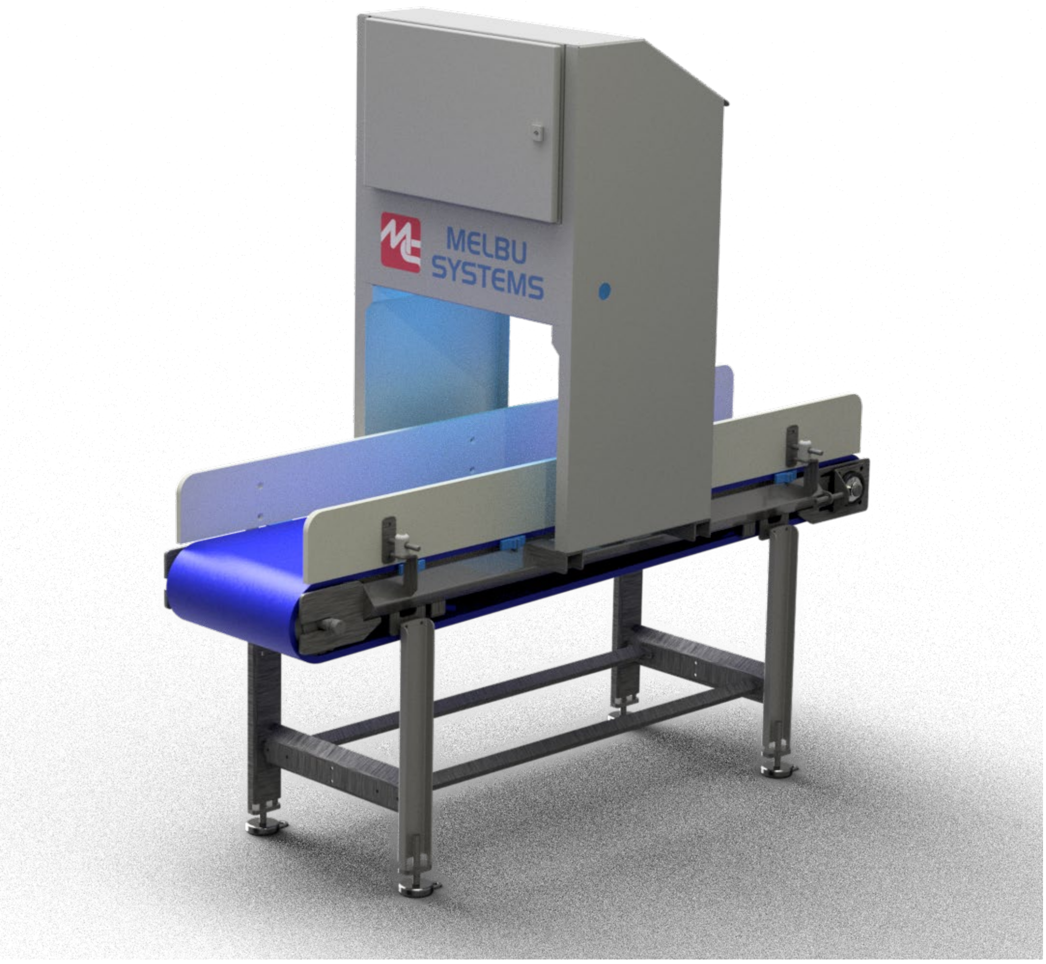

Figure 2: Latest version of CatchScanner

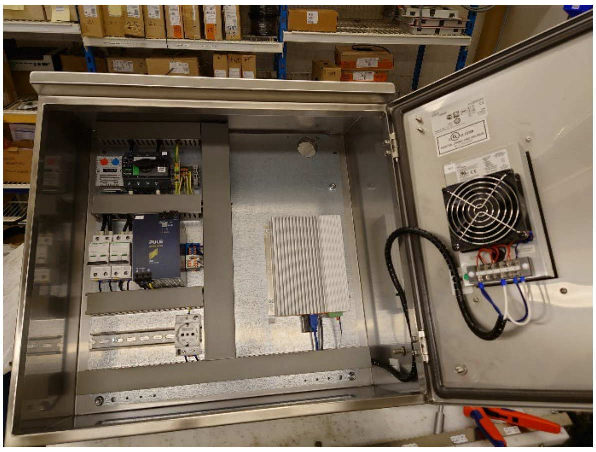

Figure 3: Cabinet 1 on the latest version of CatchScanner

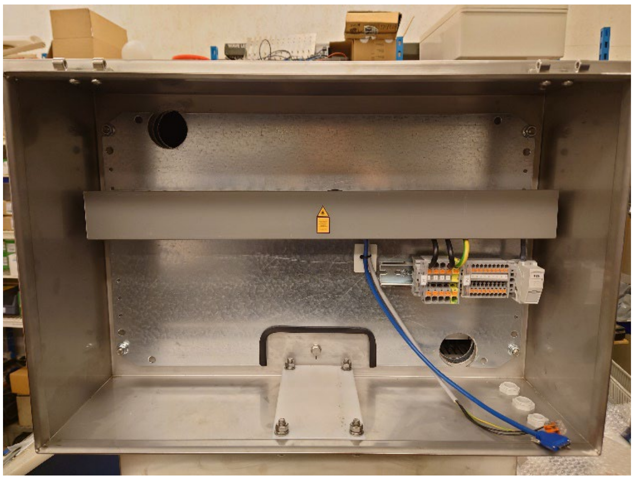

Figure 4: Cabinet 2 on the latest version of CatchScanner

Figure 5: Assembly of CatchScanner, touchscreen and conveyor belt

Figure 6: Thermoelectric cooler

3.2. Prototypes used for testing

During SMARTFISH H2020 there have been several prototypes. When designing and building the CatchScanner there have been many aspects to consider. From one version of a prototype to the next, different issues appeared, both design- and hardware-wise, which had to be solved by redesign and addition or change of components. In addition, the different data collection locations required custom dimensions to fit in the fish processing lines. Some of the prototypes are showcased in Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12.

The tested version of CatchScanner onboard “Kågtind 2” is shown in Figure 7. To make the CatchScanner fit into the processing line onboard a special version of CatchScanner was built. A dedicated conveyor was installed on top of the existing conveyor for the intake of fish to the factory. On top of this there were installed (in order from right to left in Figure 7) 1. a control cabinet for the conveyor, 2. the housing and foundation for the laser and camera, 3. a cabinet for the touchscreen and rest of the electrical components and 4. a marine scale. All of this had to fit under the roof and at the same time ensure sufficient height from the laser to the conveyor belt.

Figure 7: The special version of CatchScanner that was tested on "Kågtind 2"

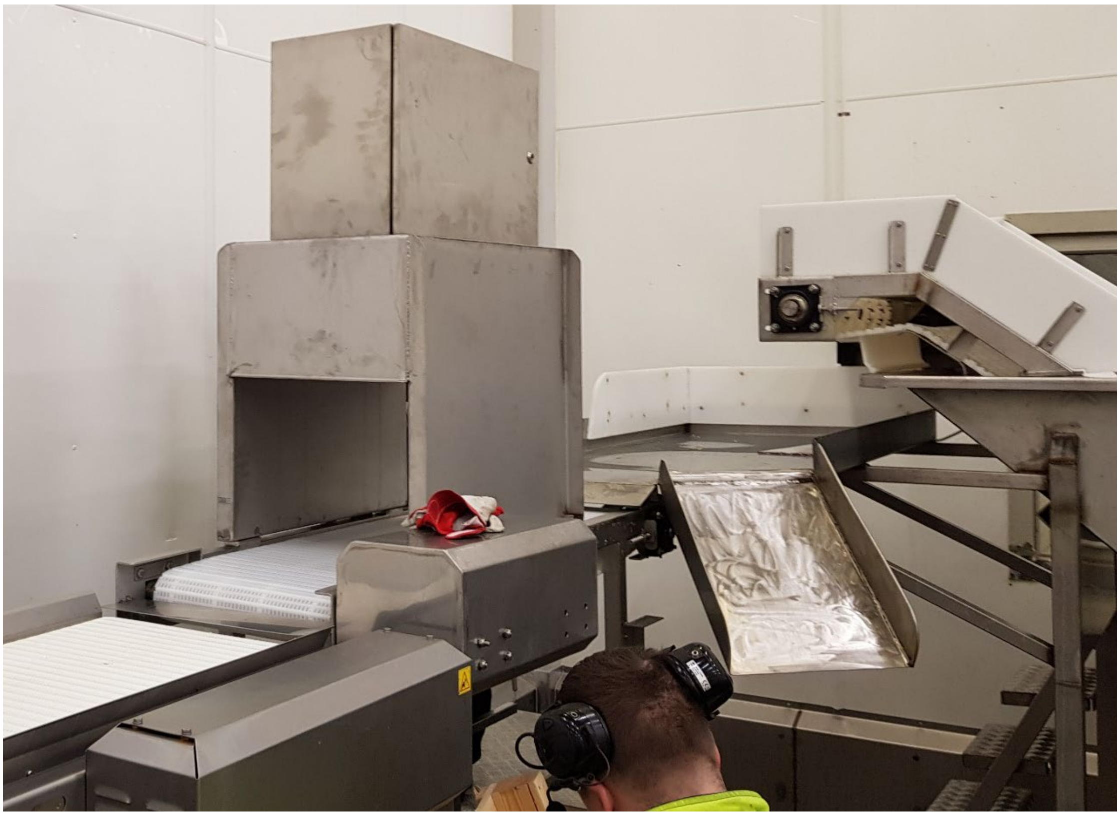

Figure 8: Prototype at Sommarøy Produksjonslag in 2019

Figure 9: Prototype at Holmøy Fiskemottak in 2020

Figure 10: Prototype at Gunnar Klo AS avd. Stø in 2020

Figure 11: Prototype A at Øksfjord Fiskeindustri in 2021

Figure 12: Prototype B at Øksfjord Fiskeindustri in 2021

3.3. Testing

3.3.1. CatchScanner

The testing of CatchScanner was carried out onboard Nergård Havfiskes trawler "Kågtind 2". The trip lasted for ten days.

The setup for the test is documented under section 3.2 and in Figure 7.

The test had to be carried out in a different way than the project group and Melbu Systems AS originally thought. Optimally the round fish would be scanned, and the internal systems onboard could be used to verify the scanner results. One of the problems onboard almost every trawler is that the fish is not weighed round. The first thing that happens when the fish comes into the factory is that it is gutted. To scan the round fish, we had to think of an optional way to get test results.

The testing was carried out in the following way:

1. Pick out a fish from the intake in the factory (Figure 13)
2. Send it through the CatchScanner (Figure 14)
3. Weigh the fish on a marine scale manually (Figure 15)
4. Enter the species and weight on the touchscreen and attach it to the photo from the scanner (Figure 16)

After the trip a data model was created from some of the samples that was registered onboard. Then the real samples were run through the CatchScanner algorithms and the results were compared to the registered data. The results are shown under section 3.7.

The positive thing about this test was that it was done under real conditions. E.g., some issues were revealed (section 3.5) and the photos of the fish that were analyzed after the trip could be tested realistically.

Figure 13: Fish intake onboard the factory at "Kågtind 2"

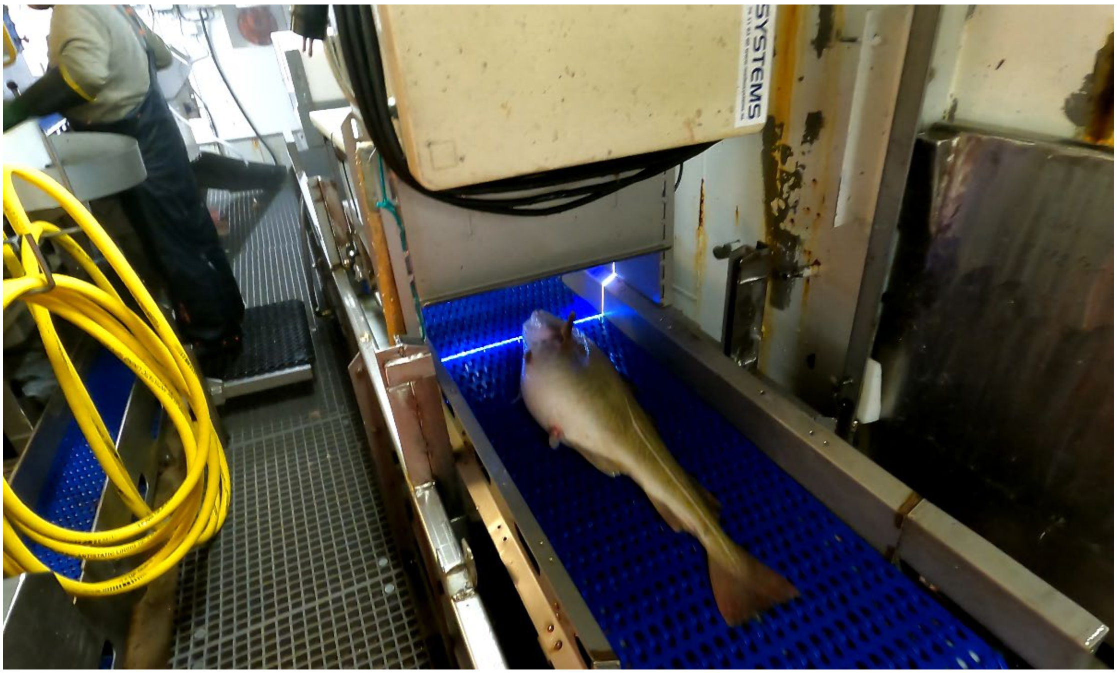

Figure 14: A cod going into CatchScanner

Figure 15: Manually weighing on marine scale

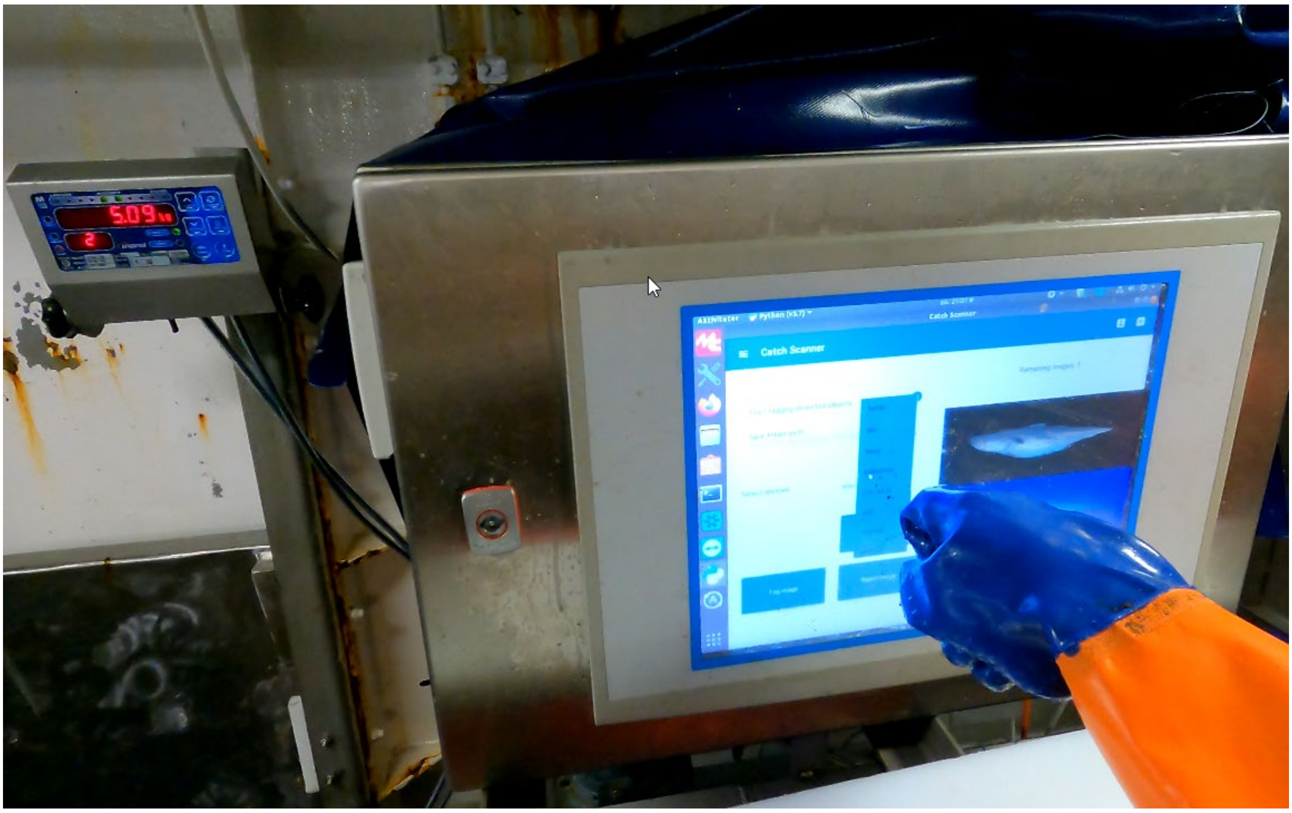

Figure 16: Register data

3.3.2. FishData

The original plan for this task was to test the FishData infrastructure alongside CatchScanner on a whitefish trawler. This had three purposes. The first was to test that the infrastructure itself works as intended, that is, that we are able to:

- collect data from a variety of on-board sensors and instruments
- store the data intermediately on board
- transfer the data to shore whenever a connection is possible
- receive the data in our on-shore data centre for further storage and processing

The second purpose was to verify that FishData can receive and store data from a CatchScanner. This is a point in itself because these data have an atypical structure. The other sensor data FishData handles are *sampled signals* and are stored and processed as time series. CatchScanner data, on the other hand, are *discrete messages*, one per fish, containing its estimated species, length, etc. The messages are generated at irregular intervals (when each fish is scanned), unlike signals which are sampled at a fixed rate. Therefore, the communication parameters and the structure of the logged data are different and must be tested separately.

The third and final purpose of the testing was to gather data for development and demonstration of information systems in Tasks 5.4 and 5.5, in particular the *Vessel Catches* web application. This is a tool for visualisation, exploration and analysis of catch composition and catch efficiency, aimed at fishers and fishery managers. (See Deliverable D5.3 for more information.)

The application is intended to show large-scale spatiotemporal information, and quite a bit of data would be needed for there to be much point. CatchScanner and FishData would have to be installed on a vessel for several weeks, perhaps months, gathering data from most or all fishing operations during this period. As described earlier, the actual CatchScanner tests ended up being somewhat more limited;

only a fraction of the full catch was scanned over a period of one week. We therefore had to change strategy to obtain data for Vessel Catches: SINTEF Ocean developed a simple simulator to generate fake but realistic-looking data for the application. We provide some details on this simulator in a subsection below.

As for testing the FishData infrastructure itself, both on-board data collection, ship-to-shore data transfer, and on-shore data handling have been tested thoroughly, albeit *outside* of the project. The system has been put through its paces in other SINTEF Ocean projects that have been running alongside SMARTFISH H2020. In fact, it has been gathering data from at least 13 vessels of various types and sizes over the last two years. (We provide a list of vessels and some information about the data collection in Appendix 1.) Most of the issues we encountered during this period were due to vessel peculiarities, and could usually be fixed through our remote configuration system. Bugs that have been discovered in FishData itself have been fixed, continuously integrated, and redeployed remotely to the vessels as needed.

The remaining thing to test was the CatchScanner–FishData integration. Doing this on a vessel would be a massive waste of time and resources, as we could do the exact same thing in the lab with no loss of generality. So, a CatchScanner and a computer running FishData were set up in different physical locations at SINTEF SeaLab in Trondheim, connected via the office network. This simulates the situation where a CatchScanner is installed in the on-board fish processing line, while the FishData system is installed somewhere else (typically on the ship's bridge or in a dedicated instrument room), separated by unknown (to the researchers) network hardware. Objects were then passed under the scanner, and we verified that they were detected and classified, and that the information about each was sent to FishData and logged faithfully in NetCDF files.

In conclusion, we were able to fulfil all three purposes of FishData testing in T6.2, but we have done so separately rather than doing it all as a single on-board test.

3.3.3. Catch simulator

To generate data for the Vessel Catches application, SINTEF Ocean developed a program that simulates the fishing operations of a trawler in a long-term (entire trips) perspective. The aim was not necessarily to represent the trawler itself or the ocean in which it's fishing in a particularly detailed or realistic fashion. Instead, the aim was to produce output data which are sufficiently realistic-looking that they could be used for development and testing of FishData. This output consists of:

- the *vessel track*, in the form of a position time series
- the *catch* as it would be registered by a CatchScanner, i.e., a list of the species, size and scan time of each individual fish caught

We will now give a brief account of the model that was developed, whose main elements are an ocean, a set of fish species, and a fishing vessel.

The ocean is modelled as a rectangular area which is initially not mapped onto any particular real-world ocean region. Distances and locations are described in terms of "simulation coordinates" whose units are meters. These can be translated into longitudes and latitudes to generate more realistic data sets after the simulation is done. The ocean is divided into a square grid, where each cell is characterised by an abundance of different fish species (in individuals/m^2).

The fish abundances are generated procedurally by a cellular automaton (CA) model. In short, the ocean grid is subdivided into an even finer CA grid, where each cell is either empty or contains fish of exactly one species. Through a series of time steps, the species compete for limited resources and die or reproduce in different parts of the grid, and eventually a somewhat realistic-looking distribution emerges. The fish densities in the coarser grid are then obtained by averaging over all the CA cells, so that each "major" cell may have more than one species.

The fish species themselves are each characterised by:

- a mean and a standard deviation of the masses of the individuals (assumed to be log-normally distributed)
- a "resource consumption" parameter which goes into the CA model and affects the absolute and relative abundances of each fish species

The vessel and its operation are characterised by:

- a description of the trawl (width of opening and maximum size of escaped individuals)
- its cargo hold capacity
- the location of the vessel's home port
- means and standard deviations of sailing speed, trawling speed, trawling duration, fish processing duration, time at port, etc.
- a relocation probability (more on that below)

The actions of the vessel are simulated using discrete-event simulation. Here is an outline of the steps that generate the vessel track:

1. The vessel starts at its home port.
2. It picks a location in the ocean at random and sails along a not-entirely-straight route to get there.
3. Once there, it starts trawling along a not-entirely-straight line. How much it catches of each species depends on the vessel/trawl parameters, the fish abundances in the cell(s) it passes through, and some randomness.
4. Then, it decides what to do next:
    - If the hold is full, it returns to its home base (goto 5).
    - With a given relocation probability, it may decide to move to a different location (goto 2).
    - Otherwise, it keeps fishing in the same area (goto 3).
5. The vessel sails along a not-entirely-straight path to its home port and the hold is emptied.
6. If the desired total simulation duration hasn't been reached yet, goto 1.

"Fish processing" is a parallel process that runs alongside steps 2–5. When a trawl track has been completed, the catch is put in a buffer, processed at a certain pace to generate realistically-spaced CatchScanner samples, and finally moved to the hold. Thus, the hold gradually fills up to its maximum capacity.

To finally turn the simulation results into a realistic-looking data set, some post-processing is required. This consists of translating simulation-spacetime coordinates into real-world locations and time points. For the Vessel Catches demonstrations (e.g. in deliverable D5.3), we used a 1000 km by 1000 km grid with its lower-left corner at 65° N, 12° W (just east of Iceland), thus covering much of the Norwegian Sea.

3.4. Training data collected

The total amount of data collected during SMARTFISH H2020 can be seen in Table 2. The only relevant data for the test onboard "Kågtind 2" were the round fish. Due to several locations with different setups and lighting conditions for the data collection, and two different laser modules used, it was decided to use only the collected data from "Kågtind 2" (Table 1) for the official testing results.

Table 1: Data collected from the testing onboard "Kågtind 2"

Species	Quantity round fish
Cod	690
Haddock	291
Halibut	361
Redfish	469
Saithe	12
Wolffish	357

Table 2: Total quantity of data collected during SMARTFISH H2020

Species	Round	Gutted	No head and gutted	Total
Cod	2230	208	1336	3774
Saithe	285	0	0	285
Haddock	794	0	0	794
Halibut	361	0	0	361
Redfish	469	0	0	469
Wolffish	357	0	0	357
Total	4496	208	1336	6040

Locations (all of them in Norway) for data collections during SMARTFISH H2020:

- Sommarøy Produksjonslag / Holmøy Fiskemottak
- Gunnar Klo AS avd. Stø
- Øksfjord Fiskeindustri AS
- J.M. Nilsen Fisk AS
- Lerøy Norway Seafoods avd. Melbu
- "Kågtind 2" (Nergård Havfiske AS trawler)

3.5. Issues encountered during testing

There were some issues encountered during the testing.

A minor issue that was encountered was the low number of saithe in the catch for the testing period. As only 12 saithe were caught it was not enough to get trustable results for this species. This is shortly described in section 3.7.

A second issue was that fish going through the scanner slid on top of the conveyor belt because of storms and heavy seas. This would distort and make the photo of the sliding individual fish useless. There was no drama surrounding this issue during the test, but it was a valuable experience. When using the CatchScanner offshore it may be necessary to have friction belts on the conveyor to make the fish lay still.

Another issue that was a little more concerning was that the height setting for the laser in the software on the industrial computer changed by itself halfway through the test. There was no good explanation for it, but it was considered and hopefully this was a one-time episode. To solve or debug this, the software needs to be tested as much as possible.

All in all, there was not too much to worry about. The test mainly went as expected.

3.6. Initial observations on suitability for use in Norwegian whitefish fisheries

During the testing onboard "Kågtind 2" some initial observations were made when considering the suitability for use of CatchScanner in Norwegian whitefish fisheries. These observations were only confirmed as there was knowledge about this prior to the trip.

Height limitations in the factory and general lack of space around the intake of fish to the factory is the main challenge in Norwegian whitefish fisheries. To solve it the area where the CatchScanner would be installed has to be reorganized. This may include shortening or widening the conveyors. This is a very typical problem for existing trawlers as they seem to have a standard setup with little room for change. New construction of trawlers from the shipyards could design in the specific space requirements for the CatchScanner, and on such new vessels it would be easier to fit the CatchScanner into the processing line. On the other hand, Danish seine purse vessels seem to be more flexible to make room for the CatchScanner.

3.7. Results

The official results from the testing onboard "Kågtind 2" is listed below and in Table 3.

- **Species recognition:** Approximately 100% correct for cod, saithe, haddock, halibut, redfish and wolffish
- **Weight estimation (pr. individual):** Less than 8% absolute average error
- **Length estimation (pr. individual):** CatchScanner uses the same algorithm to find the length of the fish as the CatchSnap program. The algorithm is applied on a calibrated image with a known resolution mapping pixel sizes to real life measurements. The algorithm was verified on the CatchSnap dataset yielding an average error of +/- 2.1 % of the correct length.

Table 3: Results for weight estimation (for batch pr. species) from the test onboard "Kågtind 2"

Species	Absolute average error	Standard deviation
Cod	0,6%	0,8%
Haddock	1,6%	1,6%
Halibut	0,6%	0,8%
Redfish	0,8%	1,0%
Saithe	11,0%*	25,7%*
Wolffish	1,3%	1,6%
*The quantity of saithe on this test was too small (12 pcs.) to conclude. It is expected that this specific species follows the same normal distribution as e.g., cod and haddock.		

The results are impressive and *good enough* (see section 3.8) for use in today's situation. To substantiate the results from "Kågtind 2" is worth to mention that data sets have been created from all data collection locations. The data sets have been tested in the lab by SINTEF Ocean and they all imply the same species recognition and weight estimation (both pr. individual and batch pr. species).

3.8. Implications of results to Norwegian Sea and Barents Sea

The CatchScanner and its testing results are highly relevant for the vessels in the Norwegian Sea and Barents Sea. There are some physical limitations, but the scanner can be installed with several custom designs.

The testing results are *good enough* for the fishermen. Species recognition, fish counting, length estimation, classification by weight, weight estimation for batches, and total weight are the most important variables for the fishermen. CatchScanner can provide all of this information, and as every scanned fish is time-stamped they have information about their catch at any time. When the database grows large the system can filter by desired values on date, species, haul, weight, etc.

As written in Deliverable D6.2 under section 2.5, Melbu Systems AS has already sold eight CatchScanners. The market potential is great, and the fishermen welcomes this technology. It will help them to have information on their catch and quotas, and the factories can implement more automation with the CatchScanner as a foundation for sorting prior to delivering to onshore factories. This is just a couple of examples to how they can use the CatchScanner. Melbu Systems AS believes that the CatchScanner has additional undiscovered potential and use-cases that will be uncovered in the future.

4. Task 6.3: Test CatchScanner and FishData in Norwegian shrimp trawl fisheries

4.1. Shrimp scanning

A summary of testing 3D camera scanning of individual and batch of shrimps

Compared to the other use-cases, scanning of shrimps has the added difficulty that a large batch of small individuals must be scanned while being able to correctly measure the volume (and thereby weight) of the batch as well as having the accuracy to measure the individual length of selected individual shrimps where the measuring points are visible. Also, the bycatch may contain fish of similar size to the shrimp. See Figure 17 for an example.

Figure 17: Bycatch mixed with shrimps

The CatchScanner hardware and system is most suitable for large demersal fish species, due to the combination of large field of view, modest resolution, and high conveyor speed used. The software is also designed for large fish, and the deep learning algorithms are trained for this purpose. Custom versions suitable for shrimp fisheries, including small-species bycatch, may be possible, but were not built for this test. Instead, to explore the potential for such custom versions for shrimp fisheries, two alternative 3D scanner sensors were used: the Azure Kinect and the RealSense D405. Both cameras capture an RGB image as well as a depth image. However, the Kinect has a much larger field of view than the D405 while the D405 can get correct readings at a much closer distance. This means that the Kinect does a decent job of measure the batch but lacks the accuracy at individual measurements while the D405 can be close enough to measure individuals, but usually doesn't have the field of view to scan the whole batch. Together these two sensors (which uses different technologies to measure depth, meaning that they can operate at the same time without causing interference) can solve both the measurement of batch and of individuals. However, at this test setup only one camera was running at the same time.

For the individual scanning the shrimp were presented one-by-one to the D405 camera to verify that the camera was able to obtain an accurate 3D measurement of the shrimp. To check this the carapace length measurement points was manually set in the color image and then transformed to the 3D point cloud by the program to calculate the distance in mm (as seen in Figure 18). The measurement was then one with a caliper, and the 3D camera-based measurement was typically found to be within less than ±1 mm of the caliper measurement. Hence, assuming a deep learning algorithm can be trained to identify the key points associated with the carapace, then 3D camera-based measurements can accurately measure its length.

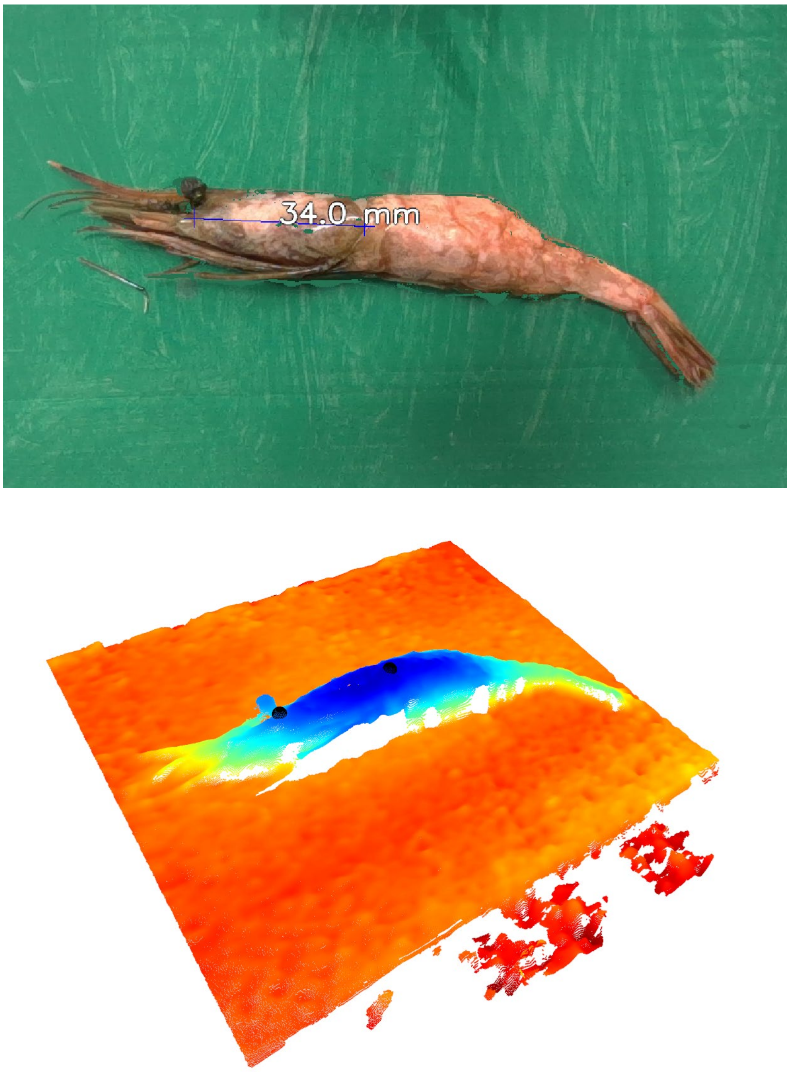

Figure 18: RealSense D405 camera scan of a single shrimp. Manually measured distance visualized in both color image (upper) and 3D point cloud (lower).

While it is possible to use this workflow in the Kinect images as well, finding the accurate measurement points is much harder. Even for a human. This is because of the resolution of the color camera and the distance the Kinect must be away from the batch to observe the whole batch and get a correct depth reading. As an example, some measurement points were manually entered in the Kinect color image and then, as with the D405, calculated in mm by transforming the points to the 3D point cloud (Figure 19).

Figure 19: Measurements in Azure Kinect RGB image

To check the accuracy of batch scanning a several batches of varying size and weight were presented to the Azure Kinect. Each batch was weighted, and the 3D scan of the batch was saved. Then, in post processing the volume of each batch was estimated based on the depth map and 3D point cloud. A weight-volume correlation was then calculated using a linear regression.

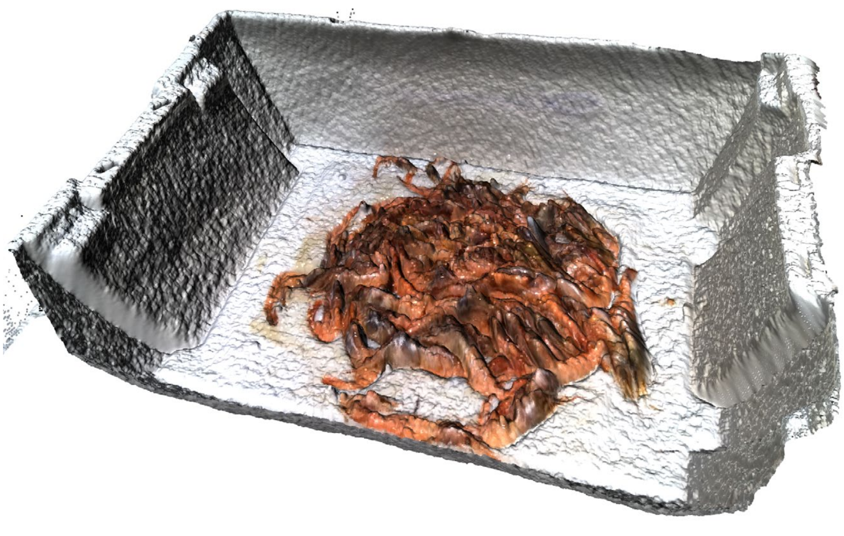

Figure 20: Colored point cloud from Azure Kinect of a batch of shrimps

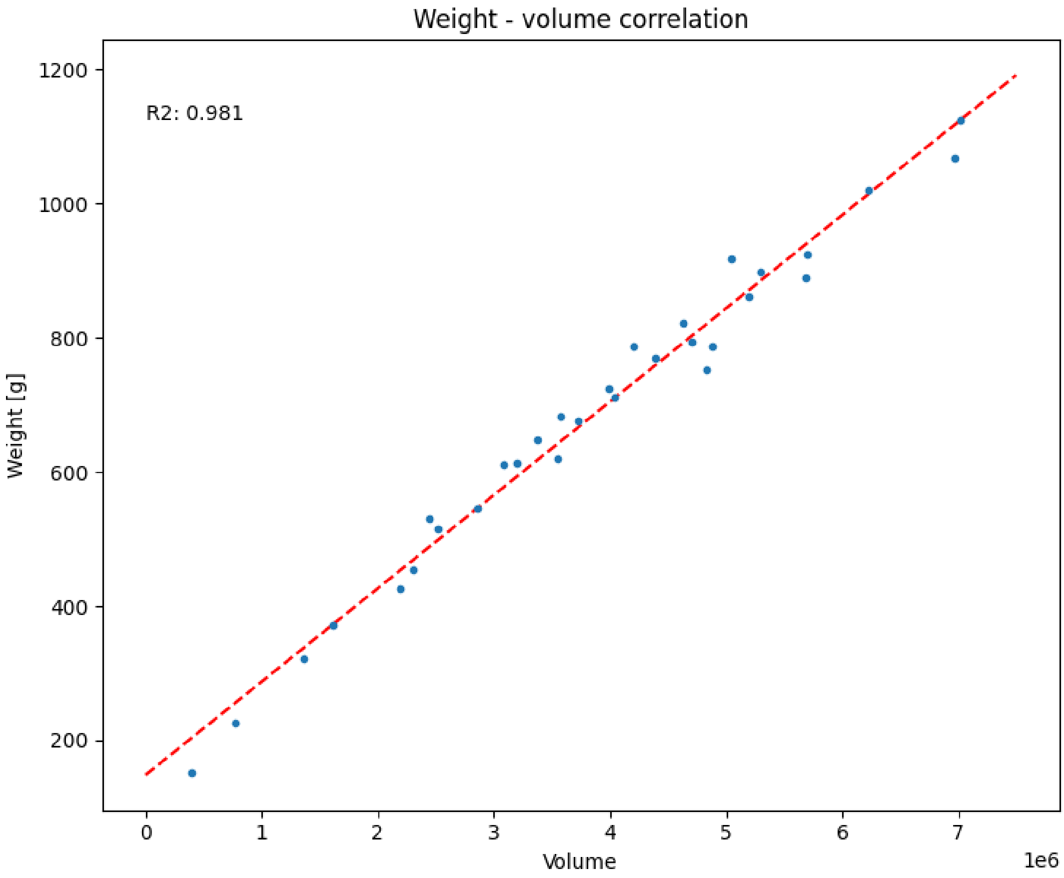

Figure 21: Correlation between the weight of each shrimp batch and the volume estimated by the 3D scan using the Azure Kinect

The corresponding regression has a R2 value of 0.981 and yields an average absolute error of 5 % and an error standard deviation of 7,8 %

4.2. FishData testing

From the point of view of FishData, these tests would have been identical to the ones in T6.2, and we refer to the discussion in that section. The discussion in T6.2 states why the CatchScanner was not installed onboard a vessel to test FishData. It also explains the tests that was completed to test FishData in T4.2.

In short terms the conclusion from T6.2 was that we were able to fulfil all three purposes of FishData testing, but we have done so separately rather than doing it all as a single on-board test.

5. Task 6.4: End-user tests of FishData

The purpose of this task was to solicit feedback on the information system described in Deliverable 5.3 from potential end users. This system consists of three services:

- *Vessel catches*, for visualisation and exploration of detailed catch efficiency and catch composition data based on automatic catch recording systems
- *Fleet catches*, for visualisation and exploration of fleet-level catch data based on public catch reports
- *Forecast*, for predicting marine environmental factors that are thought to affect fishing conditions

We used a method based on informal interviews with relevant stakeholders. We focused on the usefulness of, and potential for improvement in, the *information content* of the services. The interviewees were asked questions like:

- How could these services be useful to you/your company/operations?
- Which of the presented information is *most* useful?
- Which of the presented information is *least* useful?
- What is your attitude towards sharing data like those in the *Vessel catches* service?
- How recent must the *Fleet catches* data be to be useful?
- Do you have general comments?
- Do you have suggestions for improvements?

Not all questions were answered by all participants, especially not the third one, and some of the most useful feedback was gotten under the last two points. We take these as learning points for future projects.

Note that we did not focus on the *user experience* (ease of use, accessibility, efficiency, etc.) in these interviews, except implicitly to the extent that the user experience depends on the information content or vice versa. Testing and improving user experience should be part of further development towards commercialisation, which will likely be left to commercial actors outside the SMARTFISH H2020 consortium. That said, we have received overwhelmingly positive feedback on the visual appearance of the graphical user interfaces, both in these interviews and in our promotional activities. It is our distinct impression that we made the right choice in using a map view as our primary information display and data exploration mechanism.

In the following two sections we give a narrative account of the responses we got. Any text which expresses the opinions or commentary of the researchers is set in square brackets, [like this].

5.1. Fishers

The interviews included representatives from two large fishing companies operating in two different European countries. Both companies have multiple fishing vessels participating in multiple fisheries.

The fishers generally agreed on the usefulness of the information presented by the FishData services. Knowing the catch composition and catch efficiency recently obtained by other vessels was considered to be useful for planning one's own operations. One commented that it "shortcuts" the skippers' experience and cuts out much of the guesswork. Another commented that younger skippers would be more likely to use and trust services like these, while older skippers would be more likely to rely on their own experience. The distribution of species and likelihood of catches were pointed to as the most useful information that could be obtained from the services.

One interviewee pointed to a possible danger associated with a service like *Fleet catches*: If everyone has easy access to knowledge about the locations of recent catches, we may see fishing vessels race towards the known "hot spots" rather than search for fish on their own. This may concentrate fishing efforts and put excessive pressure on certain areas, leaving other potentially resource-rich fishing areas untouched. After a bit of discussion, however, it was concluded that this would be a result of fisheries authorities' decision to make the data available, and not of *Fleet catches* per se. If the information is available, people *will* find ways to use it (including the company whose representative expressed their worry). [This is useful input that we will take with us into the upcoming *EveryFish* project[1], which is concerned specifically with the collection, sharing, and use of data for fisheries management purposes.]

On the question of how recent the data must be to be useful, there were two viewpoints: One was that "the more recent, the better". Information about *yesterday*'s catches is very useful to plan today's fishing operations. But fish tend to move around, so even 2–3 days old data have little value for all but a few special cases. Data from one week ago are useless. The other viewpoint was stated as "the more data, the better". If data are accumulated over years, the fishers can use the information to make their own inferences. [This may be fishery specific, as different species have widely different behaviour and variability of their spatiotemporal distribution.]

The question about fishers' willingness to share data generated similarly different responses. On the one hand, fishers *are* reluctant to share information, for example about good fishing spots. There is a lot of habitual secrecy and competition, even among vessels that operate under the same company[!]. On the other hand, everyone would benefit if everyone in the industry shared their data like this. [This, we already suspected. In the *SFI Harvest* centre[2], where *FishData* development is continued, one of the goals is to establish a data sharing platform where fishers have to give in order to receive. That is, by sharing your data with others, you get access to theirs.]

There was agreement among the fishers that it would be very useful to link information about catches to information about environmental factors such as seawater temperatures and weather. Both companies had observed apparent correlations between water temperature and fish abundance in their fisheries. One company's representative remarked specifically that haddock appears to be sensitive to weather, specifically that they react to surface winds by changing their swimming depth. [This is now being actively worked on in *SFI Harvest*, currently using fuzzy inference methods, and soon to be extended with machine learning methods.]

A final comment from one fisher about *Fleet catches* was that we could and should provide information about the size distribution of the fish that gets caught, as this information is present in the public database from which we draw our data. [We have looked into this, and while the information may be present in the original landing/sales slips, it does not seem to be included in the data files that get openly published.]

5.2. Fisheries management

We obtained feedback from four representatives with different roles in a national fishery management and control agency. [This was done in a group setting, not as individual interviews, some time *before* we did the interviews with the fishers. It turned out a bit more unstructured than we liked, with less concrete questions and more back-and-forth discussion between the researchers and the fisheries managers. But we learned from the experience and therefore did the fisher interviews differently.] The discussion centered on the *Vessel catches* and *Fleet catches* services, as we have no obvious use case for *Forecasts* in fisheries management.

During the introductory rounds, the fisheries managers stated that an important part of their work is to gather the relevant information about the nation's fisheries and make appropriate use of it.

Vessel catches was described as a "useful demonstration of how data can be utilised", and that it shows that the needs and wishes of fisheries management, fishers, markets, and researchers need not be in

[1] *EveryFish: Digital transition of catch monitoring in European fisheries* (2023–2026) is funded by the European Union's *Horizon Europe* research and innovation programme under grant agreement no. 101059892.

[2] SFI Harvest (2020–2028) is a *centre for research-based innovation* funded by the Research Council of Norway under grant no. 309661.

conflict. For fisheries management in particular, the ability to drill down into the details of individual catches is useful. A concrete improvement request was to have the ability to perform side-by-side comparisons of catches from different vessels. This could allow them to detect when the catch compositions obtained by one vessel is significantly different from those of similar vessels operating in the same area. [This specific issue will be investigated in the *EveryFish* project, where we will try to develop algorithms to automatically detect such deviations.]

Concerning *Fleet catches*, one fisheries manager pointed out that they do have tools to visualise these data already, but that their map visualisation solutions are not as good. They also commented that visual presentations like this are useful. [This was a point of interest to us, given that the data for this service in fact comes from a fisheries management agency.] The data preprocessing step in *Fleet catches*, which consists of associating of ERS data with landing/sales slip data, was something they themselves were working on implementing at the time.

Another fisheries manager made the same comment about *Fleet catches* as for *Vessel catches*, namely that they would like to have the ability to compare catches from different vessels within an area to detect deviations.

At the end of the meeting, we agreed to set up a new meeting with their analytics department, to present our work and discuss possible further collaboration. [At the time of writing, this has not yet taken place, but we expect many such discussions in the context of *EveryFish*.]

6. Task 6.5: Promotion

The promotion is reported in Deliverable D6.2 Promotion report and material WP6.

7. Conclusion

Testing of SeinePrecog in Task 6.1 was stopped and finalized based on results from initial tests carried out in the Oceanarium in Hirtshals in connection with WP1.

Testing results of CatchScanner and FishData in Task 6.2 and Task 6.3 was good enough for fishermen and highly relevant. The CatchScanner will be further tested and developed in the EU funded innovation project "EveryFish". The testing results on whitefish was especially seen as a success.

In Task 6.4 (End-user tests) there was agreement among the fishers that it would be very useful to link information about catches to information about environmental factors such as seawater temperatures and weather.

The promotion (T6.5), especially the trade fairs and direct contact with customers, were a success. The feedback from stakeholders proves that there is great interest in technology systems like the CatchScanner.

Further work on the products and applications from WP6 will focus on CatchScanner. The CatchScanner will be installed on several vessels and Melbu Systems will continue to develop the product regardless of innovation projects. This is a decision based on the good results from testing in SMARTFISH.

8. Appendix 1: On-board installations of FishData

As mentioned in the section on Task 6.2, FishData has been used in SINTEF Ocean projects running parallel to SMARTFISH H2020; and has been installed on a number of vessels. Some of these projects are confidential in nature, so there is a limit to how much information can be shared about them, if any. But Table 4 below contains a (possibly incomplete) list of vessels on which the FishData infrastructure has been used to collect data over the past two years.

Table 4: Vessels with FishData infrastructure

Vessel name	IMO no.	Vessel type	Nationality
Arctic Swan	9258739	Trawler	Norwegian
Båtsfjord	9184457	Trawler	Norwegian
Christina E	9554573	Purse seiner	Norwegian
Eros	9617973	Purse seiner	Norwegian
Euskadi Alai	9733480	Tuna vessel	Spanish
Gadus Njord	9640970	Trawler	Norwegian
Harvest	9669756	Purse seiner	Norwegian
Herøyhav	9657210	Purse seiner	Norwegian
Jai Alai	9733478	Tuna vessel	Spanish
Kings Bay	9617985	Purse seiner	Norwegian
Leinebjørn	9605542	Purse seiner	Norwegian
Ligrunn	9647784	Purse seiner	Norwegian
Olympic Challenger	9398292	Light subsea construction vessel	Norwegian

The details of which data get collected vary from project to project and from vessel to vessel. Common to virtually all of them are the following:

- position, speed, and course over ground from GPS
- heading and rate of turn from gyrocompass

- speed through water from the speed log[3]

These are usually received over an NMEA 0183 communication channel. Other data which are collected on a case-by-case basis may come from

- motion sensors (linear and angular acceleration, angular velocities), power systems (engine power/rpm/torque/consumption, generator power/voltage/current, etc.)
- propulsion systems (propeller rpm/torque, rudder angle, etc.)
- deck machinery (winch rpm/torque/hydraulic pressure, trawl-wire payout distance, etc.)
- fishing gear (depth, trawl door distance, etc.)

Often, these are received via MODBUS channels. Sometimes, proprietary protocols are required, in which case specialised protocol converters have been written to feed the information into FishData.

[3] Not to be confused with a logbook or log file, the name of this sensor stems from the days of sail, when mariners would measure a ship's speed using a wooden log attached to a rope with regularly-spaced knots.