EU request on indicators of the pressure and impact of bottom-contacting fishing gear on the seabed, and of trade-offs in the catch and the value of landings

Advice summary

ICES advises on a set of indicators for assessing pressure and impact on the seabed from mobile bottom-contacting fishing. These indicators are selected based on their ability to describe impacts on a continuous scale that can be used in the evaluation of trade-off between the fisheries and their impacts on the seabed.

The indicators for pressure include four indicators reflecting the annual pressure and one multiannual indicator representing the persistency in the geographical distribution of the pressure.

ICES advises on two impact indicators: one describes the average impact in an area and the other indicates the proportion of the area with impacts below a given threshold. In order to assess the impact on ecosystem functioning and the response to fishing pressure, ICES has developed and parameterized two methods, one for each of the seabed impact indicators, for those parts of the Greater North Sea that are shallower than 200 m.

Fishing pressure was found to be highly aggregated. In the Greater North Sea, a relatively high impact occurred in deeper waters and in muddy habitats. The two methods showed different results in shallow water areas with high natural disturbance.

The trade-off analysis indicated that landings in weight and value were also concentrated at the highly aggregated (core) fishing grounds. The relatively high landings per unit of impact at the core fishing grounds imply that an overall reduction of fishing impact on the seabed, achieved by reducing fishing at the peripheral grounds, may result in a smaller reduction in landings and a larger reduction in pressure than if the reduction were at the core fishing grounds.

A demonstration advice product for the Greater North Sea ecoregion, including maps, is provided in Annex 1 in order to illustrate possible future approaches to annual advice on this topic.

Request

This advice is in response to the following request from the European Commission (DG ENV):

Evaluate indicators for assessing pressure and impact on the seafloor from bottom-contacting fishing. Using this assessment, demonstrate trade-offs in catch/value of landings relative to impacts and recovery potential of the seafloor.

Elaboration on the advice

Pressure indicators

ICES advises the use of five indicators and maps for the pressure from mobile bottom-contacting fishing gear: four annual indicators and one multiple year indicator, as shown in the table below. The indicators can be applied by regional, subregional sea, or broadscale habitat type within that sea, and assessed by total bottom-contacting fishery, a métier, or a combination of métiers. Three of these indicators rely on gridding of the considered area. ICES has currently adopted a $0.05^{\circ} \times 0.05^{\circ}$ grid, the c-square, for this purpose.

Annual pressure indicator	Description	Notes
1 – Intensity	Average number of times the area is swept by bottom-contacting fishing gears. Estimated as the sum of swept area for all vessels using bottom-contacting gears or by métier divided by the total area of the considered area (regional/ subregional sea, or broadscale habitat type within that sea).	'Swept area' is an estimate of the area of seabed in contact with the fishing gear and is a function of gear width, vessel speed, and fishing effort. This indicator is a proxy of the number of times the area is swept.
2 – Proportion of grid cells fished	The number of grid cells (c-squares) fished at least once (irrespective of the swept area within the cell), divided by the total number of grid cells (c-squares) within the considered area.	
3 – Proportion of area fished	The sum of swept area across all grid cells in a considered area, 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 grid cells.	This indicator provides the best estimate of the proportion of area fished.
4 – Aggregation of fishing pressure	The smallest proportion of the grid cells (c-squares) where 90% of the total swept area occurs.	

Multiple year indicator	Description
5 – Persistently unfished areas	In order to understand the length of time that grid cells remain unfished, Indicator 2 could be evaluated over six years.

In general, fishing pressure is highly aggregated. The proportion of grid cells at depths of less than 200 m that were fished in 2015 (Indicator 2) was 80% for the North Sea, while the proportion of the area fished (Indicator 3) was 54%. 90% of the fishing pressure in 2015 was aggregated (Indicator 4) into 36% of the grid cells. These percentages are scale dependent and depend on the current spatial resolution; should this resolution change, these percentages would change also.

Impact indicators

ICES advises the use of two annual impact indicators and maps for the impact from mobile bottom-contacting fishing gear as shown in the table below. These indicators can be applied by regional/subregional sea, or by broadscale habitat type within that sea and assessed by total bottom-contacting fishery, métier, or a combination of métiers.

ICES advises that the metrics used should reflect complementary aspects of the benthic community response: effect on ecosystem functioning, and response to fishing pressure. For each indicator, ICES therefore advises use of more than one quantitative methodology. ICES has developed and parameterized two methods for parts of the North Sea; the longevity (LL1) and the population dynamic (PD2). The longevity composition of a benthic community is a proxy for biodiversity and tracks the change in benthic community composition in response to trawling. The population dynamic method indicates how bottom trawling affects the biomass of the benthic community using the relative biomass as a proxy for the amount of functioning still remaining in the community (e.g. bioturbation, facilitation, nutrient cycling, reproductive output, secondary production). If present, this functioning helps maintain not only the local community as a whole, but the wider biodiversity (an important part of the integrity of the seabed) as well. These methods can be used in other regional and subregional seas, but have yet to be parameterized by ICES. However, for other regional/subregional seas, other methods may be more appropriate depending on available information.

Impact indicators	Method	Short description
1 – Impact	PD2 and LL1	Annual average fishing impact across grid cells in an area.
2 – Area below impact threshold	PD2 and LL1	The proportion of grid cells with an impact below a (chosen) impact threshold at a regional or subregional scale.

For the North Sea, both methods found a relative high impact (Impact Indicator 1) in deeper waters and in muddy habitats. In shallow habitats exposed to moderate to high shear stress, the two methods gave different results. The population dynamic method (PD2) found impact to be mainly determined by the level of fishing pressure and less by differences in seabed sensitivity. The longevity method (LL1) predicted low impact, despite high fishing pressures, in shallow waters that are exposed to high natural disturbance. The underlying reasons for this difference require further investigation. The average impact of all bottom trawling in 2015 was 0.24 (0 = no impact, 1 = maximum possible impact), slightly lower than in 2009 and 2010. Impact varied between habitats, being highest in mud (0.33) and mixed sediment (0.31) and lowest in coarse sediment (0.26) and sand (0.22). Since 2009, the impact has shown a slight decrease in mud and coarse sediments, and a slight increase in mixed sediment.

The proportion of the grid cells in the North Sea (Impact Indicator 2) with a low impact (< 0.2) is around 0.5 in muddy sediments and 0.6 in other habitats.

Landings in weight/value indicators

ICES advises the use of four annual indicators to describe the landings or value of fish, as shown in the table below.

Annual landings/value indicators	Short description
Landings in weight	Total weight of landings (kg) within the assessed region, métier, or habitat.
Landings in value	Total value (Euros) of landings within the assessed region, métier, or habitat.
Landings in weight per c-square	Average weight (kg) of landings per c-square.
Landings in value per c-square	Average value (Euros) of landings per c-square.

Trade-off assessment

Landings in weight or value per unit area indicators can be used in assessing the trade-off in relation to the environmental impact and recovery potential of the seabed from mobile bottom-contacting fishing gear by area (regional/subregional sea, or broadscale habitat type within that sea).

The impact indicators can be compared with the landings/value indicators to assess trade-offs between the environmental impact and recovery potential of the seabed from fisheries using mobile bottom-contacting gears and the landings in weight and/or value of the fisheries. These trade-off assessments are informative at broad spatial scales. However, in assessment of impact of management measures, different trade-offs may be required depending on the management objectives and measures.

For the Greater North Sea (see Annex 1), the seabed within the core fishing grounds (high fishing intensity) was of lower status (higher impact score), but the landings (kg) per unit of impact were higher than in the peripheral fishing grounds (lower fishing intensity). Conversely, the seabed in the peripheral grounds had a higher status, but made a relatively small contribution to the overall landings and value.

The relatively high landings per unit of impact at the core fishing grounds imply that an overall reduction of fishing impact on the seabed, achieved by transfer of fishing pressure from the peripheral grounds to core grounds, might result in a smaller reduction in landings than if the transfer went the opposite way. The most sensitive species are affected at low trawling intensities, whereas only the more resilient species survive in the core fishing areas. A small increase in the pressure will therefore have little additional impact in the core fishing areas.

The general implications of management measures have been illustrated in this advice. Fisheries are by nature dynamic, responding to changes in management and in the environment. This advice used equilibrium relationships (steady-state models) between fishing pressure and impacts, and observed landings and value. It is possible to resolve the issues addressed in this advice and provide further advice, but all of the modelling approaches require that specific management objectives are defined (and potential management measures taken) and may be limited by availability of data.

A demonstration advice product for the Greater North Sea ecoregion is provided in Annex 1. The format of this product aims to make the spatial and temporal patterns of all of the indicators readily apparent to non-experts. Although the assessment in this demonstration was carried out with one (PD2) of two possible methods, this does not imply that ICES recommends that method above the other (LL1).

Suggestions

If these indicators are to be used to evaluate management strategies, ICES regards it as important that they be tested against realistic scenarios. These management scenarios will require management input and decisions.

Some management scenarios may require modelling at higher definitions of métier (e.g. DCF level 6). If these higher definitions are used, further exploration of trade-off scenarios will be needed. This will require increased involvement of the stakeholders affected by potential decisions.

The information underpinning the indicators could potentially be improved in a number of ways; testing might reveal which data or model require most improvement. For example, at present the broadscale habitat type assigned to each grid cell (c-square) is based on the habitat modelled for the centre of that grid cell. This potentially means that a relatively small area of a particularly sensitive habitat would be missed, or an area of apparent higher habitat heterogeneity would not be well described. Making relatively sparse habitats the focus of management will require improved knowledge of the location and extent of these areas and their benthic fauna as these are often poorly determined by the current methods, particularly for bottom types that are not readily sampled by box or grab sampling. Similarly, an increase in resolution and accuracy of fishing pressure will only improve habitat impact estimates if accompanied by a similar resolution and accuracy of the underlying habitat map. The actual fished area within a regional sea area will be different to the calculated c-square area (generally lower offshore, higher inshore). If this was to be improved, this would require vessel monitoring system (VMS) data at a higher spatial resolution and inshore would additionally require the use of a monitoring system for smaller (< 12 m) vessels. In all cases, the full supply of relevant VMS and logbook data from all countries fishing in an area is essential.

The outcome of the impact assessment [(fraction of (un)impacted habitat) / (fraction of habitat at a certain state)] is dependent on the assessment method used and the spatial resolution of the fishing pressure data layer (presently $0.05^{\circ} \times 0.05^{\circ}$). A change in spatial resolution will result in an overall change in the assessed habitat state. This means that the setting of threshold values is method dependent. Therefore, a benchmarking process to formally agree on a methodology and parameterization, including threshold values, is required to harmonize the “good environmental status (GES) concept” across regions.

The impact models applied were parameterized for infaunal communities of those parts of the Greater North Sea shallower than 200 m. Further analysis of benthic community structure, in relation to habitat and including both infauna and epifauna, is required to improve the parameterization of the model and thus application in other regional or subregional seas, and in deeper waters.

The PD2 method can be used to estimate the time it takes a community to recover to an unimpacted state. This recovery time will vary as a function of fishing pressure and the longevity composition of the benthic community.

In evaluating overall regional seabed status from the effects of bottom fishing, context dependency of other significant region-specific pressures will need to be included in the models. This is for example evident in the Baltic Sea when evaluating the effects of bottom fishing, where both natural and anthropogenic oxygen deficiencies will need to be considered.

The models used in this advice have mainly examined the effects of mobile bottom-contacting gears on benthos quality. Other ecological consequences of this disturbance, such as foodweb consequences or the effects of sediment suspension, have not been explicitly modelled. The interconnectivity of all marine life through foodwebs means that every management decision will have an effect, sometimes in opposing directions, on every part of the system. It is important that these further ecological consequences are taken into account to reduce the risk that management produces unwanted results.

Basis of the advice

Background

ICES is requested to 1) propose a set of indicators for assessing physical disturbance pressures from bottom-contacting fishing gears and their environmental impacts on seabed habitats/sea-floor integrity, and 2) develop an approach on how to demonstrate the trade-off between catch/value of landings per unit area and the environmental impact and recovery potential of the seafloor (from the above assessments). The assessment scale should be suitable biogeographic subdivisions of the MSFD regions and subregions, and per MSFD broad habitat type (or more finely-defined habitat types). Within this context, maps and indicators (a-c, below) should include demonstration products for at least one MSFD (sub)region and take account of developments on these issues within the Regional Sea Conventions.

a) Map and indicator(s) of fishing intensity (physical disturbance), for the most recent 6-year period (and for earlier periods where possible);
b) Map and indicator(s) of the area impacted by bottom fishing (in same 6-year periods), and the percentage (%) of each MSFD broad habitat type impacted per subdivision;
c) Maps and indicator(s) assessing the benefits of the fishery (by weight and/or value) compared with its degree of impact on the seabed (taking account of the frequency of trawling and the ability of the habitat to recover after fishing), at the c-square scale (or other appropriate spatial resolution).

This advice is based on ICES (2016a) that recommended specific pressure and impact indicators and the use of a quantitative approach based on biological principles to provide continuous (rather than stepped) indicators. The outputs of the approaches taken are illustrated and described in the demonstration advice product for the Greater North Sea ecoregion (Annex 1).

Methods

<u>Pressure indicators</u>

ICES (2016b) defines the swept area as the cumulative area contacted by a fishing gear within a grid cell over one year. The swept area ratio (SAR, also defined as fishing intensity) is the swept area divided by the surface area of the grid cell. The area contacted by fishing gear is provided by geographically distinct vessel monitoring system (VMS) points for which speed and course are available at intervals of maximum 2 hours, coupled with information on vessel size and gear used derived from EU logbooks (ICES, 2017a; Eigaard *et al.*, 2016).

Vessel speeds representing fishing activity are assigned to a 0.05° × 0.05° grid, about 15 km² at 60°N latitude, which is the spatial resolution adopted by ICES: the c-square approach. ICES does not have access to information on vessel position at a finer scale than this, due to national confidentiality reasons.

Each c-square was assigned to a EUNIS level 3 habitat type using the habitat modelled at the centre point of the c-square.

Estimates on total SAR within each grid cell were calculated by métier and habitat. A total of four métiers (otter trawl, beam trawl, dredge, and demersal seine) and four broadscale habitat types (coarse, sand, mud, and mixed) were specifically considered. These habitat types were chosen as the new Commission decision on MSFD was not available when the expert work was undertaken.

The pressure and impact indicators are discussed in detail in ICES (2017a).

<u>Impact indicators</u>

ICES evaluated various impact indicators, of which two quantitative methods were derived from approaches that make use of the longevity composition of the benthic community (Rijnsdorp *et al.*, 2016), to assess habitat sensitivity to fishing.

The PD2 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.). The biomass component of the PD2 method is a proxy for ecosystem (functioning) processes, for example, nutrient cycling or energy flow through foodwebs.

The LL1 method is a statistical model that estimates the habitat-specific longevity composition of the community and the effect of trawling on this composition (Rijnsdorp *et al.*, 2016). The basis of this relationship is that long-lived species, because of their lower growth rates and later age at maturity, have a lower recovery rate and they are therefore generally more sensitive to fishing mortality. The model includes an interaction of the effect of trawling and shear stress on the seabed as trawling has lower impacts in habitats with high shear stress (high natural disturbance). The indicator estimates the reduction in the proportion of long-lived taxa (maximum lifespan > 10 years) caused by trawling. The species-specific longevity traits were derived from a literature review (Bolam *et al.*, 2014).

<u>Landings/value indicators</u>

Landings values (Euros) and weights (kg) were calculated from logbook data, by countries submitting these data, prior to submission to ICES.

<u>Trade-offs</u>

As an example, ICES (2017b) used the PD2 assessment methodology (see above and ICES, 2017a) 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. The resultant landings and value metrics were aggregated across selected métiers, allowing impacts to be assessed at regional or subregional levels. Because trawling is aggregated at the regional sea scale, trade-offs between core and peripheral fishing grounds were examined.

Caveats

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

- Data on the location of fishing by vessels smaller than 12 m are not available and therefore not included in the assessment. This introduces a bias in the assessment that is expected to be strongest in coastal areas.
- VMS data were not supplied from certain countries both within and outside the EU, introducing a bias in pressure in areas fished by these countries. In EU waters, the greatest bias will be in the Bay of Biscay, the southern Celtic Seas, and in Iberian waters.
- The calculation of fishing intensity, as well as of surface and subsurface abrasion, is inferred from a suite of VMS data, including vessel speed. However, fishing speed was not always supplied, and in such cases, estimates were based on average supplied fishing speed values.
- Fishing pressure indicators are dependent on the spatial resolution of the fishing pressure data. The indicators in the demonstration advice (Annex 1) are calculated at a resolution of 0.05° × 0.05°.
- It is possible that the valuation of landings has been treated differently by different countries, potentially introducing bias.
- Habitat maps at the regional scale may be both biased and uncertain, but the degree of this is usually unknown.
- The level of detail in benthic knowledge is variable by region and by habitat. Assessments at a regional sea scale do not encapsulate the consequences of this heterogeneity.
- Not all of benthos is included in the assessment, especially epifauna. Therefore, harder habitats in particular are omitted from the assessment.
- The relative lack of knowledge of biological features and species traits of the broadscale habitat types in deeper waters means that ICES can, at present, only advise on impacts on seabeds shallower than 200 m.

Additional information

ICES is confident that this advice can provide guidance for assessing the abrasion effects of bottom-fishing on broadscale habitats at the regional scale. However, in the longer term, a number of improvements to the underlying information used in this advice could be made that would likely help improve assessments on the smaller scale, or on more detailed habitat types.

There are several inputs to the assessment of the state of seabed habitats, most of which could be improved to reduce uncertainty and increase precision. Habitat maps could be improved and widened in their coverage with further surveys. The greatest gains can be achieved where fishing occurs; no (or only poor) habitat maps exist for areas that might contain more sensitive habitats than those mapped at present. Currently there is a mismatch between spatial resolution of pressure data (c-squares) and habitat data, and there is a need to develop methods for rationally assigning habitat types to spatial pressure units. Many of the c-square cells will have more than one broadscale habitat type and a range of sensitivities. Similarly, information about the prevailing benthic communities should be refined.

Fishing pressure maps could be improved in a number of ways; the greatest gains could be made by ensuring that all ICES Member Countries fully report their fishing activity (VMS data and logbook records) when requested. The lack of available information on the activities of fishing vessels under 12 m in length means that there will be underestimation of the pressure and impact in coastal areas. ICES (2016) estimated that the proportion of mobile bottom fisheries conducted by vessels under 12 m length in the North Atlantic (and adjacent seas) was 18% of fishing effort and 12% of the landings. Potential approaches to improve this situation would require further research. Further gain could also be made through studies to improve knowledge of the impacts of individual métiers on each broadscale habitat type.

Benthic datasets (infauna and epifauna) and associated traits need to be further analysed to determine the habitat-specific community compositions required to:

a) improve knowledge of the longevity composition of the benthic communities of different habitats;
b) make reasonable predictions for additional areas and habitats; and
c) ground-truth the outputs.

A prediction of fishing abrasion of different sediment layers for different habitats, more detailed than mere surface/subsurface abrasion, would greatly improve the PD2 impact indicator estimations.

The framework to evaluate trade-offs between fisheries and benthic impact used equilibrium relationships between the pressure and impact, and landings in weight and/or value at regional scales. Further improvements could be made by:

1. Developing the economic modelling methods to reveal the financial implications of spatial management measures, including the effects on vessel running costs as well as price flexibilities that lead to variation in the revenues arising from the sale of catches.
2. Modelling displacement of effort, taking into account technical interactions between fleet segments as well as the influence of other pressures such as wind farms, shipping lanes, gravel extraction, etc.
3. Increasing the understanding of spatial and temporal distributions of target fish populations based on, e.g. fishery-independent survey data time-series such as the International Bottom Trawl Survey. This would enable better modelling of displacement of effort and its consequences.

Improved models of the ecosystem effects of mobile bottom-contacting fishing should include:

1. Ecological consequences, in particular the cascading trophic effects on non-target species, e.g. charismatic top predators, species composition, and abundance of targeted resources.
2. Additional ecosystem functions of primary fishing grounds, i.e. functions not directly related to the benthic community such as spawning areas for fish stocks.
3. A framework/methodology to ensure that the different habitat types (common as well as rare and sensitive habitats) are equally represented in any areas with management-based effort reduction, to secure the integrity of biodiversity and ecosystem functions and services.

4. Ecological processes at a regional scale (e.g. dispersal and connectivity across the seabed) in relation to habitat quality and patterns of fragmentation.

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Annex 1

The demonstration advice is provided on the following pages.