REPORT OF THE 2020 ICCAT MEDITERRANEAN SWORDFISH STOCK ASSESSMENT MEETING

(Online, 25 May - 2 June 2020)

"The results, conclusions and recommendations contained in this Report only reflect the view of the Swordfish Species Group. Therefore, these should be considered preliminary until the SCRS adopts them at its annual Plenary meeting and the Commission revise them at its Annual meeting. Accordingly, ICCAT reserves the right to comment, object and endorse this Report, until it is finally adopted by the Commission."

1. Opening, adoption of agenda and meeting arrangements

The meeting was held online due to the outbreak of Coronavirus (COVID-19), and particularly in Madrid, which obliged the ICCAT Secretariat to close. Therefore, it was decided to set an online meeting, from 25 May to 2 June 2020. Dr. George Tserpes (EU-Greece), the Mediterranean Swordfish Species Group rapporteur ("the Group") and meeting Chairman, opened the meeting and welcomed participants. Dr. Miguel Neves dos Santos (ICCAT Assistance Executive Secretary) welcomed the participants and thanked the efforts made by all participants to remotely attend the meeting. He also thanked Dr. Henning Winkle for attending the meeting as invited experts and providing his expertise to the Group.

The Secretariat provided information on how to use the online platform for the meeting (Microsoft TEAMS). The Chair reviewed the Agenda, which was adopted with several changes (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The List of Documents and Presentations provided to the meeting is attached as **Appendix 3**. The abstracts of all SCRS documents and presentations provided at the meeting are included in **Appendix 4**. The following served as rapporteurs:

Sections	Rapporteur
Items 1, 9	M. Neves dos Santos
Item 2.1, 2.2, 2.3	C. Palma, A. Kouadri-Krim
Item 2.4	D. Macias
Item 2.5, 2.6	F. Garibaldi, A. Di Natale
Item 4	A. Kimoto, J. Urbina, M. Ortiz
Item 5	G. Tserpes, D. Mantopoulou, B. Mourato, H. Winker, J. Ortiz de Urbina, A. Kimoto, M. Ortiz
Item 6	G. Tserpes, D. Mantopoulou, B. Mourato, H. Winker, M. Ortiz, A. Kimoto
Item 7	G. Tserpes, R. Coelho
Item 8	G. Tserpes, M. Neves dos Santos

2. Summary of available data submitted according to the swordfish intersessional meeting deadlines

The largest majority of the Mediterranean swordfish (SWO-M) fisheries statistics and biological information used in the current stock assessment, was revised and updated during the Report of the 2020 ICCAT intersessional meeting of the Swordfish Species Group (Anon., 2020, *in press*). During the meeting, a time schedule was established to revise and update some pending datasets foreseeing the estimations of both catch-at-size (CAS) and catch-at-age (CAA) matrices. Overall, all the deadlines were properly accomplished.

Under this section, several documents were presented on fisheries statistics (SCRS/2020/028, SCRS/2020/076) and biological information (SCRS/2020/043, SCRS/2020/058, and SCRS/2020/074).

2.1 Catches

After the prohibition of gillnets in the Mediterranean, more than 95% of SWO-M total catches are since 2008 associated with longline (LL) fisheries. Eight CPCs (descending order of importance: EU-Italy, EU-Spain, EU-Greece, Morocco, Tunisia, Algeria, EU-Malta, and Turkey) account for the majority of those catches. This information, available in the ICCAT official Task I nominal catches (T1NC), lacks almost completely (exceptions: EU-Greece and EU-Spain in some years) the dead discards of undersized SWO catch series component. The Secretariat recalled that, estimations of both dead and live discards are mandatory data requirements to be reported under T1NC.

The document SCRS/2020/028 presented preliminary estimations of longline (LL) dead discards of undersized fish, obtained using the available Task 2 size frequencies (T2SZ) of three fleets (EU-España, EU-Greece, EU-Malta) who reported under their T2SZ datasets, fish below the ICCAT minimum size regulation on landings (90 cm in 2014, and updated to 100 cm in 2017). For these three fleets no estimations of dead discards were made, once it was assumed (the Secretariat should require to each concerned CPC a confirmation of this situation) that discards of undersize fish were included in the T1NC catches reported. The estimation of dead discards was made for the 5 remainder LL fleets (EU-Italy, Morocco, Tunisia, Algeria, and Turkey) which have not reported under T2SZ fish below 100 cm since the 2010. The estimated dead discards obtained represent overall about 12% to 14% between 2008 and 2017 and increased to 24% in 2017-2018, when the current minimum size was implemented, of the total LL catches.

The Group discussed these preliminary estimations and noted that catches of undersize SWO are dependent on the fishing season and the gear selectivity, characteristics that should be taken into account on future improvements of dead discards estimates. It was also noted that, some CPCs have experienced a transition from the traditional surface swordfish longline (LL-surf), to the so-called American style longline (LLAM) and the meso-pelagic longline (LLMESO) since 1999. The Group has recommended several times to ICCAT CPC the need to revise the reported statistics (Task I and Task II) taking into account the LL gear type discrimination over time. No major progress was made in this matter in the last two years.

The observations carried out in the last ten years (2010-2019) in the Ligurian Sea by onboard observers on the Italian longline fishing vessels using the two different gears, mesopelagic longline (LLMESO) and American style longline (LLAM), demonstrate that catches of undersized fish are strictly dependent on gear type, selectivity and seasonality. The LLMESO is mainly used from late May to early October with a discard rate of about 6.3% in numbers and 1.6% in weight, and even if used in autumn catches of undersized fish are extremely low. The LLAM is mainly used in the last quarter of the year. Combining the effects due to surface deployment, use of light baits and season, when young swordfish are becoming fully recruited to the gear, discarded catches are higher, raising up to the 41.0% in numbers and 17.2% in weight of the total swordfish catches.

Finally, the Group adopted the preliminary dead discards estimations presented in document SCRS/2020/028, for inclusion “as SCRS best estimates” in the T1NC database. However, the Group noted that these estimations should be considered provisional and be properly replaced in the future by the CPCs own estimations.

The Group noted again that the information from the national observer programmes are not available for most of the CPCs. The Group considers that this information (since 2019 officially known as, ICCAT CPCs “domestic observer programmes”, a mandatory data requirement reported under form ST09) is crucial to improve the estimations of both undersize swordfish catches and dead/alive discards. However, the current status of the ST09 related data currently compiled by the Secretariat (highly incomplete, heterogeneous structures, and currently under a full revision) does not permit to use this data in the above context. The details of the roadmap established to fully revise and utilize this important dataset, are described in the Report of the 2020 Intersessional meeting of the Swordfish Species Group (Anon., 2020, *in press*).

The total T1NC catches (landings and dead discards), presented in **Table 1** (the dead discard component included in T1NC is shown in **Figure 1**), are considered the best scientific estimations of SWO-M total removals to be used in the current stock assessment.

2.2 Length compositions

The size data (T2SZ) available is primarily reported by CPCs, but also includes data from ICCAT special observer programs, sampling initiatives by CPCs, and data recovery projects financed by ICCAT. During the recent years, a reasonable portion of T2SZ information was recovered and revised to include higher time-area resolution. All the updates were analysed in the 2020 Swordfish intersessional meeting (Anon., 2020, *in press*).

Important T2SZ recoveries includes, (a) the ICCAT data recovery project (SCRS/2020/020) who compiled highly detailed fishing operations of three Italian fleets (harpoons, gillnets, and longlines) operating in the Strait of Messina and in the southern Tyrrhenian Sea, with individual weights of SWO caught between 1972 and 1989, and, (b) the full T2SZ revision of the EU-Greece longline surface fleet between 2003 and 2017.

All the T2SZ information available on SWO-M was used to estimate the catch-at-size (CAS) and catch-at-age matrices. **Table 2** presents the SCRS catalogue for SWO-M for the period 1989 to 2018, showing the existing T2SZ datasets (DSet=t2, cells with "b") used in the CAS estimations.

In relation to the undersized SWO not reported within the T2SZ datasets to ICCAT, the Group reiterated the need that each CPCs revise those datasets, in particular after 2008, by including the undersized SWO available by gear type.

2.3 Catch at size/age data

Task II size samples (T2SZ) and Task II catch-at-size (T2CS) for the Mediterranean swordfish stock (SWO-Med) have been regularly submitted by the main fishing fleets in the last two decades. Both size datasets (T2SZ, T2CS), have been used in the past (Anon. 2017; Anon 2015), for estimating the overall CAS and CAA matrices. Following the recommendations of the work plan for the SWO-Med in 2019, the Secretariat did a full update of the CAS and CAA matrices for the period 1972-2018, including all the revisions made to both T1NC and T2SZ over the past four years. The details are presented in document SCRS/2020/076.

CAS matrix
The final overall CAS matrix obtained is presented in **Table 3**. As in previous CAS estimations of SWO-M, the same set of substitution rules were used, as replacement rules for missing T2SZ or T2CS data. However, given the large recoveries of T2SZ over the last three years, a large portion of the extrapolations are covered by T2SZ and T2CS. This can be observed in **Figure 2**, where the majority of the years (except 1982 and 1983) have the total catches (T1NC) covered by at least 50% of the corresponding size data (T2CS or T2SZ). On the last two decades, T1NC catches are generally covered by nearly 70% of the corresponding size data, being the reminder 30% based on substitutions.

The **Figure 3** presents the weighted (by fleet and gear) mean weight estimations (kg) obtained from new the CAS estimations. The mean weights obtained from the CAS of the 2016 Swordfish Stock Assessment (Anon., 2017) was included for comparison. Overall, both series shown similar long-term trends, declining from about 30 kg since the seventies to around 25 kg in the end of the 90's, oscillating around 25 kg until 2010 and increasing to 30-35 kg until 2018. The latest mean weight estimations show more consistency (less variation) between years.

CAA matrix
The CAS was converted to CAA using two approaches. The first one, decomposes the overall size distribution by year, assuming that they represent the combination of size distributions from multiple ages classes, or a mixture distribution of size at age (Kell and Kell, 2011). This method, used in the 2016 stock assessment, requires a mean and variance priors for each age class, which were estimated from the current von Bertalanffy growth model for Mediterranean swordfish (Tserpes and Tsimenides, 1995). The second one, is the traditional age slicing which estimates the age of each size class using the inverse von Bertalanffy growth equation.

Both CAA estimations (**Tables 4** and **5**, respectively) include the estimated dead discards of the four longline fleets, which assumed the same CAS distribution for the fleets that have reported discards (EU-España, and EU-Greece). **Figure 4** show the relative age proportions of the two slicing approaches used (slicing and the mixture distribution, respectively).

The CAA estimated by the *Mixture approach* was used in age structure models (XSA and a4a) as decided by the Group.

2.4 Indices of abundance

One new index of abundance was presented during the meeting to the Group. Document SCRS/2020/043 reported standardized catch rates for the Spanish longline fishery in the western Mediterranean, for the period 1988-2018. Swordfish catch rates in number of fish and biomass were analysed by means of a General Linear Modelling approach assuming a negative binomial and a log-normal error distribution, respectively. Both series showed notable annual fluctuations without any definite trend for the period under study.

The Group asked about the use of the data coming from only surface longline or both, surface and mesopelagic series in the standardization. The speaker answered that both series were used in this paper. The Group point out that in previous meeting the general agreement was to treat both series (surface and mesopelagic longlines) together.

2.5 Biology

Document SCRS/2020/058 presented an additional list of annotated bibliography related to Italian authors, including the overview of all papers. The full list now includes about 700 papers and the contents can be explored thanks to the annotations. It was discussed the opportunity to move this annotated bibliography to a most advanced database with electronic metadata which is currently already under study. It was also discussed the possibility for having direct links to all documents in pdf, but this will imply a huge workload and important costs, due also to the difficulty of manipulating also historical documents. The discussion pointed out that an annotated bibliography also provides the background for avoiding any useless duplication of efforts and studies, and the Secretariat proposed to recommend all scientists to possibly provide similar annotated bibliographies for each CPC.

Document SCRS/2020/074 discussed stage 2 of the gonadal maturity scale for swordfish, a point raised by a presentation (SCRS/P/2020/005) provided in the previous ICCAT Swordfish Species Group intersessional meeting (Anon, 2020 (*in press*)). The document clarified that all existing gonadal maturity scales, both macroscopic and histological, set stage 2 as developing and never as mature; therefore, the previous studies used consistent classifications.

The discussion pointed out the differences between macroscopic and histological scale, highlighting that also large adult (sexual mature) females could be found at stage 2, not only during the yearly initial gonadal development, but also recovering after a previous spawning activity. It was highlighted that the macroscopic maturity stage 2 can be found in either sexually immature juveniles (i.e.: fish that are maturing for the first time, which technically could become sexually mature because of the gonad development) and potentially sexually mature adults (i.e.: fish that has previously spawned). It was clarified again that this is linked to the right stage 2 classification according to the most accepted scale and this is particularly important for the calculation of the L_{50}. A workshop within the biological sampling project has been planned to take place in later 2020, with the main objectives of establishing ageing and histology reference sets.

The Group discussed also the reproductive aspects of the swordfish in relation to the maturation process and the percentage of mature females at different ages. Differences between Mediterranean areas can exist and that it would be very useful to have representative samplings in all the various parts of the Mediterranean, being the Mediterranean swordfish a single panmictic population, but avoiding starting from scratch, because many data are already available in previous studies. Swordfish might reach L50 at a lower size in some areas and particularly in the Levantine Sea, due to the different oceanographic conditions and the size structure of the local population and it was noted that for the same reasons L50 seems higher in the Ligurian Sea. The need of a standardization of the methods used for the calculation of L50 was also highlighted.

During the intersessional meeting, the Group agreed that the L50 adopted in the last 2016 and previous stock assessments (de la Serna *et al*., 1995), was too high (142.2cm) and possibly not representative of the real situation in the entire Mediterranean basin. The possibility to adopt for the present stock assessment a different progression for females (0 mature at age 1, 15% mature at age 2, 65% mature at age 3 and 100% mature at age 4) was proposed by the Chair. It was not decided to adopt the L50 value from Marisaldi *et al*., 2020, noting that these papers show various problems in the calculations of the L50 and, therefore, should be better checked before considering them.

Considering that this parameter is crucial for the assessment and it is particularly relevant when using the slicing, it was proposed to deepen the matter in a future workshop to be held under the umbrella of the ICCAT Swordfish Project in a near future.

2.6 Other relevant data

No further documents were presented under this Agenda item, nor additional discussion was necessary.

3. Relative abundance indices: overview of indexes to be potentially used based on the output of the swordfish intersessional meeting

During the 2020 Intersessional meeting of the Swordfish Species Group several of the indices of abundance available for the Mediterranean stock was discussed (see section 7.2 *in* Anon., 2020, *in press*). Additional information is provided in section 2.4 of this report. Briefly the Group reviewed three indices of abundances from the Greece longline, EU-Italy Ligurian longline, and the Morocco longline fisheries targeting swordfish. The Group decided to include the Greek and Morocco longline index as presented, and recommended revisions for the EU-Italy Ligurian index, splitting the index for the mesopelagic and the surface "American style" longline gears as they are very different in terms of fishing effort and operations, and unlikely to account for these differences in the standardization model. The Group also agreed to an intersessional workplan requesting that other CPCs provided indices of abundance in advance to the assessment meeting for consideration to be included. The Group also noted that changes in discard rates over time series may have affected the estimates of the overall trends for all indices.

Document SCRS/2020/043 presented the standardized index for the EU-Spain longline swordfish 1988 – 2018, operating mainly in the western Mediterranean region. The index used trip-based information of catches and fishing effort collected by observers and fishery reports. The index included factors of area, quarter and their interactions. Diagnostics, fits and results were presented in both numbers and biomass indices, the Group considered them appropriate and recommended to use the biomass index as the diagnostics indicated better fit overall.

It was inquired if the index considered factors that may have affected catchability and if the data included discards. The authors indicated that no other factors were available for the standardization and some of the catch effort information was from the domestic observer program.

Document SCRS/2020/027 that was presented during the 2020 Intersessional Swordfish Species Group meeting in March (Anon., 2020, *in press*) was updated for this meeting and a presentation was provided with the updated results following the recommendations from the Group. The index for the mesopelagic longline 2010-2019 from the Ligurian Sea was selected as index of abundance for this fishery. The model included the year, month, bait type and soaking time as predictors in the standardization process. Results both in number and biomass indicated a general declining trend in the index since 2010, reaching in 2018 its lowest value.

Authors emphasized that the operations of the mesopelagic longline are not comparable with the surface longline; for example the gear is left for several days at sea (up to three) contrary to the surface longline, where a single day operation is the norm. They use a different hook and type of bait (natural and artificial bait) and operate at different times of the year (mainly late May - early October) compared to the surface longline fleet using the American style longline (October - December). Also, the larger mesopelagic vessels in the Mediterranean may set several longline gears in a trip, while intercalating setting and haul-back among deployed gears.

Afterwards, the Group reviewed the available standardized indices for the Mediterranean swordfish (**Table 6**) and updated the evaluation table (**Table 7**). The Group agreed to include the following four indices for the assessment models: a) the Greek longline index (1987-2018), b) the Italian Ligurian mesopelagic index (2010-2018), c) the Moroccan longline index (2012-2018), and d) the Spanish longline index (1988-2018). Three of these indices were available in both numbers and biomass, the Group recommended using the biomass indices for the Surplus Production models, and when possible the number indices for the age-structured models, although they were not available by age class (**Figures 5 and 6**). Finally, historic indices of abundance used in prior assessments were considered, such as the

Moroccan gillnet index (1999-2011), the Sicilian longline index (1991-2009), the Sicilian gillnet index (1990-2009), and the Ligurian longline surface index (1990-2009). It was noted that historic indices are not relevant for the XSA model, as the model requires information in the most recent period. Overall, the Group only considered using the historic Ligurian longline surface index within the a4a model as a sensitivity case.

It was noted that recent management regulations (minimum size implementations Rec. [13-04], and Rec. [16-05]) may have affected the trend of the indices, as it is likely that discards at sea are not always included in the catch-effort time series. The Group recommended that CPCs intensify their effort to collect information regarding discards of undersize swordfish both within their targeting fisheries as well as from other longline fisheries where juvenile swordfish are reportedly caught, such as the albacore and bluefin tuna longline fisheries. The Group also recommended improving fishery data collection for the different types of longline fleets currently operating in the Mediterranean Sea to account for differences in selectivity and or catchability within the standardization of catch and effort data.

4. Methods and other data relevant to the assessment based on the output of the swordfish intersessional meeting

4.1 Assessments models and Preliminary runs

The Group agreed to apply two age structured models (XSA and a4a) and one Bayesian State-Space Production Model (JABBA). This followed the decisions of the data preparatory meeting in March 2020 (Anon., 2020, *in press*). Considering the time limitations and the nature of the meeting (held online), it was not feasible to apply additional approaches such as ASPIC or particular data-poor models. During the meeting, a tentative analysis of catch only model was conducted based on the JABBA results.

The Group generally discussed the use of the estimated discards in the assessment models (see section 2.3). In the preliminary runs (see section 5), 2 age structured models demonstrated the results with/without the estimated discards, while JABBA provided only the scenario with the discards. The Group felt that the currently available discards information reported by CPCs does not reflect fully dead discarded undersized swordfish for Mediterranean swordfish. However, it was also noted that the current approach could be revisited by CPCs (e.g. fewer discards seem to exist in certain mesopelagic fisheries). On the other hand, discards of undersized swordfish that may exist in various albacore or bluefin tuna fisheries have not been considered in the current discards estimation. Finally, the Group agreed to include the estimated discards within the total catch time series used as input to the current assessment.

4.1.1 XSA (Extended Survivors Analysis)

Document SCRS/2020/077 provided preliminary assessments of the Mediterranean swordfish stock performed by Extended Survivors Analysis (XSA) implemented in FLR (Kell *et al.*, 2007). The method has been previously used for providing advice for the Mediterranean swordfish stock (ICCAT, 2015; 2017). The available catch-at-size (CAS) data covered the period 1985-2018 and the catch-at-age (CAA) data used in the assessments were generated using a statistical approach. The analysis included five model runs:

(a) Continuity run; having the same settings and using CPUE series from the same fleets employed for tuning the 2016 assessment, i.e., constant natural mortality M=0.2, Greek, EU-Spain and Moroccan longline CPUE indices. XSA control settings are available in **Table 8**.

(b) Candidate run 1; assuming constant M, without discards and considering all available recent tuning indices, i.e. standardized scaled CPUEs from the Greek, EU-Spain, Moroccan, and Ligurian longline fisheries. XSA control settings are available in **Table 8**.

(c) Candidate run 2; assuming Lorenzen M, without discards. Apart from the modified M vector, all other data and settings were similar to Candidate run 1.

(d) Candidate run 3; assuming constant M, with discards. Similar to Candidate run 1, but including discards, estimated from SCRS/2020/028.

(e) Candidate run 4; Lorenzen M, with discards. Similar to Candidate run 2, but including discards.

Document SCRS/2020/077 included detailed estimates of recruitment, biomass, SSB, and fishing mortality, as well as various diagnostic plots and retrospective analysis for each run.

It was clarified that XSA treats all provided indexes as numbers for the given ages and it is ideally required to provide age-specific indices if available. Regarding the model settings, it was explained that shrinkage options were preferred as preliminary trials indicated better model performance.

The Group noted minor differences between runs using constant or Lorenzen M and suggested the adoption of constant M for the final runs, i.e. candidate runs 1 and 3. It was also suggested to include the Spanish abundance index in numbers for the final runs, instead of the biomass one used in the document, although no major changes are expected given the generally similar pattern of both indices.

4.1.2. a4a (Assessment for All)

Document SCRS/2020/078 presented the preliminary stock assessment results using a statistical catch-at-age model: developed within the framework of Assessment for All (a4a) Initiative of the European Commission Joint Research Centre (Jardim *et al.*, 2015). The a4a method utilizes catch-at-age data to derive estimates of historical population size and fishing mortality and, unlike XSA, model parameters are estimated by working forward in time while analyses do not require the assumption that removals from the fishery are known without error.

The key model settings for four runs are as follows:

- Catch-at-age data since 1985
- Use 5 CPUEs (Greek, Moroccan, Spanish, Ligurian, and Sicilian longline) considered to be representative of the 2-4 age-group.
- Age 5 plus group
- Maturity: 15%, 65%, 100% at ages 2, 3, and over 4
- Other technical parameter settings are shown in **Table 9**.

Four runs were:

1: constant M, without discards
2: Lorenzen M, without discards
3: constant M, with discards
4: Lorenzen M, with discards

The document presented the fits to indices, estimated recruitment, biomass, SSB, and fishing mortality, and retrospective analysis for each run.

The authors made several technical clarifications to the questions by the Group. It was clarified that the model did not use a stock and recruitment relationship for estimating recruitment, a4a is a forward calculation, and the model does not need to assume the conditions before the model starts, like the Stock Synthesis model. The unit of all indices was biomass and a4a can treat the unit of index correctly in the model.

After the presentations and overall discussions on the model runs, the Group requested further analyses to incorporate Ligurian surface longliners 1991 to 2009, and to be provided reference points. The authors provided the results, which were consistent with the preliminary runs.

4.1.3. JABBA Bayesian state-space Production model

SCRS/2020/082 presented the preliminary stock assessment results applying the Bayesian state-space production model JABBA (Winker *et al.,* 2018) applied to the entire available catch time series (1950-2018), including the estimated discards, by fitting four standardized long-line CPUE (in weight) indices for Greek, Moroccan, Ligurian, and EU-Spain longline fleets.

The authors described the development of two reference candidate models, which use alternative assumptions about the intrinsic growth rate (*r*) and the shape of the production function. For the Reference model we assumed a prior distribution for *r* with a mean of 0.47 and CV of 0.49 (log.sd = 0.46) which was derived from a Leslie matrix model approach using Monte-Carlo simulations, as done during the 2014 Swordfish Stock Assessment meeting (Anon., 2015), and updated with current biological parameters. As an alternative scenario, the authors newly developed an *r* prior distribution with an associated shape parameter of a Pella-Tomlinson production function from an Age-Structured Equilibrium Model (ASEM) approach with Monte-Carlo simulations (Winker, 2020). Regarding the two assumptions of M (constant M and Lorenzen M), the *r* prior distributions generated separately were combined into a single joint *r* prior.

Accordingly, the two candidate models were specified as:

(1) Reference model: with log(r) ~ N(log(0.45),0.46) and a fixed input value of $B_{MSY}/K = 0.5$ (Schaefer)
(2) ASEM model: with log(r) ~ N(log(0.206),0.2) and a fixed input value of $B_{MSY}/K = 0.38$

Common to both models was initial biomass depletion in 1950, which was considered to be close to an unfished state by assuming lognormal prior ($\varphi = B_{1950}/K$) with a mean = 1 and CV of 10%. All catchability parameters were formulated as uninformative uniform priors, while additional observation variances were estimated for indices by assuming inverse-gamma priors to enable model internal variance weighting. Instead, the process error of log(By) in year *y* was estimated "freely" by the model using an uninformative inverse-gamma distribution with both scaling parameters setting at 0.001. Each model was run with three Monte-Carlo Markov Chains (MCMCs), each comprising 30,000 iterations that sampled with a burn-in period of 5,000 for each chain and thinning rate of five iterations. Accordingly, the marginal posteriors were represented by a total of 15,000 iterations for each model.

To evaluate CPUE fits, the model-predicted CPUE indices were compared to the observed CPUE and run tests were performed on the log-residuals for each CPUE index to quantitatively evaluate the randomness of residuals and potentially identify model misspecification. In addition, a Jackknife analysis was also performed on the influence of CPUE indices. To check for systematic bias in the stock status estimates, we also performed a retrospective analysis for each model by removing one year of data at a time sequentially (n = 5), refitting the model and comparing quantities of interest (i.e. biomass, fishing mortality, B/B_{MSY}, F/F_{MSY}, $B/B0$ and MSY) to the reference model that is fitted to the full time series. To compare the bias between the models, it was computed the Mohn's (1999) rho (ρ) statistic.

In addition, the authors explored the robustness to various levels of under reporting prior to 1987 (i.e. the first year of catch data that were included in the 2016 XSA model). Four sensitivity runs were examined by multiplying the early catches from 1950 to 1986 by factors of 1.2, 1.5, 2 and 3, (i.e. underreporting of 20%, 50%, 100% and 200%).

4.2 New information for assessment (historical data)

In 2020, and following the recommendations from prior assessments, the data input and auxiliary information has substantially improved for the current evaluation of the Mediterranean swordfish stock. Section 2 in this report provides specific details on each new or updated element in reference to fishery and biological data inputs. Briefly, the catch series 1950-2018 has been updated and reviewed thoroughly adding historic catches for the 1972-1983 period, reallocating a significant portion of historic catches (1970's, 1980's) that were reported without gear specification into the appropriate fishing gear classification, and including estimates of discards for the longline fishery for the latest years (2008-2018). In addition, the size and CAS information has been thoroughly reviewed and updated for the 1972-1989 period, that made possible to extend the CAA estimation back to 1972. In addition, recent biological research on Mediterranean swordfish has been incorporated and updating the input biological parameters for the models, improving the estimation and robustness of important assessment model parameters such *r*.

Nevertheless, there is still uncertainty in other data and information, particularly in the ageing of the catch. Two approaches were used to estimate CAA, but they exclusively rely on a growth model and show large differences in estimates of the CAA (SCRS/2020/076). The lack of aged samples or age-length-keys greatly constrained the precision of the CAA estimation, plus the limited time series (1985-2018) available for the age-structure models greatly limited the ability of the models to fully capture the historic range of catch and productivity of this stock.

5. Stock status results

5.1 Results

5.1.1 XSA (Extended Survivors Analysis)

The Group noted minor differences among runs using constant or Lorenzen M as presented in document SCRS/2020/077 (see section 4) and suggested the adoption of constant M for the final runs, i.e. similar to candidate runs 1 and 3 in SCRS/2020/077. It was also suggested to include the Spanish abundance index in numbers for the final runs, instead of the biomass one used in the preliminary runs, although no major changes are expected given the generally similar pattern of both indices.

In line to the above considerations, in the two final runs ("Base" and "Discard") presented in SCRS/P/2020/029, constant M=0.2 was assumed and the Spanish longline index was expressed in terms of numbers. Catch at age data covered the period 1985-2017 and four standardized CPUE series extending up to the latest years were used: Greek longliners (SCRS/2020/021), Moroccan longliners (SCRS/2020/026), EU-Spain longliners (SCRS/2020/043) and Ligurian longliners (SCRS/2020/027). The standardized CPUE indices were not differentiated by age and were considered to be representative of the 2-4 age-group abundances (**Figure 7**). Fleet catchability was assumed to be independent of year-class size for all terminal years. Regarding maturity, it was assumed 15% and 65% maturation at ages 2 and 3 respectively. Full maturity was considered from age 4 onward. Weights-at-age were derived from the mixture analysis and were consistent with the CAA. The F range (fbar) was set to ages 2-4. Details regarding the configuration of the XSA control object are shown on **Appendix 5**.

Regarding the base run, estimates of recruitment, SSB, catch and fishing mortality are shown in **Figure 8**, while stock number and F-at-age estimates by year are provided in **Appendix 5.** Results indicate that recruitment follows a decreasing trend, particularly in the last decade while current SSB levels are about 35% of those observed at the beginning of the period. Fishing mortality in the most recent years is slightly lower than previously observed. **Figure 9** shows the XSA estimates by CPUE series, while the retrospective analyses is shown in **Figure 10**. Apart from some discrepancies observed in recruitment, there is not any particular pattern in the retrospective plots. Various diagnostic plots indicating the goodness of fit of the CPUE residuals are shown in **Appendix 5.** Those include (a) plots of the residuals against fitted values to check the variance, (b) plots of the residuals against year to check for systematic patterns that may indicate a poor fit, (c) calibration regression plots to compare the fits to the observations for ages 2, 3 and 4, respectively, (d) plots checking for autocorrelation that may introduce bias, (e) QQ plots aiming to check for log-normality and (f) the relative weighting for each terminal year Ns by CPUE observation (XSA uses inverse variance weighting, in that CPUE series with poor fits are down-weighted in the fit).

Results of the discard run are shown in **Figure 11**, while stock number and F-at-age estimates by year are provided in **Appendix 5.** Results indicate that recruitment follows a decreasing trend in the last decade while current SSB levels are less than half of those observed at the beginning of the period. Fishing mortality fluctuates throughout the examined period, but without any specific overall trend. **Figure 12** shows the XSA estimates by CPUE series, while the retrospective analyses is shown in **Figure 13**. Similarly to the base run, there is not any particular pattern in the retrospective plots apart from some discrepancies observed in recruitment. As in the case of the base run, a series of diagnostic plots are shown in **Appendix 5**.

Comparison of the results of the two runs is shown in **Figure 14**. Overall patterns are quite similar, but recruitment and mortality estimates for the more recent years are higher in the case of the discard run.

5.1.2 Statistical catch-at-age model: a4a Assessment for all

The Group reviewed the results, provided by the document (SCRS/2020/078) for preliminary assessment runs using a4a statistical catch – at – age model. Four runs were presented as preliminary, one assuming constant natural mortality (M = 0.2), one assuming a natural mortality vector calculated using Lorenzen formulation and two runs with the abovementioned mortality vectors including estimated discards obtained from SCRS/2020/028. Each model structure kept the same among all runs and can be found in the SCRS/2020/078, a smoother was added to the catchability of Ligurian surface longline. Diagnostic tests in terms of residuals presented and some problematic patterns in recruitment residuals were apparent in all cases. Retrospective plots showed no pattern in harvest, SSB and Catch although a slight pattern in the terminal years appeared in the recruitment.

Following the recommendation of the Group and in line with the XSA runs, the assessments assuming a constant natural mortality considered adequate to assess the status of the stock. The Group requested for two final a4a runs, taking into consideration an additional standardized CPUE index, the one of the Ligurian surface longliners, expressed in biomass.

The final a4a runs, presented in the document SCRS/P/2020/030 used CAA data from 1985 to 2018 like the preliminary runs. Five standardized CPUE biomass indices were considered, Greek longliners (SCRS/2020/021), Moroccan longliners (SCRS/2020/026), EU-Spain longliners (SCRS/2020/043), Ligurian mesopelagic longliners (SCRS/2020/027), Sicilian longliners (Tserpes *et al.* 2011) and the historic Ligurian surface longliners (Fulvio *et al.,* 2015) as suggested by the Group. All indices were considered representative of ages 2-4. The standardized CPUE indices are shown in **Figure 15**. Each model was configured the same way as in the preliminary runs and can be found in the **Appendix 6**. Age plus group was set to 5 while the F range was set to ages 2-4. The results of the two different runs can be found in **Figures 16** and **17**, respectively.

The results among the runs were very close, besides the estimated recruitment in recent years where the discards run estimation was a bit higher. Moreover, the uncertainty around estimates of the recruitment appeared high in both cases. The trajectory of SSB revealed a slight declining trend and after the mid-2000s fluctuated around 7,500 t. Diagnostic tests were performed for both CAA and standardized CPUE indices residuals and are presented in **Appendix 6.** A negative pattern in the recruitment residuals is present in both runs, where it should be noted that this was probably the result of lack of a tuning index for age 0. Retrospective analysis conducted for both cases, did not show any particular pattern except for the recruitment were some discrepancies were observed. Retrospective analysis for each run is presented in **Figures 18** and **19**. MCMC runs were performed for the two final runs as an alternative to the maximum likelihood estimation (MLE) that is being used as a default estimation procedure in the assessment. Comparisons of the results between the two approaches are presented in the **Figure 20**.

5.1.3 Bayesian Surplus Production model JABBA

The Group reviewed the results (SCRS/2020/082) obtained with JABBA Bayesian surplus production model. This document presents details on the model diagnostics and stock status estimates for two preliminary scenarios. For the 'Reference' model it was used an existing prior distribution for *r* which was derived from a Leslie matrix model approach with Monte-Carlo simulations during the 2014 Mediterranean Swordfish Stock Assessment meeting (Anon., 2015), while for the 'ASEM' model it was derived a new *r* prior from an Age-structured Equilibrium Model (ASEM) with Monte-Carlo simulations. Results for *r* prior distributions and median shape parameter with corresponding B_{MSY}/K values, are included also for comparison, the *r* prior distributions generated from the two *M* assumptions into a single joint *r* prior are shown in **Table 10** and **Figure 21**. For the 'Reference' model the *r* prior was $log(r) \sim N(log(0.45),0.46)$ with a fixed input value of B_{MSY}/K = 0.5 (Schaefer model-type) and for 'ASEM' model the *r* prior with $log(r) \sim N(log(0.206),0.2)$ and a fixed input value of B_{MSY}/K = 0.38 (Pella-Tomlinson model type) (**Figure 21**).

The model fits and run tests conducted on the log-residuals to each of the four standardized CPUE LL indices are shown in **Figures 22** and **23**. Both models appeared to fit CPUE data reasonably well, and run tests indicated no evidence to reject the hypothesis of randomly distributed residual patterns for all four indices. The goodness-of-fit was very similar for the 'Reference' model (RMSE = 28.4%; **Figure 24)** and the 'ASEM' model (RMSE = 28.7%; **Figure 24**). JABBA residual diagnostic plots indicated a conflict between positive residuals for EU-Spain LL CPUE fits and negative residuals for the other three CPUE indices for the last two years 2017-2018 (**Figure 24**). Analysis of process error deviates show a negative trend in most recent years (**Figure 24**), which might be partially explained by the association of the decreasing trend in abundance with decrease in landings in recent years.

Marginal posterior distributions along with prior densities for both models are shown in **Figure 25**. The medians of marginal posteriors for r were 0.414 and 0.188 for the 'Reference' and the 'ASEM' models, respectively (**Table 11)**. The estimated median of marginal posterior for K was 135,017 tonnes for the 'Reference' model and 194,523 tonnes for the 'ASEM' model. Estimates of *MSY* showed similar values between models (13,811 tonnes for the 'Reference' model and 12,931 tonnes for the 'ASEM' model, **Table 11**). The marginal posterior median for B_{MSY} varied between 67,509 tonnes ('Reference' model) and 73,928 tonnes ('ASEM' model), while F_{MSY} median estimates were slightly higher for the 'Reference' model (0.207) than the 'ASEM' model (0.176) (**Table 11**).

In general, both models showed similar trends for the medians of B/B_{MSY} and F/F_{MSY} over time, and the discrepancy of values between the models became less since the 1990s, with an overall decreasing trend of biomass from 1970 to the most recent year (**Figure 26**). The F/F_{MSY} trajectory showed a gradual increasing trend between 1970 and the mid-1980s, a sharp increase in the late-1980s (around 0.5 to 1.0 in a few years), and the relatively stable afterwards (**Figure 26**). The estimated biomass has been less than the MSY level since the mid-1990s for the 'Reference' model (B_{2018}/B_{MSY}=0.650), whereas it has dropped under the MSY level since the mid-2010s for the 'ASEM' model (B_{2018}/B_{MSY}=0.777). Since the late 1980s after the sharp increase, the estimated fishing mortality have been fluctuated at over MSY level for the 'Reference' model (F_{2018}/F_{MSY}=0.990) and at around MSY level for the 'ASEM' model (F_{2018}/F_{MSY}=0.880) (**Table 11**).

A retrospective analysis for five years indicates no evidence of strong patterns with Mohn's rho statistic within the acceptable range of -0.15 and 0.20 (**Figures 27** and **28**; **Table 12**). However, the 'Reference' model indicated slightly stronger retrospective patterns with regards to stock status trajectories B/B_{MSY}, F/F_{MSY} and B/B_0 for the retrospective runs through in 2013 and 2014 (**Figure 27**), which may also explain the notably smaller retrospective bias for these quantities in the 'ASEM' model (**Figure 28**).

The Jackknife sensitivity analysis of CPUE indices showed that Greek and the EU-Spain LL CPUE were highly influential with regards to stock status trajectories and *MSY* (**Figures 29** and **30**). Removing the Greek LL index resulted in much more optimistic stock status trajectories, with biomass level well above B_{MSY}. Removing the EU-Spain LL index, would result in considerably more pessimistic stock trajectories, estimating that the stock was overfished since the mid-1990s. The 'ASEM' model was generally slightly less sensitive to the Jackknife index analysis when compared to the 'Reference' model.

The second sensitivity analysis explored the robustness to various levels of under reporting prior to 1987 by multiplying the early catches from 1950 to 1986 by factors of 1.2, 1.5, 2 and 3, (i.e. assumed underreporting of 20%, 50%, 100% and 200%, **Figure 31**). The motivation of this sensitivity analysis was primarily related to the conflicting stock status results between JABBA, and the age-structure models XSA and a4a. For these sensitivity model runs the increasing of the historical catch time series resulted in a systematic increase in the estimates of K and *MSY* and the decline in stock biomass between 1970 and the late 1980s (**Figure 32 and 33**). Only by raising the historical catch by a factor of three (200%) would result in a decrease of the stock biomass to levels about 50% of B/B_{MSY} by 1990, which would be roughly similar to the results from the 2016 XSA assessment model results. If this historic catch (1950-1986) were correct, it would imply that the Mediterranean swordfish stock surpass the historic catches of both North Atlantic and South Atlantic swordfish stocks, something that the Group considered were unlikely for that time period.

However, it is important to point out that the minimum size regulations by some CPCs, technological creeping associated to changes in the fishing practices targeting Mediterranean swordfish, as reflected by the changes on market and consumption of this species could potentially causes under reporting and uncertainty in the early period of catch time series. Hence, all these factors combined should be considered for better understanding the catch evolution for this stock.

JABBA surplus production phase plots for the 'Reference' and 'ASEM' models are shown in **Figure 34**. In general, it revealed similar patterns for both models. The peak in catches in 1982 concurred with the onset of an extended period of overfishing associated with continues declines in stock biomass and eventually led to an overfished stock. Accordingly, Kobe biplots show the typically anti-clockwise pattern with the stock status moving from underexploited through a period of unsustainable fishing to the overexploited phase (**Figure 34**). The resulting stock status posteriors for 2018 from each model would however have somewhat different implications for management actions. The 'ASEM' model is more optimistic with regards the current fishing levels, F_{2018}/F_{MSY}, with a cumulative probability of over 60% (yellow + green) that current fishing mortality is sufficiently low enough to facilitate stock rebuilding. The 'Reference', by contrast, suggests that there is a more than 50% probably that stock remains overfish and that overfishing is still occurring (**Figure 34**).

5.2 Final results and Synthesis of Stock Status

The Group reviewed two XSA runs (constant M with/without discards, SCRS/P/2020/029), two a4a runs (constant M with/without discards, SCRS/P/2020/030), and two JABBA runs (Reference and ASEM models, SCRS/P/2020/028).

An important difference between the two age-structured models, XSA and a4a, and the surplus production model JABBA was that the whole catch series from 1950 to 2018 was used as input into JABBA, whereas both XSA and a4a could only be initiated in 1985, thus omitting the catch information for the period 1950-1984. With regards to the JABBA model, the Group discussed the assumption that relative stock biomass was close to unfished level in 1950 (~ 99% of the carrying capacity). The Group agreed that factors such as the limited and localized number of fisheries at that time, their artisanal character (boats did not even have an engine), and the slowdown in fishing activity due to the Second World War, would suggest this assumption is reasonable and in agreement with the expert knowledge of scientists well familiar with the Mediterranean swordfish fisheries. The Group noted that this early period is now considerably more reliable due to a number of Task I revisions that lead improvement of the historic catch data (see details below).

The Group specifically discussed the differences in the stock status between XSA (including discards) and JABBA models in 1985 (i.e. the first year considered in XSA). The XSA final run including discards estimated that *SSB* in 1985 was at 54.1% of SSB_{MSY} and 9.67% of unfished SSB_0, whereas the joint results from the two JABBA models ('Reference' and 'ASEM') estimated that the stock levels where still sustainable by 1985, with B/B_{MSY} = 1.59 and *B/B0* = 0.70 (**Figure 35**). The Group then examined the catch time series relative to the estimates of MSY from XSA (MSY = 16,300 t) and JABBA (joint-MSY = 13,325 t), which showed that catches remained always below MSY for the period 1950-1985 in the case of both models (**Figure 35**). However, overfishing of a previously underexploited stock can theoretically only occur once the catches start exceeding levels at MSY (see green shaded area in **Figure 35**), and even then, fishing mortality may initially remain below F_{MSY} until biomass is fished down and approaches B_{MSY} (c.f **Figure 34** in section 5.1.3 of this report). Furthermore, XSA predicted that despite very low stock levels in 1985, MSY could still be exceeded over the next four years 1986-1989, and support catches over the next two decades (1990's and 2000's) above 80% of MSY despite a decreasing stock biomass (**Figure 35**).

The Group therefore agreed that it is biologically implausible that the Mediterranean swordfish stock could have been overfished to low biomass levels of less than 60% SSB_{MSY} and less than 10% of SSB_0 as estimated by the XSA model, considering that total catches never had exceeded 14,000 t prior to 1985. The presented a4a model results were broadly comparable with XSA results, and hence produced the same conflicts between the catch history and the initial low stock biomass in 1985. Considering all evidence, the Group decided to provide the scientific advice for the Mediterranean swordfish stock based on both JABBA models ('Reference' and 'ASEM').

However, the Group noted that the JABBA assessment runs showed a systematically negative pattern in the process error variation of biomass over the period 2005-2016 (**Figure 36**), which was also observed in the form of a strong negative trend in recruitment residuals in both XSA and a4a. Possible causes may be linked to environmental factors, but may also be relate to other factors such as unaccounted fishing mortality of undersized fish, changes in selectivity, or a combination thereof. Irrespective of the underlying cause, all models indicate that stock's productivity has been below average in the last decade. The Group discussed that this is of particular relevance when projecting the future stock status based on an average stock productivity from 2019 onwards, which is how projections are currently implemented in all three modelling platforms (JABBA, XSA, and a4a). The Group noted that approaches exist to account for such serial correlation in process error deviations and that this is inherently associated with increased uncertainty about the future (Chang *et al., in press*; background paper). The Group recommended that this and comparable approaches for age-structured models should be further explored in future and agreed that the current projections for Mediterranean swordfish are associated with a risk to be overly optimistic and should therefore be interpreted with caution.

The Group also discussed the resulting differences in the benchmark estimates (Reference Points) of the current stock assessment in 2020 with respect to the previous one in 2016 (Anon., 2017). It was noted that since the 2016 assessment there have been several changes both in the fisheries operations and in the data available as in input to the assessment models, which have undergone substantial revisions and the integration of new data for the 2020 evaluation. Briefly, some of the new data related to these changes would be:

1. A general improvement in the information available for the Mediterranean swordfish stock, including:

   (a) A comprehensive review of Task I nominal catches, with the inclusion of the EU-Italy GILL catches between 1972 and 1983 (Figure 1 in Anon., 2020, *in press,* in March SWO report);

   (b) A significant increase in information related to the size distributions of the fish, that provided a new full and revised CAS estimation.

2. Change in the models used for the assessment of the stock:

   (a) Until 2016, the assessment advice was based on an age-structured approach for providing the management advice. However due to lack of Indices of abundance for the earlier period (prior to 1987), the start time for this model input was 1985, when the stock was already under high exploitation with the highest historic catch occurring in 1987. Therefore, the model could only be informed by a declining trend and giving the significant uncertainty in the aging of the catch, the model was unable to properly estimate stock productivity (e.g. lack of contrast in the catch data).

   (b) In 2020, instead this evaluation included a Bayesian Surplus production model that started in 1950 and was able to use all the historic catch information available, in addition the model used updated biological information to construct better parameter priors more consistent with the expected population dynamics of the Mediterranean swordfish.

Both JABBA models considered different production functions (Schaefer and Pella-Tomlinson model type) and incorporated previously considered as well as the most recent biological information into the *r* prior distributions. The Group agreed that combining the results of both production models is desirable to better account for model structural uncertainties. Error uncertainty in model fit results is characterized by running Monte-Carlo Markov Chain (MCMC) posteriors of biomass and fishing mortality developed from 30,000 MCMC iterations in total (three MCMC chains of 5,000 iterations in each model).

The trajectory of B/B_{MSY} in the joint marginal posterior distributions showed a relatively stable pattern between 1950 and 1970 followed by a sharp decrease until the mid-1990s to an overfished status (**Figure 37** and **Table 13**). Since the early 2000s the relative biomass had remained stable at levels below B_{MSY} until 2010 where it started to decrease again. The biomass in 2018 was estimated to be 0.72 relative to B_{MSY} with 95% credibility intervals (CI): 0.38-1.28 (**Table 14**). The F/F_{MSY} trajectory showed an increasing trend since the beginning of time series as the fishery has been developed, crossing F_{MSY} in the middle of 1980s. Since the late 1980s after the sharp increase, the estimated fishing mortality has fluctuated at around *MSY* level (F_{2018}/F_{MSY}=0.929) (**Figure 37** and **Table 13**).

The medians and 95% CI of the joint marginal posterior distributions for the reference points are shown in **Table 14**. The estimated median of marginal posterior for B_0 was 169,231 tonnes (85,506- 274,312 t), while estimates of *MSY* was 13,325 tonnes (10,899-17,346 t). The joint marginal posterior median for B_{MSY} varied between 71,319 tonnes and the F_{MSY} median estimates was 0.186 (**Table 13**).

Finally, a Kobe phase plot is presented to provide multi-model inference based on combined of both JABBA models (**Figure 38**), which predicts with 86.7% probability that stock biomass remains below levels that can produce MSY in 2018, with a 41.1% probability that the stock is overfished and overfishing is still occurring (red) and a 45.6% probability that the stock is overfished but overfishing is not occurring (yellow). In summary, the current Mediterranean swordfish biomass (B_{2018}) remained below B_{MSY}, while the current fishing mortality rate is being close to and/or below the sustainable level (F_{MSY}) that would allow rebuilding to biomass levels that support MSY in the short- to medium term.

6. Projections

For future projections, the Group agreed to use a combination of projection results from both JABBA models ('Reference' and 'ASEM') to produce the advice recommendations, including the Kobe-2-Strategy Matrices. Uncertainty is characterized in the form of Monte-Carlo Markov Chain (MCMC) posteriors of B/B_{MSY} and F/F_{MSY}, which are stochastically forward projected over the range of alternative fixed catch scenarios within the JABBA model using JAGS. Each model was run 15,000 iterations using three MCMC chains of 5,000 each. Thus, the joint marginal posterior distributions of the projections were constructed with 30,000 MCMC iterations in total. In accordance with the Group's recommendations, the projections were conducted for a range constant catch scenarios, including a reference scenario of zero catch and then covering a range from 9,000 t to 15,000 t at specific intervals and for a period of 10 years (2019-2028). Projections were not carried out beyond 2028 due to uncertainty in recent recruitment. The catches for 2019 and 2020 were set to be 9,879 t and 9,583 t, which corresponds to the TAC set for 2019 and 2020, respectively [Rec. 16-05, paragraph 4].

The projections of biomass (**Figure 39**) show that with catches as high as 10,000 t the stock can recover to B_{MSY} by the end of the projection period (2028) with 60% probability [Rec. 16-05, paragraph 1]. Note that there is a one-year lag effect between the catch removal with an instant effect on fishing mortality and the biomass response in the following year. Therefore, implementing the TAC in 2020 is instantly affecting F/F_{MSY} in 2020, but this affects the estimate for B/B_{MSY} in the following year. Given that the 2018 biomass is estimated by the joint model to be below sustainable biomass levels (B_{2018}/B_{MSY} = 0.72, see **Table 14** in Section 5.2 of this report) that could produce an estimated *MSY* of 13,325 tons (10,899-17,346), it would require the total catch to be below 8,000 tons or below 10,000 tons to rebuild the stock to B_{MSY} by 2025 or 2028, respectively, with a probability of at least 60% (**Tables 15 and 17**).

Current rate of exploitation was estimated to be at F_{2018}/F_{MSY} = 0.93 for 2018, which indicates that current fishing mortality by targeting fisheries is below the reference value of F_{MSY}. Accordingly, projections of fishing mortality (**Figure 39**) show that catches up to 9.000 or 10,000 t would result in probabilities higher than 60% for not expecting overfishing by 2021 or 2022, respectively (**Table 16**).

However, it is important to note that the JABBA assessment runs showed a systematically negative pattern in the process error variation of biomass (2005-2016), which increases uncertainty in current stock status and immediate stock projections. If stock productivity were to remain below average, this would lead to over-optimistic predictions for the near future. Hence, the Group recommends that these projections should be interpreted with precaution.

7. Recommendations

7.1 Recommendations with financial implications

Data recovery plan

The Group has noted important improvements in historical T1 and T2 data when comparing to the information available in the 2016 assessment (Anon., 2017). However, the available CPUE data for the earlier period are still limited. Therefore, the early period of the fisheries cannot be fully accounted in the stock assessment models. As such, the Group recommended conducting a recovery of historical data, so that the entire history of the fishery is taken into account when assessing the stock. Particular effort should be dedicated to collecting available information from the major fisheries of the early years, with focus in fisheries with limited data. [Estimated cost: €10,000; Priority: medium given that will be used for next assessment (priority level to be revised)].

7.2 Recommendations without financial implications

7.2.1 Recommendations on research and statistics

Fisheries

- The Group noted that very few studies on longline selectivity were carried out in the past in the Mediterranean; moreover, they were generally limited in time and space and mainly focusing on the evaluation of the by-catch components of the swordfish fishery. Considering the differences showing up in terms of catch composition, CPUE, and size distribution of the swordfish catches, among the various longline types, it is recommended the development of selectivity studies by CPCs, in order to identify practices (gear design, hook size and bait type) and fishing strategies that can reduce undersized swordfish discards.

- Though the monthly probability to catch undersized swordfish, or the monthly discard rate has been examined in certain Mediterranean swordfish fisheries, there is no recent estimation of the monthly proportion of recruits and spawners in the Mediterranean swordfish catches. The Group recommended that monthly estimation of spawner and recruit proportion in the catches on a fine spatial scale, could facilitate management decisions for spatio-temporal restrictions.

- The Group agreed that data from the domestic observer programs are essential for assessment and management purposes, as they can provide fine resolution information on undersized catches and discard rates by fishery. Regarding the reporting ST09 form for domestic observer program data the Group recommends: (a) to include the mesopelagic and American style longline in the gear selection list, (b) to clarify better the selection of depth range for the fishing operations, (c) to have all form to be completed without exclusion [remove the "optional" from sub-form C in ST09] and this data should be used exclusively for scientific purposes in line with Rec. [16-14].

- The Group recommends that all ICCAT CPCs revise and replace the provisional dead discards estimations here adopted, using the best available information (port sampling, domestic observer data, etc.) at the National level. For that purpose, each CPC should allow their national scientists to have access to all the pertinent information.

- The Group reiterated the recommendation made by the SCRS in 2019 to obtain size and biological data to better characterize the discards of Mediterranean swordfish:

  To the SCRS and the ICCAT Commission on allowing sampling on undersized swordfish: Currently there are Minimum Sizes established for Atlantic swordfish (Recs 17-02 and 17-03) and Mediterranean swordfish [Rec. 16-05]. Those "minimum sizes" refer to either "taking and landing" or "catching and retaining on board", depending on each specific Recommendation or paragraph. In order to allow the collection of biological samples during commercial fishing operations on undersized swordfish (e.g., vertebrae, tissue, reproductive tracts, stomachs) the SCRS recommends that the Commission considers establishing a new ICCAT recommendation allowing such procedures. The sampling on undersized swordfish would only be carried out if:

1. Specimens are dead at the haulback;
2. Samples are collected by a fishery observer and
3. The biological samples are taken in the framework of a research project notified, endorsed and carried out within the priorities of the Swordfish Species Group and the SCRS.

Abundance indicators

- Given the clear differences between the longline gears targeting Mediterranean swordfish (e.g. traditional surface longline, American style longline and mesopelagic longline) the Group recommended that the CPCs provide catch-effort data by gear category, as well as information on the proportion of their fleet operating in each of these categories. This information is necessary for estimating standardized indices of abundance from fisheries statistics.

- The Group recommends to consider in the standardization procedures important oceanographic changes that have occurred recently in the Mediterranean Sea (e.g. eastern Mediterranean transient) and may have impacted the availability of the stock to some fisheries, and/or the recruitment success of the population.

- The Group noted important oceanographic changes may be affecting recruitment success in the population and availability of the stock to some fisheries and recommends that the Sub-committee on Ecosystems identify indicators of the oceanographic pressures and status of the abundance of swordfish larvae.

- The Group recommends the inclusion of discards in the standardization of catch and effort data as they represent part of the catch.

- Although CPUE by age is the usual input for the age-structured analyses, the Group recognized that this must be based on an increased level of sampling, not merely substitution of the current data. Therefore, it is recommended that increased ageing sampling takes place, so that age-length keys or catch at age and CPUE by age can be developed. To achieve this goal, the Group noted that it is important to collect size and hard parts together with the catch and effort data to provide meaningful CPUEs.

Assessment

- The Group agreed on the increasing importance of the Mediterranean swordfish discards in reference to the total catch, and that part of these discards are due to minimum catch size of 100 cm LJFL [Rec. 16-05, paragraphs 15 and 16]. The Group recommends that for better inclusion of those discards in the assessment models, a more comprehensive reporting of swordfish discards at sea is necessary in both directed and other large pelagic fisheries in the Mediterranean. Similarly, it is recommended to explore integrated assessment models with more fleet, selectivity and environmental options to better model and evaluate the impact of discards, environment and or selectivity modifications/regulations in the dynamics of the stock and its recovery status.

- The Group recommended that the next stock assessment for Mediterranean swordfish should be carried out not before 2024 in order to give more time for additional data to be collected that will allow evaluation of the management measures adopted through Rec. 16-05 and the progress on stock rebuilding. A data preparatory meeting should be conducted in advance to analyze and prepare data for the stock assessment. Nonetheless, the Group should review in 2022 the available fisheries indicators (catch, indices of abundance, etc.) to monitor the trend of the stock status. If, there is a change in stock status indicators during the interim period, as for example a dramatic drop in nominal catches or in average sizes, then the stock assessment should be carried out before 2024.

7.3 Recommendations on management

- Over the last 50 years stock biomass shows declining trends, starting with the period around 1970-1990, when the fishery was in a strong developing phase. In the following period until about 2010, declining trends were rather modest accompanied by small-scale fluctuations. In the most recent period, the stock biomass has continued to decline. As expected, fishing mortality followed an opposite trend with sharper increases during the 1980s. Current stock biomass is about 30% lower than that corresponding to MSY, while fishing mortality is around F_{MSY}. According to the Commission objectives the stock requires rebuilding and relevant scenarios were simulated assuming different levels of quota. Analysis indicated that the probability of stock rebuilding within the next five years (2025) is slightly over 60% if quota equal to 8,000 t are adopted. The probability increases if lower quota levels are selected. As there are uncertainties on stock productivity these estimates may be over-optimistic and should be interpreted with caution.

- The Group noted that since the establishment of minimum catching sizes, particularly after the recent increase imposed through Rec. 16-05 the discard levels of undersized swordfish are increasing at least for certain fisheries and are largely dead. However, discards are not being reported for all fleets. Though an attempt has been made to statistically estimate discard levels and consider them in stock assessment models, the real volume of total discards is unknown due to this under-reporting. Such under-reporting leads to false estimates of the overall catch volume and consequently bias stock status estimates and projections of future stock size under different management measures.

8. Other matters

8.1 Executive Summary

The Group also revised and updated the Mediterranean Swordfish Executive Summary. However, the final version including figures, tables and minor text additions related to the State of the Stock will be updated during the Species Group meeting in September.

9. Adoption of the report and closure

The report was adopted during the meeting. The Chair and the Secretariat thanked all the participants for their efforts to work effectively and efficiently throughout the meeting. The meeting was adjourned.

References

Anon. 2015. Report of the 2014 ICCAT Mediterranean Swordfish Stock Assessment meeting (Heraklion, Greece, 21-25 July 2014). Collect. Vol. Sci. Pap. ICCAT, 71 (5): 1870-1979

Anon. 2017. Report of the Mediterranean Swordfish Stock Assessment session (Casablanca, Morocco, 11-16 July 2016). Collect. Vol. Sci. Pap. ICCAT, 73 (3): 1005-1096

Anon. 2020. *In press.* Report of the Swordfish Species Group intersessional meeting (Online, 16-19 March 2020): 41 p.

Chang, Y.J., Winker, H., Sculley, M., Hsu, J., 2019. Evaluation of the status and risk of overexploitation of the Pacific billfish stocks considering non-stationary population processes. Deep. Res. Part II Top. Stud. Oceanogr. in press. https://doi.org/10.1016/j.dsr2.2019.104707

Jardim, E., Millar, C.P., Mosqueira, I., Scott, F., Osio, G.C., Ferretti, M., Alzorriz, N., Orio, A., 2015. What if stock assessment is as simple as a linear model? The a4a initiative. ICES J. Mar. Sci. 72, 232–236.

Kell, L.T., Mosqueira, I., Grosjean, P., Fromentin, J., Garcia, D., Hillary, R., Jardim, E., Mardle, S., Pastoors, M.A., Poos, J.J., Scott, F., Scott, R.D., 2007. FLR : an open-source framework for the evaluation and development of management strategies. ICES J. Mar. Sci. 64, 640–646.

Marisaldi, L., Basili, D., Candelma, M., Sesani, V., Pignalosa, P., Gioacchini, G., and Carnevali, O., 2020. The challenge to assign maturity stages: development of a histology-validated macroscopic criteria based on the GI. Collect. Vol. Sci. Pap. ICCAT, 76(3): 304-314.

Mohn, R., 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES J. Mar. Sci. 56, 473–488. https://doi.org/10.1006/jmsc.1999.0481

Winker, H., Carvalho, F., Kapur, M., 2018. JABBA: Just Another Bayesian Biomass Assessment. Fish. Res. 204, 275–288. https://doi.org/http://doi.org/10.1016/j.fishres.2018.03.01

Winker, H., Mourato, B., Chang, Y. 2020. Unifying parameterizations between age-structured and surplus production models: an application to Atlantic white marlin (*kajikia albida*) with simulation testing. Collect. Vol. Sci. Pap. ICCAT, 76(4): 219-234.

Table 1. Task 1 nominal catches (T1NC, t) of SWO-M by year, catch type and gear group, between 1950 and 2018. The LL dead discards series between 2008 and 2018, with the exception of EU-Spain (6.7 t in 2015 and 83.5 t in 2018), are preliminary estimates (SCRS/2020/028) adopted by the Group. The total catches used in the 2016 stock assessment (SA2016) is also shown (with the relative difference, %) for comparison.

	Catch type / gear group										TOTAL catches (SA2016)	Relative difference (%)
	Landings								Dead discards	TOTAL		
Year	LL	GN	HP	HL	PS	TW	others	UN	LL			
1950	586									586	586	0
1951	580									580	580	0
1952	337									337	337	0
1953	501									501	0	100
1954	452									452	452	0
1955	340									340	340	0
1956	393									393	393	0
1957	395	250								645	250	158
1958	414	500								914	914	0
1959	401	200								601	200	200
1960	403	112								515	112	360
1961	500	112								612	206	197
1962	591	112								703	300	134
1963	498	224								722	318	127
1964	686	112								798	394	103
1965	1423	112					1	224		1760	1760	0
1966	1192	336						224		1752	1752	0
1967	869	111					1	336		1317	1317	0
1968	2570	115	194				1	560		3440	3440	0
1969	3313	133	277							3723	3723	0
1970	2993	99	249							3341	3341	0
1971	4496	76	402				1			4975	4975	0
1972	5399	5247	513				1			11160	5973	87
1973	4362	3985	388							8735	4809	82
1974	4564	4684	462				3			9713	5043	93
1975	3888	4219	416							8522	4314	98
1976	4318	4914	312							9544	4637	106
1977	4838	4791	417							10046	5285	90
1978	5186	5377	756			8				11327	5966	90
1979	5200	4980	475							10655	5547	92
1980	6230	5216	501							11947	6579	82
1981	6450	4873	461							11784	6814	73
1982	6112	3730	356							10198	6343	61
1983	6313	4016	366				1			10696	6896	55
1984	6709	6658	294				5			13666	13666	0
1985	7169	7816	298	1		1	5	3		15294	15292	0
1986	8166	8130	469							16765	16765	0
1987	8776	9219	325							18320	18320	0
1988	10250	9645	468				2			20365	20365	0
1989	7875	9542	345							17762	17762	0
1990	7346	8280	379				12			16018	16018	0
1991	7365	7971	397				12			15746	15746	0
1992	7631	7076					2			14709	14709	0
1993	7377	5819					4	65		13265	13265	0
1994	8985	6978					18	101		16082	16082	0
1995	6319	6648	11		0		11	26		13015	13015	0
1996	5884	5998	10				4	157		12053	12053	0
1997	5389	9195	12				5	92		14693	14693	0
1998	6674	7577	12			57	4	45		14369	14369	0
1999	6223	7372				52	3	49		13699	13699	0
2000	7129	8335	11			51	3	39		15569	15569	0
2001	7498	7420			4		6	78		15006	15006	0
2002	8042	4695					2	75		12814	12814	0
2003	10748	4870	7		2	0	8	58		15694	15674	0
2004	10877	3332	5	112	45		4	20	9	14405	14405	0
2005	10954	3265	6	175	56		7	46	113	14622	14600	0
2006	11323	3400		72	47		1	56	16	14915	14893	0
2007	11113	3023		1	22		1	48	19	14227	14227	0
2008	11479	587	27	0	12		2	30	1546	13683	12164	12
2009	11020	477		0	2	4	3	333	1396	13235	11840	12
2010	11918	411		1	3	3	2	926	1488	14754	13265	11
2011	10288	388		1	3	24	3	744	1191	12640	11450	10
2012	9131	0		2	34	15	3	727	1133	11046	9913	11
2013	9047	2		4	13	24	2	5	973	10070	9096	11
2014	9718	3	2	3	7	10	5	53	1168	10969	9794	12
2015	10675	1	32	5	19	20	1	0	1230	11983	9966	20
2016	10878	0	7	4	17	17	6	1	1369	12300		100
2017	8345		35	4	11	4	3	0	1988	10390		100
2018	6934	0	29	2	17	12	1	0	1682	8677		100

Table 2. Standard SCRS catalogue of SWO-M on Task 1/2 data availability by major fishery (flag/gear combinations ranked by order of importance) and year (top panel: 1960-1989; bottom panel: -1989-2018). Only the most important fisheries (representing ±97.5% of Task 1 total catches) are shown. For each data series, Task 1 (DSet= "t1", in t) is visualised against its equivalent Task 2 availability (DSet= "t2") scheme. The Task 2 colour scheme has a concatenation of characters ("a"= T2CE exists; "b"= T2SZ exists; "c"= T2CS exists) that represents the Task 2 data availability in the ICCAT-DB system.

Species	Stock	Status	FlagName	GearGrp	DSet	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Rank	%	%cum
					T1 Total	515	612	703	722	798	1760	1752	1317	3440	3723	3341	4975	11160	8735	9713	8522	9544	10046	11327	10655	11947	11784	10198	10696	13666	15294	16765	18320	20365	17762			
SWO	MED	CP	EU.Italy	GN	t1													5187	3926	4669	4209	4907	4757	5357	4936	5203	4803	3690	3800	6344	7395	7661	8400	8779	8865	1	41.1%	41%
SWO	MED	CP	EU.Italy	GN	t2													ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	1		
SWO	MED	CP	EU.Italy	LL	t1									1374	1963	1767	2846	3631	2748	3268	2946	3435	3330	3750	3455	3642	3362	2583	2660	2719	3169	3283	3600	3763	3799	2	26.8%	68%
SWO	MED	CP	EU.Italy	LL	t2									-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ab	ab	ab	ab	ab	ab	2		
SWO	MED	CP	EU.España	LL	t1	403	406	403	404	404	1200	1000	700	1000	1100	900	1100	1300	1105	700	89	89	667	720	800	750	1120	900	1321	1243	1219	1337	1134	1760	1250	3	10.6%	79%
SWO	MED	CP	EU.España	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	a	ab	a	ab	ab	ab	-1	-1	-1	abc	ac	ac	a	ac	ac	3		
SWO	MED	CP	Algerie	LL	t1														100	196	500	368	370	320	521	650	760	870	877	884	890	847	1820	2621	590	4	5.3%	84%
SWO	MED	CP	Algerie	LL	t2														-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	4		
SWO	MED	CP	EU.Greece	LL	t1																						91	773	772	1081	1036	1714	1303	1008	1120	5	3.6%	87%
SWO	MED	CP	EU.Greece	LL	t2																						-1	-1	-1	-1	-1	b	ab	ab	-1	5		
SWO	MED	CP	EU.Italy	HP	t1									194	277	249	402	513	388	462	416	312	417	756	475	501	461	356	366	294	298	469	325	468	345	6	3.5%	91%
SWO	MED	CP	EU.Italy	HP	t2									-1	-1	-1	-1	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	6		
SWO	MED	NCO	NEI (MED)	LL	t1																					728	672	517	532	552	499	524	566	598	598	7	2.3%	93%
SWO	MED	NCO	NEI (MED)	LL	t2																					-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	7		
SWO	MED	CP	Maroc	LL	t1		94	188	94	282	223	192	169	196	250	214	326	229	183	193	118	186	144	172	167	161	167	165	43	39	38	92	40	62	97	8	1.8%	95%
SWO	MED	CP	Maroc	LL	t2		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	8		
SWO	MED	CP	Turkey	GN	t1	112	112	112	224	112	112	336	111	115	133	99	76	60	59	15	10	7	34	20	44	13	70	40	216	95	190	226	557	589	209	9	1.6%	97%
SWO	MED	CP	Turkey	GN	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	9		

as of 2020-05-26

Species	Stock	Status	FlagName	GearGrp	DSet	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Rank	%	%cum
					T1 Total	17762	16018	15746	14709	13265	16082	13015	12053	14693	14369	13699	15569	15006	12814	15694	14405	14622	14915	14227	13683	13235	14754	12640	11046	10070	10969	11983	12300	10390	8677			
SWO	MED	CP	EU.Italy	LL	t1	3799	2617	2442	3518	3260	3844	3035	2617	2458	2458	2680	2639	2236	1841	5844	5452	5560	5253	4564	5246	5438	5919	5313	4474	3304	3921	4883	4540	3882	2289	1	28.2%	28%
SWO	MED	CP	EU.Italy	LL	t2	ab	b	ab	ab	b	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	b	ab	ab	b	bc	abc	abc	abc	abc	abc	abc	abc	abc	abc	bc	1		
SWO	MED	CP	EU.Italy	GN	t1	8865	6105	5698	4077	3070	3921	4264	2657	3632	3632	3632	4863	4152	1698	2540	1483	1891	2373	1948								0				2	17.3%	45%
SWO	MED	CP	EU.Italy	GN	t2	ab	ab	ab	ab	ab	ab	b	b	b	b	b	ab	b	-1	b	b	b	b	-1								-1				2		
SWO	MED	CP	EU.España	LL	t1	1250	1438	1132	790	1293	1402	1351	1040	1184	1409	867	1396	1402	1421	1165	930	860	1405	1648	2063	1994	1785	1730	1580	1605	2019	2289	1732	1487	1470	3	10.6%	56%
SWO	MED	CP	EU.España	LL	t2	ac	ac	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	3		
SWO	MED	CP	EU.Greece	LL	t1	1120	1344	1904	1456	1568	2520	974	1237	750	1650	1520	1960	1730	1680	1230	1129	1424	1374	1907	989	1132	1494	1306	877	1731	1344	761	761	392	350	4	9.7%	66%
SWO	MED	CP	EU.Greece	LL	t2	-1	ab	ab	ab	ab	ab	ab	-1	-1	ab	ab	ab	ab	b	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	ab	b	ab	ab	4		
SWO	MED	CP	Maroc	GN	t1		866	1186	1883	2068	2109	1518	2461	4653	2905	2979	2503	2266	2230	1629	1299	722	603	615	587	477	410	387								5	8.9%	75%
SWO	MED	CP	Maroc	GN	t2		-1	-1	-1	-1	b	-1	-1	-1	c	bc	abc	abc	b	b	b	b	b	b	abc	-1	abc	abc								5		
SWO	MED	CP	Maroc	LL	t1	97	371	508	807	517	527	169	273	245	323	259	205	754	1149	1670	1954	1801	1455	1107	1713	1388	1501	800	1003	963	968	604	1395	1350	1368	6	6.7%	81%
SWO	MED	CP	Maroc	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	bc	abc	abc	abc	abc	abc	abc	6		
SWO	MED	CP	Tunisie	LL	t1	159	176	181	178	354	298	378	352	346	414	468	483	567	1138	285	791	791	949	1024	1232	1233	1238	1267	1265	1262	1302	1307	1273	1377	1338	7	5.7%	87%
SWO	MED	CP	Tunisie	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	a	a	a	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	7		
SWO	MED	CP	Algerie	LL	t1	590	173	173	6	173	185	247	247	247	178	126	166	439	347	238	174	93	496	492	977	570	560	234	433	467	693	705	842	755	725	8	2.9%	90%
SWO	MED	CP	Algerie	LL	t2	-1	b	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	a	a	-1	-1	ab	ab	ab	ab	ab	-1	-1	-1	8		
SWO	MED	CP	Algerie	GN	t1		539	389	389	389	415	560	560	560	590	531	599	642	467	427	233	311	87	108												9	1.9%	92%
SWO	MED	CP	Algerie	GN	t2		-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1												9		
SWO	MED	CP	EU.Malta	LL	t1	122	135	129	85	91	47	72	72	100	153	187	175	102	257	163	195	362	239	213	260	266	423	532	503	460	376	489	410	330	308	10	1.8%	94%
SWO	MED	CP	EU.Malta	LL	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ac	ac	ac	-1	-1	-1	abc	bc	ab	abc	ab	ab	ab	abc	ab	abc	abc	abc	abc	abc	10		
SWO	MED	CP	Turkey	GN	t1	209	243	100	136	292	533	306	320	350	450	230	370	360	300	274	317	341	337	352												11	1.4%	95%
SWO	MED	CP	Turkey	GN	t2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	ab	ab	ab	ac	c							11		
SWO	MED	CP	Turkey	LL	t1														70	76	69	84	73	71	441	344	382	217	76	111	71	45	90	556	544	12	0.8%	96%
SWO	MED	CP	Turkey	LL	t2														-1	-1	-1	-1	-1	-1	a	a	a	ab	a	ab	abc	abc	bc	ab	abc	12		

Table 3. SWO-M overall catch-at-size (CAS) matrix by year and LJFL 5 cm classes (lower limit) including estimates of dead discards longline fleets 2008-2018.

Sum of Catch / Li (5 cm LJFL)	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
30	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0		0	0	31	56	3	0	0	40	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0		0	0	79	56	20	49	60	40	0	31	0	0
45	0	0	0	0	0	0	0	0	0	0		0	0	79	109	3	24	30	40	0	63	0	0
50	0	0	0	0	0	0	0	0	0	0		0	0	155	332	13	48	83	57	60	844	332	17
55	0	0	0	0	0	0	0	0	0	0		0	0	186	334	122	296	438	948	1,163	1,230	1,243	1,207
60	0	0	0	0	0	0	859	0	1,125	1,164	1,103	509	8	851	1,256	368	824	1,034	3,804	4,990	3,169	2,059	3,150
65	0	0	0	0	0	0	0	0	375	388	368	170	206	1,819	1,282	1,034	1,513	2,624	5,028	5,502	9,897	4,679	5,359
70	0	0	0	0	0	0	859	628	750	776	735	339	3,180	3,499	1,825	1,419	8,570	5,207	17,583	19,827	14,370	8,485	13,392
75	0	0	0	0	0	0	859	0	1,500	1,552	1,470	678	7,069	6,030	2,651	2,765	15,339	6,521	12,504	14,093	14,412	15,888	15,649
80	1,833	1,484	1,551	1,319	1,470	1,645	2,606	628	1,500	1,552	1,470	678	10,226	11,808	5,143	3,884	27,186	9,386	15,566	12,405	15,187	24,391	15,264
85	1,837	1,485	1,554	1,323	1,470	1,645	887	1,256	2,999	3,105	2,940	1,356	11,521	14,157	9,462	4,531	21,851	10,755	27,965	17,718	18,631	34,452	13,828
90	6,415	5,194	5,429	4,616	5,268	5,758	6,972	13,821	4,499	4,659	4,410	2,034	14,159	20,132	12,698	6,408	32,604	11,899	34,852	24,888	18,609	44,767	31,304
95	25,661	20,775	21,716	18,464	20,697	23,031	10,702	7,581	7,873	8,195	7,718	3,560	14,780	23,955	16,562	8,248	33,479	17,675	40,875	35,071	22,959	51,142	48,025
100	16,496	13,355	13,960	11,870	13,381	14,806	3,688	4,107	5,733	5,956	5,728	2,977	15,731	32,780	19,076	9,715	32,599	24,797	54,400	47,429	43,615	58,538	59,100
105	9,121	6,678	7,009	5,935	7,278	7,482	6,435	5,406	5,643	6,389	9,341	4,352	16,615	25,681	17,601	11,242	18,825	21,132	53,599	48,518	60,162	53,814	61,093
110	11,001	8,757	9,153	8,759	9,736	10,006	12,702	8,407	8,272	9,362	13,189	14,100	23,110	28,571	23,904	13,338	17,386	17,822	65,274	56,892	59,642	53,840	63,589
115	25,374	15,245	18,530	18,827	16,221	21,201	23,093	14,771	23,109	25,255	27,638	25,953	43,594	36,569	39,765	43,410	23,839	16,315	52,019	49,897	47,052	42,108	54,706
120	37,297	29,742	31,674	27,687	20,460	33,578	40,810	33,103	48,245	42,824	45,130	51,330	74,549	51,346	62,610	72,233	52,127	50,944	74,980	51,704	47,641	32,368	48,535
125	52,025	39,809	44,433	44,466	37,636	55,274	55,300	48,075	64,402	55,249	46,593	72,357	94,105	71,730	78,606	95,272	65,382	79,431	67,470	39,514	35,132	32,738	39,780
130	28,708	31,841	41,888	34,879	39,421	49,388	56,466	53,860	63,914	54,692	35,822	56,929	61,827	70,647	74,016	92,428	95,242	104,335	47,718	39,690	30,985	27,331	32,443
135	30,452	30,774	39,494	38,254	48,441	42,880	47,707	38,790	50,999	49,922	35,106	32,165	32,703	47,999	43,884	59,246	79,614	90,683	31,374	30,990	21,182	21,788	25,939
140	25,960	10,741	17,837	17,329	21,151	15,417	20,675	15,083	19,486	18,037	12,451	21,414	25,199	19,422	26,456	36,175	56,128	48,831	21,484	26,425	21,155	16,107	18,056
145	18,813	11,487	16,008	13,859	16,807	12,987	11,869	12,963	10,613	12,545	7,856	9,497	16,711	15,087	20,025	30,034	33,350	23,006	10,816	17,323	18,045	12,290	13,579
150	17,734	11,338	14,328	10,326	14,285	11,578	10,680	6,626	6,851	7,883	8,160	10,163	13,446	12,239	16,810	17,167	24,611	16,347	11,206	15,900	16,649	10,013	11,359
155	8,166	5,840	6,021	5,316	6,885	5,826	8,819	5,394	7,871	6,806	7,995	4,691	5,799	6,842	9,730	11,975	13,182	11,429	8,026	12,580	11,050	9,177	10,648
160	6,717	5,433	4,480	3,829	5,281	4,803	7,926	5,142	3,909	3,851	3,914	5,502	6,088	10,445	9,787	10,622	12,736	4,215	6,883	10,019	11,141	7,355	9,851
165	4,057	4,812	3,006	2,073	2,941	2,715	3,703	7,383	3,272	3,418	3,916	2,689	3,231	7,657	10,120	7,653	8,147	4,469	5,451	6,478	6,696	6,055	7,339
170	3,052	3,056	2,738	1,989	2,267	2,909	3,067	3,802	5,204	5,555	5,692	2,772	3,627	6,124	7,129	5,058	7,167	6,042	4,821	7,429	6,754	5,149	7,073
175	2,655	2,999	2,236	1,366	1,759	2,085	2,602	4,479	2,634	2,836	3,119	1,887	1,042	3,852	4,256	3,556	5,094	3,283	4,008	4,888	4,972	4,415	5,574
180	2,573	1,946	1,547	667	829	904	3,805	3,601	3,055	3,955	3,155	2,213	984	4,484	3,640	2,795	3,189	1,490	2,815	3,861	3,440	2,982	4,998
185	2,079	2,414	1,669	1,323	1,533	1,724	1,821	214	2,250	2,420	2,635	1,273	247	1,326	2,686	2,619	3,181	530	1,143	2,436	2,110	2,562	3,599
190	1,066	656	58	0	32	0	0	1,559	806	1,017	950	339	1,046	2,191	2,337	1,140	731	1,103	2,324	1,919	1,660	1,861	2,966
195	678	278	58	244	32	119	0	800	430	629	582	170	79	795	821	1,685	494	365	1,010	1,396	1,911	844	1,983
200	599	2	40	15	157	2	0	628	751	776	964	352	96	406	1,700	370	287	208	1,060	882	962	1,107	1,605
205	0	379	0	0	0	0	0	0	0	239	429	0	25	183	994	701	149	81	277	377	580	421	580
210	0	106	29	0	0	0	0	42	1,125	1,641	1,317	764	39	120	150	108	115	30	399	179	379	205	1,006
215	4	1	3	4	0	0	0	889	0	239		0	11	60	99	75	84	60	42	45	133	97	417
220	304	2	8	11	0	0	859	628	375	627	382	170	4	4	111	41	16	8	41	309	108	120	249
225	916	777	776	659	735	823	14	628	0	0		0	35	0	7	9	13	13	54	137	196	222	251
230	0	0	0	0	0	0	0	0	375	388	368	170	2	0	7	9	0	2	0	173	103	38	191
235	9	1	5	7	0	0	8	0	1	0		0	2	0	0	0	0	0	0	45	32	30	49
240	4	1	3	4	0	0	0	628	0	0		0	2	0	5	6	0	0	0	0	31	7	104
245	9	1	5	7	0	0	0	0	0	0		0	0	2	0	0	0	0	0	0	0	8	10
250	0	0	0	0	0	0	0	0	0	0		0	0	0	43	0	0	3	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0		0	0	2	0	18	2	0	0	0	0	57	0
260	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	7
265	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
270	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
275	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
280	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
285	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0
290	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	24	30	0	0	0	0	0
Total	341,614	267,408	307,245	275,429	296,174	328,586	345,794	300,925	359,945	343,904	302,647	333,553	501,102	539,346	528,142	557,516	695,497	592,715	687,997	613,150	572,921	591,086	633,870

Sum of Catch / Li (5 cm LJFL)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
30	34	0	0	0	0	0	0	0		0	0		0	0	57	0	0	8	0	0	0	0	0	0
35	365	0	0	0	0	0	0	0		0	0		0	0	38	0	0	4	0	0	0	0	0	0
40	451	0	0	0	0	0	10	0	183	0	0		0	0	0	0	774	68	0	0	0	8	6	0
45	97	0	0	0	0	0	20	0	93	104	400	191	0	0	0	0	774	60	0	0	24	0	0	0
50	98	0	0	607	186	0	105	0	1,697	3,212	3,703	107	34	90	78	36	5,328	418	6	12	42	0	25	472
55	872	196	163	5,192	95	56	217	0	2,404	11,006	13,643	550	3,940	5,178	118	579	15,837	550	73	25	36	0	185	1,527
60	8,520	594	921	6,671	2,858	638	398	107	8,228	5,034	10,569	3,334	10,947	5,165	641	776	17,820	867	67	216	224	61	546	689
65	3,577	676	1,880	3,538	1,241	2,106	804	404	13,880	13,925	11,318	3,273	10,041	3,832	1,743	10,923	30,741	2,348	730	922	951	429	231	704
70	7,822	16,455	9,816	10,669	3,931	5,139	10,079	1,323	11,161	19,918	10,240	2,514	7,512	1,214	2,729	23,116	42,760	5,459	1,920	1,346	3,079	2,508	1,881	753
75	13,182	30,583	11,126	17,509	9,113	6,191	8,551	7,640	6,149	12,273	5,130	4,605	4,220	7,782	12,664	39,136	43,358	9,040	3,526	2,569	4,444	3,563	2,564	3,217
80	20,390	55,302	16,058	25,476	16,002	13,557	15,509	17,454	6,674	19,256	5,861	6,712	11,831	23,272	25,958	25,521	32,180	10,701	5,913	4,924	6,584	8,772	2,615	3,049
85	26,091	33,170	59,439	70,432	23,575	22,468	22,141	29,159	13,490	35,798	12,266	14,446	20,404	40,533	51,454	56,718	37,778	27,421	18,744	13,899	21,638	23,780	4,354	5,956
90	46,268	50,841	87,291	84,897	48,998	39,162	46,925	51,813	27,141	73,087	23,842	22,637	66,430	74,520	56,001	48,584	33,310	47,101	40,723	26,163	52,762	58,279	21,234	14,833
95	71,406	44,785	122,233	97,961	71,333	44,055	69,957	43,622	38,356	44,389	37,689	32,906	65,306	82,732	66,446	51,165	44,287	55,455	45,798	37,938	65,823	81,944	49,351	37,622
100	76,817	31,685	106,935	77,965	64,200	58,933	80,888	47,610	57,235	48,553	55,598	46,052	71,694	88,202	61,277	48,633	48,230	49,277	42,906	42,472	48,394	62,565	65,959	55,899
105	60,290	38,667	52,955	45,290	61,249	55,717	63,784	56,810	63,756	40,286	49,295	52,589	33,316	64,197	53,853	43,383	43,572	42,920	38,444	38,602	35,049	45,866	45,638	43,168
110	42,973	25,914	55,870	52,310	55,403	69,268	53,555	49,731	68,607	46,804	41,895	69,324	35,620	69,282	67,254	48,531	45,599	37,356	43,353	44,404	47,334	39,630	42,025	36,528
115	33,000	31,911	34,862	38,290	45,686	59,929	50,456	40,480	55,824	38,445	29,743	43,564	49,172	44,246	37,929	30,137	29,387	25,742	29,070	30,856	31,321	23,379	16,558	16,642
120	32,761	35,688	38,916	35,400	37,766	46,703	45,678	33,622	55,512	38,026	23,841	38,290	36,327	29,697	30,088	29,357	24,129	19,144	24,551	28,616	32,319	24,039	14,512	16,227
125	27,871	30,884	28,331	24,965	33,475	36,780	39,469	34,960	39,240	30,811	20,009	32,740	32,153	28,313	25,709	25,797	23,519	16,990	21,932	26,148	25,504	23,891	12,317	13,106
130	25,083	27,674	33,359	28,422	28,347	39,519	33,513	30,723	34,617	28,362	18,238	27,103	32,507	24,527	19,596	25,576	21,292	18,521	18,498	23,860	21,749	22,630	14,085	12,563
135	19,428	19,541	24,243	19,708	20,670	24,230	24,165	19,867	24,491	21,962	16,535	18,519	20,337	18,495	15,910	22,537	18,550	10,760	11,164	17,747	17,884	18,776	11,657	12,661
140	14,611	14,602	12,818	12,826	18,163	16,483	19,330	15,980	20,762	16,282	14,418	15,158	18,273	15,112	15,155	20,714	15,308	10,988	10,993	16,881	15,305	15,717	11,595	11,449
145	10,608	9,248	8,596	10,100	13,594	14,084	16,083	12,373	15,562	13,632	12,194	10,477	13,281	10,983	13,832	17,010	18,640	11,317	10,186	13,155	10,603	14,519	11,434	9,385
150	7,604	7,797	12,650	11,831	11,352	13,145	12,681	8,591	14,920	12,646	15,209	11,882	12,691	9,261	11,355	16,178	11,281	9,953	7,598	10,089	9,982	10,653	10,459	8,868
155	7,681	9,007	9,885	11,906	9,038	9,681	7,608	8,632	11,219	10,861	13,722	11,990	12,434	7,692	10,975	14,114	9,789	7,236	6,702	7,727	6,805	8,927	10,069	7,641
160	7,242	6,764	5,031	7,211	7,552	8,743	7,406	6,993	10,094	8,780	10,332	7,998	8,129	7,280	9,382	12,608	5,912	6,847	6,025	6,142	6,001	8,719	9,528	6,202
165	4,635	4,920	4,409	6,553	4,013	7,963	6,347	6,293	7,392	8,517	11,922	8,717	8,211	5,384	7,445	8,339	3,605	5,120	4,365	4,950	4,473	6,933	5,961	5,172
170	6,107	5,037	5,241	6,899	6,045	7,846	4,110	5,182	5,976	7,696	9,147	7,145	5,266	3,705	5,343	7,265	4,283	5,514	4,022	4,735	4,117	5,352	6,377	4,440
175	4,156	4,071	3,421	4,037	3,140	4,126	3,380	3,534	3,652	4,745	7,768	5,526	4,111	2,342	2,841	5,653	5,783	4,974	4,062	4,222	3,674	3,858	4,830	2,626
180	3,516	2,847	2,177	3,792	2,596	3,826	2,635	3,018	4,085	3,991	5,826	5,318	3,403	2,018	2,399	2,765	3,144	3,443	2,682	2,345	2,972	2,508	3,294	2,082
185	3,304	2,430	2,265	2,237	1,917	3,497	1,655	2,451	1,749	2,409	5,808	6,005	3,181	1,311	1,445	1,752	2,505	3,217	2,398	1,693	2,215	1,442	3,115	1,795
190	1,651	1,402	1,080	1,622	1,935	2,649	1,816	1,549	2,292	2,813	2,946	1,872	1,230	941	859	2,691	1,231	2,745	1,925	782	1,903	680	1,672	1,040
195	1,338	1,182	900	1,083	914	1,073	1,440	1,100	1,180	1,446	2,303	2,588	1,781	720	1,146	1,576	751	2,244	1,134	399	1,178	997	1,528	967
200	1,177	1,110	1,346	806	714	811	1,387	779	1,314	1,718	2,285	2,238	1,062	736	670	1,360	912	1,075	1,069	445	1,079	785	829	811
205	835	844	759	440	377	724	720	544	772	774	1,160	1,383	600	700	393	500	847	1,167	698	739	592	557	206	480
210	583	474	386	283	471	260	616	431	1,030	505	1,144	1,441	717	728	313	291	263	422	344	591	572	221	242	137
215	378	178	186	228	86	141	348	195	109	265	1,108	581	201	104	177	138	74	162	189	112	104	99	21	200
220	193	1,699	204	123	195	306	205	144	89	220	757	738	471	103	137	105	654	48	79	173	292	6	228	20
225	122	70	64	30	50	2	143	72	103	99	417	10	86	0	28	63	200	12	126	460	512	449	11	14
230	57	36	67	56	50	0	87	72		119	159	83	15	271	93	17	399	40	64	303	332	426	8	63
235	77	43	0	29	25	42	41	24	4	167	145	73	75	118	54	42	162	0	4	166	464	438	3	11
240	23	8	0	0	25	21	0	0	34	25	160	74	69	103	0	28	81	5	8	3	292	0	5	6
245	33	12	0	0	74	15	0	0		0	15		0	0	0	6	389	31	1	1	0	26	3	2
250	9	0	0	0	0	130	0	0	1	0	53	223	0	115	47	0	4	0	0	5	191	0	0	0
255	9	0	2	0	61	0	20	0	1	0	15		0	0	0	0	0	0	1	18	0	0	0	0
260	9	0	0	28	37	0	0	0	1	0	15		0	60	0	7	0	0	0	0	64	0	0	1
265	0	0	0	0	0	0	0	0		39	40		0	51	0	0	0	0	1	6	0	0	0	0
270	0	0	0	0	50	0	0	0		0	0		0	9	47	0	0	0	0	0	0	0	0	7
275	0	1	0	0	0	0	0	0		0	0	12	0	0	0	0	0	0	0	0	0	0	0	0
280	0	0	0	0	0	0	0	0		0	0		0	51	0	0	0	0	0	0	0	0	0	0
285	0	0	0	0	0	15	0	0		0	0		0	0	0	0	0	0	0	0	0	0	0	0
290	0	0	0	0	0	15	0	0		0	0		0	0	47	0	0	0	0	0	0	0	0	12
Total	593,356	548,345	755,883	727,421	606,604	620,047	654,281	543,280	631,081	628,998	508,884	520,987	607,077	681,174	613,726	643,729	645,443	456,768	412,092	416,862	488,884	523,431	387,158	339,046

Table 4. CAA matrix (slicing inverse-VB) including estimated dead discards from longline fleets 2008 – 2018.

YearC	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9P	Total
1972	-	51,509	86,268	130,348	49,500	12,958	5,729	2,487	1,260	1,555	341,614
1973	-	41,699	66,501	108,353	28,584	12,387	5,562	2,668	383	1,269	267,408
1974	-	43,590	72,073	138,475	36,981	9,448	4,277	1,445	86	869	307,245
1975	-	37,064	67,107	128,997	30,637	7,184	2,429	1,059	244	708	275,429
1976	-	41,634	59,662	139,719	40,179	9,723	3,061	1,239	126	831	296,174
1977	-	46,227	77,441	159,818	29,754	9,525	3,522	1,356	121	823	328,586
1978	1,719	24,673	86,245	176,070	35,184	12,545	7,005	1,472	-	882	345,794
1979	628	24,627	61,690	156,909	27,190	15,908	7,913	1,438	1,303	3,318	300,925
1980	2,924	20,169	89,397	195,373	28,570	10,680	6,868	2,906	655	2,402	359,945
1981	3,027	20,971	88,147	174,985	29,926	11,027	8,001	3,044	1,100	3,676	343,904
1982	2,867	19,773	99,263	128,176	25,696	11,586	7,806	3,223	1,017	3,240	302,647
1983	1,322	9,421	129,633	148,057	27,258	10,039	4,909	1,288	271	1,353	333,553
1984	1,690	81,081	187,342	175,704	39,561	10,556	3,618	1,224	146	182	501,102
1985	9,759	106,423	148,484	203,322	36,156	21,783	8,621	2,735	1,497	567	539,346
1986	6,796	64,711	160,481	205,961	49,264	23,653	8,661	4,649	1,347	2,618	528,142
1987	4,207	36,539	138,807	282,198	61,134	20,922	6,952	3,643	1,911	1,202	557,516
1988	8,927	171,055	102,700	281,294	88,991	28,549	9,014	3,729	683	555	695,497
1989	9,368	78,094	109,714	312,367	59,356	16,691	4,759	1,556	456	353	592,715
1990	32,860	200,435	243,816	151,699	30,591	15,416	6,931	3,321	1,411	1,516	687,997
1991	36,704	163,928	201,891	123,822	49,500	20,364	9,334	3,758	2,254	1,594	613,150
1992	34,087	156,586	196,227	100,115	47,036	21,642	9,089	3,725	2,356	2,059	572,921
1993	16,023	226,215	195,220	89,263	32,695	16,825	7,502	3,880	1,510	1,953	591,086
1994	27,569	194,967	216,650	110,454	37,863	22,029	11,044	6,444	3,094	3,756	633,870
1995	19,856	270,687	160,587	80,475	27,189	15,984	8,974	4,538	2,069	2,997	593,356
1996	34,866	222,703	145,767	83,586	29,989	13,968	7,864	3,668	1,794	4,142	548,345
1997	21,846	380,181	194,916	99,174	29,730	16,706	6,280	3,041	1,650	2,358	755,883
1998	32,059	358,399	184,758	83,346	32,913	20,588	8,710	3,406	1,520	1,721	727,421
1999	9,380	182,651	253,000	96,030	36,806	15,237	6,469	3,568	1,590	1,873	606,604
2000	7,605	126,155	276,137	126,774	40,408	23,912	9,385	5,609	1,953	2,108	620,047
2001	17,440	199,737	254,324	111,737	39,390	16,060	7,183	3,109	2,284	3,016	654,281
2002	10,297	195,896	182,016	89,663	34,090	16,831	7,275	3,677	1,656	1,878	543,280
2003	41,176	127,457	266,732	114,886	43,207	20,782	7,929	3,759	2,403	2,749	631,081
2004	53,052	236,338	172,035	88,188	38,879	21,348	8,795	4,744	2,288	3,330	628,998
2005	55,039	149,628	138,038	61,807	41,989	28,867	14,358	8,527	4,213	6,419	508,884
2006	12,977	141,859	197,874	80,525	36,123	22,535	11,945	7,310	3,836	6,004	520,987
2007	37,991	247,354	156,130	90,733	38,425	19,147	8,131	3,840	2,447	2,881	607,077
2008	18,210	301,699	226,448	79,708	30,624	13,863	4,668	2,067	1,159	2,729	681,174
2009	5,421	237,967	224,836	76,306	38,262	19,260	6,210	2,234	1,479	1,751	613,726
2010	40,492	260,375	161,346	90,334	51,109	22,785	8,828	3,917	2,422	2,122	643,729
2011	95,943	218,815	180,005	79,528	39,618	14,373	8,628	3,484	1,369	3,680	645,443
2012	8,635	194,975	134,349	55,873	28,915	15,079	8,387	5,591	2,510	2,454	456,768
2013	3,350	141,875	148,570	63,827	27,361	12,760	6,969	3,555	1,823	2,002	412,092
2014	5,099	95,734	174,082	81,789	32,448	14,888	6,994	2,370	616	2,841	416,862
2015	6,781	186,173	158,819	77,867	29,773	12,709	7,076	3,858	1,841	3,986	488,884
2016	3,325	215,089	163,137	73,755	36,053	18,328	7,314	2,265	1,330	2,837	523,431
2017	3,312	129,145	139,012	45,855	32,518	20,510	9,326	4,358	1,956	1,167	387,158
2018	4,596	115,848	121,877	43,659	27,474	14,710	5,307	2,620	1,462	1,492	339,046

Table 5. CAA matrix (mixture distribution) including estimated dead discards from the longline fleets 2008- 2018.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6 Plus	Total
1972	1	62,589	116,621	106,369	33,002	13,365	9,666	341,614
1973	1	48,997	91,311	83,476	26,009	10,609	7,005	267,408
1974	1	56,271	104,795	96,560	29,882	12,071	7,665	307,245
1975	1	50,359	94,412	87,458	26,995	10,879	5,325	275,429
1976	0	54,288	100,956	93,752	29,175	11,838	6,164	296,174
1977	1	60,107	112,691	104,214	32,172	12,968	6,433	328,586
1978	878	47,471	114,688	122,526	41,126	19,104	0	345,794
1979	0	53,728	100,796	94,460	28,975	11,746	11,220	300,925
1980	2,026	44,618	118,122	136,674	40,391	18,113	0	359,945
1981	857	30,201	109,296	141,301	42,500	19,749	0	343,904
1982	776	22,008	101,744	118,510	39,628	19,980	0	302,647
1983	678	25,960	114,673	133,611	40,113	18,518	0	333,553
1984	0	95,976	174,096	159,703	50,338	20,852	137	501,102
1985	3,711	100,498	185,390	170,234	55,417	24,096	1	539,346
1986	2,070	80,775	178,200	178,280	60,521	28,295	0	528,142
1987	2,256	86,807	187,699	190,215	61,577	28,962	0	557,516
1988	4,447	135,166	231,918	221,616	71,925	30,426	0	695,497
1989	5,888	109,881	200,117	191,426	60,389	25,013	0	592,715
1990	10,033	136,060	239,899	210,755	65,164	26,077	9	687,997
1991	8,529	119,930	213,274	187,465	59,523	24,424	5	613,150
1992	8,021	111,762	200,132	174,183	55,773	23,050	0	572,921
1993	6,589	121,644	208,714	174,800	56,255	23,084	0	591,086
1994	4,032	121,669	231,397	186,118	62,893	27,761	0	633,870
1995	11,308	120,790	208,645	175,595	54,969	22,047	1	593,356
1996	13	134,877	187,226	151,117	51,335	23,778	0	548,345
1997	3,740	159,523	269,634	222,874	70,993	29,118	1	755,883
1998	14,551	150,363	251,491	216,716	67,415	26,885	1	727,421
1999	3,803	122,369	218,077	181,574	57,740	23,040	2	606,604
2000	0	112,254	240,360	174,117	66,490	26,773	54	620,047
2001	1,896	129,580	239,672	193,452	62,951	26,730	0	654,281
2002	0	109,194	193,543	162,843	53,239	22,715	1,745	543,280
2003	15,107	121,985	219,163	191,461	59,514	23,850	0	631,081
2004	18,431	127,851	214,889	186,521	58,077	23,227	1	628,998
2005	57,643	59,154	187,918	83,771	71,674	48,725	0	508,884
2006	2,006	72,838	209,269	146,896	59,327	30,651	0	520,987
2007	15,370	120,797	209,288	182,444	56,602	22,577	0	607,077
2008	8,988	158,225	394,418	45,192	73,713	2	636	681,174
2009	14	153,431	287,750	82,711	89,195	0	625	613,726
2010	715	141,169	220,860	190,296	63,504	27,185	1	643,729
2011	48,823	250,184	180,587	90,042	52,175	23,633	0	645,443
2012	2,223	97,461	164,453	125,879	45,420	21,332	1	456,768
2013	162	80,799	153,481	114,196	42,481	20,972	1	412,092
2014	6	69,814	162,575	119,991	44,876	19,601	0	416,862
2015	0	84,659	277,608	52,682	59,456	13,604	876	488,884
2016	0	105,987	184,704	155,784	49,946	20,197	6,814	523,431
2017	374	69,451	144,391	110,631	42,255	20,056	1	387,158
2018	3,716	60,439	126,388	97,731	35,161	15,610	0	339,046

Table 6. Relative abundance indices available for the 2020 Mediterranean swordfish stock assessment.

Period	1987-2018	1987-2018	2010-2019	2010-2019	2012-2018	1988-2018	1988-2018	1999-2011	1991-2009	1990-2009	1991-2009
SCRS paper	SCRS/2020/021	SCRS/2020/021	SCRS/2020/027	SCRS/2020/027	SCRS/2020/026	SCRS/2020/043	SCRS/2020/043	SCRS/2010/083	SCRS/2014/105	SCRS/2010/085	SCRS/2014/112
Country/Location	Greece	Greece	Liguria	Liguria	Morocco	Spain	Spain	Morocco	Sicily	Sicily	Ligurian Sea
Gear	Longline	Longline	Longline (meso)	Longline (meso)	Longline	Longline	Longline	Gillnet	Longline	Gillnet	Longline
Unit	weight	number	weight	number	weight	number	weight	weight	weight	weight	
Used in 2016 XSA	Yes	No	No	No	Yes	No	No	No	No	No	No
Use in 2020 SA	Use				Use	Use		No	No	No	Sensitivity only
Year	GRC_LL	GRC_LL	LIG_LL	LIG_LL	MOR_LL	SPN_LL	SPN_LL	MOR_GN	SIC_LL	SIC_GN	LIG_LL
1987	214.7	9.55									
1988	238.2	10				3.40	127.76				
1989						2.33	115.50				
1990	234.5	14.87				2.46	124.56			8.3	
1991	316.8	10.86				2.92	85.88		100.3	9.8	88.5
1992	127.4	4.01				3.05	74.20		98.5	16.9	66.1
1993	211.4	13.27				3.04	98.34			13.0	68.8
1994	298.4	10.38				3.28	120.48		99.5	9.5	90.6
1995	181.4					3.11	96.20		124.2	14.7	94.6
1996						2.73	82.06			9.3	94.3
1997						2.68	83.99		75.9	14.0	101.1
1998	250.2	5.66				2.89	93.77		127.6	10.1	144.9
1999	172.7	5.87				2.67	87.30	58.3	151.5	12.7	101.9
2000	125.9	4.69				2.47	122.76	66.7	93.3	14.9	134.7
2001	130.6	4.95				2.75	85.68	43.1	144.0	13.1	181.6
2002	107.3	4.41				3.37	128.38	56.0	204.8		140.3
2003	128.6	3.88				2.90	81.83	48.2	82.2		152.3
2004	125.6	8.88				2.56	61.26	58.4	111.2	15.2	98.9
2005	131.5	4.8				2.79	84.28	70.7	123.2	12.1	80.8
2006	136.5	5.8				2.89	112.69	66.2	140.6	30.7	125.0
2007	140.6	5.31				3.17	120.07	63.2	81.1		240.0
2008	134.0	5.31				3.10	152.84	69.2	87.0	3.3	208.2
2009	121.9	5.53				2.54	98.10	55.6	99.1	2.0	123.4
2010	141.4	6.51	332.03	7.95		2.64	106.68	51.9			
2011	116.3	5	239	7.17		2.77	102.68	46.5			
2012	106.5	4.94	143.5	5.29	276.9	3.07	131.75				
2013	167.9	8.69	158.52	5.03	164.0	2.82	88.38				
2014	128.4	5.72	224.52	8.01	190.5	2.85	95.17				
2015	115.7	5.82	160.05	5.14	156.8	2.85	86.05				
2016	125.5	6.32	145.51	5.62	59.0	2.86	70.79				
2017	70.7	3.7	118.75	4.19	67.9	2.79	122.10				
2018	84.3	4.65	88.53	3.38	91.4	2.57	106.27				

Table 7. Summary of the evaluation CPUE table for the Mediterranean swordfish stock assessment.

SCRS Doc No.	SCRS/2020/021	SCRS/2020/027	SCRS/2020/026	SCRS/2020/043	SCRS/2010/083	SCRS/2014/105	SCRS/2010/085
Index Name:	Greece longline	Liguria longline	Morocco longline	Spain longline Biomass	Morocco gillnet	Sicily longline	Sicily gillnet
Data Source (state if based on logbooks, observer data etc)	Observations	vations at landings and a	Fish market statistics	Observer aboard	Fish market statistics	Observations	Observations
Do the authors indicate the percentage of total effort of the fleet the CPUE data represents?	No	No	No	Yes on catches	No	No	No
If the answer to 1 is yes, what is the percentage?				43% latest years			
Are sufficient diagnostics provided to assess model performance??	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient
How does the model perform relative to the diagnostics ?	Well	Well	Well	Well	Well	Well	Well
Documented data exclusions and classifications?	NA	NA	NA	Yes	NA	NA	NA
Data exclusions appropriate?	NA	NA	NA	Yes	NA	NA	NA
Data classifications appropriate?	NA	NA	NA	Yes	NA	NA	NA
Geographical Area	East Med	Ligurian Sea	St. Gibrartar, West Med	Western Med	Strait of Gibraltar, West Med	Central Med	Central Med
Data resolution level	trip	trip	trip	trip	trip	trip	trip
Ranking of Catch of fleet in TINC database (use data catalogue)	1-5	NA	6-10	1-5	1-5	NA	NA
Length of Time Series	longer than 20 years	6-10 years	6-10 years	longer than 20 years	11-20 years	11-20 years	11-20 years
Are other indices available for the same time period?	Few	Few	Few	Few	Few	Few	Few
Are other indices available for the same geographic range?	None	None	Few	Few	Few	None	None
Does the index standardization account for Known factors that influence catchability/selectivity? (eg. Type of hook, bait type, depth etc.)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Estimated annual CV of the CPUE series	Medium	Medium	Low	Low	Low	Medium	Medium
Annual variation in the estimated CPUE exceeds biological plausibility	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely
Is data adequate for standardization purposes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is this standardised CPUE time series continuous?	No	Yes	Yes	Yes	No	No	No
For fisheries independent surveys: what is the survey type?							
For 19: Is the survey design clearly described?							
Other Comments	Index both Numbers and Biomass Localised (< 10 x 10 degrees)	Index in Numbers and biomass. Recommend to use Biomass index	Localised (< 10 x 10 degrees)	Index both Numbers and biomass Recommend use Biomass index	Localised (< 10 x 10 degrees)	Localised (< 10 x 10 degrees)	Localised (< 10 x 10 degrees)

Table 8. XSA control settings for Continuity run and Candidate runs for the Mediterranean swordfish.

Parameters	Continuity run	Candidate runs
shk.n	TRUE	TRUE
shk.yrs	10	10
rage	1	1
maxit	100	100
shk.f	TRUE	TRUE
shk.ages	2	4
fse	0.5	0.5
min.nse	0.3	0.3
qage	6	6
window	100	100
tsrange	10	20
tspower	1	1
vpa	TRUE	TRUE
F range:minbar	2	2
maxfbar	4	4

Table 9. Parameter settings applied to a4a for the Mediterranean swordfish.

Parameters	Settings
the initial age structure N1	a smoother (N : ~s(age, k = 3))
the recruitment R	a smoother (R:~s(year, k = 15)
separable F model	with age and year effect modeled using splines (~s(year, k =17) + s(age,k=3)
the catchability of the surveys *q*	a constant model (~1) was assumed for the Greek, Spanish and Sicilian longline indices, while a smoothing effect on the year was assumed for Moroccan and Ligurian longlines, due to the trend in the residuals.

Table 10. Results for *r* prior distributions and median shape parameter with corresponding B_{MSY}/K values generated an Age-Structured Equilibrium Model (ASEM) with a Beverton-Holt Stock-Recruitment relationship using Monte-Carlo simulations.

Parameter	**Scenario**			
	Reference	***M* Constant**	***M* Lorenzen**	**Joint**
r	0.49	0.186	0.176	0.181
sd of log(*r*)	0.47	0.198	0.207	0.204
B_{MSY}/K	0.5	0.38	0.38	0.38
shape *m*	2	1.06	1.08	1.07

Table 11. Summary of posterior quantiles presented in the form of marginal posterior medians and associated with the 95% credibility intervals of parameters for the Bayesian state-space surplus production models for Mediterranean swordfish.

	Reference model			***ASEM model***		
Estimates	**Median**	**2.50%**	**97.50%**	**Median**	**2.50%**	**97.50%**
K	135017	79495	259387	194523	139243	290538
r	0.414	0.219	0.748	0.188	0.129	0.268
ψ *(psi)*	0.996	0.821	1.204	0.994	0.820	1.200
σ_{proc}	0.094	0.045	0.163	0.084	0.038	0.150
F_{MSY}	0.207	0.11	0.374	0.176	0.121	0.251
B_{MSY}	67509	39748	129693	73928	52919	110417
MSY	13811	11275	21476	12931	10709	17468
B_{1950}/K	0.991	0.755	1.265	0.989	0.758	1.25
B_{2018}/K	0.329	0.186	0.597	0.296	0.155	0.51
B_{2018}/B_{MSY}	0.65	0.376	1.33	0.777	0.404	1.41
F_{2018}/F_{MSY}	0.99	0.312	1.686	0.880	0.373	1.679

Table 12. Summary Mohn's rho statistic computed for a retrospective evaluation period of five years. The larger the threshold the stronger the retrospective bias.

	Stock Quantity					
Scenario	***B***	***F***	***B/B*** $_{MSY}$	***F/F*** $_{MSY}$	***B/K***	**MSY**
Reference	0.061	-0.057	0.158	-0.173	0.158	0.045
ASEM	0.086	-0.078	0.101	-0.132	0.101	0.042

Table 13. Estimates of biomass, fishing mortality, biomass relative to B_{MSY}, and fishing mortality relative to F_{MSY} between 1950 and 2018 in the form of joint MCMC posteriors of JABBA model runs (‘Reference’ and ‘ASEM’ models) for Mediterranean Swordfish with 95% credibility intervals.

	Biomass			Fishing mortality			B/B_{MSY}			F/F_{MSY}		
Year	Median	95%LCI	95%UCI	Median	95%LCI	95%UCI	Median	95%LCI	95%UCI	Median	95%LCI	95%UCI
1950	166334	79573	286551	0.004	0.002	0.007	2.271	1.581	3.185	0.019	0.013	0.028
1951	164594	79509	285516	0.004	0.002	0.007	2.228	1.586	3.165	0.019	0.013	0.028
1952	163633	79219	283719	0.002	0.001	0.004	2.217	1.573	3.151	0.011	0.008	0.016
1953	163179	79329	283636	0.003	0.002	0.006	2.208	1.578	3.135	0.017	0.011	0.024
1954	162847	79952	282616	0.003	0.002	0.006	2.199	1.569	3.135	0.015	0.010	0.022
1955	162326	79948	283488	0.002	0.001	0.004	2.195	1.564	3.138	0.011	0.008	0.017
1956	162337	79673	281358	0.002	0.001	0.005	2.199	1.557	3.135	0.013	0.009	0.019
1957	161879	79847	280619	0.004	0.002	0.008	2.193	1.567	3.131	0.022	0.015	0.032
1958	161739	79766	278276	0.006	0.003	0.011	2.188	1.561	3.118	0.031	0.021	0.045
1959	161463	79369	278628	0.004	0.002	0.008	2.180	1.551	3.102	0.020	0.014	0.030
1960	161406	79398	278104	0.003	0.002	0.006	2.182	1.549	3.112	0.018	0.012	0.026
1961	161173	79502	277125	0.004	0.002	0.008	2.181	1.552	3.106	0.021	0.014	0.031
1962	161469	79224	277061	0.004	0.003	0.009	2.179	1.548	3.118	0.024	0.016	0.035
1963	161350	79104	275819	0.004	0.003	0.009	2.177	1.546	3.104	0.025	0.016	0.036
1964	161295	79118	273488	0.005	0.003	0.010	2.177	1.550	3.116	0.027	0.018	0.040
1965	161066	79351	274834	0.011	0.006	0.022	2.175	1.554	3.110	0.060	0.040	0.088
1966	159640	78183	273633	0.011	0.006	0.022	2.154	1.538	3.091	0.060	0.040	0.088
1967	158869	77861	271862	0.008	0.005	0.017	2.143	1.524	3.080	0.045	0.030	0.067
1968	158665	77567	271166	0.022	0.013	0.044	2.148	1.523	3.060	0.119	0.080	0.175
1969	156275	76452	268793	0.024	0.014	0.049	2.114	1.502	3.038	0.130	0.087	0.191
1970	154805	75384	267637	0.022	0.012	0.044	2.091	1.480	3.032	0.118	0.078	0.174
1971	154066	74867	266397	0.032	0.019	0.066	2.082	1.473	3.012	0.177	0.117	0.260
1972	151665	73390	263596	0.074	0.042	0.152	2.050	1.450	2.976	0.403	0.266	0.595
1973	143866	67157	254272	0.061	0.034	0.130	1.939	1.345	2.862	0.334	0.216	0.497
1974	140688	65924	250399	0.069	0.039	0.147	1.901	1.310	2.810	0.381	0.243	0.569
1975	136419	64412	244661	0.062	0.035	0.132	1.850	1.271	2.752	0.343	0.217	0.516
1976	134562	64248	243216	0.071	0.039	0.149	1.836	1.254	2.730	0.388	0.245	0.585
1977	132439	63700	239539	0.076	0.042	0.158	1.803	1.235	2.692	0.415	0.260	0.629
1978	129766	62606	237620	0.087	0.048	0.181	1.773	1.212	2.644	0.476	0.297	0.724
1979	126340	61332	233153	0.084	0.046	0.174	1.727	1.178	2.592	0.460	0.284	0.700
1980	124651	60256	229208	0.096	0.052	0.198	1.707	1.162	2.563	0.523	0.322	0.790
1981	121748	59556	224779	0.097	0.052	0.198	1.671	1.137	2.520	0.527	0.320	0.803
1982	119512	58454	221246	0.085	0.046	0.174	1.643	1.108	2.481	0.465	0.283	0.708
1983	119182	59525	218892	0.090	0.049	0.180	1.647	1.119	2.446	0.488	0.297	0.734
1984	118598	60695	217038	0.115	0.063	0.225	1.644	1.127	2.419	0.627	0.383	0.927
1985	114963	59123	211464	0.133	0.072	0.259	1.594	1.100	2.347	0.724	0.435	1.062
1986	110034	56682	205567	0.152	0.082	0.296	1.530	1.054	2.270	0.830	0.488	1.208
1987	104322	53667	199440	0.176	0.092	0.341	1.459	0.990	2.168	0.958	0.546	1.388
1988	98083	50778	191426	0.208	0.106	0.401	1.374	0.924	2.066	1.134	0.626	1.639
1989	90257	45160	181231	0.197	0.098	0.393	1.265	0.834	1.955	1.077	0.575	1.575
1990	87056	43657	177013	0.184	0.090	0.367	1.223	0.800	1.908	1.007	0.528	1.482
1991	82948	41330	169480	0.190	0.093	0.381	1.166	0.755	1.823	1.037	0.546	1.543
1992	76613	37407	157851	0.192	0.093	0.393	1.079	0.686	1.676	1.048	0.554	1.580
1993	79223	39283	162197	0.167	0.082	0.338	1.113	0.717	1.752	0.916	0.473	1.365
1994	82428	41658	169040	0.195	0.095	0.386	1.154	0.752	1.845	1.072	0.543	1.593
1995	75904	37559	157345	0.171	0.083	0.347	1.067	0.681	1.692	0.938	0.479	1.409
1996	73171	36084	151294	0.165	0.080	0.334	1.031	0.649	1.631	0.900	0.465	1.373
1997	73902	36924	150474	0.199	0.098	0.398	1.040	0.660	1.624	1.084	0.567	1.653
1998	74352	37475	152588	0.193	0.094	0.383	1.045	0.669	1.644	1.059	0.541	1.592
1999	71484	35912	147776	0.192	0.093	0.381	1.005	0.644	1.592	1.048	0.532	1.569
2000	69840	35525	144374	0.223	0.108	0.438	0.983	0.630	1.571	1.218	0.621	1.827
2001	65922	32955	137542	0.228	0.109	0.455	0.929	0.591	1.477	1.244	0.629	1.880
2002	64292	32010	135982	0.199	0.094	0.400	0.907	0.574	1.461	1.088	0.544	1.654
2003	63567	32101	132689	0.247	0.118	0.489	0.899	0.571	1.420	1.347	0.688	2.029
2004	61467	30675	129320	0.234	0.111	0.470	0.868	0.549	1.382	1.279	0.654	1.936
2005	63760	31906	134533	0.229	0.109	0.458	0.900	0.574	1.444	1.251	0.633	1.886
2006	67307	33970	142006	0.222	0.105	0.439	0.949	0.606	1.544	1.213	0.603	1.813
2007	69367	34803	147313	0.205	0.097	0.409	0.976	0.621	1.615	1.124	0.547	1.687
2008	70578	35110	149833	0.194	0.091	0.390	0.995	0.628	1.669	1.059	0.508	1.614
2009	69186	34298	146824	0.191	0.090	0.386	0.973	0.613	1.616	1.048	0.510	1.588
2010	70193	34956	149730	0.210	0.099	0.422	0.989	0.626	1.656	1.150	0.555	1.747
2011	66251	32151	142839	0.191	0.088	0.393	0.931	0.577	1.571	1.047	0.496	1.610
2012	64573	30669	140029	0.171	0.079	0.360	0.908	0.554	1.539	0.939	0.442	1.470
2013	63632	30508	136378	0.158	0.074	0.330	0.894	0.551	1.499	0.867	0.414	1.349
2014	62625	30445	133253	0.175	0.082	0.360	0.881	0.542	1.473	0.960	0.461	1.492
2015	58467	28354	125152	0.205	0.096	0.423	0.823	0.505	1.371	1.122	0.539	1.754
2016	54019	25725	118294	0.228	0.104	0.478	0.763	0.457	1.284	1.244	0.590	1.996
2017	51258	23105	115903	0.203	0.090	0.450	0.725	0.409	1.262	1.106	0.510	1.870
2018	50692	22101	116525	0.171	0.074	0.393	0.719	0.382	1.278	0.929	0.421	1.680

Table 14. Summary of reference points (median and 95% credibility intervals) presented in the form of joint MCMC posteriors of JABBA model runs ('Reference' and 'ASEM' models) for Mediterranean swordfish.

Estimates	Median	Lower 95%CI	Upper 95%CI
B_0	169231	85506	274312
F_{MSY}	0.186	0.116	0.344
B_{MSY}	71319	42562	113758
MSY	13325	10899	17346
B_{2018}	50692	22101	116525
F_{2018}	0.171	0.074	0.393
B_{2018}/B_0	0.312	0.168	0.557
B_{2018}/B_{MSY}	0.719	0.382	1.278
F_{2018}/F_{MSY}	0.929	0.421	1.680

Table 15. Estimated probabilities of the Mediterranean swordfish stock being above B_{MSY} (not overfished) for a range of fixed total catches of 0 – 15,000 tonnes over the projection horizon 2021-2028 based on joint projection MCMC posteriors of JABBA model runs ('Reference' and 'ASEM' models).

TAC | Year	2021	2022	2023	2024	2025	2026	2027	2028
0	31	52	71	84	92	96	98	99
7000	31	41	51	59	67	73	77	81
8000	31	39	47	55	61	67	71	75
9000	31	38	44	50	56	60	64	68
10000	31	36	41	46	50	53	57	60
10250	31	36	40	45	49	52	55	58
10500	31	35	39	43	47	50	53	56
10750	31	35	39	42	45	48	51	53
11000	31	34	38	41	44	47	49	51
11250	31	34	37	40	43	45	47	49
11500	30	34	37	39	41	44	45	47
11750	31	33	36	38	40	42	43	45
12000	30	33	35	37	38	40	41	43
12250	30	32	34	35	37	38	39	40
12500	30	31	32	34	35	36	37	38
12750	29	31	32	33	33	34	35	35
13000	29	30	31	31	32	33	33	33
14000	25	25	25	25	25	25	25	24
15000	21	20	20	19	18	18	17	17

Table 16. Estimated probabilities of the Mediterranean swordfish stock being below F_{MSY} (overfishing not occurring) for a range of fixed total catches of 0 – 15,000 tonnes over the projection horizon 2021-2028 based on joint projection MCMC posteriors of JABBA model runs ('Reference' and 'ASEM' models).

TAC | Year	2021	2022	2023	2024	2025	2026	2027	2028
0	100	100	100	100	100	100	100	100
7000	84	87	90	91	93	94	94	95
8000	76	80	83	85	87	88	90	91
9000	68	72	75	77	80	81	82	84
10000	58	62	65	68	70	72	73	74
10250	56	60	62	65	67	69	71	72
10500	54	57	60	62	64	66	68	69
10750	51	54	57	59	61	63	64	66
11000	49	52	55	57	59	60	61	63
11250	47	50	52	54	56	57	58	59
11500	45	47	49	51	53	54	55	56
11750	43	45	47	48	50	51	52	53
12000	41	43	44	46	47	48	49	50
12250	39	40	42	43	44	45	45	46
12500	37	38	39	40	41	42	42	43
12750	35	36	37	38	38	39	39	40
13000	33	34	35	35	36	36	36	36
14000	27	27	27	26	26	26	26	25
15000	22	21	20	20	19	18	18	17

Table 17. Estimated probabilities of the Mediterranean swordfish stock being above B_{MSY} and below F_{MSY} (green zone) for a range of fixed total catches (0 – 15,000 t) over the projection horizon 2021-2028 based on joint projection MCMC posteriors of JABBA model runs ('Reference' and 'ASEM' models).

TAC | Year	2021	2022	2023	2024	2025	2026	2027	2028
0	31	52	71	84	92	96	98	99
7000	31	41	51	59	67	73	77	81
8000	31	39	47	55	61	67	71	75
9000	31	38	44	50	56	60	64	68
10000	31	36	41	46	50	53	57	60
10250	31	36	40	45	49	52	55	58
10500	31	35	39	43	47	50	53	56
10750	31	35	39	42	45	48	51	53
11000	31	35	38	41	44	47	49	51
11250	31	34	37	40	43	45	47	50
11500	31	34	37	39	42	44	45	47
11750	31	34	36	38	40	42	43	45
12000	31	33	35	37	39	41	42	43
12250	31	33	35	36	37	38	39	40
12500	31	32	33	35	36	37	38	38
12750	31	32	33	34	35	35	36	36
13000	31	32	33	33	33	34	34	34
14000	31	30	30	29	29	28	28	27
15000	31	29	27	26	24	23	22	21

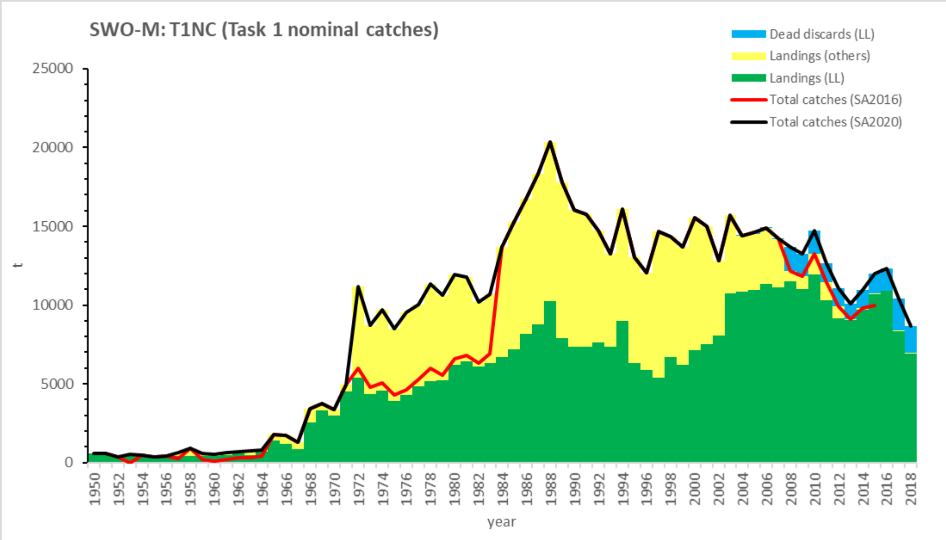


Figure 1. SWO-M total nominal catches (T1NC, t) by year, showing total landings (LL and other gears) and dead discards (reported and estimated in SCRS/2020/028). The total catches used in the 2016 stocks assessment (SA2016) is shown for comparative purposes.

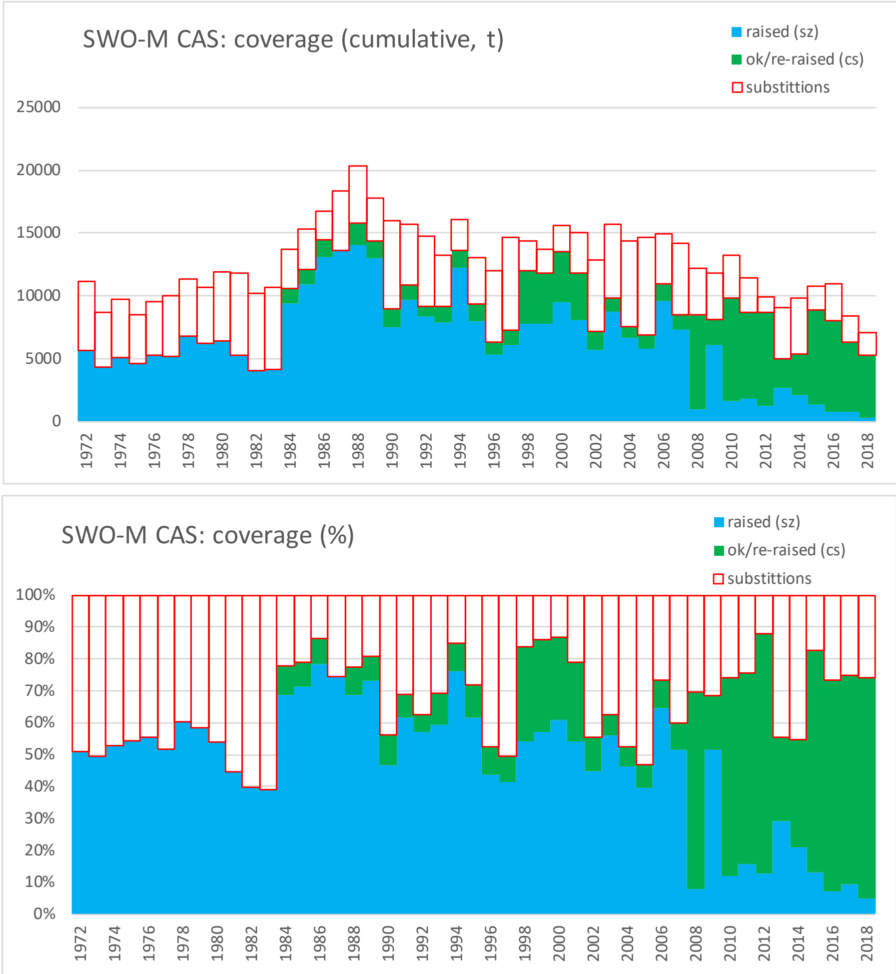


Figure 2. Task 1 nominal catches (T1NC, t) covered by size information in each year. Series in "blue" represent raised T2SZ data. Series in "green" represent T2CS (re-raised or not) data. The series in "red" indicate that no size information exists and a substitution was made. Whereas the top panel shows cumulative T1NC absolute catch series, the bottom panel shows the relative ratio.

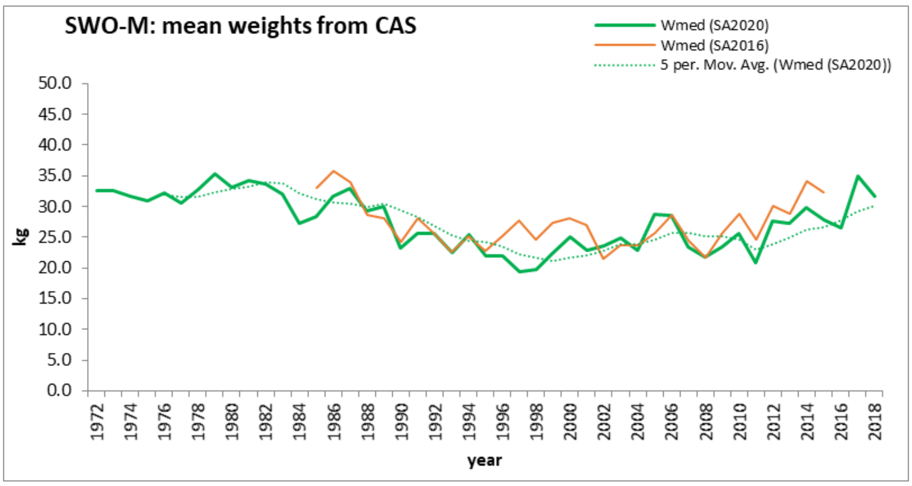


Figure 3. Weighted (flag and gear) yearly mean weights (kg) obtained from the two CAS matrices estimated and used in the 2016 and the 2020 stock assessments (respectively SA2016 and SA2020 series). The 5-year period moving average is shown only for the latest series (SA2020).

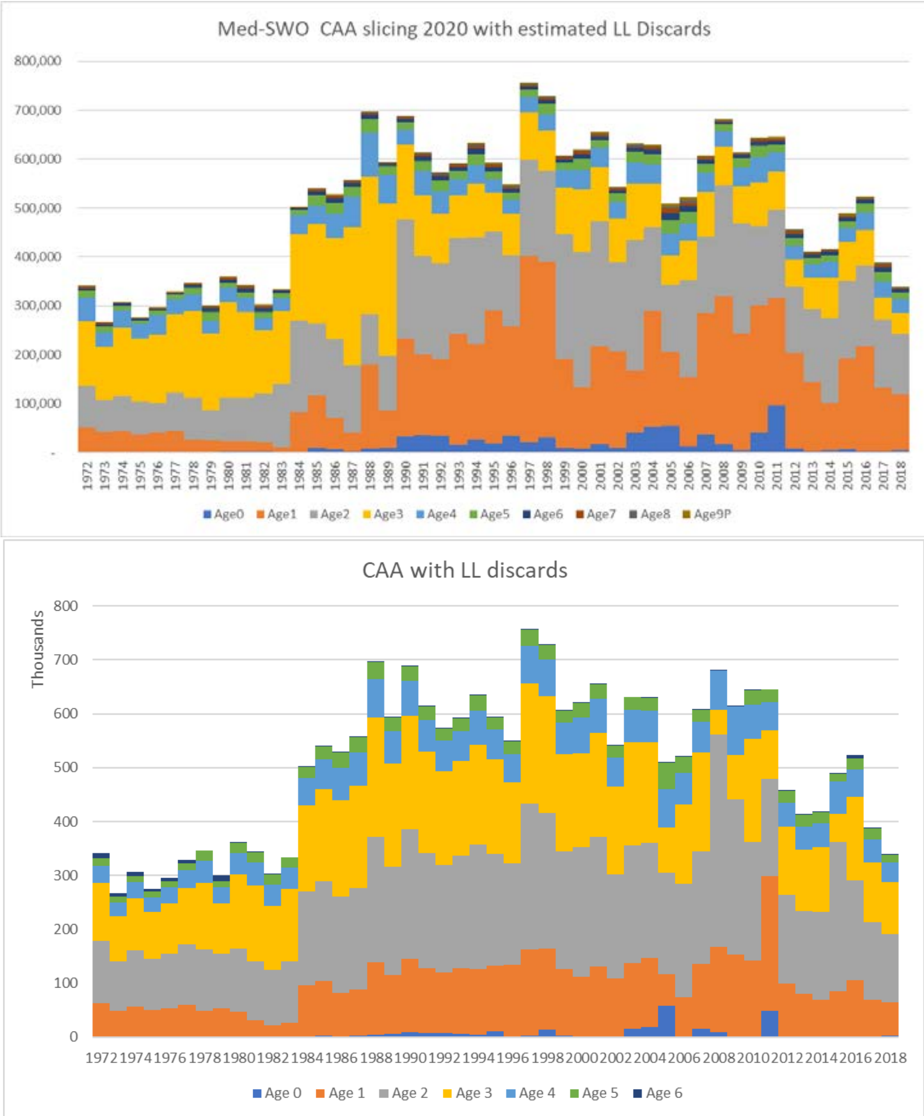


Figure 4. Relative age proportions of the two slicing approaches used (top: slicing with inverse VB; bottom: mixture distribution).

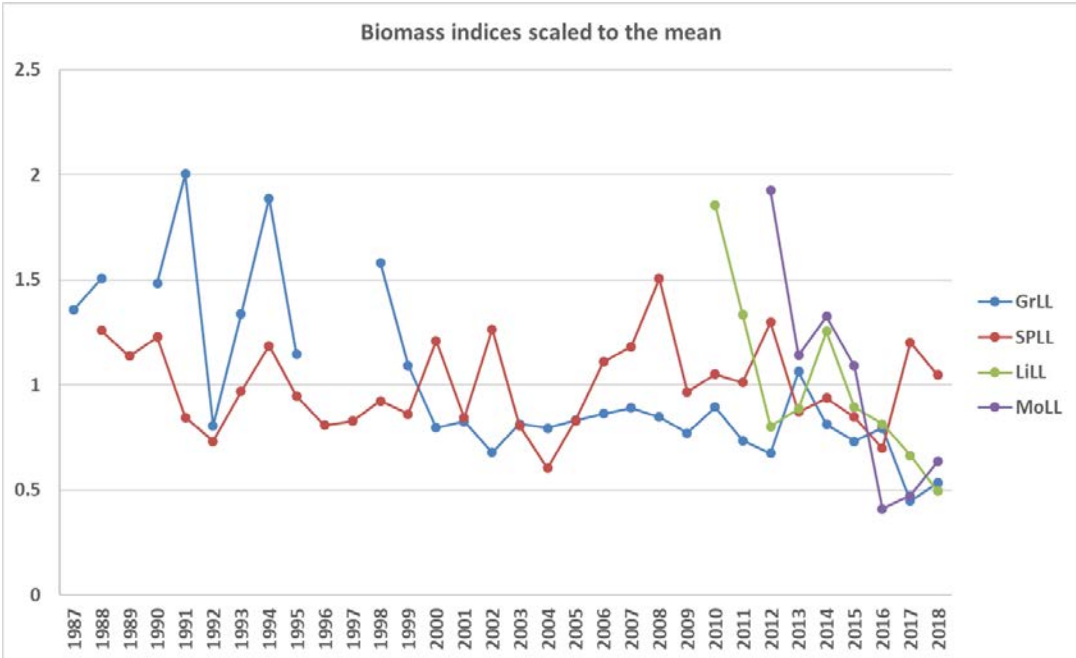


Figure 5. Indices of abundance in biomass (scaled to the mean) used for the Med-SWO stock assessment models.

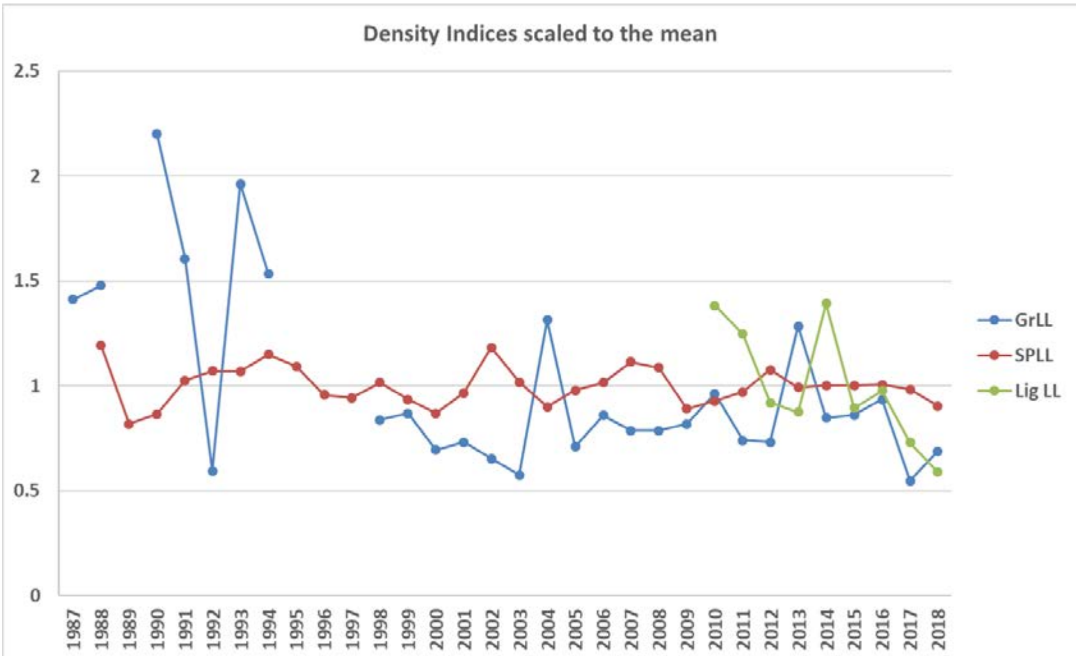


Figure 6. Indices of abundance in numbers (scaled to the mean) used for the Med-SWO stock assessment models.

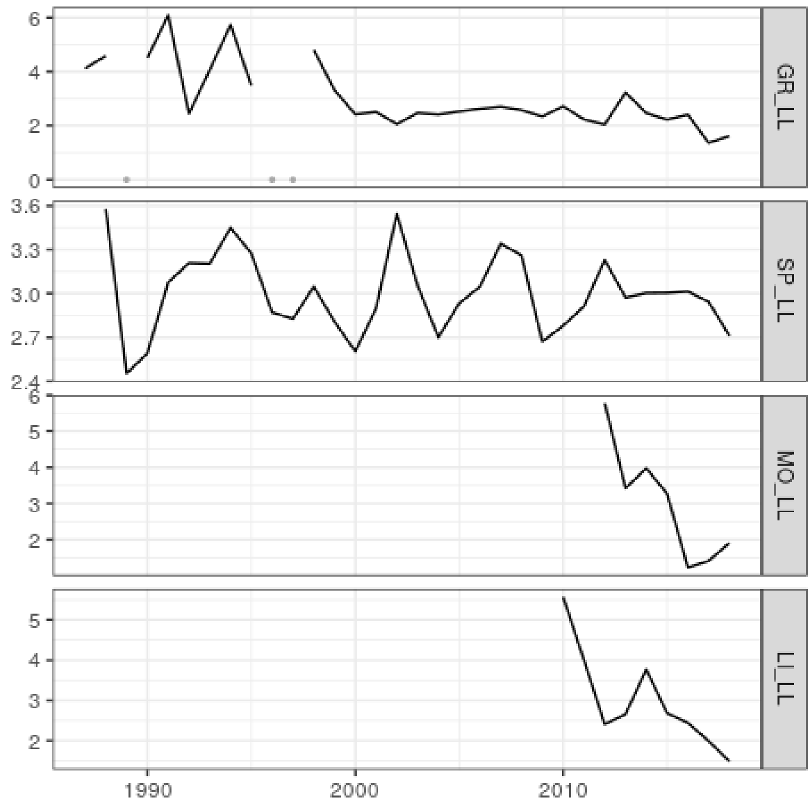


Figure 7. Time series of scaled standardized CPUE indexes by fleet: GR_LL= Greek longline, SP_LL=Spanish longline, MO_LL=Moroccan longline, LI_LL=Ligurian Longline.

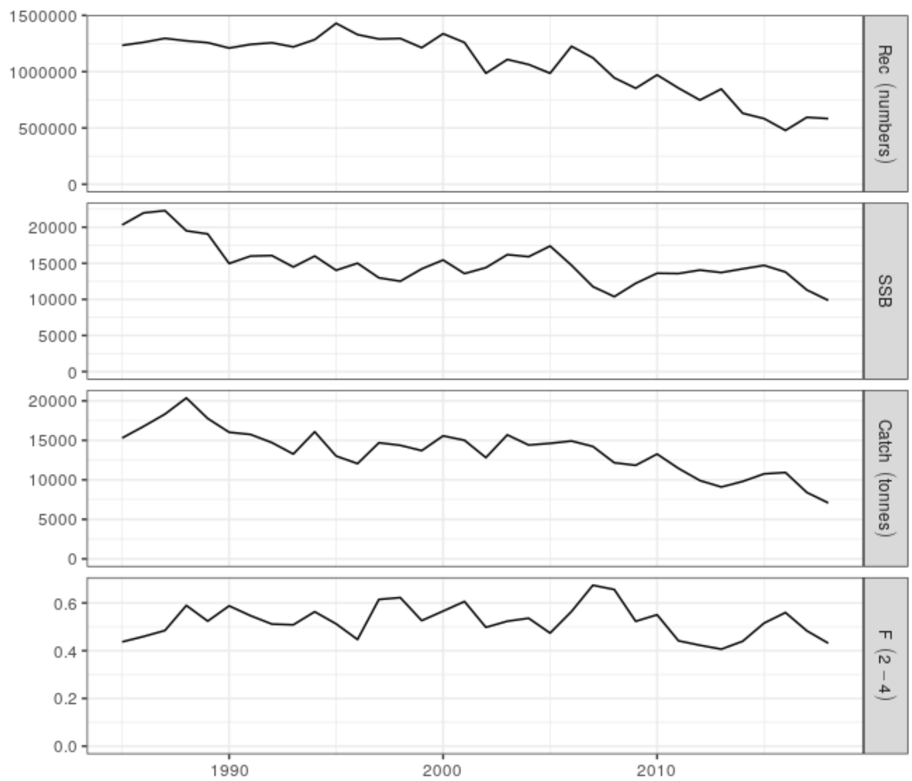


Figure 8. XSA time series estimates for the base run.

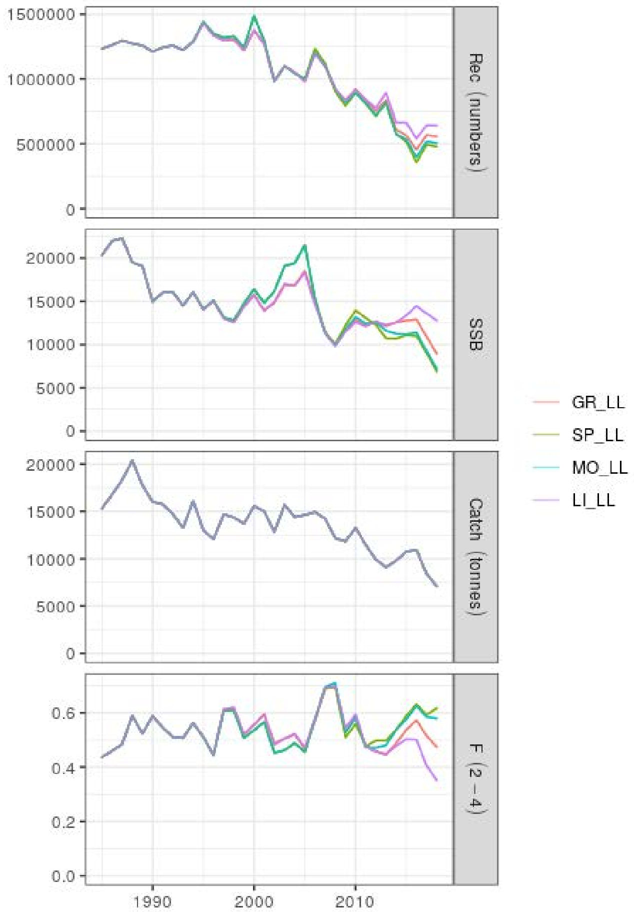


Figure 9. XSA time series estimates by CPUE, for the base run.

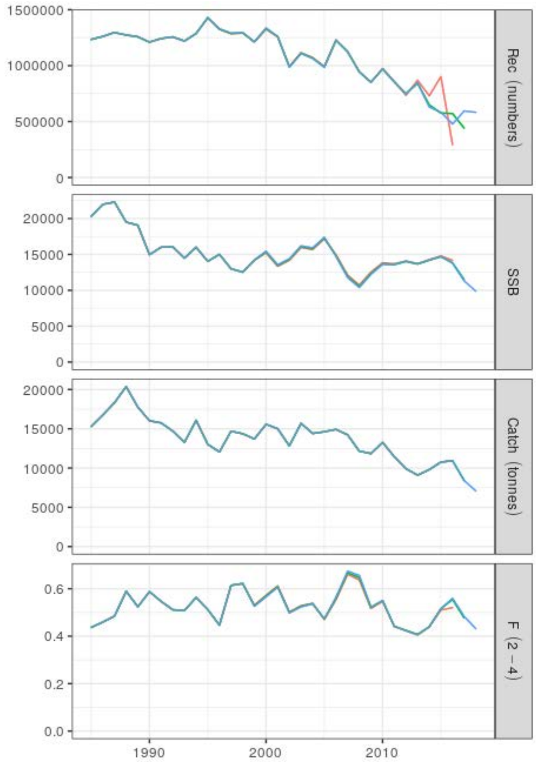


Figure 10. Retrospective plot for the XSA base run.

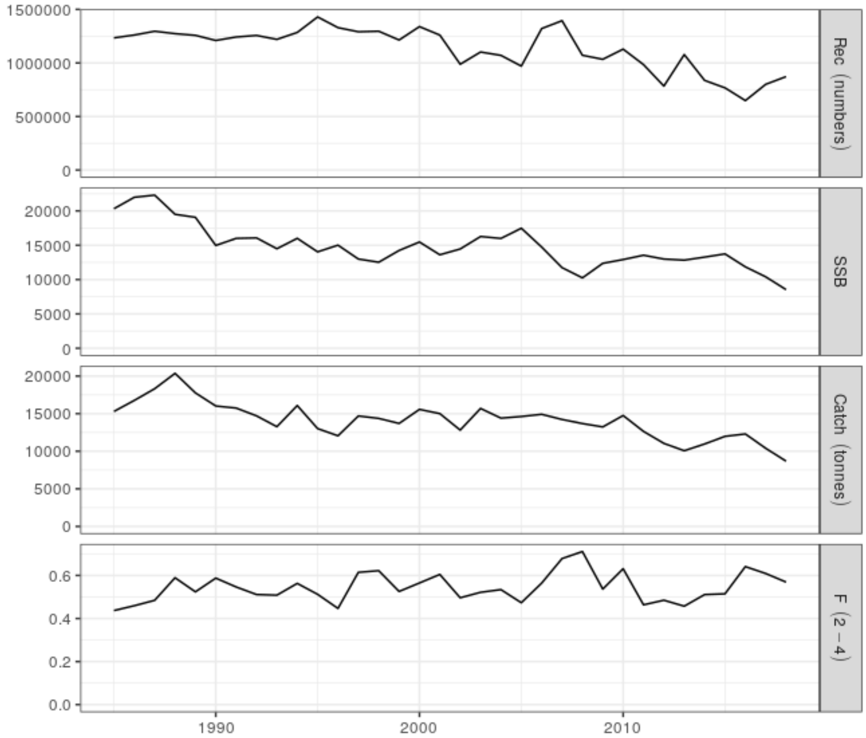


Figure 11. XSA time series estimates for the discard run.

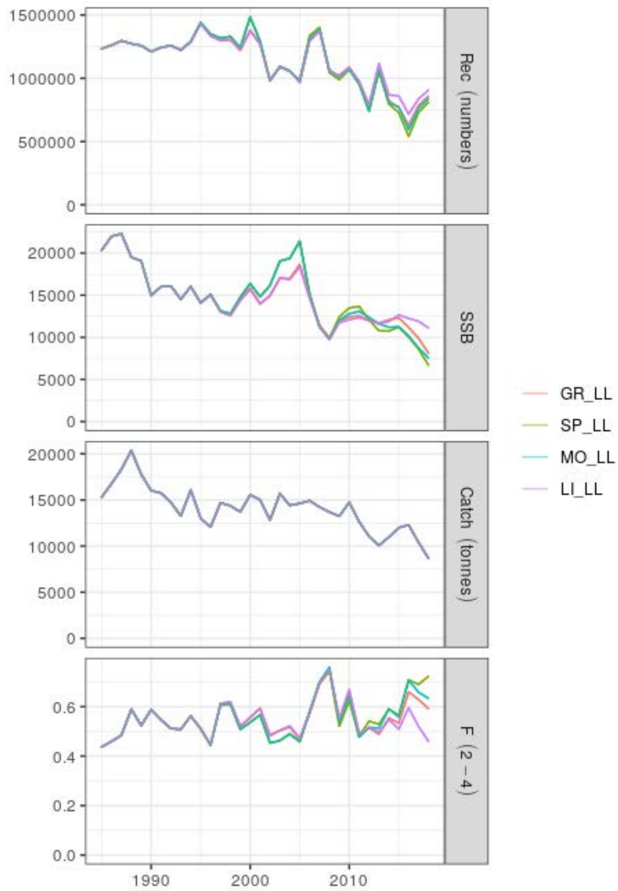


Figure 12. XSA time series estimates by CPUE for the discard run.

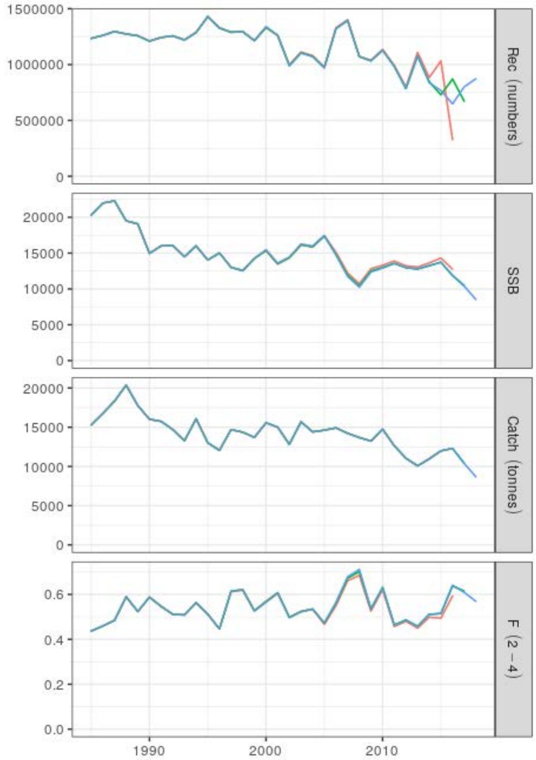


Figure 13. Retrospective plot for the XSA discard run.

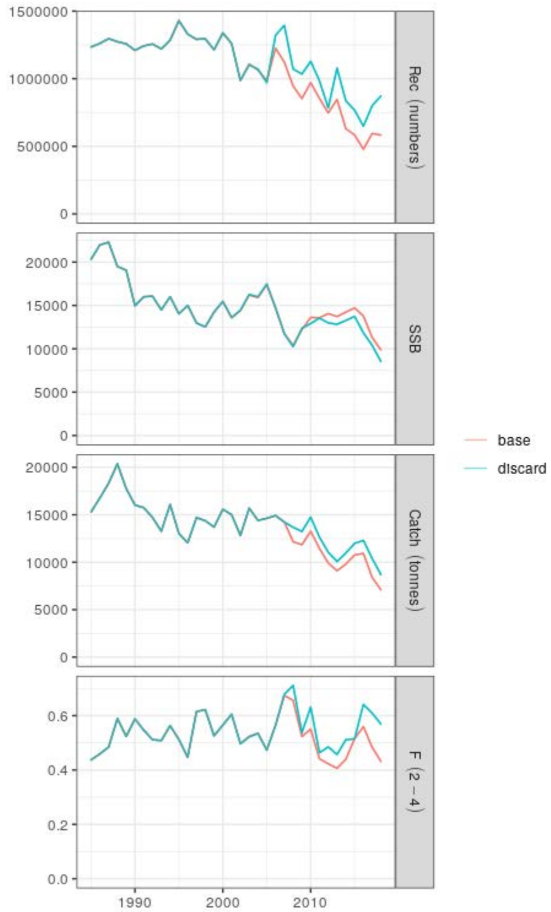


Figure 14. Comparison of estimates among base and discard XSA runs.

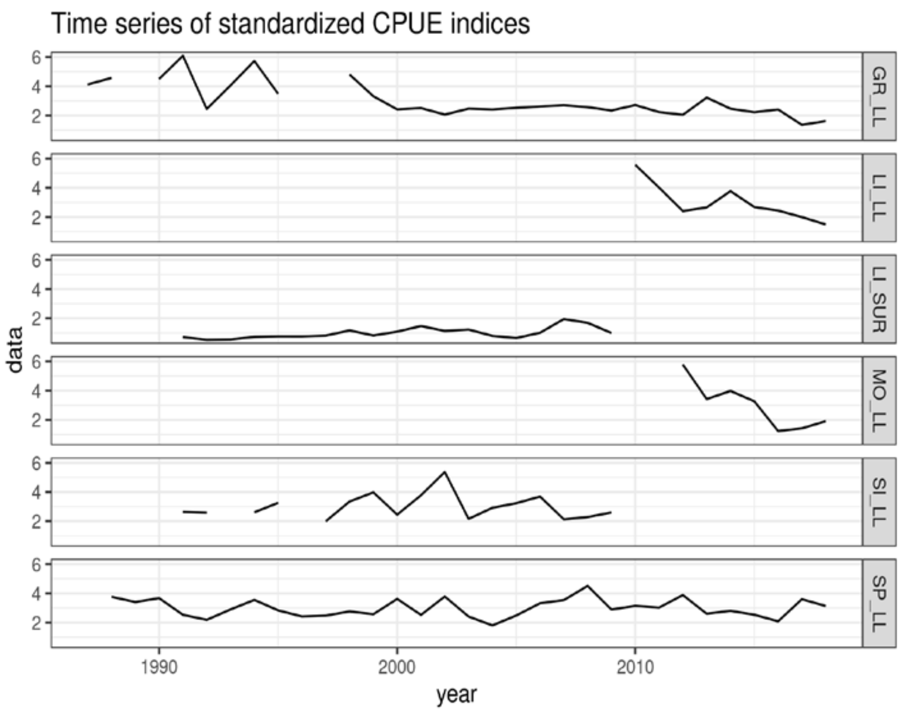


Figure 15. Time series of scaled standardized CPUE indexes by fleet: GR_LL = Greek longline, SP_LL = Spanish longline, MO_LL = Moroccan longline, LI_LL = Ligurian longline, SI_LL = Sicilian longline, LI_SUR = Ligurian surface longline.

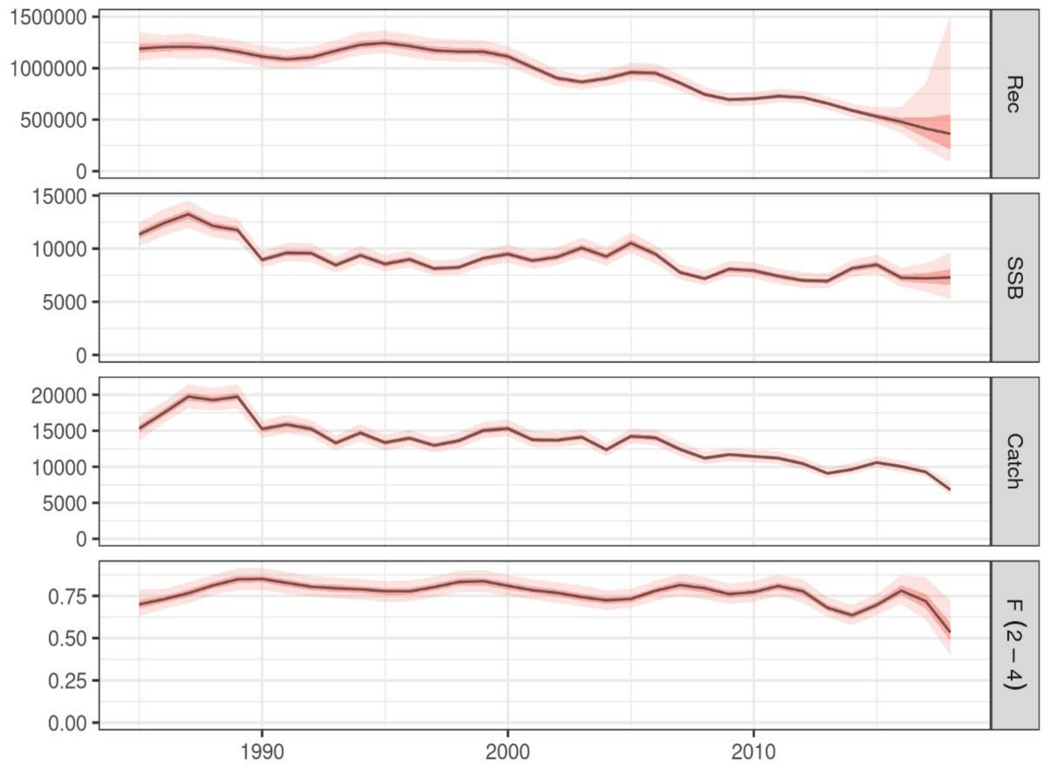


Figure 16. a4a constant M run without Discards. Summary of assessment results. Trends in recruitment, spawning stock biomass (tonnes), catch (tonnes) and fishing mortality for ages 2 – 4. 10%, 25%, 75% and 90% CIs.

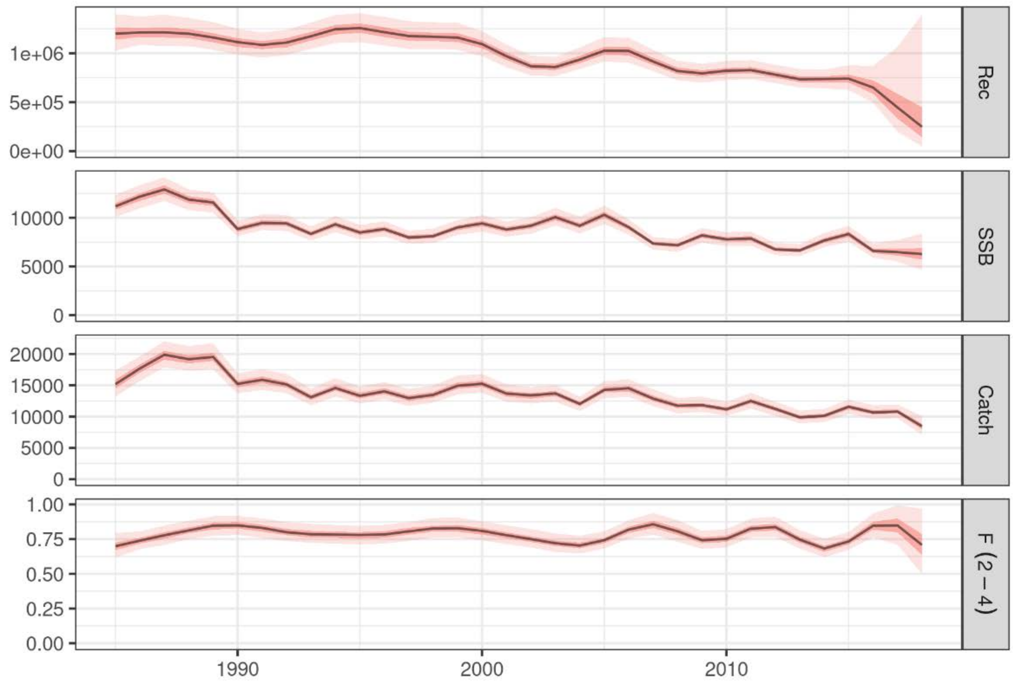


Figure 17. a4a constant M run with Discards. Summary of assessment results. Trends in recruitment, spawning stock biomass (tonnes), catch (tonnes) and fishing mortality for ages 2 – 4. 10%, 25%, 75% and 90% CIs.

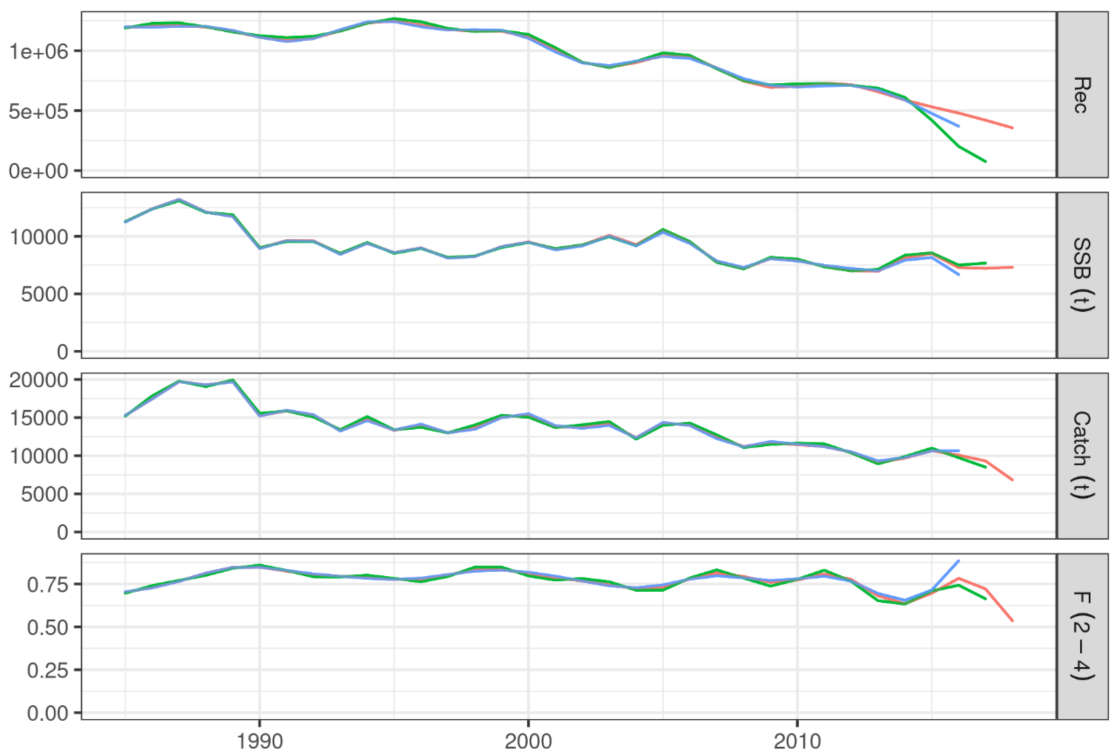


Figure 18. a4a constant M run without discards. Retrospective plot.

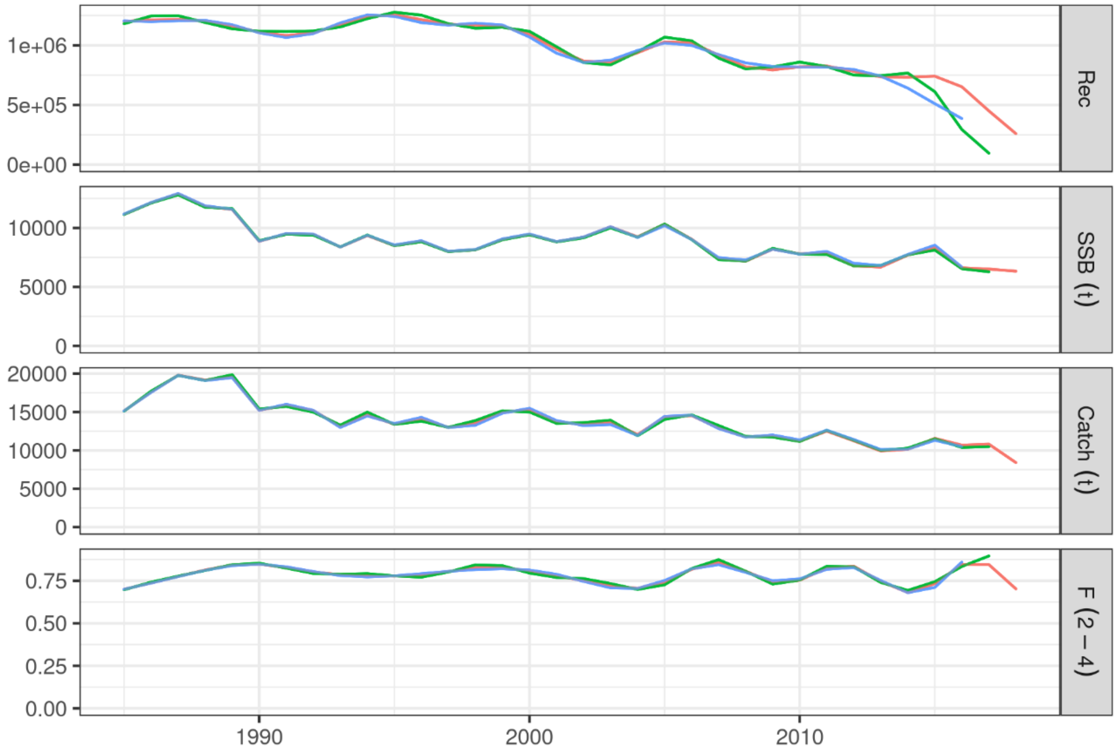


Figure 19. a4a constant M run with discards. Retrospective plot.

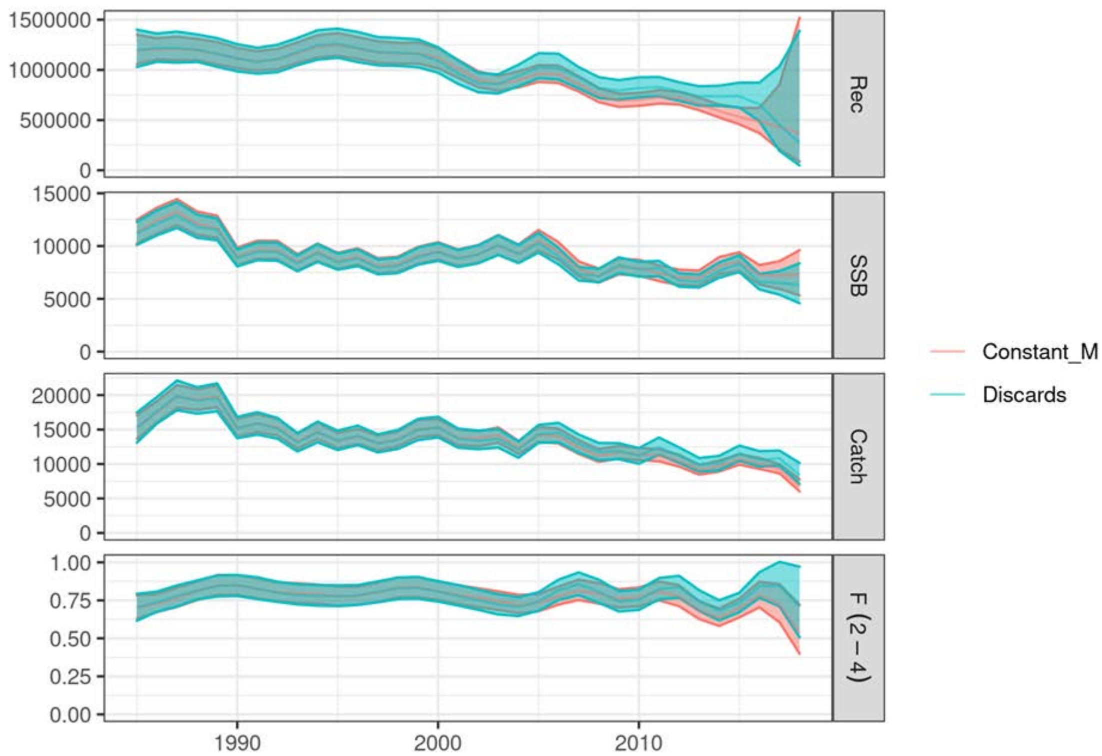


Figure 20. a4a Comparative plot between Constant M run and Discards.

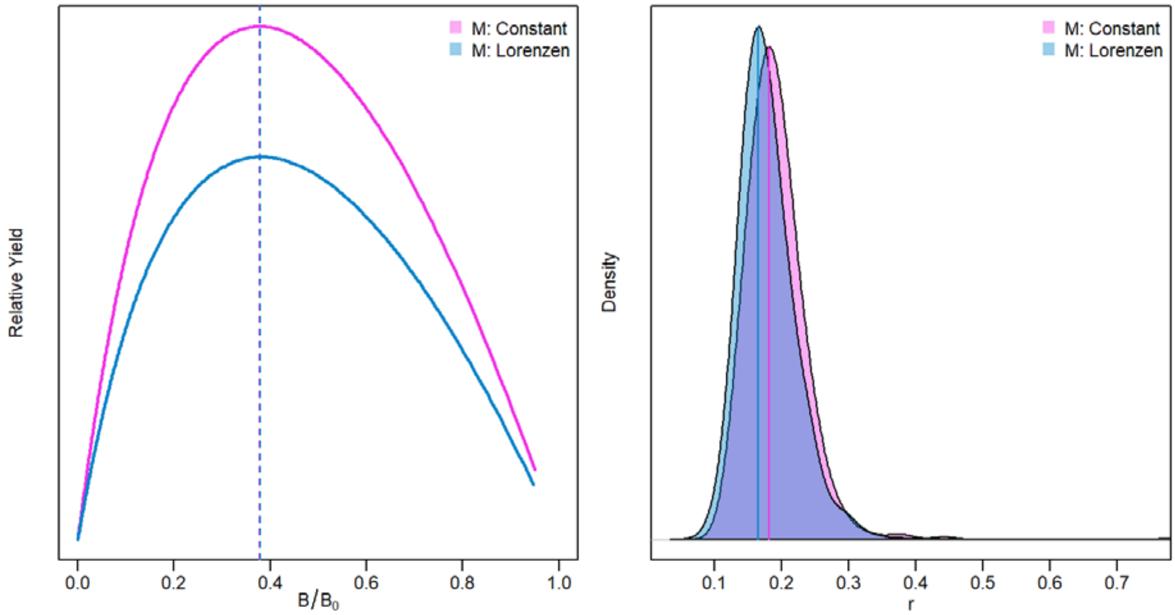


Figure 21. Results of Age-Structured Equilibrium Model (ASEM) with a Beverton-Holt Stock-Recruitment relationship using Monte-Carlo simulations. Left panel: Estimates of yield curves by *M*; Right panel: Density distributions of simulated *r* values by *M*.

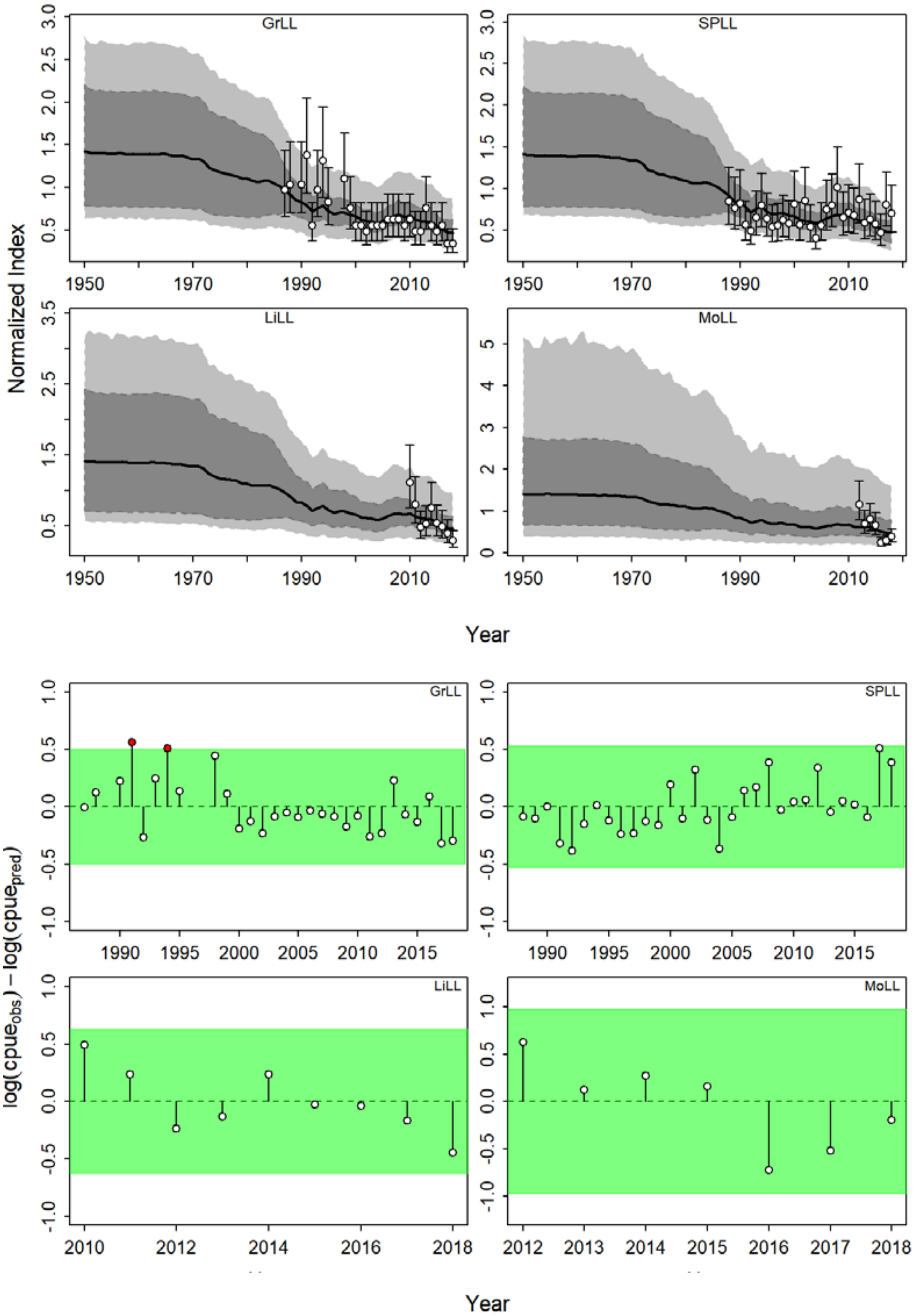


Figure 22. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line; upper panels) and runs tests (bottom panels) for CPUE of Mediterranean swordfish for the Bayesian state-space surplus production model JABBA for the 'Reference' scenario. Runs tests evaluate the randomness of the time series of CPUE residuals by fleet. Green panels indicate no evidence of lack of randomness of time-series residuals (*p*>0.05), while red panels (not shown here) indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

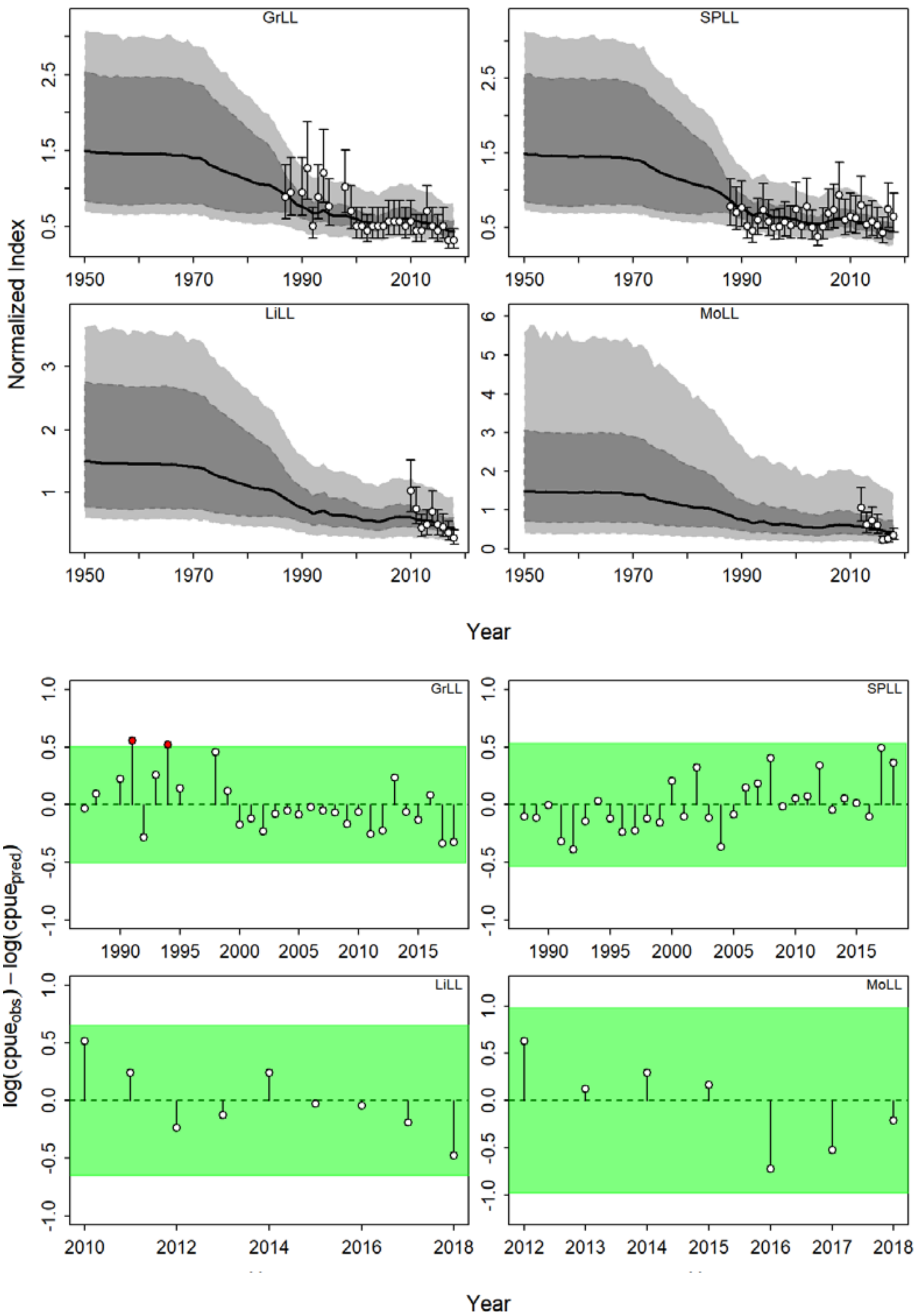


Figure 23. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line; upper panels) and runs tests (bottom panels) for CPUE of Mediterranean swordfish for the Bayesian state-space surplus production model JABBA for the 'ASEM' scenario. Runs tests evaluate the randomness of the time series of CPUE residuals by fleet. Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels (not shown here) indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

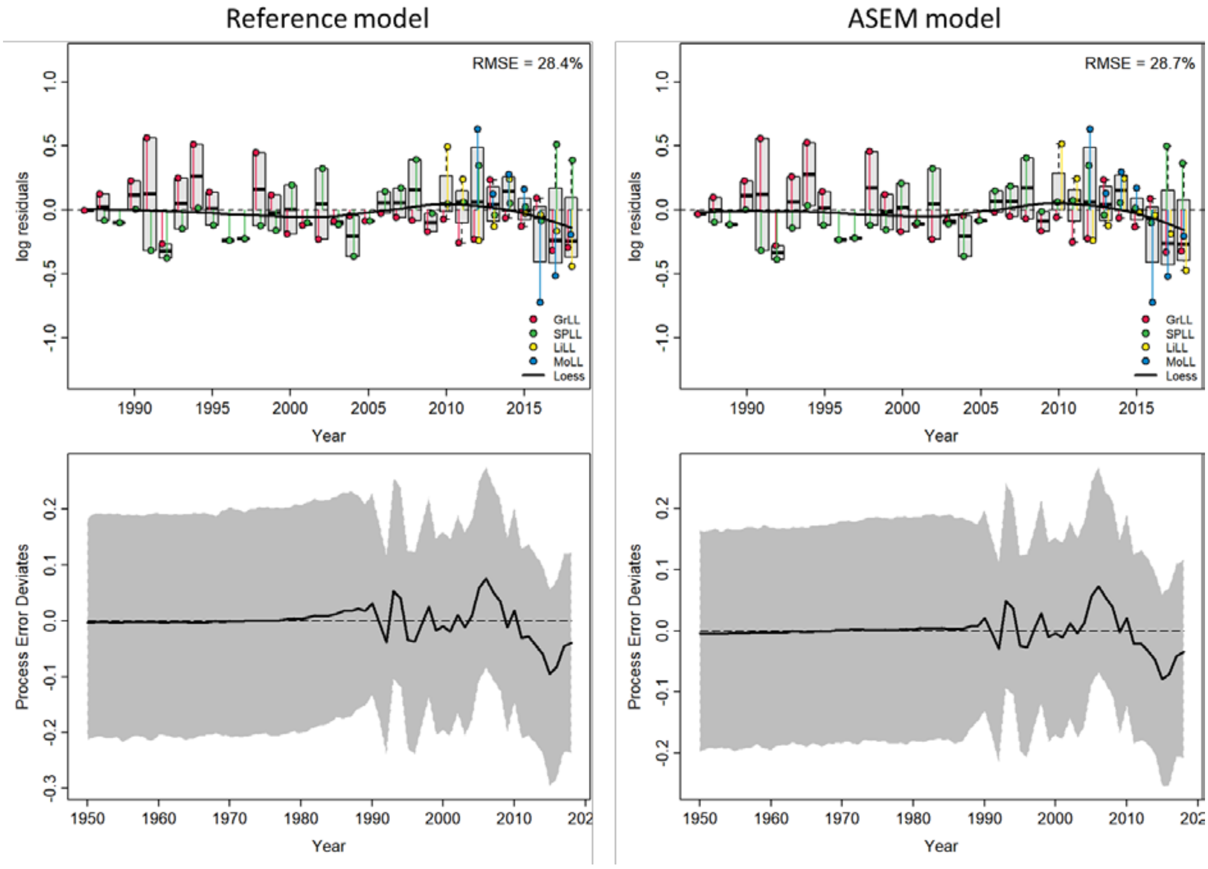
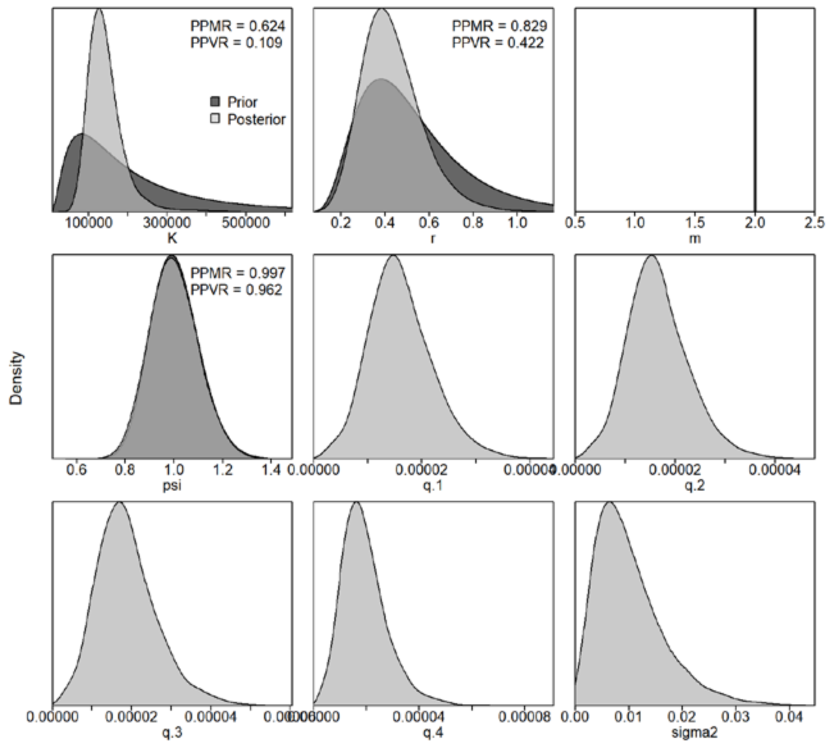


Figure 24. JABBA residual diagnostic plots for alternative sets of CPUE indices examined for each scenario (Left: Reference model; Right: ASEM model) for Mediterranean swordfish. Top panels: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate a loess smoother through all residuals. Bottom panels: Process error deviates (median: solid line) with shaded grey area indicating 95% credibility intervals.

Reference model



ASEM model

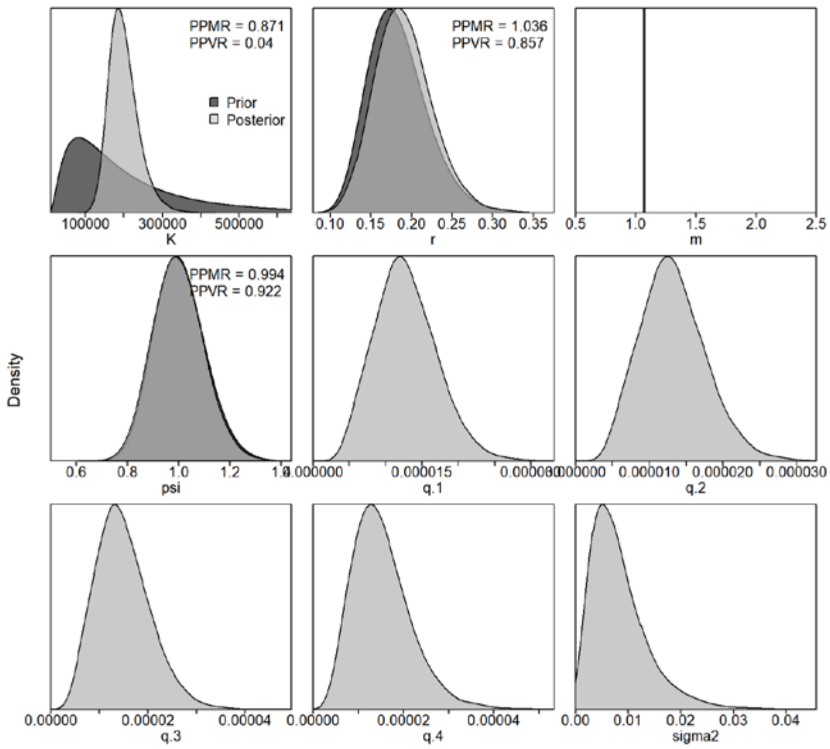


Figure 25. Prior and posterior distributions of various model and management parameters for the Bayesian state-space surplus production model for Mediterranean swordfish. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances. Upper panels: 'Reference' model and; Bottom panels: 'ASEM' model.

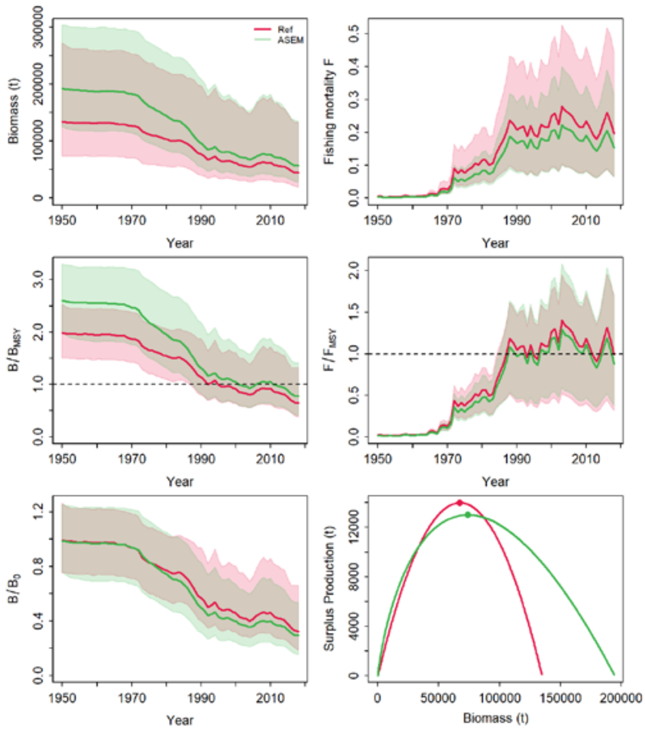


Figure 26. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean swordfish.

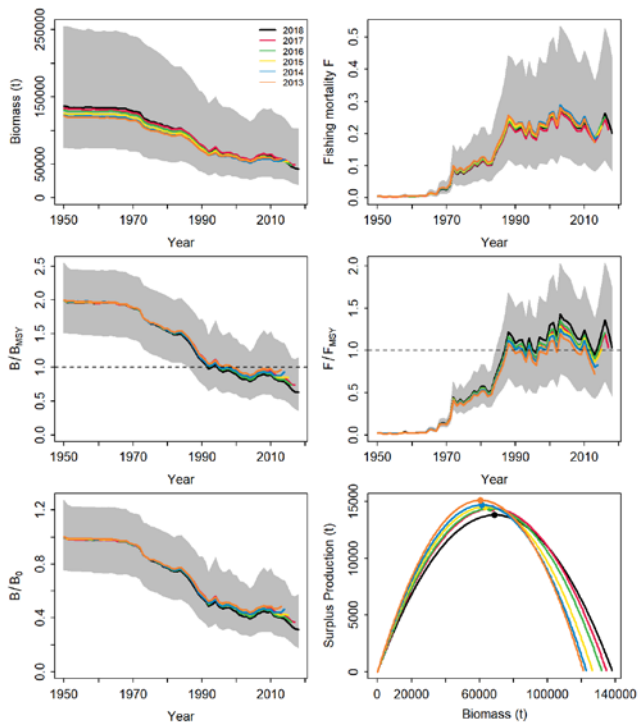


Figure 27. Retrospective analysis performed to the Reference model, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean swordfish.

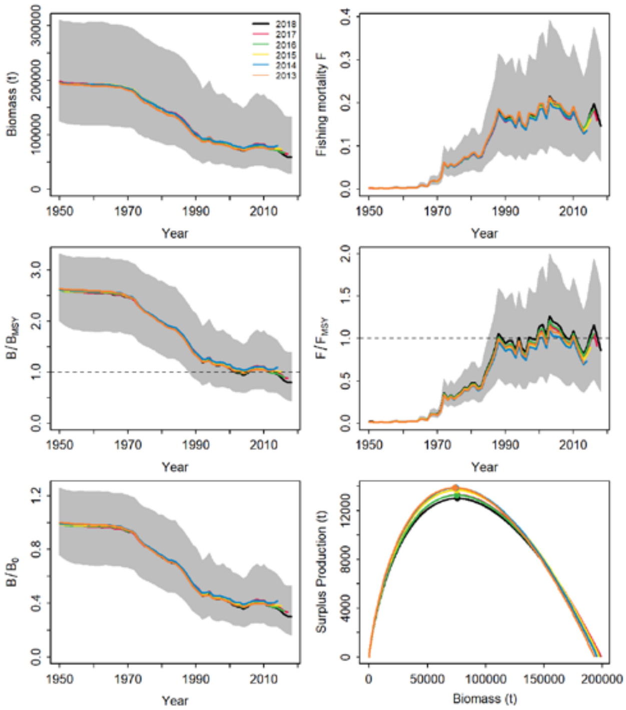


Figure 28. Retrospective analysis performed to the ASEM model, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean swordfish.

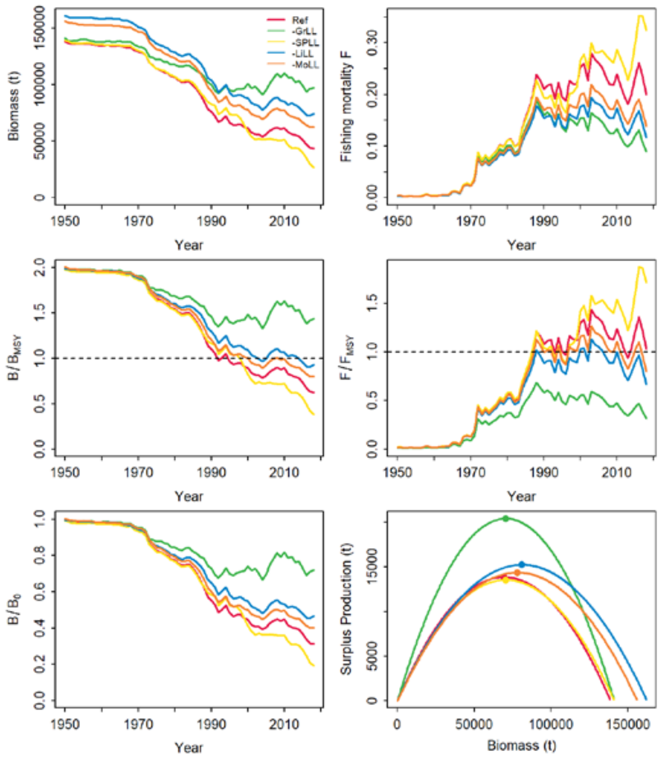


Figure 29. Jackknife index analysis performed to the Reference model, by removing one CPUE fleet at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean swordfish.

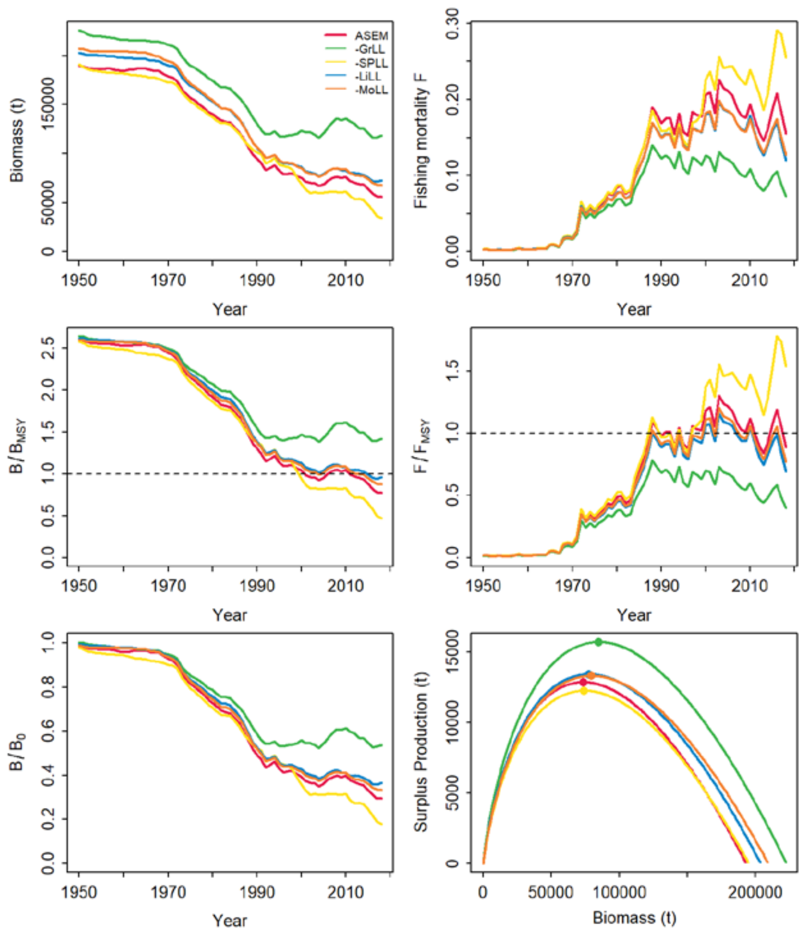


Figure 30. Jackknife index analysis performed to the ASEM model, by removing one CPUE fleet at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean swordfish.

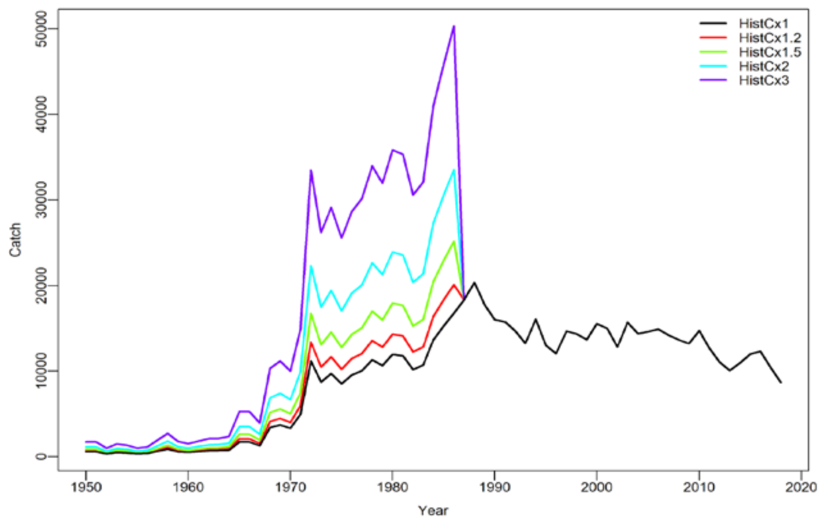


Figure 31. Alternative catch time series used in sensitivity runs to explore potential impacts of underreporting of early catches 1950-1986 by 20% (HistCx1.2), 50% (HistCx1.5), 100% (HistCx2) and 200% (HistCx3) on the JABBA assessment outputs.

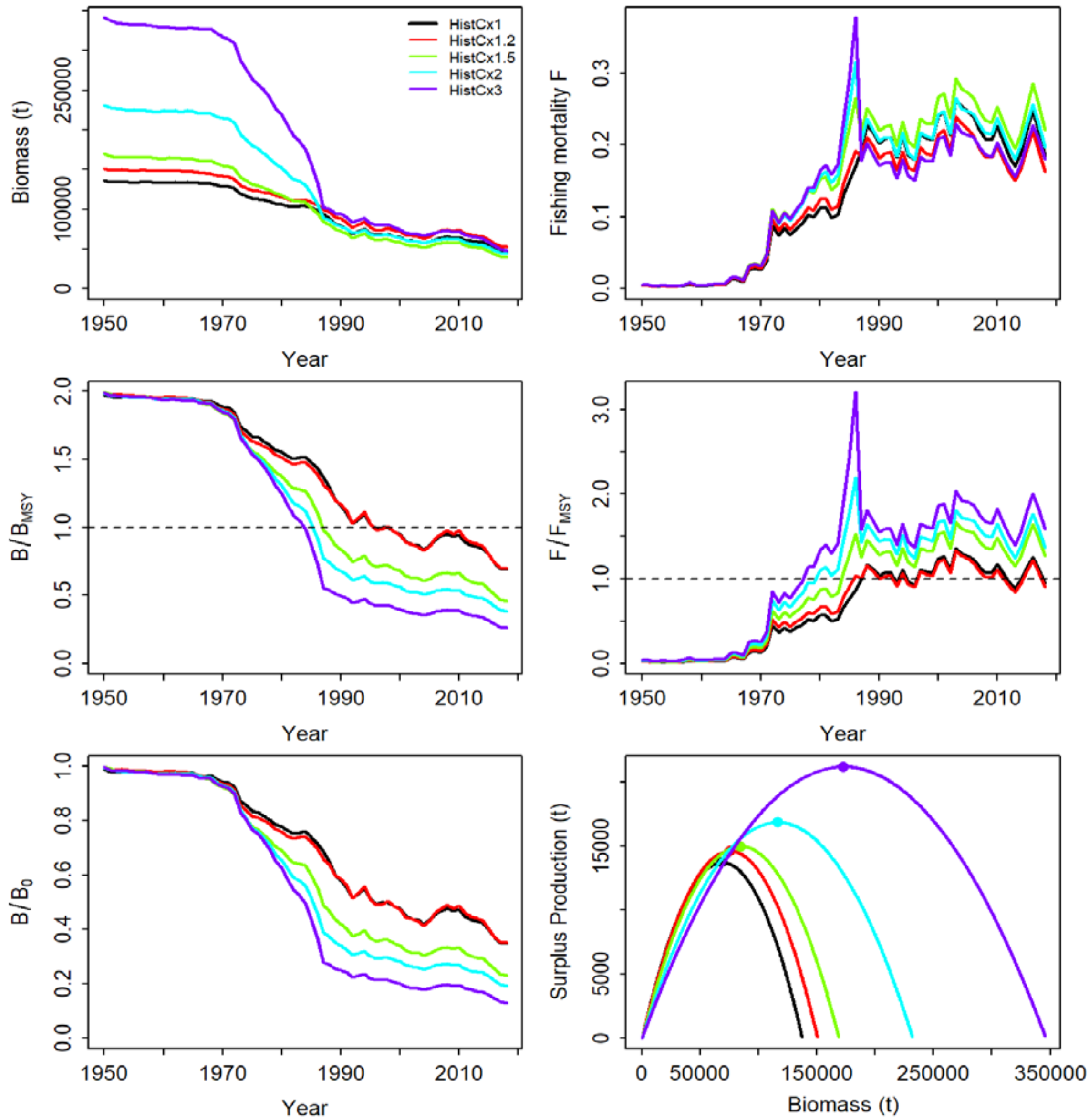


Figure 32. Sensitivity analysis performed to the Reference model for each assumption with regard to historical catches (multiplying the early catches from 1950 to 1986 by factors of 1.2, 1.5, 2 and 3) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean swordfish.

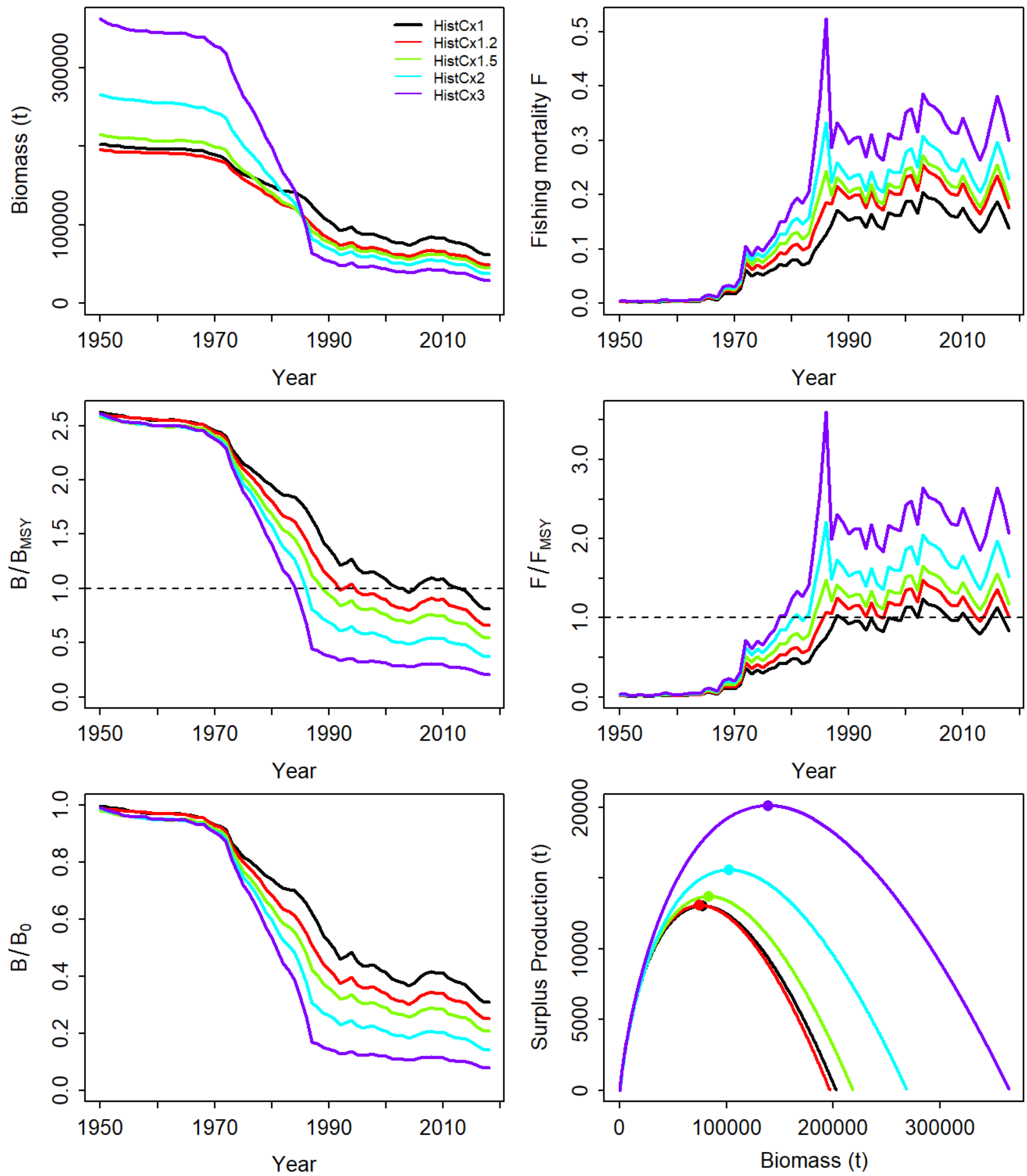


Figure 33. Sensitivity analysis performed to the ASEM model for each assumption with regard to historical catches (multiplying the early catches from 1950 to 1986 by factors of 1.2, 1.5, 2 and 3) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean swordfish.

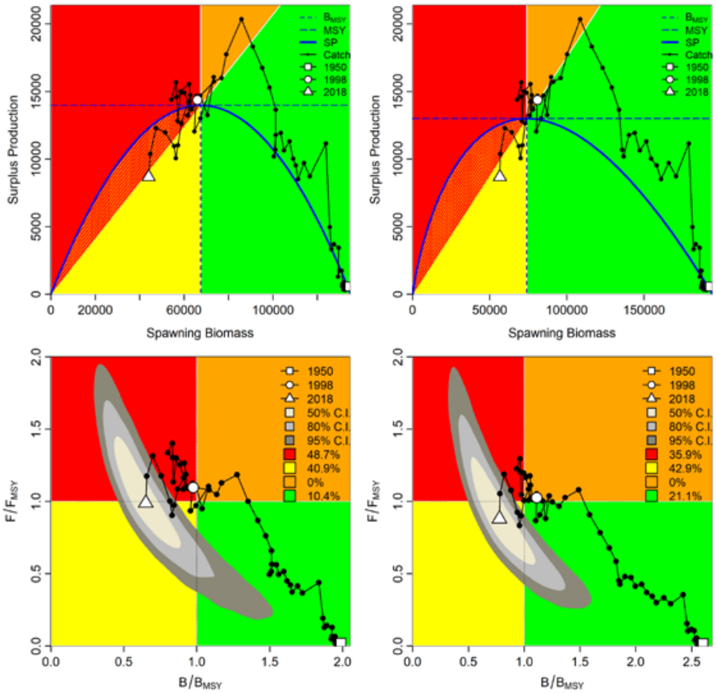


Figure 34. JABBA surplus production phase plot for the Reference Model (left panels) and the ASEM model (right panels) showing trajectories of the catches in relation to B_{MSY} and *MSY* (top panels) and Kobe phase plot showing estimated trajectories (1959-2018) of B/B_{MSY} and F/F_{MSY} for the Bayesian state-space surplus production model for the Mediterranean swordfish (bottom panels). Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

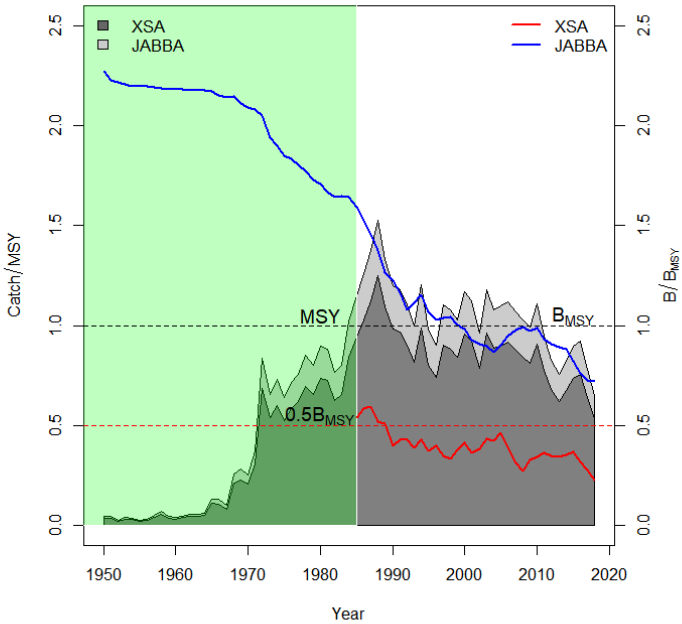


Figure 35. Illustration of catch series (1950-2018) relative to estimates of MSY (Catch/MSY) for the XSA final run including discards and combined JABBA model ('Reference' and 'ASEM') on the left y-axis and the corresponding model-precited trajectories of SSB/SSB_{MSY} and B/B_{MSY}, respectively, on right y-axis. The green-shaded areas demarcate the period (1950-1985) when catches remained below MSY and, accordingly, the stock would be expected to be in the green quadrant of the Kobe phase plot ($B > B_{MSY}$ and $F < F_{MSY}$) . Dashed black horizontal line denote catch and biomass levels at MSY, respectively and dashed red line denotes biomass level at 50% B_{MSY}.

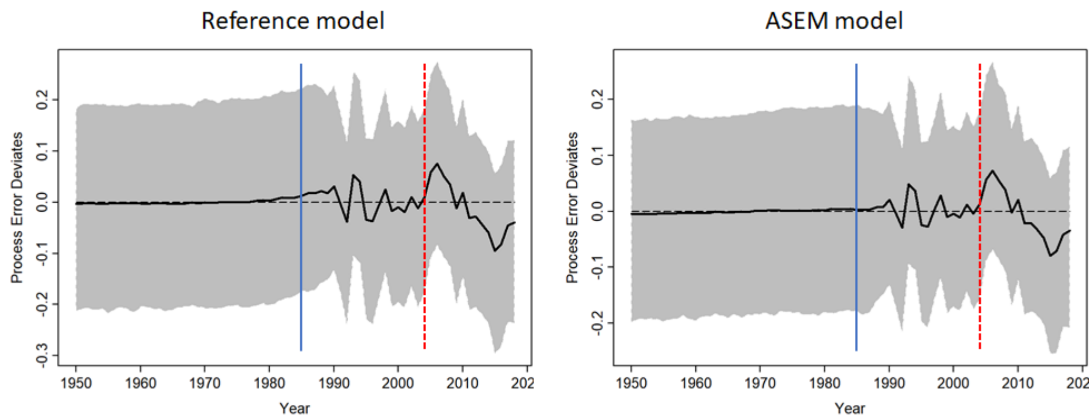


Figure 36. Process error deviates on the estimated biomass on log-scale (median: solid line) for JABBA models (Reference and ASEM models). Blue vertical lines show the year 1987 when relative abundances indices started to inform the model and red lines denote 2004 as the approximate year when the minimum size regulation was put in place.

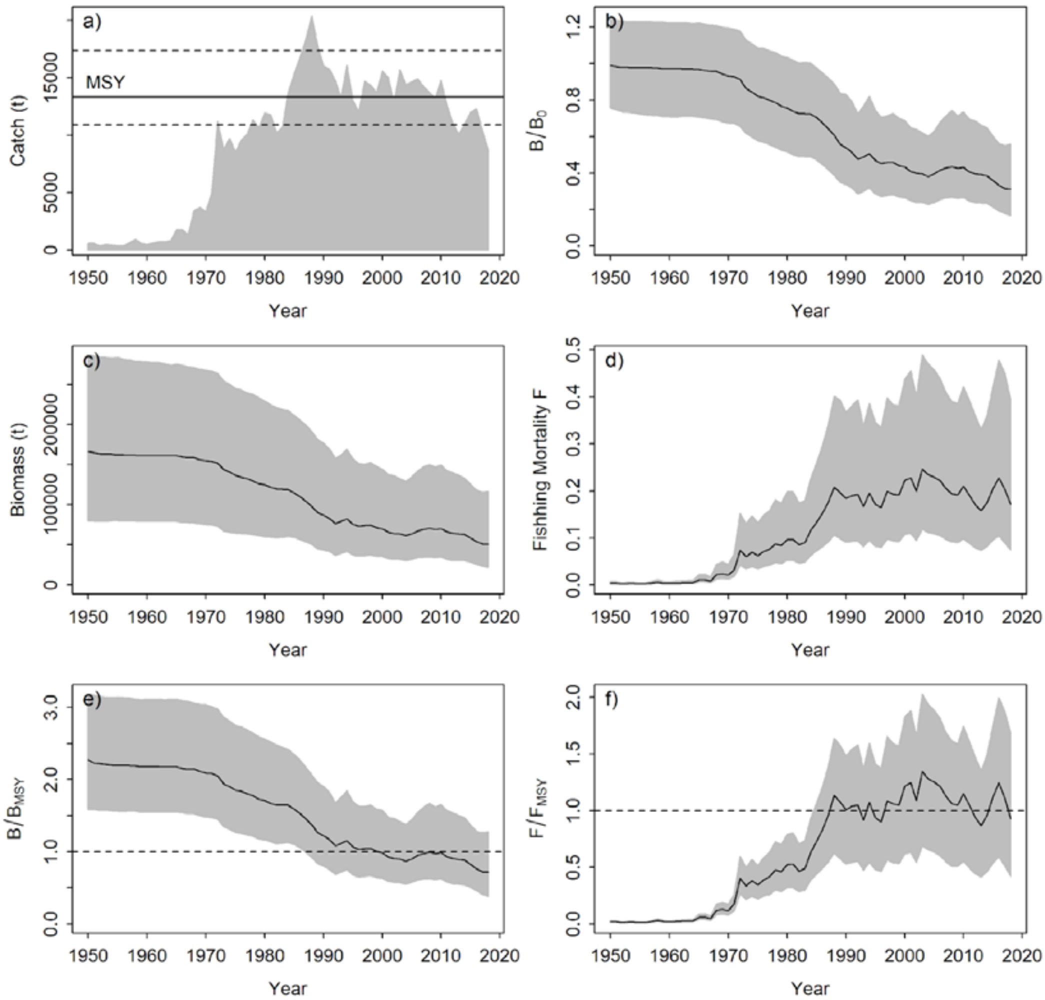


Figure 37. Final JABBA assessment model results for the Mediterranean swordfish in the form of joint MCMC posteriors of JABBA model runs ('Reference' and 'ASEM' models). (a) Catch time series depicting the *MSY* estimate with associated 95% credibility interval (dashed line); (b) biomass relative to B_0 (B/B_0) (upper panels); (c) trends in biomass and (d) fishing mortality; (e) trends of biomass relative to B_{MSY} (B/B_{MSY}); and (f) fishing mortality relative to F_{MSY} (F/F_{MSY}).

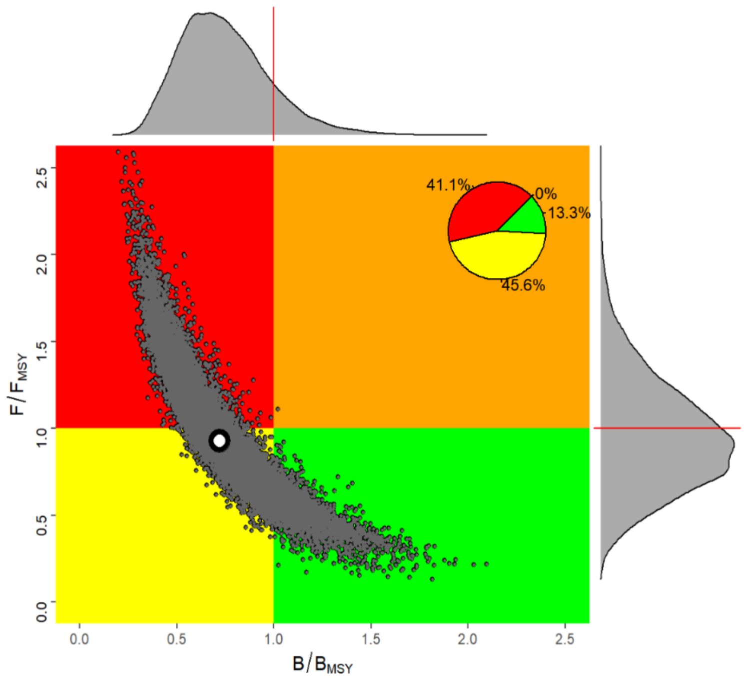


Figure 38. Kobe phase plot showing the combined posteriors of B_{2018}/B_{MSY} and F_{2018}/F_{MSY} presented in the form of joint MCMC posteriors of JABBA model runs ('Reference' and 'ASEM' models) for Mediterranean swordfish. The probability of posterior points falling within each quadrant is indicated in the pie chart.

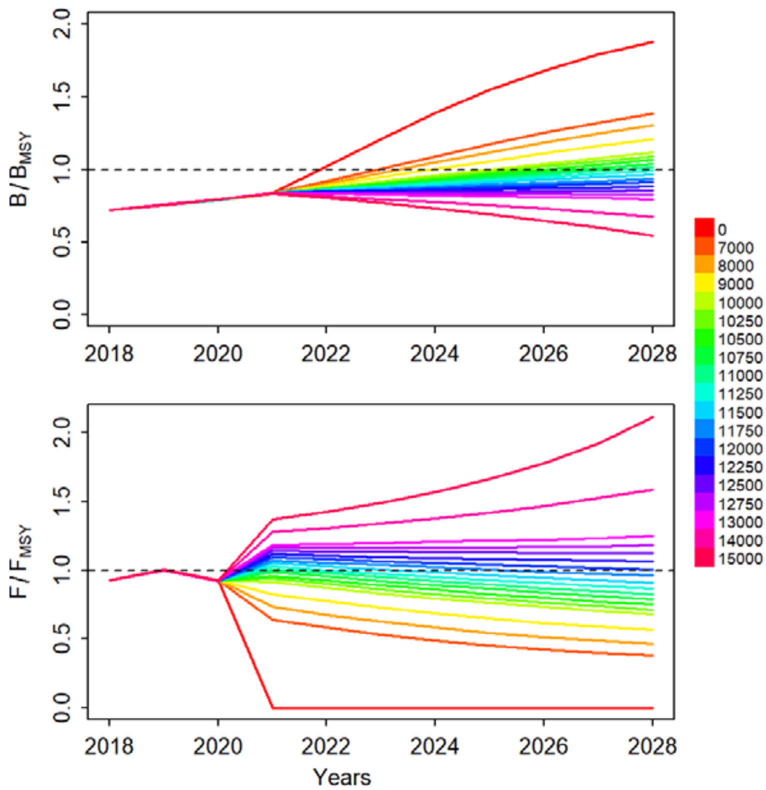


Figure 39. Trends of projected relative stock biomass (upper panel, B/B_{MSY}) and fishing mortality (bottom panel, F/F_{MSY}) of Mediterranean swordfish under different TAC scenarios (0 – 15,000 t), based on the combined projections of JABBA model runs ('Reference' and 'ASEM' models). Each line represents the median of 30000 MCMC iterations by projected year.

Appendix 1

Agenda

1. Opening, adoption of agenda and meeting arrangements
2. Summary of available data submitted according to the swordfish intersessional meeting deadlines
   - 2.1 Catches
   - 2.2 Length compositions
   - 2.3 Catch at size/age data
   - 2.4 Indices of abundance
   - 2.5 Biology
   - 2.6 Other relevant data
3. Relative abundance indices: overview of indexes to be potentially used based on the output of the swordfish intersessional meeting
4. Stock assessment methods and other data relevant to the assessment based on the output of the swordfish intersessional meeting
   - 4.1. Assessments models and Preliminary runs
     - 4.1.1. XSA
     - 4.1.2. a4a
     - 4.1.3. JABBA SPM
   - 4.2. New information for assessment. Historical data
5. Stock Assessment results
   - 5.1. Results
     - 5.1.1. XSA
     - 5.1.2. a4a
     - 5.1.3. JABBA SPM
   - 5.2. Synthesis of Stock Status and Final results
6. Projections
7. Recommendations
   - 7.1. Recommendations with financial implications
   - 7.2. Recommendations without financial implications
   - 7.3. Recommendations on management
8. Other matters
   - 8.1. Executive Summary
9. Adoption of the report and closure

Appendix 2

List of Participants

Intersessional Meeting of the Swordfish tuna Species Group (Online, 16 – 20 March 2020)

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Appendix 3

List of Papers and Presentations

Number	Title	Authors
SCRS/2020/028	Estimation of undersize Mediterranean swordfish (*Xiphias gladius*) catches by the main longline fleets between 2008 – 2018	Ortiz M.
SCRS/2020/043	Standardized Catch Rates for Mediterranean Swordfish (*Xiphias gladius* Linnaeus, 1758) from the Spanish Longline Fishery: 1988-2018.	Saber S., Macías D., García S., Riojax P., Góomez-Vives M.J., Godoy D., Meléndes M.J., Puerto M.A., and Ortiz de Urbina J.
SCRS/2020/058	Additions to the Italian annotated bibliography on swordfish (*Xiphias gladius*, Linnaeus, 1758) and comprehensive overview.	Di Natale A.
SCRS/2020/074	A clarification about stage 2 maturity in female swordfish (*Xiphias gladius*, Linnaeus, 1758)	Di Natale A., Garibaldi F., and Corriero A.
SCRS/2020/076	Estimation of catch at size and catch at age for the Mediterranean swordfish (*Xiphias gladius*) assessment 2020	Ortiz M., and Palma C.
SCRS/2020/077	Assessment of the Mediterranean swordfish stock by means of extended survivor analysis (XSA)	Tserpes G.,and Mantopoulou-Palouka D.
SCRS/2020/078	Assessment of the Mediterranean swordfish stock by means of assessment for all initiative (a4a)	Mantopoulou-Palouka D., and Tserpes G.
SCRS/2020/082	Developing of Bayesian state-space surplus production models JABBA for assessing Mediterranean swordfish (*Xiphias gladius*) stock	Mourato B.L., Winker H., Kimoto A., and Ortiz M.

SCRS/P/2020/028	Stock status, projections and K2SM for an ensemble of two JABBA assessment scenarios for Mediterranean swordfish (*Xiphias gladius*)	Winker H., Kimoto A., Mourato B.L., Tserpses G., and Ortiz M.
SCRS/P/2020/029	Final Assessment of the Mediterranean swordfish stock by means of extended survivor analysis (XSA)	Tserpes G.,and Mantopoulou-Palouka D.
SCRS/P/2020/030	Final Assessment of the Mediterranean swordfish stock by means of assessment for all initiative (a4a)	Mantopoulou-Palouka D., and Tserpes G.

Appendix 4

SCRS Document and Presentations Abstracts as provided by the authors

SCRS/2020/028 - Estimates of undersize Mediterranean swordfish catches were estimated using the size samples (task2sz) from the longline gear for 2008 – 2018. ICCAT minimum size landing regulations were implemented in 2014 (90 cm LJFL) and updated again in 2017 (100 cm LJFL). Prior research indicated that not all fleets have reported undersized catches/discards that can account for a significant percentage of the swordfish caught by the longline operations, which is currently the main fishing gear in the Mediterranean Sea. Estimated discards since 2008 represent overall about 12% to 14% between 2008 and 2017, and this increased to 24% in 2017/18 when the current minimum size was implemented.

SCRS/2020/043 – Standardized relative abundance indices for swordfish (*Xiphias gladius* Linnaeus, 1758) caught by the Spanish surface longline in the western Mediterranean Sea were estimated for the period 1988-2018. Standardized CPUEs in number were estimated through a General Linear Mixed Modelling (GLMM) approach under a negative binomial (NB) error distribution assumption. Standardized CPUEs in biomass were estimated through a General Linear Mixed Modelling (GLMM) approach under a log-normal error distribution assumption. The main factors in the standardization analysis were fishing area and time of the year (quarter). The standardized indices showed notable annual fluctuations without any definite trend for the period under study.

SCRS/2020/058 – After the very first attempt to list together the many papers published so far on swordfish (Xiphias gladius) by Italian scientists, concerning the biology of this species, the fisheries and many other scientific and cultural issues, it was necessary to prepare an addition to the annotated bibliography published in 2019. Therefore, the present paper provides 185 additional papers, all annotated with specific keywords, which brings the available papers on this species up to 715, all duly annotated. This paper also provides an overview of the papers published over the centuries and decades, the main authors and the score of the main topics and themes included in the papers. This updated bibliography was set together to serve the scientists and to help them in finding some rare references that might be useful for their work.

SCRS/2020/074 – Recent documents generically provided the misleading information that most of the previous assessment of stage 2 maturity in female swordfish (*Xiphias gladius*) were erroneous. This short paper provides the augmented evidence that stage 2 maturity was always correctly attributed to female gonads which were in a developing stage and not mature. This clarification is important for avoiding uncertainties and spending unnecessary funds for searching what is already established since many decades.

SCRS/2020/076 – Catch-at-Size and catch-at-age of Mediterranean swordfish was estimated and preliminary analyses performed for its use within the stock evaluation models. The estimates used the size/catch at size data and or catch-at age data submitted to the Secretariat by CPCs under the Task II requirements, and new information from data recovery projects. With the new information it was possible to estimate and revise the CAS from 1972 to 2018, updating also the fishing gear associated with most of the annual catches within this period. Catch at age was estimated using two approaches; an estimation based on decomposing size mixture distributions and a monthly age-slicing growth function inversion. Both approaches assumed the current von Bertalanffy growth model for Mediterranean swordfish with estimates of variance of size at age. Results indicated that about 70% of the total catch is of ages 1, 2, and 3. Preliminary estimates of overall mortality were also produced from a catch curve analysis indicating on average total mortality Z of 0.56 (± 0.15 st.dev) and full fishery selectivity at age 2-3.

SCRS/2020/077 – Updated assessments of the Mediterranean swordfish stock are performed by means of Extended Survivors Analysis (XSA). They include a continuity run employing the model settings used in the 2016 ICCAT assessment, as well as candidate runs using modified model settings and two different assumptions regarding natural mortality-at-age. Additionally, scenarios assuming discards have been considered. All assessment runs indicate that the stock is overexploited and the current fishing mortality rates are higher than those corresponding to maximum sustainable yield (MSY) levels.

SCRS/2020/078 – Assessments of the Mediterranean swordfish stock are performed using a statistical catch-at-age model, developed in the framework of the Assessment for All (a4a) Initiative of the European Commission Joint Research Centre. Four runs are presented, including assumptions on natural mortality and the presence of discards in the catch. The model structural components are kept the same for each run. All of the assessment runs indicate that the stock is overexploited and the current fishing mortality rates are higher than those corresponding to maximum sustainable yield (MSY) levels.

SCRS/2020/082 – Bayesian State-Space Surplus Production Models were fitted to Mediterranean swordfish (*Xiphias gladius*) catch and CPUE data using the 'JABBA' R package. This document presents details on the model diagnostics and stock status estimates for two preliminary scenarios. For the 'Reference' model we used an existing prior distribution for r with log(r) ~ N(log(0.45),0.46) with a fixed input value of BMSY/K = 0.5 (Schaefer model-type), while for the 'ASEM' model we derived a new r prior with log(r) ~ N(log(0.206),0.2) and a fixed input value of BMSY/K = 0.38 (Pella-Tomlinson model type) from an Age-structured Equilibrium Model with Monte-Carlo simulations.. In general, our results suggest that both candidate models provide reasonably robust fits to the data as judged by the presented model diagnostic results. The only notably difference in terms of performance is the slightly improved retrospective pattern for the 'ASEM' model. Both models predicted an overall similar exploitation history, with the peak in total catches in 1982 (~ 20,000 tons) also demarcating the onset of an extended period of overfishing. This was associated with continuous declines in stock biomass and eventually led to an overfished stock. The model-specific stock status posteriors for 2018 showed that the 'ASEM' model was more optimistic with a cumulative probability of over 60% (yellow + green) that current fishing mortality is currently sufficiently low enough to facilitate stock rebuilding. The 'Reference' model, by contrast, suggests that there is a more than 50% probably that stock remains overfish and that overfishing is still occurring. However, sensitivity analysis with regards various levels of under reporting early catches prior to 1987 revealed that the JABBA assessment result strongly dependent on the reliability of the historical catch time series. Raising the historical catch by a factor three would result a decrease in biomass levels of about 50% of B/BMSY by 1990, which would be broadly comparable to the otherwise considerably more pessimistic 2016 XSA assessment model predictions.

SCRS/P/2020/028 – Summary of the Mediterranean swordfish assessment results applying Bayesian State-Space Surplus Production Models (JABBA) in SCRS/2020/082 was provided with the Kobe plot, Chicken feet plots and Kobe 2 matrix based on the agreed projection settings by the Group for "Reference" and "ASEM" models. The projections were conducted for a range constant catch scenarios, including a reference scenario of zero catch and then covering a range from 9000 t to 15,000 t at specific intervals and for a period of 10 years (2019-2028). The catches for 2019 and 2020 were set to be 9,879 t and 9,583 t, which corresponds to the TAC set for 2019 and 2020, respectively.

SCRS/P/2020/029 – Updated assessments of the Mediterranean swordfish stock are performed by means of Extended Survivors Analysis (XSA) during the meeting based on SCRS/2020/077. Two runs are developed using the Spanish longline index in number, with and without discards. Results indicate that recruitment follows a decreasing trend, particularly in the last decade while current SSB levels are less than half of those observed at the beginning of the period.

SCRS/P/2020/030 – Further stock assessment results applying a4a to the Mediterranean swordfish stocks were provided for the requests by the Group based on SCRS/2020/078. The Ligurian surface longline index from 1991 to 2009 was additionally incorporated, and the two new runs results were provided with their reference points assuming constant M with/without discards. The updated results were similar to those in SCRS/2020/078, and the Group accepted those runs as final a4a results.

Appendix 5

XSA FINAL RUNS

Table 1. Control settings for the XSA runs.

Parameters	Settings
shk.n	TRUE
shk.yrs	10
rage	1
maxit	100
shk.f	TRUE
shk.ages	4
fse	0.5
min.nse	0.3
qage	6
window	100
tsrange	20
tspower	1
vpa	TRUE
F range:minbar	2
maxfbar	4

a. Base run

Table 2. Estimates of stock number-at-age for the base run.

```
age 1985       1986       1987       1988       1989       1990
  0 1.2342e+06 1.2608e+06 1.2960e+06 1.2736e+06 1.2578e+06 1.2099e+06
  1 9.9524e+05 1.0067e+06 1.0307e+06 1.0589e+06 1.0383e+06 1.0241e+06
  2 7.1831e+05 7.2933e+05 7.5615e+05 7.6961e+05 7.5197e+05 7.5689e+05
  3 4.3199e+05 4.2551e+05 4.4068e+05 4.5496e+05 4.2689e+05 4.4040e+05
  4 1.9422e+05 1.9654e+05 1.8446e+05 1.8665e+05 1.6873e+05 1.7326e+05
  5 9.3050e+04 1.0660e+05 1.0379e+05 9.2859e+04 8.4970e+04 8.0926e+04
  6 4.6495e-01 2.2168e+00 1.7596e+00 1.9186e+00 1.2792e+00 5.1920e-01

age 1991       1992       1993       1994       1995       1996
  0 1.2423e+06 1.2567e+06 1.2201e+06 1.2847e+06 1.4294e+06 1.3292e+06
  1 9.8120e+05 1.0089e+06 1.0212e+06 9.9271e+05 1.0479e+06 1.1601e+06
  2 7.2301e+05 7.0143e+05 7.3097e+05 7.3208e+05 7.0821e+05 7.5396e+05
  3 4.0946e+05 4.0499e+05 3.9869e+05 4.1487e+05 3.9651e+05 3.9476e+05
  4 1.6632e+05 1.6255e+05 1.7106e+05 1.6583e+05 1.6788e+05 1.6524e+05
  5 7.9824e+04 7.9648e+04 8.0122e+04 8.6508e+04 7.6665e+04 8.5283e+04
  6 1.0600e+01 1.1466e-01 1.0407e+00 1.0089e+00 1.3154e+00 3.8134e+03

age 1997       1998       1999       2000       2001       2002
  0 1.2903e+06 1.2950e+06 1.2130e+06 1.3371e+06 1.2590e+06 9.8627e+05
  1 1.0883e+06 1.0529e+06 1.0470e+06 9.9110e+05 1.0947e+06 1.0287e+06
  2 8.3678e+05 7.5494e+05 7.3322e+05 7.5226e+05 7.1476e+05 7.8549e+05
  3 4.5205e+05 4.4817e+05 3.9779e+05 3.9351e+05 4.0404e+05 3.7557e+05
  4 1.7995e+05 1.6515e+05 1.6772e+05 1.7043e+05 1.6181e+05 1.5203e+05
  5 8.6839e+04 7.9816e+04 7.1075e+04 8.2619e+04 7.7562e+04 7.2902e+04
  6 2.5433e+00 7.5124e-01 9.8436e-01 1.3544e+00 5.4097e-01 1.3812e+04

age 2003       2004       2005       2006       2007       2008
  0 1.1083e+06 1.0635e+06 9.8586e+05 1.2255e+06 1.1229e+06 9.4534e+05
  1 8.0749e+05 8.9355e+05 8.5403e+05 7.5341e+05 1.0011e+06 9.0551e+05
  2 7.4935e+05 5.5802e+05 6.2235e+05 6.4558e+05 5.5152e+05 7.1655e+05
```

3	4.7460e+05	4.2106e+05	2.6909e+05	3.4234e+05	3.4523e+05	2.6824e+05
4	1.5606e+05	2.1160e+05	1.7234e+05	1.4444e+05	1.4509e+05	1.1523e+05
5	7.4652e+04	7.1087e+04	1.1789e+05	7.7345e+04	6.4388e+04	6.4915e+04
6	1.0293e+00	1.4869e+00	5.7480e-01	1.2341e+00	1.3012e+00	1.8418e+03

age	2009	2010	2011	2012	2013	2014
0	8.5267e+05	9.7132e+05	8.5398e+05	7.4769e+05	8.4627e+05	6.3066e+05
1	7.6529e+05	6.9810e+05	7.9459e+05	6.5258e+05	6.1099e+05	6.9270e+05
2	6.4149e+05	5.2453e+05	4.7600e+05	4.6709e+05	4.7412e+05	4.4875e+05
3	3.1029e+05	3.4559e+05	2.7794e+05	2.8117e+05	2.6930e+05	2.7984e+05
4	1.6443e+05	1.5350e+05	1.4128e+05	1.3586e+05	1.3491e+05	1.3040e+05
5	3.3272e+04	7.0501e+04	7.4571e+04	7.1432e+04	7.5835e+04	7.6539e+04
6	1.3666e+03	4.5857e-01	1.9034e+00	1.8562e+00	2.3768e-01	9.1212e-01

age	2015	2016	2017	2018
0	5.8328e+05	4.7859e+05	5.9481e+05	5.8293e+05
1	5.1634e+05	4.7755e+05	3.9183e+05	4.8662e+05
2	5.3089e+05	3.8666e+05	3.2289e+05	3.0422e+05
3	2.5558e+05	2.6395e+05	1.9181e+05	1.8823e+05
4	1.3534e+05	1.3246e+05	1.0133e+05	8.9787e+04
5	6.9523e+04	6.1405e+04	7.1211e+04	4.7828e+04
6	1.6656e+04	3.7343e+04	2.2439e+00	6.4978e-01

Table 3. Estimates of harvest-at-age for the base run.

age	1985	1986	1987	1988	1989	1990
0	3.6919e-03	1.5087e-03	2.0751e-03	4.2898e-03	5.5152e-03	9.4804e-03
1	1.1086e-01	8.6216e-02	9.2098e-02	1.4228e-01	1.1611e-01	1.4816e-01
2	3.2361e-01	3.0380e-01	3.0804e-01	3.8934e-01	3.3503e-01	4.1437e-01
3	5.8752e-01	6.3587e-01	6.5910e-01	7.9190e-01	7.0177e-01	7.7375e-01
4	3.9988e-01	4.3856e-01	4.8634e-01	5.8693e-01	5.3476e-01	5.7494e-01
5	3.5546e-01	3.6611e-01	3.8639e-01	4.7761e-01	4.2191e-01	4.7781e-01
6	3.5546e-01	3.6611e-01	3.8639e-01	4.7761e-01	4.2191e-01	4.7781e-01

age	1991	1992	1993	1994	1995	1996
0	8.1095e-03	7.5182e-03	6.2385e-03	3.7254e-03	8.7756e-03	1.6187e-09
1	1.3565e-01	1.2222e-01	1.3284e-01	1.3771e-01	1.2922e-01	1.2668e-01
2	3.7956e-01	3.6493e-01	3.6640e-01	4.1319e-01	3.8445e-01	3.1155e-01
3	7.2384e-01	6.6183e-01	6.7721e-01	7.0471e-01	6.7529e-01	5.8561e-01
4	5.3631e-01	5.0746e-01	4.8180e-01	5.7154e-01	4.7729e-01	4.4335e-01
5	4.4384e-01	4.1411e-01	4.1456e-01	4.5678e-01	4.1656e-01	3.6680e-01
6	4.4384e-01	4.1411e-01	4.1456e-01	4.5678e-01	4.1656e-01	3.6680e-01

age	1997	1998	1999	2000	2001	2002
0	3.3944e-03	1.2547e-02	2.0485e-03	1.2958e-05	2.0115e-03	6.5333e-09
1	1.6570e-01	1.6181e-01	1.3065e-01	1.2688e-01	1.3193e-01	1.1688e-01
2	4.2438e-01	4.4072e-01	4.2236e-01	4.2158e-01	4.4351e-01	3.0385e-01
3	8.0691e-01	7.8290e-01	6.4760e-01	6.8865e-01	7.7743e-01	6.7821e-01
4	6.1296e-01	6.4315e-01	5.0805e-01	5.8725e-01	5.9733e-01	5.1124e-01
5	5.0249e-01	5.0715e-01	4.2716e-01	4.5885e-01	5.0870e-01	4.2876e-01
6	5.0249e-01	5.0715e-01	4.2716e-01	4.5885e-01	5.0870e-01	4.2876e-01

age	2003	2004	2005	2006	2007	2008
0	1.5370e-02	1.9378e-02	6.8906e-02	2.2437e-03	1.5203e-02	1.1296e-02
1	1.6953e-01	1.6170e-01	7.9816e-02	1.1193e-01	1.3444e-01	1.4471e-01
2	3.7643e-01	5.2935e-01	3.9768e-01	4.2595e-01	5.2080e-01	6.3692e-01
3	6.0775e-01	6.9333e-01	4.2222e-01	6.5849e-01	8.9725e-01	2.8937e-01
4	5.8632e-01	3.8499e-01	6.0117e-01	6.0791e-01	6.0425e-01	1.0422e+00

5	4.7275e-01	4.8179e-01	5.8348e-01	5.5491e-01	5.3320e-01	5.2755e-01
6	4.7275e-01	4.8179e-01	5.8348e-01	5.5491e-01	5.3320e-01	5.2755e-01

age	2009	2010	2011	2012	2013	2014
0	2.1610e-09	8.2627e-04	6.8961e-02	1.9157e-03	2.4618e-04	2.2476e-07
1	1.7775e-01	1.8295e-01	3.3131e-01	1.1948e-01	1.0860e-01	6.6050e-02
2	4.1852e-01	4.3509e-01	3.2647e-01	3.5068e-01	3.2726e-01	3.6294e-01
3	5.0381e-01	6.9450e-01	5.1581e-01	5.3437e-01	5.2525e-01	5.2640e-01
4	6.4688e-01	5.2195e-01	4.8202e-01	3.8304e-01	3.6677e-01	4.2893e-01
5	3.3503e-01	5.1559e-01	3.9366e-01	3.3577e-01	3.0832e-01	3.0085e-01
6	3.3503e-01	5.1559e-01	3.9366e-01	3.3577e-01	3.0832e-01	3.0085e-01

age	2015	2016	2017	2018
0	2.5404e-08	9.9621e-07	7.5485e-04	3.5328e-03
1	8.9225e-02	1.9135e-01	5.3090e-02	6.8659e-02
2	4.9880e-01	5.0104e-01	3.3965e-01	3.3155e-01
3	4.5726e-01	7.5734e-01	5.5905e-01	5.3277e-01
4	5.9031e-01	4.2063e-01	5.5079e-01	4.2985e-01
5	2.0524e-01	3.5724e-01	4.2669e-01	3.9316e-01
6	2.0524e-01	3.5724e-01	4.2669e-01	3.9316e-01

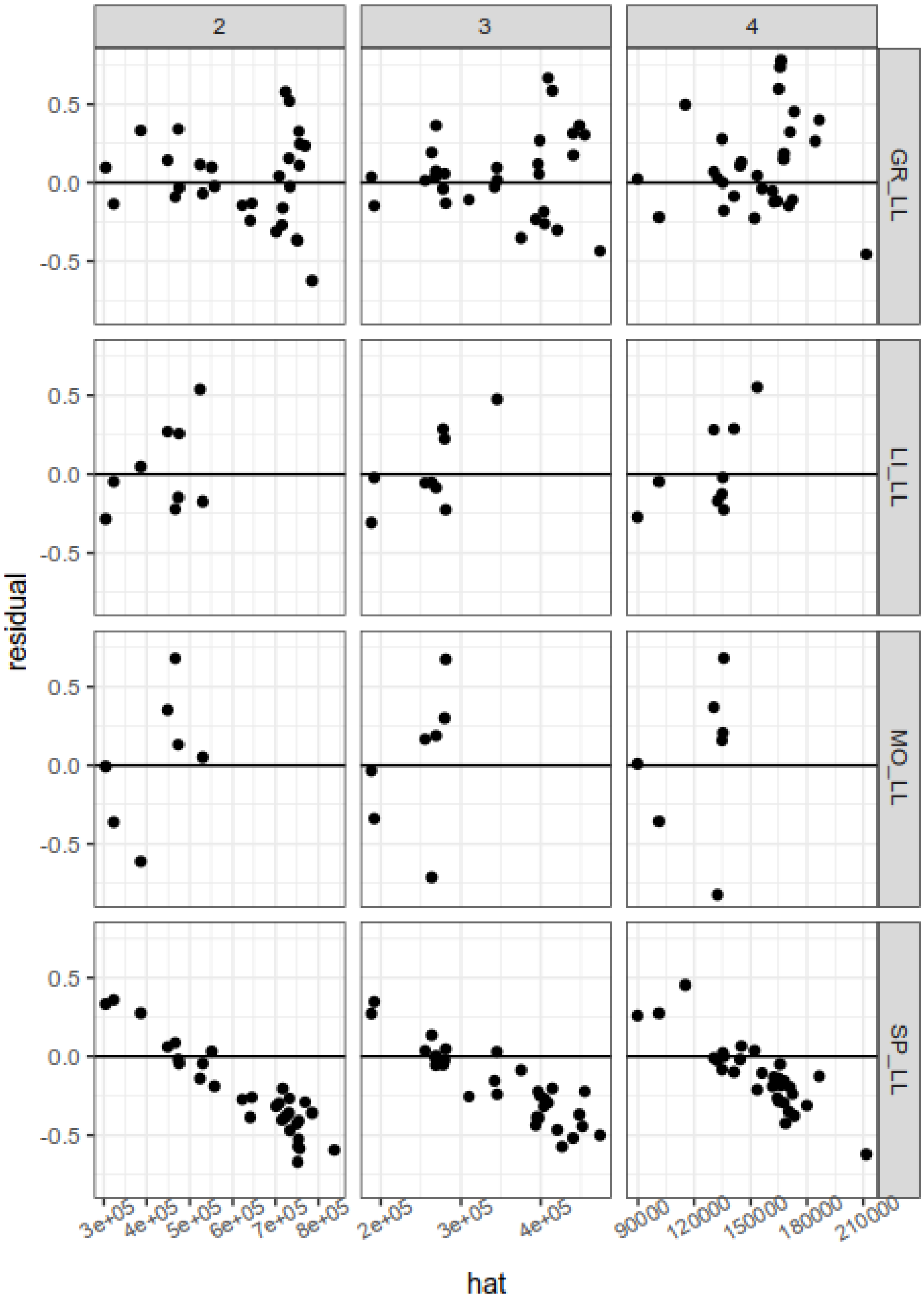

Figure 1. Residuals against fitted value for the base run.

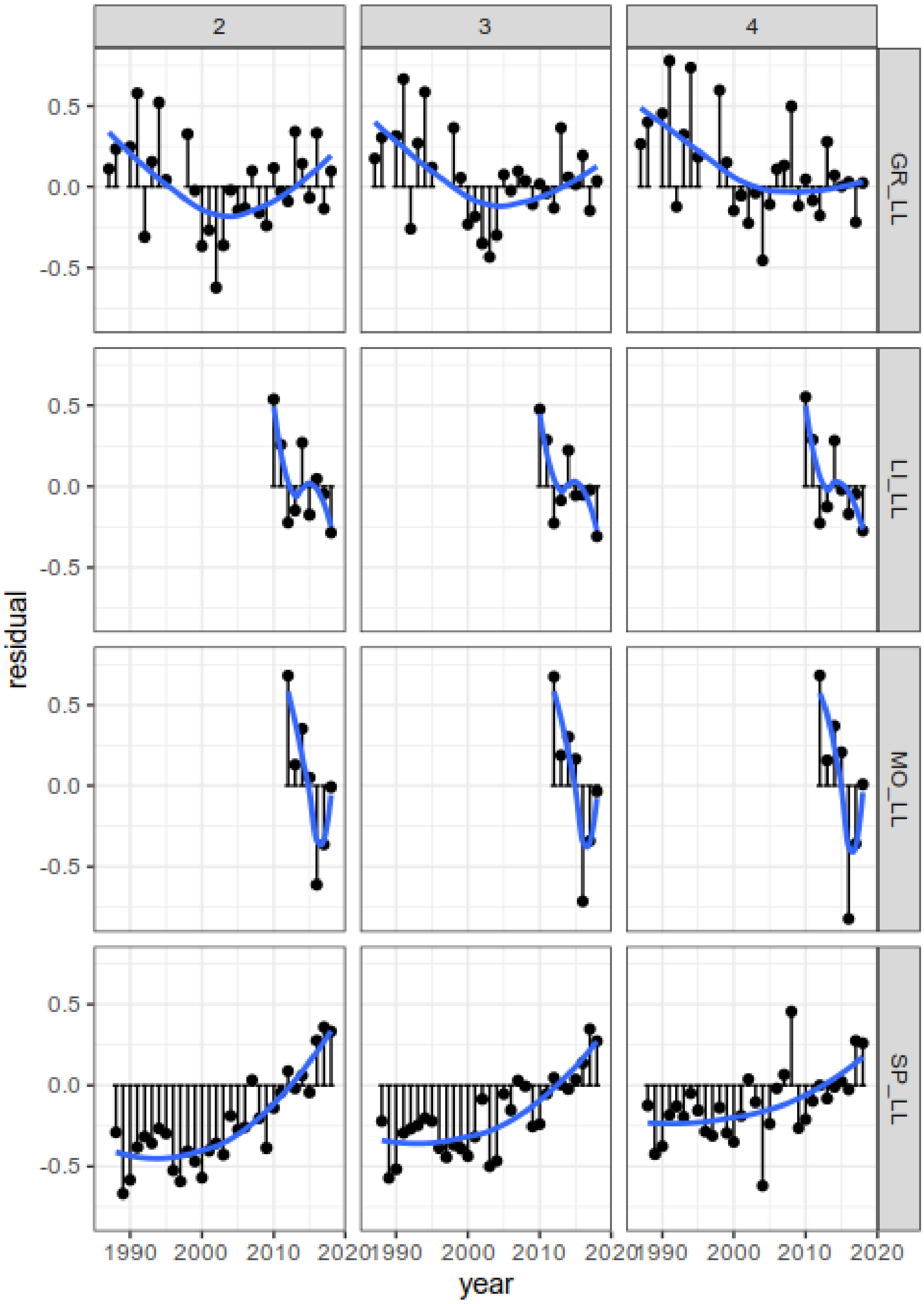

Figure 2. Residuals by fleet against year for the base run.

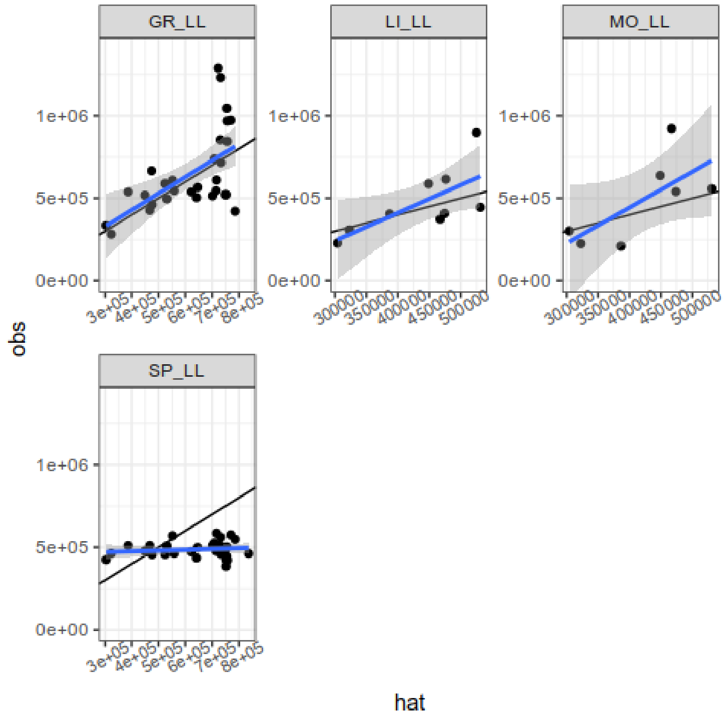

Figure 3. Calibration regression plots for age 2 for the base run. The blue line is a linear regression fitted to the residual pairs and the black line is the y=x line. If the index is proportional to stock abundance, then the blue and black lines should coincide.

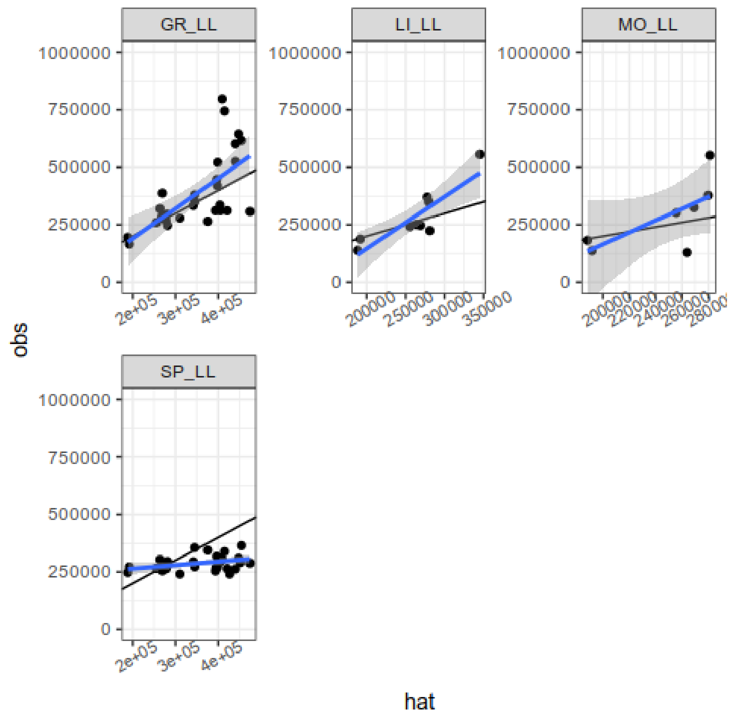

Figure 4. Calibration regression plots for age 3 for the base run. The blue line is a linear regression fitted to the residual pairs and the black line is the y=x line. If the index is proportional to stock abundance, then the blue and black lines should coincide.

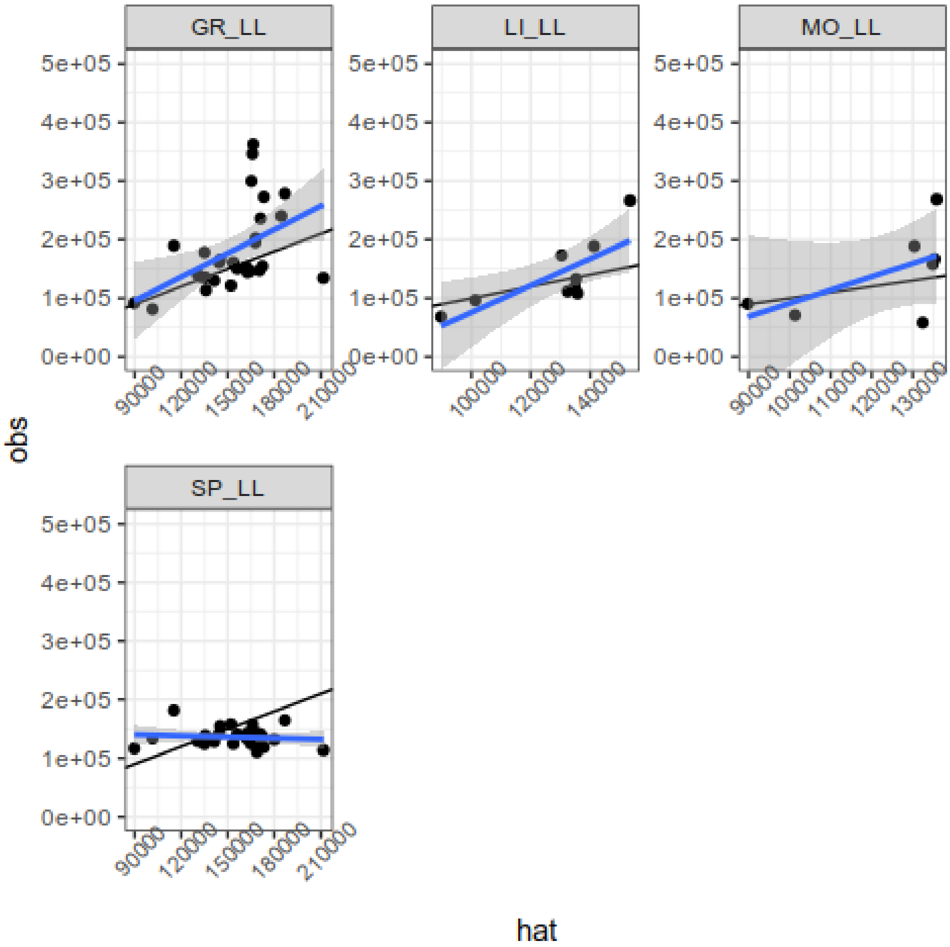

Figure 5. Calibration regression plots for age 4 for the base run. The blue line is a linear regression fitted to the residual pairs and the black line is the y=x line. If the index is proportional to stock abundance, then the blue and black lines should coincide.

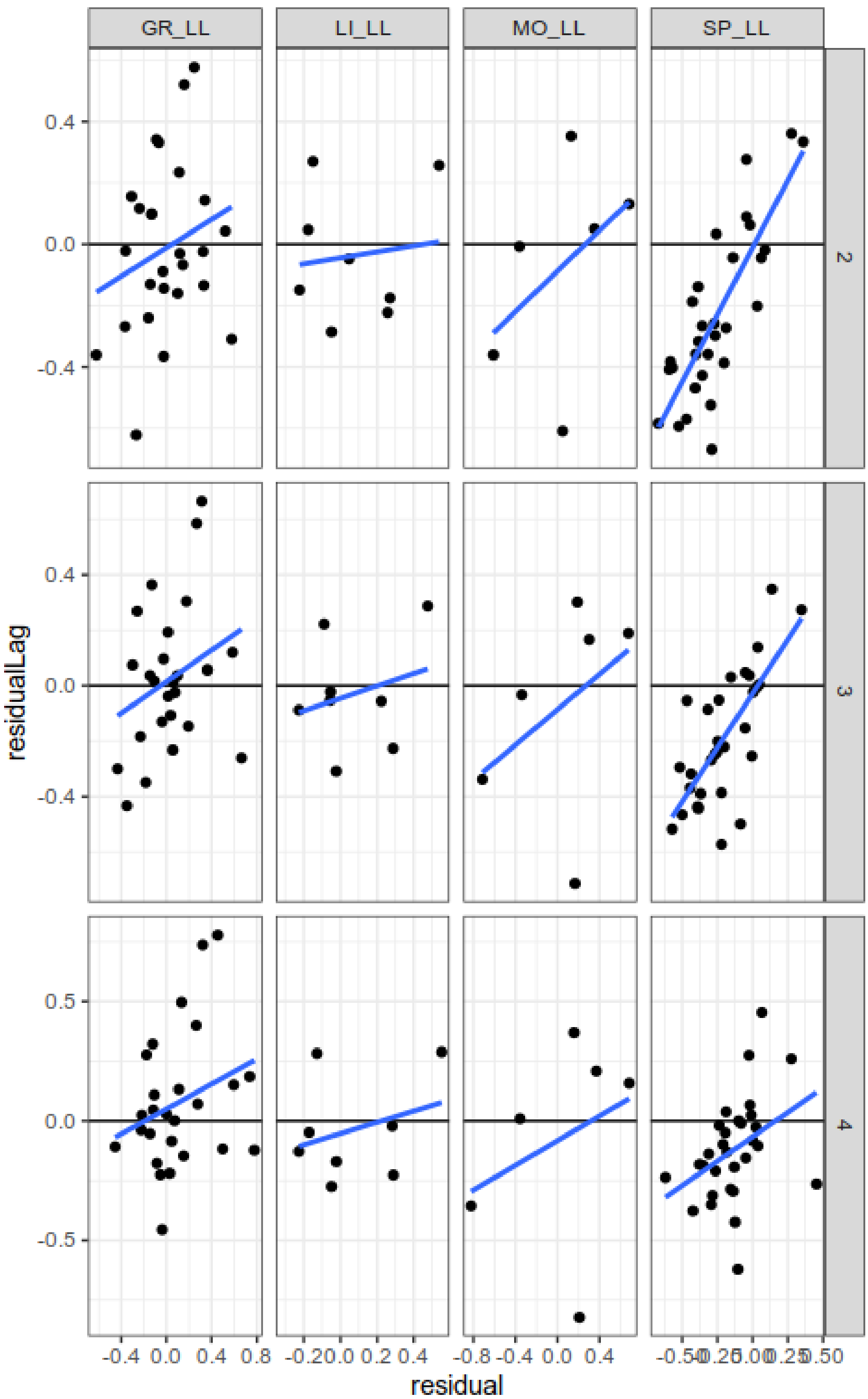

Figure 6. AR plots of lagged residuals for the base run. Blue line is the regression fitted to the data pairs. If residuals are uncorrelated then the slope of the regression should be 0.

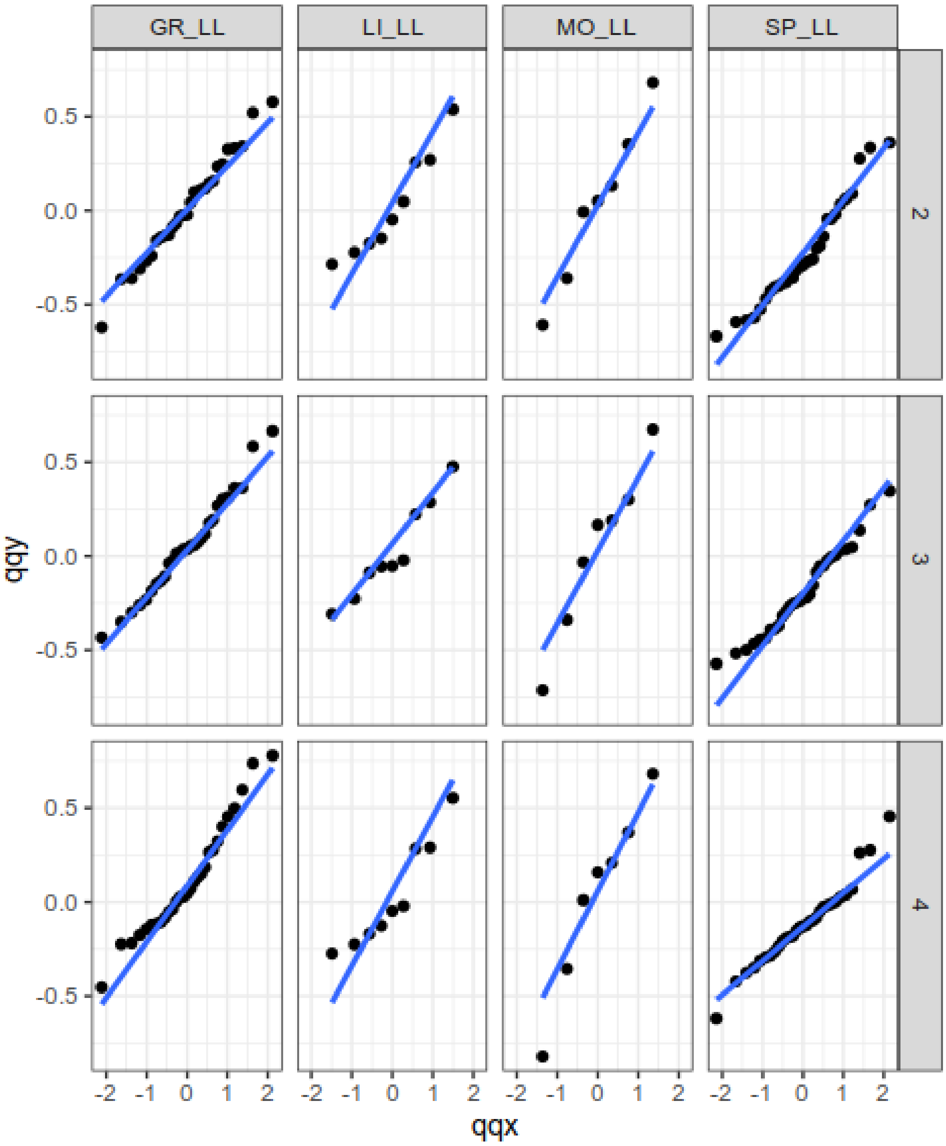

Figure 7. QQ plots to check for log normality (i.e. points and line should coincide) for the base run.

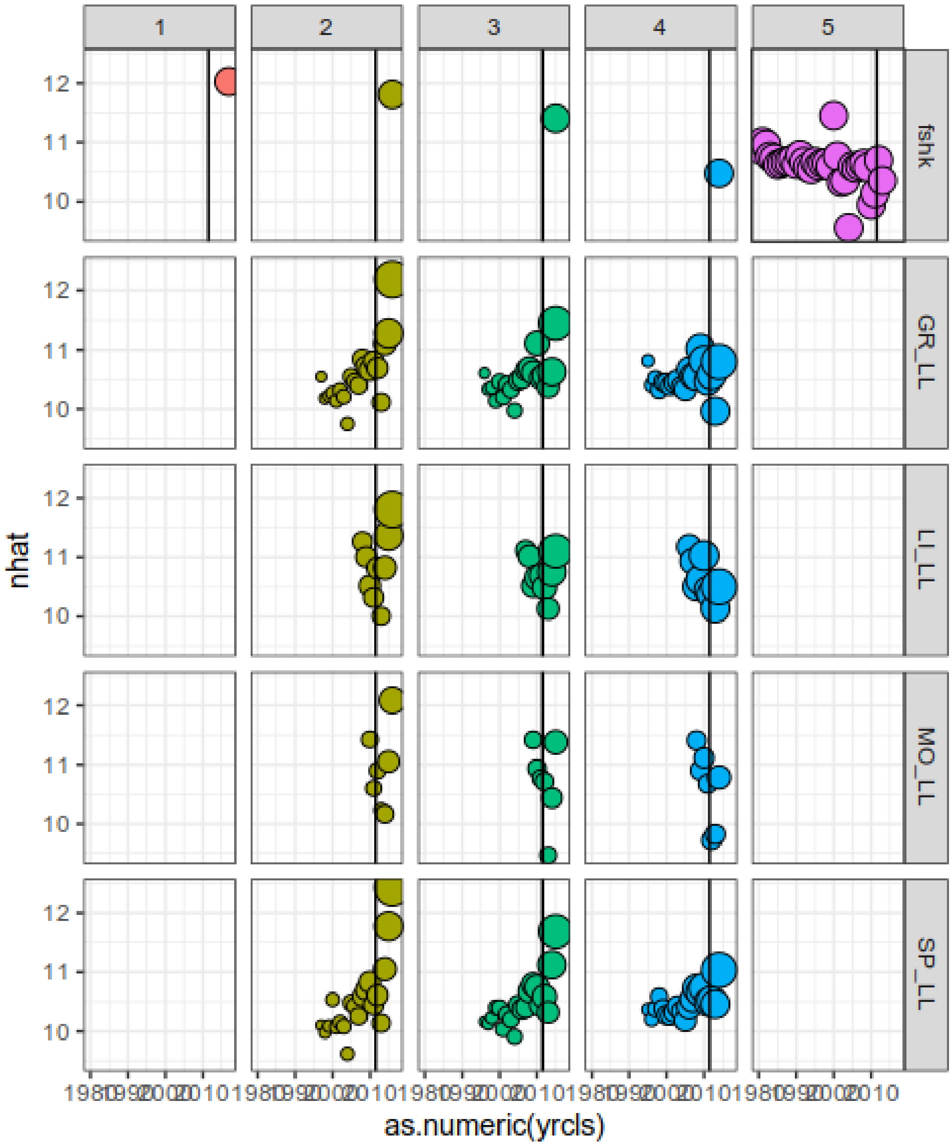

Figure 8. Weights for terminal year Ns for each CPUE observation and shrinkage to the mean F(fshk) for the base run. The vertical line identifies the range used for shrinkage to age in the terminal ages. Points correspond to individual cohorts.

b. Discard run

Table 4. Estimates of stock number-at-age for the discard run.

age	1985	1986	1987	1988	1989	1990
0	1.2342e+06	1.2608e+06	1.2960e+06	1.2736e+06	1.2578e+06	1.2099e+06
1	9.9524e+05	1.0067e+06	1.0307e+06	1.0589e+06	1.0383e+06	1.0241e+06
2	7.1831e+05	7.2933e+05	7.5615e+05	7.6961e+05	7.5198e+05	7.5689e+05
3	4.3199e+05	4.2551e+05	4.4068e+05	4.5496e+05	4.2690e+05	4.4040e+05
4	1.9422e+05	1.9654e+05	1.8446e+05	1.8665e+05	1.6873e+05	1.7326e+05
5	9.3051e+04	1.0660e+05	1.0379e+05	9.2859e+04	8.4970e+04	8.0927e+04
6	4.6495e-01	2.2168e+00	1.7596e+00	1.9186e+00	1.2792e+00	5.1920e-01

age	1991	1992	1993	1994	1995	1996
0	1.2423e+06	1.2567e+06	1.2202e+06	1.2848e+06	1.4295e+06	1.3295e+06
1	9.8121e+05	1.0089e+06	1.0212e+06	9.9276e+05	1.0480e+06	1.1602e+06
2	7.2302e+05	7.0144e+05	7.3098e+05	7.3210e+05	7.0825e+05	7.5403e+05
3	4.0946e+05	4.0500e+05	3.9870e+05	4.1488e+05	3.9653e+05	3.9480e+05
4	1.6632e+05	1.6255e+05	1.7107e+05	1.6584e+05	1.6789e+05	1.6526e+05
5	7.9825e+04	7.9649e+04	8.0123e+04	8.6511e+04	7.6669e+04	8.5291e+04
6	1.0600e+01	1.1466e-01	1.0407e+00	1.0089e+00	1.3154e+00	3.8137e+03

age	1997	1998	1999	2000	2001	2002
0	1.2911e+06	1.2961e+06	1.2142e+06	1.3392e+06	1.2602e+06	9.8803e+05
1	1.0885e+06	1.0535e+06	1.0479e+06	9.9211e+05	1.0964e+06	1.0297e+06
2	8.3687e+05	7.5517e+05	7.3375e+05	7.5298e+05	7.1558e+05	7.8692e+05
3	4.5211e+05	4.4824e+05	3.9797e+05	3.9393e+05	4.0462e+05	3.7624e+05
4	1.7998e+05	1.6520e+05	1.6777e+05	1.7058e+05	1.6216e+05	1.5251e+05
5	8.6852e+04	7.9837e+04	7.1112e+04	8.2665e+04	7.7683e+04	7.3183e+04
6	2.5437e+00	7.5144e-01	9.8488e-01	1.3551e+00	5.4182e-01	1.3865e+04

age	2003	2004	2005	2006	2007	2008
0	1.1021e+06	1.0707e+06	9.7041e+05	1.3209e+06	1.3947e+06	1.0717e+06
1	8.0893e+05	8.8846e+05	8.5994e+05	7.4076e+05	1.0792e+06	1.1280e+06
2	7.5016e+05	5.5920e+05	6.1818e+05	6.5042e+05	5.4117e+05	7.8049e+05
3	4.7576e+05	4.2172e+05	2.7005e+05	3.3894e+05	3.4918e+05	2.5980e+05
4	1.5660e+05	2.1255e+05	1.7287e+05	1.4522e+05	1.4232e+05	1.1842e+05
5	7.5040e+04	7.1531e+04	1.1866e+05	7.7781e+04	6.5026e+04	6.2664e+04
6	1.0347e+00	1.4962e+00	5.7857e-01	1.2411e+00	1.3141e+00	1.6382e+03

age	2009	2010	2011	2012	2013	2014
0	1.0340e+06	1.1289e+06	9.8426e+05	7.8385e+05	1.0782e+06	8.3685e+05
1	8.6933e+05	8.4657e+05	9.2362e+05	7.6178e+05	6.3975e+05	8.8260e+05
2	7.8098e+05	5.7365e+05	5.6602e+05	5.3152e+05	5.3587e+05	4.5098e+05
3	2.8736e+05	3.8168e+05	2.7195e+05	3.0145e+05	2.8763e+05	3.0096e+05
4	1.7203e+05	1.6102e+05	1.4279e+05	1.4192e+05	1.3423e+05	1.3330e+05
5	3.1571e+04	6.8922e+04	7.5002e+04	7.0175e+04	7.5455e+04	7.1796e+04
6	2.2850e+03	1.5430e+00	2.6183e-01	1.6989e+00	1.8414e+00	1.4985e+00

age	2015	2016	2017	2018
0	7.6740e+05	6.4841e+05	8.0051e+05	8.7248e+05
1	6.8515e+05	6.2830e+05	5.3087e+05	6.5506e+05
2	6.5964e+05	4.8466e+05	4.1899e+05	3.7207e+05
3	2.2358e+05	2.9183e+05	2.3144e+05	2.1363e+05
4	1.3903e+05	1.3570e+05	1.0019e+05	9.0753e+04
5	6.8908e+04	6.0675e+04	6.6368e+04	4.4249e+04
6	4.4352e+03	2.0470e+04	2.3355e+00	8.1960e-01

Table 5. Estimates of harvest-at-age for the discard run.

age	1985	1986	1987	1988	1989	1990
0	3.6919e-03	1.5087e-03	2.0751e-03	4.2897e-03	5.5152e-03	9.4803e-03
1	1.1086e-01	8.6216e-02	9.2098e-02	1.4228e-01	1.1610e-01	1.4816e-01
2	3.2361e-01	3.0380e-01	3.0803e-01	3.8934e-01	3.3503e-01	4.1437e-01
3	5.8752e-01	6.3586e-01	6.5910e-01	7.9190e-01	7.0177e-01	7.7375e-01
4	3.9988e-01	4.3856e-01	4.8634e-01	5.8692e-01	5.3475e-01	5.7494e-01
5	3.5546e-01	3.6611e-01	3.8639e-01	4.7761e-01	4.2191e-01	4.7780e-01
6	3.5546e-01	3.6611e-01	3.8639e-01	4.7761e-01	4.2191e-01	4.7780e-01

age	1991	1992	1993	1994	1995	1996
0	8.1094e-03	7.5180e-03	6.2382e-03	3.7251e-03	8.7748e-03	1.6182e-09
1	1.3565e-01	1.2222e-01	1.3284e-01	1.3770e-01	1.2921e-01	1.2667e-01
2	3.7955e-01	3.6493e-01	3.6639e-01	4.1317e-01	3.8442e-01	3.1152e-01
3	7.2383e-01	6.6182e-01	6.7719e-01	7.0468e-01	6.7525e-01	5.8554e-01
4	5.3630e-01	5.0745e-01	4.8179e-01	5.7151e-01	4.7725e-01	4.4330e-01
5	4.4383e-01	4.1410e-01	4.1455e-01	4.5676e-01	4.1653e-01	3.6676e-01
6	4.4383e-01	4.1410e-01	4.1455e-01	4.5676e-01	4.1653e-01	3.6676e-01

age	1997	1998	1999	2000	2001	2002
0	3.3923e-03	1.2537e-02	2.0464e-03	1.2937e-05	2.0096e-03	6.5216e-09
1	1.6566e-01	1.6170e-01	1.3053e-01	1.2674e-01	1.3171e-01	1.1677e-01
2	4.2433e-01	4.4056e-01	4.2199e-01	4.2108e-01	4.4287e-01	3.0321e-01
3	8.0676e-01	7.8272e-01	6.4718e-01	6.8760e-01	7.7575e-01	6.7651e-01
4	6.1284e-01	6.4290e-01	5.0783e-01	5.8656e-01	5.9561e-01	5.0918e-01
5	5.0240e-01	5.0697e-01	4.2688e-01	4.5853e-01	5.0768e-01	4.2672e-01
6	5.0240e-01	5.0697e-01	4.2688e-01	4.5853e-01	5.0768e-01	4.2672e-01

age	2003	2004	2005	2006	2007	2008
0	1.5458e-02	1.9247e-02	7.0041e-02	2.0814e-03	1.2224e-02	9.2943e-03
1	1.6920e-01	1.6271e-01	7.9246e-02	1.1395e-01	1.2410e-01	1.6763e-01
2	3.7594e-01	5.2789e-01	4.0096e-01	4.2204e-01	5.3381e-01	7.9918e-01
3	6.0574e-01	6.9179e-01	4.2037e-01	6.6775e-01	8.8131e-01	2.1226e-01
4	5.8358e-01	3.8292e-01	5.9865e-01	6.0346e-01	6.2029e-01	1.1220e+00
5	4.6966e-01	4.7799e-01	5.7839e-01	5.5081e-01	5.2639e-01	5.5253e-01
6	4.6966e-01	4.7799e-01	5.7839e-01	5.5081e-01	5.2639e-01	5.5253e-01

age	2009	2010	2011	2012	2013	2014
0	1.5045e-05	6.9921e-04	5.6230e-02	3.1339e-03	1.6575e-04	7.3432e-06
1	2.1571e-01	2.0256e-01	3.5257e-01	1.5176e-01	1.4966e-01	9.1175e-02
2	5.1595e-01	5.4641e-01	4.3003e-01	4.1406e-01	3.7693e-01	5.0163e-01
3	3.7919e-01	7.8319e-01	4.5036e-01	6.0903e-01	5.6907e-01	5.7227e-01
4	7.1469e-01	5.6404e-01	5.1041e-01	4.3171e-01	4.2575e-01	4.5984e-01
5	3.5652e-01	5.6413e-01	4.2346e-01	4.0519e-01	3.6357e-01	3.5588e-01
6	3.5652e-01	5.6413e-01	4.2346e-01	4.0519e-01	3.6357e-01	3.5588e-01

age	2015	2016	2017	2018
0	1.0066e-10	3.7639e-08	5.1508e-04	4.7104e-03
1	1.4618e-01	2.0516e-01	1.5545e-01	1.0716e-01
2	6.1552e-01	5.3913e-01	4.7362e-01	4.6508e-01
3	2.9933e-01	8.6905e-01	7.3618e-01	6.9124e-01
4	6.2916e-01	5.1524e-01	6.1728e-01	5.5095e-01
5	2.4454e-01	4.5336e-01	4.0227e-01	4.8793e-01
6	2.4454e-01	4.5336e-01	4.0227e-01	4.8793e-01

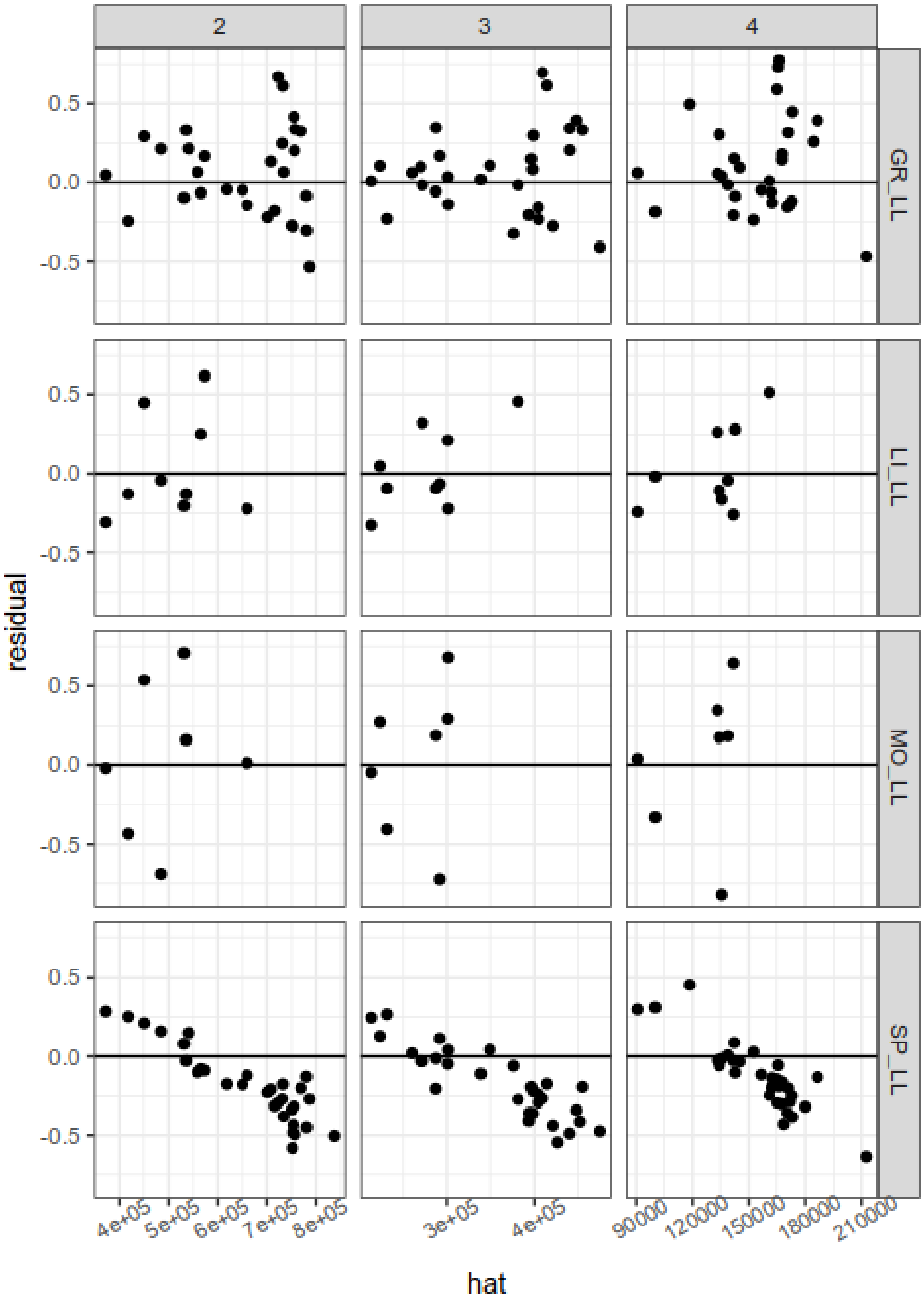

Figure 9. Residuals against fitted value for the discard run.

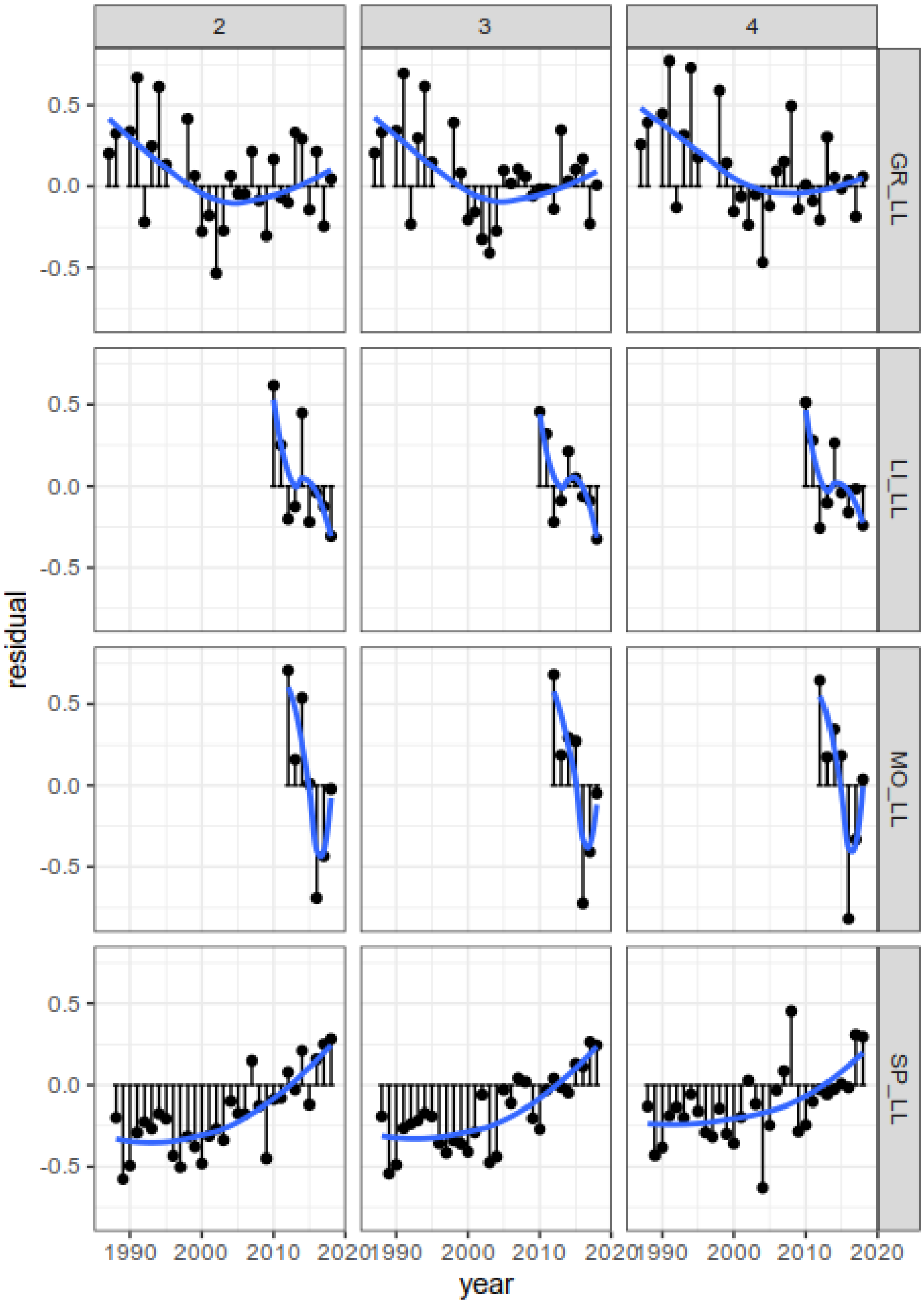

Figure 10. Residuals by fleet against year for the discard run.

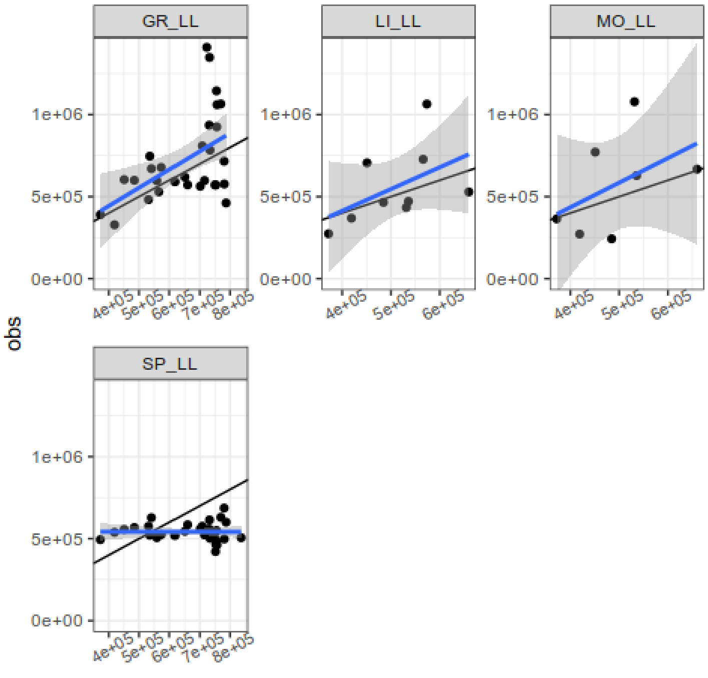

Figure 11. Calibration regression plots for age 2 for the discard run. The blue line is a linear regression fitted to the residual pairs and the black line is the y=x line. If the index is proportional to stock abundance, then the blue and black lines should coincide.

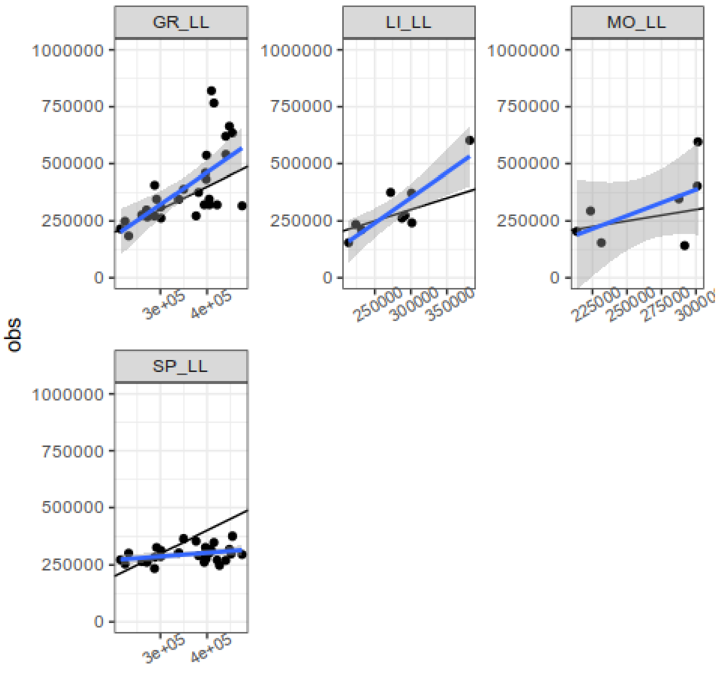

Figure 12. Calibration regression plots for age 3 for the discard run. The blue line is a linear regression fitted to the residual pairs and the black line is the y=x line. If the index is proportional to stock abundance, then the blue and black lines should coincide.

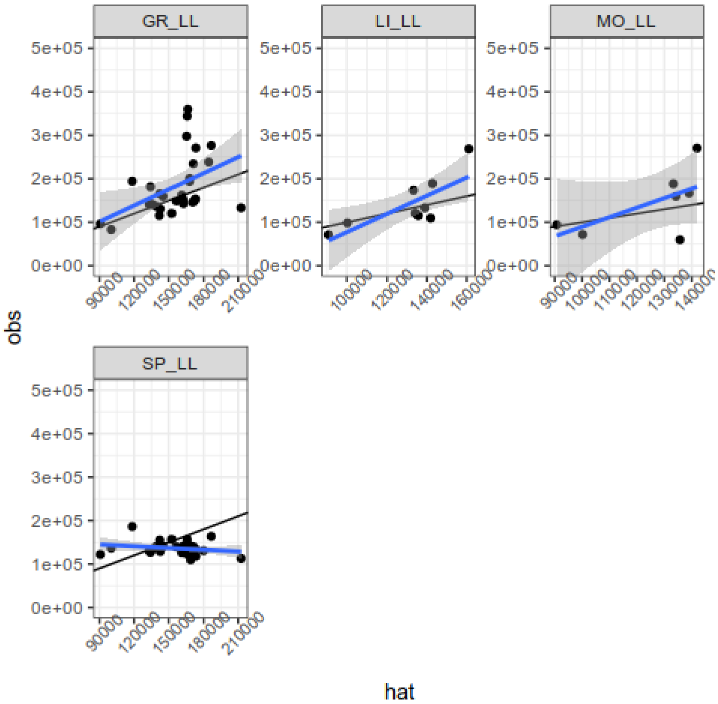

Figure 13. Calibration regression plots for age 4 for the discard run. The blue line is a linear regression fitted to the residual pairs and the black line is the y=x line. If the index is proportional to stock abundance, then the blue and black lines should coincide.

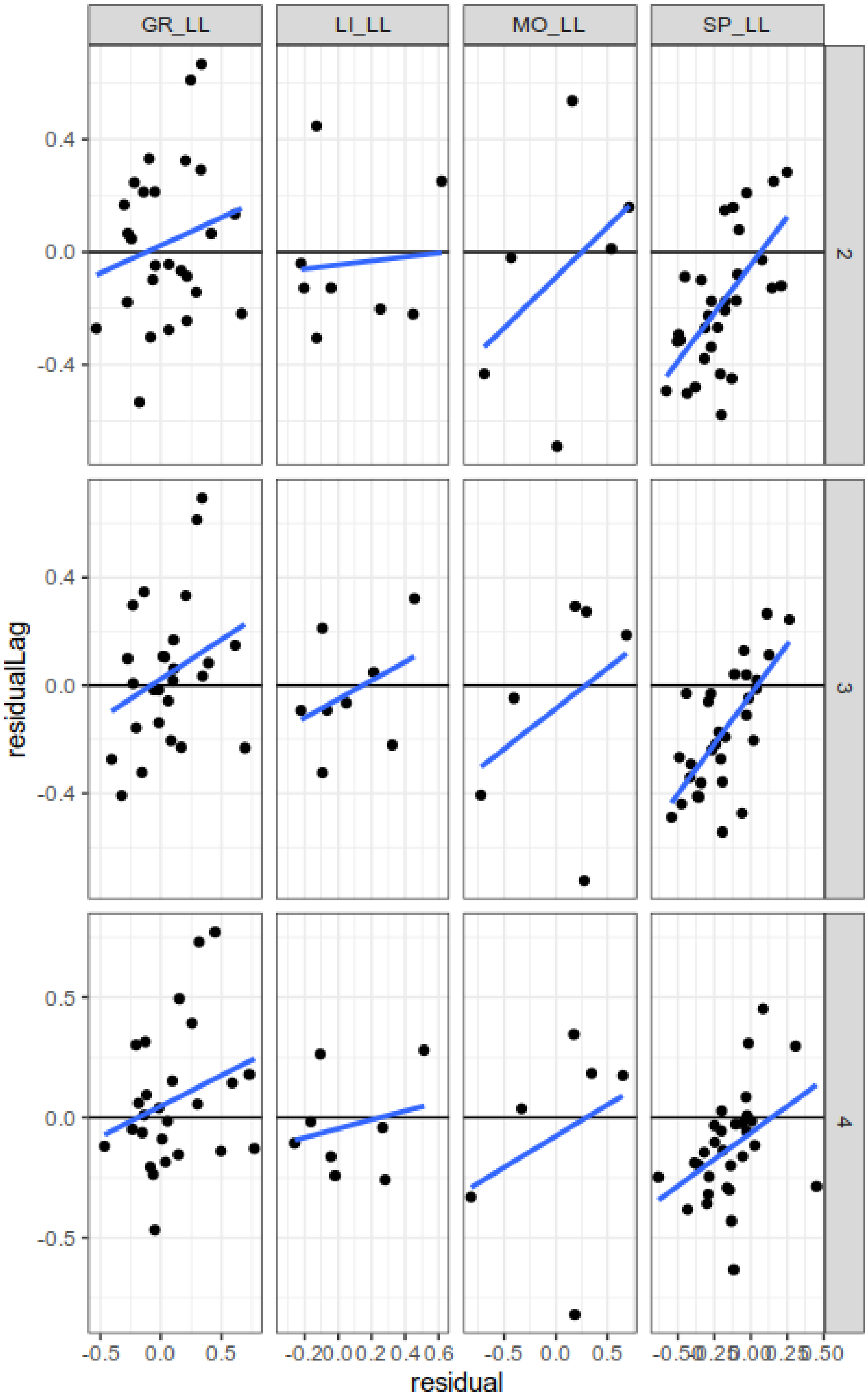

Figure 14. AR plots of lagged residuals for the discard run. The blue line is the regression fitted to the data pairs. If residuals are uncorrelated then the slope of the regression should be 0.

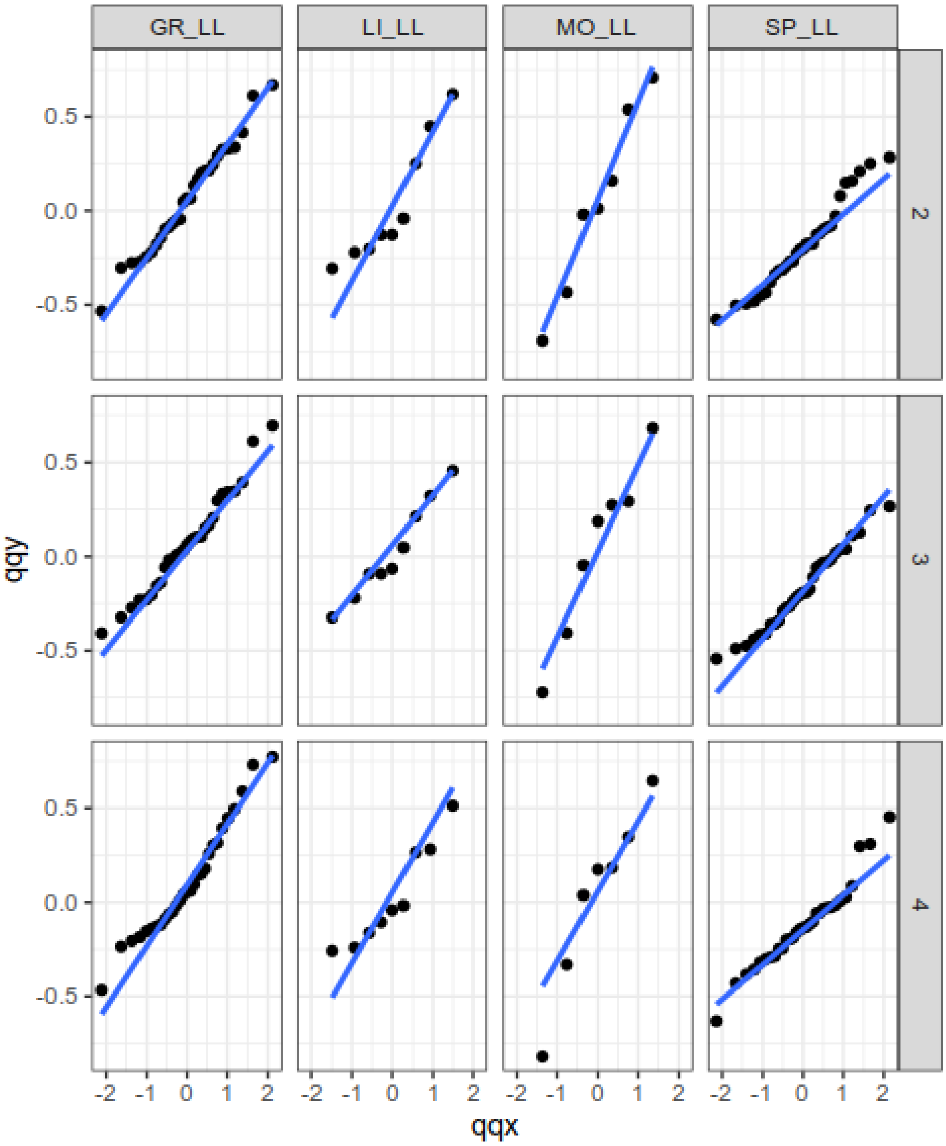

Figure 15. QQ plots to check for log normality (i.e. points and line should coincide) for the discard run.

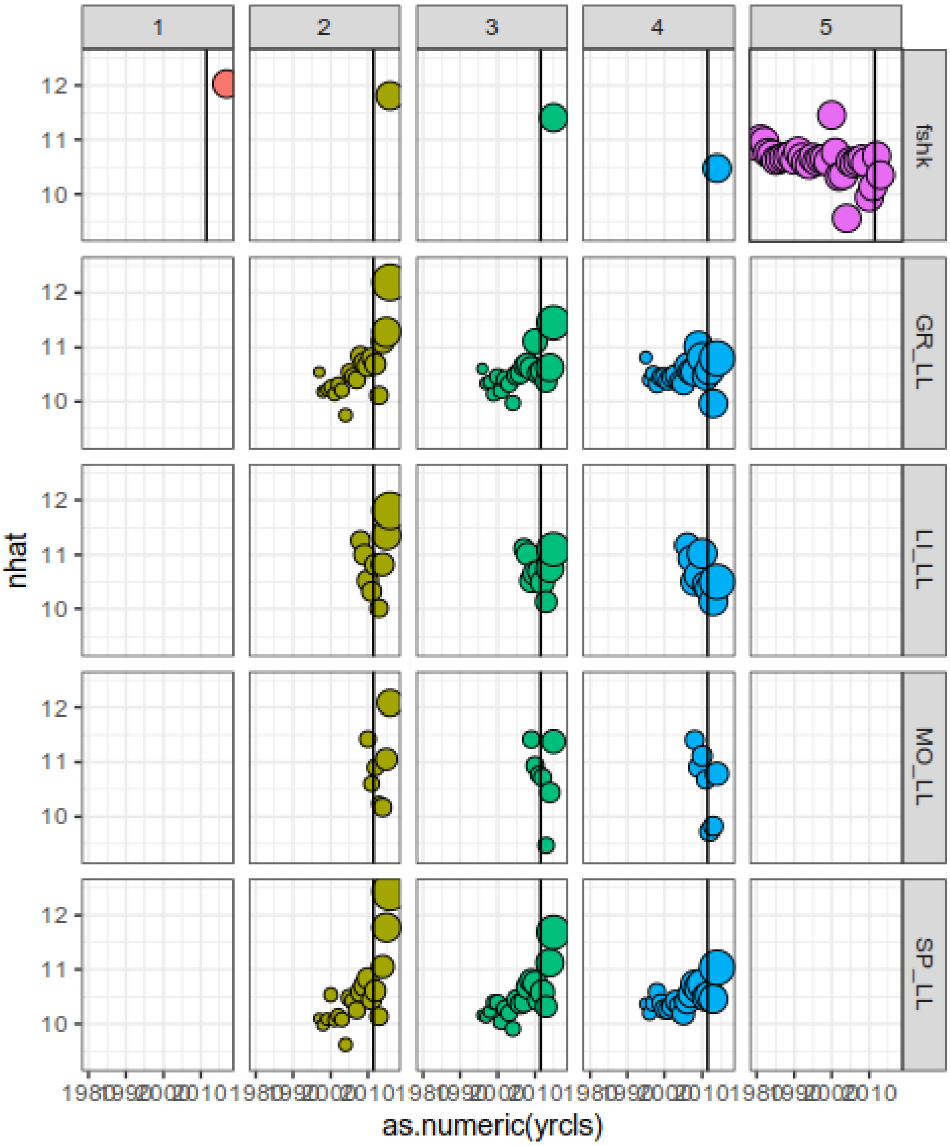

Figure 16. Weights for terminal year Ns for each CPUE observation and shrinkage to the mean F(fshk) for the discard run. Vertical line identifies the range used for shrinkage to age in the terminal ages. Points correspond to individual cohorts.

Appendix 6

A4A FINAL RUNS

1. Introduction

The final runs of the Mediterranean Swordfish, using statistical catch-at-age method a4a, are presented in the current document. Following the recommendation of the Group, the assessments assumed a constant natural mortality considered adequate to assess the status of the stock. The Group requested for two final a4a runs, assuming constant mortality vector with and without discards. The final runs took into consideration an additional standardized CPUE index, the one of the Ligurian surface longliners, expressed in biomass.

2. Materials and Methods

The final a4a runs used CAA data from 1985 to 2018 and five standardized CPUE biomass indices were considered. The first run assumed a constant mortality vector M = 0.2, while the second assumed also a constant M including discards estimates as derived from the SCRS/2020/028. The six CPUE indices are: Greek longliners (SCRS/2020/021), Moroccan longliners (SCRS/2020/026), Spanish longliners (SCRS/2020/043), Ligurian longliners (SCRS/2020/027), Sicilian longliners (SCRS/2014/105) and the historical Ligurian surface longliners (SCRS/2014/112) as suggested by the Group. All indices were considered representative of ages 2 – 4. The standardized CPUE indices are shown in **Figure 1**.

The same final model setup was applied in the two runs and the structure of submodels can be found in **Table 1**. Age plus group was set to 5 and the F range was set to ages 2 – 4.

3. Results

The results among the runs were considered similar, besides the estimated recruitment in recent years where the discards run estimation was a bit higher. A downward trend in the residuals, begging in the mid-1990s is present in both runs. Moreover, the uncertainty around estimates of the recruitment appeared high in both cases at the end of the time series. The trajectory of SSB revealed a slight declining trend and after the mid-2000s fluctuated around 7,500 t. The results of the two final runs are plotted in **Figures 2** and **3**. Diagnostic tests were performed for both CAA and standardized CPUE indices residuals and are presented in **Figures 4 - 7.** A negative pattern in the recruitment residuals is present in both runs, where it should be noted that this was probably the result of lack of a tuning index for age 0. Quantile – quantile plots for both CAA and standardized CPUE indices showed some heavy tails in the recruitment and are presented in **Figures 8** and **9**. Retrospective analysis conducted for both cases did not show any particular pattern, except some discrepancies that were observed for recruitment. The retrospective analysis for each run is presented in **Figures 10** and **11**. MCMC runs were performed for the two final runs as an alternative to the maximum likelihood estimation (MLE) that is being used as a default estimation procedure in the assessment. The plots comparing maximum likelihood estimation and MCMC are presented in **Figures 12** and **13.** Comparisons of the results between the two approaches are presented in **Figure 14**. For the estimation of biological reference points, a Beverton Holt Stock Recruitment relationship was assumed. Given the lack of sufficient data, an empirical relationship with high steepness value was developed. The reference points values along the final year's estimation for the SSB and F are presented in **Table 2**.

Table 1. Sub-models set up for the final a4a runs assuming constant M and discards run. ~1 stands for the constant model while ~s( ) are thin plate regression splines.

F-at-age	$\boldsymbol{F}$	~s(year, k =17) + s(age, k = 3)
Recruitment	$\boldsymbol{R}$	~s(year, k =15)
Catchability	$\boldsymbol{Q}$	~1 for GG_LL, SP_LL, SI_LL ~s(year, k = 3) for MO_LL ~s(year, k = 3) for LI_LL ~s(year, k = 9) for LI_SUR
Observation Variance of the catch	$\boldsymbol{\sigma^2}$	~s(age, k = 3)
Observation Variance of the indices	$\boldsymbol{\tau^2}$	~1 for all indices
Initial age structure	$\boldsymbol{N}$	~s(age, k = 3)

Table 2. Biological reference points and terminal values for F and SSB for the two a4a final runs.

Estimates	**Constant M**	**Discards**
F_{2018}	0.536	0.702
SSB	7312	6332
MSY	14548	13783
F_{MSY}	0.383	0.375
B_{MSY}	45862	43513
F/F_{MSY}	1.397	1.871
B/B_{MSY}	0.500	0.518

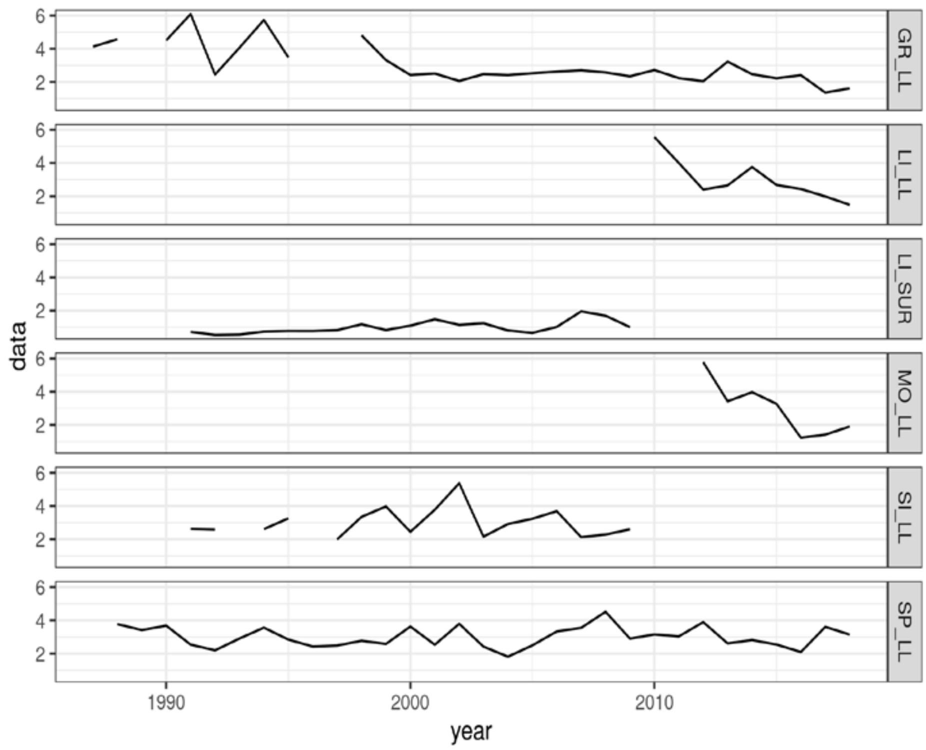

Figure 1. Time series of scaled standardized CPUE indices by fleet: GR_LL = Greek longline, SP_LL = Spanish longline, MO_LL = Moroccan longline, LI_LL = Ligurian longline, SI_LL = Sicilian longline. LI_SUR = Ligurian Surface longline.

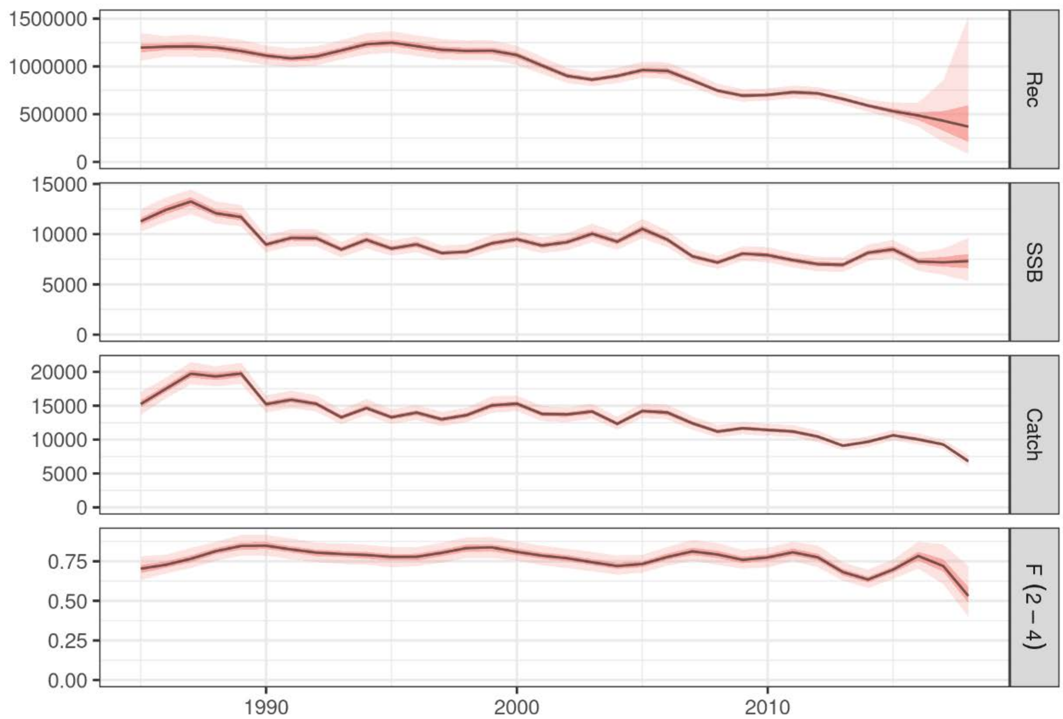

Figure 2. Estimated time series for the Constant M run. 50% and 90% CIs.

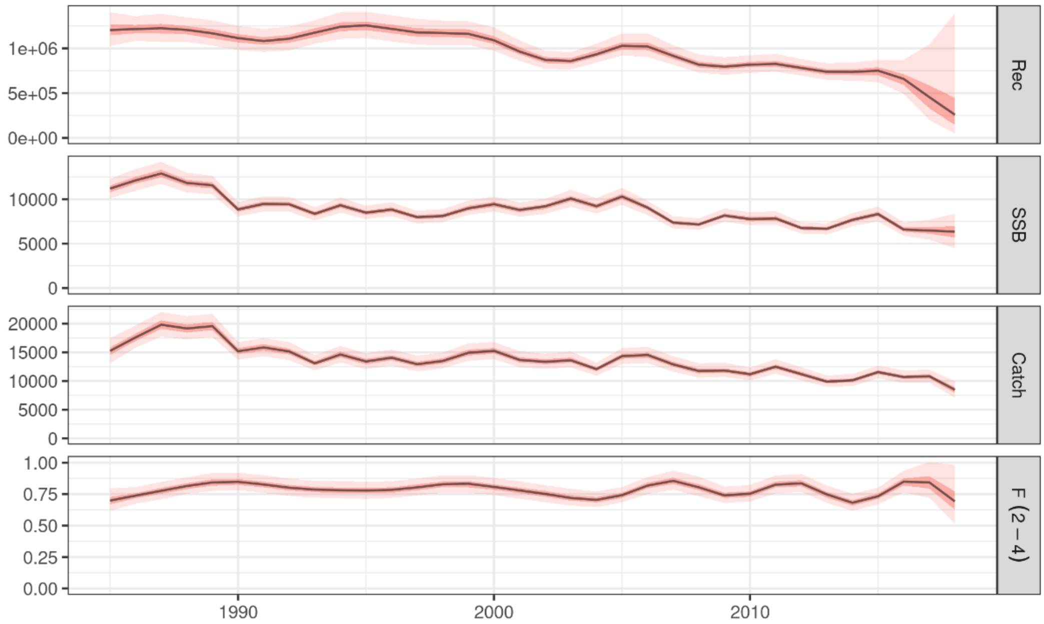

Figure 3. Estimated time series for the Discards run. 50% and 90% CIs.

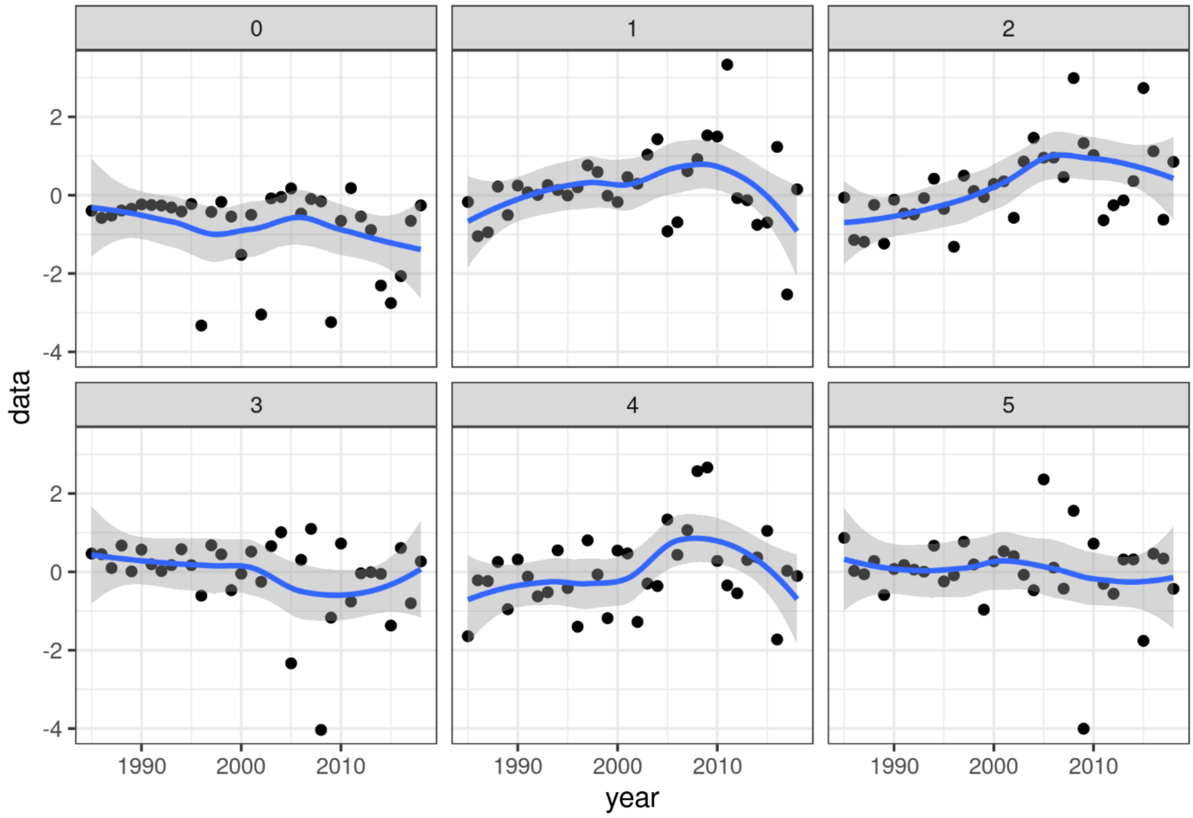

Figure 4. Standardized residuals for catch numbers for Constant M run.

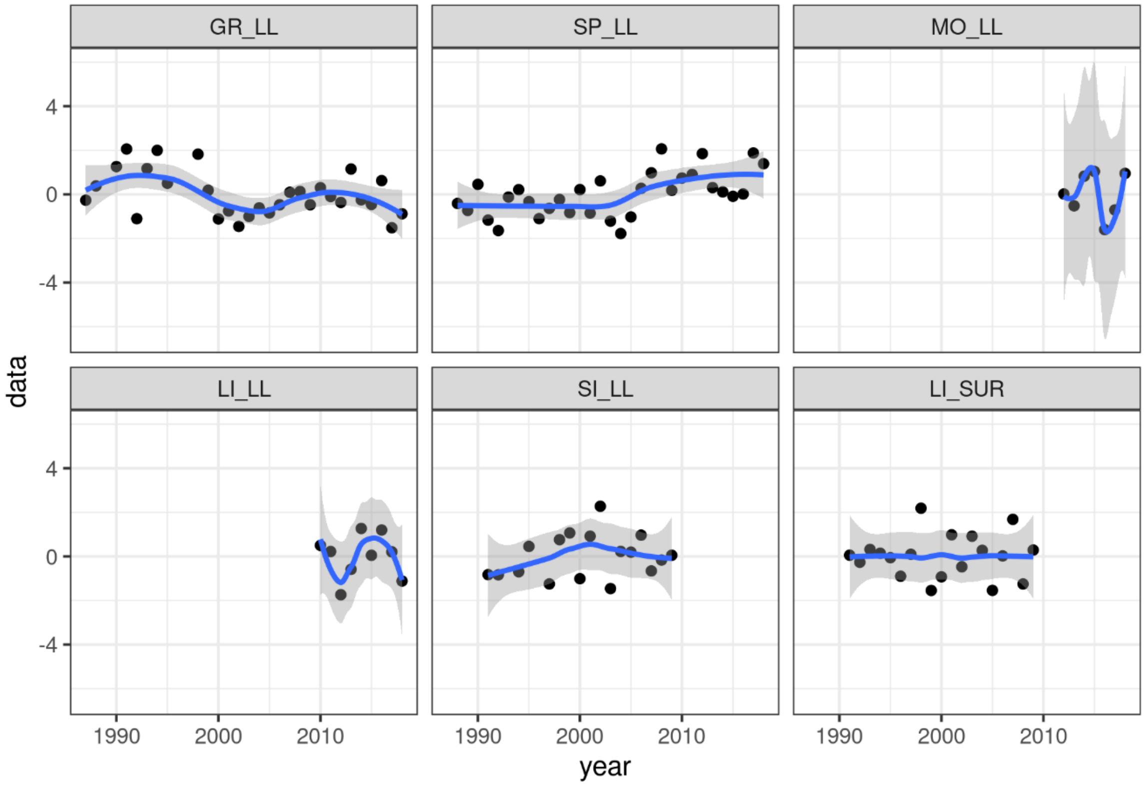

Figure 5. Standardized residuals for biomass indices for Constant M run.

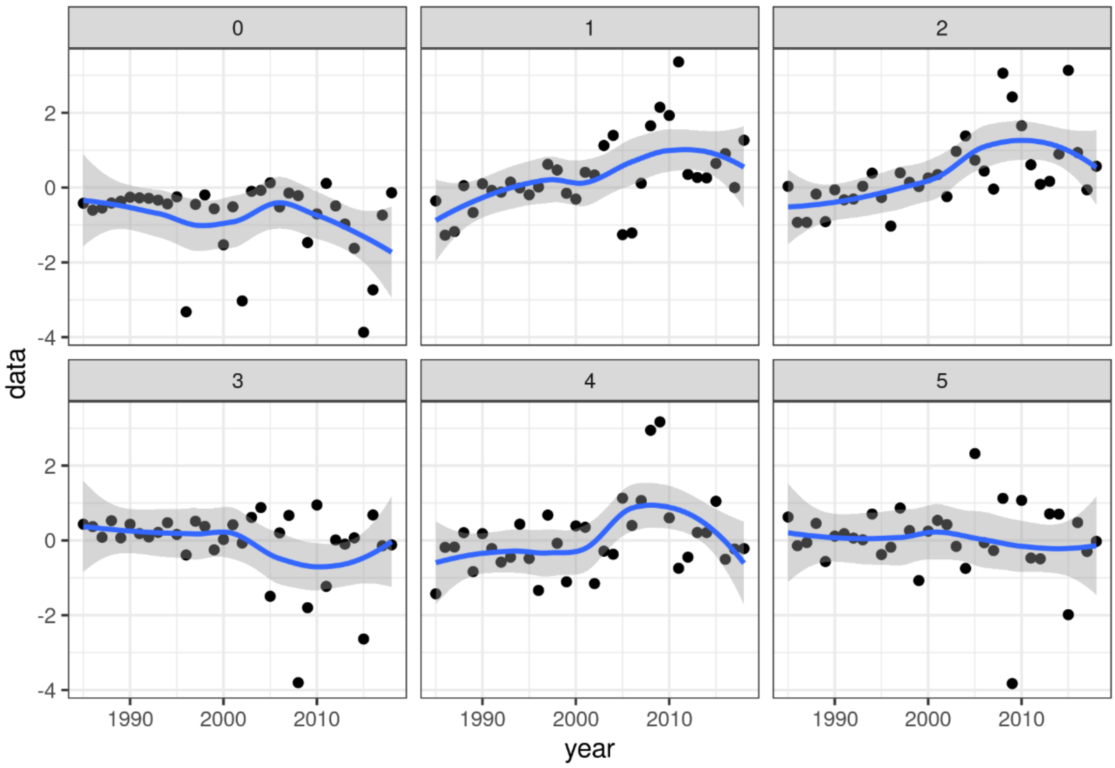

Figure 6. Standardized residuals for catch numbers for Discards run.

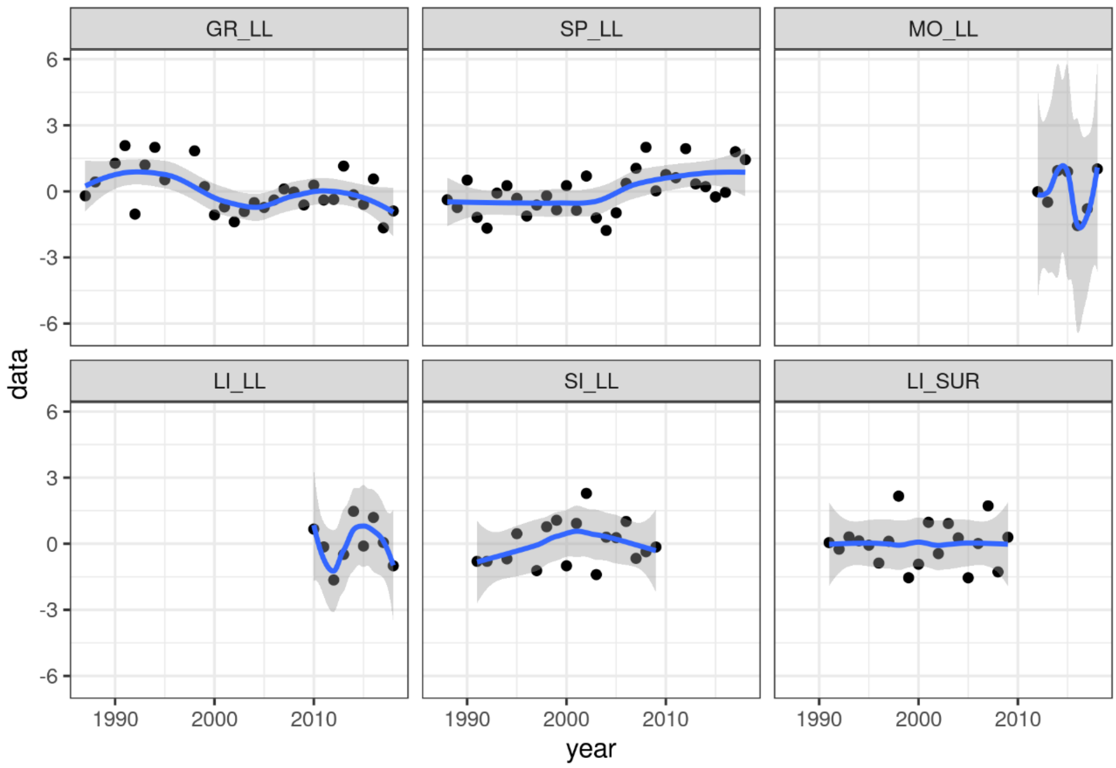

Figure 7. Standardized residuals for biomass indices for Discards run.

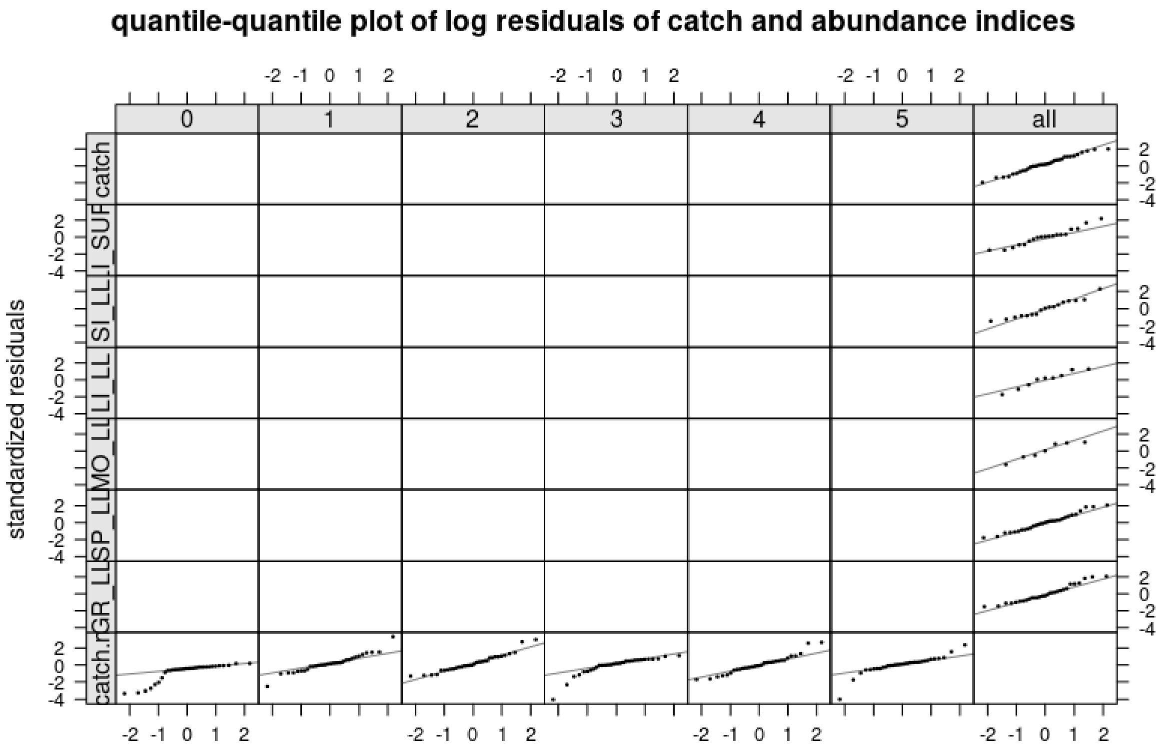

Figure 8. Quantile – quantile plots for catch numbers and biomass indices for Constant M run.

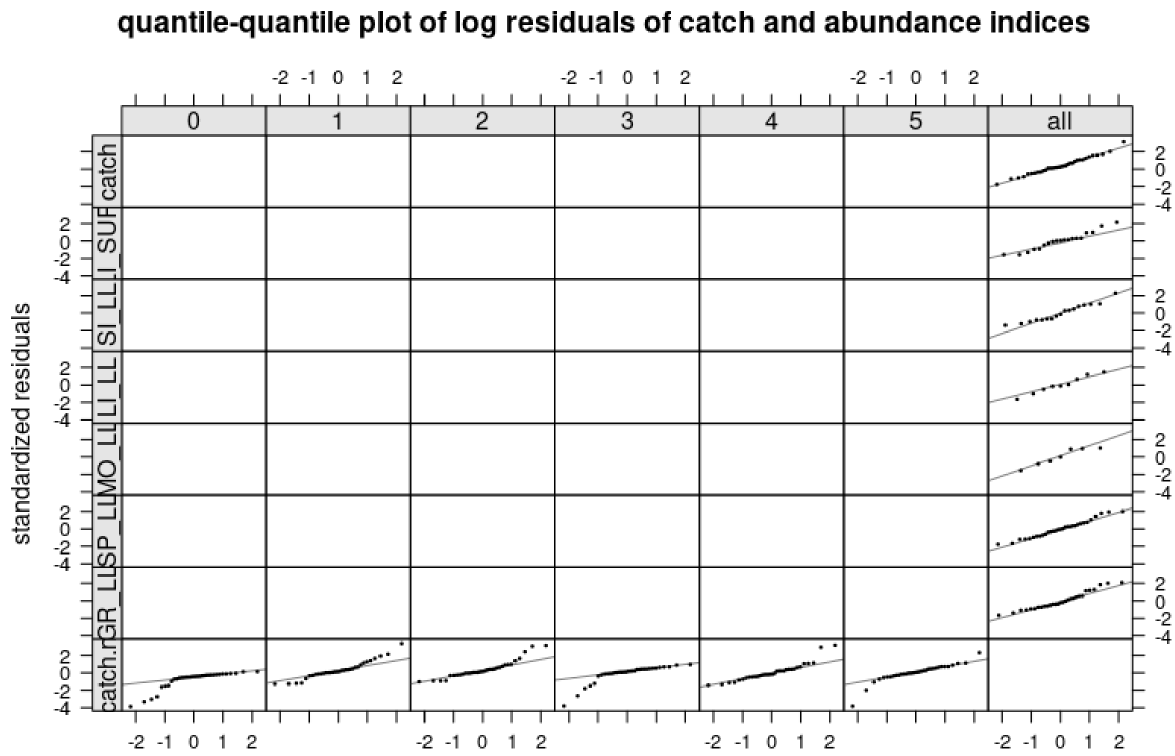

Figure 9. Quantile – quantile plots for catch numbers and biomass indices for Discards run.

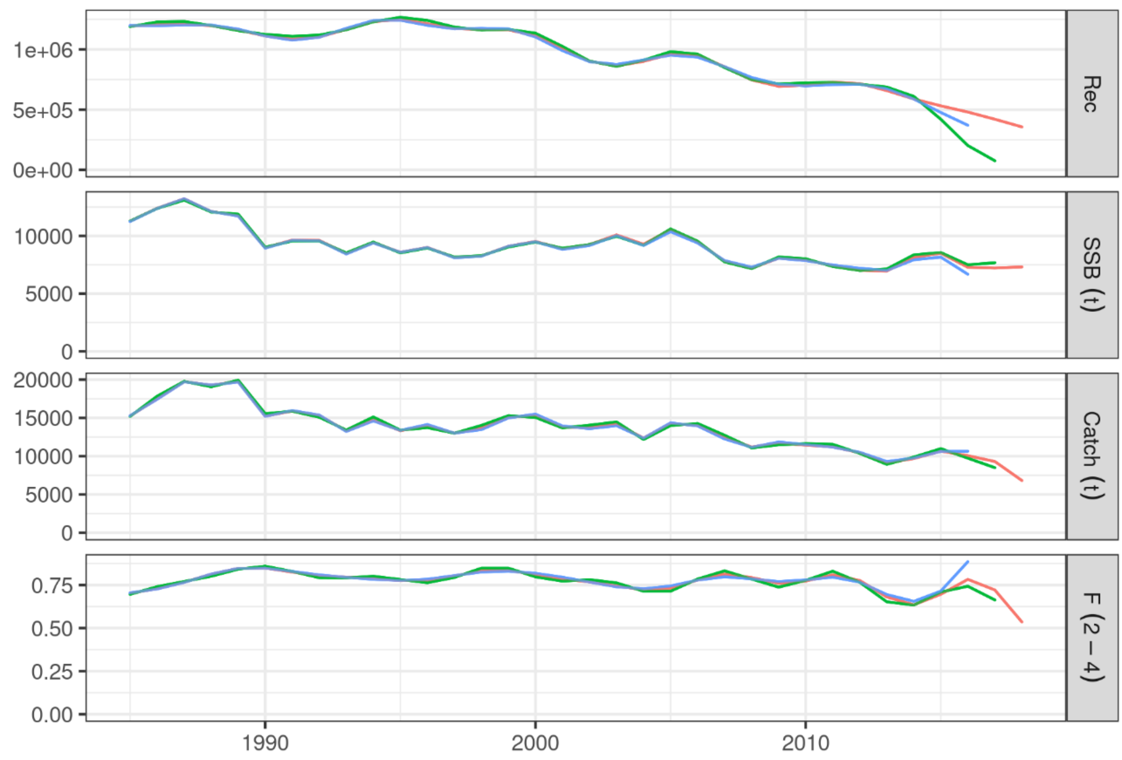

Figure 10. Retrospective plots for Constant M run.

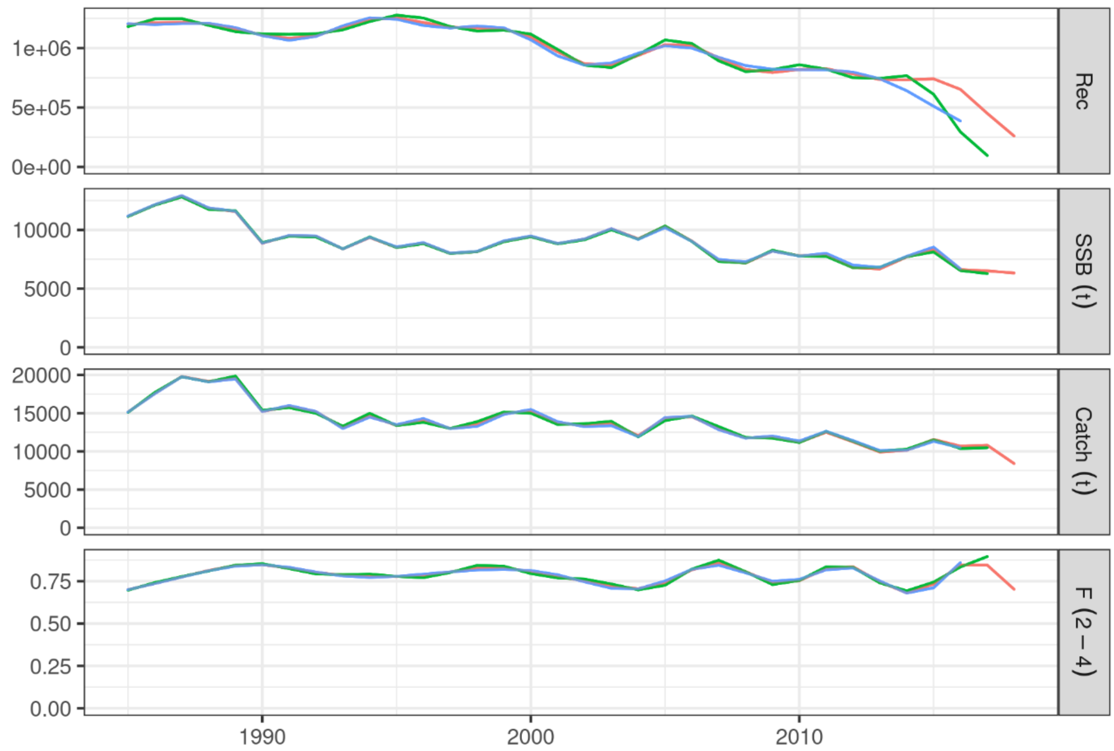

Figure 11. Retrospective plots for Discards run.

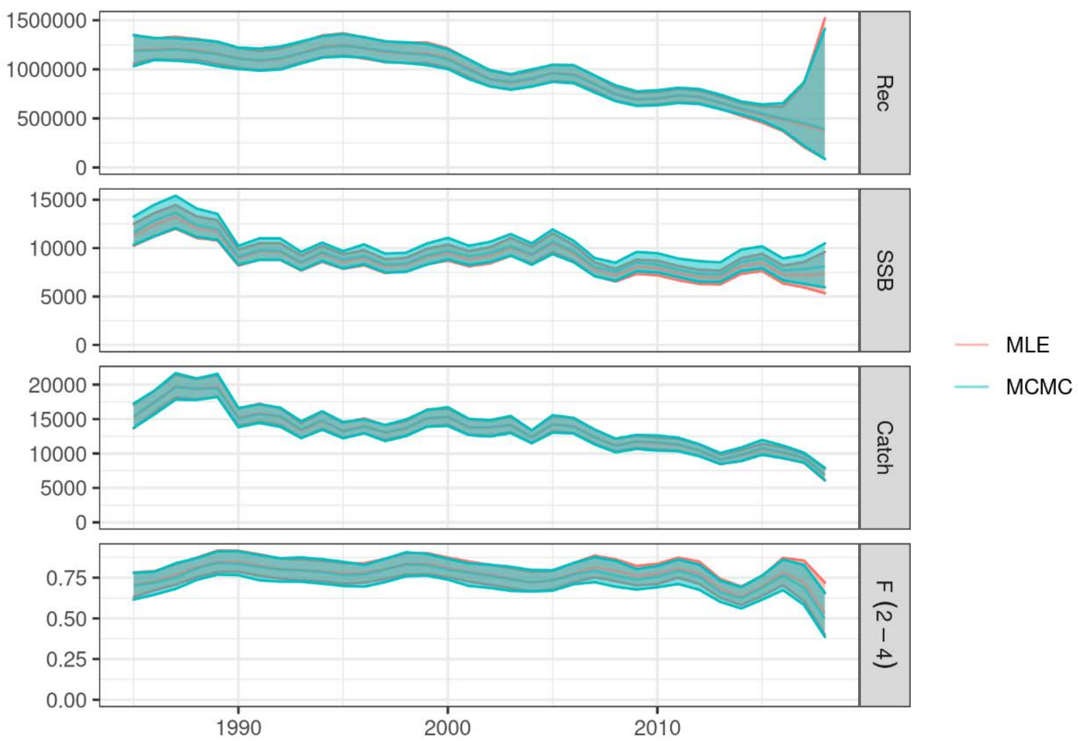

Figure 12. Comparative plot between MLE fit and MCMC for Constant M run.

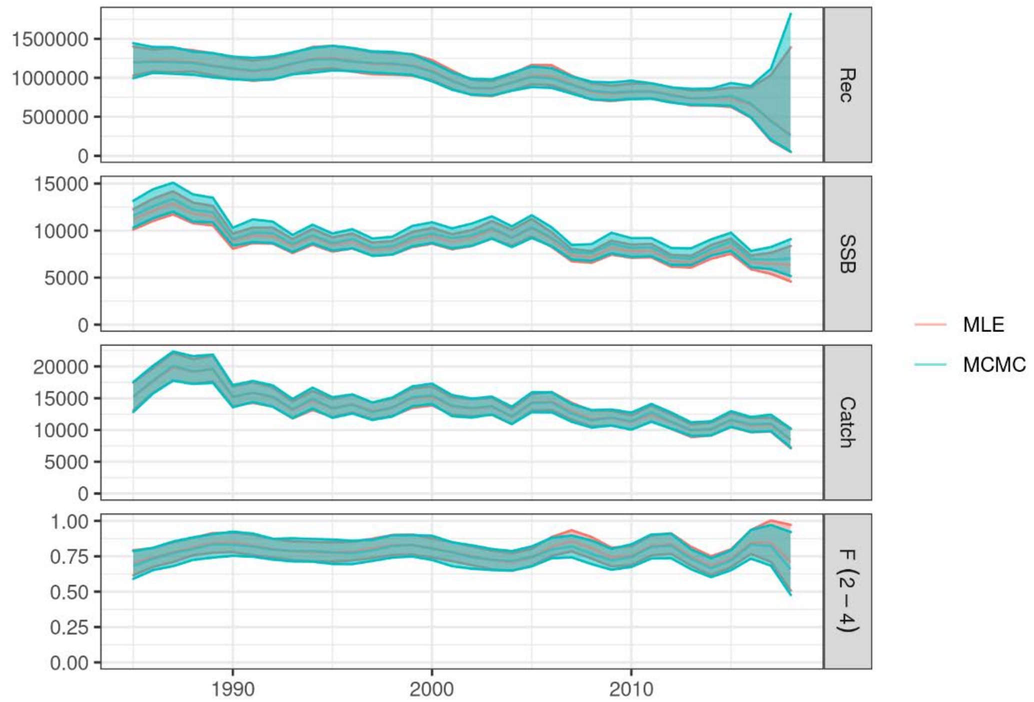

Figure 13. Comparative plot between MLE fit and MCMC for Discards run.

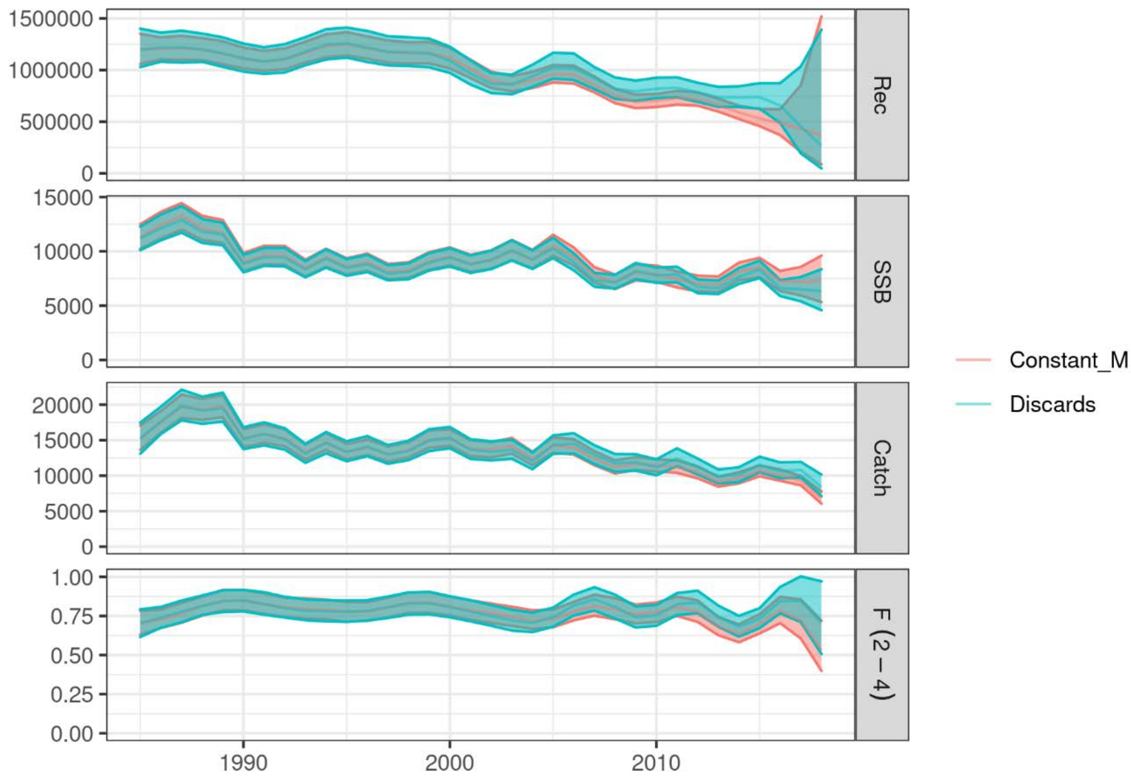

Figure 14. Comparative plot between Constant M run and Discards.