An opportunistic comparison of a pulse and a traditional beam trawl fishing gear

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Summary

Beam trawls are criticized for their negative impact on benthic ecosystems. Pulse trawls may be an environmental more friendly alternative. In addition to the environmental benefits, the pulse trawl is expected to improve the catch efficiency for the main target species (sole *Solea solea*). Here, we report on an opportunistic comparison between a pulse and traditional tickler chain beam trawl (TCBT). Catch efficiency for sole and plaice was determined in 39 paired hauls, during which both vessels fished parallel, and by comparing average landings during commercial hauls in which the vessels fished in close proximity of each other. Additionally, total catch quantity and composition and benthos composition were compared between both gears. Unfortunately, the TCBT fished with a smaller mesh size than the pulse trawl (67mm versus 80mm). To take account of the differences in mesh-size, plaice and sole catches for the comparative hauls were corrected using selection ogives of recent mesh-size selection experiments. The current study found a 23% higher catch efficiency for market sized sole and a non-significant 3% lower catch efficiency in market sized plaice. The improved size selectivity observed in a similar experiment in 2011, when pulse fishing was just introduced, could not be corroborated. With the exception of Norway lobster and spider crabs, all benthic invertebrate species showed lower catch rates in the pulse-trawl. Due to the difference in cod-end mesh-size, the results of the experiment should be interpreted with caution.

1 Introduction

Bottom trawls are among the most widely used fishing gears to catch demersal species, but are criticised for their adverse effects on the marine environment *(Halpern et al., 2008; Jennings and Kaiser, 1998),* such as high discard rates with low survival probabilities *(Heath and Cook, 2015; van der Reijden et al., 2017)* and the damaging of (biogenic) structures *(Jennings and Kaiser, 1998).* Among the various bottom trawl techniques, beam trawls have the highest bottom impact *(Eigaard et al., 2015)* due to heavy tickler chains that are arranged across the opening of the net and penetrate down to 80 mm into the bottom *(Eigaard et al., 2015; Paschen et al., 2000).* The pulse-trawl may pose an environmental more friendly alternative. This technique has replaced the traditional tickler chains by lighter electrodes which induce electric pulses *(Soetaert et al., 2015),* and is believed to increase sole catch and simultaneously reduce benthos catches and environmental impact *(Depestele et al., 2018, 2015; Soetaert et al., 2015; van Marlen et al., 2014, 2006; van Stralen, 2005).*

In 2011, when the first commercial pulse trawls were introduced, a comparative fishing experiment was conducted between a traditional tickler-chain beam-trawl (hereafter TCBT) and two pulse trawlers *(van Marlen et al., 2014).* Results showed a reduction in overall catch rate and undersized plaice, while the catch rate (kg/ha) for market-sized plaice (*Pleuronectes platessa*) and sole (*Solea solea*) did not differ significantly (van Marlen et al., 2014). Catch efficiency of a fishing gear generally increases over time due to technological developments and improved skills of the fishermen, especially when new techniques are introduced *(Eigaard et al., 2014; Rijnsdorp et al., 2008).* It is therefore important to collect data on the current pulse-trawl catch efficiency and selectivity.

This study reports on an opportunistic comparison between a pulse-trawl and a TCBT, during the Dutch industry survey in summer 2015. A comparative fishing experiment was conducted to determine a conversion factor between plaice and sole catches of the standard survey fishing gear and a pulse-trawl in the industry survey. Additionally, catch efficiency and selectivity for plaice, sole, and benthos were compared between both gears. Although the survey fishing gear comprised a TCBT using a smaller meshed cod-end (~70 mm) than regular TCBTs, the results of this opportunistic study may contribute to the study of selectivity changes in the sole and plaice fishery.

2 Materials and Methods

2.1 Vessels

The comparative fishing experiment was conducted with two commercial vessels between the 10th and 21st of August 2015 **(Table 1).**

The TCBT was equipped with 7 tickler chains from the shoes, 18 tickler chains from the ground rope, and a cod-end mesh size of 67 mm due to delivery of wrong nets. The pulse-trawl was equipped with a pulsewing with 24 electrodes placed 45 cm apart, a pulse frequency of 60 Hz and a pulse width of 330 µs.

The pulse trawl had a cod-end mesh size of 80 mm. Three datasets were collected: (1) experimental hauls (30 min) during which the vessels fished parallel to each other at prescribed locations; (2) in between experiments hauls (max 120 min), hauls conducted while heading towards the next prescribed location; (3) and commercial hauls (90-120 min) during the night at locations selected by the fishers.

Table 1. Particulars of participating vessels.

	UK45	**UK64**
Length vessel (m)	40,92	39,67
Depth vessel (m)	5,12	4,76
Engine power (kW)	1491	1491
Gross Tonnage (GT)	462	418
Gear (width, m)	HFK Pulse Wing 12m	Tickler chain beam trawl 12m
Cod-end mesh size (mm)	80	67
Main fishing speed (knots)	4.8 - 5	6.5
Experimental hauls	39	39
Commercial hauls (night time)	17	20
Commercial hauls (day time)	27	32

2.2 Experimental hauls

A total of 39 experimental hauls were performed during daytime **(Figure 1).** Start location and time and fishing direction were equal, but due to differences in towing speed, the end position of the haul differed between the vessels. Exact positions at hauling and shooting and environmental factors (wind, waves) were recorded. Total catch quantity was recorded (number of baskets [35 L]) and all sole and plaice from the starboard catch were measured (cm below). Two baskets were randomly sampled from the portside catch (sample weight: 43-83 kg, median= 56 kg). The fraction weights of landings (marketable fish), fish discards (undersized and non-marketable fish), elasmobranches, and benthos and debris were determined. From the benthos fraction, a subsample of 1 bucket (12 L) was taken, sorted, and the number of individuals was recorded per species. Colonial species were recorded as present/absent only.

To compensate for the different mesh sizes of the cod-ends, we applied a length-specific correction on the plaice and sole catches in the TCBT. Using selection ogives (Sole: selection factor = 2.9, selection range = 4.2 cm; Plaice: selection factor = 1.9, selection range = 2.0) from a recent mesh selection experiment *(BENTHIS, 2018; P. Molenaar, unpublished data)*, we estimated the length-specific retention probability ratio for a 80 mm cod-end in relation to the used 67 mm cod-end.

The observed numbers-at-length were then multiplied by this ratio, yielding the expected smaller number-at-length for a cod-end with 80 mm meshes. The weight of both the original and corrected numbers-at-length was determined with a species-specific length-weight-relation, and expressed as kg/ha.

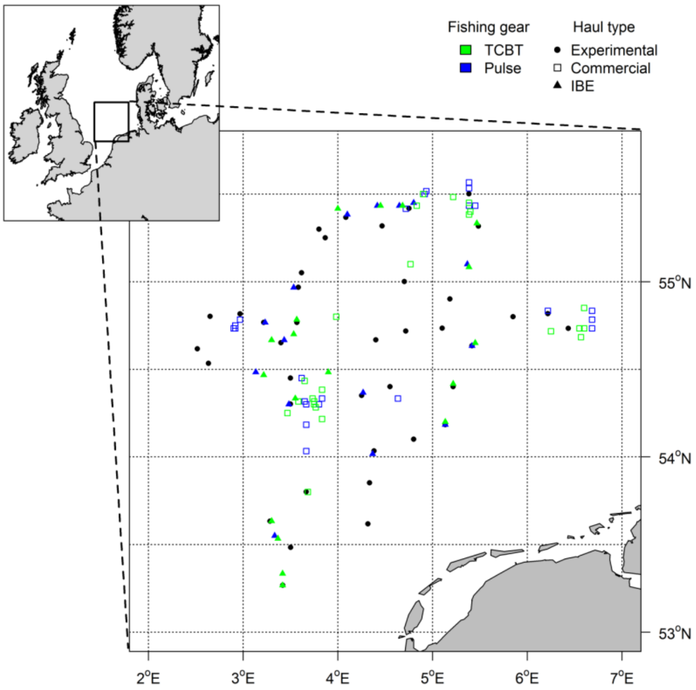

Figure 1. Locations of the hauls

Due to gear damage (1 haul), an extreme catch (1 haul), incomplete length measurements (2 hauls), and unsorted benthos (4 hauls), 37, 36, and 34 paired hauls were available for sole, plaice, and benthos catch comparison respectively.

Differences in both original and corrected market-sized and undersized plaice and sole catch rates (kg/ha) were identified using simple paired t-tests and t-tests of the geometric mean of plaice and sole catch ratios. Zero observations were compensated by adding the lowest catch value to all hauls (market-sized sole - 1 observation; undersized sole – 4 observations).

To test for relative differences in catch compositions between both gears, the weights of the three subgroups (landings, fish discards, and benthos & debris) were scaled using the D-1-dimensional simplex method and tested with a multivariate 2-sample E-test of equal distributions *(van den Boogaart and Tolosana-Delgado, 2008).*

2.3 Commercial hauls

Both vessels performed hauls in between the experimental hauls (hereafter referred to as ‘IBE-hauls’) and during night time. The fishing locations were determined by the skipper which precluded a pairwise comparison of the catch rate. A comparison of the mean catch rate, however, was possible because both vessels remained fishing in close proximity of each other **(Figure 1).**

In total, 96 commercial hauls (UK45 – 44; UK64 – 52) were performed. The skipper recorded the weights of the processed main target species (sole, turbot and brill in kg; plaice in baskets) per haul. In addition, auction slips were available, with total landings per species per week.

Data recording differed between both skippers, with no end position registration of the TCBT hauls. Swept area per haul was therefore calculated as the product of the beam width, haul duration and average towing speed, with the latter being derived from VMS-data. Swept area of the pulse hauls were calculated as the product of the beam width and the distance between the start and end position of the haul. The catch rates for marketable sole and plaice (kg/ha) were subsequently determined per haul. Differences between gears were revealed using Welch’s T-tests.

3 Results

3.1 Sole and plaice catch efficiency

For the experimental hauls, corrected mean catch rates (kg/ha) of both market-sized (M) and undersized (U) sole were significantly higher for the pulse-trawl (M: 0.760 ± 0.098 kg/ha; U: 0.086 ± 0.028 kg/ha (mean ± SE)) than for the TCBT (M: 0.450 ± 0.054 kg/ha; U: 0.023 ± 0.004 kg/ha. (**Table 2**). No significant differences in catch rates were observed for plaice (Pulse M: 6.746 ± 0.936; U: 12.329 ± 1.728. TBCT M: 7.977 ± 1.201, U: 10.936 ± 1.450). The geometric mean ratios show that the pulse trawl caught 22.6% (95% CI: 14.1% - 31.3%) and 53.5% (95% CI: 41.8% - 65.1%) more market-sized and undersized sole than the TBCT, respectively **(Table 2).**

Table 2. Catch efficiency in the experimental hauls. Summary statistics of the paired t-test and the geometric mean ratios (GMR; pulse/beam) of the original and corrected catches. P-values <0.05 are displayed in bold.

		Mean catch rate (kg/ha) ± SE		Paired t-test			Ratio t-test		
		TCBT	Pulse	df	t	p-value	GMR (95% CI)	t	p-value
Corrected	Market-sized plaice	7.977 ± 1.201	6.746 ± 0.936	35	-0.68	0.504	-0.029 (-0.259 - 0.201)	-0.26	0.799
	Undersized plaice	10.936 ± 1.450	12.329 ± 1.728	35	0.74	0.467	0.054 (-0.107 – 0.214)	0.68	0.503
	Market-sized sole	0.450 ± 0.054	0.760 ± 0.098	36	4.67	<0.001	0.226 (0.141 – 0.311)	5.39	<0.001
	Undersized sole	0.023 ± 0.004	0.086 ± 0.028	36	2.42	0.023	0.535 (0.418 – 0.651)	9.32	<0.001
Original	Market-sized plaice	7.977 ± 1.201	6.746 ± 0.936	35	0.68	0.504	-0.029 (-0.259 – 0.201)	0.26	0.799
	Undersized plaice	10.986 ± 1.457	12.329 ± 1.728	35	0.71	0.482	0.052 (-0.109 – 0.212)	0.65	0.520
	Market-sized sole	0.465 ± 0.057	0.760 ± 0.098	36	4.55	<0.001	0.213 (0.129 – 0.298)	5.12	<0.001
	Undersized sole	0.038 ± 0.006	0.086 ± 0.028	36	1.95	0.059	0.266 (0.163 – 0.369)	5.24	<0.001

The analysis of the commercial hauls, which could not be corrected for mesh size differences, resulted in a similar conclusion **(Table 3).** Based on the auction slips, which reflect the catch of marketable fish in all hauls combined, the pulse-trawl had a higher catch rate (kg/ha) for sole (1.27 to 0.85 kg/ha) and a slightly lower one for plaice (8.15 to 8.76 kg/ha), compared with the TCBT **(Table 3).**

Comparison of the sole catch rates showed that the pulse-trawl caught about twice as much sole than the TCBT during the night (t = 2.839, df = 28.765, p-value = 0.008), while during IBE-hauls sole catches were equal between both gears (t = -0.7599, df = 31.565, p-value = 0.453).

For plaice, similar catch rates were observed during the night (t = 1.0997, df = 41.841, p-value = 0.278) and IBE-hauls (t = -1.2035, df = 25.321, p-value = 0.240).

Table 3. Details of commercial hauls. IBE=In Between Experiments.

	Haul type	Hauls	Swept area (ha)	Fishing time (h)	Catch rate plaice (kg/ha)	Catch rate sole (kg/ha)
Pulse	All	83	1907.2	86.1	8.15	1.27
	At night	27	806.1	36.4	13.40 ± 12.70	2.43 ± 2.26
	IBE	17	618.5	27.9	5.51 ± 6.16	0.53 ± 0.53
TCBT	All	89	2651.4	98.0	8.76	0.85
	At night	32	1442.4	53.3	10.31 ± 7.86	1.07 ± 0.57
	IBE	19*	652.2	24.1	9.77 ± 13.98	0.70 ± 0.80

* 1 haul was not taken in account during calculation of catch rates, as species-specific catches were not registered by the skipper for this haul.

3.2 Total catch and composition

The pulse-trawl caught on average 53% (Linear regression: t = 18.58; p-value = <0.001) less than the TCBT, with 29.7 ± 3.24 kg/ha against 53.0 ± 5.83 kg/ha (mean ± SE; **Figure 2**).

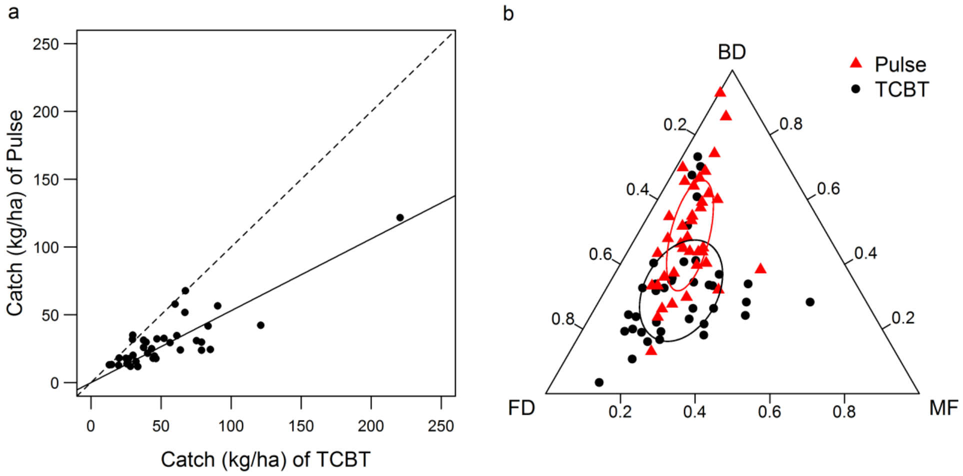

Figure 2. Total catch (in kg/ha). Dashed line represents equal catches, solid line represent observed regression between pulse and TCBT catches (a). Ternary diagram of the catch composition scaled using the D-1-dimensional simplex method (b). FD= fish discards, MF= marketable fish, BD= Benthos and debris. The half-diameters of the ellipses are the square-root of the eigenvalues.

Catch composition differed significantly (Multivariate 2-sample E-test of equal distributions E-statistic = 2.3171, p-value = < 0.01, **Figure 3**), mainly due to reduced catches (kg/ha) of benthos and debris by the pulse-trawl (Pulse: 32.75% ± 2.69%; TCBT: 48.74% ± 2.78%).

The difference was smaller for fish discards (pulse: 47.72% ± 2.53%; TCBT: 36.70% ± 2.12%) and landings (pulse: 20.25% ± 1.83%; TCBT: 14.01% ± 1.17%).

The ratio between fish discards and landings was rather similar between the fishing gears, with both gears catching three times more discards than landings (pulse: 3.16 ± 0.29; TCBT: 3.87 ± 0.68).

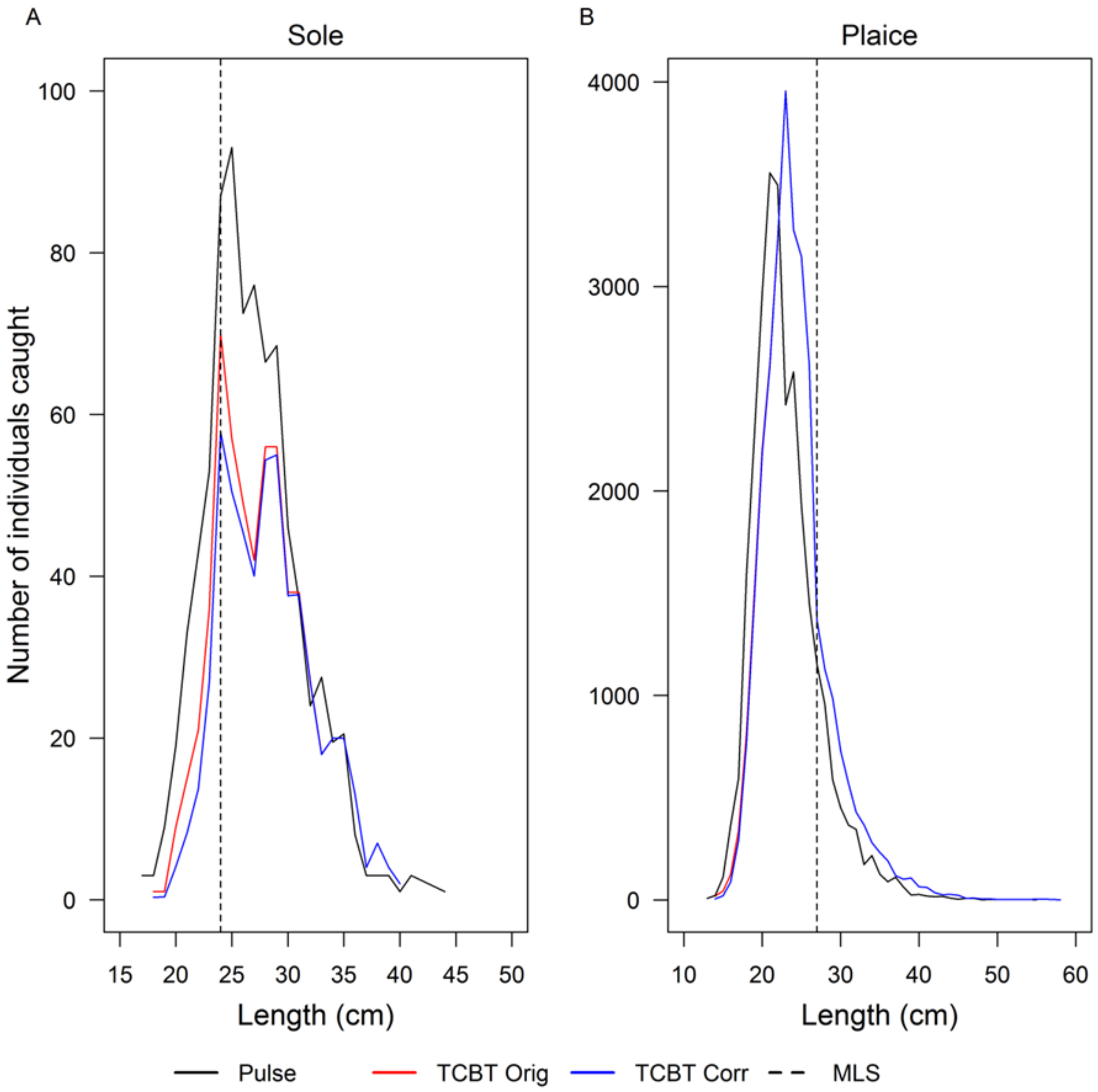

Figure 3. The total number of individuals per length for sole (A) and plaice (B) caught by the pulse and TCBT. For the TCBT, the original and mesh size corrected estimates are shown as red and blue line respectively. The dashed line represents the Minimum Landing Size (MLS).

3.3 Benthos composition

With the exception of Norway lobster *(Nephrops norvegicus)* and spider crabs *(Hyas spp),* all benthic invertebrate species showed lower catch rates in the pulse-trawl, with the prickly cockle *(Acanthocardia echinata)*, the sand sea star *(Astropecten irregularis)*, the sea mouse *(Aphrodita aculeate)* and the common whelk *(Neptunea antiqua)* showing the largest differences (**Table 4**). Also when grouped taxonomically (crustaceans, gastropods, bivalves and asterozoans), the pulse-trawl caught overall significantly less than the TCBT.

When the species are grouped per habitat, both the infauna and epifauna were caught less by the pulse than by the TCBT (Pulse infauna: 3.70 ± 1.91, epifauna: 269.13 ± 43.47. TCBT infauna: 15.78 ± 3.30, epifauna: 791.81 ± 111.84), with a more pronounced reduction in infauna species than epifauna species (Infauna: geometric mean ratio pulse/TCBT=-0.82, t = -8.627, df = 33, p-value = <0.001; Epifauna: geometric mean ratio pulse/TCBT=-0.44, t = -5.643, df = 33, p-value = <0.001).

Table 4. Catch rates (mean ± SE) of benthic invertebrates per species and per group. The values in bold indicate significant differences (p-value of paired t-test<0.05). Habitat indicated epifauna (epi) or infauna (in).

Group	Species	Scientific name	Habitat	Pulse (n/ha)	TCBT (n/ha)	Ratio P/B (species)	Ratio P/B (group)
Crustacea	Swimming crab	Liocarcinus holstatus	Epi	14.07 ± 3.37	22.64 ± 3.46	0.62	0.65
	Hermit crab	Pagurus bernardus	Epi	11.47 ± 2.36	22.51 ± 4.24	0.51	
	Sandy swimming crab	Liocarcinus depurator	Epi	10.08 ± 3.66	11.46 ± 2.35	0.88	
	Norway lobster	Nephrops norvegicus	In*	1.38 ± 0.71	1.09 ± 0.52	1.27	
	Edible crab	Cancer pagurus	Epi	0.18 ± 0.07	0.55 ± 0.23	0.33	
	Masked crab	Corystes cassivelaunus	In	3.02 ± 1.92	4.10 ± 1.04	0.74	
	Spider crab	Hyas sp.	Epi	0.12 ± 0.07	0.09 ± 0.07	1.33	
	Angular crab	Goneplax rhomboides	Epi	0.30 ± 0.25	0.37 ± 0.19	0.80	
Gastropoda	Necklace shell	Euspira sp.	Epi	0.00 ± 0.00	0.69 ± 0.44	-	0.32
	Red whelk	Neptunea antiqua	Epi	0.13 ± 0.09	0.17 ± 0.09	0.79	
	Common whelk	Buccinum undatum	Epi	1.13 ± 0.65	3.13 ± 0.77	0.36	

Table 4. continued

Group	Species	Scientific name	Habitat	Pulse (n/ha)	TCBT (n/ha)	Ratio P/B (species)	Ratio P/B (group)
Bivalvia	Other bivalves	Bivalvia	In	0.10 ± 0.07	2.16 ± 1.25	0.05	0.08
	Great scallop	Pecten maximus	Epi	0.03 ± 0.03	0.00 ± 0.00	-	
	Queen Scallop	Aequipecten opercularis	Epi	0.18 ± 0.12	0.33 ± 0.28	0.57	
	Prickly cockle	Acanthocardia echinata	In	0.38 ± 0.16	9.20 ± 2.59	0.04	
	Ocean quahog	Arctica islandica	In	0.20 ± 0.09	0.32 ± 0.16	0.64	
Asterozoa	Sand sea star	Astropecten irregularis	Epi	171.89 ± 38.03	623.66 ± 106.12	0.28	0.31
	Common star fish	Asterias rubens	Epi	35.87 ± 6.63	53.88 ± 12.35	0.67	
	Common brittle star	Ophiothrix fragilis	Epi	5.38 ± 2.62	12.62 ± 6.79	0.43	
	Serpent star	Ophiura ophiura	Epi	7.08 ± 5.23	10.45 ± 4.33	0.68	
	Serpent’s table brittle star	Ophiura albida	Epi	0.00 ± 0.00	0.70 ± 0.55	-	
	Luidia sp.	Luidia sp.	Epi	0.00 ± 0.00	2.30 ± 0.73	-	
Other	Sea mouse	Aphrodita aculeata	Epi	7.38 ± 1.41	21.74 ± 3.82	0.34	0.34
	Ascidiaceans	Ascidiacea	Epi	0.23 ± 0.22	0.72 ± 0.71	0.32	0.32
	Green sea urchin	Psammechinus miliaris	Epi	3.61 ± 1.38	3.63 ± 1.22	0.99	0.99
	Anemones	Sagartia sp.	Epi	0.00 ± 0.00	0.18 ± 0.17	-	

* not included in the group-analysis as only the discard fraction is present in the benthos sample.

4 Discussion

This report presents the results of an opportunistic comparison between a large pulse-trawl and a large TCBT. However, due to unintended differences in the cod-end mesh-size between the pulse-trawl and the TCBT, the results should be interpreted with caution. Using results of a recent mesh selection experiment, we corrected the size distributions of the caught sole and plaice for the difference in mesh size, but for other species, no independent data were available to correct for the difference in mesh size.

The comparison of relative catch efficiencies of pulse and the TCBT estimated in 2015 (this study) and in 2011 (van Marlen *et al.* 2014) suggests that the catch efficiency of the pulse trawl for market-sized sole has increased, whereas the catch efficiency for plaice remained equal. Our study showed a 23% higher catch rate of market-sized sole in the pulse trawl, but no significant difference in the catch rate of market-sized plaice. Van Marlen *et al.* (2014) reported equal catch ratios for both market-sized plaice (0.939, p=0.8776) and sole (1.025, p=0.6214). A recent analysis of landings and effort data of pulse and TCBT trawlers, revealed that large pulse trawlers caught 17% more sole and 32% less plaice per hour fishing. Corrected for the 22% lower towing speed of the pulse trawlers (ICES, 2018), pulse trawlers had a 52% higher catch rate of sole and 12% lower catch rate of plaice per area swept (Poos et al. 2020).

The increase in catch efficiency of sole differed between groups of vessels (Poos et al., 2020). Vessels that were the first to switch to the new technique, including the vessels studied by van Marlen et al (2014), gradually increased their catch efficiency during the year following the gear switch, while vessels switching in 2011 or later increased their efficiency almost immediately. An increase in the catch efficiency of sole in the innovative pulse trawl is not surprising. The first vessels that switched to pulse trawling in 2010 experienced various operational problems with the new gear and had to develop their skills (Taal and Klok, 2012). It is well established that technical innovations result in higher catch efficiencies over time (Eigaard, 2010; Rijnsdorp *et al.*, 2008).

The difference in catch efficiency between sole and plaice is likely related to the difference in the cramp response of the fish to the pulse stimulus (van Stralen, 2005). The cramp response immobilise the fish which can no longer respond to the approaching trawl. Sole respond by bending in a U-shape by which they come loose from the sea bed and can easily be scooped up by the trawl. Cramped plaice do not change their posture and may be pass underneath the ground rope of the trawl.

For the discard size class, van Marlen et al. (2014) showed in his Figure 8 that the pulse trawl caught significantly less plaice discards than the TCBT. As the electrical potential difference over the body increases with fish size, we expect that electrical stimulation may improve the size selectivity if fish above a certain body size respond to the electrical stimulus (Soetaert et al., 2014).

The results of our study, however, do not support an improved size-selectivity of the pulse trawl. Whereas the length-distribution retention plots of van Marlen *et al*. (2014) showed lower catches of undersized plaice and sole in the pulse trawl compared to the TCBT, we show an increase in both the mesh size corrected and uncorrected estimates. This could potentially be explained by the fishing location. This opportunistic catch comparison was performed during the industrial survey, in a region that would not be selected by any fishermen to target sole as they are locally not really abundant. Hence, the larger overall catch efficiency of pulse trawls for sole could have resulted in a better retention of the available sole.

We observed that sole catch efficiency differed between the three haul types studied, with significantly higher catches during night time than the TCBT, but equal catches during daytime. Increased sole catches at night have been reported before and are related to the nocturnal feeding behaviour of sole (de Groot, 1971; Rijnsdorp *et al.,* 2000; Ryer, 2008). This observation, however, could also indicate that prevailing light conditions affect the strength of mechanical stimulation (Ryer, 2008), but not of electrical stimulation. Notwithstanding the underlying mechanism, the unequal increases in diurnal cycles observed in this study emphasize that future comparative fishing experiments should include commercial night hauls to assess overall catch efficiency differences.

Except for two crustacean species, the pulse trawl caught substantially less benthic invertebrates, in particular infaunal species. The lower catch of benthos is likely related to the lack of the tickler chains that penetrate for several centimeters into the sea bed and may dig out infaunal species (Paschen *et al*., 2000; Depestele *et al.,* 2018). The higher catch rates suggested for Norway lobster and spider crabs may be related to the specific response of these animals to the pulse stimulus.

Norway lobsters may leave their burrows when exposed to a pulse stimulus. The lower bycatch of benthic invertebrates in the pulse trawl contribute to a reduction of the adverse impact of the sole fishery on the benthic ecosystem due to the mechanical disturbance. The effect of electrical stimulation is currently being investigated (ICES, 2018).

This study confirms that pulse trawls have a higher catch efficiency for sole, the main target species of the fishery, but not for plaice, but does not support an improved size selectivity. The results of the catch comparison of undersized fish and benthos, however, is affected by the difference in cod-end mesh between the pulse trawl and TCBM and should be interpreted with caution.

Despite the lack of support for a reduced catch efficiency for undersized flatfish, the improved species selectivity for sole is expected to result in a reduction in the bycatch of undersized flatfish which is dominated by plaice. Hence, the transition from TCBM to pulse trawling in the bottom trawl fishery for sole could reduce discard quantities, which is especially interesting under the EU-wide implemented Landing Obligation, as well as reduce the impact on the benthos due to mechanical disturbance.

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6 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

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Justification

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The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

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With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.