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Project DEGREE

Development of fishing Gears with Reduced Effects on the Environment

Report from a cruise onboard RV G. O. Sars 22.11 – 03.12.2008:

Comparing the impact of two bottom trawls

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Institute of Marine Research, Bergen, Norway October 2009

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Start harbor: Tromsø, Norway 22.11.09

End harbor: Tromsø, Norway 03.12.09

Call at: Kirkenes 28.11.09

Contents

Objectives

Main objectives

The main objective of the cruise was to compare physical and biological bottom impact and relative catch rates from a bottom trawl rigging developed during the DEGREE project (the “plate gear trawl”) with a standard bottom trawl used for cod fisheries in the Barents Sea (the “rockhopper trawl”).

- The “plate gear trawl” or “new trawl” was rigged with a modified plate gear consisting of seven specially designed bobbins and plates between them, and with trawl doors rigged to barely touch the bottom
- The “rockhopper trawl” or “old trawl” consisted of a conventional rockhopper gear with doors rigged to go steady on the bottom.

Materials and methods:

Vessel and area

The experiments were undertaken in the Varanger Fjord, northern Norway (Figure 1). This area with shallow waters is well protected from most winds directions (except for easterly) and has almost no undercurrent, which ensures good working conditions for carrying out engineering trials with rather low variability in physical measurements. This also makes the area well suited for studies of bottom impact, i.e. running ROV . The area has a trawl ban, which enabled us to find pristine sea bottom without visible tracks from previous trawling.

Figure 1. The experiments were conducted in the inner part of the Varanger fiord in northern Norway not far from the Russian border.

The experiments were done onboard the research vessel RV G.O.Sars, owned by IMR, Norway (see picture on front page). The vessel (LOA 77.5) is well suited for trawling, having a 18 m wide trawl deck with four trawl winches and room for two sets of trawl doors. It is also suited as a platform for running ROVs, being equipped with DP (Dynamic positioning system) and HIPAP (hydro acoustic positioning system). Several grab systems exist on board for taking bottom grab samples, for measuring seawater condition (STD) and others. In addition to normal echo sounders and sonar, it is equipped for detailed multi- beam mapping of the sea bed topography (Olex).

Trawl equipment

Three days previous to cruise start, a team of five gear experts participating in the Degree project gathered in Tromsø to build the trawl gears and to rig the trawls for the planned experiments.

The trawl

The same trawl was used all experiments. The trawl type was a modified “Selstad 444” (Figure 3). The headline and fishing line length were 45.6 m and 25.4 m respectively. The vertical opening was about 4.4 m. The net material was 155 mm PET and 145 mm PET in the cod end. The rigging of sweeps etc. is shown in Figure 4.

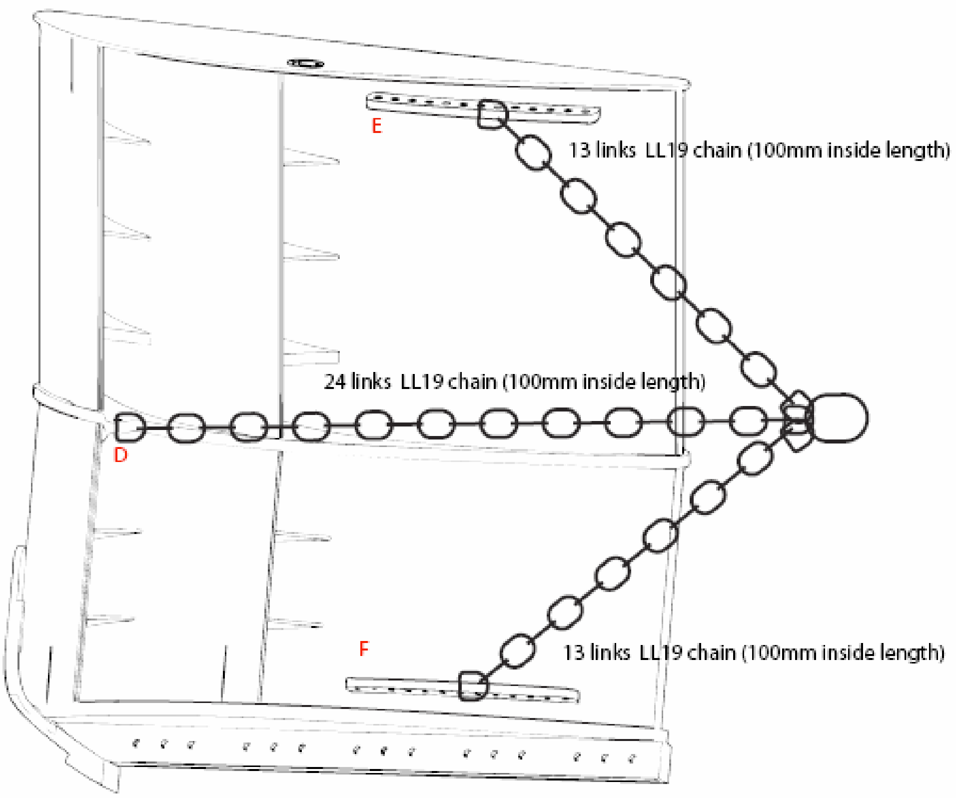


Figure 2. Thyborøn trawl doors 120” Type 12 were used on both trawls.

The doors

The same doors were also used for both trawl riggings. They were Thyborøn doors 120” Type 12 (Figure 2). The rigging of the doors were different for the rockhopper and the plate gear trawl. When trawling with rockhopper gear the doors were rigged the way that is usually done during bottom trawling in the Barents Sea, with good bottom contact in order to make the trawl spread well, and to create mud clouds to herd the fish. While trawling with the plate gear trawl the doors were rigged to barely touch the bottom. In fact it turned out that the doors did not touch bottom at all. The sweep length and attachment point of the doors for the two trawl riggings were decided from a set of engineering trials described later.

Rockhopper gear (conventional gear)

The rockhopper gear (Figure 5) was built up by rubber disks drawn on a chain. These were 18” in the mid sections and 16” in the wing ends. The distance between the dishes was 21 cm (8”) in the middle and 42 cm (16”) in the sides. Between the dishes rubber pieces (8”) were inserted. A rockhopper gear is touching the bottom in all its length. I addition the gear is not rolling, but is connected directly to the trawl. This causes a friction between the bottom and the ground gear along the whole cross section.

Modified plate gear

The modified plate gear (Figure 6 and Figure 7) was built up by rubber plates 500 mm x 540 mm. 7 specially designed bobbins were inserted between the plates to lift them of the bottom (Figure 8). Three 16” bobbins in the midsection were mounted directly on a 19 mm chain between the plates. Four bobbins, two on each side, were mounted in a special frame between the plates. In theory the bobbins should lift the plates 70 mm above the bottom (Figure 9). The plates were mounted in a slightly lifting position in the middle and vertical in the sides.

A problem with the original plate gear was its sensitivity for obliquity. One single connection of the gear to the fishing line could spoil the setup and reduce its fishing efficiency. On the last cruise successful tests were made to connect the gear to a wire attached to the fishing line. This setup makes the gear self-adjusting and therefore not so sensitive for obliquity. In future use this setup is recommended and should be tested in further commercial fishing trials.

Modified dandolino and sweep lifter

Experiments to reduce the bottom impact from the dandolino (the dandolino is the bobbins on the aft end of the sweeps) and the sweeps in front of the ground gear were undertaken on the cruise. The new design consisted of two bobbins mounted on a axle fastened 90° from the sweep direction (Figure 10). The rolling directions of these bobbins were closer to the towing direction than the conventional way to put the bobbins directly on the sweeps. The new design did not act as expected, and this design was therefore not used during the impact tows. The modified dandolino was tested in station number 349 and 350. The sweeplifter was tested on station 349. Figure 11 shows the design of the modified dandolino and sweep lifter.

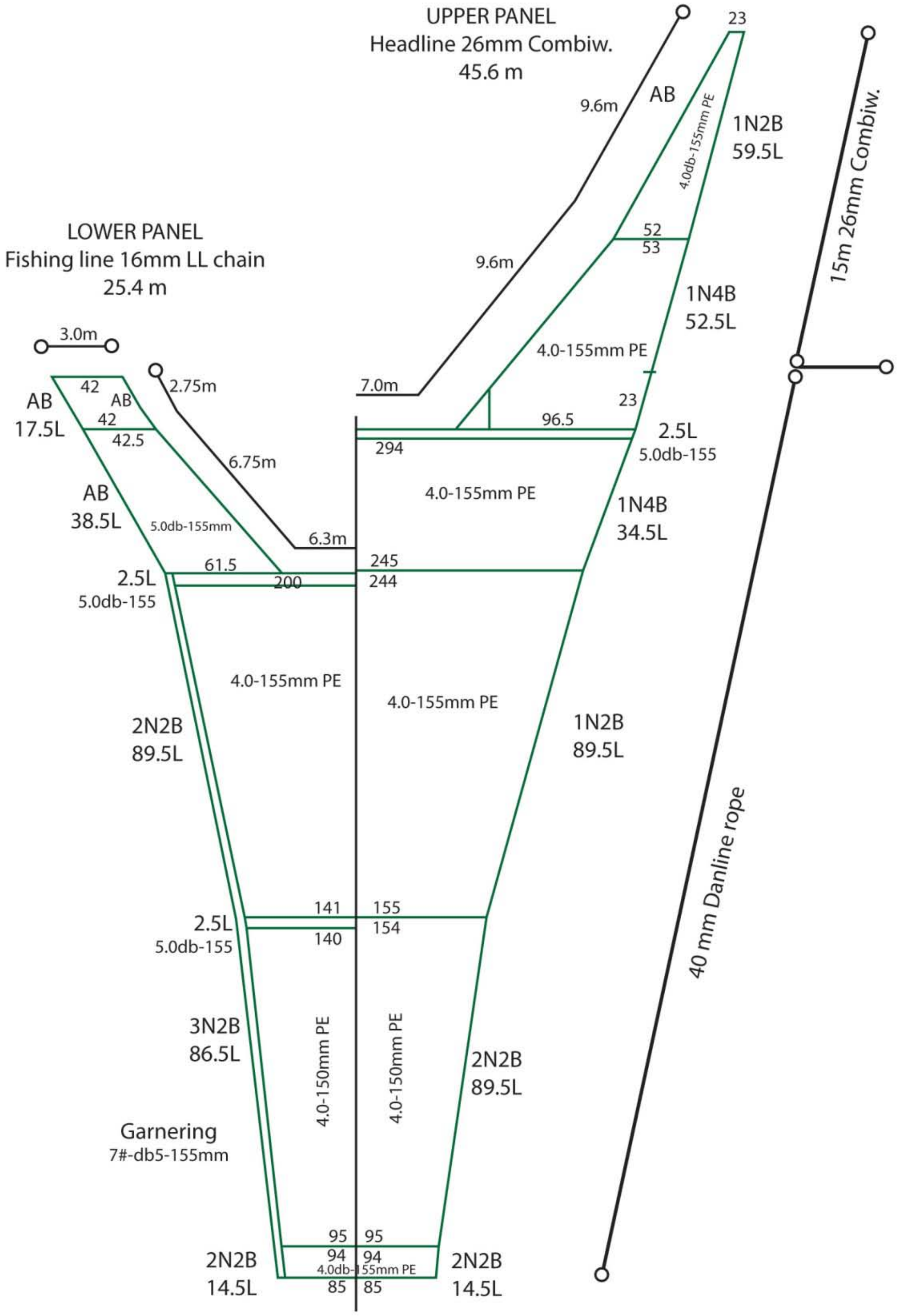
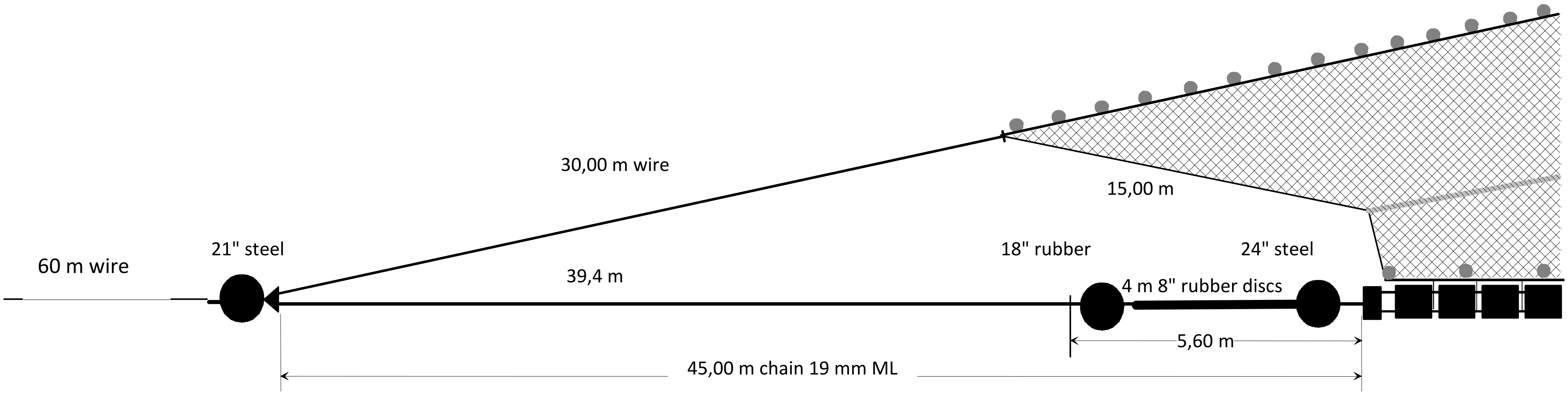


Figure 3. The trawl used during the experiments. "Selstad 444" (modified)

Figure 4. Rigging of the sweeps. The same rigging was used both on the plate gear and the rockhopper trawl.



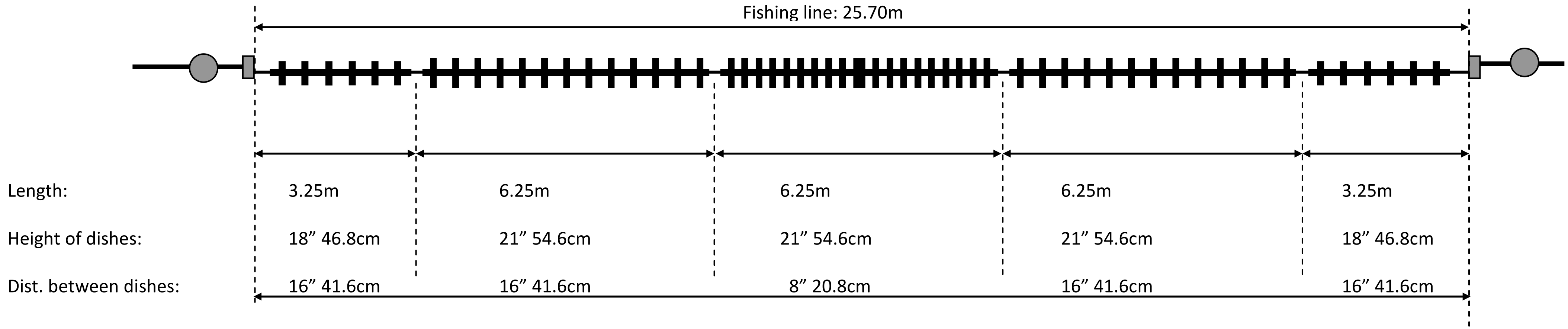


Figure 5. Rockhopper gear used on the “rockhopper trawl”.

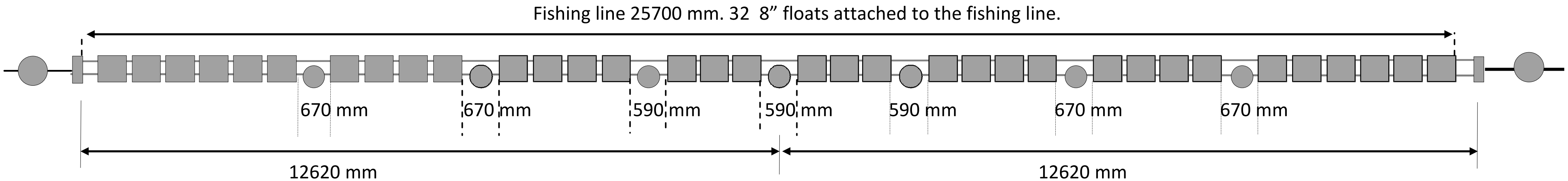


Figure 6. Plate gear combined with rolling bobbins as used on the “new” trawl

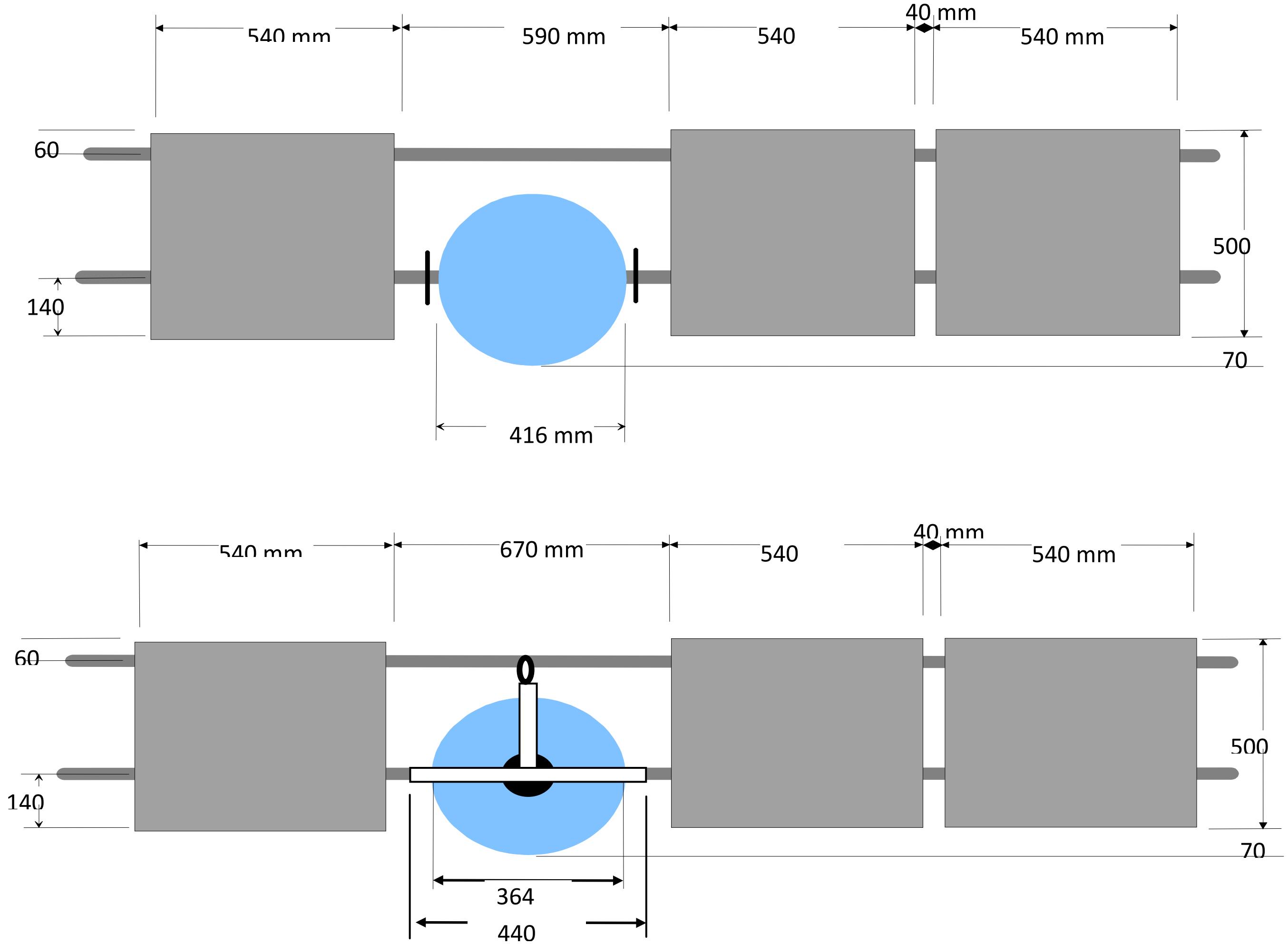


Figure 7. Dimensions of the modified plate gear, mid section (top) and side section (bottom)

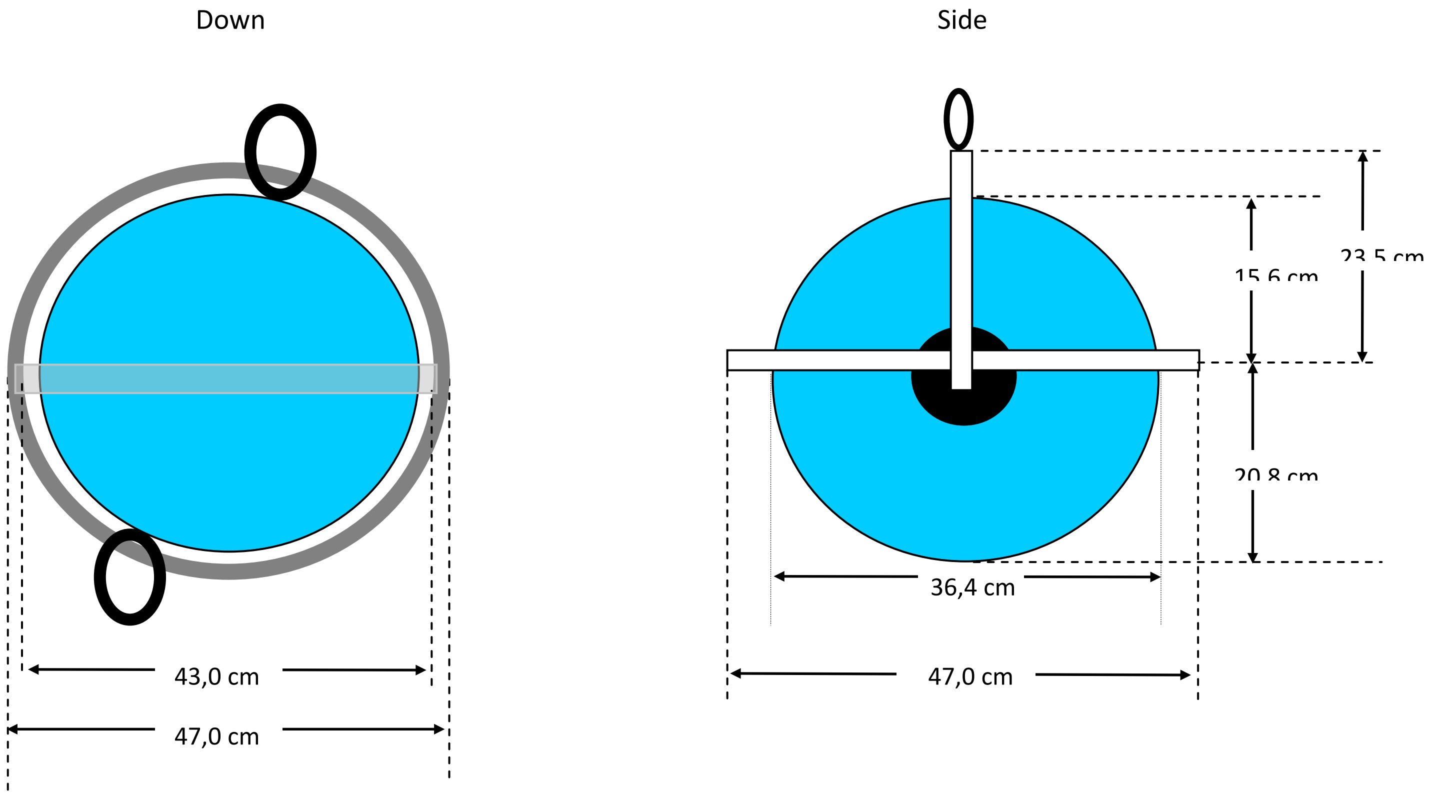


Figure 8. Bobbins used on the wings of the trawl gear specially designed to roll in the towing direction of the trawl

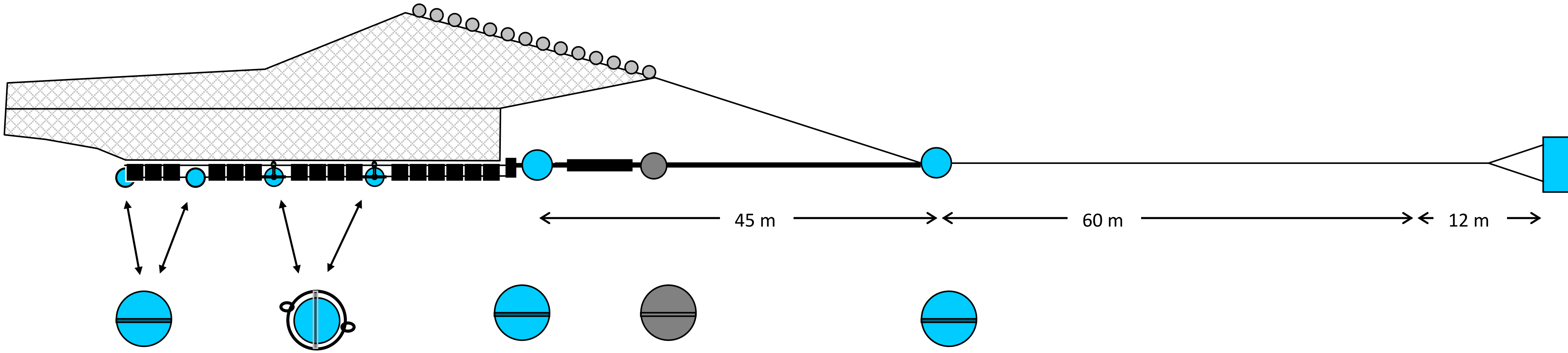


Figure 9.Final rigging of the modified plate gear and sweeps

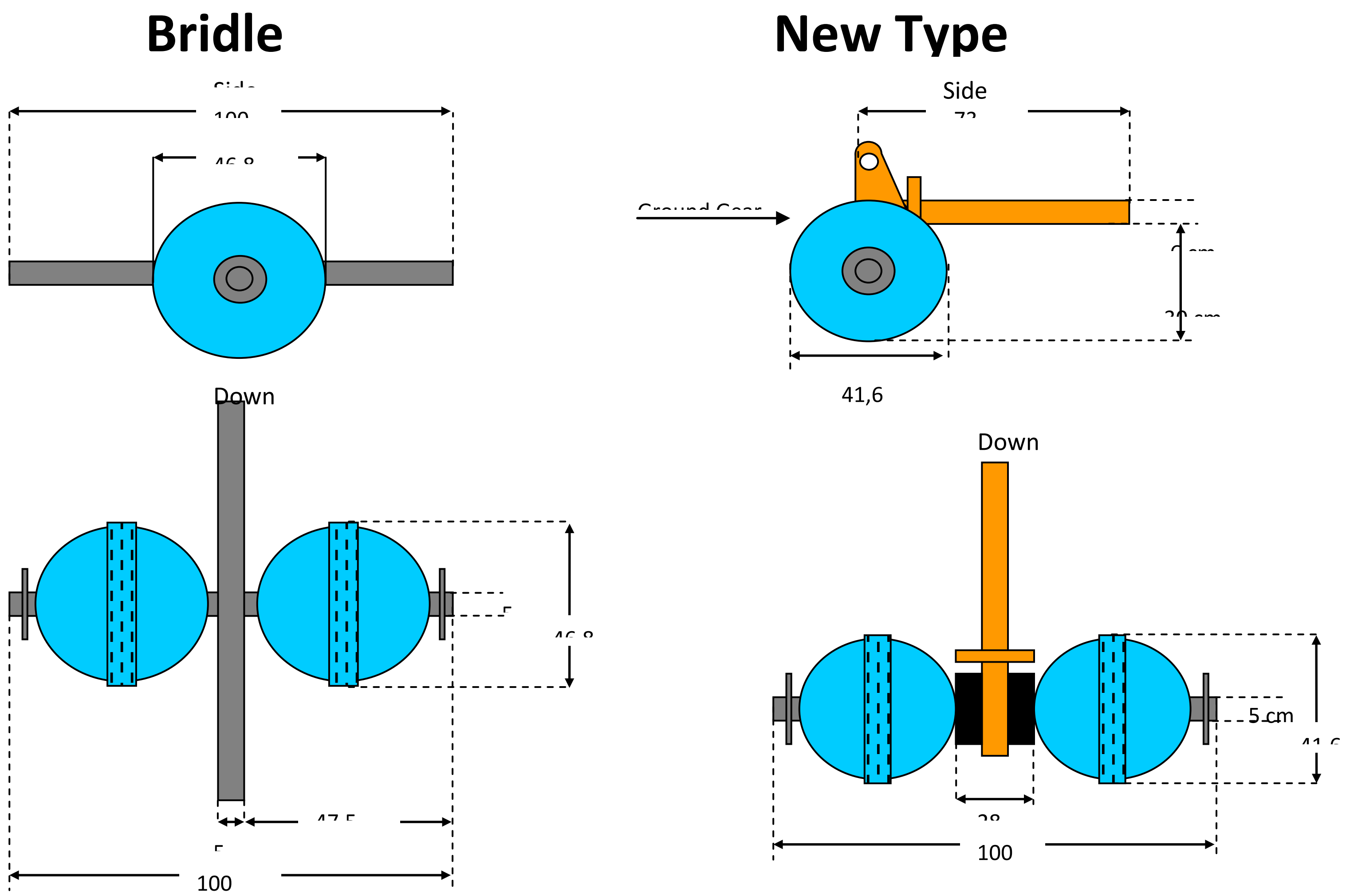


Figure 10. Experimental rollers initially placed on the bridles to lift them from bottom. These were abandoned early in the experiments.

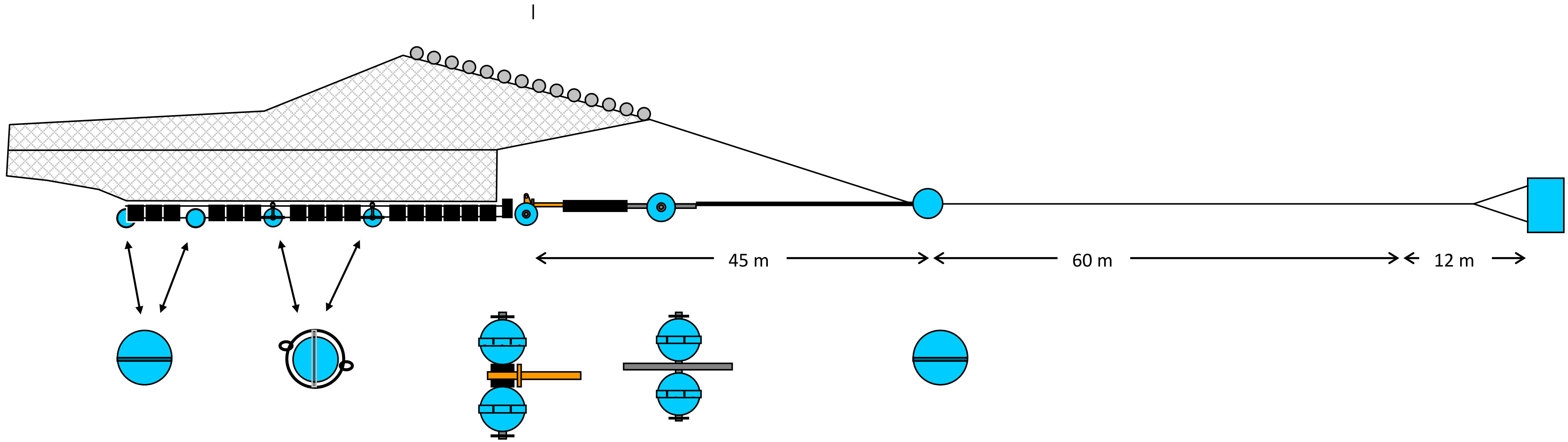


Figure 11. Placement of the modified dandolino and sweep lifter. These modifications were abandoned early in the experiments.

Figure 12. One of the bobbins specially designed to always roll in the towing direction of the trawl.

Documentation of trawl performance

The performance of the trawl was visually inspected using the towed underwater vehicle FOCUS fitted with a lowlight SIT camera and scanning sonar. This was used to evaluate the bottom contact of doors and ground gears, the trawl configuration a.o..

The trawl was equipped with different sensors in order to assess their working parameters and behavior.

- Geometry sensors were used to measure headline height, door to door distance, door depth, tilt and pitch angles of doors and sensors to measure the angle of the plates on the gear.
- Sounders also measure the seabed depth;
- Warp length and warp tension were measured.
- The speed over the water was measured by an electromagnetic speed sensor placed on the head rope. This speed was used as reference speed for all the experiments as it enables the integration of possible undercurrents, which can highly affect the trawl gear behavior.
- A tension meter was mounted between the doors and the sweeps behind each trawl door measured the tension of the trawl. However, one did not work properly. Therefore tension was only measured at one side at the time. In addition the tension on the winches was recorded.

Data from the different sensors were logged in a data base onboard the vessel.

Engineering trials

A series of tows were performed prior to the experiments of bottom impact with the following objectives:

(1) to study the behavior of the plate gear trawl, as it is known to be sensitive to plate gear adjustments, and to adjust its rigging in order to make it work properly and avoid damages due to possible digging into mud.
(2) To modify the ***dandolino*** and lift the sweeps from the bottom in order to reduce the bottom effect.
(3) to find door adjustments, by altering the bracket warp attachment position, in order to obtain a door as light as possible on the seabed ,
(4) For plate gear trawl: to find combinations of warp length & trawl speed over water, for a given depth and bottom sediment type, in order to achieve a trawl gear as light as possible on the seabed. These combinations allow to get a trawl where
    a. doors are most of the time off the bottom, which ensures very low impact or even no impact at all,
    b. plate gear rests on the bottom which ensures good fishing efficiency.
(5) to adjust the doors and the rigging of the rockhopper trawl, to adapt the warp length and towing speed so that the doors remain on the bottom, and achieve a standard behavior as commonly used by the professional fishermen

It must be noticed that herding effects can be lowered by the doors and sweeps off bottom with possible lower fishing efficiency for certain species.

Method

- A door depth sensor was used to assess its height over the seabed
- A head rope height sensor (vertical opening of the trawl) was used to assess the plate gear contact on the seabed using the image provided by this sensor: the seabed, the ground gear and the head rope were represented on the screen which enables to determine the moment at which the ground gear lifts off the bottom. For instance, for some measurements, the vertical trawl opening was bigger than the standard opening (around 4.4 m for the trawl considered). However, the plate gear could still be on the seabed, which ensures a good fishing efficiency for the plate gear.

The experimental protocol:

- Speeds over water were changed in order to observe the door lift off the bottom. The minimum speed was 2.5 knots to avoid ground gear digs into the mud. The maximum speed was around 3.3 knots, where the doors were clearly off the bottom for reasonable a warp length.
- The speed increase steps were chosen so as to observe the moment when the doors lifted off the bottom (series of measurements were done just before and after they lifted off the bottom). Thus, the speed step was reduced around this critical speed (around 0.1 knot).
- For the plate gear trawl the warp lengths were chosen such that they maintained the plate gear on the bottom and enable the doors to lift off the bottom. This warp length parameter is particularly important :
    - Too long warps will not allow lifting the doors off the bottom (except when using high towing speed, but then the trawl also will lift because of its hydrodynamic drag).

    - Thus “optimal” combinations will be found with rather short warp lengths. But too short warp lengths may cause stability problems and even make the plate gear or at least the lower bridles lift off the bottom.
- For the rockhopper trawl, we started with warp length 2 times bottom depth, then increased the speed until the trawl was lifting from bottom. We thereafter selected the speed so that the doors were stable on bottom. At last we shortened the warp length until the doors lifted from bottom.
- Once a configuration was settled (speed and warp length), a 5 minutes stabilisation time was held.
- Thereafter the trawl geometry data were logged for 15 minutes and the average values were used for the further results and discussion.

Simplifying assumptions

- We assume that the catch has negligible an effect on the trawl tensions and shape.
- We measured the distance between the doors and the seabed using (1) the onboard sounder and (2) the door depth sensor. The value (1) – (2) was used as the distance between door and seabed. One problems is that the result from the measurements of (1) and of (2) are not made at the same place. The distance between the two measurement points was almost the warp length (average value : 600 m). Thus, when the seabed depth changes along the trawl track it is useful to introduce a correction when calculating (1) – (2). The correction is based on the average time needed to move from measurement point (1) to measurement point (2): about 6:30 minutes (600 m at 3 knots). An interpolation function for depth in order to be able to calculate automatically the depth difference between the vessel and the door was used. The results presented hereafter integrate this simplified correction.

Investigating impact of trawls

Cod end catches

Fish catches were only collected and measured during the bottom impact tows (Hauls 354, 355, 362, 363 and 364). The trawl hauls done for testing trawl performance and for adjusting of trawl doors were done with open cod end.

During the bottom impact hauls, all catch from the cod end was identified to species, counted and length measured.

Mapping of bottom impact

The purpose of the work was to assess the physical and biological impact of the two trawl riggings and to compare the relative impact of the two:

1. The trawl with the plate gear as specified previously and with lightly rigged doors as determined during the engineering trials

2. The same trawl but with the rockhopper gear and normal (“heavy”) rigged doors, also as specified during the engineering trials

Multibeam mapping of seabed prior to trawling

Before starting trawling, a detailed bottom map of the inner Varanger fiord was made using multibeam mapping (Olex) (Figure 14). A relatively flat and homogenous area, large enough for the planned impact trawl hauls was chosen. Engineering hauls were run during night, but outside the borders of the impact haul area.

The ROV

The ROV used for seabed mapping was a SUB-fighter 15K, made by SPERRE Ltd (Figure 13). It was equipped with seven 2000W thrusters enabling a speed over ground of about 3.5 knots. One HD camera for high quality recordings as well as three other cameras used for orientation and surveying were placed on the ROV. It was also equipped with a scanning sonar for navigation, a depth sensor, compass, 4 x 250W halogen lights and HMI gas lights 2 x 400W.

The ROV was fitted with a HIPAP positioning system which enabled communication between the ROV and the DP (Dynamic Positioning) system of the vessel. During ROV surveys the vessel was set in “follow target” modus, so that the movements of the ROV controlled the movements of the vessel. Navigation data from the vessel and ROV was stored using NaviPac format.

The HD video material was stored using Final Cut Pro, while data from one of the other cameras was stored on conventional DVD format. Visual observations were logged in a logging program developed at IMR, Norway where events seen on the screen during surveying were recorded and classified and stored together with navigation data from the vessel.

Figure 13. The ROV Subfighter 15K (left) used for bottom habitat mapping. The right picture shows the surface control equipment and observation screens.

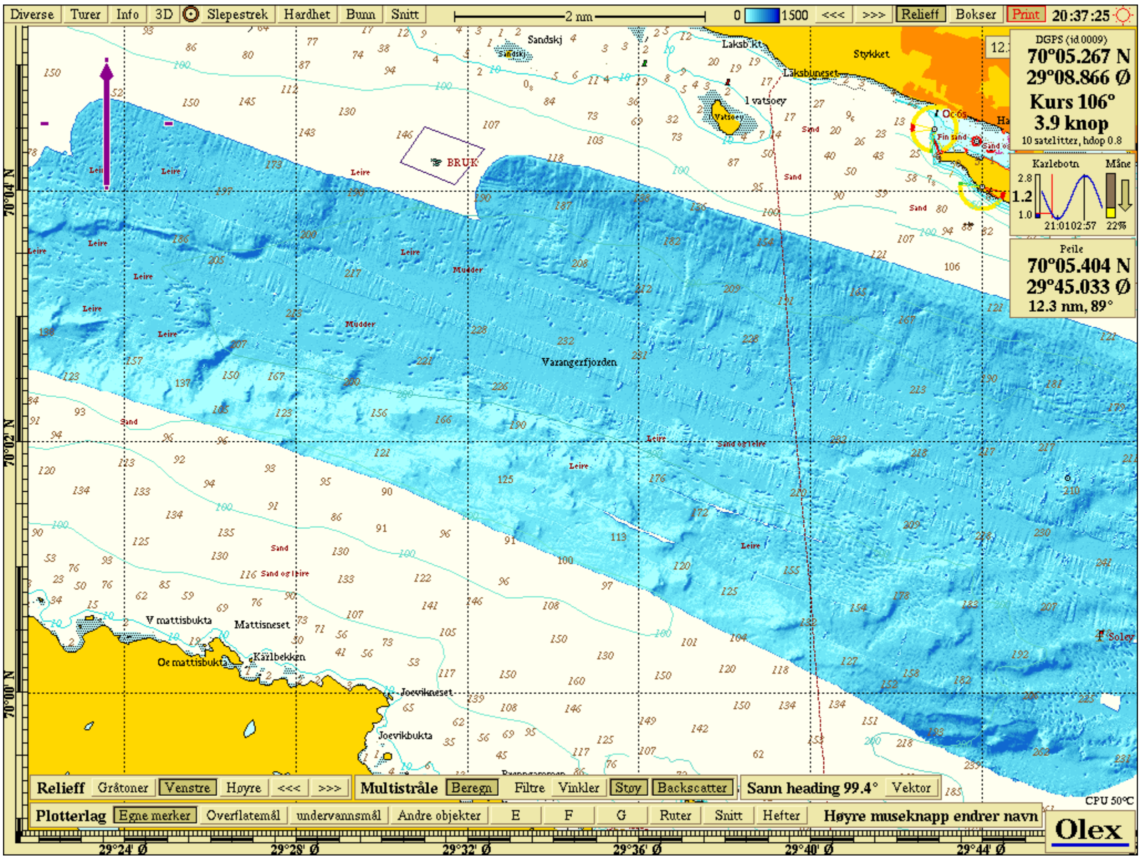


Figure 14. Multibeam map of the investigation area made before the trawl experiments begun.

Impact trawl hauls and ROV survey

Before trawling, the investigation area was surveyed with ROV in order to map possible existing trawl tracks or other footprints in the bottom substrate from previous activities (see Figure 15). No traces from fishing gears or other human activity were observed, but the bottom was more or less covered with footprints from the king crab (*Paralithodes camtschatica*).

The original plan was to compare the two trawls on two different bottom types, one soft and one harder bottom, if time permitted. It was, however, decided that if time should be a limiting factor, we would concentrate on doing a proper investigation on soft bottom only. This turned out to be the case, and hard-bottom hauls was therefore skipped.

Two hauls with each trawl, each haul lasting for 30 minutes, were carried out at a bottom depth of about 230 m. A fifth haul was done (haul 355) during which the warps of the plate gear trawl by mistake was too long (as long as during rockhopper hauls). As a consequence the trawl doors went hard in bottom. This haul was therefore left out of the analyses, although it was interested to see that as predicted this small detail in rigging made a huge difference on bottom impact from the trawl doors.

Table 1. Overview of bottom impact hauls

Station nr.	Trawl type	Date	Time (UTC) start	Position start	Position stop
354	Plate gear, light doors	27.11.2008	08:55	7002.55N 2937.20E	7002.06N 2941.76E
355	Plate gear, heavy doors*	28.11.2008	02:19	7002.39N 2836.19E	7002.98N 2932.02E
362	Rockhopper gear, heavy doors	29.11.2008	06:00	7002.24N 2937.23E	7001.65N 2941.87E
363	Rockhopper gear, heavy doors	29.11.2008	22:41	7002.89N 2933.67E	7002.28N 2938.17E
364	Plate gear, light doors	30.11.2008	12:26	7002.57N 2936.82E	7003.19N 2932.36E

*By mistake the tow was done with too long warps (identical to rockhopper trawl)

Figure 15 shows the localization of the trawl hauls as well as placement of CTD, grab samples and current meter localization. Figure 16 shows an idealized ROV survey track after trawling. First the trawl path was crossed twice with the ROV in order to trace, if possible, the tracks of the different trawl components. It turned out that this could be done fairly easy, except for the trawl doors on the plate gear trawl that did not touch bottom. When the tracks from the different trawl components were identified, the direction of the ROV was turned 90^o, and each individual track was followed for 15 minutes.

A CTD sample and a grab sample were taken close to each trawl track.

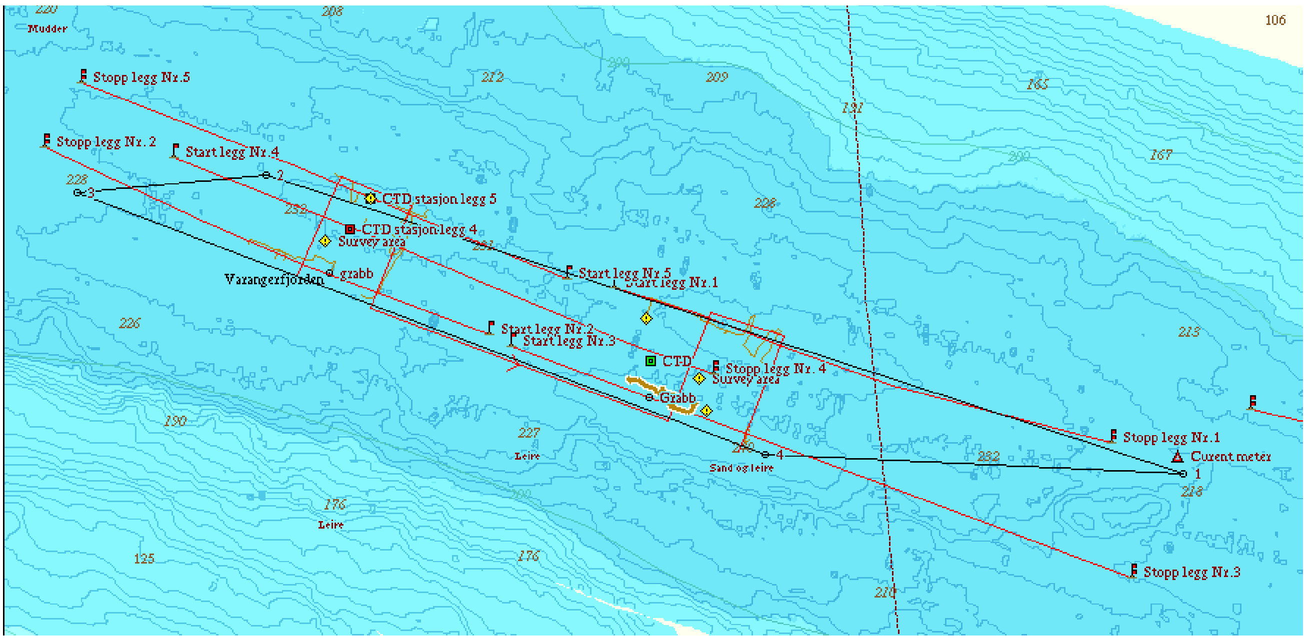


Figure 15. Location of trawl hauls (red lines), pre trawling ROV survey (red lines crossing the area at four locations, after trawling ROV surveys (orange lines), CTD stations (yellow tags), and current meter location (red triangle) in the investigation area. (Note that "legg Nr 1" equals haul 354, "legg Nr 2" equals haul 355, "legg Nr 3" equals haul 362", legg Nr 4" equals haul 363, and "legg Nr 5" equals haul 364).

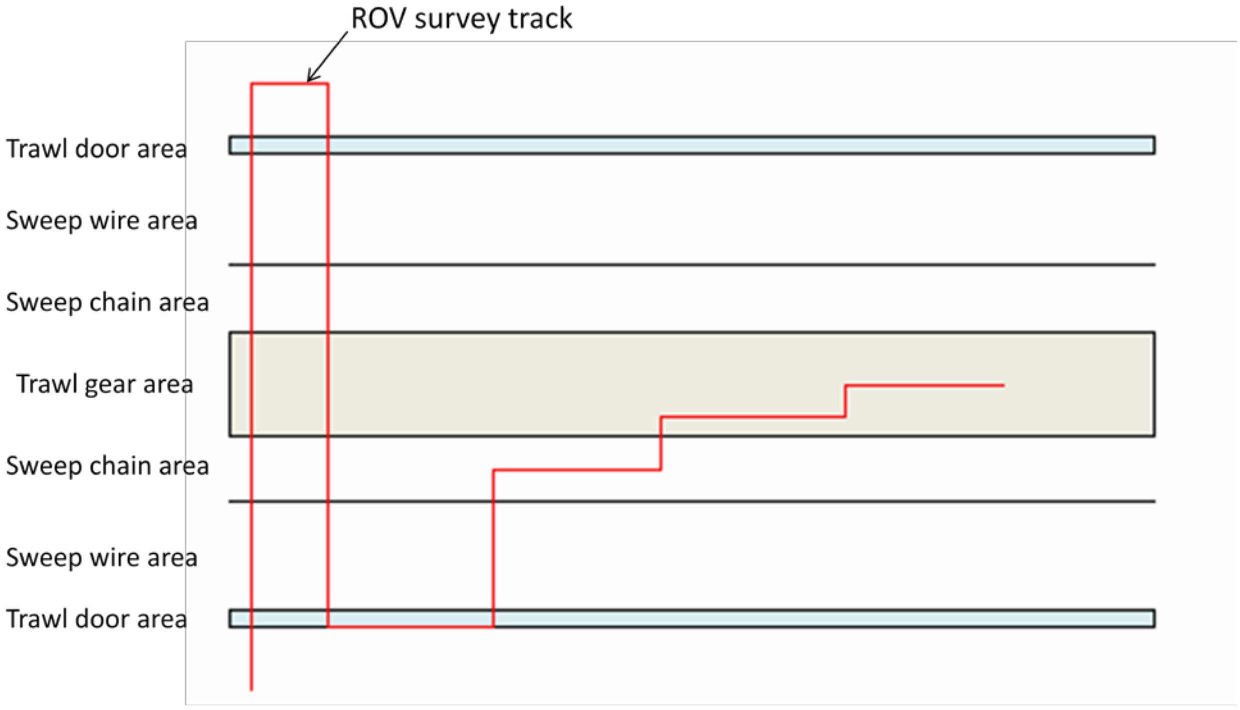


Figure 16. Principal outline of ROV survey relative to the bottom footprints of the different trawl components.

Analysis of bottom impact data

The video material from the survey was analyzed using the image processing and analyses program ImageJ. Two laser pointers, 10 cm apart horizontally, were used to measure cross section, width and breadth of the visible tracks where possible. Measurements of the depth of the tracks were more difficult, as the pictures only gave a two dimensional view of the bottom.

Benthos from collecting bags .

In order to compare the amount and possible differences between the two ground gears in digging of benthos and associated substrate, two collecting bags (opening 500 x 300 mm, mesh size 5 mm) were fitted inside the mouth of the trawl. One was placed just behind the ground gear on the middle of the trawl, while the other was placed 2.5 m further into the trawl. After each impact haul, the species, number of species and total weight of the samples was identified.

Grab samples

A grab sample was taken at each impact trawl haul. A sediment sample was taken out. Thereafter the sediments was washed away, and the remaining bottom dwelling specimens were identified and weighted.

Current

A current meter was placed in the outskirts of the bottom impact study area (Figure 15).

Turbidity

A turbidity meter (SAIV Ltd) was attached to one of the CTD rigs onboard the vessel. However, the frame could not be lowered closer than 5 m off the bottom. Turbidity was measured 5, 10, 20 and 30 m off bottom. First measurement was taken 45 min after trawling, and thereafter +1, +1 and +2 hours after the first measurement. One set of measurements was taken at a plate gear track, one at a rockhopper track and one at a control site.

Results

Investigating trawl performance

Plate gear trawl behavior

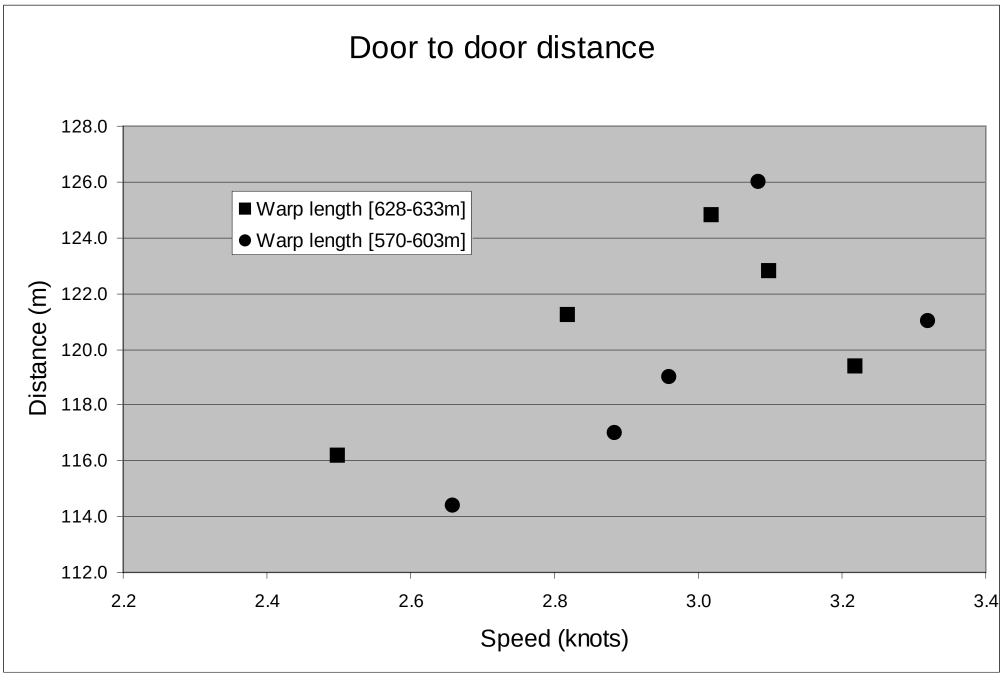


Figure 17. Distance between doors against speed over water for 2 warp length classes

The door to door distance is represented on Figure 17. The distance increases till a speed of about 3 knots and then decreases at higher speed. This is caused by the effect of doors lifting off the bottom and trawl drag increase. The optimal speed regarding the door efficiency used with this plate gear trawl seems to be around 3 knots. We can also observe a usual result : average door distance increases with warp length. However the relative variation of door distance with speed and warp length is rather low : maximum 10% in the ranges considered.

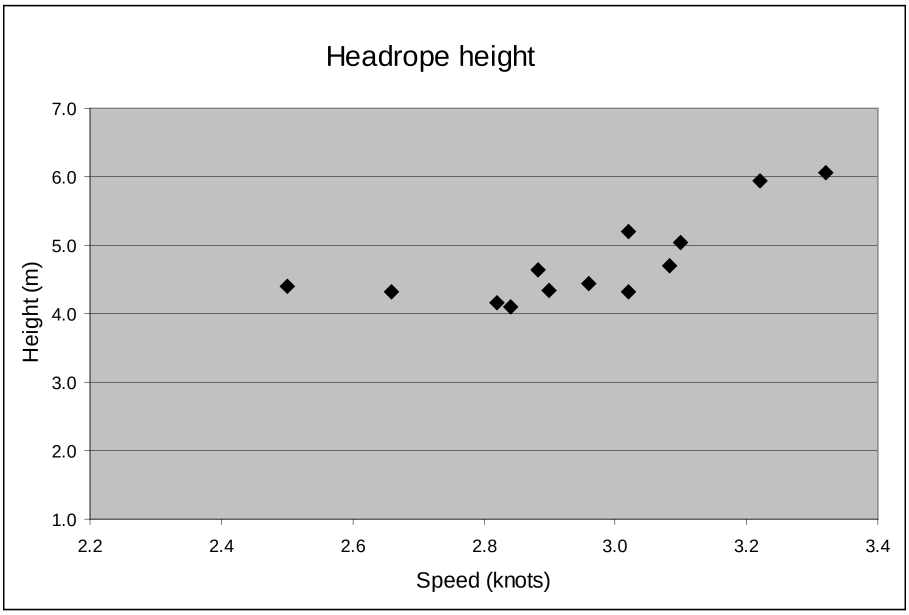


Figure 18. Headrope height against speed over water for different warp lengths

The headrope height is represented on the graph (Figure 18). There is no differentiation for warp length classes as the influence on headrope height of warp length, in the range [570 – 628m] is not very sensitive. In the speed range [2.5 – 3.0 knots], one can observe the usual behaviour for headrope height when the speed over water increases : the vertical opening of the trawl slightly decreases because of the net drag increase. Then we can observe that under a higher speed the headrope height increases. This is due to doors and sweeps lift-off bottom. If the speed keeps increasing, the lower bridle will also lift off the bottom and the headrope height will keep increasing. Then the contact of the ground gear on the seabed will be affected. This has clearly been observed on the headrope sensor screen for the highest speeds.

Finding speed & warp length combinations for light fishing

We are now looking for combinations of speed over water and warp length that enable to fish with doors off the bottom most of the time and ground gear on bottom. This enables very low impact of doors on the seabed and good fishing efficiency for species not sensitive to herding effect of doors and sweeps.

Figure 19 presents the door to bottom distance (blue bubbles) and headrope height (red bubbles).

The diameter of blue bubbles directly equals averaged door to bottom distance. The diameter of red bubbles is calculated in order to amplify the gap between the average headrope height in normal fishing conditions for this trawl (4.4 m, Figure 18) and the height of headrope in the case of speed too height and/or warp length too short.

The “good combinations” can be found on Figure 19 where we have a big blue bubble and no or almost no red bubble. These points are underlined in the Figure in the green area.

We can conclude from these trials that light fishing with doors off the bottom and ground gear on the bottom can be achieved using speed over water in the range [2.9 – 3.1] knots and warp length in the range [570 – 630] m. These combinations are only for average depths in the range [200 – 230] m.

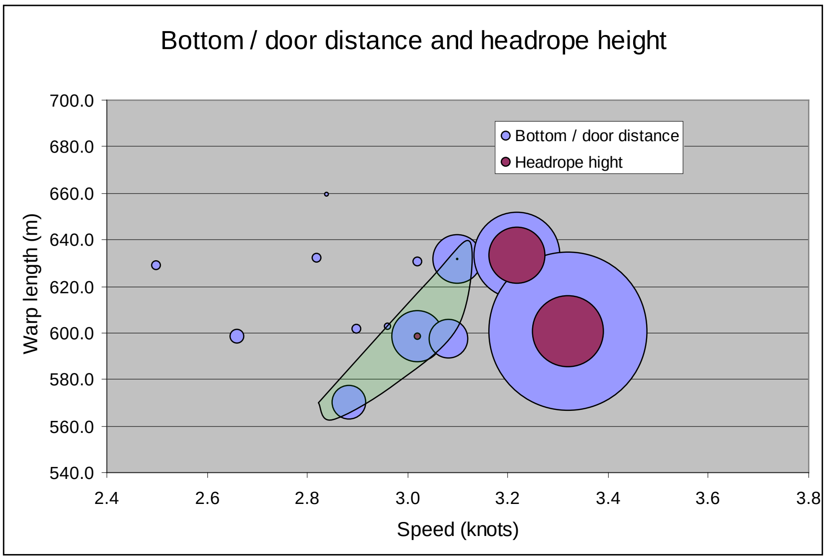


Figure 19. Door height and headrope height as a function of warp length and speed over the water

Basic measurements in the investigation area

The results from the CTD probes are shown in Annex 4. The water temperature in the upper water layers (0–260 m) was +5.3°C. At 260– 270 m there was a thermocline with the temperature decreasing to about +4°C at bottom. Likewise the salinity increased from just about 34.2 ppm in the upper layers to 34.6 below the thermocline. This pattern did not change much during the experiments.

Current measurements showed that tidal currents were dominating in the experiment area, and that the currents were weak as may be expected inside a sheltered fiord. This also meant that the mud clouds made by trawling on the soft sediments used a long time to drift away. This was a problem for the visibility during the ROV-surveys. They could not be run until several hours after trawling.

Investigating biological impact

Fish catches

Only two valid hauls were taken with each trawl type, each one lasting for 30 min only. This amount of catch data is, of course, much too scarce to draw any conclusions as to whether there is a difference in catchability of fish. Table 2 shows the weight of the catch of the two types. The variability in the few hauls is more pronounced than difference in catch level. More hauls have to be undertaken in order to be able to compare the catchability of the two trawls. The fish catch was dominated by cod *(Gadus morhua)* and haddock (*Pollachius virens*), with a few individuals of flatfish (*Hippoglossoides platessoides* and *Glyptocephalus cynoglossus*) as bycatch.

Table 2. Total weight of fish catch in the four valid bottom impact hauls, each lasting 30 min with a towing speed of 3 knots.

Gear type	Haul no.	Weight [kg]
Plate gear	354	99.58
	364	389.4
Rock hopper	362	231.04
	363	288.56

Benthos catches in collecting bags

As for the fish catches the low number of hauls makes it impossible to draw any conclusion on statistical differences between the two trawls in the amount of benthos caught in the collecting bags inside the trawl mouth. In both trawls the amount of catch was larger in the hindmost bag.

Table 3. Total weight of catch in collecting bags for benthos. Bag no 1 was placed immediately behind the ground gear, while bag no 2 was 2.5 m further behind in the trawl belly.

Gear type	Haul no.	Bag no.	Weight [kg]	Total weight [kg]
Plate gear	354	1	0.039	1.73
		2	1.263	
	364	1	0.023	
		2	0.406	
Rock hopper	362	1	0.406	2.14
		2	0.693	
	363	1	0.145	
		2	0.896	

Likewise, it was not possible to do any statistical comparison of the species composition between the bag samples from the two gear types because the number of hauls was too few. The samples were all dominated by tubes from sedentary polycheatas. These are not shown in Figure 20 because they were not living material. The living polychaet were seldom seen. Figure 20 shows the number of specimens of the different benthic groups found in the collecting bags. The number of bivalvia, eupausiidae and holothurioidae were all more numerous in the bags on the rockhopper gear than on the plate gear trawl. This indicates that the rockhopper gear digs up more benthic species than the plate gear. The difference was particularly large in the bags right behind the ground gear.

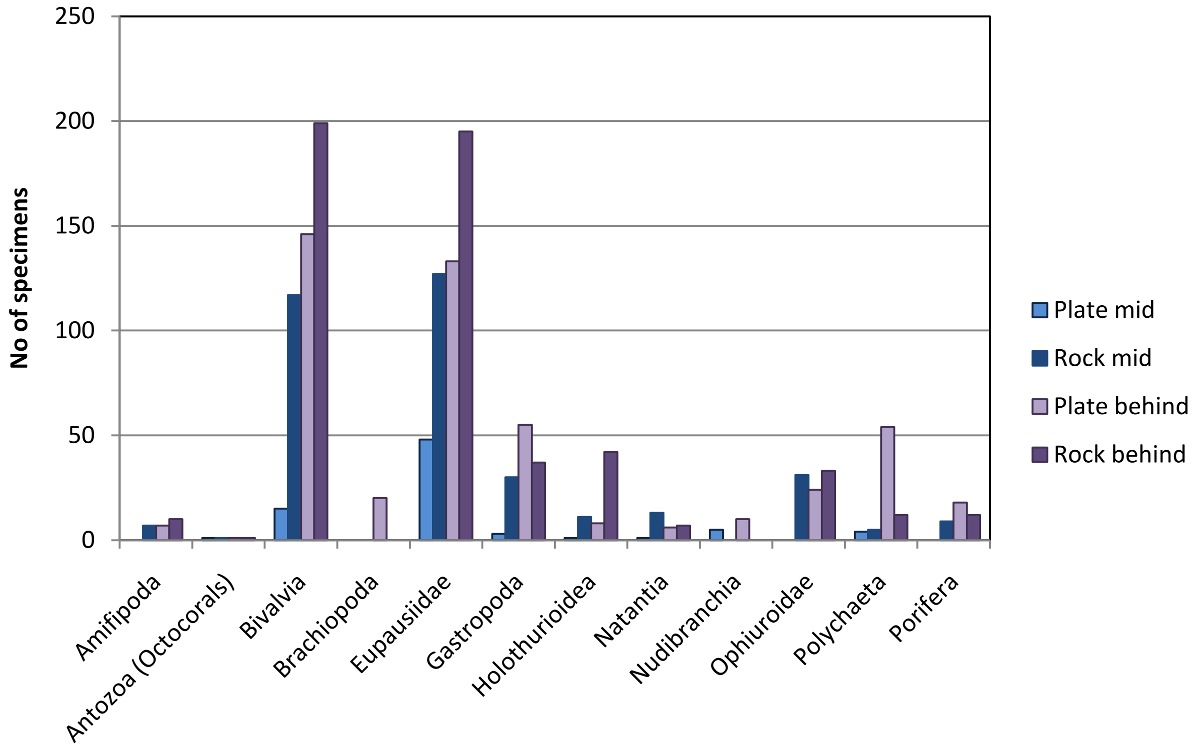


Figure 20. The number of specimens (sum of the two hauls of each trawl type) of benthic species caught in the collecting bags of the two trawl in the valid impact hauls. Plate mid and Rock mid refers to the bags attached in the belly close to the ground gear, while Plate Behind and Rock behind were placed 2.5 m further behind on the under belly.

ROV observations of biological impact on bottom dwelling species

The benthic fauna in the investigation area had a low biodiversity. The top substrate consisted of very soft clay with fine particles. The bottom was almost completely flat and looked like a moon landscape. This is a typical and favorable substrate for polychaetas. The tube dwelling sedentary polychaet Spiochetopterus typicus totally dominated the visible benthic species. The tip of the tubes protruded from the bottom (Figure 21), and after passage of the trawl it could frequently be seen that the exposed part of the tubes had increased relative to the untouched ground (Figure 22). It also looked like the tube ends were bent in the towing direction of the trawl. It is difficult to know the biological significance of these findings. Most tubes seemed to be old and unoccupied, and we do not know if the polychaets are able to dig down into the sediments at the passage of the trawl.

In addition to the polychaets, benthic amphipodes were frequently observed together with euphausids, mysids and shrimps (natantia). Octocoralles, bivalves and few brachiopods were also observed. The most common species are shown in Appendix 3.

It was initially planned to identify and quantify the fauna along the ROV track, and quantify the damage inflicted by the different components of the trawl. As the species composition was so dominated by the polychaete tubes, where the living organisms could not be observed, this turned out to be an impossible task.

Grab samples

As on the top bottom layer, the infauna seen in the sediments of the grab samples was totally dominated by the empty tubes of Spirochaetopterus typicus. Not many living specimen were found.

Figure 21. A typical bottom in the experiment area with the tubes of sedentary polychaeta protruding from the sediments. In addition a octocoral (Anthozoa) and a shrimp (*Pandalus borealis*) can be seen.

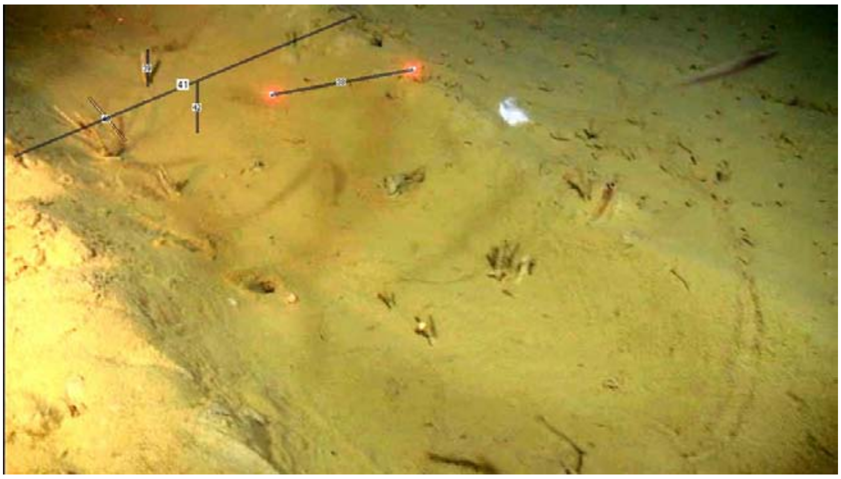


Figure 22. Track from a bobbin where exposed polychatea tubes may be seen protruding from the sediments.

Investigating physical impact

Particle distribution of sediments

Table 4. Particle distribution (%) in bottom sediments samples taken with grab at each of the bottom impact hauls

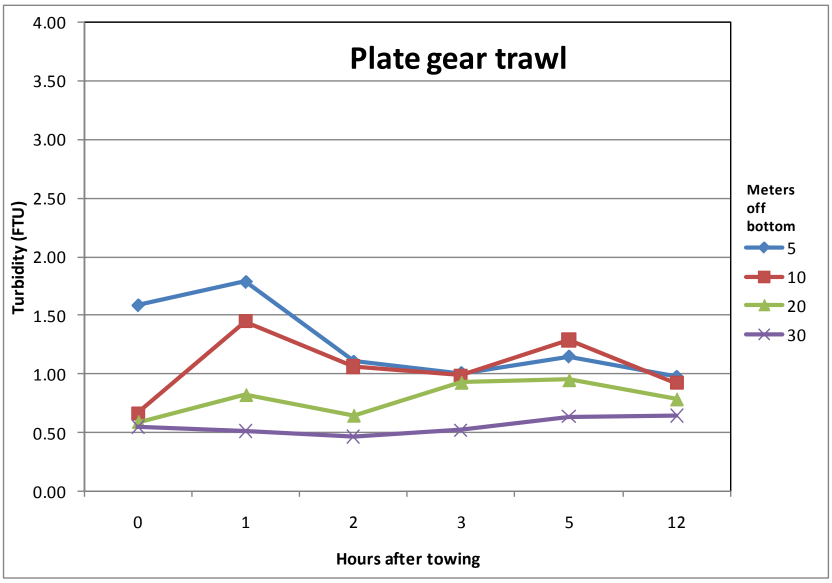
Haul no	Clay + Silt (< 63 µm)	Sand (63-2000 µm)	Gravel (>2000 µm)
354	97.6	2.4	0.0
355	98.1	1.9	0.0
362	98.3	1.7	0.0
363	98.1	1.9	0.0
364	97.9	2.1	0.0

The sediments in the investigation area consisted of very soft sediments with about 98 % of the particles smaller than 63µm (clay and silt).

Turbidity measurements

Turbidity measurements were only done after two bottom impact hauls, one with each trawl type. The bottom sediments were extremely soft, and only small disturbances of the sea bed (e.g. by a shrimp or fish touching the bottom) caused significant mud clouds.

Figure 23 shows the development of the turbidity 1, 2, 3, 5 and 12 hours after towing. For the plate gear trawl there seems to be an increase in turbidity at the lower measure point 5 m off bottom, decreasing with time after towing. For the rockhopper trawl the turbidity at the lower measuring point was much more variable. This may be caused by drifting of the particles due to currents, or they may be caused by artifacts like high densities of plankton and other organisms. The immediate impression is, however, that the rockhopper gear causes a higher turbidity, probably by digging more into the bottom sediments. More measurements should be done to control these findings. I must be stressed, however, that the closest measuring point to the bottom was at 5 m distance. It is reason to believe that the highest particle density was in the area closes to the bottom, at least initially.



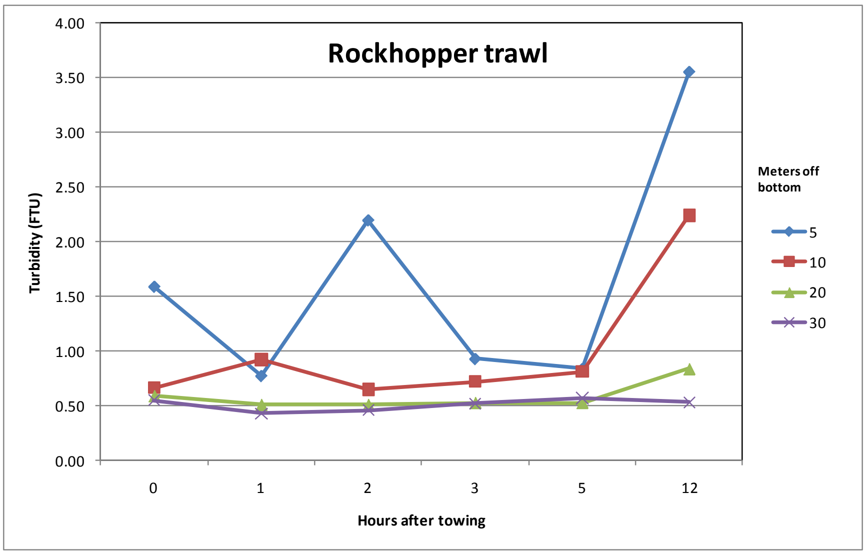


Figure 23. Measured turbidity above trawl paths of plate gear and rockhopper trawls. Turbidity was measured at varying times after towing and at different distances from the bottom. “0 hours” is control measurements done off the trawl paths

Table 5. Measured turbidity (Formazin Turbidity Units (FTU)) at one rockhopper and one plate gear trawl path. Measurements were done at different distances from bottom as well as at different times after trawling.

	Distance off bottom (m)	Control area		1 hour		2 hours		3 hours		5 hours		12 hours	
		Average	Std	Average	Std	Average	Std	Average	Std	Average	Std	Average	Std
Rock hopper	5	1.59	1.24	0.77	0.14	2.19	0.29	0.93	0.07	0.84	0.08	3.55	0.37
	10	0.66	0.19	0.92	0.14	0.65	0.07	0.72	0.07	0.81	0.07	2.24	0.19
	20	0.59	0.12	0.51	0.09	0.51	0.09	0.53	0.11	0.53	0.10	0.84	0.13
	30	0.55	0.07	0.43	0.07	0.46	0.05	0.52	0.05	0.57	0.18	0.53	0.14
Plate gear	5	1.59	1.24	1.79	0.37	1.10	0.10	1.01	0.10	1.15	0.11	0.98	0.07
	10	0.66	0.19	1.45	0.15	1.06	0.14	0.99	0.13	1.29	0.11	0.92	0.09
	20	0.59	0.12	0.82	0.10	0.64	0.11	0.93	0.15	0.95	0.09	0.78	0.10
	30	0.55	0.07	0.51	0.05	0.47	0.05	0.52	0.05	0.64	0.06	0.64	0.10

Investigating physical impact using ROV

The doors

Only the rockhopper trawl had doors touching the bottom (Figure 24). Initially we strived to make the doors of the plate gear barely touch the bottom, believing that it was difficult to lift the doors while simultaneously keeping the door spread. The initial hauls inspected with the towed vehicle Focus showed, however, that the doors were lifted a short distance from bottom while the trawl configuration was maintained. The lifting was confirmed during the ROV observations of the trawl paths. No tracks could be seen from doors in the path of the valid plate gear hauls. In the track of haul no 355 where the plate gear trawl by mistake was run with longer warps (700 m instead of 600 m, i.e. as long as in rockhopper hauls), deep furrows from the doors were found.

Figure 24. Tracks of door from the rockhopper trawl. The black bars shows measurements done to size the track. The distance between the red laser lights was 10 cm.

One interesting observation was that the doors did not seem to follow a steady track on the bottom. The depth of the door path varied, and also the amount of aggregated mud within the path. It seemed that the mud aggregated in front of the door while towed along until the dung of mud reached a certain size/weight. Then the door seemed to flip over the sediment pile, and stay floating above the bottom for some meters. It thereafter landed on bottom, started to dig into the mud and build up a new sediment pile, and a new cycle started.

Figure 25. A pile of mud sediment deposited by a trawl door on the rockhopper trawl.

The sweep area

The construction of the sweeps was identical on both trawls (Figure 4). The total length of 105 m was divided in three main parts split by discs/bobbins. On the Focus shots it was seen that the wire part (closest to the door) did not touch the bottom. This was verified with the ROV, where little visible tracks could be seen on the sediments from this part of the sweeps. It seemed that it only touched the bottom infrequently, causing minor re-suspension or mud lumps to be scattered over the seabed.

The chain part of the sweeps had a higher bottom contact. In the tracks of both trawls the chain made a regular undulating pattern on the bottom where the dimensions of the waves fitted perfectly to the size of the chain links (Figure 26). Small piles of mud were scattered irregularly over the bottom.

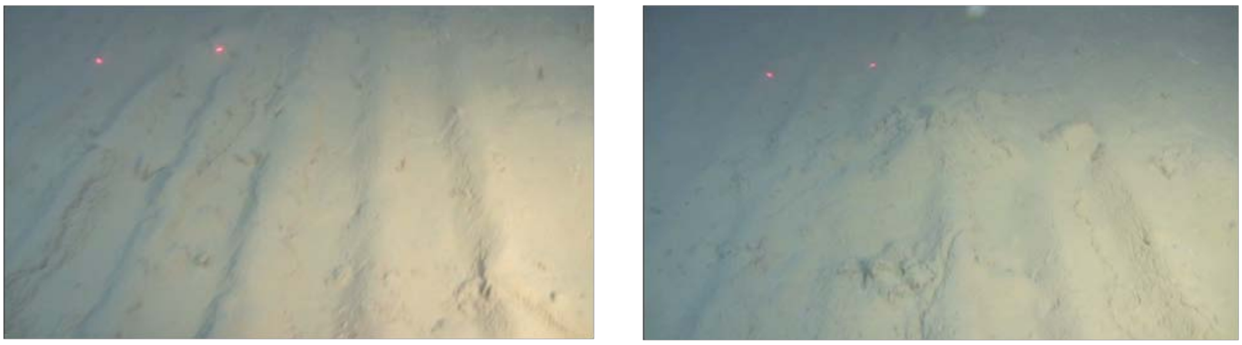


Figure 26. Track from chain part of the sweep. Small piles of mud can be seen scattered above the chain tracks. The distance between the red laser spots is 10 cm.

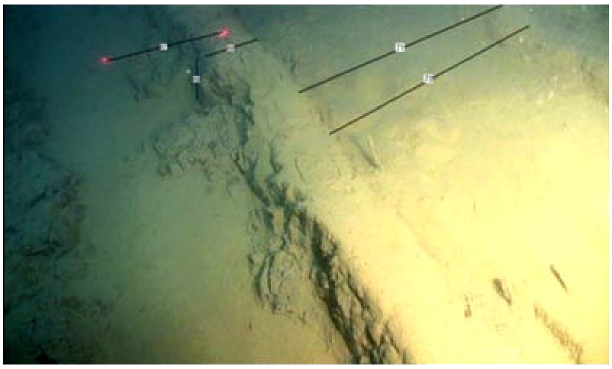
bobbins

The different parts of the sweeps were linked with steel or rubber discs (see Figure 4), which made clear tracks on the bottom (Figure 27). These tracks had an average cross section of between 15 and 25 cm, and were more or less identical on both trawls.

Figure 27. Two tracks from bobbins on the sweeps. Black bars are used for measuring of tracks. The distance between the red laser points is 10 cm.

The rockhopper gear

The rockhopper ground gear was seen to have a major impact on the sea bed sediments. The ROV inspections revealed that it had been going heavily on bottom all along its cross section. The tracks from each single rubber disc could be distinguished on the bottom. The digging was so deep that even the spaces between the discs were impacted by the gear. It is clear that the rockhopper gear influences the seabed in the total width of the gear.



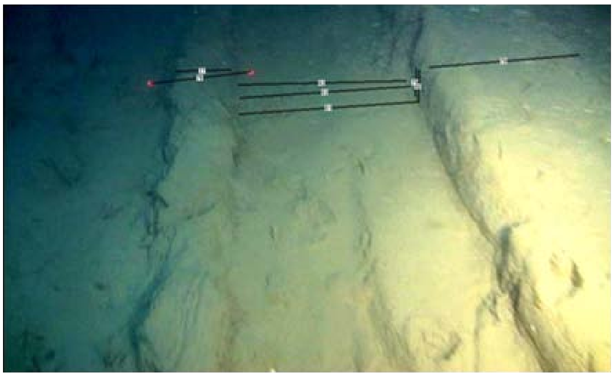


Figure 28. Tracks from the rockhopper ground gear, showing major impact on the sea bed. Tubes from tube dwelling polychaets have been stripped by the gear. Distance between the red laser pointers is 10 cm.

The plate gear

The track of the plate gear, consisting of 34 rubber plates, strapped between 7 bobbins (16’’) could also be discerned on the bottom surface. While crossing over the path of the ground gear with the ROV, each single bobbins track could be identified (Figure 29), while the plate sections were more difficult to distinguish (Figure 30). Generally, the plate closest to the bobbins had made a shallow track in the bottom, while the other plates seemed to either not having touched or barely touched the sediments. It also seemed that the gear must have had a somewhat undulating movement, as the depth and visibility of the plate tracks varied. However, anticipating that only the bobbins and the closest plates touch the bottom, a maximum of 50 % of the cross section of the plate gear influenced the bottom sediments, contrary to the rockhopper where the whole cross section impacts the sea bed. In addition the depth of the digging of the rockhopper gear was much more severe.

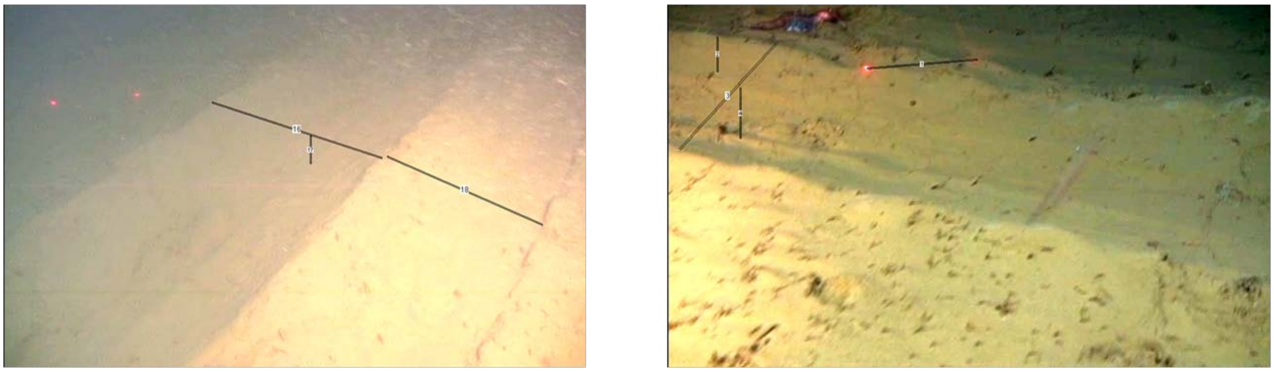


Figure 29. Tracks from the plate gear. One of the bobbins may be seen, and on the left picture, also one of the plates adjacent to the disc has made at track in the sea bed. The distance between the two red laser pointers is 10 cm.

Figure 30. Tracks from plates on the sea bed.

In some areas the tubes of Spiochaetopterus could be seen protruding from the sea bed more than in the control areas, obviously exposed by the passage of the ground gear (Figure 31).

Figure 31. Tracks from plates of the plate gear. Tubes from tube dwelling polychaets has been exposed by removal of sediments.

Measurements of tracks

Table 6 shows measurements of the tracks from the different trawl components taken from the ROV pictures. The accuracy of the width measurements may be considered relatively good, while the depth measurements are approximations based on the vertical lines fitted visually into the 2 dimensional photo frames.

Table 6. Average measurements of width and depth of the different trawl components from the ROV shots. Particularly the depth measurements have a low accuracy.

		Width				Depth		
Component	**Trawl type**	**N**	**Mean (cm)**	**SD**		**N**	**Mean (cm)**	**SD**
Door	Rockhopper trawl	2	(42.17)*			7	6.43	2.77
	Plate gear trawl		0.00				0.00	
Bobbins on sweep	Rockhopper trawl	8	20.20	4.86		6	3.08	0.60
	Plate gear trawl	7	21.43	2.28		7	2.68	0.59
Sweep chain part	Rockhopper trawl	13	5.37	1.14		13	1.27	0.22
	Plate gear trawl	6	5.32	1.22		6	1.26	0.27
Ground gear	Rockhopper discs	6	14.59	4.34		6	2.80	1.26
	Rockhopper: space betw discs	6	4.75	0.69				
	Plate gear: plates	8	10.15	1.10		7	0.68	0.06
	Plate gear: bobbins	12	19.20	4.27		12	3.46	0.77

The measurements of the width of the door tracks are approximate, as on most pictures only parts of the track could be seen simultaneously. But as on the plate gear trawl the doors did not touch the bottom at all, the impact of the doors of the rockhopper trawl was considerably more severe. As already mentioned, the sweeps were identical on both trawls and measurements of the physical impact of the sweep of the two trawls did not differ much in width or depth.

In addition to the doors, the ground gear part was what distinguished between the two trawls. On the plate gear trawl, it was mainly the seven bobbins that made visible tracks on the seabed, while only a few of the plates could be traced on bottom. At average about 50% of the cross section of the plate gear could be seen impacting the sea bed, and the depth of the plate tracks was small (less than 1 cm as measured). The rockhopper discs made visible tracks all along its cross section, and even the space between the discs seemed to be impacted by the gear. In addition the digging depth was significantly more severe.

Discussion

The final research cruise described in this report had the objective to compare the physical and biological impact of the bottom trawl modifications developed during the DEGREE project to a standard bottom trawl used in the Barents Sea cod fisheries. The "new" trawl was fitted with the last modification of the plate gear developed during the project as well as trawl doors (standard Thyborøn doors) rigged to barely touch the bottom. The commercial trawl used for comparison was rigged with a conventional rockhopper ground gear and the doors were rigged to go heavy on the bottom as normally rigged during commercial bottom trawling.

To find the optimal rigging of the doors for minimum bottom impact we carried out engineering trials where different combinations of speed through water and warp lengths were tested. We looked for combinations enabling us to fish with the doors off, or nearly off, the bottom, while the ground gear was still on bottom and the door spread was maintained. This enabled almost no impact of the doors on the seabed while hopefully keeping an acceptable fishing efficiency for species not sensitive to herding effects of doors. However, it is assumed that most fish species are herded by the doors and sweeps (Engås and Godø 1989), and these trawl components may therefore be important for the fishing efficiency. In our experiments we found suitable combinations of speed and warp length, but too few hauls were conducted to investigate if the fishing efficiency of the trawl was maintained as the doors were lifted off the bottom. More fishing experiments are therefore needed before it may be concluded that this rigging can be recommended for commercial use by the fishing fleet.

The plate gear was tested in a commercial fishing trial at an earlier stage of the DEGREE project (see DEGREE Periodic Activity Report No 1). The experience was, however, that although the gear seemed to fish better than the conventional rockhopper gear during the first phase of the experiments, it proved to be extremely sensitive for obliquity, and even the wear and tear after a few hauls made the angles of the plates to change to suboptimal, and the catches rates decreased. In this last experiment a new modification of the plate gear was tested, where the plates were mounted on a wire attached under the fishing line. This setup made the gear self-adjusting and therefore not so sensitive to obliquity. The new modification seemed to function very well, but more tests have to be conducted in order to prove its stability during normal fishing conditions.

The physical and biological impact on the bottom habitat of the two trawls was compared. Only two valid impact hauls was done with each trawl, both on very soft sediments. This is of course too few hauls to obtain a full statistical comparison between the two trawls. However, all parameters measured indicated that the plate gear trawl had a lower impact on the bottom substrate and benthic organisms than the conventional rockhopper trawl. The physical impact on the bottom was visually inspected and measured by ROV technique. In addition the turbidity of the water volume above the trawl tracks at different time steps after trawling was measured. A higher turbidity above the rockhopper trawl path indicated that the rockhopper gear raised more sediments than the plate gear trawl. This was probably both due to the heavier doors and the heavier gear on the conventional trawl. The larger impact of the rockhopper trawl was also confirmed by the ROV observations where the rockhopper trawl was documented to have a larger impact on the bottom sediments both horizontally and vertically than the plate gear. The difference in door rigging added to the difference in sediment disturbance.

Less data was obtained on biological impact. The rate of throwing up of bottom dwelling species by the ground gears was measured using two collecting bags mounted inside the mouth of the trawl at different distances behind the ground gear. Although the number of hauls was low, the results indicated that the rockhopper dug up more living material than the plate gear. This tendency was confirmed by the ROV investigations. The bottom type, where the experiments were conducted, had a low biodiversity. Tube dwelling polychaetes dominated the fauna. It was not possible from the ROV recordings to classify benthic organisms on the sea bed according to level of damage inflicted by the trawl components. Earlier investigations on soft bottom have not clearly demonstrated long term effects of trawling on benthic organisms (Ball *et al.* 2000; Hansson *et al.* 2000; Drabsch *et al.* 2001), but it is obvious that living organisms can only be damaged by a trawl if hit by one of its components during towing. Acknowledging that the area impacted by the trawl components as well as the depth of their digging into the sediments is what decides the severity of the impact on bottom living species (see eg. He and Delouche 2004; Rose *et al.* 2000), it must be concluded that the new gear developed during the DEGREE project has the potential to reduce the impact of bottom trawling if taken into use by the fishing fleet.

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Annex 1. Events overview

Date	Time start	Time stop	Event type	Station no	Locality	Comments
23.11.2008	11:37	13:05	Trawl haul	347	Persfjorden	Rockhopper trawl, 3 collection bags; Catch and benthos measured
23.11.2008	ca. 11:40	ca. 12:50	Focus	Not noted	Persfjorden	Focus observations of trawl, part. trawl gear
23.11.2008	14:36	16:50	Trawl haul	348	Persfjorden	Rockhopper trawl without colletion bags; Catch not take care of
23.11.2008	ca. 14:45	ca. 16:30	Focus	Not noted	Persfjorden	FOCUS obs. of trawl, part. doors. Test of turbidity measurements
24.11.2008	03:00	18:00	Bottom mapping multi beam sounder	Not noted	Varangerfjord	Because of wind, vessel had to use low speed, and only map with wind from behind, i.e. west-east
25.11.2008	08:29	09:47	Trawl haul	349	SE of Vardø	Plate gear. The double danlenos were both turned upside down, which effected the gear (twist of wings).
25.11.2008	09:07	09:31	Focus	3	SE of Vardø	Time set for FOCUS station is time for video recording. Spent a long time to find the trawl. Focus was set just as the trawl touched bottom
25.11.2008	12:21	13:55	Trawl haul	350	SE of Vardø	Plate gear. The double bobbins on sweep removed. Swivels attached to both sides of double danlenos.
25.11.2008	12:22	13:42	Focus	4	SE of Vardø	Visibility very bad. Tried to observe ground gear and double danlenos. Danlenos again upside down. Also ground gir on wings seemed to be somewhat distorted.

25.11.2008	17:56	19:31	Trawl haul	351 + 352	SE of Vardø	Probl with log file. Start new stno after about half hour. Testing plate trawl with standard danlenos. Plates attached to fishing line. Tried to do engineering trials with doors, but problems manouvering Focus
25.11.2008	18:06	19:19	Focus	5	SE of Vardø	First looked at danlenos and gear. Focus lost manouvering ability after running down i observation hole on trawl. Had to cancel planned engeneering trials with towing speed.
26.11.2008	16:03	18:53	ROV	37	Varangerfjord	Baseline runs - 2 transects with ROV (Files ROV01)
26.11.2008	15:02		Strømrigg	186	Varangerfjord	Employed current meter
26.11.2008	20:04	07:00	Trawl haul	353	Varangerfjord	Engineering hauls to test influence of speed and warp length (plate gear trawl). Includes Equipment tests below
26.11.2008	20:17	20:23	Equipment test	0	Varangerfjord	Engineering haul (plate gear). The first 3 Equip tests refers to the same tow, but changing speeds.
26.11.2008	20:28	20:39	Equipment test	1	Varangerfjord	Eng. haul, new speed (plate gear).
26.11.2008	21:25	21:36	Equipment test	2	Varangerfjord	Eng. haul, new speed (plate gear).
26.11.2008	22:11	23:37	Equipment test	3	Varangerfjord	New Eng. haul (plate gear).
27.11.2008	00:57	02:36	Equipment test	4	Varangerfjord	New Eng. haul (plate gear).
27.11.2008	03:10	04:50	Equipment test	5	Varangerfjord	New Eng. haul (plate gear).
27.11.2008	05:41	06:41	Equipment test	6	Varangerfjord	New Eng. haul (plate gear).
27.11.2008	08:55	09:25	Trawl haul	354	Varangerfjord	First impact haul with plate gear. 600 m warp, speed 2.9 knots
27.11.2008	10:31	11:04	ROV station	38	Varangerfjord	Tried to observe st.nr. 354. The turbidity too high to make any observations (Files ROV02)
27.11.2008	12:20	13:51	ROV station	39	Varangerfjord	Base line observation transect across impact tow area, western part (Files ROV03)

27.11.2008	15:20	19:58	ROV station	40	Varangerfjord	Survey around plate gear st.nr. 354. Could identify all parts of the trawl, except for doors, which probably had not touched bottom in investigation area. (Files ROV04)
27.11.2008	20:23	20:45	Grab		Varangerfjord	Grab sample of bottom in ROV-survey area stnr 354
28.11.2008	02:19	02:48	Trawl haul	355	Varangerfjord	Second impact haul with plate gear and light doors. Wire length wrong: 700 m instead of 600. 3 knots
28.11.2008	12:15	13:54	ROV station	41	Varangerfjord	Monitoring of haul 355. Had to stop because of gale. Did not manage to look at ground gear part, only door, sweep and danleno area
28.11.2008	17:41	18:50	Trawl haul	356	Varangerfjord	Engineering hauls to test influence of speed and warp length (rockhopper)
28.11.2008	19:12	20:02	Trawl haul	357	Varangerfjord	Engineering hauls to test influence of speed and warp length (rockhopper)
28.11.2008	20:37	21:05	Trawl haul	358	Varangerfjord	Engineering hauls to test influence of speed and warp length (rockhopper)
28.11.2008	21:50	22:24	Trawl haul	359	Varangerfjord	Engineering hauls to test influence of speed and warp length (rockhopper)
28.11.2008	22:45	23:22	Trawl haul	360	Varangerfjord	Engineering hauls to test influence of speed and warp length (rockhopper)
28.11.2008	23:47	00:39	Trawl haul	361	Varangerfjord	Engineering hauls to test influence of speed and warp length (rockhopper)
29.11.2008	06:00	06:30	Trawl haul	362	Varangerfjord	First impact haul with rockhopper gear. 690 m wire and 3 knots
29.11.2008	08:26	08:39	ROV station	42	Varangerfjord	Attempt to observe plate haul 355 mid gear. Turbidity still too high
29.11.2008	11:37	11:54	ROV station	43	Varangerfjord	Attempt to observe rockhopper haul 362. Turbidity too high

29.11.2008	13:12	13:24	ROV station	44	Varangerfjord	Observed plate haul 355 mid gear. Turbidity lower. Successful inspection
29.11.2008	13:42	14:43	ROV station	45	Varangerfjord	Attempt to observe rockhopper haul 362. Turbidity still too high
29.11.2008	17:30	19:44	ROV station	46	Varangerfjord	Observed rockhopper st.nr. 362. Groundgear tracks easy to follow. Doors had been jumping
29.11.2008	20:26	21:04	CTD/turbidity	551	Varangerfjord	Base line CTD and turbidity measurements inside towing area
29.11.2008	21:13		Grab station	74	Varangerfjord	Grab sample at trawl path st.nr 355
29.11.2008	21:45		Grab station	75	Varangerfjord	Grab sample at trawl path st.nr. 362
29.11.2008	22:41	23:13	Trawl haul	363	Varangerfjord	Second impact haul with rockhopper gear. 690 m wire, 3 knots
29.11.2008	23:56	00:30	CTD/turbidity	552	Varangerfjord	CTD and turbidity measurements above trawl track 363 45 minutes after hauling
30.11.2008	01:01	01:33	CTD/turbidity	553	Varangerfjord	CTD and turbidity measurements above trawl track 363 one hour later
30.11.2008	02:03	02:35	CTD/turbidity	554	Varangerfjord	CTD and turbidity measurements above trawl track 363 one hour later
30.11.2008	03:59	04:36	CTD/turbidity	47	Varangerfjord	CTD and turbidity measurements above trawl track 363 two hours later
30.11.2008	10:17	10:22	ROV station		Varangerfjord	Observed rockhopper st.nr. 363. Groundgear tracks easy to see and follow. Doors had been jumping
30.11.2008	10:51	11:31	CTD/turbidity	556	Varangerfjord	CTD and turbidity measurements above trawl track 363. Latest measurement.
30.11.2008	12:26	12:56	Trawl haul	364	Varangerfjord	Impact trawl haul with plate gear and light doors. To replace haul 355 where sweeps were shot 100 m too long.
30.11.2008	13:39	14:19	CTD/turbidity	557	Varangerfjord	CTD and turbidity measurements above trawl track 364 45 minutes after hauling

30.11.2008	14:45	15:30	CTD/turbidity	558	Varangerfjord	CTD and turbidity measurements above trawl track 364 one hour later
30.11.2008	15:46	16:24	CTD/turbidity	559	Varangerfjord	CTD and turbidity measurements above trawl track 364 one hour later
30.11.2008	17:51	18:44	CTD/turbidity	560	Varangerfjord	CTD and turbidity measurements above trawl track 364 two hours later
30.11.2008	19:48	22:21	ROV station	48	Varangerfjord	Observed plate haule st.nr. 364. No door tracks.Probably lifted
30.11.2008	22:47	23:23	CTD/turbidity	561	Varangerfjord	CTD and turbidity measurements above trawl track 364. Last measurement
30.11.2008	23:27		Grabb	76	Varangerfjord	Grab at st.nr. 364
30.11.2008	23:53		Grabb	77	Varangerfjord	Grab at st.nr. 363
01.12.2008	07:5|	09:36	Trawl haul	365	Persfjorden	Haul with plate gear on shallower (130 m) and harder bottom. Plates on gear sliding on wire. Focus observation and observation with RS camera. Very nice shots.
01.12.2008	08:00	09:20	FOCUS		Persfjorden	Observed plate gear with sliding plates during towing on hard bottom. Event not recorded in ref file
01.12.2008	11_12	11:50	Trawl haul	366	Persfjorden	Haul with plate gear. Changed angle of attack by moving attachment point one "hole". Changing wire length to demonstrate door angle and bottom contact. Observation with two RS cameras (not FOCUS)

Annex 2. Engineering measurements

Measurements plate gear trawl

Depth	Depth Pb D	Depth Sb D	Door dist	Warp Pb	Warp Sb	Tilt 4R	Tilt 4P	Speed	Tens P	Tens St	Header height	Time	Door/ bott dist	Avr speed	Avr warp lgth	Avr door/ bott dist	Avr door dist	Avr header height	Avr tilt4R	Avr tilt4 P
m	**m**	**m**	**m**	**m**	**m**	**deg**	**deg**	**knots**	**tons**	**tons**	**m**		**m**	**knot**	**m**	**m**	**m**	**m**	**deg**	**deg**
warp length 660 m																				
227	208	207	123	662	665	60	14	3.3	5.8	5.9	5.8	-	19.5	3.32	660.4	20.4	123.2	5.96	11.8	17.8
226	203	202	124	658	661	43	13	3.3	6.9	6.9	6	-	23.5							
220	205	203	123	658	662	-19	34	3.3	7	6.8	6	-	16							
227	204	200	123	658	662	48	14	3.4	7	6.9	6	-	25							
226	208	208	123	661	657	-73	14	3.3	6.9	6.8	6	-	18							
reduce speed																				
224	222	220	127	659	655	43	36	3.1	6.1	6.3	4.2	-	3	3.04	657.5	0.3	124.8	4.2	60.6	28.8
223	221	222	124	656	658	44	36	3	6.4	5.9	4.2	23:06	1.5							
221	221	220	126	654	657	76	29	3.1	6.3	6.4	4.2	23:09	0.5							
219	221	219	125	658	658	75	26	3	6.3	6.3	4.2	23:11	-1							
215	215	220	122	658	662	65	17	3	6.1	6.1	4.2	23:14	-2.5							
reduce speed																				
215	217	215	129	659	662	46	35	2.9	6.3	5.3	4.2	23:17	-1	2.84	659.3	-6.2	122	4.1	62.6	20.2
214	215	214	121	657	660	69	18	2.8	5.5	5.7	3.6	23:23	-0.5							
208	214	210	119	655	658	67	17	2.8	5.7	5.7	4.2	23:26	-4							
202	213	211	120	659	662	64	17	2.8	5.6	5.4	4.3	23:30	-10							
190	207	204	121	659	662	67	14	2.9	4.6	5.4	4.2	23:34	-15.5							
Charging 2 sensors during 15 minutes,																				
Warp length : 600 m																				
220	212	212	122	600	608	71	16	2.8	4.6	5.3	4.2	01:02	8	2.66	598.2	4.7	114.4	4.32	44.4	15.2

221	216	218	108	585	603	71	16	2.5	5.3	5.4	4.3	01:07	4							
222	218	220	116	585	602	68	16	2.6	4.9	4.3	4.3	01:09	3							
224	218	221	114	596	603	-7	13	2.7	4.1	5.3	4.5	01:12	4.5							
225	220	222	112	597	603	19	15	2.7	4.4	5.5	4.3	01:15	4							
225	222	223	112	598	602	-73	13	2.9	5.5	5.6	4.5	01:19	2.5	2.9	601.4	3	115.4	4.34	43	13.2
225	222	223	116	600	603	71	15	2.9	4.8	5.7	4.3	01:21	2.5							
225	222	224	116	601	603	72	12	2.9	5.7	5.6	4.3	01:24	2							
226	223	223	117	600	603	72	14	2.9	5.8	5.7	4.3	01:26	3							
229	223	225	116	601	603	73	12	2.9	5.7	5.4	4.3	01:28	5							
229	222	225	116	601	602	74	13	2.9	5.8	5.8	4.3	01:30	5.5							
228	224	226	116	601	602	74	12	2.8	4.7	5.7	4.5	01:33	3							
Increase speed by 0.2 knots																				
218	222	225	116	602	604	66	16	3	6	5.6	4.3	01:41	-5.5	2.96	602.7	2.9	116.6	4.44	66.4	16.4
222	221	225	116	602	604	69	16	2.9	5.9	5.8	4.5	01:43	-1							
226	219	219	120	602	603	65	18	2.9	5.8	4.7	4.9	01:45	7							
226	215	220	110	601	604	71	13	3.1	5.9	4.9	4.2	01:47	8.5							
226	219	222	121	601	604	61	19	2.9	5.9	5.4	4.3	01:50	5.5							
Increase speed by 0.2 knots																				
228	204	212	119	600	605	15	15	3.3	5.7	5.7	6.1	01:56	20	3.32	600.6	27	121.4	6.06	36.6	20
227	196	201	122	597	603	39	16	3.5	6.8	6.8	6.1	01:59	28.5							
225	196	200	123	597	603	45	14	3.3	6.8	6.8	6.1	02:01	27							
225	195	197	122	597	603	40	21	3.3	6.8	6.8	6	02:03	29							
225	194	195	121	598	603	44	34	3.2	6.9	6.8	6	02:06	30.5							
Reduce speed by 0.1 knots as plate gear is flying																				
223	212	212	119	597	602	24	15	2.9	6.1	6.1	6.1	02:12	11	3.02	598.3	5.6	122.2	5.2	23.2	14.4
221	214	214	122	596	601	42	14	3	6.5	6.3	5.3	02:14	7							
220	217	216	123	596	600	33	14	3.1	6.4	6.4	5.1	02:16	3.5							
218	215	214	123	596	600	-34	14	3	6.3	6.3	4.9	02:18	3.5							
216	213	213	124	595	600	51	15	3.1	6.3	6.1	4.6	02:20	3							
217	211	212	124	595	599	51	16	3.1	5.9	6.3	4.8	02:23	5.5	3.1	597.5	8.7	126.2	4.7	39.2	23.8
214	209	210	135	595	600	14	36	3.1	6.3	6.4	4.6	02:26	4.5							

215	208	210	125	595	600	43	36	3.1	6.3	6.3	4.9	02:28	6							
217	208	210	124	595	600	43	16	3.1	6.4	6.3	4.6	02:31	8							
221	206	208	125	595	601	45	15	3.1	6.3	6.3	4.8	02:33	14							
221	206	208	124	595	600	45	15	3	6.4	6.2	4.5	02:35	14							
End of this tow																				
New warp length : 630 m																				
Start with low speed, 2.6 knots																				
221	215	215	116	625	635	59	-33	2.6	5.5	5.2	4.3	03:22	6	2.5	628.6	4	116.2	4.4	57.8	4.8
224	220	219	116	625	634	39	4	2.5	5.4	5.2	4.5	03:26	4.5							
225	221	219	116	624	633	61	19	2.5	5.2	4.8	4.4	03:28	5							
225	223	220	118	624	632	69	18	2.4	5.2	4.2	4.3	03:30	3.5							
224	224	222	115	624	630	61	16	2.5	5.1	4.1	4.5	03:32	1							
Speed increase of 0.2 knots																				
227	224	221	117	628	633	66	15	2.9	5.7	4.7	4.2	03:39	4.5	2.82	632.1	2.4	121.2	4.16	61.8	20.4
228	225	222	120	629	634	66	15	2.8	5	5.8	4	03:41	4.5							
225	225	223	121	631	634	63	15	2.8	6	5	4	03:43	1							
226	226	225	127	631	635	46	23	2.7	5.8	5	4.3	03:45	0.5							
227	226	225	121	631	635	68	34	2.9	5.9	6	4.3	03:47	1.5							
Speed increase of 0.2 knots at 3:49																				
219	223	221	127	628	632	43	13	3	6.2	5.4	4.6	03:53	-3	3.02	630.2	3.3	124.8	4.32	10.8	13.8
219	222	221	126	627	633	45	13	3.1	6.1	6.1	4.5	03:55	-2.5							
226	222	222	125	628	633	-28	14	3	5.6	6.2	4.3	03:57	4							
227	219	219	126	628	633	-76	14	3	6.2	6	4.2	03:59	8							
226	215	217	120	628	632	70	15	3	6	6.1	4	04:01	10							
Speed increase of 0.1 knot																				
228	219	218	124	628	635	11	14	3.1	5.3	5.4	4.8	04:06	9.5	3.1	631.7	8	122.8	5.04	14	14.6
226	216	216	123	628	636	-14	16	3.1	6.4	6.2	5.3	04:08	10							
225	218	217	122	628	636	-14	15	3.1	6.5	6.3	5.1	04:10	7.5							
225	219	219	122	628	635	44	14	3.1	6.5	6.3	5.1	04:12	6							
225	218	218	123	628	635	43	14	3.1	6.4	6.4	4.9	04:14	7							
	door behavirour unstable for this speed (scanmar display)																			

Speed increase of 0.1 knot																				
225	211	209	119	631	635	58	35	3.3	6.8	6.6	5.8	04:21	15	3.22	633.1	13.1	119.4	5.94	32.2	23.2
223	210	209	120	632	635	43	34	3.2	6.6	6.6	6	04:23	13.5							
222	210	209	119	632	635	65	15	3.2	5.7	6.6	6.1	04:25	12.5							
221	210	208	119	632	635	2	15	3.2	6.8	6.7	6	04:27	12							
221	210	207	120	631	633	-7	17	3.2	6.6	6.6	5.8	04:29	12.5							
modification of the chains pour door contact sensors																				
Warp length 570 m																				
213	207	210	120	566	572	44	15	2.8	4.9	5.1	4.6	06:03	4.5	2.9	570.1	8.3	120.2	4.6	15.7	12.7
216	207	209	121	567	573	44	12	2.9	5.9	5.9	4.5	06:05	8							
219	207	208	121	567	573	44	15	2.9	5.9	5.8	4.3	06:06	11.5							
219	208	207	121	567	573	-7	14	2.9	5.8	5.9	4.6	06:08	11.5							
212	210	210	119	567	574	-90	-20	2.9	5.9	5.9	4.9	06:12	2							
222	210	210	119	568	574	59	40	2.9	4.9	5.1	4.9	06:15	12							
Fish very light																				
increase speed to 3 knts																				
224	202	201	118	568	574	42	37	3.1	6.4	6.4	6.3	06:20								
225	218	217	117	568	575	-44	14	2.9	5.7	5.7	4.8	06:27								
226	221	221	117	567	574	42	14	2.7	5.4	5.5	4.6	06:29								

Measurements rockhopper trawl

Depth	Door depth Port	Door depth STB	Speed	Tens Pt	Tens Stb	Door Spread	Warp Pt	Warp Stb	Tilt Port	Tilt Stb	Headline height	Backstrop tens Pt	Backstrop Tens Stb	Time UTC	
213	207	205	2.9	5.1	5.3	128	601.3	603.7	-3.18	1.22	5.1		3.6	1740	
215	208	206	3.1	6	5.9	132	601.3	603.3	-4.18	0.21	4.6		3.5	1743	
215	212	209	2.4	5.3	6	131	600.9	603.3	-4.16	-2.19	4.2		3.6	1746	
215	215	212	2.9	5.5	5.4	128	600.6	602.9	-4.15	-1.16	3.9		3.2	1748	
217	215	213	2.8	5.6	5	133	599.4	600.6	-3.14	0.16	4		3.3	1750	
220	214	213	3	5.6	5.2	134	598.6	601.3	-4.15	-1.17	4		3.3	1755	**Note shot more wire-660**
220	221	218	3	5.9	5	134	660	663	-5.13	-1.14	3.9		3.8	1806	
220	220	218	3.1	5.8	45.7	140	660	663	-6.14	-3.16	3.9		3.7	1809	
218	219	219	3.3	6	5.5	137	659	663	-6.13	-2.16	3.8		3.8	1814	
220	219	222	3.2	5	5	135	659	664	-6.14	-2.16	3.9		3.9	1816	
224	218	213	3.1	6.1	5.5	133	660	663	-5.13	-1.16	3.8		3.9	1820	
217	223	223	2.9	3.8	3.6	132	655	661	-3.14	1.15	4.3		3.3	1827	**Changed speed to 2.8kts**
219	224	221	2.8	4.8	4.4	125	658	657	4.14	6.13	4.3		2.9	1831	
224	221	217	2.9	4.9	5	132	658	657	-2.14	3.13	4.3		3.2	1833	
224	216	215	3	4.7	5	117	658	659	1.14	2.14	4.2		3.2	1836	
221	225	221	2.8	4.9	5.2	137	657	661	1.13	0.13	3.8		3.3	1846	
223	223	218	2.9	4.6	5.5	136	655	661	1.14	4.13	4.2		3.7	1850	
227	226	226	2.9	5.2	4.8	133	659	663	-4.14	1.16	3.9		3.1	1919	**Note Changed direction**
226	226	228	3	5.9	5.1	133	660	664	-4.15	-2.16	3.9		3.6	1921	
222	225	226	3	5.9	5.3	135	660	664	-5.13	-2.16	3.9		3.7	1924	
219	223	227	3	5.6	5.4	133	660	665	-4.13	0.16	3.9		3.6	1926	
225	224	226	2.9	5.9	5.9	133	660	664	-4.13	-2.16	4		3.4	1929	
228	218	220	3.2	6.1	5.5	135	660	664	-5.14	-4.13	4.9		4.4	1933	**Changed speed to 3.2kts**
229	214	216	3.1	6.2	6.2	130	657	664	-3.17	-4.17	5.3		4.2	1935	
230	212	210	3.2	5.5	5.8	128	656	662	-2.18	1.2	6.3		4.3	1940	
226	209	211	3.3	6.7	5.6	128	656	663	-2.19	3.21	6.3		4.2	1945	

225	213	215	3.3	6.7	6.4	125	656	662	-1.19	1.19	6.3		4.1	1947	
225	223	226	2.7	4.9	5.4	127	656	662	5.15	8.16	3.9		3.1	1951	**Speed 2.8kts**
224	224	226	2.7	4.7	5	132	656	661	2.15	6.16	4		3.1	1953	
222	224	225	2.6	5.1	5.1	132	655	660	7.14	11.15	4.2		3.1	1955	
221	224	225	2.7	5	4.5	130	656	660	5.13	7.15	4		3.1	1957	
218	222	224	2.9	4.3	4.4	133	656	661	2.14	7.16	4		3.3	1959	
224	223	224	3	5.5	5.2	134	650	656	-4.15	-1.17	4	n/a		2153	**Change direction and move tension shackle to stb side**
216	222	224	3	5.6	5.1	134	647	652	-5.15	-3.16	4	n/a		2158	
223	220	225	2.9	5.5	5.5	133	647	651	2.16	1.16	4.2			2202	
223	212	215	3	5.4	5.6	130	648	649	-2.14	2.15	3.9			2206	
223	221	24	3	6.1	6.1	129	648	649	-4.14	0.16	4			2211	
224	220	223	2.7	5.6	5.4	131	656	660	0.15	3.15	3.9			2216	**Shot 10m more wire**
224	222	226	2.8	5.4	5.7	128	656	658	2.14	5.15	4			2220	
225	221	224	2.8	5	5.2	129	655	660	3.15	2.16	4			2224	
220	218	215	3.2	6.2	5.6	130	658	660	-6.13	1.15	5.1			2250	**Changed direction**
223	217	214	3.2	5.9	5.4	131	657	659	-4.14	0.16	4.2			2252	
222	221	219	2.8	5.9	5.9	132	655	658	0.14	1.15	3.9			2257	
215	222	221	2.9	5.6	5.5	127	654	657	-1.14	4.15	4			2300	
225	218	220	2.7	4.9	5.8	131	660	661	1.14	14.14	4			2303	
225	217	219	2.9	5.7	5.1	129	658	661	0.12	2.13	3.8			2308	
226	223	223	2.7	5.4	5.3	128	657	659	6.12	9.14	4.3			2313	**Change Speed to 2.8kts**
222	225	226	2.7	5.1	4.9	124	656	658	3.13	7.15	4.2				
225	225	227	2.9	6.1	6	132	644	653	0.15	2.16	4.2			2355	**Haul turn and shoot reduce warp by 10m**
218	224	225	2.9	6	6	131	643	653	-2.15	2.16	4			2400	
220	224	225	2.9	5.1	5.8	130	643	652	-2.15	0.16	3.9			00:03	
226	219	222	3	8.7	8.3	133	662	640	-10.13	-7.12	3.8			00:06	**Shorten warp by 5m**
226	221	221	3	5.7	5.2	126	662	645	-1.15	-1.16	3.8			00:10	
226	224	225	3.1	5.6	5.6	132	644	649	-4.17	-3.17	4.3			00:14	

225	222	226	3	6.1	6	134	644	649	-4.15	-3.17	3.9	00:19	
224	221	226	3	5.3	5.9	133	635	643	-2.15	-2.16	3.6	00:25	**Shorten warp by 5m**
222	220	223	2.9	5.3	6.1	126	636	644	-2.16	-2.17	9.4	00:28	
218	220	223	3	5.3	5.5	134	636	644	-4.15	-2.17	4	00:31	
218	219	224	2.8	5.5	5.4	133	635	642	2.16	4.16	4	00:34	
217	215	221	2.9	5.7	5.7	132	634	641	2.16	4.17	4.2	00:36	**Start to lift from bottom**
215	217	219	2.9	5.6	5.4	127	625	641	-1.15	1.16	3.6	00:39	**Haul turn**

Annex 3. Benthos

PORIFERA (Sponges)

Pseudosuberites sp.

ANTHOZOA (Corals)

Octocoralls: *Capnella glomerata*

POLYCHAETA

Harmothoe sp.

Nepthys sp. (longisetosus?)

POLYCHAETA

Tubes of *Spiochaetoperus typicus*

Spiochaetoperus typicus

Ampelisca sp.

AMPHIPODA (order)

EUPHAUSIIDAE (family)

Meganyctiphanes norvegica

NATANTIA (suborder)

Pandalus borealis

BIVALVIA

Arctinula greenlandica

Two species of *Bivalvia*. The upper is *Cardium sp*. The lower is most possibel *Portlandia arctica.*

GASTROPODA (snails)

HOLOTHUROIDEA

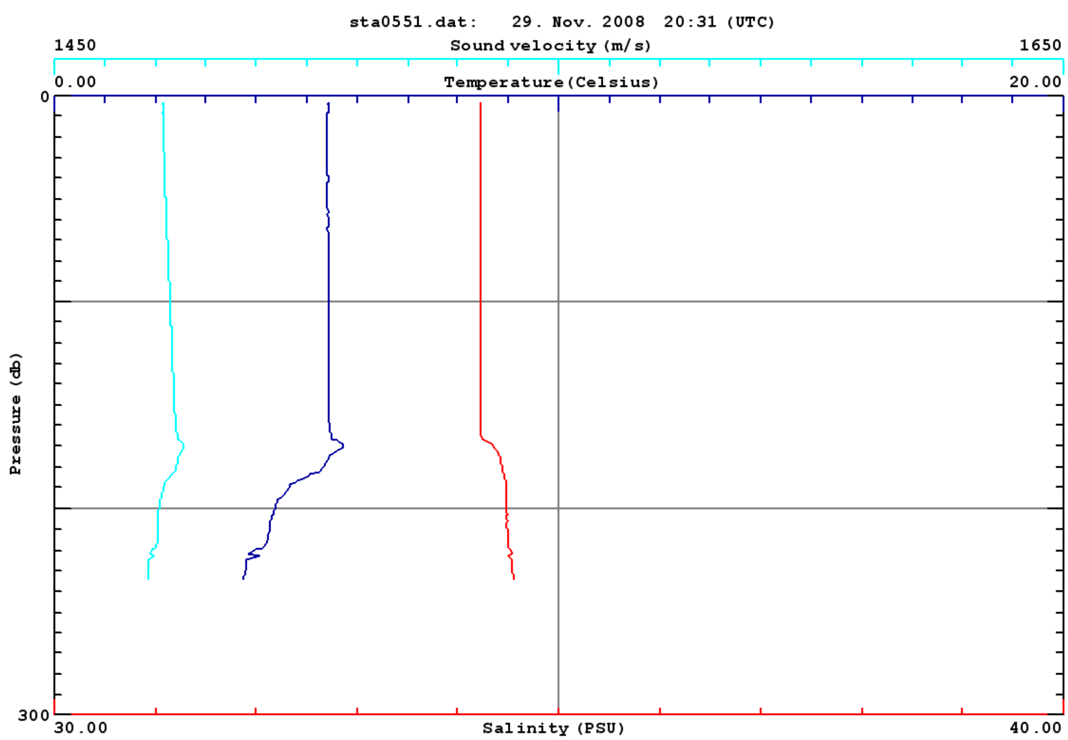
OPHIUROIDEA

Ophiura sp.

Annex 4. CTD data

Background measurement

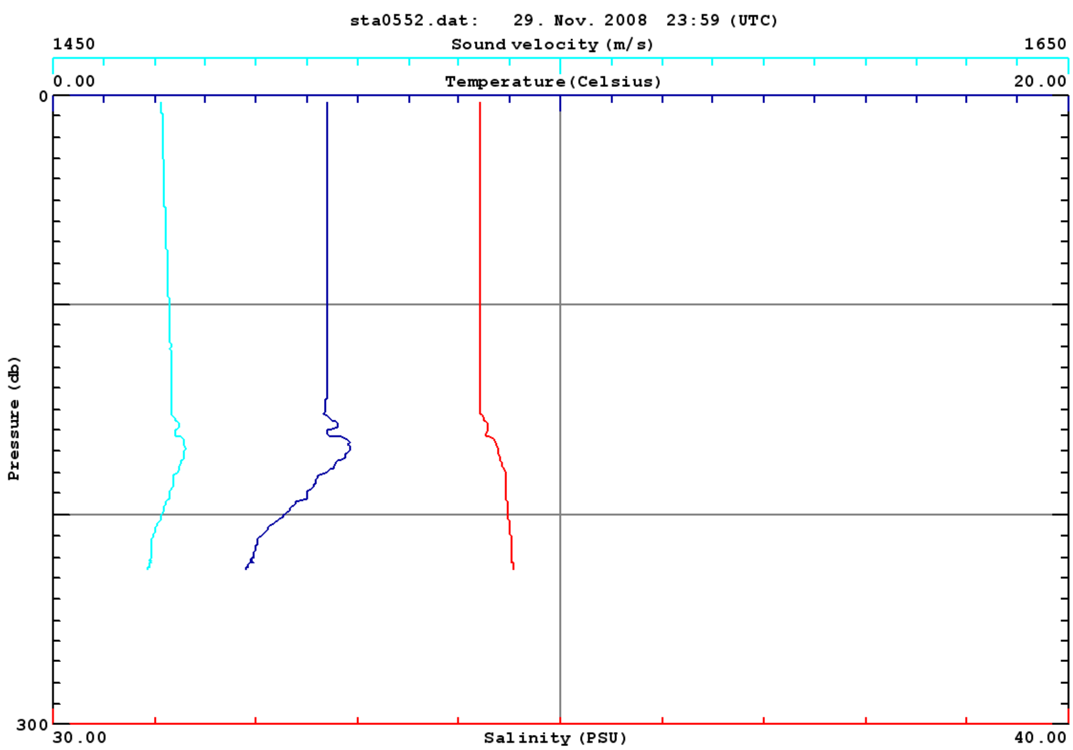
In experiment area before trawling
CTD Station: 0551
System UpLoad Time = Nov 29 2008 20:31:37
NMEA Latitude = 70 02.32 N
NMEA Longitude = 029 37.55 E
NMEA UTC (Time) = 20:31:32
Echodepth: 231
Wind-Dir/Force: 21 05
Air-Temp (dry): -5.7
Weather Sky: 4 4



Haul 363 (Rockhopper trawl)

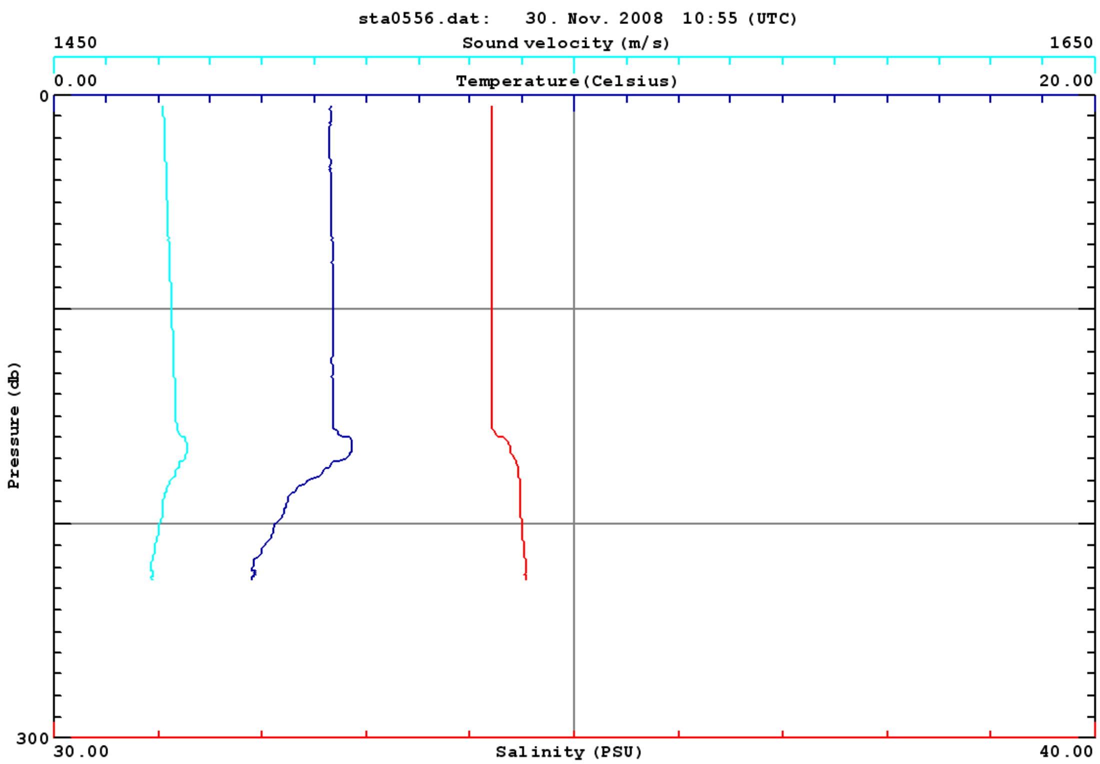
At trawl path of haul 363 45 min after trawling

- System UpLoad Time = Nov 29 2008 23:59:09
- NMEA Latitude = 70 02.74 N
- NMEA Longitude = 029 34.78 E
- NMEA UTC (Time) = 23:59:04
- Station: 0552
- Echodepth: 230
- Log: 2187.481
- Wind-Dir/Force: 21 07
- Air-Temp (dry): -8.3
- Weather Sky: 4 4



At trawl path of haul 363 12 h after trawling

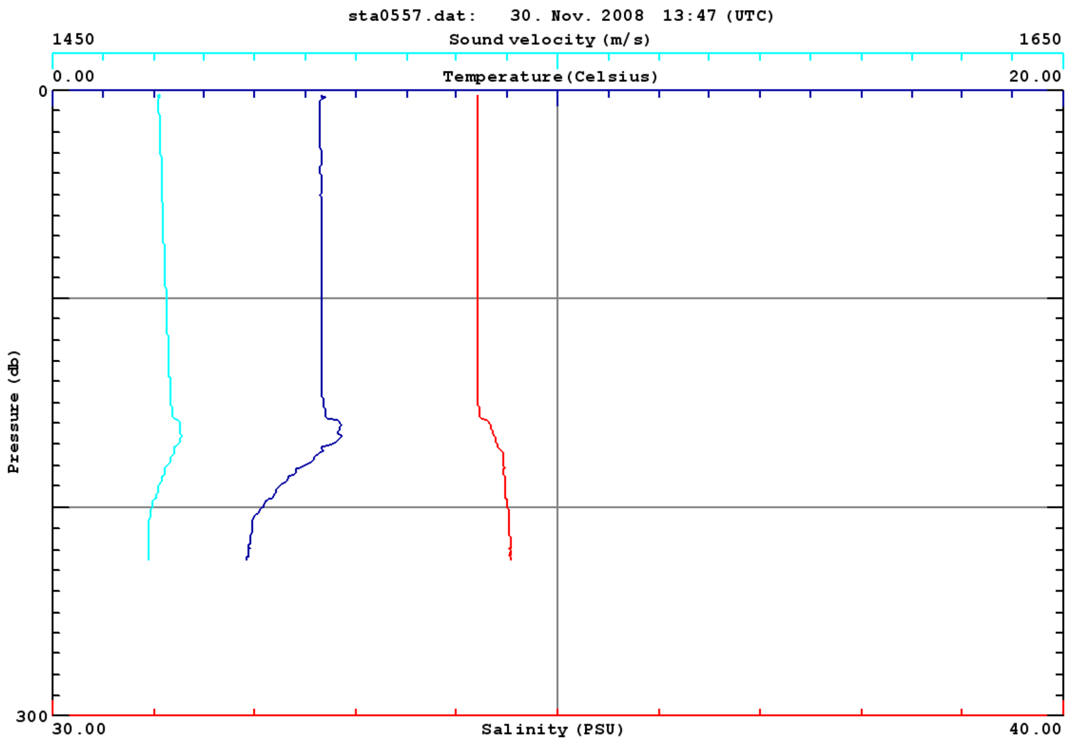
- System UpLoad Time = Nov 30 2008 10:55:16
- NMEA Latitude = 70 02.74 N
- NMEA Longitude = 029 34.79 E
- NMEA UTC (Time) = 10:55:11
- Station: 0556
- Echodepth: 230
- Log: 2190.579
- Wind-Dir/Force: 22 13
- Air-Temp (dry): -6.3
- Weather Sky: 4 4



Haul 364 (plate gear trawl)

At trawl path of haul 364 45 min after trawling

- System UpLoad Time = Nov 30 2008 13:47:57
- NMEA Latitude = 70 02.83 N
- NMEA Longitude = 029 34.97 E
- NMEA UTC (Time) = 13:47:52
- Station: 0557
- Echodepth: 230
- Log: 2198.772
- Wind-Dir/Force: 14 07
- Air-Temp (dry): -4.6
- Weather Sky: 4



At trawl path of haul 364 12 h after trawling

- System UpLoad Time = Nov 30 2008 22:51:45
- NMEA Latitude = 70 02.83 N
- NMEA Longitude = 029 34.97 E
- NMEA UTC (Time) = 22:51:40
- Station: 0561
- Echodepth: 230
- Log: 2205.210
- Wind-Dir/Force: 14 24
- Air-Temp (dry): -1.5
- Weather Sky: 4 4