Published 30 May 2018
https://doi.org/10.17895/ices.pub.4379

The Netherlands request on the comparison of the ecological and environmental effects of pulse trawls and traditional beam trawls when exploiting the North Sea sole TAC

Advice summary

ICES advises that there are fewer ecological and environmental effects of using pulse trawls than traditional beam trawls when exploiting the total allowable catch (TAC) of North Sea sole.

i) Both pulse and traditional beam trawls can be used to harvest the target flatfish stocks (sole and plaice) sustainably (at fishing mortalities in accordance with the MSY approach). Pulse trawls have been increasingly used in the North Sea flatfish fisheries since 2009. Over this period, the fishing mortality has reduced and stock biomass has increased, mostly due to an overall decrease in effort.

ii) The rate of injuries inflicted by mechanical impact on fish during the catch process is likely to be lower in pulse trawls than in traditional beam trawls. Cod suffer a relatively high injury rate when exposed to pulses, but the increase in the overall mortality of the North Sea cod stock caused by these injuries is presently negligible. Flatfish (sole, plaice, and dab), seabass, and small-spotted catshark do not suffer pulse-induced injuries.

iii) Pulse trawls do not mechanically penetrate as deeply into sediments as traditional beam trawl and will therefore have a lesser mechanical effect on the benthos.

iv) Pulse trawls have a reduced footprint and mechanical impact on the benthos compared with traditional beam trawls. The few studies of the effects of electrical pulses indicate no incremental mortality on benthos from the pulse trawls. It can therefore be expected that effect on the structure and functioning of the benthic ecosystem is less for pulse trawls.

v) Incremental effects from repetitive exposure to pulse gear are expected to be low.

ICES recognizes that gaps exist in the knowledge of the potential effects of both gears; however there is considered to be sufficient information to compare the two gears.

Request

ICES is requested [by The Netherlands] *to compare the ecological and environmental effects of using traditional beam trawls or pulse trawls when exploiting the TAC of North Sea sole, on (i) the sustainable exploitation of the target species (species and size selectivity); (ii) target and non-target species that are exposed to the gear but are not retained (injuries and mortality); (iii) the mechanical disturbance of the seabed; (iv) the structure and functioning of the benthic ecosystem; and to assess (v) the impact of repetitive exposure to the two gear types on marine organisms.*

Elaboration on the advice

This ICES advice compares the effects of pulse trawls with those of traditional beam trawls when fishing for sole in the North Sea; it does not consider other forms of electrical fishing, such as for brown shrimp (*Crangon crangon*) or razorshells (*Ensis spp*).

i) Sustainable exploitation of the target species (species and size selectivity)

ICES advises that there is no difference in the feasibility of sustainable exploitation (maintaining $F \leq F_{msy}$) of the fishable biomass of the major stocks of flatfish when fishing using either traditional beam trawls or pulse trawls. Over the past six years, when both gears have been in use for the sole fishery, indicators of sustainability (fishing mortality, stock biomass) have improved for the target stocks, mostly due to an overall decrease in fishing effort. The catch is constrained by TACs, and this has not changed with the introduction of pulse trawls. Differences in catch efficiency should not impact the total amount of fish removed.

Catch rates and species composition at present differs between gears, with lower catch rates of plaice and higher catch rates of sole in pulse trawls. ICES considers that pulse trawls could contribute to a technical solution to some problems emerging during the implementation of the landing obligation, as the catchability of sole is higher in this gear (the more valuable but rarer species) and that of plaice is lower (the less valuable but more abundant species). No catchability information is available for other flatfish species caught in either gear (turbot, brill); however, these stocks are currently considered to be harvested sustainably.

ii) Target and non-target species that are exposed to the gear but are not retained (injuries and mortality)

ICES infers that the rate of the injuries inflicted by mechanical impact during the catch process is likely to be lower in pulse trawls than in traditional beam trawls. Both gears expose organisms to mechanical impacts. There is no comparative information on the fate of organisms passing through the nets from traditional beam trawls or from pulse trawls. Pulse trawls are towed at a lower speed than traditional beam trawls, and there are no tickler chains in pulse trawl gear, so injuries due to collision with the gear are likely to be less frequent and less severe. The codends are identical between the two gears. Impacts on benthic communities are advised in section iv) below.

Pulse trawls differ from traditional beam trawls in that they expose organisms to electrical pulses. There is considerable variation in the ability of organisms to detect electrical stimulation and also in their responses to stimulation. There is insufficient information available on the detection threshold of organisms or on adverse response thresholds to be able to quantitatively assess the potential effect of electrical exposure at the population level.

There is evidence that the exposure to pulses can result in spinal fractures and haemorrhages in cod and whiting, but not in flatfish (sole, plaice, and dab), seabass, and small-spotted catshark. Most injuries occurred in sizes of fish that would be retained by the gear and would be killed anyway. It can be inferred that the injury rate of those that escape from the gear would be substantially less than the overall average for cod examined (42%). The proportion of cod caught in the pulse fishery is presently less than 1% of the overall catch of cod in the North Sea.

There is no information available on the effects on any species at early life history stages after exposure to the sole pulse. However it is unlikely that any effects would have population level effects.

Many elasmobranch fish are sensitive to electrical fields. There is some evidence showing that the ability of the small-spotted catshark, one of the more commonspecies in the southern North Sea, , to detect prey using its electrosensitive sensory system was not significantly affected after being exposed to a sole pulse. Its feeding and reproductive behaviours were not altered in a longer-term experiment.

No studies have been conducted to investigate the possible adverse effects of sub-lethal exposure on the maturation process, the quality of gametes, or spawning behaviour of any fish species.

iii) The mechanical disturbance of the seabed

ICES advises that the use of pulse trawl compared with traditional beam trawl reduces the mean gear penetration depth from 4.0 cm to 1.8 cm in fine sand.

The overall mobilization of sediment into the water column is inferred to be lower for pulse trawling than for traditional beam trawling. This is associated with the lower average towing speed of pulse trawling. However, because there is a shift of pulse trawling effort from coarser to finer sediments, an increase in sediment mobilization is likely to occur in those areas.

iv) The structure and functioning of the benthic ecosystem

ICES notes that no rigorous experimental study simultaneously examining the impact of pulse trawl and traditional beam trawl on the structure and functioning of the benthic community has been completed, but that the Impact Assessment Pulse Fisheries project will be reporting in 2019. This project should provide results that can be used in assessing the effects of pulse trawls on the structure and functioning of benthic ecosystems. As noted in section iii) above, the penetration depth of the pulse trawl is generally about 50% less than traditional beam trawl when carried out in similar sediment types. Benthic invertebrates tend to decrease in density with depth in the sediment. The mechanical impact of pulse trawling is thus likely to cause less impact on benthic communities; the reduction in impact is likely to be less than 50% than traditional beam trawl. The degree of reduction will depend upon substrate type, taxonomic group, and size class.

The increased catching efficiency of sole of pulse trawl compared with traditional beam trawl will mean that there will be smaller area of the seabed towed for the same catch of sole. This means that, for the same catch of sole, a smaller area of the benthic ecosystem will be affected mechanically by the gear. The limited evidence indicates that invertebrates in the track of the trawl show no detectable effects of electrical stimulation.

The lack of evidence of reproducable or consistent effects on invertebrates from electrical stimulation similar to that used on pulse trawls at the individual and species levels suggests that there is unlikely to be any effect of such electrical stimulation on the structure and functioning of the benthic ecosystem.

There are no specific studies on the non-lethal effects of electrical stimulation from pulse trawls on invertebrates.

v) Assessment of the impact of repetitive exposure to the two gear types on marine organisms

ICES advises that incremental effects from repetitive exposure to pulse gear are not likely as little sensitivity has been found for any organism to electrical stimulation. The probability of repetitive disturbance is also low. Within the most intensively trawled ICES rectangles, the proportions of 24 m × 24 m squares subject to trawling more than once per week are estimated at 0.3% (pulse) and 0.8% (beam trawl).

Basis of the advice

The main basis for this advice is from the work of two ICES expert groups: the Working Group on Electrical Trawling (WGELECTRA) (ICES, 2018a) and he Working Group on Ecosystem Effects of Fishing ActivitiesWGECO (ICES, 2018b).

i) Sustainable exploitation of the target species (species and size selectivity) – background

ICES considers the trawl fisheries targeting flatfish in the southern North Sea to be mixed fisheries. Catches of the defined primary target species, sole, cannot be taken without a significant bycatch of other species, namely plaice, but also brill, turbot, flounder, and dab. For both beam and pulse trawl gears, the largest fraction of the catch (in terms of individuals and weight) consists of plaice. Flatfish stocks caught with these gears were assessed as harvested sustainably when ICES last assessed each stock in 2017 (ICES, 2017a). A substantial fraction of the catch of these fisheries is discarded, but this may change with the implementation of the EU landing obligation by January 2019. The extent of the change will depend upon the degree of compliance with the landing obligation or if there are exemptions from the landing obligation, e.g. due to high survival rates of discarded fish.

The transition from traditional beam trawls to pulse trawls in the North Sea mixed flatfish fishery has considerably changed the species composition in the catch. The amount of fish landed per hour of fishing (landings efficiency in weight) for sole has increased by about 30%. Adding the increase in sole discards per hour, this would imply a comparable increase in catch per hour of fishing (catch efficiency in weight). The landings efficiency for plaice has decreased by about 40%. The difference in species selectivity between the two gears is attributed to differences in the cramp response between fish species. The pulse stimulus causes a cramp response that immobilizes the fish, but sole will bend in a U-shape which makes it more accessible to the gear, whereas plaice lie flat and may be less accessible.

The higher catch efficiency of the pulse trawl for sole implies that the sole quota can be caught in less fishing time than with the traditional beam trawl. Considering only the pulse licence holders, their fishing effort (fishing hours) targeting sole decreased by 9% between 2009 and 2017, while their share of the Dutch quota increased by 27%. As the catch efficiency for other species is lower, the pulse trawl fishery could be classified as targeting sole alone; when targeting other flatfish species these vessels are using other trawls. The reduced catch efficiency for plaice has potential implications for the level and geographical distribution of effort in plaice fisheries.

The analysis of the distribution patterns of the traditional beam trawl and the pulse trawl revealed that pulse trawl fishing has increased locally in some areas, such as off the Thames estuary and near to the Belgian and northern French coasts. The change in spatial distribution is related to the lighter weight of the pulse trawl which can be used on softer grounds than the traditional beam trawl. This change in distribution of fishing effort may be changing the relative pressure on local components of the sole stock but there is insufficient information available on stock structure to enable analysis of the potential effect of these changes.

The change in distribution, and the subsequent increase in fishing intensity, in areas where vessels holding pulse licences were not fishing has changed the areal fishing pattern of North Sea sole fisheries, which may impact other fisheries that traditionally fished in these areas.

ICES notes that pulse trawls use 46% less fuel than traditional beam trawls per hour of fishing.

ii) Target and non-target species that are exposed to the gear but are not retained (injuries and mortality) – background

The comparison of the two fishing gears for exposure to mechanical disturbance and for exposure to electrical pulses is done separately. The area exposed to electrical pulses will be slightly larger because the electric field extends beyond the width of the gear. However the electric field strength decays exponentially and drops to just 1% of the strength at the electrode by about two metres.

Mechanical injury can be caused by fish encountering gear components such as the tickler chains, the codend, and the warps. Because the pulse gear is towed at a lower speed and has no tickler chains, it is inferred that mechanical injuries are less likely to occur and are less serious with pulse trawls than with traditional beam trawls. The cleaner catch (e.g. due to fewer stones, sand, and other material) in pulse trawl codends further suggests that fewer fish may be mechanically injured in the catch process. All these factors support the conclusion that mechanical injuries per unit of sole caught are less common and less serious with pulse trawls than with traditional beam trawls.

Experiments and field observations have documented pulse-induced injuries in cod and whiting. Some of these injuries are sufficiently severe to cause death. These injuries are only observed at pulse intensities that would occur within the trawl track. Based on limited sampling and studies, the likelihood of spinal fractures and spinal abnormalities in cod shows a dome-shaped relationship with body size – i.e. lower injury rates for small and large sized individuals, but higher injury rates for medium sized individuals. Above 18 cm (the size of 50% retention in the codend used by both gears), injury rates can reach over 40% in intermediate sizes, with some evidence of lower injury rates for larger cod. However cod comprised less than 1% of the total fish catch in these fisheries, and few large cod were observed in the study. For cod smaller than 18 cm, the limited available evidence suggests the injury rate is much lower even with experimental pulses stronger than those used in the fishery.

The actual possible incremental mortality of the pulses, inflicted on individual cod and small enough to pass through the codend without being retained, is consequently inferred to be low, and well below 40%. Any injury or mortality inflicted by electrical pulses on fish of sizes that would be retained by the trawl gear would not be incremental mortality, because these fish rarely survive capture by trawls, even if released when the gear is hauled.

There is no information available on the survival of fish at early life history stages after exposure to the sole pulse. Experiments with a pulse of a lower frequency than that used for sole (5 Hz) suggest that certain larval stages of cod, but not of sole, show higher mortality when exposed to field strengths occurring in close range of the conductor. No effect was found for egg stages. The population level effects of a possible reduced survivorship of larvae due to pulse exposure is considered to be low because of the low exposure rate and the fact that for healthy stocks there is strong compensatory density-dependent mortality later in their life cycle. The exposure rate could be higher for eggs laid directly in the sediments in the path of the pulse trawls, but few fish in the North Sea are known to lay eggs directly on sandy or muddy substrates. However, flatfish late stage larvae undergoing metamorphosis and juveniles are close to the bottom.

There is limited experimental or field evidence of the impacts of the electrical pulses on fish behaviour. Effects on feeding would be expected to be greatest on species that use electrosensitive foraging strategies, such as elasmobranchs. However, studies on small-spotted catshark have reported that feeding resumed normally after exposure to pulses in a tank experiment. The ability of the species to detect prey using its electrosensitive sensory system was not significantly affected after being exposed to a sole pulse stimulus.

iii) The mechanical disturbance of the seabed – background

The total sediment penetration depth was estimated by adding the measured depth of sediment disturbance by the gear to the modelled depth of erosion due to sediment mobilization in the wake of the gear. The depth of disturbance was measured with a sediment profile image camera to 3.4 cm and 1.0 cm for traditional beam and pulse trawl, respectively. The depth of the eroded sediment layer was modelled to 0.6 m and 0.8 cm, respectively.

In the same experiments multi-beam echosounder measurements showed that in traditional beam trawl tracks the sediment was uniformly deepened following passage of the gear. The sediment in pulse trawl tracks was more heterogeneously deepened.

The overall mobilization of sediment into the water column is inferred to be lower for pulse trawling compared to traditional beam trawling based on the lower hydrodynamic drag associated with the lower average towing speed of pulse trawling (speed reduction of 19% for larger vessels above 221 kW and 14% for smaller vessels). A shift of trawling effort from coarser to more fine sediments is inferred to increase sediment mobilization.

iv) The structure and functioning of the benthic ecosystem – background

There is a sound scientific basis that beam trawls cause significant mortality among benthic invertebrates and that mortality scales with the penetration depth of the gear. Three field studies on the impact of pulse trawls suggest a lower mortality than traditional beam trawls that is consistent with the reduced penetration depth of the gear. The catch per hour of benthic invertebrates in pulse trawling is reduced by 38%–72% in large vessels in two comparative fishing experiments. In these larger vessels there was an average 62% reduction in the discard rate of benthic invertebrates, but in smaller vessels (≤ 221 kW) there was a 6% higher discard rate.

The increased catch efficiency for sole resulted in a reduced surface area swept after the transition from beam trawls to pulse trawls by 2017 Dutch-flagged licence holders between 2009 and 2017. The footprint – defined as the surface area fished during a year at least once – decreased by 18%, and the total surface area swept reduced by slightly more than 30%.

Organisms that occur within the trawl path between the head rope and the penetration depth of the gear will be exposed to mechanical disturbance by both gears. The electrical pulse extends deeper into the sediment. Recent experiments have found no evidence that exposure to the electrical pulses results in measurable additional mortality in the invertebrate species studied, although some early exploratory studies with small samples suggested that some impacts could occur. The available studies do not show that exposure to a pulse stimulus adversely affects growth or increases the risk of disease reflecting an impaired immune system. The limited number of studies, however, implies that a possible adverse effect cannot be excluded.

Electrolysis can cause the formation of chlorine gas (Cl_2) in saltwater. Currently, there is no evidence suggesting that sole pulses lead to electrolysis.

v) Assessment of the impact of repetitive exposure to the two gear types on marine organisms –background

Some of the effects of repeated exposure to the two gear types are considered in the earlier sections of this advice. For example, the effects of both types of fishing gear on the target and non-target fish stocks (non-sessile species) are not just caused by one pass of the gear but are the result of cumulative effects of the gear over time and space.

The effects of repetitive exposure to traditional beam trawls or pulse trawls on organisms are mainly a result of sensitivity to the direct gear impact (mechanical or mechanical + electrical) and the intensity of the impact.

Within the four ICES rectangles most intensively trawled by this fishery, the proportions of unit areas the size of the gear (24 m × 24 m) subject to repetitive trawling at intervals of less than one week are estimated at 0.3% (pulse) and 0.8% (beam trawl). This also assumes that organisms occurring in the trawl track of the full width of the gear are exposed above their sensitivity threshold.

In an ICES rectangle trawled at an annual intensity of five–the maximum intensity observed–about 35% of the unit areas the size of the gear will be trawled for a second time within a month and about 70% will be trawled for a second time within three months. If the ICES rectangle were being trawled seasonally and all trawling occurred during a period of six months, almost 60% of the unit areas the size of the gear would be trawled for a second time within a month, and about 90% within three months.

The intensity calculations further assumed that all organisms are sessile. If organisms are attracted to the fishing grounds trawled by pulse trawlers, the estimated exposure probability will increase and the intervals between repetitive exposures would theoretically be shorter. Along the same lines, for animals that are repelled by the electric field the exposure will be less and the interval between repetitive exposures would theoretically be longer.

Additional information

The beam trawl fishery in the North Sea

The southern North Sea flatfish fishery is described in the ICES Greater North Sea Ecoregion Fisheries Overview (ICES, 2017b). Five countries (Germany, the Netherlands, Belgium, France, and the UK) undertake the fishery using beam trawls, pulse trawls, otter trawls, gillnets, and trammelnets. Sole represents the most important species in terms of the annual value to the beam trawl fishery, with plaice forming the greatest part of the landings by volume.

Between 2010 and 2017 the number of vessels using pulse trawls in the Dutch flatfish fishery operating in the North Sea has increased to 78 (of which 58 > 221 kW), and a handful of Dutch vessels operating with traditional beam trawls are now left.

Table 1 Sole in Subarea 4. Catch distribution by fleet in 2016 as estimated by ICES. “Other beam (incl. pulse)” are vessels flagged to Belgium, Germany, and the UK. BMS = below minimum size.

<table>
<tr><th>Catch</th><th colspan="6">Wanted catch</th><th colspan="2">Unwanted catch</th></tr>
<tr><td rowspan="3">15350 tonnes</td><td colspan="3">Beam trawl (including pulse) 91.25%</td><td rowspan="2">Gillnets 3.83%</td><td rowspan="2">Trammelnet 2.74%</td><td rowspan="2">Other 2.18%</td><td rowspan="2">Discards</td><td rowspan="2">BMS landings</td></tr>
<tr><td>NL trad. Beam 3.75%</td><td>NL Pulse 71.25%</td><td>Other beam (incl. pulse) 16.25%</td></tr>
<tr><td colspan="6">14127 tonnes</td><td>1208 tonnes</td><td>15 tonnes</td></tr>
</table>

The general design of the two gears

Traditional beam trawl for flatfish

A beam trawl is a demersal trawl whose horizontal spread during trawling is maintained by a horizontal beam or wing across the net mouth, supported at both sides by beam trawl shoes or centrally by a nose, maintaining the vertical spread. To this steel structure, a conical net is attached with a round to V-shaped net opening often rigged with tickler chains or a chain matrix to startle the target species (Figure 1).

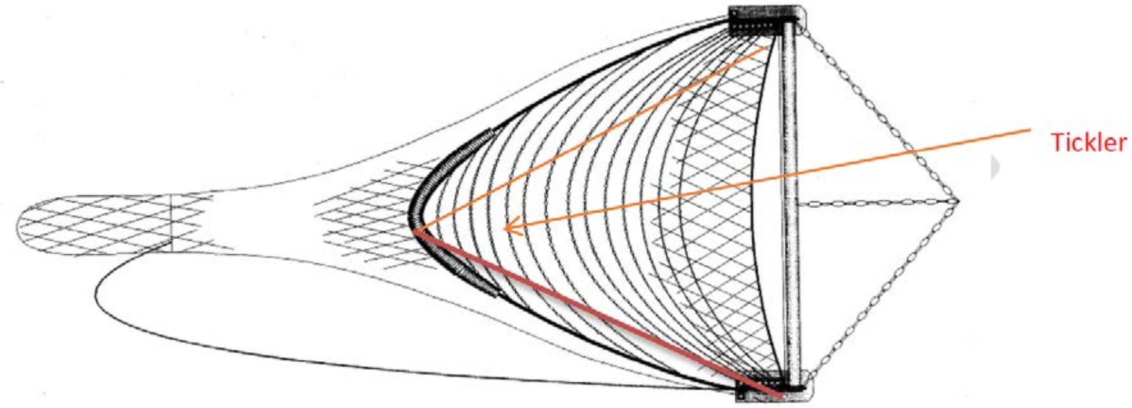

Figure 1 Schematic of traditional beam trawl

Pulse trawl for flatfish

A pulse trawl is a demersal trawl with a net opening rigged with electrodes generating an electric pulse field to startle the target species. The sole pulse trawl as used in the North Sea is a demersal trawl whose horizontal spread during trawling is maintained by a horizontal beam or wing across the net mouth, at supported both sides by beam trawl shoes or centrally by a nose, maintaining the vertical spread. To this steel structure, a conical net is attached with a square net opening rigged with electrodes which stretch from the beam to the groundrope and are spaced at regular distances. A disc-protected rope is rigged alongside each electrode to take the tension during fishing.

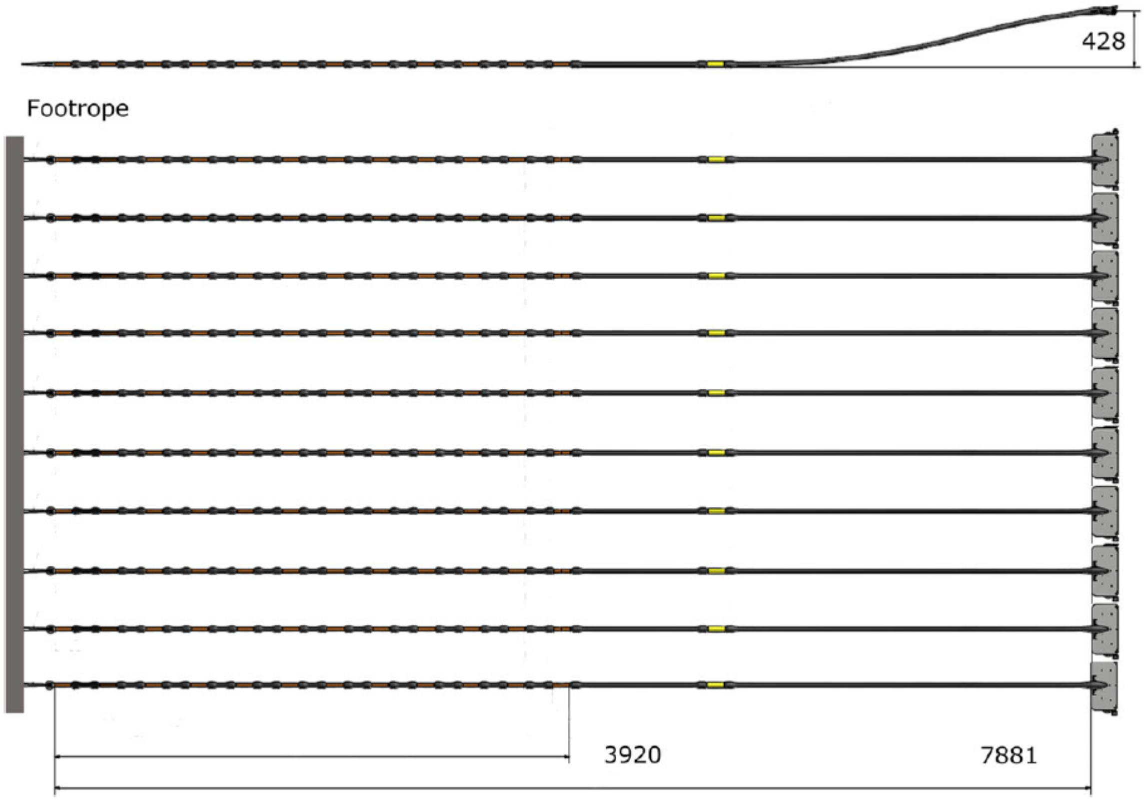

Figure 2 Rigging of the electrodes of a 4 m pulse trawl used by Euro cutter vessels (221 kW).The bottom panel shows the top view of ten electrodes rigged betwen the wing and the groundrope. Each electrode consists of 12 conductor elements, evenly placed over a length of 3.92 m that are in contact with the seabed.

Sources and references

ICES. 2017a. Report of the Working Group on Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). 26 April–5 May 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:21. 1232 pp.

ICES. 2017b. Greater North Sea Ecoregion–Fisheries Overview. 4 July 2017. 29 pp

ICES 2018a. Report of the Working Group on Electrical Trawling (WGELECTRA). 17–19 April 2018, IJmuiden, the Netherlands ICES CM 2018/EOSG:10. 155 pp.

ICES 2018b. Report of the Working Group on the Ecosystem Effects of Fishing Activities (WGECO). 12–19 April 2018, San Pedro del Pinatar, Spain. ICES CM 2018/ACOM:27. 65 pp.