Impact of fisheries on seabed bottom habitat

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Fisheries from The Netherlands, Germany, Denmark and Sweden

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Summary

The Marine Stewardship Council (MSC) released new certification requirements in 2014. The new requirements come with new guidelines for scoring fisheries for several Performance Indicators (PIs). One of the adjusted PIs is PI 2.4.1: the Habitats outcome indicator:

"*The Unit of Assessment (UoA) does not cause serious or irreversible harm to habitat structure and function, considered on the basis of the area(s) covered by the governance body(s) responsible for fisheries management.*"

Up to now, the new guidelines for this PI have not yet been translated into an operational performance indicator. An international group of fisheries organisations, from the Netherlands, Denmark, Germany and Sweden, is interested in applying for MSC accreditation or for renewal of existing accreditation. For them it is relevant to know how the new guidelines for PI 2.4.1 translate into a scoring of their fisheries. Therefore, the fisheries organisations requested WMR to develop a methodology for assessing fisheries' impact on the North Sea seabed which could be used in assessments for MSC accreditation.

WMR combined the MSC guidelines with a methodology for assessing fisheries' impact on the seabed developed in collaboration with partners in the International Council for Exploration of the Sea (ICES). A so-called 'Population Dynamic' method was applied, which indicates how bottom trawling affects the biomass of the benthic community relative to an undisturbed situation. Recovery of a habitat is an important aspect in determining whether serious or irreversible harm is caused by a fishery. The benthic invertebrate community consists of many different taxa that differ in their sensitivity to fishing disturbance. This difference in sensitivity is reflected in the parameterisation which distinguishes between an average sensitivity (sensitivity I) and a high sensitivity (sensitivity II). Recovery of Seabed Integrity (SI) is used as an indicator for serious or irreversible harm. This methodology was applied for habitats with status type 'commonly encountered'.

Data that were used are satellite (VMS) and logbook data giving information on the spatial distribution and intensity of the fisheries. Information on North Sea habitats was obtained from EMODnet EU Sea Map and data on recovery rates and gear specific impact rates were obtained from an EU project called 'BENTHIS'. The methods were applied to 11 UoAs for four different countries, in four different management areas (North Sea, Skagerrak, Kattegat and Eastern English Channel).

The analysis comprised of a definition of the current state of seabed integrity (SI), based on historic fishing intensity. For each UoA a study area or 'footprint' was defined by gear and management area. Next, for each grid cell (1-minute longitude by 1-minute latitude) the fishing intensity was calculated from VMS data for three different gear groups: Beam Trawl (BT), Demersal Otter Trawls (TR) and Danish Seine (SDN). It was then possible to assess recovery rates for each grid cell (relative increase of biomass per year). The SI was calculated for the moment right after fishing impact and then for respectively 1, 5, 10 and 20 years after ceased fishing. Two indicators were used to assess whether recovery of the habitat to 80% of its unimpacted structure was achieved:

- T80% > 0.95K: the top 80% of least impacted grid cells have an SI of at least 0.95 K, meaning that biomass is at more than 95% of the carrying capacity (K).
- 100% > 0.80K: all grid cells in the study area have an SI of at least 0.80 K, so biomass is more than 80% of K.

For habitats with status type 'Vulnerable Marine Ecosystem' (VME) we did not apply the methodology. In order not to cause any serious or irreversible harm to VMEs, the VMEs should not be fished at all. If that is taken into account during assessments for MSC accreditation, it is not relevant whether the VME habitat recovers. We did overlay maps of fishing by UoA with maps of vulnerable habitats (based

on either ICES or OSPAR data) in order to see whether VMEs may be a relevant theme during assessments for MSC accreditation.

Habitats with status type ‘minor’ were not considered, as with our interpretation these are insignificant in the North Sea and data for carrying out the above (or any) methodology is lacking.

The analyses show that for the scenario with Sensitivity I (average recovery rates) none of the UoAs causes serious or irreversible harm to the commonly encountered habitats. I.e. recovery up to 80% is achieved within 20 years for both indicators. If the other Sensitivity is applied (II, with lowest recovery rates), the results are different. The ‘T80% > 0.95K’ indicator always reaches the threshold value within 20 years, but the ‘100% > 0.80K’ indicator does not reach the threshold value for 6 UoA. The 6 UoAs are the TR groups from Denmark (North Sea and Skagerrak), Germany (North Sea), the Netherlands (North Sea) and Sweden (Skagerrak) and the BT group from the Netherlands (North Sea). This may mean – dependant on whether both indicators should reach the threshold value or not – that for these 6 UoA it could be concluded that they do cause serious or irreversible harm to the habitat.

Overlaying fishing activities by UoA with VMEs in the North Sea show us that there may be an issue for the German TR unit on the North Sea. This UoA has a minimal overlap with VMEs according to the ICES database. However, if data on threatened and/or declining species and habitats from OSPAR are used, a larger overlap is found.

The methodology developed in this study can be a useful starting point for assessing the impact of fishing on the sea bed. It is not yet fully developed to be used in the framework of MSC accreditation: there are still several issues to be dealt with. First of all, a decision needs to be made on which performance indicator(s) to use: the ‘T80% > 0.95K’ indicator or the ‘100% > 0.80K’ indicator, or both. Second, a choice needs to be made about the sensitivity to be used.

Another issue that needs to be considered concerns the UoAs. Each UoA may have a negligible impact on the seabed compared to the whole fleet. However, all UoAs together may cause serious or irreversible harm to the seabed. It is therefore important to be aware of the context in which the UoA is practicing the fishery.

Since the MSC criteria on seafloor impact caused by fisheries are not without ambiguity, this study provides in a tentative interpretation of the guidance provided by MSC. In this innovative study we made a first attempt to apply state-of-the-art methodologies to calculate the impact of fishing on the seabed in an assessment against specific criteria. We present a bandwidth of results: from a relatively strict interpretation of the criteria to a looser interpretation of the criteria. As the discussion on the interpretation of the criteria is as yet unresolved there is no scientific basis for any preferred interpretation: this is up to the certifying body.

1 Introduction

Fisheries organisations from the Netherlands, Germany, Denmark and Sweden are considering applying for a (new) assessment in order to gain MSC certification. Since October 2014, MSC has new certification requirements (MSC, 2014). Fishing organisations from the four countries requested WMR, through CVO, to translate the new requirements that come from “Principle 2: Environmental impact of fishing” and specifically the impact on the seabed habitats into an operational Habitats outcome Performance Indicator (PI 2.4.1, Table 1.1).

In this report we provide the state-of-the-art knowledge that would allow for an assessment of the impact of the Units of Assessment (UoA) of the Netherlands, Germany, Denmark and Sweden on the seabed habitats.

Since the MSC criteria on seafloor impact caused by fisheries are not without ambiguity, this study provides in a tentative interpretation of the guidance provided by MSC. In this innovative study we made a first attempt to apply state-of-the-art methodologies to calculate the impact of fishing on the seabed in an assessment against specific criteria. We present a bandwidth of results: from a relatively strict interpretation of the criteria to a looser interpretation of the criteria. As the discussion on the interpretation of the criteria is as yet unresolved there is no scientific basis for any preferred interpretation: this is up to the certifying body.

Table 1.1. PI 2.4.1 habitats outcome Performance Indicator Scoring Guidepost (PISGs).
SG = scoring guidepost, i.e. the benchmark level of performance. (MSC 2014)

Component	PI	Scoring issues	SG60	SG80	SG100
Habitats	Outcome status **2.4.1** The UoA does not cause serious or irreversible harm to habitat structure and function, considered on the basis of the area covered by the governance body(s) responsible for fisheries management in the area(s) where the UoA operates.	(a) Commonly encountered habitat status	The UoA is **unlikely** to reduce structure and function of the commonly encountered habitats to a point where there would be serious or irreversible harm.	The UoA is **highly unlikely** to reduce structure and function of the commonly encountered habitats to a point where there would be serious or irreversible harm.	There is **evidence** that the UoA is highly unlikely to reduce structure and function of the commonly encountered habitats to a point where there would be serious or irreversible harm.
		(b) VME habitat status	The UoA is **unlikely** to reduce structure and function of the VME habitats to a point where there would be serious or irreversible harm.	The UoA is **highly unlikely** to reduce structure and function of the VME habitats to a point where there would be serious or irreversible harm.	There is **evidence** that the UoA is highly unlikely to reduce structure and function of the VME habitats to a point where there would be serious or irreversible harm.
		(c) Minor habitat status			There is **evidence** that the UoA is highly unlikely to reduce structure and function of the minor habitats to a point where there would be serious or irreversible harm.

2 Habitats outcome Performance Indicator Scoring Guideposts (PI 2.4.1)

The Performance Indicator Habitat outcome (PI 2.4.1) deals with the impact a Unit of Assessment (UoA) has on habitat structure and function. It is described by MSC (2014) as:

"The **UoA** does not cause **serious or irreversible harm** to **habitat structure and function**, considered on the basis of the **area(s) covered by the governance body(s) responsible for fisheries management**."

MSC intends that the scores will be determined for three different types of **habitat status**: commonly encountered, vulnerable marine ecosystems and minor encountered. For the commonly encountered habitat we attempt to match the outcome of our assessments to the MSC's **probability** terminology in order to reflect that there is no harm caused to the habitat.

In this chapter we will look into each of the highlighted elements mentioned above.

2.1 Unit of Assessment (UoA)

MSC defines a Unit of Assessment as: "The target stock(s) combined with the fishing method/gear and practice (including vessel type/s) pursuing that stock, and any fleets, or groups of vessels, or individual fishing operators or other eligible fishers that are included in an MSC fishery assessment. In some fisheries, the UoA [...] may be further defined based on the specific fishing seasons and/or areas that are included." (MSC, 2015)

The fishing methods (gear groups) dealt with are listed in Table 2.1, by country and by management area. Table 2.2 gives a description of each gear group. The inclusion of gear groups depends on the availability of data provided by the client and on the availability of parameters required for the analyses, such as depletion and recovery rate. For SDN for example, data from the Danish fishery are available but there are no parameter estimates for depletion and recovery rate. Therefore the SDN group is included in the TR group, which has most likely the most similar parameter values. For the Netherlands, beam trawl fisheries excluding pulse fisheries (BT) and demersal otter trawls (TR) are considered. For Sweden, Germany and Denmark the TR group is analysed.

In this study, we do not explicitly take target stocks into consideration (but they are, implicitly, part of the metier distinction): we specifically look at the impact of gears on seabed habitat. This means that we also do not take into account of differences in mesh size: we assume that the impact of a TR gear with 70 mm is the same as the impact of a TR gear with 100 mm. We decide to do this because we do not expect a difference in impact on the seabed between different mesh sizes, but also because of the availability of parameters needed for the analyses. Those parameters are currently only available for generic gear groups like beam trawl and otter trawl.

Note: We only analyse the bottom impact for active gears. The bottom impact of passive gears (e.g. gill nets, long line, hand line or nephrops creel pots) cannot be estimated with the available methodology. Expert knowledge tells us that the impact of these gears is very low compared to the impact of active gears. For example: gill net fisheries are allowed to carry up to 25km of net with an expected sideway impact of 1m. This amounts to a maximum of $0.05km^2$ of swept area on a daily basis and an associated fishing intensity[1] of one trawl pass every 500 days, i.e. $1/500d^{-1}$. In comparison to beam trawling, with an estimated daily swept area of $\sim5km^2$ and associated fishing intensity of one trawl pass every 50 days, i.e. $1/50d^{-1}$, gillnet fishing is considered at least one order of magnitude smaller. In our report we will not further quantify the impact.

Table 2.1 List of gear groups considered per country
Bold print shows where data for this management area and for this country were provided by the client. Gear group abbreviations are explained in table 2.2.

Countries	Kattegat (IIIas)	Skagerrak (IIIan)	North Sea (IV)	Eastern English Channel (VIId)
Denmark	TR	TR	TR	
Germany		TR	TR	
The Netherlands			BT	
		TR	TR	TR
Sweden	TR	TR	TR	

Table 2.2 Description of gear groups

Gear	Gear description
BT	Beam trawl, excluding pulse fisheries and shrimp fisheries
SDN	Danish (anchor) seine
TR	Demersal otter trawls, all combined. Including: TR Skagerrak/Kattegat (rules = 120 mm or 90 mm with separator grid or very large mesh escapement); TR1 Demersal otter trawl or flyshooter, mesh size > 100 mm; TR2 Demersal otter trawl or flyshooter, mesh size 70 - 100 mm; TR PRAWN Demersal otter trawl (mesh size > 35 mm for pandalus with escapement window, sometimes with separate 120 mm codend for fish); SDN Danish Seine; and SSC Scottish seine.

2.2 Serious or irreversible harm

If no serious or irreversible harm to habitat structure and function is inflicted by a Unit of Assessment (UoA), it can obtain a positive score on Performance Indicator Habitat outcome. This “no serious or irreversible harm” means that a habitat can recover to at least 80% of its unimpacted structure, biological diversity and function within 5-20 years after the UoA would stop fishing. Serious or irreversible harm includes “the loss or extinction of habitat, depletion of key habitat-forming species or associated species to the extent that they meet criteria for high risk of extinction, and significant habitat alteration that causes major change in the structure, function, and/or diversity of the associated species assemblages” (MSC, 2014).

MSC acknowledges current limitations to the availability of methods to assess biological diversity and therefore suggests that other proxies can be used, such as species diversity (incl. species richness and species evenness) and abundance. (MSC, 2014)

[1] Fishing intensity is defined as the area swept within a grid cell (in km^2) divided by the surface area of that grid cell. Hence, a fishing intensity of 1 indicates that the total surface area is fished once in a year.

2.3 Habitat structure and function

A habitat is a chemical and bio-physical environment, including biogenic structures (MSC, 2015). The structure and function of a habitat is important in determining the ecosystem services provided by the habitat (food supply, water purification, etc.).

For MSC assessments, the habitat's structure and function (i.e. the ecosystem services that it provides), including abundance and biological diversity is of concern. Both the impact of a fishery on the habitat and on the habitat's delivery of ecosystem services are considered.

Another word which is often used when we speak about a habitat's structure and function is '**seabed integrity**'. Seabed integrity (Descriptor 6 in the Marine Strategy Framework Directive) reflects the characteristics (physical, chemical and biological) of the seabed (MSFD, 2008). These characteristics delineate the structure and functioning of marine ecosystems, especially for species and communities living on the sea floor (benthic ecosystems). To characterize the seabed it is common to distinguish various types of seabed according to: depth, substrate type and species composition.

2.4 Habitat status

In the assessment, the Unit of Assessment is scored for three different types of habitat status:

1. Commonly encountered;
2. Vulnerable Marine Ecosystems (VMEs);
3. Minor: all other habitats.

A commonly encountered habitat is a habitat that regularly comes into contact with a gear used by the UoA. In the scientific literature that assessed fishing impacts on the seabed habitat, only the sensitivity of gravel, sand and mud habitats could be determined (see reviews Collie, 2000; Hiddink et al, 2017). For pragmatic reasons we therefore consider those habitats as "commonly encountered". Because of their high sensitivity, we consider VMEs separately as for these habitats any fishing should be avoided. All remaining seabed areas are classified as 'minor'.

2.4.1 Vulnerable Marine Ecosystems (VMEs)

A Vulnerable Marine Ecosystem (VME) contains habitats that may be vulnerable to impacts from fishing activities. According to FAO guidelines (FAO, 2009: paragraph 42) VMEs have one or more of the following characteristics:

- Uniqueness or rarity: an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems.
- Functional significance of the habitat: discrete areas or habitats that are necessary for survival, function, spawning/reproduction, or recovery of fish stocks; for particular life-history stages (e.g., nursery grounds, rearing areas); or for ETP species.
- Fragility: an ecosystem that is highly susceptible to degradation by anthropogenic activities.
- Life-history traits of component species that make recovery difficult: ecosystems that are characterised by populations or assemblages of species that are slow growing, are slow maturing, have low or unpredictable recruitment, and/or are long lived.
- Structural complexity: an ecosystem that is characterised by complex physical structures created by significant concentrations of biotic and abiotic features.

FAO identifies several species groups, communities, and habitat-forming species that may form VMEs and may be indicative of the occurrence of VMEs. These are certain cold water corals and hydroids; some types of sponge-dominated communities; communities composed of dense emergent fauna where large sessile protozoans and invertebrates form an important structural component of habitat;

and seep and vent communities comprised of invertebrate and microbial species found nowhere else. If the FAO guidelines are applied in shallow and/or inshore waters, the definition of VME could include other species groups and communities.

For this study, we also consider the list of threatened and/or declining species and habitats established by OSPAR – the convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Commission, 2008).

VME databases
For the North East Atlantic, there are three different databases that are relevant when considering VMEs. ICES and NAFO set up a database on the distribution and abundance of VMEs (and organisms considered to be indicators of VMEs) across the North Atlantic. OSPAR has a habitat reference database: a spatial dataset with habitats contained within the OSPAR list of threatened and/or declining species and habitats covering the North East Atlantic. FAO has a database containing records of management measures implemented by Regional Fisheries Bodies throughout the world's oceans.

Online accessible databases
ICES/NAFO: http://www.ices.dk/marine-data/data-portals/Pages/vulnerable-marine-ecosystems.aspx
OSPAR: http://www.emodnet-seabedhabitats.eu
FAO: http://www.fao.org/in-action/vulnerable-marine-ecosystems/en/

VMEs in the greater North Sea
We retrieved data from the online databases from ICES and from OSPAR, on respectively the 23rd of August 2017 and on the 31st August of 2017. In Figure 2.1 the positions of VMEs included in the ICES database are plotted; in Figure 2.2 the positions of threatened and/or declining species and habitats according to OSPAR are plotted. For the OSPAR data, also the list of habitats included on the map is presented (Table 2.3).

Figure 2.1 *Map of VME habitats based on the ICES data. Source: http://vme.ices.dk/map.aspx, (data downloaded 23-08-2017).*

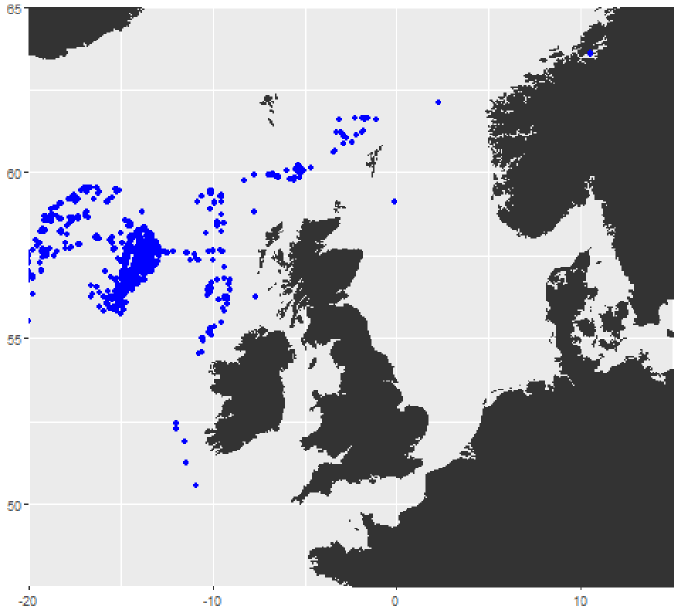


Figure 2.2 *Map of surveyed habitats contained within the OSPAR list of threatened and/or declining species and habitats. Source: http://www.emodnet-seabedhabitats.eu (data downloaded 31-08-2017).*

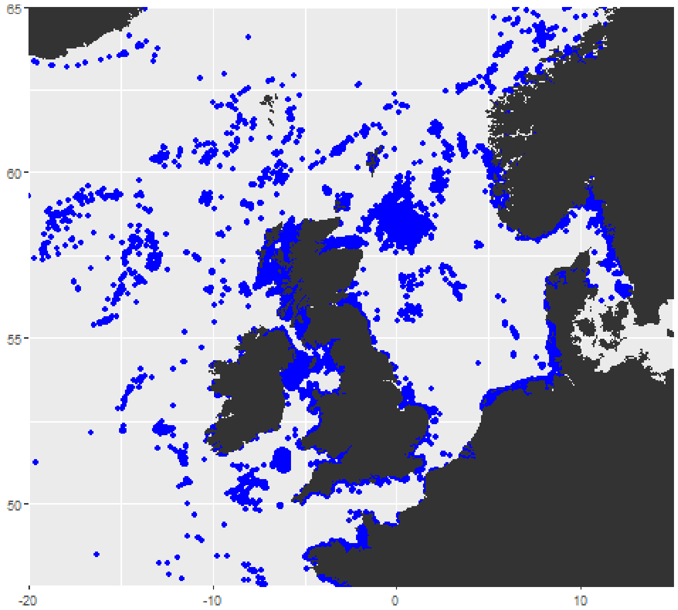


Table 2.3 OSPAR habitats on the list of threatened and/or declining species and habitats established by OSPAR (OSPAR Commission, 2008).

Habitat types included in the data retrieved from http://www.emodnet-seabedhabitats.eu *(see also Figure 2.2)*

Habitat
Carbonate mounds
Coral gardens
Deep-sea sponge aggregations
Intertidal mudflats
Intertidal Mytilus edulis beds on mixed and sandy sediments
Littoral chalk communities
Lophelia pertusa reefs
Maerl beds
Modiolus modiolus horse mussel beds
Ostrea edulis beds
Sabellaria spinulosa reefs
Seamounts
Sea-pen and burrowing megafauna communities
Zostera beds

2.5 Probability

MSC defined the scores for the Performance Indicator on the probability that the UoA reduces structure and function of the commonly encountered habitats to a point where there would be serious or irreversible harm (MSC, 2014):

- Unlikely (SG60): < 40th percentile of the indicator used
- Highly unlikely (SG80): < 30th percentile
- Evidence (SG100): ≤ 20th percentile

Definitions used by MSC considering this subject are (MSC, 2015):

Scoring Guidepost, SG: the benchmark level of performance established by the assessment team in respect of each numeric score or rating for each indicator sub-criterion.

Probability interpretations "highly (un)likely": Probability interpretations of terms such as "Highly likely" are provided for general guidance and for when quantitative measures are available, not to imply that a quantitative measure is required.

Evidence: Verifiable information or records pertaining to the quality of an item or service or to the existence and implementation of a quality system element, which is based on visual observation, measurement or test that, can include independent witnesses, peer-reviewed scientific research, or otherwise verifiable and credible information.

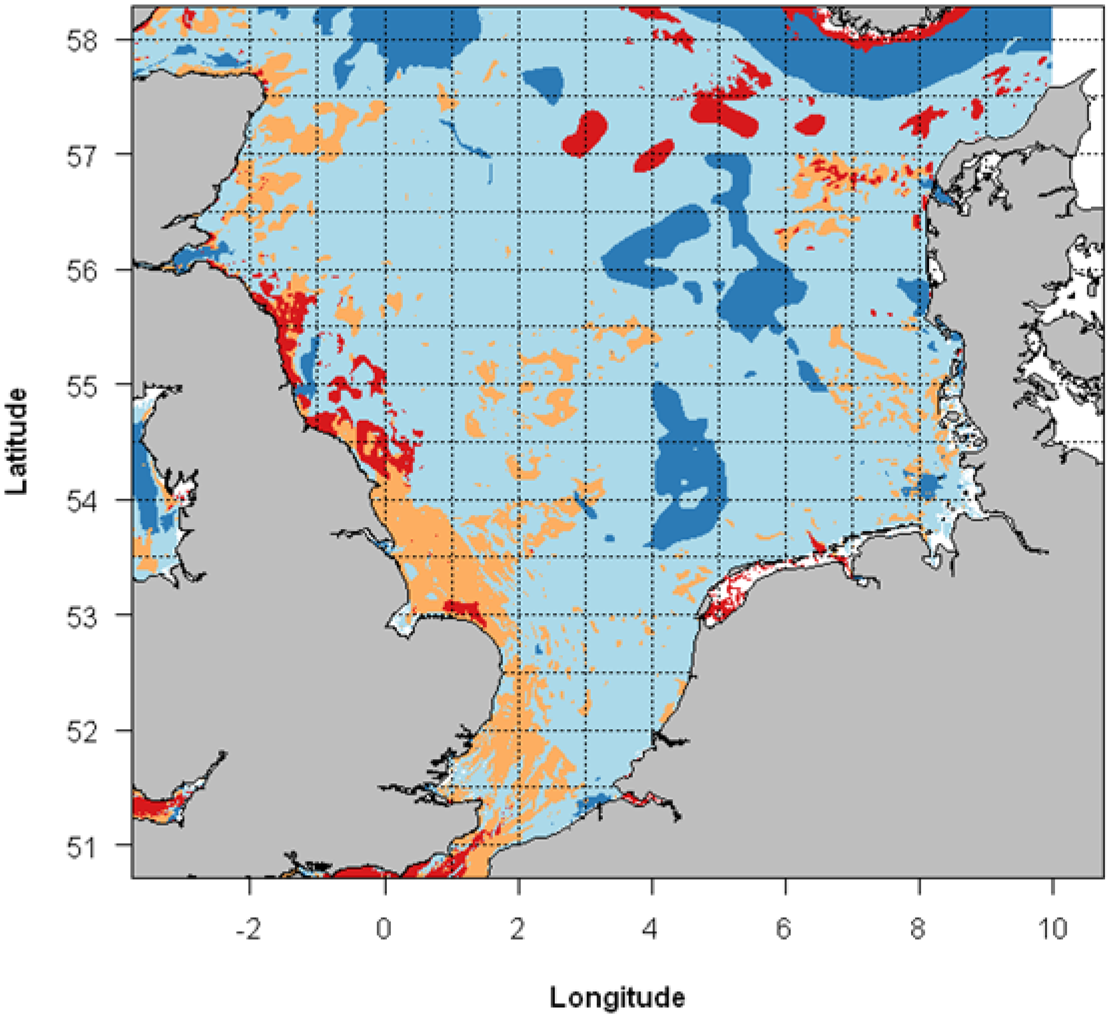
3 Methods

3.1 Data

VMS and logbook data for vessels represented in the Unit of Assessment (UoA) were used for the years 2014-2016 for the Netherlands, Germany and Sweden. For Denmark, data from the years 2013-2015 were analysed because the 2016 were not available. VMS and logbook data were combined to associate VMS pings with gear utilisation. VMS pings were classified as 'fishing' or 'other behaviour' and only fishing pings were retained. Fishing tracks in between two consecutive VMS pings were reconstructed to obtain high-resolution fishing impact data. Interpolated tracks were thereafter aggregated at a regular grid with a 1-minute by 1-minute longitudinal and latitudinal scale. The process followed is described in more detail in Hintzen et al. 2010, Hintzen et al. 2012 and Eigaard et al. 2015. Historic fishing intensity was obtained from Eigaard et al. 2016.

Habitat information was obtained from EMODnet EU Sea Map and classified as coarse, sand, mud or other (see Figure 3.1). Habitat specific recovery rates and gear specific instantaneous impact rates were obtained from the EU FP7 project BENTHIS that fed directly into the ICES process that has led to the "*EU request on indicators of the pressure and impact of bottom-contacting fishing gear on the seabed, and of trade-offs in the catch and the value of landings*" advice (ICES 2017) which we took as the basis for this study.

Figure 3.1 *Eunis habitats map. Dark blue: mud, blue: sand, yellow: coarse, and dark red: other (often rock).*



3.2 Methodology

To assess whether a UoA does not cause serious or irreversible harm to habitat structure and function, new methodology had to be developed. In this report, we rely on methodology developed in collaboration with a large team of WMR employees, through the EU FP7 project BENTHIS and the ICES process that has led to the ICES advice: "*EU request on indicators of the pressure and impact of bottom-contacting fishing gear on the seabed, and of trade-offs in the catch and the value of landings*" (ICES, 2017a).

Using this methodology, ICES advice lists two types of methodologies, i.e. a longevity method and a population dynamic (PD) method, that are suitable to assess the impact of fishing and provide some metric for seabed status which can be used to determine if the UoA caused serious or irreversible harm. The longevity method estimates the shift in the longevity composition of the benthic community in response to trawling. It can be considered a proxy for biodiversity. The PD method indicates how bottom trawling affects the biomass of the benthic community relative to an undisturbed situation. The two metrics are complementary in that they both describe structural aspects of the benthic community that determine its functioning, e.g. bioturbation, facilitation, nutrient cycling, reproductive output, secondary production, and hence its capacity to deliver ecosystem services. Both methods have been considered by a large group of scientists, appear in peer-reviewed literature (Rijnsdorp, 2016; Pitcher, 2017; Hiddink et al., 2017) and were carefully scrutinized during the ICES process that culminated in the ICES 2017 advice.

As stated above, the PD and the longevity methods measure different aspects of the impact: reduction of benthic biomass and the change in community composition, respectively. In areas with high natural disturbance, the community is composed of shorter lived organisms having a faster recovery. As the PD method estimates the recovery rate of the habitat from the longevity composition, it incorporates the effect of natural disturbance. The PD method does not include an effect of natural disturbance on the depletion rate.

Our assessment was primarily based on the Population Dynamic (PD) method as this specifically considers recovery. The longevity method does not allow us to estimate the recovery rate, meaning it cannot be used to assess the impact according the MSC criteria. While using the PD method, we applied the parameters that apply to the most sensitive part of the benthic community, i.e. that with the highest longevity. By doing that, we were able to distinguish a "worst case" (i.e. the slowest recovery possible). Hence, our analysis distinguishes two sensitivities, the first being the PD based on average recovery rates and a worst case based on lowest recovery rates.

The assessment consists of a number of steps:

1) Define the current state of the Seabed Integrity (SI);
2) Define the study area for each of the UoAs;
3) Derive fishing intensity for each of the UoAs per year;
4) Calculate recovery and biomass based on the PD methodology;
5) Define indicators to assess SI and to assess whether serious or irreversible harm was caused;
6) Create three fleet configurations for the analysis to evaluate the effects of the UoA in a wider context;
7) Evaluate SI over a period of 20 years without fishing to assess whether recovery takes place.

1) The **current state of SI** for each analysis was derived based on the historic fishing intensity (HFI), following:

$$SI_0 = 1 - \frac{d}{r} * HFI$$

Where *d* refers to the instantaneous depletion rate of a specific gear and *r* indicates the recovery rate which is habitat specific. The benthic invertebrate community consists of many different taxa that differ in their sensitivity to fishing disturbance. This difference in sensitivity is reflected in the parameterisation which distinguishes between an average sensitivity and a high sensitivity. Both parameters were taken from ICES 2017 advice and habitats as given in the EUNIS map in section 3.1.

HFI was taken directly from Eigaard et al. 2016 and is therefore identical for all UoAs. Depending on the sensitivity analyses, the SI is different. Calculations take place per grid cell and each grid cell is associated with one dominant habitat only. Where different gear types had been active in one grid cell, *d* was weighted according to the effort (in area swept by each gear type). HFI is finally calculated as the sum of all swept area estimates summed for all gear types divided by the surface area of a grid cell.

2) The **study area** for each of the UoAs was defined as the footprint of the entire fishery (grid cells trawled by a gear and management area specific) as observed in Eigaard et al. 2016. If areas were visited by the UoAs that were not part of the footprint they were excluded from the analyses. The volume of these areas is small compared to the footprint areas.

3) **Fishing intensity** (FI) per grid cell was calculated from the VMS data as described in section 3.1. Different metiers were clustered into only 3 gear types: BT, TR and SDN. The SI after impact is then derived as:

$$SI_1 = SI_0(1-d)^{FI}$$

4) **Recovery time** is calculated following the equation below.

$$RT = -\frac{1}{r}\ln(\frac{\frac{SI_1}{\theta}-SI_1}{1-SI_1)})1$$

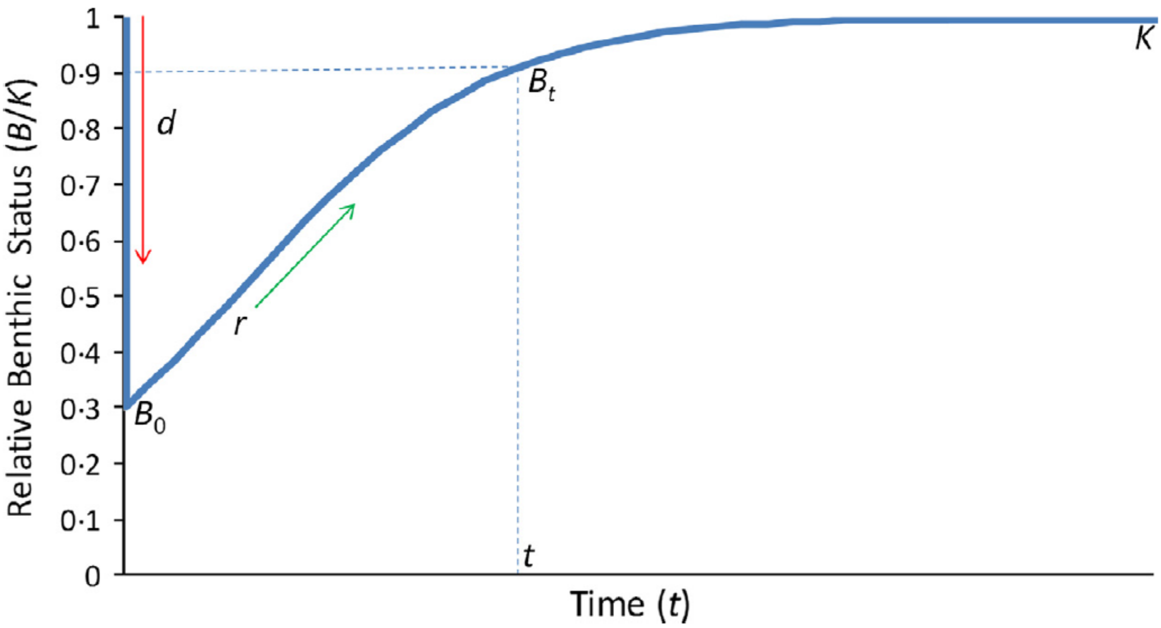
r is recovery rate (i.e. relative increase of biomass per year), θ is any fraction of carrying capacity (K) at which recovery is deemed to have occurred and fraction *d* is the depletion caused by fishing. Biomass is calculated following:

$$B_t = SI_1 \frac{1}{SI_1 + (1-SI_1)e^{-rt}}$$

Where t is time in years after the impact.

A schematic of biomass and recovery is given in Figure 3.2.

Figure 3.2 *Schematic representation of a trawl impact and recovery experiment, with changes in abundance (B) as a proportion of carrying capacity (K) described with the logistic equation. Abundance is depleted from K to B_0 by experimental trawling at time 0 depending on depletion rate d and number of trawls T, i.e. $B_0 = (1 - d)^T$. Recovery follows at rate r so that abundance is B_t after time t, eventually approaching K asymptotically. (from Pitcher et al. 2016).*



The parametrisation of the recovery rate *r* in the two formulas to calculate *RT* and B_t was based on work by the ICES WKBENTH workshop to evaluate regional benthic pressure and impact indicator(s) from bottom fishing (ICES, 2017b). Different recovery rates for the longevity classes in the benthic community were applied: see Table 3.1. The longevity composition of the benthic community of a grid cell was estimated from the habitat specific longevity compositions and the Eunis-3 habitat of the grid cell (Figure 3.1).

Note that whenever a fishing intensity would remove all biomass, we assume that 1% of its carrying capacity in biomass is replenished directly, ensuring that recovery is possible. This is not an unlikely assumption as benthic invertebrates are known to recolonize areas that were depleted.

Table 3.1 Estimates of depletion *d* and recovery rate *r* by gear and habitat type. For both parameters we distinguish between benthic taxa with an average sensitivity and a high sensitivity to fishing disturbance. (ICES, 2017b)

TR: demersal otter trawls, BT: beam trawl, TD: dredge

Gear type	Habitat type	Average sensitivity		High sensitivity	
		d	*r*	*d*	*r*
TR	other	0.06	0.525	0.16	0.133
	coarse	0.06	0.487	0.16	0.123
	sand	0.06	0.495	0.16	0.126
	mud	0.06	0.583	0.16	0.148
BT	other	0.14	0.525	0.25	0.133
	coarse	0.14	0.487	0.25	0.123
	sand	0.14	0.495	0.25	0.126
	mud	0.14	0.583	0.25	0.148
TD	other	0.20	0.525	0.30	0.133
	coarse	0.20	0.487	0.30	0.123
	sand	0.20	0.495	0.30	0.126
	mud	0.20	0.583	0.30	0.148

5) A **recovery criterion** was used to assess whether serious or irreversible harm to habitat structure and function would be caused by the UoA. MSC states that habitats should be able to recover to at

least 80% of its unimpacted structure, biological diversity and function within 5-20 years after the UoA would stop fishing (see also paragraph 2.2). Two different indicators were applied to assess whether this 80% is obtained (see also Table 3.2):

1. 80% of the surface area should be recovered. In practice this means that 80% is recovered up to at least 95% unimpacted uncertainty threshold (UUT). We call this the "**T80% > 0.95K**" indicator.
2. 100% of the surface area has a biomass above 80% of unimpacted, i.e. > 0.8. We call this the "**100% > 0.80K**" indicator.

Table 3.2 Recovery criteria: indicators for serious or irreversible harm. SI stands for Seabed Integrity; K is the carrying capacity. For the criteria to be met, the top 80% of the gridcells should have an SI of 0.95K and/or 100% of the gridcells should have an SI of more than 0.80K.

SI threshold grid cell	80% surface	100% surface
0.95K	T80% > 0.95K indicator	
0.80K		100% > 0.80K indicator

These two recovery criteria can be applied in a more or less restrictive way. The most restrictive application would require both criteria to be met. Alternatively it could be sufficient if at least one of the criteria is met. Something in between would require additional rules if the other criterion is not met. For example it could be argued that if <80% (hence not meeting the 1st criterion, but > 70%) of the surface area is (only just) below the UUT while the remaining area percentage is unimpacted, the seabed should be considered sufficiently recovered to allow the UoA to pass the criterion.

6) For three **fleet configurations** the above indicators were calculated: a so called 'All', an 'All except UoA' and the 'Only UoA' configuration.

- The All configuration includes the whole fleet, i.e. a certain gear group in a certain management area for all countries together (for example: TR North Sea). The results for this fleet configuration indicate what on average the seabed integrity would be if no differences to recent fishing intensity would take place.
- The All except UoA fleet configuration consists of trips within a certain gear group and management area, without the trips belonging to the UoA. The results of this fleet configuration provide insight into the extent to which the habitat would improve if there would be no fishing by the UoA. If the difference is small between the 'All' and 'All except UoA', one may assume that the impact of the UoA is currently limited.
- To quantify the impact of the UoA alone, the indicators are calculated for the UoA of one country in isolation from any other fleet. Here, the starting condition (SI_0) equals 1 rather than being based on the HFI, i.e. in the simulation the UoA starts fishing on virgin ground. For 2015 and 2016, the SI starting conditions follow from the fishing activity and recovery in 2014.

7) Consequently, the seabed integrity **SI was projected 20 years into the future** assuming no fishing activity. This exercise was repeated for the community after the 2014 impact, after the 2015 impact and after the 2016 impact. Hence, the 20 year period projection for the 2014 impact ends in 2034 and for the 2016 impact in 2036.

Finally, an average SI of 2014-2016 was taken per grid cell and the range of SI values over all grid cells in the study area are shown in the results.

Table 3.3 Summary of tested sensitivities and variables for each Unit of Assessment (UoA)

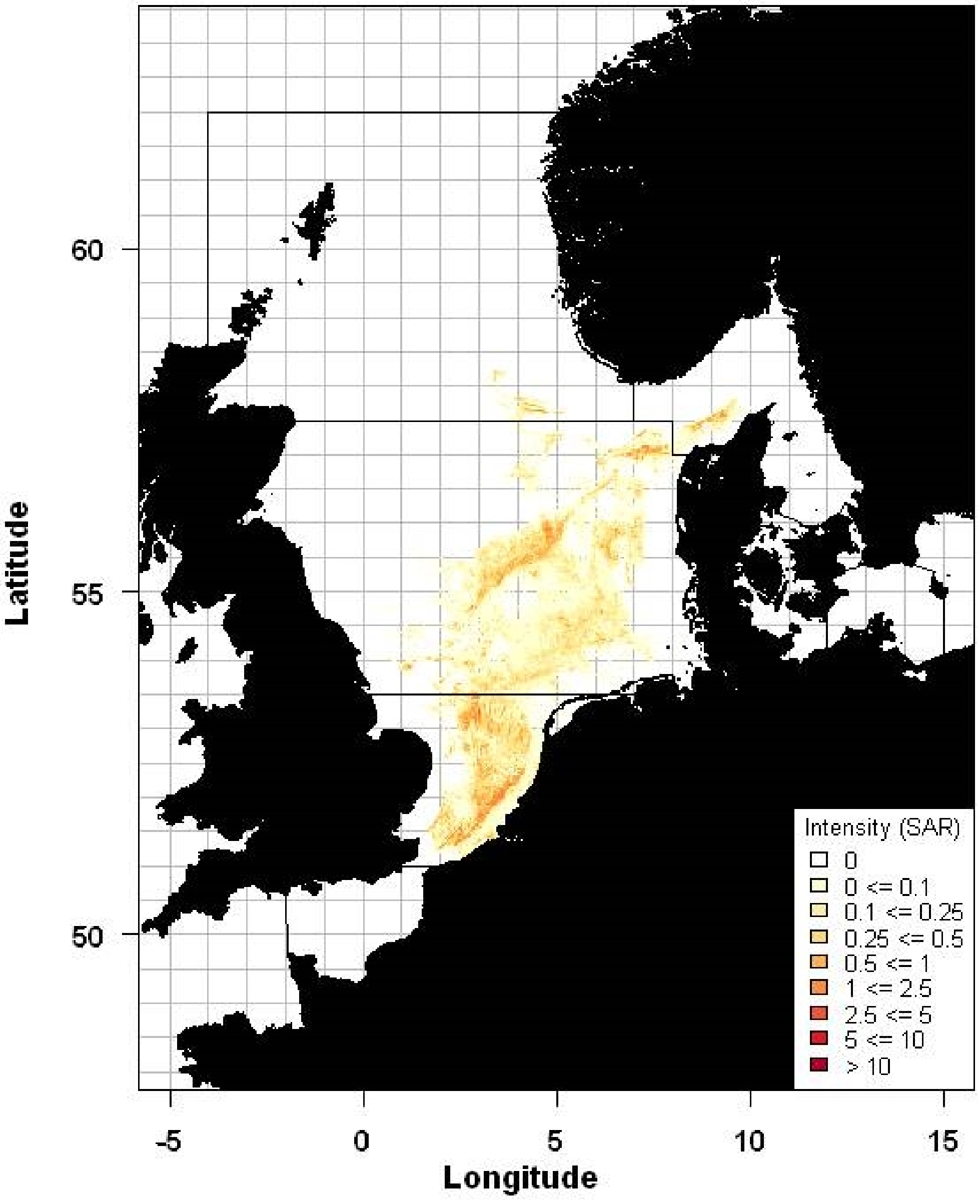
Variable	Values
Sensitivity	I: default Population Dynamic (PD), average recovery rates II: PD + worst case, slowest recovery rates
Fleet configuration	All All, except UoA UoA only
Time steps	t_{start} – start year, before ending of fishing t_0 – same year, immediately after fishing t_1 – 1 year after fishing has stopped t_5 – 5 years after fishing has stopped t_{10} – 10 years after fishing has stopped t_{20} – 20 years after fishing has stopped
Recovery criteria	100% > 0.80K – All grid cells in the study area have an SI of at least 0.80K T80% > 0.95K – the 80% of grid cells which are least impacted have an SI of more than 0.95K

4 Results

For each country and each Unit of Assessment (UoA) the scenarios and variables as described in chapter 3 were applied. The results are presented by country, gear group and management area in Annex I to IV. A more extensive interpretation of the results is included for the Dutch beam trawl fishery in the North Sea (paragraph 4.1). By means of this example, the reader should be able to interpret the results for the other UoAs as well. A summary table of the results per UoA and per country is presented in paragraph 4.2. Paragraph 4.3 deals with overlap in space between the studied UoAs and Vulnerable Marine Ecosystems (VMEs).

4.1 Interpretation of the results for the Dutch beam trawl unit

Figure 4.1 Footprint & fishing intensity for the Dutch beam trawl (BT) UoA in 2014-2016.



The results of the analyses for the Dutch beam trawl unit in the North Sea are presented in Annex III: Table III.1 and Table III.1. These tables contain the exact same data as Table 4.1 and Table 4.2 printed below.

First we have a look at the results of **Sensitivity I** (Table 4.1), our default Population Dynamic scenario with average recovery rates.

- We start with fleet configuration ‘all’, where the average Seabed Integrity SI is calculated for the whole fleet. Our indicator ‘100% > 0.80K’ has a starting value of 0.02K: this means that biomass is at 2% of the carrying capacity K. After impact, SI decreases to a value of 0.01K. Only when fishing is stopped for 20 years, the SI will be able to recover to ‘100% > 0.80K’. Our other indicator, ‘T80% > 0.95K’ tells us what the average SI is for the 80% least impacted grid cells. The starting value for the whole fleet is 0.69K. After impact it decreases and when fishing is stopped it recovers – after 10 years we reach a situation in which ‘T80% > 0.95K’.
- If we consider the whole fleet without the Dutch BT unit (‘All except UoA’), we also reach a situation of ‘100% > 0.80 K’ after 20 years. ‘T80% > 0.95K’ is reached after 5 years, which is quicker than for the ‘All’ fleet configuration.
- When assessing the Dutch BT unit in isolation (‘Only UoA’), ‘100% > 0.80K’ is reached after 5 years, while the ‘T80% > 0.95K’ remains above any threshold from the start.
- Conclusion for this UoA when applying Sensitivity I: the recovery criterion is met within 20 years for both indicators, meaning that this UoA does not cause serious or irreversible harm to the habitat. If only the ‘T80% > 0.95K’ indicator would be considered, the criterion is met from the beginning. If it would be decided that both indicators should be above the threshold value, the criteria is met 5 years after fishing has ceased.

Next, we consider the results for **Sensitivity II**, where the Population Dynamic scenario is combined with the slowest recovery rates (‘worst case’) (Table 4.2).

- For the whole fleet (‘All’) and the whole fleet without the Dutch BT unit (‘All except UoA’), the recovery criteria are not met within 20 years.
- For the Dutch BT unit in isolation (‘Only UoA’), the average SI of the total area does not reach the required value higher than 0.80K within 20 years. The 80% of least impacted grid cells have an average starting SI above 0.95K. After impact it is reduced below 0.95K and after 5 years without fishing the average SI above 0.95K again.
- Conclusion for this UoA when applying Sensitivity II: the recovery criterion is met within 5 years only for the ‘T80% > 0.95K’ indicator. If it is decided that at least one indicator should reach its threshold value, this would mean that the UoA does not cause serious or irreversible harm to the habitat. However, the other indicator does not meet its threshold value within 20 years. So if it would be decided that both indicators (or the most stringent one) should be above the threshold value, the recovery criterion is not met within 20 years after fishing has ceased and the conclusion would be that the UoA causes serious or irreversible harm to the habitat.

Table 4.1 Proportion of the gear footprint fulfilling the recovery criterion: Dutch beam trawl in the North Sea. Sensitivity I (PD), average recovery rates.

Contents are equal to those of Table III.1 in Annex III. SI is the Seabed Integrity expressed as proportion of carrying capacity K. Values in the green cells meet the indicator for serious or irreversible harm. Values are green when the indicator value is above threshold.

Fleet configuration	Recovery criterion	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
All	100% > 0.80K	0.02	0.01	0.02	0.10	0.57	0.99
	T80% > 0.95K	0.69	0.58	0.69	0.94	1	1
All except UoA	100% > 0.80K	0.02	0.01	0.02	0.10	0.57	0.99
	T80% > 0.95K	0.70	0.60	0.71	0.95	1	1
Only UoA	100% > 0.80K	0.54	0.33	0.45	0.86	0.99	1
	T80% > 0.95K	0.99	0.97	0.98	1	1	1

Table 4.2 Proportion of the gear footprint fulfilling the recovery criterion: Dutch beam trawl in the North Sea. Scenario II "PD + worst case longevity".

Contents are equal to those of Table III.2 in Annex III. SI is the Seabed Integrity expressed as proportion of carrying capacity K. Values are green when the indicator value is above threshold.

Fleet configuration	Recovery criterion	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
	T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
	T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
Only UoA	100% > 0.80K	0.210	0.084	0.094	0.147	0.245	0.533
	T80% > 0.95K	0.955	0.921	0.929	0.957	0.977	0.993

4.2 Summary of tables

We summarised the results of recovery that are presented in Annex I-IV for each Unit of Assessment (UoA) in Table 4.3. Based on the analyses for the fleet configuration 'Only UoA', we list the number of years after which the indicators for recovery meet their threshold. The last column shows the highest value of both indicators, which enables to assess whether the recovery criterion is met if both indicators should be above their threshold value.

When Sensitivity I is applied, the recovery criterion is met for all indicators meaning that none of the UoAs causes serious or irreversible harm to the habitat. When Sensitivity II is applied – the worst case scenario – the '100% > 0.80K' indicator does not meet its threshold within 20 years for the following UoAs:

- Danish TR in the North Sea and in the Skagerrak
- German TR in the North Sea
- Dutch BT and TR in the North Sea
- Swedish TR in the Skagerrak

Table 4.3 Proportion of the gear footprint fulfilling the recovery criterion by Unit of Assessment (UoA)

Summary of the tables presented in Annex I-IV for fleet configuration 'Only UoA'. Values are green when the indicator value is above threshold.

Country	UoA	Sensitivity	Recovery Criterion by Indicator		
			100% > 0.80K	*T80% > 0.95K*	*Both*
Denmark	TR_North Sea	I	20	0	20
		II	>20	5	>20
	TR_Skagerrak	I	10	1	10
		II	>20	10	>20
Germany	TR_North Sea	I	10	0	10
		II	>20	0	>20
	TR_Skagerrak	I	1	0	1
		II	20	0	20
The Netherlands	BT_North Sea	I	5	0	5
		II	>20	5	>20
	TR_North Sea	I	5	0	5
		II	>20	0	>20
	TR_Skagerrak	I	0	0	0
		II	10	0	10
	TR_English Channel	I	0	0	0
		II	10	0	10
Sweden	TR_North Sea	I	0	0	0
		II	20	0	20
	TR_Skagerrak	I	5	1	5
		II	>20	20	>20
	TR_Kattegat	I	5	0	5
		II	20	1	20

4.3 VMEs

By means of overlaying ICES data on VMEs and OSPAR data on threatened or declining species and habitats with VMS data by UoA, we could list the occurrences of overlap between the fisheries and the areas with sensitive habitats. The swept area by country and UoA in areas with VMEs or threatened or declining species and habitats is presented by year in Table 4.4.

There hardly is an overlap with VMEs from ICES data, but the overlap with habitats containing threatened or declining based on OSPAR data shows higher overlap.

Table 4.4 Swept area by Unit of Assessment (UoA) in grid cells where VMEs (according to ICES) or threatened and/or declining species and habitats (according to OSPAR) are observed.

Grid cells of 1x1 minute

Country	UoA	Source	Year	Swept Area overlaying sensitive areas (km^2)
Denmark	BT_North Sea	OSPAR	2013	37,2
		OSPAR	2014	52,7
		OSPAR	2015	54,0
	SDN_North Sea	OSPAR	2013	2,5
		OSPAR	2014	5,3
		OSPAR	2015	3,1
	TR_North Sea	ICES	2013	1,7
		OSPAR	2013	557,5
		OSPAR	2014	99,1
		OSPAR	2015	245,1
	TR_Skagerrak	OSPAR	2013	2,5
		OSPAR	2014	0,3
		OSPAR	2015	1,9
Germany	TR_North Sea	ICES	2015	0,1
		OSPAR	2014	10,9
		OSPAR	2015	14,2
		OSPAR	2016	16,0
The Netherlands	BT_North Sea	OSPAR	2014	2,2
		OSPAR	2015	1,5
		OSPAR	2016	0,9
	TR_Eng. Channel	OSPAR	2015	0,0
		OSPAR	2016	0,0
	TR_North Sea	OSPAR	2014	30,7
		OSPAR	2015	4,2
		OSPAR	2016	8,8
Sweden	TR_Kattegat	OSPAR	2014	20,2
		OSPAR	2015	19,2
		OSPAR	2016	24,3
	TR_Skagerrak	OSPAR	2014	868,0
		OSPAR	2015	760,7
		OSPAR	2016	871,9

5 Discussion and recommendations

This report shows a first attempt to develop an operational performance indicator for assessing a specific fisheries' impact on the seabed. This Habitats outcome indicator should reflect that *"The Unit of Assessment (UoA) does not cause serious or irreversible harm to habitat structure and function, considered on the basis of the area(s) covered by the governance body(s) responsible for fisheries management".* Where "does not cause serious or irreversible harm" implies that *"a habitat can recover to at least 80% of its unimpacted structure, biological diversity and function within 5-20 years after the UoA would stop fishing"*.

Since the MSC criteria on seafloor impact caused by fisheries are not without ambiguity, this study provides in a tentative interpretation of the guidance provided by MSC. In this innovative study we made a first attempt to apply state-of-the-art methodologies to calculate the impact of fishing on the seabed in an assessment against specific criteria. We present a bandwidth of results: from a relatively strict interpretation of the criteria to a looser interpretation of the criteria. As the discussion on the interpretation of the criteria is as yet unresolved there is no scientific basis for any preferred interpretation: this is up to the certifying body.
We analysed two possible interpretations and hence two possible performance indicators:

- T80% > 0.95K: the top 80% of least impacted grid cells have a Seabed Integrity (SI) of at least 0.95 K, meaning that biomass is at more than 95% of the carrying capacity (K).
- 100% > 0.80K: all grid cells in the study area have an SI of at least 0.80 K, so biomass is more than 80% of K.

Of which the latter appears to be the more stringent. Another possible interpretation is to estimate the mean status and its recovery, including the areas that are not trawled by the UoA. We have not included this indicator because this indicator will be determined by the size of the untrawled areas relative to the trawled area more than by the impact in the trawled area (see below).

The calculation of the indicators was based on state-of-the-art methodologies to assess fisheries impact on the seabed. These methodologies and their parametrisation allowed us to distinguish two scenarios ('sensitivities'):

I. Average situation (based on the median values): Strict Population Dynamic approach;
II. "Worst case" (parametrisation based on the 5% percentile of each of the two parameters that determine the benthic invertebrate communities' sensitivity).

In addition we evaluated the outcome of the assessment for three different fleet configurations ('All', 'All except UoA' and 'Only UoA'). The 'All' configuration gives us the baseline: it shows the current situation. The 'All except UoA' shows us to some extent how the UoA contributes to the current situation. But it does not yet *quantify* the impact of the UoA, because in reality the UoA does not operate in isolation. That is why we also have the 'Only UoA' configuration, where we start the simulation on virgin ground: the first impact on a habitat is always worse than the second or third etc..

Sensitivity II can be applied in habitats where the structure and function of the benthic ecosystem is determined by taxa that are particularly vulnerable to bottom trawls. The application to the habitats in this study does not relate to specific taxa but assumes a generic occurrence of insensitive and sensitive species and should therefore be interpreted as such.

The above considerations illustrate that the definition of the UoA and the different interpretations of what this assessment is supposed to show determine the outcome of this assessment.

Pertaining to the three different types of habitat status:

1. Commonly encountered;
2. Vulnerable Marine Ecosystems (VMEs);

3. Minor: all other habitats.

We propose to apply different approaches to assess any UoA in relation to those types. For the commonly encountered habitats recovery can be assumed relevant and the performance indicators based on the different interpretations apply. For the VMEs the assumption is that recovery is negligible and that therefore more stringent criteria should apply, e.g. no overlap between the UoA and the VME should occur in order to allow accreditation. However, the definition of the VMEs is still an issue which needs to be resolved (see paragraph 5.3).

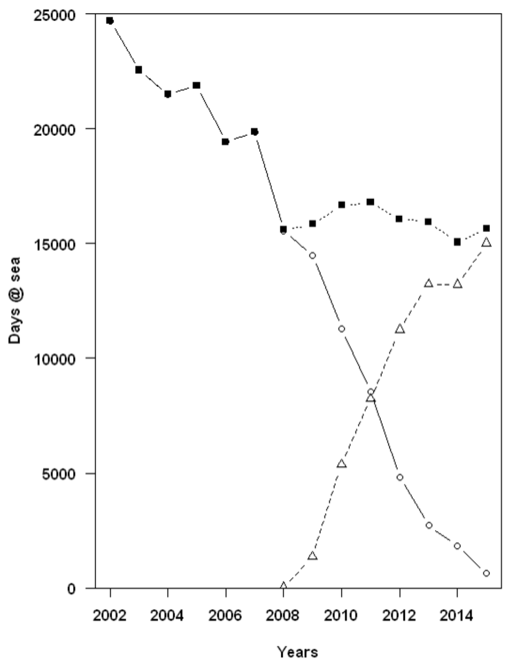
Finally we want to emphasize that this exercise is a first attempt to apply state-of-the-art methodologies to calculate the impact of fishing on the seabed in an assessment against specific criteria. If anything, this exercise has shown that the possible interpretations of the MSC criteria need to be clarified before the current methodology to assess a fishing fleet's impact on the seabed can be applied in such an assessment. We have attempted to provide solutions and highlight issues that prevent a straightforward application of the methods in such an assessment. We are keen to engage in a (further) discussion with MSC on how to resolve these issues in order to conduct such an assessment. Needless to say that as it currently stands the outcome of this assessment should not be used for accreditation of any of the UoA considered.

5.1 Definition of the Unit of Assessment

Shifts within a UoA in terms of the (number of) vessels included have an effect on the actual impact of the UoA on the seabed. As an example we take the beam trawl unit of the Netherlands: this particular UoA has recently undergone major changes with the introduction of the pulse trawl. The subsequent shift of much of the vessels to this gear caused a major reduction in number of vessels in what has now become the beam trawl UoA (Figure 5.1). This has markedly reduced the impact this UoA could have had and points to the issue that any UoA can be defined such that by its sheer size (or lack thereof) it will never compromise the "serious or irreversible harm" criterion.

We cannot assess whether this issue is also relevant for other UoAs, but the possibility of these changes in how the UoA is defined and its implications for the outcome of such an assessment should be taken into account.

Figure 5.1 *Effort in the Dutch BT group: black squares show the total number of days at sea per year; the circles show the traditional beam trawl fishery; and the triangles represent the pulse trawl fishery.*



5.1.1 Consequences of expansion of a UoA

If a UoA receives accreditation by MSC, it implies that other fishing vessels that were not part of the UoA, but do carry similar gear and target similar species, could opt to become part of the UoA in order to benefit from the accreditation too. This could mean that a UoA expands after accreditation, which is likely to result in a higher impact on the seabed habitat(s). Whether or not the issue of definition of the UoA, specifically in relation to its size and composition in terms of fishing vessels is sufficiently covered by the current MSC process is open for debate and can be evaluated upon request. To that end one would need to quantify how fishing vessels aggregate over time and space and how an increase in the UoA would alter the habitat potential to recover. A doubling of the UoA does not necessarily result in twice as much habitat impacted but could tip some areas into such a depleted state that recovery in 5-20 years is impossible. Alternatively, we provide the status of the habitat and potential of recovery based on the historic fishing activity by gear group as obtained from Eigaard et al. 2016.

5.2 Definition of the reference area

When assessing a UoA this was always done for a specific reference area. This is because in the study area (the North Sea), a large area is not impacted by the mobile bottom gears that are studied here and hence any assessment would show that a large proportion of the seabed is not affected simply because the fleet has never fished there. These areas with a historic fishing pressure of 0 are relevant when considering the overall impact of fisheries, but bias the perception that we may give here on the impact of the fishery. If for example 90% of the North Sea is never trawled by a UoA, it would almost automatically indicate that the fishery has no adverse effect on habitat quality (as 90% of the habitat is in pristine condition). However, if 90% of the North Sea is un-exploitable to this fishery, the remaining 10% is far more informative. It is therefore advisable to only consider the exploitable area of a UoA. Since the exploitable area is not defined yet for each of these UoA (and would require an extensive analysis), we relied on the historic area of impact, rather than the theoretical exploitable area. This, however, may bias the results. If, for example, a fishery historically only fished in a 1x1 mile square and continues to do so, we would define the exploitable habitat as this 1x1 mile area. Given the aggregated fishing activity in this small habitat, the biomass may not be able to recover. The exploitable habitat will in reality be much larger and the fishing footprint would be considered to be very low. Hence, investing in research to define the theoretical exploitable habitat is necessary to provide unbiased results on the impact of a single UoA here. Attempt to define the exploitable habitat for different metiers (gear + target species combinations) in the North Sea are underway but not readily available. Alternatively an assessment method needs to be developed that is not affected by this issue.

5.3 Natural disturbance

When the impact of fishing on the seabed is studied, it is relevant to also take into account that there is natural disturbance of benthic communities, too (e.g. Bricheno et al, 2015).

In areas with high natural disturbance, the community is composed of shorter lived organisms having a faster recovery. As the PD method that we applied estimates the recovery rate of the habitat from the longevity composition, it incorporates the effect of natural disturbance. The method does not include an effect of natural disturbance on the depletion rate. The longevity method takes account of the statistical relation between natural disturbance and trawling intensity. The method, however, does not provide insight in how this interaction works. The strong interaction could, but not necessarily, indicate that the PD method overestimates the impact of trawling in areas with high natural disturbance for instance due to an effect of natural disturbance on the depletion rate. This issue needs further investigation.

5.4 Definition of VMEs

When assessing the impact of a UoA on a VMEs, it is essential to be aware how this VME is defined in terms of the data used.

If we base our conclusions on the available VME data from the ICES portal, there is hardly any overlap between the fishing area of the studied UoAs and the VMEs. However, the data from the ICES VME database are obtained by a group of partners not including several key data collecting organisations around the North Sea (e.g. WMR in the Netherlands, ILVO in Belgium, Cefas in the United Kingdom, DTU Aqua in Denmark, vTI Germany, Institute of Marine Research in Sweden). This makes it likely that the data in the database do not contain all the available information on VMEs.

If we base our conclusions on the available data on threatened or declining species or habitats from the OSPAR database, much more overlap is observed.

It is recommended to assess whether the ICES and OSPAR databases can be synchronised. At the moment, there are many differences between the databases, while to some extent they are supposed to be dealing with a similar subject, i.e. vulnerable species and habitats.

6 Conclusions

The state-of-the-art methodology currently available, and described in this report, does allow the type of assessment as required to for the Performance Indicator Habitat outcome (PI 2.4.1) which deals with the impact a Unit of Assessment (UoA) has on habitat structure and function.

Since the MSC criteria on seafloor impact caused by fisheries are not without ambiguity, this study provides in a tentative interpretation of the guidance provided by MSC. In this innovative study we made a first attempt to apply state-of-the-art methodologies to calculate the impact of fishing on the seabed in an assessment against specific criteria. We present a bandwidth of results: from a relatively strict interpretation of the criteria to a looser interpretation of the criteria. As the discussion on the interpretation of the criteria is as yet unresolved there is no scientific basis for any preferred interpretation: this is up to the certifying body.

7 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V.

Furthermore, the chemical laboratory at IJmuiden has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2021 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation. The chemical laboratory at IJmuiden has thus demonstrated its ability to provide valid results according a technically competent manner and to work according to the ISO 17025 standard. The scope (L097) of de accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

On the basis of this accreditation, the quality characteristic Q is awarded to the results of those components which are incorporated in the scope, provided they comply with all quality requirements. The quality characteristic Q is stated in the tables with the results. If, the quality characteristic Q is not mentioned, the reason why is explained.

The quality of the test methods is ensured in various ways. The accuracy of the analysis is regularly assessed by participation in inter-laboratory performance studies including those organized by QUASIMEME. If no inter-laboratory study is available, a second-level control is performed. In addition, a first-level control is performed for each series of measurements.
In addition to the line controls the following general quality controls are carried out:

- Blank research.
- Recovery.
- Internal standard
- Injection standard.
- Sensitivity.

The above controls are described in Wageningen Marine Research working instruction ISW 2.10.2.105. If desired, information regarding the performance characteristics of the analytical methods is available at the chemical laboratory at IJmuiden.

If the quality cannot be guaranteed, appropriate measures are taken.

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Justification

Report C012/18
Project Number: 4311100057

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

Approved: Adriaan Rijnsdorp
Senior Researcher

Signature:

Date: 5th of March

Approved: Dr. T.P. Bult
Director

Signature:

Date: 5th of March

Annex I Fisheries Denmark

Denmark_TR – Demersal Otter Trawls including Danish Seines

Figure I.1 Footprint & fishing intensity for the Danish TR UoA in 2014-2016. Fishing intensity (SAR = Swept Area Ratio) is defined as the area swept within a grid cell (in km2) divided by the surface area of that grid cell. Hence, a fishing intensity of 1 indicates that the total surface area is fished once in a year.

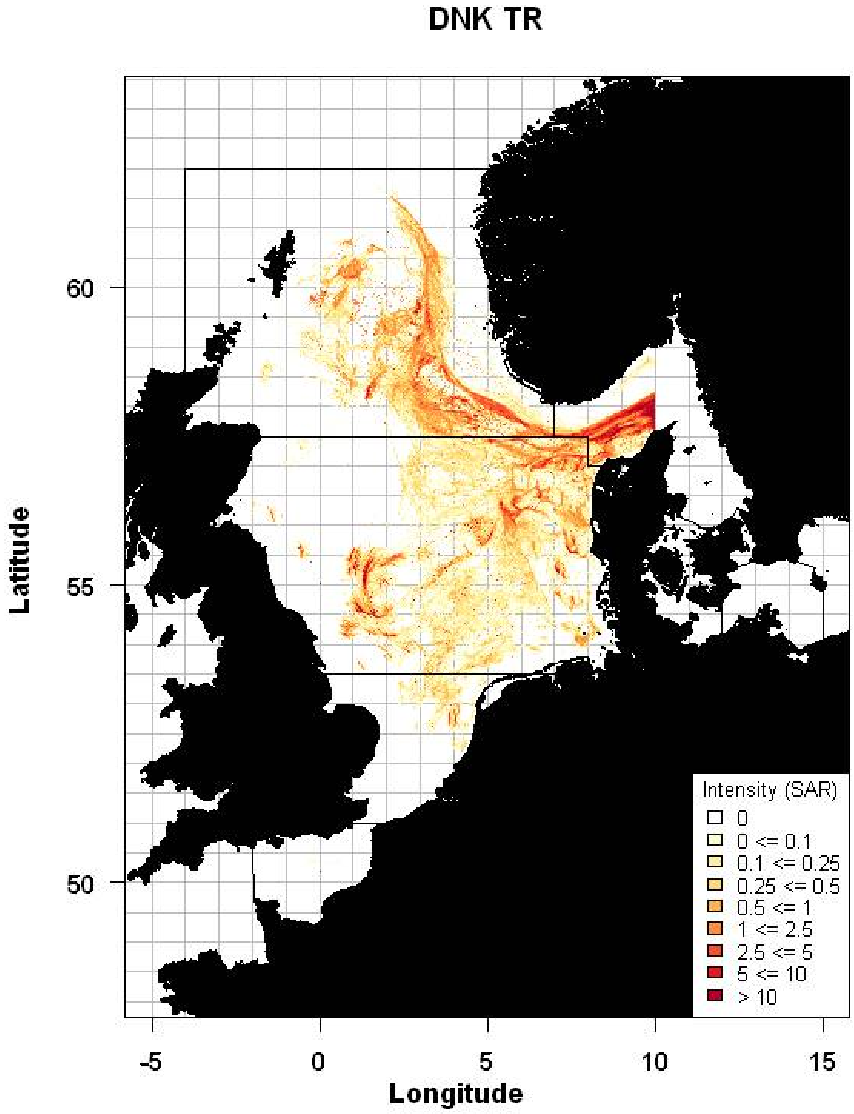
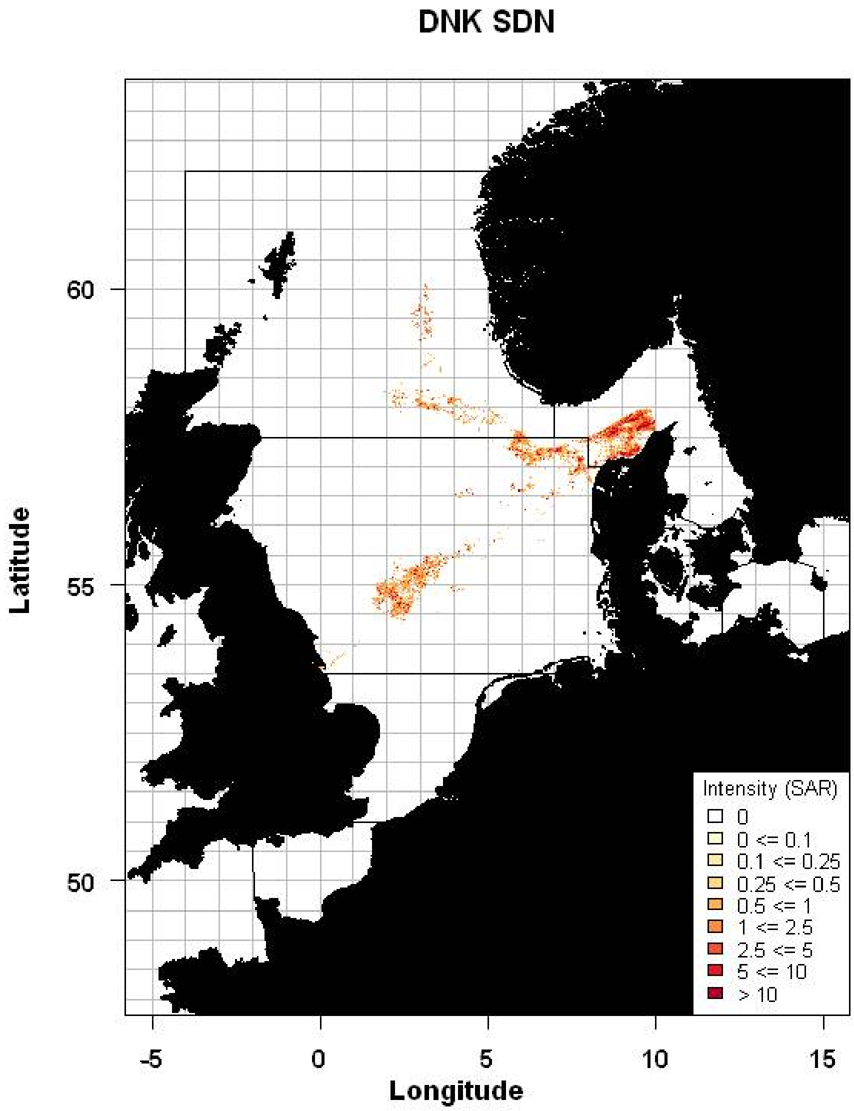


Figure I.2 Footprint & fishing intensity for the Danish SDN UoA in 2014-2016. Fishing intensity (SAR = Swept Area Ratio) is defined as the area swept within a grid cell (in km2) divided by the surface area of that grid cell. Hence, a fishing intensity of 1 indicates that the total surface area is fished once in a year.



Management area: North Sea

Table I.1 - Proportion of the gear footprint fulfilling the recovery criterion: Danish demersal otter trawl in the North Sea. **Sensitivity I (PD), average recovery rates**.

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR North Sea	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.745	0.646	0.753	0.960	0.997	1
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.754	0.659	0.764	0.962	0.997	1
	Only UoA	100% > 0.80K	0.021	0.013	0.021	0.134	0.648	0.996
		T80% > 0.95K	0.994	0.975	0.985	0.998	1	1

Table I.2 - Proportion of the gear footprint fulfilling the recovery criterion: Danish demersal otter trawl in the North Sea. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR North Sea	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.971	0.912	0.922	0.953	0.975	0.993

Management area: Skagerrak

Note: The data provided by the client for the Skagerrak were cut off east from 10 degrees longitude. The results below are based on the available data only.

Table I.3 - Proportion of the gear footprint fulfilling the recovery criterion: Danish demersal otter trawl in the Skagerrak. **Sensitivity I (PD), average recovery rates**.

UoA	**Fleets**	**Areas**	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Skagerrak	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.018	0.010	0.018	0.157	0.775	0.999
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.018	0.010	0.018	0.157	0.775	0.999
	Only UoA	100% > 0.80K	0.319	0.151	0.226	0.679	0.962	1
		T80% > 0.95K	0.992	0.940	0.963	0.995	1	1

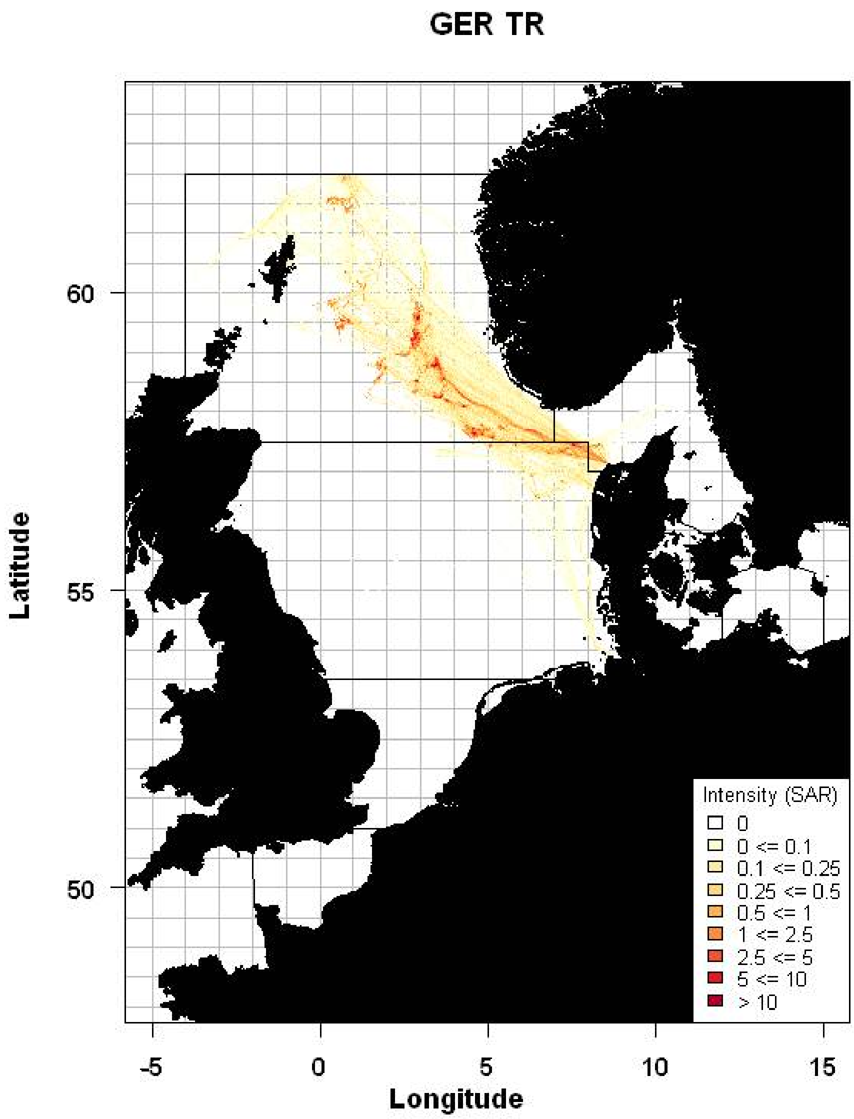
Table I.4 - Proportion of the gear footprint fulfilling the recovery criterion: Danish demersal otter trawl in the Danish Otter Trawl in the Skagerrak. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	**Fleets**	**Areas**	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Skagerrak	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	0.036	0.011	0.012	0.020	0.036	0.117
		T80% > 0.95K	0.976	0.878	0.891	0.933	0.964	0.990

Annex II Fisheries Germany

Germany_TR – Demersal Otter Trawls

Figure II.1 Footprint & fishing intensity for the German TR UoA in 2014-2016. Fishing intensity (SAR = Swept Area Ratio) is defined as the area swept within a grid cell (in km2) divided by the surface area of that grid cell. Hence, a fishing intensity of 1 indicates that the total surface area is fished once in a year.



Management area: North Sea

Table II.1 - Proportion of the gear footprint fulfilling the recovery criterion: German demersal otter trawl in the North Sea. **Sensitivity I (PD), average recovery rates**

UoA	**Fleets**	**Areas**	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR North Sea	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.745	0.646	0.753	0.960	0.997	1
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.746	0.648	0.755	0.960	0.997	1
	Only UoA	100% > 0.80K	0.322	0.035	0.057	0.304	0.839	0.999
		T80% > 0.95K	1	1	1	1	1	1

Table II.2 - Proportion of the gear footprint fulfilling the recovery criterion: German demersal otter trawl in the North Sea. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	**Fleets**	**Areas**	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR North Sea	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	0.017	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	1	1	1	1	1	1

Management area: Skagerrak

Table II.3 - Proportion of the gear footprint fulfilling the recovery criterion: German demersal otter trawl in the Skagerrak. **Sensitivity I (PD), average recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Skagerrak	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.018	0.010	0.018	0.157	0.775	0.999
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.018	0.010	0.018	0.157	0.775	0.999
	Only UoA	100% > 0.80K	0.854	0.781	0.854	0.977	0.998	1
		T80% > 0.95K	1	0.999	1	1	1	1

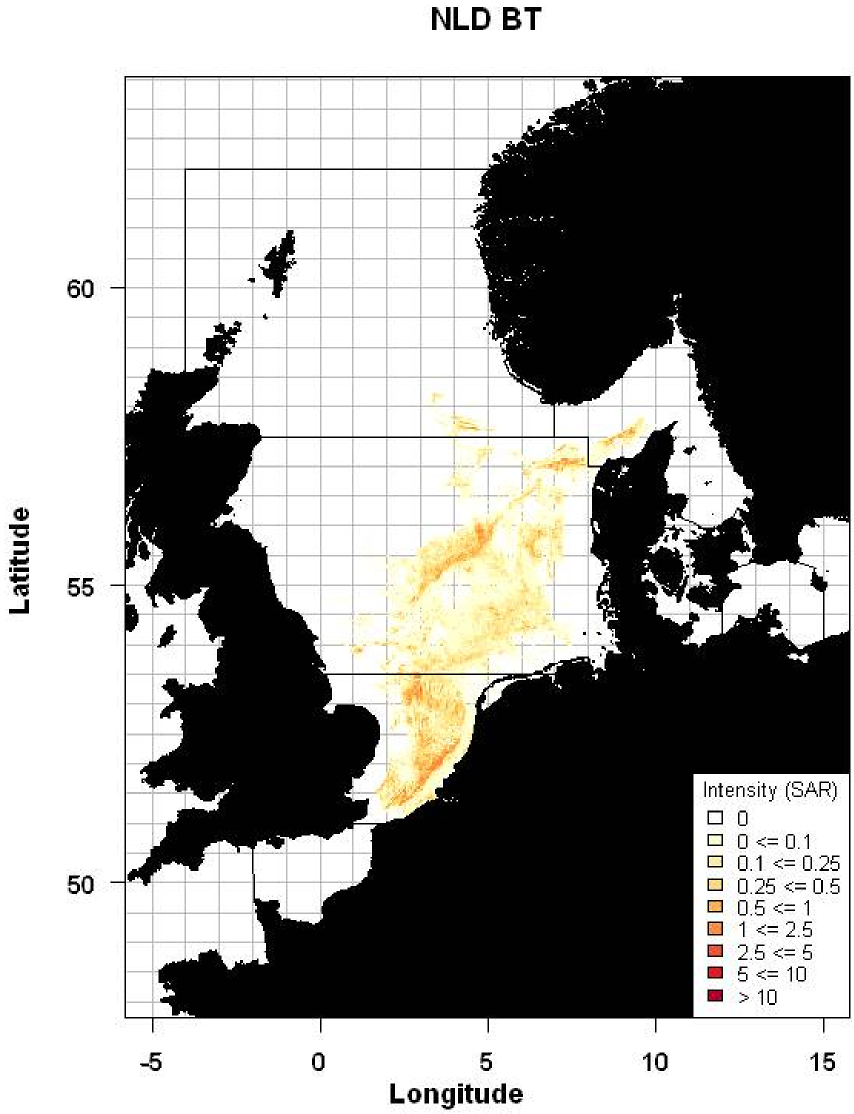
Table II.4 - Proportion of the gear footprint fulfilling the recovery criterion: German demersal otter trawl in the Skagerrak. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Skagerrak	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	0.406	0.349	0.384	0.529	0.680	0.882
		T80% > 0.95K	1	0.998	0.998	0.999	0.999	1

Annex III Fisheries the Netherlands

NLD_BT – Beam Trawls

Figure III.1 Footprint & fishing intensity for the Dutch BT UoA in 2014-2016. Fishing intensity (SAR = Swept Area Ratio) is defined as the area swept within a grid cell (in km2) divided by the surface area of that grid cell. Hence, a fishing intensity of 1 indicates that the total surface area is fished once in a year.



Management area: North Sea

Table III.1 - Proportion of the gear footprint fulfilling the recovery criterion: Dutch Beam Trawl in the North Sea (no pulse fishery included) . **Sensitivity I (PD), average recovery rates**

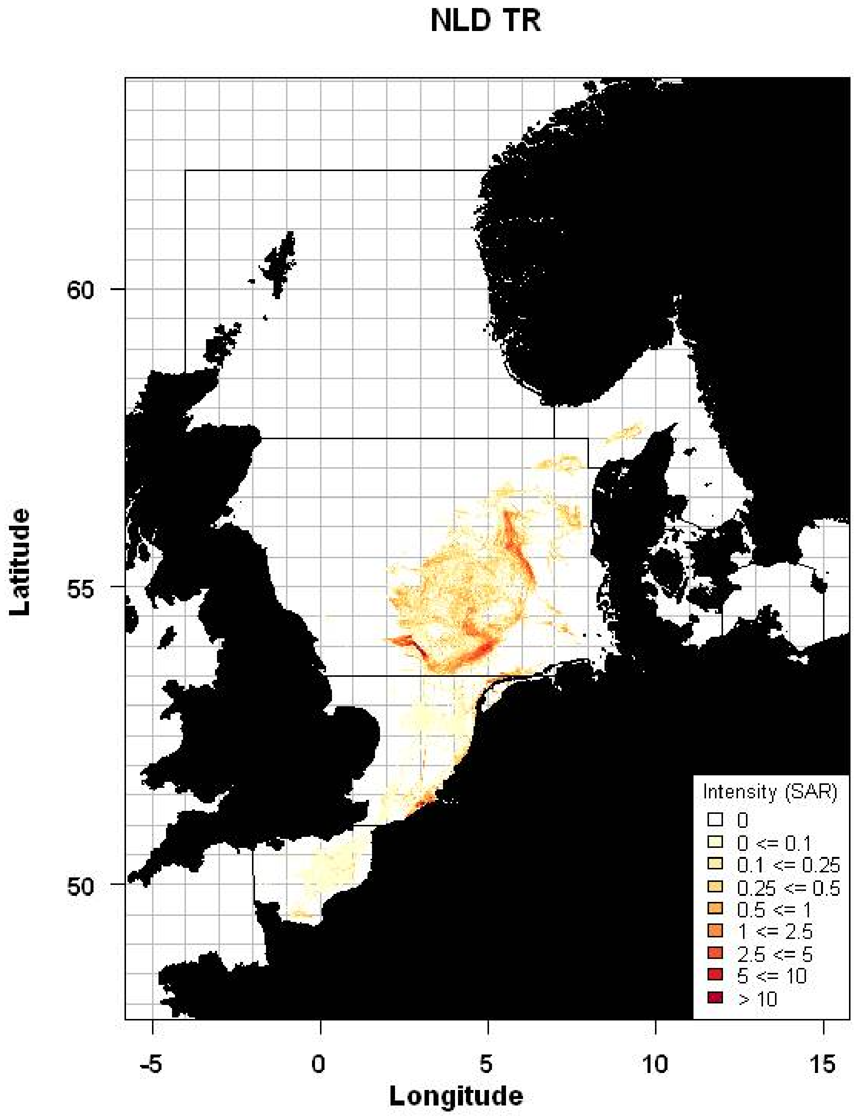
UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
BT_North Sea	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.685	0.577	0.692	0.943	0.995	1
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.702	0.598	0.711	0.948	0.995	1
	Only UoA	100% > 0.80K	0.542	0.334	0.451	0.856	0.986	1
		T80% > 0.95K	0.986	0.967	0.980	0.997	1	1

Table III.2 - Proportion of the gear footprint fulfilling the recovery criterion: Dutch Beam Trawl in the North Sea. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
BT_North Sea	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	0.210	0.084	0.094	0.147	0.245	0.533
		T80% > 0.95K	0.955	0.921	0.929	0.957	0.977	0.993

NLD_TR – Demersal Otter Trawls

Figure III.2 Footprint & fishing intensity for the Dutch TR UoA in 2014-2016. Fishing intensity (SAR = Swept Area Ratio) is defined as the area swept within a grid cell (in km2) divided by the surface area of that grid cell. Hence, a fishing intensity of 1 indicates that the total surface area is fished once in a year.



Management area: North Sea

Table III.3 - Proportion of the gear footprint fulfilling the recovery criterion: Dutch Demersal Otter Trawl in the North Sea. **Sensitivity I (PD), average recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR_North Sea	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.745	0.646	0.753	0.960	0.997	1
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.746	0.650	0.756	0.961	0.997	1
	Only UoA	100% > 0.80K	0.852	0.488	0.610	0.919	0.993	1
		T80% > 0.95K	1	1	1	1	1	1

Table III.4 - Proportion of the gear footprint fulfilling the recovery criterion: Dutch Demersal Otter Trawl in the North Sea. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR_North Sea	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	0.615	0.175	0.194	0.285	0.429	0.726
		T80% > 0.95K	1	1	1	1	1	1

Management area: Skagerrak

Table III.5 - Proportion of the gear footprint fulfilling the recovery criterion: Dutch Demersal Otter Trawl in the Skagerrak. **Sensitivity I (PD), average recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Skagerrak	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.018	0.010	0.018	0.157	0.775	0.999
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.018	0.010	0.018	0.157	0.775	0.999
	Only UoA	100% > 0.80K	1	0.828	0.887	0.983	0.999	1
		T80% > 0.95K	1	1	1	1	1	1

Table III.6 - Proportion of the gear footprint fulfilling the recovery criterion: Dutch Demersal Otter Trawl in the Skagerrak. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Skagerrak	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	1	0.601	0.631	0.739	0.842	0.949
		T80% > 0.95K	1	1	1	1	1	1

Management area: Eastern English Channel

Table III.7 - Proportion of the gear footprint fulfilling the recovery criterion: Dutch Demersal Otter Trawl in the Eastern English Channel. **Sensitivity I (PD), average recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR English Channel	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.184	0.122	0.184	0.613	0.948	1
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.186	0.123	0.186	0.617	0.949	1
	Only UoA	100% > 0.80K	0.877	0.814	0.877	0.980	0.998	1
		T80% > 0.95K	0.996	0.984	0.990	0.999	1	1

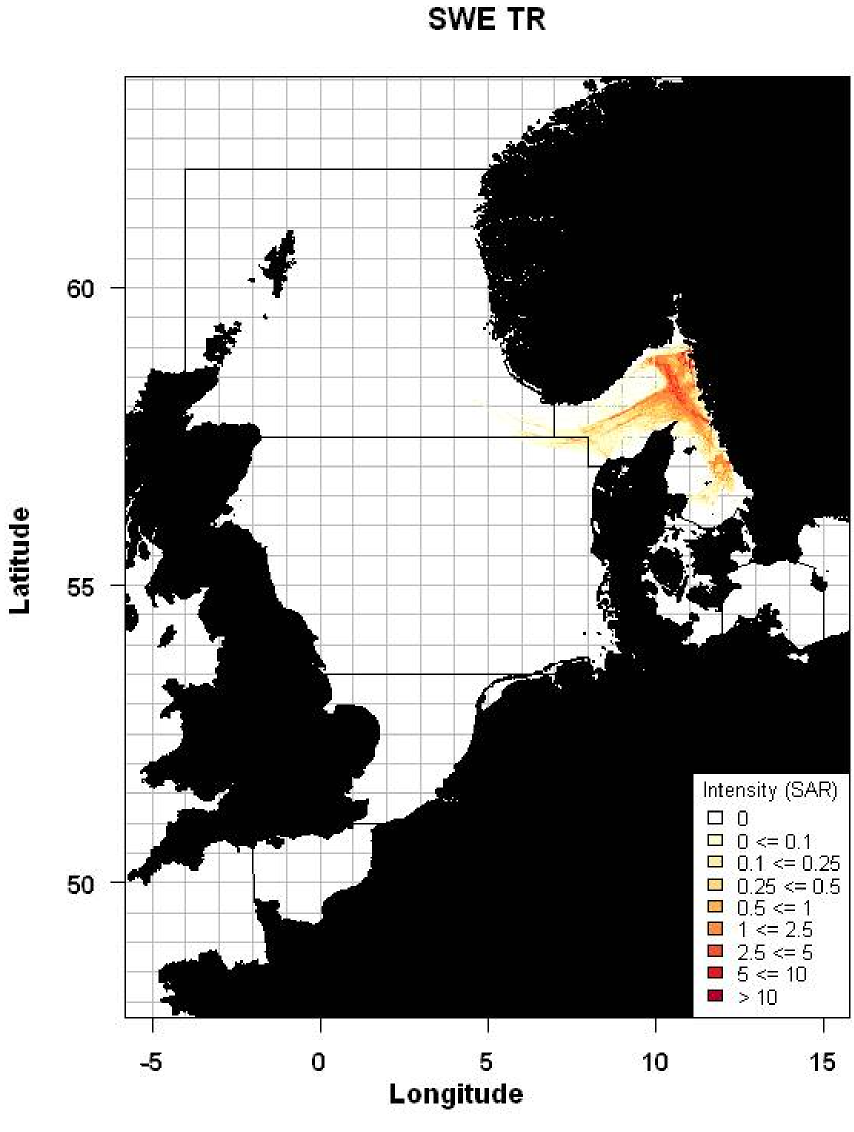
Table III.8 - Proportion of the gear footprint fulfilling the recovery criterion: Dutch Demersal Otter Trawl in the Eastern English Channel. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR English Channel	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.018	0.033	0.106
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.018	0.033	0.106
	Only UoA	100% > 0.80K	0.668	0.604	0.633	0.738	0.839	0.947
		T80% > 0.95K	0.986	0.963	0.967	0.980	0.989	0.997

Annex IV Fisheries Sweden

Sweden_TR – Demersal Otter Trawls

Figure IV.1 Footprint & fishing intensity for the Swedish TR UoA in 2014-2016. Fishing intensity (SAR = Swept Area Ratio) is defined as the area swept within a grid cell (in km2) divided by the surface area of that grid cell. Hence, a fishing intensity of 1 indicates that the total surface area is fished once in a year.



Management area: North Sea

Table IV.1 - Proportion of the gear footprint fulfilling the recovery criterion: Swedish Demersal Otter Trawl in the North Sea. **Sensitivity I (PD), average recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR_North Sea	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.745	0.646	0.753	0.960	0.997	1
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.745	0.646	0.753	0.960	0.997	1
	Only UoA	100% > 0.80K	0.872	0.807	0.872	0.980	0.998	1
		T80% > 0.95K	1	1	1	1	1	1

Table IV.2 - Proportion of the gear footprint fulfilling the recovery criterion: Swedish Demersal Otter Trawl in the North Sea. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR North Sea	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	0.458	0.425	0.455	0.577	0.717	0.896
		T80% > 0.95K	1	1	1	1	1	1

Management area: Skagerrak

Table IV.3 - Proportion of the gear footprint fulfilling the recovery criterion: Swedish Demersal Otter Trawl in the Skagerrak. **Sensitivity I (PD), average recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Skagerrak	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.018	0.010	0.018	0.157	0.775	0.999
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.018	0.010	0.018	0.157	0.775	0.999
	Only UoA	100% > 0.80K	0.782	0.227	0.345	0.844	0.990	1
		T80% > 0.95K	0.987	0.921	0.953	0.995	1	1

Table IV.4 - Proportion of the gear footprint fulfilling the recovery criterion: Swedish Demersal Otter Trawl in the Skagerrak. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Skagerrak	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.011	0.010	0.011	0.019	0.034	0.112
	Only UoA	100% > 0.80K	0.227	0.011	0.013	0.024	0.049	0.183
		T80% > 0.95K	0.939	0.740	0.766	0.852	0.921	0.980

Management area: Kattegat

Table IV.5 - Proportion of the gear footprint fulfilling the recovery criterion: Swedish Demersal Otter Trawl in the Kattegat. **Sensitivity I (PD), average recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Kattegat	All	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.428	0.303	0.435	0.882	0.992	1
	All except UoA	100% > 0.80K	0.016	0.010	0.016	0.103	0.568	0.994
		T80% > 0.95K	0.436	0.316	0.448	0.886	0.993	1
	Only UoA	100% > 0.80K	0.837	0.680	0.775	0.960	0.996	1
		T80% > 0.95K	0.995	0.984	0.991	0.999	1	1

Table IV.6 - Proportion of the gear footprint fulfilling the recovery criterion: Swedish Demersal Otter Trawl in the Kattegat. **Sensitivity II – PD worst case, slowest recovery rates**

UoA	Fleets	Areas	SI at start	SI after impact	SI after 1 year	SI after 5 years	SI after 10 years	SI after 20 years
TR Kattegat	All	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.012	0.010	0.012	0.021	0.042	0.163
	All except UoA	100% > 0.80K	0.011	0.010	0.011	0.018	0.033	0.106
		T80% > 0.95K	0.012	0.010	0.012	0.021	0.042	0.163
	Only UoA	100% > 0.80K	0.443	0.273	0.298	0.410	0.562	0.815
		T80% > 0.95K	0.977	0.948	0.954	0.974	0.987	0.997

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