Report

Use of semi-pelagic trawling for reducing bycatch in shrimp trawls

Trials onboard R/V Johan Ruud 02.02.15 – 06.02.15

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ABSTRACT

Abstract heading

The present study evaluates whether lifting the trawl doors and sweeps from the seabed can reduce bycatch in shrimp trawl fisheries. We carried out a catch comparison and catch ratio analysis between two gear setups, one with the trawl doors and sweeps at the seabed (the traditional way) and the other with the doors and sweeps lifted. The study was carried out on American plaice. The results showed that when fishing with the doors and sweeps at the seabed, the gear is significantly more efficient at catching flatfish. The gear setup with the doors and sweeps at the seabed captures between 50% and 70% more American plaice than the gear setup with the doors and sweeps lifted. This difference is significant for sizes between 10 and 36 cm. Further, this efficiency is size dependent and increases with fish size. The results obtained are encouraging for the shrimp fishing industry as lifting the doors and sweeps from the seabed could help mitigate fish bycatch problems, and reduce bottom impact.

Further studies are recommended to investigate if lifting the doors and sweeps from the seabed is equally efficient at reducing bycatch of other species, and if it also affects the shrimp catches.

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1 Introduction

In the Norwegian trawl fishery for deep-water shrimp (*Pandalus borealis*), shrimpers experience in periods of the year too high numbers of retained juvenile fish (0- and I-group) of commercially important species like cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), redfish (*Sebastes spp.*) and Greenland halibut (*Reinhardtius hippoglossoides*). Even though fishermen use the Nordmøre (NM) grid in their trawl, the catches of juveniles are often still too high, and therefore additional bycatch reduction measures are still sought. According to current regulations, fishing grounds are closed whenever shrimp catches contain more juveniles than 8 cod or 20 haddock or 3 redfish or 3 Greenland halibut per 10 kg shrimps. In practical terms, many northern inshore shrimp grounds are closed for several months because too high numbers of fish fries occur in the area. Effective reduction on small fish, including juveniles of commercially important species, during shrimp trawling would improve the management of this fishery and fishers would get more access to the fishing grounds.

Other typical bycatch species northern shrimp fisheries are Norway pout (*Trisopterus esmarkii*), whiting (*Merlangius merlangus),* American plaice (*Hippoglossoides platessoides*), Lemon sole (*Microstomus kitt),* capelin (*Mallotus villosus*), herring (*Clupea harengus*), polar cod (*Boreogadus saida*) and blue whiting (*Micromesistius poutassou).* Large proportions of especially Norway pout, polar cod, capelin and herring may be retained and cause extra sorting for the fishers. By-catches of small/juvenile fish have no commercial value and create only problems in the Norwegian shrimp fishery. Juvenile bycatch implies additional sorting onboard, loss of landings and income when fishing grounds are closed, and also represent a challenge for the future generations of these bycatch species. Thus, measures (additional to the NM grid) that would reduce the amount of bycatch in the gear are sought.

In the last decade the authorities around the world have focused on the reduction of the environmental impact of trawl fisheries in general. Apart from the impact at the seabed created by the trawl doors and the ground gear, the fuel consumption in bottom trawling should also be reduced. In Norway, several whitefish trawlers have changed from traditional bottom trawl doors to semi-pelagic doors that are towed just above or in slight contact with the seabed. There have also been advances on the development of lighter ground gears that would substitute the traditional rockhopper gears (Grimaldo et al., 2013).

Lifting the doors from the seabed implies a risk for partially losing the herding effect of the doors and the sweeps. For whitefish trawling such a loss of herding can make the fisheries less effective (see Sistiaga et al., 2015, for further information on this issue). For shrimp trawling, however, lifting the doors and sweeps from the seabed should imply a reduction of bycatch without any loss of shrimps, since the swimming ability of the deep-water shrimp is assumed to be negligible. This reduction of bycatch of course also depends on the swimming ability of the bycatch,.

In this report we present the results from a preliminary trial carried out to investigate whether lifting the trawl doors and consequently the sweeps from the seabed could be used as a bycatch reduction measure in shrimp fisheries.

2 Materials and Methods

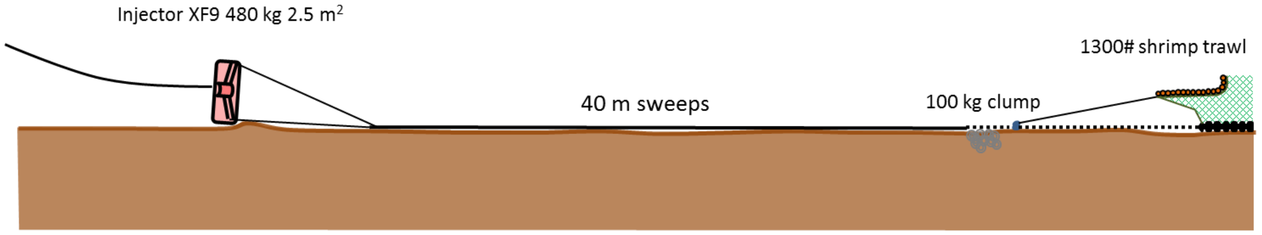
Our trials were made with the 30 m (LOA) research vessel "Johan Ruud". We used a 1300 mesh shrimp trawl with a 52 m long fishing line, i.e. a typical trawl size for the inshore/coastal shrimp trawler in Norway. The experiments were performed at fishing depths of 175-190 m and towing times were restricted to 30-40 minutes (see Table 1).

Two setups (a and b, cf. Figure 1) were tested and compared during the trials. The rigging of both setups were identical. The ground-rope was built as a rockhopper gear with 14” discs which were spaced 30 cm in the center and 60 cm in the side sections. The length of the toggles attaching the ground-rope to the fishing line was ca. 30 cm. The bridles we used were 40 m long and the high aspect ratio trawl doors we employed were of the type Injector XF9 (2.5m^2 and 480kg). To ensure that the trawl had seabed contact at all times, we attached 100 kg clumps at the lower wings of the trawl. In some hauls we used a NordMøre grid (NM). The grid angle and water flow through the grid was measured with a Scanmar grid sensor and were in the range 44-46° and 0.7-0.9 knots, respectively.

Thus, the only difference between the two setups (Figure 1) was the height of the trawl doors above the seabed, which was controlled by the skipper adjusting the warp length and trawling speed.

To control the geometry of the trawl we used a set of distance sensors (Marport MFX, Marport Deep Sea Technologies Inc., Iceland), a set of door sounders (Marport door sounders, Marport deep sea technologies Inc., Iceland) and a trawl height sensor (Scanmar HC4-HT60, Scanmar, Norway). The sounders were used to control the height of the doors over the seabed at all times, which was key to ensure that the two different setups had the planned configuration and geometry (Figure 1).The trawl height sensor was placed at the center of the headline to control the height of the trawl and ensure that there was contact between the rockhopper gear and the seabed. Using the data from the different sensors, we manually registered the distance between the doors, the height of the doors over the seabed, trawl wing distance, trawl height, towing speed and towing time every fifth minute during trawling. We then calculated the average values for these quantities by first calculating the average values for each haul and thereafter using the average of each haul to calculate a cruise average. We used the same procedure to calculate the average standard deviations.

Setup a



Setup b

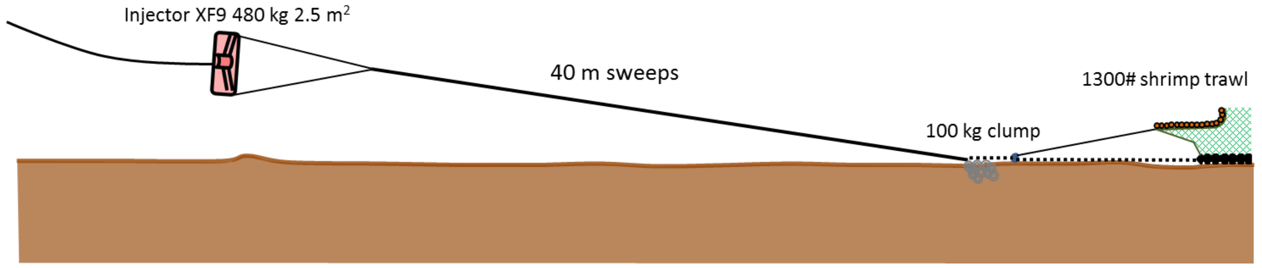


Figure 1: Setup *a* and *b* used during the sea trials.

All fish in all hauls were measured to the nearest cm and there was no subsample.

2.1 Herding data analysis

We wanted to investigate if there were differences in catch efficiency between the two setups, i.e. if setup *b* is less efficient than setup *a*, and if any such difference is related to the size of fish.

The trials included tests with and without a selectivity grid in the trawl. Only the tests without a grid are included in the catch comparison analysis.

2.1.1 Catch comparison

The catch comparison rate is defined as the catch efficiency of setup b (normally the new setup tested) divided by the summed efficiency of setup *b* and setup *a*. If the number of hauls included in the analysis for each of the setups is equal and both setups fish equally efficient, then the result for catch comparison is 0.5. If with equal number of hauls setup *b* is more efficient, then the catch comparison result would be > 0.5. On the other hand, if setup *a* is more efficient, the catch comparison result will be < 0.5. The catch comparison is actually only a middle-step necessary to calculate the catch ratio, which provides a more intuitive result of the comparison between the setups. A more detailed explanation on the calculation of the catch comparison rate follows bellow.

We use the traditional design with the trawl doors at the seabed as baseline in the analysis. To assess the relative length-dependent catch efficiency effect of changing from setup *a* to setup *b*, we employed the the catch comparison analysis described in Krag et al. (2014a). We were interested in the length-dependent catch comparison rate values summed over the hauls carried out with setup *a* and setup *b* being compared. We assumed that the relative catch performance between the two groups of hauls, would be representative of how these designs would perform relative to each other in a commercial fishery. During experimental fishing, the catch data obtained with setup *a* and setup *b* were neither collected in pairs nor during the same amount of hauls. Hence, to estimate the functional form of the summed catch comparison rate (the experimental being expressed by Equation 2) between the catch data from the hauls carried out with setup a were summed and compared with the summed data collected using setup b by minimizing the following equation:

$$-\sum_{l}\left\{\sum_{i=1}^{aq} na_{li} \times ln\left(1.0 - cc(l,\boldsymbol{v})\right) + \sum_{j=1}^{bq} nb_{lj} \times ln\left(cc(l,\boldsymbol{v})\right)\right\} \qquad (1)$$

where ***v*** represents the parameters describing the catch comparison curve defined by $cc(l,\boldsymbol{v})$, and na_{li} and nb_{lj} are the numbers of fish measured in each length class *l* for respectively setup *a* and *b*. In equation (1), *aq* and *bq* are the number of hauls carried out with setup *a* and *b*, and the inner summations in the equation represent the summations of the data from the hauls. The outer summation in the equation is the summation over the length classes *l*. Equation (1) is equivalent to maximizing the likelihood for the observed data based on a maximum likelihood formulation for binominal data (see Herrmann et al. (2013) for further information on this subject).

The experimental summed catch comparison rate, cc_l, where *l* denotes the fish length is given by:

$$cc_l = \frac{\sum_{j=1}^{bq} nb_{lj}}{\sum_{i=1}^{aq} na_{li}+\sum_{j=1}^{bq} nb_{lj}} \qquad (2)$$

When not only the catch efficiency between setups *a* and *b*, but also the number of hauls are equal ($aq = bq$), the expected value for the summed catch comparison rate would be 0.5. In case of unequal number of deployments, $bq/(aq+bq)$ would be the baseline to judge whether or not there is a difference in catch efficiency between setups *a* and *b*. The experimental cc_l is often modelled by the function $cc(l,\boldsymbol{v})$, which has the following form (Krag et al., 2014b):

$$cc(l,v) = \frac{exp(f(l,v_0,\ldots,v_k))}{1+exp(f(l,v_0,\ldots,v_k))} \qquad (3)$$

where f is a polynomial of order k with coefficients v_0 to v_k. Thus $cc(l,\mathbf{v})$ expresses the probability of finding a fish of length l in the catch of one of the hauls with setup *b* given that it is found in the catch for one of the setups, *a* or *b*. The values of the parameters $\mathbf{v}$ describing $cc(l,\mathbf{v})$ are estimated by minimizing equation (1), which are equivalent to maximizing the likelihood of the observed data. We considered f of up to an order of 4 with parameters v_0, v_1, v_2, v_3 and v_4. Leaving out one or more of the parameters $v_0 \ldots v_4$ led to 31 additional models that were also considered as potential models for the catch comparison $cc(l,\mathbf{v})$ between *a* and *b*. Among these models, estimations of the catch comparison rate were made using multi-model inference (Burnham and Anderson, 2002). The models were ranked and weighed in the estimation according to their AICc values (Burnham and Anderson, 2002). The AICc is calculated as the AIC (Akaike, 1974) but it includes a correction for finite sample sizes in the data. Models that resulted on AICc values within +10 in the value of the model with lowest AICc value were considered for the estimation of $cc(l,\mathbf{v})$ following the procedure described in Katsanevakis (2006) and in Herrmann et al. (2014). We use the name combined model for the result of this multi-model averaging. The ability of the combined model to describe the experimental data was evaluated based on the *p*-value, which quantifies the probability to obtain by coincidence at least as big discrepancy between the experimental data and the model, assuming that the model is correct. This *p*-value, which was calculated based on the model deviance and the degrees of freedom, should in principle not be less than 0.05 for the combined model to describe the experimental data sufficiently well (Wileman et al., 1996).

The confidence limits for the catch comparison curve were estimated using a double bootstrapping method. The procedure accounted for between haul variation in the availability in fish and catch efficiency by selecting *aq* hauls with replacement from the pool of *a* type hauls and *bq* hauls with replacement from the pool of *b* type hauls during each bootstrap repetition. Within-haul uncertainty in the size structure of the catch data was accounted for by randomly selecting fish with replacement from each of the selected hauls separately. The number of fish selected from each haul was the same as the number of fish caught in that haul. These data were then combined as described above, and the catch comparison curve was estimated. We performed 1000 bootstrap repetitions and calculated the Efron 95% (Efron, 1982) confidence limits for the catch comparison curve. By applying the above described combined model approach for each bootstrap repetition we accounted also for the effect of uncertainty in the model selection in the confidence limits for the catch comparison curve. To identify sizes of fish with significant difference in catch efficiency we checked for length classes where the confidence limits for the combined catch comparison curve and the baseline rate for no effect ($=bq/(aq+bq)$) did not overlap.

2.1.2 Catch ratio

The catch ratio indicates the relative efficiency setup *b* compared to (divided by) the fishing efficiency of setup *a*. Thus, this ratio is a direct comparison between both setups. Thus, if the catch efficiency of both setups is equal, catch ratio should always be 1.0. If setup *b* is catching in average 25% more fish than setup *a*, then catch ratio would be 1.25. Contrary, if catch ratio=0.75 it would mean that setup *b* is only catching 75% of that setup *a* is catching. A more detailed explanation on the calculation of catch ratio is given below.

The catch comparison rate *cc(l,***v***)* cannot be used to quantify directly the ratio between the catch efficiency of setup *a* vs setup *b* for a fish of length *l*. Instead, we used the catch ratio *cr(l,***v***)*. For the experimental data, the average catch ratio for a length class *l* is expressed as follows:

$$cr_l = \frac{\frac{1}{bq}\sum_{j=1}^{bq} nb_{lj}}{\frac{1}{aq}\sum_{i=1}^{aq} na_{li}} \qquad (4)$$

Simple mathematical manipulation based on (2) and (4) yields the following general relationship between the catch ratio and the summed catch comparison:

$$cr_l = \frac{aq\times cc_l}{bq\times(1-cc_l)} \qquad (5)$$

Which also means that the same relationship exists for the functional forms:

$$cr(l,\boldsymbol{v}) = \frac{aq\times cc(l,\boldsymbol{v})}{bq\times\left(1-cc(l,\boldsymbol{v})\right)} \qquad (6)$$

One advantage of using the catch ratio the way it is defined by (4) and (6) is that it gives a direct relative value of the catch efficiency between setup *a* and setup *b*, and the catch comparison rate does not. Further, the way catch ratio is defined by (4) and (6), it provides a value independent of the number of hauls carried out with setup *a* and *b*. Using equation (6) and incorporating the calculation of *cr(l,***v***)* for each relevant length class into the double bootstrap procedure described for the catch comparison rate, we estimated the confidence limits for the catch ratio. We used the catch ratio analysis to estimate the length dependent effect in catch efficiency of changing from setup *a* to setup *b*.

The analyses for the current study were carried out using this tool. SELNET has previously been applied to analyze size selectivity data (Sistiaga et al., 2010; Frandsen et al., 2011; Wienbeck et al., 2011; Eigaard et al., 2011; Herrmann et al., 2012; Madsen et al., 2012; Tokac et al., 2014; Herrmann et al., 2014; Özbilgin et al., 2015; Sala et al., 2015) and catch comparison data (Krag et al., 2014a) collected with trawls.

2.2 Shrimp measurements

The swimming ability of the deep-water shrimps is assumed to be negligible when compared to the towing speeds used in this fishery (approx. 2.3 knots). However, to get an indication on whether there could be differences in the shrimp size distribution captured with setup *a* and *b*, we measured the carapace of every individual in a sample of two kg-s of shrimps taken from each of the hauls carried out in Grøtsundet. The measurements were made using a calliper. Ideally, the quantity and size distribution of shrimp should be measured for a large number of hauls. However, because of the time constraints in these trials, such an analysis was not possible in this case.

3 Results

For the catch comparison and catch ratio analyses it is important that the hauls compared are collected in the same fishing area and in as similar fishing conditions as possible. An overview of the hauls is given in Table 1. A total of 17 hauls were carried out, of which 15 were carried out in Balsfjord and 2 in Grøtsundet (See Figure 2). Two hauls (no. 2 and 4) had to be discarded due to vast amounts of mud in the gear. Of the remaining 13 hauls in Balsfjord, 6 were with setup *a* and 7 with setup *b* and 4 of each of these were without grid (see Table 1). Early inspection of the data showed that the five hauls carried out with the grid did not contain sufficient fish to carry out a catch comparison or catch ratio analysis, mostly because the grid effectively released large quantities of fish. Thus, we excluded all hauls carried out with a grid (i.e. 5 hauls in Balsfjord and both 2 hauls in Grøtsundet. The analysis was therefore based on 4 hauls with each of setups *a* and *b* in Balsfjord.

Table 1: Overview of the 15 valid hauls carried out during the experimental period. The amount of shrimps in the codend in each of the hauls is also provided.

Date	Field	Gear	Haul nr.	Grid	Setup used	Start (kl.)	Stop (kl.)	Tow time (min)	Depth (m)	Lat. Start	Lon. Start	Lat. Start	Lon. Start	Shrimps codend (kg)
03.02.2015	Balsfjord	Shrimptrawl	1	No	Setup a	08:25	09:05	40	184	69°22'428''	19°03'632''	69°21'353''	19°06'571''	83.2
03.02.2015	Balsfjord	Shrimptrawl	3	No	setup b	11:45	12:25	40	185	69°22'460''	19°03'560''	69°21'310''	19°06'650''	98
03.02.2015	Balsfjord	Shrimptrawl	5	No	setup b	15:00	15:40	40	186	69°22'524''	19°03'415''	-	-	—
03.02.2015	Balsfjord	Shrimptrawl	6	No	setup a	17:00	17:40	40	185	69°22'298''	19°03'863''	-	-	42
03.02.2015	Balsfjord	Shrimptrawl	7	No	setup a	19:20	20:00	40	183	69°22'486''	19°03'553''	69°21'362''	19°06'439''	41
04.02.2015	Balsfjord	Shrimptrawl	8	No	setup b	08:45	09:25	40	186	69°22'300''	19°03'700''	-	-	36
04.02.2015	Balsfjord	Shrimptrawl	9	No	setup b	10:15	10:55	40	186	-	-	-	-	38
04.02.2015	Balsfjord	Shrimptrawl	10	No	setup a	11:40	12:20	40	-	-	-	-	-	35
04.02.2015	Balsfjord	Shrimptrawl	11	Yes	setup a	14:15	14:55	40	186	-	-	-	-	42
04.02.2015	Balsfjord	Shrimptrawl	12	Yes	setup b	16:20	17:00	40	186					21
04.02.2015	Balsfjord	Shrimptrawl	13	Yes	setup b	18:00	18:40	40	-	-	-	-	-	36
05.02.2015	Balsfjord	Shrimptrawl	14	Yes	setup b	08:35	09:15	40	-	69°22'381''	19°03'552''	-	-	12
05.02.2015	Balsfjord	Shrimptrawl	15	Yes	setup a	10:00	10:40	40	-	-	-	-	-	59.4
05.02.2015	Grøtfjord	Shrimptrawl	16	Yes	setup a	14:35	15:05	30	175	69°47'745''	19°19'108''	69°47'420''	19°15'885''	37.5
05.02.2015	Grøtfjord	Shrimptrawl	17	Yes	setup b	16:00	16:30	30	181	-	-	69°47'675''	19°18'868''	37.5

Figure 2: The map shows the location (areas marked in orange) in Balsfjord and Grøtsundet where we carried out the experiments.

Table 2 shows that the trawl geometry behaves as expected when the doors are lifted from the seabed. For setup *b* the average trawl door height is well above the seabed, while for setup *a* the door is clearly at or close to the bottom. We see that when the doors are lifted, and the wing spread is reduced and trawl height increased. There is a small difference in tow speed, i.e. the average speed is higher for the case with lifted doors, which implies that the difference in spread and trawl height is in fact larger than indicated in Table 2.

Table 2: Trawl geometry data collected during the cruise.

		Wing dist. (m)	Trawl height (m)	Dist. Between doors (m)	Tow speed (kn)	Door height (m)
Setup a	Average	19.45	8.78	39.54	2.23	0.16
	St. Deviation	0.66	0.22	1.15	0.08	0.30
Setup b	Average	17.26	10.77	34.35	2.41	6.20
	St. Deviation	0.43	0.28	0.88	0.07	1.77

We used the 8 hauls collected without the grid in Balsfjord as basis for the catch comparison and catch ratio analysis. The potential differences in fish herding between setup *a* and *b* were based on the American plaice only. Data were collected for cod, haddock and Norway pout also, but sufficient data for analysis were only obtained for American plaice. The results for the catch comparison analysis for American plaice are shown in Figure 3. Because the number of hauls collected with setup *a* and *b* is equal (4), the expected value for the summed catch comparison rate if both setups are fishing equally efficient, is 0.5.

The catch comparison results show first of all that the method of analysis described in Section 2.1 represents the data well. This is also reflected by the p-value of the model fit). The *p*-value for the model fit is 0.0209. As described in Section 2.1.1 it should ideally not be less than 0.05. The lower *p*-value can be explained by over-dispersion in the data and the experimental method applied, and since the *p*-value is still higher than 0.01 it is acceptable. Thus, differences observed between the model and the data can be a coincidence.

The catch comparison results indicate that setup *a* is more efficient at catching American plaice than setup *b*. The results show a clear length dependency in the data as the difference between both setups increases with increasing fish size. Further, these differences are significant for length classes between 10 and 36 cm (Figure 3 and 4). The catch ratio figure (Figure 4) shows that on average, setup *a* captured between 50% and 70% more American plaice than setup *b*, demonstrating a clear effect of lifting the doors and the sweeps from the seabed on the catch efficiency of this species.

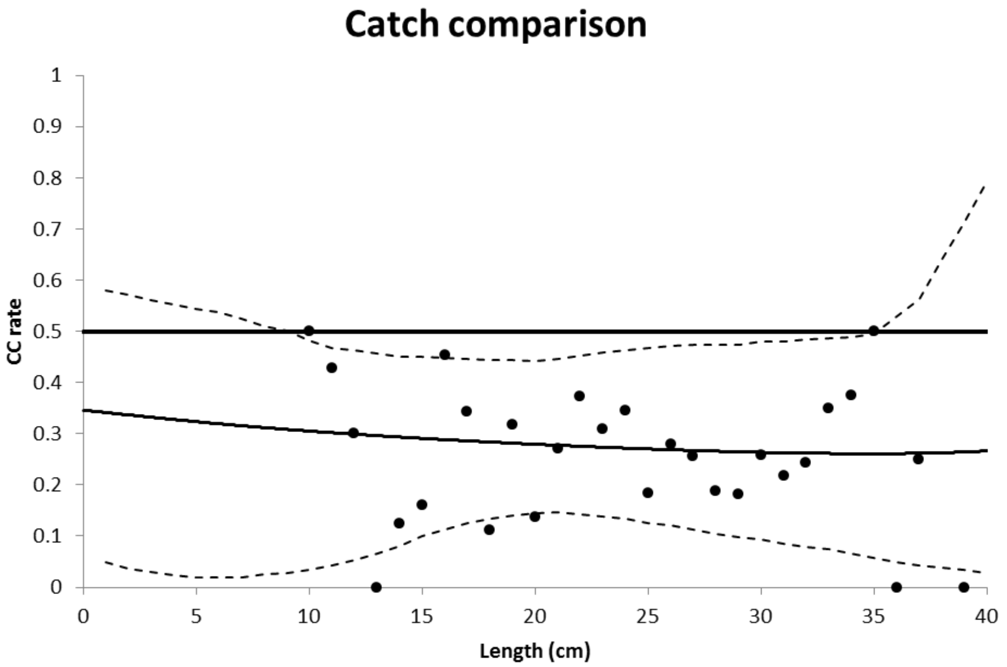


Figure 3: Catch comparison curve (section 2.1.1. (full black line)) and 95 % confidence intervals (stippled lines) estimated for American plaice based on the 8 hauls collected during the sea trials in Balsfjord. The points in the plot repesent the observations. The full black horizontal line represents the line where setup *a* and *b* would be fishing equally. Values below this line indicates that setup *a* is more efficient, and values above this line indicates that setup *b* is more efficient.

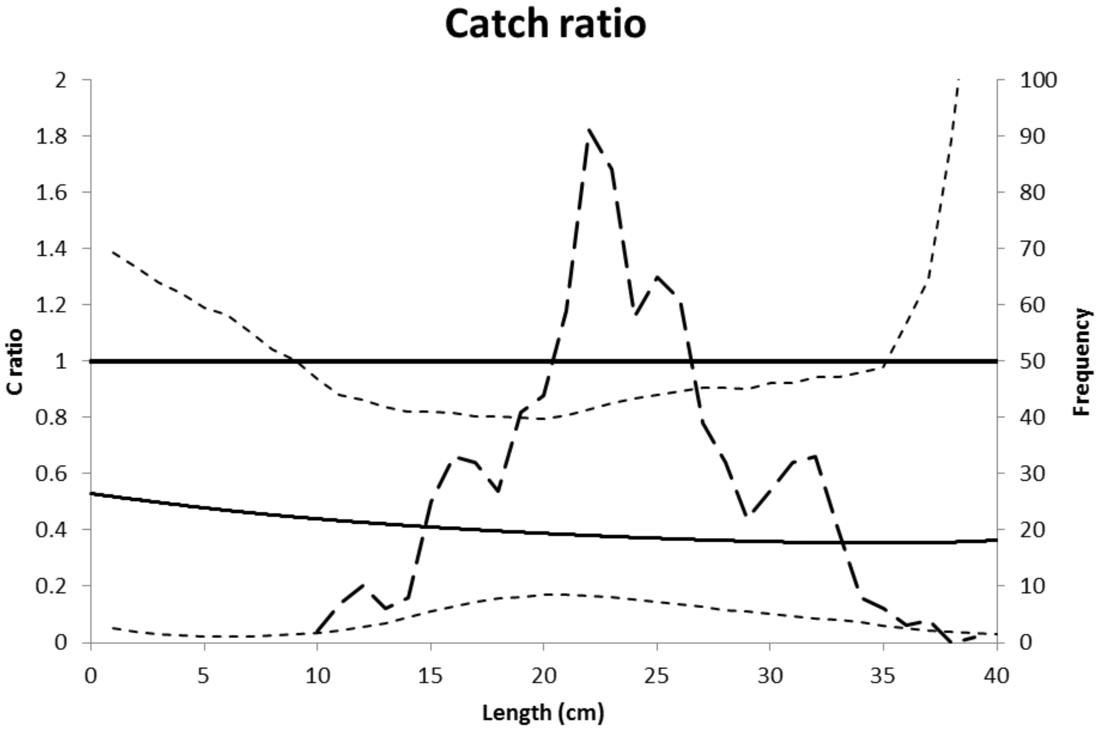


Figure 4: Catch ratio curve (section 2.1.2. (full black line)) and 95 % confidence intervals (stippled lines) estimated for American plaice based on the 8 hauls collected during the sea trials in Balsfjord. The dashed line shows the fish size distribution in all 8 hauls. The full black horizontal line represents the line where setup *a* and *b* would be fishing equally. Values below this line indicates that setup *a* is more efficient, and values above this line indicates that setup *b* is more efficient.

Regarding the shrimp distribution caught with both setups, Figure 5 shows a comparison of the distribution of shrimps captured in hauls 16 (setup *a*) and 17 (setup *b*). Because we had measurements only in one haul for each setup we cannot account for any between haul variation, meaning that the potential differences found between the two distributions showed here could likely be a coincidence.

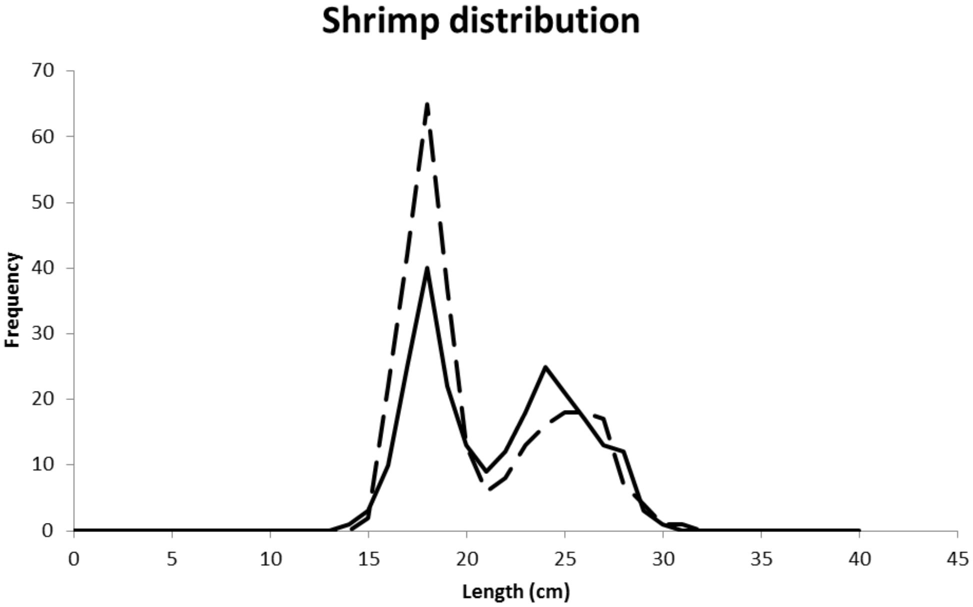


Figure 5: Distribution of shrimp samples taken respectively from hauls 16 (full line) (doors at seabed) and 17 (dashed line) (doors lifted).

4 Discussion

The present study shows the results of an experiment carried out to evaluate whether lifting the trawl doors and sweeps from the seabed can lead to a reduction of bycatch in shrimp trawl fisheries. Even though we captured and measured several other species during the cruise, the bycatch results were based only on the American plaice. This was the only bycatch species captured in abundant enough numbers to run a comparison analysis. We based the comparison on 8 hauls, which is a low number for statistical analysis. However, the amount of fish captured in these 8 hauls included in the analyses was high, which makes the results robust (Fig. 4). The results showed that when fishing with the doors and sweeps at the seabed (i.e. the traditional way), the gear is significantly more efficient at catching flatfish. Further, this efficiency is size dependent and increases with fish size. This size dependency is in good agreement with findings in earlier studies, which have documented that the swimming ability of flatfishes increases with increasing size (Winger et al., 2010). The herding effect of the sweeps on flatfish have for long been documented (Ryer, 2008), but to our knowledge this is the first time this is studied in relation to potential bycatch reduction in shrimp fisheries. If we assume that the swimming ability of deep-water shrimps is negligible compared to the trawling speed used in this fisheries, the result imply that a cleaner shrimp fishery with less bycatch can be achieved. Further, flatfish are known to create clogging problems in sorting grids, hence a reduction of flatfish entering the trawl should also mitigate this issue.

Greenland halibut is one of the most important bycatch species in Norwegian shrimp fisheries. The results obtained for the American plaice are encouraging because it is likely that other flatfish species like Greenland halibut behave similarly in front of the trawl. Another important bycatch species in the shrimp fishery is cod, for which there is a documented herding effect of the sweeps (Engås and Gødo, 1989; Sistiaga et al., 2015). However, the cod is not as bottom seeking as flatfish, and a reduction in herding effect from lifting the doors and sweeps may not be as strong as that for American plaice studied here. Hence, it is important to carry out further tests with sufficient amounts of shrimps and bycatch that would allow concluding on the potential benefits of lifting the sweeps and doors for this fishery.

In this study, the number of hauls and quantities of shrimps captured in each haul were not high enough to analyse whether the change in the setup also affected the shrimp catches. Considering the poor swimming ability of shrimps we may assume that the change in setup should not affect shrimp catches much. However, this should be verified before final conclusions are drawn.

In many shrimp fisheries bycatch of fish juveniles is a major problem. The results in this study show that lifting the doors and sweeps from the seabed likely will reduce juvenile and fish bycatch in shrimp trawls and reduce the overall bottom impact from shrimp trawling considerably. We therefore recommend that further trials are carried out in the near future.

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