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Report

Further tests on the functioning and efficiency of the semi-circle spreading gear (SCSG)

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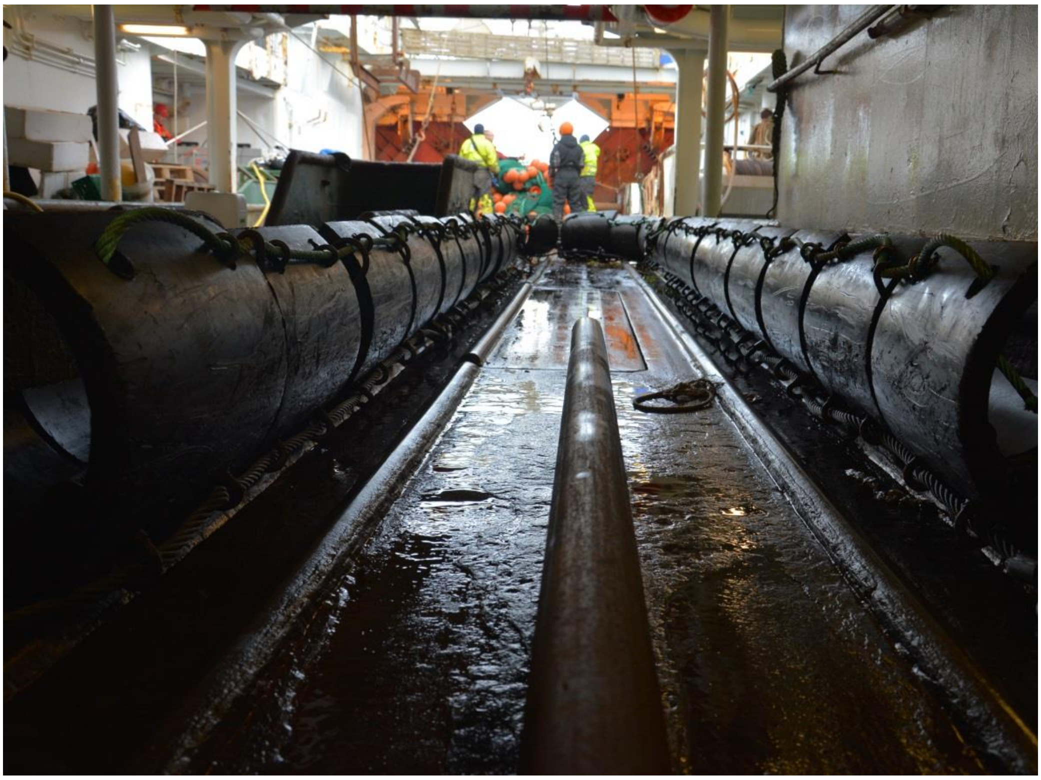

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Report

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ABSTRACT
Based on the initial tests carried out in 2013 we carried out a follow up test at sea that evaluated the performance of the Semi-Circular Spreading Gear (SCSG) based on underwater video recordings, information collected from underwater acoustic sensors and catch comparison analysis between a traditional rockhopper gear and the tested semi-circle gear. The results showed that in general the SCSG functioned well as a ground gear. This is in good agreement with the conclusions from the earlier trials. Compared to the traditional rockhopper the SCSG showed to have similar spreading force capacity and fishing efficiency for cod. Further tests with the SCSG are necessary, but then in a commercial fishing situation. The tests should aim at improving the construction materials of the gear so that they stand commercial activity over a long period of time and at directly comparing the performance of the SCSG gear with a rockhopper gear over a high number of tows.

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1 Introduction

The activities described in this report are part of Work Package 3 (WP3: Development of new ground gear) of the project "MultiSEPT" ("Development of multirig semi-pelagic trawling", Norwegian Research Council Project Nr. 216423/O70). The aim of the project is to reduce NOx- and other environmental emissions and to increase the energy efficiency of trawling operations for deep-water resources, and includes the development of a new ground gear that will reduce energy consumption and make bottom trawling more environmentally friendly. Grimaldo et al. (2013) tested a semi-circular spreading gear (SCSG) as an alternative to the more traditional rockhopper ground gear used in the gadoid fisheries in the Barents Sea. Initial tests in a flume tank and preliminary sea trials showed that this light and simple gear-rigging performed surprisingly well, maintaining good bottom contact, passing bottom obstacles very easily and having a higher wingspread than the traditional rockhopper ground gear.

To follow up on these promising results we have carried out further tests at sea and evaluated the performance of the SCSG based on underwater video recordings, information collected from underwater acoustic sensors and catch comparison analysis between a traditional rockhopper gear and the tested semicircle gear. This report presents the results of these tests.

2 Materials and methods

2.1 Trawl gear

We carried out the sea trials onboard the research vessel RV Helmer Hanssen (63.8 m LOA and 4080 HP) in the period 08.03.14 – 14.03.14. The vessel is a former shrimp trawler that is well suited for trawl experiments as it has a double 50 m long trawlway and separate bins to keep catches separated when necessary. The area chosen for the tests was off the coast of Finnmark (Northern Norway), with good availability of cod (*Gadus morhua*) during the trial period. We used two identical ALFREDO 3 trawls entirely built in 80mm PE netting. The trawls were rigged with two Thyborøn T2 bottom trawl doors (10m2 and 3000 kg each), 75 m sweeps (30 m + 45 m) and a 108 m ground gear (Figure 2). The trawls had a headline of 36.5 m, a fishing line of 18.9 m and 810 meshes circumference (80 mm nominal mesh size). The foremost sections of the ground gear on both trawls had five 21" steel bobbins (61 cm in diameter) on each side, and then one trawl was rigged with an 18 m long rockhopper with 21" rubber disks and 8"x 8" spacers (Figure 3), or the other with an 18 m long SCSG built in 50 cm x 50 cm HDPE pipe (Figure 4).

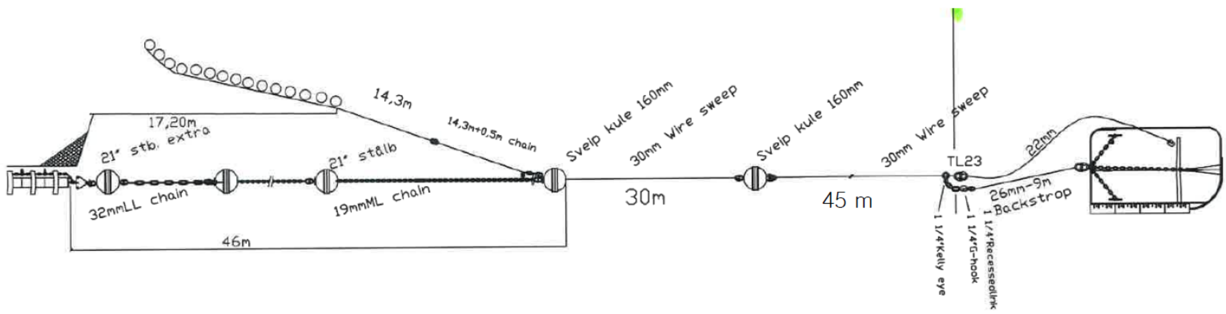

Figure 2: Overview of the ground gear used during the experiments.

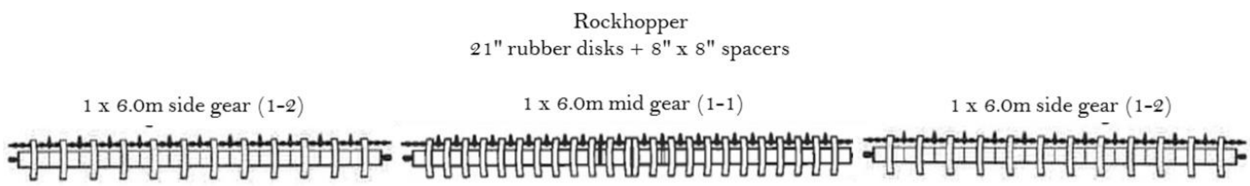

Figure 3: Scheme of the rockhopper gear used during the experiments.

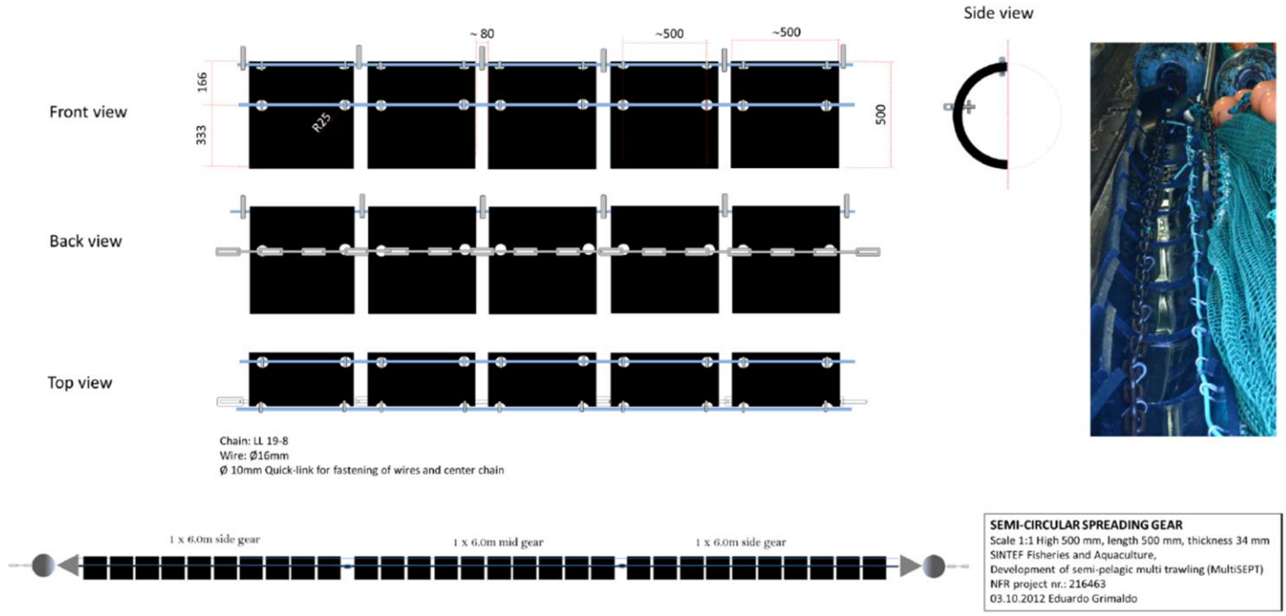

Figure 4: Scheme of the SCSG gear used during the experiments.

Further specifications on the gear and the trawl used in the present trials can be obtained from Grimaldo et al. (2013) as they were identical in both experiments.

2.2 Acoustic sensor equipment used

We used a combination of Scanmar (Scanmar AS, Norway) and Marport (Marport deep sea technologies Inc., Iceland) acoustic sensors to monitor the performance of the two gears tested. In addition to the door distance and trawl height, which are traditionally used to control the gear, we used a set of distance sensors placed at the lower wings of the trawl to monitor and compare the spreading by the rockhopper gear and the SCSG. The door distance and trawl height were respectively monitored by a set of Scanmar distance sensors (110KHz) and a Scanmar HC4-HT60 height sensor. The wing distance on the other hand was monitored by a set of Marport MFX distance sensors (144KHz).

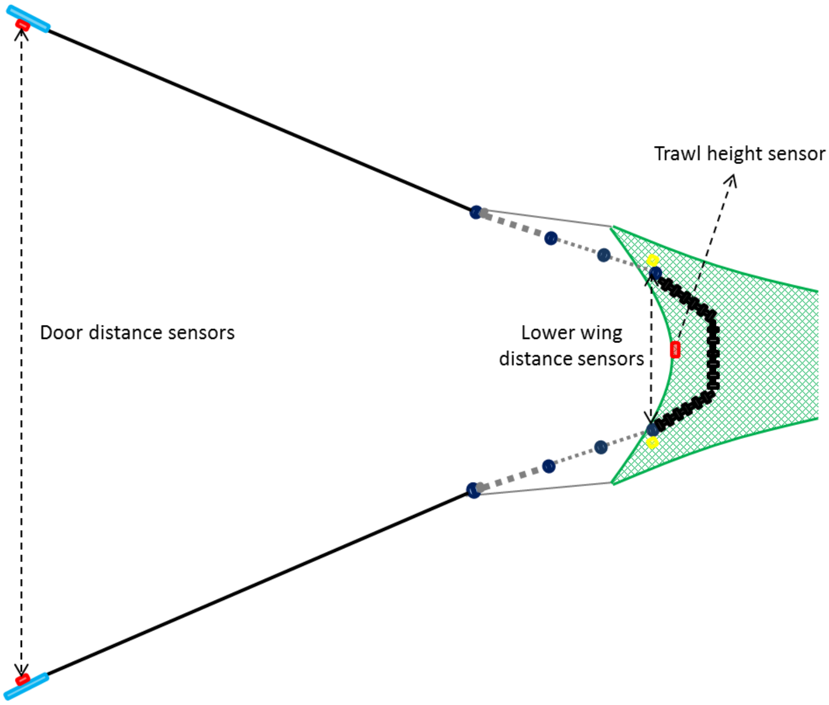

Figure 5: Position of the different monitoring sensors used in the trawl.

2.3 Video recording systems

We used three different camera systems to monitor the performance of the SCSG:

- A Simrad Kongsberg OE1324 Enhanced SIT low light camera (with a sensitivity of 2×10^{-4} lux, connected to a self-contained recorder unit with DV tape and batteries) (www.km.kongsberg.com).
- A trawlcam camera system (with a sensitivity of 2×10^{-4} lux) (www.trawlcamera.com).
- An Imenco Basking greytip color camera system (with a sensitivity of 0.0001 lux, connected to a self-contained recorder unit with a 300GB hard disc and batteries) (www.imenco.no).

2.4 Catch comparison analysis

To assess whether there was any difference between length-dependent catch efficiency of the rockhopper gear and the SCSG gear, we used a catch comparison analysis (Krag et al., 2014). We were interested in the length-dependent values the catch comparison rate undertakes averaged over hauls. These values provided information about how catch efficiency varied on average when using the rockhopper gear compared to the SCSG. In the experimental procedure, the hauls carried out with both gears were alternated, meaning that the catch data for the two setups could be paired. Thus, the structure for each haul pair created showed the frequency of fish captured for each length class in the test1 (Rockhopper gear) and test2 (semicircle gear) (Figure 6).

	Pair 1	
Length	Test 1	Test 2
30,5	0	0
31,5	0	0
32,5	0	0
33,5	0	0
34,5	0	0
35,5	0	0
36,5	0	0
37,5	0	0
...	...	...
119,5	0	0
120,5	0	1
121,5	0	0
122,5	0	0
123,5	0	0
124,5	0	0
125,5	0	0
126,5	0	0
127,5	0	0
128,5	0	0
129,5	0	1
Sampling	1	0.75

Figure 6: Structure of the analysis pairs.

The two pair in each haul was standardized to have the same towing time as the haul with the longest duration. In addition, in the hauls where due to the volume of fish captured subsampling was necessary, the sampling factor was multiplied by the subsampling factor as well. For example, for a haul with a towing time that was half that of the other haul in the pair, and for which 25% of the cod in the codend were measured, the sampling factor would be calculated as 0.25 x 0.5 = 0.125. The standardization procedure was carried out to compensate for differences in catch size caused by differences in towing time. Without this standardization, the assessment of the catch comparison would be biased.

The experimental averaged catch comparison rate, CCl, where l denotes the fish length, is given by:

$$CC_l = \frac{\frac{1}{a}\sum_{i=1}^{a}\left\{\frac{n1_{li}}{q1_{li}}\right\}}{\frac{1}{a}\sum_{i=1}^{a}\left\{\frac{n1_{li}}{q1_{li}}\right\}+\frac{1}{b}\sum_{j=1}^{b}\left\{\frac{n2_{lj}}{q2_{lj}}\right\}} \qquad (1)$$

The experimental CCl is often modelled by the function CC(l), which has the following form (Krag et al; 2014):

$$CC(l,v) = \frac{\exp(f(l,q_0..q_k))}{1+\exp(f(l,q_0..q_k))} \qquad (2)$$

where f is a polynomial of order k with coefficients q0 to qk so v = (q0,...,qk). Thus, CC(l, v) expresses the probability of finding a fish of length l in the gear when fished with setup 1 given that it is found when fished with one of the two setups. A value of 0.5 for CC(l, v) would mean that the likelihood of finding a fish of length l in any of the two setups is equal, implying that changing from one setup to the other would not have any effect on the catch efficiency. We considered f up to an order of 4 with parameters q0, q1, q2, q3, and q4. Selection of the best model for CC(l, v) among the 32 competing models was based on a comparison of the Akaike's Information Criterion AIC values for the models. The model with the lowest AIC value was selected (Akaike, 1974).

The confidence limits for the catch comparison curve were estimated using a double bootstrapping method. We performed 2,000 bootstrap repetitions and hence calculated the Efron 95% (Efron, 1982) confidence limits for the catch comparison curve. The catch comparison analyses were performed using the software SELNET (Sistiaga et al., 2010; Eigaard et al., 2011; Frandsen et al., 2011; Herrmann et al., 2012).

Because we used the alternate haul method, a patchy distribution of fish in the fishing area would create undesired balance in the fish quantity available for one gear and the other. This unbalance would fade out when increasing the amount of hauls carried out, but when the hauls or comparisons between the gears are limited, a single haul where the availability of fish was abnormally high or low can create substantial differences in the trend shown by the rest of the hauls. To investigate if there was such a case in this dataset, we run a "jacknife" analysis. In such an analysis, the overall analysis is run multiple times eliminating one haul pair the time. Thus, if the result obtained for the overall analysis varies substantially when one of the pairs is removed, it would mean that one haul or both hauls of that pair is influencing the mean results away from the result that the rest of the haul pairs would otherwise show.

3 Results

3.1 Overview of the data collected during the cruise

During the sea trial period we collected a total of 16 hauls. These 16 hauls made a total of 8 haul pairs that were used as the comparison base for the two different tested gears. The two main species harvested during the cruise were cod and haddock (*Melanogramus æglefinnus*). A few individuals of redfish (*Sebastes spp*.), Greenland halibut (*Reinhardtius hippoglossoides*) and diverse other flatfish were also caught in each haul, but the numbers were so low that were not considered in the study in any way.

Table 1: Overview of the 16 hauls carried out during the cruise.

Haul Nr.	Pair	Gear	Date	Position (N)	Position (E)	Shoot time	Trawlin time (min)	Depth (m)	Catch cod (kg)	Catch haddock (kg)	Total catch (kg)
1	1	Rockhopper	8.3.14	71°15'00"	24°14'00"	11:00	20	332	3090,6	515,3	3605,8
2		SCSG	8.3.14	71°14'80"	24°20'20"	16:15	15	316	2226,4	348,3	2574,6
3	2	SCSG	8.3.14	71°14'00"	24°27'00"	20:25	70	306	2118,3	288,1	2406,4
4		Rockhopper	9.3.14	71°13'20"	71°13'80"	08:45	15	308	8320,6	356,0	8676,6
5	3	Rockhopper	10.3.14	71°17'60"	25°45'80"	00:35	10	301	1208,9	97,3	1306,2
6		SCSG	10.3.14	71°16'30"	26°19'00"	03:50	15	288	722,3	80,1	802,4
7	4	SCSG	10.3.14	71°16'00"	26°36'00"	05:40	25	285	2544,5	267,8	2812,4
8		Rockhopper	10.3.14	71°16'90"	26°53'40"	09:35	18	279	3687,7	781,7	4469,4
9	5	Rockhopper	10.3.14	71°15'50"	26°53'60"	14:39	24	278	153,5	303,8	457,3
10		SCSG	10.3.14	71°15'80"	26°42'00"	15:56	60	283	893,2	247,9	1141,1
11	6	SCSG	10.3.14	71°16'60"	26°24'00"	18:32	80	286	2189,3	214,4	2403,6
12		Rockhopper	10.3.14	71°17'30"	26°05'90"	23:00	59	282	6987,7	161,4	7149,2
13	7	Rockhopper	11.3.14	71°16'80"	26°25'30"	08:47	15	286	747,2	92,9	840,1
14		SCSG	11.3.14	71°17'20"	26°18'90"	11:25	18	285	2465,4	162,3	2627,7
15	8	SCSG	11.3.14	71°16'40"	26°24'00"	15:38	15	287	1329,7	101,9	1431,6
16		Rockhopper	11.3.14	71°18'00"	26°17'00"	17:40	15	276	458,2	52,8	511,0

3.2 Underwater recordings and information from the acoustic sensors

The underwater recordings showed that the SCSG performed well as a trawl ground gear. The gear ran smoothly on the seabed and as documented in previous sea trials (Grimaldo et al., 2014), it showed to pass over stones and rocks very easily, and visually more easily than the rockhopper, without longer sections of the gear being lifted. Compared to the rockhopper gear, the SCSG gave approximately 2.5 % more wing end spred The fishing line was more stretched and acquired a more flat curve in the centre of the gear (Figure 7).

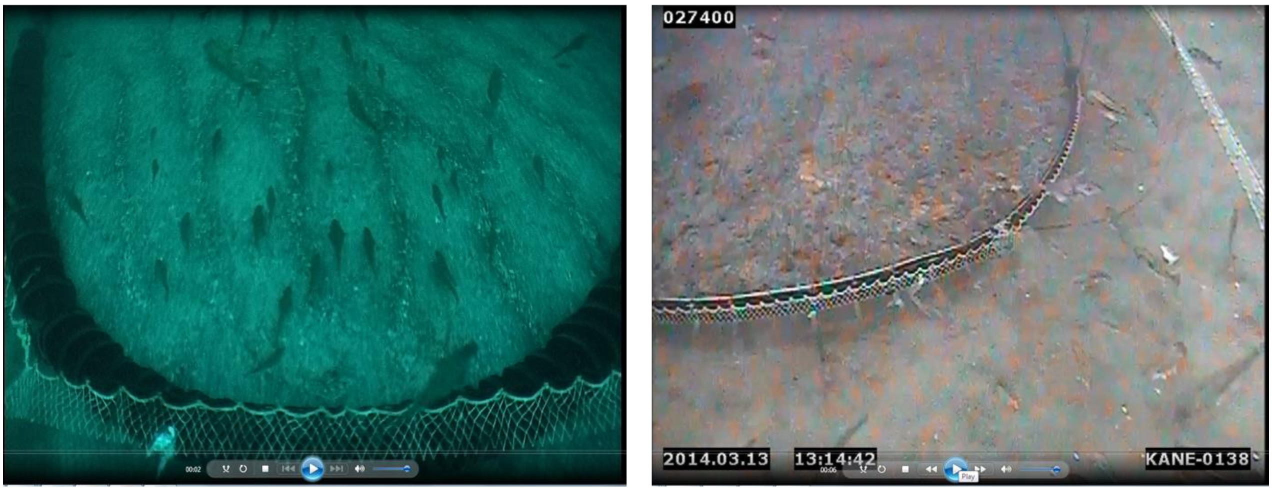

Figure 7: Images showing the performance and spreading power of the rockhopper gear (left) and the SCSG (right). The spreading distances shown were obtained from the acoustic sensors.

The sensor data showed that for the same average trawl speed, the SCSG had a slightly higher average values for the distance between the lower wing ends, trawl height and door distance compared to the rockhopper gear. However, the differences in average values were too small to be statistically significant.

Table 2: Average values and standard deviation (in brackets) values for diverse parameters registered for the rockhopper and the SCSG gear.

	Av. speed	Av. Dør distance	Lower wing distance	Trawl height
Rockhopper	3.7 (0.29)	123.2 (5.70)	16.5 (0.44)	4.9 (0.38)
SCSG	3.7 (0.29)	126.3 (3.50)	16.9 (0.75)	5.2(0.29)

3.3 Catch efficiency

A straightforward catch comparison analysis in suggests that the rockhopper gear has a higher catch efficiency than the SCSG for the length interval 56-75 cm. The curve also shows some length dependency in the length span where the amount of measured fish is biggest, but the length dependency does not show any steady pattern as the difference in efficiency between the gears first increases up to ca. 73 cm and it decreases thereafter.

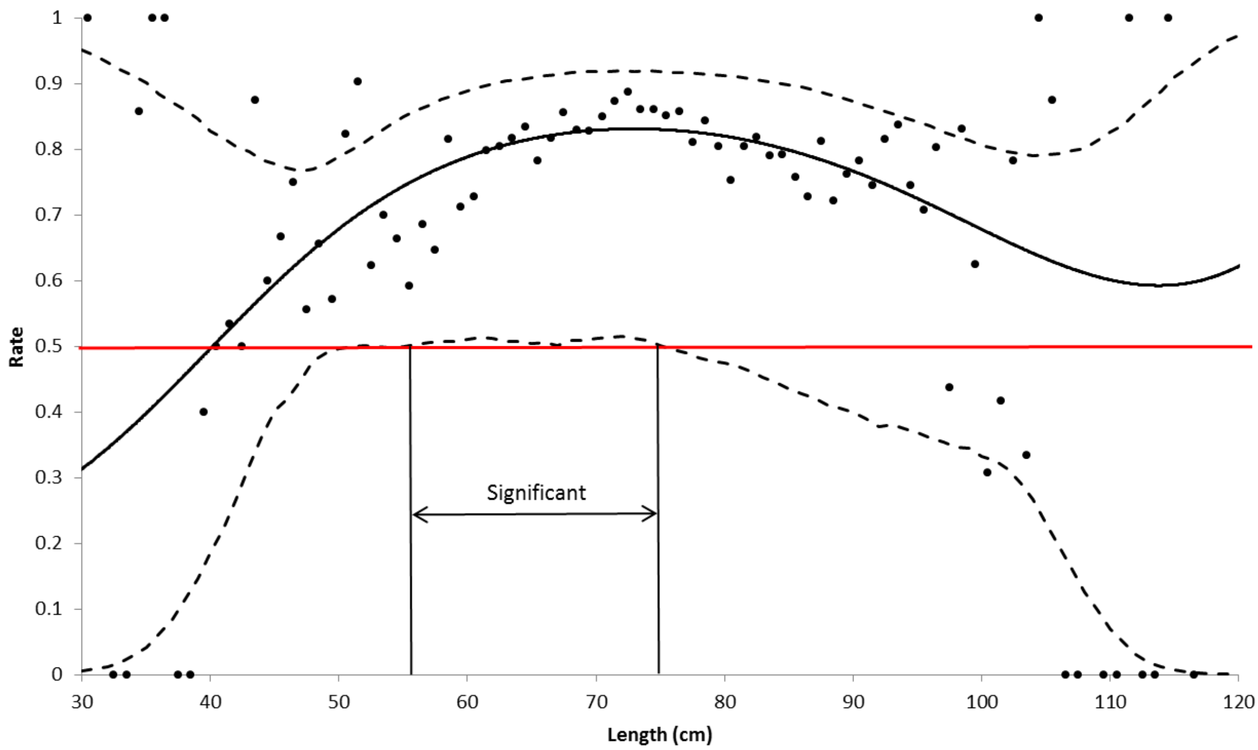

Figure 8: Catch comparison curve (full line) and confidence intervals (stippled lines) for the average catch comparison curve between the rockhopper gear and the SCSG considering all 8 collected haul pairs. The red line at 0.5 rate shows the point were both gears had had the same fishing efficiency; when the curve lies above this line the rockhopper is more efficient, and when the curve lies below the red line the SCSG is more efficient

The distribution of fish in ht earea was very patchy, and the towing time for most hauls was very short (10-20 minutes) and the availability of fish for the different hauls quite random and unbalanced. Therefore, we decided to carry out a "Jacknife" analysis (see Section 2.4) to investigate whether any of the pairs in the dataset had special influence in the results and whether this influence was profound enough to change the results significantly. The results of this analysis showed that haul pair number 2 indeed has a strong influence on the overall results (Figure 9).

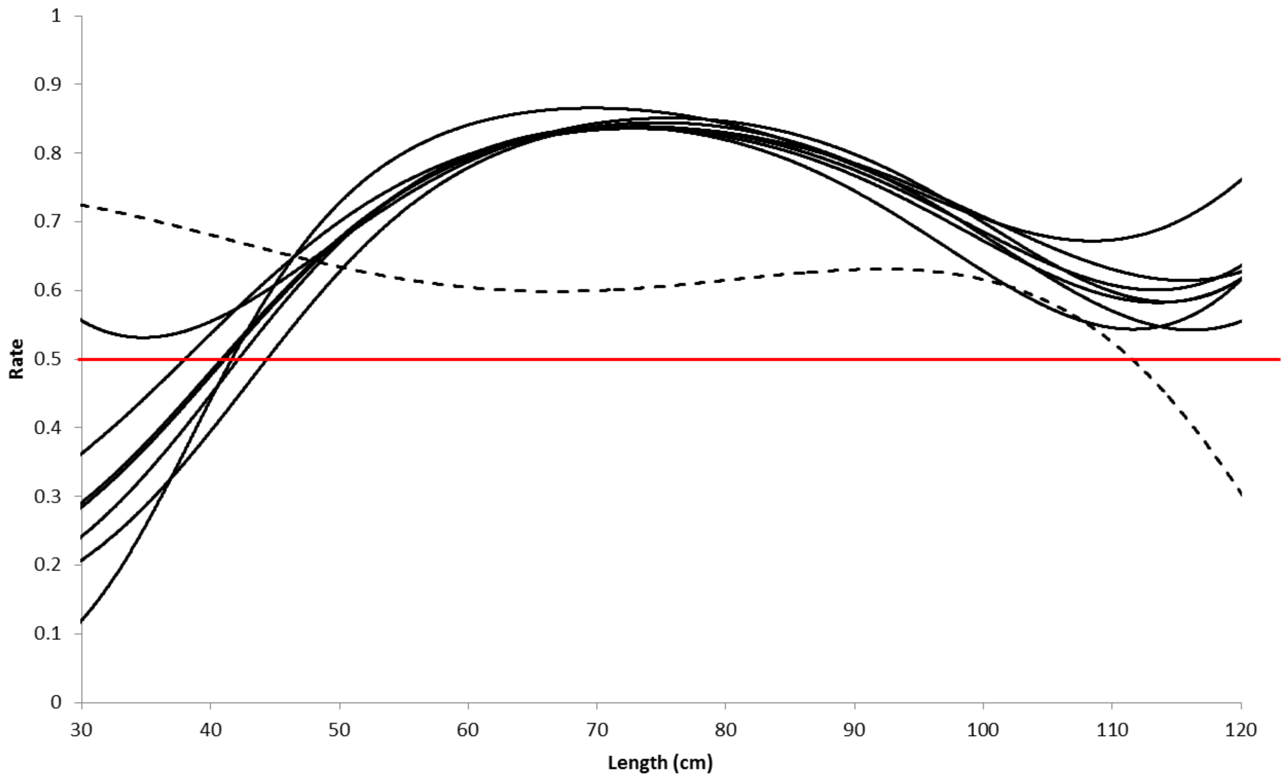

Figure 9: Jacknife showing how the mean catch comparison curve would look taking away one haul pair from the analysis at the time. The full black lines show similar results when haul pairs 1, 3, 4, 5, 6, 7 and 8 are withdrawn from the analysis. The stippled black line shows the case where haul pair nr 2 is withdrawn from the analysis. The red line at 0.5 rate shows the point where both gears had had the same fishing efficiency.

Thus, we run a final analysis of the data considering pairs 1, 3, 4, 5, 6, 7, and 8, i.e. excluding pair 2. The mean curve of this analysis (full curve Figure 10) is identical to the stippled curve in Figure 9. When haul pair 2 is withdrawn from the dataset the curve acquires a flatter shape in the zone between 50 and 100 cm (this is the length span where the amount of measured fish is biggest), which means that the potential difference in catch efficiency is non-length dependent. The confidence intervals for the average curve in Figure 10 show that the difference in fishing efficiency between the two gears become non-significant when haul pair number two is withdrawn from the dataset.

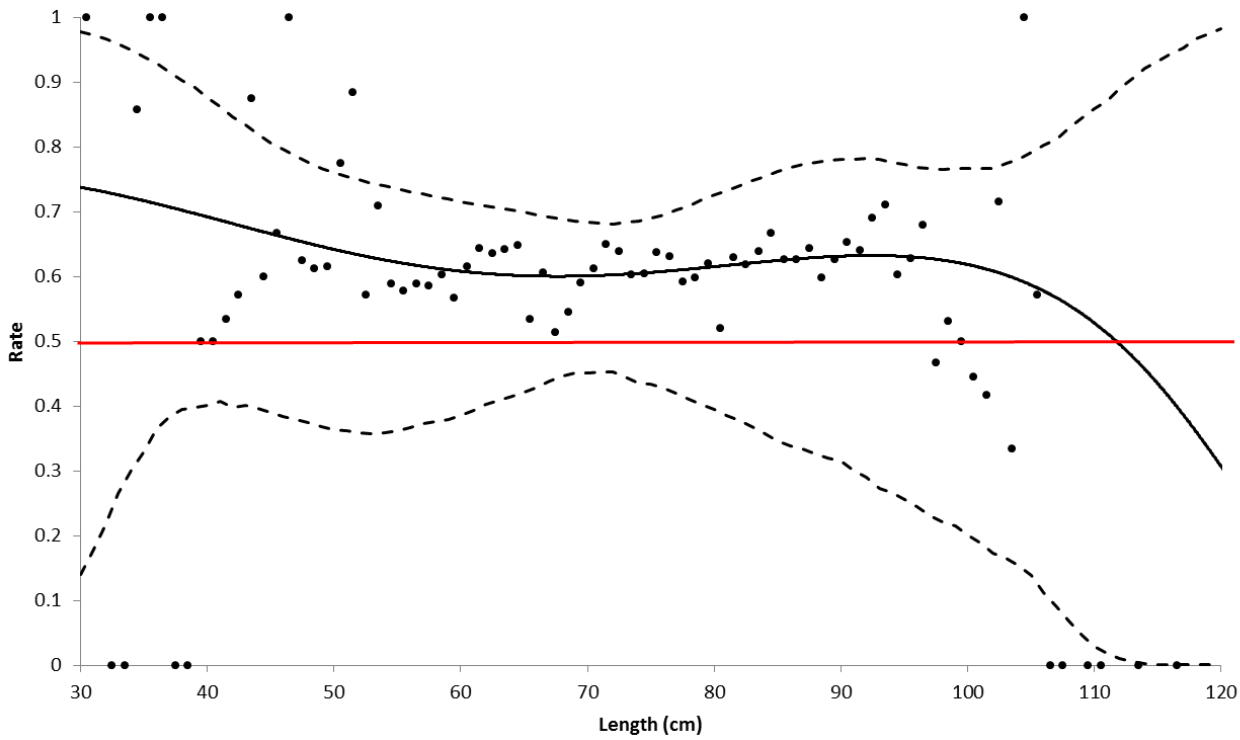

Figure 10: Catch comparison curve (full line) and confidence intervals (stippled lines) for the average catch comparison curve between the rockhopper gear and the SCSG considering all collected haul pairs except for haul pair nr 2. The red line at 0.5 rate shows the point where both gears had had the same fishing efficiency.

4 Discussion

This report describes a study carried out to follow up the initial tests of the SCSG in 2013.
The underwater recordings showed that the SCSG functioned well as a ground gear. These observations were also supported by the sensor data, which showed similar (slightly higher) spread and height values for the SCSG than for the rockhopper gear. In a previous study carried out with the SCSG, the lower wing end spreading was found to be approximately 7 % higher for the SCSG than for the rockhopper gear for the same door spreading and towing speed (Grimaldo et al. 2013). In the present trials, the SCSG was found to have approximately 2.5 % higher wing end spreading than the rockhopper gear. However, in this case the door spreading was also approximately 2.5 % higher for the SCSG case, hence, which could have contributed to the to the 2.5 % wider opening of the SCSG.

To run proper catch comparison studies, it is necessary that the fish in the fishing grounds is homogeneously distributed so that the availability of fish for the gears compared becomes close to equal over time. Other important parameters to consider are sufficiently many hauls and sufficiently long haul duration.

In the present trials, the catch comparison analysis is subject to a considerable degree of uncertainty, because of the patchy distribution of fish in the fishing areas, the limited number of hauls (16 hauls - 8 pairs), and the very short duration of most of the tows (15-20 minutes). The variability between the hauls is so high that the overall results can be very dependent on a few or even a single haul. Indeed, we found that haul pair 2 had such an influence on the overall results, see Figures 8-10.

We therefore argue that the results from these trails are more reliable when excluding this haul pair from the analysis. Then there were no significant differences between the catch efficiency for the rockhopper and SCSG. This is also in accordance with the video observations, showing that the amount of fish overrun by the SCSG was not higher than that overrun by the rockhopper gear. For the latter it has been estimated that as much as 1/3 of the fish in front of the gear is lost below or between the gear elements (Ingolfsson and Jørgensen, 2006).

The tests carried out in 2013 and 2014 indicate that the SCSG probably is at least just as efficient as the rockhopper, and that it gives a slightly higher wing end spreading. We may also expect that the closer spacing between gear elements can reduce the loss of fish, given that the SCSG maintains sufficient bottom contact. Further tests with the SCSG are therefore necessary, but must then be done during commercial fishing and over a longer period of time. The aim with these tests should be to:

- Improve the construction materials of the gear so that they stand commercial activity over a long period of time.
- Asses the performance of the SCSG based on the skipper's experience with this and the rockhopper over a period of time
- If feasible, compare the SCSG gear with a rockhopper gear over a high number of tows, preferably in a double trawl setup. In this manner much of the uncertainty created by the alternate haul method would not exist.

5 Acknowledgements

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