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Scientific, Technical and Economic Committee for Fisheries (STECF) - Evaluation of fishing effort regime in the Western Mediterranean – part IV (STECF-19-14)

Edited by Clara Ulrich and Cecilia Pinto

Joint Research Centre

EUR 28359 EN

Contact information

Name: STECF secretariat

Address: Unit D.02 Water and Marine Resources, Via Enrico Fermi 2749, 21027 Ispra VA, Italy

E-mail: jrc-stecf-secretariat@ec.europa.eu

Tel.: +39 0332 789343

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Authors:

STECF advice:

Abella, J. Alvaro, Bastardie, Francois, Borges, Lisa, Casey, John, Catchpole, Thomas, Damalas, Dimitrios, Daskalov, Georgi, Döring, Ralf, Gascuel, Didier, Grati, Fabio, Ibaibarriaga, Leire, Jung, Armelle, Knittweis, Leyla, Kraak, Sarah, Ligas, Alessandro, Martin, Paloma, Motova, Arina, Moutopoulos, Dimitrios, Nord, Jenny, Prellezo, Raúl, O'Neill, Barry, Raid, Tiit, Rihan, Dominic, Sampedro, Paz, Somarakis, Stylianos, Stransky, Christoph, Ulrich, Clara, Uriarte, Andres, Valentinsson, Daniel, van Hoof, Luc, Vanhee, Willy, Villasante, Sebastian, Vrgoc, Nedo

EWG-19-14 report:

Ulrich, C., Accadia, P., Billet, N., Bitetto, I., Certain, G., D'Andrea, L., Mannini, A., Martin, P., Merzeraud, M., Murenu, M., Perez, J.L., Pinto, C., Romagnoni, G., Russo, T., Sbrana, M., Spedicato., M.T..

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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 is the fourth of a suite of STECF EWG reports dedicated to the fishing effort regime in the Western Mediterranean Sea, following EWG reports 18-09, 18-13 and 19-01.

The group was requested to progress on an operational mixed-fisheries model for Effort Management Unit 1 (i.e. GSAs 1-2-5-6-7), to update mixed fisheries models and F-E analyses with the most recent data and the most recent stock assessments., and to draft a mixed-fisheries advice including relevant scenarios and displays.

In EMU 1, good progresses were achieved in combining effort and catch data from both France and Spain into the bioeconomic multifleet model IAM. The model is now able to run and perform management simulations on the stock of hake (combined assessment in GSAs 1-2-5-6-7). Time did not allow to include additional stocks at this stage, but the required elements are now in place and adding these should be fairly straightforward in the future.

The updates of the F-E analyses performed in EWG 18-09 and 18-13 with the most recent time series did not change the perception of the lack of relationship between fishing effort and fishing mortality. For many stocks and fleet segments, the relationship using effort expressed as fishing days has no obvious slope, indicating that the limited reduction of effort observed in the recent years did not have any visible effect on reducing fishing mortality yet. Supplementary analyses were performed using effort expressed in hours instead of days, which improved the relationship to some extent. This is consistent with previous statements in previous reports that fishing effort would be best expressed and managed in terms of fishing hours than fishing days:

Extended simulation work was performed regarding management scenarios, especially in EMU 2 (GSAs 8-9-10-11). The multi-fleet BEMTOOL model was updated and extended, and 6 scenarios involving effort reductions, sometimes combined with spatial closures, were simulated in a stochastic approach. Also, the individual-based spatial model SMART was updated, and the outcomes of the spatial closures scenarios was used to parameterise the spatial scenarios in BEMTOOL. Finally, the simpler NIMED model was also updated and run, but its results were not compared to the two other models. In EMU 1, the IAM model (hake alone) was used to perform 3 runs of effort reduction, one of them including a French proposal for a spatial closure in the Gulf of Lion.

Finally, a 3-pages synthetic advice is proposed, summarising the key findings of the simulations. A key outcome is that the proposed closure of the coastal zone down to 100 m deep, max 6nm from the shore, is unlikely to contribute to reducing hake catches. Rather, it can have an adverse effect if the fleets reallocate their effort further away where important concentrations of juvenile exists.

In the light of the F-E relationships analyses, all results presented in this report are considered to be overoptimistic since they assume a true reduction in F if effort decreases, which may in reality be limited during the first years of effort reductions.

SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF) – Evaluation of fishing effort regime in the Western Mediterranean – part IV (STECF-19-14)

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

EWG 19-14 was a follow-up of the EWG 18-09 held in June 2018, the EWG 18-13 held in October 2018 and the EWG 19-01 held in March 2019.

The EWG had the following TORs:

TOR 1. Progress on an operational mixed-fisheries model for Effort Management Unit 1 (i.e. GSAs 1-2-5-6-7) according to EWG 19-01 conclusions.

TOR 2. Update mixed fisheries models and F-E analyses with the most recent data and the most recent stock assessments.

TOR 3. Develop a draft mixed-fisheries advice including relevant scenarios and displays. To the extent possible, the following management scenarios should be tested in each Effort Management Unit (EMU)*:

a) Baseline;

b) 10% reduction in 2020 + 30% from 2021 to 2024;

c) 10% reduction in 2020 + 30% from 2021 to 2024 + closures areas;

d) F within the range of FMSY of the most vulnerable stock by 2024; and

e) F within the optimal harvest by 2024.

* Linear reductions (in fishing days) and equally distributed by fleet segments.

TOR 4. Discuss future steps.

Regarding the TOR 1, STECF observes that EWG 19-01 in March 2019 had considered two possible avenues for future work:

- Extending the IAM to the GSAs along the Spanish coasts, with appropriate stocks and fleets data;
- Further developing the FLBEIA application with appropriate fleets data:

STECF observes that the first option was selected by the EWG 19-14. During the EWG the French and Spanish fleets were explicitly incorporated in a specific setting of the IAM model although still only one stock (hake) has been included. STECF agrees with EWG 19-14 that it will be straightforward to incorporate the dynamics of other assessed stocks such as red mullet, but notes that the EWG did not have the time to do this in the timeframe of the meeting. STECF also notes that some economic variables for the Spanish fleets were not updated in the EWG 19-14, although they are available through DCF economic transversal data and the Spanish Ministry of Fisheries.

Regarding the TOR 2, STECF observes that the EWG updated the landings, fishing mortality and fishing effort as requested by the TOR. The EWG also made a comparison between the three data sources (Annual Economic Report (AER), Fishery Dependent Information (FDI) and Mediterranean and Black Sea call (MBS)). STECF observes that there are still discrepancies between the three data sources for landings and effort; these discrepancies should to be transmitted to the data providers to match the effort data used in the EWGs with the Member States baseline effort levels. STECF notes also that similar discussions took place in the FDI EWG 19-11, which formulated some suggestions on how to move forward (see section 5.2 of this plenary report).

STECF observes that most of the updated fishing mortality–fishing effort (F-E) relations are flat or have the slope in the opposite direction (so that larger effort have corresponded to lower fishing mortality in the historical time series) and differ from the regressions that are forced through the origin (assuming that zero effort implies zero fishing mortality). In other words, in most cases, in the ranges of effort realised in the past, fishing mortality has not been proportional to effort. This implies that future effort reductions cannot be expected to lead to equivalent reductions in fishing mortality (hyperstability). This is a well-known phenomenon and a well-known drawback of effort management, as documented in STECF EWG 18-09.

A number of simulations were presented in TOR 3, both for EMU 1 and EMU 2. As a general comment for this TOR, STECF notes that for all these simulations a constant catchability was assumed, implying proportional changes between effort and F, despite the outcomes of TOR 2 and the issue of hyperstability discussed above. The results of the scenarios presented in TOR 3 are thus "best case" outcomes. In reality, though, it is likely that F will decrease to a lesser extent and thus SSB and catch will increase to a lesser extent than they do in the simulations.

For EMU 1, different scenarios were tested using IAM. These scenarios were based on the reduction in fishing days (scenario b of TOR 3), in which only the global OTB (trawlers) effort is reduced by 10% in the first year (2020), and then incrementally reduced every year to reach an effort reduction of 40% in 2024. On top of this scenario, a spatial closure was also simulated (scenario c of TOR 3). Additionally, and also on top of scenario b, a "gear selectivity" scenario was simulated assuming that gear restrictions to improve juvenile selectivity and avoid fishing mortality at age 0 are implemented from 2020 onwards (without closure), without impacting other ages. STECF observes that from the results of the simulations performed by the EWG, all three scenarios lead to an increase in hake SSB, with scenario c of TOR 3 (effort reduction + closure) reaching the highest hake SSB. Overall, at the end of the projection period (year 2025), landings of hake, under the assumptions of the simulations, are likely to reach similar levels as prior to the management plan for trawlers (those affected by the plan), while long liners and gillnetters will benefit from higher landings than prior to the management plan. STECF observes that no conclusions can be drawn on the mean value of the landings of all the species, because the dynamics of other species than hake were not incorporated in the simulation. This also prevented the EWG from providing simulations of scenarios d and e (TOR 3).

For EMU 2 the EWG followed the suggestion made in the EWG 19-01, and BEMTOOL was used to perform simulations for all the scenarios defined by the TOR. Scenario e of the TOR (optimal harvest by 2024) has been interpreted by the EWG in two different ways: firstly by closing the nursery areas of European hake on top of scenario c to maximise the protection of the most overexploited stock, and secondly by searching for MEY (Maximum Economic Yield) i.e. obtaining the level of effort that maximizes the difference between total revenue and total cost. Prior to running the BEMTOOL model, the SMART model was run to simulate effort displacement owing to closures; the outcomes of SMART were input into the BEMTOOL model for the corresponding scenarios.

Regarding the hyperstability issue discussed above, STECF acknowledges that simulating the optimal spatial allocation of the fleet using SMART is a way to partially capture one of the mechanistic drivers of the hyperstability effect. Nevertheless, other sources of this hyperstability still remain, such as the elasticity of substitution between the three main inputs (capital, labour and fish stocks). STECF notes that owing to the lack of consideration of this elasticity of substitution, when optimizing the fishery using three different economic indicators (GVA, ROI and

Profits), the results obtained are the same independently of the indicator used. STECF observes that with the type of bioeconomic models used, the hyperstability effect is not easy to parameterise and model. Modelling approaches mechanistically accommodating hyperstability, for example by assuming that under effort reduction the least profitable trips are removed first, exist in the literature as reviewed in EWG 18-09 (e.g. Kraak et al., 2008; Van Oostenbrugge et al., 2008), and some initial trials for modelling this were also explored in EWG 19-01. STECF agrees that further investigations should perhaps be tried.

STECF observes that from the simulations performed in EMU 2, scenarios based on a reduction of F for the most vulnerable stocks (scenario d) and overall effort reduction (scenarios b and c), meet the F objectives for all the species expect for hake where additional measures will be required to bring the fishing mortality to FMSY. STECF observes that for scenarios e (optimal harvest) results for maximizing the economic indicators (ROI, GVA and Profits) provide the result that the optimal MEY effort level is around 60% of the baseline effort, which is close to the actual effort reduction foreseen in the MAP. STECF notes that this MEY is calculated as the highest value of the three indicators in the year 2024, without considering the transition phase (2020-2023), and keeping the number of vessels constant.

STECF observes that the attempt to have a MEY reference point is a step forward in the economic evaluation of the effort regime in the Mediterranean. However, they are still preliminary and should be further analysed and discussed in future EWGs. Not least, the main outcome is that F_{MEY} in a mixed fishery model could imply lower optimal biomass levels than those using F_{MSY} as a reference point. They also highlight that using F_{MSY} reference levels for the most vulnerable stocks, could cause the underutilization of other stocks according to the F_{MSY} individual stock targets.

STECF observes that the EWG also provides some further steps that should be considered in future EWGs of this suite (TOR 4), including the further analysis of the hyperstability phenomenon, further developing the modelling in EMU 1, the issue of different estimations of fishing effort in different databases and the definition of mixed-metiers vs. deep water metiers in the MAP.

STECF conclusions

STECF concludes that the EWG 19-14 as the most recent EWG of a suite of previous EWGs dedicated to the same issue is clearly progressing towards closing the gap to have an assessment of the consequences of the effort regime in the Mediterranean Sea.

STECF concludes that, for EMU 1, the model is not yet fully operational to have an overview of the consequences of the effort management and that it has to be further developed including other species, updating the economic parameters of the Spanish fleet and including uncertainty estimates.

STECF concludes that in the draft advice sheet example provided under TOR 1, the hyperstability effect and therefore the likely overestimation of the recovery of the stock should be highlighted more strongly, and that the results should be treated as the maximum recovery level foreseen.

STECF concludes that for EMU 2 the assessment of the hyperstability phenomenon should be explored further and that the assumptions and methods used under EMU 2 can help on refining the work done in EMU 1.

STECF concludes that the reasons of the differences of the effort and landings data of the three data sources, identified by the EWG should continue to be monitored in future EWGs and that these discrepancies should be to be transmitted to the data providers to match the effort data used in the EWGs with the Member States baseline effort levels.

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Contact details of STECF members

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Name	**Affiliation[1]**	**Email**
Abella, J. Alvaro	Independent consultant	aabellafisheries@gmail.com
Bastardie, Francois	Technical University of Denmark, National Institute of Aquatic Resources (DTU-AQUA), Kemitorvet, 2800 Kgs. Lyngby, Denmark	fba@aqua.dtu.dk
Borges, Lisa	FishFix, Lisbon, Portugal	info@fishfix.eu
Casey, John	Independent consultant	blindlemoncasey@gmail.com
Catchpole, Thomas	CEFAS Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk, UK, NR33 0HT	thomas.catchpole@cefas.co.uk
Damalas, Dimitrios	Hellenic Centre for Marine Research, Institute of Marine Biological Resources & Inland Waters, 576 Vouliagmenis Avenue, Argyroupolis, 16452, Athens, Greece	shark@hcmr.gr
Daskalov, Georgi	Laboratory of Marine Ecology, Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences	Georgi.m.daskalov@gmail.com

Name	**Affiliation**[1]	**Email**
Döring, Ralf (vice-chair)	Thünen Institute [TI-SF] Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute of Sea Fisheries, Economic analyses Herwigstrasse 31, D-27572 Bremerhaven, Germany	ralf.doering@thuenen.de
Gascuel, Didier	AGROCAMPUS OUEST, 65 Route de Saint Brieuc, CS 84215, F-35042 RENNES Cedex, France	Didier.Gascuel@agrocampus-ouest.fr
Grati, Fabio	National Research Council (CNR) – Institute for Biological Resources and Marine Biotechnologies (IRBIM), L.go Fiera della Pesca, 2, 60125, Ancona, Italy	fabio.grati@cnr.it
Ibaibarriaga, Leire	AZTI. Marine Research Unit. Txatxarramendi Ugartea z/g. E-48395 Sukarrieta, Bizkaia. Spain.	libaibarriaga@azti.es
Jung, Armelle	DRDH, Techopôle Brest-Iroise, BLP 15 rue Dumont d'Urville, Plouzane, France	armelle.jung@desrequinsetdeshommes.org
Knittweis, Leyla (vice-chair)	Department of Biology, University of Malta, Msida, MSD 2080, Malta	Leyla.knittweis@um.edu.mt
Kraak, Sarah	Thünen Institute of Baltic Sea Fisheries, Alter Hafen Süd 2, 18069 Rostock, Germany.	sarah.kraak@thuenen.de
Ligas, Alessandro	CIBM Consorzio per il Centro Interuniversitario di Biologia Marina ed Ecologia Applicata "G. Bacci", Viale N. Sauro 4, 57128 Livorno, Italy	ligas@cibm.it; ale.ligas76@gmail.com
Martin, Paloma	CSIC Instituto de Ciencias del Mar Passeig Marítim, 37-49, 08003 Barcelona, Spain	paloma@icm.csic.es
Motova, Arina	Sea Fish Industry Authority, 18 Logie Mill, Logie Green Road, Edinburgh EH7 4HS, U.K	arina.motova@seafish.co.uk
Moutopoulos, Dimitrios	Department of Animal Production, Fisheries & Aquaculture, University of Patras, Rio-Patras, 26400, Greece	dmoutopo@teimes.gr

Name	Affiliation[1]	Email
Nord, Jenny	The Swedish Agency for Marine and Water Management (SwAM)	Jenny.nord@havochvatten.se
Prellezo, Raúl	AZTI -Unidad de Investigación Marina, Txatxarramendi Ugartea z/g 48395 Sukarrieta (Bizkaia), Spain	rprellezo@azti.es
O'Neill, Barry	DTU Aqua, Willemoesvej 2, 9850 Hirtshals, Denmark	barone@aqua.dtu.dk
Raid, Tiit	Estonian Marine Institute, University of Tartu, Mäealuse 14, Tallin, EE-126, Estonia	Tiit.raid@gmail.com
Rihan, Dominic	BIM, Ireland	rihan@bim.ie
Sampedro, Paz	Spanish Institute of Oceanography, Center of A Coruña, Paseo Alcalde Francisco Vázquez, 10, 15001 A Coruña, Spain	paz.sampedro@ieo.es
Somarakis, Stylianos	Institute of Marine Biological Resources and Inland Waters (IMBRIW), Hellenic Centre of Marine Research (HCMR), Thalassocosmos Gournes, P.O. Box 2214, Heraklion 71003, Crete, Greece	somarak@hcmr. gr
Stransky, Christoph	Thünen Institute [TI-SF] Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute of Sea Fisheries, Herwigstrasse 31, D-27572 Bremerhaven, Germany	christoph.stransky@thuenen.de
Ulrich, Clara (chair)	IFREMER, France	Clara.Ulrich@ifremer.fr
Uriarte, Andres	AZTI. Gestión pesquera sostenible. Sustainable fisheries management. Arrantza kudeaketa jasangarria, Herrera Kaia - Portualdea z/g. E-20110 Pasaia – GIPUZKOA (Spain)	auriarte@azti.es
Valentinsson, Daniel	Swedish University of Agricultural Sciences (SLU), Department of Aquatic Resources, Turistgatan 5, SE-45330, Lysekil, Sweden	daniel.valentinsson@slu.se
van Hoof, Luc	Wageningen Marine Research Haringkade 1, Ijmuiden, The Netherlands	Luc.vanhoof@wur.nl

Name	**Affiliation**[1]	**Email**
Vanhee, Willy	Independent consultant	wvanhee@telenet.be
Villasante, Sebastian	University of Santiago de Compostela, Santiago de Compostela, A Coruña, Spain, Department of Applied Economics	sebastian.villasante@usc.es
Vrgoc, Nedo	Institute of Oceanography and Fisheries, Split, Setaliste Ivana Mestrovica 63, 21000 Split, Croatia	vrgoc@izor.hr

REPORT TO THE STECF

EXPERT WORKING GROUP ON EVALUATION OF FISHING EFFORT REGIME IN THE WESTERN MEDITERRANEAN – PART IV (EWG-19-14)

SETE, FRANCE, 30 SEPTEMBER 4 OCTOBER 2019

1 INTRODUCTION

This report is the fourth of a suite of STECF EWG reports dedicated to the fishing effort regime in the Western Mediterranean Sea.

The first EWG in June 2018 (STECF 18-09) addressed a number of issues related to managing fisheries with fishing effort regimes. Building on a review of previous experiences worldwide, the report highlighted the main and well known concern that catchability (relationship between fishing effort and fishing mortality) is not constant since fishers will increase their efficiency in order to maintain their historical catch and revenue levels in spite of effort reduction[1]. This was corroborated by quantitative analyses of differences in catch efficiency between fishing trips using trip-based data from Italy and Spain, differences that are only little explained by features such as vessel size or fishing area. Also, a study was presented monitoring continuous increase in gear size (width, opening, twin trawl etc) in the Mediterranean, highlighting a potential for further increase in fishing efficiency that may counteract the expected effect of effort reduction. Finally, a comparison of the completeness and consistency of the various datasets on catch and effort by fleet segments available at the JRC was performed, highlighting a number of gaps.

The second EWG in October 2018 (STECF 18-14) built further on these results. The relationship between fishing effort and fishing mortality, aggregated at the level of fleet segment and year, was analysed for a number of the MAP stocks using the available time series of stock assessment. This relationship is never linear, and in most cases it cannot even be detected in the time series. This means that a reduction of fishing effort will not translate by a similar reduction of fishing mortality at least in the first years of implementation. Secondly, the trips analyses were extended to new data from France, showing similar results as for Italy and Spain. Finally, a first review of existing bioeconomic mixed fisheries models in the Western Med was conducted. Considering that many models are potentially available but that none of them is directly operational for the purpose of the MAP, a 2 years road map was agreed to improve the availability and use of such models.

Accordingly, the third EWG in March 2019 (STECF 19-01) focused uniquely on updating and improving mixed-fisheries models. Several models of various complexity were presented and tested for the two regions (EMU & and EMU2). Good progresses were achieved but the most important issue left was the need to develop a single combined model for EMU1 including data from both Spain and France together, instead of the existing models by GSA. In addition, the EWG listed numerous other issues and future questions regarding data and models' dimensions (e.g. stock definition, inclusion of other species than the MAP species etc).

This fourth report is thus the continuation of this work, progressing further on these issues in order to have models and datasets fully operational for providing mixed-fisheries advice on the MAP.

1.1 Terms of Reference for EWG-19-14

The group is requested to:

TOR 1. Progress on an operational mixed-fisheries model for Effort Management Unit 1 (i.e. GSAs 1-2-5-6-7) according to EWG 19-01 conclusions.

[1] http://www.fao.org/gfcm/fishforum2018/presentations/en/, Theme 1 session 2

TOR 2. Update mixed fisheries models and F-E analyses with the most recent data and the most recent stock assessments.

TOR 3. Develop a draft mixed-fisheries advice including relevant scenarios and displays. To the extent possible, the following management scenarios should be tested in each Effort Management Unit (EMU)*:

a) Baseline;

b) 10% reduction in 2020 + 30% from 2021 to 2024;

c) 10% reduction in 2020 + 30% from 2021 to 2024 + closures areas;

d) F within the range of FMSY of the most vulnerable stock by 2024; and

e) F within the optimal harvest by 2024.

* Linear reductions (in fishing days) and equally distributed by fleet segments.

TOR 4. Discuss future steps.

1.2 Main findings

The main objective of this EWG is to produce a draft mixed-fisheries advice providing relevant findings to managers, as requested in ToR 3.

The following section is the first attempt of this advice, where key results and considerations are summarised in a 4 pages stand-alone document that can be easily shared and discussed further.

KEY FINDINGS FOR EMU 1 (GSAs 1 2 5 6 7)

The MAP baseline of 10% effort reduction in 2020 for all Spanish and French trawlers fleets followed by a 30% additional reduction implemented between 2021 and 2024 is expected to have positive effects on the stock of Hake, although that would not be sufficient to reach Fmsy by 2025. The biomass is expected to grow substantially even under the current poor levels of recruitment, due to a better survival of juveniles and an increase of the population of adult hake. This population growth could maintain the hake landings levels around their current value, thus rapidly offsetting the effects of effort reduction on revenue.

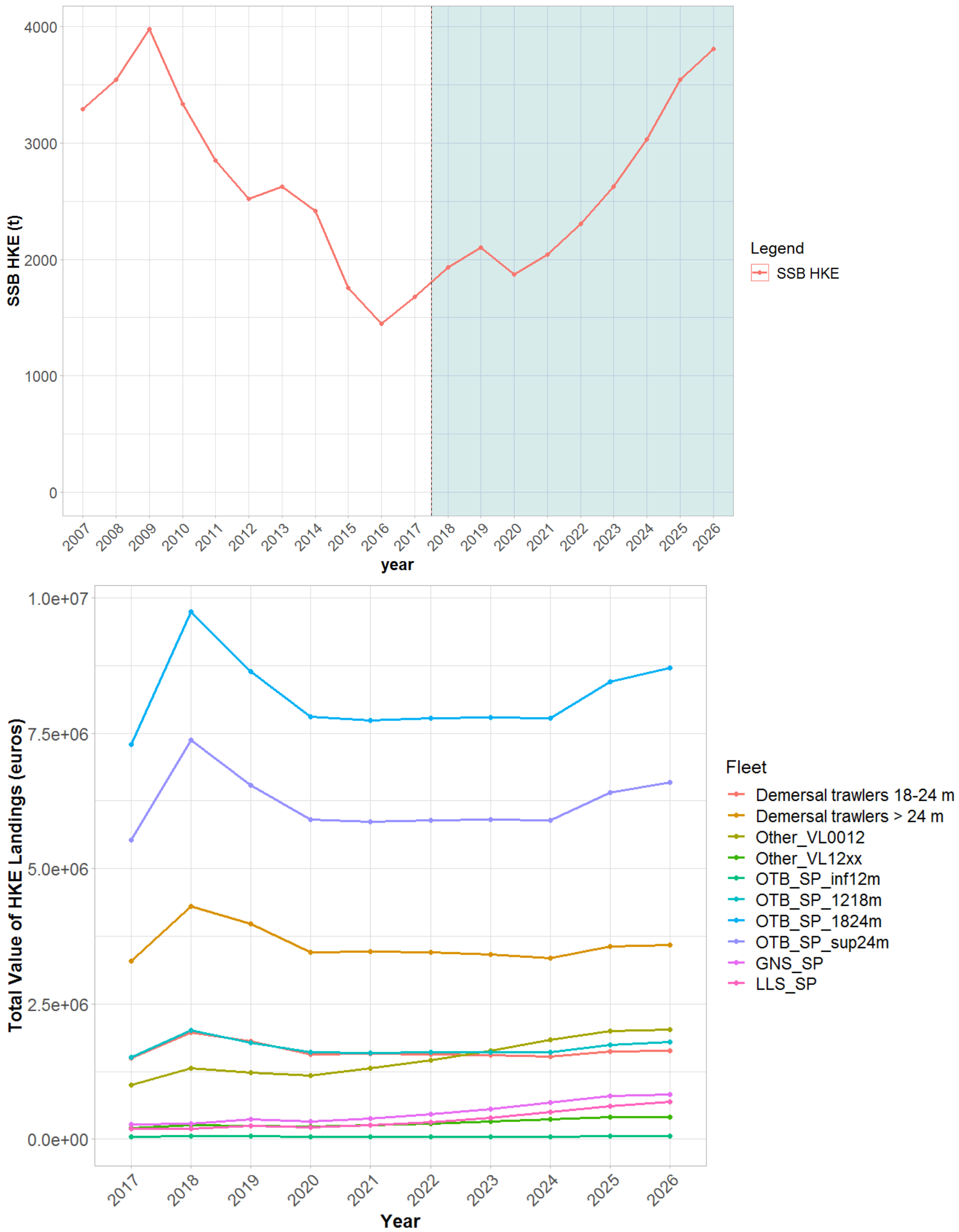


Figure 1.2.1.1. EMU 1 (IAM model). Predicted Hake SSB (top) and hake revenues by fleet segment (bottom) under the MAP scenario of effort reduction

Additional measures to protect the hake juveniles such as selectivity improvements or a large closure (area deeper than 90 m being closed 8 months a year) were also simulated, showing additional benefits for the stock without affecting significantly the landings and value levels.

The longliners and gillnetters, not covered by the MAP, are expected to beneficiate economically from the reduction of the trawlers' effort.

The effects on the other stocks have not yet been assessed.

KEY FINDINGS FOR EMU 2 (GSAs 8 9 10 11)

The most overexploited stocks in EMU 2 are blue-and-red shrimp and hake, for which a constant effort may lead to a further decrease of biomass. The reduction of fishing effort foreseen in the MAP would not be sufficient to reach Fmsy in 2025 for hake, red mullet in GSA 9, giant red shrimp and blue and red shrimp. The MAP closure proposal (down to 100m deep or 6 nm from coast) is not expected to bring substantial protection to the stocks, except for red mullet. Additional closures of hake nursery areas would reduce juvenile catches and contribute to higher levels of hake biomass, but would not contribute to reaching Fmsy on the adult stock. The impact of the various scenarios are more variable for the other stocks than they are for hake.

In terms of economic impact, the MAP 40% effort reduction is closed to the scenario of Maximum Economic Yield (MEY).

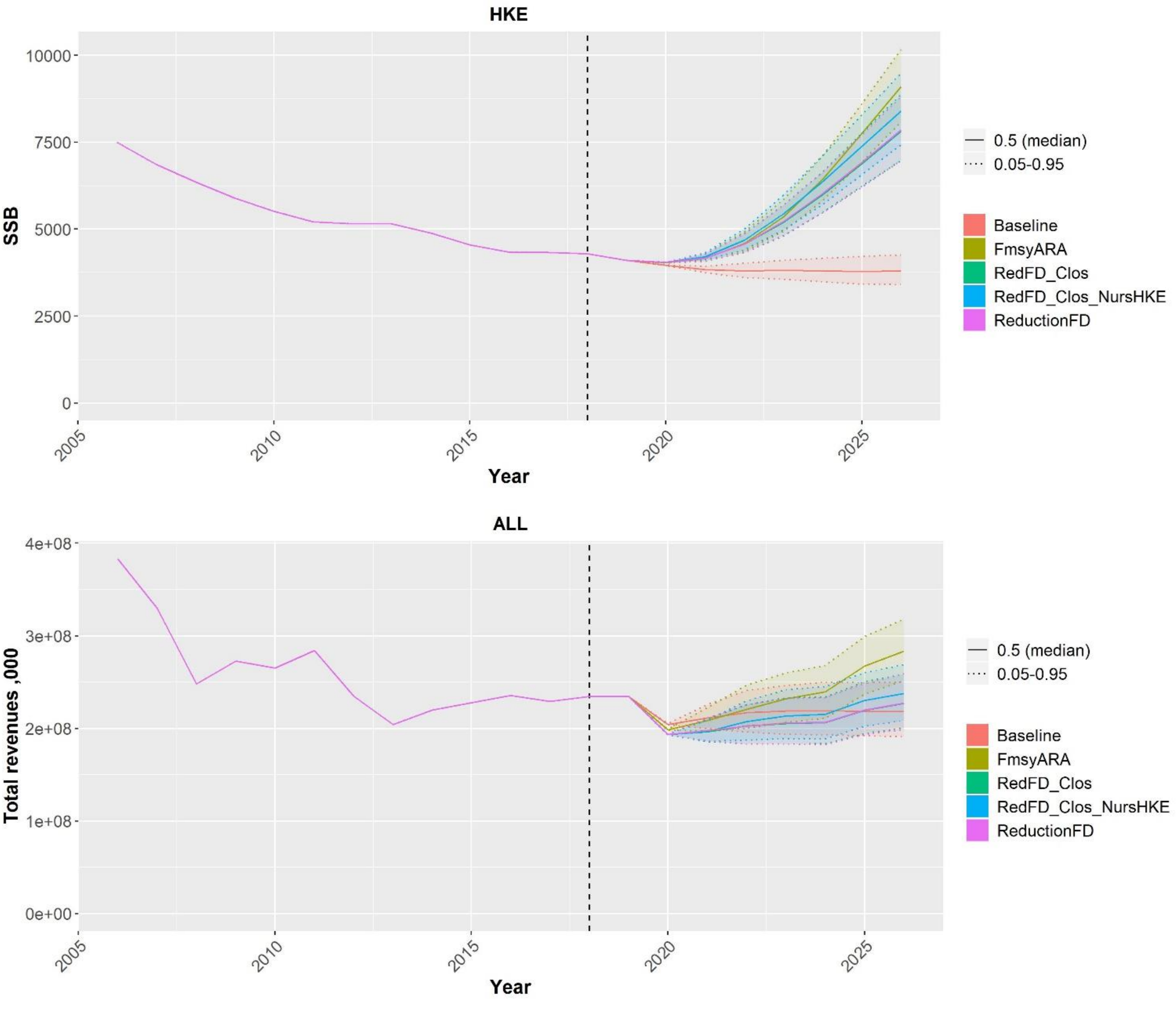


Figure 1:1.2.2. EMU 2 (BEMTOOL model). Predicted Hake SSB (upper) and total revenues for all stocks and fleets (bottom) under six scenarios (Baseline = constant effort. FmsyARA = F within the range of F_{MSY} of the most vulnerable stock (ARA) by 2024; ReductionFD = 10% reduction in 2020 + 30% from 2021 to 2024;

RedFD_Clos=same as ReductionFD + MAP closure; RedFD_Clos_NursHKE = same as RedFD_Clos +closure of hake nursery areas).

Both for EMU 1 and EMU 2, the analyses of hake distribution suggest that the closure of the coastal area (100 m deep – max 6nm from coast) may have adverse effects on hake stocks, since most of the juvenile catches are located outside of this area and a relocation of fishing effort to these deeper zones may increase hake catches.

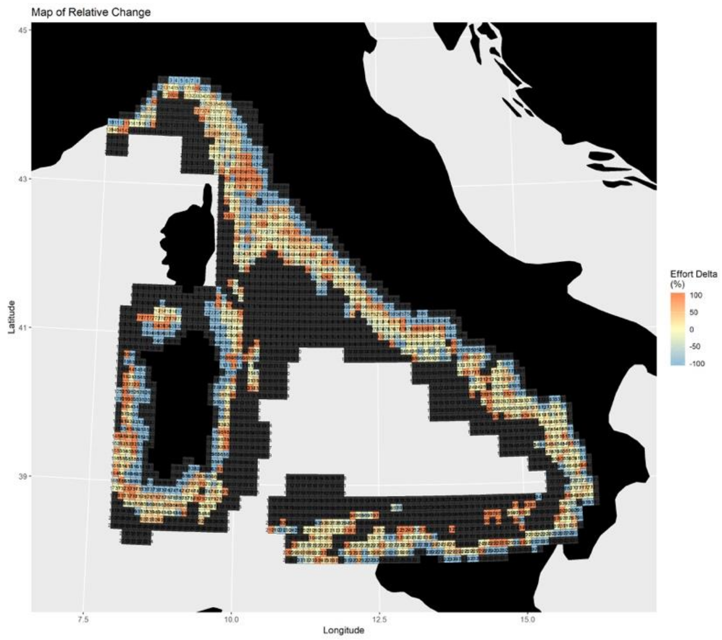


Figure 1.1.2.3 EMU 2 (SMART Model) – Map of the relative differences between observed and optimized effort resulting from the implementation of the all year Spatial Closure of the -100m isobath/6 NM scenario.

METHODS AND DATA SOURCES

Two different fleet-based mixed-fisheries models have been used for the two EMUs. While based on similar approaches, data sources and modelled dynamics, the models used in the two areas differ in their implementation and state of completion.

The selection of models among existing options and the workplan for subsequent development was performed during STECF EWG 19-01.

In EMU 1, no global model covering all Spanish and French fleets in all GSAs 1,2,5,6,7 did exist prior to EWG 19-01. Therefore, some work was necessary to select the most appropriate modelling platform and extend it to cover the required stocks and fleets. Progresses were achieved during STECF EWG 19-14, where French and Spanish effort and hake catch data for 10 fleet segments were brought together in the IAM model (Merzereaud et al., 2011). 3 deterministic scenarios were performed on hake. The effects on the other stocks have not yet been assessed.

EMU 2 extends along the coast of a single Member State, and several models already existed prior to EWG 19-01 covering all Italian activities in GSAs 9, 10 and 11. These models were updated and adapted during EWGs 19-01 and 19-14 for the purpose of the MAP evaluation. The available models differ widely in their scale and purposes, and were therefore used in complementarity. BEMTOOL is a multi-species multi-gear bio-economic simulation model for mixed fisheries simulating the effects of management options on stocks and fisheries on a fine time scale (month). It includes 14 fleet segments and 7 stocks. 6 stochastic scenarios were performed, and their results are compared in a combined multi-criteria approach. SMART (Russo et al., 2014) is an individual-based model where each fishing vessel is considered as an independent agent that operates to maximize gains (as difference between revenues and costs), which can thus explore the potential effects of different spatial and/or temporal closures taking into account the potential reallocation of fishing vessels towards other fishing grounds. In EWG 19-14, these two models were coupled for running the area closure scenarios**,** where SMART was used to simulate the effects of a closure in terms of resulting effort distribution and fishing mortality, which was then used to calibrate the selectivity change for the fleets in the BEMTOOL simulations, allowing thus to compare this scenario with the other scenarios not involving spatial closures.

IMPORTANT ISSUES IN RELATION TO THE ADVICE

A major concern regarding the management of mixed demersal fisheries by effort limits is the uncertain relationship between fishing effort and fishing mortality, which implies that a reduction of fishing effort in terms of e.g. days at sea will likely not translate into an equivalent reduction of fishing mortality (an effect referred to as "hyperstability"). The main reasons for this are well documented. They are that i) there are great differences between the performances of individual vessels, with some vessels fishing more per day at sea than others (STECF EWG 18-09 showed for example that for some of the fleets covered by the MAP, the most efficient trips may be two to five times more efficient than the average trips within the same vessel length class). ii) when fishing effort is reduced, fishermen are incentivised to maintain their previous level of revenues and catches by becoming more efficient through tactical choices (where and when to fish) and technological investments (more powerful motor engine, larger gears). This will negate some of the expected reductions in fishing mortality, especially during the first years of effort reduction. These aspects have been thoroughly analysed and explained in EWG 18-09. Indeed, relationships between the available time series of fishing effort and fishing mortality were fitted for a number of the MAP stocks in EWGs 18-13 and 19-14, with no obvious patterns to be seen.

The consequence of this is that the true positive effects of effort reductions on the stock biomass remain unclear, and the scenarios presented above can be considered to be overoptimistic. Scenarios accounting for hyperstability were explored during EWG 19-01, but not pursued in EWG 19-14 due to time constraints. Such scenarios require a number of assumptions to be made in order to quantify a plausible alternative catchability value.

Bioeconomic models rely on modelling the population dynamics of fish stocks and the economic dynamics of fleets. In the case of multi-species fisheries, such as the western Mediterranean demersal fisheries, the number of fish stocks for which there are parameters to populate a population dynamics models are typically few. For instance, in EMU1 demersal fisheries produce of the order of 60 species in significant quantities, but only 5 are concerned by the Multi-Annual management Plan. These 5 species are, naturally, the main species in terms of landings and economic importance and stock assessments are regularly produced. However, they represent 20% or less (depending on the GSA) of the total demersal fisheries production. Hence the population dynamics of the majority of demersal stocks ("secondary species" or commercial bycatch) is not well-known and the effect of the effort reduction proposed in the MAP on these secondary species cannot be assessed with any accuracy.

Another issue discussed in EWGs 18-13 and 19-14 is a degree of mismatch between various databases regarding the actual level of fishing effort and catches of some fleets. Effort data are collected in several databases with different purposes, and the estimates provided differ sometimes. The sources of these inconsistencies are being investigated, and, to the extent possible, they will be corrected in next year's datacalls.

2 ToR 1: Progress on an operational mixed-fisheries model for Effort Management Unit 1

2.1 Recall on the main issues and conclusions from EWG 19-01

EMU1 covers the GSAs bordering two Member States, Spain and France. Different Member States means different access to data, and different developments according to the national and/or regional priorities. As a result, the existing models reviewed by STECF EWG 19-01 did not cover the entire EMU1. IAM and ISIS-FISH, developed in France, covered only GSA 7. MEFISTO, developed by CSIC in Barcelona, covered mainly GSA6, although some applications were developed for GSA5 in the past. No models cover the GSAs 1 and 2.

Three options for future work were thus considered by the experts during the EWG 19-01:

- Extending IAM to the GSAs along the Spanish coasts, with appropriate stocks and fleets data
- Further developing the FLBEIA application with appropriate fleets data
- Implementing a BEMTOOL application from scratch, to be consistent with EMU2.

After the EWG, the conclusion reached by the experts was that the preferred option would be the first one (extending IAM), on the basis that this is this model where most expertise is in the region.

This ToR is thus specifically intended to review the progresses achieved in this initiative.

2.2 Development of the IAM model for EMU 1

During the previous STECF EWG-19-01 meeting, a very first version of the IAM model had been built, focusing on Hake and explicitly modelling 5 French fleets: 3 French trawlers (<18m, 18-24m and >24m) and 2 French non-trawlers (<12m and >12m), while spanish vessels were all pooled together. The model explored various exploitation scenarios and their consequences on hake, but largely without economic results (only French fleets were assigned detailed prices and economic parameters). The analysis, which was carried out at both spatial scales of stock assessment (stock GSA 7 alone and stock GSA 1,5,6,7 combined), suggested an increase in hake landings of gillnetters and longliners as these fleet segments were not impacted by the management plan but beneficiated from the reduction of trawlers effort, and highlighted also the difficulty to reach Fmsy by 2025. Our conclusions highlighted the need to further develop the model, by explicitly including the spanish fleets, extending the economic inputs information to all considered fleets in order to give access to more relevant and robust economic indicators, and including explicitly additional stocks. These were the objectives of the new French – Spanish IAM group gathered for STECF EWG-19-14.

As a preparation for the group, a preliminary input file has been built beforehand. On the basis of the parameterization carried out for the EWG19-01, and the initial year being kept (2017), it was mostly an update of the "Fleet" parameter sheets containing the economic, activity and production-related data for the French fleet segments. During the group, a work of finalization was done, in particular in terms of completion of the biological data for Hake (for example, the addition of catch-at-age data for Spanish vessels to enrich fishing mortality allocation process, the refined assessment of a transition matrix between age and commercial categories, and complementary integration of segments for Spanish vessels). Some modifications in the implementation of the scenarios were also made to meet the specifications of the ToR for the group.

Regarding the update on the French fleet parameters, data regarding number of vessels, horsepower, fleet capacity, fishing effort, landings and prices per species, sales revenue, LPUE, discards, landing costs, fuel costs, other fixed and variable costs, crew share, investment and maintenance costs, insurance costs were documented for all fleets. The French fleet categories were the same as for the first implementation of the IAM model, i.e. demersal trawlers 18-24m, demersal trawlers >24m, other vessels <12m and >12m (no vessel were included in the demersal trawlers <18m category). The "other" vessels are essentially gillnetters, but encompass all forms of French small-scale fisheries in the Gulf of Lions (pots and traps, lamparo, longliners, ...).

For the update on the Spanish fleet parameters, the same information than the French fleet has been updated, except for fleet storage capacity, fuel costs, variables costs, crew share, insurance costs, and investment costs. Six Spanish fleet segments are considered, four for demersal trawlers: 06-12, 12-18, 18-24 and >24m; and gillnetters and longliners.

The data sources used for the French and Spanish update were the DCF transversal data, the DCF data on catches, sources from both the french and the spanish fisheries ministry, the Annual Economic Report, and the results of the EWG 19-10 on the Mediterranean Stock Assessment (2017 data taken for global input parameterization, and 2018 fishing mortality applied in 2018). The EWG19-14 updated the parameters for HKE (Merluccius merluccius) stock dynamics, LPUE data per fleet segments for MUT (Mullus barbatus), ANE (Engraulis encrasicolus), PIL (Sardina pilchardus), OCT (Octopuses), MAC (Scomber scombrus), MNZ (monkfishes), ZZZ (total catch excepting the selected species), and total catch per fleet segments, for the Spanish fleets in GSAs 1, 5, 6 7. Catches of these species in GSA 2 (Alboran Island) are almost nil. For the Spanish fleets, the number of vessels, kW and GT were taken from the economic transversal data (2016, the most recent information in the database). The following parameters were updated, by species and fleet: catch at age (for HKE ; data for MUT was also provided for Spanish vessels in order to integrate MUT stock dynamics, but it was eventually not done due to time constraints), mean weight at age (for HKE), total catch, total income, mean price by species, mean price by commercial category (HKE) and LPUE. The input on the activity of the fleets (fishing days, hours at sea per day) and crew were based on the expert's knowledge on the fisheries. In Spain, fishing days and days at sea are the same value, since the vessels return to port, daily. The maximum number of hours at sea for bottom trawlers is 12 hours per day.

Thanks to this update work, both French and Spanish fleets are now explicitly represented in this specific setting of the IAM model. For example, the economic consequences of for example differences between countries in species market prices can now be taken into account.

Hake was still the only stock which is at present dynamically represented in the model, but other stocks could be considered dynamically and parameterized from stock assessment outputs such as EWG 19-10 (MUT for example). This could not be done during the EWG because of time constraints, but all elements are now in place and adding these could be relatively straightforward to do in the near future. Other economic variables for the Spanish fleets are still to be updated (e.g. fuel, salaries, depreciation, maintenance, insurances, investment by vessel, non-variable costs, etc.). This information is available in the DCF economic transversal data and the Spanish Ministry of Fisheries. By combining these two data sources it will be possible to complete the IAM data for Spanish fleets.

3 TOR 2: UPDATE ANALYSES OF THE RELATIONSHIP BETWEEN FISHING EFFORT AND FISHING MORTALITY USING THE MOST RECENT DATA SETS AND STOCK ASSESSMENTS.

3.1 Introduction

STECF EWG 18-09 and 18-13 performed a number of analyses aiming at identifying potential relationships between fishing effort and fishing mortality. In most cases these analyses were unsuccessful, with no visible relationships to be observed over the time series of available data.

Most of these analyses were however performed on older datasets, since many of the stock assessments of the MAP stocks had not been updated since 2014-2015.

To support the implementation of the MAP, updated assessments of the main MAP stocks were performed by STECF both in 2018 and 2019 (EWG 18-12 and 19-10). Accordingly, EWG 19-13 updated the F-E analyses with the most recent data, to monitor the most recent trends in catchability.

During the EWG 19-14 the relationship between fishing mortality and days at sea for some stocks of the target species of the Western Mediterranean MAP was analysed by using the updated information on F and E (Table 3.1.1).

Table 3.1.1 – Summary of advice from EWG 19-10 by area and species considered in EWG19-14. F 2018 is estimated F in the assessment, and used in the short term forecast for 2019. Change in F is the difference (as a fraction) between target F in 2020 and the estimated F for 2018. Change in catch is from catch 2018 to catch 2020. Biomass status is given as an indication of trend over the last 3 years for stocks with time series analytical assessments. Biomass reference points are not available but is noted if stock status is considered to be in a low state or high state due to exploitation rate. A4A was the method used for all assessment analysed. Gear considered and related to the assessment are reported too

Area	Species	Method/ basis	Fbar	F 2018	F 2020	Change in F	Catch 2018*	Catch 2020	Change in catch	F_{MSY} ($F_{0.1}$ as proxy)	Biomass (status)	Gear related
1_5_6_7	HKE	a4a	1-3	1.84	0.38	-79%	3444	1268	-63%	0.38	low/stable	OTB+GNS+LLS
9_10_11	HKE	a4a	1-3	0.74	0.22	-70%	2086	772	-63%	0.22	declining	OTB+GNS+LLS
9_10_11	DPS	a4a	1-2	0.88	0.97	10%	1422	1301	-9%	0.97	high/stable	OTB
9_10_11	ARA	a4a	2-5	1.45	0.39	-73%	387	72	-81%	0.39	declining	OTB
9_10_11	ARS	a4a	1-3	1.37	0.45	-67%	681	199	-71%	0.45	declining	OTB+GNS* (* gsa 10 only)

3.2 Results

The EWG 19-14 analysed stocks for which a combined assessment was carried out.

In the western GSAs (EMU1), the relationship between days at sea and fishing mortality was analysed for the stock of European hake (HKE) in GSAs 1, 5, 6, 7. In the eastern GSAs (EMU2), this was investigated for HKE in the GSAs 9,10 and 11 combined, deep-water rose shrimp (DPS) in the GSAs 9,10 and 11 combined, giant red shrimp (ARS) in the GSAs 9,10 and 11 combined and blue and red shrimp (ARA) in the GSAs 9,10 and 11 combined.

Days at sea were extracted from the MEDBS Data call 2019. For GSA 7, only Spanish data were available for the whole data series. French data were available only for the period 2015-2018. Fishing mortalities were obtained from the last stock assessments performed on the target species by the STECF stock assessment working group (EWG 19-10). However, the results of the stock assessments WG, report a fishing mortality for age classes not split among the various GSAs. Using as a factor the ratio between the number of individuals per age class caught in each GSA and the total number of individuals caught in the combined GSAs EWG 19-14 divided the Fbar by single GSA. When catch information by age where available also by fleet segment and GSA the Fbar was disaggregated by fleet too. It was not possible to analyse the relationship between fishing mortality and days at sea by fleet-length segment as the catch by age class per fleet segment was not available.

To evaluate the relationship between fishing mortality and effort by species and GSA the matrix with the partizionated Fbar for all stock was join merged with data of fishing effort reported in the DCF Mediterranean and Black Sea call. Additionally, numbers of fishing hour and primary production, derived by SMART, have been included in the data matrix for HKE in MU2.

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

3.2.1.1 Trend in effort (days at sea)

The trends of days at sea for the species and areas under study are reported in Figure 3.2.1 and Table 3.2.1. The stock assessment on HKE included mostly catch data of bottom trawling (OTB) which is the main gear exploiting the species in the areas. In GSAs 1, 5, 6 and 7, most of the landings come from otter trawls. The contribution of set nets (GNS) and longlines (LLS) to the total landing is around the 4% each. The number of days at sea for OTB is particularly high in the case of GSA 6 compared to the other GSAs. In the western geographical area, there is an evident tendency to a reduction of days at sea over the years. Days at sea for France in GSA 7 are missing for the period 2004-2014.

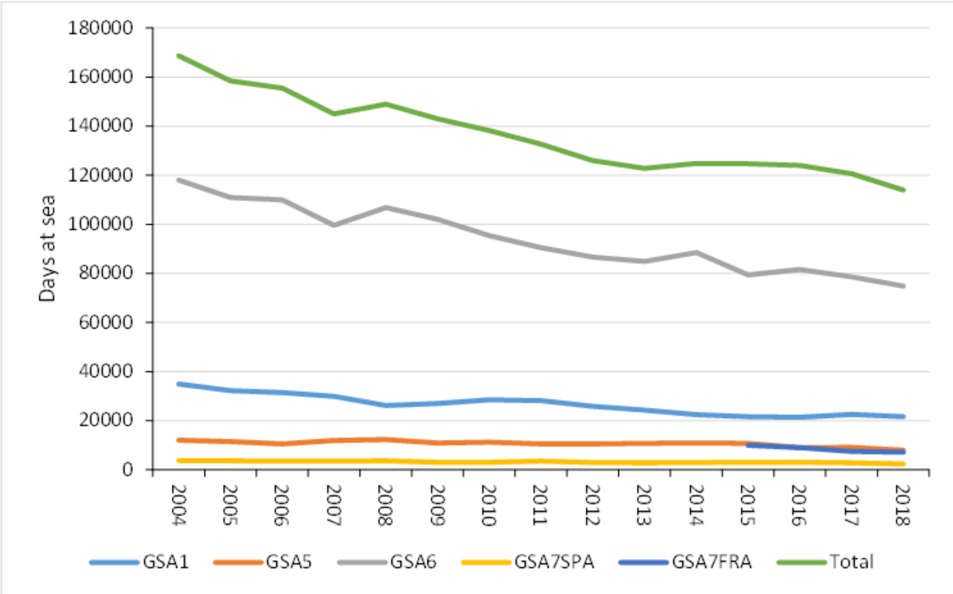


Figure 3.2.1 - Trends of fishing days of OTB for the fleet fishing in GSAs 1, 5, 6 and 7 and in the management Unit 1 (whole western GSAs).

Table 3.2.1 – Days at sea of the bottom trawling for the member states fishing in GSAs 1, 5, 6 and 7 and in the management Unit 1 (whole western GSAs).

MS	GSA	Gear	Mètier	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
SPA	SA 1	OTB	All	34951	32295	31443	29917	26201	27017	28476	28170	25851	24334	22395	21587	21345	22537	21633
SPA	SA 5	OTB	All	12012	11497	10507	11907	12226	10934	11239	10498	10568	10769	10936	10714	8959	9158	7947
SPA	SA 6	OTB	All	118076	110957	110008	99638	106867	102005	95438	90470	86587	84882	88528	79421	81649	78530	74820
SPA	SA 7	OTB	All	3714	3626	3550	3553	3694	3008	3097	3486	2966	2791	2966	3064	3090	2840	2357
FRA	SA7	OTB	All												9939	8965	7488	7193
SPA+FRA	Total	OTB	All	168753	158375	155508	145015	148988	142964	138250	132624	125972	122776	124825	124725	124009	120553	113950

3.2.1.2 Stock assessment data

The catch numbers at age and the overall fishing mortalities at age for HKE in Management Unit 1 and the corresponding Fbar (1-3) estimated during the STECF EWG 19-10 stock assessment for the GSAs 1, 5, 6 and 7 combined are reported in Table 3.2.2 and Table 3.2.3. The period covered is 2007-2018.

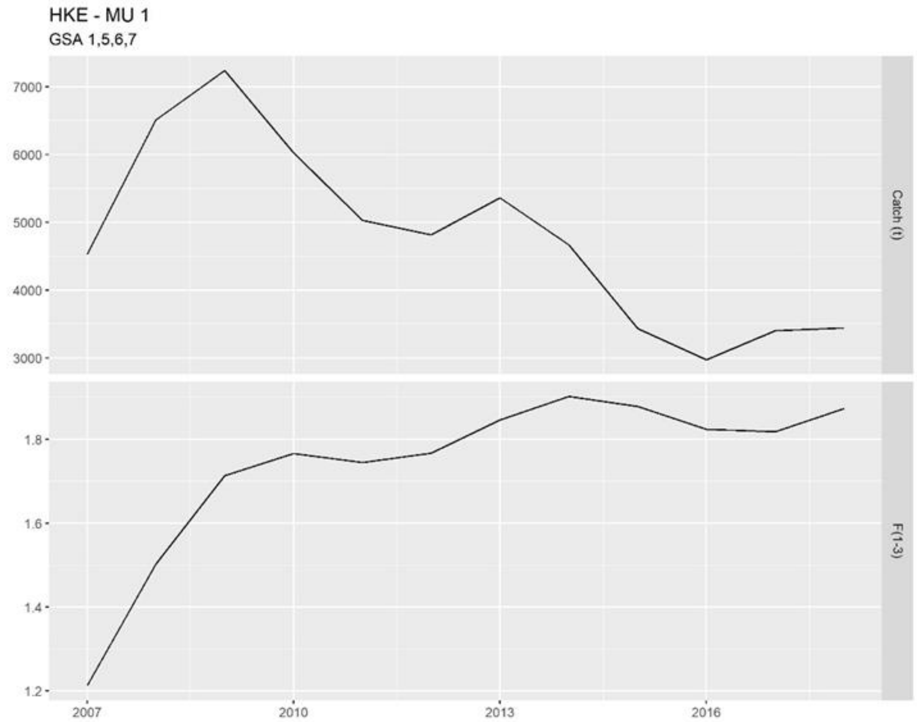


Figure 3.2.2 - Fbar and catch from the assessment (EWG 19-10) of European hake in the management Unit 1 (whole western GSAs).

Table 3.2.2 – Fishing mortalities at age for HKE in GSAs 1, 5, 6 and 7 combined.

age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	0.33	0.52	0.45	0.21	0.1	0.1	0.15	0.22	0.19	0.13	0.13	0.19
1	1.17	1.45	1.66	1.71	1.69	1.71	1.79	1.84	1.82	1.76	1.76	1.81
2	1.43	1.77	2.02	2.08	2.05	2.08	2.17	2.24	2.21	2.15	2.14	2.21
3	1.04	1.29	1.47	1.51	1.49	1.51	1.58	1.63	1.61	1.56	1.56	1.6
4	0.41	0.82	1.89	4.14	5.41	3.42	1.5	0.87	0.88	1.1	1.08	0.76
5	0.06	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09

Table 3.2.3 – Catch in number at age by the whole western geographical area for HKE stock.

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	77833	200167	76971	40391	61207	40234	63755	70862	17256	8814	9848	11313	12731	7115	12791	9216	15281
1	96716	291306	100698	61286	83136	57769	99090	102931	45529	36253	35970	42203	35554	22645	31721	25574	40337
2	2118	7541	2748	2949	3753	3377	2598	5381	5148	4323	2620	22869	3641	2223	1611	2060	2097
3	236	632	293	410	592	503	272	527	404	333	220	6151	231	169	98	110	177
4	47	204	35	49	55	92	94	125	98	61	39	1581	25	25	18	16	12
5	21	38	15	5	17	23	16	14	11	9	3	338	4	2	1	4	1

Table 3.2.4 – Catch in number at age by GSA of HKE in the management unit 1.

GSA	age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GSA 1	0	0	1140	2219	279	3399	100	240	524	147	176	8	0	0	2	4	1018	894
GSA 1	1	0	2722	5404	1466	4261	1593	1269	3511	2669	3784	2272	1263	925	682	916	2788	3155
GSA 1	2	0	317	378	356	350	219	260	417	1003	474	279	283	200	138	103	177	251
GSA 1	3	0	64	37	54	46	41	38	73	110	35	21	32	23	11	5	10	22
GSA 1	4	0	4	5	5	1	7	8	6	13	3	1	2	1	2	0	1	1
GSA 1	5	0	1	1	1	2	1	4	1	0	0	0	0	0	0	0	0	0
	age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GSA 5	0	1	5	64	12	10	35	9	84	15	8	14	67	98	9	12	5	338
GSA 5	1	743	327	534	774	1019	1457	1024	641	609	542	386	1038	906	624	465	347	1167
GSA 5	2	62	42	47	73	74	112	57	28	97	64	42	46	78	66	36	57	51
GSA 5	3	4	2	5	5	6	15	11	5	4	8	7	4	8	6	4	4	4
GSA 5	4	1	1	1	1	1	3	3	2	2	1	2	2	1	2	1	1	0
GSA 5	5	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
	age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GSA 6	0	52181	193133	68513	33831	55005	36996	52960	66437	11429	6784	7833	5629	6118	4144	7203	6497	9942
GSA 6	1	55271	270345	83446	47326	70885	45172	67227	83437	26015	23501	23568	21717	16057	12112	18289	16904	26112
GSA 6	2	567	4882	1226	1647	1986	1668	1126	1854	2604	2547	1600	1763	2120	1244	878	978	1296
GSA 6	3	72	398	141	257	285	252	104	279	214	249	147	200	149	114	75	83	121
GSA 6	4	7	159	11	29	21	46	50	95	70	50	27	24	18	14	13	12	8
GSA 6	5	0	15	9	2	8	13	2	9	7	6	2	2	3	1	0	2	1
	age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GSA 7 ESP	0	31	183	95	464	99	232	164	123	141	186	188	305	336	93	226	98	11
GSA 7 ESP	1	2281	1909	362	1127	378	501	1596	1676	939	906	1453	2355	1348	460	748	376	402
GSA 7 ESP	2	216	224	116	187	223	167	89	285	143	85	79	19877	195	120	58	89	56
GSA 7 ESP	3	69	72	43	57	105	93	55	49	28	14	12	5887	22	14	7	5	10
GSA 7 ESP	4	30	24	13	12	21	26	17	12	5	4	4	1549	3	4	2	1	1
GSA 7 ESP	5	21	10	4	2	5	7	5	3	1	1	1	333	1	0	0	1	0
	age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GSA 7 FRA	0	25620	5705	6080	5804	2694	2870	10381	3694	5524	1659	1805	5312	6179	2866	5346	1598	4096
GSA 7 FRA	1	38420	16004	10951	10594	6592	9045	27973	13667	15297	7520	8291	15831	16318	8767	11303	5160	9502
GSA 7 FRA	2	1274	2076	981	685	1121	1210	1066	2796	1301	1154	620	900	1047	656	537	759	442
GSA 7 FRA	3	91	96	68	37	150	103	64	120	48	28	33	28	28	24	6	8	20
GSA 7 FRA	4	9	15	5	3	11	10	16	11	8	2	6	4	1	2	2	1	1
GSA 7 FRA	5	1	12	1	0	2	1	6	0	3	1	0	2	0	0	1	1	0

Table Table 3.2.2 and table 3.2.4 were used to split F by GSA. The overall F at a given age was divided by the ratio of catch in number at given age of the given GSA out the overall catch in number at the same age to derive the F at age by each GSA and then to estimate Fbar (1-3) by GSA as the arithmetic average on F at age 1 to 3 of each GSA (Figure 3.2)

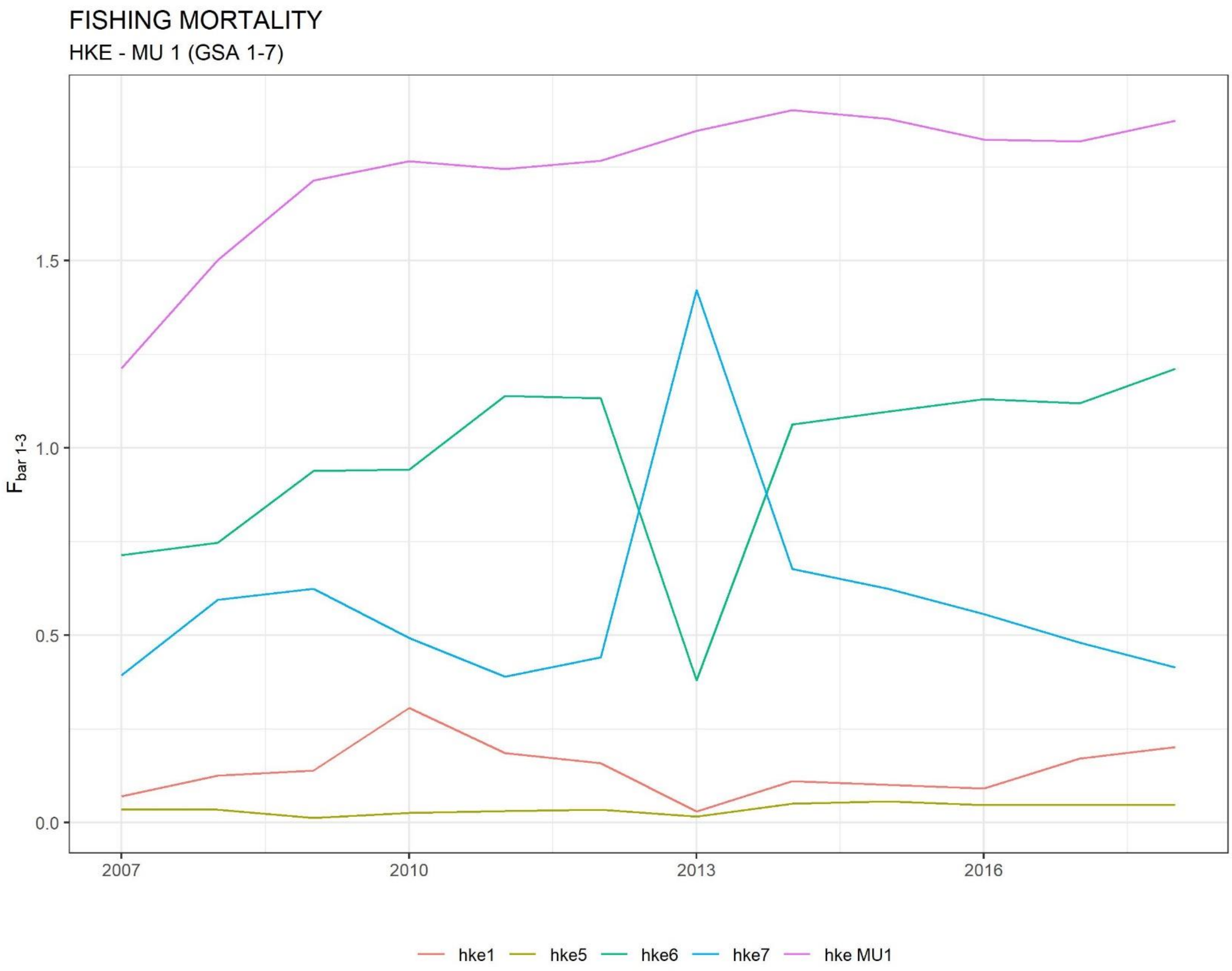


Figure 3.2.3 - Fbar (1-3) of European hake by GSAs in the management Unit 1 (whole western GSAs).

Table 3.2.5 – Fishing mortalities by gsa for HKE in MU1.

gsa	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	0.07	0.13	0.14	0.31	0.19	0.16	0.03	0.11	0.1	0.09	0.17	0.2
5	0.04	0.03	0.01	0.03	0.03	0.03	0.02	0.05	0.06	0.05	0.05	0.05
6	0.71	0.75	0.94	0.94	1.14	1.13	0.38	1.06	1.1	1.13	1.12	1.21
7	0.39	0.59	0.62	0.49	0.39	0.44	1.42	0.68	0.62	0.56	0.48	0.41

3.2.1.3 Fishing mortality –effort relationship

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

The relationship between the effort (days at sea) and the fishing mortality for HKE in each GSA of MU1 is reported in Figure 3.2. The points are distributed in a cloud of values. The lines reported in the graph hypothesize a linear relationship between fishing effort and fishing mortality. The solid line represents the linear regression on the observed values. The dashed line represents the linear regression forced to pass from the origin according to the reasonable assumption that F is nihil when no fishing effort is exerted on the stock.

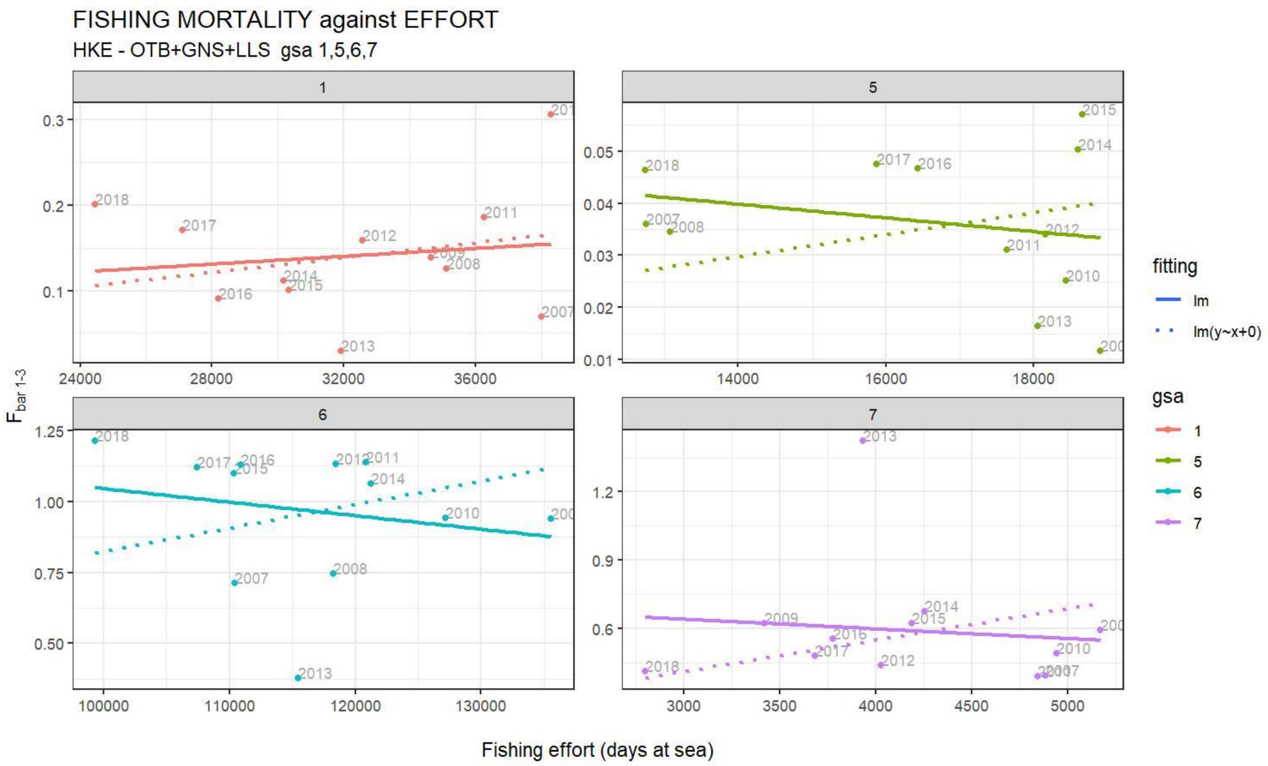


Figure 3.2.4 – Relationship between total effort and Fbar for HKE by GSA in the management unit 1. Continuos line: linear regression on the observed points. Dashed line: linear regression forced through the origin.

In the same way as the single GSAs, the values for the overall western Management Unit MU1 are distributed in a cloud that does not allow to highlights any clear relationship between fishing mortality and the fishing effort (days at sea).

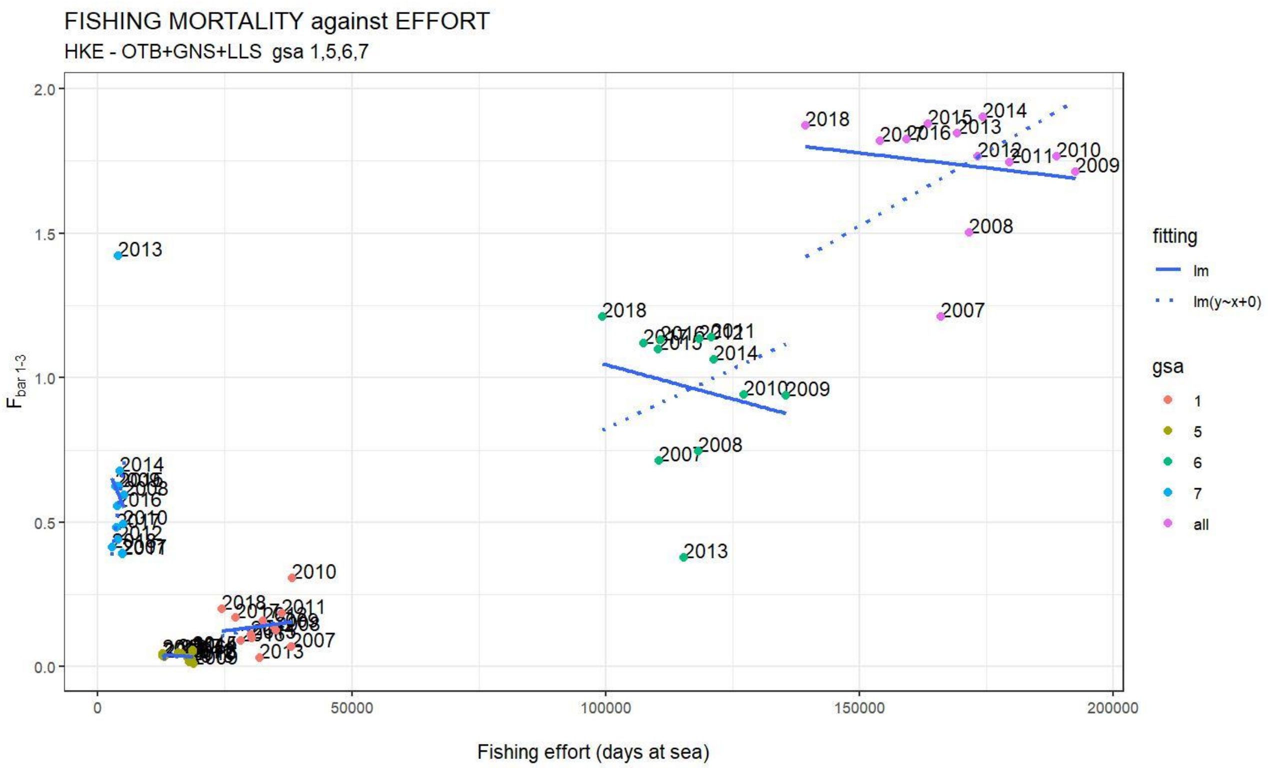


Figure 3.2.5 – Relationship between nominal effort and Fbar(1-3) for hake in GSAs 1, 5, 6 and 7. Blue line: linear regression for each GSA and for the GSAs combined. Blue dashed line: linear regression forced through the origin for each GSA and GSAs combined. Data for the individual GSAs are the same as in Figure 3.2.4.

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

Table 3.2.6 – Parameters of the relationship between nominal effort and Fbar for the European Hake in GSAs 1, 5, 6 and 7.

variable	gsa1	gsa5	gsa6	gsa7	gsa 1-7	model
(Intercept)	0.067	0.058	1.521	0.769	2.085	Fbar = a+b* days at sea
days at sea	2.28E-06	-1.31E-06	-4.76E-06	-4.24E-05	-2.05E-06	Fbar = a+b* days at sea
r.squared	0.019	0.053	0.035	0.012	0.023	Fbar = a+b* days at sea
Pr(>F)	0.666	0.472	0.561	0.74	0.636	Fbar = a+b* days at sea
days at sea	4.33E-06	2.12E-06	8.24E-06	0.000138	1.02E-05	Fbar = 0+b* days at sea
Pr(>F)	2.99E-05	8.90E-06	8.73E-08	4.01E-05	1.39E-10	Fbar = 0+b* days at sea

3.2.2 Eastern GSAs (9-10-11) - Management Unit 2.

3.2.2.1 Trend in effort (days at sea)

The stock assessment on HKE in GSAs 9, 10 and 11 combined included bottom trawling (OTB) which is the main gear exploiting the species in the areas, and other gears like gillnet (GNS) and trammel net (GTR). The trends of days at sea for the different gears in the Management Unit 2 were reported in Figures 3.2.6-3.9 and Tables 3.2.6. A notable decreasing trend in days at sea was observed for bottom trawling from 2005 to 2011. In the last years, the total days at sea remained quite constant.

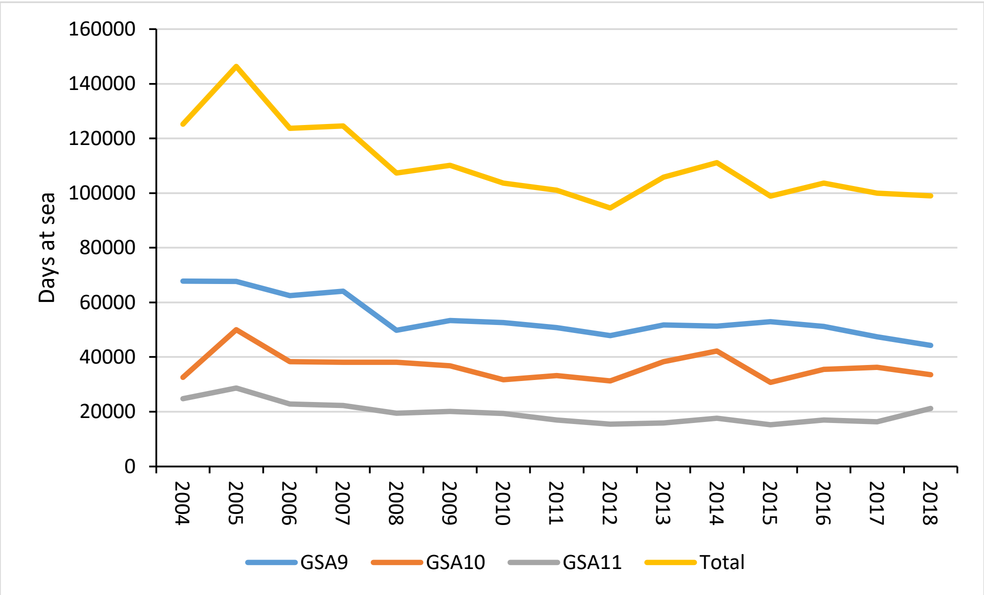


Figure 3.2.6 - Trends of the nominal fishing effort of the bottom trawling for the fleet fishing in GSAs 9, 10 and 11 and in the management Unit 2 (whole eastern GSAs).

Table 3.2.7 – Days at sea of the bottom trawling for the fleet fishing in GSAs 9, 10 and 11 and in the management Unit 2 (whole eastern GSAs).

GSA	Gear	Mètier	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
SA 9	OTB	All	67828	67714	62517	64161	49759	53330	52606	50737	47851	51715	51286	52900	51257	47457	44296
SA 10	OTB	All	32555	50056	38364	38151	38109	36749	31741	33256	31223	38270	42227	30709	35479	36271	33570
SA 11	OTB	All	24827	28645	22836	22321	19435	20128	19321	17018	15472	15872	17583	15278	16926	16285	21190
Total	OTB	All	125209	146415	123716	124633	107303	110207	103668	101011	94547	105858	111096	98887	103661	100013	99056

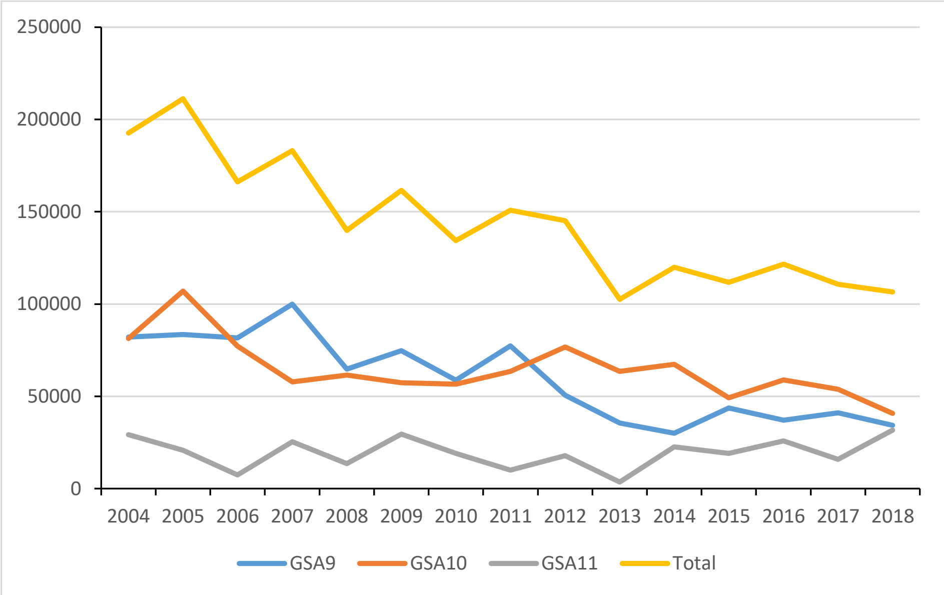


Figure 3.2.7 - Trends of the days at sea of the gillnet for the fleet fishing in GSAs 9, 10 and 11 and in the management Unit 2 (whole eastern GSAs).

Table 3.2.8 – Days at sea of the gillnet for the fleet fishing in GSAs 9, 10 and 11 and in the management Unit 2 (whole eastern GSAs).

GSA	Gear	Mètier	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
SA 9	GNS	DEF	82163	83555	81689	99988	64755	74733	58778	77407	50561	35473	30015	43630	37026	41019	34219
SA 10	GNS	DEF	81333	107011	77224	57771	61523	57400	56551	63445	76737	63474	67356	49189	58865	53789	40737
SA 11	GNS	DEF	29164	20713	7357	25301	13594	29522	19058	9951	17886	3557	22603	19003	25768	15862	31629
Total	GNS	DEF	192660	211279	166270	183060	139872	161655	134387	150802	145184	102505	119973	111822	121660	110671	106584

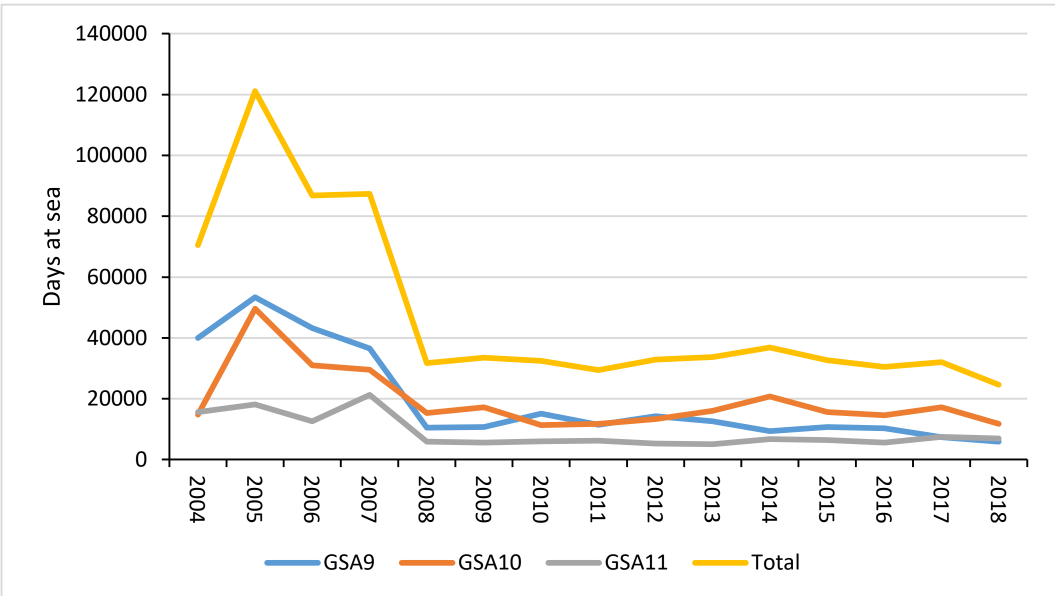


Figure 3.2.8 - Trends of the days at sea of the bottom trawling for the fleet fishing deep water resources in GSAs 9, 10 and 11 and in the management Unit 2 (whole eastern GSAs).

Table 3.2.9 – Days at sea of the bottom trawling for the fleet fishing for deep water resources in GSAs 9, 10 and 11 and in the management Unit 2 (whole eastern GSAs).

GSA	Gear	Mètier	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
SA 9	OTB	MDD+DWS	40038	53342	43238	36512	10538	10694	15069	11425	14239	12623	9331	10684	10291	7402	5930
SA 10	OTB	MDD+DWS	14775	49591	30987	29520	15273	17241	11354	11787	13346	16000	20750	15587	14546	17238	11743
SA 11	OTB	MDD+DWS	15673	18151	12628	21299	5891	5581	6045	6259	5304	5047	6779	6392	5595	7436	6959
Total	OTB	MDD+DWS	70486	121083	86854	87331	31703	33515	32467	29472	32889	33670	36861	32663	30432	32075	24632

3.2.2.2 Stock assessment data

European hake (HKE)

The catch numbers at age and the overall fishing mortalities at age for HKE in MU 2 and the corresponding Fbar (1-3) estimated during the STECF EWG 19-10 stock assessment for the GSAs 9, 10 and 11 combined are reported in Table 3.2.10 and Table 3.2.11 (Fig. 3.2.9). The period covered is 2005-2018.

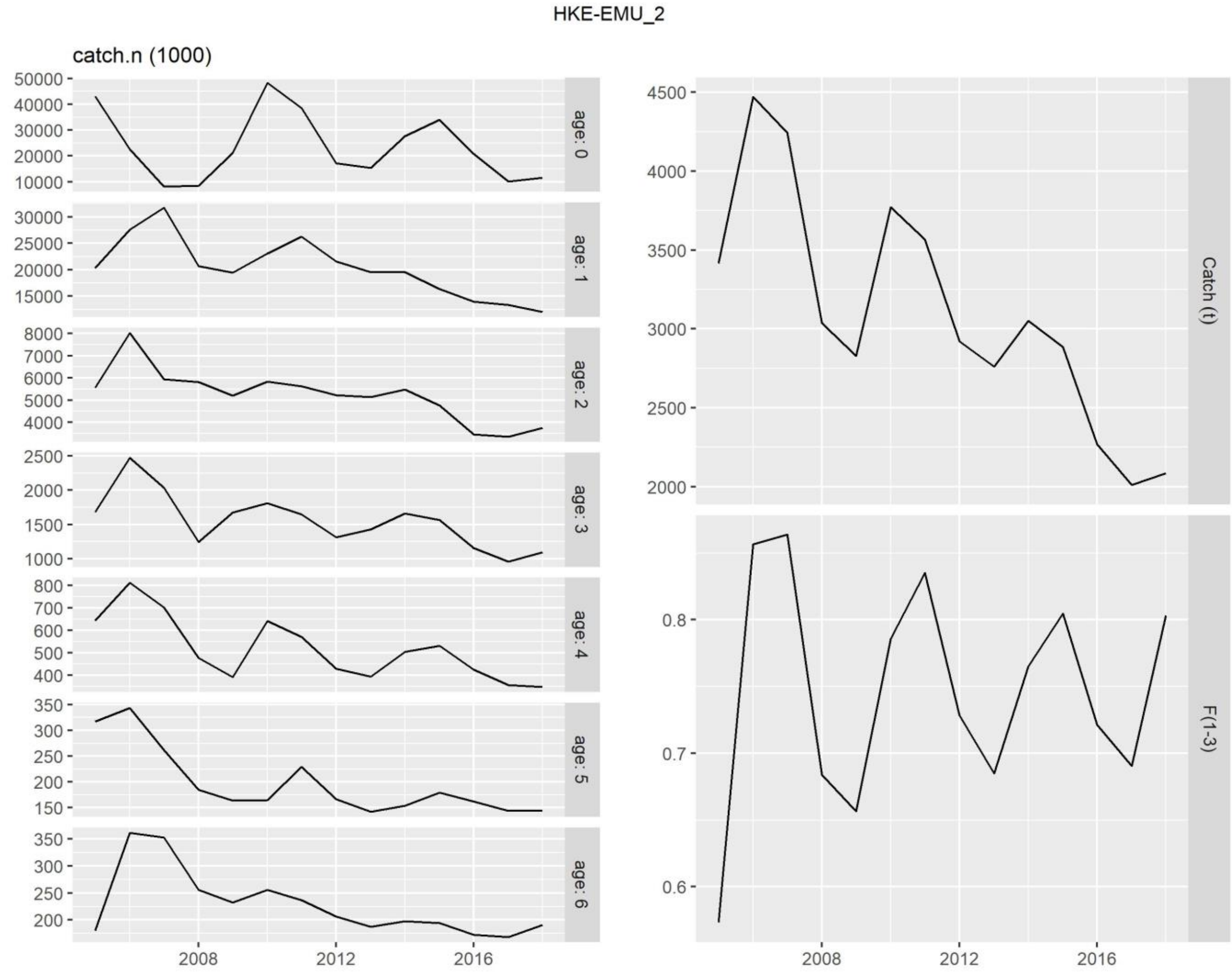


Figure 3.2.9 - Fbar and catch from the assessment of European hake (EWG 19-10) in the management Unit 2 (whole eastern GSAs).

Table 3.2.10 – Catch in number at age for HKE in MU 2.

AGE	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	17925	43181	4197	2833	68685	23911	39382	20973	11893	33166	24925	25139	8832	9416
1	20328	37196	22335	18366	27891	18203	27877	14582	21213	11879	13907	15084	13006	10152
2	4969	5213	5250	4982	5593	5763	5025	5198	6280	5596	4410	3800	3141	3575
3	1389	2287	1890	1194	1626	1751	1685	1279	1471	1912	1523	1203	736	1167

4	462	943	584	403	331	649	564	422	376	565	485	349	366	423
5	145	202	163	176	109	190	230	153	106	174	144	106	140	104
6	329	259	185	244	216	273	274	169	126	172	216	162	144	169

Table 3.2.11 – Fishing mortalities at age for HKE in the western eastern Mediterranean (GSA 9,10,11).

age	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
0	0.3	0.16	0.09	0.1	0.19	0.36	0.32	0.18	0.18	0.31	0.41	0.28	0.16	0.14
1	0.63	0.94	0.95	0.75	0.72	0.87	0.92	0.8	0.75	0.84	0.89	0.79	0.76	0.88
2	0.59	0.88	0.89	0.7	0.67	0.81	0.86	0.75	0.7	0.79	0.83	0.74	0.71	0.83
3	0.5	0.75	0.75	0.6	0.57	0.68	0.73	0.63	0.6	0.67	0.7	0.63	0.6	0.7
4	0.38	0.57	0.57	0.45	0.43	0.52	0.55	0.48	0.45	0.51	0.53	0.48	0.46	0.53
5	0.26	0.39	0.39	0.31	0.3	0.36	0.38	0.33	0.31	0.35	0.37	0.33	0.31	0.37
6	0.17	0.26	0.26	0.2	0.2	0.23	0.25	0.22	0.2	0.23	0.24	0.22	0.21	0.24

The catch numbers at age by gsa and fleet used for the assessment were provided during the EWG 19-14 (Table 3.2.10, Figure 3.2.9) and were used to disaggregate the Fbar estimation both by gsa-gear (Table 3.2.12, Figure 3.2.11) and gsa (Table 3.11, Figure 3.12).

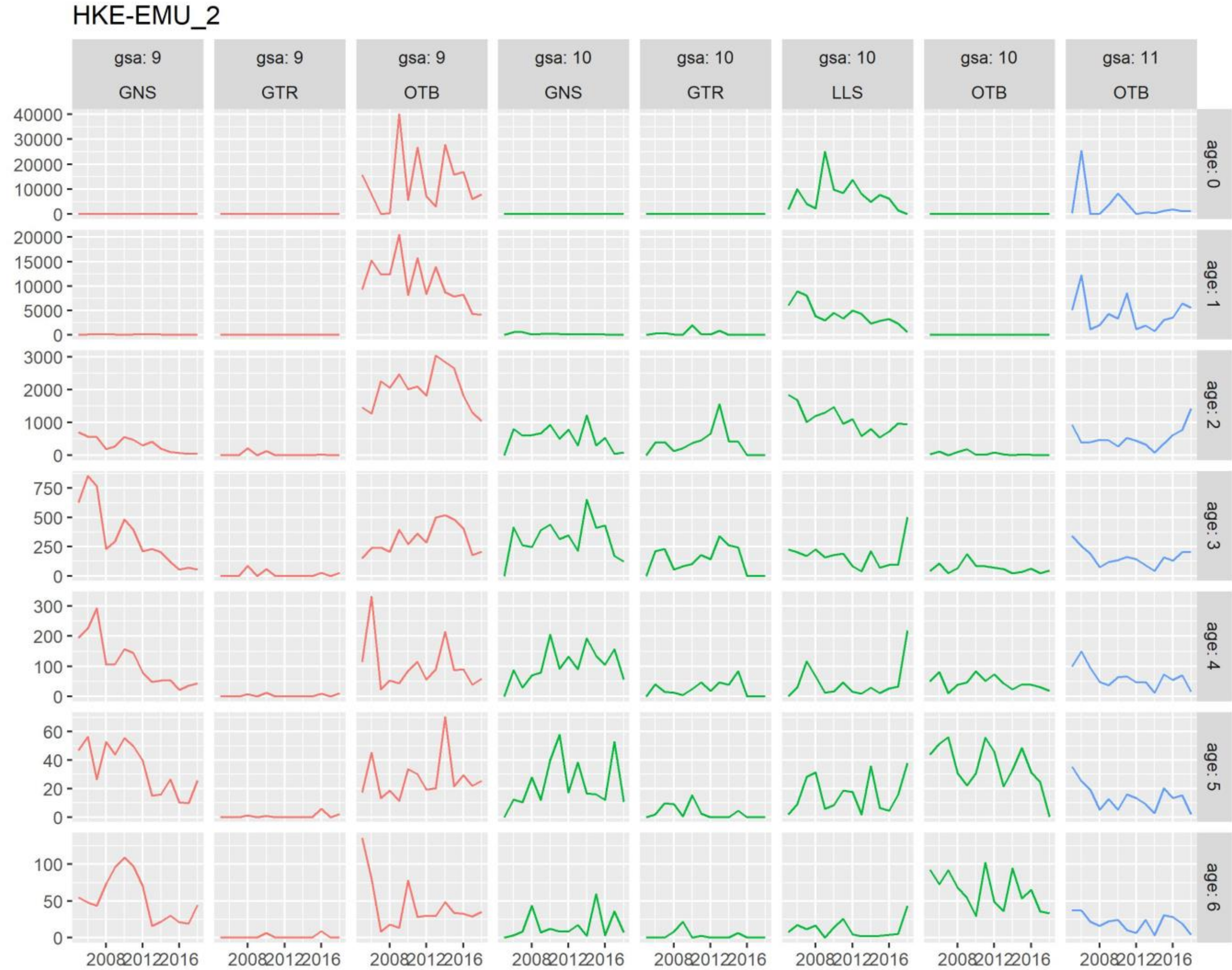


Figure 3.2.10 - Catch in number at age by fleet for HKE in GSAs 9, 10 and 11.

Table 3.2.12 – Catch in number at age by fleet for HKE in GSAs 9, 10 and 11.

gsa	gear	age	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
9	GNS	0	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
9	GNS	1	6	29	17	26	18	14	27	36	45	17	2	6	1	4
9	GNS	2	708	567	560	193	279	555	469	295	419	208	105	71	46	58
9	GNS	3	626	854	769	230	296	484	394	210	231	203	119	53	70	57
9	GNS	4	194	226	293	106	107	156	145	79	49	53	54	22	36	43
9	GNS	5	47	56	26	53	44	55	50	40	15	16	27	10	10	26
9	GNS	6	55	48	43	73	96	109	97	70	16	22	30	21	19	45
9	GTR	0				0		0						0		0
9	GTR	1				48		42						6		1
9	GTR	2				215		124						28		14
9	GTR	3				87		57						25		27
9	GTR	4				8		12						10		11
9	GTR	5				1		1						6		2
9	GTR	6				0		6						9		1
9	OTB	0	15731	7888	58	351	40010	5683	26699	7248	3016	27849	15884	16931	6091	7970
9	OTB	1	9245	15227	12318	12319	20488	8122	15674	8365	13900	8677	7826	8234	4331	4090
9	OTB	2	1455	1274	2265	2053	2477	2020	2099	1815	3048	2850	2661	1813	1308	1042
9	OTB	3	150	239	243	208	394	271	361	286	500	519	485	407	177	208
9	OTB	4	116	331	24	53	43	86	114	57	90	214	87	90	39	59
9	OTB	5	17	45	13	18	11	34	30	19	20	70	21	29	22	25
9	OTB	6	136	80	8	18	14	78	28	30	29	48	34	33	29	35
gsa	**gear**	**age**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
10	GNS	0		0.02	3.10	3.37	3.40	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
10	GNS	1		572	509	109	147	205	126	59	199	103	43	68	6	1
10	GNS	2		797	599	610	670	935	508	795	306	1213	297	525	41	82
10	GNS	3		417	261	248	390	439	314	345	215	652	409	430	171	123
10	GNS	4		88	30	70	79	205	92	132	90	193	136	106	157	56
10	GNS	5		12	10	28	12	40	58	17	38	17	16	12	53	11
10	GNS	6		3	8	43	7	12	8	9	17	2	59	3	36	7
10	GTR	0		0	0	0	0	47	0	0	0	0	0			
10	GTR	1		277	366	21	4	2006	197	31	865	0	71			
10	GTR	2		389	399	134	218	367	453	664	1563	438	416			
10	GTR	3		211	232	53	82	104	180	144	338	262	244			
10	GTR	4		40	15	13	5	24	47	20	46	39	83			
10	GTR	5		2	10	9	0	15	2	0	0	0	5			
10	GTR	6		0	0	9	22	0	2	0	0	0	6			
10	LLS	0	1821	9952	4136	2316	25058	9814	8395	13652	8047	4821	7667	6296	1536	116
10	LLS	1	5991	8897	8029	3796	2929	4450	3319	4932	4316	2316	2893	3206	2236	528
10	LLS	2	1850	1681	1021	1198	1302	1474	954	1104	587	796	551	735	968	943
10	LLS	3	228	204	172	227	157	177	189	83	37	212	71	95	95	502
10	LLS	4	2	29	116	66	12	17	47	15	10	29	11	27	32	219
10	LLS	5	2	9	28	31	6	8	19	18	2	36	7	4	15	38
10	LLS	6	8	17	11	16	0	14	25	5	2	2	2	4	5	43
10	OTB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	OTB	1	5	16	0	26	1	0	0	13	0	0	0	0	0	0
10	OTB	2	26	113	0	104	188	11	18	81	25	9	27	10	2	0
10	OTB	3	43	107	24	66	189	87	83	69	59	22	35	62	21	47
10	OTB	4	50	80	11	39	47	84	51	73	43	24	41	40	31	19
10	OTB	5	44	51	56	31	22	31	56	46	22	33	49	31	25	0

10	OTB	6	92	73	92	68	55	30	102	49	37	94	54	65	36	33
gsa	**gear**	**age**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
11	OTB	0	372	25341	0	162	3614	8367	4288	73	829	496	1374	1911	1205	1330
11	OTB	1	5080	12177	1097	2020	4303	3364	8533	1146	1889	767	3074	3565	6433	5528
11	OTB	2	930	393	406	475	459	276	524	444	333	82	354	618	776	1435
11	OTB	3	342	255	189	75	118	133	164	142	91	41	160	132	202	203
11	OTB	4	99	149	94	48	38	64	67	46	49	13	73	54	71	16
11	OTB	5	35	25	19	5	13	5	16	13	9	3	20	13	15	2
11	OTB	6	38	37	22	16	23	24	10	6	24	3	31	28	19	4

The catch numbers at age by gsa and fleet used for the assessment were provided during the EWG 19-14 (Table 3.2.11) and were used to disaggregate the Fbar estimation both by gsa-gear (Table 3.2.13, Figure 3.2.10) and gsa (Table 3.2.14, Figure 3.2.11).

Table 3.2.13 – Fishing mortalities by gsa and fleet for HKE in MU2.

gsa	gear	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
9	GNS	0.10	0.13	0.13	0.05	0.05	0.09	0.08	0.05	0.05	0.03	0.02	0.01	0.02	0.02
9	GTR				0.03		0.01						0.01		0.01
9	OTB	0.17	0.23	0.33	0.30	0.32	0.26	0.34	0.29	0.35	0.40	0.41	0.33	0.23	0.24
10	GNS	0.00	0.10	0.08	0.07	0.07	0.10	0.08	0.10	0.04	0.13	0.08	0.11	0.05	0.03
10	GTR	0.00	0.05	0.06	0.02	0.02	0.06	0.05	0.06	0.11	0.05	0.06	0.00	0.00	0.00
10	LLS	0.01	0.02	0.00	0.02	0.03	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01
10	OTB	0.16	0.19	0.19	0.15	0.10	0.16	0.12	0.16	0.08	0.12	0.11	0.12	0.14	0.19
11	OTB	0.13	0.15	0.06	0.06	0.07	0.08	0.15	0.07	0.05	0.03	0.11	0.13	0.24	0.31

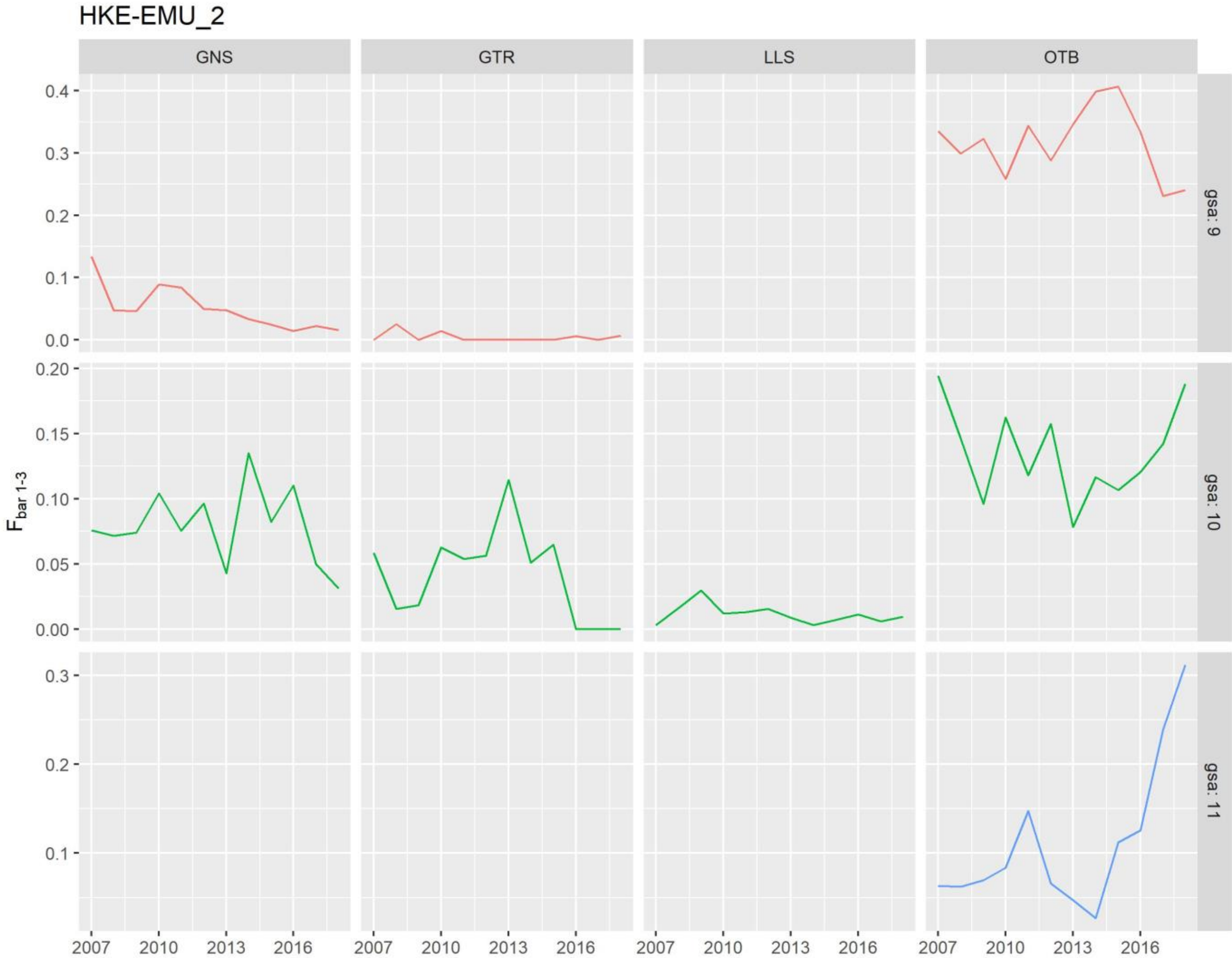


Figure 3.2.11 - Fbar (1-3) disaggregated by fleet and gsa for HKE in the management Unit 2 (whole eastern GSAs).

Table 3.2.14 – Fishing mortalities by gsa for HKE in MU2.

gsa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
9	0.27	0.35	0.47	0.37	0.37	0.36	0.43	0.34	0.39	0.43	0.43	0.35	0.25	0.26
10	0.17	0.35	0.33	0.25	0.22	0.34	0.26	0.33	0.24	0.31	0.26	0.24	0.20	0.23
11	0.13	0.15	0.06	0.06	0.07	0.08	0.15	0.07	0.05	0.03	0.11	0.13	0.24	0.31

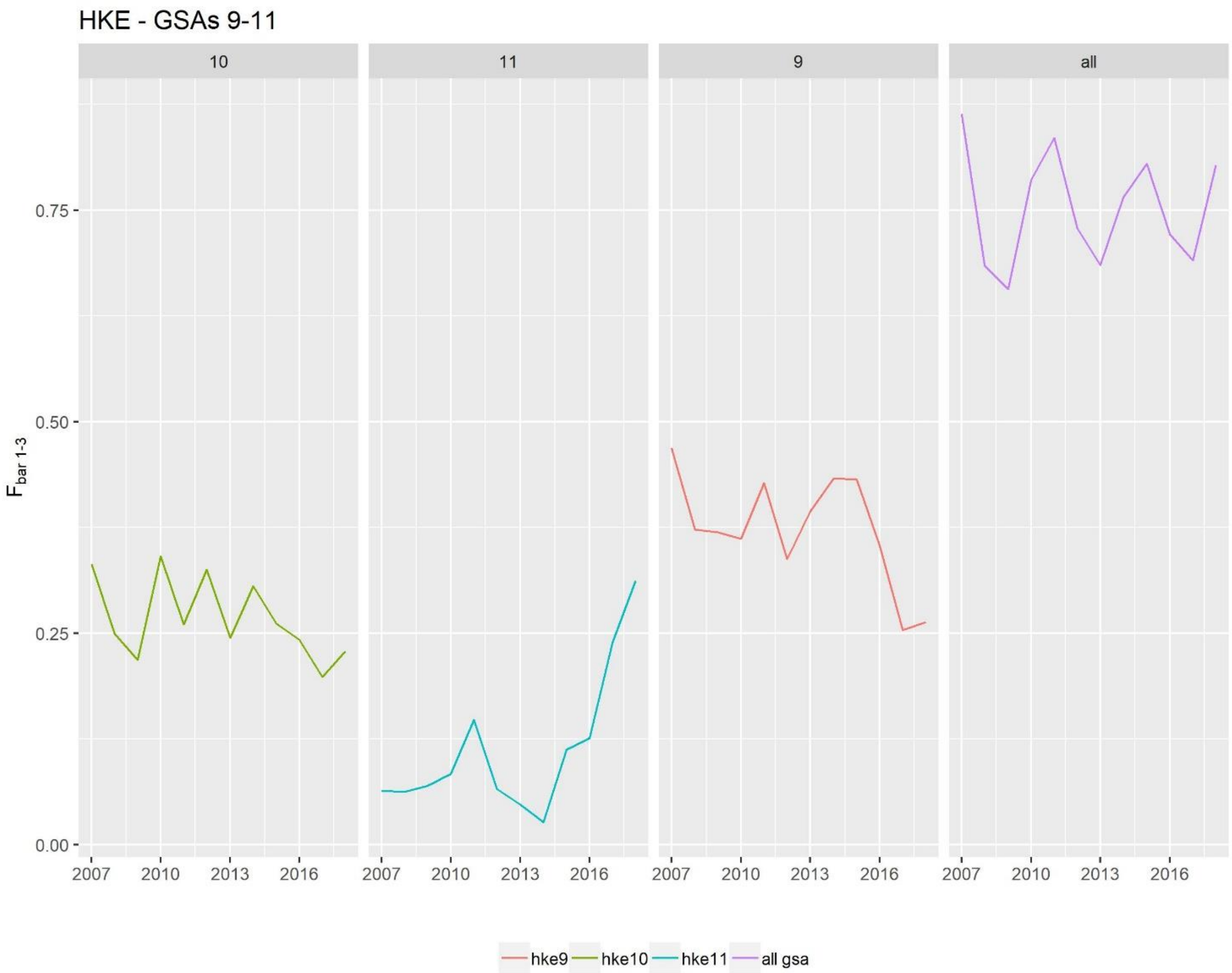


Figure 3.2.12 - Fbar (1-3) for HKE in GSAs 9, 10 and 11.

DPS in EMU 2

The catch numbers at age and the overall fishing mortalities at age for DPS in MU 2 and the corresponding Fbar (1-2) estimated during the STECF EWG 19-10 stock assessment for the GSAs 9, 10 and 11 combined are reported in Table 3.2.15 and Table 3.2.16 (Fig. 3.2.13). The period covered is 2009-2018.

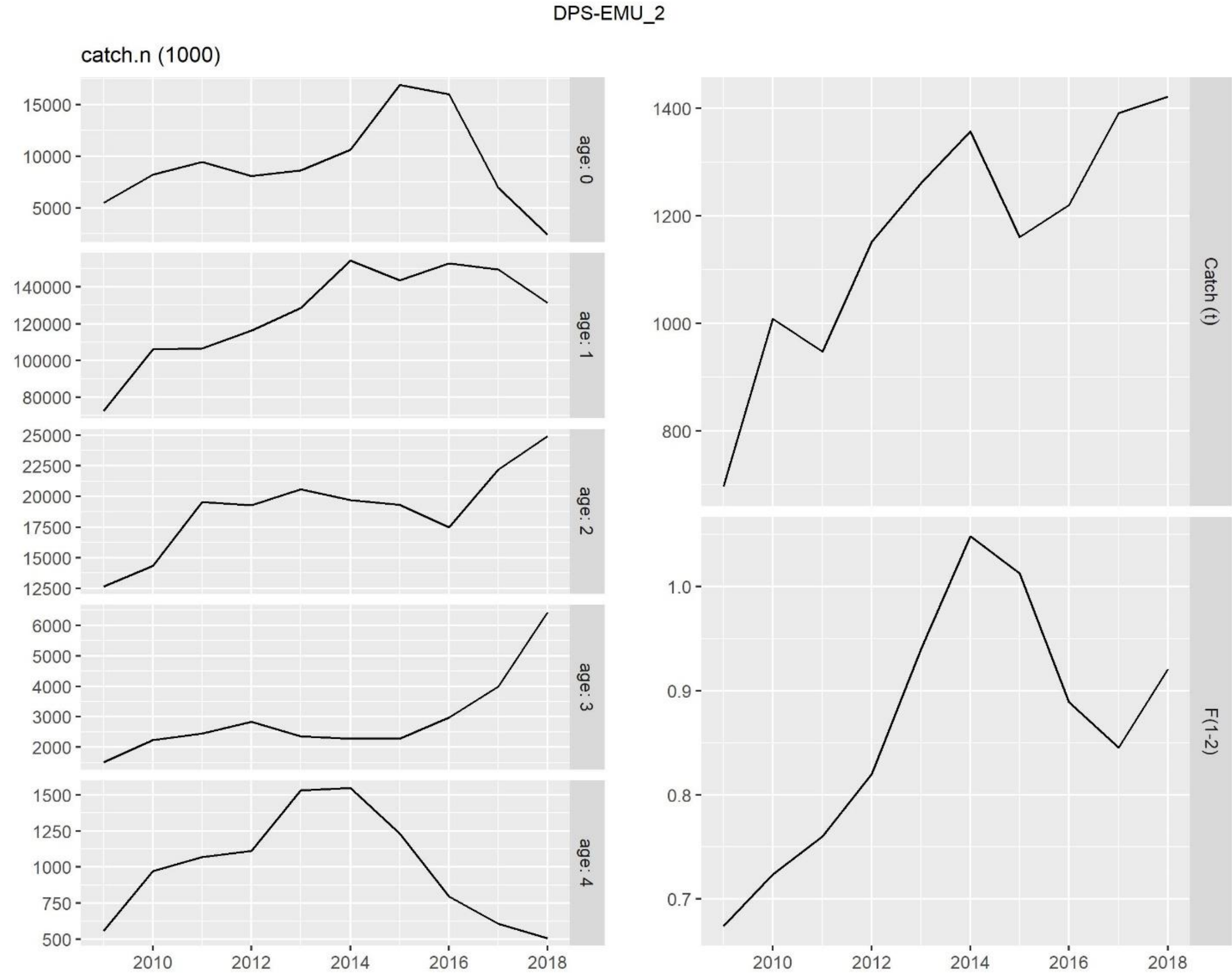


Figure 3.2.13 - Fbar and catch from the assessment of DPS (EWG 19-10) in the Management Unit 2.

Table 3.2.15 – Catch in number at age for DPS in MU 2.

GSA	age	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
9	0	30288	26197	83288	19570	19265	48512	92663	71636	53990	42156
9	1	35996	60195	77686	79219	76083	71565	125917	113849	114445	114863
9	2	3512	2966	4286	4929	3741	4155	1645	4771	2282	280
9	3	270	270	306	471	718	155	17	903	189	10
9	4	325	98	124	163	189	40	13	227	61	10
10	0	316735	66153	98205	88584	91474	105340	165154	188424	79199	15324
10	1	211217	38165	39431	36527	44784	62588	36332	29401	61060	48182
10	2	666	82	123	213	17	115	108	14	373	5
10	3	8	2	2	4	1	2	2	2	2	2
10	4	8	2	2	1	1	2	2	2	2	2
11	0	103	336	3574	1426	899	256	1240	791	880	3716
11	1	2645	2705	7292	4329	2564	2197	4088	2462	4012	7872
11	2	344	304	625	171	169	89	119	144	17	57
11	3	7	6	11	41	7	7	8	8	6	6
11	4	7	6	8	7	7	7	8	8	6	6

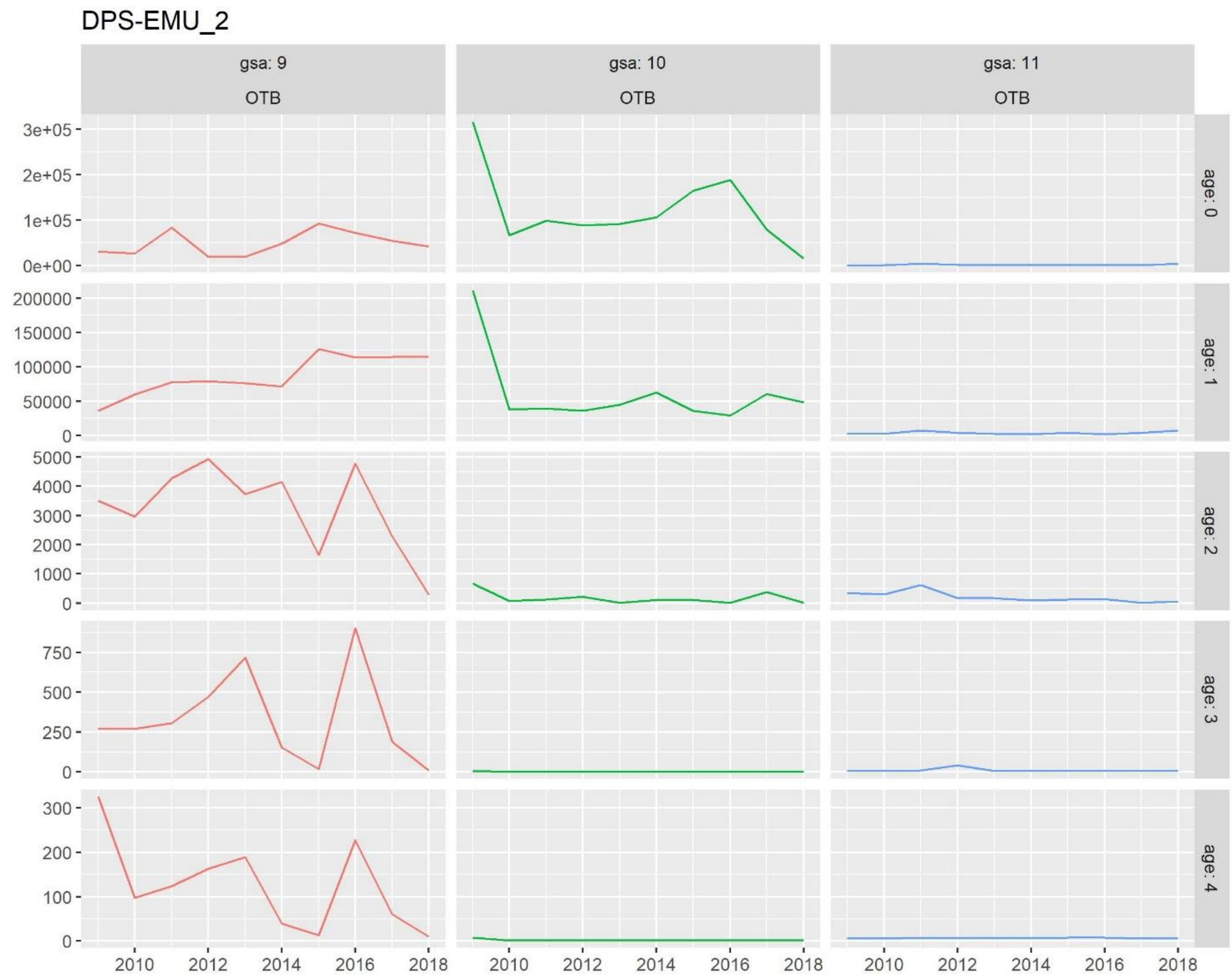


Figure 3.2.14 - Catch in number at age by fleet for DPS in GSAs 9, 10 and 11.

The catch numbers at age by gsa and fleet used for the assessment were provided during the EWG 19-14 (Table 3.2.15) and were used to disaggregate the Fbar estimation by gsa (Table 3.2.16, Figure 3.2.15).

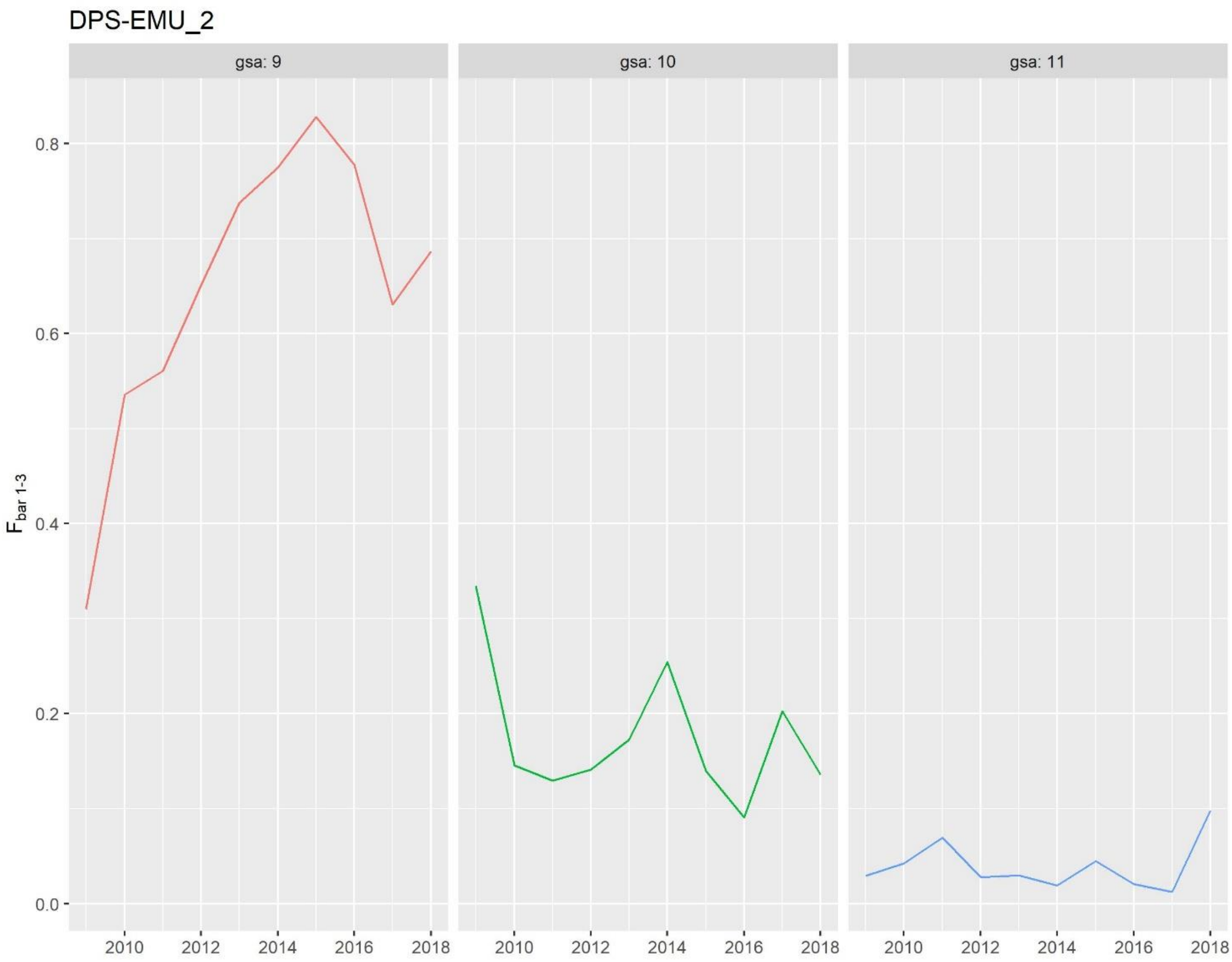


Figure 3.2.15 - Fbar (1-2) disaggregated by gsa for DPS in the Management Unit 2.

Table 3.2.16 – Fishing mortalities by gsa for DPS in MU2.

Species	gsa	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
DPS	9	0.31	0.54	0.56	0.65	0.74	0.77	0.83	0.78	0.63	0.69
DPS	10	0.33	0.15	0.13	0.14	0.17	0.25	0.14	0.09	0.20	0.14
DPS	11	0.03	0.04	0.07	0.03	0.03	0.02	0.04	0.02	0.01	0.10

ARS in EMU 2

The catch numbers at age and the overall fishing mortalities at age for ARS in MU 2 and the corresponding Fbar (1-3) estimated during the STECF EWG 19-10 stock assessment for the GSAs 9, 10 and 11 combined are reported in Table 3.2.17 (Fig. 3.2.16). The period covered is 2005-2018.

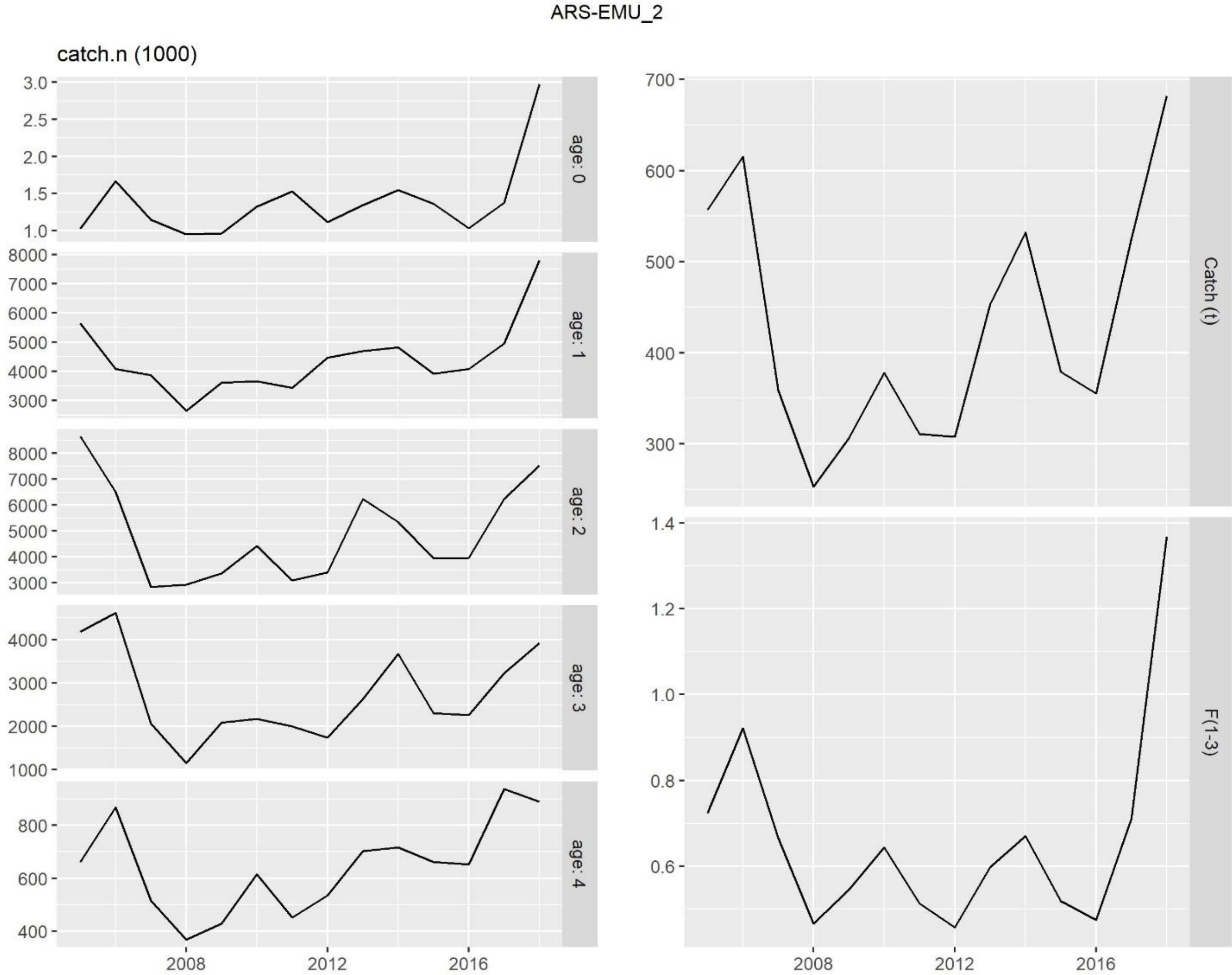


Figure 3.2.16 - Fbar and catch from the assessment of ARS (EWG 19-10) in the Management Unit 2.

Table 3.2.17 – Catch in number at age for ARS in MU 2.

gsa	age	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
9	0	5	0	0	0	0	10	0	0	0	0	0	0	0	0
9	1	196	114	32	115	72	422	189	219	109	140	78	251	69	136
9	2	512	482	246	297	278	546	537	504	195	168	326	379	273	286
9	3	450	378	194	180	167	348	427	376	164	141	227	261	172	217
9	4	253	210	140	96	97	91	230	204	64	38	168	109	124	107
10	0	0	0	0	0	0	4	1	189	4	0	2	1	94	0
10	1	7821	6307	2433	829	2517	2530	932	3176	5101	3516	2876	2295	7154	3841
10	2	7043	3604	2792	1493	2590	2679	1486	2219	6319	4369	2712	2349	4050	5666
10	3	3901	3266	2246	522	1566	888	941	866	1936	3261	1656	1200	1753	2106
10	4	321	529	317	181	242	250	270	142	467	748	267	250	471	636
11	0	0	0	0	0	0	5	5	5	0	0	14	0	0	0
11	1	1062	269	138	615	1692	577	1467	705	359	697	776	1073	1287	2042

11	2	971	945	368	592	1210	1028	1111	722	509	634	817	1287	2171	1459
11	3	278	447	233	235	708	534	697	412	371	426	586	803	1442	1711
11	4	0	218	75	3	154	169	89	128	97	67	160	220	498	152

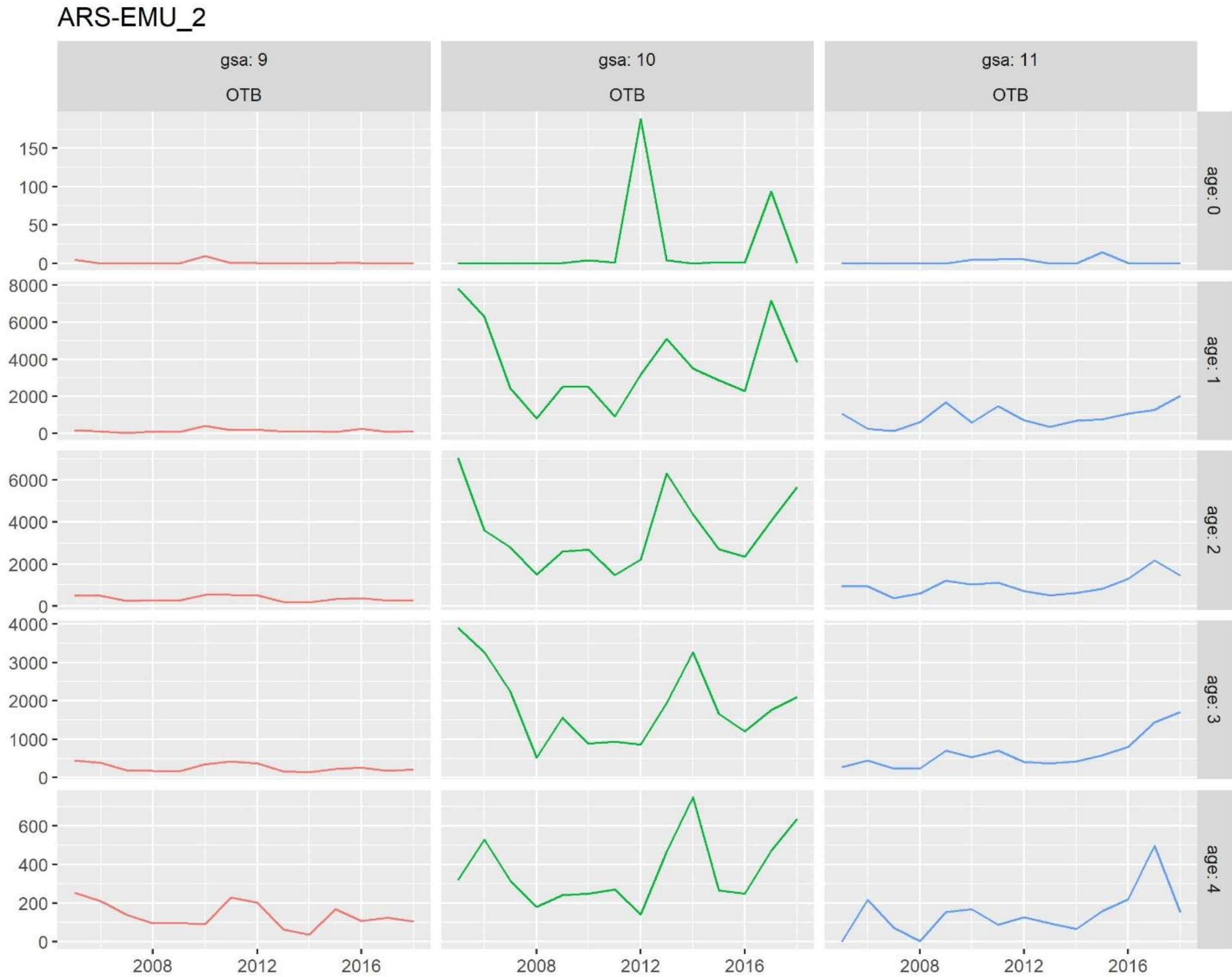


Figure 3.2.17 - Catch in number at age by fleet for ARS in GSAs 9, 10 and 11.

The catch numbers at age by gsa and fleet used for the assessment were provided during the EWG 19-14 (Table 3.2.17) and were used to disaggregate the Fbar estimation by gsa (Table 3.2.18, Figure 3.18).

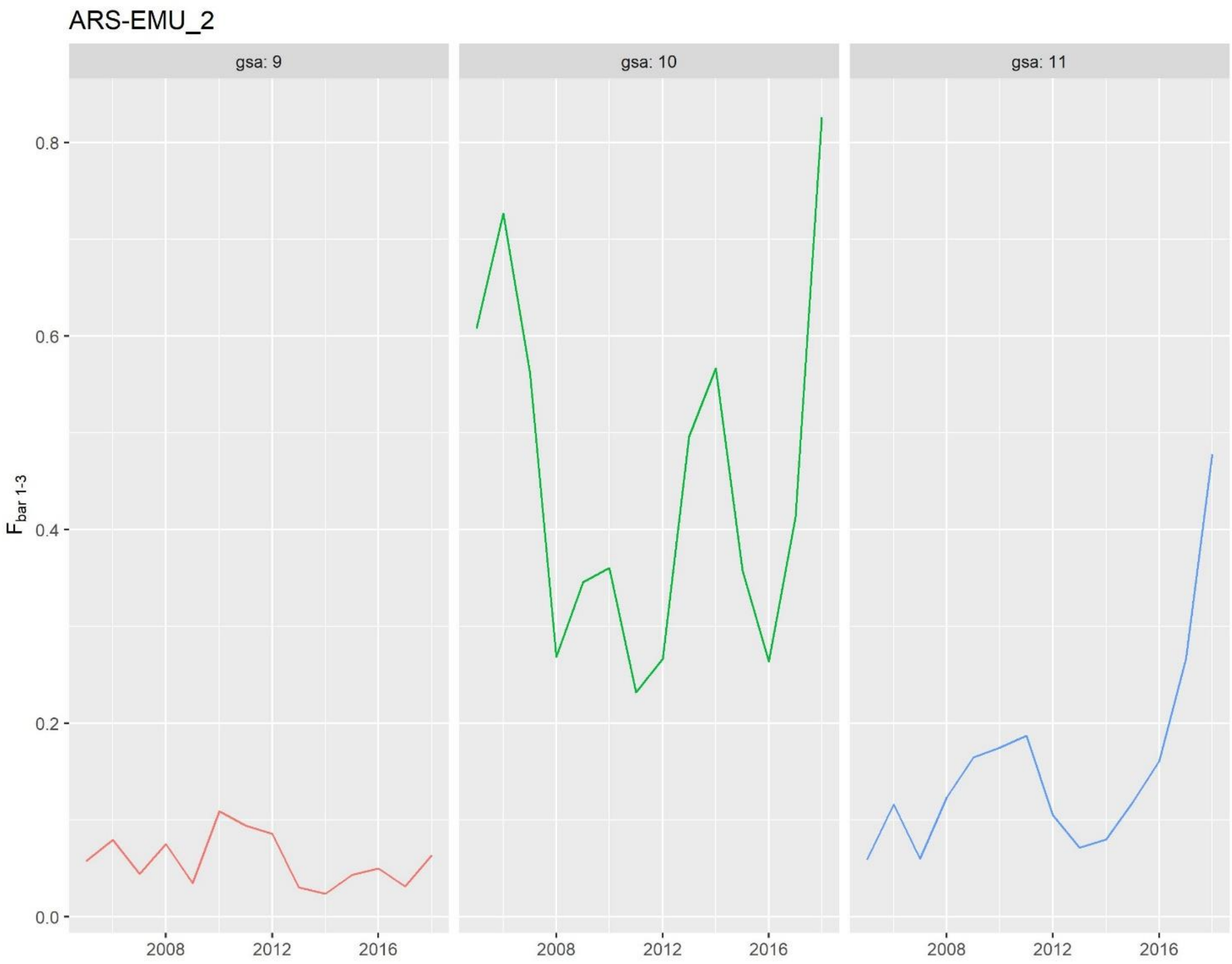


Figure 3.2.18 - Fbar (1-3) disaggregated by gsa for ARS in the Management Unit 2.

Table 3.2.18 – Fishing mortalities by gsa for ARS in MU2.

Species	gsa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ARS	9	0.06	0.08	0.04	0.08	0.03	0.11	0.09	0.09	0.03	0.02	0.04	0.05	0.03	0.06
ARS	10	0.61	0.73	0.56	0.27	0.35	0.36	0.23	0.27	0.50	0.57	0.36	0.26	0.41	0.83
ARS	11	0.06	0.12	0.06	0.12	0.16	0.17	0.19	0.11	0.07	0.08	0.12	0.16	0.27	0.48

ARA in EMU 2

The catch numbers at age and the overall fishing mortalities at age for ARA in MU 2 and the corresponding Fbar (2-5) estimated during the STECF EWG 19-10 stock assessment for the GSAs 9, 10 and 11 combined are reported in Table 3.2.19 (Fig. 3.2.19). The period covered is 2006-2018.

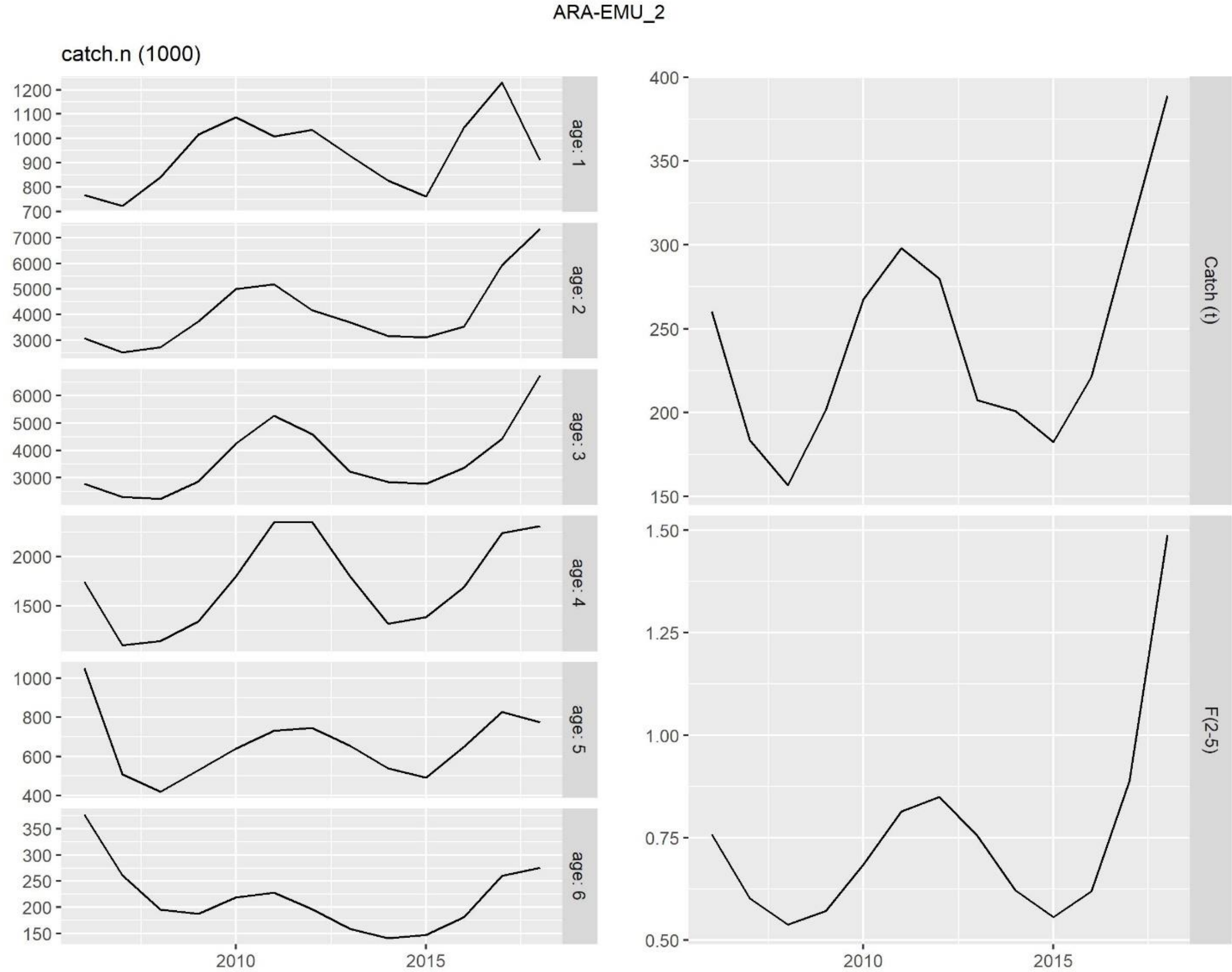


Figure 3.2.19 - Fbar and catch from the assessment of ARA (EWG 19-10) in the management Unit 2.

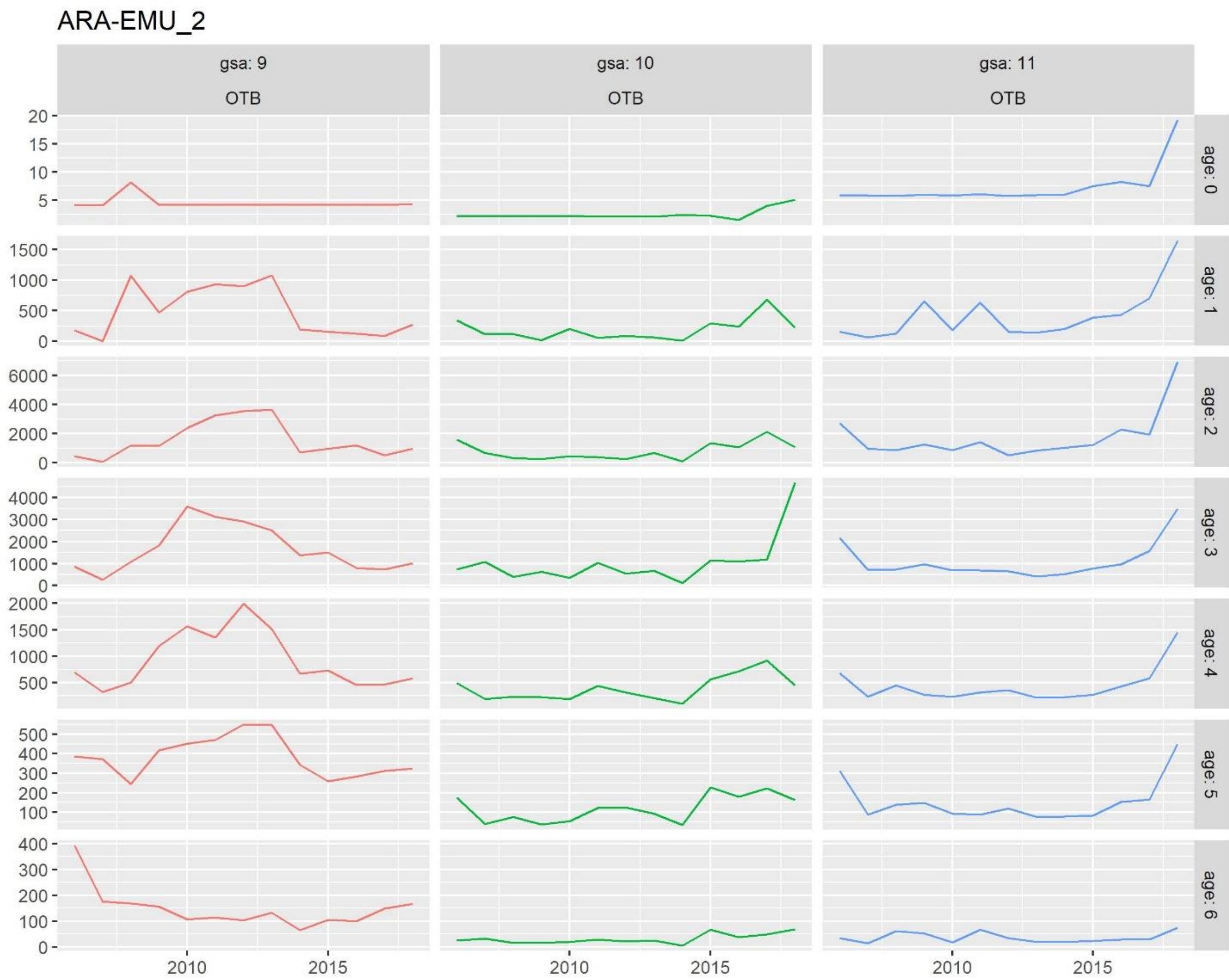


Figure 3.2.20 - Catch in number at age by fleet for ARA in GSAs 9, 10 and 11.

Table 3.2.19 – Catch in number at age for ARA in MU 2.

gsa	age	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
9	0	4	4	8	4	4	4	4	4	4	4	4	4	4
9	1	179	6	1072	474	807	935	905	1080	194	159	124	88	270
9	2	460	63	1191	1170	2408	3282	3555	3663	719	980	1191	504	965
9	3	852	266	1077	1831	3596	3122	2924	2508	1373	1509	808	740	1014
9	4	692	321	497	1198	1565	1357	1997	1518	666	734	457	464	583
9	5	387	373	244	419	452	471	549	547	342	259	283	312	324
9	6	392	175	169	156	107	114	103	132	66	106	99	149	167
10	0	2	2	2	2	2	2	2	2	2	2	2	4	5
10	1	338	120	117	17	200	54	86	61	14	296	241	681	225
10	2	1574	665	314	266	457	384	271	670	88	1352	1062	2124	1070
10	3	724	1066	400	617	359	1038	548	678	122	1134	1099	1176	4684
10	4	496	191	232	227	191	434	310	209	99	560	717	915	451
10	5	176	39	76	38	54	121	124	94	36	227	179	222	163
10	6	25	32	16	16	19	28	21	25	5	67	38	48	69
11	0	6	6	6	6	6	6	6	6	6	8	8	7	19
11	1	153	65	123	656	178	630	153	138	199	387	431	699	1645
11	2	2716	959	859	1252	889	1415	535	839	1038	1220	2300	1939	6955
11	3	2168	709	742	971	699	688	659	406	517	783	960	1571	3499

11	4	675	238	450	269	234	317	354	213	228	271	429	580	1456
11	5	311	89	138	147	92	88	119	77	79	83	154	165	449
11	6	33	14	61	52	18	67	34	20	19	23	29	29	74

The catch numbers at age by gsa and fleet used for the assessment were provided during the EWG 19-14 (Table 3.2.19) and were used to disaggregate the Fbar estimation by gsa (Table 3.2.20, Figure 3.2.21).

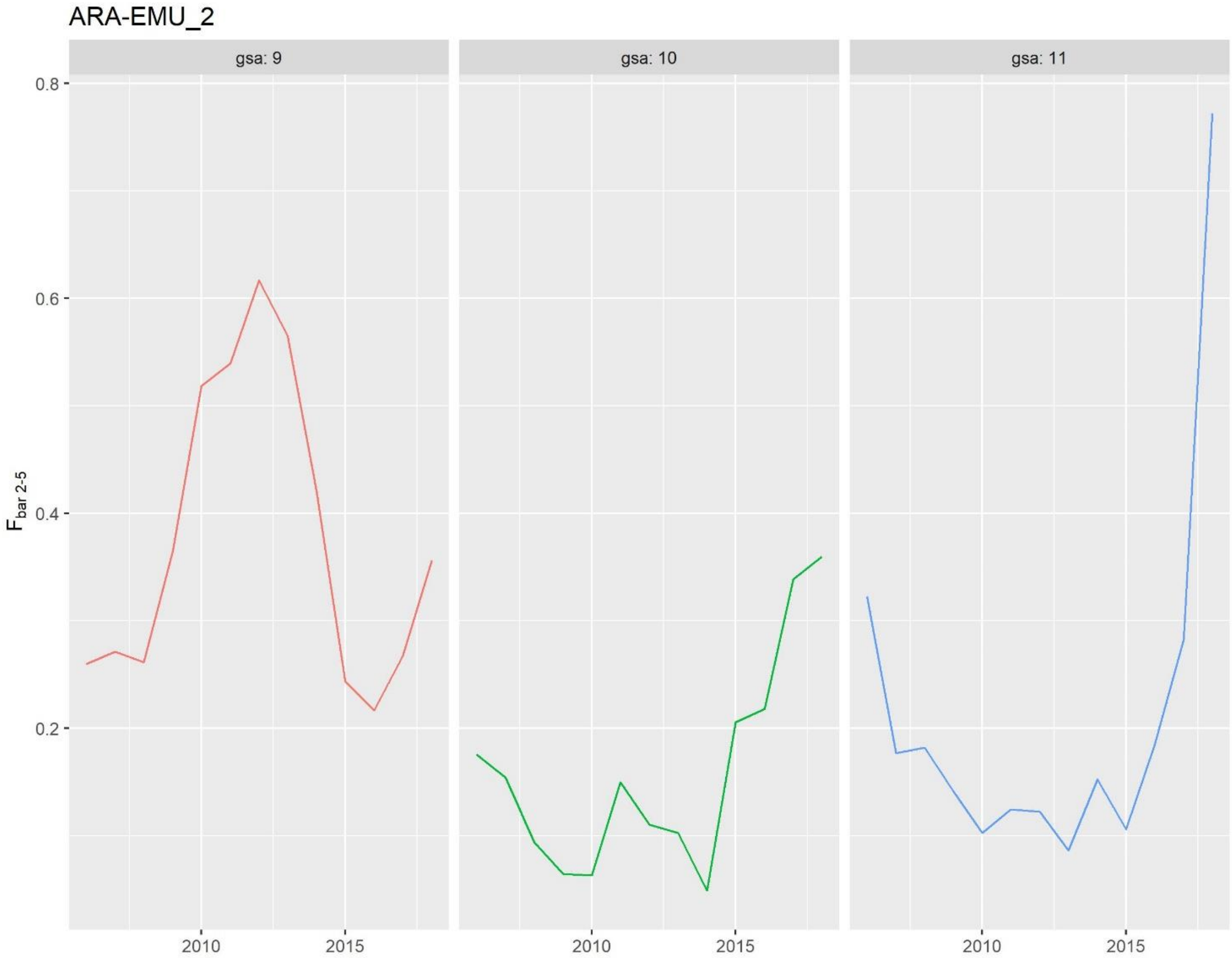


Figure 3.2.21 - Fbar (2-5) disaggregated by gsa for ARA in the Management Unit 2.

Table 3.2.20 – Fishing mortalities by gsa for ARA in MU2.

Species	gsa	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ARA	9		0.26	0.27	0.26	0.36	0.52	0.54	0.62	0.57	0.42	0.24	0.22	0.27	0.36
ARA	10		0.18	0.15	0.09	0.06	0.06	0.15	0.11	0.10	0.05	0.21	0.22	0.34	0.36
ARA	11		0.32	0.18	0.18	0.14	0.10	0.12	0.12	0.09	0.15	0.11	0.18	0.28	0.77

3.2.2.3 Fishing mortality –effort relationship

Hake in GSAs 9, 10 and 11

In tables 3.2.15 and 3.2.16 the relationship between the effort of fleet targeting hake and the fishing mortality for HKE in GSAs 9, 10 and 11 combined is reported.

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

Taking in to account the fleet targeting HKE and then considered in the assessment, the relationship between the effort, as number of hours of fishing (3.2.12) or days at sea (3.2.13), and the estimated fishing mortality for HKE in GSAs 9, 10 and 11 is reported. The number of fishing hours were derived by summarizing the data by year and fleet operating in the MU2 and at depth range of 100-400 meter in order to avoid an overestimation of the fleet activity. In the figure below the red lines are the regressions between F and effort data for the period 2007-2018 for each GSA and for the whole MU. The black dashed lines are the regressions forced through the origin. While the relationship hours of fishing/Fbar was significant for the gsa11 only, the days at sea the relationship is better for the management unit considered as a whole.

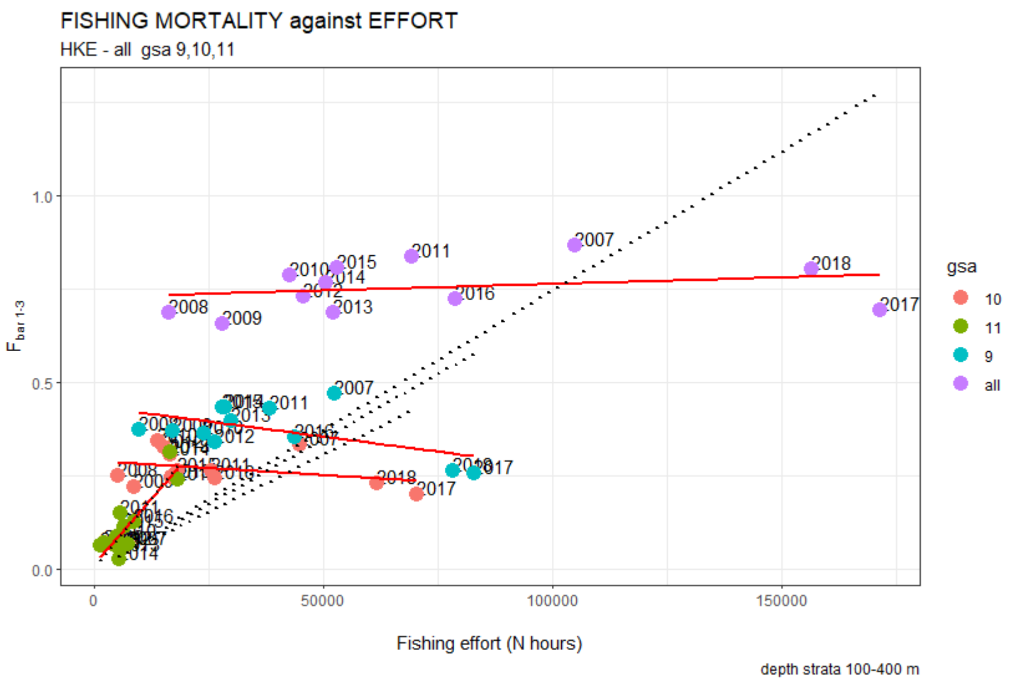


Figure 3.2.22 – Relationship between effort (fishing hours) and Fbar for hake in GSAs 9, 10 and 11. Red line: linear regression for each GSA and for the GSAs combined. Black dashed line: linear regression forced through the origin for each GSA and for the GSAs combined.

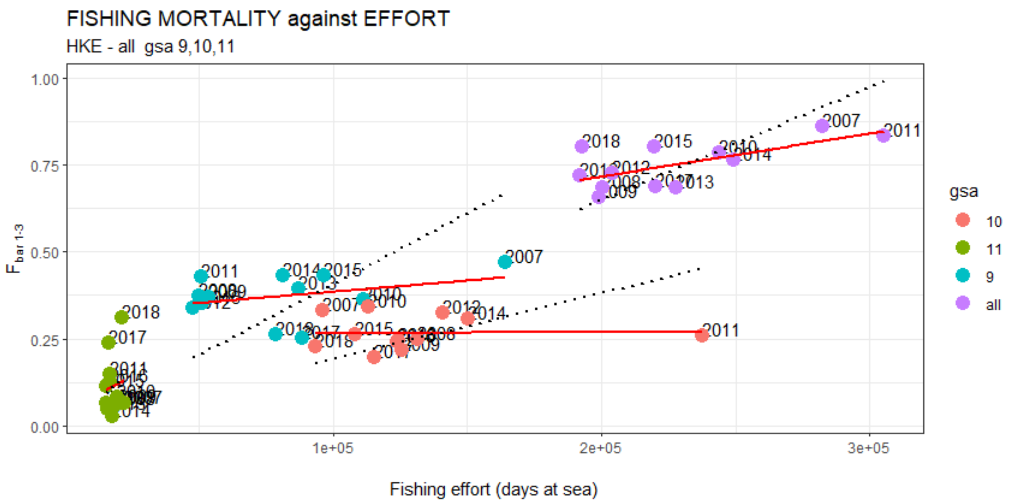


Figure 3.2.23 – Relationship between effort (days at sea) and Fbar for hake in GSAs 9, 10 and 11. Red line: linear regression for each GSA and for the GSAs combined. Black dashed line: linear regression forced through the origin for each GSA and for the GSAs combined.

Table 3.2.21 – Parameters of the relationship between effort (N fishing hours) and Fbar for the European Hake in GSAs 9, 10 and 11.

variable	gsa9	gsa10	gsa11	gsa 9-11	model variable
(Intercept)	0.434	0.287	0.011	0.727	Fbar = a+b* N hours
NHOURS	-1.61E-06	-7.50E-07	1.41E-05	3.50E-07	Fbar = a+b* N hours
r.squared	0.308	0.11	0.761	0.064	Fbar = a+b* N hours
Pr(>F)	0.061	0.291	0	0.426	Fbar = a+b* N hours
NHOURS	6.95E-06	6.10E-06	1.52E-05	7.44E-06	Fbar = 0+b* N hours
Pr(>F)	0.000755	0.00269	2.81E-07	0.426	Fbar = 0+b* N hours

Table 3.2.22 – Parameters of the relationship between effort (days at sea) and Fbar for the European Hake in GSAs 9, 10 and 11.

variable	gsa9	gsa10	gsa11	gsa 9-11	model variable
(Intercept)	0.32	0.265	0.038	0.47	Fbar = a+b*days_at_sea
days_at_sea	6.46E-07	1.67E-08	4.13E-06	1.24E-06	Fbar = a+b*days_at_sea
r.squared	0.112	0	0.013	0.446	Fbar = a+b*days_at_sea
Pr(>F)	0.288	0.967	0.722	0.018	Fbar = a+b*days_at_sea
days_at_sea	4.08E-06	1.91E-06	6.21E-06	3.25E-06	Fbar = 0+b*days_at_sea
Pr(>F)	3.03E-06	6.47E-07	0.000689	0.0176	Fbar = 0+b*days_at_sea

Given the availability of effort as number of fishing hour by GSA and by fleet a non parametric regression technique was applied to model the relationships between variables. By using the R library MGCV (Wood, 2011) several GAM models were tested in order to better define the relationship of effort and F.

By first all the explanatory variables, models were modified and better selected taking in to account in addition to the visual inspection, the Akaike Information Criterion (AIC), the Generalized Cross Validation (GCV) and the goodness of fit (adjusted R2 and deviance).

Two disaggregation levels were used: at GSA level and at fleet level. As an additional information for purpose of modelling, at GSA level the primary production (PP) was also used. The PP estimations were derived by using remote sensing images and the SMART tool. As stated by Russo et al. (2019) the combination of primary production and satellite-based information of fishing activities can improve our ability to capturing the main trends of yield, productivity and overexploitation rate of demersal stocks.

Summary of results and diagnostic of the best gam model are reported below (disaggregation levels =GSA) (Figure 3.2.14-17, table 3.2.17). Fishing activity in terms of fishing days together with PP is significant related to Fbar.

Table 3.2.23 – GAM summary of the best model for the European Hake in the management unit 2.

```
Family: Gamma
Link function: log

Formula:
Fbar ~ year + gsa + s(NHOURS) + PP + days_at_sea * PP + NHOURS *
    catch + PP * catch

Parametric coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)     0.000e+00  0.000e+00      NA       NA
year           -5.361e-04  5.303e-04  -1.011  0.32234
gsa11          -1.881e-01  3.561e-01  -0.528  0.60238
gsa9           -3.081e-01  5.485e-01  -0.562  0.57956
PP             -1.774e-07  9.541e-08  -1.859  0.07555 .
days_at_sea     1.220e-05  6.253e-06   1.951  0.06315 .
NHOURS          2.711e-05  1.721e-05   1.576  0.12851
catch          -5.361e-04  8.157e-04  -0.657  0.51747
PP:days_at_sea -1.897e-12  7.747e-13  -2.449  0.02220 *
NHOURS:catch   -2.686e-08  1.335e-08  -2.012  0.05580 .
PP:catch        2.854e-10  9.599e-11   2.974  0.00671 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
            edf Ref.df     F p-value
s(NHOURS) 2.551  3.472 6.514 0.00156 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Rank: 18/20
R-sq.(adj) =  0.787   Deviance explained = 89.5%
GCV = 0.097373  Scale est. = 0.06213   n = 36
```

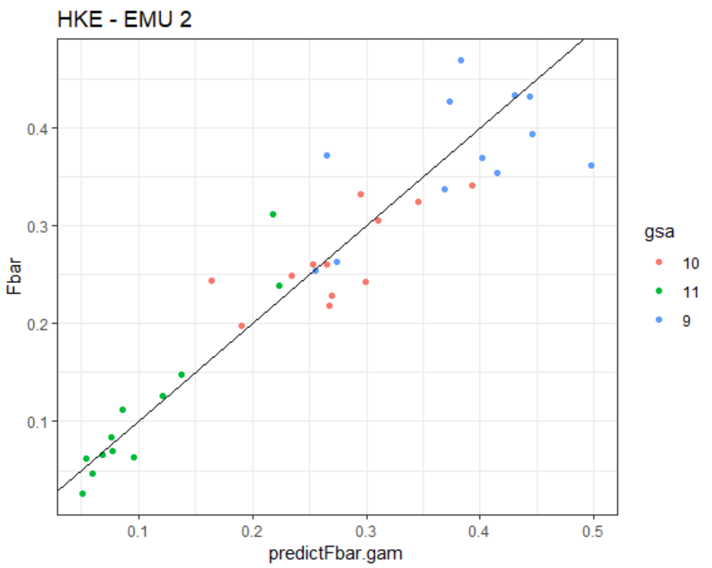


Figure 3.2.24 – Response and fitted values estimated by the GAM for Hake in the management unit 2.

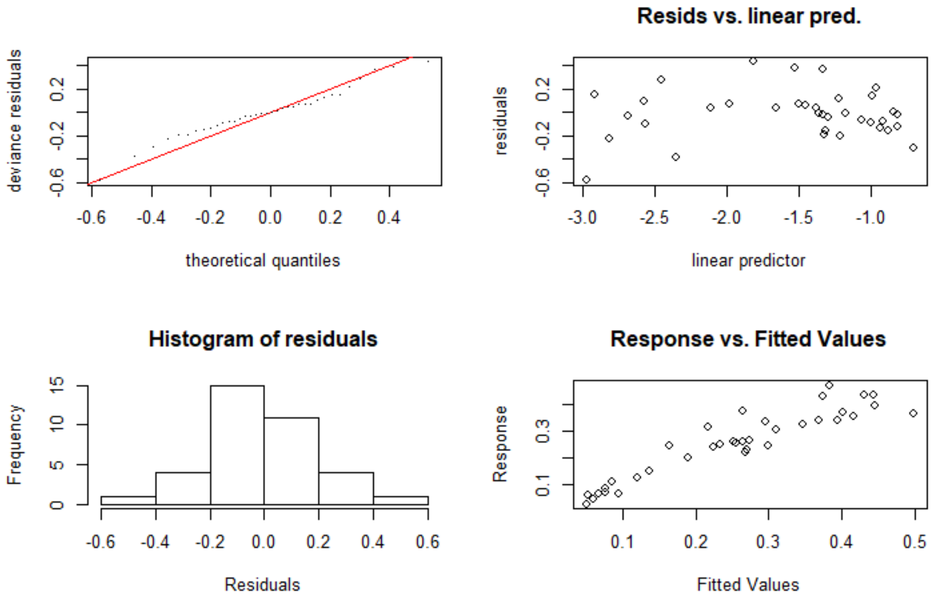


Figure 3.2.25 – GAM model diagnostic.

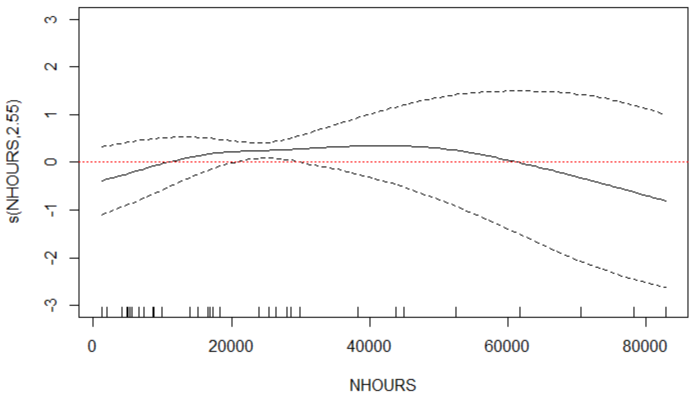


Figure 3.2.26 – GAM model diagnostic. Effects for smoothed factors

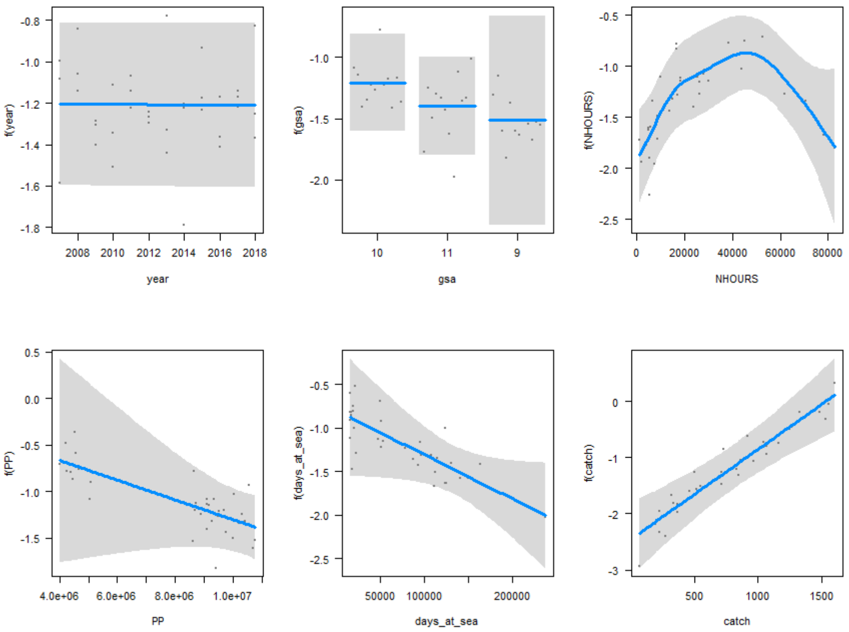


Figure 3.2.27 – GAM model diagnostic. Expected value (blue line), a confidence interval for the expected value (gray band), and partial residuals (dots) for all model predictors.

By using as disaggregation levels both GSA and gear the effect of number of fishing hours is more significant (table 3.2.18). Results and diagnostic of the best gam model are reported below (Figure 3.2.18-20).

Table 3.2.24 – GAM summary of the best model for the European Hake in the management unit 2.Data are disaggrated by gear and gsa.

```
Family: Gamma
Link function: log

Formula:
Fbar ~ year + gsa + gear + s(NHOURS) + days_at_sea + NHOURS *
    catch + days_at_sea * catch

Parametric coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)        2.291e+01  3.011e+01   0.761  0.45001
year              -1.386e-02  1.490e-02  -0.930  0.35633
gsa10              3.067e-01  1.648e-01   1.862  0.06805 .
gsa11              2.820e-01  2.092e-01   1.348  0.18329
gearGTR           -1.286e+00  5.287e-01  -2.432  0.01834 *
gearLLS           -1.866e+00  2.355e-01  -7.922 1.23e-10 ***
gearOTB            6.523e-01  2.485e-01   2.625  0.01121 *
days_at_sea        3.072e-05  9.945e-06   3.089  0.00316 **
NHOURS             1.958e-05  7.577e-06   2.583  0.01249 *
catch              4.116e-03  7.636e-04   5.390 1.55e-06 ***
NHOURS:catch      -2.113e-08  9.241e-09  -2.287  0.02612 *
days_at_sea:catch -4.900e-08  1.707e-08  -2.871  0.00582 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
             edf Ref.df     F p-value
s(NHOURS) 0.4557 0.7821 0.016   0.912

Rank: 20/21
R-sq.(adj) =   0.76   Deviance explained =   91%
GCV = 0.13959  Scale est. = 0.11057    n = 67
```

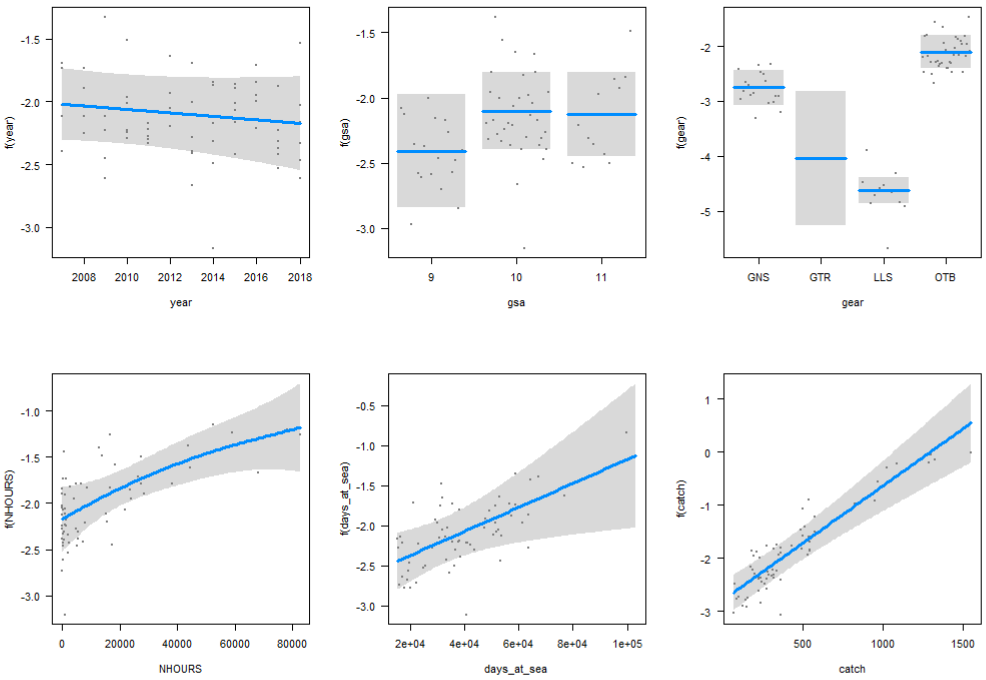


Figure 3.2.28 – GAM model diagnostic. Expected value (blue line), a confidence interval for the expected value (gray band), and partial residuals (dots) for all model predictors.

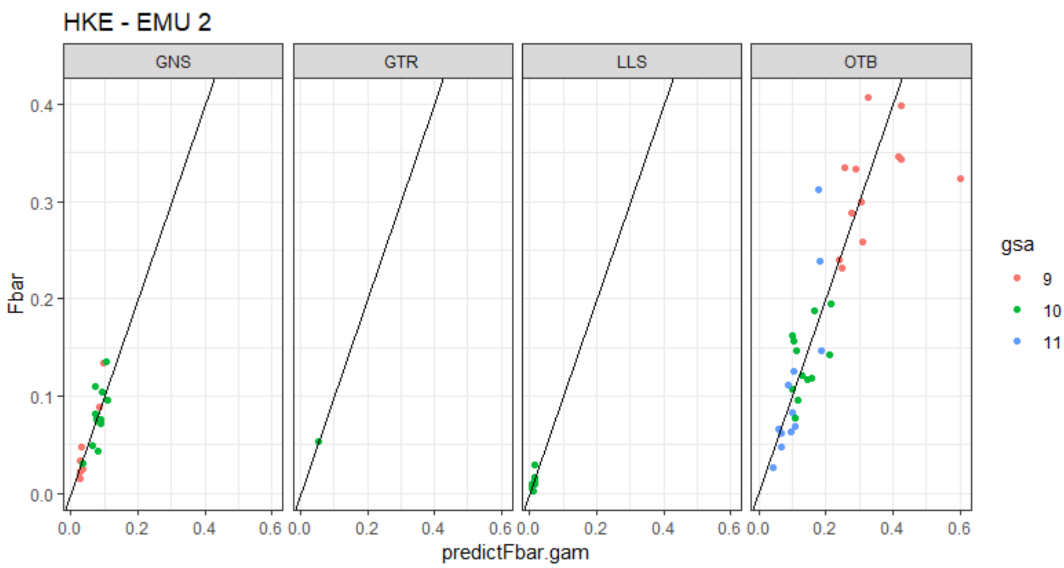


Figure 3.2.29 – Response and fitted values estimated by the GAM for Hake in the management unit 2.

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

The relationship between F and effort in fishing days and numbers of fishing hours is showed for DPS in GSAs 9, 10 and 11 in Figure 3.2.30 and 3.2.31.

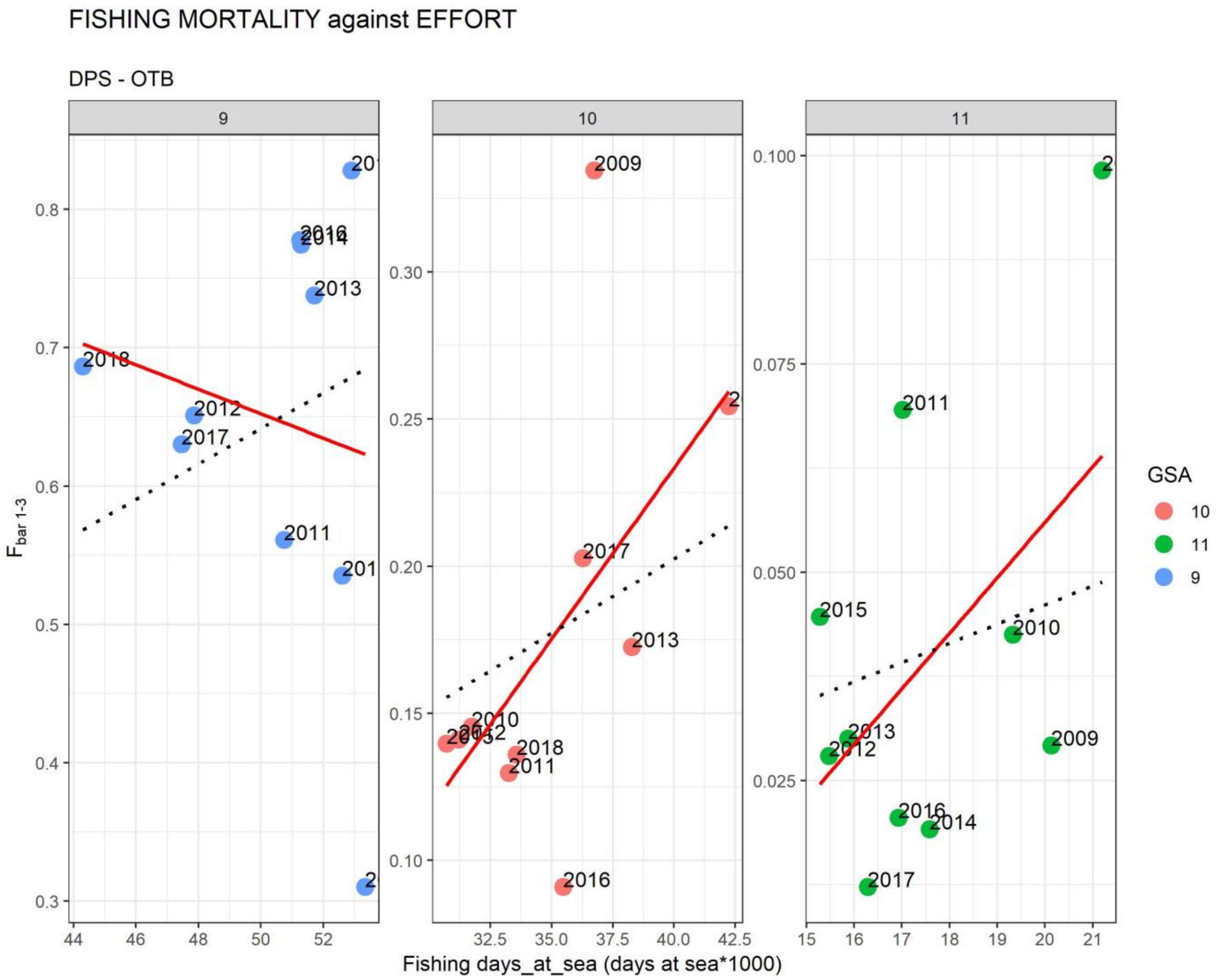


Figure 3.2.30 – Relationship between effort (fishing days) and Fbar for Deep-water rose shrimp in GSA 9, 10 and 11. Red line: linear regression for each GSA. Black dashed line: linear regression forced through the origin for each GSA.

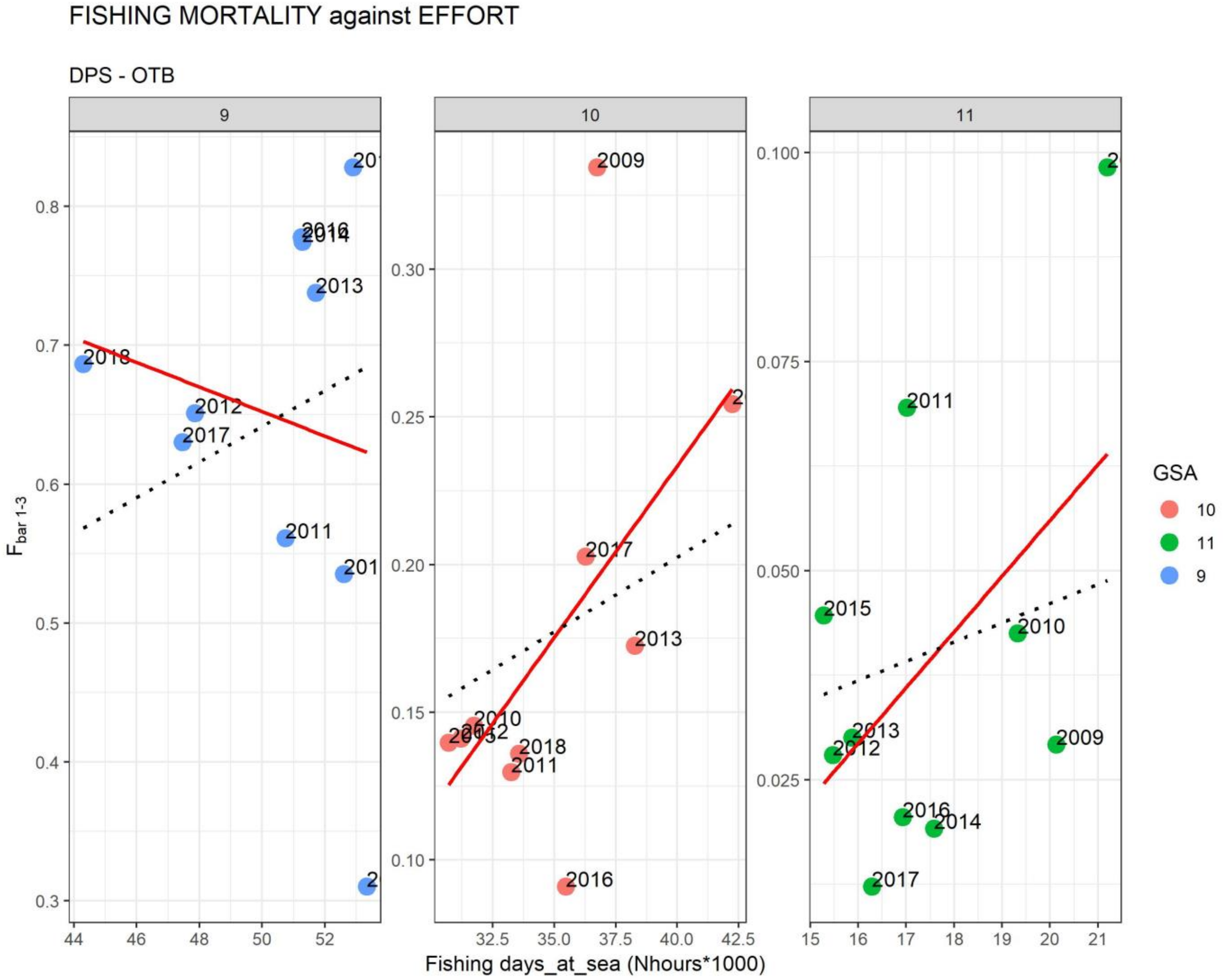


Figure 3.2.31 – Relationship between effort (numbers of fishing hours) and Fbar for Deep-water rose shrimp in GSA 9, 10 and 11. Red line: linear regression for each GSA. Black dashed line: linear regression forced through the origin for each GSA.

The main parameters of the linear relationships between Fbar and fishing effort (both in day at sea and number of fishing hours) in the Management Unit 2 are reported in table 3.2.26 and 3.2.27. The relationship is significant when number of hours are considered.

Table 3.2.25 – Parameters of the relationship between effort (days at sea) and Fbar for Deep-water rose shrimp in GSAs 9, 10 and 11.

variable	gsa9	gsa10	gsa11	gsa 9-11	model
(Intercept)	1.094	-0.231	-0.077	-0.321	Fbar = a+b*days@sea
days_at_sea	-0.00884	0.0116	0.00667	0.0178	Fbar = a+b*days@sea
r.squared	0.028	0.338	0.268	0.767	Fbar = a+b*days@sea
Pr(>F)	0.643	0.078	0.125	0	Fbar = a+b*days@sea
days_at_sea	0.0128	0.00506	0.0023	0.00969	Fbar = 0+b*days@sea
Pr(>F)	5.24E-07	9.21E-06	0.000496	2.40E-10	Fbar = 0+b*days@sea

Table 3.2.26 – Parameters of the relationship between effort (days at sea) and Fbar for Deep-water rose shrimp in GSAs 9, 10 and 11.

variable	gsa9	gsa10	gsa11	gsa 9-11	model	variable
(Intercept)	0.647	0.181	0.033	0.258	Fbar = a+b*Nhours	
NHOURS	0.00017	-0.000379	0.000597	0.00205	Fbar = a+b*Nhours	

r.squared	0	0.01	0.078	0.012	Fbar = a+b*Nhours
Pr(>F)	0.965	0.78	0.435	0.56	Fbar = a+b*Nhours
NHOURS	0.0235	0.00453	0.00201	0.0106	Fbar = 0+b*Nhours
Pr(>F)	0.0076	0.0564	0.0201	0.56	Fbar = 0+b*Nhours

Giant red shrimp in GSAs 9, 10 and 11

The relationship between F and effort in fishing days and numbers of fishing hours is showed for ARS in GSAs 9, 10 and 11 in Figure 3.2.32 and 3.2.33.

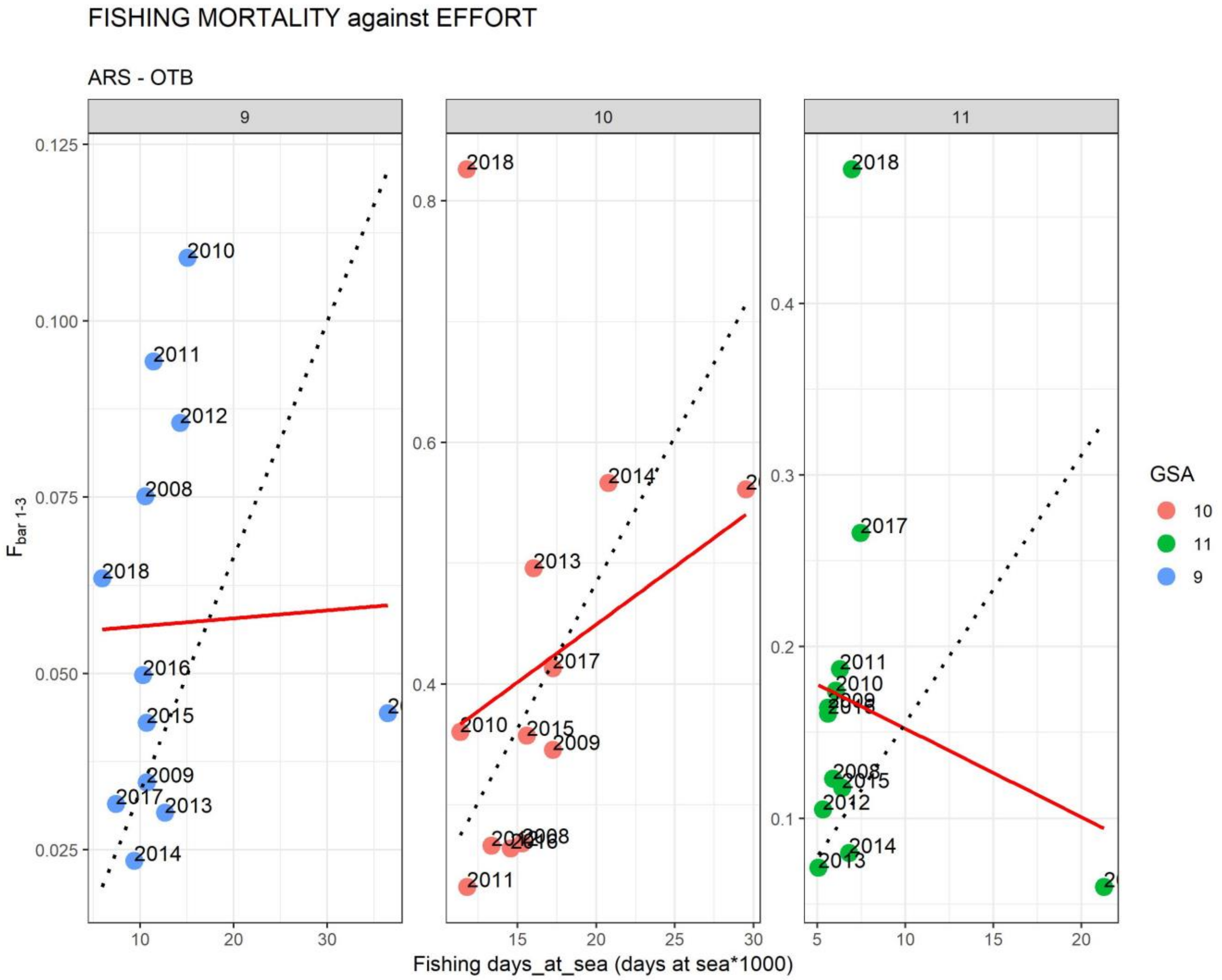


Figure 3.2.32 – Relationship between effort (fishing days) and Fbar for Giant red shrimp in GSA 9, 10 and 11. Red line: linear regression for each GSA. Black dashed line: linear regression forced through the origin for each GSA.

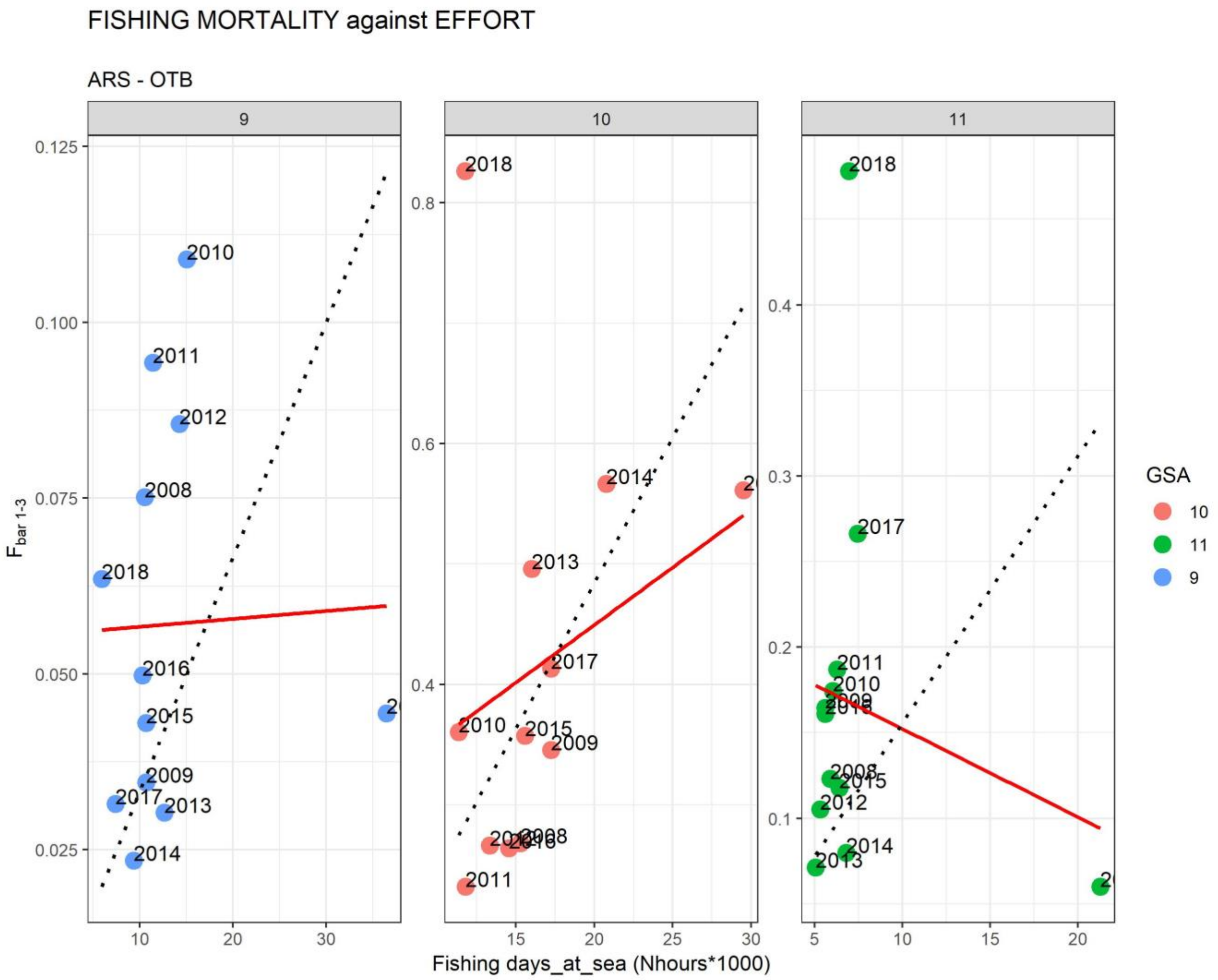


Figure 3.2.33 – Relationship between effort (numbers of fishing hours) and Fbar for Giant red shrimp in GSA 9, 10 and 11. Red line: linear regression for each GSA. Black dashed line: linear regression forced through the origin for each GSA.

The main parameters of the linear relationships between Fbar and fishing effort (both in day at sea and number of fishing hours) in the Management Unit 2 is reported in table 3.2.27 and 3.2.28.

Table 3.2.27 – Parameters of the relationship between effort (days at sea) and Fbar for Giant red shrimp in GSAs 9, 10 and 11.

variable	gsa9	gsa10	gsa11	gsa 9-11	model variable
(Intercept)	0.056	0.258	0.204	0.119	Fbar = a+b*days@sea
days_at_sea	0.000112	0.00956	-0.00514	0.00766	Fbar = a+b*days@sea
r.squared	0.001	0.076	0.04	0.075	Fbar = a+b*days@sea
Pr(>F)	0.923	0.386	0.533	0.105	Fbar = a+b*days@sea
days_at_sea	0.00333	0.0242	0.0156	0.0151	Fbar = 0+b*days@sea
Pr(>F)	0.00138	9.07E-06	0.0125	0.105	Fbar = 0+b*days@sea

Table 3.2.28 – Parameters of the relationship between effort (days at sea) and Fbar for Giant red shrimp in GSAs 9, 10 and 11.

variable	gsa9	gsa10	gsa11	gsa 9-11	model variable

(Intercept)	0.059	0.348	0.092	0.161	Fbar = a+b*Nhours
NHOURS	-0.173	4.73	8	4.12	Fbar = a+b*Nhours
r.squared	0.008	0.251	0.684	0.101	Fbar = a+b*Nhours
Pr(>F)	0.788	0.097	0.001	0.06	Fbar = a+b*Nhours
NHOURS	2.02	14.4	12	9.59	Fbar = 0+b*Nhours
Pr(>F)	0.0221	0.00569	7.48E-05	0.0596	Fbar = 0+b*Nhours

Blue and red shrimp in GSAs 9, 10 and 11

The relationship between F and effort in fishing days and numbers of fishing hours is showed for ARA in GSAs 9, 10 and 11 in Figure 3.2.34 and 3.2.35.

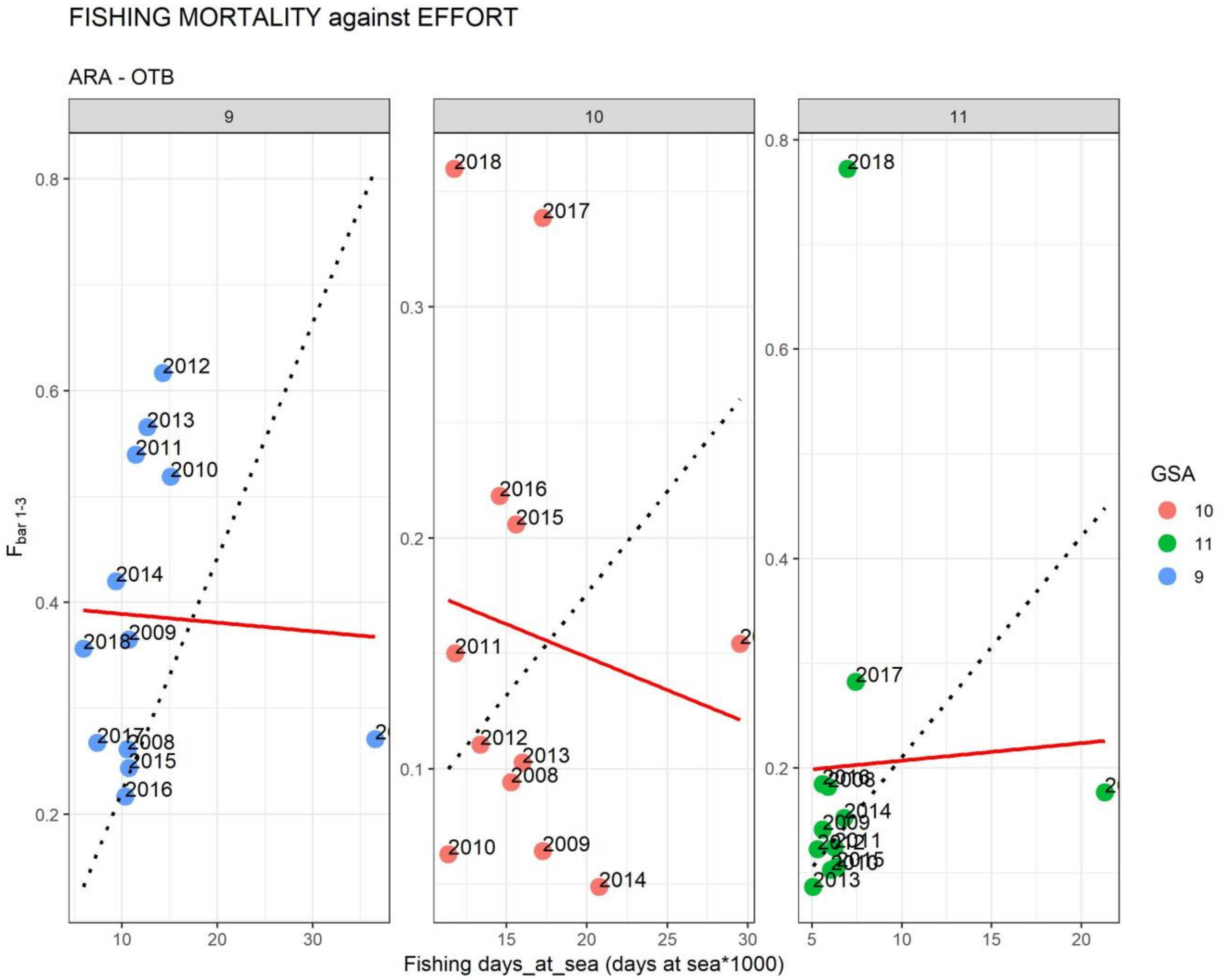


Figure 3.2.34 – Relationship between effort (fishing days) and Fbar for Blue and red shrimp in GSA 9, 10 and 11. Red line: linear regression for each GSA. Black dashed line: linear regression forced through the origin for each GSA.

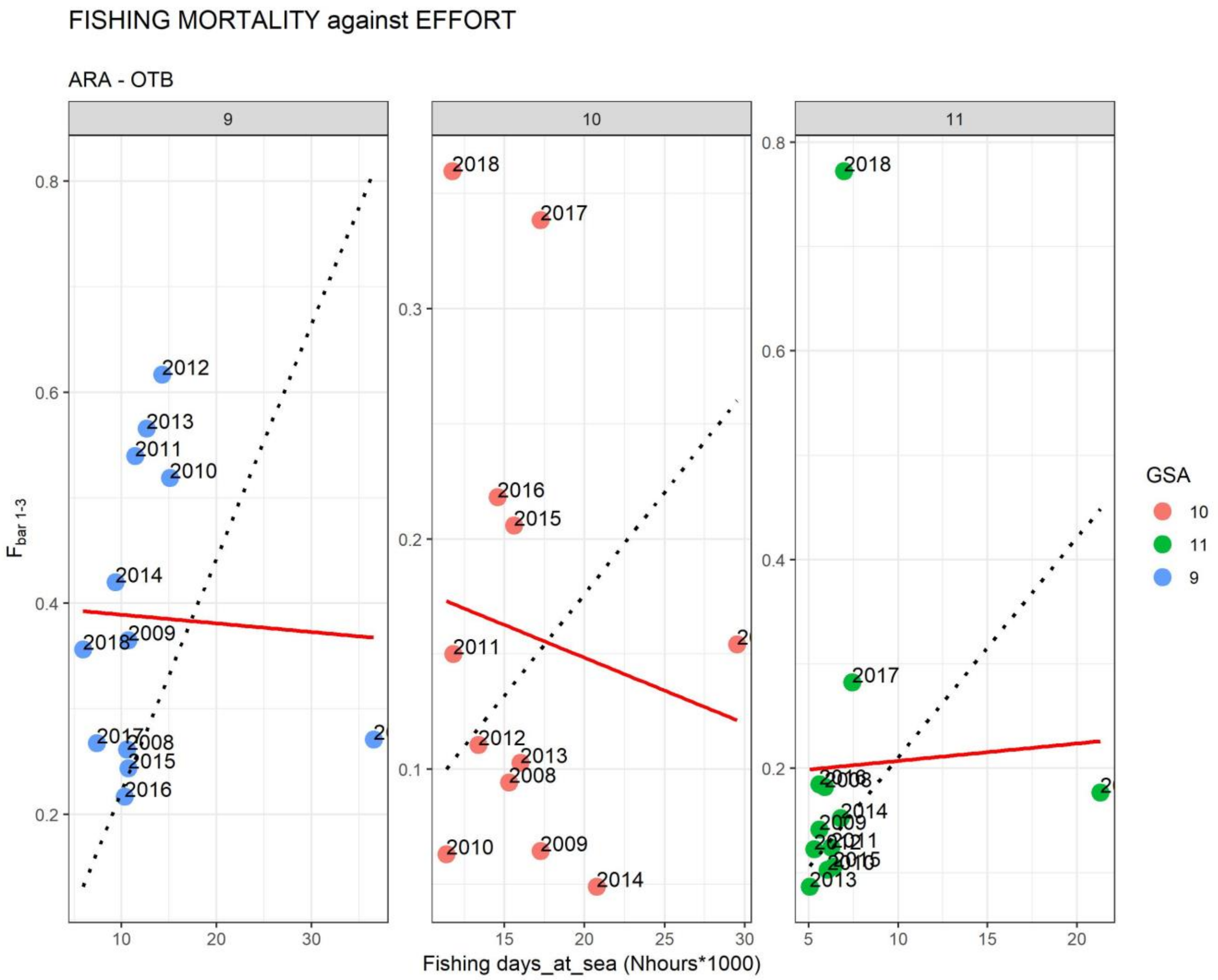


Figure 3.2.35 – Relationship between effort (numbers of fishing hours) and Fbar for Blue and red shrimp in GSA 9, 10 and 11. Red line: linear regression for each GSA. Black dashed line: linear regression forced through the origin for each GSA.

The main parameters of the linear relationships between Fbar and fishing effort (both in day at sea and number of fishing hours) in the Management Unit 2 are reported in table 3.2.29 and 3.2.30.

Table 3.2.29 – Parameters of the relationship between effort (days at sea) and Fbar for Blue and red shrimp in GSAs 9, 10 and 11.

variable	gsa9	gsa10	gsa11	gsa 9-11	model	variable
(Intercept)	0.397	0.205	0.191	0.261	Fbar = a+b*days@sea	
days_at_sea	-0.00082	-0.00285	0.00167	-0.000893	Fbar = a+b*days@sea	
r.squared	0.002	0.019	0.002	0.001	Fbar = a+b*days@sea	
Pr(>F)	0.888	0.67	0.903	0.839	Fbar = a+b*days@sea	
days_at_sea	0.0222	0.00881	0.0211	0.0155	Fbar = 0+b*days@sea	
Pr(>F)	0.000845	0.00122	0.0135	0.839	Fbar = 0+b*days@sea	

Table 3.2.30 – Parameters of the relationship between effort (days at sea) and Fbar for Blue and red shrimp in GSAs 9, 10 and 11.

variable	gsa9	gsa10	gsa11	gsa 9-11	model	variable

(Intercept)	0.406	0.092	0.092	0.19	Fbar = a+b*Nhours
NHOURS	-1.34	4.93	12.1	4.85	Fbar = a+b*Nhours
r.squared	0.018	0.761	0.582	0.167	Fbar = a+b*Nhours
Pr(>F)	0.679	0	0.004	0.013	Fbar = a+b*Nhours
NHOURS	13.7	7.46	16.1	11.3	Fbar = 0+b*Nhours
Pr(>F)	0.0163	5.52E-05	0.000138	0.0133	Fbar = 0+b*Nhours

3.2.3 Conclusions

The analyses carried out during STECF EWG19-14 allowed to deepen the results obtained during the previous meeting. The modeling exercise on HKE in MU 2 shows that the difficult to correlate fishing mortality and effort exerted by the fleets exploiting the stocks is due to the quality of effort and other accessory information used. The increase of accuracy in measuring the fishing activity by using fishing hours instead of fishing days improve the results of modelling and give a more reliable estimation of fishing effort exerted on fish stock. Moreover the use of a more flexible approach (GAM) allow to better catch the main trends of the response variable.

3.3 Data issues and comparison of the fishing statistics between the three data calls

As in 2018, the EWG performed a number of comparisons between the various sources of transversal information (effort and landings data) available to the EWG in the various datacalls, in order to spot and, if possible, correct for discrepancies.

3.3.1 Landings comparison

Time series of landings data were analysed at stock level (GSA and species) and countries.

In the following table are reported time series available according to the three Data Calls: Annual Economic Report (AER), Fishery Dependent Information (FDI) and Mediterranean and Black Sea call (MBS).

Table 3.3.1 – Time series available in the EU three official Data Calls

Data Calls	Time series
MBS (Med and Black Sea)	2002-2018
AER (Annual Economic Report)	2008-2017
FDI (Fisheries Dependent Information)	2015-2018

3.3.1.1 Italy

Figure 3.3.1 – Total species landings comparison between AER and MBS Data Call for Italian GSAs

Data between AER and MBS calls are basically the same in GSA9 (Ligurian and Northern Tyrrhenian Seas), differ in the last two years in GSA10 (Southern Tyrrhenian Sea) and show high discrepancy in GSA11 (Sardinian seas). Likely discrepancy in GSA11 is due to the fact that data provided concerned only metier selected by the ranking system or metier for which biological samples were collected throughout the year.

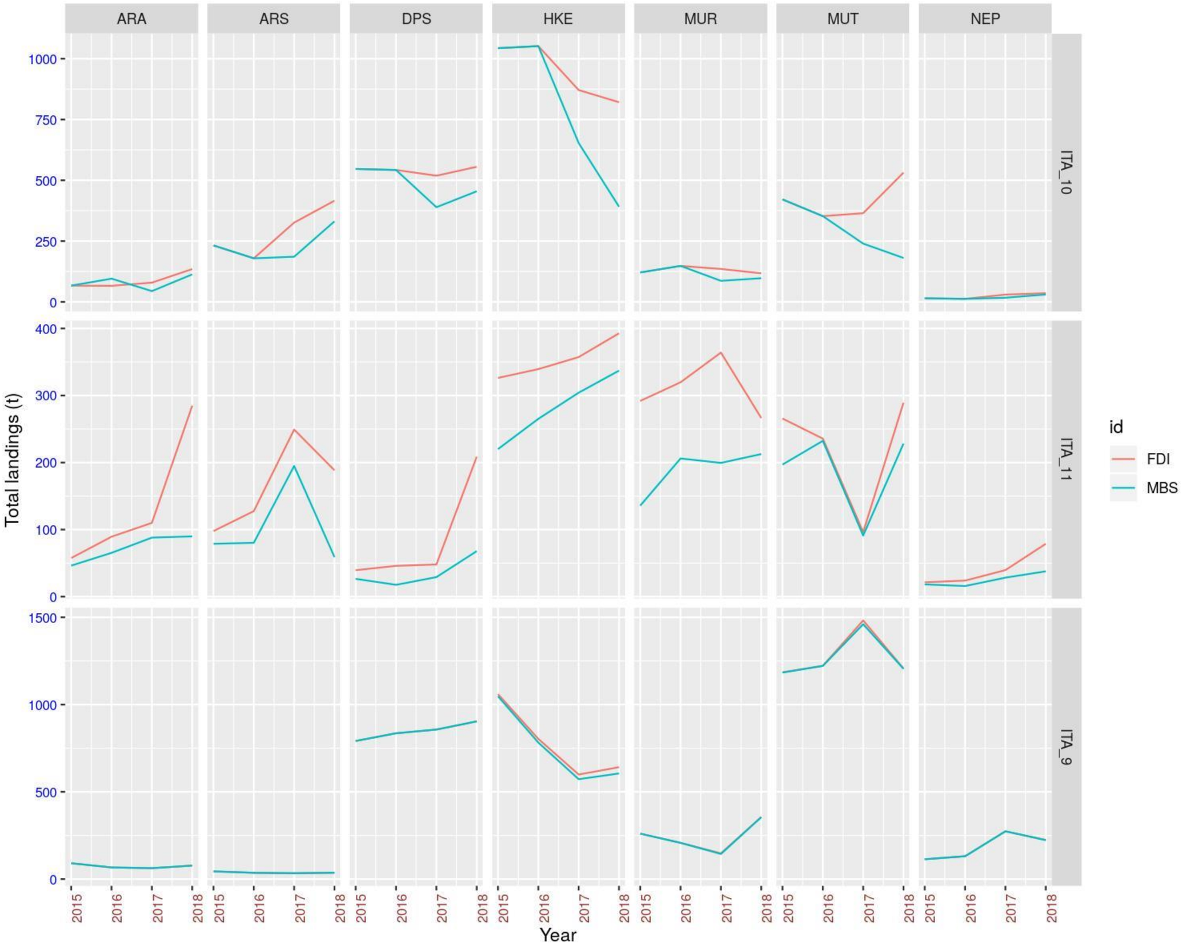


Figure 3.3.2 – Total species landings comparison between FDI and MBS Data Call for Italian GSAs

As in the previous comparison reported landings through FDI and MBS are basically the same in GSA9 (Ligurian and Northern Tyrrhenian Seas), differ in the last two years in GSA10 (Southern Tyrrhenian Sea) and show high discrepancy in GSA11 (Sardinian seas).

Data provided through AER and FDI calls are the same so the graph of comparison is not shown.

3.3.1.2 France

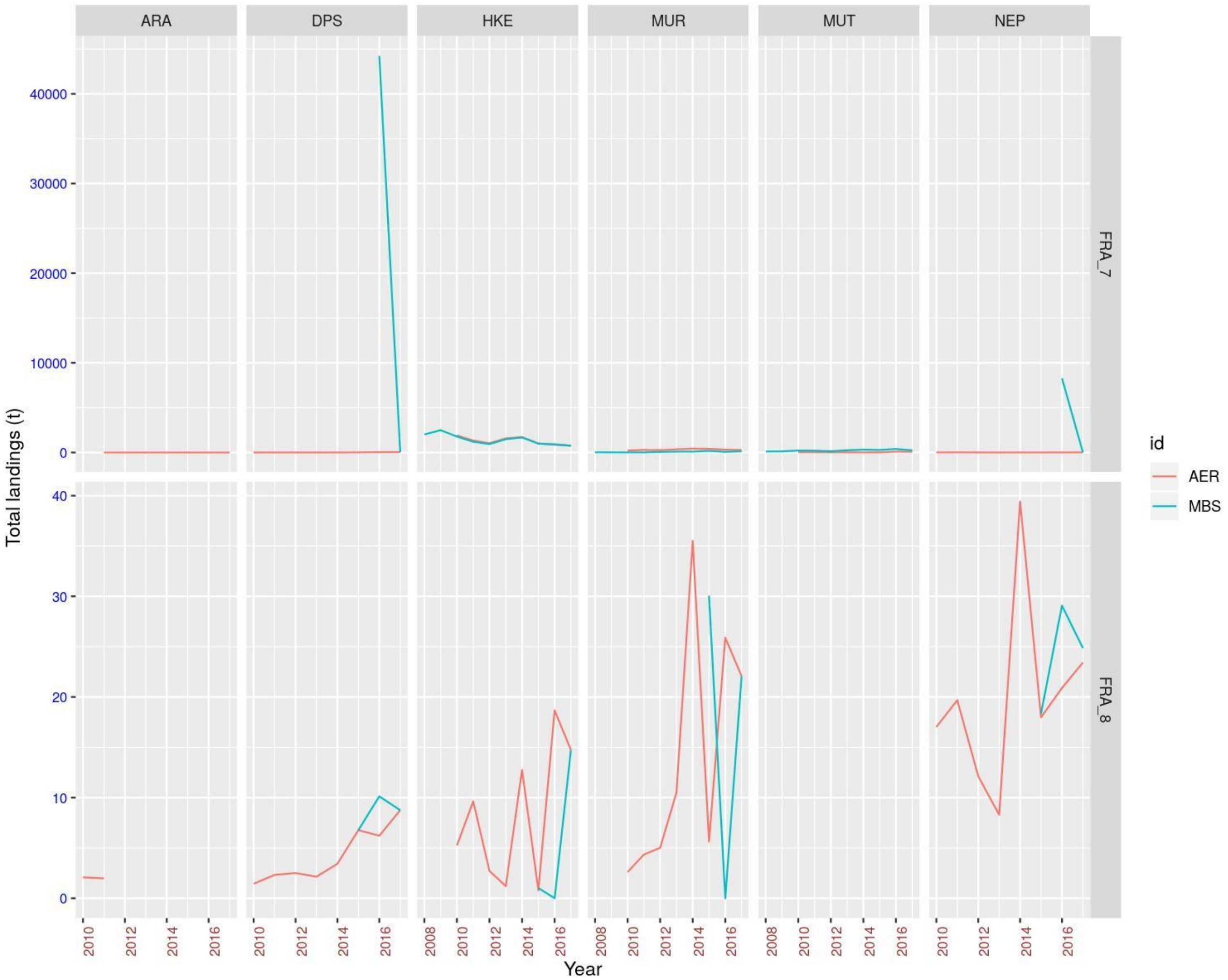


Figure 3.3.3 – Total species landings comparison between AER and MBS Data Call for French GSAs

Wrong unit of measures were used in GSA7 (Gulf of Lion) in reporting landings of DPS and NEP in the MBS data call. Removing these two species from the analyses was possible compare data for the other species (Figure x1.2.2). Hake comparison seems good while there are still mismatching in red mullet species (MUT and MUR) in GSA7 and discrepancy in GSA8 (Corsica Island) data. In the case of mullets it seems that species landings were switched between them in the AER data call because in the Mediterranean red mullet (MUT) usually show highest landings compare to striped mullet (MUR). This fact is confirmed using FDI data (figures x.1.2.3-4.)

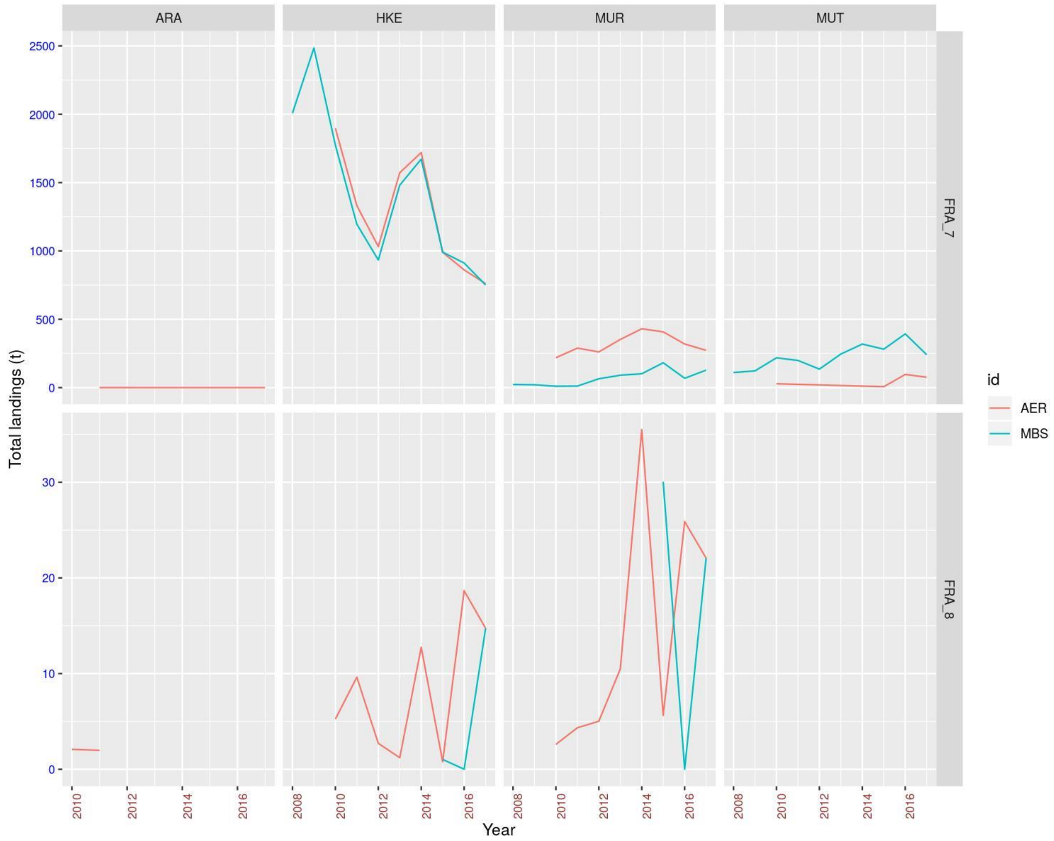


Figure 3.3.4 – Total species landings comparison between AER and MBS Data Call for French GSAs removing DPS and NEP data.

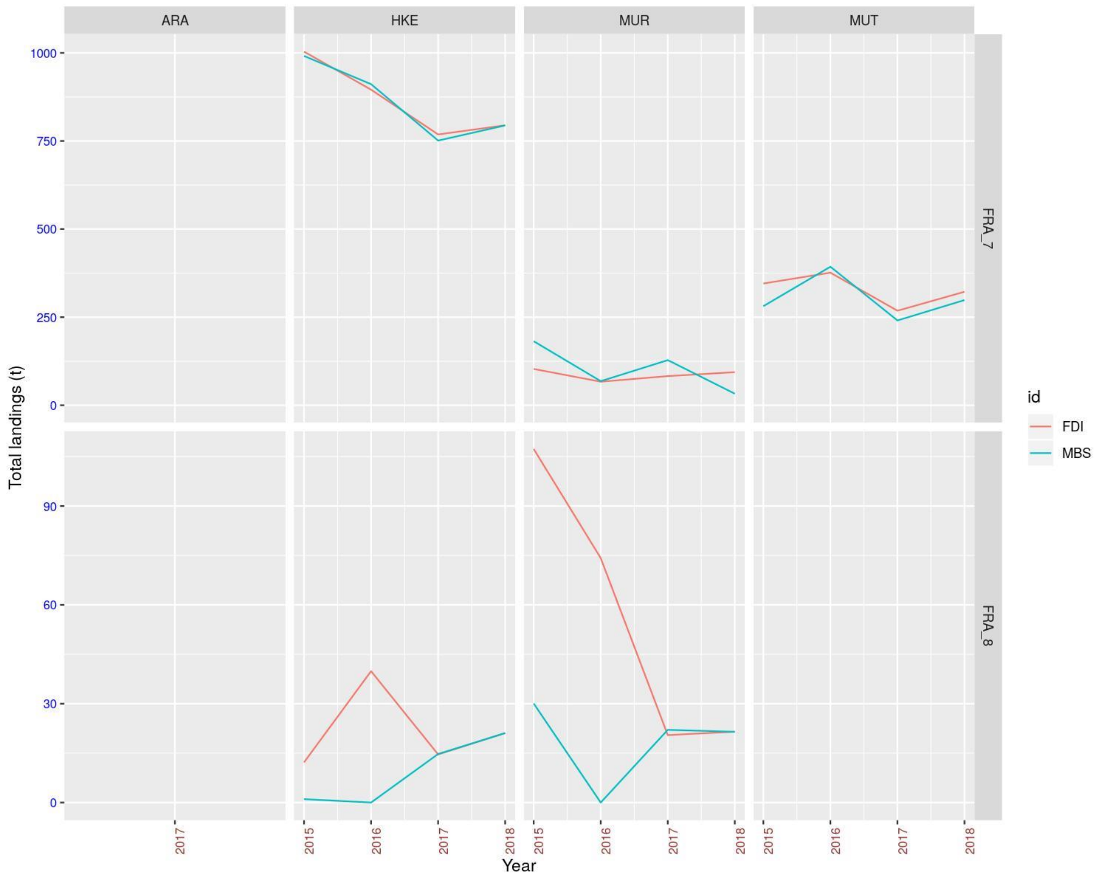


Figure 3.3.5 – Total species landings comparison between FDI and MBS Data Call for French GSAs removing DPS and NEP data.

Landings comparison between FDI and MEDS seems in agreement in GSA7 but still differ in GSA8.

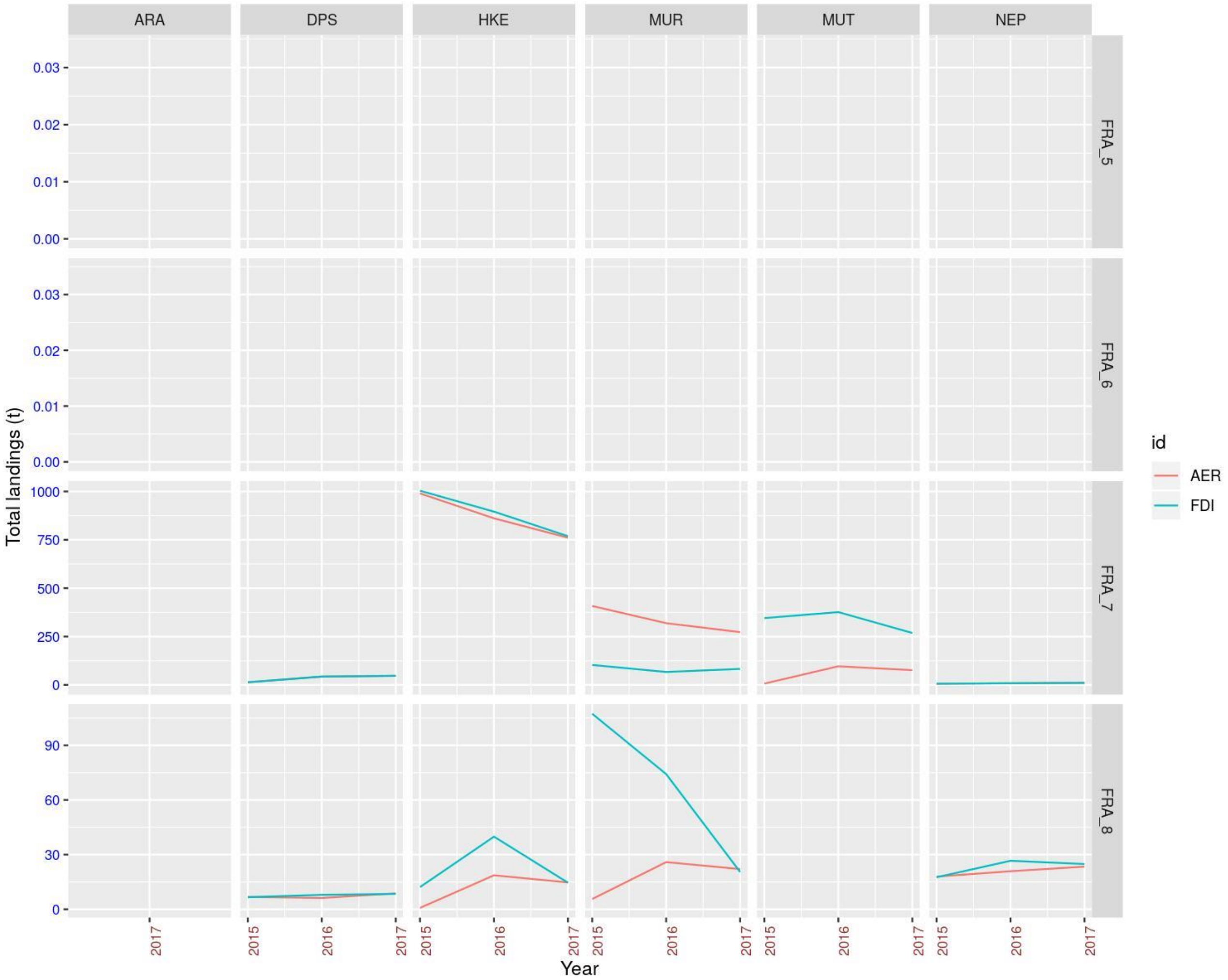


Figure 3.3.6 – Total species landings comparison between FDI and MBS Data Call for French GSAs.

3.3.1.3 Spain

Figure 3.3.7 – Total species landings comparison between AER and MBS Data Call for Spanish GSAs.

Spanish landings comparison show that in almost all stocks landings provided through MBS call are higher than AER ones. This fact it is difficult to explain based on ranking system metier selection effect and/or biological samples availability as happened likely in GSA11, because it is expected that in AER all the landings in the area are provided. FDI and MBS comparison is really good (Figure x.1.3.2) and still bad between FDI and AER (Figure x.1.3.3).

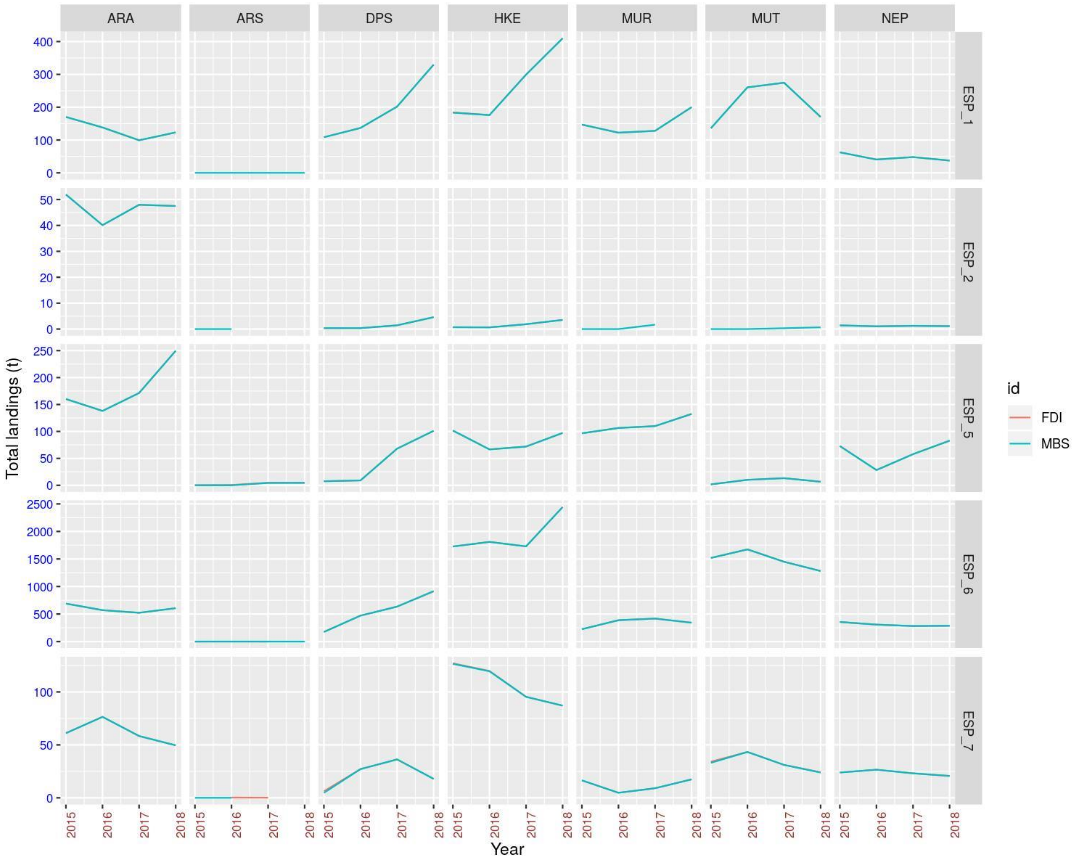


Figure 3.3.8 – Total species landings comparison between FDI and MBS Data Call for Spanish GSAs.

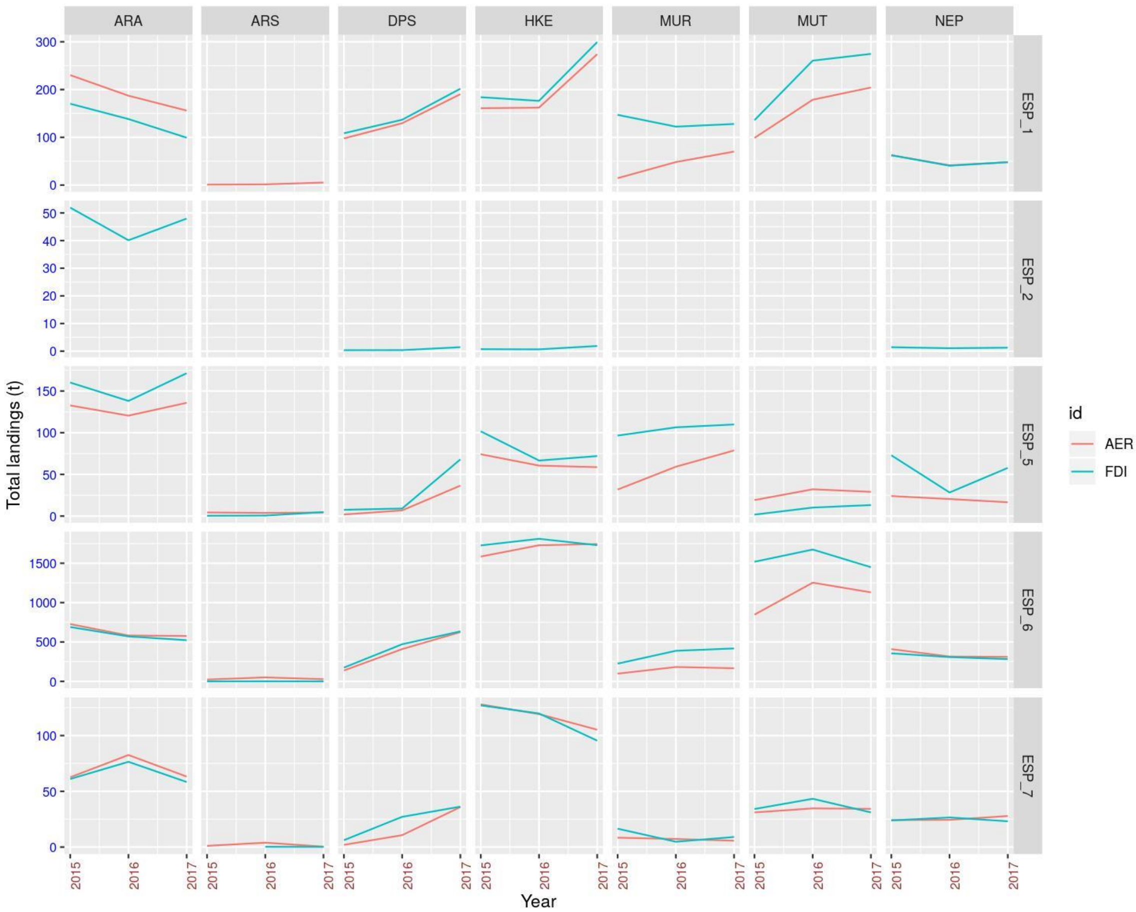


Figure 3.3.9 – Total species landings comparison between FDI and AER Data Call for Spanish GSAs.

3.3.2 Effort comparison

Time series of effort data as fishing Days were analysed both at vessel length, country and GSA levels.

3.3.2.1 Italy

Figure 3.3.10– Total fishing days by vessel length comparison between AER, FDI and MBS Data Call for Italian GSAs.

Data provided through the three calls by vessel length (Figure x2.1) and total (Figure x2.2) are both perfectly in agreement

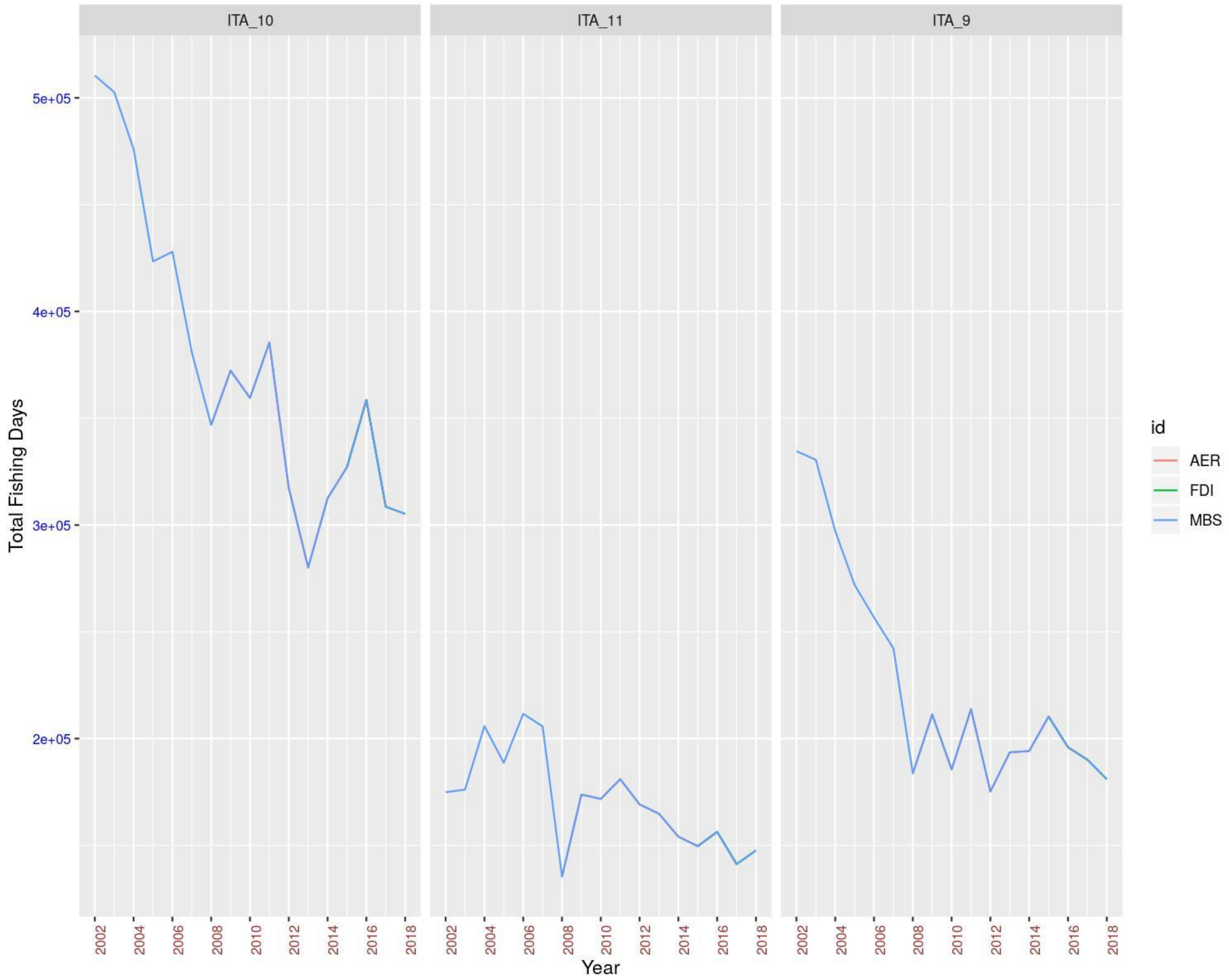


Figure 3.3.11 – Total fishing days by area comparison between AER, FDI and MBS Data Call for Italian GSAs.

3.3.2.2 France

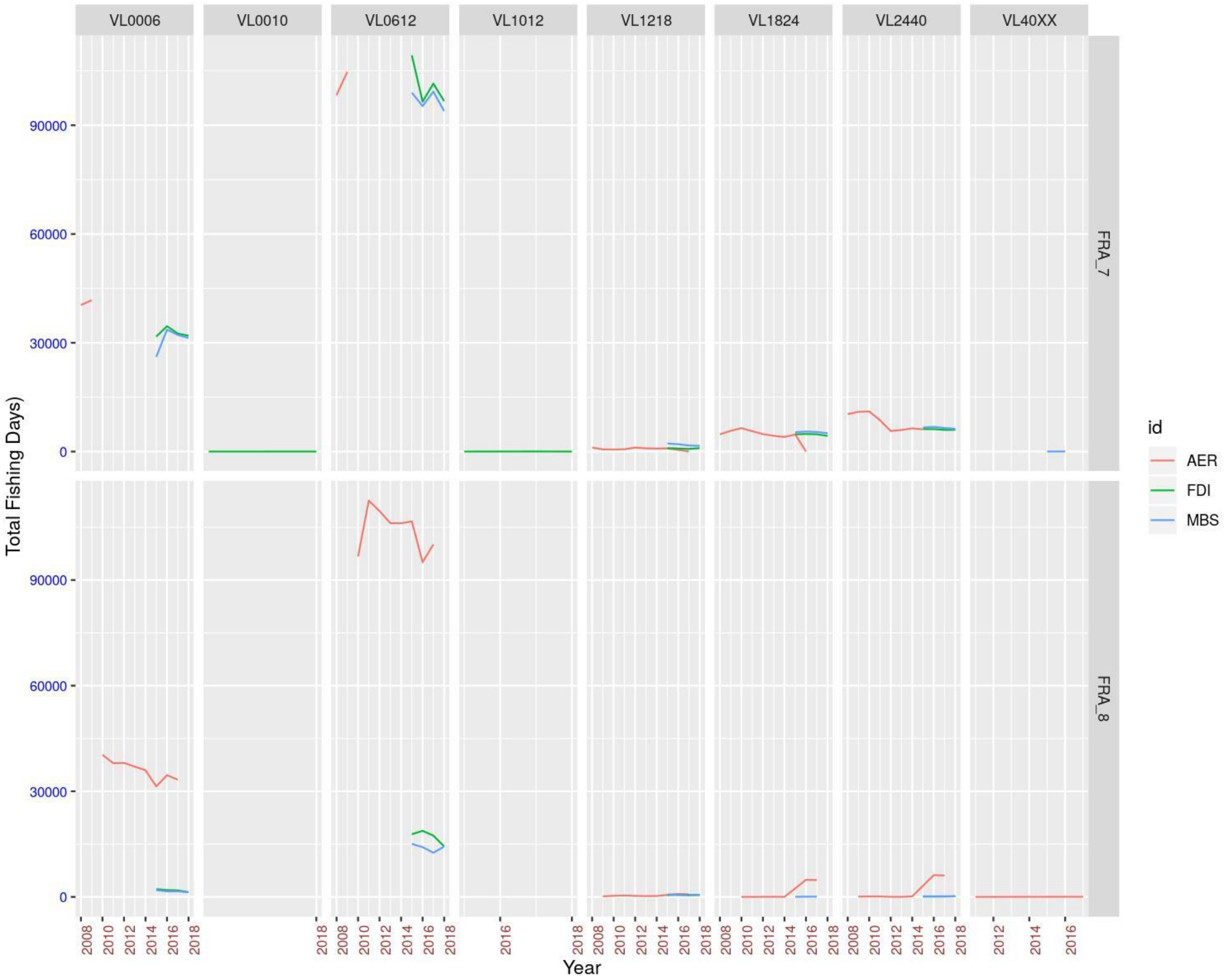


Figure 3.3.12 – Total fishing days by vessel length comparison between AER, FDI and MBS Data Call for French GSAs.

Data provided through the three calls show high discrepancy in VL0006 and VL0612 in GSA8. Aggregating fishing days at GSA level, became clear that in AER data call there was a switch of effort data between GSA7 and GSA8 from 2010 onward. Basically, GSA7 data were assigned to GSA8 and viceversa (Figure x2.4).

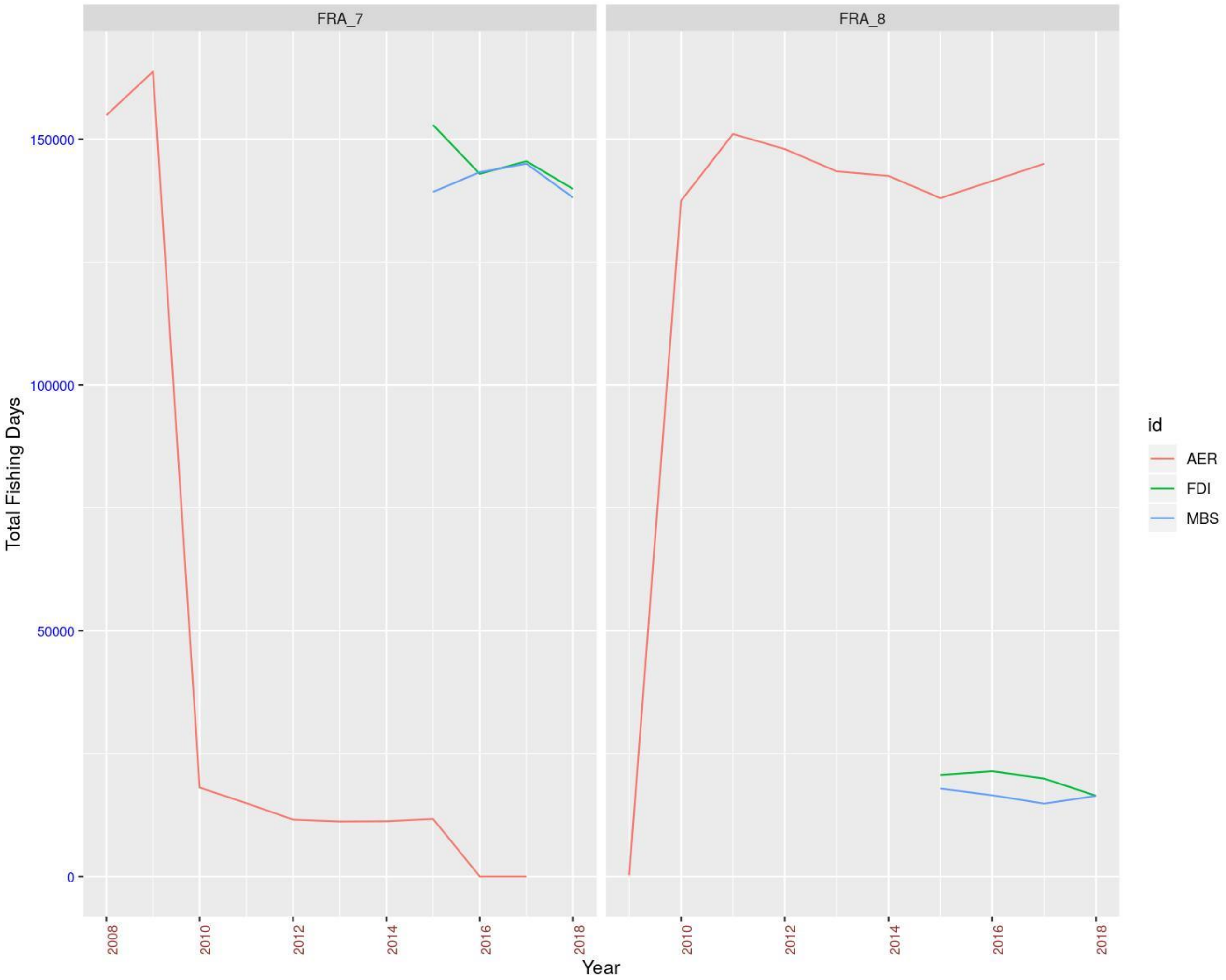


Figure 3.3.13 – Total fishing days by area comparison between AER, FDI and MBS Data Call for French GSAs.

3.3.2.3 Spain

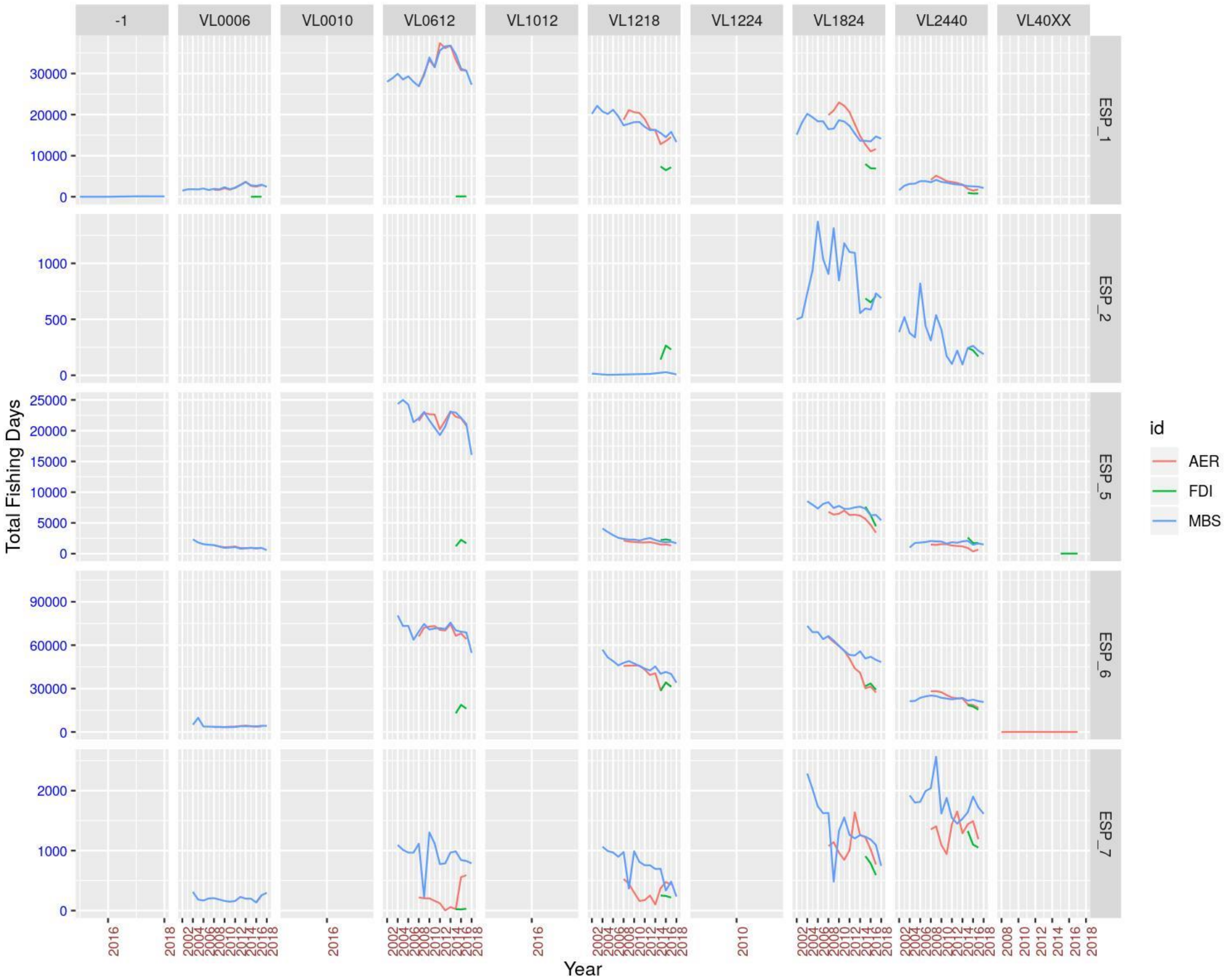


Figure 3.3.14 – Total fishing days by vessel length comparison between AER, FDI and MBS Data Call for Spanish GSAs.

Data provided through the three calls show a general mismatch pattern which it becames more evident when data are aggregated at GSA level (Figure x2.6). In particular FDI values are almost always lower respect data provided through the other two data calls. Moreover FDI effort by GSA in the last year wasn't provided.

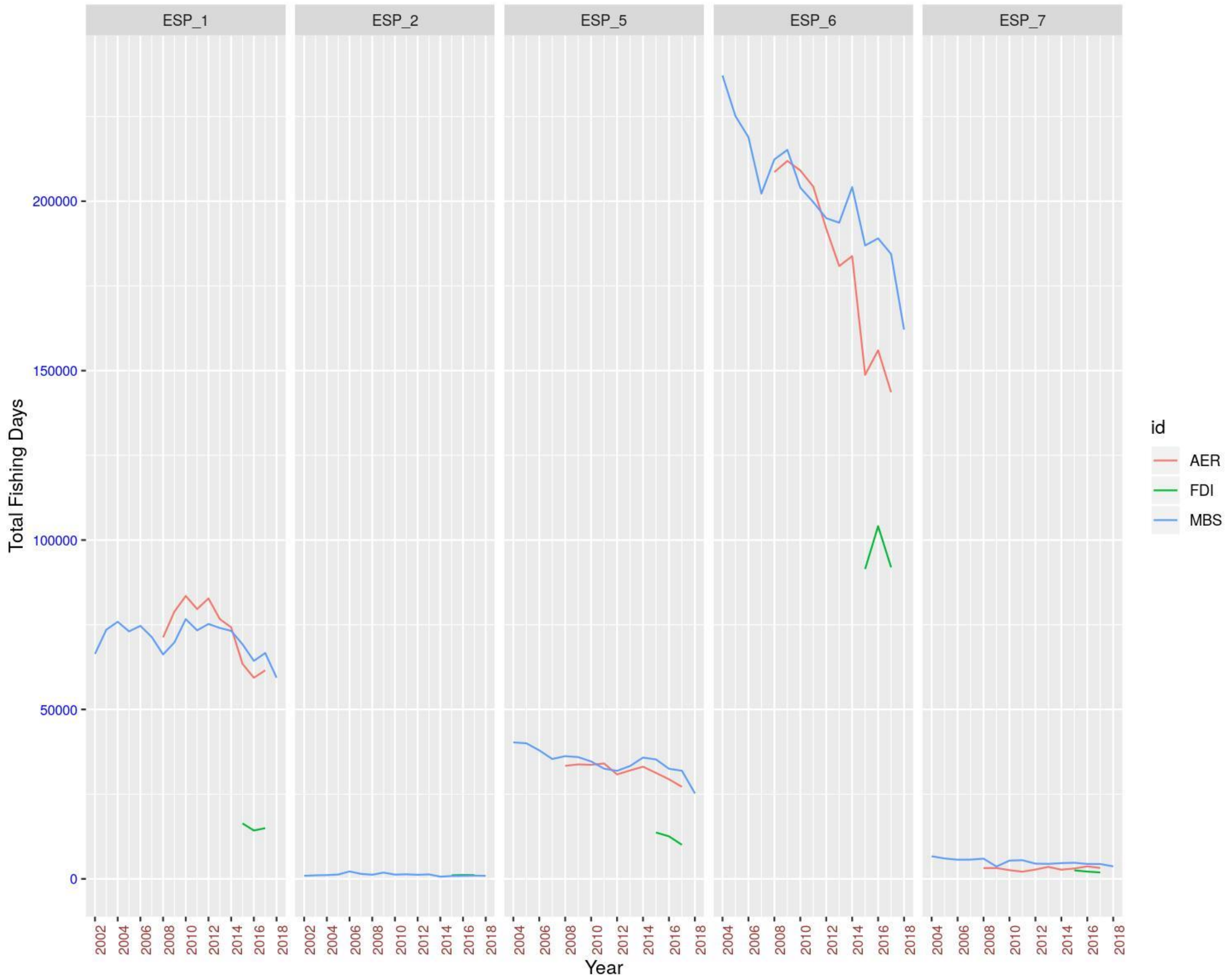


Figure 3.3.15 – Total fishing days by area comparison between AER, FDI and MBS Data Call for Spanish GSAs.

3.3.3 Trends in fishing effort

STECF EWG1914 tried to analyses trend in effort (as Fishing days) in the different country/GSA/vessel length combinations using the longest time series available namely the MBS data call. Data refer only to Otter Bottom Trawl gear (OTB) which represent the most important gear exploiting the species reported in the MAP.

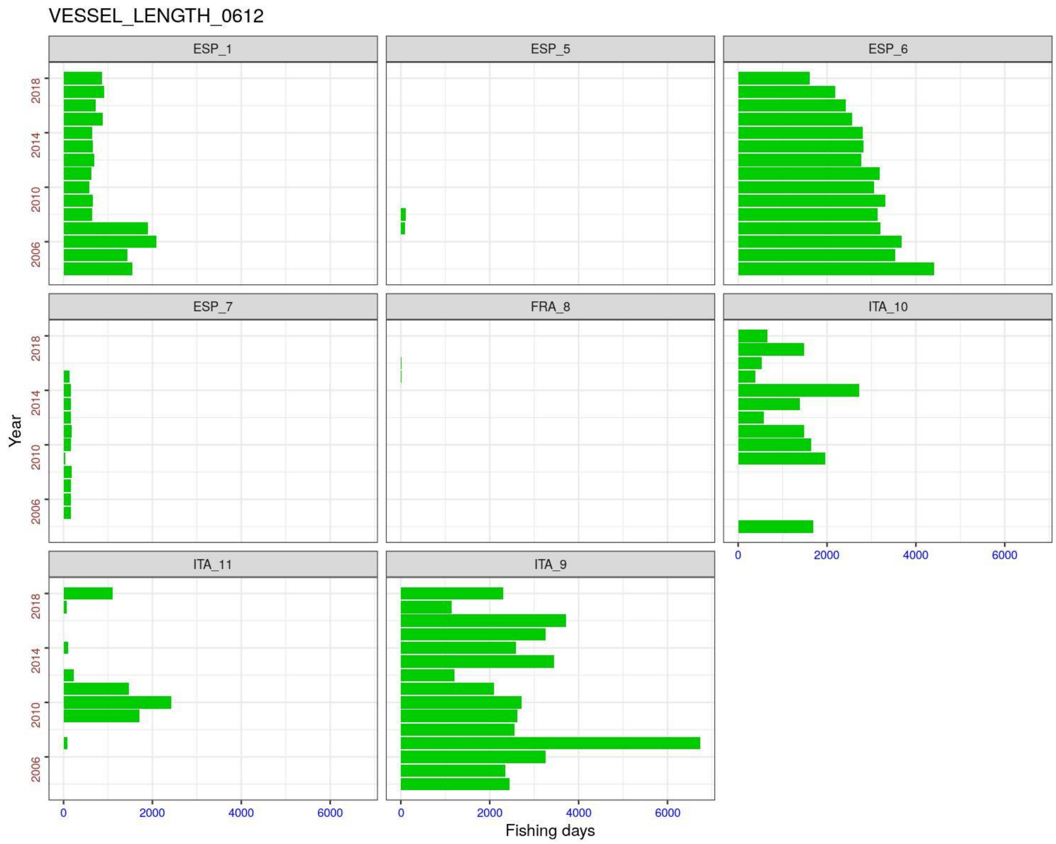
In particular fishing days were standardized according to a Z scores approach:

Z_score= (Xi – Xmean)/SD

where Xi is total fishing days for year i at GSA/Country/VL level, Xmean is the mean fishing days value for the whole time series at GSA/Country/VL level and SD is the standard deviation for the whole time series at GSA/Country/VL level.

Analysis for France was affected to the fact that data are available only from 2015 onward. Italian data from 2002 and 2003 were discarded because no information at vessel length level were reported.

Figure 3.3.16 – OTB 0006m. Total fishing days trend by country and area Top: Absolute value; Bottom: as Z scores values



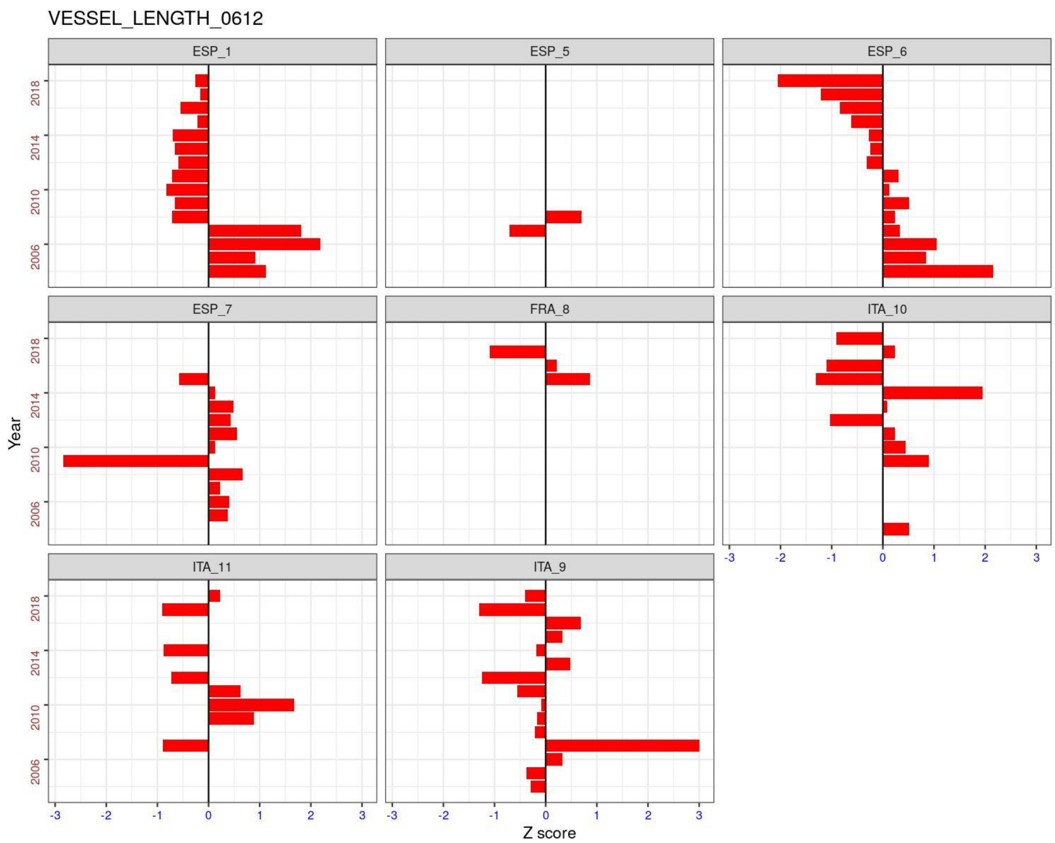


Figure 3.3.17. OTB 6-12m. Total fishing days trend by country and area Top: Absolute value; Bottom: as Z scores values

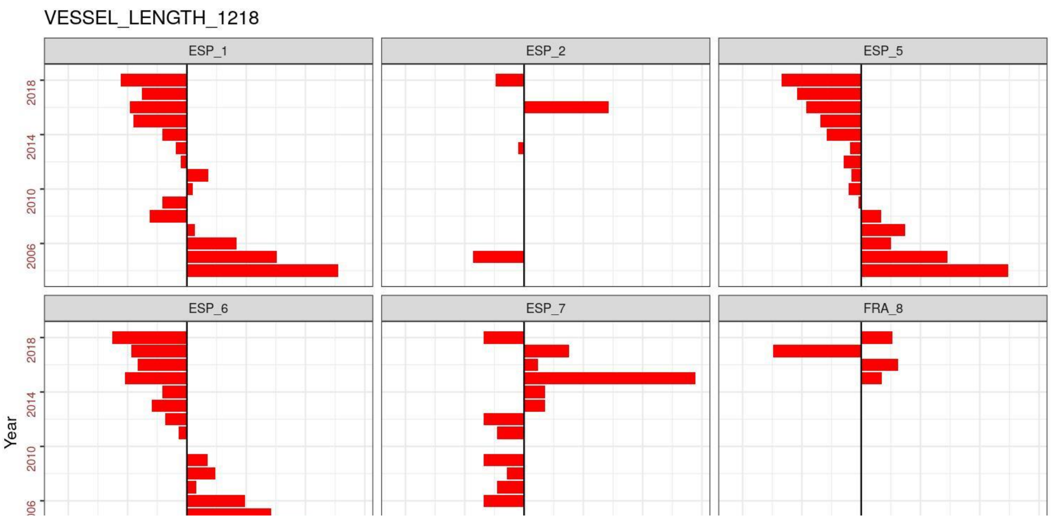
Figure 3.3.18. OTB 12-18m. Total fishing days trend by country and area Top: Absolute value; Bottom: as Z scores values

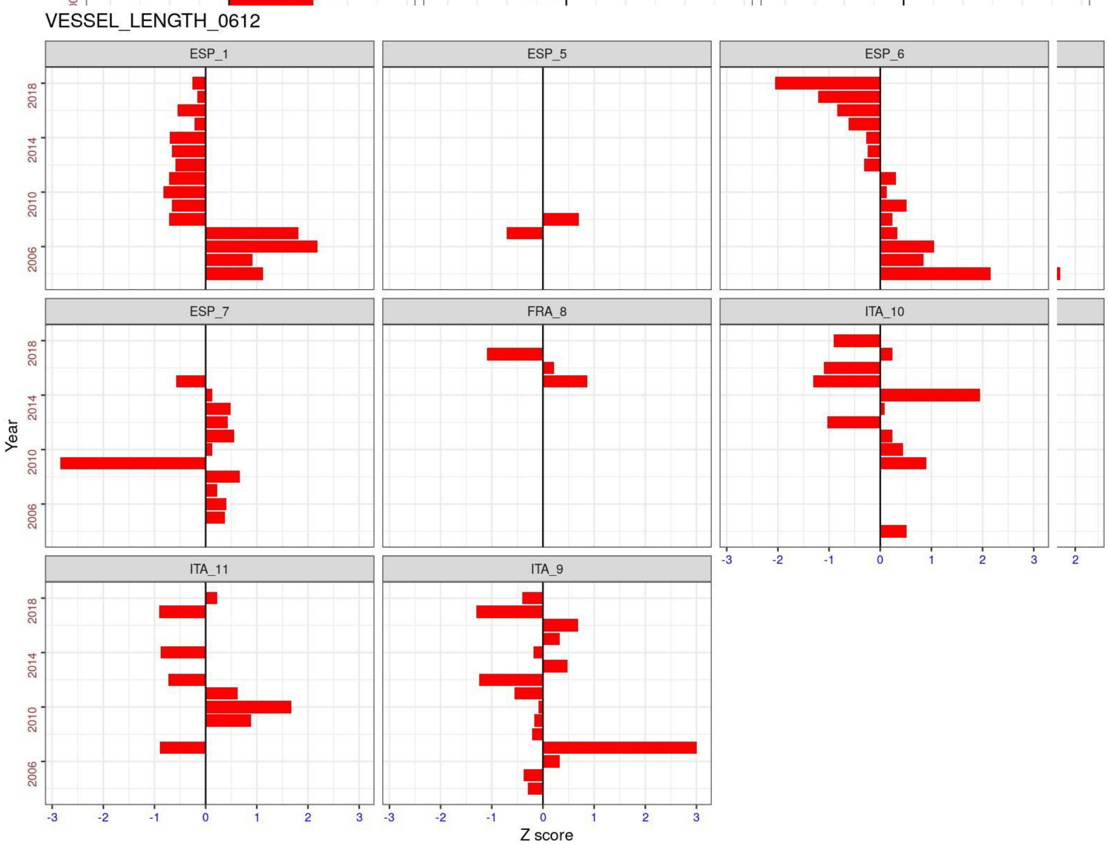
Figure 3.3.19. OTB 18-24m. Total fishing days trend by country and area Top: Absolute value; Bottom: as Z scores values

Figure 3.3.20. OTB 24-40m. Total fishing days trend by country and area Top: Absolute value; Bottom: as Z scores values

Fishing days allocate to the smallest trawler are very few. Data are scattered and reported only for GSA1 (Alboran Sea), GSA6 (Northern Spain) and GSA9 in Italy.

Fishing days allocate to trawlers having vessel length between 6-12m are more painted on respect on the smallest ones in particular in GSA1, GSA6 and GSA9. In this latter area 2007 value is off of scale (three times more of the whole period). In GSA6 is clear the high reduction in fishing days occurred during the years





Fishing days allocated to trawler having a vessel length between 12-18m m are quite consistent in time. Data of 2010 is missing in GSA6 Spain. In GSA10 values in 2004 and 2005 are respectively the lowest and the highest in the whole series. MS should check.

Trawler fleet having vessel length between 18-24m is mainly active in GSA1,5,10 and 11 and in particular in GSA6 and 9. In GSA6 data are missing for 2010. Again is clear that a huge reduction in fishing days occurred during the years in GSA1,6 and 9. In GSA11 in the last year there was a turnaround trend for which fishing days increase.

Largest trawlers are present in particular in GSA6. In Italy the main fleet seems located in GSA11 (Sardinian waters). A decreasing trend in fishing days has been take in place in GSA1. In GSA11 in the last year there was a turnaround trend for which fishing days increase.

3.3.4 Conclusions

Underneath the main issues spotted during the quality check.

LANDINGS

1) Italy GSA11 for the whole period and Italy GSA10 in the last two years provided less landings information through MBS data call on respect of the other two calls. This discrepancy could be due to the fact that for these two areas only landings for the metier selected by the ranking system and/or only landings for metier for which biological sampled were collected were provided. Anyway these is an issues because it is clearly stated in the Official Data Call Letter (and in the Annex 2) that all the landings must be provided.

2) Wrong unit of measures were used in GSA7 (Gulf of Lion) in reporting landings of DPS and NEP in the MBS data call. Moreover red mullet landings (MUT and MUR) in GSA7 were switched in the AER data call. Corsica Island (GSA8) show a general mismatch patter between the different calls.

3) Landings comparison in Spanish areas show that in almost all stocks landings provided through MBS call are higher than AER ones. This fact it is difficult to explain based on ranking system metier selection effect and/or biological samples availability as happened likely in GSA11, because it is expected that in AER all the landings in the area are provided. FDI and MBS comparison is really good and still bad between FDI and AER. AER data should be checked.

EFFORT

1) Effort data provided by Italy throught the three data calls were perfectly in agreement both by vessel length and total by GSA.

2) Data provided through the three calls show high discrepancy in VL0006 and VL0612 in GSA8. Aggregating fishing days at GSA level is clear that in AER data call there was a switch between GSA7 and GSA8 from 2010 onward (GSA7 were assigned to GSA8 and viceversa). Data before 2015 are missing in the MBS dataset.

3) Data provided through the three calls show a general mismatching pattern more evident when data are aggregated at GSA level. In particular FDI values are almost always lower respect data provided through the other two data calls. Moreover FDI effort by GSA in the last year wasn’t provided.

TREND IN EFFORT

1) France data before 2015 are missing. Member State should be provide these data in the next MBS data call.

2) Italy GSA11 shows an increasing effort in term of fishing days in the last year (2018) both in VL1824 and VL2440. Member State should check if actually these data are correct.

3) Italy GSA9 value in 2007 (VL0612) is three times more of the whole period. Member State should check.

4) Spain GSA7 value in 2009 (VL0612) is three times less of the whole period. Member State should check.

5) Spain GSA6 value in 2006 (VL1218) is missing. Member State should check.

6) Italy GSA10 values in 2004 and 2005 (VL1218) are respectively the lowest and the highest in the whole series. Member State should check.

7) Spain GSA7 value in 2015 (V1218) is almost three times more of the whole period. Member State should check.

8) Spain GSA6 2010 data are missing (VL1824).

9) Spain GSA7 value in 2015 (V1218) is almost three times more of the whole period. Member State should check.

10) Spain GSA7 value in 2009 (VL1824) is almost three times less of the whole period. Member State should check.

11) Spain GSA2 value in 2006 (VL2440) is more than two times of the whole period. Member State should check.

12) Spain GSA7 value 2009 (VL2440) is more than two times of the whole period. Member State should check.

13) Spain GSA5 value in 2004 (VL2440) is less than two times of the whole period. Member State should check.

14) Italy GSA9 values in 2005 to 2008 (VL2440) are missing. Member State could check.

15) Italy GSA9 value 2004 (VL2440) is more than two times of the whole period. Member State should check.

4 MANAGEMENT SCENARIOS AND RESULTS (TOR 3)

4.1 EMU 1 (GSA 1-2-5-6-7)

4.1.1 Considerations on the possible closure in GSA 7 based on catch and effort information

To help parameterize IAM scenario (c) 10% reduction in 2020 + 30% from 2021 to 2024 + closures areas, we used assumptions derived by a recent work carried out in LHM-MARBEC (France) regarding the design of spatial closure to protect juvenile Hake. As part of the Management Plan for the demersal trawlers in the Mediterranean, spatial closures are envisioned as a tool to additionally reduce fishing mortalities on selected species and age. In the Gulf of Lions, the national objective is to define spatio-temporal closure to reduce hake juveniles captures by 20%. Hence, a collaborative process has been engaged with the Fishermen representatives to identify potential scenario for spatial closure, which in turn have been evaluated in terms of their capacity to reach the objective of 20% capture reduction in Hake juvenile.

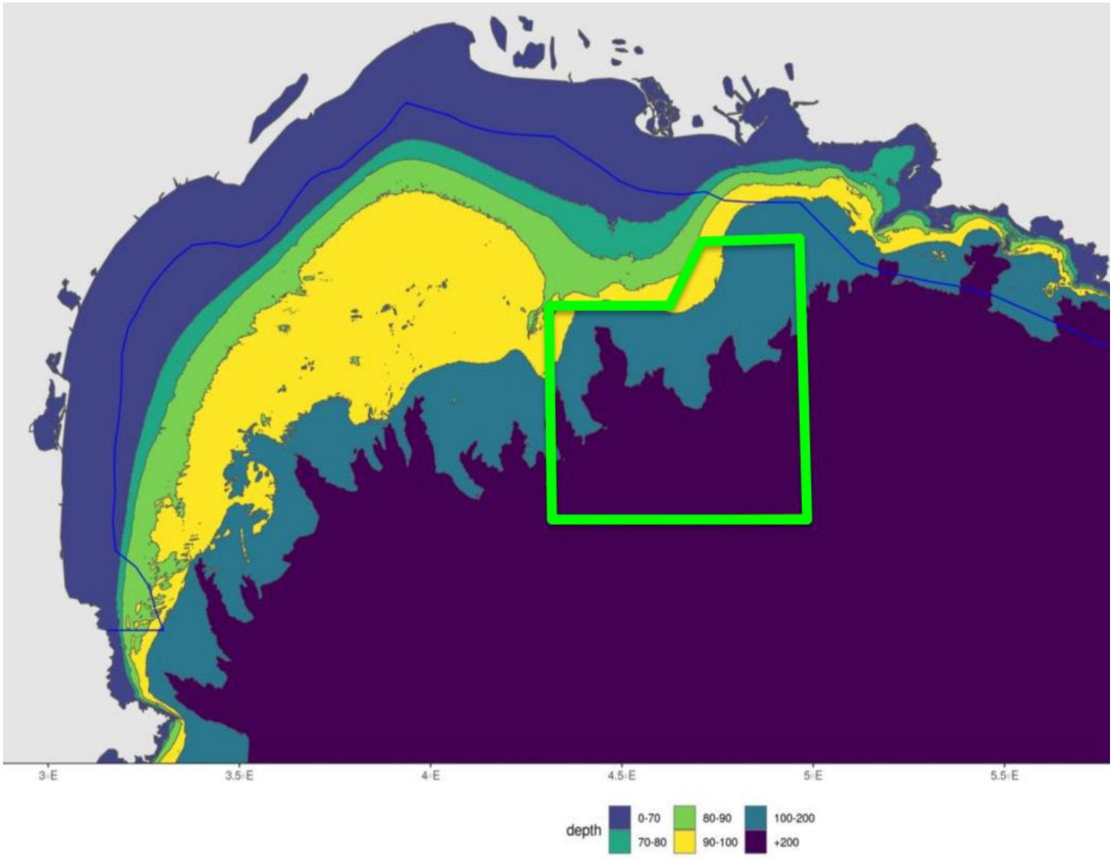
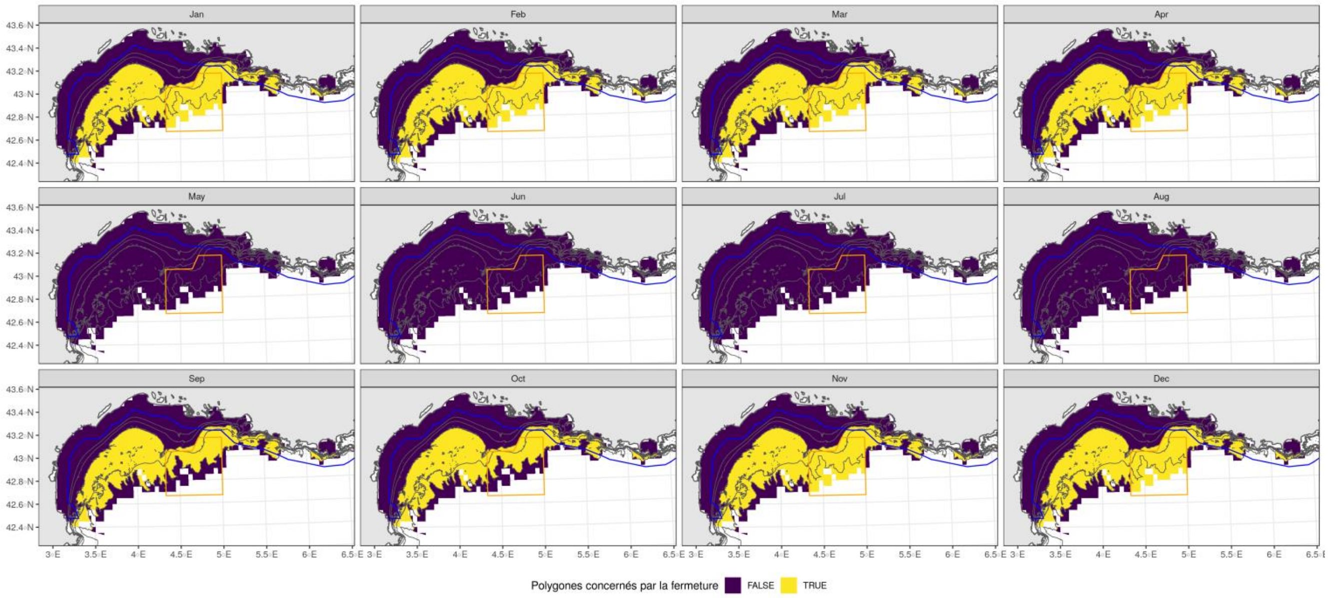


Figure 4.1.1. Closure scenario in GSA 7

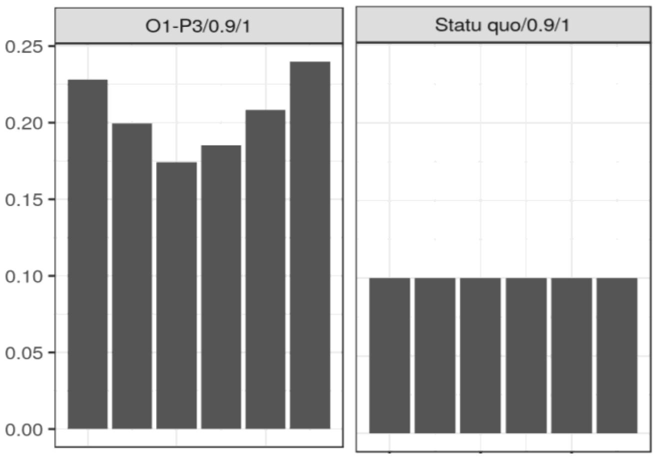
The closure scenarios envisioned for the management plan in the Gulf of Lions were a combination of depth sector (represented by colour shade) and the extended GFCM box (the green polygon) closed to all trawling activity for various amount of time (6-9 months). The closure scenarii were also incorporating a global effort reduction of 10% as envisioned by the first year of the plan.

The analyses to investigate the consequences of a given scenario was to first estimate spatial hake catches per age, spatial area (on a grid of 0.33*0.33 decimal degree) and month, together with fishing effort (in hours), for a baseline period (2015-2017). We used a combination of landings, VMS data and observation data routinely available through the DCF to get this baseline. Then, we compared the amount of hake juvenile captures under this baseline with the amount of hake juvenile captured with a spatial closure scenario, to check whether or not that scenario would reach the 20% objective in capture reduction of Hake juveniles. Note that when estimating captures under a scenario, the total effort contained within the spatio-temporal closure is redistributed outside of it, proportionally to the effort already there, as a way to account for fishing effort redistribution.

This process was able to identify some closure scenario that would lead to a reduction of hake juvenile capture. It is now up to the French ministry of fisheries and to the European Commission to agree on which precise scenario to implement, but all scenarios reaching 20% had in common to close a rather wide area in the outer shelf for a rather long (~8 months) period of time, as illustrated in the figure below, in which each map corresponds to a month and yellow areas corresponds to the closure.



Now, to estimate how much such a spatial closure might affects the fishing mortality at age, we calculated, in the same way that we did for the juveniles, how hake capture at all ages would change with such a closure.



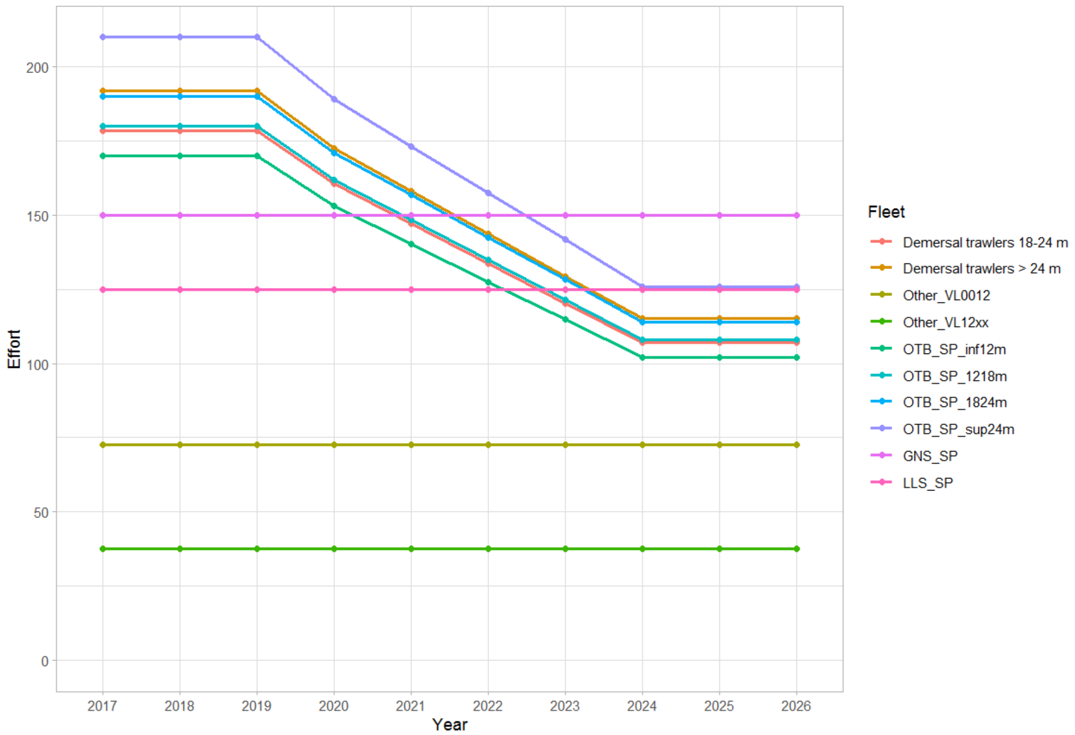
The graph above illustrate how a spatio-temporal closure (left panel) will reduce hake captures (y-axis, in %) at age (x-axis, 0, 1, 2, 3, 4, 5+) when compared to no spatio-temporal closure (right panel). Note that both scenarios incorporate a global effort reduction of 10%. The expected effect of the closure is a greater capture reduction, especially in the early and last life stages. We used these estimates as a basis to distort capturability at age expected under spatial closure scenario c), and assuming that Spanish GSAs (1,5,6) would implement spatial closures with a similar effect than the ones proposed in GSA 7.

We used these estimates as a basis to twist the fishing mortality expected under spatial closure scenario c), and assuming that Spanish GSAs (1,5,6) would implement similar spatial closure than the ones proposed in GSA 7.

4.1.2 Scenarios based on the IAM bioeconomic modelling

Most of the time of the meeting was dedicated to document and update the IAM parameters as described in section 2.2. However, we were able to run the newly parameterized model over some scenarios, representing the global reduction envisioned in scenario (b), and augmented by a spatial closure (c). To investigate the remaining scenarios (d and e), the IAM model should be again extended with several stock dynamics, which could not be done within the time frame of the EWG.

Three scenarios were investigated using the IAM model. The reduction in Fishing days (RedFD) defined in scenario b), in which only the global OTB effort is reduced by 10% on the first year (2020), and then incrementally reduced every year to reach an effort reduction of 40% in 2024, the effect of which is exemplified in the figure below for all fleets, in which effort is represented in terms of number of days at sea per vessel per year:

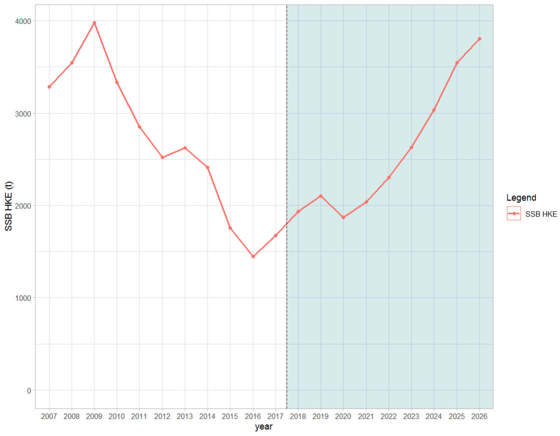


Then, in addition to the OTB effort reduction, the "spatio-temporal closure" ("Clos") scenario assumes that spatio-temporal closures are implemented in GSA 1,5,6,7 (applied from 2020) and effectively reduce hake capture at juvenile and late stage. Lastly, the "gear selectivity" scenario (RedFD_Sel) assume that gear restrictions to improve juvenile selectivity and avoid fishing mortality at age 0 are implemented in 2020 (without closure), without impacting other ages. RedFD_Clos and RedFD_Sel are translated in the IAM model in terms of change of the catchability at age fort all demersal trawlers in 2020, according to the table below:

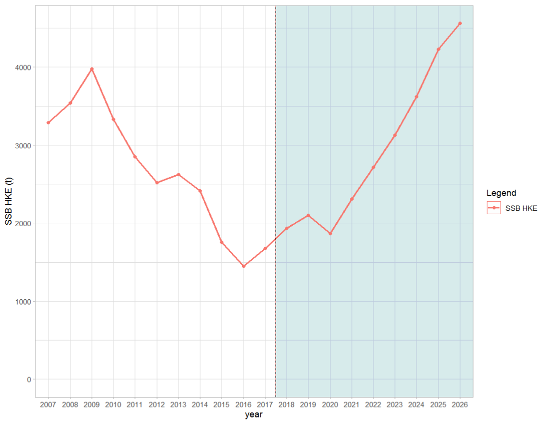
	RedFD	RedFD_Clos	RedFD_Sel
i__0	1	0,856	0
i__1	1	0,889	1
i__2	1	0,917	1

i__3	1	0,906	1
i__4	1	0,878	1
i__5+	1	0,844	1

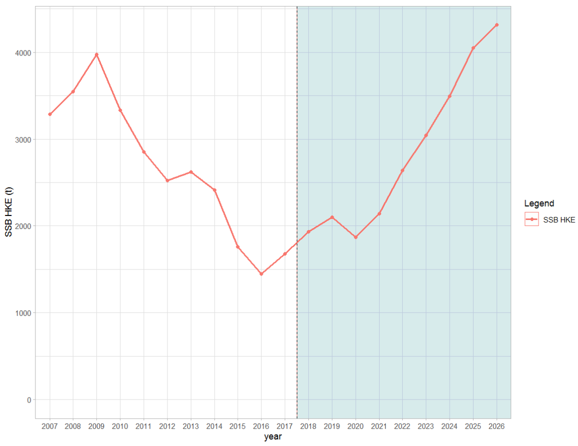
Changes in SSB expected under RedFD scenario



Changes in SSB expected under RedFD_Clos Scenario

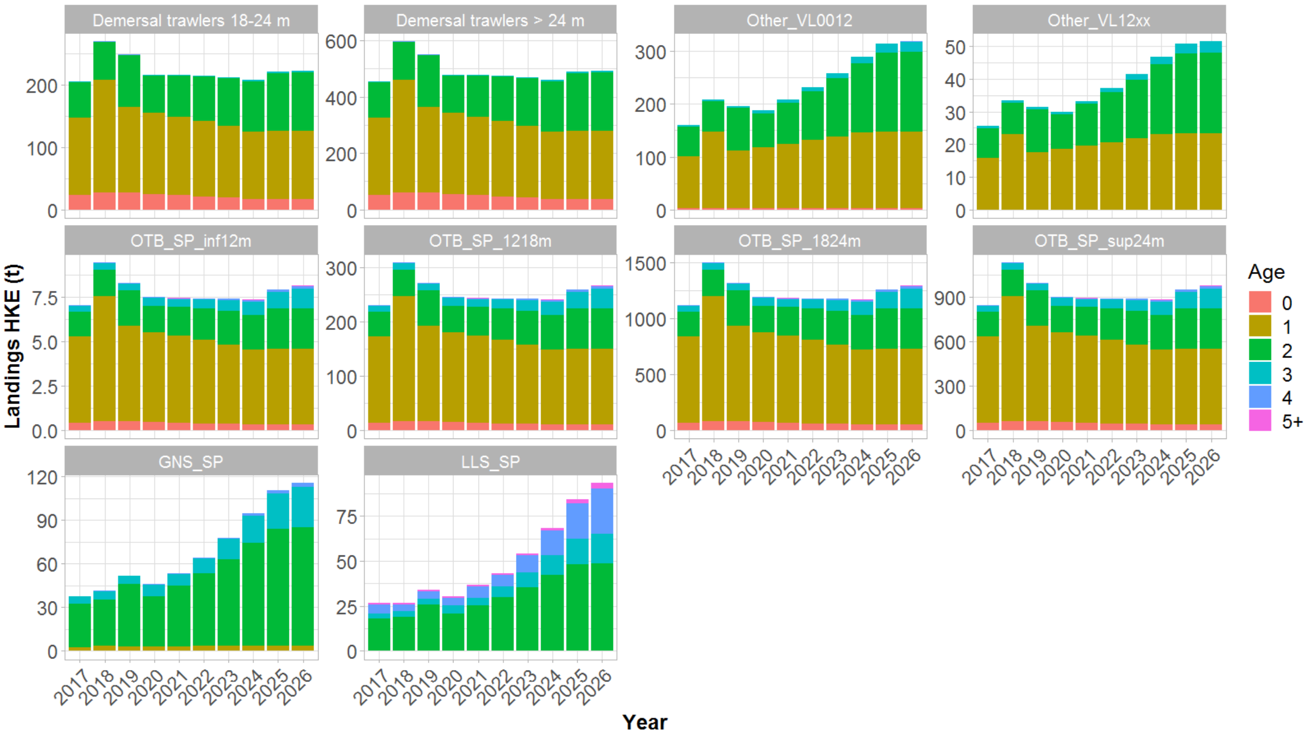


Changes in SSB expected under RedFD_Sel Scenario



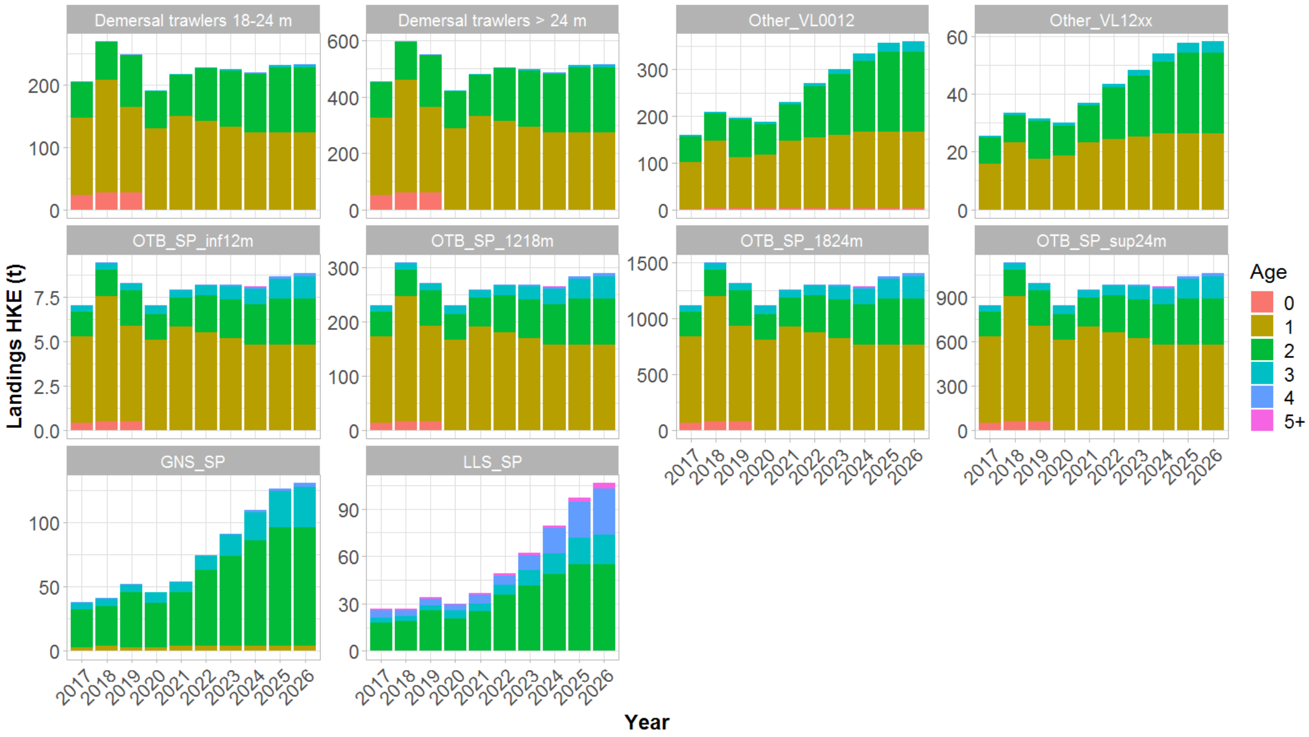
All three scenarios lead to an increase in SSB, with RedFD_Clos scenario reaching the highest SSB in 2026.

Changes in Total Landings at age expected under RedFD scenario



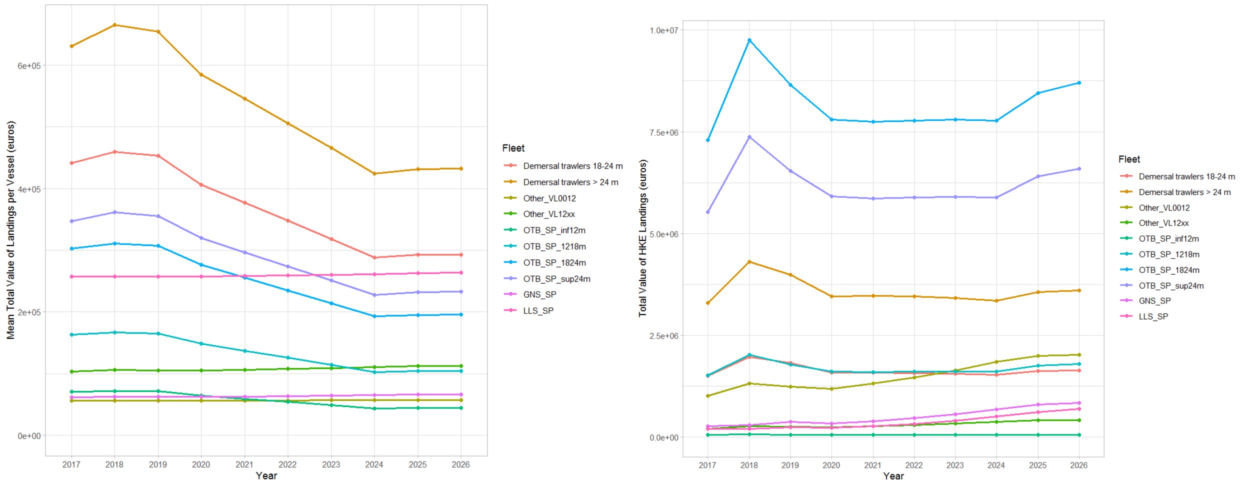
Changes in Total Landings expected under RedFD_Clos scenario

Changes in Total Landings expected under RedFD_Sel scenario

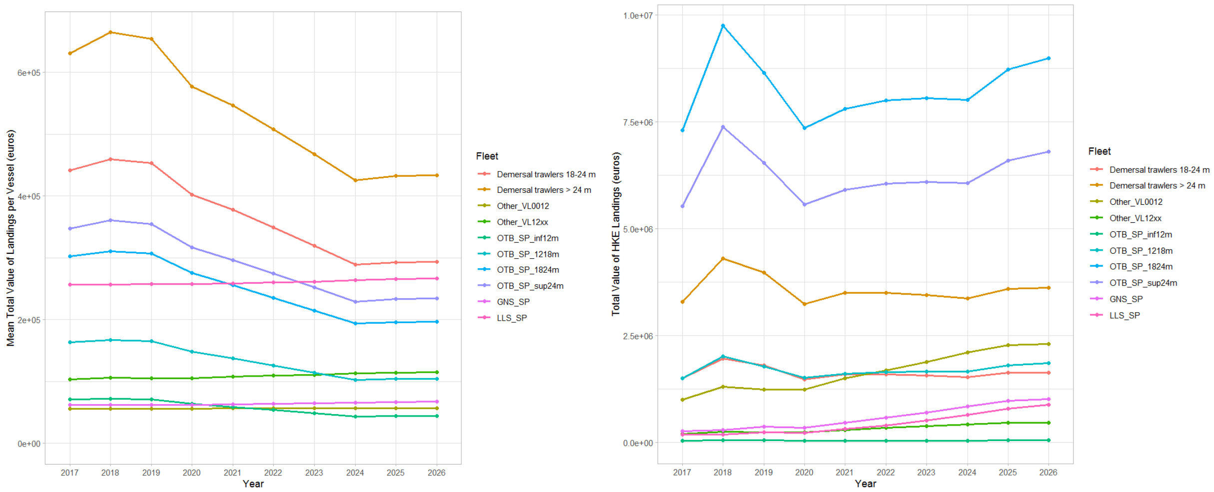


These projections confirm that Hake landings should either remain stable or increase, depending on scenario and fleet, following the application of the management plan. Largest increase in landings are expected in gillnetters and longlines, which are not concerned by the plan. The proportion of older individuals (age 2+) should also increase in the catch for all fleets. Both scenarios RedFD_Sel and RedFD_Clos outperforms RedFD in terms of landings.

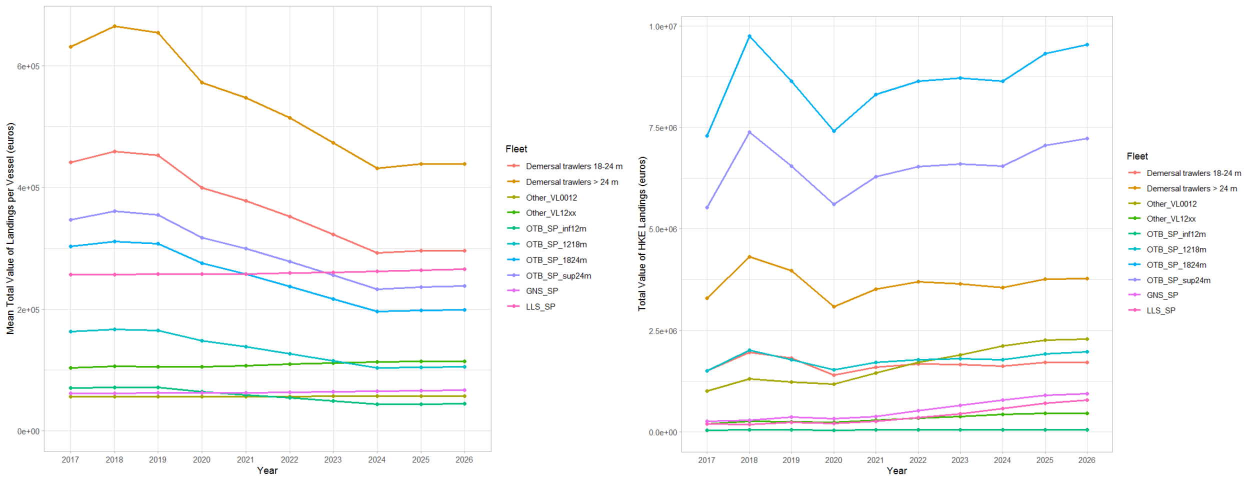
Changes in mean value of landings (all species together, left panel) and hake landing value (right panel) per fleet under RedFD scenario



Changes in mean value of landings (all species together, left panel) and hake landing value (right panel) per fleet under REdFD_Clos scenario

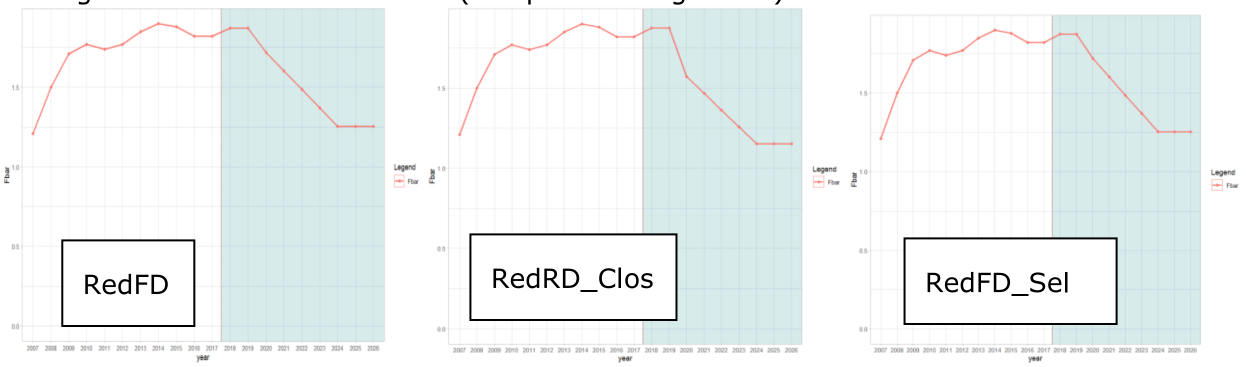


Changes in mean value of landings (all species together, left panel) and hake landing value (right panel) per fleet under RedFD_Sel scenario



In all three scenarios, mean value of landings (all species together) evolve similarly and stabilize around the same values by 2025. Again, gillnetters and longliners are the fleet segments which benefit most from the management plan. Although the mean total vaklue of landings per vessel will decline for most fleet, the hake landing value remains stable, suggesting that the loss that fishing vessel will encounter is mostly attributable to a reduction in landings of other species induced by the global effort reduction. However, since only hake is dynamically modelled, potential positive effects of reduced fishing effort on the other species are not taken into account. Hence, the left-panel figures should be interpreted as a worst-case scenario. It is worth noting that RedFD_Sel scenario leads to the highest hake landings values, especially for the largest spanish trawlers (18-24 and 24+).

The figure below shows how Fbar (computed on ages 1-3) evolves under the three scenarios.

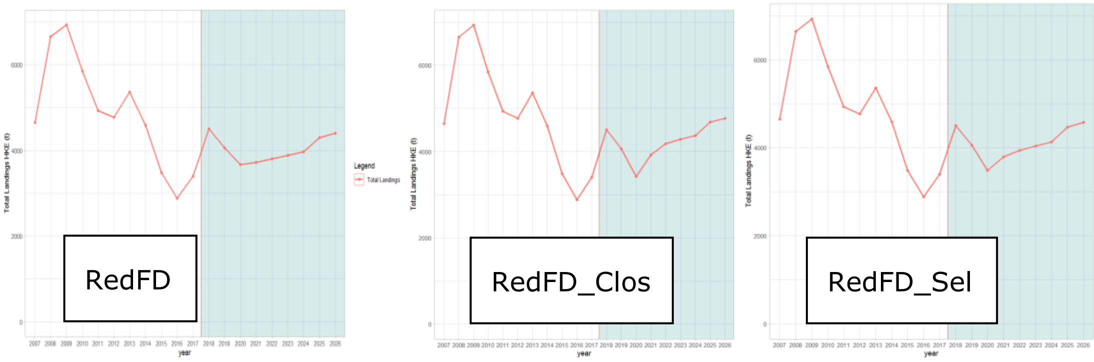


In all cases, the fishing mortality on the stock should decrease, but is likely to remain quite high when compared to the value of $F_{0.1}$, 0.38, estimated by STECF WG19-10 as a proxy for F_{msy}. Further effort reduction measures, perhaps targeting other fleet segments, will probably be necessary to reach the goal of bringing the hake stock in GSA 1,5,6,7 at sustainable harvesting levels.

Lastly, the economic consequence of the plan on the gross profit per vessel of the French fleet has been investigated:

These figures shows that the evolution of the gross profit per vessel is very similar across the three scenario. Hence, the existence of additional management measures dedicated to reducing hake fishing mortality does not seem to have any major economic impact on the French fleet. This figure could not be obtained for the spanish fleet due to the lack of documentation of socio-economic parameters.

Finally, to provide a simpler overview of the anticipated effect of the management plan, we simply computed how the total hake landings (all fleets pooled together) are expected to change following the three scenarios.



In all cases, during the first years of the plan, total hake landings will be maintained to a similar level, and then are supposed to slowly increase, especially when additional measures (scenarios _Clos and _Sel) are implemented.

To investigate the remaining scenarios (d and e), the IAM model should be again extended with several stock dynamics, which could not be done within the time frame of the EWG.

4.1.3 Discussion

The output of our scenario analysis suggest that following the implementation of the plan – and assuming proper compliance from the fishing industry - hake SSB should increase up to similar values than in the 2005-2010 period. The implementation of a spatio-temporal closure could provide additional benefits to the recovery of the stock without generating any substantial cost to the fishery. At the end of the plan, the predictions suggest that the stock will still be over-exploited, with F_{bar} still higher than its expected value at $F_{0.1}$.

The implementation of the IAM model for GSA 1,5,6,7 carried out during the STECF meeting is still in its infancy. Two major elements are still missing. The most important one is probably the incorporation of further stock dynamics beyond hake. For some stocks already assessed at the level of GSA 1,5,6,7; such as red mullet, the only constraint is time. However, for many stocks that have become of major importance to the trawl fishery in the recent years, such as for example Eledones in the GSA 7, no stock assessments are available. Hence, the development of joint assessment in GSA 1,5,6,7 will be a first and mandatory step to the implementation of several stock dynamics in the IAM model. The second element is the further documentation of socio-economic parameters, especially for the spanish fleets, to better anticipate the economic consequences of management measures. Hence, should the IAM development be pursued, effort should be prioritized on these two aspects in the coming working groups.

4.2 EMU 2 (GSAs 8-9-10-11)

4.2.1 BEMTOOL

- *State of completion during EWG 19-14*

Following the decision taken at STECF-EWG 19-01, BEMTOOL bioeconomic mixed fishery bio-economic simulation model was implemented for EMU2. During the EWG 19-14, DCF data (FDI and MED&BS Data Call, landings, discards, fishing effort, biological and economic parameters) and results from the assessments carried out during the EWG 19-10 were analysed, to allow the parameterization of the BEMTOOL model. This was first parameterized in the hindcasting mode for the seven stocks covered by the Multiannual Management Plan (MAP) in the eastern part of the western Mediterranean (GSAs 9-10-11). Two of the stocks were newly assessed during EWG 19-10 and implemented in BEMTOOL for the first time, while the assessments related to the other five stocks were updated on the basis of the work done at EWG 19_01 using the most recent assessments from EWG 19-10. Assessed fishing mortality, spawning stock biomass and the observed catches were compared with the simulated ones. Short-term forecasts from the assessment models accepted in EWG 19-10 were compared to the short-term forecasts from BEMTOOL, using the same setting of assumptions about Fbar and recruitment for 2019, and the same level of F reduction. Stock-recruitment relationships of the seven stocks were estimated using Eqsim.

- *Space and time scale*

The model covers the eastern side of the western Mediterranean. This area belongs to the FAO fishing area 37.1; sub-division 1.1 and 1.3; it includes three geographical subareas (GSA) according to the GFCM convention[2]: GSA9 – Ligurian Sea and North Tyrrhenian Sea; GSA10 – Southern and Central Tyrrhenian Sea and GSA11, composed by Western (GSA11.1) and Eastern (GSA11.2) Sardinia. As the model is not spatially explicit, the spatial scale covers the whole area. The time scale of the available DCF data goes from 2006 to 2018. The time scale of the model encompass the same time range for the hindcasting. For 2019 an invariant situation compared to 2018 is assumed. The forecasts are covering the period from 2020 to 2024. The time basis of the BEMTOOL model is the month. The reference years on which the reductions of effort in fishing days are computed are 2015-2017. Average reference fishing days are thus calculated for this time frame.

- *Stocks*

The stocks taken into consideration in BEMTOOL simulations are those for which analytic stock assessment results from EWG 19-10 were available:

- European hake in GSAs 9, 10 and 11 (HKE);
- Red mullet in GSA9 (MUT9);
- Red mullet in GSA10 (MUT10);
- Deep-water rose shrimp in GSAs 9, 10 and 11 (DPS);
- Giant red shrimp in GSAs 9, 10 and 11 (ARS);
- Norway lobster in GSA9 (NEP9);
- Blue and red shrimp GSA9, 10 and 11 (ARA).

[2] Res. GFCM/33/2009/2 on the establishment of geographical subareas in the GFCM area of application

Stock recruitment relationships used for projecting the seven stocks are reported in Fig 4.2.1, while Table 4.2.1 reports the parameters of the stock-recruitment relationships for the seven stocks.

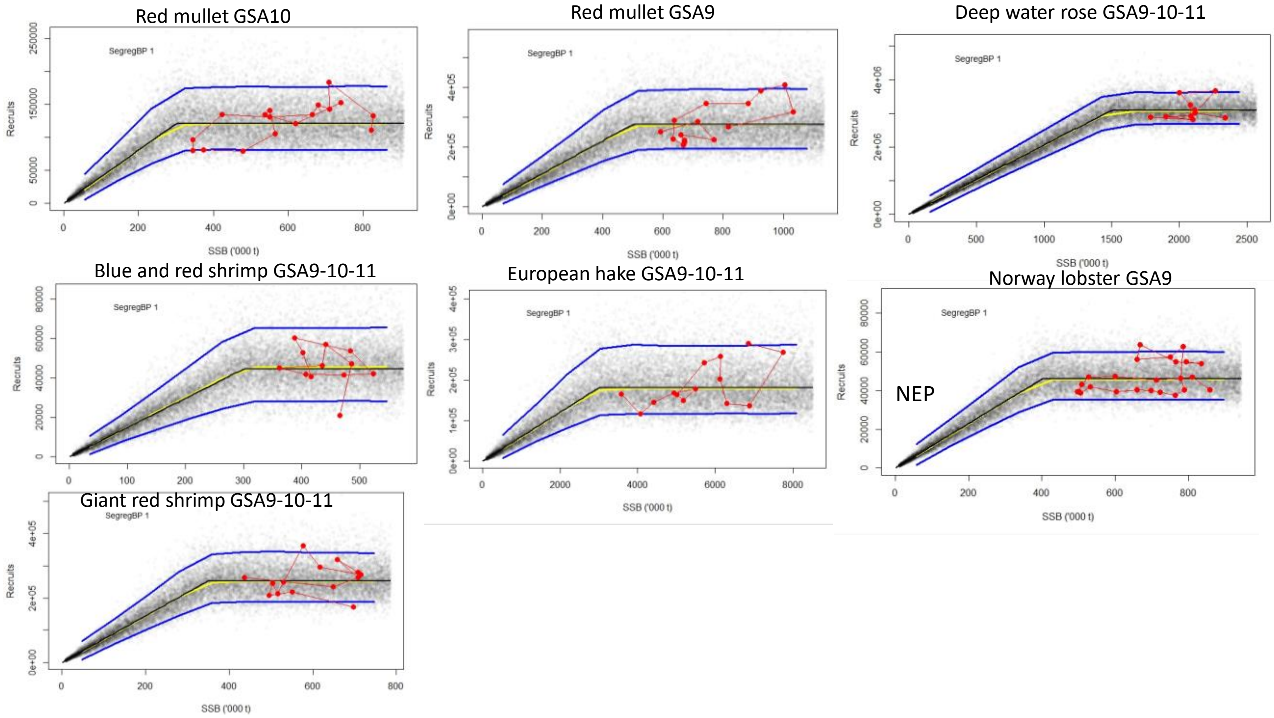


Figure 4.2.1 *Stock recruitment relationships of the seven stocks modelled.*

Table 4.2.1 *Parameters of the stock recruitment relationships*

Stock	Break Point (b)	a
European hake GSAs 9-10-11	3000	60.16
Red mullet GSA9	500	548.41
Red mullet GSA10	300	404.76
Deep water rose shrimp GSAs 9-10-	1500	2061.3
Giant red shrimp GSAs 9-10-11	350	724.64
Norway lobster GSA9	400	114.68
Blue and red shrimp GSAs 9-10-11	300	149.9

The relevant results of the assessment for the model parameterization, i.e. the current fishing mortality (F_{curr}) and the reference point (**$F_{0.1}$**) are reported in the Table 4.2.22.

The table also reports the upper and lower range of F_{MSY}, according to the formulas used in EWG 19-10:

$$F_{low} = 0.00296635 + 0.66021447 \times F_{0.1}$$

$$F_{upp} = 0.007801555 + 1.349401721 \times F_{0.1}$$

where $F_{0.1}$ is a proxy of F_{MSY}.

and the needed reduction to reach $F_{0.1}$ for each stock.

Considering the ratio between the current fishing mortality and the reference point ($F_{curr}/F_{0.1}$ and $F_{curr}/F_{0.1upper}$), the stocks more at risk are blue and red shrimp (ARA; ratios=3.72, 3.34) and European hake (HKE; ratios=2.72, 2.42). Red mullet in GSA10 (MUT10) is the stock least impacted (ratios=1.16; 0.85), after deep water rose shrimp (DPS) in GSA 9-10-11, which is considered sustainably exploited (ratios=0.91; 0.67).

Table 4.2.2 *Results of the assessments from EWG 19-10 relevant for BEMTOOL parameterization. The computation of the reduction by stock to reach $F_{0.1}$ is also reported.*

Stock	F_{curr}	$F_{0.1}$	$F_{curr}/F_{0.1}$	$F_{0.1lower}$	$F_{0.1upper}$	F_{curr}/F_{upper}	**% red to $F_{0.1}$**
HKE	0.74	0.22	3.34	0.15	0.31	2.42	70.
MUT9	1.58	0.58	2.73	0.39	0.79	2.00	60
MUT10	0.48	0.41	1.16	0.27	0.56	0.85	10
DPS	0.88	0.97	0.91	0.64	1.32	0.67	-10
ARS	1.37	0.45	3.04	0.30	0.62	2.21	67
NEP9	0.31	0.20	1.55	0.13	0.28	1.11	35
ARA	1.45	0.39	3.72	0.26	0.53	2.72	73

- *Fleets*

In the simulation and forecast scenarios 14 fleet segments, shown in table 4.2.3, have been considered. These include both active and passive demersal gears operated by fleet segments that rely on, and influence, some or all of the stocks included in the MAP.

Table 4.2.3 *Fleet segments included in the BEMTOOL simulations and forecast scenarios by GSA, gear type including demersal trawlers (DTS) and polyvalent passive gears (PGP) for vessel length (VL) segments.*

	GSA 9	**GSA 10**	**GSA 11**
DTS	GSA9_DTS_VL1824	GSA10_DTS_VL1218	GSA11_DTS_VL1218
	GSA9_DTS_VL1218	GSA10_DTS_VL1824	GSA11_DTS_VL1824
	GSA9_DTS_VL2440		GSA11_DTS_VL2440
PGP	GSA9_PGP_VL0012	GSA10_PGP_VL0006	GSA11_PGP_VL0012
	GSA9_PGP_VL1218	GSA10_PGP_VL0612	GSA11_PGP_VL1218

- *Comparison of model's short-term forecast with the single-stock advice predictions*

Table 4.2.4 reports the results of the comparison between the short term forecasts in EWG 19-10 with the results from BEMTOOL in EWG 19-14. The BEMTOOL model captures the changes of catch in percentage for most stocks, with only deep-water rose shrimp (DPS) showing some discrepancy between assessment and simulation in the magnitude of change. SSB status was captured well by BEMTOOL simulations, showing a similar direction with the STF, except for Norway lobster in GSA9.

Table 4.2.4 *– Comparison of the short terms forecasts of EWG 19-10 with the results from BEMTOOL (EWG 19-14). F red indicates the reduction in fishing mortality to reach F0.1, implemented based on the level of F0.1 applied in the EWG 19-10. Column F0.1 shows the threshold calculated by BEMTOOL (cfr with table XX above).*

	Catch 2018		**Catch 2020**		**% Catch change**		**SSB trend (2019-2021)**	
Stock	EWG 19-10	BEMTOOL	EWG 19-10	BEMTOOL	EWG 19-10	BEMTOOL	EWG 19-10	BEMTOOL
HKE	2086	2668	772	988	-63%	-63%	Increas.	Increas.
MUT9	1393	1197	512	514	-63%	-57%	Increas.	Increas.
MUT10	403	427	309	359	-23%	-16%	Increas.	Stable
DPS	1422	1381	1301	997	-9%	-28%	Decreas.	Decreas.
ARS	530	637	215	209	-60%	-67%	Increas.	Increas.
NEP	216	268	142	160	-34%	-40%	Increas.	Stable/Decreas.
ARA	387	327	94	74	-76%	-77%	Increas.	Increas.

- *Baseline Run 2020-2024*

Six scenarios have been implemented to test the possibility of matching the MAP requirements. First deterministic runs were done to get a first feedback on:

1) the completeness and coherence of inputs and of the BEMTOOL parameterization;
2) the different scenarios settings.

Then, given the computation time, stochastic runs were performed in a second steps and are here reported.

Scenarios were the following according to ToR 3:

a) Baseline, with the days at sea in 2019 and 2020 equal to the average of 2015-2017;
b) ReductionFD, 10% reduction in 2020 + 30% from 2021 to 2024;
c) RedFD_Clos, 10% reduction in 2020 + 30% from 2021 to 2024 + MAP closure areas (6nm and less than 100m depth);
d) FmsyARA, F within the range of F_{MSY} of the most vulnerable stock by 2024;
e) F within the optimal harvest by 2024

For the **Scenario e)** the optimal harvest, two interpretations were followed:

i) improving the exploitation pattern of the trawl fisheries for one of the main impacted stock in EMU 2, i.e. the European hake, delaying the size at first capture and thus increasing the current mean length of the age class contributing more to the stock biomass (so toward the reduction of the ratio between critical length and optimum length);
ii) optimal economic harvest, estimating the level of effort that maximises three economic variables: profit, gross value added and return of investments (ROI), through application of the Maximum Economic Yield (MEY) reference point.

Two scenarios were consequently implemented, **the scenarios e1) and e2).**

e1) RedFD_Clos_NursHKE, F within the optimal harvest by 2024, implemented on the scenario c) closing also the nursery areas of European hake compared to scenario c).
e2) FoptMEY, F within the optimal harvest by 2024, following the concept of optimum sustainable yield as the level of effort that maximizes the

difference between total revenue and total cost; MEY has been used as reference point considering the whole production and all the fleets.

Linear reductions (in fishing days) and equally distributed by fleet segments have been applied.

For the **scenario ReductionFD** the basis was given by the number of fishing days by fleet as the average in the period2015-2017.

For **scenario RedFD_Clos** the basis was given by the knowledge on the distribution of the juveniles of key species (see paragraphs below) and the fleet activity by month in the depth range 50-100 m (based on VMS data). Thus, the closure of the depth range to 100 m depth (or 6 nautical miles from the coast) was designed as follows:

- for all DTS fleets of GSA 9 in July, August and October (to protect recruitment of red mullet);
- for all DTS fleets of GSA 10 in July, August and October (to partially protect recruitment of deep-water rose shrimp, considering that in GSA10 red mullet is exploited almost sustainably);

The fleet selectivity was shaped to take into account that red mullet is very poorly caught on grounds deeper than 100 m and individuals living at such depth are of large size. Thus restricting the trawling for 3 months (plus the month of September, already banned) within 100 m depth would almost avoid the capture of red mullet (recruitment in summer-early autumn in coastal areas). This was the justification to delay the size at first capture in that period to 15 cm total length. The same is only partially true for deep water rose shrimp, whose recruits are present all year round, with main peaks in spring and autumn. Nursery of this species are mainly located between 100 and 200 m depth in GSAs9, 10 and 11, but young of the year can be also found at depth between 50 and 100m, thus the fleet selectivity was only little adjusted for the deep water rose shrimp, delaying the size at first capture from 17 to 19 mm carapace length.

The following equation, internally applied by the model to recalculate the fishing mortality, was used to reshape the fleet selectivity, acting on the *Sel* parameter:

$$F_f(a) = (Z_{inp} - mean(M)) * Sel_f(a) * f_{act,f} * p_f \; ;$$

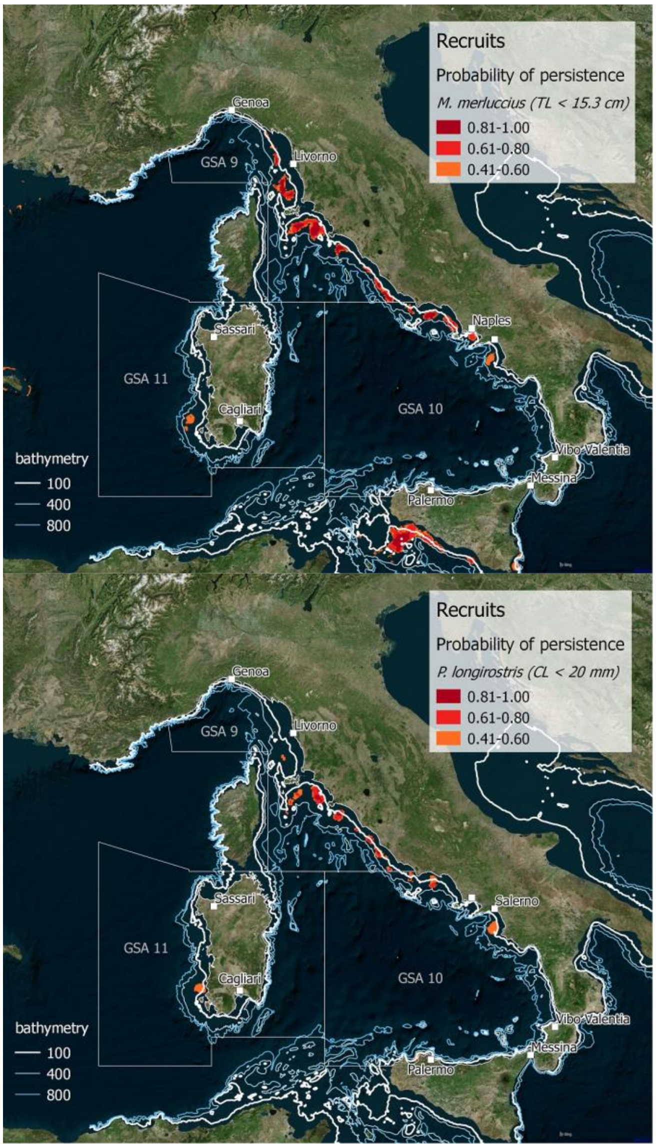
where $f_{act,f}$ in the forecast is the ratio between the product of the number of fishing days, the number of vessels and the average GT (or Kw) of the fleet segment *f* for each month of forecast to the product of the number of fishing days, the number of vessels and the average GT (or Kw) of the fleet segment *f* in the last year of the simulation. This quantity considered as reference for the application of change in fishing effort. $Sel_{f(a)}$ is the fleet selectivity at a given length/age; p_f is the monthly ratio between the fleet segment catch to the total catch in the simulation (in the forecast it is fixed as an average of the last (*n*) years).

For European hake, instead, the closure of grounds within 100 m depth does not imply any change, because the nursery of this species, which recruits all year round with main peaks in spring-summer and late summer-autumn, are mainly located between 100 and 200 m depth, and in GSA11 also between 250 and 300m depth (Lembo et al., 2000; Bartolino et al., 2008; Lembo et al., 2010; Druon et al., 2015).

At spatial scale, the fleet activity by month in the depth range 50-100 m was provided by the SMART application. The fleets which operated for at least 70% of their time in this depth range was approximately 10%. This value was used to calibrate the fleet selectivity in the scenario RedFD_Clos.

The geographical distribution of the key life stages of some target stocks of the MAP is reported in figure 4.2.2. EMU2 is characterized by important nurseries of European hake (especially in GSA9 and in the northernmost part of GSA10), where the concentration of juveniles is among the highest of the whole Mediterranean (MEDISEH project on MEDITS data; Giannoulaki et al., 2013; Colloca et al., 2015). In the hot spots areas more than 20% of European hake juveniles are concentrated on a surface representing approximately 1% of the entire GSA area. Aggregations of spawners of this species are instead more concentrated in GSA11, while relevant aggregations of juveniles and spawners of deep-water rose shrimps are especially located in the southern part of GSA9, in GSA10 and in GSA11 (Fig. 4.2.2). These areas are also in partial overlap with the nursery of European hake.

Figure 4.2.3 reports the overlap between the nursery areas of European hake and the historical fishing grounds of the GSA9 and of the northern part of GSA10. The overlap is quite wide southern and northern of Elba Island in GSA9 and in the Gaeta Gulf of GSA10 (results from the project SAFENET[3]). Figure 4.2.3 also shows the results of the connectivity analysis (modelling the drift of particles released in one place to other places) conducted in the project SAFENET. The connectivity matrix has a strong diagonal structure, indicating that retention plays an important role in the area. Almost all successful particles (i.e. those reaching a nursery) released from Sicily and Calabria remain in the region of origin, whereas a substantial percentage of particles released from Campania, Lazio and Tuscany is transported toward the region immediately to the north. As a consequence, 87% of the particles arriving in Liguria come from Tuscany. At the basin scale, about 4% of the successful particles released in GSA 10 reaches GSA 9 (results from the SAFENET project). Thus a network of protection for the European hake nursery can be considered more effective to improve the exploitation pattern for this stock.



[3] MARE/2014/41. SafeNet Sustainable Fisheries in EU Mediterranean waters through network of MPAs. WP5. Addressing the spatial dimension of fisheries sustainability: a case study in the Western Mediterranean Sea. Paco Melià, A. Radici, C. Piccardi, M. Belharet, I. Bitetto, P. Carbonara, G. Lembo, M. T. Spedicato, A. Calò, J. Claudet, M. Coll, X. Corrales, A. Di Franco, T. Font, P. Guidetti, A. Ligas, J. Lloret, C. Piroddi, G. Prato, R. Sahyoun, P. Sartor, J. Steenbeek, D. Vilas.

Figure 4.2.2 *Hot spots of nursery of European hake (left) and of deep-water rose shrimp (right). The bathymetry of 100m depth is marked in white. The scale represents the probability of finding a hot spot on the basis of the time series used.*

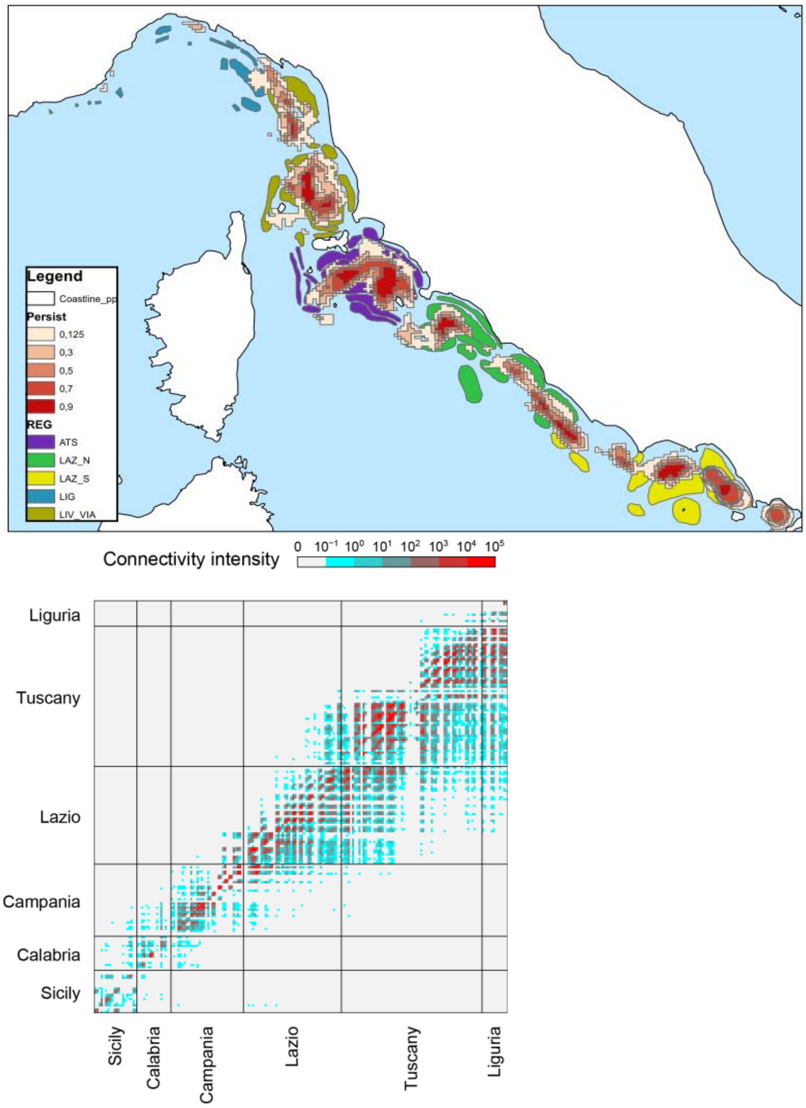


Figure 4.2.3 *Overlap of nursery areas of European hake in GSA9 and in part of GSA10 with historical fishing grounds (from Sbrana et al., 2013) (left) and connectivity of European hake nursery among the regions of the GSA9 and GSA10.*

For the scenario **FmsyARA**, the basis was reducing the effort of all fleets so to achieve F_{MSY} for the most impacted species which, on the ground of the information derived from the latest assessment, was the blue and bed shrimp.

For **scenario** RedFD_Clos_NursHKE the basis was to improve, in addition, the exploitation pattern for European hake, introducing the closure of the nursery areas. This was implemented delaying the size at first capture of European hake from 9 to 15 cm in the months in which the recruitment of the species is higher, i.e. March, April, September and October. The basis of this setting was represented by the knowledge on the migration of hake post-recruits from the nursery hotspots to the surrounding areas, which take place when hake is about 15-16 cm total length (Lembo et al., 2000, Bartolino et al, 2008; Lembo et al., 2010).

For **scenario FoptMEY** the basis was the application of the level of effort reduction that provides the highest economic benefit.

- *Runs performed and analysed during EWG 19-14*

The scenarios were run as described above for the purpose of the MAP, and their performance was evaluated on the basis of biomass, catch, F, revenues and current revenues to break-even revenues (CR/BER). The latter is an economic indicator that shows how close the current revenue of a fleet is to the revenue required for the economic break even. Ratios > 1 indicate that enough income is generated to cover operational costs (variable and non-variable costs) and therefore break-even. If the ratio is less than 1, insufficient income is generated to cover operational costs and therefore the fleet is in a loss.

Figure 4.2.4 reports the reached F for each scenario and stock. The scenario FmsyARA will bring the stock of ARA at Fmsy, though one of the more exploited stocks as HKE will remain above Fmsy, while stocks as MUT10, NEP9, DPS and ARS will be underutilized, with F in some cases below Flow.

In the baseline scenario the SSB is expected to remain approximately stable for MUT9, MUT10, NEP9 and ARS9-10-11. A decrease is predicted for HKE and more markedly for ARA. A slight increase is foreseen only for DPS (Figure 4.2.5). Catches would be quite stable for some stocks, slightly increasing for DPS and NEP9 and decreasing for ARA (Figure 4.2.6). Total revenues and R/BER are predicted to be slightly decreasing (Figure 4.2.7 and 4.2.8).

Under the RedFD scenario the F reduction was not sufficient to reach F_{MSY} for HKE, MUT9, ARS and ARA. This scenario would result in an increase of SSB for all stocks, more sharped for HKE (Figure 4.2.5). Under this scenario catches would be lower than the baseline for most stocks, or similar for MUT9, but higher for HKE and ARA (Figure 4.2.6). The total revenues across all fleets decrease until 2021, when these started increasing again. According to the forecast, and considering the overall revenues across all fleets, the effort reduction scenario would be more profitable than status quo only after 2025 (Figure 4.2.7). In terms of R/BER over all fleets, the RedFD scenario would become more profitable than Baseline by 2022. The latter is forecasted to stabilise while all others are forecasted to increase (Figure 4.2.8).

The fishing closure scenario (RedFDClos) provided generally similar and consistent forecast with the RedFD scenario: F was identical or very similar between these scenarios (Figure 4.2.4). The only stocks affected are the two red mullet, which showed lower F in the fishing closure scenario and, as result, higher SSB (Figure 4.2.5). Catches of the two stocks decreased more rapidly under the RedFDClos scenario, to then grow rapidly and reach similar levels to those of RedFD scenario by 2022 (MUT9) and 2024 (MUT10) (Figure 4.2.6). For all other stocks, both in terms of SSB and catches, the fishing closure scenario was similar to the effort reduction scenario. Similarly, neither total revenues nor R/BER were influenced by the fishing closure scenario in a visible way compared to the effort reduction scenario (Figure 4.2.7 and 4.2.8).

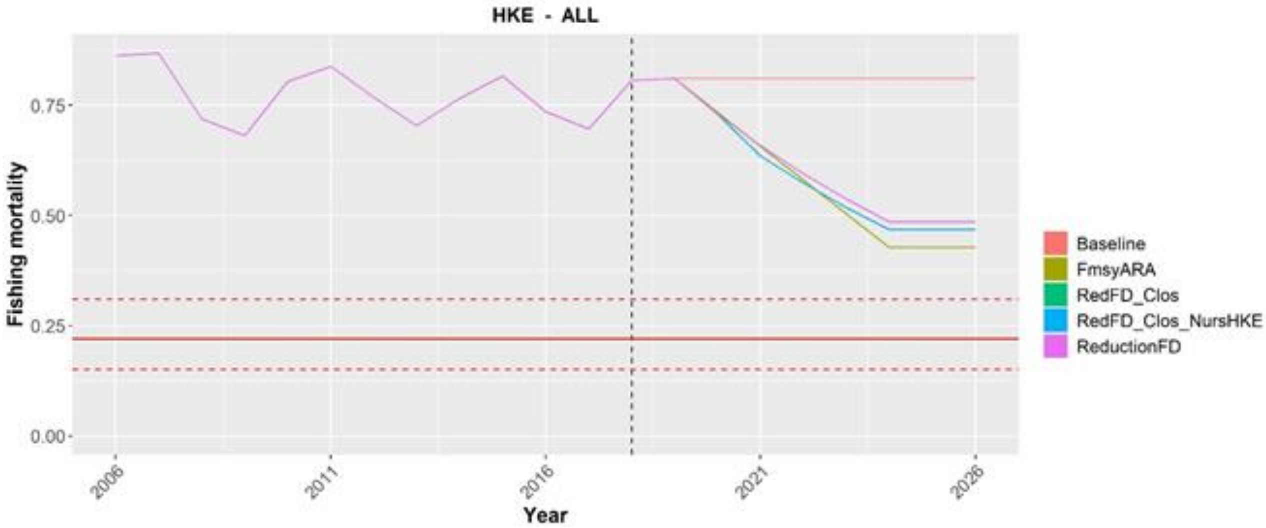
The scenario FmsyARA allowed to reach the reference point for ARA (Figure 4.2.4). For MUT9 F reached a buffer area between F_{MSY} and Flow, but for MUT10 F would reach a value lower than Flow as well as for DPS and NEP9. For ARS F would be in between F_{MSY} and Flow. For HKE instead F would be higher than Fupper. This indicates that an improvement of the HKE stock could necessitates an improvement in the exploitation pattern to mitigate a possible severe reduction of fishing activity to reach F_{MSY} in the phase following the transition. Under this scenario the improvement of the optimal length (Table 4.2.10) would be comparable to the RedFD scenario and lower than in the scenarios RedFDClos and RedFD_Clos_NursHKE. Under the FmsyARA SSB would increase above historical level for all stocks (Figure 4.2.5), including HKE and is thus resulting in a better improve of SSB level for all the stocks. For all stocks except ARA this scenario resulted in catches levels lower than any other scenarios (Figure 4.2.6). For ARA, this resulted in an initial decline in catches that was rapidly reversed: by 2025 catches of this stock were higher under this scenario then under any of the others. Under the F_{MSY} scenario, several stocks are underutilised, in particular MUT10, DPS, ARS, NEP9. From the economic perspective, the F_{MSY} scenario outperformed the baseline scenario and the alternative scenarios in terms of revenues and of R/BER, when considering all fleets aggregated (Figure 4.2.7 and 4.2.8). When considering the patterns at fleet level, however, it is clear (see Table 4.2.8) that the FMSY scenario results in lower revenues for the demersal fleet, compared to the alternative scenarios, while the PGP fleet revenue increase. Similarly, R/BER is higher under F_{MSY} scenario than any others for PGP fleets, but lower than most others for DTS fleets (Table 4.2.9).

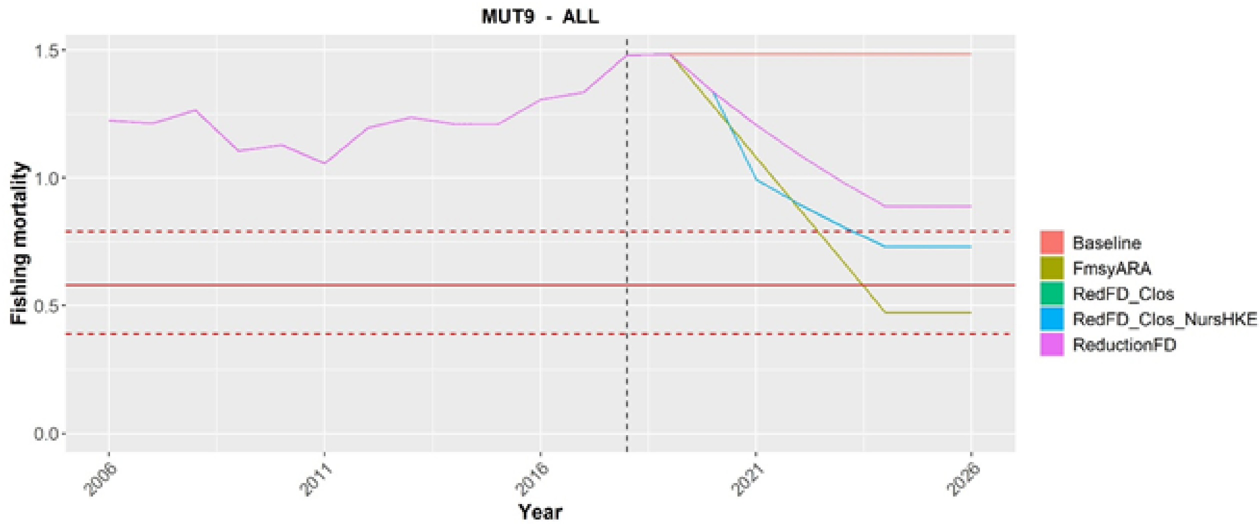
The scenario RedFD_Clos_NursHKE, resulting in an effort reduction in fishing days combined to the closure of the area within 100 m depth and of the nursery areas of hake provided results consistent with its purpose of improving the exploitation pattern of hake by reducing capture of juveniles. The resulting reduction in F is however not as large as under the FMSY scenario, falling short of reaching the reference level, although performing better than the effort reduction scenarios, with or without closure within 100m depth (Figure 4.2.4). SSB of hake increased under this scenario, more than under ReductionFD, but slightly less than in F_{MSY} scenario (Figure 4.2.5). Catches are lower in this scenario compared to Baseline, at least until 2024; however they are higher than under the other scenarios (Figure 4.2.6) and stock as MUT10, NEP9, DPS remain less underutilized than under the FmsyARA scenario. Catches of MUT9 and MUT10 is similar under the RedFD_Clos_NursHKE scenario to those of the ReductionFD and RedFD_Clos scenarios, and higher anyway than the F_{MSY} scenario. Under the economic perspective, the total revenues under this scenario are below the revenues at the baseline scenario until 2024, after which they increase. R/BER (all fleets) shows instead a rapid increase, albeit lower than under FMSY, it was higher than the baseline scenarios (Figure 4.2.8). The situations described are representative of the fleet as a whole: separating the fleet segments, revenues and R/BER by 2024 (reported in Table 4.2.8 and 4.2.9) show that for PGP the MEY scenario is the most profitable, while it s highly unprofitable for DTS fleet. The scenario RedFD_Clos_NursHKE is, instead, the most profitable for this fleet, and the second most profitable for PGP, placing itself as a suitable trade-off in terms of conflicting interests between fleet segments.

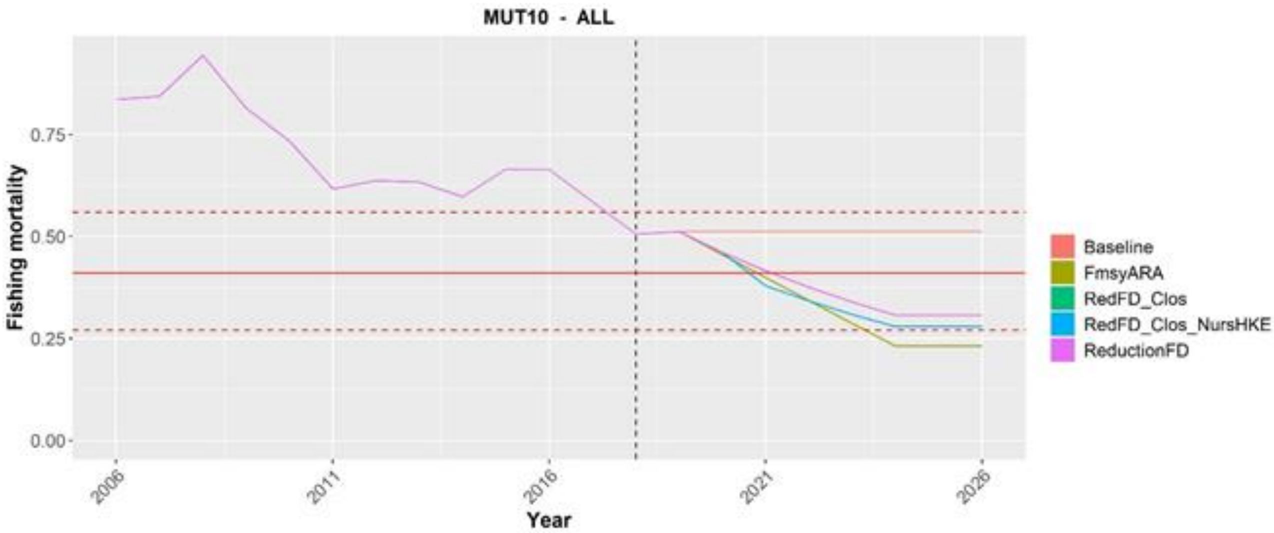
Under the scenario Maximum Economic Yield (MEY), the optimal effort identified (i.e. the level of effort maximising a set of economic variables by 2024) was 0.6 compared to the effort at status quo (Figure 4.2.9). This resulted in an optimal economic yield which requires a reduction of F of 40%: the same effort reduction applied with the ReductionFD, and lower compared to the RedFD_Clos scenarios and RedFD_Clos_NursHKE under which, for some stocks, the reduction of F is higher, due to the change in fleet selectivity. For MUT9 and MUT10, for example, F is reduced by 46% and 51% respectively, though the reduction required, for example for MUT10, for getting sustainable exploitation level would be much less. Similar consideration holds for DPS. These results suggest on the one side that the reduction required to bring the more exploited stock to sustainable levels is economically suboptimal. On the other side, however, this result suggest that neither economic optimum nor RedFD_Clos_NursHKE scenarios might achieve the sustainable exploitation of all stocks.

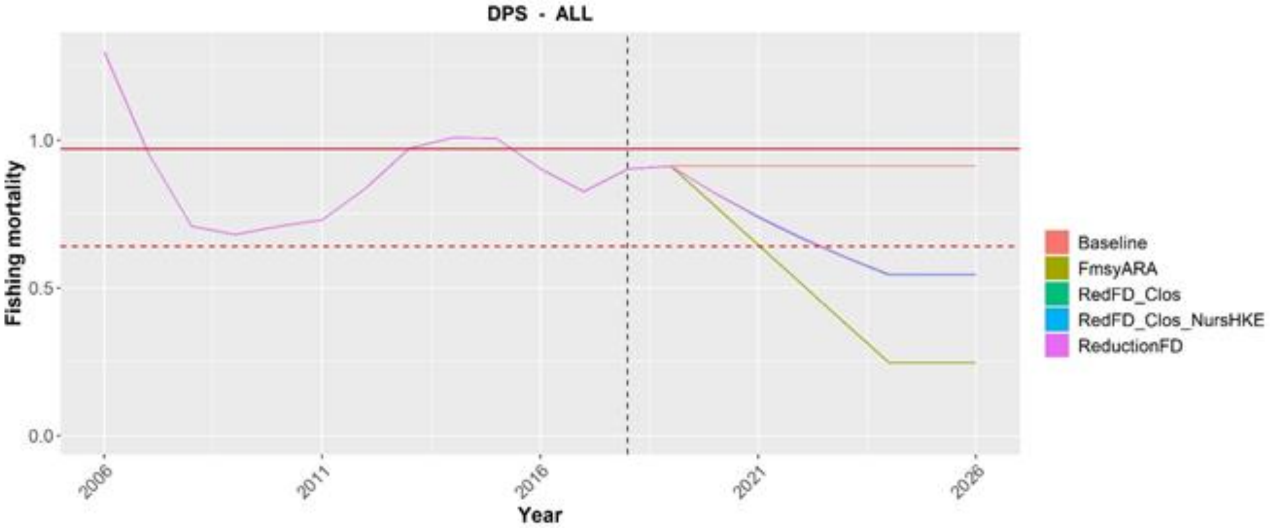
Results from the Multicriteria Decision Analysis comparison among the scenarios are shown in Figure 4.2.10. MEY evaluation is embedded in the MCDA process, because MEY is a reference point considered in the MCDA. These results highlight that the best performing scenario, considering the biological objective, is FmsyARA, followed by the RedFD_Clos_NursHKE, which indeed counterbalance the production and economic and social components.

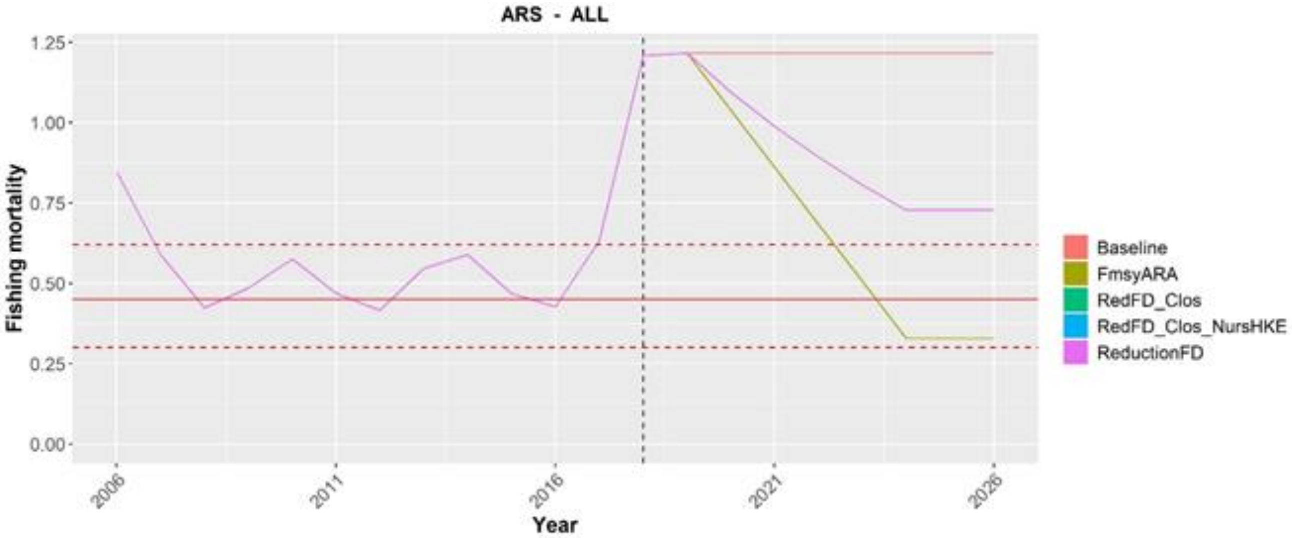
Following EWG 19-01, it is important to highlight that the results from EWG 19-14 are based on the assumption that a reduction in F is a direct consequence of a reduction in effort. Inclusion of hyperstability in BEMTOOL was explored by EWG 19-01, where the relationship between fishing effort and fishing mortality was assumed non-linear. In the present study, hyperstability was not included for time constraints. This aspect would require further insight as well as the design of the measures based on the closing areas and nursery grounds and/or other areas (as the deepest ones).

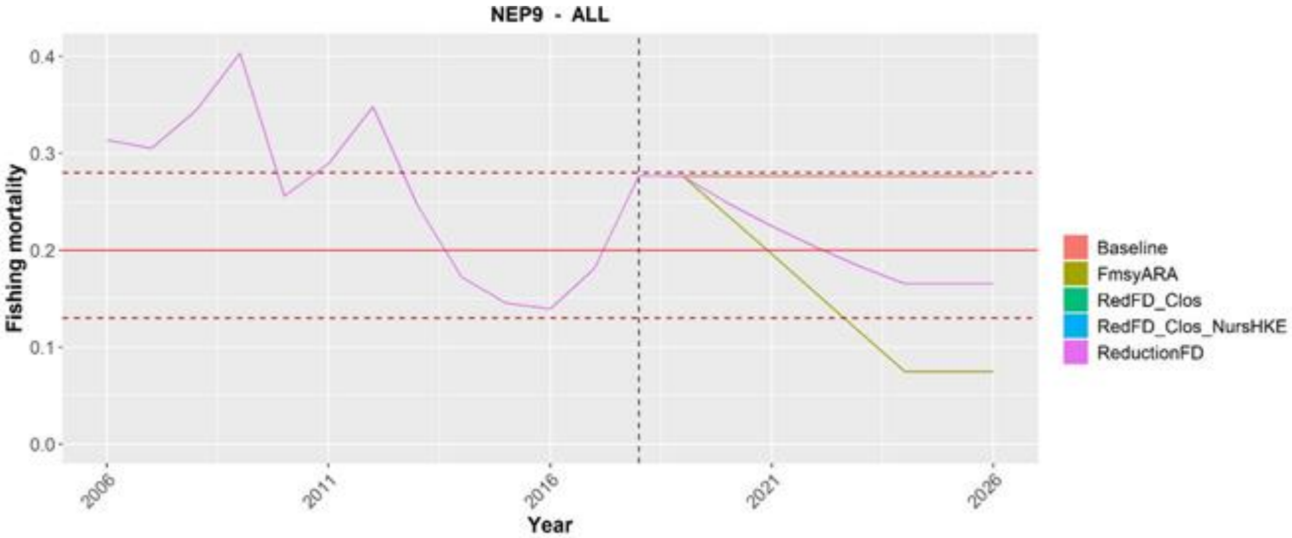

HKE - ALL
Fishing mortality
0.00
0.25
0.50
0.75
2006
2011
2016
2021
2026
Year
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD


MUT9 - ALL
Fishing mortality
0.0
0.5
1.0
1.5
2006
2011
2016
2021
2026
Year
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD


MUT10 - ALL
Fishing mortality
0.00
0.25
0.50
0.75
2006
2011
2016
2021
2026
Year
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD


DPS - ALL
Fishing mortality
Year
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD


ARS - ALL
Fishing mortality
Year
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD


NEP9 - ALL
Fishing mortality
Year
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD

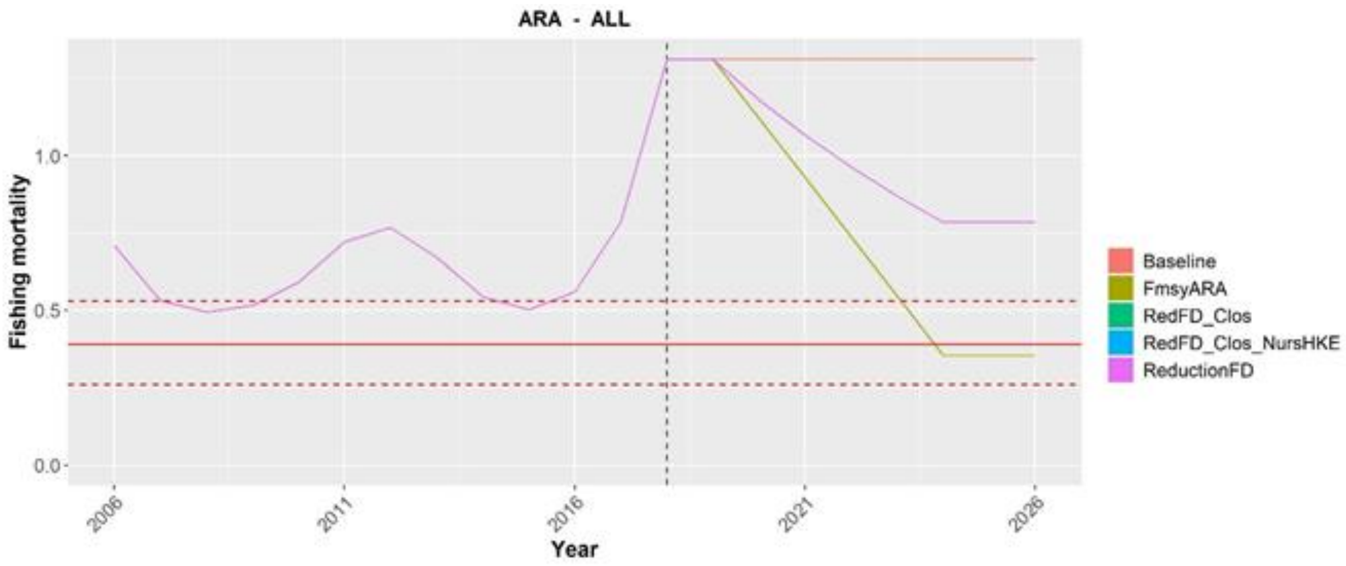
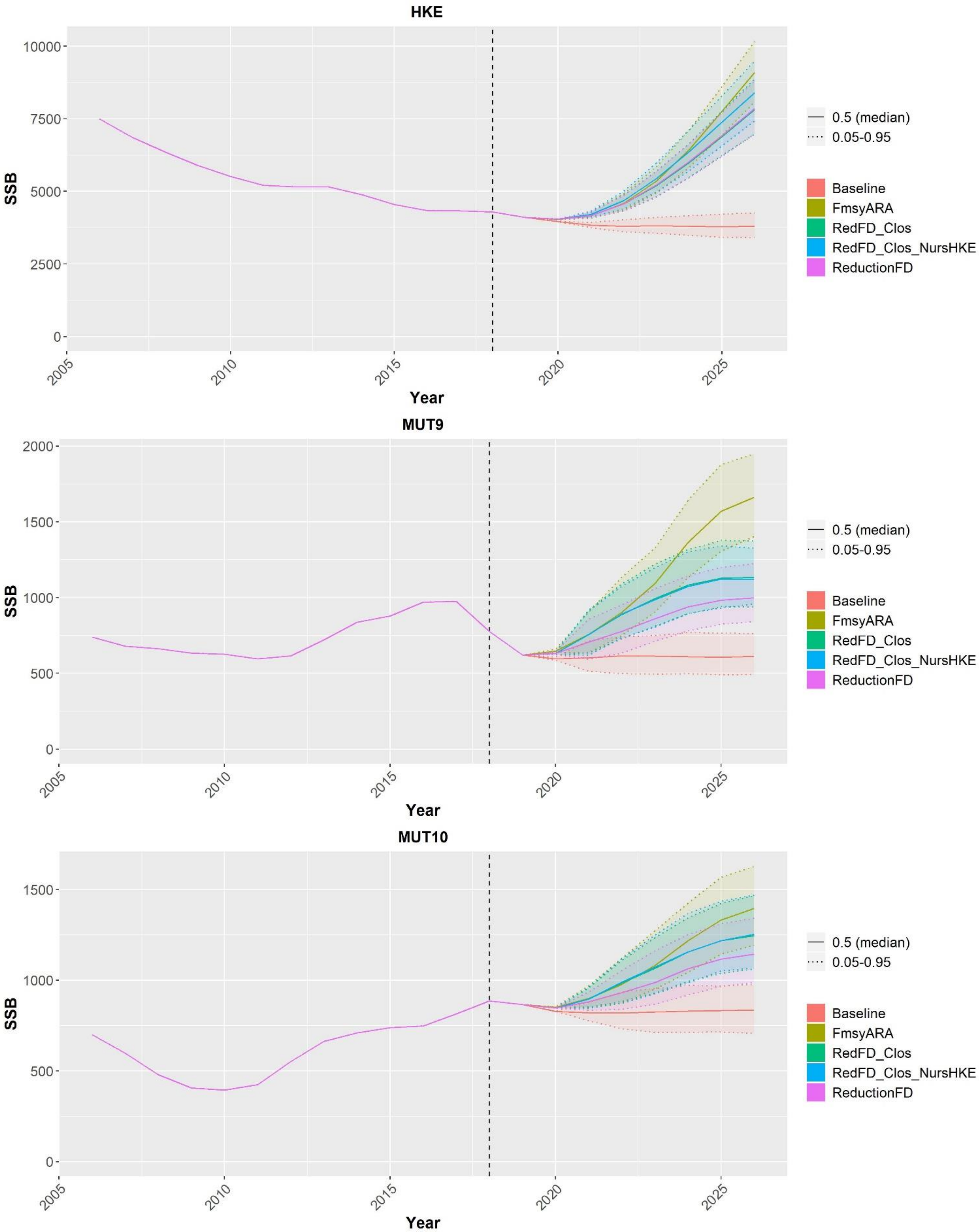
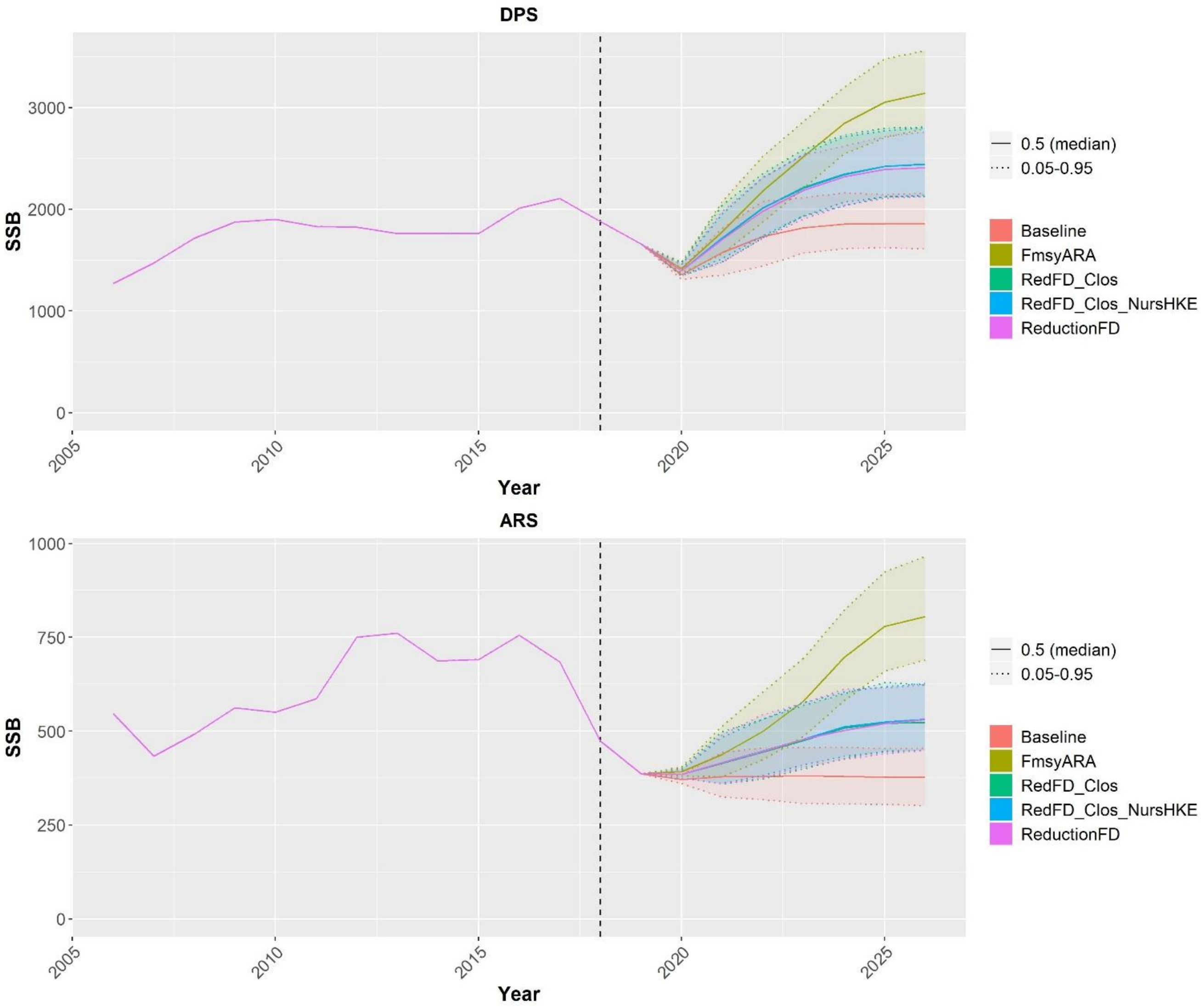


Figure 4.2.4 – BEMTOOL. Trajectories of the fishing mortality (F) for the seven stocks in the hindcasting phase (until 2019) and in the forecast phase (after 2019) under the alternative scenarios. The black vertical dashed lines corresponds to 2018. Red horizontal solid line correspond to the F_{MSY}=F0.1, and red horizontal dashed lines correspond to Fupper and Flower.

SSB


HKE
SSB
Year
0
2500
5000
7500
10000
2005
2010
2015
2020
2025
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD
MUT9
SSB
Year
0
500
1000
1500
2000
2005
2010
2015
2020
2025
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD
MUT10
SSB
Year
0
500
1000
1500
2005
2010
2015
2020
2025
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD



DPS
3000
2000
1000
0
SSB
2005
2010
2015
2020
2025
Year
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD
ARS
1000
750
500
250
0
SSB
2005
2010
2015
2020
2025
Year
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD

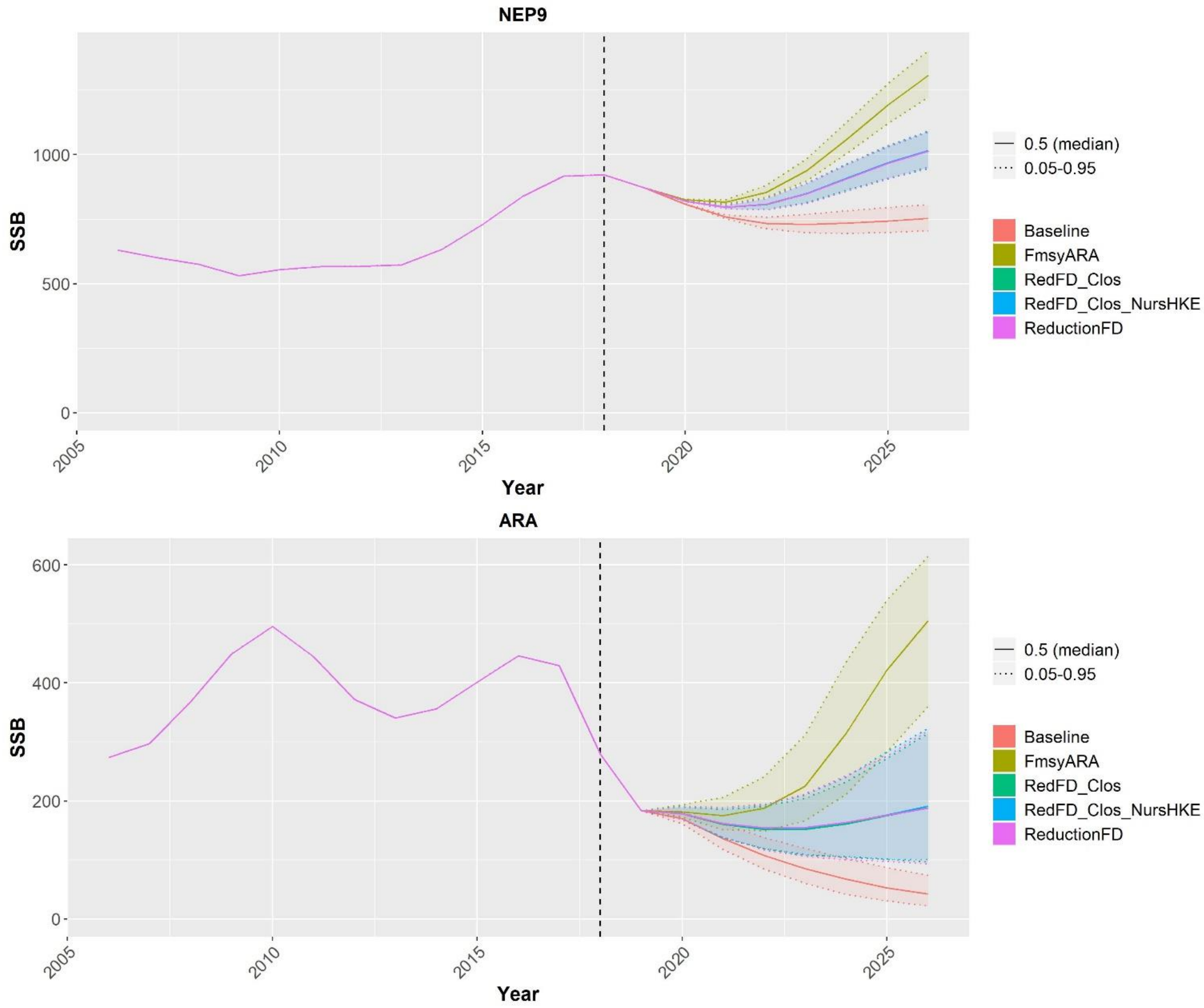
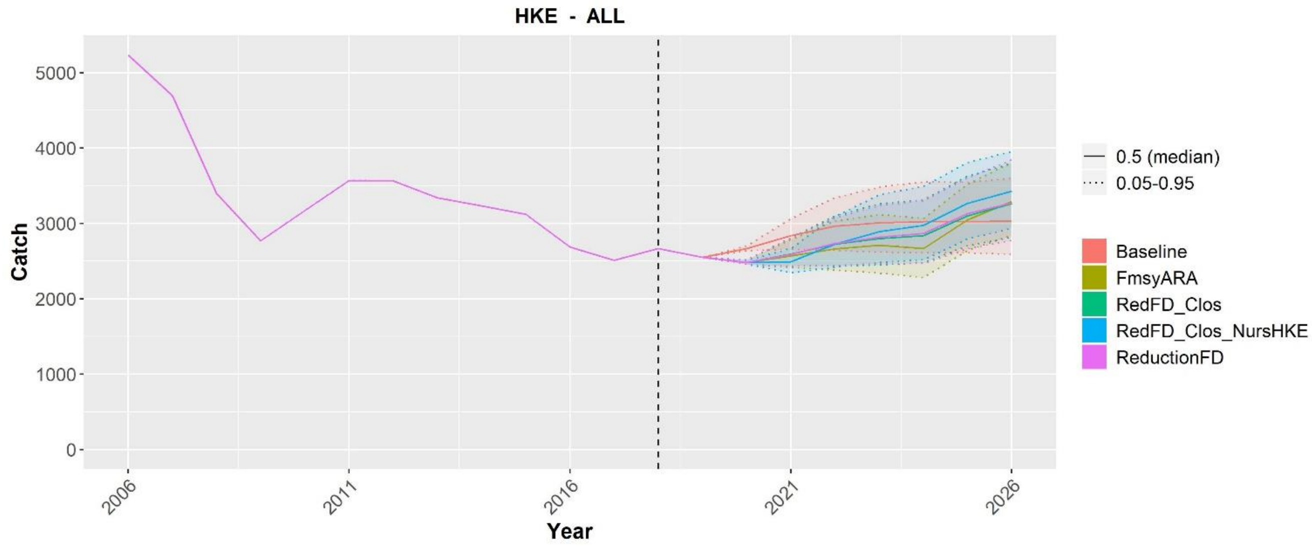
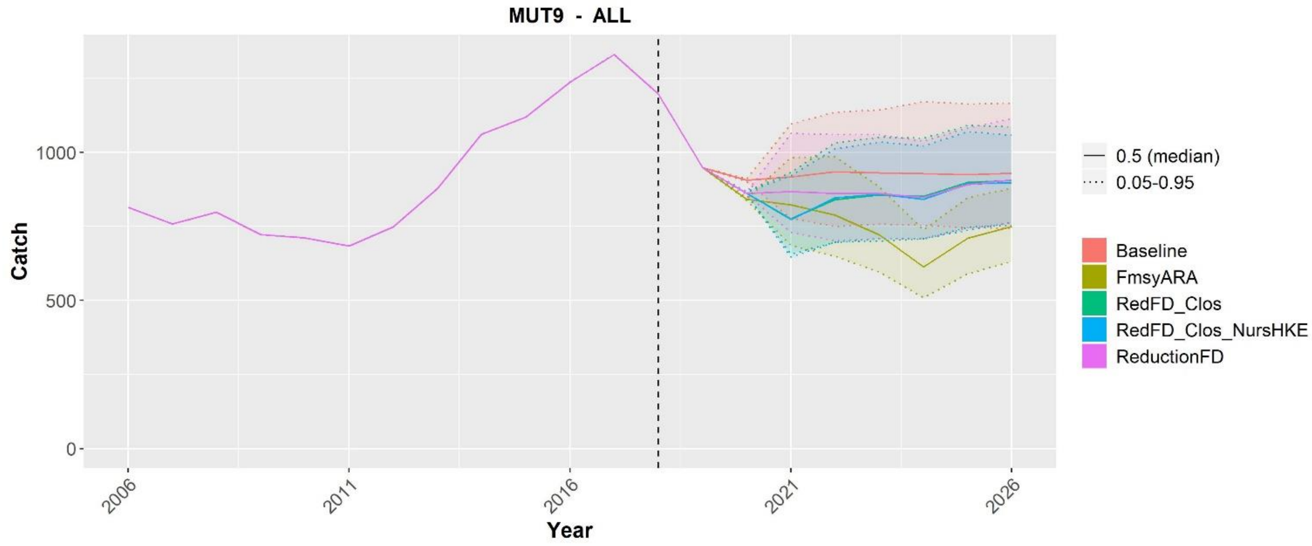


Figure 4.2.5 – BEMTOOL. Trajectories of the SSB (in tons) for the seven stocks in the hindcasting phase (until 2019) and in the forecast phase (after 2019) under the alternative scenarios. Solid lines correspond to medians, while shaded area correspond to interquantile range between 5th and 95th quantiles, indicated by the dashed lines. The black dashed lines corresponds to 2018

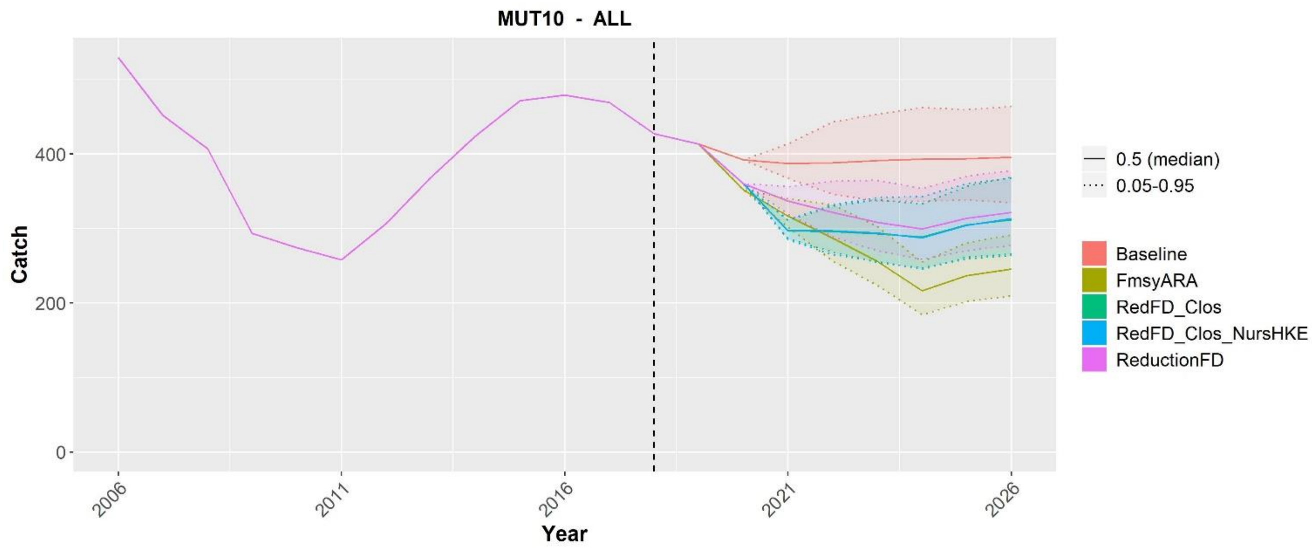
Catches:



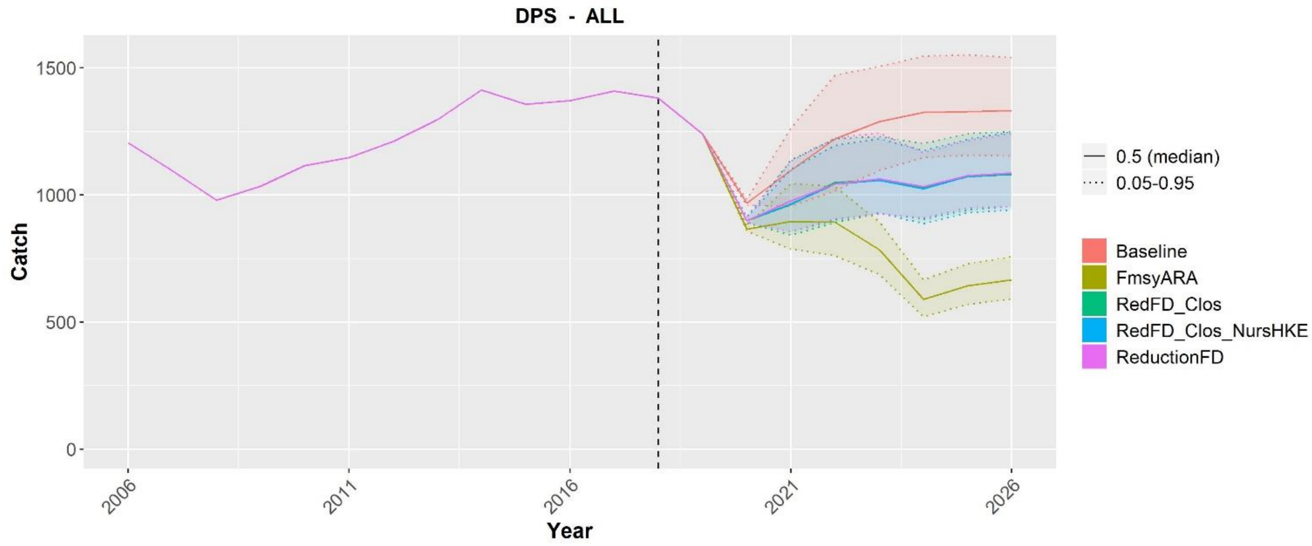
HKE - ALL
Catch
Year
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD

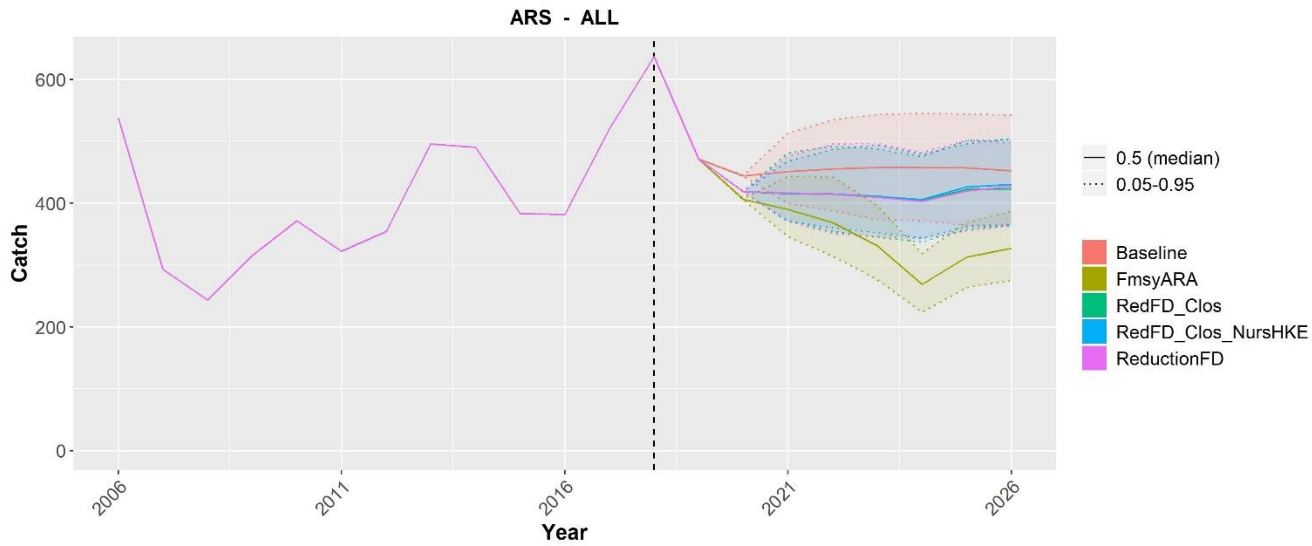


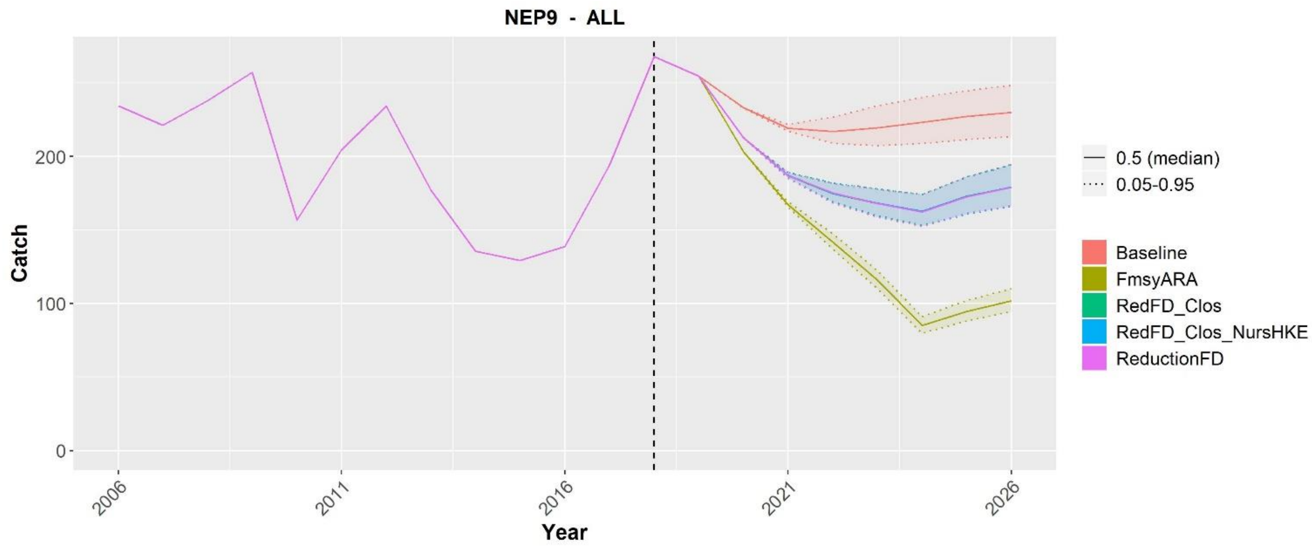
MUT9 - ALL
Catch
Year
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD



MUT10 - ALL
Catch
Year
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD


DPS - ALL
Catch
Year
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD


ARS - ALL
Catch
Year
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD


NEP9 - ALL
Catch
Year
0.5 (median)
0.05-0.95
Baseline
FmsyARA
RedFD_Clos
RedFD_Clos_NursHKE
ReductionFD

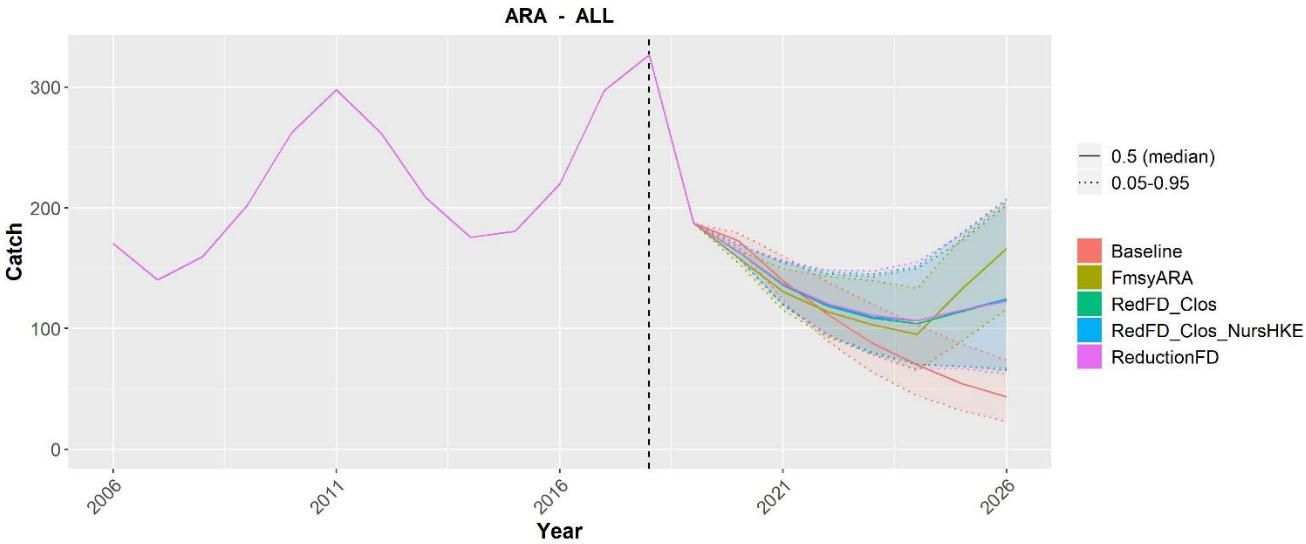


Figure 4.2.6 – BEMTOOL. Trajectories of catches (tons) for the seven stocks in the hindcasting phase (until 2019) and in the forecast phase (after 2019) under the alternative scenarios. Solid lines correspond to medians, while shaded area correspond to interquantile range between 5th and 95th quantiles, indicated by the dashed lines. The black dashed lines corresponds to 2018

Total revenues

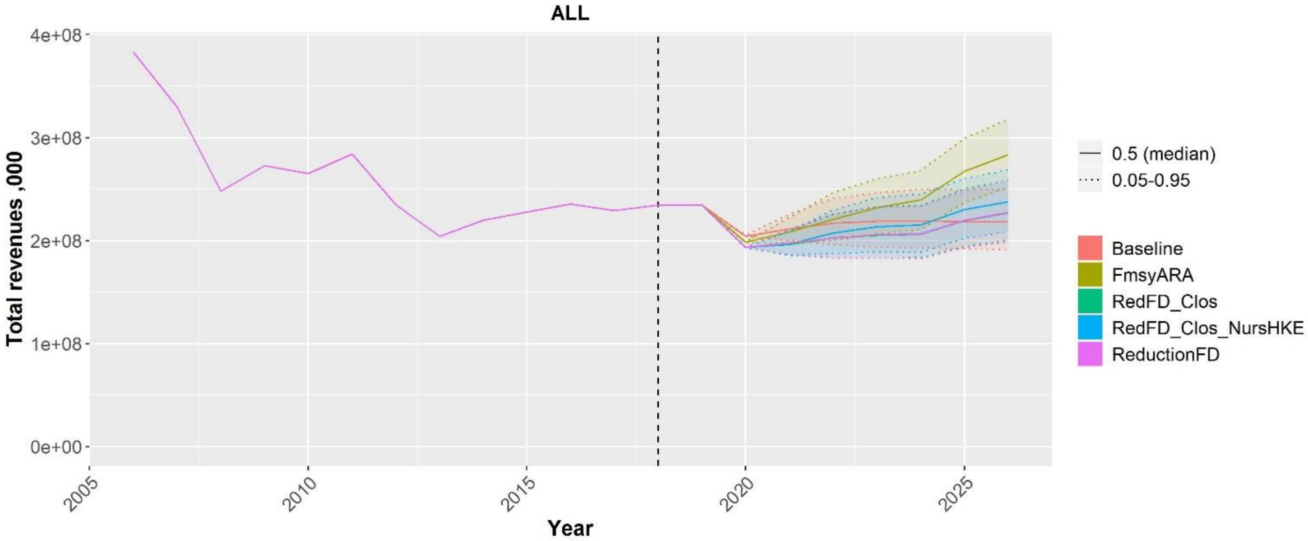


Figure 4.2.7 – BEMTOOL. Trajectories of revenues (thousand Euro) for all fleets combined in the hindcasting phase (until 2019) and in the forecast phase (after 2019) under the alternative scenarios. Solid lines correspond to medians, while shaded area correspond to interquantile range between 5th and 95th quantiles, indicated by the dashed lines. The black dashed lines corresponds to 2018.

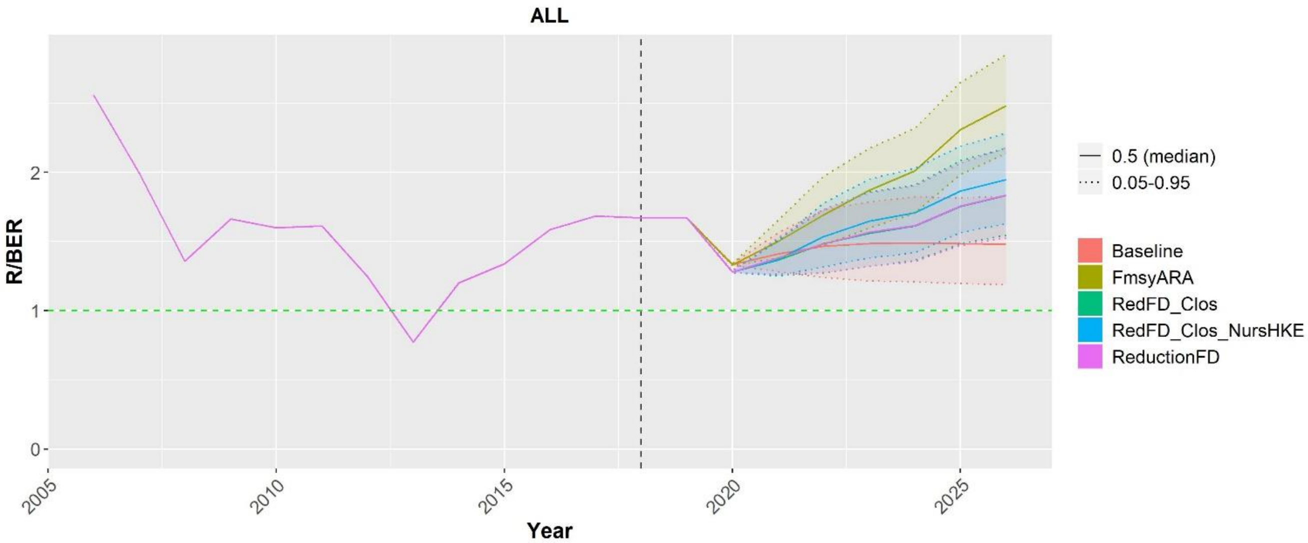


Figure 4.2.8 – BEMTOOL. Trajectories of current revenues/Break-Even Revenues (R/BER) ratio for all fleets combined in the hindcasting phase (until 2019) and in the forecast phase (after 2019) under the alternative scenarios. Solid lines correspond to medians, while shaded area correspond to interquantile range between 5th and 95th quantiles, indicated by dashed lines. The black dashed lines corresponds to 2018. The green horizontal dashed line indicates R/BER=1, the threshold of profitability of the fishery.

Table 4.2.5. Changes (in percentage) of F of the seven stocks in the three tested scenarios compared to the baseline scenario. This is referred to 2024.

Stock	Baseline	ReductionFD	RedFD_Clos	FmsyARA	RedFD_Clos_NursHKE
ARA	2.62	-40%	-40%	-73%	-40%
ARS	2.43	-40%	-40%	-73%	-40%
MUT10	1.02	-40%	-46%	-55%	-40%
MUT9	2.97	-40%	-51%	-68%	-42%
HKE	1.62	-40%	-40%	-47%	-46%
NEP	0.55	-40%	-40%	-73%	-51%
DPS	1.82	-40%	-40%	-73%	-40%

Table 4.2.6. Changes (in percentage) of the spawning stock biomass (SSB) of the seven stocks in the tested scenarios compared to the baseline scenario. This is referred to 2024 (SSB in baseline are reported in tons).

Stock	Baseline	ReductionFD	RedFD_Clos	FmsyARA	RedFD_Clos_NursHKE
ARA	67	143%	139%	368%	143%
ARS	380	32%	34%	83%	35%
MUT10	830	28%	39%	47%	26%
MUT9	610	54%	77%	124%	67%
HKE	3801	59%	58%	69%	39%
NEP	735	24%	24%	44%	76%
DPS	1855	25%	26%	53%	24%

Table 4.2.7. Changes (in percentage) of the catches of the seven stocks by fleet groups (DTS and PGP) in the tested scenarios compared to the baseline scenario. This is referred to 2024 (the catches in baseline are reported in tons).

DTS	Baseline	ReductionFD	RedFD_Clos	FmsyARA	RedFD_Clos_NursHKE
ARA	70	53%	49%	36%	52%
ARS	458	-12%	-12%	-41%	-11%
MUT10	336	-24%	-29%	-61%	-23%
MUT9	896	-9%	-9%	-41%	-5%
HKE	2038	-6%	-7%	-54%	-29%
NEP	223	-27%	-27%	-62%	-10%
DPS	1326	-22%	-22%	-56%	-27%
PGP	**Baseline**	**ReductionFD**	**RedFD_Clos**	**FmsyARA**	**RedFD_Clos_NursHKE**
MUT10	57	-22%	-14%	51%	4%
MUT9	31	2%	20%	163%	-14%
HKE	987	-4%	-5%	74%	18%

Table 4.2.8. Changes (in percentage) of the revenues of the seven stocks by fleet groups (DTS and PGP) in the tested scenarios compared to the baseline scenario. This is referred to 2024.

DTS Fleet	Baseline	FmsyARA	RedFD_Clos	ReductionFD	RedFD_Clos_NursHKE
GSA10_DTS_VL1218	11979317	-42%	-11%	-10%	-11%
GSA10_DTS_VL1824	16172612	-39%	-10%	-9%	-9%
GSA11_DTS_VL1218	7086839	-37%	0%	1%	5%
GSA11_DTS_VL1824	5961838	-35%	-1%	-1%	2%
GSA11_DTS_VL2440	6595364	-32%	-2%	-2%	-1%
GSA9_DTS_1824	29162046	-43%	-10%	-9%	-8%
GSA9_DTS_VL1218	25501334	-42%	-11%	-10%	-10%
GSA9_DTS_VL2440	2802847	-45%	-8%	-9%	-7%
PGP Fleet	**Baseline**	**FmsyARA**	**RedFD_Clos**	**ReductionFD**	**RedFD_Clos_NursHKE**
GSA10_PGP_VL0006	7924041	49%	-7%	-8%	-1%
GSA10_PGP_VL0612	34806310	53%	-4%	-4%	3%
GSA11_PGP_VL0012	26855310	52%	-4%	-4%	3%
GSA11_PGP_VL1218	5792029	53%	-4%	-3%	3%
GSA9_PGP_VL0012	30756692	62%	-1%	-2%	6%
GSA9_PGP_VL1218	7746873	55%	-3%	-3%	3%

Table 4.2.9. Changes (in percentage) of the R/BER ratio of the seven stocks by fleet groups (DTS and PGP) in the tested scenarios compared to the baseline scenario. This is referred to 2024.

DTS Fleets	Baseline	ReductionFD	RedFD_Clos	FmsyARA	RedFD_Clos_NursHKE
GSA10_DTS_VL1218	2.02	5%	3%	-29%	4%
GSA10_DTS_VL1824	0.74	24%	23%	-12%	24%
GSA11_DTS_VL1218	1.74	28%	27%	-24%	36%
GSA11_DTS_VL1824	0.60	49%	48%	-5%	57%
GSA11_DTS_VL2440	0.14	193%	189%	85%	199%
GSA9_DTS_1824	1.15	16%	16%	-23%	19%
GSA9_DTS_VL1218	3.36	0%	-1%	-33%	0%
GSA9_DTS_VL2440	0.89	12%	14%	-30%	17%
PGP fleets	**Baseline**	**ReductionFD**	**RedFD_Clos**	**FmsyARA**	**RedFD_Clos_NursHKE**
GSA10_PGP_VL0006	2.07	-4%	-2%	64%	5%
GSA10_PGP_VL0612	1.49	2%	1%	69%	10%
GSA11_PGP_VL0012	2.11	2%	1%	67%	10%
GSA11_PGP_VL1218	0.79	33%	32%	119%	48%
GSA9_PGP_VL0012	1.71	8%	9%	84%	18%
GSA9_PGP_VL1218	1.96	8%	8%	75%	17%

Table 4.2.10. Changes (in percentage) of the optimal length of the seven stocks in the tested scenarios compared to the baseline scenario. This is referred to 2024.

Scenarios (in 2024)	optimal length							
	ARA	ARS	DPS	HKE	MUT10	MUT9	NEP9	Unit
Baseline	13.8	18.4	16.9	182.4	100.3	90.7	31.4	mm
ReductionFD	0.6%	8.1%	2.4%	26.2%	3.1%	11.3%	10.0%	% respect to baseline
RedFD_Clos	0.6%	8.1%	3.6%	29.6%	13.6%	15.5%	8.5%	% respect

								to baseline
FmsyARA	2.3%	23.2%	7.4%	26.3%	17.6%	20.0%	16.6%	% respect to baseline
RedFD_Clos_NursHKE	0.3%	6.7%	3.1%	30.4%	13.6%	16.7%	10.0%	% respect to baseline

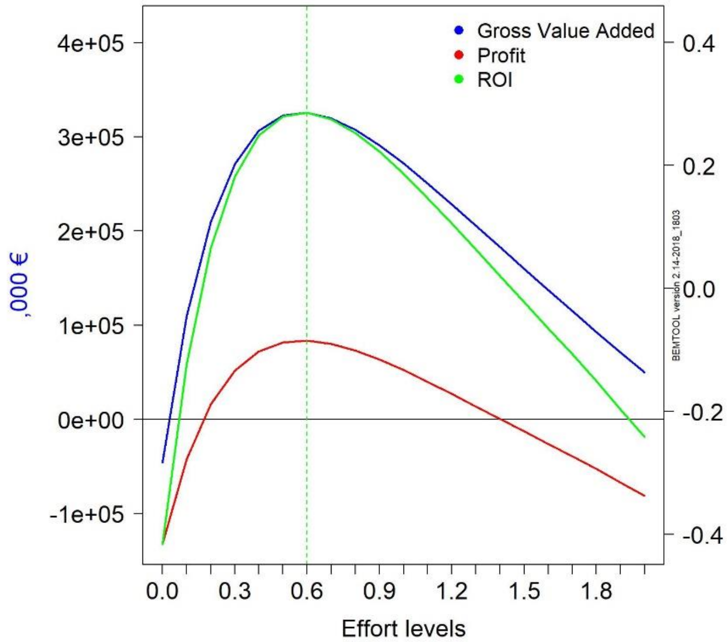


Figure 4.2.9. Maximimum Economic Yield (MEY) curves maximising three economic variables: Gross Value Addedd, Profit and Return of Investment (ROI) by 2024. The green vertical line shows the level of MEY, identified at 0.6 of the status quo effort.

Table 4.2.9. Maximimum Economic Yield (MEY) values for each of the three variables optimised: Gross Value Addedd, Profit and Return of Investment (ROI) by 2024. The green vertical line shows the level of MEY, identified at 0.6 of the status quo effort.

Fleet_segment	Species	Year	Variable	Value	Unit
ALL	ALL	ALL	MEY.gross.value.added	32564562&	euro
ALL	ALL	ALL	MEY.profit	83559776	euro
ALL	ALL	ALL	MEY.ROI	0.286	

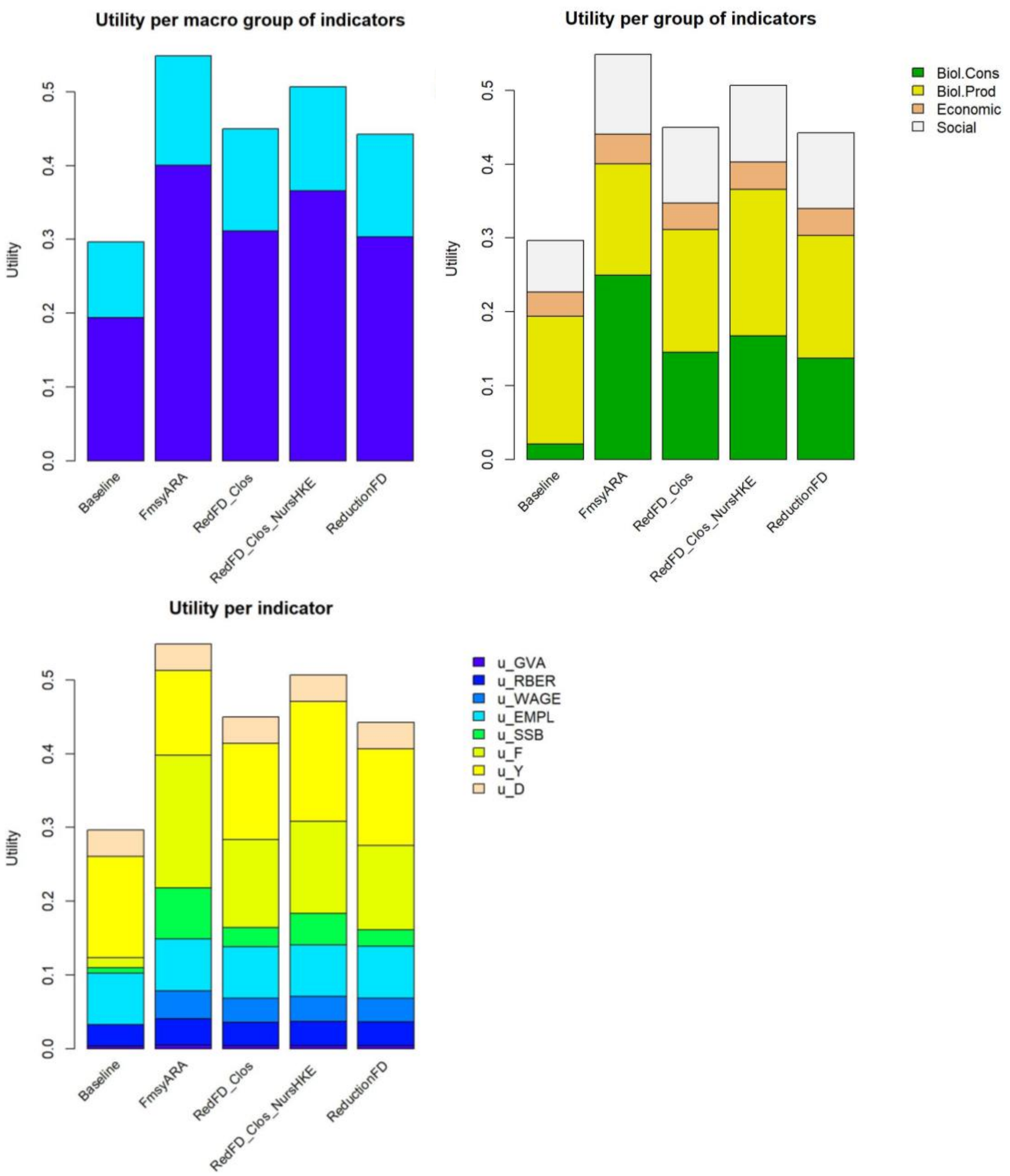


Figure 4.2.10 – BEMTOOL. Results from the Multicriteria Decision Analysis comparison among the scenarios (MEY evaluation is embedded in the MCDA process, because considered as reference point).

References

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4.2.2 SMART

Following the work done within the STECF-EWG 19-01, the SMART bioeconomic model was further implemented for EMU2. In particular, during the EWG 19-14, the input datasets for landings, effort (by VMS), and economic parameters (fuel prices, price at the market of resources by species/ size class), and resources status (i.e. abundance indexes from MEDITS survey) were integrated to cover the period 2012-2018.

The rationale of the SMART model, as well as the workflow of the smartR package, can be summarized in the following logical steps:

1. Use landings and catch data, combined with VMS data, to estimate the spatial/temporal productivity of each cell, in terms of aggregated LPUE by species;
2. Use catch data to estimate the Length-Frequency Distribution (LFD) and the Age-Frequency Distribution (AFD), by species, for each cell/time;
3. Use VMS data to assess the fishing effort by vessel/cell/time;
4. Combine LPUE, LFD/AFD and VMS data to model the landings by vessel/species/length class/time;
5. Estimate the cost by vessel/time associated to a given effort pattern and the related revenues, which are a function of the landings by vessel/species/length class/time (step 4);
6. Combine costs and revenues by vessel, at the yearly scale, to obtain the incomes, which are the proxy of the vessel performance. Incomes could be aggregated at the fleet level to estimate the overall performance;
7. Use estimated landings by species/age, together with survey data, to run MICE model for the selected case of study in order to obtain a biological evaluation of the fisheries.

Each of these steps corresponds to a different module of the package. Within SMART, the key aspect is represented by the optimization, at the scale of each vessel, of the fishing effort pattern at the monthly temporal scale. This is done through the iterative exploration of alternative vessel-specific effort patterns and evaluation of the corresponding catch converted in revenues and compared with the total costs to estimate the gains.

A detailed description of the method is available in Russo et al., 2019.

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Application of the SMART model to the West Med MAP

The spatial productivity (monthly LPUE as grams of catch per meter of LOA and hour of fishing) was estimated using landings and VMS data, according to the procedure of Russo et al., 2018 and Russo et al., 2019. In the same time, the economic parameters needed to model the relationships between: 1) fishing effort and its related costs (crew salaries, fixed costs, etc.); 2) spatial fishing footprint and its related costs (i.e. fuel consumption); 3) yield and production costs (i.e. commercialization); 4) yield and revenues (using the prices at market of the different species by size class) were collected and integrated into the model. Values of prices at the market by species and length class, together with the price of fuel, were partially retrieved by Russo et al. (2014b) and integrated using the public databases provided by the "Istituto di servizi per il mercato agricolo alimentare" (ISMEA http://www.ismea.it/flex/FixedPages/IT/WizardPescaMercati.php/L/IT) and by the Ministry of Economic Development (https://dgsaie.mise.gov.it/prezzi_carburanti_mensili.php).

Space and time scale

For this application of SMART to the case study of Western Mediterranean Effort Management Unit 2, the resolution of the square grid for the GSAs 9, 10 and 11 was increased from the 30 x 30 nm of the EWG 19-01 to cells of 6 x 6 nm (Figure X1X). The cells covering the area deeper than 800m depth were excluded to reduce complexity and computational time required for the simulations.

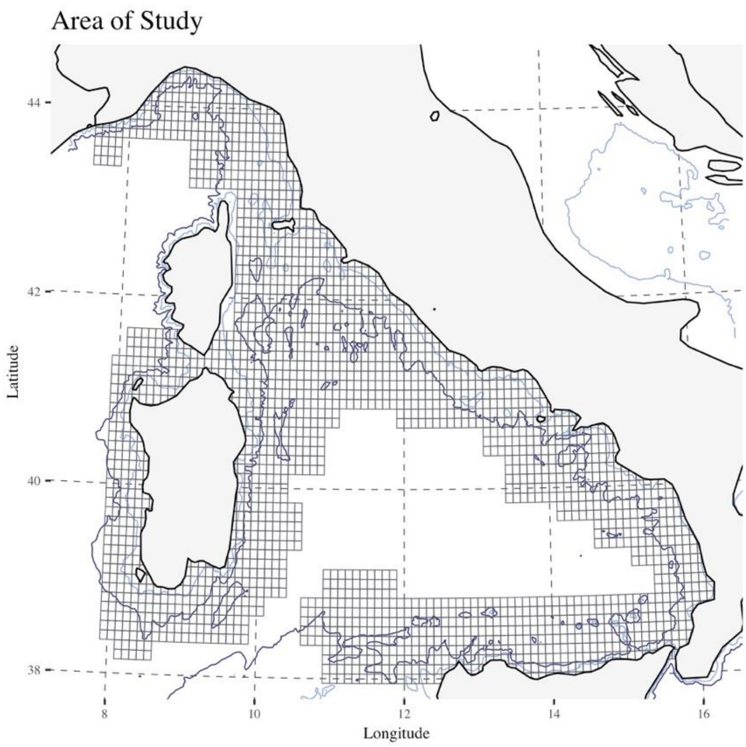


Figure 4.2.2.1 – Area of the Effort Management Unit 2 case study considered in the Western Mediterranean EWG 19 14. Square grid of 6 x 6 nm used for the implementation of SMART on the Italian GSAs in the Tyrrhenian Sea (9 – 10 - 11).

Compared to the EWG 19-01, also the temporal ranges were extended. The considered time series starts in 2012 and ends in 2018.

Accordingly, 84 months' temporal series of LPUE (Figure 4.2.2.4) and AFD (proportion of age classes/length by species) were estimated for the cells of the grid, together with accessory economic models. These represent the basis for the simulation of different effort scenarios, including the status quo.

Fleets

The fleet included in the analyses is composed by the Italian trawlers with LOA equal or larger than 15m, that is the portion of the fleet equipped with VMS. The native VMS pings were pre-processed using the VMSbase platform (Russo et al., 2014) and coupled, at the level of single vessels and at a monthly scale, with logbook, landings and economic data (fuel consumption, etc.). Figure 4.2.2.2 depicts the average hours of fishing across the time series by cell.

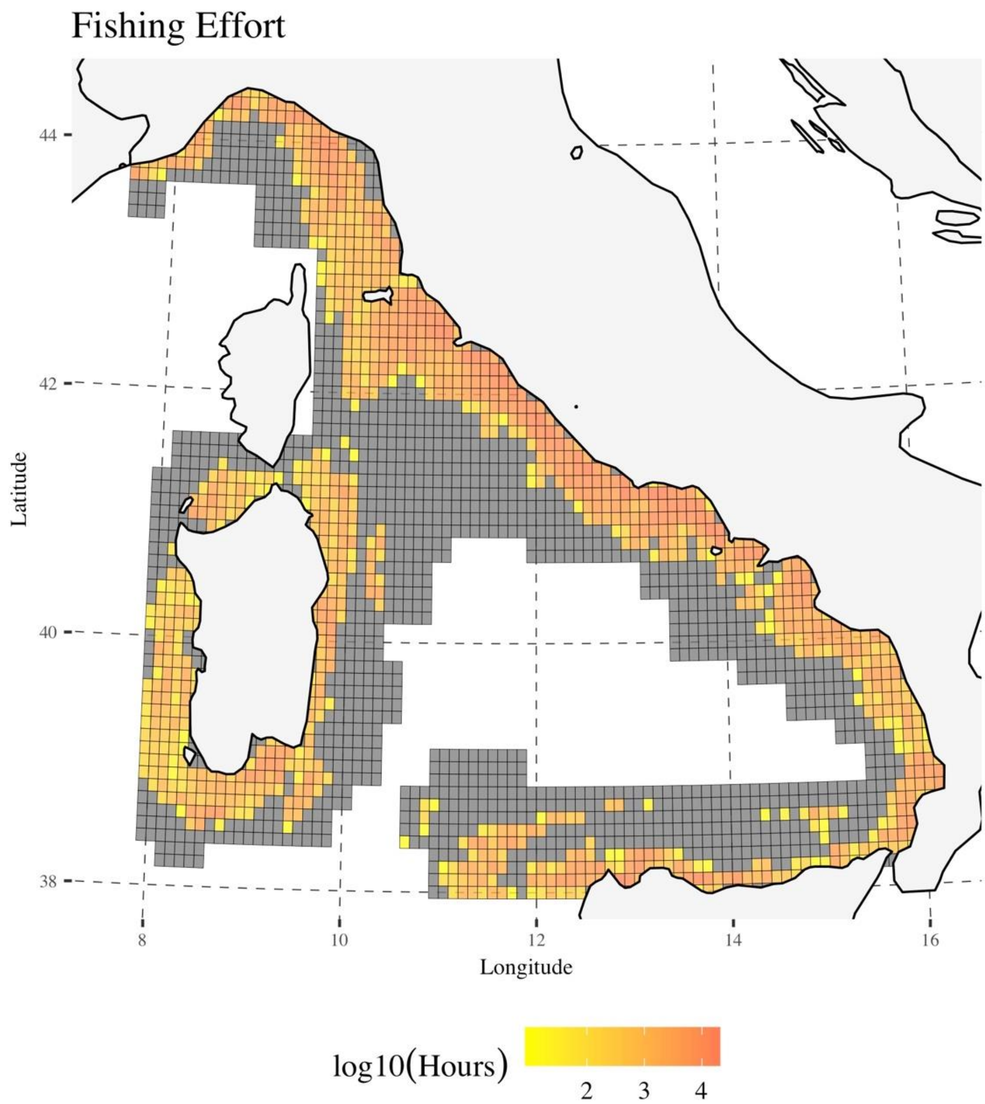


Figure 4.2.2.2 – Map of the average fishing hours (in logarithmic base 10 scale represented by a color scale from yellow – low to orange - high) as grams of catch per meter of LOA and hour of fishing, for the 24 months' temporal series (years 2015- 2016).

Stocks

Four species of the MAP were considered for this implementation of SMART. Namely: the Giant red shrimp (*Aristeomorpha foliacea* - ARS), the Deep-water rose shrimp (*Parapenaeus longirostris* – DPS), the Hake (*Merluccius merluccius* – HKE), and the Red mullet (*Mullus barbatus* – MUT). The relationships between these stocks and the fleet of trawlers is described in Fig. 4.2.2.3.

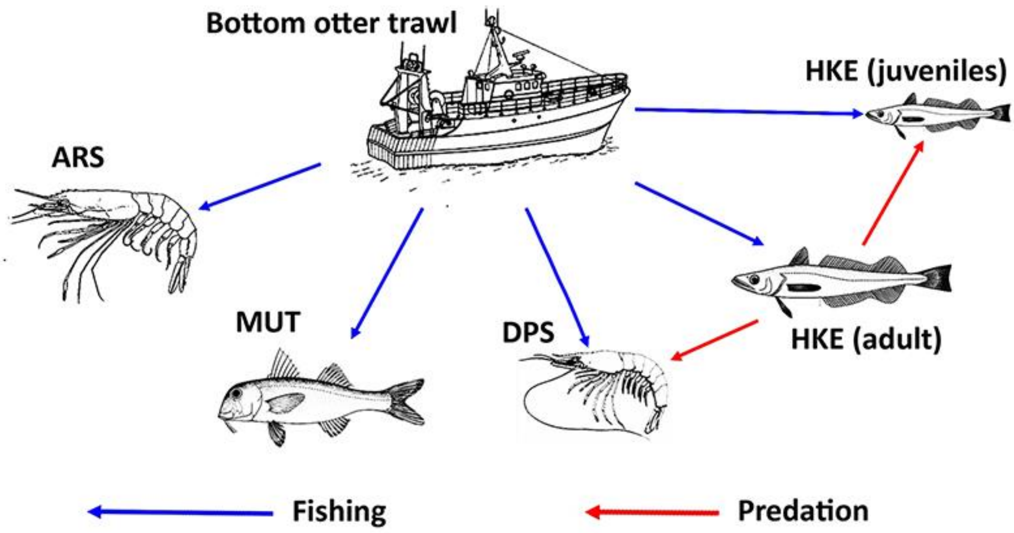


Figure 4.2.2.3 – Representation of the relationships between trawl fishing and the four stocks considered for the application of SMART in the EMU2, together with the main trophic relationships between stocks. Adult HKE is a predator of DPS and HKE juveniles. MUT and ARS were considered as stand-alone stocks with no trophic relationship with other investigated species.

The mean LPUE patterns estimated for these four species are represented in Fig. 4.2.2.4.

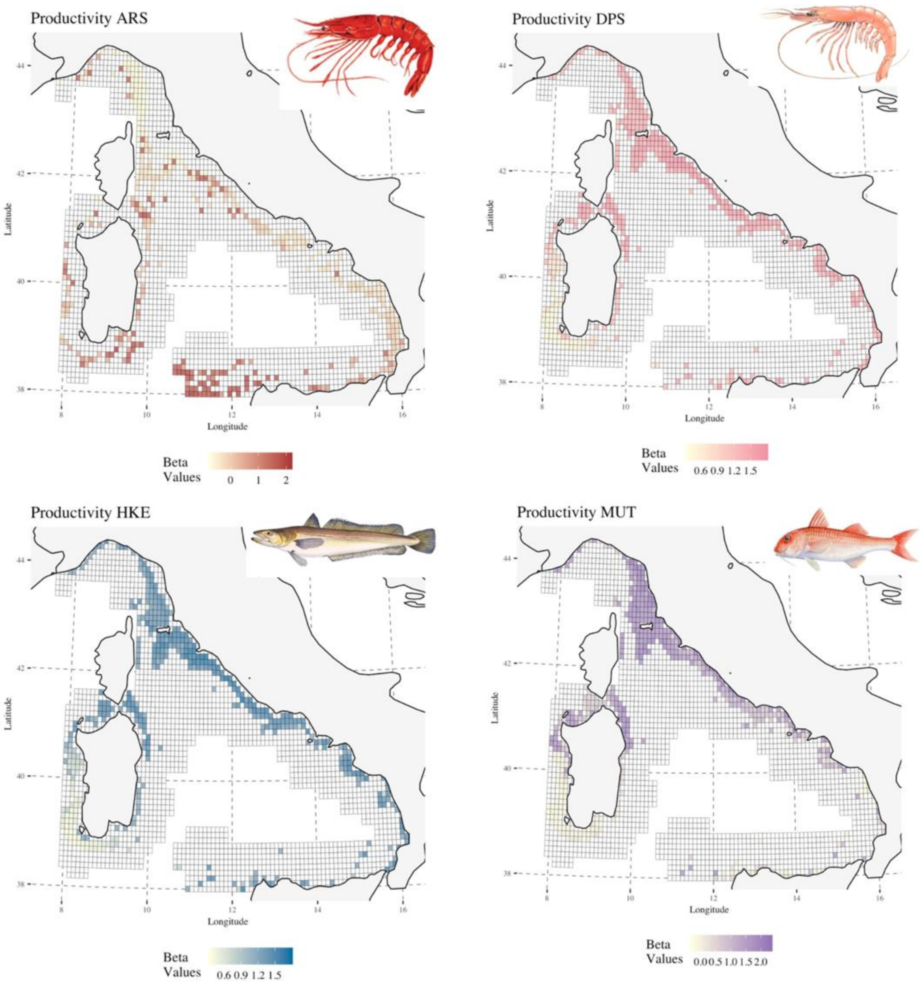


Figure 4.2.2.4 – Spatial distribution of LPUE (kg/m/h) by species, as mean for the period 2012–2018

Simulated Scenarios

The SMART model is devised to estimate the potential effect of whatever management actions on the effort (including reduction of fishing capacity, effort, or spatial closures) instead of directly setting a desired value of F for the target stocks and evaluate the related effects of this new exploitation patter. Thus, the SMART model was used to assess the potential effect of a 10% decrease of trawling effort, which is rather different from the F reduction in single-stock advice used as benchmark for the EWG.

The complete list of the tested scenario is:

- All year Spatial Closure of -100mt isobath/6 NM;
- Effort Reduction of 10%;
- Effort Reduction of 40%;
- Effort Reduction of 10% + 3 month Spatial Closure (May - July);
- Effort Reduction of 40% + 3 month Spatial Closure (May - July).

In the SMART modelling approach, the effort displacement resulting from the scenario simulation is obtained according to an individual based optimization of the observed pattern of effort of each fishing vessel following a strategy of profit maximization (Fig. 4.2.2.5).

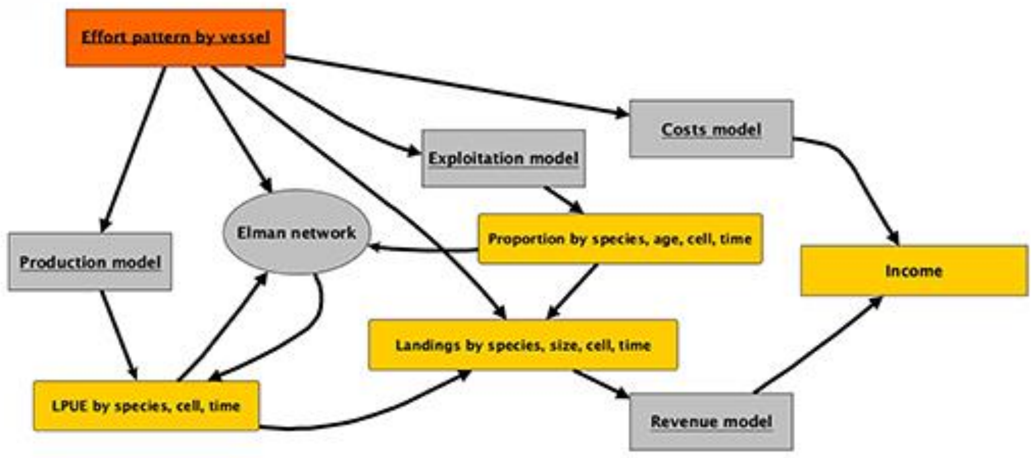


Figure 4.2.2.5 – Workflow of the Individual-Based Model used to optimize the effort pattern of each vessel

The simulated pattern of effort after are summarized as the relative differences between the observed and optimized cumulated value of fishing hours (figures 4.2.2.6, 4.2.2.7, 4.2.2.8, 4.2.2.9, 4.2.2.10). The colour scale indicates the direction and intensity of the changes, from light blue (a decrease of effort) to orange (an increase of effort). The first simulated scenario 'all year Spatial Closure of the -100m isobath/6 NM' (Figure 4.2.2.6), clearly shows the complete elimination of fishing effort around the coasts and the subsequent redistribution of the lost fishing time into the more distant fishing areas. It is also noticeable the attractiveness of some particular area with a high revenue potential with a large increase of effort. The other four scenarios which entail an overall reduction of total effort, mainly highlight the general decrease across all the regions, except for some small areas affected by a net increase of fishing pressure. Simplifying, the simulations having only a reduction of total effort (effort reduction of 10% and 40%, figures 4.2.2.7 and 4.2.2.8) display a general repelling effect of the more distant fishing grounds. Instead, the scenarios with the combination of reduction of total effort and three months of coastal closure (figures 4.2.2.9 and 4.2.2.10) reveal a milder repulsion of the offshore areas with a balancing effect of the area closure and the resulting concentration of displaced effort around the more central areas (between the offshore and coastal cells).

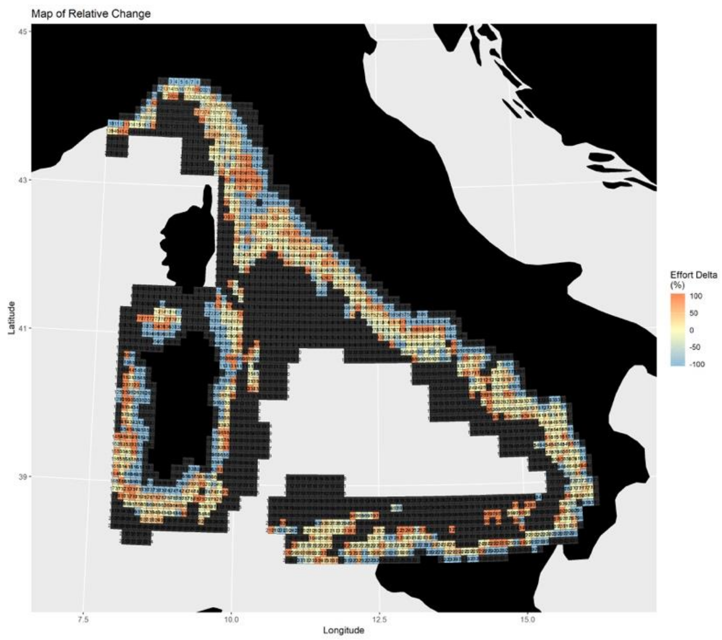


Figure 4.2.2.6 – Map of the relative differences between observed and optimized effort resulting from the implementation of the all year Spatial Closure of the -100m isobath/6 NM scenario.

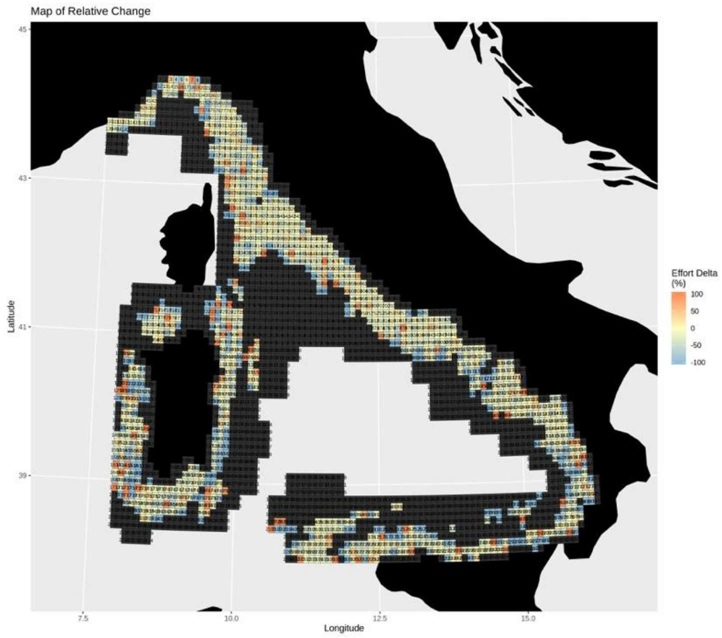


Figure 4.2.2.7 – Map of the relative differences between observed and optimized effort resulting from the implementation of the Effort Reduction of 10% scenario.

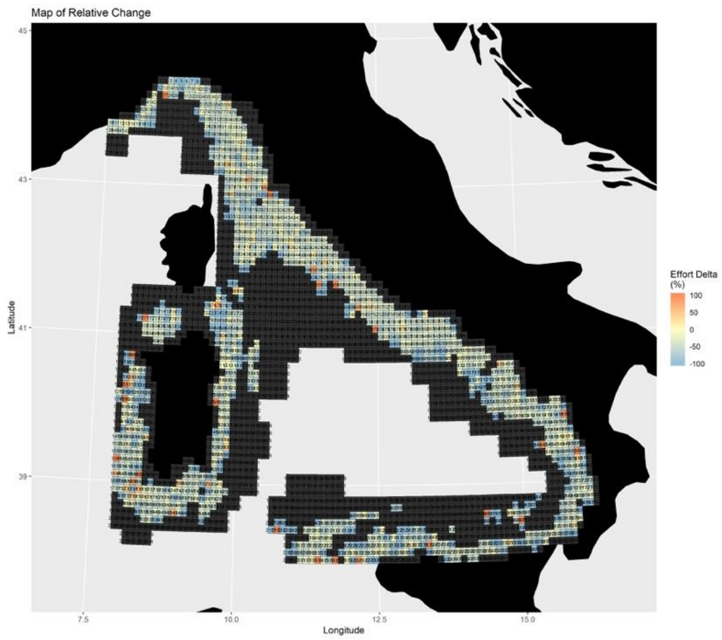


Figure 4.2.2.8 – Map of the relative differences between observed and optimized effort resulting from the implementation of the Effort Reduction of 40% scenario.

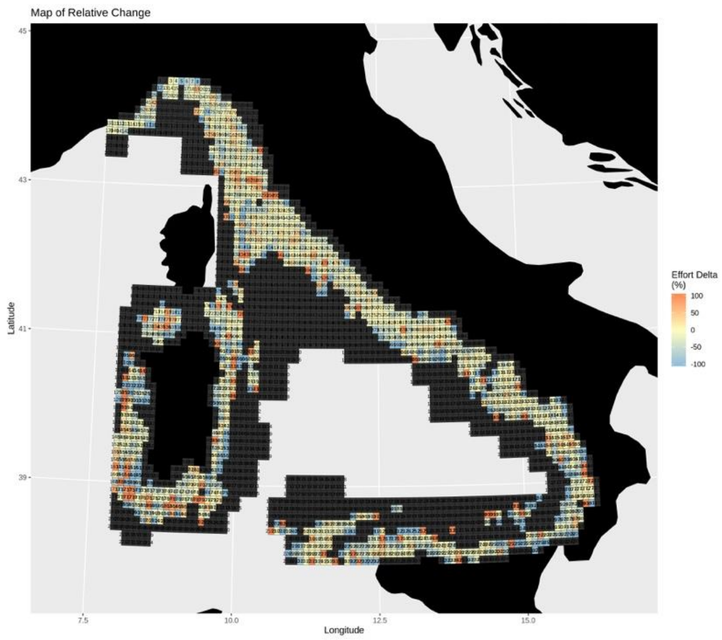


Figure 4.2.2.9 – Map of the relative differences between observed and optimized effort resulting from the implementation of the Effort Reduction of10% with 3 months Spatial Closure scenario.

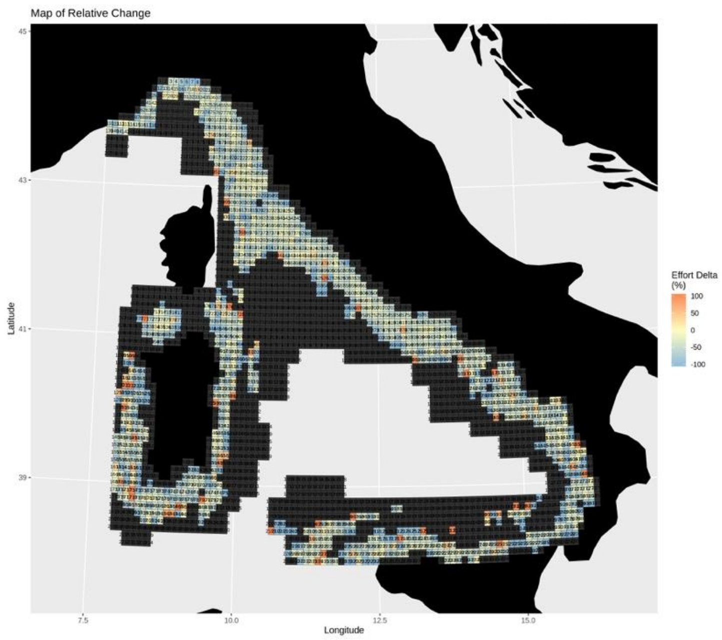


Figure 4.2.2.10 – Map of the relative differences between observed and optimized effort resulting from the implementation of the Effort Reduction of 40% with 3 months Spatial Closure scenario.

In general, the flat reduction of the fishing effort (scenarios RedFD 10% and RedFD 40%) is expected to determine a corresponding reduction of fishing hours in some areas (cells) far from the coast. This effect is evident in different parts of the Tyrrhenian Sea, and it seems to act in opposition to the estimated effect of the coastal closure. These effects are summarized by scenario and depth range in Figs. 4.2.2.11.

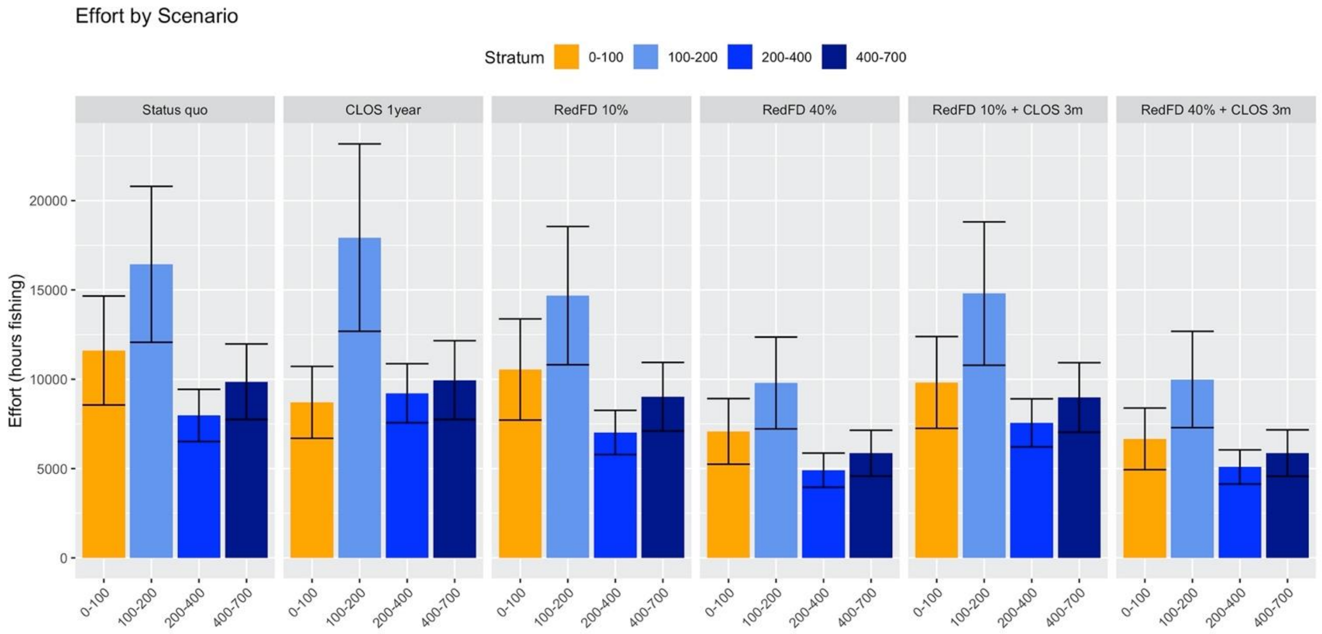


Figure 4.2.2.11 – Barplots of the expected total annual fishing effort (in hours fishing) by depth stratum and scenario.

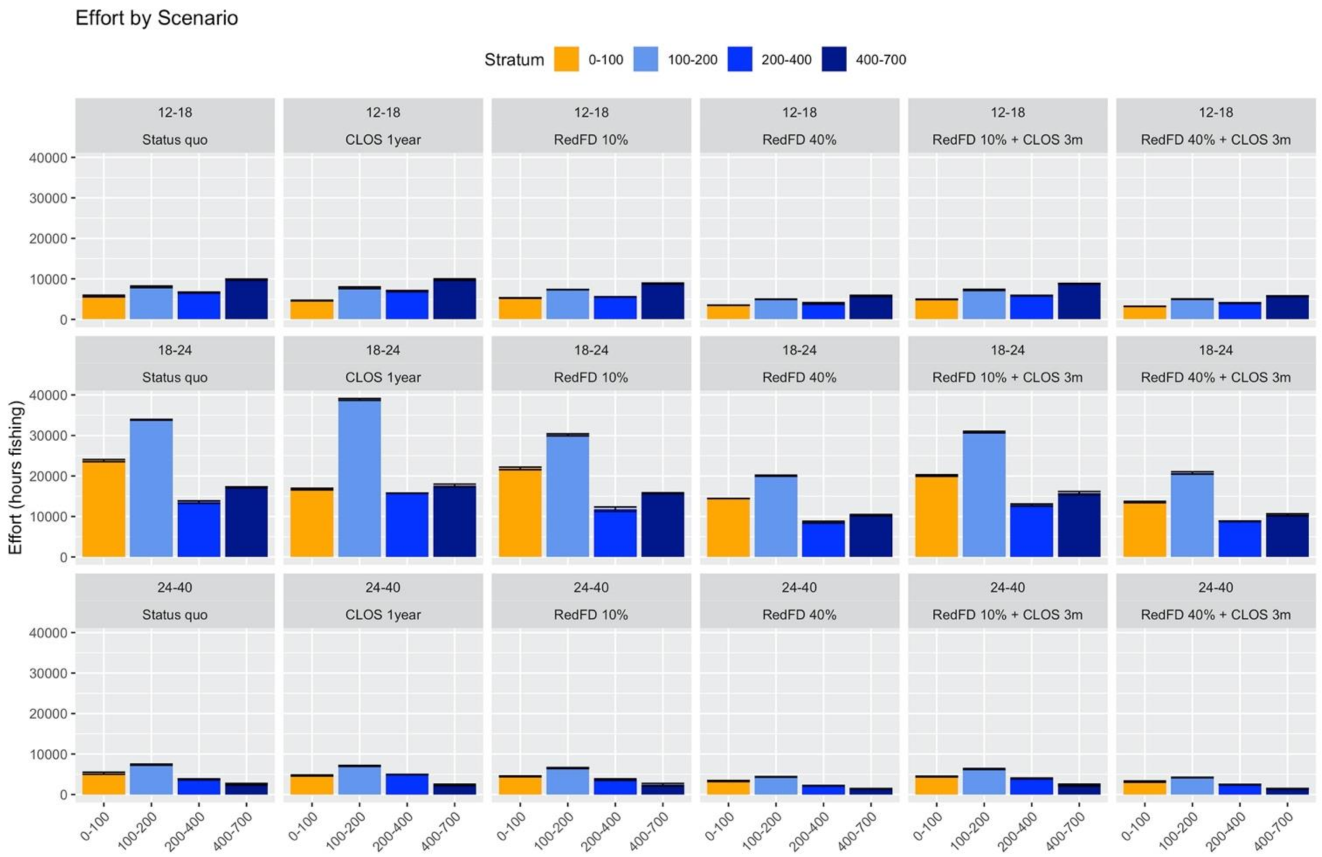


Figure 4.2.2.12 – Barplots of the expected total annual fishing effort (in hours fishing) by depth stratum, length class of vessels, and scenario.

Inspecting the changes of fishing effort by bathymetric strata, it seems that the closure of the coastal area, if not combined with a reduction of the total annual effort, is likely to determine an increase of effort in the depth range 100-200 m. In contrast, the “flat” (without spatial closures) reductions of the effort correspond to lower pressure on deeper strata.

Effects on the stocks

The effects of the new fishing effort pattern (as predicted by SMART after the estimation of the effort displacement) on the exploited stocks are summarized in Fig. 4.2.2.13. Concerning the Status quo, the closure of the coastal area is expected to determine a substantial reduction of fishing mortality for MUT and, to a smaller extent, for DPS. Conversely, the fishing mortality for HKE and ARS could increase when coastal fishing grounds are not accessible to the fleets. The reduction of the temporal activity (total annual fishing effort) leads to an important reduction of mortality for MUT, but less for the other stocks. If spatial and temporal measures are combined, positive effects can be detected for MUT and ARS, but also HKE and DPS if the effort reduction is high (i.e. 40%).

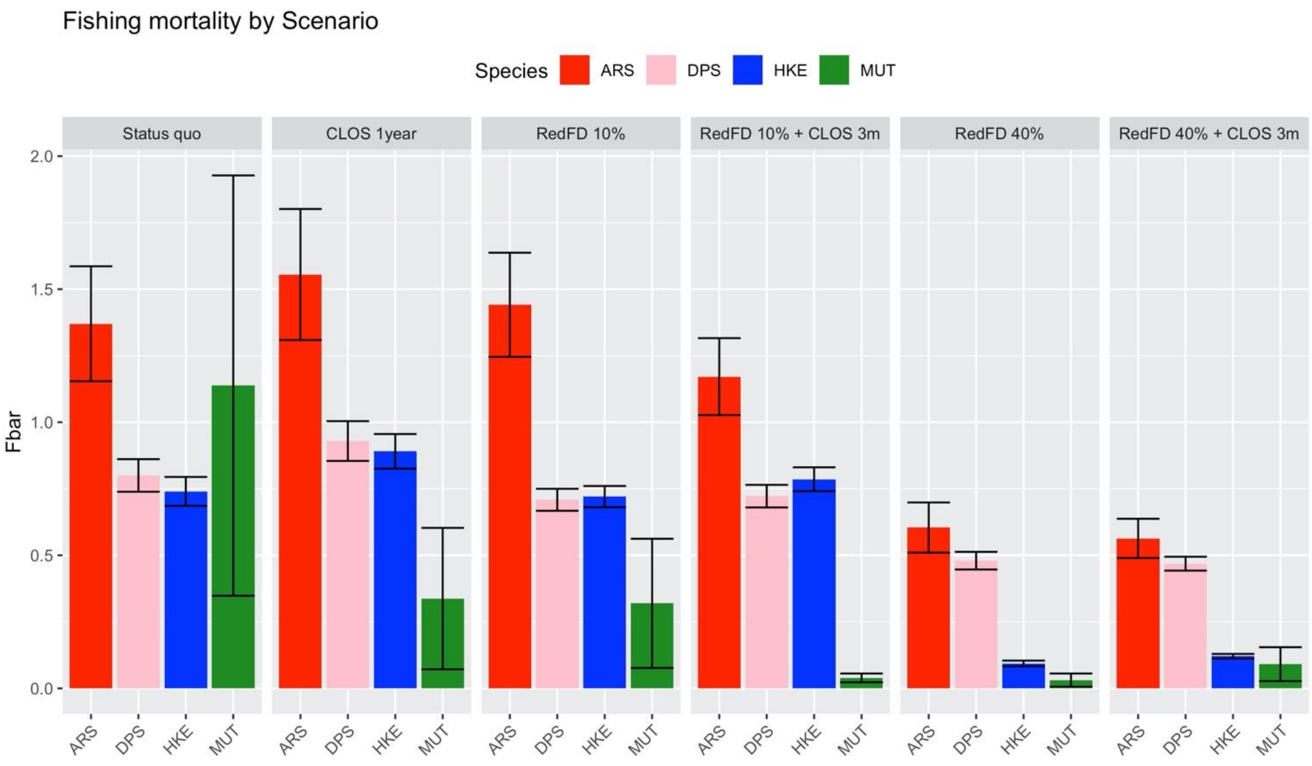


Figure 4.2.2.13 – Barplots of the effects of the new fishing effort pattern (as predicted by SMART after the estimation of the effort displacement) on Fbar estimates of the exploited stocks.

These effects can be better evaluated as overexploitation rate (F_{bar}/F_{MSY}) (Fig. 4.2.2.14). A condition of sustainable exploitation ($F_{bar}/F_{MSY} < 1$) occurs, for three of the four stocks (i.e. with the exception of ARS), with a 40% reduction of the total annual effort, while the 3 months closure seems to be substantially irrelevant.

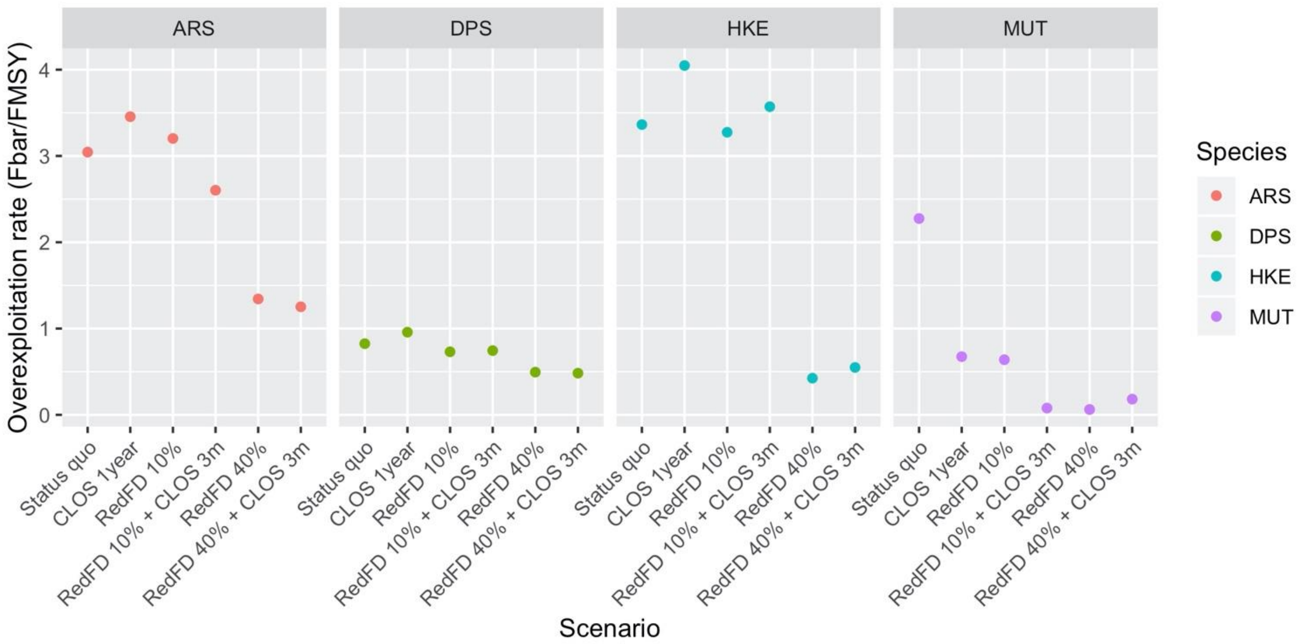


Figure 4.2.2.14 – Scatterplots of the the effects of the new fishing effort pattern (as predicted by SMART after the estimation of the effort displacement) on the overexploitation rate (F_{bar}/F_{MSY}) estimates of the stocks under evaluation.

It is important to stress that these values of F_{bar} are estimated in the first year of full implementation of each scenario. Thus, the long-term effects of each scenario were further estimated using the projection function of SMART model. The results are represented in Fig. 4.2.2.14. In summary, recovery is expected, in the medium term, for all the four stocks, but for the crustaceans (ARS and DPS), the second part of the trends is characterized by a decrease of SSB. This could be explained, in the case of DPS, with the effect of the predation by HKE. For ARS, it is important to stress that the ratio F_{bar}/F_{MSY} is still larger than 1 in all the inspected scenario. In this way, the planned measures should improve the status of this stock but do not allow it to reach sustainable exploitation.

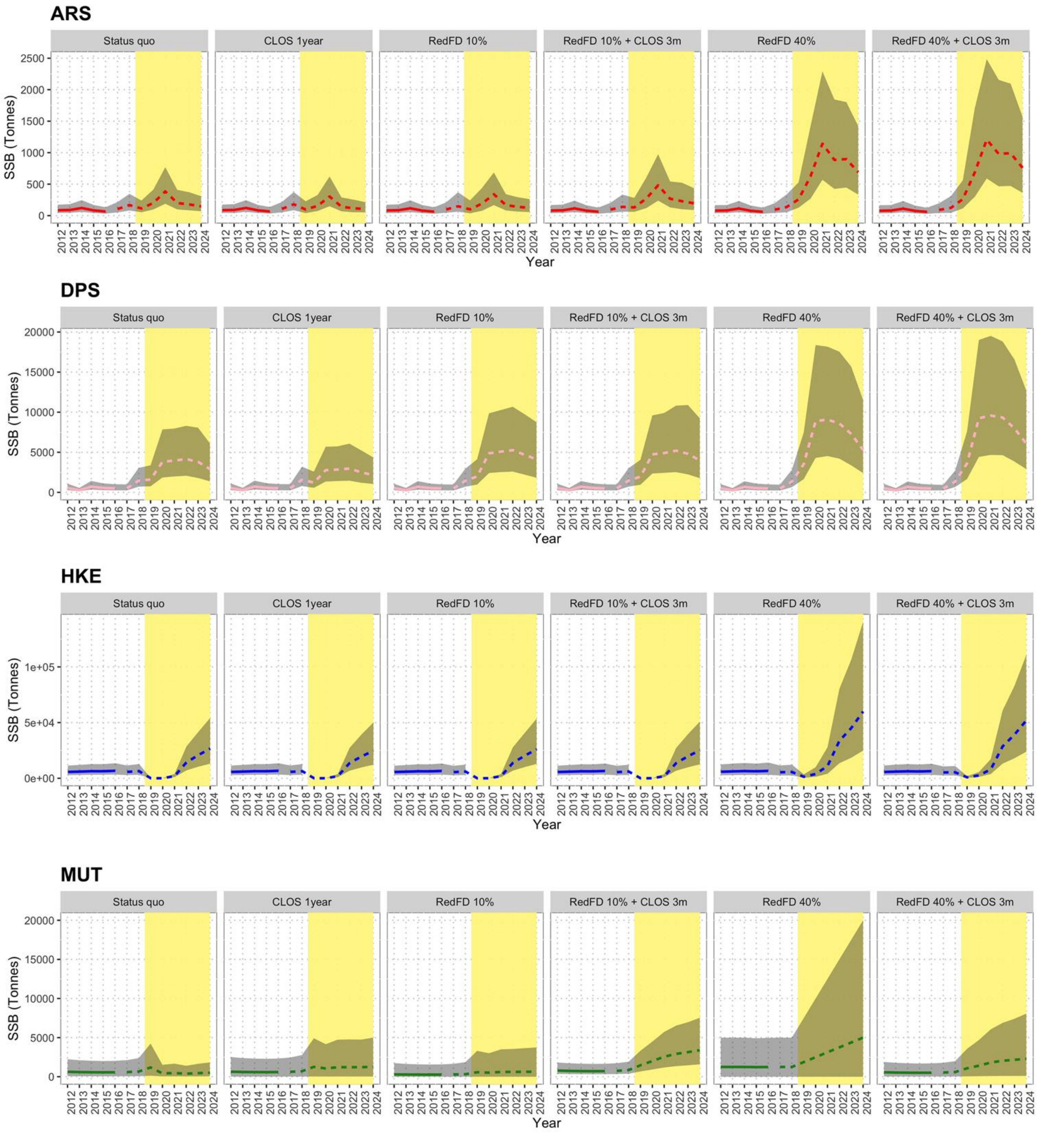


Figure 4.2.2.15 – Forecasted trends of Spawning stock biomass (SSB=) by species and scenario. The white background identifies the observed time series (years 2012–2018), while the yellow background corresponds to prediction (years 2019–2024). In the predictions, the dashed line marks the mean trend over 100 simulations, while the gray area corresponds to the standard confidence interval.

4.2.3 NIMED

As reported in the STECF EWG 19-01, a limitation encountered for producing scenarios simulations through the NIMED model was related to the need of data on catch at age by stock and fishing gear (at least for the most relevant ones) as model's input. Data provided from the stock assessments did not achieve this level of detail. Catch at age was provided by stock without the quotas from each fishing gear. During the EWG 19-01, the problem was overcome using an "equivalent effort" measure. However, this solution does not allow for estimating variations in fishing effort differentiated by fleet segment.

To simulate changes in fishing effort by fleet segment, during the EWG 19-14 the model was adapted by splitting the fishing mortality at age by fishing gear (OTB and "others"), where OTB is related to all fleet segments included in the fishing technique DTS (demersal trawlers) and "others" is related to the fleet segments defined as PGP (passive polyvalent). The splitting of the fishing mortality in two groups of vessels was based on the distribution of landings between the two fleets.

Using the fishing mortality differentiated by fishing gear, the model produces estimates of landings by stock for two fleets: vessels using OTB (predominantly) and vessels using other gears. Each of these fleets includes several fleet segments. A further distribution of landings among these fleet segments was based on the "equivalent effort" measure and assuming constant ratios between CPUE among the fleet segments using the same fishing gear (the same approach adopted during the EWG 19-01).

The model was updated also in relation of the data used and the stocks considered for simulation.

Transversal data (days at sea, landings in weight and value by stock) and data on capacity (number of vessels, GT and kW) for 2018 were added in the model, where data for that year was previously estimated. Furthermore, data from the last available stock-assessment were used in the new simulations. The data available allowed the number of stocks included in the model to be extended, and so the percentages of the total landing values simulated by the model.

Compared to the previous settings of the model, two new stocks were included in the model: Nephrops norvegicus (NEP) in GSA 9 and Aristeus antennatus in the combined GSAs 9, 10 and 11. The stocks included in the model are reported in the table below.

Table 4.2.3.1 – Stock included in the western Mediterranean MAP for the EMU 2 and simulated in NIMED

Common name	Scientific name	FAO code	GSAs	Model
European hake	Merluccius merluccius	HKE	(9-10-11)	Y
Red mullet	Mullus barbatus	MUT	9 - 10	Y - Y
Deep-water rose shrimp	Parapenaeus longirostris	DPS	(9-10-11)	Y
Norway lobster	Nephrops norvegicus	NEP	9 – 11	Y - N
Giant red shrimp	Aristaeomorpha foliacea	ARS	(9-10-11)	Y
Blue and red shrimp	Aristeus antennatus	ARA	(9-10-11)	Y

The fleet segments included in the model are those selected during the EWG 19-01. The next table reports the relevance of each fleet segment in terms of landings for each stock and the relevance of the 7 stocks simulated on the total revenues of each fleet segment.

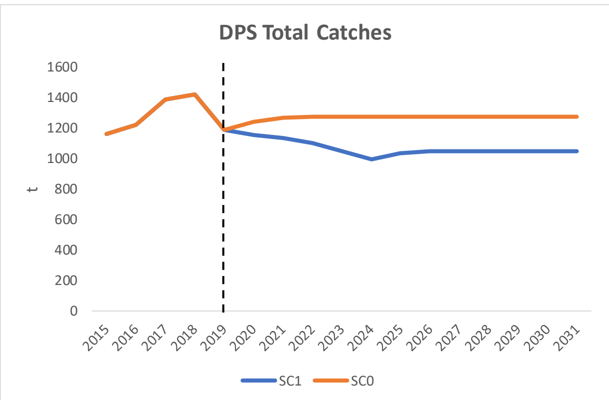
In 2018, the selected fleet segments contributed to the 93% of the total landings of European hake in the area (GSAs 9, 10 and 11), 99% of the total landings of red mullet in GSA 9 and 98% of total landings of red mullet in GSA 10. The landings of the other stocks included in the model are completely covered by the selected fleet segments. Even if the coverage of the total landings by stock is almost complete, the coverage of the total revenues by fleet segment is limited. The 7 selected stocks represent a percentage of the total revenues varying from 6% for the PGP VL1218 in GSA 10 to 67% for the DTS VL2440 in GSA 11. Clearly, a low percentage of revenues covered by the selected stocks produces also a low reliability of the simulated economic outcomes.

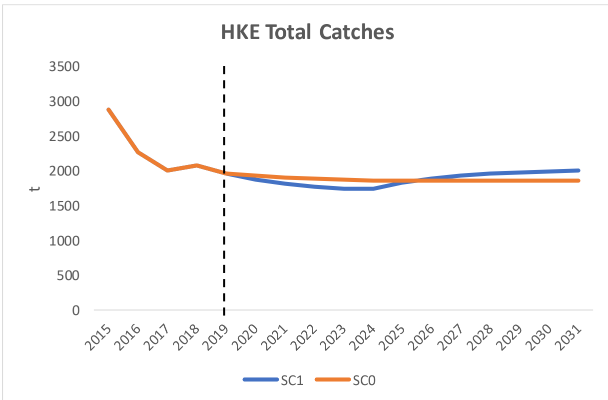
Table 4.2.3.2 – Coverage of total landings and total revenues in the NIMED model

GSA	Tech	LFT	HKE	MUT 9	MUT 10	DPS	NEP 9	ARA	ARS	Revenues
9	DTS	VL0612	0%	1%		0%	0%	0%	0%	16%
9	DTS	VL1218	7%	47%		21%	52%	8%	3%	40%
9	DTS	VL1824	14%	44%		32%	46%	7%	3%	40%
9	DTS	VL2440	2%	3%		2%	2%	0%	0%	31%
9	PGP	VL0612	5%	4%		0%	0%	0%	0%	8%
9	PGP	VL1218	6%	1%		0%	0%	0%	0%	19%
10	DTS	VL1218	5%		39%	18%		9%	22%	50%
10	DTS	VL1824	8%		40%	15%		18%	43%	53%
10	PGP	VL0006	2%		9%	0%		0%	0%	9%
10	PGP	VL0612	24%		10%	0%		0%	0%	19%
10	PGP	VL1218	0%		0%	0%		0%	0%	6%
11	DTS	VL1218	6%			3%		6%	3%	15%
11	DTS	VL1824	6%			3%		11%	6%	27%
11	DTS	VL2440	7%			7%		41%	21%	67%
COVERAGE			**93%**	**99%**	**98%**	**100%**	**100%**	**100%**	**100%**	

The model can simulate changes in fishing effort and selectivity, but it cannot be used to simulate areas closures or the achievement of optimal levels in terms of fishing mortality and/or harvest as it is not an optimization model. As a consequence, NIMED was used to simulate only two management scenarios under TOR 3: Status Quo (SC0: no change in fishing effort) and Scenario 1 (SC1: 10% reduction in fishing effort in 2020 and 7.5% reductions each year from 2021 to 2024 (a total of 40% effort reduction)).

The projections of total catches for each of the 7 simulated stocks are shown in Fig. 1. Except for HKE, a 40% reduction in the fishing effort of trawlers would produce a decrease in total catches. This reduction is expected to be stronger for ARA and ARS and quite limited for MUT (both in GSA 9 and 10). As reported in the EWG 19-01 report, the outputs of the NIMED model can be compared with outcomes from other models to highlight and analyse potential differences. However, the current version of NIMED uses constant recruitment (generally, the geometric mean of the last 3 years); while other models, like BEMTOOL, use stock-recruitment relationships. The different approach in the stock-recruitment relationships impacts significantly on the estimation of total catches by stock and consequently also on the economic outcomes.





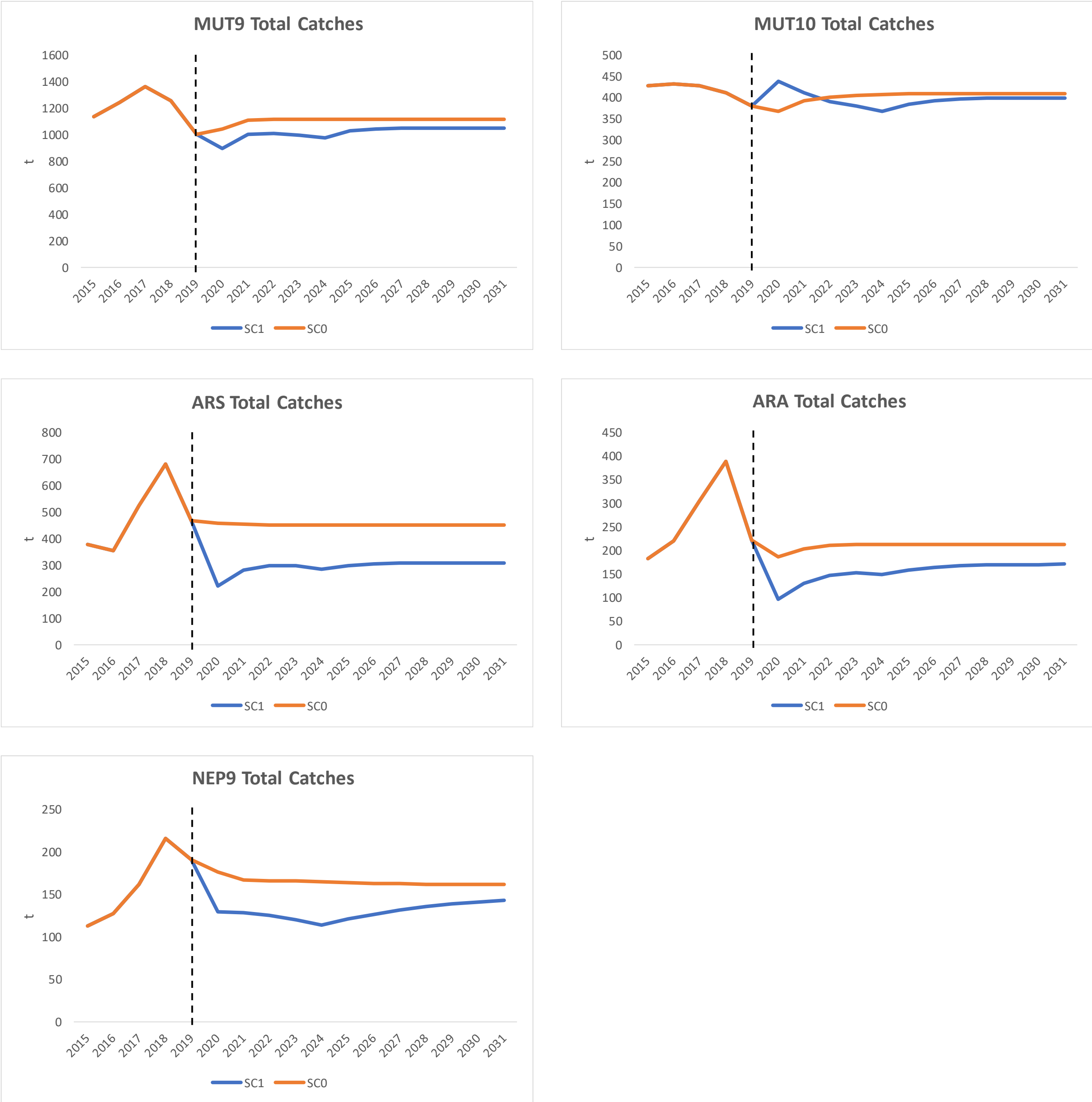


Fig. 4.2.3.1 – NIMED Projections of total catches by stock under scenarios 0 (baseline) and scenario 1 (40% reduction in fishing effort)

4.2.4 Relationships and complementarity between the models

As explained above in section 4.2.1, the two models SMART and BEMTOOL were coupled for running the scenario **RedFD_Clos.** SMART provided, for the fleets equipped with VMS, the frequency distributions in terms of: number of vessels operating within the depth range 50-100m and total number of vessels equipped with VMS, and number of days spent in the depth range 50-100m and outside this depth range, by month and GSA. The fleets which operated for at least 70% of their time in the depth range 50-100 m was considered. The effort spent in the depth range was evaluated around 10%. This value was used to calibrate the selectivity of the fleets in the scenario RedFD_Clos, using, in addition, the knowledge on the recruitment of the target species.

As reported in the section 4.2.1, for scenario RedFD_Clos_NursHKE the basis was to improve, in addition to the spatial closure, the exploitation pattern for European hake, introducing the closure of the nursery areas. This was implemented delaying the size at first capture of European hake from 9 to 15 cm in the months in which the recruitment of the species is higher, i.e. March, April, September and October. The basis of this setting was represented by the knowledge on the migration of hake post-recruits from the nursery hotspots to the surrounding areas, which take place when hake is about 15-16 cm total length (Lembo et al., 2000, Bartolino et al, 2008; Lembo et al., 2010). Given that in SMART a similar scenarios was not implemented and due time constraints we have not considered the effects of the possible relocation of the effort outside the nursery. However, considering the number of months with limited access to the nursery and according to the project SAFENET outcomes (deliverable 5.1 on spatial closure), the consequences of the effort displacement outside the nursery areas should be limited. These could be a matter of investigation in future EWG.

The NIMED model is independent and its results have not been compared to the other models.

5 REMAINING ISSUES AND FUTURE STEPS (TOR 4)

5.1 Issues important for the advice and the interpretation of the results

A major concern regarding the management of mixed demersal fisheries by effort limits is the uncertain relationship between fishing effort and fishing mortality, which implies that a reduction of fishing effort in terms of e.g. days at sea will likely not translate into an equivalent reduction of fishing mortality (an effect referred to as "hyperstability"). The main reasons for this are well documented (cf EWG 18-09). They are that i) there are great differences between the performances of individual vessels, with some vessels fishing more per day at sea than others (STECF EWG 18-09 showed for example that for some of the fleets covered by the MAP, the most efficient trips may be two to five times more efficient than the average trips within the same vessel length class). ii) when fishing effort is reduced, fishermen are incentivised to maintain their previous level of revenues and catches by becoming more efficient through tactical choices (where and when to fish) and technological investments (more powerful motor engine, larger gears). This will negate some of the expected reductions in fishing mortality, especially during the first years of effort reduction. These aspects have been thoroughly analysed and explained in EWG 18-09. Indeed, relationships between the available time series of fishing effort and fishing mortality were fitted for a number of the MAP stocks in EWGs 18-13 and 19-14, with no obvious patterns to be seen.

The consequence of this is that the true positive effects of effort reductions on the stock biomass remain unclear, and the scenarios presented above can be considered to be overoptimistic. Scenarios accounting for hyperstability were explored in BEMTOOL during EWG 19-01, but not pursued in EWG 19-14 due to time constraints. Such scenarios require a number of assumptions to be made in order to quantify a plausible alternative catchability value.

Bioeconomic models rely on modelling the population dynamics of fish stocks and the economic dynamics of fleets. In the case of multi-species fisheries, such as the western Mediterranean demersal fisheries, the number of fish stocks for which there are parameters to populate a population dynamics models are typically few. For instance, in EMU1 demersal fisheries produce of the order of 60 species in significant quantities, but only 5 are concerned by the Multi-Annual management Plan. These 5 species are, naturally, the main species in terms of landings and economic importance and stock assessments are regularly produced. However, they represent 20% or less (depending on the GSA) of the total demersal fisheries production. Hence the population dynamics of the majority of demersal stocks ("secondary species" or commercial bycatch) is not well-known and the effect of the effort reduction proposed in the MAP on these secondary species cannot be assessed with any accuracy.

5.2 Future steps

The analysis on F/EFF relationship with non-parametric techniques could be extended to other species.

here is a need to further develop the combined IAM model for EMU 1 and include more stocks. Including the MUT stocks is rather straightforward and the data are already available, but for other stocks this will be more time-consuming. It is worth noting that initiatives are being developed in Ifremer to include this work into broader research projects, the financing of which being still pending.

Beside, it is suggested that BEMTOOL and SMART could tentatively applied to EMU 1, in order to have a similar modelling approach. This would be a very interesting approach, but too comprehensive to be done in the frame of STECF EWGs, and options for engaging into this would need to be be discussed.

A number of remaining issues and model extensions have already been discussed in EWG 18-13 and 19-01, some of which are still to be addressed.

- The issue of different estimations of fishing effort in different databases is still pending (section 3.3 above). The sources of these inconsistencies are being investigated, and, to the extent possible, they will be corrected in next year's datacalls.
- The definition of mixed-metiers vs. Deep water metiers has not been discussed further. The discussion in EWG 19-01 section 11.2 are still pending.
- The issue of the multiple assessments of hake with different stock definitions should hopefully be solved in the coming GFCM hake benchmark (december 2019).

Simualting the effects of spatio-temporal closures in a medium-term projection is not straightforward, since many mixed-fisheries models (including the ones presented here but also the ones like FLBEIA discussed in EWG 19-01) are not spatially explicit. In the models used here (IAM and BEMTOOL) this was made by assuming fixed changes in the fleets selectivity and catchability. For IAM this was parameterised using current fishing patterns; In BEMTOOL this was made by using the outcomes of SMART analyses of effort reallocation. But many issues remain. Should other spatial analyses be required, alternative options to model these in a more integrated way should be discussed.

6 CONTACT DETAILS OF EWG-19-14 PARTICIPANTS

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

STECF members		
Name	Affiliation[1]	**Email**
MARTIN Paloma	CSIC, Barcelona, Spain	paloma@icm.csic.es
ULRICH Clara (Chair)	IFREMER, Nantes, France	clara.ulrich@ifremer.fr

Invited experts		
Name	Address	Email
ACCADIA Paolo	NISEA, Salerno, Italy	accadia@nisea.eu
BITETTO Isabella	COISPA, Torre al Mare (BA), Italy	bitetto@coispa.it
BILLET Norbert	IFREMER, Sete, France	norbert.billet@ifremer.fr
CERTAIN Gregoire	IFREMER, Sete, France	gregoire.certain@ifremer.fr
D'ANDREA Lorenzo	University of Rome of Tor Vergata, Roma, Italy	dandrea.lorenz@gmail.com
MERZEREAUD Mathieu	IFREMER, Centre de Bretagne, France	mathieu.merzereaud@ifremer.fr
MURENU Matteo	University of Cagliari, Cagliari, Italy	mmurenu@unica.it
PEREZ, Jose Luis	IEO, Spain	Joseluis.perez@ieo.es
ROMAGNONI Giovanni	COISPA, Torre al Mare (BA), Italy	romagnoni@coispa.it
RUSSO Tommaso	University of Rome of Tor Vergata, Roma, Italy	Tommaso.Russo@Uniroma2.it
SBRANA Mario	CIBM, Livorno, Italy	msbrana@cibm.it
SPEDICATO Maria Teresa	COISPA, Torre al Mare (BA) , Italy	spedicato@coispa.it

JRC experts		
Name	Affiliation[1]	**Email**
Alessandro Mannini Cecilia Pinto (focal)	JRC, Ispra, Italy JRC, Ispra, Italy	Alessandro.Mannini@ec.europa.eu Cecilia.Pinto@ec.europa.eu

European Commission		
Name	Affiliation[1]	**Email**
PINTO Cecilia (JRC secretariat)	JRC, Ispra (VA), Italy	Jrc-stecf-secretariat@ec.europa.eu

Observer		
Name	Affiliation[1]	**Email**
PIRON, Marzia	Mediterranean Advisory Council (MEDAC)	marzia_piron@hotmail.it

7 LIST OF BACKGROUND DOCUMENTS

Background documents are published on the meeting's web site on: http://stecf.jrc.ec.europa.eu/web/stecf/ewg1914

List of background documents:

EWG-19-14 – Doc 1 - Declarations of invited and JRC experts (see also section 7 of this report – List of participants)

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