

## 11.2.2 Request from HELCOM for ICES to review the BalticBOOST WP3.2 tool to assess the impact of fisheries on seafloor habitats

### Review summary

ICES organized three independent reviews to be undertaken on HELCOM's project BalticBOOST WP3.2 "Tool" to assess the impact of fisheries on seafloor habitats. The Tool's aim is to enable HELCOM to assess the effects of fishing with mobile bottom contacting gear on benthic species and habitats in the Baltic Sea, taking into account the HELCOM classification scheme of biotopes, biotope complexes, and habitats in the Baltic Sea (HELCOM BSEP 139). In addition to producing a Tool, the BalticBOOST's project WP3.2 was also tasked to produce a detailed inventory and description of the interactions with benthic habitats/species of the Baltic Sea when fishing with mobile bottom-contacting gears. The reviews are included in unchanged form, apart from some formatting and minor corrections. For consistency "seabed" has been replaced throughout with "seafloor".

The three reviewers were asked to examine three key underlying questions:

1. Have appropriate scientific methodologies been applied?
2. Can the outputs of BalticBOOST WP3.2 be used as a management tool to assess fisheries impacts on the seafloor in the Baltic Sea?
3. Which modifications, if any, are required in the future to ensure that the developed tool can be used for management purposes?

The reviews are based on a draft received 28 October 2016 of "BalticBOOST Fisheries Impact Evaluation Tool (FIT) with Application to Assess the Bottom Fishing Footprint in Western Baltic Sea (ICES Subdivisions 22-24)" (see Annex 1).

### Request

Request from HELCOM for ICES to review BalticBOOST WP3.2 Tool to assess the impact of fisheries on seafloor habitats:

*In 2012-2013 HELCOM developed a preliminary version of an EXCEL-based tool (called Generic Tool) that provided science-based information on the interactions between different types of fishing gears and habitats and species in the Baltic Sea. Under the HELCOM BalticBOOST project, an advanced and more detailed version of the existing Generic Tool is being developed.*

*BalticBOOST is an EU co-financed project coordinated by HELCOM which started in September 2015 and will continue until December 2016. The general objective of the project is to improve regional coherence in the implementation of marine strategies through improved data flow, assessments, and knowledge base for development of measures. Under its WP 3.2, BalticBOOST more advanced version of the tool is being developed that provides information on both the extent and the impacts of fisheries on the seafloor, including the spatial distribution and coverage of different habitats of fishery. The work is based on literature review and expert knowledge, and also includes case studies from selected areas. This new tool is intended to support managers in the development of conservation plans, maritime spatial planning and programmes of measure.*

*The project is to deliver:*

- *A detailed inventory and description of interactions between fishing with mobile bottom contacting gears and benthic habitats/species of the Baltic Sea,*
- *An operational HELCOM Generic Tool to assess the effects of fishing with mobile bottom contacting gear on benthic species and habitats in the Baltic Sea, taking into account the HELCOM classification scheme of biotopes, biotope complexes, and habitats in the Baltic Sea (HELCOM BSEP 139).*

*The aim of the ICES review is to, in particular, address the following questions:*

- *Have appropriate scientific methodologies been applied?*
- *Can the outputs of BalticBOOST WP3.2 be used as a management tool to assess fisheries impacts on the seafloor in the Baltic Sea?*
- *What modifications, if any, are required in the future to ensure that the developed tool can be used for management purposes?*

*Within the above context, ICES is requested to facilitate an independent review of BalticBOOST WP3.2.*

## **ICES review / technical service**

To address the request from HELCOM for ICES to review BalticBOOST WP3.2 Tool to assess the impact of fisheries on seafloor habitats ICES appointed three independent reviewers: Reviewer 1, Laura Robson (UK); Reviewer 2, Neil Campbell (Scotland); and Reviewer 3, Annabelle Aish (France).

The document for review was supplied to ICES on 28 October 2016 by Project Coordinator Marco Milardi of HELCOM (Baltic Marine Environment Protection Commission), titled “BalticBOOST Fisheries Impact Evaluation Tool (FIT) with Application to Assess the Bottom Fishing Footprint in Western Baltic Sea (ICES Subdivisions 22–24)” (see Annex 1). The three reviewers worked from 28 October 2016 to 11 November 2016 to deliver independent reviews of the document. The scope of the reviews was to look at underlying scientific methodologies, their usefulness in a management, and to suggest modifications. The reviews also commented on the completeness of the BalticBOOST WP3.2 deliverables, as well as the scientific content presented in the document.

### **Reviewer 1**

The BalticBOOST project aimed to improve the HELCOM-developed “Generic Tool”, which provided science-based information on the interactions between different types of fishing gears and habitats and species in the Baltic Sea. The objective of the analysis under work package 3.2 of BalticBOOST was to develop a workflow for relating the fishing pressure from different fishing activities to the response of the affected components, both fish stocks and habitats, within a tool. The new tool, FIT, is intended to support managers in the development of conservation plans, maritime spatial planning, and programmes of measure.

The aim of this ICES review was to, in particular, address the following questions:

1. Have appropriate scientific methodologies been applied?
2. Can the outputs of BalticBOOST WP3.2 be used as a management tool to assess fisheries impacts on the seafloor in the Baltic Sea?
3. Which modifications, if any, are required in the future to ensure that the developed tool can be used for management purposes?

#### **1. Have appropriate scientific methodologies been applied?**

The swept area approach to mapping fishing intensity applies a method utilized widely by scientific practitioners and this seems an appropriate use of the method for the project. I would assume the decision to use only 2 years of vessel monitoring system (VMS) data is based on data limitations and will be updated in the future with new data. However, the use of only 2 years of data seems to have resulted in the choice to use the first metric of trawling footprint (metric i), which calculates the percentage of grid cells trawled (per habitat or management area), regardless of intensity. This then accounts for the fact that untrawled areas of partially trawled grid cells might well be trawled in future years. However, this would, I assume, lead to an overestimate of the amount of trawling occurring per year (though it is interesting that Figure 5 does not show much difference between

metrics i and ii). Perhaps a better approach would be to gather additional VMS data per year to allow a more accurate year-on-year review. Metric ii seems to me a more accurate and reliable approach.

The seafloor integrity method utilizes the quantitative longevity approach to the sensitivity of benthic communities and their response to fishing impact, as developed under BENTHIS WP2. This moves away from qualitative “categorical” approaches that have been used in similar studies (for example the OSPAR common indicator BH3 – physical damage) which consider both resistance and resilience of communities in sensitivity scoring. The BENTHIS approach allows for a more data-driven approach to assessment of fishing impact, but includes a number of assumptions which should be addressed in future development of the FIT tool. The use of a North Sea dataset to set the reference longevity composition for the Baltic Sea habitats has been clearly mentioned in the report, but additional assumptions should also be taken into account, as detailed in the ICES WKFBI Report 2016 (ICES, 2016). Additionally, what must not be forgotten is the applicability of these modelled methods in “real life” scenarios. As such, a sense check of the final fishing intensity and seafloor integrity maps with experts and stakeholders in the fisheries sector for the Baltic Sea is important, to determine whether the maps are a reasonably accurate reflection of the distribution, and thus potential impact, of fishing activity.

With the use of longevity of taxa as a proxy for determining the sensitivity of the benthic communities, this seems to miss one of the commonly used attributes of sensitivity, i.e. the resistance, or tolerance, of species. Longevity seems to focus purely on resilience, or recovery potential, and doesn’t take into account other traits, such as living habitat or morphology (it is a little unclear in Figure 2 how the traits mentioned were used). It would be interesting to apply some of this knowledge on functional traits to cumulative biomass curves, recognizing that most traits will not be continuous variables, to see if other sensitivity-related traits respond to changes in fishing intensity.

The method for application of landings data seems good, although detail on the limiting assumptions for applying international landings to VMS fishing positions would be useful as well. The results showing origin of cod landings was very interesting and could be a useful way of detailing key hotspots for fishing of specific species.

Overall, I feel sound scientific methodologies have been applied, but as with all areas, some aspects could do with further development to limit the number of assumptions used to develop the seafloor integrity maps.

## **2. Can the outputs of BalticBOOST WP3.2 be used as a management tool to assess fisheries impacts on the seafloor in the Baltic Sea?**

At this point I do not feel that the method for seafloor integrity, using the longevity approach, is developed enough to be able to be confident in the outputs of the work to be used as a key management decision tool, but it could be used as part of a package of tools. The quantitative approach allows a data-driven approach to understanding impact of trawling on benthic habitats, but these analyses can still have some inherent inaccuracies and assumptions which should be identified before it is used more widely.

There are also limitations with the availability of VMS data that will impact the final outputs. There is a continuous evidence gap when working on pressures and impacts of fisheries, and in this project raw VMS data were only available for Denmark, Sweden, and Germany. Additionally, it is only briefly noted that VMS is currently only available for vessels >12 m. As such fishing pressure may be underestimated without the addition of smaller vessels’ and other countries’ raw VMS data.

Providing management measures for fisheries has become an increasing requirement, particularly with the increase in marine protected areas (MPAs) being designated in European waters. Although there are limitations in data quality and extent for the BalticBOOST WP3.2 project, these are not aspects that are likely to be improved in the imminent future. As such, the FIT tool does provide a good step forward in being able to provide evidence-based advice on management, but the seafloor integrity method should be developed further before application to management. Additionally, as noted above, expertise from stakeholders should be applied to quality assure the outputs of the work and to ensure that if the tool is used for conservation plans, programmes of measures, and maritime spatial planning, then expert knowledge has also been used in the process.

### 3. Which modifications, if any, are required in the future to ensure that the developed tool can be used for management purposes?

The swept area intensity mapping has limitations related to VMS data use, as mentioned above, but many of these won't be resolved in the imminent future. As such, its use within the FIT tool seems a suitable method to including fishing intensity information. It could simply be improved with additional years of VMS and countries' data.

I would suggest reviewing the two metrics of trawling intensity, and perhaps focus future work on only the second metric to avoid overestimates of the percentage of habitat where trawling occurs. Alternatively, only include, for example, half a grid cell in the percentage calculations when a grid has only been trawled for half of a year. This is a relatively minor point.

Future development of the longevity approach is needed to firstly apply Baltic Sea reference data to the tool, but also to address some of the other assumptions in the seafloor integrity calculations. Some of these are mentioned in the conclusions already, such as identifying longevity distributions for biogenic habitats and highly exposed habitats separately, which I think would be valuable additions to the work. Further thought could be put into the use of epifaunal longevity composition, particularly for the circalittoral and infralittoral rock habitats where other trawling seems to be occurring (Figure 5). Of course an additional limitation is that the longevity composition comes from a reference "untrawled" area. However, how much confidence do we have that this area has been untrawled? It would be interesting to look into reference areas in more detail if collecting data from the Baltic Sea to produce these reference compositions. As mentioned above, one key gap seems to be the use of other functional traits, which influence tolerance in the sensitivity assessment and which could be explored further.

The application of the landings data seems a simple, but useful, addition to the tool to support indicator development for MSFD Descriptor 3.

A final modification needed is the inclusion of a confidence or "certainty" assessment in the final outputs. This would allow the user to understand which areas show the greatest confidence in the underlying data.

### Conclusions

Overall, I feel the work has successfully applied some very useful and interesting analyses to mapping fisheries impacts by developing a tool that could be used more widely than the Baltic Sea, thus meeting the requirements of the project. However, further development of the seafloor integrity method is needed before the tool is used widely to assess fisheries impacts.

### Reviewer 2

A Review of the BalticBOOST Fisheries Impact Evaluation Tool (FIT) with Application to Assess the Bottom Fishing Footprint in Western Baltic Sea (ICES Subdivisions 22–24). This review addresses the development of a tool to assess the impacts of bottom fishing on the benthic ecosystems of the western Baltic. Specifically, the terms of reference frame the review as a response to three issues.

- Have appropriate scientific methodologies been applied?
- Can the outputs of BalticBOOST WP3.2 be used as a management tool to assess fisheries impacts on the seafloor in the Baltic Sea?
- Which modifications, if any, are required in the future to ensure that the developed tool can be used for management purposes?

Following a review of the general content of the paper, these specific points will be addressed.

## Introduction

The authors begin by establishing the need for the impact evaluation to, and the context behind its development. This section introduces the concepts discussed later in the paper and provides examples from the literature of their use. The central one of these is the introduction of the workflow, relating fishing pressure of the various fishing activities to the response of some of the affected components (fish stocks, benthic habitats) in order to address the needs for an evaluation tool of how fishing impacts the marine ecosystem. The authors stress the importance of considering the human aspects of fishing, encouraging the consideration of socio-economic factors by expressly considering the trade-off between environmental impacts and the benefits which fishing generates. This approach is being applied in a number of similar studies and represents an excellent way to engage decision-makers and convey relative benefits when evaluating policy options.

## Methods

### *Swept Area Intensity or Swept Area Ratio*

Data availability issues are a common problem in studies based on vessel monitoring system (VMS) data. Concerns focus on the sharing of personal and commercially sensitive data, and therefore it is important to address the limitations which the different “scales” of data sharing impose on the methods to which that data can be applied. An aggregated index of swept area, generated via an ICES data call and processed by the Working Group on Spatial Fisheries Data (WG-SFD) is contrasted with an approach where raw VMS data is provided by the countries participating in the study and processed in a manner described in a number of peer-reviewed publications, presumably using tools such as the VMStools R Library, although this is not clearly expressed. The nature of the VMS and logbook data is not described here (e.g. What is the polling frequency? Is fishing activity logged by tow/day/trip? By what means are fishing and steaming determined? etc.). It could be assumed that these are as described in the Control Regulation.

Although this section presents both the aggregated (swept area ratio) and disaggregated (swept area intensity) approaches, it does not explain the reasoning behind the choice of one over the other going forwards into the assessment. Presumably the flexibility in development of approaches which the disaggregated data allows is a strong factor. It would be helpful to understand the proportion of total fishing activity which is present in the disaggregated data (e.g. the combined Danish, Swedish, and German effort), compared to the aggregated WG-SFD data.

These points aside, the approach taken in data processing appears to be consistent with those used elsewhere, and is based upon the relevant literature.

### *Trawling Footprint*

On the basis of the VMS and logbook data a “Trawling Footprint” was generated as a proxy for bottom fishing activity. This indicator shows the extent of fishing with mobile bottom-contacting gears, and reflects the proportion of the total seafloor area (management area or habitat type) that is trawled annually during the period of analysis. Two approaches to calculating the extent of the footprint – firstly, as the percentage of the grid cells of a management area or habitat type where any quantity of trawling has been recorded irrespective of its intensity; and secondly, the area of the seafloor trawled at least once a year.

With a two-hour interval between VMS polls, and assuming a fishing speed of 3 knots, a vessel could cover a distance of 11 km, or around eight 1' × 1' cells between the recordings of position. Much of the perceived impression of the scale of impacts in any given cell is therefore dependent on the choices made regarding interpolation between VMS positions. It could be a helpful exercise to repeat the analysis, assuming straight-line travel between VMS points as a measure of the “absolute minimum” of fishing impact. Given the large data set, independence of VMS reporting from the start of fishing activities, and the assumption of uniform distribution of impacts within grid cells, is it necessary to interpolate at all? An equally valid approach with a large data set such as this, where we are less concerned about the activities of individual vessels, would be to treat each VMS “ping” within a cell to represent an impact of [average fishing speed × polling interval × gear width]?

In the final sentence of this section it is explained that separate footprints were derived for trawl, seine, and dredge fishing activities. For the sake of clarity it would be more helpful if the footprints were referred to consistently as “Fishing Footprints” rather than “Trawling Footprints”, given the differences in relative impact the three gears have on the seafloor.

### *Seafloor Integrity*

Estimates of seafloor integrity were calculated on a  $1' \times 1'$  grid, based on the principle that a trawling frequency within each grid cell of less than the lifetime of a particular organism would not be conducive to the survival or recolonization of the species to which that organism belongs. The authors recognise that the longevity composition of the western Baltic is not yet defined and that a proxy from the North Sea has been used. Nevertheless, this seems a logical and defensible approach.

### *Origin of Landings*

The approach used in assigning landings to positions, using VMS and logbook data and the VMStools library in R, is the standard means of producing such spatial distributions. It would be helpful in understanding the degree of precision of the tool, to know what proportion of landings and VMS data remain unlinked, due to absent fishing activity on days where landings have been declared, or for days where VMS suggests there was fishing activity for which no corresponding logbook information is available.

## **Results**

The results show that methods developed previously provide a good representation of the spatial distribution of fishing activity, both combined and for individual gears. It should be noted that the significance or concept of “abrasion” presented in the caption to Figure 3 is not explained elsewhere in the paper. It is surprising to see such a high proportion (~40%) of infra- and circalittoral rock being fished by otter trawls, as measured by both metrics, given the likelihood of damage to trawl nets when fishing on rock bottoms (Figure 5). This may be an artefact of the small areas which these seafloor types contribute to the study area, overlapping with an area where trawling is carried out, given the assumption of uniform distribution of effort within cells. It may be helpful to explore this phenomenon in greater depth.

The plot of seafloor integrity shown in Figure 6 demonstrates the utility of the index in understanding impacts of fishing gears on the seafloor. It seems strange that the index is only presented for areas where VMS shows fishing activity – presumably in areas where fishing activity is not taking place the index is also 1. If the intent is to show these areas are unfished, I believe that is apparent from figures 4 and 5.

## **Discussion**

The discussion addresses the differences in fishing pattern seen between the *Nephrops* grounds of the Kattegat and the whitefish grounds of the central Baltic. Areas such as the *Nephrops* grounds score low on the Shannon diversity index (SDI) metric, and yet remain a home to significant numbers of long-lived benthic fauna, such as the *Nephrops* themselves. Perhaps it could be more clearly expressed what message we are supposed to take from the maps of this indicator. The authors recognise the need for more work in transposing this indicator from the North Sea and I agree that this is a very good idea.

### *FisheriesImpactTool Software*

Finally, the tool developed by the BalticBOOST project is addressed. The conceptual approach of combining VMS-derived fishing intensity and information on longevity of benthic organisms as a means of developing indicators of ecological impact is a sound idea. The workflow proposed in Figure 8 also appears a reasonable approach; however, as noted earlier, the relative contributions of raw and aggregated VMS to the process are not adequately explained.

## Specific Questions

### *1. Have appropriate scientific methodologies been applied?*

On the basis of the data available to this study, the methods applied, in terms of processing VMS, linking to catch information and interpolation of fishing activities are all standard approaches used in a number of other studies. The issues in developing a seafloor integrity index specific to the benthic fauna of the western Baltic has been raised in the paper and clearly represents a shortcoming in the methodology. However, given the gross similarities between the North Sea and the Baltic, and with the proviso that the results are provisional, this approach can also be considered valid.

### *2. Can the outputs of BalticBOOST WP3.2 be used as a management tool to assess fisheries impacts on the seafloor in the Baltic Sea?*

The methods presented here represent a tool for the partial assessment of impacts of fisheries on the seafloor of the Baltic. VMS data is only available from vessels of lengths greater than 12 m. A preliminary examination of the EU fleet register shows that the combined fleets of Germany, Denmark, and Sweden comprises 5 048 vessels; however, only 824 of these are of sufficient size to be required to carry VMS equipment. Of the remainder, approximately 250 are recorded as using trawl, seine, or dredge gears. While it would be incorrect to assume that all of these small vessels operate in the Baltic Sea, their actual area of operations is unknown, and it is likely that they operate closer to the shore than larger vessels. Some means of accounting for the impact of these fishers would be necessary for managers to have confidence in the tool. This could take the form of conducting fishers' surveys, providing GPS data-loggers to small vessels, or development of a smartphone app. At the very least, acknowledgement should be made of the partial picture of effort distribution which is presented in the current study – discussion of this limitation is currently absent.

### *3. Which modifications, if any, are required in the future to ensure that the developed tool can be used for management purposes?*

The methods presented in this paper represent a fundamentally sound approach for the assessment of the impacts of fishing on the seafloor based on the data which is currently available. A number of areas where further work would be beneficial, such as the development of a Baltic benthic longevity metric, are acknowledged in the paper.

Further to the actions proposed in response to the previous question, a two-hour interval between VMS polls could be considered too long an interval, given the nature of the Baltic Sea and its fisheries, making it difficult to properly assess fishing activities. In this period a vessel can haul its nets, steam some distance and commence fishing again, creating a confusing pattern of headings and distances between consecutive pings at apparent fishing speeds. The simplest, yet most significant modification which could be made to ensure the utility of this tool to managers would be to increase the polling frequency of VMS on vessels fishing in the Baltic Sea to a time interval relevant to the size of the cells being considered and the average speed of vessels fishing in this area. This lies beyond the scope of methodological changes which can be made within the project, and would rely on action by fishery administrators, through their national monitoring centres.

## Reviewer 3

**Note:** Many of my comments are based on ideas developed and discussed during the ICES “Workshop on guidance on how pressure maps of fishing intensity contribute to an assessment of the state of seafloor habitats (WKFB1)” (outlined in the final WKFB1 report (ICES, 2016)) as well as feedback received on this ICES report by reviewers (see Box 1 below: Review of the ICES WKFB1 Report 2016). I would recommend that these two documents be considered by the authors of the BalticBOOST Fisheries Impact Evaluation Tool (FIT) to support reflection and future refinement of their WP3.2 tool.

## Assessment of question 1: Have appropriate scientific methodologies been applied in developing the BalticBOOST WP3.2 tool?

The Fisheries Impact Evaluation Tool developed by the BalticBOOST project comprises several methodological steps, which are reviewed in turn below.

**A general comment:** When explaining how methodologies have been created and applied, it is essential to be clear and consistent in the use of terminology. The clarity of the “FIT” document was somewhat undermined by variable use of key terms such as “pressure”, “trawling”, “sediment”, and “seafloor integrity”, and it was sometimes unclear whether terms were used with a full understanding of what they might imply. A glossary of terms would therefore be a particularly useful addition to the final report (see for example the glossary in ICES, 2016).

### I. Method to evaluate fishing pressure

- More clarity would be welcome on the decision to use raw VMS vs. aggregated VMS data. Were they two “parallel” sources of data (as indicated in the text) or alternative sources of data? If the coverage of the ICES WGSFD country-aggregated VMS data is “good”, it would be helpful to understand why BalticBOOST decided not to use them, and instead used VMS data from the 3 main (but not exclusive?) countries that fish in the western Baltic.
- The authors explain that “the swept area ratio is calculated for surface and subsurface abrasion separately”. It would be worth indicating that the subsurface abrasion layer implicitly includes surface abrasion (but not the other way around).
- The authors refer to assigning fishing gear types to a “bottom trawling” category, based on their physical characteristics. A more generic term for this category, such as “mobile demersal fishing”, would avoid confusion between “trawls” as one gear type and all towed gear types that cause physical abrasion.
- The methods section would benefit from a breakdown of how the authors assigned fishing gear types to the two pressure categories (a simple table for example), as well as how the surface and subsurface abrasion categories themselves were defined. These definitions are only briefly presented in the results section (Figure 3). In Figure 3, surface abrasion (called “sediment abrasion” here) is defined as < 2 cm, whilst subsurface abrasion as > 2 cm. This approach is not entirely consistent with surface/subsurface definitions in similar methods under development (such as the Benthic Habitats Indicator 3 (BH3) under OSPAR) where surface abrasion is not considered to imply any penetration of the substratum. Regardless of which definitions are ultimately used, it would be worth cautioning that the actual depth of abrasion depends not only on the gear category but also on the inherent hardness/softness of substratum type in question (i.e. gravel vs. mud).
- The proposed methodology is based on the assumption that mobile demersal fishing has a “uniform distribution within grid cells”. Although this assumption is understandable and pragmatic from a methodological point of view, it does not always reflect reality. Explaining the consequences of this assumption in relation to the final impact assessment would be helpful.

### II. Method to identify presence and sensitivity of benthic habitats

- There is little information given about the source of habitat maps used in the BalticBOOST project, or their associated confidence limits. A reference in Figure 1 to the source of habitat maps should be added at the very least (presumably EUSeaMap?).
- A decision was made to undertake the “FIT” analysis at EUNIS level 3. This could be in part because at this level in the EUNIS classification, full coverage maps of Europe’s seafloor are available. Explaining the consequences of this decision in terms of the robustness of the final “Seafloor Integrity Index” would improve the transparency of the report. EUNIS level 3 units are broadscale habitats categorized by biological zone (depth), substratum type, and energy. Biological information (i.e. community composition) is not available at EUNIS level 3. However, the sensitivity of seafloor habitats is largely determined by their associated species/assemblage (Tyler-Walters *et al.*, 2001; Tillin and Tyler-Walters, 2014; La Rivière *et al.*, 2016).
- Following on from the previous point: biogenic habitats (created by benthic species) can be particularly sensitive to physical pressures associated with mobile demersal gears. Given the ecological significance of these biogenic habitats,



their omission from this study (in terms of the potential for underestimating impact) should be more clearly explained and justified.

### III. Method to evaluate the impact of fishing pressure on benthic habitats

- The authors use a BENTHIS longevity approach to assess the likely impact of abrasion on seafloor habitats. The advantages and disadvantages of this type of quantitative/continuous mechanistic approach (as opposed to an expert-driven categorical approach) have been documented in detail by ICES (2016) and by the reviewers of the ICES WKFB Report 2016. The BENTHIS approach in particular has been critiqued in both ICES reports (see Box 1 below).
- Using the “reference longevity composition” of North Sea habitats in a Baltic Sea assessment raises questions about the scientific legitimacy of transposing biological information from one biogeographic region to another, and these limitations are acknowledged by the authors at the end of the report. As already outlined, EUNIS level 3 habitats (ex. “Sublittoral coarse sediment (A5.1)”) comprise many different sub-habitats with different community composition (both within and between biogeographic regions). This different community composition will affect the “reference longevity composition” values (see also comments on biogenic habitats above).
- According to Figure 2, the North Sea habitats “reference longevity composition” appears to cover only 3 EUNIS soft substratum types (citing Rijnsdorp *et al.*, 2016). It is unclear how this information was then “converted” to the 4 substratum types of the BalticBOOST study (i.e. Sublittoral coarse sediment (A5.1), Sublittoral sand (A5.2), Sublittoral mud (A5.3), and Sublittoral mixed sediments (A5.4)).
- Hard substratum types do not seem to be covered by the BalticBOOST Seafloor Integrity estimates, although they are presented in Figure 5 (“Footprint” per EUNIS habitat). The authors acknowledge that “the analysis of footprints per habitat and gear type demonstrated that otter trawling takes place extensively in all habitat types.” A short explanation as to how and why EUNIS level 3 hard substratum types were excluded from the final SBI map (Figure 6) would help the reader/policy-maker better understand the limitations of the final maps.

### Assessment of question 2: Can the outputs of BalticBOOST WP3.2 be used as a management tool to assess fisheries impacts on the seafloor in the Baltic Sea?

The BalticBOOST Fisheries Impact Evaluation Tool and its associated outputs represent a useful starting point for discussion on managing fisheries impacts in the Baltic Sea, especially in the context of the Marine Strategy Framework Directive.

However, caution should be used in applying the outputs in their current form, particularly without a clear breakdown of caveats and confidence limits associated with the different data layers. The authors themselves acknowledge these limitations and describe the index values and maps as “preliminary”.

Specific comments on some of the outputs of the BalticBOOST WP3.2 (taken from the “Results” section) are provided below:

- Figure 3 refers to maps of “all bottom contacting gears” but does not include static gears in contact with the seafloor (pots/traps, etc.). The term “mobile demersal gears” would be more appropriate based on the methodology as described.
- Figure 4 shows “seafloor impact at the surface level”, but the gear groups listed are typically associated with both surface and subsurface abrasion. Could this be clarified?
- In the text of the “Results” section, reference is made to the “area/cells trawled” or the “trawling footprint”. As previously mentioned, this could cause confusion amongst managers as trawling is just one gear type considered in the “mobile demersal gear” category.
- The notion of Seafloor Integrity could benefit from more explanation both in the Methods and Results section, in order for managers to understand the meaning (and relevance) of sentences such as “Seafloor integrity estimated at the subsurface level revealed that most grid cells either have a low (<0.18) or a high (>0.82) integrity”. This explanation would also help them interpret the possible management consequences of Figure 6.
- Figure 6 presents a somewhat binary picture of the impact of trawling and, as the authors explain, corresponds quite closely to maps of subsurface trawling intensities (Figure 3 – map on the left). The extensive areas in blue in Figure 6 correspond to an SBI value of “0.83 – 1” (1 meaning “no taxa impacted”). From a policy-maker/manager’s perspective this

map could be interpreted as indicating that a large proportion of the western Baltic is not significantly impacted by mobile demersal fishing (where it occurs).

- The idea of presenting data from Bastardie *et al.* (2016) in Figure 7 is interesting, and complementary to maps of benthic impact. This type of information could be useful to take into account in a management context (see “Assessment of question 3” below).

**Assessment of question 3: Which modifications, if any, are required in the future to ensure that the developed tool can be used for management purposes?**

Firstly, certain methodological aspects could be re-examined before the BalticBOOST WP3.2 tool is used in a decision-making context (see also responses to Question 1). Specifically:

- The possibility of further improvement of the BENTHIS approach or equivalent (see reviews in ICES, 2016 and Box 1 of this review), and particularly the relevance of using North Sea BENTHIS “reference longevity composition” data within a Baltic study/tool.
- The issue of broadscale habitat categories (EUNIS level 3) “masking” the habitat complexity (and thus sensitivity/likelihood of impact) across the western Baltic. The “EUNIS/full-detail habitat map classification” on the EMODnet Seabed Habitats interactive mapping portal (<http://www.emodnet-seabedhabitats.eu/>) gives an indication of habitat variation in the western Baltic at several levels of the EUNIS classification. Ideally, habitat variation within each EUNIS level 3 unit (hard and soft substratum) should be taken into account in evaluations of seafloor integrity or vulnerability. This is particularly important for biogenic habitat management (and recovery). This modification would also bring the “FIT” tool closer to one of the original objectives of WP3.2, which is to develop a tool that takes into account “biotopes, biotope complexes, and habitats in the Baltic Sea (HELCOM BSEP 139).”

Secondly, the report could be improved by including a short discussion on the historical effects of (demersal) fishing, and the risk of “shifting baselines” in the evaluation of benthic habitat impacts. As explained in ICES (2016), “bottom trawling has been an ongoing activity for more than 100 years and consequently persistent effects on benthic communities need to be expected. This means that sensitive species could have been replaced by opportunistic and less sensitive species over time.” Managers and policy-makers need to be aware of the legacy of these past effects, particularly when setting objectives for the good environmental status (GES) of benthic habitats that takes the recovery of certain (biogenic) habitats into account.

Finally, the authors could consider elaborating on how the fine spatial distribution of fish catches shown in Figure 7 is intended to be used in the context of the BalticBOOST “FIT” tool. Is the objective (as suggested in the introduction) to inform a type of “Cost-Benefit Analysis” where socio-economic benefits of fisheries in terms of revenues from catches (of different fleets/fisheries) are compared to socio-economic impacts of fisheries on benthic habitats? This would be a useful development, as it could potentially help managers to make judgements on the most ecologically and economically “efficient” fisheries management measures. (However, the economic evaluation of the goods and services provided by benthic habitats [and how different levels of pressure compromise the provision of these goods and services] is still somewhat in its infancy). Or is the objective of including Figure 7 more focused on the potential for establishing levels of fishing in the Baltic that are in line with definitions of GES for both Descriptor 3 (namely the concept of maximum sustainable yield [MSY]) and Descriptor 6 (as suggested in the conclusion, and by Figure 8)? These two objectives are not incompatible of course, but it would be interesting to understand the authors’ intention.

**BOX 1: Review of ICES WKFBI REPORT 2016**

Review group: Jan Geert Hiddink (chair), Jake Rice, Drew Lohrer, Andy Kenny  
June 2016

“The BENTHIS longevity approach implicitly assumes that a trawl pass kills 100% of adult organisms, and therefore gives a worst-case assessment of the state of the seafloor. Because of this, it is important that the acknowledgment that this is very much a worst-case assessment is not lost when communicating this. It should not be difficult to adapt the approach to take account of the instant mortality caused by a trawl being  $< 100\%$ , by evaluation where the [inverse of the trawling frequency  $\times$  fraction instant mortality]  $>$  longevity. Moreover, if instant trawl mortality is  $< 100\%$ , there will likely be a faster rate of recovery, as not all individuals will be forced to “reset” back to year 0 again. Meta-community dynamics (which are acknowledged as being potentially important on page 69) also have the potential to affect recovery rates. That is, if there is high variability in fishing pressure in adjacent grid cells, the lesser disturbed areas may contribute larval propagules to the more disturbed areas. This increases complexity into the modelling, but some simple ways of incorporating this concept could be trialled. Although the BENTHIS longevity approach may be a worst-case assessment, the BENTHIS population dynamics approach may be overly optimistic. The colour scales on the GIS maps (even for quantitative analyses, e.g. figures 7.3 and 7.5) can make a very big difference to the appearance of the maps, especially considering that the colour interval classes are not uniform in size. The BENTHIS population dynamics approach does not differentiate among the various species in the community; it suggests that “community biomass can be used as a proxy for the state of the seafloor (Seafloor Integrity SI)”. In reality, however, biomass (similar to total abundance and richness) likely reaches pre-disturbance levels well before true recovery occurs. High seafloor integrity is dependent upon having mixtures of young and adult organisms and at least a few large, long-lived, functionally important species; this would take longer than simple biomass recovery, and so using biomass recovery as the proxy would not protect many of the most functionally important species. Biomass is probably a good proxy for the functioning of the ecosystem, but not necessarily for the size or longevity distribution of biodiversity. When using this approach to assess SI it therefore has to be highlighted that it works as an indicator for particular aspects of integrity, but not others. The BENTHIS 1 approach needs a justification for choosing the 80 and 90% of benthic biomass as the target or at least the management benchmark. Alternatively, it could perhaps calibrate relative to biomass of fish when all fish stocks are being exploited at just below  $F_{MSY}$  relative to virgin biomass?”

**Sources and references**

ICES. 2016. Report of the Workshop on guidance on how pressure maps of fishing intensity contribute to an assessment of the state of seabed habitats (WKFBI), 31 May–1 June 2016, ICES HQ, Copenhagen, Denmark. ICES CM 2016/ACOM:46. 109 pp. [http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2016/WKFBI/01\\_WKFBI%20Report%202016.pdf](http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2016/WKFBI/01_WKFBI%20Report%202016.pdf).

La Rivière, M., Aish, A., Gauthier, O., Grall, J., Guérin, L., Janson, A-L., Labrune, C., Thibaut, T., and Thiébaud, E. 2016. Assessing benthic habitats' sensitivity to human pressures: a methodological framework – Summary report. Rapport SPN 2016-87. MNHN. Paris. 42 pp.

Tillin, H. M., and Tyler-Walters, H. 2014. Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 1 Report: Rationale and proposed ecological groupings for Level 5 biotopes against which sensitivity assessments would be best undertaken. JNCC Report No. 512A. Joint Nature Conservation Committee, Peterborough. 68 pp.

Tyler-Walters, H., Hiscock, K., Lear, D. B., and Jackson, A. 2001. Identifying species and ecosystem sensitivities. Report to the Department for Environment, Food and Rural Affairs from the Marine Life Information Network (MarLIN). Contract CW0826. Marine Biological Association of the UK. Plymouth, [Final Report]. 98 pp.

## **Annex 1**

Draft 28 October 2016 of “BalticBOOST Fisheries Impact Evaluation Tool (FIT) with Application to Assess the Bottom Fishing Footprint in Western Baltic Sea (ICES Subdivisions 22–24)”.

# BalticBOOST Fisheries Impact Evaluation Tool (FIT) with Application to Assess the Bottom Fishing Footprint in Western Baltic Sea (ICES Subdivisions 22-24)

## Introduction

Fishing is one of the dominant anthropogenic activities affecting marine ecosystems (Halpern *et al.*, 2008) and there is global concern about adverse effects of particularly bottom trawls on seabed habitats and the structure and functioning of benthic ecosystems (Dayton *et al.*, 1995; Watling and Norse, 1998; Jennings and Kaiser, 1998). We introduce here a workflow for relating the fishing pressure issued from the different fishing activities to the response of some of the affected components (fish stocks, benthic habitats) in order to address the needs for an evaluation tool of how fishing impacts the marine ecosystem. As a matter of proof, the objective of the below analysis is to study the footprint of fishing with mobile bottom-contacting gears in the Western Baltic Sea during 2010–2012 and compare it across habitat areas. Bottom fishing distribution and intensity (calculated as swept area in a grid cell divided by surface area of a grid cell) is analyzed at a resolution of 1×1 minute longitude and latitude for different EUNIS habitat types and main gear groups, distinguishing between surface and subsurface footprints. Furthermore, an indicator of seabed integrity is estimated at the same grid cell resolution. The characterized fishing pressure is further coupled to information on fish and shellfish landings in order to make explicit the trade-off between impacts and the revenue made out of the sales from the impacting fisheries. This coupling should support end-users and practitioners further by incorporating the first steps of an economic dimension of the concerned fishing practices. This tool can ultimately apply to any area as soon as the required area-specific data are available. Subcomponents of the tool are also to be informed and downscaled to particular areas supported by specific cases studies.

## Methods

### Methods – swept area intensity or swept area ratio

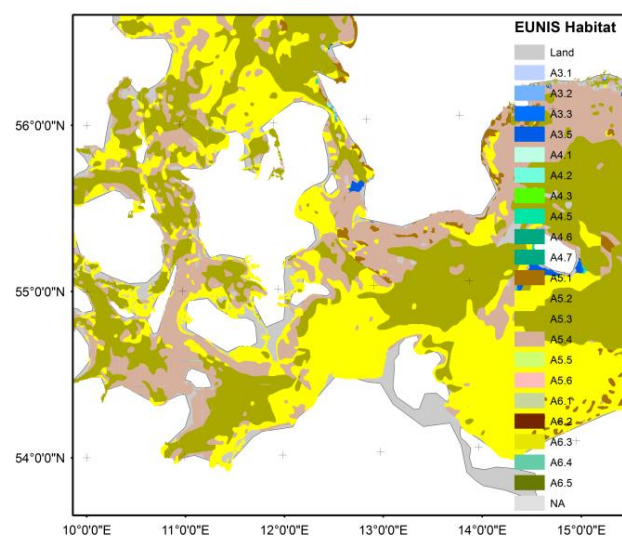
Two parallel sources of data are set up depending on whether the raw or aggregated VMS data are used (see diagram further below) while the workflow from aggregated VMS data is an approximation of the one starting from the raw VMS data. Working on data issued by a data call from ICES, ICES WGSFD is generating aggregated swept area ratio (SAR) on a c-square grid from the individual country aggregated VMS data. The coverage obtained by the ICES data call is good given most of the European countries submitted data to ICES (ICES WGSFD 2016). Alternatively, in the present application, raw VMS data were available and extracted 2010-2012 VMS data from Denmark, Sweden and Germany, the three main active countries in the western Baltic, were coupled to logbook data also based on methodology developed by Bastardie *et al.* (2010) and Hintzen *et al.* (2012). Individual logbook observations for bottom trawling were assigned to different functional gear groups (métiers) based on target species and gear type information (Eigaard *et al.*, 2016a). Relationships between gear dimensions and vessel size (e.g. trawl door spread and vessel power) for each métier (Eigaard *et al.*, 2016a) were used to assign the swept-width of gear to each logbook trip. In addition to the total width of the gear used to estimate the surface impact, the subsurface impact was estimated based on information on the dimensions of the gear components that penetrate into the seabed (Eigaard *et al.*, 2016a). The extended logbook data were combined with interpolated vessel tracks from VMS data (Hintzen *et al.*, 2010). In this way the total seabed area swept by a given vessel and fishing gear

over the three-year period could be estimated taking into account the gear footprint of the métiers. The total area swept annually was estimated within grid cells of 1x1 minute longitude and latitude, which corresponds to approx. 1.9 km<sup>2</sup> at 56°N with cell size gradually increasing or decreasing the further south or north it is located. The annual intensity was then calculated by dividing the total area trawled in each grid cell with the size of the grid cell. The swept area ratio is calculated for surface and subsurface abrasion separately.

### Methods – trawling footprints

A western Baltic “Trawling Footprint” was estimated as an indicator of benthic fishing pressure in the area (Eigaard *et al.* 2016b). This indicator shows the extent of fishing with mobile bottom-contacting gears, and reflects the proportion of the total seabed area (management area or habitat type) that is trawled annually during the period of analysis. Under the assumption of uniform distribution within grid cells the extent of bottom trawled was calculated in two ways: (i) percentage of the grid cells of a management area or habitat type (after standardization for differences in grid cell size) where any quantity of trawling has been recorded irrespective of its intensity; (ii) area of the seabed trawled at least once a year. This first metric (i) includes the untrawled parts of grid cells where trawling intensity was less than once a year. The second metric (ii) was calculated as the sum of the surface area of the fully trawled grid cells (trawled  $\geq 1$  year<sup>-1</sup>) plus the sum of the swept areas of partially trawled grid cells (trawled less than once a year). The first footprint calculation (i) acknowledges that the data used (2010–2012) only covers a relatively short time-step. If a longer time step would be considered the untrawled parts of the grid cells would be increasingly likely to be trawled.

The Trawling Footprint was estimated by both methods described above as proportions of the different EUNIS habitat type areas (Level 3) in the Western Baltic (Figure 1) where fishing with mobile bottom contacting gear occurs. The footprints were estimated separately by gear type (Bottom otter trawl; Seine; Dredge).



**Figure 1.** Distribution of EUNIS habitats (level 3) in the w. Baltic Sea.

## Methods – Seabed integrity

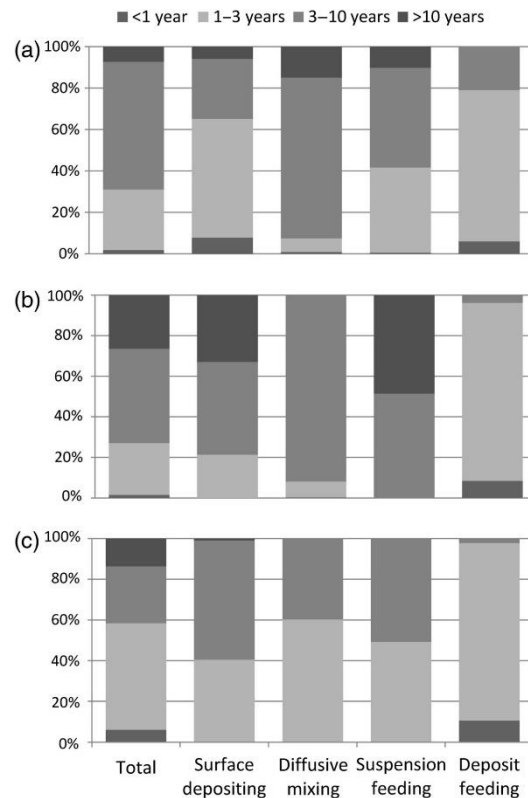
The integrity of the seabed was estimated for the Western Baltic using the longevity approach developed in BENTHIS WP2 (Eigaard *et al.* 2016b). The seabed integrity index (SBI) was estimated for grid cells of 1×1 min. longitude and latitude by combining the annual intensity estimates with the longevity composition of the biomass from a reference (untrawled) area. The main principle of the approach is that if the reciprocal of the trawling intensity, which reflects the average time interval between two successive trawling events, is less than the life span of an organism, the integrity of the seabed habitat to provide a place to live for the organism may be compromised (Rijnsdorp *et al.*, 2016). Because the reference longevity composition of the different habitat types in the Western Baltic is not yet established, the assumption was made that the only established reference longevity composition so far, from the North Sea (Eigaard *et al.* 2016b after Rijnsdorp *et al.* 2014; Table xx; North Sea parameter estimates defined for EUNIS level 3 A5.1, A5.2, A5.3, and A5.4), also applies for all the habitat types in the Baltic Sea. This is of course a substantial simplification and consequently the index values and maps should be considered preliminary. Even so the SBI approach was applied for the purpose of demonstrating methodology and output type:

$$SBI = \exp(\alpha + \beta \left(\ln \frac{1}{t}\right)) / (1 + \exp(\alpha + \beta \left(\ln \frac{1}{t}\right)))$$

With  $t$  is the trawling intensity and  $\alpha$  and  $\beta$  are the coefficients of the logistic regression of the cumulative biomass (specific to each habitat; e.g. Figure 2) against log of the life span of the taxa, with the estimates given in Table 1.

*Table 1: Alpha and beta parameter estimates obtained from Rijnsdorp et al (2016) to deduce the seabed index (SBI) from habitat specific biomass longevity distributions (as described in Eigaard et al. 2016).*

EUNIS Level3	$\alpha$	$\beta$
A5.1	4.77415	2.64516
A5.2	-7.6857	4.424618
A5.3	5.72813	4.151049
A5.4	4.11021	2.801233



**Figure 2.** The proportion of biomass of longevity classes (<1, 1–3, 3–10, and >10 years) of the infaunal community (total) and two types of bioturbators (surface depositing, diffusive mixing) and two feeding types (suspension feeding, deposit feeding) in three habitat types: (a) A5.1, Sublittoral coarse sediment; (b) A5.2, Sublittoral sand; (c) A5.3, Sublittoral mud. From A. D. Rijnsdorp et al. ICES J. Mar. Sci. 2016;73:i127-i138

### Methods – Origin of landings

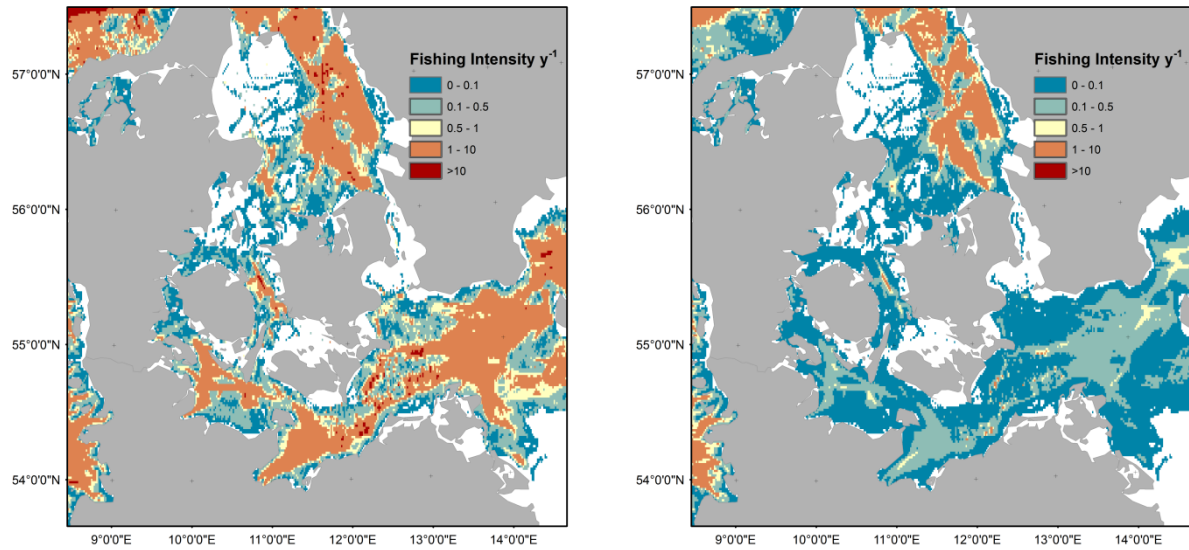
Within the tool, the spatial distribution of the retained catches (landings) declared in fishermen's logbooks was obtained following the methodology developed in Hintzen et al 2012, introducing VMStools (an R package) for processing the VMS data and couple them to logbooks declaration in a most standard way. VMStools is applied here and embedded in the present fisheries impact assessment tool to assign a piece of the landings in kg per trip per ICES rectangle per fishing day evenly to the discrete positions (on the same trip, rectangle and day) detected as fishing events by the analysis of the individual VMS tracks. Alternatively, at a coarser scale, the international landings collected at the ICES rectangle level by EU STECF can dispatch over the VMS fishing positions, with some limiting assumptions.

### Results

Fishing with mobile bottom-contacting gears is widely distributed with high intensities over the Western Baltic and Kattegat (Figure 3, left). The entire eastern half of Kattegat has a high fishing pressure level with annual intensities between 1 and 10, but also substantial areas of the Arkona Basin, north and south of Bornholm and the most south-western part of the Baltic (Kiel and Mecklenburg Bay) has annual intensities above 1. A few localized hotspots in these high-pressure areas have annual intensities above 10. Disregarding the western Kattegat and the inner Danish waters most of the area shown has intensities

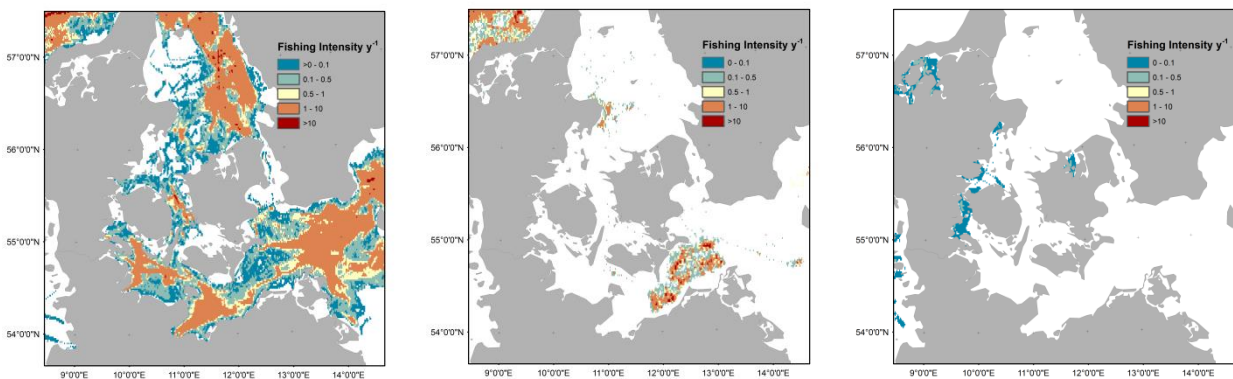


above 1. When estimating the subsurface intensity the same picture of pressure distribution emerges, but with the intensities scaled substantially down (only the areas in Kattegat with intensities above 1 and otherwise the high-pressure areas experience annual intensities from 0.1 to 1) (Figure 3, right).



**Figure 3.** Annual average fishing intensity (2010-2012) at the surface level (left; sediment abrasion < 2 cm) and subsurface level (right; abrasion ≥ 2 cm) for all bottom contacting gears from Denmark, Sweden and Germany.

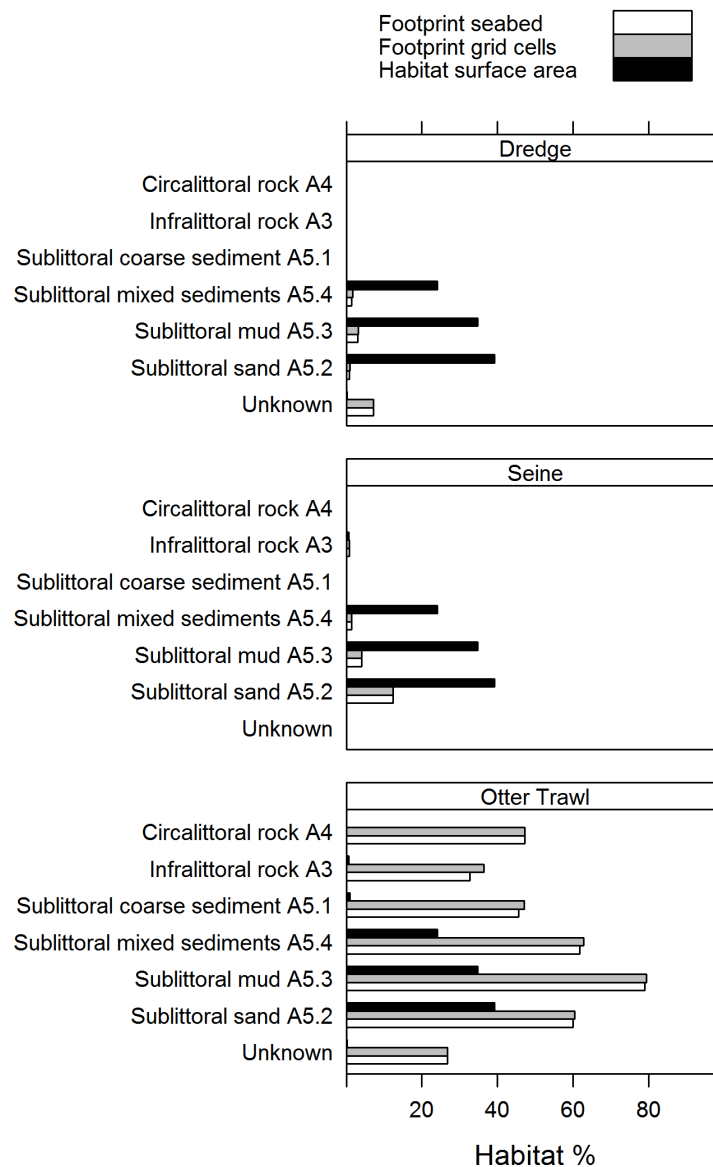
When separating the fishing pressure by gear type, it becomes clear that otter trawling is the main gear in the area (Figure 4, left). Demersal seining takes place nearly exclusively in the Arkona Basin, the south-eastern part of Mecklenburg Bight and a small part of western Kattegat (Figure 4, middle), whereas dredging is restricted to Danish fjords, straits and coastal areas (Figure 4, right)



**Figure 4.** Annual average fishing intensity (2010-2012) with seabed impact at the surface level by main gear groups. Left: Otter Trawl, middle: Demersal Seine, right: Dredge.

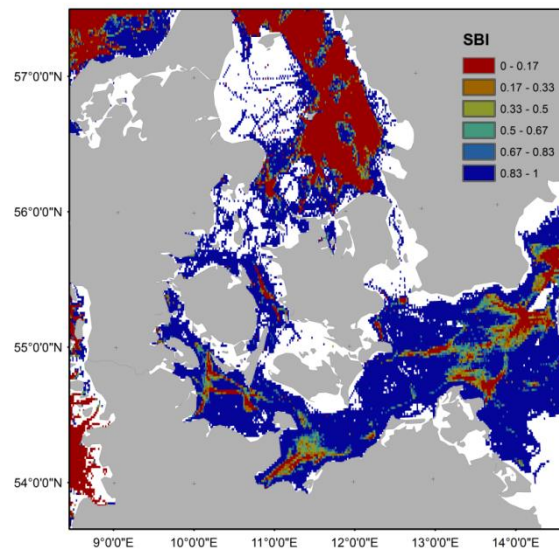
Figure 5 shows the footprints estimated by metric i (the percentage of all the grid cells trawled, irrespective of intensity) and metric ii (area of the seabed trawled at least once a year) alongside the relative surface area of the habitat type. The analysis shows that otter trawling takes place extensively in all habitat types and that the proportion of grid cells trawled ranges between 40% and 80%, also for the hard substrates

(circa- and infralittoral rock). Dredging and seining only takes place on sublittoral sand (A5.2), sublittoral mud (A5.3) and sublittoral mixed sediments (A5.4), with a clear preference for sand for the seiners. Both these fishing gears have much smaller footprints compared to otter trawling (less than 15% across all habitat types). For all gears and habitats metric i and metric ii provide almost identical estimates.



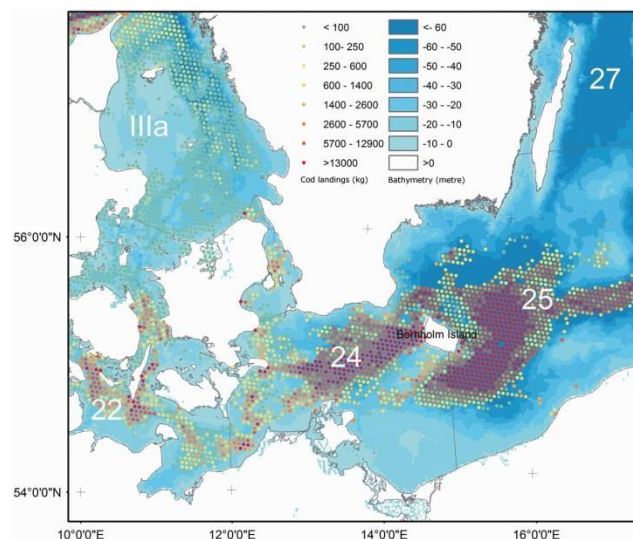
**Figure 5.** Footprint per EUNIS habitat within SD 22-24 and per fishing activity (Dredge, Seine, Otter Trawl) from Danish, Swedish and German fleets. The trawling footprint is estimated by metric i (the percentage of all the grid cells trawled, irrespective of intensity, grey bars) and metric ii (area of the seabed trawled at least once a year, white bars) and plotted alongside the relative surface area of each habitat type in the studied area (black bars).

Seabed integrity estimated at the subsurface level revealed that most grid cells either have a low (<0.18) or a high (>0.82) integrity (Figure 6). More intermediate values are only observed in smaller areas north of Bornholm, in the Arkona Basin and in the Kiel and Mecklenburg Bays.



**Figure 6.** Seabed integrity Index (SBI) values corresponding to the subsurface trawling intensities (after Rijnsdorp et al, 2016, and Eigaard et al.2016, accepted) For the seabed integrity indicator, 0=all taxa impacted and 1=no taxa impacted). The white areas show grid cells that were untrawled.

The importance of coupling the spatial occurrences of fishing to the logbook declaration was illustrated by characterizing the cod spatial origin of the (retained) catches within the Baltic Sea made by a subset of the Danish fishers (Figure 7, from Bastardie et al. 2016). Using recent development in the analysis of fisheries data, in particular VMStools presented in Hintzen et al. (2012), we show that the fine spatial distribution of the catches can be obtained by different type of gears. This is at a much lower geographical scale that it was available so far (at best, the ICES rectangle) which creates useful new information on various fisheries spatial impact-related aspects.



**Figure 7.** The Central Baltic Sea region with ICES area codings and bathymetry (in blue levels) are shown together with the spatial origin of the 2012 cod landings in kg (red levels circles). Source: Bastardie et al. 2016.

## Discussion

The maps of trawling intensity show a somewhat different picture for Kattegat and the Western Baltic area. In Kattegat approximately half the area (western part) is untrawled or trawled at low intensities, whereas practically all the eastern half is trawled at intensities above 10. This apparent either-or level of fishing pressure most likely reflects that Nephrops trawling is the dominant fishery in Kattegat and that this species is very abundant throughout the deeper soft-sediment parts (eastern half of Kattegat) but not present at all in the shallower areas (western half).

In contrast, the western Baltic area has a more heterogeneous distribution pattern of fishing pressure with intensive bottom trawling in localized areas, and medium to low-intensity trawling elsewhere. It is likely that this heterogeneity in the western Baltic reflects certain morphological features, such as gradients in bathymetry, changes in bottom type or the occurrence of un-trawlable grounds. A second mechanism generating trawling hotspots and heterogeneity is related to the patchiness in the distribution patterns of the target fish and their prey (Rijnsdorp *et al.*, 2011; Ellis *et al.*, 2014). Cod is the dominating target species in the Western Baltic and this species can be expected to be patchier in distribution than the Nephrops in Kattegat.

The difference in the dominating target species of the two areas is also reflected in the subsurface trawling intensity map, where it is clearly reflected that the gear-footprint of a Nephrops trawl in Kattegat has a substantially higher proportion of subsurface impact than the gear-footprint of a cod trawl in the Western Baltic (Eigaard *et al.*, 2016a).

The analysis of footprints per habitat and gear type demonstrated that otter trawling takes place extensively in all habitat types. The broad diversity of habitats trawled, ranging from muddy or sandy sediments, via coarse and mixed sediments to rock and other hard substrata, is related to the wide range of bottom trawls and technology that has evolved over time and allowed fishers to move into formerly untrawlable habitats (Valdemarsen, 2001; Rijnsdorp *et al.*, 2008; Eigaard *et al.*, 2014). In contrast, demersal seining in the area has a clear preference for sandy habitats, reflecting this gear type's poorer ability to fish on rougher bottom (Eigaard *et al.*, 2016a).

For all gears and habitats metric (i) and metric (ii) provided almost identical footprint estimates, reflecting that only a small part of the grid cells are fished at annual intensities less than 1. This means that the Western Baltic bottom trawl fishery is very conservative in nature when it comes to choice of fishing grounds and tends to fish the same grid cells across years (keeping in mind of course that the analysis only covers the period from 2010-2012 and VMS obligation was extended from 2012 onwards to also cover vessels larger than 12 meter).

In general the seabed integrity of grid cells was either high ( $>0.82$ ) or low ( $<0.18$ ). Areas with intermediate seabed integrity were sparse (Figure 5). This dichotomy relates to the trawling intensity profile and the longevity distribution of the benthic community. High seabed integrity will be restricted to grid cells with a trawling intensity of less than  $0.1 \text{ year}^{-1}$ , because taxa with a life span of  $>10$  years comprise  $< 18\%$  of the biomass of the benthic community. It is only a narrow range of intensity ( $0.1\text{--}0.5 \text{ year}^{-1}$ ) for which SBI takes middling/moderate values. Most cells have either high or low trawling intensity and so the SBI is either high ( $>0.82$ ) or low ( $<0.18$ ), respectively.

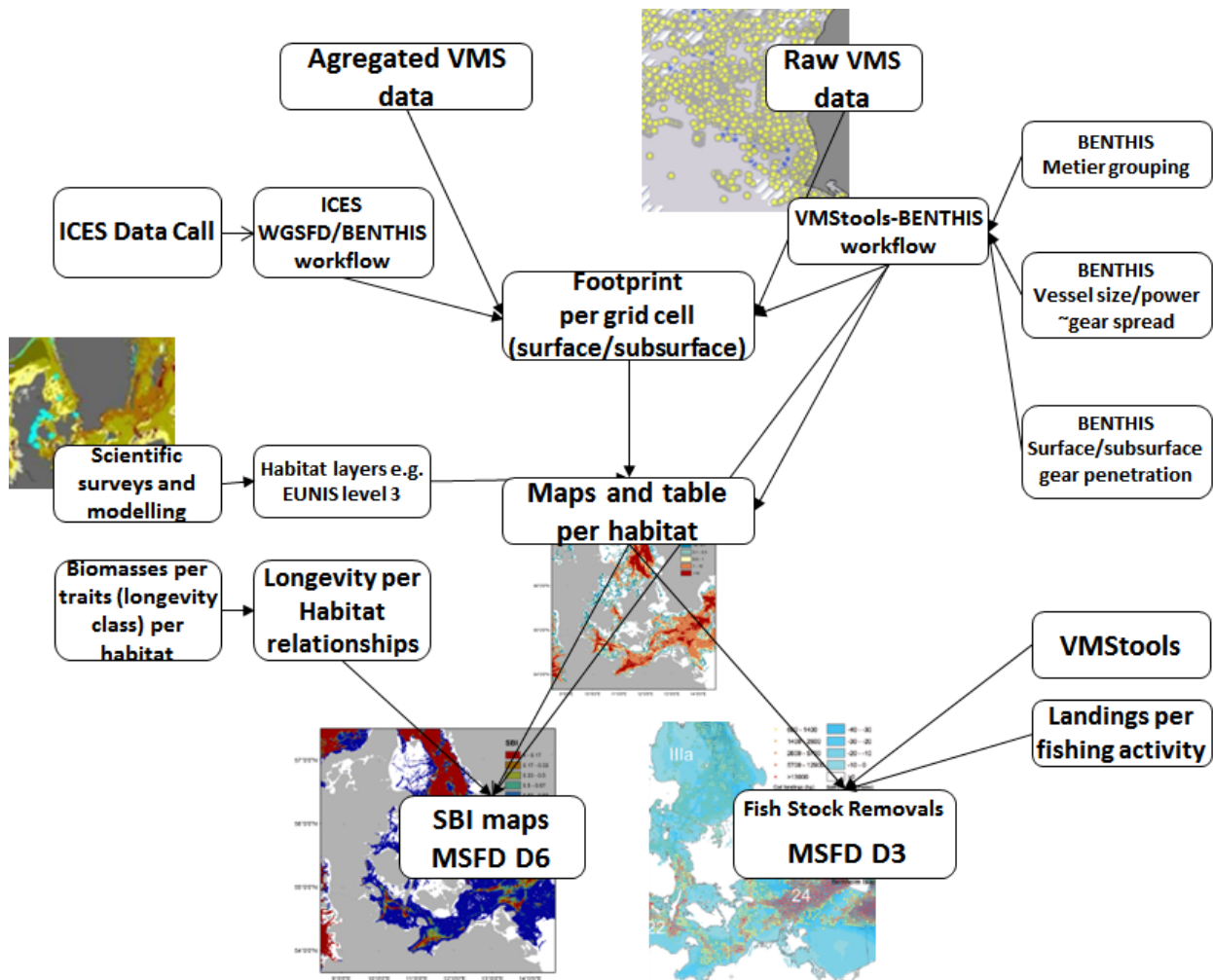
*It should, however, be highlighted that the seabed integrity estimated in this paper should be considered as a first attempt. Due to a lack of benthic community information, the same longevity distribution (extrapolated from soft-sediment habitats in the North Sea) was applied to all habitat types in the western Baltic and Kattegat. It is very likely that the longevity distribution of the benthic community will differ across*

*habitats*. Hence, the extrapolated critical trawling intensity from the North Sea ( $0.1 \text{ year}^{-1}$ ) will not be appropriate for e.g. biogenic habitats, which are characterized by taxa with much longer life spans (Clark *et al.*, 2016). On the other hand, in habitats exposed to high natural variations, taxa with relatively short life spans may dominate more. Hence, the critical trawling intensity may be refined when information on the longevity distribution of the benthic community becomes available for different habitat types in the Baltic. Also the use of trawling intensities with subsurface impact for estimating seabed integrity (based on the North Sea soft-sediment community) may alternate with the use of surface intensities (e.g. in habitats dominated by emergent fauna) according to improved information of habitat types and community composition.

### **The 'FisheriesImpactTool' (FIT) Software**

FisheriesImpactTool is the tool delivering this assessment and has been developed by the WP3.2 BalticBOOST project based on the experience acquired during EU-FP7 BENTHIS and ICES Working Group on Spatial Fisheries Data (WGSFD 2015). FIT answers requests about the need for guidance on how pressure maps of fishing intensity contribute to an assessment of the state of seabed habitats. FIT is first used for mapping the fishing surface and subsurface pressure on both the habitats and the fish communities. The 'BENTHIS longevity approach' is further deployed by FIT to relate, in a mechanistic quantitative approach, the pressure to meaningful biological response and ecological impact indicators as described during the joint ICES WKFBI workshop (ICES, 2016)/BalticBOOST Workshop held in Copenhagen in late June 2016. In this approach, the longevity is the habitat-specific key species attribute (biological trait) used as a proxy for defining the sensitivity of the habitats and benthic communities under pressure. Information on longevity produces the index of seabed impact (SBI) when crossed with the information on the fishing pressure (Rijnsdorp *et al.* 2016).

The tool workflow (see diagram, Figure 8) is designed to answer the question about how much pressure of fishing with mobile bottom-contacting gears affects the benthic habitats and communities (MSFD Descriptor 6) and the commercially-important fish and shellfish exploited in the area (in line with MSFD Descriptor 3) by quantifying the spatial distribution of the fishing pressure and removals of fish from the fisheries. The tool itself is a set of R routines hosted by a specific github repository online (<https://github.com/frabas/FisheriesImpactTool>), and which further offers a way to track the versions of the tool when amended (the github platform is an online service for versioning control system).



**Figure 8.** Conceptual diagram of the Fisheries Impact Tool hosted at <https://github.com/frabas/FisheriesImpactTool>

## References

- Bastardie, F., Nielsen, J. R., Ulrich, C., Egekvist, J., and Degel, H. 2010. Detailed mapping of fishing effort and landings by coupling fishing logbooks with satellite-recorded vessel geo-location. *Fisheries Research*, 106: 41–53
- Bastardie, F., Nielsen, J.R., Eero, M., Fuga, F. Rindorf, A. 2016. Effects of changes in stock productivity and mixing on sustainable fishing and economic viability. *ICES Journal of Marine Science*, in press, 10.1093/icesjms/fsw083

- Clark, M., Althaus, F., Schlacher, T., Williams, A., Bowden, D., and Rowden, A. 2016. The impacts of deep-sea fisheries on benthic communities: a review. *ICES Journal of Marine Science*, 73(Suppl. 1): i51–i69.
- Dayton, P. K., Thrush, S. F., Agardy, M. T., and Hofman, R. J. 1995. Environmental-Effects of Marine Fishing. *Aquatic Conservation-Marine and Freshwater Ecosystems*, 5: 205–232.
- Eigaard, O. R., Marchal, P., Gislason, H., and Rijnsdorp, A. D. 2014. Technological Development and Fisheries Management. *Reviews in Fisheries Science & Aquaculture*, 22: 156–174.
- Eigaard, O., Bastardie, F., Breen, M., Dinesen, G., Hintzen, N., Laffargue, P., Nielsen, J., *et al.* 2016a. Estimating seabed pressure from demersal trawls, seines, and dredges based on gear design and dimensions. *ICES Journal of Marine Science*, 73 (Supplement 1): i27–i43.  
doi:10.1093/icesjms/fsv099
- Eigaard O.R., Bastardie F., Hintzen N., Buhl-Mortensen L., Buhl-Mortensen P., Catarino R., Dinesen G.E., *et al.*, 2016b. Benthic impact of fisheries in European waters: the distribution and intensity of bottom trawling. *ICES Journal of Marine Science*, in press.
- Ellis, N., Pantus, F., and Pitcher, C. R. 2014. Scaling up experimental trawl impact results to fishery management scales — a modelling approach for a “hot time”. *Canadian Journal of Fisheries and Aquatic Sciences*, 71: 733–746.
- Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., *et al.* 2008. A global map of human impact on marine ecosystems. *Science*, 319: 948–952.
- Hintzen, N. T., Piet, G. J., and Brunel, T. 2010. Improved estimation of trawling tracks using cubic Hermite spline interpolation of position registration data. *Fish.s Research*, 101: 108–115.
- Hintzen, N. T., Bastardie, F., Beare, D., Piet, G. J., Ulrich, C., Deporte, N., Egekvist, J., *et al.* 2012. VMStools: Open-source software for the processing, analysis and visualization of fisheries logbook and VMS data. *Fisheries Research*, 115–116: 31–43.
- Horwood, J. 1993. The Bristol Channel Sole (*Solea solea* (L)) - a Fisheries Case-Study. *Advances in Marine Biology*, 29: 215–367.

- ICES. 2016. Report of the Workshop on guidance on how pressure maps of fishing intensity contribute to an assessment of the state seabed habitats (WKFB1), 31 May 31 May –1 June 2016, ICES Headquarters, Copenhagen, Denmark. ICES CM2016/ACOM:46.108pp
- Jennings, S., and Kaiser, M. J. 1998. The effects of fishing on marine ecosystems. *Advances in Marine Biology*, 34: 201–352.
- Rijnsdorp, A. D., Poos, J. J., Quirijns, F. J., HilleRisLambers, R., de Wilde, J. W., and Den Heijer, W. M. 2008. The arms race between fishers. *Journal of Sea Research*, 60: 126–138.
- Rijnsdorp, A. D., Poos, J.J., and Quirijns, F.J. 2011. Spatial dimension and exploitation dynamics of local fishing grounds by fishers targeting several flatfish species. *Canadian Journal of Fisheries & Aquatic Sciences*, 68: 1064–1076 .
- Rijnsdorp, A. D., Bastardie, F., Bolam, S. G., Buhl-Mortensen L., Eigaard O.R., Hamon K.G., Hiddink, J.G., *et al.* 2016. Towards a framework for the quantitative assessment of trawling impacts on the seabed and benthic ecosystem. *ICES Journal of Marine Science* (2016), 73(Supplement 1), i127–i138. doi:10.1093/icesjms/fsv207
- Valdemarsen, J. W. 2001. Technological trends in capture fisheries. *Ocean & Coastal Management*, 44: 635–651.
- Watling, L., and Norse, E. A. 1998. Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting. *Conservation Biology*, 12: 1180–1197.