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Report

New active fishing gear

Function tests of new Y-design trawl

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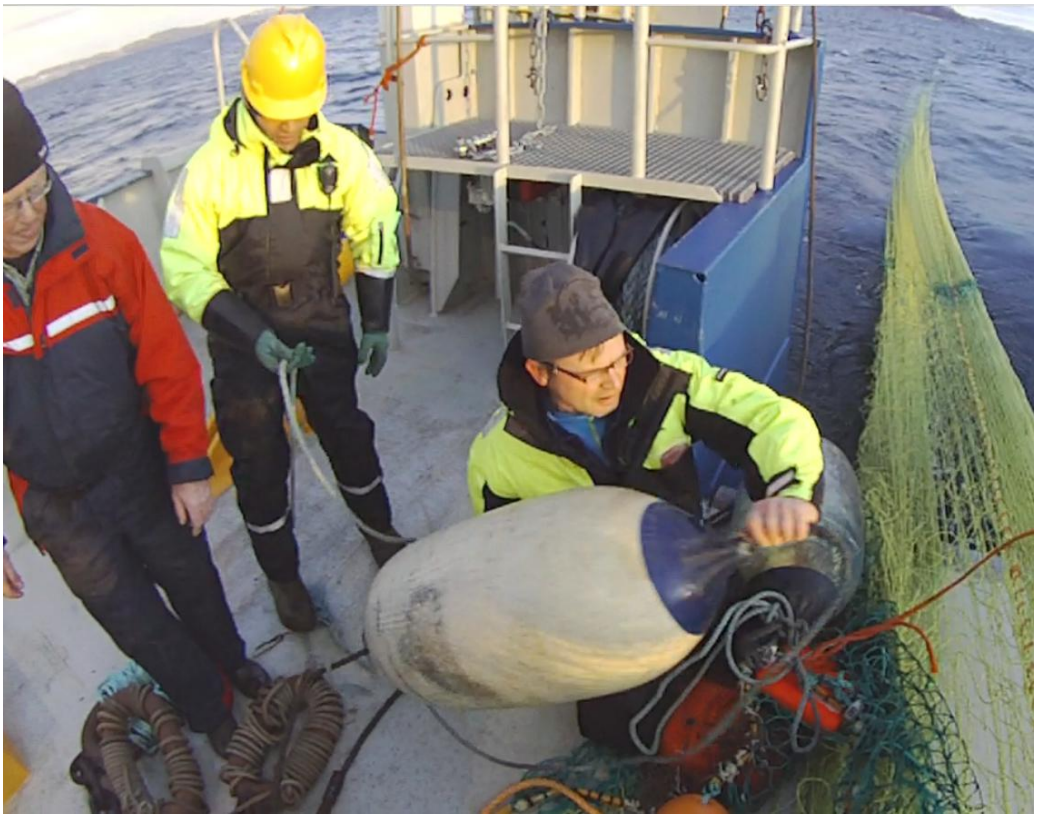

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ABSTRACT

Function tests at sea of an Y-design trawl (scale 1:1.75) were performed on board the research vessel Gunnerus and the Danish seiner Nordnes (December 05-09, 2012).

The Y-design trawl was operated as pelagic trawl and semi-pelagic trawl, at towing speeds that varied between 2.0 and 4.6 knops.

Measurements of distance between doors, distance between wings, height of headline, bottom contact, and tension per warp, were performed by using electronic sensors.

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APPENDICES

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1 Introduction

This report summarizes the proposed full-scale trials in autumn 2011 in the project “New active fishing gear” which is being financed by the Research Council of Norway (NFR) and the Fisheries and aquaculture industrial research fund (FHF).

Based on the proposed test matrix (Winter and Gjøsund, 2010) and model tests performed in the Flume tank at Hirtshals, Denmark in autumn 2011 (Hansen, 2011), the concept based on the Y-design (see 1.1 for details) was the most interesting to test at sea. The aim was to conduct controlled sea trials on board the R/V "Gunnerus" in a well known area (in relation to bottom type, depths, obstacles, etc) close to Trondheim - Norway. We envisaged 1-2 weeks from September - mid October, and possibly in mid-November to December. "Gunnerus" is a vessel with strong enough engine power (1000kW) to operate a full scale trawl as those tested in Hirtshals. However, Gunnerus lacks strong enough winches, and therefore it seemed most appropriate to build a trawl in scale 1:2 in relation to the dimensions of the net as pelagic trawl for a large trawler. It was in addition pointed that the trawl could also be tested as a seine by a small commercial seine vessel.

The priority was to test the Y-design trawl as pelagic and semi-pelagic trawl, and if possible as seine, but it would depend on it is technical and time-feasibility.

The skipper Tormund Grimstad (Nordnes AS), Bjørnar Isaksen (HI) and Jan Tore Øvredal (HI) were involved in the planning and implementation of the experiments.

1.1 Full scale Y-design trawl

The Y-design trawl is a net with four selvedges. The four selvedge lines however have a special configuration. The special feature of this principle is that the designer can control the degree of mesh opening in a larger part of the net compared to a net of conventional design.

It can be seen from the sketch in appendix 1 (A1) that one selvedge begins in the centre of the headline and joins two mirrored net panels into an upper panel. In the same way a selvedge starts in the centre of the fishing line and joins two mirror pieces into a lower panel. The netting along these two centre selvedges are cut to add meshes to the sections. It is then possible to use a steeper cut at the outer edges of the panels. The black lines in the net plan in appendix 1 (A1) show the line of bars which divides the net into areas where the degree of mesh opening can be controlled by the designer and areas in the netting where the degree of mesh opening is given by the equilibrium between water flow and tension in the netting in a given position.

The degree of mesh opening in the central part of the net limited by the two black lines running from the wing tips is always governed by the distances the netting is hung to the headline or the fishing line. The degree of opening of the meshes between this line and the line starting where the breasts meet the outer selvedge is controlled by the difference in length of the upper and lower bridle. This is due to the nature of the distribution of tension in a piece of netting.

The full stretched circumference of the net is 280 m at the fishing circle. The length of the headline and the fishing line is 163 m. The mesh sizes given in the net plan is full mesh size.

2 Objective

The objective of this series of tests at sea was to perform function and geometry measurements of a Y-design trawl (scale 1:1.75) operated as pelagic trawl, and as semi-pelagic trawl.

3 Materials and Methods

3.1 Tests on board R/V Gunnerus

Part of the experiments was performed on board the R/V Gunnerus (Fig 1) between 02-08December, 2012. R/V *Gunnerus* is equipped with the latest technology for a variety of research activities within biology, technology, geology, archeology, and oceanography and fisheries research. This vessel is 31.25 m LOA, 9.90 m B, and is powered by a 1000 kW diesel electric engine (Siemens 2 x 500 kW). Deck equipment is compose by two Mjosund 6 ton trawl winches (wire D=14 mm, L=1000 m), a Mjosund 5 m^3 net drum, D=2000mm, d=320mm, and a 14 m Palfinger deck crane.

Fig 1. R/V Gunnerus starboard side view. (Photo: Fredrik Skoglund)

3.1.1 Small scale model of Y-design trawl and its rigging

During this series of tests we used a Y-design trawl in scale 1:1.75 (see Appendix A and B for details). However, the mesh sizes and the twine diameters were not scaled down! The rigging of the trawl was composed by two 3.5m^2 Egersund pelagic trawl doors (~10.7 m^2 in full scale) and 60 m long bridles (~105m long in full scale).

Scaling ratio was as follows:

- The linear scale ratio of models: 1:1.75
- The speed scale ratio: 1:1.32
- The area scale ratio: 1:3.06
- The force scale ratio: 1:5.35

3.1.2 Electronic equipment:

We used a combination of Scanmar and Simrad sensors to monitor the geometry and configuration of the net while towing. Table 1 shows a specific list of the sensors used during the trials. Fig 2 shows the position of the sensors in the Y-design trawl.

Table 1: Electronic equipment used onboard R/V Gunnerus.

Sensor	Owner	Number	Placement	Main purpose	Comments
Door distance sensor (with depth) SCANMAR	HI	2	Trawl doors Wings	Measure distance and depth at the doors and wings.	These will be alternated between door/wing distance/depth measurements.
Door distance sensor SCANMAR	Gunnerus	2	Trawl doors Wings	Measure distance between doors and wings.	These will be alternated between door/wing distance measurements.
Bottom contact sensor SCANMAR	HI	2	Bottom gear	Measure bottom contact.	
Bottom contact sensor StarOddi	SINTEF	6	Bottom gear	Measure bottom contact.	
Speed sensor SCANMAR	HI	1	Headline	Measure the actual speed of the trawl in the water.	
Trawl eye SCANMAR	HI	1	Headline	Measure the vertical opening of the net at 2-3 positions	
Height sensor SCANMAR	Gunnerus	1	Headline	Measure the vertical opening of the net at 2-3 positions	
12 ton shackles SCANMAR	HI	1	Trawl doors	Measure stretch behind the doors	
10 ton shackles STRAINSTALL	SINTEF	2	Warps	Measure stretch in warps	
Transducer	HI	1	On the side of the vessels		
Control unit	HI	1	Wheel house		

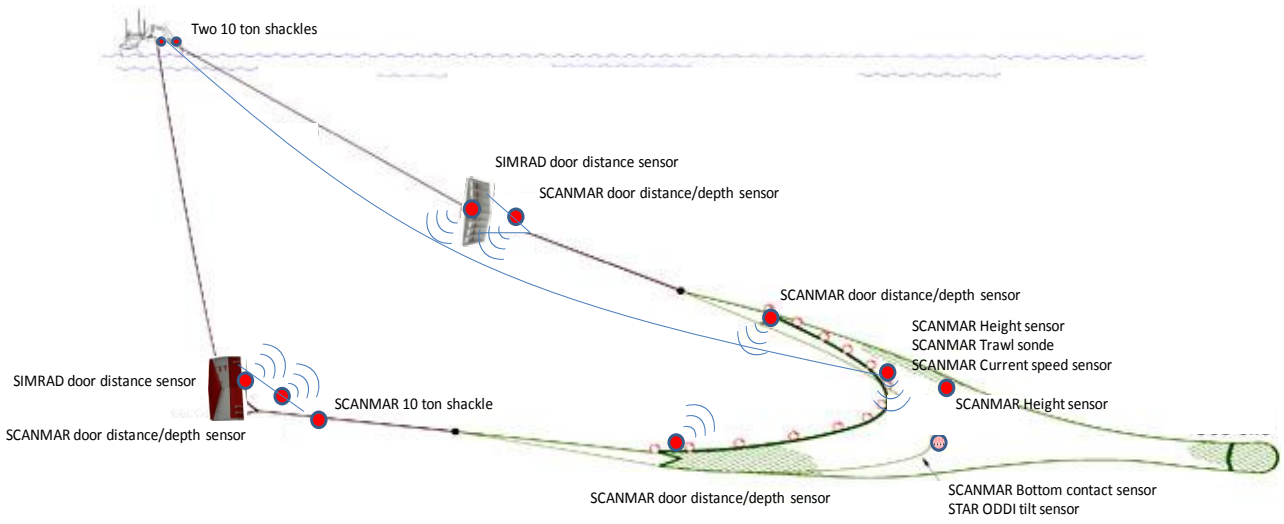


Fig 2. Position of the sensors in the Y-design trawl.

Star Oddi bottom contact sensors

We used a "Star Oddi tilt sensor" fixed to a specially designed aluminum frame to measure bottom contact. The aluminum frame had an 80 cm bar (3 cm diameter) that was attached to the center of the fishing line in a way that it hung from it while towing. When the fishing line of the trawl was close (< 1 m) to the seabed, the hanging bar came into contact with the sea floor and its orientation started changing from vertical/hanging (0°) to fully horizontal (90°). Because the aluminum bar hung from the fishing line and a 60 cm skirt was attached on it, bottom contact would be achieved before the position of the bar was fully horizontal (see appendix D for details).

The "Star Oddi tilt sensor" is capable of measuring 360° orientation changes in 3 axes, although for the present measurements only the changes in one of the axis (X-axis) were considered. Angles different from 0° registered by the sensor indicated in principle that the aluminum bar was in contact with the seabed (low angle values < 20° could also be expected due to towing speed specially at high speeds). However, because the total length of the aluminum bar hanging from the fishing line is 1 m and the 60 cm skirt is hanging from the fishing line certain considerations need to be made. Depending on the angle of the skirt with respect to the fishing line, bottom contact will be achieved at different angle values registered by the "Star Oddi tilt sensor". The higher the angle of the skirt with respect to the fishing line, the higher the angle needed in the aluminum bar to achieve bottom contact.

The results from the "Star Oddi tilt sensor" indicated the periods at which the trawl was in contact with the seabed. During the trials, the working angle of the skirt with respect to the fishing line was not registered and therefore it is difficult to interpret when exactly the skirt touched the seabed. However, when the Star Oddi tilt sensor showed an increase in the angle it suggests that the skirt was very close to the bottom. The results from the sensor show that during test 3 and 4 the trawl was fishing semi-pelagic; either in contact or very close to the seabed (see appendix E for details). These results are in agreement with those observed from the Scanmar bottom contact sensor during the trials.

3.1.3 Participants

Table 2 shows the list of participants during the cruice on board the R/V Gunnerus.

Table 2: List of participants during the cruise on board the R/V Gunnerus.

Name	Institution	05.Dec	06.Dec	07.Dec	08.Dec
Eduardo Grimaldo	SINTEF	x	x	x	x
Manu Sistiaga	SINTEF	x	x	x	x
Bjørnar Isaksen	HI		x	x	x
Jan Tore Øvredal	HI		x	x	x
Tormund Grimstad	Nordnes AS		x	x	x
Svein Helge Gjøsund	SINTEF		x	x	x
Barry O'Neil	Marine Scotland		x	x	
Jarle Mork	NTNU		x		

3.1.4 Testing area

The area chosen for the tests 1-4 are shown in Fig. 3. These areas were suggested by the skipper of R/V Gunnerus. The criteria for choosing these areas was based on the skipper's experienced and the knowledge gained from earlier experiments in the area.

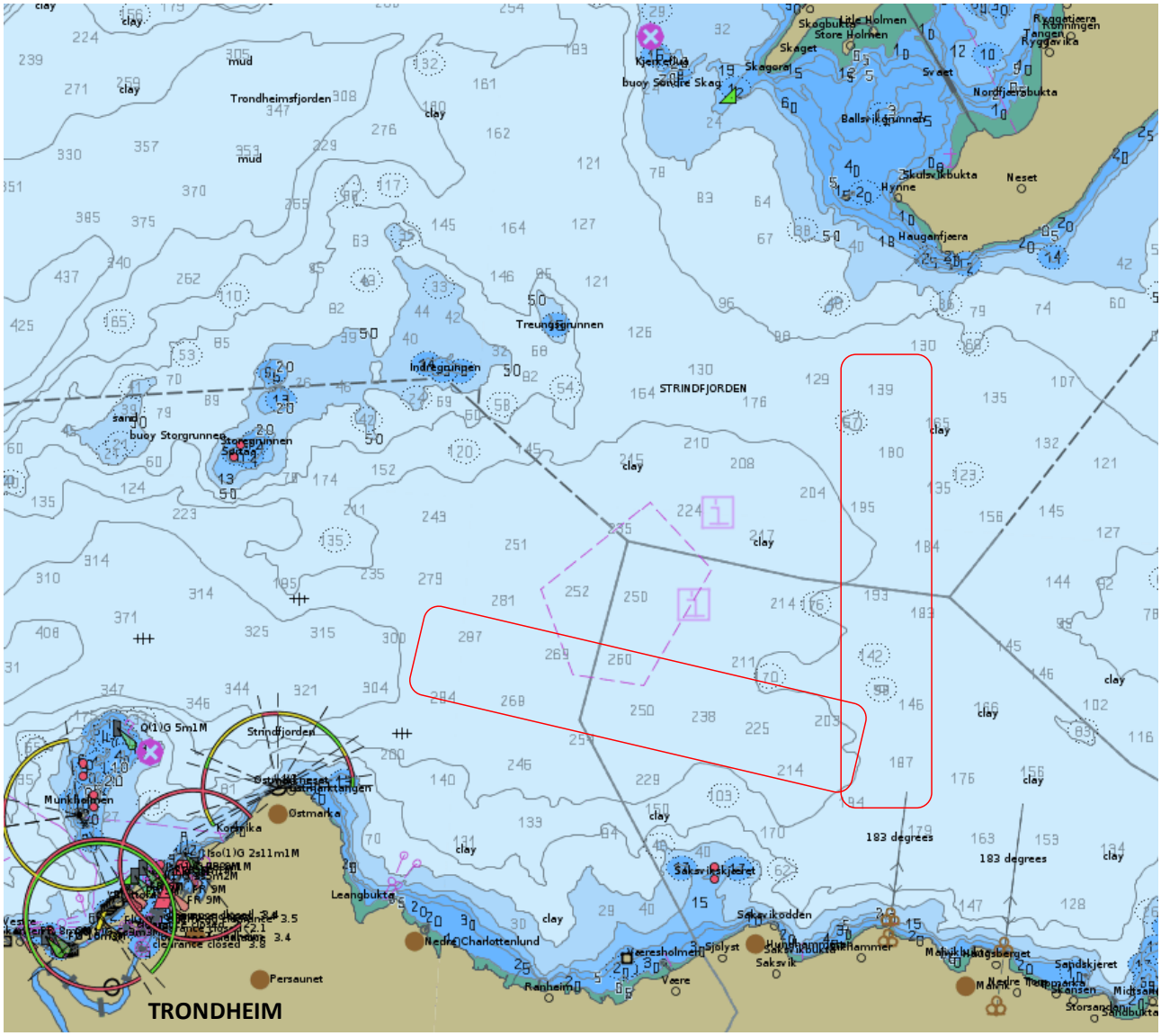


Fig 3. Area (red boxes) in which test 1-4 were performed.

3.1.5 Trial setup

The plan for the sea trials include four tests (Test 1-4) with the net operated as a pelagic trawl and a semi-pelagic trawl. During these tests, the towing speed will vary between 2.0 - 4.5 knots; the length of the setback was set at 1.75m, 3.5m and 5.3m; and the weight of the clumps that were attached to the lower bridle were 535 and 803kg. Tables 3-6 give an overview of the setup used in the four different tests.

Table 3:

Test 1 Pelagic trawl 3.5m setback 535 kg clump per wing							
Measurements	**Sensor**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**
Towing speed	Speed sensor						
Distance between the doors	Door distance/depth sensor						
Distance between the doors/ depth of doors	Door distance/depth sensor						
Distance between wings	Distance sensor						
Height of the headline	Trawl eye						
Tension behind the doors	Shackle						
Tension starboard warp	Shackle (S)						
Tension port warp	Shackle (P)						
Water speed	Speed sensor						

Table 4:

Test 2 Pelagic trawl 5.3m setback 803kg clump per wing							
Measurements	**Sensor**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**
Towing speed	Speed sensor						
Distance between the doors	Door distance/depth sensor						
Distance between the doors/ depth	Door distance/depth sensor						
Distance between wings	Distance sensor						
Height of the headline	Trawl eye						
Tension behind the doors	Shackle						
Tension starboard warp	Shackle (S)						
Tension port warp	Shackle (P)						
Water speed	Speed sensor						

Table 5:

Test 3 Semi-pelagic trawl 3.5m setback 535 kg clump per wing							
Measurements	**Sensor**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**
Towing speed	Speed sensor						
Distance between the doors	Door distance/depth sensor						
Distance between the doors /depth of doors	Door distance/depth sensor						
Distance between wings /depth of wings	Distance sensor						
Bottom contact fishing line	Star Oddi sensor						
Bottom contact fishing line	Bottom contact sensor						
Height of fishing line	Trawl eye 1						
Tension behind the doors	Shackle						
Tension starboard warp (S)	Shackle (S)						
Tension port warp (P)	Shackle (P)						
Water speed	Speed sensor						

Table 6:

Test 4 Semi-pelagic trawl 1.75m setback 803 kg clump per wing							
Measurements	**Sensor**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**
Towing speed	Speed sensor						
Distance between the doors	Door distance/depth sensor						
Distance between the doors /depth of doors	Door distance/depth sensor						
Distance between wings /depth of wings	Distance sensor						
Bottom contact fishing line	Star Oddi sensor						
Bottom contact fishing line	Bottom contact sensor						
Height of fishing line	Trawl eye 1						
Tension behind the doors	Shackle						
Tension starboard warp (S)	Shackle (S)						
Tension port warp (P)	Shackle (P)						
Water speed	Speed sensor						

For each test, a series of 20-minute measurements were performed for each towing speed. Data from the SCANMAR sensors s were logged on a PC. In addition, manual registering of all SCANMAR and SIMRAD sensors was done with 5-minute intervals. Data from the 10 ton shackles were logged separately on a data logger.

3.2 Tests on board Danish seiner /trawler Nordnes

The Danish seiner/trawler Nordnes (Fig 5) was chartered on 09 December 2012 to perform similar function tests with the Y-design trawl to those performed by R/V Gunnerus. This vessel is 26.52 m LOA, 7.35 m B, and is powered by a 761 kW diesel engine (Caterpillar 3512). Deck equipment is compose by two 20 ton winches (wire D=20 mm, L=1000 m), and a 6 m^3 net drum. The Y-design trawl and its rigging were similar to that used on board R/V Gunnerus, except for the dimension of the trawl doors. On board Nordnes we used slightly smaller trawl doors (0.5m^2) than those used on board R/V Gunnerus. The trawl doors used on board Nordnes were: 3m^2 Egersund pelagic trawl door. In full scale these doors would be ~9m^2.

Fig 5. Danish seiner/trawler Nordnes.

3.2.1 Electronic equipment:

We used some of Nordness' electronic equipment to monitor the geometry and configuration of the Y-design trawl. Table 7 shows a specific list of the sensors used during the trials:

Table 7: Electronic equipment used on board Danish seiner/trawler Nordnes.

Sensor	Number	Placement	Main purpose
Door distance sensor SCANMAR	2	Trawl doors	Measure distance and depth at the doors and wings.
Trawl sonde SCANMAR	1	Headline	Measure mouth opening and bottom contact.
Trawl eye SCANMAR	1	Joint 1(top panel)	Measure the vertical opening of the net at joint 1
Water speed	1	Boat	Measure water speed

The testing plan on board Nordnes included two tests (Test 5-6) with the trawl operated as a pelagic trawl and a semi-pelagic trawl. During these tests, the towing speed varied between 2.9 - 4.2 knots. The length of the setback was initially set at 1.6m and later reduced to 0m. The weight of the clumps that were attached to the lower bridles was 720kg. Measurements of warp tension were obtained from the tension in the winches.

3.2.2 Testing area

The area chosen for the tests 5-6 are shown in Fig. 6.

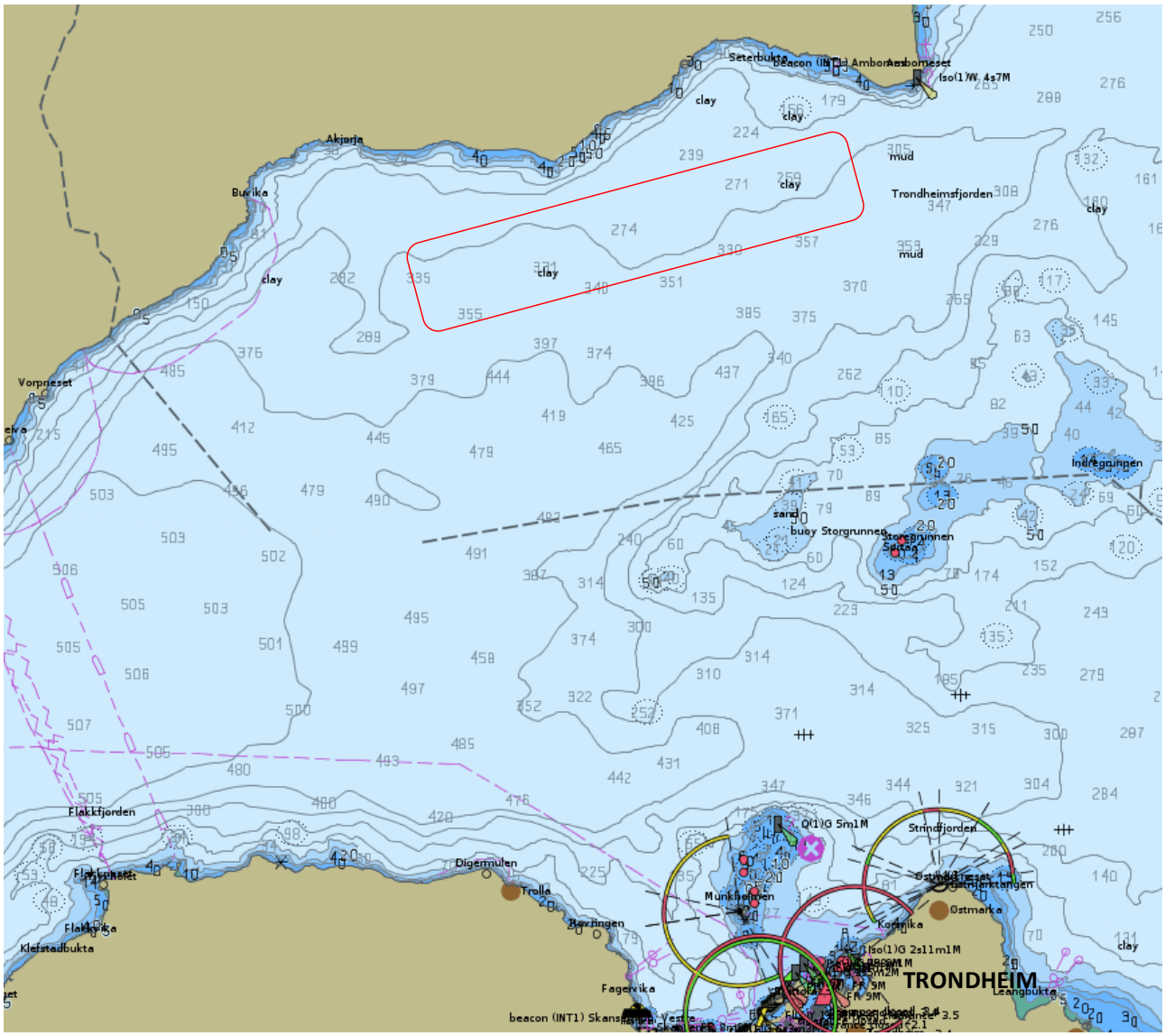


Fig 6. Area (red box) in which test 5-6 were performed.

4 Results

The results of the experiments are summarized and presented in separate figures, one for each test. The analysis of the geometry measurements shows in general clear tendencies of the main characteristics of the Y-design trawl. For an easier visualisation of these tendencies, a linear trendline have been fitted to the data points. Three main measurements are presented in each test: Distance between doors, distance between wings and height of the headline. Additional information on other geometry measurements is given in appendix F.

4.1 Pelagic trawling

The results from the tests with the Y-design trawl used as pelagic trawl (Test 1-2) are shown in Fig 7-8. Generally, the trawl was pretty stable and the geometry of the trawl did not vary much when changes in setback and weight clumps were performed. Specifically, the distance between doors varied between 87.8m and 145.1m at corresponding towing speeds equal to 2.4 and 4.2 knops. The distance between the wings varied between 52.5m and 89.2m and the height of the headline between 7.2m and 22.3m.

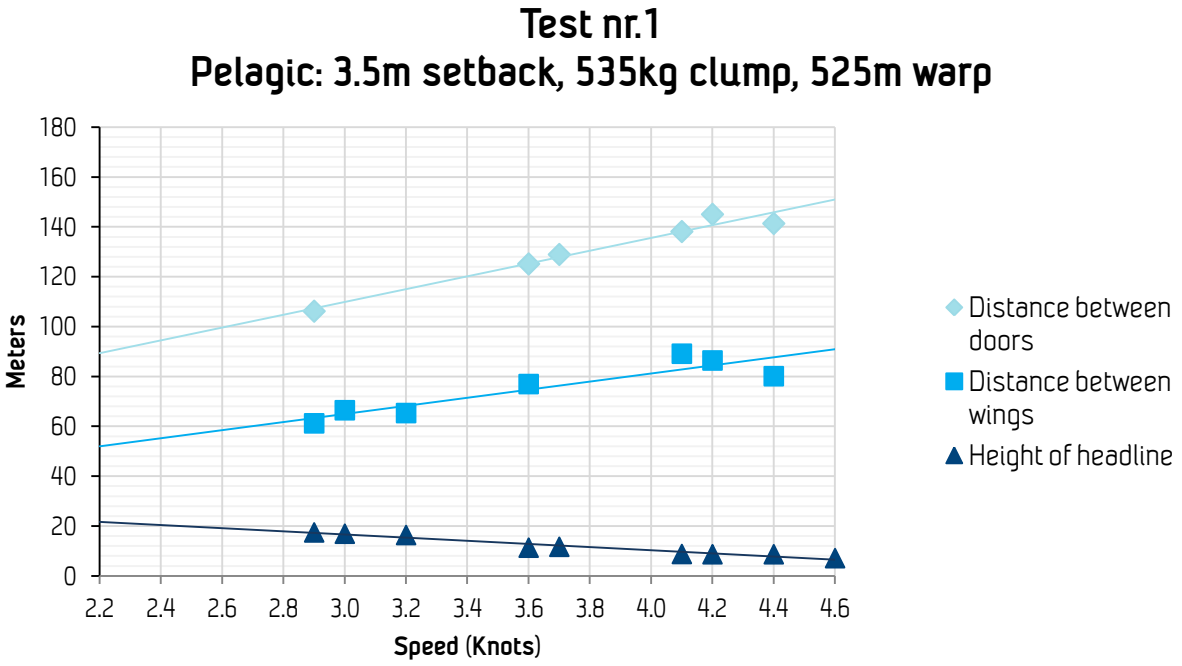


Fig 7. Geometry measurements of Y-design trawl used as pelagic trawl. The trawl was rigged with 3.5m setback, and weight clumps of 535kg. Warp length was approximately 525m through out the duration of the test.

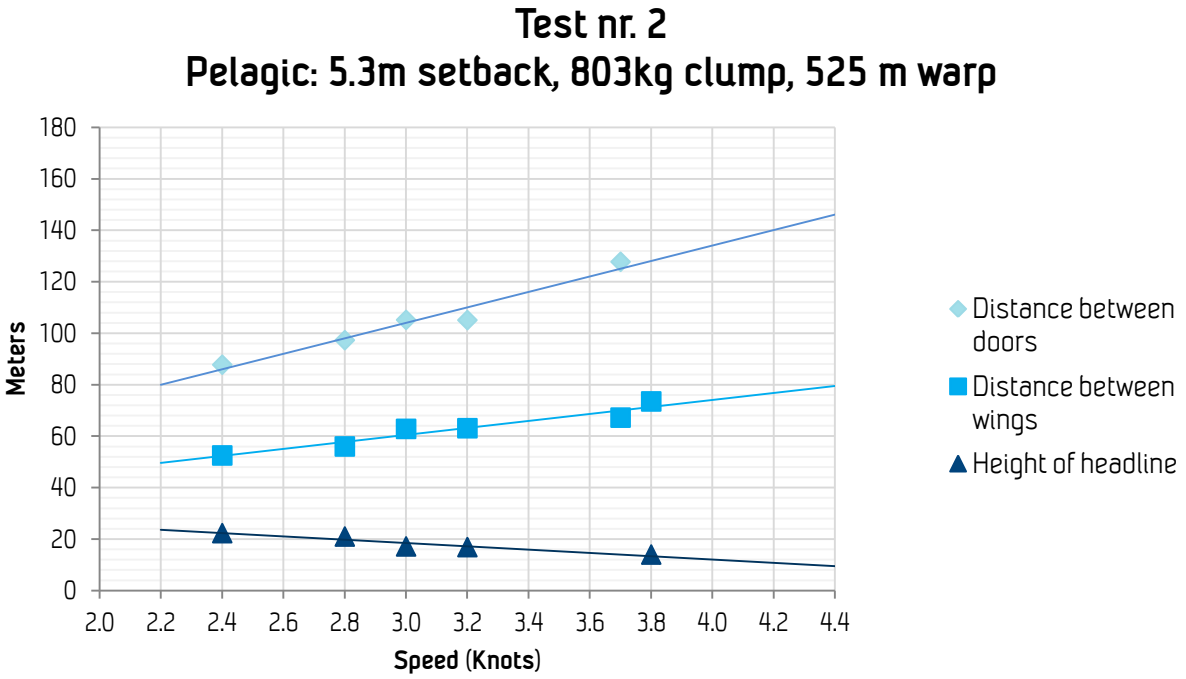


Fig 8. Geometry measurements of Y-design trawl used as pelagic trawl. The trawl was rigged with 5.3m setback, and weight clumps of 803kg. Warp length was approximately 525m through out the duration of the test.

The warp tension measurements performed with the shackles are not presented as part of the results because two reasons. First, they failed to give time series of load measurements over 8.56 tons. This is because one of the channels was set to register volt measurements in the range 0-1V, instead of both channels being in the range 0-10V, as it should have been. This mistake caused that all measurements above 1V (equivalent to ~8.56 tons) were not logged. Second, the rigging of one of the shackles stopped working on day 2, and the other on day 3. Therefore, few and incomplete data is available from the shackles.

4.2 Semi-pelagic trawling

4.2.1 R/V Gunnerus

The results from the tests with the Y-design trawl used as semi-pelagic trawl on board R/V Gunnerus are shown in Fig 9-10. Generally, used as semi-pelagic trawl, the trawl geometry was more sensitive to rigging changes (changes in setback and weight clumps) and speed changes than when it was towed as pelagic trawl. Specifically, the distance between doors varied between 114.8m and 138.1m at corresponding towing speeds equal to 2.9 and 4.1 knops. The distance between the wings varied between 57.5m and 84.5m and the height of the headline between 9.3m and 18.5m.

Especially interesting is the effect of reducing setback on the height of the headline. Accordingly, with a 3.5m setback, the changes in the headline height are very small (approximately 2 m) when either towing at 2.9 or 3.7 knops. Contrarily, with a 1.75 m setback, the height of the headline becomes very sensitive to changes in towing speed (Fig 11).

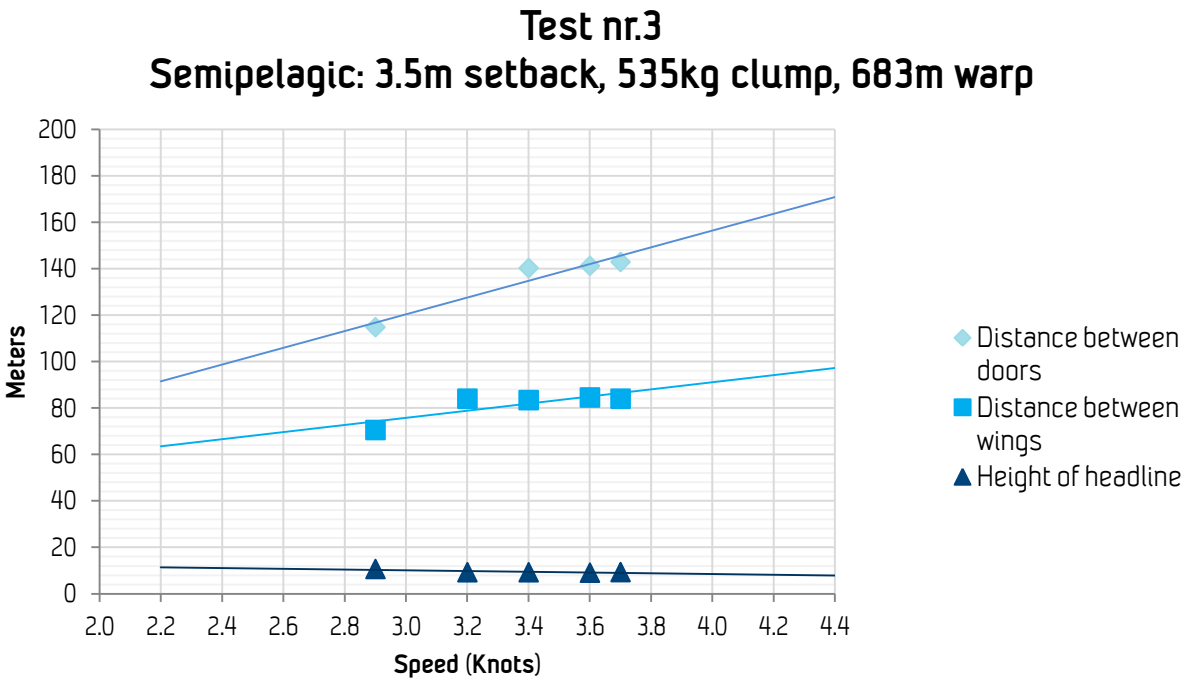


Fig 9. Geometry measurements of Y-design trawl used as semi-pelagic trawl. The trawl was rigged with 3.5m setback, and weight clumps of 535kg. Warp length was approximately 683m through out the duration of the test.

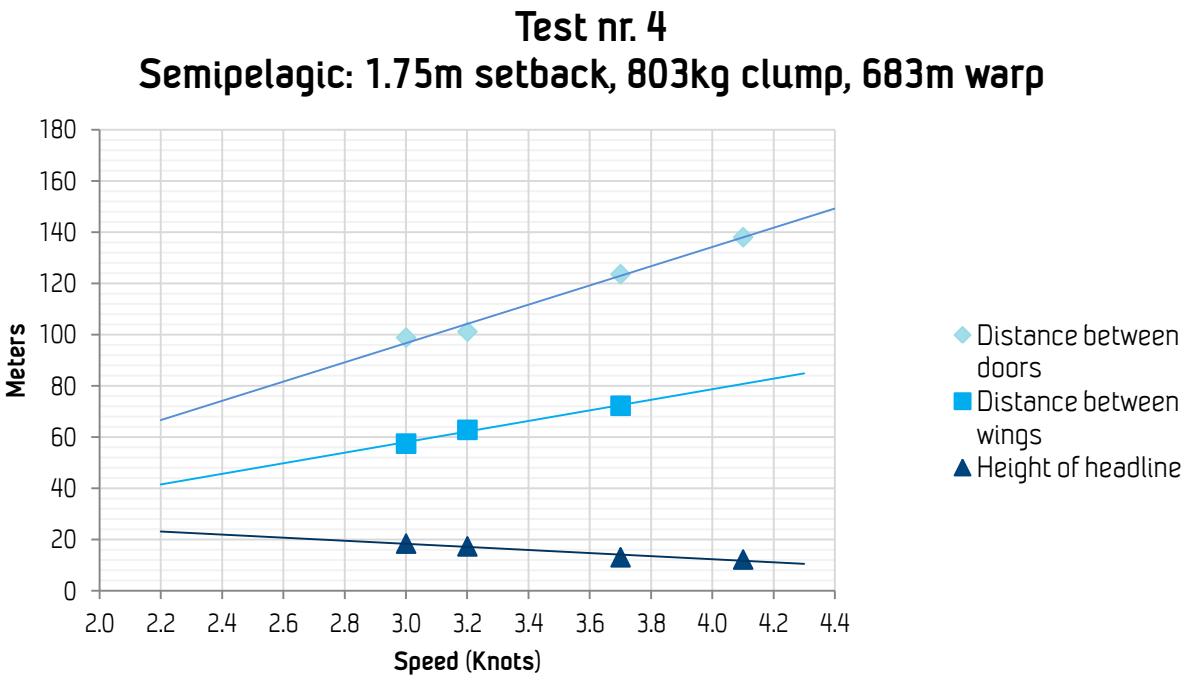


Fig 10. Geometry measurements of Y-design trawl used as semi-pelagic trawl. The trawl was rigged with 1.75m setback, and weight clumps of 803kg. Warp length was approximately 683m through out the duration of the test.

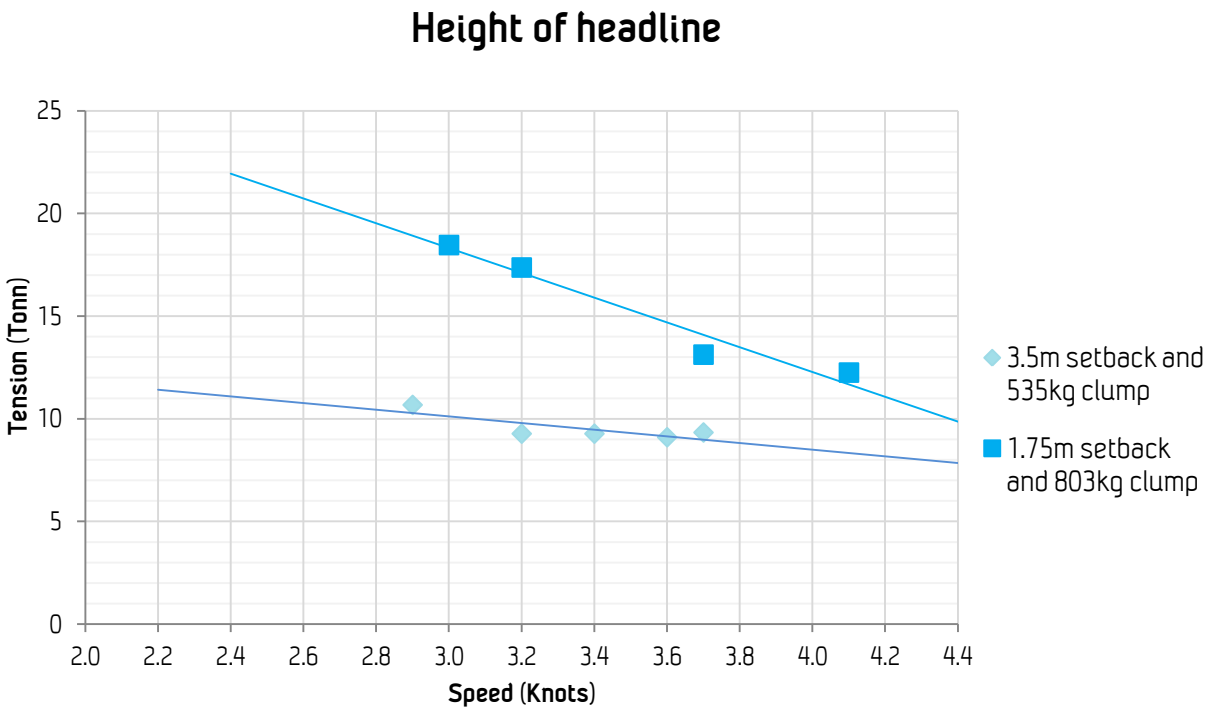


Fig 11. Height of headline during tests 3-4. Test 3: 3.5m setback, 535kg clump and 683m warp. Test 4: 1.75m setback, 803kg clump and 683m warp.

Warp tension measurements were performed in test 3-4 by using R/V Gunnerus' winch control system (shown in appendix F). These tension measurements are however very vague and contain a great amount of uncertainty because the system has not been calibrated in the last 4 years.

4.2.2 Danish seiner Nordnes

The geometry measurements obtained on board Danish seiner Nordnes are difficult to be directly compared to those obtained on board R/V Gunnerus. This mainly because of the setup differences that were used in each of the boats (setback lengths, warp lengths, clumps weight, warp diameter, use of sonde cable, etc). In addition, there were also differences in the size of the doors (~1.53m^2), and probably also differences in its rigging.

Very generally, the changes in trawl geometry registered on board Nordnes are very similar to those registered on board R/V Gunnerus. The trawl geometry was also sensitive to changes in setback and towing speed. More specifically, the distance between doors varied between 127.8m and 164.5m at corresponding towing speeds equal to3.0 and 4.5 knops. The distance between the wings varied between 73.5m and 95.2m and the height of the headline between 10.7m and 20.3m.

Fig 13-14 show the geometry measurements obtained in tests 5 and test 6.

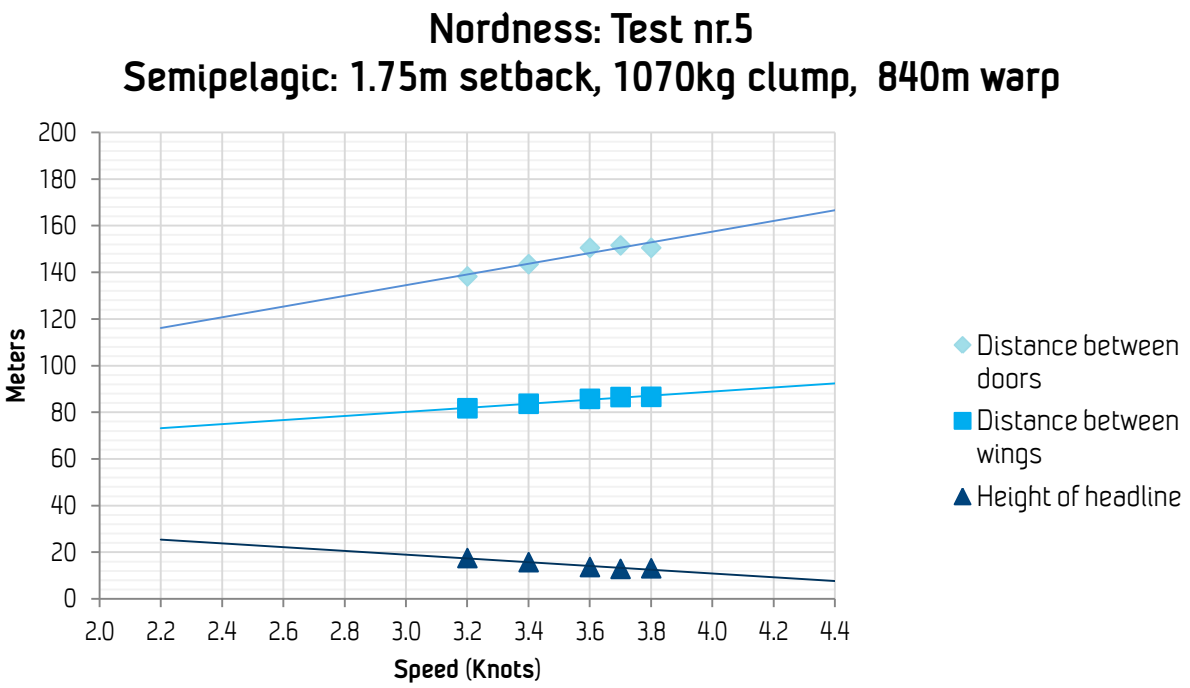


Fig 13. Geometry measurements of Y-design trawl used as semi-pelagic trawl. The trawl was rigged with 1.75m setback, and weight clumps of 1070kg. Warp length was approximately 840m through out the duration of the test.

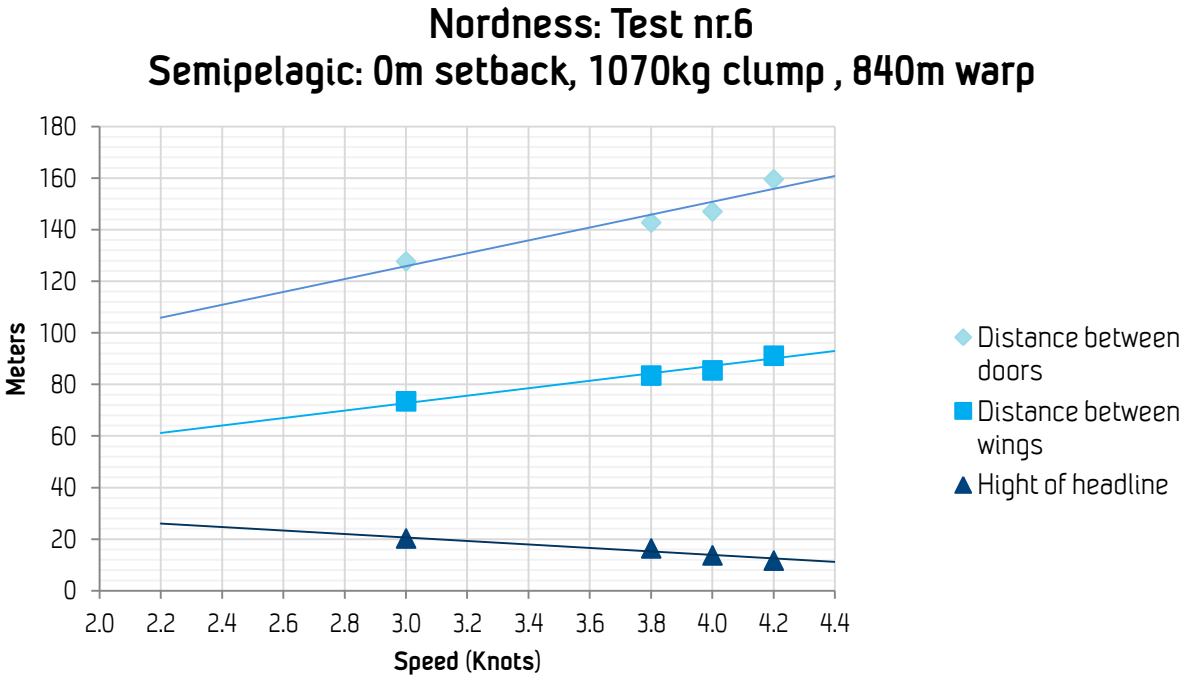


Fig 14. Geometry measurements of Y-design trawl used as semi-pelagic trawl. The trawl was rigged with 0m setback, and weight clumps of 1070kg. Warp length was approximately 840m through out the duration of the test.

During tests 6 the bosom of the trawl was apparently touching the seafloor. This is an unwanted situation since it may cause damage of the lower panels of the trawl. The fact that the bosom of the trawl was in contact with the seabead could have been the result of removing the entire setback: Not using setback may have tightened the lower bridles and the fishing line, and pressed the entire trawl against the seabed. Fig 15 confirms this statement by showing how the height of the trawl was reduced by approximately 3m when the setback was reduced from 1.75m to 0m with out any significant variation of the trawls' wing spread (see Fig 13-14).

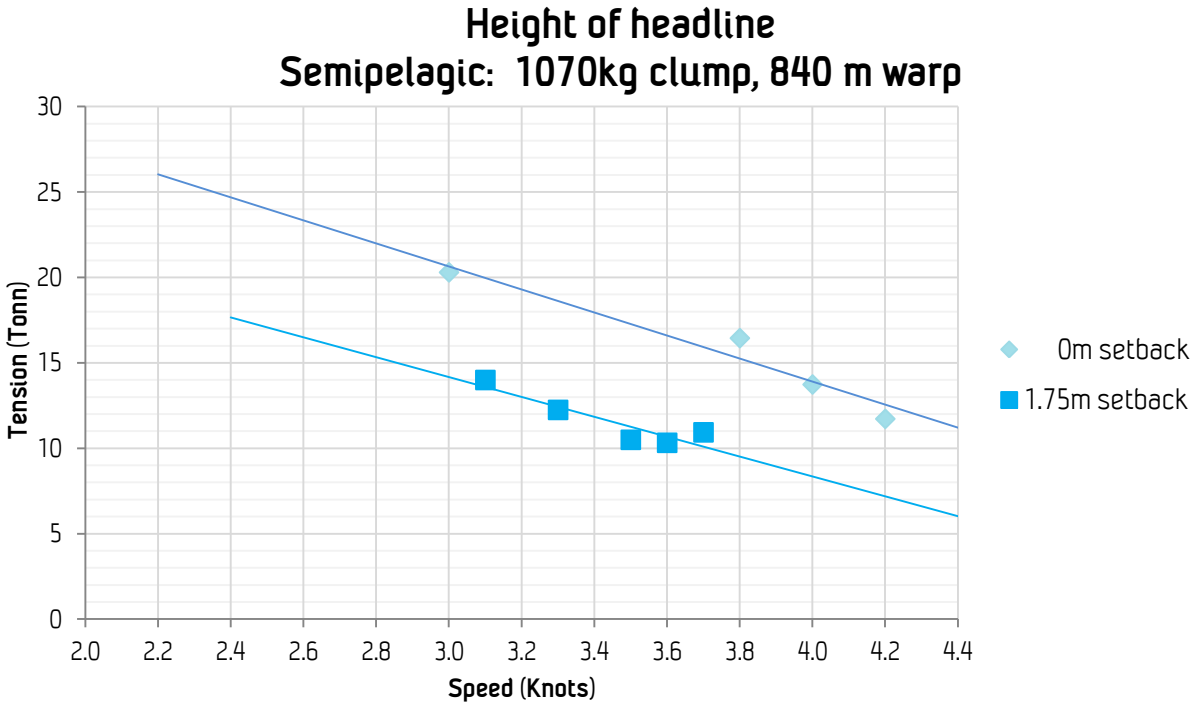


Fig 15. Height of headline during tests 5-6. Test 5: 1.6m setback, 360kg clump and 600m warp. Test 6: 0m setback, 550kg clump and 600m warp.

Warp tension measurements were performed in test 5-6 by using Nordnes' winch control system (see appendix E for details). These tension measurements are more reliable than those from R/V Gunnerus because, according to the skipper of Nordnes (Mr. Tormund Grimstad) the winch control system of this vessel had been calibrated 4 weeks before the experiments.

The measurements of warp tension of tests 5-6 are shown in Fig 16.

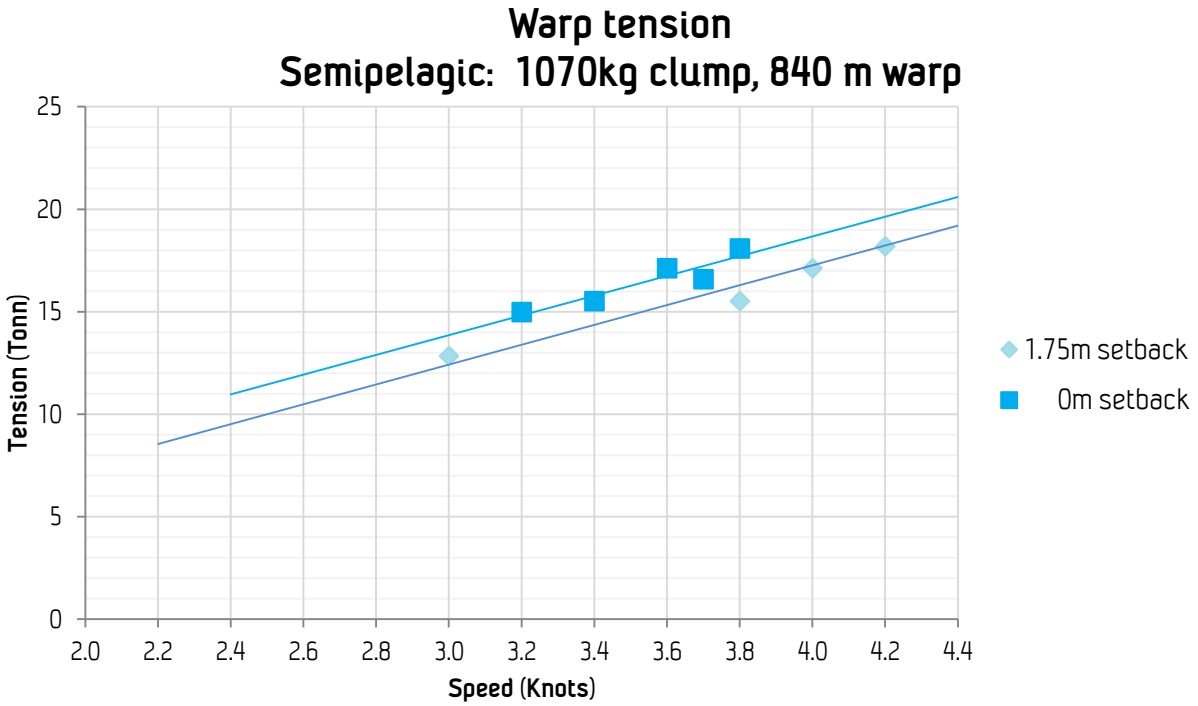


Fig 16. Warp tension measurements of Y-design trawl used as semi-pelagic trawl. The trawl was rigged with 1.75m and 0m setback. Weight clump was 1070kg. Warp length was approximately 840m through out the duration of the test.

5 Discussions

The results presented in this report show a well functioning design of trawl that can easily be operated as pelagic trawl or as semi-pelagic trawl. Some technical problems have been identified though (boson touching the seabed), and demand adjustments before full-scale test are carried out.

It's not possible to directly compare the results from the experiments on board F/F Gunnerus, DS Nordnes, and those from Hirtshals. This is mainly because of the difference in trawl doors' sizes, and also differences in bridles' length.

It is not clear whether the use of sonde cable affected the geometry of the Y-design trawl.

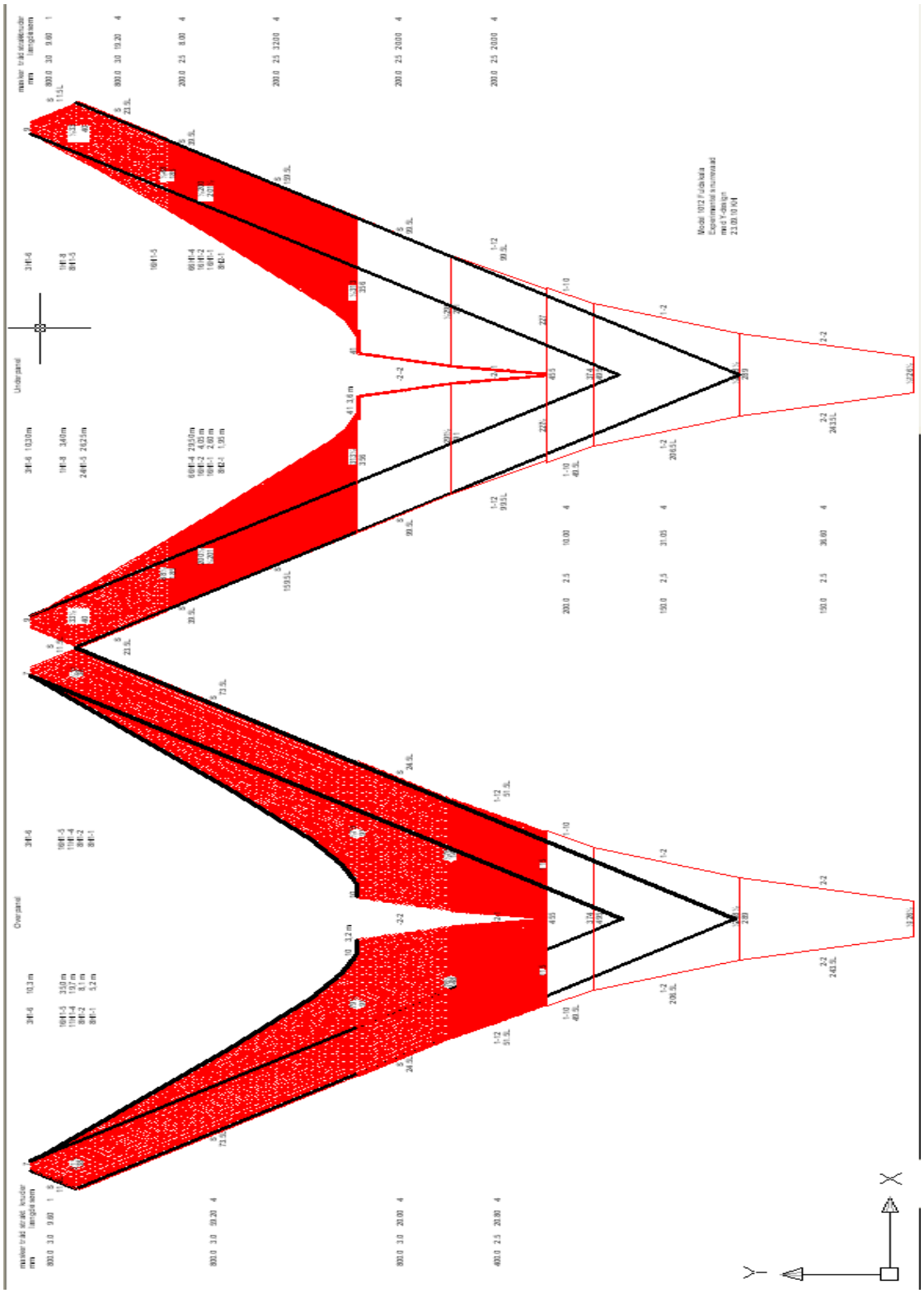
Finally, no documentation of the ground gear's operation was performed in any of the tests. Therefore, the geometry and functioning of the skirt is unknown.

6 References

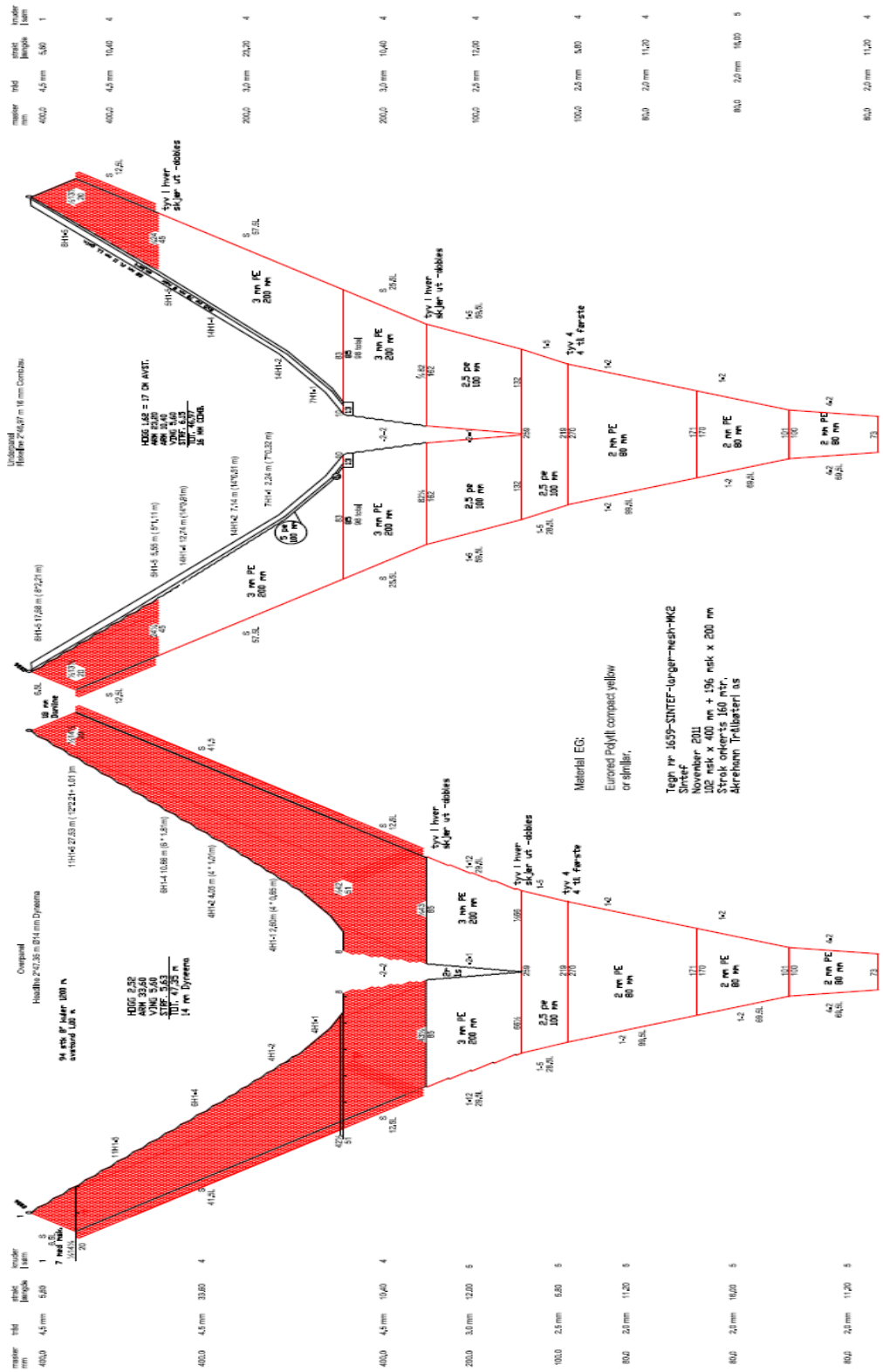
Hansen, K. 2011. New active fishing gear: Model tests and analysis of new design concepts. SINTEF report nr. A20244. Unrestricted. ISBN 978-82-14-05205-3.

Winter, M., Gjøsund, S.H. 2010. New active fishing gear. Report from project workshop in Hirtshals, Dec. 14-15, 2009. SINTEF report Nr. SFH80 A103023. Unrestricted. ISBN 978-82-14-04942-8.

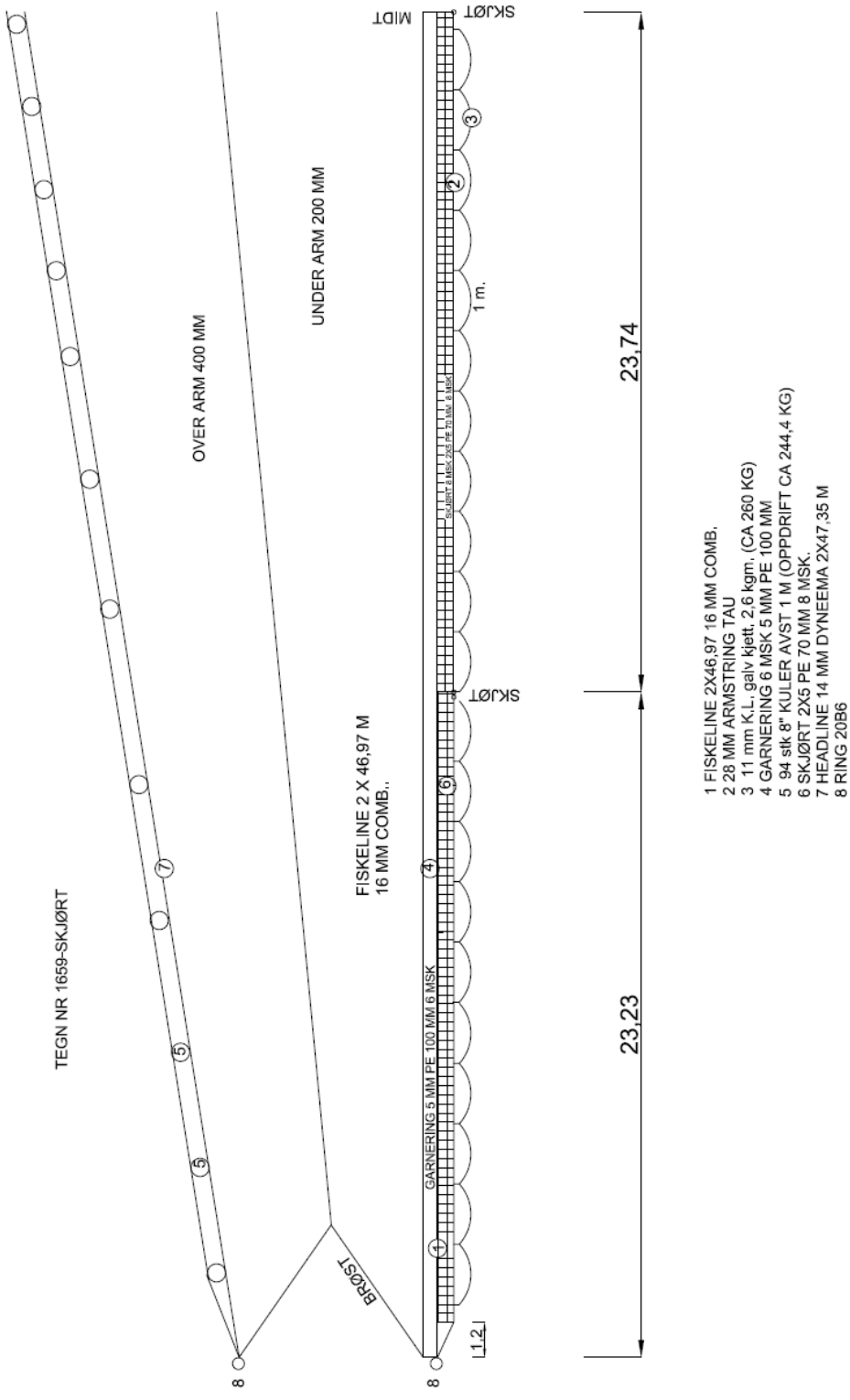
A Appendix: Y-design net plan – Full scale



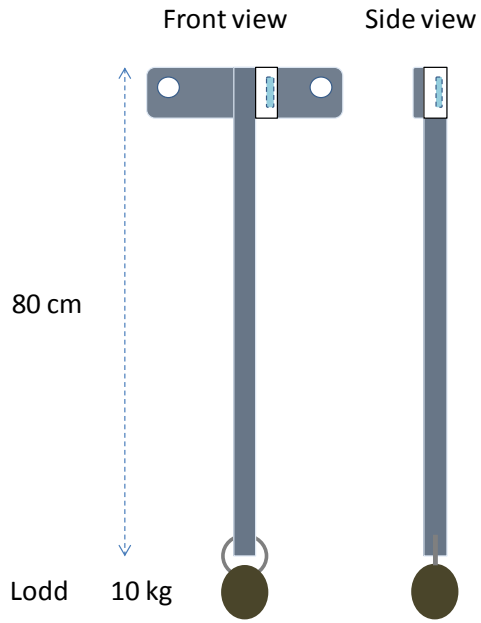
B Appendix: Y-design net plan – Scale 1:1.75

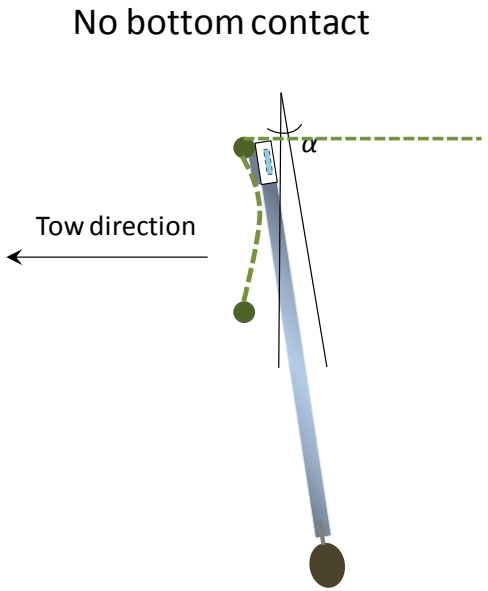


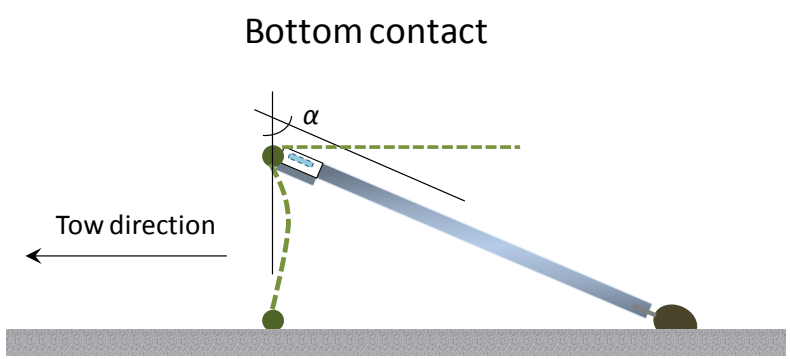
C Appendix: Detailed specification of wings and skirt



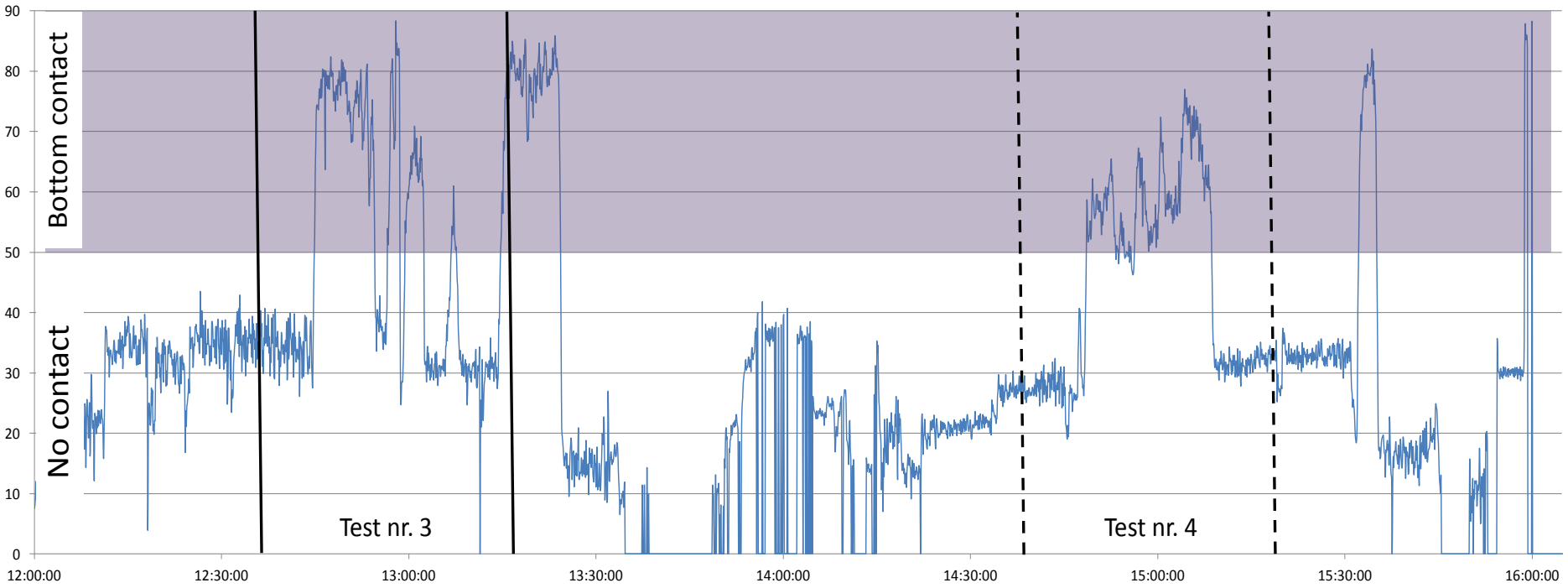
D Appendix: Description of the bottom contact sensor that was built with the "Star Oddi tilt sensor"







E Appendix: Time series of bottom contact logged with the Star Oddi tilt sensor – Bottom contact sensor



The blue line in the figure shows the change in angle (degrees) (Y-axis) registered by the "star oddi tilt" sensor along time (X-axis). The red and purple areas cover the areas where the skirt comes into contact with the seabed at two different working angles. The green area shows the area where, with the skirt hanging vertically from the fishing line (0°), the distance from the skirt to the seabed is above 30 cm.

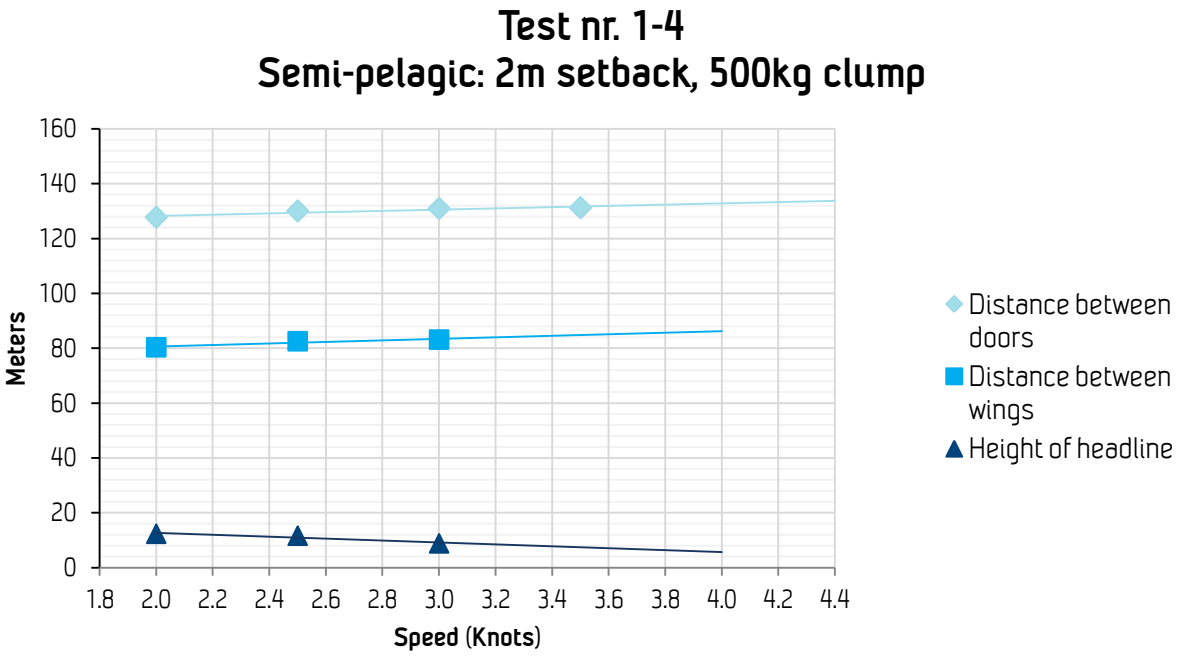
F Appendix: Overview of tests and measurements (transformed to full scale)

Test nr.	Setback (m)	Clump weight (kg)	Warp length (m)	Measurement	Speed (knots)															
					2.4	2.8	2.9	3.0	3.2	3.4	3.6	3.7	3.8	4.0	4.1	4.2	4.4	4.5	4.6	4.7
1	3.5	535	525	Distance between doors			106.2				125.2	129.0			138.2	145.1	141.4			
				Distance between wings			61.3	66.5	65.4		77.0				89.2	86.5	80.2			
				Height of headline			17.5	17.0	16.5		11.4	11.7			8.8	8.8	8.8		7.2	
				Wire tension			15.5	15.5	15.5		15.5	15.5			16.1	16.1	16.1		16.1	
2	5.3	803	525	Distance between doors	87.8	97.3		105.2	105.1			127.8								
				Distance between wings	52.5	56.0		62.8	63.1			67.2	73.5							
				Height of headline	22.3	21.0		17.2	16.9				14.0						7.9	7.7
				Wire tension	11.8	11.8		11.8	11.8			11.8	11.8						16.6	16.6
3	3.5	535	683	Distance between doors			114.8			140.3	141.2	142.9								
				Distance between wings			70.5		84.0	83.4	84.5	84.0								
				Depth of door (port)			297.5		301.0	292.8	287.7	293.0								
				Depth of door (sb)			299.3		302.8	297.3	284.2	285.6								
				Depth of wing (port)			302.8		304.5	299.3	292.3	294.0								
				Depth of wing (sb)			302.8		304.5	299.3	292.3	294.0								
				Depth of fishing line			315.0		316.8	311.5	306.3	308.6								
				Height of headline			10.7		9.3	9.3	9.1	9.3								
				Wire tension			11.8		11.8	13.9	14.4	15.0								

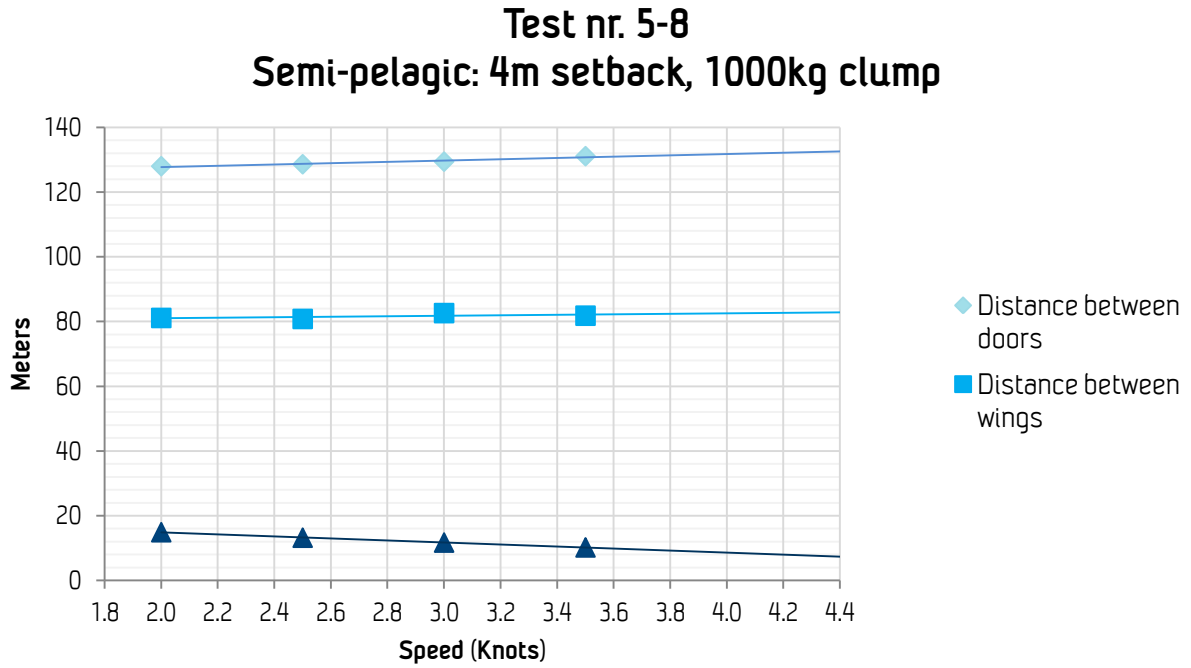
4	1.75	803	683	Distance between doors				98.9	101.2			123.6			138.1				
				Distance between wings				57.5	62.9			72.3							
				Depth of door (port)				273.0	290.5			266.9			274.8				
				Depth of door (sb)				276.5	278.5			265.1			278.3				
				Depth of wing (port)				289.6	291.4			272.1			283.5				
				Depth of wing (sb)				288.8	288.3			276.5			287.0				
				Depth of fishing line				308.0	309.3			293.1			301.0				
				Height of headline				18.5	17.4			13.1			12.3				
				Wire tension				12.3	12.7			14.7			14.4				
5	1.75	1070	840	Distance between doors					138.3	143.5	150.5	151.6	150.5						
				Distance between wings					81.7	83.7	85.8	86.5	86.6						
				Height of headline					17.5	15.8	13.7	12.9	13.1						
				Height at first joint					14.0	12.3	10.5	10.3	10.9						
				Wire tension					15.0	15.5	17.1	16.6	18.1						
6	0	1070	840	Distance between doors				127.8					142.8	147.1		159.6		164.5		
				Distance between wings				73.5					83.5	85.5		91.2		95.2		
				Height of headline				20.3					16.5	13.7		11.7		10.7		
				Height at first joint				14.9					12.3	10.9		9.1		8.4		
				Wire tension				12.8					15.5	17.1		18.2		20.2		

G Appendix: Measurements of the Y-design trawl used as semi-pelagic trawl performed in the test tank in Hirtshals, Denmark, (Hansen, 2011)

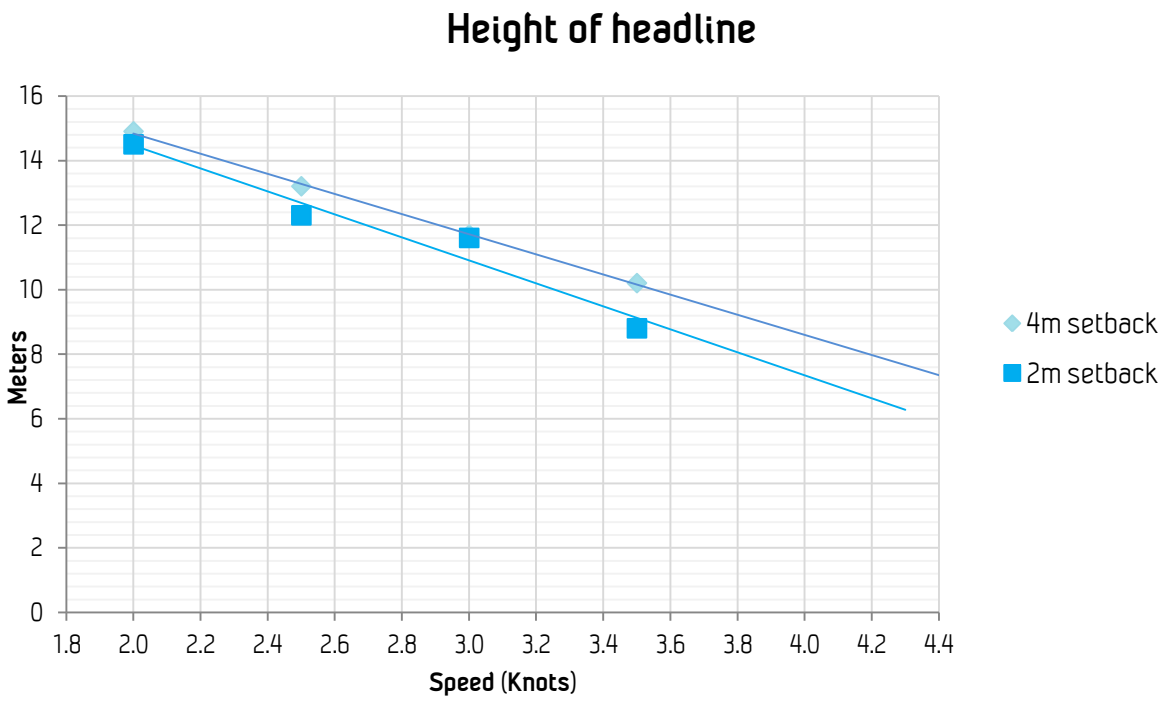
Test nr.	Setback (m)	Clump weight (kg)	Measurement	Speed (knots)			
				2.0	2.5	3.0	3.5
1, 2, 3, 4	2	500	Distance between doors (m)	127.7	130.0	130.9	131.2
			Distance between wings (m)	81.6	80.3	82.5	83.1
			Height of headline (m)	14.5	12.3	11.6	8.8
			Wire tension (tons)	5.7	7.4	9.8	12.4
5, 6, 7, 8	4	1000	Distance between doors (m)	128.0	128.6	129.4	131.1
			Distance between wings (m)	81.1	80.8	82.6	81.8
			Height of headline (m)	14.9	13.2	11.7	10.2
			Wire tension (tons)	6.1	8.2	10.7	13.6



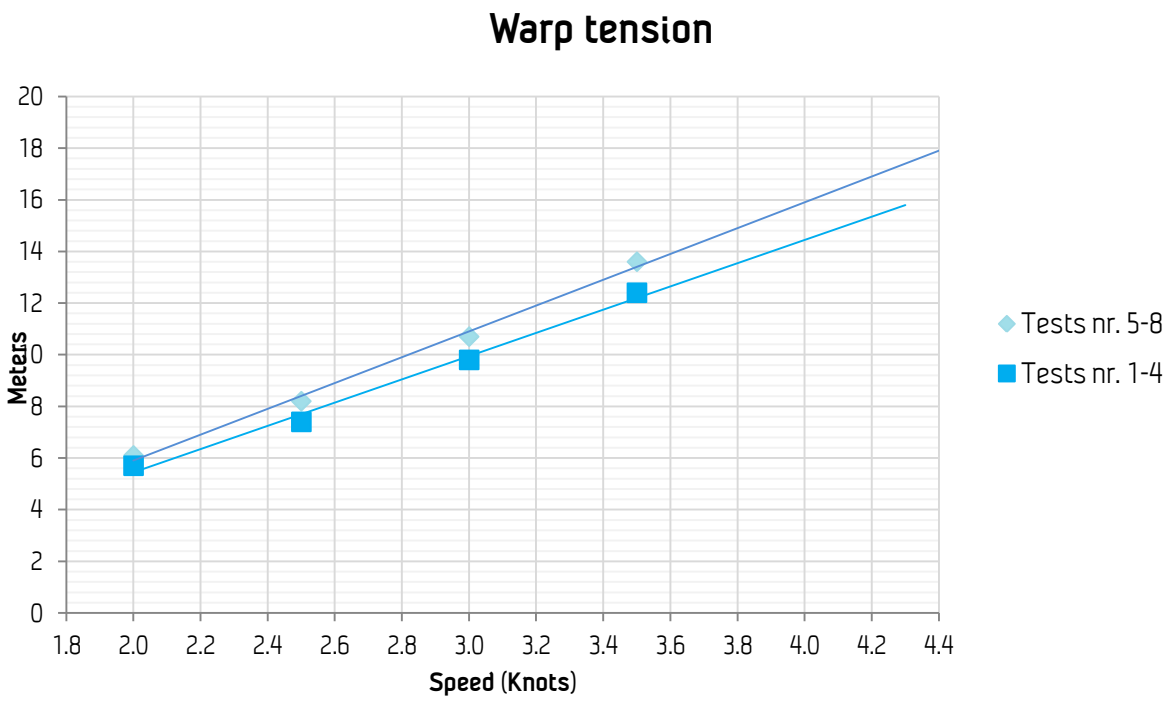
G1. Geometry measurements of Y-design trawl used as semi-pelagic trawl. The trawl was rigged with 2m setback, and weight clumps of 500kg.



G2. Geometry measurements of Y-design trawl used as semi-pelagic trawl. The trawl was rigged with 4m setback, and weight clumps of 1000kg.



G3. Height of headline during tests 1-8. Test 1-4: 4m setback, 500kg clump. Test 5-8: 2m setback, 1000kg clump.



G4. Warp tension measurements of Y-design trawl used as semi-pelagic trawl. Test 1-4: The trawl was rigged with 4m and 500kg clump per wing. Tests 5-8: The trawl was rigged with 2m setback and 1000kg clump per wing.

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