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Bericht

über die 687. Reise des FFS Solea
vom 14.03 **bis** 04.04.2014

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Das Wichtigste in Kürze

Schleppnetze lassen üblicherweise kleine Fische entkommen, wohingegen mittelgrosse und grosse Tiere gefangen werden. Allerdings spielen die grossen und damit älteren Fische einer Art eine wichtige Rolle bei der Nachwuchsproduktion, weil sie, im Gegensatz zu kleineren Tieren, stabilere und höhere Reproduktionsraten aufweisen. Es gibt also gute Gründe die sehr grossen Tiere zu schonen und in den kommerziellen Fängen zu vermeiden. Um dies zu erreichen, wurde ein neues fangtechnisches Konzept entwickelt. Dieses ermöglicht es auch grossen Fischen während des Schleppens zu entkommen. Es kombiniert zwei bekannte Selektionsmethoden, nämlich Steert- und Gitterselektion. Zusätzlich zu der Maschenselektion im Steert wurde deshalb ein Stahlgitter im Schleppnetztunnel montiert. Dieses Gitter verhindert, dass grosse Fische den Steert erreichen und sie stattdessen durch eine Öffnung das Netz verlassen können. Das Ergebnis ist schliesslich eine glockenförmige Selektionskurve, bei der nur mittelgrosse Fische gefangen und kleine und grosse Tiere entkommen werden. Das Konzept wurde erfolgreich am Beispiel des Dorsches (Gadus morhua) in der Ostsee getestet. Aufbauend auf diesem Experiment wurden nun verschiedene Konfigurationen des Gitters und der Öffnung getestet, um deren Auswirkungen auf den Fang zu untersuchen. Dieses neuartige Konzept und die Ergebnisse der durchgeführten Experimente sollen hier darstellt werden.

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1 Introduction

Protecting small fish (often equated in argumentations with 'juveniles') from fishing is currently one of the key strategies to preserve or recover the sustainability of exploited stocks in world fisheries. In conjunction with other management measures, the optimization of the size selection of commercial gears has been widely applied to reduce the fishing pressure on small fish, by focusing the fishing pressure on medium and larger fish.

Older fish can produce larger spawn with higher quality of eggs than younger fish. Recent studies connecting the reproductive biology and population dynamics of exploited stocks outlined alternative management strategies, where the reduction in the fishing pressure on larger fish could increase the reproductive success and hence support a good stock status [1, 2], bringing into question the current management strategy mentioned above

A potential way to reduce the fishing pressure on large fish is to alter the selectivity of commercial gears focusing the fishing pressure on medium sizes of the exploited population. Albeit such size selectivity profile is common in fixed gears such as gillnets [4], it was not available for active gears, such as trawls.

The selectivity of trawl gears have been historically controlled by altering the mesh size in the codend [6, 4], i.e. the end part of the trawl gear where most of the size selection occurs. The size selection process in the codend can be understood as a 'simple' filtering process: The bigger the fish is, the fewer the options it has to escape through the meshes. Based on this argumentation, it is clear that altering the size selection in the codend alone is not a sufficient strategy if the goal is to avoid catches of larger fish.

During the FFS Solea cruise `SO687`, we met the technical challenge of achieving an alternative size selection pattern for trawl gears. For this purpose, an experimental gear was designed with alternative technical solutions to simultaneously avoid catches of the smallest and largest fish available in the targeted population. The design of the experimental gear attempted to achieve three different selective events occurring when a fish encounter the trawl :

1. the fish can escape when it is too big (e.g. guided out of the net)
2. the fish can escape when it is too small (e.g. escape through codend meshes) , or
3. the fish is caught when medium sized

The main aim of the present study is to widen the horizon for size selectivity in trawl gears, by demonstrating that alternative selectivity patterns for trawls in general are feasible through new developments in fishing technology .

2 Material and Methods

2.1 Experimental trawl

The experimental trawl was developed using a T300/60 gear as baseline. Two selection devices were mounted one after another to establish a stepwise size selection system, which should provide the desired size selection pattern. The first selection device was a steel grid, mounted after the belly section of the gear to block the passage of large fish further into the aft of the net tunnel. To achieve this, the grid bars were widely spaced, allowing only small and medium-sized fish to pass through the grid towards the codend. On the other hand, an outlet positioned right in front of the grid in the upper panel of the net, should allow big fish to escape from the trawl. The major technical challenge is related with how fish interacts with grids blocking the tunnel: underwater observations in Norwegian fisheries found that fish tend to herd in front of the grids and hence reduces the contact of the fish with the grid. This contact between fish and grid is necessary for the grid size selection to occur. Extrapolating this to our study, such behavior could increase the possibilities that fish encounter the escape outlet before they contact the grid. This potential problem was addressed by mounting a small net panel -loosely attached to the fore edge of the outlet- to make the excluder outlet less visible for fish herding in front of the grid. The so-called 'Masked Escape Outlet' is denoted hereafter as MEO.

The catch process continues for small and medium fish, which are able to pass the grid area towards the codend. The second size selection process in the experimental gear is therefore determined by the selectivity properties of the codend. This process is the same as in standard gears, where only small fish have any probability to escape through the codend meshes.

The resulting catch observed in the codend is therefore profiled by the combination of two independent size selection processes, differing in purposes and acting sequentially along the gear. Such a combined size selection process should result in a bell-shape curve of probabilities along the range of available length classes. Obtaining a size selection with bell-shape signature during the current experiment would be therefore a proof of success for this study.

Further details on the experimental gear (e.g. used mesh sizes and grid bar distances) can be found in [5].

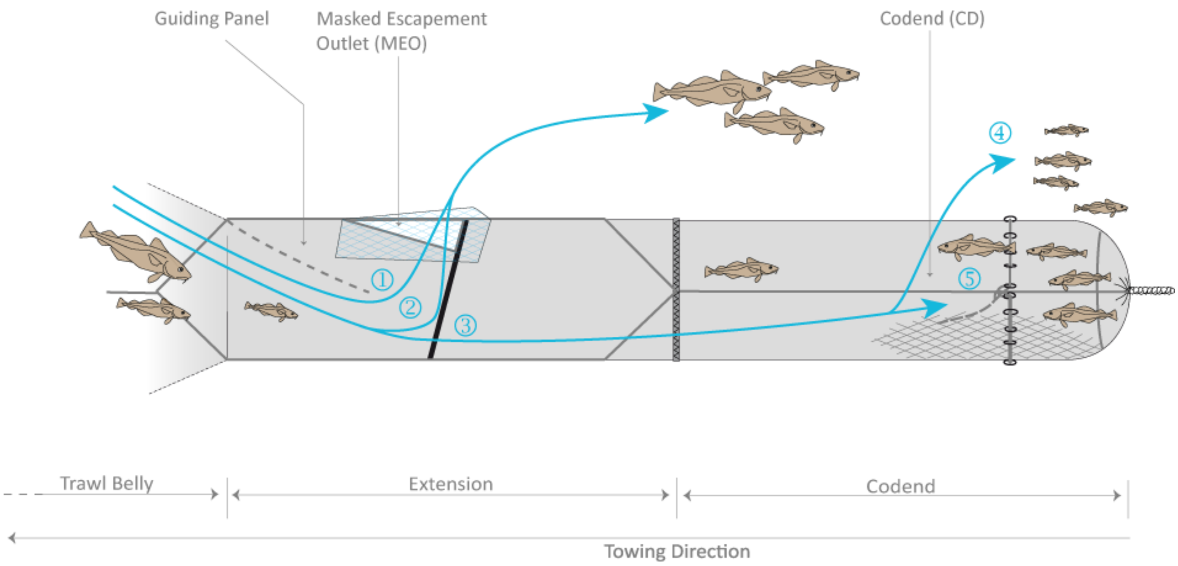

Figure 1: Illustration of the grid and codend selection system used to obtain bell-shaped trawl selectivity. In addition to technical details the different traits of fish entering the extension piece are illustrated: 1) fish not contacting the grid and escaping through MEO; 2) fish contacting the grid, but not be able to successfully pass through; 3) fish contacting the grid and passing through and entering the codend; 4) fish escaping through the codend meshes; 5) fish finally caught within the test codend.

2.2 A model for describing bell shaped selection curves

2.2.1 Model Structure

A structural model based on the selection process expected to occur in the trawl during towing is proposed to describe the partial selectivity of each of the selection devices, while the combination of the partial selection events should yield the targeted bell-shaped selection curve. Considering the experimental selection system, and assuming that the probability for a fish to be retained in the codend depends on the individual body length, the bell shape selection curve can be defined as:

$$r_{bs}(l) = 1.0 - e_{meo}(l) - e_{codend}(l) \tag{1}$$

Where the full probability (1.0) to observe a fish in the codend is subtracted by the length dependent probability that fish escape through the outlet above the grid ($e_{meo}(l)$), and the length dependent probability that fish escape through the codend meshes.

More in detail, the $e_{meo}(l)$ function accounts for the sum of two different events in the grid area:

$$e_{meo} = (1 - C_{grid}) + C_{grid} \times r_{grid}(l) \tag{2}$$

With C_{grid} being a binomial variable that can be interpreted as the probability for a fish to efficiently contact the grid area, that is, becoming available to the grid size selection. On the other hand, r_{grid} is a monotonic function describing the size selection properties of the grid.

As mentioned above, the parametric structure of equation 2 accounts for two different events: the probability that fish escape through the outlet before they contact the grid ($1 - C_{grid}$), and the probability they are rejected after contacting the grid, because they are too big to pass through the bar spacing ($C_{grid} \times r_{grid}(l, v)$). Both events in summation define the escapement probability through the outlet.

The third term in the right hand side in Equation (1) describes the probability for a fish to escape through the codend meshes once it entered the codend. The selectivity of the codend is only available for the fish passing through the grid bars, therefore e_{codend} is conditioned by the first selectivity event as it follows:

$$e_{codend} = (1 - e_{meo}) \times (1 - r_{codend}(l)) \tag{3}$$

Where $1 - e_{meo}$ can be interpreted as the probability for a fish to reach the codend (or in other words, the probability of passing though the grid towards the codend ($1 - e_{meo}(l) = e_{grid}(l)$), and $1 - r_{codend}(l)$ the probability of escapement through the codend meshes. The retention probability of the codend ($r_{codend}(l)$ can be simply derived from Equation 6 as:

$$r_{codend}(l) = 1 - \frac{e_{codend}}{1 - e_{meo}} \tag{4}$$

To describe the size selection properties of the grid ($r_{grid}(l)$) and the codend $r_{codend}(l)$, we use here the well-known *logit* function, specifically transformed into a form allowing the direct estimation of the selectivity parameters of interest:

$$r(l) = \frac{e^{log(9) \times \frac{l - L50}{SR}}}{1 + e^{log(9) \times \frac{l - L50}{SR}}} \tag{5}$$

where L50 is the length with 50% probability of retention, and SR is the range between the lengths with 75% and 25%.

2.2.2 Data collection

The estimation of the model described above requires direct and quantitative observations of fish escaping through the outlet in front of the codend, fish escaping through the codend meshes, and fish retained in the codend. We used an experimental design based on covers method [6] to collect the required data. In addition to the common setup based on covering the codend with a small mesh net cover, it was required the use a top cover to collect those fish that used MEO to escape from the catch. The experimental design involves therefore the definition of three different compartments:

- TC = Top cover to collect all those individuals escaping through MEO ($n_{meo,l}$).
- CC = Cover codend to collect all those individuals escaping through the codend meshes ($n_{cc,l}$).
- CD= Codend, containing the final catches of the gear ($n_{cd,l}$).

2.2.3 Model Estimation

The bell-shape curve, together with the selectivity parameters of the grid and the codend are estimated by maximizing the *Ln* of the specific likelihood mass function of Equation 1 to the experimental data previously pooled over hauls:

$$-\sum_{l}\left\{\sum_{h=1}^{H} n_{cd,l} \times ln(r_{bs}(l)) + \sum_{h=1}^{H} n_{tc,l} \times ln(e_{tc}(l)) + \sum_{h=1}^{H} n_{cc,l} \times ln(e_{codend}(l))\right\} \quad (6)$$

Where the outer summation is over length classes l in the experimental data and the inner over experimental fishing hauls h, $1 \ldots H$.

The diagnosis of goodness of fit of the model to the experimental data was based on the p-value, model deviance versus degrees of freedom, and finally the inspection of the model curve to reflect the length based trend in the data.

2.2.4 Inference

The Maximum Likelihood estimation using Equation 6 requires the aggregation of the experimental data over hauls. Such procedure results in stronger data to estimate the *population* selectivity, at the expense of lost of the natural variation between hauls. To account correctly for the effect of between haul variation in the size selection we use a double bootstrap method to estimate the Efron percentile Confidence Intervals for both the estimated parameters in 6 and the resulting curves r_{bs}, $e_{meo}(l)$ and $e_{codend}(l)$. We use 1000 bootstrap iterations for each species in each design investigated.

2.3 Experimental setups

Significant efforts have been invested to date on investigating the selectivity properties from a wide range of codends in the Baltic sea cod fishery [3], however, previous information on the effectiveness of the grid system herein adopted was limited. In addition, the potential effect of the grid on codend selectivity was unknown. Due to this lack of prior information, it was decided to test different experimental setups by combining different codends, grid bar-spacings, different angle of attack of the grid, and the presence/absence of the net piece to mask the excluder opening (MEO:Y-MEO:N) . The underlying idea was to start with a first experimental setup (which was chosen on the available knowledge) and based on a real time assessment of the selective properties of such first setup, to introduce step-wise alterations in further setups until a well defined bell shape curve is found 1. If a sufficient number of hauls for each each setup would be collected, the data could be used for further investigations such as:

- To Investigate the potential effect of MEO on fish-grid contact
- To investigate potential relationships between grid bar-spacing with fish-grid contact likelihood.
- To investigate potential relationships between angle of attack of the grid and fish-grid contact likelihood.

3 Results

3.1 Operational information

A total of 57 hauls were successfully performed during the cruise on fishing grounds in Mecklenburg Bay and Arkona Sea. The range of fishing depths was $13.8m - 47.3m$ and the tow duration ranged between $10' - 120'$. Further operational information can be found in Table 2.

Three pilot hauls (setup-0, Table 2) were performed at the beginning of the cruise (March 14) to assess the dynamic behavior of the different components of the experimental gear. During the pilots hauls, it was found that a fraction of fish entering in the zone of the grid did not used any of the pre-established paths (MEO or grid bar-spacing). A non-experimental compartment was created *ad-hoc* to account for this catch fraction, being referred hereafter as the TU (TUnnel) compartment. The TU compartment represented a minor fraction of the catch volume and therefore it was not included in the analysis. Six different gear setups combining different grid specifications and codends were tested during the fishing trials (Table 3). Setup-1 was used from 17 to 20 of March resulting in 11 valid hauls. Setup-2 was established by replacing the original codend in setup-1 (T90120D3) by a codend with reduced selectivity (T90105D4), being tested from 21 to 23 March (11 valid hauls). The basic idea with setup-2 was to move the partial size selectivity curve of the codend to the left, in order to better define the bell-shape functional form in the experimental data. setup-3 was defined by reducing the grid angle of attack (AK) from 75^{circle} to 45^{circle} (degrees from the horizontal). Two pelagic trawls were performed in March 24 to assess the structural behavior of setup-3 by underwater video observations. The mentioned reduction in the angle of attack reduced at the same time the height of the net tunnel significantly; such undesirable effect might produce a confounding effect on the performance of the grid and therefore only 2 experimental hauls were performed by setup-3, being discarded for further analysis.

The underwater video recordings also showed deformations in the grid shape and grid bars due to usage. The grid was removed and fixed onboard. A total of 8 additional hauls with setup-2 were performed between March 25 and 26 once the grid was fitted back into the net. Setup-4 was established after removing the net panel used to mask the excluder opening in front of the grid (MEO:N). Only 1 haul was performed with this setup (March 27), due to significant grid deformation. The damaged grid was immediately removed by a new grid with 42.5mm bar spacing (setup-5). A total of 10 valid hauls were carried out with setup-5 from March 27 to 29 . The setup-6 was established by introducing again the net panel covering the excluder hole (MEO:Y). Ten valid hauls were obtained with setup-6 from March 27 to April 02. Finally, the grid was unmounted from the gear (setup-7) to assess if the codend selectivity is influenced by the presence of the grid. A total of two hauls were obtained with Setup-7 (Analysis of setup 7 experimental data not presented in this report).

G (mm)	AK (degrees)	MEO	T90120D3	T90105D4	
50	75	Y	setup-1 (11)	setup-2 (18)	
		N	-	setup-4 (1)	
	45	Y	-	setup-3 (2)	
		N	-	-	-
42.5	75	Y	-	setup-6 (10)	
		N	-	setup-5 (10)	
	45	Y	-	-	
		N	-	-	

Table 1: Identification of the Experimental setups and sampling effort (number of hauls, in brackets). G= Grid bar spacing, AK=Grid Angle of attack, T90120D3=T90 codend with 120mm mesh size, double twine 3mm thick, T90105D4=T90 codend with 105mm mesh size, double twine 4mm thick.

Fishing Area	Setup	Haul	Date	Time	Op. Duration	Sweep duration	Lat.	Long	Wire (m)	Depth (m)	Doors spread (m)	CC	CD	TC	Total
Mecklenburger Bucht	0	1	14.03.14	12:10:57	50.20	-	5412,117N	01158,158E	0	18.70	-	53.19	53.11	111.10	217.40
Mecklenburger Bucht	0	2	14.03.14	12:56:45	24.20	10.00	5411,836N	01156,840E	27	18.70	-	-	-	-	0.00
Mecklenburger Bucht	0	3	14.03.14	14:04:30	87.00	67.50	5411,779N	01156,785E	27	18.70	-	-	-	-	0.00
Mecklenburger Bucht	1	4	17.03.14	8:54:52	176.50	120.00	5412,276N	01159,550E	101	15.20	15	219.37	110.53	22.00	351.90
Mecklenburger Bucht	1	5	17.03.14	12:32:32	161.00	120.00	5412,281N	01159,667E	111	15.20	6	304.44	126.59	28.69	459.72
Mecklenburger Bucht	1	6	18.03.14	6:06:08	135.50	120.00	5412,246N	01200,850E	106	14.20	4	66.52	95.12	13.02	174.66
Mecklenburger Bucht	1	7	18.03.14	9:12:12	162.10	120.00	5412,213N	01149,147E	110	20.80	11	153.75	129.93	69.62	353.29
Mecklenburger Bucht	1	8	18.03.14	12:14:11	143.40	120.00	5412,226N	01201,075E	110	14.30	8	496.08	185.57	32.38	714.03
Mecklenburger Bucht	1	9	19.03.14	6:47:04	146.50	120.00	5412,248N	01200,927E	108	14.30	2	7.26	112.29	95.22	214.78
Mecklenburger Bucht	1	10	19.03.14	9:43:14	143.30	120.00	5412,291N	01148,511E	110	21.30	7	152.10	129.90	245.91	527.90
Mecklenburger Bucht	1	11	19.03.14	12:45:42	137.00	120.00	5412,316N	01200,212E	111	14.80	9	258.48	170.98	35.52	464.98
Mecklenburger Bucht	1	12	20.03.14	6:01:22	150.20	120.00	5412,217N	01200,968E	-	13.80	3	377.54	188.80	176.39	742.73
Mecklenburger Bucht	1	13	20.03.14	9:06:30	152.50	120.00	5412,669N	01146,501E	110	23.50	14	5.95	187.89	12.68	206.52
Mecklenburger Bucht	1	14	20.03.14	11:55:44	158.70	120.00	5412,433N	01158,131E	110	16.80	13	158.52	83.48	454.28	696.28
Mecklenburger Bucht	2	15	21.03.14	8:17:50	148.90	120.00	5412,227N	01200,860E	110	14.00	5	208.97	499.16	166.88	875.01
Mecklenburger Bucht	2	16	21.03.14	10:59:20	146.60	120.00	5412,568N	01147,101E	110	22.50	9	252.96	476.35	423.28	1152.58
Mecklenburger Bucht	2	17	21.03.14	14:11:19	124.70	90.00	5412,254N	01200,422E	110	14.50	10	252.29	687.92	211.37	1151.58
Arkonasee SD 24	2	18	22.03.14	6:07:35	154.00	90.00	5442,635N	01311,190E	166	26.00	17	9.85	94.30	6.62	110.77
Arkonasee SD 24	2	19	22.03.14	8:38:41	114.40	90.00	5445,378N	01329,785E	220	40.60	55	38.77	179.35	17.03	235.15
Arkonasee SD 24	2	20	22.03.14	10:46:49	142.10	120.00	5450,315N	01327,635E	-	45.80	49	139.12	528.66	257.90	925.68
Arkonasee SD 24	2	21	22.03.14	13:35:49	144.40	120.00	5452,660N	01315,529E	267	45.20	58	214.15	360.74	126.98	701.88
Arkonasee SD 24	2	22	23.03.14	6:04:17	148.60	120.00	5450,871N	01327,368E	270	46.00	30	40.72	343.69	142.75	527.16
Arkonasee SD 24	2	23	23.03.14	8:47:56	152.80	120.00	5452,610N	01315,166E	277	45.20	70	109.13	277.98	394.93	782.04
Arkonasee SD 24	2	24	23.03.14	11:33:31	140.70	120.00	5452,540N	01330,885E	277	46.90	57	124.65	364.37	307.01	796.04
Arkonasee SD 24	3	25	24.03.14	9:06:19	105.40	83.30	5443,277N	01333,911E	278	37.80	40	328.03	278.29	327.59	933.91
Arkonasee SD 24	3	26	24.03.14	11:06:38	164.00	118.20	5447,095N	01327,416E	278	43.70	31	65.02	289.81	437.61	792.44
Arkonasee SD 24	2	27	25.03.14	6:04:56	118.10	90.00	5443,108N	01334,162E	269	37.80	63	177.12	162.75	404.56	744.43
Arkonasee SD 24	2	28	25.03.14	8:17:57	123.00	90.00	5446,249N	01327,203E	277	42.10	33	98.04	193.77	248.44	540.24
Arkonasee SD 24	2	29	25.03.14	11:13:14	123.70	90.00	5452,708N	01317,896E	278	45.90	56	127.77	238.12	395.44	761.33
Arkonasee SD 24	2	30	25.03.14	13:24:13	107.50	83.00	5451,740N	01325,720E	278	46.70	61	78.94	161.51	160.96	401.40
Arkonasee SD 24	2	31	26.03.14	6:03:05	125.20	90.00	5442,895N	01334,491E	268	37.90	37	83.18	193.23	2.97	279.39
Arkonasee SD 24	2	32	26.03.14	8:12:25	118.90	90.00	5447,130N	01327,431E	269	44.20	25	220.00	267.07	6.55	493.62
Arkonasee SD 24	2	33	26.03.14	11:07:05	111.00	90.00	5452,675N	01315,017E	-	45.60	45	55.30	178.90	140.55	374.75
Arkonasee SD 24	2	34	26.03.14	13:14:17	143.30	120.00	5452,483N	01323,161E	278	46.40	60	258.92	403.78	149.08	811.77
Arkonasee SD 24	4	35	27.03.14	6:08:34	148.20	120.00	5443,135N	01334,086E	268	38.00	54	18.84	234.23	621.04	874.11
Arkonasee SD 24	5	36	27.03.14	9:17:58	117.10	89.00	5452,545N	01322,613E	269	46.00	47	54.17	147.38	817.31	1018.86
Arkonasee SD 24	5	37	27.03.14	12:33:20	124.70	90.00	5453,121N	01333,527E	278	47.10	52	160.22	257.19	923.72	1341.13
Arkonasee SD 24	5	38	28.03.14	6:08:47	124.20	90.00	5443,195N	01334,093E	269	38.10	35	144.46	172.51	454.45	771.42
Arkonasee SD 24	5	39	28.03.14	9:06:46	85.50	60.00	5452,556N	01325,866E	277	46.60	36	6.11	95.22	241.57	342.89
Arkonasee SD 24	5	40	28.03.14	11:20:35	119.70	90.00	5453,987N	01334,671E	278	47.30	38	83.73	161.88	636.49	882.10
Arkonasee SD 24	5	41	28.03.14	14:04:13	69.50	50.30	5452,502N	01322,777E	278	46.60	50	15.10	68.60	55.89	139.59
Arkonasee SD 24	5	42	29.03.14	6:06:03	113.10	90.00	5445,153N	01330,800E	269	40.40	42	279.02	299.88	279.90	858.80
Arkonasee SD 24	5	43	29.03.14	8:10:09	104.10	90.00	5449,402N	01328,001E	277	45.30	49	146.80	180.27	528.21	855.29
Arkonasee SD 24	5	44	29.03.14	11:04:02	116.00	90.00	5452,683N	01318,204E	279	45.50	57	14.25	120.40	452.80	587.44
Arkonasee SD 24	5	45	29.03.14	13:38:09	113.30	90.00	5451,827N	01325,742E	279	46.40	34	123.98	212.22	230.85	567.04
Arkonasee SD 24	6	46	30.03.14	6:33:29	132.30	90.00	5443,404N	01333,747E	-	37.60	44	100.83	128.44	674.22	903.49
Arkonasee SD 24	6	47	30.03.14	8:46:31	116.20	90.00	5448,038N	01327,612E	276	44.30	46	114.14	160.97	161.58	436.69
Arkonasee SD 24	6	48	30.03.14	11:01:18	111.40	90.00	5452,642N	01320,167E	-	45.80	39	31.62	74.38	257.29	363.28
Arkonasee SD 24	6	49	31.03.14	5:09:09	114.50	90.00	5442,824N	01334,622E	267	37.30	43	172.60	122.61	531.41	826.63
Arkonasee SD 24	6	50	31.03.14	7:13:51	120.20	90.00	5446,951N	01327,425E	277	43.30	48	111.32	179.33	380.49	671.14
Arkonasee SD 24	6	51	31.03.14	10:06:34	118.40	90.00	5452,633N	01314,144E	-	44.90	51	16.89	70.87	288.90	376.66
Arkonasee SD 24	6	52	31.03.14	12:35:27	114.10	90.00	5452,668N	01316,221E	279	45.40	51	30.18	90.87	85.30	206.34
Arkonasee SD 24	6	53	01.04.14	5:05:08	121.80	90.00	5443,310N	01333,948E	268	38.00	36	87.47	231.08	551.44	869.99
Arkonasee SD 24	6	54	01.04.14	7:35:13	119.00	90.00	5444,889N	01331,222E	268	39.80	43	194.93	319.58	439.22	953.73
Arkonasee SD 24	6	55	01.04.14	10:12:39	118.80	90.00	5452,615N	01319,299E	278	45.70	59	24.65	84.30	260.52	369.47
Arkonasee SD 24	7	56	02.04.14	4:59:41	109.80	90.00	5446,862N	01327,373E	-	43.40	39	-	-	-	0.00
Arkonasee SD 24	7	57	02.04.14	7:16:42	108.90	90.00	5452,549N	01322,266E	269	45.40	41	-	-	-	0.00

Table 2: Operational information of the experimental fishing hauls. Physical information related to the initial phase of the haul back process.

3.2 Catch description

The total biomass caught during the cruise was 33121.44 kilo; 43.8% of the total catch was found in the Top Cover (TC), 33.7% in the codend (CD), and 21.3% in the cover codend (CC). Catch profile was dominated by cod 82.9%, followed by flounder (7.2%), dab (3.7%) and plaice (2.4%). The volume of cod observed in setups 1, 2 and 3 was balanced among the different compartments, while it was mostly found in the Top Cover from setups 5 and 6, this 1).

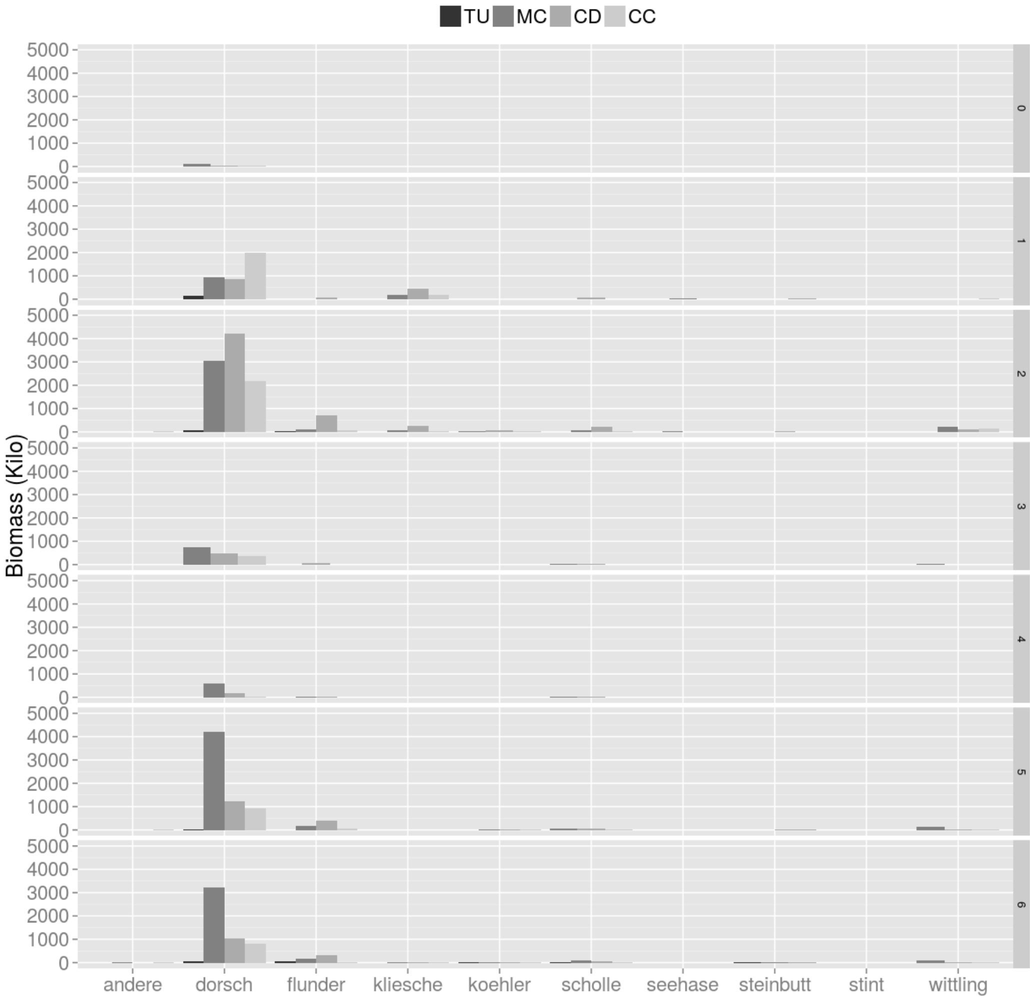

Figure 2: Catch volume by species and compartments (TU=Tunnel, MC=MEO Cover, CD=Codend and CC= Cover Codend) over the different gear setups.

3.3 Data analysis

The model proposed in this study (Equation 1) described well the selection process observed in the experimental gear, achieving better goodness of fit than any other size selection model used in the literature to describe trawl gears selectivity (modelling comparison not presented in this report, refer to references given below). The best model for setup-2 estimated $\sim 73\%$ of fish entering in the tunnel efficiently contacted the grid, being therefore available for size selection. The model estimated lower C_{grid} for the setups using the grid with narrower bar-spacing ($\sim 60\%$ and $\sim 56\%$ for setup-5 and setup-6, respectively). The L50 for the grid used in setup-2 ($50mm$ barspacing) was estimated in $L50_{grid} \sim 48cm$, significantly higher than the $L50_{grid}$ estimated for setup-5 and setup-6 ($42mm$ barspacing). The $L50_{grid}$ estimations for the last two setups were very similar, and completely overlapped by the Confidence Intervals of the estimations. Although not significant, The grid with shorter selection range parameter SR_{grid} was the $50mm$ bar spacing grid used in setup-2. As expected, the selectivity of the codend was similar in all analyzed setups, with no significant differences in the selectivity parameters.

Device	Function	Parameter	setup2	setup5	setup6
Grid		C_{grid}	0.73 (0.64-0.83)	0.60 (0.39-0.95)	0.56 (0.44-0.78)
		$L50_{grid}$	47.93 (46.45-49.46)	35.65 (29.41-38.43)	37.60 (32.22-40.32)
		SR_{grid}	8.40 (5.72- 12.14)	12.80 (7.00-19.99)	15.12 (8.484-22.253)
Codend		$L50_{codend}$	29.70 (28.22- 30.94)	29.33 (27.81-30.06)	28.57 (27.196-29.867)
		SR_{codend}	11.05 (10.17-11.82)	9.58 (8.36-11.58)	10.63 (9.07-12.70)
		Deviance	217.57	181.11	201.49
		DOF	171	177	171
		R2-Value	0.77	0.84	0.39

Table 3: Estimations of the selectivity parameters of the three gear setups, by the proposed model (Equation 1).

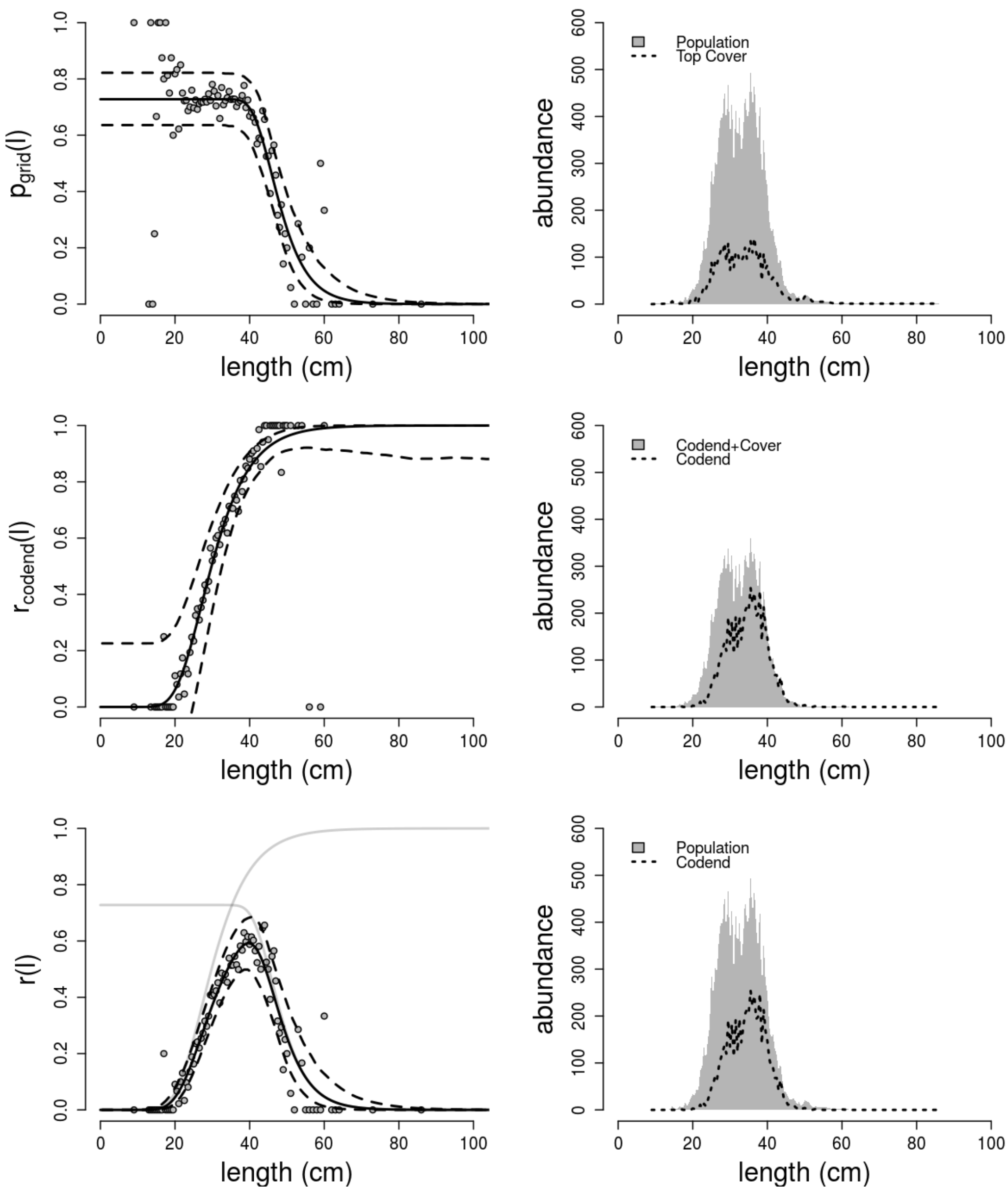

Figure 3: Experimental data and size selection model outputs from setup-2. Left: Size selection curves for cod, including experimental data (points) and 95% confidence limits (Top: size selection of grid with vertical bars and 50mm bar distance; Middle: size selection of T90 105mm codend; Bottom: selectivity curves of grid and codend (grey lines) and resulting combined selectivity curve (bell-shaped curve)). Right: Catch within a given compartment (stippled curve) in relation to the length distribution encountering the relevant selection device (grey shaded area)

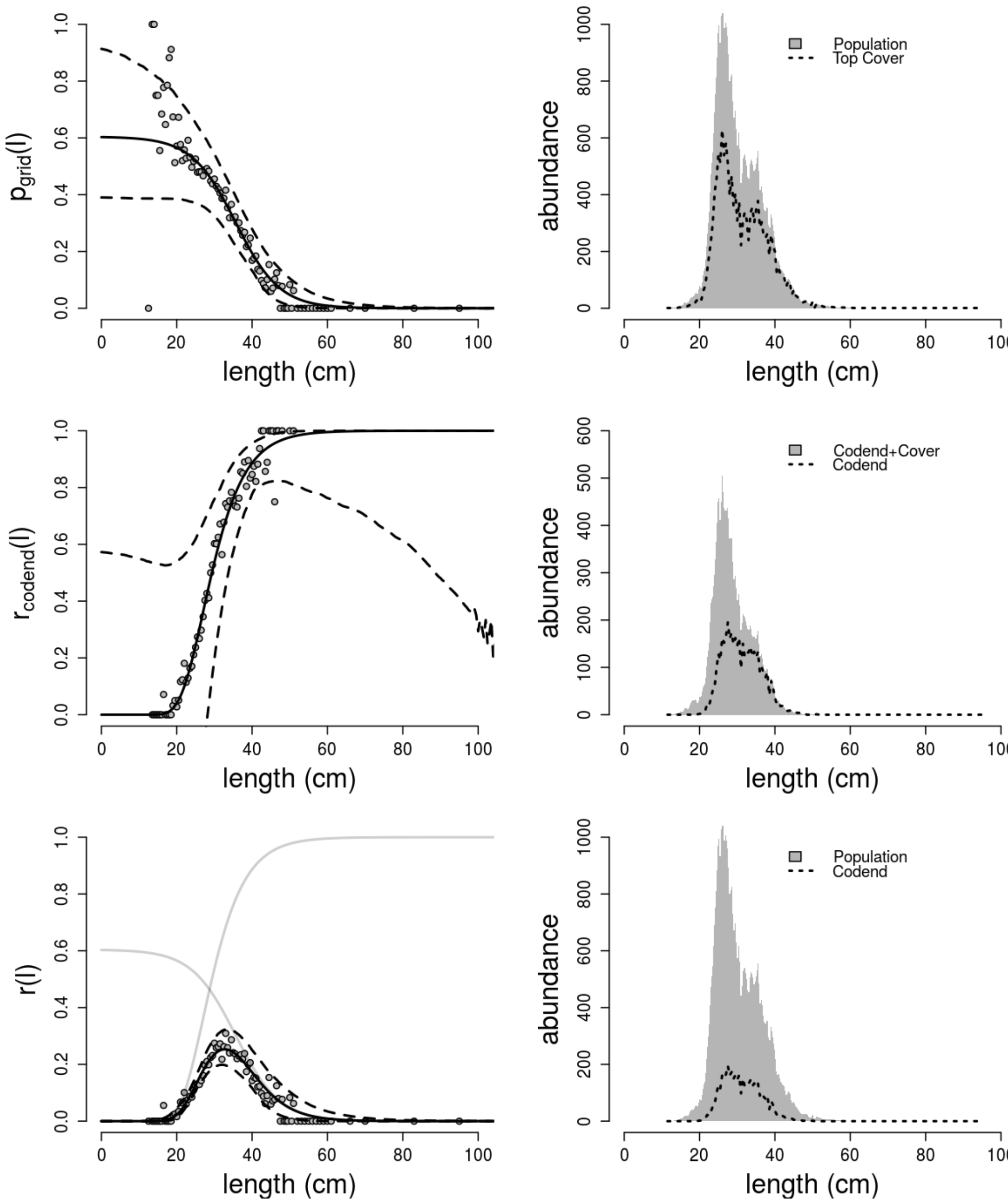

Figure 4: Experimental data and size selection model outputs from setup-5. Left: Size selection curves for cod, including experimental data (points) and 95% confidence limits (Top: size selection of grid with vertical bars and 42.5mm bar distance and MEO:N; Middle: size selection of T90 105mm codend; Bottom: selectivity curves of grid and codend (grey lines) and resulting combined selectivity curve (bell-shaped curve)). Right: Catch within a given compartment (stippled curve) in relation to the length distribution encountering the relevant selection device (grey shaded area)

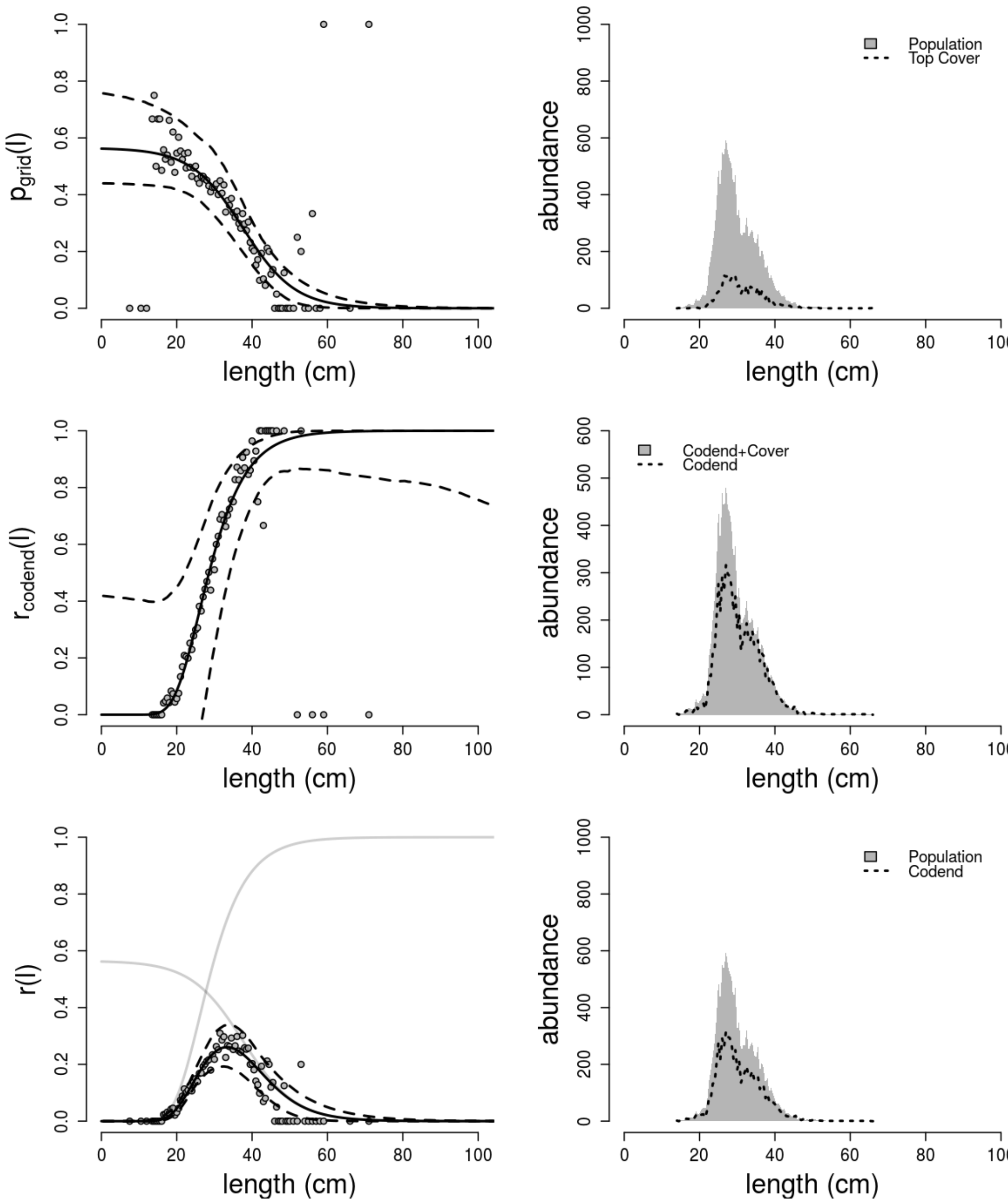

Figure 5: Experimental data and size selection model outputs from setup-6. Left: Size selection curves for cod, including experimental data (points) and 95% confidence limits (Top: size selection of grid with vertical bars and 42.5mm bar distance and MEO:Y; Middle: size selection of T90 105mm codend; Bottom: selectivity curves of grid and codend (grey lines) and resulting combined selectivity curve (bell-shaped curve)). Right: Catch within a given compartment (stippled curve) in relation to the length distribution encountering the relevant selection device (grey shaded area)

4 Discussion

- The aim of the present study was to broaden the horizon for size selectivity in trawl gears by demonstrating the feasibility of alternative selectivity patterns, different to the traditional S-shaped pattern. In particular, the practical exercise associated to this study attempted to simultaneously reduce the catchability of the smaller and larger individuals in the available fish population. The goodness of fit of the bell-shaped selection curves fitted to the experimental data demonstrated that different exploitation patterns to the classic S-shape curve are possible in trawl fisheries, by means of gear technology.

- The technological strategy adopted to achieve our goal combined two well-known size selection devices in fishing gear technology, integrated sequentially in the trawl to establish a dual selection system which has been tested for the cod-directed trawl fishery in the Baltic Sea. We used a grid to specifically sort out the large individuals for the target species, while allowing smaller fish to enter in the codend. This purpose of grid usage is new for target species.

- Because no previous baseline was available during the design of the present study, the first gear specification was established as a starting guess based on our fishing technology experience. The starting setup evolved into seven different gear specifications defined *ad-hoc* during the cruise. This work flow strategy was possible thanks to the real time observation of underwater video recordings and the data analysis conducted directly at sea. Such dynamic working facilitated the onboard decision making process.

- We achieved well defined bell-shape curves in three of the gear setups. The setup with the wider bar-spacing (setup-2, $50mm$ bar-spacing) achieved a higher C_{grid} value than the setups-5 and setup-6, which used the narrow bar-spacing grid ($42mm$). We speculate that a reduced bar-spacing might increase the wall-effect produced by the grid in the tunnel, which could enhance the avoidance behavior of fish.

- Setup-5 and setup-6 differed each other in the presence/absence of the piece of net used to mask the upper opening. The small and not significant differences in C_{grid} estimations from both setups indicates the masking net did not improved the performance of the grid system.

- The grids were made in steel to ensure the stability of the predefined bar-spacing. Nevertheless, underwater observations showed the initial structure of the grid was affected after several hauls. This problem occurred due to the forces acting on the grid when stored in the drum net. The grid ageing affected the stability of the bar-spacing. the modeling results presented in this report only used the hauls were the grid presented its original shape, and the hauls selection was based on UW observations. The experience gathered in this study provide us with guidelines for future developments of grids systems.

Final remarks

The data produced during the present sea cruise were used in the following studies:

- Stepputtis, D., Santos, J., Herrmann, B., Mieske, B., 2015. Broadening the horizon of size selectivity in trawl gears. Fisheries Research. http://dx.doi.org/10.1016/j.fishres.2015.08.030.

- Haase, S., 2015. Aged and children first! Challenges in the development of a new selectivity concept in trawl fisheries. Bachelor thesis. University of Oldenburg.

- Haase, S.,Santos, J., Stepputtis, D., Schtz, A., 2015. Alte und Kinder zuerst!. Entwicklung eines neuen Selektionskonzeptes in der Schleppnetzfischerei. Posterbeitrag zum Deutschen Fischereitag 2015 in Rostock

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(*) First half of the cruise, (**) Second half of the cruise

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