Toktrapport/Havforskningsinstituttet/ISSN 15036294/Nr. 13-2019 English version

Research Cruise Report [2021825]: FV "Vikingbank"

Catch Control in the Blue Whiting Pelagic Trawl Fishery.

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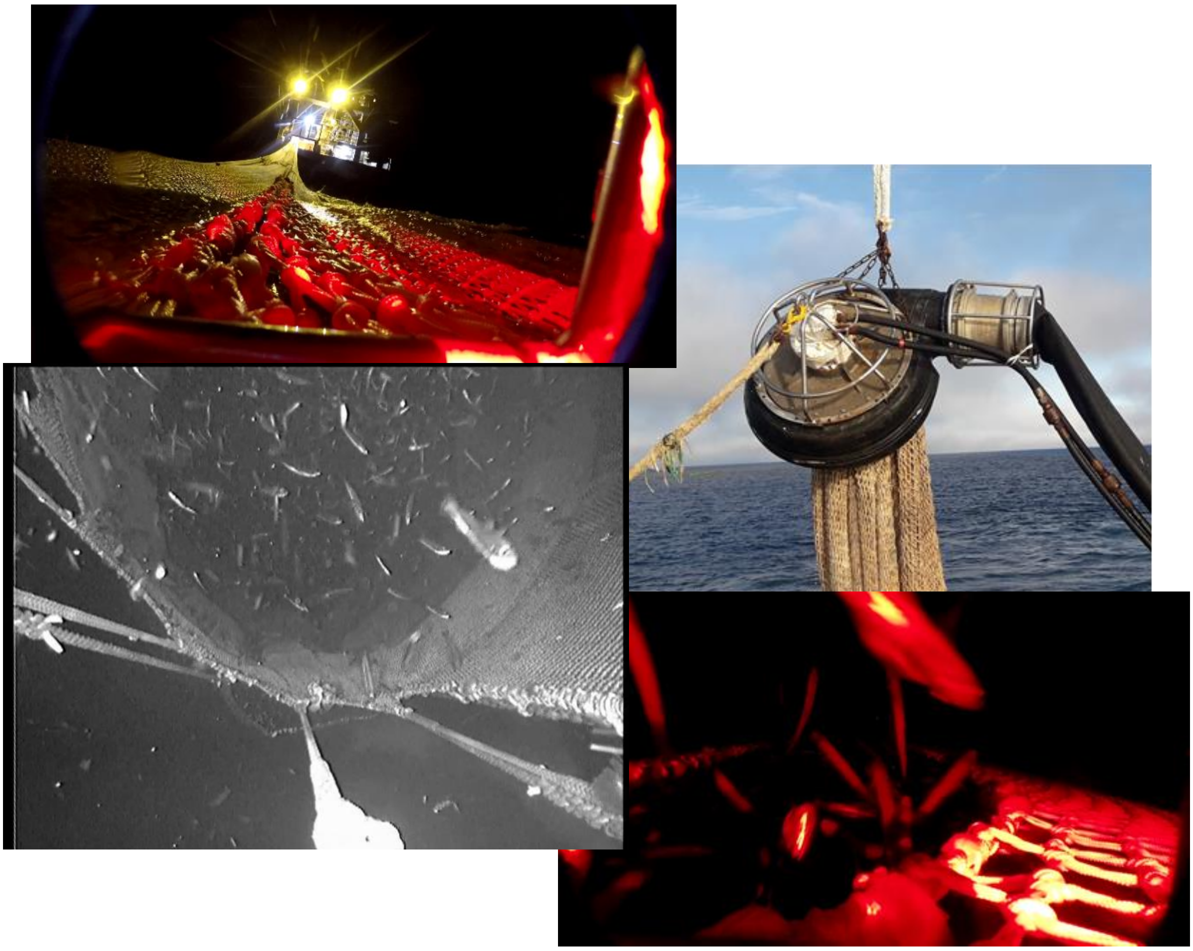

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1. Background

In 2017, the Norwegian Seafood Research Fund (*Fiskeri- og havbruksnæringens forskningsfinansiering*; FHF) received input from blue whiting fishermen recommending that research should be conducted to investigate challenges regarding catch control and health and safety in the blue whiting fishery. The Institute of Marine Research (IMR), the Directorate of Fisheries (FDir) and FHF contributed to a feasibility study, with the aim of investigating the likely causes of bursting and sinking codends in the blue whiting fishery in the north-east Atlantic. This preliminary study revealed 3 main challenges:

1. A danger of bursting and sinking trawl codends bags at the surface, following explosive decompression of the captured blue whiting (and their swimming bladder gases) due to a rapid ascent from fishing depths of >400m.
2. The wastage of large quantities (often hundreds of tonnes) of fish in the event of a bursting codend,
3. The risk to the safety of the vessel and crew in the event of a bursting codend following an explosive ascent or during the retrieval of a sinking codend.
4. The need to regulate catch volumes more effectively; specifically limiting catch sizes to manageable quantities that remain within individual vessel capacity and quota limits.

The preliminary results were used as a justification for a project to specifically address these challenges, Catch Control in the Blue Whiting Fishery [*Fangstkontroll i fisket etter kolmule, FHF-prosjekt nr 901542*], which commenced in 2019. The project's goal is to find methods that reduce the risk of bursting and sinking codends in the blue whiting fishery, as well as regulate the catch based on the remaining load capacity of the vessel.

The first research cruise of this project was conducted in March, 2019 (Kvalvik & Lilleng, 2019). It investigated the effectiveness of a catch limitation system and codend release mechanism, both of which were based on principles used in the Norwegian demersal seine net fishery for cod. Depth sensors were also mounted on the entire trawl, to monitor the geometry of the trawl, particularly during haul-back. Observations of the catch limitation and release mechanisms were made using underwater camera systems, capable of enduring the hydrostatic pressures at fishing depths >400m. The work did not specifically focus on vessel and crew safety because mitigation of risks due to bursting and sinking codends will be a direct benefit of achieving effective catch control.

1.1. Cruise Aim and Objectives.

The aim of this research cruise was to further develop the catch control methods and technologies initially investigated in cruise one by addressing the following objectives:

1. Investigate the effectiveness of three designs of catch control rigs to retain target catch during fishing operations and then release excess catch once the catch limited is reached.

2. Investigate the effectiveness of the catch limit release mechanism on the trawl codend (Prototype by Foss Tech).; https://www.fosstech.no/pressure-operated-actuator.html

3. Monitor the geometry of the trawl and codend, particularly during haulback.

4. Develop methods for the rapid release of the pump from the trawl codend, as a countermeasure in the event of sinking codends.

5. Develop methods to assess the vitality and injuries of fish being released from the catch control rigs.

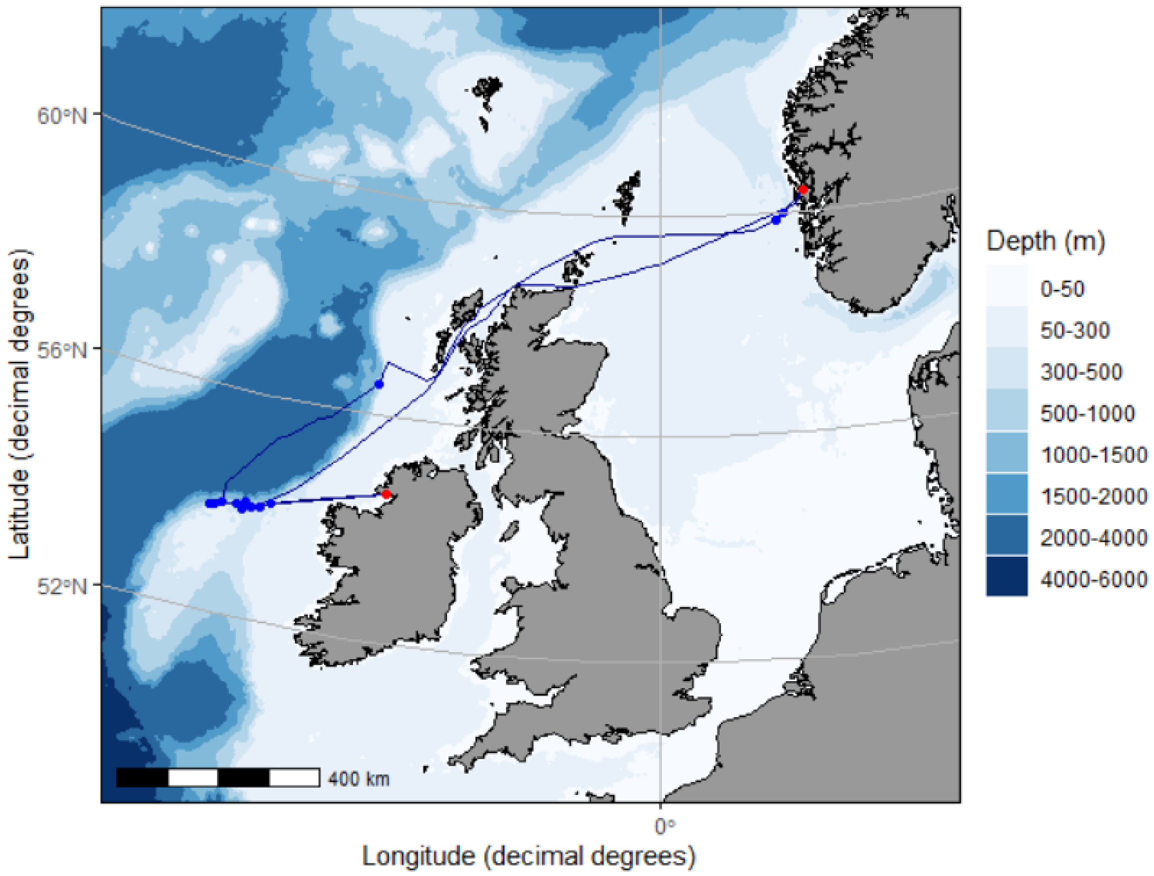


Figure 1 – Chart of cruise track (dark blue line), trawl hauls (blue points) and harbours visited (Bergen, Norway, and Killybegs, Ireland; red points). Details of the purpose, times and detailed positions of the trawl hauls can be found in table 1.

2. Narrative

The research cruise began on 9th March, 2021, at Nykirkekaien, Bergen, where the vessel (MF Vikingbank, R-3-K) was loaded and prepared. To reduce the risk of infections from COVID-19 during the cruise, the fishing and scientific crews had observed a ten-day quarantine (in accordance with national and institute guidelines). In addition, all scientific crew-members took COVID-19 tests prior (<4 days) to embarking; the results of which were presented with self-declaration forms to the skipper before embarkation.

The vessel left Bergen harbour at 1205 (UTC) on 9th March, 2012 and sailed directly to deep water off the coast of Norway to conduct some test hauls, before proceeding to the UK sector. The vessel entered UK waters on 10th March at 03:00 [59.68 N 1.95 E]. Stormy weather had been forecast, so we then proceeded to the Minch, off the west coast Scotland, for some shelter during the worst of the storm on 11th March. On the morning of 12th March we left the Minch and sailed west-north-west to the edge of the continental shelf to begin searching for blue whiting. Here a further test-haul was conducted on the evening of 12th March, during a brief lull in the stormy weather. Then, guided by improved weather forecasts and reports of catches around Porcupine Bank, we headed south, crossing into Irish waters on 13th March at 00:30 [56.36 N 9.41 W] and arriving on the fishing grounds on the morning of 14th March.

There were thirteen hauls taken during the cruise: 3 test-hauls (without targeting catch) and 10 specifically targeting blue whiting (Table 1). The first two test-hauls were conducted in deep water off the Norwegian coast, with the aim of checking the trawl and catch control rig 1 were correctly rigged, as well as fitting depth sensors (section 5) and testing the catch limitation release system (section 4). A third test haul was conducted in deep water at the continental shelf edge, west of Scotland, to further practice camera fitting methods and positioning, in preparation for "live hauls" targeting blue whiting schools.

Fishing hauls commenced on 14th March, at Porcupine Bank (Table 1). A total of 7 hauls were taken between 14-16th March, with catches ranging from 45 to 320 tonnes. The vessel then sailed to Killybegs to deliver the catch; arriving on the evening of 17th March, and delivering a total of 947.5 tonnes on 18th and 19th March. The vessel then returned to Porcupine Bank and recommenced fishing on 20th March, taking a further three hauls with catches ranging from 50 to 370 tonnes (total catch ~710 tonnes), which all included bycatches of porbeagle and bluefin tuna (Table 1).

The return journey started at 0700 of 21st March, after the final catch had been pumped aboard. We left Irish waters at 03:00 on 22nd March [56.08 N 8.50 W] and then proceeded via the Minch and Pentland Firth to Bergen, arriving at Nykirkekaien at 03:00 UTC on 24th March. After offloading the scientific crew and equipment, MF Vikingbank then proceeded to Karmsund to deliver the catch on 25th March [blue whiting: 689 tonnes; bluefin tuna: 420 kg; hake: 100 kg].

2.1. Fishing Vessel and Gear

MF Vikingbank (R-3-K) [owned by Cetus AS] is 61.75 metres long and has a beam of 11.6 metres, with a gross tonnage of 1190 tonnes. She is a combination vessel, capable of fishing with either pelagic trawl or purse-seine. For fish location and characterisation the vessel is equipped with Simrad SU 90, Simrad ES 70 and Furuno TimeZero sonars.

Figure 2 – FV Viking Bank (R-3-K)

For this cruise, the vessel was equipped with a pelagic trawl from Vonin, Capto 2016, (2016 metres stretched circumference), fitted with a ~1300m^3 capacity codend (Appendix B). The total length from trawl doors to codend was approx. 875 meters. Thyborøn 3.5 tonne (13.11m^3) trawl doors were fitted to the upper sweeps, while the lower sweeps were weighted with ~1.5 tonne chain bundles. The trawl winch system was controlled using a Pentagon Autotrawl system.

The geometry of the trawl was monitored throughout each haul using Simrad FS 70 Trawl Sonar and depth sensor, fitted to the headline, and Scanmar door spread sensors. The codend contents were monitored using four Simrad PI 32 catch sensors and a Scanmar TrawlEye echosounder (see section 4 for more details).

Additional instrumentation on the bridge included: an Olex Navigaton system; dual Furuno Telchart ECDIS systems; Simrad ES70 and Furuno TimeZero echosounders; a Kaieo ADCP for monitoring water current; and Deif Malling anemometer for wind speed and direction.

Table 1 – Haul Summary: details of test rigs, catch and fishing operation times.

Haul Details				**Catch**		**Doors Deployed**			**Towing Start**			**Heaving Start**			**Doors Recovered**			**Codend on Surface**
Haul No.	Catch Control Rig	Sampling Trawl Fitted	Date	Target catch (blue whiting) tonnes	Bycatch	Time (UTC)	Position - Decimal		Time (UTC)	Position - Decimal		Time (UTC)	Position - Decimal		Time (UTC)	Position - Decimal		Time (UTC)
							Lat	Long		Lat	Long		Lat	Long		Lat	Long	
TestHaul_01	Rig #1 hexagonal meshes	no	09-03-21	NA	0	16:04:00	59.9975	4.5055	NA	NA	NA	16:21:00	59.9878	4.5226	16:27:00	59.9671	4.5202	NA
TestHaul_02	Rig #1 hexagonal meshes	no	09-03-21	NA	0	18:22:00	59.8735	4.2457	18:36:00	59.8502	4.2440	18:48:00	NA	NA	18:49:00	59.8433	4.2435	NA
TestHaul_03	Rig #1 hexagonal meshes	no	12-03-21	NA	0	20:06:35	56.5648	-9.1971	20:54:57	56.5144	-9.1913	21:11:58	56.4989	-9.1864	21:38:40	56.4874	-9.1721	NA
Haul_01	Rig #1 hexagonal meshes	no	14-03-21	45	0	12:19:53	53.9165	-13.4769	12:42:00	53.9217	-13.4303	13:40:50	53.9491	-13.3490	14:11:05	53.9550	-13.3227	14:22:35
Haul_02	Rig #1a - cover top & bottom	no	14-03-21	200	0	17:23:58	53.9523	-13.2953	17:43:00	53.9499	-13.3407	22:28:30	53.8352	-13.6864	22:55:08	53.8296	-13.7089	NA
Haul_03	Rig #1b - top closed & bottom cover removed	no	15-03-21	63	argentine (3t)	9:21:31	53.9433	-13.2983	9:47:35	53.9207	-13.3358	11:39:25	53.8726	-13.5053	12:07:30	53.8803	-13.5302	12:21:50
Haul_04	Rig #1b - top closed & bottom cover removed	yes	15-03-21	125	0	15:09:49	53.8646	-13.6555	17:35:05	53.8558	-13.8560	22:43:00	54.0290	-13.0375	23:13:40	54.0433	-13.0286	NA
Haul_05	Rig #2 - 2m diamond meshes, all panels	no	16-03-21	140	1 porbeagle & 1 tuna (~300kg)	8:48:49	53.9735	-12.8626	9:11:10	53.9779	-12.8115	12:02:00	54.0575	-12.5986	12:33:49	54.0660	-12.5733	12:45:15
Haul_06	Rig #3 - slots in all panels	no	16-03-21	80	0	16:24:16	54.0659	-12.5908	16:40:00	54.0435	-12.5938	18:06:00	53.9712	-12.5546	18:30:50	53.9592	-12.5450	18:42:35
Haul_07	Rig #3 - slots in all panels	no	16-03-21	320	0	21:17:02	53.9704	-12.4023	21:38:00	53.9745	-12.4435	0:39:00	53.9523	-12.7111	1:05:46	53.9462	-12.7340	1:16:00
Haul_08	Rig 4 - hybrid Rig #3 & #1 on bottom panel	no	20-03-21	370	porbeagle	0:42:16	54.1198	-11.8383	0:58:00	54.1185	-11.8801	7:29:00	53.9616	-12.4548	7:47:45	53.9596	-12.4735	7:58:00
Haul_09	Rig 4 - hybrid Rig #3 & #1 on bottom panel	yes	20-03-21	50	1 tuna (~180kg)	12:07:35	53.9101	-12.6875	12:45:00	53.9412	-12.7132	16:55:00	53.9630	-12.3163	17:12:51	52.9645	-12.2984	17:27:00
Haul_10	Rig 4 - hybrid Rig #3 & #1 on bottom panel	no	20-03-21	270	2 tuna (420kg) & hake (100kg)	23:10:20	54.0296	-12.1262	23:30:00	54.0167	-12.1630	6:59:00	53.9171	-12.8222	7:12:40	53.9199	-12.8338	7:23:00

Table 2a – Summary of fishing operation parameters during towing.

Haul No.	Fishing Operations (Towing)															
	Course (degrees)		Towing Speed (knots)		Trawl Wire Length (m)		Water Depth (m)		Headline Depth (m)		Door Spread (m)		Water Current Direction (deg.) at 200m		Water Current Speed (m/s) at 200m	
	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range
TestHaul_01	NA	NA	NA	NA	NA	NA	NA	176 - 176	NA	120 - 120	NA	204 - 204	NA	200 - 200	NA	0.2 - 0.2
TestHaul_02	181±12.7	180 - 182	3.3±11.4	2.4 - 4.2	331±12.7	330 - 332	286.5±57.2	282 - 291	114.9±100.4	107 - 122.8	193.7±57.2	170 - 216	NA	NA	NA	NA
TestHaul_03	169.2±2.7	166 - 173	3.5±0.1	3.3 - 3.5	1154±6.6	1145 - 1162	736.4±8.7	729 - 744	407.2±17	387.6 - 428.8	NA	NA	155.4±7.2	147 - 163	NA	0.1 - 0.1
Haul_01	62.1±4.2	52 - 79	3.4±0.1	3 - 3.7	1209±14.5	1170 - 1255	685.7±20	645 - 753	433.1±9	388.5 - 454.6	NA	328 - 328	57.4±10.2	49 - 92	0.6±0.1	0.4 - 0.7
Haul_02	246.1±7.8	175 - 267	3.4±0.1	2.5 - 3.7	1163.3±12.7	1085 - 1250	737.2±31.6	582 - 822	447.5±8	388.6 - 494.8	326±3.2	321 - 329	241.7±14.3	142 - 292	0.2±0.1	0.1 - 0.5
Haul_03	243.9±2.8	233 - 256	3.6±0.1	3.4 - 4	1036.6±27.8	940 - 1121	494.8±18.6	444 - 539	361.4±9.5	323 - 380.1	326.3±7.2	323 - 328	245.4±7.1	215 - 268	0.4±0.1	0.2 - 0.6
Haul_04	73±29.4	30 - 352	3.8±0.2	3 - 4.2	1118.5±73.9	875 - 1315	547.8±65.8	407 - 769	398.3±42	259.2 - 547.1	328±12.7	327 - 329	92.4±42.9	11 - 321	0.2±0	0.1 - 0.4
Haul_05	57.2±5.2	48 - 75	3±0.3	2.1 - 3.5	1332.3±25	1240 - 1400	1134.7±251.6	613 - 1752	482.6±23.2	351.9 - 516.3	NA	329 - 329	213.8±78.8	44 - 344	0.1±0.1	0.1 - 0.3
Haul_06	164.3±3	161 - 169	3.2±0.2	2.8 - 3.5	1186.4±59.4	1070 - 1275	929.6±242.8	633 - 1293	432.9±49.8	316.9 - 479.7	297±393.9	266 - 328	146.1±27.5	96 - 195	0.1±0	0.1 - 0.2
Haul_07	270.8±7.7	242 - 291	3.4±0.2	2.8 - 4.6	982.3±67	725 - 1230	578.8±47.6	479 - 809	366.9±28.8	269.9 - 472.6	316.4±11.8	283 - 330	226.7±66.8	16 - 343	0.1±0	0.1 - 0.2
Haul_08	250.1±6.7	215 - 283	3.6±0.1	3.2 - 4	1025.2±27.7	840 - 1162	655.7±50.6	456 - 950	356.3±12.6	236.1 - 421	316.5±10	286 - 329	223.9±19.7	62 - 342	0.1±0	0.1 - 0.3
Haul_09	78.8±9.8	0 - 115	3.7±0.1	1.9 - 4.9	915.8±24.1	710 - 1000	557.5±22.5	445 - 683	335.8±8.8	264.4 - 383.4	317.1±5.4	257 - 330	104.6±33	4 - 357	0.1±0	0.1 - 0.2
Haul_10	252.1±6.2	234 - 314	3.5±0	3.2 - 3.9	819.2±13.4	693 - 856	450.6±16.2	395 - 681	276.2±5	237.2 - 307.4	313.8±4.9	270 - 330	180.5±37.1	17 - 352	0.1±0	0.1 - 0.2

Table 2b – Summary of fishing operation parameters during haul-back.

Haul No.	Fishing Operations (Haul-back)															
	Course (degrees)		Towing Speed (knots)		Trawl Wire Length (m)		Water Depth (m)		Headline Depth (m)		Door Spread (m)		Water Current Direction (deg.) at 200m		Water Current Speed (m/s) at 200m	
	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range	Mean ± CI	Range
TestHaul_01	193.5±31.8	191 - 196	2±2.5	1.8 - 2.2	NA	NA	NA	175 - 175	NA	112 - 112	NA	NA	NA	44 - 44	NA	0.1 - 0.1
TestHaul_02	NA	180 - 180	NA	3.1 - 3.1	NA	NA	NA	NA	NA	74 - 74	NA	NA	NA	NA	NA	NA
TestHaul_03	146.6±6.8	125 - 171	2.2±0.2	1.5 - 2.9	457.5±186.1	0 - 1180	736.7±3.8	735 - 738	321.5±48.1	149.6 - 419.1	197±55.8	49.8 - 325	128±21.2	120 - 137	0.1±0	0.1 - 0.1
Haul_01	68±5.5	58 - 85	2.2±0.1	1.9 - 2.4	543.3±226.5	0 - 1165	764.9±2.6	759 - 768	319.2±84.3	111 - 455	209.9±79	92.6 - 327	49.3±27.4	38 - 60	0.4±0.3	0.3 - 0.5
Haul_02	247.6±5.1	232 - 254	2.1±0.2	1.7 - 2.3	451.1±295.3	0 - 1085	597.5±10.6	582 - 616	285.8±89.9	122.1 - 423.1	176.6±88	0 - 323	248±165.6	93 - 310	NA	0.1 - 0.1
Haul_03	237.9±2.6	229 - 242	2.3±0.2	1.7 - 2.6	525.5±270.4	0 - 1121	504±14.3	483 - 539	286.8±73.6	131.9 - 399.1	171.8±87.6	0 - 327	247.1±14.4	216 - 272	0.2±0	0.1 - 0.2
Haul_04	63.9±84.4	13 - 356	2±0.2	1.6 - 2.3	570±285.7	0 - 1250	NA	NA	358.6±94.3	138.6 - 516.2	172.7±86	0 - 310	104±90.4	2 - 212	0.1±0	0.1 - 0.1
Haul_05	60±3	50 - 67	2.1±0.3	1 - 2.5	475±230.2	0 - 1085	1483.6±51.7	1420 - 1624	266.2±90.5	102.7 - 442.5	148±91.8	0 - 299	272.9±18.9	240 - 334	0.2±0.1	0.1 - 0.4
Haul_06	154.8±2.2	149 - 162	2.1±0.1	1.9 - 2.6	473.4±205.2	0 - 1070	499.1±28	463 - 632	292.6±62.4	124.2 - 425.6	186.3±69	0 - 321	181±139.3	97 - 303	NA	0.1 - 0.1
Haul_07	245.4±2.9	239 - 255	2.1±0.1	1.7 - 2.6	517.3±203.9	0 - 1085	483.6±8	465 - 516	296.2±58.8	122.8 - 413.3	188.6±67.7	0 - 325	255.6±46.9	192 - 314	0.1±0	0.1 - 0.1
Haul_08	260.7±6.1	249 - 275	2±0.3	1 - 2.3	339.2±190.8	0 - 790	464±1.1	462 - 467	234.8±49.1	128.9 - 304.1	185.1±73.9	0 - 300	221.3±124.3	0 - 353	0.1±0	0.1 - 0.1
Haul_09	82.1±1.7	79 - 85	2.5±0.3	2.3 - 3.5	302.9±167.8	0 - 590	447.6±3.3	444 - 457	234.7±60	111.9 - 322.6	155.1±67.7	0 - 258	130.5±39	94 - 147	NA	0.1 - 0.1
Haul_10	292.5±7.2	283 - 311	2.1±0.2	1.8 - 2.6	264.2±181.8	0 - 693	417.1±1.6	414 - 420	177±40.1	100.8 - 235	155.4±75.2	0 - 258	53.9±98.5	0 - 293	0.1±0	0.1 - 0.1

2.2. Special note on bycatch

The project team was aware of anecdotal evidence from the Norwegian fishing fleet that there may be a problem in the blue whiting fishery with bycatch of large species, including sharks and tuna. This issue was confirmed during this cruise by the observation of bycatches of porbeagle (*Lamna nasus*) (IUCN status [NE Atlantic]: critically endangered) and/or bluefin tuna (*Thunnus thynnus*) (IUCN status [Europe]: near threatened) in 40% (4 of 10) of hauls targeting blue whiting on the Porcupine Bank fishing grounds (see table 1).

Figure 3 – Top: Porbeagle (*Lamna nasus*) caught in haul 05 and released alive; Bottom: Tuna (*Thunnus thynnus*) caught in haul 09, whch was dead on arrival on deck.

During haul 05, a porbeagle and bluefin tuna were observed to be caught in the trawl ahead of the catch control rig (CCR), as it was heaved to the boat. The porbeagle was caught by its teeth in the netting, but was successfully cut free from the netting on deck and released alive back to the sea, after a crew member cut a plastic strip from around its thorax. The tuna remained in the water and was successfully released alive from the trawl by slipping it out of the escape opening in the CCR (Rig 2), suggesting that a CCR with large bottom openings could be further developed to reduce the bycatch of unwanted large species in the catch. There were a further three hauls (08-10) with bycatch (one porbeagle and three tuna), but unfortunately none of these animals were released alive.

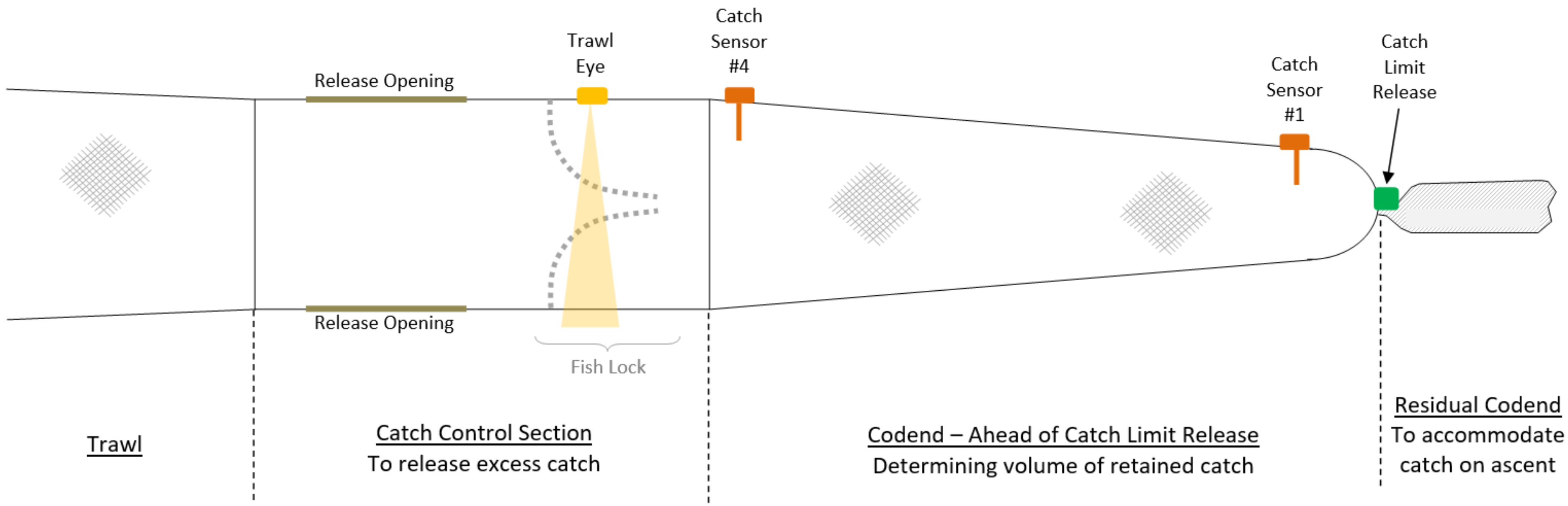


Figure 4 – Catch Control Rig – General Overview: consists of a cylinder of netting, approximately 10m long, inserted between the trawl and codend, that incorporates two key components: escape openings and a “fish lock”. The rig should allow free passage of the catch from the trawl into the codend during the fishing process, until the codend is full. The escape openings therefore should prevent escape during the normal fishing process, but once the codend is full should then enable fish to escape freely with minimal risk of crowding and abrasive injury. The fish lock should permit free passage into the codend during the normal fishing operation. But, once the codend is full and/or during heaving, the catch on the codend side of the fish-lock should press against the fish-lock netting, closing it, and preventing any loss of the catch retained in the codend through the escape opening. The catch sensors and trawl-eye are technologies that inform the skipper of when the codend is full of catch. The catch limit release mechanism releases the retained catch into the residual codend during haul-back/heaving (see section 4).

3. Effectiveness of three designs of catch control rigs.

<u>Objective:</u> to develop a method to retain target catch during fishing operations until the catch limit is reached, when all excess catch should then be efficiently released.

To achieve this, three different designs multi-component catch control rigs (figure 4) were investigated on this cruise:

- Rig 1 - Large mesh A: 2.7 m hexagonal stitches (top and bottom panels only) (figure 5a);
- Rig 2 - Large mesh B: 2m diamond stitches (all panels) (figure 5b); and
- Rig 3 - Four slots: as originally tested in research cruise one (Kvalvik & Lilleng, 2019) (figure 5c).

Further to these, a fourth design (Rig 4) was constructed during the cruise; a hybrid combining the bottom escape opening from Rig 1 into the bottom panel of Rig 3 (see below).

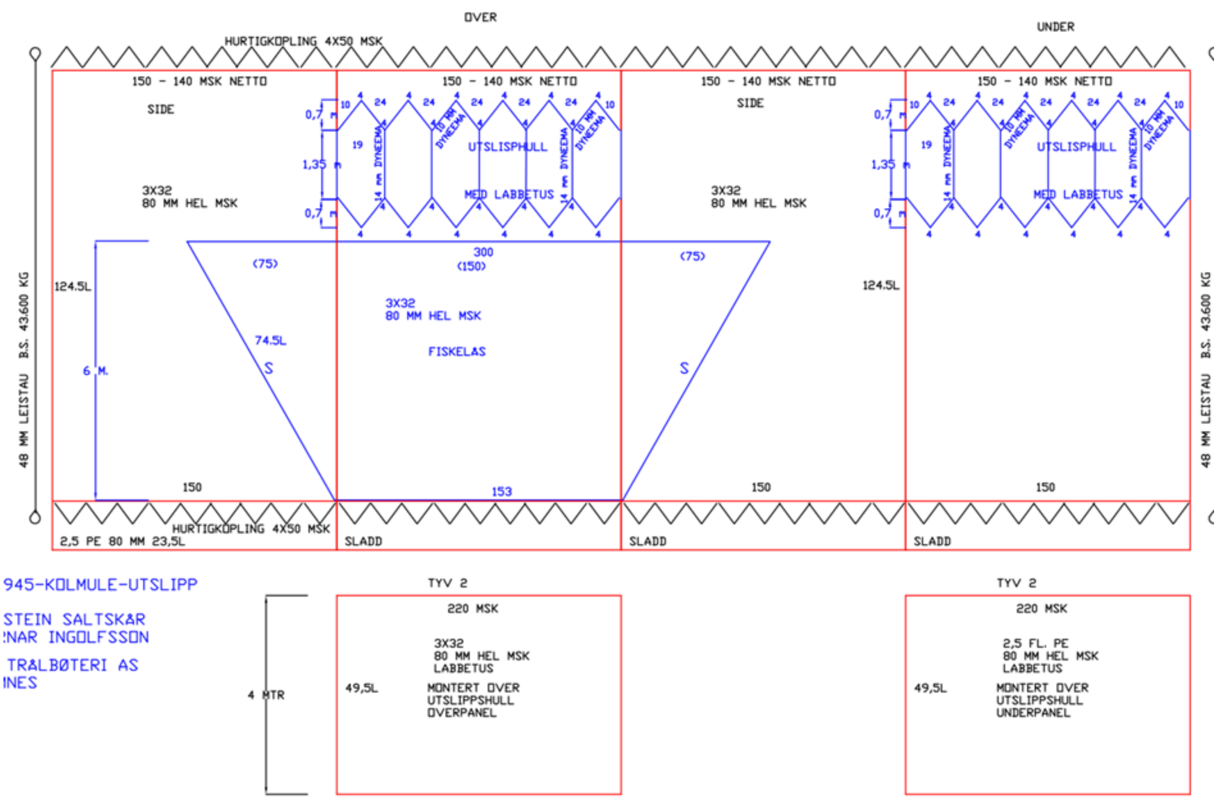


Figure 5a – Net Drawing of Catch Control Rig 1: 2.7m Hexagonal Meshes in Top & Bottom Panels.

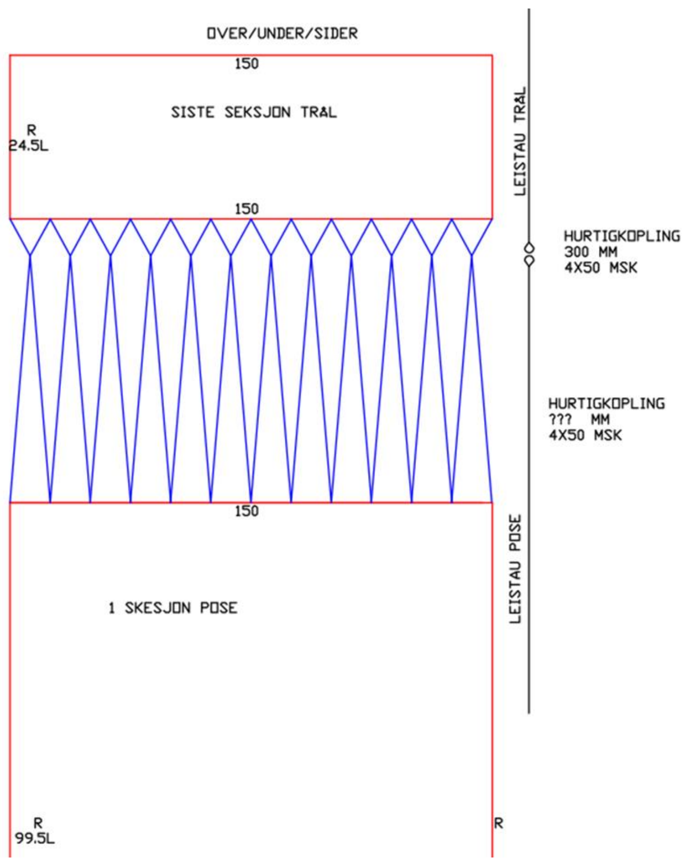


Figure 5b – Net Drawing of Catch Control Rig 2: 2.0m Meshes in all four Panels.

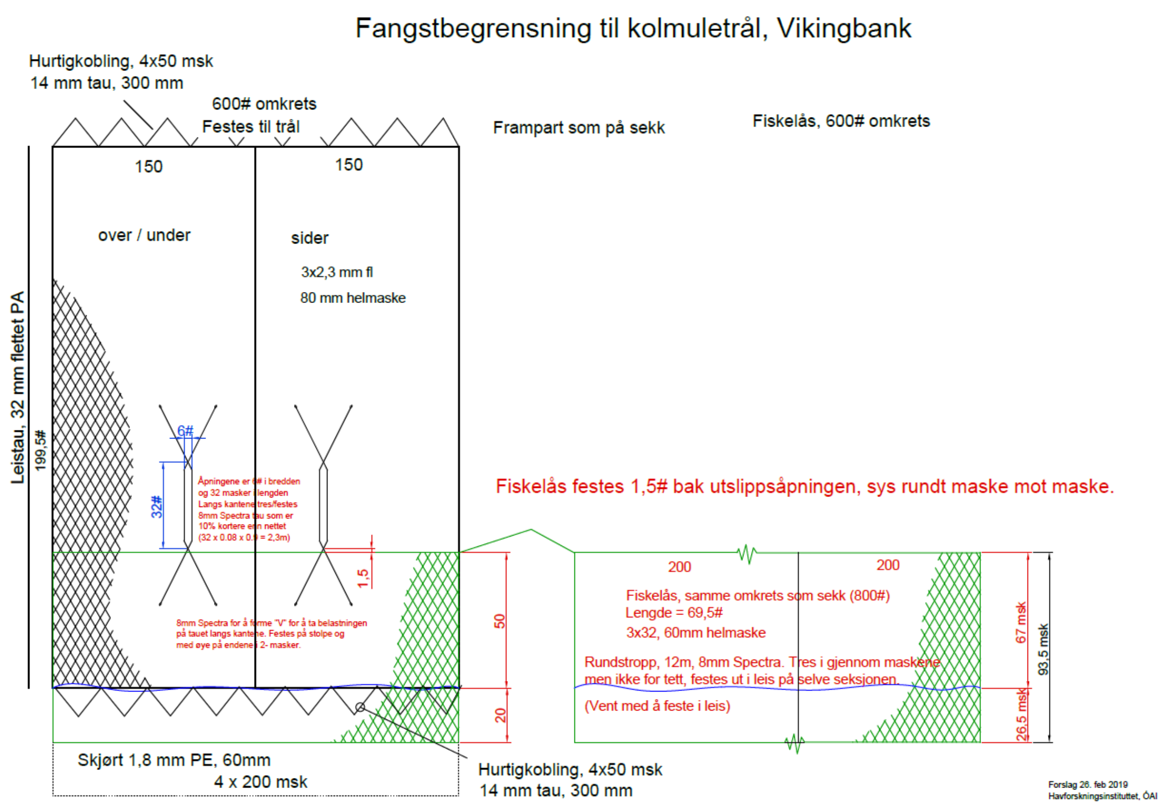


Figure 5c – Net Drawing of Catch Control Rig 3: 2.5m long slot, one in each of four Panels.

3.1. Materials and Methods.

The effectiveness of the catch control rigs (CCRs) to retain and release catch was assessed using underwater camera systems placed in various positions on the trawl and rigs themselves. Appendix A gives a detailed description of these camera systems, and their deployments and positioning. In addition to the camera systems, the trawl and CCR was monitored using: a Simrad Sonar and depth sensor on the trawl headline; Scanmar door spread sensors; Scanmar Trawl-Eye on the CRR (figure 4); and 16 depth loggers at various location along the trawl, CRR and codend (see sections 4 and 5 for further details and discussion).

3.2. CCR escape openings – preliminary observations and developments.

These results are based on preliminary observations, and more in-depth analysis will be required before conclusive inferences can be confirmed.

When fitted to the trawl, all four rigs appeared to take up their designed geometry and were stable. The only exception was in haul 8, when a collection of cameras at the trailing edge of the bottom escape opening in Rig 4 appear to have distorted the bottom panel.

Hauls 01 and 02 demonstrated a consistent and usable behaviour in blue whiting passing through rig 1; where blue whiting generally swam upwards and concentrated in the upper part of the CCR. This manifested as continuous and unacceptably high escape rate from the top escape openings of the CCR, but with concurrently very low escape rates from the bottom escape openings (Figure 6). Building on this observation, in hauls 03 and 04, the top escape opening was closed using a netting panel (80 mm mesh size) to successfully minimise escapes, while a loose netting cover panel on the bottom panel was removed. There was no evidence of any substantial increase in the escape rate of fish from the bottom opening as a result. The same excessive escapes from the top panel, with very low escape rate from the bottom panel, were also observed in Rig 2 during haul 05. Rig 3 has more restricted escape openings than Rigs 1 and 2, so the escape rate from the top panel was substantially reduced in hauls 06 and 07, but still remained higher in comparison to the very low escape rate from the bottom panel during normal fishing operations (figure 7).

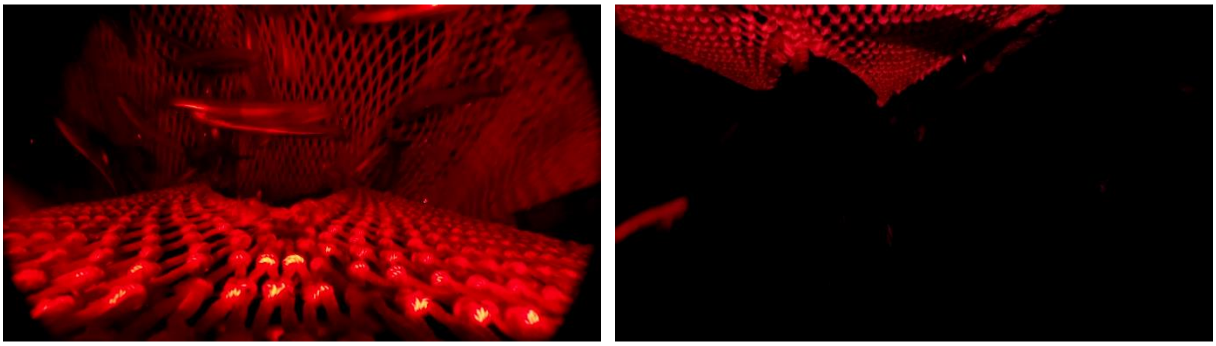


Figure 6 – Haul 02 (Rig 1a – Hexagonal mesh release opening, with cover panels) at 22:23:17 (5 minutes before haul-back). Left: High escape rate of blue whiting via top panel opening; Right: Very low escape rate of blue whiting via bottom panel opening.

At the end of the normal fishing operations, when the codend is full and the vessel is preparing to heave the trawl, the CCR should allow any excess catch in and ahead of the CCR to easily escape. This was evident for Rigs 1 and 2, with massed escapes occurring at approximately the same time that the catch sensors and/or the trawl-eye indicated that the codend was full (see section 4). For Rig 3, as the catch in the codend began to approach the catch limit, the slots in both the top and bottom panels opened up forming almost circular escape openings (figure 7). This facilitated a substantial increase in escapes from the top panel, when fish density increased inside the CCR (figure 7). However, at very high densities, it was suspected that these openings would be insufficient to allow the release of sufficient numbers of fish to avoid excessive crowding and/or abrasive injury.

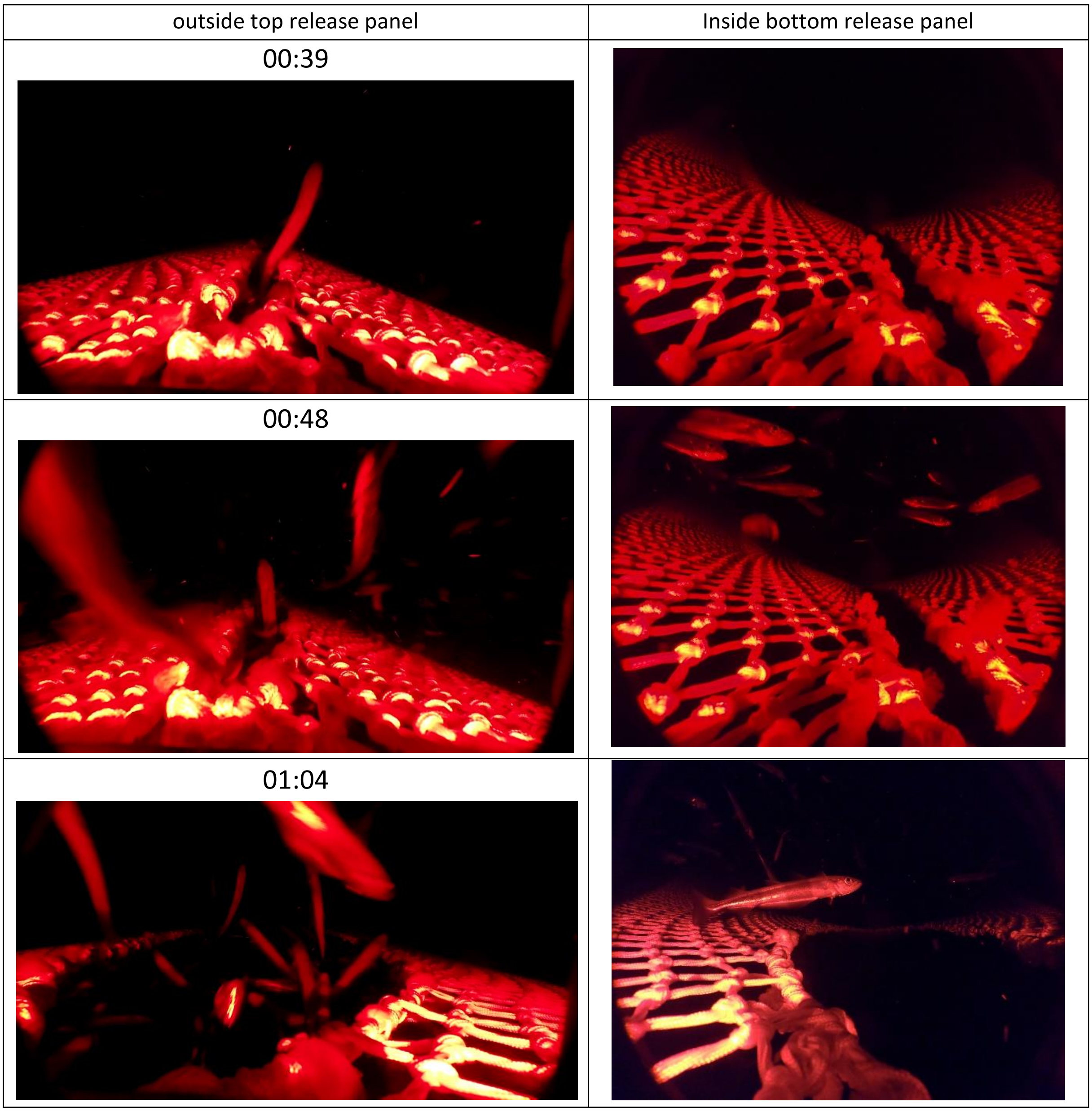


Figure 7 – Haul 07 (Rig 3). Left – outside top release panel; Right – Inside bottom release panel. Top: 00:39 – Haul-back starts; low density inside CCR; slots closed and few escapes. Centre: 00:48 – Sensor #4 on; density increases; slots begin opening; escapes increase in top panel. Bottom: 01:04 – 16min after Sensor #4 on; slots almost fully open; high escape rate in top panel, few escapes in bottom panel.

Based on these observations, it was decided to construct a new CRR (Rig 4) using a hybrid design of Rigs 1 and 3; where Rig 3 formed the top and side panels, with the large hexagonal mesh escape opening from Rig 1 inserted in the bottom panel. This rig was tested in hauls 08 to 10, and preliminary observations suggest that this prototype CCR may be suitable for further development. Escapes from the top panel (with a slot) appear to be minimal during normal towing. There were some escapes from the bottom escape opening (hexagonal meshes) during normal fishing operations (Figure 8), but these could be reduced with further modification to the CRR. For example, with the inclusion of guiding panels to lift fish close to the bottom panel over the opening as they pass through the CRR towards the codend. Furthermore, the bottom escape opening was very successful at releasing fish when densities increased at the end of normal fishing operations (Figure 8).

Figure 8 – Haul 10 (Rig 4). Left: 06:59 – Haul-back starts; few escapes from bottom release opening. Right: 07:39 – During haul-back; mass escape of fish from bottom release opening.

3.3. Fish-locks – preliminary observations.

Two different "fish-lock" designs were tested during the cruise. Rig 1 incorporated a netting panel that was fixed to the top panel, approximately 0.3 m to the aft of the escape opening, and then fixed on a diagonal line down to about halfway down the side panels (and toward the codend). The operation of this design (type 1) was only observed once, in haul 03, but appeared to have worked successfully on that occasion. During haul-back in haul 03, it was apparent that the catch in the codend moved forward and started to collect at the top of the fish-lock. This build-up of catch progressively pushed the panel down, eventually sealing it closed on the bottom panel, thus preventing any substantial loss of catch from the codend during haul-back (figure 9).

The second design of fish-lock (type 2) was incorporated into Rig 3 (and 4) and consisted of a cylinder of netting, with the leading edge fixed to the top, bottom and side panels of the CRR, 0.1m behind the escape opening panels. The aft end of the cylinder was initially loosely constricted by a loop of Dyneema twine treaded around the opening and fixed to either side of the CRR. However, before haul 06, there were concerns that this constrictor line would be too restrictive and could cause a build-up of catch on the wrong side of the lock during normal fishing operations, thus blocking the entrance to the codend and forcing excessive loss of catch via the CRR escape openings. Therefore, the constrictor line was removed. The only clear observations of this fish-lock were made during haul 09, when it was evident that the netting cylinder was completely ineffective as a fish-lock; moving freely back and forth in the CRR and not preventing any loss of catch from the codend during haul-back (figure 10).

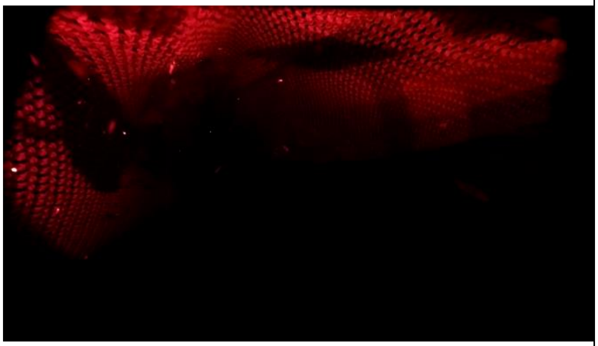
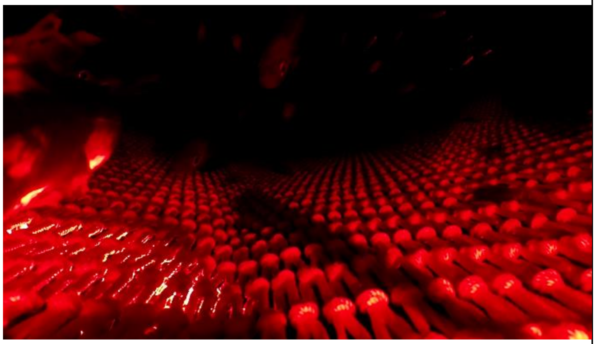
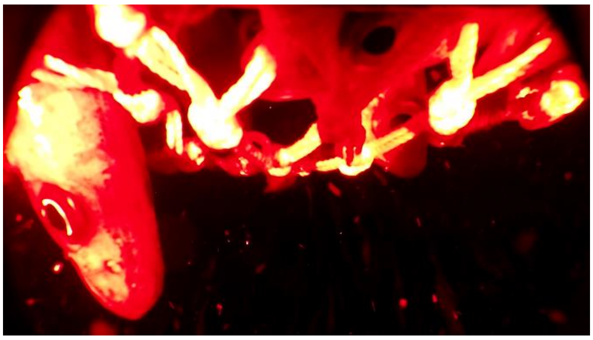
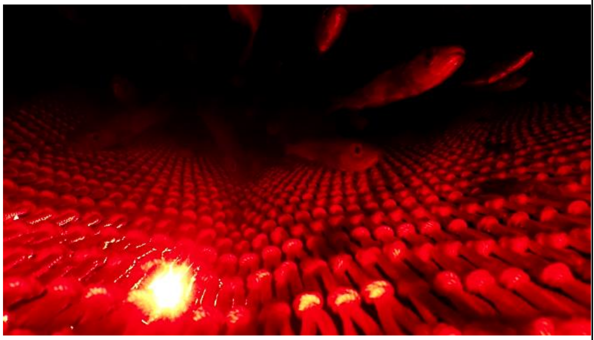
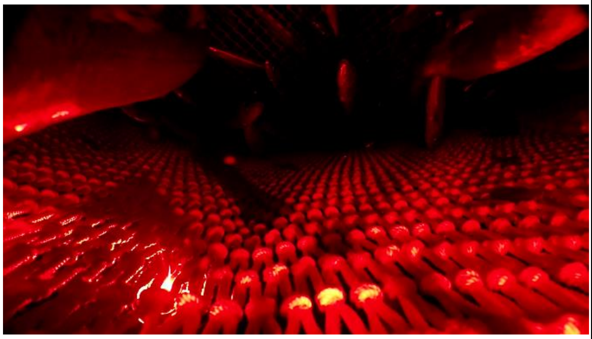
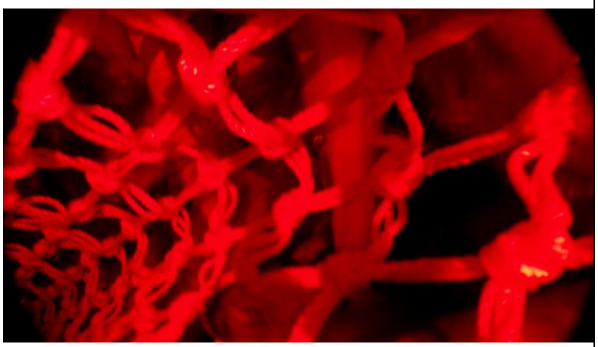
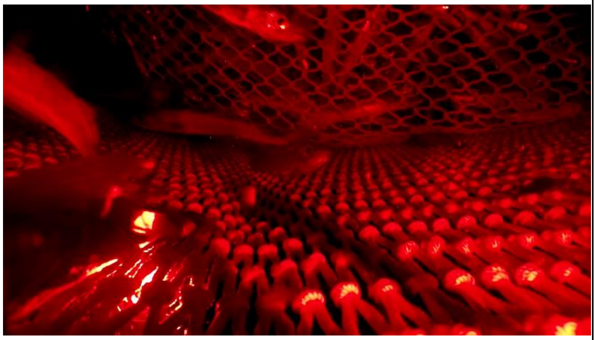
5B: Top, inside, looking back	6B: Bottom, inside, looking back
12:17:00	12:17:00
	
12:17:10	12:17:10
	
12:17:20	12:17:22
	
12:17:30	12:17:30
	

Figure 9 – Haul 03 (Rig 1b). Sequences of images of the fish-lock (type 1) successfully closing during haul-back. Left: Top panel looking back; Right: Bottom panel looking back.

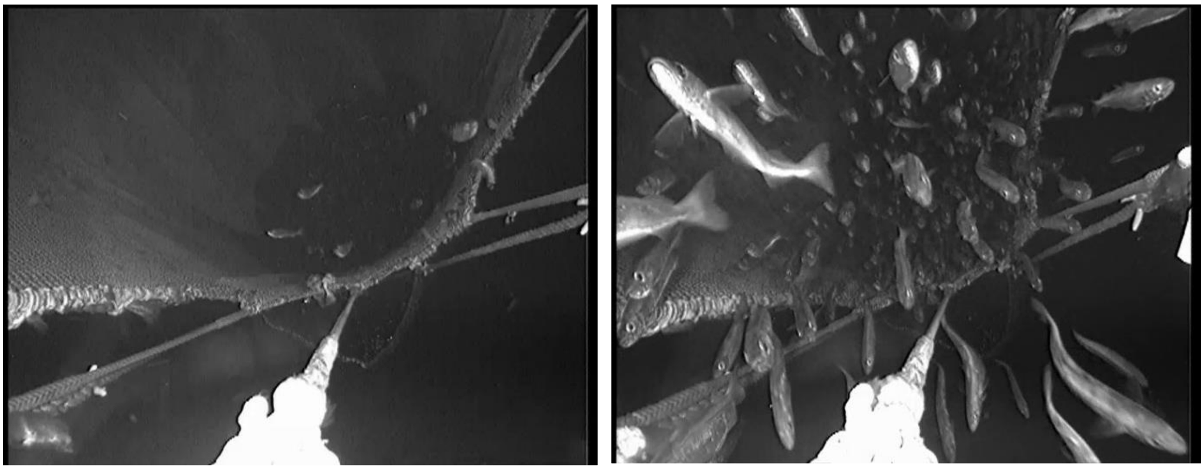


Figure 10 – Haul 09 (Rig 4) Fish-lock (type 2) fails to close during haul-back. Left: 17:15:05 – fish-lock open and loose in catch control rig. Right: 17:22:25 – fish swim out through fish-lock as codend ascends to surface.

4. Catch limitation release system

Objective: Investigate the effectiveness of the catch limit release mechanism on the trawl codend (Prototype by FossTech company).

The catch limitation release (CLR) is a device that can be placed at different locations along the length of the codend, to limit the effective volume of the codend and thus the volume of the retained catch. At a pre-determined depth (between 50 and 150m) during haul-back, the release mechanism opens allowing the restrictor-rope wrapped around the codend to release, which results in the retained catch moving (with the towing induced flow inside the trawl) into the residual codend. If timed correctly, this transfer of the catch from the retaining codend into the residual codend should dissipate the catch over a larger volume within the codend. This will prevent the catch concentrating at the terminal end of the codend, which provides two keys benefits: i) fish can freely decompress, evolving expanding gas from ruptured swim-bladders and body cavities during ascent; and ii) dissipate buoyant lift from the catch over a large surface area in the ascending codend, thus increasing drag and reducing acceleration during ascent.

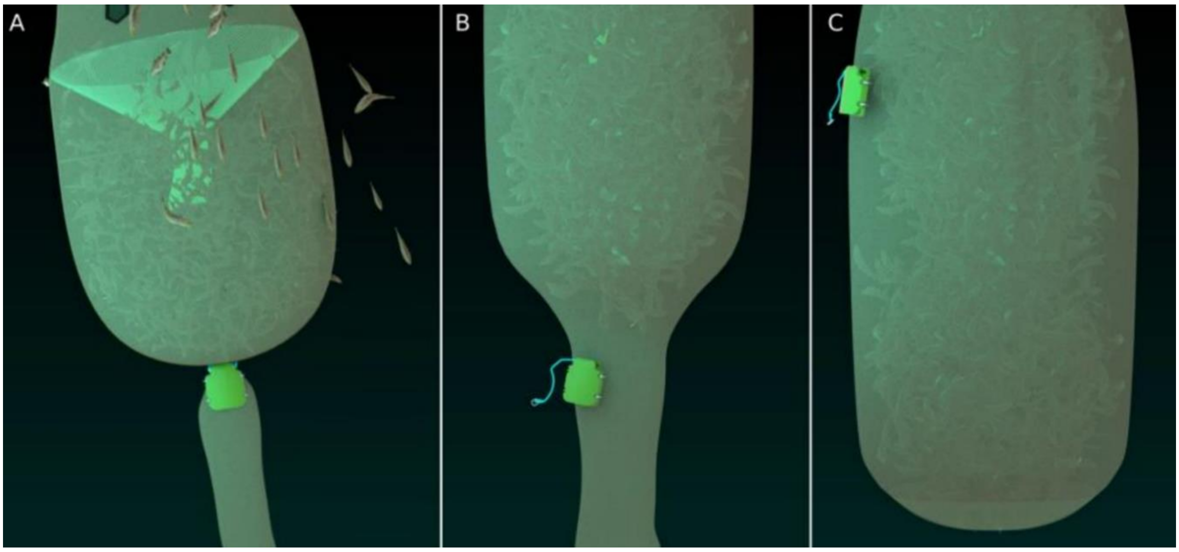
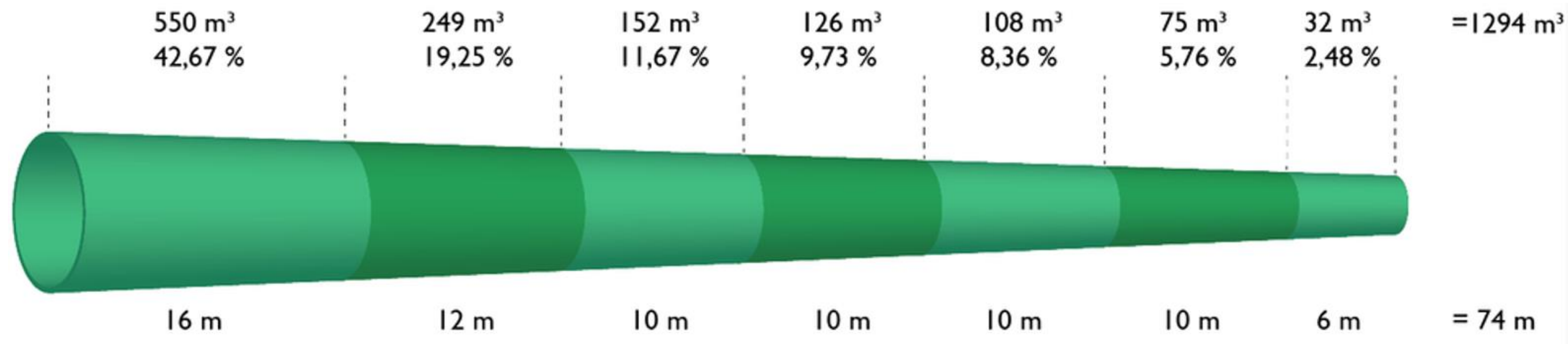


Figure 11 - Artist impression of the Catch Limitation Release in operation. A: catch is retained in the codend ahead of the closed CLR; B: the trigger depth is reached and the CLR opens; and C: the retained catch dissipates into the residual component of the codend [Source: IMR; https://www.hi.no/resources/publikasjoner/rapport-fra-havforskningen/2018/2-2018_sluttrapport_sekkeapner.pdf].

4.1. Materials and Methods.

The CLR was fitted to the codend on all hauls, and its successful operation (i.e. opening and release of the restrictor line) was confirmed visually each time the codend was recovered. Cameras were deployed to film its operation on Test Hauls 01 and 02 and Haul 09 ("dome-frame") and in hauls 03, 04 and 05 ("FlyCam").



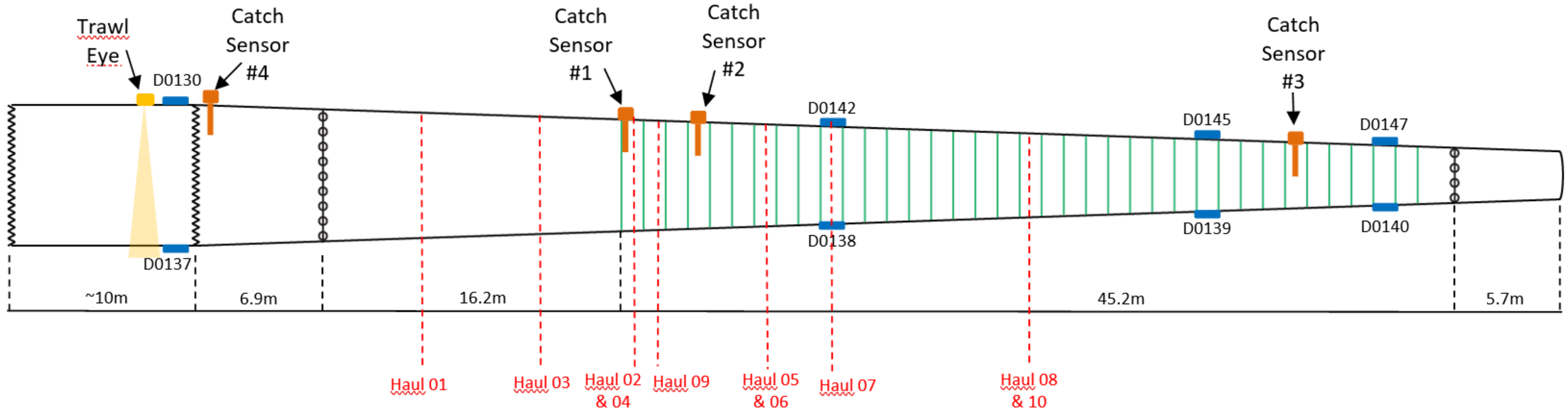


Figure 12 - Top: volume estimates for the conically shaped codend on the Vikingbank trawl [Not to scale; figure by L. Kvalvik]. Bottom: positions on the codend of the Catch Limitation Release (CLR) for each haul (in Red) (see also table 3); also shown are the relative positions of the Trawl Eye (yellow), Catch Sensor units (orange) and depth-loggers (blue) [Not to scale; figure by L. Kvalvik & M. Breen].

Table 3 – positions of the Catch Limit Release unit (CLR), for each haul, and the Scanmar Trawl-Eye and Simrad Catch Sensors (#1 - #4), relative to their distance from the front end of the codend and the positions of the codend roundstrops (numbered from the front).

	Positions relative to: Roundstrops (numbered from	Distance behind Codend front
Trawl Eye	*ahead of codend*	*-3.92*
Catch Sensor #4	ahead of 1	2.12
Catch Sensor #1	1 - 2	23.54
Catch Sensor #2	4 - 5	27.88
Catch Sensor #3	31 - 32	59.58
CLR Haul #01	ahead of 1	13.57
CLR Haul #02	1 - 2	25.13
CLR Haul #03	ahead of 1	19.30
CLR Haul #04	1 - 2	25.13
CLR Haul #05	7 - 8	34.67
CLR Haul #06	7 - 8	34.67
CLR Haul #07	10 - 11	38.06
CLR Haul #08	19 - 20	45.91
CLR Haul #09	2 - 3	25.66
CLR Haul #10	19 - 20	45.91
10mm rope (Haul #9)	1 - 2	23.22

Figure 13: FossTech's prototype Catch Limitation Release (CLR). Left: CLR unit fitted to codend. Right: restrictor line and fastenings.

In addition to visual observations, the codend was equipped with four Simrad PI 32 catch sensors and a Scanmar Trawl-Eye echosounder to estimate what volume of catch it contained. In principle, as the codend filled, it would trigger each catch sensor in turn, starting with the sensor furthest aft (ahead of the CLR). When the catch sensor that was furthest forward was triggered (i.e. CS #4) this would indicate the codend was full, and any excess catch should now be exiting via the escape openings in the CCR. Alternatively, the Trawl-Eye gives information about the density of the catch immediately beneath it, in this case in and below the CCR. A full codend should be indicated by high densities inside the CCR (i.e. red shading on the echogram image), and escaping fish should be seen as marks below the CCR (figure 14).

In addition to the CLR units, on haul 09, a 10mm nylon constrictor rope (breaking strength ~2080 kg) was added to the codend at 23.22 m from the leading edge of the codend (between round-strops 1 and 2).

Normal haul-back procedure: Once the decision is made to heave the trawl, the trawl wires are winched in at a rate of ~45 metres per minute, while the propeller pitch is set to 55%. This is continued until the doors are at the gallows. Then, the propeller pitch is reduced to 40% and the trawl sweeps are heaved in onto the net-drum, until there is resistance as the codend begins a buoyant ascent and starts to drag back on the gear. At this point, the headline ascent rate may stop, or even begin sinking. In response, the skipper stops heaving on the sweeps and reduces the net-drum hydraulic pressure to 90 bar, to allow the sweeps to slip out again as the codend approaches the surface. At this time, the vessel's speed through the water will usually decrease, and may even reverse, and the vessel's heading can veer by as much as 90^{o}. Once the codend is on the surface, the skipper reduces the propeller pitch to 25% and recommences heaving the sweeps and trawl onto the net-drum.

4.2. Preliminary Results and Discussion

The CLR successfully operated on all 13 hauls. Video of it opening was also obtained during Test haul 02 and Haul 09. Three attempts to film it using the "FlyCam" in hauls 03, 04 and 05, all failed (appendix 1). Further analysis will be needed to accurately determine whether the CLR triggered at the target depth (150m), by relating the trigger times on the video to data from the depth sensors (section 5).

With respect to determining when the catch limit had been reached, and excess catch was likely escaping via the openings in the Catch Control Rig (section 3), the combination of both the Simrad Catch Sensors and the Scanmar Trawl-Eye units proved informative. The Trawl-Eye consistently provided interpretable information on the density of catch in the CCR and, most informatively, when excess catch appeared to be escaping beneath the CCR. In general, the Simrad Catch Sensors triggered as expected (in reverse order, ahead of the CLR position)(tables 3 & 4). Therefore, a positive and constant signal from catch sensor #4, along with indications that catch was escaping from the CCR, was taken as a definitive signal that the catch limit had been reached. However, on three hauls (04, 05 and 07) haul-back was started before a positive consistent signal had been received from catch sensor #4, because the Trawl-Eye indicated that high densities of fish were accumulating in the CCR (hauls 04 and 05). Further video analysis is required to confirm whether these indicators are true signals that the catch limit has been reached, and whether they correlate with increased escapes at the escape openings.

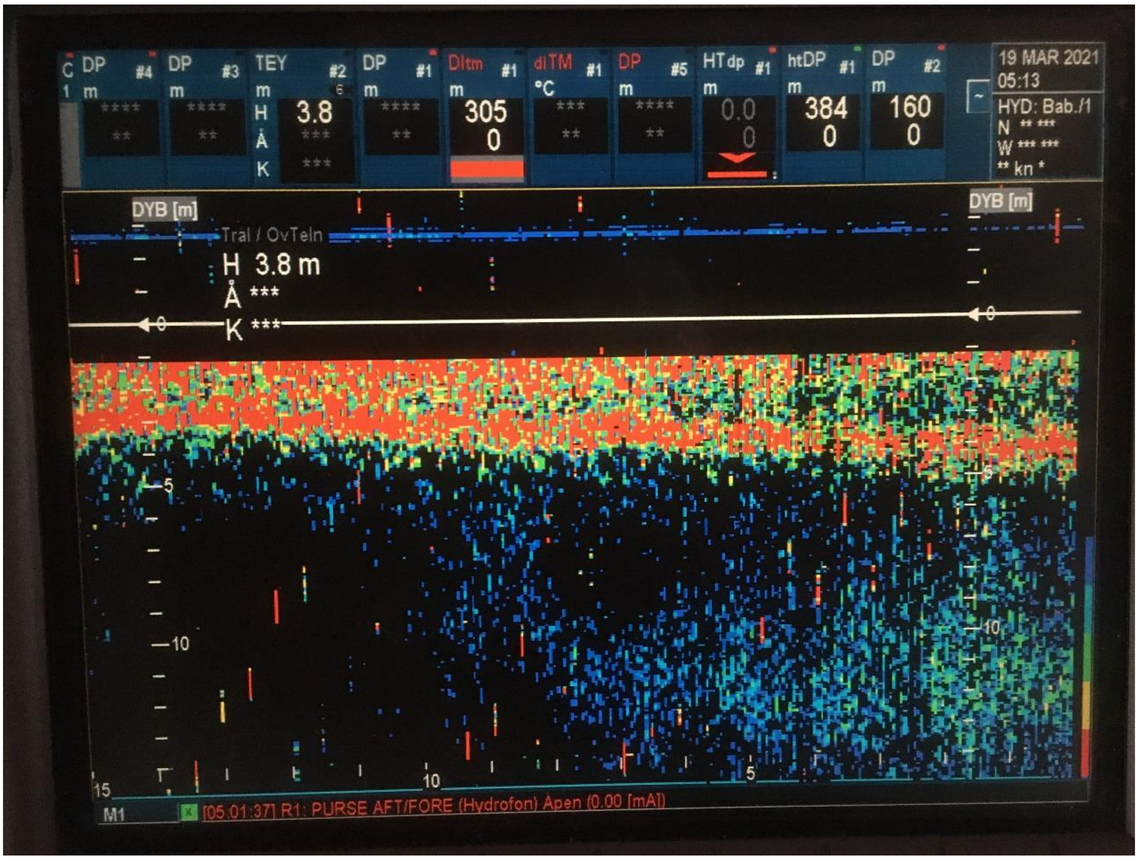


Figure 14 - Haul 09 [1653] View of Trawl-Eye screen, 2 minutes before starting haul-back. Indicators in this image that suggest the catch limit has been reached include: consistently strong (red colouration) signals at top of screen suggest there are high densities of fish inside the CCR; the diameter of the CCR appears to be increasing, as its lower boundary moves further down from the top of the screen; and increasing frequency and strength of signals from beneath the CCR suggest fish are beginning to escape from the lower release opening. [Note – screen shows 15 minutes of echosounder data, with most recent signals displayed to the right].

Some catch sensor units failed to trigger in some hauls when catch should have been accumulating at that location (i.e. hauls 04, 05, 06 and 07) and/or some sensors triggered apparently prematurely, when no catch should have been accumulating at that location (i.e. hauls 03, 06 and 09). The inconsistency in haul 09 can be partially explained by the fact that an additional constrictor rope had been added just ahead of catch sensor #1 (between round-strops 1 and 2). Therefore, catch sensor #1 should have triggered after catch sensor #4, when enough catch had accumulated ahead of the restrictor rope to break it (breaking strain ~2080 kg). Furthermore, video analysis (from position 10F) suggests the constrictor rope broke just at the start of haul-back; 25 minutes and 57 seconds before the CLR opened during haul-back. Further analysis, integrating observations and data from all cameras and instruments, is required to better clarify this. However, the presence of the constrictor rope cannot explain why catch sensor #2 (i.e. aft of the CLR and the constrictor rope) triggered 20 minutes before catch sensor #4 and 51 minutes before catch sensor #1.

Table 4 – Summary of the catch limitation results for each haul, including the theoretical target codend volume, based on the position of the Catch Limitation Release (CLR) unit, and the resultant catch volumes and weights. Also shown are the times for the start and end of the towing phases of the haul, as well as the times individual catch sensors gave consistent positive signals. Catch sensors positioned aft of the CLR are shaded in grey.

Haul	Catch Volume (m^3)			Catch Weight tonnes	Towing Start Time	Catch Sensor Trigger Time				Heave Start Time	Codend on Surface
	Target	Actual	Proportion			#3	#2	#1	#4		
Haul_01	446.1	48.9	0.11	45	12:42	NA	NA	NA	13:26	13:40	14:22
Haul_02	717.9	217.4	0.30	200	17:43	NA	NA	19:15	22:28	22:28	NA
Haul_03	591.3	68.5	0.12	63	9:47	NA	11:36	NA	11:23	11:39	12:21
Haul_04	717.9	135.9	0.19	125	17:35	NA	NA	19:33	NA	22:43	NA
Haul_05	884.9	152.2	0.17	140	9:11	NA	9:23	NA	12:19	12:02	12:45
Haul_06	884.9	87	0.10	80	16:40	18:12	16:51	NA	17:39	18:06	18:42
Haul_07	934	347.8	0.37	320	21:38	NA	NA	22:14	0:48	0:39	1:16
Haul_08	1030.9	402.2	0.39	370	0:58	NA	3:12	4:51	7:15	7:29	7:58
Haul_09	728.4	54.3	0.07	50	12:45	17:23	16:30	17:21	16:50	16:55	17:27
Haul_10	1030.9	293.5	0.28	270	23:30	7:23	4:45	5:27	6:32	6:59	7:23

Finally, as anticipated, the resultant catch volume (and weight), generally increased the further aft the CLR was positioned on the codend, as the theoretical volume of the receiving codend increased (table 4 and figure 15). However, the resultant catch volumes only represented a small proportion of the corresponding theoretical codend volumes (range 0.07 – 0.39)(table 3). In addition, larger catch volumes generally occupied a higher proportion of the corresponding theoretical codend volume. One possible explanation for this is that larger codend volumes may allow higher densities of catch to accumulate before "excess catch" begins escaping from the openings in the CCR. This could be related to the increased time required to collect larger catches, which may increase the probability of fish becoming exhausted and falling back to the rear of the codend, as time progresses. This process could be verified by appropriate positioning of cameras and/or Trawl-Eye units along the codend.

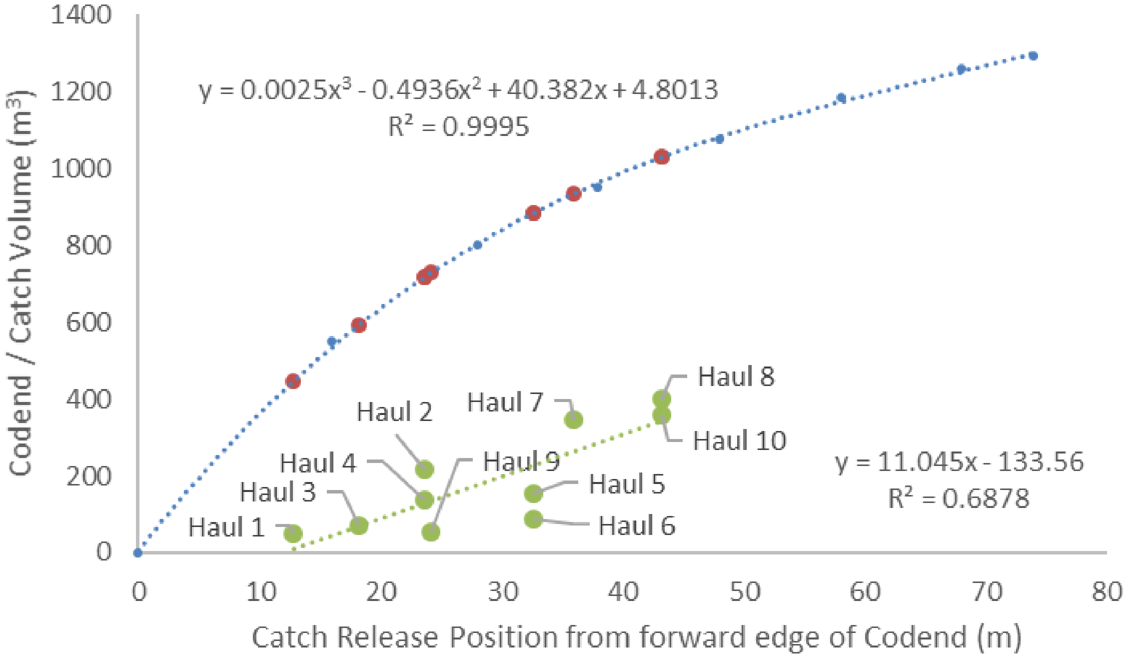


Figure 15 - The relationship between the position of the Catch Limit Release and the resultant codend and catch volumes. Theoretical (third order polynomial) codend volume estimates are shown in blue, and theoretical volume calculated specifically for each haul in red. The resultant catch for each haul is shown in green, with a fitted linear relationship.

5. Monitoring trawl and codend geometry.

Objective: Monitor the geometry of the trawl and codend, particularly during haulback.

To improve our understanding of the causes of rapid and explosive codend ascents and develop methods to avoid them, this project will be monitoring the geometry of several different trawls during fishing operations. This will inform us about ascent rates under different conditions, catch sizes and haul-back practices, from which mitigation measures, monitoring technologies and best practice can be developed.

5.1. Materials and Methods.

On this research cruise, the trawl was fitted with fifteen Star-Oddi Starmon TD (depth & temperature) and one Star-Oddi Starmon Tilt (depth, temperature & 3D-tilt) sensors (see figure 16 and table 5 for position details). Each sensor was protected inside a steel cylindrical housing, inside a webbing sheath (figure 16), with the exception of D.0148 which was housed inside the FS 70 Trawl Sonar housing. Depth sensors D-0120 to D-0123 were fitted and removed at the start and end of each haul, to prevent them being damaged on the net-winch drum. Each was colour coded (to match the trawl colour-code system) to aid accurate and consistent placement each haul. Details of trawl and trawl doors are provided in section 2.1.

Table 5 - Depth sensor positions on and ahead of the catch control rig (CCR) and codend.

	Positions relative to:	
Depth Sensor ID	Round-strops (numbered from front)	Distance behind Codend front (Scaled to stretch length)
D-0124 and D-0127	*60m Ahead of Catch Control Rig*	
D-0138 and D-0142	10 - 11	37.42
D-0139 and D-0145	27 - 28	54.17
D-0140 and D-0147	35 - 36	63.40

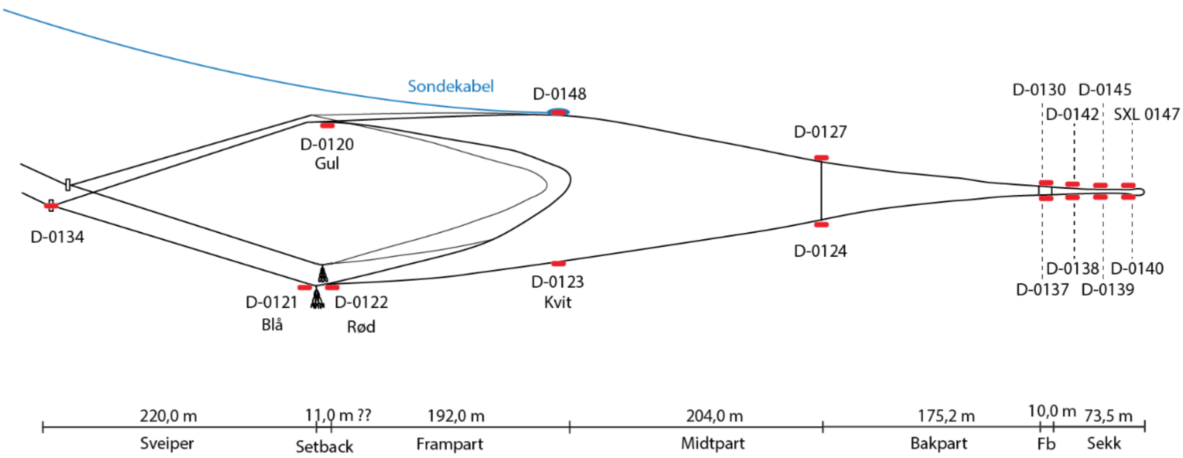


Figure 16 - Positions and Identity Code for depth sensors on the trawl. Detailed positions for the codend depth sensors are detailed in table 5. Note – Sensors D0124 and D0127 are incorrectly located in this diagram, they were actually 60m ahead of the Catch Control Rig. [Source: Liz Kvalvik].

Figure 17 – a depth sensor (D-0130) in its protective housing and sheath fixed to the top of the CCR.

To support the depth profile data, supplementary data was collected from instruments on the bridge, including: milestone events times and positions during the fishing process (table 1); course and towing speed (Olex Navigaton system); trawl wire length and winch speed (Pentagon Autotrawl); door spread (Scanmar); trawl mouth opening dimensions and shape (FS 70 Trawl Sonar); headline depth (FS 70 Trawl Sonar depth sensor); water depth (Simrad ES70 and Furuno TimeZero echosounders); water current and direction at 200m (Kaieo ADCP); wind-speed and direction (Deif Malling anemometer); and wave height (visual estimate).

5.2. Preliminary Results and Discussion

All sensors were recovered and their recorded data successfully downloaded, with the exception of D-0130 which had flooded. Analysis of the data is ongoing and will be reported later.

6. Estimating load on codend-pump connection.

Objective: to estimate the maximum load on the codend-pump coupling, to support the development of a quick release mechanism to decouple the pump from the trawl codend.

The method used today to release the trawl codend from the fish pump on board the vessel is time consuming, and can risk injury to the crew and damage to equipment. Unforeseen events during the pumping process can mean it takes a long time to empty the trawl codend. In the worst case, this can result in the catch losing buoyancy and, as a result, the trawl codend sinking, with several hundred tonnes of fish. Such events can be extremely hazardous to the vessel and crew, as the safe working loads of deck equipment and cables can quickly be exceeded. To improve safety, as well as simplify the operation, the development of a quick-release coupling between the codend and pump has been proposed. This device should enable the remote release of the pump head from the codend skirt and should incorporate an auto-release function to ensure a safe-release when safe working loads are exceeded.

To begin the development of this remote release device, we need some information about maximum loads experienced by the pump-codend coupling during commercial fishing operations.

Figure 18 - Left: the pump-head funnel; and Right: pump with pump skirt connected [Source: J. Saltskår].

6.1. Materials and Methods.

When the codend had been hauled to the stern of the vessel, it was detached from the trawl and hauled around to the starboard side of the vessel. Here the codend skirt (aft end) was attached to the pump system and the leading end of the codend fed into the triplex, which was then used to lift the codend from the water, as the pump emptied it.

The most commonly used fish pumps by Norwegian fishing vessels are manufactured by Karm, Rapp Hydema and Seaquest. The fish pump used on "Vikingbank" was a Seaquest 18 "Weight 850 kg. Maximum capacity up to 3500 m^3 per hour.

Current practice for coupling a pump-head to a codend is to use a chain (thickness 10mm; breaking strength 12 tonnes) wrapped around the codend skirt and pump-head funnel, and locked with a shackle (figures 18 and 19). To estimate the maximum load on this chain, a cord was attached as a "weak-link" across a bight of three chain links (figure 21). A new chord weak-link was fitted as the chain was fitted to the pump-codend coupling, and inspected after each pumping event. The twine used for the weak-link was Tendon Accessory Chord (Tendon, 2021). A range a different twine thicknesses, and corresponding breaking strengths, were sourced for the research cruise (table 3).

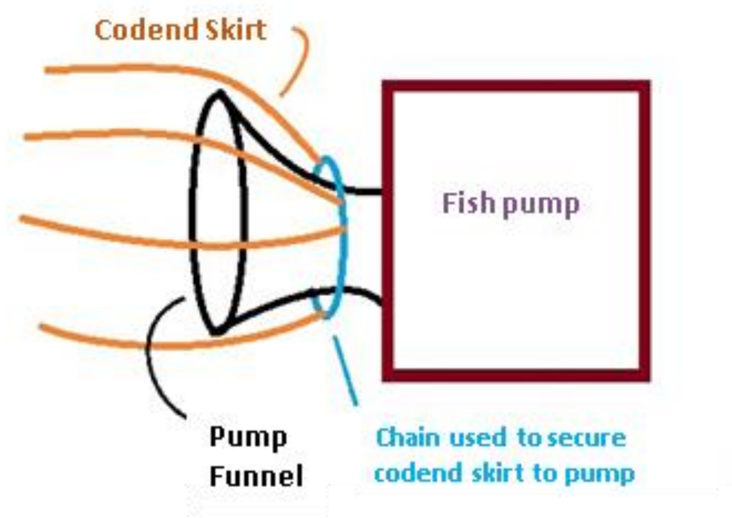


Figure 19 - The chain is used to secure the codend skirt around the pump spout. A shackle of 1.5 tons breaking strength is used to lock the chain [Source: J. Saltskår].

Table 6 - Tendon Accessory Cord summary details by diameter.

Diameter	Colour Code	Breaking Strength daN	Breaking Strength kgf	Certification
2mm	Blue or Yellow	120	122.4	CE 0408
3mm	Blue (or black)	190	193.8	CE 0408
4mm	Blue-Yellow (or Red)	340	346.7	EN 564, CE 1019
5mm	Yellow or Blue	510	520.1	EN 564, CE 1019
6mm	Red or Green	1000	1019.7	EN 564, CE 1019
7mm	Yellow or Red	1300	1325.6	EN 564, CE 1019
8mm	Red or Orange	1640	1672.3	EN 564, CE 1019
9mm	Red	1900	1937.5	CE 0408

Source: https://www.mytendon.com/en/products/accessories/accessory-cords/c-23/

Note – the breaking strength of twine is approximately halved by a knot (Prado, 1990).

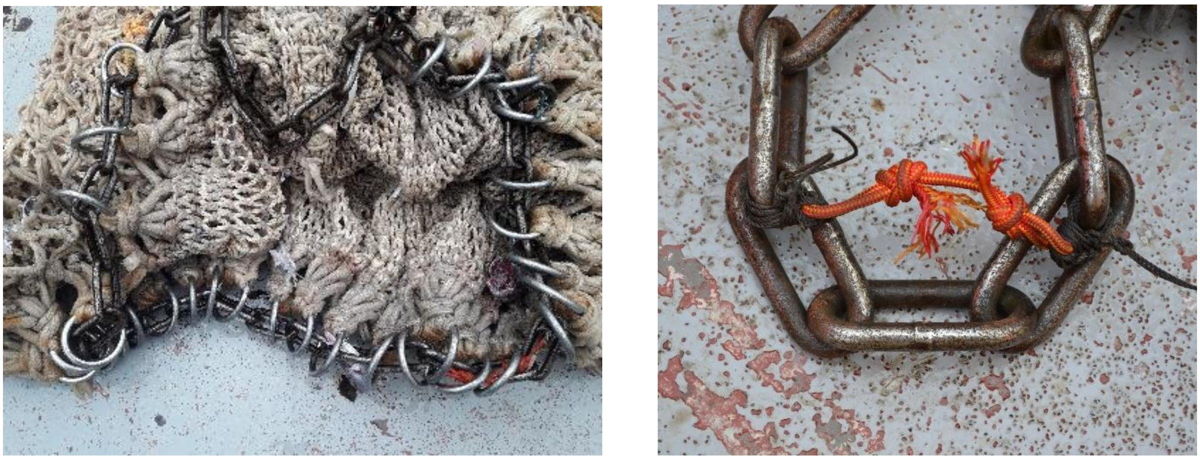


Figure 20 – Left: End of codend skirt showing the coupling chain fed through rings fixed to the netting. Right: Test twine set up as "weak-line" within a bight if chain [Source: J. Saltskår].

6.2. Preliminary Results and Discussion

Test-twines were fitted on all 10 hauls where fish were caught and pumped aboard the vessel (table 7). In only two hauls were the breaking strengths of the test-twines exceed, hauls 01 and 02, which had 3mm twines attached to the coupling chain. This suggests that in these hauls loads on the coupling chain exceeded approximately kg (assuming approximately 50% of breaking strength), but as the chain shackle remained intact loads did not exceed 1500 kg. [Note - the breaking strength of a twine approximately halves when a knot is tied in it; Prado, 1990]. In all remaining hauls, a twine thickness of 4mm (breaking strength: 346.7 kg) was used and was noted to have been intact after each pumping event. However, in three hauls (05, 06 & 08) is was noted to have stretched or slipped on the chain. To address any potential slipping of the twine, in hauls 08 to 10, the twine was more securely tied to the chain using an additional two knots on the other end of the chain link.

It should be noted that, although in hauls 03 to 10 the load on the coupling chain appears to have not exceeded ~173 kg (assuming 50% breaking strength), these hauls were conducted under relatively calm conditions (wave heights <1.5m) and so are not likely to be representative of the maximum forces experienced during typical commercial fishing conditions.

This simple and reproducible method should be able to approximately estimate maximum loads, or at least whether pre-set limits have been exceeded. However, it does have several limitations. Firstly, this incremental approach will likely require many replicates to precisely estimate maximum loads under a range of conditions and catch sizes. Moreover, it is not possible to identify when the maximum load occurred during the pumping event, which would be informative when defining appropriate mitigations and safe working practices. It is recommended that a compact and robust load-cell should be developed for attaching to the coupling chain. This should be able to tolerate loads up to 1.5 tonnes (i.e. the breaking strength of the coupling chain) and be able to monitor dynamic loads during the pumping process, over a range of conditions and catch sizes. Such a technology is also likely to be a necessary component in the development and operation of a safe and remotely operated codend-pump decoupling device.

Table 7 - Summary of Pumping Event Results by Haul. Pumping Times refer to the time when the pump was first lifted off the deck (start) to the time it was returned to the deck (stop).

Haul No.	Pumping times		Wind		Wave Height	Test Twine	
	Start	Stop	dir. (deg.)	str (m/s)	(m)	mm	Status
Haul_01	15:05:20	15:22:13	145	12	3	3mm	Twine broken
Haul_02	23:43:11	00:37:42	160	9	2.5	3mm	Twine broken
Haul_03	13:03:36	13:29:26	200	9	1.5	4mm	Intact
Haul_04	00:04:26	00:36:27	220	6	1.5	4mm	Intact
Haul_05	13:18:47	13:52:04	90	3	1.5	4mm	Stretched but intact
Haul_06	19:16:58	19:47:37	0	0	1.5	4mm	Stretched but intact
Haul_07	01:52:20	04:17:58	230	5	1.5	4mm	Intact
Haul_08	08:30:24	10:18:54	330	7	1	4mm (non-slip rig)	Stretched but intact
Haul_09	18:07:26	18:29:49	0	0	1	4mm (non-slip rig)	Intact
Haul_10	07:59:22	09:00:27	230	6	1	4mm (non-slip rig)	Intact

7. Methods for assessing the vitality and injuries of fish released from the catch control escape openings.

Objective: Develop methods to assess the vitality and injuries of fish being released from the catch control rigs.

This project is developing methods of controlling catch sizes and releasing excessive catch at the fishing depth, before the trawl is hauled to the surface. It follows therefore, as part of a responsible and sustainable fishery, these released fish should be uninjured and in a good state of vitality, as minimal indicators that these fish are capable of surviving the capture and release process.

7.1. Materials and Methods.

A small sampling trawl (figures 21 and 22) was tested to establish whether it could collect a small sample of fish (~30) escaping from the opening in the CCR and deliver that sample to the vessel with minimal physical trauma and injuries induced by the sampling process. As the preferred release opening is in the bottom panel of the CCR (see section 3), it was necessary to adapt the sampling trawl to work upside-down, because it was initially developed to float above a release opening. To facilitate this change, small weights were added to the sampling trawl "headline" when it was deployed in haul 04. This was later modified to a length of chain along the full length of the headline, in haul 09.

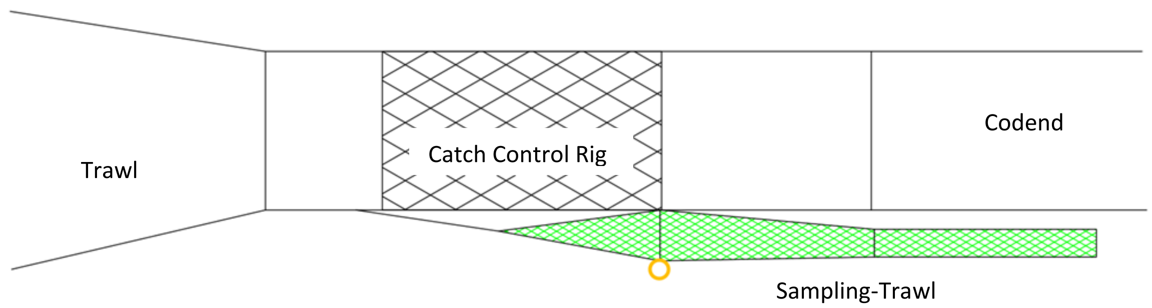


Figure 21 - Sampling-trawl beneath the catch control rig to collect fish released from the bottom opening.

In addition to monitoring the behaviour of fish in the trawl (section 3), on this cruise we also used a suite of behaviours/reflexes to monitor the "vitality" of individual fish sampled from the catch after pumping from the codend (haul 03) and for a sample taken from the escape opening sampling trawl (haul 04). "Vitality" is an objective measure of how alive an animal is, or conversely how close to death it is. Its objective measurement relies on using a selection of behavioural metrics, or reflexes, that can reliably indicate their ability to respond to a range of different stimuli, both contextual and physical. In this assessment, nine different metrics were used; 5 free swimming observations (in an observation tank) and 4 observations while handling (see table 6.1). Each fish was then photographed to record any external injuries, and its length and weight recorded.

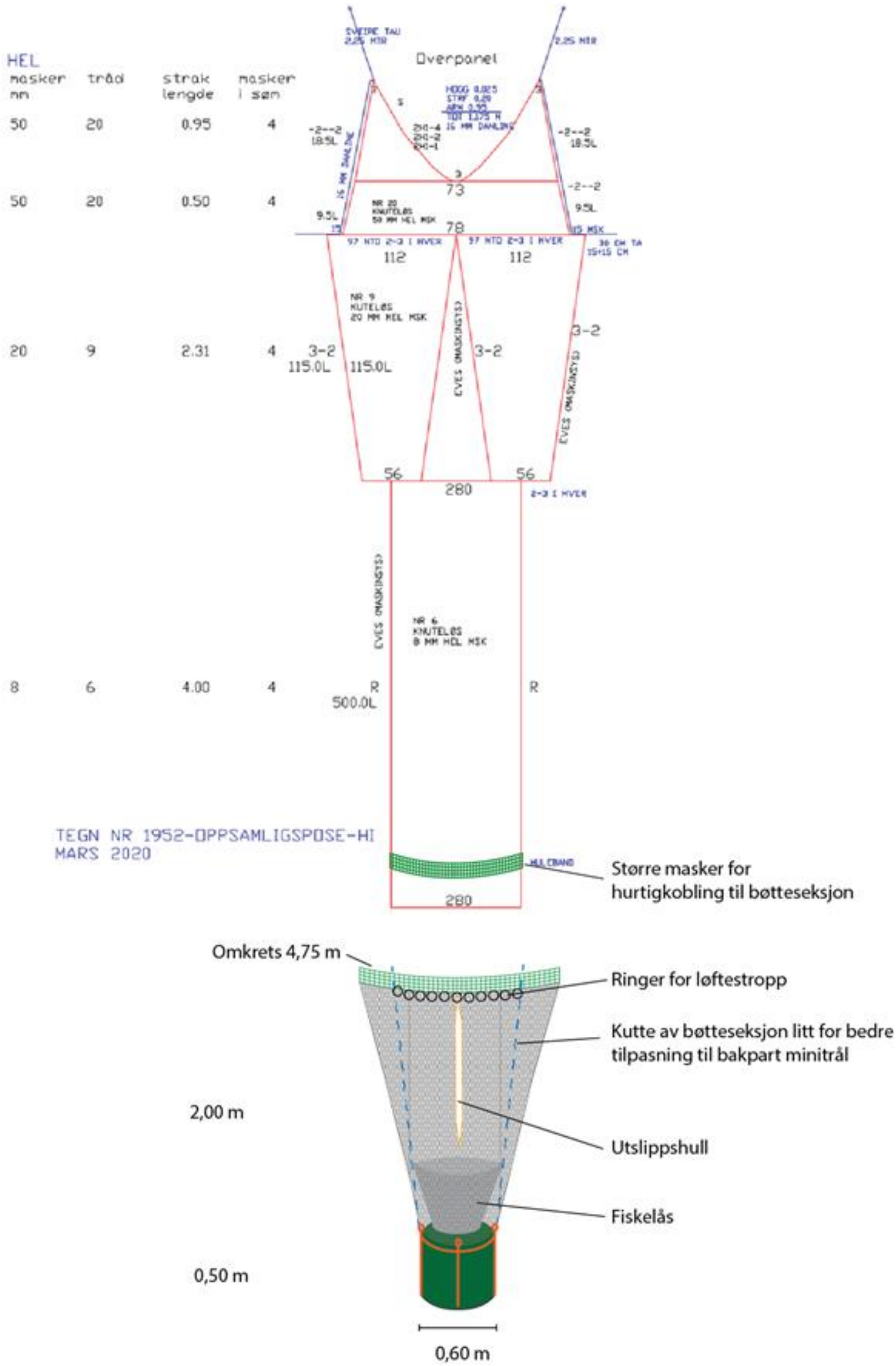


Figure 22 - Plan of the release opening sampling trawl [Source: O. Ingolfsson/L. Kvalvik].

Table 8 – Summary of vitality metrics used for blue whiting sub-sampled from the pumped catch and escape opening sampling trawl.

	Test	Positive Response	Negative implications (i.e. response absent or weak)
Free Swimming Observations			
Evasion 1	Fish transfered from net into observation tank	A "startle" response, or swims around tank seeking "escape".	Fish lacks awareness of substantial change in environment. Or is unable to respond due to exhaustion, or physical injury.
Orientation / Self-righting	Fish transfered from net into observation tank	Can self-orientate dorsal side up within 5 seconds of transfer.	Fish has lost a basic reflex - balance. Therefore, swimming and avoidance of potential threats will be severely compromised.
Head Complex	Fish transfered from net into observation tank	A coordinated and regular use of mouth and operaculae - indicative of normal respiration (> 1 per 10 sec).	Absence - respiratory failure, fish is dead or close to death. Very strong - fish may be hypoxic or fatigued.
Evasion 2	Observer's hand, in water, approaches fish from side; in preparation for "caudal reflex test (see below).	A "startle" response, or swims around tank seeking "escape".	Fish lacks awareness of potential visible threat. Or is unable to respond due to exhaustion, or physical injury.
Caudal Reflex	Observer touches, or attempts to hold, caudal fin.	Fish immediately (<1 sec) attempts to swim away from physical contact.	Fish lacks awareness of potential physical threat. Or is unable to respond due to exhaustion, or physical injury.
Observations While Handling			
Body Flex 1 - Restrained	Observer hold fish firmly in clenched hand, with thumb and fore-finger just posterior of operculae.	Fish should flex its tail musculatur in an attempt to escape (< 3 sec). [NB - test starts in water, as observer attempts to remove fish from tank].	Fish lacks awareness of strong physical threat (i.e. restraining). Or is unable to respond due to exhaustion, or physical injury.
Vestibulo-ocular response	Observer - while holding fish as above - rotates fish on the longitudinal axis.	Fish should attempt to hold eye steady, with respect to horizonal. That is, looking from the posterior, the eye should appear to look down, as the head is rotated clockwise; and *vice versa* .	Fish has lost a basic reflex - balance. May indicate loss of functionality in brain stem.
Mouth Closure	Observer - while holding fish as above - uses finger to open open fish's mouth.	Fish should attempt to resist opening action. May also respond with a "head-complex motion" and/or "body flex" (< 3 sec).	Fish lacks awareness of an intrusive physical threat. Or is unable to respond due to exhaustion, or physical injury.
Body Flex 2 - Flat surface	Fish is laid, unrestrained, on a flat surface.	Fish should flex its tail musculatur (< 3 sec).	Fish lacks awareness of substantial change in physical status - i.e. released but emersed. Or is unable to respond due to exhaustion, or physical injury.

To monitor oxygen concentrations in the pumped catch, a Rinko 1D oxygen logger (inside a protective housing) was fitted inside the codend skirt during pumping in haul 03. This provided oxygen concentrations (% saturation and mg/l), as well as temperature (°C) and depth (m), every second.

Figure 23 – Rinko oxygen logger, inside protective housing, being fitted inside the codend skirt before was coupled with the fish pump during Haul 03.

7.2. Preliminary results and discussion.

Video observations in haul 04 indicated that the mouth of the sampling trawl was not adopting the correct shape (figure 24, left), possibly due to insufficient and/or poor placement of weights. However, the sampling trawl did collect a small sample of fish, mostly blue whiting (n = 25) (see vitality results below). To improve the shape of the sampling trawl mouth opening, a length of chain was stitched to the headline and video observations during haul 09 confirmed the mouth was fully open and stable (figure 24, right). This also successfully collected a sample of fish, again mostly blue whiting (n = 23), along with some argentine and lantern fish.

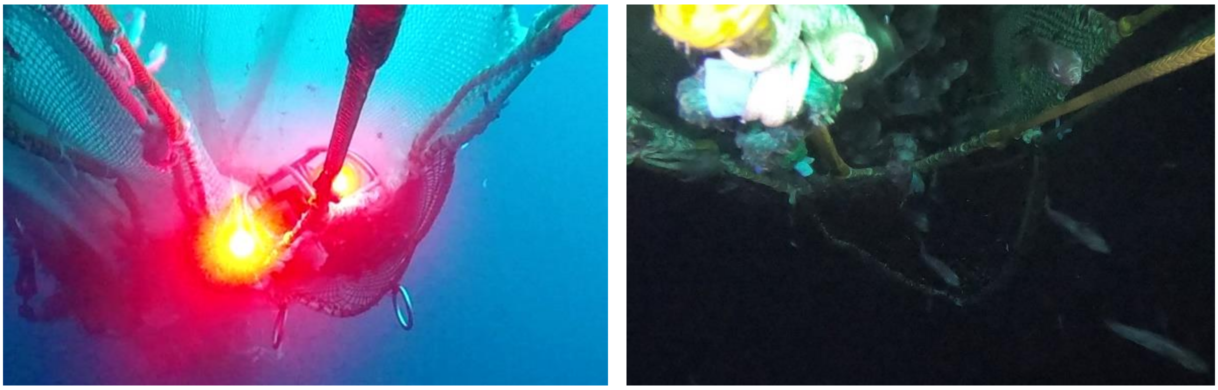


Figure 24 - underwater images (from camera position 7B) of the sampling trawl fitted to the bottom release opening. Left: haul 04 – trawl held open by two metal rings; beneath “dome camera frame” (position 6F). Right: better shaped trawl opening formed by chain fixed to headline; fish entering sampling trawl opening.

The mean vitality of blue whiting in the sampling trawl was 0.218 ± 0.090, as compared to just 0.014 ± 0.023 in fish pumped from the codend. Assuming all fish with a zero vitality score were dead, this translates to survival proportions of 0.36 (95% CI: 0.20 – 0.55) and 0.13 (0.04 – 0.36) for the sampling trawl and codend samples, respectively. Two fish from the sampling trawl had relatively high vitality scores (0.667 and 0.778), while the maximum vitality score from the sample from the codend was only 0.167. The proportion of floaters in each sample was 0.84 (0.65 - 0.94) and 0.63 (0.39 – 0.82) for the sampling trawl and codend samples, respectively.

The mean oxygen concentration in the codend skirt during pumping was 10.72 ± 0.01 mg/l [95.4 ± 0.1 % saturation], with a minimum of 5.49 mg/l [83.7 % saturation]. This suggests that oxygen concentration in the catch was depressed, but does not provide evidence of hypoxia. To establish more robust estimates of conditions inside the codend during the capture process, it would be informative to develop methods of deploying oxygen logger (with a suitable depth rating; >800m) inside the main body of the catch inside the codend.

Amongst both samples of fish there were examples of injuries resulting from physical trauma and decompression, including: scale loss, skin contusions, bleeding eyes, missing eyes, ruptured abdominal cavities. With respect to the fish from the sampling trawl it is not possible to say whether these injuries occurred during capture, or as part of the process of sampling and bringing the sample to the surface. Unfortunately, many of the photographs taken of the fish from the sampling trawl were over-exposed, so it will not be possible to quantify the injuries in these samples.

If we consider the codend sample as a positive control (i.e. a sample in which the subjects are expected to be maximally compromised, due to fatigue, physical trauma and decompression), these results imply that the welfare status of sampling from the sampling trawl may be marginally better. As these two groups of fish have been subjected to the same level of stress and injury from decompression, this suggests that the levels of fatigue and physical trauma may be less in the fish escaping through the release opening in the CCR.

In conclusion, this cruise has demonstrated that the sampling trawl is a viable technique for collecting live samples from the release opening in the CCR. Moreover, the vitality assessment method was applicable to blue whiting and evidence of injuries from physical and decompression trauma was observable in both the codend and sampling trawl samples. Due to the small sample sizes in this trial and loss of injury data, as well as the extreme decompression experience by these samples when they are brought to the surface, it remains unclear whether this approach will provide any meaningful evidence on the welfare status of fish released from the CCR. However, it is recommended that these trials should be repeated on future cruises to obtain a larger number of replicates from both the sampling trawl and codend, so that a judgement based on more robust empirical evidence can be made on the validity of this approach.

8. Summary and Recommendations

This cruise has successfully tested three different catch control rigs and observed the behaviour of fish passing through and escaping from them. These observations revealed a consistent behaviour in the target fish (i.e. generally swimming upwards when passing through the CCR), which could be utilised to improve the design of the CCR. Based on these observations a fourth design of CCR was constructed and tested. This was a hybrid of rigs 1 and 3, with escape resistant panels on the tops and sides (from Rig 3) and a large hexagonal mesh opening on the bottom panel, to facilitate the discharge of excessively large catches. It is recommended that this design is further developed and tested as part of this project.

Two types of fish lock were tested in the CCR. Only type 1 (in Rig 1) was demonstrated to work successfully in one haul. Future work in this project should focus on further developing and testing this important component of the CCR. This will include consistent and replicated video observations to demonstrate functionality.

A prototype catch limitation release (CLR) system, by FossTech, was also tested on this cruise. It successfully opened on each haul and work is ongoing, as part of the trawl geometry component of this project, to confirm whether it released at the predetermined depth and what effect this delayed release of the catch had on the ascent rate of the trawl codend. As anticipated, catch sizes (volume and weight) generally increased the further aft the CLR was positioned on the codend. However, there was some variation between actual and anticipated catch size, based on the position of the CLR. Moreover, catch volumes only accounted for a small proportion of the available theoretical codend volume. Further work should establish a predictable relationship between CLR position and resultant catch sizes (with estimates of uncertainty). In addition, the reliability of the methods used by the skipper to determine when the catch limit of the codend has been reached, e.g. Simrad catch sensors and Scanmar Trawl-Eye, should be assessed by direct comparison with the underwater observations from this and future research cruises.

This cruise identified several positions for cameras that could be informative during future investigations in this project (see appendix A for details). It is recommended that future work in this project should utilise multiple and synergistic camera positions in each haul to answer specific pre-determined research questions. This will require a substantial increase in the camera and light equipment required for each cruise (see comments above) to ensure coverage and redundancy.

Maximum loads on the pump-codend coupling chain did not exceed 173 kg (assuming 50% of twine breaking strength, due to the presence of knots). However, these observations were conducted under relatively calm conditions (wave heights <1.5m) and so are not likely to be representative of the maximum forces experienced during typical commercial fishing conditions. Furthermore, it is recommended that a compact and robust load-cell should be developed for attaching to the coupling chain to better monitor dynamic loads during the pumping process, over a range of conditions and catch sizes. Such a technology is likely to be a necessary component in the development and operation of a safe and remotely operated codend-pump decoupling device.

The sampling trawl has been shown to be a viable technique for collecting live samples from the release opening in the CCR. Moreover, the vitality assessment method was applicable to blue whiting and evidence of injuries from physical and decompression trauma was observable in both the codend and sampling trawl samples. It is recommended that vitality and injury assessments should be repeated on future cruises for a larger number of replicates from both the sampling trawl and codend.

Finally, this cruise confirmed anecdotal evidence that there is a potential problem with bycatch of large species, for example: porbeagle (*Lamna nasus*) (IUCN status [NE Atlantic]: critically endangered) and bluefin tuna (*Thunnus thynnus*) (IUCN status [Europe]: near threatened). It is recommended that further work should be conducted to better characterise this potential problem in terms of vulnerable species and capture rates. This will require international collaboration between the nations whose fleets prosecute this fishery: Denmark, Faroe Islands, France, Iceland, Ireland, Netherlands, Norway, UK and Russia. Furthermore, the remit of this project should be expanded to include further work to investigate whether the large escape opening in Rig 4 could be optimised to also promote the escape of these large bycatch species.

9. Acknowledgments

This cruise was jointly funded by the Norwegian Fisheries Directorate (*Fiskeridirektoratet*), the Norwegian Seafood Research Fund [*Fiskeri- og havbruksnæringens forskningsfinansiering; FHF*] and the Institute of Marine Research (IMR) as part of the Catch Control in the Blue Whiting Fishery [*Fangstkontroll i fisket etter kolmule*] FHF project number 901542. The project and authors are also grateful to the governments and authorities of Ireland and the United Kingdom for granting permission to conduct this research in their territorial waters.

The authors are very grateful to the skipper (Anders Klovning) and crew of MF Vikingbank, who were very supportive and resourceful throughout the cruise. The catch control rigs were designed in collaboration with industry representatives and manufactured by *Åkrehamn Trålbøteri AS* (rigs 1 and 3) and *Egesund Trål AS* (rig 2).

We also thank our colleagues Shale Rosen, Manu Sistiaga and Terje Jørgensen for their advice and input in preparation for the cruise.

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Appendix A – Notes on underwater camera and light operation and positioning.

There was a total of 38 underwater camera deployments during 13 hauls, of which there were 21 (55%) successful and complete observations, 7 (18%) partial/incomplete observations and 10 (26%) failed deployments (see table A1 for details). The single most common failure (7 out of 10) was premature camera shutdown or frozen images in the GoPro 7 cameras, in either the (T-housing or Group B underwater housings). The cause of this systematic failure is unknown and, because the GoPro 7s were the main/most numerous camera we had, this was a major problem. However, it was later remedied by setting the GoPro 7 cameras to record in time-lapse mode (2 fps), then compiling the still images into a video to ease playback and time-synced analysis.

The main camera system used underwater observation was the "dome-frame" containing a camera (GoPro 5 or 7) in a GroupB Benthic+GPH deep-water housing, with two Brinyte DIV01 diving lights (Red or White; see below for more discussion) in GroupB GPH deep-water housings (figure A1). This is a very robust and versatile camera/light rig, that is ideally suited for the challenging conditions encountered in this fishery. Although, because of the necessarily low-profile of the frame, the camera has a limited perspective (only approximately half-view) when attached to a closed/small mesh netting panel (see below for further discussion). As discussed, the most reliable camera was the GoPro 5; which we now have only a few of. Therefore, it is strongly recommended that we source more GoPro 5s or find an alternative camera/housing combination to fit the "dome-frame". Furthermore, it is also recommended we make at least three more "dome-frames" (we currently have 3), to maximise camera placements and/or optimise turn-around times.

Figure A1 – "dome-frame" with camera (in a B-group housing), and with two red lights (left), and being fitted/removed from the trawl (right).

The JT Electric Trawl Camera ["TrawlCam"](Figure A2) has a highly sensitive camera, which produced the best images of any of the cameras in the low/red light field. Also, being able to tilt the camera proved advantageous in several situations. However, it did have a very slow data download rate which limited operations and/or risked data security. That is, 1 hour of video took approximately 30 mins to download, so for repeat deployments it was necessary to redeploy the camera without fully downloading the video; risking loosing data from multiple hauls should the camera flood or be lost. Furthermore, it has an approximately 20-hour storage capacity. In combination with a data download backlog, this meant important observation times were lost at the end of haul 10, when storage capacity was exceeded. Finally, the housing attached points were not very robust (cracking on the first deployment, haul 05). This necessitated *ad hoc* repairs and reinforcement of the structure by the vessel's engineers, which proved to be very durable. Finally, the camera is only fitted with white/green lights, so when using red-light it was necessary to deploy a dome-camera frame fitted with red-lights alongside the TrawlCam to illuminate the subject area.

Figure A2 – the JT Electric Trawl Camera (Left), with a reinforcing base-plated fitted by the Vikingbank's engineers during the cruise (right).

The "flying camera" (figure A3), lifted above the subject area using a kite system [positions 3 and 4], has the potential to provide very informative perspectives, both structurally and behaviourally. However, care must be taken during placement and deployment to avoid potential entanglement, e.g. in large open meshes in the escape panels [position 3] or with the codend round-strops [position 4]. Furthermore, it was generally deployed with only one light fitted, which was generally insufficient for clear illumination. It is recommended that future deployments should have at least two lights fitted, and/or if using red lights the subject area could be locally illuminated with a separate "dome-frame" fitted with 2/3 red lights.

Red light was used primarily for behavioural observations. It appears that blue whiting are blind to the red light used here, or at least did not respond adversely. That is, there was no evidence of phototaxis; i.e. no rapid or well-define changes in behaviour/swimming direction when fish enter the light field. Furthermore, on several occasions fish were observed inadvertently swimming into the camera/light assembly, apparently unable to see/avoid it. However, red light is rapidly attenuated in water so is a poor illumination source at ranges greater than 2m. The use of additional red lights on subject area may improve illumination. In particular, localised, oblique illumination of a subject area reduces loses due to attenuation (i.e. reduces the distances the photons travel from source, to subject to camera). However, backlighting with red light did not work, because the receiving camera was effectively blinded by the high contrast (e.g. haul 04, position 6F).

Figure A3 – the "Flying Camera" housing with tether line (Dyneema) and kite [Source: J.Saltskår].

White light was used when improved illumination was required for clear observation of structural/mechanical components of the catch control rigs. White light was generally avoided in situations where behavioural observations were important, because white light will be visible to blue whiting, and other deep-water species, and may affect behavioural responses in the light field. There may be some supporting evidence of this during haul 09, where light was used to better illuminate the escape opening structure. But a more systematic comparative analysis of behavioural responses will be required before any definitive conclusions can be made.

This cruise identified several positions for cameras that could be informative during future investigations in this project (see figure A4 and table A1 for details). Note, the position nomenclature developed during the cruise, so is rather *ad hoc*. A more systematic and intuitive naming system may aid accurate and consistent camera placement during future cruises, in addition to the practice of pre-deployment labelling of each camera, with respect to its intended position, adopted on this cruise. Pre-marking known camera positions on the trawl also greatly improved ease and accuracy of placement during deployment.

The most informative positions for observing escaping fish from the catch control escape openings were positions 1F and 2F, on the outer trailing edge of the escape openings. Here, it is easier to distinguish escaping fish because the inherent flow forces them towards and past the camera. However, because of the restricted perspective of the cameras in these positions, it is necessary to pair these with cameras in respective positions on the inside of the catch control rig, to make inferences about the likely drivers of escapes (e.g. increase fish density). Internal camera positions were also informative about the structure/shape of the catch control rigs and their subcomponents.

Having multiple perspectives at the same time can be very informative and synergistic when interpreting complex operations, like the catch control processes described in this report. For example, a sudden increase escape rates at position 1F, may be explained by an increase in fish density at position 5F; which in turn could be explained by either an increase in density at 6B, as the codend fills, or because of a failure in the fish lock during hauling. It is recommended that future work in this project should utilise multiple and synergistic camera positions in each haul to answer specific pre-determined research questions. This will require a substantial increase in the camera and light equipment required for each cruise (see comments above) to ensure coverage and redundancy. However, caution should be used not to overload one area of the net with too many cameras because this could distort the net (e.g. haul 08; positions 2F, 6F and 6B).

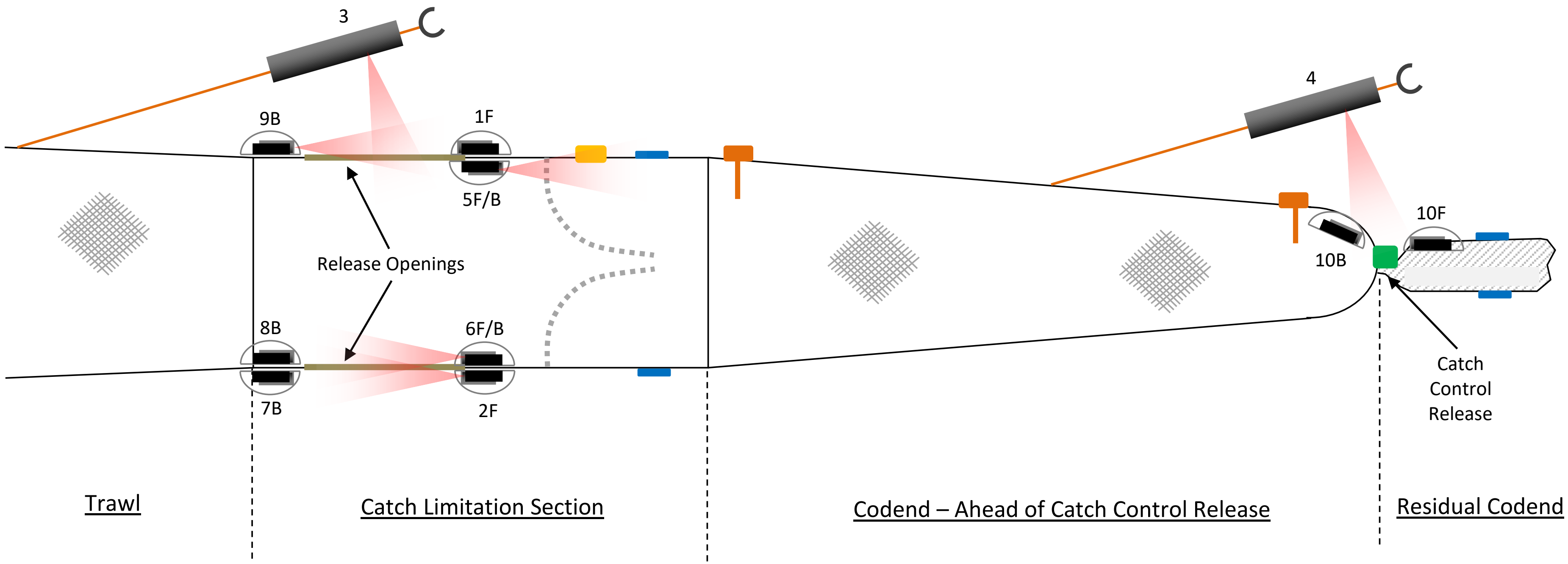


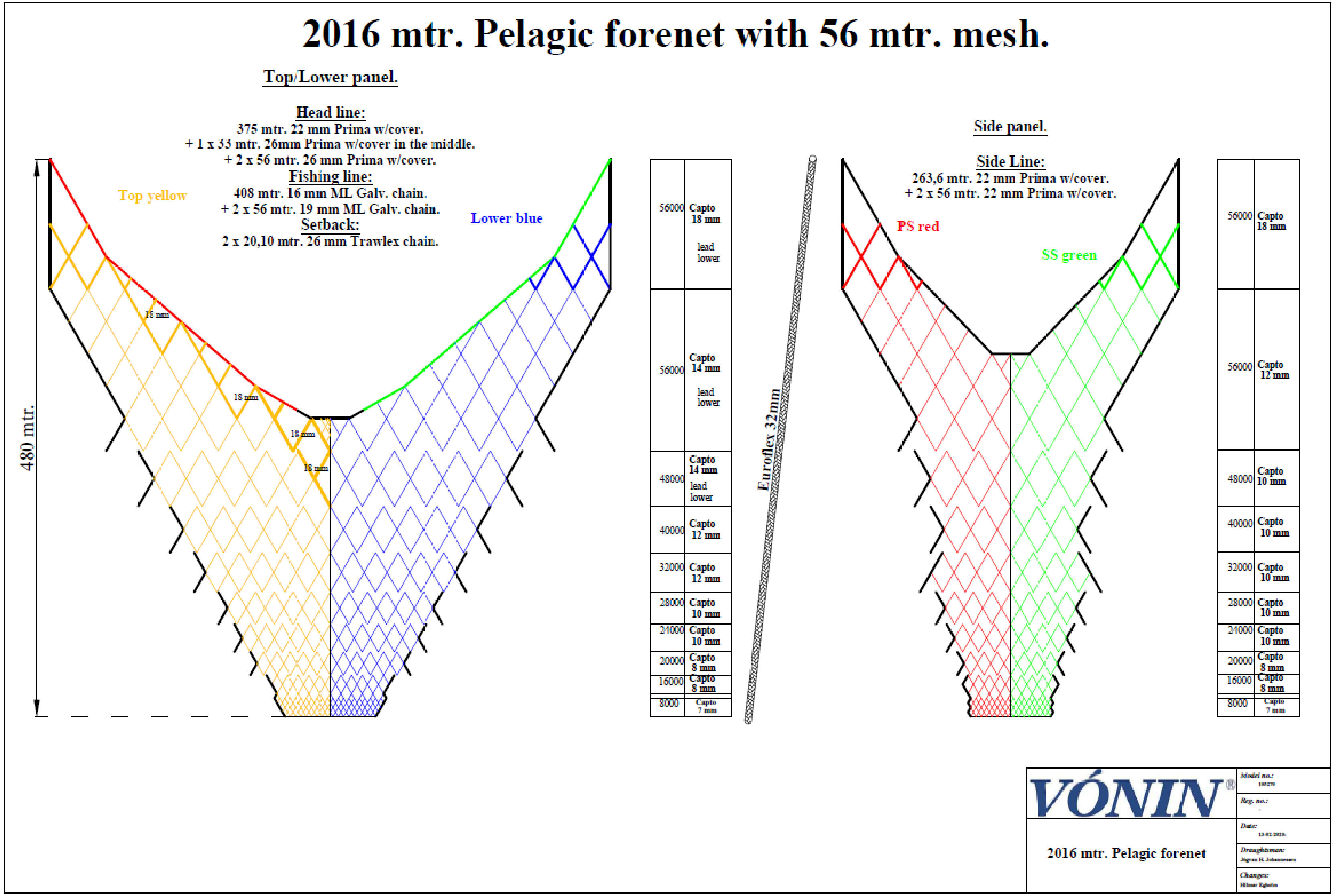
Figure A4 – Camera positions on the Catch Control Rigs and Codend. Post-script F means the camera was forward facing (toward the mouth of the trawl) and post-script B means the camera was backwards facing (towards the codend). The red shaded triangles provide an approximate indication of the illuminating light field in some example positions. See figures 4 and 12 for further explanation of the fishing gear components.

Table A1 – Overview of camera deployments and observations by haul. Successful deployments are highlighted in green; partially successful deployments are highlighted in light grey; and failed deployments highlighted in dark grey.

Haul	Position	Camera	Lights	Notes	Position	Camera	Lights	Notes	Position	Camera	Lights	Notes
Test_1	10B	Cam A	2 Red	Video Frozen at 00:30:54								
Test_2	9B	Cam A	2 Red	Video Frozen	10B	Cam B	2 White	Release in GP064498.MP4 at 14:48.				
Test_3	1F	Cam C	2 White	To film FlyCam (CamD)	3	Cam D	1 Red	Test positioning of FlyCam => tangled in top panel meshes				
Haul_01	1F	Cam B	2 Red	Escapes via Rig 1 top panel	2F	Cam C	2 Red	Few escapes via bottom panel with cover, until end [GP103562; ~07:30]	3	Cam D	1 Red	Stills=> compiled into video; stopped early after 44:27
Haul_02	1F	Cam B	2 Red	Escapes via Rig 1 top panel with cover	2F	Cam C	2 Red	Few escapes via Rig 1 bottom panel with cover	3	Cam D	1 Red	Shutdown during haul
Haul_03	2F	Cam A	2 Red	Stopped on deck	4	Cam D	1 Red	Camera froze near surface at start	5B	Cam B	2 Red	Fish high in codend; fish lock fill at 17:05 [GP144503]
	6B	Cam C	2 Red	Few fish low in codend until ~08:00 ; see fish lock fill at 14:53 [GP143564]								
Haul_04	4	Cam D	1 Red	Light Flooded	6F	Cam B	2 Red	Red lights from 7B spoil shots	7B	Cam C	2 Red	some film early in haul, incl sampling trawl; cam flooded at 13:50 [GP083566]
Haul_05	1F	Trawlcam	2 Red	High escape rate at top; Lights in separate housing	2F	Cam B	2 Red	Very low escape rate at bottom	4	Cam D	1 Red	Camera and frame lost
Haul_06	1F	Trawlcam	2 Red	No escapes at top?; poor positioning; Lights in separate housing	5F	Cam B	2 Red	Good views of internal structure & fish density; few escapes				
Haul_07	1F	Cam B	2 Red	opening slit at end => high escapes; same time as catch sensor #4 on	6F	Cam A (TL)	2 Red	Higher density match escapes in 1F; slit opening also matches 1F				
Haul_08	1F	Cam A	2 Red	Cam failed after 1 min	2F	Cam B	2 Red	Some escapes via bottom opening; especially at end 13:16 [GP274510]	3	Cam H	1 Red	Lighting dim and camera shutsdown before end of haul
	6F	Cam I (TL)	1 Red	As for pos 2F; NB - multiple camers distoring shape of FB section	6B	Trawlcam	1 Red	See fish lock work at end of haul; Light in Cam I housing; but too dim				
Haul_09	7B	Cam I (TL)	2 White	View of sampling trawl and escapes from bottom panel	8B	Trawlcam	2 White	Continuous escapes (behaviour affected by light?); sampling trawl	10F	Cam B	2 White	Good views of catch release working
	3	Cam H	1 White	Not deployed [left on deck]								
Haul_10	7B	Cam B	2 Red	multiple escapes from bottom; massed escape at end: 9:26 [GP324514]	8B	Trawlcam	2 Red	multiple escapes from bottom; cam shut down early before end of haul	9B	Cam I (TL)	2 Red	No TL video to review; still images appear OK, but no escapes seen.
	3	Cam H	1 Red	Offset to overview side panel, but light too dim; cam shutdown early								

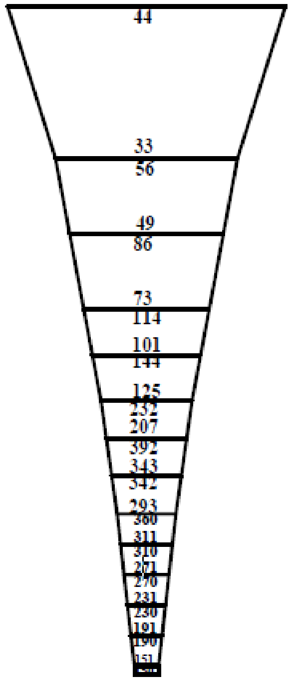
Camera A: GoPro Hero 7 (Group B underwater housing + other housing when used in the wheelhouse)
Camera B: GoPro Hero 5 (Group B underwater housing)
Camera C: GoPro Hero 5 (Group B underwater housing)
Camera D: GoPro Hero 7 (T-housing underwater housing)
Camera E: GoPro Hero 4 (plastic housing used in the wheelhouse)
Camera F: GoPro Hero 4 (plastic housing used in the wheelhouse) - DEFECTIVE BATTERY
Camera G: GoPro Hero 3 (plastic housing used in the wheelhouse)
Camera H: GoPro Hero 3+ (plastic housing used in the wheelhouse + underwater housing)
Camera I: GoPro Hero 7 (used in the wheelhouse with powerbank + GroupB underwater housing when in water
Camera J: GoPro Hero 7 (used in the wheelhouse with powerbank)

Appendix B – Trawl Drawings



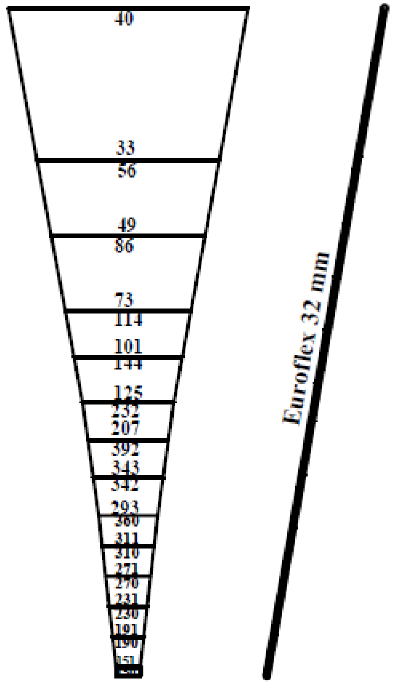
2016 mtr. Pelagic belly.

Top/lower panels.



40m (38)	9½	4000	Br.Nylon. 8 mm
20m	9½	2000	Br.Ny. 5 mm
20m	19½	1000	Br.Ny. 4 mm
12m	19½	600	Br.Ny. 3 mm
12m	29½	400	Br.Ny. 2,5 mm
10m	49½	200	Br.Ny. 2,3 mm
10m	99½	100	Br.Ny. 2,3 mm
10m	99½	100	Br.Ny. 2,3 mm
8m	99½	80	Br.Ny. 2,3 mm
8m	99½	80	Br.Ny. 2,3 mm
8m	99½	80	Br.Ny. 2,3 mm
8m	99½	80	Br.Ny. 2,3 mm
8m	99½	80	Fl. 2 x 2,3 mm
1,2 m	11½	100	Nylon 2 x 4 mm

Side panels.



VÓNIN®

2016 mtr. Pelagic belly.

Model no.	103857
Reg. no.	1265
Date:	11-06-2019:
Draughtsman:	Jógvan H. Johannesen
Changes:	Hilmar Egholm