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National Institute of Aquatic Resources

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Lotte Kindt-Larsen, Thomas Noack, Finn Larsen, Casper Willestofte Berg
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Colophon

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Preface

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DTU Aqua, Kgs. Lyngby

August 2022

Lotte Kindt-Larsen

Content

Summary

The overall goal of the project was to develop innovative fishing gears which can constitute alternatives to gillnet and hook fisheries in areas where seal depredation is causing significant catch losses. Specifically, the project has worked on optimization of a mini-seine targeting cod and flatfish, trialling the Pontoon-trap at Bornholm and collecting data on potential catch rates over the year for the fish pots.

As a first step the seine had to be optimized in order to obtain better catches, as technical and gear failures had been identified in earlier tests of the mini-seine. First the drums were adjusted to reach a better ratio between force and speed of the system. Second, by adding a remote control of the drums which made the system more adaptable to the working conditions on-board a small vessel. The results showed that several of parameters were improved but the hydraulic engines could not be rebuilt to achieve the optimal power.

The second step was to investigate how seine rope length, seine rope diameter and seine net affected the catch efficiency. Here seine rope length was found to have a positive significant effect on the catch efficiency even though setting and retrieving longer ropes takes more time. Seine rope diameter did not have any effect on the catches. Catch efficiency did not differ significantly between the tested seine nets as long as each net was rigged properly.

To optimize catch rates, different layout patterns of the seine ropes were tested. The results indicated that when seine ropes had been laid out in an open circle the highest catches were obtained, which was most likely due to the increased size of the fishing area covered. It is, however, important not to cover the biggest possible area, as this changes the angle of the seine rope towards the towing directions, which becomes problematic as this might allow fish to escape during the herding process.

In order to make sure that no fish left the seine-net once they were caught a so-called stop-net was tested. In the first test of the stop-net no significant effect in total catches was found when fishing with or without the stop-net. Only catches of dab were significantly higher when fishing with stop-net. These observations could further be supported by video observations done inside the seine net. Here the recordings showed also that the stop-net stayed quite open even though the seine net did not move at all. Therefore, similar trials had to be repeated, but instead of higher retrieval speeds, slower retrieval speeds should be tested in combination with the stop-net.

Additionally to the test of slower retrieval speeds the second test of the stop-net included an optimisation process of it, which could finally allow for a comparison between catches of the mini-seine and the gill nets.

In general, the catches during the experimental phase were low. Thus it was difficult to compare the catches form gillnets with the mini-seine net. In general, the gillnet catches were highest for the coastal and lowest for gillnet set close to the seine fishing locations. When trying to compare the maximal gillnet catches by upscaling the catch from both the coastal positions and the positions close to the seine net positions, the catches from the mini-seine were somewhat in between. This outcome bases on the catches of flounder, a species dominating the catches, but with very low commercial value. The raised catches of turbot and plaice were highest for seine, while raised catches of cod were very low for all. The differences between the coastal gillnet and gillnet not used under optimal conditions shows how important the right location is for proper gillnetting.

In summary, the seine seems to be more suitable for catching the more valuable species turbot and plaice but catches of flounder are smaller. However, such trials should be repeated when there is more fish in the area.

The Pontoon-trap was modified to fish at Bornholm at a greater depth than in earlier trials by adding an extra pontoon, a longer connector and ballast to adjust the levelling at the surface. The trap fished for 54 days, but daily catches of cod above the minimum landing size were only a little more than 1 kg. The trap frame was found not to be sufficiently strong to cope with the impacts of current and wind. These issues combined with a lack of interest from Danish fishermen led to abandoning further trials with the Pontoon-trap.

The last part if the project focussed on pot fishery. Sets of ten collapsible fish pots were given to eight fishers around Denmark, who were asked to fish with them in all conscience for a longer periods. The fishers could use their own preferred bait, soak times and fishing areas. All catches were registered for each pot set and the results showed that there was large variation in catches both in terms of regions but also over the year. However, the catches were the highest in those months which are most affected by depredation from seals.

During all trials a cooperation with the commercial fishery was essential. All participating fishers was somehow affected by the seal conflict and had a wish to solve this. The fisher's ideas and views, from modifications of the seine to design of the pots were in all work packages taken into account, and the project really benefited by a close collaboration.

1. Background and project aims

From a fishing gear research perspective, the ongoing conflict between passive fisheries and depredating seals can be solved by two options: i) modification of conventional gears used in the commercial fishery or ii) use of innovative alternative seal-safe fishing gears. The present project focused on the second option, more precisely the improvement of existing seal-safe fishing gears. Within the project, three alternative gears were supposed to be tested, i) the mini-seine, ii) the pontoon trap and iii) fish pots. As the title of the project implies, all three gears have been investigated and tested by previous projects in some way or other. The aim of this project was thus to investigate if and how these gears could be developed to a stage where they would be considered profitable fishing gears by the commercial sector.

The mini seine offers the same characteristics as the conventional demersal seine systems, but is drastically reduced in size (sein rope length, seine rope diameter, seine net) to fit on a small fishing vessel. The mini seine system has been tested in a previous EMFF project ("Seal-safe fishing") here, however, various technical failures of this system were identified. The most serious issues were i) difficulties in handling of the system; ii) the retrieval speed of the gear, i.e. the system could not retrieve the fishing gear at the desired speed; and iii) the fragility of the system, i.e. increased load on the system (e.g. when getting stuck) caused the compartments to break. These technical failures thus shaped the aims of work package 1 "Optimisation of the mini seine". Here the aim was to solve these problems, to further understand which parameters affect the efficiency of the gear and finally to compare the catch efficiency of the optimized mini seine with the catch efficiency of a conventionally used gillnet. Due to the declining cod (*Gadus morhua*) stocks in the Baltic, the intended target species of the gear moved from cod to flatfish such as plaice (*Pleuronectes platessa*) and flounder (*Platichthys flesus*), i.e. the original target species of demersal seines.

The Pontoon-trap was originally developed in Sweden for the salmon fishery, but has also been used for other species like herring and, to a limited extent, for cod. Earlier trials in Danish waters were inconclusive, but had identified several problems particularly with respect to handling and stability of the Pontoon-trap. The initial plan of work package 2 "Optimisation of the pontoon trap" was to solve these problems, to describe fish behaviour around the gear and to determine catch efficiencies for the Pontoon-trap. However, following a trial at Bornholm, it became apparent that the Pontoon-trap in its existing form was not suited for Danish waters. Thus, the work package was terminated, and the remaining funds distributed to the other work packages.

Several times fish pots have been suggested as a fishing gears that can serve as alternative sustainable fishing gears to the traditional gillnets. Additionally to their environmental friendly characteristics like minimum impacts on the seabed and very low bycatches of seabirds and marine mammals, they can easily be modified to become seal-proof. The design of the fish pots tested within the project is based on previous studies aiming at developing such seal-safe fish pots. Important factors that need to be considered in this process are i) tightness of netting (so seals cannot push their head into the pot), ii) generally small mesh of strong material (so seals cannot bite through it) and iii) restricted circumference of openings (so seals cannot enter the pot). The aim of work package 3 "Pot fishing" was the long-term documentation of catches and handling in various pot-fishing regions. Sets of ten fish pots were given to eight fishers around Denmark, who were asked to fish with them in all conscience for a longer period and to report the data to the scientists.

Overall aim of the project was to develop and test the mentioned alternative seal-safe fishing gears further into the direction, where they could be considered profitable, to test them under various conditions (e.g. seasons, locations), to compare them to conventional fishing gears (e.g. gillnet) and further to let them be tested by the commercial sector.

2. Mini-seine

The aim of the first part of the project was to optimise the mini-seine system. As mentioned before, the system had already been used in a previous EMFF project “Seal-safe fishing” journal no. 33113-I-16-084. The results from “Seal-safe fishing” showed that the mini-seine represents a potential seal-safe alternative to gillnets. However, further research, tests and modifications to the system were necessary as several challenges like technical failures of the system or missing knowledge about suitable seining grounds had been faced. Additionally, more knowledge was needed to understand what factors determine catch efficiency of the mini-seine. To investigate those, the mini-seine was tested under similar conditions as in the previous project (location: Bornholm), but for logistic reasons also with another vessel and in other regions (Great Belt). The details about the different experiments will be explained separately below.

2.1 Assessment and optimisation of the mini-seine system prototype

2.1.1 Adjustments of the rope drums

The mini-seine system from the previous project (Figure 1A) was adjusted first, by changing parts of the rope drums in order to reach a better ratio between force and speed of the system. This allowed a faster set and haul of the ropes. Second by adding a remote control to controller of the drums (Figure 1B). This allowed the rope drums to be controlled from other positions than behind the drums, which made the system more adaptable to the working conditions on-board a small vessel.

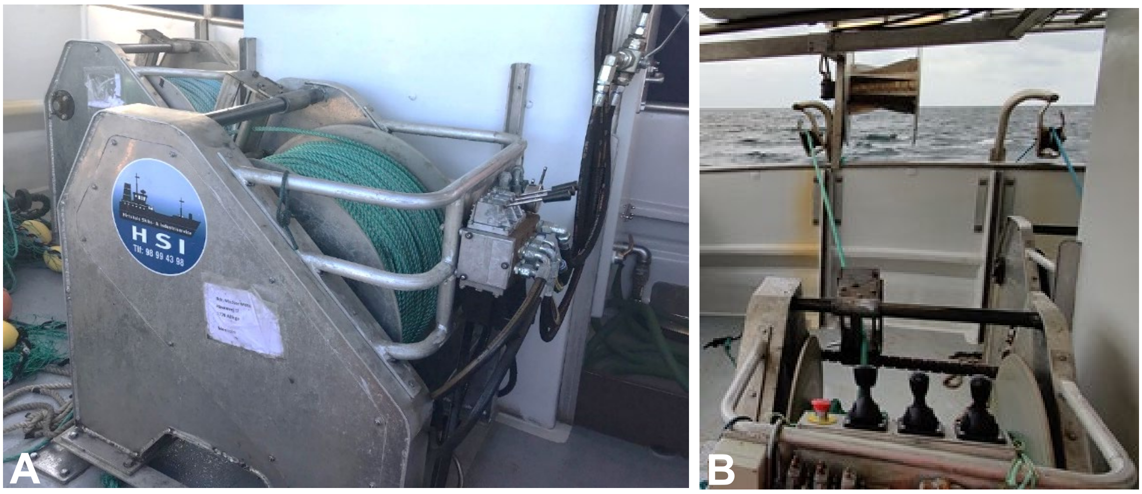

Figure 1. Mini-seine system. A. Original system. B. Added Remote controls to facilitate operation.

Tests of the adjusted seine systems were conducted in in summer/autumn 2019. The aim was to test if the new adjustments improved the seine performance and handling of the “new” hauling system. To be able to evaluate the new hauling system, the seine net itself (Figure 2) was not changed. As in the earlier trial, the seine net was 36 m long with 234 meshes in the fishing circle which was used with a 22 m long (12 mm “Taifun”) ground-gear. The ground-gear was equipped with 45 rubber discs (diameter: 10 cm; spacing: 50 cm), 11 bobbins (diameter: 17 cm) and 1.7 kg lead-chain. The seine ropes used were 880 m 14 mm ropes on each side.

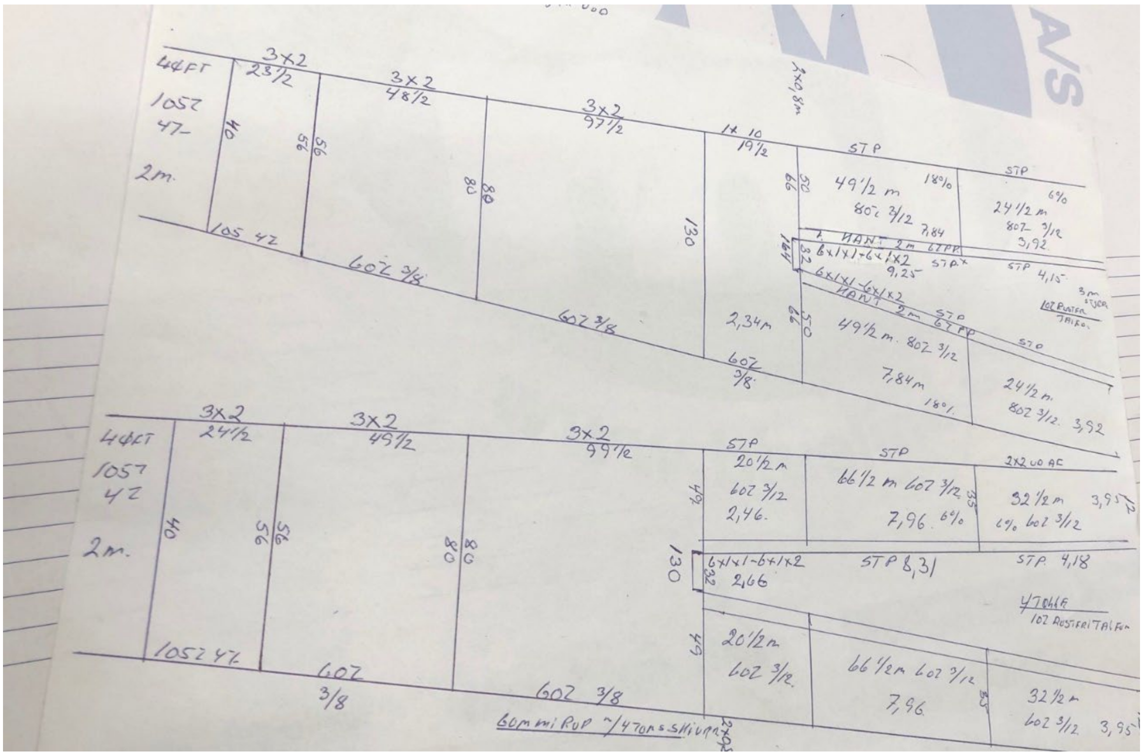

Figure 2. Seine net drawing.

Detailed catch data were not collected during the trials. DTU Staff and the fisher focussed on the handling of the hauler and its performance in all types of conditions. A total of 49 test hauls were conducted of which 35 were valid.

After the test trials, it was concluded that the adjustments to the system had improved the hauling system. The main improvement was that all fishing operations could now be conducted by a single person. However, despite the set and retrieval speeds were improved, these was still not optimal.   This was mainly because the engines used for the rope drums were too small. If they should be improved to the next level, one would need to change the engines. This was, however, not possible within this project. An additional outcome of the test trials was that the rope diameter of 14 mm should be increased for two reasons: i) the small diameter made it possible for the ropes to stretch over time, i.e. after a period of time the ropes´ length changed, which can have drastic effects on the herding efficiency of the gear; and ii) thin ropes dig more easily into the sediment causing the gear to get stuck and thus the fishing process to be aborted.

Alongside with seine trials additionally, gillnets (8 nets á 50 m; nominal mesh opening: 55 mm) were set 13 times. This was set to get information about good gillnet fishing areas which were needed in the later trials. Here similar species as in the mini-seine were caught, e.g. mainly cod, flounder and plaice.

2.1.2 Trials 2020 around Bornholm– target species: flatfish

The project was originally designed to test the feasibility of catching cod with a mini-seine. However, due to the low cod stocks in the Baltic Sea, it was decided to target flat fish species in order to investigate the mini-seine´s performance in catching flatfish instead of cod. Possible targets were flounder or preferably more valuable species like plaice or turbot (*Scophthalmus maximus*).

The trials were conducted at several locations around Bornholm in summer/autumn 2020 (Figure 3) using the adjusted hauling system together with the same seine net as mentioned above (Figure 2). The seine rope diameter was changed to 18 mm in order to avoid that the ropes get stuck in the sediment while hauling. However, as the rope diameter was increased, the length of seine rope had to be shortened down to three coils (3*220 m = 660 m) per side in order to fit on the rope drums.

Alongside the mini-seine, gillnets were set to be able to compare gillnet catches with seine-net catches. The net fleets were set in approximately the same areas at the same times. The gill-nets used were 300 m long consisting of 6 panels (height: 1.5 m, mesh opening: 130 mm). The distances between seine and gillnet fishing locations were kept as small as possible, but the gears could not be used at the exact same grounds (Figure 3) as the optimal fishing grounds differ for the two gears. Demersal seining needs to be conducted on flat bottoms with as few structure as possible in order to protect the seine ropes, while gillnets should be set of rather structured grounds. For each haul of seining and each set of gillnet, the soaktime and haul time was recorded. The catches were sorted by species and weight, and each individual was length-measured (Table 1 and Table 2).

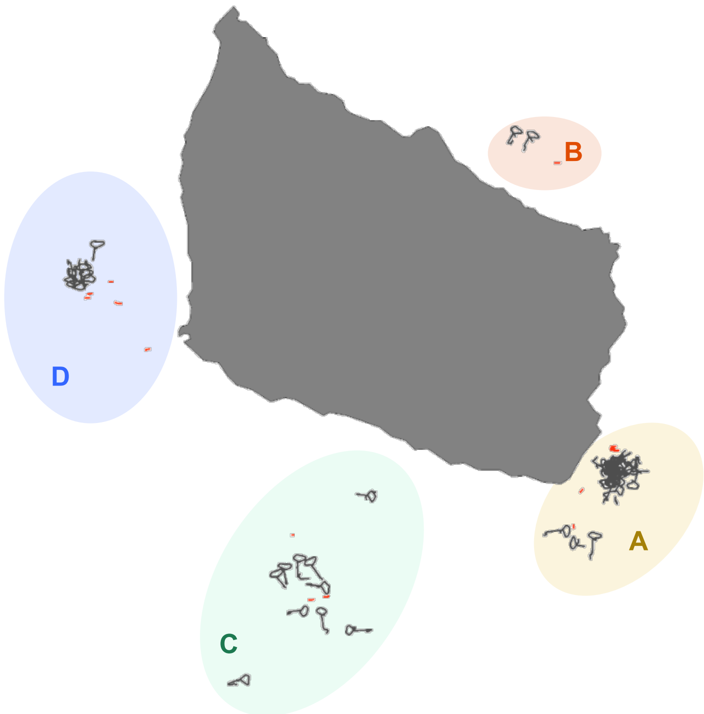

Figure 3. Fishing locations (A: Dueodde; B: Gudhjem; C: Rønne banke; D: Rønne.) of "Bornholm 2020 (target: flatfish)". Grey: Mini-seine hauls. Red: Gillnet sets.

Table 1. Haul overview – mini-seine - Bornholm 2020 (target: flatfish). Given estimates are mean values including min- and max-values in brackets.

Area	Hauls	Haul duration (min)	Catch (kg)				
			Total	Cod	Flounder	Plaice	Turbot
Dueodde	32	70 (59-109)	10.7 (0-35.4)	0.5 (0-5.5)	7.7 (0-32.5)	1.5 (0-11.8)	1 (0-5.8)
Gudhjem	2	69 (67-71)	8.8 (2.4-15.2)	8.4 (2.3-14.5)	0.4 (0-0.7)	0.1 (0-0.1)	0 (0-0)
Rønne B.	12	77 (61-91)	13 (4.1-27.8)	0.1 (0-1.7)	8.8 (3.6-15)	3.4 (0.3-11)	0.6 (0-4)
Rønne	15	79 (66-109)	9 (0.3-24.1)	2.4 (0-14)	3.6 (0-10.5)	2.5 (0.1-8.8)	0 (0-0.2)

Table 2. Set overview – gillnet - Bornholm 2020 (target: flatfish). Given estimates are mean values including min- and max-values in brackets.

Area	Sets	Soak time (min)	Catch (kg)				
			Total	Cod	Flounder	Plaice	Turbot
Dueodde	8	660 (370-1211)	47.7 (1.3-128.2)	0.3 (0-1.1)	22.7 (0.1-60.5)	0.1 (0-0.3)	0.8 (0-3)
Gudhjem	1	340 (340-340)	7.2 (7.2-7.2)	0.2 (0.2-0.2)	3.4 (3.4-3.4)	0 (0-0)	0 (0-0)
Rønne B.	3	421 (165-618)	10.3 (6-17.6)	0.8 (0-2.5)	3.9 (1-8.8)	0.3 (0-0.7)	0.1 (0-0.3)
Rønne	5	905 (111-1540)	15.4 (0-48.9)	2.6 (0-7.3)	4.6 (0-20.8)	0.4 (0-1)	0.2 (0-0.8)

Although these general catch overviews allow for saying that species compositions are similar for both gears, further analyses regarding catch efficiencies between the two gears were not conducted at this stage as the mini-seine system was still not functioning properly.

Hauling data

Besides catch data, information about the fishing procedures (times of fishing events in order to calculate retrieval speed) were recorded and underwater (UW) cameras (Paralenz DiveCamera+) were used to record how the seine behaved underwater. Calculated retrieval speeds are shown in Fig. 4, red boxes). These were, however, lower than the preferred hauling speed of 3 kn (1.54 ms^{-1}, Fig.4 blue box) in any case. The UW video footage also revealed that cod was swimming from the cod-end towards the net mouth. This could indicate that the mini-seine system was not able to retrieve the seine net with speed high enough to retrieve the cod catches.

To counteract this issue, and to speed up the hauling times, a second smaller seine net was tested. The idea was that a smaller seine net was to provide less resistance in the water column and thus be able to move the seine faster in the water column due to its smaller size and lighter weight. The small seine had the following characteristics: meshes around fishing circle: 129; total length: 27 m; groundgear: 21 m long, 10 mm "Taifun" with 75 rubber discs (diameter: 7.5-12 cm; spacing: 15-25 cm). Furthermore, a 2 kg lead-chain has been added to the groundgear to hold the seine as close to the seabed as possible during hauling. The results, however, showed that the small seine only improved the retrieval speed marginal. This indicated that in order to increase the retrieval time of the seine one would need to increase the engine size of the hauling system. Thus, again it was decided not to do the comparison to the gillnet catches as the mini-seine had not functioned properly.

Instead, it was decided to test the seine nets on a small commercial demersal seiner providing a properly functioning seine system and especially the hauling. These trials and results will be given in the following chapter (see 2.2).

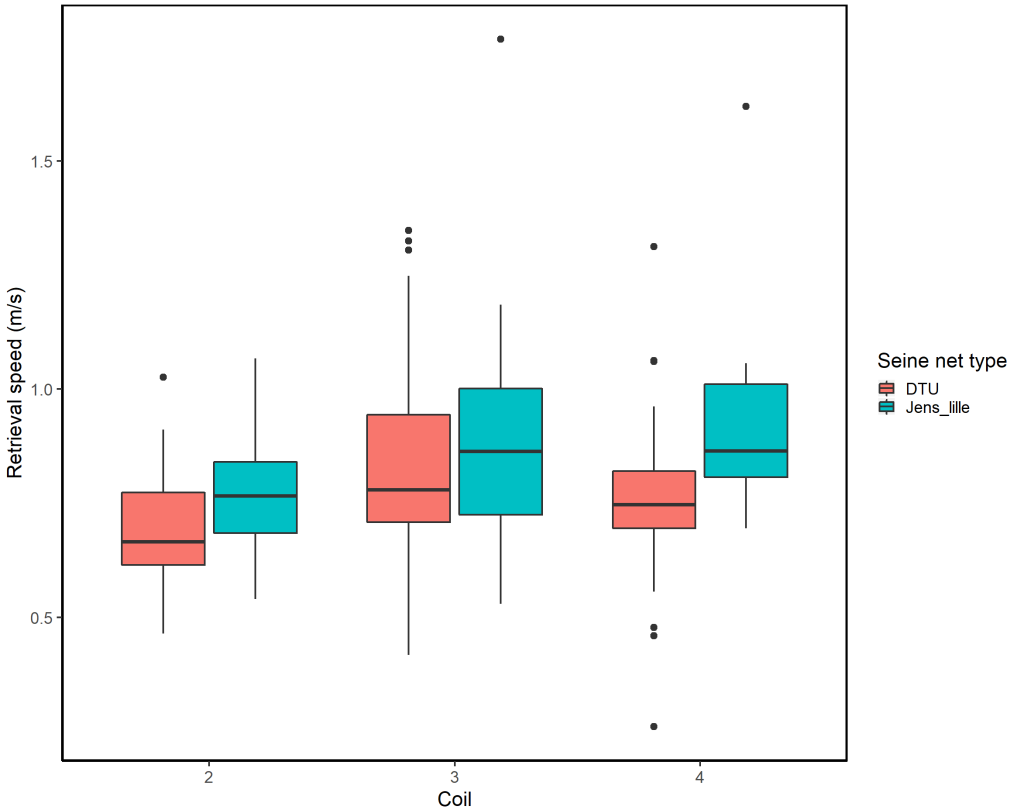

Figure 4. Comparison of retrieval speeds for seine rope coils 1, 2 and 3 depending on seine net used (DTU: standard seine net, Jens_lille: small seine).

2.2 Investigation of gear-related parameters affecting catch efficiency of demersal seines

2.2.1 Trials 2020 in Great Belt: Seine rope length, seine rope diameter, net type and fishing behaviour

The aim of these trials was to identify how the parameters seine rope length, seine rope diameter and seine net affect the catch efficiency. The idea was to keep all three gear parameters as small as possible to simplify the handling process on-board a small vessels. To compensate for potential catch losses, it was afterwards investigated, if adaptions to the lay-out pattern could improve the catch efficiency.

Experiment 1 “Gear characteristics”
The trials were conducted on-board a commercial Danish seiner (LOA: 12 m, engine power: 82 kW). The trials were conducted in the Great Belt (Figure 5, “Experiment 1”), where the vessel usually operates fishing with 8 coils (~220 m each, producing two sets of ~1760 m each) of seine rope with 22 mm in diameter (“Randers Reb”, 0.45 kg·m−1). Each seine rope was separated into two parts of equal length (4 coils each), allowing to fish with either four or eight coils of seine rope, thus testing how rope length affects catch efficiency. To evaluate if the seine rope

diameter affected the catch efficiency, a second set of seine ropes of 18 mm in diameter ("Randers Reb", 0.34 kg·m−1) was used. To investigate how seine net shape and size affects the catches, different seine net types were tested during the experiment (Table 3). All seine nets were equipped with the same kind of tapered cod-end (PET 4 mm double twine; nominal mesh size: 125 mm; 70 open meshes in circumference; length: 3 m; number of selvedge's: two with four meshes included in each selvedge). This experiment was called "Gear characteristics". Due to COVID-19 pandemic, these trials were mainly conducted as self-sampling study, i.e. the fishers collected the data and did the required gear changes themselves, and reported the data to the scientists after every fishing day.

Experiment 2 "Layout patterns"

The second experiment ("layout patterns") of these trials compared catches between hauls with three different rope layout patterns (Figure 6). It was conducted in Musholm Bay (Figure 5, "Experiment 2") in shallow waters of maximum 10 m as required by the equipment – namely the surface connection system (SCS), which allowed tracking specific points of the seine rope during the fishing process. Experiment 2 was entirely conducted with the 18 mm seine ropes and seine net type 2 (Table 3).

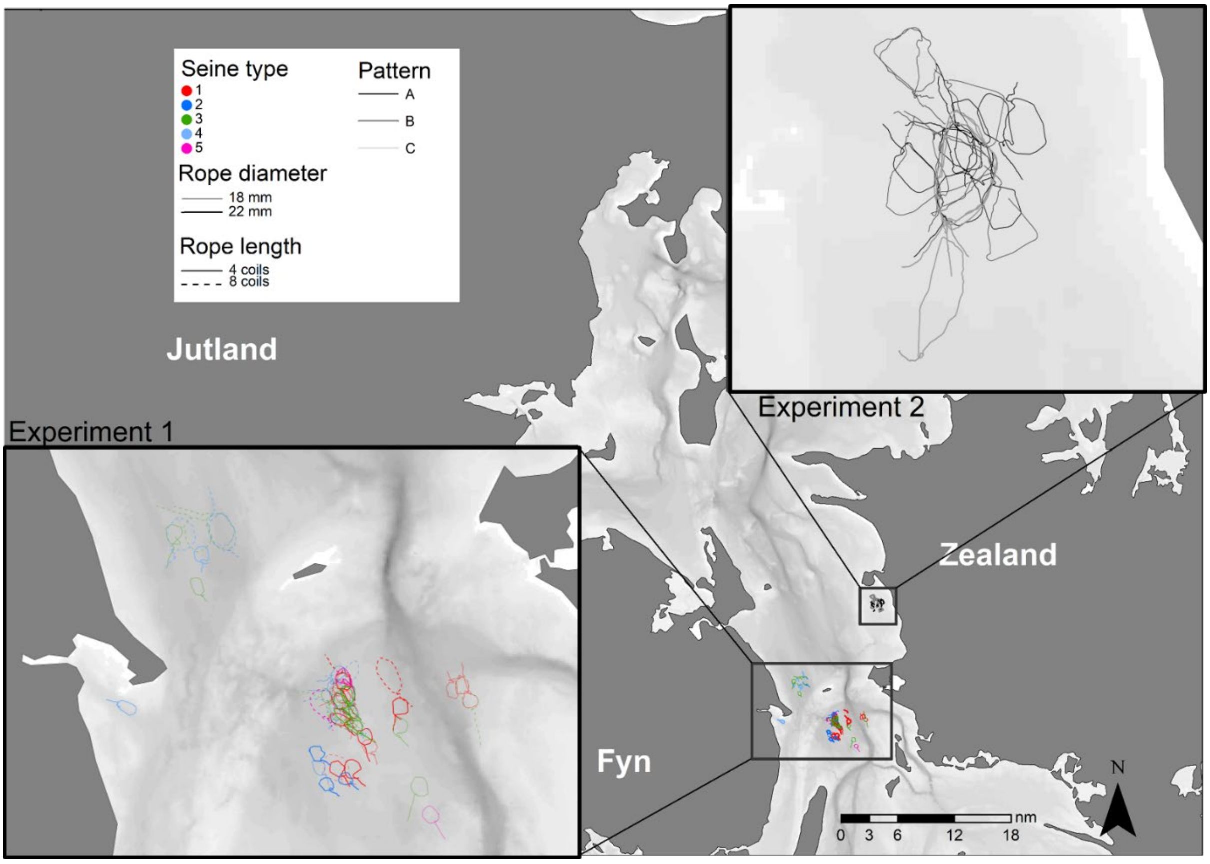

Figure 5. Fishing locations of trials "Great Belt 2020" (experiment 1 "gear characteristics", experiment 2 "layout patterns").

Table 3. Overview – seine types applied in experiment 1 “gear characteristics” including information about total length of the seine net (including cod-end), groundgear, meshes around fishing circle (#) and further comments to the respective nets.

Seine	Length	Groundgear	#	Comments
1	35.5 m	31 m (12 mm “Taifun”) with 106 rubber discs (diameter: 8-12 cm; spacing: 15-37 cm)	267	- warps for horizontal spread
2	36 m	22 m (12 mm “Taifun”) with 45 rubber discs (diameter: 10 cm; spacing: 50 cm), 11 bobbins (diameter: 17 cm) and 1.7 kg lead-chain	215	- warps for horizontal spread
3	27 m	21 m (10 mm “Taifun”) with 75 rubber discs (diameter: 7.5-12 cm; spacing: 15-25 cm) and 2 kg lead-chain	129	- Dan Leno for horizontal spread
4	36 m	22 m (12 mm “Taifun”) with 45 rubber discs (diameter: 10 cm; spacing: 50 cm), 11 bobbins (diameter: 17 cm) and 1.7 kg lead-chain	215	- same as 2, but ground gear not tightened - warps for horizontal spread
5	27 m	21 m (10 mm “Taifun”) with 75 rubber discs (diameter: 7.5-12 cm; spacing: 15-25 cm) and 2 kg lead-chain	129	- same as 3, but groundgear not tightened - Dan Leno for horizontal spread

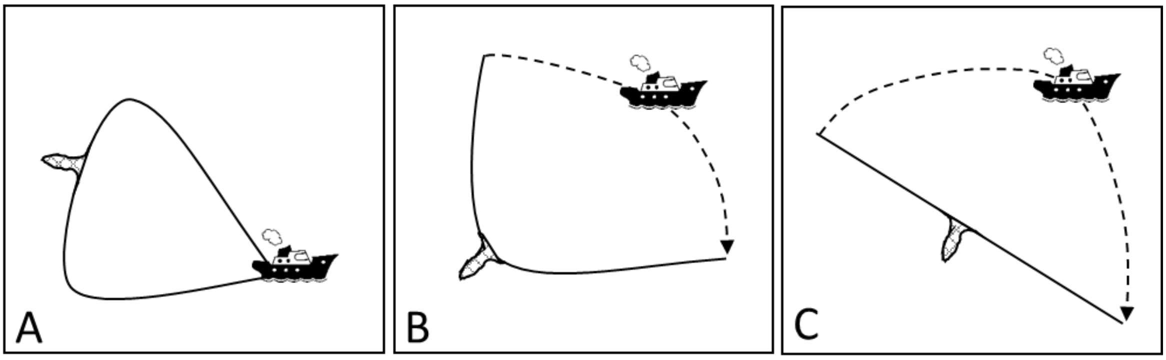

Figure 6. Seine fishing patterns in experiment 2 “layout patterns”. Stippled line represents part of fishing track, which is supposed to be towed on the rope.

In total, 93 valid hauls were conducted within experiment 1 “gear characteristics”, with plaice being the dominating species (Table 4). Therefore, the following analyses focused solely on plaice. Seine rope length was found to be the only parameter having significant effects on catch efficiency (Figure 7, Table 5) – even when catch per unit effort (CPUE; catch per hour) where taken into account for different hauling times when fishing with different rope length as setting and retrieving longer ropes takes more time. Seine rope diameter did not have any significant effect (Figure 8, Table 5). Effects of seine net type on catch efficiency were similar for all three net types properly rigged (Figure 9, Table 5). Only net types 4 and 5 (equivalent to net types 2 and 3, respectively, but not properly rigged) showed significantly lower catches

Table 4. Overview – fishing operations: experiment 1 “gear characteristics”. Given estimates are mean values including min- and max-values in brackets.

Coils	Dia	Seine	Hauls	Haul duration [min]	Covered area [km2]	Catch_Total [kg]	Catch_Plaice [kg]	MCRS-ratio Plaice [%]
4	18	1	11	39 (35-44)	0.33 (0.29-0.38)	17.9 (7.0-49.5)	13.2 (4.0-43.0)	30.7 (13.0-50.0)
4	18	2	8	39 (36-41)	0.34 (0.30-0.38)	20.6 (5.0-33.8)	15.9 (3.0-28.0)	28.0 (12.3-50.0)
4	18	3	9	37 (28-46)	0.36 (0.24-0.54)	29.0 (5.5-56.0)	23.7 (3.5-49.0)	38.4 (20.0-57.1)
4	18	4	0	-	-	-	-	-
4	18	5	1	43 (43-43)	0.44 (0.44-0.44)	5.7 (5.7-5.7)	2.2 (2.2-2.2)	9.1 (9.1-9.1)
4	22	1	10	41 (39-45)	0.40 (0.32-0.46)	15.5 (6.6-29.0)	11.6 (5.0-26.0)	28.6 (14.3-42.9)
4	22	2	6	40 (33-44)	0.29 (0.26-0.34)	13.0 (6.5-18.2)	9.3 (5.0-15.0)	26.0 (16.7-40.0)
4	22	3	7	37 (35-39)	0.33 (0.31-0.37)	18.0 (11.0-26.0)	13.1 (5.0-22.0)	41.6 (30.8-54.5)
4	22	4	4	43 (39-46)	0.39 (0.39-0.39)	9.1 (6.5-13.3)	7.0 (6.0-10.0)	17.9 (1.6-33.3)
4	22	5	3	41 (35-50)	0.37 (0.37-0.37)	9.7 (3.5-13.0)	7.1 (1.3-11.0)	27.2 (22.2-36.4)
8	18	1	4	73 (71-79)	1.14 (1.14-1.15)	61.3 (39.3-91.3)	48.8 (36.0-68.0)	19.5 (11.8-33.3)
8	18	2	8	78 (40-102)	1.16 (0.39-1.54)	56.0 (22.3-122.0)	31.2 (15.0-60.5)	29.7 (9.9-52.0)
8	18	3	5	80 (67-102)	1.25 (0.84-1.48)	36.7 (17.0-93.0)	27.4 (9.0-78.0)	18.3 (9.1-33.3)
8	18	4	0	-	-	-	-	-
8	18	5	0	-	-	-	-	-
8	22	1	6	77 (68-95)	1.16 (1.16-1.16)	63.9 (48.0-87.1)	50.6 (33.0-67.0)	14.8 (3.5-23.1)
8	22	2	2	76 (75-76)	NA	53.7 (53.0-54.3)	41.5 (40.0-43.0)	21.8 (18.6-25.0)
8	22	3	2	77 (75-78)	NA	21.0 (13.0-29.0)	12.5 (4.0-21.0)	39.3 (28.6-50.0)
8	22	4	3	76 (72-81)	1.42 (1.34-1.51)	27.7 (15.0-48.0)	17.3 (12.0-26.0)	42.7 (35.7-50.0)
8	22	5	4	70 (61-77)	1.17 (1.12-1.22)	27.2 (20.0-37.0)	15.5 (14.0-17.0)	29.2 (23.5-33.3)

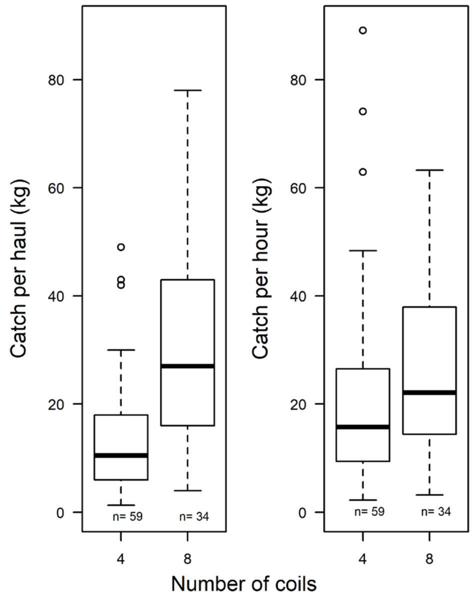

Figure 7. Observed catches per haul (left) and per hour (right) of plaice in experiment 1 "gear characteristics" separated by number of used seine ropes.

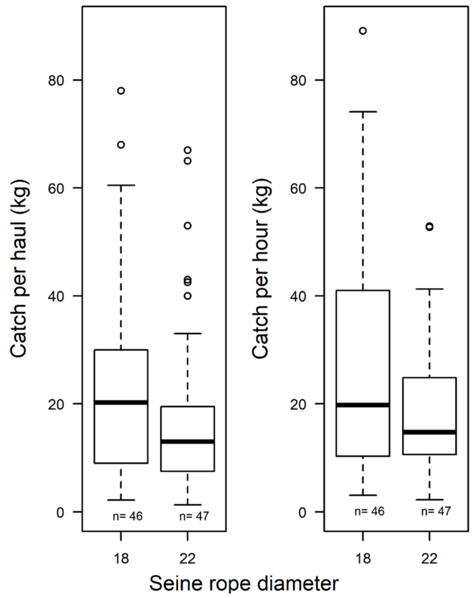

Figure 8. Observed catches per haul (left) and per hour (right) of plaice in experiment 1 "gear characteristics" separated by diameter of seine ropes.

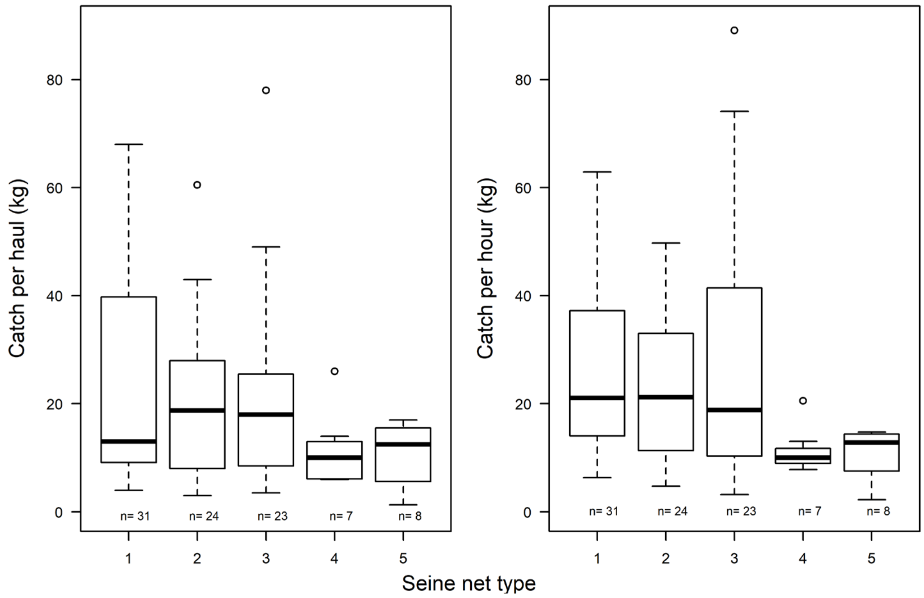

Figure 9. Observed catches per haul (left) and per hour (right) of plaice in experiment 1 "gear characteristics" separated by seine type used.

Table 5. General Linear Mixed model (GLMM) output for catches of plaice (log-transformed) including significance levels (*: p<0.05) from experiment 1 "gear characteristics".

Predictor		Estimate ± SE	Z	p
Intercept		2.972 + 0.163	18.269	<0.001*
Rope_coils				
	8	0.358 + 0.152	2.345	0.019*
Rope_dia				
	22	-0.101 + 0.172	-0.583	0.560
	Seine type			
	2	-0.118 + 0.189	-0.624	0.533
	3	-0.096 + 0.190	-0.506	0.613
	4	-0.656 + 0.301	-2.179	0.029*
	5	-0.872 + 0.282	-3.096	0.002*
Random effect				
	Trip	Variance: 0.009	StdDev. 0.097	

For Experiment 2 ("Layout patterns"), 19 valid hauls were conducted of which 12 were used for catch comparisons (Table 6). As flounder was the dominating species (Table 6) for this experiment, following analyses will focus solely on this species.

The bootstrapped results indicated layout pattern B to give highest catches – especially when looking at CPUE instead of absolute catches (Figure 10). This can be explained by the larger fishing area covered (Table 6). Although the area covered when fishing with pattern C is even larger (Table 6), lower catches than for pattern B show that something else plays an important role in herding the fish (Figure 10). This might be the angle of the seine rope towards the towing directions, which might allow fish to escape during the herding process.

Table 6. Overview – fishing operations: experiment 2 “layout patterns”. Given estimates are mean values including min- and max-values in brackets.

Pattern	Hauls	Covered area [km^2]	Haul duration [min]	Catch_Total [kg]	Catch_Flounder [kg]	MCRS-ratio Flounder [%]
A	5	0.29 (0.24-0.40)	40 (36-46)	23.9 (20.0-37.3)	22.9 (17.2-36.0)	7.5 (2.8-14.6)
B	4	0.49 (0.46-0.53)	53 (49-55)	44.7 (19.4-86.8)	43.4 (17.8-84.0)	8.6 (4.0-12.1)
C	3	0.92 (0.69-1.06)	75 (69-82)	28.3 (20.7-33.2)	27.4 (20.2-32.0)	11.2 (9.4-13.3)

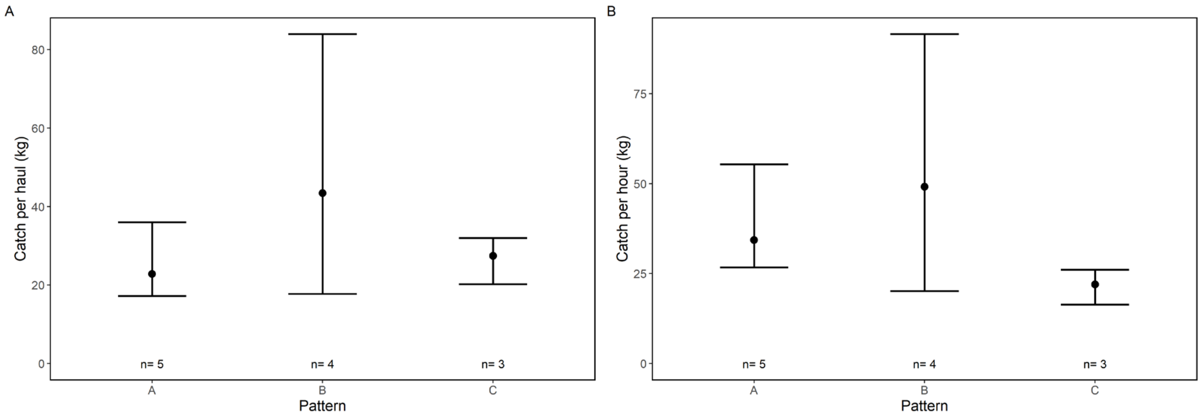

Figure 10. Bootstrapping results (±CI) for catches of flounder per haul (left) and per hour (right) in experiment 2 “layout patterns” separated by fishing pattern.

Contrary to the catching efficiency, the layout pattern did not have any significant effect on the length of the captures fish, as shown by the bootstrapped lengths of flounder (Figure 11).

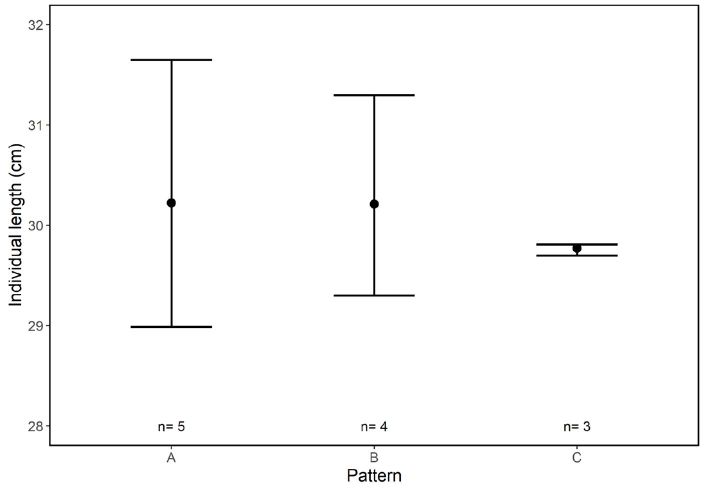

Figure 11. Bootstrapping results (±CI) for mean length of flounder in experiment 2 “layout patterns” separated by fishing pattern.

2.2.2 Trials 2021 in Fehmarn Belt: Retrieval speed, stop-net

The idea for these trials came up after it could be seen in 2020 that the mini-seine system was not capable of fishing sufficiently fast (see 2.1.2). The following trials thus had two main aims: i) identify the effect fishing speed has on catch efficiency of cod and other species, ii) investigate, if a stop-net can prevent catch losses of cod and other species caused by slow retrieval speeds. The idea of the stop-net was to i) stay opened when fishing speeds are high and fish are entering the cod-end and ii) close when fishing speeds are low, so the pathway of fish aiming to escape through the tunnel of the seine net gets blocked (Figure 12).

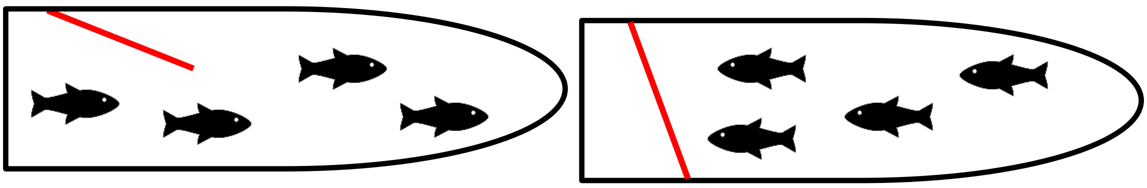

Figure 12. Operating principle of stop-net.

The trials were conducted in January 2021 south of Rødby (Figure 13) as this region is well-known for good catches of cod in this season. The trials were conducted onboard a commercial fishing vessel. The standard fishing behaviour was modified by fishing with different speeds (normal speed and faster) and by using the described stop-net in about 50% of the hauls. The gear used was the same as in the previous trial but limited to 18 mm seine rope.

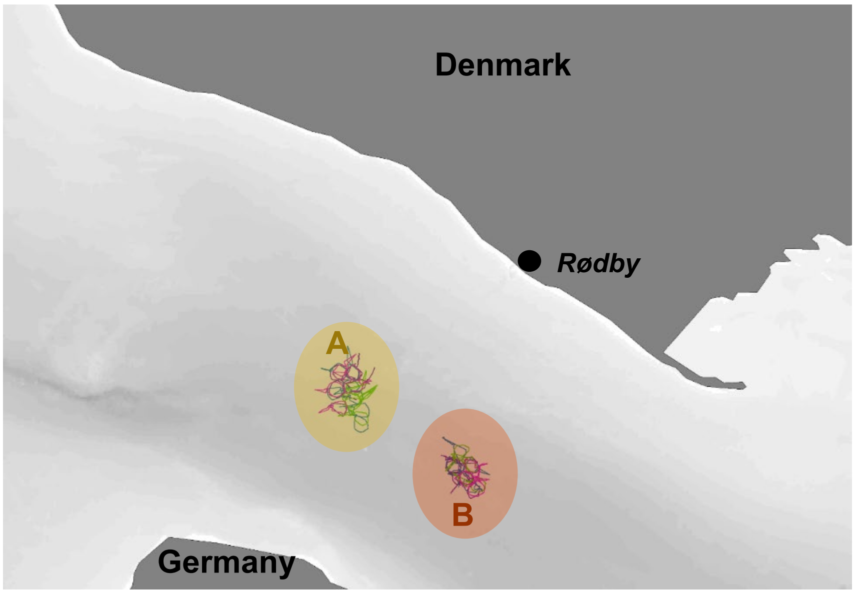

Figure 13. Fishing locations (A: Rødby_north. B: Rødby_south) of "Fehmarn Belt 2021".

In total, 37 valid hauls were conducted, with catches seeming to be higher in the northern area and dab (*Limanda limanda*) being the dominant species, but cod, flounder and plaice also occurring regularly (Table 7).

Table 7. Haul overview – Fehmarn Belt 2021. Given estimates are mean values including min- and max-values in brackets.

Area	Hauls	Haul duration (min)	Catch (kg)				
			Total	Cod	Dab	Flounder	Plaice
Rødby_n	19	41 (37-55)	51 (26-121)	3 (0-13)	18 (6-44)	11 (5-30)	8 (4-17)
Rødby_s	18	40 (35-48)	32 (10-68)	7 (0-38)	7 (1-19)	7 (1-17)	5 (2-10)

A GLMM could not identify significant differences between the total catches when fishing without versus when fishing with stop-net (Figure 14 left). Only catches of dab were significantly higher when fishing with stop-net (Table 8). These observations could further be supported by video observations done inside the seine net. Furthermore, the recordings showed that the stop-net stayed quite opened even though the seine net did not move at all (e.g. in the period when the second seine rope is laid out). A possible explanation for these observations were that the normal fishing was fast enough, thus masks the function of a stop-net or in other words: it makes the use of a stop-net redundant. Therefore, similar trials should be repeated, but instead of higher retrieval speeds, slower retrieval speeds should be tested in combination with the stop-net. To counteract the fact that the net stays very opened, it could be made from sinking material and some weight could be attached to it or it needs to be mounted into the net in a different way.

Contrary to the factor "stop-net", total catches got significantly affected by the factor "retrieval speed", i.e. were significantly smaller when fishing faster (Figure 14). Catches of flounder and plaice were significantly smaller when fishing faster (Table 8). See 2.2.3 for details about actual retrieval speeds of the different trials.

An explanation for lower catches when fishing faster is the limited swimming speed of some species, flatfish in particular, i.e. the fish cannot compete with the speed of the seine rope. Thus, the herding process is negatively affected and the fish can escape from the herding before entering the net. It shows very nicely that not only too slow fishing, but also too fast fishing can negatively affect the catch efficiency of the gear.

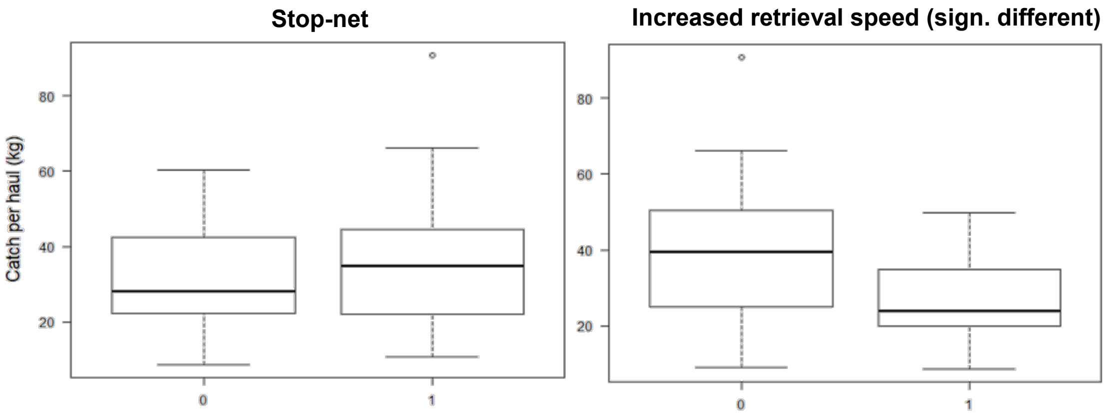

Figure 14. Comparison of average total catch for no stop-net (19 hauls) vs. stop-net (18 hauls) and normal retrieval (20 hauls) vs. fast retrieval (17 hauls).

Table 8. Comparison of average catch of cod, dab, flounder, and plaice for no stop-net (19 hauls) vs. stop-net (18 hauls) and normal retrieval (20 hauls) vs. fast retrieval (17 hauls) included information about significance of differences between values based on GLMM (numbers in grey: model did not converge, numbers normal: not significant, numbers in bold: significantly different).

Factor		Hauls	Catch (kg)			
			Cod	Dab	Flounder	Plaice
Stop-net	Yes	19	6.5	**6.1**	8.8	6.0
	No	18	4.0	**5.7**	9.0	9.3
Speed	Normal	20	5.4	6.8	**10.7**	**9.1**
	Fast	17	5.1	4.8	**6.6**	**5.9**

2.2.3 Trials 2021: Retrieval speed and stop-net around Bornholm

This experiment can be considered as a follow-up of the experiment described in 2.2.2. As i) it could be identified that the performance of the stop-net could not be assessed for the fishing speeds used in the experiment, and ii) it could be shown that also too high fishing speeds could affect catch efficiency negatively, the aim of this experiment was thus to investigate the catch efficiency when fishing slower than normal and to assess the stopnet´s performance under slow conditions. The gear used was the same as in the previous trial.

These trials were conducted in autumn 2021 again on-board a commercial fishing vessel, but this time in the waters around Bornholm (Figure 15). Additionally to the trials in Fehmarn Belt, two 150 m long gillnets, each consisting of 3 panels (height: 1.5 m, mesh opening: 130 mm) were used. This allowed to finally provide a fair comparison of a seining system and gillnets. The results of this sub study are shown in 2.3.

The experimental setup was similar to the one in the Fehmarn Belt trials, but instead of fishing faster than normal, the retrieval speed was reduced as far down as the engine of the vessel allowed for. Furthermore, a lot of focus was put on the improvement of the stop-net. Those could be verified by the use of underwater cameras assessing the stop-net´s performance followed by immediate modifications to it.

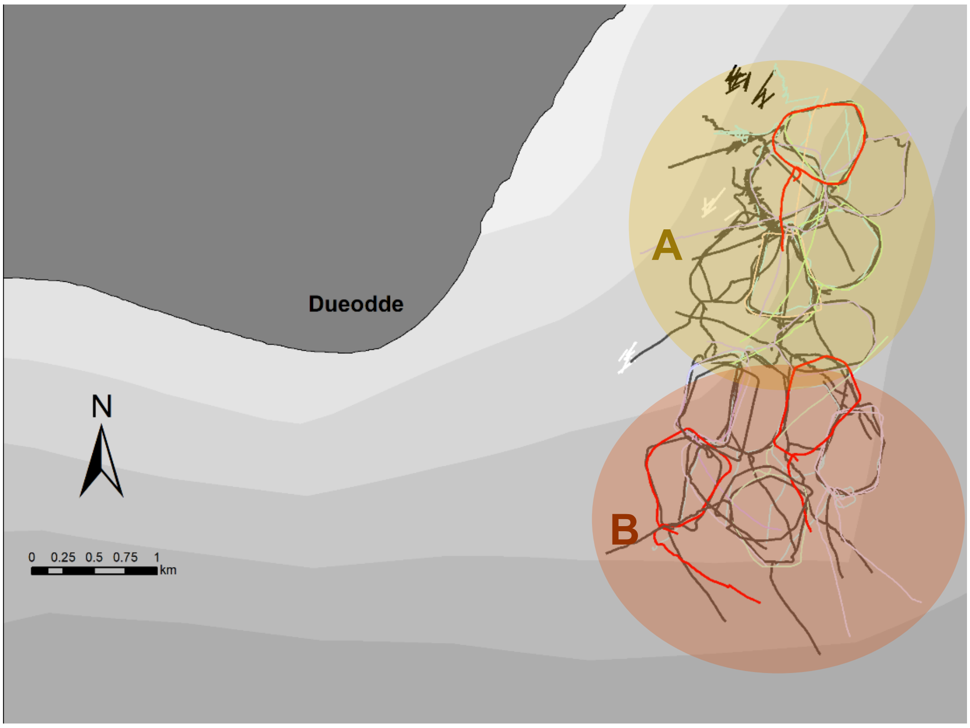

Figure 15. Fishing locations of "Bornholm 2021" (round shapes: sein hauls [grey: no stop-net, other colors: stop-net in different modification stages, red: final stop-net]; short lines: gillnet [white: close to seine, black: control location with proper gillnetting conditions]). Letters indicate separate locations (A: mid, B: south).

In total 44 valid hauls were conducted within this experiment, where flounder dominated the usually low catches (Table 9). The hauls were rather similar distributed over the two fishing locations "mid" and "south" (Table 9).

Table 9. Haul overview_seine – Bornholm 2021. Given estimates are mean values including min- and max-values in brackets.

Location	Stop-net	Speed	Hauls	Haul duration (min)	Total catch (kg)	Catch_Flounder (kg)
mid	No	normal	6	38 (34-41)	5.3 (1.6-10.9)	1.7 (0.3-2.2)
mid	No	slow	5	55 (40-61)	10.8 (1.2-29.1)	2.8 (0.5-4.2)
mid	yes	normal	5	46 (38-58)	7.5 (3.2-10.8)	3.1 (1.8-5.2)
mid	yes	slow	6	61 (58-64)	23.0 (5.9-65.7)	5.4 (2.5-8.4)
south	No	normal	6	39 (38-40)	16.0 (10-21.1)	12.8 (7.5-18.2)
south	No	slow	6	52 (43-63)	24.8 (7.0-66.5)	17.9 (4.5-63.5)
south	yes	normal	3	39 (37-42)	31.0 (27.7-36.7)	25.4 (19.1-29.3)
south	yes	slow	7	57 (49-65)	37.6 (17.5-62.2)	31.2 (12.9-56.0)

Total catches were significantly larger in the location “mid” (indicated by Figure 16 and proven by GLMM). That was also the case for the catches of flounder (indicated by Figure 18 and proven by GLM) and seemed to be also the case for plaice (Figure 19), but the model did not converge for this species. For cod and turbot, catches seemed to be higher in the location “south” (Figure 17 and Figure 20, respectively), but the GLMM did not converge for any of the two. These results are valid regardless of the value to look at – (absolute) catch per haul or (relative) catch per hour.

A safe explanation for this pattern cannot be delivered, but preferable environmental conditions for the different species are likely to be the reason.

In terms of retrieval speed, the total catches per haul were significantly higher when fishing slow (indicated by Figure 21 and proven by GLMM). After translating the values to CPUE (catch per hour), the differences are not significant any longer. This is also the case for most single species considered (cod: Figure 22, flounder: Figure 23, plaice: Figure 24). Only turbot seemed to still show higher values when fishing slow and looking at CPUE (Figure 25). As the GLMM converged only for flounder, distinct conclusions cannot be drawn here for the other species.

The surprising result that catches are not negatively affected when fishing slow as observed earlier (see 3.1.2) might be explained by the fact that the slow speed used within the present experiment was still faster than the speed used in the previous study with the actual mini-seine system (Table 10) and is still close to the fishing speed of 3 knots recommended for trawling. As the processes of trawling and demersal seining differ from each other, fishing slightly slower might even be beneficial (as shown by the present results). The retrieval speed summary shows further that a smaller and lighter seine can slightly increase the maximum retrieval speed, but only on a nearly negligible level.

The much more suitable way of counteracting the problem of slow retrieval speeds is the use of a stop-net as described above. Within these trials the average total catches (Figure 26) and catches of single species (Figure 27-30) were higher when fishing with stop-net in any case. Using a GLMM, significance could be shown for the total catch and the catch of only flounder. For the other species, the model did not converge.

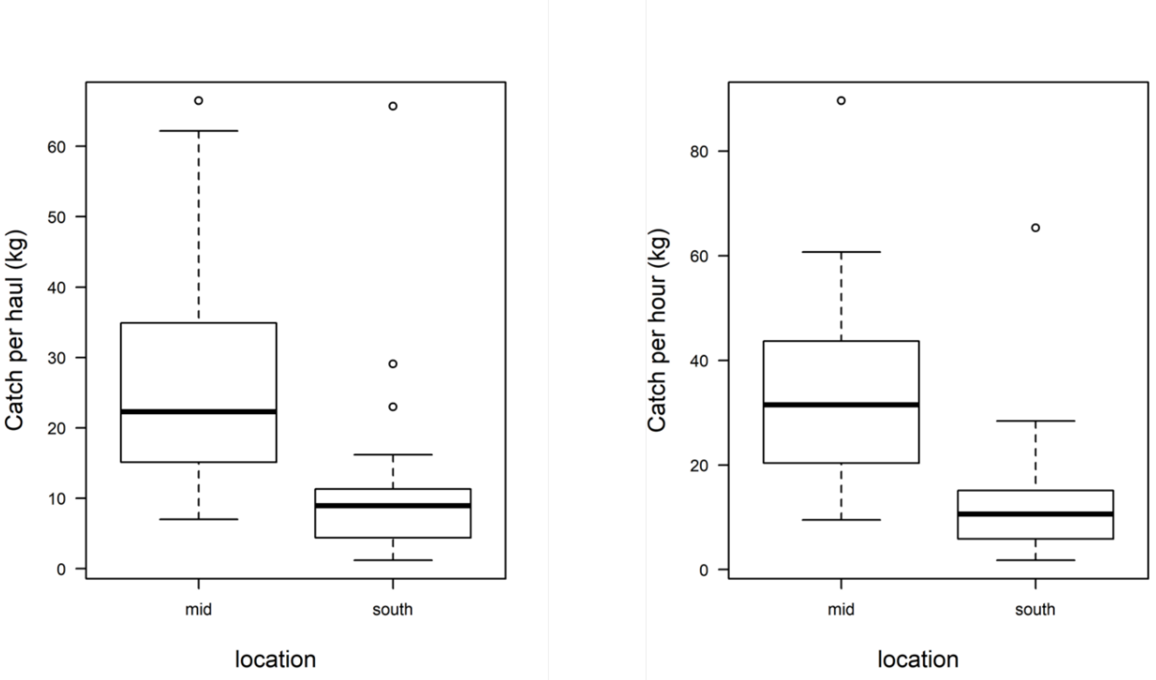

Figure 16. Comparison of average catch per haul and catch per hour – location: total catch (Bornholm 2021).

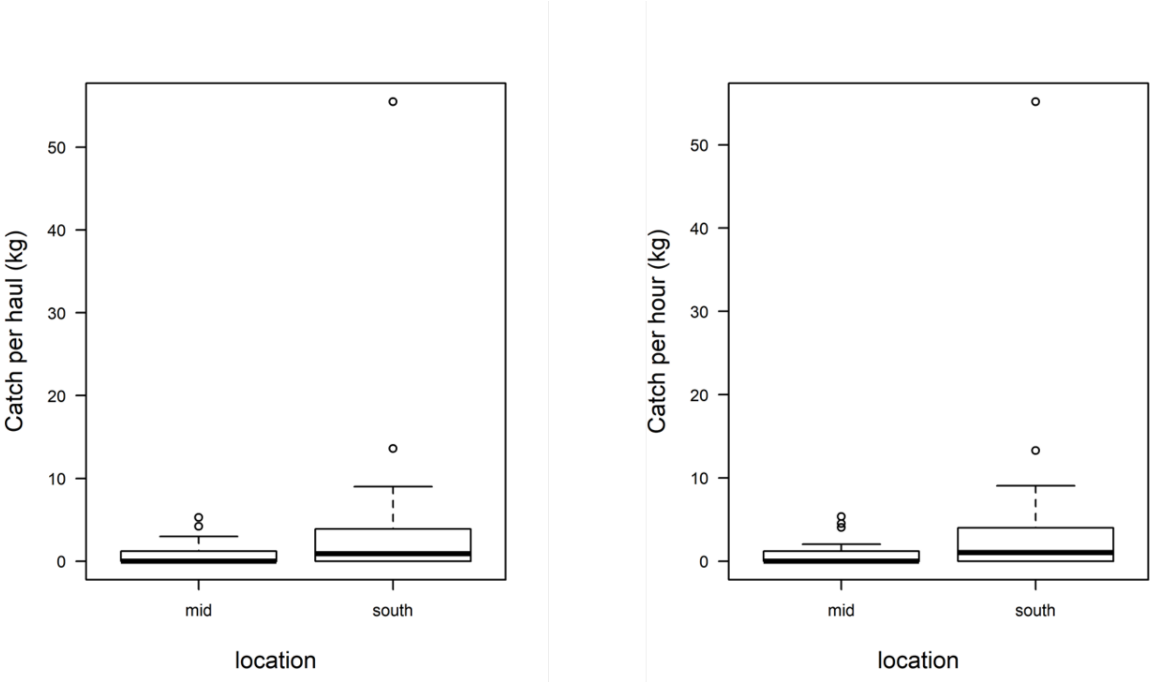

Figure 17 Comparison of average catch per haul and catch per hour – location: cod (Bornholm 2021).

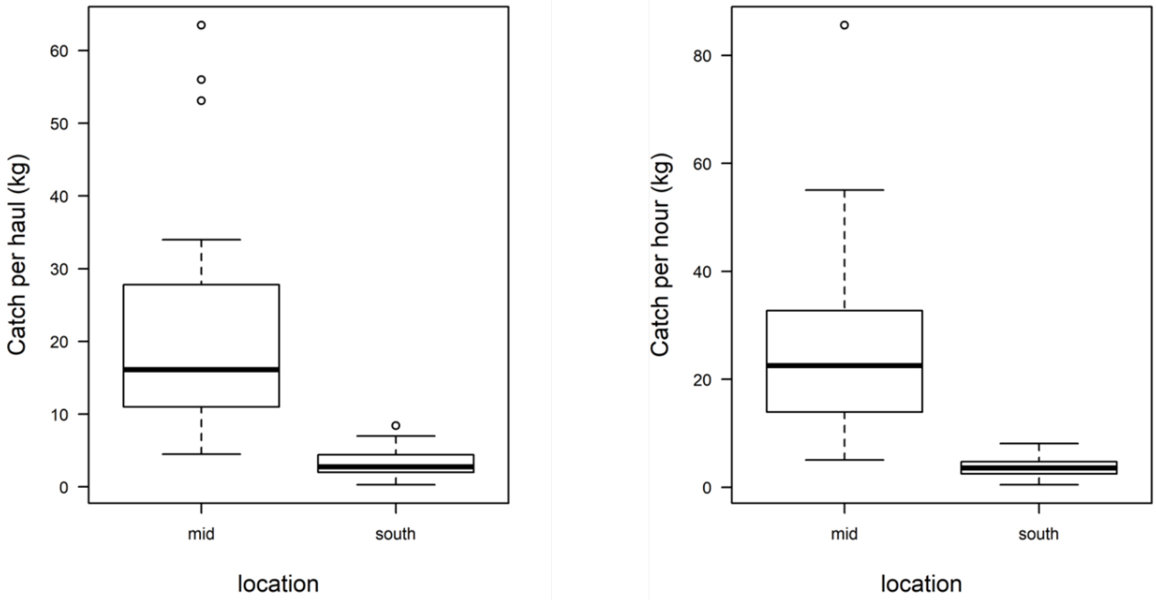

Figure 18. Comparison of average catch per haul and catch per hour – location: flounder (Bornholm 2021).

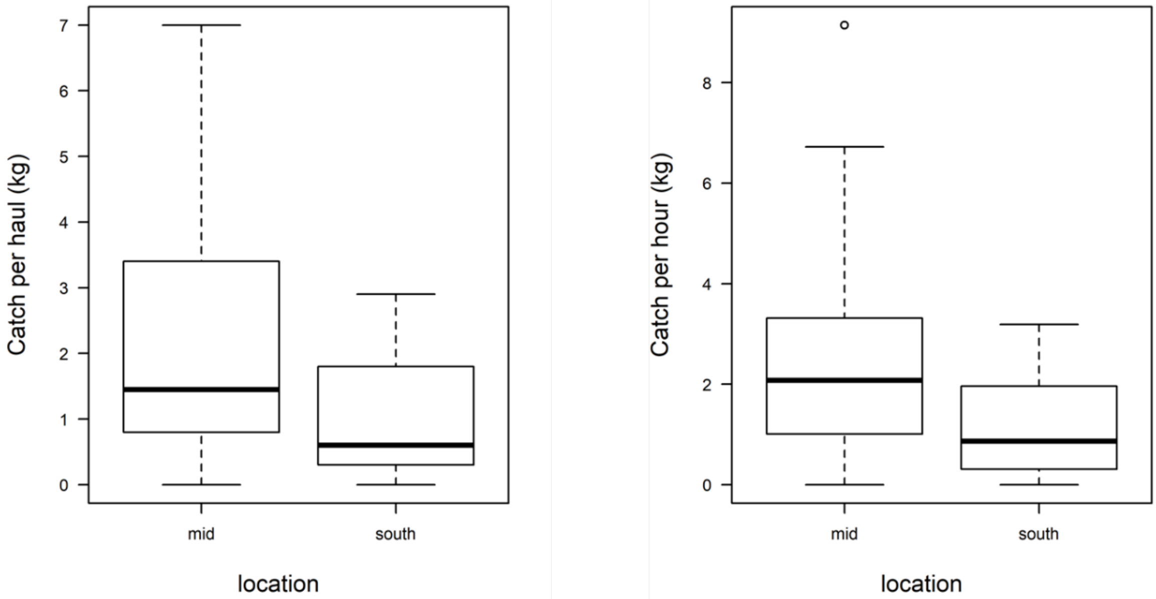

Figure 19. Comparison of average catch per haul and catch per hour – location: plaice (Bornholm 2021).

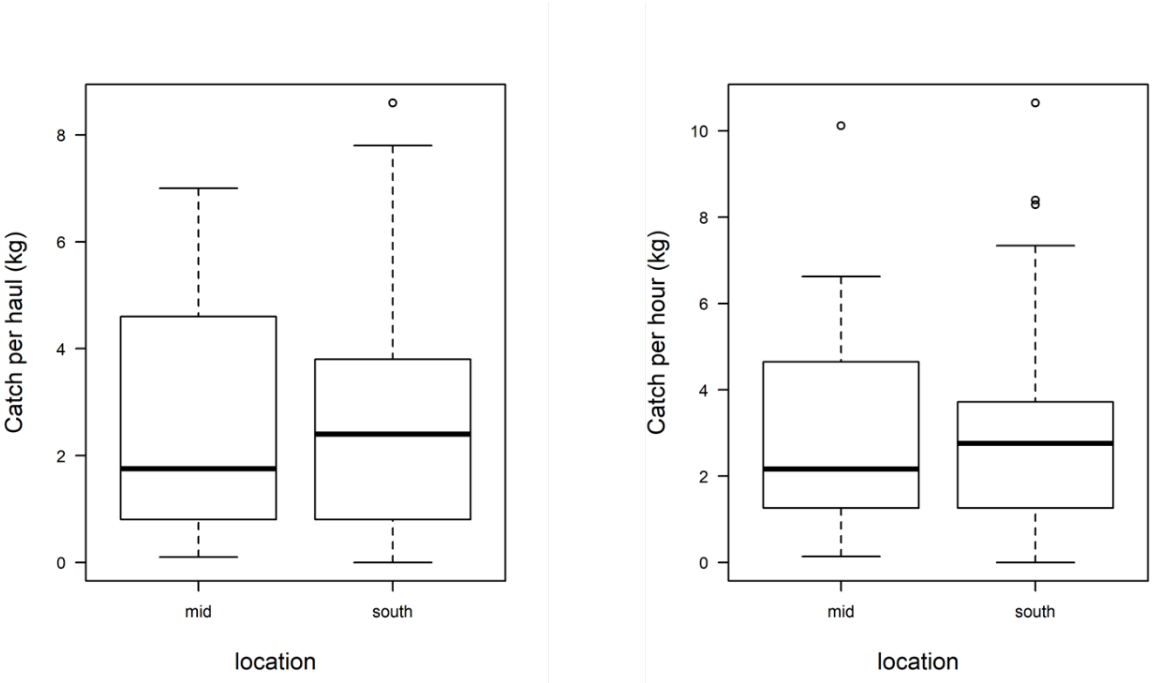

Figure 20. Comparison of average catch per haul and catch per hour – location: turbot (Bornholm 2021).

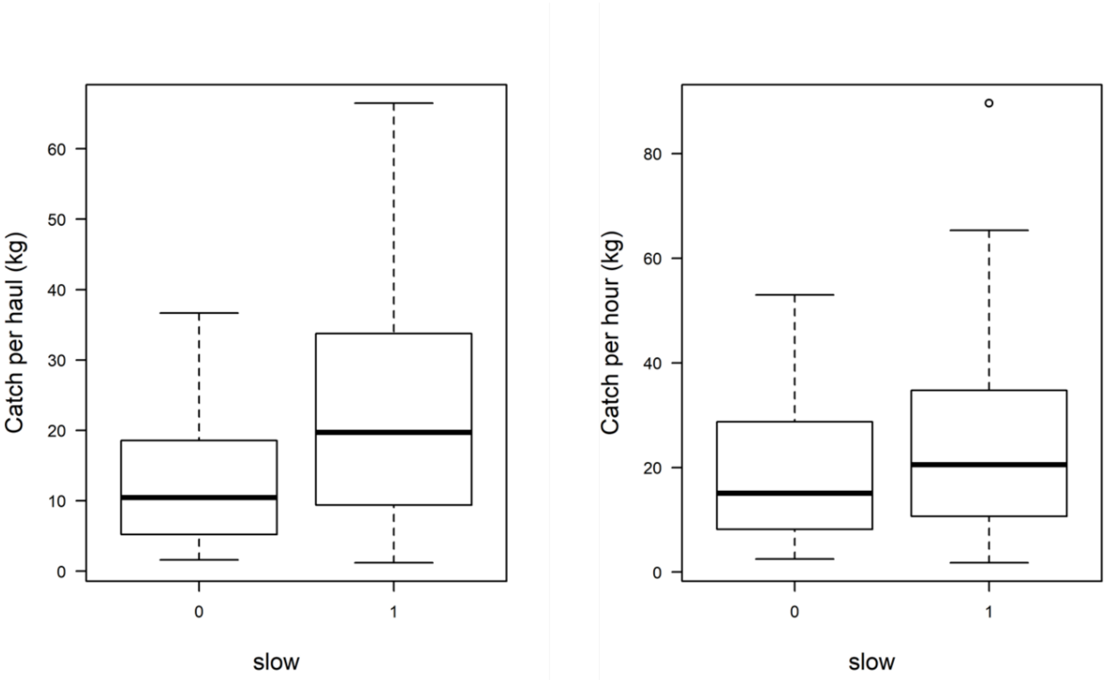

Figure 21. Comparison of average catch per haul and catch per hour – speed: total catch (Bornholm 2021).

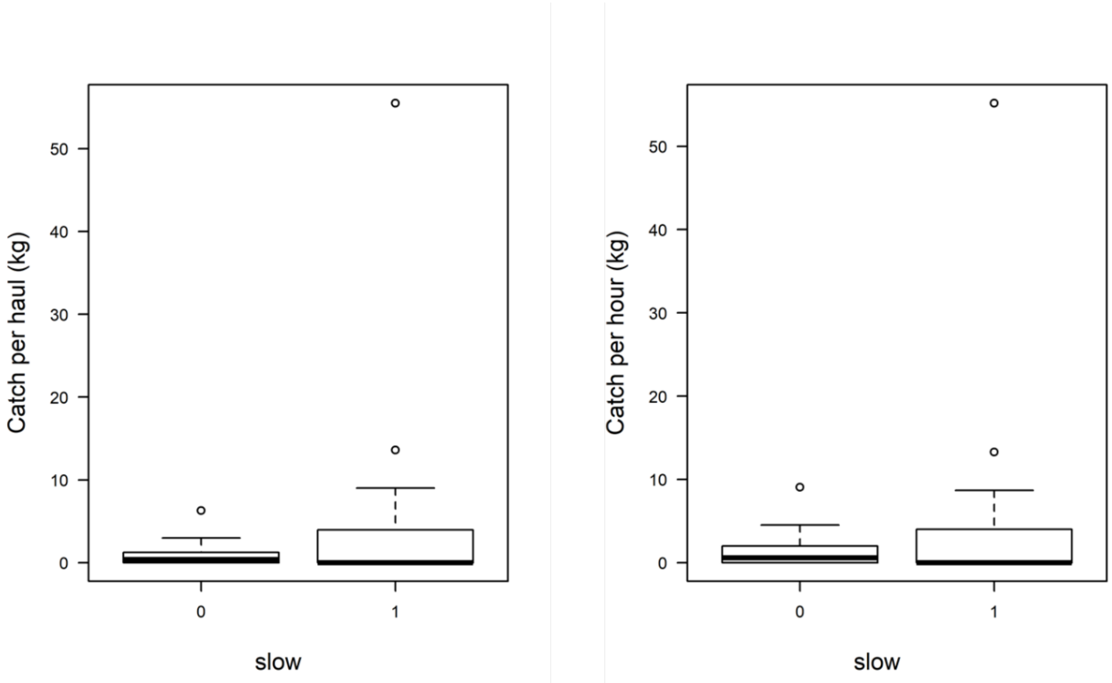

Figure 22. Comparison of average catch per haul and catch per hour – speed: cod (Bornholm 2021).

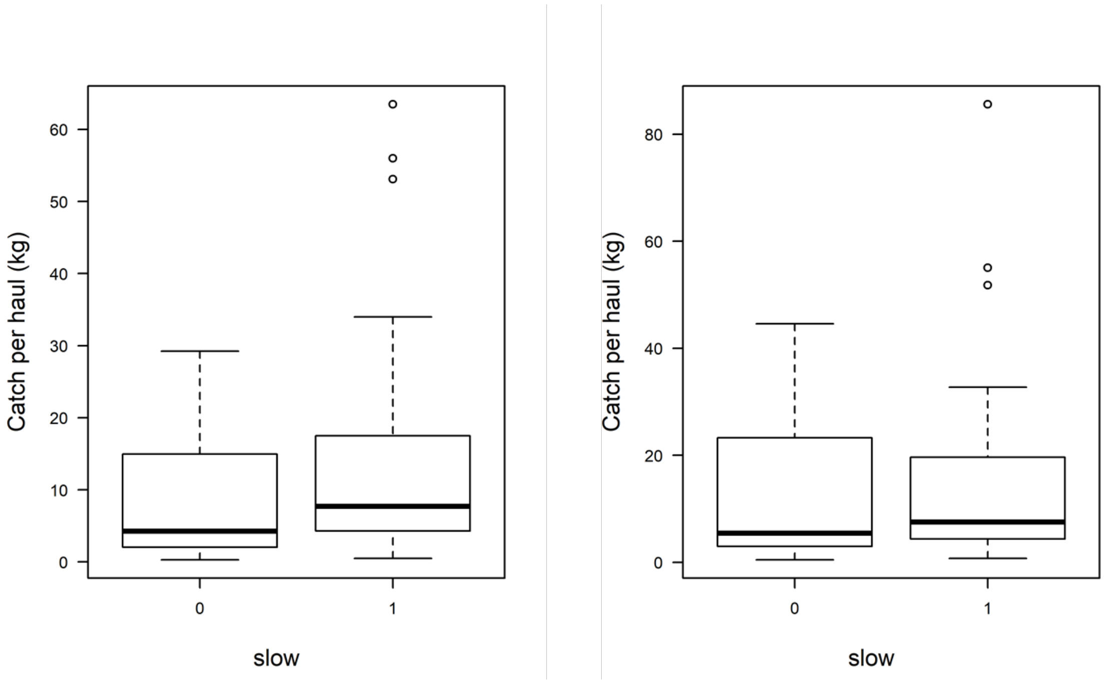

Figure 23. Comparison of average catch per haul and catch per hour – speed: flounder (Bornholm 2021).

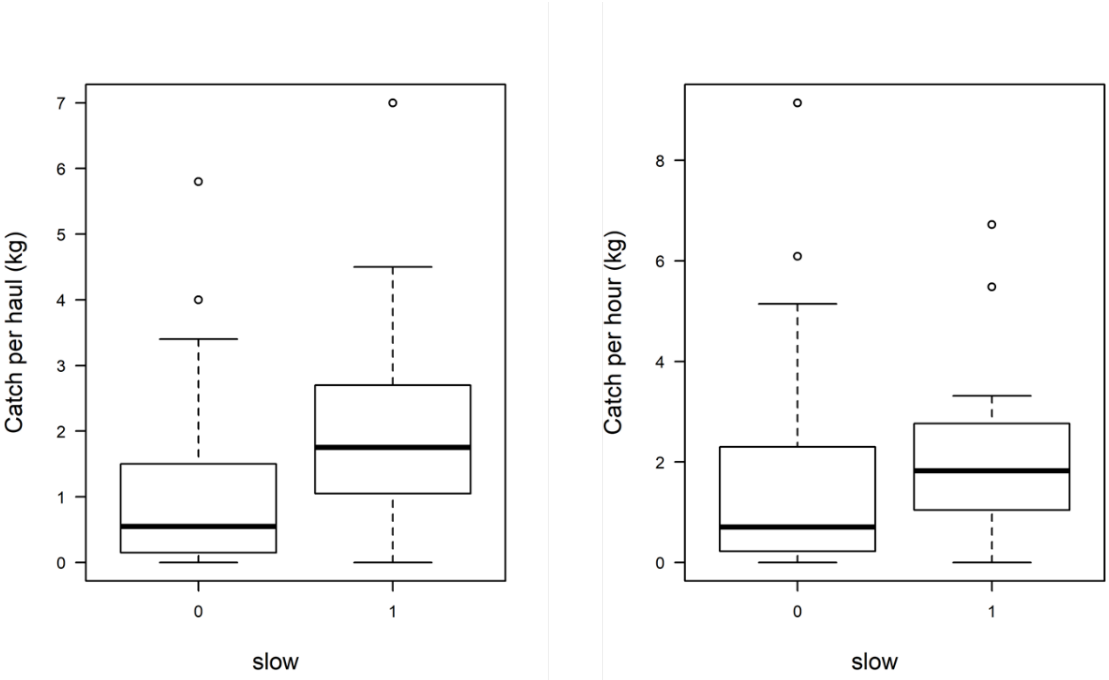

Figure 24. Comparison of average catch per haul and catch per hour – speed: plaice (Bornholm 2021).

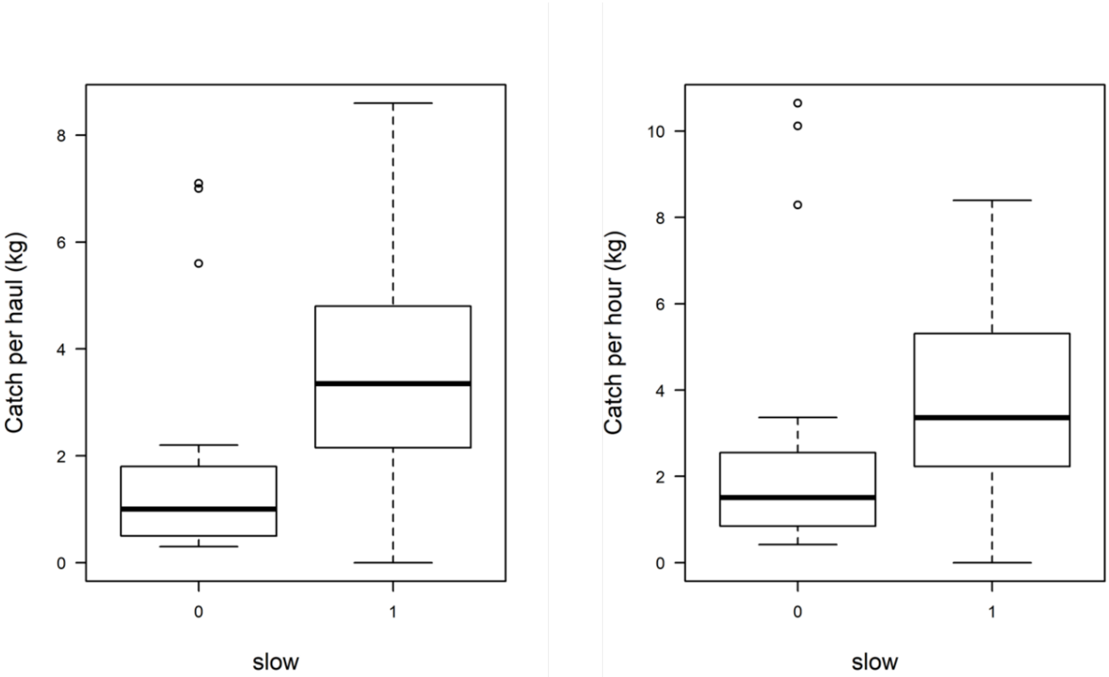

Figure 25. Comparison of average catch per haul and catch per hour – speed: turbot (Bornholm 2021).

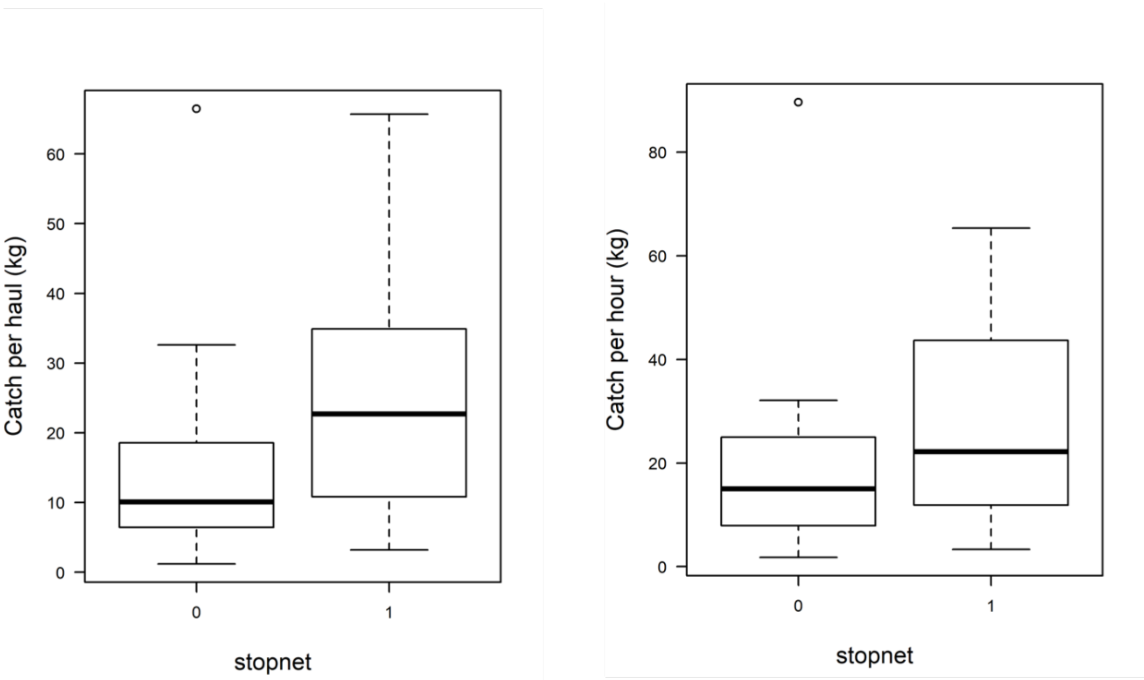

Figure 26. Comparison of average catch per haul and catch per hour – stop-net: total catch (Bornholm 2021).

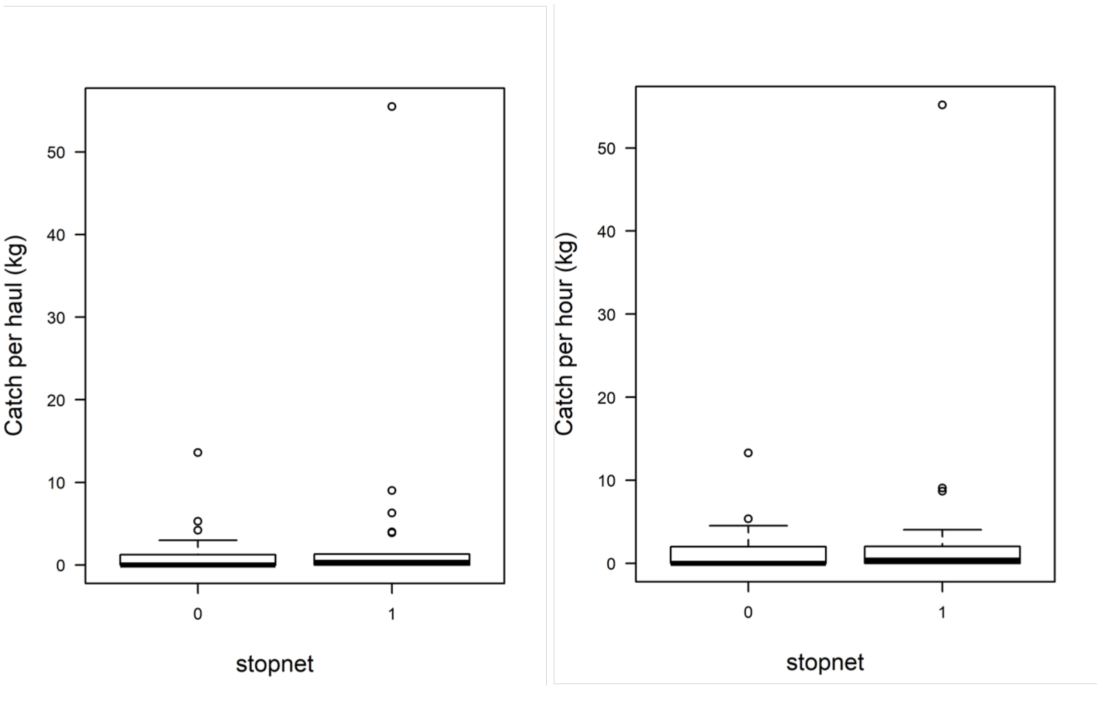

Figure 27. Comparison of average catch per haul and catch per hour – stop-net: cod (Bornholm 2021).

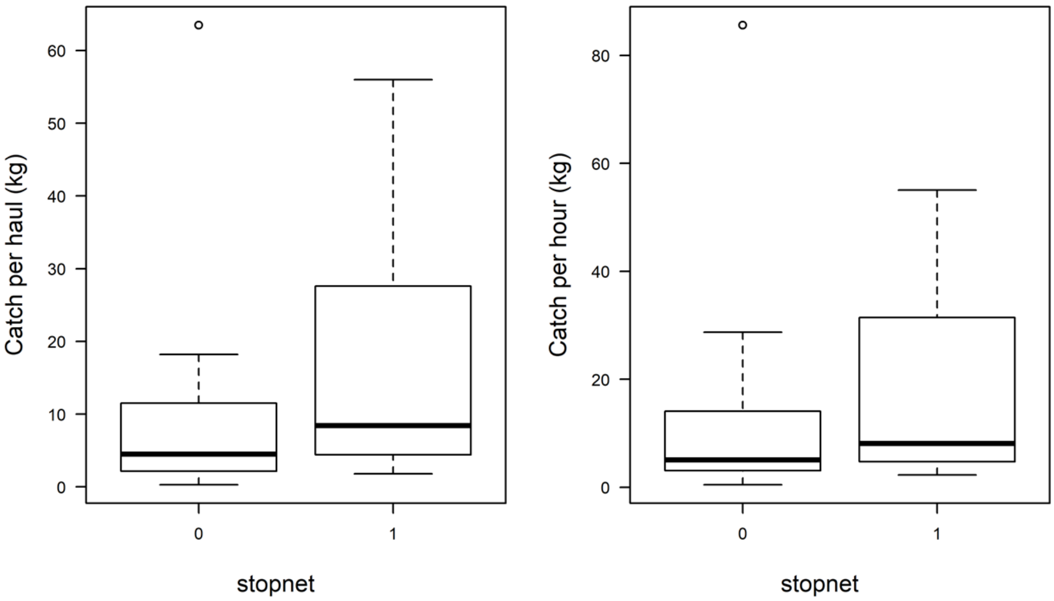

Figure 28. Comparison of average catch per haul and catch per hour – stop-net: flounder (Bornholm 2021).

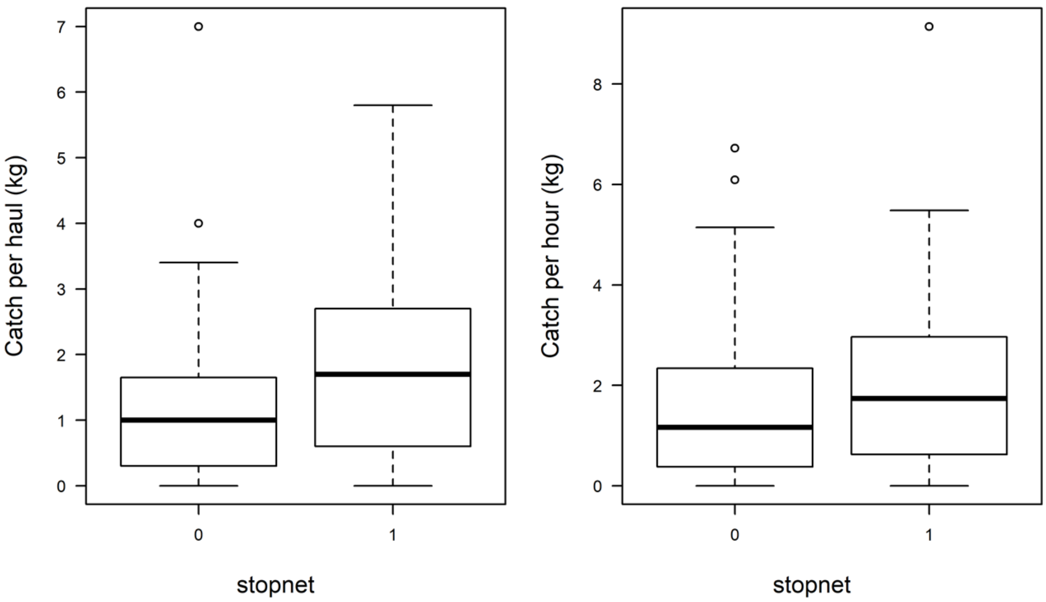

Figure 29. Comparison of average catch per haul and catch per hour – stop-net: plaice (Bornholm 2021).

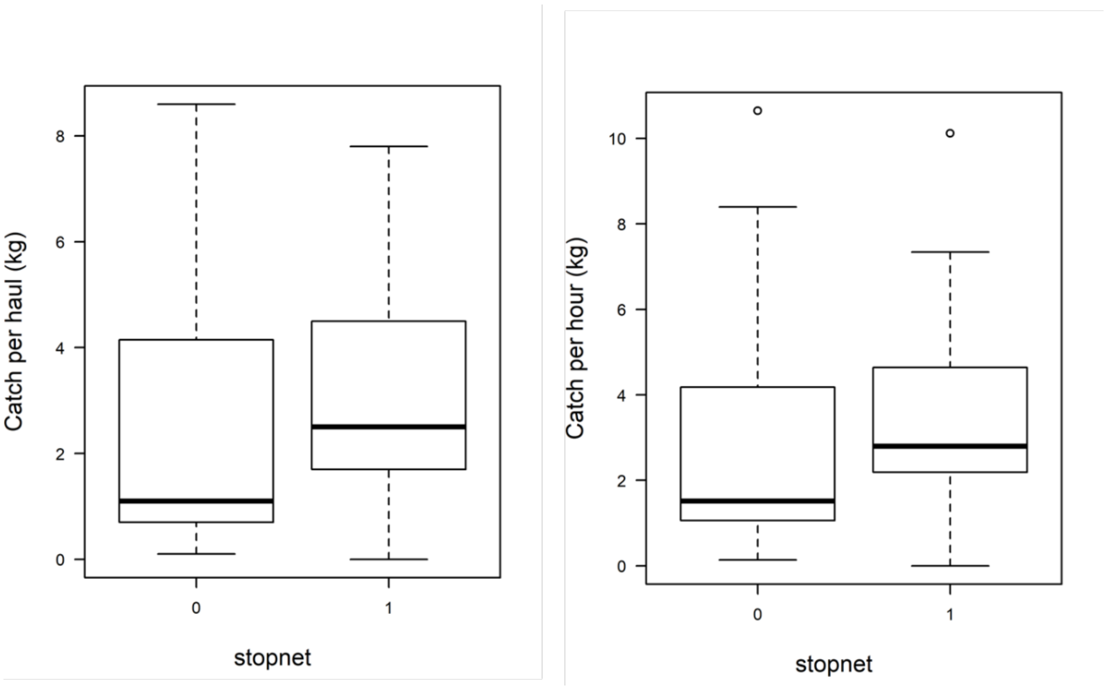

Figure 30. Comparison of average catch per haul and catch per hour – stop-net: turbot (Bornholm 2021).

Table 10. Overview of retrieval speeds (in m/s and knots). Speed for coil 1 of mini-seine is 0 because system used only 3 coils of seine rope, (red=low speed, yellow= medium speed, green= high speed).

	coil			
in m/s	**1**	**2**	**3**	**4**
Mini-seine				
normal	0.0	0.7	0.8	0.8
Rødby 2021				
normal	1.2	1.1	1.5	1.6
fast	1.3	1.3	1.6	1.8
Bornholm 2021				
normal	0.9	1.0	1.4	1.7
slow	0.6	0.7	0.9	1.3

	coil			
in knots	1	2	3	4
Mini-seine				
normal	0.0	1.4	1.5	1.6
Rødby 2021				
normal	2.3	2.2	2.8	3.1
fast	2.5	2.4	3.1	3.4
Bornholm 2021				
normal	1.8	2.0	2.6	3.3
slow	1.2	1.3	1.8	2.5

Average lengths of fish seem larger in location “south” (Table 11), which might be because that location is less protected, i.e. juvenile fish stick more to the more protected location “mid”. A GLMM assessing the effects of the parameters on the average fish length converged only for flounder, identifying speed as significant factor (even though differences are rather small; Table 11). For the other species the model did not converge.

Table 11. Average length (cm) of different species, separated by fishing location, retrieval speed and use of stop-net.

Factor	Cod	Flounder	Plaice	Turbot
Location				
mid	31.3 (25-40)	28.8 (14-40)	27.7 (22-41)	24.1 (19-41)
south	37.9 (23-52)	28.6 (22-45)	28.8 (21-35)	26.7 (17-38)
Speed				
Normal	34.4 (25-52)	28.4 (15-38)	28.3 (22-36)	25.2 (17-36)
Slow	36.9 (23-46)	28.9 (14-45)	27.9 (21-41)	25.5 (19-41)
Stop-net				
no	34 (23-52)	28.9 (14-45)	29.2 (23-37)	26.2 (18-38)
yes	37.7 (27-50)	28.7 (15-39)	27.3 (21-41)	24.8 (17-41)

2.3 Comparison of demersal seine and gillnet around Bornholm

In order to compare seine and gillnet, two 150 m long gillnets, each consisting of 3 panels (height: 1.5 m, mesh opening: 130 mm) were used additionally to the experiment described in 2.2.3. The nets were placed at a proper gillnetting location in order to provide realistic catch numbers, but also close to where the seining took place in order to fish on the same populations (Figure 15). The nets were retrieved every morning before the seine hauls took place and again in the evening before going back to port. In total, each net was set and retrieved 16 times (Table 12).

Table 12. Set overview gillnet – Bornholm 2021. Value given as average value and Min-Max in brackets.

Period	Location	Hauls	Soak time (min)	Total catch (kg)	Catch Flounder (kg)
day	**coastal**	8	443 (319-574)	2.1 (0.6-4.0)	2.0 (2.0-4.0)
day	**mid**	4	430 (344-497)	1.4 (0.7-2.2)	1.3 (1.3-2.0)
day	**south**	4	346 (271-414)	0.7 (0.6-0.9)	0.5 (0.5-0.9)
night	**coastal**	8	1136 (869-2291)	9.4 (4.2-15.1)	9.1 (9.1-14.3)
night	**mid**	4	1031 (907-1172)	3.1 (1.2-5.5)	2.8 (2.8-5.0)
night	**south**	4	1029 (970-1097)	1.1 (0.7-1.8)	0.7 (0.7-0.9)

In the following comparison between the two gears, both gillnets will be treated separately as catches differed significantly. Furthermore, the catches from day and night got merged as gillnets are usually retrieved only once per day instead of two times. In order to lift the values up to comparable values, the values form gillnets were raised by 26.67 as 80 nets can be handled by one person per day (but we used only 3). Likewise, the average catch per seine haul needed to be raised to represent a catch per day value. Here, the values were raised by 6 as six hauls can easily be conducted per day. This procedure of raising the values is in line with the previous project.

In general, the catches during the experimental phase were low (Figure 32). The total raised catches were highest for the coastal and lowest for gillnet used close to the seine fishing locations. The raised seine fishing was in between. As it can be seen for the single species, this outcome bases on the values for flounder, a species with very low commercial value. The raised catches of turbot and plaice were highest for seine, while raised catches of cod were very low for all. The differences between the coastal gillnet and gillnet not used under optimal conditions shows how important the right location is for proper gillnetting.

In summery the seine seems to be more suitable for catching the more valuable species turbot and plaice but catches of flounder are smaller. However, such trials should be repeated when there is more fish in the area as gillnets might for instance experience a saturation stage, which is unlikely to reach for the seine.

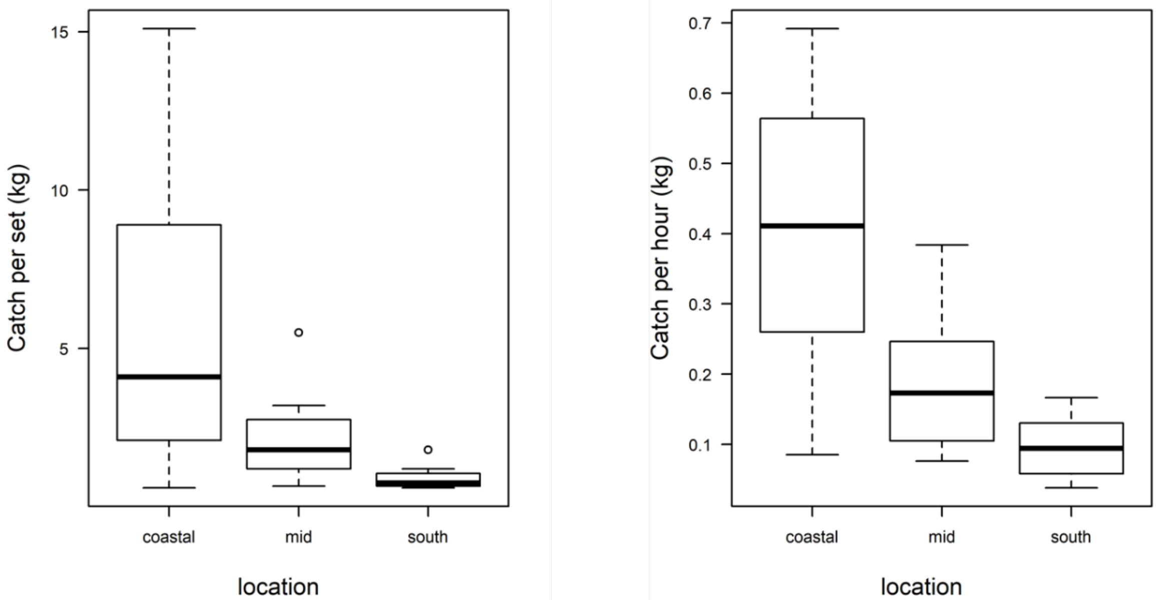

Figure 31. Average total catch per set and catch per hour for gillnets depending on location (Bornholm 2021).

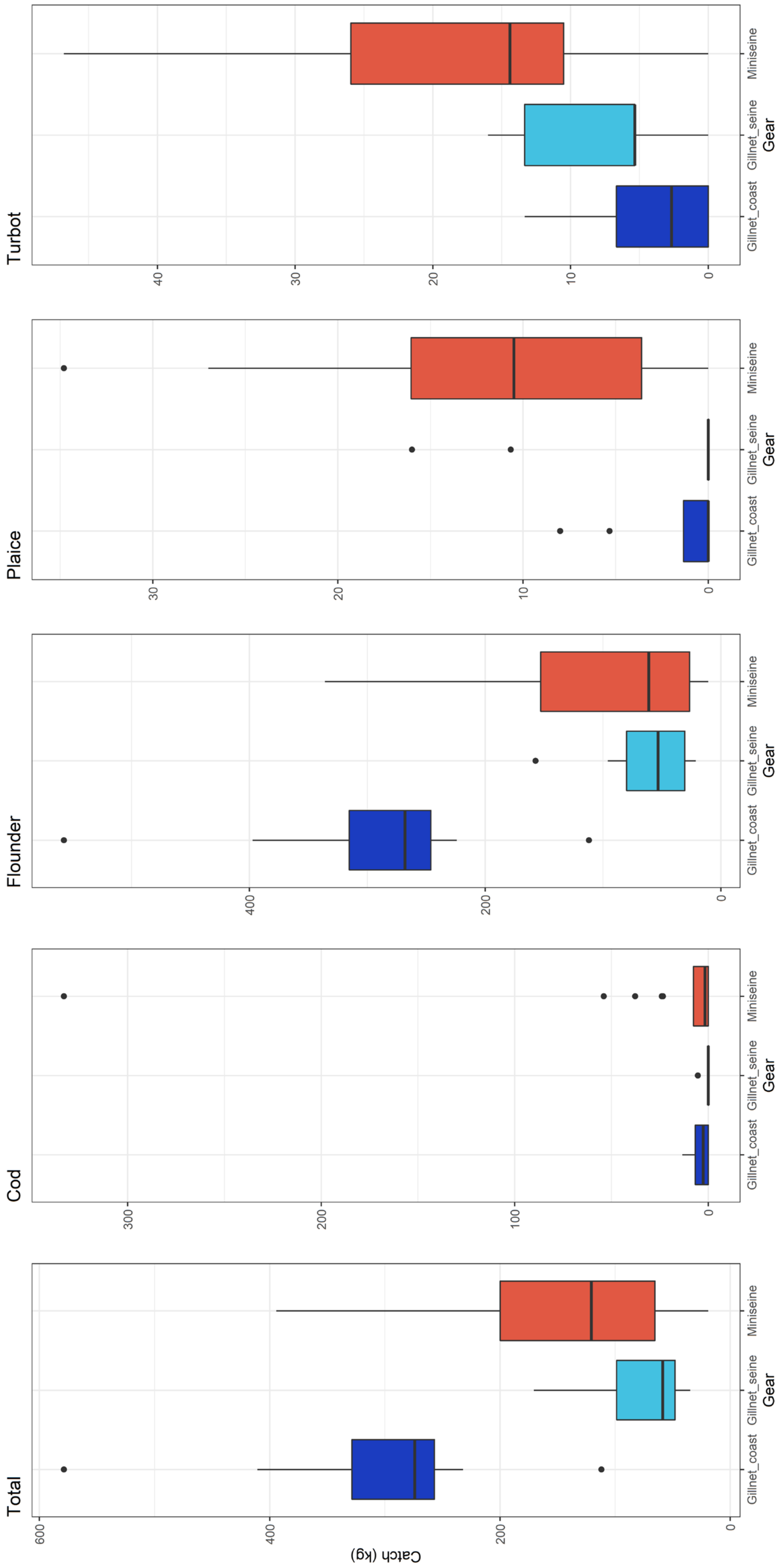

Figure 32. Comparison of raised daily catches for gillnet (80 nets á 50 m) and seine 6 hauls) based on catch data from trials “Bornholm 2021”.

3. Optimisation of the Pontoon-trap

The aim of this work package was to solve the problems that had been identified in earlier trials with the trap and to increase the catch efficiency of cod. The problems were mainly related to the stability and durability of the trap, both when standing on the seabed and when standing on the surface while being emptied of the catch. Earlier trials had been conducted in shallow waters, where the trap was more exposed to wave action, and it was thought that fishing in deeper waters would lessen this problem. However, there was very limited interest from Danish fishermen in the trap. The only fisherman interested in conducting trials with the Pontoon-trap was based on Bornholm, so it was decided to move the trap to Bornholm and conduct the trials there.

3.1 Description of the Pontoon-trap

The Pontoon-trap includes a fish house, a 12 m long connector (Danish: mundstykke), two catching arms and a lead net (Danish: rad), which is 3 m high and 100 m long (). The frame of the fish house was made from aluminium tubing and covered in strong net material, in our case Euroline Premium Plus® (45 mm square mesh, twine 1.3 mm). The fish house was 5 m long and 2.4 m high. The fish house stood on two pontoons that could be inflated using a small compressor. There was a smaller pontoon attached to the top of the fish house to increase stability while submerged. When the air is bled from the two main pontoons, the fish house will sink to the bottom and stand on the pontoons while fishing. When air is blown into the pontoons again, the fish house will rise to the surface and can be emptied of the catch (Figure 34).

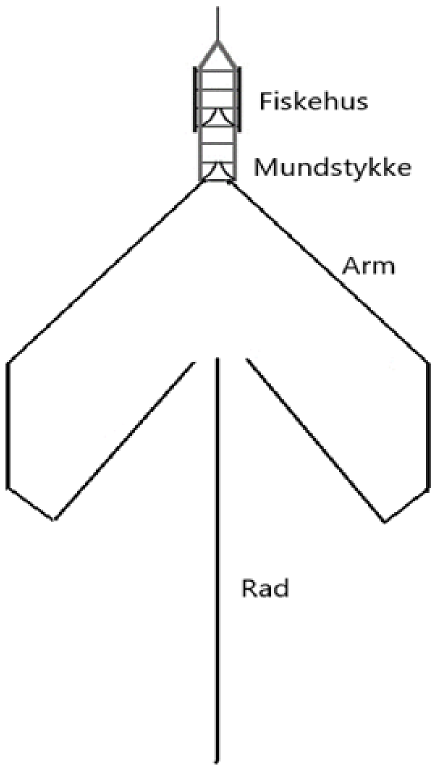

Figure 33. Schematic plan of the Pontoon-trap.

Figure 34. The Pontoon-trap on the surface while the catch is being emptied into the dinghy.

3.2 Trial at Bornholm

The trial was conducted in from 14 June to 1 July 2019 in collaboration with a local fisherman from Svaneke. The Swedish Agricultural University and an experienced Swedish fisherman provided advice and assistance in setting up the Pontoon-trap. The trap was deployed 3.4 nm southeast of Nexø at a depth of approx. 25 m. Because of the greater depth, the connector was increased by 10 m. An extra pontoon was added to the top of the fish house to increase stability, and 30 kg of ballast was added to the back end of the fish house to keep the fish house more level during emptying. The greater depth also required a stronger compressor to blow up the pontoons fully.

The trap fished a total of 54 days and was emptied 10 times during the trial. The catches are shown in Table 13. Catches included cod, flounder, plaice, whiting and turbot, with flounders dominating both in numbers and weight.

Table 13. Total catches by the Pontoon-trap at Bornholm in numbers and weight over and under the minimum landing size (MLS) for each species.

Species	Numbers > MLS	Numbers < MLS	Total weight > MLS (kg)	Total weight < MLS (kg)
Cod	89	33	56,8	10,3
Flounder	384	188	89,5	33
Plaice	19	36	6,2	6,3
Whiting		1		0,2
Turbot		1		0,3

With a daily catch of just above 1 kg of cod above MLS it is clear that the Pontoon-trap is not catching enough cod to be an alternative to gillnets or fish pots. The catches of flounder and other flatfish species are not enough to outweigh this.

The trial at Bornholm also revealed that the trap did not work well in areas with strong currents, which unfortunately are also the areas where most cod occur. Being made from aluminium tubing, the frame of the trap is not sufficiently strong to withstand the impact of the environment, particularly the currents. During the trial, the frame developed several cracks in the tubing and in one case one of the aluminium tubes broke completely.

There was also an almost complete lack of interest from Danish fishermen in trialling the trap, and with the meagre catches not helping the interest, it was decided to terminate further trials of the Pontoon-trap.

4. Pot fishing

Fish pots have been commercial used for a long time in different regions of the world. Most models, however, are not seal-proof, i.e. seals can reach the fish captured in the pots. In this project the participating fishers and DTU staff thus agreed on a seal-safe design which was based on former projects between DTU Aqua and Sweden (see Figure 35 for final design). The next step was to get information about catch rates over the year under various conditons and hear, what the fishers' opinions were on the pots.

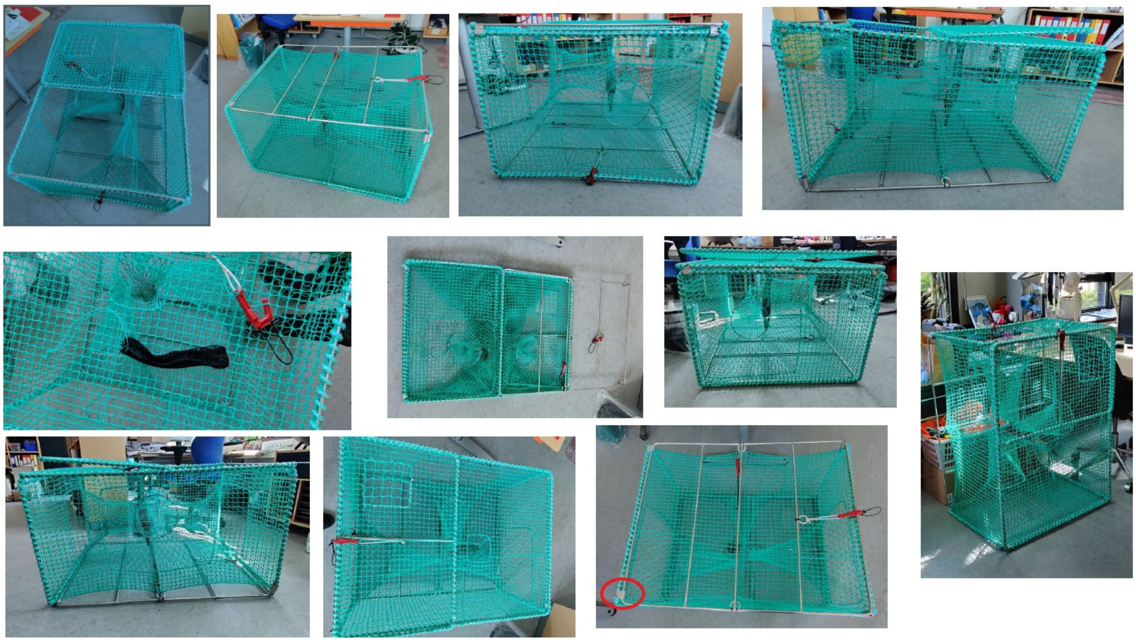

Figure 34. Final design of fish pots used in the project.

4.1 Handling and uptake by the fishery

To get the information about the fishers' opinions and investigate catch rates of the pots, 8 fishers from different places of Denmark were given 10 pots (Figure 36). The fishers did not have to any distinct sampling protocol, but the idea was for them to use them as they would in a commercially fishery in order to maximise catches and simulate natural conditions. The only two requirements were that they had to stick to official rules, and they should report data on location, time, date, bait type and obtained catches.

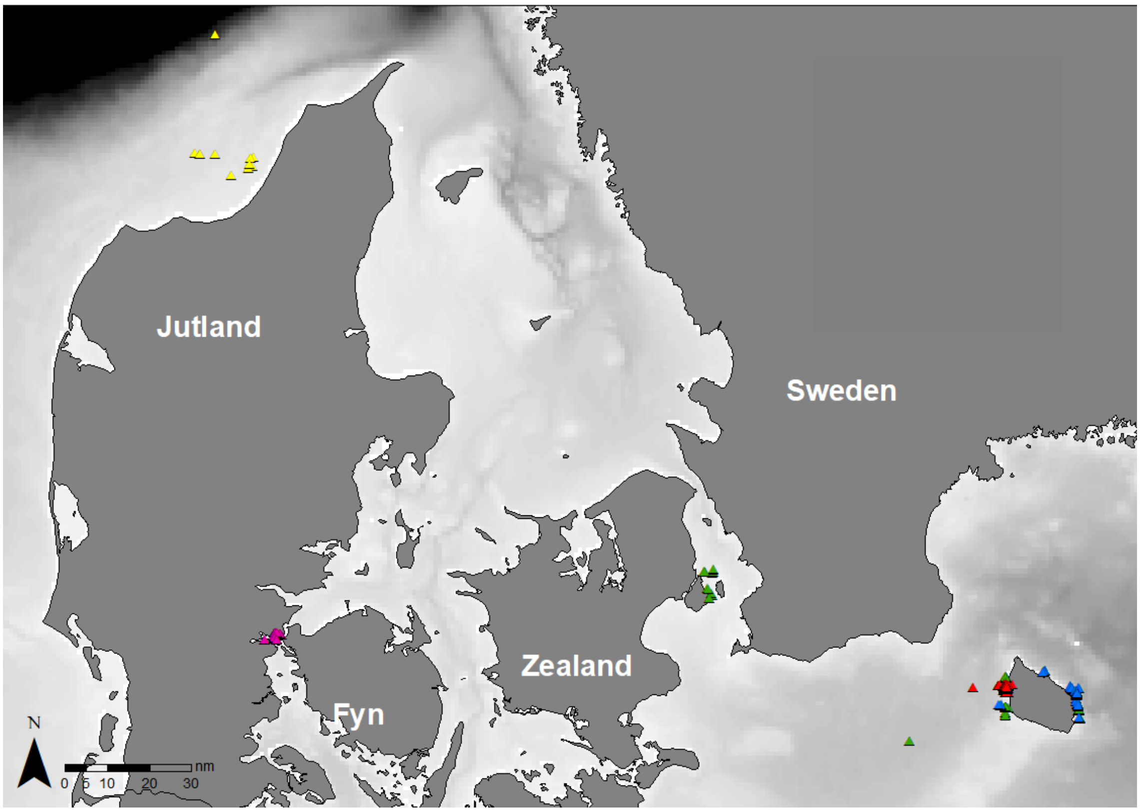

Figure 35. Pot fishing activity separated by fisher (shown by colour).

The fishers, who stayed in regular contact with us were generally quite positive about the pots. They praised the easy handling while setting and retrieving and the mechanism of how to empty the fish pots. Some fishers also told us when their colleagues were fishing in the vicinity to the fish pots with gillnets – often with a lot of seal damages while their catches in the pots was almost all the time undamaged.

A few fishers modified the pots themselves e.g. by painting an entire pot black as he believed it became more like a cave for the cods to hide in. Others attached floats to the topside of the pot (Figure 37) to avoid the pots from turning upside down while setting. Making sure how the pots lands on the seabed can be an important point. Later underwater film showed that this was in fact a problem as the pots several times did not land correctly on the bottom (Figure 38). However, as the pot had 3 entrances on different sides, this issue is not too important.

Figure 36. Fish pot with additional float on upper side.

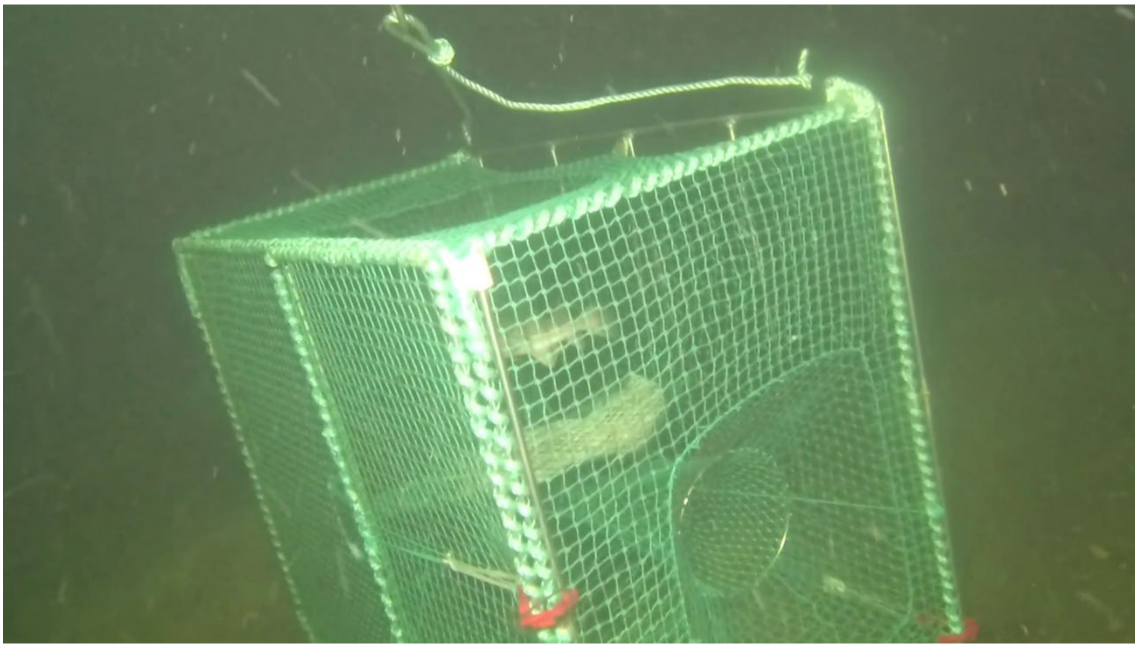

Figure 37. Pot that is not standing as intended on the seabed.

4.2 Long term catch efficiency

The date when the individual fishers entered the experiment differed and some fishers put more effort into the trials than others, the fishing periods and efforts are thus different for each fisher and area. Figure 36 above shows the positions of the different deployments of the pots. In total 898 pot-strings were analysed (Table 14).

Table 14. Number of hauled pot-strings per area.

Area	**Number of net-strings hauled**
Bornholm	441
Lillebælt	136
Øresund	2
Skagerrak	19
Sydfynske Øhav	300
Totalt	898

As mentioned, the fishers could use the bait themselves thus a brought variety of bait types were used (Herring, Sand eel, Dogfood, Herring/Sand eel, Gobies, Mackerel, Herring/sprat, Sprat, Crab, Crabs and mussels, Salmon, Mussels, Saithe, Flounder, Frozen herring waste, Shrimps. Crab/herring, Cat food, Crab/cod, Herring/mackerel, Whiting and NA). However, to simplify the analysis, the bait types were separated into 7 groups (Table 15)

Table 15. Number of strings by bait type (simplified).

Bait type	Numbers of strings by bait type
Crab	31
Herring	569
Mackerel	55
Sprat	67
Whiting	28
Other	123
NA	25

The fishers mainly caught cod and flounder; however, twelve other species of fish and four different species of crabs could be captured by the pots. This highlights the pots potential for also catching other species than the originally intended cod. This consideration is of particular interest in the recent time of decreasing cod populations. However, in this study the main focus was cod.

The catches of cod per pot and set varied from 0 up to 26 kg. The highest catches of cod were registered around Bornholm during winter.

To test which parameter that affected the catches and to find which periods of the year the pots were having the highest catches a model was used (Table 16).

Table 16. Variables and description of the model.

Variable	Description
Cn	Catch in numbers (<=38 cm only)
Cw	Catch in weight (<=38 cm only)
Lon, lat	Longitude, latitude
Depth	Average depth for the chain
Time	Time of sample (continuous)
Area	Bornholm, Lillebælt, Øresund, Skagerrak, Sydfynske øhav
Pots per string	Number of pots in the string
Soak	Soak time (days)
Bait	Bait type (only simplified version)

As the catch in numbers (C_n) is count data with a big spread in values, a negative binomial model has been chosen (Equation 1):

$$\log(\mu_i) = f_{1,\text{area(i)}}(\text{time}_i) + f_2(\text{depth}_i) + \text{U(i)}_{\text{area}} + \quad (1)$$
$$f_{3,\text{area(i)}}(\text{lon}_i, \text{lat}_i) + f_4(\log(\text{pots\_per\_string}_i) + f_5(\log(\text{soak}_i)) + \text{U(i)}_{\text{bait}}$$

where μ is the expected value of the response (C_n), f_1 to f_5 are Duchon splines with first derivative penalization. The effects for time and space (f_1 and f_3) have separate splines for each area, whereas the other spline effects are shared among areas. $U(i)_{area} \sim N(0; \sigma2_{area})$ is a random effect for area and $U(i)_{bait} \sim N(0; \sigma2_{bait})$ is a random effect for bait type. Smoothness selection was carried out with the maximum likelihood (REML) method.

The results showed that no significant effect of bait type was found. Thus, this term was removed from the model. Also, there was no indication of a non-linear effect of pots per string, so f_4 was reduced to a simple regression coefficient.

The area effect was estimated to be zero, but with very large uncertainty. Because all areas but Bornholm have only been observed for a relatively short time-interval, it is not possible to separate the area effect from the effect of time. Longer time-series in the other areas would be needed to estimate differences between areas. There was, however, a significant effect of geographical coordinates within an area. The effect of time however appears to be more important than the area. The time effects are significantly different between areas. For the Bornholm area higher catch rates were found in the winter and spring months compared to summer and autumn (Figure 39). Whether this is a recurring pattern is not possible to say without a longer time-series.

Using a soak time of three days appears to be the optimal choice (although the effect seems to increase again for very long soak times, this is associated with substantial uncertainty). The catch rate is found to be almost directly proportional to the number of pots in a string similar to what could be expected. Catch rates are also found to increase with depth up to around 25 meters but constant hereafter.

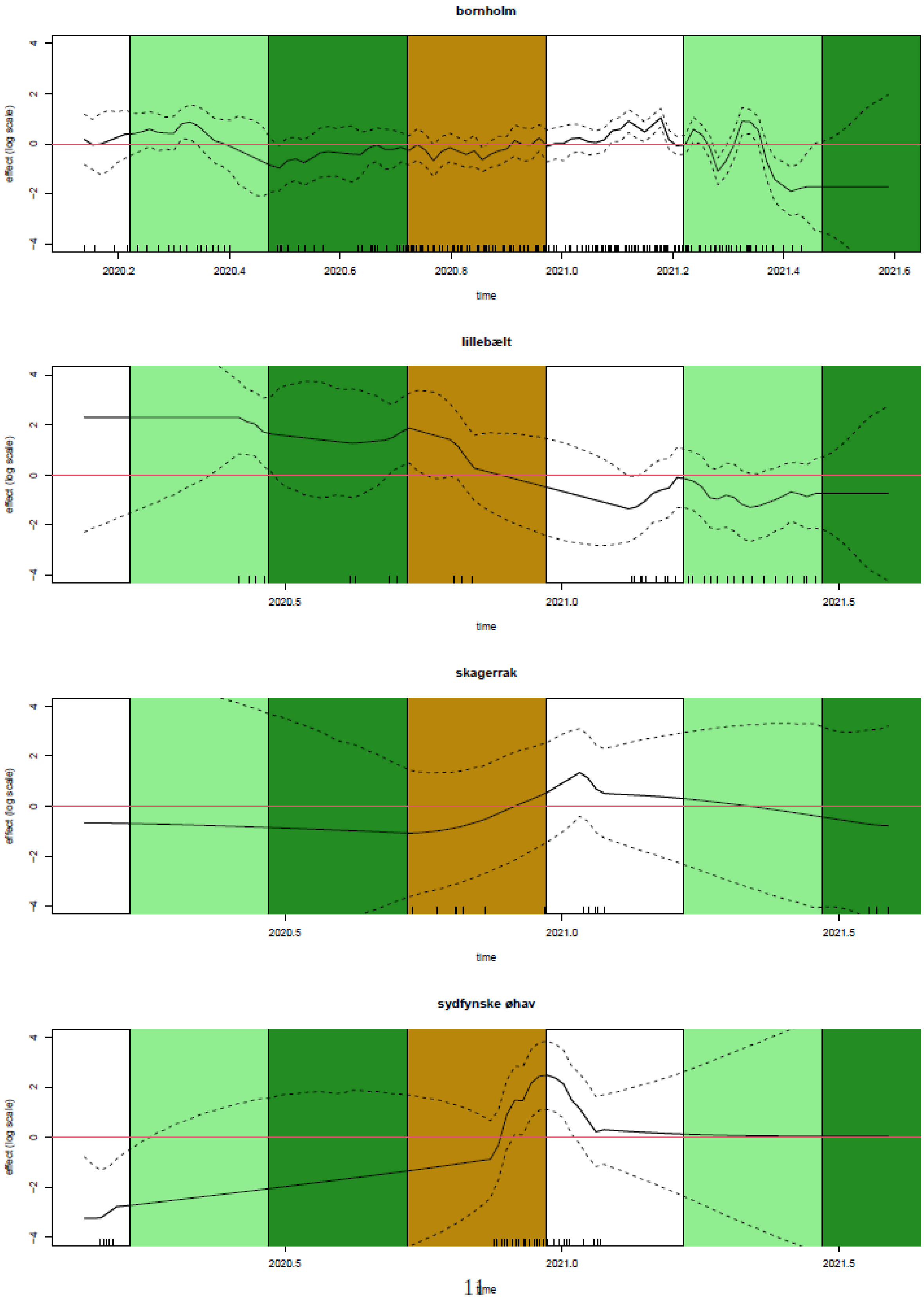

Figure 38. The modelled catches as an effect of time for the different areas.

From the model expected catches per pot in January could be calculated (Figure 40). Here it is clear that the highest catches are expected to be on the west coast of Bornholm, were the catches are model to be >4 kg per pot. It is thus likely that the pot fishery in this area can be a good alternative to the gillnets especially in the wither months where the depredation in gillnet are the most and the catches in the pots are the highst.

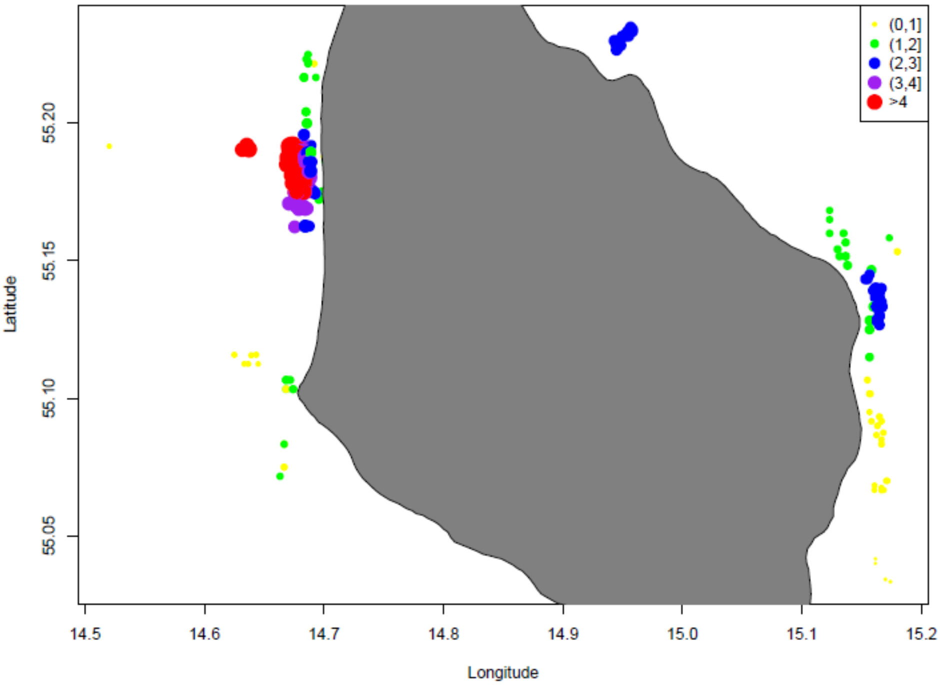

Figure 39. Modelled expected catches around the Bornholm area.

5. Collaboration with commercial fishery

During the full project, great focus was put on the collaboration with the fishery. This is truly an inportant point for the success of the trials but also for the future implementation and acceptance of the different gears

Mini-seine

The seine test trials caught al ot of attention. A lot of fishers heard about the project or have seen the seine vessel while in port. Thus, several fishers followed the rebuillding of the seine and many came to visit the vessel in port to hear about the project. The main interest was the obtained catch rates and how the system was monified. As the seine system was not easy to move between vessels, it was not possble for the fishers to test the system on their own vessel, however for two days fishers had the orpotunity to join a mine-seine trip. The trip was conducted on-board a participating commercial fishing vessel. On each trip, 5 fishers participated. Many participating fishers also came from Sweden as Swedish colleagues are testing the mini-seine system as well. The trips were a great success as the fishers were happy to join the trial, get more information and have a hands-on experience with the seine.

Pontoon trap

In the pontoon trap experiment it was far more difficult to get the fishers attention. Most fishers did not like the Pontoon trap. They thought it was too clumsy and too unflexible in terms of swaping fishing ground. As very low catches was obtained futher move were low the interest for this gear was minimal

Pots

Within this part of the project, commercial fishers got the opportunity to test seal-safe fishing gears themselves. As fish pots served the only gear within the present project that could easily be operated from any gillnetter, the offer to fishers to test gears on their own was limited to those. The opportunity got taken up quite well, resulting in eight fishers who got equipped with at least ten fish pots each. For further details on the trials and obtained results, see chapter 4.

6. Conclusions and recommendations

The results of the project have shown that both the mini-seine as well as the fish pots have the potential to compete with conventional fishing gears like gillnets but offer the additional advantage of being seal-safe. Moreover, both gears are able to catch other species than cod, which was the intended target species in the beginning of the project but cannot be considered as a profitable fish resource in the Baltic as numbers are low and decreasing. Contrary to this, the Pontoon-trap does not seem to be a viable alternative to gillnets for catching cod in the moment. Issues concerning the ability of the trap to withstand the impacts from currents and wind, combined with very low catches and a lack of interest from Danish fishermen led to abandoning further trials with the Pontoon-trap. Development work with the trap is ongoing in Germany, and if that leads to a trap without the issues identified here, it could become relevant to trial the modified trap in Danish waters.

Additionally, knowledge about factors affecting catch efficiencies and handling was collected for both gears, which can be applied in future studies. Further studies are necessary as both gears can still not be considered alternative gears to be used right away – the mini-seine system because it still needs some major modifications to increase its general power, and fish pots because the investing costs for procuring the number of pots assuring profitable fishing are very high. According to the fishers participating in the project, one fisher would need to operate around 100-150 fish pots, with one pot costing around 400 €.

Future studies regarding the mini-seine should focus on the power issue. How can more power be built into the rope drums, how can the seine be retrieved on board in a way that is more safe for the fishers and seine trials should not only be conducted in the areas around Bornholm and in the Great Belt, as many other areas are affected by the seal depredation. Future pot studies should aim to identify the best bait following a sophisticated study and further investigate, how different entrance designs might allow targeting other species than cod.

7. Acknowledgements

We would like to express our sincere gratitude to the fishers who conducted the experiments with us – either with us being on-board or by themselves and sending us the data afterwards. A special thank you to Henrik Frithiof who was part of the both the Mine-seine, Pontoon trap and Pot trials. Henrik was unfortunately lost to the sea during the time of this project and our thoughts goes to his family and loved ones.

A special thanks also goes to Jens Henriksen for his knowledge and high enthusiasm for the mini-seine trials and Arki for his hard work in fishing with the pots in the Bornholm area. Furthermore we would like to thank all other participating fishers for all their hard work.

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