# Fishing spatial-temporal pressures and sensitivities analysis for MPA Fishing Industry Collaboration Pilot FES 252: Report on Seafish workshop on the physical effects of fishing activities on the Dogger Bank

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Nov 2012

ISBN no 978-1-906634-68-1

Seafish; Environment

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Date: 30th Nov 2012

# Fishing spatial-temporal pressures and sensitivities analysis for MPA Fishing Industry Collaboration Pilot FES 252: Report on Seafish workshop on the physical effects of fishing activities on the Dogger Bank

## Summary:

Marine Spatial Planning is becoming an increasingly important influence on the management of fishing activities particularly within the introduction of Marine Protected Areas under the Marine and Coastal Access Act in the UK and Special Areas of Conservation (SACs) under the European Habitats Directive. The designation of the SACs requires that activities which may affect the features for which they have been designated should be managed to ensure favourable conservation status. Various risk assessment methods have been developed in an effort to make assessments of risks to habitat features from fishing activities.

This workshop, which is part of a larger project; Fishing Spatial-Temporal pressures and sensitivities analysis for MPAs (FES 252) carried out by NFFO and funded by EFF, is designed to review knowledge of physical actions on the seabed of fishing gear components and their environmental effects in order to contribute to this process of risk assessment.

Using examples of the gears and the main habitats encountered on the Dogger bank draft SAC the main physical actions the components of otter trawls, twin rigged trawls, both Danish anchor seine and Scottish seine, beam trawls and gill nets are described, both qualitatively in terms of types of action and quantitatively in terms of the area covered by the gear per hour fished. Possible consequent biological and ecological effects of these actions are described and discussed. The results are discussed in relation to assessing physical and ecological effects of fishing activities in relation to spatial management and gear technology design.

## Acknowledgments

The author would like to thank all those who attended and provided input into the workshop at Seafish, Grimsby in June 2012 (see Appendix 1) for list. Particular thanks are due to Bob van Marlen of IMARES, Netherlands, Dr Barry O'Neill of Marine Scotland Science and Dr Ana Ivanović of the University of Aberdeen who made substantial inputs into the manuscript post the workshop. CEFAS staff listed in Appendix 1, in particular Dr Janette Lee, are thanked for their discussion of spatial effects.

Thanks are also due to the Dale Rodmell of NFFO and the Marine Management Organisation, who initiated and financed the project under the EFF Fisheries Challenge Fund.

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# 1. Introduction

Risk assessment methods, for example; Hobday et al., (2007); Hall et al., (2008); Cotter et al., (2010); Tillin et al., (2010); Anon (2011) use expert knowledge, drawing on the published literature, to estimate resilience of marine habitats to fishing and other pressures; each habitat type is assessed for each fishing gear type or other pressures likely to affect it. In most cases the whole effect of the gear is assessed both in the published literature and in the expert judgements made concerning the environmental effects.

There have also been developments in our understanding of the physical effects of fishing gear components on the seabed, using engineering models and observations (Paschen et al., 2000; van Marlen 2010; Ivanovic et al., 2011; O'Neill et al., 2011) and also in altering gear components to reduce seabed effects (He et al., 2010).

Fundamentally, the physical actions of fishing gear on seabed habitats and species are expected to drive the ecological effects. For spatial management to succeed the prediction of ecological effects must be sufficiently accurate to allow adequate protection of species and habitats required under the regulations without placing unnecessary restrictions on fishing. The advent of engineering models and experimental observations of components of fishing gear provides an opportunity to be able to quantify physical actions of fishing gear and ultimately, with the development of suitable methods predict the ecological effects.

Whilst we do not yet have all the tools to describe likely ecological effects based on physical parameters of gear, we have enough knowledge to show that different components of the gear are behaving differently and are likely to have different physical actions and hence ecological effects. Therefore for spatial management of gear activities, perhaps allowing certain gears to be used in specified areas and for guiding development of gears designed for reduced effects on certain habitats, there is a need to dissect out physical actions of different components of fishing gear and describe their relative scale.

The main purpose of this workshop was to describe in qualitative terms the types of physical actions of the different components of fishing gears in use on the Dogger Bank draft SAC and to quantify the spatial and temporal extent of these actions per unit of fishing effort. If successful, subsequent projects could be orientated around other gear types and habitats, ultimately improving risk assessment for management of fishing activities within conservation areas.

This workshop is a part of a larger project; Fishing Spatio-Temporal Pressures and sensitivities Analysis for MPAs (FES 252); fishing industry collaboration project funded by EFF[1] and Co-ordinated by NFFO[2]. This project also has a mapping element in which CEFAS[3] will compare outputs from the statutory satellite based VMS tracking system, with output from vessels' track plotting records. The study is orientated around the Dogger Bank to complement CEFAS' work on spatial distribution of fishing effort in that location (Lee 2012).

[1] European Fisheries Fund

[2] NFFO; UK based National Federation of Fishermen's Organisations

[3] Centre for Environmental, Fisheries and Aquaculture Science

## 2. Objectives

The objectives of this workshop are;

1. The specification of the range of fishing gears in terms of their mechanical contact with the range of different seabed habitat types on the Dogger Bank and the behaviour of gear in typical sea conditions and under typical fishing regimes.

2. Collate known gear adaptations and techniques that may reduce/mitigate impacts on the seabed and discuss how these changes would affect mechanical impacts.

3. Recommendations for future work.

# 3. Workshop

A two day workshop was held with experts in gear technology and engineering, benthic ecology and conservation (see Appendix 1 for list of participants). This workshop was convened at Seafish Grimsby. The experts brought with them presentations on gear engineering and benthic ecology. The initial discussions (Sections 4 and 5) were intended to give a background overview of methods for describing environmental effects of fishing activities, and an overview of the Dogger Bank environment and fisheries.

The participants then discussed qualitatively in terms of types of physical action and biological effects of the components of the gear; Section 6. The swept area affected by the different components of the gear was calculated (Appendix 2) and presented in Table 3 to Table 6. The discussion at the workshop laid the foundations, but there was considerable refinement by correspondence and a separate meeting with CEFAS scientists (Section 7) was held to gain an overview of other information, particularly natural disturbance,

# 4. Background on fishing gear habitat interactions

Three key methodologies were discussed for studying the effects of fishing gears on benthic habitats;

- Experimental fishing impact studies where the effects of fishing are compared by making experimental manipulations, such as designating control and experimental sites, fishing at pre-set intensities and sampling post fishing to describe the effects of fishing and rates of recovery on the biota and ecosystems. These methods are synthesised in a meta analysis by Kaiser et al., (2006).

- Historic fishing intensities; in these studies indexes of fishing intensity are derived from VMS or other data such as fisheries surveillance over-flight data. Comparisons can then be carried out using spatial sampling (Hinz et al., 2008). Alternatively historical data sets can be compared with current observations and fishing effort data to track changes over time (Bradshaw et al., 2002)

- Studies which use physical and mathematical models of the physical actions of gears on the seabed. This approach has been developed under the EU funded TRAPESE (Paschen et al., 2000) and DEGREE (van Marlen 2010) projects. Subsequent work, describing the actions and effects of trawl components on the seabed in terms of the drag force, depth of penetration into the seabed and sediment displacement and quantification of the mobilisation of sediment due to the hydrodynamic action of the gear have been developed by Ivanovic et al., (2011) and O'Neill et al., (2011)

Caution should be exercised in extrapolating habitat-gear interactions from experimental and observational studies to other locations. The effect of fishing gears are highly context dependant; substrate, habitat and community type, gear type, degree of disturbance from other sources and whether, and for how long, the habitat has been already affected by fishing gear.

Information derived from these types of studies has been used to investigate overall fishing pressures by gear type in the North Sea flat-fisheries (Polet et al., 2010), using the gears beam trawl, otter trawl, twin trawl (both twin rig and twin otter trawls) seines (both Scottish and Danish anchor seine) and static gear. This study estimated penetration, fished surface area and displaced sediment averaged for all these gears for the whole of the North Sea using information from experimental studies and expert judgment.

## 5. Background on The Dogger Bank environment and fisheries

The Dogger bank environment and fisheries were discussed based on a CEFAS survey of the UK sector by Diesing et al., (2009) and a description of the fisheries based on statistical analysis of effort and catches by Lee et al., (2009)

The Dogger bank is characterised by relatively high (compared with parts of the North Sea) phytoplankton production which continues all year round with significant quantities of production settling out on the seabed.

Relative to other areas further south, the benthos contains a higher number of species, biomass and abundance. Depths vary between 15 and 70 m with the shallowest areas in the south (see where the steepest gradients are found (up to $5^{o}$). The bank forms a dome shaped formation with an essentially flat surface (Figure 1). Light penetration sufficient for plankton production occurs all over much of the surface of the bank, although there is no mention of benthic algae being present. The majority (75%) seabed habitat in the UK sector of the Dogger Bank dSAC, is according to the EUNIS[4] classification, infra-littoral or circa-littoral fine sand with gravel covering most of the remainder, with muddy sediment being almost completely absent; Figure 2. Infra-littoral meaning photic, with sufficient light to support photosynthesis on the seabed and circa-littoral or aphotic, without sufficient light for photosynthesis on the seabed.

The presence of distinct patches of gravelly sediment in slight depressions in the sandy areas are considered to be the result of wave action on a seabed containing a mixture of sand and gravel. Where gravel accumulates in patches, these areas persist because turbulent conditions above gravel tend to mitigate against settlement of sand (Diesing et al., 2006). These features, together with the presence of ripples on the surface of the sediment, are as result of the substantial effect of storm and tide induced currents over the surface of the bank. The benthic fauna found were consistent with this environment; see also Section 7.2. Although these conditions would be expected to mitigate against persistence of trawl track marks, some were observed on the surface of the bank, although it is not possible to indicated how long these tracks have persisted.

Studies (Kröncke 2011), of long term changes in the fauna of the Dogger bank have shown that during the 1920s to the 1950s there were extensive bivalve (*Mactra* and *Spisula*) patches which covered most of the shallow patches of the shallow patches of the bank during the 1920s. However, since the 1980s these species have only been found as juveniles. In the late 1980s there was an increase in the macro faunal abundance, diversity and species numbers in a biological regime shift associated with an ingress of southern species. However, this period was also associated with increased fishing activity and it is unclear whether climate or fisheries were the main drivers. Since 2001 there has been a climatic regime shift which has reversed many of these changes with a more sparse fauna now dominating, although the adult bivalve patches have not returned.

[4] European Nature Information System; http://eunis.eea.europa.eu/

The Dogger bank is currently a draft Special Area of Conservation (dSAC) under the EU Habitats Directive. This designation is due to the bank being a morphologically distinguishable sand bank feature which is distinct from the surrounding seabed, with slopes in excess of $0.1^{o}$ separating it from the ambient seafloor.

Fisheries using beam trawl, otter trawl and Danish anchor seine and Scottish seine targeting flatfish such as plaice, lemon sole, turbot and dab are important. There is an important sand eel fishery, and some gill netting, primarily on wrecks.

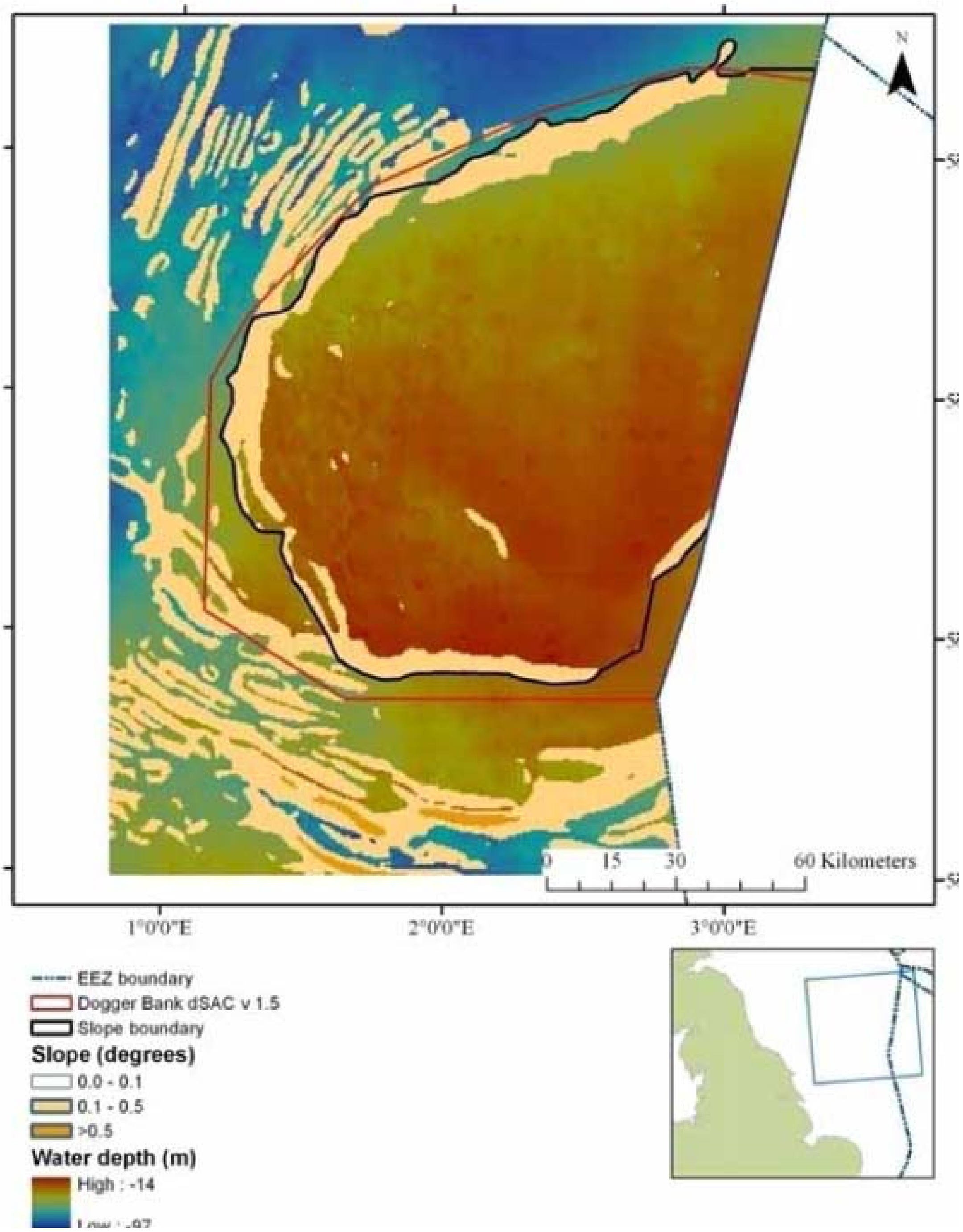


**Figure 1 Contour map and location of the UK sector of the Dogger bank; note shallow areas are in red deeper areas in blue SAC from Diesing et al., (2009)**

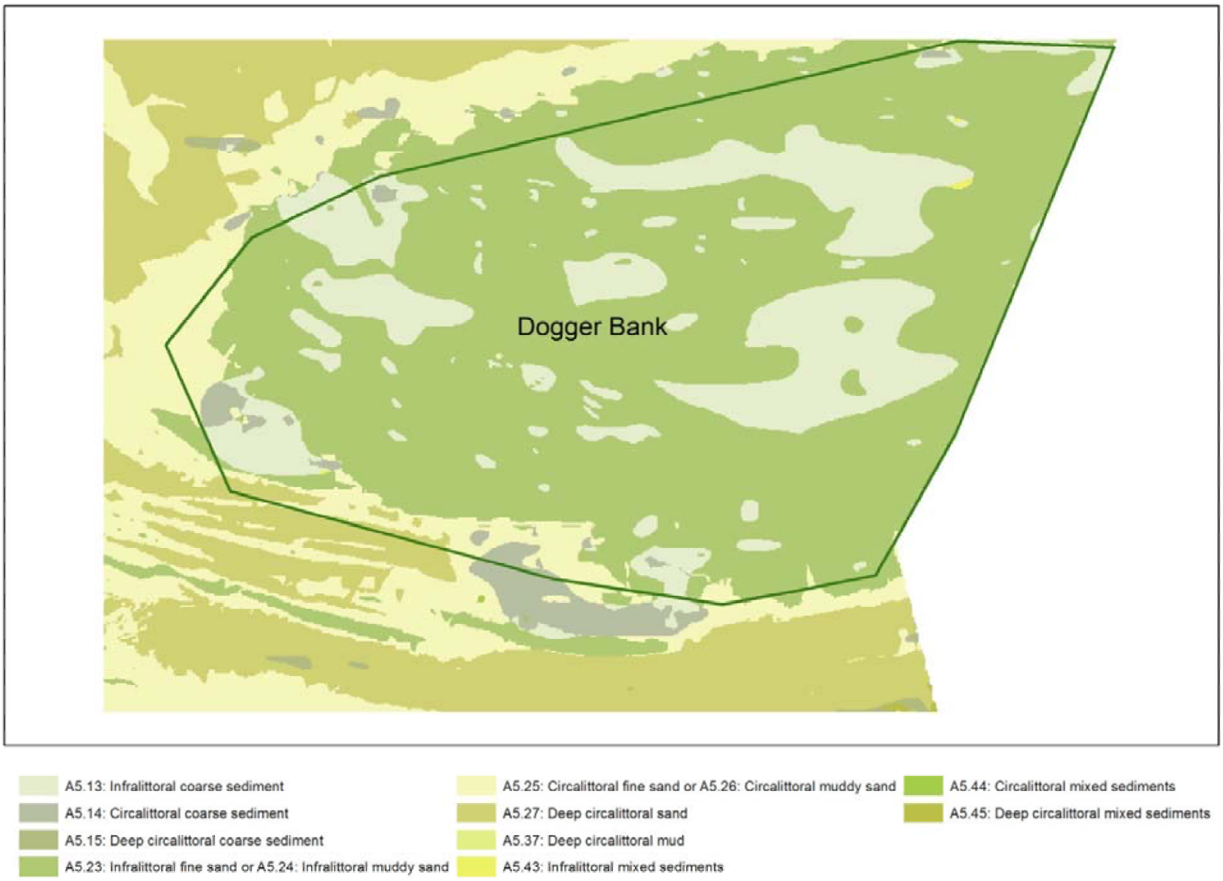


**Figure 2 Seabed types on the UK sector of the Dogger Bank; data from JNCC UKSeaMap 2010 plotted by (Lee, 2012)**

# 6. Physical actions and effects

In this section the information on the actions physical actions and biological effects on the seabed as synthesised by the workshop are brought together with literature on physical and biological effects. Prior to the workshop each of the experts was provided with a DVD containing a collection of clips of underwater video of gear working on the seabed of the types listed as being used on the Dogger bank. A menu of physical actions on the seabed and the consequent list of physical and biological effects was evolved both at and post the workshop (Table 1). For each gear component the physical actions derived from this menu were derived.

Much of the information generated was discussed at the workshop, however it was refined and finalised by correspondence. Estimates of the area affected by the various parts of the gear per hour fished were based on the calculations are shown in Appendix 2. The percentage swept area by each component expressed as a percentage of the total area affected per hour was estimated. It was then expressed as a proportional pie chart in each of the Table 3 to Table 6

Hence, Table 3 to Table 6 describe the footprint of each gear as a pie chart and ranked physical actions and potential biological and ecological effects.

## 6.1. Nature of gear action on the seabed and its effects

The physical descriptions of gear actions on the seabed are described Table 1; hydrodynamic action above the seabed, sweeping on the seabed, ploughing into the seabed, compaction and cutting of the seabed. The physical effects of these actions are dependent on the nature of the seabed, and the design of the relevant gear components.

For example, when observing the results obtained from the physical (full scale) and mathematical modelling of trawl doors and clumps, Ivanovic et al., (2011) found that in sandy sediments with sand ripples the action of these gear components tended to obliterate the sand ripples. The results also suggested that the properties of the sediments in the sand ripples may not be uniform from crest to trough; there may be less strength and hence less resistance in the upper parts of the sand ripples. On flat sandy sediments the penetration was only a few millimetres; mathematical model results corresponded well with the sea trial observations.

Therefore the concept of 'penetration' is a function of seabed topography, properties of the sediment and the gear element observed. For flat seabed it can be defined as penetration to a depth below the surface, however for sandy seabed with surface ripples induced by water currents it could be the obliteration of these ripples. Therefore, penetration is likely to be low in sandy sediments as on the Dogger bank but higher on softer muddy sediments. However, penetration by gill nets has not been quantified (Polet et al., 2010). The Dogger bank gill net fishery concentrates on wrecks, so the effects on fine sand substrates are likely to be minimal.

Interaction between the vessel and the gear can also affect its action on the seabed. For example in some of the videos of beam gear the gear can clearly be seen to be lifted off the seabed by the movement of the vessel induced by surface waves.

## 6.2. Hydrodynamic action resulting in suspension of sediments

Hydrodynamic action by the passage of the gear through the water may entrain the sediment into the water column which is consequently suspended. This may be compounded by the effect of other actions by the gear, such as ploughing which displace sediment into the water column which is subsequently acted on by hydrodynamic action further suspending sediments into the water column. O'Neill et al., (2011) examined how the interaction of different towed gear components, the seabed and the ambient water produced regions of high velocity, high bed shear stress and high turbulence, and how all of which contributed to the entrainment of sediment around and behind the gear components in contact with the seabed. Their study also demonstrated that the mass of sediment entrained in the wake of a specific gear component was related to the hydrodynamic drag of the component and the type of sediment over which it was towed.

## 6.3. Ecological effects

The workshop listed potential short term ecological effects in Table 2 as a consequence of the biological effects described in Table 1. These are ranked for each component in Tables 3-6. As with the physical effects resulting from the actions  discussed above, the duration and importance of the ecological effects are likely to be highly dependent on the species composition growth and recovery rates of  the organisms making up the benthic communities.  This has been widely examined in the literature (see section 4) and discussed further in section 7.

**Table 1 Types of physical and biological actions of fishing gear and their physical and biological effects**

| Short name | Physical action | Physical effect | Effect on biota |
|---|---|---|---|
| Hydrodynamic | The energy used in overcoming hydrodynamic drag manifests itself as accelerated fluid, turbulence and/or vortices in a wake behind the gear components | Depending on the wake contacting the seabed, the resulting shear bed stress and sediment particle size, there may be mobilisation of sediment into the water column. | Wake may cause movement or displacement of biota. Biota may get covered by sinking sediment particles. |
| Sweeping | Movement of gear components over the sea bed with minimal penetration or displacement of sediment. | Friction forces and pressure on the sea bed distributed within the sediment mass and the associated deformations/displacement. Formation of wake in water near the sea bed. Sediment may get into suspension depending on particle size, or displaced. Sea bed structure (such as ripples) may get flattened. | Gear components may collide into biota present on the sea bed surface causing damage. Some structures may get snagged, and break or being pulled out of the sediment, or roll in front of the component, or being passed over. |
| Ploughing | Movement of the gear components over seabed resulting in penetration and/or displacement of sediment. | Friction forces and pressure on and inside the sea bed, and due to large sediment movement formation of both lateral and front berms[5]. Formation of wake inside the sea bed if the sediment is not very dense. Sediment may get into suspension depending on particle size and depth in the sediment, or displaced. | Gear components may collide into biota living in the sea bed causing damage. Some structures may get snagged, cut, or break or being pulled out of the sediment, or roll in front of the component, or being passed underneath. |
| Compaction | Embedment, pressure on seabed | Pressure results in compaction of seabed sediment and the embedment of a gear element | Small effect on surface biota |
| Penetration | Piercing of seabed – cutting of seabed | Pressure on seabed surface results in intrusion of gear into seabed | Small effect on infauna |

[5] Raised mounds of sediment on the seabed on either side of the gear's wake

 

**Table 2 Potential types of ecological effect**

| Effect | Explanation |
|---|---|
| Higher mortality on infauna | Where gear may interact with fauna to cause lethal effects |
| Higher mortality on epifauna | |
| Sub-lethal effects on infauna | Where gear may interact with fauna to cause sub-lethal effects through stress or minor damage |
| Sub-lethal effects on epifauna | |
| Changes in seabed structure | Where gear may interact with the seabed to cause changes in the seabed structure |

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**Table 3 Twin trawls and otter trawl gear components; ranked actions and effects**

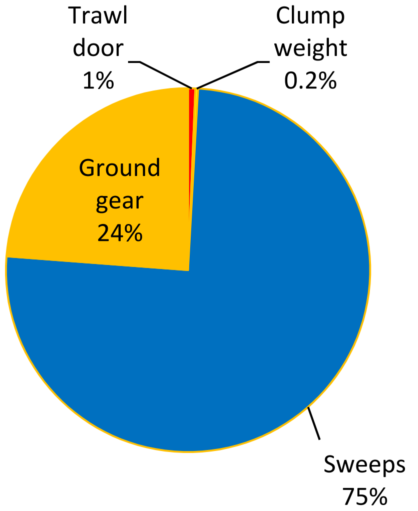
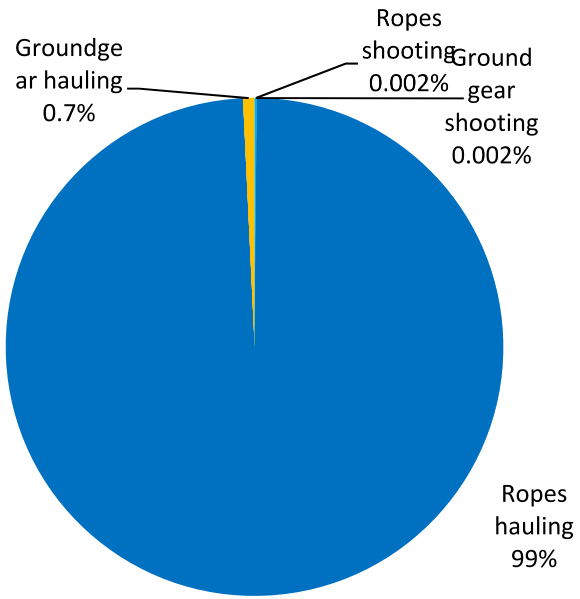
| | | | **Ranked action and effects** | |
|---|---|---|---|---|
| **Twin trawl (TT) with spread of 250m 1.4 $km^2$ per hour; area of pie chart proportional to area swept** | **Component** | **Activity** | **Physical** | **Ecological** |
|   | All | Shooting & hauling | Pelagic activity | No effect on seabed |
| | Trawl door and clump weight | Towing | **Trawl door**<br>1 Ploughing, 2 Hydrodynamic, 3 Sweeping, 4 Compaction<br>**Clump**<br>1 Ploughing, 2 Sweeping, 3 Hydrodynamic, 4 Compaction | Lethal and sub-lethal effects on epifauna and infauna, Changes in seabed structure |
| | Sweeps | Towing | 1 Sweeping, 2 Ploughing, 3 Hydrodynamic | Sub-lethal and lethal effects on epifauna, minor changes in seabed structure |
| | Ground gear | Towing | 1 Ploughing, 2 Sweeping, 3 Hydrodynamic | Lethal and sub-lethal effects on epifauna and infauna, Changes in seabed structure |

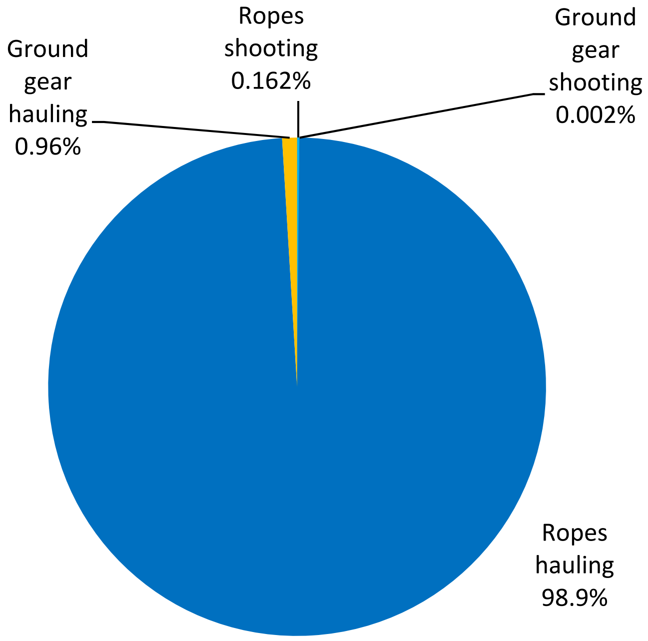
 

**Table 4** Seine Gear; **gear components; ranked actions and effects (see overleaf for Danish anchor seine)**

<table>
<tr><th></th><th></th><th></th><th colspan="2">Ranked actions and effects</th></tr>
<tr><th>Scottish seine (SS) 2.6 km² per hour; area of pie chart proportional to area swept by component</th><th>Component</th><th>Activity</th><th>Physical</th><th>Ecological effects</th></tr>
<tr><td rowspan="4">
</td><td>Ropes</td><td>Shooting</td><td>1 Compaction, 2 Sweeping</td><td>Minimal effect</td></tr>
<tr><td>Ground gear</td><td>Shooting</td><td>1 Compaction, 2 Sweeping</td><td>Minimal effect</td></tr>
<tr><td>Ropes</td><td>Hauling</td><td>1 Sweeping, 2 Ploughing, 3 Hydrodynamic</td><td>Sub-lethal and lethal effects on epi-fauna, minor changes in seabed structure</td></tr>
<tr><td>Ground gear</td><td>Hauling</td><td>1 Ploughing 2 Sweeping, 3 Hydrodynamic</td><td>Lethal and sub-lethal effects on epi-fauna and infauna, Changes in seabed structure</td></tr>
</table>

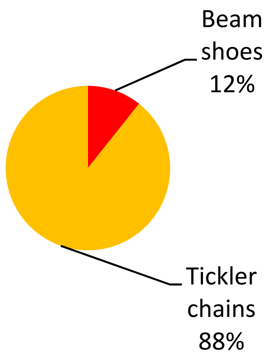
**Danish anchor seine (SDN) 2.6 km$^2$ per hour; area of pie chart proportional to area swept by component**



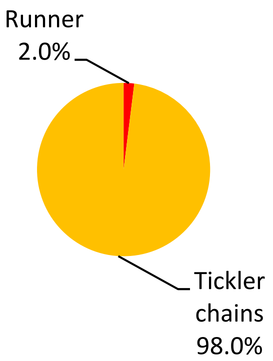

| | Ranked actions and effects | | |
|---|---|---|---|
| **Compo-nent** | **Activ-ity** | **Physical** | **Ecological effects** |
| Anchor | All | 1 Penetration, 2 Ploughing | Minimal effect |
| Ropes | Shoot-ing | 1 Compaction<br>2 Sweeping | Minimal effect |
| Ground gear | Shoot-ing | 1 Compaction, 2, Sweep-ing | Minimal effect |
| Ropes | Hauling | 1 Sweeping,<br>2 Ploughing,<br>3 Hydrodynamic | Sub-lethal and lethal ef-fects on epifauna, minor changes in seabed struc-ture |
| Ground gear | Hauling | 1 Ploughing,<br>2 Sweeping,<br>3 Hydrodynamic | Lethal and sub-lethal ef-fects on epifauna and in-fauna, Changes in sea-bed structure |

**Table 5** Beam, Sum wing and pulse wing trawls gear components ranked actions and effects(see over leaf for sum wing and pulse wing trawls)

| | | | Ranked actions and effects | |
|---|---|---|---|---|
| **Beam trawl (TBB) 0.29 $km^2$ per hour fished; area of pie chart proportional to area swept by component** | **Com-ponent** | **Activity** | **Physical** | **Ecological effects** |
|   | All | Shooting & hauling | Pelagic activity | |
| | Beam-Shoes | Towing | 1,Ploughing, 2 Sweeping,3 Compaction, | Lethal and sub-lethal effects on epifauna and infauna. Changes in seabed structure |
| | Tickler chains | Towing | 1,Ploughing, 2 Sweeping | Lethal and sub-lethal effects on epifauna and infauna, Changes in seabed structure. Little additional effect after 7th tickler chain |
| | Foot-rope with rollers | Towing | 1, Sweeping, 2 Ploughing, 3, Hydrodynamic | Little additional effect after tickler chains |

<table>
<tr><td></td><td></td><td></td><td colspan="2">Ranked actions and effects</td></tr>
<tr><td></td><td>Component</td><td>Activity</td><td>Physical</td><td>Ecological effects</td></tr>
<tr><td>Sum wing trawl 0.29 km$^2$ per hour; area of pie chart proportional to area swept by component</td><td>All</td><td>Shooting & hauling</td><td>Pelagic activity</td><td></td></tr>
<tr><td rowspan="4">


</td><td>Sum Wing</td><td>Towing</td><td>1 Hydrodynamic; uses hydrodynamic flow to maintain position in water column</td><td>Not discussed</td></tr>
<tr><td>Runner</td><td>Towing</td><td>1Ploughing</td><td>Lethal and sub-lethal effects on epifauna and infauna. Changes in seabed structure</td></tr>
<tr><td>Tickler chains</td><td>Towing</td><td>1Ploughing, 2 Sweeping</td><td>Lethal and sub-lethal effects on epifauna and infauna. Changes in seabed structure. Little additional effect after 7th tickler chain</td></tr>
<tr><td>Footrope with rollers</td><td>Towing</td><td>1 Sweeping, 2 Ploughing, 3 Hydrodynamic</td><td>Little additional effect after tickler chains</td></tr>
</table>

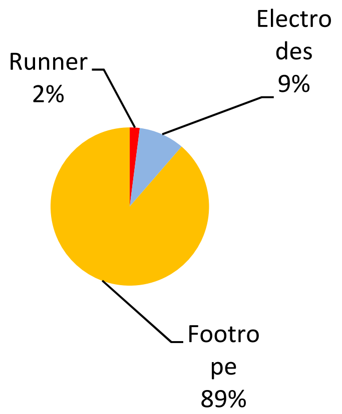
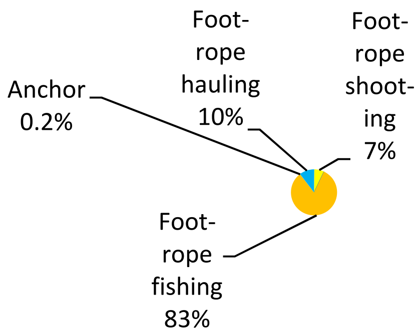
| | | | Ranked actions and effects | |
|---|---|---|---|---|
| **Pulse wing trawl 0.22 km$^2$ per hour; area of pie chart proportional to area swept by component** | **Component** | **Activity** | **Physical** | **Ecological effects** |
|   | All | Shooting & hauling | Pelagic activity | |
| | Sum Wing | Towing | 1 Hydrodynamic; uses hydrodynamic flow to maintain position in water column | Not discussed |
| | Runner | Towing | 1 Ploughing | Lethal and sub-lethal effects on epifauna and infauna. Changes in seabed structure |
| | Electrodes | Towing | 1 Sweeping, 2 Ploughing and effect of electric potential | Lethal and sub-lethal effects on epifauna and infauna; electrical stimulation. |
| | Footrope with rollers | Towing | 1 Sweeping, 2 Ploughing, 3 Hydrodynamic | Lethal and sub-lethal effects on epifauna and infauna. Changes in seabed structure |

**Table 6 Gill net; ranked actions and effects**

<table>
<tr><th></th><th></th><th></th><th colspan="2">Ranked actions and effects</th></tr>
<tr><th>Gill net (GNS) 0.0287 km$^2$ per hour; area of pie chart proportional to area swept by component</th><th>Compo-nent</th><th>Activity</th><th>Physical</th><th>Ecological</th></tr>
<tr><td rowspan="6">
</td><td>Anchor</td><td>Shooting</td><td>1 Ploughing</td><td>Lethal and sub-lethal effects on epifauna and infauna and changes in seabed structure</td></tr>
<tr><td>Footrope</td><td>Shooting</td><td>1 Compaction, 2 Sweeping</td><td>Sub-lethal effects on epi-fauna</td></tr>
<tr><td>Anchor</td><td>Fishing</td><td>1 Penetration, 2 Compac-tion</td><td>Lethal and sub-lethal effects on epi-fauna and infauna and changes in seabed structure</td></tr>
<tr><td>Footrope</td><td>Fishing</td><td>1 Compaction, 2 Sweeping</td><td>Sub-lethal effects on epi-fauna</td></tr>
<tr><td>Anchor</td><td>Retriev-ing</td><td>1 Ploughing</td><td>Sub-lethal effects on infauna and changes in seabed structure</td></tr>
<tr><td>Footrope</td><td>Retriev-ing</td><td>1 Sweeping,</td><td>Sub-lethal effects on epi-fauna</td></tr>
</table>

# 7. Discussion

The workshop was able to describe the actions of the gear in qualitative terms and provide indicative opinion on the immediate effects on the seabed and fauna. It was found possible, given the dimensions of the gear and known features of its rigging to make credible estimates of the swept area of each of the components of the gear.

Subsequent to the workshop, meetings were held with scientists at CEFAS, who had undertaken the spatial analysis side of the project (Lee 2012) and with expertise in physical oceanography and benthic ecology. Potential further work, integrating the spatial and environmental aspects was discussed. The approach described in the workshop could be used in the following;

## 7.1. Describing physical effects

The workshop was able to classify the gear action qualitatively in terms of types of action on the seabed and quantitatively in terms of the area swept by the gear. Sea bed pressures from some fishing gear actions on the seabed have been quantified; for example Paschen et al., (2000) quantifies seabed pressures from beam trawling and Ivanovic et al., (2011) quantifies forces in relation to otter boards and clump weights.

## 7.2. Describing ecological effects

The description of ecological effects were discussed at the workshop with some potential effects of the actions of the different components in epifauna and infauna described. The vulnerability of the different ecosystem components would be related to the actions of the gear described Table 1 and the characteristics of the fauna under consideration; for example epifauna could be vulnerable to sweeping whereas epi-fauna and infauna vulnerable to ploughing and sweeping. In the broader context effects on populations of the species would depend on the life history traits, rapid growing, fecund, species would be more resilient than slower growing less fecund species. Size structure of the organisms making up the benthic community may also be relevant; Queiros et al., (2006) consider the Dogger bank benthic community to be relatively resilient as a result of its size structure, when compared with less resilient communities on mud habitat.

## 7.3. Gear technology design

The framework discussed above could be used to assess the modifications of gear components to achieve different outcomes in terms of physical actions. Estimates of the swept could be compared in deciding priority.

Examples are;

**Otter trawls**; if the habitat were considered vulnerable to ploughing but not so vulnerable to sweeping then the focus would be on the ground gear, trawl doors and clump weight. There ongoing Danish project; Efficient and low impact gear in the Danish fishery for Industrial species (GEMBA Seafood Consulting, 2012) where the use of pelagic trawl doors is being examined to reduce door and sweep contact in sandeel trawls.

**Seining**; the main action of seining is sweeping by the ropes, so modifying the seine's ground gear would not have a large effect on the overall action of the gear.

**Beam trawling**; Table 5 compares the effect of ordinary beam trawling, Sum Wing and Sum pulse trawls in terms of their physical actions on the seabed. Thus the effect of the use of the runner rather than the shoes reduces the proportion of the gear effect from this type of component from 12% to 2%. The relative areas swept by pulse trawls due to their lower speed is also described, and the differing actions due to the use of electrodes rather than chains. Further analysis could be derived from the TRAPESE report; Paschen et al., (2000) which makes more quantitative descriptions of the effects of gear components. However, at present all these gears are reported as beam trawls; TBB in the fisheries statistics (van Marlen pers com).

There are other examples of gear modification given in He et al., (2010), which combined with this work could be used to guide potential gear modifications.

# 8. Further work; risk assessment

The above discussion suggests that a three stage process could be for risk assessment of the effects of fishing on habitats under consideration;

1. This workshop has been able to describe the types of gear action and cite literature (Paschen et al., 2000; Ivanovic et al., 2011) that quantifies pressures in $N/m^2$ on the seabed and estimate their spatial extent per hour fished. The actions of the different components would be averaged over the area fished. If fine scale spatial resolution can be achieved in terms of spatial extent of effort as from the work carried out by CEFAS on the fishermen's track plotter data, then the spatial resolution can be improved; see Lee (2012)..
2. The environment of the Dogger bank is a habitat that is known to be dominated by wave and tidal action. The spatial distribution of fishing action could be used in combination with oceanographic models of seabed stress due to tides and wave disturbance, to assess the relative level of the fishing and natural stress over the area of the Dogger Bank. This has already been achieved for beam trawling by Aldridge et al., (2006), on a grid resolution of 11 $km^2$ for the whole of the North Sea and Diesing et al., (2011) and work in prep, has discussed similar work for other gears. The level and nature of the seabed stress due to fishing could be compared with that arising from wave and tidal action. However, care be required in the interpretation of such information. For example ploughing action into seabed or solid on solid contact as between fishing gear and mollusc shells may have a different effect from wave and tidal stress. The description of the types of gear action on the seabed in this study would contribute to this process.
3. Once the physical actions of fishing gears have been described qualitatively and quantitatively in relation to natural disturbance, these results could be used in making improved risk assessments in relation to vulnerabilities of seabed habitats and fauna as discussed in sections 7.2 and the risk assessment methods in section 1.

This process could be repeated for other SACs or MPAs. There is increasing availability of information on marine environmental characteristics, such as seabed shear stress levels ($N/m^2$) due to tidal and wave effects which is available to a resolution of 1 $km^2$ for substantial areas of southern UK waters from surveys carried out under the Marine Aggregate Levy Sustainability Fund; examples are Eggleton et al., (2011) and Limpenny et al., (2011).

# Appendix 1 Workshop participants

Table 7 Workshop attendees (June 2012)

| Name | Affiliation |
|---|---|
| Clare Eno | Countryside Council for Wales, UK |
| Mark Gray | Seafish, UK |
| Kurt Hansen | Sintef, Denmark |
| Hilmar Hinz | University of Wales, Bangor, UK |
| Ana Ivanović | University of Aberdeen, UK |
| William (Bill) Lart (Co-ordinator) | Seafish, UK |
| Gareth Johnson | JNCC, UK |
| Phil MacMullen (Chair) | Seafish, UK |
| Bob van Marlen | IMARES, Netherlands |
| Mike Montgomerie | Seafish UK |
| Barry O'Neill | Marine Scotland, Science |
| Heidi Pardoe | Natural England |
| Hans Polet | ILVO, Belgium |
| Dale Rodmell | NFFO, UK |
| Nathan de Rozarieux | Tegen Mor, Consultants, UK |
| Helen Stevens | Natural England, UK |
| Duncan Vaughn | Natural England, UK |

Table 8 CEFAS meeting Sept 2012

| Name | Affiliation |
|---|---|
| Markus Diesing | Cefas |
| William (Bill) Lart | Seafish |
| Janette Lee | Cefas |
| Jon Rees | Cefas |
| Dale Rodmell | NFFO |
| Nathan de Rozarieux | Tegen Mor Consultants |
| Koen Vanstaen | Cefas |
| Suzanne Ware | Cefas |

# Appendix 2 Gear descriptions and swept area calculations;

see Seafish, (2005) for details of conventional gear and www.sumwing.nl/SumWing_EN.pdf for details of sum and pulse wing trawls. Dimensions are given in tables.

These descriptions are illustrative of the of calculations which could be made using the various components described by fishermen operating on The Dogger bank. Such calculations could be revised for different gear configurations.

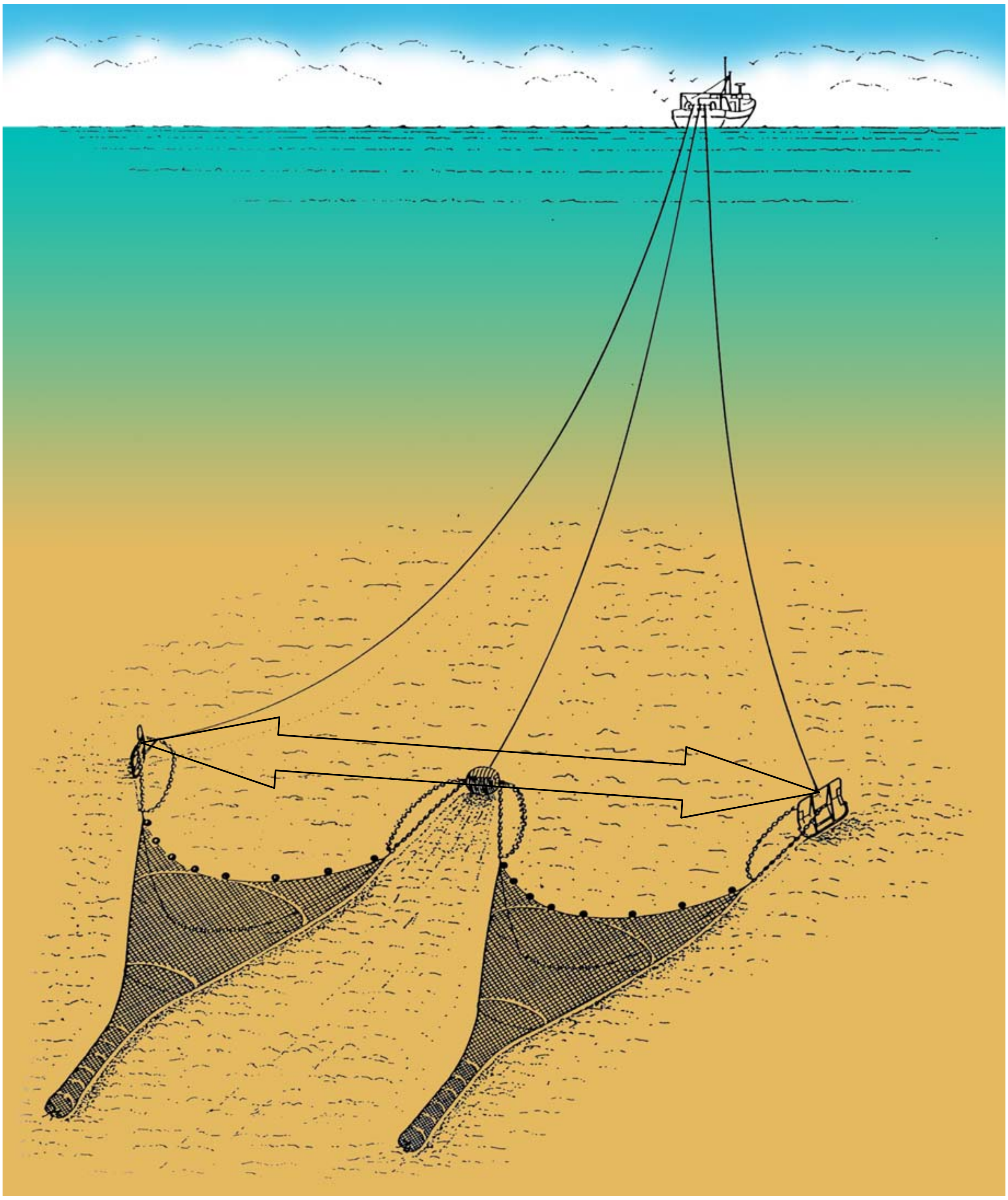


Figure 3 Twin rigged trawl, showing track width

**Table 9** Calculation of swept area of twin trawl components towed at 3 knots or 5,555 m per hour for two different trawl door spreads;

| Components | Dimensions and notes | Calculation of track width | Track width in (m) | $km^2$/h fished |
|---|---|---|---|---|
| Doors | 0.8 to 1.8 tonne, spread approx 200-250 m | 2*0.8 m wide track derived from Ivanovic et al., (2011) Note these were smaller doors than specified 0.45 tonnes | 1.6 | 0.009 |
| Spread of sweeps | Overall spread of gear = 200-250 m. Less 60 m for spread of ground gear = 140-190 m | Min width affected by sweeps alone 140 m | 140 | 0.77 |
| | | Max width affected by sweeps alone 190m | 190 | 1.05 |
| Clump | Clump weight 0.8 to 1.8 tonne; length width. | 1 * 0.6 m from Ivanovic et al., (2011); for a circa 1 tonne clump | 0.6 | 0.003 |
| Spread of trawl ground gear | About 30 m * 2 | Two trawls at 30 m spread each = 60 m | 60 | 0.2 |
| Cod end chafers if fitted | | | | Behind ground gear so no inde-pendent track |

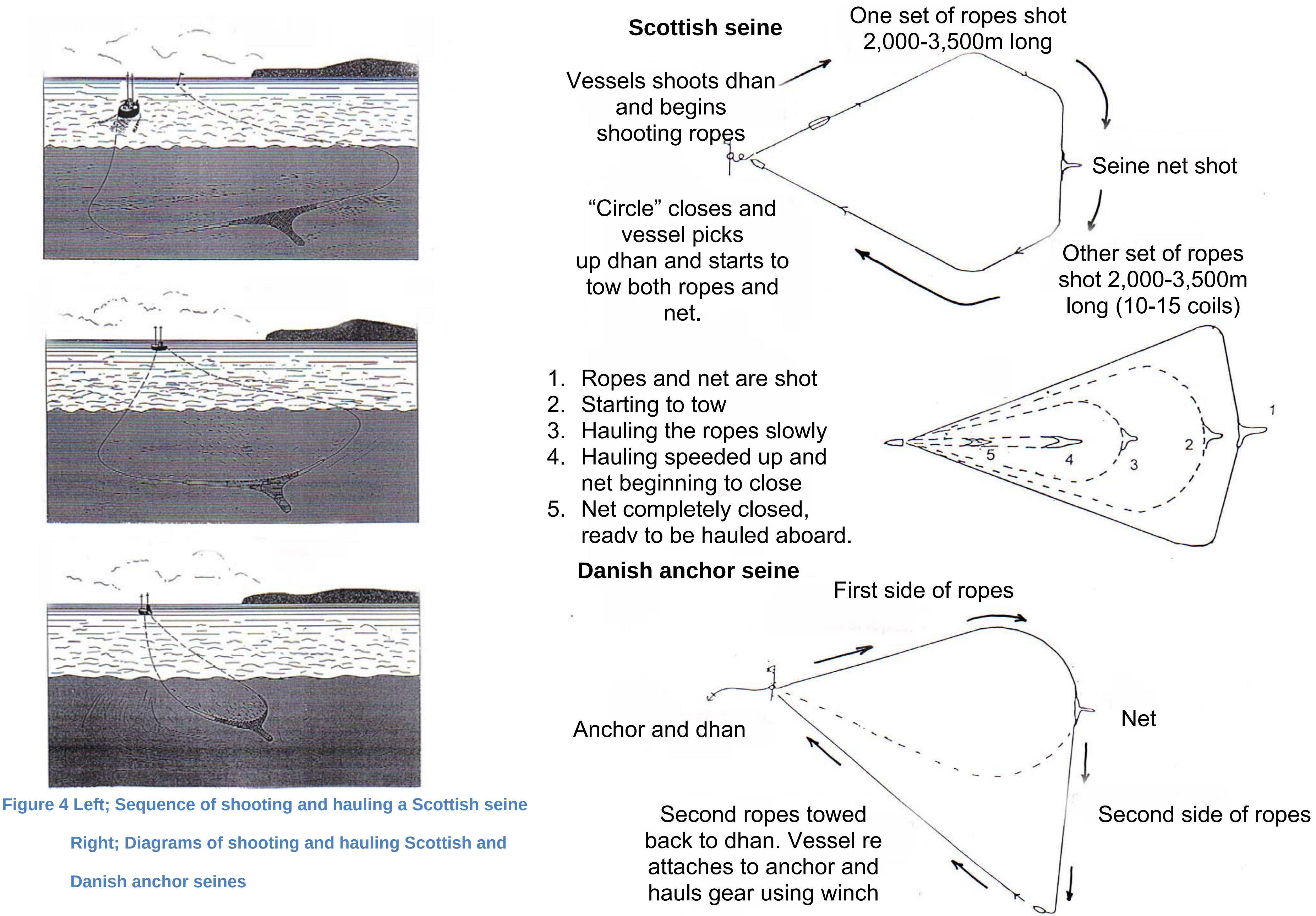



**Figure 4 Left; Sequence of shooting and hauling a Scottish seine**

**Right; Diagrams of shooting and hauling Scottish and Danish anchor seines**

**Table 10 Calculation of swept area of Danish anchor seine and Scottish seine (overleaf) components: Note seining is usually carried out in daylight so a day seining is likely to be constitute less  hours than a day trawling.**

**Danish anchor seine**

| Activity | Component | Dimensions and weights | Calculation | $km^2$/h fished |
|---|---|---|---|---|
| Shooting | Anchor | about 150 kg | | 0.000004 |
| | Ropes | 22-32 mm 3500-4000 m * 2 | Max width of contact during shooting = rope diameter, Area affected max 0.032 * 4000 *2 during shooting assuming the ropes do not move on sea bed | 0.004 |
| | Ground gear | 38 m long, spread 25 m | Max width of contact for a rubber gear of say 200 mm disks would be 200 mm, max area affected while shooting assuming the gear does not move 0.2m*38m | 0.000008 |
| Hauling | Anchor | about 150 kg | | |
| | Ropes | 22-32 mm 3500-4000 m * 2 | Total area swept in $m^2$ per hour = 780.95*seine net rope length per side-588520 apportioned to ropes and ground gear (DIFTA et al., 1996) | 2.54 |
| | Ground gear | 38 m long, spread 25 m | | 0.024 |
| | Cod end chafer if fitted | | | Behind ground gear so no independent track |
| Retrieving | Anchor | about 150 kg | Anchor lifted vertically so effect is minimal | |

**Scottish seine**

| | | | | |
|---|---|---|---|---|
| Shooting | Ropes | 3500-4000 m * 2 | Calculations as above for Danish anchor seine | 0.004 |
| | Ground gear | 60 m long, 40-45 m spread | Calculations as above for Danish anchor seine | 0.00005 |
| Hauling | Ropes | 3500-4000 m * 2 | Circumference= 8000 m ropes + 60 m for ground gear = radius = (8060 circumference/3.14)/2= 1283 , Area per haul = $3.14*1283^2$ = 5,169,639 $m^2$, Approximately 2 hours per haul so area affected per hour fishing = 2,584,820; $m^2$ proportionally apportioned to ropes and ground gear. | 2.565 |
| | Ground gear | 60 m long, 40-45 m spread | | 0.019 |
| | Cod end chafer | | | Behind ground gear so no inde-pendent track |

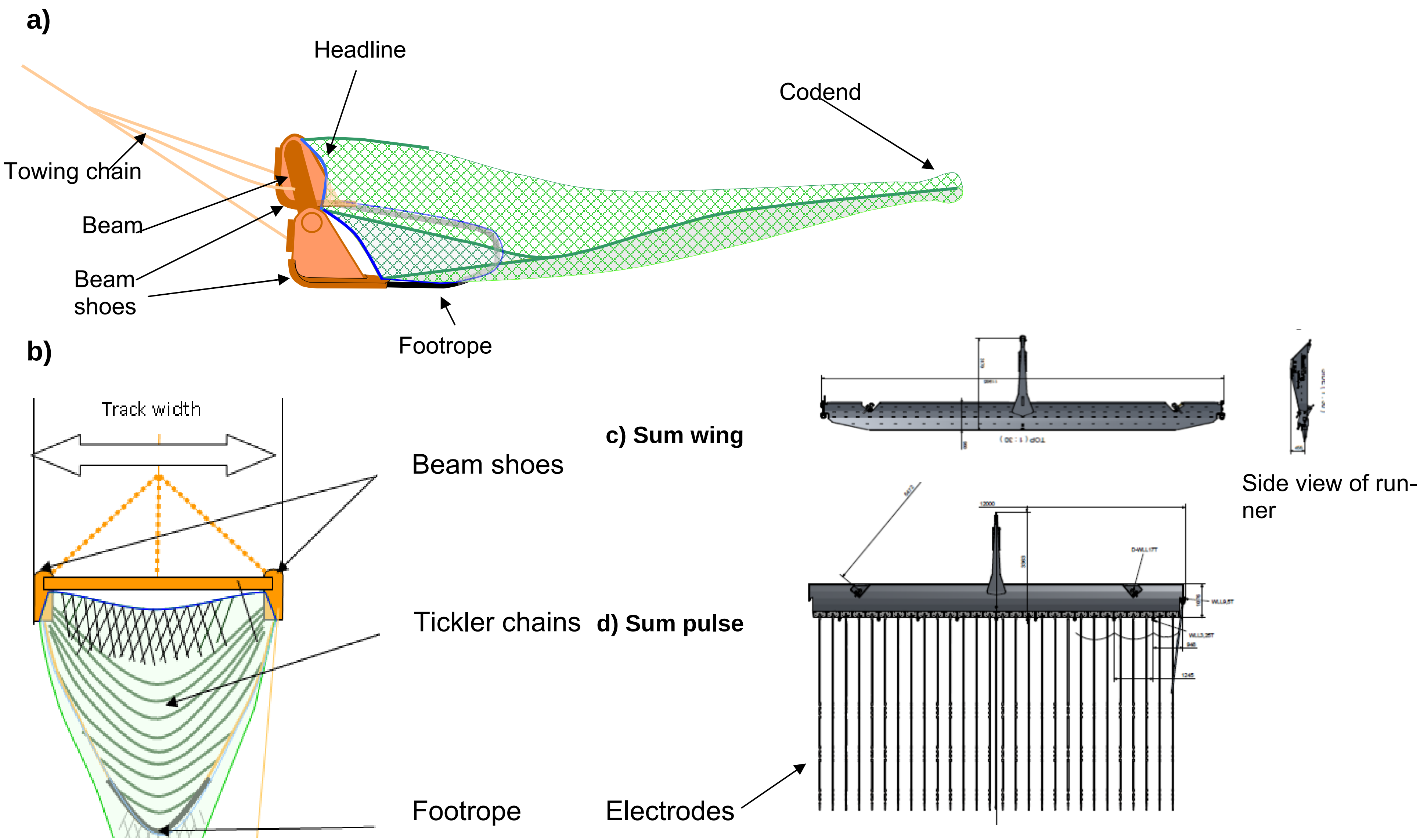



Figure 5 Beam, sum wing and sum pulse trawls. a) side view of beam trawl, b) top view of beam trawl, showing track width, c) top view of sum wing and side view of runner; this replaces beam and shoes in both sum wing and sum pulse trawl; the runner is the main point of contact with the seabed. d) top Sum pulse rig with electrodes; electrodes replace tickler chains www.sumwing.nl/SumWing_EN.pdf

**Table 11 Calculation of swept area of conventional tickler chain beam trawl, Sum Wing and Pulse Wing trawl components.**

**Beam trawl components at 6.5 knots or (6.5 * 1852 = 12,038 m/h)**

| Component | Specification | Calculation for width | Track Width (m) | **$km^2$/h fished** |
|---|---|---|---|---|
| Total width of gear; beam 2*12 m 4.5 tonne resting on shoes at either end | | | 24 | 0.289 |
| Shoes | Width of shoes = 720 mm | 4 shoes * 720 mm = 2880 mm | 2.88 | 0.035 |
| Tickler chains | 10 + 8 total weight 2 tonnes 12m * 2 – width of shoe | 2 * 12 m – 4 * 0.72 m | 21.12 | 0.254 |
| Footrope with roller | Foot rope 35 m hung behind beam | 2 * 12 m – 4 * 0.72 m but is behind tickler chains | 21.12 | 0.254 |
| Chafers | Behind trawl | | | |

| **Sum wing with runner at 6.5 knots or (6.5 * 1852 = 12,038 m/h)** | | | Track Width (m) | **km²/h fished** |
|---|---|---|---|---|
| Sum wing is neutrally buoyant with a single point of contact with the seabed on the runner; Total gear 2 * 12 m wings | | | 24 | 0.289 |
| Runners | 1*240 mm each wing | 2 runners * 240 mm = 480 mm | 0.48 | 0.006 |
| Tickler chains | 10 + 8 total weight 2 ton-nes 12m * 2 | 2 * 12 m (runner subtracted, because its passage cause heavier effects) | 23.52 | 0.283 |
| Footrope with roller | 35 m hung behind beam | 2 * 12 m (runner subtracted) but is behind tickler chains | 23.52 | 0.283 |
| Chafers | Behind trawl | | | |

| **Pulse Wing trawl components at 5 knots or (5 * 1852 = 9,260 m/h)** | | | Track Width (m) | **km²/h fished** |
|---|---|---|---|---|
| Sum wing is neutrally buoyant with a single point of contact with the seabed on the runner | | | 24 | 0.222 |
| Runners | 1*240 mm each wing | 2 runners * 240 mm = 480 mm | 0.48 | 0.004 |
| Electrodes | Weight | max 28, diameter 40 mm | 2.24 | 0.021 |
| Footrope with roller | 35 m hung behind beam | 2*(12-28*0.04-0.24), runner and electrodes subtracted | 21.28 | 0.197 |
| Chafers | Behind trawl | | | |

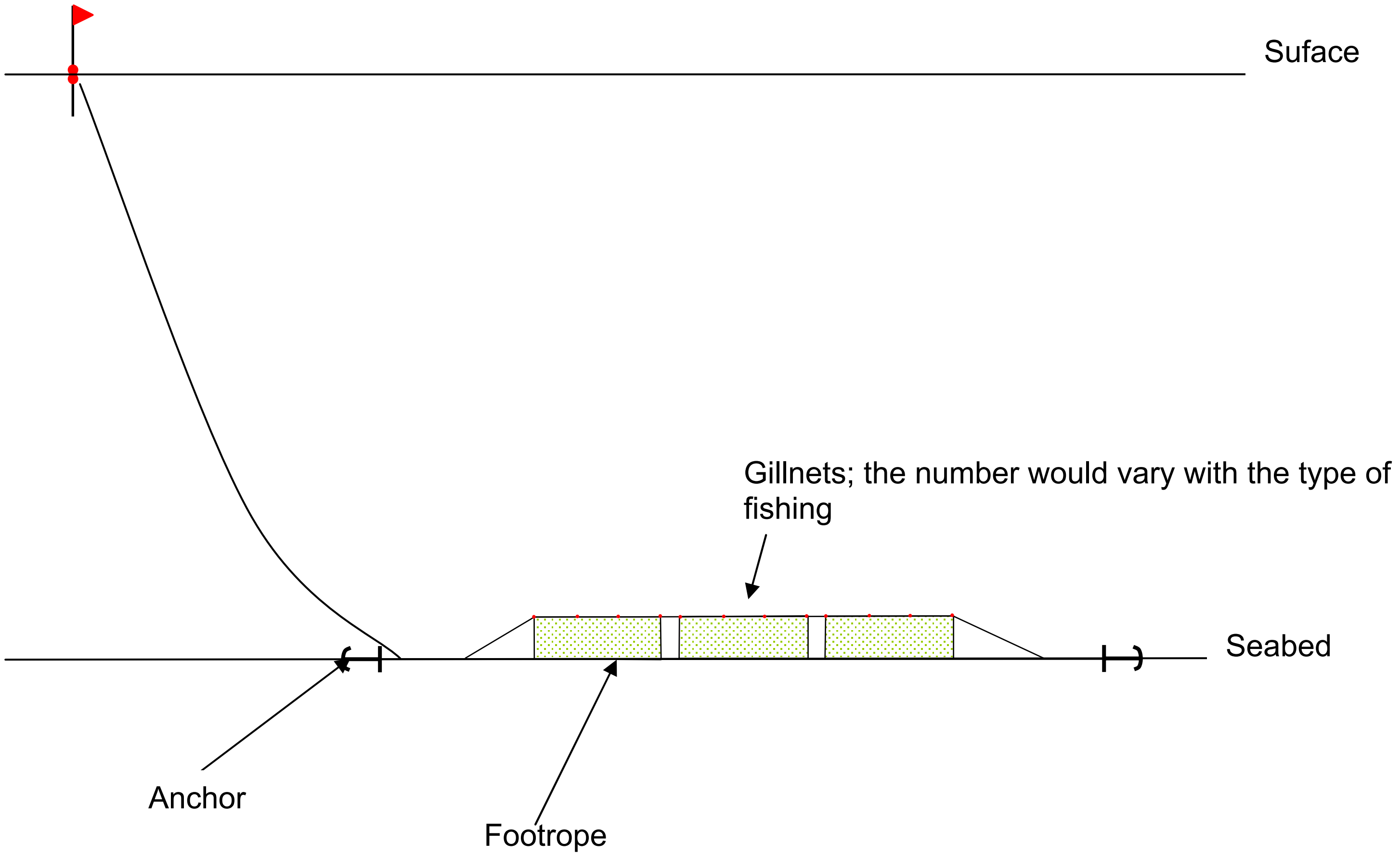



Figure 6 Diagram of gillnet configuration

**Table 12 Calculations of swept area of gill net**

**Gill net; wreck net: a total of 10 teirs; each teir of 132 m has 2 anchors. When fishing one teir is being shot or retrieved per 1/2 hour at so 9 teirs are in the water at one time.**

| Activity | Component | Gear specification | Calculation | $m^2$ per hour | $km^2$/h fished |
|---|---|---|---|---|---|
| Shooting | Anchor | 2*16 kg | Allow the anchor in each end 2*(3 m * 0.5 m) to dig | 3 | 0.00006 |
| | Footrope | 132 m No 5 lead line | Assume 1/2 the footrope from each tier is in contact with the seabed and an area affected by the gear is 3m wide * 132 m long | 198 | 0.002 |
| Fishing | Anchor | 2*16 kg | Assume no movement by anchors during fishing | | 0 |
| | Footrope | 132 m No 5 leadline | Assume 9 * 132 m per hour = 1320 meters and an effect approx 2 m wide on average= | 2640 | 0.026 |
| Retrieving | Anchor | 2*16 kg | Allow the anchor in each end 2*(3 m * 0.5 m) to dig | 3 | 0.00006 |
| | Footrope | 132 m No 5 leadline | Assume 3/4 the footrope from each teir is in contact with the seabed and an area affected by the gear is 3m wide * 132 m long/2 | 297 | 0.003 |

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