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A Study to Investigate the Potential Ecological Impacts of Pulse Trawling

A Fisheries Science Partnership project

Authors: Jo Ford, Evalyne Muiruri, Rebecca Skirrow, Michael Fox, Clement Garcia, Julie Bremner, Tom Catchpole

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Project Manager:	Mike Fox
Report compiled by:	Jo Ford
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Executive Summary

This work was carried out as part of the Fisheries Science Partnership (FSP) programme which is a Defra funded collaborative programme of scientific research between the UK Fishing Industry and scientists. This programme was introduced in 2003 to build relationships between UK fishermen and scientists and to involve fishermen in the co-commissioning of science. The primary objective of this project was to conduct a survey to assess the effects of pulse trawling off the English east coast, near to the port of Ramsgate. The fleet of large, predominantly Dutch, beam trawlers has adopted novel pulse trawl technology in recent years. The fishing grounds beyond 12 nautical miles off Ramsgate has been identified as a hotspot for pulse trawling with the local inshore fishermen reporting observations of a detrimental effect to their fishing grounds, including a perceived reduction in the Common sole (*Solea solea*) catches in the area, this perceived reduction in catch is not addressed in this report.

Pulse trawling was first used in 1992 in The Netherlands. Pulse trawling uses electrodes instead of conventional tickler chains ahead of the trawl, the pulse from these electrified wires causes the muscles of flatfish to spasm and rise out of the sediment, making them available for capture in the trawl. The pulse trawls are much lighter than regular beam trawls, and are operated at lower speeds than conventional trawls, because the sole do not evade capture when they are in spasm. This means that fuel consumption is much lower than for conventional beam trawls and there are substantial economic benefits in using pulse trawl compared with beam trawls. The lightness of the pulse trawls (in the region of 25% of a standard beam trawl) also allows them to be towed on softer grounds (Turehout, 2016). Pulse trawling is banned in the EU, under Article 31 of Council Regulation (EC) No. 850/98 which covers unconventional fishing methods and states: “The catching of marine organisms using methods incorporating the use of explosives, poisonous or stupefying substances or electric current shall be prohibited”. However, through various mechanisms the EU Commission authorised derogations for vessels operating in the southern North Sea, and in 2018, eighty-four Dutch vessel used pulse trawls. In 2018, it was decided to substantially reduce this number. While there have been several studies on the catching performance of pulse trawls and laboratory studies on the effects on the pulse technology on selected species, there has been no attempt to assess the in situ community effects of pulse trawling, including the effects on inshore fishing grounds where smaller boats are operating and reporting that their fisheries are being impacted.

A survey was designed to inform on the potential impact of pulse trawling where activity is known to be concentrated. The survey was conducted on two comparative fishing areas. These were selected following discussions with the local English fishing industry, and an assessment of VMS data, depth and sediment information. Area 1 was an area which has been fished previously by beam trawlers and, in recent years has a seen a concentration pulse trawl activity. Area 1 lies west of 12 nm east of the English coast, a regulatory boundary, to the west of which, larger beam trawlers and all pulse trawlers are prohibited. Area 2 is an area located to the west of Area 1 between 6nm and 12nm from the coast, this area has had no previous pulse trawling activity, but significant fishing activity from smaller inshore vessels using static and trawled gears. The two areas are of similar overall size and had comparable depth and sediment composition. Two sampling methods were used to determine the number and abundance of species in the two areas. In both areas, ten 30-minute otter trawls were undertaken, using twin 80mm cod ends suspended from 4m beams. Both areas were also sampled using a standard Cefas Jennings benthic trawl with a 1mm cod end mesh; 18 benthic tows were carried out in each area.

The results showed that fewer species were caught in Area 1 (east of 12 nm) than Area 2 (west of 12 nm) with a 57% lower species richness in benthic trawl catches and 21% lower in catches taken by otter trawls. There were 17 species caught using the benthic trawl in Area 2 that were not observed in Area 1. There was a lower abundance of most species common to both areas in Area 1, but notably a much higher abundance of brittle stars (*Ophiothrix fragilis)* in Area 1, and more hermit crabs (*Paguridae*). Statistical analyses showed that, when using the small mesh benthic trawl, 2.6 times more Common sole were caught in Area 1 compared with Area 2. Although fewer sole were caught in Area 1, the sole caught were significantly larger than those in Area 2. Whiting (*Merlangus merlangus*) was the most abundant fish species caught in the otter trawls in both areas, but with more than double the abundance in Area 1. Thornback ray (*Raja clavate*) catches were 47% lower in Area 1 than Area 2.

The results from this study show clear differences between the two areas in species richness and abundance of fish and in richness, volume and, to an extent, in community structure of the benthic species. The main difference between the two areas is the type and intensity of fishing activity, however, the results cannot be attributed exclusively to the effects of pulse trawling. Area 1 has seen a concentration of pulse trawl activity in recent years, but previously it was an area fished by large beam trawlers, and the relative impact of these two fishing methods cannot be separated. In

Area 2, where less intensive and less impactful fishing methods are used, there was higher benthic and fish species richness and abundance/volume. The marked differences between the two areas observed in this study raises questions on whether the historical impact of beam trawling, or the recent concentration of pulse trawl activity, has caused a reduction in species richness and abundance. It cannot be ruled out that other factors may also have driven these results. The only known difference between the two areas is in the fishing activity and it would be difficult to ascertain the nature and extent of the influence of other factors operating on the communities without gathering data on natural phenomena and human footprints over a range of scales. Unfortunately, the opportunity to conduct large scale and long-term ecological experiments to determine the community effect of pulse trawling was not taken during the transition to pulse trawling, and this study demonstrates that this research is still needed to fully understand the ecosystem impacts of using pulse trawl technology.

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Introduction

Overview

This work was carried out as part of the Fisheries Science Partnership (FSP) programme which is a Defra funded collaborative programme of scientific research between the UK Fishing Industry and scientists. This programme was introduced in 2003 to build relationships between UK fishermen and scientists and to involve fishermen in the co-commissioning of science. The primary objective of this project was to conduct a survey to assess the effects of pulse trawling off the English east coast, near to the port of Ramsgate. The fleet of large, predominantly Dutch, beam trawlers has adopted novel pulse trawl technology in recent years. The fishing grounds beyond 12 nautical miles off Ramsgate has been identified as a hotspot for pulse trawling with the local inshore fishermen reporting observations of a detrimental effect to their fishing grounds, including a perceived reduction in the common sole (*Solea solea*) catches in the area, this perceived reduction in catches is not addressed in this report.

Background

Pulse trawling was first used in 1992 in The Netherlands. Pulse trawling uses electrodes instead of conventional tickler chains ahead of the trawl, the pulse from these electrified wires causes the muscles of flatfish to spasm and rise out of the sediment, making them available for capture in the trawl. The pulse trawls are significantly lighter than regular beam trawls, and are operated at lower speeds than conventional trawls, because the sole cannot evade capture when they are in spasm. This means that fuel consumption is much lower than for conventional beam trawls and there are substantial economic benefits in using pulse trawl compared with beam trawls. The lightness of the pulse trawls (in the region of 25% of a standard beam trawl) also allows them to be towed on softer grounds (Turehout, 2016). Pulse trawling is banned in the EU, Article 31 of Council Regulation (EC) No. 850/98 covers unconventional fishing methods and states: "The catching of marine organisms using methods incorporating the use of explosives, poisonous or stupefying substances or electric current shall be prohibited" However, through various mechanisms the EU Commission authorised derogations for vessels operating in the southern North Sea, and in 2018, eighty-four Dutch vessel used pulse trawls. In 2018, it was decided to substantially reduce this number. While there have been several studies on the catching performance of pulse trawls and laboratory studies on the effects on the pulse technology on selected species, there has been no attempt to assess the effects of pulse trawling on inshore fishing grounds where smaller boats are operating and reporting that their fisheries are being impacted.

Pulse trawling is similar to beam trawling in that it uses a net which is dragged along the sea floor, held open by a rigid beam. Conventional beam trawlers use tickler chains to aggravate the seabed which encourages any fish living within the seabed to swim upwards and into the awaiting net. Pulse trawlers utilise electrified

trailing wires instead of tickler chains which send a charge of electricity through the seafloor. The pulse from these electrified wires causes the muscles of flatfish to spasm forcing them upwards and therefore into the awaiting net. There are substantial economic benefits in using pulse trawls compared with beam trawls. (Turenhout et al, 2016). The pulse trawls are much lighter than regular beam trawls and are operated at lower speeds than conventional trawls therefore the fuel consumption is much lower than for conventional beam trawls which equates to a reduction in operating costs. The lightness of the pulse trawls (in the region of 10-25% of a standard beam trawl) also allows them to be towed in softer grounds, provided access to new fishing areas previously inaccessible to beam trawls.

A review of the research into the effects of pulse trawling has identified knowledge gaps in the impacts of pulse trawling (Bremner et al, 2018). One of the gaps identified was the medium and long-term ecosystem and community impacts of pulse trawling for flatfish in the North. The main objective for this study was:

> To assess if there are differences in the abundance and diversity of fish and benthic species caught in an area that had been heavily fished by pulse trawlers in comparison to an adjacent comparable area that has had no pulse activity.

Sole Fishing in the Southern North Sea

The Southern North Sea (ICES sub area IVc) is an important fishing ground, with the east coast of England defining its western border and Belgium and The Netherlands its eastern border. From England, it is easily accessible from the north Kent coast, Essex coast and East Anglia. There are four major ports in the area (Table 1) with the main demersal fish landings being, sole, plaice and thornback ray (*Raja clavata*) (Figure 1).

Port	No of >10m Vessels registered	No of <10m Vessels Registered
Ramsgate	2	23
Whitstable	4	9
Margate	0	3
Broadstairs	0	1

Table 1: Vessels registered on the MMO monthly vessel lists (Source MMO-2019 April)

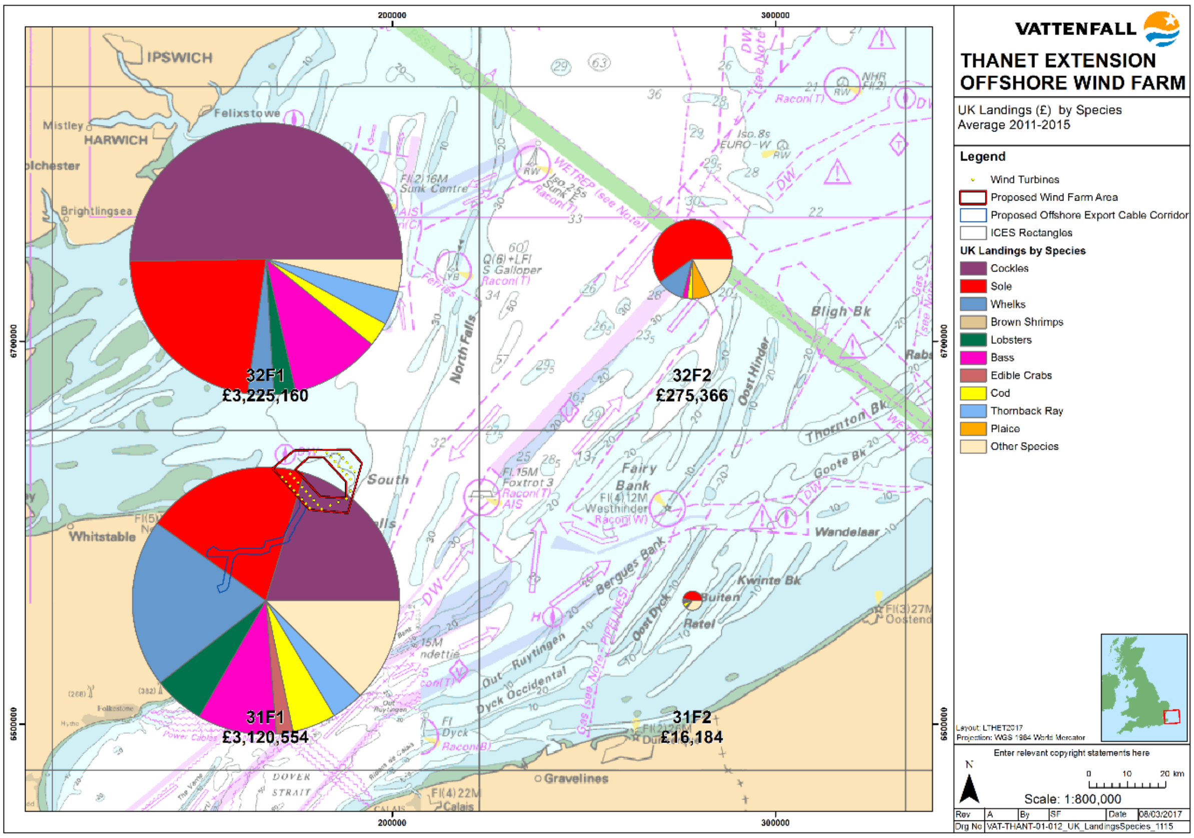

Figure 1: Average landings values (2011-2015) by species in regional study area (Source MMO 2017) (Vattenfall, 2017)

Since the Dutch started using pulse as a fishing metier in the area in 2012 local fishermen from Kent and Essex have reported unusually high numbers of dead Dover sole and plaice in their catches (Ungoed-Thomas, 2012), although these have not been scientifically corroborated. This they purport to be as a direct result of the activity of pulse trawlers in the area. They also claim that the fishing grounds are 'dead' around the 12nm line, which is as close to the English coast as the Dutch boats are permitted to fish. The view of the local industry is that the pulse trawling is killing all the benthic species living on or in the seabed, leaving behind an "an aquatic graveyard". The local fishermen also express a fear that the pulse trawlers, being much lighter than traditional

beam trawlers, can now access the softer inshore grounds - which are traditionally spawning grounds for plaice and sole (Ellis, 2012) **-** and this is affecting these stocks of these species and their fishing opportunities.

Materials and Methods

Vessel

The vessel used was the Seiont A (BM114), a 14m steel hulled Beam Trawler based out of Ramsgate in Kent.

Seiont A (BM114), a 14m steel hulled Beam Trawler based out of Ramsgate

Meeting with skippers to plan the survey

A meeting between Cefas scientists and the industry was conducted at the MMO office in Whitstable, Kent at the end of August 2018. The meeting was set up to develop a survey plan to best tackle the issues and concerns raised by the local inshore fishermen. During the meeting two survey areas were defined and a basic sampling plan was established which was then later developed into the detailed operational plan.

Area and period of operation

In total 10 days of fieldwork were conducted during October and November 2018 out of Ramsgate, ICES subdivision IVc, rectangles 31F1 and 32F1. Ramsgate is a busy port both for commercial fishing and private vessels located on the north Kent coast, England.

There were two distinct areas for the survey. Area 1 is currently regularly fished by pulse trawlers and other commercial fishing, which lies east of the 12nm line (information gathered from VMS pulse trawling (Figure 4) data and discussions with the industry, Figure 2). Area 2, between the 6nm and 12nm lines to the west of the Area 1, has had no previous pulse activity but is subject to regular commercial fishing. This area was assessed to be of similar depth and sediment type to area 1, but has had no previous pulse trawl activity. (information gathered from VMS pulse trawling data and discussions with the industry; Area 2 on Figure 2 shown in Red).

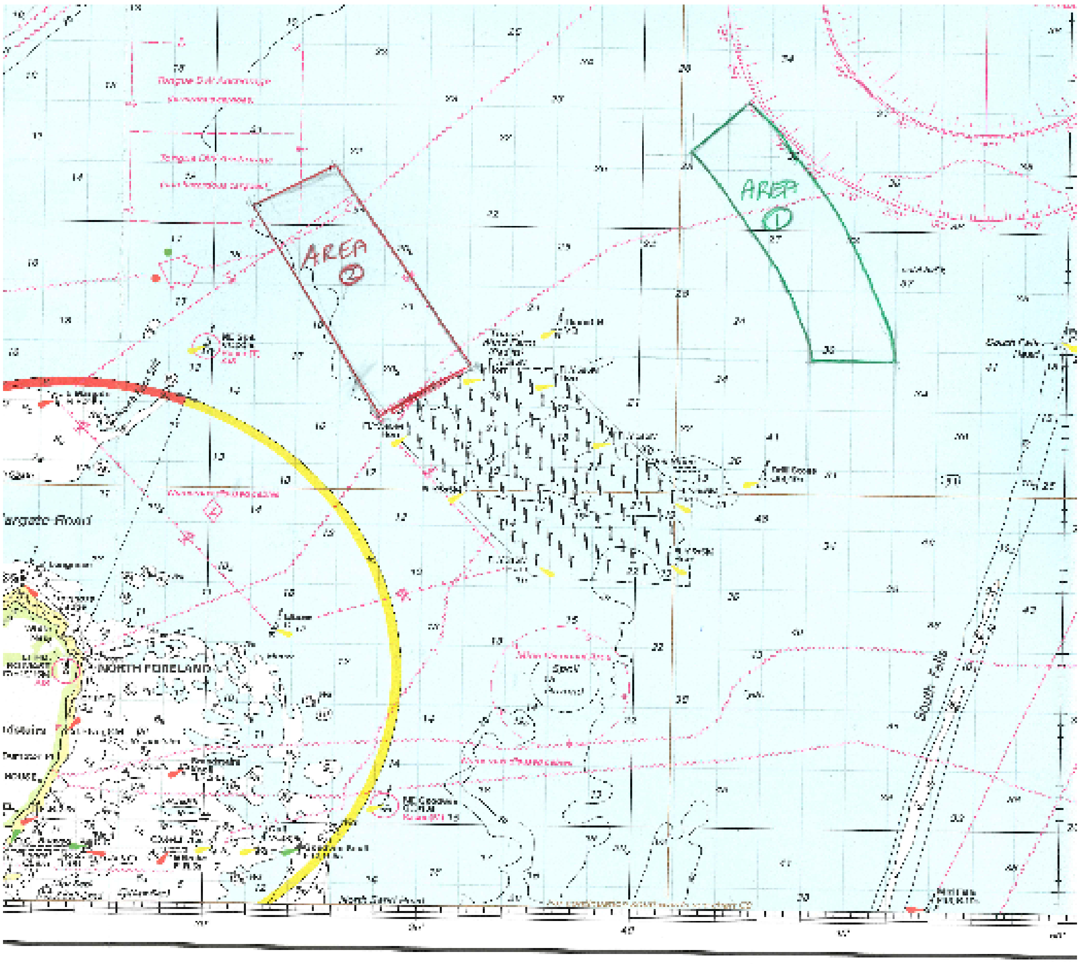

Figure 2 : Chart to show the two study areas; an output from the industry meeting to plan the survey

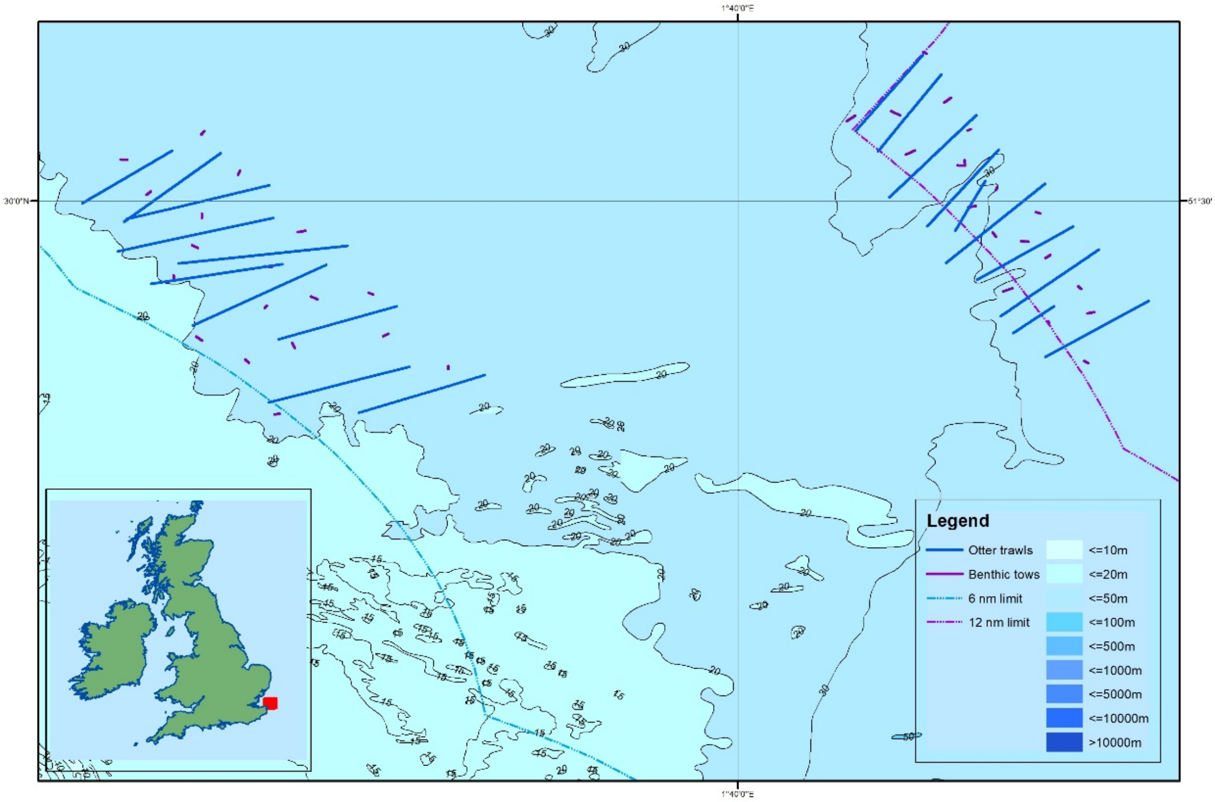

Figure 3 GIS plot of both areas showing otter trawl and benthic tow locations

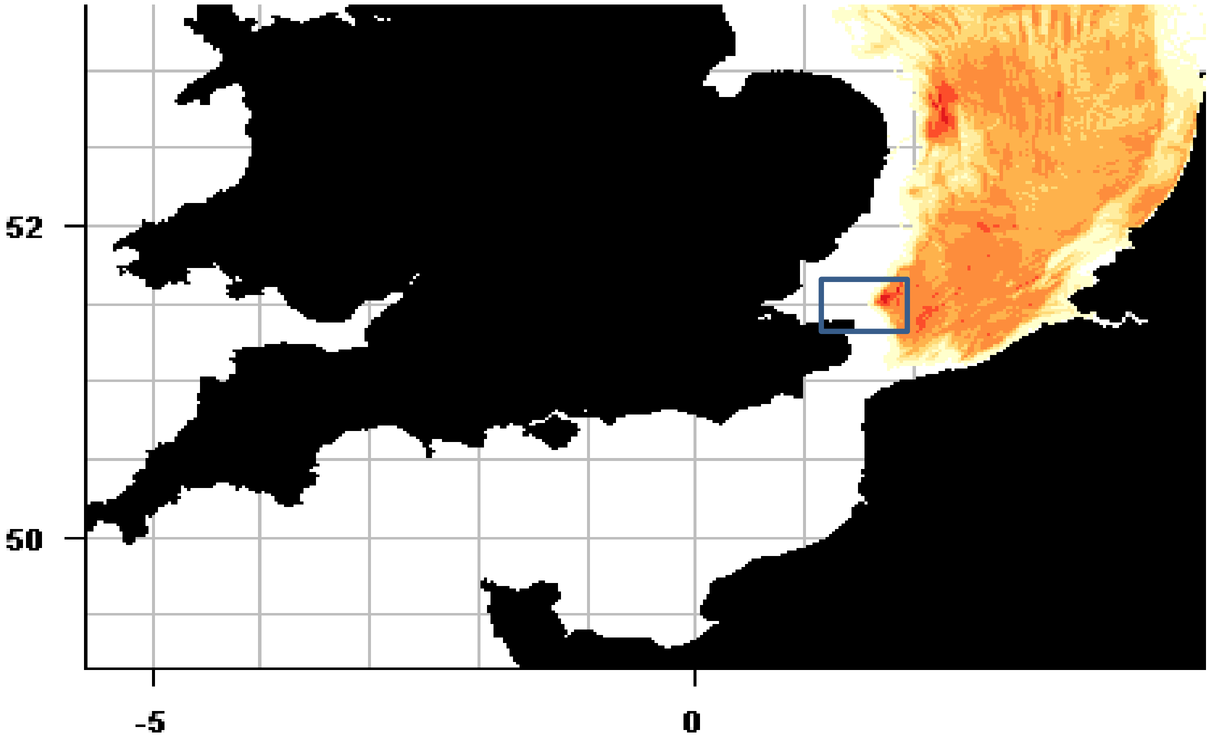

Figure 4: VMS map showing pulse trawl intensity 2009-2017 (WGElectra)

Survey Sampling Methods

There were two sampling methods used to gather data in this study, otter trawls and benthic trawls. Haul details were collected for each tow by the scientific observer including; start and end time, depth, latitude and longitude and weather conditions. The decision as to whether otter trawls or benthic trawls were to be undertaken on any set day was made according to the weather conditions and forecasts. Due to the nature of the benthic trawl being light and having to 'sit down' on the seabed, days when the weather was fine were used for benthic tows, and poorer days used for otter trawls.

Otter trawls - In each of the two areas, ten 30-minute otter trawls (Figure 5, Figure 6) were undertaken using twin 80mm cod ends suspended from 4m beams which was the vessel's standard commercial gear for targeting common sole. The tows operated under 'normal commercial practice' with the vessel towing at approximately 2.5 knots. The tows followed a linear pattern whereby the vessel towed south east to north west (or vice versa) so that no tows intersected (Figure 3). During any sea day the same number of tows occurred in each area to minimise any differences in composition which might have been attributable to tides, weather etc.

Photo 1: Otter trawl being deployed (above)   Photo 2: Catch being emptied into fish boxes

The catch from each otter trawl was collected into fish boxes by the crew and then passed to the observers for measuring. All fish species were measured to the nearest cm below and returned to the crew for sorting and gutting if required. Any non-fish species were counted, and an approximate volume taken (to the nearest 10ml) using measuring jugs. Any fish and non-fish species that were not wanted by the vessel were then returned to the sea. At no time during the study was subsampling required.

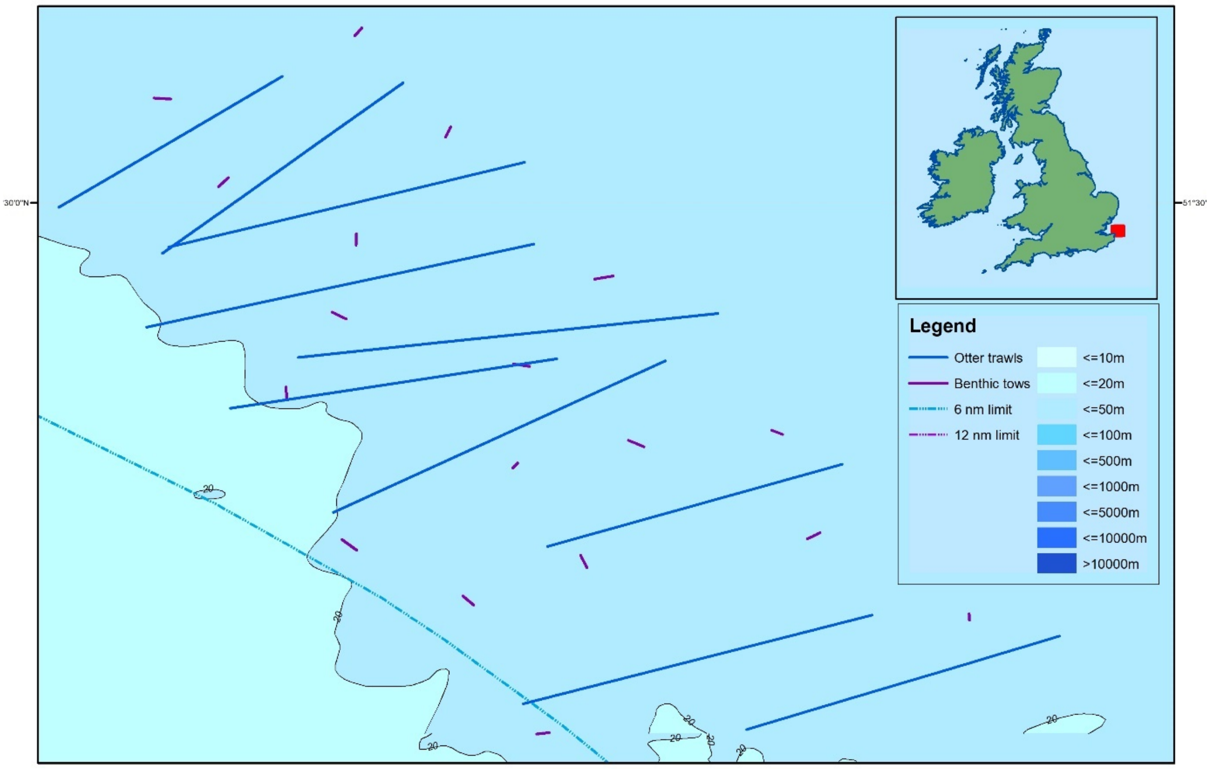

Figure 5: GIS plot of otter trawls and benthic tows conducted in area 2

Benthic trawls - This operation involved ‘drifting’ (0.5-1.0 knots) with the tide towing a 2m Jennings benthic beam trawl, with a 1mm cod end, for 5-minute tows (warp ratio 3:1); 18 tows were carried out in each area (Figure 5, Figure 6) . The tows occurred between the otter trawl tows where possible so that two benthic tows occurred between the lines of each otter trawl tow. During any sea day the same number of tows occurred in each area to minimise any differences in composition which might have been attributed to tides, weather etc.

Photo 3: Benthic trawl being deployed

Photo 4: 1mm mesh bag for washing the catch

Photo 5: Benthic haul before washing

Photo 6: Benthic haul after washing

The catch from each benthic trawl was collected by the crew into fish boxes and passed to the observers for processing. The catch was passed through a 1mm mesh bag inside a fish basket with deck hoses to wash as much mud, silt and sand as possible from the catch. The 'washings' were then analysed. All fish species were measured to the nearest cm below. Any non-fish species were counted where possible, weighed using DEM motion compensating scales and an approximate volume taken to the nearest 5ml using measuring jugs. For species that could not be counted or weighed, such as brittle stars when they occurred in very large numbers, a volume only was taken. Broken shell was assessed by volume. All benthos was returned to the sea after assessment.

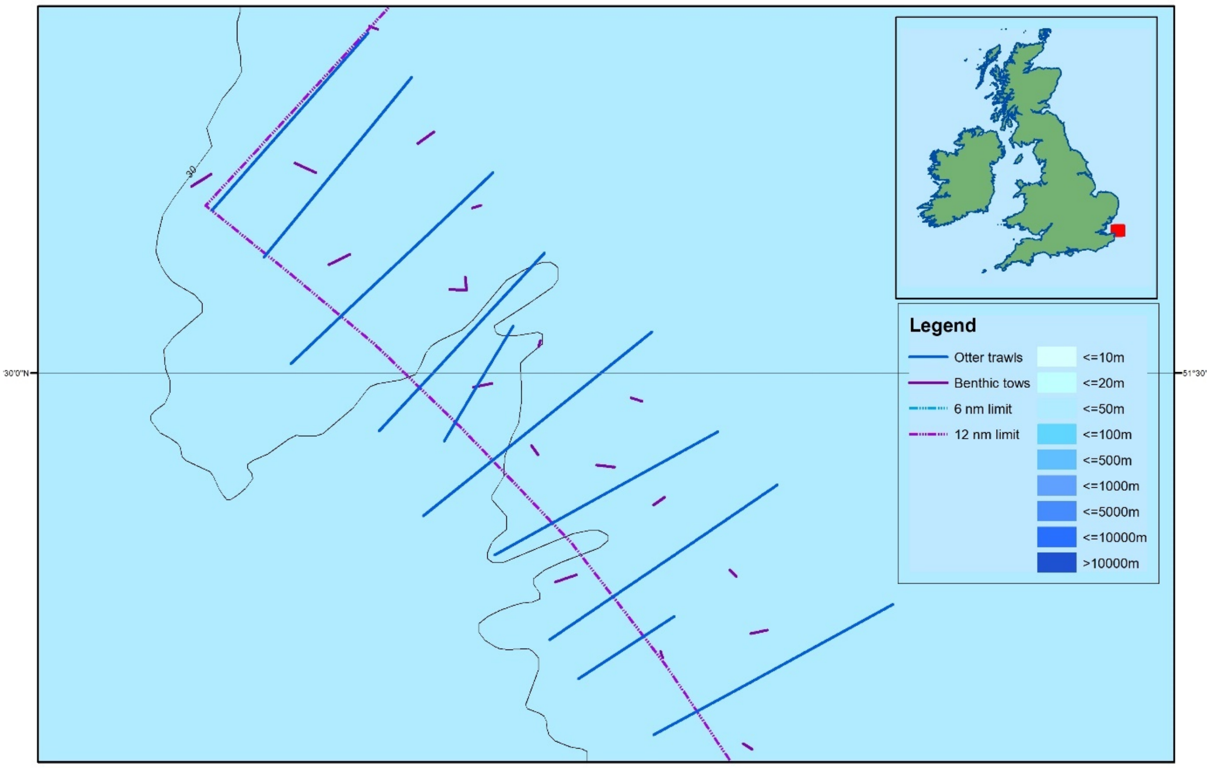

Figure 6: GIS plot showing otter trawls and benthic tows in area 1

We attempted to use cameras for a visual impact assessment of the seabed by attaching GoPros to the otter trawl and the beam of the Jennings trawl. Unfortunately, the visibility at the tow sites was too poor. Attaching lights to the beams was discussed as a possibility but discarded as the affect the lights might have had on fish behaviour was unknown and it was decided that adding another variable would create more confusion than answers.

Statistical Analysis

A total of 45 species were caught across the whole study. Visual inspection of the catches indicated notable differences in the community of individuals caught in the two areas, with many species absent in Area 1 that were present in Area 2 (Figure 7, Table 3 (appendix)). In addition to a descriptive analysis of these differences, we also performed statistical analyses on the number of different species identified – hereafter referred to as species richness – caught in each area. Species richness was standardised by the swept area (km^2) to account for differences in the distance travelled between tows, and models were fit to identify differences in species richness between the two areas.

Further analysis of the finfish in this study focused on testing if the two areas differ in terms of the abundance and length distributions of four species: sole, whiting, plaice and thornback ray. These were selected based on their catch rate and economic importance. Differences in their catch size and lengths were examined from both otter trawls and benthic trawls. However, in the case of benthic trawls, no whiting were caught and plaice and thornback rays were caught in insufficient number for statistical analyses. For these three species we focus our analysis on catches from otter trawls, and only Common sole was analysed from both gears.

As with species richness, we standardised counts for each of the four selected fish species by the swept area and applied a log transformation to meet assumptions of normality in the model. Raising factors were included in the model as an offset and, once fit, an additional conversion factor was applied to model estimates to account for bias introduced by the log-transformation of catch per unit area (Sprugel, 1983). To determine if there were any differences in the length distributions of the focal species between the two areas, quantile regression models were fit for each species, estimating lengths at the 25th, 50th and 75th percentile using the *quantreg* package (Koenker, 2017) . All analyses were performed in R, version 3.5.1 (R Core, 2018).

Of the benthos caught in this study, brittle stars (*Ophiothrix fragilis*) were too many in number to count in some tows of the benthic trawls and *Sabellaria* sp. worms cannot easily be individually counted from trawls. Thus, benthos abundance and weight values were not possible for all hauls and we faced the choice of either removing these two taxa to allow us to analyse by weight or finding another measure of benthos quantity. Rather than lose the information on brittle stars and *Sabellaria*, which are important members of the benthic communities, we instead chose to analyse

volume because that had been measured for each taxon captured in the benthic trawls. Any volumes recorded on the trip log sheets as < 5ml (below the minimum measurement marker) were considered to be 5 ml for the purposes of the analysis. The brown seaweed found in Area 2 (*Fucus spp*.) was removed from the dataset because beam trawls are not designed for surveying seaweed. Further analysis for the benthos aimed to understand whether and how the benthos communities in Areas 1 and 2 differed:

1. Total volume and evenness – this tells us whether there are differences in the total amount of organisms in each area and whether there are similar numbers of organisms per species in the two areas. Communities under pressure from e.g. trawling, should have fewer species and may become dominated by a small number of these species.
2. Multivariate ordination – principal components analysis (PCA) and permutational analysis of variance (PERMANOVA) tell us whether and how the overall structure of the communities in the two areas differs.[1]
3. Multivariate cluster analysis – to support the ordination, this method groups the hauls together based on how similar they are in terms of the volumes of each species. If the hauls fall into two groups corresponding to the two experimental areas, we have more confidence that there are indeed differences between them.

When working with trawl data, it is customary to standardise to swept area in order to account for differences in the amount of ground covered if towing speed is altered between hauls, with the standardisation process often involving raising the numbers to per 1 km^2. While we have followed this custom for species richness, we have elected not to do so for the analyses based on volume because it is an unconventional measure that is less accurate than either abundance or weight, therefore these inaccuracies could be compounded by the raising process. Omitting the standardisation step could cause problems if the towing speed varied consistently between Area 1 and Area 2 because a lower towing speed in one area would mean less ground covered and so potentially fewer organisms caught; this is probably not the case here ($\bar{x}$ 0.8 +/- 0.08 95% C.I. knots in area 1 *versus* $\bar{x}$ 0.76 +/- 0.07 95% C.I. knots in area 2), but one should be mindful the data are not standardised when interpreting the results.

[1] Technical details of the multivariate analyses: Principal components analysis computed on Hellinger-transformed volume data. Standard multivariate analysis of variance was not possible due to non-homogenous variances, so permutational analysis of variance was used instead (999 permutations). Cluster analysis computed using the Bray-Curtis similarity index and Ward's D2 clustering method.

Results

Benthic tows

A total of 45 different types of organisms were caught using benthic tows. We observed that 26 taxa were caught using benthic tows in Area 1 and 42 taxa in Area 2. Of these, the most abundant were brittle stars (*Ophiothrix fragilis*) which were collected in such volume, they could not be counted and were too heavy to weigh with the scales available. Volume figures from Area 1 showed a total volume of 15,885 ml of brittle stars were captured in Area 2 compared to 161,781ml in Area 1 indicating substantially more brittle stars (9 time more) were present in the samples from Area 1. A high volume of broken shell was also collected in both areas but was higher in Area 1 (178,850ml) compared to Area 2 (28,979ml). Of the species that we could count, hermit crabs (*Paguridae*), brown shrimps (*Crangon crangon*) and sole (*Solea solea*) were the most abundant (Figure 7). There were four species caught in Area 1 but not Area 2 (Table 3 (appendix), Figure 7); bib (*Tricopterus* luscus), bryozoan (*Celleopra* pumicosa), sand eel (*Ammodytes* marinus) and three unidentified worms. There were 17 species caught in Area 2 that were not caught in Area 1; alloteuthis squid (*Alloteuthis subulate*), common dragonet, swimming crab (*Liocarcinus holsatus*), bubble snail (*Acteon tornatilis*), gibbs sea spider (*Pisa armata*), greater pipefish (*Syngnathus acus*), green sea urchin (*Psammechinus miliaris*), masked crab (*Corystes cassivelaunus*), mussel (*Mytilus edulis*), necklace shell (*Euspira (Polinices) catena*), nut shell (*Nucula nucleus*), nut crab (*Ebalia tumefacta*) queen scallop, sand slug, sea potato, slender spider crab, spiky bivalve and tub gurnard (*Trigla (chelidonichthys) lucerna*).

Models of species richness per unit swept area indicated significant differences between the two areas ($F_{1,34}$=22.1, p<0.001), with the model estimating a 57% lower species richness in trawls from Area 1 than Area 2 (36060/km^2 *versus* 83789/km^2, Figure 8). Note that the standardisation method has resulted in richness estimates vastly higher than the actual species richness of the North Sea. These should not be taken as ‘real’ estimates of species richness – it is the proportional difference between the two areas that is important, the numbers themselves are simply an artefact of the standardisation method.

There is a pattern of lower total volume of benthos in Area 1 compared to Area 2 (Figure 9) and Figure 10 shows us that the taxa found in Area 1 are a subset of those found in Area 2. Figure 10

also shows that the communities in Area 1 are more even than those in Area 2 – it has an 'unbalanced' distribution with several low-volume taxa in a tail at the end.

When taken together, lower richness - being a subset of the inshore communities - and lower total volume indicate more pressure is occurring on the benthos communities in Area 1. The higher evenness in Area 1 is slightly counter-intuitive as we would expect communities under pressure to become dominated by one or two very abundant species. It may be that the absence of the tail of low-volume species in Area 1 has allowed the existing resources to be spread more evenly among the remaining taxa.

The multivariate ordination gives us further evidence of differences between the benthos communities in Areas 1 and 2 (Figure 11), which are statistically significant according to the PERMANOVA ($F_{1,34}$=79.824, p=0.001). The hauls from the two areas are mainly separated on the plot, with those from Area 1 spreading away from those of Area 2 and defined by higher volumes of hermit crabs, swimming crabs, *Crangon crangon* and worms, while those in Area 2 are defined by larger volumes of a wider variety of species. The ordination plot and, more clearly, the cluster analysis dendrogram (Figure 12) do, however, show that there is not complete separation between the communities from the two areas; we can see some overlap between Areas 1 and 2 in the centre of the ordination and the dendrogram shows some of the hauls from Area 1 are more similar in their taxon complement to those in Area 2 (they fall into the red group together with the hauls from the non-pulsed area).

Overall, there is sufficient evidence of a difference in the benthos between Area 1 and Area 2 – in the volumes, numbers and distribution of taxa in the two areas.

Photo 7; washings from benthic trawl in area 2

Photo 8; washings from benthic trawl in area 1, illustrating large volume of brittle stars

Otter trawls

In total, 44 types of organism were caught in the otter trawls, 29 species in area 1 and 36 species in area 2. The most abundant species caught in both areas using otter trawls were whiting (*Merlangius merlangus*), plaice (*Pleuroncentes platessa*), thornback ray (*Raja clavate*), lesser spotted dogfish (*Scyliorhinus canicula*) and dab (*Limanda limanda*). There were six species that were found in area 1 but not in area 2 (Table 4 (appendix), Figure 7), they were; cuttlefish (*Sepia* officinalis), john dory (*Zeus* faber), lemon sole (*Microstomus* kitt), lesser weaver fish (*Echiichthys (trachinus)* vipera), mollusc (*Acteon* tornatilis) and turbot (*Scopthalamus* maximus). There were 13 species present in area 2 but not in area 1 (Table 4, appendix), they were; brown crab (*Cancer pagarus*), common dragonet (*Callionymus lyra*), green sea urchin (*Psammechinus miliaris*), horse mackerel (*Trachurus trachurus*), pogge (*Agonus cataphractus*), queen scallop (*Aequipecten opercularis*), sand slug (*Philine aperta*), scaldfish (*Arnoglossus laterna*), sea potato (*Echinocardium cordatum*), slender spider crab (*acropodia tenuirostris*), solonette (*Buglossidium luteum*), spiky bivalve (*Acanthocardia spp.*), swimming crab (*Liocarcinus lucerna*), velvet swimming crab (*Necora puber*). The most notable differences in total abundance in area 2 compared to area 1 were starfish (*Asterias rubens*), where there were 14 found in total in area 1 and 2236 found in area 2, and sea mouse (*Aphrodite aculeata*) where there were 3 found in area 1 and 233 found in area 2. Hermit crabs (*Paguridae*) and whiting were the only species that were more abundant in area 1 than area 2 with 80 hermit crabs in area 1 and 7 hermit crabs in area 2 (91% lower) and 922 whiting in area 1 and 642 whiting in area 2 (30% lower).

Models of species richness per unit swept area indicated significant differences between the two areas ($F_{1,18}$=5.3, p=0.033). Fewer species were detected in the samples from Area 1 with the model estimating a 21% lower species richness in otter trawls (area 2: 1131/km^2, area 1: 897/km^2, Figure 8[2]). We have not conducted additional analyses of the benthos in the otter trawls as they are better sampled with a beam trawl and so the otter trawl benthos data are considered a support for the main analysis that took place on the beam trawl data.

[2] As for the analysis of the beam trawl data, due to the standardisation step the species richness estimates for the otter trawl data are likely higher than that which occur naturally in the North Sea; it is the proportional difference between the two areas that is of interest.

Sole

Sole was the most abundant fish caught in benthic trawls (Figure 7) and we observed that significantly fewer were caught with the benthic trawl in area 1 compared to area 2 ($F_{1,29}$=14.9, p<0.001). The model estimated that 2.6 times less sole were caught in area 1 (11294/km^2) compared to area 2 (40583/km^2, Figure 13).

Although sole caught in benthic trawls were fewer in number in area 1, we observed that these fish were significantly larger in size compared to area 2 (area 2: 9.6cm±0.42, area 1: 17.4cm±1.23, Figure 13). Quantile regression models also confirmed that sole in area 1 were significantly larger than those in area 2 at all three quartiles. That is, if sole were lined up from the smallest fish to the largest in each area, the models predicted that sole at the lower 25% point (i.e. the first quartile or 25th percentile) were 6cm longer in area 1 compared to area 2, sole from area 1 at the midpoint (i.e. the median or 50th percentile) were 11cm longer than sole from area 2 and, sole at the 75% point (i.e. the third quartile or 75th percentile) were 10cm longer in area 1 compared to area 2 (Table 2).

Sole caught in otter trawls were in far smaller numbers compared to benthic trawls (otter: 194/km^2 vs benthic: 11294/km^2 in area 1 & otter: 465/km^2 vs benthic: 40583/km^2) and, no significant difference in sole catches were detected based on hauls from otter trawls ($F_{1,15}$=2.58, p=0.129, Figure 13). Sole length distributions in otter trawls were also more similar with no significant differences detected at any percentile in quantile regression models (Figure 13, Table 2).

Whiting: Whiting was the most abundant fish caught in otter trawls and we observed a significant differences in catch per unit swept area between the two regions ($F_{1,17}$=5.92, p=0.026, Figure 7). Whiting was more abundant in area 1 with the model estimating a catch rate of 6396/km^2 in area 1 – more than double that in area 2 (3148/km^2, 103% higher). No differences were detected in the length distributions of whiting caught in area 2 verses area 1 (Figure 14, Table 2).

Plaice: No significant difference in plaice catch per unit swept area were detected between the two areas ($F_{1,18}$=2.33, p=0.145, Figure 15). Additionally, plaice from both regions were similar in size with no differences in the length distributions was detected in quantile regression models (Figure 15, Table 2).

Thornback Ray: Significantly fewer thornback ray were caught in area 1 compared to area 2 ($F_{1,18}$=7.17, p=0.015, Figure 16). Our model estimated a catch per unit area at 1613/km^2 in area 1 and 3058/km^2 in area 2, amounting to a 47% decrease in thornback ray catches. While the range of ray lengths was similar between the two areas, quantile regression models revealed significant differences at the median. That is, rays at the middle of the range (i.e. the 50th percentile) were 5cm longer in area 2 compared to area 1 (Table 2).

Figure 7 The total abundance of species from benthic and otter trawls in Area 1 and Area 2 (Volume used in analysis not abundance). The stacked bars indicate the total number of individuals of each species caught. Brittle stars were caught in high abundance with the benthic trawl but were too many too count. Sabellaria and a brown seaweed (*Fucus spp*.) seaweed were also not counted in the study and are excluded for both fishing methods in the figure however, analyses in the text were performed on volume to incorporate these species.

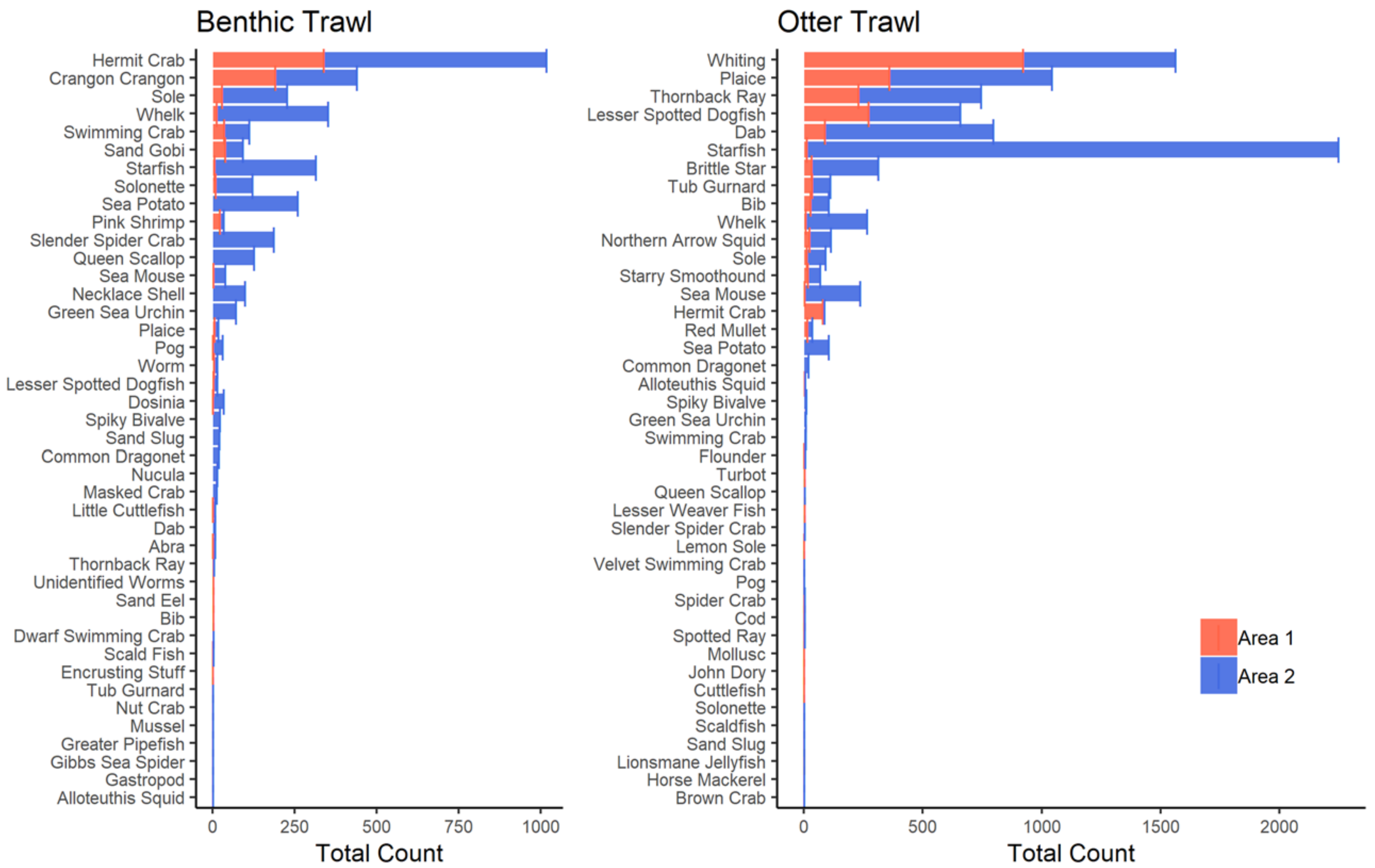

Figure 8: Species richness per unit swept area in the inshore and offshore areas. Raw data and model estimates (±95% CI) are indicated.

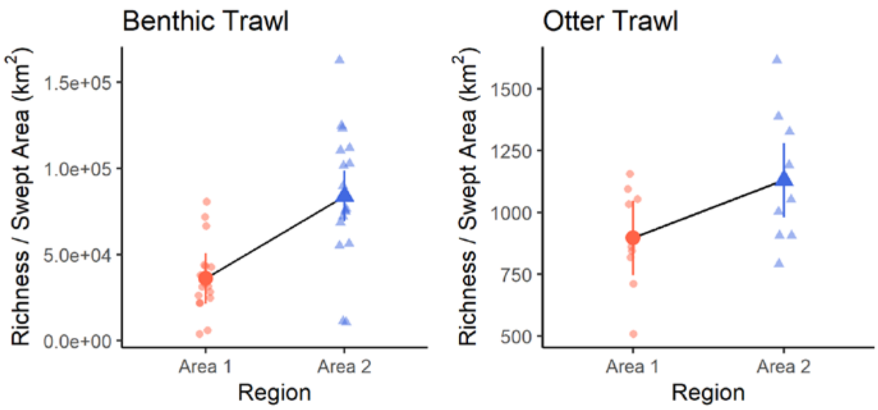

Figure 9: Total volume (litres) of benthos (beam trawl) in the two areas.

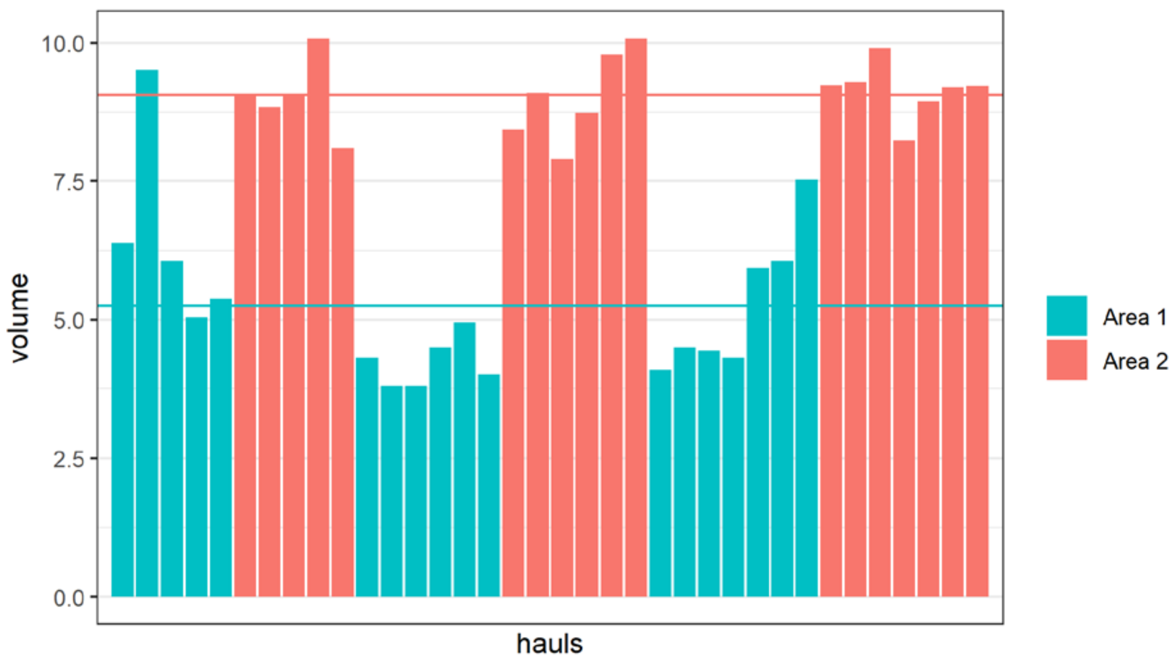

Figure 10: The evenness of the benthos communities in area 1 (orange) and area 2 (green), illustrated here as how the volume is distributed among the taxa.

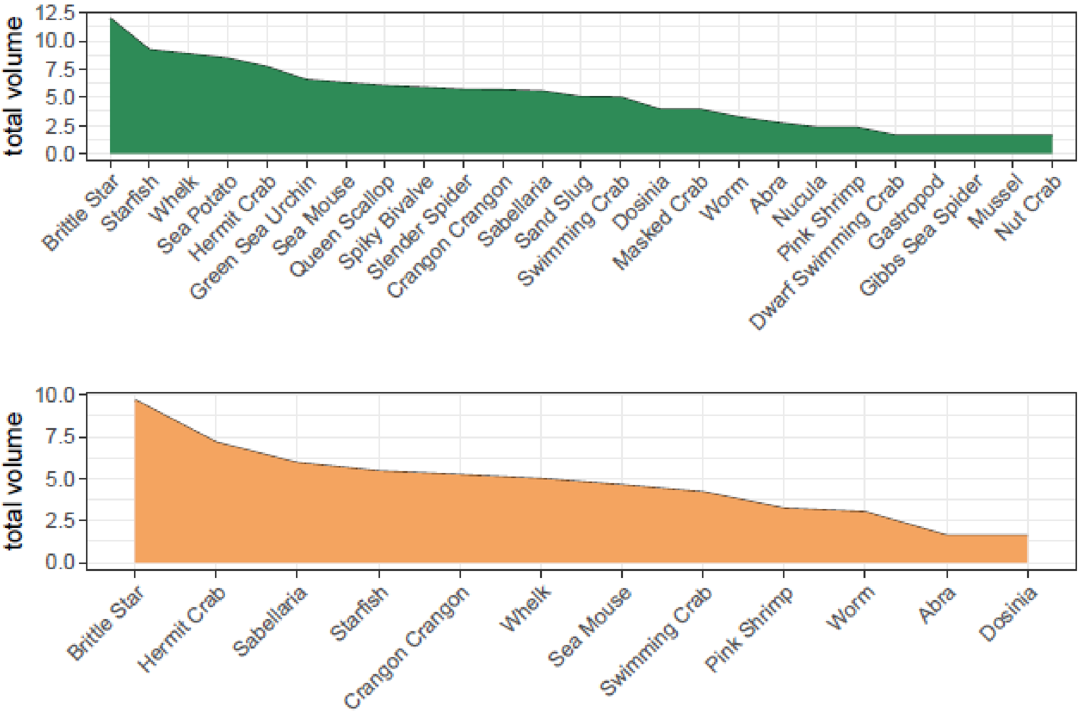

Figure 11: Principal components analysis ordination plot for benthos from the beam trawls in areas 1 and 2. The hauls are marked by circles. Hauls that are closer to each other have more similar benthos communities than those far apart from each other, so if the areas are completely different from each other the hauls from the two areas should not overlap. The arrows show the taxa that define the communities (e.g. swimming crabs and *Crangon crangon* define the hauls towards the bottom right of the plot).

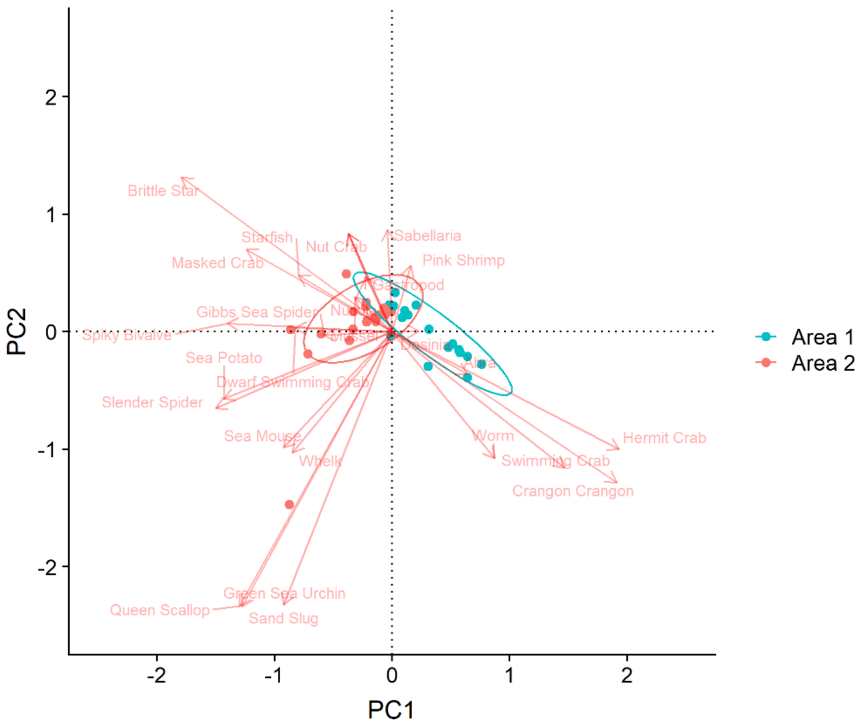

Figure 12: Dendrogram illustrating the outcome of the cluster analysis of benthos in the beam trawls. The analysis produced three natural groupings of hauls (highlighted in blue, red and green). If the communities in areas 1 and 2 are different from each other, the hauls should fall neatly into separate groups on the dendrogram.

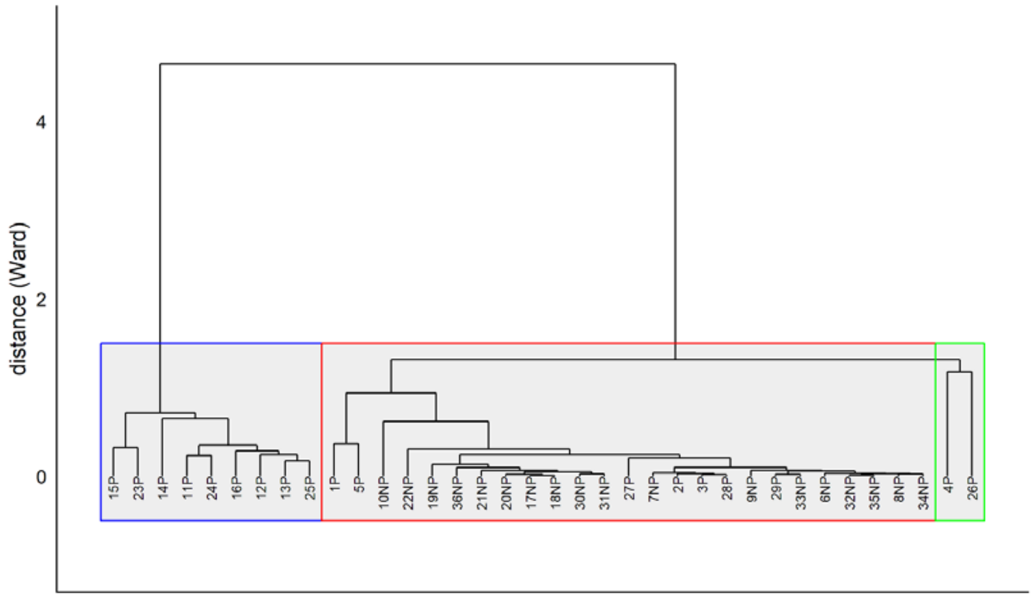

Figure 13: Differences in sole catch per unit swept area (left) and sole length distributions (right).

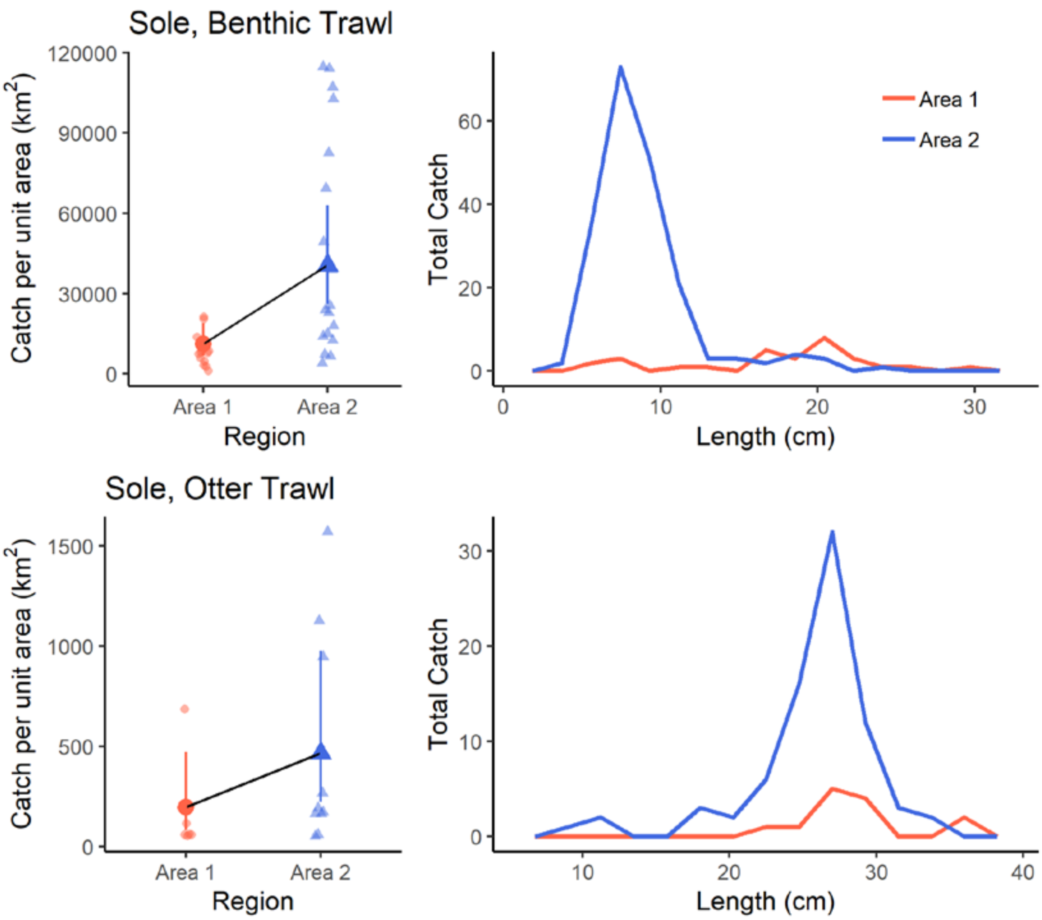

Figure 14: Differences in whiting catch per unit swept area (left) and whiting length distributions (right).

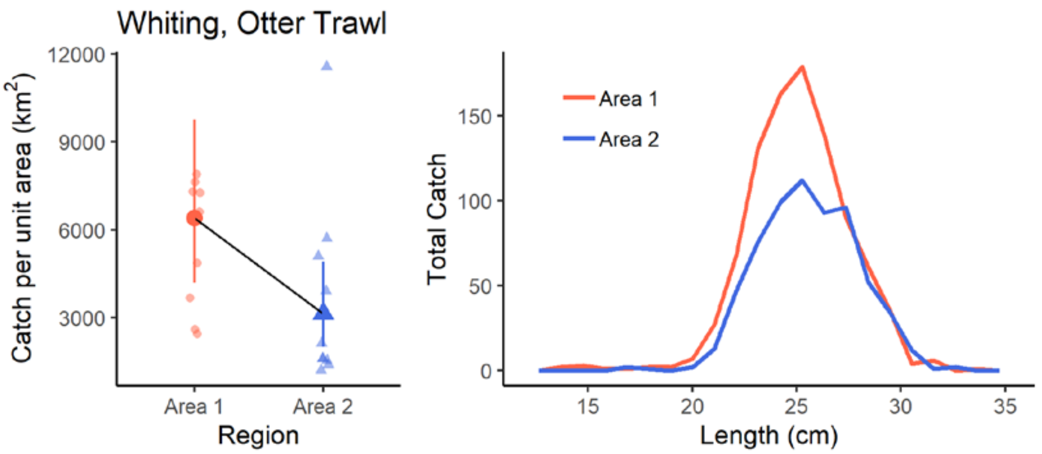

Figure 15: Differences in plaice catch per unit swept area (left) and plaice length distributions (right).

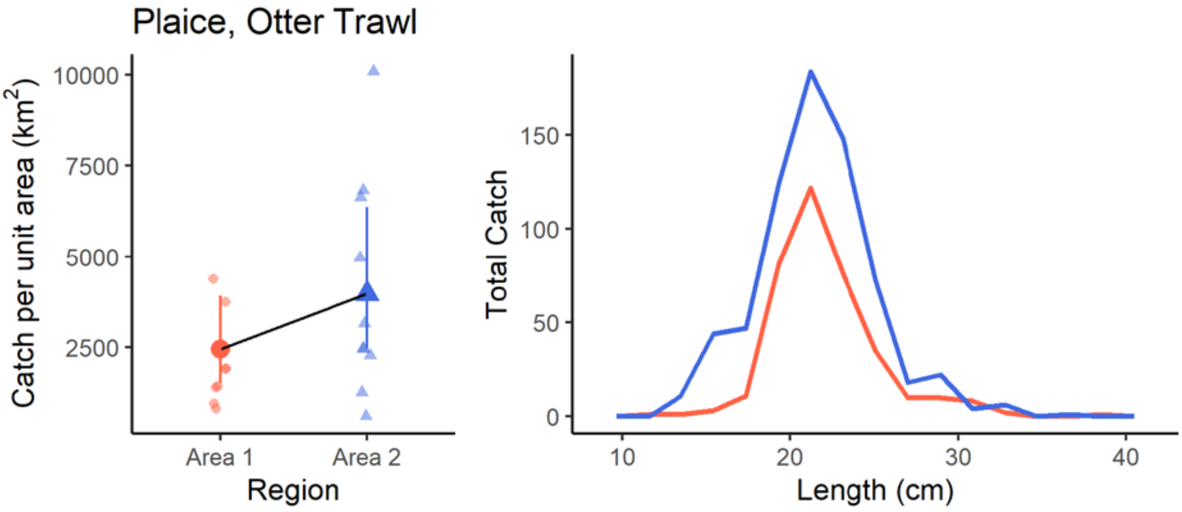

Figure 16 Differences in thornback ray catch per unit swept area (left) and their length distributions (right).

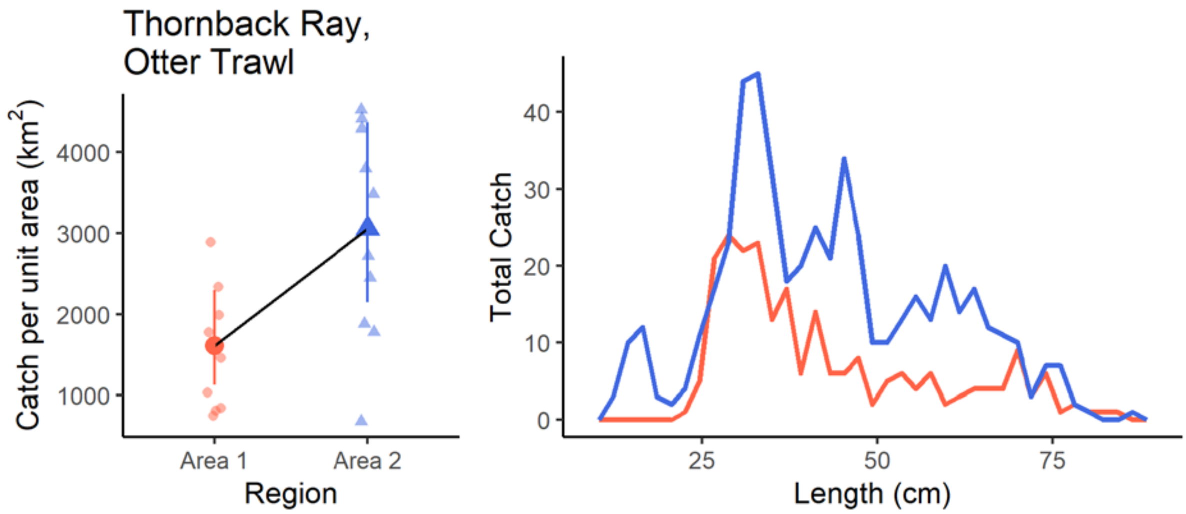

Table 2: Summary of quantile regression analyses at the 25th, 50th and 75th percentiles. Model estimates of fish lengths are provided at each percentile in cm. Where significant differences are detected between areas, these are highlighted in bold text.

	Percentile:	25th				50th				75th			
Sole		Estimate	SE	t	p	Estimate	SE	t	p	Estimate	SE	t	p
Benthic	Area 1	13	1.67	7.8		20	1.28	15.6		21	1.43	14.7	
	Area 2	7	1.89	-3.2	**<0.001**	9	1.45	-7.6	**<0.001**	11	1.62	-6.2	**<0.001**
Otter	Area 1	26	1.62	16.0		28	2.00	14.0		29	1.62	17.9	
	Area 2	23	1.85	-1.6	0.111	26	2.28	-0.9	0.384	29	1.85	0.0	1.000
Whiting													
Otter	Area 1	22	0.94	23.5		25	0.78	32.1		28	0.94	29.8	
	Area 2	23	1.39	0.7	0.474	25	1.16	0.0	1.000	28	1.39	0.0	1.000
Plaice													
Otter	Area 1	20	1.00	20.1		22	0.80	27.6		25	1.00	25.1	
	Area 2	19	1.31	-0.8	0.447	22	1.05	0.0	1.000	25	1.31	0.0	1.000
Thornback Ray													
Otter	Area 1	31	1.32	23.5		39	2.05	19.0		55	2.67	20.6	
	Area 2	32	1.61	0.62	0.535	44	2.51	2.0	**0.047**	57	3.26	0.6	0.540

Discussion

The objective for this study was to establish if there were any statistical differences in the abundance and diversity of fish and benthic organisms caught in an area that had been regularly fished by pulse trawlers (Area 1) in comparison with an adjacent equivalent area that is similar in size, depth, substrate and sediment that had had no previous pulse activity (Area 2). This objective was achieved by comparing catches from the two areas taken by 1) otter trawl and 2) benthic trawl.

Otter trawl

Ten 30-minute otter trawls were conducted in each area using the same gear and methodologies. Whiting, thornback rays, plaice and lesser spotted dogfish were the most abundant fish species in both areas (Figure 7). Our results showed that there was a 21% lower in species richness per unit of swept area in Area 2 compared with Area 1. Species present in Area 2 but not in Area 1 included; brown crab, common dragonet, green sea urchin, horse mackerel, pogge, queen scallop, sand slug, scaldfish, sea potato, slender spider crab, solonette, spiky bivalve, swimming crab and velvet swimming crab. Species present in Area 1 but not Area 2 were; cuttlefish, john dory, lemon sole, lesser weaver fish, mollusc and turbot.

Further, statistical analysis of sole and plaice showed no significant differences in catches between the two areas both in quantity caught and size differences. Whiting in Area 1 were found to be more than double the abundance in Area 2, whereas thornback ray was found to be 47% more abundant in Area 2 than Area 1.

Benthic trawl

Eighteen 5-minute benthic tows were conducted in each area using the same Jennings beam trawl and methodologies. The most abundant species in Area 2 included brown shrimp, hermit crab and gobies. There were four species which were caught in Area 1 but not Area 2; bib (*Tricopterus* luscus), Bryozoan (*Celleopra* pumicosa), sand eel (*Ammodytes* marinus) and three unidentified worms. There were 17 species caught in Area 2 that were not caught in Area 1; alloteuthis squid (*Alloteuthis subulate*), common dragonet, swimming crab, bubble snail (*Acteon tornatilis*), gibbs sea spider (*Pisa armata*), greater pipefish (*Syngnathus acus*), green sea urchin, masked crab (*Corystes cassivelaunus*), mussel (*Mytilus edulis*), necklace shell (*Euspira (Polinices) catena*), nut shell (*Nucula nucleus*). Nut crab (*Ebalia tumefacta*) queen scallop, sand slug, sea potato, slender spider crab, spiky bivalve and

tub gurnard (*Trigla (chelidonichthys) lucerna*). The most notable difference in abundance in Area 1 compared to Area 2 was the volume of brittle stars. They were often too numerous to count in Area 1, and only volumes could be taken. Volume figures from Area 2 showed 15,885ml of brittle stars compared with 160,800ml in Area 1. The number of species caught in benthic trawls was 57% higher in Area 2 compared with Area 1 and the analyses of volume, evenness and multivariate community structure show a difference in the benthic communities between Areas 1 and 2, with Area 1 containing a subset of the communities identified in Area 2.

By studying only two areas we cannot rule out that the differences observed are due to natural variation (patchiness), which is known to exist in different spatial scales (Morrisey, 1992). However, given the number of replicate tows, we consider that these are genuine differences between these two areas. Furthermore, to minimise any differences in catch composition which might have been attributable to tides and weather, the same number of otter trawl and benthic trawl tows were conducted in both areas. We tried to ensure that the two areas were similar in depth by studying admiralty charts and discussions with the industry, however, the depths of the two areas were different with an average depth of 37.4m in area 1 (minimum depth 30.7m, maximum depth 43.4m) and 24.1m in area 2 (minimum depth 20.5m, maximum depth 27.5m). This depth difference is still well within the normal depth habitat parameters of the species observed (Heessen, 2015) so is unlikely to have affected the results.

The results from this study illustrate clear differences between the two areas in species richness and abundance of fish and in richness, volume and, to an extent, in community structure of the benthic species. The main distinction between the two areas is the type and intensity of fishing activity, however, the differences observed cannot be attributed exclusively to the effects of pulse trawling. Area 1 is an area that has seen a concentration of pulse trawl activity in recent years, but previously it was an area fished by large beam trawlers. Therefore, the relative impact of these two fishing methods cannot be separated. In Area 2, where less intensive and less impactful fishing methods are used, there was higher benthic and fish species richness and abundance/volume. Had there been no difference between the areas, it would have supported the notion that the impact from pulse and large beam trawlers is comparable to other forms of fishing. The marked differences between the two areas observed in this study raises questions on whether the historical impact of beam trawling, or the recent concentration of pulse trawl activity, has caused a reduction in species richness and abundance. It cannot be ruled out that other factors may also have driven these results, and this is

shown in the benthic communities, in which there is some overlap between the two areas. The only known difference between the two areas is in the fishing activity and it would be difficult to ascertain the nature and extent of the influence of other factors operating on the communities without gathering data on natural phenomena and human footprints over a range of scales. Unfortunately, the opportunity to conduct large scale and long-term ecological experiments to determine the community effect of pulse trawling was not taken during the transition to pulse trawling, and this study demonstrates that this research is still needed to fully understand the ecosystem impacts of using pulse trawl technology.

Acknowledgements

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Appendix:

Table 3: The number of individuals of each of species caught in benthic trawls in the two areas. Brittle stars were caught in high abundance with the benthic trawl and were too many too count and are excluded from this table. Similarly, Sabellaria and brown seaweed (*Fucus spp.*) seaweed were also not counted in the study and are excluded for both fishing methods in the figure.

Species	**Area1**	**Area 2**
Abra (*Abra sp.)*	1	6
Alloteuthis Squid (*Alloteuthis subulate*)		1
Bib (*Tricopterus luscus*)	3	
Common Dragonet (*Callionymus lyra*)		19
Brown Shrimp (*Crangon crangon*)	191	249
Dab (*Limanda limanda*)		8
Dosinia *sp.*	1	33
Swimming Crab (*Liocarcinus holsatus*)		3
Bryozoan (*Cellepora pumicosa*)	1	
Bubble Snail (*Acteon tornatilis*)		1
Gibbs Sea Spider (*Pisa armata*)		1
Greater Pipefish (*Syngnathus acus*)		1
Green Sea Urchin (*Psammechinus miliaris*)		71
Hermit Crab (*Paguridae*)	339	678
Lesser Spotted Dogfish (*Scyliorhinus canicula*)	3	12
Little Cuttlefish (*Sepiola atlantica*)	2	5
Masked Crab (*Corystes cassivelaunus*)		12
Mussel (*Mytilus edulis*)		1
Necklace Shell (*Euspira (Polinices) catena)*		99
Nut Shell (*Nucula nucleus*)		15
Nut Crab (*Ebalia tumefacta*)		1
Pink Shrimp (*Pandalus montagui*)	23	11
Plaice (*Pleuroncentes platessa*)	6	11
Pogge (*Agonus cataphractus*)	2	28
Queen Scallop (*Aequipecten opercularis*)		127
Sandeel (*Ammodytes marinus*)	3	
Gobis (*Gobiidae*)	38	54
Sand Slug (*Philine aperta*)		20
Scald Fish (*Arnoglossus laterna*)	1	2
Sea Mouse (*Aphrodite aculeata*)	3	35

Species	Area1	Area 2
Sea Potato (*Echinocardium cordatum*)		259
Slender Spider Crab (*Acropodia tenuirostris*)		187
Sole (*Solea solea*)	29	198
Solonette (*Buglossidium luteum*)	10	111
Spiky Bivalve (*Acanthocardia spp.*)		23
Starfish (*Asterias rubens*)	6	309
Swimming Crab (*Liocarcinus holsatus*)	35	77
Thornback Ray (*Raja clavata*)	3	2
Tub Gurnard (*Trigla (chelidonichthys) lucerna*)		1
Unidentified Worms	3	
Whelk (*Buccinum undatum*)	12	340
Worm (*Hyalinoecia tubicola*	5	9
Total no. of individuals	**720**	**3020**

Table 4. The number of individuals of each species caught in otter trawls in the two areas.

Species	Area 1	Area 2
Alloteuthis Squid (*Alloteuthis subulate*)	3	4
Bib (*Tricopterus luscus*)	29	76
Brittle Star (*Ophiothrix fragilis*)	33	281
Brown Crab (*Cancer pagarus*)		1
Cod (*Gadus morhua*)	2	1
Common Dragonet (*Callionymus lyra*)		20
Cuttlefish (*Sepia officinalis*)	1	
Dab (*Limanda limanda*)	88	708
Flounder (*Platichthys flesus*)	1	5
Green Sea Urchin (*Psammechinus miliaris*)		9
Hermit Crab (*Paguridae*)	80	7
Horse Mackerel (*Trachurus trachurus*)		1
John Dory (*Zeus faber*)	1	
Lemon Sole (*Microstomus kitt*)	2	
Lesser Spotted Dogfish (*Scyliorhinus caniculal)*	272	386
Lesser Weaver Fish (*Echiichthys (trachinus) vipera*)	3	
Lionsmane Jellyfish (*Cyanea capilata*)	1	1
Mollusc (*Acteon tornatilis*)	1	

Species	Area 1	Area 2
Northern Arrow Squid (*Loligo forbesi*)	23	90
Plaice (*Pleuroncentes platessa*)	361	682
Pogge (*Agonus cataphractus*)		2
Queen Scallop (*Aequipecten opercularis*)		4
Red Mullet (*Mullus surmuletus*)	15	21
Sand Slug (*Philine aperta*)		1
Scaldfish (*Arnoglossus laterna*)		1
Sea Mouse (*Aphrodite aculeata*)	3	233
Sea Potato (*Echinocardium cordatum*)		105
Slender Spider Crab (*Acropodia tenuirostris*)		3
Sole (*Solea solea*)	13	79
Solonette (*Buglossidium luteum*)		1
Spider Crab (*Maja squinado*)	1	2
Spiky Bivalve (*Acanthocardia spp.*)		10
Spotted Ray (*Raja montagui*)	2	1
Starfish (*Asterias rubens*)	14	2236
Starry Smoothound (*Mustelus asterius*)	17	52
Swimming Crab (*Liocarcinus holsatus*)		8
Thornback Ray (*Raja clavata*)	230	515
Tub Gurnard (*Trigla (chelidonichthys) lucerna*)	36	75
Turbot (*Scopthalamus maximus*)	4	
Velvet Swimming Crab (*Necora puber*)		2
Whelk (*Buccinum undatum*)	8	257
Whiting (*Merlangus merlangus*)	922	642
Total no. of individuals	**2166**	**6522**

Table 5 Tow details for all tows

Date	Haul Start	Depth Start (m)	Lat Start	Long Start	Haul End	Depth End (m)	Lat End	Long End	Rectangle	Wind	Sea State	Towing Speed (knots)	Sample Type	Area
16/10/2018	09:19	37.5	51,31.94N	01,42.45E	09:49	34.1	51,30.93N	01,41.56E	32F1	1-2 SSW	Slight	2.3	Otter Trawl	Pulse
16/10/2018	10:16	37.9	51,31.686N	01,42.698E	10:46	34.5	51,30.661N	01,41.856E	32F1	3 SW	Slight	2.3	Otter Trawl	Pulse
16/10/2018	11:06	30.7	51,30.052N	01,42.009E	11:36	33.1	51,31.143N	01,43.161E	32F1	2-3 SW	Slight	2.4	Otter Trawl	Pulse
16/10/2018	11:59	31.7	51,29.669N	01,42.512E	12:29	34.8	51,30.684N	01,43.455E	32F1	2 SW	Slight	2.3	Otter Trawl	Pulse
16/10/2018	13:16	24.6	51,29.410N	01,34.824E	13:46	23.5	51,29.177N	01,32.591E	31F1	3 SW	Slight	2.3	Otter Trawl	Non Pulse
16/10/2018	13:58	20.5	51,29.338N	01,31.784E	14:28	20	51,29.780N	01,33.846E	31F1	3 SW	Slight	2.4	Otter Trawl	Non Pulse
16/10/2018	14:56	21.6	51,30.214N	01,33.795E	15:26	22.2	51,29.764N	01,31.901E	31F1	4 SW	Moderate	2.5	Otter Trawl	Non Pulse
16/10/2018	15:35	21.9	51,29.976N	01,31.316E	16:05	24.2	51,30.671N	01,32.506E	32F1	4 SW	Moderate	2.5	Otter Trawl	Non Pulse
17/10/2018	08:29:49	35	51,31.065N	01,41.443E	08:34:49	35.4	51,31.135N	01,41.555E	32F1	1-2 SW	Slight	0.5	Benthic Trawl	Pulse
17/10/2018	09:30:14	37.2	51,31.198N	01,42.032E	09:35:14	35.5	51,31.143N	01,42.151E	32F1	2 SW	Slight	1	Benthic Trawl	Pulse
17/10/2018	10:41:16	37.9	51,31.375N	01,42.825E	10:46:16	37.5	51,31.310N	01,42.733E	32F1	3 WSW	Slight	0.8	Benthic Trawl	Pulse
17/10/2018	11:19:39	34.6	51,30.478N	01,42.915E	11:24:39	33.6	51,30.481N	01,42.094E	32F1	3 WSW	Slight	0.8	Benthic Trawl	Pulse
17/10/2018	11:51:39	32.1	51,29.919N	01,43.050E	11:56:39	32.3	51,29.940N	01,43.156E	31F1	3 WSW	Slight	0.9	Benthic Trawl	Pulse
17/10/2018	12:49:38	24.2	51,30.404N	01,33.403E	12:54:38	24.3	51,30.349N	01,33.376E	32F1	1-2 WSW	Slight	0.8	Benthic Trawl	Non Pulse
17/10/2018	13:25:03	24	51,29.835N	01,32.901E	13:30:03	24.1	51,29.775N	01,32.899E	31F1	1 WSW	Slight	1	Benthic Trawl	Non Pulse
17/10/2018	14:10:42	23.8	51,29.418N	01,32.770E	14:15:42	23.9	51,29.382N	01,32.845E	31F1	1 WSW	Slight	0.8	Benthic Trawl	Non Pulse
17/10/2018	14:53:00	23.9	51,29.020N	01,32.525E	14:58:00	24	51,28.959N	01,32.530E	31F1	1 WSW	Slight	0.6	Benthic Trawl	Non Pulse
17/10/2018	15:46:05	24.5	51,28.208N	01,32.824E	15:51:05	24.5	51,28.151N	01,32.902E	31F1	1 WSW	Slight	0.6	Benthic Trawl	Non Pulse
19/10/2018	09:24	37.6	51,29.665N	01,44.443E	09:54	37	51,28.963N	01,43.172E	32F1	2-3 E	Moderate	2.3	Otter Trawl	Pulse
19/10/2018	10:20	42.5	51,29.361N	01,44.783E	10:50	37.5	51,28.479N	01,43.484E	32F1	2-3 E	Slight/Mod	2.4	Otter Trawl	Pulse

Date	Haul Start	Depth Start (m)	Lat Start	Long Start	Haul End	Depth End (m)	Lat End	Long End	Rectangle	Wind	Sea State	Towing Speed (knots)	Sample Type	Area
19/10/2018	11:20	38.2	51,28.680 N	01,45.442 E	11:50	40.6	51,27.936 N	01,44.078 E	31F1	2-3 E	Slight	2.3	Otter Trawl	Pulse
19/10/2018	12:09	30.7	51,29.185 N	01,42.764 E	12:39	36.3	51,30.234 N	01,44.067 E	32F1	2 E	Slight	2.8	Otter Trawl	Pulse
19/10/2018	13:30	25.9	51,27.695 N	01,36.644 E	14:00	23.2	51,27.197 N	01,34.979 E	31F1	1-2 E	Slight	2.6	Otter Trawl	Non Pulse
19/10/2018	14:28	22.9	51,27.335 N	01,33.789 E	14:58	24.3	51,27.807 N	01,35.646 E	31F1	2 E	Slight	2.8	Otter Trawl	Non Pulse
19/10/2018	15:38	24.6	51,28.578 N	01,33.585 E	16:08	24.3	51,29.159 N	01,34.545 E	31F1	2 E	Slight	2.8	Otter Trawl	Non Pulse
19/10/2018	16:32	22.8	51,28.345 N	01,32.769 E	17:02	22.6	51,28.818 N	01,34.516 E	31F1	2 E	Slight	2.4	Otter Trawl	Non Pulse
20/10/2018	08:51:40	43.4	51,27.885 N	01,44.588 E	08:56.4	43.6	51,27.855 N	01,44.639 E	31F1	1 NE	Slight	0.6	Benthic Trawl	Pulse
20/10/2018	09:15:40	40.7	51,28.533 N	01,44.726 E	09:20:40	43.2	51,28.515 N	01,44.631 E	31F1	1 NE	Calm	0.7	Benthic Trawl	Pulse
20/10/2018	09:37:25	37	51,29.291 N	01,44.140 E	09:42:25	37.4	51,29.249 N	01,44.077 E	31F1	1 NE	Calm	0.6	Benthic Trawl	Pulse
20/10/2018	10:03:03	38.3	51,29.475 N	01,43.753 E	10:08:03	38.5	51,29.463 N	01,43.854 E	31F1	1 NE	Calm	1.2	Benthic Trawl	Pulse
20/10/2018	10:56:00	38.5	51,29.858 N	01,43.949 E	11:01:00	38.5	51,29.858 N	01,44.930 E	31F1	1 NE	Calm	0.8	Benthic Trawl	Pulse
20/10/2018	11:39:08	38.3	51,28.807 N	01,43.515 E	11:44:08	37.2	51,28.849 N	01,43.637 E	31F1	1 NE	Calm	1.1	Benthic Trawl	Pulse
20/10/2018	12:31:00	26.1	51,27.778 N	01,36.165 E	12:36:00	25.9	51,27.813 N	01,36.163 E	31F1	1 NE	Slight	0.8	Benthic Trawl	Non Pulse
20/10/2018	13:05:44	25.5	51,28.212 N	01,35.301 E	13:10:44	25.5	51,28.245 N	01,35.369 E	31F1	1 NE	Slight	0.7	Benthic Trawl	Non Pulse
20/10/2018	13:46:23	24.8	51,28.767 N	01,35.170 E	13:51:23	24.6	51,28.789 N	01,35.111 E	31F1	1 NE	Slight	0.6	Benthic Trawl	Non Pulse
20/10/2018	14:22:40	24.1	51,28.737 N	01,34.348 E	14:27:40	23.9	51,28.702 N	01,34.432 E	31F1	1 NE	Slight	1	Benthic Trawl	Non Pulse
20/10/2018	14:56:30	23.4	51,28.124 N	01,34.094 E	15:01:30	24.1	51,28.059 N	01,34.129 E	31F1	1 NE	Slight	0.8	Benthic Trawl	Non Pulse
20/10/2018	15:36:24	22.8	51,27.182 N	01,33.928 E	15:41:24	23	51,27.157 N	01,33.027 E	31F1	1 NE	Slight	0.8	Benthic Trawl	Non Pulse
21/10/2018	08:59:06	40.3	51,28.412 N	01,44.116 E	09:04:06	40.5	51,28.375 N	01,44.130 E	31F1	1-2 W	Slight	0.7	Benthic Trawl	Pulse
21/10/2018	09:30:54	43	51,28.839 N	01,44.549 E	09:35:54	42.3	51,28.877 N	01,44.512 E	31F1	1 W	Slight	0.9	Benthic Trawl	Pulse
21/10/2018	09:55:33	37.6	51,29.587 N	01,43.381 E	10:00:33	37.3	51,29.534 N	01,43.418 E	31F1	1 W	Slight	0.6	Benthic Trawl	Pulse

Date	Haul Start	Depth Start (m)	Lat Start	Long Start	Haul End	Depth End (m)	Lat End	Long End	Rectangle	Wind	Sea State	Towing Speed (knots)	Sample Type	Area
21/10/2018	10:26:46	35.9	51,30.186 N	01,43.432 E	10:31:46	36.2	51,30.150 N	01,43.422 E	32F1	1 W	Slight	0.8	Benthic Trawl	Pulse
21/10/2018	10:59:55	38.5	51,30.957 N	01,43.093 E	11:04:55	38.4	51,30.942 N	01,43.045 E	32F1	1 W	Slight	0.8	Benthic Trawl	Pulse
21/10/2018	11:40:29	38	51,31.978 N	01,42.457 E	11:45:29	38	51,31.960 N	01,42.503 E	32F1	1 W	Slight	0.8	Benthic Trawl	Pulse
21/10/2018	12:20:22	36.9	51,30.618 N	01,42.226 E	12:25:22	36.9	51,30.676 N	01,42.345 E	32F1	1 W	Slight	0.9	Benthic Trawl	Pulse
21/10/2018	13:24:36	26.7	51,30.887 N	01,32.891 E	13:29:36	26.6	51,30.929 N	01,32.929 E	32F1	1 W	Slight	0.7	Benthic Trawl	Non Pulse
21/10/2018	13:59:45	25.2	51,30.552 N	01,31.911 E	14:04:45	25.3	51,30.561 N	01,31.018 E	32F1	1 W	Slight	0.8	Benthic Trawl	Non Pulse
21/10/2018	14:41:57	23.9	51,30.085 N	01,32.165 E	14:46:57	24	51,30.132 N	01,32.219 E	32F1	1 W	Slight	0.5	Benthic Trawl	Non Pulse
21/10/2018	15:32:41	23.2	51,29.594 N	01,34.168 E	15:37:41	23.2	51,29.610 N	01,34.267 E	31F1	1-2 W	Slight	1	Benthic Trawl	Non Pulse
21/10/2018	16:13:22	22.9	51,29.142 N	01,33.735 E	16:18:22	23	51,29.130 N	01,33.823 E	31F1	2 W	Slight	0.8	Benthic Trawl	Non Pulse
21/10/2018	16:51:43	23	51,28.615 N	01,33.759 E	16:56:43	23	51,28.588 N	01,33.733 E	31F1	2 W	Slight	0.5	Benthic Trawl	Non Pulse
21/10/2018	17:05:21	22.8	51,27.908 N	01,33.467 E	17:10:21	22.6	51,27.860 N	01,33.525 E	31F1	2 W	Slight	0.8	Benthic Trawl	Non Pulse
25/10/2018	09:40	38.9	51,28.255 N	01,43.649 E	10:10	41.9	51,28.612 N	01,44.194 E	32F1	3 NW	Moderate	1.3	Otter Trawl	Pulse
25/10/2018	10:30	32.3	51,29.612 N	01,42.883 E	11:00	35.3	51,30.268 N	01,43.276 E	31F1	3-4 NW	Moderate	1.5	Otter Trawl	Pulse
25/10/2018	11:51	27.5	51,30.637 N	01,33.149 E	12:21	26.6	51,29.730 N	01,31.868 E	32F1	3-4 NW	Moderate	2.7	Otter Trawl	Non Pulse
25/10/2018	13:07	26	51,28.907 N	01,32.229 E	13:37	27.1	51,29.169 N	01,33.968 E	31F1	3-4 NW	Moderate	1.8	Otter Trawl	Non Pulse

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Head office
Centre for Environment, Fisheries & Aquaculture Science
Pakefield Road
Lowestoft
Suffolk
NR33 0HT
Tel: +44 (0) 1502 56 2244
Fax: +44 (0) 1502 51 3865

Weymouth office
Barrack Road
The Nothe
Weymouth
DT4 8UB

Tel: +44 (0) 1305 206600
Fax: +44 (0) 1305 206601

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