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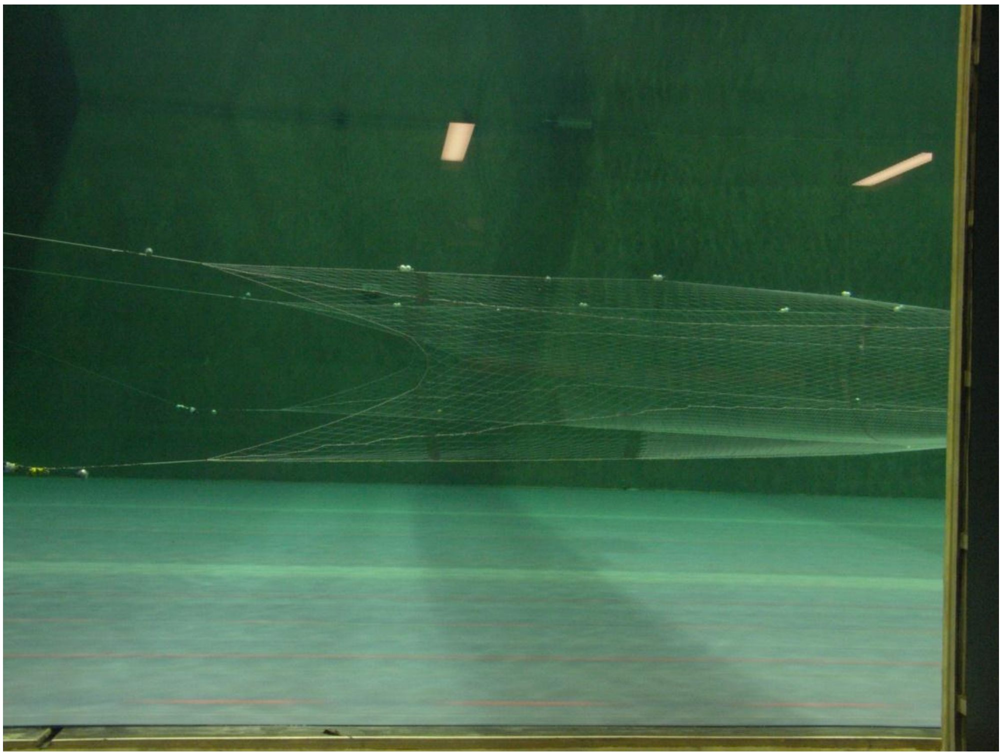
Report

New active fishing gear

Model tests and analysis of new design concepts

Author(s)
Kurt Hansen



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SINTEF Fiskeri og havbruk AS
SINTEF Fisheries and Aquaculture
Address:

NO-
NORWAY

Telephone:+47 40005350
Telefax:+47 98942226

fish@sintef.no
www.sintef.no/fisk
Enterprise /VAT No:
NO 980 478 270 MVA

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AUTHOR(S)
Kurt Hansen

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ABSTRACT

Flume tank tests

Two designs for a new active fishing gear were made, scale models constructed, and model scale tests performed in a flume tank.

Both net designs can be operated as a Danish seine, a semi-pelagic trawl or a pelagic trawl.

PREPARED BY Kurt Hansen	SIGNATURE
CHECKED BY Manu Sistiaga	SIGNATURE
APPROVED BY Vegar Johansen	SIGNATURE

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1 Introduction

The main conclusion of the workshop held in December 2009 was to further pursue the initial ideas presented at that time (for further information regarding the workshop see Winter and Gjøsund, 2010).
This report describes the development of two concepts: A combination seine and a seine design based on the Y-design principle, which enables the designer to control a larger part of the net. The principle is described in detail in the materials and method section. A scale model for each concept was tested in the flume tank. The tests were made with the two nets operated as pelagic and semi pelagic trawls. The nets were also tested in a number of conditions representing the different phases of a seining process.

2 Materials and methods

The different configurations tested in the trials presented in this report are listed in the table below. This table is only a sub set of the original test matrix presented after the workshop held in December 2009 (Winter and Gjøsund, 2010). The main difference between the original test matrix and the one presented below is that the rockhopper gear and the improved plate gear have been removed. During the process of specification of the nets it was concluded that a 160 m long rockhopper or plate gear would be impossible to handle on the vessels. It was also foreseen that it would be difficult to implement vertical kites on the wings of the nets, and they were therefore also removed from the test matrix.

Configuration	Main design concept						Ground gear		Spreading device	
	Combination seine			Y-design						
	Pelagic	Semi Pelagic	Seine	Pelagic	Semi Pelagic	Seine	Skirt	Chains	Pelagic Doors	Ropes
1	x								x	x
2		x					x		x	
3		x						x	x	
4			x				x			x
5			x					x		x
6					x			x	x	
7				x				x	x	
8						x		x		x
9						x	x			x

2.1 Main design concepts

The two different basic designs of the combination seines / trawls are shown in A.1 and 0.

2.1.1 Combination seine

The combination seine can be classified as a normal four panel net design where the reduction of the twine area (hence the towing resistance) is emphasized. The headline and footrope are hung using drop meshes to give a controlled opening to the meshes in the front end of the net. The nominal mesh size in the upper panel and the side panels are specified to be 800 mm (full mesh). In the belly section of the net a smaller mesh size -150 mm- is used. The full stretched circumference of the net is 250 m (measured around the fishing circle). The net is designed with very long wing sections and the headline length is approximately 170 m. Note that the mesh size given in the net plan is given as half mesh size.

2.1.2 Y-design

The Y-design net is also 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 A.2 that one selvedges 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 A.2 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 151 m. The mesh sizes given in the net plan is full mesh size.

2.1.3 Seining process

The seining process is dynamic, therefore the geometry of the fishing gear, the tension in the seine ropes and the speed of the net through the water change throughout the process. In the beginning the ropes are lying on the sea bed and the wings of the net are spread (the distance between the wing-ends is only limited by the length of the headline). At this stage, the net has a huge vertical opening. When the vessel starts to recover the ropes, the distance between the wing ends will gradually decrease. So will the vertical opening because the speed of the net through the water will create a force that counteracts the lifting force of the floats.

2.2 Scaling method

The two designs were built as scale models. The traditional scaling method was used in the specification of the scale models:

The linear scale ratio of the models λ_l= 1:25.
The area scale ratio λ_a =1:625.
The speed scale ration λ_v = 1:5.
The force scale ratio will then be λ_f = 1:15625 $\lambda_f = \lambda_a * \lambda_v^2$.

To achieve buoyancy in the tested models, small model scale floats (250 pieces of 8 inch deep sea floats) were attached to the headline in 7 bundles. Along the fishing line, a "skirt" made of netting (with a mesh size in 150 mm and 8 mm twine diameter) was attached to reduce the risk of tearing up the seine.

2.3 Instrumentation

The models were tested in the flume tank operated by SINTEF Fisheries and Aquaculture in the North Sea Research Centre (Hirtshals, Denmark). The main particulars of the flume tank are shown in A.3.

The tension in the towing warps or seine ropes were measured using “in line strain gauge load cells”. These load cells are supplied by the American company FUTEK (see the description in the company web site http://www.futek.com/files/pdf/Product%20Drawings/lsb210.pdf). The data logger used for the registration of the tension data is SPIDER 8, which is manufactured by the German company HBM (see the specifications in the web site http://www.hbm.com/en/menu/products/measurement-electronics-software/universal-data-acquisition-systems/standalone-daq-devices/single/categorie/daq-standalone/product/spider8/).

The geometry of the fishing gear is measured using the motion tracking system from Qualisys (see the website http://www.qualisys.com for further information). To obtain the net geometry data from qualysis, a three step procedure is followed:

1. A number of reflectors are attached to key positions in the fishing gear.
2. The spatial positions of these markers are registered by a tracking software.
3. The main geometry of the gear can be deduced from these data.

The figure below shows the combination seine tested as a pelagic pair trawl. The markers are attached to the wing-ends around the bosom and on the joints below the individual net sections in the belly.

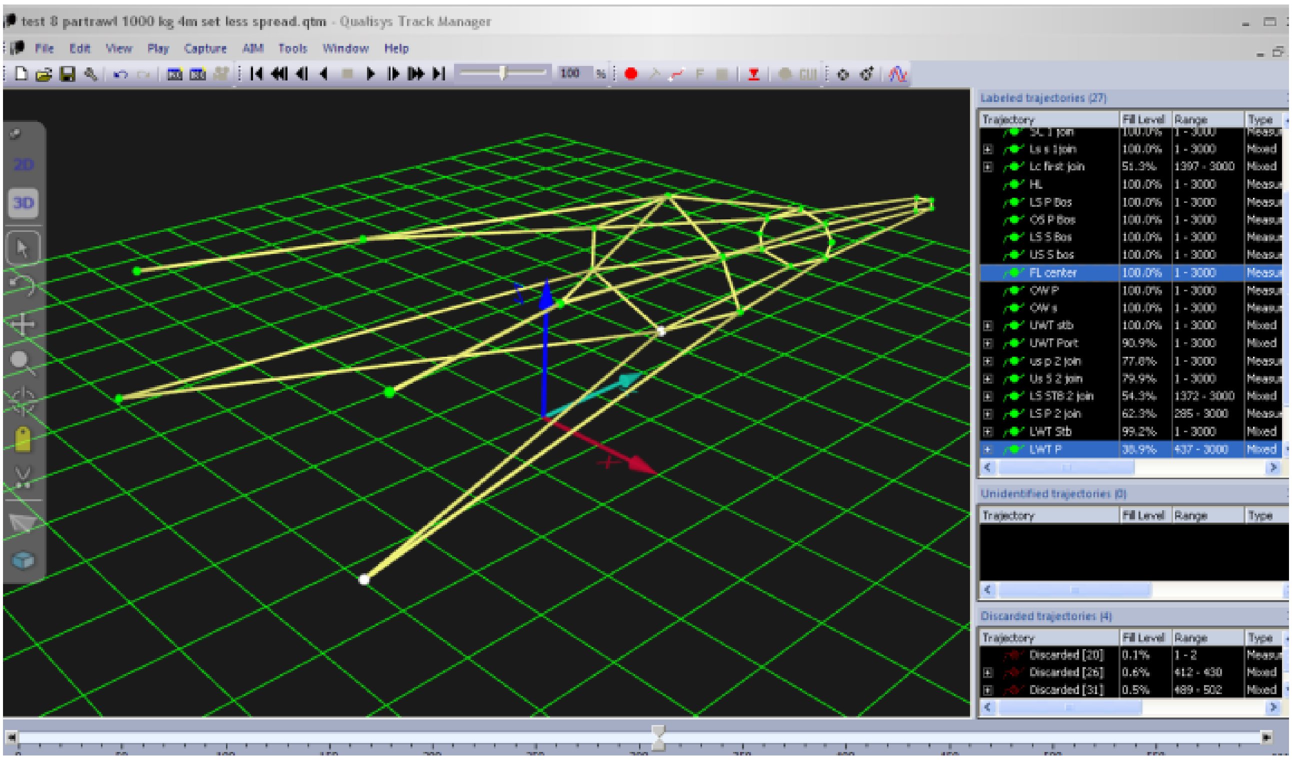

Figure 1: An example of the output from the motion tracking software used in the analysis of the performance of the seine models.

The seining process is very difficult to simulate in the flume tank because it is a dynamic process. It was therefore decided to make a number of snapshots where the conditions were kept constant. The geometry and rope tension was measured within a time frame. Changes were then made to the rope distance or towing speed and once a new steady state was achieved a new measurement was made. The geometry and tension were described following this procedure throughout the seining phase.

One of the objectives in the tests was to use the combination net as a semi pelagic trawl as well. A series of tests to measure the performance of the net were therefore made. The parameters measured were: horizontal and vertical openings of the net, the tension in the tow wires in front of the trawl doors in the single boat trawl case, and the tension in the single sweeps in the pair trawl case.

3 Results

3.1 Combination seine

3.1.1 Pelagic pair trawling

The results from the tests with the combination seine used as a pelagic pair trawl are shown in the table below.

Table 1: Test of combination seine operated as a pelagic pair trawl with different combinations of speed, horizontal openings, setback in lower bridles and wing-end weights.

Set back 2 m, clump weights 500 kg						
Speed	knots	2.0	2.5	3.0	3.5	4.0
Wing-end spread	m	78.5	77.2	75.8	75.3	75.4
Bosom height	m	22.2	19.9	18.3	16.7	15.2
Bosom width	m	39.1	38.7	37.4	37.1	37.2
Spread of 1. Join	m	17.6	17.7	16.5	16.5	16.8
Warp load per side	kg	4305.0	5373.0	6497.0	7890.0	9777.0
Speed	knots	2.0	2.5	3.0	3.5	4.0
Wing-end spread	m	62.8	61.3	59.8	58.7	58.4
Bosom height	m	22.8	22.8	21.7	20.6	19.8
Bosom width	m	35.5	33.8	32.6	31.5	30.9
Spread of 1. Join	m	17.7	16.9	15.9	14.9	14.8
Warp load per side	kg	4009.0	5083.0	6137.0	7490.0	9243.0
Set back 4 m, clump weights 1000 kg						
Speed	knots	2.0	2.5	3.0	3.5	4.0
Wing-end spread	m	62.2	62.9	60.5	59.7	59.4
Bosom height	m	26.4	24.6	24.0	22.5	21.8
Bosom width	m	33.9	34.5	32.4	31.7	31.1
Spread of 1. Join	m	16.3	17.4	15.8	15.2	15.1
Warp load per side	kg	4486.0	5685.0	6847.0	8240.0	10106.0
Speed	knots	2.0	2.5	3.0	3.5	4.0
Wing-end spread	m	80.6	79.3	77.5	77.3	76.4
Bosom height	m	23.0	21.2	19.7	18.1	17.1
Bosom width	m	40.4	39.7	38.0	38.3	37.7
Spread of 1. Join	m	18.8	18.7	17.0	16.7	17.0
Warp load per side	kg	4861.0	5990.0	7238.0	8651.0	10788.0

The horizontal distance between the wings was controlled by the length of the ropes and the position of the towing masts. When the net is operated in this way, the vertical opening will vary between 15 and 22 m when the towing speed is varied between 2 an 4 knots. At the same time the towing load of the net will increase from 84,000 N to 212,000 N when the distance between the wing tips is kept at 75 m.

3.1.2 Semi pelagic and pelagic single boat trawling

Table 2 gives information on the performance of the net when it is operated as a single boat trawl. The first nine tests shows the performance when the net is operated as a semi pelagic trawl sitting light on the seabed. In the last 2 conditions the net is operated as a pelagic trawl. This complies with row 2 and 3 in the test matrix. The results are only shown for the chain condition because it was not possible to measure any difference between the tests where a chain fishing line was used and the tests where a skirt was used.

The heights of the towing points were adjusted to keep the clump weights, which are attached to the lower wing-ends, just touching the tank floor. These adjustments correspond to a change in the wire length in real trawl operation. The vertical trawl opening decreased from 18.3 m at 2 knots to 12.2 m at 3.5 knots keeping the rest of the conditions constant (500 kg weights were attached to the lower wings and lower bridles were 2 metres longer than the upper bridles). The corresponding tension in the trawl wires varied from 100,000 N at 2 knots to 250,000 N at 3.5 knots.

An increase in the wing tip weight and the set back of the lower wing will bring along the possibility of keeping the trawl in contact with the seabed even when the trawl is towed with shorter wires. The vertical distance between the upper wings and the seabed is increased but the vertical opening of the centre of the trawl is almost constant.

The horizontal distances between the side panels and the vertical distances between the upper and lower panel were measured at 3 different positions in the trawl belly. The horizontal distances seem to increase with increasing towing speed and the vertical distances tend to be reduced when the towing speed is increased at the three positions measured.

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Table 2: Test of combination seine operated as a semi pelagic and pelagic trawl by one vessel, where different combinations of speed, horizontal openings, setback in lower bridles and wing end weights are analyzed.

Company	**SINTEF Fisheries and Aquaculture**	**Model No:**	**M1005**
Trawl	**Combination Seine**	**Scale:**	**1 : 25**
Trawl doors	**Pelagic doors**		

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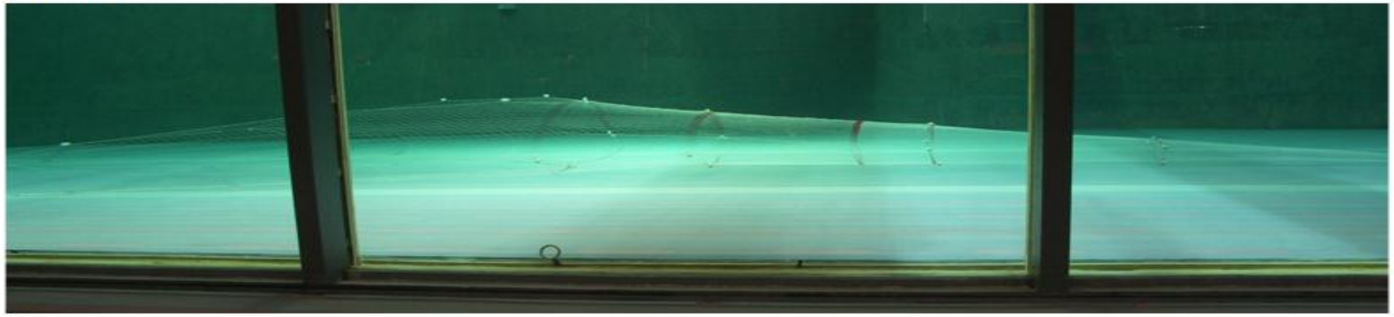
Sweepline	m
Bridles	75
Set Back	2 m
Clump Weights	500 kg
Other	



Test			1	2	3	4	5	6	7	8	9	10	11
Towing speed		knots	2,00	2,50	3,00	3,50	2,00	2,50	3,00	3,50	3,50	3,50	3,50
Distance between doors		m	128,9	130,4	132,5	133,1	131,2	132,6	131,6	128,6	103,1	103,8	77,6
Spread	Headline	m	82,2	83,9	84,9	85,6	83,9	83,5	84,4	84,5	69,6	69,8	54,3
	Bossom	m	41,7	45,0	45,7	47,0	45,2	45,2	46,0	47,7	42,1	39,5	31,8
	1. join	m	26,8	32,9	33,6	34,7	32,8	33,2	34,4	34,9	32,2	30,4	24,6
	2. join	m	11,5	11,6	12,0	12,5	12,1	12,3	12,9	13,0	13,6	12,3	11,5
	3. join	m	3,5	4,5	4,6	4,7	4,6	4,7	4,8	4,8	4,7	4,3	4,2
Height	Wingend	m	15,6	15,2	14,0	11,3	19,7	18,9	16,3	15,1	14,3	13,9	14,1
	Centre	m	18,3	15,2	14,1	12,2	17,6	16,0	13,4	11,8	12,6	14,1	18,2
	1. join	m	10,3	11,6	10,9	9,5	9,9	8,2	NA	NA	NA	NA	10,0
	2. join	m	8,2	7,5	7,1	6,5	8,0	7,6	6,9	6,3	6,0	6,8	7,3
	3. join	m	4,1	4,4	4,3	4,1	4,5	4,2	3,9	3,7	3,7	4,0	4,3
Tension per side		tons	5,1	7,3	9,8	12,7	6,3	8,2	10,8	13,8	12,5	12,2	11,4

Test	Notes	Test	Notes
1	Rigged with 2m set back and 500 kg Clumps	9	As test 5 Less spread
2	As test 1	10	As test 5 trawl in mid water
3	As test 1	11	As test 5 trawl in mid water
4	As test 1		
5	4 m set back and 1000 kg Clumps		
6	As test 5		
7	As test 5		
8	As test 5		

3.1.3 Danish seining

In Figure 2 a time series of a seining process with the combination seine is shown. This complies with row 4 and 5 of the test matrix. The towing speed is gradually increased from 0 to 2.0 knots. When the maximum speed is reached the towing masts in the flume tank are moved towards the centre of the tank following a step by step procedure. This time series provides simultaneous data for horizontal and vertical distances. The table gives data for the vertical and horizontal distances when the distance between the wing-ends is kept constant for a period.

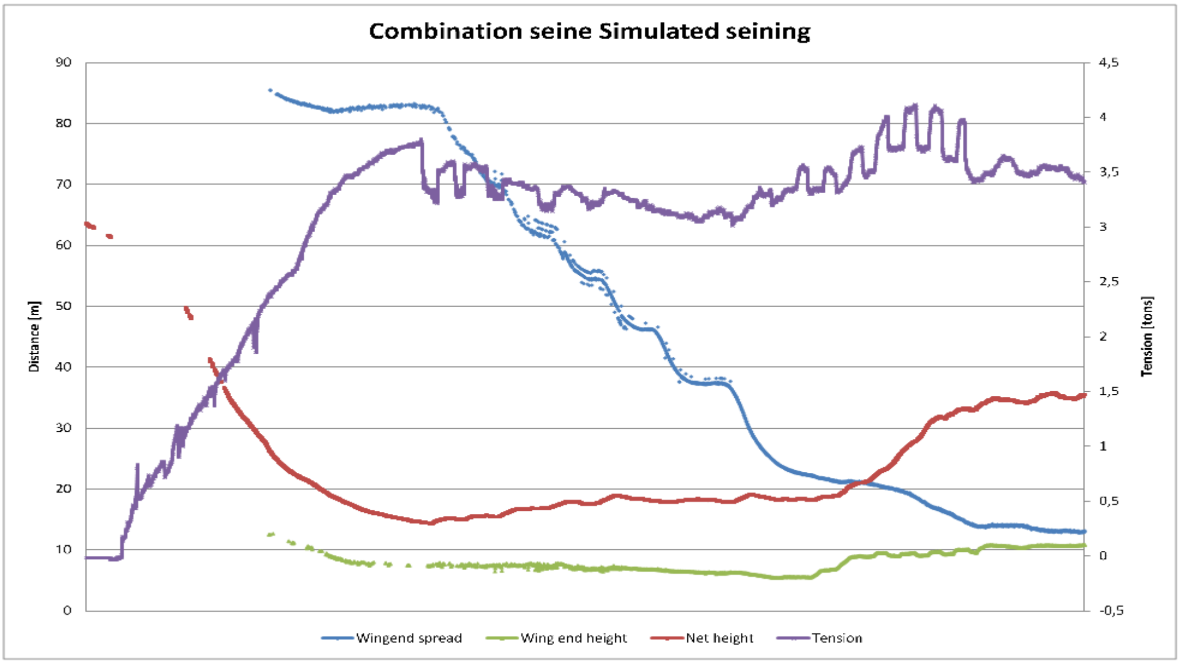


Figure 2: Time history of the seining process tested for the combination seine. Wing end spread, wing end height, net height and tension in ropes are shown.

Table 3: Measurement of performance of the Combination Seine in different phases of the seining process. Results include Wing end spread, bosom height and tension in ropes at constant speed.

Test	Speed (knots)	Tension in ropes (N)	Bosom height (m)	Wing-end height (m)	Bosom width (m)	Wing end spread (m)
1	2	36719	14.8	7.4	36.1	83
2	2	34917	15.5	7.4	33.9	73.9
3	2	33028	16.7	7.4	31.6	63.1
4	2	32184	17.7	6.9	29.1	55.4
5	2	31687	18.4	6.9	25.9	46.5
6	2	30067	18.2	6.3	22.8	37.4
7	2	31962	18.2	5.4	18.3	23.9

3.2 Y-design net

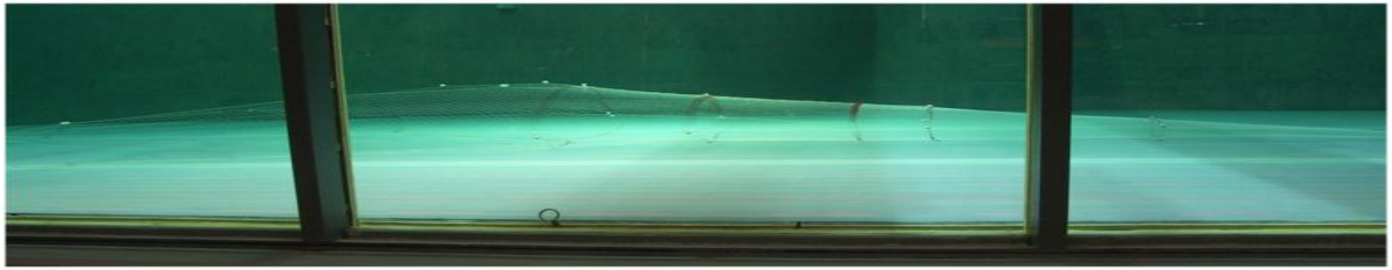
3.2.1 Semi pelagic and pelagic trawling

Table 4 shows the net, when it is used as a single boat pelagic trawl and semi pelagic trawl. Towing speeds between 2.0 and 3.5 knots were analysed and the corresponding values of vertical opening, horizontal opening and tension in the towing warps were recorded. The rigging conditions were the same as for the conventional experimental seine.

Table 4: Test of Y-design net operated by one vessel as semi-pelagic and pelagic trawl. Different combinations of speed, horizontal openings, wing end weights and extension in the lower bridles are analyzed.

Company	**SINTEF Fisheries and Aquaculture**	**Model No:**	**M1012**
Trawl	**Y-design Net**	**Scale:**	**1 : 25**
Trawl doors	**Pelagic doors**		

Sweepline		m
Bridles	75	
Set Back	2	m
Clump	500	kg
Weights		
Other		



Test			1	2	3	4	5	6	7	8	9	10	11	12
Towing speed		knots	2,5	3,0	3,5	2,0	2,0	2,5	3,0	3,5	3,5	3,5	3,5	3,5
Distance between doors		m	130,0	130,9	131,2	127,7	128,2	128,6	129,4	131,1	103,7	102,2	72,4	105,0
Spread	Headline	m	80,3	82,5	83,1	81,6	81,1	80,8	82,6	81,8	69,6	69,1	51,1	68,8
	Bossom		49,6	49,6	50,9	50,6	49,7	50,3	50,6	51,0	45,9	44,7	34,8	41,5
	1. join			33,1	33,8	32,5	33,6	34,4	34,4	36,1	33,3	33,7	28,2	31,2
	2. join	m	17,3	17,6	18,1			17,6	17,5	19,0	21,3	18,2	17,4	16,6
	3. join	m	7,7	7,4	6,7	8,1	7,5	7,9	7,7	7,7	8,0	7,6	7,7	7,3
Height	Wingend	m												
	Centre	m	12,3	11,6	8,8	14,5	14,9	13,2	11,7	10,2	12,3	14,2	21,1	16,6
												12,2	18,5	14,8
												10,6	11,6	12,8
												5,9	6,6	7,1
Tension per side		tons	7,4	9,8	12,4	5,7	6,1	8,2	10,7	13,6	13,1	13,1	12,9	12,5

Test	Notes	Test	Notes
1	Original rig	9	Smaller distance between doors
2	As test 1	10	Mid water as test 5
3	As test 1	11	Mid water
4	As test 1	12	Rigged with 2 m setback and 1000 kg clumps in mid water
5	Rigged with 4 m setback and 1000 kg clumps	13	As test 12 trawl on seabed
6, 7, 8	As test 5		

In tests one to four 500 kg clumps were attached to the wing ends and the lower bridle were 2 m longer than the upper bridles and the net is operated as a semi pelagic net.The measured vertical opening of the net varied from 14.5 m at 2 knots towing speed to 8.8 m at 3.5 knots with the clump weights kept on the sea bed. The width measured at the fishing circle was approximately 50 m for the 4 different towing speeds tested. The tension in the towing warps varied from 112000 N at 2.0 knots to 243000 N at 3.5 knots.

Similar tests were made with 4 m longer lower bridles and 1000 kg clumps attached to the wing ends. These tests are numbered five to test eight. The main difference was that the vertical opening of the net was increased by approximately one meter. Test nine is made with the same rigging as the previous tests but with a smaller distance between the trawl doors. Test ten to twelve shows the nets performance, when it is operated as a single boat pelagic trawl.

3.2.2 Danish seining

In the results from the tests in Table 5 a constant towing speed of 2 knots is assumed. The distance between the towing masts in the flume tank and hence the horizontal distance between the wings was reduced. The net was then analysed with respect to horizontal and vertical distances at more positions in the belly. The tests numbered 1-7 in the table show results when the net is rigged with even bridles and the tests numbered from 9 to 13 are when the upper bridle is 1 m longer than the lower bridle.

Table 5: Measurement of performance of the Y-design net in different phases of the seining process. Results include wing-end spread, bosom height and tension in ropes at constant speed. The geometry of the belly sections of the net is also given in the table.

Test	Speed	Tension in ropes	Vert opening 3. Join	Vert opening 2. Join	Vert opening 1. Join	Bosom Height	Wing end height	Width of 3. Join	Width of 2. Join	Width of 1. Join	Bosom width	Wing end spread
	[knots]	N	m	m	m	m	m	m	m	m	m	m
2	2	47762	NA	NA	10.6	13.3	4.3	NA	19.6	36.3	48.2	72.3
3A	2	47320	NA	7.2	11.2	14.1	4.4	6.9	20.8	35.5	45.1	62.9
3	2	46836	NA	NA	11.2	14.1	3.9	7	20.8	35.3	45.3	62.8
4	2	46116	NA	7.2	11.7	15.1	4.2	7.3	21.6	35.6	42.5	55.6
4A	2	49096	NA	7.9	12	15.5	4.4	10	21	32.1	41.6	54.9
5	2	49242	NA	9	13.7	17.6	4.4	10.3	20.1	28	36.8	46.1
5A	2	49012	NA	9	13.8	17.8	4.6	10.5	20	28.1	36.7	45.9
6	2	40851	7.3	12.4	17.9	22.1	5.1	9.8	15.4	22.7	28.7	34
7	2	44540	10.4	NA	22.7	26.9	5.9	7.8	8.8	14.3	15.3	18.8
9	2	45713	NA	7.7	10.7	12.8	5.6	9	16.1	37.2	52.1	84.3
10	2	49424	4.1	7.5	11.1	13.8	5	9.3	19.2	35	47.8	70.8
11	2	41133	4.4	8.2	12.5	16.1	4	9.9	20.8	33.3	41.5	49.1
12	2	45419	6.4	11.9	17.8	22	3.9	9.3	17	24.7	28.1	18.7
13	2	40169	9	15.9	22.5	26.9	5.4	7.1	7.4	14	13.1	0.2

4 Discussion

Two different downscaled net designs of an active fishing gear were designed, built and tested. The first net was built as a four panel net with relative small side panels and long wings. The intention was to make a net that would maintain a good vertical opening even with a large horizontal distance between the wing-ends. The second design, which was constructed using the Y-design principle in the front part of the net, was made to see if it was possible to make a net with a larger opening volume in the aft end of the belly.

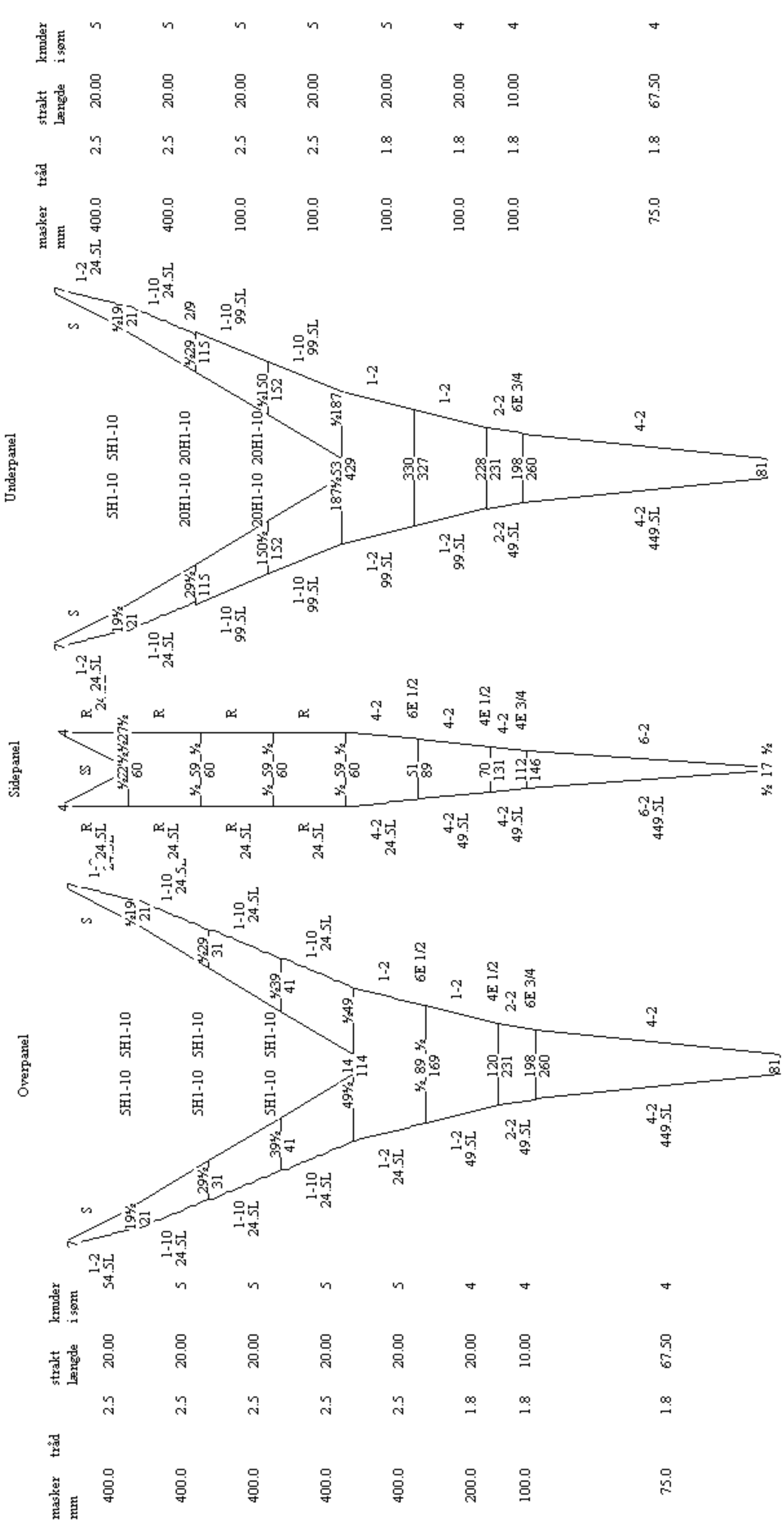
It can be concluded that the geometry in the front part of the two nets was nearly identical when tested at the same speed and with the same distance between the wing-ends. The transversal area of the aft end of the belly was much larger in the net where the Y-design principle was incorporated compared to the conventional net constructed in four panels. This indicates that more water would be filtered through the aft end of the belly, which is thought to be advantageous for the catching ability of the net.

The larger area will give a slightly larger towing resistance because the mesh size is smaller in this part of the net, but this higher towing resistance is believed to be compensated by better catch ability.

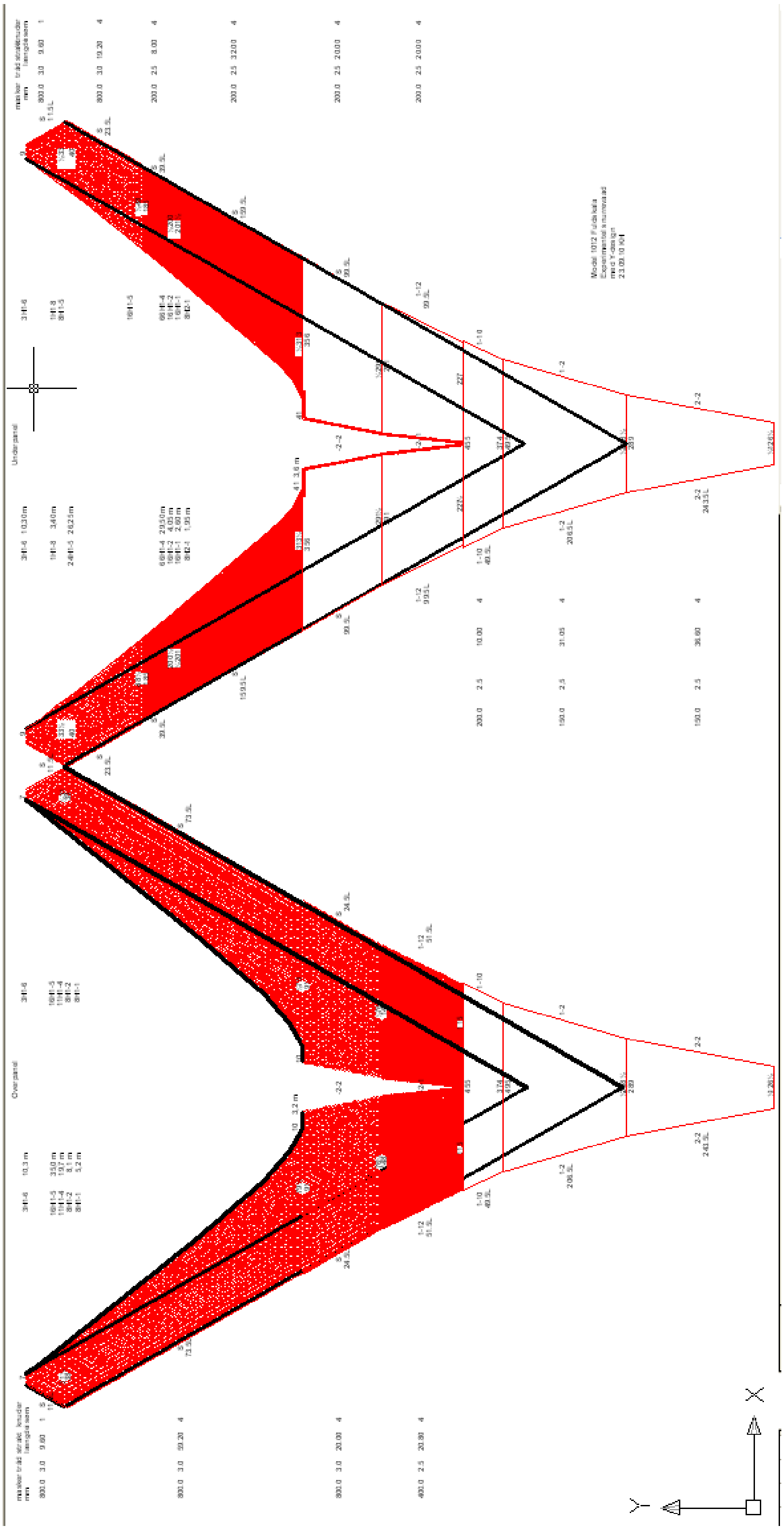
5 References

Winter, M. And Gjøsund, S.H., 2010. New active fishing gear. Report from project workshop in Hirtshals, Dec. 14-15 2009. SINTEF report NO. SFH80 A103023. Unrestricted. ISBN 978-82-14-04942-8.

6 Appendices



A.1 Combination seine full scale net plan



A.2 Y-design net full scale net plan

A.3 Description of the Flume Tank

Technical information:

Dimensions
Over-all: L: 30, H: 6, W: 8 m
Measuring section 21.3, 2.7, 8 m.
Volume of water: 1200 m³.
Windows: 20 2x3 m

Propulsion
Four propellers and motors 55 KW generate the flow.

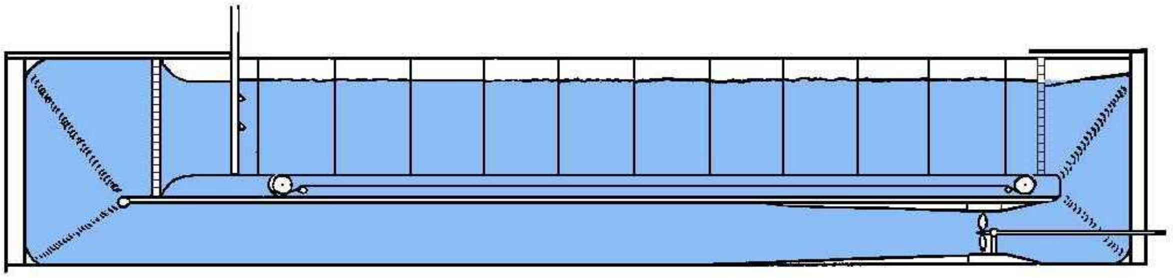
Velocity
Maximum water speed: 1 m/s
Max. simulated towing speed in scale 1:5: 4,5 knots
Max. simulated towing speed in scale 1:20: 12 knots

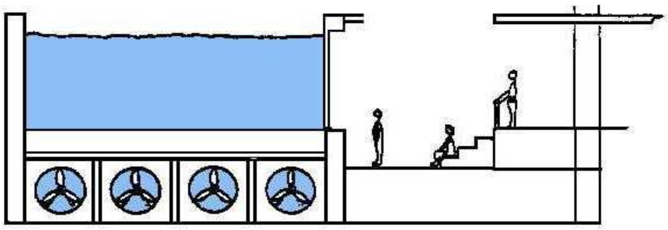
Artificial bottom
Conveyer belt type made of nylon. Speed adjustable,
can be locked with water speed.

Equipment for measuring
Object measuring: A full measurement of geometry in three dimensions is made by remote controlled video system.
Resistance and drag: Load cells using strain gauge technology. Series of load cells can measure strain from a few grams to 100 kg. Measurements are monitored by a data-logger system and converted to full-scale values.

Lights
Above the tank: 18 x 400 W daylight floodlights.
Movable on a 3x2 m frame: 6 x 1.500 W floodlights.

Video
Movable cameras are permanently displaying: Front view, in colour, top view (two cameras for spread measuring), side view (for height measuring).
Professional studio camera for documentation of tests is available.
Video hardcopy printer making prints on paper from all the installed cameras





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