WORKSHOP ON TRADEOFFS SCENARIOS BETWEEN THE IMPACT ON SEAFLOOR HABITATS AND PROVISIONS OF CATCH/VALUE (WKTRADE2)

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i Executive summary

The second Workshop on Tradeoffs Scenarios between the Impact on Seafloor Habitats and Provisions of catch/value (WKTRADE2) was established to provide input on trade-offs aspects to the Working group on Fisheries Benthic Impact and Trade-offs (WGFBIT). As such, the workshop was tasked to: 1) demonstrate the applicability of a set of approaches to better estimate fisheries revenue; 2) establish ways to assess effort reduction scenarios; and 3) explore how to (better) incorporate social factors associated with fisheries.

The workshop suggests that to improve estimates of the "value" of an area to fisheries that the contribution margin (income from landings minus variable costs) should be calculated. To do this two complementary approaches (disaggregation and mechanistic) are presented and can be developed using the current ICES VMS and logbook data, supplemented with economic data layers. A modular workflow to integrate the variables into the assessment is also presented.

Furthermore, the workshop found that redistribution of total revenue among individual fishers and fishers' communities will need to be considered to accurately predict displacement effects and impact evaluation on fisheries economics. Applying predictive modelling techniques adds to assessing a static picture (current fishing activity) because it considers displacement effects which may elucidate increased pressure on essential fish habitats, sensitive vulnerable habitats, or previously untrawled areas.

To better identify trade-offs between ecological, economic and social factors for use by the ICES working group WGFBIT, the workshop recommends also using integrative approaches (e.g. bioeconomic models, stakeholder engagement) that account for direct linkages between fish, fisheries and benthos dynamics to address issues related to MSFD, CFP and spatial management plans in a consistent way. When considering the effects of displacement the contribution margin should be accounted for as the fishing closures are likely to have indirect (positive or negative) effects. For example, protecting part of the fish stocks might lead to better catch rates and therefore fuel savings, etc. The workshop also found static models to be operational and more easily used to identify impacted fishing fleets. While, dynamic modelling approaches allow for the adaptation of fishing fleets (e.g. displacement, gear modifications), potentially mitigating the estimated impact of spatial and temporal restrictions. Static approaches are easy to use in stakeholder processes, and can facilitate stakeholder engagement. Future development of static and dynamic models will need to account for the influence of other activities (e.g. closures due to wind farm) on fisheries activities. Running scenarios using dynamic models will indicate which areas are most valuable to fisheries after spatial management scenarios are proposed. This elicits the socio-economic valuable fisheries areas.

The workshop's focus was on the spatial management scenarios so far identified by the working group WGFBIT, but the suggested workflow can also be used to address other scenarios, e.g. technical measures aimed at reducing gear penetration depths, disturbance effects and improving selectivity, habitat credits approaches that define credits related to the sensitivity of habitat and convey credits to the fishing industry to manage either collectively or individually.

The workshop also identified some follow-up work that working group WGFBIT could take on to both to improve the current scenario testing on spatial restrictions, as well as how to deal with fleet adaptation/effort displacement in reaction to the spatial restrictions. This work would benefit by stronger links to ICES working groups WGECON and WGSOCIAL to ensure the required fisheries economic expertise.

ii Expert group information

Expert group name	Workshop on Tradeoffs Scenarios between the Impact on Seafloor Habitats and Provisions of catch/value (WKTRADE2)
Expert group cycle	workshop
Year cycle started	2019
Reporting year in cycle	N/A
Chair(s)	Francois Bastardie, Denmark
	Jochen Depestele, Belgium
Meeting venue(s) and dates	4-6 September 2019, Copenhagen, Denmark (24 participants)

1 Introduction

Indicators of impacts from human activities on benthic habitats (including bottom trawling) are being developed and operationalised to assess the achievement of Good Environmental Status within the EU Marine Strategy Framework Directive (MSFD); (Descriptor 1 on maintaining the biodiversity, Descriptor 6 on seafloor integrity). These assessments support the policy making of the EU Directorate General Environment (DGENV) with science-based evidence. The Common Fisheries Policy (CFP) under the auspice of EU Maritime Affairs & Fisheries (DG MARE) regulates fishing activities at the European level. From the fishing viewpoint, there is an apparent trade-off between the conservation of the seafloor integrity (MSFD D6) and the exploitation of the marine (fish and shellfish) resources. The trade-off warrants documenting to ensure the sustainability of both the marine habitat being fished and the gains from fisheries. Considerable efforts to demonstrate these trade-offs have already been undertaken in a series of workshops in 2017: WKBENTH (28 February–3 March 2017); WKSTAKE and WKTRADE (28–31 March 2017).

Documenting the trade-off is becoming increasingly feasible given the progress made from acquiring new data that inform i) where fishing is taking place and at which intensity (e.g. WGSFD maps of fishing intensity across EU waters from the VMS data call); and ii) where sensitive marine habitats are located. The impact of the fishing pressure upon marine habitats is estimated from both the improved fishing pressures maps and the documented sensitivity of the marine habitats (WKBENTH). To assess the trade-off between fishing impacts and the value of these areas to fisheries, an assessment is needed to show which areas are most productive for each fishery and which areas are least productive but have high costs in terms of environmental impact. To inform such a trade-off on the fisheries side, previous workshops assessed landings value in space, but did not attempt to incorporate fisheries economics beyond the landings values (WKTRADE 2017).

The ICES workshops continued under the umbrella of the Working Group on Fisheries Benthic Impact and Trade-offs (WGFBIT). The ICES 2017 indicators and assessment framework (e.g. MSFD, D6) was the basis to further develop methods to evaluate benthic impact from fisheries at regional scale, while considering fisheries and seabed impact trade-offs. The assessment framework consists of three main components: fishing pressure (footprint), benthic habitat sensitivity and the resulting benthic impact. WGFBIT focused on how to best illustrate the potential of the assessment method under development. This was done by implementing a theoretical 10% reduction in fishing intensity in four ways (10% overall reduction of effort, 10% reduction by metier, by habitat type and by EEZ), and illustrated the different effects (changes in footprint, effort, landings and economic value of landings) between the implementations (see Table below). These differences highlight the potential of the current method to compare not only high-level management measures, but also various implementation strategies.

WGFBIT scenarios are by construction likely to lead to a better status in areas where the effort is being reduced, and leading to revenue loss in the fisheries from the cut in fishing opportunities imposed by the scenarios. The WGBIT trade-off analysis may be improved by including a socio-economic assessment. Instead of a reduction, fishing effort may in real world applications not be cut but be redirected to other areas. On the biological side, this will likely change the currently overly optimistic net gain on seafloor status expected from a fishing effort reduction. Ways to avoid such shortcomings should be considered. On the economic side, the displacement of fishing effort will likely exacerbate technical interactions among fisheries. This is because among others, fish movement, seasonal patterns, mutually exclusive gears, and regulations make the fish stocks differently available and accessible in time and space to different types of fishing, also constrained by how mobile the fishing vessels are.

Table extracted from WGFBIT 2018 report: Results of trade-off calculations for four different implementation scenarios of effort reduction (10% overall reduction, 10% reduction by metier, by habitat type and by EEZ). The colour scale indicates effect size relative to case 1, with red indicating a lower value and green a higher value.

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

We therefore devised WKTRADE2 as a discussion and development platform to list relevant variables describing the basic social and economic parameters of fisheries (cost and benefits) to refine the trade-off analysis. WKTRADE2 investigates ways for disaggregating these economic parameters to appropriate scales, from regional to métier/fleet-segment scale, up to a very high spatial resolution (c-squares). Hence, the group developed and provided examples on how to calculate economic value in fine spatial scale for WGFBIT to consider along proposing spatial restriction scenarios. WKTRADE2 is also documenting to which extent using sophisticated spatial dynamic and fleet adaptation modelling approaches could change the final assessment compared to the current simple static approach in testing scenarios.

The remit of WKTRADE2 was to assess possible ways to improve the current WGFBIT assessments by including social and economic parameters as well as accounting for redistribution effects of fisheries. The group of WKTRADE2 fisheries economists collected expertise in the best way possible to account for fleet reaction/effort displacement first by listing relevant social and economic variables and existing approaches that could help anticipating displacement effects when implementing (area-based) management measures. Based on the data availability of the listed variables the group suggested two complementary approaches: a disaggregation approach and a mechanistic approach. Several data and model improvements are suggested (including a workflow to feed into WGFBIT assessment) to supplement the current VMS and Logbook data call with additional economic data layers to develop approaches to calculate the "value" of an area to fisheries.

WKTRADE2 has, as such, simplified the initial trade-offs question by not searching for an estimate of the true economic value of an area, but rather looking into the actual costs and benefits of an area to fishers. True economic value would require an estimation of long-term productivity to provision fisheries with harvests as well as costs and benefits to the society at large. Future directions could point at ways of estimating such an intrinsic (economic) value from e.g. value per unit of standardized effort to a composite index such as an ocean productivity index. Assessing the true economic value of an area was, however, beyond the scope of WKTRADE2. Instead, the group investigated i) practical ways for describing the actual economic and social costs and benefits to fishers and for elucidating what could be the expected profit of areas to fishers, i.e. the contribution margin defined as the income from expected landings minus the variable costs.

A modular workflow was prepared by François Bastardie and further complemented by the group. The workflow consists of a list of variables (Annex 4) that can easily be expanded or collapsed. WKTRADE2 suggests that it is sufficient to estimate the contribution margin (income from landings minus variable operating costs) per fleet-segment to assess the economic value of an area to fisheries (therefore neglecting fixed costs e.g. insurance, loan etc.). Contribution margin was also seen as the minimum set of information required to anticipate fleet adaptation or effort displacement as a response to spatial restrictions. WKTRADE2 focused on the development of variables that allow for the calculation of the contribution margin to fulfil the request by WGFBIT.

The group identified that variable operating costs could be deduced by screening the existing economic data gathered in EU by the Scientific, Technical and Economic Committee for Fisheries (STECF). Because STECF economic data are economically sensitive and collected with a lag of two years, the data could not easily be shared and used in the WKTRADE2 context to retrieve recent spatial cost layers per fleet-segment. The group identified a recent disaggregation tool developed by the SECFISH project. The SECFISH tool could be used to retrieve a spatial disaggregation of costs from the STECF aggregated data. The group identified inconsistencies between the ICES VMS data segmentation and the STECF transversal economic data segment, which prevented to pursue the exercise to the end and to the required fine-scale spatial resolution. The group recommends to complement the ICES VMS data call with a consistent fleet-segmentation.

Alternatively to the disaggregation approach and because the latter required additional information not available to the group, discussed developing a mechanistic approach that would implement ad hoc computation from proxies of spatial cost layers for the scenario testing needs. For example, it is to some extent possible to anticipate an expected profit for fleet-segments on locations from using catch rates and fish prices obtained with the ICES VMS-logbooks data with approximations of the operating costs required for visiting these particular zones. Such approximate computations were discussed during the workshop (e.g. R routine in Annex), but require further development as well as validation with real-life data before being used in practice.

WKTRADE2 investigated using integrative approaches to release assumptions underlying static approaches. Integrative models account for direct linkages and long-term interactions between fish, fisheries and benthos dynamics. The group gives a SWOT analysis of the existing approaches to illustrate the pros & cons contrasting the simple static and the more complicated but resource demanding deployment of bio-economic models. Models with an intermediate levels of complexity are provided by statistical models to predict the fleet adaptation/effort displacement from historical data without being in position of predicting long-term trends and effects. WKTRADE2 used a concrete example to illustrate the differences between simple static rules and more sophisticated dynamic approaches in estimating the effects on the fisheries economics and the underlying relative benthic status. WKTRADE2 discussed that applying the static approach only may result in overestimating the effect of the area-based management, and for example ignoring win-win situations if fleets can adapt/displace to/from the changes.

In order to inform the simple or more sophisticated modelling approaches, WKTRADE2 expressed the common needs for using methods framed to elicit the preference of fishers in choosing where to fish (e.g., questionnaire surveys, statistical random utility models, etc.). These preferences would complement the WKTRADE2 approaches by providing weighting factors for drivers that could explain the change in fishing effort allocation over areas and seasons.

The group also stressed that a better identification of trade-offs between ecological, economic and social factors in WGFBIT, would also result from using integrative approaches (e.g. bio-economic models, stakeholder engagement) that account for direct linkages and long-term interactions between fish, fisheries and benthos dynamics to address issues related to MSFD, CFP and spatial management plans in a consistent way. WKTRADE2 also stresses that internal trade-off optimization in the scientific modelling should not attempt expressing ecological, economic and social values in a common currency, but should be tasked to present these values as transparent as possible to all stakeholder to facilitate a transparent decision-making process.

WKTRADE2 has progressed the identification of knowledge gaps required to complement the scenario-testing made by WGFBIT with social and economic factors. WKTRADE2 requests WGFBIT to account for the findings, and to consider lifting them into the next WGFBIT assessment, e.g. by integrating the proposed WKTRADE2 workflow to contrast WGFBIT fishing pressure reduction scenarios with more realistic options. It is however uncertain how the shortage in economic data identified by the group can be fixed in the short term. In this perspective, the ICES VMS data call (linked to WGSFD) could be revised for augmenting the collected dataset with a consistent fleet-segmentation, also checking why inconsistencies, revealed by our preliminary analyses, exist in landing values per area between ICES and STECF data. On the longer run, WKTRADE2 shows that comparison of approaches vote in favour of identifying practical ways for using more sophisticated spatial bio-economic models directly into WGFBIT, these models being capable of testing spatial fishing restrictions by accounting for fleet adaptation/effort displacement and drivers in individual fisher decision-making in a meaningful way. On the biological side, spatial bio-economic models have also the potential to go further than WKFBIT equilibrium assessment (assuming constant fishing effort allocation, constant catch rates etc.). Conditioning the models with the exact same parameters (depletion per type of gears, recovery per type of benthos group etc.) such models can project forward how FBIT relative benthos status will change depending on likely alternative for fleet adaptation/displacement of the fisheries.

Ecosystem effects of such a fishing pressure displacement also remains to be accounted for while these feedbacks have not been studied here. Hence, on the long run going beyond the simple static approach would require to identifying some practical ways to embed the existing more sophisticated models (bioeconomic, spatial and ecosystem) into the final assessment.

The scope of the WKTRADE2 analyses was restricted to the effect of spatial fisheries restrictions to align with the currently tested scenarios in WGFBIT, but we acknowledge and stimulate that also other ways of improving benthic status should be explored, such as the implementation of a habitat credits system or non-area based management measures like technical innovations to reduce physical contact with the seabed.

2 Data available for WKTRADE2

- Aggregated VMS-Logbooks produced by ICES WGSFD after treating data submitted by EU individual member states issued from VMS data call. VMS data from vessels, coupled with logbook data on fishing activities from 2009 to 2018 of fleets in the ICES area. ICES is mandated to request VMS and logbook information to provide its advice. This mandate is supported by international agreements and the current EU data collection framework (DCF). Submitted data to ICES are reported anonymised and aggregated in a grid of concise spatial query and representation system of 0.05 x 0.05 degree grid using the approach of C-square reference. The final aggregation per fleet-segment per c-square has been made available to WKTRADE2.

- STECF Effort, Landings and Transversal Economic data are publically available on the STECF website (https://stecf.jrc.ec.europa.eu/data-dissemination). Landings and effort data are obtained through the STECF FDI data call and the economic data through the STECF AER data call, both issued to the EU member states to submit their national statistics which are being processed, quality checked and aggregated by STECF. WKTRADE2 in its analyses used the outcomes of the STECF processing being statistics aggregated per fleet segment. The group notes that the FDI new database is a bit different to the FDI classic, which had been developed to access effort management regimes, while FDI new is trying to collate all effort, landings and biological data collected into one single database. The ongoing issue is the quality of information provided by the EU member states and there might be several different levels of information available for public that still need to be decided by STECF. STECF has recently discussed possible structure of the public tables in 2018, however in the end, data quality did has not allowed to publish the dataset yet (FDI report is available online: https://stecf.jrc.ec.europa.eu/reports/fdi).

3 Defining social and economic parameters of fishing fleets relevant to fine-scale spatial assessments (ToR a, ToR d)

Lead ToR a, ToR d: Katell Hamon

ToR a: Describe the practical steps that should be considered to (better) determine the economic costs and benefits associated with bottom fishing (fisheries revenue) at fine spatial scale (preferably at the c-square resolution: 0.05° x 0.05°); (Science Plan codes: 6.6, 6.4, 3.5)

ToR d: Explore how to (better) incorporate social factors associated with fisheries, given the different management scenarios (e.g. redistribution effects on fishing harbor communities); (Science Plan codes: 7.6, 7.1)

3.1 Introduction to the approach

The group chose from start to treat ToR a) and ToR d) jointly, given the degree of overlap and to avoid diluting the WK participants into two different groups.

At start, the group stresses that the aim of supplementing the WGFBIT tool with inclusion of social and economic factors beyond simple fishing effort metrics into trade-off analysis should not interfere with any political agenda. Political trade-offs will need to be made between ecological, economic and social factors. The ranking or prioritization of ecological, economic and social values is not a scientific process. Therefore, scientists should not attempt to express all three in a common currency (e.g., monetary value) or implement an internal trade-off optimization in the scientific modelling. The scientific task is to present the different values separately as clear as possible for a decision-making process that is transparent to all stakeholders.

However, the group recognizes that the seabed fauna and habitats support commercial fish-stock by being food, shelter and nursery areas (Colloca *et al.* 2015, Eggleton *et al.* 2018, Kritzer *et al.* 2016). Bottom trawling has the capacity to affect benthic communities (Sköld *et al.* 2018). Degrading such areas could have a negative impact on the fish stock and hence on the ecosystem service back to the fishing economy (van Denderen *et al.* 2013). If the fishing fleet moves to another area, other benthic communities can be depleted and this will add on to a negative loop. Beside this, an area with mudflats holding small opportunistic species living inside the sediment are more robust toward bottom trawling compared to an area with a coral reef. In order to maintain the sea floor integrity of a defined area, human activities need to be accounted for by balancing the trade-offs between sea floor integrity, economic and social importance of the human activities affecting the sea floor. Environmental (such as Good Environmental Status referred in EU MSFD), economic and social objectives must be balanced. To do so, the group believes that dynamics of the seafloor fauna (impact vs. recovery) and the fishing fleets must be integrated in a common analytic framework accounting for the feedback existing between the two.

First, the group investigated to which extent existing ICES initiatives on socio-economics may contribute to the FBIT framework (ICES WGSOCIAL and WGECON). Second, a section was dedicated to use of economic parameters within the FBIT framework. Third, an example was provided on how social factors can be accounted for in an FBIT framework, and why it is important to assess social factors spatially. The last chapter of this group focused on the drivers of differences in social and/or economic factors across areas, and how these drivers can be elucidated through stakeholder engagement workshops, analytical assessments of historical location choices and constraining factors in location choices, like other human activities.

3.2 Including human dimension

WGSOCIAL and WGECON are two new ICES working groups that have been initiated from the ICES Strategic Initiative on Human Dimensions (SIHD) and their first meetings took place in 2018. The main objective of both working groups is to provide indicators (social and economic) that can be used in future ICES advisory work. As such, they have a direct relevance to the 3-generation ecosystem overviews ICES plans to produce and the ICES fisheries overviews. The overarching idea being that trade-off analysis not only requires insight in ecological processes but also in social and economic dynamics.

As both working groups are only in their second year they only produced an annual evaluation report for the work done in 2019. WKTRADE2 used these evaluation reports to identify what WGSOCIAL and WGECON can offer to FBIT with respect to social and economic data.

3.2.1 ICES WGSOCIAL

WGSOCIAL can link with FBIT on two dimensions. The first one is on the definition of indicators, the second one on the inclusion of behavioral response of fishers to change. The definition of indicators is necessary and in the trade-off analysis, to account for the social dimension, relevant concepts need to be measured with appropriate indicators. WGSOCIAL has been working on listing the important concepts and producing those indicators (ToR B: "*To identify and report on culturally relevant social indicators and community data gaps that point to priorities for data collection, research, institutional needs, and training in all ICES member countries; and where possible propose systems to collect missing data*"). WKTRADE2 suggests that the FBIT framework could be used as a case study to measure these concepts. Presentations were given during WGSOCIAL on the social and cultural significance of commercial fisheries (WGSOCIAL ToR D: "*To assess and report on the social and cultural significance of commercial fishing for selected coastal regions in the ICES area*".) in the following regions: Wadden Sea (NL), Galicia (Spain), Azores (Portugal), Portugal, Sweden and the USA. In some regions quantitative social indicators will be developed (Spain, Portugal, USA), which can serve as input into the FBIT framework.

WGSOCIAL initiated a process on increased attention for social indicators in policy (DGMARE) and data collection (STECF and JRC). WGSOCIAL identified available social data and discussed options for a data call, to fill data gaps. WGSOCIAL has focused upon the existing 3rd generation Ecosystem Overviews of ICES with respect to a better inclusion of the human dimension. WKTRADE2 suggests including social factors which are of spatial importance. One of the examples could be that WGSOCIAL helps to improve the link between areas at sea and fishing harbors. WKTRADE2 expects that the spatial action radius of a fishing vessel is dependent on its type and size (as a proxy for storage capacity). To enable assessment of the spatial importance of areas at sea for a particular harbor, this information would need to be available. WKTRADE2 also assumes that identifying other links between the suggested improvements of ecosystem overviews by WGSOCIAL and possible social indicators which can be useful in processes like in the FBIT framework falls below ToR C of WGSOCIAL: "*To define and report on the information flow needed to provide trade-off analysis of fishing impacts on communities and stakeholder groups*".

Understanding fishers behavior has been identified as a field of work that should be included in WGSOCIAL (in their ToR A). It is one of the 'identified future needs for social science in ICES'. The scenarios proposed by FBIT will be affected by fishers behavior, WKTRADE2 suggests that linkages between WGSOCIAL and the FBIT framework are established in order to identify how fishers behavior can/will change in the scenarios.

WGSOCIAL have established a working relationship with WGECON as part of WGSOCIAL ToR E ("*To coordinate the provision of culturally relevant social indicators, and analysis with economic and ecological information*"). Both groups wish to work together. WGSOCIAL have made a list of which WGSOCIAL members are also member of other WG's at ICES and as such can serve as a link. WKTRADE2 requests both WGs to consider linkages to the FBIT framework, and identify how future collaboration may serve the advisory process now or in the future.

3.2.2 ICES WGECON

WGECON focuses on economics and how to improve the uptake of economic dimension in ICES work. While WGECON has already identified links with a number of ICES working groups as part of their ToR A ("*To map the current work and identify future needs for economic science in ICES, giving consideration to useful connections to international marine/ fisheries economics organisations such as IIFET, NAAFE and EAFE*"), such as WGSOCIAL, WGMRES, WKTRADE, WGMIXFISH and IEA groups, as well as the groups in charge of the Ecosystem Overviews, WKTRADE2 asks to explicitly include the links to the WGFBIT framework.

ICES covers European countries falling under the EU data collection framework (EU MAP) for which data collection standards have been developed, and data is publicly available on STECF website. But ICES also involves countries outside the EU and WGECON identified data availability and data gaps in relation to key issues relevant to ICES in their ToR B: "*To identify and report on economic data gaps that point to priorities for longer-term data collection, research, institutional needs, and researcher training in all ICES member countries; and where possible propose systems to collect missing data.*". A synthesis is being written up to be included in an overview manuscript. WKTRADE2 requests to consider the requirements to use the data spatially which are addressed elsewhere in this report. Spatially-resolved economic data are also required to analyze how displacement can be influence by economic parameters. An assessment of displacement and its drivers is being considered in the ICES WGSFD group. WKTRADE2 suggests to improve the linkages between WGSFD, WGECON and WGFBIT in relation to economic drivers of displacement (See report Section 3.5.3).

Similarly to ToR C of WGSOCIAL, WGECON aims to include economic perspective in trade off analysis in their ToR C "*To define and report on the information flow needed to provide trade-off analysis of fishing impacts and ecosystem services*". WGECON started work on this ToR in this year's meeting, and considered that it should be reformulated to more adequately describe the type of trade-off analysis, which will be considered. Based on this revised definition, the group has started developing a description of the information flow, which is required for trade-off analyses. WKTRADE2 requests to consider the FBIT framework as a potential case study to address the lack of fisheries economic expertise in the FBIT framework.

WGECON ToR D "*To assess and report on the economic significance of commercial fishing for selected coastal regions in the ICES area.*" WGECON had an initial discussion of this ToR in this year's meeting, and considered existing economic assessments across ICES, including the EU STECF work, NOAA's fisheries reporting system, and other initiatives such as the approach developed by SEAFISH in the UK, and the OECD's project to develop a regional impacts assessment approach. WKTRADE2 suggests linking this WGECON ToR to the initiative of WGSOCIAL to better define ports and to consider how this analysis may be used within the FBIT framework.

3.3 Economic data

In Europe, various fisheries economic indicators are collected and tracked over years in EU database such as STECF databases producing the Annual Economic Report (AER) every year. These indicators are the income from landings (landed volume per species times the market price), various cost posts (variables such as crew or energy costs and fixed costs), the gross value added (GVA), the net profit, and so on. WKTRADE2 discussed what would be the best economic indicator to answer the request on fisheries economic value of areas including benefits and costs. Three options were put forward: net profit, GVA and contribution margin. Net profit of a fishing firm is measured as the firm's revenue (landings value) less operating and capital costs. Operating costs include variable (crew share, fuel, ice and provisions, repair, running landings costs etc.) and fixed costs (maintenance, insurance, administration etc.). Capital costs include interest payments and depreciation. Gross Value added of a fishing firm is measured as the firm's net profit less crew share and capital costs, i.e. the surplus left of the operation to pay the crew and cover payments on loans and general depreciation. The contribution margin of a fishing firm is measured as the firm's revenue less variable operational cost. Thus, where net profit and gross value added both represents the result after deducting fixed operational costs, the contribution margin represents the economic surplus of the direct fishing operations. There are two issues with the use of fixed costs for spatial indicators, i) the first one is how to allocate fixed costs to the different activities, and ii) the second is the relevance of doing it. It might be possible to define some rules to allocate fixed costs to various areas but if the aim is to understand the economic difference between area choices, fixed costs do not contribute to this difference. Given that the aim of WKTRADE2 is to get a spatially explicit view of the economic importance of fishing operations, to be able to access the result of closing areas/reallocating effort, fixed costs are not relevant, and therefore contribution margin is the preferred indicator of the economic importance of activities. It also should be noted that data available in the STECF database are collected at the vessel level (not the firm) which is an adequate level to look at short-term dynamics.

The measure of contribution margin requires the operating variable costs to be disaggregated at the area level. Table 3.3.1 list an overview of selected variables for which data availability and feasibility to disaggregate them spatially with respect to the FBIT framework was assessed. How to obtain these costs at the right disaggregation level is the topic of WKTRADE2 ToR b) and an illustration is given in the corresponding report section. Briefly, as part of the SECFISH project, an attempt was made to disaggregate some variable costs from the fleet level (as defined by the DCMAP) down to fleet/metier level. Following the definition of the variable costs in the EU data collection framework, the following categories are included: fuel costs, crew costs, repair costs and other variable costs. Figure 3.3.1 presents the structure of the variable costs for a number of European fleets. Because of their relative importance, the fuel and crew costs have been included for further investigation in ToR b).

The fuel costs appear to be dominant in the variable cost and can be deduced from the combination of fuel consumption and fuel prices. The fuel consumption is function of the size of the vessel, the engine power, the distance travelled and the gear towed. To approximate those factors one could investigate Fuel ~ Effort relationships. Relationships for other variable costs should also be investigated.

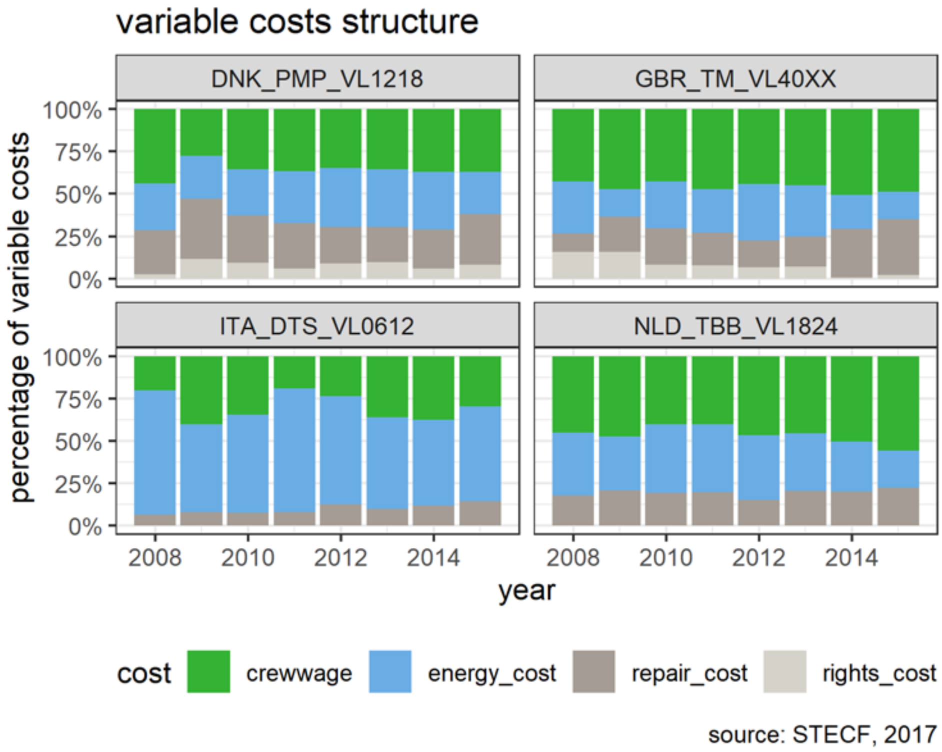


Figure 3.3.1. Costs structure of EU fleets operating with different vessel sizes using a diversity of gears: Danish polyvalent mixed passive vessels of 12–18m (DNK_PMP_VL12_18), British pelagic trawlers larger than 40m (GBR_TM_VL40XX), Italian demersal trawlers and seiners 6 to 12m (ITA_DTS_VL0612) and Dutch beam trawlers 18 to 24m (NLD_TBB_VL1824).

Table 3.3.1. Summary table listing selected variables, data availability and the feasibility to disaggregate the data spatially to inform the WGFBIT fishing benthic impact tool (FBIT). AER refers to the EU STECF Annual Economic Report database. BENTHIS metier is an aggregation per fleet-segment level intermediate between the EU data collection framework (DCF) Level 6 fleet-segmentation and the coarser 'Fishing Technique' aggregation used in AER.

Variable	**Availability (confidential / open access)**	**Data resolution**	**Can be (dis-)aggregated to FBIT resolution (how?)**			**Relevance (High / Medium / Low)**	**Case studies**	**Notes**
			c-square	BENTHIS metier	Year			
Landings value	National Logbook data (confidential), Landing value per c-square in the VMS data call, Landing value in AER (also see section xx highligting inconsistencies between VMS call and AER data)	Species Vessel Trip ICES square	Yes (using VMS data)	Yes	Yes	High		
Fuel costs	National accounting data, or AER	Fleet segment Annual	Partly (e.g., SECFISH tool applied on AER at present not at c-square spatial resolution), therefore an alternative disaggregation procedure given in Annex	Yes (e.g., SECFISH tool)	Yes	High		Vessel and trip disaggregated data available nationally at vessel level (confidential) but only for representative samples. Fleet segment aggregated AER data available publically
Fuel consumption	Ad hoc project based data	Vessel Trip	Yes (using VMS data)	yes	Yes	High	e.g. Bastardie *et al.* 2013	

Labour (crew) costs	National accounting data, or AER	Fleet segment Annual	Partly (e.g., SECFISH tool applied on AER at present not at c-square spatial resolution), therefore an alternative disaggregation procedure given in Annex	Yes (e.g., SECFISH tool)	Yes	High		Vessel and trip disaggregated data available nationally at vessel level (confidential) but only for representative samples. Fleet segment aggregated AER data available publically
Biological parameters	ICES WGFBIT ICES WGVME ICES WGIBAR	Benthos sampling	Yes including extrapolation	Not relevant	Yes/no	high	North Sea Baltic Sea Barents Sea	
Human activities	Multiple open-access data portals (EMODnet; MEDIN, BGS, OGA)	Installation License	Yes (proportion occupied)	Not relevant	Yes	Medium	North Sea (in prep. WGSFD) and other regions (in WKBEDPRESS)	See WKBEDPRESS
Oceanographic parameters			Yes including extrapolation	Not relevant	Yes/no	Medium	North Sea (in prep. WGSFD) and other regions (in WKBEDPRESS)	
Managed areas	Conservation areas/EU fisheries closures open access Member state specific closures (nationally held)	individual closure	Yes (proportion occupied)	Not relevant	Yes	Medium	North Sea (in prep. WGSFD) and other regions (in WKBEDPRESS)	

3.4 Why allocating social factors spatially is important?

The group discussed the need to spatially link fishing activity (fleet segments/metiers) and activity changes to fishing ports/communities, as the social effects of changes are likely to be felt at the port/ community level (Figure 3.4.1). The group also discussed another important social factor, being the dependence of communities on fishing activity. The latter factor requires input from nations, and cannot be answered by ICES alone.

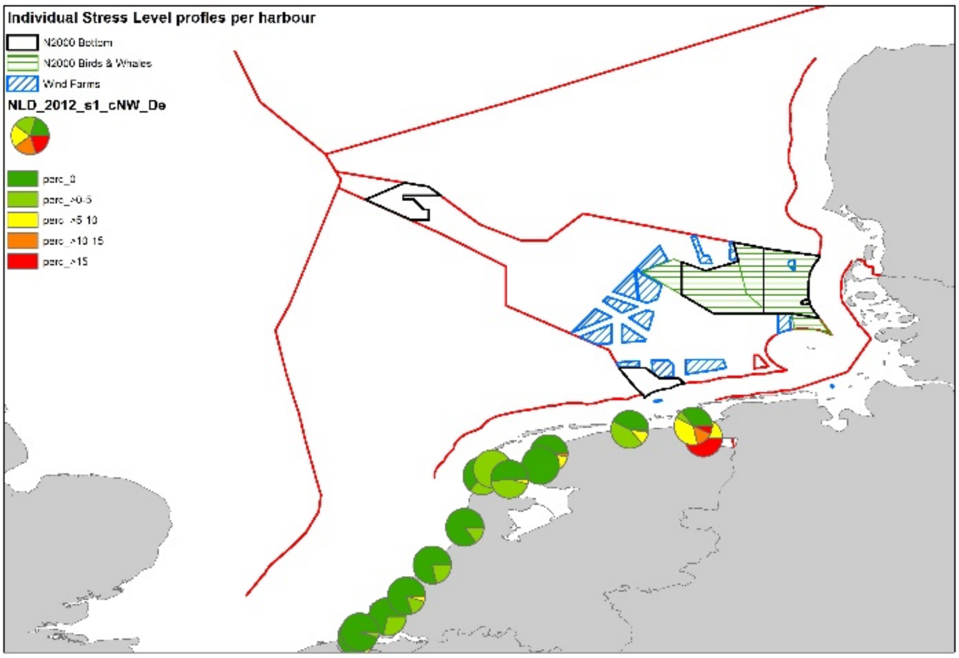


Figure 3.4.1. Test of a future “Natura 2000 and Windfarm in the German waters” Scenario. Individual Stress Level profiles of the Dutch fleet by harbour.

Local impact can be anticipated by looking at the immediate stress level that the fishing restriction could create. For example, Individual Stress Level Approach (ISLA, Schulze *et al.* 2010) looks at per vessel aggregated ‘stress level’ profiles of national fleets, coastal regions or harbours (Figures 3.4.1 and 3.4.2). Individual stress level is defined as the percentage of the total revenues of a vessel, which would get lost if an area is closed for fishing in future. The set of impacted vessels can be first identified by looking at the current link between areas proposed for closures and communities on land. This is also an important step for stakeholder engagement. With the kind of information produced in Figures 3.4.1 and 3.4.2, a discussion can start about alternative activities.

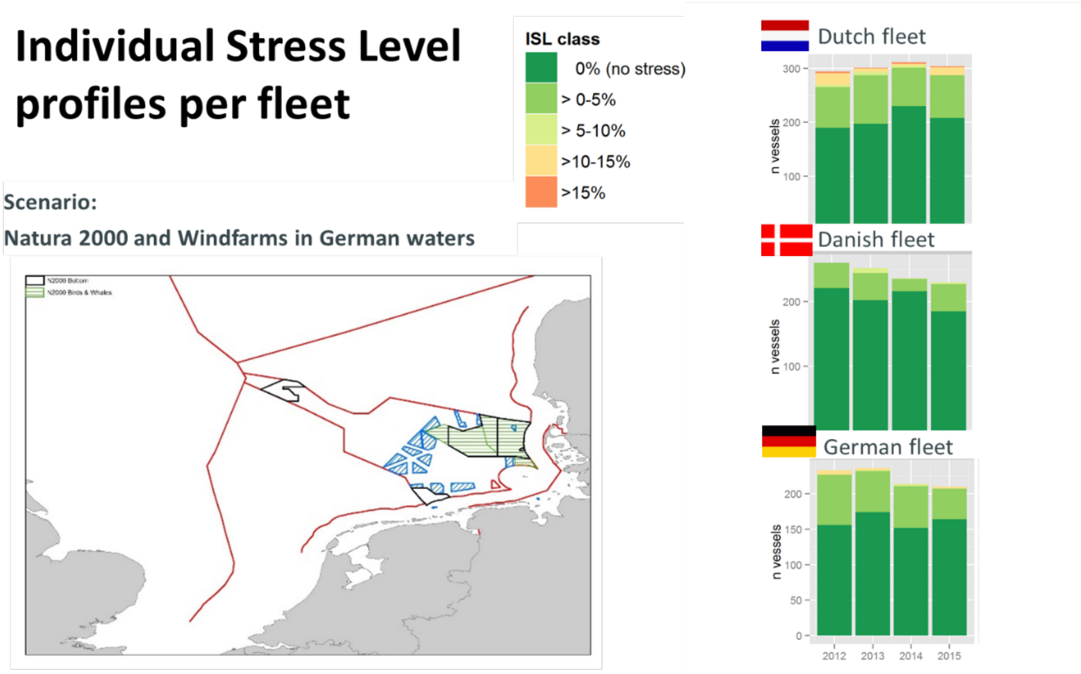


Figure 3.4.2. Test of a future "Natura 2000 and Windfarm in the German waters" Scenario. Individual Stress Level profiles of the Dutch, Danish and the German fleet assuming the effort distribution of the year 2012 to 2015.

The WKTRADE2 focus is solely on direct employment from fishing activity rather than through the supply chain. However, the indirect fishing activity or ancillary fishing activities include servicing of equipment and/or vessels, sale of fish, supplies for operations, and research and development. Oudmaijer *et al.* (2011) estimated that in the EU, income and employment as measured in FTE for ancillary activities was a third of that in the direct fishing sector. Where to draw a boundary on measuring social factors up the supply chain for certain fleet segments where there is significant levels of vertical integration is an issue that would need further consideration.

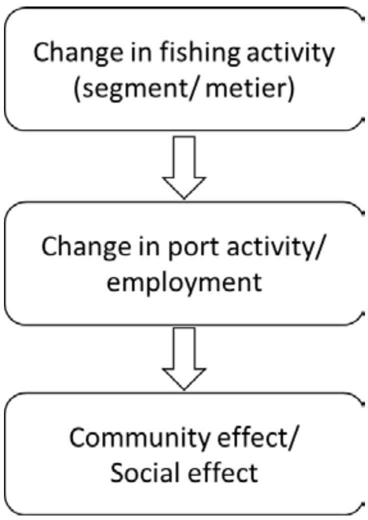


Figure 3.4.3. Linking changes in fishing activity to social effects.

Development of social indicators for ICES fleet segments/ metiers at a suitable scale might involve a new call for data (listed in Table 3.4.1) if not already collected by STECF, but in any cases data at national level would be more easily accessible rather than more relevant data at smaller spatial scale. This issue has been highlighted in the EU, and in the Atlantic region efforts have been made to disaggregate both social and economic indicators to smaller spatial scales (Foley *et* *al.*, 2014). Again the difficulty of undertaking measurement at local scale for EU should serve as an example for ICES in determining the scale and scope of measuring social factors.

The dominance of employment as a social factor is also seen within the EU Data Collection Framework with the introduction of Regulation No 2017/1004 (EC, 2017) where the only social factor considered is employment and the social and demographic characteristics of the labour force (employees and vessel owners).

Table 3.4.1. Data and data types collected under Regulation 2017/1004.

Social Factor	Data type
Age	predefined string: <=14, 15-24, 25-39, 40-64, >=65, unknown
Education	predefined string: High, Low, Medium, unknown
employment_status	predefined string: Employee, Employee full, Employee part, Owner, Unknown
fishing activity	predefined string: SCF, LSF, DWF
Gender	predefined string: Female, Male, Unknown
Nationality	predefined string: EEA, EU, national, non-EU/EEA, unknown

From the above DCF data (Table 3.4.1) the following indicators are generated (Table 3.4.2).

Table 3.4.2. Employment indicators.

Employment by gender;
Full Time Employment (FTE) by gender;
Unpaid labour by gender;
Employment by age;
Employment by education level;
Employment by nationality;
Employment by employment status;
Total FTE National.

Linking this employment data to activity by way of various fleet segments or metiers will be needed to allocate the social data spatially. Alternatively the approach may be to link both employment and the fishing activity to port (either home port/harbour) and use this data either at port level or aggregated to a higher spatial unit for policy purposes (e.g. EU NUTS unit[1] or equivalent).

The other suggested social factor that could be captured with ICES data is individual vessel movements. Vessel Monitoring System (VMS) data may be used to link fishing activity in terms of vessel numbers per port (either home port or landings port) or pattern of vessel movements per port (Table 3.4.3). Currently, if the level of data available is deemed too sensitive for confidentially purposes to be shared then data are aggregated to a higher spatial level that link in to policy units at national level (EU NUTS or equivalent).

[1] NUTS or Nomenclature of Territorial Units for Statistics are used by the EU for statistical purposes and also for policy related to regional development and for the application of regional policies.

Table 3.4.3. Possible VMS derived social indicators

Possible VMS derived social indicators
Fishing Vessels per home port/ aggregated spatial unit
Fishing vessel movements per port/ aggregated spatial unit
Landings per port/ aggregated spatial unit
Vessel density

Linking potential impact of area management to coastal communities is an important step to understand the vulnerability of those communities to changes to access to fishing grounds and capture the social trade-offs. Linking the spatial activities to coastal communities is already possible when having access to individual logbook, VMS and vessel registry data (where the origin of the vessel is indicated), those analysis can currently be done at an international level by involving researchers with access to individual data and running a standard script in all considered countries. By contrast, social data are currently collected at a too high level to be used for fine scale analysis.

3.5 Identifying important factors impacting location choices

A number of factors drives the choices made by fishers as to where to go fishing. To identify the important factors, different approaches can be used involving i) asking the fishers themselves or ii) looking at past data of location choice and inferring the factors linked to the choices. While ii) is widely used by natural scientists, i) is often neglected. Several reasons can be put forward to justify using data only, as the exhaustive coverage of the logbook data compared to engaging stakeholders from different countries, speaking different languages and sometimes difficult to access, or the difficulty to openly engage fishers on the topic of area closures. Using the expertise of the fishers themselves is expected to provide information on the factors influencing their choices, information that go beyond logbook data. Ideally, both approaches are used in combination to ensure the answers from the consultation are validated by observations and the statistical modelling is done on the relevant set of drivers selected with the actors themselves.

Beside this, engagement with stakeholders may be used to help inform choices over potential proposals in order to evaluate relative merits of different proposals and/or to inform the impacts of a specific proposal.

3.5.1 Engaging stakeholders to elicit drivers in location choices

Engagement with stakeholders can provide insights in opportunities for alternative activities not visible in the data. A range of factors are likely to influence the fishing choice, the type and extent of displacement that may occur and the strength of factors and their interrelationship. These may include:

- Availability of alternative fishing grounds (taking into account technical characteristics of the vessels, gears etc.);
- Distance from port (fishing range and steaming time);
- Expectation or occurrence of localised 'spillover' effects;
- Knowledge of alternative fishing grounds;
- Availability of fishing rights and quota;
- Individual fishers' strategies and preferences.

The group suggests using focus groups to elicit the factors influencing displacement. Additional questionnaire surveys can be used to support engagement through focus groups with fishers where it is desirable to provide further detail on the nature of impacts and effects.

Focus groups offer a way to explore the nature of displacement effects in a qualitative and potentially semi-quantitative way. Engaging with the fishing industry affected by proposals may be facilitated via the relevant regional Advisory Council/s and via national representative bodies who may help to identify port and local level associations or groups of fishers. Representative bodies may then be involved in an engagement process who can then consult directly with effected businesses or involve affected fishers who are able to impart their knowledge on anticipated displacement effects.

Engagement with stakeholders may be facilitated with the prior preparation of data and information on affected métiers, ports and associated cost information. This process will help to identify which fishing activities are likely to be affected by the proposals and how this is distributed across sectors and from which ports vessels operate and indications of the extent and significance of displacement.

Engagement via such groups may include eliciting the following information:

- How much fishing effort is likely to be displaced, how much effort foregone or whether fishers may exit a fishery altogether.
- For displaced effort, what proportion of fishing grounds, effort or revenue is affected?
- Where fishing effort is likely to be displaced to including:
  - Areas within existing fishing grounds
  - New areas or the potential for exploratory fishing in areas where suitable habitat may exist
- Attachment to port or nomadic fishing strategies.
- Other constraints including:
  - Existing fishery regulatory constraints, developments and proposals from other marine sectors and other fishery sectors (e.g. due to the distribution of static gear fisheries).
  - Other planned or proposed plans, projects or fisheries management measures.
- Where fishers are expected to exit the fishery altogether, the extent to which displacement to other gear types is likely to occur.
- In areas that are restricted to a gear type, to what extent effort by fishers using different gear types may operate in the proposed closure areas.
- The potential knock-on implications for fisheries and other marine sectors potentially affected by the displaced fisheries including from concentration of fishing effort and associated pressure on the fishery resource, gear conflict between the displaced fishery and other fisheries, upstream and downstream activities related to those fisheries and effects on the operation of other marine sectors.

The questions should include an assessment of potential significance of the loss of an area of fishing ground, as a proxy for a level of displacement vulnerability. These may include:

- Proportion of catch/effort from the area that can no longer be fished with a given gear type;
- Level of specialisation (to certain gears, certain species);
- Size of the vessel and its operating range.
- Availability and accessibility to alternative grounds and
- Fishing access (i.e. existing regulatory restrictions on fishing gears, vessels and catches;

- Cumulative and in-combination effects from other restrictions.

The consultation should also include the likelihood of changing fishing practices in reaction to a spatial constraint. Indeed, the choice could be to shift activity therefore displacing the effort from one metier to another.

The questions should help framing the impact evaluation of the management options and give the sector opportunities to discuss potential knock-on effects on the fisheries given that the areas where fishing effort may be displaced to may have knock-on social and economic effects on fisheries sectors and other marine users operating in the area/s of displacement.

Focus groups and questionnaires also offer the opportunity to account for the decision-making of the small-scale fisheries for which data collection by other means is less stringent (e.g. no VMS data for vessels below 12m, low logbooks resolution for vessels below 10m).

There are examples in the literature about the use of input from stakeholders to identify drivers of choice. Fitzpatrick *et al.*, (2017) gives an example of using discrete choice modelling with fishers through a discrete choice experiment where fishers are asked to choose between alternatives in management options. Such an exercise was undertaken using the same survey instrument with fishers from 3 fisheries in Europe; the Celtic Sea herring fishery, the Danish pelagic fishery and the Greek demersal fishery showing that preferences for fishery management options vary significantly between these groups.

Bastardie *et al.* (2013) introduced a method to reveal the decision-making behind the fishing tactics by drawing decision trees. The authors argue that decision trees made from individual questionnaires to fishers is a valuable approach to disentangle the determinants of the different behaviours of fishers and to support a quantitative analysis for the generalisation of the impacts at the macro-scale. The questionnaire is devised such as eliciting the attitude and reactions to hypothetical fishing situations to determine fishers´ s trip decisions and tactics. Decision choices on the way fishing is operated are likely to result from a mixture of various triggering factors that make reactions to encountered situations (various feedbacks, thresholds, etc.) variable. Tree-based decision classification is well suited to investigate such non-linear and mechanistic relationships. Answers from fishers are yes/no-answers that enable them to be partitioned into binary graphic trees (Figure 3.5.1.1). Such decision trees have been embedded into bio economic spatial dynamics model for fisheries such as DISPLACE (e.g., Bastardie *et al.* 2014).

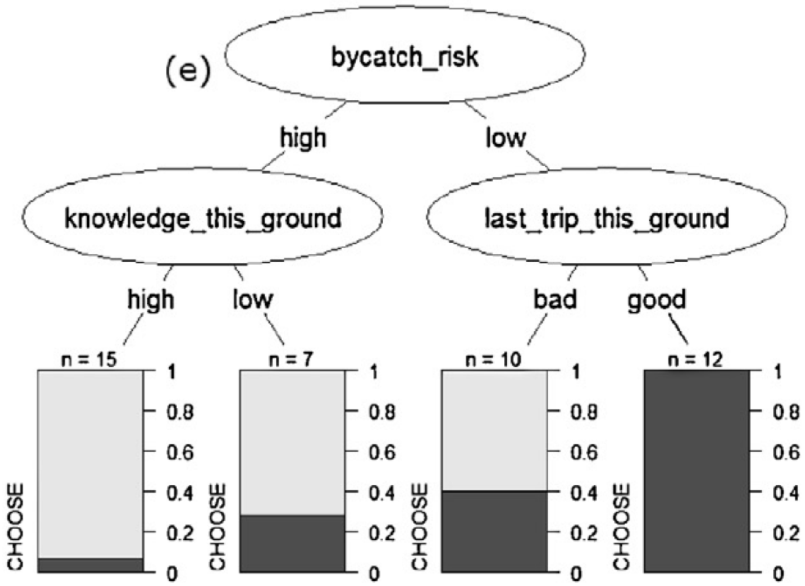


Figure 3.5.1.1. An example of decision tree relative to the location selection decision ('choose' vs. 'not choose' probabilities) elicited from yes/no answers from fishers facing hypothetical situations (extracted from Bastardie *et al.* 2013).

3.5.2 Statistical analyses of past location choices

The literature describes different approaches for statistical analysis of past fishing ground choices. The group identified random utility model (RUMs), discrete choice experiments and decision trees as ways forward to elicit the drivers behind fishing effort allocation in space and time, and potential displacement reactions.

Location choice models based on random utility models have been suggested as one approach to modelling fisher's preferences for fishing sites and as possible method for predicting displacement effects of access to fishing locations (Smith, 2000). This approach models the factors that affect the change in the behaviour of human agents and the results can be used to predict choice probabilities for each option. Additionally, the same model parameters can also be used to predict how choice probabilities change when other options are removed or added (McFadden 1974, Train 2009). Fisher's attributes can be incorporated into these models with interaction terms.

Girardin *et al.* (2017) undertook a review of modelling fleet dynamics over the past 30 years using discrete choice data aiming to standardise fisher behaviour drivers and RUMs. They classified their behaviour drivers into six common groups (fishing costs, attitude towards risk, expected gross revenue, habits, targeting and density of other vessels).

van Putten *et al.* (2012) examined the drivers of the measured behaviours that have previously been used in choice models based on random utility models (RUM) for fishers. In their review they noted that location choice models was the most common type of discrete model used in relation to fisheries within the last 30 years. The same authors also identified a number of drivers used by fleets contained within discrete choice models (Table 3.5.2.1) and for revenue and costs identified variables used (Table 3.5.2.2)

Table 3.5.2.1. Fleet drivers used in choice models identified by van Putten *et al.*, 2012.

Economic
Profit
Revenue
Cost
Opportunity costs
Satisficing
Time
Fish abundance
Work conditions
Individual
Vessel characteristics
Fisher characteristics
Fisher Motivation
Other
Group behaviour
Habits
Tech constraints
Regulations
Attitude managers

Table 3.5.2.2.Revenue and Costs Variables in Fisher's Discrete Choice Models (van Putten *et al.*, 2012).

Drivers	Variables
Revenue	
	Own revenue
	Net present value of revenue
	Variation in own revenue
	Difference between value legal and illegal catch
	Own catches
	Fish prices
	Existence value of species
Costs	
	Costs per unit of effort
	Deemed value payments
	Discarding costs
	Fuel costs/prices
	Steaming cost
	Distance to and from port
	Number of trips
	Trip length
	Effort – hours fishing
	Search time
	Steam time
	Leasing of extra quota units
	Quota prices
	Objective fine levels for illegal fishing
	Subjective perception of fine
	Subjective probability of detection
	Subjective probability of prosecution
	Subjective probability of conviction

Hynes *et al.* (2016) provides an example of a location choice approach within the ICES area for Irish bottom otter trawl vessels greater than 15m in Irish waters. A choice model for fishers was generated based on 3,160 trips by 101 vessels with each trip representing a choice for fishers in 2010. Two different choice location approaches were used. The first was based on 30 different natural fishing grounds around the coast of Ireland. The latter was creating 30 fishing grounds based on a 1 degree longitude by 1 degree latitude grid approach. VMS data was used to allocate the site choice by fishers based on speed profile. Site characteristics included in the model are shown in Table 3.5.2.3. Variance in earnings per unit engine power was used as measure of risk.

Table 3.5.2.3. Site characteristics used by Hynes *et al.* (2016).

Distance from port to fishing ground return
Earnings per unit engine power(KW)
Average number of species caught at grounds
Species
Experience
Regional Sea
Variance in earnings per unit engine power (used as measure of risk)
Percentage rock at grounds
Size of grounds
Distance from port to fishing ground return interacted with Days at Sea

Using a random parameters logit model in conjunction with the natural fishing ground choice options proved the best model fit. To test the model's prediction ability a comparison the probability of fishing at a particular site to actual fishing site choices gave differences in the range of 0.038 – -0.003 with an out of sample size 15% showing a difference of 0.05. The model was used to simulate a closure of a fishing ground by removing this site option from the model and re-estimating using the same probabilities and predicted that most of the effort would displaced in adjacent fishing grounds with the percentage changes in probability varying from +75% to 22%.

3.5.3 Other marine activities constraining the space available for fishing

One of the important drivers of fishing displacement is the availability of fishing grounds. Other activities present at sea including windmill parks and existing areas such as Marine Protected Areas (MPAs), military exclusion zones etc. can specifically restrict the space available for fishing on particular fisheries. An attempt to account for these aspects is currently ongoing within ICES WGSFD and WGSFD 2019 ToR d) is very much overlapping what WKTRADE2 is also addressing.

WGSFD has begun to identify potential physical drivers and where available locate spatial data sets (Figure 3.5.3.1). These data sets are formatted/interpolated to provide values at a c-square (0.05 x 0.05 decimal degree) spatial scale and a monthly temporal scale where appropriate and are stored along with supplementary metadata in a spatial database (Figure 3.5.3.2). The metadata fields associated with the data layers have been created to be informative to the users of the data for qualitative, static and dynamic modelling. For example if carrying out an analysis of the socio economic impacts of a spatial closure, it would be useful to know the dates of the closure, the nationalities/metiers excluded and characteristics of those fleets i.e. the distributions of home ports and the technological/social capacity of those vessels to comply with the regulation.

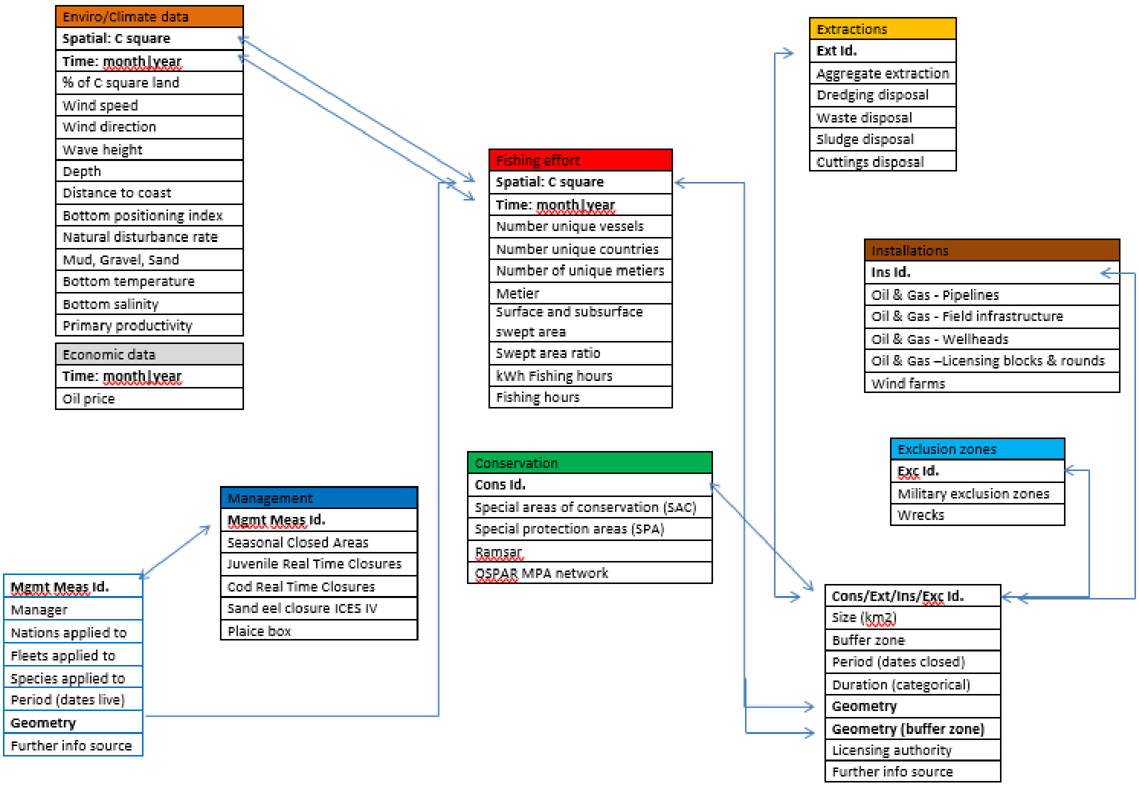


Figure 3.5.3.1. Schematic of "other activity" parameters identified by WGSFD and proposed data base structure.

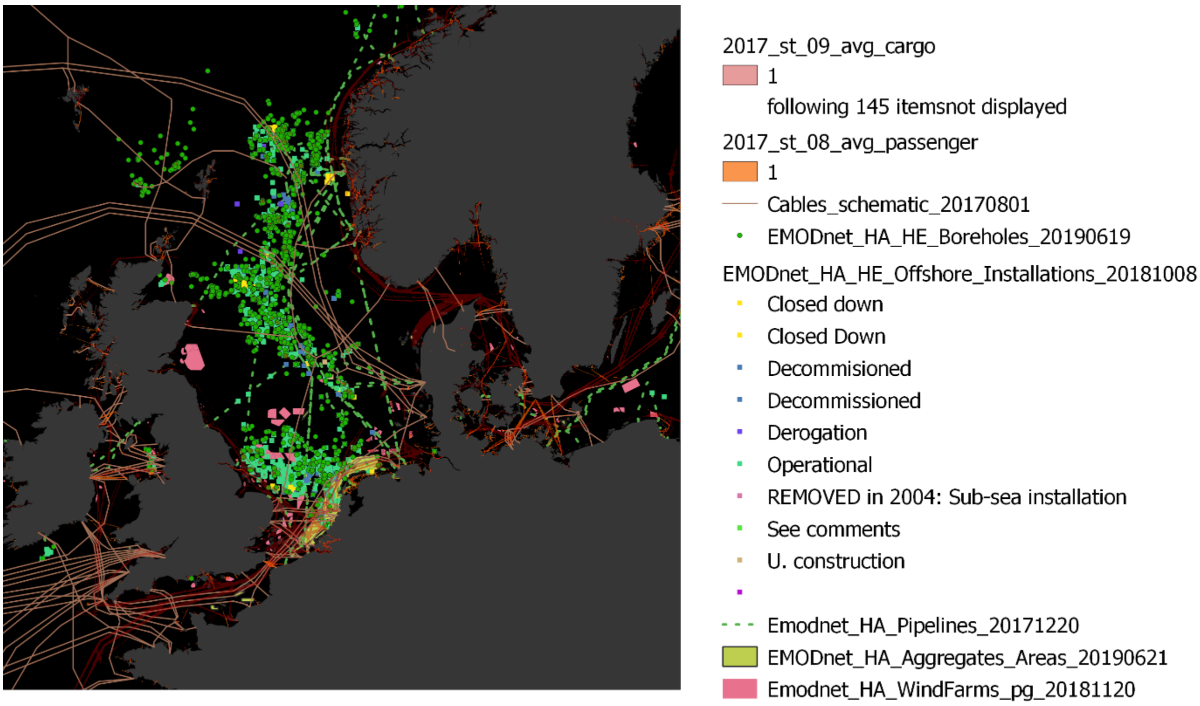


Figure 3.5.3.2. Spatial distribution of some North Sea features that are constraining the available space for fishing.

4 Applicability to obtain fisheries economic parameters on fine spatial scale (ToR b)

Lead ToR b: Jörg Berkenhagen

ToR b: Demonstrate the applicability of a set of approaches to estimate fisheries revenue at local, habitat and regional scales and for different metiers (given the present data availability and cross-regional applicability, i.e. to demonstrate what can be used in WGFBIT in 2019 and 2020 to describe trade-offs); (Science Plan codes: 6.6, 6.4, 5.4)

4.1 Introduction to the approach

The group discussed options to estimate the variable costs at spatial scale. Currently cost data are publicly available through the Annual Economic Report (AER) of the Data Collection Framework (DCF) of the EU Commission. These data are aggregated by year and by DCF fleet segment. In order to estimate cost at higher resolution, a disaggregation approach was developed in the SECFISH project. This would allow to estimate variable cost at the level of a metier as performed by a fleet segment. A spatial disaggregation is also considered.

The application of the SECFISH approach requires cost, effort and landings data at individual vessel level. These data are usually subject to confidentiality. Therefore, the SECFISH procedure can only be run with the support of national authorities and/or of institutes involved in data collection which have access to all these individual data (see Figure 4.1.1). The outcome of the SECFISH disaggregation procedure is a quantification of the correlation between transversal (capacity, effort and landings) and cost data by fleet segment or by fleet segment×metier or by fleet segment×metier×region, where applicable.

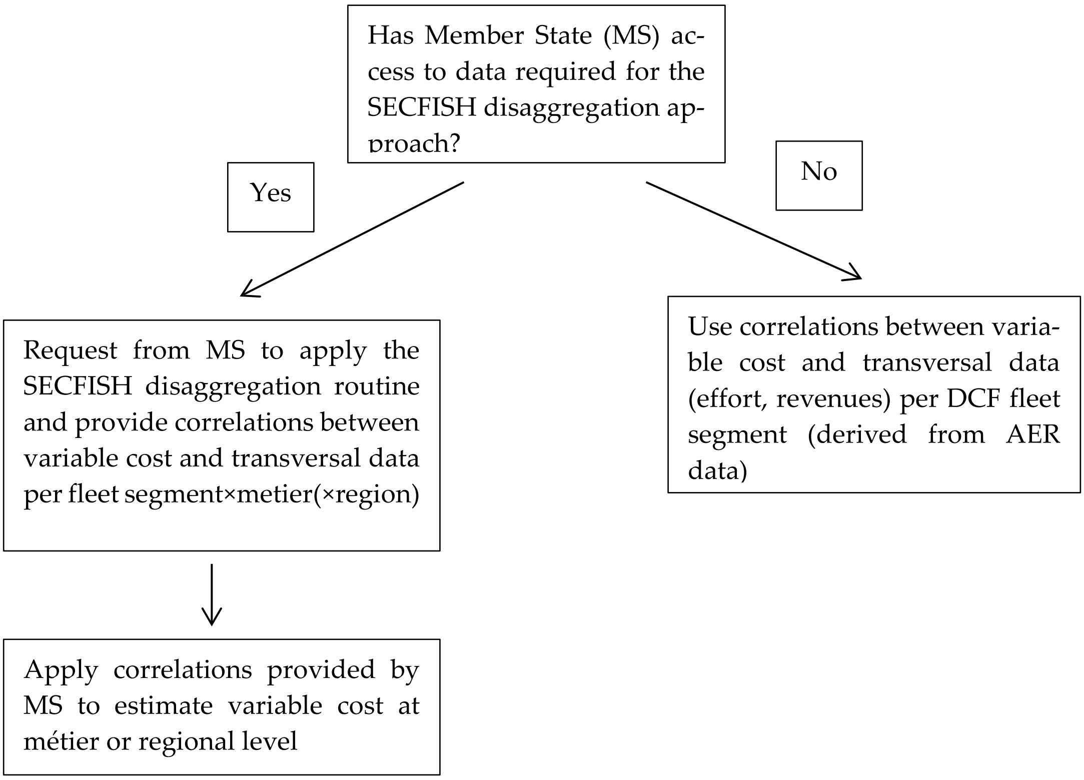


Figure 4.1.1. Workflow for the optional procedure for the application of the SECFISH routine.

Once these correlations are available cost data can be estimated on the basis of effort or landings data at the level of resolution of the latter.

For the moment, the only publicly accessible data are those from the EU data collection framework (DCF) Annual Economic Report (AER) (https://stecf.jrc.ec.europa.eu/dd/fleet). Therefore, the only operational option to assign cost to smaller spatial units is to use average cost by fleet segment per effort unit or per landings unit.

While running this exercise in the context of the workshop it turned out that the actual AER data as provided through the web interface are not complete with respect to the required effort data. Therefore, correlations between cost and effort could not be estimated comprehensively. Thus, cost variables which are regarded dependent upon effort (i.e. fuel cost, repair cost, other variable cost) could not be assigned to smaller spatial units. For details see chapter “Technical procedures for spatialization”.

4.2 The SECFISH approach (for potential use in the future)

Depending on the availability of individual vessel data, SECFISH allows to estimate disaggregation at three possible levels:

- Level 1: by fleet segment;
- Level 2: by fleet segment and by metier;
- Level 3: by fleet segment, by metier and fishing zone (defining the metier, inside the routine, as combination DCF metier-fishing zone).

According to the availability of individual vessel data, the SECFISH approach can be applied to derive, e.g. the fuel consumption for unit of effort (e.g. hours at sea) and/or other variable costs (if considered appropriate for the specific type of fishery). As an example, the ratio fuel consumption/unit of effort could be then used to spatially derive a raster of the fuel consumption by c-square, applying this information on a raster of the effort.

When applying estimates of cost ratios to spatial modelling, in case of level 1, the disaggregation of cost will be driven only by effort information while, in case individual vessel data are available also by metier (case 2) and fishing zone (case 3), the specific slopes could be used to refine the disaggregation. The higher the resolution of cost ratios, the more refined will be the effort displacement deriving from scenarios run by spatial modelling.

4.2.1 SECFISH methodology

SECFISH methodology is divided into 2 main phases:

Phase 1: individual vessel data are used to derive the correlations between variable costs and transversal variables;

Phase 2: the results of the previous phase + the official time-series of costs by fleet segment and the official time-series of effort by fleet segment and métier are used to disaggregate the costs and validate the disaggregation.

Taking into account the need of individual vessel data, Phase 1 should be carried out or authorized by member state, while Phase 2 can be carried out by any end-user, once the following input is available:

- Official costs time-series by fleet segment (through AER)
- Official transversal variables time-series by métier (through AER and FDI STECF data calls)
- Results (GLM coefficients) from phase 1

Coefficients derived from the simple linear regressions and GLM analysis as implemented in WP3 of the SECFISH project and in the SECFISH R package could potentially be required under a specific data call, to allow the feeding of spatially explicit bio-economic models during the WGFBIT in 2020, in order to describe trade-offs.

The whole workflow of the SECFISH functions can be summarized as follows, with Exploratory Analysis and GLM representing phase 1, while Disaggregation and consistency checks representing Phase 2 (Figure 4.2.1.1). R routines are available on CRAN (Bitetto *et al.*, 2019).

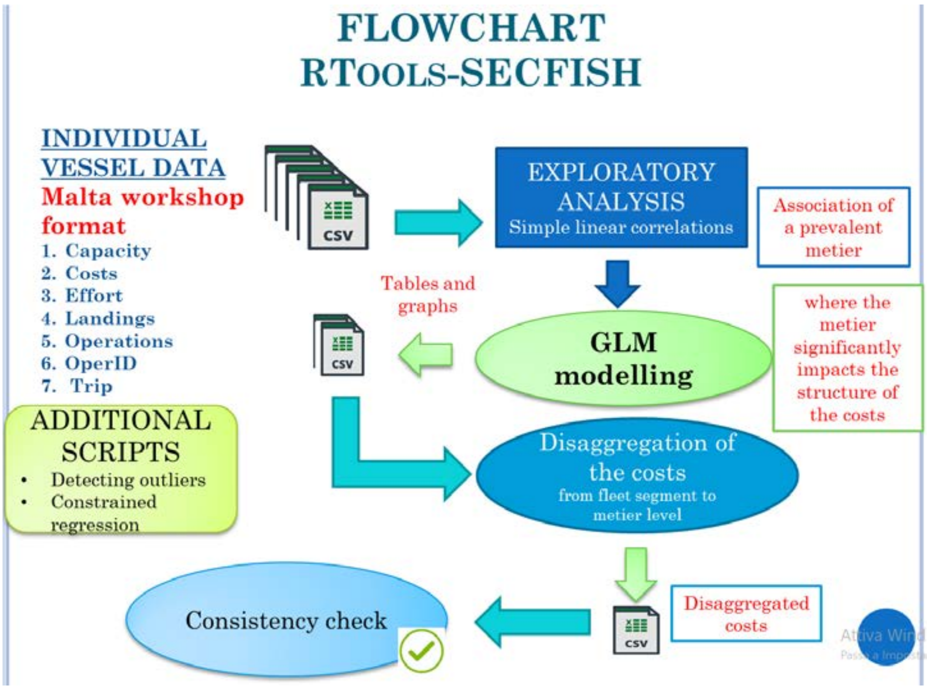


Figure 4.2.1.1. Workflow summarizing the functioning of SECFISH method.

The input required for Phase 1 follows the format of the Malta workshop on disaggregation. 7 input data frames are needed:

1. Capacity: where the information about each vessel (KW, GT, LoA, etc.) are contained;
2. Costs: where the data related to fuel costs, fuel consumption, maintenance costs and other variable costs are stored;
3. Effort: association trip-total fishing hours carried out;
4. Landings: association trip-landing and related revenue;
5. Operations: association fishing operation-number of fishing hours-metier;
6. OperID: association operation-trip;
7. Trip: association trip-vessel.

The links among the data frames is schematized in Figure 4.2.1.3, as reported in the PGECON report of 2019.

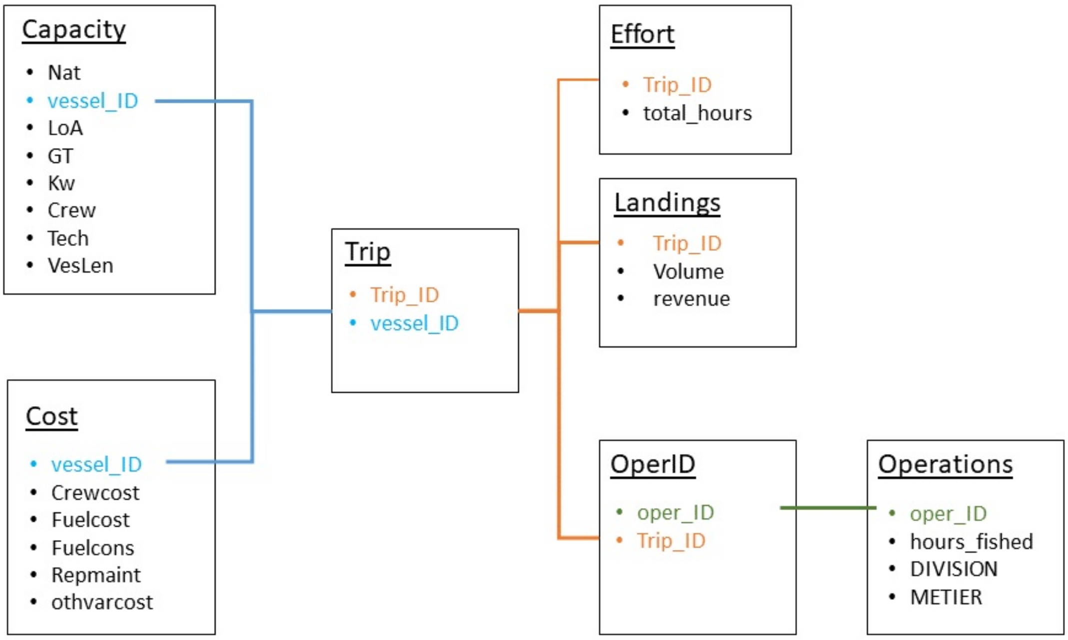


Figure 4.2.1.3. Connections among the data frames required to feed the phase 1 of SECFISH tool.

The "Operations" box can be adapted to obtain data by higher spatial dimension, i.e. including information of effort (hours_fished) by ICES rectangles or c-square, if logbook or VMS data are used, respectively.

4.2.2 Exploring the influence of the spatial dimension (ICES Division) on the cost structure: an example on the Belgian data

Individual vessel data for three years (2015–2017) are used for exploring the significance of the fishing zone (ICES Division) on the variable costs structure of the Belgian fleet. The exploratory analysis function was used to associate a prevalent metier to each vessel, defined as DCF metier combined with ICES Division, and to obtain a data frame to derive the relationships between the variable costs and the transversal variables.

On this dataset, for the fleet segment TBB VL1824 a higher fuel consumption per hour is associated to vessels fishing in zone VIId with respect to the ones visiting Division IVc. For the fleet segment TBB 2440 the fuel consumption is more variable among the fishing zones (Figure 4.2.2.1). This is also confirmed by the simple linear correlations and the GLM analysis, showing significance of the Divisions on the fuel consumption, fuel cost and labour cost (Table 4.2.2.4; Figure 4.2.2.2).

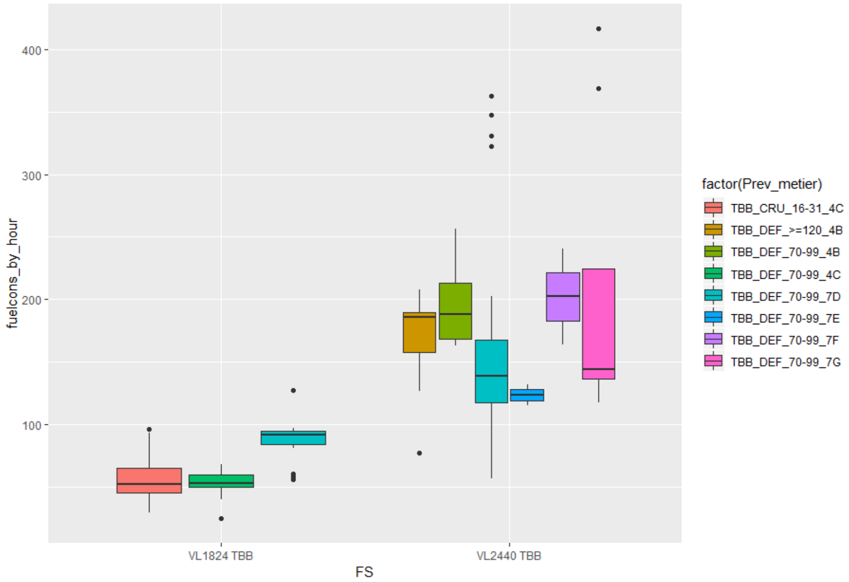


Figure 4.2.2.1. Fuel consumption by hour for TBB VL 1824 and TBB VL2440 among the metier defined as combination of DCF metier and subdivision.

Table 4.2.2.4. Summary of the GLM results of the additive model of fuel consumption versus metier (DCF metier+subdivision).

```
Call:
glm(formula = fuelcons ~ factor(Met_LOA) + Effort + 0, family = gaussian(),
    data = COSTS_temp)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-75113  -23794   -1889   23472   94722

Coefficients:
                                     Estimate Std. Error t value Pr(>|t|)
factor(Met_LOA)TBB_CRU_16-31_4C TBB -28947.116  18542.359  -1.561   0.1248
factor(Met_LOA)TBB_DEF_70-99_4C TBB -33936.344  17359.965  -1.955   0.0562 .
factor(Met_LOA)TBB_DEF_70-99_7D TBB  46928.092  18577.375   2.526   0.0147 *
Effort                                  68.344      6.612  10.337 5.21e-14 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for gaussian family taken to be 1531225920)

    Null deviance: 1.7776e+12  on 54  degrees of freedom
Residual deviance: 7.6561e+10  on 50  degrees of freedom
AIC: 1301.2

Number of Fisher Scoring iterations: 2
```

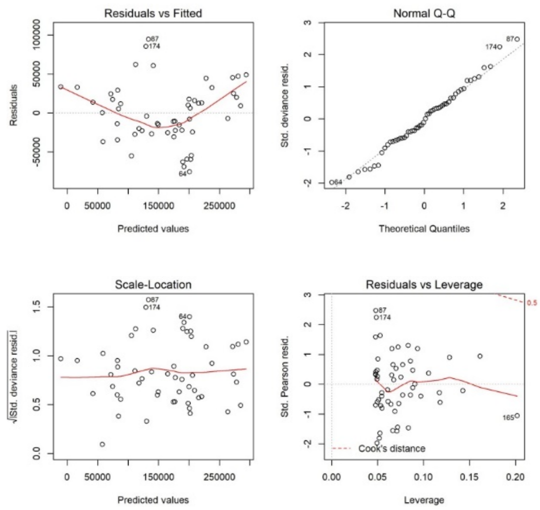


Figure 4.2.2.2. Residuals of the GLM of the fuel consumption versus metier (DCF metier+subdivision).

This case represents an example of the influence of fishing zone on the costs structure. In this situation, the SECFISH approach was used to test the significance of the fishing zone and to derive the slope of the linear correlation or, equivalently, the ratio fuel consumption/effort in subdivisions VIId and IVc. These values could be then applied to the c-squares corresponding to the above-mentioned subdivisions, crossing the information of the slope with a raster of the effort with c-square resolution. In this way, it would be possible to take into account the difference between the fuel consumption of the vessels fishing in different ICES Divisions, assuming that for the c-squares of the same Division the fuel consumption per hour is the same.

Analogously this could be done for the other variable costs (labour costs, using a raster of the revenues).

4.3 Technical procedures for spatialization

In order to provide an operational procedure based on the data which are supposed to be available, a routine was developed to assign AER effort and landings data to effort and landings data as contained in the VMS data set (provided by ICES during the workshop). The R script developed in the context of the workshop is made available on https://github.com/ices-eg/wk_WKTRADE2.

Thus far, high-resolution effort and landings data are not available from the FDI data call, but only from the VMS data call. These data are at high resolution (c-square, 0.05° x 0.05°). However, they contain information only on the gear used, but not on the fleet segment the fishing vessels are assigned to. Therefore, effort and landings by c-square per fleet segment can only be roughly estimated, based on the assumption that vessels perform fishing operations using only the gear which is identified as predominant in accordance with the DCF fleet segmentation (i.e. if a vessel is assigned to the segment "DTS" it is assumed that it performs demersal trawl and seine fishing only – which is not always the case).

This estimation procedure has distinct drawbacks as the VMS data set does neither include the length class nor the dominant gear of the vessels performing the fishery under consideration (so called "Fishing Techniques" in the STECF data). In order to estimate which fleet segment refers to specific fishing activity entries in the VMS dataset, the VMS dataset had to be aggregated by ICES area and compared with effort and landings information from the AER dataset. It has to be borne in mind that we introduce a bias when setting the predominant gear in the fleet segment equal to the gear entry in the VMS dataset. Moreover, the mismatch of length class thresholds between AER and VMS data causes further uncertainty.

In order to calculate the share of different fleet segments of the total value of catch, weight of catch and fishing effort on the c-square level, those shares had to be calculated in AER data on the subregion level and applied to the VMS data. Every c-square of the respective subareas was assumed to have the same share between the various fleet segments. This was the only feasible approach given the data structure. However, it provides only a rough estimate of cost, value and effort on the c-square level and would have been unnecessary, if fleet segment information had been available in the VMS data.

Fishing effort is considered to be the best proxy for energy, repair and other variable costs. The AER data lacked complete information on effort in kW Fishinghours, which is the unit necessary for a comparison with the VMS data. Therefore, the joined dataframe of VMS and AER data lacks a lot of information on effort and therefore on cost data. This could be avoided by either making kW Fishinghours a mandatory information of the AER data call or agreeing on another unit of fishing effort, which is available in both the VMS and the AER data.

A commented R-script containing the complete code for the basic approach for wrangling and joining the datasets and creating the raster layer is made available on https://github.com/ices-eg/wk_WKTRADE2.

Value of landings and weight of catch could be compared on the subregion level without further assumptions or calculations just by aggregating both VMS and AER data on the subregion level. While the landing weights widely corresponded, the value of the landings considerably differed between the data sets and was roughly one third lower according to the VMS data. This appears to be caused by reports of zero catch value in the VMS data, even though notable catch weights were reported by the respective métiers at the same c-square (Figure 4.3.1).

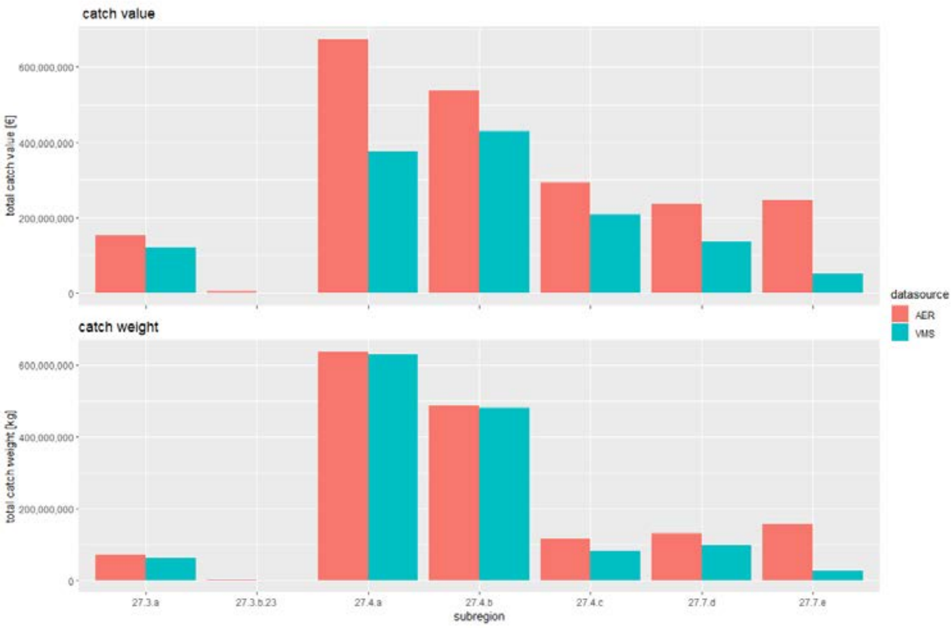


Figure 4.3.1. Total catch value [€] and total catch weight [kg] divided by FAO subregion according to AER (orange) and VMS (green) data.

4.4 Outlook on applicable approaches

The FDI data call was designed to overcome the mismatch between resolutions of fleet economic data and effort or landings data. However, even though the data have been collected and called (the 2019 data call is going to be checked and evaluated very soon, under STECF subgroup, with data updated to 2018), they are at current state not publicly available (https://stecf.jrc.ec.europa.eu/dd/effort). Furthermore, it has to be borne in mind that even the FDI data call contains information on the resolution of an ICES rectangle, which is considerably larger than the c-square as used in the VMS data call. Therefore, FDI effort and landings data would have to be adjusted to the VMS data.

In order to enhance the provision of advice in terms of effort displacement, some recommendations can be derived for the future in terms of data provisions and data calls.

First, the ICES VMS data call should include, in the future, information on the fleet segment as defined in the DCF. Second, data from the FDI data call should be made available to the working groups. Third, the SECFISH approach should be forwarded to MS, thus requesting to run the disaggregation exercise and provide the results to ICES or to the EU-COM. The results of the SECFISH exercise are basically correlations between fleet segment-metiers and effort or landings data (see also "The SECFISH approach"). The latter recommendation is more of long-term nature as it would require some preparatory work also from MS. However, on the long run this information should be collected on a regular basis by the EU-COM under the DCMAP as it provides valuable information which could be used for different purposes (e.g. evaluation of raising procedures).

The mismatch in figures for value of landings (and to a lesser extent for weight of landings) between AER and VMS data should be further investigated and fixed.

5 Accounting for fleet adaptation/effort displacement (ToR c)

Lead ToR c: Tommaso Russo

ToR c: Establish ways to assess effort reduction scenarios (as proposed by ICES WGFBIT) with special attention to:

1. *Spatial effort displacement (e.g. redistribution effects on benthic seafloor indicators, catch rates and fisheries revenue)*
2. *Effort allocation among activities (e.g. redistribution among gear types with various selectivity and impact on the seafloor, and various operating costs).*
3. *Ecosystem effects (accounting for (in)direct effects of effort reduction and displacement on benthic habitats and food webs).*

(Science Plan codes: 7.3, 6.6, 6.4)

5.1 Different approaches to assess pressure reduction scenarios: an overview

The EWG discussed the possibility of applying several families of models (most of which are already available as operative tools) to assess pressure reduction scenarios and, in particular, spatial effort displacement, effort re-allocation among activities and ecosystem effects.

The families of models defined for the following discussion comprises:

- FLAT models: No forecast of fleet adaptation (i.e. no effort displacement). An example is the Individual Stress Level approach (ISLA, Schulze *et al.* 2010).
- AD-HOC models: Primarily conceived for short-term estimation of effort displacement (i.e. 1 year) according to expert knowledge or some "simple" rule such as allocation to the nearest areas or according to the probability fields (the most similar approach to what WGFIT is currently applying).
- STATIC models: Modelling approaches applied on aggregated data (i.e. not at the scale of individual vessels). Examples are GAM (Elahi *et al.*, 2017) or RUM (Random Utility Models, see Section 5.2.3)
- DYNAMIC models: Conceived for long-term forecast (i.e., 5–10 years or more) of fleet adapation or effort displacement and for the estimation of several effort-dependent indicators. Examples are DISPLACE, SMART, SimFish, ISIS-Fish.

Each of these families is characterized by advantages and limitations, summarized in the following SWOT analysis (Table 5.1.1).

Table 5.1.1. Strengths, Weaknesses, Opportunities & Threats (SWOT) analysis of the different approaches when identifying the cost of implementing the management options.

<table>
<tr><th></th><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td rowspan="8">INTERNAL (MODEL RELATED)</td><td colspan="2">FLAT</td></tr>
<tr><td>Easiest to apply
Broadest range of applicability (i.e. could be used to address cross-boundary management questions)
Quick identification of impacted agents/stakeholders (assuming reliability of groupings)
Provide a preliminary estimation of the initial fee to implement the management strategy</td><td>Does not assume displacement of effort to alternative areas
The procedure could be shared but the data cannot
Does not consider biological trends (e.g. increasing/decreasing SSB for different stocks) and also trends in different socio and bio-economic indicators</td></tr>
<tr><td colspan="2">AD-HOC</td></tr>
<tr><td>Suitable for participatory approaches
Easy to understand and to be shared with stakeholders
Allows incorporating stakeholders advices and preferences/suggestions</td><td>Displacement is estimated using some simple models or rules, without accounting for heterogeneity of fleets/segments
Lack of generality (i.e. application limited to specific case study)</td></tr>
<tr><td colspan="2">STATIC</td></tr>
<tr><td>Easy to validate
Useful for preliminary analyses, to inspect the data, and to support more complex models</td><td>Displacement of effort to alternative areas does not account for the temporal dimension (i.e. it is restricted to the comparison between patterns before and after the closure)
Lack of generality of outputs (i.e. application limited to specific case study)</td></tr>
<tr><td colspan="2">DYNAMICS</td></tr>
<tr><td>Capturing the mechanistic relationship between effort and benthos depletion
Possibility to predict the individual feedback to management strategies (fishermen decision-making, etc.)
Better suitable to capture space/time effects
Possibility to account for crowding effects and changes of catch rate
Potential accounting for complex trip decision making process along the trip</td><td>Large number of parameters, therefore large number of assumptions
Difficult fitting/validation
Computational complexity, time/pc demanding
Computer skills needed
Tries to capture human behaviour traits which are poorly understood
Potential mismatch between fine scale and data availability</td></tr>
</table>

Table 5.1.1. Strengths, Weaknesses, Opportunities & Threats (SWOT) analysis of the different approaches when identifying the cost of implementing the management options.

	Strengths	*Weaknesses*
INTERNAL (MODEL RELATED)	FLAT	
	Easiest to apply Broadest range of applicability (i.e. could be used to address cross-boundary management questions) Quick identification of impacted agents/stakeholders (assuming reliability of groupings) Provide a preliminary estimation of the initial fee to implement the management strategy	Does not assume displacement of effort to alternative areas The procedure could be shared but the data cannot Does not consider biological trends (e.g. increasing/decreasing SSB for different stocks) and also trends in different socio and bio-economic indicators
	AD-HOC	
	Suitable for participatory approaches Easy to understand and to be shared with stakeholders Allows incorporating stakeholders advices and preferences/suggestions	Displacement is estimated using some simple models or rules, without accounting for heterogeneity of fleets/segments Lack of generality (i.e. application limited to specific case study)
	STATIC	
	Easy to validate Useful for preliminary analyses, to inspect the data, and to support more complex models	Displacement of effort to alternative areas does not account for the temporal dimension (i.e. it is restricted to the comparison between patterns before and after the closure) Lack of generality of outputs (i.e. application limited to specific case study)
	DYNAMICS	
	Capturing the mechanistic relationship between effort and benthos depletion Possibility to predict the individual feedback to management strategies (fishermen decision-making, etc.) Better suitable to capture space/time effects Possibility to account for crowding effects and changes of catch rate Potential accounting for complex trip decision making process along the trip	Large number of parameters, therefore large number of assumptions Difficult fitting/validation Computational complexity, time/pc demanding Computer skills needed Tries to capture human behaviour traits which are poorly understood Potential mismatch between fine scale and data availability

5.2 Different data needed to support static/dynamic approaches and discuss the different groups of case studies (e.g. North Sea, Baltic Sea, Mediterranean Sea)

In general, dynamic approaches incorporate agent-based models aimed to capture and reproduce the strategy adopted by each agent (i.e. individual vessel or fleet segment), ultimately determining the effort pattern and the related pressures and impacts on the ecosystem. In this way, dynamic approaches are not only data-demanding but should also be calibrated to consider specific aspects of different case studies. For instance, the distance from the harbours of different fishing grounds are likely to affect the costs if the vessels perform daily trips, as in the case of most fleets operating in the Mediterranean Sea, but this relationship could be more complex or less evident in other regions. For instance, in the DG MARE Project MANTIS, the relationship between distance of fishing grounds from the harbours and fuel cost (the so-called "spatial" component of fishing costs) was assumed to be linear, but in other areas this relationship was questioned (especially when trip duration exceeds the day). Other relevant aspects could be identified, such as the diversity of catches (i.e. the number of targeted species), should go parallel with what happens at sea. The models applied for bottom otter trawl in the Mediterranean Sea are often devised to consider a large array of species, simply because simpler (or single species) models are likely to return unrealistic output if applied on spatial basis. On another hand, this potential limitation (in terms of data needed and complexity) lead to benefit in terms of addressing the effects of different management scenarios on ecosystem services and general status of the communities (including GES and targets defined within the MSFD). Various experiences (e.g. SimFish in the North Sea in Bartelings *et al.*, 2015; and DISPLACE in the North Sea or the Adriatic Sea in Bastardie *et al.* 2014, 2017) considered the reallocation of fishing effort between different gears or metiers, given that this aspect could play a relevant role in the strategy adopted by fishers in reaction to management measures. Thus, some aspects of the models, and in particular some mechanistic relationships, should be carefully formalized according to the specific characteristics of each case study.

In order to identify some approaches to assess pressure reduction associated to different scenarios, WKTRADE2 carried out some an exercise based on the optimization module of SMART (Russo *et al.*, 2019; Figure 5.2.1). SMART includes an individual-based model (IBM) predicting the allocation of the fishing effort for each vessel under different scenarios. Starting from the observed effort pattern by vessel, several scenarios can be virtually applied in order to predict the pattern resulting from the adaptation of each vessel to the new situation. Firstly, $p_{c,t,v,}$ that is the spatial (for each cell c) and temporal (for each time t) distribution of the effort for each vessel v is reconstructed using VMS data. Afterward, this distribution is modified both in space and/or time according to the selected scenario. For a generic scenario with Fisheries Restricted Area (FRA), $p_{c,t,v}$ is set to zero if c∈FRA, where FRA is the set of cells closed to fisheries. Otherwise, $p_{c,t,v}$ is set to zero if t∈B, where B is the set of times during which a temporal stop of fishing activity is set. Since it is possible to assume that the effort would simply reallocate according to the remaining distribution rescaled to the total effort, candidate configurations were obtained by multinomial sampling points when c∉FRA|t∉B from this distribution. Checking whether the associated profit is greater than the previous ones will validate this candidate configuration. If the configuration is not valid, it will be discarded and another candidate configuration will be drawn. Otherwise, $p_{c,t,v}$ is updated and the whole procedure is repeated until a convergence criterion is met. These steps are repeatedly carried out, for each vessel, in IBM optimization. When the optimization ends for all the vessels in the fleet, aggregated revenues, costs, and profit can be computed for the whole fleet.

The ‘Simple Effort Simulator’, presented at WKTRADE2, is a general R routine/script to simulate the displacement of the fishing activity resulting from the adoption of spatial management measures. The SES tool has been created starting from the SMART model 'Simulation' module, through a simplification of the actual variables used in the original model (Figure 5.2.2). The several input datasets relative to 1) the biological aspects of the fisheries, which ultimately yield the revenue’s landscape, and 2) the economic features, which adds up to constitute the cost’s structure, are assimilated into two basic informational layers, ‘Revenues’ and ‘Costs’.

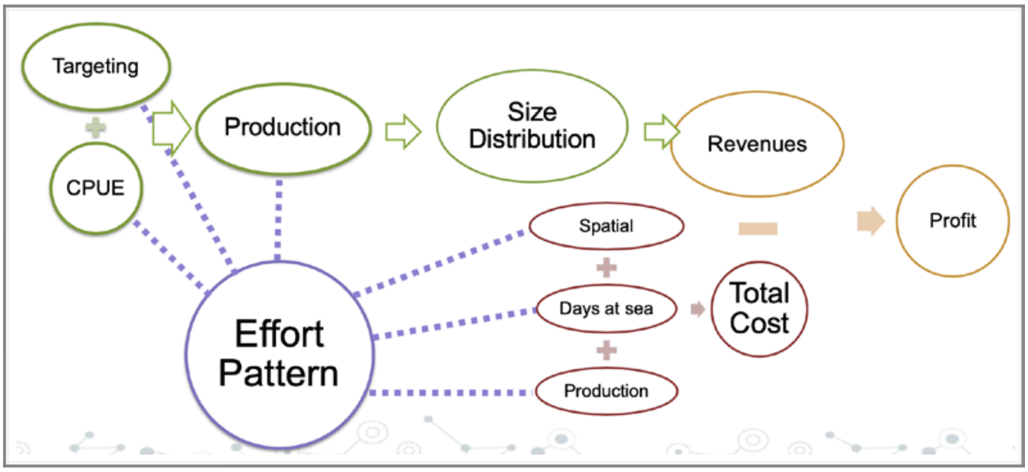


Figure 5.2.1. Original schematic description of the dataset employed in the SMART simulations.

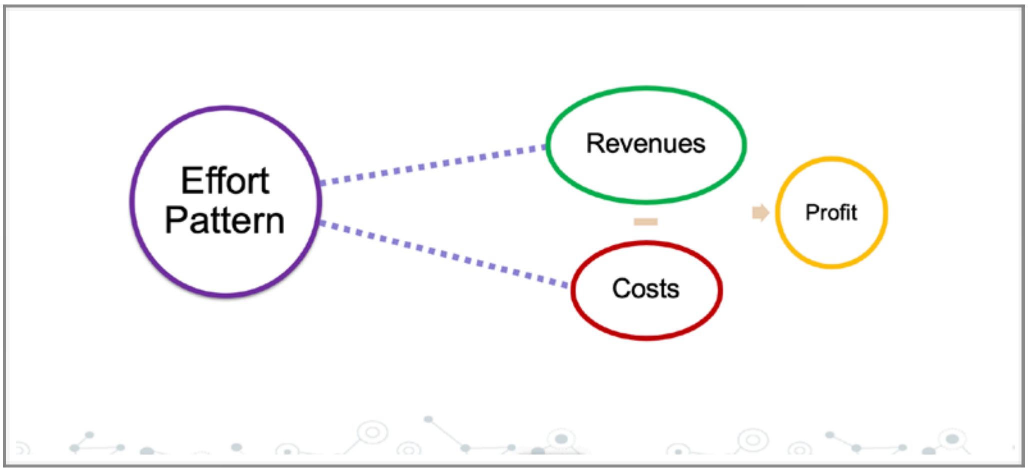


Figure 5.2.2. Simplified schematic description of the required dataset for the Simple Effort Simulator (SES) simulations.

In order to obtain a measure of performance of the fishery under an hypothetical management scenario through the forecast of a probable effort displacement, the required input of the SES tool are three informational layers, provided as numerical matrices, namely: the observed spatial distribution of effort (Effort Pattern), an estimated pattern of revenues (Revenues), and an estimated pattern of costs (Costs). The ‘Effort Pattern’ should be a matrix with individual-based records of fishing activity (i.e., hours of fishing, trawled area, number of tows, etc.) by fishing ground/grid cell. The ‘Revenues’ and ‘Costs' layers are numerical matrices that should represent the best estimable proxies of the actual yield obtainable, and expenditures to sustain, by the fishermen exerting effort into their spatial pattern of activity. The performance of the fishery is finally computed as the profit resulting from the difference between Revenues and Costs both combined with the Effort Pattern. Lastly, the determining aspect of the input setup is the definition of the area closure to address in the scenario simulation. Within the SES tool, this is a vector listing the cells to be made unavailable for fishing. The presented form of the SES tool integrates a simple procedure to automatically generate: 1) a simulated 'Environment' made of a square matrix of cells with dimension 'gridSize'; 2) an individual 'Effort Pattern' of fishing activity made of 'numbVess' number of vessels; 3) a 'Revenue' matrix; 4) a 'Costs' matrix; 5) an area to be closed. All the simulated spatial distributions are generated with and controlled by, the parameters of random normal distributions (e.g. mean and sd); (Figure 5.2.3).

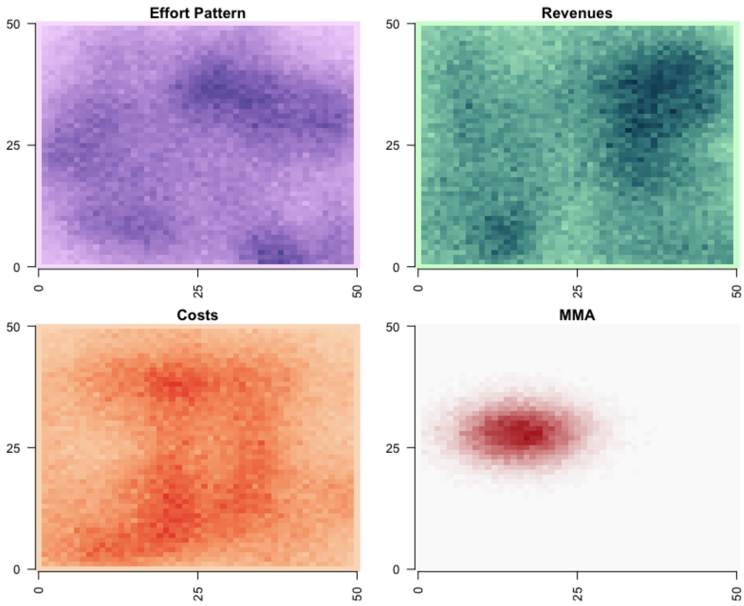


Figure 5.2.3. Visual representation of the input layers for the scenario simulation.

The evolution of the effort pattern, and the associated performance of the fishery, given by the scenario simulation performed with the SES, can be followed during the optimization through the graphical output provided. The visualised output includes four dynamic plots (Figure 5.2.4): top left) 'Vessel to optimize' time-series of the remaining number of vessels to optimise; top right) 'Effort Delta' map of the difference between the initial pattern of effort and the optimised pattern of effort; bottom left) 'Costs' time-series of the cumulated costs of the optimized pattern of effort; bottom right) 'Revenues' time-series of the cumulated revenues of the optimized pattern of effort.

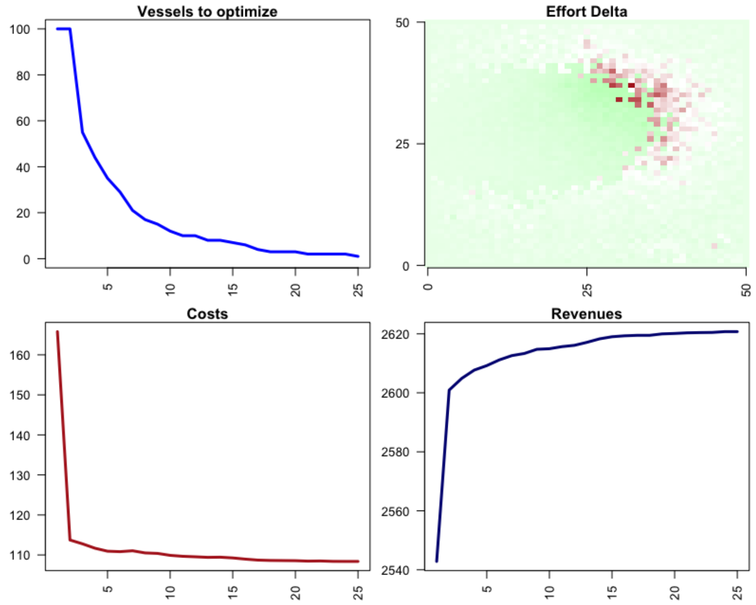


Figure 5.2.4. Screenshot of the diagnostic plot during the effort pattern optimisation.

5.3 Scenario Evaluation

5.3.1 FLAT no effort displacement

Static FLAT scenario without an effort displacement (Figure 5.3.1.1, Table 5.3.1.1). The observed effort affected by the spatial closure is lost resulting in a net reduction of the total effort equal to the sum of the effort in the closed area. The measured outcome shows a reduction of all the four computed metrics (Revenues -37%, Costs -40%, Profit -34%, Effort -38%).

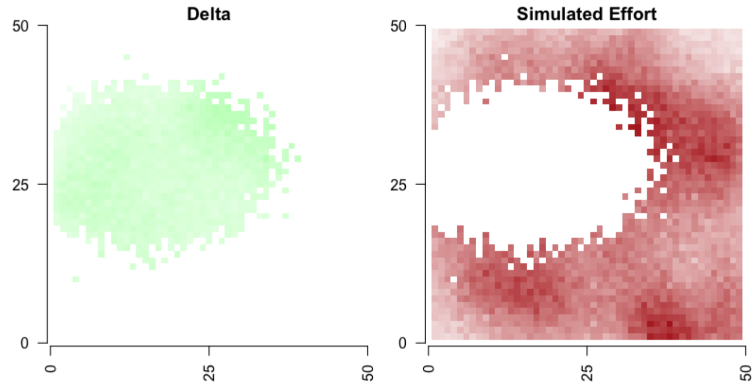


Figure 5.3.1.1. Figure of the simulated Effort Pattern (Simulated Effort, right) and the difference between observed and simulated Effort Pattern (Delta, left) with the FLAT -. no effort displacement approach.

Table 5.3.1.1. Table of the changes between the observed and simulated Effort Pattern with the FLAT - no effort displacement approach.

	observed	simulated	difference	percentage
Revenue	2542836	1606188.4	-936647.4	-36.8
Cost	1165797	695776.7	-470020.5	-40.3
Profit	1377039	910411.7	-466626.9	-33.9
Effort	227731	141433	-86298	-37.9

5.3.2 FLAT homogeneous effort displacement

Static FLAT scenario with a homogeneous effort displacement (Figure 5.3.2.1, Table 5.3.2.1). The observed effort affected by the spatial closure is spread across the open area; the sum of the effort within the closed area is divided equally among the cells in the open area. The measured outcome shows a reduction of all the computed metrics except for the total effort (Revenues -7%, Costs -12%, Profit -3%, Effort 0%).

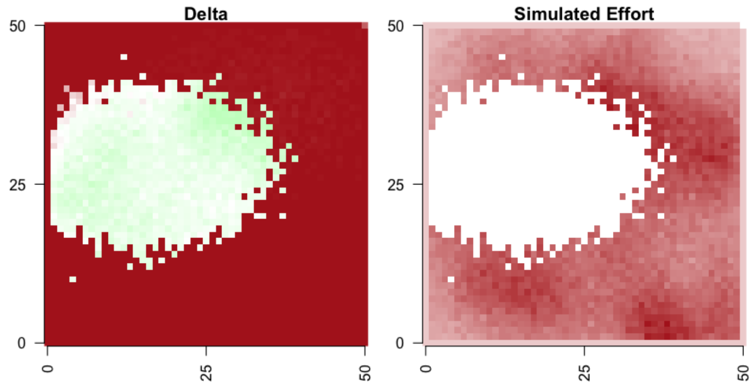


Figure 5.3.2.1. Figure of the simulated Effort Pattern (Simulated Effort, right) and the difference between observed and simulated Effort Pattern (Delta, left) with the Flat - homogeneous displacement approach.

Table 5.3.2.1. Table of the changes between the observed and simulated Effort Pattern with the Flat - homogeneous displacement approach.

	observed	simulated	difference	percentage
revenue	2542836	2367287.5	-175548.31	-6.9
cost	1165797	1030983.2	-134814.03	-11.6
profit	1377039	1336304.4	-40734.28	-3.0
effort	227731	227731.5	0	0

5.3.3 FLAT proportional to observed effort displacement

Static FLAT scenario with a proportional to observed effort displacement (Figure 5.3.3.1, Table 5.3.3.1). The observed effort affected by the spatial closure is spread across the open area, the sum of the effort within the closed area is divided proportionally to the observed values before the closure among the cells in the open area. The measured outcome shows a reduction of costs and an increase in revenues and profit (Revenues +0.2%, Costs -5%, Profit +4.5%, Effort 0%).

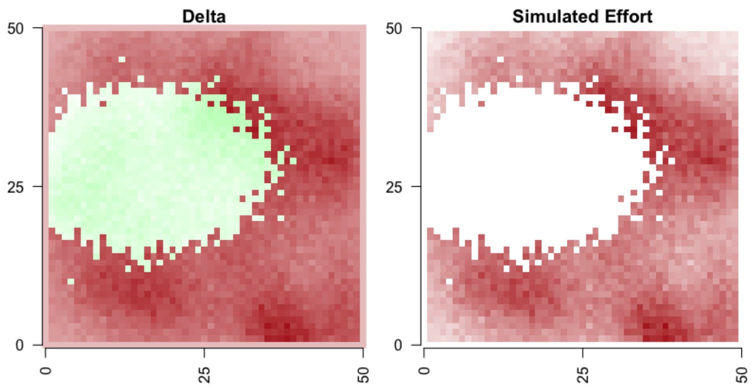


Figure 5.3.3.1. Figure of the simulated Effort Pattern (Simulated Effort, right) and the difference between observed and simulated Effort Pattern (Delta, left) with the Flat - proportional to observed effort approach.

Table 5.3.3.1. Table of the changes between the observed and simulated Effort Pattern with the Flat - proportional to observed effort approach.

	observed	*simulated*	*difference*	*percentage*
revenue	2542836	2547891.1	5055.229	+0.2
cost	1165797	1108818.9	-56978.305	-4.9
profit	1377039	1439072.2	62033.534	+4.5
effort	227731	227731	0	0

5.3.4 DYNAMIC individual based effort displacement with profit maximisation

Dynamic simple individual based effort displacement with profit maximization (Figure 5.3.4.1, Table 5.3.4.1). The simulated effort is a result of the optimization of the individual observed patterns of effort according to the modelling of a profit maximization strategy. The measured outcome shows a reduction of costs and an increase in revenues and profit (Revenues +3%, Costs -5%, Profit +9.5%, Effort 0%).

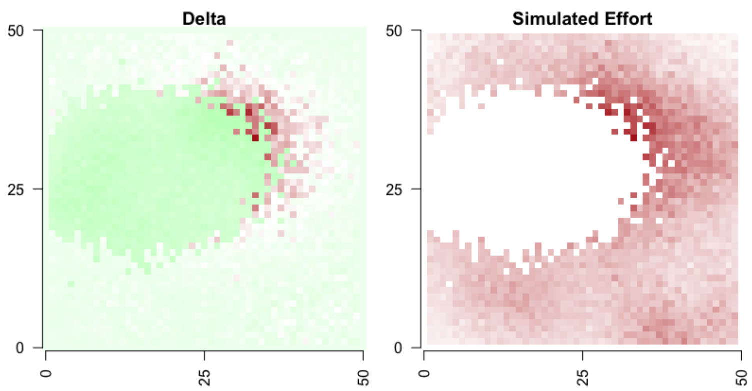


Figure 5.3.4.1. Figure of the simulated Effort Pattern (Simulated Effort, right) and the difference between observed and simulated Effort Pattern (Delta, left) with the DYNAMIC - individual based effort displacement with profit maximization approach.

Table 5.3.2.1. Table of the changes between the observed and simulated Effort Pattern with the DYNAMIC - individual based effort displacement with profit maximization approach.

	observed	*simulated*	*difference*	*percentage*
revenue	2542836	2618232	75396.3	+2.9
cost	1165797	1109920	-55877.7	-4.8
profit	1377039	1508313	131274	+9.5
effort	227731	227731	0	0

This simple exercise demonstrates that outputs from Flat or Statistical/Dynamic (SES) models could lead to remarkable differences in terms of effort displacement and therefore of predicted costs, revenues and ultimately profits.

The following figure combines the output of different modelling approaches, in terms of predicted effort displacement after the establishment of the "Pomo's Pit closure" (Figure 5.3.4.2), with an AIS-based assessment of the effective changes (Elahi *et al.*, 2018). Namely, the GAM model applied in Elahi *et al.* (2018) is used as an example of STATIC models, while the output of the DG MARE Project "MANTIS - Marine protected Areas Network Towards Sustainable fisheries in the Central Mediterranean" (http://jadran.izor.hr/mantis/index.html), obtained using SMART, and those of DISPLACE (e.g., in the INTEREG DORY project) are used as examples of DYNAMIC models.

Although the different patterns are not directly comparable due to differences in spatial resolution, modelling (e.g. fleets considered and details of implementation of rules for closures), and time-series, it is evident that the level of agreement between observed and predicted patterns largely vary. In particular, it seems that DYNAMIC models perform better in terms of their ability to capture some main trends. Apart from the reduction of the effort in the closed area, an increase of the effort (i.e. the displacement of the original effort deployed in the Pomo's Pit) is predicted by DYNAMIC models near the Vis Island, between Pomo Pit and the Dugi Otok long island, and along the Italian coast between Ancona and Giulianova. These predictions are in substantial agreement with the observed pattern.

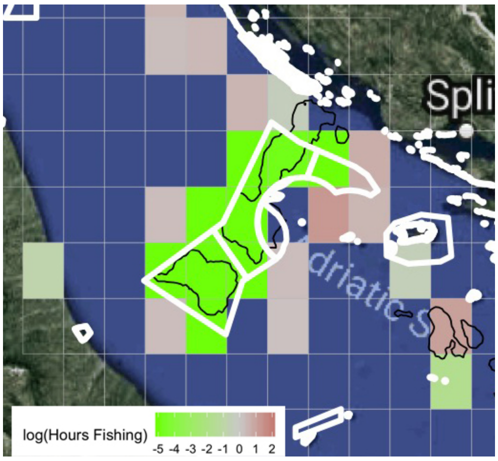
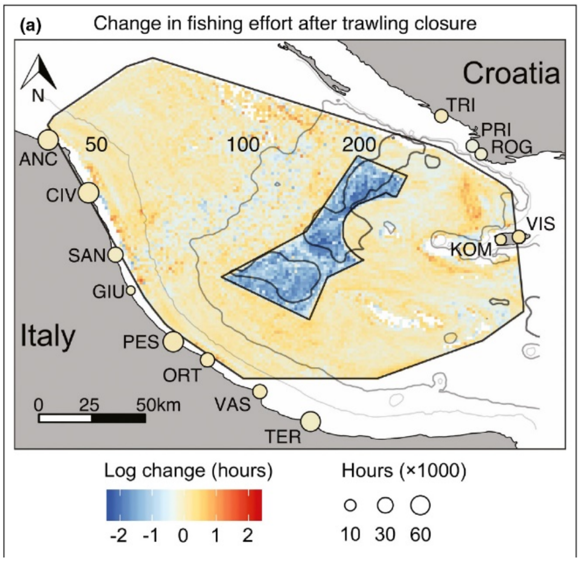
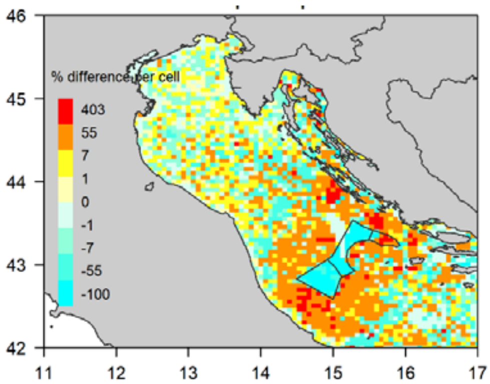
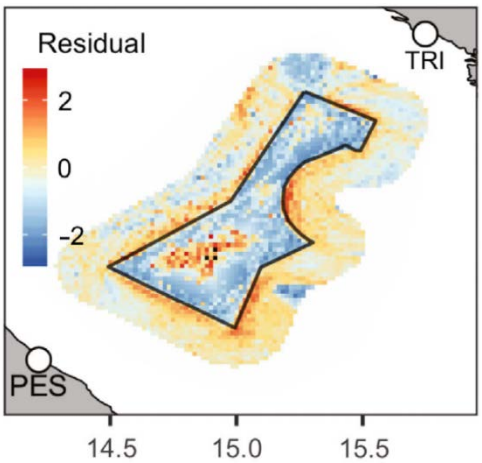
DYNAMIC MODELS	**AIS-BASED ASSESSMENT -** Figure 2 from Elahi *et al.*, 2017 (adapted). The colour gradient represents a log10 change in fishing effort; port size represents the total number of fishing hours.
SMART - Predicted change of fishing effort (in log10 scale) after the establishment of the Pomo Pit FRA, according to the output of the SMART model within the DG MARE Project MANTIS. 	
DISPLACE Adriatic – (Bastardie *et al.*, 2017) 	
STATIC MODEL – GAM (Elahi *et al.*, 2018) 	

Figure 5.3.4.2. Figure of the output of different modelling approaches.

5.3.5 Dynamic individual vessel spatial planning (DISPLACE) linked to benthos dynamics

The DISPLACE model platform and its application to the Baltic Sea ecoregion, presented at WKTRADE2, is a spatial model for simulating the movement of individual fishing vessel agents combined with an underlying spatial population dynamics model. In DISPLACE individual agents optimize their decision-making on the fly depending on their experienced catch rates on zones and the expected cost to reach the zone and return to harbours. Each vessel depletes the fish stocks individually and depending on the gear type in use. The action if the gear is also causing benthos depletion for bottom contact gears and the intensity of this depletion depend on the area swept by the specific gear informed from BENTHIS relationships. The benthos recovery occurs in-between fishing events at rates specific to the benthos groups and possibly type of habitats. The model provides a platform to also include indirect benthos killing from sediment resuspension created by the fishing gears, the commercial shipping fleet, etc.

The key aspect toward contributing to improving WKTRADE/WGFBIT analyses is that the DISPLACE benthos dynamics are initiated at start with the equilibrium assessment provided by ICES WGFBIT and the model allows stochastic projections of alternative worlds from this starting point (e.g., fleet displacement and adaptation, alternative CFP regulation including quotas, alternative fish stock productivity etc.). This contributes to approaches that allow spatial upscaling of local findings to regional scale in the perspective of anticipating management actions/plans that reduce the footprint of fishing activities or establish trade-offs between impact and economic revenue. We presented an application focusing on the identification of effective measures to reduce fisheries impacts on the seafloor: a bio-economic evaluation in the Baltic Sea. In this special case, under the auspice of EU/HELCOM Action project, we want to draw that pressure-state curves that will allow us from there to advise on the pressure level to reduce as long we know the state value we want to reach (the "good state" or GES in a MSFD context) and we know the current state. This should further allow quantifying how likely good benthos state could be achieved (per subregion) along quantifying the probable consequences on the fisheries economics (catch volume value and profits) and sustainability (FMSY in a CFP context) when implementing the spatial plans.

Preliminary outcomes (Figure 5.3.5.1) shows that reducing the fishing pressure exerted by the international Baltic fishing fleets (reduced by 5, 10, 15, 20, 25, 30% starting from the margin of the existing fishing grounds) does not lead to significant decrease in margin contribution before the 10% reduction, the fleet being able to adapt for the restriction on their grounds. A large drop is by contrast observed for reduction greater than 10%, likely due to concentrating the pressure on a narrower available space for fishing with change in catch rates. This drop is less marked however if the reduction is applied per habitat type instead of per EEZ. On the other hand, the gain in improving the relative benthos status is not clear before reducing up to 25% in the central Baltic (subdivisions 22, 24, 25) but appears already at 5% reduction in the Kattegat. Synergic effects can pop up when netters are getting restricted in Natura 2000 sites (in an attempt to minimize bycatch of marine mammals) making the fisheries more sustainable from an indirect protection effect of fish stocks.

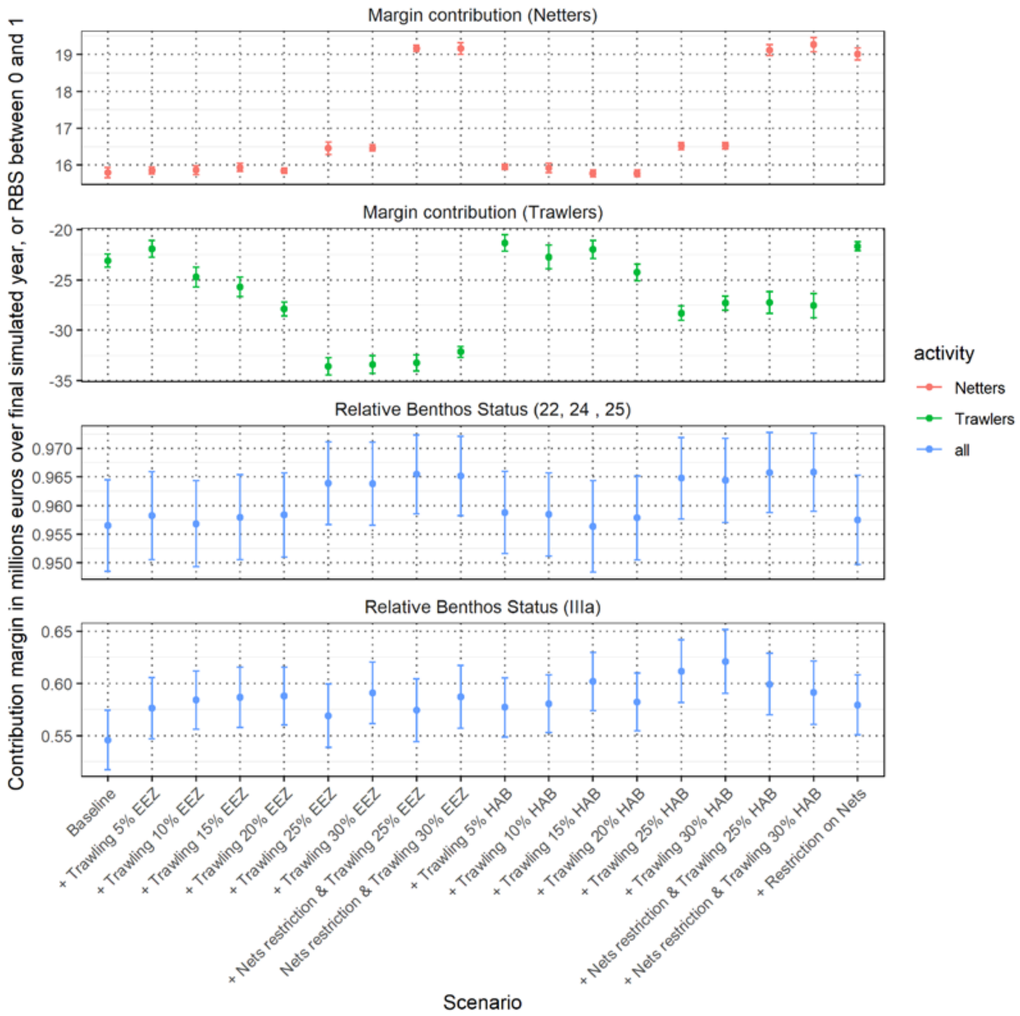


Figure 5.3.5.1. DISPLACE Baltic Sea - Simulated margin contribution and relative benthos status at the 5y simulation horizon time For Baltic Sea DISPLACE runs implementing a gradient of pressure reduction in the Baltic wide ecoregion. The reduction is applied either per EUNIS habitat type (HAB) or per country EEZ starting from the peripheral of the fishing grounds (where the lowest fishing effort deployed has been observed) in order to minimize the impact on the fisheries economics.

6 Conclusions and recommendations

Conclusions

- To improve estimates of the "value" of an area to fisheries WKTRADE2 suggests to calculate the contribution margin (income from landings minus variable costs). Two complementary approaches (disaggregation and mechanistic) to do this are presented and can be developed using the current ICES VMS and logbook data, supplemented with economic data layers. A modular workflow to integrate the variables into the assessment was presented.
- Redistribution of total revenue among individual fishers and fishers' communities will need to be considered to accurately predict displacement effects and impact evaluation on fisheries economics.
- Applying predictive modelling techniques adds to assessing a static picture (current fishing activity) because it considers displacement effects, which may elucidate increased pressure on essential fish habitats, sensitive vulnerable habitats, or previously untrawled areas.
- To better identify trade-offs between ecological, economic and social factors in WGFBIT, WKTRADE2 recommends also using integrative approaches (e.g. bio-economic models, stakeholder engagement) that account for direct linkages between fish, fisheries and benthos dynamics to address issues related to MSFD, CFP and spatial management plans in a consistent way.
- When considering the effects of displacement the contribution margin should be accounted for as the fishing closures are likely to have indirect (positive or negative) effects. For example, protecting part of the fish stocks might lead to better catch rates and therefore fuel savings, etc.
- Static models are operational and are more easily used to identify impacted fishing fleets. Dynamic modelling approaches allow for the adaptation of fishing fleets (e.g. displacement, gear modifications), potentially mitigating the estimated impact of spatial and temporal restrictions.
- Static approaches are easy to use in stakeholder processes, and can facilitate stakeholder engagement.
- Future development of static and dynamic models will need to account for the influence of other activities (e.g. closures due to wind farm) on fisheries activities.
- Running scenarios using dynamic models will indicate which areas are most valuable to fisheries after spatial management scenarios are proposed. This elicits the socio-economic valuable fisheries areas.
- WKTRADE2 focused on the spatial management scenarios so far identified by WGFBIT but the workflow can also be used to address other scenarios, e.g. technical measures aimed at reducing gear penetration depths, disturbance effects and improving selectivity, habitat credits approaches that define credits related to the sensitivity of habitat and convey credits to the fishing industry to manage either collectively or individually.

Recommendations

Based on these conclusions, WKTRADE2 informs WGFBIT on the following questions:

How to improve the current WGFBIT scenario testing on spatial restrictions?

- Listing relevant social and economic variables, it is sufficient (but necessary) to estimate the contribution margin (income from landings minus variable operating costs) per fleet-segment to assess the economic value of an area to fisheries
- Two complementary approaches: a data disaggregation approach and a mechanistic approach
- Disaggregation of economic variables on a spatial scale:
  - Variable operating costs could be deduced by screening the existing economic data gathered in EU by the Scientific, Technical and Economic Committee for Fisheries (STECF). AER (Annual economic report on European fishing fleets) data are publicly available through the JRC dissemination webpage. The group did not have access to the FDI database (Fisheries dependent information), which is likely better tailored to the request by overcoming the mismatch between resolutions of fleet economic data and effort or landings data.
  - A methodology to disaggregate costs from fleet to metier level and ICES Division is available. Fine-scale disaggregation was not achieved, because of inconsistencies between the ICES VMS data segmentation and the STECF economic data segment. Future developments could investigate this possibility when data are available at the required resolution.
- Inference of economic variables from qualified proxies
  - Approximate mechanistic computations were discussed during the workshop (e.g. R routine in Annex), but require further development as well as validation with real-life data before being used in practice.

How to deal with fleet adaptation/effort displacement in reaction to the spatial restrictions?

- Is a full dynamic model desirable?
  - WKTRADE2 recommends using integrative approaches (e.g. bio-economic models, stakeholder engagement) to assess how assumptions underlying static approaches may affect the objectives. A SWOT analysis was made to compare static, dynamic and intermediate approaches.
  - A simulation by static and dynamic approaches was compared to illustrate the differences. Ignorance of displacement effects may lead to unforeseen effects (Baum *et al.* 2003, Kaplan *et al.* 2010).
- Would 'simple' rules for effort displacement work?
  - Two methods are suggested, which are ideally used in combination.
    - Survey questionnaires, i.e. asking the fishers themselves
    - Looking at past data of location choice and inferring the factors linked to the choices. WGSFD is looking into potential drivers for effort displacement but they are lacking economic drivers. Spatial-explicit economic factors (primarily costs) are required to this end.
  - These methods should be complemented with other marine activities constraining the space available for fishing.

WKTRADE2 further requests to consider the FBIT framework as a potential case study for WGECON & WGSOCIAL to address the lack of fisheries economic expertise in current assessment frameworks.

7 References

Bartelings, H., Hamon, K. G., Berkenhagen, J., and Buisman, F. C. (2015). Bio-economic modelling for marine spatial planning application in North Sea shrimp and flatfish fisheries. *Environ. Model. Softw.* 74, 156–172. doi:10.1016/j.envsoft.2015.09.013.

Bastardie F, Nielsen JR, Andersen BS, Eigaard OR. (2013). Integrating individual trip planning in energy efficiency –Building decision tree models for Danish fisheries. Fisheries Research. 143, 119-130.

Bastardie, F., Rasmus Nielsen, J., and Miethe, T. (2014). DISPLACE: a dynamic, individual-based model for spatial fishing planning and effort displacement — integrating underlying fish population models. *Can. J. Fish. Aquat. Sci.* 71, 366–386.

Bastardie, F., S. Angelini, L. Bolognini, F. Fuga, C. Manfredi, M. Martinelli, J. R. Nielsen, A. Santojanni, G. Scarcella, and F. Grati. 2017. Spatial planning for fisheries in the Northern Adriatic: working toward viable and sustainable fishing. Ecosphere 8(2):e01696. 10.1002/ecs2.1696

Bitetto I., Malvarosa L., Spedicato M.T., Doering R. and Berkenhagen J. (2019). SECFISH: Disaggregate Variable Costs. R package version 0.1.7. https://CRAN.R-project.org/package=SECFISH

Colloca, F., Garofalo, G., Bitetto, I., Facchini, M. T., Grati, F., Martiradonna, A., Mastrantonio, G., *et al.* 2015. The Seascape of Demersal Fish Nursery Areas in the North Mediterranean Sea, a First Step Towards the Implementation of Spatial Planning for Trawl Fisheries. PLoS ONE, 10: e0119590.

EC, 2017.Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008, OJ L 157, 20.6.2017, p. 1–21

Eggleton, J. D., Depestele, J., Kenny, A. J., Bolam, S. G., and Garcia, C. 2018. How benthic habitats and bottom trawling affect trait composition in the diet of seven demersal and benthivorous fish species in the North Sea. Journal of Sea Research, 142: 132-146.

Elahi, R., Ferretti, F., Bastari, A., Cerrano, C., Colloca, F., Kowalik, J., *et al.* (2018). Leveraging vessel traffic data and a temporary fishing closure to inform marine management. *Front. Ecol. Environ.* doi:10.1002/fee.1936.

Fitzpatrick, M., Maravelias, C.D., Eigaard, O.R., Hynes, S. and Reid, D., 2017. Fisher's preferences and trade-offs between management options. Fish and fisheries, 18(5), pp.795-807.

Foley, N.S., Corless, R., Escapa, M., Fahy, F., Fernandez-Macho, J., Gabriel, S., Gonzalez, P., Hynes, S., Kalaydjian, R., Moreira, S. and Moylan, K., 2014. Developing a comparative marine socio-economic framework for the European Atlantic area. Journal of ocean and coastal economics, 2014(1), p.3.

Girardin, R., Hamon, K.G., Pinnegar, J., Poos, J.J., Thébaud, O., Tidd, A., Vermard, Y. and Marchal, P., 2017. Thirty years of fleet dynamics modelling using discrete-choice models: What have we learned?. Fish and fisheries, 18(4), pp.638-655.

Hynes, S., Gerritsen, H., Breen, B. and Johnson, M., 2016. Discrete choice modelling of fisheries with nuanced spatial information. Marine Policy, 72, pp.156-165.

Kritzer, J. P., DeLucia, M.-B., Greene, E., Shumway, C., Topolski, M. F., Thomas-Blate, J., Chiarella, L. A., *et al.* 2016. The Importance of Benthic Habitats for Coastal Fisheries. Bioscience, 66: 274-284.

McFadden, D., 1974. The measurement of urban travel demand. Journal of public economics, 3(4), pp.303-328.

Oudmaijer, S., Viool, V., Spitsbaard, K. and Kildahl Nico Nielsen, S. 2011. Study on the economic importance of activities ancillary to fishing in the EU. Report prepared for the Executive Agency for Small and Medium-sized Enterprises (EASME) and the European Commission. [Available online: https://ec.europa.eu/fisheries/study-economic-importance-activities-ancillary-fishing-eu_en]

Russo, T., D'Andrea, L., Franceschini, S., Accadia, P., Cucco, A., Garofalo, G., *et al.* (2019). Simulating the effects of alternative management measures of trawl fisheries in the Central Mediterranean Sea: application of a multi-species bio-economic modelling approach. Front. Mar. Sci. doi:doi: 10.3389/fmars.2019.00542.

Schulze, T., Schulte, K, Hamon, K. 2010. Report on economic analysis in coastal fisheries on the basis of revenue for individual profession and fishing trips. COEXIST project Deliverable D3.2 Report. 18p.

Sköld, M., Göransson, P., Jonsson, P., Bastardie, F., Blomqvist, M., Agrenius, S., Hiddink, J. G., *et al.* 2018. Effects of chronic bottom trawling on soft-seafloor macrofauna in the Kattegat. Marine Ecology Progress Series, 586: 41-55.

Smith, M.D., 2000. Spatial search and fishing location choice: methodological challenges of empirical modeling. American Journal of Agricultural Economics, 82(5), pp.1198-1206.

Scientific, Technical and Economic Committee for Fisheries (STECF) – The 2018 Annual Economic Report on the EU Fishing Fleet (STECF-18-07). Publications Office of the European Union, Luxembourg, 2018, JRC112940, ISBN 978-92-79-79390-5, doi:10.2760/56158

Train, K.E., 2009. Discrete choice methods with simulation. Cambridge University Press.

van Denderen, P. D., van Kooten, T., and Rijnsdorp, A. D. 2013. When does fishing lead to more fish? Community consequences of bottom trawl fisheries in demersal food webs. Proceedings of the Royal Society B: Biological Sciences, 280.

van Putten, I.E., Kulmala, S., Thébaud, O., Dowling, N., Hamon, K.G., Hutton, T. and Pascoe, S., 2012. Theories and behavioural drivers underlying fleet dynamics models. Fish and Fisheries, 13(2), pp.216-235.

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Annex 2: WKTRADE2 Resolution

ICES **Workshop on Tradeoffs Scenarios between the Impact on Seafloor Habitats and Provisions of catch/value** (WKTRADE2), chaired by François Bastardie, Denmark, and Jochen Depestele, Belgium, will meet at ICES Headquarters, Copenhagen, Denmark, 4–6 September 2019 to:

a) Describe the practical steps that should be considered to (better) determine the economic costs and benefits associated with bottom fishing (fisheries revenue) at fine spatial scale (preferably at the c-square resolution: 0.05° x 0.05°); (Science Plan codes: 6.6, 6.4, 3.5);

b) Demonstrate the applicability of a set of approaches to estimate fisheries revenue at local, habitat and regional scales and for different metiers (given the present data availability and cross-regional applicability, i.e. to demonstrate what can be used in WGFBIT in 2019 and 2020 to describe trade-offs); (Science Plan codes: 6.6, 6.4, 5.4);

c) Establish ways to assess effort reduction scenarios (as proposed by ICES WGFBIT) with special attention to:

   1. Spatial effort displacement (e.g. redistribution effects on benthic seafloor indicators, catch rates and fisheries revenue)
   2. Effort allocation among activities (e.g. redistribution among gear types with various selectivity and impact on the seafloor, and various operating costs).
   3. Ecosystem effects (accounting for (in)direct effects of effort reduction and displacement on benthic habitats and food webs).

   (Science Plan codes: 7.3, 6.6, 6.4)

d) Explore how to (better) incorporate social factors associated with fisheries, given the different management scenarios (e.g. redistribution effects on fishing harbor communities); (Science Plan codes: 7.6, 7.1).

Prior to the workshop, the Chairs will prepare material to address the ToRs. This group will also ensure the completion of the workshop report, and operational TAF (Transparent Assessment Framework) products for WGFBIT consideration.

ICES WKTRADE2 will report by 27 September 2019 for the attention of ACOM and SCICOM.

Supporting information

Priority	High, in response to the stepwise process of delivering guidance on sea-floor integrity for the Marine Strategy Framework Directive (MSFD). The workshop outputs will feed into ICES WGFBIT and the ongoing efforts to provide guidance on potential trade-off in the operational implementation of the MSFD.
Scientific justification	Methods for assessing seafloor impact from bottom-contacting fishing gears have been developed within ICES (ICES 2017, 2019). From an EBFM (ecosystem based fisheries management) perspective, these methods can also be used to inform managers about the interlinkages, and therefore trade-offs, between benthic impacts and the landings or revenue of the fisheries. However, an actual cost (and benefit) associated with fishing in specific locations is difficult to estimate, because it differs by metier and by other factors such as a vessel's homeport, vessel characteristics, etc. ICES

	WKTRADE2 will advise on best practices to better reflect bio-economic cost and benefit trade-offs, and, to outline progression towards potential management options (e.g. scenarios that focus on the reduction of benthic impacts). These suggestions will consider both generic applications (to all EU ecoregions), as well as more detailed regionally specific applications. ICES WKTRADE2 will use state of the art modelling approaches of key dynamics and parameters. Beyond methodological developments towards a robust fishery-benthic impact trade-off assessment, we envision the products of this WK to supplement the WGFBIT trade-off outcomes with an assessment grounded on economic and social factors. As part of the WK, effort redistribution scenarios will inform where the redistribution of fishing activity will likely occur under different effort reduction scenarios proposed as test cases by ICES WGFBIT (see below). These outputs will provide information on the scale of fisheries economic and benthic impact tradeoffs. The Greater North Sea, Baltic Sea, or Celtic Sea ecoregions are suggested as first case study areas given the wealth of data and approaches already available in these regions. It is proposed that timing of WKTRADE2 is such that it ensures that assessment outcomes resulting from the tested scenarios are available to WGFBIT (October 2019). Effort reduction scenarios The impact assessment framework developed within ICES WGFBIT for MSFD-D6 is an overall assessment of benthic status supplemented by the exploration of alternative management options to improve GES by ecoregion or national jurisdictions. In the current draft advice produced by ICES WGFBIT, selected scenarios are explored in order to reduce the footprint of human activities and establish trade-offs between impact and economic revenue. All these scenarios apply a 10% reduction in effort, but in 5 different ways: Reduce the effort of each metier in each spatial cell by 10% Close c-squares to fisheries, starting at the lowest effort c-squares, until 10% of effort has been removed Identical to 2. but where effort of each metier, rather than total effort, is reduced by 10% Identical to 2. but where effort in each habitat, rather than total effort, is reduced by 10% Identical to 2. but where effort in each EEZ, rather than total effort, is reduced by 10% The first variant represents the simplest translation of a management measure into a pressure change. It is somewhat naive, but serves as a good comparison nonetheless. Variants 2 to 4 represent different priorities and strategies in management implementation. In variant 2. the emphasis is on maximally increasing the unfished area while minimizing the loss of core fishing grounds. Variant 3. is identical but includes an ‘equal loss’ principle across metiers – the reduction in fishing effort is required for each metier. Variant 4. captures an important element of the MSFD, the goal of reaching good environmental status in each habitat. Variant 5, rather than representing a specific policy priority, is used to study the effect of national, rather than regional, implementation of the example management measure.

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

Annex 3: WKTRADE2 agenda

WEDNESDAY 4 SEPTEMBER (9:00 TO 18:00)

<table>
<tr><td>9:00-09:30 Plenary</td><td>Welcoming and housekeeping</td></tr>
<tr><td>09:30-10:30 Plenary</td><td>Presentation on the FBIT / TG SEABED framework (Sebastian Valanko, ICES)
Scientific underpinning of ICES advisory role
Presentation of WGFBIT work and expectation in relation to effort reduction scenarios?
Presentation of the ToRs a, b, c & d (Jochen Depestele, ILVO)
Presentation on the potential use of Github (François Bastardie, DTU)</td></tr>
<tr><td>10:30 – 12:00</td><td>Presentations from individual participants (~10 min)
ToR a & b & d
Presentation of WGSFD work (Webex talk, Roi Martinez, Cefas)
Presentation on a potential additional variable for ToR (a) using JRC Primary Production Index (work by Jean-Noel Druon, presented by François Bastardie)
Presentation 1 on SECFISH (Loretta Malvarosa, NISEA)
Presentation 2 on SECFISH (Jörg Berkenhagen, Thünen-Institut)
Mapping ecosystem goods and services valuation and assessing environmental risk with reference to fisheries in the North Atlantic basin as a prerequisite for the development of the ATLAS project trade-off scenarios' (Danny Norton and Oisin Callery, NUI Galway)</td></tr>
<tr><td>12:00-13:00 Plenary</td><td>Presentations from individual participants (~10 min)
Tor c - STATIC APPROACH:
Gross Value Added spatial disaggregation approach: Dogger Bank Case study (Katell Hamon, LEI)
The ISLA approach (Torsten Schultze, Thünen-institut)
Tor c - DYNAMIC APPROACH
Long-term Bio-economic assessment using SIMFISH (Katell Hamon, LEI)
SMART model + MANTIS project (Tommaso Russo, Universitá di Roma)
DISPLACE model (François)</td></tr>
<tr><td>13:00 – 14:00</td><td>Lunch</td></tr>
<tr><td>14:30-17:00 Subgroups</td><td>Group split per ToRs</td></tr>
<tr><td>17:00-18:00 Plenary</td><td>Recap of the day (TOR leads, François/Jochen)</td></tr>
<tr><td>18:30</td><td>ICE breaker</td></tr>
</table>

THURSDAY 5 SEPTEMBER (9:00 TO 18:00)

9:00-9:15	Presentation on Statistical methods implemented in the SECFISH R tool (Isabella Bitetto, COISPA)
9:15-9:30	Effort simulator (Lorenzo D'Andrea, , Universitá di Roma)
9:30-11:30 Subgroups	subgroup work per ToR
11:30-12:30 Plenary	1st subgroup report on ToRs (TOR leads)
13:30-18:00 Subgroups	subgroup work per ToR

FRIDAY 6 SEPTEMBER (9:00 TO 15:00)

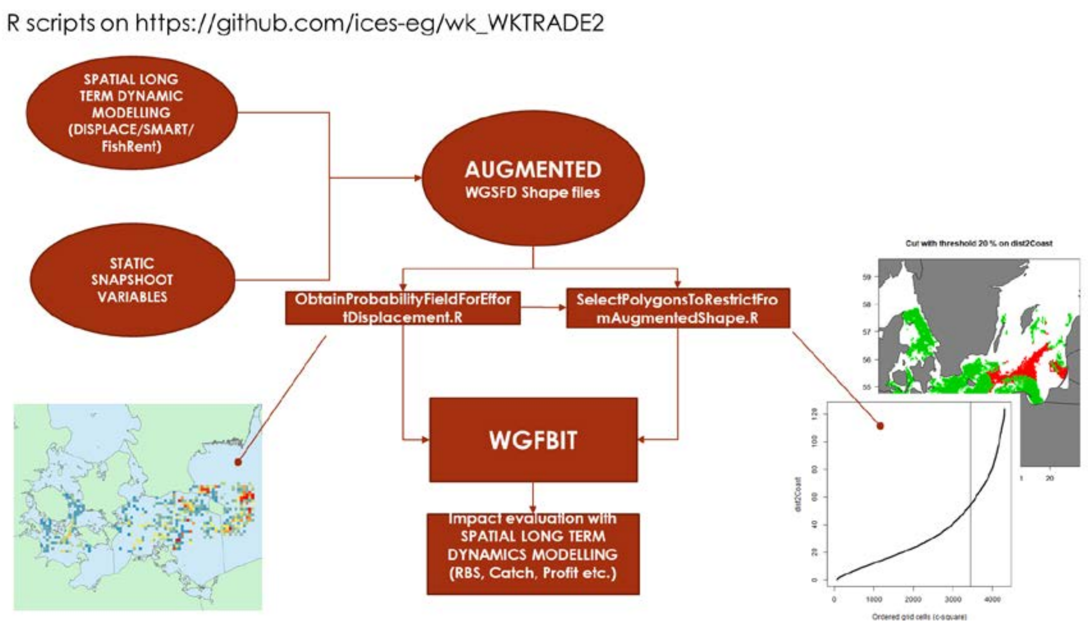
9:00-10:00 Plenary	2nd subgroups report on ToRs (TOR leads)
10:00- 12:30 Subgroups	Finalizing report writing per ToR
13:30 – 15:00 Plenary	Recap of the WK work, Discussion & Final remarks: • Output for WGFBIT (François/Jochen) • Possible follow-up? (Sebastian, ICES)

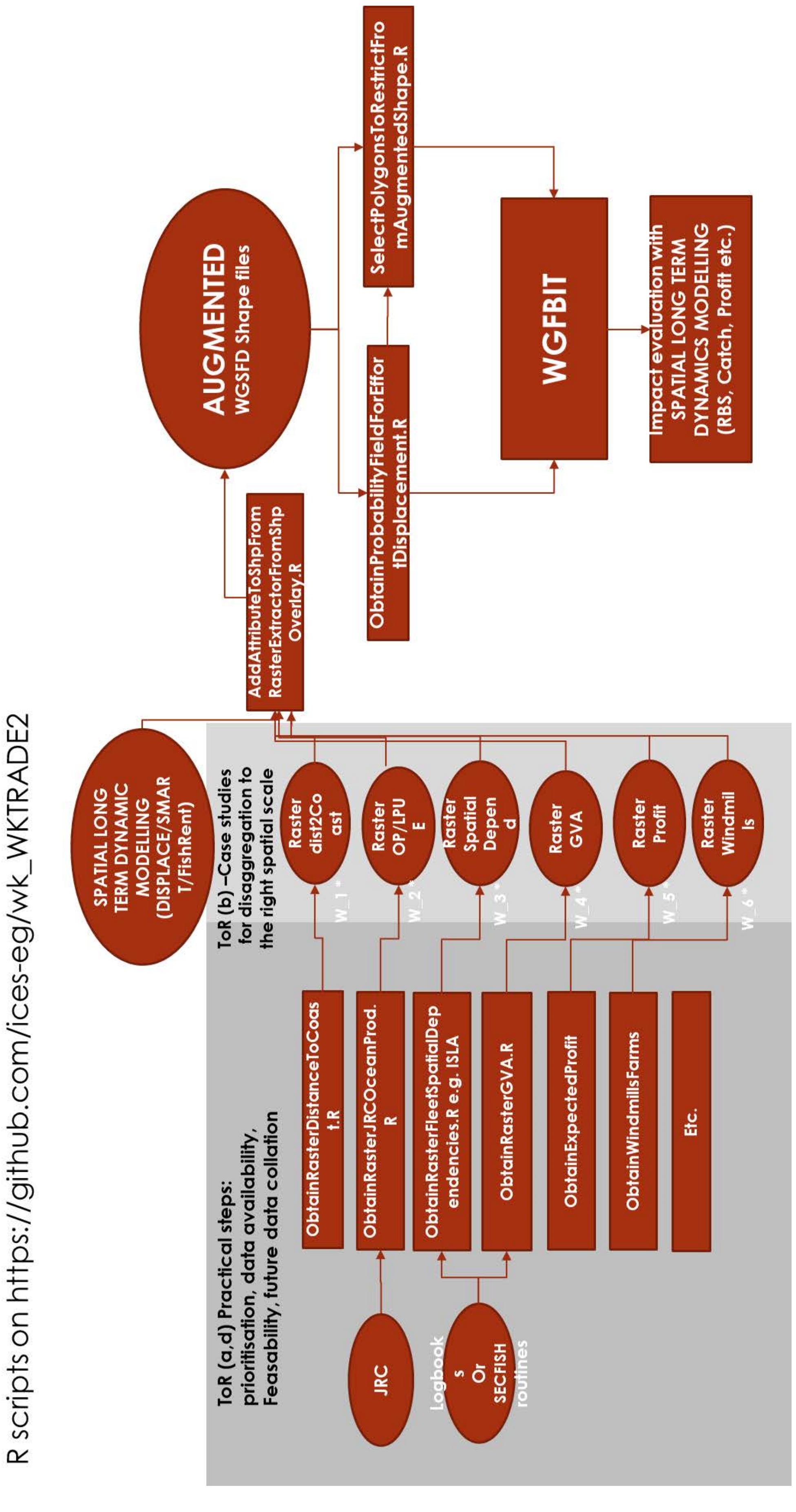
Annex 4: WKTRADE2 workflow in R

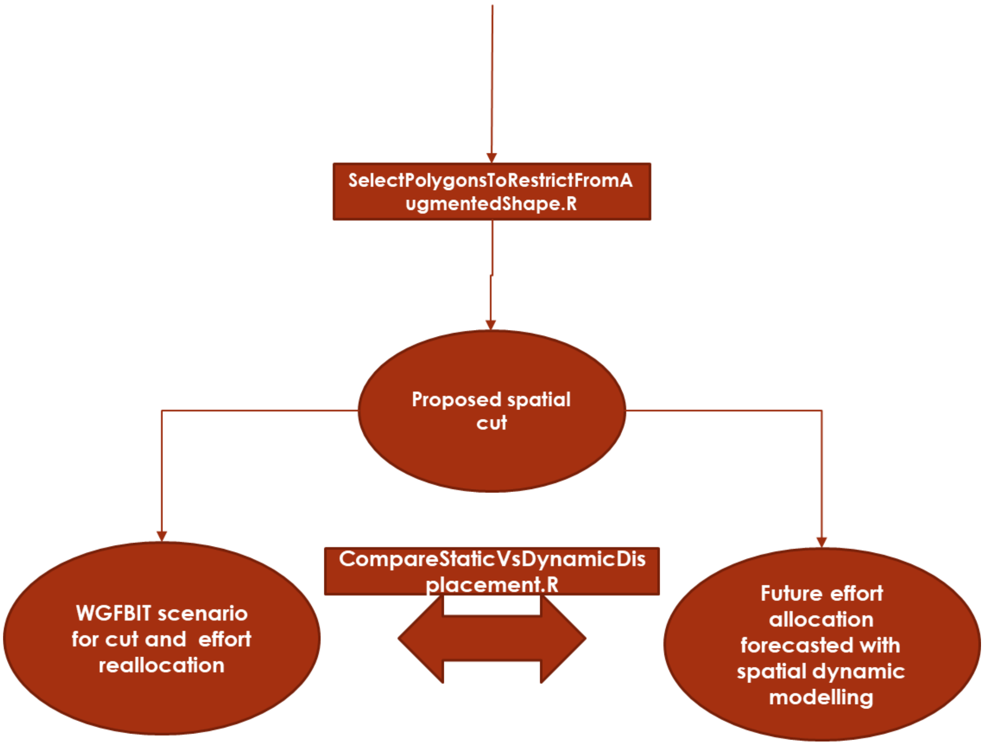
An illustrative workflow in R programming is proposed at https://github.com/ices-eg/wk_WKTRADE2 to:

- obtain a spatial layers for expected profit deduced by disaggregating the AER data per STECF transversal fleet-segment to spatial c-square
- obtain various spatial layers (e.g. for expected profit) deduced by simple mechanistic assumptions
- obtain probability fields for most likely displacement (this step would require weighting: factors for the drivers of fishermen decision making; could be elicited developing statistical RUM, or alternatively, ask stakeholders with questionnaire surveys)
- select polygons for fishing pressure displacement that could feed into WGFBIT scenario-testing

The overall structure of the workflow and the link to WKTRADE 2 issue is given in the following diagrams:




R scripts on https://github.com/ices-eg/wk_WKTRADE2
ToR (a,d) Practical steps: prioritisation, data availability, Feasability, future data collation
JRC
Logbooks Or SECFISH routines
ObtainRasterDistanceToCoast.R
ObtainRasterJRCOceanProd.R
ObtainRasterFleetSpatialDependencies.R e.g. ISLA
ObtainRasterGVA.R
ObtainExpectedProfit
ObtainWindmillsFarms
Etc.
ToR (b) –Case studies for disaggregation to the right spatial scale
Raster dist2Coast
Raster OP/LPUE
Raster Spatial Depend
Raster GVA
Raster Profit
Raster Windmills
W_1 *
W_2 *
W_3 *
W_4 *
W_5 *
W_6 *
SPATIAL LONG TERM DYNAMIC MODELLING (DISPLACE/SMART/FishRent)
AddAttributeToShpFromRasterExtractorFromShpOverlay.R
AUGMENTED WGSFD Shape files
ObtainProbabilityFieldForEffortDisplacement.R
SelectPolygonsToRestrictFromAugmentedShape.R
WGFBIT
Impact evaluation with SPATIAL LONG TERM DYNAMICS MODELLING (RBS, Catch, Profit etc.)


SelectPolygonsToRestrictFromAugmentedShape.R
Proposed spatial cut
WGFBIT scenario for cut and effort reallocation
CompareStaticVsDynamicDisplacement.R
Future effort allocation forecasted with spatial dynamic modelling

Annex 5: Summary of presentations

Presentation on the WGSFD work (Roi Martinez, Cefas)

The presentation links to Section 5.2.3 of the WKTRADE2 report.

Satellite-based assessment of marine food web productivity in European Seas (Ocean Productivity index for Fish- OPFish); (Jean-Noel Druon *et al.*, JRC)

The difficult balance between fishing effort and available resource needs to be found to reach sustainability. This balance is complex because it primarily depends on highly variable spatial and temporal processes, such as prey availability, recruitment, fish and vessel movements, all depending on climatic conditions. We propose here to compare the landings per unit effort (LPUE) estimated from VMS (Vessel Monitoring System) and logbooks data (ICES Working Group on Spatial Fisheries Data - WGSFD) with an estimate of the ocean productivity available to fish to evaluate regional and temporal discrepancies of the suitable fishing capacity across the North-East Atlantic area. The resolution of fisheries data is at 0.05-degree and annual from 2009 to 2016. Mobile bottom gears (bottom otter, demersal seine and beam trawl) were selected and aggregated while dredges were excluded as the shell weight of mollusks would have likely induced a large bias in the overall biomass estimate. The satellite-derived Ocean Productivity index for Fish (OPFish) estimates the potential production of high tropic level communities (fish). The OPFish uses the daily detection of productive oceanic features from ocean colour satellite sensors at 0.0417-degree resolution (about 4.5 km) as a proxy for food availability to fish populations. These productive features, such as eddies, were shown to attract fish and top predators (Druon *et al.* 2017, 2016, 2015, 2012) as they are active long enough (from weeks to months) to allow the development of mesozooplankton populations (Druon *et al.* 2019). Correlation peaks between demersal LPUEs and OPFish were found for OPFish integration time from forteen to twenty months. The integration time represents the mean lifetime of catches, therefore the shorter the smaller the fish. For example, the maximum correlation found using the scientific bottom trawling data (DATRAS in the NE Atlantic and MEDITS in the Mediterranean Sea) was seventeen and six months respectively with mean fish weight ten-fold higher in the former area. The overall Spearman's r found between OPFish (14 months) and the annual ICES-WGSFD data at 0.05 degree resolution was found to be of 0.32 for areas down to 500 m deep and 0.44 for areas restricted to 200 m deep. These correlation levels are notably affected by overfishing, the latter weakening the link between potential (OPFish) and effective fish productivity. The central and northern North Sea were shown to be the least areas subject to overfishing according to the comparison with the potential productivity, noting however that a disaggregation by main gear needs to be done to provide a more robust analysis. The provision of catches instead of landings would also reinforce the comparison with the potential productivity, which will progressively occur with the implementation of the discard ban. The results show that a 30% reduction of fishing effort (e.g. southern North Sea) led to an increase in landings and LPUE in the same proportion. This spatial index of productivity useful for fish shall be used to adapt the fishing effort to the local available resource accounting for the environmental effect on fish productivity. See full references here: https://fishreg.jrc.ec.europa.eu/web/fish-habitat/publications-and-press-release

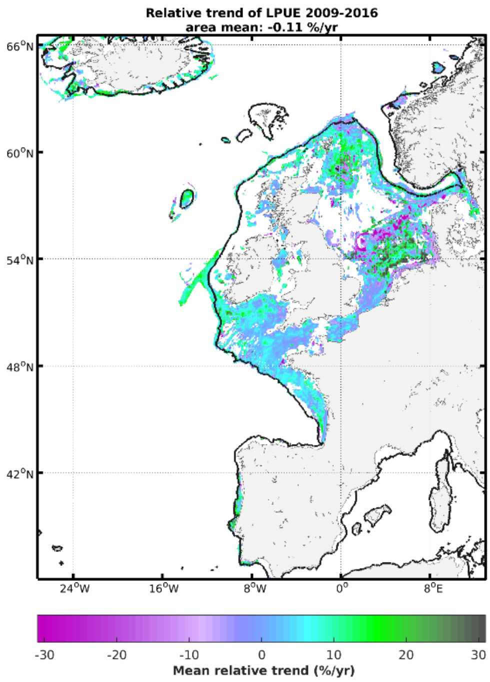


Figure OPFish. Relative trend of Landing Per Unit Effort for bottom contact gears deduced from WGSFD data.

The Italian experience in the disaggregation of costs – (Loretta Malvarosa, NISEA)

The presentation is focused on the results of the SECFISH project proposing approaches for cost data disaggregation. The SECFISH approach has origins from two DCF workshops (Hamburg, 2011 and Malta, 2012), whose main aim was to develop a dataset for the analysis of relations between vessel and métier data to disaggregate costs data at geographical, temporal and activity level. WP3 of SECFISH proposes a more sophisticated approach, i.e. using only vessel data showing a prevalent metier and including the metier as explanatory variable. It is based on three main steps: 1) exploratory analysis on data, potential outliers and linear regressions; 2) application of a Generalized Linear Model (GLM); 3) a disaggregation tool (including a consistency check). The SECFISH approach was tested on Italian data (519 vessels and 6,747 associated "trips" over 2014-2016). As the GLM run on Italian data indicated more than one segment with a significant metier influence the disaggregation step was tested only on Italian data, applying official data on costs by segments (AER) and effort by metier (FDI) the coefficients derived from the GLM. The first results from the consistency check allowed to better refine the tool by including hours*kW as explicative variable. The main conclusions derived from the test are that: a) the dataset should be large enough and representative of official data, in terms of distribution of the main explicative variable (e.g. effort) by metier, as this can bias results of disaggregation; b) the importance of properly define the threshold defining the metier to be included in the GLM and, hence, in the disaggregation step; c) for some fleet segments the relation between some variable costs and effort is not significant: a deeper analysis at a lower geographical scale could be beneficial in terms of meaningfulness of the results.

On the cost of fishing – (Jörg Berkenhagen, Thünen Institut)

WKTRADE2 was asked to provide an approach to estimate profit of fishing at high spatial resolution in order to support the work of FBIT. It is suggested to use high resolution effort and landings data to estimate cost at the same resolution. A comprehensive source of fleet economic data is the Annual Economic Report (AER) of fleet economic data as published by the EU COM. The report provides data on effort and landings at the spatial resolution of ICES areas and annual cost data per fleet segment.

Variable cost are likely to be correlated with landings or effort data. Crew cost are usually correlated with the value of landings. Fuel cost, repair cost and other variable cost are usually correlated with kW-days.

If the cost structure within a fleet segment can be regarded independent of area and gear used, the cost of fishing can be estimated as quotient of the cost type and the correlated variable. However, there is evidence that the cost structure also depends on the type of activity of a vessel. In order to address this problem a GLM approach was developed in the Secfish project.

Statistical methods implemented in SECFISH R package (Isabella Bitetto, COISPA)

The relevance of the SECFISH WP3 in addressing the incompatibility between biological data, collected by métier, and socio-economic data, collected by fleet segment was firstly illustrated, highlighting the subsequent difficulties of using both datasets for bio-economic modelling without strong assumptions. The main objectives of SECFISH was to define a methodology to disaggregate the variable costs (fuel, maintenance, other and labour costs) from the fleet segment level to the métier level. The functions developed are aimed at carrying out 2 phases: **Phase 1**: creation of a data frame associating a prevant metier to each vessel; exploratory analysis to test the following simple linear correlation: Fuel consumption/costs versus fishing activity (days at sea*kw or fishing hours);Labour costs versus revenues/ revenues minus total variable costs/ revenues minus fuel costs/ fishing activity; Maintenance costs versus fishing activity; Other variable costs versus fishing activity. GLM are then used to detect the presence of the significant influence of the metier on the cost structure. **Phase 2**: Derivation of the coefficients for disaggregation of the costs and consistency checks of the disaggregated costs. The SECFISH methodology and tool was applied so far to Italy, Germany, Belgium, Netherland and Finland fleets (described in SECFISH deliverable 3.2). Moreover, during the PGECON meeting 2019 a training session was organised on SECFISH scripts. Further explorations and application to **passive gears** and the role of the **fishing zone** on the costs structure would allow to identify areas of improvements and eventually of generalization.The application of the SECFISH tool on the fishing zone would answer to **WGBFIT** input about the need of an estimate of the "**spatial cost of fishing"**. SECFISH package was recently published on R Cran, at: https://CRAN.R-project.org/package=SECFISH, making the developed tool more easily applicable to other case studies.

Mapping ecosystem goods and services valuation and assessing environmental risk with reference to fisheries in the North Atlantic basin as a prerequisite for the development of the ATLAS project trade-off scenarios (Oisín Callery[2], Daniel Norton[3], Anthony Grehan[2,3], Stephen Hynes[3]; [2]School of Natural Sciences, NUI Galway, [3]SEMRU (Socio-Economic Marine Research Unit) and Whitaker Institute, NUI Galway)

Despite their seemingly remote nature, deep sea benthic habitats generate ecosystem services that provide benefits to society. Examples of these ecosystem services include provisioning ecosystem services such as fisheries, regulating ecosystem services such as nutrient cycling and maintenance of biodiversity and cultural ecosystems such as existence value. Using nine EU–ATLAS project[2] case studies located around the NE Atlantic, a qualitative assessment that involved mapping the level of twelve ecosystem services generated by deep sea benthic habitats was undertaken using a value transfer approach. In order to examine the spatial trade-offs between two of these ecosystem services, food provision) and biodiversity more detailed mapping approaches were developed. The food ecosystem service was measured using fisheries landing data for 43 deep water species. This landings data was available at a coarse scale (0.5° latitude by 1.0° longitude) from the EU STECF database but fishing effort derived from Global Fisheries Watch[3] AIS data was used to determine fishing activity at a finer scale (0.1° latitude by 0.1° longitude). The biodiversity ecosystem service was assessed by mapping the modelled distribution of six deep-sea vulnerable marine ecosystem indicator species. Interactions between the fisheries and biodiversity ecosystem services may be a cause of conflict and could lower the overall level of ecosystem services generated causing a net welfare loss to society. By mapping these and other ecosystem services, decision and policymakers may weight up the costs and benefits in such trade-off scenarios.

Static analysis of area closures (Katell Hamon, Wageningen Economic Research)

At sea, the international importance of Natura 2000 areas for fishing activities must be assessed before those areas can be closed for protection. Over the years, European researchers have developed methods and common data format that allow the extraction of area specific information for all countries. This is possible because of the standardization of VMS and log-book data.

This presentation focused on the overview of the international fishing activities on the Dogger Bank collected and compiled by Wageningen Research in 2017. Based on a common R script ran by the researchers from national institutes on their own data. The past effort, landings and value of landings in the areas to be closed were extracted by gear and country. The gross value added (GVA) was then estimated based on a factor GVA/value of landings calculated with DCF data from the annual economic report on the fleet level per year.

This method give an overview of the total disturbance of closure per country and gear type. In addition, individual stress analysis is done to give an insight to the repartition of the potential loss among fishing vessels.

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[2] www.atlas-eu.org

[3] globalfishingwatch.org

Individual Stress Level Analyses (ISLA) (Torsten Schulze, Thünen Institute)

Individual Stress Level Analyses (ISLA) comprises the small scale estimation of fishing effort from commercial fisheries data (TACSAT2 [vms-data], EFLALO2 [logbook-, landings- and fleet register-data). By estimating the revenue and potential loss per individual vessel from future area closures for the fisheries (e.g. wind farms or nature conservation sites), the stress per vessel can be aggregated to 'stress level' profiles of national fleets (Figure isla1), coastal regions or harbours (Figure isla2). Individual stress level is defined as the percentage of the total revenues of a vessel which would get lost if an area will be closed for fishing in future. In ISLA, "Loss" is the value of revenues gained in a specific area in the past being closed in future. Revenues might be gained in alternative fishing areas. However, ISLA does not account for displacement, crowding effects, increased cost for longer steaming distances nor for potential spill over effects from closed (managed) areas.

The output figures can easily be communicated to decision makers and other stakeholders to inform about the potential outcome of management options. ISLA allows for analysing sensitive industry data and communication of results in an anonymous way, enabling a discussion in the public. Scenarios based on spatial management (exclusion or restriction of gears in certain areas) can be tested. ISLA is implemented in R, using vms-tools functions. Due to confidentially issues of the data, currently the code needs be run by national experts. The aggregated and anonymized output can then be shared. Needed input: TACSAT2, EFLALO2, shapes of managed areas, information on management (gears, times of management applied [month, season]). For more information, see Coexist Deliverable 3.2 (Schulze *et al.* 2010: Report on economic analysis in coastal fisheries on the basis of revenue for individual profession and fishing trips). www.coexistproject.eu

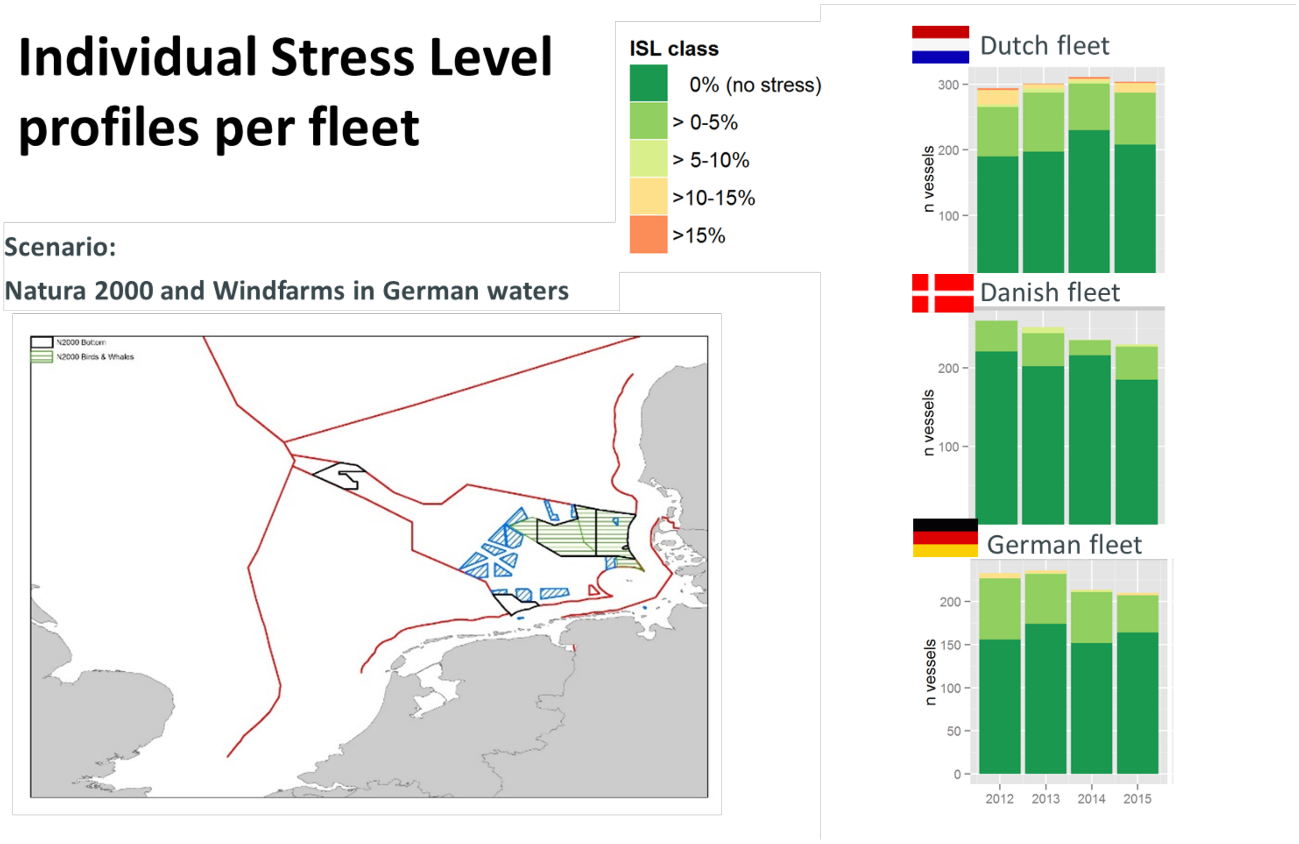

Figure 1: Test of a future "Natura 2000 and Windfarm in the German waters" Scenario. Individual Stress Level profiles of the Dutch, Danish and the German fleet assuming the effort distribution of the year 2012 to 2015.

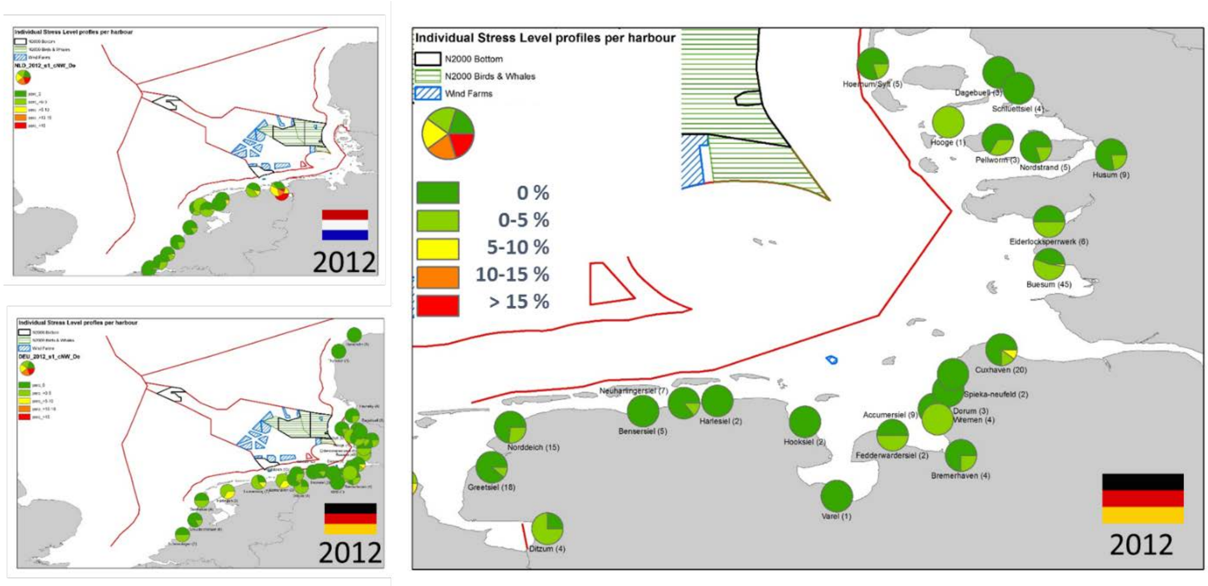

Figure 2: Test of a future "Natura 2000 and Windfarms in the German waters" scenario. Individual Stress Level profiles of harbour communities of the Dutch and the German fleet assuming the effort distribution of the year 2012.

SIMFISH dynamic bioeconomic model for area closures (Katell Hamon, Wageningen Economic Research)

SIMFISH is a multi-fleet, multi-species, spatially explicit bio-economic model. It combines population dynamics (age-structured or global models) and fleet dynamics per fleet at the metier level. The model can work in a flexible way, spatially or not depending on the data used. The minimum fleet data requirement are at the level collected in the EU for the DCF, in addition, if needed, catch, effort and steaming time can be given per area to use the spatial capabilities of the model. The model assumes a profit optimizing behaviour constrained by previous activities (a process often called inertia in models). This means that the fleets will seek to maximise their annual profit while adapting their activity (metier or spatial distribution of effort).

The model can be used to evaluate the impact of marine spatial planning, namely area closures, on the fleets by limiting their access to the biomass of the areas to be closed. In fisheries where fleets travel long distances, fish on wide areas and stocks are mobile, the estimated impact of closures is low. Indeed, in those cases the spatial and temporal resolutions might not be fine enough to capture the difference in substrates and abundance within areas (the distribution of fish stocks within an area is assumed uniform). While this type of models is useful to assess changes in fishing pattern, it underestimates the impact of closures as information sharing is assumed to be perfect (if one vessel has experience in one area, all vessels will know exactly what to expect there), crowding effect is not taken into account (the increase of density of vessels in available fishing ground may impact not only the choices but also the resulting catch rates) and it relies on fine scale biological data (species distribution at age per area) that is not always available. These dynamic approaches have to be coupled with static analysis of the past fishing patterns.

SMART model + MANTIS project (Tommaso Russo, Universitá di Roma)

We presented a spatially-explicit multi-species bio-economic modelling approach, namely SMART, applied within the DGmare project MANTIS (Marine protected Areas Network Towards Sustainable fisheries in the Central Mediterranean) to two case studies (Central Mediterranean Sea and Adriatic Sea) to assess the potential effects of different trawl fisheries management scenarios on the demersal resources. The approach combines multiple modelling components, integrating the best available sets of spatial data about catches and stocks, fishing footprint from VMS and economic parameters in order to describe the relationships between fishing effort pattern and impacts on resources and socio-economic consequences. Moreover, SMART takes into account the bi-directional connectivity between spawning and nurseries areas of target species, embedding the outcomes of a larvae transport Lagrangian model and of an empirical model of fish migration. Finally, population dynamics and trophic relationships are considered using a MICE (Models of Intermediate Complexity) approach. SMART simulates the fishing effort reallocation resulting from the introduction of different management scenarios. Specifically, SMART was applied to evaluate the potential benefits of different management approaches of the trawl fisheries targeting demersal stocks. The simulated management scenarios included both reductions of the fishing capacity and/or effort, different sets of temporal fishing closures and spatial fishing closures, including scenarios defined engaging fishers. Results showed that both temporal and spatial closures are expected to determine a significant improvement in the exploitation pattern for all the species, ultimately leading to the substantial recovery of spawning stock biomass for the stocks.

Effort simulator (Lorenzo D’Andrea, , Universitá di Roma)

The evaluation of the effects determined by the adoption of a spatial management measure can be accomplished through several modelling approaches (e.g. static vs dynamic and/or simple vs complex). In this presentation it is shown an example of how it is possible to forecast the effort displacement with a simple, dynamic, and individual-based effort simulator, implemented as an R script, having a profit maximization strategy. The simulator tool, presented at the WKTRADE2, has been created starting from the SMART 'Simulation' module, through a simplification of the actual variables used in the original model. The several input dataset relative to 1) the biological aspects of the fisheries, which ultimately yield the revenue’s landscape, and 2) the economic features, which adds up to constitute the cost’s structure, are assimilated into two basic informational layers, ‘Revenues’ and ‘Costs’. The tool provides a way to follow in real-time the evolution of the effort pattern, and the associated performance of the fishery through the graphical output provided. The visualised output includes four dynamic plots: the remaining number of vessels to optimise; a map of the difference between the initial pattern of effort and the optimised pattern of effort; the cumulated costs of the optimized pattern of effort; and the cumulated revenues of the optimized pattern of effort.

Bioeconomic DISPLACE platform (Francois Bastardie, DTU-Aqua)

DISPLACE is a spatial multi-agents bioeconomic model combined to spatial population dynamics and other activities. The aim is to support achieving economically viable, profitable fisheries. The model is accounting for real-case individual footprints and using best available fisheries-related science delivered by ICES. (such as VMS-logbooks coupled data, specific depletion effect from different gear types, etc.). In the context of evaluating the effect of fishing impacting the seafloor integrity the platform is to host ongoing development: dynamic coupling with fine-resolved predictions of fish abundance fields; dynamic coupling with benthos dynamics. The key aspect in contributing to improve WKTRADE/WGFBIT analyses is that benthos dynamic is initiated at start with the equilibrium assessment provided by ICES WGFBIT and the model allows stochastic projections of alternative worlds (e.g., fleet displacement and adaptation, alterative quotas and fish stock trajectories etc.) from this starting point. This contributes to approaches that allow spatial upscaling of local findings to regional scale in the perspective of anticipating management actions/plans that reduce the footprint of fishing activities or establish trade-offs between impact and economic revenue. We presented an application focusing on the identification of effective measures to reduce fisheries impacts on the seafloor: a bio-economic evaluation in the Baltic Sea. In this special case, under the auspice of EU/HELCOM Action project, we want to draw that pressure-state curves that will allow us from there to advise on the pressure level to reduce as long we know the state value we want to reach (the “good state” or GES in a MSFD context) and we know the current state. This should further allow quantifying how likely good benthos state could be achieved (per subregion) along quantifying the probable consequences on the fisheries economics (catch volume value and profits) and sustainability (FMSY in a CFP context) when implementing the spatial plans.

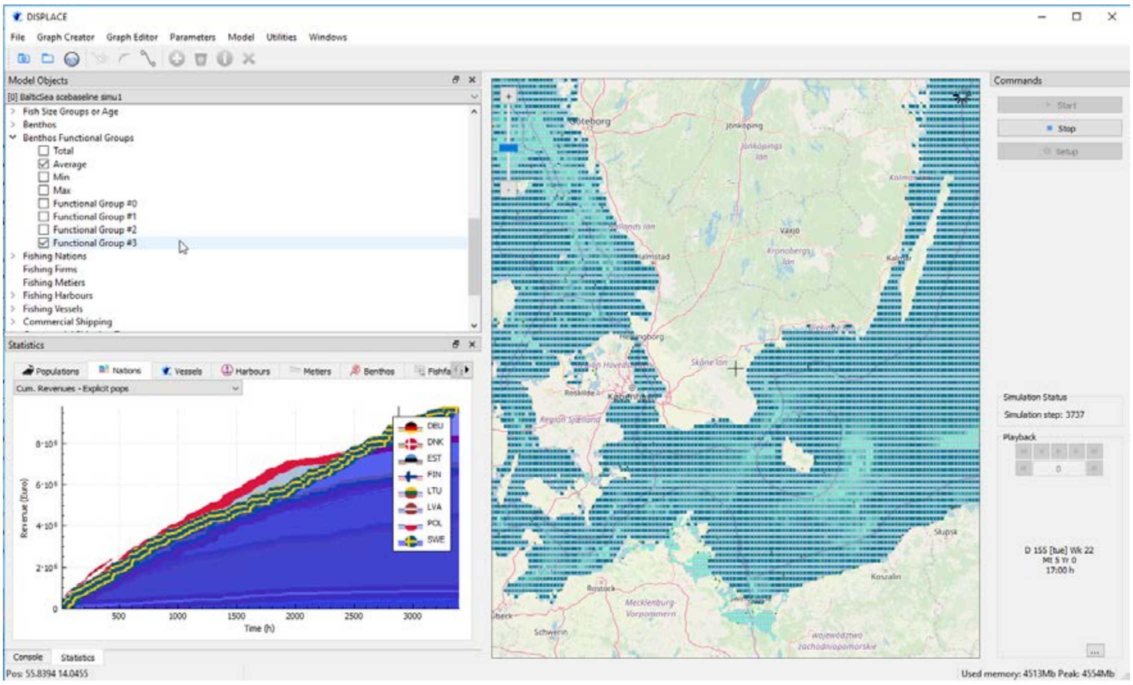

Figure 1: A random snapshot of the DISPLACE interface showing the Benthos data map layer initiated on the WGFBIT equilibrium assessment of benthos state split per longevity groups, along the simulation of catch and profit per fleet-segment (possibly aggregated per vessel, metier, harbour, and nation).