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De inspanning, waarde en aanlandingen door de Nederlandse, Britse, Deense, Duitse, Belgische, Zweedse en Franse zegenvisserij op het Nederlandse en Duitse deel van de Doggersbank vertonen in de periode 2013-2019 een lage en onregelmatige activiteit, voornamelijk gedreven door vangstmogelijkheden voor schol. Het verbod op visserij met puls zal waarschijnlijk niet leiden tot een toename van het aantal flyshoot-schepen in de Nederlandse vloot, gezien de financiële, technische, regelgevende en kennisbarrières voor transitie. De ecologische impact van zegenvisserij alleen is moeilijk te beoordelen en hoewel niet met zekerheid te bepalen, wordt de impact op de relatieve biomassa van de bodemdierengemeenschap van vroegere en huidige visserijniveaus als laag beschouwd.

The effort, value and landings by the Dutch, UK, Danish, German, Belgian, Swedish and French fishing seine fleets on the Dutch and German part of the Dogger Bank show low and irregular activity over the 2013-2019 period, driven mainly by fishing opportunities for plaice. The ban of pulse fishing is unlikely to lead to an increase of flyshoot vessels in the Dutch fleet given the financial, technical, regulatory and knowledge barriers to transition. Ecological impact of seines alone is complex to assess and while uncertain, the impact on relative benthic biomass is considered low at the past and current level of fishing.

Key words: Dogger Bank, seine fishery, Natura 2000, ecological impact, economic analysis

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Erratum for report 2020-105

04/12/2020

In the report 2020-105 on the economic importance and ecological impact of the seine fisheries on the Dutch and German management zones of the Dogger Bank, a number of errors were identified and corrected in this current version.

The numbering of the figures in chapter 3 was incorrect, with two figure 3.2. This has been corrected, together with the references to the figures in the text.

The values of the maximum percentage of decrease in relative benthic biomass in a grid cell due to the seine fishery were incorrectly transcribed in table 3.4.

Table 3.4 has been corrected and is now as follow:

Table 3.1 *Mean (standard deviation) and maximum percentage decrease in relative benthic biomass due to solely seine fisheries (%) over the period 2013-2019 for the different areas*

Country and area	Mean	Maximum
The Netherlands outside management zones	0.066 (0.052)	1.563
The Netherlands inside management zones	0.014 (0.010)	0.777
Germany outside management zones	0.041 (0.034)	0.945
Germany inside management zones	0.030 (0.035)	0.975

The introductory text of the tables in Appendix 2 has been completed for clarity and now reads:

"Benthos species by-catch (average numbers per hour) of Dutch fly-shoot fisheries (with different mesh sizes) in the North Sea, including the Dogger Bank in the period 2013-2016 compiled from Van der Reijden et al. (2014) and Verkempynck et al. (2016). Only the typical species for H1110 of the Dogger Bank (Dutch and German parts) are shown."

And

"Fish species by-catch (average numbers per hour) of Dutch fly-shoot fisheries (with different mesh sizes) in the North Sea, including the Dogger Bank in the period 2013-2016 compiled from Van der Reijden et al. (2014) and Verkempynck et al. (2016). Only the typical species for H1110 of the Dogger Bank (Dutch and German parts) are shown."

Contents

Summary

S.1 Uncertain ecological gains and limited socio-economic costs of closing the Dutch and German management zones

Dutch, UK, Danish, German, Belgian, Swedish and French fishing fleets show low and irregular demersal seine activity on the Dutch and German management zones of the Dogger Bank for the 2013-2019 period. Fishing activities are mainly driven by fishing opportunities for plaice.

The ban of pulse fishing is unlikely to lead to a substantial increase of flyshoot vessels in the Dutch fleet given the financial, technical, regulatory and knowledge barriers to transition.

The ecological impact of the demersal seine fishery alone on the benthic system is complex to assess. Despite the resulting uncertainty in outcomes, the impact on relative benthic biomass is considered low at the past and current level of fishing.

S.2 Complementary results

Over the study period, only the Dutch, Belgian, UK and Danish fleets have had activities by seines in the Dutch and German management zones. French German and Swedish fleets have recorded no activities for the seven-year study period.

While most fleets target plaice, the Dutch seiners target a mix of other species including mackerel, surmullet and cod.

The modelled ecological impact is less reliable for large epifauna, megafauna and deep burrowing species.

For both the Dutch and German part of the Dogger Bank, the typical invertebrate species are better covered than the typical fish species in the analysis.

S.3 Method

The Dutch Ministry of Agriculture, Nature and Food Quality has asked Wageningen Research to investigate the current status of seine fisheries on the management zones of the Dutch and German part of the Dogger Bank. An update of the data and analysis on the economic importance of the seine fishing activities of the Dutch, British, Danish, German, Belgian, Swedish and French fishing fleets on the Dutch and German management zones on the Dogger Bank has been prepared and broadened to include the results of the ecological impact assessment of the seine fleets. This report uses the method presented in Chapter 5 of *Effects of seabed protection on the Frisian Front and Central Oyster Grounds* (Oostenbrugge et al., 2015) for the economic analysis as well as the state-of-the-art method developed in the European FP7 project BENTHIS by Rijnsdorp and colleagues (2015) to assess the ecological impact of the seine fleets on the benthic community on the seabed.

Samenvatting

S.1 Onzekere ecologische voordelen en beperkte sociaaleconomische kosten van sluiting van de Nederlandse en Duitse managementzones

Nederlandse, Britse, Deense, Duitse, Belgische, Zweedse en Franse vissersvloten vertonen lage en onregelmatige zegenactiviteit in de Nederlandse en Duitse beheerzones van de Doggersbank voor de periode 2013-2019. De visserijactiviteiten zijn voornamelijk gedreven door vangstmogelijkheden voor schol.

Het verbod op visserij met puls zal waarschijnlijk niet leiden tot een substantiële toename van het aantal flyshoot-schepen in de Nederlandse vloot, gezien de financiële, technische, regelgevende en kennisbarrières voor transitie.

De bijdrage van de zegenvisserij aan de ecologische impact van de visserij moeilijk te bepalen. Ondanks de resulterende onzekerheid in de uitkomsten, wordt het effect van de zegenvisserij op de relatieve biomassa van de bodemdierengemeenschap van vroegere en huidige visserijniveaus als laag beschouwd.

S.2 Aanvullende resultaten

Tijdens de onderzoeksperiode hadden alleen de Nederlandse, Belgische, Britse en Deense vloten zegenvisserijactiviteiten in de Nederlandse en Duitse beheerzones. De Franse, Duitse en Zweedse vloten hadden geen activiteiten geregistreerd gedurende de onderzoeksperiode van zeven jaar.

Terwijl de meeste vloten op schol vissen, vissen de Nederlandse zegenvissers op een mix van andere soorten o.a. makreel, mul en cod.

De gemodelleerde ecologische impact is minder betrouwbaar voor grote epifauna, megafauna en diepgravende soorten.

Voor zowel het Nederlandse als het Duitse deel van de Doggersbank zijn de typische ongewervelde soorten beter gedekt dan de typische vissoorten.

S.3 Methode

Het ministerie van Landbouw, Natuur en Voedselkwaliteit heeft Wageningen Research gevraagd om de huidige stand van zaken van de zegenvisserij in de managementzones van het Nederlandse en Duitse deel van de Doggersbank te onderzoeken. Een update van de gegevens en analyse over het economische belang van de zegenvisserijactiviteiten van de Nederlandse, Britse, Deense, Duitse, Belgische, Zweedse en Franse vissersvloten in de Nederlandse en Duitse managementzones op de Doggersbank is opgesteld en uitgebreid met de resultaten van de ecologische effectbeoordeling van de zegenvloten. In dit rapport wordt voor de economische analyse de methode gebruikt die is gepresenteerd in Hoofdstuk 5 van Effecten van bodembescherming op het Friese Front en de Centrale Oestergronden (Oostenbrugge et al., 2015) en ook de in het Europese FP7-project BENTHIS door Rijnsdorp en collega's (2015) ontwikkelde methode om de ecologische effecten van de zegenvisserij op de bodemdierengemeenschap van de zeebodem te beoordelen.

1 Introduction

1.1 Towards a ban of seines on the Dutch and German management zones of the Dogger Bank

Seines still allowed in most management zones
The Dogger Bank is a shallow area that extends across the UK, Dutch, German and Danish sectors of the North Sea. The UK, Dutch and German sectors are designated as Natura 2000 sites, for the protection of habitat type 1110: 'Sandbanks which are slightly covered by sea water all the time'. To protect H1110, the governments of Germany, the Netherlands and the United Kingdom initiated a joint recommendation on fisheries regulation (Germany - The Netherlands - United, 2016), proposing a zoning system on the Dogger Bank Site of Community Interest (SCI). The following was recommended (Germany - The Netherlands - United, 2016):

- Management zones: closed areas for beam trawl, bottom/otter trawl, dredges and semi-pelagic trawls.[1] The proposed management zones cover approximately one third of the combined SCI (Figure 1.1).
- Open zones: open to not otherwise prohibited gear types.

It was questioned during stakeholder consultations whether the seine fishery could be allowed to fish in some of the protected areas in the Dutch North Sea because the impact on the seabed and benthic ecosystem was considered to be negligible. Seines are therefore allowed on most of the Dogger Bank including Dutch and British management zones.

Conservation threatened if seines allowed according to NGOs and STECF
On 24 June 2019, NGOs made a formal complaint to the Commission regarding failure to comply with Article 6(1), 6(2) and 6 (3) of Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna - the Habitats Directive - in relation to the fisheries management measures for the Dutch and UK Special Areas of Conservation (SACs) in the Dogger Bank in the North Sea (WWF and other NGO's, 2019a; b). In 2019 the Scientific, Technical and Economic Committee for Fisheries (STECF) reported on their review of the Joint Recommendation by Germany, the Netherlands and the United Kingdom regarding fisheries management measures under articles 11 and 18 of Regulation (EU) No. 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy (the Basic Regulation) for protection of sandbanks at three Natura 2000 sites designated under the Habitats Directive 92/43 EEC of 21 May 1992 (Dogger Bank) (STECF, 2019b). The following is reported (STECF, 2019b):

> 'STECF notes that fishing with seines will be allowed in almost the whole Dogger bank (>90% area), and without any fishing effort limits. STECF considers that the impact of seines (both Scottish and Danish seines) on sandy bottoms are likely to be low, since the maximum penetration depth is <2cm (Eigaard et al., 2016). However, seines might nevertheless have an impact on benthic epifauna, in particular on suspension feeders. STECF considers that there is currently not enough information to determine the impact of seines on the Dogger Bank sandbank habitat and typical species associated with this habitat. Consequently, it is not possible to conclusively determine whether the continued operation of seines will impede the achievement of the conservation objectives in the managed zones.'

[1] The German Management Zone will also be closed to demersal seines to allow analysis of the impact of such fishing gear as part of a specific monitoring programme and by a targeted experiment (Germany - The Netherlands - United Kingdom 2016).

The Dutch and German management zones to be closed for seines
In the North Sea agreement (OFL, 2020), the Dutch government proposes a ban for seines in the management zones in the Dutch part of the Dogger Bank. In addition, it is also expected that the German Management Zone will also be closed for three years to demersal seines. For those bans to come into effect, an analysis of the socio-economic impact of a closure on the fishing sector as well as an ecological assessment of the impact of seine fishing are required.

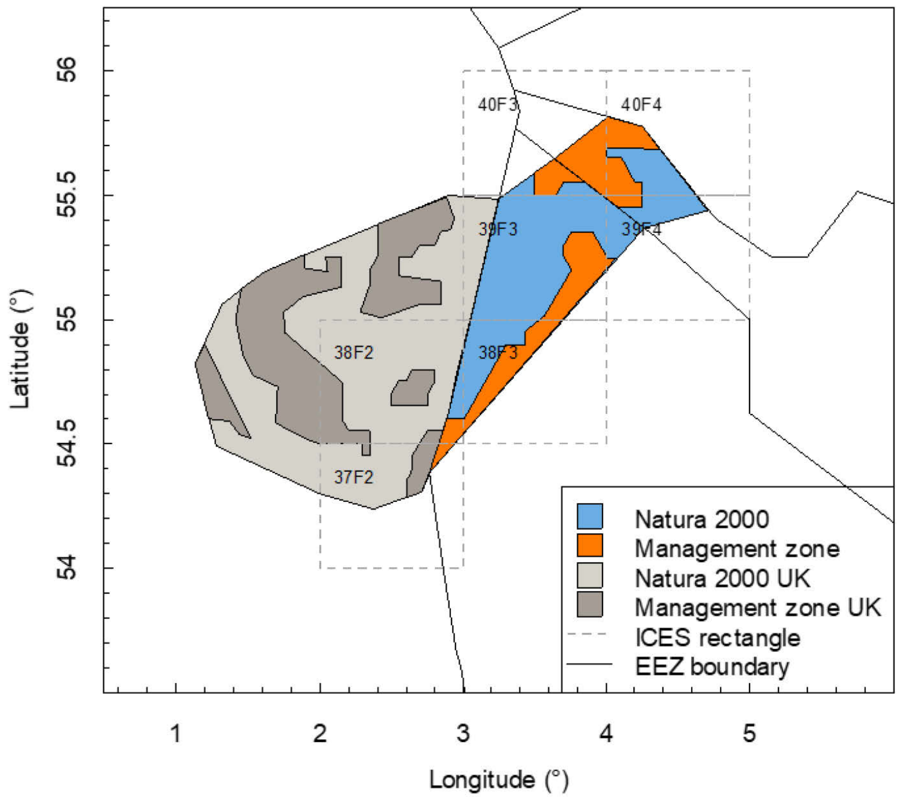

Figure 1.1 *Dogger Bank Natura 2000 areas, management zones and ICES rectangles overlapping with the German and Dutch areas*

What are the gains and costs to closing the management zones of the Dogger Bank for seines?
The ambition in the 'Noordzeeakkoord' (Ministerie van Infrastructuur en Waterstaat, 2020; OFL, 2020) to protect the Dutch management zone of the Dogger Bank (OLF, 2020) motivates this study. The new proposal to ban demersal seines together with the other bottom contact gear (Ministerie van Infrastructuur en Waterstaat, 2020; OFL, 2020) means that both Dutch and German management zones would include a ban on demersal seines. To understand the level of seine activity on the Dutch and German management zones of the Dogger Bank (hereafter named 'management zones'), Wageningen Research was tasked to update the previous overview of the fishing activity on the Dogger Bank (Hamon et al., 2017) and to estimate the past and current ecological impact of the seine activity. The potential impact was assessed in 2015 by Rijnsdorp and colleagues (Rijnsdorp, 2015; Rijnsdorp et al., 2015) and, more recent, in specific for the Dogger Bank in 2017 by (Bureau Waardenburg, 2017). This study includes an updated impact assessment, supplemented by a literature review. In addition, the potential development of the seine fishery in the Netherlands after the ban on pulse fishing is qualitatively assessed in order to evaluate potential developments in seining effort. Those methods will be used to assess the ecological gains and socio-economic costs of closing the management zones to seines.

1.2 Seine fishing in the North Sea

A seine is a fishing net that hangs vertically in the water with its bottom edge held down by weights and its top edge buoyed by floats. A demersal seine has long towing ropes extending from the wings of the seine, that herds the fish into the path of the seine (Figure 1.2). Two types of demersal seines are used in the North Sea, the Danish seine (SDN) and the Scottish seine (also called flyshoot, SSC). When a Danish seine approaches the fishing location, the process begins by dropping an anchor. Attached to the anchor is a set of marker buoys and one end of the first lead-filled seine rope, which is subsequently laid out. The seine net is attached to the other end of the first rope, so next, the seine net is set. After setting, the second rope is laid out and the vessel returns to the anchor buoys, picks up the first end of the first rope and begins hauling the seine ropes, herding fish into the path of the approaching seine net, while the area enclosed by the seine ropes gradually shrinks (Noack et al., 2019). Scottish fishermen start to fish without anchoring, making it possible to move the vessel forward during hauling and thereby including a towing phase. This technique is known as Scottish seining. Scottish seining can be regarded a hybrid between anchor seining and demersal otter trawling (Eigaard et al., 2016). Scottish seining is often conducted by larger vessels using larger gear (i.e., larger seine nets and thicker seine ropes), in comparison to Danish seining (Noack et al., 2019). A picture of the conceptual footprint of the gear and ropes of both seine types can be found in Appendix 1.

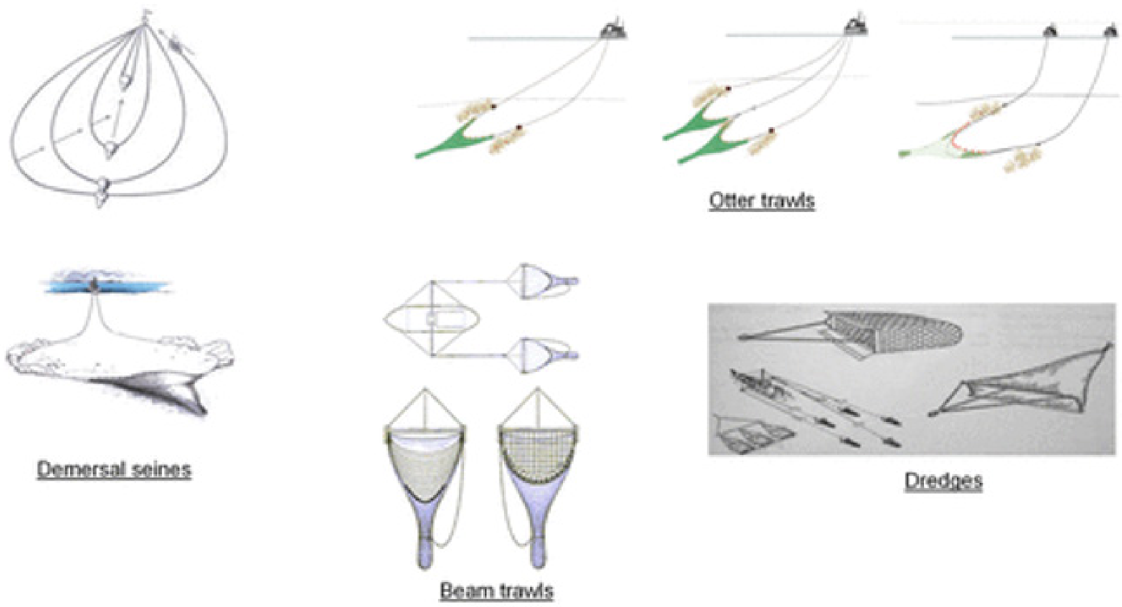

Figure 1.2 *Towing principles of the four main high-impact demersal gear groups identified: demersal seines (DSs, left), otter trawls (OTs, top right), dredges (DRBs, bottom right), and beam trawls (TBBs, centre, bottom)*
Source: Eigaard et al. (2016).

2 Methodology to assess the economic importance and ecological impact of seine fisheries

To analyse the economic importance of the seine fisheries on the Dutch and German management zones of the Dogger Bank and their ecological impact, we used a combination of quantitative and qualitative methods. Quantitative methods are used to assess the historical fishing activities on the various parts of the Dogger Bank and their economic importance and ecological impact. The fishing activity analysis is done following standard methods used in previous reports using logbook and Vessel Monitoring System (VMS) (Rijnsdorp et al., 2015; Hamon et al., 2017). The ecological impact is quantitively assessed by estimation of the overall biomass decrease due to the seine fishing activities and the number of vulnerable species. The qualitative methods include using expert knowledge to assess future development of the Dutch flyshoot fishery and literature review of the ecological impacts of seines.

2.1 Standardized processing fishing activity data

2.1.1 Data sources

Several data sources are used in this study: Vessel Monitoring System (VMS) data, catch data from logbooks (Fish Registration and Information System), and data on economic performance of all fleets that are obtained from the database of the Annual Economic Report of the EU fishing fleets (STECF, 2019a).

2.1.2 Pre-processing

The data of the above-mentioned sources are analysed in a standardised manner, where a script is developed that describes the processing and analysis of the data sets and can be applied by any nation that has similar VMS and logbook data in a standardised format.

Wageningen Research provided two scripts to collect data from the different countries. The same standardised script is applied to Dutch, Danish, German, Belgian, Swedish and British data. France uses their own software to process the data but follows similar steps as outlined by Wageningen University & Research. The scripts estimate effort, total landings, landings of the main fish species, total value of landings and the number of active vessels in the area of interest based on VMS and logbook data for the years 2013 to 2019, processed to remove erroneous fields.

The same method (and script) is used for all countries involved in this study because all of them use the same type of data, except for France (see Hintzen et al. 2012 for a description of the data format). The pre-processing of the dataset for the data follows the approach developed in Hintzen et al. (2013).

VMS records are removed when they are:
- Duplicates or pseudo-duplicates
- Not positioned on the globe
- Located in a harbour
- Located on land
- Associated with vessel speeds >20 knots.

Logbook records are removed when they:
- Are duplicates
- Have arrival times before departure times

- Start before the 1st of January of the year considered (despite the fact that the end of the trip falls
- within the considered year)
- Overlap with other trips.

2.1.3 Combine VMS and logbook data

Link VMS and log-book
To further analyse the data, the spatial resolution in the VMS data must be linked to the catch and effort data in the logbooks. Therefore, the VMS and logbook data in the ICES rectangles of interest are selected. All ICES rectangles overlapping with the Dogger Bank area are selected (see Figure 1.1). Because the focus of this study is solely on the seine fisheries on the Dogger Bank, we selected only those gear types (SSC and SDN).

VMS and logbook datasets are linked using the vessel identifier and date-time stamp. In other words, records (also called pings) in the VMS dataset that fall within the departure-arrival timeframe of a trip described in the logbook are assigned to the unique trip number from the logbook record and allow for an analysis of the two datasets simultaneously.

Define fishing activity
For each gear type, the activity of the vessel (floating, fishing or steaming) is defined based on the instantaneous speed in VMS records (Poos et al., 2013). For each ping, the state of the vessel is identified based on gear and speed. The speed thresholds are defined by each country for their own fleets based on the best available knowledge.

Assign effort and landings to pings
Each VMS ping represents a certain amount of time, usually equal to the interval rate at which VMS pings are emitted, ranging from 30 minutes to 2 hours. The fishing effort is defined as the sum of these time steps for those pings where the previous analysis indicated a 'fishing' state. The landings are recorded by trip, per ICES rectangle and day in the logbook. For this analysis, we retained the demersal seine landings of the top 10 species (in volume) and the total landings per year and per country for the ICES rectangles and gears of interest. For each trip that could be linked to VMS data, the landings and the days at sea, as registered in the logbooks, are allocated to the VMS pings in a stepwise process:
- If a match in trip, ICES rectangle, and fishing day is found, the registered landings are assigned to the VMS pings, weighted by the average time each VMS ping represents (ranging from 30 minutes to 2 hours).
- If within a matched trip, the fishing day and/or ICES rectangle cannot be matched, landings are assigned to the VMS pings based on the rest of the fishing trip.
- If no link to VMS points could be found for a trip (e.g. small vessels that do not carry VMS transducers on board), the total days at sea and landings in the adjacent ICES rectangle are aggregated.

2.1.4 Define pings in the areas of interest

The coordinates of each VMS ping are compared to the location of the ICES rectangles in the area of interest, the Dutch and German part of the Natura 2000 designated area of the Dogger Bank and the Dutch and German management zones (i.e. proposed closed areas) on the Dogger Bank (see Figure 1.1). When a VMS ping is located inside any of the areas, it is selected and assigned to the area of interest.

2.1.5 Uncertainty in the analyses

In the analyses a number of assumptions have to be made related to fishing activity, subsurface swept area and linking catches to VMS pings. Each country participating to this study uses the assumptions that best fit their data based on their local expertise and international consultation. Although these assumptions have been tested thoroughly, consultations with fishermen to verify our assumptions and international consultations on these methods have taken place, the final result remains an estimation and changes in assumptions will likely affect the numeric values presented in the results (Oostenbrugge et al., 2010). It is anticipated however that these differences do not alter the conclusions.

2.2 Defining the ecological impact of seine fishing on the Dogger Bank

2.2.1 Literature study

The literature search conducted for this study has taken the studies of Rijnsdorp (2015); Rijnsdorp et al. (2015); Bureau Waardenburg (2017), as a basis. Up to 28 November 2016, no peer-reviewed scientific publications were found describing the ecological impact of demersal seine fisheries on benthic ecosystems in the North Sea or nearby seas on the basis of field experiments (Bureau Waardenburg, 2017). A few studies were found, which reported direct field observations of the catching rate of commercial species and by-catch by demersal seine (Bureau Waardenburg, 2017).

The information from these three main studies was updated with recent findings (2017-2020) in scientific literature. Literature search was conducted using the search engines Scopus (peer-reviewed literature) and Google scholar (including non-peer reviewed literature). Keywords used were: flyshoot, Scottish seine, Danish seine, fisheries, fishing, trawling, benthic, benthos, seabed, seafloor, impact, effect.

2.2.2 Impact assessment

The impact of seine fishery in the Dogger Bank area on the benthic biomass is assessed using a method developed within the BENTHIS-project and described in (Rijnsdorp et al., 2018). In this method a statistical model (a GLM with binomial response implemented in R) is parameterised that predicts the longevity composition of the benthic biomass (= biomass in each of four longevity classes as a proportion of the total biomass) of benthic habitats and trawling intensity. The four longevity classes that are defined are: less than one year, between one and three years, between three and ten years and over ten years. It is assumed that the benthic community has been stable (no introduction or extinction) during the study period and that changes in the longevity composition are due to a number of co-variates, i.e. fishing effort and several environmental variables such as mud content. The modelled parameters were used to model the longevity distribution at different habitats and fishing effort.

This information is used to calculate the 'Relative Benthic Status' (RBS) that represents the benthic biomass relative to its carrying capacity (Hiddink et al., 2017; Pitcher et al., 2017). This is the estimated biomass of the benthic community (B) as a fraction of the maximum potential biomass of the community when no trawling takes place (K). The RBS is then calculated as B/K, and varies between 0 and 1. Low values indicate a low state of the benthic community compared to when no fishing would take place. In other words, a low RBS indicates that the benthic community is highly impacted by fishing. In the RBS function the fishing effort is multiplied with a depletion rate (fraction of benthic biomass lost due to mortality). The depletion rate of flyshoot fisheries is taken from (Rijnsdorp et al., 2020)with a depletion rate of Danish seines (0.009) that is lower than that of Scottish seines (0.016). As the depletion rate of Danish seines is estimated based on otter trawl gears we used the depletion rate for SSC for both SSC and DSN in this study. As a consequence calculated impact represents a somewhat worst case scenario in this respect. Besides the trawling frequency and the depletion value, also the recovery rate of the benthos is taken into account, for the calculation of the longevity-biomass composition of the benthic community in equilibrium *with* fishing effort. The recovery rate is depending on longevity (Hiddink et al., 2019). Long lived species will recover much more slowly than short lived species. For visual purpose, relative benthic biomass values are rescaled between 0 and 100% in this report.

The following datasets were used to parameterise the longevity composition of the benthic biomass. The longevity biomass composition of the benthic community is estimated using both box-cores and grab samples of three datasets (Bolam et al., 2014; Denderen et al., 2014; Van Denderen et al., 2015), as described in Rijnsdorp et al. (2018). The information that links benthic species to a longevity class comes from a database described in Bolam et al. (2014) and is available online. The trawling intensity, as the average annual swept area ratio (sum of the swept area of the trawling activities over the surface area of the grid cell), is calculated for each grid cell for all bottom trawl metiers[2] in the period 2010–2012 (Eigaard et al., 2016), as described in Rijnsdorp et al. (2018) as well. Not all habitat data that Rijnsdorp has used in his 2018 paper was publicly available. Therefore, all habitat information that is used in this study comes from Wilson et al. (2018). The habitat data that is used to parameterize the models consist, next to the tidal- and orbital velocity, of percent mud- and percent gravel content. Model fitting procedure, similar to Rijnsdorp et al. (2018), was applied to the dataset available here. The model, a GLM with binomial response implemented in R, tests which co-variates have most explanatory power on the longevity composition. The number of co-variates and interactions among them to include, were tested using the BIC criteria and check whether the model was able to converge.

Once parameterized, the effect of flyshoot fisheries can be calculated using the Relative Benthic Sate (RBS) function that makes use of the model outcome described above. By taking the parameters of the model and the habitat data, we calculated the potential biomass of the benthic community for each grid cell in the in the case of no seining (i.e. the K parameter in RBS = B/K). The calculation of the longevity-biomass composition of the benthic community *with* fishing effort (i.e. the B parameter in RBS = B/K) takes besides the trawling frequency and the depletion value also the recovery rate of the benthos into account, as described above.

A grid is constructed that covers the complete Dogger Bank area of the Economic Exclusive Zones of both The Netherlands and Germany. The spatial grid used here consists of cells of 0.05 degree longitude by 0.025 degrees latitude resulting in an average grid cell area of 9 km^2. All calculations were done at the level of these grid cells. Then a calculation of the subsurface Swept Area Ratios (SAR) is undertaken. SAR is calculated as the total amount of subsurface trawled per year (in km^2) divided by the surface area of a specific area (e.g. grid cell). SAR was calculated by combining Vessel Monitoring by Satellite (VMS) data and mandatory logbooks from the VISSTAT database. VMS data contain information on vessel speed and vessel position, whereas the vessel logbooks provide information on gear, vessel length and power (Hintzen et al., 2012). Speed profiles were used to distinguish speeds into steaming, fishing and floating (Poos et al., 2013). Surface and subsurface swept area were calculated following Eigaard et al. (2016) Subsurface swept area is a gear specific proportion of the surface swept area. VMS and logbook data from 2013 to 2019 were extracted. The bottom trawling gears Scottish- and Danish seines (SSC & SDN) were selected to represent the flyshoot fleet. For the calculation of the subsurface swept area (as a ratio of the surface swept area) a ratio of 0.14 were used for SSC and 0.05 for SDN gear type which is the setting for these gears in general R-scripts for calculation of fishing effort and available within WMR.

The countries Germany, Belgium, France, Denmark, Sweden and United Kingdom were asked for their flyshoot fishing effort as well. The calculations of the foreign flyshoot effort followed the same procedures and effort of all countries was summed (per grid cell and year). Using the habitat and fishing effort data the Relative Benthic State was calculated for each year and grid cell. Grid cells inside and outside the management zones of the Dutch and German Dogger Bank area were identified and grid cell means and maxima were calculated for each year and subarea and for the Economic Exclusive Zone of both The Netherlands and Germany.

[2] Metier: a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterised by a similar exploitation pattern (Commission Decision 2008/949/EC).

2.3 Defining the socio-economic importance of the Dogger Bank

2.3.1 Economic value

For each country, the effort, total landings, landings for the main species, value of landings and number of individual vessels active at the ping level is hereafter aggregated by year, subarea, gear type and vessel length category. The logbook records not linked to VMS data are also aggregated by year, ICES rectangle, gear type and vessel length category. The logbook data in the ICES rectangles of interest that were not linked to VMS data are used to estimate the coverage of VMS data and included in the data shown at the ICES rectangle level.

Vessel length is used to link the data to STECF economic data and estimate the gross value added (GVA). The value of landings data was combined with economic information from the database of the Annual Economic Report of 2019 (STECF, 2019a). In this database, revenue and costs are available per fleet.

The GVA generated in the Dogger Bank by each gear (g), vessel length category (l), country (c) and year (y) ($DBGVA_{g,l,c,y}$) was estimated using the value of landings in the Dogger Bank for the gear, vessel length category, country and year, $DBvalue_{g,l,c,y}$, obtained from the VMS and logbook analyses and the GVA per euro landed for each fleet of the same vessel length category using the gear (see Appendix 2):

$$DBGVA_{g,l,c,y} = DBvalue_{g,l,c,y} \cdot \frac{\sum_f GVA_{f,c,y}}{\sum_f value_{f,c,y}} \frac{\sum_f GVA_{f,c,y}}{\sum_f value_{f,c,y}} \qquad \forall fleets\ f \text{ with vessel length } l \text{ using gear } g$$

Because STECF 2019 data only covers economic data until 2017, 2018 and 2019 GVA values are calculated based on the GVA and fleet values of 2017. The GVA calculation is done as follow:

$$GVA_{f,c,y} = \left(value_{f,c,y} + rightIncome_{f,c,y} + otherIncome_{f,c,y}\right) - (EnergyCost_{f,c,y} + rightCost_{f,c,y} + VariableCost_{f,c,y} + RepairCost_{f,c,y} + FixedCost_{f,c,y})$$

Where *rightIncome* and *rightCost* represent the income and costs to lease quota out or in, *otherIncome* are all the other income sources apart from value of landings and right income. In addition to right costs, energy costs (*EnergyCost*), repair costs *(RepairCost*), other variable costs (*VariableCost*) and fixed costs (*FixedCost*) are also considered in the calculation of the GVA.

2.3.2 Individual dependency of Dutch vessels to the management zones

It is possible to go beyond the fleet indicators and to look at the dependency of vessels on areas to be closed. This analysis can be useful for areas that are not so important at the fleet level but where a couple of fishers fish intensively. Reallocation of effort to new fishing grounds becomes more complicated when a large part of the known fishing grounds of a fisher is closed. It is therefore important to identify whether an area closure will potentially substantially impact individuals.

At the vessel level[3] we look at the estimated proportion of revenue coming from the management zones. The ratio of the value of landings from the management zones over the total value of landings for fisher *i* is called 'individual stress-level' and is calculated per year, *y*.

$$ISL_{i,y} = \frac{DBvalue_{i,y}}{Totvalue_{i,y}}$$

[3] Given the data availability we make the assumption that a vessel represents one skipper.

Because this analysis requires access to individual vessel data, it was only performed for the Dutch fishery. As for the other countries, owing to confidentiality issues, only fleet-aggregated data were made available.

2.3.3 Relative importance of the proposed closed areas compared to the Dogger Bank

To evaluate the relative importance of the Dutch and German management zones on the Dogger Bank, we defined fishing activity in the proposed closed areas and on the total Dogger Bank separately (Figure 1.1). We present the results as percentage of the total Dogger Bank area.

2.3.4 Potential transition from pulse to flyshoot for the Dutch fleet

From 2021 onward, the pulse fishing technique will be banned from EU waters and the last 21 active licences for the Dutch fishery will also be revoked. What those fishers will choose to do is still unknown and concern was raised that those fishers could shift to flyshoot. The potential for transition from the banned pulse fishing technique was assessed qualitatively with fisheries experts taking into account the current practice of flyshoot fishers, the technical possibilities and their economic performances.

3 Results

3.1 Impact of seine fishing on seabed habitats

Seabed habitats are impacted by vessels fishing with mobile towed gears with a magnitude depending on the sensitivity of the seabed and the intensity of fishing pressure (Collie et al., 2000; Kaiser et al., 2006).

3.1.1 Intensity of fishing pressure

There are significant differences in the fishing gears deployed by commercial vessels, and in the corresponding nature of their physical contact with the seabed. Gear footprints4 of the most common gear types, including seines (Figure 1.2 and Figure 5.1), have been defined by Eigaard et al. (2016). Because of limited empirical data, the assumption was made that, for both Danish and Scottish seine fishing operations, the ground gear path constitutes 10% of the overall seine footprint and the seine ropes the remaining 90%. This theoretical estimate of 10% from Eigaard et al. (2016) might be an overestimation for the area swept by the Danish seine, based on the lower empirical estimates (~1% groundgear path) by Noack et al. (2019). However, no empirical studies have been conducted on how the seines affect sea bed and benthic organisms (Rijnsdorp, 2015; Rijnsdorp et al., 2015; Bureau Waardenburg, 2017; Rijnsdorp et al., 2020). As empirical data is lacking, the impact of seine fishery has been assessed relative to other bottom trawl gear by Rijnsdorp and colleagues (Rijnsdorp, 2015; Rijnsdorp et al., 2015; Rijnsdorp et al., 2020). The intensity of the fishing pressure varies per gear type. In general, the physical impact of fishing gear scales with the mass of the gear component and the towing speed. Therefore Rijnsdorp et al. (2015) have based their assessment of the impact of flyshoot fishery on the inferred impact based on the dimension (swept area per hour fishing of the surface and sub-surface, weight of the gear components, towing speed) of the fishing gear relative to other bottom trawl gear.

The trawling intensity is estimated as the average annual swept area ratio (sum of the swept area of the trawling activities over the surface area of the grid cell) of the corresponding grid cell for all or specific bottom trawl metiers in a certain period (Rijnsdorp et al., 2018). Because the mortality imposed by trawling increases with the penetration depth of the gear (Hiddink et al., 2017), trawling intensity is estimated for the full width of the gears (surface intensity), and for the area swept by the gear components that penetrate >2 cm into the sediment (subsurface intensity).

Intensity of the flyshoot in relation to other gear types
Flyshooters use heavier and thicker sweeps, fish a larger surface (i.e. the largest of all bottom contact gear, see Figure 3.1b) and haul the gear quicker compared to the traditional seiners (Polet and Depestele, 2010). More in specific the following is known:

- Surface footprint
  The footprint per hour fishing (Figure 3.1b) of the Scottish seine (1.6 $km^2.hr^{-1}$) is relatively large as compared to other bottom trawl gears (Danish seine - 1.0 $km^2.hr^{-1}$; otter trawl (0.3 – 1.2 $km^2.hr^{-1}$) or beam trawl (0.20 $km^2.hr^{-1}$). This footprint constitutes mainly of surface contact (Rijnsdorp et al., 2015; Eigaard et al., 2016).
- Sub-surface footprint
  The sub-surface footprint of the Scottish seine (0.1 $km^2.hr^{-1}$ (Rijnsdorp et al., 2015)) is relatively low (Eigaard et al. (2016), Figure 3.1), e.g. lower than that of the otter trawl fishery for Nephrops (0.3 $km^2.hr^{-1}$) or the beam trawl fishery for flatfish (0.2 $km^2.hr^{-1}$(Rijnsdorp et al., 2015)). However, the subsurface footprint of Scottish seining is larger than that of Danish seining ((Eigaard et al.,

[4] A gear footprint is defined by its measures of overall size (e.g. door spread for OTs, which equals the total width of this gear type and a decomposition of this overall footprint size into relative footprint contributions from the individual gear components (e.g. the doors, sweeps, and bridles of an OT) (Eigaard et al. 2016).

2016), Figure 3.1). For Scottish seine, a subsurface ratio (the proportion of the gear footprint where gear components penetrate the seafloor by 2 cm) of 0.050 was estimated ((Eigaard et al., 2016), Figure 3.1a; (Rijnsdorp et al., 2020), Table 3.1).

- Towing speed
  The towing speed is lower than that of other bottom trawl gear (Rijnsdorp et al. 2015).
- Physical impact and re-suspension of sediments
  The physical impact of the flyshoot, as well as the re-suspension of sediments, will be lower than that of other bottom trawl gear because of the lower towing speed (Rijnsdorp et al., 2015).

To assess trawling impact by use of population dynamics (estimating the decrease in biomass in response to trawling and the recovery time), Rijnsdorp et al. (2020) used depletion rates (depletion of biota caused by each trawl pass, expressed as a proportion, see Table 3.1). Empirical estimates of depletion rates are not available for seines (Rijnsdorp et al., 2020). Therefore, the depletion rate of seines was estimated by Rijnsdorp et al. (2020), using the width of gear elements that penetrate into the seafloor relative to the total gear width.

Table 3.1 *Subsurface ratio (i.e. the proportion of the gear footprint where gear components penetrate the seafloor by 2 cm) and the depletion rate per main gear type and target species*

Main gear type	Target species	Subsurface ratio	Depletion rate
Dredge	Scallops	1.000	0.200
Otter trawl	Nephrops, Pandalus, mixed fish	0.304	0.100
Otter trawl	Cod or plaice	0.078	0.026
Otter trawl	Mixed fish	0.229	0.075
Otter trawl	Mixed bentho-pelagic fish	0.220	0.073
Otter trawl	Sprat or sandeel	0.028	0.009
Seine (Danish, anchor)	Plaice, cod	0.000	0.009[c]
Seine (Scottish, flyshoot)	Cod, haddock, flatfish	0.050	0.016
Beam trawl	Brown shrimp	0.522	0.060
Beam trawl	Flatfish	1.000	0.140

[C] Danish seine has been set equal to lowest depletion rate of any otter trawl fisheries

Source: Rijnsdorp et al. (2020).

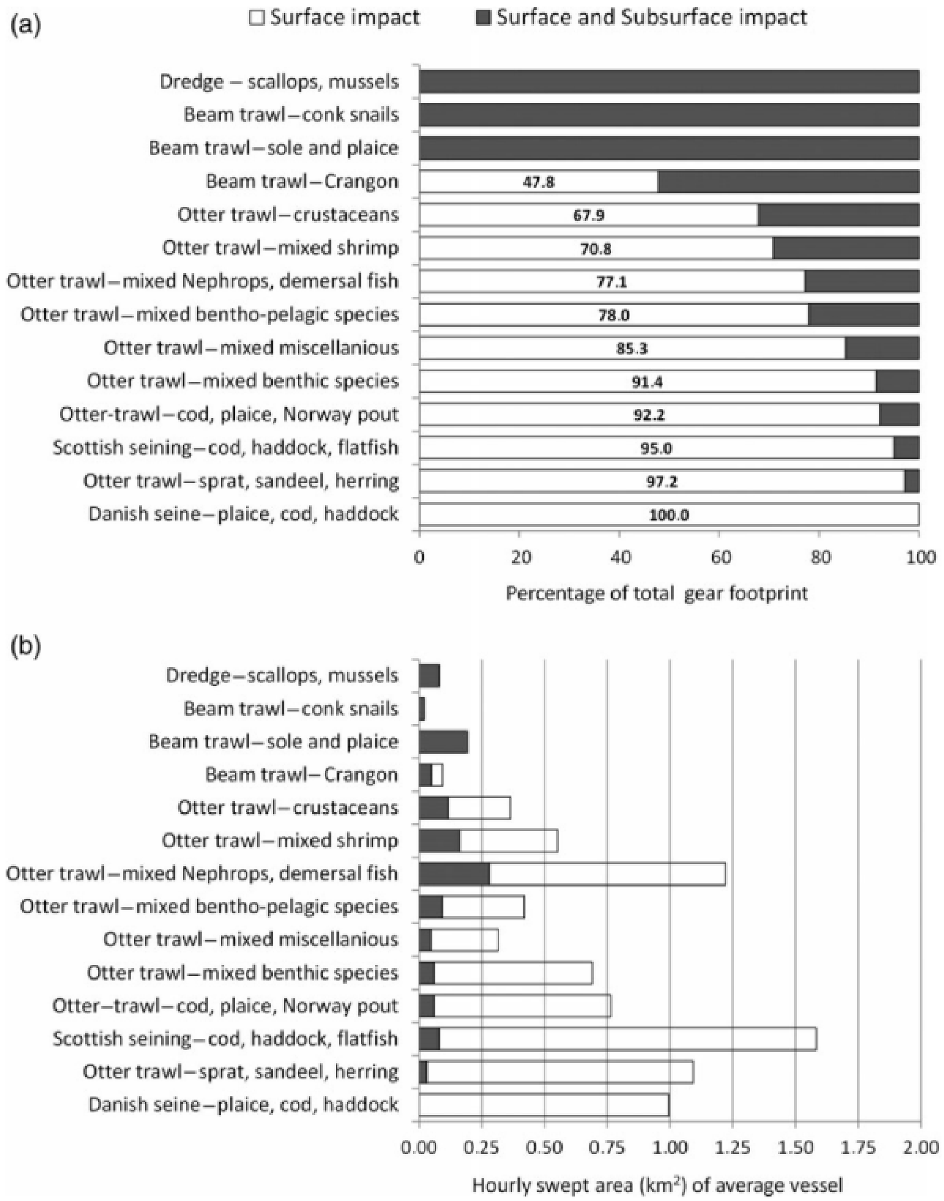

Figure 3.1 *Proportion of total gear footprint (a) and the area of seabed swept in 1 h of fishing with an average-sized vessel (b) with impact at the surface level and at both the surface and the subsurface level for the 14 BENTHIS métiers*
Source: Eigaard et al. (2016).

Seine catch and bycatch

Bureau Waardenburg (2017) describes the catch of commercial species and by-catch by flyshoot based on a few studies reporting direct field observations on fly-shoot fishery in the North Sea in 2013 including the Dogger Bank (van der Reijden et al., 2014; Verkempynck and van der Reijden, 2015; Verschueren, 2015). There are more recent field data for bycatch available: In a self-sampling programme of the Dutch seine fisheries in 2014-2016 it was found that flyshooters frequently discarded grey gurnard, whiting and horse mackerel. Almost no benthos was discarded (Verkempynck et al. 2018). A compilation of the fly-shoot fisheries bycatch of typical species for H1110 of the Dutch and German parts in the North Sea in the period 2013-2016 based on (van der Reijden et al., 2014) and (Verkempynck et al., 2018) is shown in Appendix 2. A catch of 26 fish species and 20 invertebrate species by Danish seine was reported for the Kattegat in sandy flatfish areas close to the coast and deeper whitefish grounds (Noack et al., 2017).

3.1.2 Sensitivity of habitats

As mentioned previously, besides the intensity of fishing pressure, the magnitude of trawling impact depends on the sensitivity of the seabed(Collie et al., 2000; Kaiser et al., 2006).

It is widely known that macrofaunal assemblages vary depending on the sediment type across the North Sea and a number of worm (e.g. Spintheridae, Aphroditae), mollusc (e.g. Llamellariidae), and echiurans were identified to be the most sensitive to trawling (Rijnsdorp et al., 2020 and references therein). Rijnsdorp et al. (2020) remark that these inherent differences in trawling sensitivities, combined with the habitat specificity of macrofaunal organisms, lead to the different indicator responses observed between mud and coarse sediments in their study. The method to assess the impact of bottom trawling on the benthic ecosystem developed within the BENTHIS project (Rijnsdorp et al., 2018; Rijnsdorp et al., 2020) assumes that benthic community sensitivity to bottom trawling is related to longevity composition. This method is also used for the underlying study of the impact of seine fishery on the Dogger Bank (see impact assessment in Section 2.2.2). The longevity composition is related to the sediment composition, bed shear stress, and trawling intensity. The bed shear stress reflects the level of natural disturbance. Habitats with a high level of natural disturbance are adapted to disturbance and relatively insensitive for bottom trawling. Therefore, the impact of bottom trawling will increase with a decrease in the level of natural disturbance (Rijnsdorp et al., 2015).

The occurrence of vulnerable structures and species also determines the impact of seine fishing. The impact of flyshoot fishing may be significant in sea bed habitats that are characterised by fragile physical or biogenic structures that take a long time to grow, such as gasseeps and biogenic habitats (Rijnsdorp et al., 2015). The impact will be lower for more robust long-lived taxa, or taxa that live in the seabed. Species may occur that are classified as being vulnerable for the passage of (flyshoot) fishing gear. The question whether the flyshoot fishery may have a significant impact on the sea bed and benthic ecosystem depends on the occurrence of these vulnerable structures and organisms (Rijnsdorp et al., 2015). For the underlying study, with the focus on the protected nature values of the Dogger Bank, the vulnerability is based on the conservation objectives of the Dogger Bank including the so-called typical species, see Section 3.2.1.

3.2 Ecological impact of the seine fisheries on the Dogger Bank

3.2.1 Sensitive nature values Dogger Bank

3.2.1.1 The Dogger Bank

The Dogger Bank is the largest sand bank in the North Sea (van Moorsel, 2011). A description of the species and habitats of the Dogger Bank is provided in the text box below.

Species and habitats of the international Dogger Bank (van Moorsel, 2011)

The shallow and flat top occupies a large proportion of the bank and experiences turbulent hydrodynamic conditions. The surrounding slopes offer a more stable environment. Clean sands dominate the Dogger Bank, but muddy and stony grounds are present as well. The combination of location and range of habitats of the wider Dogger Bank results in a centre of biodiversity. Due to the presence of fronts, the Dogger Bank is a year-round source of food for fish, birds as well as marine mammals up to the size of Minke whales.

The flat top of the Dogger Bank is dominated by small characteristic endobenthic species, well adapted to disturbances. Larger epibenthic species also occur in this part of the Bank, but these are ubiquitous in the southern North Sea. As such, the present community does not seem particularly vulnerable to fisheries with bottom gears. However, fisheries may have caused the disappearance of beds with high densities of bivalves. The slopes and deeper areas in the vicinity of the Dogger Bank harbour important natural values. Sandeel is especially abundant in sandy areas on the slopes. These fish are caught by industrial fisheries, but also serve as staple food for several (commercial) fishes, birds and marine mammals. Consequently, these species tend to concentrate on the borders of the Bank as well, for example the Harbour porpoise. Large and long-lived bivalves such as Flat oyster, Ocean quahog and Horse mussel have disappeared or are still present in low densities. Rays have also been known to concentrate near the Dogger Bank and the wider area is known as a spawning ground for several fish species.

3.2.1.2 Habitat protection

The conservation objectives of the habitat H1110 in the Natura 2000 areas on the Dogger Bank are described as: 'conservation of surface area and improvement of the quality of the sandbanks' (NL); 'restore the habitat to favorable condition' (UK) and 'restoration of a favorable conservation status of the habitat type (1110) including its typical and threatened communities and species' (GER). Within H1110, different subtypes are distinguished by the Netherlands, of which H1110C is specifically defined for the Dogger Bank. The specific characteristics of sand banks (habitat type H1110), including its quality, are defined as including so-called typical species and the 'presence of long-lived benthic species' (NL and GER; UK by implication) (Bureau Waardenburg, 2017).

Article 1 of the Habitats Directive (Council of the European Communities, 1992) states that the conservative status of a natural habitat will be taken as 'favourable' when:

- its natural range and areas it covers within that range are stable or increasing, and
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future, and
- the conservation status of its typical species is favourable.

  The conservation status of a species means the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations within the European territory of the Member States to which the Treaty applies(Council of the European Communities, 1992).

  The conservation status will be taken as 'favourable' when (Council of the European Communities, 1992):

  - population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
  - the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
  - there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

3.2.1.3 Sensitivity to seine fishery

To assess the ecological impact of seine fisheries on the Dogger Bank it is important to address all relevant species. Relevant species are the typical species of H1110, as mentioned above. In addition, threatened or endangered species reported as being vulnerable to seine fisheries are also considered relevant. The relevant species are addressed in more detail below.

Relevant species

For the Dogger Bank area in relation to the North Sea, the benthic community is characterised by a larger proportion of long lived and suspension feeding taxa. Among these groups, species occur that are classified as being vulnerable for the passage of flyshoot gear, such as sponges, soft corals and others (Rijnsdorp et al., 2015), see Table 3.2. Some of these have not been not listed as H1110 typical species. These include bryozoans (moss animals) *Alcyonidium diaphanum* and *Flustra foliacea*, sponges and bioengineers. Based on the list of epifauna species on and in marginal areas of the Dogger Bank (van Moorsel, 2011), four sponge species are relevant, of which *Halichondria (Halichondria) panicea* is most abundant, Bio-engineers of the North Sea are flat oyster, (*Ostrea edulis*), common mussel (*Mytilus edulis*), horse mussel (*Modiolus modiolus*), tube-building worms *Sabellaria* sp. and *Lanice conchilega*. Of these bio-engineers only *L. conchilega* is listed as typical species of H1110. In former times, horse mussels *Modiolus* formed reefs in the northern part and flat oysters (*Ostrea edulis*) in the southern part of the Dogger Bank (van Moorsel, 2011). These are not included in the conservation objectives and list of H1110 Dogger Bank typical species. (A)biotic reefs can serve as spawning areas for e.g. elasmobranchs (sharks and rays) and other fish species (Rijnsdorp et al., 2015; Bureau Waardenburg, 2017). Considering elasmobranchs, *Raja clavate* (thornback ray) is the only species reported for the Dogger Bank (van Moorsel, 2011). The sharks and rays were common on the Dogger Bank up to the beginning of the 20th century but are not listed as H1110 typical species in the Netherlands.

Sensitivity to seine fisheries

For each species an indication of the sensitivity to seine fisheries is included in the Table 3.2, as reported in literature. This can be related to vulnerability to gear passage and/or (by)catch. Many of the H1110 Dogger Bank typical species (Table 3.2) were caught by flyshoot fishery in the North Sea. These include six target species of fish (*Eutrigla gurnardus, Gadus morhua, Limanda limanda, Merlangius merlangus, Microstomus kitt, Pleuronectes platessa*) or by-catch (all other species, including one anthozoan species (*Alcyonium digitatum*), three crustaceans (*Corystes cassivelaunus, Pagurus bernhardus, Liocarcinus holsatus*), four species of echinoderm (*Asterias rubens, Ophiotrix fragilis, Ophiura ophiura, Psammechinus miliaris*), and four species of mollusc (*Acanthocardia echinata, Arctica islandica, Buccinum undatum, Neptunea antiqua*). Fly-shoot fisheries also caught rays in the North Sea: *Amblyraja radiata, Leucoraja naevus* and *Raja clavata*, and a shark species in the Channel (*Squalus acanthias*). At least five species that were caught are long-lived: *Alcyonium digitatum* (10-28 years), *Arctica islandica* (100+ years), *Pagurus bernhardus* (6-10 years), *Buccinum undatum* (11-20 years), *Neptunea antiqua* (21-100 years) (Bureau Waardenburg, 2017).

Coverage by impact assessment

The longevity–habitat relationships used in the impact assessment (see Section 3.2.2) are based on data obtained from box-core and grab samples and therefore reflect the macrobenthos community. These gear types do not effectively sample the larger epifauna and megafauna component of the seabed and therefore the biomass of deep burrowing species and larger epifaunal species will be under-estimated (Rijnsdorp et al., 2018). To support the clarification of this uncertainty in the impact assessment, for each species an indication of the degree of coverage by the current impact assessment is included in Table 3.2. This indication is based on expert judgement considering the suitability of the sampling technique and the species determination. It shows that the majority (80-84%) of the typical benthic species (either vulnerable or not for demersal seine fisheries) of the Dutch and German parts of the Dogger Bank is well covered. On the other hand, typical fish species are not covered, except for one species; the flatfish *Buglossidium luteum* (solenette). Good representation is expected for bristle worms, bivalves, brittle stars and snails and slugs. Anemones, corals, sea urchins, sponges, moss animals and starfish are moderately covered. The crustacean *Liocarcinus holsatus* (flying crab) is a mobile species that might be missed by the sampling. It is considered a highly indicative species for fishing disturbance (Wijnhoven and Bos, 2017) and is also a typical species of H1110. The species has been reported as bycatch and thus might be affected by flyshooting (Bureau Waardenburg, 2017).

Moss animals *Alcyonidium diaphanum* and *Flustra foliacea* are well sampled but might be missed by determination. These species are sensitive to seafloor abrasion, including flyshoots (Bureau Waardenburg, 2017). They are not listed as typical species. The soft coral *Alcyonium digitatum* (dead man's fingers) and the sea pen *Pennatula phosphorea* are also not well covered and might be affected by flyshoots trough seafloor abrasion and bycatch (Bureau Waardenburg, 2017). *A. digitatum* is a typical species of H1110. Starfish are not sufficiently covered due to the sampling technique, of which two species (*Astropecten irregularis* and *Luidia sarsii*) are typical species. The small (10-15 mm) sea urchin *Echinocyamus pusillus* might be missed by determination and is also a typical species. The sampling technique is not well suited for sponges. Sponge species found on the Dogger Bank are *Halichondria (Halichondria) panicea*, *Suberites ficus, Suberites virgultosus* and *Sycon ciliatum*. These species might be affected by seafloor abrasion and/or bycatch of flyshoots (Bureau Waardenburg, 2017). None of these are listed as typical species. Fish are not included in the impact assessment as the sampling technique is not suited for most of these species, except for *Buglossidium luteum*.

Table 3.2 *Species of the Dogger Bank, indicating the identification as typical species per country (NL: Netherlands; DE: Germany; UK: United Kingdom; BD: Background Document),[5] the sensitivity to demersal seining (bottom disturbance and (by)catch) as indicated in literature; and the degree of coverage by the current impact assessment based on expert judgement, addressing sampling method and determination: good (sampling method and determination is well suited for identification of species; moderate (species might be underrepresented due to suboptimal sampling and/or determination); not (species is not included in the impact assessment because of unsuited sampling method).*

Scientific Name	Typical Species	Sensitivity	Covered by impact assessment
Annelida			
Aphrodita aculeata	NL	Not vulnerable (Rijnsdorp et al., 2015)	Good
Goniada maculata	NL	Not reported	Good
Lanice conchilega	NL, UK, BD	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Magelona papillicornis	NL	Not reported	Good
Nephtys cirrosa	NL, UK, BD	Not vulnerable (Rijnsdorp et al., 2015)	Good
Nephtys hombergii	NL	Not reported	Good
Sigalion mathildae	NL, D	Not vulnerable (Rijnsdorp et al., 2015)	Good
Spiophanes bombyx	NL, D, BD	Not vulnerable (Rijnsdorp et al., 2015)	Good
Arthropoda			
Bathyporeia elegans	NL, D, BD	Not vulnerable (Rijnsdorp et al., 2015)	Good
Bathyporeia guilliamsoniana	NL, D, BD	Not vulnerable (Rijnsdorp et al., 2015)	Good
Corystes cassivelaunus	NL, UK	Sensitive (BuWa, 2017); robust (Jager et al., 2018); not vulnerable (Rijnsdorp et al., 2015)	Good
Liocarcinus holsatus	NL, UK	Sensitive (BuWa, 2017)	Moderate
Pagurus bernhardus	NL, UK	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Pagurus pubescens	D	Not reported	Good
Urothoe poseidonis	NL	Not vulnerable (Rijnsdorp et al., 2015)	Good
Bryozoa			
Alcyonidium diaphanum	UK, BD	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Moderate
Flustra foliacea	None	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Moderate
Chordata			
Ammodytes marinus	UK, BD	Not reported	Not
Arnoglossus laterna	NL, BD	Not reported	Not
Buglossidium luteum	NL, BD	Not reported	Good
Callionymus lyra	NL, UK, BD	Not reported	Not
Echiichthys vipera	D, BD	Not reported	Not
Eutrigla gurnardus	NL, UK, BD	(By)catch (BuWa, 2017)	Not
Gadus morhua *	NL, UK, BD	(By)catch (BuWa, 2017)	Not
Limanda limanda	NL, UK, BD	(By)catch (BuWa, 2017)	Not
Merlangius merlangus	NL, UK, BD	Not reported	Not
Microstomus kitt	NL, BD	(By)catch (BuWa, 2017)	Not
Pleuronectes platessa	NL, UK, BD	(By)catch (BuWa, 2017)	Not
Raja clavata *	D, BD	(By)catch (BuWa, 2017)	Not
Squalus acanthias *	None	(By)catch (BuWa, 2017)	Not
Cnidaria			
Alcyonium digitatum	NL, D, UK	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Moderate
Pennatula phosphorea	UK, BD	Not reported	Moderate

[5] Background Document to the draft Joint Recommendation for Offshore Fisheries Management on the International Dogger Bank under the revised Common Fisheries Policy (Germany - The Netherlands - United Kingdom 2016).

Scientific Name	Typical Species	Sensitivity	Covered by impact assessment
Echinodermata			
Acrocnida brachiata	NL, BD	Not vulnerable (Rijnsdorp et al., 2015)	Good
Amphiura filiformis	D, UK, BD	Not vulnerable (Rijnsdorp et al., 2015); Robust (Jager et al., 2018)	Good
Asterias rubens	UK	(By)catch (BuWa, 2017)	Moderate
Astropecten irregularis	NL, D, UK	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Moderate
Echinocyamus pusillus	NL, D	Not vulnerable (Rijnsdorp et al., 2015)	Moderate
Luidia sarsii	None	Not reported	Moderate
Ophiothrix fragilis	NL, D, UK, BD	Sensitive (BuWa, 2017)	Good
Ophiura ophiura	NL, UK	Not vulnerable (Rijnsdorp et al., 2015)	Good
Psammechinus miliaris	D, UK, BD	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Mollusca			
Acanthocardia echinata	D, BD	Sensitive (BuWa, 2017); intermediate sensitive (Jager et al., 2018); not vulnerable (Rijnsdorp et al., 2015)	Good
Aporrhais pespelecani	D, UK	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Arctica islandica	NL, D, BD	Sensitive (BuWa, 2017); vulnerable (Jager et al., 2018); not vulnerable (Rijnsdorp et al., 2015)	Good
Buccinum undatum	NL, D, BD	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Good
Ensis ensis	NL, D, UK	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Euspira nitida	NL, BD	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Gari fervensis	NL, D	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Kurtiella bidentata	NL, D, UK, BD	Not reported	Good
Mactra stultorum	BD	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Modiolus	None	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Good
Neptunea antiqua	NL, D, UK	Sensitive (BuWa, 2017)	Good
Ostrea edulis	None	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Good
Tellina fabula	NL, UK, BD	Sensitive (BuWa, 2017); not vulnerable (Rijnsdorp et al., 2015)	Good
Porifera			
Halichondria (Halichondria) panicea	None	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Moderate
Suberites ficus	None	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Moderate
Suberites virgultosus	None	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Moderate
Sycon ciliatum	None	Sensitive and vulnerable (BuWa, 2017; Rijnsdorp et al., 2015)	Moderate

3.2.2 Impact assessment

The model fitting procedure, described in Section 2.2.2, resulted in the following model predicting the benthic biomass by habitat parameters and trawling intensity (including seine fisheries):

Cumulative biomass ~ intercept + longevity class + subsurface effort + mud + gravel + Longevity : gravel + [random effect on longevity class | station/year]

Table 3.3 Parameter estimates of the fixed effects including their interactive terms

Co-variates	Estimate	Std. Error	Pr(>|z|)
Intercept	-5.493	0.293	<0.001
log(longevity)	3.423	0.164	<0.001
log(seining (subsurface effort))	0.110	0.061	0.073
Mud	0.018	0.003	<0.001
Gravel	0.022	0.012	0.068
log(longevity):Gravel	-0.018	0.006	0.005

It turned out that next to the Dutch fleet there was seine activity in the Dogger Bank area in the period 2013 until 2019 for the Danish, Belgian and British fleets (see also Section 3.3). There was no seine fishery for the French, Swedish and German fleets. The model and RBS function were used to estimate the impact of the seine fisheries on the (relative) benthic biomass in each grid cell and for each year.

In Figure 3.2 the change in relative benthic biomass is shown for the period 2013-2019 for the Dutch and German parts of the Dogger Bank area due to seine fisheries as calculated using the model outcome, RBS function, depletion- and recovery rate as described in Section 2.2.2. The percentage of benthic biomass mortality caused by solely seine is limited and fluctuates in the period 2013-2019 between zero (2016) and 0.09% (2014). In the later years (2016 - 2019) percent mortality due to seine is a bit lower compared to the first years (2013-2015).

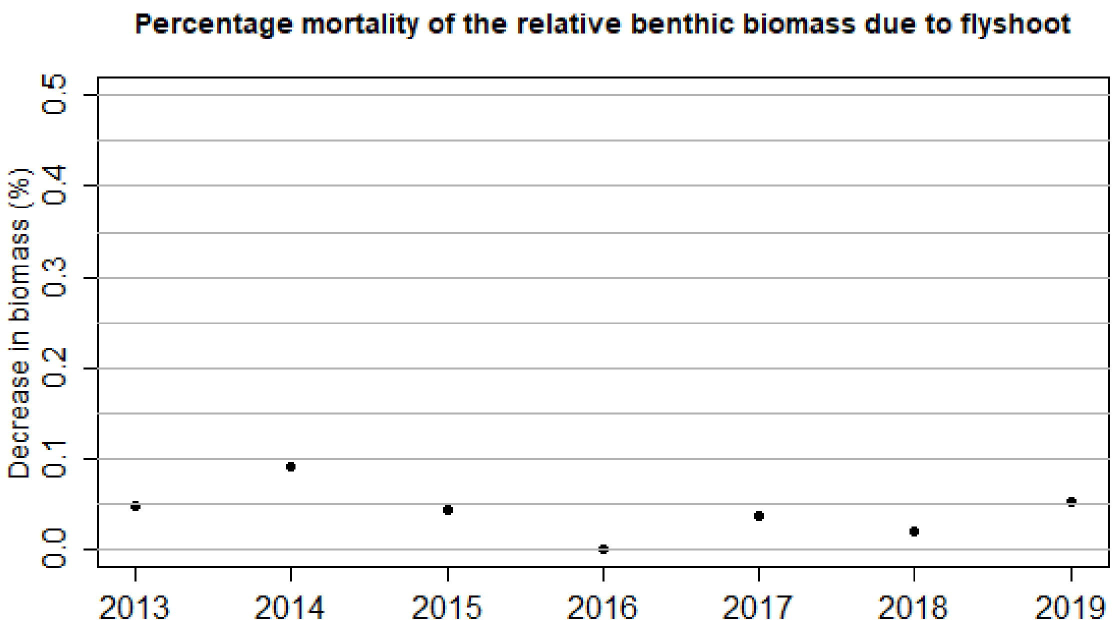

Figure 3.2 *Modelled effect of flyshoot fisheries of the Belgian, British, Danish and Dutch flyshoot fleets in the Dogger Bank (Dutch and German part) expressed as the average % reduction in each of the grid cells for the years 2013 until 2019*

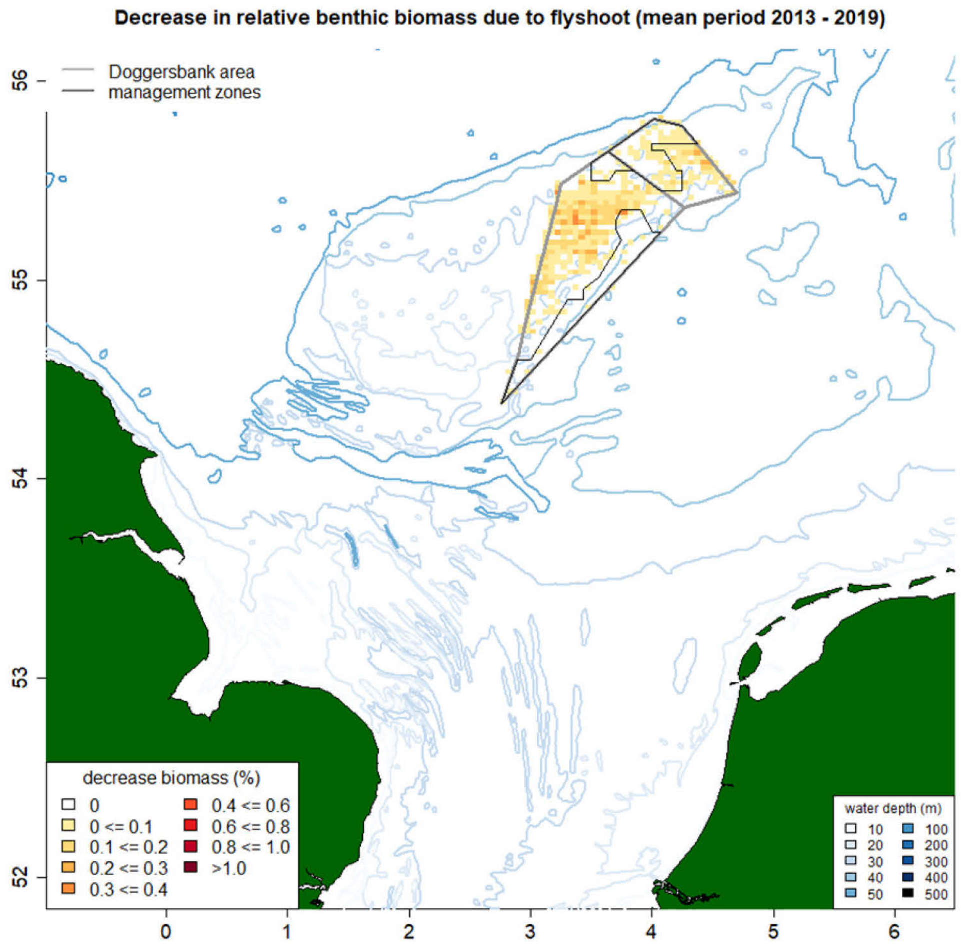

Figure 3.3 *Modelled average annual impact of flyshoot fisheries of the Belgian, British, Danish and Dutch flyshoot fleets in the Dogger Bank (Dutch and German part) expressed as the average % decrease of biomass on a spatial scale for the years 2013 until 2019*

Highest impacts were found in the central areas of the Dutch part of the Dogger Bank and in the North and East parts of the German part of the Dogger Bank, see Figure 3.3. In Figure 3.4 the impact of the seine is shown per year and subdivided by the exclusive economic zones of The Netherlands and Germany and for both inside and outside the management zones. The decrease in biomass due to seine is roughly similar between both countries in most years. In the Netherlands most impact is found outside the management zones while in Germany this depends on the year considered, see Figure 3.4 and Table 3.4. Due to local aggregation of fishing effort, grid cell maximum impacts are higher (up to 1.5% decrease in biomass in the Netherlands outside the management zone in the year 2014).

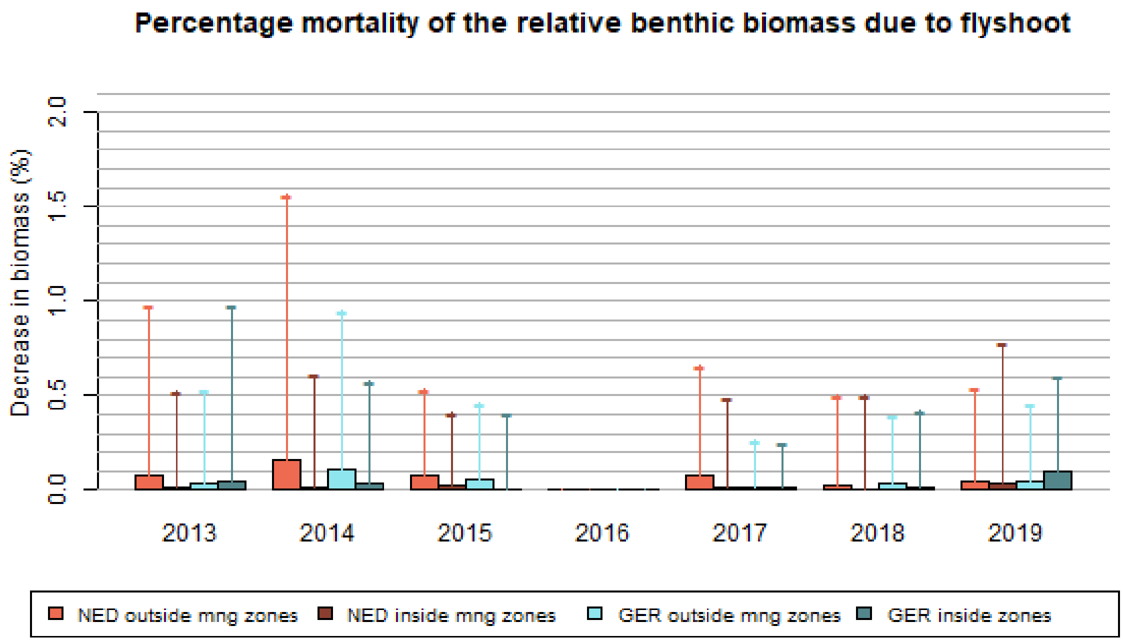

Figure 3.4 *The mean and maximum percentage decrease in relative benthic biomass due to the seine fleets per country and inside and outside the management zones. The '-' symbols show the grid cell maximum percentage decrease in relative benthic biomass*

Table 3.4 *Mean (standard deviation) and maximum percentage decrease in relative benthic biomass due to solely seine fisheries (%) over the period 2013-2019 for the different areas*

Country and area	Mean	Maximum
The Netherlands outside management zones	0.066 (0.052)	1.563
The Netherlands inside management zones	0.014 (0.010)	0.777
Germany outside management zones	0.041 (0.034)	0.945
Germany inside management zones	0.030 (0.035)	0.975

3.3 A low socio-economic importance of the Dutch and German management zones of the Dogger Bank for seine fleets

3.3.1 Low and irregular seine activity on the Dogger Bank management zones

Over the 2013-2019 period, the amount of seine fishing on the Dutch and German management zones fluctuated at low levels without trends (see Table 3.5 and Figure 3.5). The total seine effort over the seven year period is 22 days at sea, or less than 4 fishing days a year for most years, except in 2019 where it was 12 days. There has been no activity at all in 2015 on the German management zone and in 2016 on both Dutch and German management zones. Comparing this effort with previously available data (calculated from Hamon et al., 2017), we observe a decrease of the annual seine effort from six (average 2010-2015) to three days a year (average 2013-2019) on those management zones. Those values are extremely low compared to the 300 days of annual trawling effort (beam trawls and demersal trawls) on the same management zones observed between 2010 and 2015 (calculated from previous report of Hamon et al., 2017).

Seine fisheries more active on the German than Dutch management zones
On average the German management zone has been more intensely fished by seiners than the Dutch ones (19 vs 3 days over the period). This is mainly due to sporadic high effort in 2013 and 2019 by Denmark and 2018 by Belgium and 2019 by Great Britain (Table 3.5 and Figure 3.5).

Denmark has been the most active seine fleet
Denmark fished the most in the German Dogger Bank management zone with a total of 11.5 days effort resulting in 16.5 tonnes or € 35.5 thousand landings over the 2013-2019 period. However, over the seven year period of the study Danish activity has only be recorded in the German management zone for three years (2013, 2017 and 2019) and four years in the Dutch management zones (2013 and 2015, including 2014 and 2018 with negligible effort). Effort by other fleets has been even lower, Belgium totalled 4.2 days on the management zones over the period, Great Britain 5.4 days and the Netherlands 0.1 days amounting for 3.1, 7.6 and 0.1 tonnes of fish respectively for Belgium, Great Britain and The Netherlands (Table 3.5). Fleets from France, Germany and Sweden had no activity at all in the Dutch and German management zones of the Dogger Bank.

Table 3.5 *Overview of 2013-2019 effort, landings, value of landings and gross value added of the seine fisheries in the Dutch and German management zones of the Dogger Bank per country (VMS and logbook merged data). '–' represents a value rounded at 0.0*

Country	Dutch Management zones								German Management zone							
	2013	2014	2015	2016	2017	2018	2019	**Total**	2013	2014	2015	2016	2017	2018	2019	**Total**
Effort (days at sea)																
Belgium	-	-	-		0.1	-		**0.1**	0.6					3.5		**4.1**
Denmark	0.1	-	0.7			-		**0.9**	2.8				0.4		8.3	**11.5**
Great Britain		0.1	0.9				1.2	**2.2**	0.2	0.4					2.5	**3.2**
Netherlands			0.1					**0.1**								
Total	**0.1**	**0.1**	**1.7**		**0.1**	**0.0**	**1.2**	**3.3**	**3.6**	**0.4**			**0.4**	**3.5**	**10.8**	**18.8**
Landings (tonnes)																
Belgium	-	-	-		0.4	-		**0.4**	1.5					1.2		**2.7**
Denmark	0.2	0.1	0.5			0.1		**0.8**	5.2				0.7		10.7	**16.5**
Great Britain		0.5	-				1.5	**2.0**	0.7	2.1					2.8	**5.6**
Netherlands			0.1					**0.1**								
Total	**0.2**	**0.6**	**0.6**		**0.4**	**0.1**	**1.5**	**3.3**	**7.5**	**2.1**			**0.7**	**1.2**	**13.5**	**24.9**
Value (1,000 euros)																
Belgium	-	-	-		0.8	-		**0.8**	2.1					3.7		**5.8**
Denmark	0.3	0.1	0.9			0.1		**1.4**	5.6				1.4		28.4	**35.5**
Great Britain		0.8	-				2.7	**3.5**	0.7	2.4					5.0	**8.1**
Netherlands			0.1					**0.1**								
Total	**0.3**	**0.8**	**1.0**		**0.8**	**0.1**	**2.7**	**5.8**	**8.5**	**2.4**			**1.4**	**3.7**	**33.4**	**49.4**
Gross Value Added (1,000 euros)																
Belgium	-	-	-		0.5	-		**0.5**	0.9					2.2		**3.1**
Denmark	0.2	-	0.6			0.1		**0.9**	3.2				1.0		20.6	**24.8**
Great Britain		0.5	-				1.6	**2.1**	0.3	1.4					3.0	**4.8**
Netherlands			0.1					**0.1**								
Total	**0.2**	**0.5**	**0.7**		**0.5**	**0.1**	**1.6**	**3.5**	**4.4**	**1.4**			**1.0**	**2.2**	**23.7**	**32.6**

France, Sweden and Germany have declared no seine fishing in those areas for the period.

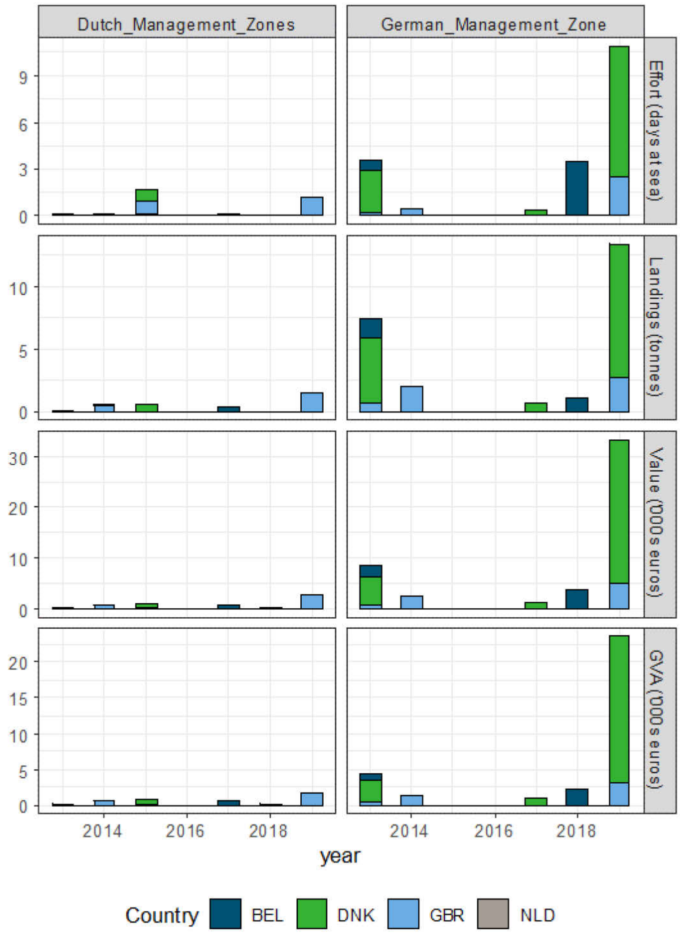

Figure 3.5 *Historical trend of the seine fishing activities by the Belgian (BEL), Danish (DNK), British (GBR) and Dutch (NLD) fleets in the Dutch and German management zones of the Dogger Bank Effort, landings, value of landings and GVA are given by country. France, Sweden and Germany have declared no seine fishing in those areas for the period. Source: Logbook data and VMS data and data from the Annual Economic report (STECF 2019), processed by WUR, CEFAS, TI, DTU, ILVO, SLU and IFREMER.*

Danes use Danish seine and other fleets Scottish seines

The type of gear used by the different national fleets on the Dogger Bank has been very stable, with Denmark operating with Danish seines (SDN) and Belgium, Great Britain and The Netherlands operating with Scottish seines (SSC) (see Figure 3.6).

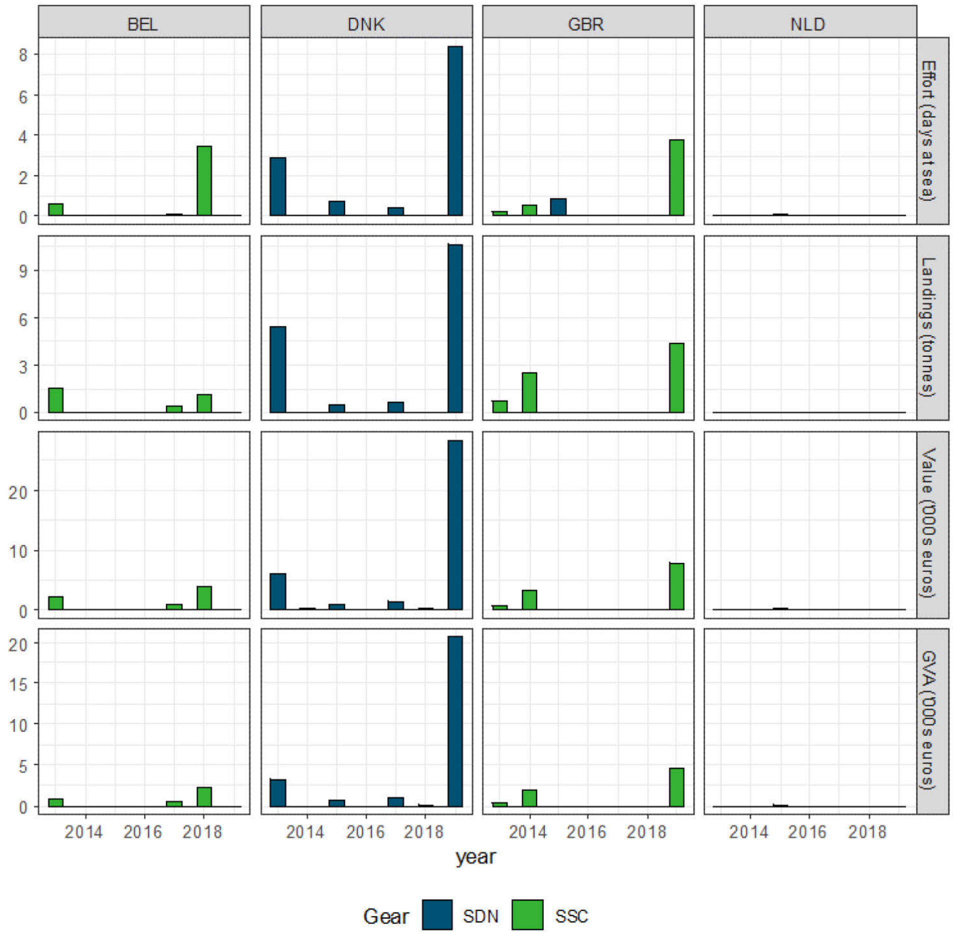

Figure 3.6 *Historical trend of the seine fishing activities by the Belgian (BEL), Danish (DNK), British (GBR) and Dutch (NLD) fleets in the Dutch and German management zones of the Dogger Bank Effort, landings, value of landings and GVA are given by gear (SDN: Danish seine, SSC: Scottish seine). France, Sweden and Germany have declared no seine fishing in those areas for the period. Source: Logbook data and VMS data and data from the Annual Economic report (STECF 2019), processed by WUR, CEFAS, TI, DTU, ILVO, SLU and IFREMER.*

3.3.2 No dependency of fishers to the management zones

Few seiners fishing in the management zones

The dependency of the Dutch fleet to the proposed closure is low at the fleet level and at the individual level. Only one Dutch vessel recorded fishing with seine in a management zone in 2015 for less than 10% of their revenue, no activity was recorded for other years (Figure 3.7). The number of vessels involved is also limited for the Belgian, Danish and British fleets, only one or two vessels of each fleet have been active on the management zones every year (data not shown for confidentiality reason).

Figure 3.7 *Number of Dutch seiners active on the Dogger Bank: in the adjacent ICES areas, on the Dutch management zones, the Dutch and German Natura 2000 areas per year and percentage of their revenue with seines in these areas. Note: no activity was recorded in the German management zone*

3.3.3 The management zones represent a small proportion of the Dogger Bank fishing

The greater Dogger Bank remains a recurring fishing ground for seiners
While the Dutch and German management zones and Natura 2000 parts of the Dogger Bank only seem to serve sporadically as fishing ground for the Dutch seiners, the area composed of the adjacent ICES rectangles (see map Figure 1.1) has been used as recurring fishing grounds for other fisheries from the beginning of the study period in 2013 (Figure 3.8). In the ICES rectangles, a decreasing trend is visible from 397 days at sea in 2013 to 163 days at sea in 2019, especially for British (from 149 to 20 days at sea) and Danish (from 110 to 25 days at sea) seiners.

Negligible seine fishing in the management zones
From an economic point of view, the management zones have had little value to the seine fishery with a maximum annual value of landings of €36 thousand (see Table 3.5) representing on average about 2% of the value of seine landings in the adjacent ICES rectangles and 10% of the value of seine landings in the Dutch and German Natura 2000 areas (Figure 3.8).

Management zones can punctually concentrate the Natura 2000 activity
Given the highly variable interannual activity for all fleets, the Dogger Bank seine activity of national fleets can be concentrated on the management zones. This was for example the case for Great Britain in 2013 (78% of Natura 2000 value from management zone) and 2019 (44%), Belgium in 2018 (100%) and Denmark in 2019 (59%).

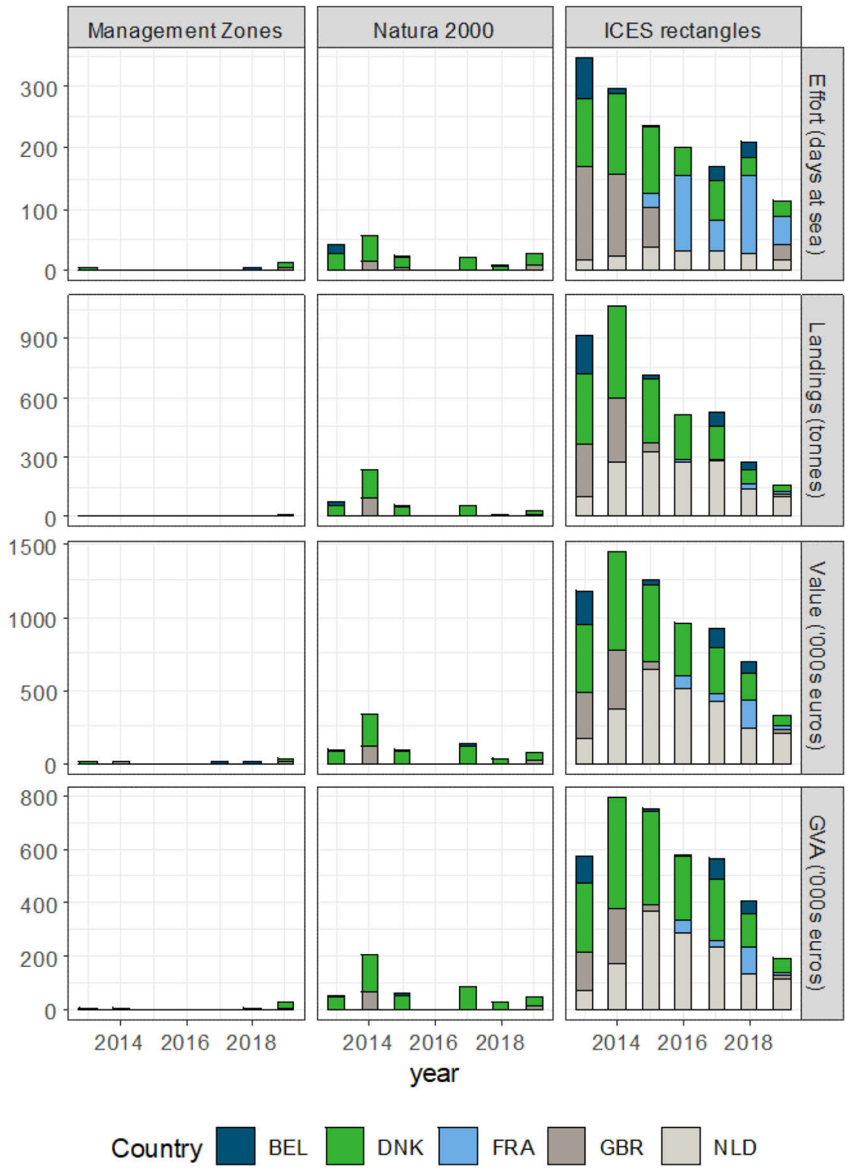

Figure 3.8 *Historical trend of the seine fishing activities by the Belgian (BEL), Danish (DNK), French (FRA), British (GBR) and Dutch (NLD) fleets in the Dutch and German management zones, Natura 2000 and adjacent ICES rectangles of the Dogger Bank. Effort, landings, value of landings and GVA are given by country. Sweden and Germany have declared no seine fishing in those areas for the period. Source: Logbook data and VMS data and data from the Annual Economic report (STECF 2019), processed by WUR, CEFAS, TI, DTU, ILVO, SLU and IFREMER.*

3.3.4 Plaice is the main seine target species on the Dogger Bank

The main species targeted on the Dogger Bank by seiners is plaice.
With 95% of the total landings on the Dutch and German Natura 2000 parts of the Dogger Bank, plaice is also the most important species inside the management zones where it represents 90% of the landings (Figure 3.9). Other flatfish species such as dab and lemon sole are also caught in small proportions in the management zones (respectively 4 and 3% of the total seine landings).

Dutch fleet targets other species
Remarkably the landing composition of the Dutch seine fleet in the ICES rectangles around the Dogger Bank is different from that of the seine fleets of other countries, the Dutch seiners catch a mix of pelagic and demersal roundfish and flatfish (see last column of Figure 3.9).

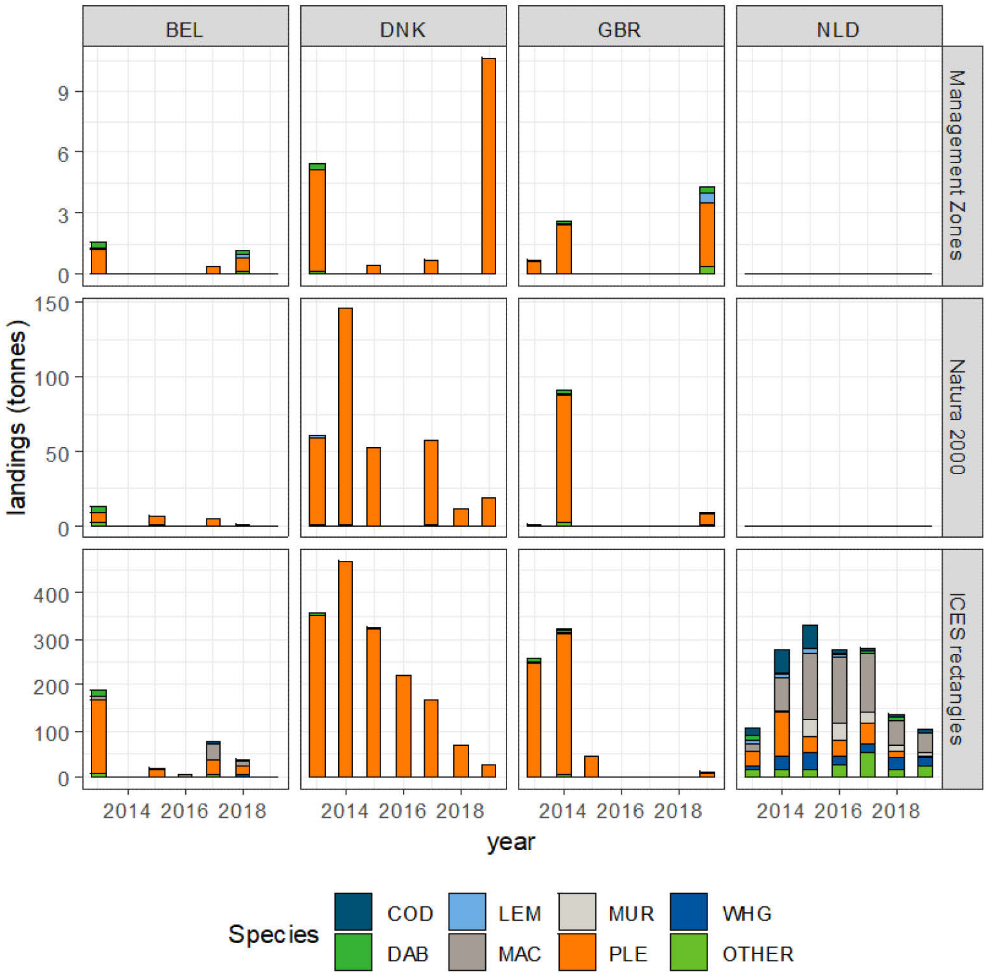

Figure 3.9 *Landings in tonnes for the top species per country on the Dutch and German parts of the Dogger Bank for seines (see Figure 1.1 for the areas)*
Source: Logbook data processed by WUR, CEFAS, TI,DTU, ILVO, SLU and IFREMER. COD = cod, DAB=dab, LEM= lemon sole, MAC = mackerel, MUR = surmullet, PLE= plaice, WHG = whiting.

3.4 Limited risk of Dutch flyshoot increase due to the ban on electric fishing

Will the ban of electric (or pulse) fishing lead to an increase in fishing vessels using flyshoot in the Dutch fleet?
Since 2008 the number of vessels fishing with flyshoot has increased from 10 to 19. The fishery has especially developed in the English Channel where Dutch fishers have been fishing on unquoted species. While there has been growing interest in flyshoot, the total number of fishing licences for the Channel is limited to 24 for Dutch fishers and to be economically profitable all year round, Dutch flyshoot fishers need that access to the Channel because summer fishing with flyshoot in the North Sea is unprofitable. Up to now, no transition from pulse to flyshoot has been observed in the fishery (pers. comm. Arie Mol). The costs to transform a pulse vessel into a flyshoot vessel have been estimated at around 1.8 million euro (Quirijns et al., 2019). According to experts, it is unlikely that banks would loan this amount. Given the total available licences (24) and the number of vessels currently active (19) a maximum increase of five extra vessels (or about 25% of the current capacity) could be seen in the coming years, but not necessarily from ex-pulse fishers. All the arguments for and against this pulse-flyshoot transition are detailed in Table 3.6.

Table 3.6 *Arguments against and for a transition from pulse fishing to flyshoot (based on expert knowledge)*

	No transition to flyshoot	Transition to flyshoot
Access to good flyshoot fishing grounds (i.e. English Channel)	Flat sandy areas without obstacles are the best fishing grounds but there is already overcrowding in those type of areas in the Channel and the North Sea	If the targeted species such as squid move North, out of the Channel in the Southern North Sea, fishing all year long would be possible
	Channel licences are limited to 24[6]	
	The largest pulse vessels (above 340 tons) are not allowed to fish on the Channel	
Access to quota	Quota for the North Sea target species of flyshoot (mackerel, horse mackerel or whiting) not available	
Economics	High investment to convert a vessel to flyshoot fishing (net roll, hydraulic crane and Marelec auto trawl system)	Gear costs are slightly lower
	When available on the market a Channel licence is expensive	
	Previous investment in sole quota would become worthless	
	As long as the fuel price remain low, fishing with beamtrawls (with chains) will likely be preferred	
Practice and knowledge transition from pulse to flyshoot	Flyshoot is a different fishing practice than beamtrawl (or pulse) requires knowledge about hydrographic conditions (current, bottom) as well as experience to keep the seine ropes under equal tensions	
Technical transition	The transformation of a pulse trawler into a flyshooter would require an investment of about 1.8 million euro	

[6] https://www.visned.nl/algemeen/nog-geen-overeenstemming-over-visserij-in-het-kanaal

4 Discussion

4.1 Ecological impact

The assessment of the impact of a bottom fishing gear on the seabed is extremely complex. The degree of contact of the gear with the seabed is depending on the gear design, fishing speed, sea floor characteristics etc. (Rijnsdorp et al., 2016 and references therein). The impact of the gear depends on the subsurface area disturbed and the depletion rate and how well these are estimated. Empirical data to support such estimates is lacking for seine fishery but has been assessed relative to other bottom trawl gear by Rijnsdorp and colleagues (Rijnsdorp, 2015; Rijnsdorp et al., 2015; Rijnsdorp et al., 2020). Therefore the results of the impact assessment should be considered as a gross estimate.

This study uses the method developed and applied by Rijnsdorp and colleagues(Rijnsdorp, 2015; Rijnsdorp et al., 2015; Rijnsdorp et al., 2020). Some considerations in the applied modelling approach which are put forward by Rijnsdorp et al. (2018) and references therein apply to this study. They include the ineffective sampling of the larger epifauna and megafauna component and deep burrowing taxa by the box-core and grab samples used to parameterize the model. As a result, the modelled effects on those components are less reliable. Based on our estimates, this impact assessment sufficiently covers 25 of the 38 typical species for H1110 in the Netherlands and 16 of the 21 typical species for H1110 in Germany. Species that are moderately covered in this study are the flying crab (*Liocarcinus holsatus*) (Dutch typical species), dead man’s fingers (*Alcyonium digitatum*) (Dutch and German typical species), two starfish species (*Astropecten irregularis* (Dutch and German typical species) and *Luidia sarsii* (Dutch typical species)) and a sea urchin *Echinocyamus pusillus* (Dutch and German typical species). Fish are not covered which includes eight species in the Netherlands and two species in Germany, of which 5 species have been reported as (by)catch by seine fisheries.

Since decades the trawling effort is intensive in the North Sea including the Dogger Bank. Therefore, it cannot be excluded that vulnerable taxa have already disappeared from the study area leading to an underestimation of the impact of trawling (Rijnsdorp et al., 2018).

Although the true impact of seine might be higher (due to presence of underestimated vulnerable fauna components) or lower (due to for example the larger natural disturbance in the Dogger Bank) the estimated impact calculated here does not lead to the expectation that there is a large additional effect of demersal seine fisheries on the benthic biomass when considered on a Dogger Bank scale. The impact of demersal seine fishery on the seafloor is smaller in case other bottom trawling types have impacted the seafloor already because the first trawl pass typically causes the largest impact (Hiddink et al., 2006). In addition, as a result of ongoing demersal fisheries the longevity distribution would be pushed to more shorter-lived species. This was mentioned for habitat type 1110 by STECF which is currently assessed as unfavourable (STECF, 2019b). As shorter-lived species recover faster, the benthic community is less sensitive to the impact of seines.

There is no consensus about how much mortality of benthic biomass can be considered as a (severe) effect. The average impact of the seine fisheries on the relative benthic biomass is limited to tenths of a percent. Locally there are some areas within the Dogger Bank that experience more frequent (most years considered here) aggregated fishing effort that resulted in slightly higher impact values. It needs to be considered that solely demersal seines are assessed here and the impact of seine, how small it might be, does add up much to other types of bottom disturbing fisheries that might lead to higher, accumulated, impact values.

Our findings are in line with the recent international review of the fisheries management measures for protection of sandbanks at the Dogger bank (STECF, 2019b). STECF considered the impact of demersal seine fisheries likely to be low, although benthic epifauna might be impacted. A lack of knowledge was identified for the impact assessment of seines on the Dogger Bank sandbank habitat and typical species associated with this habitat (STECF, 2019b). Consequently, STECF considered conclusive determination whether the continued operation of seines will impede the achievement of the conservation objectives in the managed zones not possible.

4.2 Socio-economic importance

Low importance of fishing on Dogger Bank management areas
Over the study period 2013-2019 the activity of the seine fishing fleets of Belgium, The Netherlands, Great Britain and Denmark on the Dutch and German management zones have been limited, while Germany, Sweden and France have not been active there at all. The activity is limited in terms of total activity and also in terms of the number of fishers that have been active in the areas.

Management zones can punctually concentrate the Natura 2000 activity
The management zones represent on average 10% of the Natura 2000 activity of the Dogger Bank but for some fleets and some years it can rise up to higher proportions like Belgium in 2018 (100%).

Uncertain absolute estimates of activity on the management zones
Because the seine activity on the Dogger Bank has been low and patchy over the years of the study period, the absolute estimates are uncertain. However we are confident that we capture the relative importance of the study areas and can conclude that the management zones have been of low importance to the seine fleets.

Past and current activity provide limited information about future importance
While past and current activity provide valuable information of the current socio-economic importance of the areas, we cannot predict the future importance of those areas for the seine fisheries. However given that the fishing areas of the North Sea become limited by offshore windfarms and nature protection areas, it is likely that fishers will reallocate their effort to the areas remaining open (Mol et al., 2019).

Plaice has been the main target species
Most of the landings from the management zones consisted of plaice (90%). However comparing the maximum landings of 2019 in the management zones of 15 tonnes to the advised plaice quota that year for the North Sea of 125,435 tonnes (ICES, 2020), one can expect that other fishing grounds are available.

Low risk for major switch from pulse to flyshoot in the Dutch fleet
The number of Channel flyshoot licences being limited to 24, the Dutch fleet could expand by 5 vessels in the coming year (19 licences were active in 2019). This would be an increase of 25% of the Dutch seine fleet. However, the Dutch fleet currently fished less than a day on the Dutch and German management zones of the Dogger Bank over a seven year period making it unlikely that the areas become major fishing grounds in the coming years.

5 Conclusion

Low and irregular seine activity on the Dogger Bank management zones
The economic importance of the Dutch and German management zones has been low for the seine fishery. Sporadic seine activity was reported for Belgium, the Netherlands, Great Britain and Denmark, mainly in the German part of the management zones, France, Germany and Sweden reported absolutely no activity.

Limited risk of increase in the future due to switch from pulse
The future seine activity of the Dutch fleet may increase due to an increase of flyshoot vessels. However the increase is expected to be limited to the 5 currently inactive flyshoot licenses for the English Channel, and the 10 to 19 Dutch seiners fished less than a day on the Dutch and German management zones of the Dogger Bank over the seven years study period so it is expected that the importance of the areas remains limited for the Dutch fleet.

Ecological impact highly uncertain and complex to assess
Considering the ecological impact of demersal seine fisheries on the Dogger Bank the following can be concluded:

- Benthic biomass
  The seine intensity on the Dogger Bank and concomitant impact on the relative biomass of the benthic community are low as calculated with the method of Rijnsdorp et al. (2018).
- The modelled impact is less reliable for larger epifauna and megafauna component and deep burrowing taxa. The applied method covers the majority of the relevant species for this study.
- Typical species habitat type 1110 of the Dutch part of the Dogger Bank
  - Invertebrate species
    Approximately half of the 29 invertebrate species are vulnerable for demersal seine fisheries. Most are covered by the impact assessment, five species are moderately covered.
  - Fish species
    There are nine fish species of which five are considered vulnerable for bycatch by demersal seine fisheries. In general, fish are not covered by the impact assessment.
- Typical species habitat type 1110 of the German part of the Dogger Bank
  - Invertebrate species
    Based on literature, 12 of the 19 invertebrate species are considered vulnerable for demersal seine fisheries. Most are covered by the impact assessment, two species are moderately covered.
  - Fish species
    There are two typical fish species of which one is considered vulnerable for bycatch by demersal seine fisheries. This species is not covered by the impact assessment.

Although the benthic biomass assessment indicates a low impact, this cannot be quantitively assessed for all nature values of benthic biodiversity of the Dogger Bank.

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Appendix 1 Conceptual footprint of seines

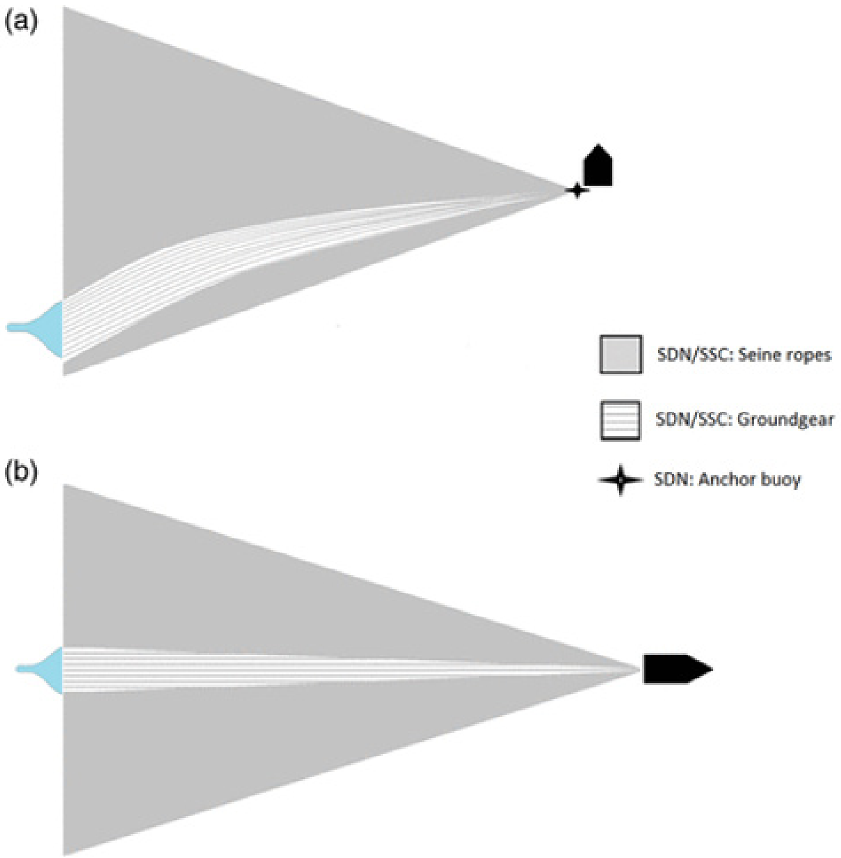

Figure 5.1 *Conceptual gear footprints of demersal seines (DSs) [(a) anchored seine/Danish seine (SDN) and (b) flyshooting/Scottish seine (SSC)]*
Source: (Eigaard et al. 2016).

Appendix 2 Bycatch of flyshoot fisheries

Benthos species by-catch (average numbers per hour) of Dutch fly-shoot fisheries (with different mesh sizes) in the North Sea, including the Dogger Bank in the period 2013-2016 compiled from Van der Reijden et al. (2014) and Verkempynck et al. (2016). Only the typical species for H1110 of the Dogger Bank (Dutch and German parts) are shown.

Species (scientific name)	Species (English name)	Species (Nederlandse naam)	SSC_DEF_>=120	SSC_DEF_100-119	SSC_DEF_70-99*)	Typical species for H1110 Dogger Bank
Acanthocardia echinata	Prickly cockle	Gedoornde hartschelp	1.64	0	0	D
Alcyonium digitatum	Dead man's fingers	Dodemansduim	15.96	0.89	12.26	NL, D, UK
Aphrodita aculeata	Sea mouse	Zeemuis	1.78	0.21	0.81	NL
Aporrhais perspelecani	Common Pelican's Foot	Pelikaansvoet	0	0	0	D, UK
Arctica islandica	Ocean quahog	Noordkromp	0.39	1.33	0	NL, D
Asterias rubens	Common starfish	Gewone zeester	9.94	12.41	3.37	UK
Astropecten irregularis	Sand sea star	Kleine kamster	4.46	3.85	0	NL, D, UK
Buccinum undatum	Common whelk	Wulk	18.23	0.29	0.20	NL, D
Corystes cassivelaunus	Helmet crab	Helmkrab	0.43	0.88	0	NL, UK
Euspira nitida	Alder's necklace shell	Glanzende tepelhoorn	0	0	0	NL
Gari fervensis	Faroe sunset shell	Geplooide zonneschelp	0	0	0	NL, D
Liocarcinus holsatus	Swimming crab	Gewone zwemkrab	1.88	8.52	0.45	NL, UK
Luidia sarsii	Starfish species	Slanke kamster	0.06	0	0	NL
Neptunea antiqua	Red whelk	Noordhoren	27.95	0.06	0	NL, D, UK
Ophiothrix fragilis	Common brittle star	Brokkelster	0.03	4.00	0	NL, D, UK
Ophiura	Brittle star	Gewone slangster	0	0.25	0	NL, UK
Pagurus bernhardus	Common hermit crab	Gewone hermietkreeft	9.79	1.77	2.18	NL, UK
Pagurus pubescens	Rough hermit crab	Ruig hermietkreeftje	0	0	0	D
Psammechinus miliaris	Green sea urchin	Kleine zeeappel	2.32	0.00	2.65	D, UK

Fish species by-catch (average numbers per hour) of Dutch fly-shoot fisheries (with different mesh sizes) in the North Sea, including the Dogger Bank in the period 2013-2016 compiled from Van der Reijden et al. (2014) and Verkempynck et al. (2016). Only the typical species for H1110 of the Dogger Bank (Dutch and German parts) are shown.

Species (scientific name)	Species (English name)	Species (Nederlandse naam)	SSC_DEF_>=120	SSC_DEF_100-119	SSC_DEF_70-99*)	Typical species for H1110 Dogger Bank
Arnoglossus laterna	Scaldfish	Schurftvis	0	0	0	NL
Buglossidium luteum	Solenette	Dwergtong	0	0.23	0	NL
Callionymus lyra	Dragonet	Gewone pitvis	0.54	1.86	56.93	NL, UK
Echiichthys vipera	Lesser weever	Kleine pieterman	0	0	0.65	D
Eutrigla gurnardus	Grey gurnard	Grauwe poon	71.54	622.19	433.53	NL, UK
Gadus morhua	Cod	Kabeljauw	41.37	0.84	26.27	NL, UK
Limanda limanda	Dab	Schar	85.04	767.28	802.79	NL, UK
Merlangius merlangus	Whiting	Wijting	28.13	17.76	1530.75	NL, UK
Microstomus kitt	Lemon sole	Tongschar	4.02	4.04	68.32	NL
Pleuronectes platessa	Plaice	Schol	105.76	351.43	52.48	NL, UK

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