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Scientific, Technical and Economic Committee for Fisheries (STECF)
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Fishing effort regime for demersal fisheries in the western Mediterranean Sea (STECF-18-09)

Edited by Clara Ulrich and Ernesto Jardim

Joint Research Centre

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Abstract

Commission Decision of 25 February 2016 setting up a Scientific, Technical and Economic Committee for Fisheries, C(2016) 1084, OJ C 74, 26.2.2016, p. 4–10. The Commission may consult the group on any matter relating to marine and fisheries biology, fishing gear technology, fisheries economics, fisheries governance, ecosystem effects of fisheries, aquaculture or similar disciplines. This report deals with the fishing effort regime for demersal fisheries in the western Mediterranean Sea.

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EWG-18-09 report:

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SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF) - Fishing effort regime for demersal fisheries in the western Mediterranean Sea (STECF-18-09)

Request to the STECF

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 Arona, Italy, from 18 to 22 June 2018. The meeting was attended by 19 experts in total, including 5 STECF members and 2 JRC experts with three observers. As the EWG report was not finalised before the STECF plenary, the STECF commented on a draft version of the report circulated on the 3rd of July and the presentations held at the plenary on the 3rd and 4th of July.

The objective of the EWG 18-09 was to carry out an assessment of the effects of effort management plans in the western Mediterranean Sea. Multi annual plan for the fisheries exploiting demersal stocks in the Western Mediterranean Sea.

STECF comments

STECF considers that the EWG ToRs represented a comprehensive review of the effort regimes ranging from literature review on experiences with effort management to an assessment of possible effects of effort management for the fisheries concerned.

The group reviewed various effort management systems from inside and outside the EU:

1 The effort regime in the Faroe Islands, which is among the most well-known example of a pure effort regime applied on demersal mixed-fisheries, implemented over more than 20 years;

2 The Queensland case which represents a complex system of individual transferable effort rights

3 The combined effort-TAC regime implemented in the European Atlantic and North Sea demersal mixed-fisheries in the frame of several recovery and management plans

4 The effort regulation in the Baltic Sea

5 Finally, a detailed review of the current effort limitations in place in the Mediterranean Sea is provided

From these cases and other literature the following the EWG deducted general features and pitfalls which are linked to effort regimes:

- The assumption behind the idea of effort regimes that effort is easier to monitor and control than landings does not necessarily hold true and can be case-dependent.

- Finding the appropriate effort measure is more complicate than for catches and is limited by the availbility of data collected in logbooks. e.g. Hours, days, kWdays. Measures such as days are not necessarily appropriate for all types of gear used and the type of fisheries;
- Because of several reasons, the relationship between nominal fishing effort and fishing mortality is often obscured;
- Moreover, effective fishing effort can be altered by targeting behaviour and skipper effect;
- If some fleet segments are restricted by effort management and not others, vessels will likely move to less regulated segments;
- The effective fishing effort can be influenced by input substitution, technological creep and hyperstability;
- In effort management idle overcapacity (inactive and partly active vessels) may remain in the fishery, and this may cause a problem when stocks start recovering following effort reduction, since this overcapacity can become active again and jeopardises the positive developments.

STECF observed that the topic of TAC vs. effort management has been widely discussed. Effort -based management creates incentives to maximize revenue and catch, and in the process expands input use and therefore costs.

Moreover, because of the issues mentioned above, the reductions in nominal effort might not result in reductions of the mortality of the fish stocks concerned, if fishermen maintain high catches in spite of effort reductions. Therefore, it is necessary to monitor whether catches are also decreasing in line with expectations, to assess whether the effort reductions are achieving their objective.

In order to carry out an analysis of the fisheries and establish an effort baseline the EWG had access to two sources of aggregated data during the meeting:

- DCF Mediterranean data call with effort data (2017)
- STECF data call for economic and transversal data (2017)

Based on an initial analysis the experts decided to retrieve the information from the economic and transversal dataset, for the period 2008-2016.

The available data sets had a number of data deficiencies and inconsistencies between landings and effort data. As a result, the EWG decided to only use the 2013-2015 data. STECF notes that the existence of these harmonised datasets on transversal and economic variables is a major improvement for the assessment of fisheries issues. However, data issues and inconsistencies between the data of various calls have been a recurring problem during the last years and the data analysis could be more meaningful if more high quality data would be available. STECF notes that the EWG suggests recomputing the effort baseline after the gaps and inconsistencies are addressed by Member States. STECF notes additionally that the 2018 FDI datacall is expected to provide a more robust dataset that may be used as an alternative for establishing the baseline.

The EWG analysed also the variation in the catch efficiency of individual vessels and trips, using two datasets with individual trip data from Italy and Catalonia. The EWG analysed that there is considerable variation in efficiency. An analysis of the LPUE quantiles shows that the most efficient trips are much more efficient (two to five times more) than the average trips. STECF observes that this large difference in the efficiency is consistent with the economic theory in a fishery under effort management; Fishers stay in the fisheries as long as they can cover their fixed and opportunity costs and wait for an expected recovery of the stocks. Therefore, the overall economic efficiency of the fishery is decreased. Furthermore, the STECF also notes that this difference in fishing efficiency between the average and the more efficient vessels decreases with the vessel length. This is also consistent with the economic theory, because in general the bigger the vessel, the higher the fixed and opportunity costs, and thus the higher the idle costs of maintaining the vessels as partly active and inefficient. There are thus comparatively fewer large vessels that are inefficient.

The EWG analysed the factors that affect vessel performance, using a GAM- based analysis of these individual trip data. Independent factors included were technical characteristics, market prices, depth, season, year and degree of specialisation on selected target species. The results show that the landings per unit effort is affected by the factors above but that the effects vary among fleets and stocks and no general trends can be found. STECF observes that (gradual) changes in these factors can have large impacts on the fishing power of a fleet and can obscure the relationship between nominal effort and fishing mortality if they are not taken into account in the measurement of the nominal effort. STECF notes that the availability of detailed trip by trip data was crucial for this type of analysis.

The working group summarised the results of a research project (MyGears), analysing the technical characteristics of fishing gears used in the Mediterranean. This project gathered data using interviews, which provided detailed information about gear design and size and their relationships with vessel size and horsepower. The study shows that as some innovations have only been implemented in part of the fleet and countries, there is ample scope for further increase of fishing power in the fleets concerned without this being shown in general trends of nominal effort; i.e. vessels could tow bigger otter trawls without changing their fishing effort and horsepower.

STECF notes that technical creep is widely known to influence fishing power. A literature study in 2014 revealed an overall estimate of around 3% technical creep per year for EU fisheries (Eigaard et al, 2014). The values for individual fisheries varied considerably, ranging from negative values to over 10% per year. STECF notes that these values can vary significantly among the different fleet segments in Mediterranean fisheries.

In order to assess the relationship between fishing effort and fishing mortality, the EWG assessed the relationships for these parameters for a number of gear-stock combinations. The EWG noted that in most cases the current estimates of nominal effort and fishing mortality do not show any clear relationship. STECF observes that over the last years, both fishing mortality and nominal effort have been relatively high and stable. Because of the relative small changes in nominal effort and fishing mortality, the variability in both the assessment of mortality and the fishing effort obscures the relationship between the two parameters. Moreover, STECF notes that effort is estimated for the entire fleet segment, regardless of the actual targeting of the fleet. Some fleet segments have been shown to be targeting some species more than others, and a better estimate of fishing effort by metier may potentially improve the relationship between effort and mortality.

With the available models the EWG assessed the effects of the multiannual plans in a number of cases. Three cases were included:

- MEFISTO Mediterranean Fisheries Simulation Tool applied to demersal fisheries in GSA 6 - Northern Spain
- IAM model applied to the French fisheries in the Gulf of Lions (GSA 7)
- Bioeconomic from GSA 9 (not included in the draft report version reviewed by PLEN 18-02 but incorporated later in the final EWG report)

STECF notes that model runs performed during the EWG were only preliminary and exploratory, and that this ToR has thus not been fully addressed. In the application of the MEFISTO model, the economic part of the model was not used. The EWG report mentions that the IAM model was not developed for the specific questions raised in the EWG and therefore, the scenarios do not correspond exactly to the ones mentioned in the TOR. Scenarios with alternative assumptions on vessel performance were not investigated. Because of this the EWG stated that the model applications need to be developed further before conclusions can be drawn.

Despite the fact that the model outcomes need to be developed further, STECF notes that the current models runs assume that there is a constant catchability, and thus a linear relationship between fishing effort and fishing mortality. This implies that in the scenarios presented, effort reduction will lead to reductions in fishing mortality and in time fish stocks will recover. However, this assumption is overoptimistic, because of all the factors that may increase the fishing power of the vessels. The actual changes in F will be likely lower than changes in nominal effort, especially at the beginning of the reduction.

Moreover, STECF notes that any positive change in the fishing mortality will not be detected before at least 3 years because of random noise in the relationship between effort and F, and because of the time needed to observe the changes in the stock assessment.

In order to facilitate a more sophisticated approach to the reduction of effort, the EWG also looked into possible ways for alternative segmentation of the fleets in the management plan (0-15m, 15-26m, 26m>). Based on the landings per sea day no clear distinction can be made. The EWG concluded that the current segmentation is to be preferred over a cruder segmentation mainly with regards to data collection and monitoring. The current segmentation is consistent with the International Standard Statistical Classification of Vessels (ISSCFV), on which a number of legal reporting requirements are based including several data calls under the data collection framework DCF. As no VMS data is available for vessels <12m, these vessels might also better deal with separately. STECF underlines that any segmentation is arbitrary and the benefits of the alternative segmentation remain unclear. STECF notes that an alternative to fleet segmentation could be to use conversion factors, for example defining effort as kW*days instead of fishing days.

STECF conclusions

STECF concludes that in order to attain the MSY targets for the western Mediterranean fish stocks in 2020, swift action is needed and reductions in fishing mortality will need to be considerable for some species. In order to prepare for such actions, the results of the EWG provide a good starting point, but further elaboration on the analysis is needed. STECF stresses the need to have consistent data as a basis for this analysis and the update of the baseline in case data are adjusted. The database resulting from the new FDI data call may provide a complete and consistent source for transversal data. Moreover, the model applications will need to be extended to show the effects of effort reduction scenarios.

STECF concludes that in order to attain MSY targets in a limited number of years for all stocks, considerable reductions in fishing mortality are necessary. Given the fact that there is ample scope for increases in the fishing power without any changes in the nominal fishing effort, STECF concludes that the reduction in fishing effort probably needs to be considerably higher than the needed reduction of fishing mortality. Moreover, increased knowledge on the technical creep in the fisheries concerned can be useful for the development for a sustainable effort management system.

STECF also notes that the current plan only limits the effort of trawl fisheries, whereas some of the species included in the MAP for demersal fisheries are also exploited by other types of fishery (e.g. longline fisheries for hake). STECF concludes that the opportunities for fishing vessels to shift to other fishing gears might be a risk to the success of the effort limitations for the trawl fleets.

STECF concludes that the proposed Management Plan indicates general reductions in effort and that the analysis of the EWG give no reasons for differentiation of the reductions for specific groups of vessels or fisheries. Anecdotal information shows that fishers may influence species composition on a day by day basis level. However, further analyses are necessary to analyse such fishing patterns,. It can also be debated whether such a detailed partitioning of effort is to be included in the EU plan or whether this should be left to the MS.

STECF comments were based on draft results provided to the committee and part of these comments have been taken into account in the final version of the report.

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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

1 EXPERT WORKING GROUP ON Fishing effort regime for demersal fisheries in the western Mediterranean Sea (EWG-18-09)

Arona, Italy, 14-18 May 2018

2 INTRODUCTION

The STECF Expert Working Group EWG-18-09 took place at the Concorde Hotel, Arona, Italy, from 18 to 22 June 2018. The chair of the EWG, Clara Ulrich, opened the EWG at 14:00h. The terms of reference for the meeting were reviewed and discussed and consequently the meeting agenda agreed. The session was managed through alternation of plenary and sub-group meetings. The meeting closed at 12:00h on 22 June 2018.

The meeting was attended by 19 experts in total, including 5 STECF members and 2 JRC experts, with three observers and 2 persons from DG Mare.

Terms of Reference for EWG-18-09

BACKGROUND

On 8 March 2018, the Commission adopted a proposal for a Multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea[1,2]. It is the fourth multiannual plan since the reform of the Common Fisheries Policy, and the second for the Mediterranean.

The proposed plan sets F_{MSY} ranges, conservation reference points and safeguards for the main demersal stocks, i.e. hake, red mullet, deep-water rose shrimp, Norway lobster, giant red shrimp and blue and red shrimp. It also covers by-catch stocks and any other demersal stocks caught in the Mediterranean Sea for which sufficient data are not currently available. The proposal applies to commercial and recreational fisheries fishing for the aforesaid stocks.

In line with a broad stakeholder consultation, the proposal introduces a fishing effort regime at EU level for all trawls exploiting the concerned stocks. Council would set a maximum total annual effort (in fishing days) for each predefined effort group in accordance with the scientific advice. Its Annex II specifies the segmentation of the effort groups, which has been categorised by target stock or group of stocks, geographical areas and overall length of vessels. Although not quantified, a substantial effort reduction is proposed during the first year of the implementation of the plan. The proposal complements the effort regime with a closure area for the use of trawls within the 100 m isobaths from 1 May to 31 July each year. Additional technical conservation measures, including for the implementation of the landing obligation, could be adopted through Regionalisation. It includes support from the European Maritime and Fisheries Fund (EMFF) for the adoption of temporary cessation measures.

Finally, the proposal foresees the possibility to amend the list of stocks and stock boundaries where the scientific advice shows a need. An evaluation of the multi-annual plan would be carried out five years after its adoption.

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[1] COM(2018)115. 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.

[2] SWD(2018)60. Commission Staff Working Document - Impact assessment accompanying the document proposal for a regulation of the European Parliament and of the Council establishing a multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean sea

Next steps: in 2018, the European Parliament and the Council will assess the proposal.

TERMS OF REFERENCE

TOR 1 - Lessons learned

Present the general knowledge on the use of fishing effort regimes as a management tool for mixed fisheries. The review should address lessons learned around the world, including main advantages, disadvantages and possible ways to move forward. Particular attention should be given to small-scale fisheries.

TOR 2 - What are the main characteristics of the trawl fishing fleet?

2.1 Provide a quantitative overview of the trawl fleet exploiting demersal stocks in the western Mediterranean Sea. Such characterisation shall include the following information, per management unit, fleet segment, Member State and from 2000 to 2016:

- No of (active and inactive) vessels
- Vessels gross tonnage and engine power
- Employment and full-time equivalent
- No of fishing days
- Energy consumption (total and per day at sea)
- Weight and value of landings
- Landings per unit effort, LPUE (average and median)
- Economic dependency (%)
- Net profit

2.2 Store the data from TOR 1.1 in an (easy-readable) electronic format such as Excel file. This additional information should accompany the final report of the EWG.

TOR 3 - What are the factors determining vessels' performance?

3.1 Identify the factors that may affect vessels' performance in the western Mediterranean demersal fisheries (e.g. seasonal and area effects, type and size of the vessel and fishing gear, fisher knowledge, price of fish or fuel). The EWG should use any information available from scientific publications, DCF, EU projects and grey literature.

3.2 Estimate the relative contribution of the factors identified in TOR 2.1 to the vessels' performance.

TOR 4 - What is the relationship between effort and fishing mortality?

4.1 Estimate the most scientifically sound relationship between effort and fishing mortality for the different fleet segments and effort management units.

4.2 Where no meaningful relationship is found, explore and propose other alternative methods to estimate a proxy relationship. In particular:

a) test and discuss the usefulness of applying percentiles (see explanation in Annex I);

b) make any appropriate comments and recommendations to improve the proposed approach in paragraph a); and

c) if the approach proposed in paragraph a) is not considered appropriate at all, propose alternative methods that could be used as a proxy relationship between effort and fishing mortality.

TOR 5 - What are the likely impacts of different management scenarios?

Assess the likely biological and socio-economic impacts of implementing the management scenarios described in Table 1. For each scenario, the EWG 18-09 is requested to run the appropriate forecast models in order to describe the likely situation of the fisheries up to 2030 and using the indicators given below:

- Fisheries indicators: catch, fishing mortality relative to Fmsy (F/Fmsy);
- Biological indicators: abundance (SSB) and recruitment;
- Socio-economic indicators: number of fleet segments and jobs at risk, and net profit.

It should be also taken into account the mitigation measures available under the EMFF.

Table 1 - Management scenarios to be tested in each effort management unit.

<table>
<tr><th></th><th>Fishing capacity
(no of vessels)</th><th>Fishing effort
(fishing days)</th><th>Strategy *</th></tr>
<tr><td>Baseline</td><td>constant</td><td>constant</td><td>n.a.</td></tr>
<tr><td rowspan="2">Scenario 1</td><td rowspan="2">- 5 % in year 1</td><td rowspan="2">- 10 % in year 1
- 10 % in year 2
- 10 % in year 3</td><td>Strategy 1 'high VP'</td></tr>
<tr><td>Strategy 2 'median VP'</td></tr>
<tr><td rowspan="2">Scenario 2</td><td rowspan="2">- 10 % in year 1</td><td rowspan="2">- 10 % in year 1
- 10 % in year 2
- 10 % in year 3</td><td>Strategy 1 'high VP'</td></tr>
<tr><td>Strategy 2 'median VP'</td></tr>
<tr><td rowspan="2">Scenario 3</td><td rowspan="2">- 10 % in year 1</td><td rowspan="2">- 20 % in year 1
- 10 % in year 2
- 10 % in year 3</td><td>Strategy 1 'high VP'</td></tr>
<tr><td>Strategy 2 'median VP'</td></tr>
</table>

where VP means vessels' performance

TOR 6 - Main conclusions and recommendations

Evaluate the findings of TOR 1-5 and make any appropriate comments and recommendations. In particular:

a) describe in concise terms the current limitations of the effort regime, including the reasons of it;
b) evaluate the impact of the different limitations; and
c) describe how these limitations could be addressed.

AOB – Discussion point on the multiannual plan

Discuss and make any appropriate comments and recommendations on the following elements of the multiannual plan: (i) the effort segmentation and; (ii) the concept of 'optimal harvest'.

Effort segmentation

The current proposal introduces the following segmentation: 2 geographical sub-areas (GSAs 1-2-5-6-7 and 8-9-10-11); 2 type of fisheries (mixed fisheries and deep water shrimps) and; 4 vessels' length groups (<12m; 12m-18m; 18-24m; and >24m) (see Figure 1, Annex II).

It has been proposed an alternative approach: 2 geographical sub-areas (GSAs 1-2-5-6-7 and 8-9-10-11); 1 type of fisheries (mixed fisheries, including deep water shrimps) and; 3 vessels' length groups (<15m; 15-26m; and >26m) (see Figure 2, Annex II).

- *What are the advantages and disadvantages of each effort segmentation?*
- *Do the vessels within each effort group have a similar fishing pattern? Which effort segmentation would provide the greatest similarity?*
- *What would be the impact on the Data Collection Framework?*

Optimal harvest

'Optimal harvest' means the best possible harvest strategy provided by the scientific advice in which the stocks concerned are fished within their respective ranges of FMSY, whilst still allowing trade-offs between environmental, social and economic sustainability (see example in Figure 3, Annex III).

- *Would 'optimal harvest' be an adequate approach for the implementation of an effort regime in the western Mediterranean demersal fisheries?*
- *How the calculation of the 'optimal harvest' could be better specified?*
- *How the boundaries of the area could be capped?*

ANNEX I

When there is no meaningful relationship between effort and fishing mortality: suggestion of an approach to be explored

For each fleet segment and effort management unit, the following data is compiled:

- Total landings of the most relevant demersal species (in Kg)
- Total fishing effort (in fishing days)
- Time series from 2013 to 2016

2) For example (percentiles to be discussed and proposed by the EWG!), the percentiles 25th, 50th and 85th of the CPUE are calculated.

3) As a precautionary approach given data uncertainties, errors and the unknown effect of the introduction of the effort regime, the percentiles 50th and 85th are retained.

→ *For illustration, a harvest ratio for trawl vessels between 12-18 m could result in something like* ***HR = 21 – 42 kg/day*** *(where, P50 = 21; and P85 = 42)*

4) The harvest ratio could be used to assess the biological and economic impact of different management scenarios, where:

Strategy 1 = HR_{P85} = high vessels' performance

Strategy 2 = HR_{P50} = median vessels' performance

5) Account taken of Fcurr and Fmsy, a fishing opportunity (a range of fishing days) could be estimated.

→ *For example:*

Baseline (only active vessels)

- *Trawl between 12-18 m = 463 vessels*
- *Total landings = 592 299 kg*
- *Fishing days = 28 308*

20% reduction needed = 118 459 Kg

Effort quota (in fishing days) = ?

a) *if each vessel fish at the level of the median: 22 563 fishing days*
b) *if each vessel fish at the level of P85: 11 281 fishing days*

→ *The effort quota for trawls between 12-18 m would be between* ***11281 - 22563 fishing days*** → *Managers to decide between that range…*

ANNEX II

Discuss point on the multiannual plan

Figure 1 – Effort segmentation included in the proposal

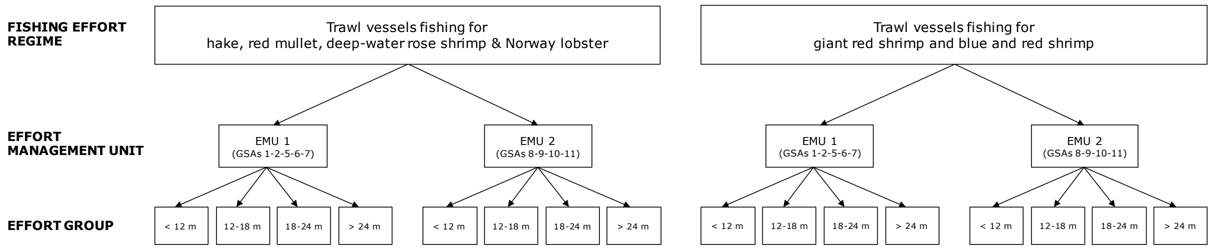


Figure 2 – Alternative effort segmentation

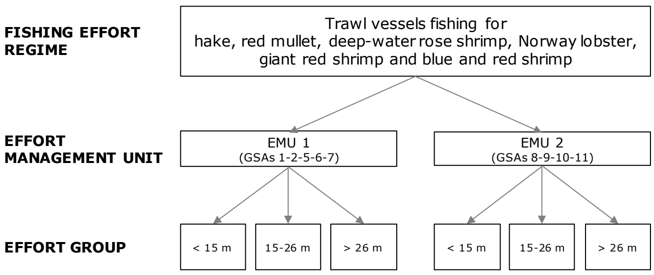
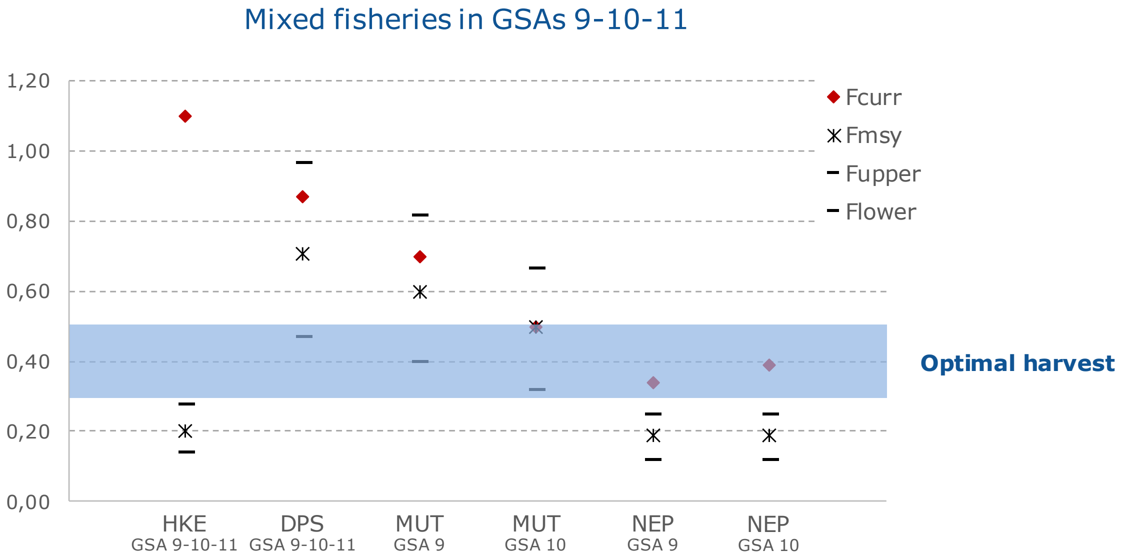


Figure 3 – Illustration of 'optimal harvest' (not real)



The area

The area and scope is well described in the Impact Assesment published by the EU (SWD(2018) 60 final).

The European coastline of the western Mediterranean Sea extends along the Alboran Sea and the Tyrrhenian Sea, covering the Balearic archipelago and the islands of Corsica and Sardinia. This corresponds to the GFCM geographical sub-areas (GSAs) 1, 2, 5, 6, 7, 8, 9, 10, and 11 (see Figure 2.1). Its geomorphology is characterised by an irregular coastline and a narrow continental shelf that is almost non-existent in certain areas such as the coast of Andalusia, but very wide in the areas of Castellon-Valencia, the Gulf of Lions, and between Italy and northern Corsica. The areas of wide continental shelf are of great importance to fisheries, particularly to bottom trawlers.

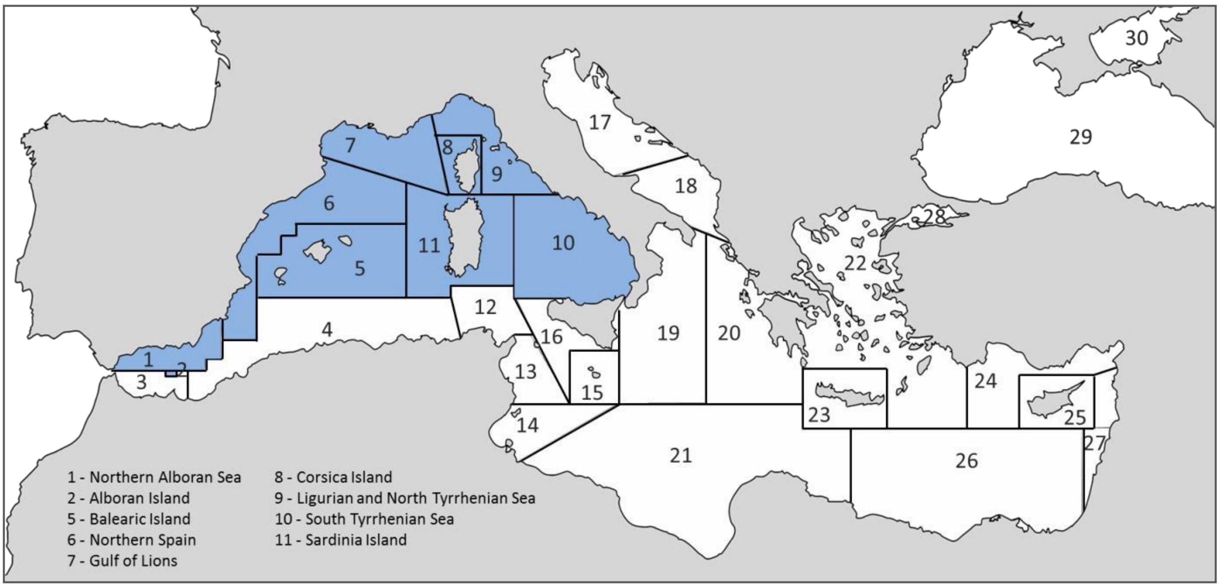


Figure 2.1. Geographical sub-areas (GSAs) in the GFCM area of application, as established in Resolution GFCM/33/2009/226. For the purpose of this initiative, the 'western Mediterranean Sea' covers GSAs 1, 2, 5, 6, 7, 8, 9, 10, and 11 (blue area)

Data available and sources of information

During the meeting, the STECF could have access to different datasets to progress on its ToRs. It must however be kept in mind that various issues and limitations have been observed in all datasets available. Therefore the analyses presented here shall be considered as exploratory and illustrative rather than absolute, and updates might occur at a later stage.

Following data were available:

2.1.1 Aggregated data

The primary data sources come from the databases hosted by JRC and populated with the different data calls (https://stecf.jrc.ec.europa.eu/data-dissemination). These data are aggregated at the level of the quarter or year, and at the level of the fleet segment gathering numerous vessels. These data are those used in ToRs 2, 4 and 5.

2.1.2 Trip-based disaggregated data

ToR3 and the AOB question on fleet segmentation cannot be answered with aggregated data, and require analyses to be conducted on some trip-based data.

No official data call had been issued, but two datasets were graciously brought in to the meeting. These datasets cover a large subset, but not all trawl fisheries involved in the West Med MAP, and allowed useful explorations of the diversity of individual fishing patterns. These data sets were:

2.1.2.1 Italian dataset

An Italian logbook dataset was provided to the meeting, in agreement with the National Correspondent. It 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). 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 5.1). 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.

2.1.2.2 Spanish (Catalonian) dataset.

A detailed dataset was provided by the observers from the Generalitat de Catalunya, focusing on the trawlers from the fishing ports of Catalonia (GSA 6). The data combined the full VMS data (filtered by speed, with fishing activity assumed to be <4 knots), daily landings per vessels from sales notes and the operational fleet census. VMS data were available for 2015-2016, and landings/fleet census over 2015-2017.

Shortly before submission of this report, some doubts were though casted on the validity of computation of the total landings (used in mixed-fisheries analyses), so all analyses there might be taken with caution.

2.1.3 Other sources of information

ToR 1 was mainly based on literature review and information found on the internet. In addition, a working document was sent by IFREMER as a contribution to ToR 5.

Species of interest

The Western MAP includes 6 species as category 1 stocks. In this report, these are referred to either as their common or latin name, or sometimes using the FAO 3-letter code. The correspondence between the three denomination is given below:

Common name	Latin name	FAO 3-letter code
Hake	Merluccius merluccius	HKE
Red mullet	Mullus barbatus	MUT

deep-water rose shrimp	Parapenaeus longirostris	DPS
Norway lobster	Nephrops norvegicus	NEP
giant red shrimp	Aristaeomorpha foliacea	ARS
blue and red shrimp	Aristeus antennatus	ARA

General comments on the ToRs

The EWG did address all ToRs. However, in all cases the analyses did not build on existing work but were developed during the meeting, and on the basis of incomplete data sets.

As such, most of the results presented in this reported shall be considered as preliminary and exploratory, and not all questions in the ToRs have been answered in full details.

The results have been presented to STECF Plenary in July 2018, and to representatives of DG Mare and member States on July 4th. It has then been agreed to organise a follow-up meeting to complete and expand the analyses developed in this report. The meeting (EWG 18-13) has been scheduled for 8-12 October 2018.

3 ToR 1: Lessons learned

The objective of this chapter is to present the general knowledge on the use of fishing effort regimes as a management tool for mixed fisheries. This reviews addresses lessons learned around the world, focusing in particular on the advantages, disadvantages and possible ways to move forward.

This section is divided in four sections. First, a number of case studies are presented, detailing current and past experiences with effort management around the world, based on literature search conducted during the meeting.

Some pure effort regimes outside of EU are presented in the first section, and primarily the contrasting examples of the Faroe Islands, and the Queensland

Then the second section focuses on the hybrid TAC/TAEs regimes trialled in Europe (Baltic Sea, North Sea, Atlantic) in the last two decades. The third section reviews the current effort limitation in place in the Western Med.

Finally, the fourth section details a number of important generic and well-known features of effort regimes, summarising the advantages and disadvantages of this system compared to TACs, and highlighting the main pitfalls that one need to be aware of.

Pure Effort regimes outside of EU

The Faroe Islands and the Queensland fisheries represent interesting contrasts on management systems in data-rich mixed-fisheries. Interestingly also, after several years of implementation, both systems are now undergoing major revisions, which now encompass some degree of catch limitations by stock, moving thus towards an hybrid system.

3.1.1 Faroes Islands

The Faroes Islands is maybe the best known example of full effort-based management used instead of TAC management for demersal mixed fisheries. It provides thus a lot of empirical experiences on the pros and cons of effort regimes, and many of these considerations are directly transposable to the Mediterranean context in spite of this being in a different context and with different species.

The demersal fisheries in the Faroe Islands have three main species: cod, haddock and saithe, distributed in different areas on the plateau and shelf. In 1994, the Faroese experimented with TAC with ITQs, but the system was abandoned after only 2 years. Instead, an effort management system was established in 1996 with large involvement of the fishing industry, and had the main objective of resolving the high discarding of the unwanted bycatch of fish induced by the TAC system (Í Jákupsstovu et al., 2007). The fundamental objective defined at the time is to regulate fishing effort so that the annual catch of the three most important demersal stocks (cod, haddock and saithe) does not exceed 33 per cent of the stocks, corresponding to controlling F at ≤ 0.45 on each of the three component stocks.

The system is described in details in (Í Jákupsstovu et al., 2007; Hegland and Hopkins, 2014). A few fleet segments are defined (trawlers, longliners, coastal over and under 15 GRT), subject to various technical rules, and in particular fleet-specific area closures. Capacity (nbr of vessels) must not increase. Maximum total effort (TAE) expressed as fishing days (i.e. days-at-sea) is fixed annually for the coming fishing year for each of the fleet groups and sub-groups. The total effort is then allocated equally between individual vessels in each of the fleet groups, except for the artisanal fleet groups which have specific allocation rules. Fishing days can be leased out for one year or sold permanently. Official effort conversion keys are used when trading effort between fleet groups in order to account for differences in fishing capacity across vessel sizes, engine power and gear types. Individual vessels can meet restrictions from effort limitation regulations by purchasing days-at-sea from other vessels. Thus, the effort management system effectively allocates individual transferrable fishing effort (ITE) rights.

After a few years of implementation however, concerns have emerged concerning weaknesses in the Faroese system (Í Jákupsstovu et al., 2007; Hegland and Hopkins, 2014; Danielsen and Agnarsson, 2018). The main concern is that the scientific advice is not taken into account properly when deciding on the effort, and the fishing mortality applied to the target stocks has remained very high, much higher than the intended target of F=0.45; which itself is much higher than the Fmsy estimates for the stocks. There are no long-term fishery management plans with pre-agreed harvest control rules, and short-term considerations prevail. Commercial fishing interests, especially from the catching sector, are strongly represented and have substantial influence on the entire decision-making process, where the often oppose the scientific advice. Additionally, the diverse fleet structure of fleet segments and métiers results in several and frequently differing interests among the fisheries representatives, which makes it difficult to gain agreement on effort cuts across different fleet fractions. Ultimately, overcapacity remains, leading to poor economic performance and profitability (Í Jákupsstovu et al., 2007; Hegland and Hopkins, 2014). The system is neither able to deal with different stock status among stocks, with a continued high targeting of cod in spite of its overfished status.

Another major issue is the failure to set up a credible system for measuring and monitoring changes in effective fishing effort, accounting for improvements in fishing efficiency to maintain high catches with declining stocks (including technical creep, Eigaard et al., 2011). Additionally, the scientific community considers that one of the fundamental problems of the effort management system is that the number of days originally allocated was too high. Too many days were distributed in order to get everybody onboard; However, in the following years, when the number of days should have been cut to better reflect the resource situation, there was no will for this. Each year a large share of fishing days remains unutilised by Faroese vessels (Danielsen and Agnarsson, 2018), indicating low profitability of using them because of low CPUE. DE facto, the fishing effort limit is thus not constraining.

Overall, the fishing effort regime seems to be highly conflictual, with fundamental differences in opinions between the scientists and the fishing industry regarding whether the system is effectively self-regulatory and sustainable or not (Hegland and Hopkins, 2014). These authors conclude that the main issue regarding fisheries management in the Faroe Islands is not the effort management system itself, but rather its inability to adjust to scientific recommendations on changes in stock biomass, and to variability and trends in catchability and fishing efficiency (Baudron et al., 2010; Eigaard et al., 2011). A major deficiency in the Faroese effort management system is the lack of a proper long-term plan including some pre-agreed rules to achieve the stock-based objectives like Fmsy.

In the most recent years though, the Faroes Islands have discussed changes and improvements in their system, and long-term management plans with single-stock focus have been proposed (Hegland and Hopkins, 2014). It appears that in reality, the Faroes are about to re-introduce a form of single-species TAC system with limitations on catches. In its latest (2018) advice on Faroese stocks[3], ICES states that "a new management system will be implemented for cod, haddock, and saithe after 1 January 2019. This management system operates with catch quotas for large vessels (trawlers and longliners), whereas it operates with fishing days for the small vessels (mainly longliners). The catch quota for the small vessels needs to be converted into fishing days. However, ICES is currently not in a position to quantify the relationship between effort and F for this stock."

[3] E.g. http://ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/had.27.5b.pdf

3.1.2 High seas fisheries in the South Pacific

The high seas bottom fisheries in the Southwest Pacific Ocean (FAO Statistical Area 81) is an example of the application of an effort based management approach for a poor data fisheries. The approach is mostly based on freezing the effort, protecting vulnerable habitats and limiting the spatial expansion of the fishery. The effects of this type of management strategies on the fishery performance is however unclear and difficult to evaluate.

The fishery is mostly conducted by vessels The high seas bottom fisheries in the Southwest Pacific Ocean (FAO Statistical Area 81) is mostly conducted by vessels flagged to New Zealand (15 trawlers and 9 bottom longliners) and Australia (4 trawlers and 8 bottom longliners). The main target species is the orange roughy (Hoplostethus atlanticus). Fisheries management in this area is provided by the South Pacific Regional Fisheries Management Organisation (SPRFMO, Figure 3.1), an inter-governmental organisation that is committed to the long-term conservation and sustainable use of the fishery resources of the South Pacific Ocean and in so doing safeguarding the marine ecosystems in which the resources occur.

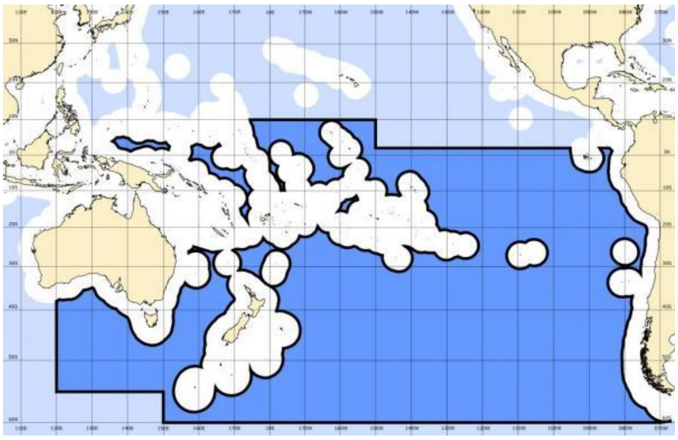


Figure 3.1 Map of the SPRFMO Area. Retrieved from https://www.sprfmo.int/about/illustrative-map-of-sprfmo-area/

Until mid 2000 assessments have not been accepted as sufficiently robust because of the highly variable levels of effort and catch between years within each of the fisheries, which can make the use of CPUE as an index of abundance uncertain. Preliminary stock assessments for orange roughy within the SPRFMO Convention Area were developed in recent years using spatially-disaggregated catch-per-unit-effort (CPUE) analyses and a Bayesian state-space biomass dynamic model. This approach served to estimate indices of stock abundance and infer stock status and trend in such low-information fisheries (Clark et al., 2017)

From 30 September 2007, these fisheries have become subject to the voluntary multilateral Interim Measures Agreement adopted by the parties to the Third International Meeting on the Establishment of a South Pacific Regional Fisheries Management Organisation.

The main measures applied were:

- Limit bottom fishing to existing levels of fishing effort and areas fished within the last several years (2002–2006).
- No further expansion of bottom fishing activities until 2010.
- Establish conservation and management measures to prevent significant adverse impacts on VMEs, and ensure long-term sustainability of deep-sea fish stocks.

- Close areas where VMEs are known or likely to occur to bottom fishing activities unless an assessment has been undertaken and management measures are in place to ensure no significant adverse impacts.
- Ensure 100 percent observer coverage on all bottom trawl vessels and an appropriate level of observer coverage on vessels using other bottom fishing gears.

In 2018 the "Conservation and Management Measure for the Management of Bottom Fishing in the SPRFMO Convention Area" (CMM 03-20181) established a set of rules wich are based on a combination of spatial measures particularly to protect VME and catch regulations. The CMM includes: 1) to restrict bottom fishing to within the bottom fishing footprint of fishing vessels flying the flag of a Member or Cooperating non-Contracting Party (CNCP). The fishing footprint is established as the distribution of historical bottom fishing in the Convention Area of all vessels flagged to a particular Member or CNCP over the period 1 January 2002 to 31 December 2006. 2) to limit bottom fishing catch in the Convention Area to a level that does not exceed the annual average levels of that Member or CNCP over the period 1 January 2002 to 31 December 2006; 3) require vessels flying their flag to cease bottom fishing activities within five nautical miles of any site in the Convention Area where evidence of a VME is encountered above given threshold levels.

3.1.3 Queensland East coast trawl fishery

The fleet decreased consistently from approximately 1400 licenced operators in early 1980's to 800 vessels at the introduction of the Plan to 520 as of May 2004.

Fishing days have historically been used to measure and record fishing effort in the Queensland east coast trawl fishery (QECTF). In the past, a fishing day has simply been a day in which a particular vessel or vessels fished.

During the effort allocation process, days fished were counted from individual logbooks in the QECTF. These days formed the basis of the decisions regarding the allocation of effort. As a result of this process, each licence was allocated a certain number of "fishing days".

A Fisheries (East Coast Trawl) Management Plan was adopted in 1999 ("the Plan") to consolidate aspects of trawl fishery management and provide a basis for further development of the fishery towards ecological sustainability and economic viability.

The Plan defined the nature of an effort unit as: (a) an authority; (b) a quota for the east coast trawl fishery. An Effort Management System (EMS) was introduced in 2001 following extensive consultation, negotiation and modelling. EMS represented the single most significant management regime in the trawl fishery and probably the largest operational change in a fishery in Queensland's history. Immediately prior to the introduction of the EMS, the State and Commonwealth Governments implemented a structural adjustment scheme (buy-back) that removed 99 licenses from the fishery.

The EMS was based on Effort Units (EUs): once the number of fishing days that each operator was entitled to had been calculated, these days were converted to EUs based upon the size of each individual vessel (measured in Hull Units). Therefore a EU is a standardised measure of fishing effort; hence a large vessel requires more EUs than a smaller vessel to make one fishing day.

The effort unit change according to the license type (i.e. T1, T2).

The number of effort units used on the fishing day is worked out by applying the following formula:

$$EU = 1/EUCF$$

where EU means the number of effort units used. 1 means the fishing day. EUCF means the effort unit conversion factor for the boat used.

The total number of fishing units is established annually. Each person who holds an eligible licence holds a number of effort units.

EUs were introduced into the QECTF to account for the fact that a small vessel is not likely to exert the same amount of "fishing power" in one active day as a larger boat.

The EMS is based upon an inter-tradeable system, it was important that some commensurate measure of effort was introduced that could be traded between licences.

An EU is a standardised measure of fishing effort. The number of EU used on the fishing day by a vessel is related to its LOA: a large vessel requires more EUs to make one fishing day than a small vessel. In this way effort creep, whereby whole fishing days are transferred from small vessels to large ones, is countered. After the adoption of the Plan (2000-2004) the majority of EUs have been transferred from medium to large boats. The total change in EU holdings within the fleet was not considered to be a reflection of adverse conditions for small operators.

Tracking temporal changes in effort creep was considered pivotal to effective management of the fishery to ensure the fishing effort remains sustainable. Average "effort creep" was set between 0.2 and 1.6% per year since 1989, depending on the sector of the fishery. These estimates of effort creep were used in the stock assessments of principal species and to standardise Catch per Unit Effort (CPUE) estimates.

An effort review (GER) was done in 2004. It represented a formal review of the levels of effort resulting from the EMS.

According to the review the trawl fishery has undergone significant structural adjustment following the introduction of the Plan, first of all in term of a significant reductions in fishing effort that was the major contributor to the sustainability of the fishery. Input controls, in the form of limits on net size, Bycatch Reduction Devices (BRDs), turtle excluder devices and permanent closures have significantly reduced the negative impacts of trawling on principal and permitted species and bycatch in the fishery. The main target species of the fisheries are prawns and scallops. The available assessments indicated that the majority of the stocks are fully exploited or sustainable exploited: e.g. the eastern king prawns and saucer scallops biomasses were at about BMSY in 2001; tiger / endeavour prawns were considered as fully exploited

This effort-based management framework appeared however costly to administer, inflexible and increasingly ineffective in ensuring the sustainability of fisheries resources and the economic viability of fishing sectors. (Kerrigan et al., 2004). Furthermore, it does not allow to reduce competition for shared resources between sectors.

In June 2017, the Queensland Government released the *Queensland Sustainable Fisheries Strategy,* the outcome of a significant stakeholder consultation exercise in 2016, done by the National authorities (Fisheries Queensland, Department of Agriculture and Fisheries 2017). The current effort-based management framework was considered inappropriate because costly to administer, inflexible and increasingly ineffective in ensuring the sustainability of fisheries resources and the economic viability of fishing sectors. Furthermore, it did not allow to reduce competition for shared resources between sectors.

The new proposed strategy include things like splitting the management of some fisheries into regions, introducing quotas or limits on fishing days, improving fishing gear technology, reviewing fish size and possession limits and having temporary and flexible closures for fishing

The objectives of the strategy is to achieve a more modern and responsive system of fisheries management, built upon a foundation of better data and research, stronger stakeholder engagement and more responsive decision-making. A key aspect of the reform is developing harvest strategies for all the involved fisheries, to set clear harvest limits and allocate fishery resources in a more transparent manner.

The management options are still under discussion (see next paragraph) and they are not excluding to keep a control effort regime to achieve sustainable cach for the main stocks.

This Strategy sets out clear targets to be achieved by 2020 and 2027 and a range of actions to deliver on the vision and targets. There are 33 actions across ten reform areas.

Key actions include:

- additional monitoring and research (including new technologies);
- setting clear sustainable limits for each commercial fish stocks;
- working groups and a Sustainable Fisheries Expert Panel to engage stakeholders;
- establishing harvest strategies for all fisheries which set clear targets for fishery performance, triggers for action;
- and clear decision rules for the actions that will be taken;
- piloting regionally based fisheries management.
- satellite tracking on all commercial fishing vessels;
- helping facilitate industry led structural adjustment to reduce the number of fishing licences and improve sustainability and profitability.

By 2020 the strategy aims at set sustainable catch limits based on achieving at least maximum sustainable yield for all Queensland fisheries (around 40-50% biomass). By 2027 set sustainable catch limits based on achieving maximum economic yield for all Queensland fisheries (around 60% biomass).

Reform of the East coast otter trawl fishery

A discussion paper has been issued in 2017 (https://publications.qld.gov.au/dataset/sfs-discussion-papers-fisheries-reform/resource/7f7b1769-e70a-4005-97b3-a0403dbc6ec8) to start a stakeholder debate on the subject. Implement harvest strategies that manage at the stock level and are based on sustainable catch limits for all Queensland fisheries by 2020 is considered a key action for the fishery.

Although catches for most of the stocks are considered acceptable under the current effort regime and that the fishery has reduced the impact on the ecosystem via improved gear selectivity (e.g. turtle excluder devices and bycatch excluding devices), the fishery still suffer of major issues:

- unsued effort units (38% in 2017) can be activated increasing pressure on the stocks;
- scallops at very low biomass raise sustainability concern;
- pressure on eastern king prawn stock;
- inability to make changes to protect a stock or a region (need to change the scale of management and associated effort control);
- protected species interactions;

The objectives of the reform are indicated in table 3.1.

The strategy requires that fisheries be divided into management "units". A management unit may be the target species, biological stock boundaries, a geographical boundary related to the fishery, gear or combination of these. In most but not all cases the unit will be based on specific geographical regions that allow for management arrangements to be applied at the appropriate scale. The strategy states that the preference is to manage the stock level.

Table 3.1. Fisheries objectives for the Queensland east coast trawl fishery

Ecological objectives	Socio-economic objectives	Management objectives
• achieve Sustainable Fisheries Strategy 2017 – 2027 biomass objectives for target and by-product species • understand fishery interactions and impacts on bycatch, threatened, endangered and protected (TEP) species • demonstrate there is no unacceptable risk to bycatch, TEP species and the ecosystem • actively pursue testing and implementation of new and effective technologies to minimise ecological risks.	• maximise commercial economic benefits • maximise value of the commercial product (e.g. fish, crab, prawn) • improve the social benefits of the fishery to the community • reduce waste and bycatch.	• ensure fisheries management is meeting the expectation of sectors and the community • improve data and undertake more regular stock assessments to inform management decisions • manage excess capacity to improve socio-economic benefits and minimise the risk of overfishing.

The trawl fishery is considered to do not under a proper management allowing for a harvest strategy that responds to changes in stock abundance or other circumstances. Consideration needs to be given to the existing system of individually transferable effort units and how it would fit with any future management options along with the highly variable nature of the stocks in this fishery. To move to a more adptable and flexible system a number of management options have been identified as starting basis for a discussion although the strategy clearly states a preference for the adoption of output controls, like quota, wherever possible. The options includes:

- **individual transferable catch quota**: Total allowable commercial catches (TACCs) would be set for key species or groups of multiple species and individual quota units allocated to individual commercial fishers. One of the problem is how to allocate reliable catch quota for short live species such as shrimps whose biomass is higly dependent on recruitment fluctuations.
- **individual transferable effort units (ITEs) allocated to management regions**: existing effort units or individual transferable effort units (ITEs): ITEs would be allocated to each of the proposed management regions, creating a pool of effort units in each region. In each management region a total allowable commercial effort (TACE) would be set based on biomass targets for key stocks. This sets the total number of effort units that can be used for each management region.
- **regional total allowable effort caps**: in each of the proposed management regions the TACE would be set based on biomass targets. The existing effort unit system would remain in place so no allocation process is required.

- **allocate individual licences to a management region**: this option would involve permanently allocating individual licences (to each of the proposed management regions (rather than allocating effort units) based on where fishers want to fish.

Combined TACs / effort regimes in EU demersal fisheries

3.1.4 Baltic Sea

The number of species of fishing interest in the Baltic Sea is rather limited. The main Baltic fisheries consist of fisheries targeting pelagic species (herring and sprat) and of fisheries targeting demersal species, primarily cod but also some flatfish species, (notably plaice and flounder), often in association. Some further Baltic fisheries are also designed to target, more specifically, salmonids.

First steps of managing of main fish stocks in the Baltic Sea were taken by the International Baltic Sea Fishery Commission (IBSFC, 1974-2005) which was responsible for the management of shared Baltic Sea fishery resources. Shortly after 1990, it became obvious that the important stocks were in a poor state and that the fisheries were not under satisfactory control. IBSFC reacted with several resolutions aimed at remedial actions, by reducing fishing mortality on depleted stocks and improving selectivity in cod fishery.

The IBSFC effort resulted in the development of the Baltic Salmon Action Plan (1997), the Long-Term Management Strategy for Cod Stocks in the Baltic Sea (1999), the Long-Term Management Strategy for the Sprat Stock in the Baltic Sea (2000), the Recovery Plan for Baltic Sea Cod (2001), and the Long-Term Objectives and Strategies for the Management of Baltic Sea Herring (2000–2002) (Aps and Lassen, 2010).

The management steps taken by the IBSFC included mostly various technical measures and TAC distribution between the fishing countries. After the IBSFC the European Commission has taken over the management of the Baltic fisheries on the basis of scientific advice from ICES.

Baltic Sea effort regime, focused on cod stocks was in place from 2006 and first evaluated by the STECF SGMOS 09-04 in the context of the management plan for Baltic cod (Council Regulation (EC) No 1098/2007) (STECF 12-09). Since then the effort-related information has been collected from the relevant Member States via annual JRC Data Calls, compiled by the JRC and evaluated by the relevant STECF EWGs.

3.1.5 Capacity and effort regulation in recent decades

The Commission's Green Paper (EC, 2009) identified overcapacity as a fundamental problem of the CFP as it encourages overfishing. One of the major problems encumbering the implementation of the sustainable fisheries in the Baltic has been the overcapacity in national fishing fleets, particularly after the accession of four new Baltic Member States to the EU in 2004. To overcome this problem, the European Commission initiated capacity reduction measures like ship scrapping programs. Largest reductions (> 30% of fleet capacity removed) were observed in the North Sea and Baltic areas (BE, NL, DK, SW, LV, EE) in 2000-2011. However, some MS used the decommission process also to modernize their remaining fleets (EC 2013).

In addition to the capacity regulation, the Baltic cod has been subject to a specific multiannual management regime since 2007 when the EC agreed on a management plan for cod in the Baltic Sea (EC 1098/2007). This Regulation established absolute limits on mortality rates for the two Baltic cod stocks and establishes a procedure for the setting of annual TACs, including maximum limits for inter-annual variation either to increase or decrease fishing possibilities). It also provided for some specific technical measures (notably areas and periods with restricted fishing activities) and established a fishing effort regime for some types of cod fisheries (based on vessel size, gear used, areas and period), associated with specific provisions regarding controls and inspection of cod fisheries.

So, alongside the reductions in F, the plan also specified a 10% reduction in total fishing days at sea per year until the target F has been reached. This rule applied to trawls, Danish seines, gillnets, entangling nets or trammel nets with mesh size >=90mm and longlines. In addition, fishing with the aforementioned gears and net types is totally forbidden from 1st to 30th April in SD 22-24 and from 1st July to 31st August in SD 25-28. However, by way of derogation, fishing vessels with an overall length of less than 12 m were permitted to use up to five days per month divided into periods of at least two consecutive days from the maximum number of days absent from port during the closed periods. The plan was complemented with a number of additional closed areas and as another effort restriction, the maximum fleet capacity measured in kW is limited to the reference value calculated for 2005 for each member state. ICES had evaluated the management plan in 2009 and considered it to be in accordance with the precautionary approach.

In general, the plan found widespread approval among the fishers, because it improved planning reliability for fishers´ organizations considerably. Conversely, there are indications that the reduction in fishing effort stipulated in the MP had also strong adverse effects on small-scale fishers. The survey, performed among the German fishers furthermore revealed that this fishery segment using passive fishing gear is among the most vulnerable, because it is the interest group with the lowest income, little resilience to cope with further restrictions, and no lobby to improve their position (Strehlow, 2010).

The significant reduction of fishing capacity and TAC regulation has supported also a declining trend in nominal fishing effort deployed in the Baltic, particularly in demersal fisheries (e.g. STECF 16-20). For example a substantial decrease in total effort of main regulated gears (otter trawl and gillnets) in kWdays at sea was observed for main cod fishery areas A (-38%) and B (-65%) from 2004 to 2010 and the less pronounced decline has continued since then. The unregulated gears showed the similar pattern. (STECF 14-20). The results of evaluation of fishing activities (days at sea) with main regulated gears (otter trawl and gillnet) also showed a clear decreasing trend over the areas A and B from total of 153,000 days at sea in 2004 to 76,000 days in 2013. The decreasing trend was observed both in regulated gillnets and otter-trawls. In Area A the fishing activity decreased in 2004-2010 and stabilised then at around 37,000- 38,000 days in 2010-2012. A new decrease to 34,000 days was observed in 2013.

The uptake of days at sea with regulated gears against the available days remained clearly below the available maximum (36-38% in area A and 34-47% in area B) for all Member States.

The analysis of potential connections between the fishing effort and fisheries mortality revealed that with respect to the Western Baltic cod (area A) the correlations between the summed partial Fs of regulated fisheries for catch and landings of the major fisheries and their estimated fishing efforts are significant for the period 2003-2013. The partial Fs of most of the Member States fisheries using regulated gears were also closely correlated with their specific effort estimates in kW days at sea. (STECF 14-20). For the Eastern Baltic cod fishery (Area B) the similar results were obtained for 2003-2012 (STECF 13-21). This indicates that effective fisheries management by fishing effort in units of kWdays at sea may appear possible, also as an auxiliary measure to catch constraints and technical measures (STECF 14-20).

Within the framework of the reformed CFP, the fisheries management of the Baltic Sea resources has been moved towards the achievement of Maximum Sustainable Yield (MSY) exploitation rates (at the latest in 2020 for all stocks), and the gradual elimination of discards (in practice those which are the subject of the main fisheries in the Baltic). The Commission also considered that the management regimes in place did not allow sufficient predictability concerning the proper conservation of the stocks in the Baltic, or concerning fishing opportunities (i.e. economic possibilities) for fishermen. For Baltic cod, the management plan of 2007 was not in line with the new MSY objective, some of its measures no longer addressed the realities of the stocks, and the maintaining of the present fishing effort regime was considered unnecessary.

So, the EC agreed on a new Multiannual management plan – MAP (COM(2014)614 for Baltic cod, herring and sprat. The new Baltic MAP aim inter alia:

- To cover, in a single management plan, the three main fished species distributed in eight stocks in the Baltic Sea, namely two for cod, five for herring and one for sprat, with the aim to achieve and maintain MSY for these stocks. The plan would also cover, and ensure the conservation of, some flat fish species also caught when fishing for cod, herring or sprat;
- Where possible, to set for each of these stocks some management reference points, namely a target range of fishing mortality (an expression of the rate at which fish are removed from the stock by fishing) in line with the MSY principle as from 2015, and a minimum level of the spawning stock biomass (total amount/weight of fish which are of an age to reproduce) which fishing management measures should strive to conserve;
- To set some specific control and enforcement provisions, as well as to set a regular evaluation of this multiannual plan;
- To set some specific rules with regard to the implementation of the landing obligation.

The associated repeal of the former plan covering Baltic cod only ((EC) No 1098/2007), also put an end to some existing cod fisheries management measures, particularly the fishing effort limitation which consisted of limiting fishing periods for certain gear types and the closing of certain areas to cod fishing. This was seen contributing towards simplifying the legislative environment and a reduction in administrative burdens on Member States and the fishing industry.

3.1.6 Atlantic and North Sea

Métier-based effort regulations have been enforced in European waters in the last decades. In 2001, urgent recovery measures were implemented for the North Sea cod stock, including a reduction of 80% of the TAC in 4 years (between 2000 and 2003). This TAC reduction did not lead to reductions in fishing effort during these years; but rather to increased discards. Effort restrictions (days at sea) were then introduced in 2003 to supplement TACs in areas covered by the cod recovery plan (North Sea, Kattegat, Irish Sea, West of Scotland, EC, 2004), to secure that catches, and thus fishing mortality actually reduced in accordance with the harvest control rule. Effort restrictions have been updated annually. Subsequently, similar recovery or management plans including effort restrictions were introduced in relation to several other stocks, including northern and southern hake, western channel sole and North Sea sole and plaice fisheries. Categories (métiers) for days at sea limits were defined in terms of gear type and cod-end mesh size combinations. 'Special condition' categories were also defined such that a vessel qualifying for such status would be entitled to a greater number of days at sea than the default value for the same gear-mesh size group.

In the case of the cod recovery plan, effort restrictions were indexed to the required restrictions in fishing mortality. For the North Sea flatfish management plan, the effort restrictions were sat at a fixed rate of 10% reduction per year until the fishing mortality target was reached for both stocks, in line with the Baltic Sea example above.

STECF was tasked to evaluate the effects of these regulations. This requires extensive compilation of effort and catch data, aggregated such that the hierarchy of gear, mesh size and special condition status match those defined in the effort regime. These exercises proved to be difficult, time-consuming, error-prone and often inconsistent across EU Member States. A main reason was that the days at sea categories were not always matched with the categories defined in the Data Collection Framework (DCF, 2008) and required more detailed information than usually available in the national scientific institutes.

The implementation of the 2004 days at sea system in led to strong protests from the fishing industry questioning both its fairness and its basis (Ulrich et al., 2012). The system was implemented as a top-down command and control system, and was conceived on the assumption that cod catches could simply be reduced by reducing the cod-directed fishery. As cod is caught by most gears in the North Sea, most mixed demersal fisheries were affected by the system and the industry considered this conservation measure to be neither efficient nor fairly shared. The protests pressured the Member States to exempt some of their fleets. This resulted in increasingly detailed micromanagement, and an even more complex set of regulations that basically changed every year.

In 2008, the system was no longer considered sustainable, controllable and effective by the EC, and a complete new approach for effort control was agreed with Members States. This moved from limitations at the level of the individual vessel and métier by month and/or year to limitations at the level of the Member States over broader gear/mesh size categories. This gave Member States more flexibility to manage their own fleets. This system was implemented in 2009 (EC, 2008b), based on a baseline fixed at the average of the three preceding years (2004-2006). The most interesting aspect is that the 2008 plan introduced new mechanisms aiming at encouraging cod-avoidance behavior in the fishing industry. Fishing restrictions would be less severe for those fleet segments that would demonstrate increased selectivity and avoidance.

STECF (2011) and (Kraak et al., 2013) conducted a detailed evaluation after two years of implementation of that plan. The increased use of incentives-based management was evaluated as a positive innovation, but it was also pointed out that there was still little support from the industry towards the effort constraints induced by the plan. And after two years, it was too early to be able to detect positive changes in the system, as a few more years of data are needed to distinguish trends (Fernandes and Cook, 2013). Looking backwards however, it is unclear whether the strong concerns against the effort regime in the North Sea was because the idea of effort limitation itself, or because of the stringent and inflexible harvest rule. In 2012, when the North Sea cod stock did begin to show signs of recovery, the situation was indeed that stock biomass and CPUEs were increasing while the legally binding HCR called for further TAC and effort reductions. Between 2013 and 2015, the HCR-based advice has then been rejected every year after long and conflictual negotiations (Ulrich et al., 2017).

In spite of these conflicts, it is obvious that the effort regimes combined with TACs targets have been successful at reducing fishing mortality and recovering some of their target stocks, such as North Sea cod, Northern hake and North Sea sole and plaice. The cod management plan mechanisms have also incentivised national bottom-up initiatives of increased selectivity and avoidance, for ex. the Conservation Credit Schemes in Scotland and the Fully Documented Fisheries trials with Electronic Monitoring in a number of Northern countries.

Current effort limitations in the Western Mediterranean Sea

3.1.7 Fishing capacity

According to the Regulation (EC) No. 2371/2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy (articles 11 to 16, Adjustment of fishing capacity) from 2002 to 2013 the European states reduced their fleet capacity. The policy of trawlers decommissioning continued with the Reg. (EU) No 1380/2013 on the Common Fisheries Policy and it is still in progress.

The variation of the trawlers capacity by countries from 2008 onwards in terms of numbers, gross tonnage and engine power is reported in Table 3.2

Table 3.2 Total capacity in terms of number, gross tonnage and engine power in kw of active trawlers in the western Mediterranean by country. The variation in percentage from the 2008 to 2016 is also reported (var%) (Data from AER 2017).

trawler capacity		2008	2009	2010	2011	2012	2013	2014	2015	2016	var%
	France	67	72	83	78	67	57	63	63	63	-6.0
Number	Italy	709	724	695	659	632	635	638	649	624	-12.0
	Spain	895	870	788	731	692	661	654	615	597	-33.3

	France	**5345**	**5645**	**7221**	**7169**	**5888**	**4801**	**5509**	**5679**	**5679**	**6.3**
GT	**Italy**	**26615**	**26886**	**25524**	**24025**	**23193**	**23323**	**23920**	**24552**	**22296**	**-16.2**
	Spain	**54414**	**52648**	**47592**	**43554**	**40957**	**39084**	**38769**	**35891**	**35005**	**-35.7**
	France	**20096**	**21131**	**24867**	**23605**	**20115**	**17172**	**18837**	**19050**	**19050**	**-5.2**
Power	**Italy**	**141181**	**143743**	**136527**	**128995**	**123386**	**125107**	**127868**	**130753**	**122151**	**-13.5**
	Spain	**173654**	**166115**	**148715**	**136277**	**128202**	**121538**	**120286**	**111766**	**107702**	**-38.0**

Considering the trawler capacity by countries it is evident that the French trawlers operating in the Mediterranean remained quite constant in the last 9 years. A light reduction between 5 and 6% in terms of Number and Engine power while a light increase of about 6% was registered when GT is considered. The French fleet capacity was the lower in the area, amounting at 63 vessels, with 5679 GT and 19050 engine power in kw in 2016.

In Italy in the last years, a marked decrease in fishing units was registered. Considering 2008 as the base reference year, a decline of 12% in the number, of 16% in GT and of 14% in engine power was recorded. The Italian fleet capacity was the higher in terms of number of vessels and engine power, with 624 vessels, 22296 GT and 122151 kw of engine power in 2016.

The decrease of trawler fleet capacity in Spain was stronger, amounting for 33% in number of vessels, 35% in GT and of 38% in engine power. The Spanish fleet capacity was the higher in terms of GT, with 597 vessels, with 35005 GT and 107702 engine power in kw in 2016.

3.1.8 Fishing activity

The fishing activity of trawlers by countries from 2008 onwards in terms of days at sea, including the percentage variation between 2008 and 2016, is reported in Table 3.3

Table 3.3 Activity in terms of days at sea of active trawlers in the western Mediterranean by country. The variation in percentage from the 2008 to 2016 is also reported (var%) (Data from AER 2017).

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**var%**
France	10328	11195	na	na	10026	9343	10547	11320	10925	5.8
Italy	106986	110669	103796	100128	95366	102884	109019	100327	104549	-2.3
Spain	162859	156133	149182	141778	134633	129814	129601	125129	125430	-23.0

French trawlers have the lowest level of fishing activity, while the amount of days at sea of Italy and Spain are very similar, being the Spanish ones lightly higher. In terms of variation an increase of about 6% for France, a light 2% decrease for Italy, and a strong reduction of 23% for Spain is recorded.

The temporary stopping of trawling activities is, together with the control of the mesh size and the establishment of the biological protection areas, one of the tools available to the Administrations for the management of stocks exploited by fisheries in the Mediterranean.

Although it may be oriented towards different objectives, in the context of Mediterranean fisheries, temporary stopping was mainly aimed at reducing the capture of juveniles. Precisely in accordance with this objective, the measure therefore concerned almost exclusively trawling, which is the one that causes of the great mortality on the juvenile fraction of fish stocks.

3.1.8.1 Italy

No maximum fishing days per year is fixed in Italy. Seasonal closure of trawling have been adopted since 1988 with a trawling ban of 45 days that in the last years was reduced to 30 continuative days. This temporary cessation of trawling has proved particularly effective and produced a significant increase in the abundance of some species, especially for those showing a faster growth and a relatively early age of sexual maturity, such as the red mullet and cephalopods. Considering biological issues and the exploitation context the resumption of trawling at the end of summer - early autumn, when the young red mullets move to deeper bottoms, even if still concentrated and vulnerable to the trawl, would act in a similar way to the increase of the mesh of the net (Caddy, 1999). This measure, in fact, would allow to increase the size of first capture of young specimens, a major probability to survival to adults and having sizes deemed most appropriate for market. In fact, in the specific case of the mullet, given that the species matures sexually at about 1 year of life, the effect of the measure also result in the increase in the number of individuals that will reach the age of first sexual maturity, with beneficial effects on subsequent recruitment. This fishery is carried out all round the year. The number of vessels fishing on coastal resources may increase during the winter season, when the weather conditions do not allow the operations far from the ports. Normally, vessels perform daily trips, amounting for a total of 150-160 fishing days.

Bottom trawlers cannot operate on Saturdays, Sundays and during holidays all year round. During the eight weeks following the seasonal closures trawlers cannot operate on Friday

3.1.8.2 France

In the continental coasts of France and Corsica island, trawling takes place all year round and no seasonal stop of activities is implemented. Due to the combination of local and national regulations, the maximum number of days-per-vessel is limited to 250 days per year. Trawling is prohibited on Saturdays, Sundays and national holidays. (Decree "Arrêté du 28 février 2013 portant adoption d'un plan de gestion pour la pêche professionnelle au chalut en mer Méditerranée par les navires battant pavillon français. NOR: TRAM1304962A. Version consolidée au 19 juin 2018»). Regarding fisheries targeting demersal species, the activity is shared between trawling for different species which are targeting according their seasonal occurrence and market requests. The fishing activity legislation limits the time at sea (fishing days) but not the number of tows to carry out every day nor other variable as vessel speed.

3.1.8.3 Spain

No maximum fishing days is fixed in Spain. A trawling ban ranging from 30 to 60 days according the areas is adopted in the Spanish Mediterranean from Murcia Region up to the border with France. The calendar of the ban is different by areas in order to guaranty an interrupted availability of fresh product in the Spanish markets. In the recent past a trawling ban of up to 90 days was adopted in Alboran Sea, but such seasonal closures are not currently adopted in Andalusia Region. The maximum operational time of trawlers is 12 hours per day and trawling is forbidden during the night. Trawling is also prohibited on Saturdays, Sundays and public holidays.

3.1.9 Fishing effort

The fishing effort of trawlers by countries from 2008 onwards calculated as mean engine power in kw times total number of fishing days of active trawlers by country, including the percentage variation between 2008 and 2016, are reported in Table 3.4.

Table 3.4 Nominal fishing efforts in thousands of units calculated as mean engine power in kw times total number of fishing days of active trawlers by country. Since Spanish data of 2016 is not available in the AER 2017, the variation was calculated considering 2015.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	Var%
France	3188	3449	0	0	3109	2888	3242	3469	3409	6.9
Italy	21698	22693	20821	20322	19773	20717	22554	20464	21363	-1.5
Spain	50484	48401	45326	42116	37378	39812	39477	36697	nc	-27.3

French trawlers showed an increase of fishing effort of about 7% from 2008 to 2016. A light decreasing of fishing effort resulted from Italian data, while the decrease of effort of Spanish trawlers was the highest amounting to about 27%.

Considering the state of high overfishing of most of the demersal resources in the Mediterranean (FAO, 2016) , the current regime of effort management based on control of fishing capacity and activity applied by the European Mediterranean countries, was not able to reverse the exploitation state of demersal resources in the Western Mediterranean and to reach the target of exploitation at MSY of European CFP.

Generic features and pitfalls of effort regimes

A fishing effort regime intends to regulate fishing effort, while a TAC regime intends to regulate catches. However in both cases, the ultimate objective is not effort or catch, but to obtain and maintain a fishing mortality F which is in line with a given objective, typically Fmsy. However F cannot be measured and controlled directly, so regulating effort and catches are thus only an indirect manner to regulate fishing mortality, assuming that there is some linkages between the two.

This section reviews thus the known implementation challenges and the main pitfalls that may prevent achieving the F-based objective. These have been well studied and described in the scientific literature

3.1.10 Monitoring and control

A major concern against catch management in the Mediterranean Sea is the difficulty to control and monitor the catches of the numerous fleets spread along the Sea. Demersal fisheries target species mixes often without clear dominant species. Landings occur over an extremely high number of ports and landing places, and the majority of vessels are small scale fisheries whose catches are difficult to quantify.

There is thus a belief that effort is easier to monitor and control than landings. However, monitoring effort can also be challenging. If effort information comes from logbooks, it can be as difficult to monitor the amount of effort exerted by a vessel as it is to monitor its catches, especially for small vessels not required to fill in logbooks. Effort limits would then need to be simple to enforce when applied to vessels without logbooks.

A major difference though, is the advantages offered by the use of VMS (Vessel Monitoring System) for monitoring and controlling effort. VMS data offer a cheap and well-established way to collect information on the duration and location of a fishing trip (Bastardie et al., 2010; Hintzen et al., 2012). VMS can distinguish between fishing time and steaming time, and many additional useful effort descriptors can be inferred under some assumptions (Needle and Catarino, 2011; Russo et al., 2011; Russo, Parisi and Cataudella, 2011). AIS (Automatic Identification System) can also be used to complement that knowledge (Russo et al., 2016). These spatio-temporal effort data offer thus a very promising alternative to logbooks for monitoring and controlling fishing effort under the effort regime. This is further reinforced if VMS data are to be collected from all vessels and not only those above 12m, as proposed in the 2018 EC proposal on Control Regulation.

3.1.11 Defining the metrics and units to measure nominal fishing effort

Nominal fishing effort describes the resources allocated to fishing, which can be expressed in different angles and using different units: such as time (days or hours fished), capital (number of vessel days, length or horsepower of vessel), labour (number of person hours or number of crew) or gear (mesh size or number of hooks). However information on hours fished or technical specification on the number, dimension and sweeping/soaking time of fishing gears is largely missing and cannot be used for monitoring.

The most common and available measure of time-related effort will thus be expressed in days fished, following the specification of logbooks where a logbook sheet must be filled-in for each day where a fishing gear is deployed.

However, fishing days alone are poor descriptors of the actual catching power of a vessel, due to large differences across vessel size and types. A number of studies have thus been performed to assess alternative measurable metrics of effort that would capture some these differences (McCluskey and Lewison, 2008). Some earlier research have found some correlation between the fishing power of a vessel and its engine size (Watson et al. 2000, 2006; Marchal et al. 2002). More recently, (Bell, Watson and Ye, 2017) correlated the average number of days fished by vessel with vessel length or GT and gear type for a number of fleets, and applied these correlations to the world wide fleet register to reconstruct a global time series of days fished since 1950.

Additionally, a direct issue in the case of in the European Western Mediterranean is that most trips are daily trips. They thus all count as one fishing day, whereas the available information described in section 0 shows that during a day at sea, the real number of hours exerting effective fishing operations may vary dramatically across fleets, not least due to differences in legislation between countries. The risk of fishing trips become longer (more hours fished in a day) in case of restrictive effort regime, and its impact on fishing mortality cannot be fully assessed here. But this should be monitored when the effort regime is implemented.

In the Baltic Sea, EU fishing effort limitation were expressed in days at sea. In the North Sea and Atlantic, EU fishing effort limitation were expressed in kWdays, i.e. fishing days by vessel weighted by the kW of its engine power. This measure of kW*days prevents vessels maintaining catch levels through increases in vessel engine power without penalties.

Care must be given to the calculation of the metric. Once a baseline of effort is established the methodology for calculating the effort must be kept the same. This is especially relevant to the days at sea. If the days at sea measure is rounded up to whole days for the baseline this should remain the approach thereafter. The ability to interpret the days at sea measure, especially how to apportion between multiple gears and/or areas within a single trip can lead to considerably different results for a given fishing trip scenario, as was demonstrated at a workshop on transversal variables [4]. A follow-up workshop[5] proposed a standard approach for days at sea (and fishing days) calculations and produced a package[6] that performs the calculations on typical logbook derived data . It would be possible to apply the package for calculation of days at sea by any vessels falling under the remit of the western Mediterranean effort regime.

This issue is relevant for the question of defining the unit for the baseline discussed in ToR 2.

3.1.12 Relationship between nominal fishing effort and fishing mortality

The management objective is expressed in terms of fishing mortality, which measures a form of ratio between the catches of the fisheries and the abundance of the stock. Replacing this with effort would imply having a predictable relationship between fishing effort (E) and fishing mortality (F), linked with each other by the catchability coefficient q (F=qE). E is here to be defined and measured in the units where it will be actually controlled and managed, as this is by regulating this metric that effects on fishing mortality are intended.

E and F are linked with each other at minima, in the sense that if there is no fishing at all (E=0), then there is no fishing mortality (F=0).

Beyond that, the relationship can take many different forms (Figure 3.2). A linear relationship would imply that catchability is constant regardless of stock abundance, and that catches per unit of effort (U) fluctuate proportionally to stock biomass (U=qB).

A log-shaped relationship would mean that catchability is not constant, typically that catchability can increase at low stock size in order to maintain high catches and CPUE ($U=qB^{\alpha}$).

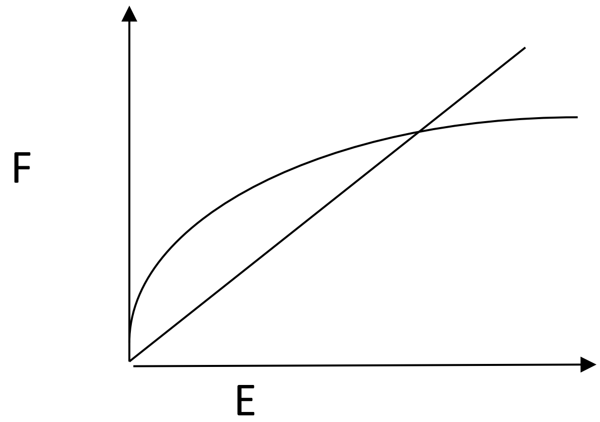


Figure 3.2. relationship between fishing effort and fishing mortality un der different catchability assumptions

More often though, the relationship can remain very unclear, especially in overfishing states where both fishing effort and fishing mortality is high, and it is necessary to have contrasts in the

[4] REPORT ON THE WORKSHOP ON TRANSVERSAL VARIABLES (Linking economic and biological effort data (call) design). 2015 – 80 pp. EUR27153; doi: 10.2788/385049

[5] Castro Ribeiro, C., Holmes, S., Scott, F., Berkenhagen, J., Demaneche, S., Prista, N., Reis, D., Reilly, T., Andriukaitiene, J., Aquilina, M., Avdič Mravlje, E., Calvo Santos, A., Charilaou, C., Dalskov, J., Davidiuk, I., Diamant, A., Egekvist, J., Elliot, M., Ioannou, M., Jakovleva, I. Kuzebski, E., Ozernaja, O., Pinnelo, D., Thasitis, I., Verlé, K., Vitarnen, J., Wójcik, I..Report of the 2nd Workshop on Transversal Variables. Nicosia, Cyprus. 22-26 February 2016. A DCF ad-hoc workshop. 109pp.EUR 27897; doi 10.2788/042271.

[6] Finlay Scott, Nuno Prista and Thomas Reilly (2016). fecR: Fishing Effort Calculator in R. R package version 0.0.1. https://CRAN.R-project.org/package=fecR

time series of F and E (i.e. historical data where F and effort have both been high and low over time) in order to understand when the relationship is somehow linear and when it is not.

A study by (Fernandes and Cook, 2013) on 57 ICES stocks showed for example some interesting relationships appearing in the most recent years where both fishing effort (expressed in kWdays) and fishing mortality had reduced significantly compared to the previous decade, during which no obvious relationship was apparent. (Figure 3.3).

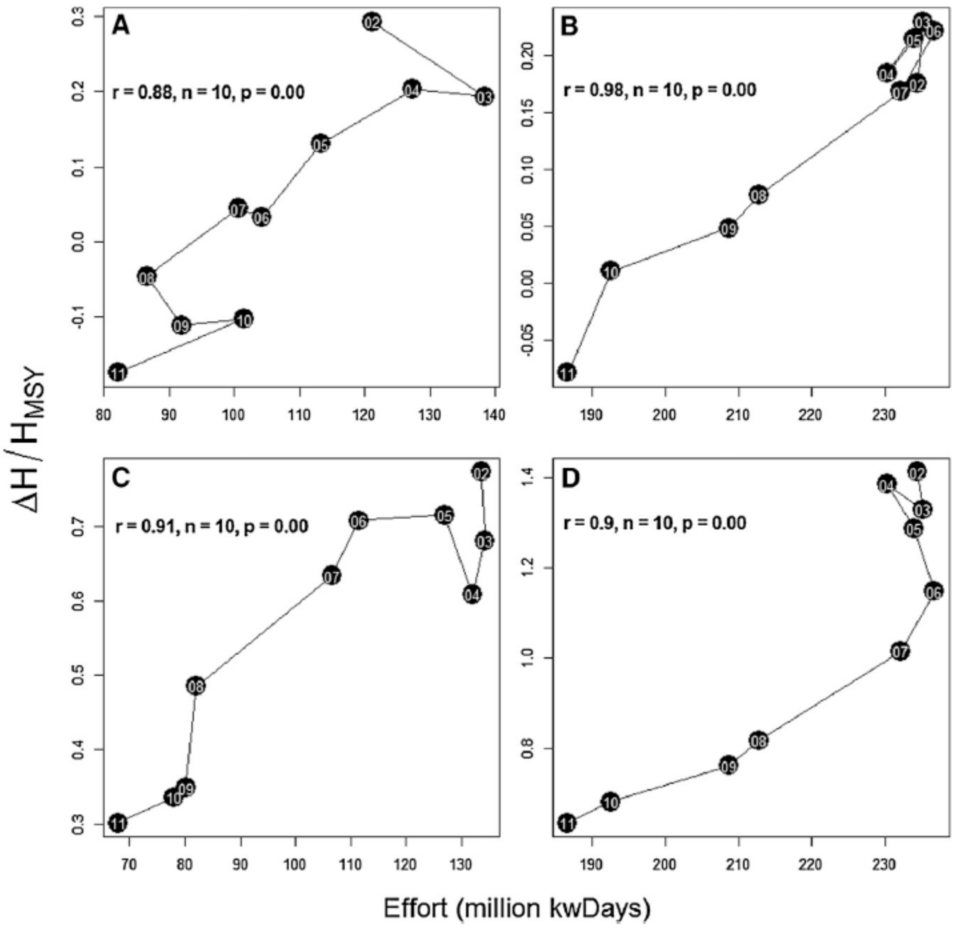


Figure 3.3. 2002-2011 Relationships between Fishing Effort and the Mean Difference in Exploitation Rate Relative to Fmsy for 57 ICES stocks (A) pelagic fishing gear and species (herring, mackerel, sprat, horse mackerel), (B) demersal fishing gear (bottom trawls, otter trawls, seine nets, drift nets) and species (haddock, whiting, hake, saithe, Norway pout), (C) beam trawls and flatfish (plaice, sole, megrim, halibut), and (D) demersal fishing gear and for cod stocks (Fernandes and Cook, 2013)

In contrast, a similar study performed for the Mediterranean stocks where there are only limited variability in the recent time series of F and E did not show any significant relationship (Cardinale, Osio and Scarcella, 2017).

This issue is further investigated in the ToR 4 of this report.

Another difficulty when relating nominal effort to fishing mortality is that boats with the same capacity exerting the same number of days at sea but using different gears or operating in different grounds are expected to produce quite different effects on the stocks. The impact of each fishing effort measure can be very different in different grounds as catchabiity may show important differences, depending both on the efficiency of the gear but also the availability of the resource in the area.

Many Mediterranean fisheries use bottom trawl nets targeting different species assemblages over areas and seasons. The use of overall effort of the whole fleet can thus be misleading if used directly as an indicator of the fishing pressure exerted on any single stock or fish assemblage, since the fractions of the overall amount of effort which is directed to each target might be quite different. A disaggregation of the fleets by targets makes effort quantification more useful for management purposes as it may explain better any observed change in the stock's status. As such the separation of effort across different metiers within the overall effort by fleet shall be investigated. Data by metier were not analysed during this working group, but additional analyses could be conducted when the combined fleet-metier FDI dataset is available in the second half of 2018.

3.1.13 Nominal and effective fishing effort, skipper effect and technical creep

Part of the difficulty in identifying a meaningful relationship between fishing effort and fishing mortality lies also in the difference between the nominal and the effective fishing effort. As mentioned above, the nominal effort is the measurable quantity of fishing effort in terms of e.g. days/hours at sea or number of nets/pots etc. The effective effort is the unmeasurable quantity defining the actual impact that the this fishing effort truly has on the fish stocks. The effective effort differs from the nominal effort because two equal units of effort (e.g. one fishing day) will have two different impacts, not only between different fleets, metiers and gears, but also between two fishers with the same type of vessel, and between two fishing trips of the same vessel. This difference in effectiveness is included in the concept of "fishing power".

There has been considerable research done in order to improve the quantification of the fishing power and thus of effective fishing effort, in particular in relation with the need to derive true indices in abundance for the assessment of stocks where no fisheries-independent survey data are available, like in the tuna fisheries (Maunder and Punt, 2004). But extensive analyses have also been performed in Europe in relation with the fishing effort regimes. These analyses try to explain some of the variance in the CPUE of individual vessels and trips, by the use of additional measurable and quantifiable variables, and thus reduce the weight of unexplained variability commonly referred to as "skipper effect". For example, (Marchal et al., 2006) suggested measurable indices of spatial diversity within a trip as an indicator of the vessel's searching behaviour and its ability to locate high densities. Similarly, (Rijnsdorp, Daan and Dekker, 2006; Quirijns, Poos and Rijnsdorp, 2008; Tidd, 2013) measured differences in targeting behaviour in the beam trawl flatfish fishery linked to the spatio-temporal distribution of the various stocks, fuel costs and quota availability.

Studies were also conducted to measure the impact of the technical specifications of the gears, though using data usually not available in standard logbooks data. For example, both (Marchal et al., 2007) and (Mahévas et al., 2011) collected through interviews additional information on e.g. gear type, groundrope type, length of net used per day, headline length, crew size, weight of otter board, number of winch or net drums etc. They observed a sometimes very strong explanatory effect of these additional variables on the relationship between fishing effort and fishing mortality, explaining a large part of the "skipper effect". (Marchal et al., 2007) could also relate some of the improvement of fishing power over time to the uptake of groundbreaking electronic technology such as GPS, sonars and computers in the 80s and 90s. The role of technological development is meant to play an important role in changes in fishing power over time, a phenomenon called "technological creep". (Eigaard et al., 2014) estimated this to be around 3% per year in average, while (Damalas, Maravelias and Kavadas, 2014) estimated this to vary by species and be up to 6% per year in the greek waters. (Pauly and Palomares, 2010) noted though that this average creep results most likely from a combination of many years with slow improvements and a few years with rapid increases following the appearance of a new technology (Figure 3.4).

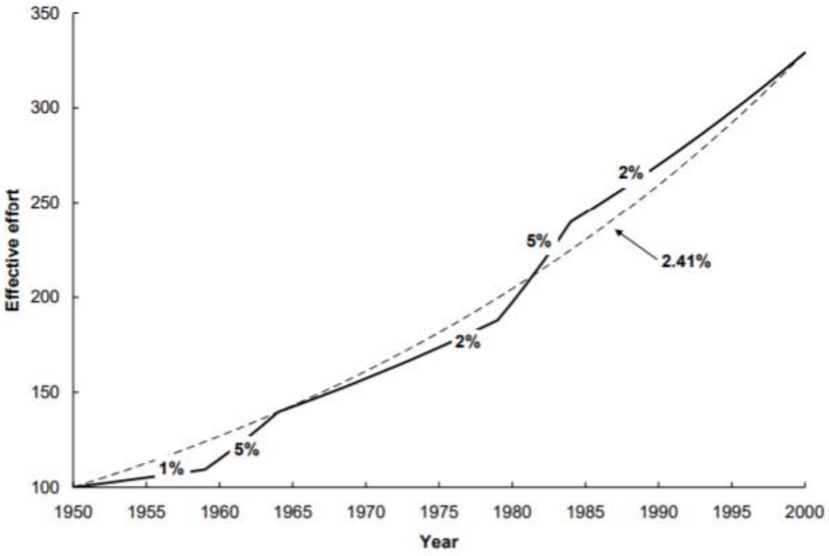


Figure 3.4 simulation of increase in fishing power over a 50 years period consisting of a mixture of background rates (C=1-2%) and rapid increases (5%) due to technological innovation (Pauly and Palomares, 2010).

Both aspects described above (measurable factors affecting the differences between CPUE and technical creep) are investigated further in the context of the Mediterranean Sea in the ToR 3.

3.1.14 Overcapitalisation, input substitution, "capital stuffing" and hyperstability

All the words above refer to the same central concept with fishing effort regime, which is that fishers will naturally tend to look for ways to counteract the effort limitation through additional investment in equipment and increased catchability ("hyperstability") in order to maintain their overall catch level. A typical effect is what is referred to as "input substitution", which is that when some types of inputs are regulated (e.g. number of fishing days, motor horsepower, vessel size, mesh size), then fishers might tweak the non-regulated inputs in order to achieve the same catch efficiency (for example by increasing the numbers of hours fishing per day, the trawling speed, the vessel width or the number of mesh in the trawl circumference etc). Another substitution effect that can be observed, is the tendency for vessels to adapt into the lest regulated categories, even if that can lead to a decrease in fishing efficiency. A common example is what happens with coastal closed areas. Typically, if some areas are closed to large vessels, e.g. vessels above 12m, then a large fleet of vessels with a length of 11.99m will develop. Such effects have been for example observed in the English Channel (Pascoe and Robinson, 1998) and in North Sea Plaice Box (Beare et al., 2013) or in the Australia's banana prawn fishery (Kompas et al., 2004).

In the EU Cod recovery plana, it was also observed that vessels switched from cod-targeting large mesh size trawls to Nephrops-targeting small mesh size trawls, whose effort that was reduced less severely. This had the perverse and unintended consequence of increasing bycatches and discards of small cod. (Kraak *et al.*, 2013).

Effort regimes are thus in fisheries economics generally characterized as inefficient, with an incentive structure leading to overcapitalisation (FAO 2016). Seminal papers, as Squires (1987), Kompas et al. (2004), or Da Rocha et al (2016) in the Mediterranean, show that policies based on input control lead then to a fishery with more fishing firms with lower productivity, and overcapitalization. The source of this overcapacity is based on the existence of imperfect markets: fishers do not have a secured market to insure the risk derived from the variability induced by natural fluctuations and management constraints. They cannot judge what the future will hold so they invest in some kind of insurance to minimize the risks. In this situation, the less productive vessels stay in the fishery as inactive or partly active fleets, just paying the idling costs to wait for better times, which reduces the average productivity of the fleet. The result of input controls, will be that more vessels with reduced efficiency are required to achieve the same biological targets, compared to non-distortionary instruments limiting the catch/landings (i.e ITQs). This all implies an overcapitalized fleet.

This overcapitalisation can be a threat to stock recovery, as there is a risk that when stocks increase after the substantial reduction of the effort of the active fleets, this idle overcapacity can become active again and bring stocks back to their overfishing states, thus jeopardising the benefits expected to the active fleet.

3.1.15 Summary: effort regime vs. TAC regime

The topic of TAC vs. effort management is not new, and has been discussed in many places of the world where the collection of fisheries data is uncertain. FAO held a workshop on that topic in 2012, the proceedings of which provides a very useful summary of the pros and cons of both systems mainly in a right-based context with effort- or catch- based fishing rights allocated to groups of or individual users (Squires, 2016). A number of other synthetic reviews on the topic exist

The workshop found that effort rights-based management might be more effective at managing fishing mortality where uncertainty in catch data and thus in biomass and TAC estimates is more important than uncertainty in the estimates of the catchability coefficient.

However, effort rights-based management creates incentives to maximize revenue and catch, and in the process creates incentives to expand input use and costs (overcapitalisation). Thus, effort management requires continued monitoring and adjustment in the Total Alloawable Effort (TAE) and capacity to counter ongoing increases in fishing power.

Conversely, catch rights-based management generates stronger incentives to reduce effort and costs as well as increase price and, thereby, revenues through improved quality or smoothing out seasonality of production. But catch rights-based management requires monitoring of the population and catches, control of catches, and dealing with catches beyond quotas.

In a narrow economic sense, the workshop concluded that catch rights are superior, but once the costs of research to improve stock assessments and the associated risks of determining the quota and costs of monitoring, control, surveillance, and enforcement are taken into consideration, the choice between the two forms of management becomes more complex and less clear. The results will be case specific.

Because of the pros and cons of both management regimes, hybrid systems of both catch and effort are increasingly employed to manage marine fisheries in order to capture the advantages of both approaches, with one approach forming the dominant management system and the second one serving as a complement to achieve the objectives of the first. In the Mediterranean context, this would imply regulating effort, but keep monitoring that catches decrease accordingly in order to achieve reductions in fishing mortality. If effort decreases but not catches, this would mean that fishers have compensated through increased fishing efficiency.

4 ToR 2: MAIN CHARACTERISTICS OF THE TRAWL FISHING FLEET

This section presents the work done to address the ToR. A key outcome of this work though is that the data set available to STECF was incomplete. The baseline presented here can thus only be considered to be preliminary, and the data will need to be revised by Member States before the baseline can be considered robust.

Data sources

When discussing the best approach to describe 'main demersal fisheries' EWG18 09 discussed the fact that fisheries are driven by economic factors. As such data on landings values as well as weight should ideally be considered. Moreover, experts agreed that to describe fisheries in terms of species and catch composition, data on all species caught is required.

Two data sources were available to experts during EWG18 09:

- DCF Mediterranean data call with effort data (2017)
- STECF data call for economic and transversal data (2017)

Both data sources have inherent limitations. Whilst the DCF Mediterranean data call contains information on fisheries at metier level, it does not contain data on landing weight and landings value. The STECF data call for economic and transversal data from 2002 to 2008 were collected at supra region level, that is aggregating values from GSA1-2-5-6-7-8-9-10-11, and landings data from some GSA were not reported at metier level. The experts therefore decided to retrieve the information from the economic and transversal dataset, but restricted to the period 2008-2016.

An exploratory analysis revealed several problems with the data submitted by Member States in response to the economic and transversal data call (Figure 4.1).

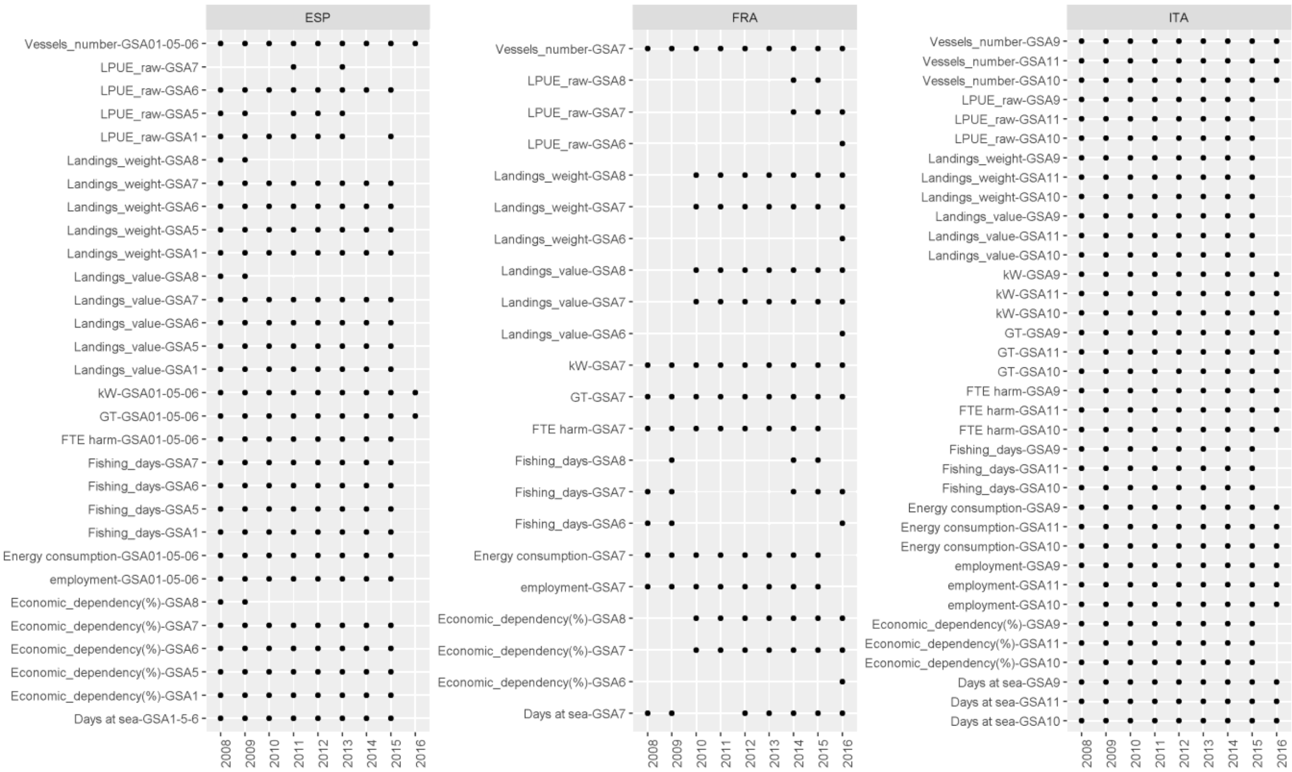


Figure 4.1: Results of preliminary analysis of the datasets used. The three plots show the distribution of information required to address TOR 2 across Member State along the period considered (2008-2016).

The information contained in both datasets showed limitations that, beside the lack of data, are mainly related to: i) different levels of aggregation and/or ii) low accuracy in the definition of the areas or of the fishery from which the data come from. The most important problems found in the considered dataset are:

- All economic variables reported in the economic and transversal data call for GSA1-5-6 are aggregated together. The EWG decided to also aggregate effort and landings to provide a description of bottom trawl fisheries of these areas. Furthermore, lack of specification of landings by gear make it impossible to distinguish landings coming from bottom trawlers from other gears categorised to the same fishing technique. This is because landings data for these areas refer only to gear type "Not Known" (NK). In addition, it was impossible to estimate the LPUEs for species landed by bottom trawling fisheries in these areas.
- Data on fleet capacity, employment and energy consumption are not available for GSA8
- Effort data in GSA 7-8 are not available for the years 2010-2013 making estimation of a complete time series for LPUEs impossible.
- Data on net profit are only available at country level for the entire Mediterranean area. For Spain and France all data can be allocated to the Western Med, but not for Italy where data are mixed between several Mediterranean regions. Therefore, data for Italy for a sub-set of the areas fished by the national fleet (GSA9-1-11) are not available.

The proposed effort management regime has two geographical units, each consisting of several GSAs. Data from GSA1-5-6-7 were flagged as "western" while those from GSA8-9-10-11 as "eastern". Under the proposed effort scheme the DCF vessel length categories VL0006, VL0010 and VL0612 are merged into a category VL0012, while the other segments considered are the standard DCF categories VL1218, VL1824 and VL2440.

Since effort 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[7]. Bottom trawling gears (OTB, OTT, PTB, TBB) were flagged as "BOTTOM_TRAWLERS", while all other gears as "OTHERS"; in *Table 4.1* the gears belonging to these two categories are listed by country. Taking in account the problem regarding landing data from GSA 1-5-6 described above, when possible the same approach used to differentiate effort from different gears was used also for landings data. Considering only the bottom trawl gears, the total number of species landed are 271. The EWG 18 09 decided to distinguish landings data of the target species (MUT, HKE, DPS, NEP, ARA, ARS), that is those defining bottom trawling fisheries in the Western Mediterranean, from the other species landed by these fisheries. Landings weight, landings value and LPUE of the target species were reported at species levels, while all other species (a total number of 265) were aggregate using the code "other". For GSA1-5-6 the inability to join landings and effort by gear type, made it impossible to estimate LPUE for the bottom trawling fisheries in the GSAs of the western management unit. *Figure 4.2* show results from the explorative analysis and illustrates the differences in availability of data and the aggregation level of landings and effort data.

EWG18 09 decided to restrict the analysis to the years 2013 and 2015 to identify the most important features of the fisheries subject to effort regime controls because landings data for all MS was only available for these years. Baseline information regarding the demersal fishery were provided as mean values of the considered variable during this period.

[7] Because of a dominance criterion used in defining fishing technique, non-trawl gear effort and landings can be recorded under the DTS fishing technique code.

Table 4.1: list of fishing gear present in the effort data

Country	Fishing_technic	Gear	Fishing_technic	Gear	Country	Fishing_technic	Gear	Fishing_technic	Gear	Country	Fishing_technic	Gear	Fishing_technic	Gear
ESP	BOTTOM_TRAWLERS	OTB	OTHERS	DRB	FRA	BOTTOM_TRAWLERS	OTB	OTHERS	NK	ITA	BOTTOM_TRAWLERS	OTB	OTHERS	GTR
ESP	BOTTOM_TRAWLERS	PTB	OTHERS	FPO	FRA	BOTTOM_TRAWLERS	OTT	OTHERS	OTM	ITA			OTHERS	LLS
ESP	BOTTOM_TRAWLERS	OTT	OTHERS	GNS	FRA			OTHERS	GTR	ITA			OTHERS	LLD
ESP	BOTTOM_TRAWLERS	TBB	OTHERS	GTR	FRA			OTHERS	LHP	ITA			OTHERS	SB
ESP			OTHERS	LLD	FRA			OTHERS	LTL	ITA			OTHERS	GNS
ESP			OTHERS	LLS						ITA			OTHERS	PS
ESP			OTHERS	MIS						ITA			OTHERS	NO
ESP			OTHERS	NK						ITA			OTHERS	OTM
ESP			OTHERS	NO										
ESP			OTHERS	OTM										
ESP			OTHERS	PS										
ESP			OTHERS	DRH										
ESP			OTHERS	LHP										
ESP			OTHERS	SV										
ESP			OTHERS	FYK										
ESP			OTHERS	GTN										
ESP			OTHERS	LTL										
ESP			OTHERS	GND										
ESP			OTHERS	GNC										

Figure 4.2: Abundance of records in Landings and Effort dataset by gear and fleet segment in the MS involved in the effort regime control.

Final dataset used by EWG 18-09

When discussing the best approach to constructing the baseline data set required to describe demersal fisheries in the western Mediterranean, the EWG decided to provide the required variables at the most disaggregate level possible, using a codification that allows data to be aggregated to the level required by the effort regime.

Because of the differences in aggregation levels and lack of specification in the dataset analysed, the number of records contained in the final dataset were different across the variables considered. In each table, the records represent the combination of country, management unit, GSA, year, fishing technique and gear (when it was available).

The following table were created to store the information required:

- **Vessels_number**. number of active vessels at fishing technique level. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS) and Year.
- **GT**. Gross tonnage of the active vessels. Records are a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS) and Year.
- **Kw**. Engine power of active vessels. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS) and Year.
- **Fishing_days**. Number of fishing days. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear and Year.
- **Days_at_sea**. Number of fishing days at sea. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear and Year.
- **Encons**. Total energy consumption (Litres). Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear, Species and Year.
- **Employ**. Total number of employees and the correspondence in fulltime equivalent. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear, Species and Year.
- **Landing_weight**: Total weight (Kg) of each species landed. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear, Species and Year.
- **Landing_value**. Total value (€) of each species landed. Records are a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear, Species and Year.
- **LPUE**. The ratio between total landings weight and total effort of each species landed. Value used for the estimation of LPUE are obtained from tables **Landing_weight** and **Effort** for a total of 1073 records. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear, Species and Year. This table consider all records that have matching values in in Landings_weight and Effort
- **LPUE_raw**. The ratio between Total landings weight and effort of each species landed. Value used for the estimation of LPUE are obtained from a combination of left and right joins between table **Landing_weight** and **Landing_value** for a total of 2011 records. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear, Species and Year. This table considers all records present in both tables, that is also those records present in one table only and do not have a matching in the other.
- **Economic_dependency(%)_gsa**. The ratio between the value of each species and the total value of landings. Each record is a combination of Management unit, Country, Area (GSA), Fishing technique, Fleet segment (FLS), Gear, Species and Year.
- **Economic_dependency(%)_ManUnit**. The ratio between the value of each species and the total value of landings obtained from the aggregation of landings value by GSAs of the same management unit (Western/Eastern). Each record is a combination of Management unit, Country, Fishing technique, Fleet segment (FLS), Gear, Species and Year.

- **Income_Costs**. All variables required to estimate total incomes and total expenditures. Each record is a combination of Country, Fleet segment (FLS) and Year.

Description of demersal fisheries in the western Mediterranean by GSA (Average 2013-2015)

The description below is based on the current dataset used by EWG 18-09. It would need to be updated when the gaps and inconsistencies flagged in section 0 are addressed.

4.1.1 GSA 1-5-6

According to the most recent available data, Table 2 reports the main features of trawl fisheries in these areas. In the period 2013-2015, 644 vessels, on average, were involved in demersal fisheries in these areas. This fleet was mostly composed by the segments VL1824 (50%), followed by VL1218 and VL2440, while VL0012 was present with a low number of vessels.

Landings in GSA1-5-6 are obtained selecting only gears belonging to the DTS fishing technique. Since landing data for GSA1-5-6 are reported without the specification of the gear but with the code that correspond to "not known" gear it was not possible to exclude landings from non-trawl gear included under the DTS code. Taking in account this problem and considering only the 6 target species, the most landed species is *Merluccius merluccius* (HKE), followed by *Mullus barbatus* (MUT), *Aristeus antennatus* (ARA), *Parapenaeus longirostris* (DPS), *Nephrops norvegicus* (NEP) and *Aristaeomorpha foliaceae* (ARS) (*Figure 4.3*A). Considering the total value of landings, the most valuable species is *Aristeus antennatus* (ARA), followed by *Merluccius merluccius* (HKE), *Parapenaeus longirostris* (DPS), *Nephrops norvegicus* (NEP), *Mullus barbatus* (MUT) and *Aristaeomorpha foliaceae* (ARS) (*Figure 4.3*B). In the considered period (2013-2015), target species represent 36.7% of total landings value overall; by length category 49.6% and 57.3% of total landing value of VL1218 and VL1824 respectively, and 65% of total landings value of VL2440 (*Figure 4.3*C).

Table 4.2: Main features of trawl fisheries in GSA1-5-6. The values reported represent the average values during the period 2013-2015

Country		**Spain**			
Fleet segment		**VL0012**	**VL1218**	**VL1824**	**VL2440**
Number of active vessels	(#)	21	158	322	143
Vessel tonnage	(thousand GT)	0.17	3.97	19.66	14.11
Engine power	(thousand kW)	0.76	12.07	59.70	45.34
Employed	(person)	50.75	574.58	1261.16	702.76
FTE	(#)	42.80	529.37	1166.85	645.84
Effort	(fishing days)	1679.67	22220.00	44343.67	21734.00
Landing weight	(tonne)	303.42	3704.56	10177.30	5643.38
Landing value	(million €)	1.18	15.91	62.83	36.51
Energy consumption	(thousand litre)	508.88	11414.40	44842.59	29231.56
Consumption per day	(litre/day at sea)	144.01	383.45	687.54	985.60

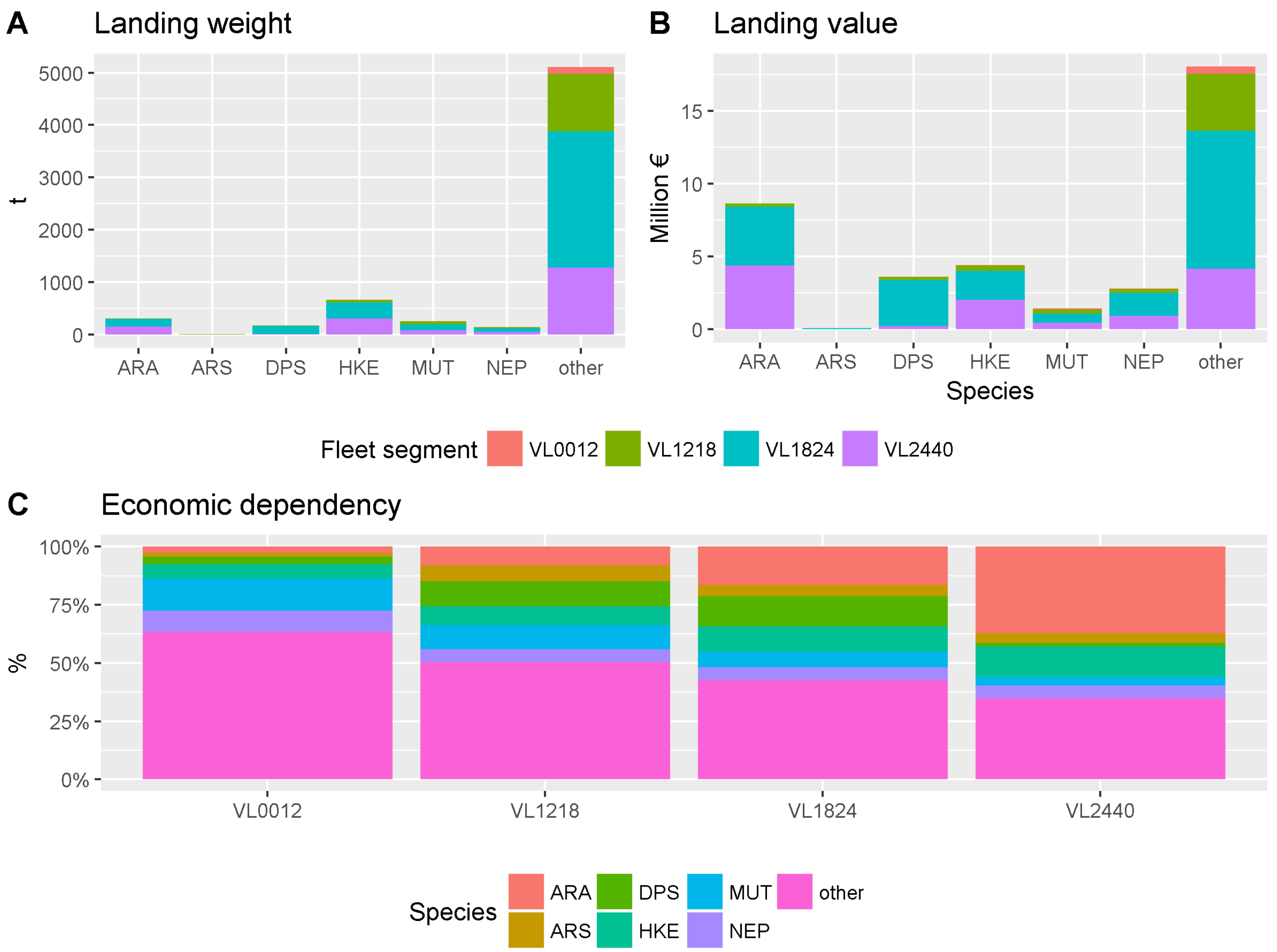


Figure 4.3: A) Mean landing weight by species during the 2013-2015. B) Total landings value by species during the period 2013-2015. C) Economic dependency of demersal fishery by species. The category "other" represent the mean value of the total landings of all other species excluding the 6 target species.

4.1.2 GSA 07

According to the most recent available data, Table 3 reports the main features of trawl fisheries in GSA07. This area is exploited by two national fleets (Spain and France). However, except for effort and landings, Spanish data regarding all economic variables are not available. In the period 2013-2015, 61 vessels from the French fleet, on average, were involved in demersal fisheries in this area. This fleet was mostly composed by the segments VL1824 and VL2440 that together account for more than 90% of the vessels, while there were few vessels from the VL0012 and VL1218 categories.

Considering the target species, the most landed species is *Merluccius merluccius* (HKE) while *Mullus barbatus* (MUT), *Parapenaeus longirostris* (DPS) and *Nephrops norvegicus* (NEP) represent, on average, a very low portion of the total landings weight. *Aristeus antennatus* (ARA) and Aristaeomorpha foliaceae (ARS) are completely absent from landings (*Figure 4.4*A). Reflecting the pattern of landings weight, the most valuable species is *Merluccius merluccius* (HKE) while the economic value of other target species are negligible (*Figure 4.4*B). In the considered period (2013-2015), target species represent 3% of total landings value in vessel length segment VL0012, about 99% and 20% of total landing value of VL1218 and VL1824 respectively, and 24% of total landing value of VL2440 (*Figure 4.4*C).

For all species, it is possible to observe a positive relationship between size of vessels (fleet segment) and LPUEs (*Figure 4.5*).

Table 4.3: Main features of trawl fisheries in GSA07. The values reported represent the average values during the period 2013-2015 excepting landings weight and landing value, which are reported as an average value for the period 2014-2015

Country		**Spain**			**France**			
Fleet segment		**VL1218**	**VL1824**	**VL2440**	**VL0012**	**VL1218**	**VL1824**	**VL2440**
Number of active vessels	(#)	-	-	-	2	4	26	29
Vessel tonnage	(thousand GT)	-	-	-	0.02	0.10	1.70	3.52
Engine power	(thousand kW)	-	-	-	0.15	0.89	8.09	9.26
Employed	(person)	-	-	-	-	-	97.12	139.06
FTE	(#)	-	-	-	-	-	64.10	110.48
Effort	(fishing days)	90.50	1167.00	1420.33	57.00	-	4229.37	5575.27
Landing weight	(tonne)	10.75	251.38	311.62	13.63	0.08	1782.64	2087.75
Landing value	(million €)	0.05	1.62	2.87	0.07	0.00	6.82	7.37
Energy consumption	(thousand litre)	-	-	-	44.04	-	5466.38	10081.26
Consumption per day	(litre/day at sea)	-	-	-	281.41	-	1245.47	1780.35

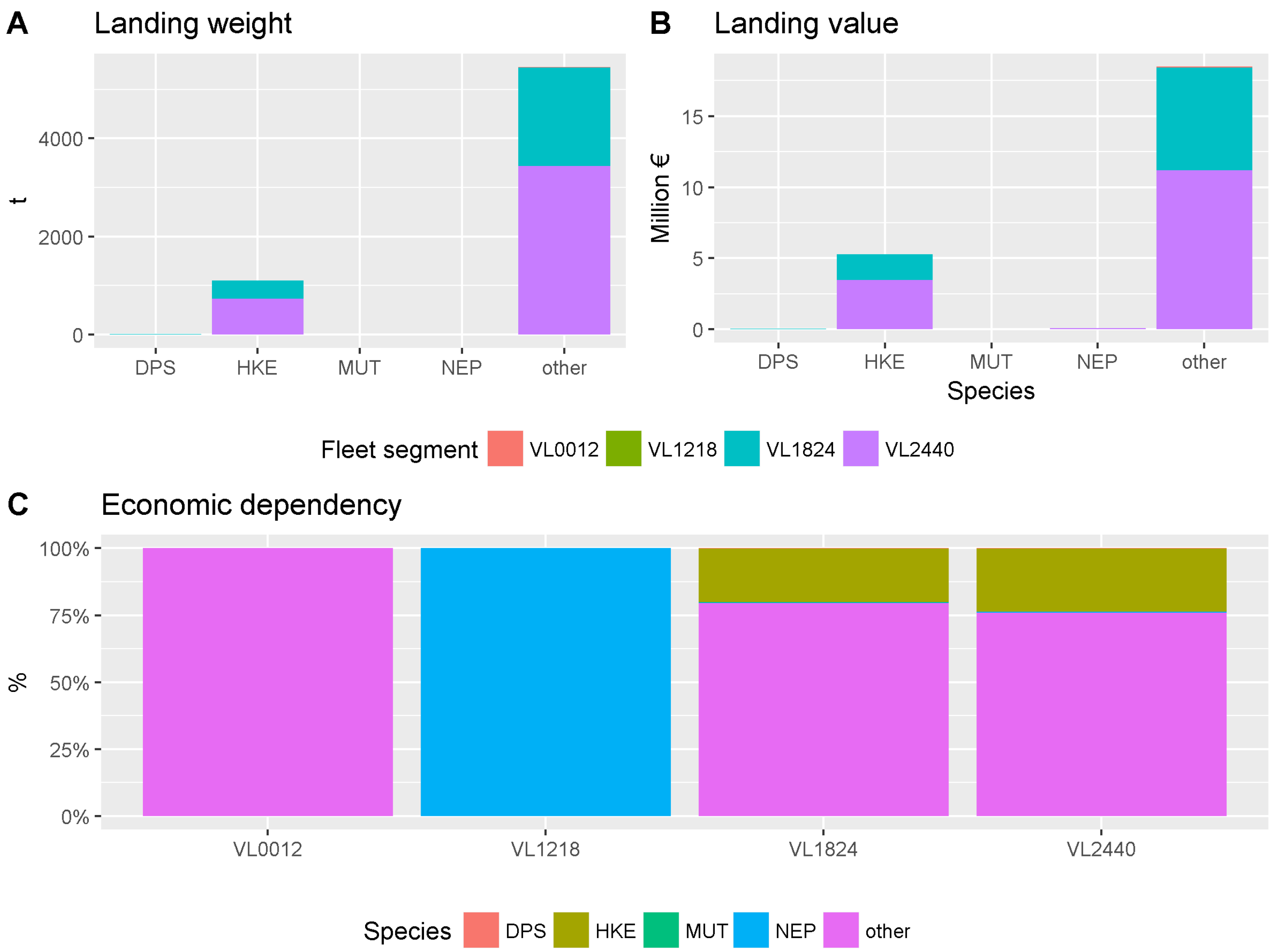


Figure 4.4: A) Species average landing weight across fleet segments. B) Mean landings value of species across fleet segments. C) Economic dependency of fleet segment by species estimated on average landings value. All variables represent average values during the period 2014-2015. The category "other" represents the mean value of the total landings of all species excluding the 6 target species.

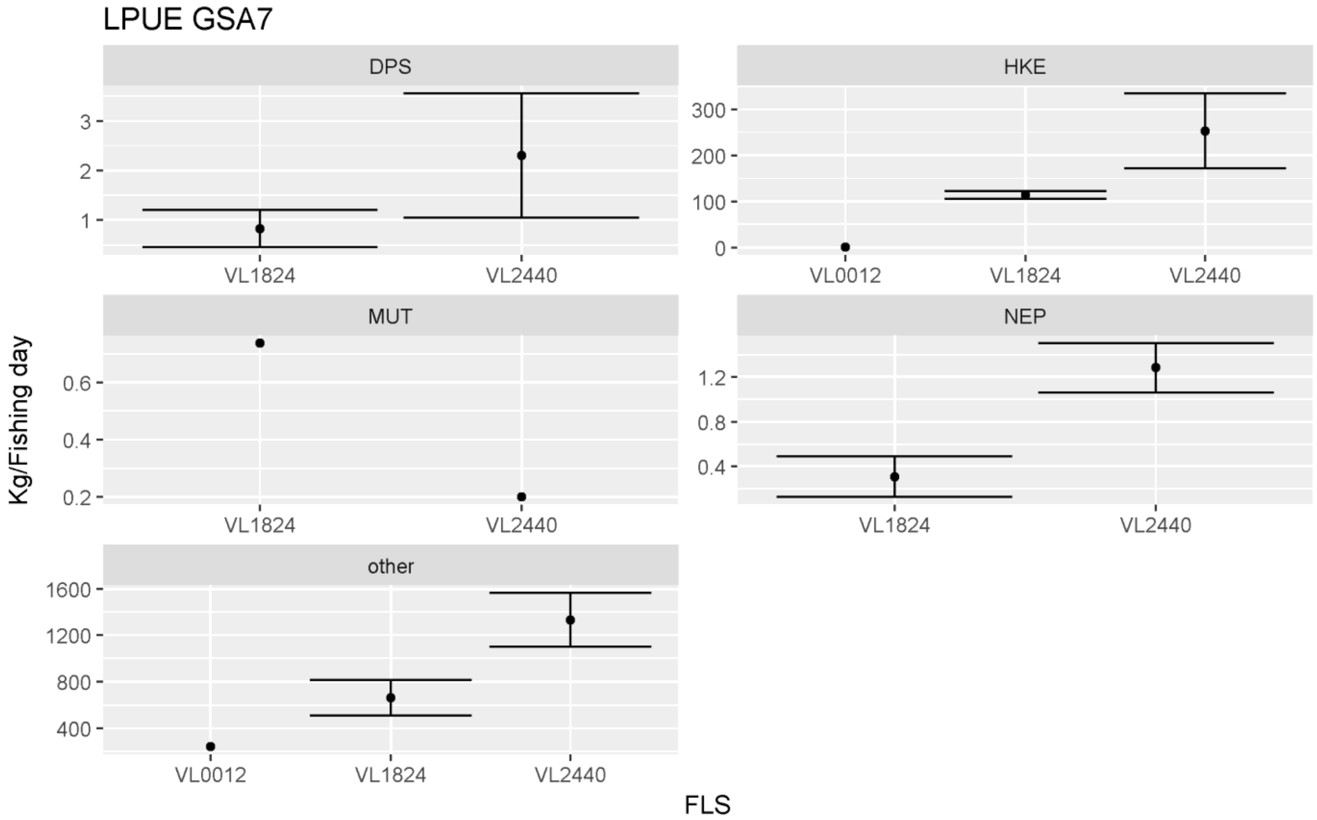


Figure 4.5. Average LPUE of GSA7 with error bar representing standard error, estimated by species across fleet segment for the period 2014-2015. Single points indicate that LPUEs refer to only one observation

4.1.3 GSA 08

The main features of demersal fisheries present in GSA08 are not available in the dataset used in EWG18 09. Table 4.4 reports only effort and landings data for the period available. Landings are available from 2012, while effort data only for the period 2014-2015.

Considering the limitation of data coming from this area, *Nephrops norvegicus* (NEP) is the most landed species in terms of total weight, among the target species, followed by *Parapenaeus longirostris* (DPS) and *Murluccius merluccius* (HKE). *Mullus barbatus* (MUT), *Aristeus antennatus* (ARA) and *Aristaeomorpha foliaceae* (ARS) are completely absent from landings for the period considered (2014-2015) (Figure 4.6A). Consistent with total landing weight, *Nephrops norvegicus* (NEP) is also the most valuable species in terms of landings value, followed by *Parapenaeus longirostris* (DPS) and *Murluccius merluccius* (HKE) (Figure 4.6B). In the considered period (2013-2015), target species represent 82% of total landings value of VL0012, they represent about 60% and 61% of total landing value of VL1218 and VL1824 respectively, and 40% of total landing value of VL2440 (Figure 4.6C).

Figure 4.7 reports the mean value of LPUE of the target species of bottom trawl fishery in GSA08. The mean LPUE of *Murluccius merluccius* (HKE) shows a positive relationship with vessels size (fleet segment). *Parapenaeus longirostris* (DPS) shows a peak in LPUE for fleet segment VL1824. A peak in LPUE for fleet segment VL1824 is also shown for *Nephrops norvegicus* (NEP). This species has low LPUE in fleet segment VL1218 and similar intermediate values for VL0012 and VL2440.

Table 4.4: Main features of trawl fisheries in GSA08. The values reported represent the average values during the period 2013-2015 excepting landings weight and landing value, which are reported as an average value for the period 2014-2015

Country		**France**			
Fleet segment		**VL0012**	**VL1218**	**VL1824**	**VL2440**
Number of active vessels	(#)	-	-	-	-
Vessel tonnage	(thousand GT)	-	-	-	-
Engine power	(thousand kW)	-	-	-	-
Employed	(person)	-	-	-	-
FTE	(#)	-	-	-	-
Effort	(fishing days)	85.00	264.92	11.00	151.67
Landing weight	(tonne)	8.24	35.64	4.50	33.01
Landing value	(million €)	0.12	0.32	0.04	0.21
Energy consumption	(thousand litre)	-	-	-	-
Consumption per day	(litre/day at sea)	-	-	-	-

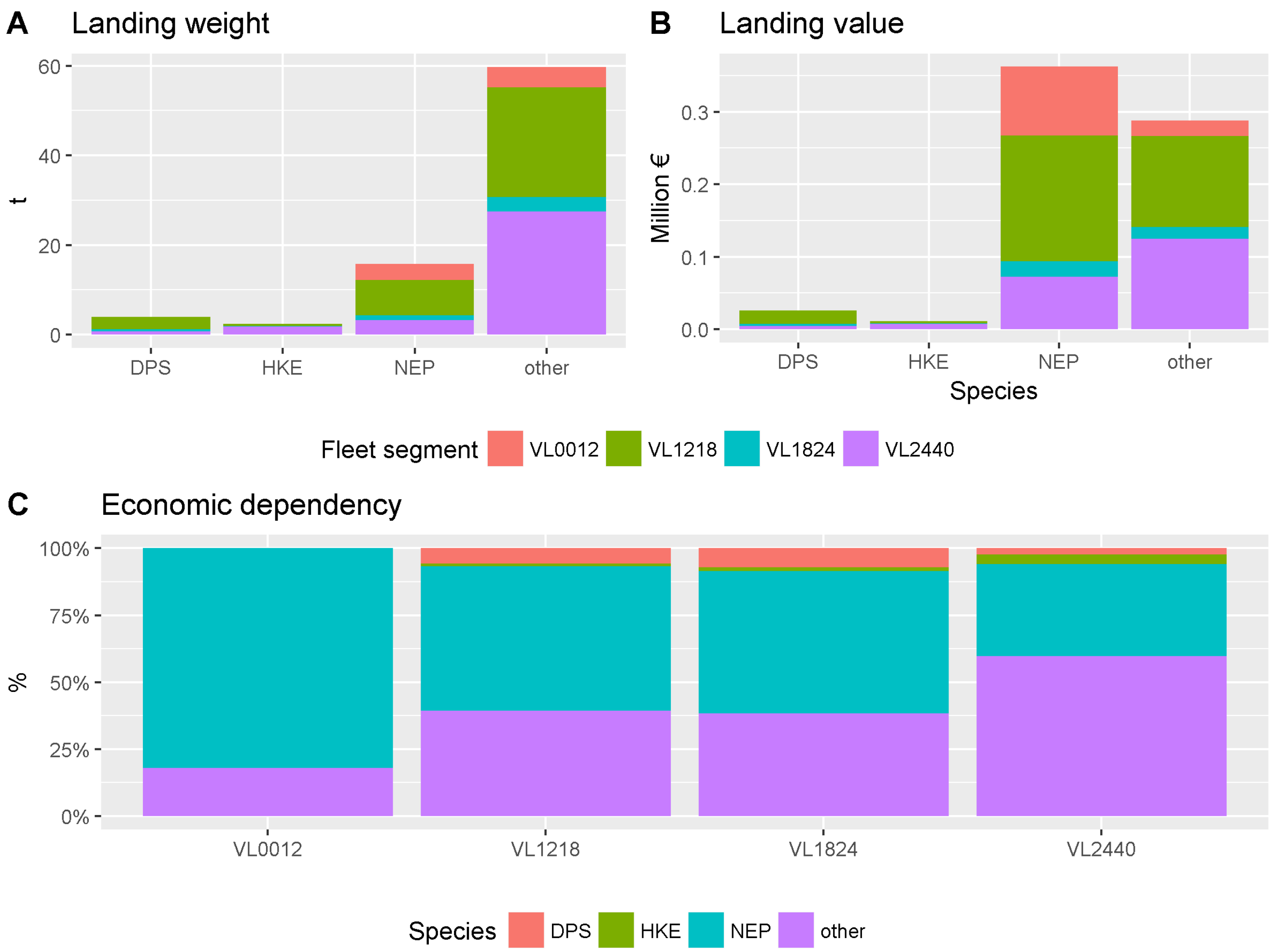


Figure 4.6: A) Species average landing weight across fleet segments. B) Mean landings value of species across fleet segments. C) Economic dependency of fleet segments by species estimated on average landings value. All variables represent average values during the period 2014-2015. The category "other" represents the mean value of the total landings of all species excluding the 6 target species.

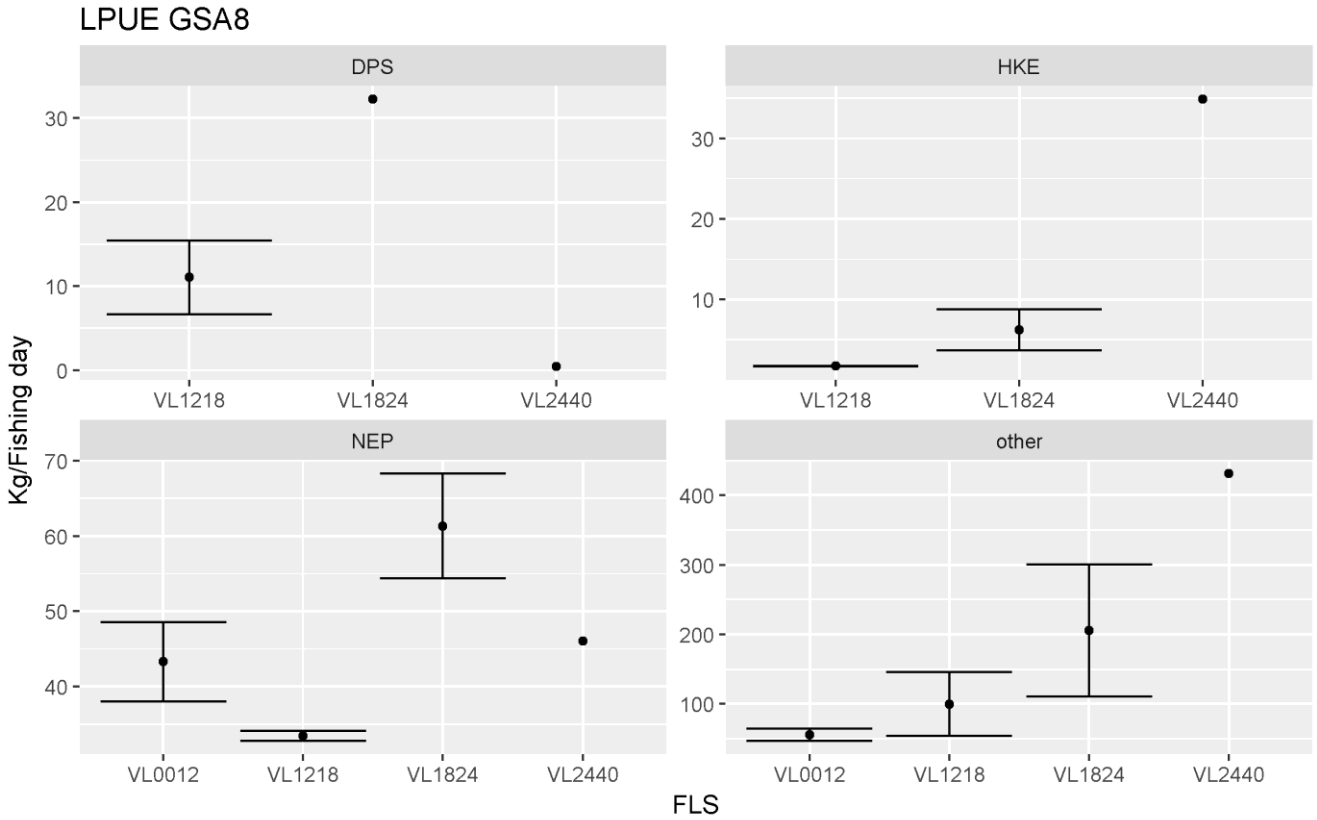


Figure 4.7: Average LPUE of GSA8 with error bar representing standard error, estimated by species across fleet segment for the period 2014-2015. Single points indicate that LPUEs refer to only one observation

4.1.4 GSA 09

According to the most recent available data, Table 4.5 reports the main features of trawl fisheries in these areas. In the period 2013-2015, 283 vessels, on average, were involved in demersal fisheries in these areas. This fleet was mostly composed of the segments VL1218 (50%) and VL1824 which together account for more than 87% of vessels. The number of vessels belonging to VL0012 are greater than those belonging to VL2440.

Considering the target species, the most landed species are *Murluccius merluccius* (HKE)*, Mullus barbatus* (MUT) and *Parapenaeus longirostris* (DPS) followed by *Nephrops norvegicus* (NEP), *Aristeus antennatus* (ARA) and *Aristaeomorpha foliaceae* (ARS) (Figure 4.8A). The economic values of target species follow the pattern of landings weight (Figure 4.8B). In the considered period (2013-2015), target species represent 13% of total landings value of VL0012, they represent about 44% and 41% of total landing value of VL1218 and VL1824 respectively, and 61% of total landing value of VL2440 (Figure 4.8C).

Average LPUEs of target species showed a positive relationship with vessels size expect for *Aristeus antennatus* (ARA) for which LPUE are greater in VL1218 and VL2440 than VL1824 (Figure 4.9).

Table 4.5: Main features of trawl fisheries in GSA09. The values reported represent the average values during the period 2013-2015

Country		**Italy**			
Fleet segment		**VL0012**	**VL1218**	**VL1824**	**VL2440**
Number of active vessels	(#)	24	130	119	10
Vessel tonnage	(thousand GT)	0.13	2.74	6.51	0.87
Engine power	(thousand kW)	1.75	20.14	33.12	4.71
Employed	(person)	46.52	356.62	377.27	33.11
FTE	(#)	35.06	318.83	340.60	30.44
Effort	(fishing days)	2091.00	23101.54	23541.57	1889.95
Landing weight	(tonne)	124.84	2738.43	4343.23	261.81
Landing value	(million €)	1.30	23.25	32.51	2.54
Energy consumption	(thousand litre)	578.18	11127.48	18613.79	1784.27
Consumption per day	(litre/day at sea)	242.46	479.46	788.36	942.84

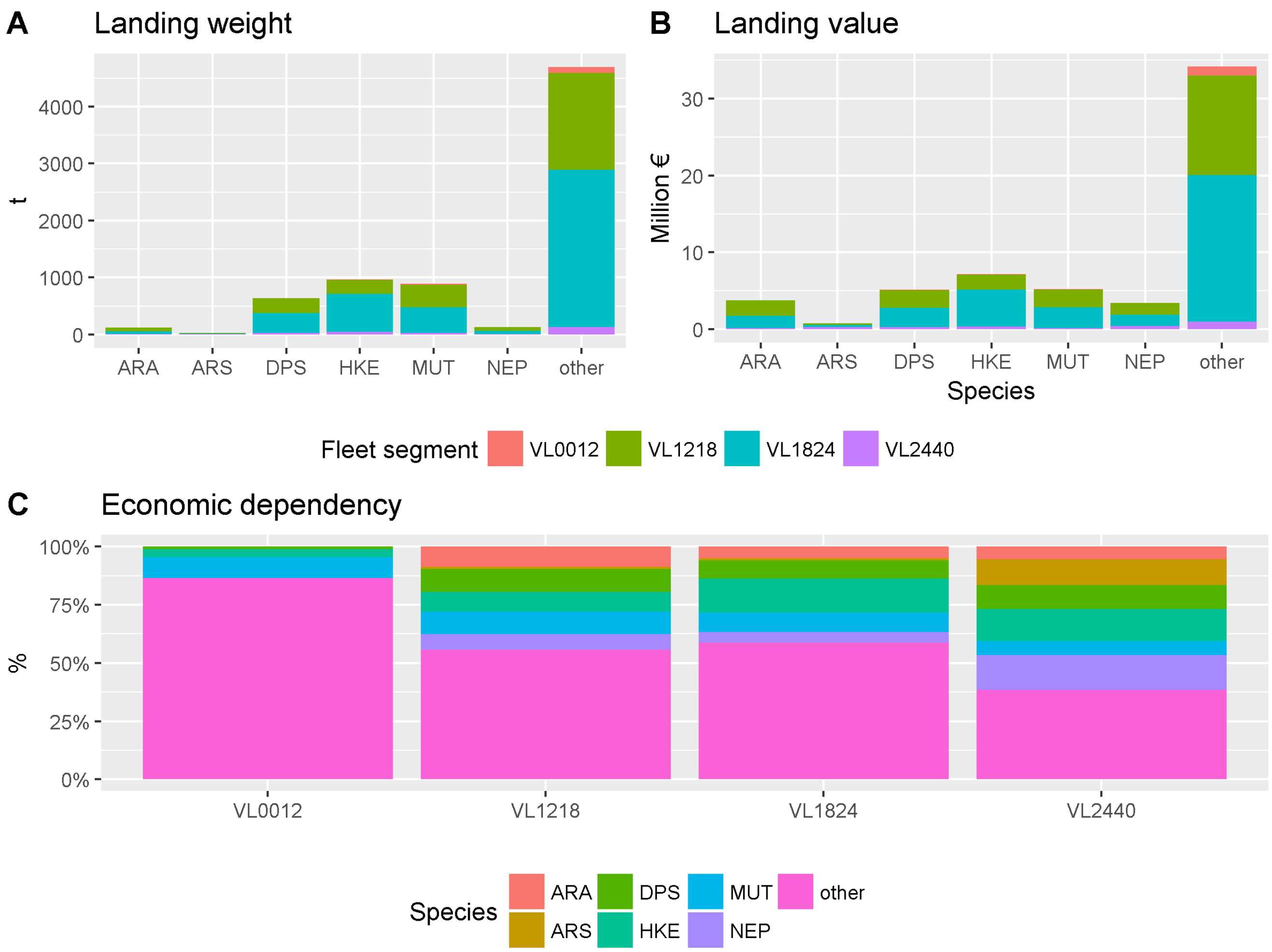


Figure 4.8: A) Species average landing weight across fleet segments. B) Mean landings value of species across fleet segments. C) Economic dependency of fleet segments by species estimated on average landings value. All variables represent average values during the period 2013-2015. The category "other" represents the mean value of the total landings of all species excluding the 6 target species.

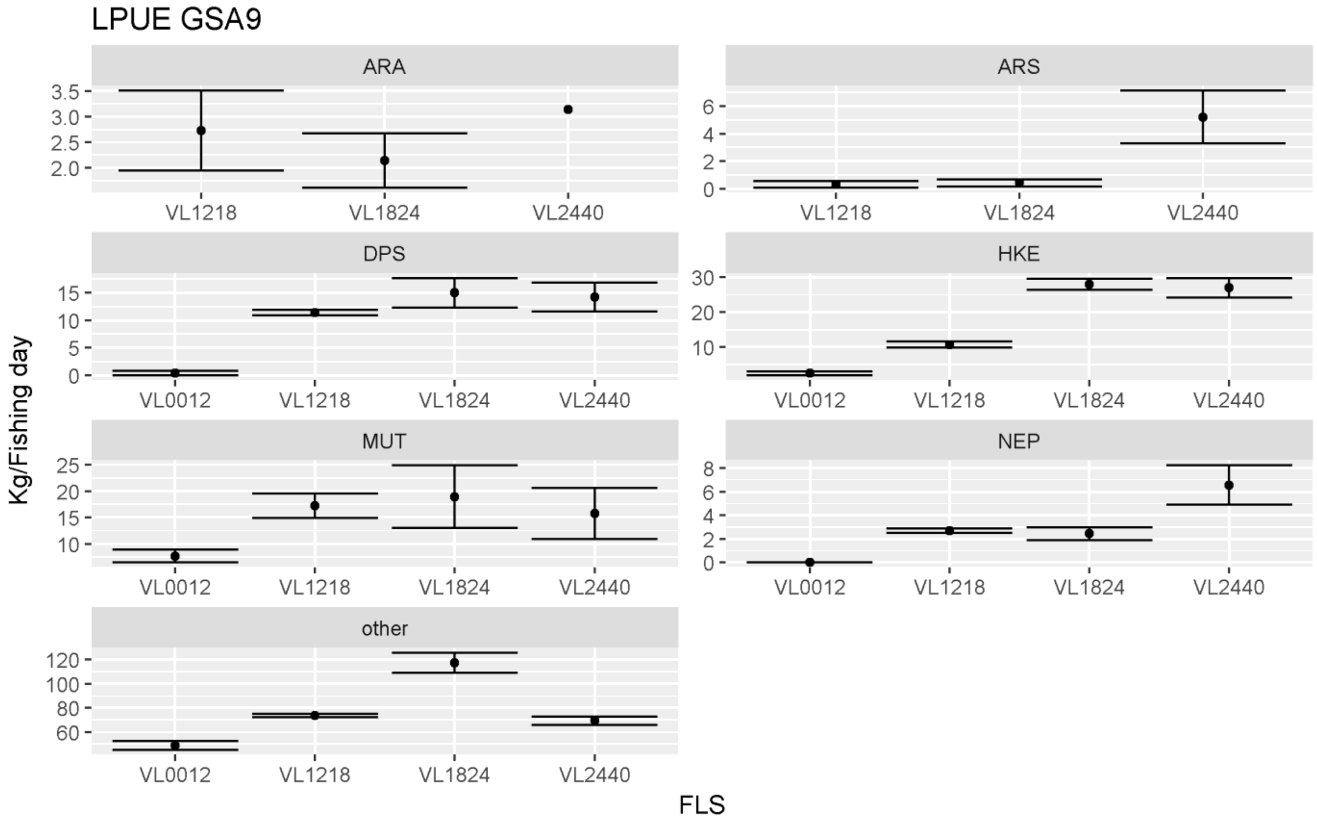


Figure 4.9: Average LPUE of GSA9 with error bar representing standard error, estimated by species across fleet segment for the period 2013-2015. Single points indicate that LPUEs refer to only one observation

4.1.5 GSA 10

Table 4.6 reports the main features of trawl fisheries in GSA10. In the period 2013-2015, 236 vessels, on average, were involved in demersal fisheries in these areas. This fleet was mostly composed by the segments VL1218 (60%) and VL1824 (35%). The number of vessels belonging to VL0012 are low and vessels belonging to VL2440 are absent.

Considering the mean total landings weight in the period 2013-2015, the most landed species is *Parapenaeus longirostris* (DPS) followed by *Mullus barbatus* (MUT), *Aristaeomorpha foliaceae* (ARS) and *Murluccius merluccius* (HKE); *Nephrops norvegicus* (NEP) and *Aristeus antennatus* (ARA) represent a small portion of total landings weight (Figure 4.10A). Considering the mean economic values of species, the most valuable species is *Aristaeomorpha foliaceae* (ARS), followed by *Parapenaeus longirostris* (DPS), *Murluccius merluccius* (HKE) and *Mullus barbatus* (MUT) (Figure 4.10B). In the considered period (2013-2015), target species represent 39% of total landings value of VL0012, they represent about 50% and 52% of total landing value of VL1218 and VL1824 respectively (Figure 4.10C).

Average LPUEs of target species showed a positive relationship with vessels size expect for *Mullus barbatus* (MUT) for which LPUE is reduced for VL1824 (Figure 4.11).

Table 4.6: Main features of trawl fisheries in GSA10. The values reported represent the average values during the period 2013-2015

Country		**Italy**		
Fleet segment		**VL0012**	**VL1218**	**VL1824**
Number of active vessels	(#)	10	143	83
Vessel tonnage	(thousand GT)	0.04	2.50	5.13
Engine power	(thousand kW)	0.54	19.13	22.42
Employed	(person)	21.17	388.93	317.69
FTE	(#)	14.13	307.21	267.23
Effort	(fishing days)	943.67	20544.33	12862.48
Landing weight	(tonne)	59.24	1730.70	2222.61
Landing value	(million €)	0.33	11.19	16.99
Energy consumption	(thousand litre)	148.68	7609.52	9123.85
Consumption per day	(litre/day at sea)	111.34	343.31	689.67

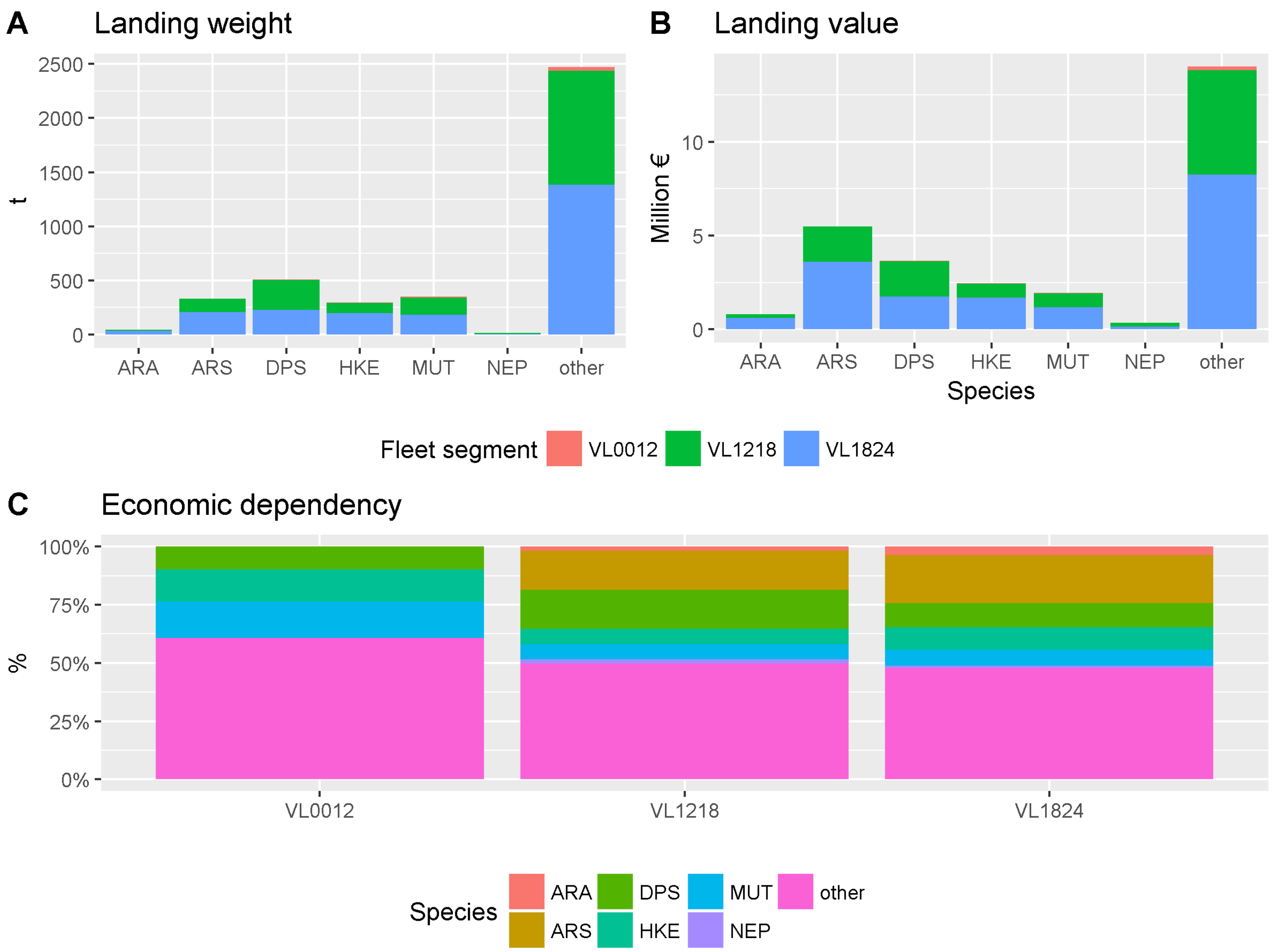


Figure 4.10: A) Species average landing weight across fleet segments. B) Mean landings value of species across fleet segments. C) Economic dependency of fleet segments by species estimated on average landings value. All variables represent average values during the period 2013-2015. The category "other" represents the mean value of the total landings of all species excluding the 6 target species.

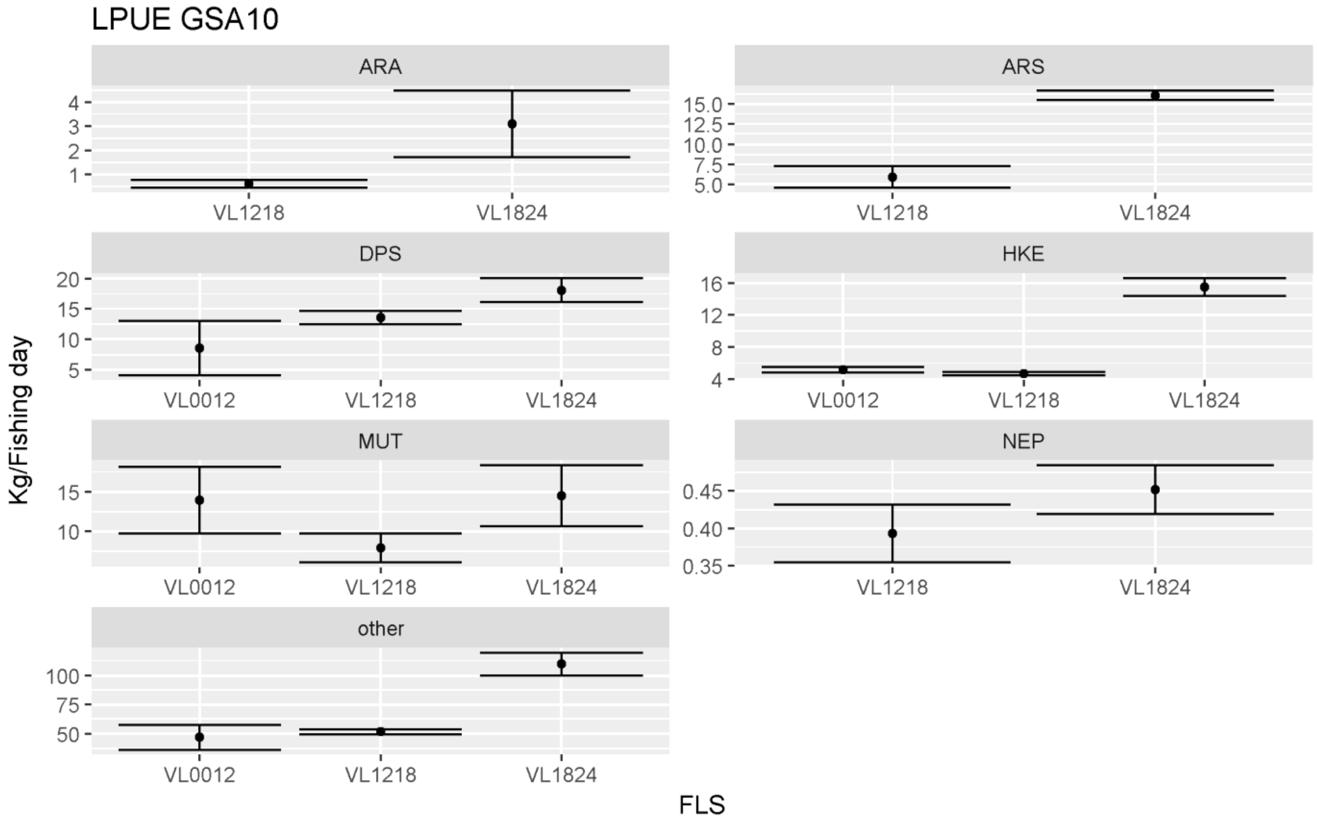


Figure 4.11: Average LPUE of GSA10 with error bar representing standard error estimated by species across fleet segment for the period 2013-2015. Single points indicate that LPUEs refer to only one observation

4.1.6 GSA 11

According to the most recent available data, Table 4.7 reports the main features of trawl fisheries in GSA11. In the period 2013-2015, 122 vessels, on average, were involved in demersal fisheries in this area. This fleet was mostly composed by the segments VL1218 (57%); VL1824 and VL2440 account for 26% and 17% respectively, while VL0012 is absent.

Considering the mean total landings weight in the period 2013-2015, the most landed species are *Merluccius merluccius* (HKE) and *Mullus barbatus* (MUT) followed by *Aristaeomorpha foliaceae* (ARS) and *Aristeus antennatus* (ARA); *Parapenaeus longirostris* (DPS) and *Nephrops norvegicus* (NEP) represent a small portion of total landings weight (Figure 4.12A). Considering the mean total landings value, the most valuable species are *Aristaeomorpha foliaceae* (ARS) and *Aristeus antennatus* (ARA), followed by *Merluccius merluccius* (HKE) and *Mullus barbatus* (MUT) (Figure 4.12B). In the considered period (2013-2015), target species represent 35% of total landings value of VL1218, they represent about 27% of total landing value of VL1824 and 63% of total landing value of VL2440 (Figure 4.12C).

Table 4.7: Main features of trawl fisheries in GSA11. The values reported represent the average values during the period 2013-2015

Country		**Italy**		
Fleet segment		**VL1218**	**VL1824**	**VL2440**
Number of active vessels	(#)	70	32	21
Vessel tonnage	(thousand GT)	1.06	1.91	3.04
Engine power	(thousand kW)	8.81	8.53	8.76
Employed	(person)	182.11	128.48	99.63
FTE	(#)	154.49	105.92	88.10
Effort	(fishing days)	7904.39	3857.05	3016.34
Landing weight	(tonne)	898.04	775.21	634.36
Landing value	(million €)	5.63	5.60	5.90
Energy consumption	(thousand litre)	2456.23	2244.78	3479.96
Consumption per day	(litre/day at sea)	266.80	559.16	1148.29

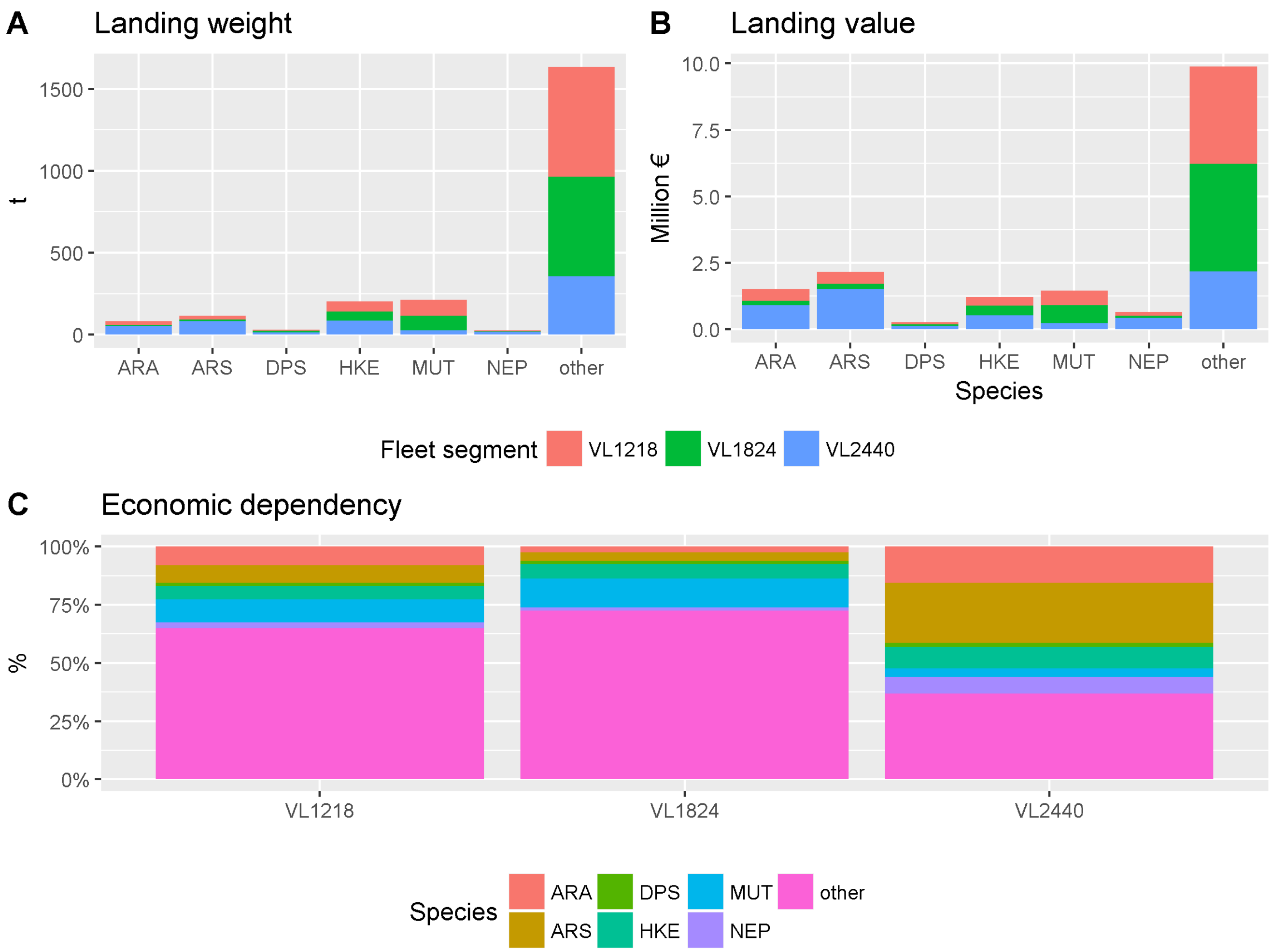


Figure 4.12: A) Species average landing weight across fleet segments. B) Mean landings value of species across fleet segments. C) Economic dependency of fleet segments by species estimated on average landings value. All variables represent average values during the period 2013-2015. The category "other" represents the mean value of the total landings of all species excluding the 6 target species.

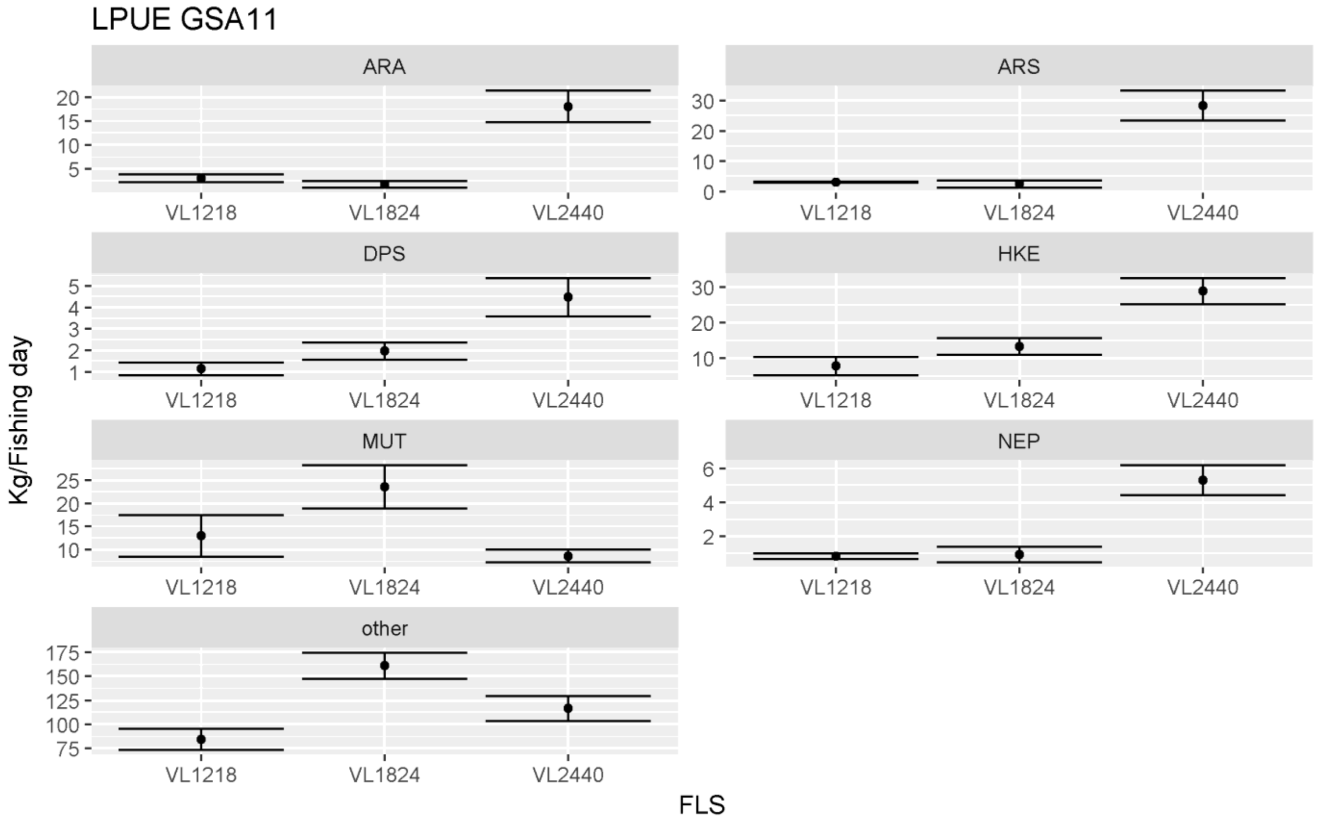


Figure 4.13: Average LPUE of GSA11 with error bar representing standard error, estimated by species across fleet segment for the period 2013-2015. Single points indicate that LPUEs refer to only one observation.

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.

Data regarding income and expenditure were used to estimated net profits. Data are available only at country level without the possibility to split data at GSA levels. Figure 4.14 show the estimated net profit only for Spain and France, Italian data are not reported because there is not possibility to distinguish data coming from the western waters of Italy from the other areas in which Italian fisheries occur. Furthermore, data for French VL0012 and VL1218 are not available.

Net profit is estimated following the formula reported in Annual Economic Report 2017, that is:

Net profit = Landings Income + Other Income – crew costs – unpaid labour – energy costs – Repair and maintenance costs – Other variable costs – Non-variable costs – Depreciation – Opportunity cost of capital.

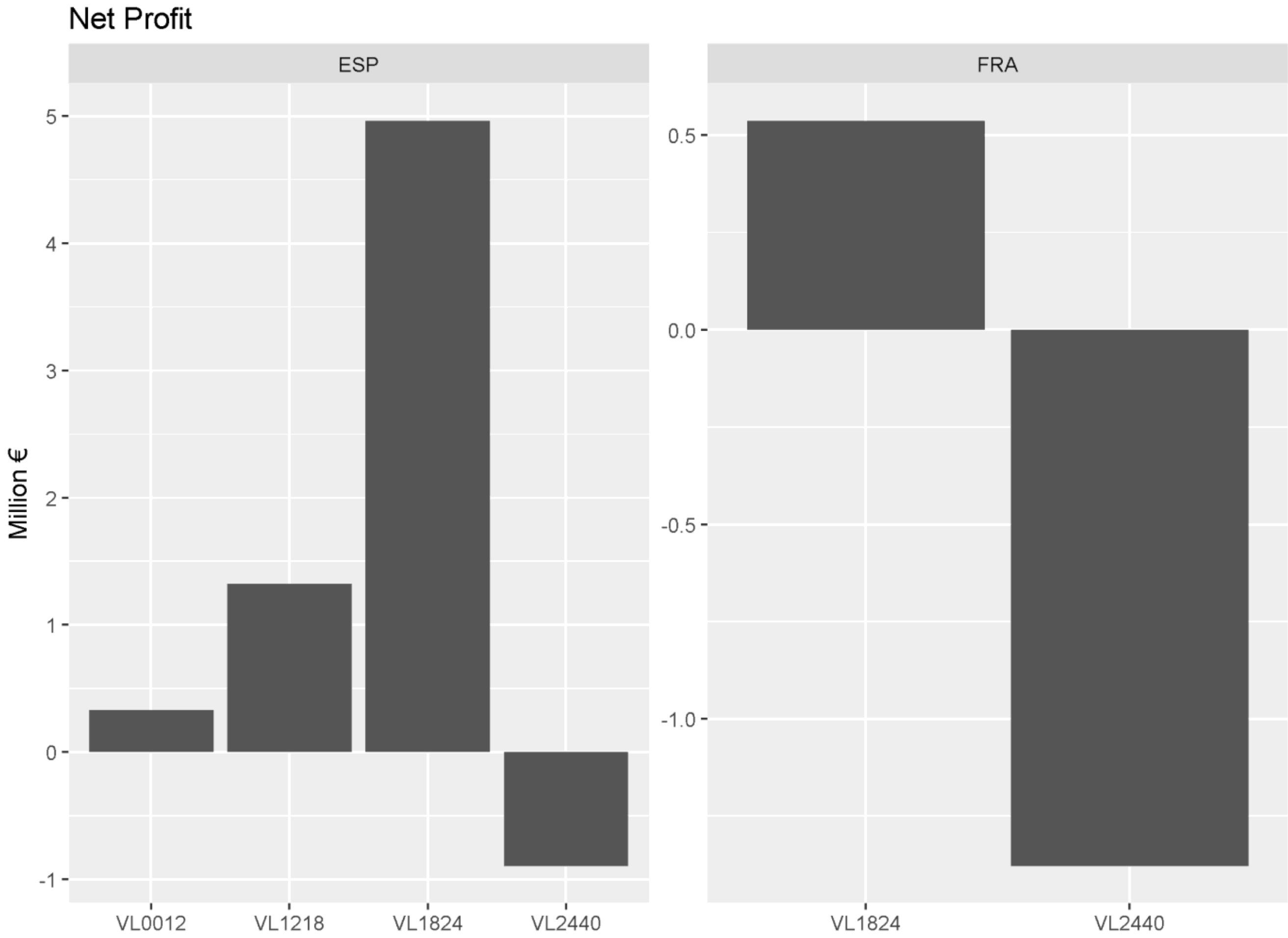


Figure 4.14: Mean net profit estimated during the period 2013-2014

4.1.7 Western management unit (GSA1-5-6-7)

Table 4.8 reports the main features of trawl fisheries in the western management unit. In the period 2013-2015, 640 vessels, on average, were involved in demersal fisheries in this area. This fleet was mostly composed by the segments VL1218 (53%), followed by VL1824 (36%); both VL0012 and VL2440 represent about 5% of the fleet.

In the western management unit, the main fleets involved in the demersal fisheries come from Spain and France. Since landings information include data from of GSAs 1-5-6, where landings weight and value has not been specified by gear, the information about landings could contain data not coming from bottom trawl fisheries. Considering the target species, the most landed species is *Merluccius merluccius* (HKE), followed by *Mullus barbatus* (MUT) and *Aristeus antennatus* (ARA) (Figure 4.15A). Considering total landings value, the most valuable species is *Aristeus antennatus* (ARA) followed by *Merluccius merluccius* (HKE), *Parapenaeus longirostris* (DPS) and *Nephrops norvegicus* (NEP) (Figure 4.15B). Target species represent about16% of total landings value for VL0012, 26% for VL1218, 50% for VL1824 and 54% of VL2440 (Figure 4.15C).

Table 4.8: Main features of trawl fisheries in GSA1-5-6-7. The values reported represent the average values during the period 2013-2015.

Managment unit		**Western**			
Fleet segment		**VL0012**	**VL1218**	**VL1824**	**VL2440**
Number of active vessels	(#)	33	342	234	31
Vessel tonnage	(thousand GT)	0.18	6.29	13.55	3.91
Engine power	(thousand kW)	2.29	48.09	64.07	13.46
Employed	(person)	67.69	927.66	823.45	132.74
FTE	(#)	49.19	780.53	713.75	118.54
Effort	(fishing days)	1698.67	6684.10	13180.98	7328.50
Landing weight	(tonne)	13.63	0.08	1782.64	2087.75
Landing value	(milion €)	0.07	0.00	6.82	7.37
Energy consumption	(thousand litre)	726.86	21193.23	29982.42	5264.22
Consumption per day	(litre/day at sea)	195.40	388.30	733.88	1069.31

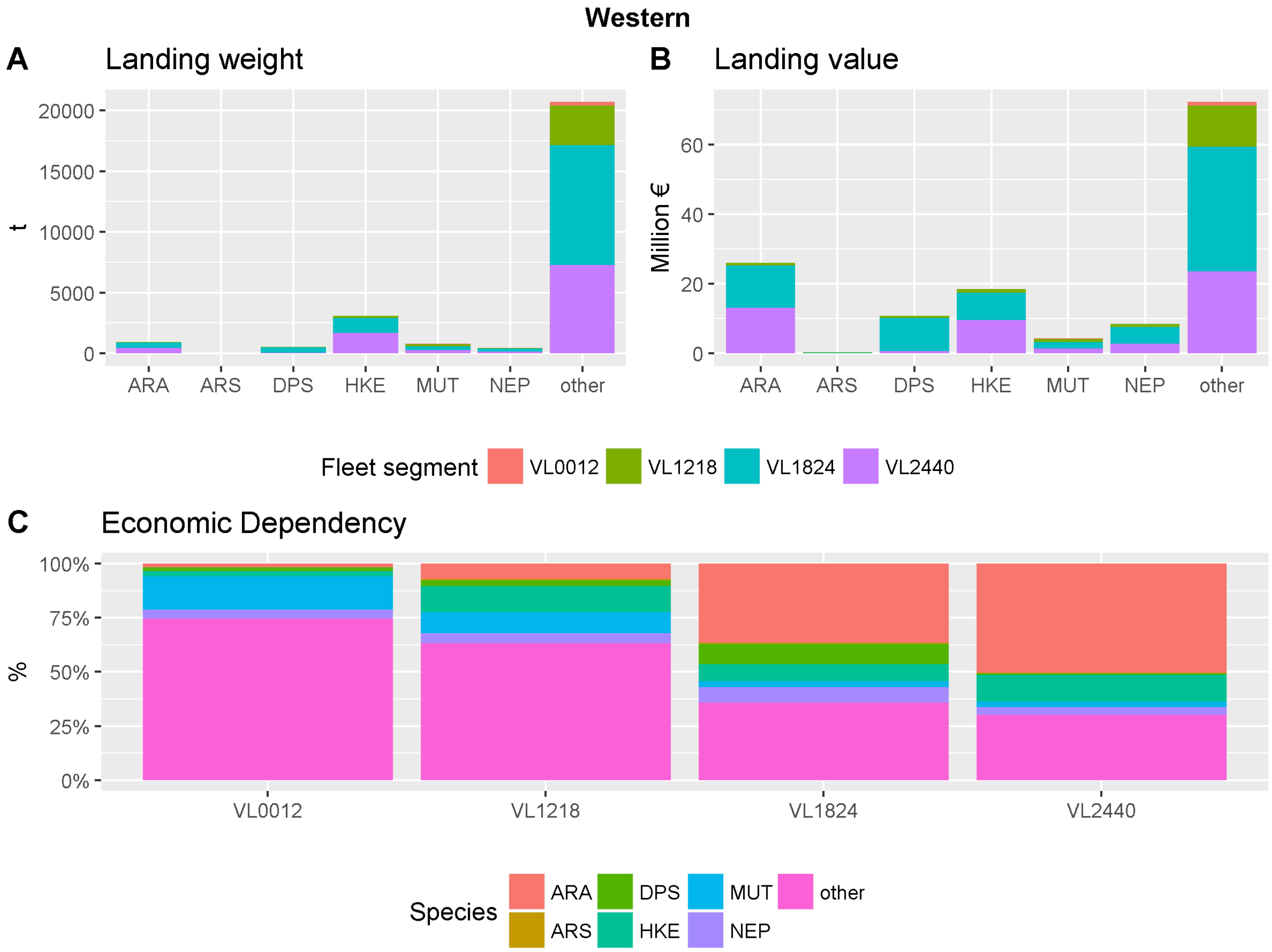


Figure 4.15: A) Species average landing weight across fleet segments. B) Mean landings value of species across fleet segments. C) Economic dependency of fleet segments by species estimated on average landings value. All variables represent average values during the period 2013-2015. The category "other" represents the mean value of the total landings of all other species excluding the 6 target species.

4.1.8 Eastern management unit (GSA8-9-10-11)

Since economic information for GSA8 are not available, the reported information about fleet capacity and economic performance refer only to GSA9-10-11. Table 4.9 reports the main features of trawl fisheries in the eastern management unit. In the period 2013-2015, 704 vessels, on average, were involved in demersal fisheries in this area. This fleet was composed mostly by the segments VL1824 (49%), followed by VL1218 and VL2440 (23% and 24% respectively) and VL0012 (3%).

In the eastern management unit, the main fleets involved in the demersal fisheries come from Italy and France. Considering the target species, the most landed species is *Merluccius merluccius* (HKE), followed by *Mullus barbatus* (MUT) and *Parapenaeus longirostris* (DPS) (Figure 4.16A). Considering total landings value, all species show a similar value in landings (Figure 4.16B). Targets species represent about 21% of total landings value for VL0012, 44% for VL1218, 43% for VL1824 and 61% of VL2440 (Figure 4.16C).

Table 4.9: Main features of trawl fisheries in GSA8-9-10-11. The values reported represent the average values during the period 2013-2015.

Managment unit		**Eastern**			
Fleet segment		**VL0012**	**VL1218**	**VL1824**	**VL2440**
Number of active vessels	(#)	22	162	348	172
Vessel tonnage	(thousand GT)	0.18	4.07	21.36	17.63
Engine power	(thousand kW)	0.86	12.97	67.79	54.60
Employed	(person)	50.75	574.58	1358.28	841.82
FTE	(#)	42.80	529.37	1230.95	756.32
Effort	(fishing days)	3091.33	51726.88	40268.43	4956.85
Landing weight	(tonne)	189.58	5402.81	7345.55	929.19
Landing value	(milion €)	1.71	40.40	55.14	8.65
Energy consumption	(thousand litre)	523.56	11414.40	50308.97	39312.83
Consumption per day	(litre/day at sea)	143.91	380.29	722.72	1113.01

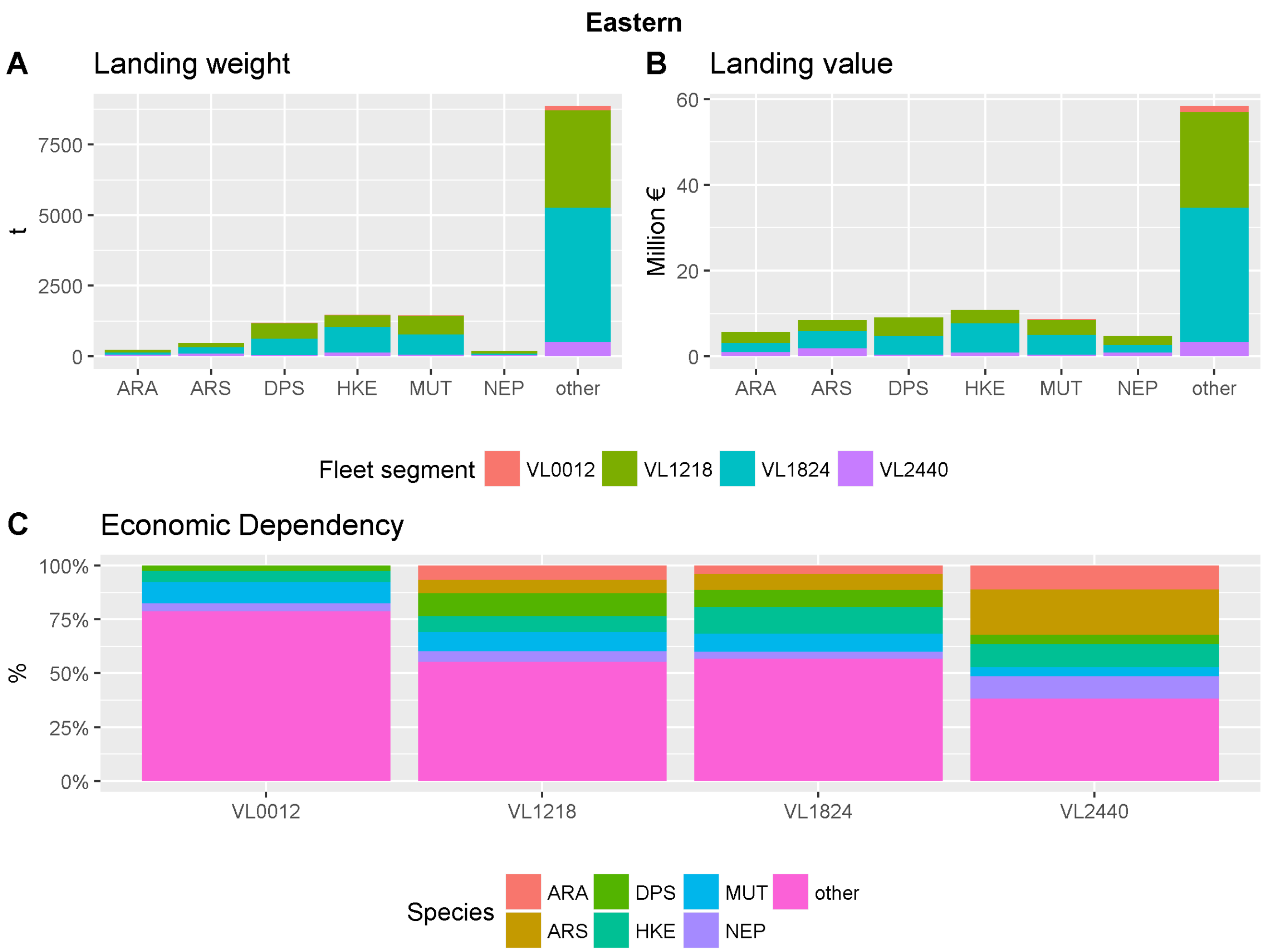


Figure 4.16: A) Species average landing weight across fleet segments. B) Mean landings value of species across fleet segments. C) Economic dependency of fleet segments by species estimated on average landings value. All variables represent average values during the period 2013-2015. 4.17The category "other" represents the mean value of the total landings of all other species excluding the 6 target species.

Additional graphs showing the time series of data between 2008 and 2016 are given in Annex 1.

5 ToR 3 What are the factors determining vessels' performance?

This section presents the results of quantitative analysis to estimate factors that affect vessels performance, mix-fisheries effects, and a summary of the MyGears project where some of the issues related with gear performance were discussed in depth.

For the quantitative analysis the EWG used LPUE as an indicator of vessel performance. The data available were provided by Italy and Spain, in both cases preliminary data, and referred to fishing operations by day and vessel. The analysis quantified the variability of LPUE by trip, and evaluates the effect of a number of available explanatory variables (such as vessel length, season, area and specialisation) on this variability. For mix-fisheries the analysis looks into non-mix operations, as a proxy for specialization of the fleet.

The third part of this section summarises the outcomes of a research project, MyGears, which analysed the diversity of trawls size and design across the Mediterranean Sea, and the potential for fishing power increase if fishers would switch to more efficient gears. The information on trawls technical characteristics is not routinely available in logbooks, and must be collected through interviews.

Analysis of the variability in LPUE by species and trip

For the analysis presented in this section, vessels performance was defined as the catch per unit of effort (CPUE). The analysis of factors affecting vessels' CPUE was carried out by fitting GAMM models to identify from a set of predictor variables which ones are significantly affecting vessels' performance. The analysis was carried out using a dataset from Italy that merges logbooks with VMS, providing landings by day for all species. An attempt was done to apply the same approach to a Spanish Catalonian dataset of the same type. However, due to time limitations it wasn't possible to run a full analysis. In this section only the fits to Italian data are presented, Annex 2 shows the details of model fitting including results for Catalonia.

5.1.1 data

The analysis presented here is based on data aggregated by fishing day. Ideally, this analysis should be done on a haul-by-haul basis to avoid hiding specific features of the process, by merging the daily activity in a single record.

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). 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 5.1). 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.

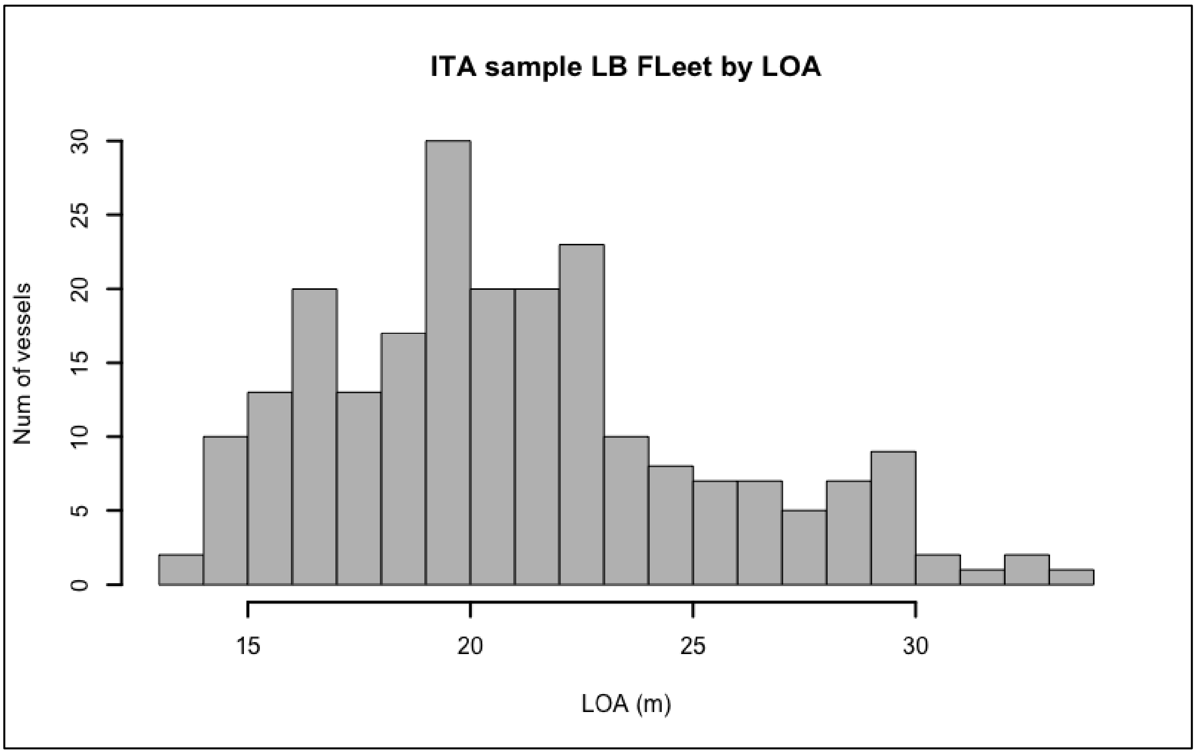


Figure 5.1 The fleet of trawlers corresponding to the records in the logbook dataset analyzed for the EWG 18-09. The area of activity is represented by the GSAs 9, 10 and 11 (Tyrrhenian Sea).

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 CPUE 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 UUOO of the Italian DCF network.

A graphical screening of the integrated dataset (Annex 3) evidenced that:

1. Most of the vessels operate mainly on the stratum 0-100m, irrespectively of Season and year. Given that the logbook records correspond to daily catches and the shelf of the North Tyrrhenian Sea is very narrow, it is possible to hypothesize that trawlers often combine fishing activities at different depths and distances from the coast;
2. The distributions of the estimated CPUE by LOA and Season, and by LOA and Year do not show relevant differences (Annex 3).

5.1.2 analysis

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 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 was fitted as smoothed variable accounting for the heterogeneous distribution of the species in the marine environment, given that the species in the MPA are associated to different depth strata;
- 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;
- Species fraction of catch (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., 2008);
- 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.

5.1.3 Results

The results of this modelling exercise are extensively reported in Annex 2. Here we shortly discuss the main results by species and the general conclusions with respect to the aims of Tor3.

Hake

All the predictors with the exception of price at market 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. The trends for some smoothers are well supported by the knowledge about the biology of this species, e.g. its distribution with Depth (Figure 5.2).

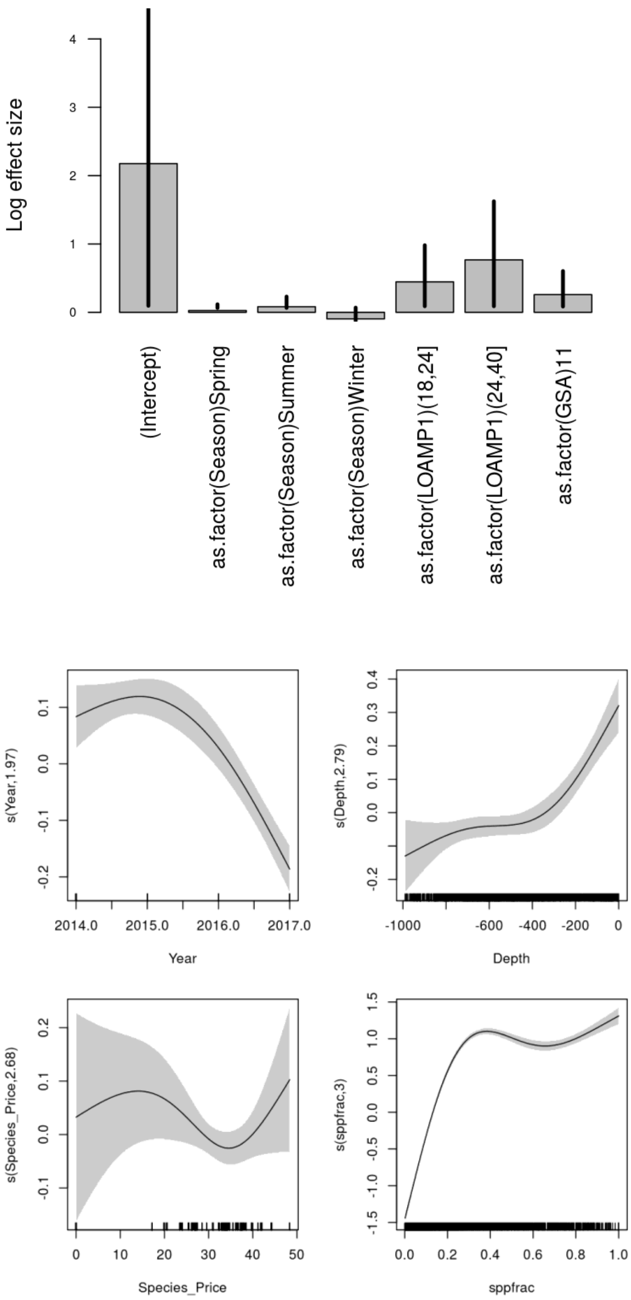


Figure 5.2 Hake.Top panel: main effects and their relative sizes. Bottom panel: fixed (left) and smoother (right) effects on LPUE.

Deep water rose shrimp

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. The trends for some smoothers are well supported by the knowledge about the biology of this species, e.g. its distribution with Depth (Figure 5.3).

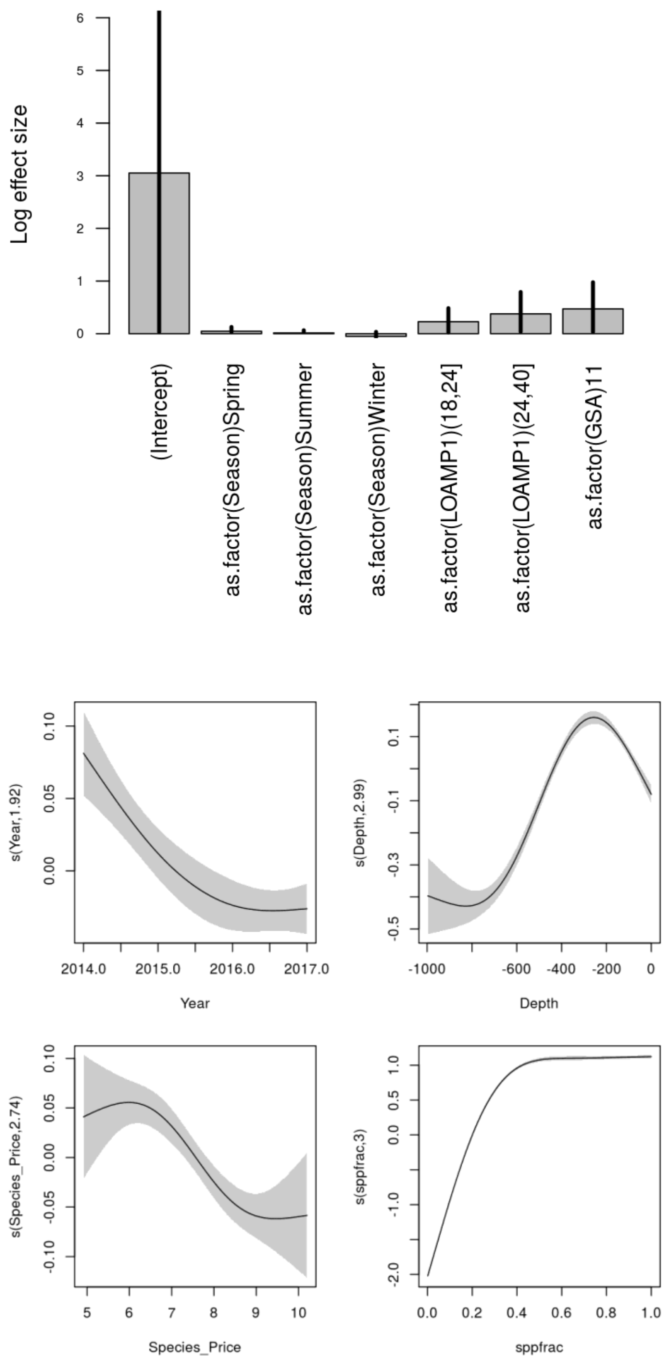


Figure 5.3 Deep water rose shrimp. Top panel: main effects and their relative sizes. Bottom panel: fixed (left) and smoother (right) effects on LPUE.

Red mullet

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. The trends for some smoothers are well supported by the knowledge about the biology of this species, e.g. its distribution with Depth (Figure 5.4).

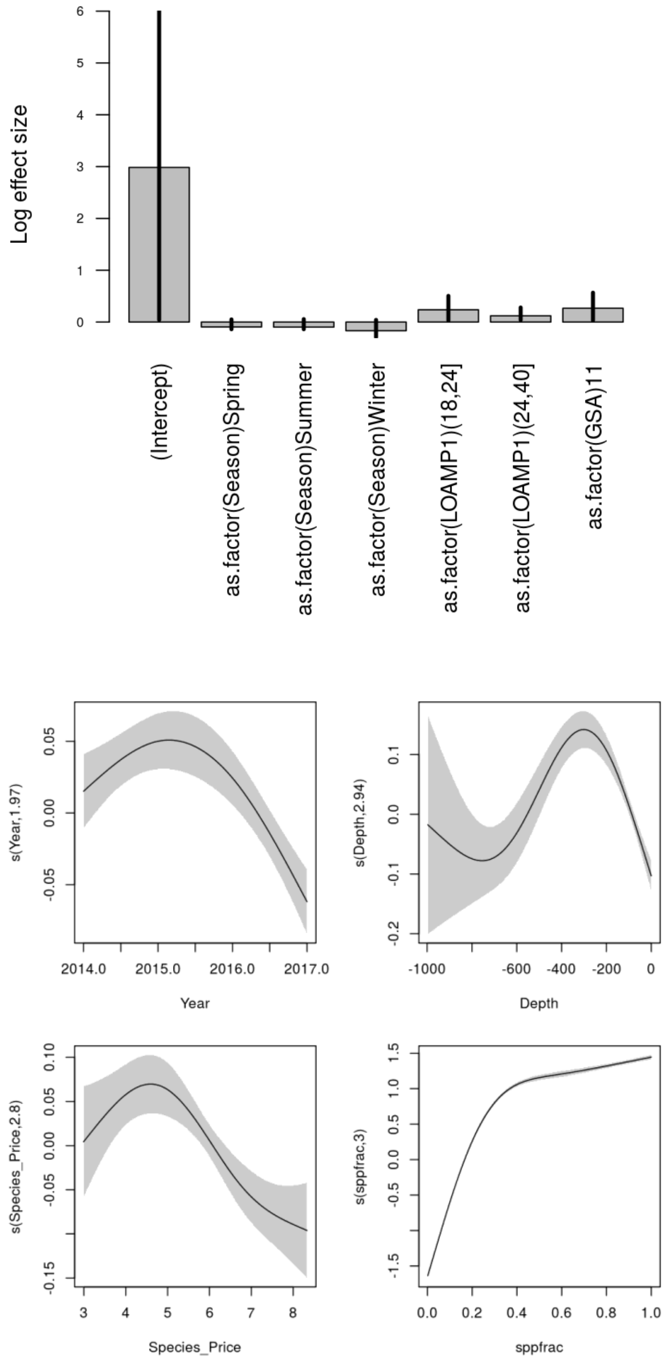


Figure 5.4 Red mullet. Top panel: main effects and their relative sizes. Bottom panel: fixed (left) and smoother (right) effects on LPUE.

Giant red shrimp

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 weights of the LOA classes resulted more important that the one obtained for the previously described species. The trends for some smoothers are not fully coherent with the knowledge about the biology of this species (Figure 5.5).

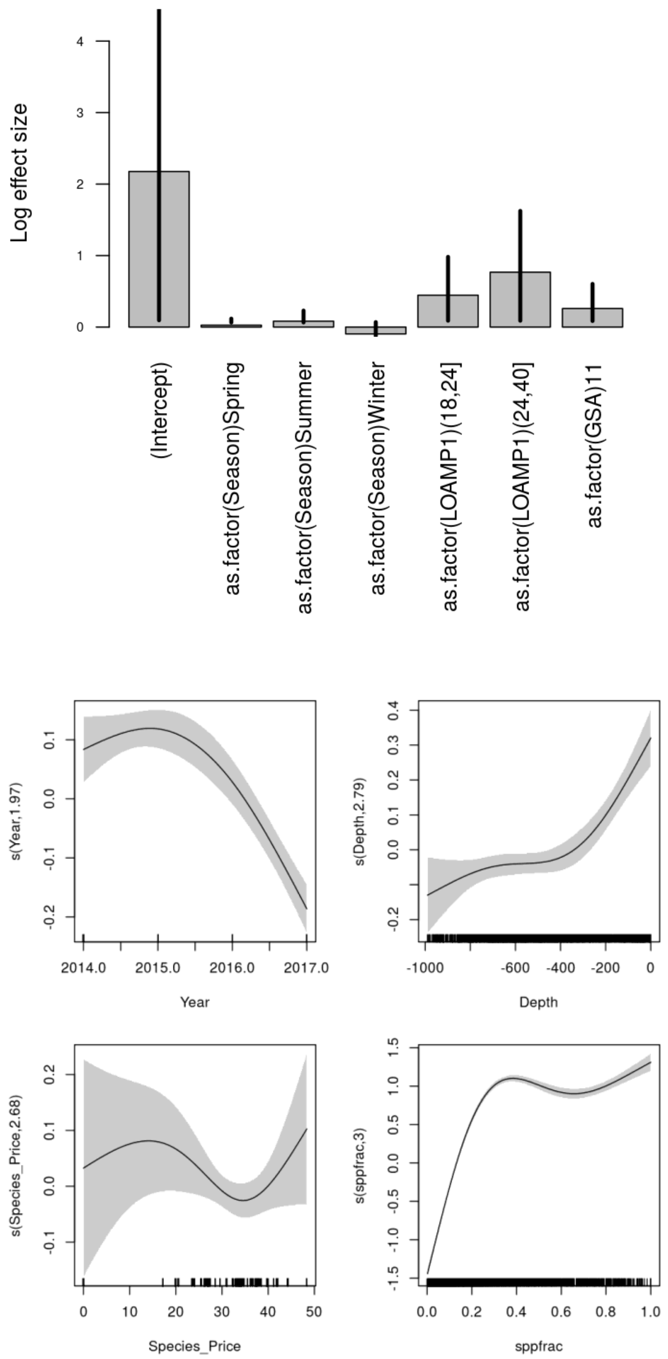


Figure 5.5 Giant red shrimp. Top panel: main effects and their relative sizes. Bottom panel: fixed (left) and smoother (right) effects on LPUE.

Blue and red shrimp

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. Smoothed effects are presented in Figure 5.6.

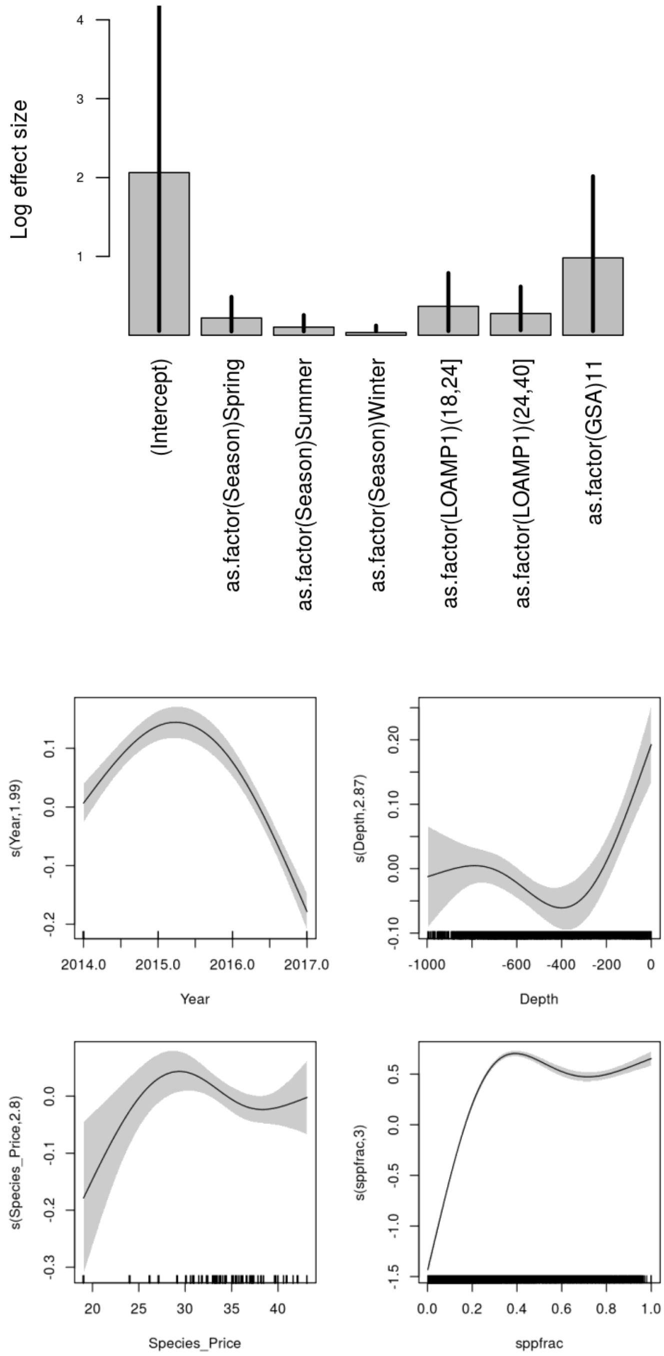
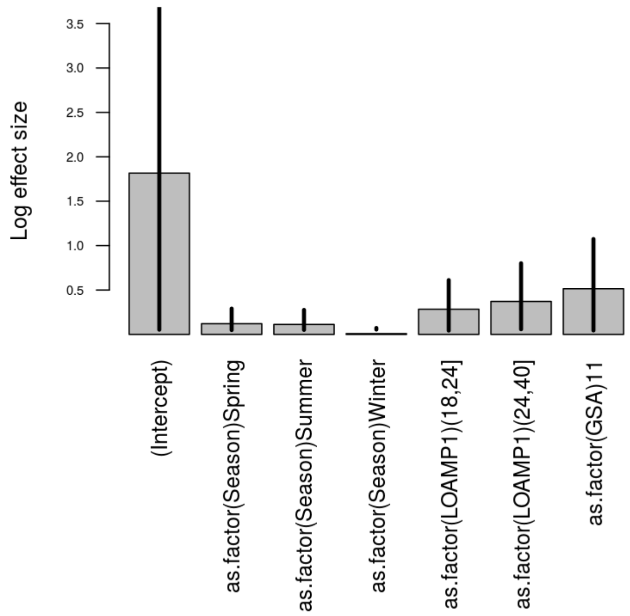


Figure 5.6 Blue and red shrimp. Top panel: main effects and their relative sizes. Bottom panel: fixed (left) and smoother (right) effects on LPUE.

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. The trends for some smoothers are well supported by the knowledge about the biology of this species, e.g. its distribution with Depth (Figure 5.7).



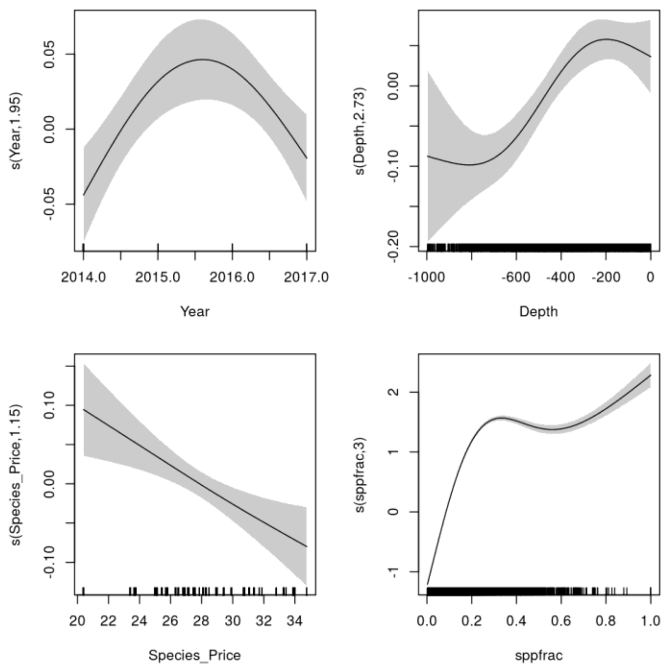


Figure 5.7 Norway lobster. Top pannel: main effects and their relative sizes. Bottom panel: fixed (left) and smoother (right) effects on LPUE.

5.1.4 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.
- Larger trawlers are more efficient that small ones. Apart from the cases of red mullet (which is a typical species of the shelf) and of the giant and red shrimp, the best LOA class in terms of CPUE is represented by the segment [24-40). 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 always 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.

Mixed fisheries

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. The species targeted by the MAP are not all in the same level of over-exploitation and are likely to create unwanted cross species limitations if very strong technical interactions exist. 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 here is based on data aggregated by fishing day. Ideally, this analysis should be done on a haul-by-haul basis to allow a proper evaluation of the mixed-fisheries nature of the fishery. As mentioned above the Italian data refers to all landings above 50kg/day per species, while the Spanish Catalonian data refers only to the species in the MAP. Furthermore, some doubt remain on the correctness of the computation of total landings for Catalonia. As such the analysis should be considered preliminary only.

For this analysis the EWG computed the fraction of the landings per species in a daily basis. For example, a value of 0.6 refers to one single species accounting for 60% of the daily landings. As such it can be seen as a proxy for specialization. The more specialized the fleet is the larger fraction of the landings will be of a single species.

Figure 5.8 presents the results for Italian and Spanish Catalonian trawl fleets. Both fleets show a high percentage of trips with mix landings, however the Italian trawl fleet seems to be more specialized. For Italy up to 40% of the trips are rather targeted, with a single species taking at least 50% of the landings. The same statistic for the Spanish Catalonian fleet is only about 10%.

These results are affected by the daily aggregation of logbook, which doesn’t allow a finer spatial analysis. Nevertheless, it’s possible to speculate that the complex array of catch is determined by the sequence, during the same day, of fishing events in different area/depth strata.

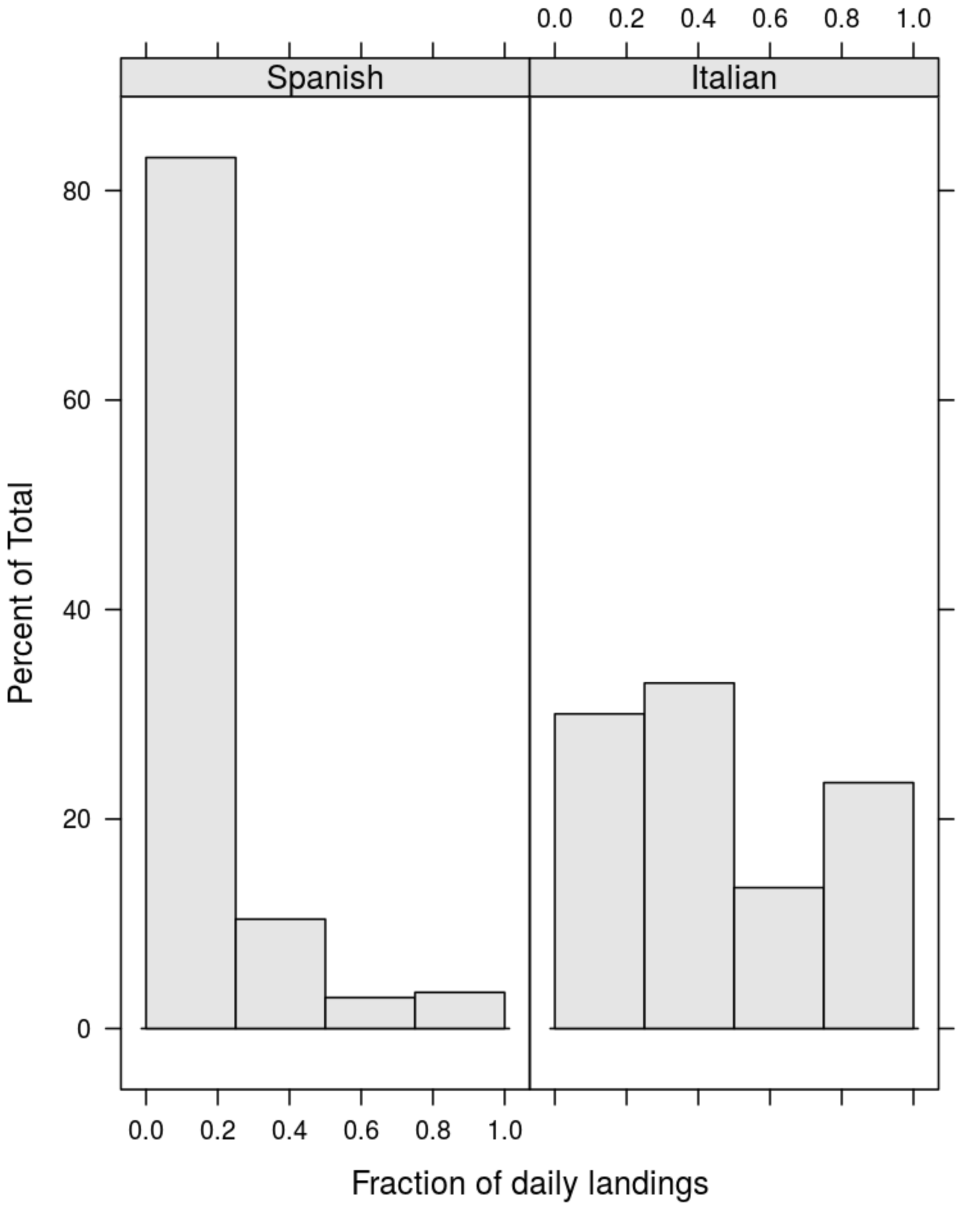


Figure 5.8 Percentage of trips by maximum fraction of daily landings of a single species [Preliminary result subject to caution for Catalonia].

More detailed results by vessels size and species are given in Annex 3.

5.1.5 LPUE quantiles

The ToR 4 requires information on LPUE quantiles, to assess the difference between average and more efficient vessels. So these are computed with the same data as above.

For both the Italian and Catalonian datasets, the tables below displays the average LPUE per species per day at the 50th quantile (median trip) and at the 85th quantile (efficient trip). 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 2 to 5 times more efficient than the median ones.

Table 5.1. 50th and 85th quantile of LPUE, Catalonian dataset. Upper: absolute value (kg/day). Lower: relative to the 50% quantile.

Length	Percentiles	TOTAL	*N. norvegicus*	*P. longirostris*	*M. merluccius*	*M. barbatus*	*A. antennattus*
X <12	HR p0,50	9	2	4	3	6	1
	HR p0,85	22	10	15	9	18	3
12≤ X ≤ 18	HR p0,50	21	5	5	8	10	16
	HR p0,85	49	20	15	22	35	51
18≤ X ≤ 24	HR p0,50	44	4	6	15	14	34
	HR p0,85	82	22	19	46	43	65
X ≥24	HR p0,50	70	6	6	18	25	45
	HR p0,85	123	33	25	67	64	85

Length	Percentiles	TOTAL	*N. norvegicus*	*P. longirostris*	*M. merluccius*	*M. barbatus*	*A. antennattus*
X <12	HR p0,50	1	1	1	1	1	1
	HR p0,85	2.4	5.0	3.8	3.0	3.0	3.0
12≤ X ≤ 18	HR p0,50	1	1	1	1	1	1
	HR p0,85	2.3	4.0	3.0	2.8	3.5	3.2
18≤ X ≤ 24	HR p0,50	1	1	1	1	1	1
	HR p0,85	1.9	5.5	3.2	3.1	3.1	1.9
X ≥24	HR p0,50	1	1	1	1	1	1
	HR p0,85	1.8	5.5	4.2	3.7	2.6	1.9

Table 5.2. 50th and 85th quantile of LPUE, Italian dataset. Upper: absolute value (kg/day). Lower: relative to the 50% quantile.

Length	Percentiles	TOTAL	*A. antennattus*	*N. norvegicus*	*P. longirostris*	*A. foliacea*	*M. merluccius*	*M. barbatus*
X <12	HR p0,50							
	HR p0,85							
12≤ X ≤ 18	HR p0,50	16	21	12	20	20	16	30
	HR p0,85	65	41	30	76	69	40	90
18≤ X ≤ 24	HR p0,50	18	20	12	28	24	13	19
	HR p0,85	70	60	30	79	60	56	79
X ≥24	HR p0,50	20	19	8	44	15	16	19
	HR p0,85	60	44	22	98	40	68	61

Length	Percentiles	TOTAL	*A. antennattus*	*N. norvegicus*	*P. longirostris*	*A. foliacea*	*M. merluccius*	*M. barbatus*
X <12	HR p0,50							
	HR p0,85							
12≤ X ≤ 18	HR p0,50	1	1	1	1	1	1	1
	HR p0,85	4.1	2.0	2.5	3.8	3.5	2.5	3.0
18≤ X ≤ 24	HR p0,50	1	1	1	1	1	1	1
	HR p0,85	3.9	3.0	2.5	2.8	2.5	4.3	4.2
X ≥24	HR p0,50	1	1	1	1	1	1	1
	HR p0,85	3.0	2.3	2.8	2.2	2.7	4.3	3.2

Trawl design and potential for future increase in fishing efficiency in the Mediterranean Sea

5.1.6 Introduction

Commercial fishers continuously adapt their activities to the prevailing conditions by changing the physical inputs of production (technological development) and the way these inputs are used to harvest target species (tactical adaptation) (Marchal et al., 2007). Because of technical creeping, there is evidence that the **efficiency** of fishing vessels has increased over the last decades (Eigarrd et al., 2009, 2011, 2014).

Fishing effort is traditionally estimated by combining available physical measurements of fishing capacity and fishing activity (FAO, 1999). **Fishing activity** is typically estimated by the duration of fishing trips. Such a definition ignores a number of factors, which may potentially impact fishing pressure, including the number and the size of gears deployed, or the effective time used for fishing. For management purposes, **fishing capacity** is frequently defined by some physical attributes of the operating vessel (engine power, gross tonnage) aggregated across vessels exhibiting similar characteristics. However, the harvesting potential (**fishing power**) of a vessel is also highly dependent on many other factors including the individual skipper’s ability, as well as technical characteristics such as gears deployed and on-board electronic equipment (Marchal et al., 2007, Sala et al., 2013, Notti et al., 2013).

5.1.7 Rationale

Many studies have demonstrated that the link between capacity, effort and fishing mortality is imprecise (Sala et al., 2013, Notti et al., 2013) and they demonstrated that this relationship could be more precisely quantified if metrics relating to the size or amount of gear deployed are included in fishing capacity indicators.

Recently a number of studies (Marchal et al., 2007, Eigaard et al., 2014). investigated the effect of the technological development of fishing fleets on time variations in fishing efficiency. Such investigations were often based on the analysis of variations in catch per unit effort (cpue) generally restricted by vessel information available from logbooks, which typically includes engine power, vessel length, and/or gross tonnage.

The introduction of new gear and technology includes both larger marked technological investments (e.g. acoustic fish finding equipment, electronic navigation tools) and smaller stepwise improvements of the gear (e.g. different gear typology, changes in the trawl design), which themselves do no not result in marked changes of a vessels capacity but in conjunction give a noticeable capacity increase over time.

Several studies denoted the necessity of refining measures of fishing capacity and fishing activity, as there is the evidence that fishing effort descriptors that are not traditionally measured (gear type, headline or groundgear length, etc.) may have a substantial impact on catch rates. Overall, the studies (Marchal et al., 2007, Eigaard et al., 2014) suggest that some elements of the key processes of technological creep should be used to adjust fishing effort. Table 5.3 outlines fishing gear factors that have been identified as affecting catchability.

Table 5.3. Fishing gear factors which have been found to affect fish catchability in trawling operations. Source: Dunn et al., 2006.

Factor	Effect	Examples/References
Towing speed	If the net moves too slow fish may evade the trawl, too fast and the sweeps may over-run the fish before herding can occur, although speed is not thought to affect selectivity.	Dahm et al. (2002) Piasente et al. (2004)
Catch rate	Catch rate is related to fish density (see above)	Gunn & Glass (2004)
Catch volume	A larger weight of catch increases codend drag, which can close up the meshes in front of the codend.	Erickson et al. (1996) O'Neill & Kynoch (1996) O'Neill et al. (2005)
Ground gear	The length, height, and design of the bobbins will determine the ease with which fish may escape under the footrope.	Godø et al. (1999) Walsh (1992)
Mesh size and shape	The size of the meshes will determine the size of fish which can escape through them. Includes twine characteristics.	see Section 3.6.4.1
Mesh colour	Affects the amount of contrast generated	Wardle (1986)
Mesh shrinkage	Mesh may shrink with net use.	Madsen & Holst (2002)
Ground gear	Fish may react earlier to heavier ground gear	Main & Sangster (1983)
Trawl doors	The doors themselves, or the mud clouds that they produce, may herd some species.	Somerton (2004) Harden-Jones et al. (1977)
Sweeps and bridles	The sweeps, bridles, or the mud clouds that they produce, may herd some species. For some species, catch rates may increase with increasing sweep length. In low light the herding effect may be reduced. Also affected by the angle of attack.	Engås & Godø (1989a) Glass & Wardle (1989) Somerton (2004) Walsh & Hickey (1993)
Net spread	For a given trawl configuration, net spread will increase with depth. Increased net spread will increase herding and catch rates, but may ultimately overspread the gear resulting in lower headline height, and/or reduced bottom contact, and thus changing reducing catching efficiency.	Szalay & Somerton (2005)
Headline height	Effective fishing height may vary depending on species behaviour. For example, cod concentrate on the bottom when young, and in midwater when older, so age structure of population affects catchability. Vertical distribution may also vary with fish density, and fish may make vertical migrations. Increasing net spread can reduce headline height, and reduce catching efficiency for some semi-pelagic species.	Godø & Wespestad (1993) Hjellvik et al. (2002) Szalay & Somerton (2005)
Bottom contact	The ground gear may not be on the seabed all of the time. An increase in groundrope distance above the seabed of only ~5 cm (caused by an increase in net spread) has been correlated with decreasing catch rates for several species, most significantly for benthic species.	Szalay (2004) Szalay & Somerton (2005)
Codend size and length	Thought to be a major factor determining selectivity, although no experimental studies were found.	Wileman et al. (1996)
Codend attachments	Additions to the codend, such as strengthening bags, or extra panels of netting (often used on the underside of the codend for protection) have been found to affect selectivity, presumably by masking the codend meshes.	Kynoch et al. (2004) Özbilgin & Tosunoğlu (2003)
Vessel effect	Some species of fish may move away from the fishing vessel. This may be largely due to vessel noise. There is no clear evidence of fish deliberately avoiding fishing vessels because of detecting echosounder pulses. A "skipper effect" has also been identified for some trawl surveys, due to different people recording tow information in a different way, for example the point at which a trawl starts and stops fishing.	Kriger & Sigler (1996) Popper et al. (2004) Szalay (2004)
Tow length	Tow duration affects catch rates of some species. Presumably related to the swimming endurance of different species.	Alderstein & Ehrich (2002) Dahm et al. (2002) Godø et al. (1990)

5.1.8 Materials

Council Regulation (EC) Nr. 1967/2006, concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean, establishes that technical specifications limiting the maximum dimensions of floatline, footrope, circumference or perimeter of trawl nets along with the maximum number of nets in multi-rig trawl nets shall have been adopted in accordance with regulatory procedure. EC Reg. 1967/2006 acknowledges that establishing the maximum dimension and number of fishing gears per vessel represents a way to control and limit the fishing effort. In 2013, an European study (named *myGears, Sala et al., 2013*) has systematically collected information through surveys on relevant initiatives of professional associations and specialized consultants, as well as on existing literature and data, including technical national and European reports, college and PhD theses, popular articles, conference and meeting proceedings, papers produced by non-governmental organisations and other forms of non-scientific literature.

The study investigated the relationship between vessel- (LOA, towing force, engine power) and trawl-metrics to help refine fishing capacity definition by considering the fishing gear deployed. The first objective was the information collection on the characteristics of trawl nets used in different Mediterranean fisheries. Specifically, the *myGears* project improved the technical knowledge on trawl gears and vessels specifications by addressing the following items:

- definition and identification, suitable for enforcement and control purposes, of the maximum and minimum dimension of floatline, footrope, circumference or perimeter at various levels of the trawl nets;
- nominal minimum/maximum linear dimensions and number of meshes in the front end and/or posterior transversal cross-sections of both the trawl body, extension piece and codend *sensu-stricto*;
- identification of otterboard size (width, height, projected area and weight), material, and typology (oval, Vee, cambered, multi-foil, vertical, etc.), along with the maximum/minimum number of nets in multi-rig trawl nets;
- information on engine power, towing force, vessel design and technology including propulsion system;
- nominal minimum/maximum longitudinal dimensions and number of meshes both in the codend *sensu-stricto* and extension piece. Relations between longitudinal and transversal dimensions at various levels of the trawl nets.

More precisely, in order to gather the information abovementioned, *myGears* has defined some main trawl typologies (e.g. pelagic, semi-pelagic, demersal-, bottom-trawl) corresponding to different target species groups, which basically represent different trawl fishing strategies in the Mediterranean (see Annex 4 for details). These strategies concern either swept volume or swept area with respect to species that are either herded or not by various components of a trawl gear. Furthermore, different trawling technique (e.g. single-boat trawling, pair-boat trawling, multiple trawling) have been defined in order to homogenize information collection and to rationalize the field direct measurements.

As second objective, the project specifically investigated the link between vessel capacity and the size of the gear deployed. In order to analyse the influence of trawl type and trawling technique on the relationship between vessel, door and trawl size, linear mixed modelling have been applied.

5.1.9 Results

Likewise other studies (Marchal et al., 2007, Eigaard et al., 2014), the project *myGears* evidenced that gear types, size and techniques have varied considerably over time for most of the Mediterranean fleets.

5.1.9.1 Trawling technique

Marchal et al (2007) observed for the French trawlers an emergence of twin trawls in the 1980s (see for example Figure 5.9), which was associated with fishing for Nephrops. The horsepower of the small French otter trawlers increased over time, whereas that of the larger French trawlers decreased. Such decrease in horsepower resulted from the emergence of new vessels working as pair-trawlers. Such vessels do not need as much horsepower as traditional single-trawl vessels. Therefore, the use of engine power as a typical descriptor of the Fishing capacity should be treated with caution, because there is the evidence of a gear effect on engine power demand.

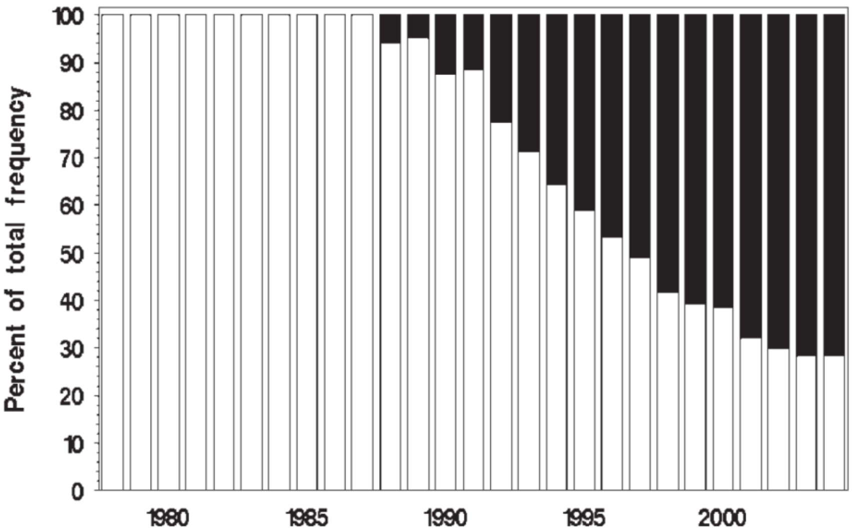
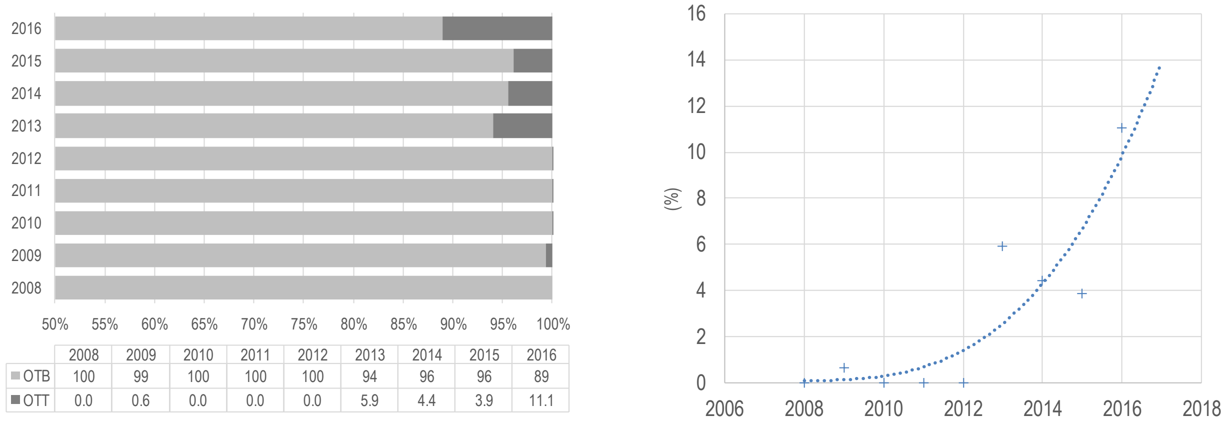


Figure 5.9. Annual changes in gear types for French otter trawlers, all length classes (white, single otter trawls; black, twin trawls). Source: Marchal et al. (2007).

Based on the transversal EFFORT data as provided by EU Member States for the 2017 DCF fishing fleet economic data call (Table 5.4), a similar trend, even though less evident (Figure 5.10), can been seen in the Mediterranean gears with a shift from single- (OTB) to twin-trawl (OTT).

In 2016, more than 11 % of the Mediterranean demersal fleets were twin-trawlers (Figure 5.10)



	2008	2009	2010	2011	2012	2013	2014	2015	2016
OTB	100	99	100	100	100	94	96	96	89
OTT	0.0	0.6	0.0	0.0	0.0	5.9	4.4	3.9	11.1

(a) (b)

Figure 5.10. Annual changes in gear types for Mediterranean (Italy, Spain, France) otter trawlers based on transversal EFFORT data as provided by EU Member States for the 2017 DCF fishing fleet economic data call (OTB: single-trawl; OTT: Otter twin-trawl).

5.1.9.2 Trawl size

In the case studies examined by Marchal et al (2007), based on a selection of Danish, French, and Spanish fleets, both headline length and vertical opening increased over time. Trawl size, as reflected by the headline length, had a positive effect on catch rates of hake by all French trawlers and on catch rates of Norway lobster by the small trawlers. Often otter trawlers equipped with twin trawls have longer headline and higher vertical opening than those equipped with single trawls.

Information collection in the project *myGears* showed a similar trend in Mediterranean otter trawls (e.g. OTB, OTT and PTB pooled) with a continuous increment in the groundgear length, which is directly related to headline length. By standardizing the groundgear length by the LOA (e.g. FL/LOA) the ratio presents an increment of 6-4 % every 10 years (Figure 5.11), with a total increase from the 1950s to 2010 of around 32 % on average.

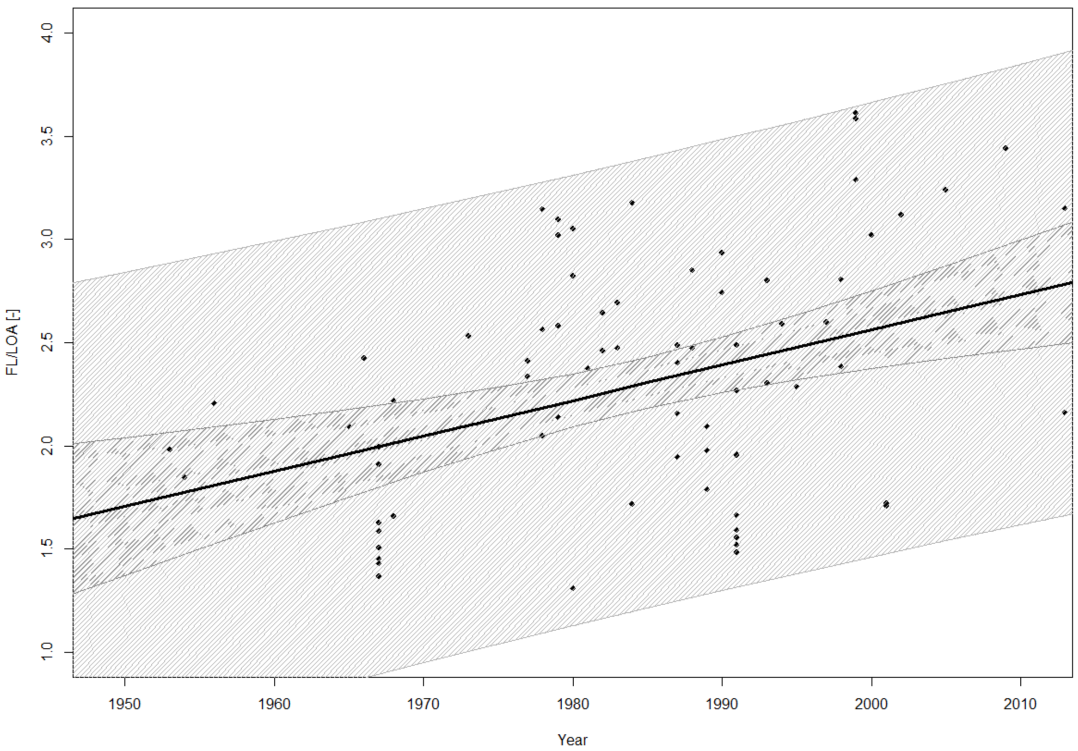


Figure 5.11. Annual changes in the ratio between the groundgear and vessel LOA in Mediterranean otter trawls (OTB, OTT). Data source: Sala et al (2013).

Year	fit	lwr	upr	Incr.(%)
1950	1.62	1.24	2.00	-
1960	1.71	1.37	2.04	5.3
1970	1.79	1.50	2.08	5.0
1980	1.88	1.63	2.13	4.8
1990	1.96	1.75	2.18	4.6
2000	2.05	1.87	2.23	4.4
2010	2.13	1.99	2.28	4.2

An analysis of the *myGears* data for vessel power (hp) was carried out using a segmented regression approach by OTB2 and OTB4. The data clearly showed two different patterns, this result indicates that there is a relationship between power and groundrope with the main factor trawl type (OTB2 or OTB4) influencing groundrope. This suggests that vessels <500 hp tend to deploy the largest practicable gears (OTB2=OTB4), presumably to catch the most fish. Interestingly many larger vessels could tow much larger nets (e.g. by shifting to OTB4) than they currently do. This raises the question of what would happen if all the vessels towed as large a net as possible.

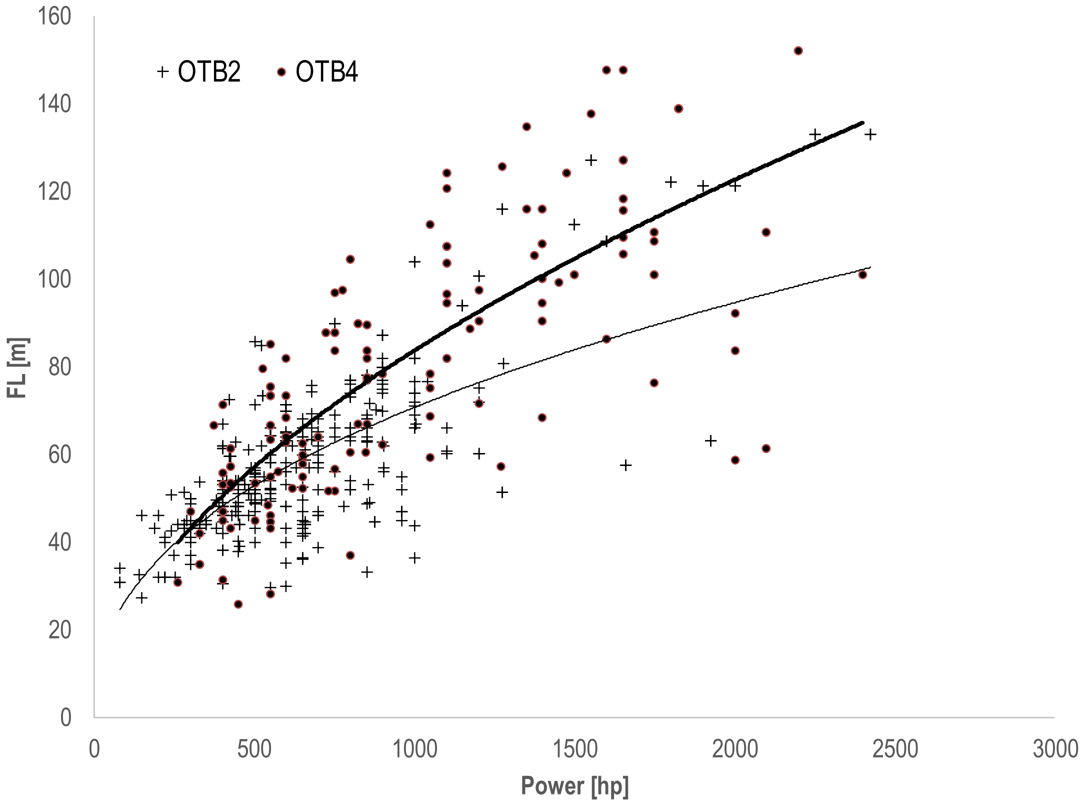


Figure 5.12. Relationships between groundgear (FL) and vessel power (Power) in Mediterranean otter trawls (OTB, single-trawls). Data source: Sala et a (2013)[1].

5.1.9.3 Otterboard size

A wider spread between the trawl doors implies a wider swept area and then higher herding and catchability (Dunn 2006). Harden-Jones et al (1977) attached acoustic transponding tags to flatfish, and monitored their behaviour in response to trawl gear. The experiments showed that the otterboards had a greater herding effect than the bridles, and that the efficiency of the trawl was 44 % when the fish started between the trawl doors, 22% between the doors and the wing ends, and 61 % when directly in the path of the net.

The project *myGears* showed a growing trend in Mediterranean otterboards size (OTB, OTT and PTB pooled) with a continuous increment in the door area (see OBA in Figure 5.13a), which is the product of door length and height. By standardizing OBA by LOA (e.g. OBA/LOA) the ratio presents an increment of 6-10 % every year (Figure 5.13b), and from the 1950s to 2013, the ratio increased on average of around 75 % in total.

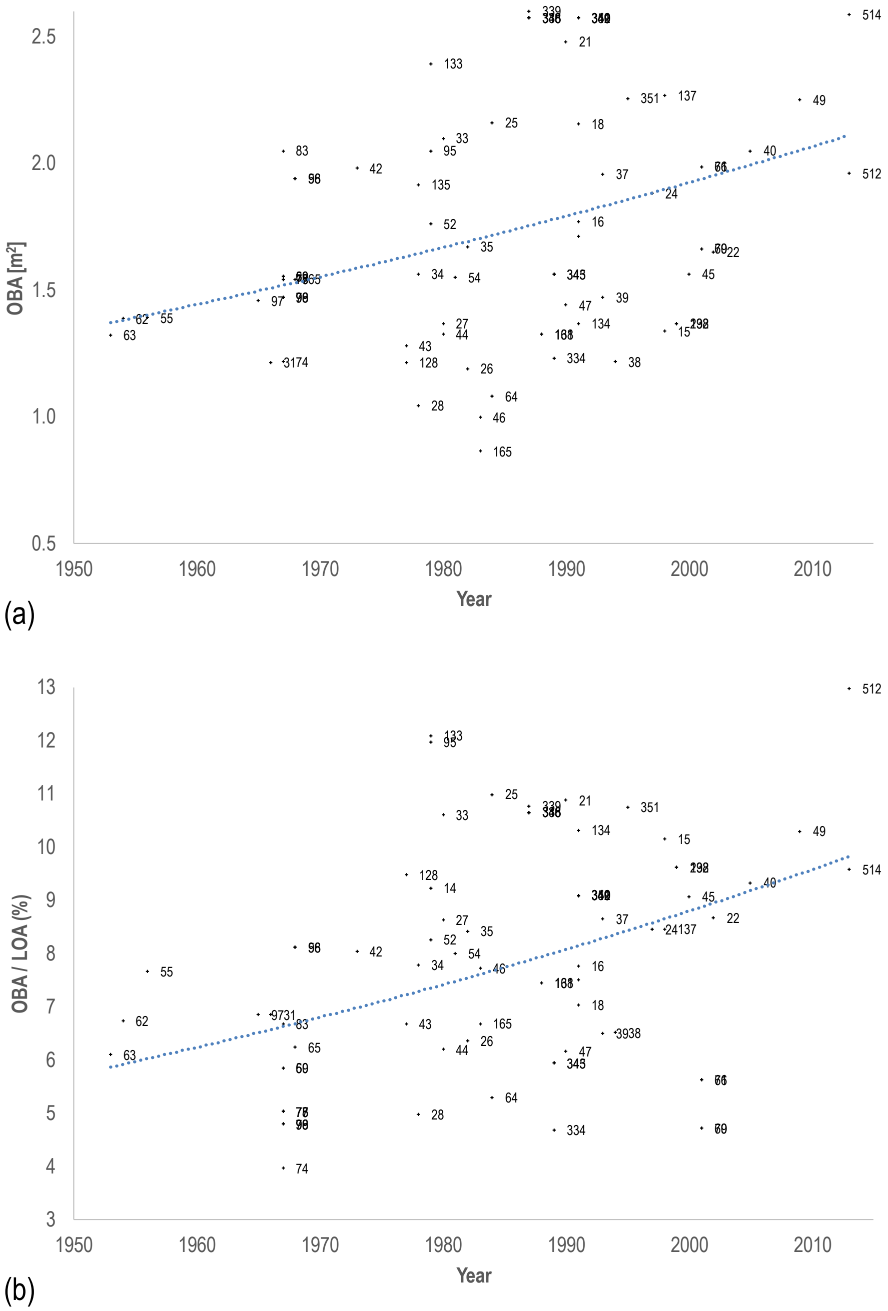


Figure 5.13. Annual changes in otterboard area, OBA (product of door length and height) and (b) ratio between OBA and vessel LOA in Mediterranean otter trawls (OTB). Data source: Sala et al, 2013.

5.1.10 Discussion

Fishing vessel capacity for trawlers is generally expressed in terms of length, tonnage, and engine power, assuming that a larger vessel has a greater fishing power. Management uses effort-control measures such as kW-day limits based on this assumption. The perception of bigger the vessel, the greater the fishing power, in particular for trawlers translates through to effort management. As effort can be defined as the use of capacity with time, effort control is often expressed in kW-days. Then, if a vessel has twice the engine power, it gets half as many days at sea. However, various studies have shown that vessel size and effort can only partially explain differences in fishing power (Reid et al, 2011, Pout et al., 2008). This is often treated as a human or a skipper factor, but it represents the non-physical or unaccounted factors in evaluating fishing power. One issue commonly overlooked is that fishing is actually done by a net, towed by a vessel, so arguably fishing power should consider both components of the fishing system, i.e. the vessel and the gear. One source of the skipper factor could be the choice, design, and rigging of the nets utilized.

Many studies have shown a weak and noisy relationship between effort and modelled catches, and explanatory models often require the inclusion of a skipper or vessel effect to explain the variance. A key element in this effect is the choice of gear size. Relationships have been investigated by Reid et al. (2011) between metrics of the vessel (length, tonnage, and power) and the gear towed (length of groundgear, or circumference of the net opening). Often, the vessel size did not correlated with that of the gear, or did so only for smaller vessels (1000 hp). The key implication is that effort management based on vessel metrics alone is not appropriate, because it is a poor predictor for gear size, and hence for fishing power. If this will be proved also for the Mediterranean fisheries, effort restrictions may actually encourage the adoption of larger gears for a given vessel, to maximize the value of a limited-time resource.

Analysis of the effects of vessel and gear properties on fishing efficiency in Marchal et al. (2007) clearly showed that collecting non-trivial information on fine-scale technological change allows more insight into the factors affecting fishing power. The gear effect appeared to be dominant over the vessel effect, with other several studies showing a greater efficiency in otter trawlers using twin-trawls than single trawls when fishing Norway lobster, but a lesser efficiency when fishing hake (Sangster et al., 1998).

Overall, Marchal et al. (2007) provided some insight into the key processes of technological creep. The main results suggest that fishing effort descriptors that are not traditionally measured (e.g. gear type, headline or groundgear length) may have a substantial impact on catch rates. Such variables are currently not routinely recorded in logbooks. Their results suggest that they should be.

Table 5.4. Fishing gear DCF code, name and class and corresponding DCF fishing technology code.

code	description	gear_class	fishing_tech
PS	Purse seines	SURROUNDING NETS	PS
LA	Lampara nets	SURROUNDING NETS	PS
SB	Beach seines	SEINE NETS	DTS
SDN	Danish seines	SEINE NETS	DTS
SSC	Scottish seines	SEINE NETS	DTS
SPR	Pair seines	SEINE NETS	DTS
TBB	Beam trawl	TRAWLS	TBB
OTB	Bottom otter trawl	TRAWLS	DTS
PTB	Bottom pair trawl	TRAWLS	DTS
OTM	Midwater otter trawl	TRAWLS	DTS_or_TM
PTM	Pelagic pair trawl	TRAWLS	TM
OTT	Otter twin trawl	TRAWLS	TM
DRB	Boat dredges	DREDGES	DRB
DRH	Hand dredges	DREDGES	DRB
HMD	Mechanised dredges including suction dredges	DREDGES	DRB
LNB	Boat-operated lift nets	LIFT NETS	DFN
LNS	Shore-operated stationary lift nets	LIFT NETS	DFN
GNS	Set gillnets (anchored)	GILLNETS AND ENTANGLING NETS	DFN
GND	Driftnets	GILLNETS AND ENTANGLING NETS	DFN
GNC	Encircling gillnets	GILLNETS AND ENTANGLING NETS	DFN
GTR	Trammel nets	GILLNETS AND ENTANGLING NETS	DFN
GTN	Combined gillnets-trammel nets	GILLNETS AND ENTANGLING NETS	DFN
FPO	Pots	TRAPS	FPO
LHP	Handlines and pole-lines (hand-operated)	HOOKS AND LINES	HOK
LHM	Handlines and pole-lines (mechanised)	HOOKS AND LINES	HOK
LLS	Set longlines	HOOKS AND LINES	HOK
LLD	Drifting longlines	HOOKS AND LINES	HOK
LTL	Troll lines	HOOKS AND LINES	HOK
NK		GEAR NOT KNOW OR NOT SPECIFIED	
NO		No gear	
FPN	Stationary uncovered pound nets	TRAPS	FPO
FYK	Fyke nets	TRAPS	FPO
SV	Beach and boat seine		
MIS	Miscellaneous Gear		
HAR	Harpoons		

6 ToR 4 - Relationship between fishing mortality and fishing effort

Published results from Cardinale et al. 2017

Cardinale et alii. (2017) analyzed the available stock assessments and effort data for many commercial species and fleets in the Mediterranean Sea since 2003. More than 500 stock assessments results were collated, which cover 26 different species and 27 GSAs or combination of GSAs. The authors compared Forecast Catches with Real Catches. Short-term forecasts have been conducted for 2 or 3 years starting from the reference year of the assessment. Short-term predictions were mostly based on the results of XSA or alternative models. Scenarios assuming different Fs were tested including F consistent with MSY. The catches relative to the F reference points were predicted assuming recruitment in the next 2 years equal to the geometric mean of the previous 3 years. Predicted catches were compared with the real catches for each stock.

Exploration of temporal trends in F and effort was performed for the main species and fisheries operating in the Mediterranean Sea. The selected species were European hake, red mullet, deep-water rose shrimp, Norway lobster, giant red shrimp, blue and red shrimp, European anchovy, and sardine.

The analysis shows that there has been no apparent relationship between nominal effort and fishing mortality for all species in the time frame investigated. Fishing mortality has remained stable during the last decade, for most species, showing only a significant decline for red mullet and giant red shrimp and an increase in the case of sardine stocks. Current F is always larger or much larger than FMSY for all species.

F was scaled by the level of FMSY allowing comparisons among stocks. GAMs were used to account for the unbalanced design in the data available between years and GSAs. Results showed that effort was not significantly related to F/FMSY in any of the model fitted except for deep water pink shrimp The authors state however that the shape of the effect of effort on F/FMSY for deep water pink shrimp is contradictory to the expectations (decreasing F/FMSY with increasing effort).

					Predictors				
Model	Time series	Dev. Explained (%)	r^2	n	GSA	Year	Effort	F trend	Average F/F_{MSY}
Hake*	2004–2014	84.5	0.81	70	<0.001	ns	ns		8.1
Red mullet*	2005–2014	92.9	0.91	78	<0.001	<0.008	ns	↘	3.2
Deep water pink shirmp^	2006–2014	81.3	0.76	50	<0.001	ns	<0.01		2.1
Norway lobster*	2004–2014	95.1	0.93	35	<0.001	ns	ns		2.9
Giant red shrimp^	2006–2014	76.3	0.70	30	<0.001	<0.03	ns	↘	1.7
Blue and red shrimp^	2008–2014	84.6	0.78	20	<0.001	ns	ns		2.5
Anchovy^	2002–2014	87.2	0.84	46	<0.001	ns	ns		1.8
Sardine*	2002–2014	80.4	0.73	46	<0.001	<0.002	ns	↗	2.0

For model details see Section Materials and Methods.
**Log link.*
^Identity link.

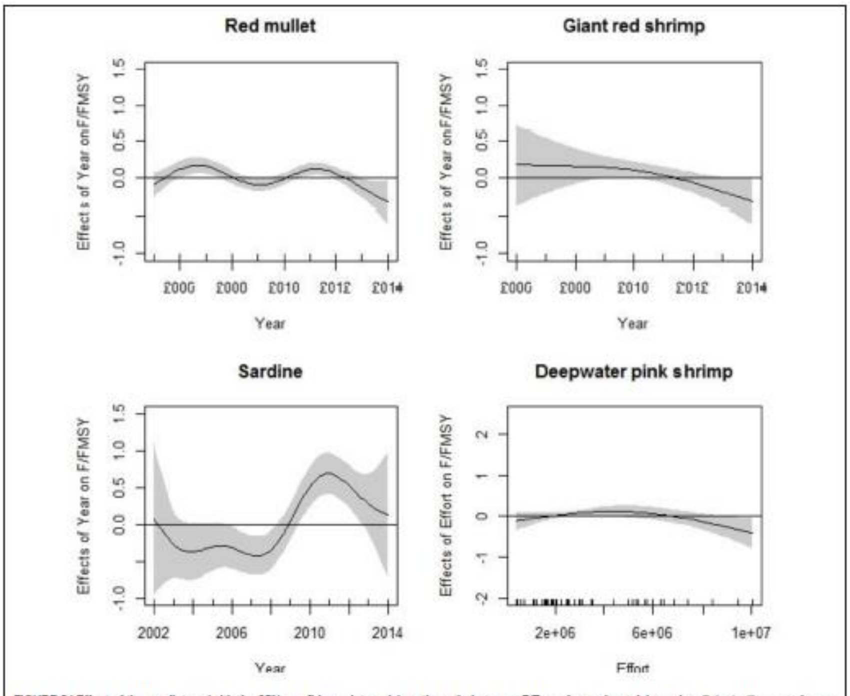


FIGURE 2 | Effect of the predictors (with the 95% confidence intervals) on the ratio between F/F_{MSY} for each model species. Only significant predictors were shown. For model details see Material and methods.

Figure 6.1 Effect of the predictors (with the 95% confidence intervals) on the ratio F/FMSY for each model species. Only significant predictors were shown, i.e. year effect for Red mullet, giant red shrimp and sardine, and fishing effort effect for deepwater pink shrimp. (from Cardinale et al, 2017).

One of the main results from this analysis is that nominal effort appears not correlated with fishing mortality. The authors state that the results demonstrate that management based mainly on reduction in nominal effort has failed in the Mediterranean Sea. They recommend choosing for the future alternative management measures as a TAC based system for achieving the objectives of the CFP. The authors state that results prove the ineffectiveness of the putative effort reductions to control fishing mortalities in the area, the continuous non-adherence to the scientific advice, and the existence of ineffective national management plans as a primary management failure.

Comments from STECF EWG: this paper does not explain which effort data have been used and the data are not provided in the article, so the actual trends and variations in fishing effort between 2007 and 2015 are not known. It cannot thus be ascertained whether the lack of significant relationship is due to the measure of effort used (nominal effort) and the difficulty to partition it on the different stocks, or to the simple fact that both time series of F and E are not contrasted enough and have remained within the same high range over the 8 years of data analysed.

Western GSAs 1-5-6-7

To investigate the relationship of fishing mortality with effort in Management Unit 1 (GSAs 1,5,6,7), effort values were extracted from Annual Economic Report files. Management Units include two groups: Group 1 for mixed fisheries and Group 2 for deep water shrimp fishery. Effort was calculated per corresponding metiers.

Fishing mortality was extracted from the most updated stock assessments contacted under GFCM or STCEF specialised working groups for the target species. In the cases that both bodies had performed an assessment on the same year the rationale was to adopt the values from the GFCM assessments as it is the acting RFMO with better experience of the prevailing conditions of the stocks.

6.1.1 Trend in nominal effort

The trends of nominal trawl effort for the species and areas under study are reported in Figure 6.2 and Figure 6.3. A reduction in fishing effort is evident in all cases along the period investigated.

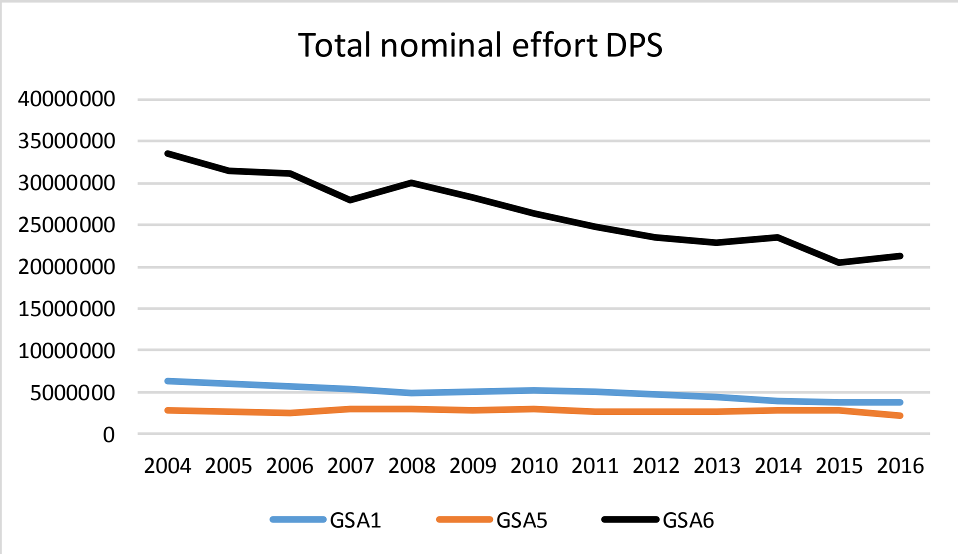


Figure 6.2 – Trends of the nominal fishing effort of the bottom trawling for the fleet fishing for deep-water rose shrimp in GSAs 1, 5 and 6.

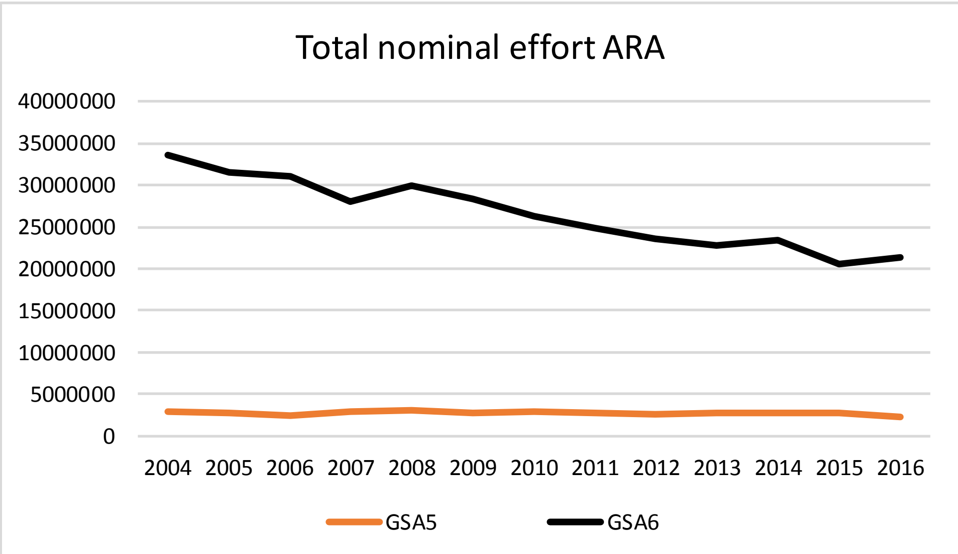


Figure 6.3 – Trends of the nominal fishing effort of the bottom trawling for the fleet fishing for blue and red giant shrimp in GSAs 5 and 6.

6.1.2 *Stock assessment data*

Fishing mortalities per species and areas extracted from Stock Assessments are given in Table 6.1 .

Table 6.1 – Fishing mortalities (F_{bar}) for DPS and ARA in GSAs 1, 5 and 6.

Species	GSA	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
DPS	1			1.35	1.15	1.21	0.63	0.58	0.63	1.04	0.71	0.90	0.87	1.07	0.79	0.78	
DPS	5	1.07	1.14	1.28	0.75	0.24	0.49	0.31	0.46	0.45	1.05	0.84	0.47	0.97	0.97	0.71	0.95
DPS	6	2.86	1.99	2.10	1.30	1.30	1.34	2.00	1.97	1.27	1.51	1.50	1.43	1.33	1.81	1.29	1.73
ARA	5	0.69	0.67	0.74	0.72	1.04	0.66	0.67	0.78	0.79	0.85	0.93	0.77	0.75	0.62	0.80	0.46
ARA	6	1.03	1.44	1.20	1.59	1.29	0.87	0.91	1.27	1.30	1.09	1.15	1.13	0.70	0.90	0.97	0.66

6.1.3 *Fishing mortality – nominal effort relationship*

DPS in GSAs 1 and 5

The relationship between the nominal effort of bottom trawling and the fishing mortality for deep-water rose shrimp in GSA 1 is reported in Figure 6.4 (left). The points are distributed in a cloud of values showing a linear relationship of F and Effort. Given the aggregated level of the data used there is no ability to discriminate factors that lead to varied amounts of fishing effort when the same level of effort is applied. The assessment carried out on this stock indicates a sustainably exploited stock when the optimal harvest rule applies. The lines reported in the graph hypothesize a linear relationship between fishing effort and fishing mortality. The black line represents the linear regression forced to pass from the origin.

On the right is presented the relationship between F and the nominal effort in GSA 5 with all vessel segments combined and it is clear that there is not any correlation when all segments data are aggregated.

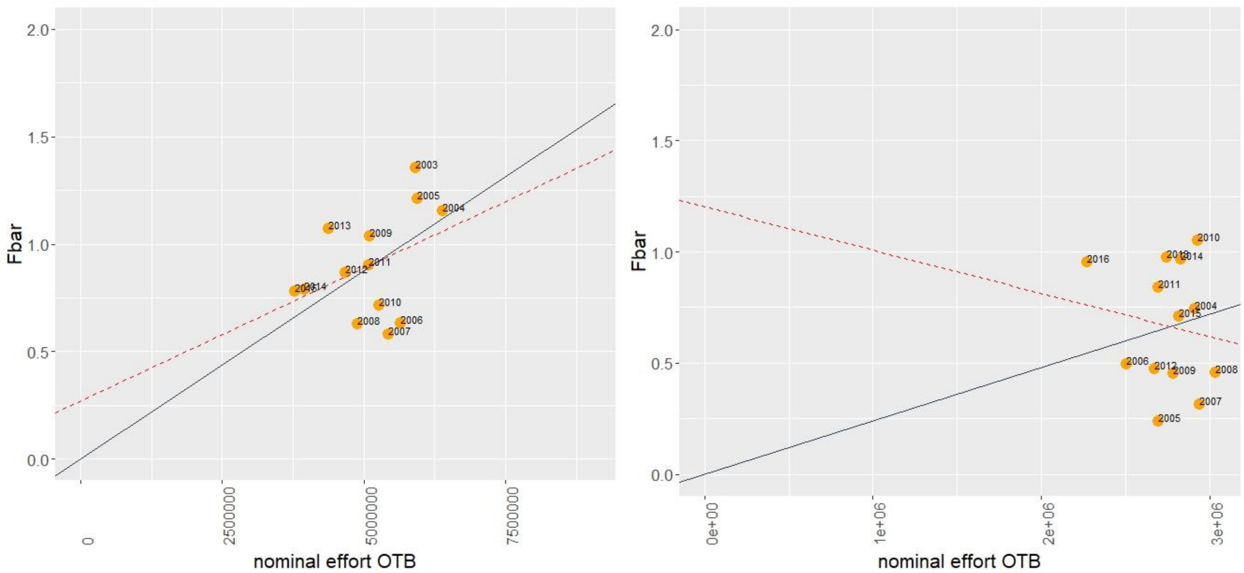


Figure 6.4 – Relationship between total nominal effort and Fbar for DPS in GSA 1 (left) and GSA 5 (right) Red dashed line: linear regression on the observed points. Black line: linear regression forced through the origin.

Primary data will help get an insight of the conditions affecting the results. There was an attempt to perform the same analysis per vessel segment in order to observe correlation properties that each segment presents (Figure 6.5). It is interested to see a more correlated relationship of F to fishing effort for segment VL2440.

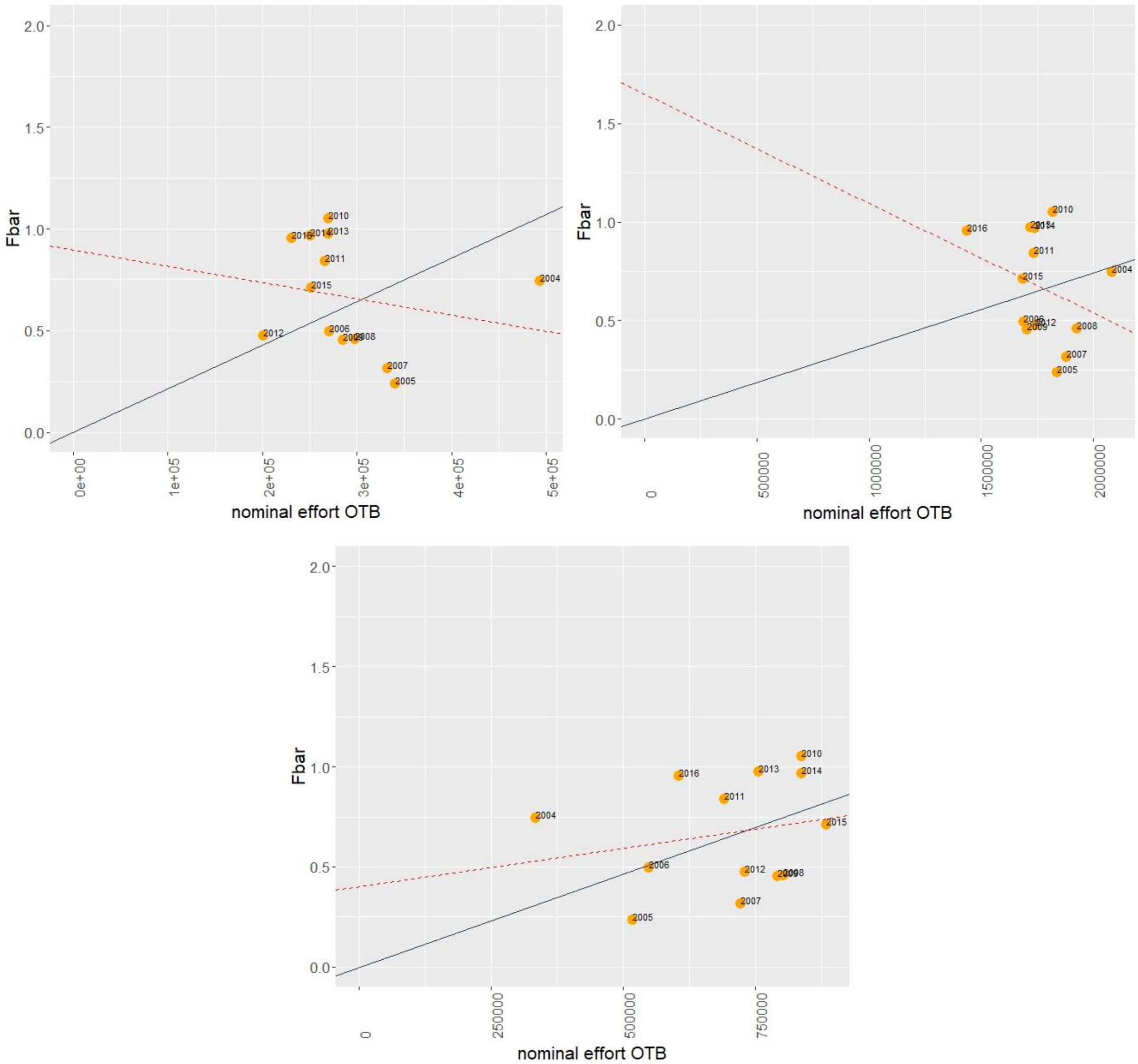


Figure 6.5 – Relationship between total nominal effort and Fbar for DPS in GSA 5. Top left: vessel length segment VL1218. Top right: vessel length segment VL1824. Below: vessel length segment VL2440. Red dashed line: linear regression on the observed points. Black line: linear regression forced through the origin.

ARA in GSAs 5 and 6

In Group 2 of management Unit 1 which corresponds to deep sea fisheries (ARA and ARS) it is very interesting to observe a high correlation of Nominal Effort with F for ARA in GSA 6. This comes in line with the anecdotal operational practice of these fleets that they need to apply a certain effort in order to constitute the grounds productive. Detailed primary data are ofcourse needed to enrich the analysis further in order to spot the specific drivers that create F variations around similar values of Effort. Also, primary data can help discriminate effort data much better, filter out outliers and cross check the results over other parameters and indexes.

It is worth mentioning that this is the only case analyzed in this work with such a clear signal.

The relationships between the nominal effort of bottom trawling and the fishing mortality for blue and red giant shrimp in GSAs 5 and 6 are reported in Figure 6.6 .

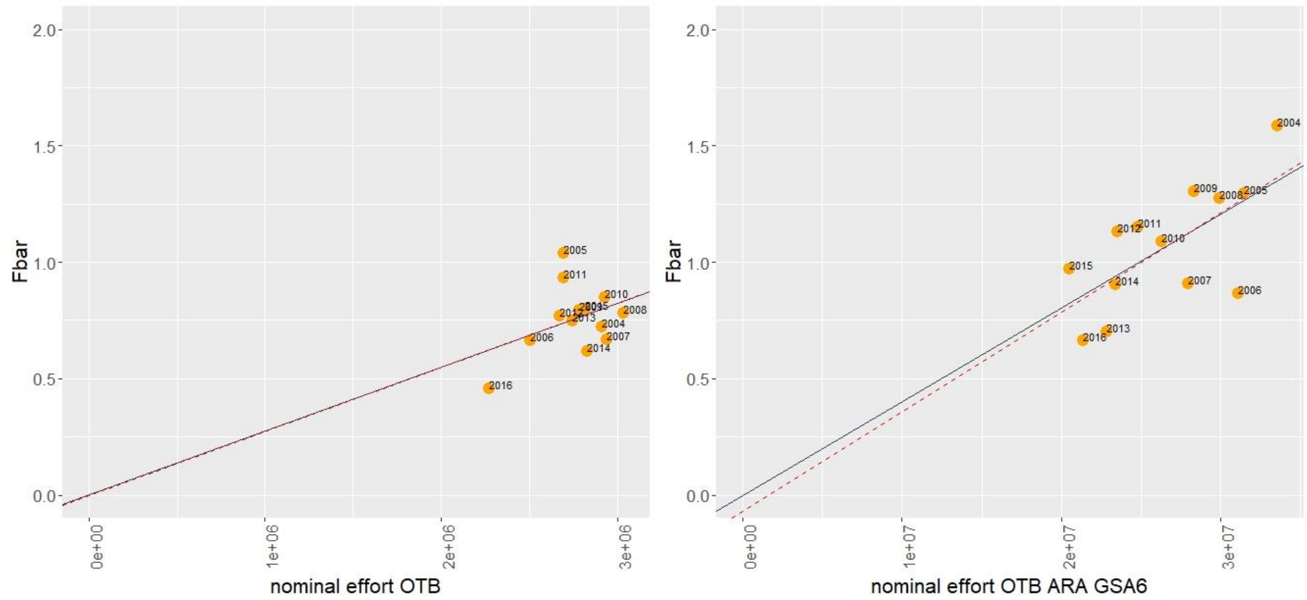


Figure 6.6 – Relationship between total nominal effort and Fbar for ARA in GSA 5 (left) and GSA 6 (right). Red dashed line: linear regression on the observed points. Black line: linear regression forced through the origin.

Eastern GSAs (9-10-11)

The relationship between effort and fishing mortality has been investigated for some selected stocks in western Italian GSAs. The analyses were therefore carried out on the Management Unit 2 including GSAs 9, 10 and 11. Fishing effort was expressed as nominal fishing effort (fishing days x fishing capacity). Fishing mortality was obtained from the last stock assessment performed on the target species by the STECF stock assessment working groups.

During EWG 18-09 the relationship between Fbar and effort was explored using a linear relationship forced through the origin to explore the implications of using a constant proportionality between these two variables.

6.1.4 Trend in nominal effort

The trends of nominal fishing effort for the main gears in the Management Unit 2 are reported in Figure 6.7. Gillnet and trammel net effort showed an evident decreasing trend along the period investigated (2002-2016), with minimum value in 2013 for gillnet and in 2016 for trammel net.

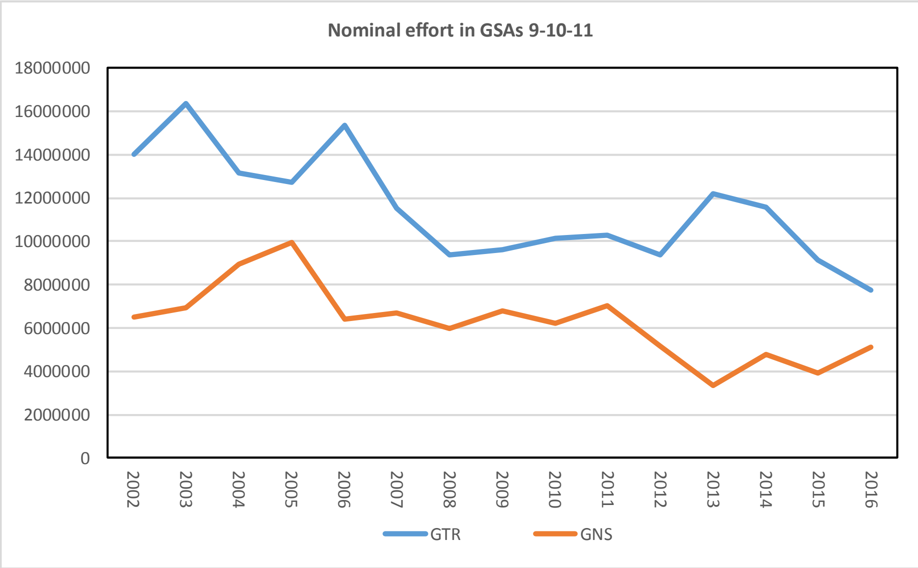


Figure 6.7 – Trends of nominal fishing effort for gillnet (GNS) and trammel net (GTR) fisheries.

Concerning bottom trawling, a notable decreasing trend in fishing effort was observed from 2005 to 2011 (Figure 6.8). In the last years, the effort remained quite constant with small fluctuations. The same trend was observed splitting the effort among the different vessel length segments. The 18-24 and 12-18 segments produced the highest nominal effort in the area.

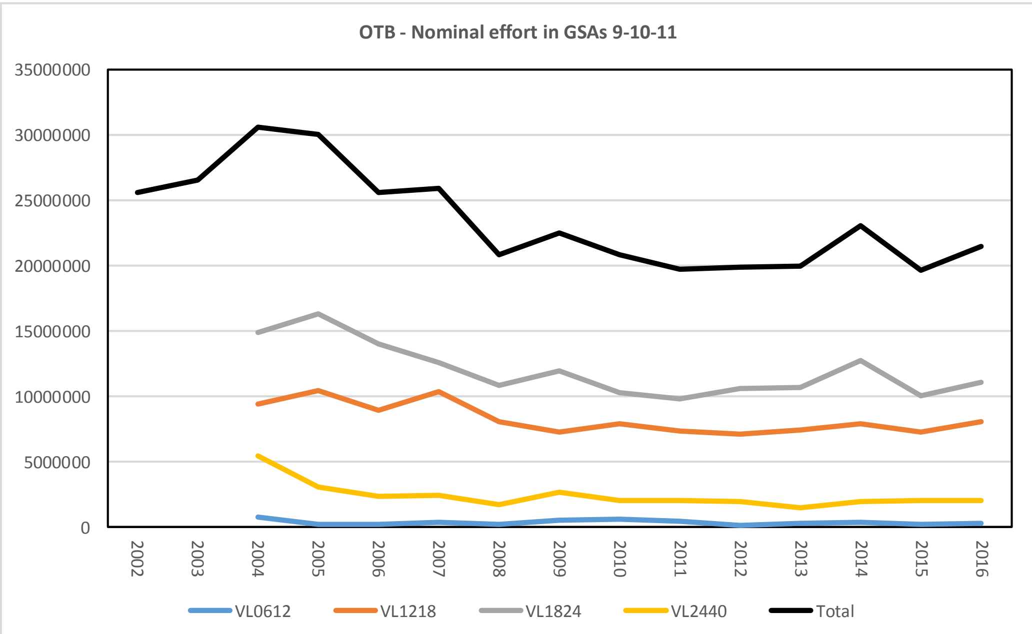


Figure 6.8– Trends of the nominal fishing effort of the bottom trawling for the total fleet and for the vessel length segments.

6.1.5 Stock assessment data

The fishing mortalities for the analysed species are reported in Table 6.2. The fishing mortality for hake was estimated during the EWG15-11 STECF stock assessment for the GSAs 9-10-11 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 during the EWG16-17 STECF stock assessment for the GSAs 9-10-11 combined. The period covered is 2006-2014, the Fbar was computed on the 0-2 age classes.

Estimation of fishing mortality for Norway lobster was done during the EWG16-17 STECF stock assessment for the GSA 9. The period covered is 2005-2015, the Fbar was computed on the 2-6 age classes.

Estimation of fishing mortality for giant red shrimp was done during the EWG15-11 STECF stock assessment for the GSA 9. The period covered is 2006-2014, the Fbar was computed on the 1-3 age classes.

Table 6.2 – Fishing mortalities for the analyzed species.

Species	GSA	Fbar	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
HKE	9,10,11	Fbar1-4		1.22	1.04	1.07	0.89	1.04	1.22	0.97	0.85	1.05	
DPS	9,10,11	Fbar0-2		1.08	0.78	0.64	0.54	0.59	0.56	0.80	0.77	0.83	0.87
NEP	9	Fbar2-6	0.574	0.48	0.64	0.51	0.64	0.44	0.51	0.54	0.52	0.42	0.34
ARS	9	Fbar1-3		0.59	0.52	0.65	0.67	0.65	0.59	0.63	0.32	0.13	

6.1.6 *Fishing mortality – nominal effort relationship*

Hake in GSAs 9-10-11

In Figure 6.9 is reported the relationship between the nominal effort of bottom trawling and gillnets and the fishing mortality for hake in GSAs 9-10-11 combined. The red dashed line is the regression between F and effort data for the period 2006-2014, whilst the black line is the regression forced through the origin. Only the latter one was significant ($p<0.01$; $R^2>0.98$). The poor contrast in the time series can be probably the main reason explaining the lack of a relationship between F and effort. with fishing mortality that does not seem to have substantially declined as effect of the observed effort reduction.

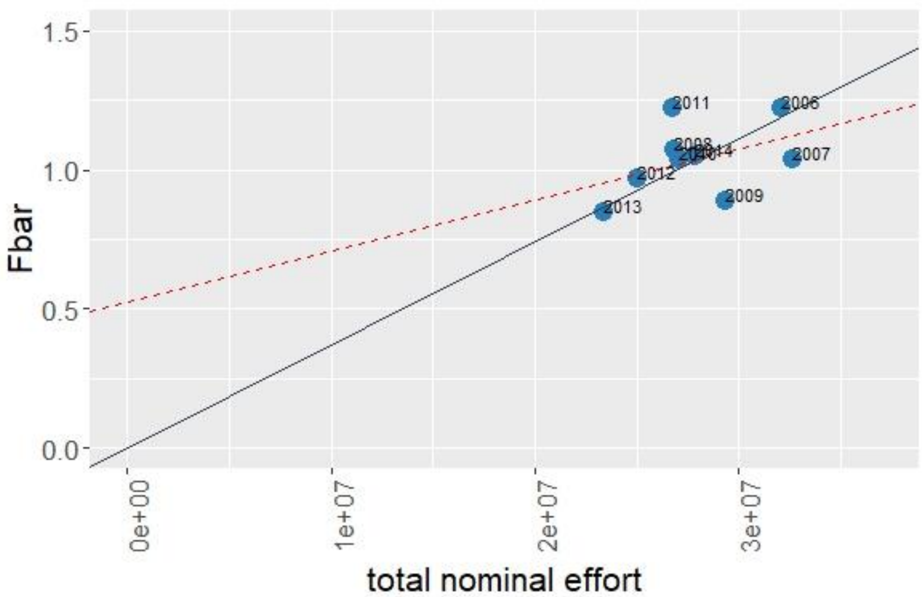


Figure 6.9 – Relationship between total nominal effort and Fbar for hake in GSAs 9-10-11. Red dashed line: linear regression on the observed points. Black line: linear regression forced through the origin.

In a next step, the partial annual F due to the two main trawl segments exploiting hake, the 18-24 m LOA and 12-18m LOA was calculated as follows:

F_{18-24}= F*(catchF_{18-24}/total catch)

F_{12-18}= F*(catch F_{12-18}/total catch)

where F in the mean fishing mortality in th year I and catch F_{18-24} and $catch_{12-18}$ is the catch due to the two trawl segment. Annual partial F values were calculated separately for the three GSAs and their linear relationships with the corresponding partial nominal effort (i.e. the effort due to each trawl segment in each GSA) explored.

<u>Partial F for bottom trawling of 18-24 length segment.</u>

The relationships between partial F and effort of the 18-24m trawlers was then explored by GSA and combining the values from the three areas as shown inFigure 6.10 . The black dashed line is the linear regression over all the F/effort points. The colured lines are the linear regressions of each GSA separately. The pooled linear regression was significant ($p<0.01$ and $R^2=0.55$) indicating that the effect of effort on F seems to be similar in the three areas. When the three GSAs are examined separately, the F/effort relationship disappear for GSA 9 where the high level of effort generate more variability in F, whilst it appears more consistent at low effort levels in GSA 10 and 11.

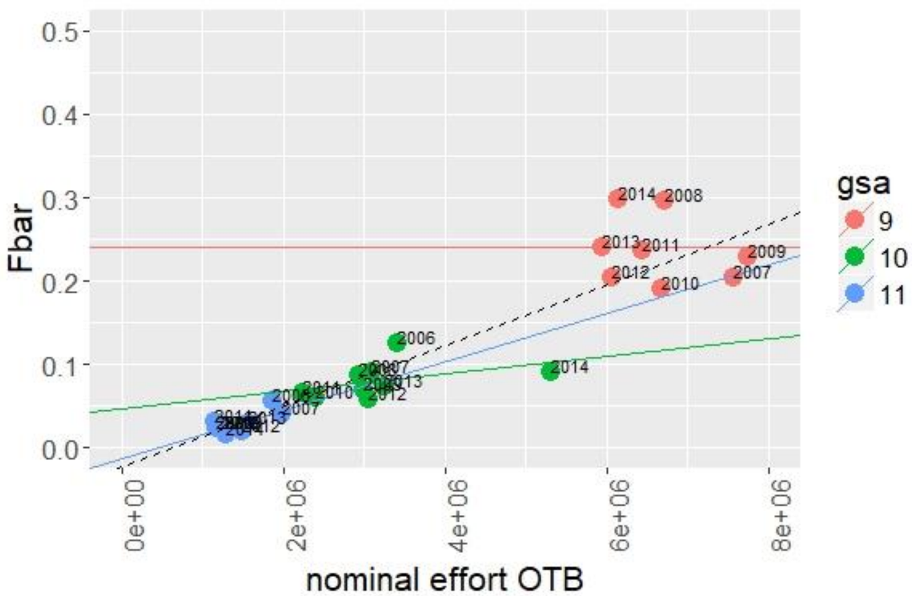


Figure 6.10 – Relationship between nominal effort for the 18-24 vessels length segment and Fbar for hake in GSAs 9-10-11. Black dashed line: linear regression for GSAs 9-10-11 combined. Red line: linear regression for GSA 9. Green line: linear regression for GSA 10. Blue line: linear regression for GSA 11.

<u>Partial F for bottom trawling of 12-18 length segment.</u>

Trawlers between 12 and 18 m LOA produced low annual catches and therefore lower F compared with the 18-24 segment. The relationship between F and effort is similar in GSA 9 and 10 (i.e. similar effort values produced similar F values) with GSA 11 trawlers again producing lower catches and F (Figure 6.11).

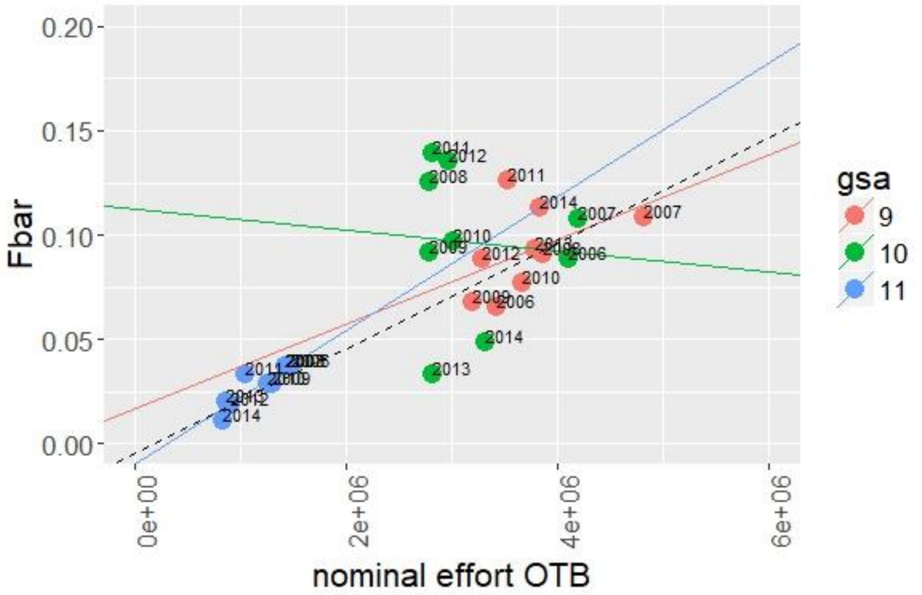


Figure 6.11 – Relationship between nominal effort for the 12-18 vessels length segment and Fbar for hake in GSAs 9-10-11. Black dashed line: linear regression for GSAs 9-10-11 combined. Red line: linear regression for GSA 9. Green line: linear regression for GSA 10. Blue line: linear regression for GSA 11.

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

The relationship between F and effort for *Parapenaeus longirostris* in GSA 9 shows that F can range in a wide range for the same effort values (Figure 6.12). It is well known in GSA 9 that the dynamic of this stock is strongly driven by climate with a positive effect of the warming trend (Ligas et al., 2011; Colloca et al., 2014).

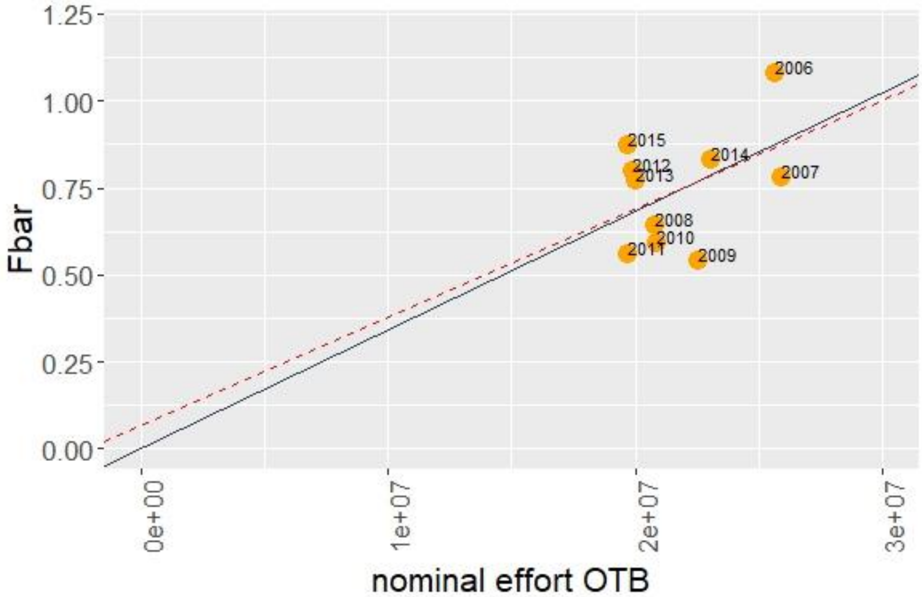


Figure 6.12 – Relationship between total nominal effort and Fbar for deep-water rose shrimp in GSA 9. Red line: linear regression through the observed values. Black dashed line: linear regression forced to pass from the origin.

Norway lobster in GSA 9

Also in this case the relationship between F and effort is not significant with the F_{2-6} ranging between 0.35 and 0.60 independently by the nominal effort (Figure 6.13).

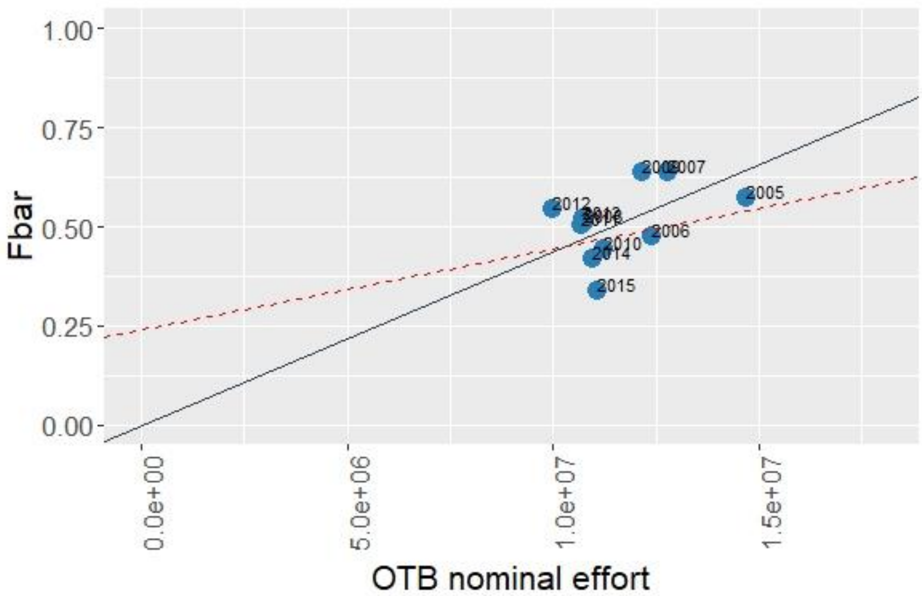


Figure 6.13 – Relationship between total nominal effort and Fbar for Norway lobster in GSA 9. Red line: linear regression. Black line: linear regression forced to pass from the origin.

Giant red shrimp in GSA 9

The Fbar of *Aristaemorpha foliacea* was compared with the nominal effort of the deep water trawling in GSA 9 (Figure 6.14). The large reduction in effort observed between 2006-20207 and 2008-2014 did not led to a corresponding reduction in F.

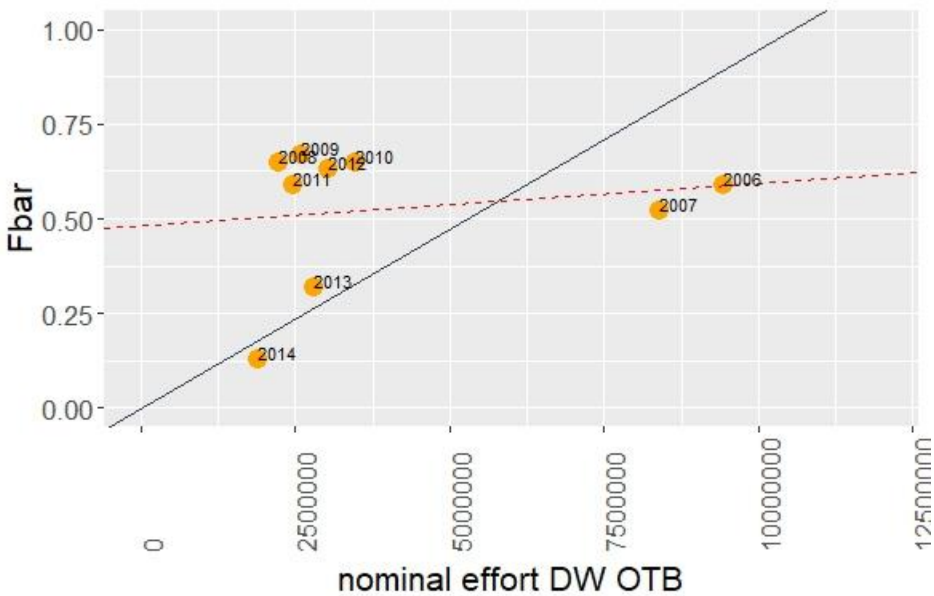


Figure 6.14 – Relationship between nominal effort for bottom trawling deep fishery and Fbar for Giant red shrimp in GSA 9. Red line: linear regression on the observed points. Black dashed line: linear regression forced to pass from the origin.

5.5 Conclusions

The average fishing mortality values of the main demersal stocks in western Mediterranean are not generally correlated to the nominal effort exerted by the trawl fleets exploiting the stocks.

The lack of a significant relationship between F and effort was already observed by Cardinale et al. (2017) 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. A more accurate measure of the fishing time (*e.g.* fishing hours) would be probably necessary to measure fishing effort. Finally, the environmental variability increases the noise especially for short life species such as DPS whose catch is strongly dependent by recruitment. However, the example for *Aristeus antennatus* in GSA 6 is promising because it shows that when a substantial reduction in effort is applied (about 30% between 2004-2005 and 2015-2016) the F displayed a substantial decreasing. Also in the case of hake in GSAs 9-10-11, the lowest F values were obtained in GSAs 10 and 11 featured by lowest effort values if compared with GSA 9. The same exercise should be replicate with assessments for the main target stocks updated with 2016 and 2017 data to incorporate the more recent trend in F and effort.

7 ToR 5 Bioeconomic simulations

Several existing models developed and used for other purposes have been used for ToR5, one for each of the three GSA 6 (MEFISTO model, CSIC), 7 (IAM, IFREMER) and 9 (NISEA model).

MEFISTO Mediterranean Fisheries SimulationTool applied to demersal fisheries in GSA 6 - Northern Spain

MEFISTO is a multi-species, multi-fleet bioeconomic 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 submodel, that simulates the dynamics of the stock, and an economic submodel. In MEFISTO the link between the economic submodel and the biological submodel is made through the fishing mortality vector, which can vary endogenously following certain behavioural 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). It has been applied to Mediterranean fisheries (e.g. Maynou *et al.* 2006; Merino *et al.* 2015; Guillén *et al.* 2012).

MEFISTO is a useful simulation tool in the context of mixed fisheries as it allows knowing the response of the stocks to different management measures. During the simulations the economic module of MEFISTO was disabled. Capacity reduction was simulated as fishing days reduction.

The scenarios tested were:

Scenario	
1	5% capacity reduction in yr 1 + 10% fishing days reduction in yr 1,2 and 3
2	10% capacity reduction in yr 1 + 10% fishing days reduction in yr 1,2 and 3
3	10% capacity reduction in yr 1 + 20% fishing days reduction in yr 1,10% in yr 2 and 3

MEFISTO start-up requires the establishment of an initial stock situation. 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, or when the species had not been previously assessed, these three assessed years were generated with pseudo-cohort analysis (VIT; Lleonart and Salat 1997). $F_{0.1}$ resulting from Yield per Recruit analysis was taken as a proxy for F_{MSY}. Recruitment was assumed constant during the simulation period. The simulations duration was 15 years and the model initialization i.e. time required to rebuild the spawning stock biomass (SSB), was set to 15 years. Thus, simulation starts in 2018 and run to 2032 (2030 corresponds to year 13 in the figures below).

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; results not presented). 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* (MUR), deep water rose shrimp *Parapenaeus longirostris* (DPS), anglerfish *Lophius piscatorius* MON), black-bellied angler *Lophius budegassa* (ANK), greater forkbeard *Phycis blennoides* (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.

COM(2018) 115 final "Proposal for a multi-annual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea" applies to the following stocks in GSA 6: *Aristeus anntenatus, Parapenaeus longirostris, Merluccius merluccius, Mullus barbatus* and *Nephrops norvegicus*. These four stocks are among those selected for the MEFISTO simulations.

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 (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.

Within a gear, the catch of a species obtained by each fleet segment is different. The fleet segments as defined in the DCF are based on the length overall (LOA) and are the following: VL0612 (6-12 m LOA), VL1218 (12-18 m LOA), VL1824 (18-24 LOA) and VL2440 (24-40 m LOA). The EC Fleet Register specifies the characteristics of each vessel (http://ec.europa.eu/fisheries/fleet/index.cfm). Based on the overall vessel length each vessel was assigned to its corresponding fleet segment. Fleet as used here corresponds to the combination of gear and fleet segment. A total of seven fleets were considered, 3 bottom otter trawl (OTB), 2 longline (LL) and 2 GTN (gillnet and trammel net). Fishing mortality by species and fleet was calculated from the total fishing mortality F taken from the stock assessment and the corresponding landings by species and fleet. The economic transversal data were used for this calculation (https://stecf.jrc.ec.europa.eu/web/stecf/reports/economic).

The proposed management scenarios represent a reduction of fishing days by 35%, 43% and 51% respectively in scenarios 1, 2 and 3.

	Fishing days in year 3						
	sq	Scenario 1	reduction (%)	Scenario 2	reduction (%)	Scenario 3	reduction (%)
OTB-VL1218	180	117	0.35	102	0.43	87	0.51
OTB-VL1824	190	123	0.35	108	0.43	92	0.51
OTB-VL2440	210	136	0.35	119	0.43	102	0.51

Stocks and fleets (combination gear-fleet segment) considered in the simulations run with MEFISTO in GSA 6.

Species Code	Scientific name	Fleets
ANK	*Lophius budegassa*	OTB-VL1218
ARA	*Aristeus antennatus*	OTB-VL1824
DPS	*Parapenaeus longirostris*	OTB-VL2440
GFB	*Phycis blennoides*	LL-VL0612
HKE	*Merluccius merluccius*	LL-VL1218
LDB	*Lepidorhombus boscii*	GN-VL0612
MON	*Lophius piscatorius*	GN-VL1218
MUR	*Mullus surmuletus*	
MUT	*Mullus barbatus*	
NEP	*Nephrops norvegicus*	

Length-weight relationship and growth parameters used in the simulations, the same as in the assessements.

Stockname	a	b	Linf	K	t0	Reference
ANK	0.0232	2.85	102.0	0.15	-0.05	STECF (2015b)
ARA	0.0020	2.51	77.0	0.38	-0.07	STECF (2015a)
DPS	0.0031	2.49	45.0	0.39	0.00	STECF (2013a)
GFB	0.0034	3.25	49.3	0.31	-0.09	STECF (2013b) (GSA09)
HKE	0.0068	3.04	110.0	0.18	0.00	STECF (2015a)
LDB	0.0643	2.27	45.6	0.15	-0.59	Landa *et al.* 2011
MON	0.0182	2.93	140.0	0.11	-0.70	STECF (2017)
MUR	0.0084	3.12	40.1	0.16	-1.88	STECF (2014) (GSA05)
MUT	0.0062	3.16	34.5	0.34	-0.14	GFCM (2015)
NEP	0.0010	3.08	74.1	0.17	0.00	STECF (2016)

Recruitment timing in GSA 6, by species and month, expressed in percentage.

	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
1	0.24	0.00	0.22	0.00	0.01	0.00	0.23	0.00	0.00	0.00
2	0.23	0.00	0.28	0.00	0.01	0.00	0.27	0.00	0.00	0.00
3	0.15	0.00	0.28	0.00	0.01	0.00	0.27	0.00	0.00	0.00
4	0.00	0.15	0.22	0.00	0.01	0.00	0.23	0.00	0.00	0.00
5	0.00	0.23	0.00	0.22	0.01	0.23	0.00	0.00	0.00	0.23
6	0.00	0.24	0.00	0.28	0.01	0.27	0.00	0.00	0.00	0.27
7	0.00	0.23	0.00	0.28	0.22	0.27	0.00	0.00	0.00	0.27
8	0.00	0.15	0.00	0.22	0.24	0.23	0.00	0.00	0.00	0.23
9	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.30	0.30	0.00
10	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.40	0.40	0.00
11	0.15	0.00	0.00	0.00	0.01	0.00	0.00	0.30	0.30	0.00
12	0.23	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00

F_{MSY} estimated in the assessments. These F_{MSY} values are used as reference for the calculation of the ratio F/F_{MSY} resulting from the different MEFISTO scenarios. $F_{0.1}$ is used as a proxy of F_{MSY}.

Species Code	Scientific name	FMSY(F0.1 YperR)	Assessment Method	References
ANK	Lophius budegasa	0.14	XSA	STECF (2015b)
ARA	Aristeus antennatus	0.36	XSA	STECF (2015a)
DPS	Parapenaeus longirostris	0.269	XSA	STECF (2013a)
GFB	Phycis blennoides	0.78	VIT	This study
HKE	Merluccius merluccius	0.26	XSA	STECF (2015a)
LDB	Lepidorhombus boscii	0.903	VIT	This study
MON	Lophius piscatorius	0.467	VIT	This study
MUR	Mullus surmuletus	0.663	VIT	This study
MUT	Mullus barbatus	0.449	XSA	GFCM (2015)
NEP	Nephrops norvegicus	0.175	XSA	STECF (2016)

7.1.1 Results of the simulations

Results of the simulations under scenarios 1 (Figure 7.1), 2 (Figure 7.2) and 3 (Figure 7.3) are shown below: catches (t), $F_{(bar\text{-}catch)}$, mean biomass (t) and SSB (t). Year 4 corresponds to the situation after the implementation of fishing effort reduction in the previous three years, as defined in the three scenarios. Year 13 corresponds to the situation in 2030.

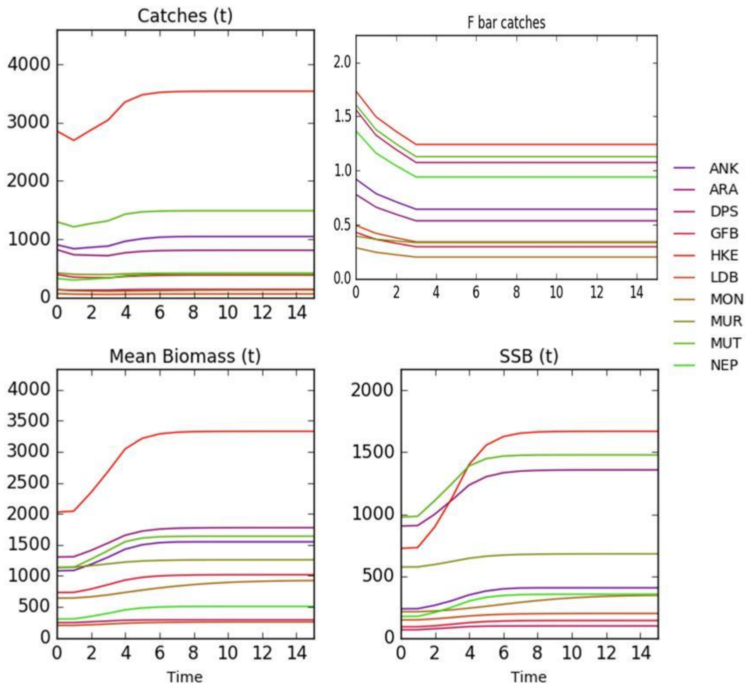


Figure 7.1 Scenario 1

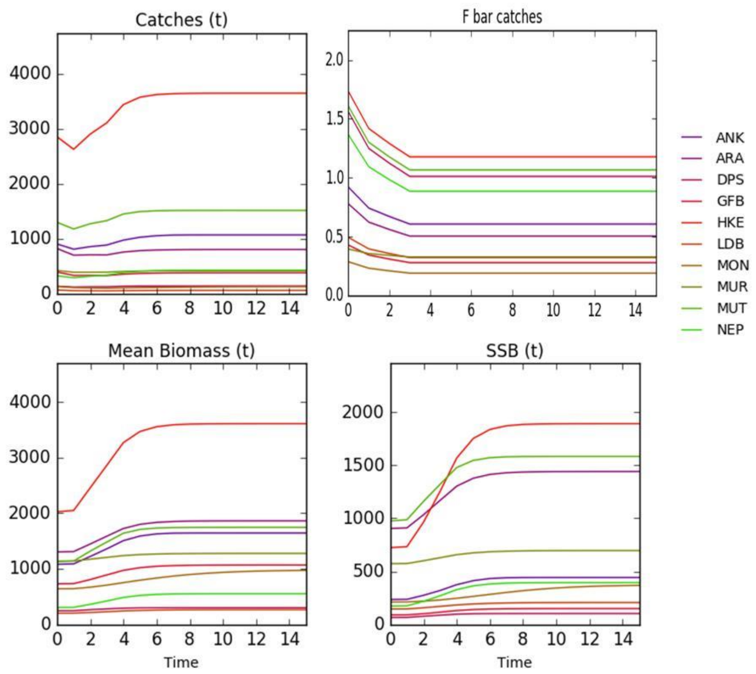


Figure 7.2 Scenario 2

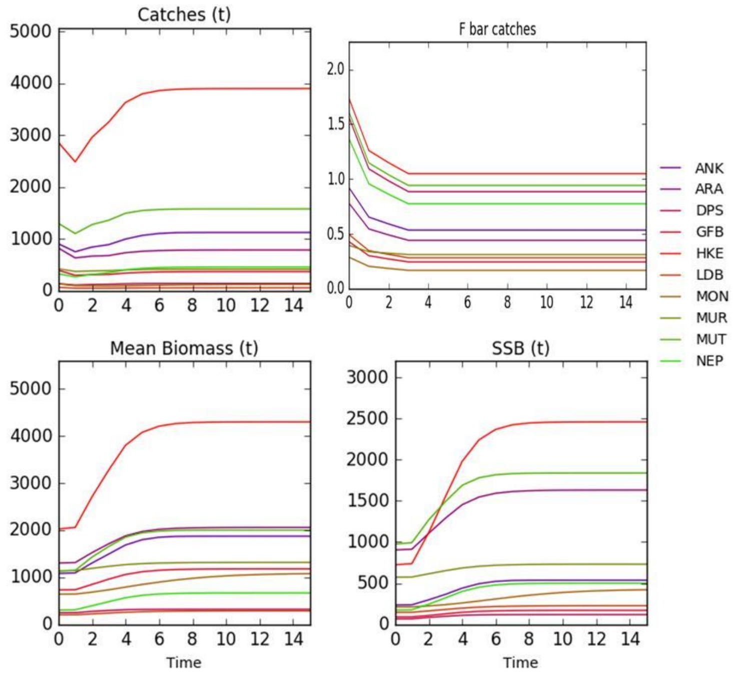


Figure 7.3 Scenario 3

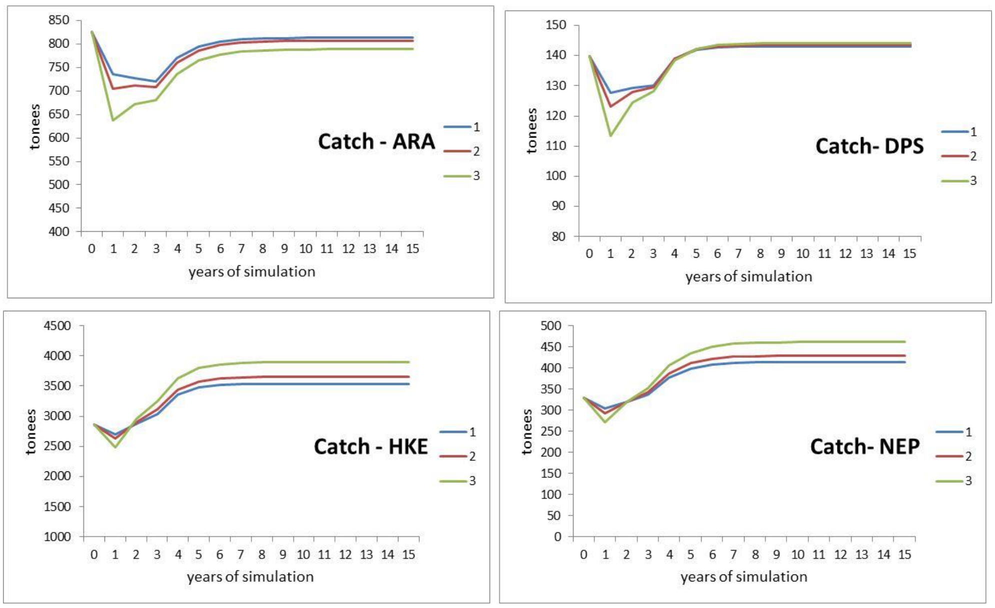


Figure 7.4 Results of the simulations of catch for Aristeus antennatus (ARA), Parapenaeus longirostris (DPS), Merluccius merluccius (HKE) and Mullus barbatus (MUT) in GSA 6

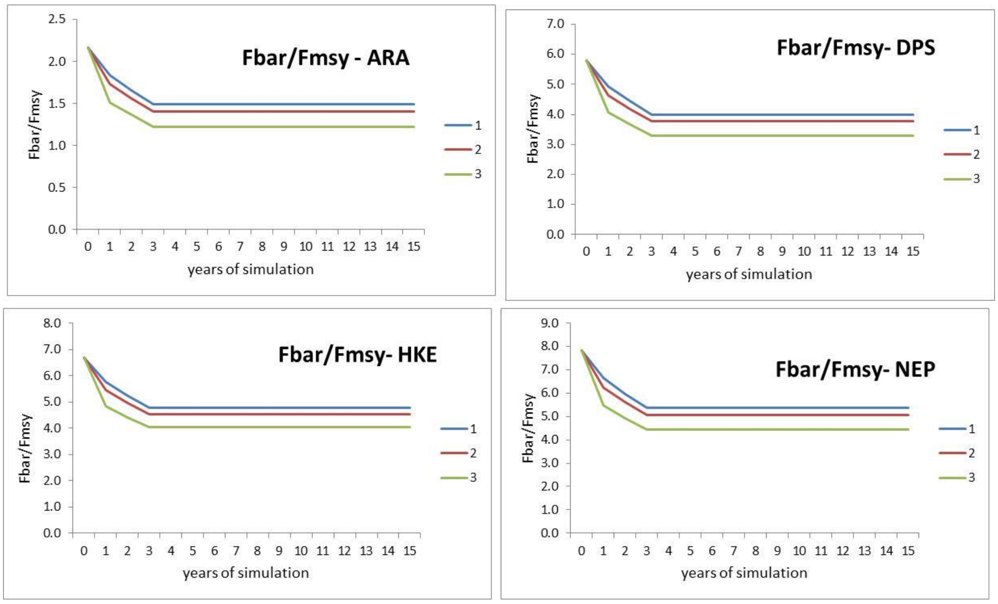


Figure 7.5 Results of the simulations of fishing mortality relative to FMSY (Fbar/F0.1) for Aristeus antennatus (ARA), Parapenaeus longirostris (DPS), Merluccius merluccius (HKE) and Mullus barbatus (MUT) in GSA 6.

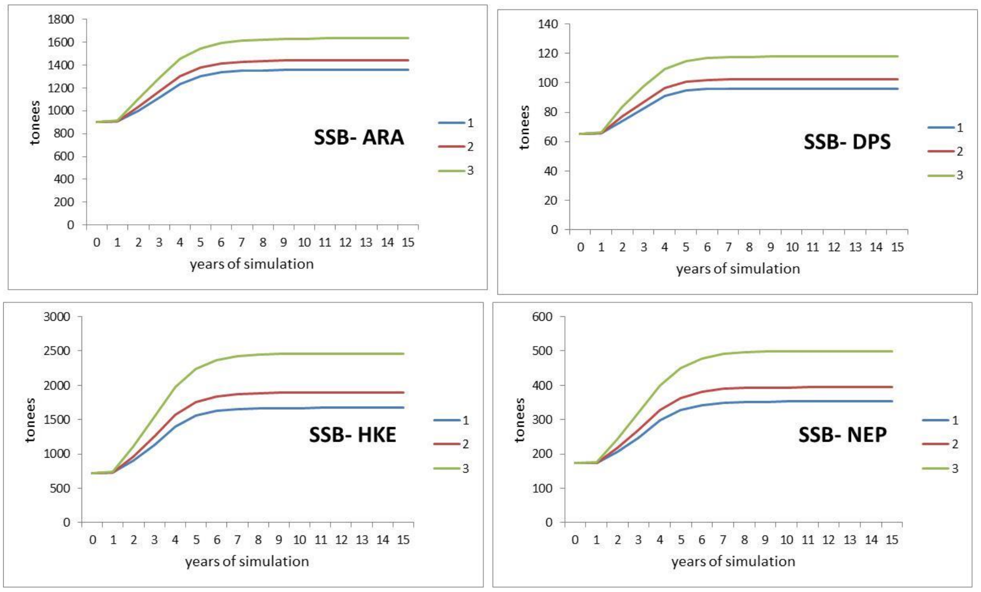


Figure 7.6 Results of the simulations of SSB for Aristeus antennatus (ARA), Parapenaeus longirostris (DPS), Merluccius merluccius (HKE) and Mullus barbatus (MUT) in GSA 6

The stock response is for an increase in catches after a decrease during the three years of implementation of effort reduction (years 1 to 3), except in the case of *Aristeus antennatus*, confirming the characteristic specialization of this fishery. This stock is targeted by the largest trawlers (VL24-40). As expected, scenario 3, with the strongest fishing effort reduction, would lead to the lowest values F/F_{MSY} and highest SSB. Results from scenarios 1 and 2 are quite similar.

Table 7.1 Fisheries indicators: catch.

CATCH (tonnes)

Scenario 1	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	908	825	140	398	2858	70	137	425	1301	329
1	839	736	128	352	2694	62	120	401	1214	303
2	862	728	129	345	2872	59	113	398	1271	319
3	884	720	130	340	3040	57	108	397	1316	337
4	966	770	139	364	3352	60	113	409	1431	378
5	1011	795	142	377	3475	62	117	416	1471	399
6	1036	805	143	383	3516	64	120	419	1484	408
7	1046	810	143	386	3530	64	124	421	1488	412
8	1048	812	143	388	3534	65	127	422	1489	413
9	1048	813	143	388	3536	65	129	422	1489	414
10	1048	813	143	389	3536	65	131	422	1489	414
11	1048	813	143	389	3536	65	131	423	1489	414
12	1048	813	143	389	3536	65	132	423	1489	414
13	1048	813	143	389	3536	65	133	423	1489	414
14	1048	813	143	389	3536	65	133	423	1489	414
15	1048	813	143	389	3536	65	133	423	1489	414
Scenario 2	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	908	825	140	398	2858	70	137	425	1301	329
1	813	704	123	336	2629	59	114	393	1181	293
2	859	711	128	335	2905	57	108	394	1276	320
3	888	709	130	334	3111	56	104	395	1333	343
4	978	761	139	358	3442	59	109	408	1453	387
5	1030	787	142	372	3577	61	113	415	1497	411
6	1058	798	143	379	3625	62	117	419	1512	422
7	1070	803	143	382	3641	63	121	420	1516	426
8	1072	805	143	383	3647	63	125	421	1518	428
9	1072	806	143	384	3649	63	127	422	1518	428
10	1072	807	143	384	3649	64	129	422	1518	429
11	1072	807	143	385	3650	64	130	422	1519	429
12	1072	807	143	385	3650	64	130	422	1519	429
13	1072	807	143	385	3650	64	131	422	1519	429
14	1072	807	143	385	3650	64	131	422	1519	429
15	1072	807	143	385	3650	64	131	422	1519	429
Scenario 3	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	908	825	140	398	2858	70	137	425	1301	329
1	755	637	113	302	2485	52	102	377	1106	272
2	845	671	124	314	2957	53	99	385	1277	319
3	892	681	128	318	3252	52	96	391	1362	353
4	999	736	138	344	3630	56	102	405	1496	405
5	1070	765	142	359	3795	58	106	413	1549	435
6	1107	778	143	366	3858	59	111	416	1569	450
7	1122	784	144	370	3882	60	116	419	1576	457
8	1125	787	144	372	3891	60	119	420	1578	460
9	1126	788	144	373	3895	61	122	420	1579	461
10	1126	789	144	373	3896	61	124	420	1580	461
11	1126	789	144	373	3896	61	125	420	1580	461
12	1126	789	144	374	3897	61	126	420	1580	461
13	1126	789	144	374	3897	61	127	421	1580	461
14	1126	789	144	374	3897	61	127	421	1580	461
15	1126	789	144	374	3897	61	127	421	1580	461

Table 7.2 Fisheries indicators: fishing mortality relative to FMSY (F/FMSY). F_{bar} and $F_{0.1}$ taken as proxies of F_{MSY}, were used for the calculation of F/F_{MSY}

	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
FMSY(F0.1 YperR)	0.14	0.36	0.269	0.78	0.26	0.903	0.467	0.663	0.449	0.175

Scenario 1	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	6.578	2.164	5.803	0.550	6.669	0.547	0.614	0.595	3.583	7.808
1	5.622	1.839	4.932	0.468	5.757	0.465	0.526	0.552	3.069	6.637
2	5.080	1.655	4.439	0.422	5.240	0.420	0.476	0.527	2.777	5.973
3	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
4	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
5	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
6	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
7	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
8	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
9	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
10	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
11	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
12	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
13	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
14	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376
15	4.593	1.490	3.995	0.380	4.775	0.378	0.431	0.505	2.514	5.376

Scenario 2	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	6.578	2.164	5.803	0.550	6.669	0.547	0.614	0.595	3.583	7.808
1	5.303	1.731	4.642	0.441	5.453	0.438	0.497	0.538	2.897	6.247
2	4.794	1.558	4.178	0.397	4.966	0.395	0.449	0.514	2.622	5.622
3	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
4	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
5	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
6	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
7	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
8	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
9	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
10	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
11	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
12	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
13	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
14	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060
15	4.335	1.402	3.760	0.358	4.528	0.356	0.407	0.494	2.375	5.060

Scenario 3	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	6.578	2.164	5.803	0.550	6.669	0.547	0.614	0.595	3.583	7.808
1	4.666	1.515	4.062	0.386	4.844	0.384	0.438	0.509	2.554	5.466
2	4.220	1.363	3.656	0.348	4.419	0.347	0.396	0.488	2.314	4.919
3	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
4	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
5	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
6	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
7	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
8	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
9	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
10	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
11	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
12	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
13	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
14	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427
15	3.818	1.227	3.290	0.314	4.036	0.312	0.359	0.470	2.097	4.427

Table 7.3 Fisheries indicators: SSB (tonnes)

SSB

Scenario 1	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	234	904	65	89	723	145	211	572	975	173
1	236	908	66	89	730	146	211	573	983	174
2	263	1000	74	97	898	154	217	593	1110	205
3	301	1114	82	110	1131	165	226	618	1247	248
4	347	1235	91	123	1401	177	240	644	1390	298
5	379	1303	95	132	1558	185	255	660	1449	328
6	396	1334	96	136	1627	191	271	669	1469	343
7	403	1348	96	138	1654	194	287	674	1476	349
8	404	1354	96	139	1664	195	301	677	1478	351
9	404	1356	96	140	1668	196	313	678	1478	352
10	404	1357	96	140	1669	197	323	678	1479	352
11	404	1357	96	140	1669	197	330	679	1479	353
12	404	1357	96	140	1669	197	336	679	1479	353
13	404	1358	96	140	1669	197	340	679	1479	353
14	404	1358	96	140	1669	197	342	679	1479	353
15	404	1358	96	140	1669	197	344	679	1479	353
Scenario 2	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	234	904	65	89	723	145	211	572	975	173
1	236	909	66	89	733	146	212	574	986	175
2	274	1034	77	100	964	157	219	600	1160	217
3	320	1169	87	115	1255	170	230	628	1321	270
4	374	1303	97	130	1568	183	246	657	1478	327
5	412	1378	100	140	1752	193	264	674	1546	363
6	432	1413	102	145	1837	198	283	684	1571	381
7	440	1429	102	147	1872	202	301	690	1579	389
8	442	1436	102	148	1884	204	318	693	1582	392
9	442	1439	102	149	1889	205	332	694	1583	393
10	442	1440	102	149	1890	205	343	695	1583	394
11	442	1440	102	149	1891	206	352	695	1583	394
12	442	1441	102	149	1891	206	358	695	1583	394
13	442	1441	102	149	1891	206	362	695	1583	394
14	442	1441	102	149	1891	206	365	695	1583	394
15	442	1441	102	149	1891	206	367	695	1583	394
Scenario 3	ANK	ARA	DPS	GFB	HKE	LDB	MON	MUR	MUT	NEP
0	234	904	65	89	723	145	211	572	975	173
1	237	912	66	90	737	146	212	574	992	176
2	297	1105	84	106	1112	163	223	614	1268	244
3	363	1289	97	127	1550	180	238	651	1491	321
4	439	1453	109	146	1979	197	259	684	1689	400
5	493	1546	115	157	2241	208	283	705	1781	451
6	522	1592	117	163	2369	216	308	717	1818	478
7	532	1614	117	167	2424	220	332	724	1831	491
8	535	1623	118	168	2446	223	353	727	1836	496
9	536	1628	118	169	2455	224	372	729	1838	498
10	536	1630	118	169	2458	225	387	730	1838	499
11	536	1631	118	169	2459	225	398	730	1838	500
12	536	1631	118	169	2459	226	406	730	1839	500
13	536	1631	118	169	2460	226	412	731	1839	500
14	536	1631	118	169	2460	226	417	731	1839	500
15	536	1631	118	169	2460	226	419	731	1839	500

MEFISTO allows user-defined models for recruitment. The relationship SSB-R was explored based on the most recent available assessments. Since no clear pattern was observed, the simulations were run assuming constant recruitment. The examples below correspond to stocks included in the proposal for the establisment of a multi-annual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea.

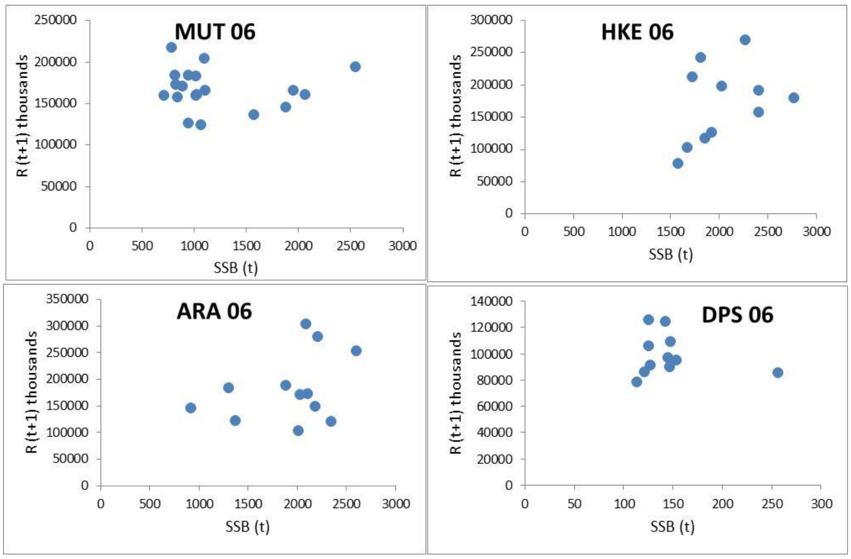


Figure 7.7 Fisheries indicators: Recruitment

SSB (t) and Recruitment (t+1) relationship of *Mullus barbatus* (MUT), *Merluccius merluccius* (HKE), *Aristeus antennatus* (ARA) and *Parapenaeus longirostris* (DPS) is GSA 6 taken from the most recent available stock assessments.

7.1.2 Further work:

In future simulations MEFISTO should include economic indicators and stochasticity.

Outputs from an IAM model applied to the French fisheries in the Gulf of Lions (GSA 7)

7.1.3 IAM model setup

This section presents the current application of the IAM model to the French fisheries of the Gulf of Lions. To note that the application has not been developed in the context of the STECF EWG 18-09, therefore the structure of the model and the scenarios simulated do not correspond exactly to the requirements of the TOR 5 of this working group.

The Impact Assessment bio-economic Model for fisheries management (IAM) has been built to assess biological and socio-economic impacts of scenarios of:

- Fisheries management,

- Evolution of the economic context (variation of input or output prices),

- Evolution of the environmental context (variation in recruitment…).

IAM is an integrated multi-species and multi-fleets model coupling biological dynamics of fish stocks with economic dynamics. The model estimates for each scenario the impacts of management scenarios in terms of F, SSB, Biomass, total catches, catches, gross revenue, and gross cash flow by fleet and per year. See Merzéréaud et al. (2011) and Macher et al. (2011) for more details on the structure and characteristics of the model and Raveau et al. (2012), Guillen et al. (2013, 2014, 2016) and Bellanger et al, (in press) for example of applications.

7.1.4 Species and fleets

The IAM model has been applied to the French fisheries of the Gulf of Lions (GSA 7) in Western Mediterranean Sea. It is important to note that this application is at a preliminary stage and have to be further developed and updated.

7.1.4.1 Selected Species

The model focuses on Hake (*Merluccius merluccius*), Sardine (*Sardina pilchardus*) and Anchovy (*Engraulis encrasicolus*). Hake is represented through an explicit age-structured population dynamic based on GFCM stock assessment (GFCM, 2016), while Sardine and Anchovy are static species.

7.1.4.2 Selected Fleets

The aggregation of the vessels used in this model is based on the Ifremer segmentation named "FLOTILLE_RESTIT" (Macher et al., 2015). This segmentation is based on the activity (i.e. "metiers" used), fishing zone (i.e. "rayon d'action") and the length class of the vessels. It corresponds to aggregation of vessels with homogeneous fishing strategies, cost structure and revenues.

The fleets that are explicitly modelled in IAM have been selected according to their contribution and dependency on catches of Hake, Sardine and Anchovy, but also according to economic data available.

- The 7 selected fleets are listed below:
- 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

7.1.4.3 Contribution to landings

Figure 7.8 summarizes the technical interactions taken into account in the model between species and fleets. It shows the repartition of the 2015 landings between fleets. These data were used to calibrate the fishing mortalities within the model.

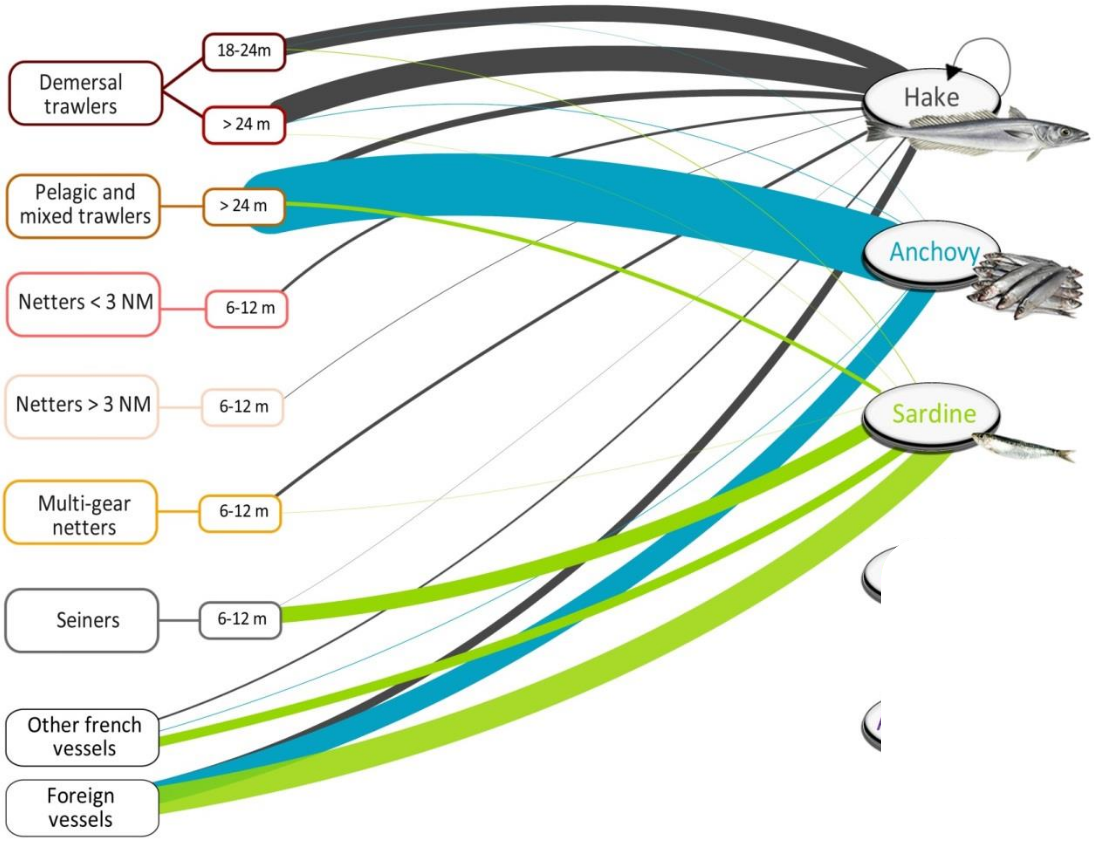


*Figure 7.8**.** Repartition of the 2015 landings by fleet and species. The width of the arrows is proportional to the total fish landed in weight by fleet. Data source: Ifremer, SIH, DPMA, Eurostat.*

7.1.4.4 Dependencies of fleets on landings values by species

Figure 7.9 displays the economic dependencies of the different modelled fleets on revenues from Hake, Sardine, Anchovy and other species.

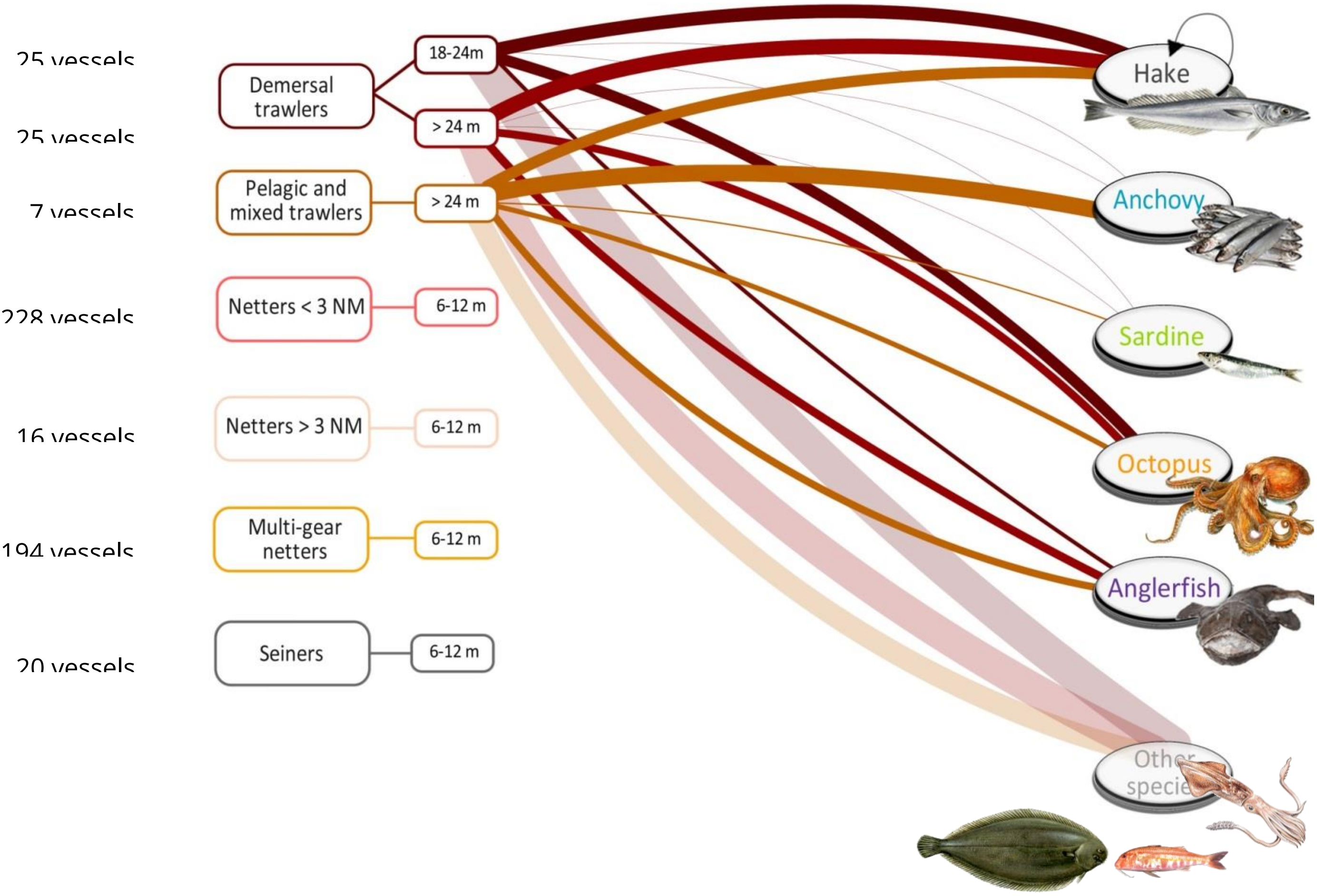


Figure 7.9. Mean dependency by vessel (in % of the 2015 revenue). The width of the arrows is proportional to the dependence (in terms of revenue) of the fleets on the various species (2015 data) Data source: Ifremer, SIH, DPMA.

7.1.5 Inputs parameters and outputs of the model

The model is calibrated with transversal data for 2015 (Ifremer, SIH, DPMA) and economic cost-structure data for 2013 (CASD[8]).Economic data are based on availability and quality of data at the moment of the calibration. Economic inputs data are calibrated with 2015 gross revenue assuming constant cost-structure as a percentage of the gross revenue calculated based on 2013 data. Initial number of vessels and nominal fishing effort are based on 2015 data. The initial parameters for the Hake population dynamic are based on GFCM assessment on the year 2015 (data source: GFCM, 2016).

Warning: The model is calibrated using available data, which may not be fully reliable. In particular:

[8] This work has been partly supported by a public grant overseen by the French National Research Agency (ANR) as part of the « Investissements d'avenir » program (reference: ANR-10-EQPX-17 – Centre d'accès sécurisé aux données – CASD)

- The values for the biological parameters of Hake population dynamics imply that Hake biomass is very sensitive to recruitment. Further work on the Hake stock-recruitment relationship should be carried out.
- the lack of reliable crew share data does not allow estimation of crew wages and gross cash flows. Consequently the economic indicators that are displayed in this study are limited to Revenue and Gross Value Added.

Uncertainty on recruitment was included in the Hake population dynamic. In the absence of known stock-recruitment relationship and established recruitment scenario, different recruitment scenarios were tested[9]. The selected recruitment scenario in our analyses is based on random values of recruitment drawn from a Normal law distribution with associated mean and standard deviation calculated from 2008-2015 historical data.

Simulations starts in 2015 and run to 2030, with 1000 simulations by scenarios to take into account the uncertainty on recruitment (the same matrix of recruitment was used for each scenario).

- Main outputs of the model are (for each simulated year):
- Spawning Stock Biomass (SSB) of Hake
- Total fishing mortality of Hake
- Total landings of Hake per fleet
- Mean landings of Hake per vessel per fleet
- Annual number of vessels by fleet
- Total effort by fleet (in number of days at sea)
- Mean effort per vessel by fleet (in number of days at sea)
- Total revenue per fleet
- Mean revenue per vessel per fleet
- Total gross value added (GVA) by fleet
- Mean gross value added per vessel by fleet

Since data of fishing capacity (number of vessels) and fishing effort (number of days at sea) are now available for 2016 and 2017, these data were integrated in the model for the 2016 and 2017 years.

7.1.6 Tested scenarios

The scenarios that were tested are based on those proposed in the TOR 5 of the EWG 18-09 and are summarized in Table 7.4. The scenarios of reduction of effort start in 2019. Fishing capacity and effort in 2018 are assumed identical to the one observed in 2017.

It is important to note that the changes in fishing capacity and fishing effort concern only the trawl fleets (i.e. demersal trawlers superior to 24m, demersal trawlers 18-24m, and pelagic and mixed trawlers superior to 24 m). Fishing capacity and fishing effort of the other modelled fleets are constant (compared to 2017 values).

[9] Simulations with a uniform distribution instead of a normal law distribution are displayed in Appendix B.

Table 7.4. Scenarios analysed.

	Fishing capacity for trawl fleets (nb of vessels)	**Fishing effort per vessel for trawl fleets** (nb days at sea)
Baseline (BL)	constant (same than in 2017)	constant (same than in 2017)
Scenario 1	-10% in 2019 (and constant afterwards)	-10% in 2019 (compared to 2018) -10% in 2020 (compared to 2019) -10% in 2021 (compared to 2020) (and constant afterwards)
Scenario 2	-20% in 2019 (and constant afterwards)	-10% in 2019 (compared to 2018) -10% in 2020 (compared to 2019) -10% in 2021 (compared to 2020) (and constant afterwards)
Scenario 3	-20% in 2019 (and constant afterwards)	-20% in 2019 (compared to 2018) -10% in 2020 (compared to 2019) -10% in 2021 (compared to 2020) (and constant afterwards)

7.1.7 Simulation results

Performances of the 4 simulated scenarios are compared in figures 3 to 11, which display the trajectories of Hake SSB, Hake fishing mortality, Hake total landings per fleet, number of vessels, total effort per fleet, revenues and Gross Value Added (GVA). The graphs display the mean -over the 1000 simulated trajectories - annual values and the associated 95% confidence interval given by the quantile of the indicator iterations distribution. If we consider one particular trajectory, there is some inter-annual variability, however mean annual values do not exhibit it. Therefore, to show the inter-annual variability, one particular trajectory is displayed in Annex 5 section A (figures A.1 to A.9).

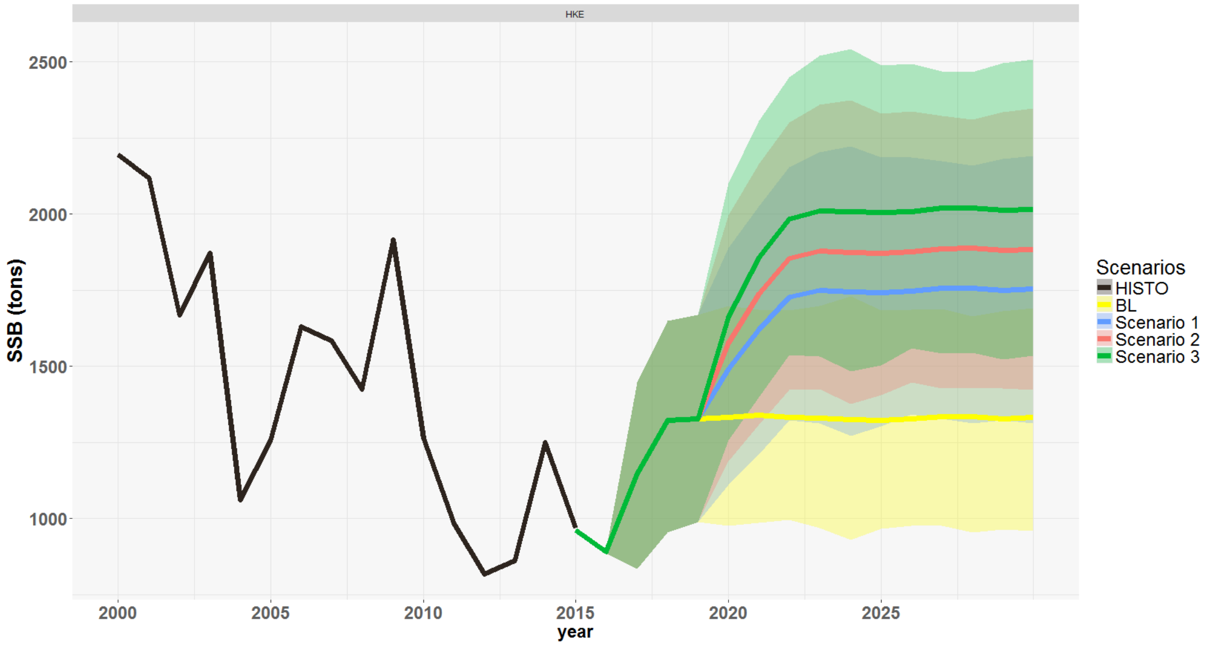


Figure 7.10. Hake SSB (in tons). The colored area includes 95% of the values per year and the plain line corresponds to the mean annual value per year.

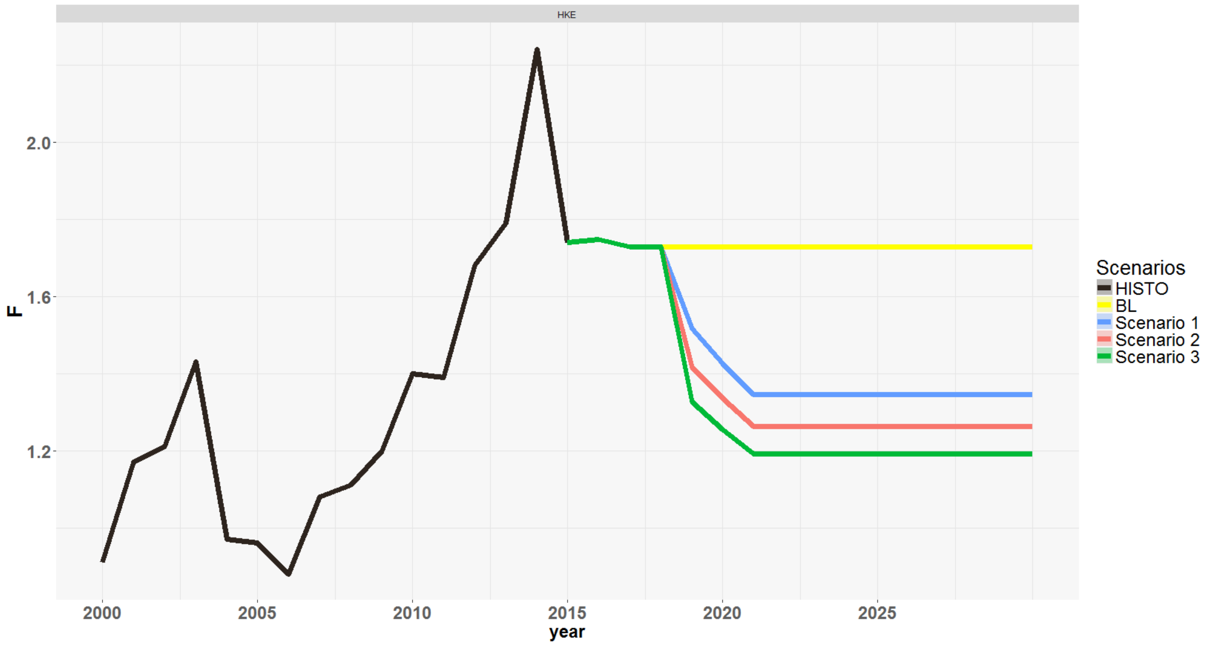


Figure 7.11. Fishing mortality of Hake.

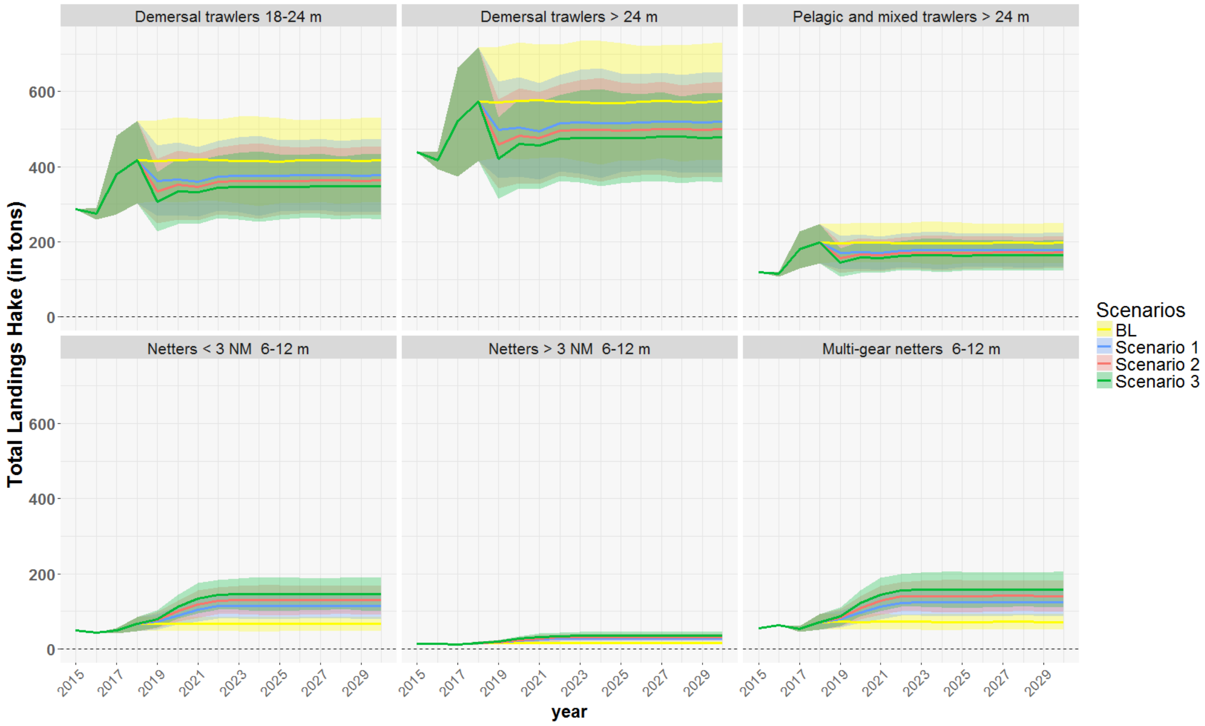


Figure 7.12. Total annual landings of Hake per fleet (in tons). The colored area includes 95% of the values per year and the plain line corresponds to the mean annual value per year.

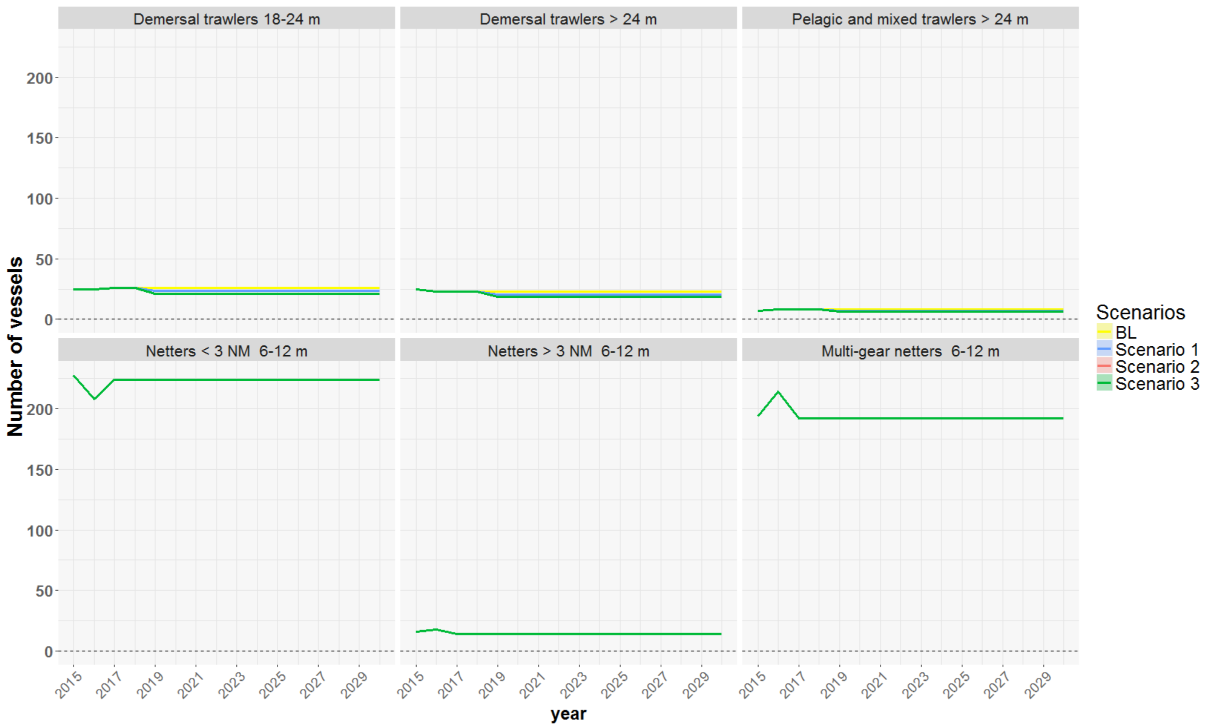


Figure 7.13 Number of vessels by fleet.

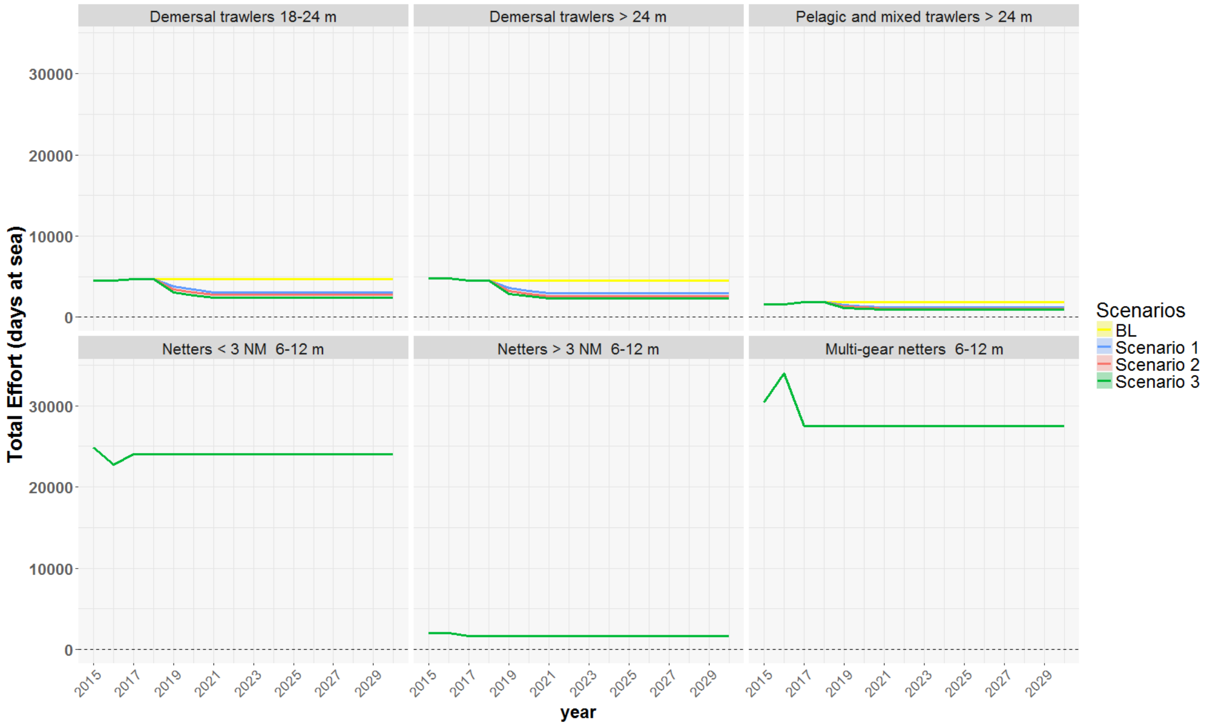


*Figure 7.14 Total annual effort (i.e. number of vessels*nominal fishing effort) in days at sea per fleet.*

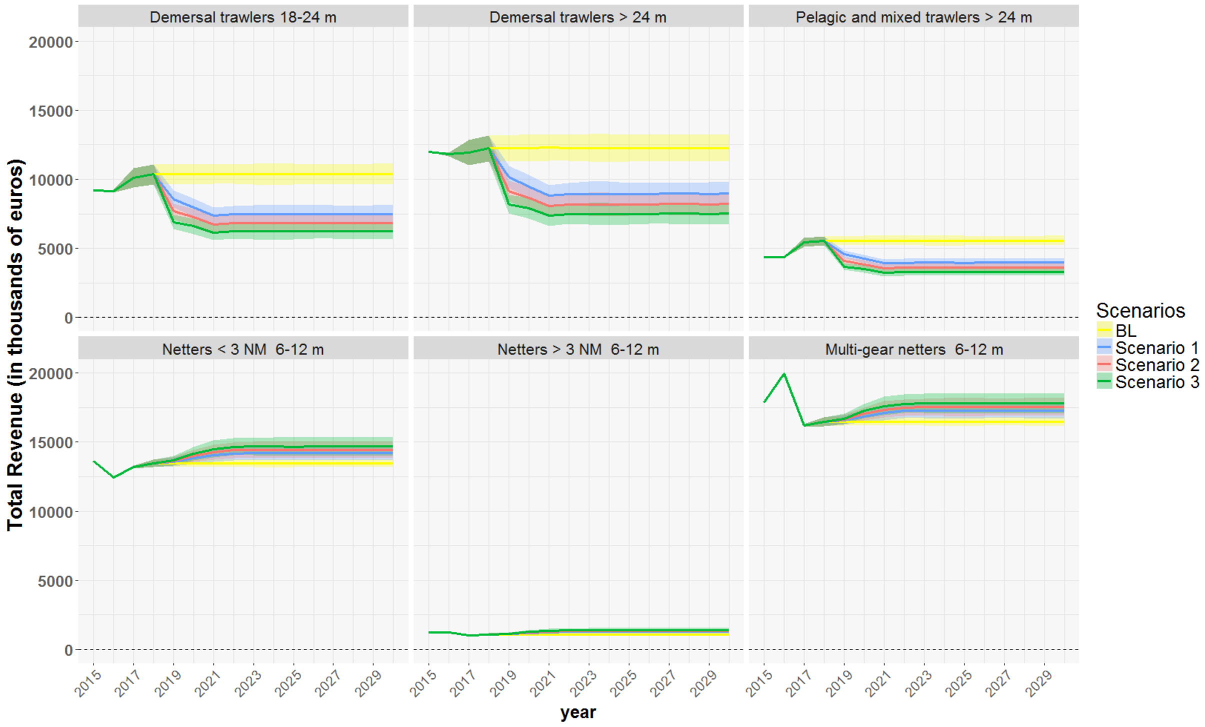


Figure 7.15 Total revenue (values of landings) in thousands of euros per fleet. The colored area includes 95% of the values per year and the plain line corresponds to the mean annual value per year

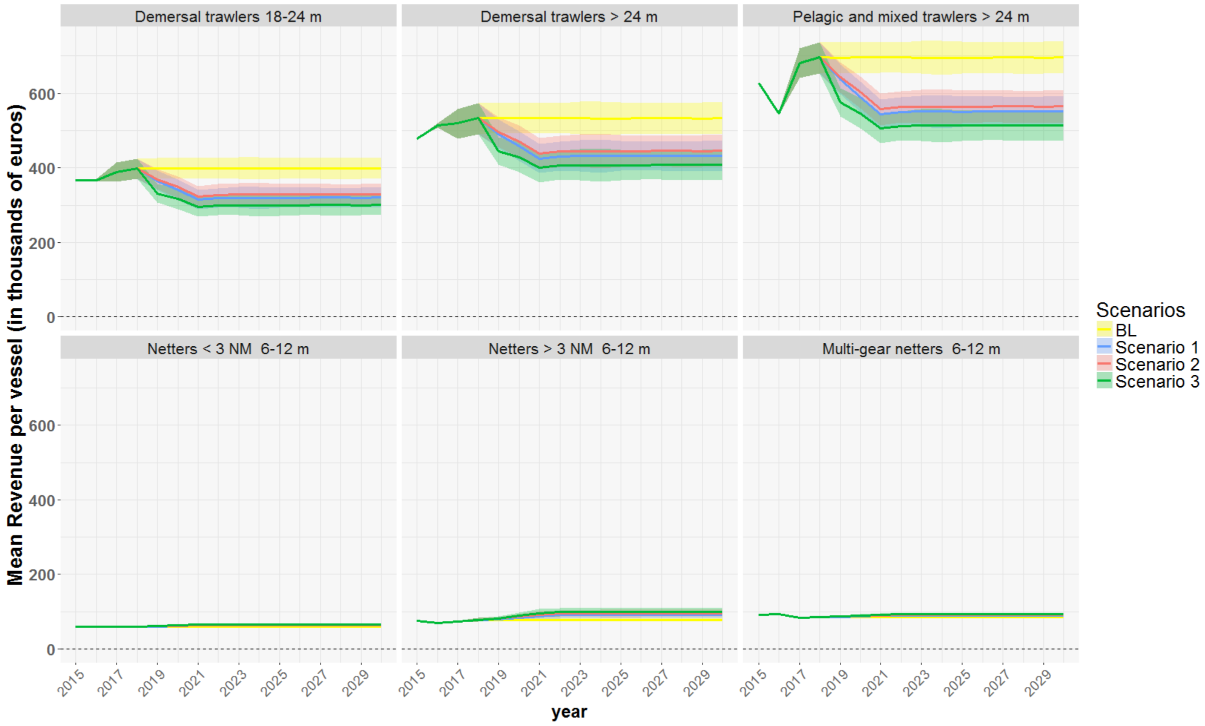


Figure 7.16 Mean revenue (in thousands of euros) by vessel per fleet. The colored area includes 95% of the values per year and the plain line corresponds to the mean annual value per year.

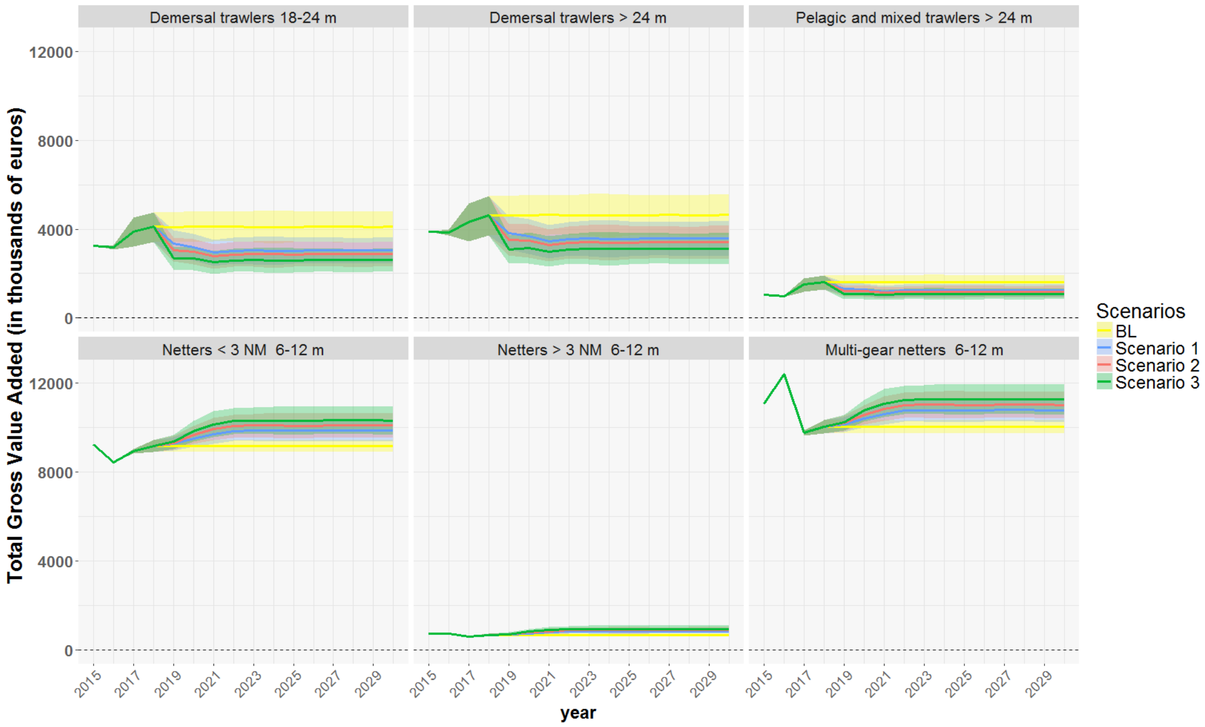


*Figure 7.17**.** Total Gross Value Added (in thousands of euros) per fleet. The colored area includes 95% of the values per year and the plain line corresponds to the mean annual value per year.*

Figure 7.18. Mean Gross Value Added (in thousands of euros) by vessel per fleet. The colored area includes 95% of the values per year and the plain line corresponds to the mean annual value per year.

7.1.8 Synthesis

Table 7.5. Comparison of bio-economic impacts of fishing effort scenarios between 2018 and final year of the simulation (i.e. 2030).

	Scenario	**Baseline**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Biological impacts	Hake SSB	~	+	++	+++
	Hake fishing mortality (relative to FMSY)	~	-	--	---
Socio-Economic Impacts	**Hake total landings**				
	French Trawlers	~	-	--	--
	Other French fleets	~	+	++	+++
	Nb of vessels	~	-	-	--
	Mean annual Revenues				
	French Trawlers	~	-	--	---
	Other French fleets	~	+	+	++
	Mean Revenues per vessel				
	French Trawlers	~	-	-	---
	Other French fleets	~	+	+	+
	Mean Gross Value Added (GVA)				
	French Trawlers	~	-	-	-
	Other fleets		+	+	++
	Mean Gross Value Added (GVA) per vessel				
	French Trawlers	~	--	-	--
	Other fleets	~	+	+	++

-	negative impacts
~	undifferentiated or no impact
+	positive impacts

Bio-economic simulations for the demersal fleets in GSA 9

Under the ToR 5 it was requested to assess the likely biological and socio-economic impacts of implementing the management scenarios described in Table 1. Four scenarios were simulated: the baseline scenario, where both fishing capacity and effort are assumed to be constant, and three alternative scenarios assuming different variations in the number of vessels and the days at sea. The column "Strategy" was not considered for simulations. Vessels' performance is assumed to be homogeneous among the vessels belonging to the same fleet segment. No investments in technology and/or change in fishing strategy increasing productivity are considered by the model.

Simulations were carried out through a bio-economic model under development within the Horizon 2020 research project "Science, Technology, and Society Initiative to minimize Unwanted Catches in European Fisheries (MINOUW)". A short description of the bio-economic model is reported in the Annex 6.

Scenarios were simulated for the demersal fisheries in the Ligurian and North Tyrrhenian seas (GSA 9). In 2016, the active demersal fleets operating in GSA 9 consisted of 1360 vessels: 262 demersal trawlers (DTS) over 12m and almost 1100 vessels using passive gears (PGP). Most of the polyvalent passive vessels were lower than 12m. Demersal trawlers are vessels using predominantly bottom otter trawl, while the polyvalent passive vessels use mainly set gillnet, trammel nets, longline, traps and pots. The main species targeted by trawlers are deep-water rose shrimp, red mullet and European hake; while the most important species in terms of revenues for polyvalent passive vessels are swordfish, European hake and surmullet.

Trawlers showed a bigger size compared to the other fleet segments. Trawlers represented only 19% of the total number of vessels but 78% in terms of GT and 56% in terms of kW. These vessels produced around two third of the total landings in weight and 64% of total landings in value. The polyvalent vessels lower than 12m contributed to the total landings for around 30% both in weight and value, while polyvalent vessels over 12m produced around 5% of total landings.

Table 7.6 – Fishing capacity, production and profits of the demersal fleets in GSA 9 (2016 data)

Fleet segment	N	GT	LOA	kW	Landings (t)	Revenues (K€)
DTSVL1218	133	2775	1936	20611	2624	23886
DTSVL1824	120	6664	2526	33164	4520	38727
DTSVL2440	9	818	230	4325	223	2297
PGPVL0012	1035	2087	7434	35629	3360	31336
PGPVL1218	63	796	852	9781	516	5054
ALL	1360	13140	12978	103510	11244	101300

Source: MIPAAF data sourced from ITAFISHSTAT

7.1.9 The model dimensions

As reported above, the fleet operating in GSA 9 demersal fisheries consist 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. Data for the five fleet segments were used in the model and socioeconomic indicators were estimated for each of them. The link between the biological and the economic components of the model goes through the catches and landings by species and fishing gear. To implement this link all vessels belonging to demersal trawlers fleet segments were assumed to use bottom otter trawl as fishing gear.

Regarding the polyvalent passive vessels, these were assumed to use set gillnet and trammel nets.

Fishing gear	Description
OTB	Bottom otter trawl
GNS+GTR	Set gillnet + Trammel net

Fleet Segments	Technique
9_DTSVL1218	Demersal trawlers
9_DTSVL1824	Demersal trawlers
9_DTSVL2440	Demersal trawlers
9_PGPVL0012	Polyvalent passive
9_PGPVL1218	Polyvalent passive

Five species 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 list of stocks included in the model with the values of fishing mortality assessed in 2015 and the $F_{0.1}$ are reported in Table 7.7 .

Table 7.7 – F and $F_{0.1}$ for the stocks simulated by the model

Stocks	English name	F 2015	$F_{0.1}$
HKE	European hake	0.90	0.26
NEP	Norway lobster	0.34	0.19
MUR	Surmullet	0.49	0.52
MUT	Red mullet	1.38	0.59
DPS	Deep-water rose shrimp	0.71	0.71

7.1.10 Scenarios implementation

The scenarios were implemented in the model as follows:

- The Baseline scenario was simulated assuming only a reduction by 8% for the demersal trawlers 18-24m and 24-40m in 2018 as foreseen by the already adopted national fleet decommissioning plans. This reduction in the number of vessels were included in all simulated management scenarios. No additional variation was assumed under the baseline scenario.
- As for the alternative scenarios, the reductions in the number of vessels and fishing days reported in Table 1 of the ToRs were applied only to demersal trawlers assuming 2019 as year 1. The three years implementation period is 2019-2021.
- The reductions in fishing days were applied to the average days at sea per vessel as estimated on the last year of available data; while the reduction in capacity was applied to the number of vessels resulting after the application of the already adopted national fleet decommissioning plans.
- The total number of days at sea is calculated as number of vessels times average days at sea per vessel. The cumulated effects on the fishing effort for the demersal trawlers 12-18m, 18-24m and 24-40m under each scenario are reported in Table 7.8 .

Table 7.8 – Reductions in total days at sea by fleet segment and scenario

	BASELINE					SCENARIO 1			
Fleet segment	**2018**	**2019**	**2020**	**2021**	**Fleet segment**	**2018**	**2019**	**2020**	**2021**
DTSVL1218	0%	0%	0%	0%	DTSVL1218	0%	-15%	-23%	-31%
DTSVL1824	-8%	-8%	-8%	-8%	DTSVL1824	-8%	-21%	-29%	-36%
DTSVL2440	-8%	-8%	-8%	-8%	DTSVL2440	-8%	-21%	-29%	-36%
	SCENARIO 2					**SCENARIO 3**			
Fleet segment	**2018**	**2019**	**2020**	**2021**	**Fleet segment**	**2018**	**2019**	**2020**	**2021**
DTSVL1218	0%	-19%	-27%	-34%	DTSVL1218	0%	-28%	-35%	-42%
DTSVL1824	-8%	-25%	-33%	-40%	DTSVL1824	-8%	-34%	-40%	-46%
DTSVL2440	-8%	-25%	-33%	-40%	DTSVL2440	-8%	-34%	-40%	-46%

7.1.11 Simulation OUTCOMES

Indicators requested under ToR 5 are:

- Fisheries indicators: catch, fishing mortality relative to Fmsy (F/Fmsy);
- Biological indicators: abundance (SSB) and recruitment;
- Socio-economic indicators: number of fleet segments and jobs at risk, and net profit.

The model does not simulate the SSB, but the total biomass. Regarding the recruitment, as the model uses constant recruits, the related indicator is not provided.

Regarding the other indicators, these are reported in the following tables for two years:

- Year 2021, which represents the first year after the simulated implementation of the measures (period 2019-2021). Outcomes in 2021 can be considered as short-term effects.
- Year 2025, which can show medium-term effects of the management measures simulated under each scenario. Year 2030, requested by the ToR, was also simulated but the related outcomes are not reported in this document.

7.1.11.1Fisheries and biological indicators

Fisheries and biological indicators include catch, fishing mortality relative to Fmsy (here $F_{0.1}$) and abundance expressed here in terms of biomass.

The 2021 and 2025 projections of catch, $F/F_{0.1}$ and biomass by stock are shown in absolute values for the baseline scenario and in percentage variations with respect to the baseline for the alternative scenarios in Table 7.9 to Table 7.11.

In 2021 the alternative scenarios show levels of catches lower than the baseline for all stocks. As this is the first year after the implementation of the reductions in fishing effort, scenarios with stronger effort reductions produce also stronger reductions in catches. However, the effects are differentiated by stock. Norway lobster and deep-water rose shrimp are the most sensitive stocks to the variations in fishing effort. In 2025, the level of catches for the alternative scenarios are still lower than the baseline except for European hake. However, the distances with the baseline are reduced if compared with 2021. This is due to the medium-term positive effect on the stock biomass, which counterbalances to some extent the reduced fishing effort.

Table 7.9 – Percentage variations in catch by stock under the alternative scenarios compared to the baseline in years 2021 and 2025

	YEAR 2021				**YEAR 2025**			
Catch	**Baseline (t)**	**Sc. 1**	**Sc. 2**	**Sc. 3**	**Baseline (t)**	**Sc. 1**	**Sc. 2**	**Sc. 3**
HKE	1562	-5%	-5%	-6%	1584	7%	8%	8%
NEP	168	-21%	-23%	-28%	171	-9%	-10%	-14%
MUR	281	-5%	-5%	-6%	281	-4%	-4%	-5%
MUT	1351	-10%	-11%	-13%	1351	-4%	-5%	-7%
DPS	720	-17%	-19%	-23%	720	-13%	-15%	-19%

Table 7.10 shows the simulated values of $F/F_{0.1}$ by stock. These depend on the reductions in fishing effort and the landings composition of the fleet segments. The effects on the fishing mortality do not change from 2021 to 2025 as the management measures are implemented in the period 2019-2021 and no additional measure is foreseen after 2021. All stocks are similarly affected except for surmullet, which is mainly targeted by polyvalent passive vessels. However, this stock as well as deep-water rose shrimp would not need additional reduction in fishing mortality as these show values of F lower than $F_{0.1}$ under the baseline scenario. Regarding the other stocks, the reductions in fishing mortality under the most impacting scenario (scenario 3) would allow the achievement of $F_{0.1}$ only for Norway lobster (F_{2021} and F_{2025} = 0.18).

Table 7.10 – Percentage variations in $F/F_{0.1}$ by stock under the alternative scenarios compared to the baseline in years 2021 and 2025

	YEAR 2021				**YEAR 2025**			
$F/F_{0.1}$	**Baseline**	**Sc. 1**	**Sc. 2**	**Sc. 3**	**Baseline**	**Sc. 1**	**Sc. 2**	**Sc. 3**
HKE	3.15	-30%	-34%	-41%	3.15	-30%	-34%	-41%
NEP	1.63	-31%	-34%	-42%	1.63	-31%	-34%	-42%
MUR	0.86	-6%	-7%	-8%	0.86	-6%	-7%	-8%
MUT	1.89	-29%	-33%	-40%	1.89	-29%	-33%	-40%
DPS	0.82	-31%	-34%	-42%	0.82	-31%	-34%	-42%

The effects of the management scenarios on the biomass are reported in Table 7.11. Stock biomass is positively affected by all alternative scenarios compared to the baseline. The positive impact of the reductions in fishing effort are expected to be registered from 2021, the first year after their implementation. This effect is expected to be strengthened over time with higher values in 2025. European hake is the stock with the highest benefits from the effort reduction, while surmullet shows a limited increase in biomass. Generally, stronger reductions in fishing effort are expected to produce stronger increases in biomass.

Table 7.11 – Percentage variations in biomass by stock under the alternative scenarios compared to the baseline in years 2021 and 2025

	YEAR 2021				YEAR 2025			
Biomass	**Baseline (t)**	**Sc. 1**	**Sc. 2**	**Sc. 3**	**Baseline (t)**	**Sc. 1**	**Sc. 2**	**Sc. 3**
HKE	6550	15%	19%	28%	7309	58%	70%	95%
NEP	863	7%	9%	12%	880	21%	25%	32%
MUR	1404	1%	1%	2%	1404	2%	3%	3%
MUT	3595	8%	10%	15%	3595	14%	16%	21%
DPS	2594	7%	8%	11%	2594	11%	12%	16%

7.1.11.2Socio-economic indicators

Socio-economic indicators include employment and net profit. The 2021 and 2025 projections for these indicators by fleet segment are shown in absolute values for the baseline scenario and in percentage variations with respect to the baseline for the alternative scenarios in Table 7.12 and Table 7.13.

The effects of the management scenarios on the levels of employment do not change from 2021 to 2025 (Table 7.12) as the number of employees is assumed to be linearly dependent on the number of vessels, which is constant from 2019 onwards. Indeed, the reduction in fishing capacity under all scenarios is implemented in 2019 and no additional measure is foreseen after 2021. Furthermore, the same variations in fishing capacity are assumed for all fleet segments.

Table 7.12 – Percentage variations in employment by fleet segment under the alternative scenarios compared to the baseline in years 2021 and 2025

	YEAR 2021				YEAR 2025			
Employment	**Baseline**	**Sc. 1**	**Sc. 2**	**Sc. 3**	**Baseline**	**Sc. 1**	**Sc. 2**	**Sc. 3**
DTSVL1218	371	-5%	-10%	-10%	371	-5%	-10%	-10%
DTSVL1824	342	-5%	-10%	-10%	342	-5%	-10%	-10%
DTSVL2440	28	-5%	-10%	-10%	28	-5%	-10%	-10%
PGPVL0012	1534	0%	0%	0%	1534	0%	0%	0%
PGPVL1218	159	0%	0%	0%	159	0%	0%	0%

Table 7.13 shows the net profit by fleet segment in thousands of euro for the baseline scenario and in percentage variations for the other management scenarios. Net profits are affected negatively by the amounts of landings, which generally perform worse than the baseline as reported in Table 5, and positively by the reductions in costs due to a lower number of vessels and days at sea. The final outcomes show a general increase in net profits for all fleet segments except for trawlers 12-18m in 2021. The positive economic performance, which is registered already in 2021, is expected to be strengthened over time with higher values in 2025. Scenario 2 is expected to perform better than the other scenarios for the fleet segments directly affected by the management measures, the demersal trawlers. As for the passive polyvalent vessels, these are not directly affected by the management measures included in the simulated scenarios. These

vessels would have only benefits from reductions in the fishing effort for trawlers: stronger reductions of trawlers would produce better benefits for polyvalent passive vessels. Therefore, scenario 3 would be the best scenario for these vessels.

Table 7.13 – Percentage variations in net profit by fleet segment under the alternative scenarios compared to the baseline in years 2021 and 2025

	YEAR 2021				YEAR 2025			
Net Profit	**Baseline (K€)**	**Sc. 1**	**Sc. 2**	**Sc. 3**	**Baseline (K€)**	**Sc. 1**	**Sc. 2**	**Sc. 3**
DTSVL1218	7555	-5%	-3%	-6%	7580	3%	5%	2%
DTSVL1824	8130	8%	12%	12%	8074	16%	20%	18%
DTSVL2440	592	4%	10%	7%	598	19%	25%	23%
PGPVL0012	12601	32%	39%	55%	13586	67%	79%	104%
PGPVL1218	4802	28%	35%	51%	5496	83%	97%	129%

7.1.12 Final remarks

Simulations carried out on the four scenarios described in Table 1 showed that the best results in terms of reductions in F would be achieved under scenario 3, while the best economic performance for the trawl fleet is expected under scenario 2. However, some model limitations should be considered.

The model does not consider the different strategies that vessels can adopt to increase their productivity. The current version of the model assumes a linear relationship between fishing effort by fleet segment and the related partial fishing mortality by stock. Investments in technology and changes in fishing strategy would increase productivity affecting the relationship between fishing effort and fishing mortality. This would reduce the actual impact of the management scenarios on the fisheries. Furthermore, model uncertainty is not simulated and included in model outcomes.

8 ALTERNATIVE FLEET AND FISHERIES SEGMENTATION

The current proposal introduces the following segmentation: 2 geographical sub-areas (GSAs 1-2-5-6-7 and 8-9-10-11); 2 type of fisheries (mixed fisheries and deep water shrimps) and; 4 vessels' length groups (<12m; 12m-18m; 18-24m; and >24m) (see Figure 1, Annex 3).

It has been proposed an alternative approach: 2 geographical sub-areas (GSAs 1-2-5-6-7 and 8-9-10-11); 1 type of fisheries (mixed fisheries, including deep water shrimps) and; 3 vessels' length groups (<15m; 15-26m; and >26m) (see Figure 2, Annex 3).

- *What are the advantages and disadvantages of each effort segmentation?*
- *Do the vessels within each effort group have a similar fishing pattern? Which effort segmentation would provide the greatest similarity?*
- *What would be the impact on the Data Collection Framework?*

STECF investigated differences across the segmentations for the Italian and Catalonian datasets.

Distribution of vessel size

The following data are analysed using left segmentation, i.e. a vessel at LOA equal to 14.99m will belong to the group [0-15) while a vessel with LOA 15.00 m will belong to the group [15-26m). There are a number of vessels with the exact length declared, so the choice of right or left segmentation can make a slight difference in the histograms below.

8.1.1 Catalonian dataset

In this dataset, vessel sizes range from 9 to 28 m, with the highest number of vessels being in the group 14-16 and 21-24m. There are no obvious cuts or clusters of size, except for the small representation of vessels sized 12-13m.

If the length category 15-26m LOA were used it would contain over 70% of Catalonian trawl vessels.

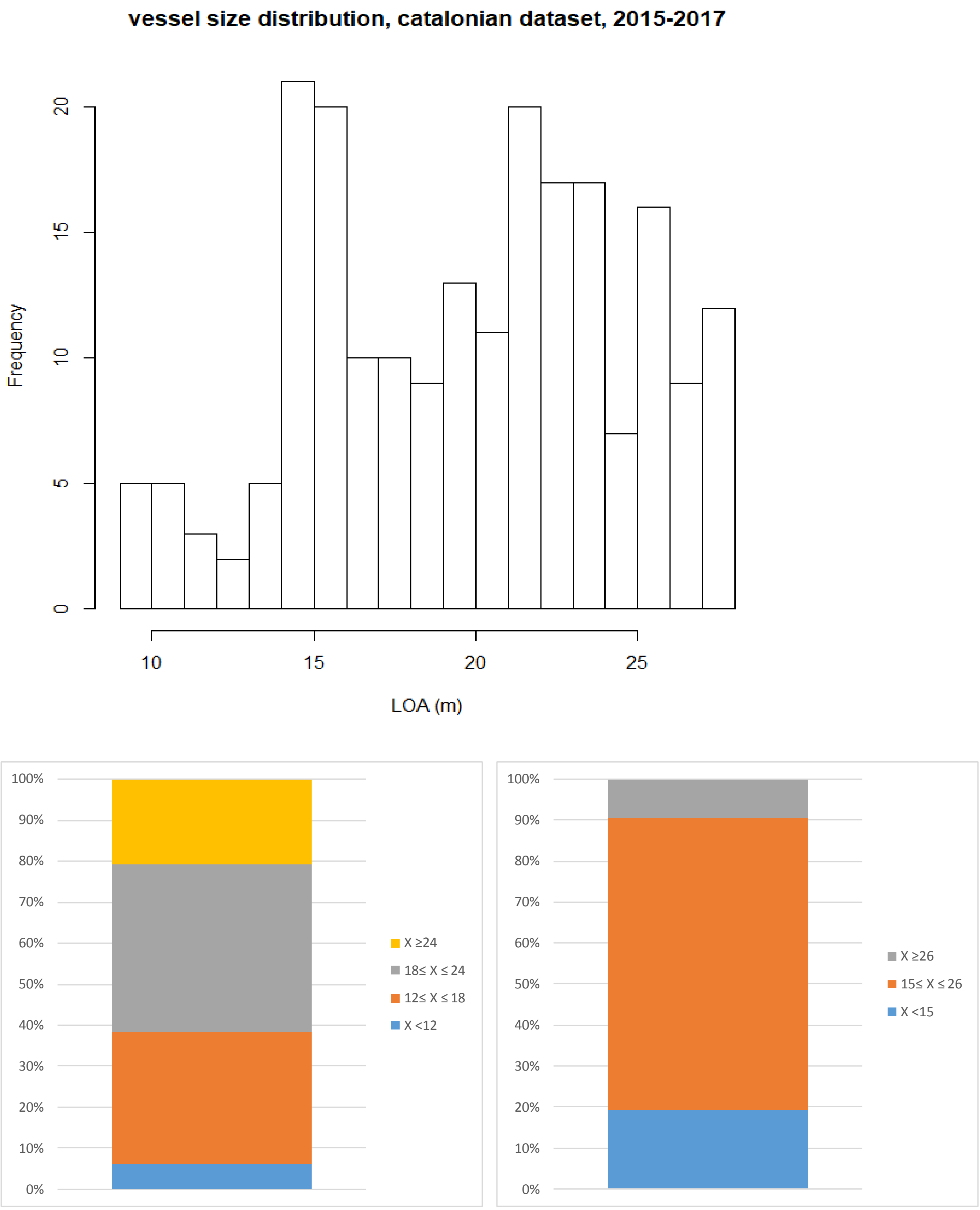
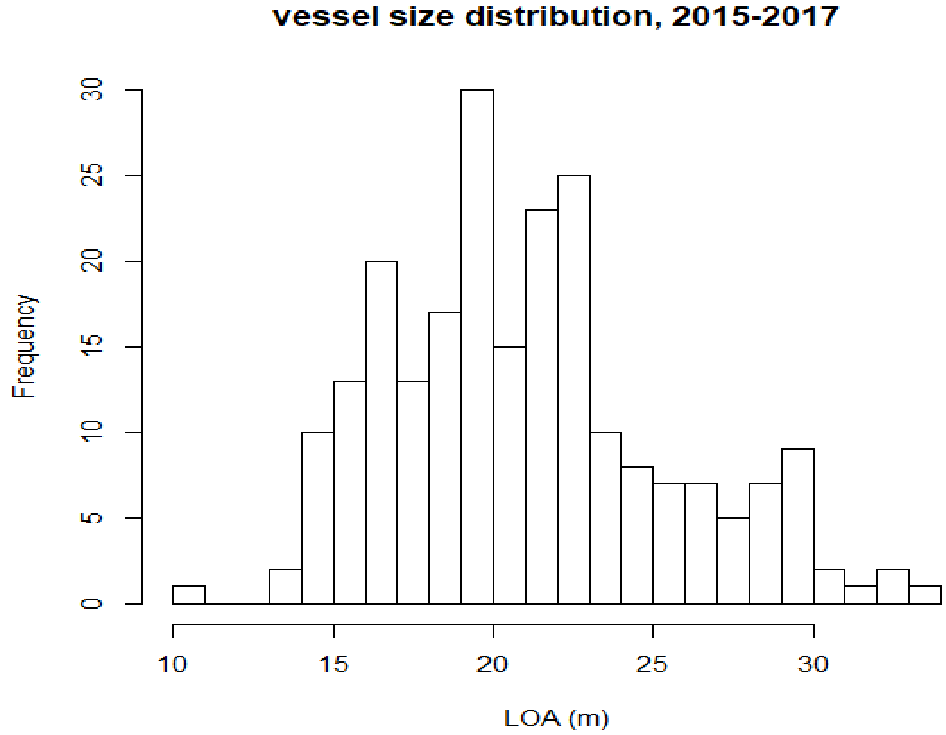


Figure 8.1. Catalonian dataset. vessel size distribution. Top: histogram by LOA. Bottom: distribution across two possible segmentations.

8.1.2 Italian dataset

This data set is the most comprehensive possible after removing data with quality issues.



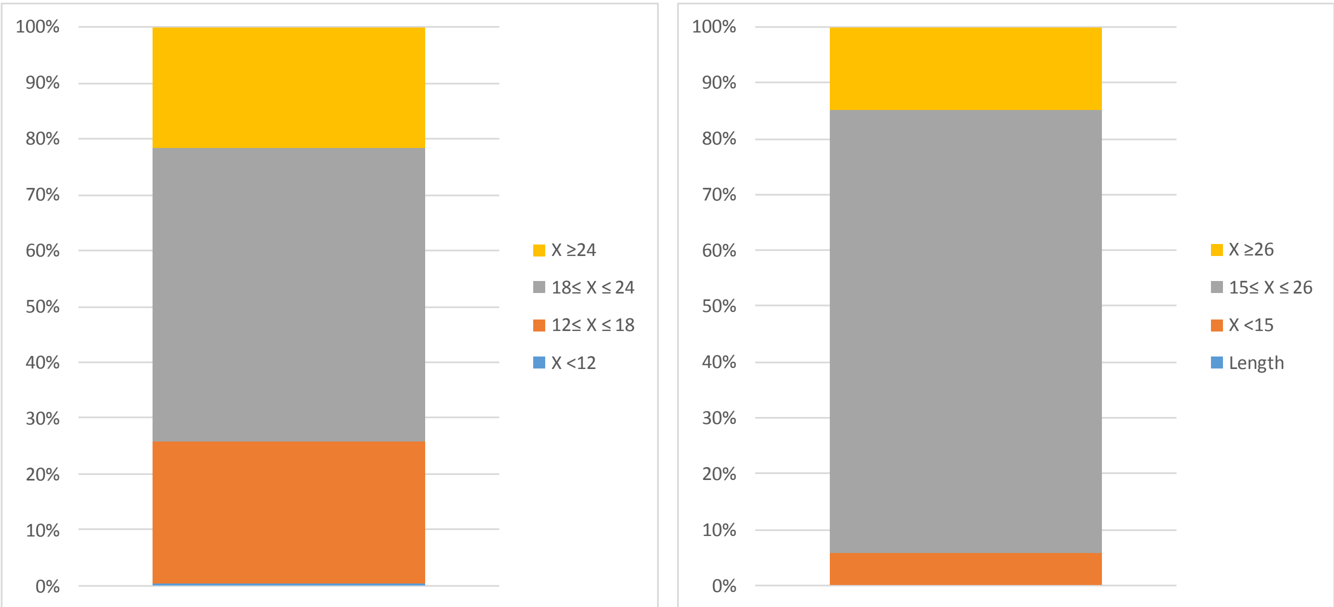


Figure 8.2. Italian dataset. vessel size distribution. Top: histogram by LOA. Bottom: distribution across two possible segmentation.

The italian dataset shows a large number of vessels between 14 and 23 meters, but several vessels are also up to 30m plus. Again there is no clear indication how to define the segmentation. 80% of the vessels would fall in the category 15-26m.

8.1.3 Fleet economic dataset

Using the fleet economic data set the amounts of fleet effort, measured in fishing days, was considered for the different length classes in the current multi annual plan proposal. Data from all three countries fishing in the area (France, Italy and Spain) was only available for 2014 and 2015. Fishing days were summed across the two years. Data was filtered to only include that classified by fishing technique DTS (Demersal trawlers and/or demersal seiners). Data still included effort by non-trawl gears[10]; the 'bottom trawler' columns of Figure 8.3 how the effort of gears that would be subject to the effort management plan. western (GSA 1-5-6-7) and eastern (GSA 8-9-10-11)

In the western area the greatest proportion of fishing days is taken by vessels 18-24m LOA but no single length category proves dominant. French trawl effort is only from vessels above 18m LOA.

In the eastern area effort is dominated by Italian vessels. In terms of fishing days, the Italian trawl effort is split roughly evenly between vessels above and below 18m LOA.

Trends of effort by vessel length category and by individual GSA are supplied in Annex 1.

It was not possible to make equivalent figures for the alternative segmentation as DCF data are not collected according to these vessel length categories.

[10] Fishing technique is decided using a dominance criterion. Therefore, fishing days may be recorded for non-trawl gear if a vessel uses both trawl and non-trawl gear but with the majority of effort using trawl gear.

Figure 8.3. Fishing days (2014 and 2015 data summed) by vessel length segment. Eastern = GSAs 1-2-5-6-7; Western = GSAs 8-9-10-11.

Differences in fishing patterns and LPUE with vessel size

8.1.4 Catalonian dataset

Analysis of data from the Catalan regional trawl fleet (for the years 2015 to 2017) by vessel size show a continuum of catch composition, mainly with regards to a decreasing proportion of red mullet *(Mullus barbatus)* and an increasing proportion of blue and red shrimp (*Aristeus antennattus*) with vessel size. The LPUE for the other species of interest to the effort management plan, Norway lobster (*Nephrops norvegicus*), Deep-water rose shrimp *(Parapenaeus longirostris)* and Hake *(Merluccius merluccius)* are little different to the length category below.

Similar patterns are observed with the alternative segmentation, but the predominance of blue and red shrimp landings for the large vessels is more pronounced (>50%), indicating that vessels above 26m target blue and red shrimp more than vessels 24-25 m length.

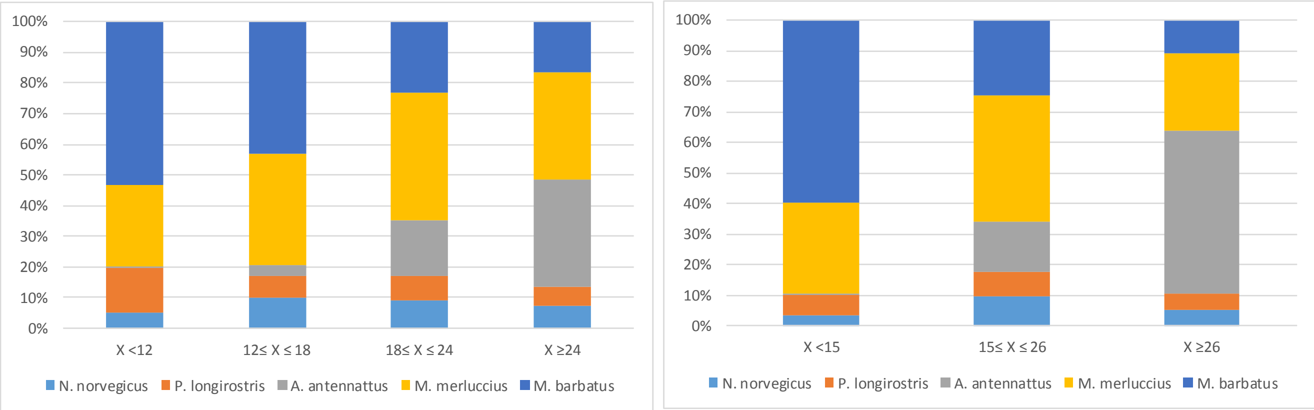
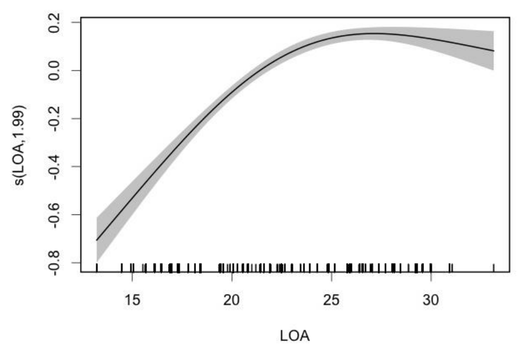


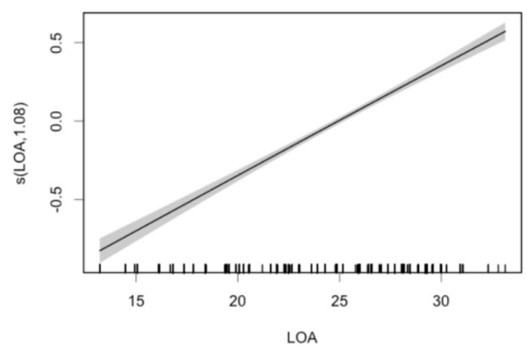
Figure 8.4. Proportion by species in landings by fleet segments for two different segmentation, Spain (Catalonina) dataset

8.1.5 Italian dataset

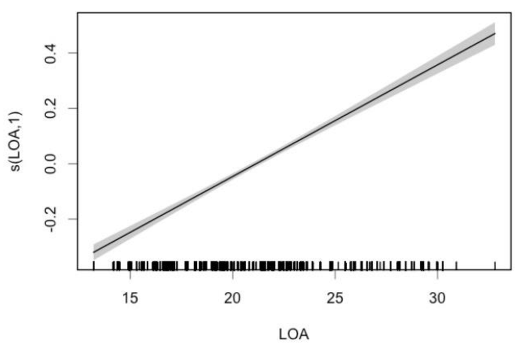
An exploratory alternative GAMM model was fitted to the Italian dataset, similar to the one explained in section **Error! Reference source not found.**, but this time using vessel size as a continuous smooth variable instead of categorical. The smooth vessel size effect by species is reported on Figure 8.5



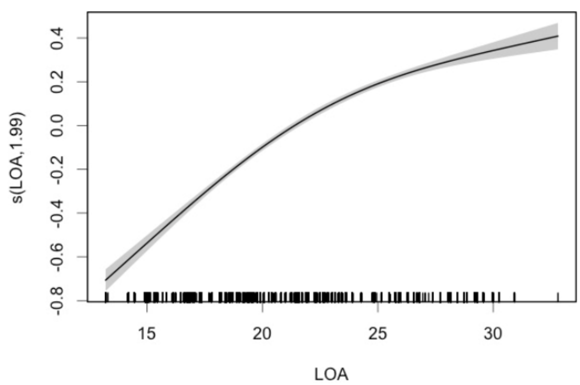
ARA



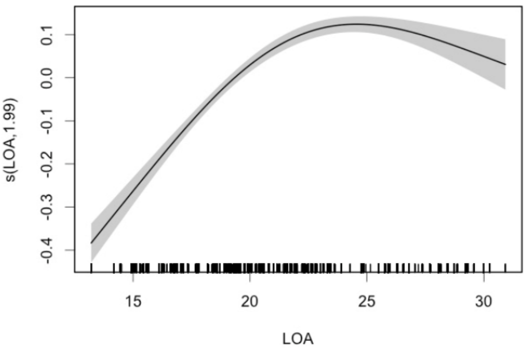
ARS

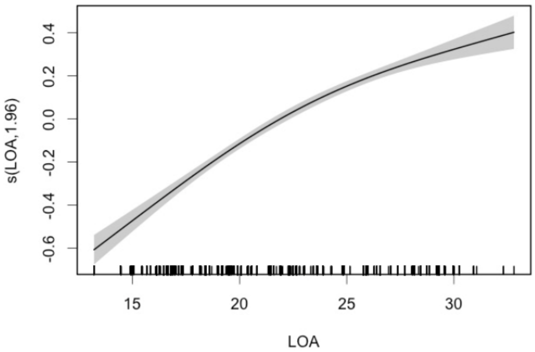


DPS



HKE





MUT NEP

Figure 8.5. Smoothed effect of vessel size on the LPUE by species

The smoothed effect of vessel size is relatively strong and continuous. For giant red shrimp (ARS), deep water rose shrimp (DPS), hake (HKE) and Norway lobster (NEP), LPUE increases regularly with vessel size, without clear thresholds. For Red mullet (MUT), highest relative LPUE effect is observed around 23-26m length, while for blue and red shrimp (ARA) it is observed beyond 25-26m.

8.1.6 Fleet economic dataset

Aggregating data according to the western (GSA 1-5-6-7) and eastern (GSA 8-9-10-11) spatial divisions of the proposed management plan section 4 shows, by the DCF vessel length categories, the main features of the trawl fisheries (Table 4.8 and Table 4.9) and landings weight and landings value of the both the species under the proposed plan and all other species combined; also the economic dependency by vessel length category on the different species (Figure 4.15 and Figure 4.16).

In the western area the activity is from Spanish (including Catalonian) and French vessels. From this international data set the increasing importance of blue and red shrimp (*Aristeus antennattus*) with increasing vessel size is clear from the economic dependency metric. From an economic dependency perspective, the decreasing importance of red mullet *(Mullus barbatus)* is less significant. As with the data from Catalonia, however, the economic dependency suggests a continuum with vessel size rather than a clear change point.

In the eastern area the activity is predominantly from Italian vessels. The relative economic dependency between species under the plan is very similar between the 12-18 and 18-24m vessel length classes. Vessels greater than 24m show a higher dependence on giant red shrimp while vessels below 12m LOA show almost no dependence on any of the shrimp species.

It was not possible to make equivalent figures for the alternative segmentation as DCF data are not collected according to these vessel length categories.

Mixed-fisheries

To investigate whether it is more appropriate to define one or two fisheries (mixed fishery alone or mixed-fishery and deep-water shrimp, EWG 18-09 considered the actual level of mixing at trip level in the two disaggregated datasets. The details of the analyses are those reported in Annex 3.

The main analyses was to consider the percentage of trips having low or high percentages of each species.

8.1.7 Catalonian dataset

NB: the validity of computation of the total landings used in mixed-fisheries analyses is uncertain, so all analyses there are preliminary and subject to caution

In this dataset, more than 80% of the trips have none of the 6 species of the proposed plan representing more than 20% of the landings, indicating a highly mixed fishery Figure 8.6.

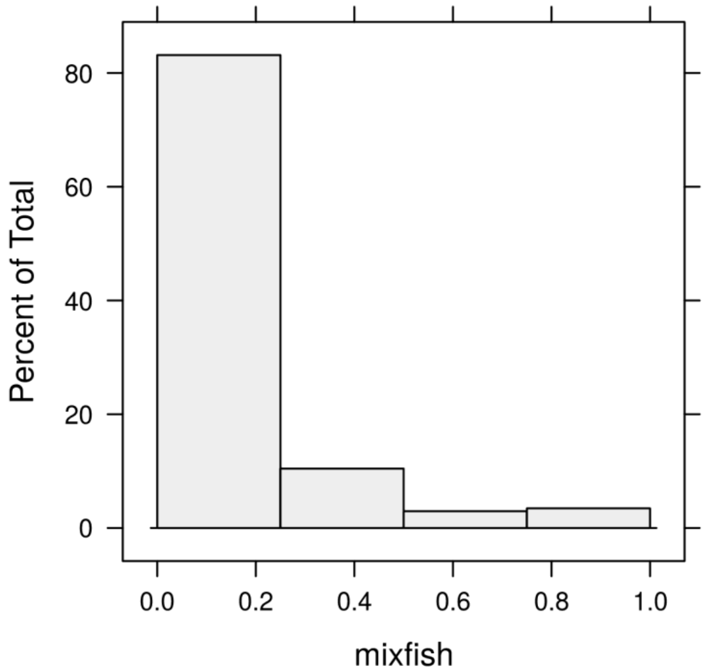


Figure 8.6: Trips by maximum fraction of the landings across the species in the MAP [Preliminary result subject to caution]

Looking in more detail, this mixing appears across most species and vessel sizes, and there are only a very small amount of trips which are specialised on the red and blue shrimp ARA. These trips represent less than 20% of the trips of the largest trawlers [24-40m] (Figure 8.7).

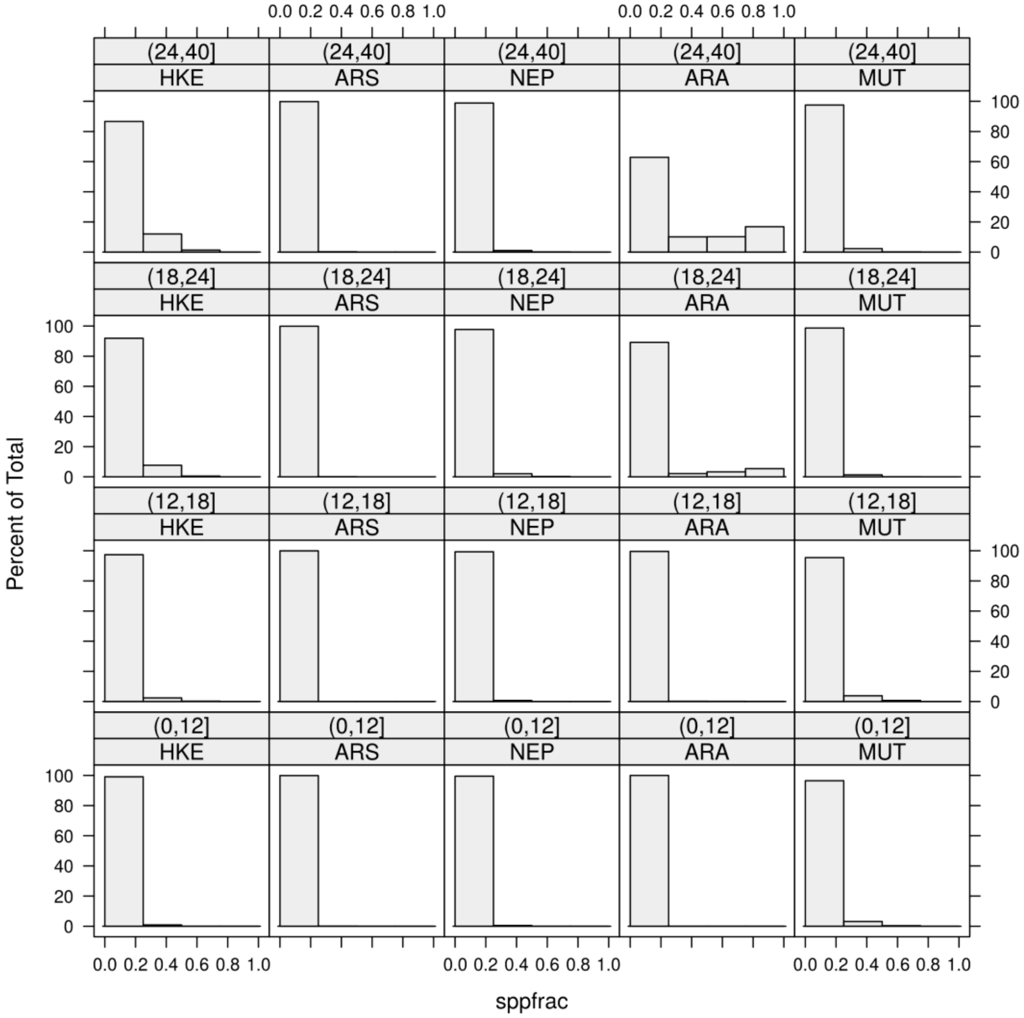


Figure 8.7: Trips by fraction of the landings and species in the MAP and LOA [Preliminary result subject to caution]

8.1.8 Italian dataset

In the Italian dataset, the picture is rather different. Here, around 40% of the trips catch more than 50% of a single species (Figure 8.8).

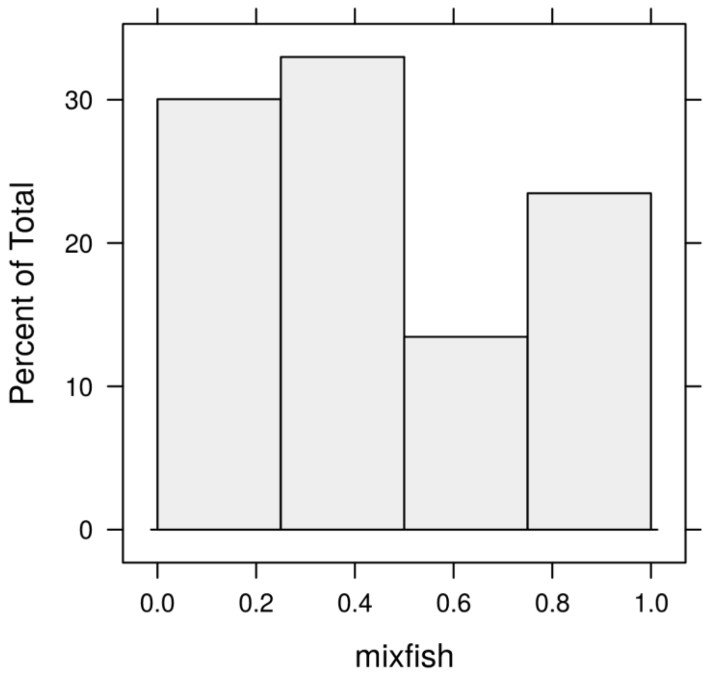


Figure 8.8 : Trips by maximum fraction of the landings across the species in the MAP

However, the picture is also more complex, since some degree of specialisation is observed across several segments and towards several species (Figure 8.9). For example, around 20% of the trips in the fleet segments [18-24) and [12-18) have more than 80% of deep sea rose shrimp (DPS) in their landings, another 20% have more than 80% of red mullet, and yet another 20% have more than 80% of red and blue shrimp (ARA).

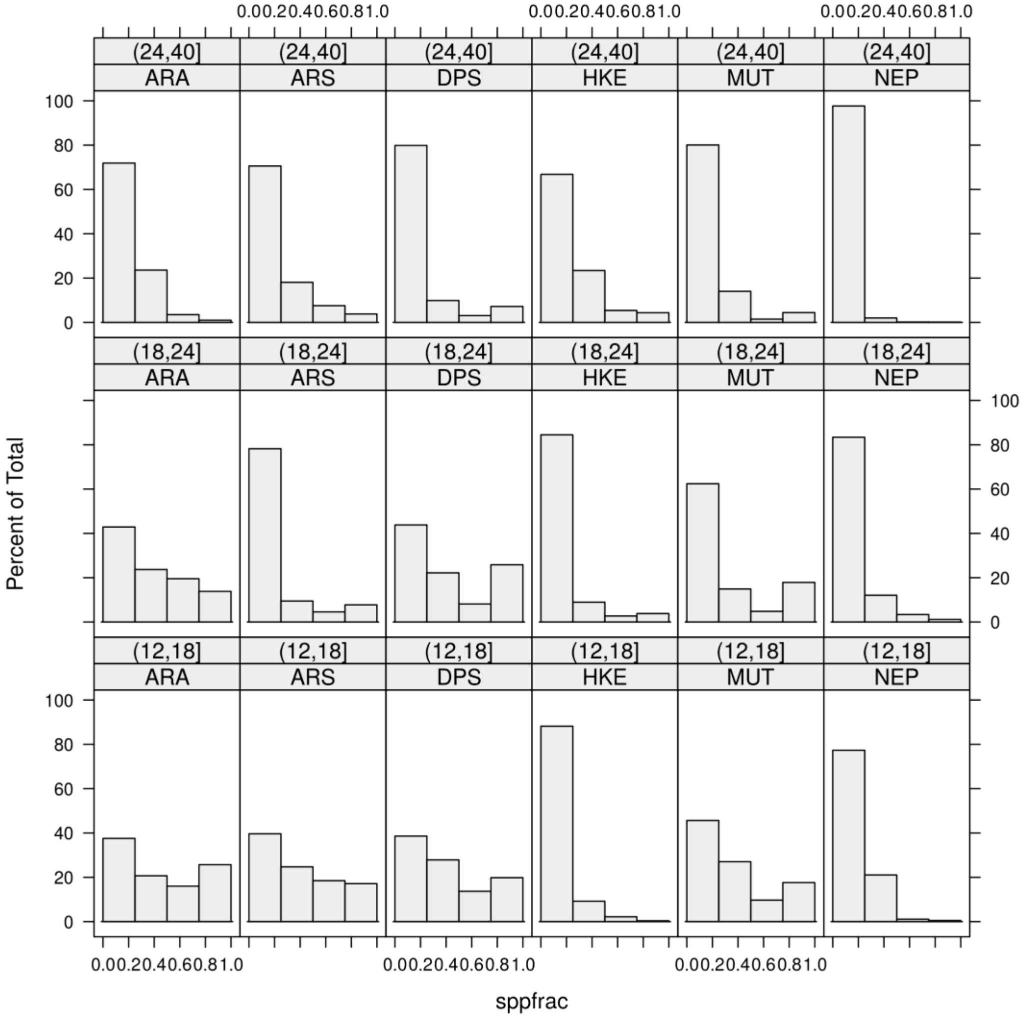


Figure 8.9 : Trips by fraction of the landings and species in the MAP and LOA

Impact on the Data Collection Framework

The data collection framework (DCF) uses the vessel length categories of the current multi annual plan proposal. These vessel length categories are in line with internationally agreed categories as outlined by the FAO, International Standard Statistical Classification of Vessels (ISSCFV) see http://www.fao.org/3/a-bt985e.pdf

If the alternative segmentation were used the vessel length categories would not be compatible with the current DCF data calls. Data to monitor trends in effort, landings and economic performance of the vessels in relation with the implementation of the effort management plan would need to be collected through a new, dedicated data call.

It would then not be possible to make direct comparisons of effort, landings (and therefore lpue) with previous years and with non-trawl gear types, using data held in the existing DCF databases, because of the difference in vessel length categories. Comparisons of economic performance to other fleet segments (using non-trawl fishing techniques) would again be compromised by different length categories to the Fleet Economic database. As explained in Box 1, past experiences with different datacalls using different vessel sizes categories have shown the negative implications of doing so, and the impossibility to thus obtain a consistent overview of biological and economic descriptors of the various fleet segments.

It should also be noted that VMS data is required for all vessels >12m LOA. If it were considered that detailed spatial data would help to review the progress of the management plan (cf section 3.1.10) it would probably be beneficial to have segments where detailed spatial data can be obtained from all vessels. To introduce a length category <15m LOA would mix vessels with and without VMS.

Box 1. An example of standardising categories across data calls

— The DCF follows the ISSCFV vessel length class categories. Economic data for EU fishing fleets is collected according to these categories and the Annual Fleet Economic data call collects data according to them.

— A Fisheries Dependent Information (FDI) data call also exists. This was initially set up to provide information on the effort trends of fleets subject to effort management regimes incorporated into single species long term management plans (e.g. the cod plan of the North Sea and surrounding waters and the Hake & Nephrops plan of the Iberian peninsula). When the database was first designed VMS was mandatory for vessels >15m and different effort rules applied in one region for vessels using VMS. Therefore, a vessel length split at 15m was employed.

— It was realised that the FDI database held transversal data (effort and landings) at a more disaggregated level than the economic database, (it also held some biological data including discard data). Improvements in bio-economic modelling were possible (e.g. the ability to consider individual gear types) if the data sets could be linked. The main obstacle to this linking was the differences in vessel length categories.

— The problem remained long after it was identified because the FDI database had become well established and it did not seem possible to replace the long time series of data. However, after the introduction of the revised CFP and area based multi annual plans (MAPS) it was decided to begin a new time series of FDI data compatible with the economic data set and vessel length categories were made those of the DCF.

Conclusions

Regarding the definition of fisheries, and the suitability of defining one or two fisheries, the conclusions are also difficult to draw. A striking result is that there are clear differences in the signals in the Italian and Catalonian datasets. The Catalonian fisheries seem highly mixed, with a very limited degree of specialisation. Conversely, the Italian fisheries seem more targeted, with a higher degree of specialisation, in particular on deep sea shrimps. In the Italian case, there might thus be scope for defining several fisheries, while it is less obvious on the Catalonian side.

From the current vessel size distribution there are no obvious cuts between categories, with vessel LOA spanning over a continuum of size. The current segmentation is consistent with the International Standard Statistical Classification of Vessels (ISSCFV), on which a number of legal reporting requirements are based including several data calls under the data collection framework DCF. Metiers-based info as well. These will still have to be addressed. It is also worth noting that vessels <12m have different level of information available, without VMS, and might need to be dealt with separately.

There are some differences in catch composition between small and large vessels, with the deeper and more remote species like red and blue shrimp being predominant for the largest vessels. However, the five other species are caught by all vessel sizes in variable quantities. The analyses of ToR3 have also revealed that the vessel size is only a limited predictor of LPUE variability, and many more factors may explain differences. For 4 species, the smoothed vessel size effect in the Italian dataset analyses was almost linear, indicating no natural threshold.

A large vessel length category (15-26m) would represent by far the biggest proportion of currently registered vessels with large differences in fishing efficiency, targeting behaviour and catch composition.

In conclusion, it is clear that any vessel size segmentation is arbitrary, and neither of the two alternative proposals seem to represent an obvious segmentation of the fleets. The datasets used show also some differences between the management areas proposed, so it is uncertain whether the alternative proposal would be any more suitable than the current one for the entire region.

It is necessary to account for differences in fishing power between small and large vessels. One may consider the alternative option of measuring and regulating effort not expressed in terms of fishing days alone, but in terms of fishing days weighted by a metric of fishing power, e.g. vessel size, horsepower or kilowatts. This is for example what has been used in the effort regime in the EU Atlantic and North Sea, where effort was regulated in terms of kWdays (cf section 3.1.11.)

9 Optimal harvest

Question was raised about a potential 'Optimal harvest', i.e. a harvest strategy provided by the scientific advice in which the stocks concerned are fished within their respective ranges of FMSY, whilst still allowing trade-offs between environmental, social and economic sustainability.

In the Mediterranean Sea where most of the stocks are overfished, the current fishing mortality is not only above Fmsy but also above the upper range of Fmsy, for those species where it has been defined.

For the 6 stocks included in the Management plan, important reductions in mortality are required for most stocks in the management unit 1 (GSA 1 to 7) (Figure 9.1), and less so in the management unit 2 (GSA 8-11, Figure 9.2).

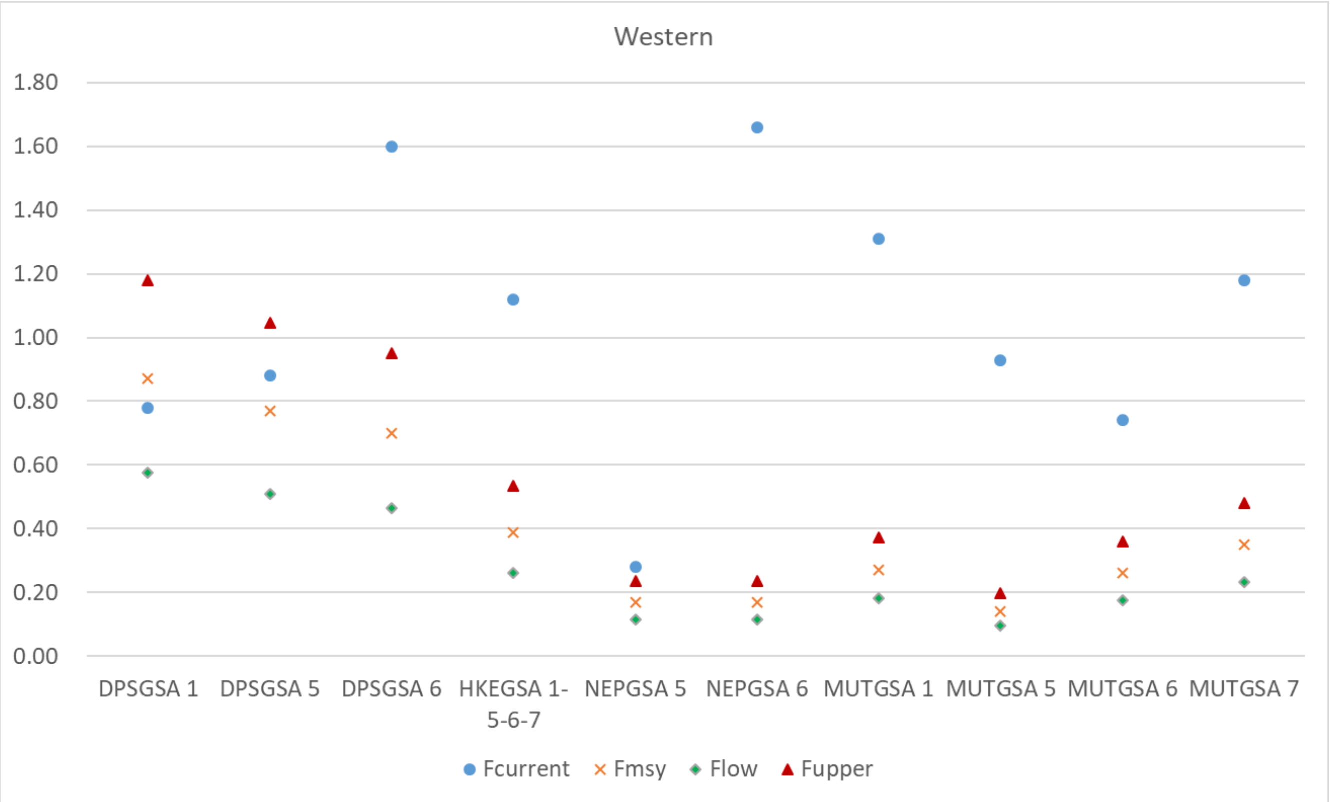


Figure 9.1. current fishing mortality and Fmsy ranges for stocks in Management unit 1 (GSAs 1 to 7).

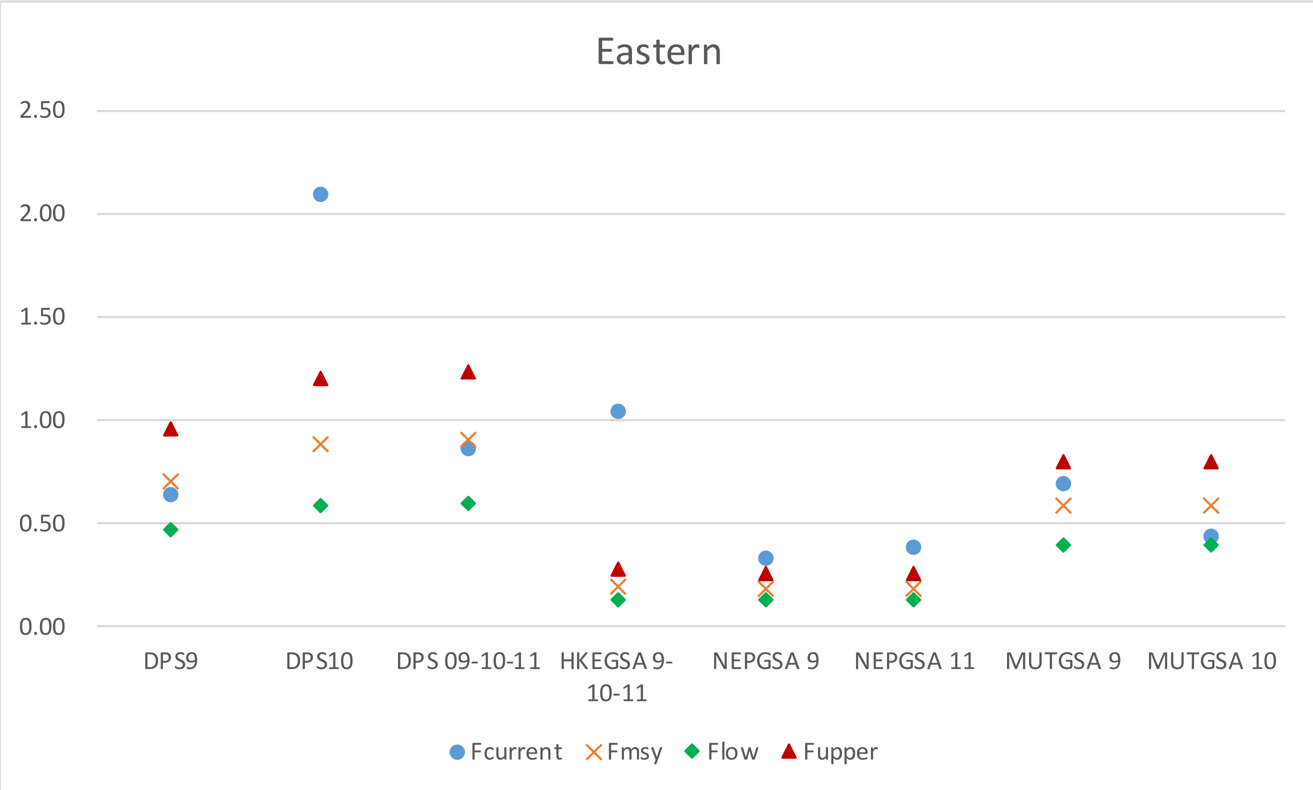


Figure 9.2. current fishing mortality and Fmsy ranges for stocks in Management unit 2 (GSAs 8 to 10).

It appears therefore unlikely to determine a unique level of fishing effort that would satisfy the objective of reaching Fmsy by 2020 for all stocks without major reductions. And as long as fishing mortality is above Fupper, the flexibility given by the MSY ranges is irrelevant.

In management unit 1 (GSA 1-7), given the mixed nature and the poor selectivity of most trips described in section 0 (*provisional result), it appears difficult to elaborate single-stock effort strategies, until fishermen can demonstrate that they change their fishing practices and reduce their catches of the most exploited stocks via changes in fishing gears and/or avoidance of fishing grounds.

In management unit 2 where a number of stocks are less overexploited and fisheries are more specialised, further discussion could take place on possible strategies, focusing in particular on options to avoid and recover hake without overly affecting the more targeted fisheries

Defining a "best possible strategy" for mixed-fisheries effort would also requires agreeing on a number of concepts: best with regards to what, and in which year? What are the acceptable trade-offs ? Is it a best possible compromise for everybody or can there be winners and losers?

10 ToR 6 : CONCLUSIONS AND RECOMMENDATIONS

Summary by ToR

In conclusion, the EWG 18-09 could address all ToRs to some extent. Although only limited preparatory work could be done in advance of the meeting, it has been possible during the meeting to put together a great number of exploratory analyses using a variety of datasets, in order to give a quite comprehensive picture of the challenges and options for the effort regime in the Western Mediterranean Sea. Special thanks is given to Italy and to the Generalitat of Catalunya who graciously provided an extensive trip-based dataset, without which most analyses could not have been performed. Interestingly, these two datasets have allowed the highlighting of both some commonalities but also some differences in the fishing patterns between the two proposed management areas and fleets concerned, thus illustrating the diversity of situations across the region.

The main results obtained for the various ToRs can be summarised as follows:

ToR 1: Lessons learnt. Effort regimes have been trialled in many other places in the world, especially in areas like the Mediterranean where landings are not easy to monitor and control. There is thus extensive knowledge on the potentials but also on the pitfalls and main threats that can prevent achieving the objectives of reducing fishing mortality. It is advisable to learn from these experiences and understand these pitfalls in order to integrate them in the design of the effort management plan. With regards to monitoring and controlling fishing effort, available technologies (VMS and AIS) provide valuable additional information to logbooks.

ToR 2: Baseline. The available transversal data for establishing the baseline are incomplete, and a number of gaps have been identified. These will need to be addressed by the Member States. The data and analyses presented in ToR 2 and ToR 4 are based on the available data and might thus be revised afterwards. Alternatively, the 2018 FDI Data Call is expected to provide a new and better basis for transversal data compared to the existing one, and this might be investigated further during autumn 2018 after completion of the STECF FDI working group.

Once a baseline is established, it is important that the monitoring of effort is performed and measured in the same way as the baseline.

The economic dependency of the fleet segments on the 6 species included in the plan is very variable, with dependency increasing with vessel sizes. For vessels less than 12m, these species represent around 25% of their average revenue, while they can represent up to 75% of the revenue for the largest trawlers.

ToR 3: Vessel performance. There are large individual differences in CPUE between fishing vessels and between fishing trips, with efficient trips catching 2 to 5 times more than average trips within the same fleet segment. Some measurable factors can explain a part of these differences but they are variable across species, and most of the variability still occurs even after account has been taken of these factors.

Gears design and size are important descriptors, but not well known and monitored. Trawls are constantly becoming wider, larger and more efficient in the Mediterranean, and there is a huge potential for further efficiency increase and technical creep in the Western Mediterranean. This might be further reinforced when effort becomes limiting.

ToR 4: Relation between F and E. This relation is poorly defined in most cases, and not linear. This can be explained by a number of issues, an important one being the lack of contrast in the historical time series, with F and E having remained largely stable and high over the last 8 years. There are many other factors contributing to blurring this further, including differences in targeting different species between vessels and technological creep. Effort will first need to be reduced significantly before any effects on fishing mortality can be observed.

ToR 5: Bioeconomic simulations. A number of bioeconomic models are available for the main demersal fisheries in GSAs 6, 7 and 9, making it possible to conduct some projections following various scenarios. However, the results of models assuming a constant catchability (decrease in fishing mortality proportionally to decrease in fishing effort) will likely be overoptimistic in terms of stock recovery, because of the likely increase in fishing efficiency when fishing effort is limited. Other factors of poor implementation have not been considered but are likely to occur too. .

AOB 1: Alternative fleet segmentation. There are no obvious and simple ways to define meaningful segmentation of vessel size and fisheries groups, because of the diversity of fleet structure and catch composition within and between each segment. Any segmentation will remain somehow arbitrary. Alternative segmentations have the drawbacks to be outside of the international categorisation used in a number of data reporting frameworks, not least under the Data Collection Framework DCF, and would not be compatible with current databases collecting biological and economic indicators.

AOB 2: Optimal Harvest. Many stocks included in the plan are exploited largely above Fmsy and Fupper, providing little flexibility to define a mixed-fisheries effort within the MSY range, especially in the Management Unit 1 (GSAs 1-7). Fisheries are also quite mixed. Further discussion would also be necessary to further define the objectives and time frame alongside which such effort should be estimated.

Recommendations and additional considerations

A central issue is that reducing fishing mortality is essentially linked to reducing catches, with effort being only an indirect means to achieve this. It is therefore recommended to monitor closely whether catches change when the effort regime is implemented, and to adapt the effort reduction accordingly.

Inactive and partly active vessels represent a threat against any effort regime, maintaining an important overcapacity in the system. Once stocks start recovering following reductions in fishing effort and catches, the profitability and economic attractiveness will increase also and this idle overcapacity may become active again, thus jeopardising the benefits for the active vessels that underwent the effort reduction. This issue of inactive capacity should be addressed in the early stages of the effort regime.

Even if successfully implemented from day 1, any positive effect on stock recovery will not be observed in the stock assessments before at least 3 years, the time for the stock and fishery to react and a stock assessment to be performed the following year. Medium-long term commitments are thus necessary.

Inspiration can be taken from a number of effort reduction plans in the mixed-fisheries of the Baltic Sea and Northern Europe successfully implemented during the previous decade, where objectives were defined in two phases. These plans distinguished between a recovery phase building on annual effort reduction targets until a given objective is reached for the most overexploited target stock, and secondly a management phase building on the flexibility of the MSY ranges to maintain the mixed-fisheries in a sustainable state.

The exploratory analyses of the two trip-based datasets from Italy and Spain (Catalonia) respectively have evidenced contrasting patterns between these two regions, with the fisheries being to some extent less mixed and more targeted in some segments of the Italian fleets. These two datasets represented only a subset of the entire trawling fleet of the three Member States, and the mixed fisheries for the Catalonian data are subject to caution, so these results are preliminary; but they illustrate that there might be different options that can be implemented by the different member states in order to reach the same common objectives set in the EU regional management plan. This can include spatial considerations.

Because of the predominance of small crustaceans as major target species for a number of vessels, protection of nurseries and use of selective gears (e.g. gears incorporating a grid) sorting out juveniles of overexploited fish stocks, such as hake, should be considered as a way to contribute to achieving the mixed-fisheries objectives of the plan.

However, decreasing the fishing mortality on hake requires also decreasing catches of adult hake, and not of juveniles only. Therefore, selectivity and closed areas alone will not be sufficient to achieve the single-stock objectives for that species.

The automatic monitoring of position and activity of trawlers via VMS can contribute to ensure the compliance of the fishing effort regime.

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13 LIST OF ANNEXES

Electronic annexes are published on the meeting's web site on: https://stecf.jrc.ec.europa.eu/ewg1809

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ANNEX 1 - FURTHER DESCRIPTION OF THE MEDITERRANEAN FLEET DATA AND TRENDS BASED ON THE TOR 2 DATASET

ANNEX 2 - FACTORS AFFECTING VESSELS PERFORMANCE

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Background documents are published on the meeting's web site on: https://stecf.jrc.ec.europa.eu/ewg1809

List of background documents:

EWG-18-09– Doc 1 - Declarations of invited and JRC experts (see also section 12 of this report – List of participants)

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