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Interim Report of the Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT)

12-16 November 2018

ICES Headquarters, Copenhagen, Denmark

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Executive summary

The Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT) develops methods and performs assessments to evaluate benthic impact from fisheries at regional scale, while considering fisheries and seabed impact trade-offs. WGFBIT has built upon the ICES 2017 indicators and assessment framework (e.g. MSFD, D6). The assessment framework consists of three main components: fishing pressure (footprint), benthic habitat sensitivity and the resulting benthic impact. The framework is used to estimate trade-offs relating to the distribution of impact with other factors important for management (e.g. fisheries economics). The primary goal this first year of WGFBIT was to build a technical guideline document that explains the framework (Annex 4 of this report). The accompanying R code to compute WGFBIT indicators follows the ICES Transparent Assessment Framework (TAF) guidelines. Second, a roadmap to apply the assessment to other regions was made (scoping of data availability and gaps). Third, discussions were held on intersessional collaborative research to support the goals of WGFBIT.

The first meeting of WGFBIT brought together 27 scientists of different expertise with a wide geographical spread, representing all regional seas except the Black Sea and Southern Iberian coast.

WGFBIT uses fishing pressure layers from mobile bottom contacting fishing gears (MBCG) generated by the Working Group on Spatial Fisheries Data (WGSFD). Suggestions for improvement of the fishing pressure layer were discussed, in particular regarding how the variety of habitats, structures and other pressures within the c-squares can be taken into account. The group also explored how sediment resuspension and smothering can be included as a pressure layer.

A subgroup worked on the development of methods, applicable on EU region wide scale, to assess the sensitivity of the seabed to bottom-contacting fishing gear, in order to determine the impact/status of the seabed. It was decided to focus on applying the PD2 (“Population Dynamics 2”; ICES, 2017; further mentioned as PD) method for all regions. The group summarized the data needs and missing information for the different regions and developed a strategy for ground-truthing the modelled impact from the PD method. Furthermore, the group summarized methods for setting thresholds that reflect the boundary between good and poor status. As benthic habitats are the assessment units within the regions, we checked and linked the EUSeamap 2017 map with the broad scale MSFD habitats and identified gaps. This should help to run the assessment in a standardized way for the regions in year 2 and 3 of WGFBIT. In future WGFBIT sessions, we can explore additional indicator approaches in order to compare, cross-check and ground-truth results of various indicators.

An impact subgroup reviewed the methods developed in the BENTHIS project and WKBENTH, in particular the “PD” method, in relation to the Terms of Reference of WGFBIT, for which it is considered highly suitable. The advantages of this method are a strong rooting in general concepts of population dynamics and the fact that it is a single indicator summarizing impact across the entire benthic community. Furthermore, the PD method lends itself well to the Transparent Assessment Framework (TAF) standard adopted by ICES because it can be applied in an identical way across regions. A number of key improvements to the method were scoped, and partly implemented, during the

meeting: (1) quantification of the effect of uncertainty in input parameters. This would enable using a worst-case approach, facilitating proper application of the precautionary approach principle. It was decided that a Monte Carlo approach will be implemented to allow an estimate of uncertainty effects, and this will be implemented intersessionally. (2) It is essential for useful application that the assessment can be carried out for a subset of the area. The code was adapted during the workshop to facilitate the specification of either a specific EEZ or other management unit/subregion (e.g. OSPAR/HELCOM).

A trade-off subgroup focused on how to best illustrate the potential of the assessment method under development. This was done by implementing a theoretical 10% reduction in fishing intensity in 4 ways (10% overall, by metier, by habitat type and by EEZ), and illustrating the different results (changes in footprint, effort, landings and economic value of landings) between the implementations. These differences highlight the potential of the current method to compare not only high-level management measures, but also various implementation strategies.

1 Administrative details

Working Group name

Working Group on Fisheries Benthic Impact and Trade-off (WGFBIT)

Year of Appointment within current cycle

2018

Reporting year within current cycle (1, 2 or 3)

1

Chair(s)

Ole Ritzau Eigaard, Denmark

Gert van Hoey, Belgium

Tobias van Kooten, The Netherlands

Meeting dates

12–16 November 2018

Meeting venue

ICES HQ, Copenhagen, Denmark

2 Terms of Reference

a) Building from 2017 ICES work (WKTRADE, WKBENTH, and WKSTAKE) produce a framework for MSFD D6/D1 assessment related to bottom abrasion of fishing activity at the regional / subregional scale and identify key ecological processes input requirements.

b) Apply the framework to make a regional assessment for the North Sea, Celtic, Baltic and Barents Seas.

3 Summary of Work plan

For an EU MSFD D6/D1 assessment related to bottom abrasion of fishing activity at the regional / subregional scale identify key ecological processes required as input. Priority should be given to decide on a quantitative framework based on on biological processes, and to improve the parameterisation of framework components. The framework should allow for an overall assessment of benthic status and for the exploration of alternative management options to improve GES. Worked-out examples (and findings from WKTRADE 2017) should be used to ensure that a framework for addressing the above is established. The framework should be generic enough that it allows cross regional comparison and specific enough that it addresses regional-specific trade-offs (i.e. incorporating other pressures than fisheries). The framework should take into account complementarity to the ICES Fisheries Overviews (FOs) and Ecosystems Overviews (EOs), and provide input to overviews. The group will work between sessions to ensure required information is worked up to conduct assessments using the suggested framework (in preparation for year 2 meeting and advisory products).

4 List of Outcomes and Achievements of the WG in this delivery period

The first meeting of WGFBIT attracted scientist of different disciplines (fishing pressure, benthic sensitivity, impact and trade-off) with a good geographical spread (Norway, Sweden, Finland, Denmark, Germany, Netherlands, Belgium, France, Italy, Greece, Ireland, United Kingdom, Iceland). Scientists were representing all regions, except the Black Sea and Southern Iberian coast.

We do not yet have real outcomes (publications, or outputs), but the following results were achieved (or are in progress)

- A technical guideline document (living document) describing the FBIT assessment input requirements, method and procedure. The document needs to serve as background document for policy makers and scientists that want to understand the fishery benthic impact assessment outcomes for the different regions.
- An update to the assessment R code to be able to carry out the assessment for specific EEZ areas and other subregions.
- With regards to the fishing pressure, it is now assumed that fishing tracks are randomly distributed rather than side by side.
- It is decided to make use of the proportional part of habitats in a c-square instead of the habitat type of the centroid point in the c-square.
- An evaluation of the need to include other human activities causing abrasion is discussed or on how to include structures preventing fishing into the maps.
- It was also investigated how sediment resuspension and smothering can be included as a pressure layer.
- Compilation of a table for all regions with indication of data sources, longevity relation update, relevant habitats.
- Compilation of the availability of longevity traits information for benthos and epifauna (megafauna) for each region.
- Defining the workplan for expanding the PD method over the regions for updating and validating the longevity and ground truthing.
- A set of showcase scenarios was developed to highlight the potential of the assessment framework under development to study the consequences of various management measure implementations (trade-off). These were already partly implemented in the assessment code.
- A method for how to include parameter uncertainty into the assessment, which will be implemented intersessionally.

5 Introduction

5.1 Seafloor integrity and the state of seabed habitats

In European waters the Marine Strategy Framework Directive (MSFD) has been introduced as one of the main legislative instrument to implement Ecosystem-based Management (EBM). EBM is a tool used to manage human activities affecting marine ecosystems, which aims to find a balance between conservation and sustainable use. ICES role is to provide the evidence for ecosystem-based decision making for the management of fisheries and other sectors in the ICES area. The evidence is required to explore the consequences of likely trade-offs between the services these human activities provide and the impacts these activities have on biodiversity of species and habitats.

Part of the MSFD, as noted in Descriptor 6 (D6), aims to maintain the integrity of the seafloor to ensure marine biodiversity and the provision of living resources. The overarching goal of D6 is for seafloor integrity to be at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected. These D6 requirements have led to the development of methods to assess impact on benthic habitats from anthropogenic activities, particularly bottom trawl fisheries, across EU member countries and Regional Sea Conventions (RSCs). In parallel to D6, such methods are also used to assess impact in relation to Descriptor 1 (D1) that has as overarching goal to maintain biological diversity.

For MSFD D1 and D6 purposes, ICES has acted as a facilitator for setting methodological standards that can ensure operationalizing of a regional assessment of the seafloor (ICES 2016, 2017). In this work, ICES noted that there are two broad management objectives associated with the state of seabed habitats (ICES 2016):

1) The first is the protection and conservation of particularly valued and sensitive habitats and communities in shallow and deep waters. In a global context, some of these habitats and communities have been described and defined as Vulnerable Marine Ecosystems (VMEs). The sensitivity of areas holding these VME indicator species and/or habitat is such that any bottom-impacting fishing may severely or permanently damage and degrade them. As a consequence many become closed to these forms of fishing. Once particularly valued and sensitive habitats and communities have been defined, the main scientific activity needed for such areas is to find and map them – the main management need is to bring forward appropriate control measures. ICES recommended therefore that the state of these areas be assessed separately from the state of other seabed habitats (e.g. ICES 2018, advice on VMEs and fisheries footprint).

2) The other objective relates to the state of more widespread habitats and communities that are not covered by the category of particularly valued and sensitive habitats and communities. These habitats may be less sensitive, but their health may be valued for their ecosystem services and is required under the MSFD to maintain biodiversity and sea-floor integrity. Condition metrics for these areas are required under the EU's Marine Strategy Framework Directive to ensure that structure and functions of ecosystems are safeguarded and that benthic ecosystems are not adversely affected.

ICES has proposed a set of pressure and impact indicators and an assessment framework to evaluate the state of the widespread habitats and communities that are affected by human activities, either causing physical loss (D6C1) or physical disturbance (D6C2) to the seabed (ICES 2017). The assessment framework consists of three main components (Figure 1): pressure (footprint), benthic habitat sensitivity and benthic impact. The assessment framework is able to aggregate the proposed indicators to the spatial scale of biogeographic subdivisions of the MSFD regions and subregions, and per MSFD broad-scale habitat type, and, to assess indicator change over time. The approach also allows for evaluation of trade-offs (an integral part of EBM) relating to the distribution of impact and recovery potential of the seafloor with factors that are important for management (e.g. fisheries economics). Such information can be used, for example, when exploring management scenarios under different policy requirements.

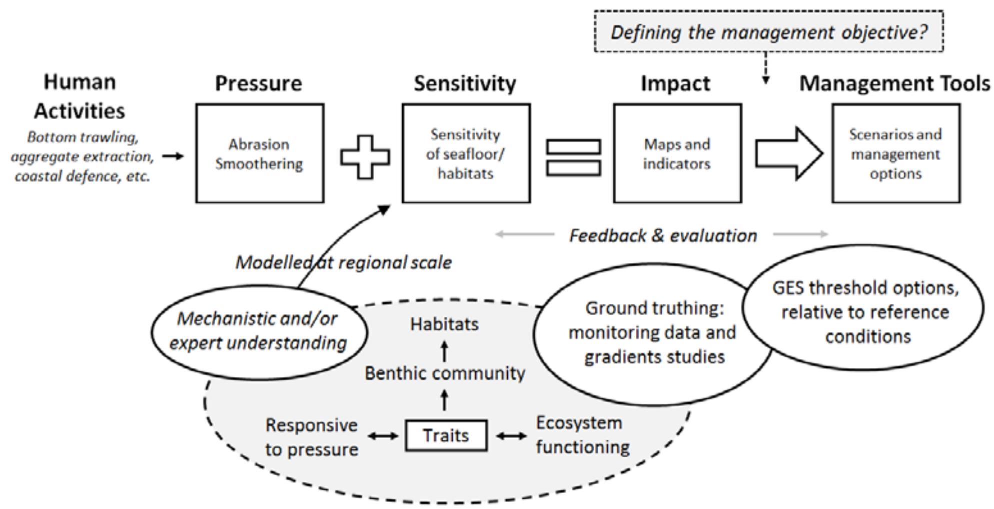


Figure 1. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activities.

5.2 WGFBIT seafloor assessment approach

WGFBIT aims to further operationalize the suggested seafloor assessment framework, with respective indicators and to extend the assessment framework over the whole EU and ICES region.

WGFBIT has reviewed the two methods that have both been used within the assessment framework of ICES to evaluate benthic impact (ICES 2017). The two methods are the PD (Population Dynamic) method, which uses habitat- and gear-specific mortality and recovery dynamics to derive local impact scores, and the LL2 method, which calculates the degree to which communities (in particular long-lived species) can attain their natural age distributions given local fishing intensity. The advantage of the PD method are a strong rooting in general concepts of population dynamics and the fact that it is a single indicator summarizing impact across the entire benthic community. The LL2 method focuses on the long-lived species, under the assumption that these are the most sensitive to trawling. The PD method lends itself better to the Transparent Assessment Framework (TAF) standard adopted by ICES because it can be applied in an identical way across regions. The LL2 method is essentially a statistical method, which would use different input data for different regions. For the PD method, the methodological differences affect the derivation of parameter values, but not the assessment procedure itself. Mainly on the basis of this advantage, the PD method was taken forward in this working group. For the North Sea and Irish Sea applications, the data analysis underlying the LL2 method for those areas is used to derive the parameters for the PD assessment in those regions. For other regions, the LL2 analysis provides a published example for how the parameter derivation for the PD assessment could be approached.

WGFBIT has described in Annex 4 of this report the methodology of the ICES assessment approach that is currently used in both the North and Celtic Sea ecoregion. For both ecoregions, pressure and impact are evaluated for each broad-scale habitat type. The evaluation follows Annex 1 "*demonstration product*" (ICES 2017) and code and data products are available (https://github.com/ices-eg/FBIT). In this first year report of WGFBIT, the working group has considered how the assessment approach can be further improved and groundtruthed, and, how the approach can be transferred to other EU and ICES regions (see following chapters).

5.3 Other ICES initiatives linked to WGFBIT

ICES organised a workshop WKBEDPRES1 (24–26 October 2018) in response to an EU advice requests to identify benthic physical disturbance (D6C2) pressure layers available within ICES and the European and wider marine community across four EU regions – including the mapping of pertinent data flows and the establishment of criteria needed to ensure the practical use of the data in assessing benthic impact. Preliminary analysis indicated that the key human activities that resulted in physical disturbance on the seabed are very similar for the four EU regions examined (Baltic Sea, North East Atlantic, Mediterranean and Black Sea). Fishing is found to be the most extensive cause of physical abrasion. Aggregate extraction and dredging are also of relevance in most regions, but much less extensive.

The workshop concluded that the data flows and quantitative methodologies for the processing of physical disturbance from bottom fishing currently exist within ICES (i.e. within WGFBIT and WGSFD) and were deemed appropriate for EU e.g. MSFD purposes for assessing the seafloor. These methodologies are in line with previous ICES advice on indicators (ICES 2016, 2017). However, similar data flows are yet to be established for the Mediterranean and Black Sea. Future calls should also take into account other sources of data reflecting activity causing seabed abrasion to allow for better coverage (e.g. AIS). Relevant data from HELCOM, OSPAR and the EMODnet human activities data portal may also be of use in the assessment and should be explored. Similar to the ICES VMS/logbook data call, data flows for other pressure (e.g. aggregate extraction and dredging) need to be better established to ensure consistent collation at the regional scale from national level. This needs to done using data management practices, of which ICES's TAF (transparent assessment framework) is an integral part of. In addition to physical disturbance pressures data, ICES will in early 2019 run a similar workshop to identify data flows for activities resulting in physical loss (D6C1/C4) pressures, i.e. permanent alteration of the habitat from which recovery is impossible, such as construction activities (e.g. offshore windfarms).

WGFBIT have in their meeting taken into account the information highlighted by WKBEDPRES1 with regard to the specific data needs to service the underlying methods of the indicators. WGFBIT will collaborate with the advice process of WKBEDPRES to help ensure data needs are met. This also means that an overall WGFBIT assessment framework of the seafloor (impact and pressure) can be featured in the future iterations of the ICES "Fisheries Overviews Advice" and "Ecosystem Overviews Advice" for each ecoregion.

6 Progress report on ToRs and workplan

The meeting was structured into three subgroups (following the three components of the assessment framework: pressure, sensitivity and impact/trade-offs) that worked together on ToR A to further develop the assessment framework. In all subgroups it was considered how the assessment approach can be improved and groundtruthed, and, how the approach can be transferred to other EU and ICES regions (see sections 7-9). Section 10 describes what has been achieved in relation to applying the assessment methodology in a regional assessment (ToR B).

7 Pressures

This section considers pressures affecting the sea-floor. The recent ICES WKBEDPRES1 was focused on this topic, so WGFBIT continued the WK-discussions on how data from different pressures can be included in the current pressure estimation workflow. Procedures for assessing the pressure from mobile bottom contacting fishing activities are already well established in ICES, so WGFBIT considered if improvements can be made to some of the caveats in data and methodology for calculating fishing pressure indicators.

One of the caveats is related to the spatial resolution of the c-square, which is 0.05*0.05 degrees in the ICES data call, corresponding to approximately 15-20 km^2 in the North Sea. The variation of habitat types within the c-squares in the Greater North Sea was analysed and it was discussed if the proportion of different habitats within a c-square can be used instead of, as currently, the habitat type of the c-square mid-point. Further, it was discussed that parts of a c-square might also be used for purposes like windfarms, sand and gravel extraction, oil-rigs or other structures, preventing fishing activity by mobile bottom contacting gears, or areas might be closed for fishing activities for other reasons, e.g. Natura 2000 areas or MSFD protected areas. All these purposes can restrict the area of a c-square where fishing pressure can occur, and the fishing pressure estimation might be adjusted accordingly in the future, e.g. by splitting up the c-square by uses and concentrating the fishing pressure to a smaller area of relevance.

In addition, it was discussed how resuspension and smothering of the sediment as a result from fishing activities can be included in the future pressure estimation, based on ongoing work.

7.1 Fishing abrasion

In the WGFBIT 2018, the data product that ICES developed as advice for OSPAR (ICES, 2018) was used as fishing pressure layer for the Greater North Sea assessment. The dataset is created based on an annual ICES VMS logbook data call.

A standardized workflow to answer the data call has been developed as an R-script, using the Vmstools R package. VMS and logbook data from the fishing vessels are merged, a speed filter is applied to estimate where fishing is taking place and landings are distributed on the VMS positions with fishing activity. Data are processed nationally, and aggregated to the exchange format before submission to ICES. When the data are received by ICES, a quality check report is generated, with inconsistencies pointed out, and sent back to the submitting country for them to explain or resubmit. The workflow is illustrated in Figure 2 below.

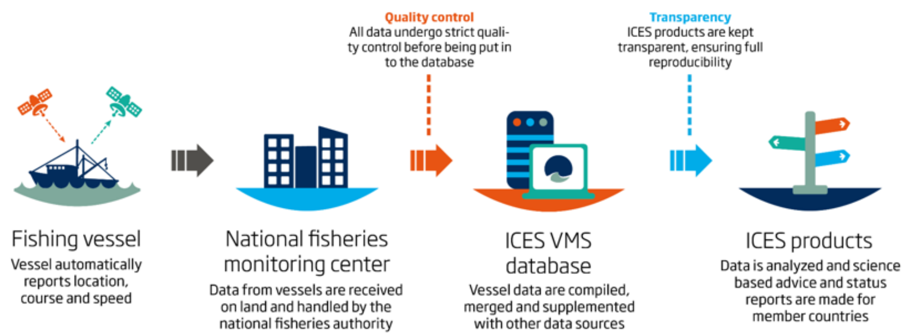


Figure 2. An illustration of the workflow of VMS data from fishing vessel to ICES products. Source: ICES.

A workflow based on the Benthis research project has been developed by the ICES WGSFD, and is now run by the ICES datacentre to estimate the swept area of mobile bottom contacting fishing gears, using the fishing hours, average speed and a relationship between vessel size and gear width, developed in the Benthis project (Eigaard *et al.*, 2016). The surface swept areas are calculated by Benthis métier (Eigaard *et al.* 2016) and summed across métiers to give a total fishing pressure (swept area) from all mobile bottom contacting gears The swept area estimates are aggregated by year by c-square (grid cells of 0.05*0.05 degrees) and divided by c-square surface area to provide annual grid cell swept area ratios (SARs) for the OSPAR region. C-square SARs are provided both as surface and subsurface; surface abrasion is defined as disturbance of surface features only (top 2cm of sediment), and subsurface abrasion is penetration and/or disturbance of the sediment deeper than the surface of the seabed (≥ 2cm). The resulting outputs are presented to WGSFD to make quality checks. The procedures are also described in the Technical guidelines in annex 4.

7.1.1 Caveats and future work

When interpreting the fishing pressure maps for mobile bottom contacting gears, some of the caveats relevant to the WGFBIT and discussed at the meeting are listed below:

Fishing vessels without VMS

The ICES data call requests VMS data, but part of the European fishing fleet is not covered by VMS. Fishing vessels smaller than 12 meters are not required to have VMS. According to EU (1224/2009, article 9) fishing vessels of less than 15 meters length fishing in territorial waters of the flag Member State or never spending more than 24 hours at sea from the time of departure to the return to port are not required to have VMS. Member states are implementing this article differently, some requiring VMS on all vessels above 12 m.

The vessels without VMS are often fishing in coastal areas, and many of the smaller vessels are using passive gears. Although there is currently no EU requirements for the vessels without VMS to have vessel position data, there are several examples of national legislation requiring part of this fleet to have vessel position data.

AIS data is only a requirement for fishing vessels larger than 15 m, but some smaller vessel are using the AIS security system, and these data can give information on fishing activity for a proportion of the fleet without VMS. One of the ToRs proposed for WGSFD 2019 is to evaluate inclusion of AIS data in the ICES data call.

The VMS datacall was not answered by all countries

Most countries in the Baltic and Atlantic region answered the datacall in 2018, but data from Spain, Greenland, Faroe Islands and Russia are missing. Spain has submitted data, but at the moment of the WGFBIT meeting 2018 it has not been approved after quality checks.

C-square resolution

The resolution of the VMS data in the VMS data call is the 0.05*0.05 degrees c-squares (corresponding to 15–20 km^2 in the North Sea), meaning that one c-square might contain several habitats. One of the ToRs for WGSFD 2019 is to make a voluntary test data call on 0.01 degree resolution, using interpolation methods between VMS positions. The minimum interval between VMS positions is currently 2 hours, but several countries have implemented requirements for more frequent VMS positions.

7.1.2 Improving the fishing pressure indicator calculations

As the procedures of making the fishing pressure maps are already well established by ICES WGSFD and the ICES datacentre, it was discussed how these outputs can be improved in relation to the fishing pressure indicators.

7.1.2.1 Assuming random distribution of fishing tracks instead of side-by-side

The swept area given in the present outputs sums all the swept areas calculated by c-square, implying an assumption that the fishing tracks do not overlap. Instead of assuming the worst-case scenario where the trawl tracks occur back-to-back in a given c-square (Figure 2.a), we might better assume a random distribution of trawling tracks within c-squares (Figure 2.b); (see ICES WGSFD 2017 and Ellis *et al.*, 2014). The indicator of total area fished estimated when assuming a random distribution of trawling tracks is less than for the back to back (unlikely) assumption. This effect is illustrated in Figure 4 (indicator on area swept by all mobile bottom contacting gears, assuming 3 different distributions of trawling pattern within c-squares).

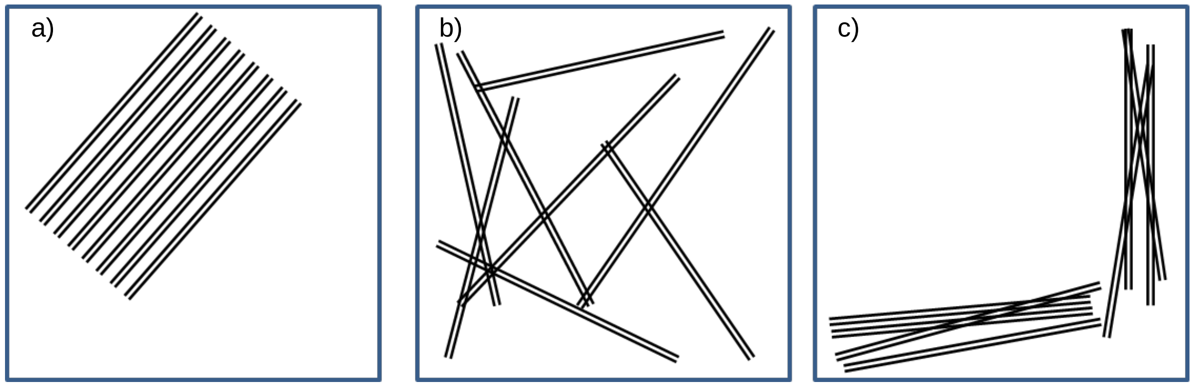


Figure 3. Illustration of trawling track patterns within a grid cell. a) regular trawling, b) random trawling, c) aggregated trawling. From WGSFD 2017.

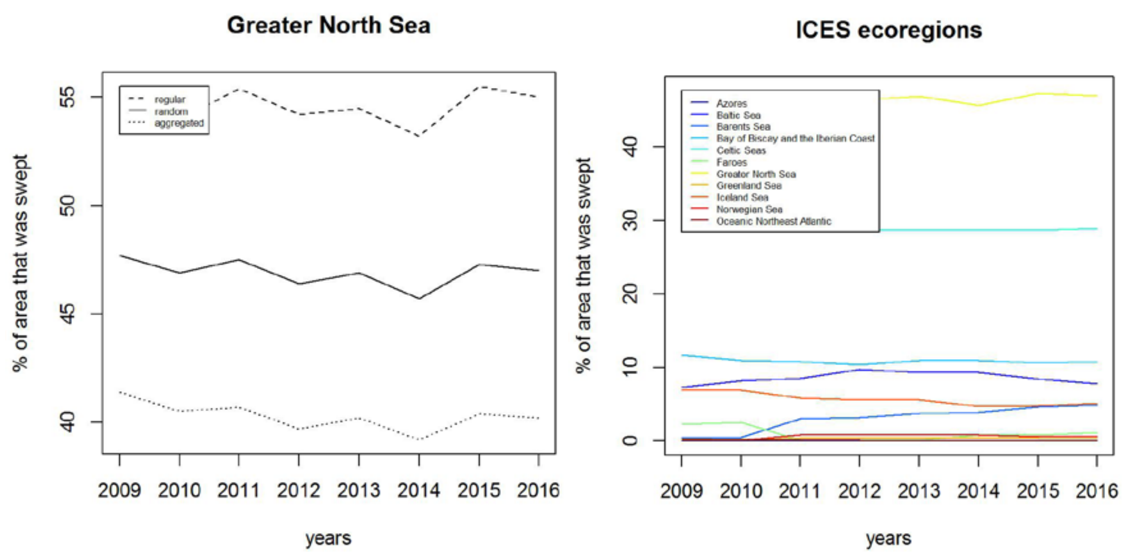


Figure 4. Left) Percentage of the Greater North Sea area that was swept by all mobile bottom contacting gears, assuming 3 distributions of trawling pattern within c-squares. Right). Percentage of ICES ecoregion area that was swept by all mobile bottom contacting gears, assuming random trawling pattern within c-squares. From WGSFD 2017.

7.1.2.2 Discussion on threshold for when a SAR is considered fishing activity

ICES has advised on a set of indicators for assessing pressure and impact on the seabed from mobile bottom-contacting fishing (ICES 2017). The advice includes four indicators reflecting the annual pressure (1: intensity, 2: proportion of c-squares fished, 3: proportion of area fished, 4: aggregation of fishing pressure), one multiannual indicator representing the persistency in the geographical distribution of the pressure and two annual impact indicators (impact and area below impact threshold).

When calculating the annual pressure indicator number 2 – "Proportion of c-squares fished", c-squares presenting a fishing pressure below the arbitrary threshold of 0.01 are excluded. 1% of the c-squares in the ICES data products for Bottom Fishing Intensity – Surface 2015 that was used for the WGFBIT demonstration workflow have a SAR value less than 0.01. A SAR histogram of all c-squares (Figure 5) indicates that the considered cells represent only a minor portion of the total area and these are therefore not removed in the WGFBIT pressure data, as there was no obvious threshold. If there is a calculated Surface SAR, it is because fishing activity with mobile bottom contacting gears has been reported in that c-square, even though it has a low value.

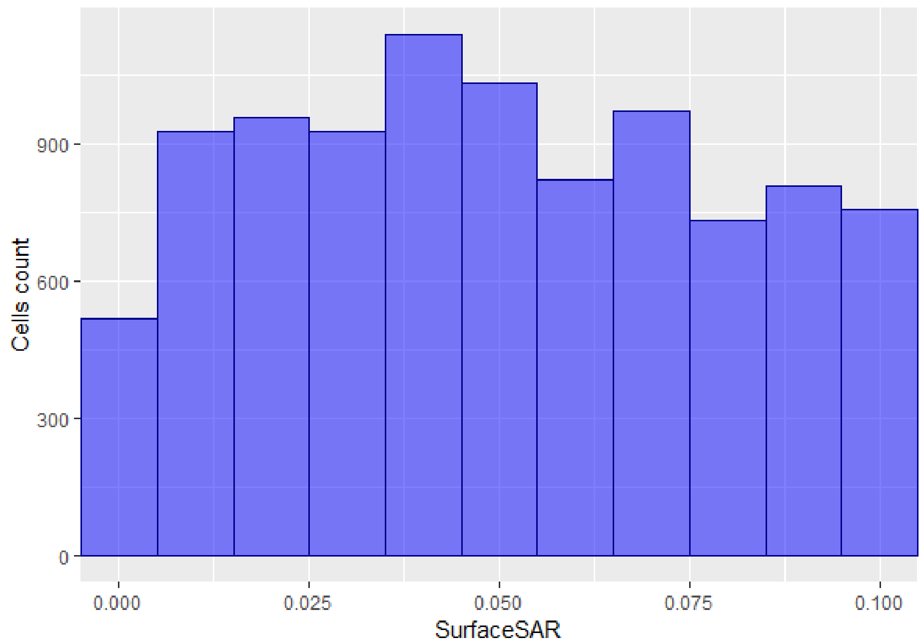


Figure 5. SurfaceSAR histogram considering only the c-squares falling within the range 0-0.1. The vertical axis is the number of c-squares within the SurfaceSAR range on the horizontal axis. Data source: "*OSPAR request on the production of spatial data layers of fishing intensity/pressure*". ICES Technical Service sr.2018.14 https://doi.org/10.17895/ices.pub.4508

7.1.2.3 Issues for the ICES Working Group on Spatial Fisheries Data (WGSFD) 2019 to consider

During discussions on potential improvement of the fishing pressure dataset, it was agreed that some of the issues would be better dealt with by ICES WGSFD. Below is a list of issues for WGSFD to consider during their meeting in 2019:

- Would it be possible to make a dataset with swept area calculations available with 0.01 degrees resolution for WGFBIT to test how it will affect the resulting indicators in 2019?
- Could uncertainties in SAR estimates be informed from the variation in relationships between vessel size and gear width (including minimum and maximum values)?
- Would it be possible to take technological creep into account in the SAR calculations?
- Inclusion of longlines in the deep-sea fisheries as they can affect biogenic structures and sediment/habitat microtopography. Static gears in the Mediter-

ranean and Baltic regions can also have extensive contact with the seabed (WKBEDPRESS). Can layers with these fishing activities be produced, so that they can be used as pressure layers?

- Could a documentation be provided on how the value of landings is assigned by different countries when answering the VMS/logbook datacall?
- Discuss if the output could be made available in an .RData format or in a SQL database, including c-squares without fishing activity.

7.1.3 Dividing c-squares by habitat proportion

7.1.3.1 Proportion of habitat, instead of using the habitat in the center point of the c-square

The change in biomass produced by the pass of a fishing gear is related to the type of habitat that is impacted. The SAR as fishing pressure indicator and the EU Sea Map habitat type by c-squares are the data sources used for this analysis. Firstly, fishing effort is aggregated by 0.05*0.05 degrees c-squares within ICES Ecoregions, then this fishing pressure (SAR) is linked to the EU Sea Map habitat type within each c-square to assess (model) how the interactions between different habitats and the fishing gears changes invertebrate biomass. Previously, the habitat type directly overlapping the central point of each c-square has been assumed to represent the full c-square (the centroid method).

An alternative method is proposed to obtain a more precise representation of the different habitat types present in a c-square (the proportion method). This method consists in the application of a spatial analysis technique that calculates the proportion of each habitat type present in a c-square. Firstly, the EU Sea map habitat distribution layer is spatially intersected with the layer with the ICES ecoregions c-squares to calculate the absolute habitat type area within each cell. Secondly, each habitat type area is divided by the total area of the related c-square, to obtain the habitat proportion present in each c-square. To assure the correct application of the proposed method, the sum of the habitats proportion by c-square must sum to one. The method is summarized in the formula below, where i is the habitat type (1 …. n) within a grid cell j, the habitat type area is AH and AC is the total c-square area.

$$\sum_{i=1}^{n} \frac{AHi}{ACj} = 1$$

A graphical presentation of this method application is found in Figure 6, the example shows a c-square unit with 70% sand and 30% mud. The central point method would give a highly erroneous interpretation of habitat occurrence in such a c-square.

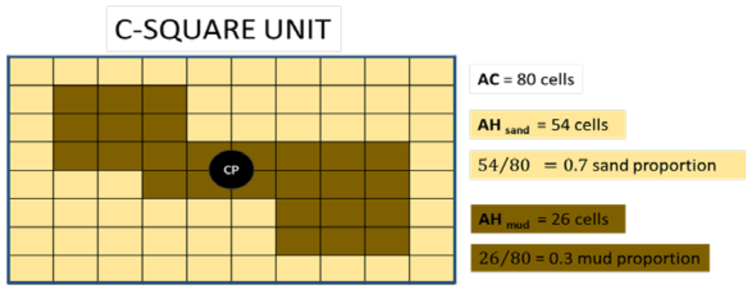


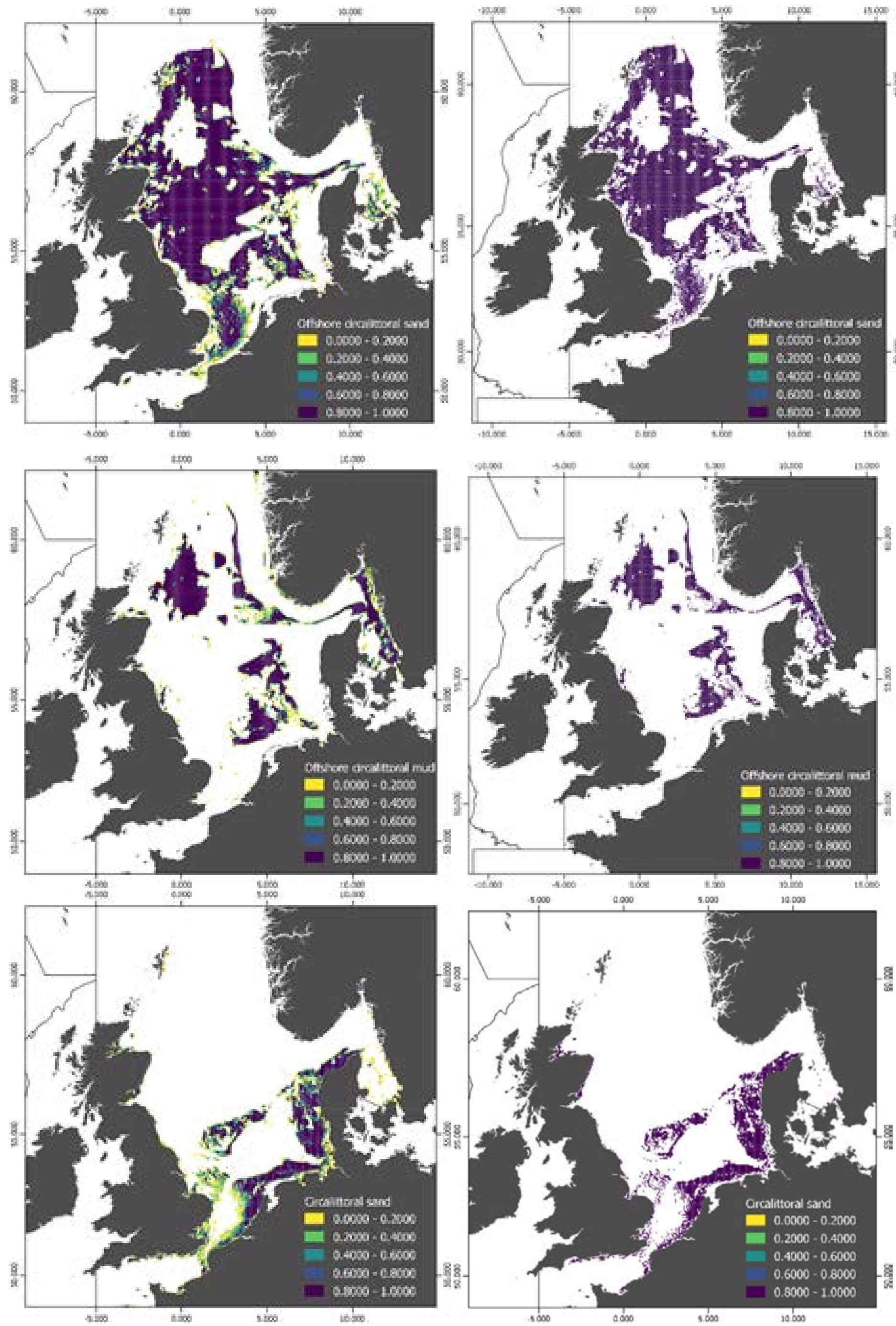
Figure 6. Illustration of a fictive distribution of sand and mud within a c-square.

When comparing the outputs of the two methods a substantial difference in the habitat distribution within the ICES Greater North Sea Ecoregion is observed (Table 1).The centroid method substantially underestimates the presence of each of the MSFD habitat categories, while the proportion method provides a more realistic estimate of total habitat distribution. . The Table 1 below shows the ratio of number of c-squares by MSFD habitat category compared to the total number of c-squares within the Greater North Sea ecoregion. Note that in the column with habitat from proportions within c-squares, the same habitat can be present in several c-squares, and therefore the column does not sum to 1.

Table 1. The ratio of number of c-squares with a given MSFD habitat type within compared to the total number of c-squares within the Greater North Sea ecoregion. Note that in the column with habitat from proportions within c-squares, , the same habitat can be represented in several c-squares.

MSFD Habitat Type	Habitat from proportion within c-squares	Habitat from c-square centroids
'Infralittoral coarse sediment'	0.03	0.01
'Circalittoral mud'	0.03	0.01
'Circalittoral mixed sediment'	0.03	0.01
'Offshore circalittoral mixed sediment'	0.04	0.01
'Offshore circalittoral rock and biogenic reef'	0.05	0.01
'Infralittoral sand'	0.07	0.02
'Upper bathyal sediment'	0.1	0.1
'Circalittoral coarse sediment'	0.11	0.04
'Offshore circalittoral coarse sediment'	0.17	0.1
'Circalittoral sand'	0.18	0.1
'Offshore circalittoral mud'	0.19	0.13
'Offshore circalittoral sand'	0.47	0.37

The following maps (Figure 7) illustrate the spatial distribution of the four more represented habitats in the Greater North Sea ecoregion, the left column maps show the result of the proportional method and right column shows results of the centroid method. The latter creates a fuzzy effect surrounding the core habitat areas that will affect the model that estimates the change in benthic biomass linked to fishing impact.


Offshore circalittoral sand
0.0000 - 0.2000
0.2000 - 0.4000
0.4000 - 0.6000
0.6000 - 0.8000
0.8000 - 1.0000
Offshore circalittoral sand
0.0000 - 0.2000
0.2000 - 0.4000
0.4000 - 0.6000
0.6000 - 0.8000
0.8000 - 1.0000
Offshore circalittoral mud
0.0000 - 0.2000
0.2000 - 0.4000
0.4000 - 0.6000
0.6000 - 0.8000
0.8000 - 1.0000
Offshore circalittoral mud
0.0000 - 0.2000
0.2000 - 0.4000
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0.6000 - 0.8000
0.8000 - 1.0000
Circalittoral sand
0.0000 - 0.2000
0.2000 - 0.4000
0.4000 - 0.6000
0.6000 - 0.8000
0.8000 - 1.0000
Circalittoral sand
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0.6000 - 0.8000
0.8000 - 1.0000

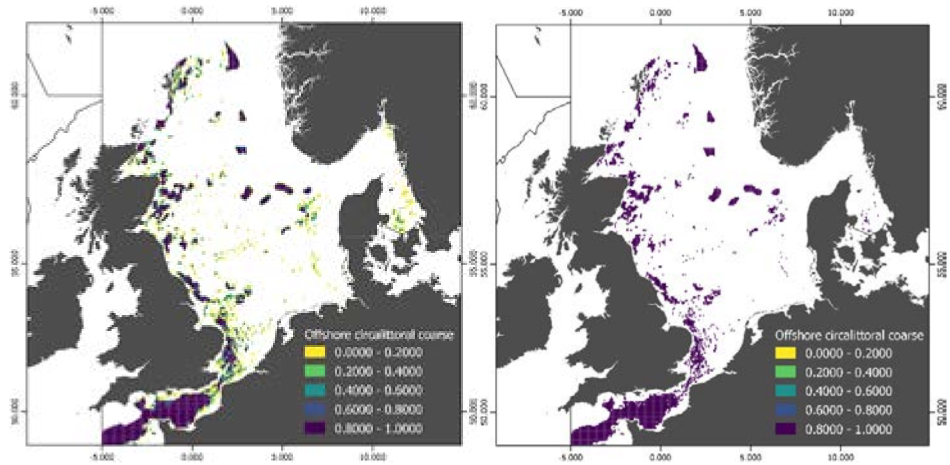


Figure 7. Proportion within c-squares of the four habitat types: offshore circalittoral sand, offshore circalittoral mud, circalittoral sand and offshore circalittoral coarse sediment. The maps in the left column are based on the method using the proportion of habitats within c-squares, the maps in the right hand column are based using the habitat type of the centre point of the c-square

The results of the proportional habitat analysis indicates that the Greater North Sea is largely dominated by offshore circalittoral sandy sediments, followed by offshore circalittoral muddy and coarse sediments. The density graph of c-squares within Greater North Sea by MSFD habitat category in figure 8, shows the distribution of c-squares in the ecoregion by proportion of habitat type. On the y-axis is the proportion of c-squares in the ecoregion, and on the x-axis the habitat proportion by c-square. This means that those habitat types with a thin tail across the x-axis values and a high peak near to 1 (e.g. dark blue colour representing Upper bathyal sendiment) are tending to be unique habitats in c-squares in the region. On the contrary, the sediments with less presence in the ecoregion are represented with a higher peak at the beginning of the x-axis and a thin tail approaching the value of 1 (e.g. Circalittoral mud). Sand (pink colours) is widespread in the region, but is often the only habitat in a c-square, while Infralittoral rock and biogenic reefs (green) are more often present in c-squares together with other habitats.

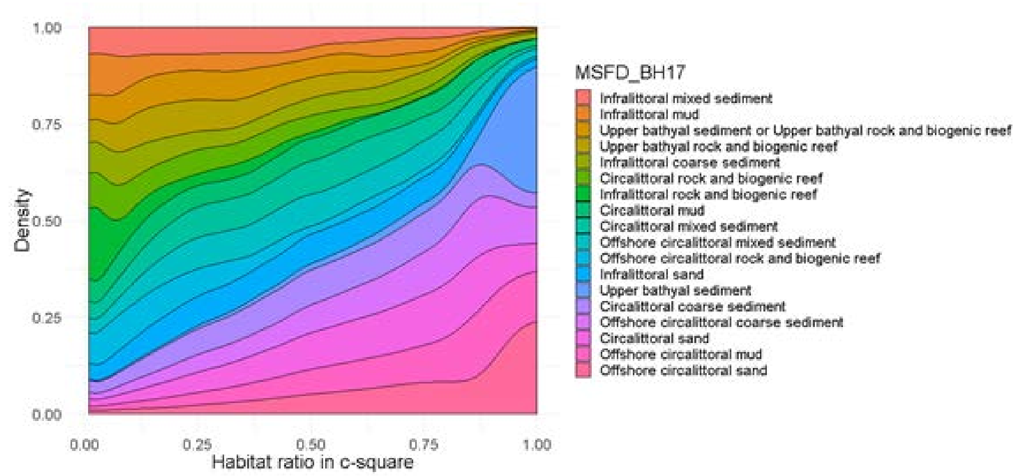


Figure 8. Density of habitat ratio within c-squares.

Finally, the relation between swept area ratio (SAR) and habitat type is shown in the following graphs in Figure 9. These graphs indicate that the offshore circalittoral mud and coarse sediments are the sediments that are most frequently impacted by bottom contacting fishing gears. When looking at the only the subsurface SAR the offshore circalittoral mud, sand and coarse sediments are, in this order, the most impacted by bottom contacting fishing gears. A further analysis is needed to investigate if these fishing impact trends are similar across different fishing gear metiers.

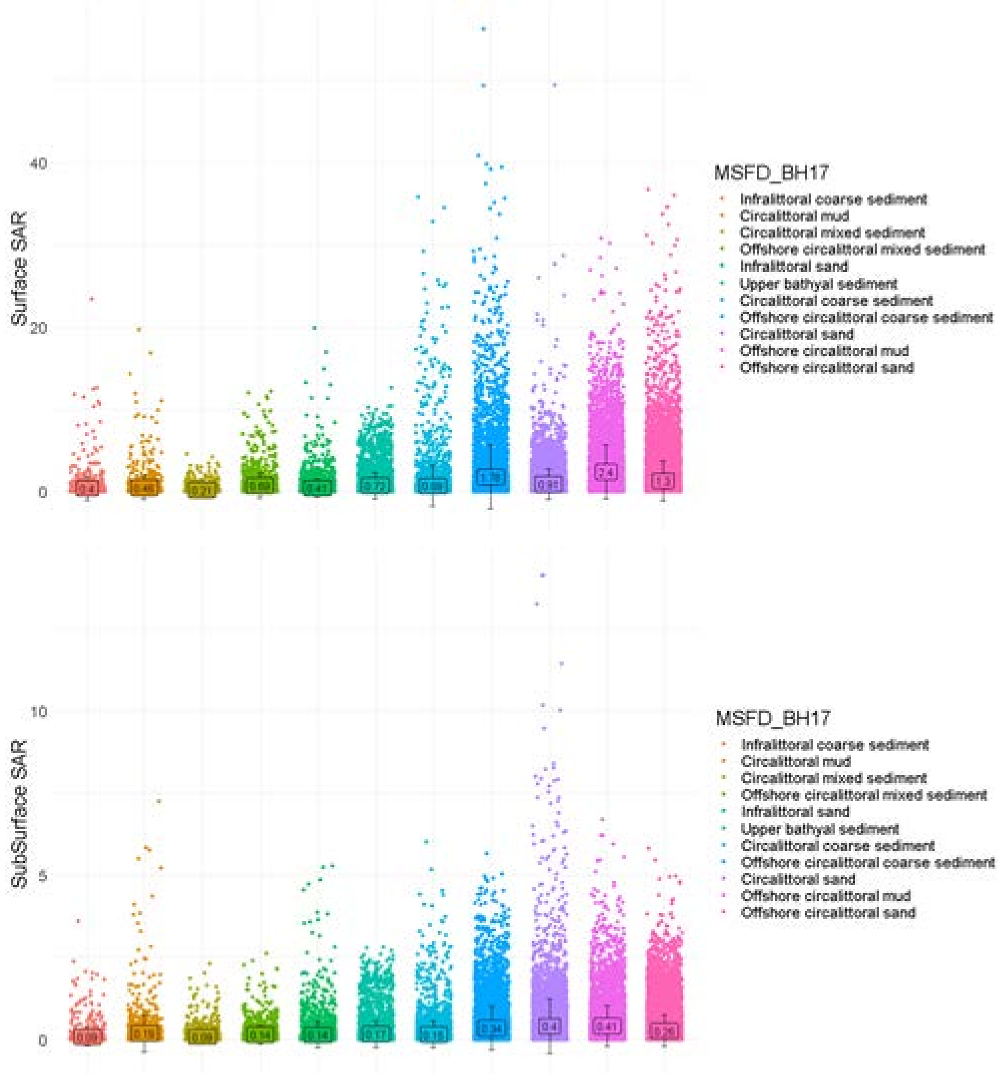


Figure 9. Surface and subsurface SAR by habitat type. Note that the scale of the Y-axis is different for the two panels.

7.1.3.2 Spatial analysis workflow

The analysis described above has been performed in a combined platform system, using PostGIS SQL databases for the spatial analysis and the R language for graphs and statistical analysis. The SQL and R scripts are made available below in order to make the analysis repeatable with new MSFD habitats categories. The results of all analysis described are provided at the c-square spatial unit, therefore all results and indicators are spatially related using the c-square identifier (e.g. habitat distribution and fishing pressure). Below the conceptual inputs, procedures and outputs are listed.

Habitat analysis

MSFD HABITAT BY C_SQUARES (benthic habitat sensitivity analysis)

INPUTS: EU SeaMap Emodnet, ICES/MSFD ecoregion c-squares, lookup table new habitat categories (sharepoint/Data/euseamap_MSFD_habitat_code.csv)

a. Join revised MSFD Broad Habitat look-up table with the EU Sea MAP using "MSFD_BH17" and "substrate" columns .
b. Calculate the proportion of habitat within a c-square , performing spatial join between Ecoregion c-squares and EU SeaMap new habitat classes.
c. OUTPUTS: c_squares with proportion habitat data integrated (columns: c_square_id, MSFD_BH17, substrate, rev_MSFD_BH17, proportion).

SILT % BY HABITAT PRESENCE BY C_SQUARES (uses: resuspension analysis)

INPUTS: *MSFD habitats by c-square* layers, Folk sediment classification look up table.

- Join *MSFD HABITAT INTO C_SQUARES* layer with folk classification table (to create) using 'substrate' (?) field .
- Calculate the proportion of silt per habitat occurrence within the c-square.
- OUTPUTS: c-squares with proportion of silt integrated.

Human activities pressures

FISHING IMPACT PRESSURES BY C_SQUARE

INPUTS: WGSFD advice layers (surface/subsurface SAR by fishing metier), ICES/MSFD ecoregion c-squares.

- Calculate the proportion of SAR by habitat within a c-square , performing spatial join between Ecoregion c-squares and EU SeaMap new habitat classes.
- OUTPUTS: c_squares with SAR proportion by habitat data integrated.

OTHER ACTIVITIES/STRUCTURES PRESSURES BY C_SQUARE

INPUTS: ICES/MSFD ecoregion c-squares, spatial layers other activities (windfarms, dredging aggregate).

- Join other activities layer.
- Calculate the proportion of other activities layer within a c-square.
- OUTPUTS: c_squares with proportion other activities/structures data integrated.

7.1.4 Exclusion of structures, habitats and regulations that are incompatible with bottom fishing from the c-square area that can be fished

The SAR can be underestimated within c-squares if fishing does not occur on the entire sediment surface area of the c-square due to spatial constraints created by other uses of the marine space. In these c-squares it is likely that the assumption of an even or random distribution of the fishing tracks is violated. There will be an underestimation of the fishing intensity on a portion of the c-squares where the fishing is concentrated, and an overestimation on the portion where fishing is incompatible (e.g. windmill parks). However, in the impact assessment the net effect on the depletion rate (d) would not be different unless the depletion (d) is habitat specific and the different habitat types within a cell are fully described. One requirement would then be to divide the c-square grid cell by different types of pressures.

WKBEDPRES1 provides input for how to establish a workflow on the collection of other pressures on the benthic habitats that would be applicable to the whole MSFD region. An ICES data call to collect other pressures than fishing data is under development and will address aggregate extraction data, dredging and sediment deposits data and anchoring sites data. As first approximation, EMODnet Human Activities layers could be used for testing purpose.

The c-square resolution of 0.05 might not be adequate for other pressures. Fishing could then be first aggregated at c-square resolution of 0.01 for integration with other pressures and for doing the actual impact assessment, while the assessment outcome itself could still disseminated at the 0.05 resolution. For an assessment that would account for the effect of other pressures, additional investigations will be required to figure out what would be the depletion rate d for each type of pressure. In addition, not all pressure types are mutually exclusive and the use of a compatibility matrix among pressures should then be investigated, as well as cumulative impacts created by overlapping pressures.

7.2 Resuspension and smothering

The interaction of towed fishing gear components, the seabed and the ambient water produces a region of high velocity, high turbulence, high shear bed stress and a pressure drop all of which may contribute to entrainment and mobilization of sediment behind the gear component in contact with the seabed.

O'Neill and Summerbell (2011) demonstrate empirically that the quantity of sediment mobilized behind a gear component is related to the hydrodynamic drag of the component and that the finer the sediment the more that is mobilized. This, they explain, is due to the fact that for a body in a steady flow, the energy associated with overcoming the hydrodynamic drag acting on a gear component manifests itself as turbulence in the wake, which will give rise to a pressure drop and a shearing action, both of which can cause sediment to mobilize. Hence, the greater the hydrodynamic drag, the greater the turbulence in the wake and the greater the quantity of sediment put into the water column. O'Neill and Ivanović (2016) develop an empirical model that describes the amount of sediment added to the water column in terms of the hydrodynamic drag of the component and the proportional silt fraction of the sediment (% of sediment < 63 µm) as follows:

$$q = 2.602 s_f + 1.206x10^{-3} H_d + 1.321x\,10^{-2} s_f H_d$$

where q is the mass of sediment put into the water column per m^2 swept, s_f is the silt fraction and H_d is the hydrodynamic drag per metre width of the gear component (Nm^{-1}). This expression permits the estimation of the amount of sediment put into water column in the wake of towed bodies on sediments with silt fractions ranging from 0.02 to 0.69.

This type of predictive model could be used to provide more detailed descriptions of the physical impacts of fishing activities. It would allow the variation that exists between gears within a fishery, the in-year variation of fishing effort and natural disturbance and the variability of seabed type to be taken into account. This would allow a level of investigation consistent with the variation of gear type and design and at spatial and temporal scales consistent with the available fishing effort and sediment type data.

To do this at a c-square grid level we need:

(i) the silt fraction (s_f) of the sediment in each c-square grid
(ii) the swept area in a c-square grid by métier

and for the 'average fishing gear' of each métier we need:

(i) the gear spread (s_m)
(ii) the gear component dimensions (so we can calculate frontal area, a_{mi})
(iii) the hydrodynamic drag coefficient (c_{mi}) of each gear component
(iv) the towing speed (U_m)

Thus, we can calculate the averaged summed length of all tows ($l_m = A_m/s_m$), and the drag of gear component i of the gear used by métier m is $h_{mi} = 0.5\rho U_m^2 c_{mi}\, a_{mi}$. Information on the gear component dimensions can be found in Eigaard *et al.* (2016) and estimates of the hydrodynamic drag coefficient of each gear component can be found in O'Neill *et al.* (in prep).

Using the formula above we can calculate the mass mobilized per meter towed by gear component i of métier m to be

$$q_{mi} = 2.602 s_f + 1.206x10^{-3} h_{mi} + 1.321x\,10^{-2} s_f\, h_{mi}$$

and the mass mobilized by the fishing gear of métier m per metre towed is then $q_m = \sum_i q_{mi}$

and the total mass mobilized by all the fishing gears of métier m in the c-square grid is

$$Q_m = q_m A_m / s_m$$

and the total quantity of sediment mobilized by fishing activity in a given c-square grid is

$$Q = \sum_m Q_m.$$

To get the silt fraction (S_f) at the c-square level the following steps need to be taken:

- Get the proportion of MSFD habitat type by c-square and the Folk sediment classification look up table.
- Join layer with proportion of MSFD habitat type by c-square with Folk classification table using 'substrate' field.
- Calculate the proportion of silt per habitat occurrence within the c-square.

8 Benthic habitat sensitivity

Fishery result in physical disturbance of the sea-bottom, which cause mortality and injury of specimen, leading to changes in abundance and biomass of certain species within a community and sometimes-total loss of certain fragile species. Therefore, we need to determine the sensitivity of the species community within a habitat. The species' capability to respond to physical disturbance (see box) are fundamental to determine the sensitivity of the benthic community within a habitat. In practice, several approaches are developed to assess the state or sensitivity of benthic communities to this physical disturbance (ICES WKBENTH 2017). In ICES WKBENTH 2017 report, the quality of those indicator approaches are evaluated based on frameworks developed in ICES (2002), Rice and Rochet (2005), and Queiros *et al.* (2016). Finally, as an example, ICES used the PD2 (further referred to as PD: "Population dynamic") and LL1 assessment methodology (not further tackled for the moment) to examine the relationship between the pressure and impact of bottom-contacting fishing gear on the seabed as well as the seabed status and the consequent catch and value of landings in their advice (ICES, 2017). This was displayed for the Greater North Sea area. The LL1 methodology was not further taken onboard for the moment, as it is currently not applicable outside the North Sea region, due to the need for data on physical forcing factors (e.g. bottom shear stress) in the modelling approach. This information is not available for other regions are not a relevant factor for that region (cf deep sea areas, Baltic sea).

The aim of this subgroup (and WGFBIT) is to develop operational methods, applicable on EU region wide scale, to assess the sensitivity of the seabed to bottom-contacting fishing gear to finally determine the impact/status of the seabed. As a first step, we decided to examine the PD method for all regions, wherefore we summarize the data needs and gaps for the different regions (see 8.2), explore the availability of longevity information for benthic species across regions (see 8.3) and develop a strategy for ground truthing (see 8.6). Next to it, we discussed already possible improvements for the method (see 8.4) and summarize methods for threshold setting (see 8.5). As benthic habitats were the assessment units within the regions, we checked the link between the EUSeamap 2017 map with the broad scale MSFD habitats and identify gaps (see 8.7). This should help to execute the analyses for determining the impact of bottom fishery in a standardized way for the regions in year 2 and 3 of WGFBIT. These outcomes serve as an example of how we can assess the benthic seafloor status (D6, MSFD) across regional scales based on a common language. During WGFBIT process, the utility of other indicator approaches can be further explored to assess seafloor integrity status on large scale or used to ground truth the regional indicator approaches.

Species typology in response to disturbance

Different species' responses to disturbance over time can be defined. In the context of bottom trawl fishing, an important parameter is trawling frequency that modulates species' response. Instantaneously, a haul can damage or kill an organism depending on its sensitivity to the gear (e.g. degree of body fragility) and the magnitude of the disturbance. Then, in case of consequent demographic or biomass depletion, another type of response is recovery through adult migration or offspring settlement. Recovery depends on trawling frequency so that the higher the frequency, the slower the recovery. In case of a null degree of sensitivity, organisms are resistant, i.e. no damage or population depletion is consequent from a trawl disturbance. In the case of a non-null degree of sensitivity, two types of species can be characterised by combinations of sensitivity and recovery. A resilient species is primarily characterised by a fast recovery following damage or depletion, independently of sensitivity, so that juvenile or adult mortality do not impair population survival over time under a disturbance regime. By contrast, a vulnerable species experiences substantial damage or depletion following a minimum disturbance with a recovery time exacerbated by maintained or increased disturbance frequency. These concepts are synthetized in **Error! Reference source not found.**.

Table 2. from ICES (2018). Species typology in response to the effect of physical disturbance. Each species type is defined by a combination of functional properties (sensitivity and recovery). Note that the combination of low sensitivity with high vulnerability is not evidenced in the "Life history approach"(A, r and K type of species, Beauchard *et al.*, 2017) from ICES WKBENTH 2017 (ICES, 2017).

Functional ability	Species type		
	Resistant	Resilient	Vulnerable
Sensitivity	None	Low or High	High
Recoverability	Not applicable	High	Low

8.1 Update of technical guideline

The rationale, scope and aim of the PD sensitivity methodology is outlined in a technical guideline document (Annex 4). In short, the PD method is a mechanistic model that estimates the total reduction in community biomass (B) relative to carrying capacity (K), corresponding to the estimated fishing intensity. Total community biomass relative to carrying capacity (B/K) describes the equilibrium state, i.e. the interaction between the depletion caused by fishing and the recovery of the benthic community. The impact is given by 1−B/K (Pitcher *et al.*, 2017). The depletion rates are estimated from a meta-analysis providing gear-specific depletion rates (Hiddink *et al.*, submitted), while recovery rates are derived from a longevity-specific meta-analysis (Hiddink *et al.*, in prep.). This method assumes that the sensitivity to trawling depends on the longevity of species and communities, as explained in the next section. This approach therefore requires estimates of the longevity of all species in a community. In section on ground truthing (8.6), it is explained how we can derive those longevity estimation for a (sub-)region. The biomass component of the PD method is a proxy for ecosystem (functioning) processes, for example, nutrient cycling or energy flow through foodwebs.

8.2 Geographical scoping/gaps

The aim of data summary table was to summarize the data from which the PD method could be assessed in the various sub-regions and especially in others than in the North Sea where it has been developed. More precisely, it has been though to evaluate at which methodological extent these other subregions (Baltic Sea, Celtic Seas, English Channel, Bay of Biscay, Mediterranean) can be assessed on the basis of the PD method (see details in separate texts per region). Does it for example require the establishment of new biomass-longevity curve to parametrize the method? In that case, specific data set with preferably no or minimal fishing pressure over environmental gradients (natural drivers) are needed. Other relavant issues are 1) how well the PD method works at EUNIS level 2 (= MSFD broad habitat type), or whether there needs to be longevity profiles established at finer levels (e.g. to distinguish between vegetated and non-vegetated shallow sediment habitats) and 2) whether the MSFD broad habitat types are too coarse (e.g. in bathyal zone - see lines 596-598) and it would be better to underatake assessments at finer habitat resolutions, provided the results can still be aggregated up to MSFD BHTs).

The datasets identified can indeed be used for two main purposes. The first is related to the establishment, when necessary, of new biomass-longevity curves based on reference datasets for a set of regionally relevant benthic habitats and associated communities, preferably without fishing pressure. The second purpose is related to the ground-truthing of the method with a new set of data across the various habitats and that would ideally cover wide fishing pressure gradients.

8.2.1 Mediterranean habitats

The Mediterranean is a deep water, non-tidal, warm, highly saline sea (limited fresh water inputs) with many parameters showing West-East and North-South gradients. It is generally an oligotrophic sea particularly to the East and South. It is bordered by 21 coastal states of which 8 are EU Member States, 4 with large sea areas and marine activities (ES, FR, IT, GR). The Sea has a high coastal population presence particularly on the Northern coasts and large seasonal population changes through tourism. The Sea is divided into 4 major sub-regions, although there are several more sub-divisions by eco-region.

Mediterranean broad scale habitat maps (new EUNIS level 2) are available through EMODnet at high resolution (Figure 10). However the data is highly modelled (limited ground-truthing), with low accuracy at the finer scale. The Mediterranean is a deep sea and mostly dominated by bathyal (upper and lower) sediments, with smaller areas of shelf (circalittoral mud and offshore circalittoral mud) and coastal infralittoral muds. The circalittoral and bathyal zones are where most bottom contact from fishing gears takes place (trawling is forbidden deeper than 1000 m depth). It is probable that the least accurate habitat maps are in shallower waters (infralittoral), particularly differences between the broad habitats (sands and muds) and their distributions. There is an issue in the EMODnet habitat maps in the Mediterranean that some MSFD classification broad habitat types are grouped e.g. Abyssal for all sediment types and Upper and lower bathyal sediment types grouped as "Upper Bathyal Sediment or Lower Bathyal Sediment".

Certain 'biogenic' habitats are very important including shallow Posidonia meadows (infralittoral) and maerl beds (infralittoral and circalittoral), with different degrees of area protection from fishing (current limitation within 3 nm of the coast or 50 m depth, but with various local derogations). Distribution maps (actual and modelled/predicted) exist for Posidonia meadows (from coastal to approximately 40 m depth), but are more limited for maerl grounds (EMODnet, through habitat suitability models), which can occur to deep waters (100 m). VMEs (and in some cases MPAs) exist concerning sponges, gorgonians, framework corals, Isidella and seapens.

EMODnet mapping is an on-going action and is in step-wise expansion phase with updates. The major gaps in the Mediterranean mapping work, are the very limited groundtruthing/sampling for habitat information towards more accurate habitat maps and although EMODnet is a coordinated action with good participation, funding is lacking for survey work, particularly, for example, in mapping of maerl beds and deeper waters for the presence of VMEs.

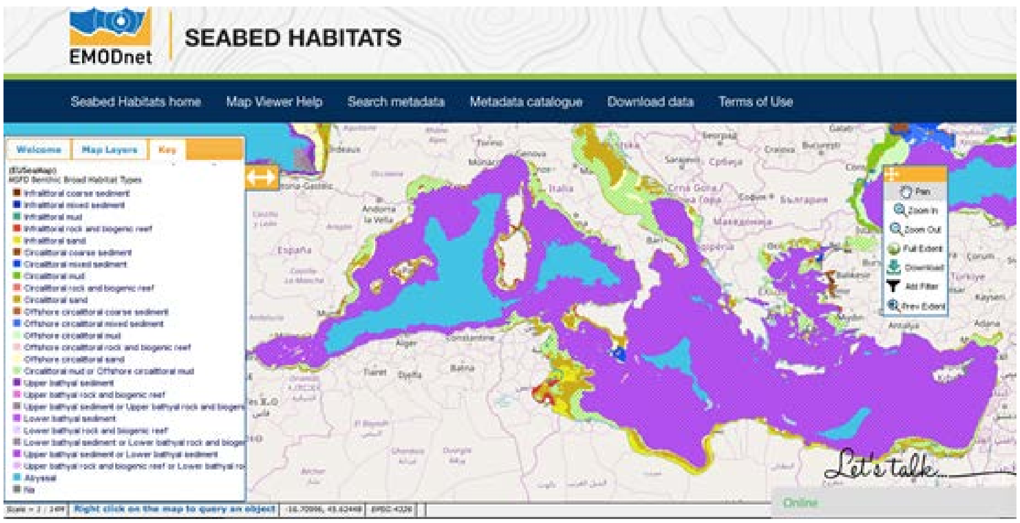


Figure 10. EMODnet MSFD habitats distributions in the Mediterranean Sea (EUNIS level 2 – 2016 Revision).

There is undoubtedly a wide variety of benthic datasets in the Mediterranean, particularly in EU countries (8 out of 21 of the coastal states are EU) and especially from members of this group representing Spain/France/Italy/Greece, although there is little coordination or standardisation (e.g. type of sampler, sieve size, or updating correct species names). There is one major compiled resource through the MEDOBIS-MARBEF project (http://www.marbef.org/data/imis.php?module=dataset&dasid=481) and on-going coordinated observation work including the JERICO-Next EU project that includes benthic samples (http://www.jerico-ri.eu).

8.2.2 (Sub-)Arctic

The (sub-)Arctic region has a huge spatial extent, great biodiversity and special oceanographic settings. Despite the importance of the biological resources in Arctic and sub-Arctic waters, and the increasing levels of human activities, a coherent compilation of knowledge of benthic habitats and especially vulnerable benthic species within this region is lacking. Therefore, the NovasArc project (Nordic Project On vulnerable marine ecosystems and anthropogenic activities in arctic and sub-arctic waters, https://novasarc.hafogvatn.is) aimed to map the distribution of Vulnerable Marine Ecosystems (VMEs) in Norwegian, Icelandic and Faroese waters, as well as in other areas of the Greenland and Norwegian seas. The project aims to map the distribution of commercial fisheries and other human activities as well, and identify possible conflict areas. Information from this project will serve partially the needs for the WGFBIT work for this region.

8.2.3 Bay of Biscay-Celtic Sea

The Bay of Biscay sub-region is characterized by the coexistence of strong natural gradients linked to depth, coastal influence, latitudinal zonation. Most of the offshore sedimentary habitats are different from the already parametrized habitats (for the implementation of PD) of the North Sea, both in term of community structure and composition (e.g Burrowing megafauna muds, biogenic habitats like maërl beds or cold water corals). Data potentially useful to tackle the challenge of implementing PD in the Bay of Biscay unfortunately include only very seldom infauna data taken from grabs outside the very coastal zone (i.e. offshore <3 nm from the coast) and mainly linked to the Water Framework Directive observation network. Offshore circalittoral habitats are however well covered by yearly monitoring for the megafauna component (sampled using trawls). One of the main issue in this subregion for the calculation of PD consists in the fact that even when infauna data are available for a given habitat type, their amount and spatial coverage are limited to specific opportunistic campaigns, potentially prevailing the generality of the biomass-longevity relationship that can be made. In addition, it appears difficult to assume these data are free from the effect of fishing pressure. Therefore, the assessment of the effect of fishing pressure based on the PD method would not describe deviation from a reference state. Megafauna data should offer a better coverage of a various sets of habitats under wider fishing pressure gradients. The resolution at which the habitats are taken into account is also of concern since, at the scale of the Bay of Biscay, clear biogeographic gradients of species occurrence. As well, for coastal sediment, the broad MSFD habitats types level disallow for the localization of biogenic habitats.

8.2.4 Baltic Sea

In the Baltic Sea, fishing with bottom contacting gear was identified to have an effect on, and thus be relevant primarily for MSFD/EUNIS level habitats spanning infra-, circa- and offshore circalittoral habitats. The working group based this on expert opinions and recent reports (e.g. Sköld *et al.* 2018). The group noted that bottom fishing in shallower coastal littoral habitats do occur to some degree, and could be assessed in the future. The habitat types identified and included as relevant span coarse, mixed, sand and mud sediments (i.e. MB, MC and MD levels 3-6). Biogenic habitats were not included at this point in the assessment regarding data. The group identified a number of already available data sources (data sets, studies, ca. 15 in total) spanning the habitats. The data covers primarily infauna densities and biomass to lowest possible taxonomic level, most often species level. Some gradient studies of trawling impact are also available. The group concluded that data could easily be combined with trait data.

8.2.5 Greater North Sea

The habitats in the Greater North Sea are well characterized and for the main habitat types the PD longevity relations are established. Except biogenic habitats are not taken into account, which are in some cases much difficult to detect or predict their occurrence (E.g. Sabellaria reefs). Beside it, much more benthic data is available (cf table), than used for building the longevity relations, which give the opportunity to execute an appropriate ground truthing in the coming years.

8.2.6 Summary

In relation to gaps to execute the impact analyses over the regions, some aspects need further attention in the next years.

- Biogenic habitats and VME's need to be included in the assessment in one or another way.
- There are real data gaps for infauna for some areas (Bay of Biscay, most of the (sub-)Arctic).
- Epifauna and megafauna data should be tested to include in the PD approach to allow a wider applicability (Bay of Biscay; (sub-)Arctic).
- In this way, the availability of appropriate benthic datasets need to be further enlarged within EMODNET biology.

8.3 Compilation of the longevity traits information

To assess the applicability of the PD approach across a wider spatial extent, and across a broader range of MSFD seabed habitats than previous (i.e., those addressed under Rijnsdorp *et al.*, 2018 for the Greater North Sea), the relationships between biomass longevity distribution and habitat characteristics need to be quantified. This will be undertaken using ground-truthed, empirical data from the Barents Sea, Celtic Sea, Norwegian Shelf and the Mediterranean Sea (and others). To fulfil this, there is a need to acquire longevity information for a wider range of taxa than currently exists.

8.3.1 Approach

Longevity data acquired under the EU-funded BENTHIS project were used as the initial basis for the traits information under WGFBIT. The majority of these data were initially made available from a data mining exercise by Cefas under the auspices of independent projects. Additional traits information was provided by participants from a number of collaborative partners under BENTHIS based on their individual infaunal and epifaunal data for the traits assessment under the project.

A spreadsheet of the BENTHIS longevity data was placed on the WGFBIT SharePoint. Additional sources of longevity data (e.g., those for Baltic Sea taxa; Gogina *et al.*, 2016, as cited by van Denderen *et al.*, submitted) were added as separate sheets on this file. For the Mediterranean macrofaunal trait data are available for a variety of species (approximately 350 genera) primarily from muddy sands and muds (Aegean Sea, parameterised in the BENTHIS project). The Longevity trait is in 5 classes (<1, 1-3, 3–10, 10–50, >50 years). Data on further species in other areas could be acquired with using expert opinion and database information from other regions (e.g. North Sea or BENTHIS project databases) or specific resources (e.g. http://polytraits.lifewatchgreece.eu). Mega/epifaunal traits are also available for the same sedimentary areas (Aegean Sea, approximately 200 genera from Agassiz trawl surveys).

Although progress was made during the meeting, it is a task of WGFBIT during the coming year to continue to populate this spreadsheet with longevity data for additional taxa. These taxa will reflect those represented in the ground-truthing samples for the additional regions and habitats. In essence, this spreadsheet will act as a repository for the longevity data for the application of the PD approach over a wider geographical area.

The WGFBIT identifies a number of points associated with the acquisition and use of longevity information, which need to be further addressed:

- While longevity information for many taxa were acquired from published sources (papers, books, grey literature), gaps in taxonomic longevity information are filled using best professional judgement and using information pertaining to closely-related taxa.
- Exact sources of traits information for each taxon will not be cross-referenced. Thus, for some taxa, longevity information based on a population in one geographical area may, in some cases, be used for data for different geographical regions.
- While the accuracy of this procedure cannot be quantified, the WG is confident that the resulting data provide a good approximation of the longevity distribution for each data point.
- It was discussed by WGFBIT that there is a possible need to adjust the current longevity trait modalities to accommodate the longer-lived taxa (discriminate between less than 20 or more), especially for deeper waters.

8.4 Further scoping of PD

At the meeting, we discussed further scoping issues for the PD method, based on the caveats within the method:

- Validation of model outputs by comparison with field samples.
- Most ecosystems constitute of different components that are sampled using different gears (e.g. grabs vs. trawls). How do we combine such sample data in the estimation on longevity-biomass distributions, and validation?
- The current implementation assumes an equilibrium between benthic state and trawling (benthos is adapted to certain level to a certain continuous trawling frequency), but when large changes in trawling pressures occur this may not be accurate. A dynamic implementation of the logistic model may be more appropriate in that case.
- Semi-chemostat dynamics rather that logistic dynamics may capture the inflow of recruits and larvae from surrounding areas better and result in more realistic recovery times from low RBS. This would require a re-estimation of r.
- The model does not include any spatial dynamics. Implementing flows of migrants or recruits from surrounding areas would be a very complex process and would require coupling to a hydrodynamic model.

- The model estimates relative biomass at the moment, which is suitable for assessing for the state relative to what it could be. For some other applications, assessing the absolute biomass may be more appropriate. This would require estimating carrying capacity for all c-squares.
- Quantitatively evaluate how declines in biomass relate to declines in species richness and functioning. Hiddink *et al.* (2006) presents a method to link loss of size classes to loss of species richness, which could be a starting point.
- Consider implementing the method for numerical abundance for systems where biomass distributions cannot be estimated
- Sensitivity testing of the outcomes to different assumptions in the approach.

8.5 Threshold setting of indicators

During the meeting, we had a discussion on methodologies for setting thresholds in relation to this FBIT framework. MSFD requires an assessment per MSFD broad habitat type (or other habitats defined by Member States) at biogeographically-relevant scales (e.g. southern North Sea). This needs an output which is the proportion (%) of the habitat in the assessment area which is in a good state (above a specified threshold value for habitat quality). The application of the trawl impact assessment methodology (FBIT) will give a RBS score for each c-square. Evaluating whether a regional sea is in a good environmental state will require defining a threshold beyond which a c-square is considered to be in a good state, and second threshold, which is the fraction of the c-squares that needs to be beyond the first threshold for the regional sea to be considered in a good state.

WGFBIT discussed what principles could lead to scientifically justified thresholds. It is important to keep in mind that the RBS is a way to quantify sea floor integrity and the structure and function of benthic ecosystems.

Different suggestions that were discussed were:

- Signal to noice ratio (Heiskanen *et al.*, 2016; Chuševė *et al.* 2016). From RoC curves established with longevity distributions obtained from well known impacted and unimpacted samples (golden standards assessed independently), identify indicator threshold the best indicating the border between good and moderate status while minimizing the probability to detect false positive and negative (concepts of sensibility and specificity).
- Define the threshold as the bottom interval of the range of variation under undisturbed conditions? This should take account of shifting baselines, and should take into account of climate change etc.
- Based on the biodiversity – function – biomass relationships. How much biomass can be lost before functioning is impaired? For functions like bioturbation, irrigation, filter feeding capacity, bentho-pelagic coupling.
- How much food do you exploited fish stocks need? If fish are exploited at MSY and reduced by 50%, do we only need 50% of the benthos to feed them?
- What level of biomass corresponds to none of the longevity classes disappearing?
- Evaluate the shape of the response – pressure curve. If there are thresholds in the curve, the good threshold can be based on that.

- Evaluate trade-offs between RBS and value, and identify thresholds or inflection points
- A different definition of sustainability is where recovery to within the natural range is possible within a generation (Rossberg *et al.*, 2017). The threshold would therefore be defined as allowing recovery rather than maintaining state.
- Evaluate the spatial distribution of the assemblage, and ensure that is connectivity maintained by avoiding too much fragmentation of c-squares that are still in a good state.
- Work with a chosen year baseline. This is not based on a good-bad state threshold but on a year with which you measure progress and change in state (towards better/improved) due to policy requirements. Use for example the first year of MSFD as your baseline (as the MS report every 6 years and mesure progress and distance to their GES targets between cycles). Or work with the year 2010 which is the year that is generally thought as the baseline year for measuring progress made against the EU biodiversity strategy 2020 targets. However, this approach merely gives a baseline from which to judge change in status, it cannot be assumed that the habitat was in good status in the baseline year.

Examples of threshold chosen in other assessment frameworks were also discussed:

- Marine stewardship council: VMEs need to be maintened at 80% of undisturbed state. Other main habitats need to be able to recover within 20 years.
- IUCN guidelines for threatened species define thresholds for declines and state
- Habitats directive: thresholds used for decrease in habitat extent (e.g. if less than x% decrease or less than X% difference from reference value and stable trend then this can be classified as FCS).
- The WFD also defines thresholds, and FBIT should examine how those were chosen.
- Sustainable fish stock exploitation often results in fish stocks being fished down to B_{MSY} , which is around 0.5 of unfished SSB, Bpa = 0.2. FMSY, Fpa?

8.6 Ground truthing

Ground-truthing is important to test the outcomes, assumptions and predictions of the indicator approaches used and should be done with independent datasets across regions and habitats. The ground-truthing should focus at one side on the relation of certain parts of the indicators (longevity for PD method) and the fishery pressure. Beside this, it is also essential to ground truth if the degree of impact or degradation in status in a certain area corresponds with these predicted by the models (PD in this case). Ideally, therefore, a benthic monitoring program with appropriate spatial and temporal scale in relation to fishery pressure is necessary, which is currently lacking in all areas. Therefore, we start to compile relevant datasets for the habitats in each region (see 8.2) and hope to compare the PD outcomes with other regional indicator approaches in the near future.

In first instance, to apply the PD method to other regions, the longevity distribution for the habitats in that region need to be constructed or adapted, as indicated in Figure 11. In order to take the trait work on to modelling of longevity and impacts, representative data sources need to be identified within specific eco-regions (many in the Mediterranean Sea). Sufficient samples from undisturbed (or at least very low impact) sites are required to parameterise the different habitat classes required for the assessment. These samples require a) biomass that can be assigned at the species level (individual species biomass, or split to individual species from group biomass, and conversion to AFDW), b) associated depth data for "depth zone" classifications and c) sediment granulometry data to assign to sedimentary classes. Time period (when the samples were taken – i.e. how old the samples are) is not seen to be a major issue. Beside it, the longevity relations were ideally build on data of low fishery pressure areas in a continuous way (based on the main environmental drivers of the region). But, we were realistic that this scenario cannot be applied for all regions, wherefore alternative pathways were allowed, which probably result in less confident results.

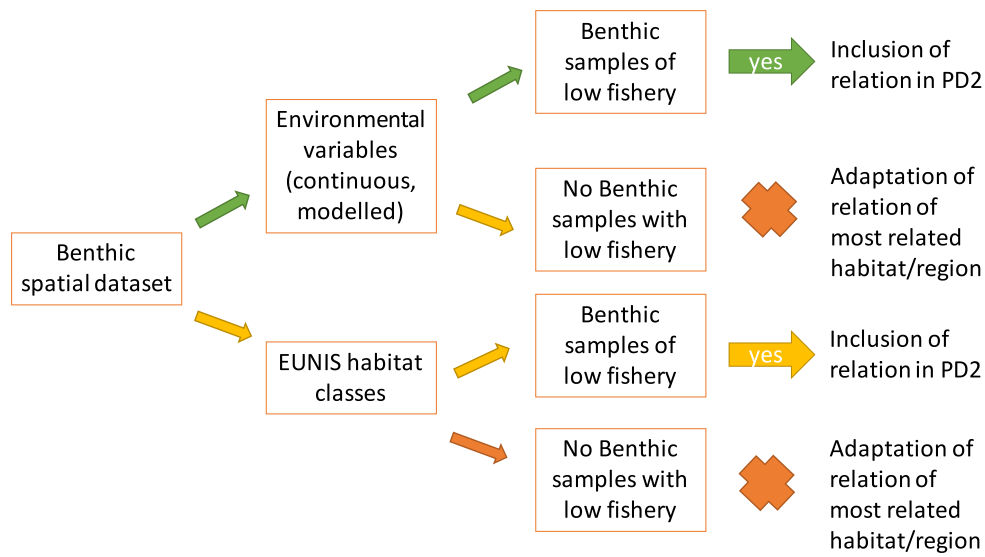


Figure 11. Pathway for updating longevity distributions.

Secondly, the outcome of the PD method need to be validated, which can be achieved via different ways.

- Validation of the longevity relations by comparing the new ones with those of the North Sea (Benthis);
- Impact assessment: Is the predicted relative state by PD in correspondence with the "true":
  - Relative biomass of the habitat/area (a 'reference' K [carring capacity] still needed)
  - Tested/comparing it by comparing it with other benthic state indicators on (sub-) regional level.

First example of ground truthing longevity: some thoughts

Benthic trait data from EMODnet (EMODnet Biology, 2018) covering most of the European northwest shelf were used to illustrate age distributions among MSFD habitats and to assess the validity of the reference longevity distributions for the PD model. The sampling stations × traits data, weighted by individual densities, did not highlight substantial differences of distributions between habitats. Most of distributions were characterised the dominance of classes in the 1–10 years interval. However, it can be argued that individual densities may be less relevant for expressing species community health since high biomass densities can translate the presence of high numbers of old individuals, whereas high numbers of individual can refer also to high numbers of young individuals. A complete biomass-weighted version of this EMODnet data product should be available in the coming months. For the present time, biomass densities are available for the entire North Sea (ICES, 2017), and enables a first assessment per gross habitat (Figure 12). Except for the category under-represented "Mixed sediment", under-represented, sand and coarse substrata are more skewed to the old age classes than mud substrata.

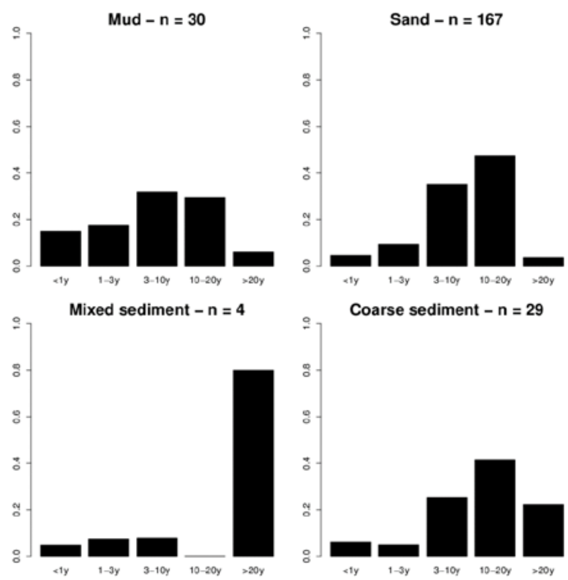


Figure 12. Biomass frequency distributions per age class and for each substratum type defined in the longevity approach, over the whole North Sea (North Sea Benthos Survey). "n" indicates the number of samples.

However, this habitat classification, restricted to the nature of the substrata, exhibits an issue. The geographical distribution of the biomass classes displays a clear preference of high old class biomasses (> 20 years) for mud in the southeastern part, centred on Oyster Ground (Figure 13).

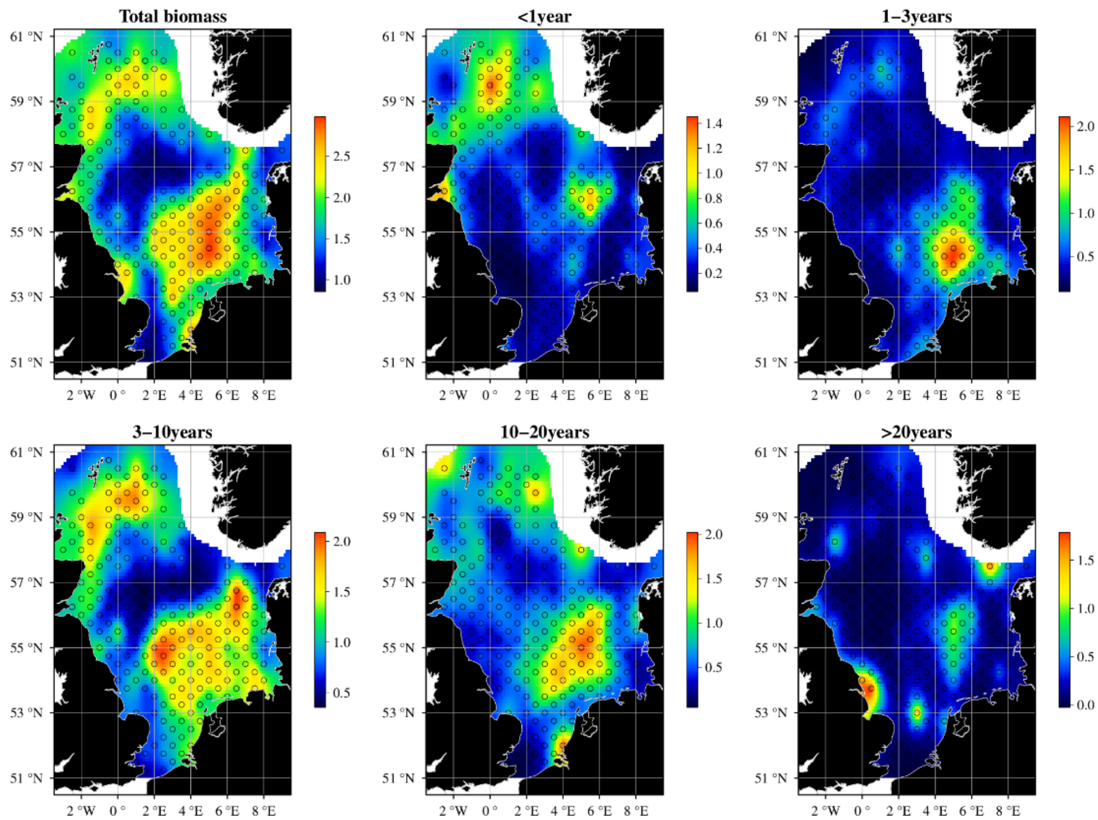


Figure 13. North Sea Benthos Survey, absolute biomass per sample (log-transformed values of ash-free dry weight m^{-2}**). From ICES WKBENTH (2017). Points represent the sampling stations.**

By contrast, lowest values centred on Fladen Ground are encountered in the north, though this area is classified as "Offshore circalittoral mud" like Oyster Ground.

A compositional contrast between the benthic communities of these two areas was initially highlighted in the work of Künitzer *et al.* (1992). Whereas Oyster Ground is populated by a large diversity of species of various life spans, the Fladen ground community is mainly composed of organisms resilient to disturbance as highlighted in the "life history approach" in the WKBENTH report (ICES, 2017). Hence, setting a same GES reference for these two different communities can lead to critical management issues (e.g. restricting fishing activity when overestimating sea floor vulnerability, or reciprocally). This also means that characterising habitats solely on substratum characteristics is too restrictive and that a mechanistic description of old age class distributions is necessary to a theoretically-sound application of the longevity approach.

8.7 Habitat issue

MSFD broad habitat types are directly equated to EUNIS level 2 classes (in GES Decision EU 2017/848 and Evans 2016) and are applicable to all MSFD regions. The more detailed biotopes (levels 4–6) vary by region due in particular to differing biogeographic characteristics in each region (see 8.2). The MSFD broad habitat types, will be considered as the minimal assessment units for evaluating benthic fishery impact. Nevertheless, assessments on more detailed habitat level (more than EUNIS level 2) is preferable. Therefore, we will ensure a correct link per region between the preferred and minimal required habitat level for executing the FBIT framework. This will be further documented in the next meetings.

9 Impact and trade-offs

9.1 Impact

The group reviewed the methods developed in the BENTHIS project. The two methods on the table were the PD method, which uses habitat- and gear-specific mortality and recovery dynamics to derive local impact scores, and the LL2 method, which calculates the degree to which communities (in particular long-lived species) can attain their natural age distributions given local fishing intensity. The advantage of the PD method are a strong rooting in general concepts of population dynamics and the fact that it is a single indicator summarizing impact across the entire benthic community. The LL2 method focuses on the long-lived species, under the assumption that these are the most sensitive to trawling. The PD method lends itself better to the Transparent Assessment Framework (TAF) standard adopted by ICES because it can be applied in an identical way across regions. The LL2 method is essentially a statistical method which would use different input data for different regions. For the PD method, the methodological differences affect the derivation of parameter values, but not the assessment procedure itself. Mainly on the basis of this advantage, the PD method will be taken forward in this working group. For the North Sea and Irish Sea applications, the data analysis underlying the LL2 method for those areas will be used to derive the parameters for the PD assessment in those regions. For other regions, the LL2 analysis from this area provides a published example for how the parameter derivation could be approached.

The current version of the assessment framework is unable to quantify the effect of uncertainty in the estimates of the assessment input: the logistic growth rate and mortality rate per unit fishing effort, the local fishing effort and the local habitat classification. This is seen as an important limitation because it precludes proper application of the precautionary approach. The uncertainty in these four assessment inputs is quantified, and it was decided that a Monte Carlo approach would be an appropriate method to estimate the effect of this uncertainty on the assessment outcome. This approach will be implemented intersessionally, and results will be presented to the working group in year 2.

The current code producing the PD assessment for the North Sea and Celtic sea does not have functionality to carry out an assessment for a subset of the area. This was seen as a limitation, and the code was adapted during the workshop to facilitate the specification of either a specific EEZ or another subregion.

Finally, the technical guideline document accompanying the PD assessment method has been extended and improved, in order to inform future policymakers and MSFD assessors.

9.2 Trade-off

Discussions in the trade-off subgroup focused on the goal of the trade-off calculations in the current developmental state of the assessment. It was decided that the main goal should be to showcase the potential of the assessment to study the consequences of differences in the implementation of management measures. The measure we decided to take as an illustration of example was a reduction of 10% in fishing effort. This number was chosen for illustrative purposes. This was implemented in 4 different ways:

1) Close c-squares to fisheries, starting at the lowest effort c-squares, until 10% of effort has been removed;
2) Identical to 2. but where effort of each metier, rather than total effort, is reduced by 10%;
3) Identical to 2. but where effort in each habitat, rather than total effort, is reduced by 10%;
4) Identical to 2. but where effort in each EEZ, rather than total effort, is reduced by 10%.

These variants represent different priorities and strategies in management implementation. In variant 1. the emphasis is on maximally increasing the unfished area while minimizing the loss of core fishing grounds. Variant 2. is identical but includes an 'equal loss' principle across metiers – the reduction in fishing effort is required for each metier. Variant 3. captures an important element of the MSFD, the goal of reaching good environmental status in each habitat. Variant 4, rather than representing a specific policy priority, is used to study the effect of national, rather than regional, implementation of the example management measure.

For the trade-off scenarios presented, we use the swept area ratio (SAR) as a descriptor of the value of areas to the fishermen. In earlier studies, the value of the fish caught at each location was used. However, value does not capture the cost to fishermen of fishing in that area. Areas which generate a lot of expensive fish, may do so at great cost to the fishermen. In that case the profitability of the area can be low or even negative. An actual cost associated with fishing in specific locations is difficult to calculate, because it would differ by metier but also by other factors such as a vessel's homeport, vessel characteristics, etc. However, the actual SAR found at a location is likely an approximation of the net profitability of the location, effort is likely to be concentrated on the most profitable fishing grounds. The 'fringe' areas with low effort may be areas where profitability is high only during small a period of the year and/or in specific locations known only to few fishermen.

Results[1] (Table 3) show that there are considerable differences between units that the reduction is applied to, and that there is also considerable variation compared to an overall reduction (case 1). In some units the effects are stronger than expected based on the '10% overall reduction' case (e.g. change in footprint in the Jersey EEZ), whereas in some units the effects are dampened (e.g. state change in the Norwegion EEZ). These results illustrate the importance to be specific about the scale of implementation when developing and evaluating management strategies.

We do present changes in the catches and value collected in the entire assessed region as a result of the various implementation variants (Table 3). Changes in the landings represent the effect of the effort reduction on the fish populations and hence can relate the

[1] It is important to note that these results are an illustration of the capabilities of the method only. They are not advice for or against any specific policy or implementation.

effect of the management of seafloor integrity to the management of fish stocks. The effect on the total value of the landings is likely related to the economic value of the fishing industry.

Another advantage of using SAR rather than catch value is that calculating management variants 1-4 now can be done in full on the pressure data and the outcome of the assessment (impact layer), and no additional data is required. This ensures that for any region where the assessment can be carried out, the management variants 1-4 can also be calculated.

The technical guideline document accompanying the PD assessment method has not yet been updated to include the above, as coding these scenarios into the assessment has not yet been finished. This will be done intersessionally and will be finished before WGFBIT 2019.

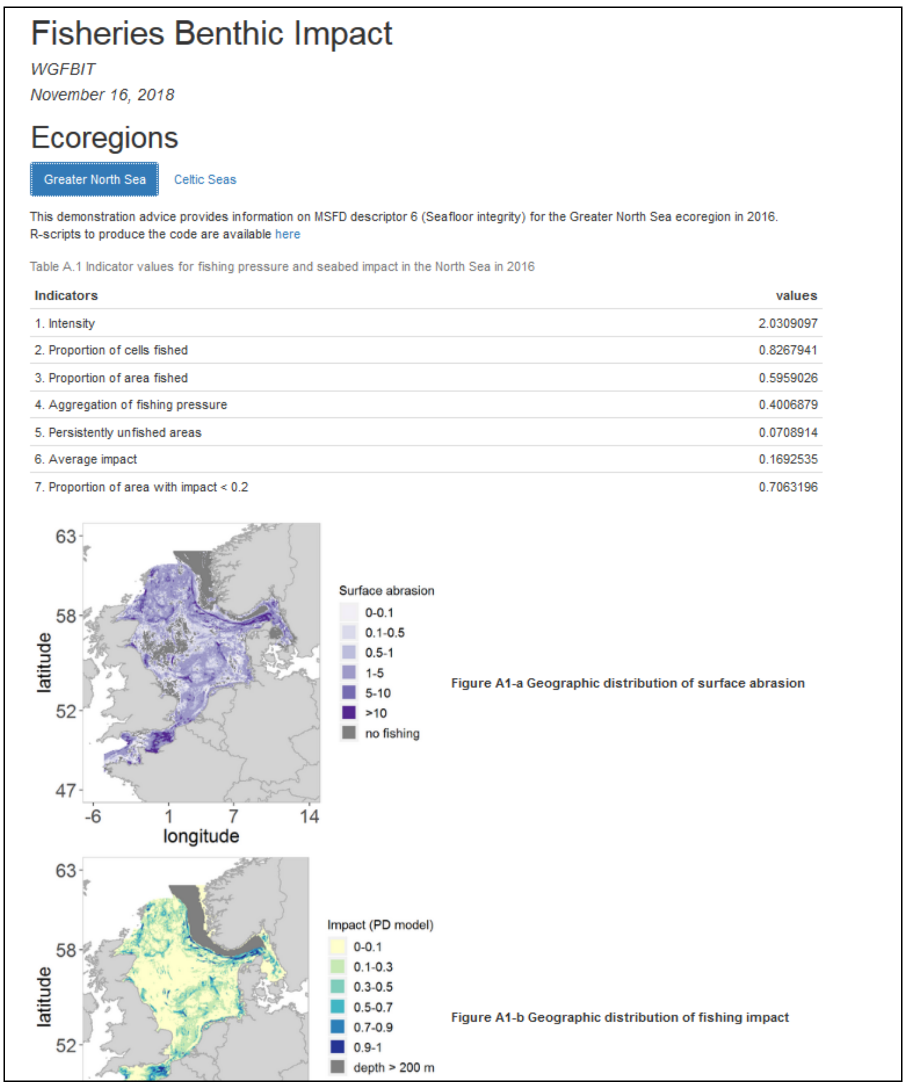
Table 3. Results of trade-off calculations for management variant 1–4 (main text), by the management unit they are applied to. The colour scale indicates effect size relative to case 1, with red indicating a lower value and green a higher value.

		State increase (%)	Footprint reduction (%)	Landings value loss (%)	Catch value loss (%)
1: Overall 10% reduction in effort		2.6	52.3	19.2	15.3
2: Reduction by métiers	OTCRU	7.4	64.2	10.0	8.0
	TBB	10.2	54.8	13.4	10.6
	OTREST	8.2	53.5	23.3	12.6
3: Reduction by EUNIS habitat	A5.15	4.9	56.8	12.0	11.9
	A5.25 or A5.26	4.1	53.5	21.7	18.1
	A5.27	2.4	51.7	14.9	16.2
	A5.37	2.5	29.0	9.7	8.6
	A6.5	0.7	59.0	39.1	7.3
4: Reduction by EEZ	Belgian EEZ	9.0	27.9	13.8	14.9
	Danish EEZ	5.2	51.7	31.1	20.2
	Dutch EEZ	2.6	40.7	19.8	12.1
	French EEZ	8.8	59.9	12.3	12.1
	German EEZ	2.0	44.0	14.6	10.3
	Guernsey EEZ	3.2	51.9	7.1	9.1
	Jersey EEZ	2.8	66.4	10.1	14.5
	Joint regime area Sweden / Norway	1.4	23.5	7.3	5.4
	Norwegian EEZ	1.1	48.6	10.3	12.1
	Swedish EEZ	2.3	43.5	15.6	9.2
	United Kingdom EEZ	2.3	53.6	15.6	16.2

10 Assessment on a regional scale (ToR B)

An updated assessment was carried out for the North Sea and Celtic Sea analogous to what was produced in WKBENTH, based on 2016 fishing pressure data and using the 2017 update to the habitat classification (MSFD broad habitat categories). In addition, functionality was added to carry out the assessment for specific national Exclusive Economice Zones and for specific management units or sub-regions used by OSPAR. We believe this functionality is critical for adoption of the method by member states and for comparison with the OSPAR method of assessment.

As integral part of the ICES TAF framework and to allow transparency and reproducibility, R-code of the assessment and data products for 2016 and 2017 are available online (https://github.com/ices-eg/FBIT). These will be used to produce a user-friendly overview document inter-sessionally (Figure 10.1).



Fisheries Benthic Impact

WGFBIT

November 16, 2018

Ecoregions

Greater North Sea | Celtic Seas

This demonstration advice provides information on MSFD descriptor 6 (Seafloor integrity) for the Greater North Sea ecoregion in 2016.
R-scripts to produce the code are available here

Table A.1 Indicator values for fishing pressure and seabed impact in the North Sea in 2016

Indicators	values
1. Intensity	2.0309097
2. Proportion of cells fished	0.8267941
3. Proportion of area fished	0.5959026
4. Aggregation of fishing pressure	0.4006879
5. Persistently unfished areas	0.0708914
6. Average impact	0.1692535
7. Proportion of area with impact < 0.2	0.7063196

Figure A1-a Geographic distribution of surface abrasion

Figure A1-b Geographic distribution of fishing impact

Figure 10.1 Fisheries benthic impact overview document.

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12 Revisions to the work plan and justification

None.

13 Next meetings

The next WGFBIT meeting will take place on 7–11 October 2019 in Ancona, Italy.

Annex 1: List of participants

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Annex 2: Recommendations

	Recommendation	Adressed to
1.	WGSFD to consider the list of identified tasks in section 7.1.2.3 of WGFBIT 2018 report, and incorporate them into their work plan to ensure links to WGFBIT in 2019.	WGSFD
2.	BEWG to review the WGFBIT benthic data table adding relevant data sources where relevant. BEWG should do this in the context of the PD method as described in the WGFBIT 2018 report, to ensure the approach can be developed across other regions and ground truthed.	BEWG
3.	The ICES Data Centre is requested to make server space (web application server) available for pressure/habitat maps, that would better ensure the running of the WGFBIT assessment process using TAF principles.	ICES Data centre
4.	Relevant SCICOM SSGs and ACOM vice chairs to ensure a joint workshop with targeted experts and WGs (e.g. WGECON, WGMAR) on "tradeoff scenaios between the impact on seafloor habiatst and provision of catch/value" (see draft resolutions in Annex 3 of WGFBIT 2018 report). Preparations/coordination in advance of the workshop should be done to ensure the proposed workshop building on from 2017 ICES workshop WKTRADE to produce operational scenario products that can be implemented in WGFBIT in 2019 within the suggested framework using TAF principles (see WGFBIT 2018 report).	WGMARS, WGECON, WGSocial

Annex 3: Draft resolution for an ICES Workshop on tradeoffs scenarios between the impact on seafloor habitats and provisions of catch/value (WKTRADE2)

ICES WKTRADE2- Workshop on tradeoffs scenarios between the impact on seafloor habitats and provisions of catch/value (ICES WKTRADE2), chaired by Chair (country), Chair (country), will meet in Copenhagen, Denmark, XX-XX May 2019.

ICES WKTRADE2 will produce fishing effort redistribution outputs based on modelled responses to five different management scenarios that focus on the reduction of benthic impacts. ICES WKTRADE2 will suggest further refinement of effort reduction scenarios and seafloor status indicators, suggested by ICES WGFBIT, to better reflect bio-economic cost and benefit trade-offs, and to outline progression towards potential management options. These suggestions will consider both generic applications (to all ecoregions), as well addressing issues related to regionally specific applications (see ICES WGFBIT three-year work plan). ICES WKTRADE2 will use state of the art modelling approaches of key dynamics and parameters to examine:

a) spatial displacement effects (1) redistribution among areas/habitats from opportunistic vs. repeated fishermen choices, constrained within geographical ranges and affecting the underlying catch rates, and 2) further redistribution effects among fishing harbor communities).

b) changes in effort allocation among activities (redistribution among gear types with various selectivity and impact on the seafloor, and various operating costs).

c) ecosystem effects (accounting for the risk of trophic cascading beyond the use of an overall biomass of benthos or fish).

d) socioeconomics issues (addressed in a CFP and/or deep-sea access regulation (EU) 2016/2336 context that will broaden the tradeoffs advice with new elements from the three pillars for sustainable CFP -social, economic and environmental).

Effort redistribution outputs will be used to inform where the redistribution of fishing activity will likely occur under the five different 10% effort reduction scenarios proposed as test case by ICES WGFBIT (see "scientific justification"). These outputs will provide information on the scale of economic tradeoffs compared against the impact on seafloor assessment outcomes. The Greater North Sea or Baltic Sea ecoregions are suggested as first operational case study given the wealth of data and approaches already available in this ecoregion. It is proposed that timing of ICES WKTRADE2 is such that it ensures that assessment outcomes resulting from the tested scenarios are available to WGFBIT (October 2019).

Prior to the workshop, the Chairs, together with three experts (from approved ICES WGFBIT, ICES WGMARS, and ICES WGECON) will prepare material to address the TORs. This group will also ensure the completion of the workshop report, and operational TAF (Transparent Assessment Framework) products for ICES WGFBIT consideration.

ICES WKTRADE2 will report by 30 June 2019 (via HAPISG) to the attention of ACOM and SCICOM.

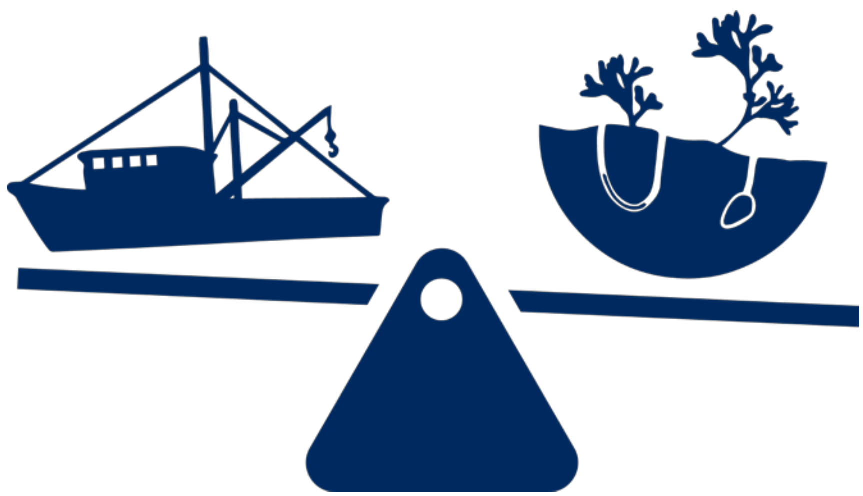
Supporting information

Priority	High, in response to the stepwise process to delivering guidance on sea-floor integrity for the Marine Strategy Framework Directive (MSFD). The workshop outputs will feed into ICES WGFBIT and the ongoing efforts to provide guidance on potential trade-off in the operational implementation of the MSFD, for example, in the context of other legislative drivers such as the CFP and/or the deep-sea access regulation (EU) 2016/2336.
Scientific justification	The impact assessment framework developed within ICES WGFBIT for MSFD-D6 is an overall assessment of benthic status supplemented by the exploration of alternative management options to improve GES by ecoregion or national jurisdictions. In the current draft advice produced by ICES WGFBIT, selected scenarios are explored in order to reduce the footprint of human activities and establish trade-offs between impact and economic revenue. All these scenarios apply a 10% reduction in effort, but in 5 different ways: Reduce the effort of each metier in each spatial cell by 10% Close c-squares to fisheries, starting at the lowest effort c-squares, until 10% of effort has been removed Identical to 2. but where effort of each metier, rather than total effort, is reduced by 10% Identical to 2. but where effort in each habitat, rather than total effort, is reduced by 10% Identical to 2. but where effort in each EEZ, rather than total effort, is reduced by 10% The first variant represents the simplest translation of a management measure into a pressure change. It is somewhat naive, but serves as a good comparison nonetheless. Variants 2 to 4 represent different priorities and strategies in management implementation. In variant 2. the emphasis is on maximally increasing the unfished area while minimizing the loss of core fishing grounds. Variant 3. is identical but includes an 'equal loss' principle across metiers – the reduction in fishing effort is required for each metier. Variant 4. captures an important element of the MSFD, the goal of reaching good environmental status in each habitat. Variant 5, rather than representing a specific policy priority, is used to study the effect of national, rather than regional, implementation of the example management measure. These scenarios by construction are likely to lead to a better status in areas where the effort is being reduced, while leading to some revenue loss affecting the fisheries from the cut in fishing opportunities imposed by the scenarios. Because in the present specifications the tested scenarios lead to such predicable outcomes, the WGBIT trade-off analysis would therefore gain at being refined to supplement the draft advice with more socioeconomic grounds. In reality, fishing effort may very well be redirected to the surroundings or to some other areas more remotely located. On

	the biological side, this will likely change the currently overly optimistic net gain on seafloor status expected from a fishing effort reduction if some displaced effort further deplete some other areas and ecosystem components, potentially vulnerable habitats, or previously unfished areas, or redirecting toward essential fish habitats. Ways to avoid such transfer should be considered. On the economic side, reducing the fishing opportunities will likely exacerbate the technical interactions among fisheries. This is because among others, fish movement, seasonal patterns, mutually exclusive gears, and regulations make the fish stocks differently available and accessible in time and space to different types of fishing, also constrained by how mobile the fishing vessels are. The current ICES WGFBIT draft advice gain/loss estimates will benefit from an understanding of how the human activities will redistribute in response to management and from the inclusion of fishery economic evaluation down to the actual fisheries and specific cost structures impacted by the scenarios. We know from our long experience of fisheries dynamics and fisheries behavior, bio-economic modeling and model development (as listed in ICES WGECON or EU STECF Bioeconomic modelling) that specific approaches are needed to capture the feed-back mechanisms in the system (such as, fisheries dynamics, technical interactions and fishery responses to changes in resource situations and management). Some proposed relevant models: DISPLACE, Honeycomb, STRATHE2E, etc.
Resource requirements	ICES Data Centre and secretariat.
Participants	Workshop with researchers and RSCs investigators. In particular ICES working group experts from: ICES WGFBIT, ICES WGMARS, and ICES WGECON. Industry representatives will also be invited to provide input. If requests to attend exceed the meeting space available ICES reserves the right to refuse participants. Choices will be based on the experts' relevant qualifications for the Workshop. Participants join the workshop at national expense.
Secretariat facilities	Data Centre, Secretariat support and meeting room
Financial	None
Linkages to advisory committees	Direct link to ACOM and SCICOM.
Linkages to other committees or groups	Links to WGSFD, WGFBIT, WGMPCZM, WGECON, CSGMSFD and SCICOM.
Linkages to other organizations	Links to OSPAR, HELCOM, Barcelona Convention, Bucharest Convention.

Annex 4: Technical guidelines document for assessing fishing impact from mobile bottom-contacting fishing gears

Version 1; 7 February 2019



International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Intended use

The target audience for this guidance document are experts involved in national level implementation (and reporting) of MSFD, experts from regional seas conventions (Baltic Sea, North–East Atlantic, Mediterranean and Black Sea areas), as well as, other stakeholders. The document presents an overview of the ICES benthic impact assessment framework to promote understanding and dissemination of an assessment method that can be applied at the regional scale and across European Seas.

The document comes together with open-source code and data products to run the assessment (https://github.com/ices-eg/FBIT), following the guiding principles of ICES Transparent Assessment framework (TAF). The assessment framework has been developed through an iterative process of open workshops that have been peer-reviewed, evaluated by an advice drafting group and approved by ICES Advisory Committee, ACOM (ICES 2016, 2017).

Please note that this document, as well as, the underlying code to run the assessment will be updated based on feedback and further developments. Ownership of this guidance document is with the ICES working group on Fisheries Benthic Impact and Trade-offs (WGFBIT).

Recommended format for purposes of citation

ICES. 2019. Technical guideline document for assessing fishing impact from mobile bottom-contacting fishing gears (version 1; 7 February 2019) *within:* 2018 Report of the Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT).

1. Introduction

In European waters the Marine Strategy Framework Directive (MSFD) has been introduced as one of the main legislative instrument to implement Ecosystem-based Management (EBM). EBM is a tool used to manage human activities affecting marine ecosystems, which aims to find a balance between conservation and sustainable use. ICES role is to provide the evidence for ecosystem-based decision making for the management of fisheries and other sectors in the ICES area. The evidence is required to explore the consequences of likely trade-offs between the services these human activities provide and the impacts these activities have on biodiversity of species and habitats.

Part of the MSFD, as noted in Descriptor 6 (D6), aims to maintain the integrity of the seafloor to ensure marine biodiversity and the provision of living resources. The overarching goal of D6 is for seafloor integrity to be at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected. The D6 requirement have led to the development of methods to assess impact on benthic habitats from anthropogenic activities, particularly bottom trawl fisheries, across EU member countries and Regional Sea Conventions (RSCs). In parallel to D6, such methods are also used to assess impact in relation to Descriptor 1 (D1) that has as overarching goal to maintain biological diversity.

For MSFD D1 and D6 purposes, ICES has acted as a facilitator for setting methodological standards that ensure operationalizing of a regional assessment of the seafloor (ICES 2016, 2017). In this work, ICES noted that there are two broad management objectives associated with the state of seabed habitats (ICES 2016):

1) The first is the protection and conservation of particularly valued and sensitive habitats and communities in shallow and deep waters. In a global context, some of these habitats and communities have been described and defined as Vulnerable Marine Ecosystems (VMEs). The sensitivity of areas holding these VME indicator species and/or habitat is such that any bottom-impacting fishing may severely or permanently damage and degrade them. As a consequence many become closed to these forms of fishing. Once particularly valued and sensitive habitats and communities have been defined, the main scientific activity needed for such areas is to find and map them – the main management need is to bring forward appropriate control measures. ICES recommended therefore that the state of these areas be assessed separately from the state of other seabed habitats (e.g. ICES 2018, advice on VMEs and fisheries footprint).

2) The other objective relates to the state of more widespread habitats and communities that are not covered by the category of particularly valued and sensitive habitats and communities. These habitats may be less sensitive, but their health may be valued for their ecosystem services and is required under the MSFD to maintain biodiversity and sea-floor integrity. Condition metrics for these areas are required under the EU's Marine Strategy Framework Directive to ensure that structure and functions of ecosystems are safeguarded and that benthic ecosystems are not adversely affected.

This document presents the technical guidelines for an assessment framework that can be used to assess the state of these more widespread habitats and communities (**Figure** 14**. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity.Figure** 14). The document will be annually updated after the WGFBIT meeting. We refer to Appendix 1 for definitions of all conceptual and technical terms related to the assessment that might invoke confusion.

1.1 Use of the assessment framework

The document describes the methodology of an assessment approach that can be used to derive a set of indicators for assessing physical disturbance pressures from bottom-contacting fishing gears and their environmental impacts on seabed habitats (**Figure** 14). The framework allows for evaluation of trade-offs between catch/value of landings per unit area and the environmental impact and recovery potential of the seafloor. The assessment framework is able to derive the indicators at the spatial scale of biogeographic subdivisions of the MSFD regions and subregions, and per MSFD broad habitat type (or more finely-defined habitat types), and, can be assessed over time.

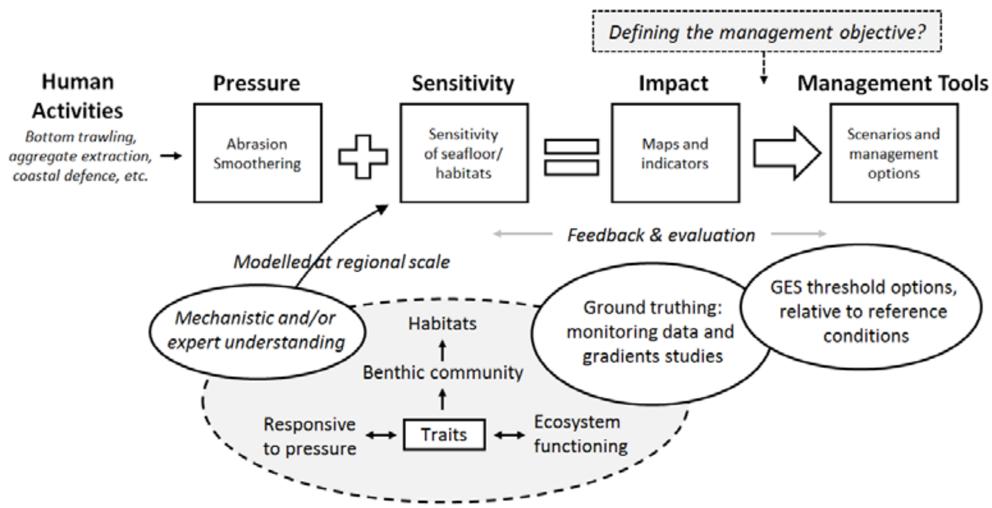


Figure 14. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity.

2. Assessment framework – pressure: seafloor abrasion from fishing activities

Bottom trawling is a type of fishing in which a net, or other collection device, is dragged over the seabed to catch demersal fish, crustaceans and shellfish. Bottom trawl fisheries are a key human activity in the EU waters that cause physical disturbance to the seafloor (Eigaard *et al.*, 2017, Amoroso *et al.*, 2018). The most commonly used gears for bottom trawl fishing are beam trawls, otter trawls, seines and dredges. To estimate fishing pressure from these bottom contacting gears, the different fishing activities (gear types) have been translated into a common fishing pressure metric. This allowed to describe the spatial and temporal distribution of fishing activities – and simultaneously consider their characteristic ecological footprint (Figure 15). To derive the fishing pressure metric data has been used from satellite tracking of fishing vessels (Vessel Monitoring by Satellite data - VMS) and fisheries logbooks.

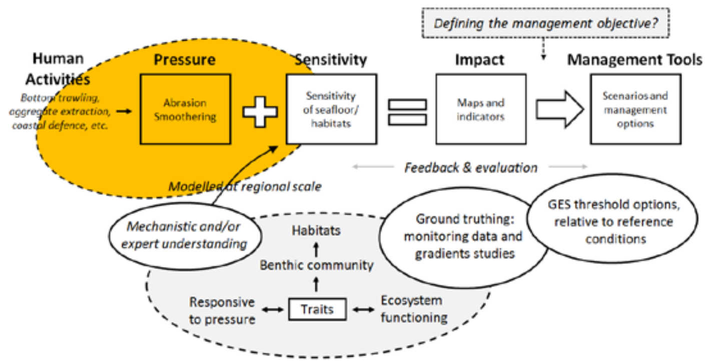


Figure 15. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity. Pressure part is highlighted in orange.

2.1 Estimating fishing pressure

To estimate fishing pressure it is necessary to provide a spatially resolved index of fishing intensity for mobile bottom contacting gears. Fishing intensity is defined as the area swept per unit area, i.e. the area of the seabed in contact with the fishing gear in relation to a surface area of the grid cell. Fishing intensity is based on VMS and fisheries logbook data. In its raw format, VMS data are geographically distinct points, so-called “pings”, providing information about the vessel, its position, instantaneous speed and heading. VMS transmits at regular intervals of approximately 2 hours, but with higher polling rates for some countries. VMS data points can be linked to logbook data in order to get additional information about the vessel flag country, gear code (equivalent to Data Collection Framework (DCF) level 4), fishing activity category (DCF level 6), average fishing speed, fishing hour, average vessel length, average engine power (kW), total landings weight and total value of all species caught. Following some analytical steps to identify e.g. misreported pings (ICES WGFSD 2015), the vessel state (steaming, fishing or floating) is identified using the speed information. Only data, which are assumed to represent fishing activity, are then assigned to a 0.05 x 0.05 degrees grid, about 15 km² at 60°N latitude, using the C-square approach (Rees 2003).

In order to calculate the fishing intensity values, certain assumptions about the spread of the gear, the extent of bottom contact and the fishing speed of the vessel need to be made (ICES WGSFD Report 2015). Submitted VMS datasets usually contain information on the gear based on standard DCF métiers (from EU logbooks, usually at the resolution of métier level 6) and the gear-specific fishing speed, but not on gear size and geometry. Therefore, vessel size - gear size relationships developed by the EU FP7 project BENTHIS project (Eigaard *et al.*, 2016) are used to approximate the bottom contact (e.g. gear width). To do this, it is necessary to aggregate métier level 6 to lower and more meaningful gear groups (so-called “Benthis métiers”), for which assumptions regarding the extend of bottom contact were robust. Following this, fishing effort (hours) is aggregated per c-square for each métier and year. Fishing speeds are based on average speed values for each métier and grid cell submitted as part of the data call, or, where missing, a generalized estimate of speed was derived. Similarly, vessel length and engine power are submitted through the data call but where missing, average vessel length/engine power values are taken from the BENTHIS survey (Eigaard *et al.*, 2016). Parameters necessary to approximate the missing information are listed in Table 4.

Fishing intensity values per gear group, grid cell and year are afterwards calculated. For towed gears (otter trawls, beam trawls, dredges), fishing intensity is described by:

$$SA = \sum evw \qquad (1)$$

for Danish seines as:

$$SA = \sum(\pi(w2\pi)^2(e/2.591234)) \qquad (2)$$

and for Scottish seines as:

$$SA = \sum(1.5\pi(w2\pi)^2(e/1.91125)) \qquad (3)$$

where *SA* is the swept-area, π the number pi, *e* is the time fished (h), *w* is the total width (m) of the fishing gear (gear group) causing abrasion, and *v* is the average vessel speed (m/h).

The swept-area information is additionally aggregated across métiers for each gear class (otter trawl, beam trawl, dredge, demersal seine) with two layers, one for surface abrasion and one for subsurface abrasion (as proportion of the total area swept). To account for varying cell sizes of the C-square grid, swept-area values are additionally divided by the grid cell area:

$$SAR = SA/CA \qquad (4)$$

where *SAR* is the swept-area ratio (number of times the cell is theoretically swept), *SA* is the swept-area, and *CA* is the cell area.

Table 4. Parameter estimates of the relationship between vessel size (LOA as length in m) or power (kW) and gear width, the average gear width causing abrasion (surface and subsurface), the corresponding proportion of subsurface abrasion and the average fishing speed for each BENTHIS métier, derived from Eigaard *et al.* (2016) and ICES (2015).

Gear class	Benthis metier	Model	Gear width causing abrasion (m)	Subsurface proportion (%)	Fishing speed (knots)
Otter trawl	OT_CRU	$5.1039\ kW^{0.4690}$	78.92	32.1	2.5
	OT_DMF	$9.6054\ kW^{0.4337}$	105.47	7.8	3.1
	OT_MIX	$10.6608\ kW^{0.2921}$	61.37	14.7	2.8
	OT_MIX_CRU	$37.5272\ kW^{0.1490}$	105.12	29.2	3.0
	OT_MIX_DMF_BEN	$3.2141\ LOA + 77.9812$	156.31	8.6	2.9
	OT_MIX_DMF_PEL	$6.6371\ LOA^{0.7706}$	76.21	22	3.4
	OT_MIX_CRU_DMF	$3.9273\ LOA + 35.8254$	113.96	22.9	2.6
	OT_SPF	$0.9652\ LOA + 68.3890$	101.58	2.8	2.9
Beam trawl	TBB_CRU	$1.4812\ kW^{0.4578}$	17.15	52.2	3
	TBB_DMF	$0.6601\ kW^{0.5078}$	20.28	100	5.2
	TBB_MOL	$0.9530\ LOA^{0.7094}$	4.93	100	2.4
Dredge	DRB_MOL	$0.3142\ LOA^{1.2454}$	16.97	100	2.5
Demersal seines	SDN_DMF	$1948.8347\ kW^{0.2363}$	6536.64	5	NA
	SSC_DMF	$4461.2700\ LOA^{0.1176}$	6454.21	14	NA

2.2 Calculating weight and value of fisheries landings

In the workflow for answering the ICES datacall, the function splitAmongPings from the Vmstools R package can be used to distribute landings or value of landings among the VMS positions where fishing activity is assumed. There are some choices within the function to distribute the landings either according to the time interval between the VMS pings or to split equally out on the pings. This can be done either by day, by ICES rectangle or by trip. As there are different options in the function, it might be implemented differently by nations.

3. Assessment framework – Habitat sensitivity

To convert patterns of fishing pressure into patterns of impact, the underlying seafloor sensitivity needs to be estimated (Figure 16). WGFBIT uses the so called "*PD method*" to assign sensitivity and derive impact. PD stands for 'Population Dynamics model'. WGFBIT uses the PD method, mainly due to the following advantages:

- The method is strongly rooted in general concepts of population dynamics and summarizes impact across the entire benthic community with a single indicator.

- The method is based on a large body of scientific work, which has been published in peer-reviewed scientific journals (Hiddink *et al.*, 2017; Pitcher *et al.*, 2017; Hiddink *et al.*, 2018; Rijnsdorp *et al.*, 2018).
- The method uses habitat- and gear-specific mortality and recovery dynamics to derive local impact scores.
- The method lends itself to the Transparent Assessment Framework (TAF) standard adopted by ICES because it can be applied in an identical way across regions.

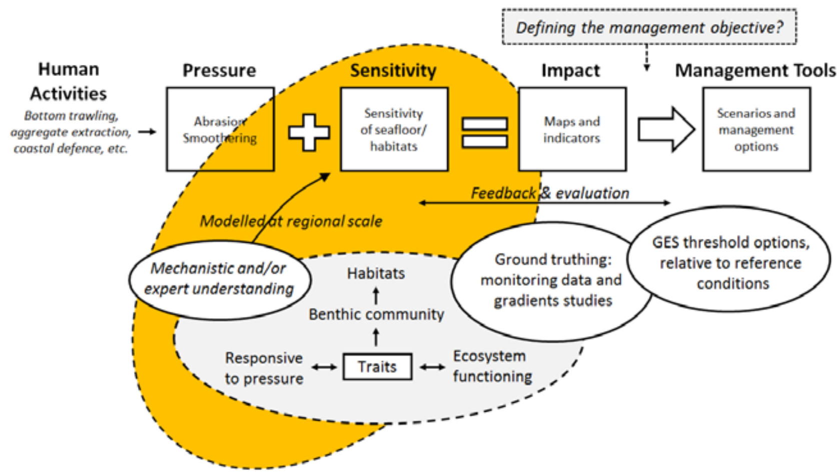


Figure 16. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity. Sensitivity part is highlighted in orange.

Below we describe how the PD method can be used to assess the impact of bottom trawling on the state of the seabed. An overview of the pieces of information required to perform an assessment, and how they are combined into a final estimate of benthic status is shown in Figure 17. The assessment methodology consists of a trawl impact model and its parameter estimates that are based on a generic understanding of trawl impacts and applicable for any fishery (Figure 17A), and a region and habitat-specific estimate of the longevity distribution of benthic biota (Figure 17B) that is used to derive the recovery rate in Figure 17A. Together with the pressure (section 0), this sensitivity leads to an estimate of the impact (Figure 17). The sections below explain how these are derived and applied.

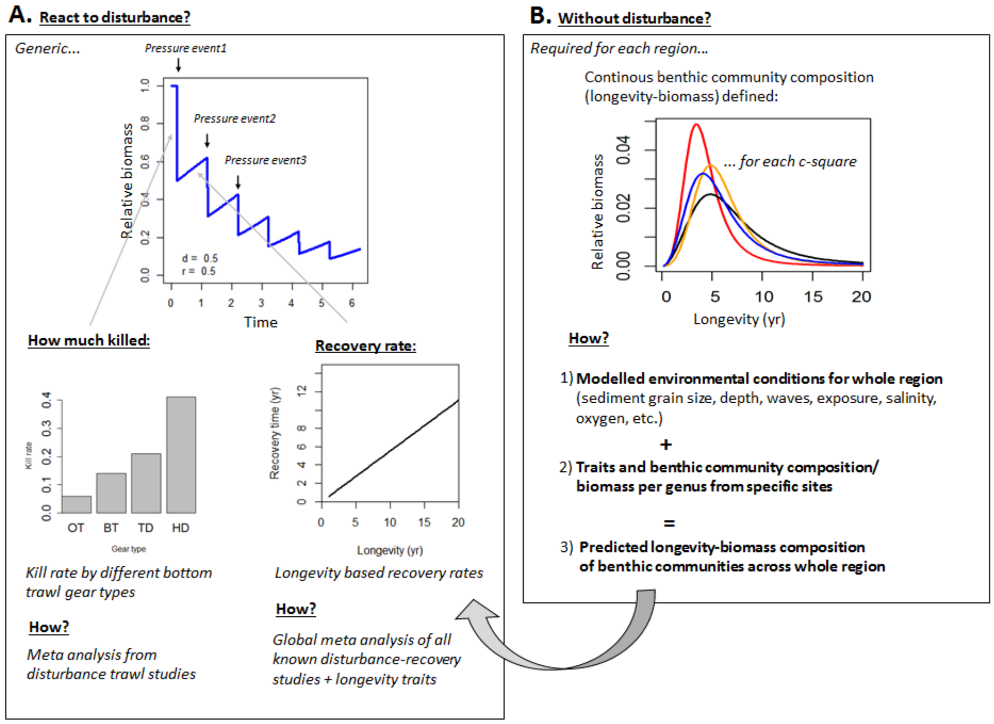


Figure 17. A flow diagram of how data layers and relationships derived from synthesis and analysis of the literature are combined to derived RBS (Relative Benthic Status) in the FBIT framework.

3.1 Population model

This section explains how the recovery rather and fraction biota killed by different gears are combined to estimate trawling impacts (top figure in

Figure 17A). The PD method is a quantitative method for assessing the risks to benthic habitats by towed bottom-fishing gears. The method is based on a simple equation for relative benthic status (RBS, defined as the biomass *B* relative to the carrying capacity *K*), derived by solving the logistic population growth equation for the equilibrium state (Pitcher *et al.*, 2017).

RBS = B/K = 1- F d/r

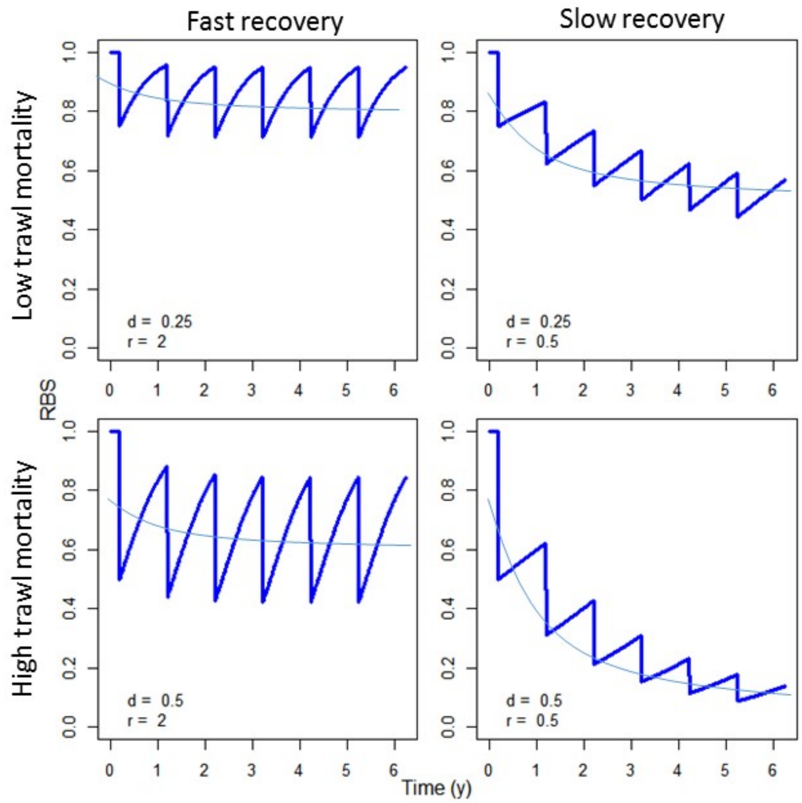


Figure 18. The effect of trawling depend on both the trawl mortality (depletion *d*) and the recovery rates (*r*) of the benthic community. In this example, trawling occurs once a year, and after trawling recovery of the relative benthic state (RBS) occurs.

In this case, trawling effort (F = SAR) is defined as the total area swept by trawl gear within a given area of seabed in one year divided by that area of seabed (units y^{-1}, see 0). Depletion *d* is the fraction mortality per trawl pass estimated from experimental trawling studies. *r* is the intrinsic rate of population increase.

The impact of trawling on benthic biota depends on both d and r (Figure 18), and sensitivity to trawling depends on the ratio of d over r, and is therefore proportional to the reciprocal of the recovery rate r.

Previous work aiming to categorise the impact of human pressure on ecosystems has been using a variety of terminology to typify the sensitivity to pressure (e.g. https://www.marlin.ac.uk/sensitivity/sensitivity_rationale). 'Resistance' as used in such frameworks is equivalent to (1-d), while 'resilience' is equivalent to r, and 'Sensitivity' is generally defined as the 'product' of resistance (i.e. (1-d) * r) and often categorised in limited number of categories. The RBS equation above shows that sensitivity in our approach is equivalent d/r, and d and r are quantified based on empirical estimates rather than categorised based on expert opinion.

Estimating RBS therefore requires only maps of fishing intensity and habitat type – and parameters for impact and recovery rates, which have been taken from meta-analyses of all available studies of towed-gear impacts. The assessment produces a relative benthic state estimate (RBS) for each c-square in the assessed region, based on just two parameter values (depletion *d* and the intrinsic rate of population increase *r*, a metric of recovery rate) and the fishing intensity.

3.2 Systematic review of the evidence

The parameter estimates for *d* and *r* and their uncertainties were based on a collation from published experimental and comparative studies of the effects of bottom trawling on seabed habitat and biota following a systematic review protocol (Hughes *et al.*, 2014), thereby avoiding selection bias. Studies were included if the abundance *B* (as numbers or biomass) of benthic species, genera and families, of either infauna and/or epifauna, was reported. This includes all studies that passed the quality selection criteria, and covers both infauna and epifauna sampled using grabs, dredges, trawls, photo and video, and a wide variety of habitats, although most studies were from the temperate northern hemisphere. The parameter estimates are therefore applicable to benthic communities in general, and constitute a synthesis of all the evidence available.

The validity of the estimates of *d* and *r* depends on the quality and design of the included studies, and the extent to which the control locations in the studies used to estimate *r* representing unfished reference conditions. Valid estimates of *d* and *r* will lead to a carrying capacity estimate for unfished conditions. If studies are carried out in areas where unfished control stations represent a situation that is different from the pristine state from 100s of years ago (e.g. where oyster reefs were lost), the carrying capacity estimate, and RBS estimates, produced using this method will be relatively to the state of the seabed as it could currently be without fishing, not relatively to an unknown state in which it could have been at some historic point in time.

3.2.1 Response variable: total community biomass

This methodology estimates RBS, which is estimated here as the benthic biomass of the whole benthic community relative to its carrying capacity. This metric is used because it is expected to be a proxy for the structure and function of benthic ecosystems. A high community biomass will coincide with communities where the body size distribution, age structure as well as numbers of the benthic fauna are close to natural, and a community biomass correlates to the energy flow through food webs and other ecosystem processes that are linked closely to biomass (e.g. nutrient cycling, bioturbation and food provisioning for fish and sea birds). Recovery in numbers is driven more strongly by recruitment than recovery of biomass, which is driven by increases in the size and age structure of the population through growth of individuals.

A comparison of different responses variables using all studies from our systematic review showed that community biomass is the most sensitive indicator of trawling impacts as it is most responsive, while community abundance and species richness were less sensitive, and diversity indices are not suitable as state indicators for monitoring the effect of bottom trawling (Figure 19, Hiddink *et al.* in prep).

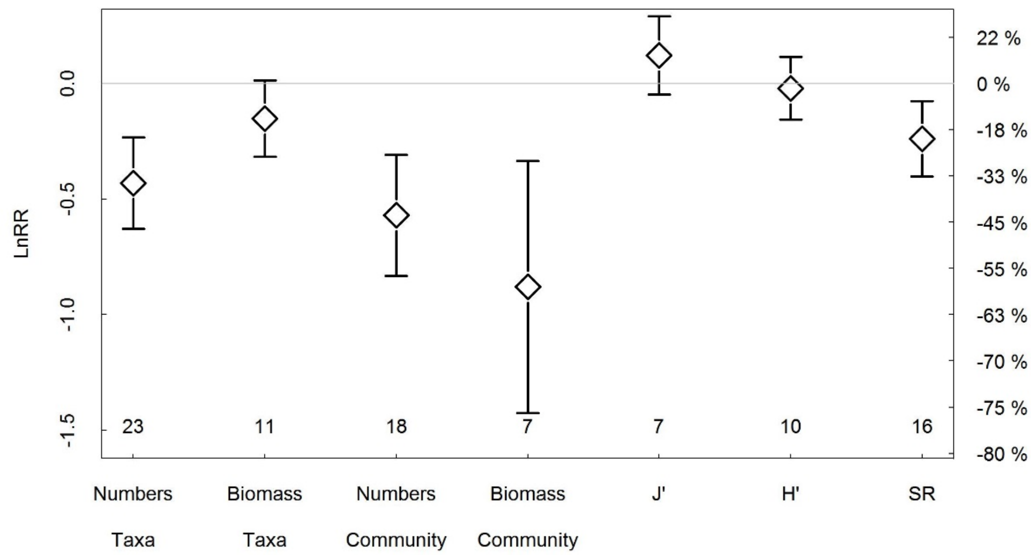


Figure 19. Outputs of the meta-analysis of control-impact studies with 95% confidence intervals. If the 95% confidence interval overlaps 0 the effect was not significant. The right-hand axis gives % changes for ease of interpretation. J': Evenness, H': Shannon-Wiener diversity index, SR: species richness (from Hiddink *et al.* in prep).

3.2.2 Depletion, *d*

This section explains how we estimated values for 'How much killed' in Figure 14A. Bottom trawls [here defined as any towed bottom-fishing gear, including otter trawls (OTs), beam trawls (BTs), towed (scallop) dredges (TDs), and hydraulic dredges (HDs)] are used to catch fish, crustaceans, and bivalves living in, on, or above the seabed. The meta-analysis in Hiddink *et al.* (2017) provided estimated for depletion *d* for the biomass of the whole community of benthic invertebrates. Estimates of depletion d and penetration depth *P* by gear type were very closely correlated (Figure 20) (Pearson's r = 0.980, P = 0.020). OTs had the smallest impact, removing on average 6% of organisms per trawl pass and penetrating on average 2.4 cm into the sediment. Median penetration depths were 2.7 and 5.5 cm for BTs and TDs, respectively, and the corresponding median depletions per trawl pass were 14 and 20%, respectively. HDs had the largest impact, removing on average 41% of organisms per pass and penetrating 16.1 cm. These values are generic estimates over all habitats.

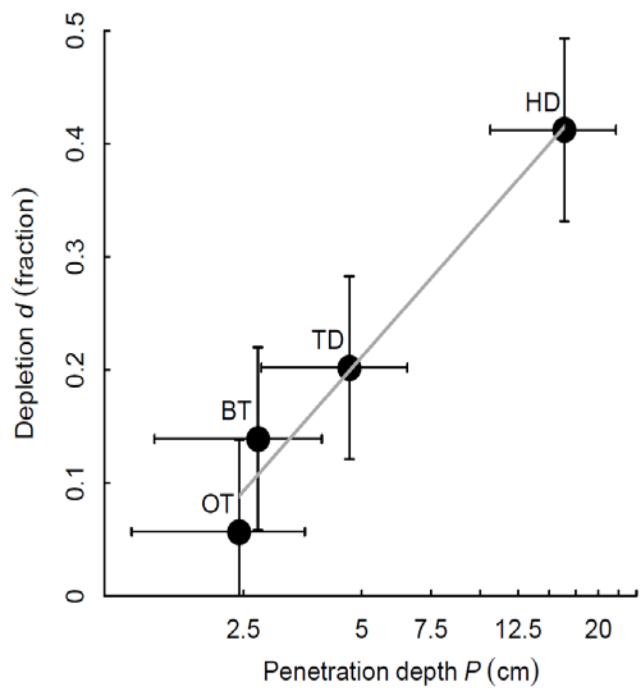


Figure 20. The relationship between the penetration depth P and depletion d of macrofaunal community biomass and numbers caused by a single trawl pass for different trawl gears (means ± SD) (Hiddink *et al.*, 2017).

Assessments can use the *d* estimates presented here by mapping their metiers onto these broad gear categories, or alternatively derive *d* if *P* of a gear is known. Work is underway to provide P and d estimates that depend on gear as well as sediment type, and suggest a deeper P in mud and gravel compared to sandy sediments (Pitcher *et al.* in prep). The *d* estimates presented here are for whole benthic communities, and not differentiated for different habitats. More specific estimates for different habitats, and different components of the benthos are available in Sciberras *et al.* (2018) and may be appropriate to use for assessments of particular components of the ecosystem.

3.2.3 Longevities trait information

The PD method assumes that the sensitivity to trawling is proportional to the reciprocal of the longevity of species and communities, as explained in the next section. This approach therefore requires estimates of the longevity of all species in a community.

Owing to scarce data and high uncertainty in longevity (T_{max}) estimates for individual species, longevities were assigned to taxa with a fuzzy-coding approach by Bolam *et al.* (2017). This database assigns fractional scores to each of four T_{max} categories (<1, 1-3, 3-10, >10yr, chosen to encompass the range of possible attributes of all the taxa), depending on the affinity of the species with these categories, and summing to one. Fuzzy coding allows taxa to exhibit multiple T_{max} categories to different degrees, and helps to address the uncertainty in and absence of direct T_{max} measurements for many benthic invertebrate species and expected differences in T_{max} within species linked to latitude and environment.

3.2.4 The intrinsic rate of population increase *r* (recovery rate)

This section explains how we estimated values for 'Recovery rate' in Figure 17A. The effect of any given rate of trawl mortality on a population will depend on its life-history, whereby populations with low *r*, low natural mortality rates (*M*) and greater longevity (T_{max}) have an increased sensitivity to trawling disturbance (Duplisea *et al.*, 2002). For example, Tillin *et al.* (2006) demonstrated that benthic epifauna with T_{max} >10yr decreased in abundance with trawling, but that no such reduction occurred for fauna in the same areas with T_{max} <2yr.

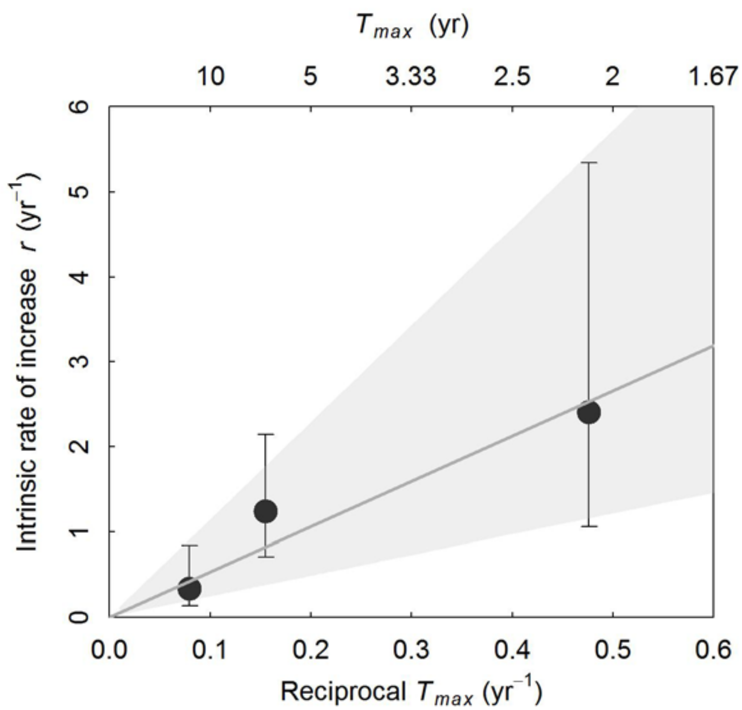


Figure 21. Relationship between *r* and longevity T_{max} estimated from gradient studies (*r* = 5.31 / longevity, R^2 = 0.96, $F_{1,1}$ = 73.9, P = 0.013).The points and error bars are *r* estimates and their 95% confidence intervals, while the solid line is the fitted regression line. The shaded areas indicats the regression fits through the upper and lower confidence intervals of the data (upper: *r* = 11.44 / longevity, lower: *r* = 2.43 / longevity) (Hiddink *et al.*, 2018).

Hiddink *et al.* (2018) showed that the effect of bottom trawling in comparative studies increased with longevity, with a 2-3× larger effect on biota living >10yr than on biota living 1-3yr. We attribute this difference to the slower recovery rates of the longer-lived biota. This work showed that *r* closely relates to the inverse of longevity of benthic fauna, and that this matches theoretical expectations (Figure 21).

3.2.5 Habitat sensitivity

The distribution of longevities can then be used to estimate the sensitivity to trawling of a habitat. A benthic community with many long-lived species will have a lower mean *r* than a community with many short-lived species. Because the effect of trawling is proportional to the ratio of d/r, a lower r with result in a higher impact at the same intensity of trawling. Figure 22 illustrates this, using two hypothetical habitats. A habitat will be sensitive to trawling if a large fraction of the biomass of the community, in an untrawled community, is made up of long-lived species with a low *r* (Figure 22a). A habitat will be less sensitive to trawling if a large fraction of the biomass of the community, in an untrawled community, is made up of short-lived species with a high *r* (Figure 22b). This results in sensitivity of habitats to bottom trawling being higher in habitats with higher proportions of long-lived organisms (Figure 22). Because the biomass of the high *r*, short-lived, species will respond less to trawling that the biomass of the low *r*, long-lived, species, total community biomass will respond differently depending on the longevity composition of the community at no trawling.

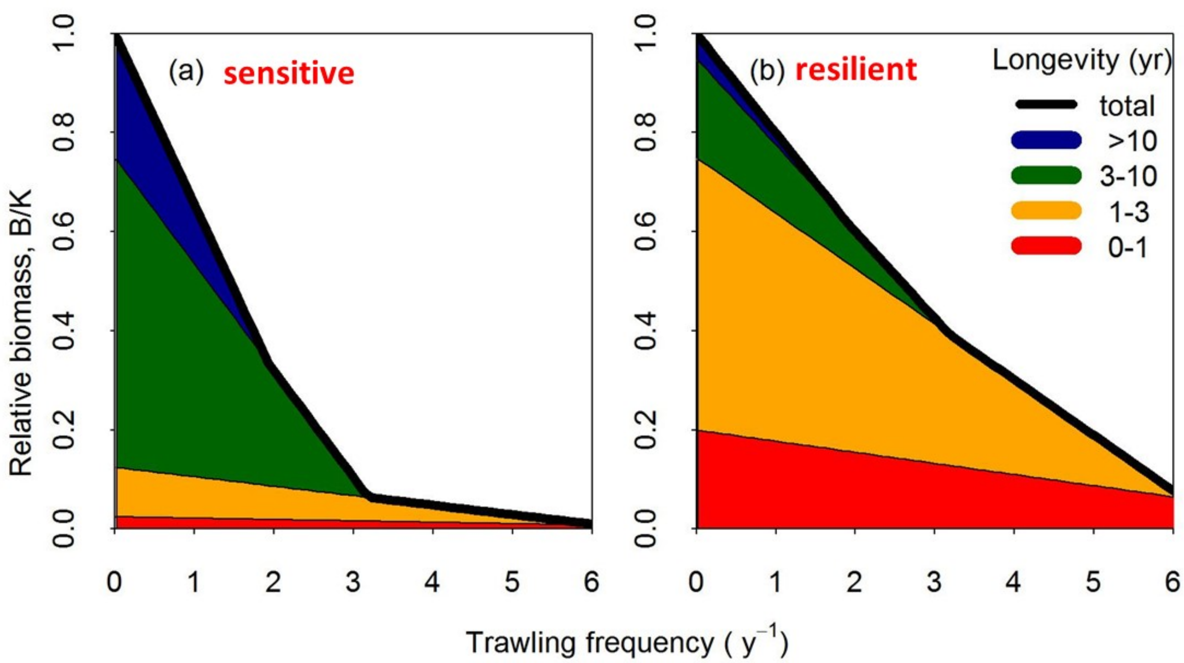


Figure 22. An example of how the longevity distribution of a benthic community at no trawling affects the response of total community biomass to bottom trawling.

Differences in longevity distribution of benthic communities are likely to be related to the environment they live in. Habitats with high levels of other disturbance, for example by waves, or hypoxia, are likely to have a low fraction of long-lived species as these disturbances will have already led to the loss of such species, and are instead dominated by short-lived fauna. As a result, communities in high natural-disturbance environments with shorter-lived fauna will be less sensitive to anthropogenic disturbance, as shown in several previous studies (Hiddink *et al.*, 2006; van Denderen *et al.*, 2015; Rijnsdorp *et al.*, 2018).

This means that where the longevity of a species or the longevity distribution of a community is known or can be inferred, our estimates of depletion and intrinsic rate of increase can be combined with high-resolution maps of trawling intensity to assess trawling impacts at the scale of the fishery or other defined unit of assessment.

3.2.6 Estimating the biomass-longevity distribution of untrawled communities

This section explains how we estimated the continuous benthic community composition in Figure 17B. The quantification of habitat sensitivity is therefore dependent on estimating the biomass-longevity distribution of untrawled communities. Such relationships were fitted by Rijnsdorp *et al.* (2018) from the cumulative biomass distribution of infaunal invertebrates by T_{max} category from 401 stations in the English Channel and southern North Sea, as determined from grab and box core samples in untrawled locations (Figure 23). For North Sea infauna, the fraction of biomass of long-lived species increases in coarser sediments and at lower tidal bed shear stress, and the fraction of short-lived fauna is higher in mud habitats. These relationships can be used to predict the biomass-longevity distribution for each c-square.

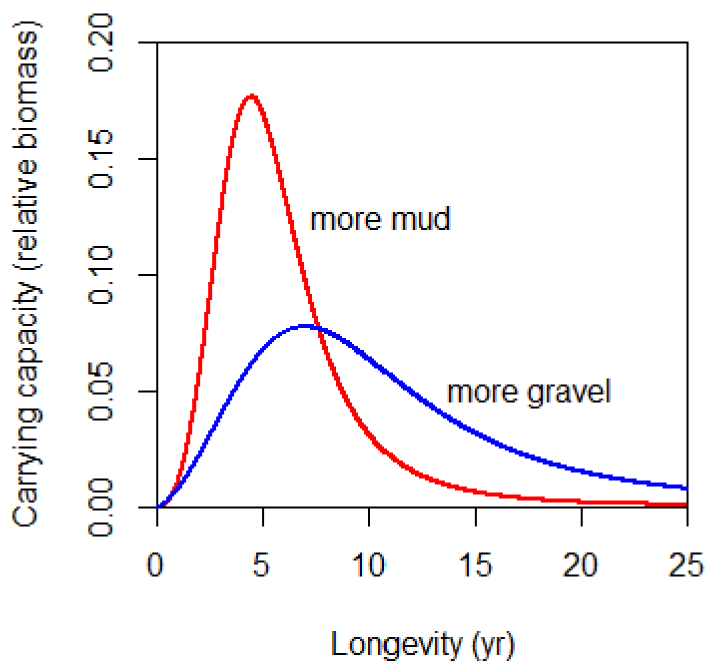


Figure 23. Examples of the relative biomass–longevity relationship of the untrawled benthic community for a habitat with 50% mud and 50% sand (red line), and for a habitat with 50% gravel and 50% sand (blue line). Bed shear stress = 0.1 N m^{-2}.

To apply the PD approach to other areas, the biomass-longevity distribution of untrawled communities will need to be estimated in relation to environmental variables. This will require samples (which can include grabs, cores, video, photo, dredges or trawls) of benthic communities over the main environmental gradients. A significant fraction of these samples need to be taken at no or low trawling locations. Estimates of current carrying capacity may underestimate the carrying capacity of habitats when there is uncertainty on how 'trawl-free' the data really are. Rijnsdorp *et al.* (2018) describes how to derive these relationships from the data.

If environmental data layers (e.g. sediment composition, bottom shear stress, salinity, …) are not available but EUNIS classified habitat maps are available, it may be possible to derive a longevity distribution by EUNIS habitat instead.

3.3 Bringing it all together

For each c-square, we now have an estimate of the SAR (section 0) and *d* (0), the fraction of biomass in each longevity category for the benthic community (13.1.4) and the corresponding *r* values (13.1.2). Relative Benthic Status (RBS) is now estimated for each c-square as the sum of the relative biomasses of all the longevity classes, as in Figure 17.

The cumulative effects of several different metiers will be combined in the final RBS values for each c-square. Fishing impact is simply 1 – RBS, where an RBS = 0 corresponds to impact = 1 and vice versa. Analyses can evaluate the impact by EEZ, EUNIS habitat and any other desired scale.

3.4 Handling of uncertainty

The confidence intervals of *d* and *r* have been estimated and can be propagated into the final outputs. Other sources of uncertainty come from the longevity distribution in untrawled locations and the pressure maps, and currently no methods have been applied to propagate this uncertainty.

3.5 Assumptions and limitations

The outputs of this work come from a model, and the outputs are only as good as the simplifications, assumptions and parameter estimates used. The logistic population growth model that is used is one of the simplest ecological models and is used here exactly because of this simplicity. The simplicity makes the approach transparent and allows the robust estimation of the parameter values. More complex approaches are available (e.g. Hiddink *et al.*, 2006), but the much higher parameter demands of such models make it very difficult to extend them to larger areas.

The parameter estimates used here are as robust as the current state of knowledge allows given that they synthesize all available evidence. Nevertheless, these parameter estimates are only applicable to the studies that they were based on, and at the moment most studies were carried out in temperate sedimentary habitats on infauna and epifauna, for towed bottom gears.

The approach creates a spatial prediction of fishing impacts, but does not include spatial ecological processes. This means that processes like recruitment and dispersal are not included, and that the state of a c-square does not depend on the state of the c-squares around it.

The method predicts the relative community biomass, which is the biomass as a fraction of what it would be without bottom trawling. This has the advantage that it is easy to compare between the state of different habitats, and that the data demands of the approach are lower. It does however also mean that in final products, all c-squares will be equally weighted regardless of the amount of biomass they can support, and areas that can support a high biomass are not given more importance. If a data layer predicting biomass carrying capacity can be provided, absolute biomass can be predicted using this approach.

3.6 FAQ

- The model estimates relative total community biomass, how does this relates to seafloor integrity, biodiversity, structure and function?

Community biomass is known to correlate to many ecosystem functions, and when local biomass is decreasing, local biodiversity and species richness will also be declining. Ecosystem processes that benthos provide such as bioturbation, nutrient cycling, and food provisioning for higher trophic levels such as fish and seabirds, are all tightly linked to benthic biomass.

- Some opportunistic species will increase in abundance in response to trawling, how does this approach capture this?

After trawling, smaller, short-lived species may increase in abundance when they are released from competition and predation by the larger, long-lived species. The availability of discards may also provide a small food subsidy to some species, although this has been shown to be a very minor fraction of the diet for benthos. Because the species that can increase in abundance are generally small, the total community biomass will largely reflect as loss in the larger species, and an increase in smaller opportunistic species will hardly affect total community biomass. These emergent effects are already incorporated in our parameter estimates as they will have been present in the studies that were used to estimate the parameters.

- How did the underlying studies that provided the input data find unfished areas? Is not all of the seabed already trawled? How do we know what the pristine condition could be like?

Many of the studies that were used went through a careful process of site selection to ensure the true effect of trawling was detected. Unfished areas do occur in all seas, and have been used in many of the studies as 'control' locations. For example, Amoroso et al. (2018) showed that even in the most heavily trawled seas such as the North and Adriatic seas, around 20% of the areas is not trawled. Other studies have included 'control' locations that were infrequently trawled and were a large fraction of the seabed is likely to have been untouched by trawling for many years. Nevertheless, there may have been some loss of the most sensitive fauna since 100s of years ago, and we cannot quantify how much using current methods. As a result, trawl impacts may be understimated when there is uncertainty on how 'trawl-free' the control locations have been in the last century. However, managers will need to manage the ecosystem that is currently here, rather than one that might have been there a very long time ago, and this approach does provide the tools to do this.

- How does the method deal with other pressures, such as aggregate dredging, invasive species and hypoxia?

The interaction of natural disturbance with trawl disturbance is considered through the untrawled longevity distribution of the fauna. Other anthropogenic pressures are currently not considered (although an approach to evaluate the interaction of hypoxia and trawling has been developed for the Baltic outside this WG). Other pressures that cause abrasion, such as aggregate dredging, might be included relatively easy in future developments.

4. Assessment framework – Fishing impact

Fishing impact is estimated by combining information from fishing pressure (defined as surface and subsurface abrasion from bottom contacting gears, see 0) and benthos sensitivity (characterized by the community's susceptibility to fishing mortality and its ability to recover, see 0) (Figure 24). It is here assessed according to the PD method, which is a mechanistic model that estimates the total reduction in community biomass (B) relative to carrying capacity (K), corresponding to the estimated fishing intensity (1-B/K; Hiddink *et al.*, 2017, Pitcher *et al.*, 2017).

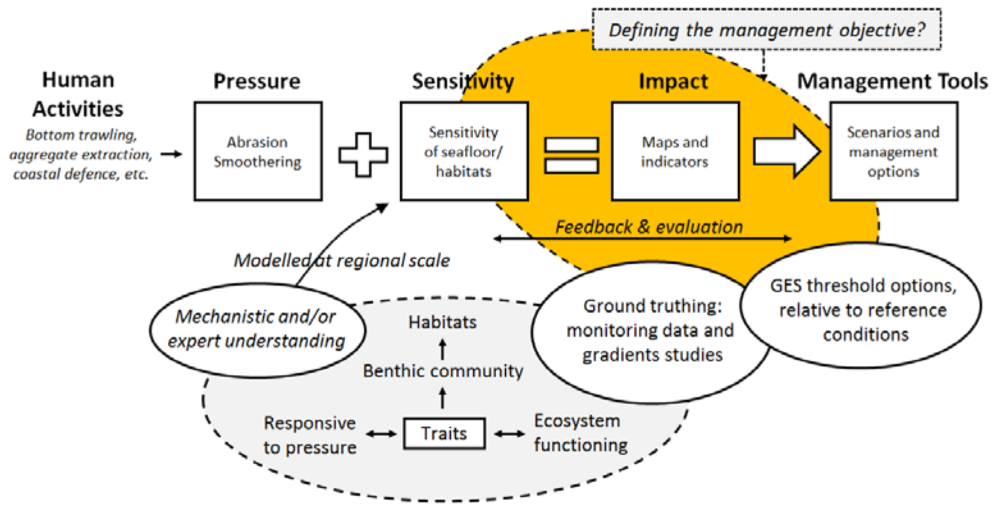


Figure 24. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity. Impact part is highlighted in orange.

4.1 Fishing impact indicator

Fishing impact is calculated on a spatial grid of 0.05x0.05 degree resolution using the C-square approach (Rees 2003) and being in accordance with the spatial resolution of the underlying pressure information. It is directly dependent on the local longevity distribution of the benthic community (based on sediment fraction of gravel, sand and mud and tidal bed shear stress, see 13.1.4) and the annual surface abrasion from bottom contacting gears (currently available from 2009 to 2016). This means that the indicator does not consider temporal changes in the community sensitivity, but in fishing pressure.

Grid cell-specific annual impact indicator values are visualised as maps, and are reported in a table per EUNIS habitat. Further ICES (2017) advised to use two area-specific annual indicators: First, the local impact indicator averaged across c-squares, and second, the proportion of c-squares with an impact below a predefined threshold level (Table 5). Both indicators are currently provided per year and ecoregion, the latter for an impact threshold value of 0.2.

Table 5. Indicators for assessing fishing impact

Annual impact indicator	Description
1. Impact	Annual average fishing impact across grid cells in an area (1-B/K)
2. Area below impact threshold	The proportion of grid cells with an impact below a (chosen) impact threshold at a regional or subregional scale.

Furthermore, c-squares and thus impact indicators of assessed ecoregions are related to EUNIS habitat types (level 2). Currently, the habitat type modelled at the center point of the c-square is used but it is envisaged to consider the relative proportion of habitat types within each grid cell. Similarly, impact indicators are calculated separately for three major gear groups (Shrimp trawling, other Otter trawling, beam trawling), thus indicating their relative contribution to the overall benthic impact and providing the opportunity to relate métier-specific impacts to other indices like catch and landings.

4.2 Running the assessment and input data

Documentation (r-code) for assessing pressure and impact in the North and Celtic Sea is available on GitHub (see Appendix 2). The following input data are necessary to calculate fishing impact on a 0.05x0.05 degrees grid and aggregate estimates to regional and subregional indicator values. Datasets are currently specific for the North Sea and Celtic Sea:

1) Seabed depth: Taken from BENTHIS, original source DBSEABED – Chris Jenkins http://instaar.colorado.edu/~jenkinsc/dbseabed/
2) Sediment fractions (gravel, sand, mud): Taken from Wilson *et al.* (2018) A synthetic map of the north-west European Shelf sedimentary environment for applications in marine science Earth Syst. Sci. Data, 10, 109-130 https://www.earth-syst-sci-data.net/10/109/2018/
3) Tidal bed shear stress: Estimated using a 2-dimensional hydrographic model. This model predicts shear stress (the force per unit area exerted on the seabed by the tidal currents: N m−2) per sampled station on a 1/8° longitude by 1/12° latitude spatial scale. The shear stress calculations are explained in more detail in Hiddink *et al.* (2006). Contact person: John Aldridge / Jan Hiddink
4) EUNIS habitat categorisation (level 3): Taken from EMODNET EUSEAMAP as downloaded on 7 March 2018 http://www.emodnet.eu/
5) Bottom trawl fishing disturbance: ICES 2017 surface and subsurface abrasion taken from sr.2017.17 "*OSPAR request on the production of spatial data layers of fishing intensity/pressure*" http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2017/Special_requests/OSPAR.2017.17.pdf

4.3 Uncertainties in impact estimates

The PD approach to estimate fishing impact provides a relative value, relating the total reduction in community biomass (B) due to abrasion (currently only from fishing) to the locally assumed carrying capacity (K). Thus, impact values cannot be directly validated with empirical measures. Furthermore, the current version of the assessment framework is unable to quantify the effect of uncertainty in the estimates of the assessment input.

This relates to the values of the logistic growth rate and mortality rate per unit fishing effort, to the spatial heterogeneity in the local fishing effort and to the local habitat classification according to EUNIS habitat types. In order to address the uncertainty of the PD model, a Monte Carlo approach can be used modulating model parameters *d* an *r* according to their observed variability, and evaluate their influence on the assessment output. This approach will be implemented intersessionally, and results will be presented to the working group in year 2.

4.4 Priorities for future developments

- Subregional/national impact assessments: EEZ polygons and regional management units/subregions (e.g. OSPAR/HELCOM) will be included in the analysis;
- Improvement of impact indicator estimates in relation to habitat type: Proportion of EUNIS habitat types within c-squares will be considered;
- Impact indicators in relation to métier level 6: A lower métier level will be considered to evaluate their relative contribution to the impact and by this improving trade-off assessments;
- Other pressures: Consideration of other pressures affecting benthic communities in the PD approach;
- Other ecoregions (e.g. Baltic Sea, Mediterranean): Estimation of impact for other ecoregions, which includes deriving novel sensitivity estimates and the related PD-model parameters. For the latter, other input parameters are likely necessary to consider.

New approaches to estimate impact: In case assumptions for the PD model do not hold in other ecoregions or subregions, different approaches to assess benthic impact need to be considered.

5. Assessment framework – Trade-offs

5.1 Assessment of trade-offs

The evaluation of trade-offs between human activities and environmental impact is an integral part of Ecosystem-based management. For bottom trawl fishing, trade-offs relate to the distribution of impact and recovery potential of the seafloor with factors that are important for management (e.g. fisheries economics).

The WGFBIT seafloor assessment framework also allows for evaluation of trade-offs between catch/value of landings per unit area and the environmental impact and recovery potential of the seafloor (e.g. 2017 ICES workshop WKTRADE). Such information will be required in the exploration of management scenarios under different policy requirements (e.g. MSFD, CFP, and the deep-sea access regulation EU 2016/2336); (Figure 25).

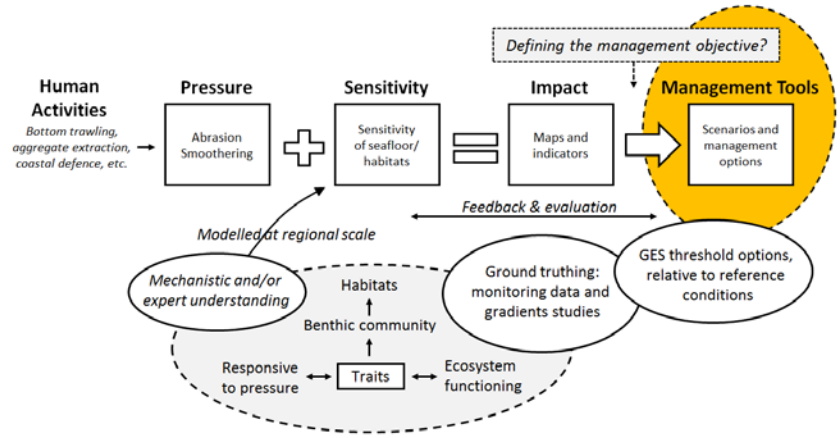


Figure 25. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity. Assessment of trade-offs part is highlighted in orange.

Investigations of the cumulative proportion of the swept area, total landings (kg), and value (€) in relation to the surface area of an ecoregion indicate that large proportions of each of the parameters occur in relatively small parts of the area. E.g. almost 80% of the fishing pressure (swept area) and landings, and about 70% of the value, occur in only 20% of the surface area of the Greater North Sea ecoregion. It is thus feasible to estimate the change in fishing impact by reducing the fishing pressure to a varying degree.

As a first step, landings and value are contrasted with the available pressure and state indicators per ecoregion and EUNIS habitat type. Secondly, a ratio is calculated between the gear type-specific impact indicator and landings respectively value, indicating which gear type causes the highest impact in relation to its relative economic importance.

C-squares can be ranked according to the level of fishing pressure they encounter, either per ecoregion, EUNIS habitat type or other spatial area. Then options can be evaluated how much landings or value is generated in areas with the lowest fishing pressure (in %). Results are contrasted in a table and are also presented as a map.

5.2 Development of future trade-off scenarios

In the current state of the assessment framework, scenarios considering fisheries displacement and/or economic impacts cannot be properly developed. We thus propose to showcase the potential of the assessment framework to evaluate changes in fishing impact and landings and value according to potential reductions in fishing pressure. The current version of the assessment framework does not yet include the following trade-off scenarios. However, implementation will be done intersessionally or at WKTRADE2.

The default measure for illustration is a reduction of 10% in fishing pressure. This will be implemented in five different ways:

1) Reduce the effort (SAR) in each grid cell to the predefined level, considering métiers (because of their effect on PD model parameters);

2) Reduce 10% of the effort (SAR) by "closing" c-squares that currently get the least pressure (starting with c-squares getting the lowest pressure, until 10% of SAR has been removed);

3) Identical to 2 but reducing pressure by métier-/ gear group-level to the predefined level;

4) Identical to 2 but reducing pressure in each habitat type to the predefined level;

5) Identical to 2 but reducing pressure on the national EEZ level to the predefined.

The first variant represents the simplest translation of a management measure into a pressure change. It corresponds to an overall reduction in effort. Variants 2 to 4 represent different management priorities and strategies. In 2 the unfished area is maximally increased, while the loss of core fishing grounds is minimized. Variant 3 is identical but includes an 'equal loss' principle across métiers. Variant 4 captures an important element of the MSFD, the goal of reaching good environmental status in each habitat while 5 is rather used to study the effect of a national, rather than a regional reduction of fishing pressure.

Impact indicators, landings and values can then be compared between scenarios (no reduction vs. options for 10% pressure reduction).

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Appendix 1

Terminology and definitions

At its first meeting, WGFBIT discussed and agreed on adopting a framework to guide their work. A draft set of definitions that has been used in previous ICES work, namely WKBENTH (2017), WKBEDPRES1 (2018) and in the context of the technical guidelines for the ICES Ecosystem Overviews were also adopted. Central to adopting the WGFBIT framework is a common understanding of how benthic species respond to disturbance, in order to know the status of the benthic community as a whole including the associated habitat (see Figure 26). Below we describe the definitions related to benthic impact from trawling (17.1) and we describe how to differentiate between physical loss and physical disturbance (17.2).

During the WGFBIT meeting, it was further agreed that the EU's WG GES document (GES_20-2018-06) describing the policy and ecological context within which to consider "good environmental status" for MSFD Descriptor 1 (seabed habitats) and Descriptor 6 (sea-floor integrity) will be a useful source of information when revisiting definitions in the next WGFBIT meeting in 2019.

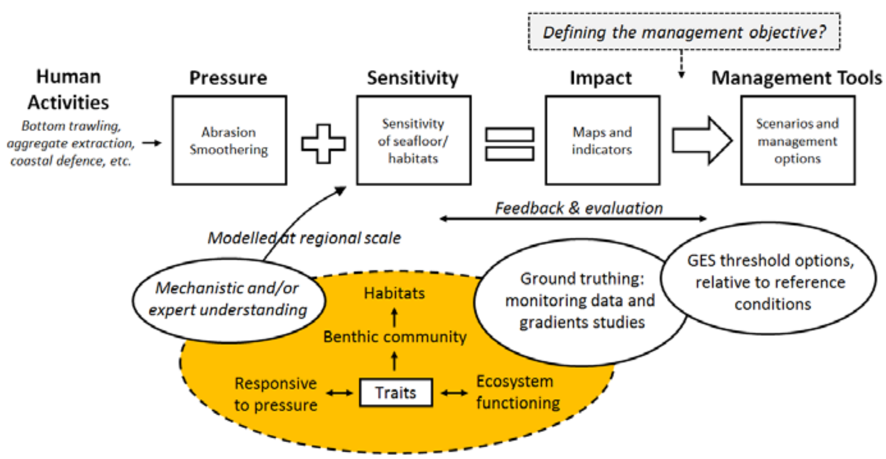


Figure 26. Conceptual diagram of the steps taken in developing management tools for assessing pressure and impact on the seafloor from human activity. Benthic community part is highlighted in orange.

Definitions related to benthic impact from trawling

Different species' responses to disturbance over time can be defined. In the context of bottom trawl fishing, an important parameter is trawling frequency that modulates species' response. Instantaneously, a haul can damage or kill an organism depending on its sensitivity to the gear (e.g. degree of body fragility) and the magnitude of the disturbance. Then, in case of consequent demographic or biomass depletion, another type of response is recovery through adult migration or offspring settlement. Recovery depends on trawling frequency so that the higher the frequency, the slower the recovery. In case of a null degree of sensitivity, organisms are resistant, i.e. no damage or population depletion is consequent from a trawl disturbance. In the case of a non-null degree of sensitivity, two types of species can be characterised by combinations of sensitivity and recovery. A resilient species is primarily characterised by a fast recovery following damage or depletion, independently of sensitivity, so that juvenile or adult mortality do not impair population survival over time under a disturbance regime. By contrast, a vulnerable species experiences substantial damage or depletion following a minimum disturbance with a recovery time exacerbated by maintained or increased disturbance frequency.

Within the above context, and to ensure common understanding, WGFBIT have proposed the below set of definitions:

Activity: a human action or endeavour that has the potential to create pressures on the marine environment (e.g. aquaculture or tourism); where activities are usually grouped in sectors, each one of which encompasses many activities and sub-activities (e.g. fishing, bottom trawling, etc.); (Smith *et al.* 2016, Elliott *et al.* 2017).

Pressure: the mechanism through which an activity has an actual (or potential) impact on the ecosystem (e.g. for otter trawling or beam trawling fishing activity, one pressure would be abrasion to the seabed); (Robinson *et al.* 2008, Smith *et al.* 2016, ICES 2016).

Fishing pressure: The physical abrasion of the seabed by bottom-contacting fishing gears. The pressure is expressed as the ratio between the sum of the area swept by the fishing gear (with components having a surface or subsurface penetration) per year and the total area of the site (swept-area ratio - SAR).

Species sensitivity: The intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery.

Resistance: The ability of a receptor to tolerate a pressure without changing its character

Impact: The effects (or consequences) of a pressure on an ecosystem component. The impact is determined by both exposure and sensitivity to a pressure (ICES 2016).

Degree of impact: The level of impact on the seabed should be considered in the ranking; where low impact activities are ranked below high impact activities for the same level of spatial/temporal coverage. Low impact activities are those which cause minor direct mortality/damage on benthic organisms, resulting in adverse effects/impacts that lie within the bounds evidenced across cycles of natural variation. High levels of impact can be considered to have occurred where the activity results in adverse effects/impacts to the benthic habitat and its communities beyond what might be expected from natural disturbances. Issues on sensitivity/resilience/recovery of specific benthic groups (faunal or traits) and functional habitats are discussed in section 3.2 on modelling and smothering.

Areal coverage: This must consider two aspects: the spread of the activities footprint at a regional scale and its spatial coverage within the footprint. For example, for a given degree of impact, if an activity occurring throughout the region is split into small, discrete areas, this would rank lower than similarly impactful activities that have a higher areal coverage but are not as widespread across the region. Activities that occur over the entire region, and are continuously distributed throughout this area, would be regarded as having the maximum areal coverage possible.

Recoverability (or resilience): The time that a receptor needs to recover from a pressure, once that pressure has been alleviated.

Fishing impact: The effects (or consequences) of fishing pressure on an ecosystem component. The impact is determined by both exposure and sensitivity to a pressure.

Fishing intensity indicator: A characteristic of the footprint of the fisheries, on either spatial or temporal scales (or both).

Benthic impact indicator: A characteristic of a benthic habitat that can provide information on ecological structure and function.

How to differentiate between physical loss and physical disturbance?

The Commission Decision (EU) 2017/848 of 17 May 2017 defines physical loss and physical disturbance as:

"3. Physical loss shall be understood as a permanent change to the seabed which has lasted or is expected to last for a period of two reporting cycles (12 years) or more.

4. Physical disturbance shall be understood as a change to the seabed from which it can recover if the activity causing the disturbance pressure ceases."

With this in mind, WGFBIT agreed that physical loss (see example "substrate loss" below) can be defined as any activity that results in a permanent alteration of the habitat from which recovery is impossible, such as construction activities and changes in substrate composition after aggregate extraction. Activities that disturb benthic biota, but do not change the benthic substrate permanently, can be considered as disturbance (see examples, "abrasion" and "smothering" below), even when full recovery would take longer than 12 years, as long as recovery to the original state can be expected given enough time (WKBEDPRES1, 2018).

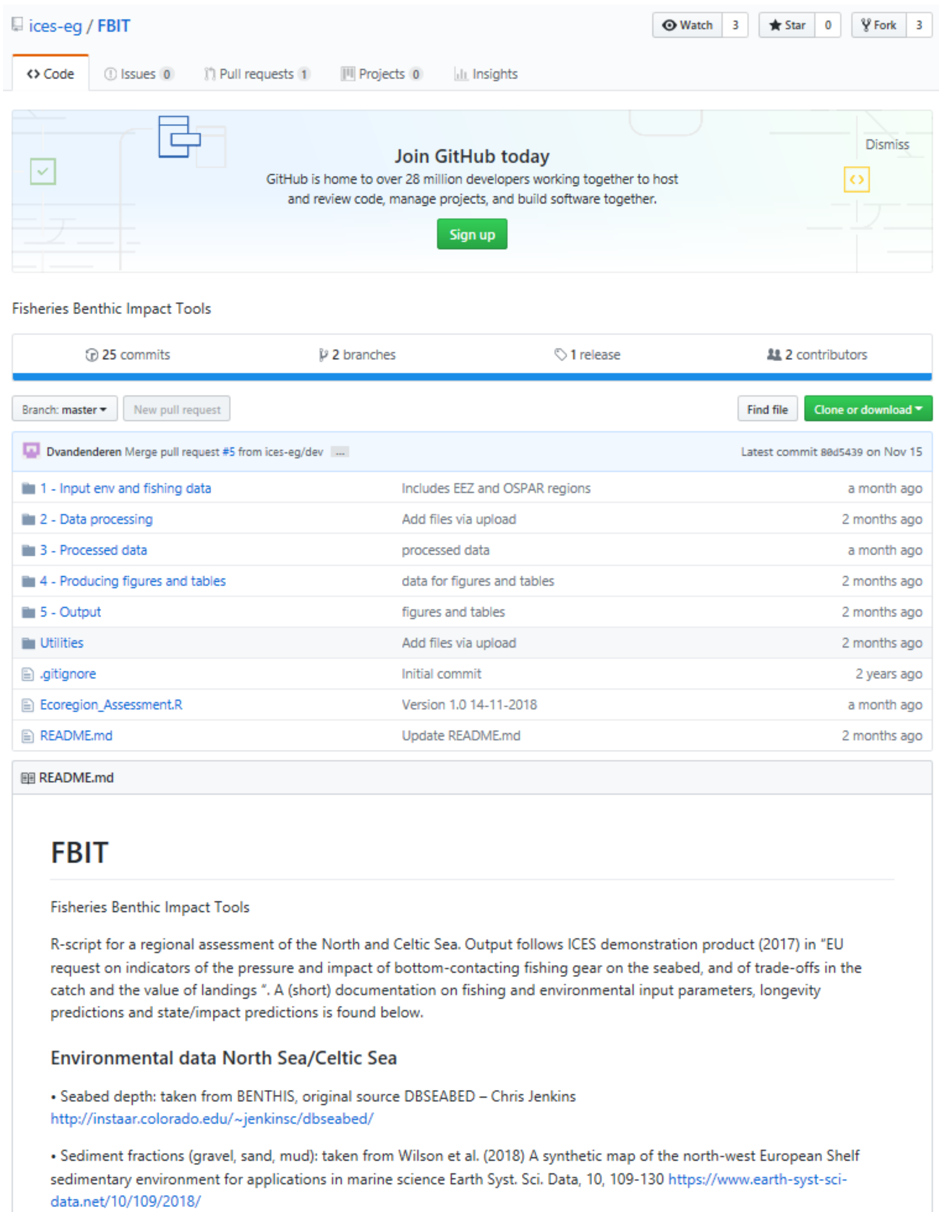
Substrate loss: This pressure type includes both: the permanent loss of coastal habitats (associated with activities such as land claim, new coastal defences); and the permanent change of one marine habitat type to another through a change in substratum, including artificial substrates (e.g. concrete). Associated activities include the installation of infrastructures such as hydrocarbon production facilities, wind farm foundations, marinas, pipelines, cables, and scour protection.

Abrasion: Abrasion pressures relate to disturbance of the substrate at or below the surface of the seabed; aggregate and other mineral extraction is not covered by this pressure. Abrasion pressure is associated with bottom-contacting mobile and set fishing activities, in particular otter trawling, dredging for shellfish, and navigation and beam trawling. Other activities with a limited spatial footprint also cause abrasion.

Smothering: Smothering pressures relate to siltation or sedimentation on the surface of the seabed. Activities associated with this pressure type include marine and coastal construction, aquaculture, land claim/reclamation, navigation dredging, disposal at sea, marine mineral extraction, fishing, cable and pipeline laying, and various construction activities.

Appendix 2: R-documentation for assessing pressure and impact indicators

R-documentation for assessing pressure and impact in the North and Celtic Sea: https://github.com/ices-eg/FBIT


ices-eg / FBIT

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Fisheries Benthic Impact Tools

25 commits | 2 branches | 1 release | 2 contributors

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Dvandenderen Merge pull request #5 from ices-eg/dev ... Latest commit 80d5439 on Nov 15

1 - Input env and fishing data	Includes EEZ and OSPAR regions	a month ago
2 - Data processing	Add files via upload	2 months ago
3 - Processed data	processed data	a month ago
4 - Producing figures and tables	data for figures and tables	2 months ago
5 - Output	figures and tables	2 months ago
Utilities	Add files via upload	2 months ago
.gitignore	Initial commit	2 years ago
Ecoregion_Assessment.R	Version 1.0 14-11-2018	a month ago
README.md	Update README.md	2 months ago

README.md

FBIT

Fisheries Benthic Impact Tools

R-script for a regional assessment of the North and Celtic Sea. Output follows ICES demonstration product (2017) in "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 ". A (short) documentation on fishing and environmental input parameters, longevity predictions and state/impact predictions is found below.

Environmental data North Sea/Celtic Sea

• Seabed depth: taken from BENTHIS, original source DBSEABED – Chris Jenkins http://instaar.colorado.edu/~jenkinsc/dbseabed/

• Sediment fractions (gravel, sand, mud): taken from Wilson et al. (2018) A synthetic map of the north-west European Shelf sedimentary environment for applications in marine science Earth Syst. Sci. Data, 10, 109-130 https://www.earth-syst-sci-data.net/10/109/2018/