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Report

of the 275 cruise RV CLUPEA
from 07th **to** 24th **October** 2013

Cruise leader: Juan Santos

Summary

The research cruise `Clupea 275` was designed to investigate the effectiveness of Square Mesh Windows (SMW), inserted in the upper side of the net ahead of a codend in the demersal trawl fishery. Further, two different techniques to improve the efficiency of the escaping window were developed and tested during the cruise. A fishing data collection scheme was established to compare the catches from the gear mounting the SMW (test gear) to the catches of a non-selective gear (reference). In addition, we used Under-Water (UW) recordings to assess how different species react when entering in the area where the SMW is fitted. The catch comparison study and the UW observations demonstrate poor performance of the tested selection device, not improved significantly by the modifications proposed herein.

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On the effectiveness of inserting Upper Square Mesh Windows ahead of the codend

Juan Santos, Bernd Mieske and Daniel Stepputtis

1 Introduction

Large quantities of juveniles fish or unwanted species are bycaught and subsequently discarded in European fisheries. Although the potential solutions for discards not only depends on gear technology [4], affecting catch profiles by improving size and species selection in trawl gears is an essential tool used in many management strategies worldwide. Because codend is the part of the gear where most of fish escapes occur [6], attempts to improve the selectivity of fishing gears have been historically focused on alterations in the codend netting, for example changing the mesh size, the mesh orientation, the mesh geometry or number of meshes in circumference.

Traditionally, the codend selectivity is usually defined under a single-species perspective, even in demersal mixed fisheries. An increased research effort has been invested in recent times to develop multispecies selection systems to address the bycatch problem in such cases. The multispecies selection approach often involves the use of alternative selection devices to supplement the codend selectivity. A review on the reported developments reveals Square Mesh Windows (SMW) to be one of the most used devices in European waters [3]. The SMW functioning relies on utilising fish escaping behaviour and assist escapements by maintaining an open mesh structure in a certain area of the gear. SMWs are usually fitted in the upper panel of the tunnel (the net section connecting the codend to the trawl belly), assuming that some species will alter their swimming direction upwards to meet the escape window, while others do not perform any escapement reaction, being passively drifted towards the codend. The combination of the USMW (Upper Square Mesh Window) and the codend should therefore produce a species-based sequential selection system along the longitudinal axis of the gear. Examples can be found in *nephrops* fisheries [1,2], where selectivity for gadoids bycatch is theoretically addressed by the USMW, while *nephrops* size selection is defined in the codend.

Previous research to improve the efficiency of SMW has been mainly focused on finding an optimal position in the longitudinal axis of the trawl [1, 7, 8]. Surprisingly, the assumption that fish will swim towards the USMW is kept in most of the reviewed studies, even though natural behaviour for many fish species is to stay clear of the netting [6] or that it can exist differences in escaping behavior between young and mature fish. Based on these argumentations, it should not be surprising that some studies on USMW have reported very limited effectiveness. One example can be found in [5], where the proposed USMW did not improve the selectivity of a standard gear for species such as Hake (*Merluccius merluccius*) and Cod (*Gadus morhua*).

The research cruise `Clupea275` was designed to investigate the effectiveness of inserting SMW in the upper panel of the extension piece, therefore not directly influenced by codend dynamics (as the case of BACOMA window). The sampling scheme was designed to compare the catches from a gear mounting the USMW to catches of a non-selective reference gear. In addition, we utilize Under Water recordings (UW) to assess how different species react when entering the area where the USMW is fitted. Because we were not interested in the size selection of the USMW, but in the probability of efficient contacts with the USMW, a very large mesh size was used in the USMW construction to avoid any size selection process. In turn, this USMW design enabled us to investigate potential dependency between the contact probability and the fish size. Finally, two different gear alterations were tested to improve the efficiency of USMW attempting to stimulate fish to perform upwards escaping reactions in the vicinity of the

USMW area. The aims of this research topic are summarized as follows:

i To assess the USMW performance in terms of efficient fish contact.

ii To investigate if such contact probability depends on fish length.

iii To develop and test different stimulating techniques to optimize USMW efficiency.

2 Material and Methods

The sea trials were carried out from 07^{th} to 24^{th} October 2013 using the RV/*Clupea*, a 28.80 m, 478 kW German research vessel. The fishing grounds were located in Mecklenburg bay and Arkona waters (ICES Subdivision 24). Two demersal $TV300/60$ trawls were used in a twinrig-setup. The codends and the extension pieces were made of small mesh netting ($T0PE60S4$; 30mm bar length) to retain all fish within the length range used in analysis. One of the gears mounted a USMW in the tunnel. The gear with the USMW is hereafter referred as test gear, while the gear with no USMW is referred as reference gear. The USMW was made of very large meshes ($T45PE400S3$; 200mm bar length), which should facilitate full escapement possibilities for all fish of all lengths classes, which efficiently contact the window. This test gear configuration is denoted as setup 1 (the baseline for the experimental fishing to adress aims `i` and `ii` of the present study). The sea trials were split into two different phases; development and design of stimulating techniques to address aim `iii`, and the experimental fishing for quantitative data collection.

2.1 Definition of stimulating devices setups

Short pelagic tows (to obtain good visibility) were performed to assess the stability and hydrodynamical behaviour of different test configurations by underwater observation. Further, we tested different modifications in the extension piece to improve the probability of fish contacts to the window. All modifications were based on using floating ropes fitted to the lower panel underneath the USMW. We expected that the presence, and the shaking motion of the ropes in the way of the fish (at least roundfish) to the codend should stimulate fish swimming reactions upwards towards the window. Different mounting configurations were proposed and their hydrodynamical behaviour assessed by UW video recordings in pelagic trawling. The two best configurations were denoted as setup 2 and setup 3, to be tested in experimental fishing.

2.2 Experimental fishing

Data collection

The experimental design was chosen to perform a catch comparison [9] using the twin trawl rigging available on the vessel. Twin trawling allows the reference and the test gear to be towed in the same fishing ground at the same time, enabling a direct catch comparison between both gears at haul level. Let n_t be the number of fish caught in the test system, n_r the number of individuals caught in the reference system, and $n_+ = n_t + n_r$, the total catch, then the catch proportion in test codend for a given haul is,

$$p = \frac{n_t}{n_+} \tag{1}$$

Which can be used to empirically assess the loss/gain of fishing efficiency of the *test* gear in relation to the *reference* gear. The catch proportion in test (p) only can takes values between 0 and 1. Values of $p \sim 0.5$ are interpreted as equal fishing efficiency for both gears. In the current experiment, $p \sim 0.5$ would mean fish entering the test gear do not use the USMW to escape. Values of $p < 0.5$ is related to lower catch efficiency in test gear, meaning that fish to some extend use the USMW. Based on statistical theory, we assume that the number of fishes in the *test* codend follow a binomial distribution,

$$n_t \sim Binom(n_+, p) \tag{2}$$

Because we are interested not only on the effectiveness of USMW as escaping area, but also in assessing if such effectiveness is dependent to fish length we extend (2) to

$$n_t(l) \sim Binom(n_+(l), p(l)) \tag{3}$$

where $p(l)$ is an unknown curve describing the influence of fish length on the effectiveness of USMW.

Data analysis

Curve estimation

In catch comparison studies the $p(l)$ curve is usually estimated by linearising the observed catch proportion in test codend using the logit link function:

$$\hat{p}(l) = \frac{\exp\left(\beta_0 + (\beta_1 + \ldots + \beta_j) \times l\right)}{1 + \exp\left(\beta_0 + (\beta_1 + \ldots + \beta_j) \times l\right)} \tag{4}$$

Where β_0 is the curve intercept and $(\beta_1 + \ldots + \beta_j)$ is a vector of polynomial coefficients to smooth the effect of fish length on the relative catch rates. For the present study we propose an alternative smoothing approach based on penalized regression splines [10]:

$$\hat{p}(l) = \frac{\exp\left(\beta_0 + f_1 \times l\right)}{1 + \exp\left(\beta_0 + f_1 \times l\right)} \tag{5}$$

In model 5, the length effect is described by an unknown curve f_1 with a spline basis:

$$f_1(l) = \sum_{k=1}^{K} b_k(l)\beta_1 \tag{6}$$

Where b_k are known functions, K is the number of nodes and β_1 is an unknown parameter.

Under this formulation, the function f_1 becomes a parametric form depending exclusively on the estimation of the parameter $\beta_{1k}, k = 1, \cdots, K$. The method is especially useful for multivariate models; for these situations the form (6) can be extended to:

$$\eta_i = \sum_{k=1}^{K_1} b_{1k}(x_{1i})\beta_1 + \ldots + \sum_{k=1}^{K_p} b_{pk}(x_{pi})\beta_p = \mathbf{X}_i\beta \tag{7}$$

where η_i is in our specific case the logit link function. At this stage, it could be considered to use the estimation technique from the GLM framework, nevertheless the number and the positions of the smoothing nodes (K) must be predefined. A way to overcome such problem is to set a large number of nodes as default, and to control the degree of smoothness by including a penalty in the estimation process,

$$\sum_{i=1}^{n} W_i \left(Z_i - \mathbf{X}_i\beta\right)^2 + \lambda_1 \int (f_1''(X_1))^2 dx_1 + \cdots + \lambda_p \int (f_p''(X_p))^2 dx_p \tag{8}$$

The form (8) is known as P-IRLS algorithm, where the integral of the squared second derivative estimates the degree of curvature of each of the smoothing functions, being penalized by λ_j (the smoothing parameters). The p-spline smoother for length effect was estimated using the `mgcv` package, available in `R-Cran` repository.

Inference

We are not only interested on estimating $\hat{p}(l)$, but also on assessing if any relative difference in catchability described by the catch comparison curve is significant, considering the uncertainty in estimation and the natural variation of the catch process. The inference is carried out here by assessing the confidence intervals (CI) associated to the estimated curve. Differences in catchability for a given fish length will be considered significant only if the CI does not overlap the reference value of $p = 0.5$. We estimate the CI using bootstrap techniques, applied to computer-based resampling methods to simulate the variability of the predicted curves. The technique is used separately for each species and test setup as described below:

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 test and reference gears for each of the hauls h_i^* selected in the previous step. A new set of pseudo-hauls $(h_1^{**}, \ldots, h_N^{**})$ are obtained in this step, with $h_i^{**} = \{n_{tli}^*, n_{rli}^*\}$

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

4. A catch comparison curve $\hat{p}^*(l)$ is estimated using the data generated in (4)

5. Repeat steps 1 to 4 a large number of times $(b = 1, \ldots, B = 2000)$ to obtain a set of curves $\hat{p}^{*1}(l), \ldots, \hat{p}^{*b}(l)$ estimated from the simulated data

Once this process is completed, the $100 \times (1 - \alpha)$ limits of the confidence interval for the original estimation $\hat{p}(l)$ is given by:

$$(\hat{p}(l) - \hat{p}^{*1-\frac{\alpha}{2}}(l), \hat{p}(l) - \hat{p}^{*\frac{\alpha}{2}(l)}) \tag{9}$$

2.3 Underwater video recordings

Wide angle, self recording cameras sheltered within a polycarbonate housing (GoPro Hero3$^{\text{TM}}$) were placed in the top panel of the extension piece focusing the area where the USMW was mounted. Videos were used in pelagic trawls to assess the structural stability of the extension piece mounting the USMW, and to identify optimal setups of the floating rope lines. Video recordings collected during the experimental fishing were used to investigate fish behaviour in the vicinity of the USMW with and without stimulating devices, and reactions when encountering the stimulating devices in setup 2 and setup 3.

3 Results

A total of 42 hauls were performed during the cruise, whereby 9 hauls belong to the setup identification/selection stage and 34 hauls to the experimental fishing (table 1). Once the first setup stage was completed off the coast of Warnemünde, the vessel steamed eastwards to start fishing in Arkona fishing rounds. The catch profile at this area did not match with the experimental purposes and the vessel returned to Warnemünde to continue fishing. Consequently, hauls performed in Arkona fishing grounds were not used in subsequent analysis.

3.1 Definition of stimulating setups

A total of 7 short duration pelagic tows were carried out to evaluate different stimulating device configurations (Figure 1). Configurations A to C varied from each other in number of ropes, combination and type of floats attached to each of the ropes. UW observations showed for these configuration a systematic problem of entanglement between the ropes and the USMW, reducing the intended individual rope shaking movement and compressing the height of the tunnel (Figure 2). Configurations D to E were proposed *ad hoc* to avoid the entanglement problem. The reduced height of configuration E (Figure 1) did not produced entanglement problems during this stage, being selected as setup 2 for experimental fishing. Setup 3 was specified later when the experimental fishing was in process. It is characterized for having four rows of ropes connected in pairs longitudinally by high buoyancy floats, forming the M-Shape configuration showed in Figure 3.

Date	Fishing ground	Haul	Type	Setup	Position
08/10/2013	Warnemünde	1	setup	-	S
08/10/2013	Warnemünde	2	setup	-	S
08/10/2013	Warnemünde	3	setup	-	S
08/10/2013	Warnemünde	4	setup	-	S
08/10/2013	Warnemünde	5	setup	-	S
17/10/2013	Warnemünde	6	setup	-	S
17/10/2013	Warnemünde	7	setup	-	S
17/10/2013	Warnemünde	8	setup	-	S
17/10/2013	Warnemünde	9	setup	-	S
10/10/2013	Arkona	1	fishing	1	S
10/10/2013	Arkona	2	fishing	1	S
14/10/2013	Warnemünde	3	fishing	1	S
14/10/2013	Warnemünde	4	fishing	1	S
14/10/2013	Warnemünde	5	fishing	1	S
14/10/2013	Warnemünde	6	fishing	1	S
15/10/2013	Warnemünde	7	fishing	1	S
15/10/2013	Warnemünde	8	fishing	1	S
15/10/2013	Warnemünde	9	fishing	2	S
15/10/2013	Warnemünde	10	fishing	2	S
16/10/2013	Warnemünde	11	fishing	2	S
16/10/2013	Warnemünde	12	fishing	2	S
16/10/2013	Warnemünde	13	fishing	1	S
17/10/2013	Warnemünde	14	fishing	3	S
19/10/2013	Warnemünde	15	fishing	3	S
19/10/2013	Warnemünde	16	fishing	3	S
19/10/2013	Warnemünde	17	fishing	3	S
19/10/2013	Warnemünde	18	fishing	3	S
20/10/2013	Warnemünde	19	fishing	1	S
20/10/2013	Warnemünde	20	fishing	1	S
20/10/2013	Warnemünde	21	fishing	1	S
20/10/2013	Warnemünde	22	fishing	1	S
21/10/2013	Warnemünde	23	fishing	3	P
21/10/2013	Warnemünde	24	fishing	3	P
21/10/2013	Warnemünde	25	fishing	3	P
21/10/2013	Warnemünde	26	fishing	3	P
22/10/2013	Warnemünde	27	fishing	1	P
22/10/2013	Warnemünde	28	fishing	1	P
22/10/2013	Warnemünde	29	fishing	1	P
22/10/2013	Warnemünde	30	fishing	1	P
23/10/2013	Warnemünde	31	fishing	1	P
23/10/2013	Warnemünde	32	fishing	3	P
23/10/2013	Warnemünde	33	fishing	3	P
23/10/2013	Warnemünde	34	fishing	3	P

Table 1: Hauls performed during the sea trials. Position refers to the side the test gear is mounted (S=starboad, P=portside).

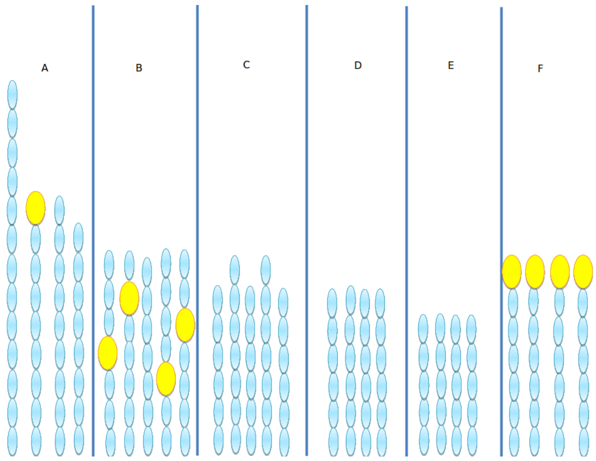

Figure 1: Different stimulating configurations tested in the setup stage

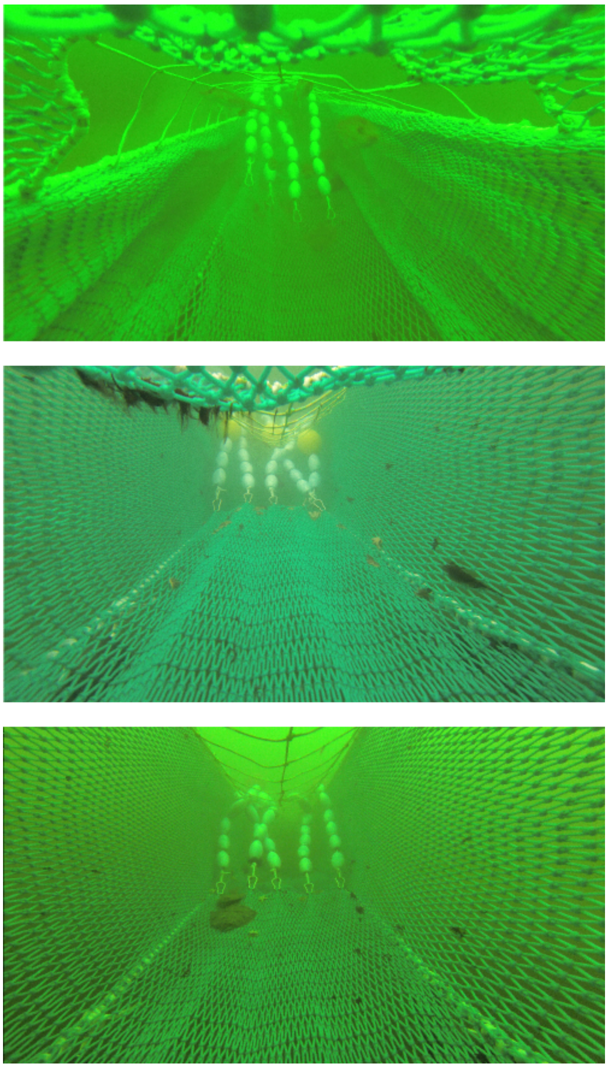

Figure 2: Entanglement problems found for most configurations tested in setup stage

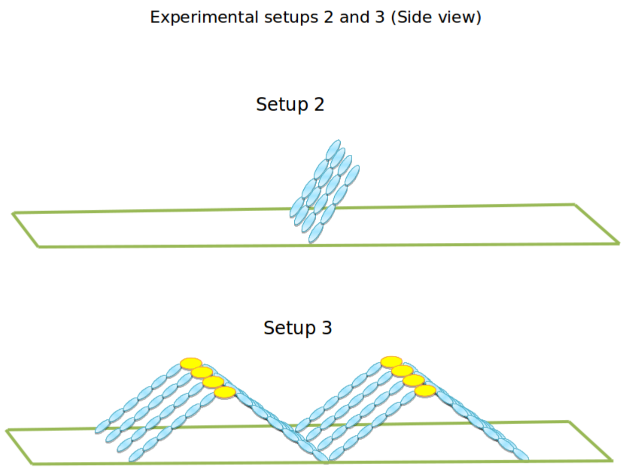

Figure 3: Schematic side view of the stimulating ropes configurations used in setup 2 and setup 3.

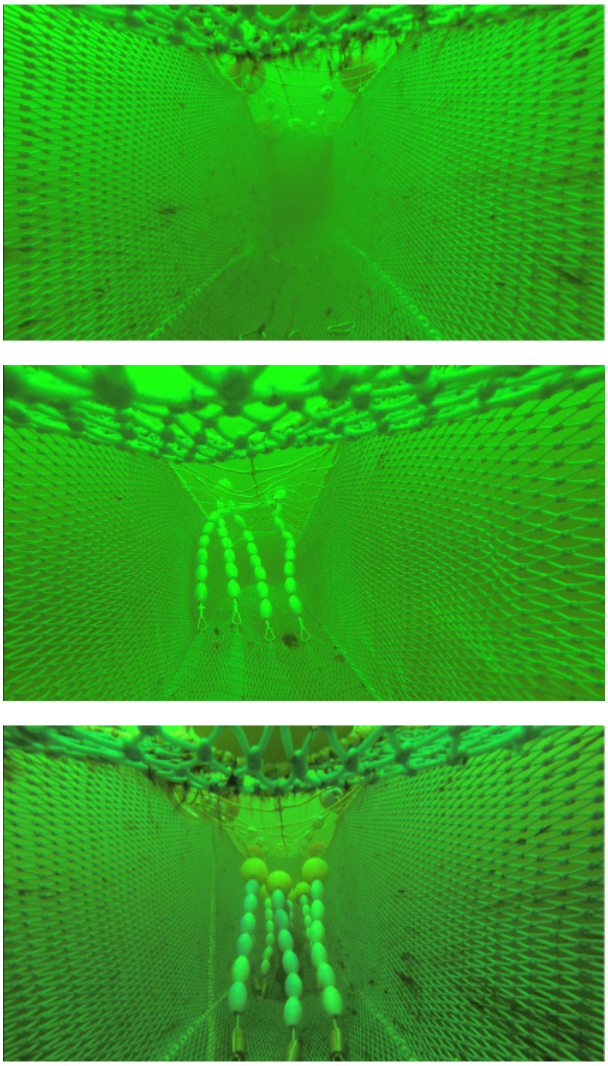

Figure 4: UW images showing frontal view of setup 1 (top) setup 2 (center) and setup 3 (bottom). Central image shows setup 2 performance was affected by entanglement problems.

3.2 Experimental fishing

Entanglement between ropes and USMW were also observed during the experimental fishing stage for setup 2 (Figure 4, center). It was observed that the entanglement not only reduced the motion of the ropes, but also the height of the water column below the USMW (as it compresses the vertical dimension of the extension piece). Both phenomena might confound the effect of the floating ropes. Consequently, it was decided to stop testing this setup after the first 4 hauls.

Catch description

The total biomass caught was 9414.9 kilo, whereby 44.1% were observed in the gear with the USMW and 55.8% in the reference gear. The catch profile was dominated by flounder (50.5%), cod (24.1%) and dab (14.2%). The catch ratio in test to the reference gear indicates small but significant catch reduction for cod and flounder in setup 1 (table 2), while the confidence limits for dab and plaice catch ratios overlap 100%, meaning no significant evidence of catch reduction in terms of weight for these species in setup 1. The presence of stimulating ropes in setup 2 significantly reduced the catch in weight for most of the studied species, specially in the case of cod $35\%(18.1 - 71.5\%)$. Setup 3 did not substantially reduced the catch ratio values from setup 1 (table 2).

Setup	Species (DE)	Species (EN)	Test	Reference	Ratio
setup1	aalmutter	eelpout	0.34	0.64	53.1 (0-Inf)
	dorsch	cod	618.46	838.54	75.4 (64.2-92.3)
	flunder	flounder	1657.52	1887.42	87.4 (76.2-96.4)
	hering	herring	7.40	24.12	31 (13-54.5)
	kliesche	dab	300.99	332.27	91 (76-113.5)
	makrele	mackerel	1.42	0.77	184.4 (80.5-475)
	scholle	plaice	78.92	102.80	77.7 (51.2-107.7)
	seehase	henfish	0.00	0.42	0 (0-0)
	seeskorpion	-	3.13	2.33	142 (68.2-252.5)
	steinbutt	turbot	44.18	65.14	68.6 (47.2-93.3)
	stint	-	2.64	5.98	45.3 (0-86)
	wittling	whiting	140.85	165.08	84.8 (60.7-107.3)
setup2	dorsch	cod	44.34	160.98	35 (18.1-71.5)
	flunder	flounder	112.74	194.86	57.3 (50.2-61)
	hering	herring	0.00	3.56	0 (0-0)
	kliesche	dab	75.42	89.78	84.5 (78.5-93.3)
	makrele	mackerel	0.00	0.36	0 (0-0)
	scholle	plaice	19.58	12.98	148.1 (47.2-222.8)
	seeskorpion		0.20	0.24	83.3 (0-Inf)
	steinbutt	turbot	5.92	6.72	86.1 (31.8-171.6)
	wittling	whiting	5.76	18.32	37.6 (27.4-76.1)
setup3	aalmutter	eelpout	3.26	0.18	1811.1 (255.6-Inf)
	dorsch	cod	257.47	347.42	73.6 (56.8-89.9)
	flunder	flounder	396.13	507.98	79.8 (54.7-106.8)
	hering	herring	3.60	18.12	22.2 (8.8-54.5)
	kliesche	dab	247.96	291.71	85.5 (73.4-101.2)
	scholle	plaice	40.21	43.59	91.9 (66.9-121.1)
	seeskorpion	-	1.86	2.24	95.1 (35.3-210.1)
	steinbutt	turbot	39.12	47.12	83.3 (51.7-119.7)
	wittling	whiting	46.02	87.40	53.9 (40.1-73.8)

Table 2: Pooled catch (Kilo) information for the test and the reference gears, and associated catch ratios (estimated as $\frac{n_t}{n_r}$) by species and experimental setups. Bootstrap CI of catch ratio in brackets.

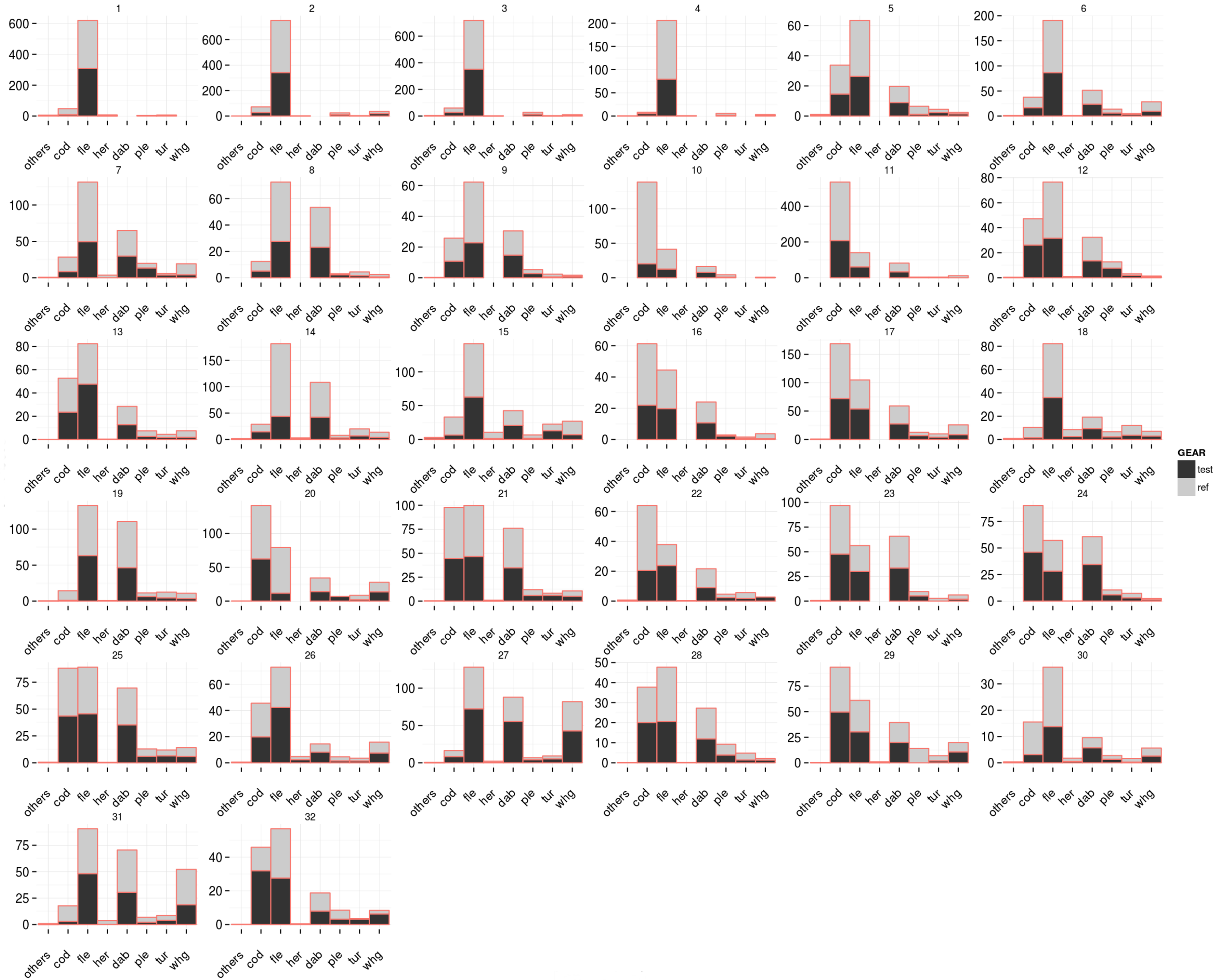

Figure 5: Cath volume (Kg) by species in test (black) and reference (gray) gears. Information shown at haul level in separated panels. FAO species codes used to facilitate the plot labelling: cod=cod, fle=flounder, her=herring, ple=plaice,tur=turbot,whg=whiting.

Catch comparison

The comparison using model (5) indicates no significant differences between test and reference catches for cod in setup 1 (Figure 6), in case of setup 2, the estimated curve indicates very low relative catchability in test gear for cod, but such difference is not significant due to the uncertainty caught by the bootstrap CI (Figure 6).The mean curve for setup 3 shows a negative trend for larger length classes, although the reduction in catchability is not clear, being only significant in the tails of the length distribution (Figure 6).

Flounder catch comparison (Figure 7) in setup 1 shows an increasing trend, but the assessment of the CI indicates not significant differences except for the extreme length classes. Finally, the model applied to dab data (Figure 8) estimates equal catchability without any clear trend over the available length classes.

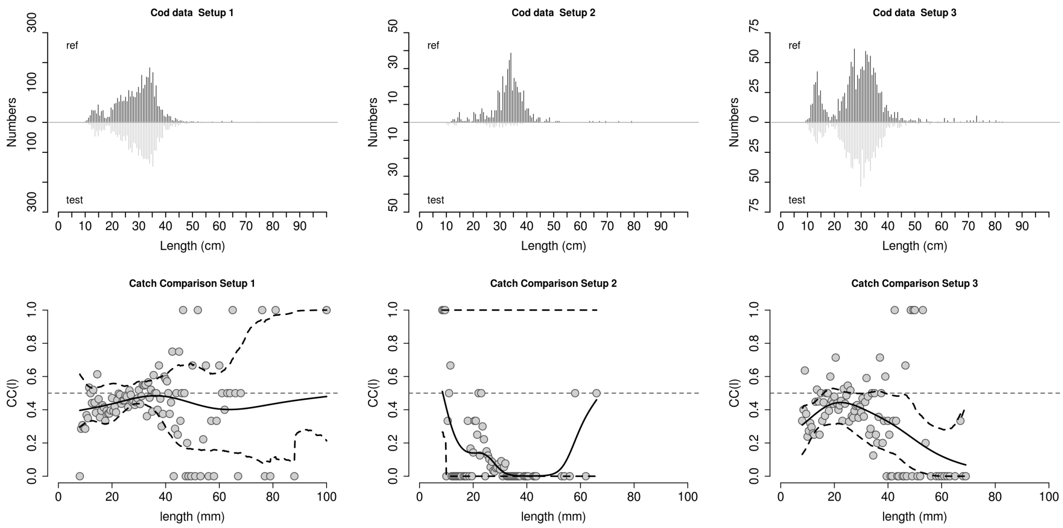

Figure 6: Cod catch comparison (model 5) between the three different test setups and the reference gear. Top panel: Observed length structure of cod catches in reference and test gears. Bottom panels: Estimated catch comparison curves (reference line of equal catchability drawn in $p = 0.5$)

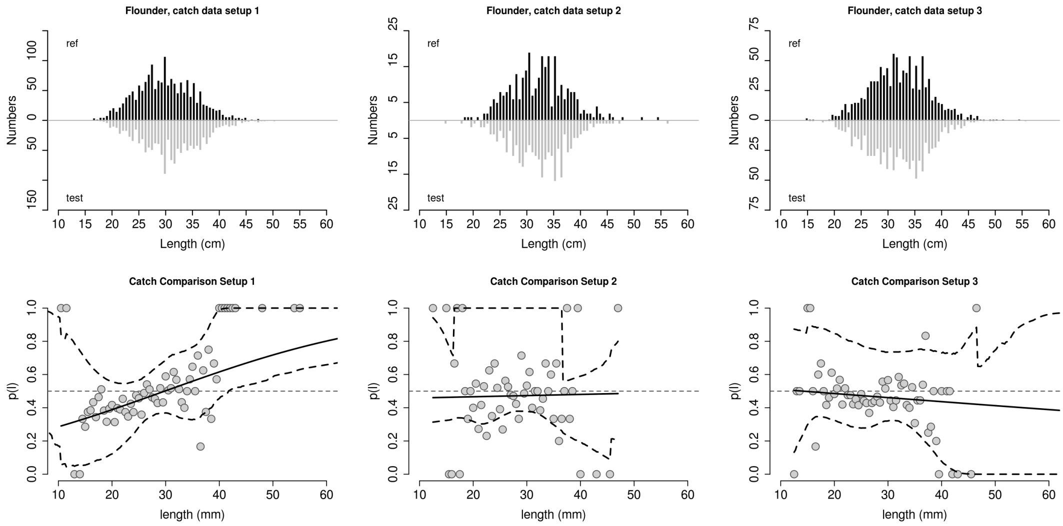

Figure 7: Flounder catch comparison (model 5) between the different test setups and the reference gear. Top panel: Observed length structure of flounder catches in reference and test gears. Bottom panels: Estimated catch comparison curves (reference line of equal catchability drawn in $p = 0.5$)

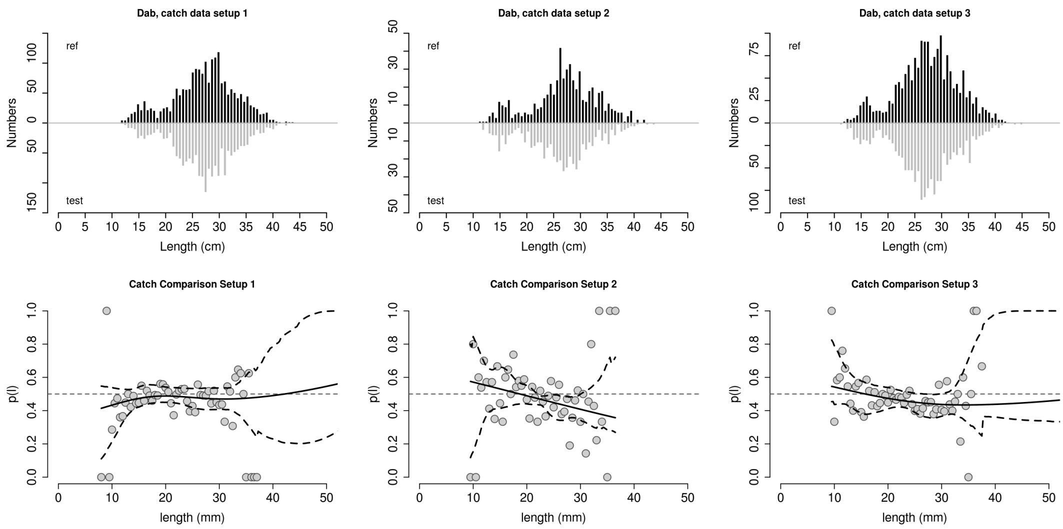

Figure 8: Dab catch comparison (model 5) between the different test setups and the reference gear. Top panel: Observed length structure of dab catches in reference and test gears. Bottom panels: Estimated catch comparison curves (reference line of equal catchability drawn in $p = 0.5$)

4 Discussion

- The $\hat{p}(l)$ curves obtained for the setup 1 yielded in general no significant differences between the test and the reference gears. The big meshes used in USMW construction suggest fish don't escape through the window because they do not efficiently contact with it. This hypothesis is supported by the video recordings taken in the vicinity of the USMW, showing most of fish drifting backwards towards the codend without performing any active response to the presence of the escaping window. These results indicates that mounting a square mesh window in the upper panel of the extension piece is not an effective strategy to stablish a sequential selection process in conjunction with the codend, at least for the species under study. Only a slight, positive length dependency in the relative catchability was found for flounder (Figure 7), suggesting that the probability that juvenile flounder meet the USMW is higher than for larger individuals. This result must be taken with caution, since the differences are not significant for most of the length classes under study.
- The configuration of the stimulating ropes used in test gear setup 2 showed a promising performance for cod, but we cannot compare this results with the cod results from setup 1, due to the entanglement problem observed for this configuration. The video observations show that the height of the net tunnel is lowered when the ropes entangle the USMW; the reduced height of the tunnel might act as a confounding effect for the experimental aims of this study, since it can raise the possibilities that a fish contacts the USMW. Further efforts should be invested to fix the problem of entanglement and test again the setup 2 without the effect of the mentioned confounding. An experimental design considering the tunnel height as fixed effect is here proposed for future sea trials on the topic.
- The setup 3 did not showed entanglement problems and therefore the effect of inserting the stimulating ropes under this configuration can be compared against the baseline (setup 1). The results in the modelling part indicate that the M-shaped configuration did not significantly improved the efficiency of the USMW. We speculate that the position of the "M" or the reduced shacking motion of the connected ropes could be the cause of the poor results obtained by this configuration. For this setup, the catch comparison curve on cod catches shows a negative length dependency (Figure 6), suggesting that the probability that older cod meet the USMW is higher than for juveniles. Again, this result must be taken with caution, since the differences are only significant in the tails of the catch profile.
- In this study we proposed an alternative technique to smooth the length effect in catch comparison studies. The method automatically find the best compromise between the descriptive power and curve variability. This model fits properly to the bootstrap scheme implemented to predict the CI, since for each of the 2000 pseudo-samples, a catch comparison curve is automatically fitted. We consider this approach as an effective tool for describing and reporting the experimental data in catch comparison studies. For deeper investigations on the contact probability and the potential fish length effect, it is recommended to use parametric models under the standard Maximum Likelihood framework.

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6 Schlussbemerkung

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