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Cruise Report
FRV „Solea" Cruise 811
14.– 29.09.2022

Scientists in charge: Juan Santos

Überblick

Es wurden Seeversuche durchgeführt, um die Leistung eines Standardsiebnetzes (Sievenetz_60mm) und dreier alternativer Geräte zur Reduzierung des Beifangs in der Nordsee-Garnelenfischerei zu bewerten: 1. Letterbox-Netz (Letterbox_60mm), 2. Elliptisches Gitter im Gehäuse (EG_60x40_24mm), und 3. Rechteckiges Gitter (RG_60x40_24mm). Die Fangvergleichsversuche (paired-gear method) zeigten, dass das Siebnetz insgesamt gut funktionierte in Bezug auf die Beifangreduktion von größeren Individuen von Beifangarten bei gleichzeitig minimalen Auswirkungen auf den Fang von Konsumgarnelen.. Die Verwendung des Letterbox-Netzes verringerte die Fängigkeit von Garnelen im Vergleich zum Siebnetz und lieferte aufgrund eines Konstruktionsfehlers auch die höchsten Beifangraten, da Fische in den Steert gelangen können, ohne mit der Sortierienrichtung (Letterbox_60mm) in Kontakt zu kommen. Das EG_60x40_24mm Gitter vertsopfte schnell aufgrund von Konstruktionsproblemen, was zu einer allgemeinen Verringerung der Fängigkeit von Ziel- und Beifangarten führte. Das einfachere rechteckige Gitter (RG_60x40_24mm) zeigte eine Verbesserung im Vergleich zum EG_60x40_24mm Gitter, blieb aber hinter dem Siebnetz zurück. Es ist zu erwarten, dass ein größeres Rechteckgitter (RG_80X60_24mm) wirksamer wäre. Die Studie zeigt die gute Leistung des Siebnetzes unter guten Fangbedingungen bei relativ geringem Vorkommen von Schwebstoffen (Seegras) und benthischen Wirbellosen. Gittersysteme zeigten ihr Potenzial als Selektionseinrichtungen zur Verminderung von Beifang, allerdings erfordern die aktuellen Konstruktionen weitere Entwicklungen, um Verstopfungen und Handhabung zu verbessern. Das konzeptionelle Design der Letterbox ist mindestens nicht für Fanggebiete geeignet, in denen Beifangarten mit hoher Schwimmfähigkeit vorkommen, wie z.B. Wittling .

Distribution list:

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Summary

In the North Sea beam trawl fishery targeting brown shrimp, sea trials were conducted to evaluate the performance of a standard sieve-net (Sievenet_60mm), and three alternative bycatch reduction devices: 1. the letterbox device (Letterbox_60mm), 2. housed elliptical grid (EG_60x40_24mm), and 3. rectangular grid (RG_60x40_24mm). Based on the paired-gear experimental method, the results obtained revealed an overall good performance of the Sievenet_60mm, in terms of bycatch reduction of the larger individuals of bycatch species, and minimal catch losses of the marketable shrimp (total length ≥ 50 mm). On the other hand, our results indicate that the Sievenet_60mm is less effective in reducing the by-catch of juvenile fish. The use of the Letterbox_60mm significantly reduced the catchability of shrimp compared to the sieve-net, and also resulted in the highest bycatch rates of plaice and whiting among the tested gears. We argue that this is the result of a flaw in the letterbox selective concept, as fish in the upper zone inside the trawl can move towards the codend without being subjected to the available sorting capabilities of the device. The EG_60x40_24mm grid quickly became clogged due to design problems, and this led to an overall reduction in catchability of target and bycatch species. The simpler rectangular grid (RG_60x40_24mm) showed an improvement compared to the former grid design, but its performance still lagged behind the Sievenet_60mm. Opportunities for further development of the rectangular grid design were identified during the trip, for example by increasing the size in order to double the selective surface of the grid (RG_80X60_24mm).

Overall, this study shows that, under good fishing conditions, such as those encountered during the cruise (with low occurrence of suspended matter (sea grass) and benthic invertebrates), the Sievenet_60mm can deliver an efficient and consistent sorting of targeted and bycatch species. Grid systems showed their potential as selection devices to reduce bycatch, but the current designs requires further development in order to tackle current issues in the fishery. Such developments should focus on a) improvements to reduce clogging events and b) facilitate handling and manoeuvres. Finally, the conceptual principle of the Letterbox_60mm can lead to inconsistent performance, specially in fishing grounds with availability of roundfish species with high swimming capabilities, such as whiting.

1 Introduction

The bycatch of non-targeted species remains to be an issue of concern in the beam-trawl fisheries targeting brown shrimp in the North Sea. This issue has been intensively addressed in the past by intense research efforts devoted to the development of bycatch-reduction devices (BRD), that were designed to provide escape possibilities to fish species before entering the codend. As a result, two types of BRD, namely sieve-nets and sorting grids, were proposed as technical solutions to reduce unwanted bycatch. These two devices are required to use since many years (EU 1241/2019 and previous regulations), consequently, fishers are obliged to mount one of them in their trawls. Historical trials in the frame of the EU-Study 98/012 "DISCRAN" (Van Marlen *et al.*, 2001) demonstrated that sieve-nets and sorting grids can potentially deliver a satisfactory catch separation. However, it also revealed performance issues that are still to be solved. For example, while using one of these devices can effectively reduce the bycatch of age 1+ fish, none of them is effective in separating age-0 fish, which is a major bycatch component for instance in German fishing grounds. Moreover, the intended sorting efficiency of sieve-nets and sorting grids designed more than two decades ago might not be appropriate to deal with present challenges in the fishery, considering catch-restrictive regulations adopted by the EU Fishing policy in 2013 (EU 1380/2013, Article 15 introducing the Landing Obligation), and changes in the environment, exploited populations and fishing conditions. For example, there is great concern in the German fishing industry about the increasing density of seaweed and bryozoans encountered by the beam trawl when fishing in coastal areas, particularly during the summer season. The presence of relative low concentration of suspended seaweed can lead to a considerable clogging of the meshes of the sieve-net, resulting in a loss of its sorting efficiency (and hence significant amount of commercial catch) and likely to an increase in fuel consumption due to increased drag during towing, thus affecting the economic viability of the fishery. Therefore, it has been identified a need to further develop the current BRDs, or to identify new concepts in the beam trawl fishery targeting brown shrimp. Under this situation, the optimization of the technologies already in place and/or the design of new technologies should be guided by the following premises:

- Better catch separation with a particular emphasis on reducing the catchability of juvenile fish
- Consistent performance from a spatio-temporal perspective
- Reduced probability of clogging due to the presence of benthic and/or suspended organisms
- Reduced size, ease of handling and accessibility compared to sieve-nets

In the brown shrimp fishery, the bycatch of quoted species such as, for example, plaice and whiting is common. Since 2019, the fishery has been granted with annual exemption (de *minimis*) to the Landing Obligation for quoted species. Because the fishery do not hold quotas for plaice and whiting, phasing out the current Landing Obligation exemptions would likely pose a problem, e.g. limiting or ending normal fishing activities of brown shrimp fishery. From the fishery point of view, it is relevant to further improve the sorting efficiency of the current BRD applied, while reducing the practical issues identified.

2 Material and Methods

2.1 Description of the tested bycatch-reduction devices (BRD)

This cruise conducted experimental fishing trials testing three BRD concepts that have been identified as potential alternatives to sieve-nets. In particular, the performance of two different sorting grid designs, developed during the DISCRAN project (Van Marlen *et al.*, 2001), and the letterbox developed in the Netherlands(Steenbergen *et al.*, 2011) were tested. The performance of a standard sieve-net was also tested during the cruise for comparison with the other devices, on the same fishing grounds, population structures and fishing conditions. To find the optimal working configuration of each of the tested BRDs, different specifications (specs) were tested. The different devices and specs are described below. For each device, a systematic gear-ID will be used throughout the document, introduced in the caption of each following section.

The Letterbox (id: Letterbox_60mm)

The letterbox (Figure 1) consists of an outlet positioned in the rearmost tapered section of the bottom sheet of the trawl. To direct fish species to the outlet, a long, v-shaped square-mesh panel is used. The panel had a height of 14 meshes turned 45 degrees to achieve a square-mesh configuration. The nominal stretched inner mesh size was 60 mm (30 mm half mesh). The bottom row of meshes of the panel is attached to the bottom sheet of the trawl. In order to hang the letterbox panel in a vertical position, a PA rope running through the top row of panel meshes is used (Figure 2). Furthermore, the vertical inclination of the panel can be manually adjusted by changing the length of the hanging rope (by shortening or elongating it). Therefore, the specs of the letterbox tested during the cruise were uniquely defined by the length of the hanging rope. The letterbox-panel wings run backwards converging around the outlet (Figure 1). The tested letter box was build by a Dutch netmaker based on the configuration used in Dutch fishery.

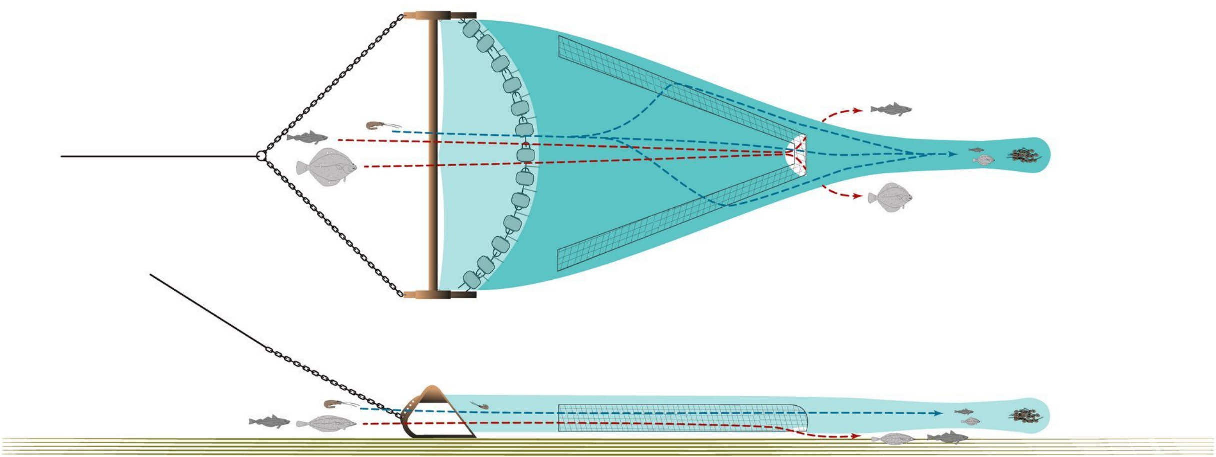

Figure 1: Top and lateral perspective of a beam trawl mounting the Letterbox_60mm. Red and blue arrows show the intended paths for respectively the targeted shrimp and bycatch fish species. Shrimp contacting the letterbox panel should be able to pass through the meshes towards the codend. On the other hand, fish species should be guided towards the outlet (Illustration: A. Schütz).

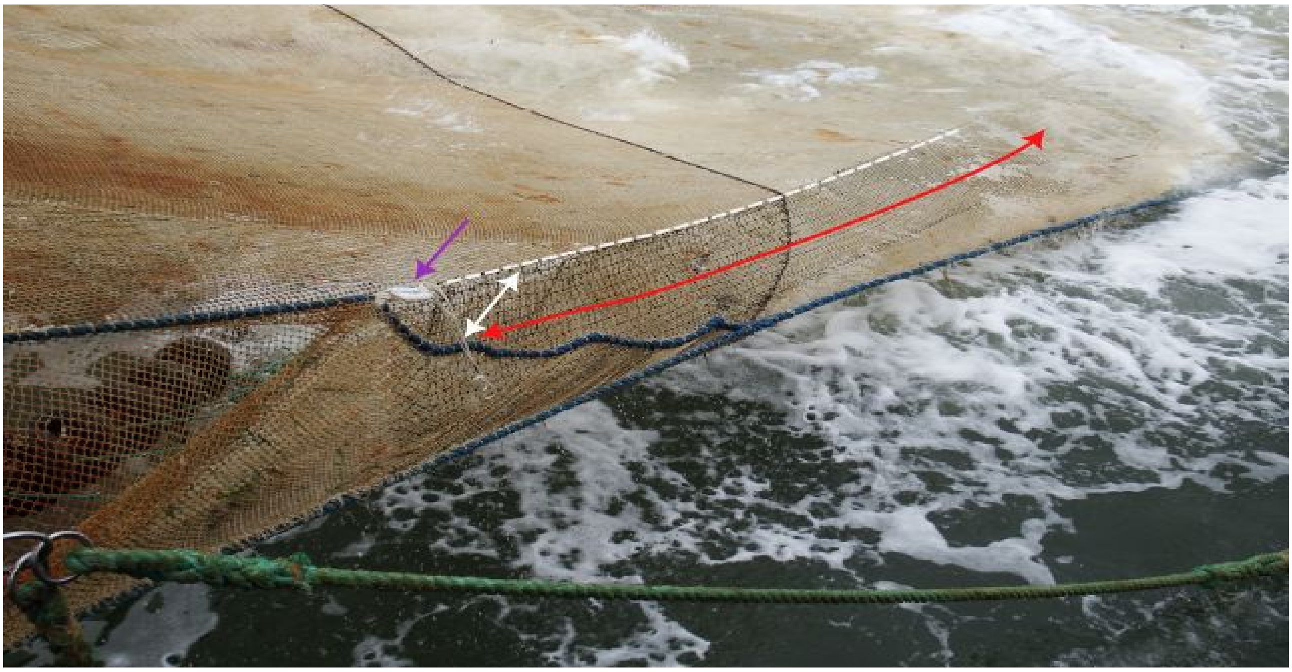

Figure 2: Port-side wing of the letterbox panel (red arrow) and the attachment point to the front section of the trawl (purple arrow). The inclination of the panel can be controlled at the attachment point by adjusting the length of the hanging rope (white arrow) which runs across the upper free meshes of the letterbox panel (dashed white line) .

***E**lliptical steel **G**rid (id: **EG**_60x40_24mm)*

This is the main grid design tested in the German fisheries during the former DISCRAN project (Figure 3). The grid is inserted in a steel structure designed to keep a stable angle of attack (~45°) during fishing. The bar spacing tested during the trials was ~24 mm in average. According to results obtained in the DISCRAN project, this bar spacing would offer the best compromise between bycatch reduction and catchability of shrimp in German fisheries. This grid was kindly provided by Dirk Sander, a fisher with long experience in the fishery who participated in DISCRAN-related commercial sea trials. Dirk also joined the current cruise, providing advice on how to mount and rig the grid to the trawl. The grid was mounted in a two-panel tunnel section (two selvedges) made of PA netting with a nominal mesh opening of 20 mm (~10 mm half mesh, Figure 4). The tunnel was 98 meshes long and had 300 meshes in circumference, being mounted as connection between the trawl body and the codend. Further details of the tunnel section can be found in Figure AI-1 of Annex I. The rigging of the EG_60x40_24mm was subjected to five different specifications, mostly related to attempts to compensate for the weight added by the grid system (5 kg), and to reach the intended 45° inclination of the grid (considered the optimal inclination of shrimp grids, according to Isaksen et al (1992)). This was done by trying different combinations of floats (each with a lifting force of 780gr) to the laterals and/or upper side of the steel frame in which the grid is housed. The effect of the different flotation specs on the vertical position of the grid relative to the longitudinal and vertical axis of the trawl was recorded using DST-tilt sensors. Two sensors were attached to respectively lateral and bottom structural bars of the grid housing. Additionally, a “guiding curtain” made of PVC ropes with lead (3.2 Kg / 100m) was developed onboard and applied with the aim of increasing the probability of shrimp contacting the lower part of the grid, which should increase the probability of passing through the bar spacings towards the codend (Figure 5).

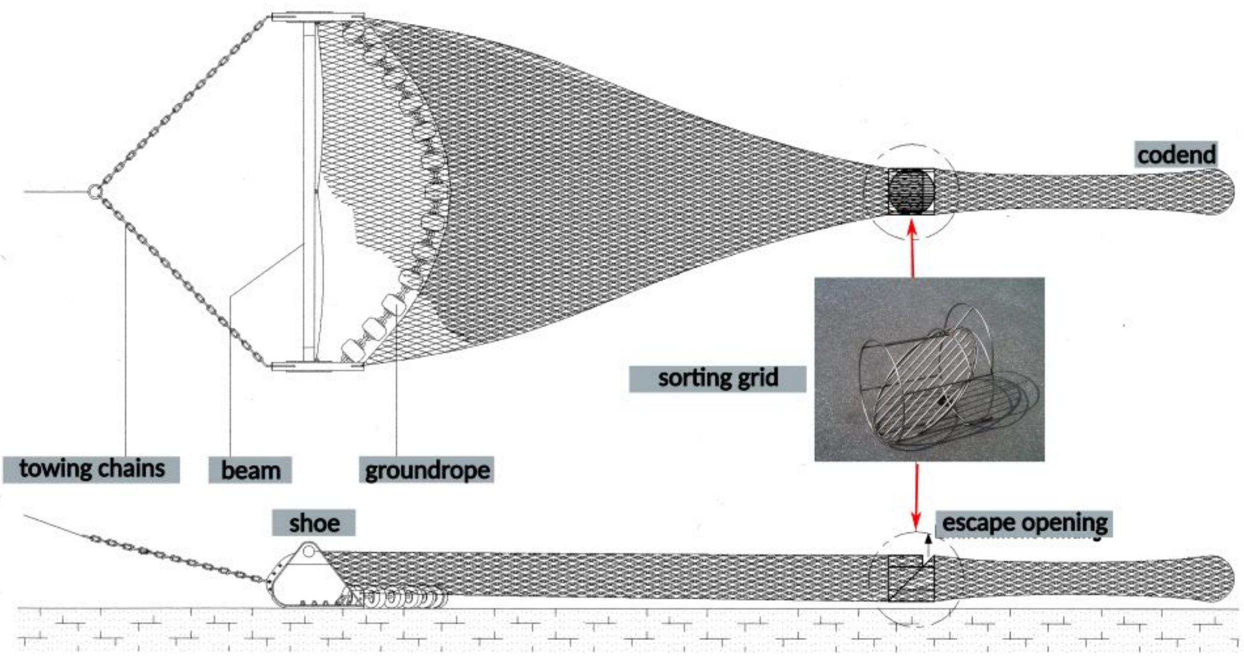

Figure 3: Top and lateral perspective of a beam trawl mounting the elliptical grid. (Illustration: W. Rehme).

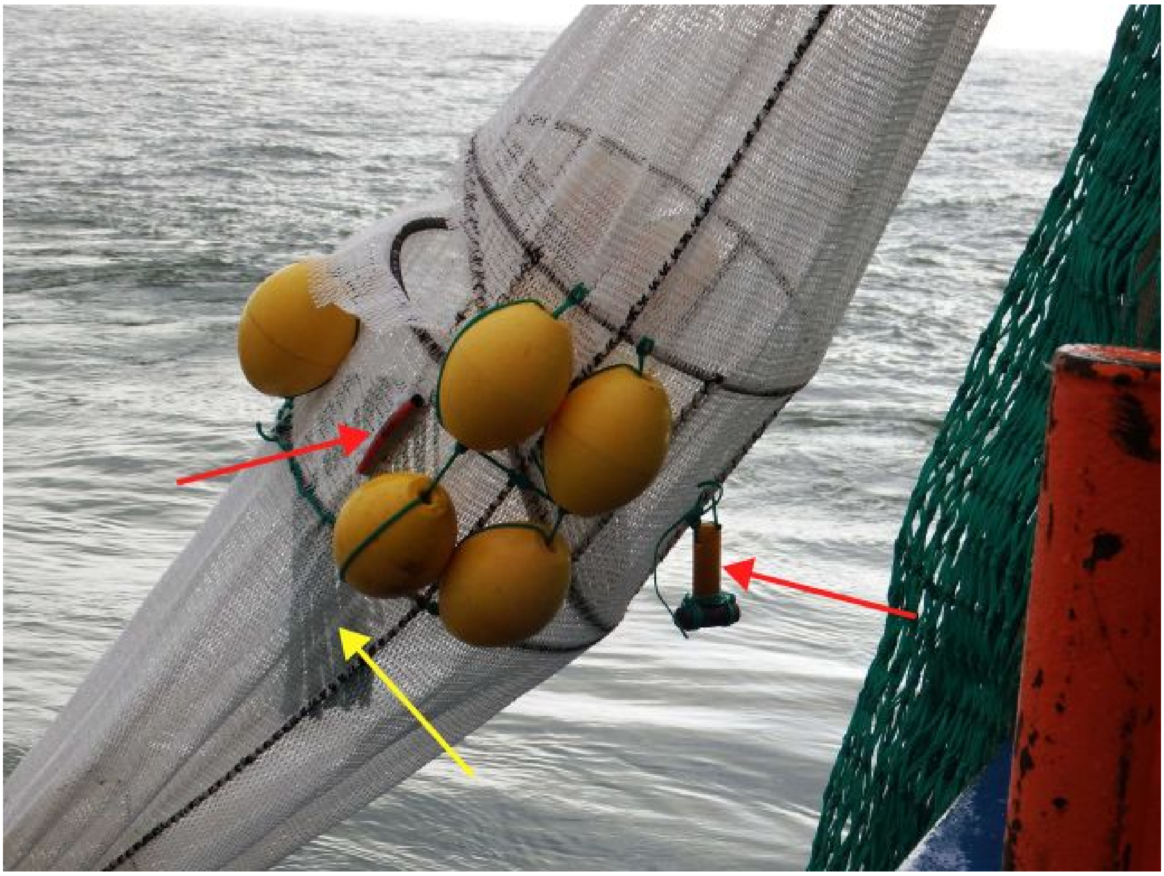

Figure 4: View of the net tunnel with the elliptical grid (EG_60x40_24mm) and its housing frame. Yellow arrow points to the "guiding curtain" made of PVC ropes with lead, designed and tested in one of the grid specs considered. Red arrows point to the sensors used to monitor the movement, orientation and bottom contact of the grid during towing.

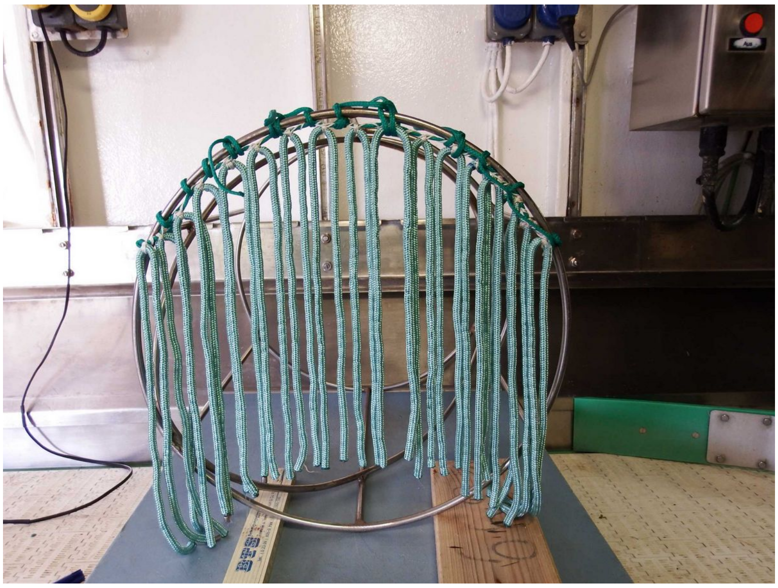

Figure 5: Front view of the "guiding curtain", built on the upper side of the housing of the EG_60x40_24mm grid. The guiding curtain aimed at increasing the probability of shrimp contacting the grid.

***R**ectangular steel **G**rids: (id: RG_60x40_24mm and RG_80x60_24mm)*

Two rectangular steel grids in different sizes were brought onboard for testing. Rectangular grids are often mounted in the net without a housing structure (which implies a reduction in weight, Figure 6), and its design aims at maximizing the sorting surface at the sides of the grid. The dimensions of the smaller rectangular grid was 60 x 40 cm (height x width), similar in size to the elliptical grid. Measuring 80 x 60 cm, the larger grid doubled the selective area of the smaller grid (Figure 7). However, due to time constraints, the larger 80x60 cm rectangular grid could not be tested during the current cruise. It is planned to test this grid design in March-April 2023 (cruises SO819-820). The RG_60x40_24mm was mounted in a net tunnel consisting of three differentiated sections: front, middle and rear sections. The middle section was a four panel (four selvedge) section. The front and rear sections were designed as adapters to facilitate the connection of the four-selvedge middle section to the two-selvedge trawl body and codend, respectively. This tunnel section was made of the same netting material as the two-panel tunnel described above. The total length of the tunnel was 98 meshes and the circumference was 298 meshes. The sides of the middle section were 77 meshes high and the top and bottom panels were 73 meshes wide. Further details of the tunnel section can be found in Figure AI-2 of Annex I. The RG_60x40_24mm grid was mounted in the middle section of the tunnel, in such a way that the attachment of each of the corners of the grid to each of the selvedges of the tunnel should provide stability to the positioning and inclination of the device during towing. In accordance to Graham et al. (2003) attempts to control the inclination of the grid were made by adding flotation at its upper corners . A second strategy to control the inclination was to attach PA lastridge ropes from the upper corners of the grid, to the join of the selvedges from the trawl and the forward tunnel adapter. The specifications of the RG_60x40_24mm tested during the cruise were therefore determined by the combination of floats, the use of lastridge ropes, and their length.

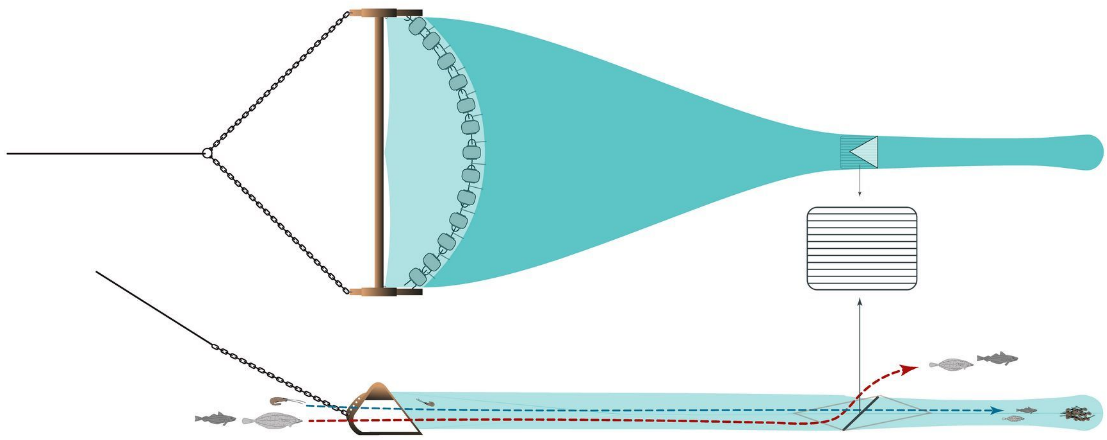

Figure 6: Top and side view of a beam trawl mounting a rectangular grid. The red and blue arrows indicate the intended paths for by-catch species and the targeted shrimp, respectively. Shrimps should make an effective contact with the grid to allow them to pass towards the codend. On the other hand, fish should be released through the exit opening in front of the grid, either because they did not effectively contact the grid, or because they were not able to pass through (because of their size) after contacting it (Figure: A. Schütz).

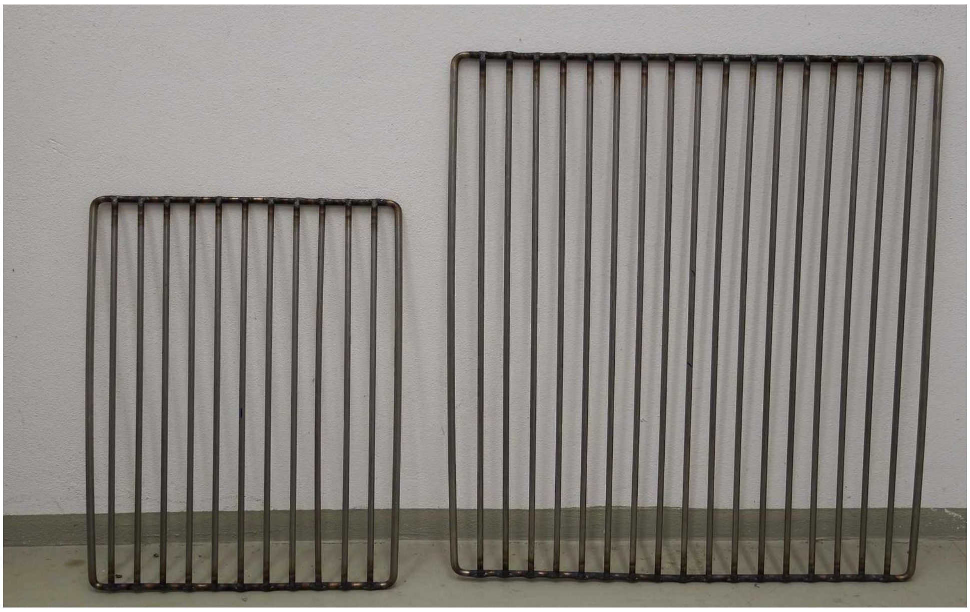

Figure 7: Left: 60x40 cm rectangular grid with 24 mm bar spacing (RG_60x40_24mm) tested during the cruise. Right: 80x60 cm rectangular grid with 24 mm bar spacing (RG_80x60_24mm) taken onboard, but not tested due to time constrains.

Sieve-net (id: Sievenet_60mm)

The last BRD tested is the widely used sieve-net, tested in the current cruise as a performance baseline for comparison with the previously described BRDs. The design tested is considered to be representative of those applied in German commercial fisheries. It was made of 2 diamond-mesh net panels, and a nominal mesh opening of 60 mm (30 mm half mesh). A technical drawing of the sieve-net as used during the trials can be found in Figure A2-1 of Annex II.

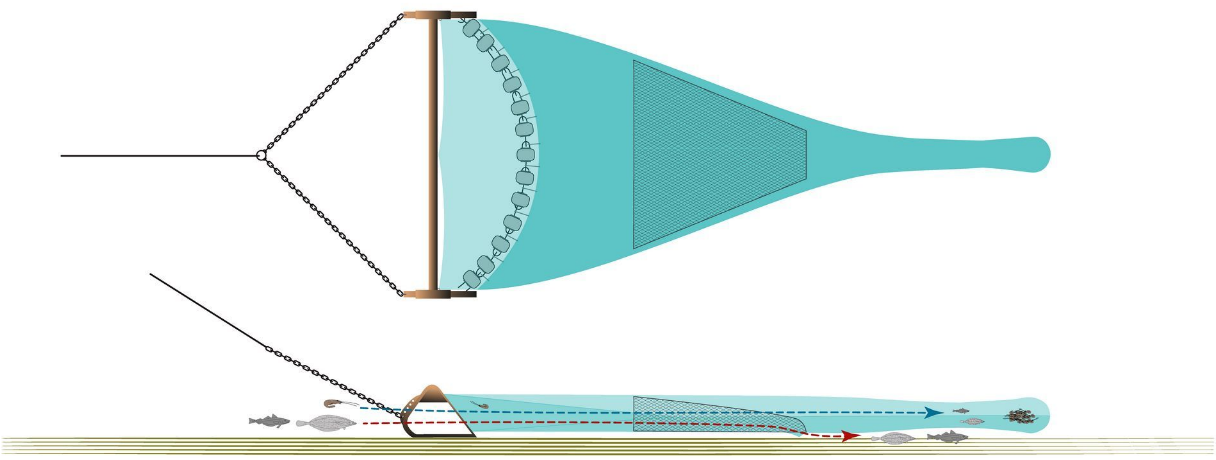

Figure 8: Top and lateral perspective of a beam trawl mounting a standard sieve net. Red and blue arrows show the intended paths for respectively bycatch fish species and targeted shrimp (Illustration: A. Schütz).

2.2 Experimental design and data collection

To assess the selectivity characteristics and catch patterns of the tested BRDs, we adapted and applied an experimental design known as the paired-gear method (Millar and Walsh, 1992; Wileman *et al.*, 1996). The experiment involved fishing with twin trawls of the same design, rigging setup and, according to previous experiences, equal nominal fishing power (Santos *et al.*, 2018). The sorting performance of each of the BRDs described above is evaluated one at a time by comparing the differences in catch from one of the trawls mounting the BRD under examination (test gear) and the catch from the twin trawl fishing without any BRD (control gear, Figure 9). Overall two pairs of trawls were used. The first pair, used here to test the Letterbox_60mm, were the old RV/Solea "Büsum" trawls. The second pair was used to test the sorting grids and the sieve-net. The later pair of trawls was built in 2019 for experimental trials during the DRopS project, therefore this pair is hereafter referred as the "DRopS" Trawls. Both pairs of trawls are equivalent in design (See Figure A2-1 in Annex II for further technical details). The catches in the test and control trawls were collected in codends of the same design, material and mesh size (nominal mesh opening ~ 20 mm, 10 mm half mesh). It has been previously shown that codends with a 20

mm mesh opening provides very limited escape possibilities for the targeted shrimp, while escapees of fish species are negligible. Thus, it can be safely assumed that the only escape possibility available to the fish entering any of the two trawls is the BRD mounted in the test trawl. This is also the case for brown shrimps in the range of sizes of interest in this study. Under the assumption that the catches of the control trawl represent well the populations and populations structures available in the fishing grounds, the catch comparison between both trawls is used here as an indirect way of assessing the selective properties of the tested BRD (i.e. without directly observing the individuals of the species evaluated that have actually escaped from capture in the test trawl). Experimental fishing trials were carried out one at a time for each device. In an initial stage, different specifications (specs) of the device in use were defined and tested for a small number of hauls. The best spec found during the initial stage was selected for further testing.
To avoid potential side effects, the mounting side of the test and control gear was swapped after some hauls – if possible.

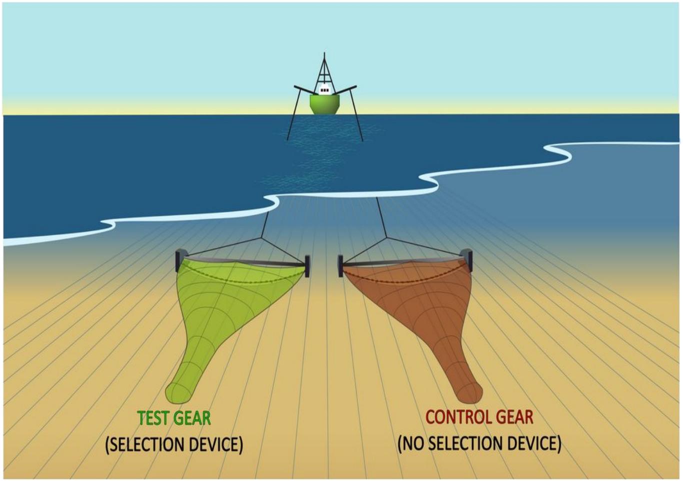

Figure 9: The paired-gear method applied involves two trawls fishing simultaneously and in parallel. This setup allows comparing catches of the trawl mounting the BRD (test) and catches of the trawl with no BRD installed (control) under the same fishing conditions and populations availability.

Catch sampling was carried out at haul level and independently for each codend (from the test and control gears) using the following procedure:

(1) The total catch from the test and control codends were collected separately using baskets provided by the vessel. Each basket, containing the unsorted catches, was weighted one by one at the vessel's scale. The total weight was recorded as the total catch in the sampled codend. The total catch in the test trawl was labeled as **Lot 10**, while the total catch in the control was labeled as **Lot 20**. In case of large catch volumes, a sample of the total catch weighting ~ 40 kg was randomly taken from the total. To facilitate the description of the following sampling steps, subsequent codification related to the test gear is used.

(2) The total catch (or sample of the total catch) was sorted into two fractions:

1. **Lot 11** Containing the targeted shrimp, other invertebrates, and fish species not considered to be of primary relevance for the objectives of the current study.

2. **Lot 12** Containing bycatch fish species considered relevant to the study (quoted species such as withing, plaice, flounder and dab).

Two different sampling schemes were applied to **Lot 11** and **Lot 12:**

(3) **Lot 11:** A sub-sample between 5 and 10 kg was taken at random from the total of the Lot. The collected sub-sample was sorted by species. Depending on the species in the sub-sample, one out of the three different sampling procedures was applied:

1. **brown shrimp:** The total weight of the subsample was recorded, followed by the collection of a sub-sub-sample of the species (~ 0.5 Kg). The sub-sub-sample was weighted and frozen for later length-measurements in the lab at the Thünen Institute of Baltic Sea Fisheries. Once in the lab, the sub-sub-sample was thawed and placed on a plate to be photographed (~40 individuals at a time). The total length of each individual was obtained by a digital image-analysis procedure combining digital scanning, and a computer-based routine developed at the Thünen Institute of Baltic Sea Fisheries for brown shrimp measurements. Total lengths were rounded down to the nearest half millimeter, providing counts of the number of shrimp per length class. A power analysis simulation conducted with previously collected data of the same data suggested a sampled size of 200 individuals per codend would provide a good trade-off between sampling effort and statistical precision. Therefore, the aim was to measure n=200 individuals per haul and gear. The weight of all measured individuals was obtained using a precision scale, and used later to estimate the global sampling ratio.

2. **other invertebrates:** The weight of the non-targeted invertebrate species in the subsample was recorded and the individuals counted.

3. **fish species:** The weight of the fish species in the subsample was collected, and the individuals length measured (total length, half-centimeter precision).

(4) **Lot 12:** The entire catch of this Lot was sorted by species. The weight of each species' sample and individual length measurements (total length, half-centimeter precision) were collected by species.

The sampling data processed onboard was collected using electronic measuring boards Scantrol, model FM50. A diagram of the sampling procedure can be found in Figure 10.

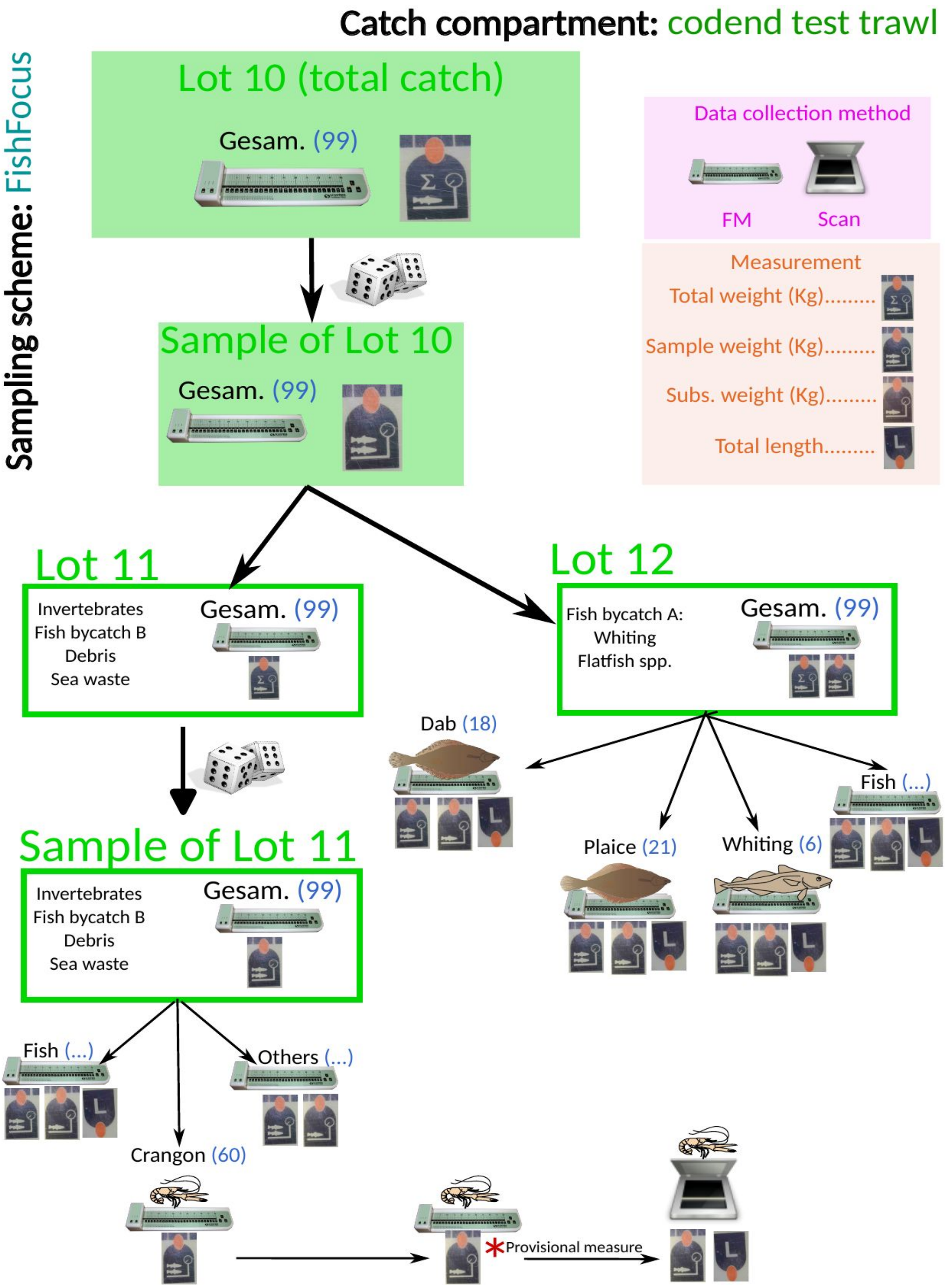

Figure 10: Flowchart describing the sampling procedure adopted during the cruise, and how the different sampling strata were gathered in the electronic measuring boards used during the sampling (Scantrol FM50). The example corresponds to samples from the test trawl. Samples from the control trawl were identified using numerical codes in the second ten (Lots 20, 21 and 22).

3 Cruise development and preliminary analysis

The sea trials took place between the 14 and 28 of September 2022, mostly in fishing grounds off the coast of Cuxhaven (*Luechter Grund*) and at fishing depths between ~10 m and ~20 m. The first BRD tested was the Letterbox (Letterbox_60mm), followed by the elliptical grid (EG_60x40_24mm), the small rectangular grid (RG_60x40_24mm), and finally the standard sieve-net (Sievenet_60mm). As previously noted, the large rectangular grid (RG_80x60_24mm) was not tested in this cruise due to time constrains. The configurations tested for each BRD, and associated catches results, are described below.

3.1 Trials with the letterbox (Letterbox_60mm)

The day before the trials, the trawl was spread out on the pier to visually inspect the constructive characteristics of the Letterbox_60mm and to better understand its functional concept. The Letterbox_60mm trawl was mounted to the starboard side of the vessel, while the other trawl with no BRD installed (control trawl) was mounted to the port side. Overall 9 hauls using the Letterbox_60mm in three different specs (Table 1) were successfully conducted during the two first days of the cruise (14 and 15 of September). The first spec tested was the "as-built" (Spec0), with no shortening applied to the hanging rope. Therefore, in Spec0, the length of the hanging rope was equivalent to the length of the letterbox panel at its joining to the bottom sheet of the trawl. During deployment of the first haul, It was observed that the letterbox panel was too loose and flapping backward (and hence having limiting sorting capabilities), which clearly indicated a need for shortening the hanging rope in order to raise and stabilize the panel. The first attempt considered a shortening of 2 m (1 m per side). However, by deploying the trawl in the water, it was clear that the 1-m shortening would transmit excessive tension to the lower sheet of the trawl, which might potentially lead to structural issues in the last tapered section where the letterbox outlet was defined. Based on that visual observation, a Spec1 was defined by shortening the hanging rope by 0.6 m (0.3 m per side). The visual observation of the letterbox Spec1 revealed a more tensioned and stable panel compared to the "as build" Spec0. Therefore, Spec1 was tested in the following experimental hauls (hauls 2 to 4). While the volume of the total catches in the test and control trawls were visually comparable during hauls 2 to 4, the question whether the shortening of the hanging rope by 0.6 m would be optimal led to a Spec2, in which a further shortening of the hanging rope was applied (overall 1 m, 0.5 m per side, 0.4 m shorter than Spec1). As no clear performance improvement was observed after two hauls using Spec 2 (hauls 5 and 6), it was decided to return to Spec1 for the remaining hauls (hauls 7 to 9). Catches were dominated by the targeted shrimp (Table 2), with an average total catch (test and control catches combined) of 46.6 kg/haul (13.1-115.4 kg/haul), followed by swimming crabs (*Portunidae spp*., 8.1 kg/haul (3.6-22.9 kg/haul)) and a mixed component of benthos species, involving non-targeted invertebrate species, sea-grass and debris (hereafter referred as "mix", 5.4 kg/haul (1.6-12.3 kg/haul)). Plaice was the most relevant species in terms of biomass caught among the TAC fish species (2.2 kg/haul (0.8-3.7 kg/haul),Table 4). The catch of other species of interest such as dab, flounder and whiting weighted in average below 0.5 kg/haul.

Table 1: List of Letterbox_60mm specs tested during the cruise, with a brief description of the modification applied to each.

Spec	Modification
Spec0	no shortening of hanging rope
Spec1	0.6 m hanging rope shortening
Spec2	1.0 m hanging rope shortening

Table 2: List of hauls conducted using the Letterbox_60mm as test trawl, and total catches (test and control combined) from the most relevant species in catches. side: side of the vessel where the test trawl was mounted.

haul	spec	date	side	Shrimp	Plaice	Flounder	Dab	Whiting	Crabs	Mix
1	0	20220914	starboard	38.09	3.74	0.10	0.01	0.15	3.61	2.40
2	1	20220914	starboard	38.06	1.62	0.22	0.00	0.23	4.19	5.44
3	1	20220914	starboard	24.02	0.84	0.00	0.00	0.07	6.07	4.43
4	1	20220914	starboard	25.55	1.36	0.00	0.00	0.31	3.76	1.58
5	2	20220914	starboard	115.35	2.56	0.30	0.46	1.09	22.95	12.28
6	2	20220915	starboard	53.15	2.70	0.00	0.18	0.26	0.00	8.85
7	1	20220915	starboard	53.06	3.47	0.09	0.07	0.18	0.00	7.72
8	1	20220915	starboard	13.08	1.37	0.00	0.02	0.03	0.00	2.30
9	1	20220915	starboard	58.64	1.72	0.95	0.02	0.13	0.00	3.67

As mentioned above, the catches obtained during the trials with the Letterbox_60mm were dominated by the targeted shrimp, with a total of 419 kg caught by the two trawls combined across the nine hauls conducted, of which 42.1% was caught in the test trawl, and 57.9% was caught in the control trawl (Figure 11). Plaice was the most important quoted fish species in catches (19 kg in total), of which 35% was caught in the test trawl, suggesting a catch reduction due to the letterbox effect. In terms of biomass, the catches of whiting, flounder or dab were very low (less than 2 kg in total). The mixed catch and swimming crabs (*Fam. Portunidae*), were the second and third most important catch components in terms of biomass, with catches across hauls summing 48 kg and 40 kg, respectively. Lower catches of unwanted invertebrates and sea-grass were found in the test trawl (35% of the total). Using the Letterbox_60mm in its “as built” spec (Spec0) led to the lowest catches in the test trawl of targeted shrimps, the “mix”, and swimming crabs, if compared to catches of the same species obtained in the control trawl (Figure 11). However, no conclusions can be drawn from this result, as only one haul with Spec0 was conducted. In terms of catch share among test and control trawls, Spec1 and Spec2 seemed to work similarly (Figure 11).

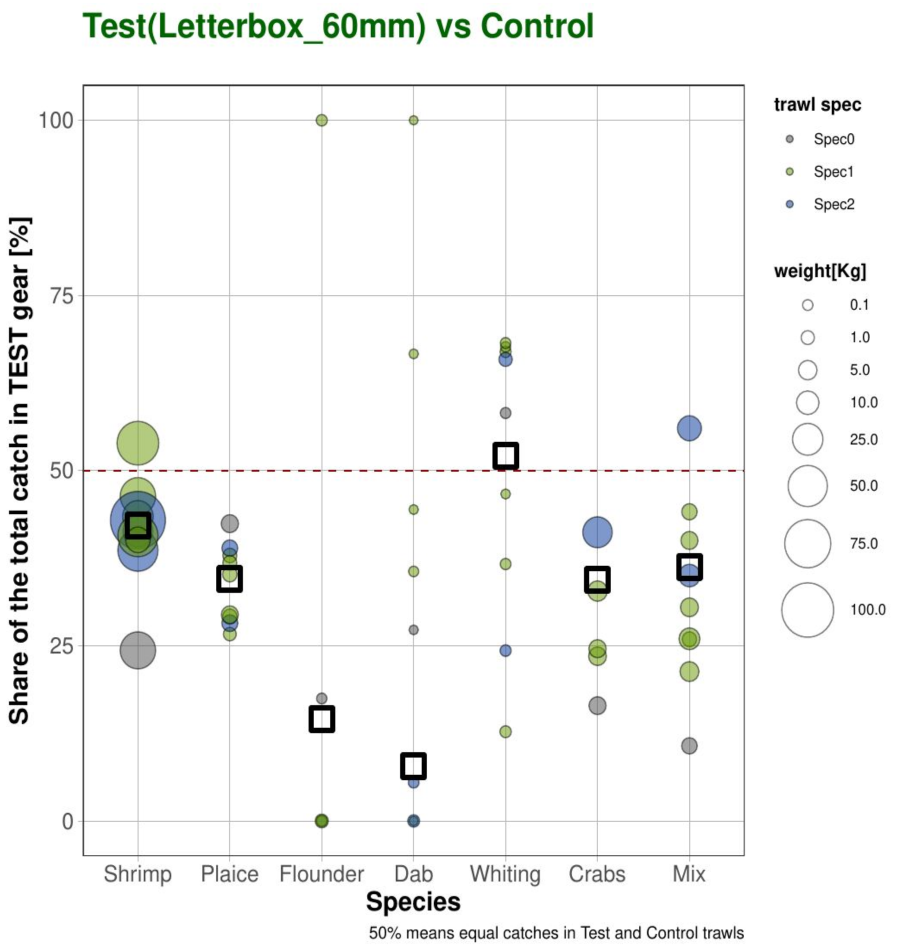

Figure 11: Catch proportions in test (Letterbox_60mm) and control trawls. Round marks show the catch share by species at haul level. The size and color of the round marks represent respectively the total catch (kg) and the spec of the test gear used. Square marks represent the average catch proportion computed using the catch data pooled across hauls. A value of 50% means equal catches in test and control gear.

4.1.2 Trials with the elliptical steel grid (EG_60x40_24mm)

Adverse weather conditions at sea forced a four-days pause in the experimental program (from 16 to 19 September), a time used to replace the "Büsum" trawls that were used for the trials with the Letterbox_60mm trials, by the pair of "DRopS"trawls to be used for the remaining experiments. It was decided to resume the cruise by starting the trials with the housed-elliptical grid (EG_60x40_24mm). The test trawl mounting the EG_60x40_24mm grid was mounted on starboard, while the control was mounted ion port-side. Altogether, 11 hauls were conducted during the two first days after resuming the cruise (20 and 21 of September), in which a total of five different specs were tested (Table 3). The first spec tested included the guiding curtain and a combination of 9 floats positioned at different zones on the grid housing structure. This spec was slightly updated during the first day of trials until the Spec4 was defined (Table 3), fishing operations and maneuvers with the test and control trawls were equivalent during this first day of tests. However, relative large catch accumulations were observed in front of the grid during the second day, especially in hauls 17 and 18. Those catch accumulations were associated to a sudden increase of sea-grass availability in the fishing grounds, leading to clear accumulation of catch in front of the grid and a blockage of the rigid outlet above it. During the haul-back of the test trawl, the catch accumulated at the trawl belly and had to be removed by time-consuming maneuvers. In an attempt to avoid blockage events, it was decided to return to the “as built” specification (Spec0, Table 3), by removing the floats and the guiding curtain from the grid system. Although less blockage events were observed for the two hauls conducted with Spec0, it was speculated that such improved situation could be a consequence of a reduced availability of sea-grass than improvements brought by the simplification of the device’s spec. Consequently, it was decided to finalize the trials with the EG_60x40_24mm grid after concluding the second day of trials. Catches during testing of the EG_60x40_24mm were again dominated by the targeted species, with an average total catch (test and control catches combined) of 37.2 kg/haul (11.6-67.1 kg/haul, Table 4), followed by swimming crabs (12.9 kg/haul (1.6-73 kg/haul)) and the mix catch component (3.1 kg/haul (0.7-11.6 kg/haul)). The catches of primary bycatch species (plaice, whiting, flounder and dab) remained low in term of biomass, and comparable to catches obtained in the previous experiment Table 4.

Table 3: List of EG_60x40_24mm grid specs tested during the cruise, with a brief description of the modification applied to each.

Spec	Modification
Spec0	as built
Spec1	Spec0 + Guiding curtain
Spec2	Spec1 + 9 x floats, 780gr lifting force each
Spec3	Spec1 + 11 x floats, 780gr lifting force each
Spec4	Spec1 + 10 x float, 780gr lifting force each

Table 4: List of hauls conducted using the EG_60x40_24mm in test trawl, and total catches (test and control combined) from the most relevant species in catches. side: side of the vessel where the test trawl was mounted.

haul	spec	date	side	Shrimp	Plaice	Flounder	Dab	Whiting	Crabs	Mix
10	2	20220920	starboard	67.07	2.74	0.00	0.33	1.23	17.86	0.67
11	3	20220920	starboard	13.90	0.48	0.05	0.28	0.07	8.48	1.74
12	4	20220920	starboard	11.62	0.19	0.22	0.00	0.01	1.56	3.96
13	4	20220920	starboard	33.22	0.71	0.14	0.15	0.18	2.28	0.74
14	4	20220920	starboard	57.90	1.64	0.10	0.53	1.12	10.72	1.57
15	1	20220920	starboard	40.64	1.65	0.06	0.92	1.24	5.58	2.09
16	4	20220921	starboard	11.91	0.27	0.00	0.00	0.10	5.88	4.38
17	4	20220921	starboard	50.70	3.04	0.00	0.69	0.60	72.97	11.64
18	4	20220921	starboard	17.41	0.73	0.00	0.50	0.23	4.43	2.52
19	0	20220921	starboard	47.14	1.89	0.00	0.36	0.23	6.50	1.46
20	0	20220921	starboard	58.06	1.56	0.00	0.42	0.13	6.04	3.09

The catch comparison among test and control gear reveals lower catches in the test trawl mounting the EG_60x40_24mm grid (Figure 12). A total of 409 kg shrimp was caught by the two trawls combined, of which 38.3% was caught in the test trawl, a slightly lower catch proportion if compared to the percentage of shrimp catches in the test trawl obtained in the previous experiment using the Letterbox_60mm (42.1% in of shrimp biomass in test trawl). Such lower catch proportion in the test gear was attributed to blockage events occurred mostly in hauls 17 and 18. Catch proportions of plaice, flounder and dab in the test trawl were lower than catches in the control trawl (respectively 32.7%, 17.2% and 6.2%), suggesting a catch reduction for those flatfish species that is equivalent to the reduction obtained with the Letterbox_60mm trawl. In contrast, a lower proportion of withing (biomass) was observed in the test trawl if compared to the trials with the Letterbox_60mm (33.4% vs 52.1%), suggesting that using the EG_60x40_24mm grid is more efficient in reducing the bycatch of whiting than the Letterbox_60mm. In average, only 25% of the total catches of benthos mix and swimming crabs were caught in the test trawl. Due to the limited number of hauls conducted, the current dataset does not allow deep comparisons between the tested specs. However, the relative low differences between tilt sensor measurements across tested specs, could be also interpreted to a limited effect of the modifications on the working functioning of the grid.

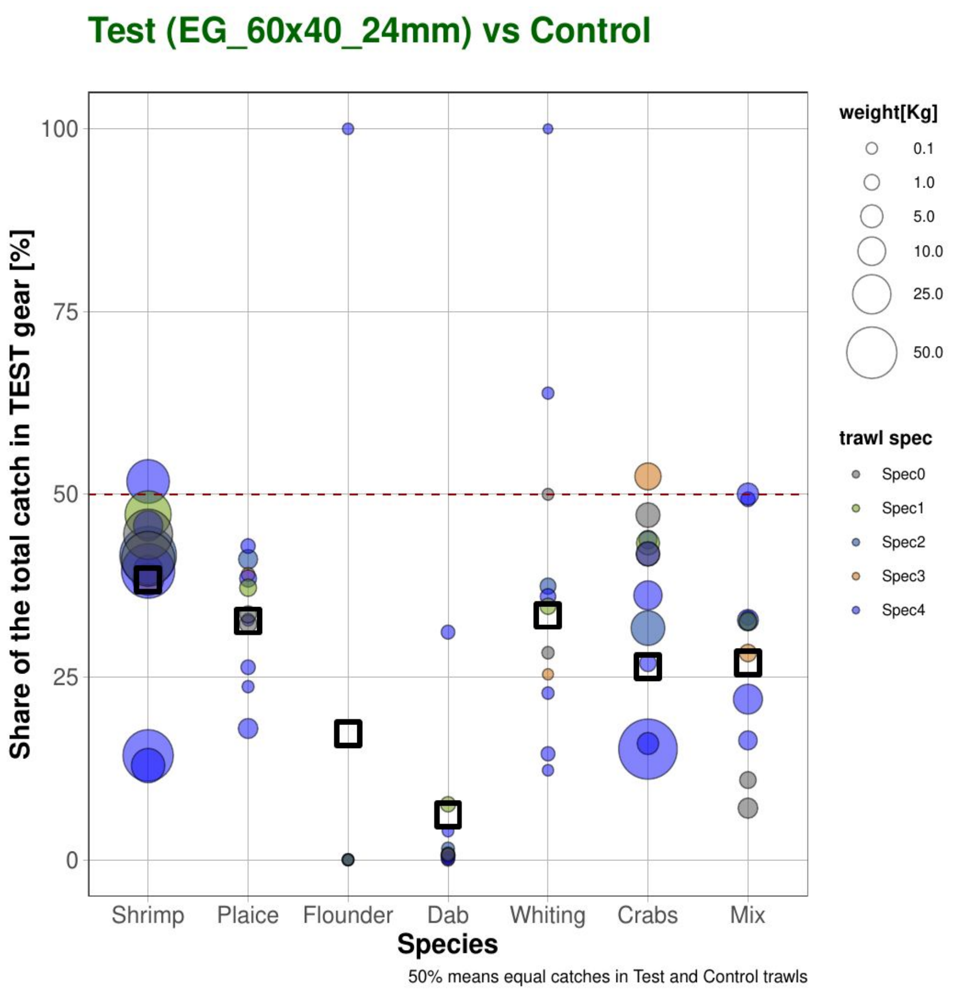

Figure 12: Catch proportions in test (housed elliptical steel grid, EG_60x40_24mm) and control trawls. Round marks show the catch share by species at haul level. The size and color of the round marks represent respectively the total catch (kg) and the Spec of the test gear used. Square marks represent the average catch proportion computed using the catch data pooled across hauls. A value of 50% means equal catches in test and control gear.

4.1.3 Trials with the rectangular steel grid (RG_60x40_24mm)

The 2 selvedge tunnel with the EG_60x40_24mm, mounted in the trawl at the starboard side of the vessel, was replaced by the 2-4-2 seldvedge tunnel mounting the RG_60x40_24mm grid. Overall, 23 hauls were conducted between 22 and 25 of September using the RG_60x40_24mm grid as test. In the first day, four different specs were tested; the “as built” (Spec0), the Spec0 with two floats added to the top corners of the grid (Spec1), Spec0 with lastridge ropes with 5 cm shortening effect (Spec2) and 10 cm shortening effect (Spec3, Table 5). Apparent reduced catches in the test grid during the first two days of trials with the RG_60x40_24mm grid led to a definition of a new modification, which consisted in reducing the opening of the outlet on the top of the tunnel, in front of the grid. The reduced outlet was tested with and without lastridge ropes (Spec4 and Spec 5 respectively, Table 5) during the last two days of trials with this grid. In order to avoid potential side effects that could result in a biased evaluation of the effect of shortening lastridge ropes on grid inclination, hauls using Spec4 and Spec5 were balanced among sides (Table 6). In terms of biomass, catches were dominated by the targeted species, with an average total catch (test and control catches combined) of 62.7 kg/haul (5.6-170 kg/haul), followed by swimming crabs (28.7 kg/haul (1.5-81.2 kg/haul)) and the mix catch component (5.9 kg/haul (1.7-13.4 kg/haul)). The catches of primary bycatch species (plaice, whiting, flounder and dab) remained low (below 2 kg/haul).

Table 5: List of RG_60x40_24mm grid specs tested during the cruise, with a brief description of the modification applied to each.

Spec	Modification
Spec0	as built
Spec1	Spec0 + 2 x floats, 780gr lifting force each
Spec2	Spec0 + lastridge ropes with 5 cm shortening effect
Spec3	Spec0 + lastridge ropes with 10 cm shortening effect
Spec4	Spec0 + Reduced outlet
Spec5	Spec0+ lastridge ropes with 10 cm shortening effect+ Reduced outlet

Table 6: List of hauls conducted using the RG_60x40_24mm in test trawl, and total catches (test and control combined) from the most relevant species in catches. side: side of the vessel where the test trawl was mounted.

haul	spec	date	side	Shrimp	Plaice	Flounder	Dab	Whiting	Crabs	Mix
21	0	20220922	starboard	9.09	0.22	0.00	0.09	0.06	1.47	2.17
22	1	20220922	starboard	39.86	0.94	0.12	0.51	0.20	3.90	2.70
23	2	20220922	starboard	26.95	0.49	0.00	0.83	0.10	5.68	1.74
24	3	20220922	starboard	24.98	0.69	0.00	0.17	0.02	2.86	5.40
25	3	20220922	starboard	17.30	0.65	0.12	0.97	0.15	7.35	5.77
26	3	20220923	starboard	27.77	0.51	0.00	0.49	0.45	3.47	6.23
27	3	20220923	starboard	5.63	0.38	0.00	0.24	0.02	2.92	4.49
28	0	20220923	starboard	12.46	0.20	0.03	0.00	0.11	5.87	4.84
29	0	20220923	starboard	46.34	1.73	0.32	2.01	2.01	13.14	13.44
30	0	20220923	starboard	52.25	1.23	0.00	1.68	0.69	10.26	5.97
31	0	20220923	starboard	169.96	4.25	0.00	2.48	1.41	79.58	5.94
33	4	20220924	starboard	144.13	2.09	0.00	0.66	2.98	33.93	10.68
34	4	20220924	starboard	79.75	0.90	0.20	0.08	3.92	35.10	5.81

35	5	20220924	starboard	113.82	1.96	1.02	0.01	5.91	81.16	12.67
36	5	20220924	starboard	88.06	2.55	0.00	0.98	1.44	49.85	4.07
37	5	20220924	starboard	87.18	1.96	0.00	0.48	2.61	35.10	3.51
38	5	20220925	port-side	73.23	1.06	0.00	1.61	2.25	25.16	2.65
39	5	20220925	port-side	92.85	0.89	0.00	0.27	1.44	41.36	9.14
40	5	20220925	port-side	72.77	0.50	0.17	0.86	0.64	31.30	8.44
41	4	20220925	port-side	44.34	0.53	0.00	0.64	0.99	35.34	3.30
42	4	20220925	port-side	90.20	1.62	0.00	0.42	7.40	75.25	5.35
43	4	20220925	port-side	89.14	1.57	0.00	1.15	3.46	44.63	3.22
44	4	20220925	port-side	35.00	0.49	0.20	0.28	1.59	34.37	8.69

As with the two previously tested BRDs (Letterbox_60mm and EG_60x40_24mm grid), lower catches were obtained in the test trawl mounting the RG_60x40_24mm grid compared to the control trawl. The two trawls combined caught a total of 1443 kg of shrimp in 23 hauls, of which 41.8% was caught in the test trawl, a slightly lower catch proportion if compared to the percentage of shrimp catches in the test trawl obtained when using the Letterbox_60mm (42.1% in of shrimp biomass in test trawl). Catch proportions of plaice, flounder and dab in the test trawl were lower than catches in the control trawl (respectively 24.2%, 3.2% and 11.6%), suggesting a catch reduction for those flatfish species equivalent the reduction obtained with the Letterbox_60mm. In contrast, a lower proportion of whiting biomass was observed in the test trawl, if compared to the trials with the Letterbox_60mm (22.7% vs 52.1%). Swimming crabs and the mixed catch were the second (492 kg) and third (93 kg) most important catch components in terms of mass. In average, 25% and 32% of the total catches of crabs and mixed catch was observed in the test codend. The catch data and the data from the DST-Tilt sensors collected from hauls 33 to 44 (Table 6) will be further analyzed in order to understand the effect of the shortening ropes on grid inclination and sorting efficiency.

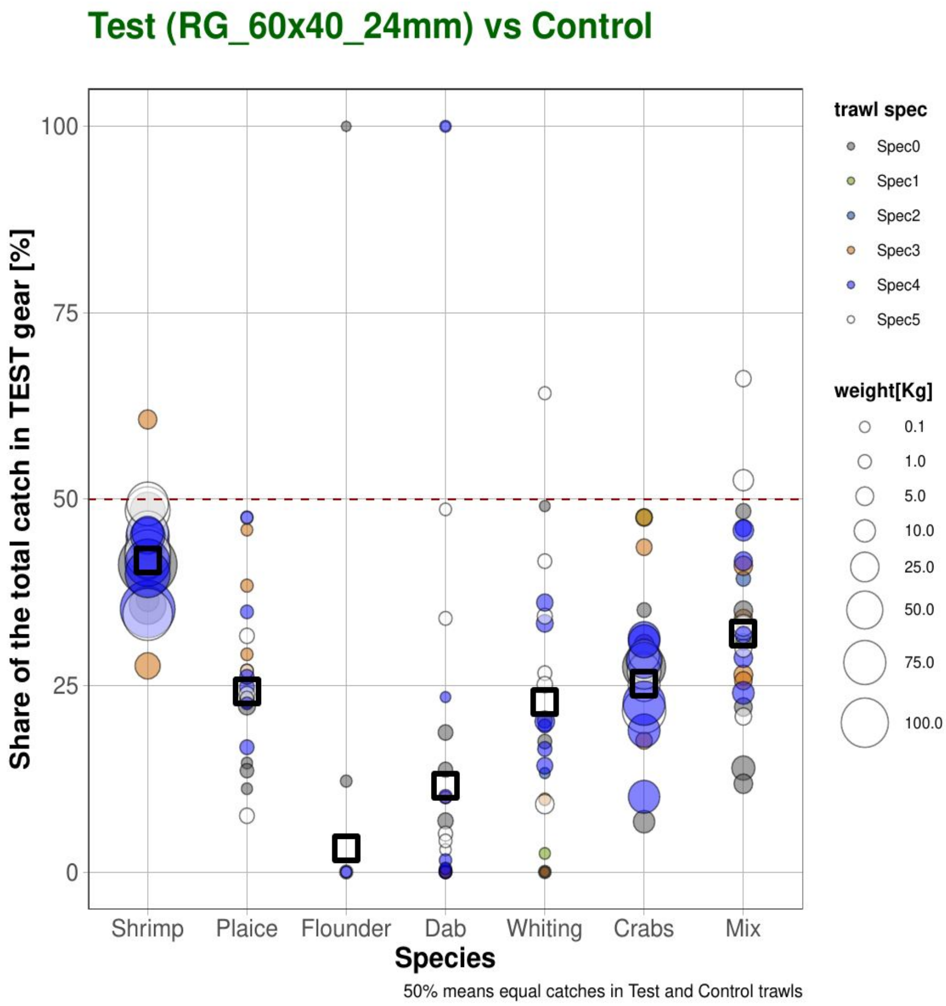

Figure 13: Catch proportions in test (rectangular steel grid, RG_60x40_24mm) and control trawls. Round marks show the catch share by species at haul level. The size and color of the round marks represent respectively the total catch (kg) and the Spec of the test gear used. Square marks represent the average catch proportion computed using the catch data pooled across hauls. A value of 50% means equal catches in test and control gear.

4.1.4 Trials with the sieve-net (Sievenet_60mm)

The last two days of trials were used to test the performance of the standard sieve-net in same fishing conditions and fishing grounds as the other BRDs tested during the cruise. The sieve-net used was built together with the trawl and have previously showed high efficiency, therefore no additional modifications of the “as built” spec was required. Overall, 12 valid hauls were conducted, of which six were conducted with the Sievenet_60mm mounted in the port-side trawl, and the remaining six in the starboard side (Table 7). The two last days of trials were characterized by a lower availability of Crangon 46.3 kg/haul (14.1-78.4 kg/haul), if compared with previous days when the RG_60x40_24mm was tested . Second most relevant species in terms of biomass were swimming crabs (18.8 kg/haul (2.6-59.1 kg/haul). Catches were cleaner of benthos, as it is reflected by a lower biomass of mix catch component caught (2.9 kg/haul (1-6.2 kg/haul)). As in the previous case, the average catches of primary bycatch species (plaice, whiting, flounder and dab) remained low (below 2 kg/haul).

Table 7: List of hauls conducted using the Sievenet_60mm in test trawl, and total catches (test and control combined) from the most relevant species in catches. side: side of the vessel where the test trawl was mounted

haul	spec	date	side	Shrimp	Plaice	Flounder	Dab	Whiting	Crabs	Mix
45	0	20220927	port-side	66.20	1.13	0.00	0.35	1.03	2.57	1.24
46	0	20220927	port-side	55.91	0.93	0.00	1.07	1.08	4.74	2.81
47	0	20220927	port-side	18.74	0.88	0.00	0.20	0.58	2.96	1.04
48	0	20220927	port-side	49.60	1.90	0.18	0.36	1.67	59.13	3.25
49	0	20220927	port-side	40.87	1.46	0.00	0.37	2.41	48.67	4.42
50	0	20220927	port-side	48.43	2.07	0.32	1.24	2.94	45.10	6.20
51	0	20220928	starboard	59.14	0.39	0.00	4.03	0.90	18.14	4.37
52	0	20220928	starboard	78.37	0.40	0.00	1.84	0.45	16.72	3.16
53	0	20220928	starboard	56.86	0.68	0.00	2.00	0.12	7.20	4.21
55	0	20220928	starboard	14.07	1.09	0.00	0.56	0.23	3.45	1.47
56	0	20220928	starboard	37.63	2.32	0.45	0.45	0.91	6.93	1.67
57	0	20220928	starboard	29.51	1.52	0.16	0.67	0.76	9.79	0.98

Of the total shrimp weight caught across hauls, 49.3% was obtained from the test codend and 50.7% in the control codend (Figure 14). Therefore, and in contrast to the other three BRDs tested (Letterbox_60mm, EG_60x40_24mm and RG_60x40_24mm), using the Sievenet_60mm did not lead to a significant reduction of shrimp catches, at least in terms of weight. Catch proportions of plaice, flounder and dab in the test trawl were lower than catches in the control trawl (respectively 20.5%, <0.1 % and 3.0%), being similar to the catch proportions obtained in the test trawl when the RG_60x40_24mm grid or the Letterbox_60mm were used. In contrast, the Sievenet_60mm showed very limited efficiency on avoiding bycatch of whiting in the range of lengths that were available during the fishing trials, as 43.0% of the total catch of this species was found in the test codend. This poor result is comparable to that obtained with the letterbox, which showed no bycatch-reduction effect on whiting bycatch.

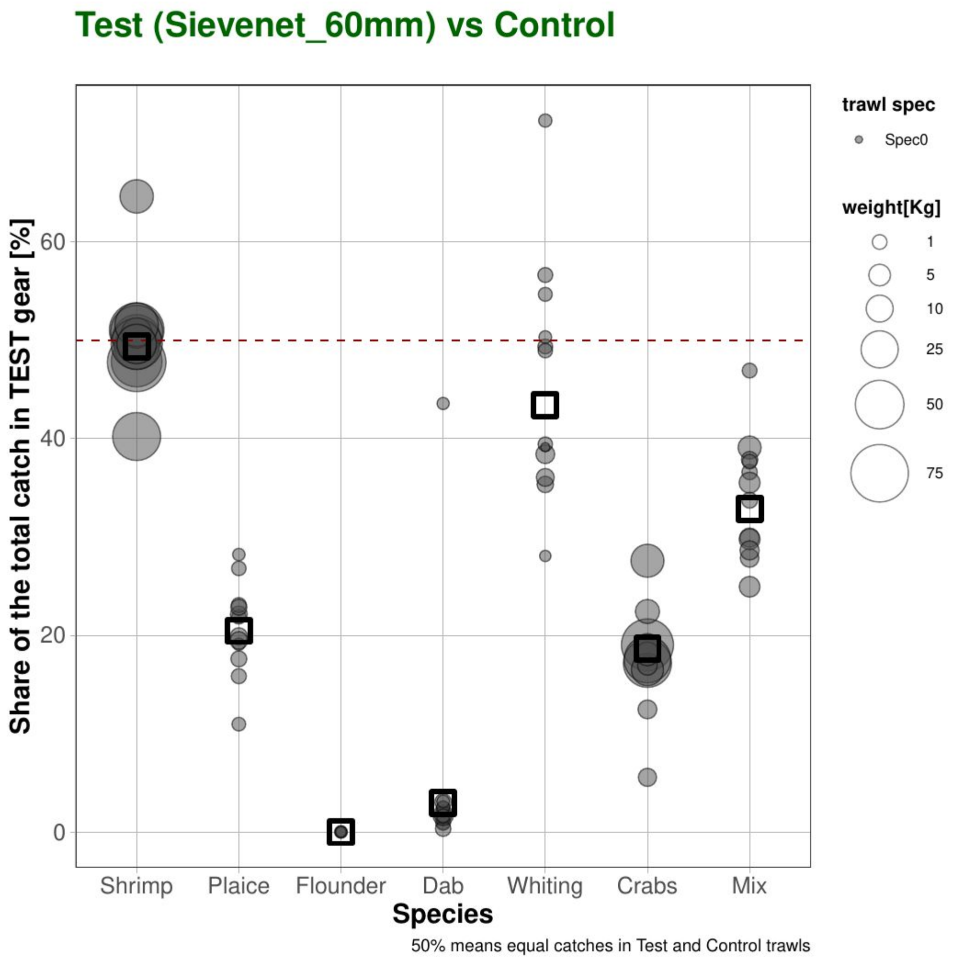

Figure 14: Catch proportions in test (standard sieve-net, Sievenet_60mm) and control trawls. Round marks show the catch share by species at haul level. The size and color of the round marks represent respectively the total catch (Kilo) and the Spec of the test gear used. Square marks represent the average catch proportion computed using the catch data pooled across hauls. A value of 50% means equal catches in test and control gear.

3.2 Preliminary analysis of performance based on length measurements

Altogether, 21573 brown shrimp were measured at the Thünen Institute of Baltic Sea Fisheries using the digital procedure described in the previous section. Of the total, 3208 individual measurements were obtained from hauls testing the Letterbox_60mm, 4406 and 9150 from hauls testing respectively the EG_60x40_24mm and RG_60x40_24mm grids, and 4809 from hauls testing the Sievenet_60mm. The average number of measurements per haul was 400 (200 per codend), and the sampling factors ranged between 0.001 to 0.067 in the test gear, and between 0.001 and 0.105 in the control gear. The resulting lengths distributions obtained in the test and control gear and across experiments were very similar (Figure 15), being the bulk of the catches in the range of lengths between 40 mm and ~70 mm.

Using any of the three alternative BRD led to catch losses of marketable shrimp (total length > 50 mm). Catch losses in the Letterbox_60mm, EG_60x40_24mm and RG_60x40_24mm grids were greater than 25% (Figure 16). In contrast, the Sievenet_60mm achieved a catch efficiency on the marketable shrimp close to 100%.

Catches of demersal fish species such as plaice, whiting, flounder or dab were in general low and mostly consisting of juvenile fish. Catch data from the TAC species, plaice and whiting, are used in this section to evaluate the bycatch reduction performance of the tested BRDs.

In total, 7053 plaice individuals were length-measured onboard, of which 1922 were measured using the Letterbox_60mm, 2127 and 1473 from hauls testing respectively the EG_60x40_24mm and RG_60x40_24mm grids, and 1531 from hauls testing the Sievenet_60mm. The sampling factors ranged between ~ 0.302 to 1.000. The lengths distributions obtained in the test and control gear and across experiments were comparable, being most of the individuals sampled below 10 cm total length (Figure 17). However, catches in the test gears tended to be lower than in the control for lengths greater than 10 cm. Due to the limited range of lengths available in catches, the catch efficiency assessment made for plaice (Figure 18) were conducted without considering catch fractions below or above species Minimum Conservation Reference Size (MCRS=27 cm). In numbers, the grid systems were more efficient in reducing the bycatch of plaice than the letterbox and sieve-net devices. Both sorting grids achieved an average catch efficiency of 42% for plaice, i.e. a 58% reduction in the bycatch of this flatfish species (Figure 18). Also in terms of numbers caught, the catch efficiency with the Letterbox_60mm and the Sievenet_60mm was respectively 65% (i.e. 35% bycatch reduction) and 55% (i.e. 45% bycatch reduction). When assessing the bycatch reduction of plaice in terms of weight, it is worth noting the superior performance estimated for the Sievenet_60mm (24% catch efficiency, i.e. 76% bycatch reduction , Figure 18). This result can be explained by a better definition of the size selection in the case of the Sievenet_60mm, which prevents the largest (and therefore heavier) individuals from entering the codend. In contrast, the wide bar-spacing used for the grid systems (24 mm) do not physically prevent larger individuals from entering the codend.

Overall 1121 whiting individuals were length-measured onboard, of which only 76 were measured using the Letterbox_60mm, while 174, 537 and 334 were measured using respectively the EG_60x40_24mm grid, the RG_60x40_24mm grid, and the Sievenet_60mm. The sampling factors ranged between ~ 0.160 to 1.000. The lengths distributions obtained in the test and control gear and across experiments were comparable, being most of the individuals sampled between 10 cm and 20 cm (Figure 19). Again, due to the limited range of lengths available in catches, the catch efficiency assessment for whiting (Figure 20) was conducted without considering catch fractions below or above species Minimum Conservation Reference Size (MCRS=27 cm). For this species, the catch efficiency indicators obtained using length measurements and weights are similar for all BRDs (Figure 20). Overall the grid systems were more efficient in releasing whiting than both the Sievenet_60mm, and Letterbox_60mm. For the later devices, the catch efficiency assessment did not find a significant effect on whiting catches (Figure 20). In contrast, using the RG_60x40_24mm resulted in an average catch efficiency of only 32% for whiting, i.e. a 68% reduction in the bycatch of this roundish species (Figure 18).

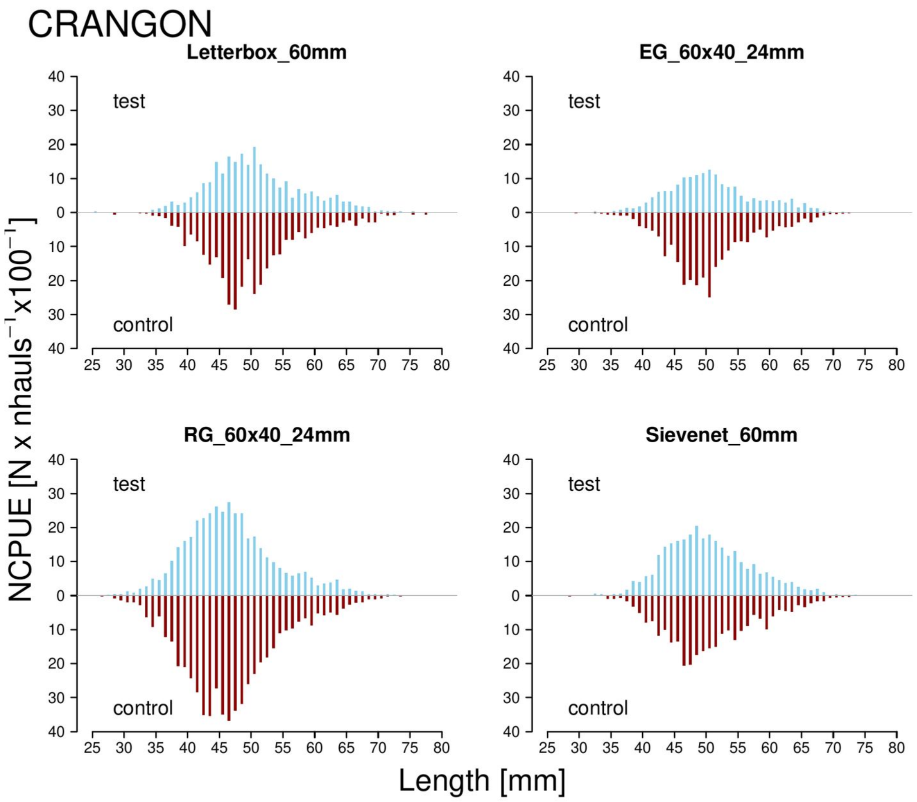

Figure 15: Length distribution of brown shrimp catches in test (blue bars) and control (red bars) gears based on length measurements obtained in the lab. The catch-per-unit-effort in numbers (NCPUE x 100^{-1}) is obtained by raising the length measurements to total catches, pooling the data across hauls, and scaling it according to the sampling effort (number of hauls conducted).

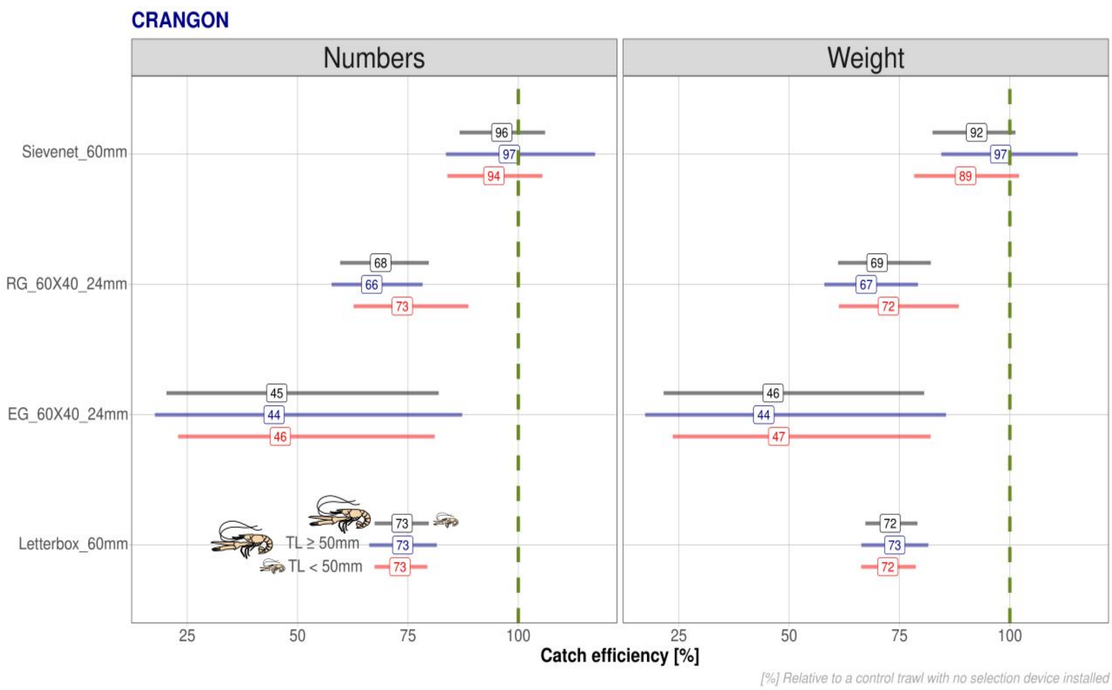

Figure 16: Catch efficiency indicators obtained for the targeted shrimp and for each of the tested BRDs tested. The indicators are presented in terms of catch abundance (estimated counts in catch, left), biomass (based on length-weight relationship transformations, right), and by catch fractions (above marketable sizes [TL>50 mm, blue], undersized [TL<50 mm, red] and the total [gray]). Vertical dashed green lines mark the value of full catch efficiency (100%). Values to the left of the vertical green line represent a loss of catch efficiency, due to the BRD used.

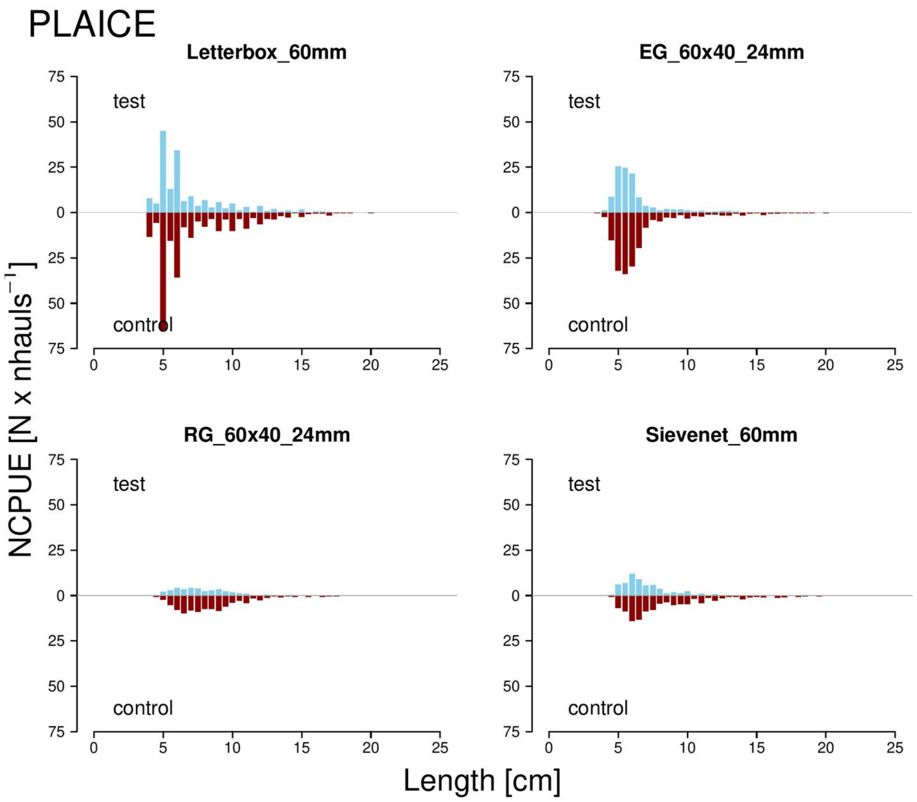

Figure 17: Length distribution of plaice catches in test gear (blue bars) and control gear (red bars) based on length measurements taken onboard. The catch-per-unit-effort in numbers (NCPUE) is obtained by raising the length measurements to total catches, pooling the data across hauls, and scaling it according to the sampling effort (number of hauls conducted).

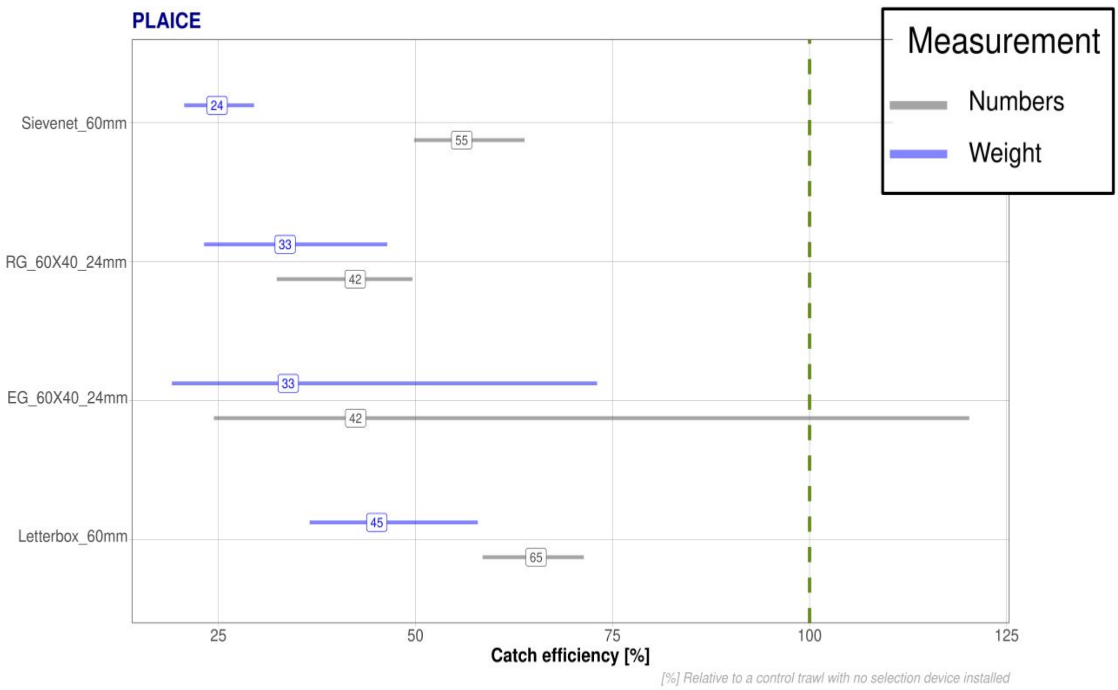

Figure 18: Catch efficiency indicators obtained for plaice and for each of the BRDs tested. The indicators are based on catch abundance (estimated numbers in catch, grey) and biomass (based on length-weight relationship transformations, lilac). Due to the limited range of lengths available in catches (most species catches made up of juveniles), no catch fractions (according to species MCRS) were considered. Dashed green line mark the value of full catch efficiency (100%). Values to the left of the vertical green line represent a loss of catch efficiency due to the BRD used.

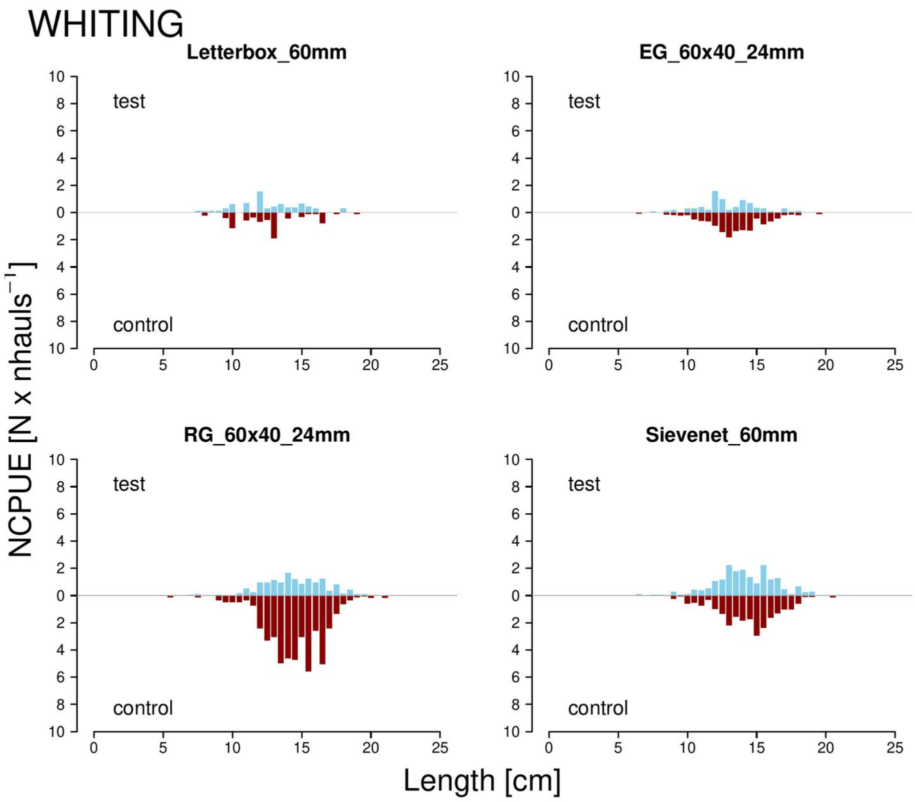

Figure 19: Length distribution of whiting catches in test gear (blue bars) and control gear (red bars) based on length measurements taken onboard. The catch-per-unit-effort in numbers (NCPUE) is obtained by raising the length measurements to total catches, pooling the data across hauls, and scaling it according to the sampling effort (number of hauls conducted).

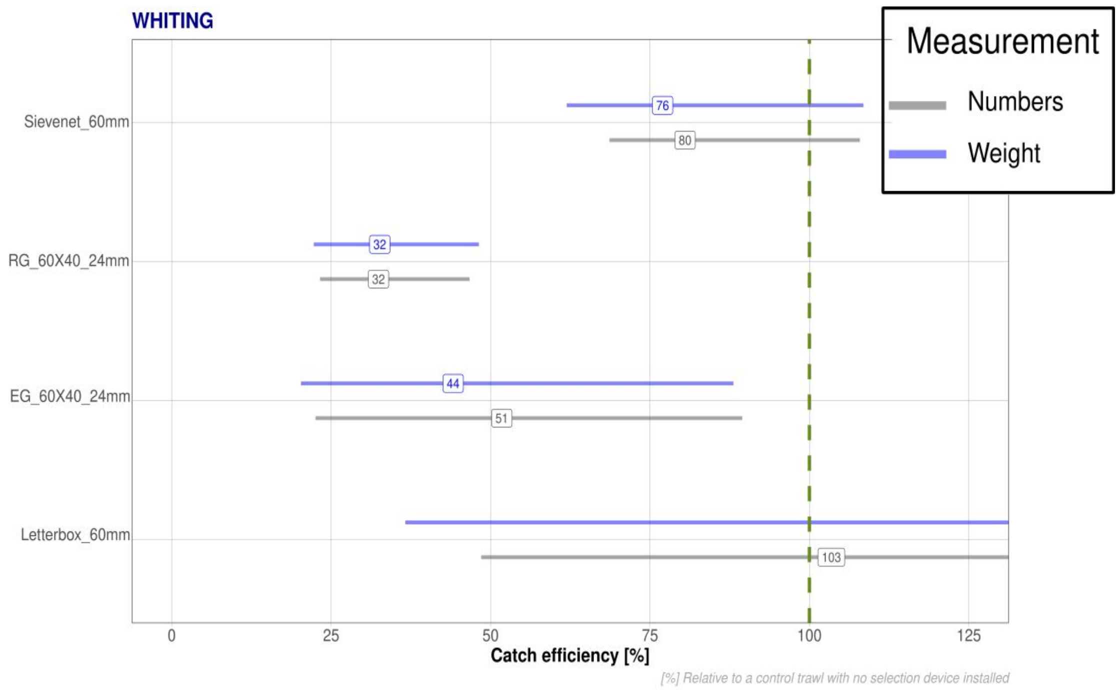

Figure 20: Catch efficiency indicators obtained for whiting and for each of the tested BRDs tested. The indicators are based on catch abundance (estimated numbers in catch, grey) and biomass ((based on length-weight relationship transformations, lilac). Due to the limited range of lengths available in catches (most species catches made up of juveniles) Vertical, no catch fractions (according to species MCRS) were considered. Dashed green line mark the value of full catch efficiency (100%). Values to the left of the vertical green line represent a loss of catch efficiency due to the BRD used.

4 Final remarks and next steps

The experimental sea trials conducted during the cruise demonstrated the good sorting efficiency of sieve-nets under favorable fishing conditions (limited presence of sea-grass and unwanted invertebrates in the fishing grounds). Based on the estimated catch efficiency indicators, it can be said that, in average, using the sieve-net does not affect the catchability of the targeted shrimp (only 3% reduction in catch efficiency = catch loss, Figure 16). However, a closer look to the paired-gear analysis shows that the catch efficiency could decrease for shrimps lengths equal or greater than 60 mm (Figure 21). Further analysis including model uncertainties will be conducted to clarify the significance of this observed trend.

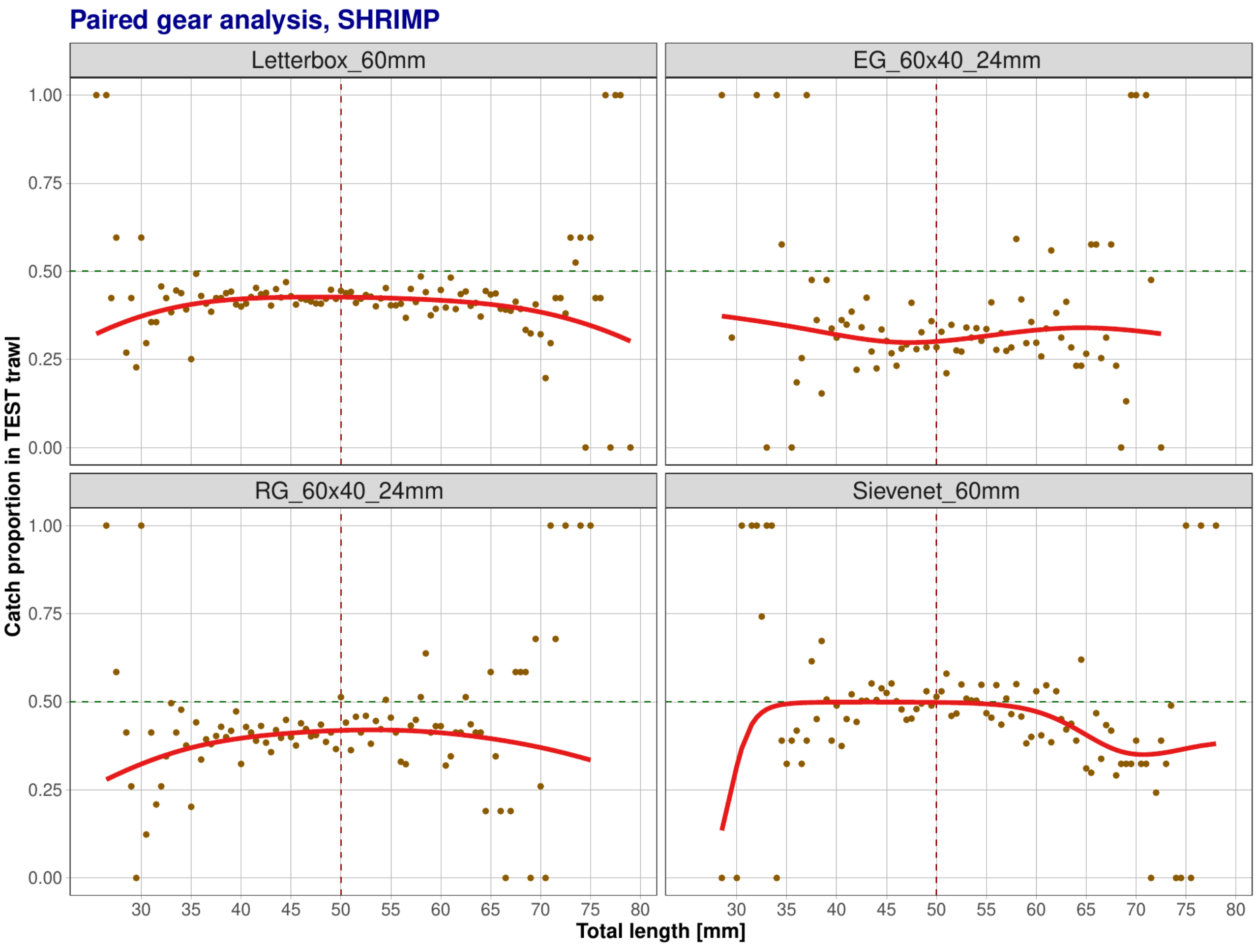

Figure 21: Catch comparison curves (solid red line) estimated for shrimp and for each BRD tested. Brown circles: experimental catch proportions of shrimp captured in the test trawl relative to the total caught across hauls. Green horizontal dashed lines positioned at value 0.50 indicate equal catch-share among test and control gears. Points below the 0.50 value represent lower catch proportion in the test gear compared to the control, while the opposite is true for points above the 0.50 value. This analysis was conducted using catch data from the most tested spec from each BRD.

During the trials, the housed-elliptical grid (EG_60x40_24mm) suffered clogging issues even with relative low availability of suspended sea-grass and unwanted invertebrates in the fishing grounds (assessed by considering the amounts of "mix" catch in the control codend). Visual observations indicated that the issue could be related to the complex design of the grid, and in particular with the presence of the steel housing. One relevant design aspect of the housing is that the bars forming the structure also define the escape opening. It is likely that the stiffness and limited dimensions of the escape opening reduced the efficiency of the grid to transport the sea-grass outside the net, being a main cause of the clogging problems observed (Figure 22). Consequently, significant amount of catches were found stacked in front of the grid, which could only be released by washing maneuvers performed by the vessel. Therefore, this catch fraction was not considered in subsequent catch-comparison analysis, explaining the low values of the catch efficiency indicators related to this grid system for the three species investigated (Figures 16, 18,20).

Figure 22: Left: Escape opening of the elliptical grid during haul-back. Right: Catch accumulation in front of the grid.

Using a simpler rectangular grid of the same dimensions and bar spacing (RG_60x40_24mm) drastically reduced the clogging issues encountered with the previous grid design, even encountering an increase in biomass availability of the “mix” fraction (~6.0 kg per haul in the control codend, versus 3.0 kg per haul during the trials with the EG_60x40_24mm grid). The escape opening of the rectangular grid was defined by simple straight (AN) cuts of the top net panel (Figure 23), and its flexible nature might have facilitated the transportation of sea-grass and other materials outside the net, preventing blockage. While the RG_60x40_24mm drastically reduced clogging issues, there are still opportunities for development to be explored for improved transportation. For example, sea-grass was often observed entangled on the upper transversal bars of grid (Figure 23). Letting the upper edge of the grid bars unconstrained by removing or reallocating the structural transversal bar could solve this issue.

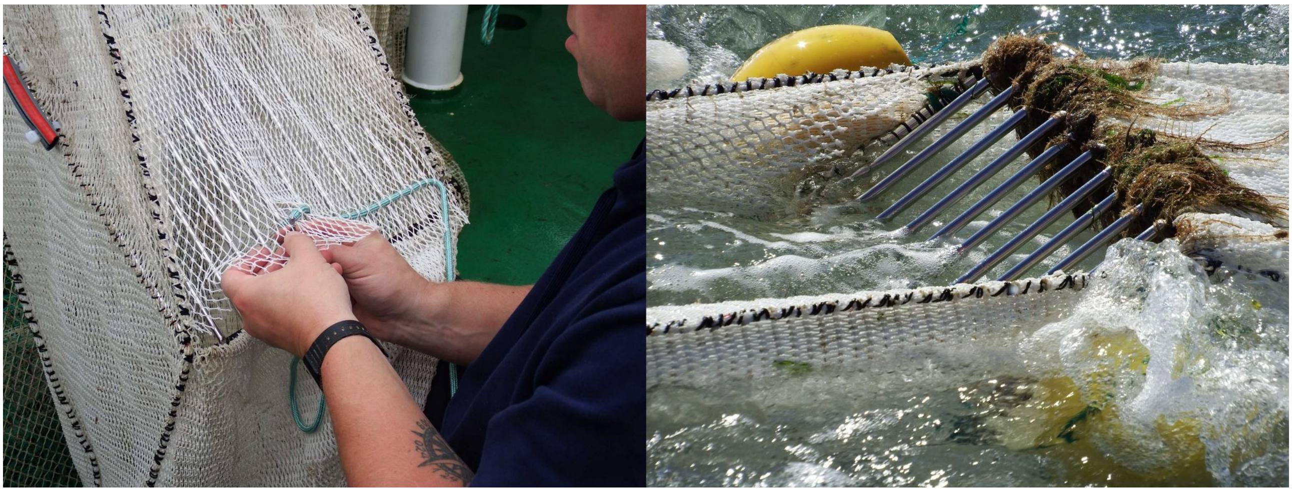

Figure 23: Left: preparing the simple escape opening on top of the RG_60x40_24mm grid. Right: Sea-grass entangled in the upper transversal bar of the grid.

While the RG_60x40_24mm grid improved the catch efficiency indicators obtained by the EG_60x40_24mm grid for the targeted shrimp (66% versus 44% average catch efficiency in terms of weight, respectively), Its performance is still far from that shown by the sieve-net (Figure 16). Underwater video recordings taken in the Baltic Sea in a subsequent cruise (SO813) to assess how the grid affect the trawl shape revealed that the tested 60X40 cm grid dimensions might be too small for the Solea 7 m - beam trawl (Figure A2-1). In particular, the reduced dimensions of the grid constrained the natural expansion of the trawl netting during towing (Figure 24, left). This produced a convex shape in front of the grid, which could led to shrimp escaping directly though the escape opening without contacting the grid. Underwater video recordings also collected during the cruise SO813 showed a much better shape of the trawl when mounting the larger RG_80X60_24mm grid (Figure 24, right). The better fit of this grid to the beam trawl and the larger selection surface available might lead to an increase in the catch efficiency for the targeted shrimp. Therefore, this design should be tested in future sea trials in the fishery. Provided that the increase in grid size improve the catch separation, further developments should involve a) the identification of an optimal bar-spacing and b) investigation of alternative grid designs made of flexible and lighter constructive materials.

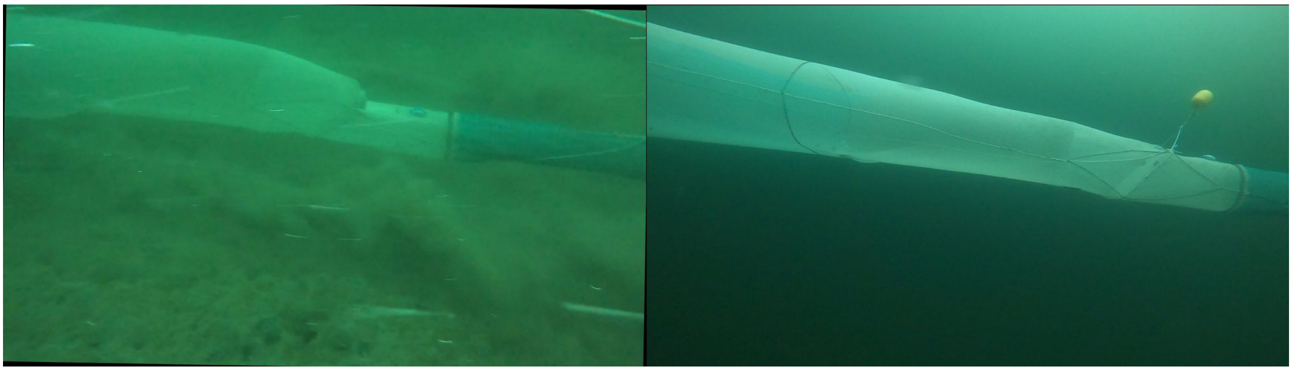

Figure 24: Snapshot from underwater video recordings collected in the Baltic Sea during the Solea cruise 813. (Cruise leader D. Stepputtis), while towing a beam trawl mounting the RG_60x40_24mm grid (left) or the larger RG_80x60_24mm grid (right).

In average, fishing with the letterbox trawl yielded the second-highest catch efficiency for the targeted shrimp (~73% catch efficiency Figure 16). On the negative side, the Letterbox_60mm produced the highest bycatch rates (Figures 18, 20). An explanation can be found in the main design principle of the device. As it was mentioned above, the side panels of the device are held up in the water column with a hanging rope running from the front to the back across the upper free meshes. This feature leave a large open space between the upper tip of the Letterbox_60mm panel and the upper panel of the trawl that can be used by fish species to avoid the intended guiding effect towards the outlet. This is probably the behavioural path followed by roundfish such as withing, explaining the lack of bycatch reduction for this species. Although this results have to be taken with caution due to the limited amounts of whiting caught during the Letterbox_60mm trials (Figure 19). In any case, this design feature suppose a serious bottleneck in the search for a consistent performance in terms of bycatch reduction.

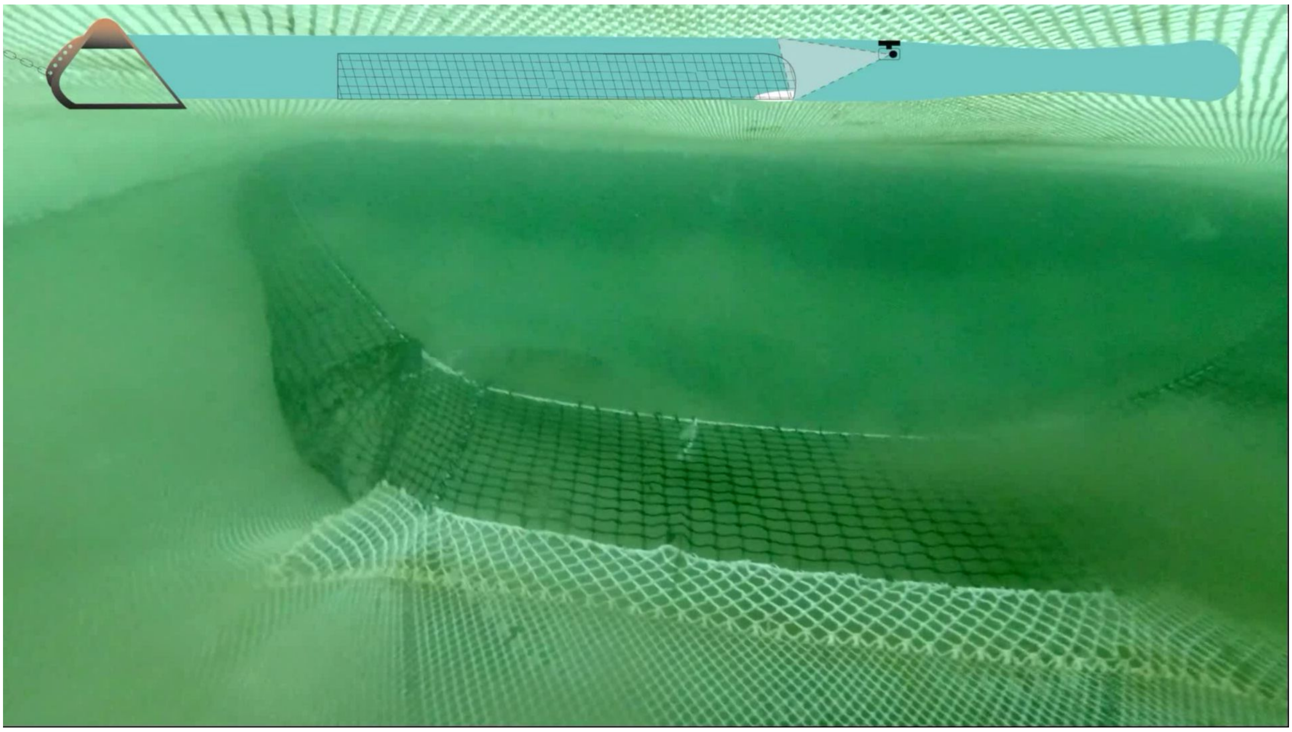

Figure 25: Underwater snapshot showing the side panels of the letterbox and the vertex where they meet, under which the exhaust opening is located.

5 Cruise participants

Name	Affiliation	Activity	Period participation
Brüger, Annika	Uni Rostock	student	All cruise
Bächtiger, Marcel	Uni Hamburg	student	All cruise
Büttner, Beate	TI	Technician	21.-29.09.
Hennings, Ina	TI/OF	Technician	All cruise
Hünerlage, Kim	TI/SF	Researcher	14.09
Sander, Dirk	VDKK	Guest fisher	14.-17.09 and 22-29.09
Santos, Juan	TI/OF	Cruise leader	All cruise
Schael, Peter	TI/OF	Tech.	16.-21.09.
Schöps, Kerstin	TI/OF	Tech.	All cruise

6 Acknowlegments

Thanks to the crew of the FFS SOLEA for their hard work. Their active participation in the development of the sea trials and their valuable suggestions on how to optimize the tested bycatch reduction devices contributed significantly to the successful completion of the cruise. We are also grateful for the support of our colleagues on shore. Special thanks go to Annemarie Schütz, who produced several of the drawings in the report and also participated in the shrimp (length) measurements on land. Thanks to Kim Hünerlage, chair of the ICES WGCRAN and colleague from TI/SF, for joining us, even if it was only for a day! Finally, many thanks to Dirk Sander for joining us. It was a pleasure to have you on board and we hope to have you on future sea trips. Of course, other interested fishermen are always welcome!

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8 ANNEX I

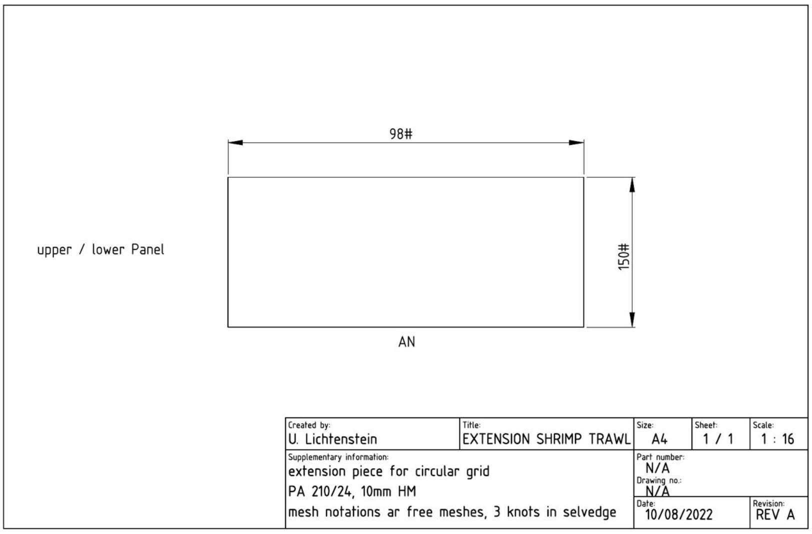

Figure AI-1: Technical details of the two-panel tunnel section (two selvedges) in which the elliptical Grid was mounted. This section was mounted between the trawl body and the codend.

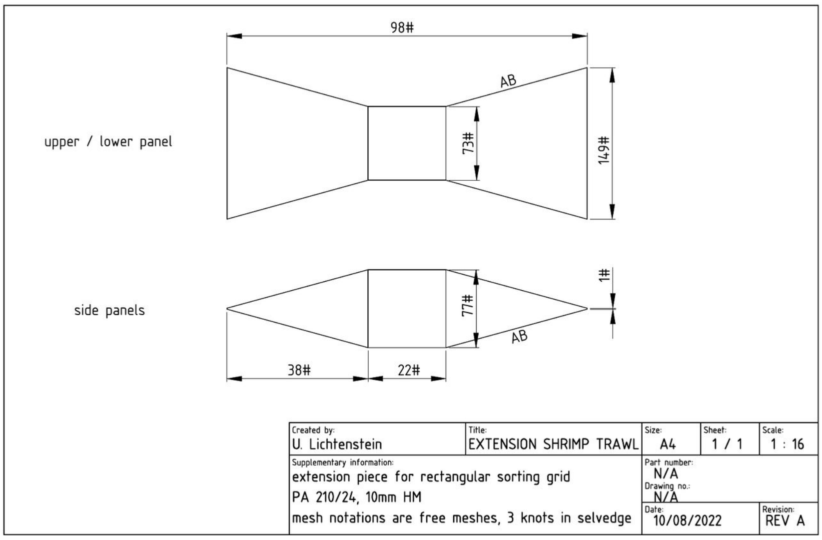

Figure AI-2: Technical details of the four-panel tunnel section (four selvedges) in which the Rectangular grid was mounted. This tunnel section was mounted between the trawl body and the codend by using 2-to-4 and 4-to-2 selvedge adapters.

9 ANNEX II

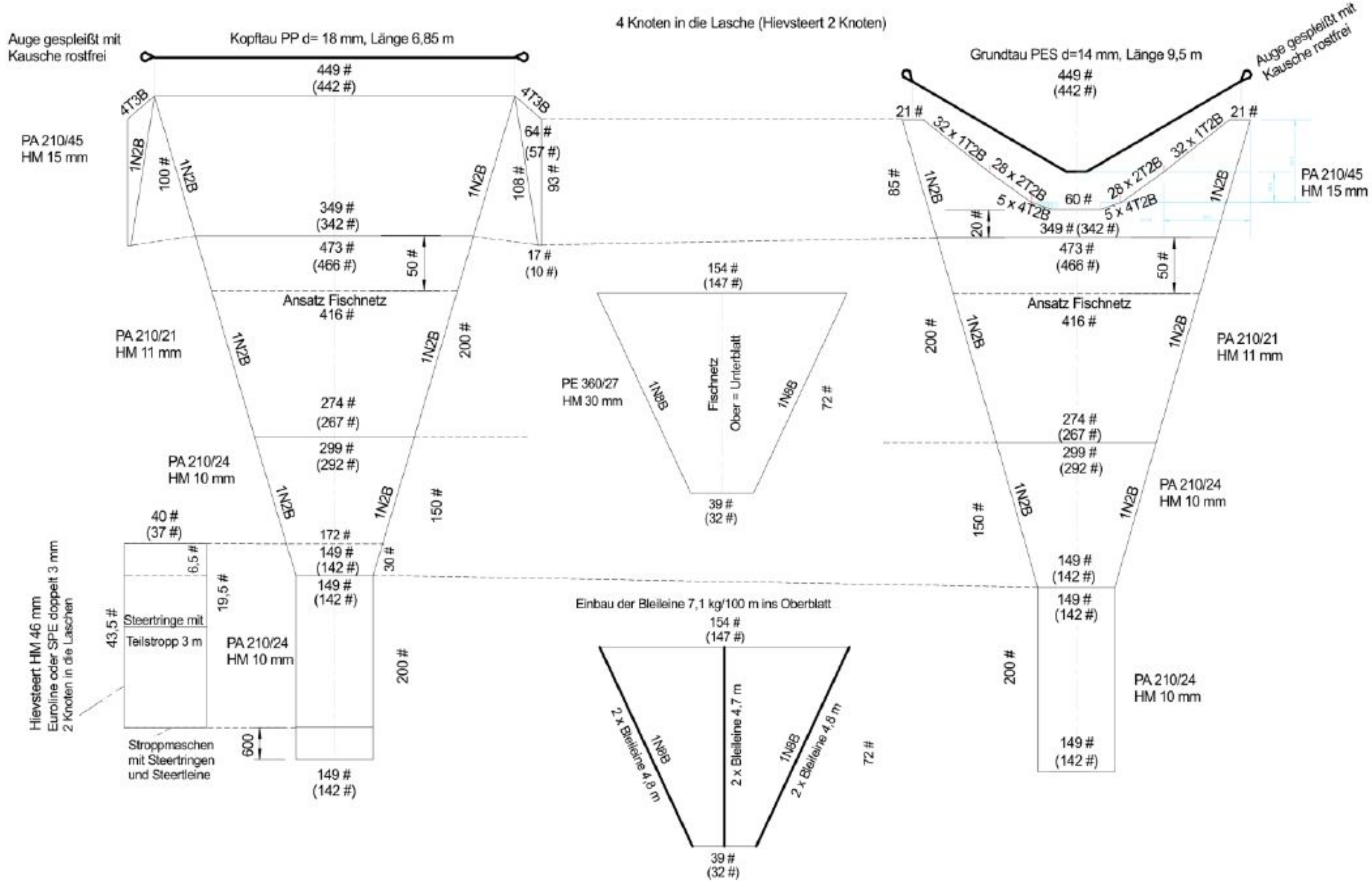

Figure A2-1: Technical drawing of the (twin) beam trawls used during the cruise, mounted with the sieve-net design used as baseline performance of BRD in the fishery.