EU request on how management scenarios to reduce mobile bottom fishing disturbance on seafloor habitats affect fisheries landing and value

Advice summary

ICES explored five management scenarios that could be used to reduce pressure and impact on the seabed caused by bottom trawling and modelled the consequences of their implementation for bottom trawling with vessels greater than 12 m. In this advice, and the accompanying four regional assessments and interactive maps, ICES uses two impact and one pressure (presence or absence of bottom trawling) indicators to describe these consequences.

ICES advises that bottom trawling is the main physical pressure exerted on the seabed across the EU's marine waters. It is spatially aggregated to form core areas where bottom trawling effort and value of catch is high and larger peripheral fishing areas where effort and value of catch is low. This general pattern is found for all métiers and in all regions.

ICES advises that some levels of bottom trawl fishing can be compatible with achieving seabed conservation objectives. However, a prerequisite for evaluating these objectives will be to define ecologically meaningful limits beyond which continued bottom trawl fishing will have adverse effects. These limits can inform the setting of Good Environmental Status (GES) thresholds for quality and areal extent.

ICES presents management scenarios that balance the economics of bottom trawling with the protection of MSFD broad habitat types by ensuring trawling continues to be concentrated in highly trawled core grounds that are already impacted and reduced in peripheral grounds that are lightly trawled. For example, the results show that collectively for the Baltic Sea, Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast, the removal of less than 10% of the total bottom trawling effort from peripheral fishing grounds will increase the overall extent of untrawled area to more than 40% in each MSFD broad habitat type in each subdivision.

Request

The European Commission request to ICES is summarized as:

ICES to advise on a set of management options to reduce the impact of mobile bottom-contacting fishing gears (MBCG) on seafloor habitats, and for each option provide a trade-off analysis between fisheries value and the seafloor impact. The trade-off is to be assessed in relation to the 22 MSFD broad habitat types in each ecological assessment area (subdivision) of the MSFD sub-regions. The advice will inform the setting of threshold values for the environmental quality of seabed habitats under the Marine Strategy Framework Directive.

The text of the request is in Annex 1.

Format of the advice

This advice consists of the advice text and a data product (ICES, 2021a) consisting of a series of interactive maps and regional assessments and the VMS aggregated fishing data (Figure 1). The advice text should be read in conjunction with the interactive maps and can also be informed by the regional assessments. Within the text, references to the interactive maps and regional assessments and their specific "sections" are made. The limitations and caveats described below should be considered before using the data products.

The data product contains i) 26 regional assessments of mobile bottom-contacting fishing gear (hereafter termed bottom trawls) covering the Baltic Sea, Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast; ii) a series of interactive maps providing the distribution of bottom trawl activity and a model of how this distribution would change as a result of implementing certain management scenarios; and iii) the VMS aggregated fishing data in CSV and shapefile format. The data product is available from ICES website.

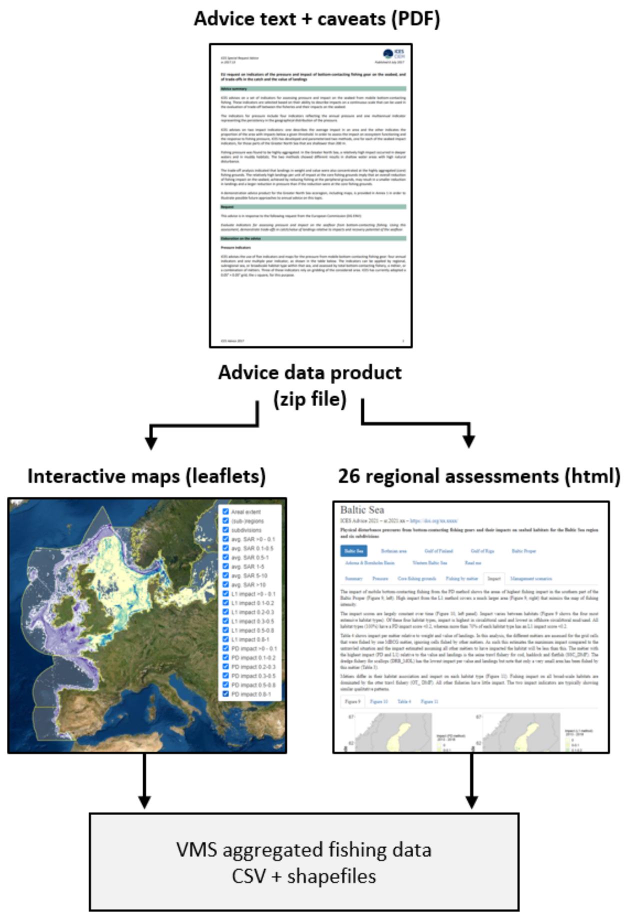

Figure 1 Diagram showing the various components of this advice: the advice text in PDF format and a ZIP file containing interactive maps, regional assessments, and the VMS aggregated fishing data in CSV and shapefile format. The aggregated CSV data products are provided by ICES to allow elements of this advice to be incorporated into spatial analysis software, e.g. GIS software. Download the ZIP file.

Elaboration on the advice

Distribution of bottom trawl fishing activity and core fishing grounds for the years 2013 to 2018

ICES finds that all bottom trawl métiers* have core fishing ground areas where fishing intensity and value of landings represents the highest 90% and larger peripheral areas where fishing intensity and value of landings is low. This pattern of smaller core and larger peripheral fishing areas is apparent at a (sub)-regional* level as well as for subdivision* seas and for all métiers. The evidence for this is shown in the "Core fishing grounds" section of each of the regional assessments in the data product. The spatial distribution of core fishing grounds are further illustrated in the "Illustration of core fishing grounds" interactive map.

A map of bottom trawling pressure in the four (sub-)regions is shown in Figure 2. ICES notes that the surface area being bottom trawled* on average per year for the period 2013–2018 by all bottom trawls varies between the sub-

* Explained in the Basis of the Advice section below.

regions and covers 66% (Bay of Biscay and Iberian Coast), 62% (Greater North Sea), 53% (Celtic Seas), and 12% (Baltic Sea) of the seabed surface area (0–200 m depth zone [Table 1]).

Similar patterns in bottom trawl footprints are observed in different Mediterranean Sea (Greece, Spain, and Italy) and Black Sea regions (Bulgaria) (Annex 5 in ICES, 2021c). However, since these patterns were produced using different methodologies and with national datasets, they are not directly comparable (either internally or with the Atlantic and Baltic Sea estimates). ICES identified key data gaps and the way forward to fill these (tables 7.4 and 7.5 in ICES, 2021c).

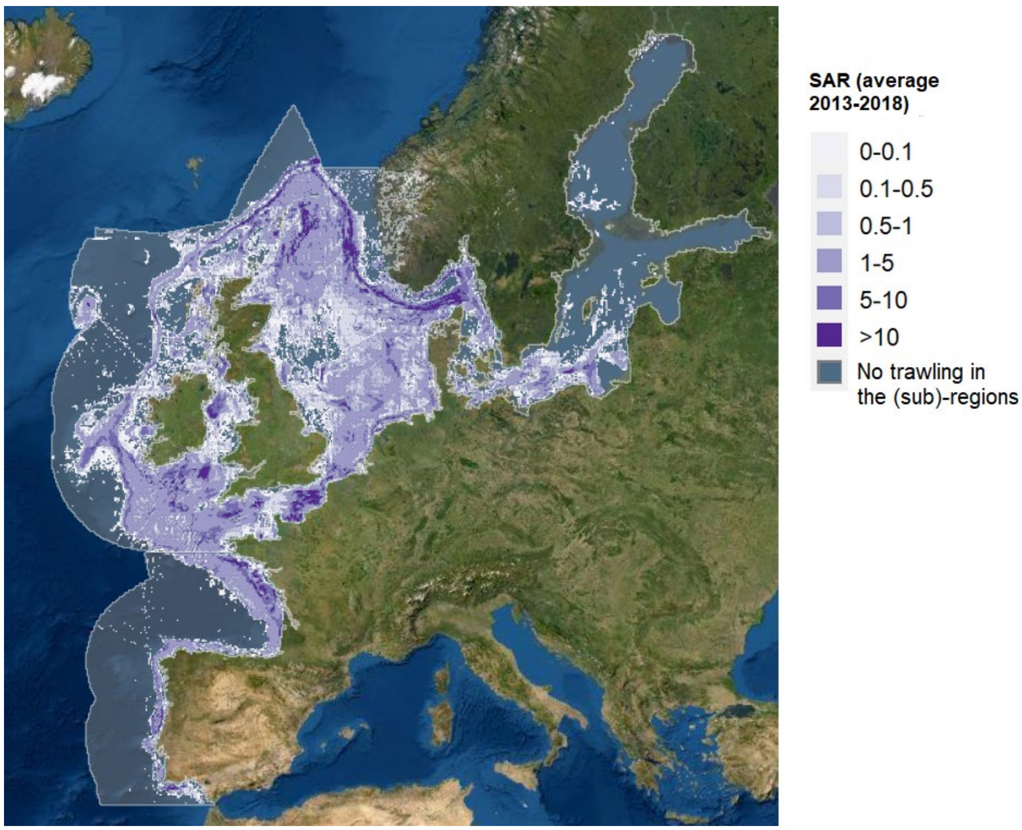

Figure 2 Bottom trawl fishing pressure (SAR*) averaged for the period 2013–2018. Screenshot is taken from the "Pressure and impact" interactive map.

ICES advises that for most métiers (mainly those using otter trawls and beam trawls to target demersal fish and shellfish) the spatial variation between years of core and peripheral fishing is limited across the six-year period but that for some métiers (targeting small pelagic fish or using demersal seines) the variation is more substantial. This pattern exists across regions and is exemplified in Figure 3 for the southern North Sea with the beam trawl for demersal fish (TBB_DMF) and otter trawl for small pelagic fish (OT_SPF) métiers.

* Explained in the Basis of the Advice section below.

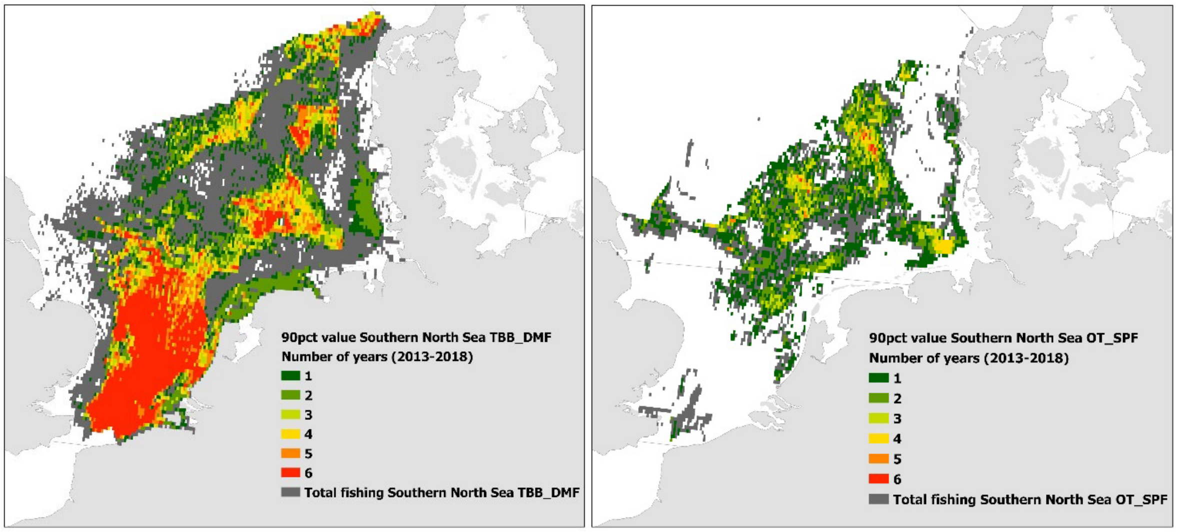

Figure 3 Example maps for two métiers in the southern North Sea that differ in their spatial variation of core and peripheral fishing area between years. Maps show the number of years a c-square* is within the 90% highest value for the period 2013–2018. The beam trawl for demersal fish (TBB_DMF; left panel) has many red c-squares, which represent the area where a high value of landings is obtained every year; the otter trawl for small pelagic fish (OT_SPF; right panel), however, shows substantial spatial variation between years in the area where a high value of landings is obtained. The dark grey represents areas bottom trawled but not within the core area for any of the six years.

Pressure and impact indicators to evaluate trade-offs

ICES uses two impact and one pressure (percentage of untrawled c-squares) indicators* to evaluate trade-offs. The first indicator of impact, PD, estimates the amount of benthic biomass (relative to carrying capacity) which will not exist in the ecosystem if the current bottom trawling intensity continues for a long time. The second impact indicator, L1, quantifies the community biomass of benthos that is affected by trawling during its lifespan. A map of bottom trawling intensity is shown in Figure 2. The “Pressure and impact” interactive map shows bottom trawling intensity and PD and L1 impact (when available).

ICES advises that the percentage of untrawled c-squares pressure indicator is useful for evaluating management options where the objective is the creation of untrawled areas as a result of the removal of all bottom trawl fishing effort from vessels greater than 12 m; this indicator is not, however, suitable for evaluating management options that involve limitations on particular métiers or technical modifications to fishing gears.

ICES notes that, in the 0–800 m depth range, a large proportion of each MSFD broad habitat* in each subdivision is located within trawled c-squares (part of the cell bottom trawled at least once in the six-year cycle, irrespective of the swept area within the cell). A much smaller proportion of each MSFD broad habitat is part of the area within bottom trawled c-squares where 90% of the core fishing effort is aggregated (see the “pressure” section in the regional assessments).

ICES advises that the Baltic Sea region experiences the lowest pressure from bottom trawling, with 73% of the c-squares untrawled at depths shallower than 200 m (Table 1). The low pressure results in a relatively low impact from bottom trawls on benthic ecosystems for both the PD and L1 indicators* when assessed at Baltic Sea level; however, it is important to note that the seabed below 100 m is often anoxic in this region and that bottom trawling is very limited in the northern part and essentially only targets Baltic herring (*Clupea harengus membras*) or vendace (*Coregonus albula*) in coastal areas. The Atlantic subregions experience much higher pressure from bottom trawling.

* Explained in the “Basis of the advice” section below.

The percentage of c-squares untrawled is around 20% in the Celtic Seas and the Bay of Biscay and the Iberian Coast. The percentage of c-squares untrawled is only 9% in the Greater North Sea at depths shallower than 200 m and 44% at depths of over 200 m, resulting in a much higher average impact from bottom trawling on the benthic ecosystem than in the Baltic Sea.

ICES advises that the pressure and impact indicators will allow an evaluation against Good Environmental Status (GES) threshold values for adverse effects and the maximum allowable extent of habitat adversely affected (see request in Annex 1) once these thresholds have been established. ICES notes that the methodology presented in this advice to evaluate trade-offs between trawling impacts and fisheries landings is independent of the (PD and L1) indicators used to quantify impacts and can readily be applied using alternative mechanistic indicators that can be modelled continuously across regional scales (see further in ICES [2016]).

The percentage of untrawled c-squares pressure indicator is easy to calculate and available for all areas and is therefore widely used in this advice. ICES notes that the percentage of untrawled c-squares pressure indicator should not be interpreted as advice that any bottom trawling fishing in c-squares automatically means that GES cannot be achieved.

Table 1 Summary of the pressure and impact indicators by (sub-)region for 0–200 and 200–800 m depths. The indicators are explained in the basis of the advice. Information to estimate PD and L1 trawling impact was only available for the Greater North Sea in areas of less than 200 m depth and for the Baltic Sea. n/a = not analysed.

(Sub-)regions	% area trawled on average per year		% C-sq untrawled 2013–2018		PD (average impact)		L1 (average impact)	
	0–200	200–800	0–200	200–800	0–200	200–800	0–200	200–800
Baltic Sea	12	n/a	73	n/a	0.01	n/a	0.12	n/a
Greater North Sea	62	36	9	44	0.12	n/a	0.66	n/a
Celtic Seas	53	54	17	23	n/a	n/a	n/a	n/a
Bay of Biscay/Iberian Coast	66	55	17	19	n/a	n/a	n/a	n/a

Management scenarios

ICES explored a set of management scenarios that, if implemented, would reduce bottom trawling pressures and impacts on the seabed. The consequences for the habitats and on value and weight of the catch are modelled (where data was available), and this trade-off is presented in various ways. The percentage of untrawled c-squares pressure indicator is used to show the extent of areas currently, or potentially, untrawled under different management scenarios.

The management scenarios considered by ICES relate to gear design and switching, effort and spatial controls, and impact quotas. During the stakeholder meeting convened by ICES, both environmental NGOs and managers indicated a preference for spatial measures (area closures for fisheries), while some fishery representatives indicated such measures as the least preferred option and instead favoured gear modifications. The consequences of both approaches are discussed below. The effects of prohibiting the use of specific fishing métiers are also discussed (setting the effort of individual métiers to zero). Management scenarios relating to gear switching, impact quotas and other forms of spatial control (i.e. coastal and/or small-scale sensitive habitats) were not taken forward to the trade-off analysis. The reasons for this are explained in the workshop report (ICES, 2021c) and include the absence of knowledge and data and difficulty in assessing at a small-scale level, in essence EUNIS levels 4 – 6.

Consequence of implementing management scenarios – the trade-off

ICES advises that the PD and L1 indicators of impact yield very different results regarding the current impact of bottom trawling and the extent to which intervention is required to reach any given areal extent threshold value. This is illustrated in two interactive maps: “Illustration of MSFD protection – PD impact” and “Illustration of MSFD protection – L1 impact”.

In these interactive maps, two hypothetical impact quality thresholds – 0.2 and 0.05 – have been selected for each of the PD and L1 indicators. The consequence of achieving a fixed percentage (ranging from 30% to 90%) of each MSFD broad habitat type in each subdivision to be within these hypothetical thresholds, is mapped. The user can switch on and off layers which show untrawled c-squares as well as trawled c-squares that are below the hypothetical impact quality threshold. The PD map shows that a much larger part of the bottom trawled area is already within the 0.2 and 0.05 thresholds compared to that shown in the L1 map. Additional layers show which c-squares require some form of management intervention to obtain a given areal extent threshold in each MSFD habitat in each reporting area. The type of management needed for the c-squares to achieve the impact quality threshold differs between PD and L1 indicators (not shown in the maps). The L1 indicator generally requires the removal of virtually all bottom trawling effort from trawled c-squares to reach the threshold; achieving a threshold for the PD indicator, however, is compatible with some level of bottom trawling and therefore may require the removal of some, but not all, effort within a c-square.

ICES notes the need for setting the impact quality thresholds for PD and L1 indicators at different numerical values because of the different nature of the two indicators.

<u>Spatial closures</u>

When closing areas to bottom trawling, an important choice is which areas to prioritize. Prioritizing the most trawled areas and prioritizing the least trawled areas have been advocated for. Intensively bottom trawled areas are where the largest impact reduction is realized when they are closed, but the cost to the fishery is often large. Closing lightly trawled areas may cost the fishery very little but can also be perceived as having little improvement because so little of the fishing effort, and the resulting impact, is removed. All stakeholder groups (managers, environmental NGOs, and fisheries representatives) preferred that ICES should focus on the least bottom trawled areas (ICES, 2021b).

The modelling undertaken by ICES shows that closing the least bottom trawled areas, either overall or by broad habitat type, leads to a large fraction of untrawled habitat and a strongly reduced impact as measured by the L1 indicator. This is achieved with a much smaller cost (in terms of catches or value) to the fishery compared to starting with the highly bottom trawled areas (Figure 5.2 in ICES, 2021c). The relationship between the reduced impact as measured by the PD indicator and lost catches or value is more linear, with relative changes in catch value and PD impact similar for any given closure, but the rate at which impact is reduced is larger when starting in lightly bottom trawled areas. The consequence of spatial closures, starting in the least trawled areas, for each subdivision per habitat type is shown in the "management options" section in the regional assessments.

For the Baltic Sea, Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast, the "Illustration of MSFD protection – untrawled" interactive map illustrates where fishery closures are needed to obtain fixed percentages (ranging from 5% to 70%) of untrawled area (based on the sum of currently untrawled and closed c-squares) in each MSFD habitat in each subdivision. It should be noted that the assumption in these scenarios is that no displacement of bottom trawling effort to currently trawled or untrawled c-squares occurs. The loss (in percent) of fishing effort across all métiers and all (sub)-regions associated with these closures is shown in Table 2. Even though the cost in terms of lost catch or value is small, the closure scenarios result in large areas being closed to bottom trawling. This may be perceived as an opportunity cost by certain stakeholders (ICES, 2021b). The costs to the fisheries will further vary regionally, being low in subdivisions that are largely untrawled but high in heavily trawled subdivisions such as the English Channel. These costs will further vary among fishing métiers and may disproportionally impact local fisheries in certain areas.

The above management scenario balances the economics of bottom trawling with the protection of MSFD broad habitat types by ensuring trawling continues to be concentrated in highly trawled core grounds that are already impacted and reduced in peripheral grounds that are lightly trawled. For example, the results show that collectively for the Baltic Sea, Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast, the removal of less than 10% of the total bottom trawling effort from peripheral fishing grounds will increase the overall extent of untrawled area to more than 40% in each MSFD broad habitat type in each subdivision (Table 2).

Table 2 The loss (in percent) of total bottom trawling effort required to achieve a minimum extent (in percent) of untrawled area (based on the sum of currently untrawled and closed c-squares) in each MSFD habitat in each subdivision collectively for the Baltic Sea, Greater North Sea, Celtic Seas, and Bay of Biscay and Iberian Coast. The "Illustration of MSFD protection – untrawled" interactive map shows the spatial consequences of the fisheries closures for each of these untrawled c-square percentages.

Loss in total bottom trawling effort (as a %)	To achieve at least the following % of untrawled area
0.1	5
0.5	10
1.7	20
3.9	30
7.2	40
11.8	50
17.9	60
26.2	70

ICES advises that some levels of bottom trawl fishing can be compatible with achieving seabed conservation objectives. However, a prerequisite for evaluating these objectives will be to define ecologically meaningful limits beyond which continued bottom trawl fishing will have adverse effects. These limits can inform the setting of Good Environmental Status (GES) thresholds for quality and areal extent.

ICES advices the future use of spatial optimization techniques to find solutions that are both practical and allow management objectives to be reached. All scenarios enacting a conservation target by modifying bottom trawling effort (including setting it to zero) in specific c-squares result in a highly fragmented landscape of fishing regulations where there may be implementation problems in terms of communication and enforcement. The use of spatial optimization routines is demonstrated for the core fishing area in ICES (2021c) and in the "Illustration of core fishing grounds" interactive map; these can be further developed so as to reduce this fragmentation.

<u>Gear modification</u>

Another way to reduce bottom trawling impact is to reduce the impact per unit effort through gear modification. Such changes to gear may reduce catch efficiency. The trade-off between gear efficiency and gear impact is explored in ICES (2021c). This is an attractive option when a strong impact reduction can be achieved with little loss in catch or value, but not if there is high catch loss for only little impact reduction.

<u>Métier prohibitions</u>

A métier prohibition scenario, where effort of individual métiers is set to zero, is analyzed for the Greater North Sea only and shows that it has relatively little effect on the extent of untrawled area. This highlights that most trawled areas in the Greater North Sea are exploited by multiple métiers. The cost in terms of lost fish or value of prohibiting single métiers is limited, except in the case of very dominant métiers. Similarly, the effect on both impact indicators (L1 and PD) of prohibiting individual métiers is limited, although highest for métiers which yield little fish (or value) per unit impact.

ICES notes that any métier prohibition scenario may not reduce bottom trawling pressure and impacts on the seabed if only the target species change and not the gear.

Indirect benefits

The benefits to the seabed and the environment generally from the removal of pressure from bottom trawls were reviewed (ICES, 2021c). These benefits include recovery in the relative abundance of sensitive and habitat-forming species and increased seabed complexity. This increased complexity can serve as refugia for species, help population connectivity, and enhance resilience to stressors and adaptation capacity to climate change.

The seabed is a globally significant carbon store; it is estimated that 0.3–1.0 Pg of organic carbon occurs in the top 10 cm of the northwest European shelf alone. The removal of bottom trawling pressure in certain habitats might increase the organic carbon content in those habitats, but more evidence is needed to assess the magnitude of this effect on the carbon balance in coastal ecosystems and its effect on climate change.

A reduction in bottom trawling can increase benthic denitrification in organic-matter-rich muddy sediments, and closing trawling grounds can thus be expected to reduce nutrient loadings on coastal waters (ICES, 2021c).

Direct benefits to fisheries include the potential for spillover of juvenile and adult fish from areas closed to fishing to those that remain open and an increase in fish abundance and improved catch per unit effort. When fishing effort is reduced, fish abundance will increase and the catch per unit effort will go up in line with this, which is beneficial to the fishers in areas that remain open.

Not all of the benefits mentioned are currently understood well enough to be modelled at a regional scale for evaluating the management scenarios. Benefits that can be quantified spatially can be included in the trade-off assessment. The effects of the removal of fishing pressure on sediment carbon and nutrients are a field of study that is quickly developing. Experts may be able to make predictions of the effect of bottom trawling on these benefits on regional scales within a few years if models and parameter estimates become more established.

Economic revenue and contribution margin

Fisheries revenue is the value of fisheries landings, which is provided through ICES vessel monitoring system (VMS) data call. The fisheries contribution margin is the value of fisheries landings minus the variable costs.

A methodology was developed to combine ICES VMS/logbook data with EU STECF Fisheries Dependent Information (FDI) and Annual Economic Reporting (AER) data and to estimate the contribution margin at the 0.05 degree c-square resolution. The estimate of the contribution margin could be an improved metric to define the areas that are most valuable to the fisheries (i.e. core fishing areas). To obtain an estimate of variable cost at the 0.05 degree c-square resolution, a method was developed that disaggregated the variable costs data (in low resolution from EU STECF AER) to the 0.05 degree c-square resolution following the spatial distribution of fishing intensity. For that reason, the contribution margin strongly correlates with fishing intensity and value/weight of landings and does not result in a substantially different core fishing footprint. Therefore, the revenue reported directly in ICES VMS data call is used in the current assessment. Future work may be able to improve the method of disaggregation to take account of the variability of costs in relation to distance from port.

Recommendation

The method for disaggregation of variable costs data can be improved if data inconsistencies (in fishing technique and métier codes) between data calls are solved within countries for the EU STECF AER and FDI data calls and for ICES VMS data call. This method could include a spatial distribution of costs by taking the distance from landing port into account if the port is included in ICES VMS data call.

Basis of the advice

ICES established the fishing pattern for bottom trawling over the period 2013 to 2018, analyzed this fishing pressure and impact (when available) for four (sub-)regions and 22 subdivisions, and modelled the consequences of implementing a number of management scenarios to reduce bottom trawling fishing pressure on seabed habitats. These consequences were modelled in terms of changes in seabed pressure and impact and the value of bottom trawling landings.

As previously advised in ICES ecosystem overviews (ICES, 2021d) and ICES advice (2019a), bottom trawling is the main physical pressure exerted on the seabed across the EU’s marine waters.

Regional assessment period and boundaries

The assessment period of bottom trawl fishing distribution and impact in the regional assessments is from 2013 to 2018, the most recent six-year period for which VMS data was available to ICES. This reflects the six-year management cycle of MSFD assessments and can, in the future, be linked to the MSFD Article 8 assessment periods. The assessments present indicators for the whole (sub-)regional/subdivisional assessment area and per MSFD broad habitat type within that area using the indicators proposed in ICES advice (2017).

The boundaries of the Baltic Sea region and the three Atlantic subregions, the Greater North Sea, Celtic Seas and Bay of Biscay and Iberian Coast, used in this advice follow the MSFD (sub-)regional boundaries. The 22 subdivisions used to produce the trade-off results are illustrative of the biogeographically relevant subdivisions of MSFD subregions, as required by the Commission Decision (EU) 2017/848 (EU, 2017). The subdivisions are partly based on HELCOM sub-basins and OSPAR Level 2 reporting areas. Using these subdivisions represents a pragmatic approach to producing the trade-off results at scales which are illustrative of the possible MSFD 'assessments'. Maps of the (sub-)regions and subdivisions are presented in the TRADE3 workshop report (figures 7.1 and 7.2 in ICES, 2021c).

Bottom trawl fishing activity

The bottom trawling distribution was estimated using data from EU countries, United Kingdom, Faroes, Iceland, and Norway. The coupling of VMS data with logbook data is currently the most practical and cost-effective method for describing the spatial dynamics of fishing activities, although in some regions the use of AIS (automatic identification system) data locally is being tested. To describe the bottom trawling footprint, fishing intensity is expressed as swept-area ratios (SAR). The swept area for bottom trawling is calculated as *hours fished × average fishing speed × gear width*. Hours fished and average fishing speed is available from ICES VMS/logbook data call (ICES, 2019b), while the gear width is estimated based on relationships between average gear widths and average vessel length or engine power (kW), as stated in Eigaard *et al*. (2016) and using ICES expert input. The SAR is the sum of the swept area divided by the area of each grid cell.

ICES uses a 0.05 × 0.05 degree grid cell resolution, referred to as 'c-squares' throughout this advice. The c-square SAR value indicates the theoretical number of times the entire grid cell has been swept if effort was evenly distributed within the cell. For example, a SAR of 2 means that 100% of the c-square is trawled two times per year, while a SAR of 0.5 means that 50% of the c-square is trawled per year. Due to data availability, analyses of the fishing footprint do not account for subgrid variation of fishing events within the c-square.

The frequency of VMS data transmission rate (pings) from individual fishing vessels varies but is transmitted with a frequency of at least once every two hours. The requirement to aggregate the VMS data received from ICES Member Countries for confidentially reasons affects what ICES can publish. A detailed description of the identification of fishing activity and discussions related to ICES VMS data can be found in the report of ICES Working Group on Spatial Fisheries Data (ICES, 2019c).

Bottom trawl métiers

For this advice, bottom trawling is divided into ten different métiers. These métiers have different characteristics in terms of their pressure and impact on the seabed. The métier codes are a combination of the fishing gear and the target species assemblage group, and they have been grouped from the EU's Data Collection Framework Level 6 métiers (EC, 2008) that are reported under ICES VMS data call (Table 3).

Table 3 Fishing métiers used in this advice and their target species.

Métier	Main gear type	Target species assemblage group	Typical target species (common name; Latin name)
DRB_MOL	Dredge	Molluscs	Scallops
OT_CRU	Otter trawl	Crustaceans	Norway lobster (*Nephrops norvegicus*), northern shrimp (*Pandalus borealis*), mixed fish
OT_DMF	Otter trawl	Demersal fish	Cod (*Gadus morhua*), plaice (*Pleuronectes platessa*), norway pout (*Trisopterus esmarkii*)
OT_MIX	Otter trawl	Mixed fish	Mixed fish
OT_SPF	Otter trawl	Small pelagic fish	Sprat (*Sprattus sprattus*), sandeel (*Ammodytes* spp.)
SDN_DMF	Danish seine	Demersal fish	Plaice (*Pleuronectes platessa*), cod (*Gadus morhua*)
SSC_DMF	Flyshooter (seine)	Demersal fish	Cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), flatfish
TBB_CRU	Beam trawl	Crustaceans	Brown shrimp (*Crangon crangon*)
TBB_DMF	Beam trawl	Demersal fish	Flatfish
TBB_MOL	Beam trawl	Molluscs	Whelk, snails, and scallops

SAR, catch weights (kg), and landing value (euro) are mapped for the ten métiers over a six-year assessment period (2013–2018) for the Greater North Sea, Baltic Sea, Bay of Biscay and Iberian Coast, and Celtic Seas.

Pressure and impact indicators

ICES (2017) advised the use of five pressure indicators that use SAR to assess the bottom trawling footprint. In this advice, two of these indicators are predominantly used. These are:

- The percentage of untrawled c-squares: The number of c-squares persistently untrawled in the six-year cycle (irrespective of the swept area within the cell in the six years), divided by the total number of c-squares and multiplied by 100.

- The percentage of area trawled on average per year: The sum of swept area across all c-squares based on the average for the six-year cycle – where swept area in a specific grid cell cannot be greater than the area of that grid cell – divided by the summed area of all c-squares and multiplied by 100.

All indicators of pressure as advised in ICES (2017) are included in the regional assessments.

In this advice, ICES used two impact indicators to estimate bottom trawl impact for the Greater North Sea and the Baltic Sea; data is, however, not available at the time of developing this advice to provide evidence of impact in the Celtic, Mediterranean, or Black Seas or in the Bay of Biscay and Iberian Coast. The first indicator of impact, PD, estimates the amount of benthic biomass (relative to carrying capacity) which will not exist in the ecosystem if the current bottom trawling intensity continues for a long time. The method to estimate the PD indicator uses explicit estimates of the removal of benthos by a single trawl event and explicitly relates longevity to recovery rates. These parameters are estimated from all globally available trawl impact studies for infauna and epifauna. For the calculation of PD impact, the depletion of benthos depends on SAR intensity and on métier type based on the penetration depth of the métier (see ICES Working Group on Fisheries and Benthic Impact and Trade offs [ICES, 2018]). The second indicator, L1, quantifies the community biomass of benthos that is affected by trawling during its lifespan. The methodology to estimate the L1 indicator is very precautionary as it assumes that all individuals of a species need to live to their maximum lifespan without encountering a trawl.

The regional assessments present the indicators of bottom trawl pressure and impact (when available) for the whole (sub-)regional/subdivisional sea area and per MSFD broad habitat type within that sea area. The spatial distribution of bottom trawl fishing pressure and impact (when available) are further shown in the "Pressure and impact" interactive map, which is based on average SAR and impact values for the period 2013 to 2018.

MSFD broad habitat types

All footprint and impact assessments on the seabed use the seabed habitat assessments required by Commission Decision (EU) 2017/848, i.e. the MSFD broad habitat types, based on the EUNIS 2016 classification (Evans *et al.*, 2016) and provided by the EUSeaMap 2019. Since this map has a finer resolution than the c-square VMS grid, the areal extent of each broad habitat type within each c-square was estimated for the regionall assessments and a uniform distribution of bottom trawling in the cell assumed, i.e. all habitat types within a c-square are trawled with equal SAR. For the three interactive maps "Illustration of MSFD protection – untrawled/PD impact/L1 impact", only the most dominant broad habitat type within each c-square was used.

Management scenarios

Management scenarios were developed that cover the range of options that could be used to reduce the pressure and impact caused by bottom trawls on seabed habitats. The consequences of their implementation were modelled. These scenarios were refined following a stakeholder workshop to inform this advisory process on the completeness of the management scenarios, the practicalities of their implementation, their strengths and weaknesses, and the most appropriate way to present the final advice (ICES, 2021b).

The following specific management scenarios were taken forward for trade-off analysis:

1) The progressive removal of fishing effort (from 5 to 99%) from c-squares for all bottom trawl métiers by either starting from the least or most trawled c-squares over the period 2013 to 2018.
2) Same as 1 but from each MSFD broad habitat type and only by starting from the least trawled c-squares.
3) The removal of effort through specific spatial control until the estimated pressure/impact on each benthic habitat is reduced to the desired level.
4) Gear modification in terms of reduced penetration depth, resulting in lower catch rate.
5) The removal of fishing effort by particular individual métiers (métier prohibition).

Evaluations of each of these management scenarios is provided in the TRADE3 workshop report (Section 5 in ICES, 2021c). Assessments of the consequences of implementing management scenarios 2 and 3 across MSFD broad habitat types are included in the section "management scenarios" in the regional assessments.

Limitations and caveats

Several limitations and caveats, listed below, should be taken into account when considering the advice. These relate to issues concerning the provision of vessel data and their interpretation, the scale at which the data are informative, and the information used to assess impact.

- VMS data on the location of fishing by vessels smaller than 12 m are not available and are not included in the assessment. Bottom trawling fishing intensity can therefore be underestimated in certain areas. This underestimation is expected to be strongest in coastal areas.
- It is essential to note that the area recorded as bottom trawled becomes smaller when estimated at finer resolution than the 0.05 × 0.05 degrees c-square resolution. Therefore, the percentages presented in this advice on area trawled and c-squares untrawled depend on the spatial grid resolution; should this resolution change, these percentages would also change. This is because fishing activity is often aggregated within the c-squares, whereas the method assumes that the fishing activity is evenly distributed within the c-squares. The VMS ping rate varies between countries with intervals of up to two hours, and the size of the c-squares used in ICES VMS data call reflects this rate.
- It should be noted that the management scenarios used in this advice do not take account of displacement of bottom trawling effort to currently trawled or untrawled areas. Behaviour of fishers is dynamic and

responds to many factors that have not been explicitly considered in this advice. These include maximizing the fishing opportunities from mixed-fishery TACs, voyage planning which optimizes time and reduces operating costs and takes account of weather conditions, avoiding dominant or abundant species when vessel quota is low, market value is low, or the biological characteristics of species are temporarily unfavourable (i.e. after spawning), and selecting fishing grounds in periphery areas that may be more suitable for vessels or métiers.

- The trade-off analysis undertaken for benthic habitats is heavily reliant on the underlying MSFD broad habitat type distribution. This information has variable levels of confidence associated with each habitat type. The majority of habitat information underpinning the regional assessments is classified as either medium or low confidence. Where there are several habitats within a c-square, fishing is further assigned to a habitat when in fact there was no fishing, e.g. high levels of trawling on rocky habitats. This limitation is enhanced by the uncertainty associated with habitat mapping. The assessments can be updated when new information on the distribution of MSFD broad habitat type becomes available.
- The advice data is based on data from the 2019 VMS data call with differences in the available information between (sub-)regions. In the Baltic Sea, data are not available from Russia. Information on landings weight and/or value are missing from some countries, especially in the Bay of Biscay and Iberian Coast and the Norwegian Trench. Specific regional data issues are described in the regional assessments.
- Information on benthic longevity, used to estimate bottom trawling impact in the L1 and PD approach, was only available for the Greater North Sea in areas of less than 200 m depth and for the Baltic Sea. The prediction of benthic community longevity is derived from infauna and small epifauna collected by cores and grabs. Community longevity is predicted in the Baltic and Greater North Sea based on spatial interpolation using environmental data layers.
- ICES notes there are many factors that influence fishers' decisions on where to fish (ICES, 2021c), and further work is required to understand better the effects on, and responses by, fishers to potential management measures.

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Access the electronic data outputs.

Annex 1 Request

ICES is requested to "*advise on a set of management options to reduce the impact of mobile bottom contacting fishing gears on seafloor habitats, and for each option provide a trade-off analysis between fisheries and the seafloor"*. Within this work ICES is requested to:

a) Provide analyses[1] of the present spatial and temporal variation in fishing intensity, catch and landings in a way appropriate to assess the footprint of mobile bottom contacting fishing gears in a six-year management cycle[2]. The analysis should include an estimation of the proportion of core fishing grounds (e.g. 90% of value/landings) for each gear grouping and per MSFD (sub)region/subdivision and should determine the spatial variation in 'core fishing grounds' over time.
b) Develop and review a suite of options to reduce impacts of mobile bottom contacting fishing gears on seabed habitats. This review should include any wider benefits to the ecosystem, including commercial fish stocks that could arise, if greater areas of seabed are left undisturbed by bottom fishing.
c) Produce a prioritized list of management options, and for each option provide a trade-off analysis between fisheries and seafloor habitats (i.e. overall benefit to the seafloor, relative to loss in revenue).
d) The trade-off analysis should consider, where possible, the revenue associated with the fishing activity per area by integrating fisheries economics data (e.g. STECF AER) with VMS/logbook data for all mobile-bottom contacting fishing gears and per gear grouping in (sub)regions. Such data can be used to analyse the possible effects of, for example, displacement, fuel cost, fishing time, etc. within suggested management options.

Other supplementary information to assist the interpretation of the request:

The Marine Strategy Framework Directive (MSFD, 2008/56/EC) requires Member States to achieve and maintain good environmental status (GES) across their marine waters, including for the seabed. GES is to be achieved for a specified set of 'broad habitat types', assessed at the scale of biogeographically relevant subdivisions of each MSFD region or subregion. For seabed habitats, the definition of GES includes quality threshold values for adverse effects on the state of a habitat and values for the maximum allowable extent of habitat loss and habitat adversely affected. These values are being established through a Union-level process led by the MSFD Technical Group on seabed habitats and sea-floor integrity (TG Seabed).

The demonstration assessment within the 2017 ICES advice (sr.2017.13) provided aggregate values for four types of bottom-contacting fishing gear groupings at the scale of the entire Greater North Sea region and in relation to the 2004 EUNIS habitat classification. In order to better understand the relationship between catch/value of landings and the levels of physical disturbance for MSFD purposes, this 'trade-off' analysis needs to consider the following two aspects:

- Mobile bottom contacting fishing: at the level of fishing gear grouping, on the basis that this is likely to be a more appropriate resolution for management purposes.
- Footprint/Impact on the seafloor: at the resolution of seabed habitat assessments required by the GES Decision (EU) 2017/848 (i.e. the MSFD broad habitat types, based on the EUNIS 2016 classification, and subdivisions of an MSFD (sub)region).

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[1] The analyses should be done using VMS and logbook data for all mobile-bottom contacting fishing gears and per gear grouping, covering, at least, the following MSFD (sub)regions, Greater North Sea, Baltic Sea, Celtic Seas, Bay of Biscay and Iberian Coastand the subdivisions for Broad Habitat Type assessments of these MSFD (sub)regions. The analysis should also consider how methods will be transferrable to the Mediterranean and Black Sea regions once data is made available. The analysis should summarize the results for the entire assessment area and per MSFD broad habitat type within the region, based on the EUNIS 2016 classification.

[2] Refers to the reporting cycle of the Marine Strategy Framework Directive, in which assessments of environmental status of seabed habitats are undertaken for 6-year periods (e.g. reported in 2012, 2018, 2024).

Given the above request for advise *on a set of management options to reduce the impact of bottom fishing on seafloor habitats, and for each option provide a trade-off analysis between fisheries and seafloor* (and respective points a-d above), the following guidance should be taken into consideration:

- Identify any key improvements needed to improve the estimates of the likely consequences of identified management options and associated data needed (e.g. the data precision, accuracy[3] and likely data gaps).
- In the Mediterranean, the work may be possible if VMS data are made available in the area of study and crossed with the daily landings of monitored vessels. Abrasion data is available/published in some areas, such as Italian, Greek (https://academic.oup.com/icesjms/article/74/3/847/2631171) and French waters (https://sextant.ifremer.fr/record/8bed2328-a0fa-4386-8a3e-d6d146cafe54/en/index.htm). In the Mediterranean, catches are reported at the GFCM Geographical Sub-Area scale which is coarser than the ICES statistical rectangles and may affect the study in the Adriatic. Moreover, up to 50% of catches in the Mediterranean may be unreported, as catches may be well below the official 50kg threshold for compulsory declaration.
- Provide an evaluation of how SAR (Swept Area Ratio)/value/landings correlates with the net profitability of each c-square.
- For exploratory purposes, the following scenario and sub-questions can be considered a starting point for the ICES work to explore management options:

  Scenario:

  As a fisheries manager I want to know what are the financial consequences and environmental gains if bottom-fishing activity reduces its footprint by a fixed proportion (e.g. at 5% intervals).*

  Sub questions:

  i. Contrast the above scenario where reductions in footprint (to meet the same overall target) are equal across all metier groupings, and detail the financial consequences.
  ii. What metier groupings are affected disproportionately in terms of profit if the decision rule targeting the reduction in footprint aims to minimise economic loss at the regional sea scale.*
  iii. What metier groupings have the greatest impact on the seafloor, relative to revenue generated from the fishing activity (catch/value)*
  iv. Explore the consequences of effort reduction and likely displacement effects of fishing effort from peripheral to core fishing grounds, or to 'new' fishing areas*
  v. Produce a prioritized list of management options that maximise overall gain in benthic seafloor status, and minimise lost revenue (catch/value).

  *It is noted that sub-questions may require linking the VMS/logbook data with more detailed economics data.

[3] WGFBIT (2018) considered the need to use a higher resolution grid of 0.01 degree resolution and a higher VMS interval than the current 2 hours, as this would allow a closer relationship to the distribution of habitat types to be made.