Scientific, Technical and Economic Committee for Fisheries (STECF) -
Fishing effort regime for demersal fisheries in the Western Mediterranean Sea - Part II (STECF-18-13)

Edited by Clara Ulrich and Ernesto Jardim
This report presents advice and discussions about a fishing effort regime for demersal fisheries in the western Mediterranean Sea. It constitutes a complementary and updated approach to that presented in April 2018.
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Request to the STECF

The STECF is requested to review the report of the STECF Expert Working Group meeting, evaluate the findings and make any appropriate comments and recommendations.

STECF observations

The working group was held in Copenhagen, Denmark, from 8 to 12 October 2018.

The EWG 18-13 was a follow-up of the EWG 18-09 held in June 2018 and was largely attended by the same experts. STECF observes that the terms of reference had been discussed internally before the beginning of the EWG but were not published and made available to the EWG participants other than EWG chair and JRC expert prior its start.

As the EWG report was not finalised before the STECF plenary, the STECF commented on a draft version of the report and the presentation held at the plenary on the 13th of November 2018.

STECF comments

STECF notes that the EWG ToRs requested to expand the outcomes of EWG 18-09 concerning the relationship between effort and fishing mortality and the analysis on the differences in fishing pattern and LPUE by fleets. These updates were based on additional data for the French fisheries made available during the meeting.

STECF notes that EWG 18-13 conducted the analysis on the basis of three datasets: Med&Black Sea, AER, FDI. STECF also observes that an additional effort has been made to complement the aggregated data with ad hoc datasets request by DGMARE to the relevant Member States. The additional datasets are referred to haul-by-haul data collected through observer on-board programmes and trip-by-trip data compiled from VMS, logbooks and sales notes. These datasets were provided by France while Italy and Spain (Catalonian fisheries) had provided the trip-by-trip dataset in June and no update was required.

An in-depth comparison of the completeness, coverage and consistency of the datasets was carried out by EWG. STECF notes that the data are overall considered more reliable than in EWG 18-09, but a number of inconsistencies between the datasets still remain, making it difficult to provide a robust quantitative description of the activity of the fleets in the Western Mediterranean.

STECF notes that EWG attempted to fit linear relationships between fishing effort and fishing mortality for a number of stocks and fleet segments. The results obtained were very similar to those of EWG 18-09, showing weak relationships in most cases. However, STECF notes that since the EWG 18-12 stock assessment data were not made available to the EWG 18-13, these fits could only be applied on older assessments with F estimates up to 2014, not 2017.

STECF appreciates the EWG exercises aimed at testing non-linear relationship and at discussing alternative ways to measures fishing effort like hours fished or swept area. However, STECF notes that even the fits of non-linear relationship remain poor and that it was not possible during the EWG to provide a full time series of alternative effort descriptors, so a relationship with fishing mortality could not be tested.

STECF observes that TOR 4 (calculate the average partial fishing mortality of trawls exploiting the demersal stocks concerned by the MAP, by type of fisheries, effort unit, fleet segment and country, as estimated in the latest stock assessments) was not addressed mainly because of lack of most
recent assessment results. STECF notes that a number of stock assessments for the MAP stocks have been performed in 2018 (EWG 18-12), but the report and assessment results were not considered final enough at the time when EWG 18-13 started and the stock assessment results were not available and could not be used by 18-13. Additionally, the analysis of datasets performed in ToR 1 did not allow for a single robust estimate of transversal data (catch and effort data by fleet and metier) and the differences between the different datasets remain unclear and poorly explained. STECF notes however that calculating these partial fishing mortalities is straightforward once the updated datasets of fishing mortality and transversal data (catch and effort) are available, and this step can thus be undertaken as part of Step 1 of the Road Map below.

STECF notes that EWG addressed TOR 5, defining a 2-year roadmap to set-up a mixed fisheries advice for western Mediterranean demersal fisheries. The plan outlines the priorities in the short and medium term, any potential gaps in knowledge/data/modelling and the actions that can be taken to overcome it. STECF notes that the EWG also considered the skills and tools needed, including the actors to be involved, but the actual selection of models and experts’ commitment should better be decided during a dedicated scoping meeting, suggested by the EWG 18-13 to be held in March 2019.

**STECF conclusions**

STECF recalls the conclusions on the opportunities and challenges in the use of fishing effort regimes as a management tool for mixed fisheries reported in PLEN 17-02, PLEN-18-01 and STECF 18-09.

STECF stresses the need to have consistent data as a basis to carry out the assessment and the monitoring of the effects of effort management plans in the western Mediterranean Sea. STECF concludes that the results of the analysis carried out by the EWG on the completeness, coverage and consistency of the various datasets available should be brought to the attention of the Member States concerned to urge the improvement of the quality of available data sets.

STECF concludes that the proposed Management Plan indicates general reductions in effort and that for the stocks and time periods analysed, in both EWGs (18-09 and 18-13) relationship between effort and fishing mortalities cannot be determined and quantified. However, STECF concludes that even if the current data of fishing effort and fishing mortality do not show a clear correlation, this would not prevent the application of procedures to simulate the impacts of effort management measures under alternative assumptions. This exercise may use one or more models that have been already applied and tested in the assessment of management options in the Mediterranean. Indeed, STECF recognizes that there are several models available even if with some various levels of coverage, development, completeness, update, complexity and user-friendliness.

Building on the suggestion from EWG 18-13, STECF proposes the following roadmap to set-up a mixed fisheries advice for western Mediterranean demersal fisheries:

<table>
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<th>I STEP (2019)</th>
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<tr>
<td><strong>MODEL SCOPING</strong></td>
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<td>Hold a dedicated STECF EWG in (March) 2019 which the main purpose of testing the suitability of various candidate models and the availability of modellers...</td>
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<td>Model(s) selection, on the basis of identified criteria (compatibility with DCF data sets and STECF/GFCM assessment results should be a prerequisite for selection) and conditioned on the availability of modellers. A list of minimum requirements for what a model for the mixed-fisheries advice should be able to do should be agreed in advance of the scoping.</td>
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<td>Identification of the financial options supporting the development of the work in 2019 and 2020.</td>
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DRAFT RUN | Agreement on scenarios, results, and draft mixed-fisheries advice on data available in 2018 (reference year 2017)

II STEP (2020)

UPDATE AND DEVELOPMENT | Update to 2019 datasets (reference year 2018)
Model(s) improvements/extension
Discussion and possible overcoming of other gaps and issues related to an operational mixed-fisheries advice: inclusion of other types of fishery that exploit stocks in the MAP, adoption of specific sub-regional fleets/metiers.

FINAL OPERATIONAL SETUP | Actual mixed-fisheries advice for 2021 (reference year 2019)

STECF concludes that this roadmap will focus mainly on the Western Med in the first place. But, as it also the case in the ICES area, it should not be excluded to expand it to a more global mixed-fisheries approach for the EU Mediterranean demersal fisheries.

Contact details of STECF members

1 - Information on STECF members’ affiliations is displayed for information only. In any case, Members of the STECF shall act independently. In the context of the STECF work, the committee members do not represent the institutions/bodies they are affiliated to in their daily jobs. STECF members also declare at each meeting of the STECF and of its Expert Working Groups any specific interest which might be considered prejudicial to their independence in relation to specific items on the agenda. These declarations are displayed on the public meeting’s website if experts explicitly authorized the JRC to do so in accordance with EU legislation on the protection of personnel data. For more information: http://stecf.jrc.ec.europa.eu/adm-declarations

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REPORT TO THE STECF

EXPERT WORKING GROUP ON
Fishing effort regime for demersal fisheries
in the Western Mediterranean Sea – Part II
(EWG-18-13)

Copenhagen, Denmark, 8-12 October 2018

This report does not necessarily reflect the view of the STECF and the European Commission and in no way anticipates the Commission’s future policy in this area
1 INTRODUCTION

1.1 Terms of Reference for EWG-18-13

TOR 1. In light of new data available, review the dataset on the trawl fleet exploiting demersal stocks in the western Mediterranean Sea as prepared by the STECF EWG 18-09.

TOR 2. In light of new data, review the outcomes concerning the relationship between effort and fishing mortality as prepared by the STECF EWG 18-09.

Given the STECF-18-09 considered that ‘a linear relationship is overoptimistic and that actual changes in F will be likely lower than changes in nominal effort’, estimate proxy linear relations under three different scenarios: optimistic (i.e. current linear relationship), conservative and pessimistic.

TOR 3. In light of new data, review the analysis on the differences in fishing pattern and LPUE by fleets as prepared by the STECF EWG 18-09.

TOR 4. Calculate the average partial fishing mortality of trawls exploiting the demersal stocks concerned by the MAP, by type of fisheries, effort unit, fleet segment and country, as estimated in the latest stock assessments.

TOR 5. Create a 2-year roadmap to set-up a mixed fisheries advice for western Mediterranean demersal fisheries. The plan should provide a detailed description of all the steps needed to achieve this goal. It should outline the priorities in the short- and medium-term, any potential gaps in knowledge/data/modelling and the actions that can be taken to overcome it. It should also specify the skills and tools needed, including the actors to be involved (e.g. for scoping decisions). The starting date of the roadmap should be 1 January 2019.

1.2 Data available and sources of information

To make progress on the ToRs the EWG had access to several datasets.

As for EWG 18-09, the primary data sources for aggregated data come from the databases hosted by JRC and populated with different data calls (https://stecf.jrc.ec.europa.eu/data-dissemination). These data are aggregated by quarter and fleet segment (AER) or metier (FDI). With regards to stock assessment results the data are aggregated at the stock level.

To complement the aggregated data, EWG 18-13 defined two more detailed datasets (Table 1.1) which formed the basis for a data request by DGMARE to the relevant Member States. These datasets referred to haul-by-haul data collected through observers on-board programmes, and trip-by-trip data compiled from VMS, logbooks and sells notes.

France sent both datasets as required for years 2012-2017 the day before the meeting started, which limited its analysis. Nevertheless, the main objectives of the EWG for ToR 3 were accomplished.

Spain didn’t send either dataset for the EWG, because that the data requests sent by the EU to the Spanish central administration did not reach the persons in charge in time. Two observers from the Spanish authorities participated though the EWG, and tried to gather a useful dataset during the EWG. But ultimately, this tentative could not be pursued by lack of time. A partial dataset of trip-by-trip data was sent by the Catalanian authorities, referring to an update of the data provided to EWG1809. This dataset allowed the group to run the analysis to support ToR 3, although partially.

Italy had provide the trip-by-trip dataset in June and no update was required.
A number of stock assessments for the MAP stocks have been performed in 2018 (EWG 18-12), but the report and assessment results were not considered final enough and the stock assessment results were not made available to 18-13.

Table 1.1 Data request in support of EWG 18 13

Dataset 1 – haul level, based on on-board observations. Each line refers to a species caught in a haul by a vessel

<table>
<thead>
<tr>
<th>Variable</th>
<th>Format</th>
<th>Units</th>
<th>Code</th>
<th>Priority</th>
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<td></td>
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<tr>
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<td>meter</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Gear</td>
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<td>DCMAP T2</td>
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<td>Mm</td>
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<td>1</td>
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<td>Gear length (fixed gears only)</td>
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<td>meter</td>
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</tr>
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<tr>
<td>Species (latin)</td>
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<td>Discards</td>
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</table>

Dataset 2 – day level, based on logbooks, sales notes. Each line refers to a species caught in a day by a vessel

<table>
<thead>
<tr>
<th>Variable</th>
<th>Format</th>
<th>Units</th>
<th>Code</th>
<th>Priority</th>
</tr>
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<tr>
<td>Vessel anonymised</td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>Lenght over All</td>
<td>numeric</td>
<td>meter</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Gear</td>
<td>character</td>
<td></td>
<td>DCMAP T2</td>
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<tr>
<td>Meshsize</td>
<td>numeric</td>
<td>Mm</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Gear length (fixed gears only)</td>
<td>numeric</td>
<td>meter</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Date</td>
<td>DD/MM/YYYY</td>
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</tr>
<tr>
<td>Effort</td>
<td>numeric</td>
<td>hour</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Longitude averaged by day</td>
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<td>degree</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Latitude averaged by day</td>
<td>numeric</td>
<td>degree</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Depth averaged by day</td>
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<td>meter</td>
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<tr>
<td>Species</td>
<td>character</td>
<td></td>
<td>FAO 3alpha</td>
<td>1</td>
</tr>
<tr>
<td>Species (latin)</td>
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<td>Landings</td>
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</table>
1.3 Summary of EWG 18-13 outcomes

The EWG 18-13 was a follow-up of the EWG 18-09 (STECF, 2018a) held in June 2018, and was largely attended by the same experts. The Terms of reference had been discussed internally but were not available to the EWG prior its start.

The main outcomes were as follows:

ToR 1: Updated dataset. STECF (2018a) had highlighted a number of issues and gaps in the transversal data (catch and effort data by fleet segment) coming from different data sets. In October 2018, a number of new data were available, owing to several other STECF EWGs having been held between June and October. The Med&Black Sea (MBS) data have been used in the stock assessment EWG 18-12 (STECF, 2018b); the Annual Economic Report (AER) data from EWG 18-07 (STECF, 2018c) were completed; and the FDI data (STECF, 2018d) were also available. EWG 18-13 conducted thus an in-depth comparison of the completeness, coverage and consistency of the three datasets. The data are overall considered more reliable than in STECF (2018a), but a number of inconsistency between the three datasets remain, making it difficult to provide a robust quantitative description of the fleets activity in the Western Mediterranean.

ToR 2: The work in ToR 2 was split into several sub-sections. In a first part, the work undertaken in EWG 18-09 ToR 4 was pursued, fitting linear relationships between fishing effort and fishing mortality for a number of stocks and fleet segments, based on older assessments. 2018 assessments (STECF, 2018b) were not available at the time where EWG 18-13 met.

Considering the single GSA within the two Management Units no significant relationships between fishing effort and F on deep water rose shrimps and hake were found. On the contrary linear relationship derived assuming the stock unit inside the two Management Units and negligible differences in catchability between fishing systems used in the different GSAs inside each Management Unit were significant but not considered very reliable by the WG due to expected differences in size of the standing stock in each GSA that could affect the catchability. However, considering the lack of contrast in the data within the single GSA, this approach could be worthy for further investigations.

A second subsection tried to fit non-linear relationship over the same data. In most case the power relationships obtained (b parameter) is less than 1, implying that fishing mortality has historically decreased less than fishing effort. However, the fits remain poor.

In a third sub-section, alternative ways to measures fishing effort are discussed, using hours fished, targeted effort or swept area. These metrics are considered to be better descriptors of effort than fishing days, and could also potentially be measured or estimated with the standard information available, owing among other to a better use of VMS/AIS data. However, it was not possible during the EWG itself to provide a full time series of such alternative effort descriptors, so a relationship with fishing mortality could not be tested.

Finally, some results from EWG 18-09 were recalled, highlighting the importance of gears design and size as important descriptors of the fishing effort, but not well known and monitored. There is a huge potential for efficiency increase and technical creep in the Western Mediterranean.

Ultimately, these analyses remain preliminary and there would be scope for analysing this relationship further. Nonetheless, the management implications of the current state of knowledge remain, as stated previously by EWG 18-09, are that i) it cannot be expected that fishing mortality will decrease by exactly the same amount as fishing effort in the first years of effort reduction in the MAP, but will likely reduce at a lesser rate and ii) it might take a few years before the effects of effort reductions can be seen in the stock assessment outcomes.

ToR 3: The work in ToR 3 was an update of the results described in sections 5 and 8 of the EWG 18-09 report. The main addition was the application of the GAM and mixed-fisheries analyses to
the French data. The French fleet is characterised by a very different structure in vessel size compared to Spain and Italy.

**ToR 4:** ToR 4 could not be completed during EWG 18-13. The updated stock assessments results from EWG 18-12 were not considered sufficiently robust and finalised at the time where EWG 18-13 met, and the data were not readily available. Additionally, the analysis of ToR 2 did not allow for a single robust estimate of transversal data (catch and effort data by fleet and metier), and the differences between the different datasets remained unclear and poorly explained. Decision is therefore still to be made on which dataset to base the actual estimates of partial fishing mortality. Performing this ToR would otherwise be straightforward once the relevant data are collected, so EWG 18-13 decided to postpone the exercise and to include it as part of Step 1 of the RoadMap.

**ToR 5:** ToR 5 was about establishing a roadmap for the work to be performed over the next two years in order to provide an operational mixed-fisheries advice for the Western Med MAP. To address this, EWG 18-13 established a detailed review of the current issues and gaps in i) mixed-fisheries models, ii) data and iii) experts’ availability and human resources limitations. EWG 18-13 provide also an overview of the mixed-fisheries advice annually published by ICES and its corresponding procedures for model and data updates and choices of scenarios.

From this, the EWG 18-13 recognised that the highest chance to obtain an operational mixed-fisheries advice is to combine a suite of expert working groups or workshops (around one per semester) together with additional funding dedicated to intersessional developments. This funding would secure the necessary time and commitment of the relevant experts, while the workshops would act as useful milestones reviewing the progresses achieved and framing their outcomes into the desired operational setup. On this basis, the EWG suggested 4 steps, corresponding more or less to the four semesters in 2019 and 2020. The most important step is the first one, which is the scoping of which model(s) to use, and the selection of the appropriate stocks and fleet/metiers definition and corresponding transversal data. This step will also establish the plan for the financial support to this scientific work. This will define the details of the following steps, recognising that the actual development of the advice is directly linked to the question of who gets funded to do the work, how much and when. EWG 18-13 recommends thus that a dedicated scoping meeting is organised in the early period of 2019, in order to agree on the following developments.
2 ToR 1: Dataset Review

"In light of new data available, review the dataset on the trawl fleet exploiting demersal stocks in the western Mediterranean Sea as prepared by the STECF EWG 18-09. Considering the limitations of the datasets previously used to provide baseline information on the trawl fleets exploiting demersal stocks in the western Mediterranean Sea, the EWG is requested to review the consistency of the new datasets that are provided to the experts. The analysis focused mainly on effort and landings data collected under the Data Collection Framework (DCF – EC 199/2008) up to 2018."

2.1 Comparison of datasets coverage

Three datasets were available to the experts during the EWG:

- The 2018 Mediterranean and Black Sea data call (MBS – Ares (2018)2385889 - 04/05/2018). The MBS data call requests data for a considerable number of tables specifically aimed at allowing stock assessments. Table reporting effort and landings are available since 2002 (STECF, 2018b).

- The 2018 New-Fishery Depend Information data call (FDI – Ares (2018) 2607160 - 18/05/2018). The STECF FDI database was developed to support the management of fishing effort management regimes. Time series are available for the period 2015-2017 (STECF, 2018d).

- The 2018 AER (STECF, 2018c). The report covers a nine-year time series (2008-2016) and includes information on the EU fleet's fishing capacity, effort, employment, landings, income and costs. Economic and transversal variables were not included in the review, a detailed description of economic features of fleets involved in the effort regime are available in EWG 18 09. Effort and landing data reported at country level, without specification of sub areas and gear, are considered as a different dataset (AER2).

The exploratory analysis of the datasets reveals that most of the problems observed during the EWG 18 09 are fixed in the most updated version of the dataset provided to the EWG, increasing the quality and temporal coverage of the time series available. However, inconsistencies across data calls are still found for all countries. A complete comparison between the variables is possible only for fishing days and landings weights that are reported in all data calls; most of the remaining variables are reported in 2 out of the 3 datasets. The EWG also focused on the difference in the methods used by Member States in the collection and estimation of effort variables (mainly fishing days and days at sea). The comparison of the three datasets revealed that:

- The most complete period covers from all the 3 data calls is the 2015-2017. In these years, effort and landings data are available from all the 3 data calls (Figure 2.2). However, temporal coverage of the MBS and AER datasets vary across countries. Temporal coverage of the MBS and AER starts from 2008 for Italy and Spain and no lack of data is found. Data for France reported in the MBS data call are available only in the period 2015-2017 while temporal gaps are present in the AER.

- A good agreement is found between fishing days reported in the 3 data calls for France and Italy, while considerable differences are found between in the FDI and the other two data calls for Spain.

- Landings data are similar in the AER and FDI data calls for France and, between MBS and FDI for Spain and Italy. However, cross checking of the gear revealed that there are problems in gear specification between landings and effort data. Landings for gear OTT, PTB, and TBB are reported in the AER for Spain without a correspondence in FDI and MBS data calls (Figure 2.3). Landings for TBB are available in MBS dataset for France without correspondence in the AER and FDI data calls.

- The 2018 Annual Economic Report on (AER) the EU Fishing Fleet (AER – EWG 18-07). The report covers a nine-year time series (2008-2016) and includes information on the EU fleet's fishing capacity, effort, employment, landings, income and costs. Economic and transversal variables were not included in the review, a detailed description of economic features of fleets involved in the effort regime are available in EWG 18 09. Effort and landing data reported at country level, without specification of sub areas and gear, are considered as a different dataset (AER2).
Effort indicators as hours at sea, estimated using georeferenced data (VMS – Vessels Monitoring System) collected under the FDI, are not available for Spain.

Figure 2.1: Correspondences between effort and landing variables is explored by tiles plot. Red cells indicate the presence of a variable (y axis) in the correspondence dataset (x axis). The AER2 dataset refers to the economic and transversal data reported at supra region level and it was reported in the analysis to highlight the difference in the aggregation level for diseases and no vessels (vessels number)
Figure 2.2: Time coverage of the considered datasets explored by Tiles plot. For each dataset (y axis on the right), red cells indicate the presence of a variable (top x axis) in a year (lower x axis) for the considered countries (left y axis).
2.2 Definition of fishing effort

When discussing which variables to include in the effort scheme, the experts first focused on fishing days and days at sea. The EWG discussed the use of these metrics in the proposed effort scheme focusing on the reliability of the data collected by member state. Although in 2016 some member states implemented a system to collect logbooks data haul by haul, the experts noted that problems related on the compilation of the logbook can influence the quality of the data.

Under the Implementing Decision (EU) 2016/1251 adopting multiannual programme for the collection, management and use of data in the fisheries sector, the following definition are reported:

- **Days at sea**: any continuous period of 24 hours (or part thereof) during which a vessel is present within an area and absent from port.
- **Fishing days**: any calendar day at sea in which a fishing operation takes place, without prejudice to the international obligations of the Union and its Member States. One fishing trip can contribute to both the sum of the fishing days for passive gears and the sum of the fishing days for active gears on that trip.

In the EC 1224/2009, which establishes a community control system for ensuring compliance with the rules of the common fisheries policy (EC 1224/2009), is also reported a generic definition of “days”:

- A day present within an area shall be any continuous period of 24 hours or part thereof during which a fishing vessel is present within the geographical area and absent from port or where appropriate deploying its fishing gear. The time from which the continuous period of a day present in the area is measured is at the discretion of the Member State whose flag is flown by the fishing vessel concerned. A day absent from port shall be any continuous period of 24 hours or part thereof during which the fishing vessel is absent from port.

Generally, in the annual economic report of economic and transversal data days at sea are reported at gear, fishing area and economic zone level. Fishing days is reported at gear, fishing area, rectangle and economic zone level. However, in the case of Mediterranean Sea, the finest spatial resolution for fishing days is reported at geographical sub areas (GSA) level (STECF, 2018c). In the case of Spain, the experts noted that due to a 12 hours-rule currently implemented for trawl fishery there is no difference between values of fishing day and days at sea and they can be considered equivalent. The results obtained in the analysis showed that also in case of France similar values are observed between the two metrics. In the case of Italy, values of days at sea reported in the MBS data call resulted ten time higher if compared to fishing days and it possible to hypothesize that an error occurred during data transmission.

The EWG also discussed the use of indicators based on georeferenced data (such as hours at sea) to better address the relationship between effort and fishing mortality. These variables are available in the new FDI data call for the period 2015-2017 and a good agreement is found with fishing days and days at sea collected under the other 2 data calls considered for all countries. Although standardized methods are proposed to estimate effort from the combination of logbook and VMS data, alternative methods were used by France and Italy to accommodate the request of FDI data call (STECF, 2018d). Italian experts stressed that several problems related to a poor consistency of logbooks and VMS data are present in the data collected in the FDI for Italy (STECF, 2018d). In addition, hours at sea are not available for Spain, while values reported for days at sea resulted not comparable with those reported in the other 2 data calls.

2.3 Comparison of fisheries data

2.3.1 The variables considered in the review

The list of the variables that are reviewed and their relative codification is reported in Table 2.1. To facilitate comparison between datasets, variables are extracted at the same aggregation level using filtering criteria that are consistent with the fisheries and the areas involved in the effort regime.
Factors used to subset data and their codification are reported in Table 2.2. Under the proposed effort scheme, vessel length categories VL0006, VL0010 and VL0612 are merged into a category VL0012, other segments considered are the standard DCF categories VL1218, VL1824, VL2440 and VL40XX. Since most of effort and landings data are specified at gear level, the experts decided first to select all fishing gear belonging to the DTS fishing technic ('Demersal trawlers and/or demersal seiners') and after, distinguish bottom trawling gears from the other gears. Bottom trawling gears (OTB, OTT, PTB, TBB) were flagged as "BOTTOM_TRAWLERS", while all other gear types as "OTHERS". Data collected under the MBS data call were provided without specification of fishing technics, then data were subset considering only the type of gear.

Table 2.1: List of variables taken in consideration.

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<tr>
<td>AER</td>
</tr>
<tr>
<td>MBS</td>
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<table>
<thead>
<tr>
<th>Effort variables</th>
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</thead>
<tbody>
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<tr>
<td>FDI</td>
</tr>
<tr>
<td>Country</td>
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<tr>
<td>---------</td>
</tr>
<tr>
<td>AER2</td>
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<tr>
<td>FDI</td>
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One fishing trip can contribute to both the sum of the fishing days for passive gears and the sum of the fishing days for active gears on that trip.

<table>
<thead>
<tr>
<th>Country</th>
<th>Type of Days</th>
<th>Formula</th>
<th>Note</th>
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<tbody>
<tr>
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<td>GT days at sea</td>
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<td>Total days at sea times the Gross tonnage of the active vessel</td>
</tr>
<tr>
<td>FDI</td>
<td>GT days at sea</td>
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<td>EWG 18-11</td>
</tr>
<tr>
<td>FDI</td>
<td>GT fishing days</td>
<td>totgtfishdays</td>
<td>EWG 18-11</td>
</tr>
<tr>
<td>AER</td>
<td>GT fishing days</td>
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<td>EWG 18-07</td>
</tr>
<tr>
<td>FDI</td>
<td>GT hours at sea</td>
<td>gthrsea</td>
<td>EWG 18-11</td>
</tr>
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<td>Hours at sea</td>
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<td>EWG 18-11</td>
</tr>
<tr>
<td>FDI</td>
<td>kW days at sea</td>
<td>totkwdaysatsea</td>
<td>EWG 18-11</td>
</tr>
<tr>
<td>FDI</td>
<td>kW fishing days</td>
<td>totkwfishdays</td>
<td>EWG 18-11</td>
</tr>
<tr>
<td>Source of data</td>
<td>Description</td>
<td>Country</td>
<td>Notes</td>
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<td>---------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>AER</td>
<td>Annual Economic Report (sub region level with gear specification)</td>
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<tr>
<td>AER</td>
<td>Number of fishing trip</td>
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<td>MBS</td>
<td>Vessels number</td>
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</tr>
</tbody>
</table>

Table 2.2: Factors used in the aggregation of data. Codification reported in bold are those used to report results of the analysis.
2.3.2 Comparison of the fishing statistics between the three data calls

The description below is based in EWG 18-09. Time series of effort and landings data are analysed at country level considering only areas (GSA) and gear involved in the effort regime. Landings data are reported also at species level. The analysis of the relative differences across data calls is explored for each variable estimating the ratio between pairs of values and results are showed at sub region and gear level. Resulting plots are manually adjusted to facilitate their evaluation and values greater than 1.5 are set to 2, if the denominator is not available or it is very small, the ratio is forced to 2.5.

2.3.2.1 Spain

Trends of time series of effort data reported at country level showed similar values in the MBS and AER2 data calls (Figure 2.4). In both datasets, the values of fishing days are equal to days at sea and their values result comparable with slight differences across dataset. Aggregated landings data are similar in MBS and FDI while lower values are reported in the AER. Relevant differences in MBS
and FDI data calls are also found for nominal effort and number of vessels. However, the number of vessels is different in all 3 data calls.

Considering, landings by species reported in Figure 2.5, a good agreement is found between the MBS and FDI data calls for MUT, DPS and HKE. The more severe differences are observed for ARS, MUT and NEP in MBS and AER data call. For these species values and trends between the AER and the other 2 data calls are very different. For all other species (ARA, HKE and DPS), lower differences and more similar trends are observed between the 3 data calls.

The ratio of mean values for the data reported at sub region and gear level are reported in Figure 2.6. Similar values are reported in the FDI and the MBS data calls for OTB in GSA1, GSA2, GSA5, GSA6 and GSA7. For the same areas, fishing days are similar in AER2 and MBS. Lack of values for GSA9, GSA10 and GSA11 are due to a mismatch between the data calls, gear TBB, OTT and PTB are reported in this area in FDI but no data are available in the MBS and AER.

---

![Figure 2.4](image1.png)

**Figure 2.4:** Time series of effort and landings data reported in the 3 data calls aggregate at country level for Spain.

![Figure 2.5](image2.png)

**Figure 2.5:** Time series of landings by species aggregate at country level for Spain
Figure 2.6: Relative differences between data calls for Spain are explored using tiles geometry at sub region and gear level. Cell colour represent the ration between mean values of the variables. Ratio are estimated between pairs of data calls and only for those variables that are present at least in 2 of them.

2.3.2.2 France

Trends of time series of effort and landings data are reported in Figure 2.7 at country level. A good agreement is found between values reported in the 3 data calls. Negligible differences and similar trends are found between the time series of effort variable (i.e. days_at_sea, fishing_days, gt_fishing_days, kw_fishing_days) and total landings of the 3 data calls. Number of vessels reported in the AER data call are greater than those reported in the other 2 data calls. Similar values and trends are found for nominal effort between the FDI and the MBS data calls.

Time series of landings by species are different across dataset, Figure 2.8. Although, similar trends are reported in the 3 data calls for DPS and HKE, considerable differences are present for NEP, MUT and HKE. Values of MUT and HKE reported in the MBS data call are very different from those reported in the other 2 data calls.

The ratio of mean values for the data reported at sub region and gear level are reported Figure 2.9. In GSA5 a good agreement is found between FDI and MBS. In GSA7 similar values are found for fishing days and days at sea between all 3 data calls.
Figure 2.7: Time series of effort and landings data reported in the 3 data calls aggregate at country level for France.

Figure 2.8: Time series of landings by species aggregate at country level for France
Figure 2.9: Relative differences between data calls for France are explored using tiles geometry at sub region and gear level. Cell colour represent the ration between mean values of the variables. Ratio are estimated between pairs of data calls and only for those variables that are present at least in 2 of them.

2.3.2.3 Italy

Trends of time series of effort and landing at country level are reported in Figure 2.10. Time series of the variables reported in the AER2 dataset for Italy are not considered in the review because they were collected considering GSA not involved in the effort scheme. A good agreement is found in time series of fishing days for which a complete correspondence between the FDI and AER datasets is found, while negligible differences with the MBS are present. The number of vessels reported in the MBS and FDI data calls showed relevant difference with values reported in the first greater than those reported in the second. On the contrary, nominal effort reported in the two data calls is similar in 2017. Landings at country levels are very similar in the MBS and AER data calls but they differ in the FDI. Days at sea reported in the MBS resulted to be too high respect than those reported in AER and FDI data calls. Days at sea of the entire Italian trawler fleet as reported in the AER2 dataset is showed in Figure 2.10 to highlight the possibility of error in the values of days at sea reported for the considered areas.

Trends of landings by species at country level are reported in Figure 2.11. A good agreement between all 3 datasets are found for DPS and NEP. Time series of HKE and MUT resulted very similar between AER and MBS while differences are found respect the FDI data calls. Time series of ARA and ARS resulted very similar in the AER and MBS data calls until 2015, in the last 2 years different values are observed in all 3 data calls.

A good agreement between the data calls is also confirmed by the ratio of the mean values reported in Figure 2.12. In all areas, similar values in all 3 data calls are found for fishing days. Landings reported in the three data calls are similar in GSA 10 while differences are found in GSA9 and GSA10. The number of vessels, is similar between FDI and MBS in GSA10 and GSA11, while it is slightly different in GSA9.
Figure 2.10: Time series of effort and landings data reported in the 3 data calls aggregate at country level for Italy. Value of days at sea for the AER2 are reported to confront the values reported in the MBS respect to those for the whole Italian trawler fleets.

Figure 2.11: Time series of landings by species aggregate at country level for Italy.
Figure 2.12: Relative differences between data calls for Italy are explored using tiles geometry at sub region and gear level. Cell colour represent the ration between mean values of the variables. Ratio are estimated between pairs of data calls and only for those variables that are present at least in 2 of them.

2.4 Summary conclusion

When discussed on the dataset to use to provide baseline information about the fleet involved in the effort regime, the experts noted that there are differences between the value reported in the available datasets. Although the great majority of problems reported in STECF (2018a) regarding quality and temporal coverage of data were fixed, several issues are still present. The most relevant are:

- MBS data for France are available only for 2015-2017. In the case of landings data for Spain, the vessel length categories are missing.
- Data reported in the AER are not available for 2017. Landings data for VL1218 are not available for 2015 GSA1-2-5-6-7. In addition, the number of vessels and days at sea reported for Italy are available only at country level and they cannot be used in the baseline information because they also include fleets operating in areas outside of the management plan (e.g. Adriatic Sea).
- The number of vessels and hours at sea in the FDI for Spain are not available.

Taking in consideration the limits of the datasets, the EWG decided to provide baseline information basing on data reported in the AER. Indeed, considering the aggregation level required for the baseline information (sub_area, gear, vessel length), the AER dataset resulted the most detailed in both landings and effort data for Spain and France. For Italy, the number of vessels, that is not available at sub region level in the AER, can be obtained from the MBS. On the contrary, days at sea reported in the MBS for Italy cannot be used because the values reported for 2015 and 2016 are not reliable.

Finally, when a direct comparison of the AER and the other two datasets was possible, trend of the time series resulted similar or with negligible differences in most cases.

2.5 Baseline information about demersal fisheries by the Management Units of western Mediterranean Sea

According to the spatial division of the effort regime controls, the western and eastern management units were described aggregating data from GSA1-5-6-7 and GSA8-9-10-11 respectively. For each variable, values from the GSAs which belong to a management unit were summed by years and fleet segments and after, the average value of the last three years was estimated.
2.5.1 Western management unit (GSA1-5-6-7)

Effort and landings data used to describe trawling fleet in the western management unit come from the AER and they refer to the period 2015-2016. Table 2.3 reports the main features of trawl fisheries in the western management unit. In the period 2015-2016, 647, on average, vessels were involved in the demersal fishery in this area. The fleet was mostly composed by the segment VL1824 (51%), followed by VL2440 (25%) and VL1218 (24%).

In the period 2015-2016, landings were about 19000 tonnes, on average, and the great part coming from VL1824 (43%), followed by VL2440 (35%) and VL1218 (17%). Considering only the target species, the most landed was HKE (1845t), followed by ARA (938t) and MUT (875t) (Figure 2.13). Altogether, target species account for about 20% of total landing. Target species represent 22% of total landings of VL2440, 20% of VL1824 and 15% of VL1218 (Figure 2.14).

Table 2.3: Main features of trawl fisheries in GSA1-5-6-7. The values reported represent the average values during the period 2015-2016.

<table>
<thead>
<tr>
<th>Fleet segment</th>
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<th>VL1824</th>
<th>VL2440</th>
</tr>
</thead>
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<tr>
<td>Vessels number</td>
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<td>331</td>
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<tr>
<td>Days at sea</td>
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<td>18970</td>
<td>44933</td>
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<tr>
<td>Fishing days</td>
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</tr>
<tr>
<td>Total landings weight</td>
<td>(tonne)</td>
<td>4362</td>
<td>8084</td>
</tr>
<tr>
<td>Target species weight</td>
<td>(tonne)</td>
<td>656</td>
<td>1646</td>
</tr>
<tr>
<td>Landings dependency</td>
<td>%</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure 2.13: Species average landing weight across fleet segments in western management unit during the period 2015-2016
2.5.2 Eastern management unit

Effort and landings data used to describe trawling fleet in the eastern management unit come from the AER and they refer to the period 2015-2016. Table 2.4 reports the main features of trawl fisheries in the eastern management unit. In the period 2015-2016, 736, on average, vessels were involved in the demersal fishery in this area. The fleet was mostly composed by the segment VL1218 (60%), followed by VL1824 (35%) and VL2440 (5%).

In the period 2015-2016, landings were about 14000 tonnes, on average, and the great part coming from VL1824 (52%), followed by VL1218 (40%) and VL2440 (8%). Considering only the target species, the most landed was MUT (1671t), followed by DPS (1357t) and HKE (1300t) (Figure 2.15). Altogether, target species account for about 36% of total landing. Target species represent 43% of total landings of VL2440, 35% of VL1824 and 37% of VL1218 (Figure 2.16).

Table 2.4: Main features of trawl fisheries in GSA8-9-10-11. The values reported represent the average values during the period 2015-2016.

<table>
<thead>
<tr>
<th>Fleet segment</th>
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<th>VL1824</th>
<th>VL2440</th>
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<tbody>
<tr>
<td>Vessels number</td>
<td>(</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days at sea</td>
<td></td>
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<td></td>
<td></td>
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<tr>
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<tr>
<td>weight (tonne)</td>
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<tr>
<td>%</td>
<td>37</td>
<td>35</td>
<td>43</td>
</tr>
</tbody>
</table>
Figure 2.15: Species average landing weight across fleet segments in eastern management unit during the period 2015-2016.

Figure 2.16: Landings dependency of fleet segments by species estimated on average landings value for the period 2015-2016 in eastern management unit.
3 ToR 2 RELATIONSHIP BETWEEN EFFORT AND MORTALITY

"In light of new data, review the outcomes concerning the relationship between effort and fishing mortality as prepared by the STECF EWG 18-09."

3.1 Additional linear regressions analyses

During the EWG18-09 the relationship between fishing mortality and fishing effort for some Western Mediterranean stocks was analysed. However, the updated stock assessments results from EWG 18-12 were yet available and could not be used by EWG 18-13, so the analyses are based on older STECF assessments.

In particular, the stocks of Deep-water rose shrimp (DPS) in GSAs 1 and 5 and the stocks of Blue and red shrimp (ARA) in GSAs 5 and 6 were analysed in the western GSAs. In the eastern GSAs, the relationship between fishing effort and fishing mortality has been investigated for Norway lobster (NEP) and giant red shrimp in GSA9, DPS and hake (HKE) in the GSAs 9,10 and 11 combined.

The EWG analysed stocks for which stock assessments for combined GSAs were available: HKE in GSAs 1, 2, 5, 6 and 7 in the western areas and HKE and DPS in GSAs 9, 10 and 11. Effort (nominal effort times fishing days) were extracted from the MEDBS Data call 2018. For GSA7, only Spanish data were available. French data were extracted from the Annual Economic report for the period 2008-2016. Fishing mortalities were obtained from the last stock assessments performed on the target species by the STECF stock assessment working groups. The results of the stock assessments report a fishing mortality for age classes, not split between the various GSAs. The subdivision was made using as a factor the ratio between the number of individuals per age class caught in each GSA and the total number of individuals caught in the combined GSAs. It was not possible to analyse the relationship between fishing mortality and fishing effort by fleet-length segments as the catch by age class per fleet segment was not available to EWG18-13.

3.1.1 Western GSAs (1-2-5-6-7) - Management Unit 1.

3.1.1.1 Trend in nominal effort

The trends of nominal trawl effort for the species and areas under study are reported in Figure 3.1 and Table 3.1. The level of fishing effort is particularly high in the case of GSA6 compared to the other GSAs, being the fishing effort very low in the small GSA 2 including the Alboran Island. In the western geographical area, there is an evident tendency to a reduction over the years. In GSA7, data for France are not available for the entire time series.
Figure 3.1 - Trends of the nominal fishing effort of the bottom trawling for the fleet fishing in GSAs 1, 2, 5, 6 and 7 and in the management Unit 1 (whole western GSAs).

Table 3.1 - Nominal fishing effort of the bottom trawling for the fleet fishing in GSAs 1, 2, 5, 6 and 7 and in the management Unit 1 (whole western GSAs).

<table>
<thead>
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<td>346923</td>
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</tr>
</tbody>
</table>

Nominal trawl effort for France in GSA 7 in missing years (2004, 2005, 2016 and 2017) was reconstructed as the mean effort in the available time series (2006-2015).

3.1.1.2 Stock assessment data

The catch numbers at age and the overall fishing mortalities at age for HKE in Management Unit 1 and the corresponding Fbar (1-4) estimated during the STECF EWG15-18 stock assessment for the GSAs 1,5,6 and 7 combined are reported in Table 3.2 and Table 3.3. The period covered is 2006-2014.
Table 3.2 – Fishing mortalities at age for HKE in GSAs 1, 5, 6 and 7 combined.

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<td>2.14</td>
<td>0.71</td>
<td>1.52</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 3.3 – Catch in number at age by GSA and by the whole western geographical area.

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<td>117.3</td>
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Table 3.4 – Fbar (1-4) by GSA and overall western area (GSAs 1, 5, 6, 7) of HKE.

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<td>0.184</td>
<td>0.111</td>
<td>0.064</td>
<td>0.078</td>
<td>0.075</td>
<td>0.124</td>
<td>0.230</td>
<td>0.202</td>
<td>0.133</td>
<td>0.159</td>
<td>0.072</td>
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<tr>
<td>1</td>
<td>1-4</td>
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<td>0.017</td>
<td>0.020</td>
<td>0.019</td>
<td>0.029</td>
<td>0.023</td>
<td>0.018</td>
<td>0.041</td>
<td>0.044</td>
<td>0.029</td>
<td>0.074</td>
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<tr>
<td>6</td>
<td>1-4</td>
<td>0.874</td>
<td>0.700</td>
<td>0.736</td>
<td>0.675</td>
<td>0.704</td>
<td>0.523</td>
<td>0.780</td>
<td>0.991</td>
<td>1.072</td>
<td>0.911</td>
<td>0.853</td>
<td>0.452</td>
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</table>
3.1.1.3 Fishing mortality – nominal effort relationship

HKE in GSAs 1, 2, 5, 6 and 7

The relationship between the nominal effort of bottom trawling and the fishing mortality for HKE in each GSA is reported in Figure 3.2. The points are distributed in a cloud of values. The lines reported in the graph hypothesize a linear relationship between fishing effort and fishing mortality. The red line represents the linear regression on the observed values. The black dashed line represents the linear regression forced to pass from the origin according to the reasonable assumption that F is nihil when no fishing effort is exerted on the stock.

In the same way as the single GSAs, the values for the overall western Management Unit MU1 are distributed in a cloud that does not allow to highlights any clear relationship between fishing mortality and the nominal fishing effort for GSA 5, 6 and 7 (Figure 3.3).

![Figure 3.2](image)

Figure 3.2 – Relationship between total nominal effort and Fbar for HKE in a) GSA1, b) GSA5, c) GSA6, d) GSA7. Red dashed line: linear regression on the observed points. Black dashed line: linear regression forced through the origin.

An attempt to derive an overall relationship between nominal effort and F was tried to combined the values by GSA assuming that the HKE of western subareas belong to a single stock according to the EU STOCKMED project (Fiorentino et al., 2015) and that differences in catchability between fishing systems used in the different GSAs are negligible.
Figure 3.3 – Relationship between nominal effort and Fbar(1-4) for hake in GSAs 1, 5, 6 and 7. Red line: linear regression for each GSA and for the GSAs combined. Black dashed line: linear regression forced through the origin for each GSA and GSAs combined. Data for the individual GSAs are the same as in Figure 3.2.

The main parameters of the estimated relationships, keeping the GSAs separated and as the whole Management Unit 1 (overall and combined) are reported in table 3.5.

Table 3.5 – Parameters of the relationship between nominal effort and Fbar for the European Hake in GSAs 1, 5, 6 and 7.

<table>
<thead>
<tr>
<th>Variable</th>
<th>gsa1</th>
<th>gsa5</th>
<th>gsa6</th>
<th>gsa7</th>
<th>gsa 1-7</th>
<th>model</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>0.054</td>
<td>0.044</td>
<td>1.222</td>
<td>0.426</td>
<td>1.942</td>
<td>Fbar = a+b*effort</td>
</tr>
<tr>
<td>Effort</td>
<td>1.48E-08</td>
<td>-4.66E-09</td>
<td>-1.66E-08</td>
<td>2.02E-09</td>
<td>-1.46E-08</td>
<td>Fbar = a+b*effort</td>
</tr>
<tr>
<td>r.squared</td>
<td>0.036</td>
<td>0.002</td>
<td>0.107</td>
<td>0.001</td>
<td>0.034</td>
<td>Fbar = a+b*effort</td>
</tr>
<tr>
<td>Pr(&gt;F)</td>
<td>0.556</td>
<td>0.901</td>
<td>0.326</td>
<td>0.929</td>
<td>0.585</td>
<td>Fbar = a+b*effort</td>
</tr>
<tr>
<td>Effort</td>
<td>2.49E-08</td>
<td>1.12E-08</td>
<td>2.70E-08</td>
<td>9.45E-08</td>
<td>3.38E-08</td>
<td>Fbar = 0+b*effort</td>
</tr>
<tr>
<td>Pr(&gt;F)</td>
<td>4.30E-06</td>
<td>0.000101</td>
<td>1.10E-06</td>
<td>3.62E-06</td>
<td>1.81E-07</td>
<td>Fbar = 0+b*effort</td>
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3.1.2 Eastern GSAs (9-10-11) - Management Unit 2.
3.1.2.1 Trend in nominal effort

The trends of nominal fishing effort for the bottom trawling in the Management Unit 2 was reported in Figure 3.4 and Table 3.6. A notable decreasing trend in fishing effort was observed from 2005 to 2011. In the last years, the effort remained quite constant with small fluctuations with exception of GSA 10.

![Figure 3.4 - Trends of the nominal fishing effort of the bottom trawling for the fleet fishing in GSAs 9, 10 and 11 and in the management Unit 2 (whole eastern GSAs).](image)

Table 3.6 - Nominal fishing effort of the bottom trawling for the fleet fishing in GSAs 9, 10 and 11 and in the management Unit 2 (whole eastern GSAs).

<table>
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<td>1338</td>
<td>3721</td>
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To verify the consistency of effort data, the relationship between nominal effort expressed as engine power (kW) per fishing days, and the fishing days as supplied by the MEDBS data call 2018 was compared. In all the three GSAs analysed the two indices of fishing effort resulted highly correlated (Figure 3.5).
3.1.2.2 Stock assessment data

The fishing mortalities for the analysed species are reported in Table 3.7. The fishing mortality for hake was estimated by STECF (2015a) for the GSAs 9, 10 and 11 combined. The period covered is 2006-2014, the Fbar was computed on the 1-4 age classes.

The fishing mortality for deep-water rose shrimp was estimated by STECF (2016a) for the GSAs 9, 10 and 11 combined. The period covered is 2006-2014, the Fbar was computed on the 0-2 age classes.

Table 3.7 – Fishing mortalities for the analyzed stocks in the western eastern Mediterranean (GSA 9,10,11).

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3.1.2.3 Fishing mortality – nominal effort relationship

Hake in GSAs 9, 10 and 11

In table 3.8 the relationship between the nominal effort of bottom trawling and the fishing mortality for HKE in GSAs 9, 10 and 11 combined is reported.
Table 3.8 – Catch in number at age by GSA and by the whole western geographical area.

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<td>5038.5</td>
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<td>403.2</td>
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<td>11</td>
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<td>38.9</td>
<td>14.0</td>
<td>20.5</td>
<td>8.8</td>
<td>26.9</td>
<td>13.8</td>
<td>9.4</td>
<td>16.3</td>
<td>4.2</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>8.7</td>
<td>3.2</td>
<td>10.7</td>
<td>11.6</td>
<td>7.7</td>
<td>2.0</td>
<td>1.7</td>
<td>7.0</td>
<td>2.6</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>8.7</td>
<td>3.2</td>
<td>3.9</td>
<td>5.6</td>
<td>2.0</td>
<td>1.7</td>
<td>1.4</td>
<td>5.3</td>
<td>2.1</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

As in the case of HKE in the Management Unit 1 an overall relationship between nominal effort and F was derived combining the values by GSA assuming that the HKE of eastern subareas belong to a single stock and that differences in catchability between fishing systems used in the different GSAs of Management Unit 2 are negligible.

In Figure 3.6 the relationship between the nominal effort of bottom trawling and the fishing mortality for HKE in GSAs 9, 10 and 11 combined is reported. The red lines are the regressions between F and effort data for the period 2006-2014 for each GSA and for the combined GSAs. The black dashed lines are the regressions forced through the origin. Most of them was significant.
Figure 3.6 – Relationship between nominal effort and Fbar for hake in GSAs 9, 10 and 11. Red line: linear regression for each GSA and for the GSAs combined. Black dashed line: linear regression forced through the origin for each GSA and for the GSAs combined. Data for the individual GSAs are the same as in Figure 3.7

In Figure 3.7 the relationships between nominal effort and fishing mortality by keeping the GSAs separated and considering the overall values in the whole management Unit 2 are displayed. In this case it is possible to identify a trend with values of fishing mortalities generally lower in the GSAs with low levels of fishing effort.
Figure 3.7 – Relationship between nominal effort (kW*fishing days) and fishing days for the bottom trawling fleet fishing in GSAs 9 (a), 10 (b) and 11 (c).

The main parameters of the linear relationships, keeping the GSAs separated and as the whole Management Unit 1 (overall and combined) are reported in Table 3.9 while catch numbers at age are shown in Table 3.10.

Table 3.9 – Parameters of the relationship between nominal effort and Fbar for the European Hake in GSAs 9, 10 and 11.

<table>
<thead>
<tr>
<th>variable</th>
<th>gsa9</th>
<th>gsa10</th>
<th>gsa11</th>
<th>gsa 9-11</th>
<th>model</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-0.032</td>
<td>0.299</td>
<td>0.035</td>
<td>0.717</td>
<td>Fbar = a+b*effort</td>
</tr>
<tr>
<td>effort</td>
<td>4.55E-08</td>
<td>2.19E-08</td>
<td>1.92E-08</td>
<td>1.47E-08</td>
<td>Fbar = a+b*effort</td>
</tr>
<tr>
<td>r.squared</td>
<td>0.309</td>
<td>0.125</td>
<td>0.166</td>
<td>0.079</td>
<td>Fbar = a+b*effort</td>
</tr>
<tr>
<td>Pr(&gt;F)</td>
<td>0.12</td>
<td>0.351</td>
<td>0.276</td>
<td>0.465</td>
<td>Fbar = a+b*effort</td>
</tr>
</tbody>
</table>

Deep-water rose shrimp in GSAs 9, 10 and 11

Table 3.10 – Catch in number at age by GSA and by the whole western geographical area.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>4924</td>
<td>4872</td>
<td>9717</td>
<td>13071</td>
<td>7504</td>
<td>33199</td>
<td>7619</td>
<td>12103</td>
<td>26556</td>
<td>57461</td>
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<tr>
<td>9</td>
<td>26312</td>
<td>13339</td>
<td>20689</td>
<td>22068</td>
<td>40079</td>
<td>39825</td>
<td>44708</td>
<td>42176</td>
<td>37541</td>
<td>55556</td>
</tr>
<tr>
<td>9</td>
<td>6957</td>
<td>3390</td>
<td>2271</td>
<td>3395</td>
<td>4044</td>
<td>2322</td>
<td>6787</td>
<td>3801</td>
<td>4422</td>
<td>4262</td>
</tr>
<tr>
<td>9</td>
<td>1760</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>622</td>
<td>1391</td>
<td>693</td>
<td>1595</td>
<td>1511</td>
<td>947</td>
</tr>
<tr>
<td>10</td>
<td>104647</td>
<td>94380</td>
<td>43768</td>
<td>36865</td>
<td>36746</td>
<td>50686</td>
<td>56509</td>
<td>66703</td>
<td>55029</td>
<td>93574</td>
</tr>
<tr>
<td>10</td>
<td>53918</td>
<td>15897</td>
<td>20689</td>
<td>22068</td>
<td>40079</td>
<td>39825</td>
<td>44708</td>
<td>42176</td>
<td>37541</td>
<td>55556</td>
</tr>
<tr>
<td>10</td>
<td>1570</td>
<td>1157</td>
<td>328</td>
<td>488</td>
<td>561</td>
<td>470</td>
<td>256</td>
<td>146</td>
<td>878</td>
<td>362</td>
</tr>
<tr>
<td>10</td>
<td>1760</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>622</td>
<td>1391</td>
<td>693</td>
<td>1595</td>
<td>1511</td>
<td>947</td>
</tr>
<tr>
<td>11</td>
<td>114495</td>
<td>102255</td>
<td>55218</td>
<td>50273</td>
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<td>86293</td>
<td>65615</td>
<td>79661</td>
<td>82006</td>
<td>152400</td>
</tr>
<tr>
<td>11</td>
<td>85691</td>
<td>32567</td>
<td>43193</td>
<td>44554</td>
<td>59624</td>
<td>60002</td>
<td>67345</td>
<td>73293</td>
<td>66354</td>
<td>74571</td>
</tr>
<tr>
<td>11</td>
<td>9263</td>
<td>4996</td>
<td>2858</td>
<td>4039</td>
<td>4776</td>
<td>3020</td>
<td>7099</td>
<td>4022</td>
<td>5339</td>
<td>4671</td>
</tr>
</tbody>
</table>
The relationship between F and effort for DPS in GSAs 9, 10 and 11 separated and combined is showed in Figure 3.8 and 3.9.

Figure 3.8 – Relationship between nominal effort and Fbar for Deep-water rose shrimp in GSA 9 (a), 10 (b) and 11 (c). Red line: linear regression for each GSA and for the GSAs combined. Black dashed line: linear regression forced through the origin for each GSA and for the GSAs combined.
Figure 3.9 – Relationship between nominal effort and Fbar for Deep-water rose shrimp in GSAs 9, 10 and 11. Red line: linear regression for each GSA and for the GSAs combined. Black dashed line: linear regression forced through the origin for each GSA and for the GSAs combined. Data for the individual GSAs are the same as in Figure 3.8.

The main parameters of the linear relationships, keeping the GSAs separated and as the whole Management Unit 1 (overall and combined) are reported in table 3.11.

Table 3.11 – Parameters of the relationship between nominal effort and Fbar for Deep-water rose shrimp in GSAs 9, 10 and 11.

<table>
<thead>
<tr>
<th>variable</th>
<th>gsa9</th>
<th>gsa10</th>
<th>gsa11</th>
<th>gsa 9-11</th>
<th>model</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>1.112</td>
<td>-0.148</td>
<td>-0.066</td>
<td>0.059</td>
<td>Fbar = a + b*effort</td>
</tr>
<tr>
<td>effort</td>
<td>-5.96E-08</td>
<td>6.70E-08</td>
<td>2.24E-08</td>
<td>3.15E-08</td>
<td>Fbar = a + b*effort</td>
</tr>
<tr>
<td>r.squared</td>
<td>0.242</td>
<td>0.401</td>
<td>0.859</td>
<td>0.203</td>
<td>Fbar = a + b*effort</td>
</tr>
<tr>
<td>Pr(&gt;F)</td>
<td>0.149</td>
<td>0.049</td>
<td>0</td>
<td>0.191</td>
<td>Fbar = a + b*effort</td>
</tr>
</tbody>
</table>

| effort   | 3.84E-08 | 7.20E-08 | 7.20E-08 | 3.41E-08 | Fbar = 0 + b*effort |
| Pr(>F)   | 1.87E-06 | 0.00039 | 0.0004 | 0.191 | Fbar = 0 + b*effort |
3.1.3 Conclusions

The analyses carried out during STECF EWG18-13 allowed to deepen the results obtained during the previous meeting STECF (2018a). The fishing mortality values of the main demersal stocks in western Mediterranean are not clearly correlated to the nominal effort exerted by the trawl fleets exploiting the stocks.

These results are in accordance with the results showed by Cardinale et al. (2017). According to the authors, the lack of a significant relationship between F and effort was observed and should be the effect of a combination of factors such as;

i) short time series of the assessments and lack of sufficient contrast F/effort (i.e. the F values are concentrate in a period of high fishing pressure on the stock);

ii) reduction in effort mostly due to the decommissioning of the less efficient vessels;

iii) temporal change in the spatial pattern in fishing effort in relation to the abundance of the main target stocks, the markets demands, etc.;

iv) nominal effort trend not reflecting the real fishing effort.

Furthermore the absence of clear pattern might be also due in low accuracy in measuring fishing mortality.

During STECF EWG18-13 the three stocks analyzed did not show a strong correlation between fishing effort and fishing mortality. However in all the 3 cases analysed the lowest F values were obtained in the GSAs featured by lowest effort values.

The relationship derived assuming the stock unit of HKE and DPS inside the two manangement Units according to the EU STOCKMED project (Fiorentino et al., 2015) and that differences in catchability between fishing systems used in the different GSAs inside each Management Unit are negligible were not considered very reliable by the WG due to expected differences in size of the standing stock in each GSA that could affect the catchability. However, considering the lack of contrast in the data within the single GSA, this approach could be worthy for further investigations. Because of the differences in hours of fishing per fishing day in different GSAs, the WG recommended to increase accuracy in measuring the fishing activity (e.g. as fishing hours instead of fishing days) would be probably necessary to estimate a more reliable fishing effort exerted on each stock.

3.2 Alternative non-linear relationships

The second paragraph of TOR 2 requested the EWG-18-13 to estimate three different relationships between changes in F and changes in nominal effort. As the linear relationship generally used was considered by the EWG-18-09 as overoptimistic, non-linear relationships should be estimated to cover the conservative and pessimistic scenarios.

The EWG-18-13 explored the potential use of the non-linear relationship $F = a \times E^b$, which can cover different scenarios from optimistic to pessimistic depending on the value of the parameter $b$, which is generally called elasticity coefficient. The elasticity coefficient indicates the percentage change that will occur in one variable (F) when another variable (E) changes one percent.

3.2.1 Using a regression model

The equation reported above can be expressed also in terms of variations from time t-1 to time t as follows:

$$\frac{F_t}{F_{t-1}} = \left(\frac{E_t}{E_{t-1}}\right)^b$$

A value of $b$ equal to 1 means a linear relationship where a percentage change by 1% in nominal effort would produce a 1% variation also in F. A value lower (higher) than 1 means that the percentage variation in F would be lower (higher) than the percentage variation in nominal effort. As $b = 1$ is considered optimistic, the estimation of this model on real data was expected to produce values of the elasticity coefficient $b$ between 0 and 1.

Data on the demersal fisheries in GSA 9 were used to test the relationship. The fishing mortality at age from 2006 to 2015 of vessels using OTB were collected for European hake (HKE), Norway lobster (NEP), Deep-water rose shrimp (DPS), striped mullet (MUT) and surmullet (MUR) (see
Regarding the nominal effort, expressed in terms of average KW by days at sea, data on KW and days at sea for the same period were collected for the three fleet segments using OTB in GSA 9: demersal trawlers of length classes 12-18, 18-24 and 24-40 (DTS1218, DTS1824 and DTS2440). Data on nominal effort is consistent with the dataset from the AER. Days at sea from the AER for the period 2008-2015 were integrated with 2006 and 2007 data provided by the EWG experts. The average KW of the active vessels, which is not available by GSA from the AER, was provided by the EWG experts. To overcome the problem of the different level of aggregation between F and E, fishing mortality at age was split by fleet segment using the landings proportions. Finally, a time series of partial Fbar was calculated for each stock and fleet segment by using the stock specific ranges adopted for the stock-assessment procedures.

Regressions of Fbar on E were carried out to estimate a total of 15 elasticity coefficients, one for each combination stock-fleet segment. Regressions were performed following two different approaches:

1) Estimating $a$ and $b$ for each combination stock-fleet;
2) Estimating $a$ by stock and $b$ for each combination stock-fleet.

The results obtained on the coefficient $b$ by the two approaches are reported in Table 3.12. The use of the same $a$ for all fleet segments (approach 2) determined also a higher homogeneity in the values of $b$ for the different stocks. However, some unacceptable values for $b$ are present under both approaches. There are some coefficients at zero (or negative) in approach 1 (4 values) and approach 2 (3 values). The zero value would mean that there is no relationship between F and E for those stock-fleet combinations, while a negative value would be in contrast with the theoretical expected relationship as an increase in E would produce a decrease in F.

The other estimated values are all acceptable even though in some cases the coefficients are greater than 1. A value greater than 1 would mean that a percentage reduction in nominal effort by 10% would determine a reduction in F higher than 10%. This is in contrast with an expected value of $b$ between 0 and 1.

Figure 3.10 reports the actual vs. fitted data for each of the 15 combinations analysed. Quadratic trend lines are designed on the fitted data estimated under the two approaches for each combination stock-fleet: blue line relates to the approach 1 and grey line to approach 2. The trend lines allow the reader to have an idea of the similarity among the outputs from the two different approaches.

Table 3.12. Estimates of model’s $b$ parameter.

| Estimates of $b$ based on the approach 1 | | Estimates of $b$ based on the approach 2 |
|-----------------------------------------|-----------------------------------------|
| DTS1218 DTS1824 DTS2440 | HKE | NEP | DPS | MUT | MUR |
|-----------------------------------------|-----------------------------------------|
| HKE | 0.00 | 0.55 | 1.23 |
| NEP | 0.22 | 0.82 | 0.36 |
| DPS | 0.00 | 0.81 | 0.00 |
| MUT | 0.98 | 0.58 | 1.11 |
| MUR | 0.00 | 1.44 | 1.30 |
|-----------------------------------------|-----------------------------------------|
| DTS1218 DTS1824 DTS2440 | HKE | NEP | DPS | MUT | MUR |
|-----------------------------------------|-----------------------------------------|
| HKE | 0.55 | 0.59 | 0.48 |
| NEP | 0.40 | 0.43 | 0.34 |
| DPS | -0.29 | -0.23 | -0.43 |
| MUT | 0.97 | 0.95 | 0.87 |
| MUR | 1.73 | 1.70 | 1.75 |
Figure 3.10 – Relationship F-E: fitted vs. actual data with trend lines for each estimation methods for each of the 15 combinations between stock and fleet segment. blue line relates to the approach 1 and grey line to approach 2.

3.2.2 Using a mixed effect model

An alternative to estimate the non-linear relationship between fishing mortality and fishing effort was explored using mixed effects models. These models allow the fit to all the stocks and fleets simultaneously, borrowing information across each.

Preliminary results are presented in Annex 01 and Figure 3.11. Results show a steeper relationship between fishing mortality and effort for MUT caught by DTS 1218 and 1824, and HKE caught by DTS 1824. On the other hand MUR shows the flattest relationship, with the other species and fleet segments somewhere in between these two groups.

Note that this approach can’t be simply converted into the exponential model used in the previous section due to the inclusion of the random effect on intercept and slope by stock. To work within a bio-economic model these results would have to be embedded in such model and fishing mortality predicted from the LME model.
Figure 3.11 Non-linear relationship between fishing mortality and fishing effort for the relevant species and fleet segments. Above: all together. Below: separated by stock and by fleet.

3.3 Exploration of alternative measures of fishing effort to try to improve the F-E relationship

With regards to gear size and nominal effort interactions the EWG recalls what was done by EWG 18-09 (STECF, 2018a) which is still considered valid.

3.3.1 Using hours fished and account for targeting

3.3.1.1 Principles

While discussing ToR 2 results in the plenary of EWG 1813, it was observed that the fishing days used in the nominal effort measurements were not the same depending on the country. Each country or regional legislations define different limits of daily fishing operations, including hours per
day allowed for fishing. In this sense, a fishing day in Spain means that the boat has been out of
the port no more than twelve hours, although there are the exceptions of the fleets exploiting the
Ibiza and Alboran Island crustacean fisheries in the slope which can be out of the port sixteen hours
due to the distance to those fishing grounds. On the other hand, in Italy a more elastic and variable
or no limitations at all does occur, and in some cases daily fishing activity is deployed day and
night. There is also an exception that allows some boats to stay at sea more than one day. For
these differences in the time allowed at sea between countries, the measure of the effort is not
standardized throughout the countries involved in the future MAP. It was also pointed out that the
other variable included in the effort measure, the KW of each of the vessels, is an uncertain value
and that perhaps the effort measure should be more simple and reliable by just using fishing days.
An option that was proposed during the discussion was to use hours of effective fishing instead of
fishing days, which would be a standardized measure of effort throughout all the countries involved.
It is pointed out that the calculation of the effective fishing hours can be done either by using VMS,
not currently requested in the official data calls, or by using the information in the log-books which
is currently requested not by day but by haul and is requested in the official data calls. Both data
sources would allow computing the effort as effective fishing hours. Having more fine measures of
effort could allow improving in the exploration of the relationship between F and effort in the core
of the proposal of the MAP. VMS have the advantage that could provide a longer time series of
effort as their implementation started in 2006.

The so-called nominal effort is the sum of the fishing effort units exerted on a resource in a given
time period. It can only be considered effective effort when effort has been standardized taking
into account the differences in fishing power and efficiency, and likely also differences in skipper
skill or any technological difference among vessels or fleets that may change the vessel’s fishing
power. Only under such conditions a direct proportionality with fishing mortality can be expected.

In the Mediterranean Sea different fractions of the fleets target different species assemblages with
very different species composition and with fishing grounds spatially separated. In consequence,
not all the fishing effort of a fleet can be computed to all the species or species assemblages because
they not remove individuals of all the populations but only for those which are present in the fishing
ground where they are operating. Fishing effort should be calculated in consequence separately for
each fishing trip targeting specific species or species assemblages. Such quantification is more
effective than the use of total effort of a fleet without considering on which species or assemblage
the effort is exerted. Fishing mortality rates on each single stock is in most of the cases caused by
only a fraction of the fleet, for which the specific resources are vulnerable. A quantification of effort
is always necessary, but availability of precise information is particularly critical in the case of an
effort regime management.

Catches or landings of each fishing trip must be quantified considering whether it targets a given
species/species mix or not. Uncertain information on effort partitioning and their links with captures
not accurately reflect annual changes in fish populations and can lead to incorrect management
advice. Statistical and ad-hoc approaches can be used for the identification of directed fishing effort
towards certain species. These approaches generally use trip species composition to infer the fished
grounds exploited during a trip. Defined minimum proportions of a species or group of species in
the catch is in general used for defining whether there was a clear target of a fishing
operation. However, the presence of these species not always represent an important fraction even
when fishers intended to catch them based on past experience. In consequence, classification of a
trip as directed to certain species or species complex (and its relative fishing effort) only based on
certain arbitrary proportions of target species over the whole catch may be misleading. Without a
correct effort partitioning, trends in the commercial catch rates (i.e. CPUEs) may not reflect the true
trend in the fisheries resource (Walters 2003), which may result in a mismanagement of the
fisheries resource and conflicts between stakeholders.

3.3.1.2 Examples of use of specific effort information related to directed effort and a more precise
effort quantification (effective hours fishing).

To obtain a series of the measure for directiveness of the fishing per year, haul-by-haul data are
required that cover the entire fished area. The information so disaggregated can be used for
different analyses of the fleet (spatial distribution of fishing effort by assemblage, seasonal changes,
links between fishing effort and fishing mortality, use of models that need information on effort)
which result necessary for the assessment of the status of exploitation of mix fisheries exploiting groundfish assemblages and for management purposes.

As shown in ToR 1, a time series of hours fished was not available to EWG 18-13. To illustrate the potential benefits of using hours fished, the results of older studies were reported (Abell et al., 2001, 2006, 2010). They present the analysis of the assemblages that are exploited by the most important fleet in the Tyrrhenian Sea (Viareggio fleet) operating in GSA9 (Figure 3.12).

![Figure 3.12. Studied area, grid used for collection of information on geographic allocation of fishing effort and trip information sheet](image)

A catch assessment project started in 1990 many years before the VMS system by installing satellite transmitters onboard the fishing vessels have been enforced. The aim of the project was to obtain more precise information about fleet behaviour, fishing strategies and their impact on resources, target species, spatial distribution of the fleets, seasonal changes in targets, identification of targeted species assemblages, quantification of fishing effort, comparison of vessels fishing power, etc. At the moment of the start of the project, fishers were not obliged to fill logbooks and hence no information on the fishery on all the fishing strategies that were present, effective time fishing by fishing strategy, fishing areas, catch composition by vessel type, size structure of the landed species and many other information useful for giving advice.

Catch and effort survey was carried out through interviews done to skippers during the landing operations. The survey covered all the fisheries in the port, for demersal and small pelagic species and includes small-scale boats. Fishermen were requested to furnish precise information on fishing area(s) and depths by haul. The operation areas were selected in a fine grid positioned on the other side of the sheet, that covers the fishing areas of the Viareggio fleet selecting the squares where they operated this day. The sheet also included information regarding the fishing vessel code in order to allow the knowledge of with their structural characteristics, date, used gear, number of tows, duration of each tow, fishers’ target, time of departure and arrival to the port and the landed composition as number of boxes or fractions of each species for each tow. Samples were purchased for reconstruction of the size composition of the landings for the main species. Information of possible discard fractions is collected using observers onboard during fishing operations. All the mentioned information was stored in a special data base in ACCESS. Georeferenced information regarding fishing effort by vessel, fleet, fishing strategy, species, period, can be represented using the specially designed software MLFD (mapper of landed fish data) (Fortunati et al, 2001, Abella et al, 2001). After the departure of the EU Data Collection program, the survey was not interrupted as sampling intensity (and hence quality and quantity of information) was much higher even though restricted to this specific port.

The available data allowed to discriminate vessels’ fishing trips exploiting the different grounds where different species assemblages inhabit. This allowed to quantify more precisely the amount of effort exerted on each species or species assemblage. Most of the species live inside limited depth intervals or grounds. Fishers’ experience is used for determining their targets. The distance from the port determines the fraction of the daily trip that they can dedicate to fish capture and the rest of the time is navigation or searching of adequate grounds where fishers expect adequate yields.
The detailed information on effort amount directed to each fish assemblage derived from the ad hoc project allowed also to perform stock assessment in the area using a non-equilibrium production model (ASPIC) for the assessment of the coastal demersal assemblage (Abella et al, 2010). This was useful for giving advice in situations of limited data for a fishery where prior stock assessments have never been done. Italian official statistics especially are still not able to provide enough information on operation areas, nor on the target species and effective effort exerted by a single vessel during each fishing trip. Population projections using ASPIC-P allowed evaluating future harvest strategies for a 10-year period for the 8 main species that represents more of the 65% of the landings and for the whole assemblage. Data of landings and specific effort of the Viareggio fleet for the period 1990-2008 were analysed. The statistical analysed population was constituted by all the vessels that operated along the years from the Viareggio port using bottom trawl nets and targeting coastal demersal species. The abundance index LPUE (landings per unit effort) was calculated for each species as “total weight in kg of the landings/fishing effort” with effort expressed as effective hours fishing excluding time spent for transfers to the fishing grounds. In the Mediterranean few attempts of using production models based on catch and effort data have been done as alternative of analytic approaches when information on age structure of the catches is not available. This is probably due to the lack of adequate information on amounts of directed fishing effort and precise quantification of effective fishing effort.

These data sets allowed then to analyse the relationships between fishing effort f and fishing mortality F, the information of directed fishing effort in effective hours fishing for each species/species assemblage was plotted against corresponding estimates of F based on age structure of the catches for the years 1991-2008. (Abella et al 2010). Reasonable results were obtained (Figure 3.13). It is considered that the exclusive use of the specific effort directed to a stock instead of the overall effort of an entire fleet category (i.e. of all the bottom trawlers or of an entire segment of the fleet targeting different resources) eliminates elements of noise. In fact, the use of overall effort does not consider the number of vessels or number of trips that really have exploited certain species nor the changes in time in fishing pressure that may have occurred due to changes in targets or other causes. The next figure shows the results obtained in the above-mentioned study for some species exploited in the coastal area.
A second part of the study was to investigate differences in fishing power of the single vessels involved.

Some vessel's characteristics (size, power) may condition the impact of a unit effort on a fish population, and hence standardization of fishing vessels should be necessarily done. When a gear is utilized by vessels with quite different characteristics or used different kinds of gear, the respective efforts must be standardized in order to compute overall effort.

It is frequently used the product of fishing activity with some measure of fishing capacity (engine power, size of the vessel, TSL) if they can in some way standardize the effort information of the single vessels. However, the relationships between structural characteristics of the vessel with fishing power (here expressed in terms in catch per unit of effort, CPUE) are seldom linear, and most of the time relationships show asymptotical shapes. This was also observed in the Viareggio fishery in GSA9 for several species, using information on single trips operating in the same depth interval, with the same target and in the same period of the year. Asymptotic or almost flat behaviour of the curves were found for the main commercial species in the area. Only in the case of very small vessels the differences in fishing power appears more evident (Figure 3.14).

The fractions of the fleet targeting different assemblages were fairly uniform regarding their structural characteristics (Kw, TSL, size), and the comparison of fishing power with such characteristics of the vessels suggested an almost similar fishing power in the observed range of sizes. In consequence, no standardization based on capacity measures was considered necessary.

Figure 3.13. Relationship between F and f for single species and for a species pool of the generalist coastal fishery. Years 1991-2008, Viareggio fleet in GSA 9
The assumption of a simple linear relationship expressing effort as \( kw \times \text{days} \) would have produced worse results. Often nominal effort measures as activity \( x \) capacity (i.e. \( KW \times \text{days} \)) are used in management areas where different fleets operate but with vessels characterised by different size structure (as it often occurs in the Mediterranean). Differences in the amount of effort (and potential fishing power) of such different fleets could not be assessed correctly if a more detailed relationship is not used. An example in the case the simplistic measure of effort is \( kw \times \text{days} \) fishing is used for comparing fleets fishing capacity, in a fleet a 100 vessels operate with engine power of 300kw and in other fleet b 300 vessels with 100kw engines, it is hard to assume that both fleets have the same fishing power even though a product can be exactly the same.

**Figure 3.14. Relationship between engine power (HP) and catch performance (Kg/h) for Mullus barbatus (a), Merluccius merluccius (b), Nephrops norvegicus (c) and in catch days (about 10 hours effective fishing) for a species pool of the generalist bottom trawl fishery (d) (Abella et al. 2006)**

Other problem regards the fishing mortality that a unit of effort may produce. Catchability coefficient may be quite different in different areas in the same management unit not only due to changes in availability/vulnerability of the resources. The rate between the swept area and the whole ground where the stock is present and potentially vulnerable can be quite different. One unit of effort removes a fraction of the population and produces mortality. As the area where the resource is distributed is much bigger, the negative impact of one unit of effort will be lower.

This is especially critical for instance for Nephrops that concentrates in spots where specific characteristics of the grounds make possible settlement and adequate food supply. The units of effort exerted over areas with different sizes must be standardized whenever we intend to compare such local efforts with fishing mortality estimates for the same areas.

An example of the use of standardized measures of effort considering area sizes is shown in the next figure. It regards the use of information proceeding from different Nephrops grounds exploited with different rates by different fleets operating in GSA9. Data proceed also in this case from the above-mentioned program of sampling using interviews during the landing operations (STECF, 2004) A fairly good correlation was obtained between effort directed to fish Norway lobster on four different grounds in GSA9 expressed as standardised effort as number of fishing trips targeting this species per unit area and estimates of total mortality Z rates (Figure 3.15). Z estimates for each of these areas derive from analysis of catch curves. One of the 4 analysed grounds is considered very lightly unexploited and others full or overexploited and such contrast is considered quite informative. The intercept with the Y axis (0 effort) can be considered a proxy estimate of natural mortality rate.
Figure 3.15. Relationship between effort (number of fishing trips standardised by the size of fishing grounds) and total mortality rate $Z$ for a number of Nephrops fishing grounds in GSA 9, years 1998-2000. Estimates of total mortality rates $Z$ are derived from the size structure

Catch per Unit Effort (CPUE) is the most commonly used index in fisheries science to monitor stock status and the effect of management measures. CPUE are often used as an index of Biomass. However, for a proper use of CPUE aimed at assessing stock status in multispecies fisheries, also in this case we need to consider how fishers direct their effort to each species or specie assemblage. Trends in the commercial catch rate may not reflect the true trend in the fisheries resource (Walters 2003), which may result in a mismanagement of the fisheries resource and conflicts between stakeholders.

Mutsert et al. (2008) stated that whenever a mis-specification of any change in the targets of fractions of the fleet and a lack of detailed knowledge of effort allocation by targets occur, data of landings may drive to errors. Many false cases of collapse based simply upon a decline of catch or catch rates or in analyses of changes in the trophic level (i.e. in the Pauly et al analysis of Black Sea and Med landings) (Pauly et al., 2005) have been observed. Mutsert et al (2008) state that targeting, variability in fishing effort, and market forces should be well known.

3.3.2 Estimating the swept areas.

EWG 18-13 attempted to refine the relationships between fishing mortalities ($F_{bar}$) and Effort by correcting the effort metric by accounting for the dimension of the fishing gears in use. Accounting for the gear size should make possible to deduce the area swept during trawling events, which is expected to relate more to different catching power, beyond using hours fished only.

The refinement of the effort metric using swept area estimates requires using individual vessel data because it is required to know the individual specifications of the fishing vessels such as the LOA or KW, the gear type in use during the haul-trip, and the conducted fisheries (target assemblage). France provided two types of individual vessels datasets for the Western Med. These two datasets differ by nature; one being trip-by-trip logbooks data covering all the trips made with the area and the second being the haul by haul observer on-board data which is a subset only of the fisheries by nature. Given that observer on-board data are not fully covering all the trips at sea, these data do therefore not comprehend the total catches made on stocks by the entire fleet. Relating declared effort in the data to swept area estimates and eventually to the overall stock assessed $F$ would be only superficial at this stage and has therefore not been attempted here.

Some knowledge on the dimensions of bottom-contact fishing gears has been recently collected and reviewed at the European scale in a recently published study (Eigaard et al 2016), including fisheries specific to the Med (e.g., OT_MIX_DMF_BEN; Figure 3.16). These estimated gear dimensions are re-used here to deduce the gear widths of trawls and dimension of seines. We use these estimates here for assigning a gear width to each record in both the datasets.
Figure 3.16. Relationship between total gear width (door spread) and vessel size by BENTHIS métier for OT. The shaded (grey) areas define Monte Carlo boot-strapped 95% confidence intervals (Eigaard et al., 2016).

The haul-by-haul data has the advantage to record the start and end positions of the hauls, making it possible to compute an estimate of the distance trawled (assuming a linear path) and together with the gear width, compute the swept area for specific hauls (Figure 3.17, right panel). The trip-by-trip data do not record haul positions by the total fishing effort of the trip. Assuming an average fishing speed, the swept area per trip can also be deduced from the vessel-specific gear dimension (i.e. Figure 3.17) multiplied by the effort in hours for that specific trip. Swept area can further be aggregated per stock and related to the fishing effort in hour metric showing that by construction the main cause explaining the swept area differences is the type of the fishing gear in use (Figure 3.17).
Figure 3.17. Relationships between Effort and Swept Area estimates per fishing gear (OTB, OTM, OTT, PS) from the French individual vessels dataset (left - French logbooks data in West Med., right - French haul-by-haul observer data). Each dot is an aggregation per fish stocks and 2012-2017 year period and, for the logbooks, among "HKE_SA 7" "MNZ_SA 7" "BFT_SA 26" "BFT_SA 5" "BFT_SA 6" "BSS_SA 7" "HKE_SA 12" "BFT_SA 13" "BFT_SA 15" "BFT_SA 16" "SOL_SA 7" "MUT_SA 7" "SBG_SA 7" "HKE_SA 5" "HKE_SA 6", for the haul by haul observer data, among "BSS_SA 7" "HKE_SA 7" "MNZ_SA 7" "MON_SA 7" "MUR_SA 9" "MUT_SA 7" "SBG_SA 7" "SOL_SA 7" "SWO_SA 7"

Applying the same gear-width relationships from Figure 3.16, this time the STECF effort dataset gathering aggregation of nominal effort per country (ESP, FRA and ITA), the spread of the swept area estimates around the nominal effort is captured (Figure 3.18 and 3.19) showing that to a same level of effort potentially corresponds several levels of actual swept areas. The full spread around a hypothetical linear model (solid line showed on Figure 3.19) is here explained by the different gear types in use (split per gear on Figure 3.18) and by the vessel size.
Figure 3.18. Relationships between French, Spanish and Italian Effort (fishing_days) and proxies for Swept Area estimates per fishing gear (DRB, OTT, OTB, PS) deduced from the STECF Effort data call dataset. Each point is a record in the dataset. Technological creeping assumed to be 5% increment a year.
Figure 3.19. Relationships between French, Spanish and Italian Effort (fishing_days) and proxies for Swept Area estimates, all fishing gears (DRB, OTT, OTB, PS) mixed, deduced from the STECF Effort data call dataset. Each point is a record in the dataset. Technological creeping assumed to be 5% increment a year.

All in all, the effort data from the STECF data call being aggregate and per large vessel size classes, is currently not adequate to deduce the swept area in a proper way. There is no doubt that individual data are best suited to deduce Swept Area estimates but the individual available data to the group were also lacking some crucial information that makes the estimation no more than an academic exercise at this stage. Hence, several points were raised during the estimation procedure:

1- Not available is the level 6 DCF métier definition (to relate to the Eigaard et al. 2016 relationships); would be needed to refine when different gear dimension are used depending on the target assemblages of species;
2- Not available is kW of vessels (to relate to SOME of the Eigaard et al. 2016 relationships);
3- Not available is the fishing speed of vessels (to properly compute the swept area);
4- Not available is the F for all stocks for all years (?) (to properly relates to F Bar);
5- Not available is all the total coverage of the effort (because we used French data here only);
6- We used rough assumptions to fill the information gaps, especially for seiners;
7- We use assumption of 5 % increment to catch technological creeping effect;
8- We did not correct for potential various gear mouth openings depending on the bathymetry.

Ultimately, we want to relate effort-kWdays with change in impact to correct for the technological creeping from a year to the next (the technological creeping is expected to shift up all the
relationships Swept-Area vs LOA or kW every year). The first priority to investigate would then be to relate a change in gear size to a change in catch rate. Hence, empirical studies or literature review could be done to measure the effect of increasing gear opening or swept area on the catch rates. The effort-KWdays can then be multiplied in the time series by this factor of catch rate improvement.

In this regards, EWG 18-13 recalls the information presented by STECF (2018a) on the continuous technical changes occurring in the Mediterranean gears, with the increasing use of larger trawls and of more efficient trawls (PTB instead of OTB), highlighting that there is potential for large technological creep in the near future.

### 3.4 Conclusion on ToR 2

The analyses performed in ToR 2, in addition to those performed by EWG 18-09, provide interesting results. For most of the stocks and fleets analysed, the relationships between F and E estimated at the aggregated level of the fishing fleet, the GSA and the year is not very clearly defined. This does not mean that this relationship does not exist (ultimately, F will always reduce if effort reduces), but that it is not yet been clearly observed in the recent years where data are available. This is to a large extent due to a lack of contrasts in the data, with most of the time series having remained in the areas of high fishing effort and high fishing mortality. But this is also linked to the measure of effort used, where summing days at sea for all trawlers together cannot be considered a precise measure of fishing effort reflecting the true fishing pressure on the individual stocks. As described in details in EWG 18-09, it is obvious that fleets can maintain a high level of fishing pressure even if nominal effort decreases, by e.g. increasing the number of hours fished in a day, the engine power and towing speed, the size and efficiency of the towed gear, the targeting behaviour etc.

Some non-linear relationships were fitted on the same data sets, providing some rough estimates of the Beta parameter and shape of the relationship indicative of the lower decrease rate.

The implications of these analyses at global scale are that i) it cannot be expected that fishing mortality will decrease by exactly the same amount as fishing effort in the first years of effort reduction in the MAP, but will likely reduce at a lesser rate and ii) it might take a few years before the effects of effort reductions can be seen in the stock assessment outcomes.

In addition, a number of exploratory analyses were conducted on the potential of using other measures of effort than fishing days, to refine the estimates of fishing effort. In particular, expressing fishing effort in terms of fishing hours and not days, and taking into account the targeting effect from the overlap in the spatial distribution between the fishing effort and the various stocks is considered would be a much more precise estimate of the actual fishing pressure exerted on the stocks. Such data can be compiled using VMS/AIS data. However, these analyses remained only preliminary on the basis of what could be achieved during and EWG with the data readily available to the EWG.

More work would be thus needed to collect the data necessary to pursue these analyses further. This would include i) updating the time series of fishing mortality with the most recent assessments from STECF (2018b); ii) collecting a longer time series of hours at sea, similarly to those now available in the FDI database for the years 2015-2017 (cf ToR 1). These two steps would be necessary to re-estimate the relationship at aggregated fleet level. Additionally, alternative time series of fishing effort could be estimated based on individual trip or haul-by-haul data, accounting for additional effects of targeting, vessel characteristics and technological creep, to improve the precision of the relationship analysis.
4 Tor 3 Vessel Performance

“What are the factors determining vessels’ performance?”

This section presents the results of quantitative analysis to estimate factors that affect vessels performance and mix-fisheries effects.

For the quantitative analysis, the EWG used LPUE as an indicator of vessel performance. The data available were provided by Italy, Catalonia (Spain), and France. Those from Italy and Spain were the ones provided in June to STECF (2018a), while the data from France were provided specifically for EWG 18-13.

All these Member States provided logbook-like data which is constituted of records for single days of fishing activity by vessel. In detail:

- Data for Italy: a single dataset (i.e. the same used for STECF 2018a) organized as landings records by day, vessel and species. Each record contains also information about species prices at market, coordinates (WGS1984 LAT & LON), fuel cost, and gear;
- Data for France: two datasets. The first one with the same structure of the other countries (landings records by day and vessels for the all the species, together with related information about prices at market, coordinates (WGS1984 LAT & LON), fuel cost, and gear); The second dataset with non-georeferenced data. To overcome this issue, the AREA of activity with respect to the partitioning in Figure 4.1 was provided. This allowed to merge the two datasets and perform the GAM modelling with respect to the GSAs;
- Data for Catalonia (Spain): a single dataset with landings records by day and vessels for the 5 species in the MAP (ARA, DPS, MUT, NEP, HKE) and the cumulated landings for the other species, together with related information about prices at market, coordinates (WGS1984 LAT & LON), fuel cost, and gear.

Figure 4.1 Spatial partitioning for the French dataset without LON/LAT coordinates. The area of activity is represented by the GSAs 7 and 8.

The analysis quantified the variability of LPUE by trip, and evaluates the effect of a set of explanatory variables like vessel length, season, area and specialisation. For mix-fisheries the analysis looked into non-mix operations, as a proxy for specialization of the fleet.

4.1 Data by country

For the analysis presented in this section, vessels performance was defined as the catch per unit of effort (LPUE). The analysis of factors affecting vessels’ LPUE was carried out by fitting GAM models to identify from a set of predictor variables which ones are significantly affecting vessels’
performance. The modelling approach was the same for the three country-specific datasets, but each dataset was subset and the analysis limited to the 5 species in the MAP: ARA, DPS, MUT, NEP, HKE.

The model chosen was based on experts’ opinion after evaluating a series of modelling options and having in mind the ToR request instead of strictly statistical aspects. As mentioned above the model chosen was a generalized additive mixed effects model, with the following variables:

- **Time (as Year)** - fitted as a smoothed variable theoretically accounting for the “temporal inertia” of the trend associated to each species (i.e. this predictor was expected to capture the “history” in the exploitation of each species);
- **Depth** – fitted as a factor with 2 levels (Shelf, corresponding to the range [0,-100m) and Slope, corresponding to the area below 100m);
- **Season** - fitted as a factor with 4 levels, assuming each season is independent;
- **LOA** - fitted as a factor with 3 levels in agreement with the MAP proposal: [12m-18m), [18m-24m), and [24-40);
- **Species price at first sale** - fitted as a smoothed predictor accounting for economic drivers in fleet behaviour;
- **Log of species fraction of the catches (sppfract)** - fitted as a smoothed predictor, assuming it’s a proxy of the targeting intention of fishers and then accounting for the target-dependent effect on the vessel performance (sensu Marchal et al., 2007);
- **GSA** - fitted as a factor with one levels for each, assuming each GSA is independent;
- **Vessel** - modelled has a random term, assuming each vessel as a specific constant average performance and all together deviate normally from a cross-vessel mean performance.

### 4.1.1 Data for ITALY

The Italian logbook dataset represents a non-random sample of the whole Italian database. Records with information in all the relevant fields (LON, LAT, Species code, Quantity, and Date of fishing activity) for the trawling vessels operating in the area of interest were selected, whereas records with empty fields or unrealistic values were discarded. A preliminary survey on the quality of logbook by LOA suggests that low-quality logbook records are randomly distributed among the standard DCF LOA classes [10-12), [12-18), [18-24), [24-40) (Figure 4.3). The dataset comprises 62394 records, related to 27102 days of fishing activity in the years 2014-2017. The corresponding fleet is mainly represented by vessels with a LOA between 15 and 25 m (Figure 4.2). Each logbook record contained the geographic coordinates (WGS 1984 geodetic system) of the centroid of the daily area of fishing activity and species-specific values of total daily catch for landings above the threshold of 50 Kg/day per species.
Figure 4.2 The fleet of trawlers corresponding to the records in the logbook dataset analyzed for the EWG 18-09. The area of activity is represented by the GSAs 9, 10 and 11 (Tyrrhenian Sea).

Figure 4.3 The number of Italian Logbook records corresponding to the different length classes and years, analyzed for the EWG 18-09. The area of activity is represented by the GSAs 9, 10 and 11 (Tyrrhenian Sea).

The preliminary processing of this dataset allowed enhancing the native information by:
- Assigning the GSA corresponding to each record by using the centroid’s coordinates;
- Estimating the sea bottom depth corresponding to each centroid of the fishing activity;
- Quantifying the relative proportion of the species in the Management Plans (namely: hake, deep water rose shrimp, red mullet, Norway lobster, giant red shrimp, and blue and red shrimp);
- Computing the daily LPUE as ratio between the total daily catch and the fishing effort;
- Associating the fuel cost and the species-specific prices at market, on a monthly scale. These series of data were kindly provided by experts participating to the EWG and operative units of the Italian DCF network.

4.1.2 Data for FRANCE

France provided two different datasets that were integrated before processing.

The first dataset, restricted to vessels with geolocation by tracking devices (VMS), comprises records with the same structure of the Italian dataset (daily logbook with information about position in WGS1984, specific composition of catches, vessel characteristics, fuel price and price at market of resources). The second dataset comprises records without information about spatial origin of catches. These two datasets were merged and harmonized as described above to obtain a single dataset with 405352 records, related to 1847 days of fishing activity in the years 2012-2017.

The corresponding fleet is mainly represented by vessels with a LOA a 25 m (Figure 4.4). Figure 4.5 shows the number of French Logbook records corresponding to the different length classes and years, evidencing that most of the records are related to the activity of vessels in the length classes [18-24) and [24-40].
According to the procedure applied for the Italian dataset, the data were integrated as follows:

- Assigning the GSA corresponding to each record by using the centroid’s coordinates;
- Estimating the sea bottom depth corresponding to each centroid of the fishing activity;
- Quantifying the relative proportion of the species in the Management Plans (namely: hake, deep water rose shrimp, red mullet, Norway lobster, giant red shrimp, and blue and red shrimp);
- Computing the daily LPUE as ratio between the total daily catch and the fishing effort;
4.1.3 Data for SPAIN (CATALONIA)

The dataset for Catalonia is, in terms of structure, similar to those for Italy and France but data were provided only for the species in the MAP together with cumulated values of catches for the other species. This allowed computing the relative importance of each species for each record. The dataset comprises 601860 records, related to 1471 days of fishing activity in the years 2015-2017. The corresponding fleet is almost uniformly represented by vessels with a LOA between 15 and above 27 m (Figure 4.6). Most of the records are related to the activity of vessels in the length classes [12-18) and [18-24), although the length class [24-40) is also well represented (Figure 4.7).

Figure 4.6 The fleet of trawlers corresponding to the records in the logbook dataset analyzed for the EWG 18-09. The area of activity is represented by the GSAs 6 and 7.

Figure 4.7 The number of Catalonia Logbook records corresponding to the different length classes and years, analysed for the EWG 18-09. The area of activity is represented by the GSAs 6 and 7.
The preliminary processing of this dataset was the same applied on the datasets for ITALY and FRANCE.
4.2 GAM modelling results

The results of this modelling exercise are extensively reported in Annexes 02a-c. Here we shortly discuss the main results by species and the general conclusions with respect to the aims of ToR3.

4.2.1 ITALY

Hake

All the predictors with the exception of price at market have a significant effect on the vessel performance (LPUE). Apart from the intercept, the species fraction of the catches and the size of the vessel and are the predictors associated to the most important effects (Figure 4.8).

![Figure 4.8 Hake. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.](image-url)
Deep water rose shrimp

All the predictors have a significant effect on the vessel performance (LPUE). Apart from the intercept, the species fraction of the catches, the size of the vessel and the area are the predictors associated to the most important effects (Figure 4.9).

Estimates and related confidence intervals

Figure 4.9 Deep water rose shrimp. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
**Red mullet**

All the predictors have a significant effect on the vessel performance (LPUE). The species fraction of the catches and (secondarily) the area are the predictors associated to the most important effects (Figure 4.10).

![Figure 4.10 Red mullet. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.](image)

**Giant red shrimp**

All the predictors have a significant effect on the vessel performance (LPUE). Apart from the intercept, the area of activity (GSA), the species fraction of the catches and the size of the vessel are the predictors associated to the most important effects (Figure 4.11).

*Figure 4.11 Hake. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.*
**Norway lobster**

All the predictors have a significant effect on the vessel performance (LPUE). Apart from the intercept, the species fraction of the catches, the area of activity (GSA) and the size of the vessel are the predictors associated to the most important effects (Figure 4.12).

![Graph showing estimates and related confidence intervals for Norway lobster predictors](image1)

![Graphs showing smoother effects on LPUE](image2)

**Figure 4.12** Norway lobster. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
4.2.2 FRANCE

Hake
All the predictors with the exception of price at market have a significant effect on the vessel performance (CPUE). The area of activity (GSA) and the species fraction in the catches are the predictors associated to the most important effects (Figure 4.13).

Figure 4.13 Hake. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
**Deep water rose shrimp**

All the predictors have a significant effect on the vessel performance (CPUE). Apart from the intercept, the size of the vessel and the species fraction of catches are the predictors associated to the most important effects (Figure 4.14).

![Diagram showing estimates and related confidence intervals]

**Figure 4.14** Deep water rose shrimp. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
**Red mullet**
All the predictors have a significant effect on the vessel performance (CPUE). Apart from the intercept, the species fraction of the catches and the area of activity (GSA) are the predictors associated to the most important effects (Figure 4.15).

![Estimates and related confidence intervals](image)

**Figure 4.15** Norway lobster. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
**Norway lobster**

All the predictors have a significant effect on the vessel performance (CPUE). The size of the vessel and the area of activity (GSA) are the predictors associated to the most important effects. In particular, the weight of the area of activity resulted more important that the one detected for the other species (Figure 4.16).

Estimates and related confidence intervals

![Figure 4.16 Norway lobster. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.](image)

Figure 4.16 Norway lobster. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
4.2.3 CATALONIA (SPAIN)

**Hake**
All the predictors with the exception of price at market have a significant effect on the vessel performance (LPUE). Apart from the intercept, the species fraction of the catches and the size of the vessel and are the predictors associated to the most important effects (Figure 4.17).

![Estimates and related confidence intervals](image)

Figure 4.17 Hake. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
**Deep water rose shrimp**

All the predictors have a significant effect on the vessel performance (LPUE). Apart from the intercept, the species fraction of the catches and the size of the vessel are the predictors associated to the most important effects (Figure 4.18).

![Estimates and related confidence intervals](image)

**Figure 4.18** Deep water rose shrimp. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
**Red mullet**

All the predictors have a significant effect on the vessel performance (LPUE). Apart from the intercept, the species fraction of the catches and the area are the predictors associated to the most important effects (Figure 4.19).

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**Figure 4.19** Red mullet. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
**Giant red shrimp**

All the predictors have a significant effect on the vessel performance (LPUE). Apart from the intercept, the area of activity (GSA), the species fraction of the catches and the size of the vessel are the predictors associated to the most important effects (Figure 4.20).

Figure 4.20 Hake. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
**Norway lobster**

All the predictors have a significant effect on the vessel performance (LPUE). Apart from the intercept, the species fraction of the catches, the area of activity (GSA) and the size of the vessel are the predictors associated to the most important effects (Figure 4.21).

**Estimates and related confidence intervals**

![Estimates and related confidence intervals](image)

**Figure 4.21** Norway lobster. Top panel: main effects and their relative sizes. Bottom panel: smoother effects on LPUE.
4.2.4 General conclusions

The results of the descriptive analysis and of the modelling exercise suggest that:

- The factors and effects included in the model were, in general, all significant in statistical terms;
- The species fraction of the catches is often a very important predictor. This means that vessels actively targeting some species are more efficient than the other ones;
- Larger trawlers are often more efficient than small ones. This could be interpreted as the consequence of the wider operative range of large vessels, that are able to select and exploit far fishing grounds but also to deploy a non-marginal portion of their daily effort on the shelf;
- The area of activity is also important to determine the CPUE. The most reliable interpretation of this finding is the (sometime) very different status of some stocks in the area of study.

4.3 Mixed fisheries and quantiles analyses for the French fleet

To complete the analysis carried out in EWG1809, LPUE quantiles and mixed fisheries analysis were carried out for the French fleet. The first were computed to assess the difference between average and more efficient vessels. The second to assess the level of mixed fisheries catches in the fleet.

Table 4.1 display the average LPUE per species per day at the 50th quantile (median trip) and at the 85th quantile (efficient trip), based on French data in a trip by trip basis. The same values are then standardised by dividing the 85th quantile by the 50th, to display the range of order of the more efficient trips compared to the median one.

The results show that efficient trips are about 2 to 7 times more efficient than the median ones.

Table 4.1. 50th and 85th quantile of LPUE, French trip-by-trip dataset. Upper: absolute value (kg/day). Lower: relative to the 50% quantile.
The mix-fisheries analysis was performed to evaluate the level of “non-mix” in the fisheries and potential impact of choke species. The rationale is that if a number of hauls are “clean”, it means a certain level of specialization exists. Fleet’s specialization should be explored/fostered to increase the probability of the MAP’s success, since the species targeted by the MAP are not all in the same level of over-exploitation. On the other hand if a haul is mostly made of one species, limiting effects by other species are less important and can be avoided.

The analysis presented in Figure 4.22 to Figure 4.26 is based on haul-by-haul data provided by the French authorities. The results show that the French fleets are not very specialized, although some exemptions exist, e.g. (12,18] meter vessels catching Nephrops.

![Cumulative distribution](image)

**Figure 4.22** Cumulative distribution the maximum fraction of the landings belonging to a single species by haul for the trawl fleets.
Figure 4.23  Hauls by maximum fraction of the landings belonging to a single species for the trawl fleets
Figure 4.24 Hauls by fraction of the landings belonging to a single species and LOA
Figure 4.25 Hauls by fraction of the landings belonging to a single species, LOA and year
Figure 4.26 Hauls by fraction of the landings belonging to the species in the MAP by LOA
5 **ToR 4. Partial F**

'Calculate the average partial fishing mortality of trawls exploiting the demersal stocks concerned by the MAP, by type of fisheries, effort unit, fleet segment and country, as estimated in the latest stock assessments.'

ToR 4 could not be completed during EWG 18-13. The updated stock assessments results from EWG 18-12 were not considered sufficiently robust and finalised at the time where EWG 18-13 met, and the data were not readily available. Additionally, the analysis of ToR 2 did not allow for a single robust estimate of transversal data (catch and effort data by fleet and metier), and the differences between the different datasets remained unclear and poorly explained. Decision is therefore still to be made on which dataset to base the actual estimates of partial fishing mortality.

Performing this ToR would otherwise be straightforward once the relevant data are collected, so EWG 18-13 decided to postpone the exercise and to include it as part of Step 1 of the RoadMap.
6  TOR 5. Road Map

"Create a 2-year roadmap to set-up a mixed fisheries advice for western Mediterranean demersal fisheries. The plan should provide a detailed description of all the steps needed to achieve this goal. It should outline the priorities in the short- and medium-term, any potential gaps in knowledge/data/modelling and the actions that can be taken to overcome it. It should also specify the skills and tools needed, including the actors to be involved (e.g. for scoping decisions). The starting date of the roadmap should be 1 January 2019."

STECF is requested to define the steps that would lead to providing a routine mixed-fisheries advice. In order to address this, it is necessary to identify the requirements for this advice, and the gaps in the current state of the art that are necessary to be filled to achieve these.

This ToR goes thus first through a number of steps. First, the actual concept of "what is a mixed-fisheries advice" is discussed by presenting in some details the current mixed-fisheries advice used in the EU North-Atlantic waters and published annually by ICES, assuming that EU is requesting an advice of the same vein, although tailored to the Mediterranean context.

Then, the requirements and the gaps are addressed. The requirements distinguish between three types of issues: i) MODELS: what are the models currently available, are they suitable for the purpose in their current form and can they be easily updated annually? or do they need to be further developed, or are new models needed? ii) DATA: what are the data requirements for these models? When and where are they made available? Are they suitable in their current definition or do they need adaptation? iii) PEOPLE: who are the experts able to perform the work, and what is their availability?

The section two is thus dedicated to review the state of the art of mixed-fisheries models for the demersal Western Mediterranean fisheries, both those presented and used in EWG 18-09, and other models known to EWG 18-13 attendees. Section three is dedicated to data issues, in particular with regards to the current definitions of fleets and fisheries, analysing whether they actually capture enough of the differences in fishing patterns and catchability across the different activities.

In the light of this detailed review of the state of the art, a road map is proposed in section 4, articulated around two STECF EWG to be held in 2019.

6.1 A summary of the mixed-fisheries advice process in European North-East Atlantic waters (ICES area)

The wording "mixed-fisheries advice” is not entirely clear, and can mean different things to different people. In the EU North-East Atlantic, “mixed-fisheries advice” has now taken a specific meaning, and refers to a specific piece of information annually published by ICES as an add-on to the usual advice on stock-by-stock fishing opportunities for the following year (TAC advice). Such a mixed-fisheries advice is published for the main demersal stocks in the North Sea\(^1\), the Bay of Biscay\(^2\) and the Celtic Sea\(^3\) (advice for the Iberian Sea and Irish Sea is in development).

There are numerous other scientific developments involving mixed-fisheries bio-economic modelling in the frame of e.g. research projects or other integrated assessments plate-forms, but these would not be referred to as “advice”. One of the main difference is that the mixed fisheries advice is, as the single-stock advice, focused on the short-term forecast, not medium or long-term projections. This means that the mixed-fisheries model used in the advice must be able to reproduce the actual deterministic single-stock forecast, in order to be directly comparable. This focus has driven a number of needs and requirements, which can be different from those involved in medium term stochastic projections, where less emphasis is put on getting the first year of the simulation "exactly right”.

This section is thus dedicated to giving a brief overview on the “mixed-fisheries advice” in its ICES sense.

\(^1\) http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/mix-ns.pdf
\(^2\) http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/mix-bbi.pdf
\(^3\) http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/mix-cs.pdf
6.1.1 What is the ICES mixed fisheries advice and which information it provides

Most fisheries catch a mixture of species and it is not entirely possible to control which species and how much of each is caught (ICES basis for advice4) For stocks exploited by mixed-species fisheries, it may not be possible to achieve the single-stock MSY catch advice for all the stocks simultaneously. Either the advised catches for some stocks will be exceeded in trying to catch the TACs of other stocks, or the TACs for some stocks will not be caught in order to prevent overshooting the TACs of other stocks. ICES has developed a mixed-species fisheries model to address this; ICES provides information on catch composition of different fisheries strategies to illustrate the tradeoffs between the strategies and highlight the risks of potential quota over- or undershoot for the following year (advice year)

The standard mixed-fisheries scenarios are shown in Table 6.1.

Table 6.1. Mixed fisheries scenarios – as in 2018 (for advice in 2019). North Sea example

<table>
<thead>
<tr>
<th>Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max</strong></td>
</tr>
<tr>
<td>“Maximum”: For each fleet, fishing effort in 2019 stops when all stock shares* of that fleet have been caught up. This option causes overfishing of the single-stock advice possibilities of most stocks.</td>
</tr>
<tr>
<td><strong>Min</strong></td>
</tr>
<tr>
<td>“Minimum”: For each fleet, fishing effort in 2019 stops when the most limiting of the stock shares of that fleet has been caught up. This option is the most precautionary option, causing underutilization of the single-stock advice possibilities of other stocks. This scenario can highlight some potential “choke species” issues.</td>
</tr>
<tr>
<td><strong>Sq_E</strong></td>
</tr>
<tr>
<td>“Status quo effort”: The effort of each fleet in 2018 and 2019 is set equal to the effort in the most recently recorded year for which landings and discard data are available (2017).</td>
</tr>
<tr>
<td><strong>Val</strong></td>
</tr>
<tr>
<td>“Value”: A simple scenario accounting for the economic importance of each stock for each fleet. The effort by fleet is equal to the average of the efforts required to catch the fleet's stock shares of each of the stocks, weighted by the historical catch value of that stock (see example further below). This option causes overfishing of some stocks and underutilization of others.</td>
</tr>
<tr>
<td><strong>COD</strong></td>
</tr>
<tr>
<td>“Cod MSY approach”: All fleets set their effort in 2018 and 2019 corresponding to their cod stock share, regardless of other catches.</td>
</tr>
</tbody>
</table>

*the term “fleet’s stock share” or “stock share” is used to describe the share of the fishing opportunities of a stock for each particular fleet in 2018, assuming that the proportion of catches by fleet for that stock in 2018 and 2019 is the same as observed in 2017.

And the standard depiction of these results are shown in Figure 6.1.

Figure 6.1. ICES North Sea Mixed-fisheries projections. Estimates of potential catches (in tonnes) by stock and by scenario. Horizontal lines correspond to the single-stock catch advice for 2019. Bars below the value of zero show undershoot (compared to single-stock advice) where catches are predicted to be lower when applying the scenario. Hatched columns represent catches that overshoot the single-stock advice.

In the last two years, a new type of scenario was presented, called “range”, developed to find a scenario within the Fmsy ranges defined as:

"range": estimates a fishing mortality by stock (using the $F_{MSY}$ ranges) which, if used for setting single-stock fishing opportunities, may reduce the gap between the most and the least restrictive TACs, thus reducing the potential for quota over- and undershoot. $F_{MSY}$ ranges are limited in accordance with the MSY approach and the MAP for stocks below MSY $B_{trigger}$.

and shown in Figure 6.2.
Figure 6.2. ICES Mixed fisheries for the North Sea. North Sea mixed-fisheries 2019 “range” fishing mortality within the $F_{\text{MSY}}$ range, compared with $F_{\text{MSY}}$, current $F$ (F in 2017), and $F$ in the single-stock advice for 2019. The “range” $F$ is the one giving the lowest difference in tonnage between the “Max” and the “Min” scenario across all stocks and fleets. For cod in the North Sea and sole in Division 7.d, $F_{\text{MSY}}$ ranges are limited in accordance with the MSY approach and the MAP when below $\text{MSY B}_{\text{trigger}}$.

Central to the mixed-fisheries advice is the explicit representation of both fishing vessels and their activity. A fishing vessel belongs to one and only one fleet, and fleet segments can be defined using any physical characteristic considered relevant: Typically a fleet would be a group of vessels with the same length class and predominant fishing gear during the year, but other criteria such as homeport might be considered.

Vessels in the fleet may have different fishing activities during the year, called métiers, which is a group of fishing operations targeting a similar (assemblage of) species, using similar gear, during the same period of the year and/or within the same area and which are characterized by a similar exploitation pattern (DCF, EC 2008). As such, the fleet describes the vessels while the métier(s) describes the fishing activity(ies) in which the fleet engages. The fleets are linked to the métiers via the fishing effort, and the métiers are linked to the species/stocks via the catchability (Figure 6.3).
**6.1.2 Brief summary of historical development of the ICES mixed-fisheries advice since inception in 2006**

The ICES development of mixed-fisheries advice started in 2006 (ICES, 2006). At that time, the North Sea cod (*Gadus morhua*) stock was at a very low level whereas the stock of haddock (*Melanogrammus aeglefinus*), which is to a large extent caught together with cod, was at its highest biomass in 30 years. In these circumstances, fishers were faced with a dilemma when the quota for cod is exhausted: stop fishing and underutilize the quota for haddock, or continue fishing and discard or illegally land overquota cod. The second option prevailed, and the cod TAC did not achieve its intended conservation objective. Rather, discards increased rapidly, and became even larger than landings in some years (Figure 6.4). Additionally, the reliability of the assessment of the cod stock was jeopardized because the catch data on which it was based became more uncertain.

![Figure 6.3. Fleets and fisheries.](image)

**Figure 6.3. Fleets and fisheries.**

Some attempts were thus performed in ICES (ICES, 2006) to develop a simple and robust approach to model the mixed fisheries and evaluate the risks of not achieving the single-stock management...
objectives. Several modelling approaches were suggested, and one of them, FCube (Ulrich et al., 2011, 2017), got selected at that time and became the standard model used.

The first actual mixed-fisheries advice was published by ICES in 2009. Since then, the approach has developed to include more stocks, and to be applied to more areas. Major work was also performed over the time to improve the definition of fleets and fisheries. The objective was to find an acceptable balance between having enough distinct categories to capture the main differences in fishing patterns between different groups of vessels and fishing activities within each country, and still be aggregated enough to reduce the number of units in the models and have adequate information (e.g. discards by metier). In 2017, the final data used for the North Sea contained for example 42 national fleets (plus the OTH fleet). These fleets engage in one to five different métiers each, resulting in 105 combinations of country*fleet*métier*area catching cod, haddock, whiting, saithe, plaice, sole and Nephrops. These fleets and métiers are not exactly the same as defined in the DCF data call, but rather represent meaningful alternative aggregations defined by the modelers, but yet still compatible with the DCF métiers and the data calls.

To achieve this advice, the greatest challenge and achievement has been to develop a streamlined procedure for the collection of data, to ensure that all the necessary data are annually and timely available, proof-checked and consistent, to be able to produce the mixed-fisheries advice at the same time as the single-stock advice. The various steps are described below.

6.1.3 The current scientific process

6.1.3.1 Which data are used and how they are updated every year

The key challenges with regards to data are the following:

- The most recent stock assessment must be available
- All catches estimated in the single-stock assessments shall be split across fleets and métiers, so that when summing up catches the same amount of landings and discards are obtained as in the stock assessment. Eventual differences between fleet-based and stock-based catches can be pooled into a “Others” fleet.
- If there are great differences in gear selectivity among, this split shall be best done by age, but if not possible, total tonnage by fleet and métiers can be used.
- Fleets and métiers definitions must be the same across all stocks

To achieve this, the procedure is as follows:

- A joint single-stock + mixed fisheries data call is issued in March\(^5\), with data to be provided a few weeks before the working groups. This data call specify catch (landings + discards) and effort data at the disaggregation level agreed and requested in the mixed-fisheries model.
- The single-stock assessment working groups meet around end of April/beginning of May and perform their assessments
- The assessment results are transmitted to the MIXFISH group end of May, which combine these with the catch and effort data by fleet, run the scenarios and produce its advice
- Both single-stock and mixed-fisheries results are reviewed together, and the advice is published jointly at the end of June.

6.1.3.2 The FCube model

The standard model used in the ICES mixed-fisheries advice is FCube (Ulrich et al., 2011; 2017). The basis of the model is to estimate the potential future levels of effort by fleet corresponding to the fishing opportunities (TACs by stock and/or effort allocations by fleet) available to that fleet, based on how the fleet distributes its effort across its métiers, and on the catchability of each of

these métiers. This level of effort is in return used to estimate landings and catches by fleet and stock, using standard forecasting procedures.

Effort distribution by métier, partial fishing mortality and catchability by fleet, métier and stock are estimated from observed catches, effort and stocks’ fishing mortality. By default, catchability and effort distribution by fleet across métiers are assumed constant in projections, but this can be modified in the model settings to run alternative scenarios.

The target F by stock (e.g. Fmsy) is then split across all fleets and métiers and converted into a “stock-dependent fleet effort”, which is the effort corresponding to a certain partial fishing mortality on a given stock. In most cases though, the effort corresponding to each single-stock advice will differ across stocks within a fleet. So the user can therefore explore the outcomes of a number of options or rules about fleet behaviour, as explained in the scenario table above.

Partial fishing mortalities are then recalculated and summed by stock. These new estimates of fishing mortality are used in standard short-term forecast instead of the initial target F, and the corresponding catches are estimated and compared with the single-stock projections.

6.1.3.3 ICES working groups and intersessional work done in the research institutes

The development of the mixed-fisheries models has to some extent taken place within research projects such as FP6 AFRAME, FP7 EFIMAS and MYFISH, EU Tender DRUMFISH. However, framing this into operational and routine advice has primarily taken place within dedicated ICES working groups, allowing experts to meet regularly. Since its first advice publication in 2009, the ICES WGMIXFISH group has met twice a year:

- A one-week meeting end of May to make the advice itself, based on the most recent stock assessment and catch and effort data (WGMIXFISH-ADVICE)
- A one week meeting in October to further develop the methods, the data etc, and solve the potential issues experienced in May (WGMIXFISH-METH).

This setup is considered to have been very useful for delivering an operational product, and for securing the long-term visibility of the work done and the commitment of experts and resources. Incidentally, it has also helped securing additional funding for the work to the national institutes through the funding of dedicated grants such as the EU tender DRumFISH.

6.1.3.4 Scenarios and questions asked by managers/recipients of advice

The actual shape and content of the mixed-fisheries advice has evolved over time, based on ongoing discussions and feedbacks between the receivers of ICES advice (EU DGMare, stakeholders) and the ICES scientists. So while the model and data sources have not changed fundamentally since 2009, the scenarios and the presentation of results has adapted over time to address the questions raised by this advice.

6.2 Available and potential Mixed-fisheries models for the Western Mediterranean demersal fisheries.

Which steps would be needed to ensure that West Med mixed-fisheries models could be routinely available and updated every year on the basis of most recent assessments?

In this section, we reviewed the necessary requirements to provide annual updates for a variety of models. The focus here is given on the existing models in their current state of the art (as of 2018). Additional model developments are treated in the next section (Chapter 6.3). Here, we first review the models as presented in STECF (2018a) (MEFISTO, IAM and NIMED). Secondly, we discuss other potential models known to the EWG 18-13 participants. In this second part, we make the distinction between mixed-fisheries models based on groups (fleets and métiers) at aggregated spatio-temporal scale (e.g. year and GSA, as is the case of the three models presented in 18-09), and mixed-fisheries models based on individuals, or agent-based (modelling individual fishermen at fine spatio-temporal scale). Other mixed-fisheries models for the Western Mediterranean might potentially exist and not be listed here, but are not known to the EWG 18-13.
6.2.1 Fleet-based Models presented in EWG 18-09

6.2.1.1 MEFISTO

MEFISTO is a multi-species, multi-fleet bio-economic model (Lleonart et al. 2003; Maynou et al. 2006). MEFISTO simulates alternative management strategies (i.e. it is not an optimization model). It includes a population dynamics sub-model, that simulates the dynamics of the stock, and an economic sub-model. In MEFISTO the link between the economic sub-model and the biological sub-model is made through the fishing mortality vector, which can vary endogenously following certain behavioral rules of the fishing firms. MEFISTO does not consider explicitly ecological external forcing factors, such as changes in fisheries productivity due to changes in temperature or primary production. Instead, the model does allow considering external economic or policy factors, such as fuel price, changes in net selectivity or fishing effort limitations, including seasonal closures that have been incorporated in the current version. MEFISTO simulates the internal dynamics of investment / disinvestment and the effort dynamics of fishing firms following standard micro-economic theory that generally assumes that the fishing firms attempt to maximize profits (Prellezo et al. 2012).

MEFISTO allows regional approach to management since an analysis of the bio-economic effects of different fleets competing for the same resource or in the same market with different local rules can be carried out (e.g. different fishing days a year or different kind of subsidies by firm).

Fleet is defined as a group of vessels using the same fishing gear to target the same pool of main species. This definition of fleet is close to the definition of fishing tactic or métier. In addition to the main species catches, MEFISTO considers also the so called secondary species: In the age-structured model, a secondary species (or pool of species) is a part of the catch of the fleet whose dynamics are not known, but it generates significant amounts of revenues for the fleet. The catches from secondary species are determined in relation (positive or negative) to a main species catches.

To parametrize MEFISTO it is needed:

- Biological data and stock assessments
  These data is available from stock assessment reports. In case a full assessment has not been carried out, it will be necessary for the user to produce an ad-hoc stock assessment using external tools.
  A type of biological information difficult to obtain are the parameters of the stock-recruitment relationship. The model offers different options, but the assumptions must be acknowledged by the user.

- Economic data
  Can be obtained by means of interviews with fishing firms (labour costs, annual fix costs, annual variable costs, opportunity costs,..) ; market parameters. The economic indicators include revenues, costs, discounted profit, gross valued added, gross profit and capital by fleet. MEFISTO uses the relationship between main and secondary species for economic issues. Then, economic indicator expresses the economic value of total catches for each fleet.

- Information on regulations
  Necessary in order to build alternative management scenarios (changes in the number of fishing days or hours; temporal closures; whether imports are likely to have an effect on prices,..).

Data input files

The input data file, described below, can be the result of some data analysis and pre-processing that can be undertaken in any spreadsheet package (not necessarily MS Excel), but the final data set that will serve as input to MEFISTO must be saved in *.xls or *.xlsx format.

The input data file (Excel format) is organised in 7 worksheets comprising the following concepts:
- stock parameters for the main species (worksheet species)
- cohorts (or age class) parameters and data for the main species (worksheet cohorts)
- type and parameters of the stock/recruitment relationship for the main species (worksheet recruitment)
- the interaction matrix between fleets and stocks (worksheet interact)
- parameters of the fleets (worksheet fleet)
- parameters and data by individual vessel (worksheet vessels)
- market parameters (worksheet parameters)

**Current coverage as presented in 18-09: which stocks, which fleets, which time frame (historical data, projections)**

MEFISTO was applied to GSA 6 demersal fisheries. The following scenarios were tested (STECF 2018a ToR 5):

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5% capacity reduction in yr 1 + 10% fishing days reduction in yr 1, 2 and 3</td>
</tr>
<tr>
<td>2</td>
<td>10% capacity reduction in yr 1 + 10% fishing days reduction in yr 1, 2 and 3</td>
</tr>
<tr>
<td>3</td>
<td>10% capacity reduction in yr 1 + 20% fishing days reduction in yr 1, 10% in yr 2 and 3</td>
</tr>
</tbody>
</table>

During the simulations the economic module of MEFISTO was disabled. Capacity reduction was simulated as fishing days reduction.

A total of 10 species were selected, which include the main target species of the demersal fisheries in GSA 6, as well as the most vulnerable species according to a Productivity and Susceptibility Analysis (PSA). The species are the following: European hake *Merluccius merluccius* (HKE), Norway lobster *Nephrops norvegicus* (NEP), red mullet *Mullus barbatus* (MUT), striped red mullet *Mullus surmuletus* (MUT), deep water rose shrimp *Parapenaeus longirostris* (DPS), anglerfish *Lophius piscatorius* MON, black-bellied angler *Lophius budegassa* (ANK), greater forkbeard *Phycis biennoides* (GBF), four-spot megrim *Lepidorhombus boscii* (LDB) and blue and red shrimp *Aristeus antennatus* (ARA). Most of these species are fished exclusively by bottom trawl, but in some cases the species catch comes from different gears, each one targeting a given size (or ages) range (e.g. *Merluccius merluccius*, *Mullus barbatus*, *Mullus surmuletus*, *Lophius piscatorius*, *Lophius budegassa*). OTB catches are in all cases much higher and sizes (or ages) smaller than those of the small-scale gears with which the resource is shared.

It is worth noting that the five stocks in GSA 6 under the proposed management plan are included in the MEFISTO simulations (*Aristeus antennatus*, *Parapenaeus longirostris*, *Merluccius merluccius*, *Nephrops norvegicus* and *Mullus barbatus*).

Fleet corresponds to the combination of gear and fleet size segment. A total of seven fleets were considered: 3 bottom otter trawl (OTB-VL1218, OTB-VL1824, OTB-VL2440), 2 longline (LL-VL0612, LL-VL1218) and 2 gillnet and trammel net (GN-VL0612, GN-VL1218).

The results of the simulations under the three proposed scenarios included biological indicators (mean biomass and SSB trends) and fisheries indicators (catches, F, $F_{\text{bar}}/F_{0.1}$).

**Requirements for the annual update of stock data**

MEFISTO start-up requires the establishment of an initial stock situation. The preparation of the input data for the model was done in the frame of the DRuMFISH research project\(^6\). DCF data were requested to be used in the project.

The data used come from the EC Data Collection Framework (DCF) and stock assessment results. The data taken from the DCF include landings, discards, length- frequency distributions and fishing fleets characteristics. Stock assessment results were taken from the most recent assessments performed by STECF (Scientific, Technical and Economic Committee for Fisheries) and GFCM

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\(^6\) (DRuMFISH Approaches to management for data-poor stocks in mixed fisheries, Contract number - EASME/EMFF/2014/1.3.2.4/ SI2.721116)
(General Fisheries Commission for the Mediterranean) Stock Assessment Working Groups. Growth parameters (length-weight relationship and VBGC parameters) and M natural mortality were the same as used in the assessments.

The input data required regarding the stock status correspond to the mean value of the last three years assessed. In some cases, i.e. when the information in the assessment reports did not allow the calculation of this 3-years mean value (results of the assessments not fully presented in the reports), or when the species had not been previously assessed, these three assessed years were generated with pseudo-cohort analysis. The selection of the parameters (growth, length-weight, M) to be used in those assessments can be rather time-consuming.

For the update of the stock data with the most recent assessments the preparation of the input data for the model should be done after the stocks assessment meetings have been held. For the update, DCF data should be made available to the scientists.

**Worksheet species**

<table>
<thead>
<tr>
<th>Excel name</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>a parameter of the length-weight relationship</td>
</tr>
<tr>
<td>b</td>
<td>b parameter of the length-weight relationship</td>
</tr>
<tr>
<td>Linf</td>
<td>L∞ parameter of von Bertalanffy growth function</td>
</tr>
<tr>
<td>K</td>
<td>k parameter of von Bertalanffy growth function</td>
</tr>
<tr>
<td>t0</td>
<td>t0 parameter of von Bertalanffy growth function</td>
</tr>
<tr>
<td>Ncohorts</td>
<td>number of cohorts of each stock --</td>
</tr>
<tr>
<td>stockname</td>
<td>name of the stock (or main species) --</td>
</tr>
</tbody>
</table>

**Worksheet cohorts**

(some data in this worksheet are estimated from VPA)

<table>
<thead>
<tr>
<th>Excel name</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>stockname</td>
<td>name of the stock (or main species) --</td>
</tr>
<tr>
<td>age</td>
<td>age of the cohort</td>
</tr>
<tr>
<td>number</td>
<td>number of individuals in the cohort</td>
</tr>
<tr>
<td>mat</td>
<td>proportion of mature individuals at age</td>
</tr>
<tr>
<td>M</td>
<td>natural mortality coefficient at age</td>
</tr>
</tbody>
</table>

**Worksheet recruitment**

<table>
<thead>
<tr>
<th>Excel name</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>stockname</td>
<td>name of the stock (or main species) --</td>
</tr>
<tr>
<td>type</td>
<td>integer indicating the type of recruitment function.</td>
</tr>
<tr>
<td>rec1</td>
<td>parameter N0, α1, α2 or α3,in the stock – recruitment function</td>
</tr>
<tr>
<td>rec2</td>
<td>parameter β1, β2 or β3 in the stock – recruitment function</td>
</tr>
<tr>
<td>k</td>
<td>age of recruitment (in years) k</td>
</tr>
</tbody>
</table>

**Worksheet interact**

(some data in this worksheet are estimated from VPA)

<table>
<thead>
<tr>
<th>Excel name</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>stockname</td>
<td>name of the stock (or main species) --</td>
</tr>
</tbody>
</table>
age  
age of the cohort

F1 to FG  
Fishing mortality by each fleet (or 'fishing gear') by age class, from fleet 1 to fleet G

Requirements for the annual update of fleet/metier catch and effort data

At the same time as the update of stock data (i.e. after the stock assessment meetings).

Worksheet fleets

Excel name  
description

fleetname  
fleet name --

NV  
number of vessels in the fleet --

dismissal  
price paid by the fisheries Administration for decommissioning vessels

Part  
share of the total revenues belonging to the owner, after discounting trade and fuel costs (in %)

NHDmax  
Activity: Maximum number of hours a day by law or physically possible

NFDmax  
Activity: Maximum number of days a year by law or physically possible

NHD  
Activity: Average number of hours a day

NFD  
Activity: Average number of days a year

ice  
daily consumption of ice

CommCost  
Commercial or trade cost, percentage paid to the fish market for the sale of fish

maxcredit  
Maximum amount of money lended by the bank, as percentage of the capital

fuelprice  
price of the fuel, in €/l, paid by each fleet

oppC  
opportunity costs, i.e. cost of using the capital invested

finC  
financial costs, costs of paying the debt incurred with the bank

varEff  
proportion of effort increase when profits are positive

Requirements for the annual update of economic data

Part of the update of the economic data should be done through interviews. These interviews should have been done before the stock assessments meetings, so as to have the full information required for the update of the input data ready once the stock assessment meetings have been held. Part of the information comes from DCF data.

Worksheet vessels

Excel name  
description

vesselname  
vessel name --

fleetname  
fleet name --

K  
capital of the vessel (€)

gt  
capacity as GT (Gross Tonnage)

credit  
debt to the bank at time = 0

consfuel  
fuel consumption in l/day

crewszie  
crew size of the vessel, including the owner if worker

otherDC  
daily costs other than fuel and ice (e.g. net mending, food for the crew, etc.)

annualC  
costs paid at an annual scale, disregarding all daily costs. It may include: engine repair, shipyard, mooring, fishing license, etc.
percFC  percentage of the annual costs that are fixed or compulsory to remain in the fishery ("unavoidable"): mooring, fishing license, etc.
percVC  percentage of the annual costs that are not compulsory, they are usually not met when the profits are negative ("avoidable"): painting, repairs, etc. Corresponds to the depreciation of the capital.
active  Boolean (0-1) indicating whether the vessel was active at time t= 0 of the simulation.
pEff   Effort (in terms of activity: days a year) of the vessel
q      relative catchability of each vessel, i.e. relative fishing power, where the average vessel has a value of 1

**Worksheet market**

<table>
<thead>
<tr>
<th>Excel name</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>fleetname</td>
<td>fleet name  --</td>
</tr>
<tr>
<td>stockname</td>
<td>stock name  --</td>
</tr>
<tr>
<td>g1</td>
<td>base or average price of main species (in €/kg)</td>
</tr>
<tr>
<td>g2</td>
<td>age-modifier of price, usually positive: larger fish fetch higher prices</td>
</tr>
<tr>
<td>g3</td>
<td>offer-modifier of price related to catch, usually negative: when the offer on the market is high, prices diminish</td>
</tr>
<tr>
<td>g4</td>
<td>offer-modifier of price related to imports, usually negative</td>
</tr>
<tr>
<td>funct2sp</td>
<td>type of function relating main species to secondary species</td>
</tr>
<tr>
<td>mu</td>
<td>parameter μ in the market relationship between main species (i) and secondary species (j)</td>
</tr>
<tr>
<td>nu</td>
<td>parameter n in the market relationship between main species (i) and secondary species (j)</td>
</tr>
<tr>
<td>price</td>
<td>average price of secondary species (in €/kg)</td>
</tr>
</tbody>
</table>

**Availability of expertise to run scenarios— what, when, who and how**

For the Spanish GSAS, the update could be done by IEO and ICM-CSIC scientists. For the updating of GSA7 the collaboration of IFREMER would be necessary.

For the updating around 6 person-month would be necessary.

6.2.1.2 IAM

**Current coverage as presented in 18-09: which stocks, which fleets, which time frame (historical data, projections)**

A bio-economic analysis based on IAM simulations was sent as a working document for EWG 18-06 (STECF 2018a). Bio-economic results of simulation of scenarios of effort and capacity reductions were presented.

Main characteristics of the application are:

Stocks included:

- Hake GSA 7 (Merluccius merluccius) – age structured model
- Sardine (Sardina pilchardus) Anchovy (Engraulis encrasicolus) Octopuses, Mackerel and Monkfish as static CPUE.
- Other species as static CPUE

Fleets modeled (based on IFREMER segmentation which account for the activity (i.e. “metiers” used), fishing zone (i.e. “rayon d’action”) and the length class of the vessels)
- Demersal trawlers superior to 24m
- Demersal trawlers 18-24m
- Pelagic and mixed trawlers superior to 24 m
- Netters under 3 nautical miles 6-12m
- Netters beyond 3 nautical miles 6-12m
- Multi-gear netters 6-12 m
- Seiners 6-12 m

Time frame

Calibration with 2015 hake assessment data, transversal data for 2015 (Ifremer, SIH, DPMA) and economic cost-structure data for 2013 (C ASD^7). Economic data are based on availability and quality of data at the moment of the calibration. Recruitment is based on 2008-2015 historical data (Normal Law).

At the time of EWG 18-13, an updated version is being developed calibrated with initial parameters for the Hake population dynamic based on GFCM assessment on the year 2016 (data source: GFCM, 2017), transversal data for 2016 (Ifremer, SIH, DPMA) and economic cost-structure data for 2016.

Projections 2015-2030

Requirements for the annual Data Update

<table>
<thead>
<tr>
<th>Data sources</th>
<th>Time of availability</th>
<th>Data available</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Update of stock data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demersal species : hake (<em>Merluccius merluccius</em>) and red mullet (<em>Mullus barbatus</em>)</td>
<td>GFCM</td>
<td>November year n (GFCM WG)</td>
<td>Outputs from stock assessment data series until year n-1</td>
</tr>
<tr>
<td>Small pelagic species, anchovy (<em>Engraulis encrasicolus</em>) and sardine (<em>Sardina pilchardus</em>)</td>
<td>PELMED, IFREMER</td>
<td>4 months after PELMED survey</td>
<td>Acoustic data, year n</td>
</tr>
<tr>
<td>Other species</td>
<td>IFREMER/SIH/DPMA</td>
<td>Year n-1</td>
<td>Statistics of production</td>
</tr>
</tbody>
</table>

Update of fleet/metier catch and effort data

<table>
<thead>
<tr>
<th>Data sources</th>
<th>Time of availability</th>
<th>Availability of typology year n-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFREMER/SIH/DPMA</td>
<td>November year n</td>
<td></td>
</tr>
</tbody>
</table>
According to schedule of availability of biological, transversal and economic data, bio-economic advice provided in year n will rely on n-2 data (and n-3 economic structure if the advice should be provided before September of year n)

**Availability of expertise to run scenarios**

Required expertise in biology, data analysis and bio-economic modelling and thematic knowledge on Mediterranean fisheries context and trends. MARBEC and EM availability with STH support.

6.2.1.3 **NIMED (Nisea Model)**

The model presented during the EWG-18-09 for simulating management scenarios for demersal fisheries in GSA 9 was developed within the Horizon 2020 research project "Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries (MINOUW)". NIMED is a multi-species and multi-fleet bio-economic model, which main components are derived from the BEMTOOL model (see below).

**Current coverage as presented in 18-09: which stocks, which fleets, which time frame (historical data, projections)**

The application of the model presented during the EWG-18-09 covered the whole demersal fleet operating in GSA 9, which consists of five fleet segments: demersal trawlers divided in three length classes – 12-18m, 18-24m and 24-40m - and passive polyvalent divided in two length classes, lower and greater than 12m. NIMED uses the same fleet segmentation as adopted within the DCF.

Five stocks were simulated by the model: European hake, Norway lobster, surmullet, red mullet and deep-water rose shrimp. These stocks represent around 30% of total landings in weight and value for the whole demersal fleet. This percentage increases for demersal trawlers to around 40%. The selection of the stocks included in the model is based on the availability of stock-assessment outcomes.

NIMED uses historical data to estimate some parameters, like recruitment and landings prices, and to compare real data with the long-term yield curve. In the application carried out during EWG-18-09, recruits were estimated as a geometric mean of the last three years data. Prices dynamic was estimated on time series since 2008 on landings and prices by stock and fleet segment.

Projections on fisheries, biological and socio-economic indicators were carried out up to 2025.

**Requirements for the annual update of stock data**

NIMED uses the following data for projecting biomass, SSB, catch, landings, discards and fishing mortality for each stock:

- Fishing mortality at age;
- Natural mortality at age;
- Stock number at age;
- Catch number at age by fishing gear;
- Discards number at age by fishing gear;
- Maturity at age;
- Mean weight at age;
- Selectivity parameters by stock and fishing gear.

Most of the data reported above are from stock-assessment results. When the outcomes of new stock-assessment are made available, the model can be updated in a short time by the model developer (NISEA).
Requirements for the annual update of fleet/metier catch and effort data

NIMED uses the following data for projecting fleet size, fishing effort in days at sea, landings by stock and total, revenues by stock and total:

- Number of active vessels by fleet segment;
- Active GT by fleet segment;
- Active KW by fleet segment;
- Number of days at sea by fleet segment;
- Landings in weight and value by stock and fleet segment;
- Total landings in weight and value by fleet segment.

All data reported above are collected through DCF in the data call for transversal data. When the transversal data are made available, the model can be updated in a short time by the model developer (NISEA).

Requirements for the annual update of economic data

NIMED uses the following data for projecting the economic variables by fleet segment and to estimate socio-economic indicators in the short, medium and long term:

- Other income by fleet segment;
- Energy consumption by fleet segment;
- Energy costs by fleet segment;
- Other variable costs by fleet segment;
- Commercial costs by fleet segment;
- Repair costs by fleet segment;
- Non-variable costs by fleet segment;
- Labour costs by fleet segment;
- Employment by fleet segment;
- FTE by fleet segment;
- Depreciation costs by fleet segment;
- Capital value by fleet segment.

All data reported above are collected through DCF in the data call for economic data. When the economic data are made available, the model can be updated in a short time by the model developer (NISEA).

Availability of expertise to run scenarios— what, when, who and how

Experts from NISEA are available to adapt the model and run scenarios. Time for model adaptations depends on the type of scenarios to be simulated. The model is currently available for simulating effort variations in GSA 9 demersal fisheries. Data update for the same fisheries is a quite fast operation, requiring few days of work. The model setting for other Italian fisheries, like the demersal fisheries in GSA 10 or GSA 11, consisting in data collection, estimation of parameters and model calibration, would require around a week of work for each additional geographical area. The relatively short time for the adaptation of the model to other Italian GSAs is justified by the consistency of Italian data with the model structure. The use of the model in non-Italian GSAs would request additional time for its adaptation to a potential different availability and structure of the input data.

6.2.2 Other existing fleet-based models for the West Med demersal mixed fisheries not presented in 18-09

6.2.2.1 BEMTOOL

BEMTOOL is a multi-species multi-gear bio-economic simulation model, which resumes and integrates the different bio-economic models and biological modelling tools developed for
Mediterranean fisheries\(^8\). It consists of six operational modules characterized by components communicating by means of relationships and equations: Biological, Impact, Economic, Behavioural, Policy and Multi Criteria Decision Analysis (MCDA) (Rossetto et.al, 2014; Russo et.al, 2017). BEMTOOL follows a multi-fleet approach simulating the effects of a number of management trajectories on stocks and fisheries on a fine time scale (month). The model accounts for length/age-specific selection effects, discards, economic and social performances, effects of compliance with landing obligation and reference points. The implementation of a decision module (Multi-Criteria Decision Analysis and Multi-attribute utility theory) allows stakeholders to weight model-based indicators and rank different management strategies. The model can simulate management scenarios based on changes in fishing pattern, fishing effort, fishing mortality and TAC. A wide set of biological, pressure and economic indicators is the default output. The uncertainty (process error) implemented in the model following Monte Carlo paradigm allows a risk evaluation in terms of biological sustainability of the different management strategies accounting for the economic performances.

In BEMTOOLv.3 (Spedicato et.al, 2017) the uncertainty component has been expanded, allowing an MSE approach. The process error is implemented besides that on the recruitment, on individual growth and natural mortality, while the model error on maturity ogive and selectivity functions. Uncertainty can be applied according to three different probability distributions: normal, lognormal and uniform.

BEMTOOLv.3 platform allows also the implementation of a scenario based on a TAC set according to an MSE approach (GFCM, 2018). Every year the model checks that the SSB level and the fishing mortality are within safe biological limits, so the TAC is set accordingly.

**Table 6.2 BEMTOOL applications**

<table>
<thead>
<tr>
<th>GSA</th>
<th>Fishery</th>
<th>Stock</th>
<th>Available Model</th>
<th>Applied for the following management measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSA 9 (Liguria and North Tyrrhenian Seas)(^1)</td>
<td>Small pelagic fisheries</td>
<td>Anchovy, Sardine</td>
<td>BEMTOOL</td>
<td>Effort restrictions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>European hake, Red mullet, Deep-water rose shrimp, Norway lobster</td>
<td>BEMTOOL</td>
<td>Effort restrictions, improve selectivity</td>
</tr>
<tr>
<td>GSA 11 (Sardinia)(^1)</td>
<td>Demersal fisheries</td>
<td>European hake, Red mullet, Giant red shrimp</td>
<td>BEMTOOL</td>
<td>Effort restrictions, improve selectivity</td>
</tr>
<tr>
<td>GSA 17 and 18 (Adriatic Sea)(^1,3,4,5)</td>
<td>Small pelagic fisheries</td>
<td>Anchovy, Sardine</td>
<td>BEMTOOL</td>
<td>Effort restrictions, TAC, combination of measures</td>
</tr>
<tr>
<td>GSA 17 (Northern Adriatic Sea)(^1,3)</td>
<td>Demersal fisheries</td>
<td>European hake, Red mullet, Spottail mantis shrimp, Common sole</td>
<td>BEMTOOL</td>
<td>Effort restrictions, improve selectivity, combination of measures</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>GSA 18 (Southern Adriatic Sea)</th>
<th>Norway lobster</th>
<th>Effort restrictions, improve selectivity, combination of measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red mullet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep-water rose shrimp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GSA 10 (Southern Tyrrhenian Sea)</th>
<th>Demersal fisheries</th>
<th>BEMTOOL</th>
<th>Landing obligation, improve selectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>European hake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red mullet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep-water rose shrimp</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GSA 22 (Aegean sea)</th>
<th>Demersal fisheries</th>
<th>BEMTOOL</th>
<th>Improve selectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>European hake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red mullet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep-water rose shrimp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horse mackerel</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


2 MIPAAF, Indagine conoscitiva sullo scarto della pesca alle specie demersali nei mari italiani: valutazioni propedeutiche per l’implementazione delle disposizioni comunitarie in tema di obbligo di sbarco (Regolamento UE 1380/2013, art. 15), April 2016.

3 Tender DGMARE 2009/05/Lot1. MAREA Framework Contract. Specific contract n° 10 "Improved knowledge of the main socio-economic aspects related to the most important fisheries in the Adriatic sea (SEDAR)" deliverable 9 Report and discussion of the outputs of scenario modelling obtained using BEMTOOL. 2015


5 Scientific Advisory Committee on Fisheries (SAC) Report of the Workshop on the assessment of management measures (WKMSE) Zagreb, Croatia, 9-11 April 2018

### 6.2.2.2 Other MEFISTO applications

MEFISTO has been applied to different Mediterranean fisheries. Among them we can mention:

**GSA 1.** Small scale fishery, fish trap. Sparus aurata, Lithognatus mormyrus (Maynou et al., 2014)

**GSA 4.** Purse seine. Sardina pilchardus (Manouel et al., 2014)

**GSA 5.** Small-scale fishing. Dentex dentex, Coryphaena hippurus, Aphid minuta, Palinurus elephas, Scorpaena scrofa, Mullus surmuletus, Sepia officinalis, Loligo vulgaris. (Quetglas et al., 2016)

**GSA 5.** Trammel net. Scorpaena scrofa, Mullus surmuletus, Sepia officinalis, Scorpaena porcus (Merino et al., 2008)

**GSA 6 (two ports).** Bottom trawl. Aristeus antennatus (Maynou et al., 2006)

**GSA 6.** Bottom trawl, longline. Merluccius merluccius (Lleonart et al., 2003)

**GSA5.** Bottom trawl. Mullus surmuletus, Aristeus antennatus, Nephrops norvegicus, Merluccius merluccius (Merino et al., 2015).}

**GSA 17.** Mid-water pair trawl. Sardina pilchardus, Engraulis encrasicolus (Sivestri and Maynou, 2009)

**GSA 20.** Bottom trawl. Aristeus antennatus and Aristaeomorpha foliacea (Guillén et al., 2012).

**GSA 22.** Bottom trawl, beach seiners. Merluccius merluccius, Mullus barbatus. (Merino et al., 2007).

### 6.2.2.3 Others

The Fcube model used in ICES has been tested in a Mediterranean context, for the demersal mixed-fisheries in the Aegean Sea (Hoff et al., 2010, Maravelias et al. 2012). More recently, a mixed-fisheries effort optimization model including data-poor stocks was developed for the Aegean fisheries as part of the DrumFish project (see note above). While this is not directly applicable to
the Western Mediterranean, there are many similarities e.g. species and fleets involved and the type of data available, so these models are valuable and potentially applicable to the Western Mediterranean fisheries with limited work involved.

There are no known applications of the FLBEIA model in the Mediterranean Sea. See also https://stecf.jrc.ec.europa.eu/dd/bioeco for a list of models available for fisheries modeling.

6.2.3 Individual-based and spatially explicit mixed-fisheries models

6.2.3.1 SMART

The SMART platform (Russo et al., 2014) is a R-based suite to model different fisheries taking into account for all the spatial and temporal dynamics of both fleets and resources. It was primarily developed for demersal fisheries, and the platform has been recently submitted to the Comprehensive R Archive Network (CRAN) repository. The SMART platform is articulated in different submodels that are devised to a) the reconstruction of the origin and the fate of catches and landings in terms of well-defined areas and times in which resources are harvested and harbours to which they are delivered for sale, respectively; b) explore the potential effects of different spatial and/or temporal closures in terms of change of the exploitation pattern and consequent effect on both resources condition and economic performance of the fleets. The SMART platform includes a Bayesian simulator to forecast the potential effects, in terms of fishing effort displacement, determined by some management measures such as Fisheries Restricted Areas (FRA).

From an operational point of view, SMART is an individual-based model and each fishing vessel is considered as an independent agent that operates to maximize gains (as difference between revenues and costs).

Moreover, the modelling of multispecies fisheries such as trawling is carried out using MICE models (Models of Intermediate Complexity in Ecosystems; Punt et al. 2016; Punt & Butterworth, 1995). The chosen framework models a Statistical Catch At Age (SCAA) with a basic population dynamic which follows the classical approach of Doubleday (1976) where the catch-at-age datasets are fitted for multiple cohorts simultaneously and the fishing mortality is split into age and year components.

SMART processes and combines the data derived from three fundamental entity of the fishery system: the environment, the working fleet and the biological resources.

<table>
<thead>
<tr>
<th>Type of data</th>
<th>Data</th>
<th>Source</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Spatial!-related costs (fuel); Activity!-related costs (crew salary); Other costs (commercialization of landings, insurance, fixed costs, etc.)</td>
<td>Data Collection Framework – Transversal variables</td>
<td>Modelling costs with respect to harbors of departure, area of fishing activity, amount of fishing days and landings</td>
</tr>
</tbody>
</table>
| Fisheries    | Vessel-specific data about landings | Data Collection Framework – Biological sampling of catches | • Modelling spatial and temporal LPUE  
• Modelling exploitation pattern  
• Modelling spatial age structure and growth pattern of resources |
| Fisheries    | Vessel-specific data about fishing effort pattern | Data Collection Framework – VMS / AIS data | Modelling the fishing effort of each vessel |
The workflow of the SMART approach is as follows:

1. Subdivide the case study into functional fishing areas (Fishing Grounds module);
2. Detect the spatial origin of the landings/catches and estimate the Landings/Catches per Unit of Effort (Lander module);
3. Determine the growth parameters and subdivide the studied stock(s) into cohorts (Growth module);
4. Estimate costs and revenues associated to a given fishing effort pattern (Performance module);
5. Simulate different management scenarios (Simulation module);
6. Assess the status of the studied stock(s) (Assessment module);
7. Forecast the middle and long-term effects of the management measure (Forecast module).

SMART was applied to the trawling in the Strait of Sicily (Russo et al., 2014) and is the main approach within the DGMARE project MANTIS, which comprises two case studies:

1. the trawl fishing in the Strait of Sicily (GSA12, 13, 14, 15, and 16) with 4 target species: red mullet, deep water rose shrimp, giant red shrimp and hake. This case study comprises both Italian and Maltese fleets operating in this area;
2. the trawl fishing in the Adriatic Sea (GSA17 and 18) with 4 target species: common sole, hake, red mullet and Norway lobster. This case study comprises both Italian and Croatian fleets operating in this area;

For each of the case studies, SMART is applied for the following purposes:

- Evaluate the potential benefits (for the resources) of the progressive implementation of a network of Fisheries-restricted areas;
- Evaluate the potential benefits of the progressive implementation of a different effort regimes (including the reduction of the fishing capacity and the regulation of the effort);
- Forecast the feedback of the fleets in terms of displacement of the fishing effort and bioeconomic performance.

Given that the application of SMART is linked to the availability of DCF data, this platform is likely to be applied in other areas of the Mediterranean Sea, including the Western part.

6.2.3.2 DISPLACE

The DISPLACE model framework (Bastardie et al. 2014) is developing a research- and advisory-based platform to transform fishermen's detailed knowledge and micro-decision-making behavior into simulation and management evaluation tools. This involves advanced methods to assess and
provide advice on the bio-economic consequences for the fisheries and fish stocks of different fishermen decisions and management options. DISPLACE is an agent-based simulation model developed to support maritime spatial planning and management issues, especially from the perspective of the fisheries. Agent-based models aim to consider the socioeconomic and ecological processes at the individual scale (e.g., the fishing vessels) to capture the effects of human decisions at that level and then go through the individual processes up to the aggregated dynamics (e.g., the fisheries as a whole or other marine ecosystem components). A particular strength of the agent-based approach is that it is an adequate level to model processes at the spatial \((2 \times 2 \text{ km})\) and the time scale (hourly time steps) closer to the spatial and time dynamics occurring in human decision-making and fish populations dynamics. It is also closer to the appropriate scale for dealing with management issues such as marine spatial planning. The agent-based approach is also keen on integrating process-based mechanistic relationships that give the advantage of being able to better predict in novel conditions. Accordingly, DISPLACE should be able to incorporate the spatial and temporal details to obtain a necessary understanding of the integrated fisheries, behavioral and resource dynamics. DISPLACE can address fleet/skipper behavior facing the experienced catches and the fisheries management in force including Effort Regime (overall capacity reduction, limits in days at sea, temporal & spatial closure to fisheries) together with multi-annual management plans in a CFP context (i.e. FMSY).

Most of bio-economic models for fisheries are working at aggregated level to fleet-segments. One of the weaknesses of these aggregated models is that they are not well-suited to easily capture individual vessel characteristics that are potentially major drivers for predicting effect of fishing on the harvested resources, such as the running costs of fishing activities (i.e., the variable fishing cost depending on vessel specific effort allocation in time and space). Aggregated models also tend by nature to ignore important differential aspects among fishers related to their various economic drivers or other individual incentives. An alternative approach is to develop models that work on a more disaggregated scale to ideally encompass mechanistic processes at the individual (vessel) level and, ultimately, let the overall pattern of effort allocation between fisheries, space and time, and eventually the differential catchabilities, emerge from all of the individual fisher’s decisions and varying fishing vessel catching power.

So far, important progress has been made in a row of applications including the Adriatic Sea, the Ionian Sea, the Black Sea, the Baltic Sea and the Irish Celtic Sea. Regional scale applications are currently being developed for the North Sea and the Baltic Sea fisheries. On the Mediterranean side, DISPLACE has been applied to the north Adriatic (GSA 17) to the Italian demersal fisheries (Bastardie et al 2017). We applied the fish and fisheries model to assess the impact of a suite of spatial plans suggested by practitioners that could reduce the pressure on the four demersal stocks of high commercial interest in the GSA 17, and that could promote space sharing between mutually exclusive activities. The Adriatic Sea application has been recently updated with most recent fish stock assessment data, extended to include the Croatian fisheries (Figure 6.5), and simulation experimental plans are ongoing. Eventually, it is further intended to expand DISPLACE to the Western Mediterranean demersal fisheries (French, Spanish and Italian fishing vessels) as soon as the data and resource are made available (data requirement described in Table 6.3).

Table 6.3: Restrained needs for developing a fisheries-centered DISPLACE regional application obtained from different sources.

<table>
<thead>
<tr>
<th>Type of data</th>
<th>DISPLACE parameters</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fisheries</td>
<td>Species specific catch rates per vessel or fleet-segments</td>
<td>STECF Effort WG/GAM modelling on national logbooks, Landings, discards by gear by stocks from ICES Intercatch database, STECF or National stats Effort per métier per vessel size from MIXFISH ICES data call or STECF Data call</td>
</tr>
</tbody>
</table>
Concerning the data, spatial distribution of the fleets and the stocks are required. The simulations are more or less accurate depending on the quality on this input. For example for the North Sea, ICES WGSFD (Spatial Fisheries Data ICES Working Group) is now routinely mapping the fishing activities at sea on a fine grid scale that can also inform the spatial fishing footprint. This database was used in the simulations performed using the DISPLACE model. In the Adriatic Sea application, VMS and AIS data have been use to map the initial fishing effort allocation. The population spatial distributions were obtained from data collected during scientific surveys. In particular, the MEDITS survey program (an international bottom trawl survey in the Mediterranean).

Figure 6.5 Random snapshot of the DISPLACE User Interface for the Demersal Italian & Croatian demersal fisheries in the northern Adriatic (GSA17). Movement and catches of individual fishing vessels are simulated at hourly time steps on a 5y time horizon. DISPLACE projected EU MSFD and AER bioeconomic indicators can be aggregated at various levels (Vessels, to Metiers, to Harbours, to Nations) and simultaneously mapped in a unified framework.

As one of the full regional scale application, the application of DISPLACE to the North Sea considered adjustment of spatiotemporal distribution of effort to maximize the profit of the whole fishery under TAC constraints. This model is used to model the catches of the North Sea fleets focusing on the Danish fishing vessels that is active in the Baltic Sea and the North Sea in 2015. For the finest
level, the simulations use hourly time steps and a 6 by 6 km geodesic spatial grid (providing 35,309 possible fishing locations). In all, 693 vessels were simulated representing 46% of the 1,505 Danish vessels for which logbooks were available in 2015. Each simulated vessel could only fish in the set of EUNIS habitats and areas where it had previously been fishing. The simulated fishing vessels were allowed to use several different gear types within the same trip. After each trip, the simulated vessels return to port and earn money from selling their landings in the harbour. Fish prices are given per stock and marketable category (small, medium, large) and the gross added value is computed from income generated by selling the landings and the actual operating costs of the trip. For the coarser level (currently, other nations than Denmark) the catches are computed from the TACs and the relative stability keys and apply on the distribution areas of the harvested stocks.

### 6.2.3.3 SWOT Analysis of individual-based models

The EWG discussed the possibility of applying several models to the case study of Western Mediterranean. Leaving aside the issues related to data availability, examples for the two main groups of modelling approaches (i.e. Fleet-aggregated models and Individual-based models - IBM) were briefly evaluated as possible options. Extensive discussions on the characteristics and the pros and cons of various models for management strategies evaluation can also be found in e.g. STECF (2017) and Nielsen et al. (2018)

Here we summarize, in the form of SWOT (Strengths, Weaknesses, Opportunities and Threats - Humphrey, 2005) analysis, the aspects related to the application of IBM, which represent the last generation of modelling approaches.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>Avoiding “averaging problems”</td>
<td>Large number of parameters, potential correlation across parameters.</td>
</tr>
<tr>
<td>Avoiding misclassification of agents (e.g. switching metiers within the same trip);</td>
<td>Large number of assumptions</td>
</tr>
<tr>
<td>Capturing the mechanistic relationship between effort and mortality (fishermen decision-making, etc.);</td>
<td>Difficult fitting/validation</td>
</tr>
<tr>
<td>Possibility to predict the individual feedback to management strategies</td>
<td>Computational complexity, time/pc demanding</td>
</tr>
<tr>
<td>Better suitable to capture space/time effects</td>
<td>Computer skills needed</td>
</tr>
<tr>
<td>Possibility to estimate parameters (including catchability) at a finer scale</td>
<td>Difficult characterization of uncertainty</td>
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<td></td>
<td>Tries to capture human behaviour traits which are poorly understood.</td>
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<table>
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<tr>
<th>Opportunities</th>
<th>Threats</th>
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<tbody>
<tr>
<td>Valorisation of datasets (including remote tracking devices such as VMS and AIS)</td>
<td>Confidentiality issues</td>
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<tr>
<td></td>
<td>Expert knowledge needed</td>
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<td></td>
<td>Outliers effect (vessels without tracking devices)</td>
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<td>Fleets coverage in the Med?</td>
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<tr>
<td></td>
<td>Biased results due to sometimes large number parameters and assumptions.</td>
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Basically, the Strengths of IBM are related to their ability of incorporating the different characteristics of fishers and fishing vessels in terms of behaviour, fishing performance and impact on the resources. This is a very important aspect since it is largely acknowledged that, in some regions such as the Mediterranean Sea, the grouping of fishing vessels in Metiers is sometime too rigid and not efficient. Moreover, the availability of data from tracking devices (i.e. VMS and/or AIS) allows to evidence (see the Tor 3 of this EWG) that some aspects of vessel-specific strategy such as the area of activity and the species targeting (at a finer scale that assemblage) have an important effect on landings and fishing performance.

The weaknesses come from the fact that IBM tend to be use a large number of parameters and sometime require a large amount of data to model human behaviour that make the model validation challenging with unknown risk for producing biased outcomes.

The applicability of such IBM model for providing mixed-fisheries advice for the Western demersal Mediterranean fisheries should be discussed as part of the Step 1 of the road map below.

### 6.2.4 Summary - availability of mixed-fisheries models and identified gaps

The review above has highlighted that there are many models available, but with some various levels of coverage, development, completeness, update, complexity and user-friendliness. There does not seem to have one obvious choice of deciding upon one model over the other at this stage.

As a next step for the road map, the EWG 18-13 suggests the following approach:

- Agree on a suite of minimum requirements for what a model for the mixed-fisheries advice should be able to do
- Hold a dedicated STECF EWG in 2019 which the main purpose of testing the operationability and suitability of various candidate models and modellers on the most recent data year.

### 6.3 Other gaps and issues to consider in order to have an operational mixed-fisheries advice

#### 6.3.1 Improvement of fishing effort definition

While discussing ToR 2 results in the plenary of EWG 1813, it was observed that the fishing days used in the nominal effort measurements were not the same depending on the country. In this sense, a fishing day in Spain means that the boat has been out of the port no more than twelve hours, although there are the exceptions of the fleets exploiting the Ibiza and Alboran Island crustacean fisheries in the slope which can be out of the port sixteen hours due to the distance to those fishing grounds. On the other hand, in Italy there is no restriction of hours per day and 15 hours a day could be considered a normal fishing trip, and there is also an exceptionality that allows some boats to stay at sea for more than one day. For these differences in the time allowed at sea between countries, the measure of the effort is not standardized throughout the countries involved in the future MAP. It was also pointed out that the other variable included in the effort measure, the KW of each of the vessels, is an uncertain value and that perhaps the effort measure should be more simple and reliable by just using fishing days.

An option that was proposed during the discussion was to use hours of effective fishing instead of fishing days, which would be a standardized measure of effort throughout all the countries involved. It as pointed out that the calculation of the effective fishing hours can be done either by using VMS, not currently requested in the official data calls, or by using the information in the log-books which is currently requested not by day but by haul and is requested in the official data calls. Both data sources would allow computing the effort as effective fishing hours. Having more fine measures of effort could allow improving in the exploration of the relationship between F and effort in the core of the proposal of the MAP. VMS have the advantage that could provide a longer time series of effort as their implementation started in 2006.

#### 6.3.2 Definition of fleets and metiers

There is an ongoing discussion whether the current fleets and metiers as used in the data calls are the best descriptors of the actual differences in fishing activities across vessels and area. In all countries, studies have been conducted to investigate the differences in catch composition. In this
section we summarise some of that knowledge first by summarising the work performed in previous STECF EWGs, then with additional insights for Spain and Italy.

6.3.2.1 Previous STECF reports dealing with catch composition in mixed-fisheries

Most of the work is found in the STECF (2015b, 2015c, 2016b, 2018a). In particular, STECF (2015b) focused on analysing the species defining the fisheries, following fisheries definition from the Data Collection Framework. For each combination of GSA, metier (DCF Level 6) and Country, standard plots of catch composition in tonnage and in value are provided, as for example for the metier GSA5_DEMSP_OTB_ESP (Bottom otter trawl targeting demersal species in GSA 5) (Figure 6.6).

![Figure 6.6 Cumulative percentage for GSA05_DEMSP_OTB (source ??)](image)

Then a global comparison plot was provided for each gear across all GSAs, target group and country, as below for the Otter trawl (Figure 6.7).
Figure 6.7. Main selected species defining the Mediterranean demersal with a bottom otter trawl gears (OTB). The species selected are landed at least by one fishery and have been selected if in each fishery they fall within the 75 % cumulative percentage of the incomes. Species in red are demersal species subject to minimum sizes as defined in Annex III of the MEDREG. Fisheries in green do not have any Annex III’s species in their landings. The bubble size represents the percentage of the incomes (value in Euros) of each species on the total incomes, which is given by the sum of the incomes considering only these main selected species (From STECF 15-14)

Finally, the analyses were supplemented by a literature review on the references published on catch composition, with references identified in the following areas (Figure 6.8).

Figure 6.8 Spatial distribution of the available studies dealing with the characterization of Mediterranean demersal fisheries (trawl and small-scale) found in the literature search by Geographical Sub-Areas (GSAs)

During the EWG 18-13, additional information was provided for Spain and Italy on issues with the current definition of fleets and metiers. The analyses are described below, and the detailed figures of the results are given in Annex 03.
6.3.2.2 Spain

The approach followed so far aiming to determine the fishing effort regime for demersal fisheries may not be able to take into consideration the multispecific character and the by-catches of the mixed bottom trawl fisheries in the Spanish Mediterranean. This is in part because some of the stocks defined in the Regulation as drivers of the mixed fisheries seem not appropriate when the particular landings of each area are analyzed. The most clear example is that of *M. barbatus* in GFCM sub-area (GSA) 5, considered as one of the stocks concerned by the Regulation, but actually being of almost negligible importance in that GSA. In that GSA it is *M. surmuletus* the important species in terms of landings and economic benefits obtained from the shallow shelf, which is therefore periodically assessed in that area (Quetglas et al. 2016).

The problem may be more generalized due to the segmentation of the fleet that has been used. The segmentation requested in the DCF may be too coarse to take into consideration the multispecific character and the variety of target species of the mixed bottom trawl fisheries in the Spanish Mediterranean. It simply considers the boats length overall and following metiers:

DEMSP: *Demersal species*. The fishing days targeting demersal fish species (either fish, cephalopods or crustaceans) from the shelf and upper slope are currently codified with this metier.

DWSP: *Deep water species*. The fishing days targeting deep crustacean species (*Aristeus anntennatus* and *Aristaeomorpha foliacea*) in the middle slope are currently codified with this metier.

MDDWSP: *Mixed demersal and deep water species*. The fishing days in which a boat has targeted both demersal fish species (either fish, cephalopods or crustaceans) from the shelf and upper slope, and deep crustacean species (*A. anntennatus* and *A. foliacea*) in the middle slope, are currently codified with this metier.

However, the segmentation of the bottom trawl fleet in Spain in 2006-2007, carried out within the Programa Nacional de Datos Básicos pesqueros, revealed a much more complex level of fishing strategies or metiers. That segmentation was made at port fleet level and included the most important Spanish Mediterranean harbours for the bottom trawl fleet. It was based on landings from daily sales bills which were analyzed using multi-variate statistical techniques such as cluster analysis.

The analyses in Annex 03 show that there is a high variability in the metiers followed by different bottom trawl fleets. Some ports did not exploit at all the middle slope, such as Sant Carles where their fishing activity was concentrated on the continental shelf. Others, even within the same GSA 6, like Llançà, exploited the shelf and slope. The boats from Vélez-Málaga in GSA 1 did not exploit the middle slope but exploited the continental shelf and upper slope, whereas in the GSA 5 the boats from Mallorca exploit the shallow and deep continental shelf and the upper and middle slope, frequently combining more than one basic fishing strategy in a single day. This variability is completely masked if the metiers used to calculate the effort for the multi-annual plan are those required in the DCF.

It is also remarkable that the target species proposed as drivers of the mixed fisheries in the western Mediterranean (*Mullus barbatus*, *Merluccius merluccius*, *Parapenaeus longirostris*, *Nephrops norvegicus*, *Aristeus anntennatus* and *Aristaeomorpha foliacea*) may not be the most indicated to set effort reductions in some areas. The examples in Annex 03 show that although these species are present in most areas, they may not be the target ones, and that most commonly, landings in the Spanish Mediterranean are composed by a large variety of species, especially when they come from the continental shelf. A larger number of species should be included in order to take into account the marked multi-species character of the Spanish bottom trawl fisheries. Some of these species are taken into account in the assessments, such as *M. surmuletus* from GSA 5, which is periodically assessed within the GFCM, however, most of other important target species at a more regional scale, besides those stocks specifically mentioned in the Regulation (Article 1(2)), are not currently periodically assessed (e.g. *O. vulgaris*, species in the mixed fish categories, *S. mantis*, *Eledone cirrhosa*...).

It must be also taken into account that some of the important by-catch species, such as those in the mixed fish category (*Trigloporus lastoviza*, *Trachinus draco*, *Chelidonichthys cuculus* and
Serranus cabrilla) from the continental shelf of the Balearic Islands, GSA 5, have also been assessed, and showed even a higher overexploitation state than M. surmuletus, one of the main target species of the continental shelf in the area (Ordines et al. 2014). Hence, although the management of multi-species fisheries based on single species assessments should also benefit the rest of species, because by reducing the excessive fishing mortalities of target species to sustainable levels the pressure on the rest of the components of the ecosystem would also decrease (Mace, 2004), it may not suffice species more vulnerable than the ones assessed.

Another important consequence of this variability of metiers and diversity of targeted species is that the actual effort exerted on the driving stocks proposed could be overestimated. This effort is currently calculated based on the metiers described in the DCF and within it, the effort exerted by fleets not targeting the driving species also counts in. A clear example of this is M. barbatus from GSA 5, which is not targeted in the area but the effort exerted on it should be that exerted by the fleet to the DEMSP metier, which includes in GSA 5 those boats targeting the continental shelf and upper slope.

Although the complex variations, most metiers are quite coincident with the main communities of demersal species and resources described in the continental shelf and slope of the Mediterranean (e.g. Massutí and Reñones (2005) in the western basin, Biagi et al. (2002) and Colloca et al. (2003) in the central area, and Kallianiotis et al. (2000) in the eastern basin), which usually identify up to four main bathymetric assemblages: the shallow shelf, deep shelf, upper slope and middle slope. The Article 3(3) of the regulation specifies that ‘The plan shall implement the ecosystem-based approach to fisheries management in order to ensure that negative impacts of fishing activities on the marine ecosystem are minimised’. Hence, the segmentation used to calculate the effort should also be able to reflect the main communities where it is exerted.

Taking everything into account, an effort should be done to improve segmentation of the fleets involved. A more detailed segmentation from the daily sales bills would allow for 1) better definition of the target species at a GSA spatial scale and 2) a better estimation of the effort exerted on them and on the communities affected.

6.3.2.3 Italy

At present, the used fleet segmentation is not enough detailed. It is possible that the current aggregation size structure and rough division in only two so-called “métiers” is functional for assessing and modelize economic consequences of alternative choices. What is important is to understand whether the same aggregation system is also sufficient for biological analyses and for the management and forecasting of the demersal mixspecies fisheries of the area.

It is reasonable to argue that the targets of vessels belonging to different segments of a fleet vary. It is likely that small vessels will prefer coastal resources due to security reasons or due to the longer time needed for reaching distant fishing grounds. On the other hand, bigger sized vessels are more independent in their choices but often choose the targeting to valuable resources living far from the coast. However, this is not a rule and large differences due to tradition, resources availability, oceanographic or geo-morphological reasons may be determinant factors for conditioning the fishers’ choices.

The proposed segmentations in the WestMed Plan are only based on vessels’ size which obliges catch and effort to be pooled without other distinction than size of the vessels or only making a rough separation in two so-called métiers (mix and deep water shrimps). In such high level of aggregation, effort data will be less informative as it is impossible to link effort with resources on which such effort apply. Results will not describe the direct effort exerted by the fractions of the fleets on the different fish assemblages or single species that in reality exist and are very well distinct when fishers define targets and operation areas. It is necessary to be able to split the fleet in more “natural” segmentations that considers not only the size or engine power of vessels utilizing the same gear type, but also based on vessels that have the same group of target species, operating with the same seasonal frequency, and exerting fishing effort with a similar exploitation pattern, which approach the original idea which is behind the métier concept. The current proposed division of only one or two groups, includes the fisheries operating close to the coast, over the shelf border and in the slope (that imply gathering portions of the fleet targeting coastal species as M. barbatus up to 100m depth, those fishing on the shelf with a species mix as target
(cephalopods, hake, etc) and those targeting *Nephrops norvegicus* at depths between 300 and 600m and where deep sea shrimps are present, also the fleet operating in deep waters over 600m..

In Annex 03 it is shown an example of identification of métiers based on catch composition. The dendrogram separates clusters for the fleet of the port of Viareggio, inside the GSA9. This fleet does not exploit deep-sea areas where the two red shrimp species live as these 2 species are not abundant in the grounds facing such port. Multivariate analysis (Hierarchical clustering) based on catch composition by vessel shows a clear distinction of métiers, mostly defined by depth interval. By choosing different depth intervals where to go to fish, fishers decide in advance what they want to catch. Catch composition is in this area very well stratified, with only few species living over a wide depth range. The analysis describes very well defined (without overlapping) clusters that can be associated with fisheries/métiers.

- a coastal fishery operating in the depth range 10-100m, (*Sepia officinalis*, *Squilla mantis*, red mullet)
- a fishery operating over the shelf between 100 and 300m (*Eledone cirrhosa*, rays, *Zeus faber*, *Scyliorhinus canicula*, *Triglidae*, *Merluccius*, *Pink shrimp*, etc)
- the fishery targeting *Nephrops norvegicus*, *Phycis blennioides*, *Micromesistius poutassou*, *squids*, etc
- In this port the fishery targeting deep sea shrimps does not exist as it occurs in other ports of the same GSA, as Santa Margherita in the North and Porto Santo Stefano towards the South, where such fishery is one of the more stable and easy to identify based on catch composition. In such fisheries, the two species of Aristaeidae shrimps red shrimps are seldom the dominant species and by-catch is mainly composed by *Phycis blennioides*, *Micromesistius poutassou*, *Lophius spp*, *Galeus melastomus*.

Other clusters can be defined and are shown in Annex 03. They represent other fisheries for instance pair midwater trawls that at this time were targeting pelagic resources or seasonal or special fisheries, where a specific stock or group of species predominate as concentrated and highly vulnerable in certain periods of the year. These fisheries are less important, and some of them are already disappeared in the area.

The division in at least 4 different species assemblages is clear for almost all the western Tyrrhenian GSAs.

The sampling plan and number of métiers should be consistent in order to obtain a sufficient number of samples (trips) useful for supporting estimates of key parameters. Such division is not the most detailed possible, but can be a good compromise.

Other fleets.

Based on the proposed stocks assuming to be representative of the fisheries in the area, it is noticed that some of them are also caught by other fractions of the fleet using different gears, for instance using the set nets or longlines utilized by the small-scale vessels. This is the case principally for hake, cuttlefish, and red mullets. Whenever in a GSA or sub-area removals from small-scale vessels are not negligible, without including such removals it results impossible to understand the reasons of the evolution of the stock status, based on observed changes in catch rates, etc and in particular to get reliable relationships between fishing effort and fishing mortality. In an effort-based management regime, the knowledge of such relationship is critical.

The 4 briefly described fishing strategies are also present in the other Italian GSAs facing the Tyrrhenian Sea, but major details are not available.

### 6.3.3 Species and stocks issues

#### 6.3.3.1 Overview

The Proposal for a Regulation of the European Parliament and of the Council, establishing a multi-annual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea, taking into account that the exploitation of most demersal stocks in this area ‘exceeds by far the levels required to achieve MSY’ considers appropriate to establish a multi-annual plan aiming for the
conservation and sustainable exploitation of demersal stocks. This plan ‘should take account of the mixed nature of the fisheries and the dynamics between the stocks driving them, i.e. hake (*Merluccius merluccius*), red mullet (*Mullus barbatus*), deep-water rose shrimp (*Parapenaeus longirostris*), Norway lobster (*Nephrops norvegicus*), blue and red shrimp (*Aristeus antennatus*) and giant red shrimp (*Aristaeomorpha foliacea*). It should also take account of by-catch species and demersal stocks for which sufficient data are not available’. Based on this, Article 1(2) of the Regulation defines the stocks of the six species (mentioned above), considered to drive the mixed fisheries in the western Mediterranean, to which the multi-annual plan should apply. In the same article, point 3, it is specified that the Regulation shall also apply to ‘by-catch stocks caught in the western Mediterranean Sea when fishing for the stocks referred to in paragraph 1. It shall also apply to any other demersal stocks caught in the western Mediterranean Sea and for which sufficient data are not available.’

The six species in the plan have a limited importance for some fisheries. Their distributions do not overlap in some cases and they make part of different species assemblages exploited by different portions of the fleet. Even though the number of métiers would increase and be more precisely defined (see above), only one or two species will constitute the effort reference for management decisions on the basis of their stock assessment. Such species can however seldom be considered as drivers of a fishery as they often represent a small fraction of the total catches in a mixed fishery. Moreover, depending on the specific species’ dynamics, catchability, etc of each one of them, the expectations regarding the evolution of the fishery after enforcing management measures based only on these selected species, the time needed for reaching any fixed management goal, the economic consequences, etc could be quite different to that potentially obtained considering alternative stocks. Probably if limitation regards only one species, misleading results will be obtained for supporting decisions to be taken aimed at a sound management of the whole fishery. The EWG considers necessary to enlarge the list, trying to include the species that are in general positioned on the top of the landings by area/port, and possibly to make assessments more precise as possible on the status of these stocks whenever such assessments have not already been done. This is especially important in order to avoid delayed recover/sub exploitation of these species since they could be more/less vulnerable to fishing impacts than the proposed ones, and hence, be more/less impacted and require larger/smaller effort reductions that those dictated by the exploitation state of the proposed stocks.

6.3.3.2 *Species included in the plan*

Six species are proposed for being included in the MP: *Merluccius merluccius, Mullus barbatus, Parapenaeus longirostris, Nephrops norvegicus, Aristaeus antennatus, Aristaemorpha foliacea*. Such species have been previously chosen during specific EWGs where they were defined a priority list of stocks mainly based on amount of landings combined with commercial value and in some cases based on vulnerability and conservation considerations.

There are however some issues with the stock identity of these species (Figure 6.9). The proposed MAP suggest the definition in the European West Mediterranean of two management sub-areas: one including GSAs 1, 5, 6, 7, 8; and the other covering GSAs 9, 10, 11. These areas are assumed (even though not explicitly mentioned) to encompass single stock units for the six selected species chosen as drivers in the MAP. STOCKMED project has not been able to define boundaries for unit stocks for these six species. While for hake, stock boundaries for one stock identified in STOCKMED (Fiorentino et al., 2015) in the Western Mediterranean should include the whole Spanish area and France, for the Italian area should exist another distributed from the Gulf of Lyons up to the Ionian Sea, for *Mullus barbatus* the “best” choice in STOCKMED assumes a single stock living along Spanish, French and Italian coasts up to the Adriatic Sea. For *Parapenaeus longirostris* a single stock is assumed present along Spanish coasts, France and only covering the Northern portion of the Tyrrhenian Sea. Other stock should extend from central Tyrrhenian Sea southward and occupying all the Italian coasts in the Straits of Sicily and part of the Adriatic. For *Nephrops* three stock units are hypothesised: one in South Spain and Balearic Islands, another in North Spanish coasts. Other stock should cover part of France and all Italian coasts up to the Sicily straits, *Aristaeus antennatus* should be divided in two stocks: one living along Spain and France and the second along Italy, Croatia and Greece, *Aristaemorpha foliacea* one single stock unit with boundaries including Spain, France and Sardinia, and a separate stock living along the Tyrrhenian Sea, Croatia and Greece.
Figure 6.9. **Stock identity for the various species (STOCKMED project)**

The definition of wide areas where few stock units are present has practical advantages. The aggregation of data from different areas implies lower costs to gather data and possibly more precise (even though less accurate) parameter estimates. Lower residuals obtained in certain estimates merging certain GSAs compared to those obtained in previous assessments using separate data for GSA were used in some EWGs for supporting decisions of fusion of GSAs.

If more than one stock is managed as a single unit, as such stocks may find important biological differences in the population parameters, but principally when they are exploited with different rates and patterns, many problems should arise.

The gathering of data from different stocks over a large area will drive to the estimation of average values obtained across the wide spatial scale. If these estimates are used for enforcing measures to all the stocks within such area, (for instance certain limit in catches or effort), for some stocks such measures could be too much restrictive while for other limitations will not be enough to meet the defined objectives.

The management area should be defined by natural spatial scales that reflect biologically meaningful units exposed to different mortality rates, and having spatial or temporal isolation of spawning groups, show microevolution of morphological or genetic characteristics, or have abundances that are affected by local processes; Waldman 2005).
6.3.3.3 Species not included in the plan but which have a stock assessment/forecast

In the Western coasts of Italy there were conducted stock assessments for other stocks than the six that were preliminarily selected.

Assessments of *Pagellus erythrinus*, *Mullus surmuletus*, *Squilla mantis*, *Micromesistius poutassou* have been done and approved in STECF EWGs. Some preliminary assessments based on yield per recruit and life tables have been also done in EWGs and in GFCM for *Galeus melastomus*, *Scyliorhinus canicula*, *Raja clavata* and *Raja asterias* for GSA9. In scientific literature assessments for some other species for a fraction of GSA9 are published that regard *Sepia officinalis*, *Squilla mantis*, *Penaeus kerathurus*, *Trigla lucerna*, *Gobius niger*.

6.3.3.4 Other species (not in the plan, no assessment)

The examples of metiers carried out by the bottom trawl fleet in different ports (section 3.2) show the importance of other species than the target ones in the MAP that are not currently periodically assessed (e.g. *Eledone cirrhosa*, *Squilla mantis* in GSA6 port of Sant Carles; *Octopus vulgaris* in Sant Carles, Llançà in GSA 6, Vélez-Málaga in GSA 1, and Mallorca in GSA 5).

One way to identify these fisheries based on different stocks than the target ones is to perform a more detailed segmentation that the one requested in the DCF, by using multivariate techniques such as cluster analysis on landings (daily sale bills, that are available). Once identified, the stocks of these assessments should be performed and/or the collection of data necessary to do it should be started.

6.3.3.5 How these other species are already included in the existing models

Total revenues by fleet segment is a crucial variable to be projected in bio-economic simulations for estimating socio-economic indicators. Revenues by stock and fleet segment, calculated as the product of landings and price at the same level of detail, are available only for the stocks included in the model. These stocks are generally not enough to calculate total revenues by fleet segment because of the great number of stocks exploited in demersal fisheries and the limited number of stocks assessed and included in the model for simulation. Therefore, the revenues calculated directly from landings and prices in the model relate only to a fraction of the total revenues of the fleet segments.

The approach generally used to overcome this problem (in models like MEFISTO and BEMTOOL) consists in using specific functional relationships between total revenues and the revenues from assessed stocks. When the fraction of total revenues represented by the revenues from assessed stocks is quite stable over time, the remaining part of revenues can be estimated by a linear relationship. Other solutions consist in estimating the landings of non-assessed stocks as a linear or non-linear function of the landings of assessed stocks and multiplying by an average price for that group of species, which is estimated on time series data. Landings of non-assessed stocks can be also estimated assuming a linear relationship with fishing effort.

MEFISTO was run with 10 species, which included the selected species for the WMed Multi-Annual plan.

6.3.3.6 Role of other species in the achievement of the other objectives of the MAP

The EWG 18-13 discussed that the MAP has other objectives than the achievement of the CFP MSY objective (Objective 1), and considered whether these could be achieved with the current selection of species to be included.

Objective 2. The plan shall contribute to the elimination of discards by avoiding and reducing unwanted catches as far as possible, and to the implementation of the landing obligation established in Article 15 of Regulation (EU) No 1380/2013 for the species which are subject to minimum conservation reference sizes and to which this Regulation applies.

The impact of an effort reduction, aiming to achieve the MSY for the selected species, was not discussed in terms of discards reduction and landing obligation. This issue needs much more
information than that treated so far. This is a complex issue that deals with spatial/temporal distribution of individuals below the minimum landing size.

Other demersal species with minimum sizes, and hence affected by the landing obligation, like *Pagellus spp*, *Mullus surmuletus*, and pelagic species abundant in the landings of demersal fisheries such as *Trachurus spp* have not been considered.

**Objective 3.** The plan shall implement the ecosystem-based approach to fisheries management in order to ensure that negative impacts of fishing activities on the marine ecosystem are minimized. It shall be coherent with Union environmental legislation, in particular with the objective of achieving good environmental status by 2020 as set out in Article 1(1) of Directive 2008/56/EC and the objectives set out in Articles 4 and 5 of Directive 2009/147/EC and Articles 6 and 12 of Council Directive 92/43/EEC.

The extent and the how the effort regime for demersal fisheries in the western Mediterranean Sea based on the selected species can contribute to improve the marine ecosystems should be scientifically supported. Demersal vulnerable species such as elasmobranches may need levels of effort reduction much higher than those needed by the species selected. On the other hand, benthic habitats protection need a spatial management of the effort rather than general reductions to be accomplished in large areas based on the level of exploitation of selected main resources.

**Objective 4.** In particular, the plan shall aim to:

(a) ensure that the conditions described in descriptor 3 contained in Annex I to Directive 2008/56/EC are fulfilled; and

(b) contribute to the fulfillment of other relevant descriptors contained in Annex I to Directive 2008/56/EC in proportion to the role played by fisheries in their fulfillment.

Below are attached the descriptors in Annex I of Directive 2008/56/EC in which fisheries can be involved:

1. Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.

3. Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

4. All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

6. Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

Descriptor 3 calls for a more general improvement taking into account “safe biological limits” of all commercially exploited species, not just the selected species ones.

The issue of how an effort regime for demersal fisheries in the western Mediterranean Sea based only on the selected species can contribute to fulfill descriptors 1, 4 and 6 should be scientifically supported. If not supported, then other species and habitats should be taken into account in the multi annual plan.

**Objective 5.** Measures in the plan shall be taken on the basis of the best available scientific advice. Where there is insufficient data, a comparable degree of conservation of the relevant stocks shall be pursued.

The selected species cannot be considered relevant stocks in some areas (see section 3.2) and so, other species should be included based on a smaller scale definition of the métiers.

6.3.4 **Timing of availability of new data**

Stock assessment results for the Mediterranean stocks are produced by GFCM and STECF and the summary results (F, SSB, R) are public. Nevertheless, the age based estimates of population size and structure, fishing mortality, etc, are not public and must be required to the above mentioned groups.
Most stock assessment groups in the Mediterranean take place in the 4th quarter, which means that the assessments are approved late in the year (STECF) or the year after (GFCM).

Effort data is compiled by the JRC through datacalls and made public after revision by STECF EWGs. Effort data follows a similar schedule as stock assessments, being made available late in the year or early next year.

Economic data is also compiled by the JRC through datacalls and made public after revision by STECF EWGs. This dataset has a further one year gap due to the MS’s procedures collecting and compiling the data. The results are made available late 2nd quarter referring to two years before.

Any work needed to support policy decision is, as such, subject to a 2 year gap, if economic data is not needed, or 3 years if economic data is required, which makes the advice less precise and robust.
6.4 Road Map for the mixed-fisheries advice

The review of the state of model and knowledge has highlighted that there is a great level of knowledge and data available for the West Med, but that not work is still necessary to get a streamlined and operational mixed fisheries advice.

6.4.1 Summary of the main gaps and issues to be addressed

6.4.1.1 With regards to models

- There are many mixed-fisheries models available, but with some various levels of coverage, development, completeness, update, complexity and user-friendliness.
- On the opposite the standard models currently applied to mixed-fisheries advice in the ICES area have not yet been applied to the Western Mediterranean fisheries (although some earlier trials have been performed in the Eastern Med).
- No models are directly available for covering all the MAP stocks in each of the two sub-areas.
- Most models available are developed towards medium-term stochastic projections, not deterministic short-term forecasts. Their results may thus not be exactly comparable with the single-stock advice for next year’s fishing opportunities.
- Many species driving the fisheries are not included in the MAP, and how to include and treat them in the mixed-fisheries advice is unclear.

6.4.1.2 With regards to data

- The effort and catch data (transversal data) currently available in the various JRC data calls (FDI, AER and MBS) differ, and it is difficult to have a robust quantitative picture of the current fisheries.
- The current definition of fleets (vessel groups based on vessel size and gear) and metiers (DCF level 6) may not be the most appropriate for describing the actual differences in fishing patterns, targeting behaviour and catchability between fishing vessels. Information is available in the national institutes at a more detailed level, but not directly available in the JRC databases.
- Stock definition and stock assessment parameters can differ between STECF and GFCM.
- There are different timings for the availability of the different datasets.
- The important species in terms of revenue are not necessarily the six ones included in the plan. There are several other important species, but they are not always assessed and cannot thus be included in a mixed-fisheries model in the same way.

6.4.1.3 With regards to experts

- Until now, model development and update has been driven and financed by research projects with varying objectives and different timing. Therefore, no structure is yet established to secure the routine update of the models through dedicated and prioritised allocation of financial and human resources in the scientific institutes.
- The available models are quite complex and not easy to update within a 5 days working group. Some additional work is necessary in the institutes, which is less likely to take place without dedicated support.
- The required modelling expertise is often limited to a small number of people in the institutes, and these people are often committed to several other tasks and their availability can be a limiting factor. Early planning is necessary to secure the involvement of the relevant persons.

6.4.2 Suggestion for a roadmap in 2019-2020

As highlighted above, there are quite a number of steps to address. And based on previous experiences with regards to experts’ participation both during and between experts working group, it is recognised that the highest chance to obtain an operational mixed-fisheries advice is to combine a suite of expert working groups or workshops (max one per semester) with additional funding dedicated to intersessional developments. This funding would secure the necessary time and
commitment of the relevant experts, while the workshops would act as useful milestones reviewing the progresses achieved and framing their outcomes into the desired operational setup.

The Road map is split into four steps, each of them including a meeting/ workshop:

Step 1: MODEL SCOPING: Model(s) selection, stock data and agreement on alternative fleet and metiers segmentation if relevant

Step 2: DRAFT RUN: Agreement on scenarios, results, and draft mixed-fisheries advice on data available in 2018 (reference year 2017)

Step 3: UPDATE AND DEVELOPMENT: Update to 2019 datasets (reference year 2018) and model(s) improvements/extension

Step 4: FINAL OPERATIONAL SETUP. Actual mixed-fisheries advice for 2021 (reference year 2019)

NB This roadmap will focus mainly on the Western Med in the first place. But, as it also the case in the ICES area, it should not be excluded to expand it to a more global mixed-fisheries approach for the EU Mediterranean demersal fisheries.

6.4.2.1 Step1 (1st semester 2019): MODEL AND DATA SCOPING, AND FUNDING PLAN

This step focuses on model(s) requirements and model selection; updated stock data (from EWG 18-12) and suggestions for alternative fleets and metiers segmentation with corresponding catch and effort data

In the first semester, some work shall be dedicated in the institutes to address the issue of alternative fleets and metiers definition, if it is felt that the current definitions as available in the JRC databases is not fully appropriate. If felt necessary, alternative segmentations shall be suggested, and the corresponding data provided. Full conversion ability with the DCF definitions shall be sought (e.g. for each trip and/or vessel, the allocation to both the DCF definition and the alternative definition should be given, in order to reach the same summed totals of catch and effort either way). The sum of catches by stock shall also be comparable to the amount used in the single stock assessment

In parallel, modellers in charge of the models described in section 2 shall investigate the feasibility of their models to address the gaps listed above and in particular

- The coverage of several GSAs (models by the two sub-areas of the plan)
- The inclusion of at least all the stocks of the 6 MAP species within the two sub-areas ( and maybe more if already included in the existing models)
- Ability to be updated with the most recent data (e.g. stock and transversal data up to 2017)
- Ability to match the most recent single-stock short-term advice (e.g. for 2019 for the stocks assessed in 2018 on 2017 data)

EWG 18-13 suggests holding an STECF EWG or scoping workshop in early 2019 to get the work started. [suggested time: March 2019, before the STECF Spring plenary]. The Workshop will specifically require the presence of both modellers and data people. One outcome of this workshop would be a description of the model(s) and data choice and of the required intersessional work (who, what, when, how) with corresponding funding requests.

This scoping could also include some discussion on the possible scenarios and results to display which will be needed in Step2.

On this basis, a discussion should take place between STECF and DG Mare during the 2019 Spring Plenary on options to support this intersessional work.

6.4.2.2 Step2 (2nd semester 2019): DRAFT RUN

In the second semester, the focus will be on performing an actual draft run of the mixed-fisheries advice with the model(s) and data selected in Step 1 and based on 2017 reference year (in order not to spend too much time on data updates). An update of the Step1 discussion should take place during the STECF July Plenary, to ensure that the decisions made in Step1 are followed and that the work is engaged as expected.
The scenarios to run and the selection of results to display should also be agreed with MARE, the progresses achieved should be reviewed during a second STECF EWG or workshop before the November STECF Plenary, which main objective will be to deliver an actual draft advice.

6.4.2.3 Step 3 (1st semester 2020): UPDATE AND DEVELOPMENT

This step will work towards making the selected model(s) and datasets more streamlined with regards to easiness of model update and data availability, including 2018 stock and transversal data, and considering the possible inclusion of more species than those of the MAP only.

Progresses with this work should be reviewed during STECF Spring Plenary, and completed before the Summer Plenary. The requirement for holding a dedicated EWG or workshop shall be discussed in January 2020 during STECF Bureau.

6.4.2.4 Step 4 (Months 19-24, 2nd semester 2020): FINAL OPERATIONAL SETUP

The major objective of this step will be to deliver an operational and up-to-date mixed-fisheries advice at the end of 2020 or early 2021, including the most recent stock and fleet data (data 2020, reference year 2019). This should therefore take place after the STECF November 2020 plenary (where stock assessment are released) but before the Spring 2021 plenary.
7 References


GFCM. 2018. Scientific Advisory Committee on Fisheries (SAC) Report of the Workshop on the assessment of management measures (WKMSE) Zagreb, Croatia, 9–11 April 2018


Mutsert K., Cowan J. H., Essington T.E., Hilborn R. 2008 Reanalyses of Gulf of Mexico fisheries data: Landings can be misleading in assessments of fisheries and fisheries ecosystems PNAS February 19, 105 (7) 2740-2744; https://doi.org/10.1073/pnas.0704354105


# Contact Details of EWG-18-13 Participants

1 - Information on EWG participant’s affiliations is displayed for information only. In any case, Members of the STECF, invited experts, and JRC experts shall act independently. In the context of the STECF work, the committee members and other experts do not represent the institutions/bodies they are affiliated to in their daily jobs. STECF members and experts also declare at each meeting of the STECF and of its Expert Working Groups any specific interest which might be considered prejudicial to their independence in relation to specific items on the agenda. These declarations are displayed on the public meeting’s website if experts explicitly authorized the JRC to do so in accordance with EU legislation on the protection of personnel data. For more information: [http://stecf.jrc.ec.europa.eu/adm-declarations](http://stecf.jrc.ec.europa.eu/adm-declarations)

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9 List of Annexes

Electronic annexes are published on the meeting’s web site on:
http://stecf.jrc.ec.europa.eu/web/stecf/ewg1813

List of electronic annexes documents:

EWG-18-13 – Annex 02a - Mixfisheries analysis and data screening - French haul by haul data. 11 pp.

10 List of Background Documents

Background documents are published on the meeting’s web site on:
http://stecf.jrc.ec.europa.eu/web/stecf/ewg0813

List of background documents:

EWG-18-13 – Doc 1 - Declarations of invited and JRC experts (see also section 08 of this report – List of participants)
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