JRC SCIENCE FOR POLICY REPORT

Scientific, Technical and Economic Committee for Fisheries (STECF)
-
Multiannual Plan for the fisheries exploiting demersal stocks in the Adriatic Sea
(STECF-19-02)

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Joint
Research
Centre

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 explores the effect of different decisions and management options, with regards to the implementation of a multiannual management plan for the Adriatic hake, red mullet, sole, deepwater rose shrimp, and spottail mantis shrimp stocks.

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TABLE OF CONTENTS

SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF) - Multiannual Plan for the fisheries exploiting demersal stocks in the Adriatic Sea (STECF-19-02)

Request to the STECF

STECF is requested to review the report of the STECF Expert Working Group 19-02, evaluate the findings and make any appropriate comments and recommendations.

STECF comments

EWG 19-02 was asked to assess the potential biological and socio-economic benefits of implementing several management options of a planned Multi-Annual Plan for the fisheries exploiting demersal stocks in the Adriatic Sea.

STECF notes that, despite the limited time available, an extensive work has been undertaken by the expert working group (EWG) to address this request. STECF considers that the quantitative analyses were carried out on the basis of the best currently available data, knowledge and models.

STECF notes however that due mainly to time constraints, the working group could not fully address the terms of reference. In particular:

Regarding ToR 2, no operating model was developed for the *Nephrops* stock in GSA 17-18 as the current assessment is performed using a production model not included in the MSE framework used by the working group, and as a consequence, this stock was excluded from the MSE (Management Strategies Evaluation) analysis. Owing to the importance of that resource for the demersal fishery of that area, it may be important, in any future analysis, to consider how to best include that stock, even with a simplified operating model. The work carried out within the EU project DRUMFISH could be useful in this regard.

For ToR 3, the scenario aiming at reaching Fmsy by 2020 and the analysis of hyperstability (when catch rates remain high while fish abundance is rapidly decreasing) were not carried out. Regarding the second point, no scenarios based on fishing effort regime by fleet segment were conducted and the simulations were directly based on fishing mortality adjustments. As already mentioned by STECF ([EWG 18-09](#)) however, the relationship between nominal effort and fishing mortality is not necessarily linear and any effort reductions may not lead to proportional reductions in fishing mortality. As a consequence, STECF agrees that the results of the simulations carried out by the EWG may be over-optimistic.

For ToR 4, the assessment of the spatial measures were only carried out for the stock of sole, since the spatial model available was parameterized for GSA 17 and the other stocks included in the request are distributed over a larger area (GSA 18 and GSA 19). Time constraint did not allow a re-parameterization of the model to include those areas.

The assessment of the potential socio-economic impacts of the management plan was also limited (cf ToR 1 below) as no economic models and/or indicators are currently included into the MSE framework used by the EWG.

ToR 1

STECF notes that the Management Strategies Evaluation (MSE) models developed in FLR and used by the EWG are single-stock and do not account for the potential technical interactions among the Adriatic Sea demersal mixed fishery.

STECF notes that although it was not possible to calculate the requested economic indicators within the MSE framework used by the EWG or to conduct mixed-fishery bio-economic analyses as in previous MAP evaluations conducted by STECF (STECF 15-04, STECF 15-08), the group did carry out some preliminary analyses. A comparison of landings in weight submitted to the Mediterranean and Black Sea Data Call and Fleet Socio Economic Data Call showed a better consistency between the two databases than what was observed in the MAP assessment in the Western Mediterranean Sea (STECF 18-09).

Using a bio-economic simulation model (NIMED, cf STECF EWG 18-09 and 18-13), several economic indicators were calculated for the baseline status-quo scenario and two are presented in the report (GVA and salary). STECF notes that there are no differences between the trend of GVA and salaries. The segment SVN-DTS is also making losses during the whole assessment period. Those "stable" developments are due to the fixing of some parameters (like the number of vessels) during the assessment period. STECF notes that this is a strong assumption, since the number of vessels would be expected to decrease in case of ongoing losses over a long period.

The economic dependency on the stocks considered in the management plan and the contribution to total landings by fleet were also reported. These analyses provide useful insights on the potential socio-economic impacts the management measures may have on the Adriatic sea demersal fleets. Among the 99 fleet segments at gear level analyzed, 22 have a dependency above or equal to 50% on the species selected for the MAP. The analysis also shows that some fleets such as the Italian and Croatian DTS (demersal trawls and seines) are dependent upon several of the species from the MAP while others, such as the Italian TBB (beam trawlers), depend on only one species (sole in that case).

STECF notes however that the bio-economic analyses carried out by the working group are limited and still preliminary. STECF considers that further work based on mixed fishery bio-economic modelling and consultation with stakeholders would be needed to better understand the socio-economic implications of the proposed Multiannual Plan,

ToR 2

STECF notes that the operating models were conditioned based on the most recent stock assessments available, and this was discussed with GFCM's secretariat to make sure that the correct models were used. Regarding red mullet and hake, alternative stock assessment fits were used to derive OM's uncertainty, to overcome the large uncertainties estimated by MCMC of official assessments. STECF considers that this "ad hoc" approach is acceptable owing to the time constraints faced by the working group but that further work may be needed in the future to better understand what are the main drivers of the uncertainties associated with stock assessments in general terms.

More generally, STECF agrees with the EWG that due to the large uncertainties associated with the stock assessments, the results have to be taken with care and considered only as indicative.

STECF notes that some robustness tests have been included into the analyses, by testing alternative stock recruitment relationships for hake, red mullet and sole, alternative natural mortality for mantis shrimp and alternative landings and discards data for hake. STECF notes that for mantis shrimp, the working group considered that it was preferable to conduct robustness

tests on natural mortality rather than on the stock-recruitment relationship, for which no satisfactory model could be selected.

STECF observes that, with the exception of red-mullet, the exploitation rate is largely above the MSY target and that bringing those stocks to FMSY levels requires a substantial reduction of fishing mortality. STECF notes thus that those stocks would benefit from the implementation of a MAP aiming at aligning the exploitation rates with the CFP objectives.

ToR 3

STECF notes that while the baseline scenario (status quo) can lead to having the spawning stock biomass below B_{lim} with more than 5% probability at short and longer term for the stocks of deep water rose shrimp, mantis shrimp and hake, the other scenarios tested (Fmsy2024 and FIXREDUX) lead to probabilities close to zero for all stocks.

STECF notes that the management options that reaches F_{msy} in 2024 using a linear decrease from 2019 onwards (Fmsy2024) performs better than the FIXREDUX option, with a lower probability of the spawning stock biomass falling below B_{lim}, a higher probability of reaching the target fishing mortality F_{msy} and more stable catches. Keeping a high exploitation level until 2021 before decreasing fishing mortality as done in FIXREDUX, leaves a shorter period to reduce F (4 years instead of 6) forcing larger annual decreases.

Overall, the management options tested lead, in the long term, to rather low probability of achieving a fishing mortality rate within +/- 20% of F_{MSY}. This is particularly the case for hake for which this probability is 0.10 in the Fmsy2024 scenario and 0.05 in the FIXREDUX scenario. As highlighted by the EWG, this result is partly due to some cyclical patterns observed in the projections. Imposing a catch limit for sole tend to slightly improve the performance of the management measures by attenuating this cyclical pattern.

From additional projections carried out by the EWG, STECF notes that the advisory process of GFCM which implies a 3 years delay between a stock assessment and the implementation of the management decision could be the main driver of the fluctuations in fishing mortality and other indicators observed in the MSE projections. These fluctuations have a negative impact on the resulting probability to reach the Fmsy target, probably leading to larger decrease than otherwise needed.

STECF notes that long-term (2031-2035) projections for hake, sole, spot-tail mantis and red mullet, should be taken with care. Over that period, SSBs is simulated to raise outside the range of historical observations, while fishing mortality is simulated to reach lower levels than historical estimates. At these projected levels of high SSB and low F, the actual dynamics of the stocks is unknown. This may introduce an extra level of uncertainty in the results which was not possible to quantify.

STECF notes that for hake, spot tail mantis shrimp and red mullet, the use of alternative operating models do not alter the main conclusions drawn from the simulations. For sole, the alternative assumption about the stock recruitment relationship has an important impact on the stock assessment and the perception of the stock status, resulting in a larger stock and lower fishing mortalities. This leads to very different starting values of F/Fmsy from the base case operating model.

ToR 4

STECF notes that to test the effects of spatial management measures, a bio-economic spatial model (DISPLACE) was linked to the MSE algorithm through the integration, in the spatially

aggregated MSE model, of changes in F at age resulting from the Fisheries Restricted Areas (FRA) implementation estimated with the spatial model. STECF notes that the working group followed this combined approach because the DISPLACE model does not include a full feed-back loop (i.e., does not include an observation model which generates observations that are used as input to the assessment model and associated short-term forecast). STECF understands that the so called "shortcut approach" where the observation and assessment errors are substituted with a stochastic process matching the stock assessment error structure can substantially underestimate the actual uncertainty, but acknowledges that further work would be needed to fully integrate DISPLACE in the Operating Model (OM).

ToR 5

Regarding the persistence analysis, some areas of high concentration of adults, juveniles and the overlap of the two were identified. However, the selected threshold of 50% used to identify high persistence was found to be inappropriate as half of the overall spatial distribution of the population of each species of interest was selected. The resulting areas may thus be of limited use to set fishing gear restrictions in the context of marine spatial planning. STECF agrees that more work is needed regarding that ToR which could be done by testing a series of larger threshold values.

STECF conclusions

STECF endorses the general conclusions and recommendations from the EWG.

With the exception of red-mullet, the exploitation rates of the stock listed in the Multi-Annual Plan are largely above the MSY target and those stocks would thus benefit from the implementation of the MAP aiming at aligning the exploitation rates with the CFP objectives.

From the results of the simulations carried out by EWG 19-02, STECF concludes that implementing a reduction of fishing mortality on the basis of the proposed options would lead to a very low probability of having the SSB falling below B_{lim} for all stocks selected. Regarding fishing mortality however, the probabilities to reach F_{MSY} and stay around it in the longer term would be rather low. STECF notes that a linear decrease from 2019 onwards (Fmsy2024) would perform better than the FIXREDUX option.

Due to time constraint, the EWG was only able to conduct very preliminary bio-economic analyses of the Multi-Annual Plan which provides a limited insight of the impact of the plan on the fishery. STECF considers that further work could be envisaged on the parameterization of a mixed fishery bio-economic simulation model to better assess the potential impacts the management measures may have on both the stocks and the fleets exploiting them. Such analyses would also permit better accounting for the technical interactions and the mixed-species nature of the fishery. Despite those limits, the analyses of the economic dependency on the stocks considered in the management plan and of the contribution to total landings by fleet provide useful information on the potential socio-economic impacts on the Adriatic sea demersal fleets.

It was not possible during the EWG, to simulate some management procedures controlling the fishing mortality via fishing effort and to test the effect of hyperstability. STECF reiterates its previous comment on the challenges in the use of fishing effort regimes as a management tool for mixed fisheries as reported in PLEN 17-02, PLEN 18-01, STECF 18-09 and STECF 18-13.

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REPORT TO THE STECF

EXPERT WORKING GROUP ON
Multiannual Plan for the fisheries exploiting demersal stocks in the Adriatic Sea
(EWG-19-02)

Ispra, Italy, 1 - 5 April 2019

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

EXECUTIVE SUMMARY

STECF was requested to test the performance of HCRs for Adriatic sea stocks of hake, sole, deep water rose shrimp, red mullet, Nephrops and spottail mantis shrimp. The HCRs were based in (i) effort management and catch limits for sole and Nephrops, (ii) two options of intermediate period effort reductions and (iii) two options of spatial management, the sole sanctuary and 6nm closures. Additionally STECF was required to estimate areas of high persistence of adults ort juveniles for the same stocks.

The ToR were addressed to the best knowledge and data available. The short time interval between the ToR's publication and the meeting limited the amount of work done. The quantitative analysis was carried out following the best modelling practices. In Annexes 1 to 4 the models used by the EWG are described.

A Management Strategies Evaluation (MSE) algorithm developed in FLR and a4a (Annex 2) was used to run the scenarios requested by the ToRs. A set of robustness scenarios were added when relevant. These scenarios were stock specific and dealt with potential uncertainties in dynamics' assumptions.

Baselines for all stocks were built by running projections up to 2035 with a target F equal to F status quo, which was computed by the average F of the most recent 3 years in the assessment.

Fisheries and biological indicators were computed for all scenarios in three time periods, short term (2018-2024), long term (2025-2035) and equilibrium (2031-2035). Where relevant confidence intervals were also computed.

With relation to the economic indicators only GVA and salary were reported for the baseline scenarios. Additionally economic dependency on MAP stocks and contribution to total landings, by fleet, were also reported.

Operating models (OM) were conditioned based in the most recent stock assessments. The selection of stock assessments was discussed with GFCM's secretariat to make sure the correct models were used. In most cases it was possible to keep the original model, with the exception of hake which required a a4a model to mimic the original stock assessment. The reference points used were obtained from the original stock assessment reports.

The scenarios were coded to accommodate the management options required. The harvest control rule was set as:

1) if y+d >= 2024 then $F_{y+d} = F_{MSY}$

2) else if FIXREDUX = TRUE and

    a. y = 2018 then $F_{y+d} = F_{SQy} \times 0.9$

    b. y = 2019 then $F_{y+d} = F_{SQy} \times 0.92$

3) else $F_{y+d} = F_{SQy} \times (1-w) + F_{MSY} \times w$

where

    $w = 1 - 1/(2023-y)$

    $F_{SQy} = (F_{y-1} + F_{y-2} + F_{y-3})/3$

d is the management lag, set to 2

implemented with a 1 year data gap and 2 years management lag.

To test the effects of spatial management measures the bio-economic spatial model DISPLACE was linked to the MSE algorithm through the changes in F at age simulated by the spatial model under each of the Fisheries Restricted Areas (FRA) described in the ToRs. The spatial model was parametrized for GSA 17 and the EWG decided to test effects in Sole only (scenarios i and iv), since the other stocks spatial distributions included GSA 18, and 19 in the case of deep water rose shrimp.

The scripts referred to in the ToRs were used to run this analysis. Some small changes in the methods were required to include 2018 data.

Effort strategies miss the target in all cases except for red mullet, forcing larger reductions than needed due to the management lag cyclical effect. In FIXREDUX this effect is more pronounced. Catch limits for sole show a better performance than their effort analogous with smaller cyclical effects. The probability of SSB falling below Blim shows a similar pattern, decreasing fishing mortality reduces risk close to 0.

Zooming into 2024, the probability of falling below Blim and probability of being within 20% of the target fishing mortality in 2024, show that the FIXREDUX strategy (Fmsy24FR) has a poorer performance than immediate linear reductions (Fmsy24). The FIXREDUX strategy forces a larger yearly reduction in F, since it tries to achieve the target in 4 years instead of 6, which introduces a larger cyclical effect. In terms of protecting SSB both strategies reduce the probability of falling below Blim close to 0.

It is important to bear in mind that uncertainty is very large and, as such, these results should be taken as indicative only.

The quality of the assessments available to condition the OMs is limited due to the short time series of data available and the usage of complex assessment models setups. Both issues end up generating estimates with large uncertainty that propagates throughout the MPs' application expanding over time.

With the exception of red mullet, the stocks analysed are strongly overexploited, which means that bringing those stocks to F_{MSY} levels requires a substantial reduction of fishing mortality.

Robustness tests showed that hake, spottail mantis shrimp and red mullet alternative OMs do not deteriorate HCRs' performance, while in the case of sole alternative assumptions about the stock recruitment relationship have a large impact in the current perception of stock status and the HCRs performance.

Long-term results for hake, sole, spottail mantis and red mullet, should be taken with care. In this period, SSBs are driven outside the observation's range, while fishing mortality is set to lower limits than historical estimates. At these levels of SSB and F stock dynamics are unknown, introducing an extra level of uncertainty in the results not possible to quantify.

The effort HCR introduces fluctuations in fishing mortality, which propagates to other variables. This cyclic behavior results from the gap between the assessment results, our perception of the stock status, and the implementation of management decisions. In this case made with 2 years of interval. On the other hand, the 2 year lag in management and 1 year gap between data and assessment, results in management decisions been taken for 3 years after the stock was assessed. In cases where catches of ages 0 to 2 are large the individuals relevant for fishing are unlikely to still exist when the management actions are applied.

Reducing the management lag from 2 to 1 year would improve the potential success of the MAP. By reducing the distance between the perception of the stock, which is used to make the management decision, and the application of such decision, part of the uncertainty introduced in

the exploitation of the stock could be removed. Furthermore, it would reduce the probability of missing the target by reducing F below the objective.

In general, the HCR that reaches Fmsy in 2024 using a linear decrease from 2019 onwards performs better than the FIXREDUX option, showing smaller probabilities of stock collapse, larger probability of reaching the target fishing mortality and providing more stability to the catches. Keeping a high exploitation level until 2021 before decreasing fishing mortality, leaves a shorter period to reduce F forcing larger annual decreases which propagate into inter-annual catch variability and more uncertain outcomes.

Hyperstability was not tested due to time constraints nevertheless it's well known that fishing mortality does not have a linear relationship with effort (STECF 2018a). Thus, it is expectable that during the initial period of effort reductions, reductions in fishing mortality are not observed. Consequently, current simulations may be over-optimistic.

The 6nm closure combined with effort reductions seems to amplify F reductions and improve SSB levels, while the "sole sanctuary" improves SSB levels without improving F. It is important to note though, that if changes in selectivity are effective, Fmsy should be recomputed to take into account those changes.

The persistence analysis identifies some areas of high concentration of adults, recruits and the overlap of the two. Nevertheless, the threshold of 50% to identify high persistence is not appropriate and ends up identifying half of the sites instead of picking sites with extraordinary abundances. The EWG considered a larger value, e.g. 75%, could be more appropriate in future work.

A full mixed fisheries bio-economics set of tests were not possible to carry out. Nevertheless, the different sources of information required showed a better consistency than in other MAP analysis.

The dependency analysis showed a maximum of 22 fleets with more than 50% economic dependency on MAP's stocks, flagging cases where relevant impacts from MAps implementation may occur. Additionally, the contribution of each fleet to total stock's landings in weight was also computed.

The implementation system was coded through yearly changes in fishing effort, in line with GFCMs practices. In alternative, a reduction by year from a baseline value can be used. In such case it would be paramount to build some check points, every two years for example, to assess if these reductions are effectively controlling fishing mortality.

1 INTRODUCTION

1.1 Background

The Adriatic Sea is the most important FAO fishing area in the Mediterranean Sea in terms of both landings and size of the fleets.

Demersals (i.e. 35000 tons in 2016) make up 25% of the landings in the Adriatic. As for the small pelagics MAPs the EU Member States (MS) are responsible for the majority of the landings in the area with Italy, Croatia and Slovenia contributing to the 90 % of the demersal landings. Albania and Montenegro share respectively 10% and less than 1% of the demersal landings.

There is no management in place in the Adriatic, under GFCM, to control fishing mortality on a yearly basis and in line with scientific advice. Limited spatio-temporal measures are implemented both in Italy and Croatia and since 2017 the Pomo/Jabuka Pit FRA was established to protect juveniles of Hake and Norway lobster.

The most important demersal stocks in the Adriatic Sea are overfished and some are at a low biomass level. Overexploitation causes a significant loss in yield, which damages fleets profitability.

There is a large overcapacity problem coupled with a shallow sea bottom area, which leads to very limited refuge for fish stocks from actively towed gears. The Adriatic Sea is classified as the EU area with the highest trawling footprint, identified as the area where 86% of the bottom surface is trawled with a high trawling frequency.

GFCM Scientific Advisory Committee has been tasked in 2018 to develop the scientific elements for an Adriatic demersal management plan to be adopted at GFCM level in 2019. The work under these TORs will be a contribution also to the SAC to facilitate the identification of the best possible management strategies.

A management strategy evaluation is requested to evaluate trade-offs and different performance indicators of a portfolio of management options ranging from input/output strategies, technical measures and different implementation time frames.

The key commercial stocks for a demersal MAP have been previously identified by STECF EWGs and are also listed under GFCM SAC key priority stocks.

1.2 ToR

For the stocks given in Table 1.2.1, the EWG 19-02 is requested:

ToR 1. Assess the likely biological and socio-economic benefits, against a baseline status quo scenario, of implementing the management options described in the following TORs 1-5, with priority to the most important scenarios included in TORs 1-3. To test the management options use the established approach implemented in previous EWGs (STECF 2015, 2016, 2018b) based on the FLR framework (Kell et al. 2007).

For each scenario, STECF-EWG 19-02 is requested to run the appropriate forecast models in order to describe the likely situation of the fisheries up to 2035 and using the indicators given below:

- Fisheries indicators: fishing mortality relative to Fmsy (F/Fmsy)

- Biological indicators: abundance (SSB and total biomass), recruitment, probability of SSB falling below Blim, Risk vs catch level, Catch variability, Average catch

- Socio-economic indicators: GVA, salary and employment, in line with the methodology outlined in STECF 16-21 (STECF 2016) or on the basis of different viable approaches.

TOR 2. Operating Model

Identification of stock assessments:

a) The biological operating model (OM) for the MSE shall be conditioned using the assessment results from the most updated stocks assessment produced by GFCM WGSAD and were necessary complemented by STECF assessments to account for stock assessment model uncertainty in the OM. The EWG shall give preference to models that allow estimation of uncertainty, in line with the recommendations of SAC and STECF EWG 17-07 (STECF 2017a).
b) In the operating model evaluate alternative recruitment models (SR).
c) Use reference points from the stock assessments

TOR 3. Management Procedure A

For the Management Procedure (MP) test the following management scenarios:

a)   Under the different MPs exploitation levels of all key stocks shall reach the maximum sustainable yield (Fmsy) by:
i.   2020 (**Fmsy2020**),
ii.   2024 (**Fmsy2024**),
iii.   Reduction of fishing mortality by 10% in 2020, 8% in 2021, and then linear reduction in F to achieve Fmsy by 2024 (**FIXREDUX**).
b)   Simulate the management mechanism to mimic the advisory process of GFCM SAC and timing for adoption of management measures in GFCM, which operates on a N+2 basis.
c)   Develop two management procedures for controlling F:
     A fishing effort regime (**EFFORT**), operating on relevant fleet segments, to be applied to all key stocks, and within this scenario evaluate the effects of presence/absence of hyperstability as defined and modelled in STECF 16-21 (STECF 2016) (**HYPER**).
     A catch limit scenario to be applied exclusively for the stock of Common sole and Norway lobster (**CATCHLIM**).

TOR 4. Management Procedure B

Assuming that the effects of the Pomo/Jabuka Pit FRA are already accounted for in the most recent stock assessments and that this FRA will remain in place for the duration of the management plan, evaluate the effect of theoretical additional protection of nursery and spawning areas as follows:

i.   For the stock of common sole simulate the effect of the implementation of a FRA divided in two areas: (a) one on the polygon identified as area of high persistence in front of the Venice lagoon in Figure 4 B in Scarcella et al. (2014) and (b) according the polygon of Fig 1 proposed for the sole sanctuary in Bastardie et al. (2017) (**FRA**).
ii.   For Norway lobster simulate the effect of the establishment of a FRA protecting 20% of the area of high persistence of spawners (**FRA**).
iii.   For European hake, simulate the effect of the establishment of a FRA protecting 20% of the area of high persistence of spawners (**FRA**).
iv.   Evaluate the effect of the closure of the coastal zone up to 6 nautical miles to all active towed gear (OTB and TBB) (**6NM**)

ToR 5. Areas of high spatial persistence of key stocks

Since protection of juvenile and adult spawners life stages can contribute to reduce fishing mortality and improve stock status, identification of the areas of high persistence can support management decision to manage some of these areas with fishing gear restricitons and in the context of marine spatial planning.

For stocks in Table 1.2.1, using the high density persistence analysis and R scripts developed in STECF EWG 17-15 (STECF 2017b), provide detailed maps for GSA 17-18 of:

a) The high persistence areas of 1st year juveniles:
b) The recurrent spawning aggregations areas.
c) Analyse the percentage of overlapping of juveniles and adults persistent areas, by individual stocks and across all stocks in Table 1.2.1, to explore the viability of the fisheries if managed trying to avoid either juveniles or spawners.

MEDITS data covering the longest time series as possible should be used and where appropriate (for *Solea solea* and possibly other stocks) SOLEMON data.

Table 1.2.1 List of stocks to be evaluated by the EWG 19-02.

Area	Common name	Scientific name
GSA 17-18	Hake	*Merluccius merluccius*
GSA 17-18	Red mullet	*Mullus barbatus*
GSA 17-18	Norway lobster	*Nephrops norvegicus*
GSA 17-18-19	Deep-water rose shrimp	*Parapenaeus longirostris*
GSA 17	Sole	*Solea vulgaris*
GSA 17-18	Spottail mantis shrimp	*Squilla mantis*

1.3 Addressing the ToRs

For The ToR were addressed to the best knowledge and data available. The short time interval between the ToR's publication and the meeting limited the amount of work done, in particular:

- The stock of Nephrops in areas 17-18 was not analyzed. This stock was assessed with a biomass production model (SPICT) which requires an alternative approach to condition the operating model.
- Runs with the target of achieving Fmsy in 2020 were not run due to time limitations and the fact that there's only one more year to 2020. The results of these scenarios would be mostly driven by assumptions made for 2018 and 2019.
- The analysis of hyperstability wasn't carried out.
- The spatial measures were carried out for Sole only, since the spatial model available was parametrize for GSA 17.
- The economic analysis was limited, since the model available was not linked with the MSE results and the MSE is single species.

The quantitative analysis was carried out following the best modelling practices. In Annexes 1 to 4 the models used by the EWG are described.

1.3.1 ToR 1

A Management Strategies Evaluation (MSE) algorithm developed in FLR and a4a (Annex 2) was used to run the scenarios requested by the ToRs. A set of robustness scenarios were added when relevant. These scenarios were stock specific and dealt with potential uncertainties in dynamics' assumptions.

Baselines for all stocks were built by running projections up to 2035 with a target F equal to F status quo, which was computed by the average F of the most recent 3 years in the assessment.

Fisheries and biological indicators were computed for all scenarios in three time periods, short term (2018-2024), long term (2025-2035) and equilibrium (2031-2035). Equilibrium and long term are terms used to distinguish the period without influence of shifts in exploitation level created by management actions, equilibrium, from the period where this influence is still having impact in performance statistics, long term. Where relevant confidence intervals were also computed.

With relation to the economic indicators only GVA and salary were reported for the baseline scenarios. Employment, which is simulated through a linear function of the number of vessels, was not reported because it is assumed to be constant over time as well as the number of vessels. Additionally economic dependency on MAP stocks and contribution to total landings, by fleet, were also reported.

1.3.2 ToR 2

Operating models (OM) were conditioned based in the most recent stock assessments. The selection of stock assessments was discussed with GFCM's secretariat to make sure the correct models were used. Table 1.3.2.1 shows the stock assessments and their sources. In most cases it was possible to keep the original model, with the exception of hake which required a a4a model to mimic the original stock assessment, in agreement with the hake benchmark suggestion.

Table 1.3.2.1 Assessment sources and structural uncertainty used to build the base case operating model and alternative operating models, respectively

Stock			Base case			Structural uncertainty			
Area	Common name	Scientific name	Model	Year	WG	S/R	M	ALB landings	Discards
GSA 17-18	Hake	*Merluccius merluccius*	SS3	2019	GFCM benchmark	x		x	x
GSA 17-18	Red mullet	*Mullus barbatus*	a4a	2018	STECF + GFCM	x			
GSA 17-18	Norway lobster	*Nephrops norvegicus*	Spict	2018	STECF + GFCM				
GSA 17-18-19	Deep-water rose shrimp	*Parapenaeus longirostris*	a4a	2018	STECF + GFCM				
GSA 17	Sole[1]	*Solea vulgaris*	SS3	2018	STECF	x			
GSA 17-18	Spottail mantis shrimp	*Squilla mantis*	a4a	2018	STECF + GFCM		x		

[1]GFCM assessment is from 2017, STECF's 2018 is an update (including the same growth data).

Alternative stock recruitment models were included when relevant. It was not possible to adjust both models suggested for all stocks, in which cases and alternative was used or none.

The reference points used were obtained from the original stock assessment reports (Table 1.3.2.2).

Table 1.3.2.2 Current F (Fcurr) and FMSY for the five stocks investigated here.

	Stock		Exploitation	
Area	Common name		Fcurr	FMSY
GSA 17-18	Hake		0.56	0.17
GSA 17-18	Red mullet		0.48	0.41
GSA 17-18-19	Deep-water rose shrimp		1.69	0.65
GSA 17	Sole[1]		0.65	0.24
GSA 17-18	Spottail mantis shrimp		1.04	0.41

[1]GFCM assessment is from 2017, STECF's 2018 is an update (including the same growth data).

1.3.3 ToR 3

The scenarios were coded to accommodate the management options required. The harvest control rule was set as:

1) if y+d >= 2024 then $F_{y+d} = F_{MSY}$
2) else if FIXREDUX = TRUE and
    a. y = 2018 then $F_{y+d} = F_{SQy}$ x 0.9
    b. y = 2019 then $F_{y+d} = F_{SQy}$ x 0.92
3) else $F_{y+d} = F_{SQy}$ x (1-w) + F_{MSY} x w

where

$w = 1 – 1/(2023-y)$

$F_{SQy} = (F_{y-1} + F_{y-2} + F_{y-3})/3$

d is the management lag, set to 2

Implemented with a 1 year data gap and 2 years management lag. In detail, the decisions made in year *y* are based in data up to year *y-1* and set the management action for year *y+2*. Such approach requires a short term projection of 2 years, which was done considering in the intermediate years F to be set at F status quo levels and recruitment to be at the level of the geometric mean over the whole period.

As mentioned above scenarios to set F at Fmsy levels in 2020 and hyperstability tests were not carried out.

1.3.4 ToR 4

To test the effects of spatial management measures the bio-economic spatial model Displace (Annex 1) was linked to the MSE algorithm through the changes in F at age simulated by the

spatial model under each of the Fisheries Restricted Areas (FRA) described in the ToRs. Changes in F were introduced in a single year, 2020, and as such only long term results can be considered.

As mentioned above the spatial model was parametrized for GSA 17 and the EWG decided to test effects in Sole only (scenarios i and iv), since the other stocks spatial distributions included GSA 18, and 19 in the case of deep water rose shrimp.

1.3.5 ToR 5

The scripts referred to in the ToRs were used to run this analysis. Some small changes in the methods were required to include 2018 data.

To estimate high persistence areas for sole and mantis shrimp a data request was sent to Italy, Croatia and Slovenia, which was accepted by the Member States.

The EWG provided analysis using the threshold of 50% as applied by EWG 17-15, nevertheless the EWG considered that a higher threshold, 75%, could be used to better identify abundance high persistent areas.

The code and data used in the analysis is available upon request.

2 ECONOMIC ANALYSIS

2.1 Comparing the economic and assessment datasets

During the EWG a comparison of landings in weight submitted to the Mediterranean and Black Sea Data Call and Fleet Socio Economic Data Call was carried out. Data by year, country, area, gear and species were compared to check if data were the same or at least in the same order of magnitude. Comparisons covered the period 2008-2017. A linear relationship was expected whether data were the same. Figure ; Figure 2.1; Figure 2.1..3 and Figure 2.1.4 depict the relationships in the data.
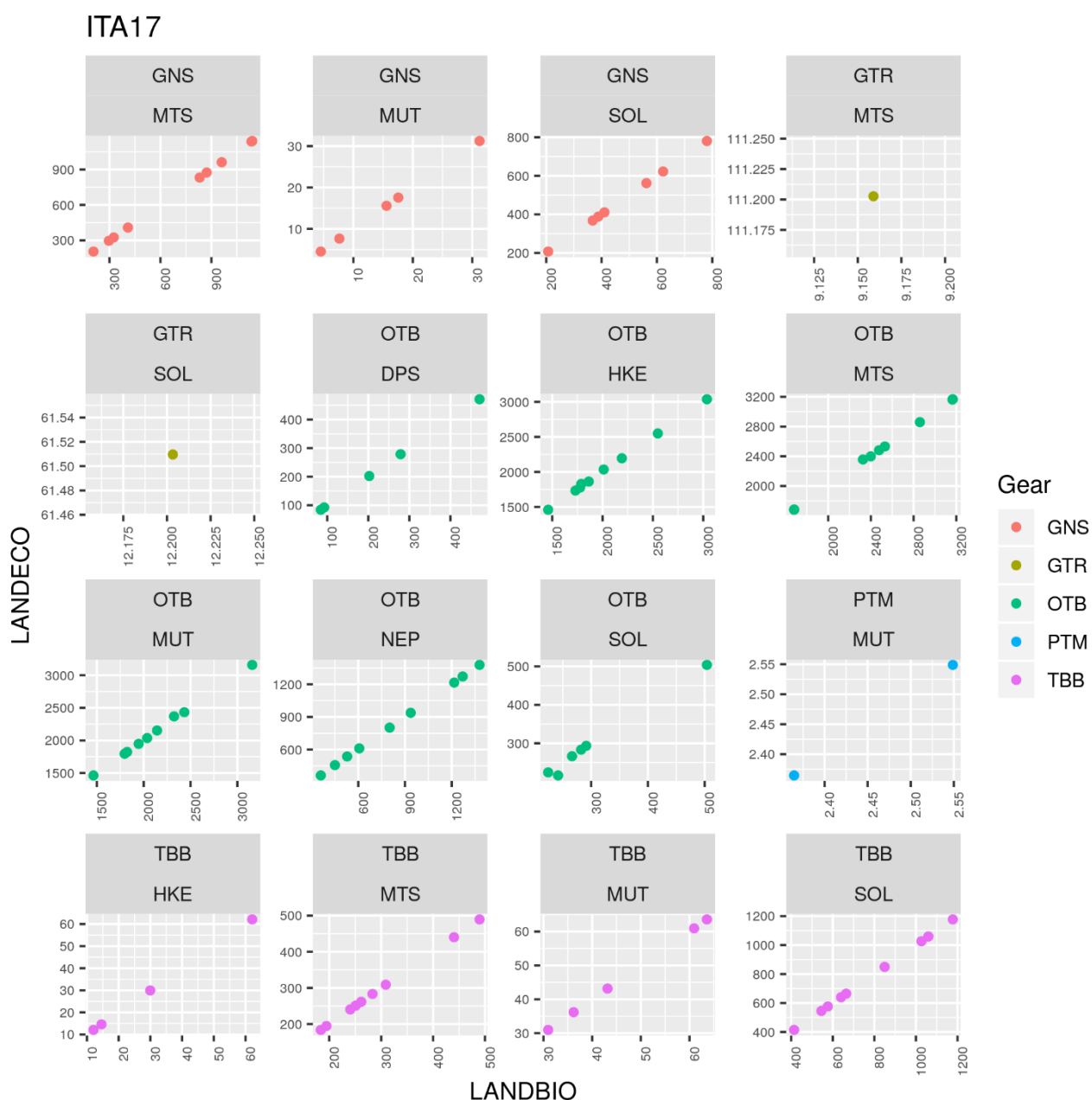
Figure 2.1.1 Comparison in landings in weight (tonnes) between data available for Italy (ITA) in GSA17. LANDECO referred to data from Fleet Socio Economic Data Call and LANDBIO from the Mediterranean and Black Sea Data Call.

For Italy (GSA17) a very good relationship was found for all the combinations (gear-species) excluding trammel net (GTR) for Spottail mantis (MTS) and Sole (SOL) for which higher landings were reported through the economic data call.
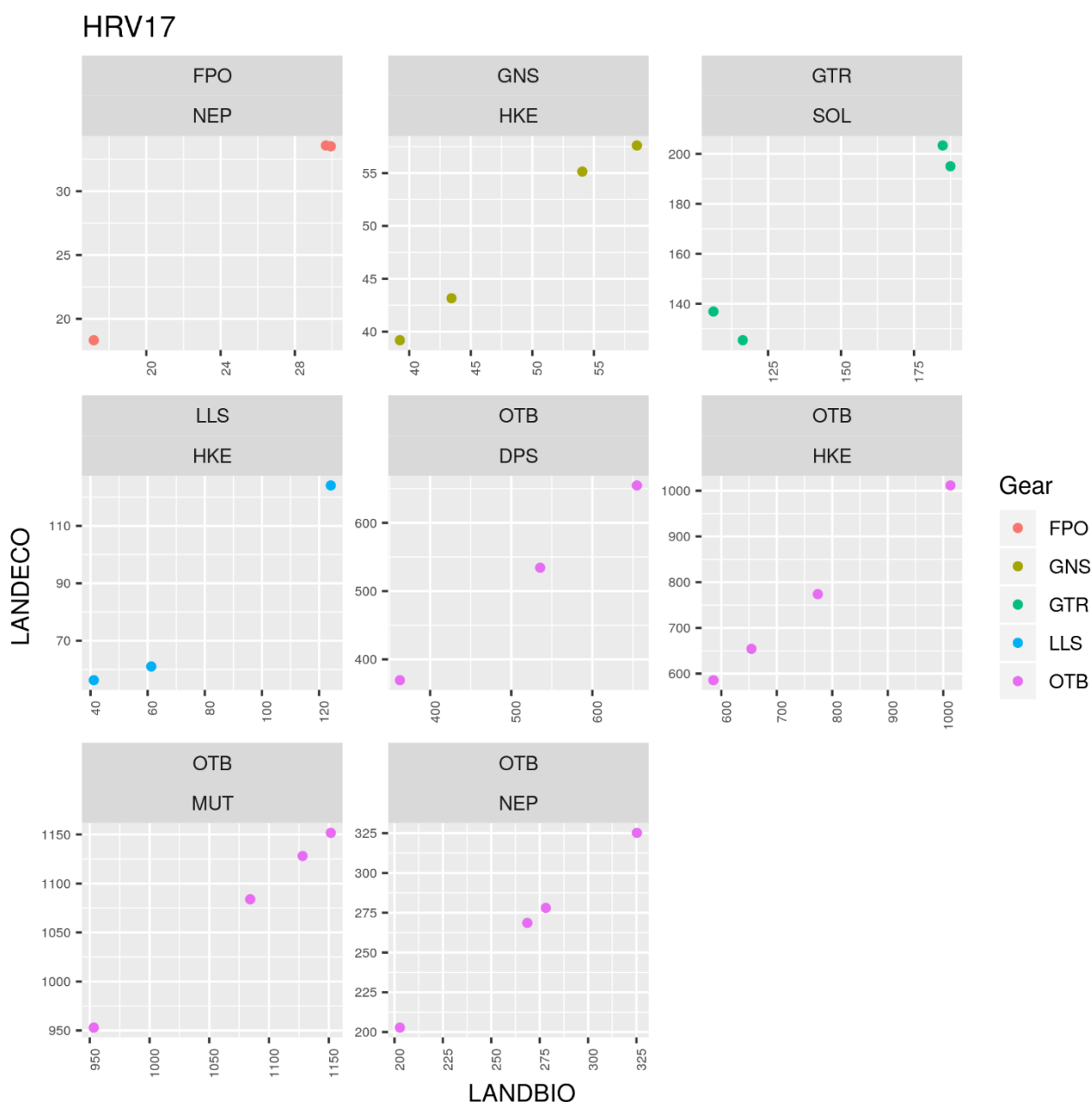
Figure 2.1.2 Comparison in landings in weight (tonnes) between data available for Croatia (HRV) in GSA17. LANDECO referred to data from Fleet Socio Economic Data Call and LANDBIO from the Mediterranean and Black Sea Data Call.

Also for Croatia (GSA17) a quite good relationship was found for all the combinations (gear-species) excluding trammel net (GTR) for Sole (SOL) and long liner (LLS) for European hake (HKE) for which slight difference in landings were spotted.
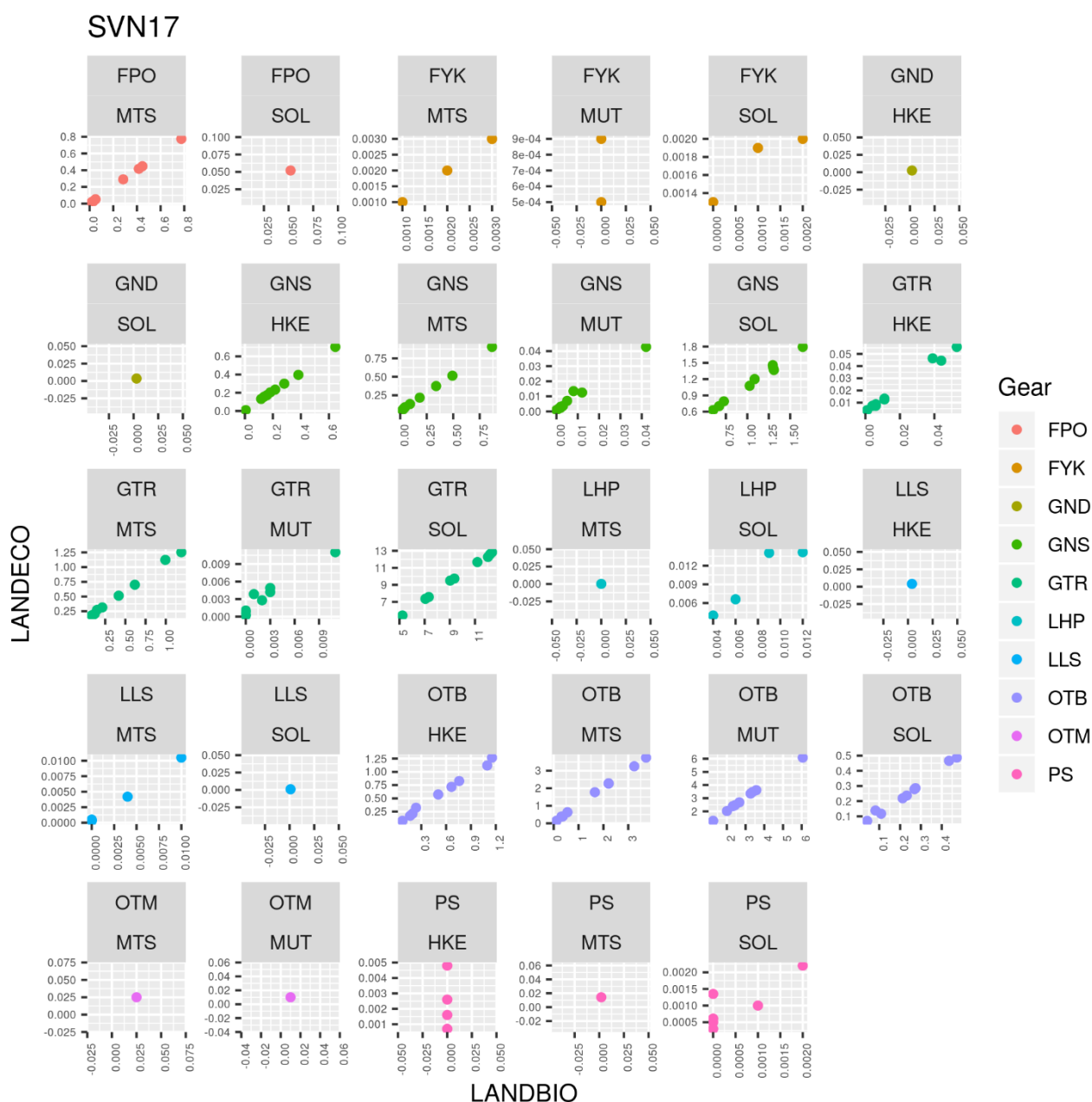
Figure 2.1.3 Comparison in landings in weight (tonnes) between data available for Slovenia (SVN) in GSA17. LANDECO referred to data from Fleet Socio Economic Data Call and LANDBIO from the Mediterranean and Black Sea Data Call.

Slovenian landings also showed a good relationship for all combinations (gear-species) in particular for the demersal trawler (OTB). Very slight discrepancies were observed for the other combinations.
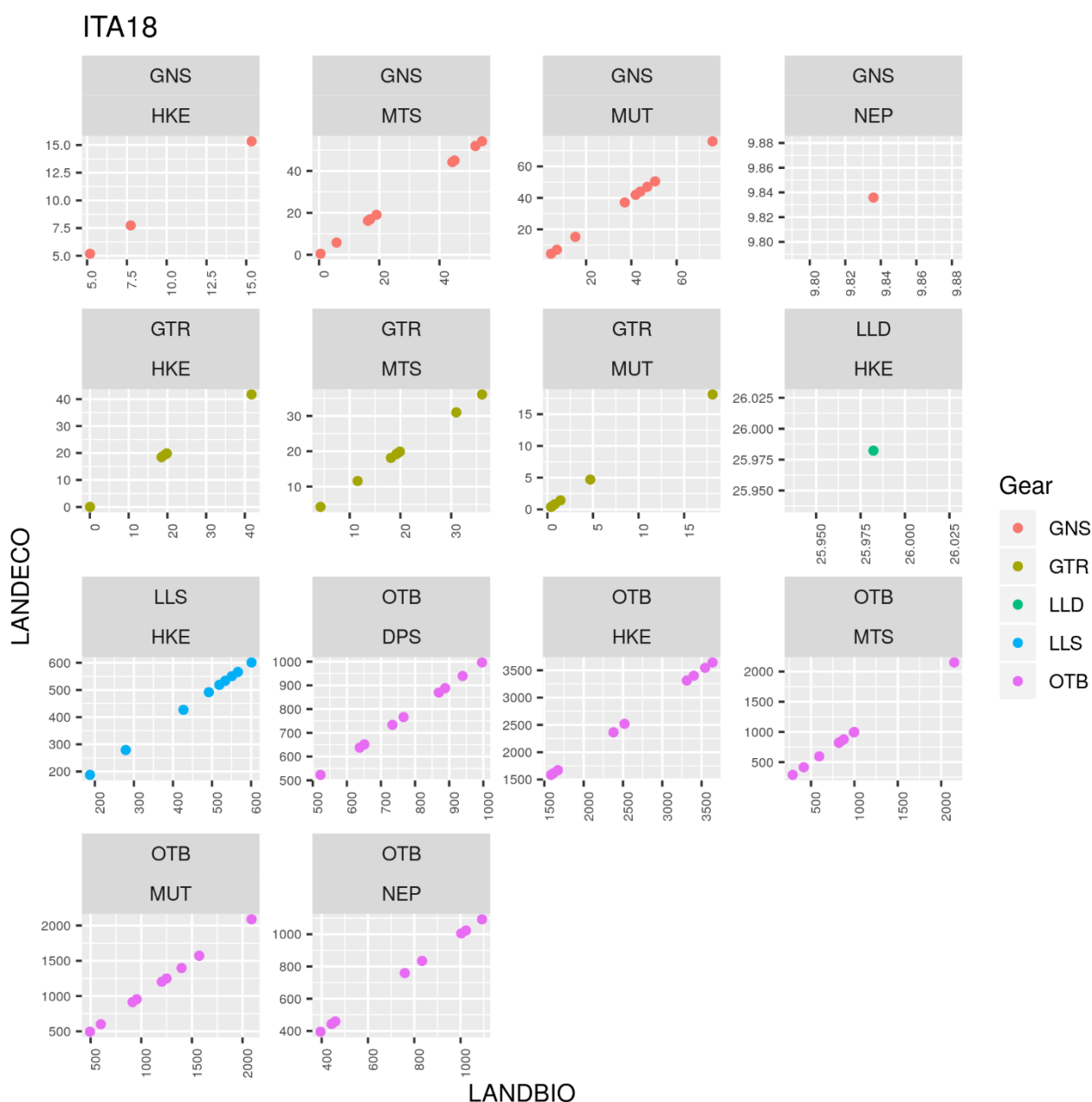
Figure 2.1.4 Comparison in landings in weight (tonnes) between data available for Italy (ITA) in GSA18. LANDECO referred to data from Fleet Socio Economic Data Call and LANDBIO from the Mediterranean and Black Sea Data Call.

For Italy (GSA18) a linear relationship was found for all the combinations (gear-species).

2.2 Fleet contribution and dependency

Fleets' contributions to total landing of MAP stocks and economic dependency on the same stocks, was carried out using DCF data from the 2018 AER (STECF 2018c), for the period 2014-2016. In both cases a three year average was computed. Contribution is computed as the percentage of the total landing weight reported by EU MS at the level of GSA 17 and 18 caught by the fleet. Dependency is computed as the share in percentage of all MAP's stocks combined in the total value of each fleets' landing.

Results indicate that DTS segments have the highest overall contribution to all species in the MAP, counting for more than 80% of landing per species (NEP 88%, MUT 95%, MTS 81%, HKE 88% and DPS 87%), except in case of sole which is dominated by Italian TBB 1824 (29%) and PGP 0612 (17%) segments.

Italian DTS 1218 have the highest contribution for MTS (49%). Contribution to HKE landing is dispersed over the segments but dominantly represented in landings made by ITA DTS 1218 and 1824 covering 64% in total. All other segments have individual contribution below 10%. Beside DTS segments only two HOK segments have contribution over 1%. For Norway lobster the Italian DTS segments (74%) has the largest contribution followed by the Croatian DTS segments with 18%.

Considering dependency tables (Table 2.2.1-3), it can be seen that both Italian and Croatian DTS segments have dependencies on six key species of 45% or more. Fleet segments operating farther from the shore show larger dependency on DPS, HKE and NEP, while ITA DTS 0612 and 1218 in GSA 17 dominantly depend on MTS. Beside DTS segments, some other have high dependency on only one or two species depending on the area they operate, like ITA TBB 2440 and 1824 with dependency of 44% and 49% on SOL, while HRV FPO 0612 dominantly depend on NEP representing 39% of landing value and DFN 1218 which depend on SOL (50%). When observing dependency on the gear level, it can be seen that some gears are showing even larger dependencies on small number of species than the segment level is showing. In this case Slovenian GND bellow 6 meters are almost exclusively depended on the sole, but this kind of information could be run by the small number of vessels using this gear on a very small area and having low activity. All OTB vessels showed high dependency on HKE, NEP and DPS. Gears that have highest dependency on HKE are LLS (ITA1218 in GSA 18 - 53%, HRV0612 - 32%), on DPS are Croatian OTB (2440-21% and 1824-20%), on MTS are Italian OTM and OTB in GSA 17 (OTM1218 – 71%, OTB0612 – 51%), on MUT are LTL and OTB (HRVLTL1218 – 30% and ITAOTB 0612 in GSA 18 – 24%), on NEP are Croatian OTB and FPO (OTB2440 – 38% and FPO0612 – 33%), and for SOL which have highest depended fishery with SLOGND0006 – 81%, ITATBB0612 in GSA 17 – 73%, HRVGTR0612 – 60% and others with dependency over 50% (Croatian and Slovenian GTR and GNS). It needs to be stressed that in some cases estimates at the gear level can based on a small number of vessels.

Values of dependency and contribution can be good indicators about how management measures will affect vessel groups in terms of their economy and what effect these will have on managed stocks. While some gears and segments have high dependency on only few species they can have at the same time very low or negligible impact to overall landing of target species and vice versa.

Table 2.2.1 Average of individual fleet segment contribution to total landing (percentages).

Fleet segments	DPS	HKE	MTS	MUT	SOL	NEP
HRV A37 DFN0006	0	0.16	0	0.04	0.12	0.01
HRV A37 DFN0612	0	0.90	0.01	0.10	5.67	0.07
HRV A37 DFN1218	0	0.01	0	0.02	0.66	0
HRV A37 DRB0612	0	0	0	0.06	0.54	0
HRV A37 DRB1218[1]	0	0.01	0.01	0.10	1.40	0
HRV A37 DTS0612	0.63	0.69	0.02	1.22	0.07	1.02
HRV A37 DTS0612[1]	0.70	1.82	0.02	2.77	0.11	1.88

HRV A37 DTS1218	4.63	4.02	0.07	8.27	0.28	2.80
HRV A37 DTS1218[1]	2.34	1.94	0.03	4.62	0.15	1.65
HRV A37 DTS1824	12.20	3.12	0.02	3.60	0.10	6.07
HRV A37 DTS2440	11.99	2.51	0	1.68	0.05	9.09
HRV A37 FPO0006	0	0.01	0	0	0	0.33
HRV A37 FPO0612[1]	0	0.07	0	0	0.03	2.00
HRV A37 HOK0006	0	0.06	0	0	0	0.01
HRV A37 HOK0612[1]	0	1.50	0	0	0.01	0
HRV A37 MGO0006	0	0	0	0	0.01	0.01
HRV A37 MGO0612[1]	0	0.01	0	0.02	0.07	0
HRV A37 PGP0006[1]	0	0.02	0	0.01	0	0
HRV A37 PGP0612	0	0.03	0	0	0	0.02
HRV A37 PGP0612[1]	0	0.03	0	0	0	0.01
HRV A37 PMP0006	0	0.01	0	0.01	0	0.01
HRV A37 PMP0612[1]	0.01	0.03	0	0.07	0.08	0
HRV A37 PS0612[1]	0	0.01	0	0.01	0.05	0
HRV A37 PS1218	0	0.01	0	0.02	0	0
HRV A37 PS1824	0	0	0	0	0	0
HRV A37 PS2440[1]	0	0	0	0	0	0
ITA A37 DRB1218[1]	0	0	0	0.01	0	0
ITA A37 DTS0612	0.05	1.19	7.08	4.09	0.76	0.07
ITA A37 DTS1218	25.73	28.62	48.87	37.14	10.82	25.74
ITA A37 DTS1824	28.56	34.85	19.97	28.11	14.31	38.37
ITA A37 DTS2440	12.68	8.74	5.02	5.87	0.75	10.54
ITA A37 HOK1218[1]	0.46	8.73	0.05	0.14	0	0
ITA A37 PGP0006	0	0	2.42	0.43	3.29	0

ITA A37 PGP0612	0	0.14	9.64	0.67	17.62	0	
ITA A37 PGP1218[1]	0	0	1.26	0.04	0.85	0	
ITA A37 PS1218[1]	0	0	0	0	0	0	
ITA A37 TBB1218	0	0.01	0.26	0	1.98	0	
ITA A37 TBB1824	0	0.61	1.88	0.57	29.23	0.25	
ITA A37 TBB2440	0.01	0.08	1.94	0.09	9.97	0.03	
ITA A37 TM1218[1]	0	0.01	1.30	0.13	0.46	0	
ITA A37 TM1824	0	0.01	0.01	0.02	0.01	0	
ITA A37 TM2440	0	0.01	0.10	0.02	0.01	0	
SVN A37 DFN0006[1]	0	0	0	0	0.11	0	
SVN A37 DFN0612[1]	0	0.01	0.01	0	0.41	0	
SVN A37 DTS1218[1]	0	0.02	0.02	0.06	0.02	0	
SVN A37 PS1218[1]	0	0	0	0	0.02	0	

[1]This is a cluster

Table 2.2.2 Average of individual fleet segment dependency on key species in terms of landing value (percentages)

Country	GSA	Technique	LOA class	DPS	HKE	MTS	MUT	NEP	SOL	ALL
Croatia	17	DTS	VL2440	21	14	0	4	38	0	77
Croatia	17	DTS	VL1824	20	17	0	9	25	1	72
Italy	17	PGP	VL1218	0	0	39	1	0	27	67
Croatia	17	TM	VL1218	4	24	0	23	0	9	61
Italy	17	DTS	VL0612	0	1	46	7	0	5	59
Italy	18	DTS	VL2440	15	16	10	4	13	0	58
Italy	17	TBB	VL1824	0	1	3	1	1	49	55
Italy	17	TBB	VL2440	0	1	10	0	0	44	55
Italy	17	DTS	VL1824	3	16	7	9	11	6	52
Italy	18	DTS	VL1824	8	18	4	4	18	0	52

Croatia	17	DTS	VL1218	6	17	0	17	10	1	52
Croatia	17	DFN	VL1218	0	1	0	1	0	50	51
Italy	17	DTS	VL2440	2	19	6	8	13	2	51
Italy	18	DTS	VL1218	5	15	7	13	11	0	51
Italy	18	DTS	VL0612	0	16	7	23	0	0	47
Croatia	17	PGO	VL0612	0	25	1	20	0	1	46
Croatia	17	DTS	VL0612	3	15	0	12	14	1	45
Italy	17	DTS	VL1218	1	7	23	6	4	4	45
Croatia	17	FPO	VL0612	0	2	0	0	39	1	42
Italy	17	TBB	VL1218	0	0	5	0	0	30	35
Italy	18	HOK	VL1218	1	34	0	0	0	0	35
Croatia	17	DFN	VL0612	0	4	0	0	0	30	35
Croatia	17	FPO	VL0006	0	1	0	0	31	0	32
Slovenia	17	DFN	VL0612	0	1	0	0	0	30	31
Italy	17	PGP	VL0612	0	0	10	0	0	14	24
Italy	17	PGP	VL0006	0	0	11	0	0	12	24
Slovenia	17	DFN	VL0006	0	0	0	0	0	21	21
Croatia	17	HOK	VL0612	0	18	0	0	0	0	18
Croatia	17	DRB	VL1218	0	0	0	1	0	16	17
Croatia	17	DRB	VL0612	0	0	0	1	0	15	16
Croatia	17	MGO	VL1218	0	8	0	5	0	0	14
Croatia	17	DRB	VL1824	0	0	0	0	0	12	13
Croatia	17	PMP	VL0612	0	2	0	2	0	5	9
Croatia	17	HOK	VL0006	0	8	0	0	1	0	9
Croatia	17	PGP	VL0006	0	7	0	1	0	0	8
Croatia	17	PGP	VL0612	0	6	0	0	2	0	8

Country	GSA	Gear	LOA class	DPS	HKE	MTS	MUT	NEP	SOL	ALL
Croatia	17	DFN	VL0006	0	4	0	1	0	3	8
Croatia	17	FPO	VL1218	0	8	0	0	0	0	8
Slovenia	17	DTS	VL1218	0	1	1	3	0	1	7

Table 2.2.3 Average of dependency on gear level on key species in terms of landing value (percentages)

Country	GSA	Gear	LOA class	DPS	HKE	MTS	MUT	NEP	SOL	ALL
Slovenia	17	GND	VL0006	0	0	0	0	0	81	81
Croatia	17	OTB	VL2440	21	14	0	4	38	0	77
Italy	17	GNS	VL1218	0	0	26	0	0	48	75
Italy	17	TBB	VL0612	0	0	0	0	0	73	73
Italy	17	OTM	VL1218	0	0	71	0	0	1	72
Croatia	17	OTB	VL1824	20	17	0	9	25	1	72
Croatia	17	NK	VL1824	15	8	0	9	30	0	62
Croatia	17	GTR	VL0612	0	0	0	0	0	60	60
Italy	17	OTB	VL0612	0	1	51	4	1	2	59
Italy	18	OTB	VL2440	15	16	10	4	13	0	58
Croatia	17	GTR	VL1218	0	0	0	0	0	57	58
Italy	17	TBB	VL2440	0	1	9	0	0	43	54
Slovenia	17	GTR	VL0612	0	0	1	0	0	53	54
Italy	17	TBB	VL1824	0	2	3	1	1	47	54
Italy	18	LLS	VL1218	0	53	0	0	0	0	53
Italy	17	OTB	VL1824	3	17	7	9	12	5	53
Italy	17	OTB	VL2440	2	20	7	9	13	1	52
Croatia	17	OTB	VL1218	6	17	0	17	10	1	52
Italy	18	OTB	VL1824	8	18	4	4	18	0	52
Slovenia	17	GTR	VL1218	0	0	1	0	0	51	51

Italy	18	OTB	VL1218	5	15	7	13	11	0	51
Croatia	17	GTN	VL1218	0	0	0	0	0	50	50
Croatia	17	OTB	VL0612	3	17	0	13	16	1	49
Italy	17	GNS	VL0006	0	0	17	0	0	32	49
Italy	17	GNS	VL0612	0	0	17	0	0	30	47
Italy	18	OTB	VL0612	0	15	6	24	0	0	46
Italy	17	OTB	VL1218	1	7	24	6	4	4	46
Croatia	17	OTM	VL1218	3	16	0	15	1	11	45
Slovenia	17	GTR	VL0006	0	0	0	0	0	40	40
Italy	17	TBB	VL1218	0	0	8	0	0	31	39
Croatia	17	LTL	VL1218	5	4	0	30	0	0	39
Croatia	17	FPO	VL0612	0	0	0	0	33	0	33
Croatia	17	LLS	VL0612	0	32	0	0	0	0	32
Italy	17	GTR	VL0006	0	0	26	0	0	3	30
Italy	17	GTR	VL0612	0	0	13	0	0	16	29
Croatia	17	FPO	VL0006	0	1	0	0	27	0	28
Croatia	17	DRB	VL2440	0	0	0	0	0	27	27
Croatia	17	LLS	VL1824	0	24	0	0	0	0	24
Slovenia	17	GNS	VL1218	0	2	0	1	0	19	23
Slovenia	17	FPO	VL0006	0	0	20	0	0	0	20
Croatia	17	OTM	VL0612	1	6	0	8	2	0	17
Croatia	17	GNS	VL1218	1	2	0	0	0	13	17
Croatia	17	DRB	VL1218	0	0	0	0	0	17	17
Croatia	17	LLS	VL0006	0	14	0	0	0	0	15
Croatia	17	GTR	VL0006	0	1	0	0	0	13	15
Croatia	17	DRB	VL0612	0	0	0	0	0	14	14

Croatia	17	LLS	VL1218	0	9	0	0	3	0	12
Croatia	17	DRB	VL1824	0	0	0	0	0	12	12
Croatia	17	FPO	VL1218	0	0	0	3	9	0	12
Croatia	17	GNS	VL0612	0	10	0	0	0	1	12
Italy	17	FYK	VL0612	0	0	9	2	0	0	11
Croatia	17	GTN	VL0612	0	0	0	0	0	10	10
Italy	17	FPO	VL0006	0	0	10	0	0	0	10
Italy	18	GTR	VL0006	0	0	4	5	0	0	9
Slovenia	17	GNS	VL0612	0	1	0	0	0	7	8
Croatia	17	GNS	VL0006	0	6	0	1	0	1	8
Slovenia	17	GNS	VL0006	0	0	0	0	0	7	7
Slovenia	17	OTB	VL1218	0	1	1	3	0	1	6
Croatia	17	FYK	VL0612	0	6	0	0	0	0	6
Italy	18	GTR	VL0612	0	0	5	1	0	0	5
Slovenia	17	OTB	VL0612	0	0	3	1	0	0	5

2.3 Economic outcomes

The economic component of the NIMED model (Annex 4) was used to simulate the effects of the baseline scenario for the Adriatic Sea demersal fisheries. Inputs to the model are the total catches and fishing mortality for each stock derived as medians of the iteration's values estimated through the a4a MSE tool. The geographical area covered by the model consists in the GSAs 17 and 18, including all relevant fleets from Italy, Croatia and Slovenia. Albanian and Montenegrin fleets are not included in the simulations because data is not available. Projections on all economic and transversal variables and related indicators were carried out in the period 2018-2035.

Stocks included in the model are reported in Table 2.3.1. Among the key commercial stocks selected for the Adriatic Sea demersal MAP, only Norway lobster was not included. Therefore, a total of 5 stocks was included in the model.

Table 2.3.1 Key commercial stocks for the Adriatic Sea demersal MAP

Common name	Scientific name	FAO code	GSAs	Modelled
European hake	Merluccius merluccius	HKE	(17-18)	Y
Red mullet	Mullus barbatus	MUT	(17-18)	Y
Deep-water rose shrimp	Parapenaeus longirostris	DPS	(17-18-19)	Y
Norway lobster	Nephrops norvegicus	NEP	(17-18)	N
Sole	Solea vulgaris	SOL	17	Y
Spottail mantis shrimp	Squilla mantis	MTS	(17-18)	Y

The selection of the fleet segments to be included in the model for simulations was based on a combination of two criteria: 1) the relevance of the fleet segment in terms of contribution to the total landings of each of the stocks included in the model; 2) the relevance of the stocks included in the model on the revenues of the fleet segments operating in the Adriatic demersal fisheries.

Based on those criteria, a total of 26 fleet segments were selected as relevant for the demersal fisheries in the Adriatic Sea and included in the model for simulation. As reported in Table 2.3.2, 14 fleet segments are from Italy (9 from GSA 17 and 5 from GSA 18), 9 fleet segments are from the Croatian fleet and 3 from the Slovenian fleet. Almost 100% of the total landings of deep-water rose shrimp, European hake, red mullet and Norway lobster are produced by these fleets, while their contribution to the total landings of the other two stocks is higher than 96%.

Table 2.3.2 Percentages of landings by stock covered by the selected fleet segments (average on the period 2014-2016)

Fleet segment	DPS	HKE	MTS	MUT	NEP	SOL
ITA_17_DTS_VL0612	0	0.11	6.02	1.78	0.04	0.68
ITA_17_DTS_VL1218	3.47	8.31	32.51	14.08	5.87	6.27
ITA_17_DTS_VL1824	13.41	24.55	16.32	25.34	25.05	13.02
ITA_17_DTS_VL2440	2.97	6.5	3.61	5.24	7.54	0.7
ITA_17_PGP_VL0006	0	0	2.35	0.04	0	3.29
ITA_17_PGP_VL0612	0	0.07	9.13	0.29	0	17.62
ITA_17_TBB_VL1218	0	0.01	0.25	0	0	1.97
ITA_17_TBB_VL1824	0	0.61	1.88	0.57	0.25	29.23
ITA_17_TBB_VL2440	0.01	0.08	1.94	0.09	0.03	9.97
ITA_18_DTS_VL0612	0.04	1.07	1.06	2.3	0.03	0.08
ITA_18_DTS_VL1218	22.27	20.3	16.37	23.06	19.87	4.55
ITA_18_DTS_VL1824	15.15	10.3	3.65	2.77	13.33	1.29
ITA_18_DTS_VL2440	9.71	2.24	1.41	0.63	3	0.05

|						
ITA_18_HOK_VL1218	0.46	8.73	0.05	0.14	0	0
HRV_DFN_VL0612	0	0.9	0.01	0.1	0.07	5.67
HRV_DFN_VL1218	0	0.01	0	0.02	0	0.66
HRV_DTS_VL0612	1.33	2.51	0.04	3.99	2.9	0.18
HRV_DTS_VL1218	6.97	5.95	0.1	12.88	4.44	0.42
HRV_DTS_VL1824	12.2	3.12	0.02	3.6	6.07	0.1
HRV_DTS_VL2440	11.99	2.51	0	1.68	9.09	0.04
HRV_FPO_VL0006	0	0.01	0	0	0.33	0
HRV_FPO_VL0612	0	0.07	0	0	2	0.03
HRV_HOK_VL0612	0	1.5	0	0	0	0.01
SVN_DFN_VL0006	0	0	0	0	0	0.11
SVN_DFN_VL0612	0	0.01	0.01	0	0	0.41
SVN_DTS_VL1218	0	0.02	0.02	0.06	0	0.02
ALL	99.98	99.5	96.73	98.66	99.92	96.37

Model Outcomes

In Figure 2.3.1, projections on GVA and salary under the Status Quo scenario are reported for aggregations of fleet segments. The Italian demersal fleet operating in GSA 17 is split in demersal trawlers, polyvalent passive and beam trawlers, while the Italian fleet operating in GSA 18 is split in demersal trawlers and vessels using hooks and lines. Croatian and Slovenian demersal fleets are split in demersal trawlers and other fleet segments.

The differences in the trends expected for these aggregations of fleet segments depend on their composition of landings and economic dependency on specific stocks. For instance, in GSA 17, the trends in GVA and salary for the Italian beam trawlers and the demersal Slovenian fleet other than trawlers is due to their strong economic dependency on sole. On the contrary, the other fleet segments operating in GSA 17, show a more stable trend given by a more balanced composition of landings among different stocks. In GSA 18, trawlers and longliners show different expected trends in the first part of projections. In this case, this is due to the higher dependency of longliners on European hake, which determines trends in GVA and salary similar to the trend in the catches of European hake.

ITA_17_DTS

ITA_17_PGP

ITA_17_TBB

ITA_18_DTS

ITA_18_HOK

HRV_DTS

HRV_Others

SVN_DTS
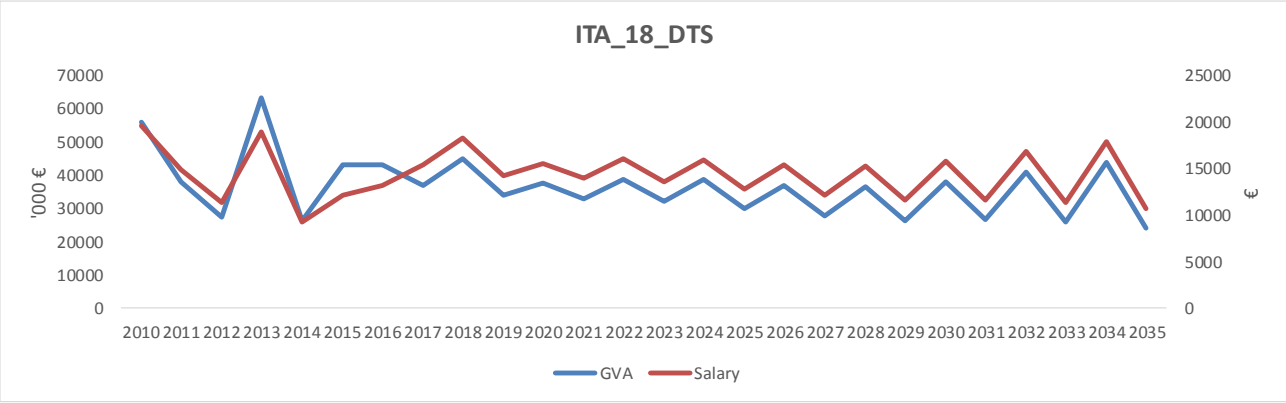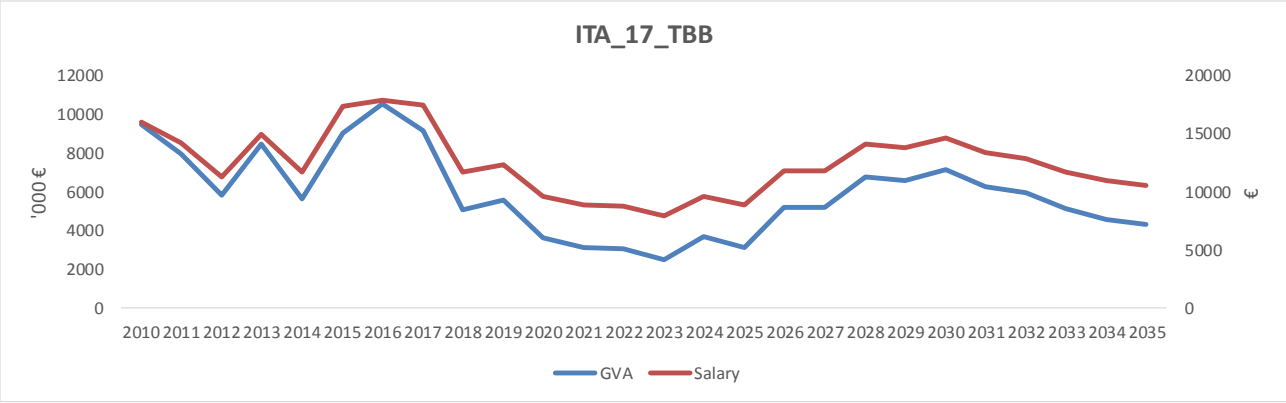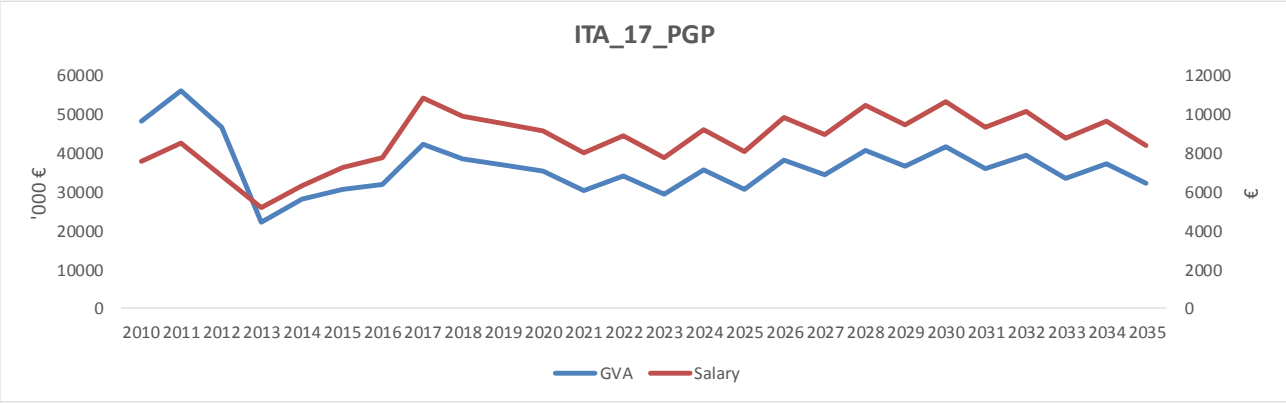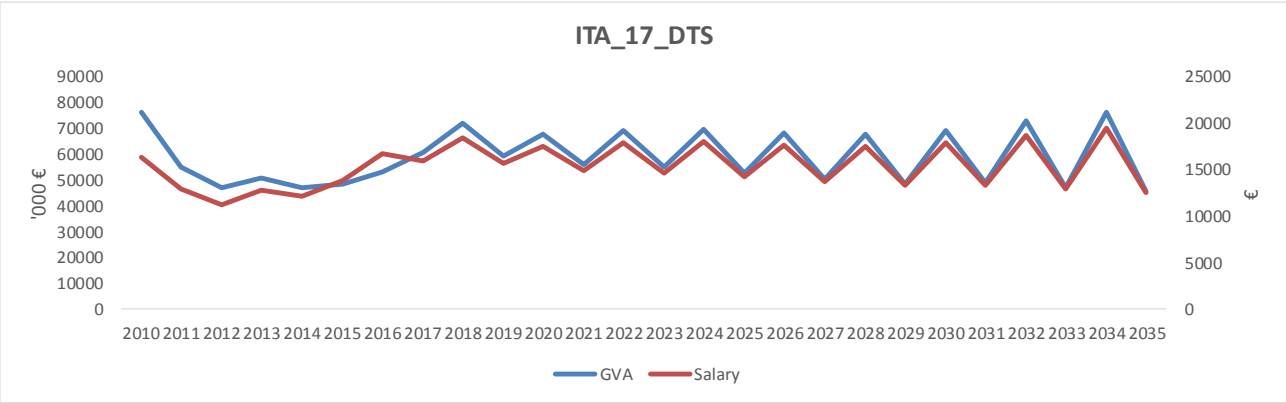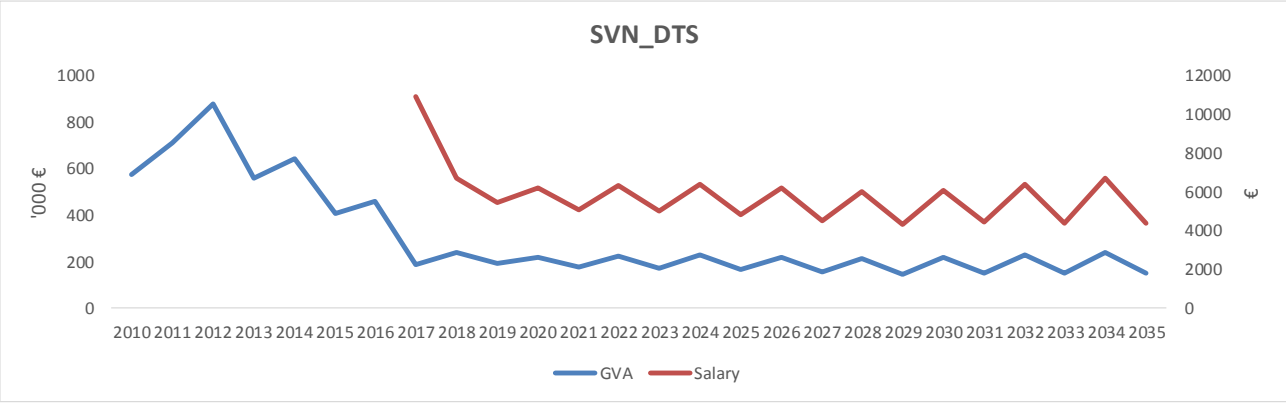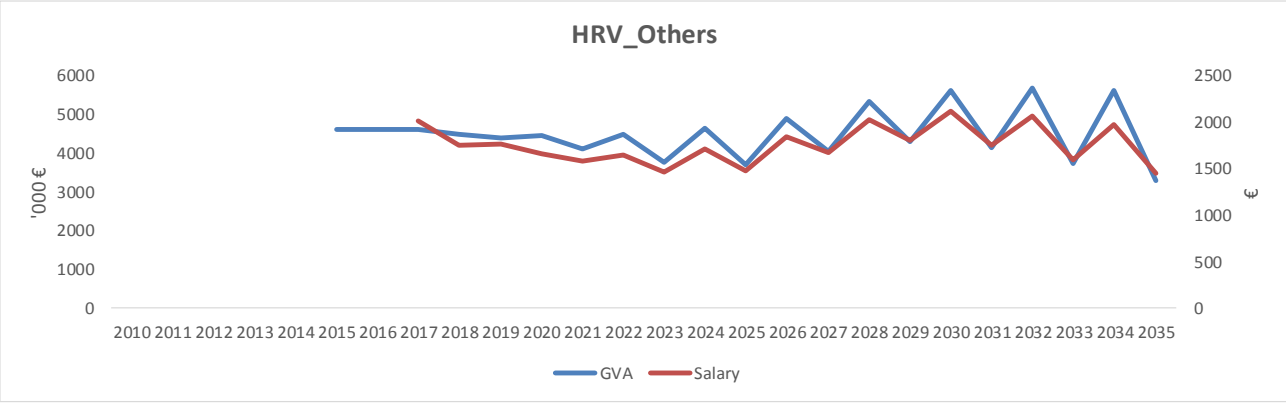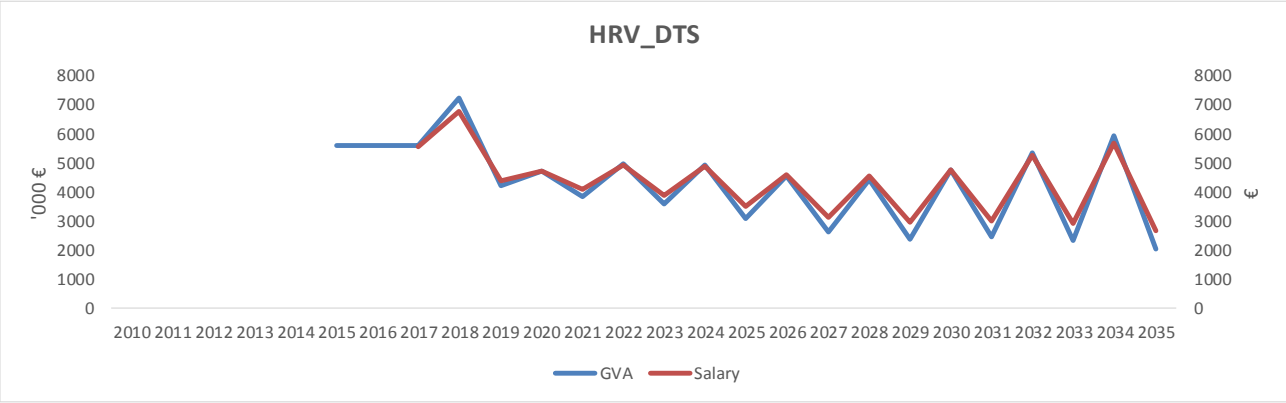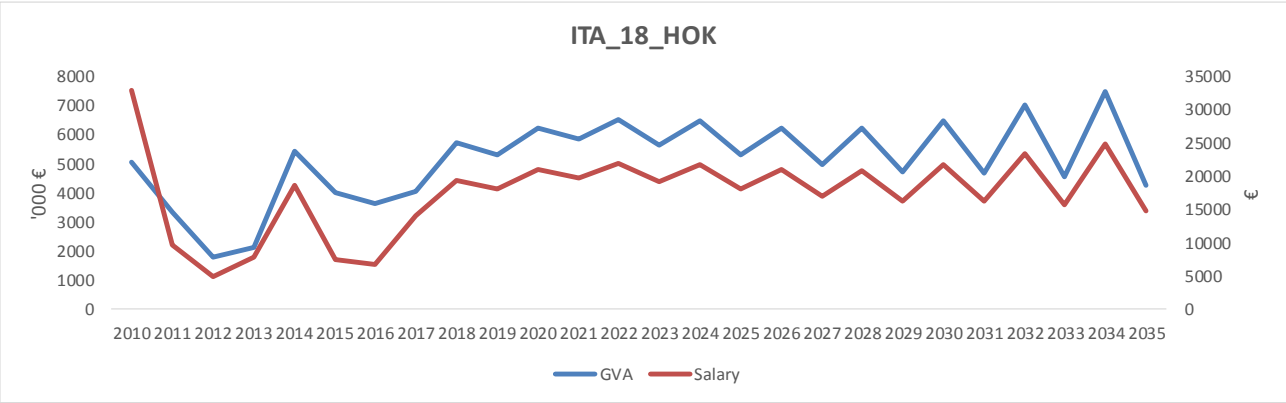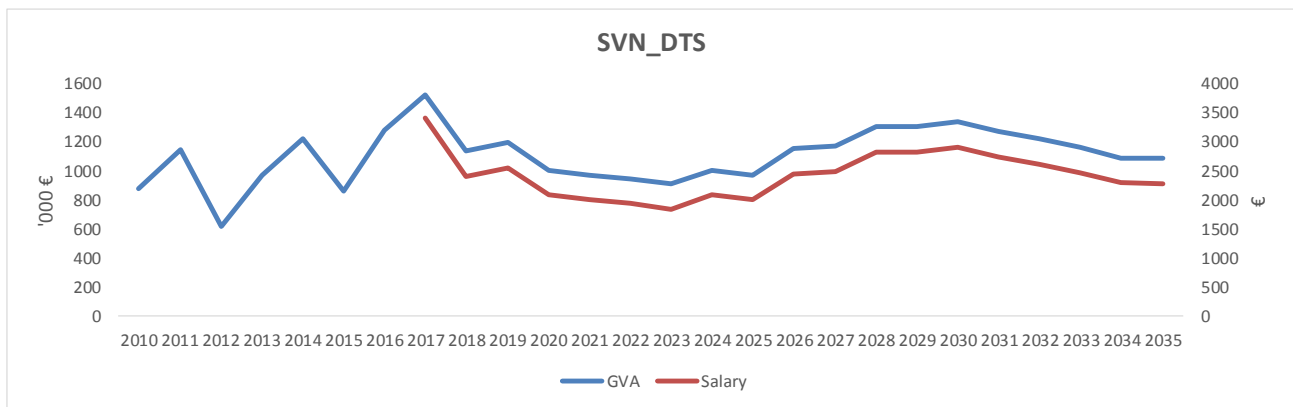
Figure 2.3.1 Projections on GVA and salary under the Status Quo scenario for different aggregations of fleet segments

The same approach can be used to test scenarios where equal effort reductions per year across all relevant fleets are set.

3 TOR 1 – METHODS AND INDICATORS

The scenarios ran for each stock are presented in Table 3.1. Alternative OMs were used as robustness tests. As mentioned above spatial management scenarios were run for sole only, as well as catch limits scenarios.

Table 3.1 Operating models and management scenarios ran. Oms other than "basecase" were used for testing the robustness of management options. Legend: 24 stands for scenarios aiming to achieve Fmsy in 2024; FR = FIXREDUX; CL = CATCHLIM; FRA = fisheries restricted area of sole sanctuary; 6NM = fisheries restricted area of 6 nautical miles. The Fsq scenario is the baseline defined by the ToRs.

Stock	OM	Management Scenarios								
		Fsq	Fmsy24	Fmsy24FR	FsqCL	Fmsy24FRCL	FsqFRA	Fmsy24FRFRA	Fsq6NM	Fmsy24FR6NM
sol17	basecase	x	x	x	x	x	x	x	x	x
	SR steepness 0.8	x	x	x						
hke1718	basecase	x	x	x						
	high discards	x	x	x						
	Albanian catches	x	x	x						
	SR B&H	x	x	x						
dps171819	basecase	x	x	x						
mut1718	basecase	x	x	x						
	SR B&H	x	x	x						
mts1718	basecase	x	x	x						
	Chenwatanabe	x	x	x						

The indicators computed followed the ToR requirements with some additions the EWG considered relevant. Three sets of indicators were computed. Time series of common summary statistics per year including the 90% confidence interval. Time aggregated indicators for short term (2018-2024) and long term (2025-2035) periods, which present an average over years of the statistics of interest. And a set of performance indicators, mostly based on probabilities for the status quo period (2015-2017), 2024 and equilibrium (2031-2035).

- Time series
    - SSB: Median Spawning Stock Biomass
    - SSBl: Spawning Stock Biomass Quantile 0.05
    - SSBh: Spawning Stock Biomass Quantile 0.95
    - C: Median Catch
    - Cl: Catch Quantile 0.05
    - Ch: Catch Quantile 0.95
    - F: Median Fishing Mortality
    - Fl: Fishing Mortality Quantile 0.05
    - Fh: Fishing Mortality Quantile 0.95
    - R: Median Recruitment
    - Rl: Recruitment Quantile 0.05
    - Rh: Recruitment Quantile 0.95
    - FFMSY: Median Exploitation status
    - FaboveFMSY: Probability of F being above FMSY
    - SSBBLIM: Probability of SSB falling below Blim
    - FonTRGT: Probability of F being in the vicinity (20%) of FMSY
- Time aggregated
    - SSB: Median Spawning Stock Biomass
    - SSBl: Spawning Stock Biomass Quantile 0.05
    - SSBh: Spawning Stock Biomass Quantile 0.95
    - R: Median Recruitment
    - C: Median Catch
    - Cl: Catch Quantile 0.05
    - Ch: Catch Quantile 0.95
    - FFMSY: Median Exploitation status
    - SSBBLIM: Average probability across years of SSB falling below Blim
    - SSBBLIMmax: Maximum probability across years of SSB falling below Blim
    - CVAR: Median absolute proportional change in catch over two consecutive years
    - CVARl: Absolute proportional change in catch over two consecutive years quantile 0.05
    - CVARh: absolute proportional change in catch over two consecutive years quantile 0.95
- Performance
    - FFMSY: Median Exploitation status.
    - FaboveFMSY: Yearly probability of F being above FMSY.
    - SSBBLIM: Yearly probability of SSB falling below Blim.
   - FonTRGT: Yearly probability of F being around 20% of FMSY.

Results are presented in the following sections and published online in tabular form.

4   ToR 2 – Operating models

4.1   Hake 17-18

4.1.1   Base case

The base case OM used in the MSE for hake, employed as a starting point the SS3 stock assessment carried out during the GFCM hake benchmark meeting (Rome, 15-18 January 2019) and finalized in February 2019. This stock assessment covered the 1998 to 2017 time span, and had 21 age-classes. Initially, an attempt was made to use the estimates of parameter uncertainty in the hake SS3 base case model to construct an OM. Runs of SS3 making use of ADMB's mcmc procedure were carried out, where the chain was set to run for over 1 million times, with a burnin period of 100,000 and then thinned down to every 1000th result (ss -mcmc 1100000 -mcsave 1000 -mcseed 20193). These runs returned completely unrealistic estimates of uncertainty in biomass and fishing mortality trajectories (Figure 4.1.1.1), which were deemed not acceptable to use for OM conditioning.
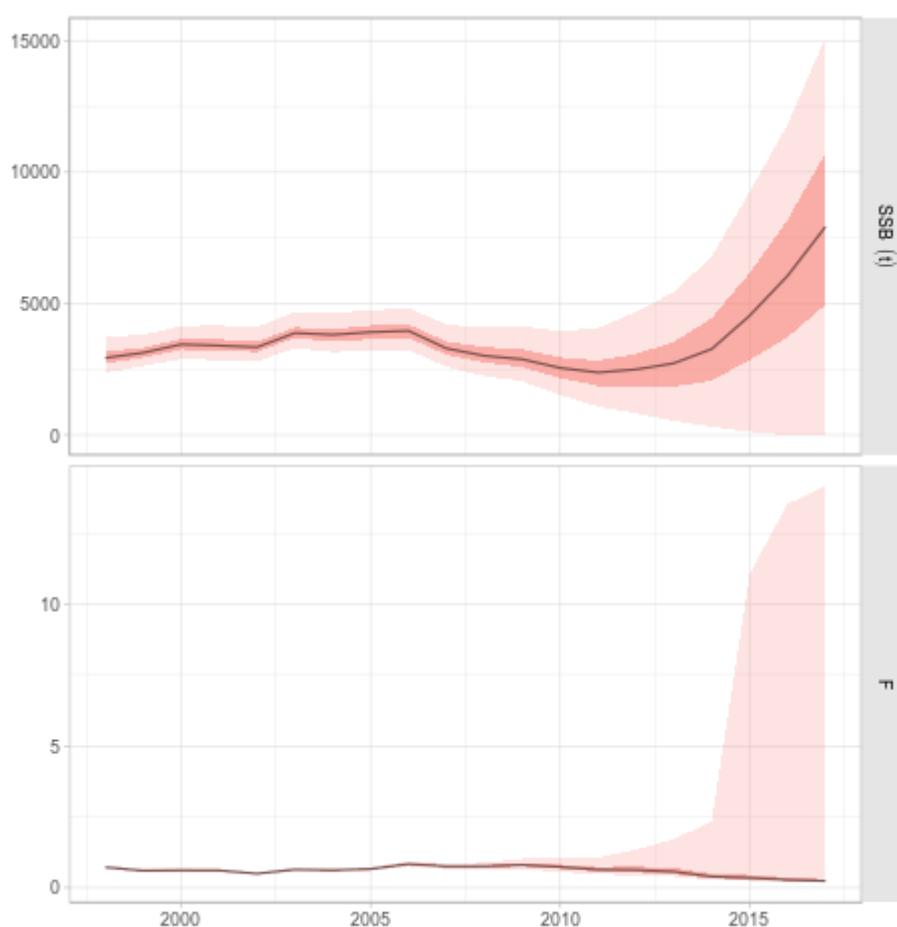
Figure 4.1.1.1 Estimates of SSB and F obtained from MCMC runs of the SS3 hake base case model. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

For this reason, input data (catch, survey, biological parameters) and assumed variables, as employed for the SS3 run, were used to develop a similar stock assessment run based on the a4a model. Our goal was to generate an a4a stock assessment that would mimic the SS3 assessment dynamics and average outputs as closely as possible. This a4a stock assessment would then be

used as the base case OM for the MSE analysis, again making use of ADMB's mcmc procedures, but considering parameter uncertainty as a fair representation of the main uncertainty in the stock. The a4a model setup differed in a number of issues. The original 21 age-classes were truncated into 7 (age-classes 0-6+), and a single MEDITS-derived index for 2002-2017 was used, which covered the whole Adriatic Sea, with both sexes combined.

The following set of submodels were used to generate the a4a assessment mimicking the SS3 assessment:

- fmodel = ~factor(year) + s(replace(age, age > 5, 5), k = 5, by = breakpts(year, seq(1997, 2017, by=2))) + s(year, k = 5, by = as.numeric(age==0))
- srmod = ~factor(year)
- n1mod = ~factor(age)
- qmod = list(~s(age, k = 5))
- vmodel = list(~s(age, k = 3),~1)

The resulting model was composed of 1000 iterations that were obtained from a run of the MCMC procedure in a4a (mcmc=1500000, burn-in=500000, thinning=1000, mcprobe=0.3). The results thus obtained showed in a very similar stock summary to SS3 (Figure 4.1.1.2), and a similar F-at-age pattern (Figure 4.1.1.3, Figure 4.1.1.4). The choice of the number of iterations, burn-in, thinning and mcprobe in the mcmc fit, was based on an extensive exploratory analyses of the mixing and autocorrelation of the chain.
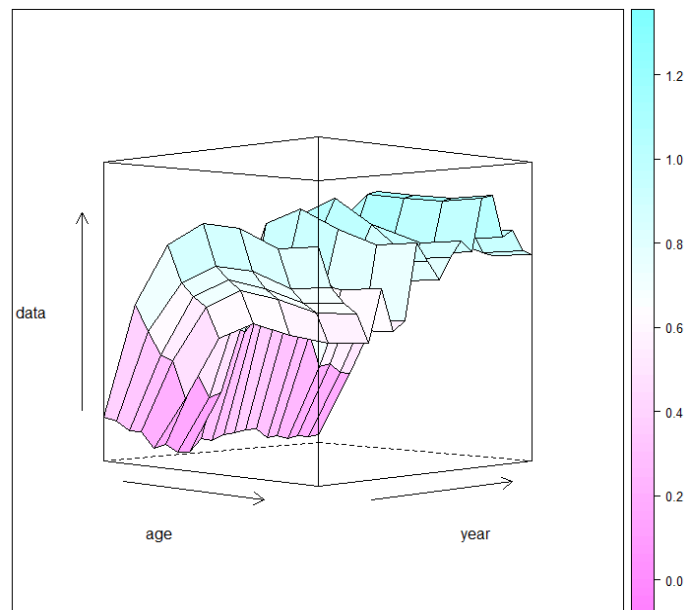
Figure 4.1.1.2 Stock summaries of the SS3 fit (blue) and the a4a mcmc fit that was built to mimic it. This a4a fit was used as the base case OM in the MSE. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.
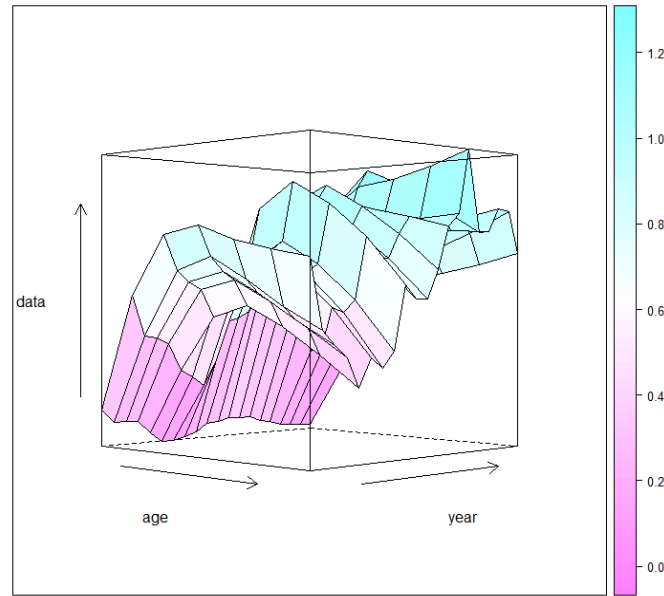
Figure 4.1.1.3 F-at-age of the SS3 fit. data: F; year: year range (1998-2017); age: ages (truncated to 0-6+).

Figure 4.1.1.4 F-at-age of the a4a mcmc fit mimicking SS3 that was used as the base case OM in the MSE. data: F; year: year range (1998-2017); age: ages (0-6+).

It should be noted that the 'SSB' generated from the SS3 and the a4a fits does not express the spawning biomass, but the stock reproductive potential of the stock. This is because the maturity ogive used by the SS3 incorporates fecundity, which increases disproportionally with age. Therefore, the 'maturity' ogive within the slot mat() of the a4a does not reach 1 within the truncated age-range 0-6+, but it only reaches ~0.85 in the plus-group.

The reference point F0.1 of the OM was set to 0.165 in accordance with the SS3 stock assessment. A Beverton-Holt (BH) stock-recruitment relationship was assumed in the OM.

4.1.2 Alternatives for robustness tests

To investigate the robustness of the management procedures, three alternative OMs were examined.

The first alternative OM used a geomean stock-recruitment relationship (instead of BH). All a4a submodels remain unchanged, and the OM summary for the period 1998-2017 was identical to the base case OM (Figure 4.1.1.2).

The second alternative OM was constructed to account for a potential misreporting of hake discards by the Croatian OTB fleet. As reported by STECF EWG 18-16 (STECF 2018d): "For Croatia the reported otter trawl discard rates of hake for last 4 years have been reduced, from around 10% to 0.2% of Croatian catch, this compares with around 3% discard rates for Italian otter trawl. Overall Croatian discards contribution has reduced from 1.4% to 0.03% of total catch. This change is likely negligible for overall perception of hake stock status but may give misleading impression of the selection at age or length in the fishery." In other words, catch numbers of undersized hake reported by the Croatian OTB were greatly reduced after the data revision (Figure 4.1.2.1).
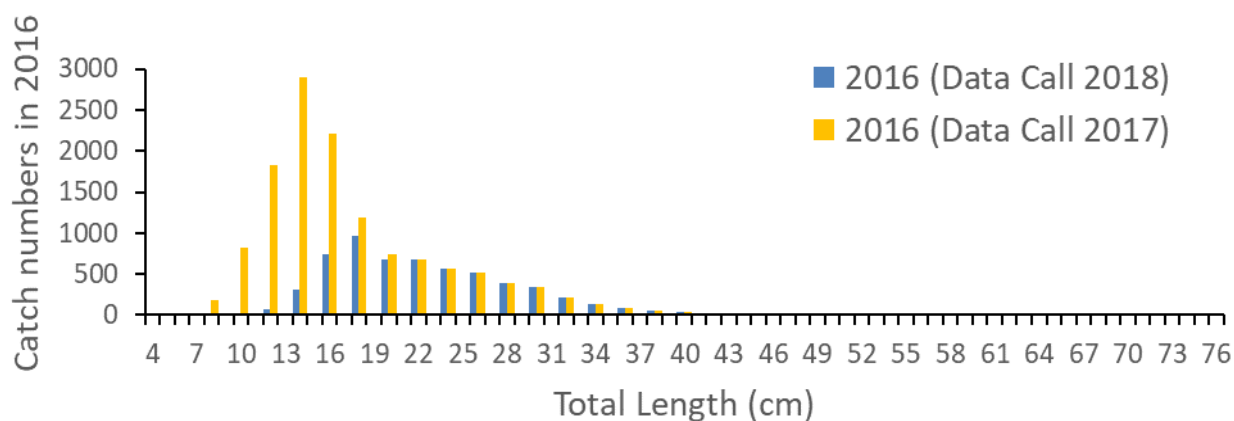

Figure 4.1.2.1 Length Frequency Distributions of catches (landings + discards) of hake from Croatian OTB in 2016 as reported for Data Call 2018 (blue) and Data Call 2017 (yellow).

To construct a 'high-discards' OM, we replaced the low-discards LFDs reported in response to Data Call 2018, by the high-discards LFDs reported in response to Data Call 2017, for years 2013-2016. The same replacement was carried out for years 2008-2012, which were available through AdriaMed and a similar data revision had taken place. For year 2017, which was only available from Data Call 2018, LFDs for lengths <20 cm were replaced using the 2013-2016 average proportion of each length class <20 cm in relation to the total numbers caught. The SS3 stock assessment was then re-run using the new LFDs for the Croatian OTB fleet, and an a4a assessment mimicking this SS3 assessment was fitted, as in the base case scenario. This a4a assessment was fitted to different catch numbers than the base run, keeping all other slots the same. Using the same sub-models as in the base case run led to non-convergence of the a4a fit, hence we changed slightly the fmodel compared to the base run keeping all other submodels the same:

- fmodel = ~factor(year) + s(replace(age, age > 5, 5), k = 5, by = breakpts(year, seq(1997, 2017, by=3))) + s(year, k = 5, by = as.numeric(age==0))

- srmod = ~factor(year)

- n1mod = ~factor(age)

- qmod = list(~s(age, k = 5))

- vmodel = list(~s(age, k = 3),~1)

This combination of submodels was used for a fit that was composed of 1000 iterations that were obtained from a run of the MCMC procedure in a4a (mcmc=1500000, burn-in=500000, thinning=1000, mcprobe=0.3). This OM had a slightly different stock summary to the baseline OM (Figure 4.1.2.2). Namely, SSB was higher and Fbar was lower in the end of the time-series compared to the base-case. This was because the higher discards in the end of the time-series resulted in higher F at ages 0 and 1 but lower Fs in ages 2+, hence a lower Fbar calculated over ages 1-4.
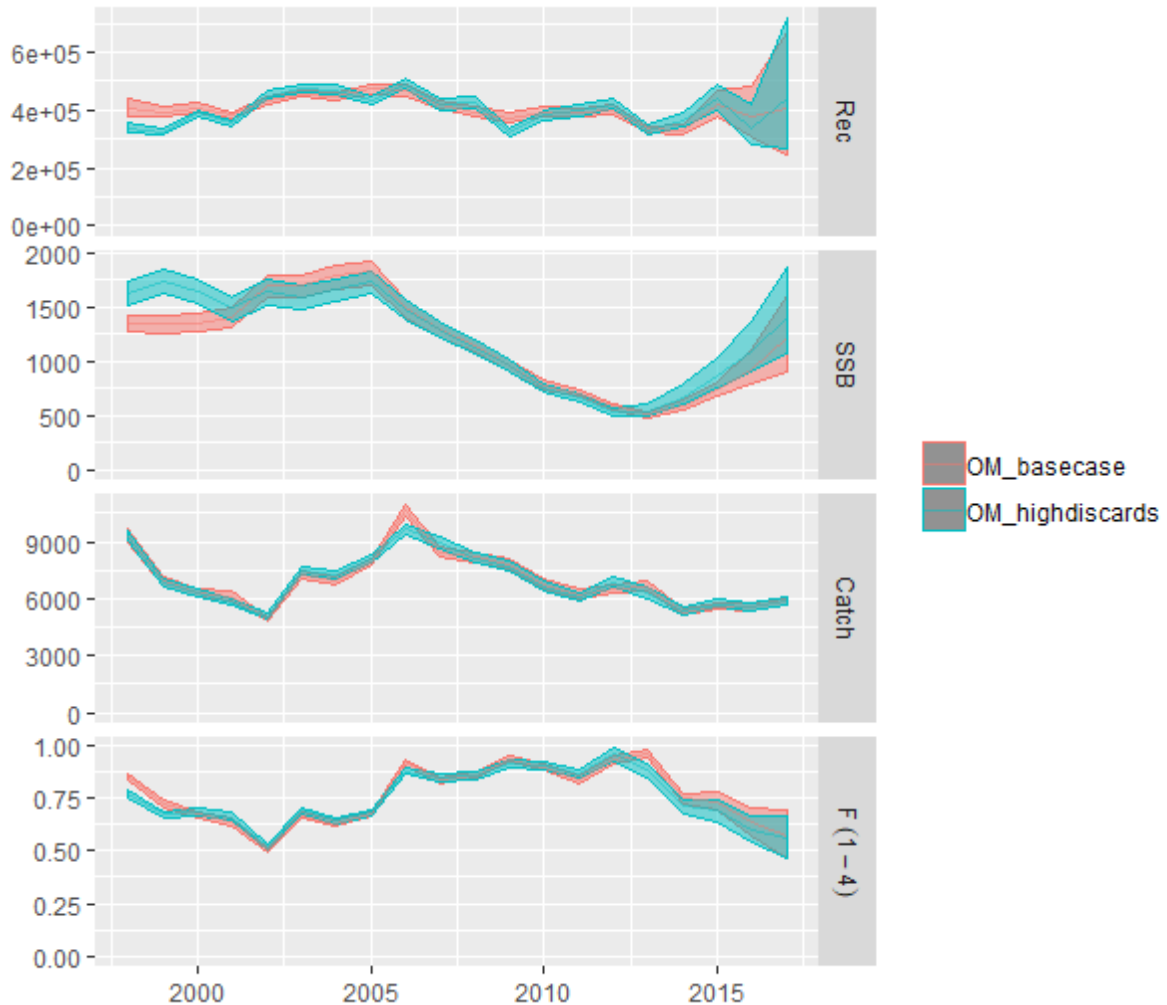
Figure 4.1.2.2 Summaries of the base case OM (red) and the "high-discards" alternative OM (blue). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

The third alternative OM was constructed to account for a potential misreporting of hake catch by the Albanian OTB fleet. As reported by STECF EWG 18-16 (STECF 2018d): "In the case of Albania, the new landings data for hake show a threefold increase in catch in the last 6 years over the previous 6 years and Albania now declares about 16% of the total Adriatic hake catch in comparison with 4% in the previous period." In other words, the total catch of hake in the latest data made available by Albania (STECF 2018d), exhibited an abrupt increase from 2012 onwards, which was not the case for the respective data made available a year earlier for STECF EWG 17-15 (STECF 2017b) (Figure 4.1.2.3).
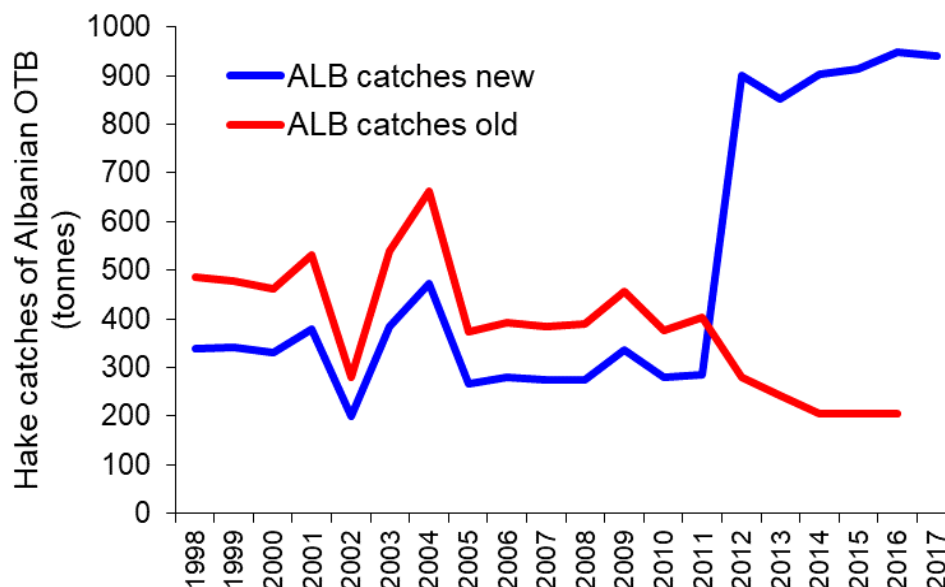
Figure 4.1.2.3 Total hake caches by the Albanian OTB fleet made available in 2017 for EWG 17-15 used in the robustness test (red) and the respective catches made available in 2018 for EWG 18-16 used in the base case runs (blue).

To construct a 'low-ALB' OM, we replaced the ALB catches reported in 2018 for 1998-2017, by those reported in 2017 for 1998-2016 (Figure 4.1.2.3). Catch in year 2017 was set equal to that of 2016 of the dataset made available in 2017. The SS3 stock assessment was then re-run using the lower total catch for Albania and an a4a assessment mimicking this SS3 assessment was fitted, as in the base case scenario. This a4a assessment was fitted to different catch numbers and different total catch than the base run, keeping all other slots the same. Using the same sub-models as in the base case run led to non-convergence of the a4a fit, hence we changed slightly the fmodel as in the case of the 'high-discards' OM, while keeping all other submodels the same. An a4a mcmc fit composed of 1000 iterations that were obtained from a run of the MCMC procedure in a4a (mcmc=1500000, burn-in=500000, thinning=1000, mcprobe=0.3) was used as the 'low-ALB' OM. This OM had a slightly different stock summary to the baseline OM (Figure 4.1.2.4). Namely, Catch and Fbar were lower and SSB was higher in the end of the time-series compared to the base case, owing to the much lower catches of the Albanian fleet in 2012-2017 compared to the base case (Figure 4.1.2.3).

Figure 4.1.2.4 Summaries of the base case OM (red) and the "low-ALB" alternative OM (blue). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

For both the 'high-discards' and the 'low-ALB' alternative OMs, the reference point F0.1 was set to 0.165 and a Beverton-Holt (BH) stock-recruitment relationship was included, similarly to the base case OM. We took this decision to have comparable MSEs; however, it should be noted that the different selectivity observed in these alternative OMs, would result in different F reference points.

4.2 Red mullet 17-18

4.2.1 Base case

The base case OM was based on the a4a stock assessment carried out during the STECF EWG 18-16 meeting (Rome, 15-21 October 2018), endorsed by the STECF PLEN 18-03 (12-16 November 2018; STECF 2018e) and presented at the GFCM WGSAD in November (19-24 November 2018). The reference point for this species is taken from the same report, namely Fmsy = 0.41.

The stock assessment is a statistical catch at age (sca) model implemented within the FLa4a framework; the assessment model is based on catch data () and MEDITS-data (). Four sub-models are used within the SCA-model: starting numbers at age (sub-)model (n1mod), fisheries

mortality (sub-)model (fmod), index catchability (sub-)model (qmod), and the stock recruitment (sub-)model (srmod). The sub-models were specified as follows:

- n1mod: ~factor(age)
- fmod: ~te(age, year, k = c(3,5)) + s(year, k = 4, by = as.numeric(age==0))
- qmod: ~s(age, k=4, by = breakpts(year, 2012))
- srmod: ~s(year, k = 4)

For further information on the stock assessment model and the assessment please refer to the STECF-report 18-16 (STECF 2018d).

There are two points that need to be addressed when turning this assessment model into an operating model (OM): (i) the ks in the tensor and smoothers, and (ii) the stock recruitment model. As the MSE uses a full feedback system, i.e. an analytical model within each time-step, it is important to increase the number of ks as the total length of the assessed time-series increases. This is done by increasing the ks incrementally according to the original number of ks (n(k) = floor(4/11 * dis$year) or floor(5/11 * dis$year)).; only the ks used to smooth over years are being increased as the number of age classes remains the same. In order to simulate recruitment in the projections, a "geomean" model is used. However, the assessment model still uses a smoother to estimate recruitment within the projections. This assumes that the average stock production remains the same regardless of changes in the SSB. The model uses the mean recruitment of all the historical assessed period. The deviance in the projected recruitment is modeled as a log-normal distribution with a standard deviation estimated from the residuals from the mean recruitment.

The uncertainty was first estimated using the MCMC-approach as implemented in the FLa4a package. The results were very large uncertainties (Figure 4.2.1.1), which are indicative of an unstable assessment model caused by (a) the state of the stock (overfished), (b) the short time-series and (c) the exploitation pattern. In order to have workable uncertainties, they were estimated using the variance-covariance matrix of the parameters (Figure 4.2.1.1).

The reference points were taken from the STECF report: Fmsy = 0.41 and Blim = 5035t.
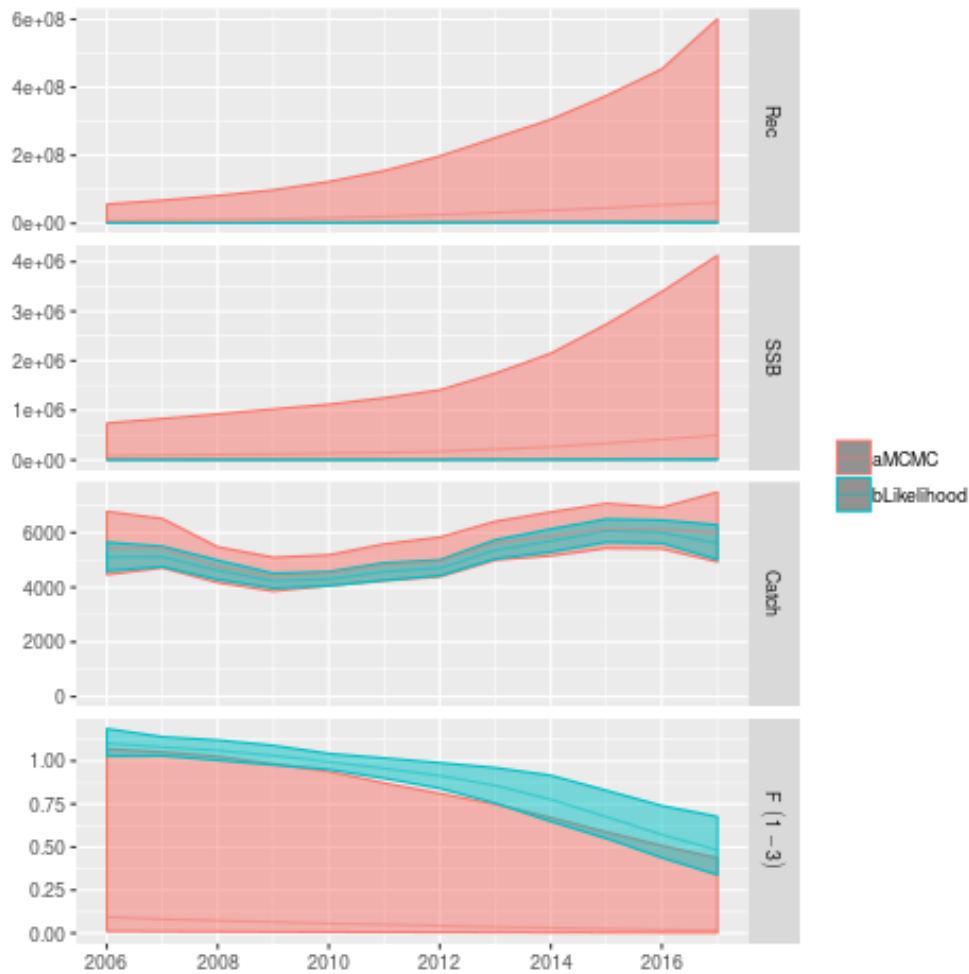
Figure 4.2.1.1 Uncertainties of stock summaries as estimated by MCMC fit (red) and estimated by using the variance-covariance matrix (blue). The OM used in the MSE was the blue model.

4.2.2 Alternatives for robustness tests

As alternative robustness test we used a different recruitment dynamic. A post-hoc fitted Beverton-Holt stock recruitment function was used to simulate the future recruitment. The following parameterisation was used:

rec ~ a * ssb/(b + ssb) (1)

The parameters *a* and *b* were 5411651 and 10156 respectively.

4.3 Deep-water rose shrimp 17-18-19

The evaluation of the stock status of the deep-water rose shrimp in the Adriatic Sea and the Western Ionian Sea was done using a4a (STECF 2018d), a statistical catch–at–age stock assessment method that utilizes catch-at-age data to derive estimates of historical population size and fishing mortality. The stock assessment was carried out during the STECF EWG 18–16 meeting (Rome, 15-21 October 2018) (STECF 2018d). The evaluation was endorsed during the STECF PLEN 18-03 (12-16 November 2018) (STECF 2018e). This assessment was also presented at the GFCM WGSAD (19–24 November 2018) and was partially endorsed, due to inconsistencies with previous assessments results. Specifically, in previous years, the assessments were performed using SS3 and in WGSAD 2017 the stock resulted as sustainably exploited. This

inconsistent behavior in the evaluation of the stock status led to the provision of a precautionary advice.

4.3.1 Base case

The base case OM was based on the a4a stock assessment endorsed by the STECF (Figure 4.3.1.1.1). The stock assessment ranged from 2002 to 2017 and had 4 age-classes (0-3+). A single survey index was used in all areas combined (Adriatic and Western Ionian Sea), derived by the MEDITS survey. Natural mortality vector was calculated using Chen and Watanabe formula (Chen and Watanabe).

The following set of submodels were used to generate the a4a stock assessment model:

- fmodel <- ~factor(replace(age, age > 1, 1)) + s(year, k = 6) + s(age, k = 2, by= breakpts(year, 2010))
- srmodel <- ~factor(year)
- qmodel <- list(~factor(age))
- n1model <- ~factor(age)
- vmodel <- list(~s(age, k = 3),~1)

Future recruitment was generated from the geometric mean (geomean). The attempt to use a MCMC – approach to estimate the uncertainties failed (*convergence or large uncertainties*) so they were estimated using the variance covariance matrix.

The Fmsy (F0.1) was set to 0.65, in-line with the stock assessment estimation.

All and all the assessment of the deep-water rose shrimp stock is quite unstable with the model not being able to explain the 3-fold increment in the catches, which also results in not so robust projections.
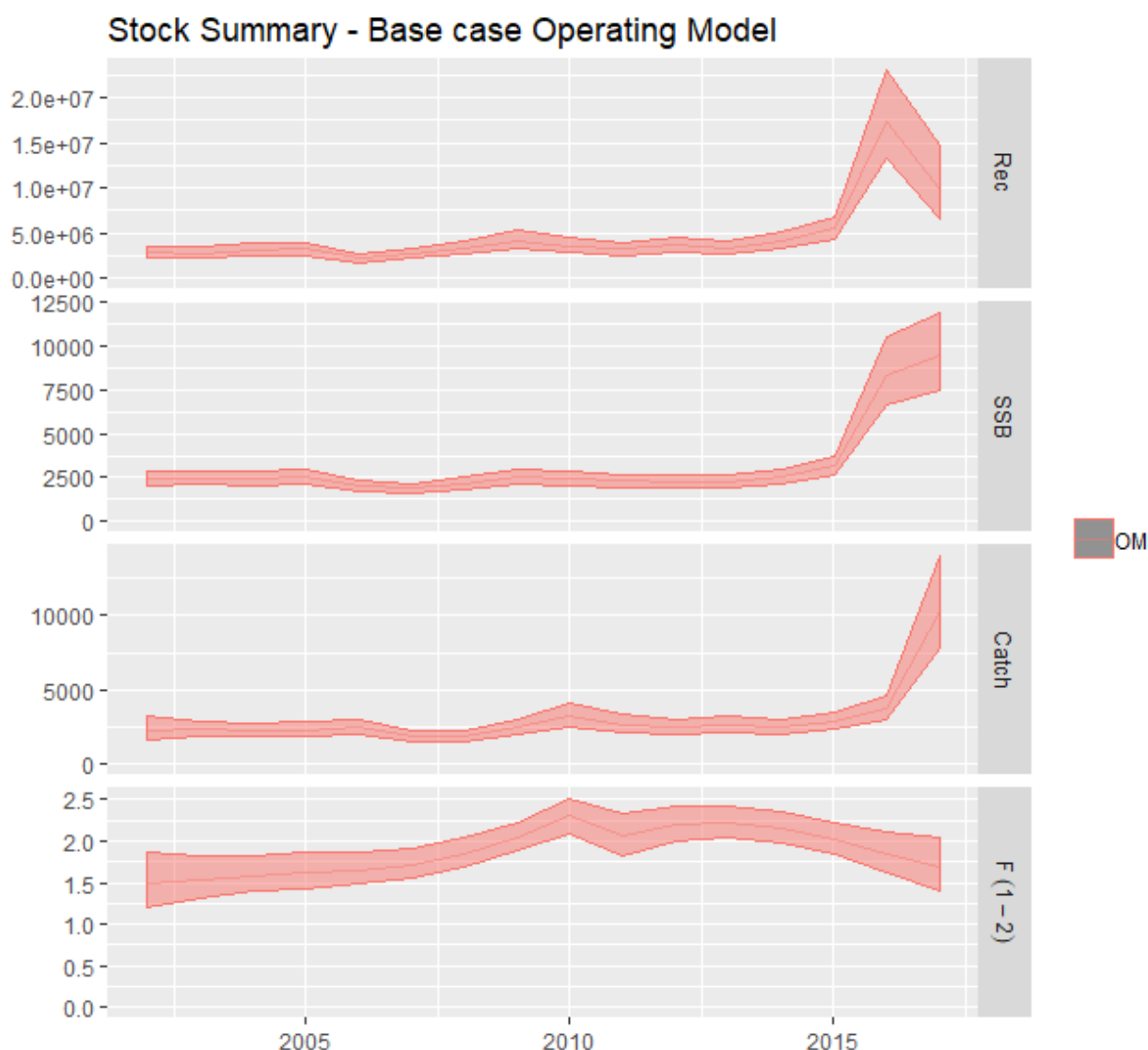
Figure 4.3.1.1 The stock summary of the a4a fit used as an OM.

4.3.2 Alternatives for robustness tests

An alternative OM was examined to investigate the robustness of the management procedure. The alternative OM used a Beverton-Holt stock recruitment relationship and resulted in identical trajectories of the recruitment as the base case OM.

4.4 Sole 17

Two different OMs were constructed for common sole (*Solea vulgaris*) in GSA 17: a base case using the same settings as the original stock assessment, and an alternative case that differed from the first in the setting of the slope parameter of the stock recruitment relationship, 0.8 instead of 1. The results obtained from the alternative OM show that the original assessment is not robust to small variations in this parameter, highlighting that care should be taken in the interpretation of results.

4.4.1 Base case

The base case OM was based on the SS3 stock assessment carried out during EWG 18-16, which was an update of the SS3 model carried out during EWG 17-15, as no assessment for sole was presented at WGSAD in 2018. This stock assessment was based on catch-at-age matrices generated using growth curves derived from otolith readings from Italy and Croatia. The reading procedures were found to be inconsistent between both countries, and a new catch-at-age matrix from new reading procedures will be available in 2020 (Scarcella G. pers. Comm.). For this reason an alternative assessment, based on newly obtained growth parameters from the new reading procedures, applied only on samples from 2014, was run in a4a to test an alternative stock assessment model with catch-at-age data obtained from a slicing procedure on length data. This second assessment was discarded as the time series available was much shorter (2006-2017) than the one used in SS3 (1980 - 2017) and made unstable by the 2014 recruitment high peak also visible in Figure 4.4.1.1.

The SS3 model was rerun within an MCMC procedure (Figure 4.4.1.1) for 1.1 million iterations (burn-in = 100000, thinning = 1000, mcprobe = 0.3) in order to obtain a range of uncertainty around each model parameter, also necessary for the projections that will be obtained from the MSE procedure.
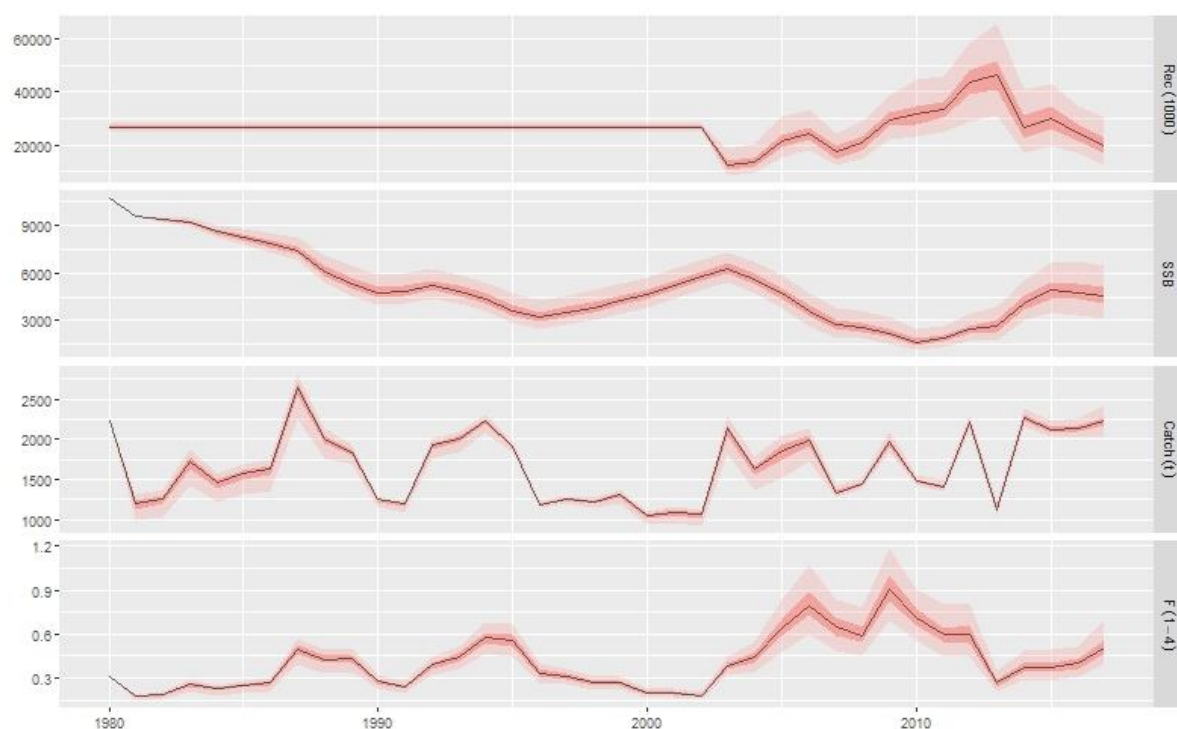
Figure 4.4.1.1 Stock summary of the SS3 mcmc fit. This fit was used as the basecase OM in the MSE.

It should be noted that the SSB generated from the SS3 fit here does not express the spawning biomass, but the stock reproductive potential of the stock. This is because the maturity ogive used by the SS3 incorporates fecundity and weight at age instead of simply the fraction mature.

The stock recruitment relationship in the SS3 model for the basecase OM was fit with a Beverton-Holt with the slope parameter set to 1.

The reference point F0.1 used in the MSE procedure was the one estimated by the SS3 assessment model reported in STECF 18-16 and had a value of 0.24. This procedure was chosen

in order to be consistent with the outcome of the official assessment, instead of using the reference points from the assessment reran within the MCMC framework.

4.4.2 Alternatives for robustness tests

A second OM was built in order to test the stock assessment robustness. In this second run the SR model had a slope of 0.8, while the rest of parameters was not changed (Figure 4.4.2.1). The model ran in a4a with a catch at age matrix obtained from a different set of growth parameters (Linf = 39.5, k=0.70, t0=-0.46) was not used to build an alternative OM as described in the previous section.
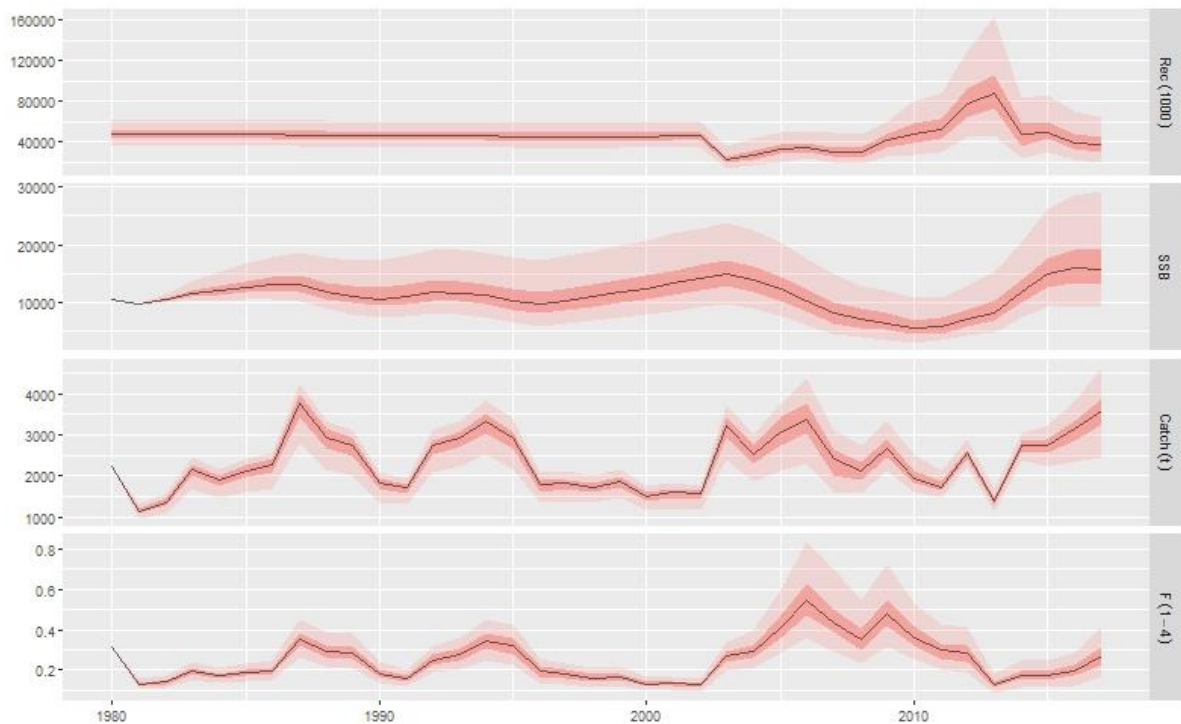
Figure 4.4.2.1 Stock summary of the SS3 MCMC output. This fit was used as the alternative case OM in the MSE.

4.5 Spottail mantis shrimp 17-18

The evaluation of the stock status of Spottail mantis shrimp in the Adriatic Sea was done using the a4a statistical catch-at-age stock assessment model. The stock assessment was carried out during the STECF EWG 18-16 meeting (Rome, 15-21 October 2018). The evaluation was endorsed during the STECF PLEN 18-03 (12-16 November 2018) and, eventually, presented at the GFCM WGSAD in November (19-24 November 2018).
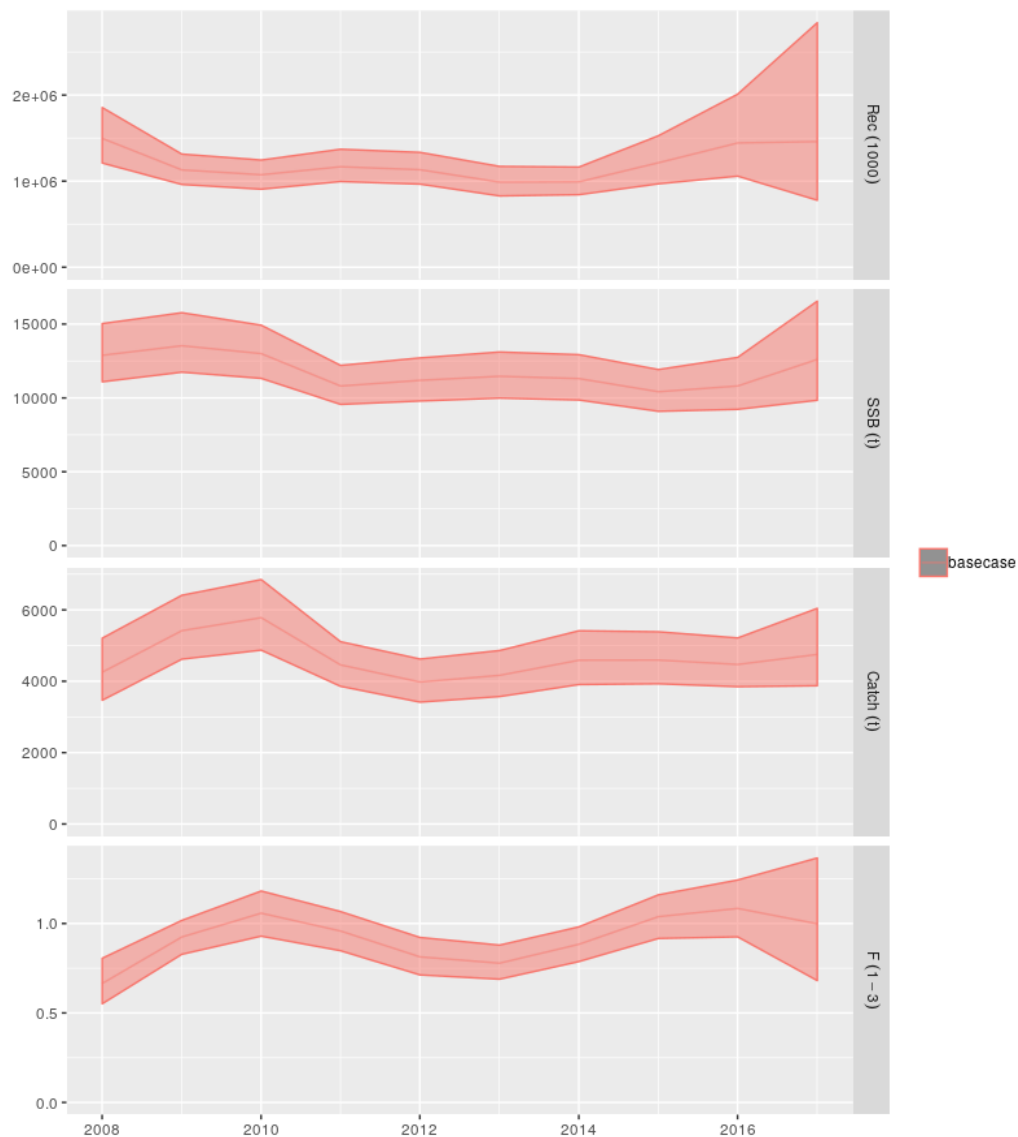
4.5.1 Base case

The base case Operating Model (OM) was based on the a4a stock assessment endorsed by STECF. The stock assessment ranged from 2008 to 2017 and had 7 age-classes (0-6). The SOLEMON survey (ranged from 2011 to 2017) covering only the North Adriatic Sea was used as an abundance index. Natural mortality was estimated by ProdBiom (Abella et al. 1997)

The following set of submodels were used for the a4a assessment:

- fmod <- ~factor(replace(age, age>4,4))+s(year, k=5)
- qmod <- list(~factor(replace(age, age>4,4)))
- srmod <- ~s(year, k = 6)
- n1mod <- ~s(age, k = 3)
- vmod <- list(~s(age, k = 3), ~1)

The MCMC fit draw 1000 iterations using a burn-in of 500000 and 1000 thinning, ADMB's mcprobe was set at 0.1. The choice of the number of iterations, burn-in and mcprobe in the mcmc fit, was based on extensive exploratory analyses. In the following figure are summarized the main stock assessment outcomes (Figure 4.5.1.1)

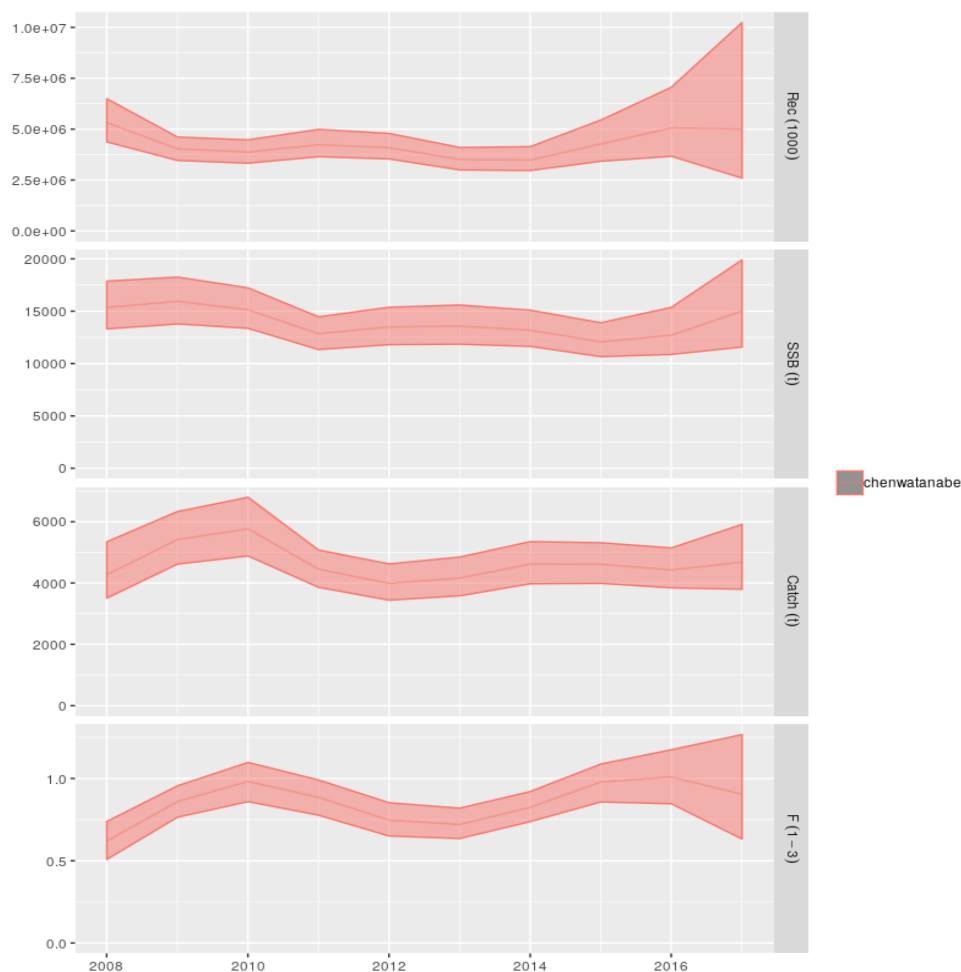**Figure 4.5.1.1** Stock summaries of the a4a fit. This a4a fit was used as the base case OM in the MSE.

4.5.2 Alternatives for robustness tests

No plausible stock recruitment relationships were found for this stock. An alternative natural mortality model was tested.

The new natural mortality vector (M) was computed according to the Chen and Watanabe (1989) formula, as following:

Age	0	1	2	3	4	5	6+
M	2.21	0.94	0.69	0.60	0.55	0.53	0.51

All the others inputs were kept identical to the base case. The following figures summarize the model conditioning outcomes (Figure 4.5.2.1, Figure 4.5.2.2)

Figure 4.5.2.1 Stock summaries of the a4a fit with the new natural mortality vector. This a4a fit was used as the alternative OM in the MSE.
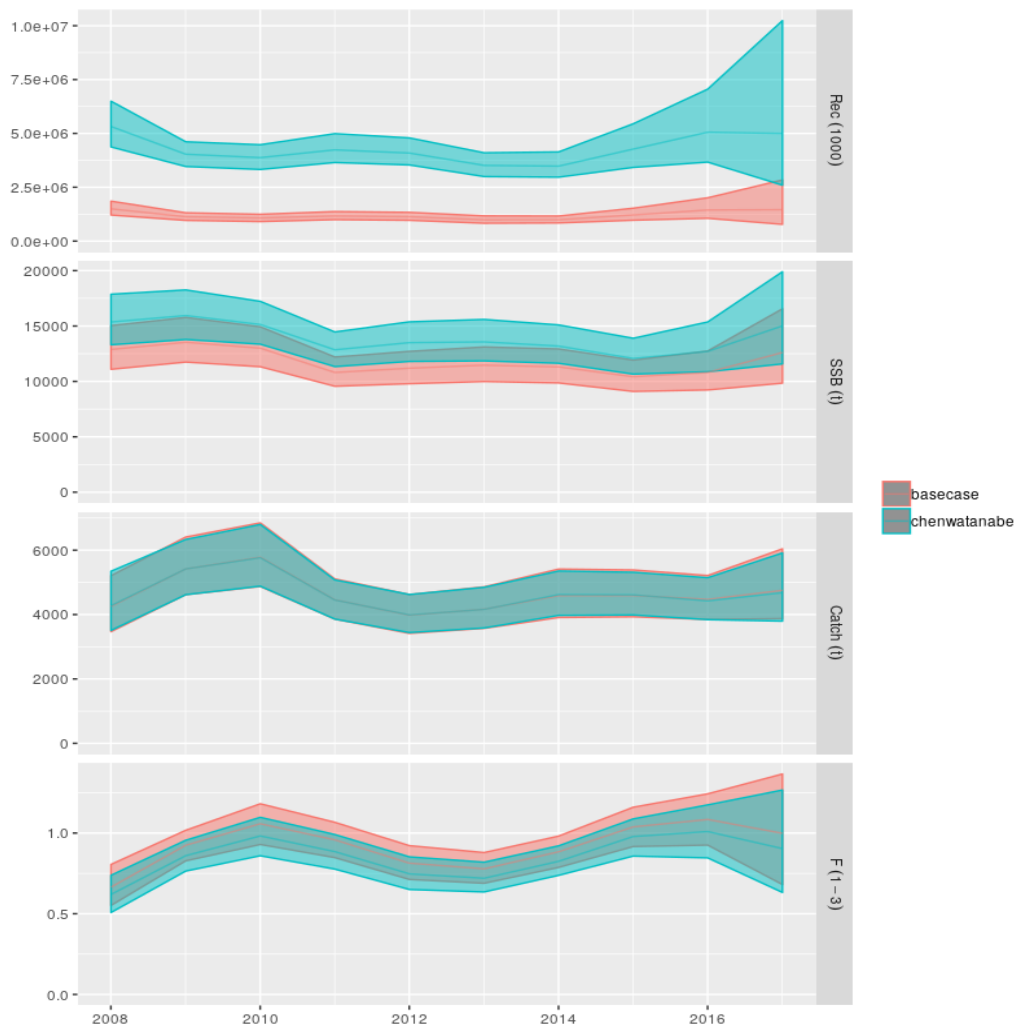
Figure 4.5.2.2 Comparison of the two OMs: ProdBiom in red and Chen Watanabe in blue.

The main effects in changing the natural mortality was a rescaling of the assessment with lower fishing mortality (F), and larger spawning stock biomass (SSB) and recruitment (Rec).

5 TOR 3 – MANAGEMENT PROCEDURE A

5.1 Hake 17-18

Compared to the baseline (Fsq), applying a management scenario of linear reduction of F to reach Fmsy in 2024 (Fmsy24) would result in more than a four-fold increase in SSB and a 40% reduction in catch in the short term (Table 5.1.1). The probability that SSB would be lower than Blim is very low (2%). A management scenario with a fixed reduction in F (Fmsy24FR) would result in a lower short-term increase of both SSB (17%) and catch (10%), the latter associated with a median negative variation of 4% (Table 5.1.1). The probability that SSB will be lower than Blim in the FmsyFR scenario would still be low (7%). Recruitment would increase slightly in both the Fmsy24 and Fmsy24FR scenarios (8% and 3% respectively) compare to the baseline, owing to the Beverton-Holt stock-recruitment relationship used. Finally, F would fall under FMSY in the case of the Fmsy24 scenario but not in the case of the Fmsy24FR scenario, where it would be more than three times higher.

In the long term (2024-2035), even bigger gains in SSB would be expected (almost 12-fold) in both the Fmsy24 and the Fmsy24FR scenarios compared to the Fsq scenario (Table 5.1.1). Catch

would be lower than the Fsq scenario: by 11% in the case of Fmsy24 scenario and by 40% in the Fmsy24FR scenario. Catch variation would be quite high: +58% and +80% in the case of Fmsy24 and Fmsy24FR scenario respectively. The risk that SSB falls below Blim would be 0 for both Fmsy24 and Fmsy24FR scenarios. An increase in SSB of about 48% with a decrease in catch of about 20% in the Fmsy24FR compare to the baseline would be expected. Recruitment would increase in both the Fmsy24 and Fmsy24FR scenarios, by 12% and 11% respectively compared to the baseline. Finally, F would fall under FMSY in both the Fmsy24 and the Fmsy24FR scenario.

Table 5.1.1 Computed indicators for the basecase OM in the short term (2018-2024) and the long term (2025-2035). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Indicator	Short-term (2018-2024)			Long-term (2025-2035)		
	Fsq	Fmsy24	Fmsy24FR	Fsq	Fmsy24	Fmsy24FR
C	7706	4590	6925	7428	6587	4473
Chi	9544	6068	8494	9186	8719	7419
Clo	6189	3523	5669	5066	3793	3357
CVAR	1.04	1.08	0.96	1.03	1.58	1.80
CVARhi	1.15	1.23	1.03	1.29	2.47	3.06
CVARlo	0.97	0.96	0.87	0.94	1.07	1.23
FFMSY	3.87	0.88	3.27	3.79	0.83	0.64
R	430207	463259	443854	426620	477364	473940
SSB	1765	7595	2062	1604	18952	18609
SSBhi	2392	11318	3886	2052	22167	22563
SSBlo	1226	5003	1081	1157	14976	13941
SSBLIM	0.08	0.02	0.07	0.17	0	0.00
SSBLIMmax	0.86	0.29	0.71	0.91	0	0.27

5.1.1 Baseline (F status quo)

There are small gains to be made in both the catch and the SSB in the Fsq scenario (Figure 5.1.1.1). This is because Fsq is at the lowest levels that have been observed since the early 2000s, hence Fsq is associated with a lighter overfishing compared to earlier years. A continuation of this low F would result in higher SSB than the current one, of a similar level to the one observed in 2003-2005. The management lag (3 years) results in unstable future trends, particularly in F and Catch.

The standard deviation of recruitment was wider in the last years of the OM (2015-2017) compared to earlier years, but from 2018 onwards the average standard deviation of the whole 1998-2017 period was applied. This resulted in the observed particular shape of the confidence intervals of recruitment (Figure 5.1.1.1).
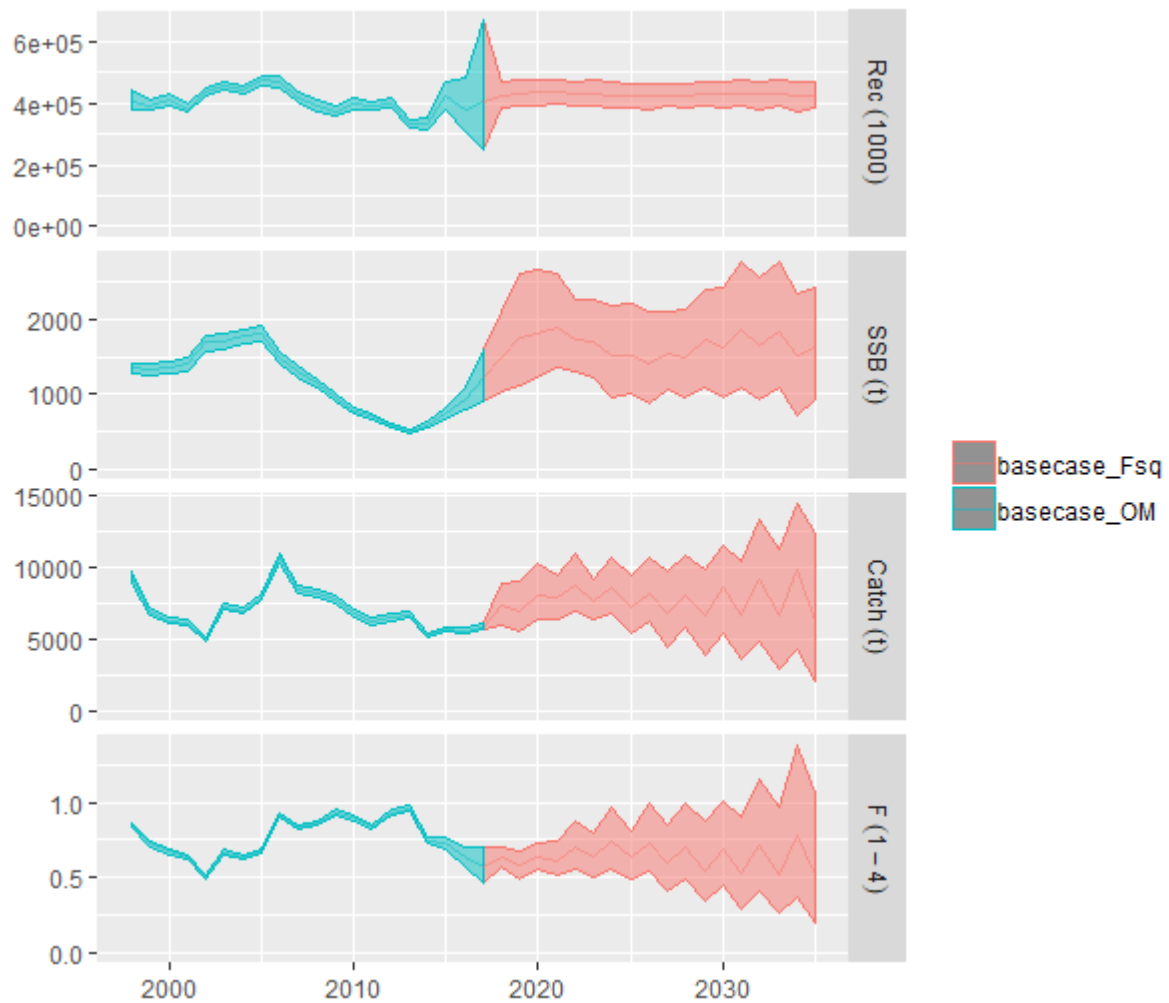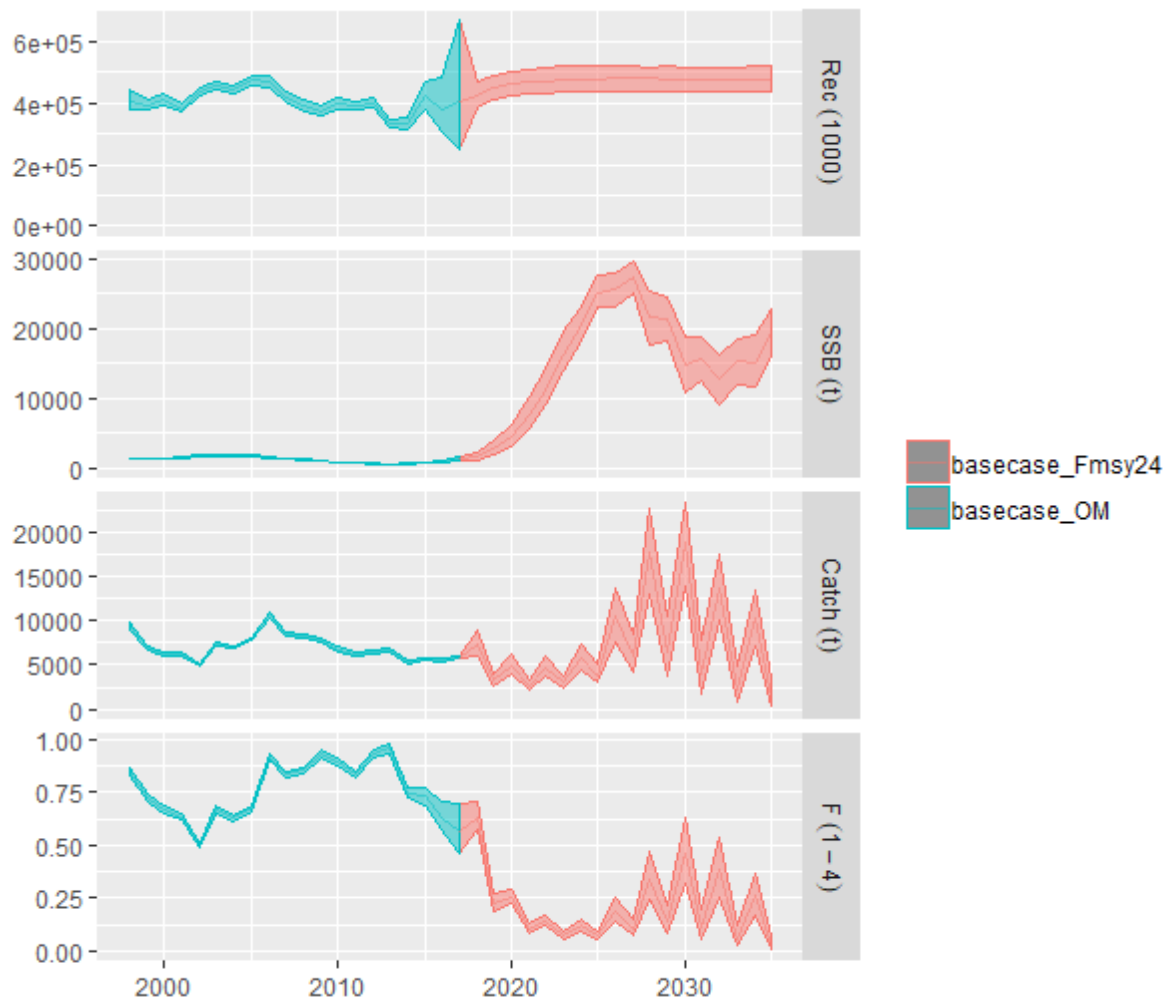
Figure 5.1.1.1 Stock summaries of the basecase OM and MP with F status quo. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

### 5.1.2 Scenario a.ii EFFORT: Fmsy in 2024 linear decrease

SSB would greatly increase in the Fmsy24 scenario (Figure 5.1.2.1). This is unsurprising, given that F would need to be reduced more than 3-fold to reach Fmsy in 2024. This great increase in SSB means that the stock would reach a size that has not been observed in recent history; hence, there is great uncertainty on how the stock biology and dynamics would look like in that case. As in the case of the Fsq scenario, the management lag (3 years) results in unstable future trends, particularly in F and Catch.

Figure 5.1.2.1 Stock summaries of the basecase OM and MP with Fmsy at 2024 with linear reduction. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

### 5.1.3 Scenario a.iii EFFORT: Fmsy in 2024 FIXREDUX

In the Fmsy24FR scenario, the reduction in F would be less sharp than in the Fmsy24 scenario (Figure 5.1.3.1). This would result in SSB starting to increase a bit later, but the increase would still be very pronounced and beyond the observed levels of SSB. The long-term trends in F and Catch would be even more unstable than in the Fmsy24 scenario, owing to the fact that the reduction in F happens later.
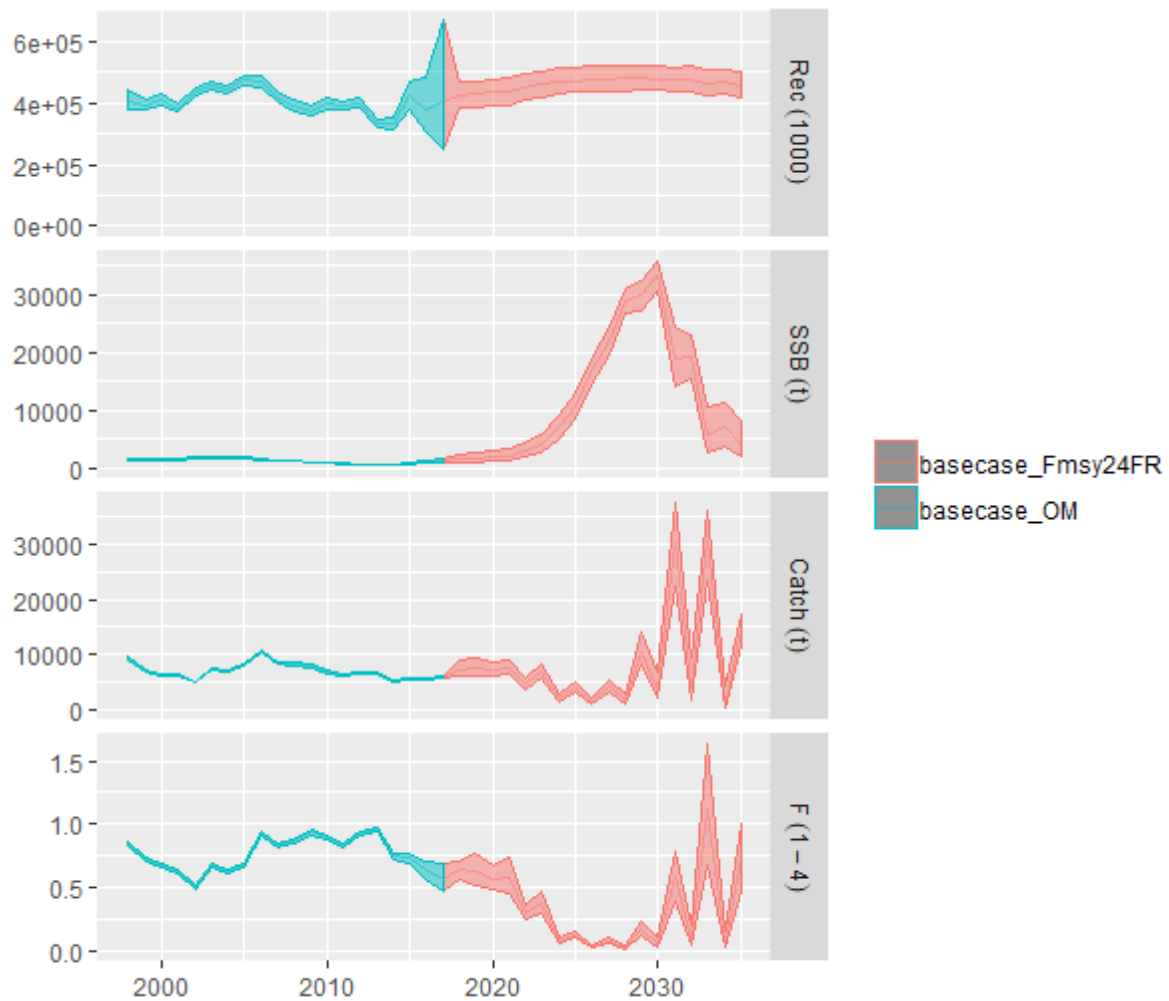
Figure 5.1.3.1 Stock summaries of the basecase OM and MP with Fmsy at 2024 with fixed reduction. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

5.1.4 Robustness tests

The robustness tests did not exhibit any significant deviances from the base-case run. The use of a geomean OM, whereby recruitment remained unchanged in the projection, resulted in very similar outputs to the base-case Beverton-Holt OM, (Figure 5.1.4.1; Table 5.1.4.1). The use of a 'high-discards' OM (Figure 5.1.4.2; Table 5.1.4.2) or a 'low-ALB' OM (Figure 5.1.4.3; Table 5.1.4.3), was associated with a lower F status quo than the base-case scenario, accompanied by higher levels of SSB, lower probability of stock collapse and slightly lower catch, but the general patterns of catch and SSB were similar to the base-case run. This lower F in the last years of the OM was due to F being higher at ages 0 and 1 but lower in ages 2-4 compared to the base-case in the 'high-discards' OM, and F being lower due to the lower catches in the 'low-ALB' OM. In other words, the original assessment is not robust to a change in selectivity or total catches.
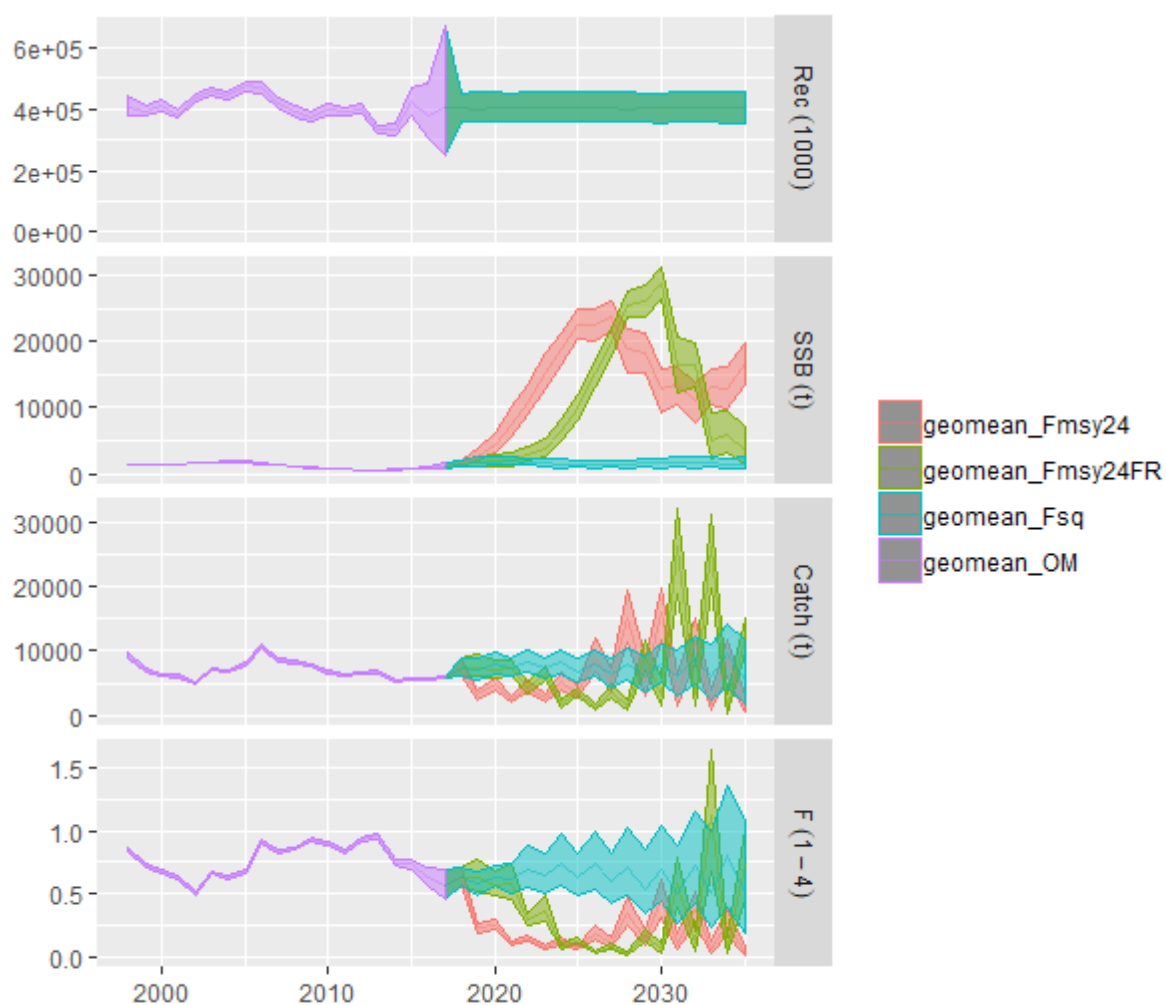
Figure 5.1.4.1 Stock summaries of the geomean OM and MPs with F status quo (blue), with Fmsy at 2024 with linear reduction (red) and with Fmsy at 2024 with fixed reduction (green). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Table 5.1.4.1 Computed indicators for the geomean OM in the short term (2018-2024) and the long term (2025-2035). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Indicator	Short-term (2018-2014)			Long-term (2025-2035)		
	Fsq	Fmsy24	Fmsy24FR	Fsq	Fmsy24	Fmsy24FR
C	7477	4285	6678	7038	5513	3961
Chi	9114	5633	8117	8703	7497	6487
Clo	6166	3335	5579	4740	3244	2035
CVAR	1.03	1.06	0.94	1.03	1.56	1.77
CVARhi	1.14	1.21	1.03	1.3	2.41	3.21

CVARlo	0.95	0.94	0.85	0.94	1.05	1.24
FFMSY	3.87	0.88	3.25	3.81	0.82	0.64
R	403941	403941	403941	402824	402824	402824
SSB	1731	7434	2055	1520	16264	16242
SSBhi	2352	11135	3721	1919	18878	19552
SSBlo	1208	5053	1076	1102	12728	12055
SSBLIM	0.1	0.02	0.07	0.21	0	0.01
SSBLIMmax	0.86	0.29	0.71	0.91	0.27	0.27

Figure 5.1.4.2 Stock summaries of the high-discards OM and MPs with F status quo (blue), with Fmsy at 2024 with linear reduction (red) and with Fmsy at 2024 with fixed reduction (green). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Table 5.1.4.2 Computed indicators for the 'high-discards' OM in the short term (2018-2024) and the long term (2025-2035). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Indicator	Short-term (2018-2024)			Long-term (2025-2035)		
	Fsq	Fmsy24	Fmsy24FR	Fsq	Fmsy24	Fmsy24FR
C	7330	4096	6600	7142	5913	3886
Chi	8989	5361	8015	8901	7474	5667
Clo	6054	3275	5498	4875	3220	3073
CVAR	1.03	1.03	0.95	1.04	1.49	1.84
CVARhi	1.11	1.15	1.03	1.35	2.5	3.28
CVARlo	0.95	0.92	0.87	0.93	1.04	1.26
FFMSY	3.7	0.87	3.13	3.66	0.89	0.65
R	409853	420502	414360	408801	426370	424863
SSB	2050	7634	2348	1895	18884	18449
SSBhi	2807	11324	4247	2458	22308	22082
SSBlo	1460	5342	1347	1386	14463	14132
SSBLIM	0.02	0	0.02	0.08	0	0
SSBLIMmax	0.43	0.14	0.57	0.73	0.27	0.27
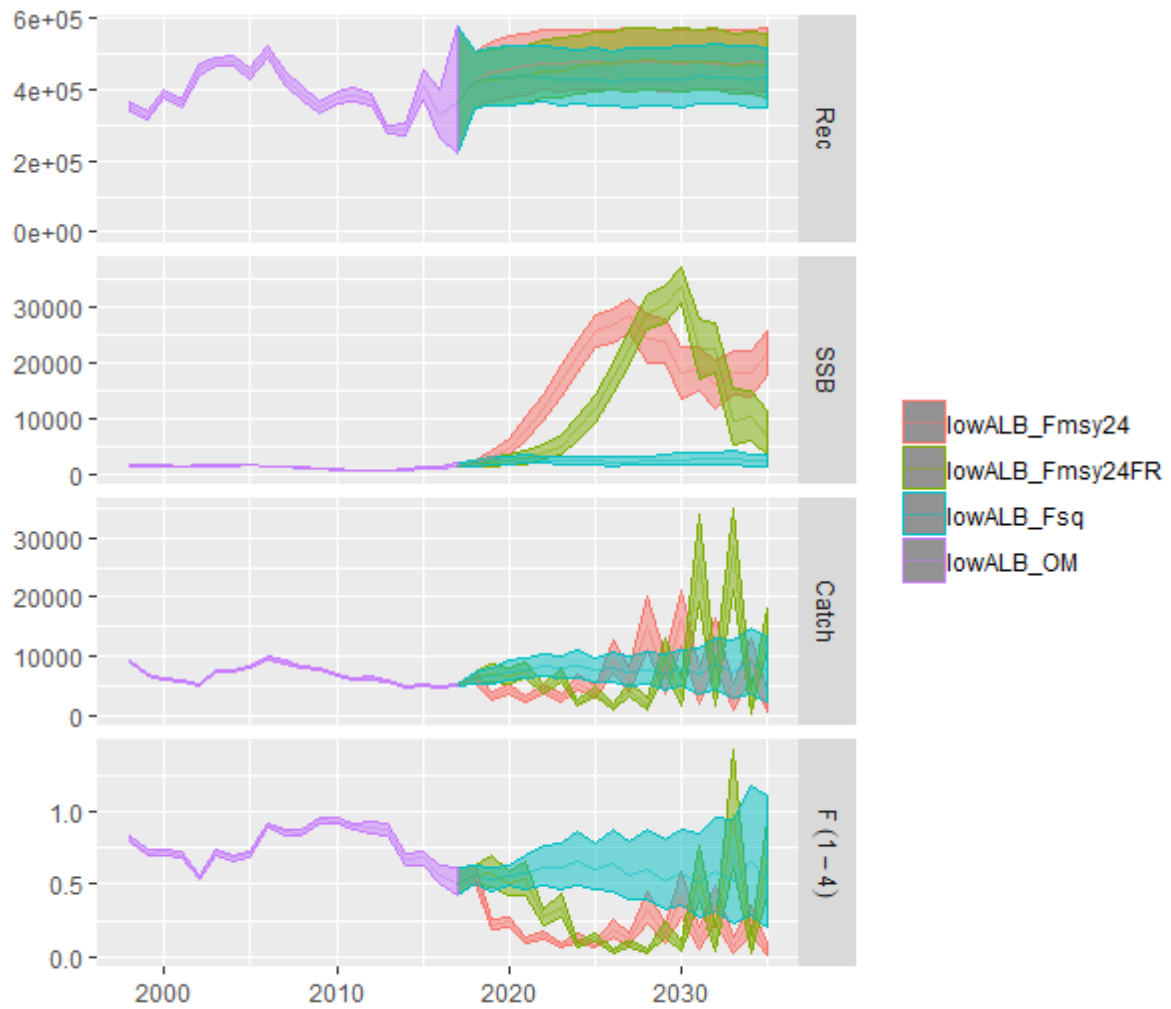
Figure 5.1.4.3 Stock summaries of the 'low-ALB' OM and MPs with F status quo (blue), with Fmsy at 2024 with linear reduction (red) and with Fmsy at 2024 with fixed reduction (green). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Table 5.1.4.3 Computed indicators (short term) for the 'low-ALB' OM in the short term (2018-2024) and the long term (2025-2035). SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Indicator	Short-term (2018-2024)			Long-term (2025-2035)		
	Fsq	Fmsy24	Fmsy24FR	Fsq	Fmsy24	Fmsy24FR
C	7412	4273	6409	7548	6389	4449
Chi	8985	5407	7617	9592	8383	7012
Clo	6033	3413	5286	5453	3512	3399
CVAR	1.06	1.06	0.99	1.03	1.48	1.73
CVARhi	1.16	1.2	1.06	1.37	2.47	3.08

CVARlo	0.99	0.95	0.9	0.93	1.01	1.23
FFMSY	3.48	0.88	2.93	3.49	0.87	0.68
R	432914	460357	442837	431068	476605	473975
SSB	2362	7869	2681	2378	21357	20954
SSBhi	3107	10892	4556	3073	25376	24839
SSBlo	1738	5549	1514	1735	16850	16251
SSBLIM	0.01	0	0.01	0.03	0	0
SSBLIMmax	0.57	0.14	0.57	0.73	0.36	0.09

5.2 Red mullet 17-18

The introduction of either of the proposed management procedure (MP) will lead to a reduction in catches in the short and long term compared to fishing under the status quo (FSQ). Although, in the long term the catches are reduced by less than 100t for the fix reduction (Fmsy24FR) MP and a little over 500t for the linear effort reduction (Fmsy24) MP (Table 5.2.1). The relative fishing mortality (F/Fmsy) is dropping from 1.41 (FSQ) to 1.22 and 0.96 (FmsyFR and Fmsy24 respectively) in the short term. By 2035, we expect the relative fishing mortality to remain nearly unchanged for FSQ (1.38), where as the other two MPs achieve fishing mortality slightly under Fmsy (Table 5.2.1). The explanation for achieving less-than-Fmsy fishing mortality whilst maintaining similar catches as FSQ lies within the stock recovery to over 12kt SSB. The basecase OM assumes constant recruitment, thus, this increase of SSB should be seen as a minimum, except cases of severe recruitment stochasticity.

Table 5.2.1 Computed indicators for the basecase OM in the short term (2018-2024) and the long term (2025-2035).

Indicator	Short-term (2018-2024)			Long-term (2025-2035)		
	Fsq	Fmsy24	Fmsy24FR	Fsq	Fmsy24	Fmsy24FR
C	5862	4984	5246	5081	4629	4984
Chi	7940	6731	6606	6074	5697	6094
Clo	4321	3762	4205	3643	3270	4041
CVAR	1.00	0.99	0.92	1.03	1.06	1.07
CVARhi	1.12	1.13	1.01	1.31	1.45	1.51
CVARlo	0.89	0.88	0.83	0.93	0.93	0.94
FFMSY	1.41	0.96	1.22	1.38	0.94	0.96
R	2150893	2150893	2150893	2160654	2160654	2160654
SSB	9985	12684	10705	9001	12169	12648

SSBhi	12989	16850	16155	10681	14405	14846
SSBlo	7753	9536	7071	7590	10112	10777
SSBBLIM	0.01	0.00	0.01	0.00	0.00	0.00
SSBBLIMmax	0.29	0.29	0.57	0.27	0.00	0.18

5.2.1 Baseline (F status quo)

Fishing under the status quo conditions, leads to no significant changes in catches; where as the SSB will drop just under 10kt (Figure 5.2.1.1). The uncertainties in the simulation of the stock under FSQ are driven by the uncertainties of recruitment. We used mean variance of the last 3 years, which is smaller than the last year estimates.
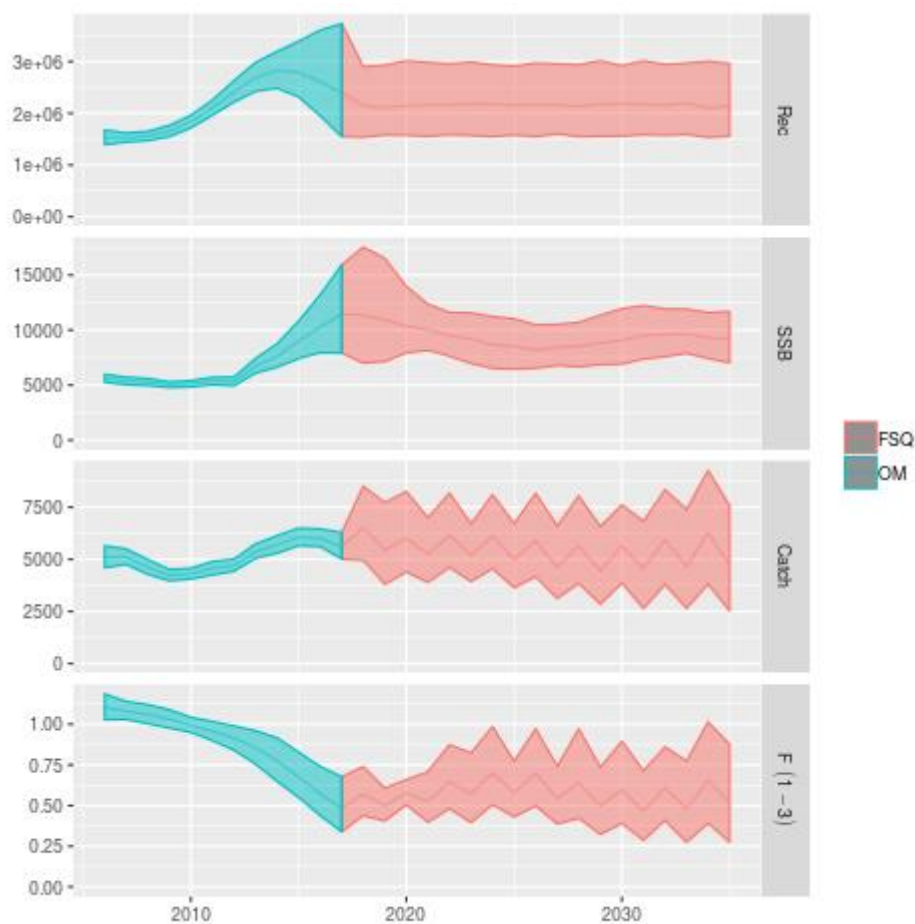
Figure 5.2.1.1 Stock summaries of the forward simulations under F-status-quo (F = 0.59) using a basecase OM.

5.2.2 Scenario a.ii EFFORT: Fmsy in 2024 linear decrease

The decrease of fishing mortality to Fmsy in 2024 leads to a reduction in catches. Fishing mortality and thus catches do oscillate around Fmsy (Figure 5.2.2.1), most likely due to the

management lag. The increase in SSB is relatively small compared to 2018, but sizable compared to the status quo scenario (3.7kt; Table 5.2.1).
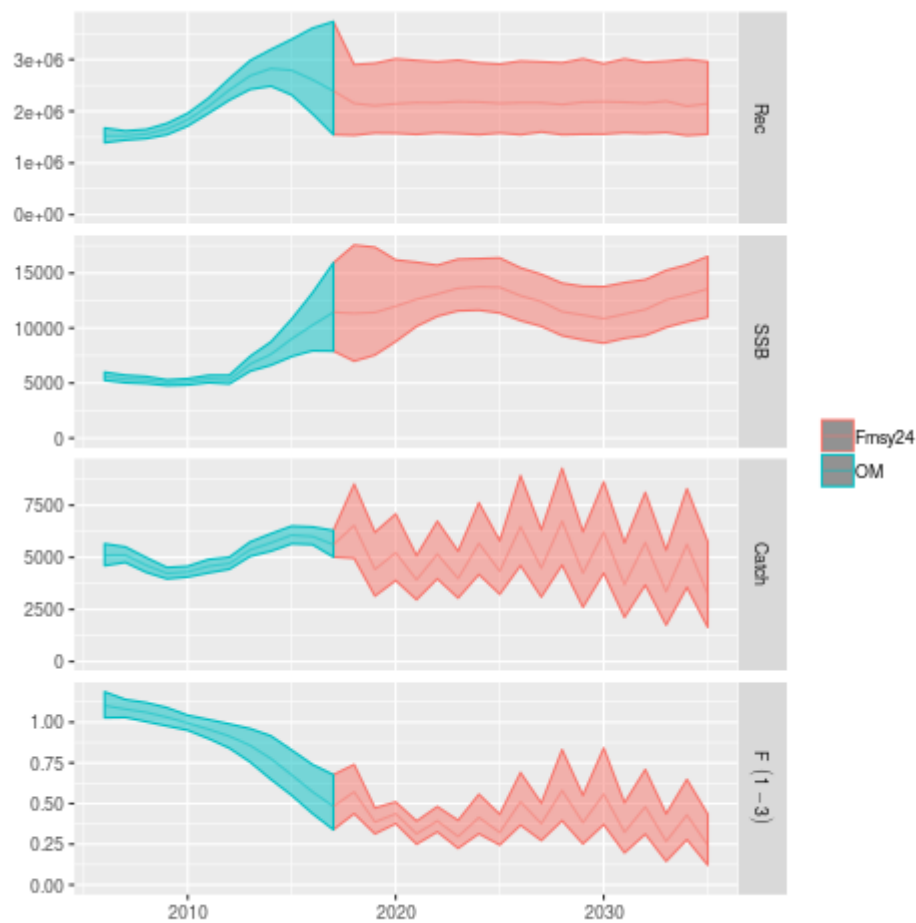
Figure 5.2.2.1 Stock summaries of simulations using a linear decline to Fmsy by 2024 using the base case OM.

5.2.3 Scenario a.iii EFFORT: Fmsy in 2024 FIXREDUX

This MP results in a slower decrease of the fishing mortality that can be observed by the short term indicator value F/Fmsy = 1.22 (Table 5.2.1). This slower decay has a knock on effect as the stocks do no quite recover to the same level as under the Fmsy24 MP. As for the two previous simulations, undulations of the fishing mortalities (and thus of the catches) does occur (Figure 5.2.3.1).
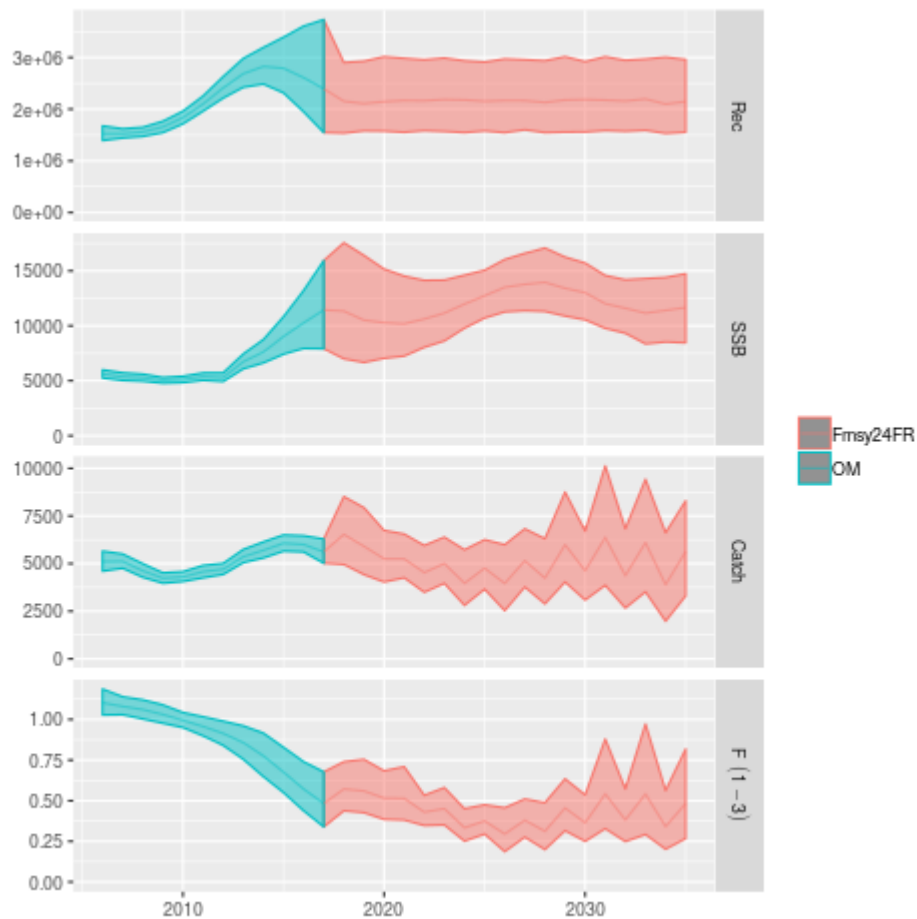
Figure 5.2.3.1 Stock summaries of simulations using a decline to Fmsy by 2024 including a fixed reduction of effort using the base case OM.

5.2.4 Robustness tests

The only robustness test was carried out by changing the stock-recruitment function to a Beverton Holt function that was fitted post-hoc to the estimates from the assessment model. The effect of this change was very small for the status quo scenario, as the SSB was nearly constant (Figure 5.2.4.1) and thus did not produce a higher level of recruitment (Table 5.2.4.1). In the other two MPs a positive feedback loop was created: the reduction of catches, leads to higher SSB, which in turn leads to higher recruitment. This is especially apparent in the long-term catch levels: an increase of around 1kt in catches was observed compared to the status quo - whilst fishing under the Fmsy level and nearly doubling SSB.

The indicators and stock summaries for the Beverton-Holt run leads to the conclusion that the MPs are robust to the mis-specification of the stock recruitment function, as long as the "real" relationship is more optimistic than the mean recruitment used in the basecase.

Table 5.2.4.1 Computed indicators for the Beverton-Holt OM in the short term (2018-2024) and the long term (2025-2035).

Indicator	Short-term (2018-2024)			Long-term (2025-2035)		
	FSQ	Fmsy24	Fmsy24FR	FSQ	Fmsy24	Fmsy24FR
C	6934	6161	6314	6575	7472	7789
Chi	9687	8794	8582	8190	9127	9496
Clo	4467	4094	4272	4686	5107	5767
CVAR	1.05	1.08	0.97	1.03	1.08	1.09
CVARhi	1.18	1.21	1.07	1.32	1.50	1.64
CVARlo	0.95	0.97	0.88	0.91	0.95	0.95
FFMSY	1.41	0.97	1.22	1.37	0.94	0.96
R	2878737	3250144	3041316	2872780	3537943	3552213
SSB	12099	15930	12856	11715	19162	19723
SSBhi	16933	22365	21455	14432	22946	23789
SSBlo	8237	9982	6523	9171	15780	15977
SSBBLIM	0.00	0.00	0.01	0.00	0.00	0.00
SSBBLIMmax	0.43	0.43	0.86	0.45	0.00	0.00
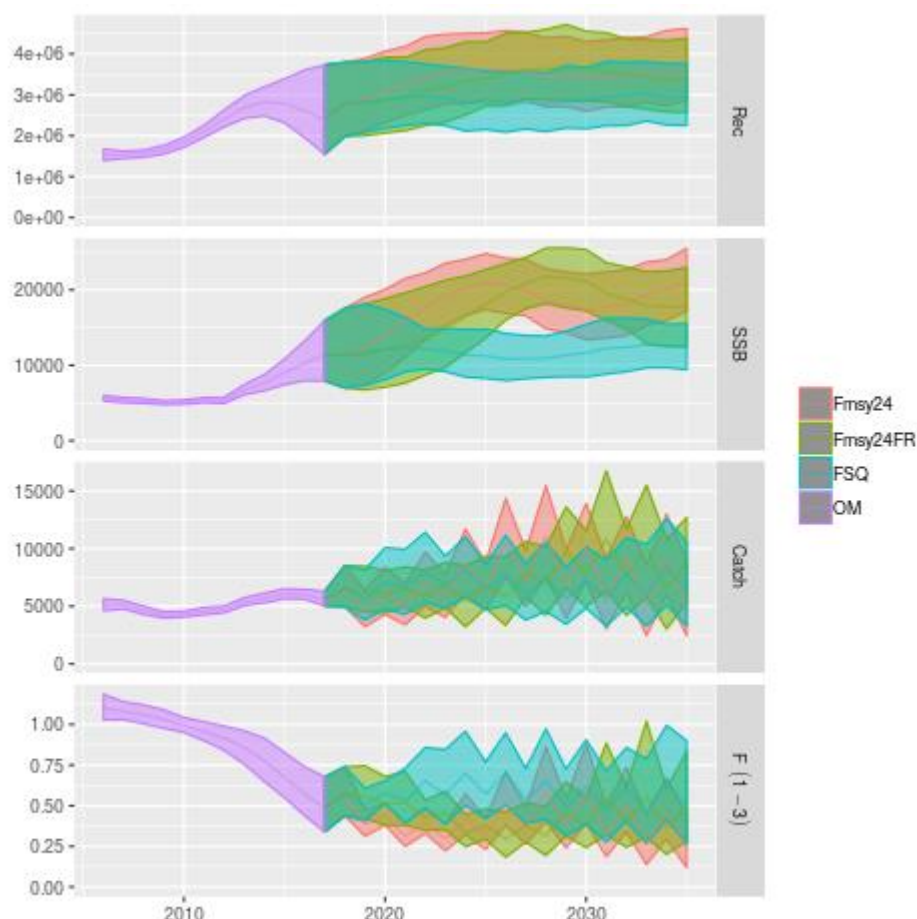
Figure 5.2.4.1. Stock summaries of the Beverton-Holt OM and MPs with F status quo (blue), with Fmsy at 2024 with linear reduction (red) and with Fmsy at 2024 with fixed reduction (green).

5.3   Deep-water rose shrimp 17-18-19

According to the calculated short-term indicators, in neither alternative scenarios to the baseline, the F will be lower than Fmsy (Table 5.3.1). The linear reduction of effort to reach Fmsy in 2024 (Fmsy24) starting in 2018 will result in the lower ratio of F over Fmsy to 1.13 by 2024. The SSB of the linear reduction by 2024 scenario is much higher than the baseline with an increase of around 45%. On the contrary the fixed reduction scenario increases SSB by 20%. Catches in the linear reduction scenario face a reduction of 30% and 15% respectively. The probability of SSB being lower than Blim is in both cases quite low (2% and 4%).

The values of indicators obtained for the same scenarios on a long-term period (2025-2035) result in an F lower than Fmsy in FIXREDUX and almost equal to Fmsy in the linear reduction scenario with values of 0.87 and 0.99 respectively (Table 5.3.1). The increase of the SSB of the Fmsy24 scenario is almost the same as the in the short-term projection while the increase in the fixed reduction scenario reaches the amount of 54%. Catches fall in around the same values in both scenarios with a decrement from the baseline of 24%. Finally in both cases the probability of SSB falling below Blim is 2%.

In the long-term the FIXREDUX gives higher SSB to the expense of lower F/F_{MSY}, missing the target, while a linear reduction reaches the exploitation target (Table 5.3.1).

Table 5.3.1 Computed short-term and long-term indicators for the base-case OM for the different effort scenarios: Baseline (Fsq), Fmsy in 2024 with linear reduction and Fmsy in 2024 with FIXREDUX

Indicator	Short-term (2018-2024)			Long-term (2018-2024)		
	Fsq	Fmsy24	Fmsy24FR	Fsq	Fmsy24	Fmsy24FR
C	3562	2628	3060	3028	2392	2376
Chi	5359	4115	4655	4099	3540	3477
Clo	2480	1733	2048	2117	1334	1566
CVAR	0.81	0.83	0.69	1.04	1.19	1.33
CVARhi	1.05	1.12	0.9	1.38	2.94	2.92
CVARlo	0.6	0.52	0.5	0.81	0.85	0.91
FFMSY	3.07	1.13	2.5	2.8	0.99	0.87
R	3952430	3889541	3889541	3942751	3954097	3954097
SSB	3089	4910	3770	3034	4896	5264
SSBBLIM	0.11	0.01	0.04	0.1	0.02	0.02
SSBBLIMmax	0.86	0.29	0.43	0.64	0.27	0.36
SSBhi	4462	7146	5522	4090	6734	7255
SSBlo	2092	3175	2480	2219	3615	3870

5.3.1 Baseline (F status quo)

In the baseline scenario, SSB will stay in low levels similar to the observed time-series except from the last two years of the assessment (Figure 5.3.1.1). While from the beginning of the time-series the stock is highly overfished, the baseline scenario projects the stock at the same levels as in the beginning. Absence of fluctuation in the observed data result in an almost flat projection of both SSB and recruitment, while the peak in the catches is only being interpreted by the model as a recruitment event.
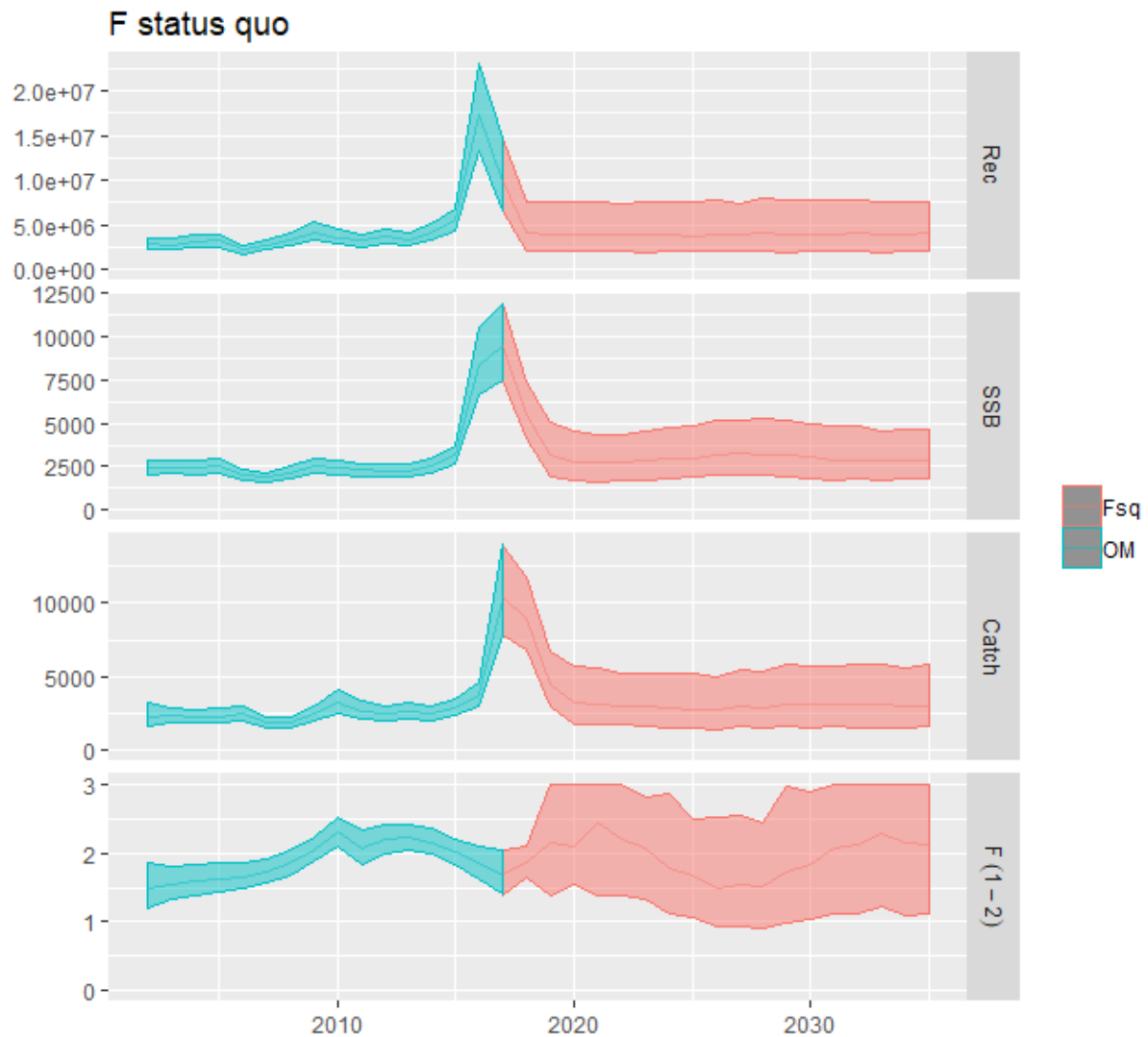
Figure 5.3.1.1 Stock summaries of the OM (basecase) and baseline MP (Fsq).

5.3.2 Scenario a.ii EFFORT: Fmsy in 2024 linear decrease

The linear decrease of effort scenario to reach Fmsy in 2024, shows a gain in the SSB both in the short and the long term (Figure 5.3.2.1). F shows a rapid reduction in the first few years to reach Fmsy with a reasonable uncertainty, while in the last ten years the uncertainty around F increases a lot. Despite the reduction in F, the ratio of F over Fmsy does not reach an acceptable value in the short term, while in the long term is just below 1.
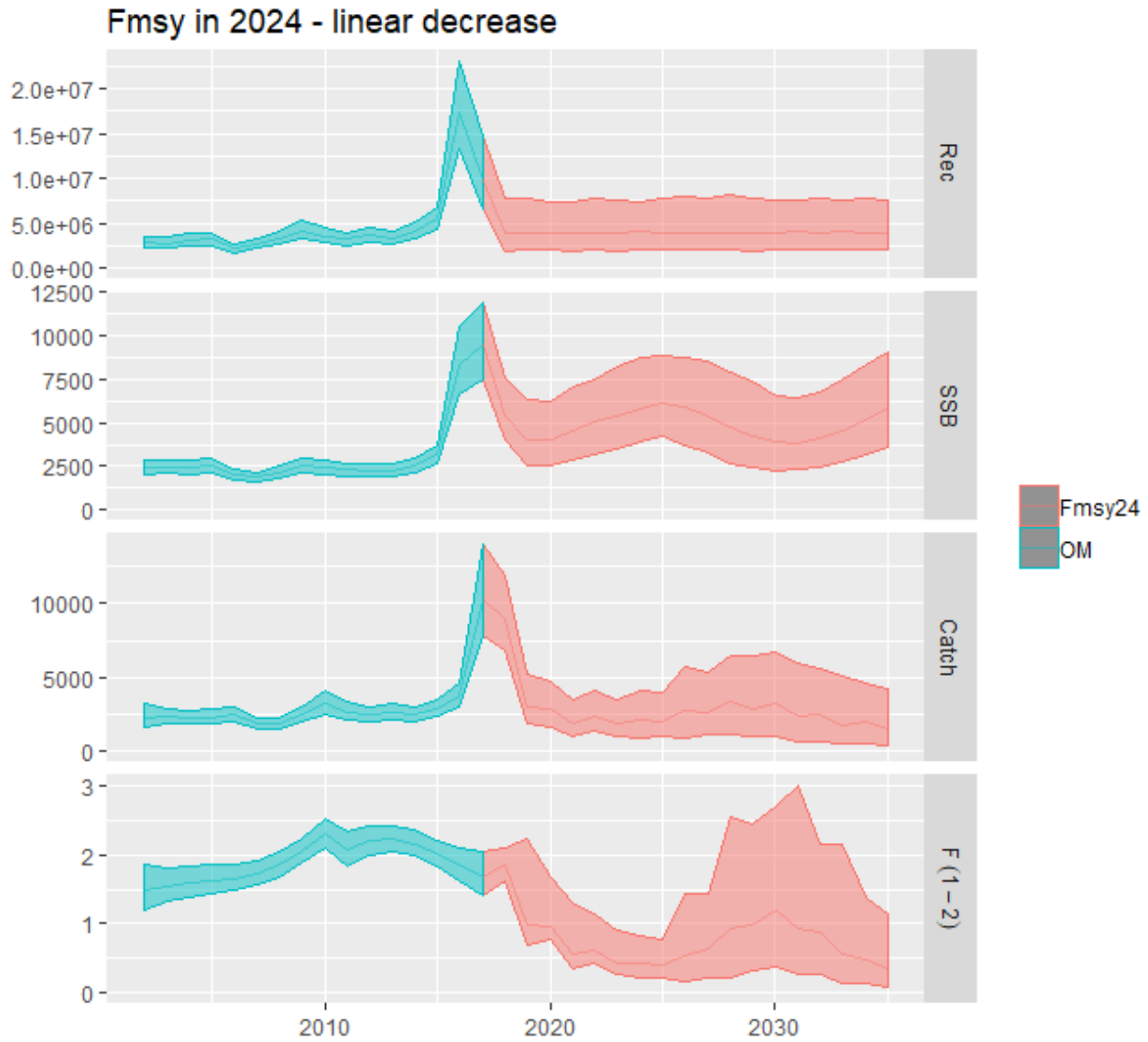
Figure 5.3.2.1 Stock summaries of the basecase OM and Fmsy in 2024 linear decrease MP (Fmsy24).

5.3.3 Scenario a.iii EFFORT: Fmsy in 2024 FIXREDUX

The FIXREDUX scenario shows a larger gain in SSB in the long term projection which is not apparent in the short term, comparing to the Fmsy24 scenario (Figure 5.3.3.1). F shows a steady decrease in the first half of the projected years but after 2030 shows an increase with great fluctuations around 1.5. This unstable behavior of F in the last years is a result of the inability of the model to explore areas never met in the time-series. The appearance of spikes in both fishing mortality and in the catch is a result of the management lag of 2 years in the projection
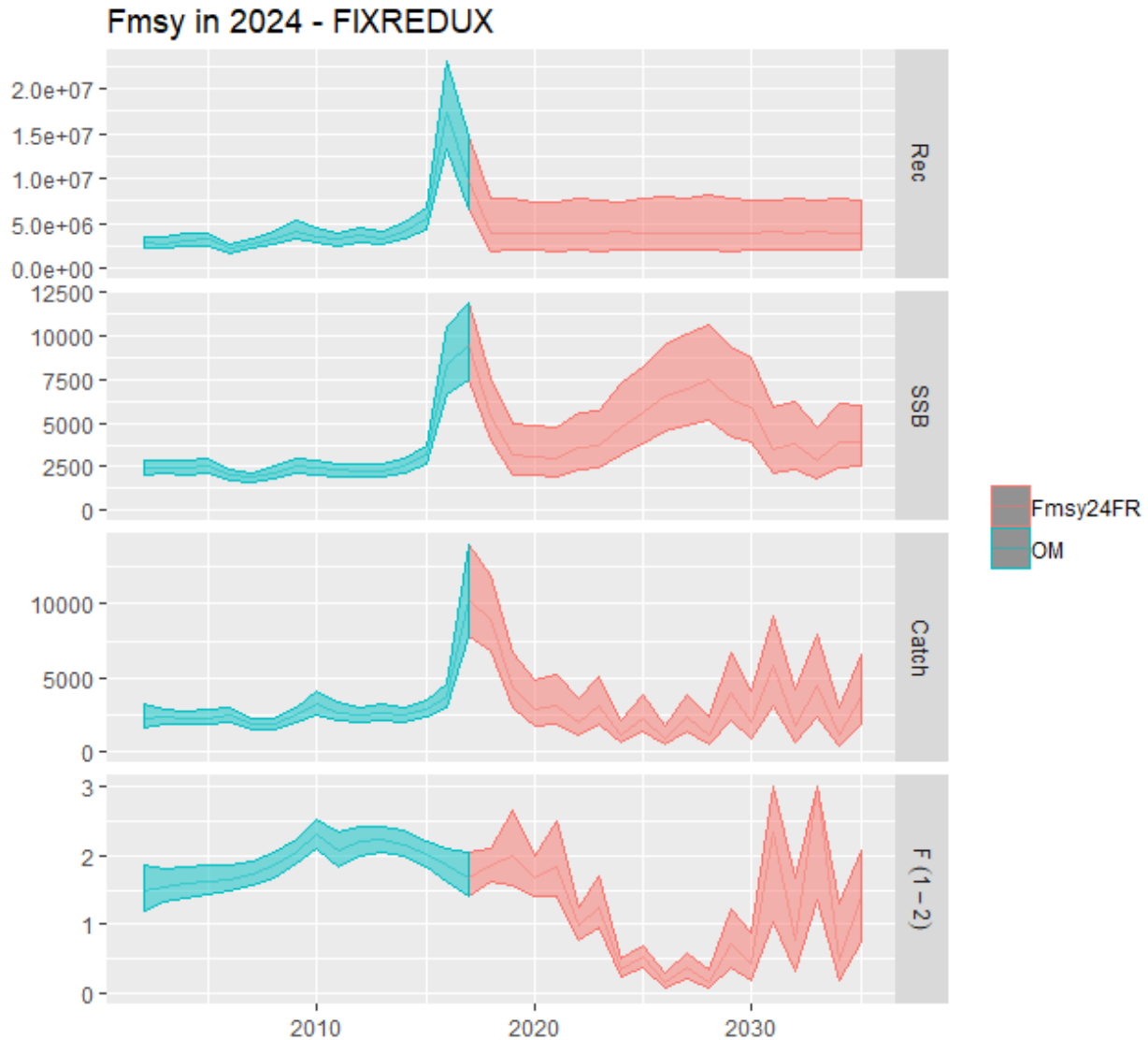
Figure 5.3.3.1 Stock summaries of the basecase OM and Fmsy in 2024 fixed reduction MP (Fmsy24).

5.4 Sole 17

Indicators obtained in the short-term projections suggest that, compared to the baseline scenario (Fsq), only a linear decrease (Fmsy24) starting in 2018 would allow to reach an F equal or smaller than Fmsy (Table 5.4.1). SSB values obtained for the Fmsy24 scenario are always higher although the probability of going under Blim (1142 t) are equal to the baseline scenario. Catch variation across the time series (CVAR, CVARhi, CVARlo) is also generally lower for this scenario. Despite a lower interannual variation, the uncertainty around the median Catch values (Chi, Clo) is high for all scenarios. Introducing catch limits do not show positive effects in the short term.

Indicators obtained from long-term projections show similar results to all scenarios with a reduction of effort aiming at reaching Fmsy by 2024 (Table 5.4.1). Again Fmsy24 is the scenario suggesting the best compromise between keeping an F equal or smaller than Fmsy, with values of SSB that never go under Blim (an improvement compared to the Fsq scenario) and reducing the

catch by 20%, an average value compared to the other scenarios. Introducing catch limits on the Fmsy24FR, with a stepwise decrease of effort, brings values close to the results of scenario Fmsy24.

Table 5.4.1 Short-term (2018-2024) and long –term (2025-2035) (in grey) indicators computed for all mp scenarios tested on the basecase OM. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Indicator	Short-term (2018-2024)					Long-term (2018-2024)				
	Fsq	FsqCL	Fmsy24	Fmsy24FR	Fmsy24FRCL	Fsq	FsqCL	Fmsy24	Fmsy24FR	Fmsy24FRCL
C	1387	1351	960	1452	1354	1589	1638	1299	1180	1311
Chi	1946	1941	1410	1843	1673	2061	2053	1737	1650	1681
Clo	861	918	635	1142	1073	1176	1193	898	658	993
CVAR	1.00	0.92	0.87	0.95	0.83	1.02	1.01	1.01	1.08	1.03
CVARhi	1.22	1.09	1.07	1.08	0.94	1.22	1.16	1.24	1.32	1.19
CVARlo	0.83	0.74	0.73	0.84	0.74	0.86	0.89	0.82	0.89	0.93
FFMSY	1.30	1.28	0.70	1.47	1.45	1.40	1.34	0.76	0.66	0.77
R	26593	26593	26593	26593	26593	26666	26666	26666	26666	26666
SSB	3828	3531	4597	3688	3416	4662	4847	7997	7944	7302
SSBhi	5661	5856	7087	6029	6213	8393	8660	12376	12289	11511
SSBlo	2469	1781	2900	2064	1310	2208	2294	4443	4825	4040
SSBBLIM	0.00	0.03	0.00	0.00	0.05	0.01	0.03	0.00	0.00	0.00
SSBBLIMmax	0.43	0.57	0.43	0.71	0.86	0.45	0.64	0.00	0.18	0.00

5.4.1 Baseline (F status quo)

In the F status quo scenario, the OM was projected up to 2035 with a fixed value of F=0.44, which is the average of the last three years (2015-2017) of estimated F, in order to be consistent with the GFCM procedure (Figure 5.4.1.1). It should be noted that this average F is lower than the last year F (0.51) as the last 5 years are characterized by an increasing trend in F. The same (but opposite) effect is visible in recruitment which shows a decreasing trend in the last 5 years; the baseline OM has a slope of 1 in the sr model which produces flat projections in all the scenarios presented in this section, but with a starting value higher than recruitment estimated in 2017. This could potentially push F to values equal to Fmsy (0.24) (not introduced in this scenario) and SSB to oscillating values in the high range, during the projection. The uncertainty range of F and of the estimated Catch is wide as it accounts for the variations present in the historical time series (Figure 5.4.1.1) hiding the interannual fluctuations due to the 3 year management lag introduced to mimic the GFCM implementation process.
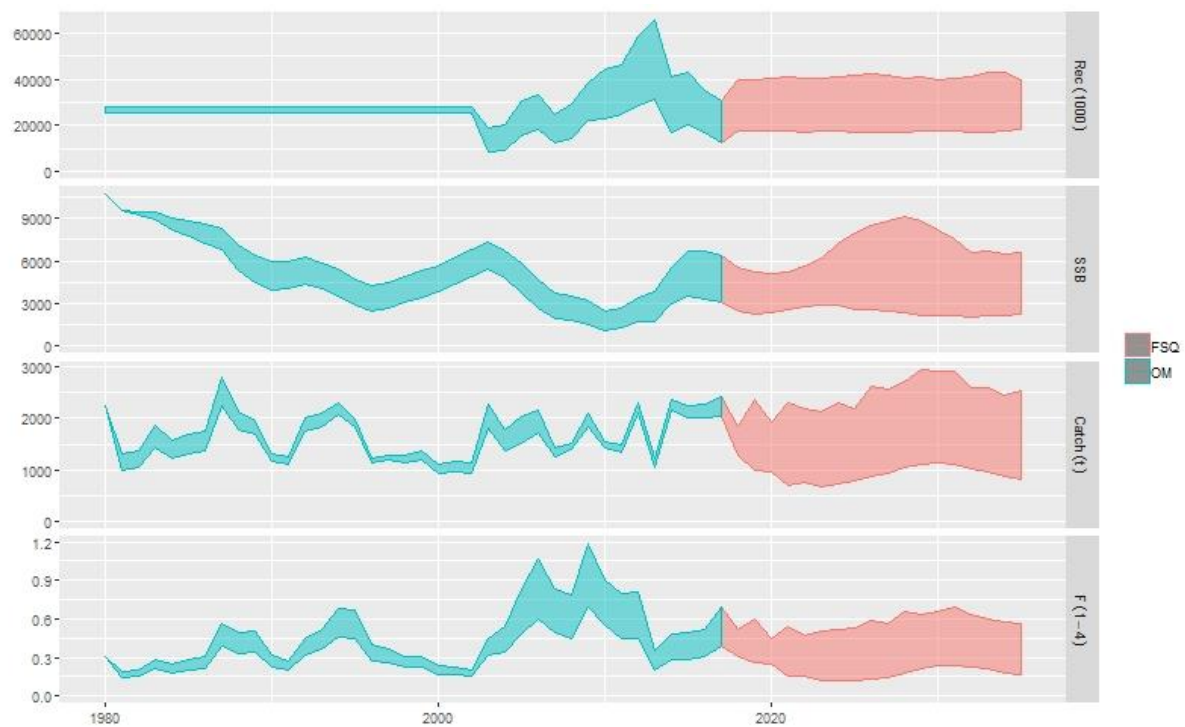
Figure 5.4.1.1 F status quo scenario on the baseline projection. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

### 5.4.2 Scenario a.ii EFFORT: Fmsy in 2024 linear decrease

In scenario a.ii, F (here assumed to have a linear relationship with fishing effort) is reduced in a linear fashion up to 2024 when a value equal or smaller than Fmsy (F01 = 0.24) is reached (Figure 5.4.2.1). After 2024, F has an increase up to 2030 and then decreases again up to 2035 although the values of F remain close to its lowest historical values. Uncertainty also increases towards the end of the projection. The oscillation is due to the management lag of 3 years introduced in the modelling process to mimic the management procedure applied within GFCM. While catch trends remain in the range of variation of its historical series, SSB follows the inverse trend of F reaching median values outside the historical trend, therefore lowering the reliability of the projection.
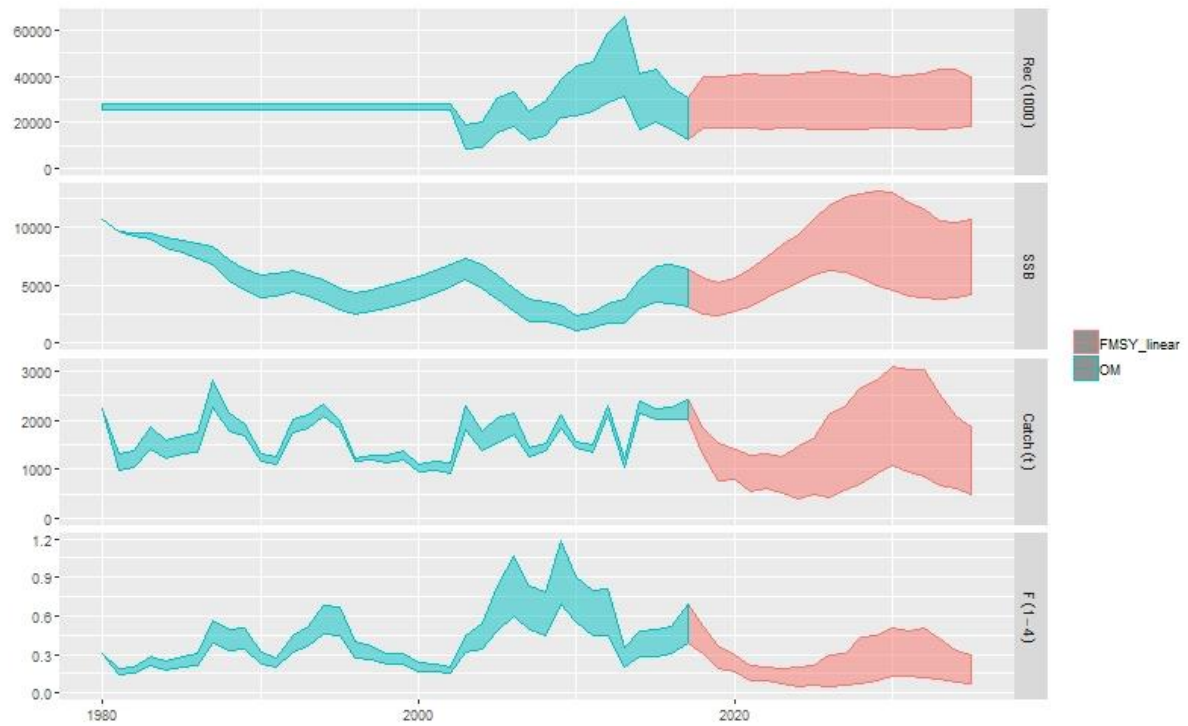
Figure 5.4.2.1 Scenario with a linear decrease up to 2024 when Fmsy is reached, on the baseline projection. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

5.4.3 Scenario a.iii EFFORT: Fmsy in 2024 FIXREDUX

The a.iii scenario implements a 10% reduction on 2020 followed by an 8% effort reduction in 2021 and then effort decreases linearly up to 2024. Therefore compared to scenario a.ii F is more stable up to 2021 and then shows a steeper decrease up to 2024 (Figure 5.4.3.1). Uncertainty ranges are bigger than scenario a.ii both for F and Catch after 2030.
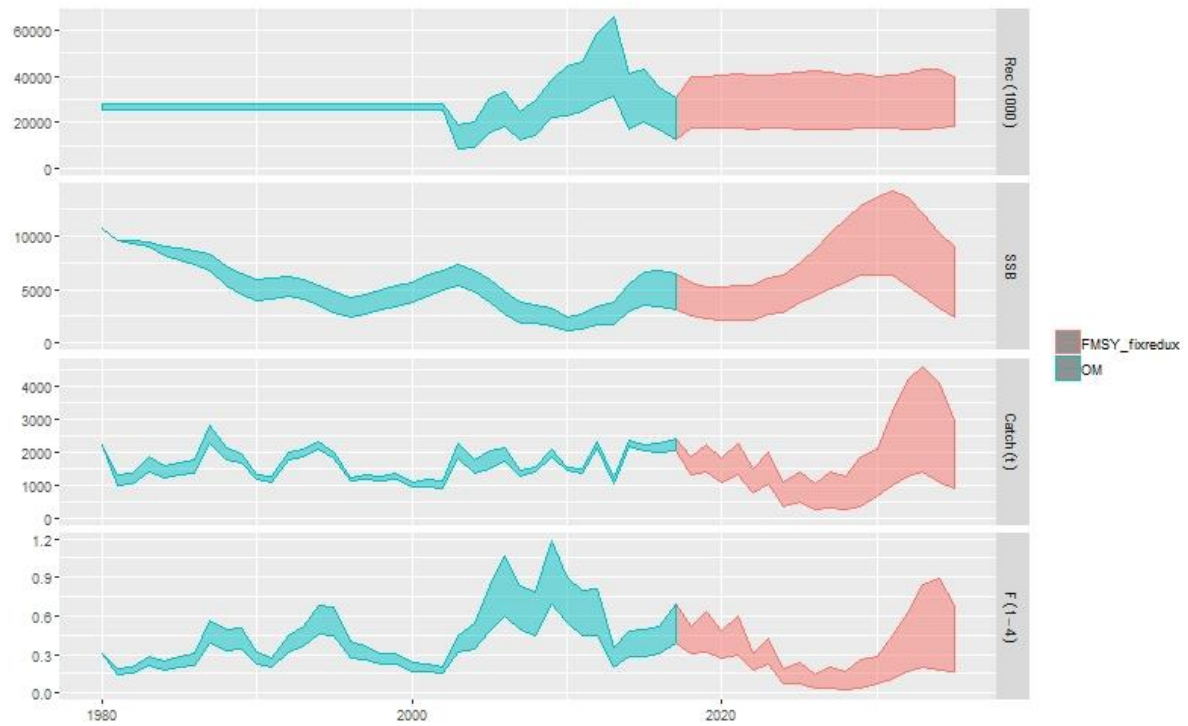
Figure 5.4.3.1 Scenario with a stepwise decrease up to 2024 when Fmsy is reached, on the baseline scenario. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

### 5.4.4 Scenario a.ii CATCHLIM: Fmsy in 2024 linear decrease

Scenario a.i introduces catch limits over the Fsq scenario; these introduce strong oscillations in the projected time series also increasing uncertainty ranges in all estimated parameters except recruitment. Values of F are on average higher than Fmsy both in the short and the long-term as the range of confidence intervals is catching the variation of the time series (Figure 5.4.4.1).
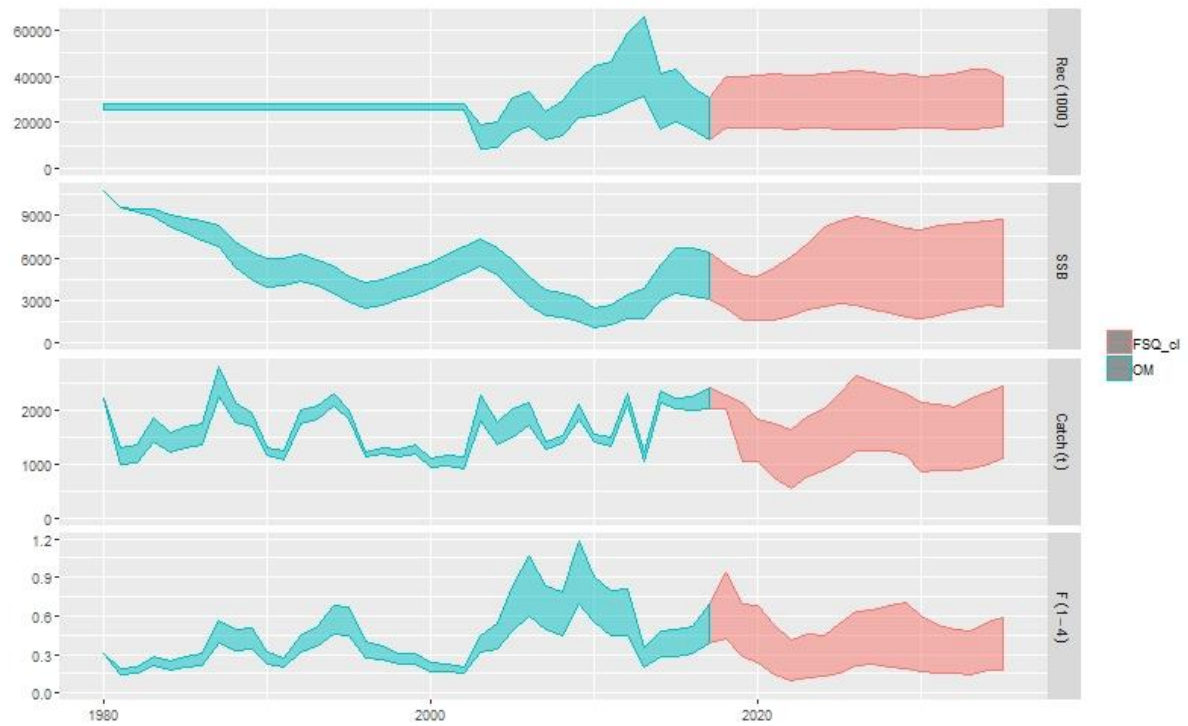
Figure 5.4.4.1 F status quo scenario after the introduction of a catch limit, on the baseline projections. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

5.4.5 Scenario a.iii CATCHLIM: Fmsy in 2024 FIXREDUX

In scenario a.iii, the introduction of catch limits over the scenario within which effort has a stepwise reduction up to 2024, shows a strong decrease in uncertainty after 2024, lack of oscillation compared to scenario a.i. and also reaching a value of F/Fmsy < 1 in the long term projection (Table 5.4.1; Figure 5.4.5.1). In this scenario as well, SSB increases to values at the limit of the historical range, with uncertainty increasing as the projection goes forward in time.
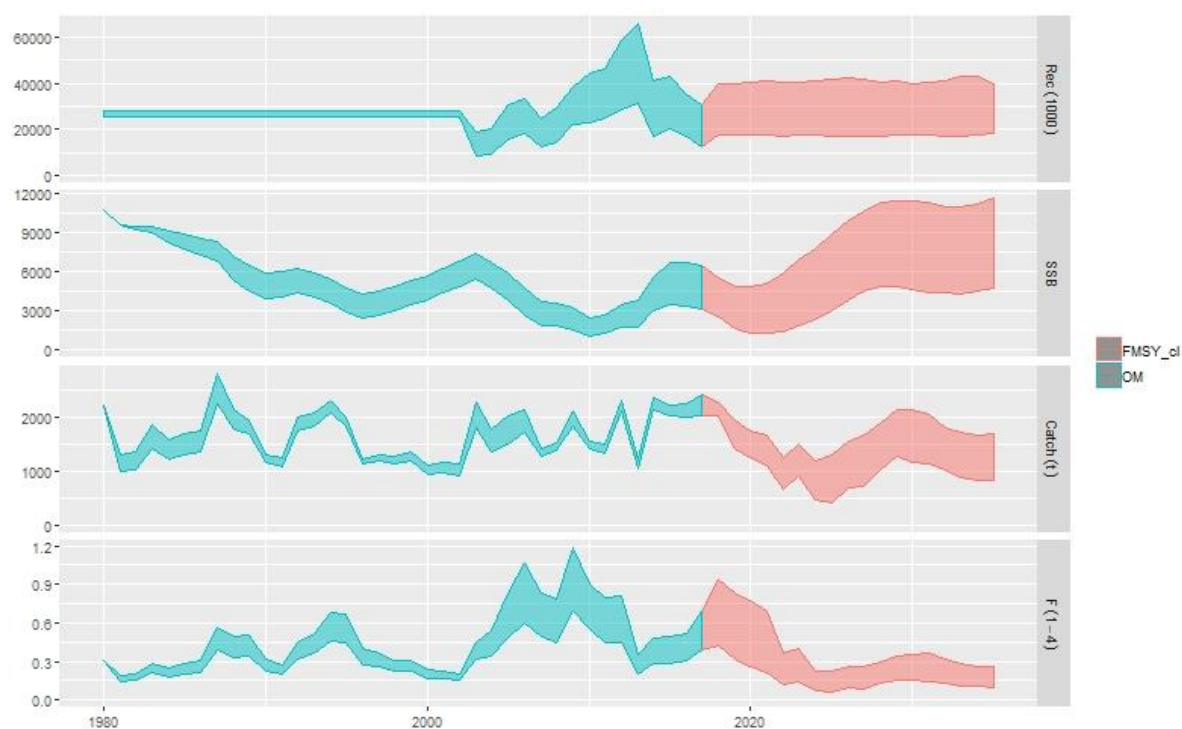
Figure 5.4.5.1 Scenario with a stepwise reduction up to 2024 when Fmsy is reached and an introduction of a catch limit, on the baseline projections. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

5.4.6 Robustness tests

The projections of all scenarios based on the alternative OM (the slope of the stock recruitment relationship is equal to 0.8 instead of 1) show a higher uncertainty range, specifically for SSB values and Catch values (Table 5.4.6.1; Figure 5.4.6.1). The F values are already close to Fmsy in 2018, therefore the Fsq scenario shows the lowest relationship of F/Fmsy in the short-term projection while in the long term it is in the same range of all other scenarios.

It should be noted that the introduction of the alternative OM in the modelling procedure shows a different starting point for the projections, with low F values and high, although more variable, SSB and Catch values. Therefore we can state that the original assessment is not robust to a change in stock recruitment relationship.

Table 5.4.6.1 Indicators for the short-term and long-term projection of all scenarios with the alternative OM. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

Indicator	Short-term (2018-2024)					Long-term (2018-2024)				
	Fsq	FsqCL	Fmsy24	Fmsy24FR	Fmsy24FRCL	Fsq	FsqCL	Fmsy24	Fmsy24FR	Fmsy24FRCL
C	1660	2061	2113	2422	2524	2180	2458	2267	2142	2481
Chi	3111	3480	3317	3296	3513	3303	3456	3351	3412	3530
Clo	797	1166	1248	1621	1668	1310	1645	1398	1122	1605
CVAR	0.92	0.95	0.96	0.99	0.93	1.00	1.00	1.01	1.03	1.02

CVARhi	1.19	1.11	1.18	1.17	1.05	1.30	1.13	1.29	1.32	1.16
CVARlo	0.72	0.77	0.81	0.88	0.81	0.75	0.89	0.79	0.82	0.91
FFMSY	0.49	0.60	0.63	0.78	0.83	0.64	0.66	0.64	0.60	0.70
R	48699	48699	48699	48699	48699	48908	48908	48908	48908	48908
SSB	14775	14434	14167	13698	13291	16206	16482	16312	16569	15427
SSBhi	30253	29462	29644	30978	29483	28450	27288	27253	27622	26704
SSBlo	7727	7180	7293	6288	6053	9126	9433	9142	9518	8569
SSBBLIM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSBBLIMmax	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
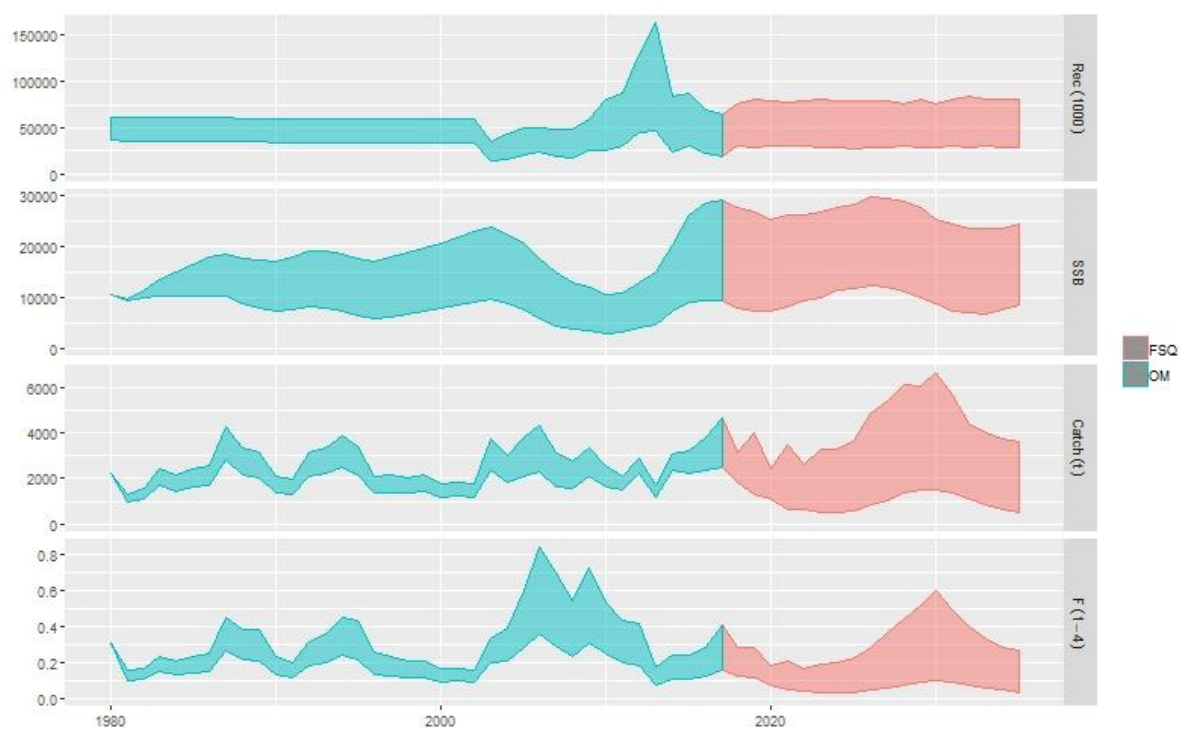
Figure 5.4.6.1 F status quo scenario on the alternative OM introduced to test the stock assessment robustness. SSB does not refer to the spawning stock biomass; it is a SS3-generated measure of the stock reproductive potential.

5.5 Spottail mantis shrimp 17-18

The main outcomes for Spottail mantis scenarios show that for this stock there is a high level of uncertainty in the estimations. Considering the median values in a status quo scenario the general pattern is quite stable (varying around the SSB and catch current levels). The probability that SSB falls below Blim is 12% and 16% in the short and long-term period, respectively (Table 5.5.1).

A reduction in F levels to Fmsy level in 2024 for both scenarios (linear and fix reduction) shows a similar pattern with an expected reduction in catches associated with a quite high increase in the SSB level. The up and down pattern in the trends of both scenarios it partially due to the gap between the year of advice and the year in which management is in place (basically a 3 years gap). This gap is associated with quite high uncertainty in the estimations of the recruitment level for 2016-2017, and results in a pattern of high uncertainty in the projections for catch and F levels. Alternative Operating Model (using as natural mortality vector the one from Chen Watanabe formula) provide results quite similar to the ones obtain running the basic OM.

Table 5.5.1 Computed indicators for the basecase OM in the short term and the long term.

Indicator	Short-term (2018-2024)			Long-term (2025-2035)		
	Fsq	Fmsy24	Fmsy24FR	Fsq	Fmsy24	Fmsy24FR
C	5243	3768	4335	4656	3544	3739
Chi	6941	5046	5305	5493	4423	4496
Clo	4113	2831	3517	3031	1967	3015
CVAR	1.01	1.05	0.88	1.05	1.20	1.17
CVARhi	1.18	1.36	1.04	1.47	2.22	1.95
CVARlo	0.89	0.88	0.78	0.94	0.96	0.97
FFMSY	2.53	0.90	1.93	2.43	0.93	0.90
R	1193186	1193186	1193186	1198851	1198851	1198851
SSB	12138	15647	13011	11619	16422	17236
SSBhi	14140	19542	16073	12831	18118	19349
SSBlo	10227	12749	10634	10425	14737	15467
SSBBLIM	0.12	0.05	0.07	0.16	0.00	0.01
SSBBLIMmax	0.86	0.43	1.00	0.73	0.18	0.27

Comparing to the baseline (Fsq), a management scenario for which a linear reduction in F to reach Fmsy in 2024 (Fmsy24) is applied, should ensure in the short term a gain in SSB of about 23% with respect to a decrease in catch of about 40% associated with a catch variation of about +5%. The probability that SSB will be lower of Blim is quite low (5%).

If a fixed reduction in F (Fmsy24FR) is applied the increase in SSB should be lower (about 7%) with a lower decrease in catch (about 21%) associated with a negative variation of about -12%. The probability that SSB will be lower than Blim is still acceptable (7%)

In the long term the same scenarios should ensure a gain in SSB of about 30% with respect to a decrease in catch of about 30% in Fmsy24 (associate positive variation of about 20%). The risk that SSB falls below Blim is 0. An increase in SSB of about 48% with a decrease in catch of about 20% in the Fmsy24FR is expected. Catch variation should be positive (about 17%) while the risk of very low level of SSB should be around 1%

5.5.1 Baseline (F status quo)

In the baseline scenario, the high level of uncertainty in the stock assessment estimation of the last two years, in particular in recruitment level, results in high levels of uncertainty in the projections of SSB and catch in the following years (Figure 5.5.1.1). In these projections, recruitment is maintained stable (as the geometric mean of the historical series). After the first two years the uncertainty in SSB estimation decrease to its historical levels while in F and Catch it remains quite high (increasing in the long term). The fluctuations observed are mainly due to the gap between the advice and the management.
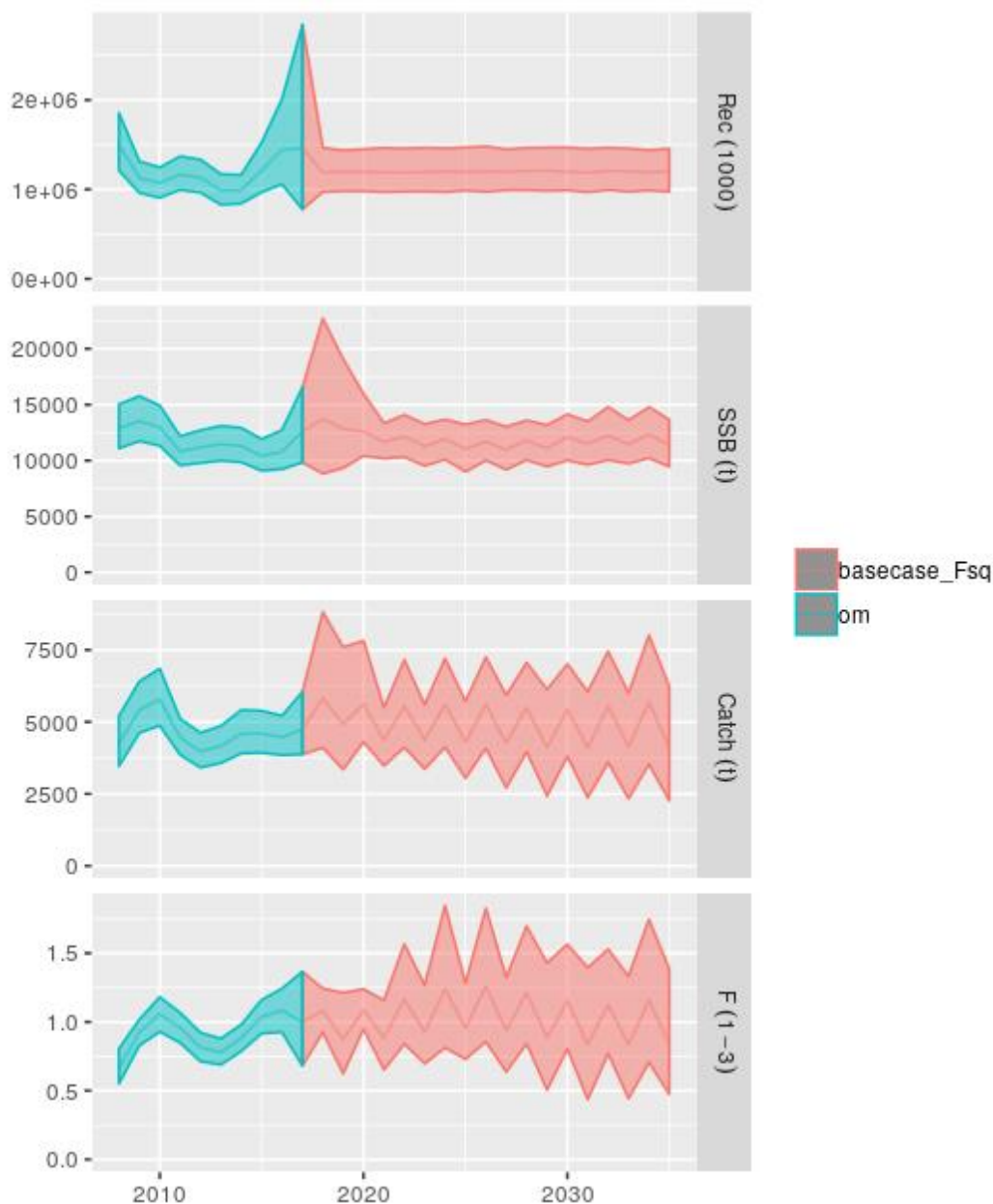
Figure 5.5.1.1 Stock summaries of the OM (basecase) and MP with F status quo.

5.5.2 Scenario a.ii EFFORT: Fmsy in 2024 linear decrease

In the scenario in which a linear reduction in F is applied there is a high level of uncertainty in estimations (Figure 5.5.2.1). In this case the reduction in F at Fmsy level reflects a decrease in catch in the short term with an increase the SSB values. In the long term, F increases a bit while SSB decreases but remains at levels never seen in the past.
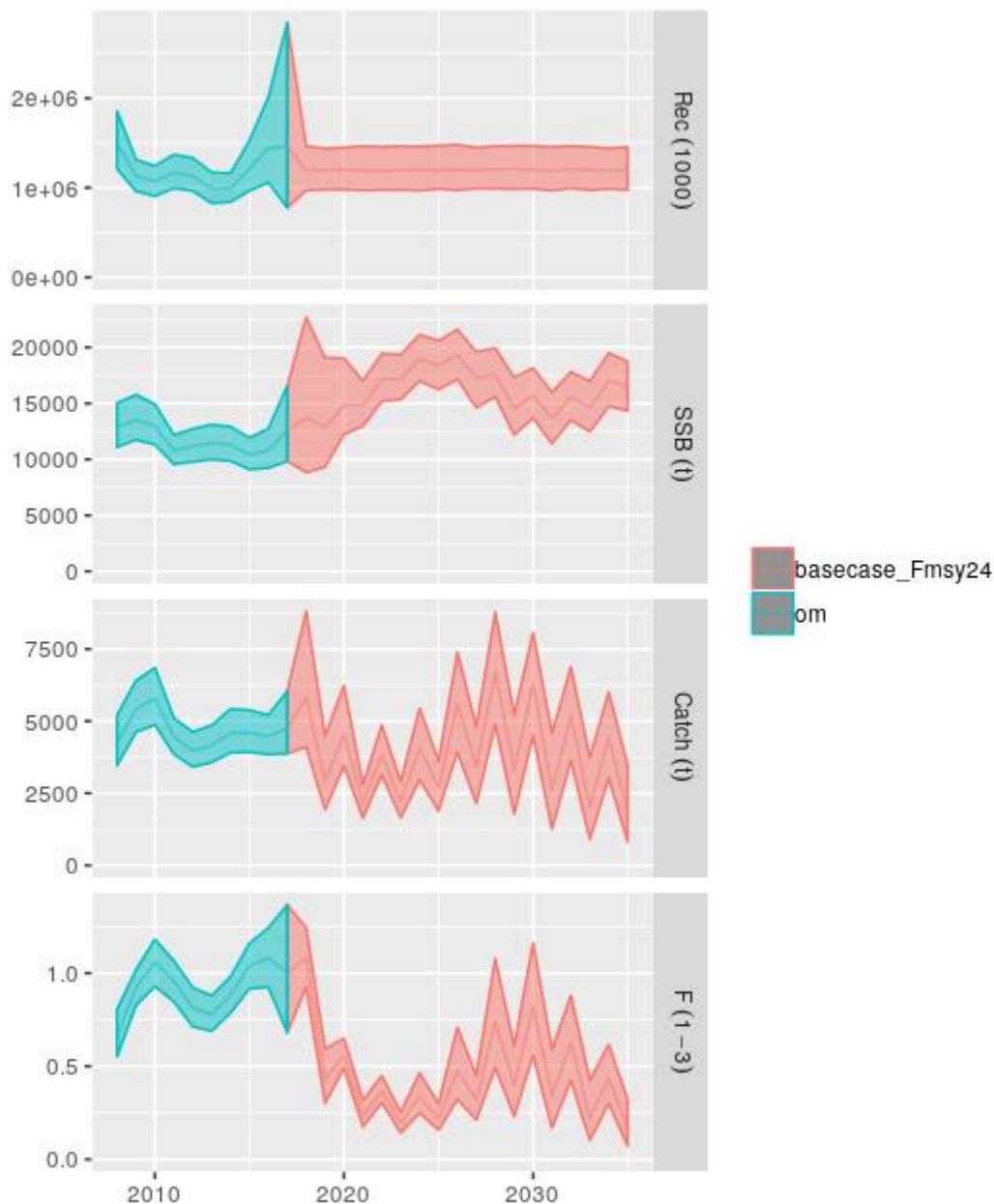
Figure 5.5.2.1 Computed indicators (short term) for the basecase OM with Fmsy at 2024 linear reduction

5.5.3 Scenario a.iii EFFORT: Fmsy in 2024 FIXREDUX

In the scenario in which a fixed reduction in F is applied there is still high level of uncertainty in estimations (Figure 5.5.3.1). The trends are quite similar to the linear reduction scenario.
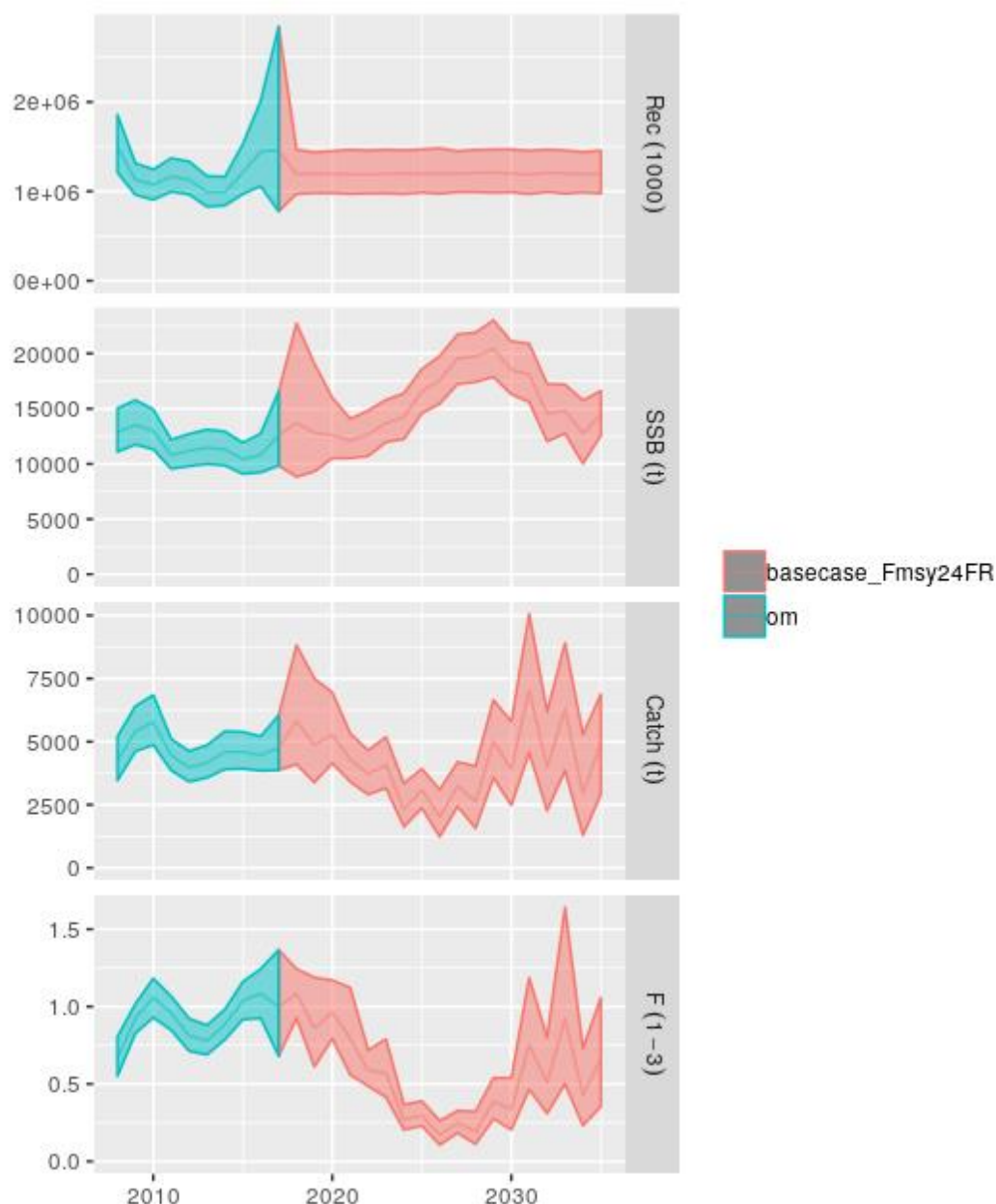
Figure 5.5.3.1 Stock summaries of the OM (basecase) and MP with Fmsy at 2024 fixed reduction.

5.5.4 Robustness tests

Comparing to the baseline (Fsq) in the alternative Operating Model (Chen Watanabe 1989) natural mortality vector), if a management scenario for which a linear reduction in F to reach Fmsy in 2024 (Fmsy24) is applied it should ensure a gain in SSB of about 19% in the short term with respect to a decrease in catch of about 40% (Table 5.5.4.1; Figure 5.5.4.1; Figure 5.5.4.2; Figure 5.5.4.3). The expected variation in catch should be around 4% and the risk that SSB fall below Blim should be around 2%.

If a fixed reduction in F (Fmsy24FR) is applied, the increase in SSB should be only of about 5% with a decrease in catch of about 23%. A negative catch variation of 12% could be expected while the rick of collapse in SSB should be very low (2%).

Applying a different natural mortality vector seems to not affect the robustness of the stock assessment. The main effect is an increase in estimated recruitment level comparing to the original OM.

Comparing to the baseline (Fsq), if the same management scenarios (Fmsy24 and Fmsy24FR) are applied, they should ensure, in a long term, a gain in SSB of about 23% with respect to a decrease in catch of about 39% in Fmsy24 scenario and an increase in SSB of about 25% with a decrease in catch of about 28% in the Fmsy24FR scenario (Table 5.5.4.1; Figure 5.5.4.1; Figure 5.5.4.2; 5.5.4.3). Expected catch variations should be positive for both scenarios (24% and 14% respectively) with an associated risk that SSB falls below Blim of 0% for both scenarios.

Table 5.5.4.1 Computed indicators for the chenwatanabe OM.

Indicator	Short-term (2018-2024)			Long-term (2025-2035)		
	Fsq	Fmsy24	Fmsy24FR	Fsq	Fmsy24	Fmsy24FR
C	5257	3713	4272	4590	3296	3576
Chi	7202	5173	5430	5729	4225	4199
Clo	4100	2817	3504	2715	1825	2549
CVAR	1.02	1.04	0.88	1.07	1.24	1.14
CVARhi	1.22	1.36	1.04	1.96	3.61	2.00
CVARlo	0.89	0.84	0.78	0.95	0.96	0.98
FFMSY	2.35	0.92	1.78	2.19	0.91	0.90
R	4244452	4244452	4244452	4243657	4243657	4243657
SSB	14208	17391	15087	13745	17630	18303
SSBhi	16580	21066	18213	15195	19312	20143
SSBlo	12065	14258	12666	12523	16060	16548
SSBBLIM	0.03	0.02	0.02	0.02	0.00	0.00
SSBBLIMmax	0.57	0.43	0.43	0.36	0.18	0.18
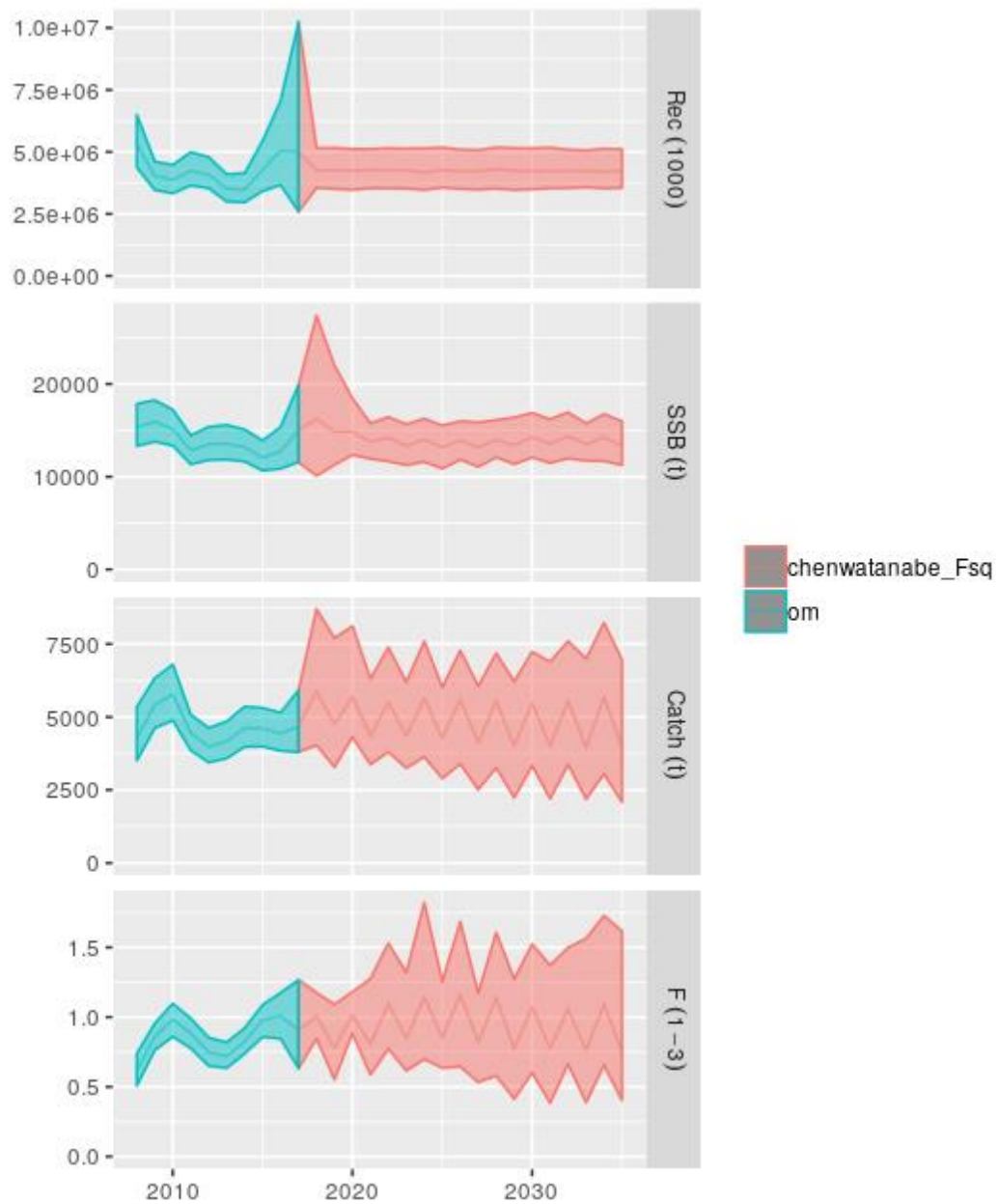
Figure 5.5.4.1 Stock summaries of the alternative OM (chenwatanabe) and MP with F status quo.
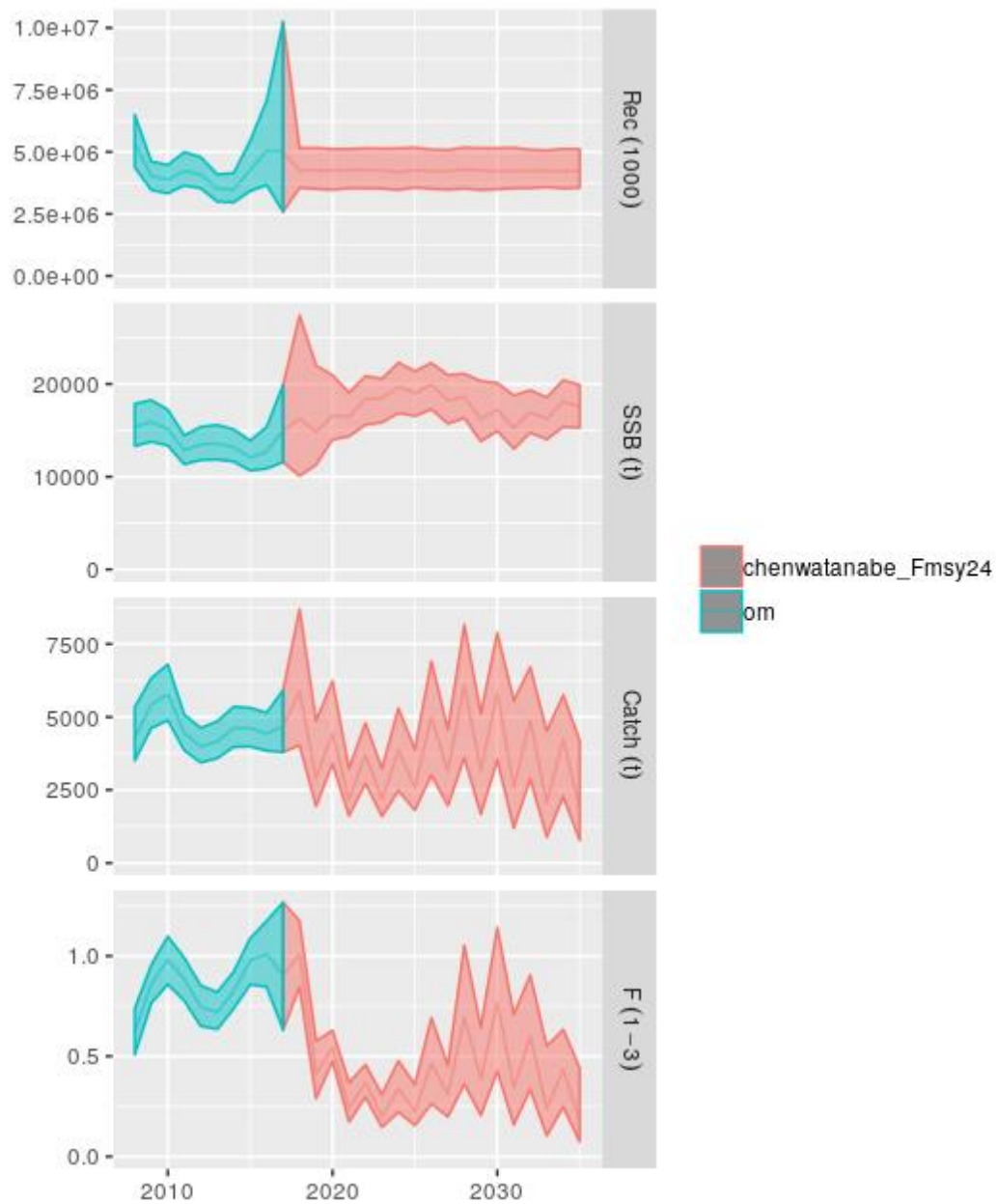
Figure 5.5.4.2 Stock summaries of the alternative OM (chenwatanabe) and MP with Fmsy at 2024 linear reduction.
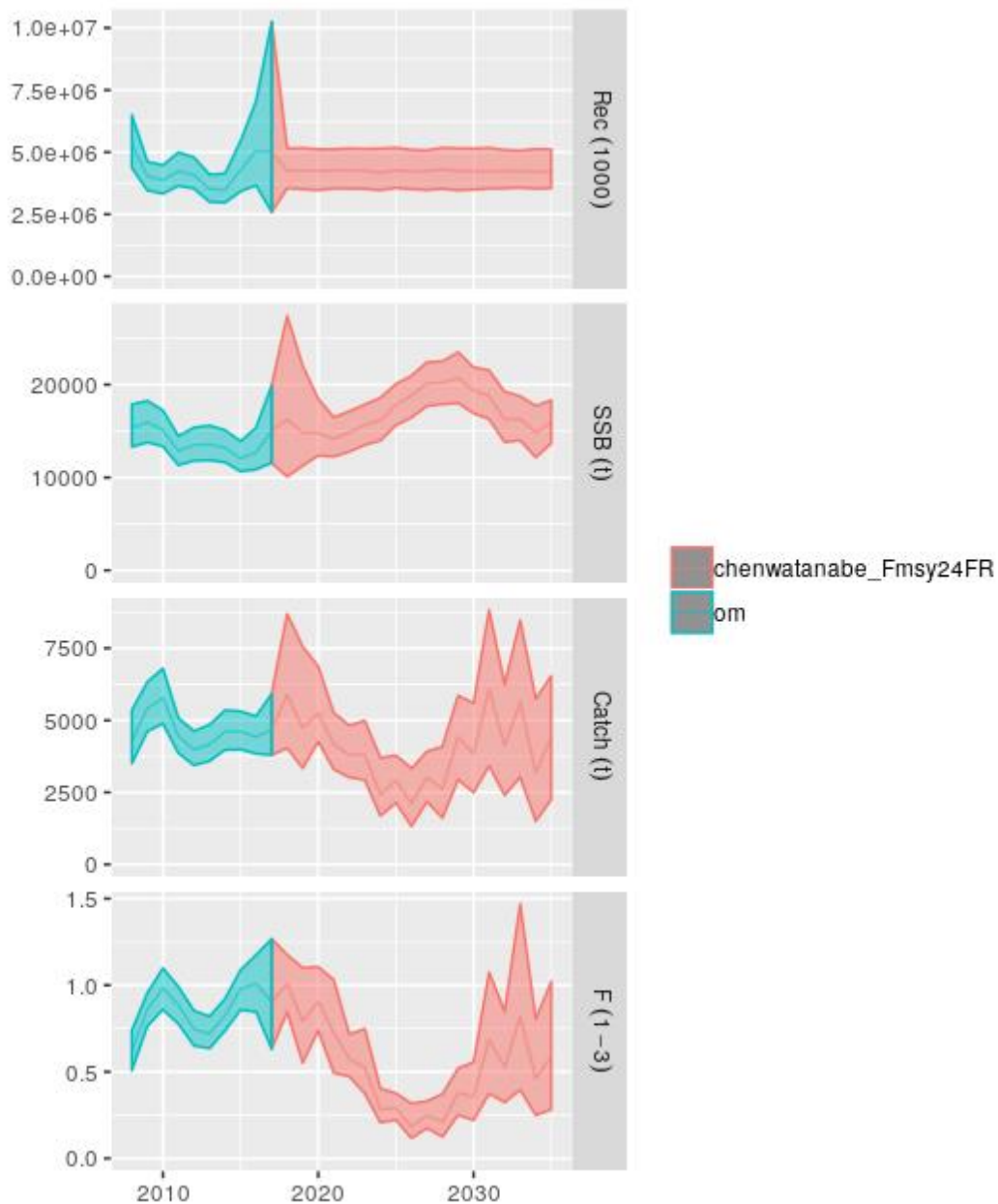
Figure 5.5.4.3 Stock summaries of the alternative OM (chenwatanabe) and MP with Fmsy at 2024 fixed reduction.

5.6 Management lag tests

To illustrate the management lag effect in MP's performance three extra scenarios were run using the stock of mantis shrimp. All scenarios were run until 2075 to investigate long term equilibrium conditions with Fmsy as target fishing mortality.

- FmsyLRSP: Stochastic projection with a HCR that achieves Fmsy in the following year with perfect implementation, ignoring any uncertainty in stock status, decision making or implementation. This is a very artificial scenario for reference only.

- Fmsy24FRLR: A full feedback MSE with target Fmsy in 2024 and FIXREDUX HCR implemented with a management lag of 2 years.
- Fmsy24FRLRML1: A similar scenario to Fmsy24FRLR where management lag was reduced to 1 year.

Figure 5.6.1 depicts the summary results.

From the Figure it is clear that effort management (Fmsy24FRLR and Fmsy24FRLRML1) adds a short cyclical component with ~2 years period. The cycle is created by managing directly F changes, since the relationship between F and effort is considered linear, while ignoring what happens between the last year in the assessment and management years.

The two-year management lag introduces a new cyclical component of about 6-7 years period which increases in variance with time. The shorter management lag of 1 year starts with a similar cycle although it stabilizes into equilibrium conditions after ~2040.

It is clear from this analysis that reducing the management lag from 2 to 1 year would improve the potential success of the MAP.
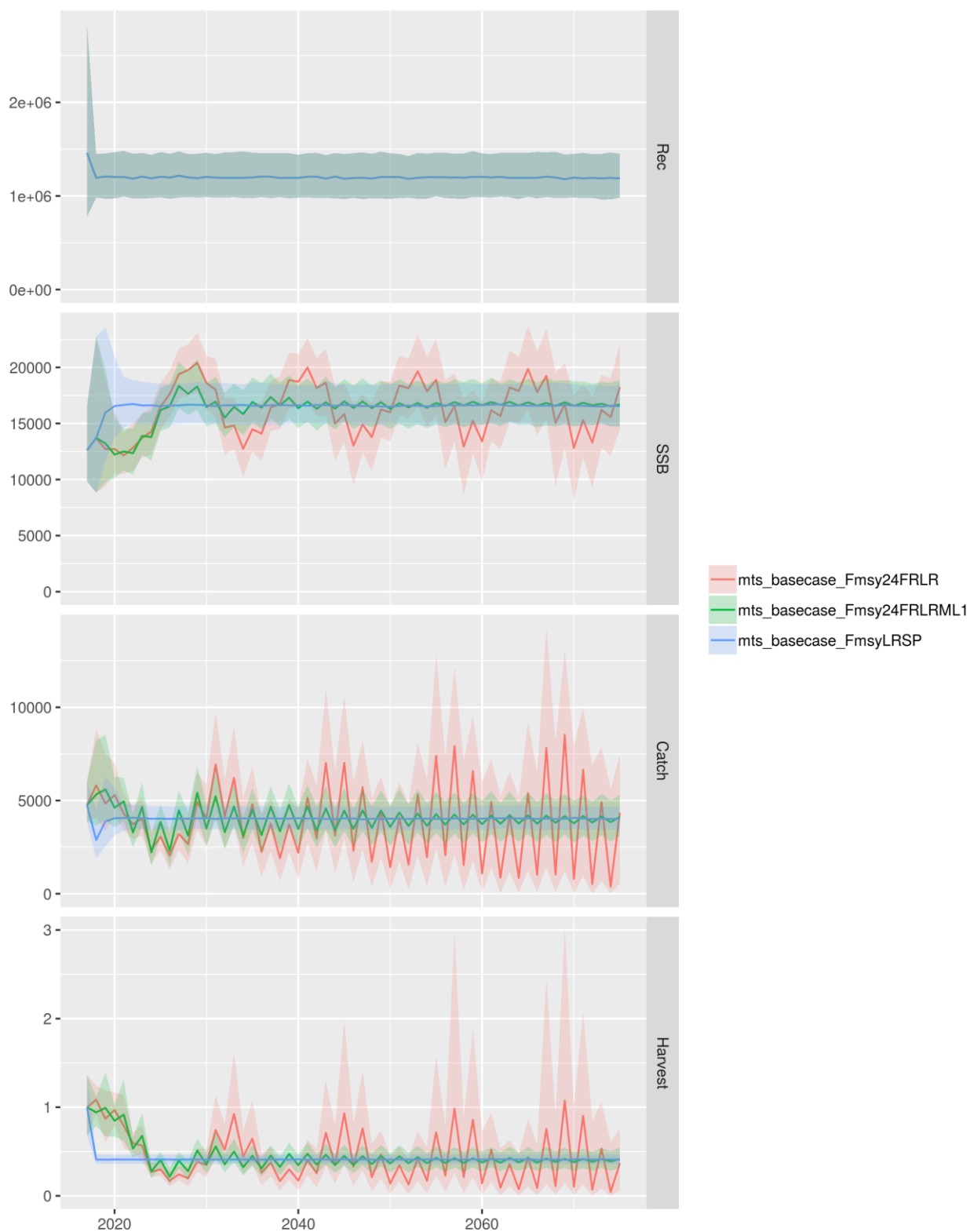
Figure 5.6.1 Management lag effect. Summary statistics with 90% confidence intervals of three scenarios run with the mantis shrimp stock basecase OM. A simple stochastic projection which achieves the target in 2019 ("FmsyLRSP"), a full feedback MSE with Fmsy 2024 and FIXREDUX HCR implemented with a management lag of 2 years ("Fmsy24FRLR"), and a similar scenario where the management lag was reduced to 1 year ("Fmsy24FRLRML1").

5.7 Summary of management procedures performance

This section presents summary results for the base case OM and the effort MPs for all stocks. It presents the probability of falling below Blim (SSBBLIM) and the probability of being within 20% of the target fishing mortality (FonTRGT) as measures of the MPs performance. Additionally, in order to better understand temporal dynamics, F/Fmsy (FFMSY) and the probability of falling below Blim time series are presented for the same OMs and MPs.

Table 5.7.1 shows the set of probabilities derived from the MP runs. Equilibrium results (2031-3035) should be considered with care, since in most cases the OMs in this period where driven outside the observation's range and as such the stock dynamics are not known. The most important conclusion to take from these results is that the FIXREDUX strategy (Fmsy24FR) has a poorer performance than the immediate linear reduction (Fmsy24). The FIXREDUX strategy forces a larger yearly reduction in F, since it tries to achieve the target in 4 years instead of 6. In terms of protecting SSB both strategies reduce the probability of falling below Blim close to 0. In equilibrium these differences wear off and both strategies perform similarly.

Table 5.7.1 Probability of being within 20% of the target fishing mortality (FonTRGT) and probability of falling below Blim (SSBBLIM) for all stocks and management scenarios in 2015-2017, 2024 and 2031-2035. For hake and sole SSB refers to a measure of stock reproductive potential.

| Indicator	name	stock	2015-2017 Status quo	Fsq	2024 Fmsy24	Fmsy24FR	2031-3035 Fsq	Fmsy24	Fmsy24FR
FonTRGT	P[F<1.2*FMSY & F>0.8*FMSY]	dps	0.00	0.02	0.26	0.07	0.02	0.16	0.11
FonTRGT	P[F<1.2*FMSY & F>0.8*FMSY]	hke	0.00	0.00	0.29	0.01	0.03	0.10	0.05
FonTRGT	P[F<1.2*FMSY & F>0.8*FMSY]	mts	0.00	0.00	0.48	0.18	0.06	0.26	0.20
FonTRGT	P[F<1.2*FMSY & F>0.8*FMSY]	mut	0.24	0.08	0.64	0.48	0.28	0.33	0.35
FonTRGT	P[F<1.2*FMSY & F>0.8*FMSY]	sol	0.06	0.22	0.08	0.07	0.24	0.25	0.23
SSBBLIM	P[SSB<BLIM]	dps	0.00	0.11	0.00	0.00	0.13	0.02	0.05
SSBBLIM	P[SSB<BLIM]	hke	0.75	0.17	0.00	0.00	0.17	0.00	0.00
SSBBLIM	P[SSB<BLIM]	mts	0.26	0.09	0.01	0.01	0.14	0.00	0.02
SSBBLIM	P[SSB<BLIM]	mut	0.00	0.01	0.00	0.00	0.00	0.00	0.00
SSBBLIM	P[SSB<BLIM]	sol	0.00	0.00	0.00	0.00	0.01	0.00	0.00

Figure 5.7.1 shows the evolution over time of F/Fmsy. Fishing at F status quo does not improve the current situation, as expected, with the exception of sole which shows an odd behavior at Fsq (see section sole). Effort strategies miss the target in all cases, forcing larger reductions than needed due to the management lag cyclical effect. In the case of FIXREDUX this effect is more

pronounced. Catch limits for sole show a better performance than their effort analogous with smaller cyclical effects.

With relation to the probability of SSB falling below Blim (Figure 5.7.2) the results depict similar outcomes. Continuing to fish at F status quo levels will keep risk at current levels, while decreasing fishing mortality reduces risk close to 0. It is important to bear in mind that uncertainty is very large, in particular when biomass becomes larger than historical levels and as such this results need to be taken as indicative only.
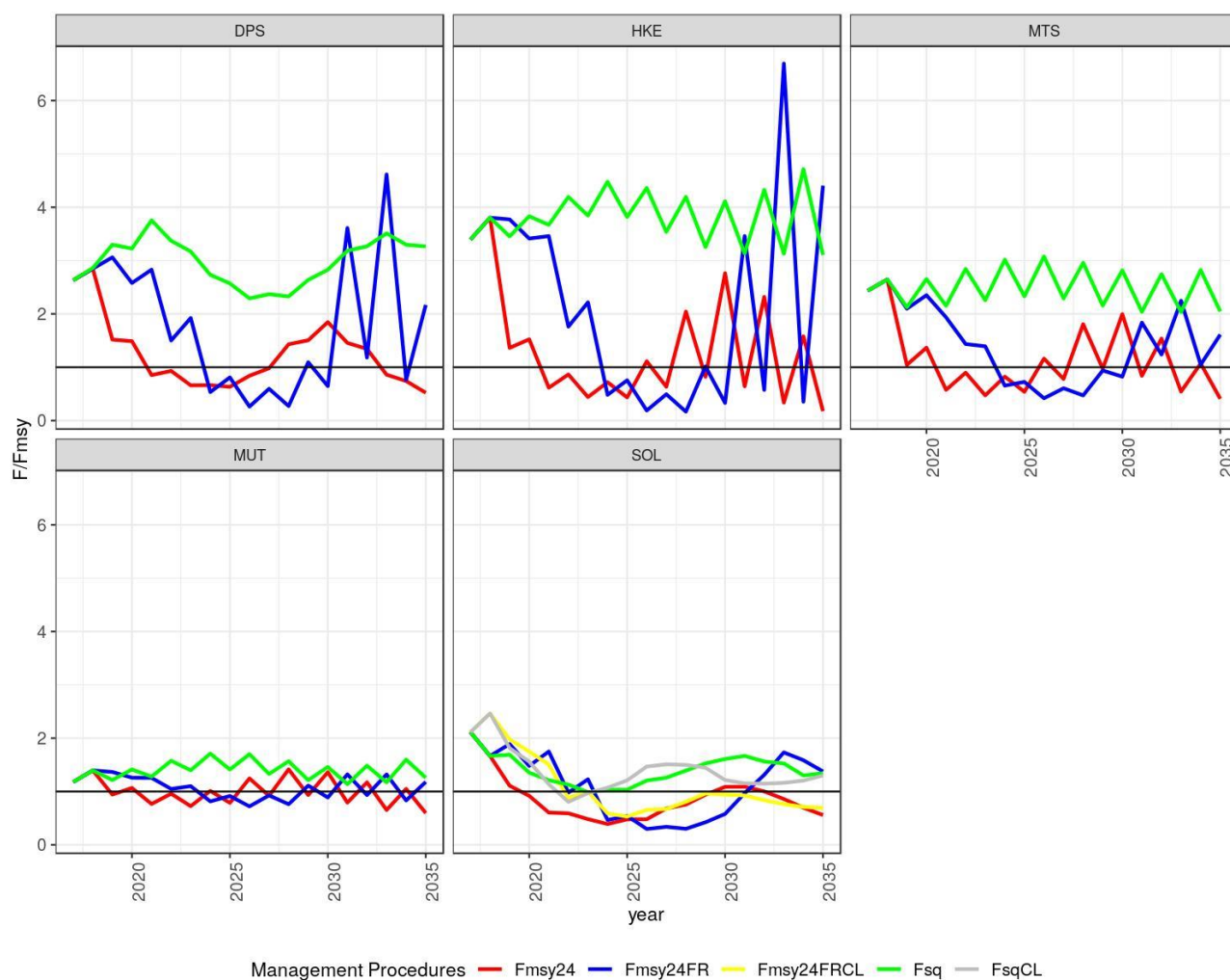
Figure 5.7.1 The temporal development of F/FMSY by stock, for each management scenario.
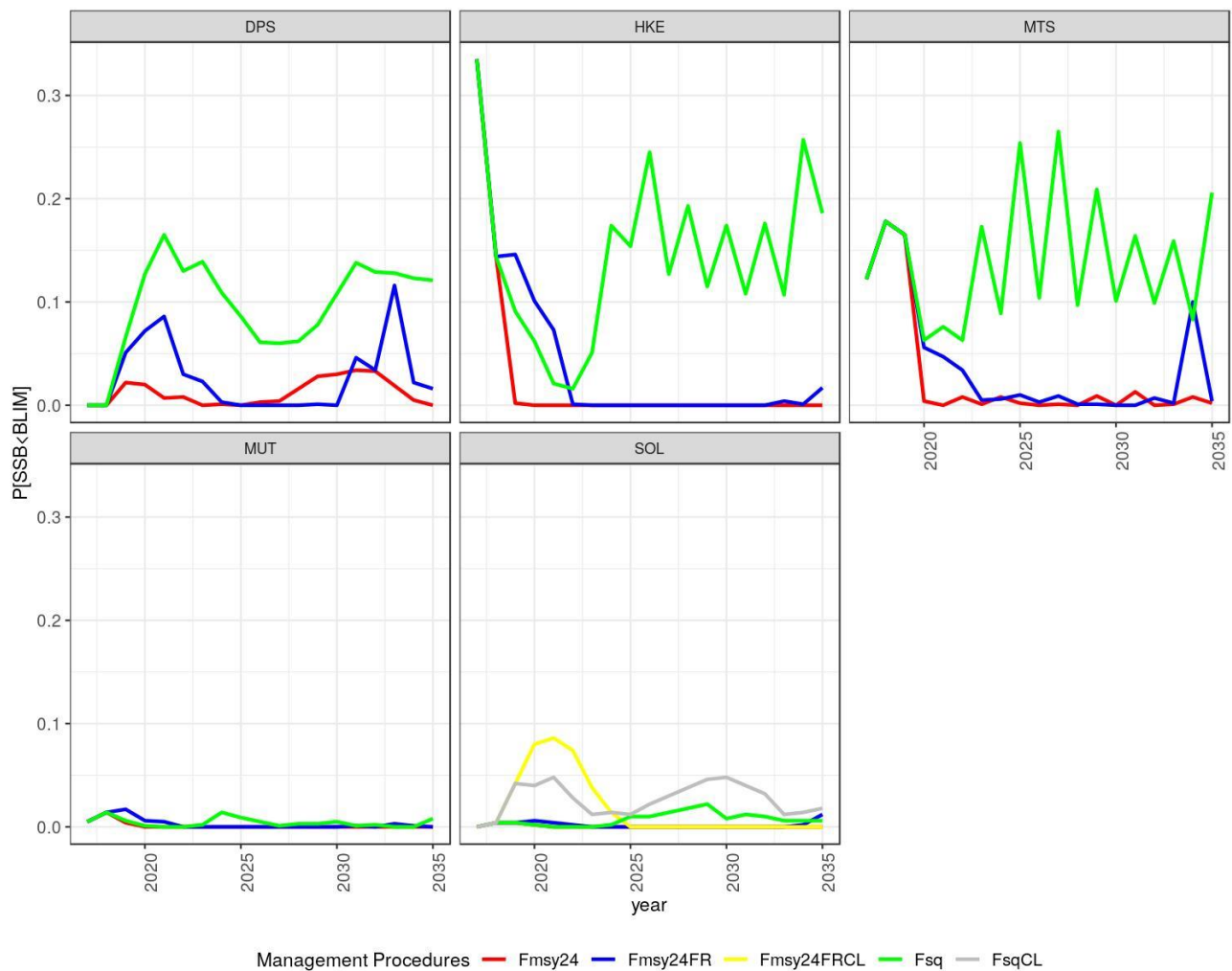
Figure 5.7.2 The temporal development of the probability of falling below Blim (SSBBLIM) by stock, for each management scenario.

6   ToR 4 – Management procedure B

6.1   Spatial management scenarios

6.1.1 Sole sanctuary

The fishing restricted area (FRA) is defined by two areas where fishing activities are not allowed: (a) the polygon identified as area of high persistence in front of the Venice lagoon in Scarcella et al. 2014 and (b) the polygon proposed for the sole sanctuary in Bastardie et. al 2017 (Figure 6.1.1.1).
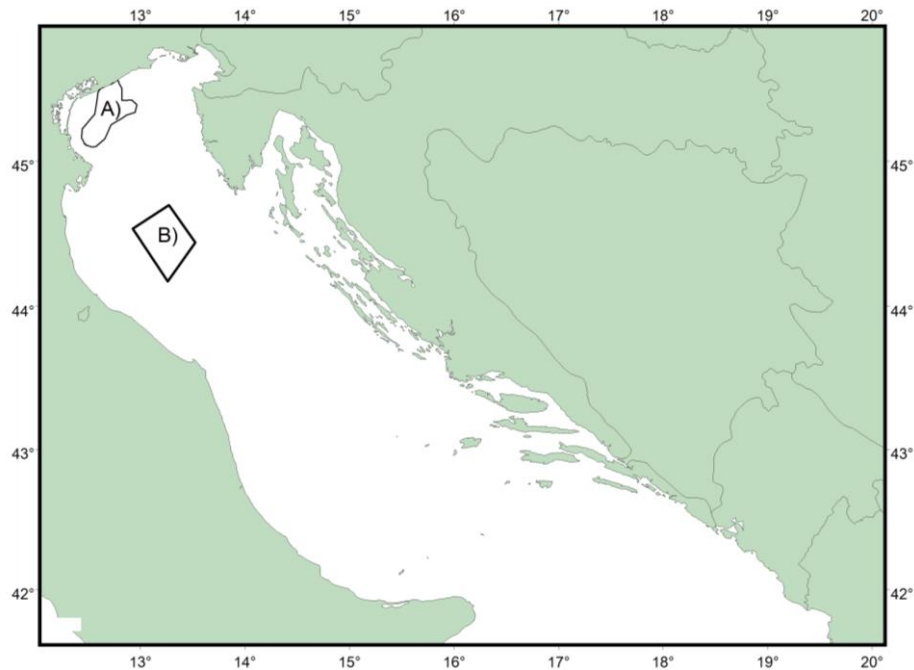
Figure 6.1.1.1 A) Northern portion of the area described by Scarcella at al. (2014) concerning the spatial and temporal persistency of the adult common sole; B) revised version of the "Sole Sanctuary" presented at the FAO AdriaMed/MedReAct Workshop "Essential Fish Habitats and Sensitive Habitats of the Adriatic Sea: state of knowledge and conservation opportunities" (WS-EFH; 20-21st February 2018, FAO-HQs) by CNR, ISPRA, IOF and FRI.

It is important to note that the areas in Figure 6.1.1.1 were recently updated during the FAO AdriaMed / MedReAct Workshop "Essential Fish Habitats and Sensitive Habitats of the Adriatic Sea: state of knowledge and conservation opportunities" (WS-EFH; 20-21st February 2018, FAO-HQs), and presented to GFCM's Working Group on VME as well as at the SubRegional Coordination meeting for the Adriatic Sea. Furthermore, a stakeholder consultation regarding the perception of the management measure related to the permanent closure of the high persistency area for common sole spawners named "sole sanctuary" is in progress in the DORY project (2014 - 2020 Interreg V-A Italy - Croatia CBC Programme).

The results obtained through the application of the bio-economic model DISPLACE refer to a cumulative effect of the Sole Sanctuary over a period of 6 years.

The exclusion of gillnetters from the Sole Sanctuary would increase the CPUE and the landings of common sole (Figure 6.1.1.2). In addition, a reduction of common sole discard would be also expected.
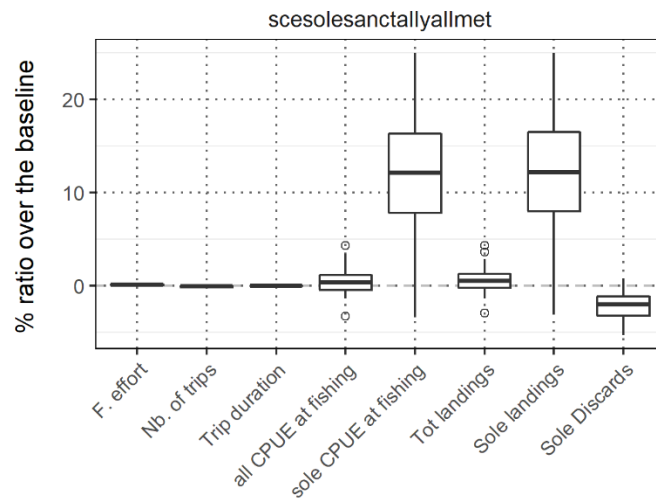
Figure 6.1.1.2 Effects of the "Sole Sanctuary" on gillnet fisheries.

The exclusion of rapido trawlers (TBB) from the Sole Sanctuary would decrease the total fishing effort, the CPUE and landings of common sole, and the discard rates of this species (Figure 6.1.1.3). On the other hand, this scenario would increase the total CPUE. Common sole is the main target species for TBB.
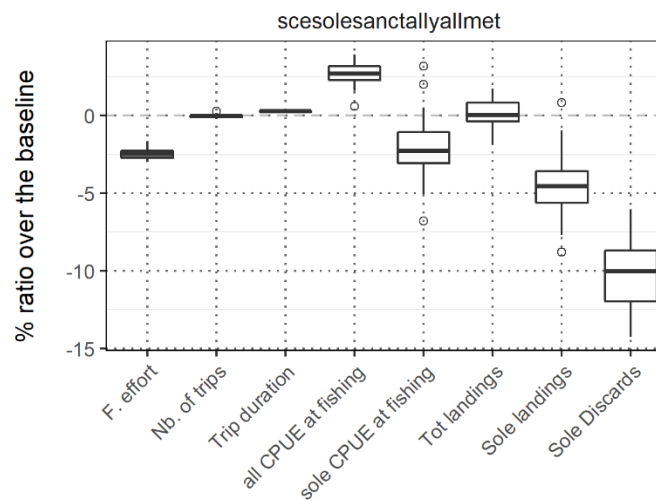
Figure 6.1.1.3 Effects of the "Sole sanctuary" on rapido trawlers (TBB).

The exclusion of bottom otter trawlers (OTB) from the Sole Sanctuary would decrease the total fishing effort, the total number of trips, CPUE and landings of common sole, and total landings (Figure 6.1.1.4). On the other hand, the trip duration and common sole's discards would increase. It should be mentioned that common sole is not a target species for OTB, as it contributes for a very small fraction of the total landings.
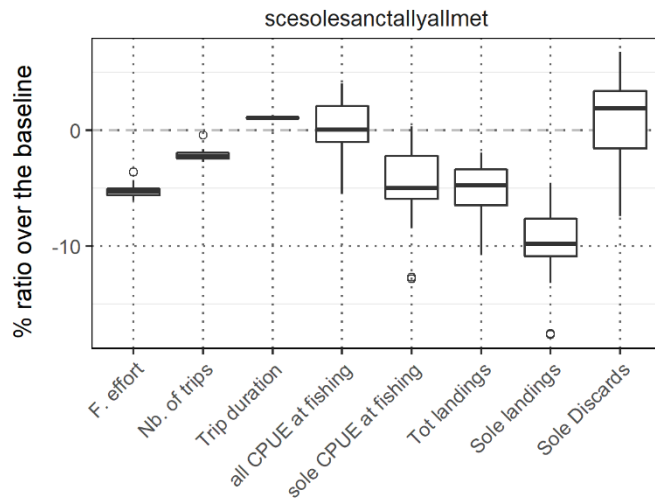
Figure 6.1.1.4 Effects of the "Sole sanctuary" on bottom otter trawlers (OTB).

Figure 6.1.1.5 shows how the total fishing effort (gillnets + OTB + TBB) will redistribute in case of the FRA's enforcement. The highest increase of fishing effort would be expected close to the NE side of area A and SW and NE sides of area B (Figure 6.1.1.5).
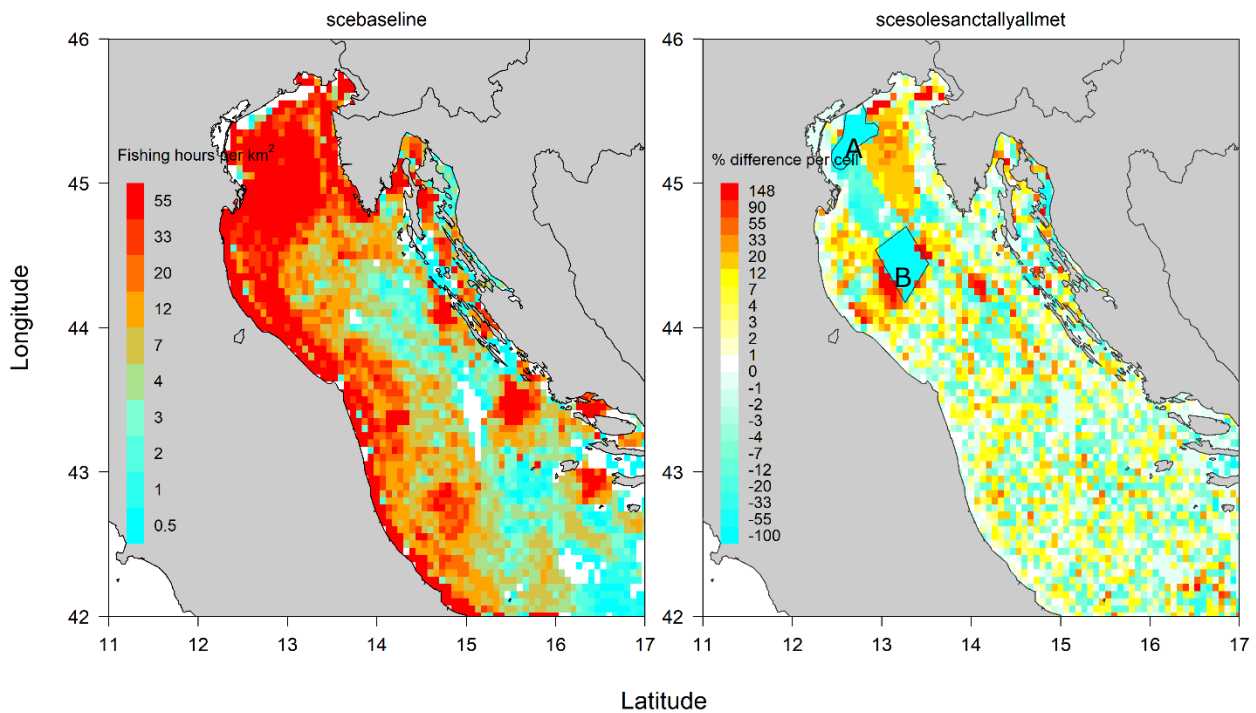
Figure 6.1.1.5 Spatial distribution of simulated fishing effort (hours). Map on the left shows the baseline and map on the right shows the redistribution of fishing effort after the institution of the "Sole Sanctuary".

Figure 6.1.1.6 shows how the common sole catches (from gillnets + OTB + TBB) will redistribute in case of fishing ban inside the Sole Sanctuary. The highest increase of common sole catches

would be expected close to border of Area B and westwards from Istria Peninsula (Figure 6.1.1.6).
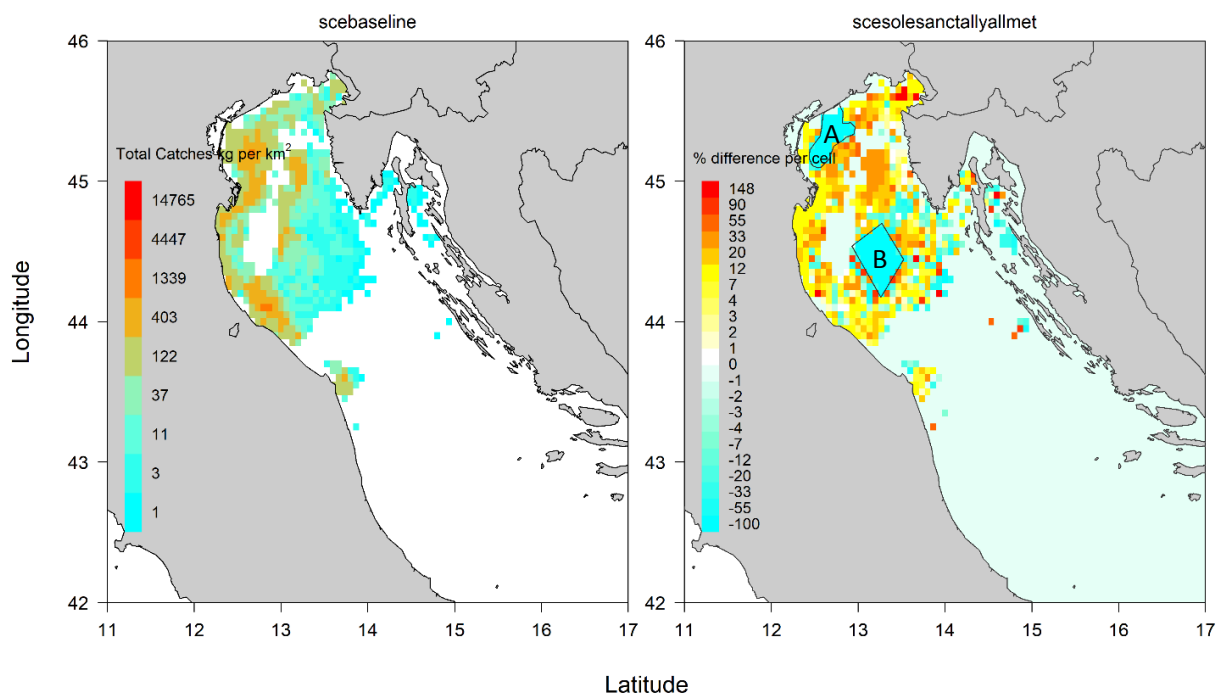
Figure 6.1.1.6 Spatial distribution of simulated common sole catches. Map on the left shows the baseline and map on the right shows the simulated redistribution of common sole catches after the institution of the "Sole Sanctuary".

6.1.2 Protection of 6nm

To test the effect of restricting the coastal zone up to 6 nautical miles to all active towed gears (OTB and TBB), the EWG used a previously set DISPLACE scenario. This scenario excluded Croatia and Slovenia's waters due to existing strict fisheries regulations and complex geomorphological characteristics of eastern Adriatic coast, as well as the Maritime Departments of Monfalcone and Trieste due to the limited presence of juveniles in the area. Annex 5 includes detailed information about these options.

EWG 19-02 notes that the proposed management scenario may generate conflicts between small-scale trawlers and large-scale trawlers. Currently, Italian small-scale trawlers (e.g. IV category fishing license "coastal fishery") operate between 3 and 6 nautical miles. Large-scale OTB generally exploit offshore fishing grounds, with the exception of large-scale TBB, which usually operates in shallow water fishing grounds (depth < 50 m). The closure of coastal waters may force the small-scale trawlers to relocate their activities outside 6 nautical miles, potentially generating conflicts with the large-scale TBB fleet.

Gillnetters will benefit from the 6nm closure to OTB and TBB in terms of higher sole CPUE and sole landings (Figure 6.1.2.1).
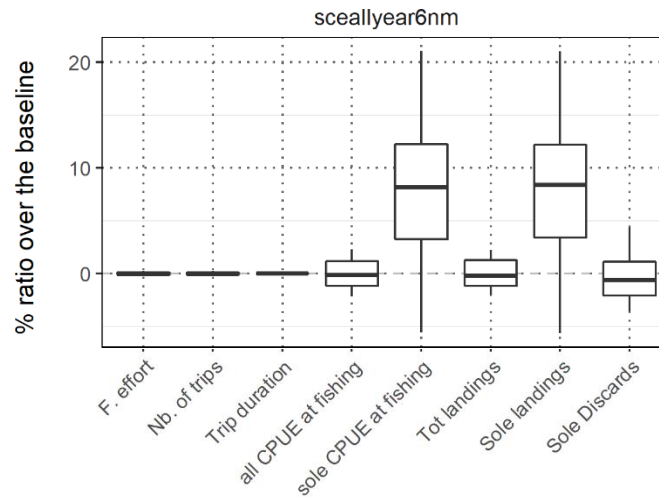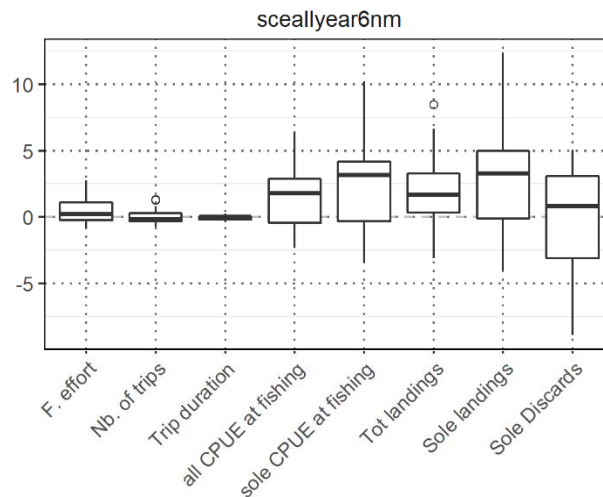
Figure 6.1.2.1 Effects of the 6nm OTB and TBB fishing closure on gillnet fisheries.

Rapido trawlers (TBB) will suffer a decrease of the fishing effort, as well as the total landings and sole landings (Figure 6.1.2.2). Discard rates for common sole will decrease and a general increase of the total CPUE would occur.
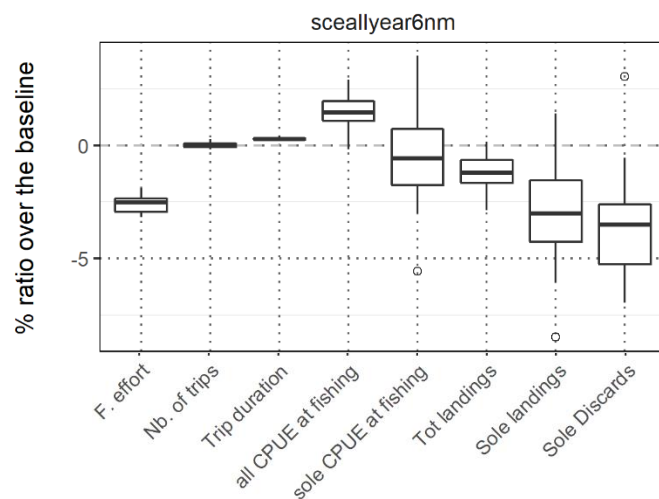
Figure 6.1.2.2 Effects of the 6nm OTB and TBB fishing closure on TBB.

For bottom otter trawlers (OTB) this scenario would produce a general increase in the CPUE of the total catch and the sole, total landings, as well as of sole landings (Figure 6.1.2.3).

Figure 6.1.2.3 Effects of the 6nm OTB and TBB fishing closure on OTB.

6.1.3 Additional tests

Tests were carried out for a set of additional management measures to better understand the sole sanctuary, its combination with the 6nm closure and implementation of non-spatial selectivity measures:

Spatial measure scenarios:

• scesoleadulsanctallyallmet - it represents a projection of the previous "sole sanctuary" scenario, splitting A area and B area separately (Figure 6.1.1.1). This scenario refers to the B area, were a high persistence of common sole adults was identified;

• scesolejuvsanctallyallmet - as above, but this scenario refers to the A area, were a high persistence of common sole adults was identified;

• scesolesanctallyallmet6nm – this scenario is a combination of the "sole sanctuary" scenario (A and B area both combined) + the "6nm" scenario;

Non-spatial measure scenarios:

• scesoleselectivity – this scenario includes two measures which are not related to spatial measures. It refers to the adoption of a 72 mm minimum stretched mesh size for gillnet, in order to increase the selectivity of the gear, oriented to avoid undersized catch of common sole. In addition it includes the adoption of a minimum landing size for the common sole set at 25 cm TL.

The effects of the "sole selectivity" scenario on gillnet fishery refer to an increase of the CPUE of both the total catch and the common sole, total landings and common sole landings (Figure 6.2.1). A strong decrease in discard rate for the common sole would be also expected.

The closure of Area A of the Sole Sanctuary would increase the CPUE of both the total catch and the common sole, total landings and common sole landings (Figure 6.1.3.1). A slight decrease in discard rate for the common sole would be also expected. The closure of Area B of the Sole Sanctuary would increase the common sole CPUE and the common sole landings (Figure 6.1.3.1).
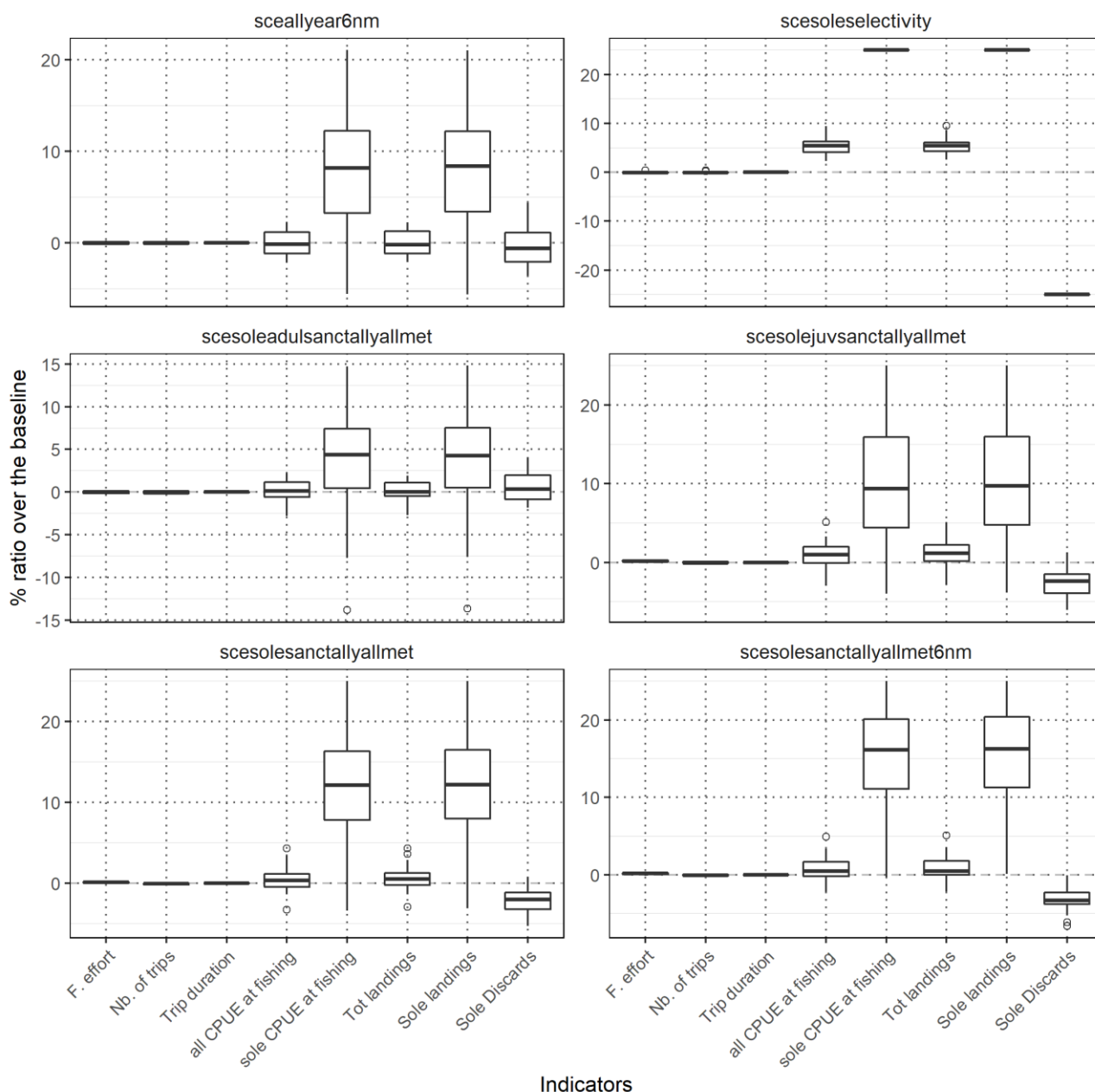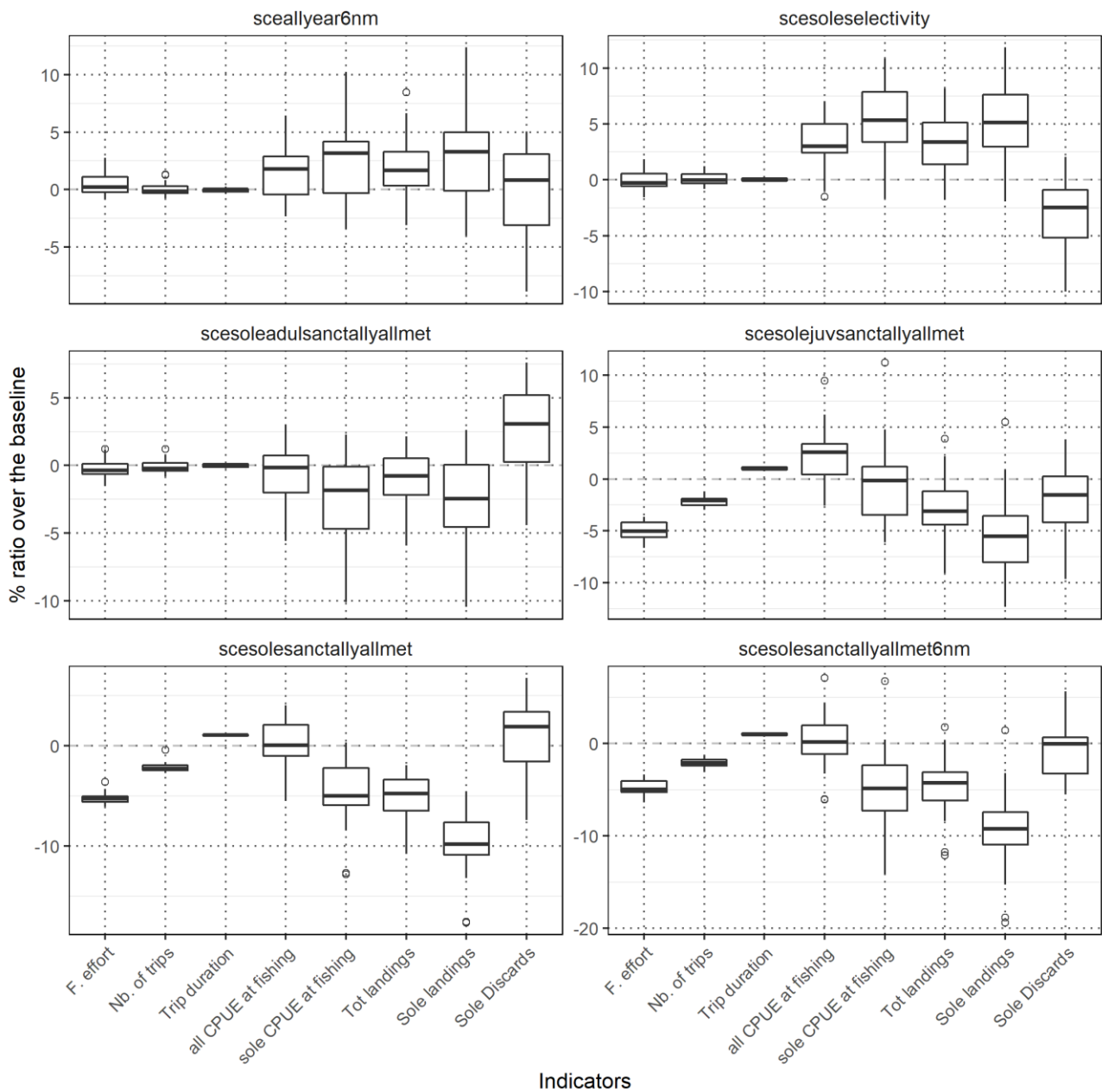
Figure 6.1.3.1 Comparison of aggregated scenario outcomes (20 stochastic replicates per scenario) on the vessel performance indicators (percent relative to the baseline) for gillnet vessels. The percentages are relative to the baseline condition for fishing effort (F. effort), number of trips (Nb. of trips), trip duration, all CPUE at fishing, Sole CPUE at fishing, total landings all simulated stocks pooled (Tot land.), common sole landings (Sole landings) and discard rates for common sole (Sole discards).

The effects of the "sole selectivity" scenario on rapido trawl fishery (TBB) refer to a decrease in discard rate for the common sole would be also expected (Figure 6.1.3.2).

The closure of Area A and B of the Sole Sanctuary would generate similar results. A general decrease would be expected in fishing effort, common sole CPUE, total landings, common sole landings and sole discard, the latter is more evident in the case of area A closure (Figure 6.2.2). A general increase in the total CPUE would be expected.
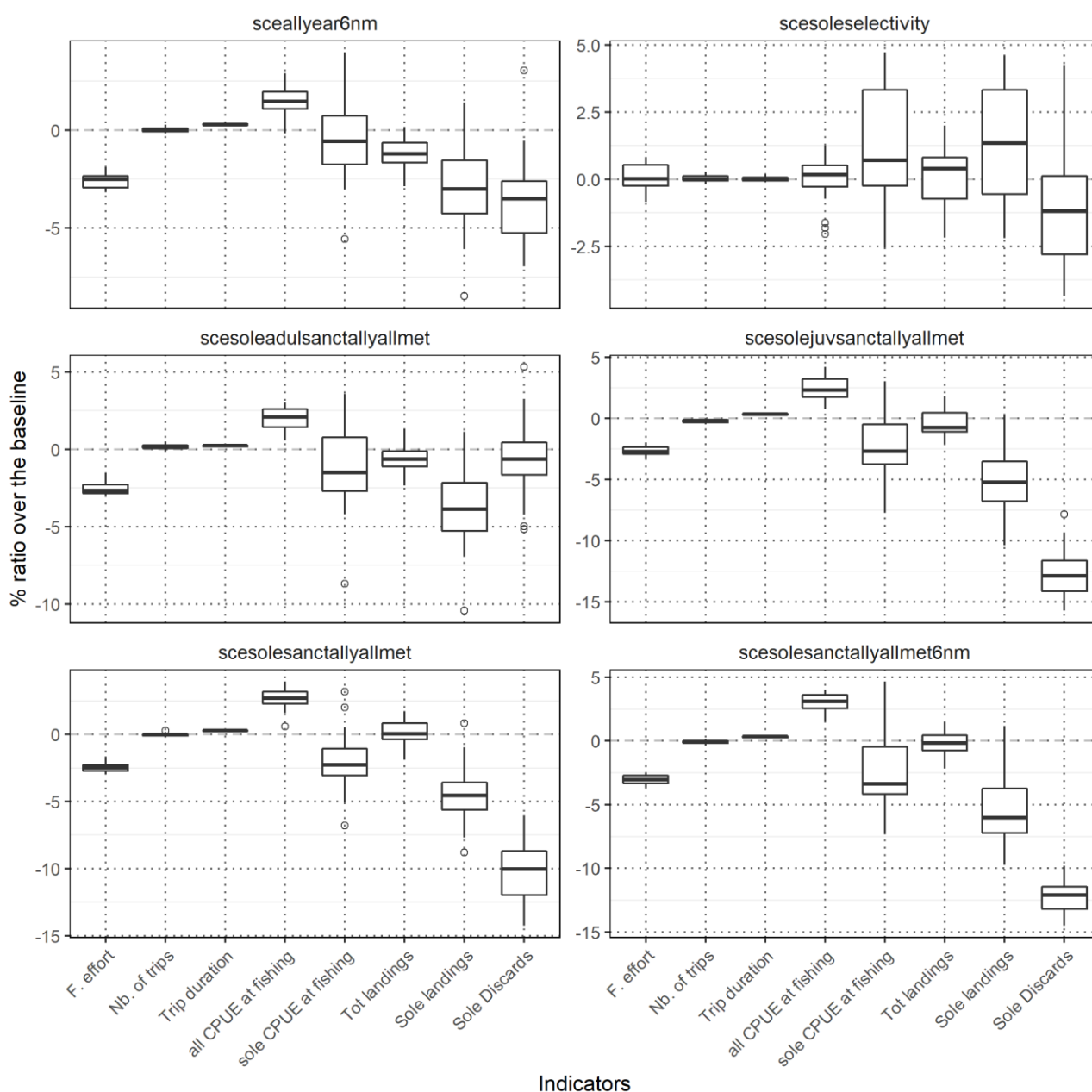
Figure 6.1.3.2 Comparison of aggegated scenario outcomes (20 stochastic replicates per scenario) on the vessel performance indicators (percent relative to the baseline) for rapido trawlers. The percentages are relative to the baseline condition for fishing effort (F. effort), number of trips (Nb. of trips), trip duration, all CPUE at fishing, Sole CPUE at fishing, total landings all stocks pooled (Tot land.), common sole landings (Sole landings) and discard rates for common sole (Sole discards).

The effects of the "sole selectivity" scenario on bottom otter trawl fishery (OTB) refer to an increase in total CPUE, CPUE of common sole, total landings and landings of common sole (Figure 6.1.3.3). A decrease in discard rates would be expected.

The closure to OTB of Area A of the Sole Sanctuary would generate a general decrease in fishing effort, number of trips, total landings, sole landings and sole discard (Figure 6.1.3.3).

The closure to OTB of Area B of the Sole Sanctuary would generate a general decrease in sole CPUE, total landings and sole landings (Figure 6.1.3.3). An increase of sole discard would be expected. In this case, it should be considered that the common sole is not the target species of OTB and it represents a small fraction of the total landing of this gear.


Figure 6.1.3.3 Comparison of aggregated scenario outcomes (20 stochastic replicates per scenario) on the vessel performance indicators (percent relative to the baseline) for bottom otter trawlers. The percentages are relative to the baseline condition for fishing effort (F. effort), number of trips (Nb. of trips), trip duration, all CPUE at fishing, Sole CPUE at fishing, total landings all stocks pooled, common sole landings (Sole landings) and discard rates for common sole (Sole discards).

The spatial distribution of effort and catches resulting from the application of these scenarios are depicted in Figure 6.1.3.4 and Figure 6.1.3.5, respectively. Average fishing mortality at age estimated by each scenario run, to be used in the MSE analysis, are reported in Table 6.1.3.1.
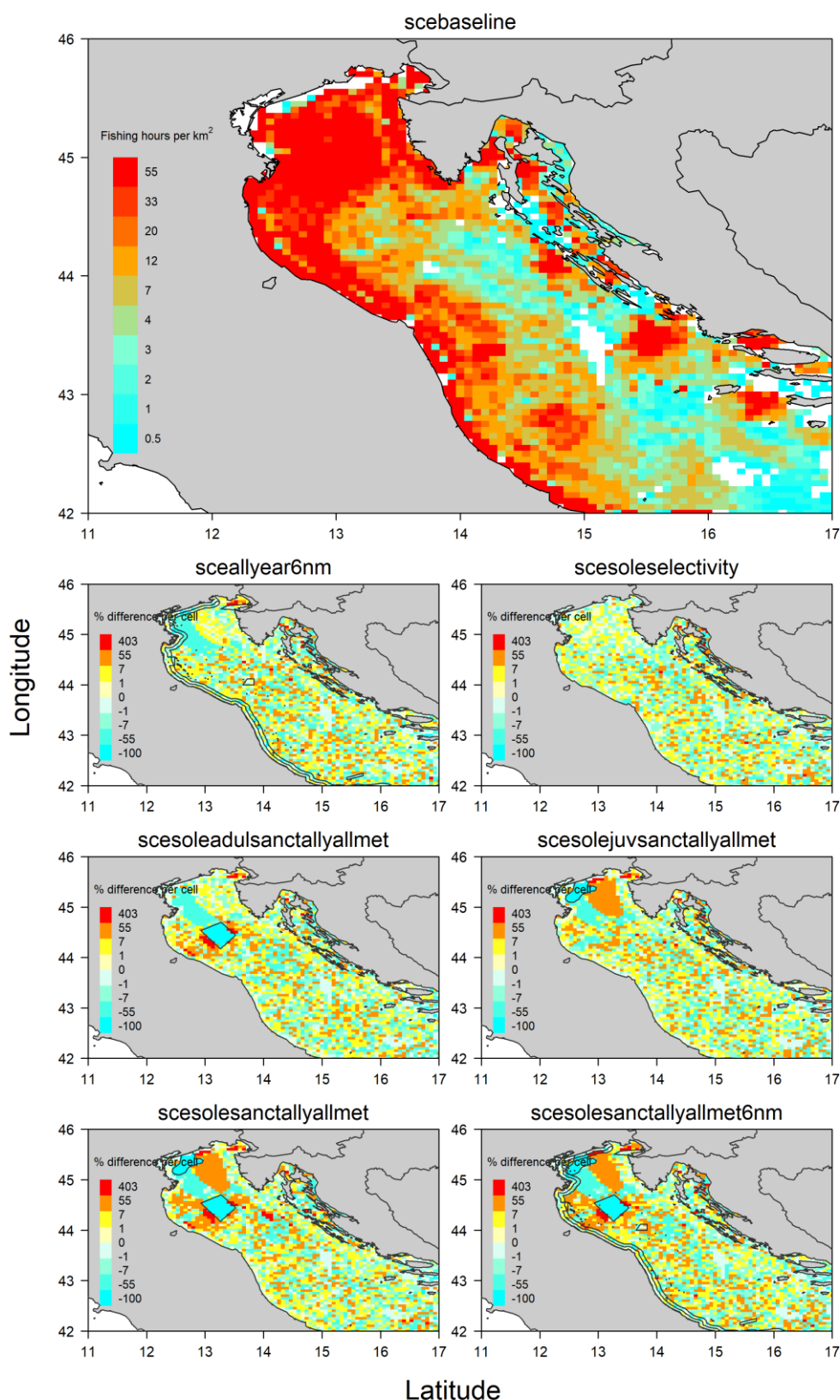
Figure 6.1.3.4 Baseline spatial distribution of the fishing effort and the percentage of relative change per scenario. Fishing efforts are given as the accumulated hours over the six-year simulation horizon averaged over the 20 replicates per scenario.
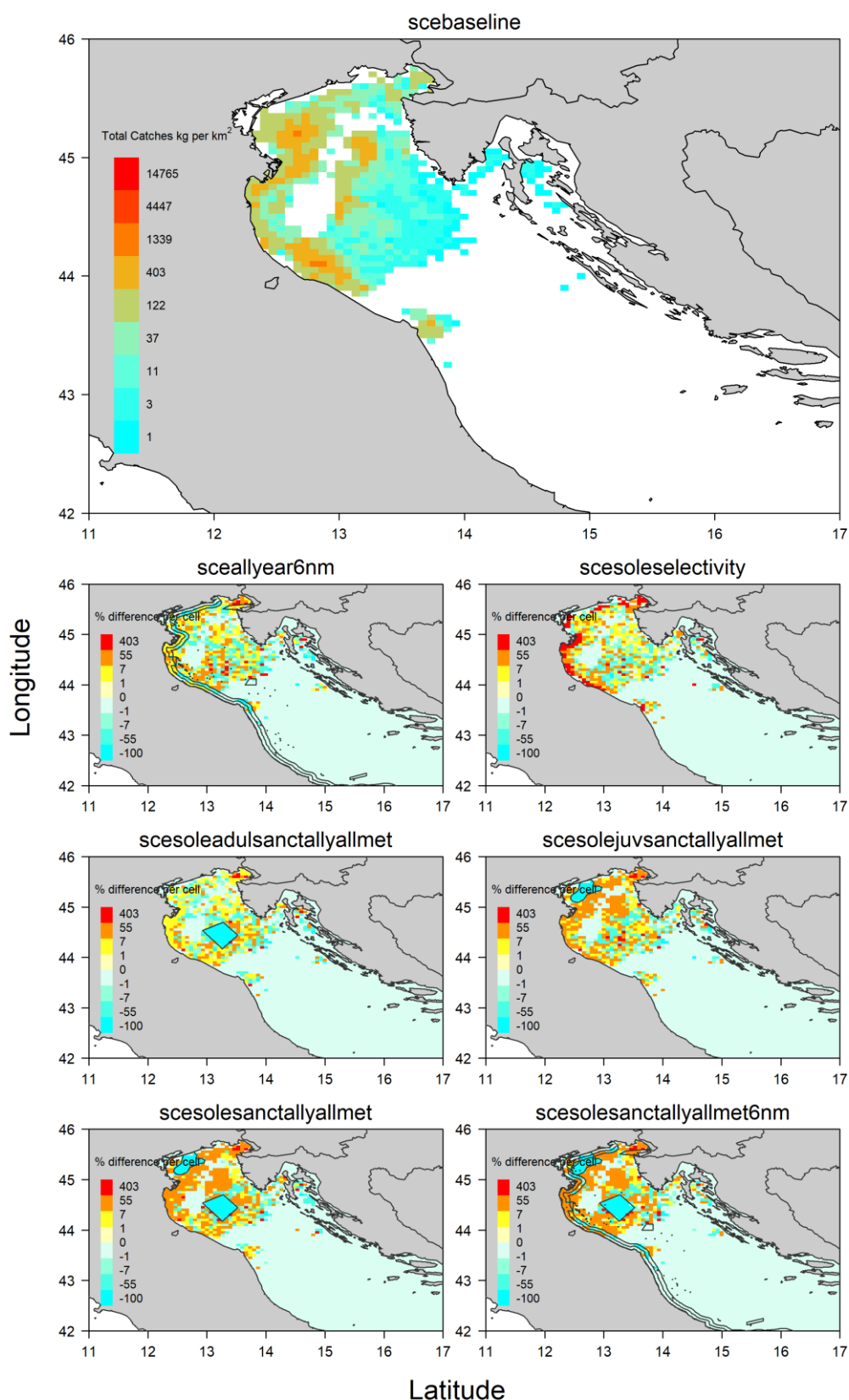
Figure 6.1.3.5 Baseline spatial distribution of the Italian and Croatian catches and the percentage of relative change per scenario. Catches are given as the accumulated tons over the six-year simulation horizon averaged over the 20 replicates per scenario

Table 6.1.3.1 Final (i.e. in year 6) simulated average fishing mortalities-at-age for GSA 17 common sole. Additional scenarios are shaded in gray.

Scenario	F0	F1	F2	F3	F4	F5	F6	F7	F8	F9
scebaseline	2.76	2.10	1.95	1.40	0.23	0.20	0.20	0.20	0.20	0.20
scesolesanctallyallmet	2.52	1.79	1.64	1.19	0.13	0.10	0.10	0.10	0.10	0.10
sceallyear6nm	2.61	1.99	1.87	1.37	0.22	0.19	0.19	0.19	0.19	0.19
scesoleselectivity	2.74	2.12	1.88	1.40	0.23	0.20	0.20	0.20	0.20	0.20
scesoleadulsanctallyallmet	2.66	2.00	1.90	1.32	0.16	0.13	0.13	0.13	0.13	0.13
scesolejuvsanctallyallmet	2.52	1.79	1.64	1.22	0.18	0.15	0.15	0.15	0.15	0.15
scesolesanctallyallmet6nm	2.47	1.79	1.62	1.18	0.13	0.09	0.09	0.09	0.09	0.09

6.2 MSE analysis for Sole 17

Changes in fishing mortality at age estimated by DISPLACE for each scenario, were introduced in the MSE runs in 2020, therefore the analysis will focus on results in 2014 and long-term (2025-2035).

The introduction of spatial closures on the baseline scenarios (F_{SQ}) does not show an improvement of the F/Fmsy relationship. A slight improvement is instead observed when spatial closures and effort reduction are combined with the 6nm closure, which seems to amplify F reductions (Table 6.2.1).

In the long term there's indications that combining effort reductions with spatial measures may increase SSB levels (Table 6.2.2). Nevertheless, it is important to note that sole results are not robust to mis-specifications of the stock-recruitment relationship and F_{SQ} estimates are optimistic.

Furthermore, it should be kept in mind that if selectivity changes, due to management measures like spatial closures, a new F_{MSY} should be calculate since a different proportion of the population will be targeted by the fleet.

Table 6.2.1 Indicators calculated only for 2024 in the scenario without and with spatial closures

	Fsq	Fsq6nm	FsqFRA	Fmsy24FR	Fmsy24FR6nm	Fmsy24FRFRA
FFMSY	1.03	0.87	0.94	0.47	0.38	0.41
SSBBLIM	0.00	0.01	0.01	0.00	0.00	0.00

Table 6.2.2 Indicators from the long-term (2025-2035) projections of spatial scenarios accounting for a variation of F depending on the spatial closure.

	Fsq	Fsq6nm	FsqFRA	Fmsy24FR	Fmsy24FR6nm	Fmsy24FRFRA
C	1589	1623	1519	1180	1177	1097
C_{hi}	2061	2116	1997	1650	1750	1635

|						
C_{low}	1176	1177	1067	658	647	603
FFMSY	1.30	1.32	1.29	0.66	0.61	0.66
SSB	3828	5025	5419	7944	8191	8357
SSBBLIM	0.00	0.01	0.01	0.00	0.00	0.00
SSBBLIMmax	0.43	0.36	0.27	0.18	0.18	0.18

Figure 6.2.1, Figure 6.2.2, Figure 6.2.3, present summaries of spatial closures effects.
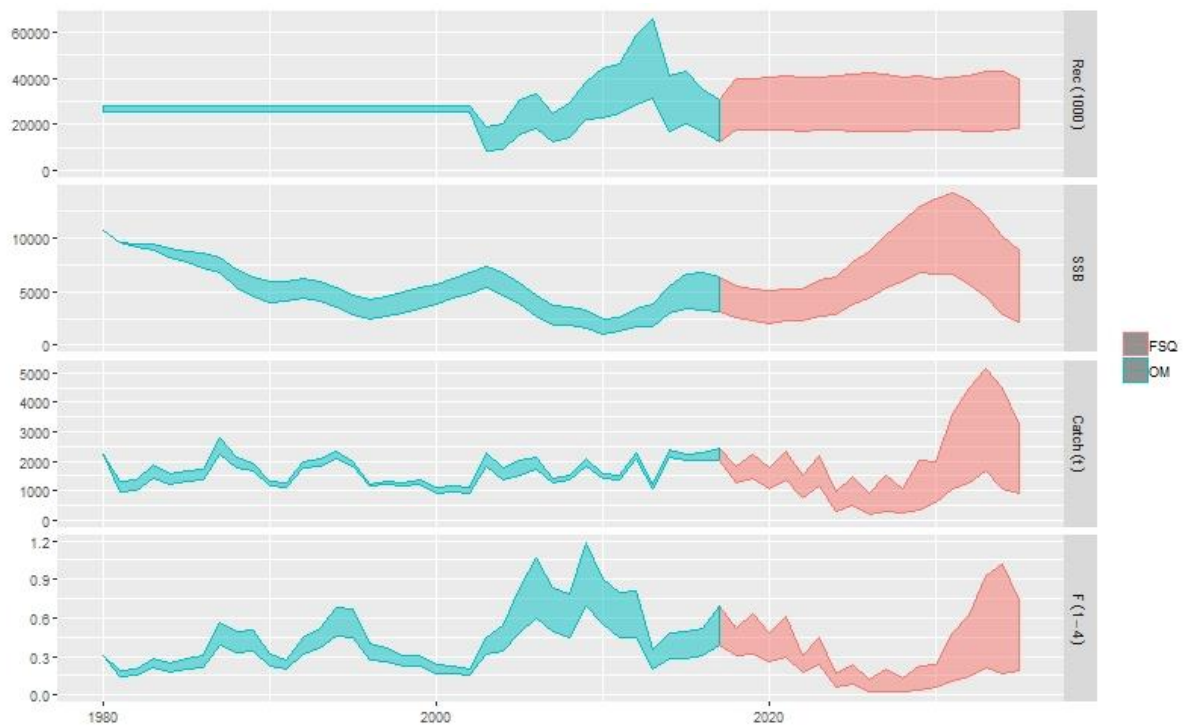
Figure 6.2.1 Projections from the baseline OM on a baseline scenario where F was modified in order to account for a spatial closure up to 6 nautical miles (Fsq6nm). SSB is the product of fecundity times the mean weight at age.
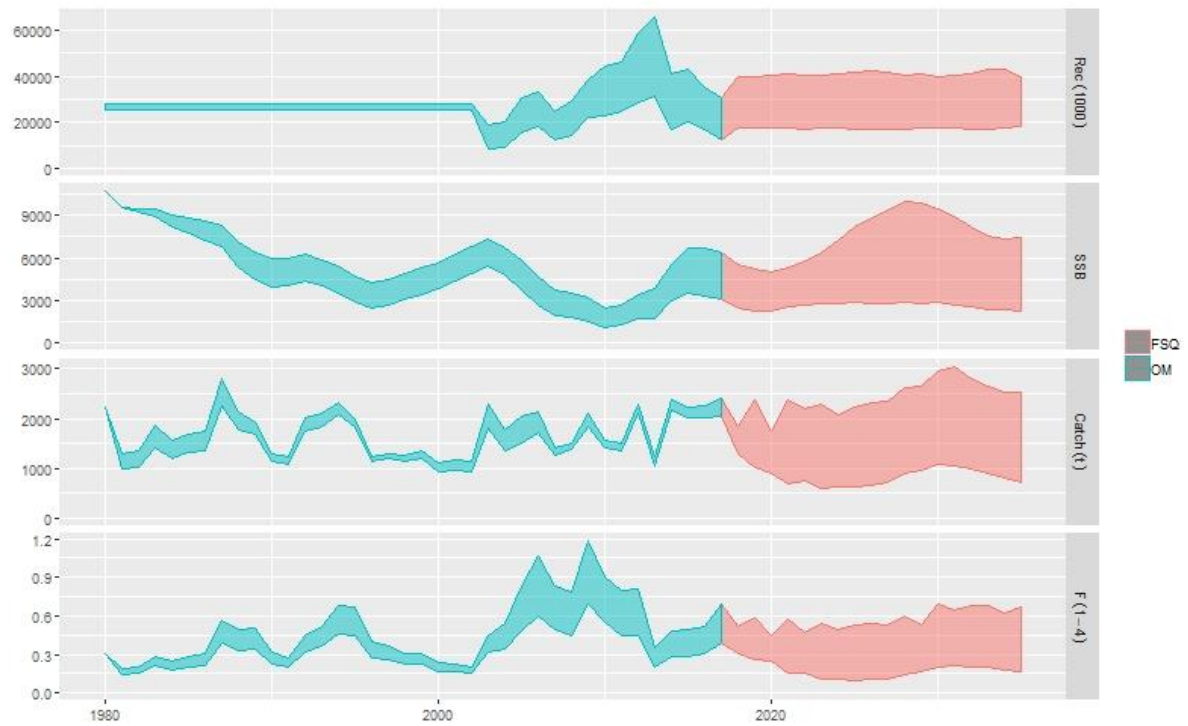
Figure 6.2.2 Projections from the baseline OM on a baseline scenario where F was modified in order to account for a spatial closure over the "sole sanctuary" (FsqFRA). SSB is the product of fecundity times the mean weight at age.
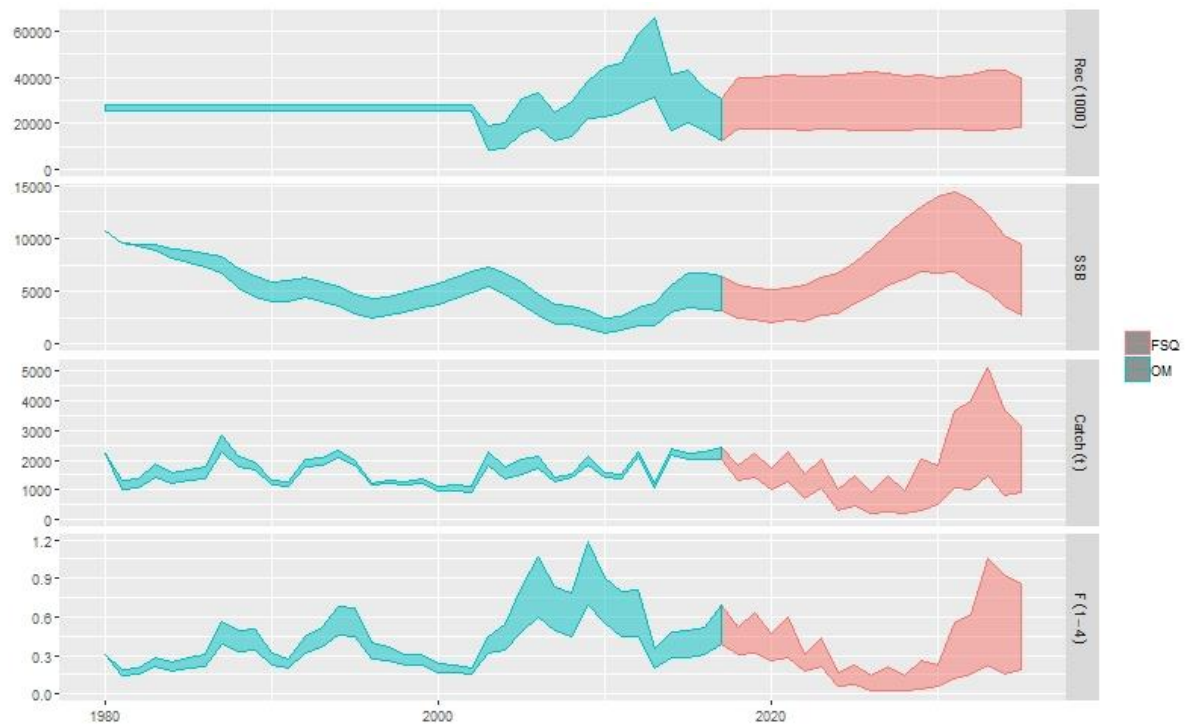
Figure 6.2.3 Projections from the baseline OM with a stepwise reduction of F up to 2024 scenario where F was modified in order to account for a spatial closure up to 6 nautical miles (Fsq6nm). SSB is the product of fecundity times the mean weight at age.

7 ToR 5 Areas of high spatial persistence of key stocks

The data for analyses of distribution of key stocks were obtained from the results of MEDITS (1996-2017) and SOLEMON (2007-2017) surveys. Information of SOLEMON surveys was made to EWG 19-02 available during the meeting and have to be treated as provisional.

The standardized length frequency distributions from MEDITS and SOLEMON were splitted in two fractions: juveniles and adults.

For the two teleosteans, Hake (HKE) and Red Mullet (MUT), a threshold based on the maturity stage of each individual caught during the survey was applied (Table 7.1). For the two crustaceans, Deep-Water Rose Shrimp (DPS) and Norway lobster (NEP), maturity stage was fully available only for females, hence the EWG agreed in applying as threshold the length corresponding to the Minimum Conservation Reference Size (MCRS) (Table 7.1). For Common Sole (SOL) and Spottail Mantis Shrimp (MTS) a threshold based on the expertise of the Adriatic researchers involved in the SOLEMON survey was applied (Table 7.1).

Table 7.1 Threshold applied to the length distributions collected by haul during the MEDITS and SOLEMON surveys to distinguish between juveniles and adults.

Species code	Juveniles	Adults	Data source	Reference
HKE	Medits Maturity Scale Stage 0-1	Medits Maturity Scale Stage >1	MEDITS	MEDITS-Handbook version 9[1]
MUT	Medits Maturity Scale Stage 0-1	Medits Maturity Scale Stage >1	MEDITS	MEDITS-Handbook version 9[1]
SOL	<250mm Total Length	>=250mm Total Length	SOLEMON	EWG19-02
MTS	<27mm Carapace Length	>=27mm Carapace Length	SOLEMON	EWG19-02
DPS	<20mm Carapace Length (MCRS)[2]	>=20mm Carapace Length (MCRS)[2]	MEDITS	Council Regulation (EC) No 1967/2006
NEP	<20mm Carapace Length (MCRS)[2]	>=20mm Carapace Length (MCRS)[2]	MEDITS	Council Regulation (EC) No 1967/2006

[1]https://www.sibm.it/MEDITS%202011/principaledownload.htm

[2]MCRS = Minimum Conservation Reference Size

7.1. ToR 5 (a,b) Provide the detailed maps of the high persistence areas of 1st year juveniles and the recurrent spawning aggregations areas

7.1.1 Methodology

An R-script, developed by the EWG 17-15 was used by the EWG 19-02 to identify samples as belonging to a particular sampling station. An R script was used to calculate the persistence of "high" values of standardized abundance for each fraction of the population: those above the 50th percentile threshold when only non-zero values are included. The 50th percentile threshold was calculated on an annual basis and following the GSA aggregation adopted in the stock assessment carried out for each stock.

Once the standardized abundance was calculated for each haul, the persistence was calculated as the number of years (hauls) within each sampling cluster with values above the 50th percentile threshold divided by the total number of years that each particular sampling cluster had been sampled, obtaining a persistence (probability) value ranging from 0 to 1 for each stock.

EWG 19-02 however suggests that in order to make distribution maps better the 75% threshold might be more appropriate to apply in order to distinguish the areas of "high "persistence.

7.1.2 Hake (HKE)

Information on main areas of distribution of juvenile hake obtained from MEDITS is presented in the Figure 7.1.2.1. The respective distribution of adult hake is shown in the Figure 7.1.2.2.

Since the main spawning period of hake occurs during the winter time and MEDITS takes place in late spring and/or beginning of summer, the results may not directly reflect the distribution pattern of spawning aggregations. However, it can be assumed that MEDITS captures the second, spring spawning fraction of hake giving thus a hint on spatial distribution of spawners.

Juvenile hake is widely distributed with exception of northwestern of the Adriatic Sea and the South Adriatic Pit. A high persistency area of occurrence was detected in the central Adriatic, in the Pomo Pit area, extending southwards to south Italy and north of Greece.

Persistent for adult hake areas presented a different pattern of distribution, with the eastern part of the Adriatic being more important than the western part. Distribution pattern both juvenile and adult hake is close to the results obtained with MEDISEH project (Colloca et al. 2013) and in good accordance with EWG 17-15 results.
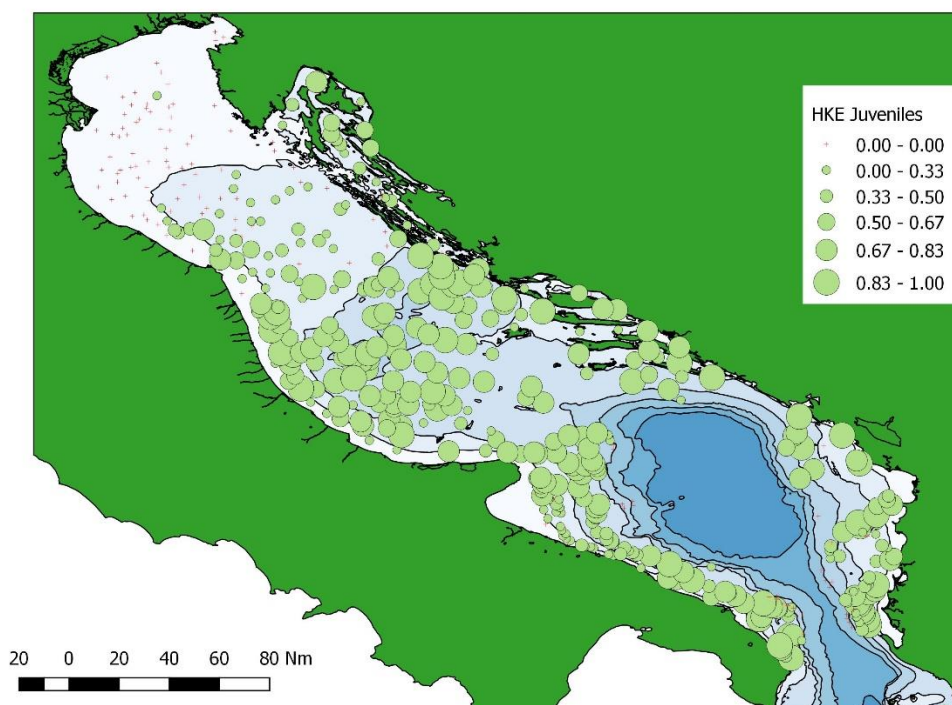
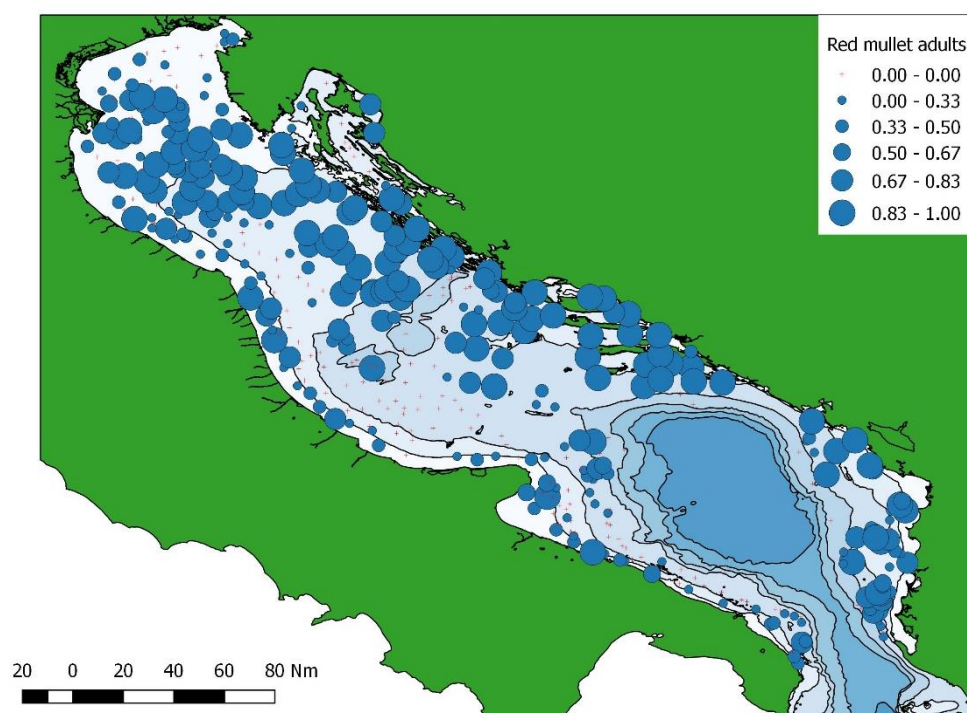**Figure 7.1.2.1** Persistence of hake juveniles at MEDITS stations in GSAs 17-18
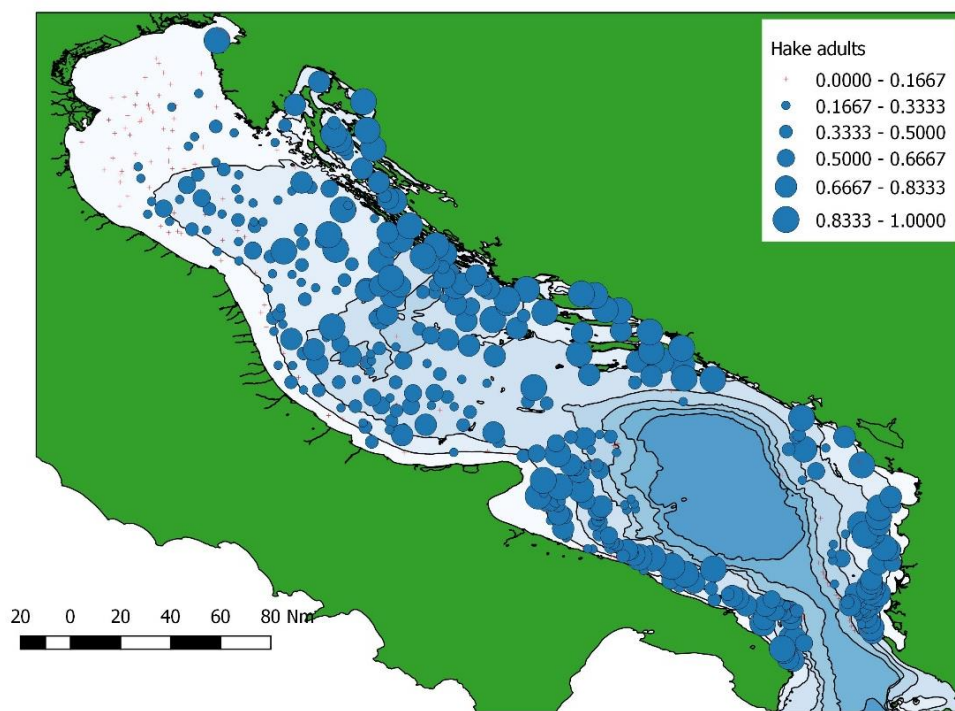
Figure 7.1.2.2 Persistence of hake adults at MEDITS stations in GSAs 17-18.

7.1.3 Red mullet (MUT)

The persistent areas of occurrence of adult red mullet are presented in the Figure 7.1.3.1. The distribution pattern indicates clear concentration of adults along the eastern coast of Adriatic and in the central area of the northern part of the sea. Since the MEDITS takes place during the spawning season and due to the high share of spawners in survey catches the MEDITS results allow also detection of the spawning areas of red mullet. The distribution pattern of spawners (Figure 7.1.3.2) indicates that the spawning areas largely overlap with the main distribution area of adults starting close to the midline in the Northern Adriatic and extends towards SE Croatian coast.

The distribution of red mullet spawning areas detected with this method is in line with the results of the MEDISEH project (Colloca et al. 2013) and with the results obtained by EWG 17-15.

The mapping of distribution of juveniles was not considered since red mullet already spawn at 1 year of age, so the immature individuals were scarcely detected with the MEDITS survey.

**Figure 7.1.3.1** Persistence of red mullet adults at MEDITS stations in GSAs 17-18.
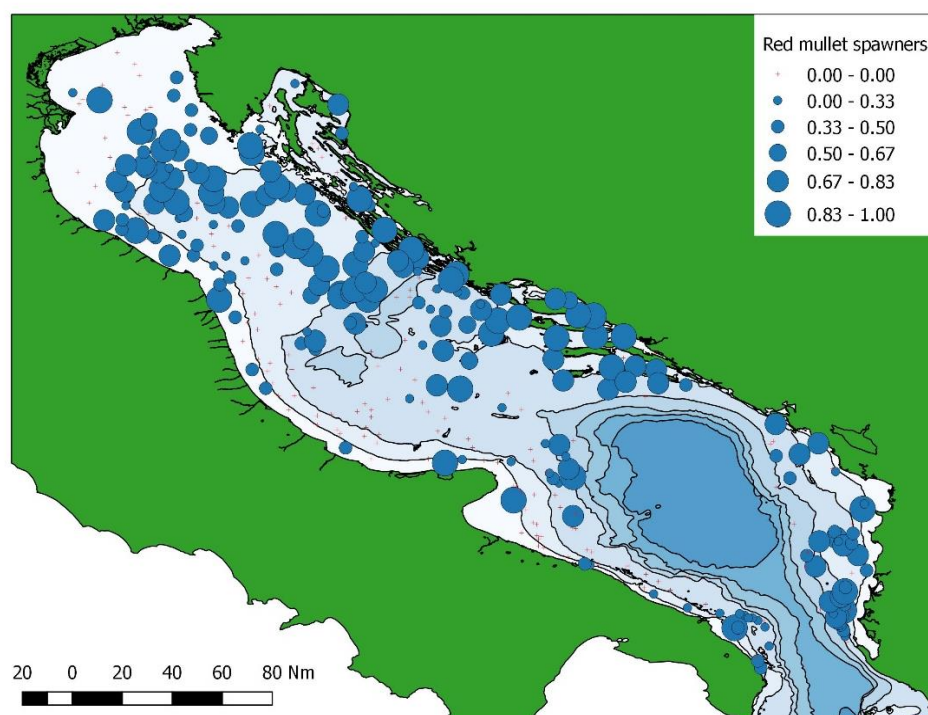
**Figure 7.1.3.2** Persistence of red mullet spawners at MEDITS stations in GSAs 17-18.

7.1.4 Deep – water rose shrimp (DPS)

The MEDITS survey does not allow the detection of spawning areas of the deep-water rose shrimp since the survey does not strictly cover its main spawning period due to continuous reproductive pattern of this species. However, the results give an overview of the distribution pattern of nursery areas of juveniles allowing concluding on potential recruitment protection measures. The juveniles show persistent occurrence in the central Adriatic Sea, East and South of Pomo Pit and well as East and West of the South Adriatic Pit (Figure 7.1.4.1). The results obtained are similar to those of EWG 17-15 and the MEDISEH (Colloca et al. 2013) project.

The adults of deep-water rose shrimp show in general similar distribution pattern, having however more persistent distribution area near Croatian coast North-East of the Pomo Pit (Figure 7.1.4.2).
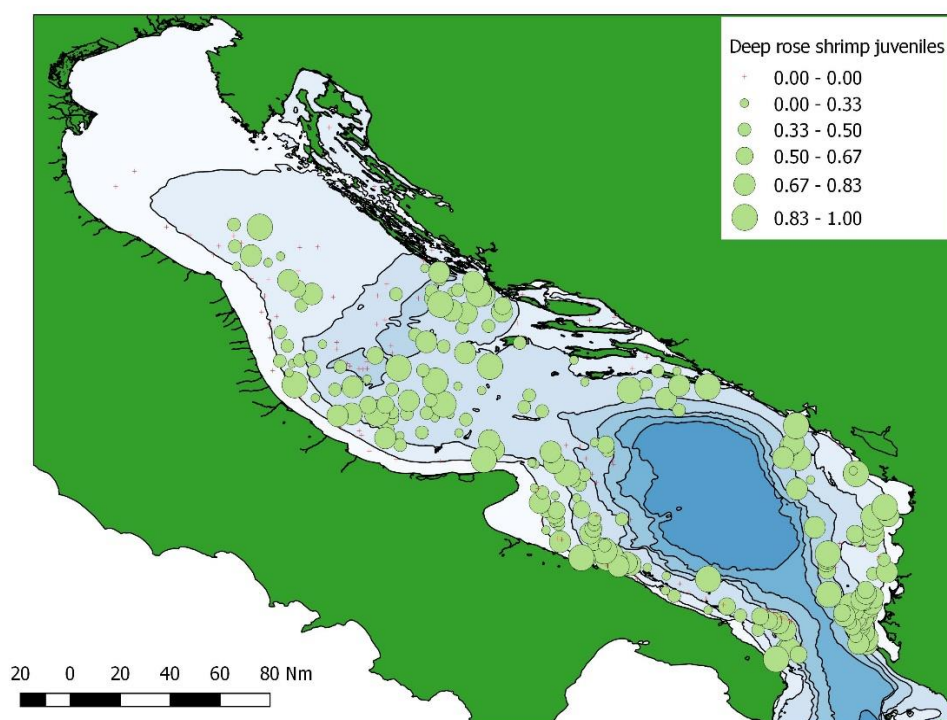
Figure 7.1.4.1 Persistence of deep-water rose shrimp juveniles at MEDITS stations for GSAs 17-18.
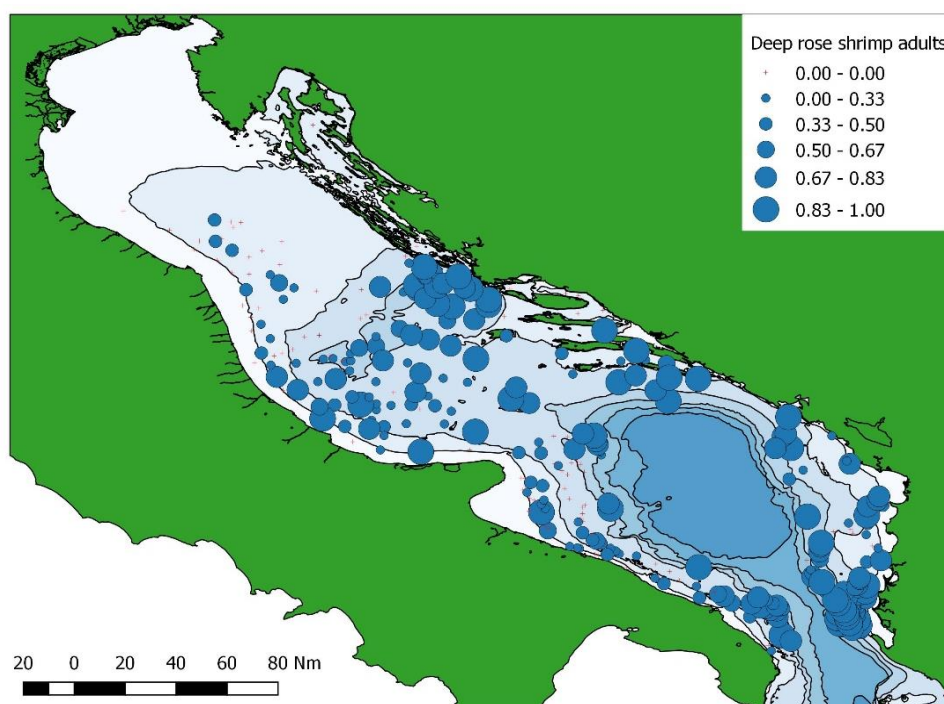
**Figure 7.1.4.2** Persistence of deep-water rose shrimp adults at MEDITS stations for GSAs 17-18

7.1.5 Norway lobster (NEP)

The distribution pattern of adults indicates at the existence of two bigger areas of persistent occurrence of Norway lobster in the Adriatic Sea. In the northern area (GSA17) the MEDITS data shows persistent areas of distribution in the area of the Pomo Pit and in the Croatian Archipelago (Figure 7.1.5.1). Second large distribution area is connected to south-eastern and western slopes of the South Adriatic Pit. The persistent areas of occurrence of juvenile lobsters were found to coincide with adults in the Pomo Pit area and on southwestern and southeastern slopes of the South Adriatic Pit (Figure 7.1.5.2).

The distribution of nursery grounds and spawning areas of Norway lobster have been analyzed during the EU project MEDISEH. According to these results GSA 17 denser and persistent patches of small specimens (juveniles) occur in the Pomo Pit area (Colloca et al. 2013). Aggregations of adults were identified in GSA 17 offshore the SW coast, in the Pomo Pit, and in north and south Croatian waters. In GSA 18 the more persistently abundant adult aggregations occur on the SE and SW slopes of the South Adriatic Pit. Thus the distribution pattern revealed by EWG 19-02 is good coherence with MEDISEH results.
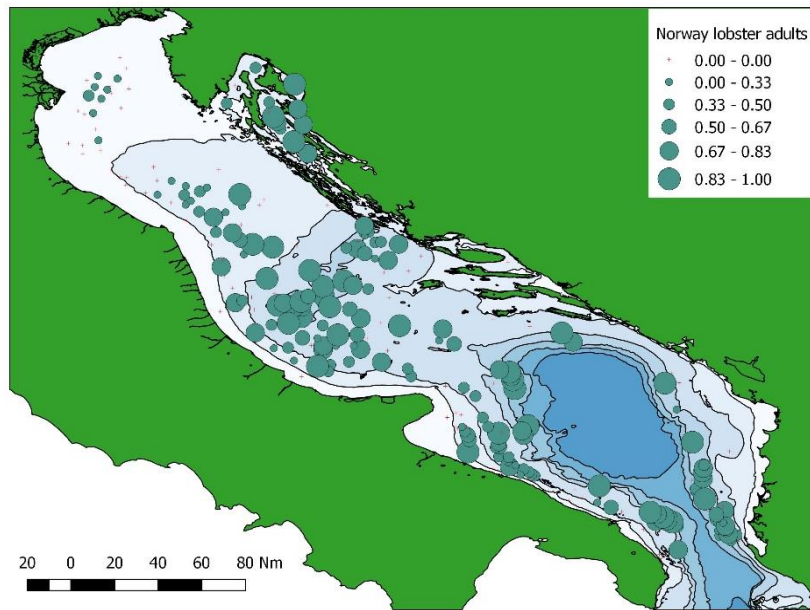
Figure 7.1.5.1 Persistence of Norway lobster adults at MEDITS stations for GSAs 17-18
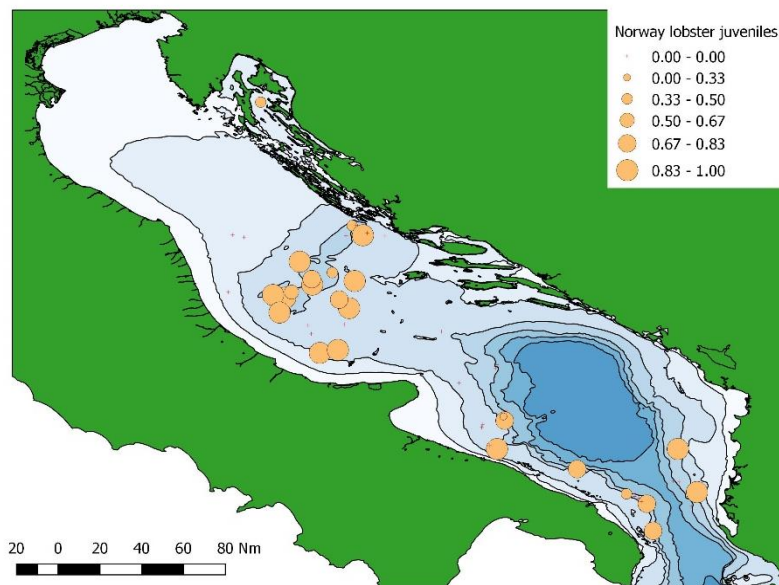

**Figure 7.1.5.2** Persistence of Norway lobster juveniles at MEDITS stations for GSAs 17-18

7.1.6 Sole (SOL)

The spatial persistence of sole adults is shown in Figure 7.1.6.1. The distribution pattern indicates higher concentration of adults in the northern part of GSA 17. Since the SOLEMON is usually carried out in November-December, in correspondence with the beginning of the spawning season of this species, such results could be used to detect the spawning areas. The highest concentration of adults was observed in the central part of the northern GSA 17, in correspondence with the so-called "Sole Sanctuary". The distribution of sole spawning areas detected with this method are in line with the results of the MAREA-MEDISEH project (Colloca et al. 2013).

The spatial persistence of sole juveniles is shown in Figure 7.1.6.2. The distribution pattern indicates higher concentration of juveniles along the north-western coast of GSA17. SOLEMON is usually carried out in November-December, during the recruitment peak of this species. Also in this case, the distribution of sole nurseries detected with this method are in line with the results of the MAREA-MEDISEH project (Colloca et al. 2013).
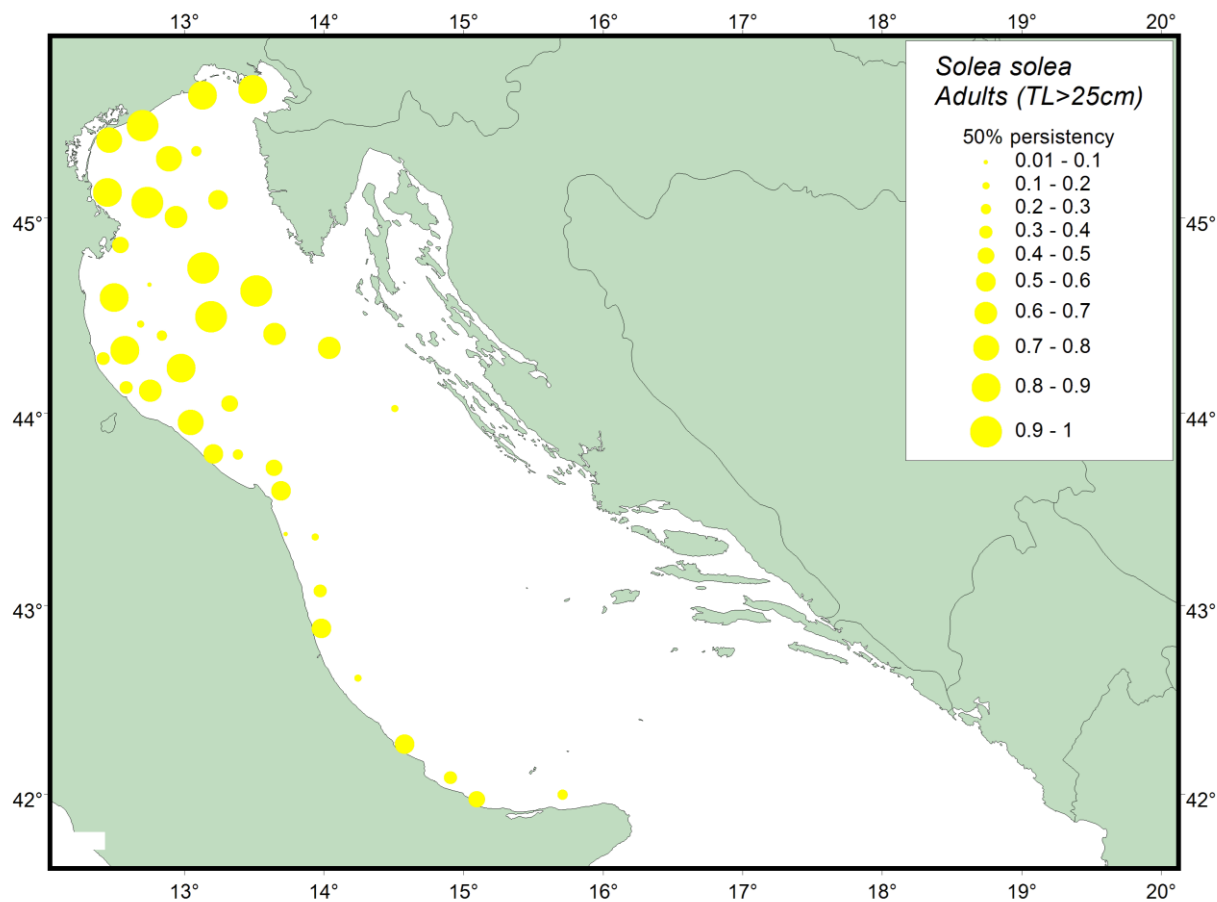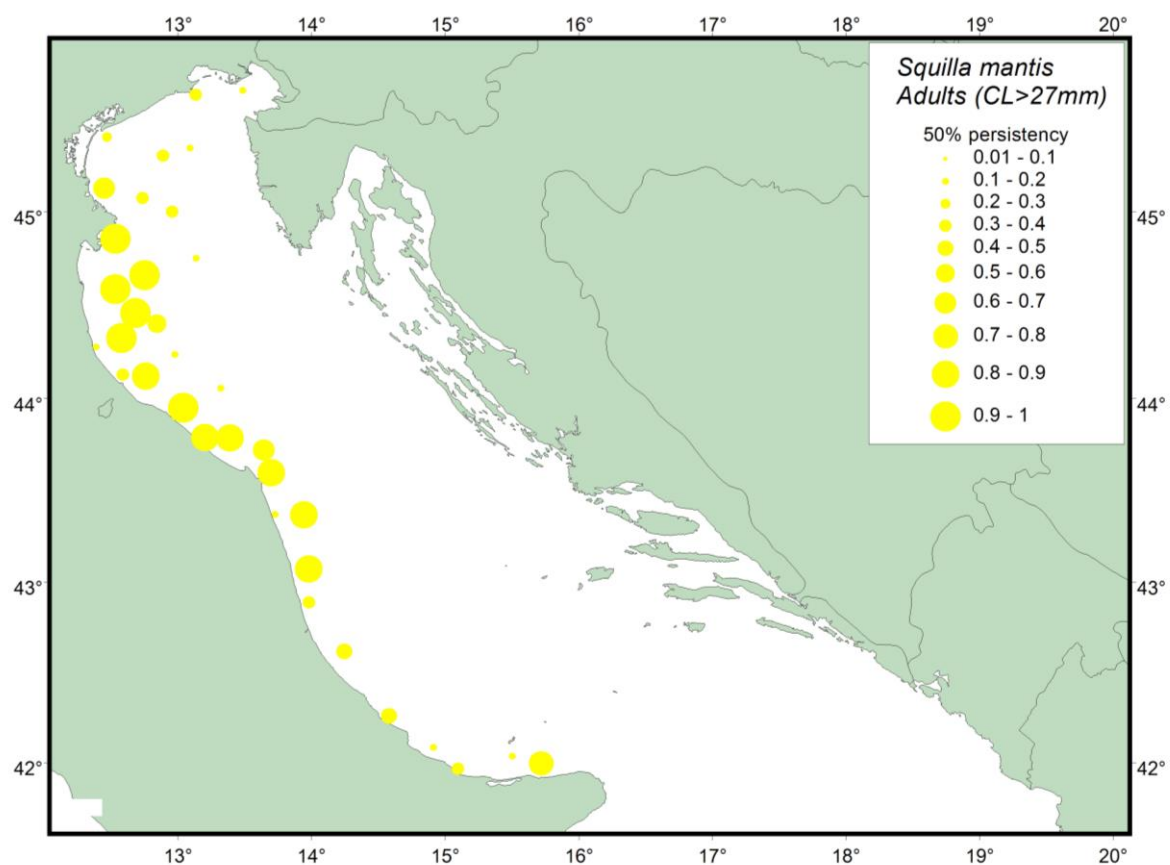

Figure 7.1.6.1 Spatial persistence of sole adults in GSA17 (data source: SOLEMON survey 2007-2017).
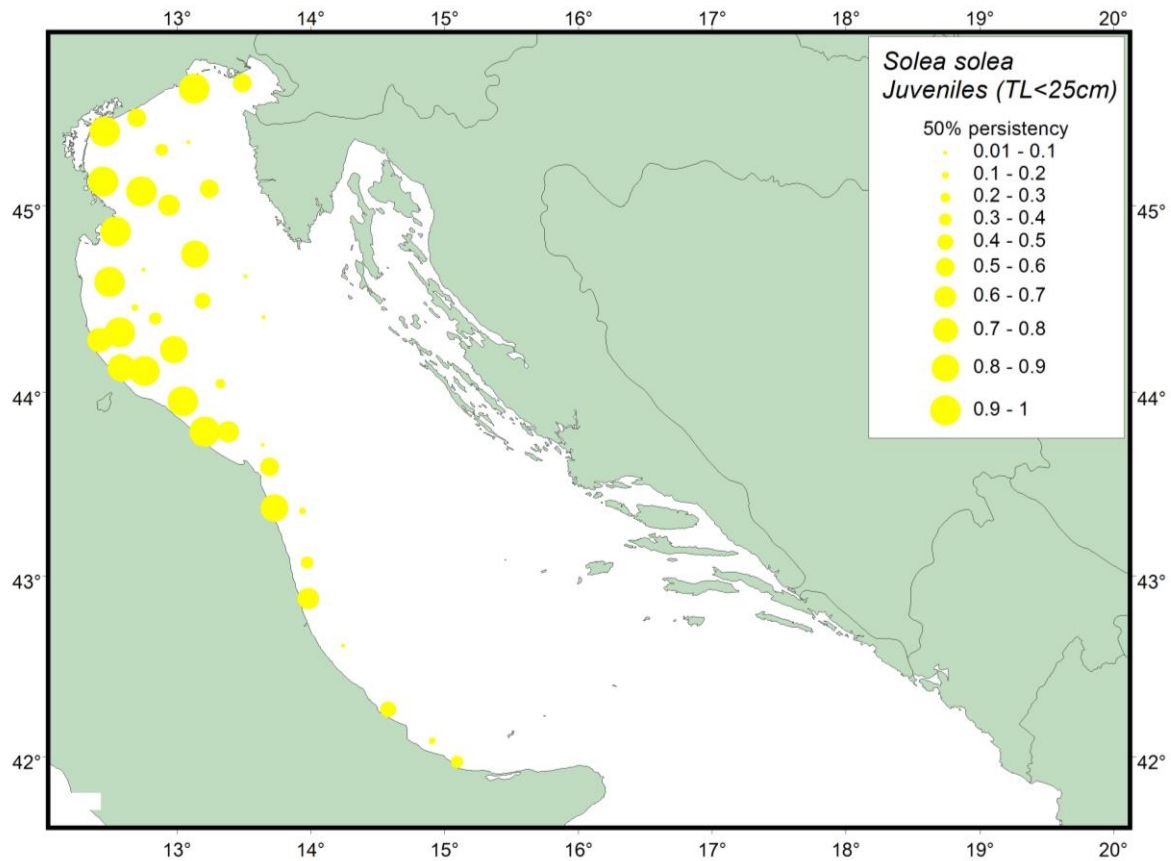
Figure 7.1.6.2 Spatial persistence of sole juveniles in GSA17 (data source: SOLEMON survey 2007-2017).
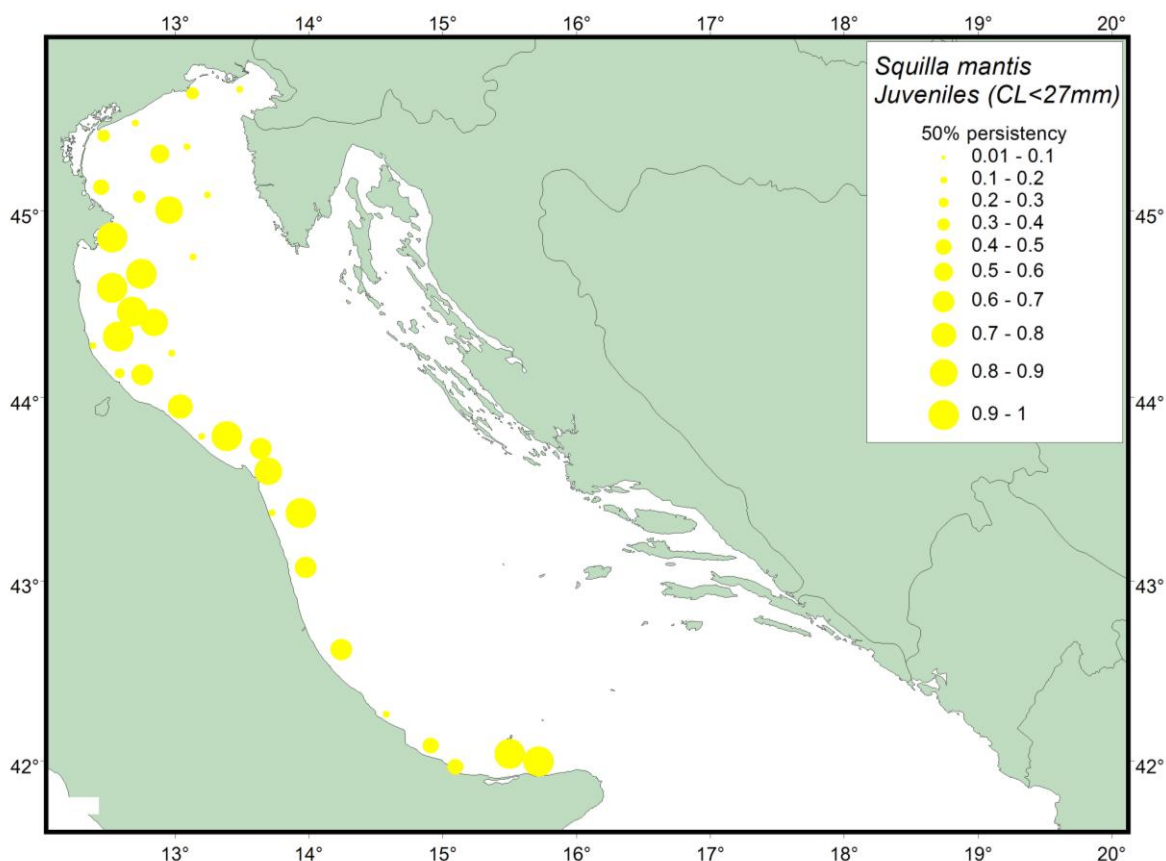
7.1.7 Spottail mantis shrimp (MTS)

The spatial persistence of spottail mantis shrimp adults and juveniles is shown in Figure 7.1.7.1 and Figure 7.1.7.2, respectively. The distribution patterns indicate for both adults and juveniles higher concentrations along the western coast of GSA17, which is characterized by shallow waters and sandy and muddy bottoms.

Figure 7.1.7.1 Spatial persistence of spottail mantis shrimp adults in GSA17 (data source: SOLEMON survey 2007-2017).

Figure 7.1.7.2 Spatial persistence of spottail mantis shrimp juveniles in GSA17 (data source: SOLEMON survey 2007-2017).

7.2 ToR 5 (c) Analyse the percentage of overlapping of juveniles and adults persistent areas, by individual stocks and across all stocks in Table I, to explore the viability of the fisheries if managed trying to avoid either juveniles or spawners.

EWG 19-02 made an attempt to evaluate to what extent the persistent areas of distribution of adults and juveniles overlap. The number of hauls where the high persistence was applied as an estimate of the areas where spatial overlapping of juveniles and adults is expected to be high (probability of occurrence of both adults/spawners and juveniles above 50%).

7.2.1 Hake (HKE)

Since the main spawning period of hake occur during the winter time and the MEDITS takes place in late spring and/or beginning of summer, the results may not directly reflect the distribution pattern of spawning aggregations. However it can be assumed that MEDITS captures the second, spring spawning fraction of hake giving thus a hint on distribution of spawners.

The analysis of EWG19-02 revealed three major areas where persistent overlapping of spawners and juveniles is highly probable: the Croatian coastal archipelago and the south-western and south-eastern slopes of the South Adriatic Pit (Figure 7.2.1.1).
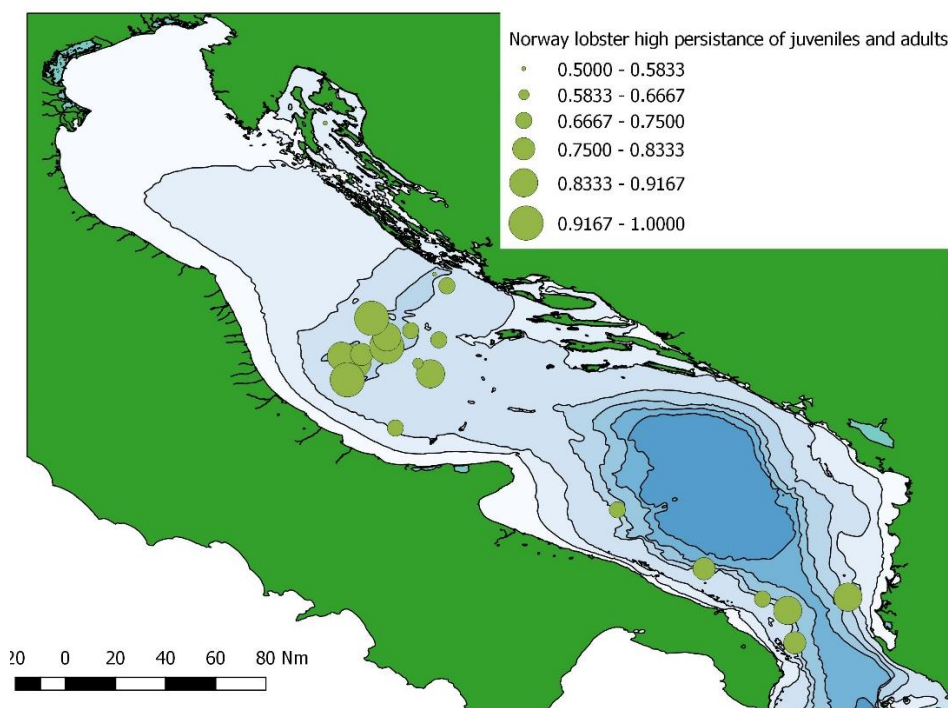
123
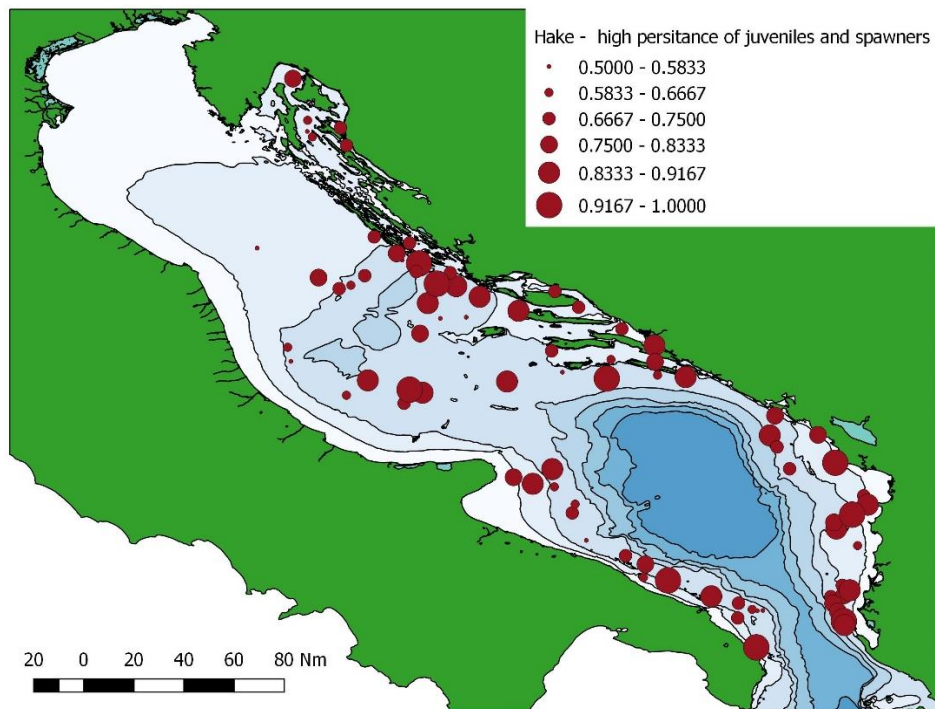
Figure 7.2.1.1 Areas of highly persistent overlapping of hake spawners and juveniles at MEDITS stations for GSAs 17-18

7.2.2 Norway lobster (NEP)

The EWG 19-02 analysis revealed that persistent overlapping of adults and juveniles of Norway lobster is highly probable in the Pomo Pit area and on the south-eastern slopes of the South Adriatic Pit (Figure 7.2.2.1).
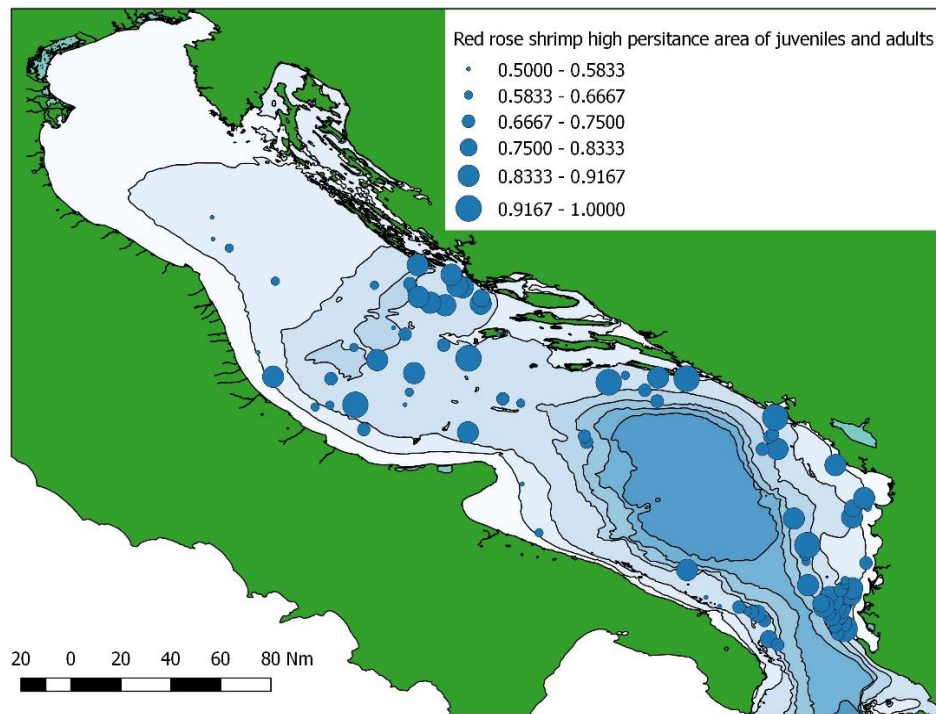
Figure 7.2.2.1 Persistence of deep-water Norway lobster adults and juveniles at MEDITS stations for GSAs 17-18

7.2.3 Deep-water rose shrimp (DPS)

Both the juveniles and adults of DPS show persistent occurrence in the central Adriatic Sea, East and South of Pomo Pit and well as East and West of the South Adriatic Pit (Figure 7.1.4.1 and Figure 7.1.4.2). The areas where the overlap of the persistent distribution pattern of both adults and juveniles is highly probable shows the similar pattern. With this respect the key areas can be observed near Croatian coast east of the Pomo Pit and in particular south-east of the South Adriatic Pit (Figure 7.2.3.1).

Figure 7.2.3.1 Persistence of deep-water rose shrimp adults and juveniles at MEDITS stations for GSAs 17-18

7.2.4 Sole (SOL)

The areas with high spatial persistence of both juveniles and adults sole are located in the northern Adriatic Sea, close to the Italian coast and between the Istria Peninsula and the Emilia-Romagna Region (Figure 7.2.4.1).
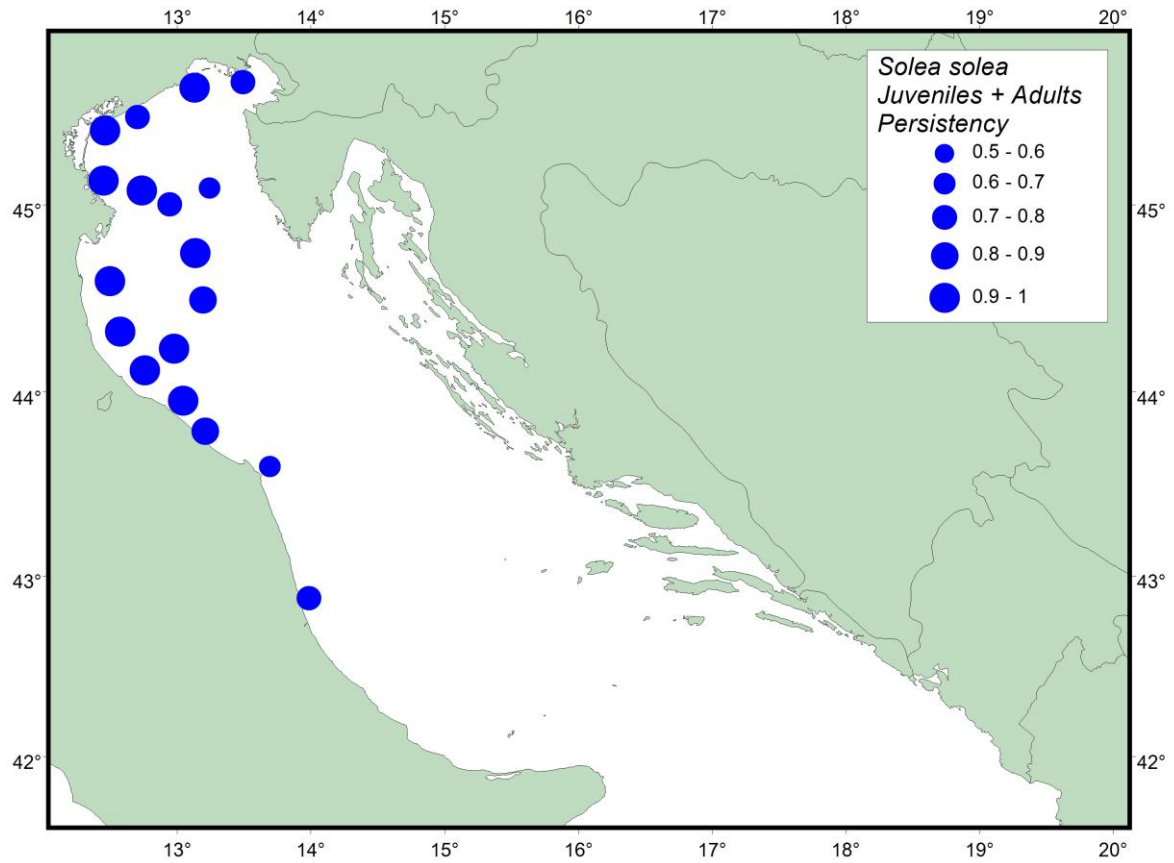
Figure 7.2.4.1 Spatial persistence of sole juveniles and adults (>50%) in GSA17 (data source: SOLEMON survey 2007-2017).

7.2.5 Spottail mantis shrimp (MTS)

The areas with high spatial persistence of both juveniles and adults spottail mantis shrimp are located along the western coast of the GSA17 (central and northern Adriatic Sea), extending from the Po River Mouth to the Abruzzo Region (Figure 7.2.5.1).
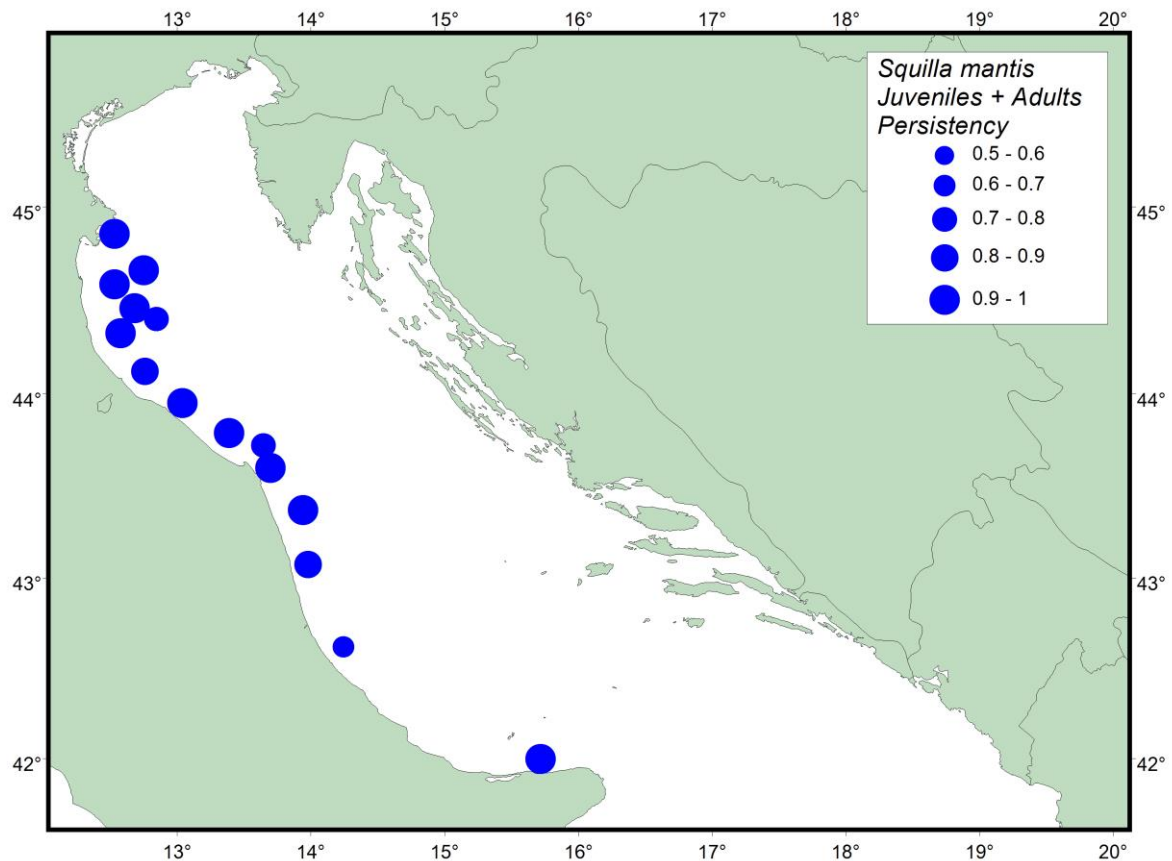
Figure 7.2.5.1 Spatial persistence of spottail mantis shrimp juveniles and adults (>50%) in GSA17 (data source: SOLEMON survey 2007-2017).

8 FINAL COMMENTS

Effort strategies miss the target in all cases except for red mullet, forcing larger reductions than needed due to the management lag cyclical effect. In FIXREDUX this effect is more pronounced. Catch limits for sole show a better performance than their effort analogous with smaller cyclical effects. The probability of SSB falling below Blim shows a similar pattern, decreasing fishing mortality reduces risk close to 0.

Zooming into 2024, the probability of falling below Blim and probability of being within 20% of the target fishing mortality in 2024, show that the FIXREDUX strategy (Fmsy24FR) has a poorer performance than immediate linear reductions (Fmsy24). The FIXREDUX strategy forces a larger yearly reduction in F, since it tries to achieve the target in 4 years instead of 6, which introduces a larger cyclical effect. In terms of protecting SSB both strategies reduce the probability of falling below Blim close to 0.

It is important to bear in mind that uncertainty is very large and, as such, these results should be taken as indicative only.

The quality of the assessments available to condition the OMs is limited due to the short time series of data available and the usage of complex assessment models setups. Both issues end up generating estimates with large uncertainty that propagates throughout the MPs' application expanding over time.

With the exception of red mullet, the stocks analysed are strongly overexploited, which means that bringing those stocks to F_{MSY} levels requires a substantial reduction of fishing mortality.

Robustness tests showed that hake, spottail mantis shrimp and red mullet alternative OMs do not deteriorate HCRs' performance, while in the case of sole alternative assumptions about the stock recruitment relationship have a large impact in the current perception of stock status and the HCRs performance.

Long-term results for hake, sole, spottail mantis and red mullet, should be taken with care. In this period, SSBs are driven outside the observation's range, while fishing mortality is set to lower limits than historical estimates. At these levels of SSB and F stock dynamics are unknown, introducing an extra level of uncertainty in the results not possible to quantify.

The effort HCR introduces fluctuations in fishing mortality, which propagates to other variables. This cyclic behavior results from the gap between the assessment results, our perception of the stock status, and the implementation of management decisions. In this case made with 2 years of interval. On the other hand, the 2 year lag in management and 1 year gap between data and assessment, results in management decisions been taken for 3 years after the stock was assessed. In cases where catches of ages 0 to 2 are large the individuals relevant for fishing are unlikely to still exist when the management actions are applied.

Reducing the management lag from 2 to 1 year would improve the potential success of the MAP. By reducing the distance between the perception of the stock, which is used to make the management decision, and the application of such decision, part of the uncertainty introduced in the exploitation of the stock could be removed. Furthermore, it would reduce the probability of missing the target by reducing F below the objective.

In general, the HCR that reaches Fmsy in 2024 using a linear decrease from 2019 onwards performs better than the FIXREDUX option, showing smaller probabilities of stock collapse, larger probability of reaching the target fishing mortality and providing more stability to the catches. Keeping a high exploitation level until 2021 before decreasing fishing mortality, leaves a shorter period to reduce F forcing larger annual decreases which propagate into inter-annual catch variability and more uncertain outcomes.

Hyperstability was not tested due to time constraints nevertheless it's well known that fishing mortality does not have a linear relationship with effort (STECF 2018a). Thus, it is expectable that during the initial period of effort reductions, reductions in fishing mortality are not observed. Consequently, current simulations may be over-optimistic.

The 6nm closure combined with effort reductions seems to amplify F reductions and improve SSB levels, while the "sole sanctuary" improves SSB levels without improving F. It is important to note though, that if changes in selectivity are effective, Fmsy should be recomputed to take into account those changes.

The persistence analysis identifies some areas of high concentration of adults, recruits and the overlap of the two. Nevertheless, the threshold of 50% to identify high persistence is not appropriate and ends up identifying half of the sites instead of picking sites with extraordinary abundances. The EWG considered a larger value, e.g. 75%, could be more appropriate in future work.

A full mixed fisheries bio-economics set of tests were not possible to carry out. Nevertheless, the different sources of information required showed a better consistency than in other MAP analysis.

The dependency analysis showed a maximum of 22 fleets with more than 50% economic dependency on MAP's stocks, flagging cases where relevant impacts from MAps implementation may occur. Additionally, the contribution of each fleet to total stock's landings in weight was also computed.

The implementation system was coded through yearly changes in fishing effort, in line with GFCMs practices. In alternative, a reduction by year from a baseline value can be used. In such

case it would be paramount to build some check points, every two years for example, to assess if these reductions are effectively controlling fishing mortality.

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[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

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11 LIST OF ANNEXES

Electronic annexes are published on the meeting's web site on:
https://stecf.jrc.ec.europa.eu/ewg1902

List of electronic annexes documents:

EWG-19-02 – Annex 1 – Bastardie F., Grati F., Bolognini L. 2019. Spatial model
EWG-19-02 – Annex 2 – Jardim E., Scott F., Mosqueira I. et al. 2018. A modular framework for the generic application of fisheries Manegement Strategy Evaluation (MSE)
EWG-19-02 – Annex 3 – Raid T., Mantopoulou-Palouka D., Isajlovic I. 2019. Spatial persistence analysis.
EWG-19-02 – Annex 4 – Accadia P. 2019. Economic model
EWG-19-02 – Annex 5 – Fabio Grati, Luca Bolognini, Edo Avdic Mravlje, Igor Isajlovic 2019. Details on closure of the coastal zone up to 6 nautical miles to all active towed gears

12 LIST OF BACKGROUND DOCUMENTS

Background documents are published on the meeting's web site on:
https://stecf.jrc.ec.europa.eu/ewg1902

List of background documents:

EWG-19-02 – Doc 1 - Declarations of invited and JRC experts (see also section 10 of this report – List of participants)

STECF

The Scientific, Technical and Economic Committee for Fisheries (STECF) has been established by the European Commission. The STECF is being consulted at regular intervals on matters pertaining to the conservation and management of living aquatic resources, including biological, economic, environmental, social and technical considerations.

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