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Bericht

über die 718. Reise des FFS Solea
vom 16.03 **bis** 07.04.2016

Fahrtleitung: Juan Santos

Das Wichtigste in Kürze

Auf dieser Reise wurde eine Vorrichtung zur Trennung von Dorschen und Plattfischen getestet. Die Vorrichtung war in einem Vierlaschentunnel angebracht, der in zwei übereinanderliegenden Steerten endete. Sie bestand im Wesentlichen aus einem schräg angeordneten Trennblatt aus breit gestrecktem T90 Netztuch mit der Maschenweite 200mm und einem starren Rechteckrahmen. Der Rahmen war senkrecht stehend fest an den Seitenblättern und dem Unterblatt angemarlt. Es wurden zwei Größen von Trennblättern getestet, einmal 2860 mm lang mit einem Anstiegswinkel von 4.5°, dann 870mm lang mit einem Anstiegswinkel von 15°. Die Trennblätter waren an der oberen Kante des Rahmens, im vorgesehen Anstiegswinkel an den Seitenblättern und schließlich an der die Trennlinie zwischen den Steerten bildenden Maschenreihe befestigt. Des Weitern wurde erbrobt, inwieweit Scheuchelemente aus Leinen und Auftriebskörpern die Artentrennung verbessern können. Die Auswertung der Versuche ergab, dass 80% der Dorsche im oberen Steert und 80% der Plattfische (Schollen, Flundern Klieschen) im unteren Steert gefangen wurden.

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1 Introduction

During the last years, the scientific advice has emphasised the need of firmly addressing the negative trends observed in the stock of the Baltic cod, but the precautionary measures taken so far have been insufficient to reverse the trend. With the objective of bringing European fisheries back to the road of sustainability before 2020, EU fisheries ministers applied a sharp quota reduction for cod (56% cut) for the current year, which directly affects trawl fleets from Denmark, Sweden and Germany.

In addition to the drastic reduction in fishing opportunities for fleets targeting cod, the limited quota can choke fishing strategies targeting other species (for example, if the quota is exhausted (long) before the quotas from (some) other species caught besides cod). Assuming that the landing obligation was correctly enforced in the Baltic Sea, it is likely that the earlier exhaustion of cod quota might alter (or even stop) the normal fishing strategy of *métiers* targeting flatfish, even if there is still quota available for them.

Applying new fishing technologies to improve species selection in commercial gears is widely recognized as one of the key strategies to reduce bycatch [2]. Following this strategy, the Thünen Institute of Baltic Sea Fisheries (TI-OF) has invested significant efforts on developing and making available Bycatch Reduction Devices (BRD) for Baltic trawl fleets during the last years. Two examples with proven effectiveness are FRESWIND (Flatfish Rigid EScape WINDows) [8] , and FLEX (FLatfish EXcluder) [9].

The devices mentioned above were designed to avoid flatfish bycatch in the cod-directed trawl fishery, taking into account the relative good fishing opportunities for cod over the last years. However, the current scenario requires a shift in the focus from flatfish reduction to cod reduction in flatfish fisheries. In contrast to the huge effort invested during the 1990s and 2000s to reduce fishing efficiency on small cod, few initiatives have been taken to completely avoid cod catches. To date, the most clear attempt was made by adapting the Atlantic *topless* trawl concept for the Baltic and the North sea [4, 6]. The footrope of the *topless* trawls is located more forward than the headline to allow roundfish to escape upwards [4]. This implies a drastic and irreversible re-design of the commercial trawls, which might not comply with today's demands for adaptive capacity to variations in available quota.

An alternative strategy to the *topless* trawl concept would be to separate cod and flatfish in the trawl body and provide different escapement opportunities for the different groups. However, a number of trials applying horizontal separator panels, conducted in the Atlantic and North Sea, demonstrated that flatfish and cod catches are difficult to split, being usually observed in the same experimental compartment [1, 5].

Contrary to these findings, experimental sea trials conducted by the TI-OF in 2014 and 2015 indicate that a good separation between cod and flatfish is possible, by following the design guides applied on FLEX. This is the conceptual basis of SORTEX (SORTing EXtension), a BRD designed under the design guides of FLEX to be used either for the reduction of flatfish or cod bycatches. Similar to the other BRD's mentioned above, the new device is based on altering a particular zone of the net tunnel connecting the trawl body and the codend. Therefore, it was designed to be easily replaced by the standard extension piece (tunnel), which is normally used by the fishermen.

This report summarises the experimental results of the fishing trials with SORTEX, conducted during the research cruise `Solea 718`. The cruise was conducted on Baltic fishing grounds located at ICES Subdivisions 22 and 24 from 16.03. to 06.04.2016. It is the objective of this report to quantify the effectiveness of the concept to split cod from flatfish catches into different compartments, a necessary step to achieve a general technical solution able to avoid flatfish or cod catches, under the specific requirements of the Baltic mixed fishery.

2 Material and Methods

2.1 Test gear

SORTEX is a 4-panel, rectangular-shaped tunnel connecting the trawl body to two codends, arranged vertically one upon the other. The tunnel is split off vertically by a net panel made of $400mm$ mesh size, mounted horizontally and with a bottom-up, backwards inclination of 4.5°. The fore edge of the panel is connected on the top of a rigid frame, which shapes the main inlet of the lower codend. Following the experience gained in previous cruises, it is expected that a large fraction of flatfish entering in the tunnel will pass through the rectangular frame towards the lower codend (hereafter referred as codend 2). On the other hand, Based on the natural roundfish behaviour of avoiding enclosed spaces, it is assumed that cod will avoid passing through the narrow inlet, being progressively driven by the oblique panel (Figure 1) towards the upper codend (codend 1) . The meshes of the oblique panel are oriented 90° in relation to the towing direction, to fit the cross shape of flatfish. This simple panel configuration offers a second path towards the lower codend to flatfish individuals that did not encounter the inlet (Figure 2). The codends used in the study were made of small mesh ($\sim 50mm$ nominal stretched size) in order to retain most of the fish lengths entering in the gear. SORTEX was connected to a demersal trawl model T300/60, spread by Thyborön doors Type 11 ($2.25m^2$).

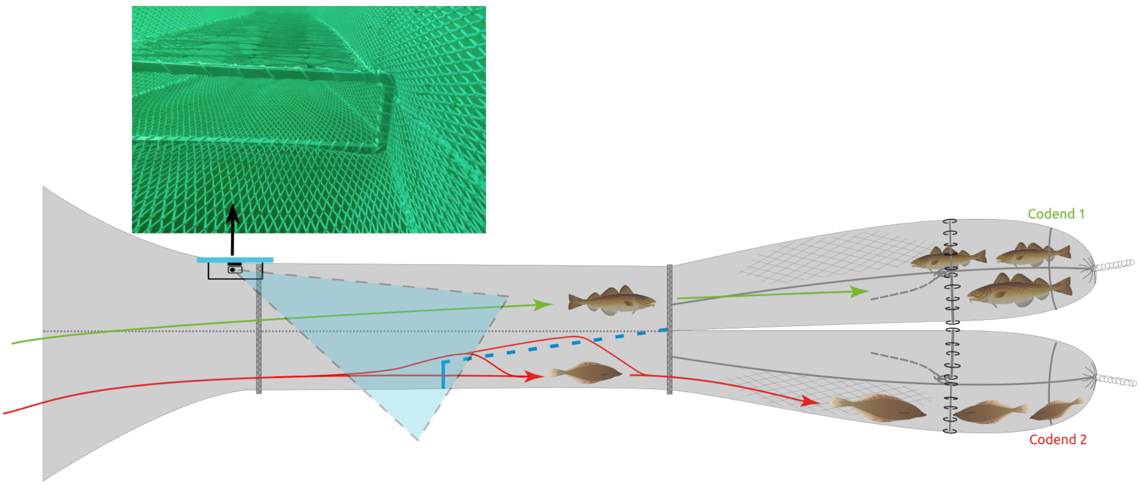

Figure 1: Side view of SORTEX, mounting the rigid frame (solid blue line), the oblique panel (dashed blue line), and the double codend system. Green arrow represents the path towards codend 1 expected for cod, while the red arrows represent the two possible paths towards the lower codend, expected for flatfish. This configuration is denoted hereafter as experimental setup 1.

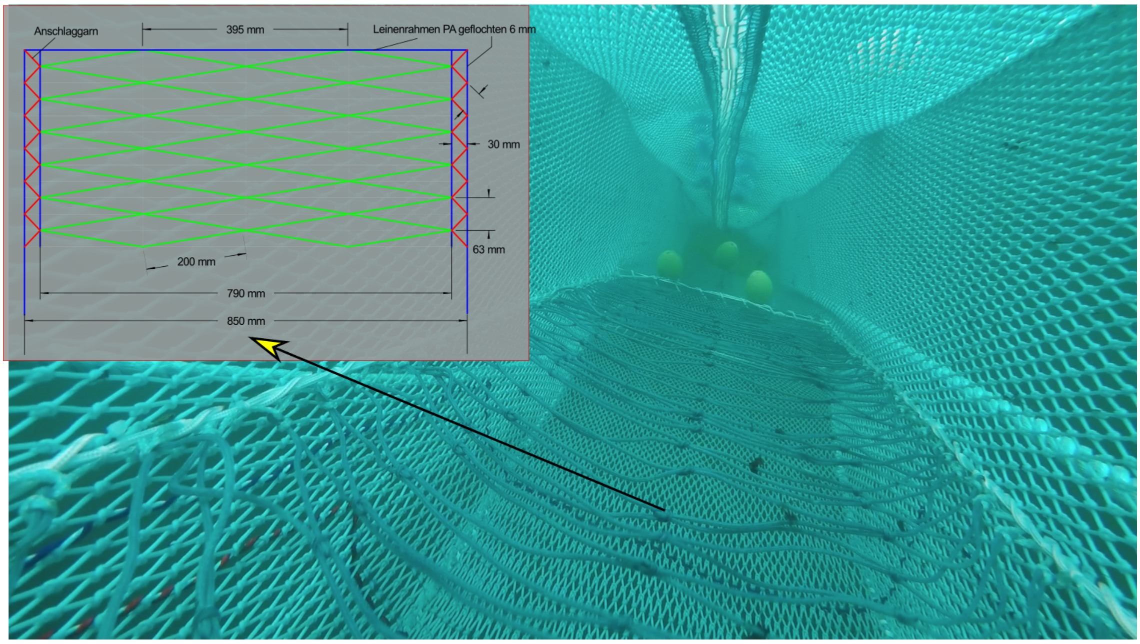

Figure 2: Constructive details of the oblique panel.

2.1.1 Experimental setups

SORTEX setup 1 Figure 1 present a free entrance to the lower codend, which might lead to poor separation of catches. Two simple modifications from the setup 1 were applied to address this potential issue. The first modification consisted on inserting $4mm$ PE standard net twines in the rigid frame. The twines were mounted loosely to make them vibrate during towing. Such vibration should stimulate the sensory system of cod in the vicinity of the inlet, deterring them from passing through towards the lower codend. The gear mounting the deterrent twines (D-twines) defined the gear setup 2 (Figure 3). The other strategy consisted on physically hindering the lower path. This was intended by inserting three mushroom-shaped obstacles in front of the inlet. The so-called mushrooms were made of $780gr$ buoyancy floats attached to the ground of the net by $30cm$ long PA ropes. This configuration induced swinging motion during towing. The visible and oscillating obstacles should force cods close to the bottom to swim upwards. The gear mounting the mushrooms defined the gear setup 3 (Figure 4).

Two additional experimental setups were tested. Setup 4 consisted in altering the inclination of the panel from the original $4,5°$ to $15°$. The aim with setup 4 was to investigate if the angle of the panel could influence the sorting efficiency. Gear modifications consisting in mounting rigid structures in the trawl body are usually not well received by fishermen. Setup 5 was defined by removing the rigid frame, to assess if similar sorting efficiency could be achieved without using rigid items in the experimental gear.

The oblique panel was designed to provide flatfish with additional opportunities of entering in the lower codend (Figure 2). Besides the main research topic of testing the 5 different setups defined above, some hauls were planned to assess the influence of the oblique panel in the sorting efficiency of SORTEX.

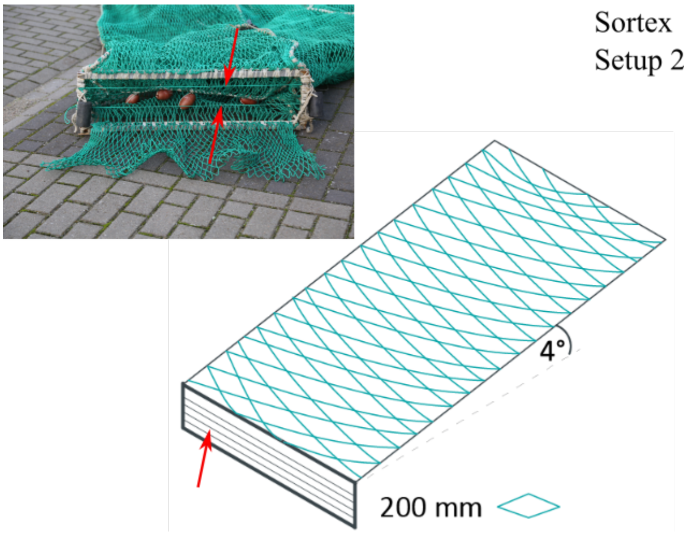

Figure 3: D-twines mounted in the rigid frame (SORTEX setup 2).

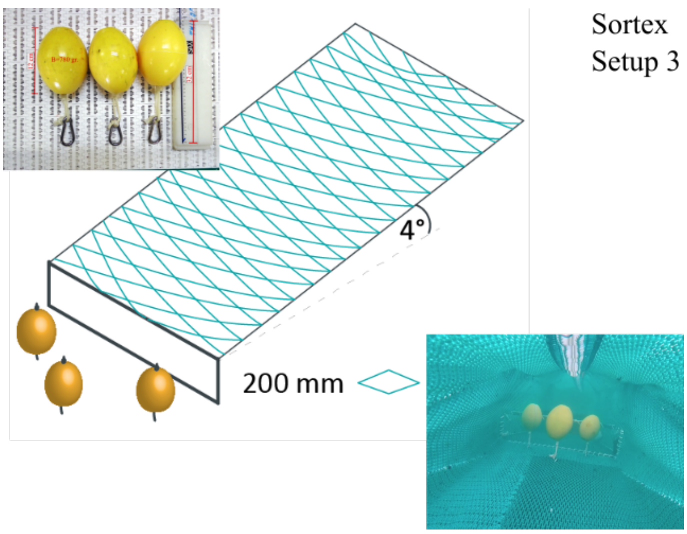

Figure 4: Mushrooms mounted in front of the inlet of the lower codend (SORTEX setup 3).

2.2 Experimental design and data collection

Before starting with the quantitative experiment, the mechanical behaviour of the gear setups 1, 2 and 3 were visually checked using Underwater Video Recordings (UWR). Any structural problem observed would be solved onboard by the netmakers, and the new gear version would be tried in the next pilot haul. This procedure was conducted successively until it was reached the desired gear performance . Different camera positions were defined with the aim of collecting information about the sorting mechanism, and the behaviour of cod and flatfish species in relation to the deterrent devices. Wide angle, self recording cameras (GoPro^{TM}Hero3/Hero4 ^{TM}) were used for this purpose.

The experimental fishing trials were planned with the main aim of collecting a wide range of length classes from cod and different flatfish species. Fishing grounds located in the Mecklenburg Bay (ICES SD 22) and Arkona Sea (ICES SD 24) were used. UWR were collected in selected haul during the fishing phase. Depth water housing model Go-Benthic^{TM}and flood beam artificial light 1400 lumens were used for fishing hauls conducted in grounds $\geq 40m$.

Haul duration was determined for each haul separately based on the abundance obtained in previous hauls. Catches obtained at haul level were sampled for each codend separately. The sampling scheme started by sorting the catch into species or groups of species. Total weight and length distribution were collected for each species by using digital scales and electronic length measurement boards ($.5cm$ precision). Sampling effort was allocated in accordance with [3].

We were interested in assessing the sorting efficiency of the different SORTEX setups. Such assessment was based on calculating the proportion of catches observed in codend 1 (upper codend) in relation to the total catches (codend 1 + codend 2) (lower codend) (Figure 1). By using small mesh codends (see sections 2.1) it was assumed that all fish length classes entering in the experimental gear would be caught in any of the codends. Being $n_{1,i}$ the number of fish caught in codend 1 (upper codend) during haul i, $n_{2,i}$ the number of individuals caught in codend 2 (lower codend), and $n_{+,i} = n_{1,i} + n_{2,i}$ the total catch, then the proportion caught in codend 1 during haul i is

$$s_i = \frac{n_{1,i}}{n_{+,i}} \tag{1}$$

which can be used to empirically assess the sorting properties of the experimental gear. s_i only can take values between 0 and 1. Values of $s_i \sim 1$ would indicate that a given species was mostly caught in codend 1, while the opposite ($s_i \sim 0$) indicate that it was mostly caught in codend 2.

2.3 Sorting efficiency model

The experimental catch proportions (Equation 1) were modelled by species and gear setup using the following empirical model:

$$S(\boldsymbol{\beta}, l) = H(\beta_0 + \beta_1 \cdot l + \beta_2 \cdot l^2 + \beta_3 \cdot l^3) \tag{2}$$

where $S(\boldsymbol{\beta}, l)$ is the averaged, length dependent sorting efficiency. The right hand side of the equation is composed by an intercept and a 3^{rd} order polynomial structure for the effect of fish length. Such polynomial structure provides high flexibility to account for non-linear patterns in the experimental data. The estimation of the values of the parameters $\boldsymbol{\beta} = \beta_0, \ldots, \beta_3$, which make the observed experimental data averaged over hauls most likely was carried out by maximizing the negative log of the likelihood function for binomial data, with respect to $\boldsymbol{\beta}$:

$$Loglik = -\sum_{l}\sum_{i}\{n_{1,il} \times \log(S(\boldsymbol{\beta}, l)) + n_{2,il} \times \log(1 - S(\boldsymbol{\beta}, l))\} \tag{3}$$

where the sums are for hauls i and length classes l. As mentioned, in Equation 2 and Equation 3 we considered a polynomial up to the order 3. Leaving out one or more of the parameters led to 15 additional simpler models that were also considered potential candidates for modelling the sorting efficiency $S(\boldsymbol{\beta}, l)$, and therefore they were also estimated using Equation 3 . Selection of the best model for $S(\boldsymbol{\beta}, l)$ among the 16 competing models was based on a comparison of their respective AICc values (AIC with a correction for finite sample sizes). The model with the lowest AICc value was finally used to describe the sorting efficiency from each of the gear setups.

The Confidence Band (CB) associated to the averaged $S(\boldsymbol{\beta}, l)$ curve was estimated by using the non-parametric technique known as block bootstrap. This technique is based on generating artificial data compartment-wise, that is, accounted for the observations in the codend 1 and codend 2 separately. This Data Generating Process (DGP) differs from the standard approach used in selectivity studies [7] and can be summarized as it follows:

1. A random sample of hauls $h_1^*, \ldots, h_N^*$ is artificially obtained by resampling with replacement on the observed N hauls $(h_1, \ldots, h_N,\ i = 1, \ldots, N)$. In other words, after the extraction of a haul, this is replaced in the original sample such that it can be chosen again

2. The same resampling technique is applied independently on catches in the lower and upper codend for each of the resampled hauls h_i^* from the previous step. A new set of pseudo-hauls $(h_1^{**}, \ldots, h_N^{**})$ are therefore computed in this step, with $h_i^{**} = \{n_{1,il}^*, n_{2,il}^*\}$

3. Catch data from (2) is pooled over the pseudo-hauls $I^* = \sum_{i=1}^{n} h_i^{**}$

4. The target log-likelihood function (Equation 3) is maximized using the data generated in (3)

5. Steps 1 to 4 are repeated a large number of times $(b = 1, \ldots, B)$ to obtain a set of sorting curves $\hat{S}^{*1}(\boldsymbol{\beta}^*, l^*), \ldots, \hat{S}^{*B}(\boldsymbol{\beta}^*, l^*)$.

Once this process is completed, the 95% limits of the CB for the average curve $S(\boldsymbol{\beta}, l)$ is given by:

$$(\hat{S}^{*(\frac{\alpha}{2})}(\boldsymbol{\beta}^*, l^*), \hat{S}^{*(1-\frac{\alpha}{2})}(\boldsymbol{\beta}^*, l^*)) \tag{4}$$

With $\alpha = 0.05$.

The resulting CB's were the inferential tools used here to compare the different gear setups tested. Comparisons were carried out pairwise, and differences in sorting efficiencies were statistically significant only for fish lengths where the compared CB's did not overlap.

3 Results

The cruise started on 16.03.2016 and it was split into two parts, before and after the Eastern pause (24.03-29.03). Catches from the first half of the cruise were used by 2 members of the research crew for cod tagging, providing support for the TABACOD project lead by the TI-OF. The first day after the Eastern pause (30.03) was used for testing a benthic sled, in development by the survey technology working group. The rest of the vessel time was used to develop the experiment described above. The first day of the cruise was used to collect video recordings of the experimental gear and to observe how fish interact with SORTEX. Six short hauls ($\sim 10'$) were conducted on 16.03.2016 in the grounds of Warnemünde at depths $\sim 15m$ for this purpose. The fishing tests with the different gear setups started on 17.03.16 in fishing grounds from Mecklenburg bay and Arkona sea (Figure 5). A total of 8 valid hauls were conducted with setup 1, setup 4 and setup 5; 7 hauls were completed with setup 2 and 10 hauls with setup 3. Towing depths ranged from $\sim 15m$ to $\sim 45m$, towing duration ranged from $\sim 30'$ to $\sim 120'$ and the towing speed averaged ~ 3.1 knots. 6 hauls conducted between 31.03 and 01.04.2016 were used to assess the influence of the oblique panel in the sorting efficiency of SORTEX.

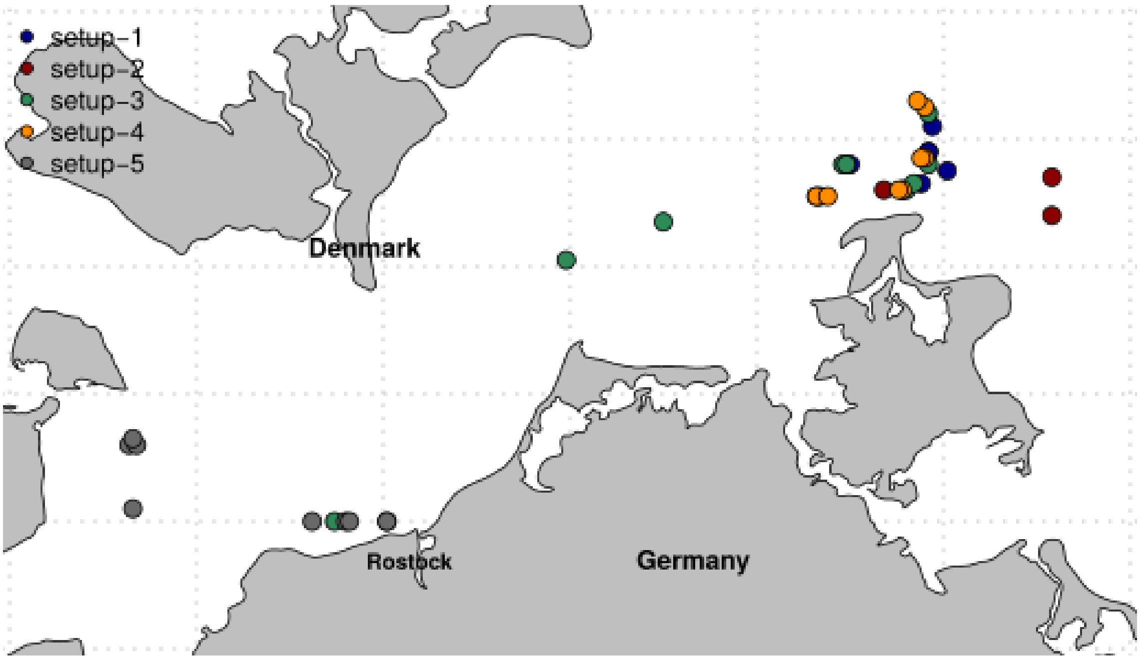

Figure 5: Spatial distribution of experimental hauls with the different gear setups.

3.1 Underwater video recordings

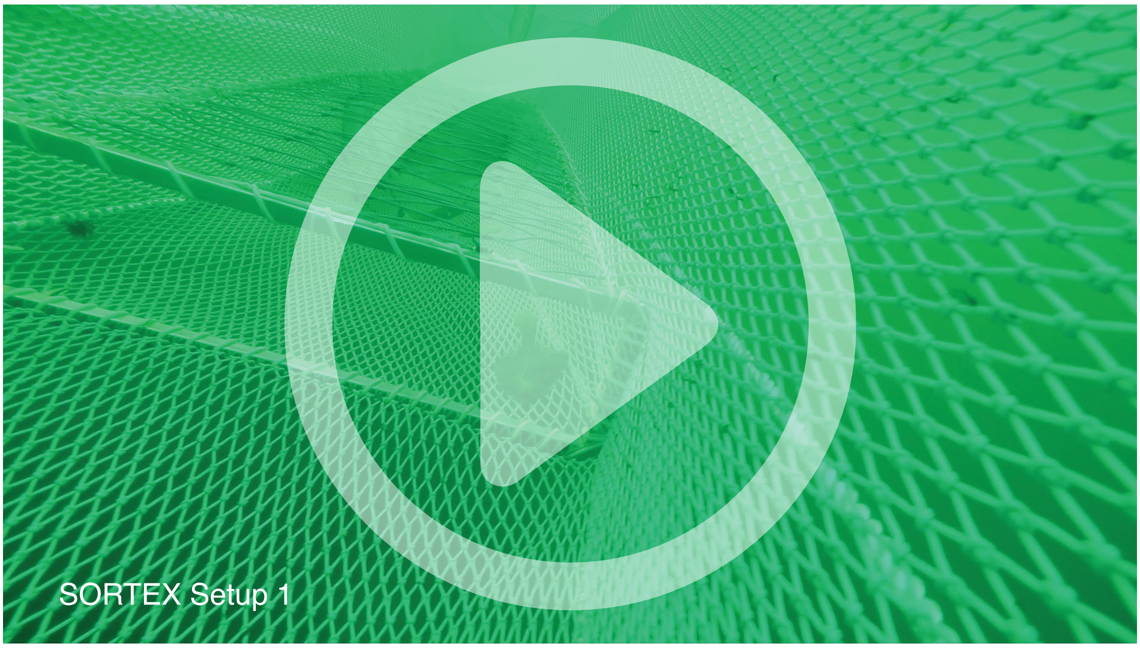

Figure 6: The video shows first a close-up view of the inlet to the lower codend, the rigid frame and the oblique panel. The water flow passing through the device shackes the oblique panel. This panel behaviour might frighten cod upwards benefiting the guiding towards the upper codend. Only one of the flatfish observed in the video avoided passing through the frame into the lower codend. Altough most of cods reacted as intended to the presence of the sorting device, some individuals were observed passing free through the inlet towards the lower codend.

Figure 7: Sequence focused on the setup 2 mounting the D-twines to hamper the free pass of cod through the inlet. It has been observed several individuals altering they swimming direction upwards after touching the twines.

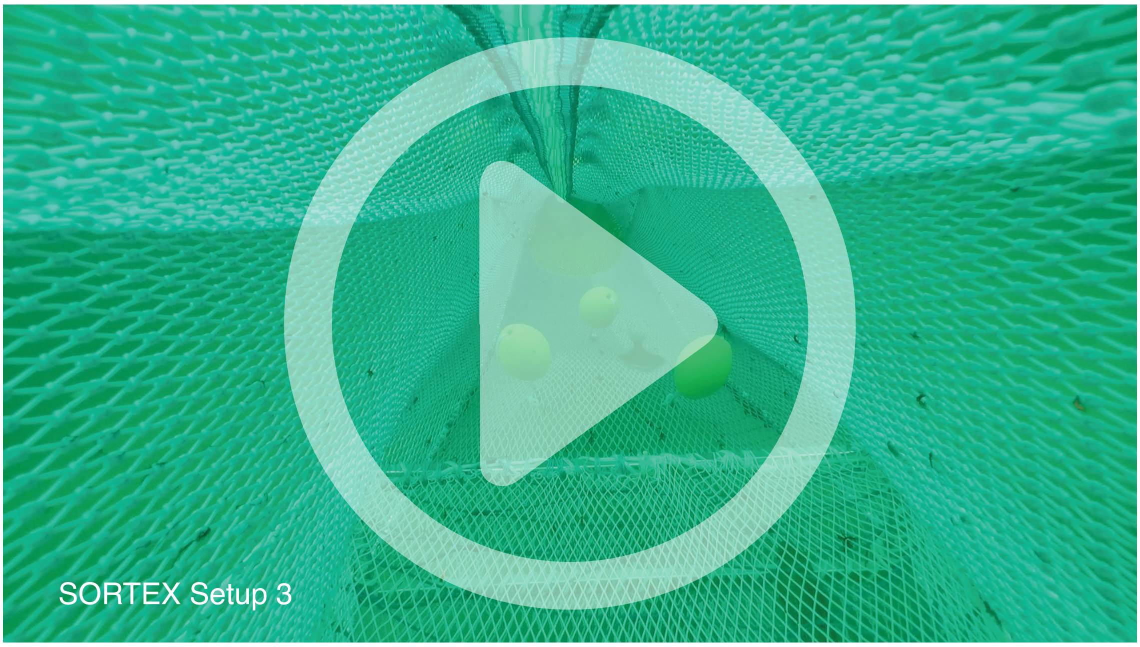

Figure 8: Several perspectives of setup 3 mounting the mushrooms in front of the inlet. Flatfish preferred to dodge the mushrooms by altering the swimming direction laterally, altough some individuals performed unexpected upwards swimming reactions. On the other hand, different cod reactions were observed. Most of the cods detected the presence of the mushrooms before entering in the zone where they were mounted, In such cases, fish avoided contacting the devices by smoothly swimming upwards. Some fish approached and even touched the flapping devices. The behavioural reactions in these cases were unpredictable.

Figure 9: The setup 4 mounting a steeper and shorter oblique panel.

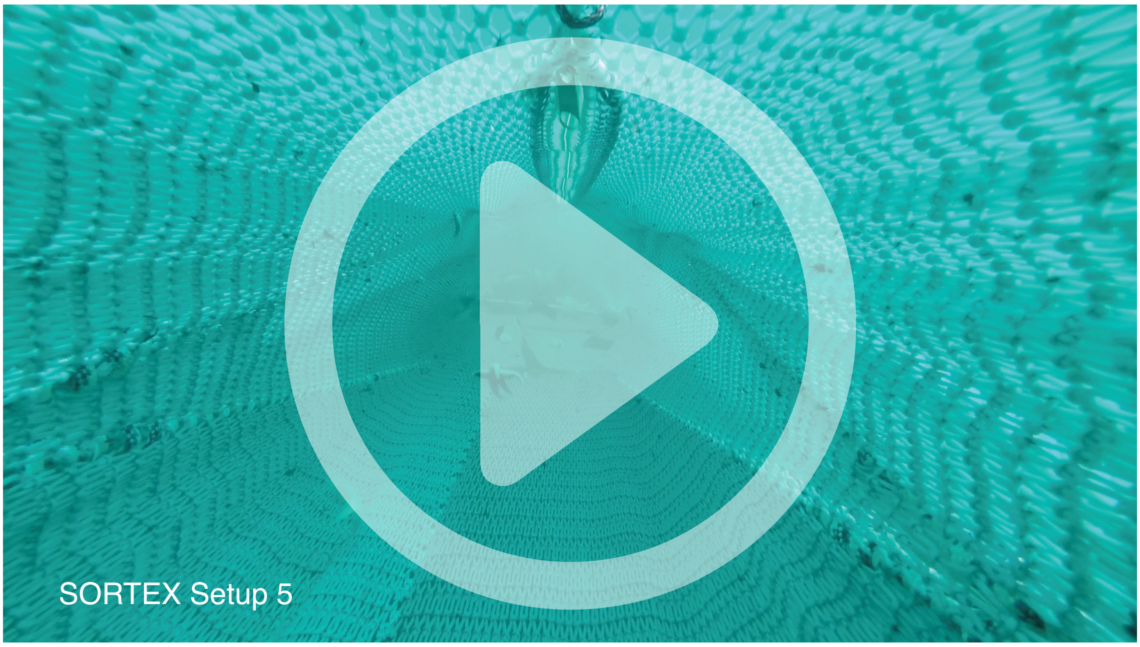

Figure 10: Setup 5 were the inlet frame was replaced by a fiber glass bar, transversely mounted 20 cm above the net floor. Withouth the rigid frame, the inlet tended to close during the haul-back. This dynamic behaviour could be applied to avoid unwanted cod passes during the final phase of the haul.

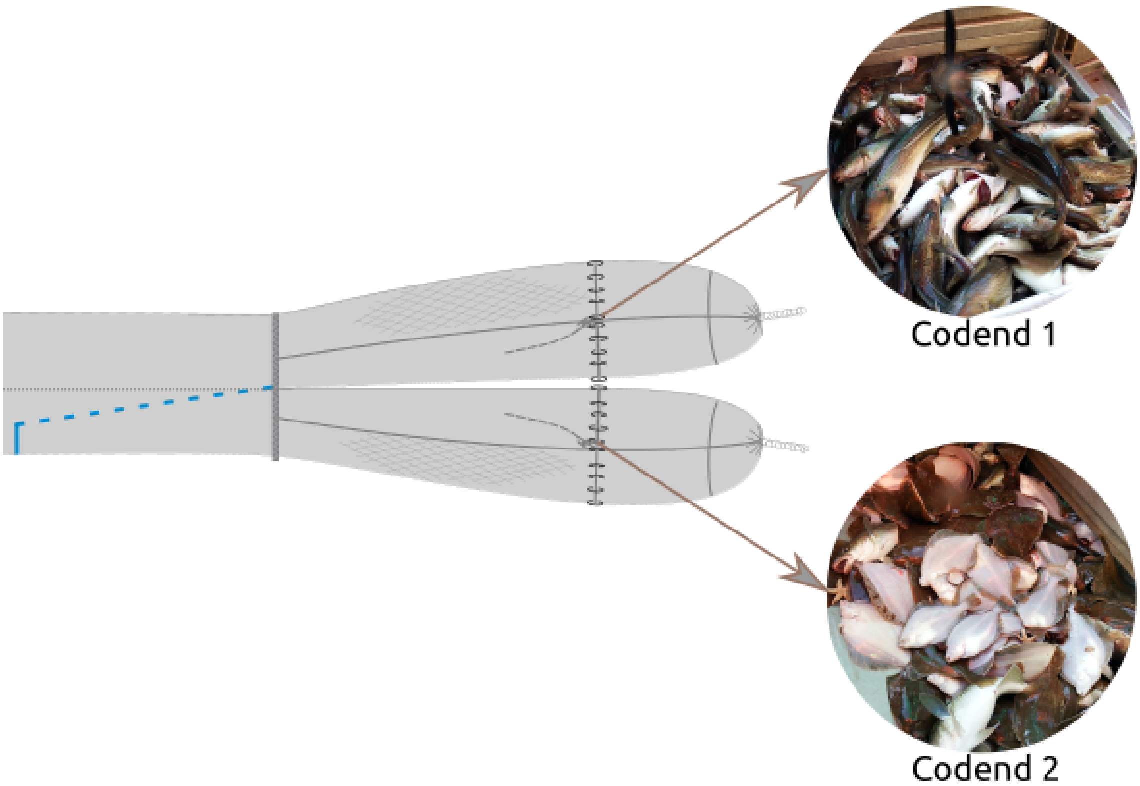

Figure 11: Visual comparison of catch profiles from codend 1 and 2.

3.2 Sorting efficiency

- Catches were similar for all setups tests, and the catch volume were almost equally distributed among codends (Figure 12). A deeper analysis shows the catch split among codends to be species-related.
- As intended, most of the cod catches occurred in codend 1 for all setups except in setup-5 (Figure 13).The estimated sorting efficiency for cod was above 80% for all setups and fish lengths except for fish larger than $60cm$ in setup 3, and for setup-5 (Figure 14). Pairwise comparison show that applying D-twines (setup 2), or increasing the angle of attack of the oblique panel (setup 4) significantly improve sorting efficiency achieved by the reference setup 1 on lengths between $20cm$ and $30cm$ Figure 15. On the other hand, removing the rigid frame reduced significantly the sorting efficiency.
- Contrary, most of plaice were caught in codend 2 (Figure 16). The probability to find the flatfish in codend 1 was in average equal (setups 2 and 5) or lower than $\sim 20\%$ (setups 1,3 and setup 4) (Figure 17). Applying deterrent twines (setup 2) significantly increased the probability to find plaice larger than $\sim 30cm$ in codend 1. Removing the rigid frame (setup 5) increased the probability to find medium-sized plaice in the upper codend (Figure 18).
- The probability to catch flounder in codend 1 using setups 1,3 and 4 was estimated in $\leq 20\%$ (Figure 20). As for plaice, setups 2 and 5 raised the averaged values obtained by the other setups. Applying deterrent twines (setup 2) significantly increased the probability to find flounder larger than $\sim 25cm$ in codend 1(Figure 21).
- Dab was the less abundant of the analysed species (Figure 22), specially in setup 2. Dab were similarly sorted as the other two flatfish species (Figure 23), and no differences were detected between setups (Figure 24).

gear	haul	station	shooting	Lat.	Long.	heaving	Lat..1	Long..1	depth	speed
setup-2	1	281	17-Mrz-2016 07:27:27	54.72	13.34	17-Mrz-2016 07:57:47	54.71	13.29	27.16	3.00
setup-2	2	282	17-Mrz-2016 08:52:07	54.71	13.16	17-Mrz-2016 10:51:57	54.72	13.35	31.43	3.30
setup-2	3	283	17-Mrz-2016 12:10:38	54.78	13.46	17-Mrz-2016 14:10:28	54.87	13.41	45.95	3.20
setup-2	4	285	18-Mrz-2016 06:58:28	54.88	14.06	18-Mrz-2016 07:59:28	54.84	14.01	41.24	3.00
setup-2	5	286	18-Mrz-2016 09:43:48	54.58	14.07	18-Mrz-2016 11:20:59	54.54	14.21	18.97	3.10
setup-2	6	287	18-Mrz-2016 13:23:39	54.68	13.79	18-Mrz-2016 14:23:29	54.73	13.79	39.44	3.10
setup-2	7	288	18-Mrz-2016 14:43:29	54.74	13.79	18-Mrz-2016 16:13:20	54.81	13.89	42.00	3.40
setup-1	8	289	19-Mrz-2016 06:53:29	54.71	13.17	19-Mrz-2016 08:53:19	54.72	13.36	31.12	3.40
setup-1	9	290	19-Mrz-2016 09:32:39	54.78	13.46	19-Mrz-2016 10:32:29	54.83	13.47	45.07	3.10
setup-1	10	291	19-Mrz-2016 10:58:59	54.82	13.47	19-Mrz-2016 12:28:50	54.75	13.50	40.02	3.40
setup-1	11	292	19-Mrz-2016 13:15:30	54.72	13.39	19-Mrz-2016 15:15:20	54.71	13.22	27.10	3.50
setup-1	12	293	20-Mrz-2016 06:58:40	54.75	13.51	20-Mrz-2016 07:58:30	54.79	13.46	43.94	3.30
setup-1	13	294	20-Mrz-2016 08:45:00	54.72	13.39	20-Mrz-2016 10:44:51	54.71	13.20	26.63	3.10
setup-1	14	295	20-Mrz-2016 11:23:11	54.76	13.25	20-Mrz-2016 13:23:01	54.73	13.43	32.91	3.30
setup-1	15	296	20-Mrz-2016 13:45:11	54.73	13.44	20-Mrz-2016 15:45:11	54.76	13.26	40.02	3.10
setup-3	16	298	21-Mrz-2016 06:59:51	54.76	13.23	21-Mrz-2016 08:59:41	54.73	13.44	32.83	3.60
setup-3	17	299	21-Mrz-2016 09:27:11	54.76	13.46	21-Mrz-2016 10:57:02	54.85	13.46	45.61	3.20
setup-3	18	300	21-Mrz-2016 11:18:22	54.84	13.46	21-Mrz-2016 12:48:12	54.76	13.47	41.13	3.50
setup-3	19	301	21-Mrz-2016 13:26:42	54.72	13.40	21-Mrz-2016 15:26:32	54.71	13.22	27.20	3.20
setup-3	20	302	22-Mrz-2016 06:57:12	54.76	13.24	22-Mrz-2016 08:56:52	54.73	13.42	33.41	3.40
setup-3	21	303	22-Mrz-2016 09:14:42	54.73	13.42	22-Mrz-2016 11:14:33	54.76	13.24	38.66	3.30
setup-3	22	304	22-Mrz-2016 13:03:53	54.67	12.75	22-Mrz-2016 14:33:43	54.62	12.64	18.46	3.30
setup-3	23	305	22-Mrz-2016 15:12:53	54.61	12.49	22-Mrz-2016 16:12:44	54.58	12.43	17.93	3.20
setup-3	24	306	23-Mrz-2016 06:51:14	54.20	12.01	23-Mrz-2016 08:21:14	54.20	11.88	19.19	3.10
setup-3	25	307	23-Mrz-2016 09:39:44	54.20	11.87	23-Mrz-2016 10:39:34	54.20	11.96	16.95	3.30
setup-4	34	316	02-Apr-2016 07:01:15	54.71	13.16	02-Apr-2016 08:30:46	54.72	13.30	29.37	3.30
setup-4	35	317	02-Apr-2016 09:12:16	54.77	13.45	02-Apr-2016 10:41:45	54.85	13.46	45.91	3.40
setup-4	36	318	02-Apr-2016 11:03:45	54.85	13.45	02-Apr-2016 12:33:16	54.77	13.45	42.45	3.00
setup-4	37	319	02-Apr-2016 13:07:47	54.72	13.39	02-Apr-2016 15:07:17	54.71	13.22	26.86	3.00
setup-4	38	320	03-Apr-2016 06:59:44	54.86	13.43	03-Apr-2016 08:59:15	54.76	13.47	41.40	3.30
setup-4	39	321	03-Apr-2016 09:40:44	54.72	13.38	03-Apr-2016 11:40:14	54.71	13.20	26.80	3.20
setup-4	40	322	03-Apr-2016 12:01:45	54.71	13.19	03-Apr-2016 14:01:13	54.72	13.36	31.55	3.00
setup-4	41	323	03-Apr-2016 14:34:43	54.77	13.44	03-Apr-2016 16:34:14	54.86	13.43	46.16	3.30
setup-5	46	328	05-Apr-2016 06:59:12	54.32	11.32	05-Apr-2016 07:59:12	54.26	11.33	21.12	3.50
setup-5	47	329	05-Apr-2016 08:28:42	54.22	11.33	05-Apr-2016 09:58:13	54.30	11.33	21.01	3.50
setup-5	48	330	05-Apr-2016 10:15:43	54.32	11.34	05-Apr-2016 11:45:13	54.38	11.41	22.81	3.30
setup-5	49	331	05-Apr-2016 12:25:13	54.33	11.33	05-Apr-2016 13:54:43	54.25	11.33	21.06	3.10
setup-5	50	332	06-Apr-2016 06:58:50	54.20	12.01	06-Apr-2016 07:58:20	54.19	11.92	17.68	3.10
setup-5	51	333	06-Apr-2016 08:17:20	54.20	11.90	06-Apr-2016 09:16:50	54.21	11.81	21.31	3.40
setup-5	52	334	06-Apr-2016 09:32:50	54.20	11.81	06-Apr-2016 10:32:20	54.19	11.91	18.43	3.30
setup-5	53	335	06-Apr-2016 10:55:51	54.20	11.91	06-Apr-2016 11:55:21	54.20	12.00	15.00	3.30

Table 1: Operational information of the hauls conducted with the different sortex setups

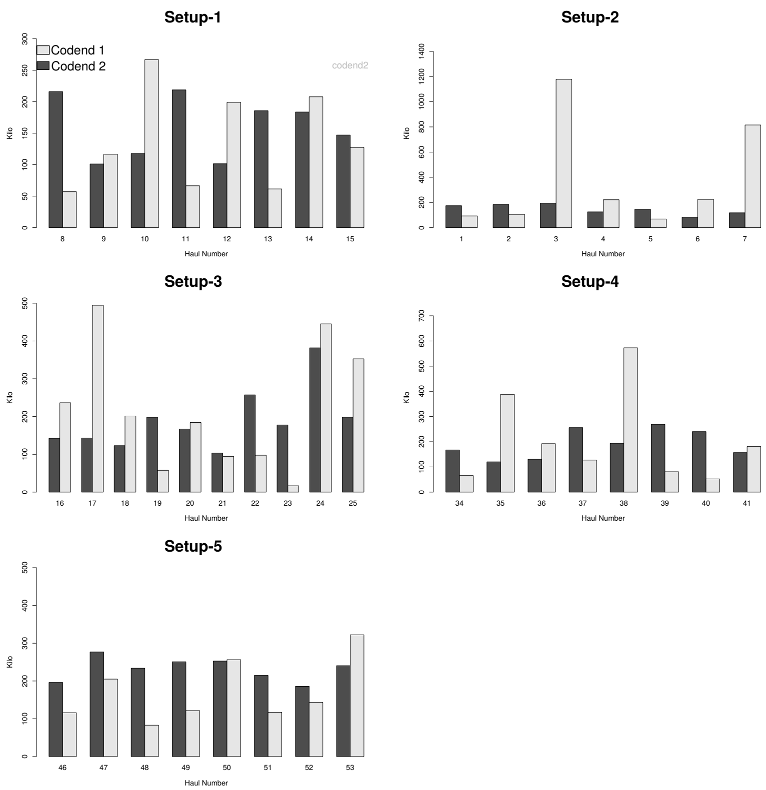

Figure 12: Total catch (biomass from all species pooled) grouped by codend (codend 1 = upper, codend 2 = lower). Hauls splitted in panels by experimental setups (1 to 5).

Cod

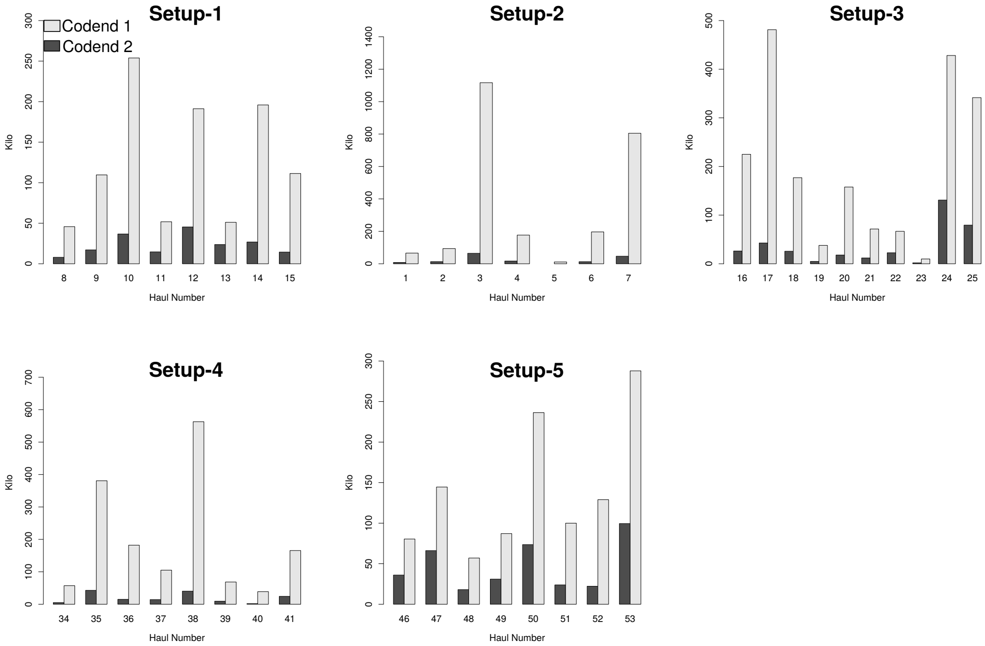

Figure 13: Cod catches (biomass) by codend, haul and setup.

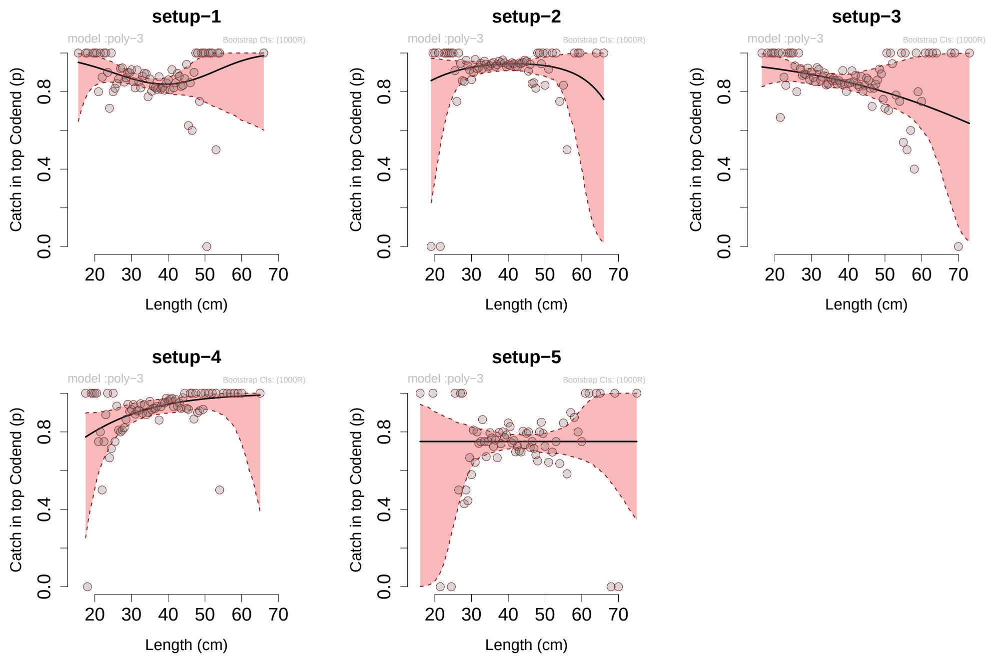

Figure 14: Probability to catch cod in the upper codend ($p(l)$) by tested setups and associated CI for the averaged curves.

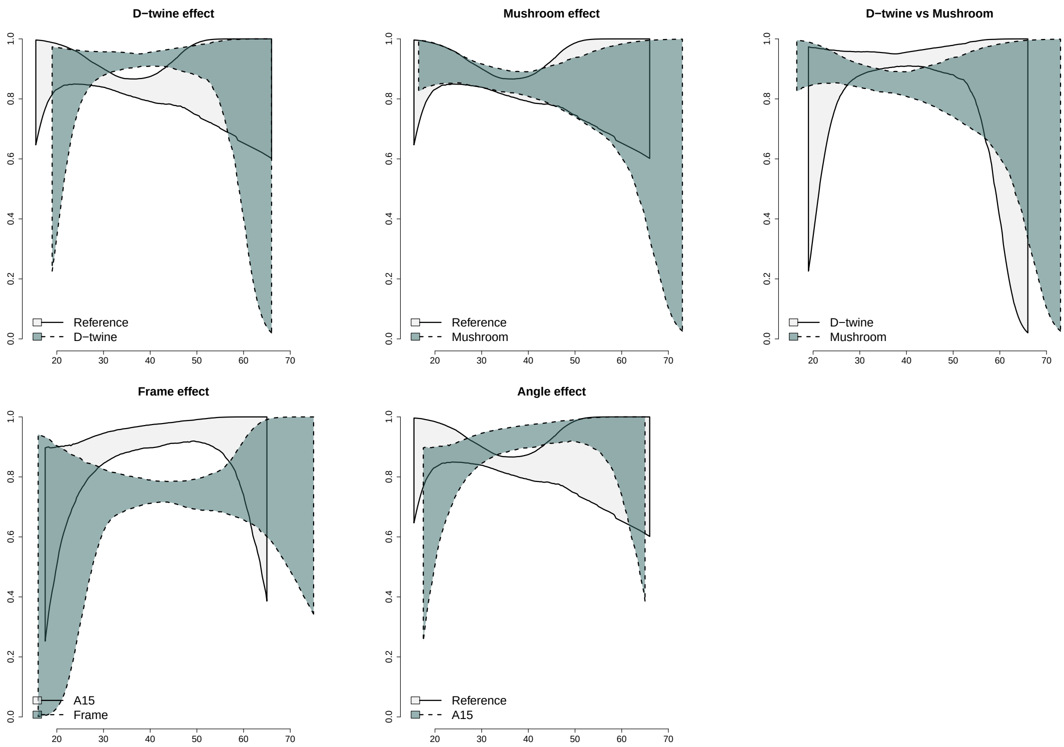

Figure 15: Pairwise comparison of the CI from the different $p(l)$ curves estimated for cod. Setup 1 is used as reference to assess the effect of adding deterrent twines (D-twine effect), adding Mushrooms (Mushroom effect) or increasing the angle of the blique panel (Angle effect). Pairwise comparison is also conducted berween setups 2 and 3 (D-twine effect vs Mushroom) and setups 4 and 5 (Frame effect).

Plaice

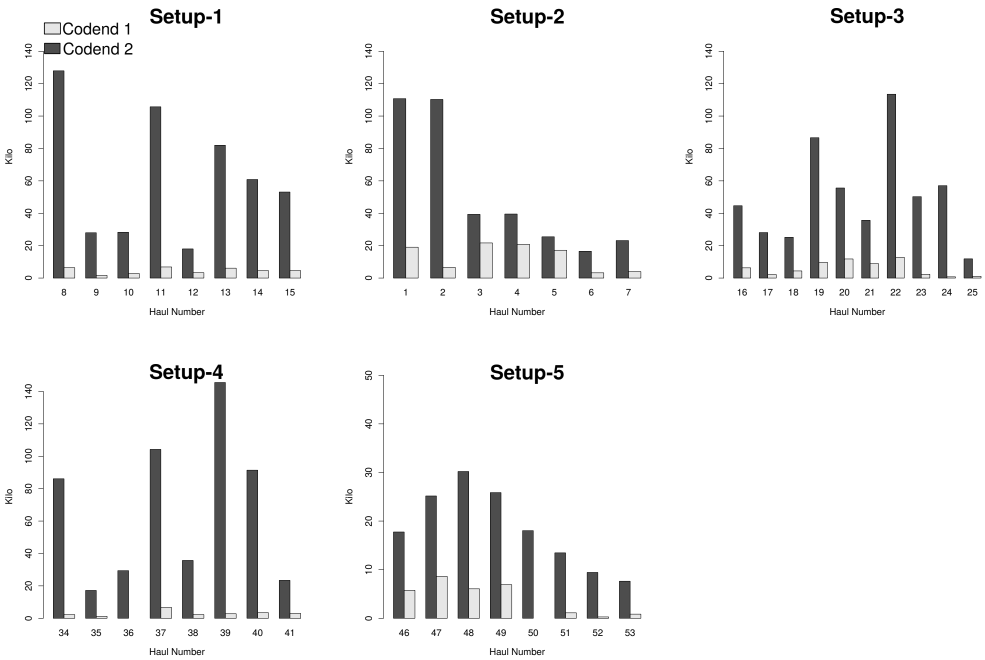

Figure 16: Plaice catches (biomass) by codend, haul and setup.

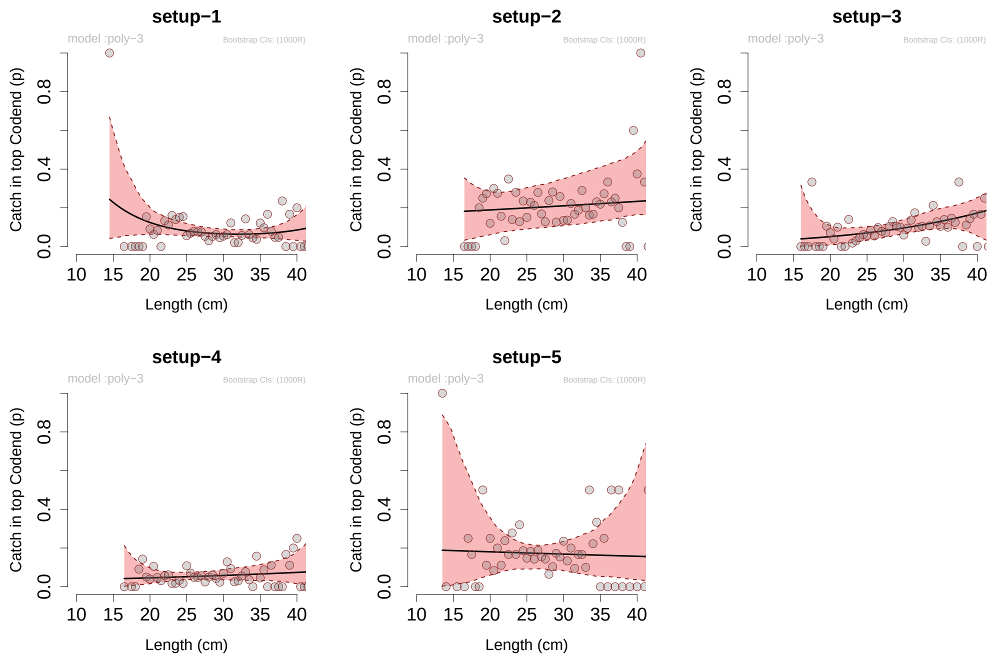

Figure 17: Probability to catch plaice in the upper codend ($p(l)$) by tested setups and associated CI for the averaged curves.

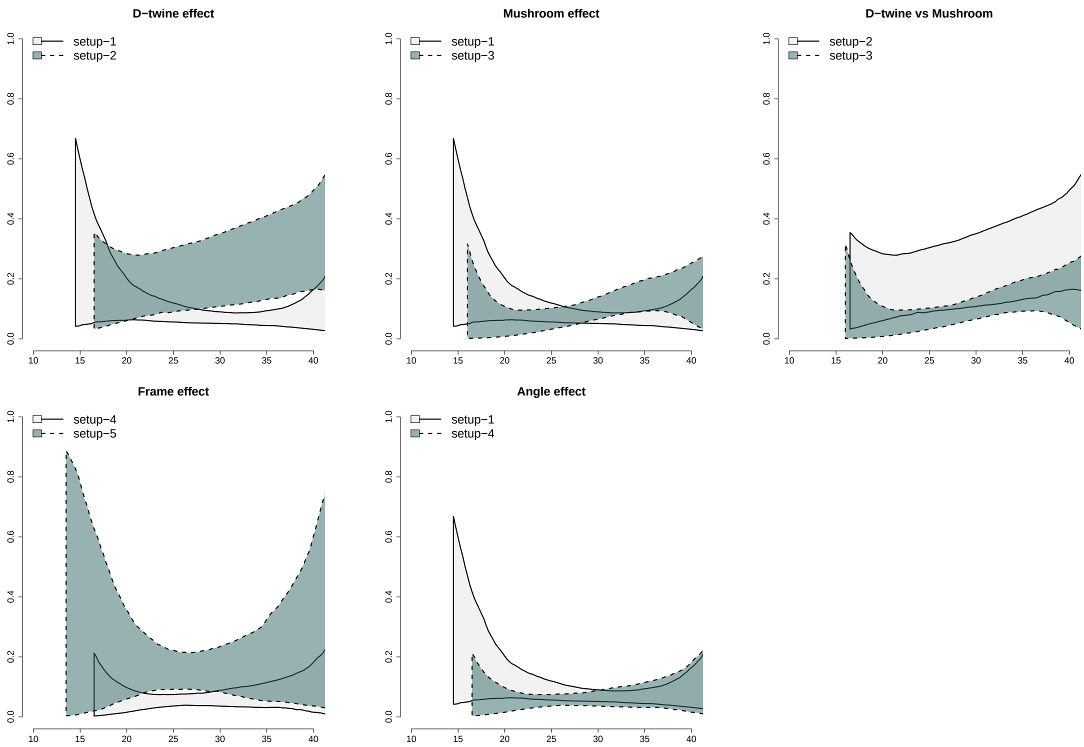

Figure 18: Pairwise comparison of the CI from the different $p(l)$ curves estimated for plaice. Setup 1 is used as reference to assess the effect of adding deterrent twines (D-twine effect), adding Mushrooms (Mushroom effect) or increasing the angle of the blique panel (Angle effect). Pairwise comparison is also conducted berween setups 2 and 3 (D-twine effect vs Mushroom) and setups 4 and 5 (Frame effect).

Flounder

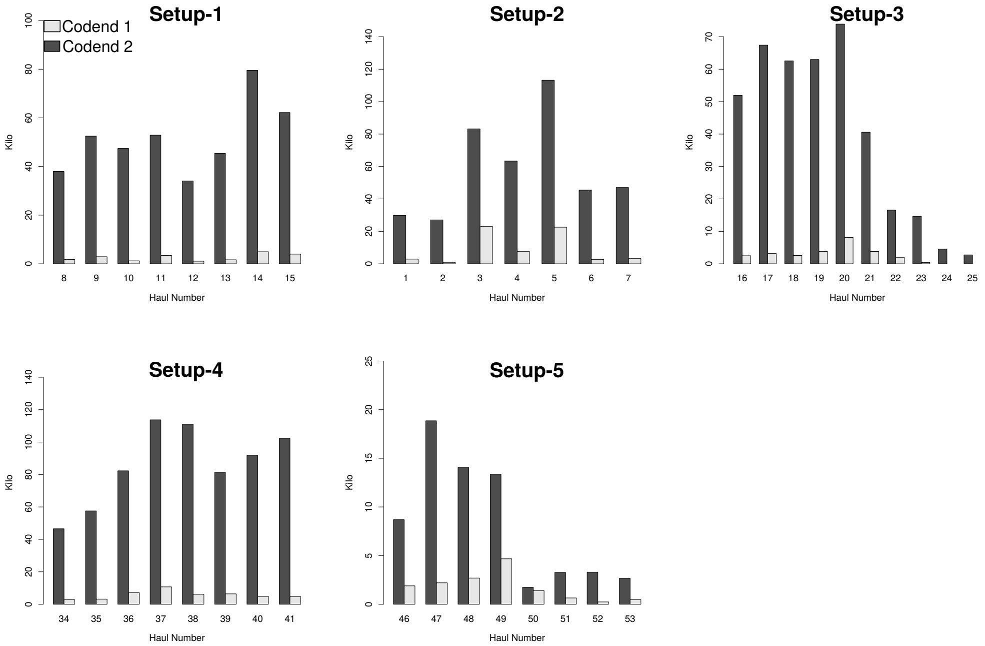

Figure 19: Flounder catches (biomass) by codend, haul and setup.

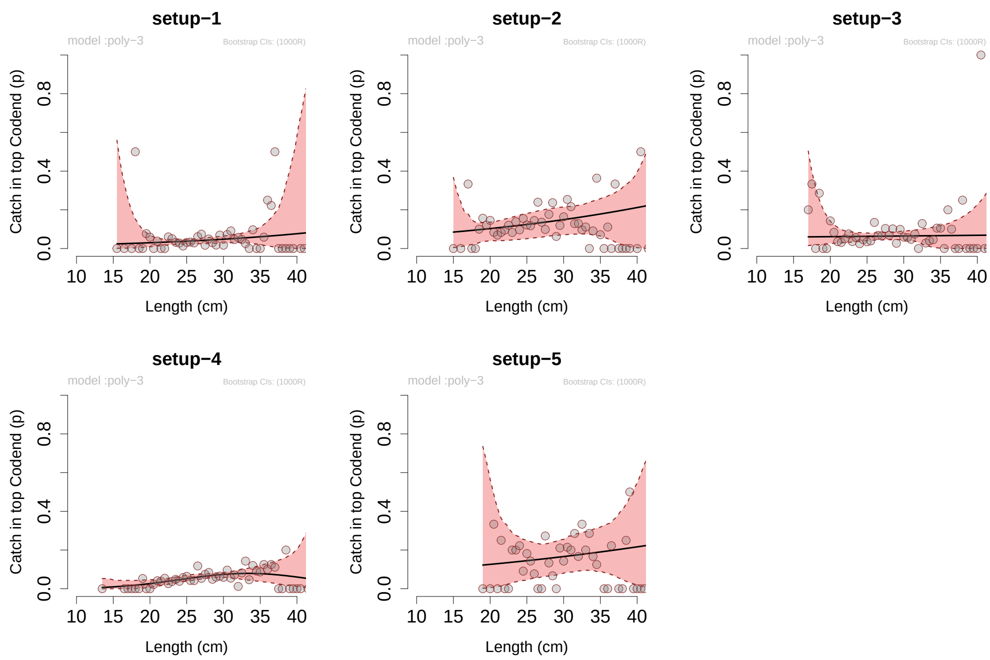

Figure 20: Probability to catch flounder in the upper codend ($p(l)$) by tested setups and associated CI for the averaged curves.

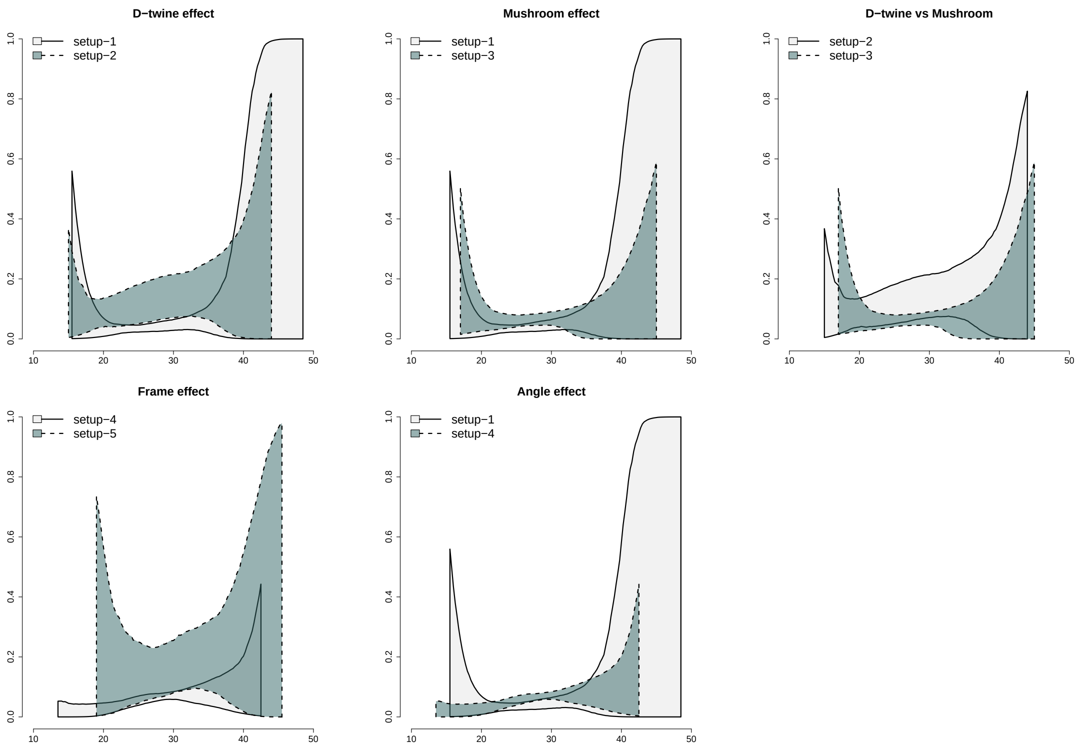

Figure 21: Pairwise comparison of the CI from the different $p(l)$ curves estimated for flounder. Setup 1 is used as reference to assess the effect of adding deterrent twines (D-twine effect), adding Mushrooms (Mushroom effect) or increasing the angle of the blique panel (Angle effect). Pairwise comparison is also conducted berween setups 2 and 3 (D-twine effect vs Mushroom) and setups 4 and 5 (Frame effect).

Dab

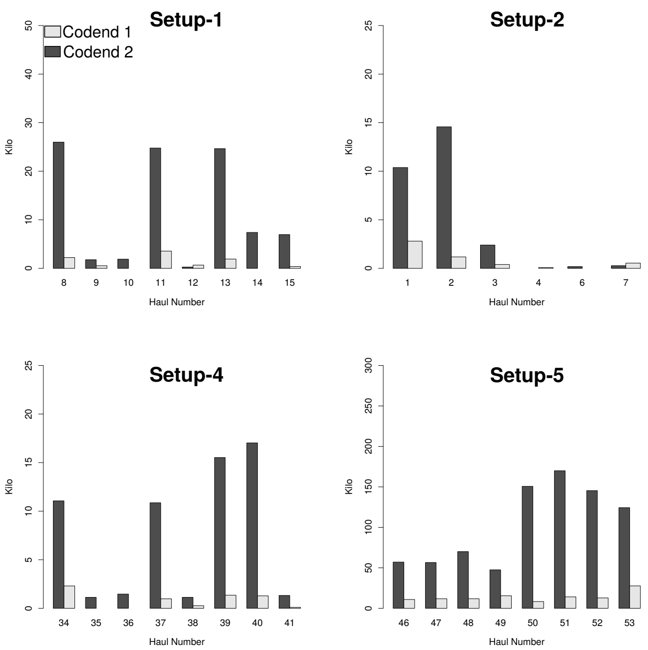

Figure 22: Dab catches (biomass) by codend, haul and setup.

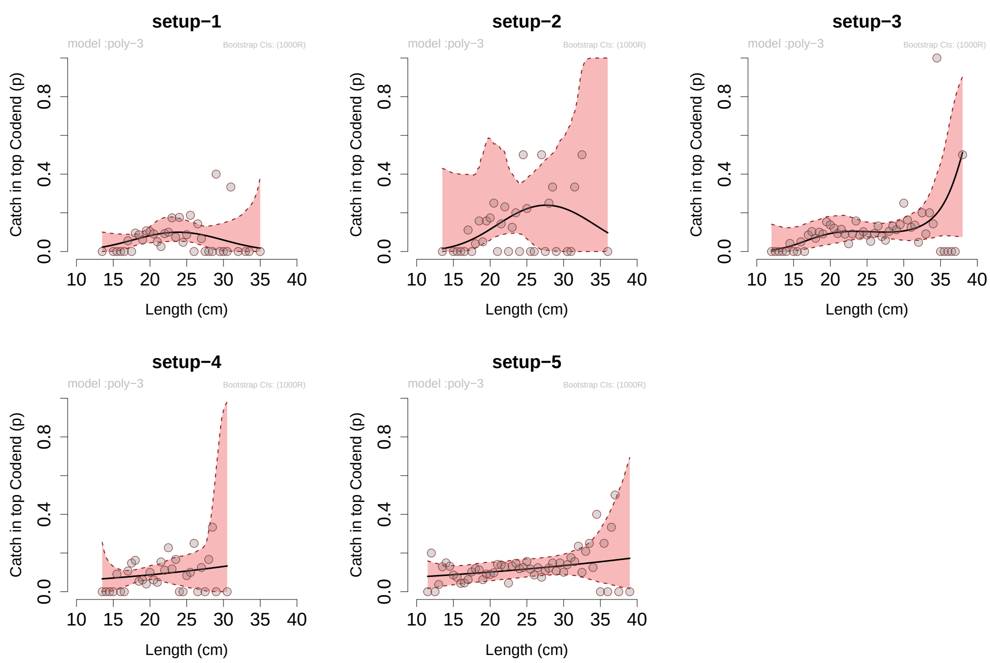

Figure 23: Probability to catch dab in the upper codend ($p(l)$) by tested setups and associated CI for the averaged curves.

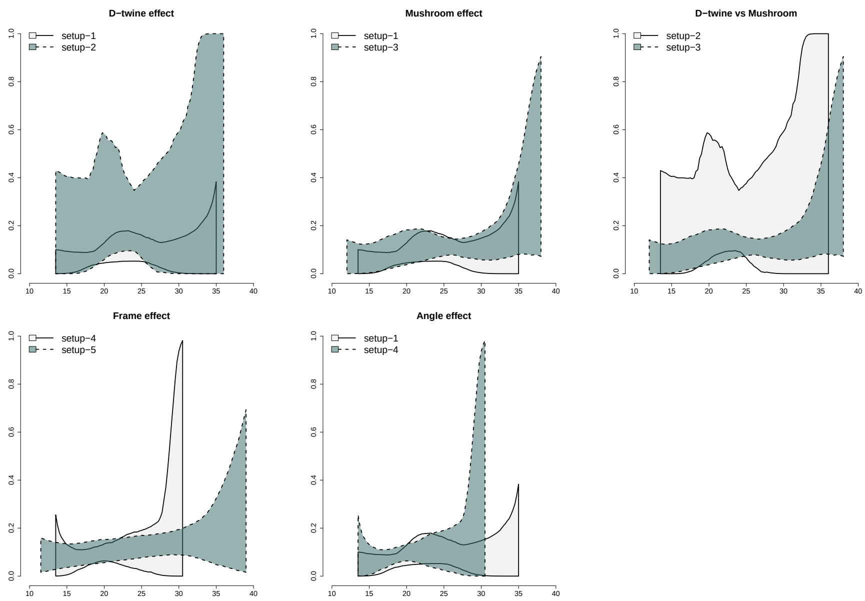

Figure 24: Pairwise comparison of the CI from the different $p(l)$ curves estimated for dab. Setup 1 is used as reference to assess the effect of adding deterrent twines (D-twine effect), adding Mushrooms (Mushroom effect) or increasing the angle of the blique panel (Angle effect). Pairwise comparison is also conducted berween setups 2 and 3 (D-twine effect vs Mushroom) and setups 4 and 5 (Frame effect).

3.3 Oblique panel performance

- Six hauls were conducted with SORTEX setup 1 to test the influence of the oblique panel on the sorting efficiency. 3 of the hauls were conducted with the oblique panel masked by small mesh panel (panel:0), while the remaining 3 hauls used the complete setup (panel:1).
- The pairwise comparison in Figure 25 show the CBs from both the masked and unmasked panel setups to overlap in all cases, except for cod with lengths between 30*cm* and 50*cm*.

gear	haul	station	shooting	Lat.	Long.	heaving	Lat..1	Long..1	depth	speed
panel:0	28	310	31-Mar-2016 11:25:14	54.21	11.78	31-Mar-2016 12:54:44	54.20	11.91	18.25	3.10
panel:0	29	311	31-Mar-2016 13:49:44	54.20	11.90	31-Mar-2016 14:49:14	54.20	11.99	15.51	3.20
panel:0	30	312	01-Apr-2016 09:07:13	54.20	11.94	01-Apr-2016 10:06:43	54.20	11.86	19.76	3.00
panel:1	31	313	01-Apr-2016 10:36:13	54.20	11.88	01-Apr-2016 12:05:43	54.20	12.02	13.91	3.20
panel:1	32	314	01-Apr-2016 12:32:43	54.20	12.00	01-Apr-2016 13:32:13	54.20	11.91	18.25	3.10
panel:1	33	315	01-Apr-2016 13:55:43	54.19	11.89	01-Apr-2016 14:55:14	54.20	11.98	16.08	3.30

Table 2: Operational information of the hauls conducted with the oblique panel masked (panel:0) and unmasked (panel:1).

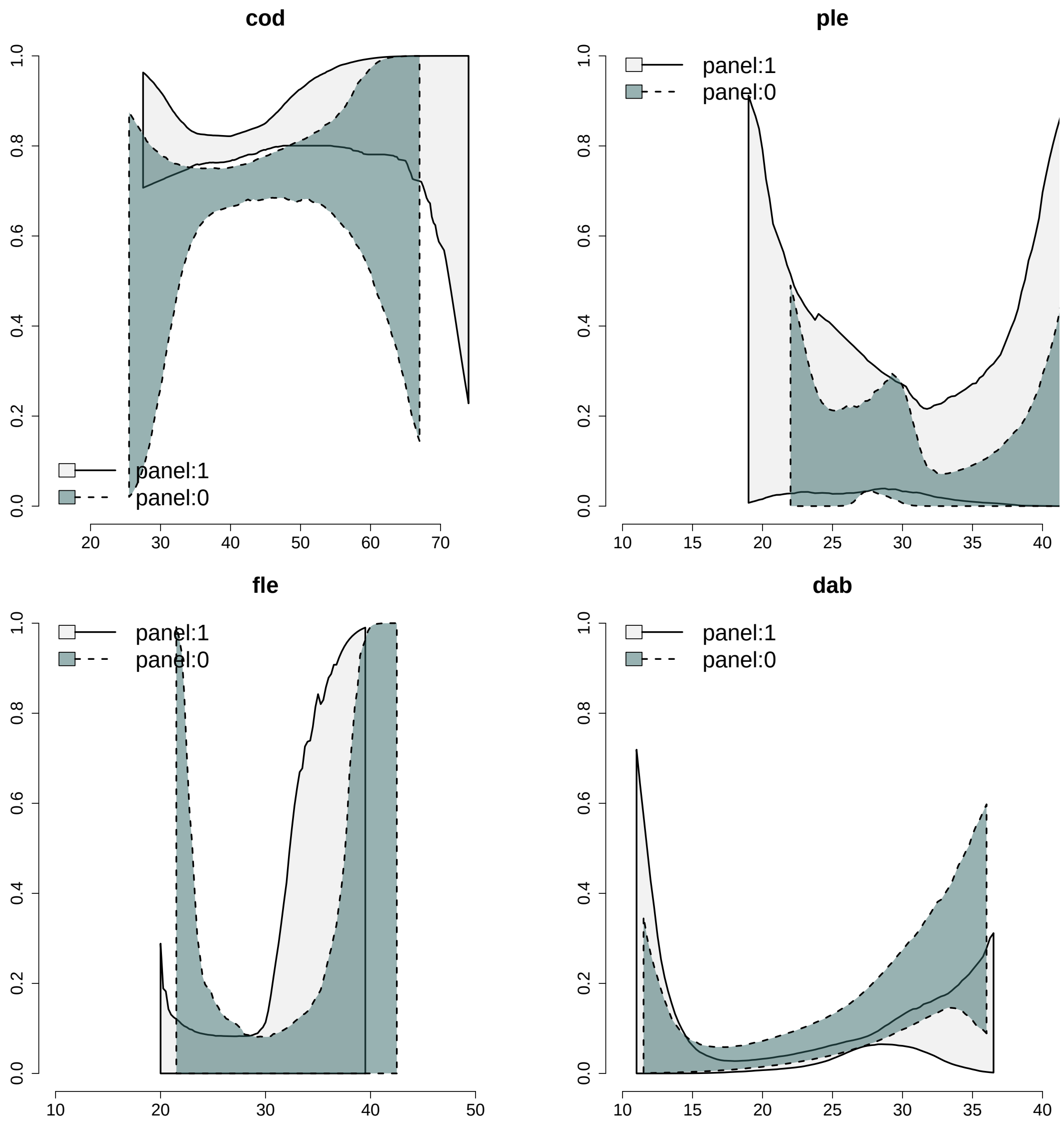

Figure 25: Pairwise comparison of the sorting efficiencies estimated for cod, plaice (ple),flounder (fle) and dab.

4 Concluding remarks

The results presented here demonstrate that separating cod from flatfish is possible in the Baltic sea through modifications of the tunnel connecting the trawl body to the codend; at least $\sim 80\%$ of cod entering in the gear was caught in the upper codend, and similar values were found for the probability to catch the flatfish species in the lower codend. These results were similar for all setups tested except when the rigid frame was removed (setup 5). Since the rigid frame was designed to keep the shape of the inlet stable during towing, we argue that its removal affected negatively the global performance of the sorting device.

Applying D-twines (setup 2), or increasing the angle of attack of the oblique panel (setup 4) showed some improvement in the sorting efficiency of cod Figure 15, but at the same these gear modifications increased the probability to catch plaice in the upper codend. In general the different modifications tested do not improve the sorting efficiency achieved by the reference design, therefore setup 1 is the specification recommended for commercial adoption.

The oblique panel did not influenced the sorting efficiency on flatfish, while it was estimated that it improved the sorting efficiency for medium-large cods. Although this improvement could be related to the shaking behaviour of the panel when unmasked Figure 6, this result should be taken with caution due to the reduced number of hauls used in the pairwise comparison.

Separate species during towing is a promising strategy towards a better control of the catch composition. Adopting an efficient sorting device in the Baltic fisheries would allow the specification of species-oriented selectivity to better account for the market preferences and the quotas restrictions imposed by the Landing Obligation. For example, under a scenario with a relative balance between cod and plaice quotas, fishermen could mount a cod-selective upper codend, and a flatfish-selective lower codend, sharpening the global size selection of the gear. Under the current fishing scenario with limited quota for cod, fishermen might completely avoid cod catches by opening the upper codend during towing. The opposite could be done to avoid flatfish catches.

Although the current European technical measures do not allow fisherman to use trawls with multiple cod-ends with different mesh sizes, the results presented here demonstrate the potential for this concept and it may be a step forward in implementing and acceptance of the Landing Obligation by the industry.

5 Research crew members

Beate Büttner**	Technician	TI-OF)
Saied Gorgin	Guest researcher	University of Gorgan (Iran)
Stefanie Haase*	Volunteer	University of Hamburg
Bernd Mieske**	Researcher	TI-OF)
Titus Rohde*	Technician (Cod tagging)	TI-OF
Juan Santos	Cruise Leader	TI-OF
Peter Schael	Technician	TI-OF
Kerstin Schöps	Technician	TI-OF

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

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