WORKSHOP ON DATA-LIMITED STOCKS OF SHORT-LIVED SPECIES (WKDLSSLS2)

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Contents

i Executive summary

MSE testing of harvest control rules based on trends in biomass indices were analysed for generic anchovy-, sprat-, and sardine-like stocks, including several operating models. Consideration was given to coupling with different Uncertainty Cap (UC) levels and biomass safeguards, and the application of simple constant harvest rates.

With regards to the coupling in time between assessment, advice, and management: results from WKDLSSLS1 were confirmed, indicating that the shorter the lag between observations, advice, and management, the bigger the catches and the smaller the risks, whereby in-year advice should always be preferred over the usual calendar (with an interim year) advice.

Rules of type 1-over-2 outperform 2-over-3 (also called 1o2 and 2o3 respectively). When applied alone (without any Uncertainty cap or Biomass safeguard) for the sprat 7.de-like stock, it was shown that the 1o2 rule is capable or reducing risk faster than the 2o3 and reaching levels below 0.05 in the long term, while the latter does not. In addition, the simulations on anchovy and sardine-like stocks show that even after combining these rules with symmetric and asymmetric Uncertainty cap levels, rule 1o2 results in smaller risks for the same catch levels as the 2o3 rules, given a common Uncertainty cap level, which indicates that 1o2 outperforms 2o3 rules for these short-lived species.

For all operating models, it was found that the 1o2 rule with symmetric UC(-0.8,0.8) implies faster reduction of risks than for any other tested UCs (particularly in the medium term), though at the expense of greater reductions of yield. For almost all Operating Models (OMs), the 1o2 rule with 20% cap was the least precautionary option. In general, inclusion of a biomass safe-guard remarkably reduces risk in the medium and long terms by slightly reducing the relative yields for the stocks that have been historically over-exploited. A biomass safeguard based on I_{stat} ($geometricMean(I_{hist}) \cdot e^{-1.645 \cdot sd(log(I_{hist}))}$) is proposed due to the greater robustness to the length of historical observations.

Application of both an uncertainty cap and a biomass safeguard (I_{stat}) to the 1o2 rule appears to perform better across all OMs and time-scales than either mechanism on its own. For short-lived stocks presumed to have been subject to an exploitation level before management at or above proxy F_{MSY} levels the 1o2 rule with 80% symmetric uncertainty cap and with biomass safeguard (I_{stat}) is the preferred option due to the faster reduction of risk levels in the first ten years (medium term). However, it should be noted that for stocks, which have likely been lightly exploited in the past, other rules may show a better balance between catches and risks. Hence, an earlier assessment of the past exploitation of the stock is very relevant to select the most suitable HCR for the management.

Application of constant harvest rate rules can maintain constant risks, but are not able to move the stock towards precautionary levels when starting from high risk status, therefore, they re-quire careful analysis of sustainable reference levels of harvest rates. Global comparisons suggest that when a careful tunning of a sustainable constant harvest rate is made by taking into account the stock life history and catchability and CV of the observation index, then such a constant har-vest rate strategy will result in higher sustainable catches for the standard allowable levels of risks (0.05). However, if such a tuning is not achievable because of poor knowledge of the stock or of the observation properties, then the WK recommends for short-lived small pelagic fish stocks, the former trend rule 1o2 with a symmetric Uncertainty Cap constraint of 80% and with Biomass safeguard (I_{stat}). However, due to the catch reduction properties it has, this trend rule should be considered a provisional HCR with the aim of achieving a better management system in about ten years or earlier. Longer application may lead to major losses of catches to the fishery in the long term.

The work of WKDLSSLS is considered unfinished. Further research on the definition of optimal harvest control rules for data-limited short-lived stocks is ongoing. Therefore, the suggested either tuned constant harvest rate or the trend rule should be taken as an interim (provisional) proposal while guidelines are refined in 2021.

ii Expert group information

Expert group name	Workshop on Data-limited Stocks of Short-Lived Species (WKDLSSLS2)
Expert group cycle	Annual
Year cycle started	2020
Reporting year in cycle	1/1
Chairs	Andrés Uriarte, Spain
	Mollie Brooks, Denmark
Meeting venue(s) and dates	14–18 September 2020, by WebEx, 17 participants

1 Introduction

1.1 Terms of Reference

The Workshop on Data-limited Stocks of Short-Lived Species (WKDLSSLS), chaired by Andres Uriarte, Spain, and Mollie Brooks, Denmark, had telematic virtual (on-line) meeting from 14 to 18 September 2020, to further develop methods for stock assessment and catch advice for short-lived stocks in categories 3–4, focusing on the provision of advice rules that are within the ICES MSY framework.

On the basis of the outcome of WKLIFE7, WKLIFE8, WKLIFE9. WKSPRAT 2018, WKSPRATMSE 2018 and WKDLSSLS 2019, the following issues should be addressed:

- Test different assessment methods for data-limited short-lived species (seasonal SPiCT, others) and provide guidelines on the estimation of MSY proxy reference points for category 3–4 short-lived species.

a) Further work on assessment methods of initial stock status relative to MSY with simpler analyses of historical catches, the abundance indices, or from expert knowledge where it is relevant.
b) Further testing of SPiCT advice rules for management for short-lived species. Evaluation of the performance of these rules either alone or in combination with uncertainty caps and biomass safeguards.

- Further explore the appropriateness of the management procedures currently in use for short-lived species by means of Long-Term Management Strategy Evaluations (LT-MSE). This will involve:

a) Revisiting, if required, the advice rules proposed in WKDLSSLS 2019.
b) Testing the effectiveness of the precautionary buffer in mitigating the short-term risks associated with the new harvest control rules being tested.
c) Further exploring the benefits of adding a biomass safeguard of minimum observed index or at a quantile of the index series to the rules either alone or in combination with uncertainty caps.
d) Revisiting, if necessary, the suitability and magnitude of the uncertainty caps explored in WKDLSSLS2019, including further testing of asymmetric uncertainty caps with variable upper and lower bounds, or assessing the effect of shifting the uncertainty cap levels in time.
e) Constant or variable harvest rate strategies instead of the trend-based rules (aligned with HCR 3.2.2 Catch rule based on applying an Fproxy–WKMSYCat34).

WKDLSSLS will report by the 14 October 2020 for the attention of ACOM.

1.2 Background

In 2019, WKDLSSLS met by the first time to address the particular problems of providing management advice for data-limited short-lived stocks such as anchovy and sardine, which pose challenges for management, because their life-history characteristics, including large fluctuations in annual recruitment, make them highly variable and raise questions about the successful application of commonly used management approaches in particular for these data-limited stocks. During WKLIFE VIII (ICES, 2018), WKMSYCat34 catch rule 3.2.1 (ICES, 2017) was tested for its performance towards achieving MSY exploitation, across a series of stocks covering an ample set of life-history categories. Such analysis proved that using Gislason mortality and sigmaR=0.3, and with the usual lags (2-over-3 rule and a year lag between assessment and advice), the 3.2.1 catch rule without further tuning resulted in collapses for stocks with k>0.32. Performance was improved by reducing time-lags (i.e. using more recent data), even for some of the k>0.32 stocks. Similar conclusions were found to apply for the 3.2.2 catch rule (the "Icelandic" rule) in terms of the clusters based on k, and the improvement in performance by reducing time-lags. Direct simulations during WKLIFE on an anchovy-like stock showed that for short-lived species in category 3 stocks with a survey index (or accepted CPUE index) monitoring system, moving from classical DLS methods with one-year lag in between advice and management to in-year advice will be beneficial as it will be using the most recent index to manage the resource. In addition, it was pointed out that 1-over-2 or 1-over-3 rules, informing on the most recent changes of these populations, seems to outperform rules 2-over-3 and 3-over-5 for In-Year advice. In addition, low (highly restrictive) uncertainty caps (e.g. 20%) worsen the performance of the HCRs for this short-lived species with high interannual variability. It was considered that further verification of these results for In-year management of other short-lived category 3 stocks and expansion of the analysis to account for some potential modifications of the harvest control rules would be needed.

Overall WKLIFE 2018 concluded that the highly fluctuating nature of short-lived species conditioned the performance of these harvest control rules and require the evaluation of *ad hoc* options for short-lived data-limited stocks (category 3 and 4). These considerations lead to the conclusion that a workshop on assessment, harvest control rules and MSE for data-limited short-lived species was needed. As many cephalopods are also short-lived species, and therefore share the problems of assessment and management of short-lived fish populations, during 2019 inclusion of experiences on cephalopod case studies were considered of interest to generalize the scope of the workshop.

During WKDLSSLS-1 the progress on assessment methods for short-lived data-limited stocks (SLDLS) and estimation of biological and MSY proxy reference points, focused on the application of the stochastic production model SPiCT (Pedersen and Berg, 2017).

Several assessments methods were essayed for the cases studies stock category 3 in ICES area. In particular, work on fitting SPiCT to case studies was made: assessments to Anchovy in 9a South resulted in a satisfactory fitting of SPiCT, whilst fits to Anchovy in 9a West and to Sprat 7de were still unsatisfactory. In addition, there were some presentations on applications of SPiCT to several Cephalopod populations. Length-based indicators of stock status were discarded as generally they are not suitable for short-lived species where recruitment induces major interannual changes in the length distribution of catches. A provisional application of a two-stage assessment was presented for Sprat in 7de, but results were still provisional.

In relation to the evaluation of management procedures for these SLDLS, MSE testing of harvest control rules based on trends of biomass indices were analysed for rather generic anchovy-, sprat-, and sardine-like stocks including several operating models. The performance of 1-over-2 and 2-over-3 HCRs for normal timing of the advice (which is the ICES default management calendar, including an interim year when the advice is produced) and for In-year advice were tested, both for symmetrical and asymmetrical uncertainty cap restrictions on interannual advice, and either supplemented or not with a biomass indicator safeguard (case studies for anchovy and sardine/sprat like stocks). All simulations coincided in pointing out that the shorter the lag between observations, advice and management, the bigger the catches and the smaller are the risks. This means that In-year advice should always be preferred over the normal calendar (with an interim) year advice for these SLDLS. Major drivers of risks are by order of relevance: historical exploitation level (and trajectory), and the harvest control rule (HCR) with its selected Uncertainty Cap (UC). This emphasizes the relevance of trying an initial assessment of the relative status of the stock regarding optimal exploitation to judge if a precautionary buffer is required to start management. Further work on the assessment of past exploitation level is required.

Regarding the trend-based harvest control rules (HCRs): In general, 1-over-2 outperforms 2-over-3 rule (ICES default rule) because for quite similar catches, 1-over-2 has slightly lower risk than 2-over-3 at any uncertainty cap level (including the case of no uncertainty cap). Regarding the application of some uncertainty caps to constrain the interannual variability in the advice, it was found that, for symmetrical application of the uncertainty cap, best performance (least risks for minimum reduction of catches) occur at 1-over-2 rule with symmetrical 80% UC. The most risky performance results were from applying a 20% uncertainty cap, both for 1-over-2 and 2-over-3, and the performance worsens with time. For asymmetrical Uncertainty Caps, tested for rules with a maximum interannual upward revision of 20%, results showed optimal performance when allowing reductions of 60% or greater percentages from the previous advices for in-year advice, and of 70% or greater for normal (calendar) advice. Intermediate rules in terms of balance between catches and risks are: 1-over-2 (with symmetrical 80%Ucap) and 1-over-2 with biomass safeguard (using either I_{min}, the minimum past observed abundance index, or $I_{trigger}$, 1.4*I_{min}). Rule 1-over-2 with symmetrical 80% Ucap was put forward as the preferred rule with a good compromise between moderate risks and catches though it can lead to major reduction of catches in the long term. So, its implementation should be better framed temporarily while improving management of the stock in 8–10 years. These conclusions were passed to WKLIFEX and the guidelines for provision of advice to short-lived data-limited stocks were updated accordingly.

As a result of the first workshop further research was envisaged as needed on the definition of proxies for biological reference points (BRPs) for management and on the optimal harvest control rules (including the SPiCT advice rules) for the management of these SLDLS, covering further testing of biomass safeguards and of asymmetric uncertainty caps or the use of constant or variant harvest rate strategies instead of the trend-based rules. In this context, the ToRs for WKDLSSLS-2 were set up.

During 2020 some feedback was gathered from the ICES case studies on short-lived stocks in category 3:

- From Anchovy 9a West, where rule 1-over 2 with UC(0.8, 0.8) was followed for provision of in-year advice for July 2020 to June 2021, it was clear that this rule had not sufficient flexibility as to follow the sudden ups and downs of the stock, resulting in catches allowing major interannual changes on the actual harvest rates on the population. This made ICES WGHANSA (ICES, 2020a) to recommend WKDLSSLS-2 to explore the applicability of Constant Harvest rates (i.e. 1-over-1 rules) to this kind of stocks. (see further details in the notes of the July 2020 Meeting on WKDLSSLS-2 preparation in Annex 3). This potential harvest rate strategy has been partly explored in this workshop, but further work was considered necessary before concluding the analysis.
- From Anchovy 9a South, where rule 1-over 2 with UC(0.8, 0.8) is followed based on stock trends produced by an analytical assessment (Gadget), a problem was generated by the revision of the most recent stock trend arising from the update of the assessment during this year, in comparison with the assessment outcome produced in 2019. Last year assessment modified the 2019 advice of 6290 t to a 2020 advice of 11322, but with the new update assessment in 2020, advice for 2019 should had been of 8057 and the advice for 2020 should have been of 14 502 t as a result of the new recent tendencies of the stock since 2017. These inconsistencies in the advice produced from the indicator index of biomass when taken from an integrated assessment can also happen in other stocks and

where circumstances not considered when testing the performance of these rules. This makes WGHANSA (ICES, 2020a) wonder whether the updated advice should go back in time until convergence of the historical assessment with the previous assessment, every time a new advice is provided. This alternative way of producing the advice when the stock trend indicators come from an integrated assessment was not yet explored in WKDLSSLS-2.

- From Sprat in 7de: The guidelines for the management of data poor short-lived species put forward in 2019 were not followed. First, the advice has always been based on the calendar year using the survey index from the year prior to the interim year y (so from y-1) to produce advice for year y+1. Next, the advice for 2020 was produced by applying rule 2-over-3 with 20% symmetric Uncertainty cap, and the advice for 2021 was produced by applying rule 1-over-2 with 20% symmetric Uncertainty cap. This means that the recommended in year advice and 80% symmetric uncertainty cap were not followed, whilst the calendar year and 20% symmetric uncertainty cap were shown in WKLDLSSLS-1 (ICES, 2019) to result in the highest risks (unsustainable in the long term) when compared to the recommended rule. Clarifications to WKDLSSLS-2 were asked by ICES HAWG (ICES, 2020b) on the relevance of the selected management calendar and uncertainty cap levels. These is-sues were again revisited in the simulations carried out this year for WKDLSSLS-2.

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- From Sprat in 7de: The guidelines for the management of data poor short-lived species put forward in 2019 were not followed. First, the advice has always been based on the calendar year using the survey index from the year prior to the interim year y (so from y-1) to produce advice for year y+1. Next, the advice for 2020 was produced by applying rule 2-over-3 with 20% symmetric Uncertainty cap, and the advice for 2021 was produced

by applying rule 1-over-2 with 20% symmetric Uncertainty cap. This means that the recommended in year advice and 80% symmetric uncertainty cap were not followed, whilst the calendar year and 20% symmetric uncertainty cap were shown in WKLDLSSLS-1 (ICES, 2019) to result in the highest risks (unsustainable in the long term) when compared to the recommended rule. Clarifications to WKDLSSLS-2 were asked by ICES HAWG (ICES, 2020b) on the relevance of the selected management calendar and uncertainty cap levels. These issues were again revisited in the simulations carried out this year for WKDLSSLS-2.

1.3 Conduct of the meeting

In total 17 participants attended and contributed to the workshop (Annex 2) with a total of 11 presentations (Annex 5) according to the agenda (Annex 1). Two preparatory online meetings took place in advance of the WKDLSSLS-2 by WebEx in May and July 2020 with some of the participants of the workshop (minutes in Annex 3), to organize the work and standardize MSE work as much as possible.

The workshop consisted mainly of presentations and discussions during the morning and individual work and writing in the afternoon, with the exception of Thursday when the plenary work extended during the afternoon. The content of the presentations were used to identify virtual sub-groups – two of which were identified:

- Subgroup 1 – focused on ToRs 1 a & b: To Test different assessment methods for data-limited short-lived species (seasonal SPiCT, others) and provide guidelines on the estimation of MSY proxy reference points for cat 3–4 short-lived species, with its work pivoting mostly on case studies.
- Subgroup 2 – focused on ToR 2 a-e: Revisiting the performance of several HCRs (including those already tested in WKDLSLS-1 in 2019); this included work on revision of the effectiveness of the precautionary buffer, of adding a biomass safeguard, the time-lag between assessment and enforcement, the suitability and magnitude of the uncertainty caps and constant or variable harvest rate strategies instead of the trend-based rules (n-over-m).

The structure of the report followed the presentations and work carried out in these two groups, ending up with the major conclusions and prospective for future work.

As a result of the many presentations and some runs actually carried out during the meeting, some work needed to be finished after the meeting and such work was planned during the last day of the meeting, mainly to achieve on time a complete production of the report. Proposing guidelines for management of short-lived data-limited species took place after the meeting, following the major conclusions agreed at the end of the meeting. The guidelines on provision of advice to short-lived data-limited stocks were passed to and reviewed at WKLIFEX (held from 5–9 October 2020).

1.4 Structure of the report

The structure of the report follows the presentations and work carried out during the meeting in the two groups.

After the introductory texts of Section 1, Section 2 presents the results of Subgroup 1 – focused on ToRs 1 a & b, dealing with assessments and definition of BRPs for the different case studies. First (Section 2.1) makes a comparison of SPiCT and Gadget estimates up to 2020 for the Anchovy in 9aSouth, as presented by Margarita María Rincón Hidalgo (IEO). Next (Section 2.2), a summary of the Testing of Harvest strategies with the anchovy in 9aWest along with a first application of SPiCT production model and variants is presented by Laura Wise, Susana Garrido & Alexandra Silva. The following two sections summarized the fitting of surplus production models to cephalopods, first to octopus in Asturias, the north of Spain (Section 2.3), by Ruben Roa, and to the cuttlefish in the English Channel (Section 2.4), by Angela Larivain. The rest of Section 2 presents a case study on sprat to the West of Scotland: Working Towards A Sustainable Future – The Scottish Mallaig Sprat Fishery by Campbell C. Pert.

Section 2 ends up with a general discussion on the applicability problems encountered when applying surplus production models to the Assessment and Management of short-lived fish species and Cephalopods.

In Section 3 the report for Subgroup 2 – focused on ToR 2 is made, where the MSE testing of HCRs based on indicator trends or in constant Harvest rates is presented for particular or generic case studies, coupled or not with biomass safeguard and with selected uncertainty cap levels. First (Section 3.1) the MSEs for a simulated stock of sprat in 7.de is presented (by Nicola Walker), whereby the performance of 1-over-2 in-year advice and of constant harvest rates are explored for different uncertainty cap constrains and biomass safeguards. Next (Section 3.2) the testing of several management advice procedures for rather generic short-lived data-limited stocks in Category 3 are presented, comprising both n-over-m trend rules and constant harvest rates again for different uncertainty cap constrains and biomass safeguards. The Section 3 ends up with by some conclusions and future directions of research regarding improvements for these management procedures (Sections 3.3 and 3.4).

The report ends with a compilation of general conclusions (Section 4) and future directions of work (Section 5).

1.5 Consideration of Timing for Advice

The time-lag between monitoring, assessment-advice and management affects the performance of any harvest control rule. Therefore, the workshop tried to quantify how the three typical timeframes affect the performance. These are:

The usual management calendar goes from January to December. Index available during the interim year y (in Figure 1.5.1 it is made available at 1st July or earlier) is used to set the TAC from January to December of year (y+1) (Figure 1.5.1.a). This means that there is no indication of age 1 in the TAC year, which for short-lived species might be the bulk of the population.

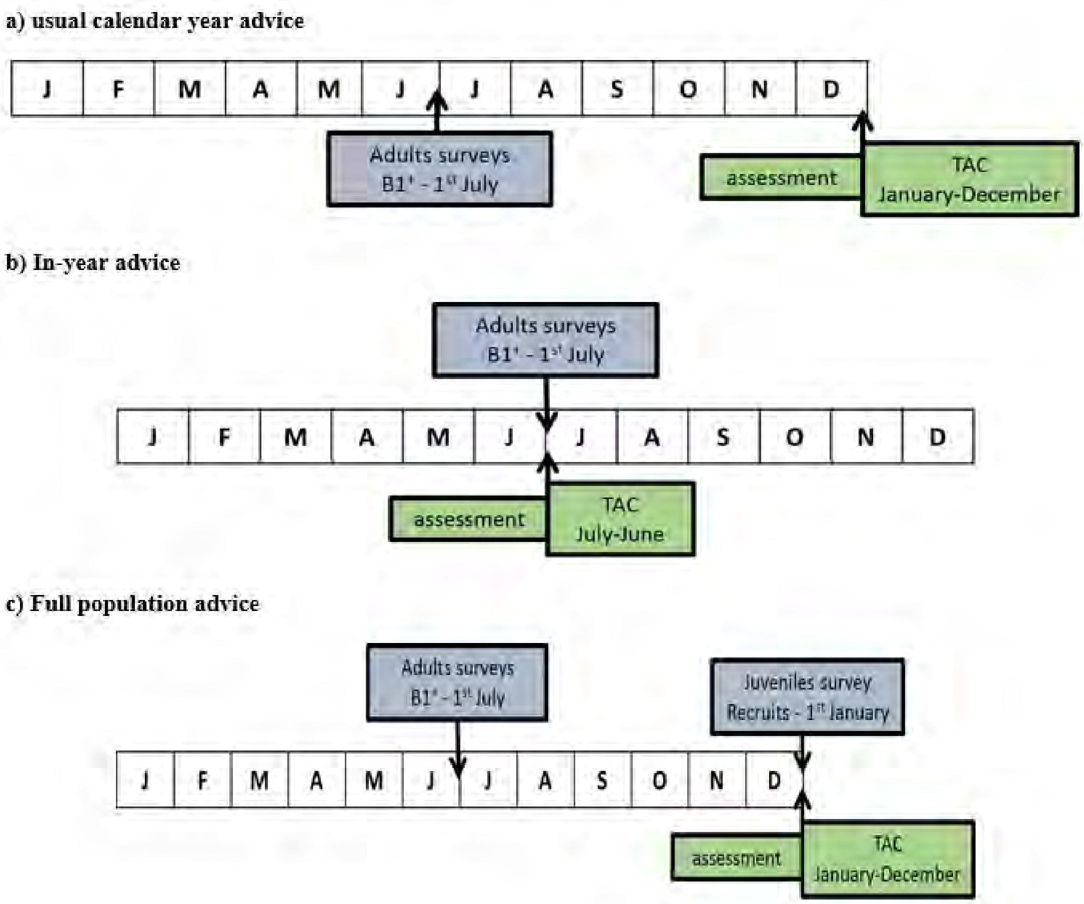

Figure 1.5.1. TAC calendars.

Two alternative management calendars are: The first one, the in-year advice corresponds with the case where the index is available during the first half of the interim year y (in the figure on 1st July) and it is used to set the TAC from July year y to June in year (y+1) (to generalize this, management will be starting in the same year when the index is made available). This means that during the second semester in year y age 1 is known, but not during the first semester of year (y+1). A second alternative case of management calendar sets the TAC from January to December in year (y+1) but based on the B1plus index on 1st January of the management year (y+1). This is the usual case when one or two surveys provide information during the interim year of both the biomass of ages 1 and older (B1+) and of the recruits at age 0; or alternatively a survey covering the entire stock (ages 0+) is carried out at the end of the interim year and it is used to the set catch option for the management year starting just 1 or a few months later. In this case, the index(es) provides information on all the age classes that are going to be exploited in year y+1. This was called here full population advice, and it was only tested in a few cases. In the latter case, as the entire management population is informed by the abundance index the capacity of achieving a good management is enhanced.

1.6 Follow-up process within ICES

The workshop was also required to review the current ICES technical guidance on advice rules for stocks in categories 3 and 4. Draft technical guidance on advice rules for short-lived stocks in categories 3 and 4 were produced and passed to WKLIFE X, which was tasked to review the draft guidelines.

ICES WKLIFE X met from 5 to 9 October 2020, online, and a summary of the work carried out in WKDLSSLS was presented to the group on the first day. The report of WKDLSSLS was not available at the time WKLIFE met, but an extensive summary of the work is included in a section of the WKLIFE report. The draft guidance on advice rules for short-lived stocks in categories 3 and 4 proposed by WKDLSSLS were reviewed by WKLIFE X on Friday 9 October.

The WKLIFE revised drafted technical guidance on advice rules for stocks in categories 3 and 4 (including the section on short-lived stocks) and the report of WKLDLSLS will be reviewed by ACOM in autumn 2020.

1.7 References

ICES. 2017. Report of the Workshop on the Development of the ICES approach to providing MSY advice for category 3 and 4 stocks (WKMSYCat34), 6–10 March 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:47. 53 pp.

ICES. 2018. Report of the Eighth Workshop on the Development of Quantitative Assessment Methodologies based on LIFE-history traits, exploitation characteristics, and other relevant parameters for data-limited stocks (WKLIFE VIII), 8–12 October 2018, Lisbon, Portugal. ICES CM 2018/ACOM:40. 172 pp.

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ICES. 2020a. Working Group on Southern Horse Mackerel, Anchovy and Sardine (WGHANSA). Draft report. ICES Scientific Reports. 2:41. 513 pp. http://doi.org/10.17895/ices.pub.5977. Publication of the full report is expected end of 2020.

ICES. 2020b. Herring Assessment Working Group for the Area South of 62°N (HAWG). ICES Scientific Reports, 2:60. 1054 pp. https://doi.org/10.17895/ices.pub.6105.

2 Subgroup 1 ToRs 1 & 2 Assessments and definition of BRPs

2.1 A comparison of SPiCT and Gadget estimates up to 2020 for the Anchovy in 9aSouth, and the last advances in Farfish-DLMtool

Margarita María Rincón Hidalgo, IEO

A comparison between the Gadget model used in 2020 to provide assessment and advice (Rincón *et al.*, WD 2020a) and a SPiCT model has been performed. The first attempt to find a suitable SPiCT model for this comparison, was to explore different scenarios, one assuming seasonal productivity, one with time-varying growth, another with both, and finally one reducing the time-series input length. The implementation results showed that these assumptions do not have a remarkable influence when compared with the standard implementation that assumes constant productivity and constant growth. This standard implementation was used to compare with Gadget outputs. It results in very similar trends of estimated absolute harvestable biomass after year 2005, the year when catches and the two survey indexes were available together for the first time in the time-series. It suggests that a good biomass estimation can be obtained using only the catches and two survey index, as model input. It is also remarkable that SPiCT stochastic Bmsy estimate (2040 t) is very close to the B_{pa} calculated in the 2020 assessment. Nevertheless, the SPiCT model catchability estimates for the surveys are very high (8.05 and 6.25 for PELAGO and ECOCADIZ surveys, respectively) and even higher than Gadget estimates (3.3 and 4.4 for PELAGO and ECOCADIZ surveys, respectively). Details on the scenarios definition and results are presented in Rincón *et al*. (WD 2020b, Annex 6.2).

The last advances of the Farfish-DLMtool were also presented. FarFish is an European project funded by the framework programme HORIZON 2020 under the topic H2020-SFS-21-2016: Advancing basic biological knowledge and improving management tools for commercially important fish and other seafood species. In this project framework, the need of tools for stock assessment has emerged but also the amount of data available has become a limitation. Thus, this has led to the development of a tool intending to be understandable by everyone and giving some outputs of different stock assessment estimations according to the data available. The tool available at https://ffdb.farfish.eu/, has two branches, one is a customized version of the Data-limited methods toolkit (Carruthers and Hordyk, 2018), and the second one implements a user interface for the SPiCT version described at (Mildenberger *et al*., 2020). A detailed version of the user guide for the tool in different languages will be available at FarFish website in 2021.

The first branch is also based on the DLMtool R package as the toolkit, but has allowed a continuous feedback process of modification by following the demands of the CS leaders and stakeholders. The first version in this process was presented in WKDLSSLS-1 (ICES, 2019) and it was focused on enhancing the data input and on easily linking that data to management-procedure testing. It is available at https://ffdb.farfish.eu/shiny/dlmgui/.

The second branch that was presented in this version of the workshop and it is available at https://ffdb.farfish.eu/shiny/SPiCTgui/. This link will redirect the user to a screen like the one displayed in Figure 2.1.1, with different tab options for data input, visualization, and results.

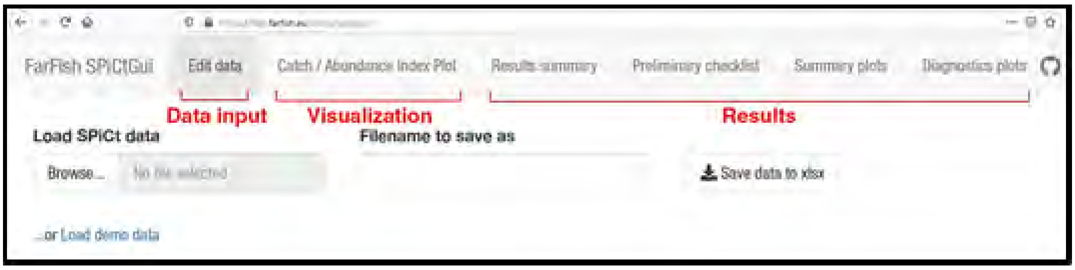

Figure 2.1.1. FarFish-SPiCTGui screenshot highlighting the different tab options for data input, visualization and results.

The data input is performed in the "Edit data" tab. In this tab, the user has two options: To upload the data or to enter the information available by hand. Uploading data can be done by clicking the "Browse" button highlighted in red in Figure 2.1.2. SPiCT data format suitable to be uploaded can be obtained after filling the excel template that is available here and saving that document in her/his machine.

Figure 2.1.2. FarFish-SPiCTGui main menu screenshot. Click on 'Browse' to load SPiCT data file.

The user can enter its data by filling the tables that appear when scrolling down and can save his progress at any time in a xlsx format file by giving name to that file in the "Filename to save as" box (red square in Figure 2.1.3) and clicking on the "Save data to xlsx" button next to it. To guide this process, it is recommended to click on the blue link "Load demo data" (Figure 2.1.4) that will fill the tables automatically, then the user can remove these data and replace them with its own. It is important to remark that if there is missing information the corresponding field can be filled with "NA" or can be left empty.

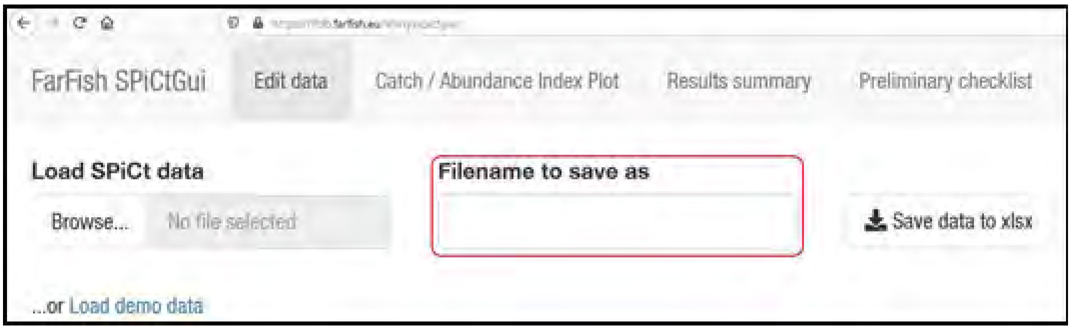

Figure 2.1.3. FarFish-SPiCTGui "Edit data" tab screenshot highlighting the field where the user provides a name to the data file to save her/his progress.

Figure 2.1.4. FarFish-SPiCTGui "Edit data" tab screenshot highlighting the 'Load demo data' hyperlink that allows to load example data.

When scrolling down the first choice to make corresponds to "Model configuration", the user can decide a seasonal productivity or time varying growth SPiCT implementation by clicking the corresponding checkbox. For the demo data, none of the checkboxes were ticked as shown in Figure 2.1.5, this corresponds to the usual SPiCT implementation described in Pedersen *et al.*, 2017.

The second heading corresponds to catch data time-series (Figure 2.1.5). The first and last year of the time-series can be modified by clicking the up and down arrows in the two boxes next to "Years:". The time-scale of the data should be modified using the options of the dropdown menu next to the last year box. The data to fill the cells corresponding to catch can be copied and pasted from an excel file. In a similar way the user can fill the "Abundance index" information (Figure 2.1.6), but in this case the user can specify the exact month of the year when the index was collected. A maximum of four indices can be incorporated for the implementation. Please take into account that the indices should account only for the exploitable biomass. A link for the SPiCT manual, as well as useful references can be found at the end of all the tabs.

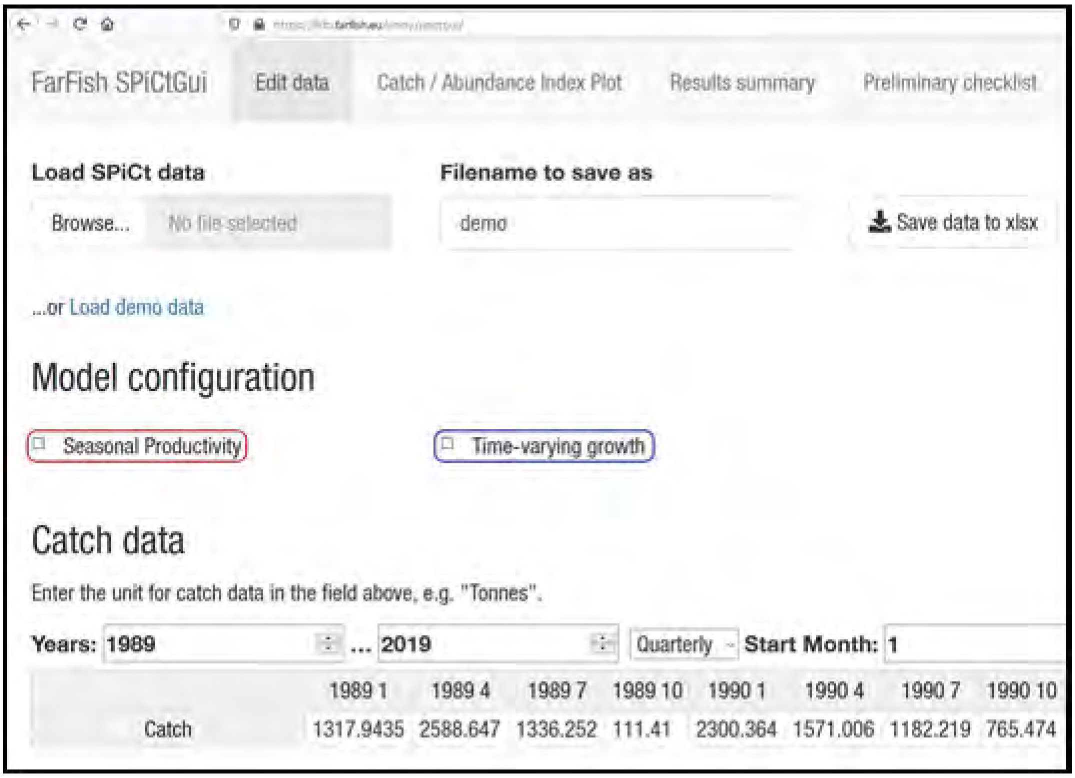

Figure 2.1.5. FarFish-SPiCTGui "Edit data" tab screenshot highlighting model configuration selection.

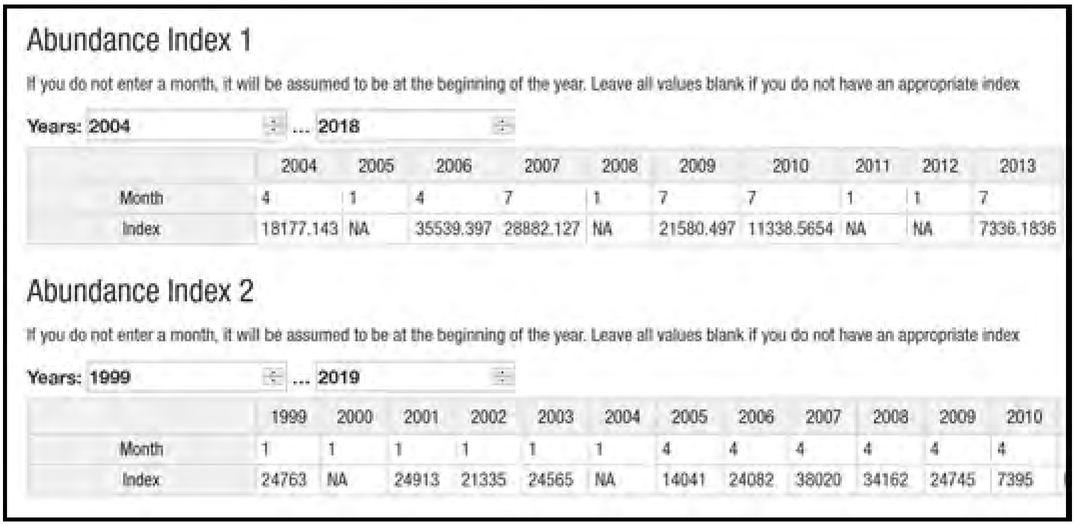

Figure 2.1.6. FarFish-SPiCTGui "Edit data" tab screenshot showing the Abundance index 1 and 2 fields, filled with demo data.

The SPiCTGui allows the user to visualize catches and abundance indices time-series (by clicking on the "Catch/ Abundance Index plot" tab, Figure 2.1.7). Please note that these plots can be downloaded by clicking on the "Download plot" button.

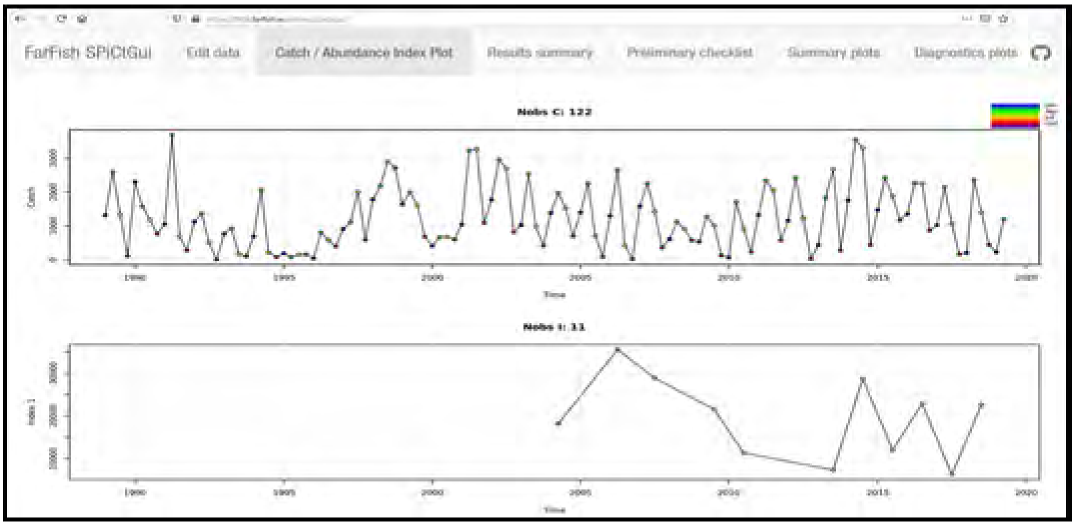

Figure 2.1.7. FarFish-SPiCTGui "Catch/ Abundance Index plot" tab screenshot showing Catch and abundance index plot visualization for demo example.

Results of SPiCT implementation are divided into four tabs: "Result summary", "Summary plots", "Preliminary checklist" and "Diagnostics plots". The first two present model results in raw and graphical formats, the third is a preliminary checking to see if the model implementation can be used for stock assessment purposes and the fourth is to check if there have been violations of model assumptions.

Information about convergence and assumptions of the model, as well as estimated parameters are presented in the "Summary results" tab (Figure 2.1.8). To have a detailed description on how to interpret these results it is recommended to read the SPiCT manual (there is also a link to the manual at the end of all the tabs, under the "References" heading). These results can also be downloaded in a format that can be read in R by clicking on the "Download SPiCT.fit Rdata" button (Figure 2.1.8).

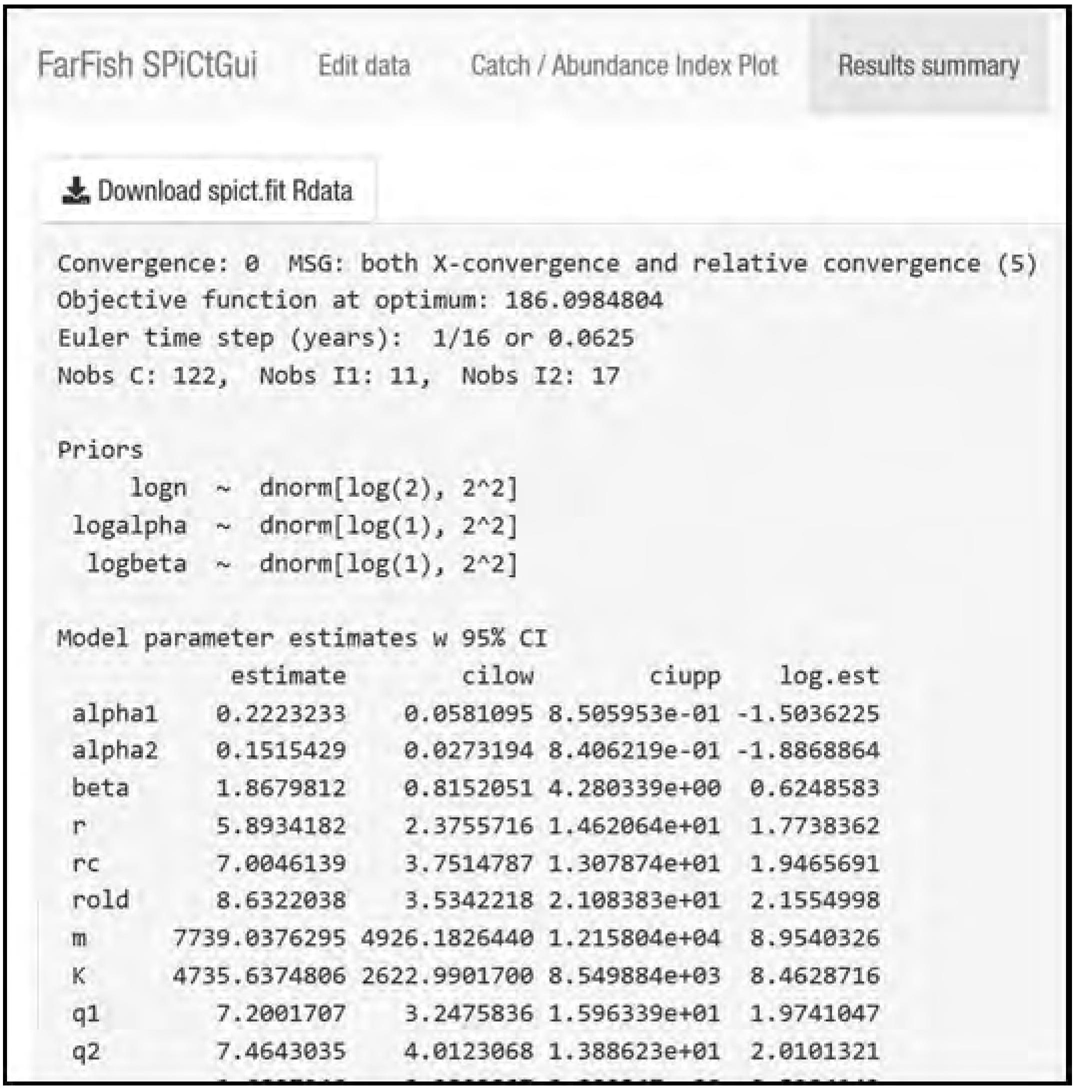

Figure 2.1.8. FarFish-SPiCTGui "Results summary" tab screenshot showing information about convergence and assumptions of the model, as well as estimated parameters for demo example.

The "summary plots" tab shows estimated biomass, fishing mortality, catch and production time-series (blue lines) with their confidence intervals (shaded blue areas), as well as estimated reference points (horizontal black lines) as can be observed in Figure 2.1.9. A detailed explanation for plot interpretation can be found in the SPiCT manual.

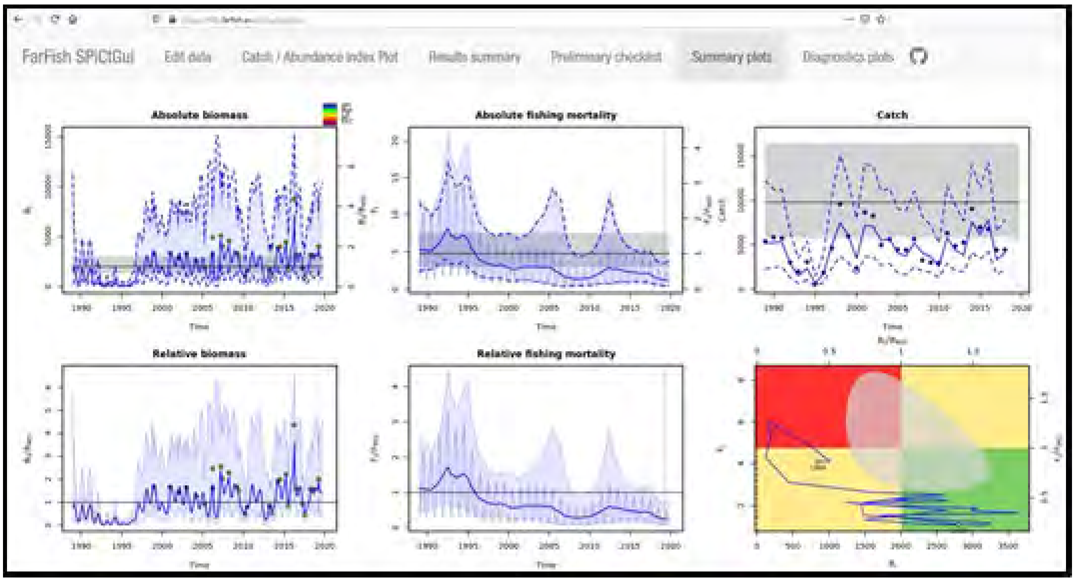

Figure 2.1.9. FarFish-SPiCTGui "Summary plots" tab screenshot showing resulting plots for demo example file.

The "Preliminary checklist" allow the user to check if the main conditions for the use of the SPiCT implementation in stock assessment are met (Figure 2.1.10). There are more conditions that should be checked, but they are still not included in the tool. In case the user wants to use the SPiCT model for stock assessment, she/he must checked the whole list that is available on the SPiCT guidelines documentation (There is also a link to these guidelines at the beginning of the tab).

The "Diagnostics plot" tab helps to see if there are violations of model assumptions (Figure 2.1.11). This can be checked by visual inspection on the colour of the titles of the plots, if they are green, no violation has been found; they will be red otherwise. Slight violations of model assumptions not necessarily invalidate model results.

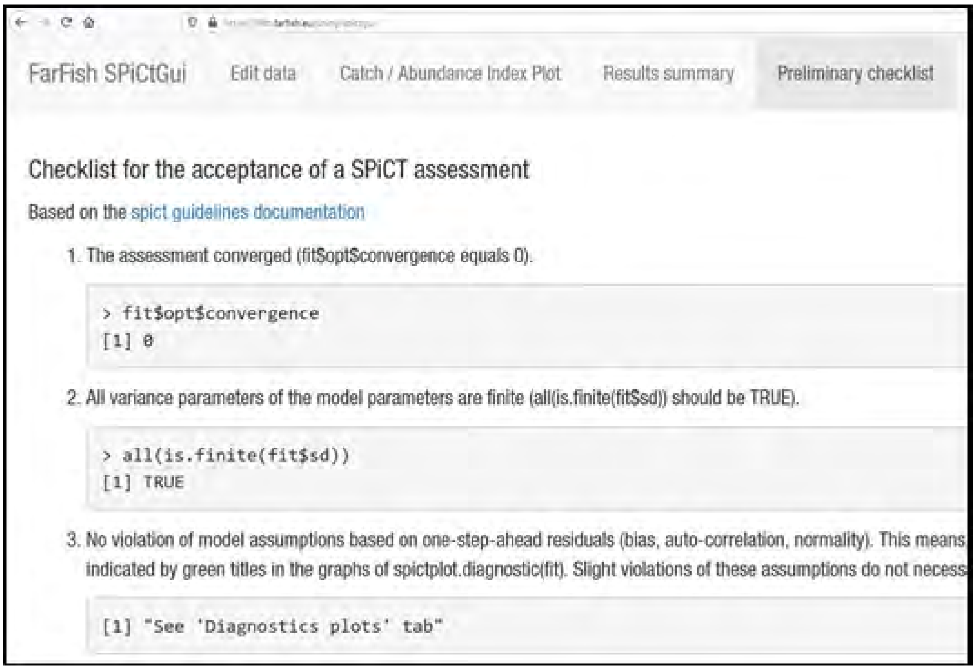

Figure 2.1.10. FarFish-SPiCTGui “Preliminary checklist” tab screenshot showing a checklist for the acceptance of a SPiCT assessment applied to demo example file.

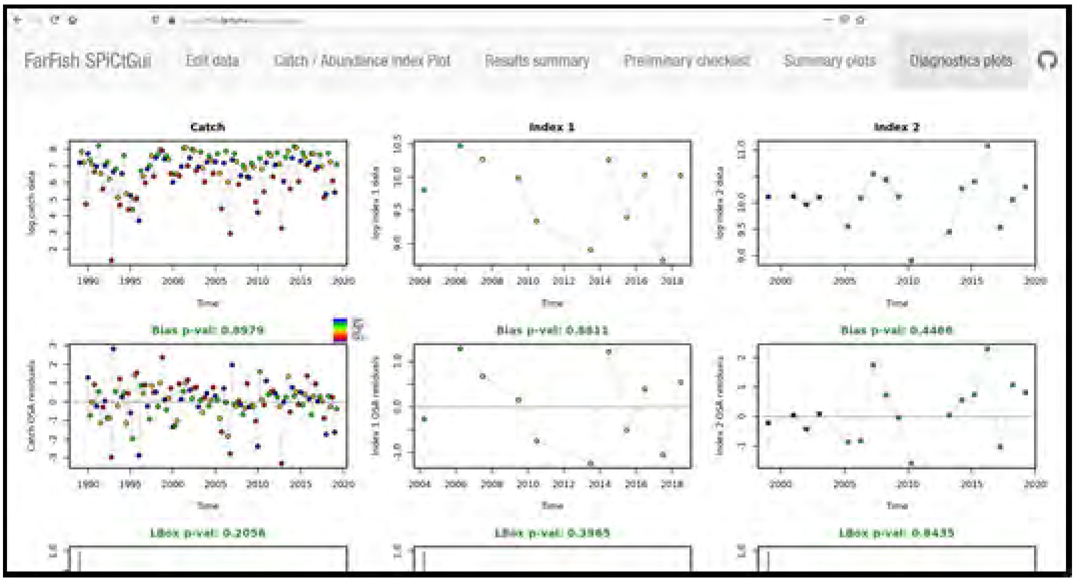

Figure 2.1.11. FarFish-SPiCTGui “Diagnostics plot” tab screenshot showing Plots for diagnostics on model assumption violations from demo example file.

2.2 Testing Harvest strategies with Anchovy in 9aWest, first application of SPiCT production model and variants

Laura Wise, Susana Garrido and Alexandra Silva

The assessment of anchovy 9.a started in 2018 as category type 3 stock after the stock benchmark in February 2018 (WKPELA 2018; ICES, 2018a). WKPELA 2018 supported the proposal of considering two different components of the stock (western and southern component) due to the different dynamics of their fisheries and populations. However, until the stock structure along the division is properly identified, the provision of advice will still be given for the whole stock, but with separate catch advice for each stock component. Both components of the stock are assessed using an interim trend-based procedure. For the Western component the biomass indicator input is taken from the results of the acoustic spring surveys covering this area (PELAGO and PELACUS estimates are summed), while for the Southern component, the biomass indicator input is obtained from the results of SSB estimates from a Gadget assessment model, using those as a relative index. The management calendar for the application of the advice was also agreed in WKPELA 2018 to be in-year, the one from 1st July of year y to 30th June of year y+1.

In 2018, when assessment for this stock was first provided, the biomass of this stock component increased significantly and the 1 over 2 rule with 20% uncertainty cap was applied. The following year, the biomass of the western component decreased by more than 90% and, since the 20% cap would lead to a very high harvest rate, an 80% cap was applied. In 2020, the survey index reached the second highest value of the time-series but the advice, following the current rule (1 over 2 with 80% uncertainty cap), was of only 4347 tonnes corresponding to a harvest rate of 0.07, one of the lowest of the last ten years. This implies a huge change in harvest rates between these two consecutive years (63% in 2019 to 7% in 2020). The expert group of WGHANSA considers that the current advice procedure for short-lived species category 3 stocks, based on the 1 over 2 ratio with an uncertainty cap of 80%, is still not flexible enough to adapt to the highly fluctuating nature of this stock component. For the observed high interannual changes in abundances, this may result in a too intense and fast reduction of catches in a very short period of years, damaging unnecessarily the fishing opportunities. WKDLSSLS-2 was asked for looking for other MP like constant harvest rates.

SPiCT (Pedersen *et al*., 2017) started to be explored in WKDLSSL 2019 to assess the Western component of this stock; further trials were carried out in the present meeting. Input data included quarterly catches in 1991–2019, total biomass from spring acoustic surveys PELACUS+PELAGO 1999–2019, biomass index (kg/hour) from the autumn Portuguese IBTS survey 1991–2018. The models had four seasons/quarters and started at the middle of the year (1st July). The performance with respect to the estimation model was tested using different datasets (survey inputs, acoustic and IBTS survey) and various model settings (priors on n and q) (Table 2.2.1). Default priors were used except in the following cases; a prior was tested for the production curve parameter, n, based on estimates for Clupeiforms from a meta-analysis (Thorson *et al.,* 2012) (log(0.599),0.342); a tight prior for the acoustic survey catchability (q1) was also tested (log(1), 1E-3) to mimic the assumption that the survey is an absolute index of abundance. Models allowing seasonal fishing mortality (fixed pattern over time) and, allowing seasonal and gradual long-term trends in productivity were also tested. These were considered reasonable assumptions given historical data and biological knowledge for the species and for similar ones. Although the IBTS survey appeared to catch mostly juveniles in years of good recruitment, there is a significant correlation between the IBTS in year y and the acoustic survey in year y+1 (WKDLSSL 2019). The acoustic survey catches mostly adult fish therefore the IBTS survey may be considered an indicator of the exploitable biomass in the following year.

Convergence success, 15 out of 18 models, was much higher than in trials carried out in WKDLSSL 2019. This was due to the use of a spline based F model (seasontype=1) instead of the coupled SDE approach (seasontype=2). All but one model showed finite variances, well-behaved catch and survey residuals as well as credible production curves (Table 2.2.1). Time-variant productivity models also converged but the confidence intervals of time-variant parameters were unrealistically high.

The best model included catches, the IBTS and the acoustic survey, and the "absolute" prior on acoustic catchability. Both catch and survey residuals were random and independent (Figure 2.2.1). A six years retrospective indicated overestimation of B/B_{MSY} and underestimation of F/F_{MSY} and the first run has a totally different trajectory (Figure 2.2.2). The confidence intervals of B/B_{MSY} and F/F_{MSY} both span two orders of magnitude being above the ICES guidelines to accept the model for stock assessment (Mildenberger *et al*., 2019; Guidelines for the stochastic production model in continuous time (SPiCT)). The model does not seem to be too sensitive to initial values (tested after the meeting) as the parameters of converged runs were comparable (the distance from the estimated parameter vector to the base vector did not exceed 3.85). Overall, the model was able to follow the large changes in biomass of the stock reasonably well (Figure 2.2.3). B_{2019}/B_{MSY} (in quarter 2) was estimated to be 0.47 CI=[0.02,9.78] and F_{2019}/F_{MSY} also in quarter 2, was estimated to be 0.47 with CI=[0.07,3.19]. The sensitivity of the model to the assumption of absolute catchability for the acoustic survey needs to be tested. Among the recent developments of SPiCT, the assumption of a regime shift in productivity may be worth exploring in the future.

Table 2.2.1. SPiCT models fitted to 9aWest anchovy.

		Survey data	Model type	Priors		Time varying productivity		Results		Uncertainty: magnitude of CI			
Run no.				n	q	Seasonal	Yearly gradual	Convergence	Production curve (0.1<Bmsy/K<0.9)	B/Bmsy	F/Fmsy	AIC	Observations
1	Defaults	acoustic index	Seasonal F	d	d	no	no	Yes	0.30	7	4	416	
2	N prior	acoustic index	Seasonal F	clup	d	no	no	Yes	0.29	7	4	412	
3	Q prior	acoustic index	Seasonal F	d	abs	no	no	Yes	0.31	7	4	404	
4	N & Qprior	acoustic index	Seasonal F	clup	abs	no	no	Yes	0.29	7	4	400	
5	Seasonal productivity	acoustic index	Seasonal F + Seasonal productivity	d	d	yes	no	No					
6	Seasonal productivity	acoustic index	Seasonal F + gradual change in productivity	clup	abs	yes	no	Yes				398	
7	Defaults	IBTS index	Seasonal F	d	d	no	no	Yes	0.37	4	3	586	
8	N prior	IBTS index	Seasonal F	clup	d	no	no	No					
9	Q prior	IBTS index	Seasonal F	d	abs	no	no	Yes	0.37	3	2	574	
10	N & Qprior	IBTS index	Seasonal F	clup	abs	no	no	No					
11	Seasonal productivity	IBTS index	Seasonal F + Seasonal productivity	d	d	yes	no	Yes				577	
12	Long-term gradual change in productivity	IBTS index	Seasonal F + gradual change in productivity	clup	d	no	yes	Yes				598	Flat time variation

		Survey data	Model type	Priors		Time varying productivity		Results		Uncertainty: magnitude of CI			
Run no.				n	q	Seasonal	Yearly gradual	Convergence	Production curve (0.1<Bmsy/K<0.9)	B/Bmsy	F/Fmsy	AIC	Observations
13	Defaults	Acoustic+IBTS indices	Seasonal F	d	d	no	no	Yes	0.38	2	3	661	
14	N prior	Acoustic+IBTS indices	Seasonal F	clup	d	no	no	Yes	0.35	4	2	659	
15	Q prior acoustic	Acoustic+IBTS indices	Seasonal F	d	abs	no	no	Yes	0.38	2	2	653	
16	N & Qprior	Acoustic+IBTS indices	Seasonal F	clup	abs	no	no	No					
17	Seasonal productivity	Acoustic+IBTS indices	Seasonal F + Seasonal productivity	d	d	yes	no	Yes	0.37	Look similar to other runs		652	Amplitude of seasonal productivity unrealistic
18	Long-term gradual change in productivity	Acoustic+IBTS indices	Seasonal F + gradual change in productivity	d	d	no	yes	Yes	0.38	Some plots fail		673	Rt plot flat

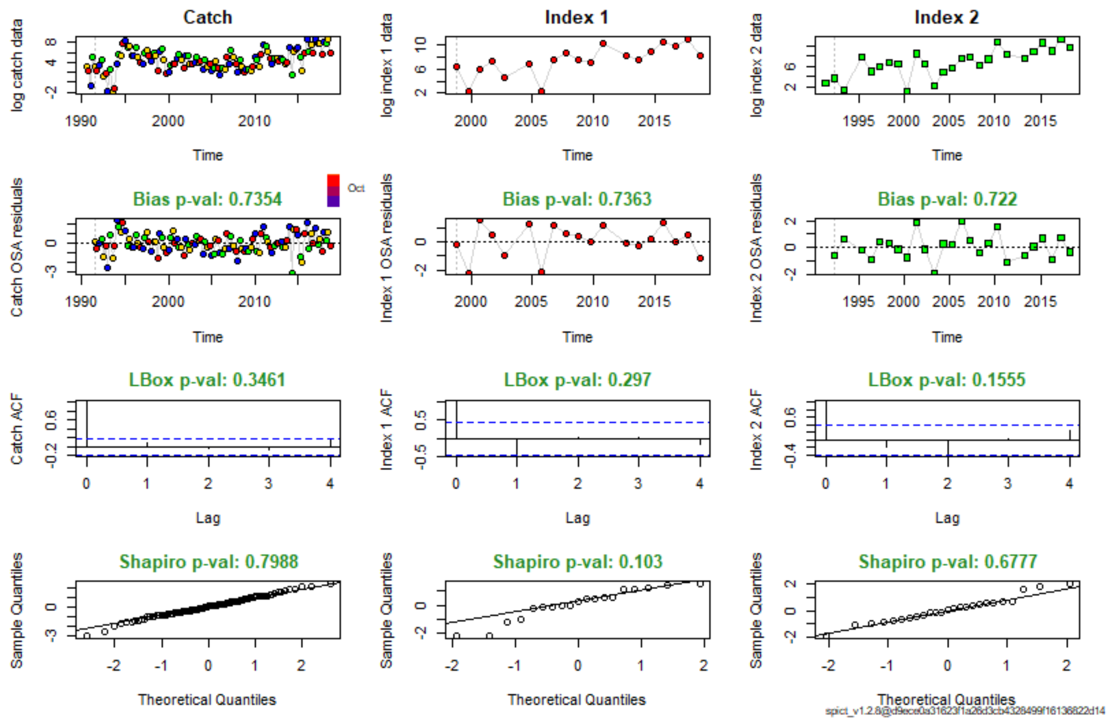

Figure 2.2.1. Residual plots of the best SPiCT model fitted to anchovy 9a. west.

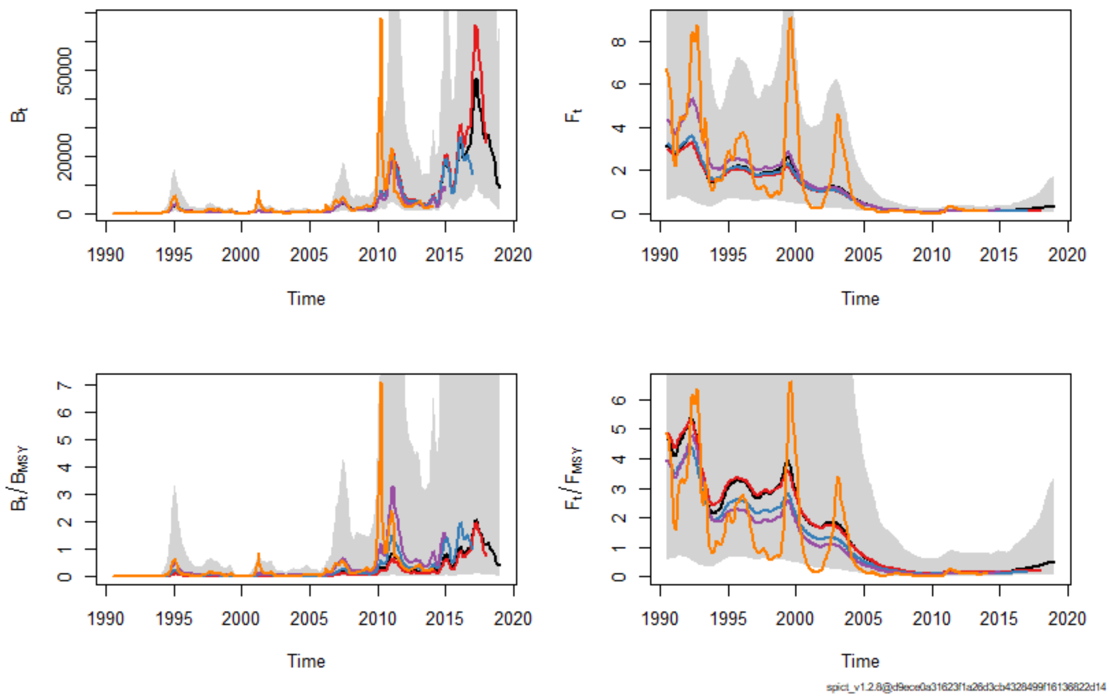

Figure 2.2.2. Retrospective plots for the best SPiCT model fitted to anchovy 9a. west.

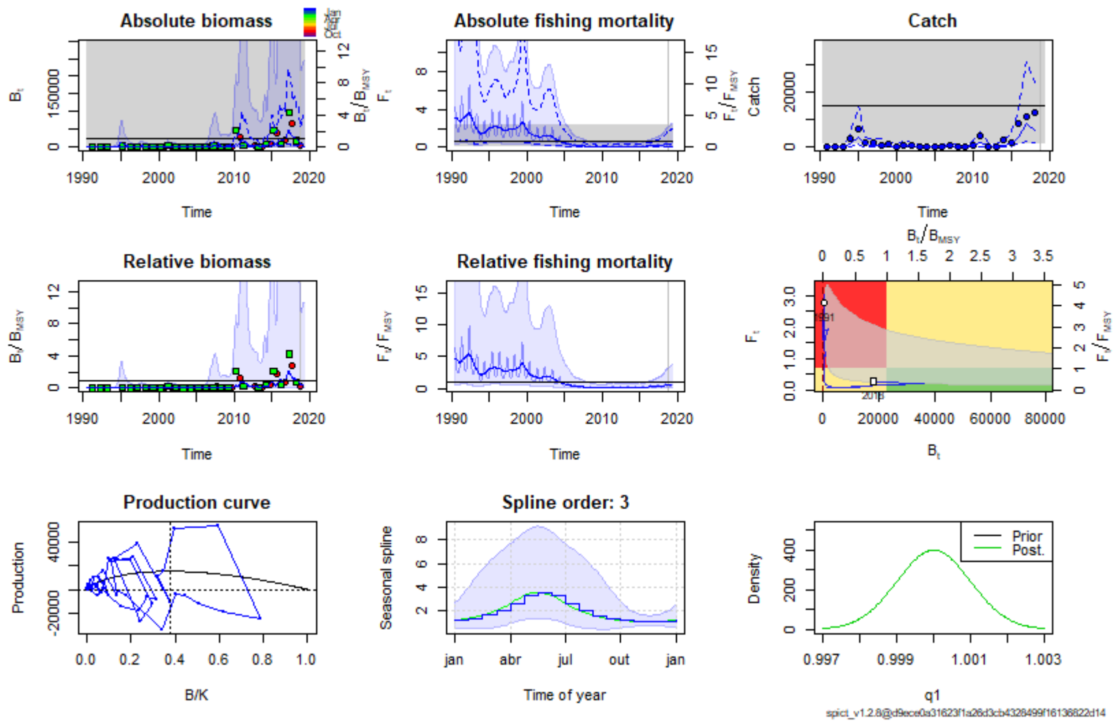

Figure 2.2.3. Summary plots of the best SPiCT model fitted to anchovy 9a. west.

An exploration of a potential stock–recruitment model to describe the productivity of this component of the stock was carried out (Figure 2.2.4). Neither the Hockey-stick model or the Ricker model show a good adjustment to the stock–recruitment pairs (Figure 2.2.5–2.2.7) but it is apparent that the productivity of this stock resembles a density-dependent relationship.

The WG considered that SPiCT was a promising approach for the assessment of this stock although the large uncertainty in parameter estimates may prevent the incorporation in an MSE context. Work was started in order to develop a management strategy evaluation (MSE) to evaluate the performance of different management rules suggested by WGHANSA (ICES, 2020) using FLBEIA (García *et al.*, 2017). The approach was to condition FLBEIA Operating Model with the best SPiCT model. The initial populations would be generated from a set of random parameters sampling from a normal distribution using the log-estimates of the parameters and the covariance matrix as estimated by SPiCT. Future work will include improving the SPiCT estimates and carry out the MSE with the different management rules proposed during the workshop, aiming at finding one that improves the quality of the advice in relation to the 1over2 with 80% cap currently used.

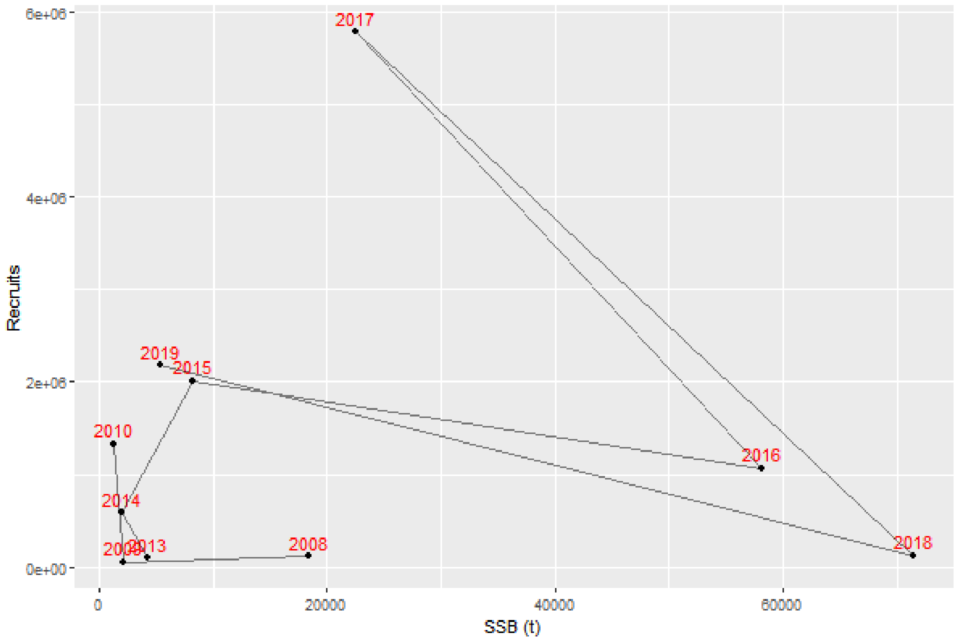

Figure 2.2.4. Stock–recruitment pairs for the Anchovy western component (2008–2019).

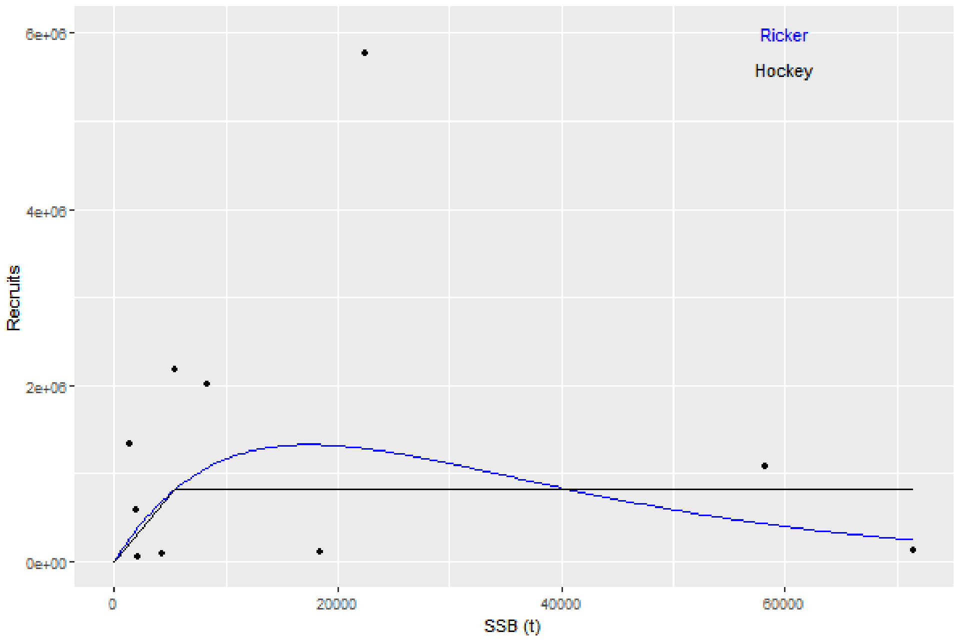

Figure 2.2.5. Fitted Hockey stick (black) and Ricker (blue) for the period 2008–2019.

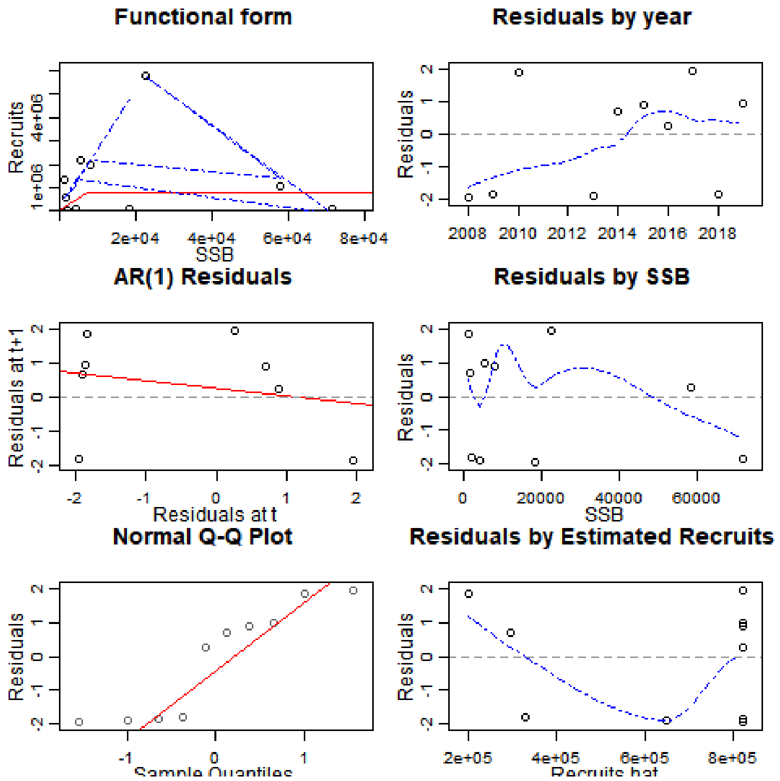

Figure 2.2.6. Hockey-stick residuals model plots (2008–2019).

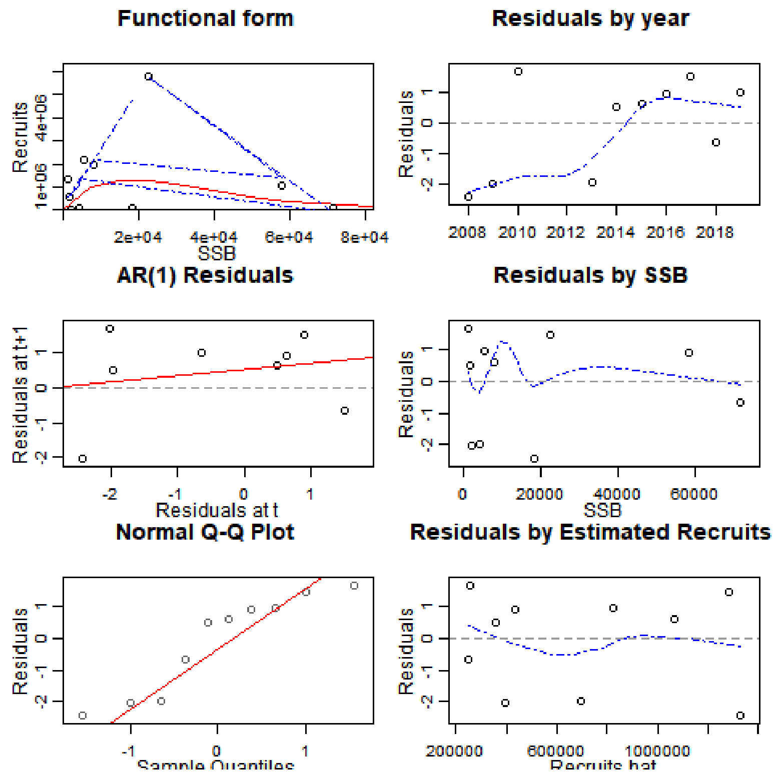

Figure2.2.7. Ricker residuals model plots (2008–2019).

2.3 Stock assessment of *Octopus vulgaris* in Asturias, Bay of Biscay with a hierarchical statistical model

Ruben H. Roa-Ureta

The octopus fishery conducted in coastal waters of Asturias (Bay of Biscay) in Spain, is the only octopus fishery in the world that has been certified by the Marine Stewardship Council (MSC). The MSC set the renewal of certification (due in 2020) conditional on establishing harvest control rules (HCR) based on the best scientific knowledge of stock exploitation status (Principle 1 of the MSC certification process). The following study case is an abridged version of a report presented to the Asturias regional administration for the purpose of MSC certification renewal. Asturias regional administration approved the presentation of this study case for the purposes of the working group.

2.3.1 Brief description of the fishery and data collection

The *Octopus vulgaris* fishery in Asturias, north-west Spain is a small-scale fishery (SSF) that has been managed through a participatory, co-management approach since 2001 (Fernández-Rueda and García-Flórez, 2007). This SSF is a single-species fishery operated by a varying number of authorized boats, currently around 40, from eight fishers' associations. Fishing is conducted with traps during a season that typically extends between December and July, most boats operated with two fishers. On any given fishing trip, a maximum of 125 traps are lifted per fisher. These traps usually stay at sea, are lifted in the morning of a fishing day, and in good days, fishers may lift the traps a second time. The total area of operation covers the western half of the coast of Asturias and has been estimated in the range of 228 to 397 km^2. This area is divided into dozens of fishing grounds with varying extension, located between the coastline and 50 m depth isobath in south-western Bay of Biscay (Figure 2.3.1). Although the magnitude of bycatch by other fleets has not been evaluated, sales data that can be traced to specific boats reveal that boats operating with gears other than the traps land very little octopi. A minimum landing weight of 1 kg per individual octopus has also been agreed upon in the co-management system regulations. When traps capture smaller octopi they are returned to sea alive and in good conditions, as witnessed by scientific observers. Furthermore, the biological sampling programme yielding weight data shows that fishers are complying to the minimum landing weight regulation (Figure 2.3.2).

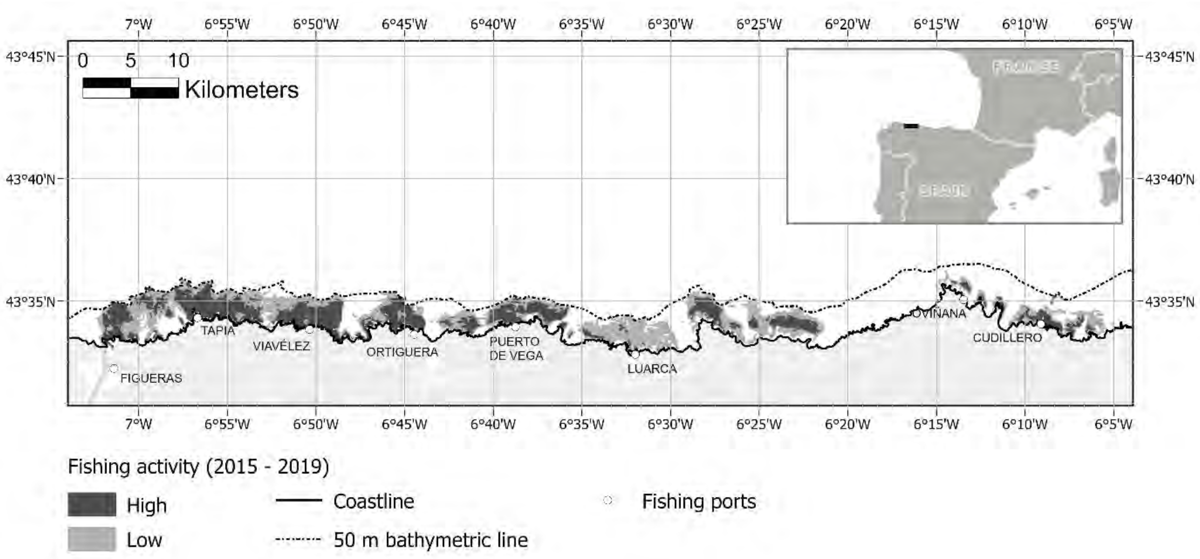

Figure 2.3.1. Map of Asturias coastal zone with *Octopus vulgaris* fishing grounds. Shaded areas are areas of high (dark shade) and low (light shade) fishing activity.

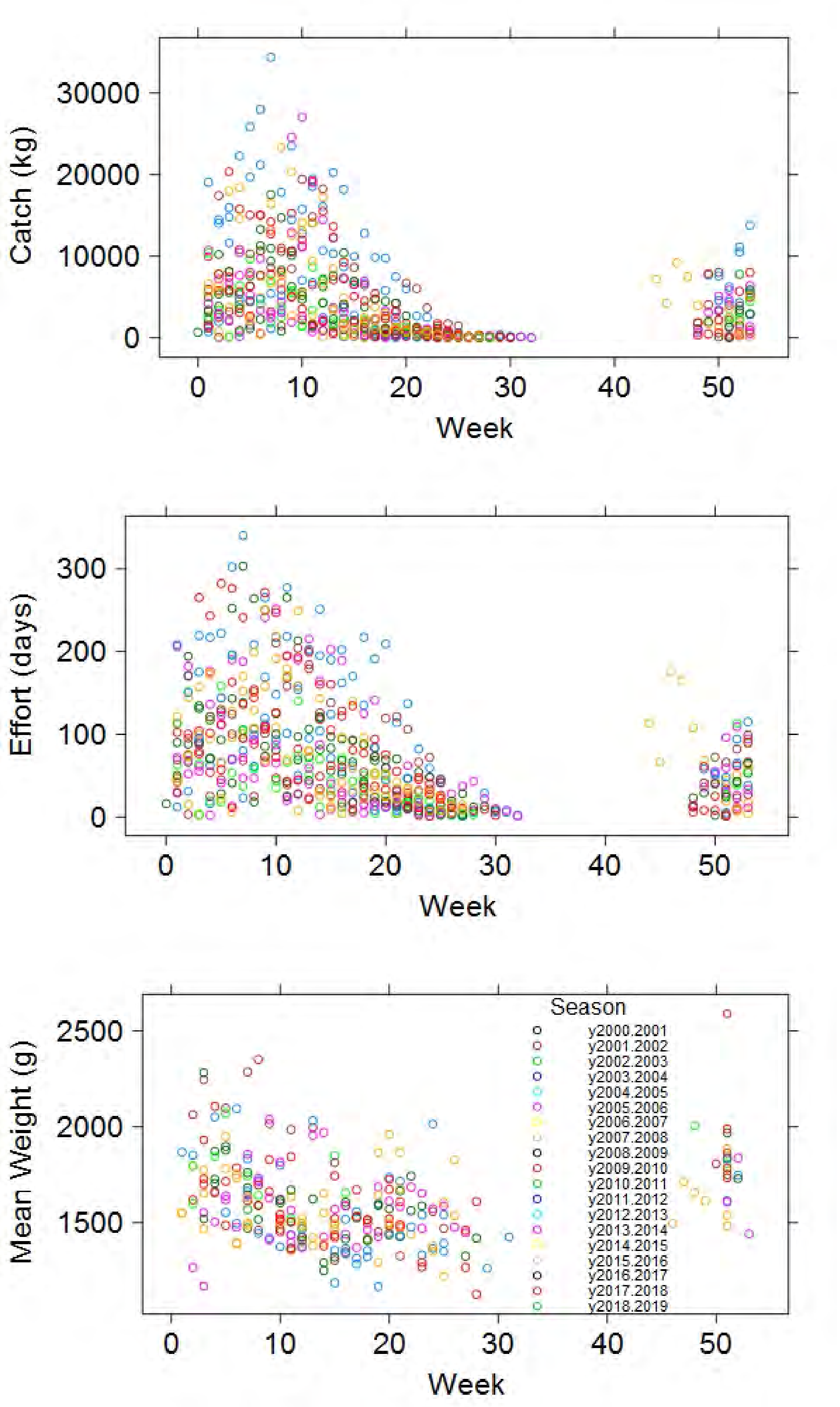

Figure 2.3.2. Raw data available for stock assessment of the *Octopus vulgaris* stock in Asturias coastal zone.

During the period of co-management (2000–2001 to 2018–2019), the data collection system includes a census of daily catch in weight and fishing effort measured as the number of boats operating on any single day. In addition to these census data, biological samples are taken on some days of the season. For the purposes of this work, biological samples provide data of mean individual weight in the catch to transform catch in weight to catch in numbers. Considering the extension of the season (normally seven months) and the sparsity of biological sampling, raw data were aggregated into weekly time-steps to fit intra-annual generalized depletion models to each season's data. Fishing effort was the total number of fishing days by all boats operating in any given week. The complete raw data available for modelling are shown in Figure 2.3.2. During the first period of co-management (2000–2001 to 2000–2008), total annual landings averaged 180 tons and total annual effort normally exceeded 3000 days of fishing. In the second period (2008–2009 to 2018–2019) landings decreased, averaging 102 tons, and effort decreased as well to less than 2000 days.

2.3.2 Stock assessment with generalized depletion models using raw data

Raw data (Figure 2.3.2) was available for 19 fishing seasons (first season: December 2000 to July 2001, last season: December 2018 to July 2019). Each season's data were composed of over 30 weeks and a database with weekly total catch in kg, weekly total fishing effort in boat-days and weekly mean octopus weight for each season was compiled from the raw data. These rapid time-step data are a source of information on stocks abundance, mortality rates and exploitation status that is tapped under the hierarchical inference framework developed in Roa-Ureta *et al*. (2015) in order to inform higher level models of annual population dynamics. Modelling these rapid time-step data also provide final results that are useful for the provision of management advice without recourse to further modelling of the annual population dynamics.

In this study case weekly data were modelled with a specialized generalized depletion model (Roa-Ureta, 2012) applied separately to each season's data. Essentially, conventional depletion models estimate initial abundance and natural mortality rate from closed populations using rapid time-step (days, weeks) data of total catch in numbers and total effort in any unit assuming a linear relation between catch on one side, and effort and abundance on the other side. Generalized depletion models follow the same logic but drop the assumption of a closed population and linear relations, thus allowing for in-season pulses of abundance that reset or accelerate the depletion and non-linear relations between causes (effort and abundance) and effect (catch).

In the present case, during the season (typically extending between December and July) population abundance is affected by two exogenous pulses. One is a positive pulse of abundance representing the recruitment of octopus from the new cohort that grow to the size retained by fishers (1 kg) and the other is a negative pulse of abundance representing the emigration of impregnated females that become unavailable to fishers because they cease feeding and devote all their time to care for their eggs in dens. Under those conditions, the generalized depletion model becomes:

$$
\begin{aligned}
C_t &= kE_t^{\alpha}N_t^{\beta} = kE_t^{\alpha} m f_t(M, N_0, C_{i<t}, R, S) \\
&= kE_t^{\alpha} m \left(N_0 e^{-Mt} - m\left[\sum_{i=1}^{i=t-1} C_{i,i} e^{-M(t-i-1)}\right] + \sum_{j=1}^{j=u} I_j R_j e^{-M(t-\tau_j)} - \sum_{l=1}^{l=v} J_j S_l e^{-M(t-\nu_l)} \right)^{\beta}
\end{aligned}
$$

where C is the expected catch, t is the time-step (i.e. the week), k is a scaling parameter, E is the observed effort, α is the effort response modulator, N is latent abundance, β is the abundance response modulator, m = exp(−M/2) is an adjustment that makes all catch happen instantaneously at mid-week, M is the weekly natural mortality rate, N0 is initial abundance of the weekly time-series, R is the magnitude of recruitment input pulses, S is the magnitude of female spawners emigration pulses, I is an indicator variable that evaluates to zero before the pulse of recruitment and 1 in the rest of the time-series, u is the number of recruitment events, τ is the week when the j recruitment happens, J is an indicator variables that evaluates to zero before the pulse of females spawning emigration and 1 in the rest of the time-series, v is the number of female spawning emigration events, and υ is the week when emigration event l happens.

The model above is the deterministic process for the expected catch under the model. The statistical framework is completed by taking the observed catch as a random variable whose mean time-series is the model above with realized time-series coming from any of a number of distributions. These distributions define the likelihood function that is to be maximised. Among these, the normal and lognormal distribution have simple formulas for the adjusted profile likelihood, an approximation that eliminates the dispersion parameter from the estimation problem. A total of six alternative likelihood functions or approximations were employed in the estimation of parameters. These are all listed in Table 2 of Roa-Ureta *et al*. (2019).

This new generalized depletion model was programmed in a new version of the R package CatDyn (Roa-Ureta, 2019). In CatDyn all parameters are free parameters to be estimated and none of them can be fixed at arbitrary values. The latest version also estimates fishing mortality per time -tep by using a numerical resolution (R function uniroot) of Baranov equation from estimates of abundance, natural mortality and catch per time-step.

2.3.3 Using results of generalized depletion models to fit a Pella-Tomlinson surplus production model

Generalized depletion models produce estimates of annual biomass, for instance, at the start of each season, but also at any other time-step during the season. These annual biomass estimates and their associated measure of uncertainty, namely their asymptotic standard errors, are input observations to fit a surplus production model. In this study case, the model fitted was the generalized surplus production model of Pella-Tomlinson,

$$B_{0,y}=B_{0,y-1}+rB_{0,y-1}\left[1-\left(\frac{B_{0,y-1}}{K}\right)^{p-1}\right]-C_{y-1}, \qquad p>1$$

where B_0 is annual biomass at the start of a fishing season, y is the year, r is the intrinsic rate of population growth, K is the carrying capacity of the environment, p is the symmetry of the production curve and C is the total annual catch. From this model, well-known formulas can be used to derive the maximum sustainable yield (MSY) and the biomass that produces the MSY, B_{MSY}. As will be shown later, the MSY is an excessive harvest rate policy because of the kind of population dynamics that short-lived species may experience, with fluctuations driven by both environmental impacts on recruitment as well as from intrinsic properties of octopus life history. Therefore, a further productivity measure is considered here, the latent productivity, defined as:

$$P_{0,y}=B_{0,y}\left(1-\left(\frac{B_{0,y}}{K}\right)^{p-1}\right)$$

Unlike the MSY, this sustainable productivity measure changes with the status of the stock because it depends on the biomass at the start of the season, thus it is responsive to recent fluctuations.

In a hierarchical model, the uncertainty coming from the original data is transported into the higher level model to preserve at least the most important part of the original uncertainty in the raw data. This is done in our approach (Roa-Ureta *et al*., 2015) by using a multivariate likelihood function, which integrates the standard errors in biomass estimates obtained from generalized depletion model. Because of fitting the depletion models separately to each season's data the multivariate likelihood simplifies to a product of distinct univariate normal distributions,

$$L_H(\{B_0, K, r, p\} | \{\hat{B}_y\}) \propto -\frac{1}{2} \sum_{y=2001}^{y=2019} \left(\log(2\pi S_{\hat{B}_y}^2) + \frac{(\hat{B}_y - B_y)^2}{S_{\hat{B}_y}^2} \right)$$

In the fit of the biomass time-series from generalized depletion models, the annual catch time-series during the period of co-management (2000–2001 to 2018–2019) was complemented with the annual catch time-series available from 1990.

Three versions of the Pella-Tomlinson model were fitted to the catch time-series covering 1990 to 2019 and the biomass time-series from generalized depletion models covering 2001 to 2019:

- a 2-parameters version where initial biomass (in 1989) was equal to the carrying capacity of the environment and the symmetry parameter (p) was fixed at 2 (Schaeffer model) while the intrinsic growth rate (r) and the carrying capacity of the environment (K) were free parameters,
- a 3-parameters version where initial biomass (in 1989) was equal to the carrying capacity of the environment while the symmetry parameter (p), the intrinsic growth rate (r) and the carrying capacity of the environment (K) were free parameters, and
- a 4-parameter version where initial biomass (in 1989), the symmetry parameter (p), the intrinsic growth rate (r) and the carrying capacity of the environment (K) were all free parameters.

The best model for the observations was selected as the model with the lowest AIC.

2.3.4 Stock assessment results

The 3-parameters version of the Pella-Tomlinson model was (by far) the best supported model by the catch and biomass (from generalized depletion models) observations (Table 2.3.1). All three parameters of the model are estimated with good precision (Table 2.3.1) and the dynamics of the stock appears to be of a stable cycle, with ups and downs in biomass around a mean of close to 2000 tons (Figure 2.3.3). With this cyclic dynamic the MSY is nearly five times higher than the highest ever recorded catch and if applied, it would lead to an exploitation rate (100*MSY/typical biomass) higher than 50%. This most certainly excessive exploitation rate under the MSY has been observed in other stocks with fluctuating dynamics (Roa-Ureta *et al*., 2015).

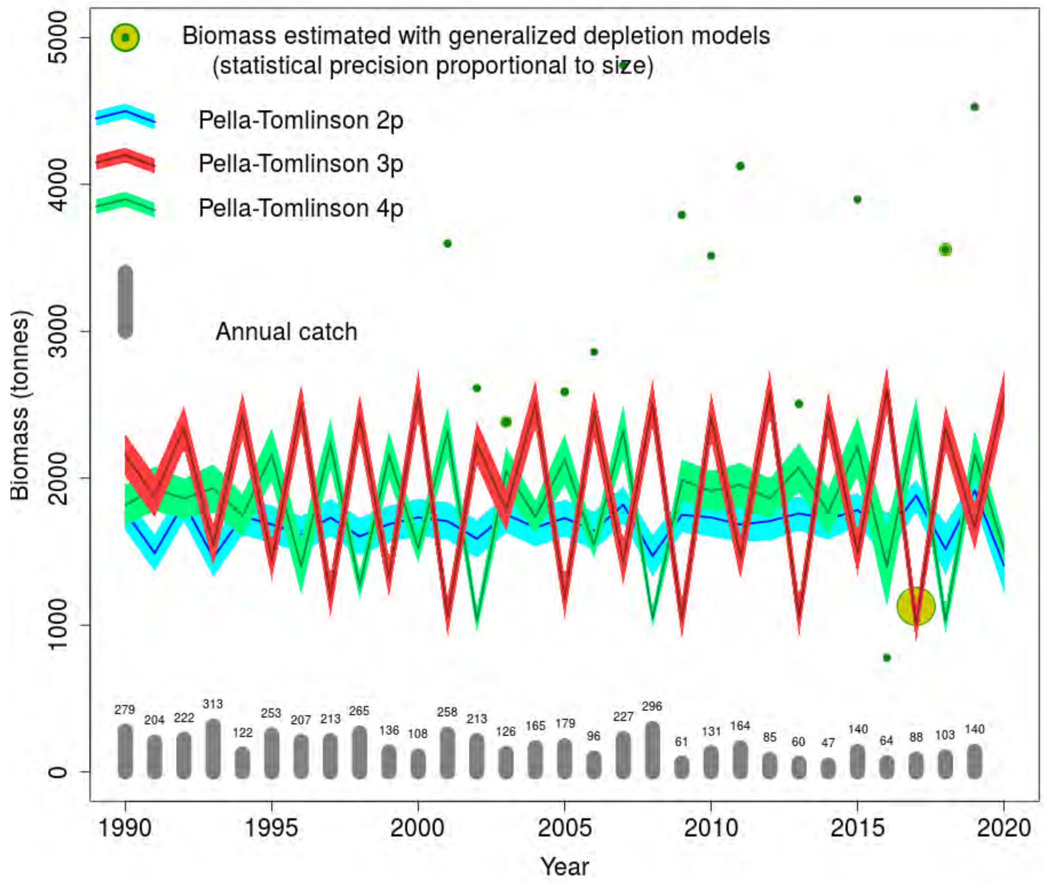

Figure 2.3.2. Raw data available for stock assessment of the *Octopus vulgaris* stock in Asturias coastal zone.

Table 2.3.1. Population dynamics and productivity of the *Octopus vulgaris* stock in Asturias, Bay of Biscay. Pella-Tomlinson 2p is the Schaeffer model with initial biomass equal to the carrying capacity K. Pella-Tomlinson 3p is the Pella-Tomlinson model with initial biomass equal to the carrying capacity K. Pella-Tomlinson 4p is the Pella-Tomlinson model with initial biomass as a free parameter. The best working model (lowest AIC) is marked in bold.

	Pella-Tomlinson 2p		**Pella-Tomlinson 3p**		Pella-Tomlinson 4p		
Parameter	Esimate	Standard Error	**Estimate**	**Standard Error**	Estimate	Standard Error	Catch (tonnes)
Akaike Information Criterion (AIC)	2816,36		**2282,58**		2705,72		
B_0 (Biomass in 1989) (tonnes)	1770	21	**2156**	**24**	1819	23	
K (tons)	1770	21	**2156**	**24**	1982	23	
r (1/año)	2,3206	0,0097	**2,4668**	**0,1133**	2,2857	0,0023	
p	2		**2,1329**	**0,0549**	2,1383	0,0003	
MSY (ton)	1027	10	**1448**	**355**	1237	63	
Biomass that produces the MSY (tonnes)	885	10	**1105**	**19**	1017	12	
Mean total latent productivity over the time series (tonnes)			**239**	**25**			
Biomass 1990 (tonnes)	1770	21	**2156**	**24**	1819	23	279
Biomass 1991 (tonnes)	1491	21	**1877**	**24**	1927	25	204
Biomass 1992 (tonnes)	1832	21	**2345**	**24**	1862	23	222
Biomass 1993 (tonnes)	1460	21	**1543**	**23**	1932	27	313
Biomass 1994 (tonnes)	1740	21	**2430**	**26**	1746	24	122
Biomass 1995 (tonnes)	1686	21	**1436**	**22**	2160	30	253
Biomass 1996 (tonnes)	1618	21	**2490**	**26**	1398	31	207
Biomass 1997 (tonnes)	1733	21	**1194**	**23**	2239	28	213
Biomass 1998 (tonnes)	1604	21	**2418**	**26**	1265	14	265
Biomass 1999 (tonnes)	1688	21	**1324**	**22**	2157	27	136
Biomass 2000 (tonnes)	1733	21	**2574**	**27**	1523	16	108
Biomass 2001 (tonnes)	1708	21	**1054**	**22**	2317	29	258
Biomass 2002 (tonnes)	1588	21	**2239**	**25**	1029	13	213
Biomass 2003 (tonnes)	1754	21	**1782**	**24**	2053	26	126
Biomass 2004 (tonnes)	1665	21	**2508**	**26**	1736	18	165
Biomass 2005 (tonnes)	1729	21	**1184**	**23**	2127	29	179
Biomass 2006 (tonnes)	1642	22	**2444**	**26**	1542	14	96
Biomass 2007 (tonnes)	1821	20	**1425**	**25**	2322	30	227
Biomass 2008 (tonnes)	1472	23	**2514**	**26**	1047	10	296
Biomass 2009 (tonnes)	1751	20	**1038**	**22**	1987	24	61
Biomass 2010 (tonnes)	1733	22	**2419**	**26**	1913	23	131
Biomass 2011 (tonnes)	1685	19	**1456**	**24**	1955	25	164
Biomass 2012 (tonnes)	1708	22	**2581**	**26**	1861	23	85
Biomass 2013 (tonnes)	1761	19	**1055**	**22**	2071	28	60
Biomass 2014 (tonnes)	1721	23	**2439**	**26**	1769	26	47
Biomass 2015 (tonnes)	1784	18	**1488**	**24**	2213	34	140
Biomass 2016 (tonnes)	1611	25	**2607**	**27**	1397	45	64
Biomass 2017 (tonnes)	1882	17	**998**	**20**	2382	28	88
Biomass 2018 (tonnes)	1516	29	**2344**	**25**	1028	14	103
Biomass 2019 (tonnes)	1917	16	**1666**	**26**	2161	28	140
Biomass 2020 (tonnes)	1407	3	**2566**	**27**	1510	15	

The alternative biological reference point corresponding to the mean total latent productivity (latent productivity plus the annual catch) provide a more reasonable harvest rate, of 289 tons. To better secure the biological sustainability of the fishery, Asturias regional administration adopted the policy of setting a Total Allowable Catch (TAC) equal to the estimated mean total latent productivity minus two times its standard error. This policy was set into official by-laws in 2020, establishing that the total catch will be evaluated at weekly time-steps during the season and whenever the accumulated total reached the TAC, the season will be terminated. In the event that the TAC was not achieved during the season, then the season will proceed until its pre-established termination date in July. Furthermore, with any new season, the newly generated data will be used to fit a further year with generalized depletion models and thus the fit of the surplus production model will be updated as well as the estimation of the mean total latent productivity.

2.4 Stock assessment trials for the cuttlefish (*Sepia officinalis*) in the English Channel (7.de) using SPiCT

Angela Larivain

With the aim to provide management advice on cephalopods, for which an increasing effort is observed to compile all valuable information regarding their biology and short-lived characteristics, preliminary diagnoses of Northeastern Atlantic cephalopod stocks using the generalized global model were deployed. European Atlantic Cephalopod stocks have already been the subject of ad hoc assessments using a wide range of tools but the available information (an abundance index and total landings) and the population biology (short-lived species with high and variable natural mortality) restrict the variety of methods that can be applied to assess the state cephalopod stocks (Pierce and Boyle, 2003). As discussed in previous WKDLSSLS session (WKDLSSLS, 2019) an attempt to fit surplus production model in continuous time (SPiCT) to evaluate a series of cephalopod stocks was conducted using R SPiCT package framework. Following previous conclusions, a special focus on the cuttlefish in the English Channel was given this year (Larivain 2020 -Working Document to this report Annex 6).

Last year, it was suggested to take into account the seasonal fishing mortality component the model allows to test in order to try better fit the short-lived species. The 'Guidelines for the use of SPiCT' (Mildenberger, 2019; https://raw.githubusercontent.com/DTUAqua/SPiCT/master/SPiCT/inst/doc/SPiCT_guidelines.pdf) and the exchange with experts was a valuable contribution to this exercise improvement. This starting point to obtain preliminary biological reference points will allow to improve assumptions and may lead to apply Harvest Control Rules (HCR) and/or Management Strategy Evaluation (MSE), now available in the SPiCT package.

The stock of interest in the English Channel (ICES divisions 7.d and 7.e) consists of the cuttlefish *Sepia officinalis*, mostly fished by FR and UK (80% of total landings). Input data included either calendar annual landings for all the country fishing in the Channel [1992–2019] (previous trials, with updated year, reminded in the WD Annex 6.1) or quarterly catch compiled for FR and UK since 2000 and 5 index (two commercial/three surveys): standardized LPUE index (kg/h) from French otter trawlers [1992–2019]; mean LPUE in November from English beam trawlers [2000–2019]; biomass index from the Channel Ground Fish Survey (CGFS) collected in September–October [1990–2019]; abundance index from the Bottom Trawl Survey (BTS) collected in July [1989–2017] and the abundance index from the South Western Beam Trawl Survey collected in quarter 1 each year (Q1SWBEAM) [2007–2018]. The index time-series were cut according to cover the catch/landings time-series when needed. The performance was tested using different datasets (combination of catch/index) and various model settings (no priors, default, n prior) and models allowing seasonal fishing mortality (fixed pattern over time) were also tested. These were considered reasonable given historical data and knowledge on the species. Although survey indices are available, they appeared to widen the confidence intervals or restricted the convergence of the model. There are two indices available in nearly the same time, the UK LPUE (November) and the CGFS (September–October), showing conflicting signals. It was then decided to remove one of the two, the CGFS survey index. Even if the UK LPUE is not covering the whole fleet, it does the whole area (CGFS only the 7.d part) so it was more appropriate to keep in.

Four scenarios were selected in the amount of the whole tested and are presented in the Larivain, 2020 -Working Document to this report (Annex 6). Convergence success for the fourth but quarterly catch inputs gave the best results in scenarios 3 and 4 (Table 1 Annex 6), with the seasonal pattern estimation of the fishing mortality (seasontype=3) well represented. All but one model (scenario 3) well-behaved and showed reasonable residuals diagnostics. Scenario 2 was dismissed as the retrospective plots showed inconsistent performance and confidence intervals were too wide. Scenario 3 did show violation of the model assumptions given by the residuals autocorrelation, and the change of the seasontype (equals to 1 or 2 – even worst) or the constraint to n prior (log(1.6), 0.8, 1) were unable to fix it.

The best model performing was concluded to be scenario 4, included quarterly FR & UK catch [2000–2019] both commercial LPUE from these countries (yearly basis). Residuals appeared randomly and independently distributed and the five years retrospective plots showed consistent performance. The confidence intervals of both relative biomass and fishing mortality (B/B_{MSY} and F/F_{MSY} respectively) are still high, even reasonable, with B/B_{MSY} spanned the two orders of magnitude required in the Guidelines (which could be revised for species like cephalopods in further exploration as for now the assessment would not be benchmarked). B_{2019}/B_{MSY} was estimated at 1.684 [CI = 0.383–7.398] and F_{2019}/F_{MSY} 0.388 [CI = 0.109–1.386] which, despite large confidence intervals, indicate that the cuttlefish stock of English Channel is reasonably exploited since 2008. Among the recent improvement in SPiCT, the assumption of a regime shift in productivity may be worth exploring in the future (with the application of the seasonal productivity parameter) also the implementation of environmental variables, known to be of a great influence on short-lived species like cephalopods.

2.5 Working Towards a Sustainable Future – The Scottish Mallaig Sprat Fishery

Campbell C. Pert

Background

In 2018, Scottish fishing vessels landed 446 000 tonnes of sea fish and shellfish with a gross value of £ 574 million. In the same year, there were 2089 active Scottish fishing vessels, which directly employed 4860 fishers. Fishing therefore plays a key role in the economy of many rural coastal communities around the Scottish coastline including Mallaig, which is a small fishing port located in northwest Scotland.

The Scottish pelagic fleet comprises a small number of large vessels (19 vessels in 2018) that fish primarily for mackerel and herring. Mackerel remains the most valuable stock to the Scottish fleet, accounting for 29% (£ 164 million) of the total value of fish landings by Scottish vessels in 2018. Over the ten years 2009–2018, the tonnage of pelagic landings has increased by nearly two fifths (39%) with real terms value rising by 14%. Sprat (*Sprattus sprattus*) is a relatively minor species for the Scottish pelagic fleet as a whole, both in the North Sea and on the west coast, however for the sector, which does target it, it represents a valuable resource.

Catch data for sprat in ICES area 6a is available from Scottish vessels from 1968 to 2017 (ICES, HAWG 2018). Landings of sprat were high in the early part of the time-series peaking with average annual landings of ~ 7000 t in the period 1972 to 1978. However, landings declined in the 1980s and early 1990s until a second peak in the period 1995 to 2000 where landings averaged just below 5000 t annually. Between 2006–2009, the fishery was virtually absent but has picked up again since 2010. Between 2012 and 2017 (ICES, 2019) total sprat landings averaged 1478 t with the largest amount (2177 t) landed in 2016. In 2018, there was no sprat fishery out of Mallaig as the fish failed to appear in the inshore waters in sufficient quantities to make the fishery viable for local vessels.

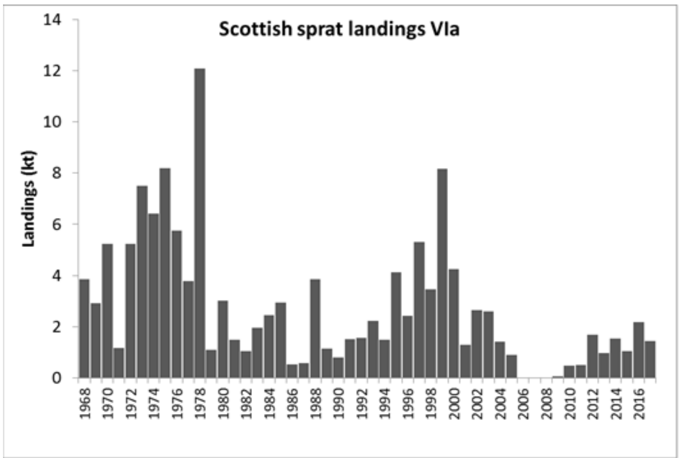

Figure 2.5.1. Landings of sprats from ICES area 6a from 1968–2017.

The sprat fishery out of Mallaig is typically targeted by small vessels (<15 m) towing pair trawls with fishing normally occurring at night with catches discharged into lorries the following morning. In recent years, two pair teams have been operating and landing into Mallaig.

The grounds which are traditionally fished for sprat are usually within a six hour steaming radius from Mallaig. Much of the fishing takes place in the vicinity of the sea lochs on the Isle of

Mull, Isle of Skye and the Scottish main land. The fishery is seasonal, mainly for human consumption, with the sprat coming into optimal condition towards the end of October or early November (occasionally as late as January). In poorer seasons, the fishing has been known to cease late November/early December.

Table 2.5.1. Annual landings by the Mallaig pair-net sprat fishery located on Scotland's west coast covering the period 2011–2019.

Year	Season	Total Sprat Landed (tonnes)
2011	21/11–8/12	504
2012	19/11–19/12	1470
2013	16/11–13/12	877
2014	17/11–12/12	1556
2015	23/11–17/12	996
2016	7/11–14/12	2131
2017	6/11–18/12	1431
2018	No Fishery	0
2019	5/11–18/12	1211

Scottish Sprat Surveys

There exists no long-term, ongoing Scottish surveys specifically targeting sprat in ICES area 6a, although there are a number of surveys, which do collect information for this species.

A Clyde herring and sprat acoustic survey was conducted in June/July 1985–1990 and then discontinued (Figure 2.5.2 details coverage). In 2012, this survey was reinstated as an October/November survey and carried out annually until 2017. Results from this survey included distribution patterns, total biomass, as well as age–length distribution for all years the survey occurred. It is unlikely that results from this survey alone provide meaningful indices for the management of the local inshore sprat fishery in the southern Minch.

Between 2001 and 2005, a series of detailed surveys were completed in selected mainland Scottish sea lochs, to the east of the Isle of Skye (Figure 2.5.2). The surveys were carried out in Q1 and Q4 with biomass estimates as well as fish age and lengths available from this survey series. These data could be potentially useful to corroborating trends seen in presently continued surveys and in the fishery.

The Scottish West Coast IBTS has been carried out in Q1 since 1981 to the present and in Q4 from 1991 onwards. Although the survey is a ground fish bottom trawl survey, it does catch sprat throughout the survey area. The survey provides numbers-at-length per haul but no age data. In the period 1981 to 2012, a total of 1434 hauls were completed and approximately half of these caught sprat. Therefore, it should be possible to develop an index for sprat in the southern Minch from these surveys.

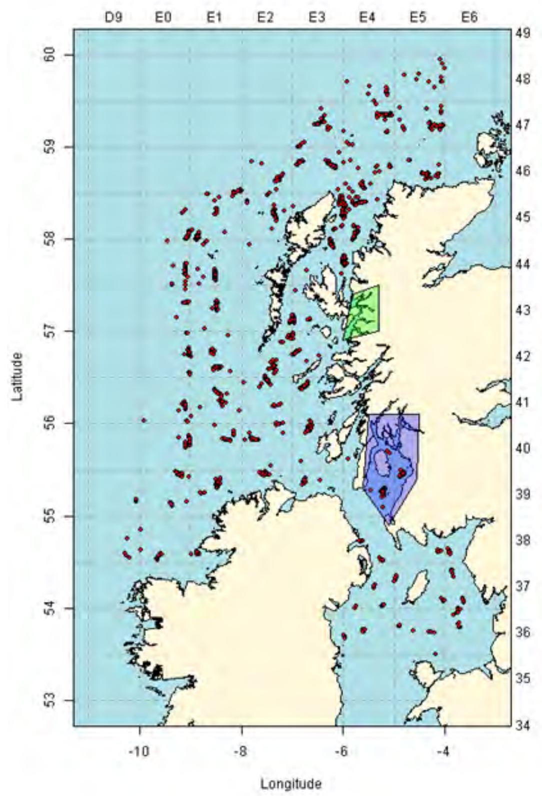

Figure 2.5.2. A number of Scottish surveys have provided sprat data in ICES area 6a over the years. In purple is the Clyde Herring & Sprat Acoustic Surveys, in green is the extent of the Sea Lochs Surveys carried out annually in Q1 and Q4 between 2001–2005 and in red are markers indicating all hauls from the Q1 and Q4 Scottish West Coast IBTS from 1985 to 2012 (this survey still occurs).

Between 1985 and 2002, the fishery was relatively well sampled by Marine Scotland Science (MSS) and length and age data exist for this period with some gaps. Sampling of sprat in 6a came to an end in 2003, and no information on biological composition of catches exists in the period 2003–2011. Sampling was resumed in 2012 and has been very well sampled since, with between four and seven samples collected annually, and on average 1173 sprats measured and 178 aged.

There is presently no TAC for sprat in 6a. From 2013 to 2017, ICES advised that catches should not exceed 3500 t. This figure was calculated as average landings over a ten year period and with a 20% uncertainty buffer applied. The advice for 2020 and 2021 from ICES includes another 20% reduction following the precautionary approach to 2800 t. It should be noted that combined landings for sprat from 6a have exceeded the ICES advice for all years it has been issued.

Currently there are no real efforts to assess or manage sprat in 6a. However, given the spatial separation between fisheries in Scotland and Ireland, and the fact that the Scottish fishery is located inshore and almost exclusively within a relatively confined area in Southern Minch and associated sea lochs, it should be possible to make an assessment of the state of the "fished stock" fished by Scottish vessels, and develop appropriate local management measures.

Therefore, a spatial limit to this "fished stock" needs to be defined so an area in which management measures can be applied, and trends within the defined area can be monitored.

Project Outline

Marine Scotland Science have begun work in collaboration with industry partners with an interest in this fishery. MSS intend to sample sprats collected during 2019 by commercial fishing boats from this small fishery for a research project to collect data with a possible view to improving the evidence base for the management of this stock. Sampling took place during September and October 2020 at the Marine Laboratory in Aberdeen. Two vessels have provided a total of 35 bags of frozen sprat with each bag containing approximately 1.5 Kg of sprats.

Sampling Methodology

For the purpose of this study, we recorded all lengths of sprats from the samples. Otoliths and biological samples were taken from three fish per half cm. Biological sampling included recording whole weight, sex and maturity (4 scale); the latter two parameters were only recorded from fish larger than 110 mm as below this size it was impossible for us to determine to any reasonable level of accuracy.

Expected Outcomes

We hope to develop length–frequency distributions as well as measures of the age, weight and maturity (if possible) of landings in the seasonal sprat fishery out of Mallaig and compare these for each sea loch in which the fishery operates, providing some indication whether they represent a homogenous mixed population or if there are variations in vital parameters between areas. Through the development of this dataset, we would hope to develop an assessment framework using the age and size compositions from the catches made by this fishery as well as additional historical data gathered during IBTS west coast ground fish surveys.

Additionally, we would look to try and define a spatial limit to this “fished stock” so an appropriate management area can be defined, suitable reference points established and trends within this area be monitored with respect to these.

Future Work

On a longer time-scale, it may be worth considering implementing a new acoustic survey timed to give information on abundance and stock composition immediately prior to the fishery, although we appreciate considerable resource implications would be involved in this option.

Additionally, we would look to expand the scope of the project to investigate unresolved stock identity issues utilising methodologies such as fish morphology, parasites as biological tags and molecular genetic studies; these should be the longer term aims with initial pilot studies likely carried out via student MSc and PhD projects.

2.6 General discussion on the applicability of Production models to the Assessment and Management of short-lived fish species and Cephalopods

Angela Larivain, Tobias Mildenberger, Margarita Rincón Hidalgo, Ruben Roa Ureta, Laura Wise

2.6.1 General characteristics of short-lived species

Short-lived species, including cephalopods, are characterized by short lifespans, high recruitment variability and natural mortality. The population dynamics is charactherised by large (multi-) annual fluctuations due to the higher proportion of young individuals reflecting the fluctuations in recruitment success, which is tightly linked to environmental conditions. The fisheries targeting short-lived species often target a large fraction of the stock in terms of size spreads, i.e. individuals are caught from a young age. Thus, the large fluctuations are often reflected in the commercial catches/landings (Pikitch *et al*., 2012; Pierce *et al*., 2010).

Often fisheries show a typical seasonality due to several features of their life cycle. For instance, fisheries taking advantage of seasonal migrations and/or spawning aggregations patterns would show marked seasonality.

Four case studies, which apply production models to short-lived species, including cephalopods, were presented in the previous subsections and are summarised in Table 2.6.1. We then list key considerations regarding the assessment (2.6.2) and the management (2.6.3) of short-lived species in a data-limited situation, using production models through the application of SPiCT (for three of them) and depletion coupled with a surplus production models for the Octopus case in Asturias (8.abd Bay of Biscay).

Table 2.6.1. Model, input data and main settings of the four case studies discussed in the workshop within ToRs 1 and 2.

	Cuttlefish in the English Channel (divisions 7.de)	Anchovy in 9a South	Anchovy in 9a West	Octopus in the Asturias
Model	SPiCT	SPiCT	SPiCT	Depletion coupled with a surplus production model
Time-series length	Quarterly French and United Kingdom landings (2000–2019); Yearly (July–June) French LPUE (2000–2019); November mean United Kingdom LPUE (2000–2019)	Quarterly landings (1989–2020); Abundance and biomass PELAGO survey index (first quarter 1999, 2001–2003, second quarter 2005–2010 and 2013–2020; Abundance index ECOCADIZ (second quarter 2004, 2006, third quarter 2007, 2009, 2010, 2013–2019).	Quarterly Portuguese and Spanish catches (1991–2019); IBTS autumn survey (1991–2018); Spring Acoustic biomass survey (1999–2019)	Depletion model using intra-annual weekly time-step of approximately 30 weeks in each season. Surplus production model using 19 years (2001–2019).
Priors	Default	Default	Default priors with the exception for N prior (logn ~ dnorm [log(0.599), 0.342] based on Thorson *et al.,* 2012) and the Q acoustic prior (logq_ac ~ dnorm [log(1), 1e-3]).	No priors are used since models are fit using maximum likelihood.
Season type	season type = 3: Combination of a spline (when seasontype=1) with a first order autoregressive (AR1) process; allows the spline to vary over time.	order 3 spline (seasontype=1, splineorder=3)	spline based F model (seasontype=1)	Not applicable

	Cuttlefish in the English Channel (divisions 7.de)	Anchovy in 9a South	Anchovy in 9a West	Octopus in the Asturias
Comments	Good fit with two commercial LPUEs indices (France otter trawlers and UK beam trawlers) and seasonal catches (quarterly). Surveys indices more uncertain as concerning only 7d division of the stock. New CGFS standardization generates residuals' autocorrelation and both surveys are not targeting cephalopods. Strong seasonal pattern in fishing mortality is well represented.		Catch and survey residuals are random and independent. Retrospective indicates overestimation of B/B_{MSY} and underestimation of F/F_{MSY}. Confidence intervals of B/B_{MSY} and F/F_{MSY} span 2 orders of magnitude. Behaves well for different initial values. The sensitivity of the model to the assumption of absolute catchability for the acoustic survey needs to be tested. The assumption of a regime shift in productivity may be worth exploring in the future.	Absolute annual biomass estimates from intra-annual depletion models play the same role that LPUE or CPUE indices play in SPiCT: they are observations to fit the surplus production model.

2.6.2 Considerations regarding the assessment of short-lived species

The case studies do not reveal a general reservation against the applicability of production models for the assessment of short-lived species. On the contrary, the large fluctuations in recruitment success and thus the catch and abundance index time-series might even be beneficial in that they can provide high contrast of periods with high and low biomass for the application of production models. Ultimately, the success in fitting surplus production models would depend upon the length and the contrast in the input dataseries.

Several points were put forward during discussion:

- When the fishery shows a strong seasonality and using seasonal catches, it is advisable to apply a seasonal productivity approach, expressed in the work of Mildenberger *et al.* (2020). The latter study considers three extensions to biomass dynamic models that accommodate time-variant productivity in fish populations leading to increased reliability of derived reference levels. The model is able to disentangle differences in seasonal fishing mortality as well as seasonal and long-term changes in productivity.
- Assessments are expected to show larger uncertainty (even in relative terms) due to larger inter-annual fluctuations.
- Check for autocorrelation in recruitment deviations.
- If possible, in cases where there are known relationships between stock productivity and environment, one should use environmental covariates in the assessment of short-lived species.
- Short-lived species are expected to have higher productivity but one should take into account that the biomass with the highest productivity is, potentially, a function of environmental conditions rather than life-history traits only.

Table 2.6.2. Important output parameters (intrinsic growth rate r, productivity m, and standard deviation of the biomass process sdB) for three case studies that used SPiCT.

Output parameters	Cuttlefish 7.de	Anchovy 9a South	Anchovy 9a West
Intrinsic growth rate (r)	1.97 [0.59–6.62]	5.58 [1.75–17.8]	0.7 [0.138–3.589]
Productivity (m)	18 332 [9624–34 920]	7574 [4864–11 791]	15 177 [1775–129 796]
Standard deviation of the biomass process (sdB)	0.474 [0.320–0.701]	1.20 [0.65–2.21]	1.748 [1.179–2.589]

2.6.3 Considerations regarding the management of short-lived species and cephalopods

- The proportionally higher representation of young individuals in the stock biomass and catches of short-lived species puts even more weight on the main challenge of sustainable fisheries management: the capability of forecasting the number of recruits in the management year. Ideally, the incorporation of environmental covariates could improve the predictability of future stock biomass with production models. This is always challenging (e.g., in some cases a relationship between recruitment and temperature has been considered to improve management, but not to improve the assessment).
- In the cuttlefish assessment in ICES area 7.de, indications of abundance coming from the commercial fisheries (LPUE index) improve the SPiCT fitting more than what was achieved from the use of survey indexes. Surveys can provide instantaneous snapshots of a population, but if not actually designed for the target species they may be rather imprecise and not as valid as LPUE from fisheries targeting the stocks of interest. Therefore, careful selection of the abundance index used to tune the assessment is to be made according to their expected precision and suitability for the stock of concern.
- The timing of advice is also very relevant when considering short-lived species. It was found that the shorter the time-lag between the observed index and the application of the management advice, the bigger are the catches and the smaller are the biological risks (see ICES, 2019). This means that one should aim for a full population advice, followed by in-year advice. In this regard, the continuous time aspect of SPiCT is useful. Also, the 1over2 rule seems to be more suitable for short-lived species.
- The general suitability of the long-term maximum sustainable yield (MSY) concept associated with a constant fishing mortality (F_{MSY}) remains questionable, due to the natural fluctuating population sizes characteristic of short-lived species. For these species, one should probably aim at fishing below MSY. One way forward, for highly variable stocks, is to consider the latent productivity instead of MSY. Latent productivity is conceptually similar to the MSY concept but it varies with the biomass of the stock while MSY is constant. This functional relation between latent productivity and biomass makes it suitable as a source of sustainable harvest rate formulas for stocks that are highly variable such as short-lived stocks. Escapement strategy (the proportional escapement management strategy coupled to depletion methods, as applied to the squid species exploited around the Falkland Islands) might also be suitable for data poor short-lived species (in fact, ICES uses the escapement strategy for short-lived species in the data-rich stock category), but this would require detailed and accurate daily or weekly LPUE from cephalopods

fisheries (Rodhouse *et al*., 2014), or unbiased direct surveying of the stock prior or during the fishing season for the short-lived fish species.

2.7 Future directions

For Cephalopods exercises

- “Seasonal data” (e.g. quarterly catch input) could be too noisy when used in a mixed recorded species: example with the two (or even more) different species in a dataset (like for Loliginidae) with different life cycle (overlap in the breeding season, different recruitment time) – aggregation of the yearly data better to use in this case.
- In other cases short time-steps (daily, weekly or others) analysis might be informative as to improve population and fishery dynamics assessment.
- Depletion method implemented at the beginning of the time-series (by setting the bkfrac prior, which sets the ratio between biomass in the initial year relative to K) was helping many cephalopods stocks to converge (from Loliginidae in Northern regions to Octopodidae in the South). This is somehow difficult to understand.
- Cuttlefish stock in the 7.de appeared to be a good candidate to try the use of MSE component available in SPiCT.
- Review the order of magnitude accepted in the relative abundance values resulting from the fitted model for short-lived species.
- Use of data at more rapid time-steps than usual (i.e. weekly catch and effort data) in depletion models may bring additional sources of information about the status of short-lived stocks and population dynamics parameters, which in turn can help inform population dynamics models running at annual time-steps.

For Anchovy 9.a West

- The WG considered that SPiCT was a promising approach for the assessment of this stock. The sensitivity of the model to the assumption of absolute catchability for the acoustic survey needs to be tested and the assumption of a regime shift in productivity may be worth exploring.
- The large uncertainty in parameter estimates should be included in the assessment model in an MSE context. The approach could be to condition FLBEIA Operating Model with the best SPiCT model.
- Future work will include improving the SPiCT estimates and carry out the MSE with the different management rules proposed during the workshop such as a constant harvest rate, aiming at finding one that improves the quality of the advice in relation to the 1over2 with 80% cap currently used.

For Anchovy 9.a South

- The WG considered that SPiCT was a promising model alternative approach for the assessment of this stock, and also to be used for comparison and validation purposes with other models. However, the resulting high catchabilities values for the surveys need further investigation.
- Future work will include the incorporation of another two surveys available, BOCADEVA (an egg survey) and ECOCADIZ RECLUTAS (a recruitment survey), in the SPiCT model.
- A SPiCT model can be used into a MSE framework to test the time of the advice right after the recruitment survey estimates are available.

2.8 Conclusions

- Surplus production models such as SPiCT seem applicable for the assessment of short-lived species, provided enough contrast is in the dataseries.
- SPiCT provides coherent estimated trends when compared with data-rich models outputs.
- Seasonality (e.g. seasonal fishing mortality) is a key factor when modelling this short-lived species, except some cephalopods, still lacking species reliable identification.
- If possible, when the stock-environment relationships are known one should use environmental variables to model short-lived species.
- For these species, one should probably aim at fishing below MSY.
- Surveys index are mostly non targeting cephalopods, or for what was seen in Ommastrephidae and Octopodidae cases, are targeting more than the exploitable biomass (e.g. juveniles caught), better trust commercial fisheries derived index (such as standardized LPUE), also available through the entire year in the covered spatial range.

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3 Subgroup 2 Testing MSE of HCRs based on indicators trends

3.1 Management strategy evaluations for a simulated stock of sprat in 7.de

Nicola Walker

3.1.1 Introduction

The purpose of this study was to use management strategy evaluation (MSE) to evaluate harvest control rules (HCRs) for a short-lived stock in Category 3, including catch rules (i.e. 1o2 and 2o3), harvest rates and variations of those rules. The MSE is conditioned on the sprat stock in divisions 7.de (English Channel) and the rules evaluated in terms of maximising yield whilst maintaining safe levels of biomass.

The core area and fishery for Channel sprat occurs in Lyme Bay, although the advice is based on ICES divisions 7.de which is a much larger area. Additionally, there is no information on the stock boundaries for this area nor the relatedness with populations which occur to the east (North Sea and Skagerrak) or west (Celtic Seas).

Data available for sprat in 7.de include landings with no disaggregation to age and estimates of biomass, with some information on age and length, from an acoustic survey (PELTIC) that has been operating in the area since 2013. Advice for sprat in 7.de follows the ICES framework for category 3 stocks although the basis of advice has varied from 1o2 (2017) to 1o3 (2018) and 2o3 (2019–2020). The most recent advice for 2021 is based on the 1o2 rule with 20% uncertainty cap and the precautionary buffer applied. Advice is provided on an annual basis where the latest estimates from the October PELTIC survey feed into an assessment in February/March to give advice starting the following January. However, it has been suggested to provide in-year advice, running from July–June, to reduce the lag between observation and implementation and to better match the timing of the fishery. There will be an inter-benchmark for this stock early 2021, where the recommendations of WKDLSSLS2 will be considered.

3.1.2 Operating models

3.1.2.1 Stocks

As a formal assessment for sprat in 7.de is lacking, the data-limited MSE framework of Fischer *et al*. (2020) was used to simulate stocks based on life history. Age-structured stocks were constructed using FLR packages FLife and FLBRP (www. flr-project.org) based on the life-history parameters in Table 3.1.1. The parameters in bold were considered by ICES WKSpratMSE (2019) and thought to incorporate the uncertainties relative to the sprat stock in the English Channel, with values in the first column and both σ_{RS} taken forward as the most likely representations of the stock. Here additional parameterisations of the length–weight equation and segmented regression stock–recruitment relationship were considered based on recent data from the PELTIC survey and the literature (Myers *et al.*, 1999), respectively. Together this gives 24 stock life histories (each black box represents a parameter combination), where those in green were considered the most likely or uncertain (four life histories based on the most likely growth and length–weight combination and two values for each of steepness, s, and recruitment variability, σ_R). The creation of stocks followed the same methodology as WKSpratMSE (see ICES WKSpratMSE 2019 and Fischer *et al.*, 2020 for further details).

Table 3.1.1. Life-history parameters assumed in the construction of biological stocks. Black boxes represent parameter combinations. Those in bold were considered by ICES WKSpratMSE (2019) while those in green are here considered the most likely or uncertain.

Growth	L∞	**16**	**16**	**13**
	k	**0.6**	**0.4**	**0.6**
	t_0	**-0.8**	**-0.8**	**-0.8**
Length–weight	a	**0.0000048**	8.00E-06	
	b	**3.19**	2.96	
Recruitment	s	**0.5**	0.65	
	B_{virgin}	**1000**		
	σ_R	**0.3**	**0.5**	

3.1.2.2 Fishing history

Starting from virgin conditions (B_{virgin}=1000), three different fishing histories were applied to the stocks for 25 years prior to the start of the projection period (Patterson, 1992; ICES, WKLIFE 7, 2018; Fischer *et al.*, 2020):

FH1 (Patterson): Fishing mortality increased exponentially from 0 to F_P corresponding to Patterson's exploitation rate (E=0.4=F/Z), which is considered to represent an appropriate level of exploitation.

FH2 (One-way trip): Fishing mortality increased exponentially from 0 to 1.5F_P. This leads to a stronger depletion and visual signs of recruitment impairment for the less resilient life histories (those with s=0.5) towards the end of the historic period.

FH3 (Roller-coaster): Fishing mortality increased exponentially from 0 to 1.5F_P, stayed at this level for five years and then decreased exponentially to F_P by the end of the 25-year historic period. This leads to strong depletion and recruitment impairment for all life histories, with the more resilient life histories beginning to recover by the end of the historic period.

3.1.2.3 Observation

Survey observations were generated from the operating model as follows:

$$I_{a,y} = q_a N_{a,y} e^{-t_s(F_a+M_a)} e^{\varepsilon_{a,y}}$$

Where q_a is survey catchability-at-age, $N_{a,y}$ are stock numbers-at-age and year from the operating model, t_s is the timing of the survey in relation to the model year and F_a and M_a are fishing and natural mortalities-at-age respectively. Following WKSpratMSE (2019), survey catchability-at-age is modelled as a logistic curve with up to 50% overestimation of older ages and with observation error applied such that $\varepsilon_{a,y} \sim N(0{,}0.5)$. For the purposes of assessing the sensitivity of harvest rates to catchability, two variations of the catchability curve were considered: (1) a higher variation with up to 100% overestimation of older ages and (2) a lower variation with no overestimation of biomass. Note that deviations from the intended extent of overestimation will occur due to the high observation error assumed.

3.1.3 Management procedure

3.1.3.1 Advice schedule

Currently advice is provided on an annual basis where the latest biomass estimates from the October PELTIC survey feed into the Herring Assessment Working Group (HAWG) estimations February/March to provide advice for the following year (1st January–31st December; Figure 3.1.1).

Figure 3.1.1. Current schedule for providing advice on fishing opportunities for Channel sprat. y relates to a calendar year. The numbers in the arrows represent the number of months between each of the processes.

Given the high natural mortality rate and consequent short lifespan of sprat, many of the fish observed in the provision of advice will die before that advice is implemented. To reduce this lag between observation and advice, it has been suggested to provide in-year advice from 1st July–30th June (see ICES, HAWG 2020 for how this has been implemented for North Sea sprat). This would result in the PELTIC survey and HAWG working group occurring in the same management year and reduce the lag between calculation and implementation of advice.

Figure 3.1.2. Suggested schedule for providing advice on fishing opportunities for Channel sprat. y relates to a management year which in this case runs from 1st July–30th June. Quantities in red signify changes from the annual schedule.

Given several issues arising from the annual time-step of the MSE, only the in-year schedule was considered for testing HCRs, although it would be expected that the relative performance of HCRs is similar between schedules. To implement these processes in the MSE, timing of the PELTIC survey (t_s) was set to 5/12 and the proportion of mortality before spawning set to 0.75, to relate the timing of the survey (October/November) and spawning (March) to the beginning of the model year.

3.1.3.2 Estimation model

Survey observations by age were multiplied by stock weights-at-age to emulate the process of obtaining a survey biomass index for provision of advice:

$$B_y^S = \sum_a w_a I_{a,y}$$

Where w_a are stock weights-at-age.

3.1.3.3 Decision model

Two types of harvest control rule (HCR) were tested:

Catch rule: Advised catch (A) is based on the most recent advised catch multiplied by the ratio (r) of the most recent biomass index value and the average of the two preceding values (1o2 rule), or the average of the two most recent biomass index values and the three preceding values (2o3 rule) (ICES WKMSYCat34, 2017).

$$A_{y+1} = rA_y; r = \frac{\sum_{i=y-x+1}^{y} B_i^s / x}{\sum_{i=y-x-z+1}^{y-x} B_i^s / z}$$

Where x is the numerator of the catch rule and z the denominator (e.g. x=1 and z=2 corresponds to the 1o2 rule).

Harvest rate: Advised catch corresponds to a fixed proportion (α) of the biomass index.

$$A_{y+1} = \alpha B_y^s$$

In addition, two stability and safeguarding mechanisms were tested in combination with the harvest control rules:

Symmetric uncertainty cap: A change limit is imposed such that the advised catch must stay within a fixed percentage (x) of the previous advised catch.

$$A_{y+1} = min\left(max\left((1-x)A_y, A_{y+1}\right), (1+x)A_y\right); x = 0.2, 0.5 \vee 0.8$$

Asymmetric uncertainty cap: Change limits are imposed such that the upper cap is larger than the lower cap and can allow advice to return to the previous level following a decrease (of x).

$$A_{y+1} = min\left(max\left((1-x)A_y, A_{y+1}\right), \frac{1}{(1-x)}A_y\right); x = 0.2, 0.5 \vee 0.8$$

Biomass safeguard: The advised catch is reduced if the new biomass index value falls below reference points derived from the historic biomass index. Three reference points were considered: I_{lim}, the lowest historic index value observed at the start of the projection period, $I_{trigger} = 1.4 I_{lim}$ and $I_{stat} = GM(B^s)e^{1.645 \cdot sd(log(B^s))}$. The reduction in advice corresponds to the distance between B_y^s and the specified reference point I:

$$A_{y+1} = bA_{y+1}; b = min\left(1, \frac{B_y^s}{I}\right)$$

Unless stated otherwise, HCRs were tested with the OMs based on the four life histories highlighted green in Table 3.1.1 in combination with all three fishing histories and up to 50% overestimation of survey biomass (12 OMs in total).

3.1.3.4 Performance statistics

Operating models were projected forward for 25 years with 500 iterations for each HCR tested.

For the calculation of risk, B_{lim} was taken as the SSB corresponding to the breakpoint of the segmented regression modelling recruitment in the OMs (40%B_{virgin} for the less resilient life histories with s=0.5 and ~31%B_{virgin} for the more resilient life histories with s=0.65).

The following performance statistics were calculated for the short (first five projection years; 26–30), medium (next ten years; 31–40) and long-term (last ten years; 41–50):

Risk: The average probability of SSB being below B_{lim} where the average is taken across iterations and the specified years of the projection period. Values <0.05 are considered acceptable.

Depletion: The average probability of SSB being below 20%B_{virgin} or 40%B_{virgin} where the average is taken across iterations and the specified years of the projection period.

Mean yield: Median of the mean catch over the specified years of the projection period across iterations.

Mean SSB: Median of the mean SSB over the specified years of the projection period across iterations.

Mean F: Median of the mean $\overline{F}$ (ages 1–3) over the specified years of the projection period across iterations.

Mean interannual catch variability (ICV): Median of the mean ICV over the specified years of the projection period across iterations.

$$ICV = \left|\frac{C_{y+1}}{C_y} - 1\right|$$

The following statistic was calculated for the whole projection period:

Collapse: The proportion of iterations where the stock collapsed at any point during the projection period. A collapse is defined as a state where SSB <1.

Harvest control rules were evaluated in terms of maximising yield whilst maintaining safe levels of risk (i.e. <5%).

3.1.4 Results

3.1.4.1 Catch rule

Testing of the 1o2 against the 2o3 rule largely agrees with the conclusions of ICES, WKDLSSLS (2019): short-term risk was influenced by initial conditions while medium to long-term the 1o2 rule was more precautionary than the 2o3 rule. Without the addition of stability or safeguarding mechanisms, the 1o2 rule reduced risk to <5% for only the most resilient life history (s=0.65 and σ_R=0.3) in the long term and only in the case where that life history had been fished sustainably (FH1). There was no situation where the 2o3 rule was precautionary. Given the consistency of the conclusion that the 1o2 rule outperforms the 2o3 rule, only the 1o2 rule is considered further.

When applying uncertainty caps to the 1o2 rule, the lowest long-term risks and, for most OMs, highest yields were obtained when applying an 80% cap (Figure 3.1.3). The symmetric cap was more precautionary than the asymmetric cap but also resulted in reductions of long-term yield, as has been noted for this stock when retrospectively applying the 1o2 rule with 80% cap to the PELTIC biomass index and past advice (van der Kooij *et al*., 2020). For almost all OMs, the 1o2 rule with 20% cap was the least precautionary option and resulted in higher probabilities of collapse (between 11–80% for both caps across OMs).

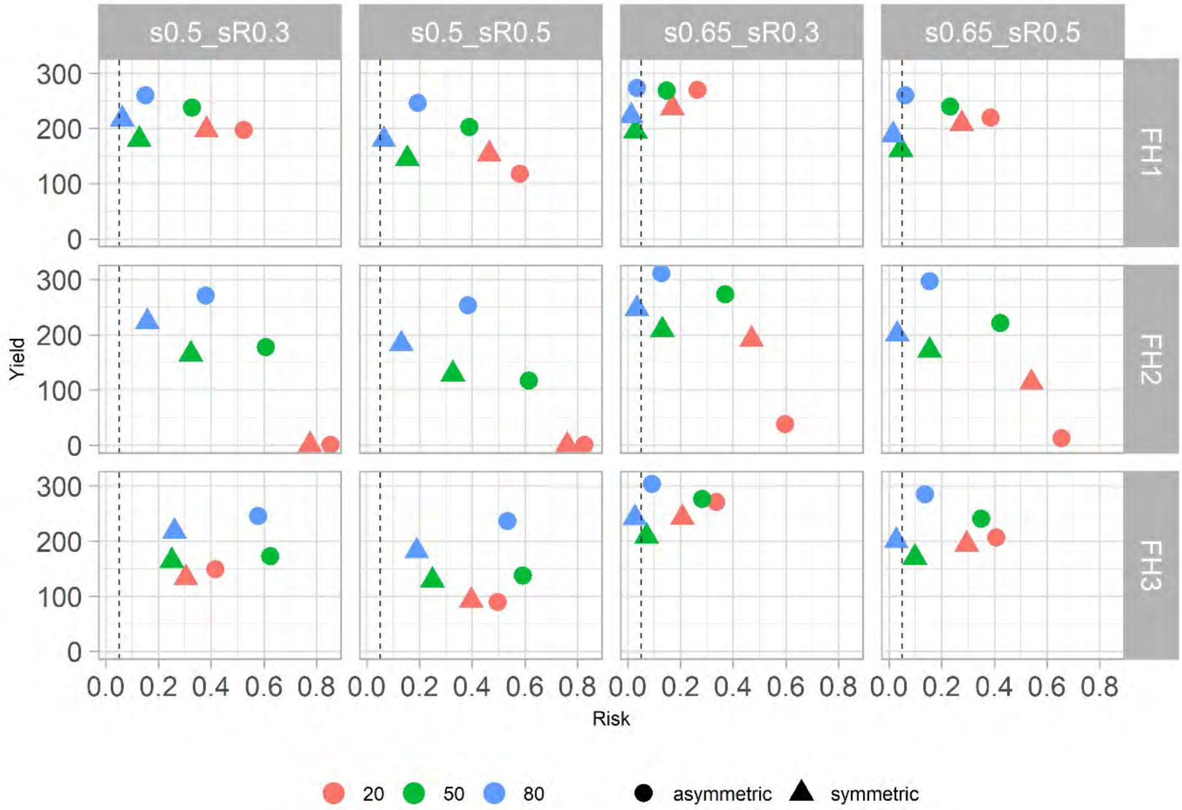

Figure 3.1.3. Long-term plots of yield against risk for the 1o2 rule with symmetric and asymmetric uncertainty caps. Recruitment parameters (steepness and variability) of the OMs are shown along the top with fishing histories along the side.

In all cases, applying a biomass safeguard to the 1o2 rule reduced risk, with risk($I_{trigger}$) < risk(I_{stat}) < risk(I_{lim}). In most cases under FH1 and FH2 (except for I_{lim} applied to the least resilient life history where s=0.5 and σ_R=0.5) application of a biomass safeguard reduced risks to <5% in the medium to long term. The more extreme historical reductions in biomass under FH3 make the biomass safeguards less reactive, as only similar, or lower index values will trigger a reduction in advice. In this case, biomass safeguards were precautionary only in the long term for some of the more resilient life histories. Although reference point updates were not modelled (i.e. biomass safeguards were based on observations from the historic period in years 1–25), Figures 3.1.4–3.1.5 show how the safeguard reference points would evolve if updated during the simulation. Figure 3.1.4 highlights two desirable properties of I_{stat}: (1) because it is based on the entire time-series of observations, it is less variable than I_{lim} or $I_{trigger}$ but still responds to trends in the index and (2) it can remain higher, and therefore more precautionary, than I_{lim} or $I_{trigger}$ following an unusually low index observation. Figure 3.1.5 shows how all three reference points remain low after a period of high exploitation under FH3, but also that biomass can recover from these low levels.

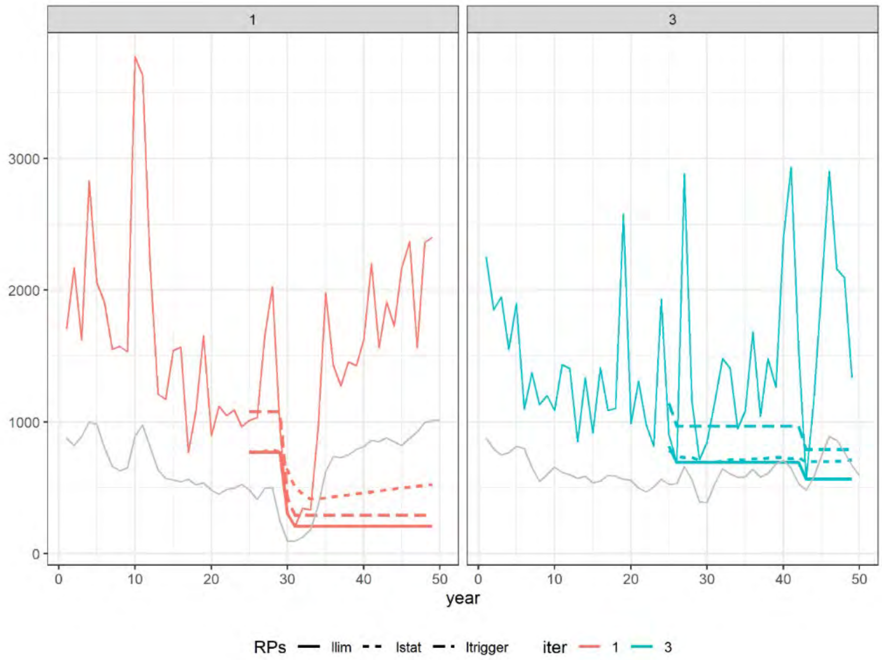

Figure 3.1.4. Evolution of biomass safeguard reference points for two iterations from an OM under FH1 (sustainable exploitation). Thin coloured lines show the biomass index, grey lines the true biomass and bold lines the evolution of each reference point according to the biomass index.

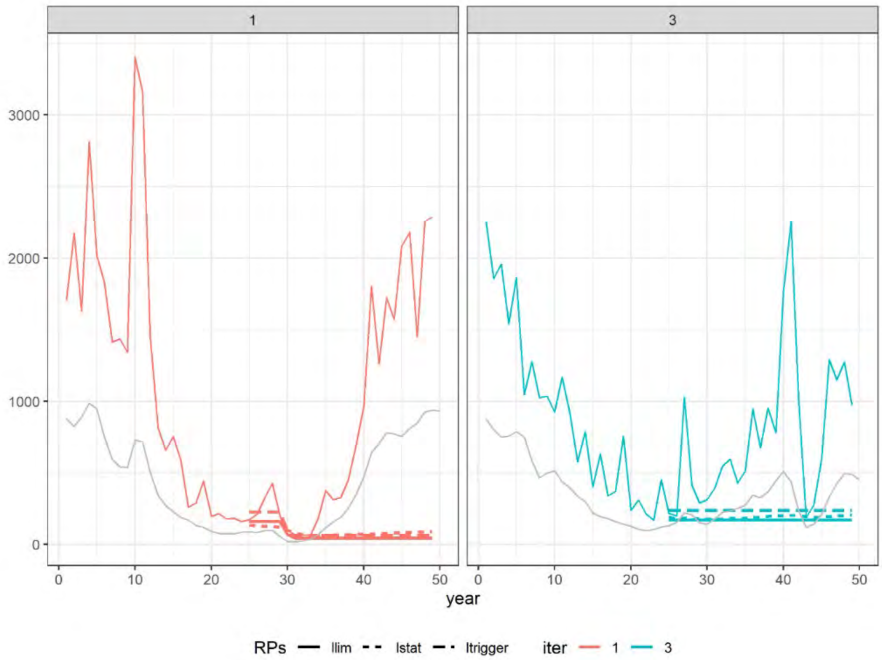

Figure 3.1.5. Evolution of biomass safeguard reference points for two iterations from an OM under FH3 (roller-coaster exploitation). Thin coloured lines show the biomass index, grey lines the true biomass and bold lines the evolution of each reference point according to the biomass index.

Application of both an uncertainty cap with a biomass safeguard (I_{stat}) to the 1o2 rule appears to perform better across all OMs and time-scales than either mechanism on its own. Time-series plots show application of a biomass safeguard to reduce the high probabilities of collapse observed for the 1o2 rule with uncertainty cap alone to 0 (Figure 3.1.6). Furthermore, in many cases, applying a biomass safeguard with uncertainty cap reduces long-term risk to acceptable levels

(<5%). Cases where long-term risk exceeds 5% correspond to one or both of the lower steepness of s=0.5 and high levels of past exploitation under FH3, with a higher maximum risk for the asymmetric cap compared to the symmetric cap (max risk symmetric = 9%; max risk asymmetric= 19%).

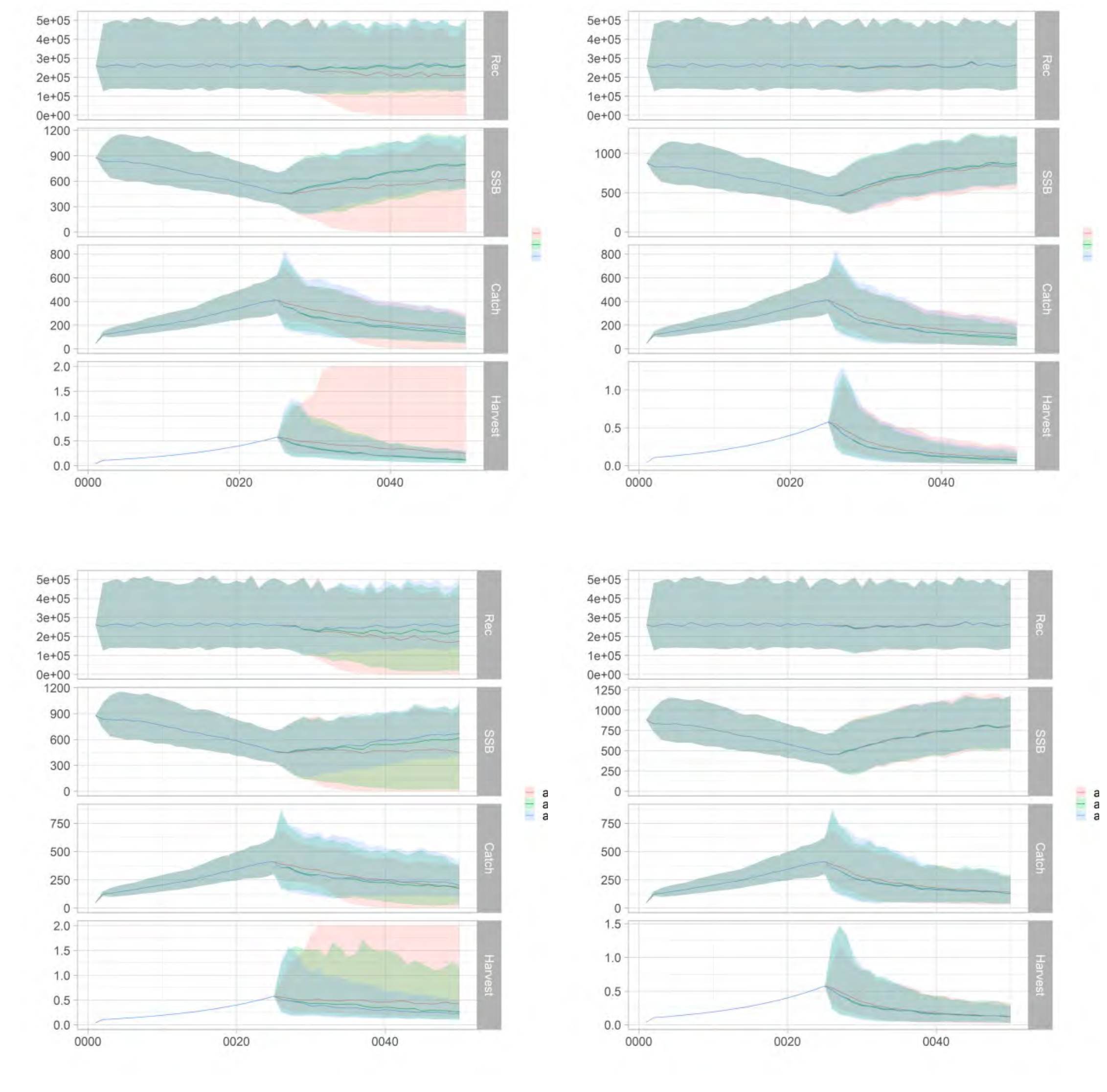

Figure 3.1.6. Time-series plots for recruitment, spawning stock biomass (SSB), catch and harvest for the 1o2 rule with (top) symmetric and (bottom) asymmetric uncertainty caps and (left) no biomass safeguard and (right) I_{stat}.

3.1.4.2 Harvest rates

ICES, WKDLSSLS (2019) found a harvest rate of 17% to lead to the highest yields whilst being precautionary across the OMs tested; however, due to uncertainties in life history and catchability, it is unknown how this harvest rate will translate to the real stock of sprat in 7.de. Here, the sensitivity of harvest rates to life history and survey catchability is tested. Each of the 24 life-history combinations in Table 3.1.1 was tested with three fishing histories (FH1, FH2 and FH3) and three survey catchabilities (0, 50% and 100% overestimation of older ages), giving 216 OMs in total. Each operating model was simulated starting with a harvest rate of 1% of the survey biomass index, and the harvest rate increased by 1% for the next simulation until all of the risk statistics (i.e. short-, medium- and long-term risk) exceeded 5%. Figure 3.1.7 shows the maximum harvest rate that an OM can sustain for at least one of the risk statistics to be <5%. Harvest rates varied from 0 to a maximum of 29%, 32% and 48% for 100%, 50% and no overestimation of biomass, respectively. In addition to survey catchability, harvest rates appear somewhat sensitive to a number of life-history parameters including the growth rate (k of the von Bertalanffy equation, which was set lower for VB2), resilience (lower for lower steepness) and recruitment variability (lower for higher variability). Aside from the second growth combination (VB2; where OMs likely exceeded 5% risk at the beginning of the projection period) harvest rates appear relatively insensitive to past exploitation and stock status at the beginning of simulations when management is implemented.

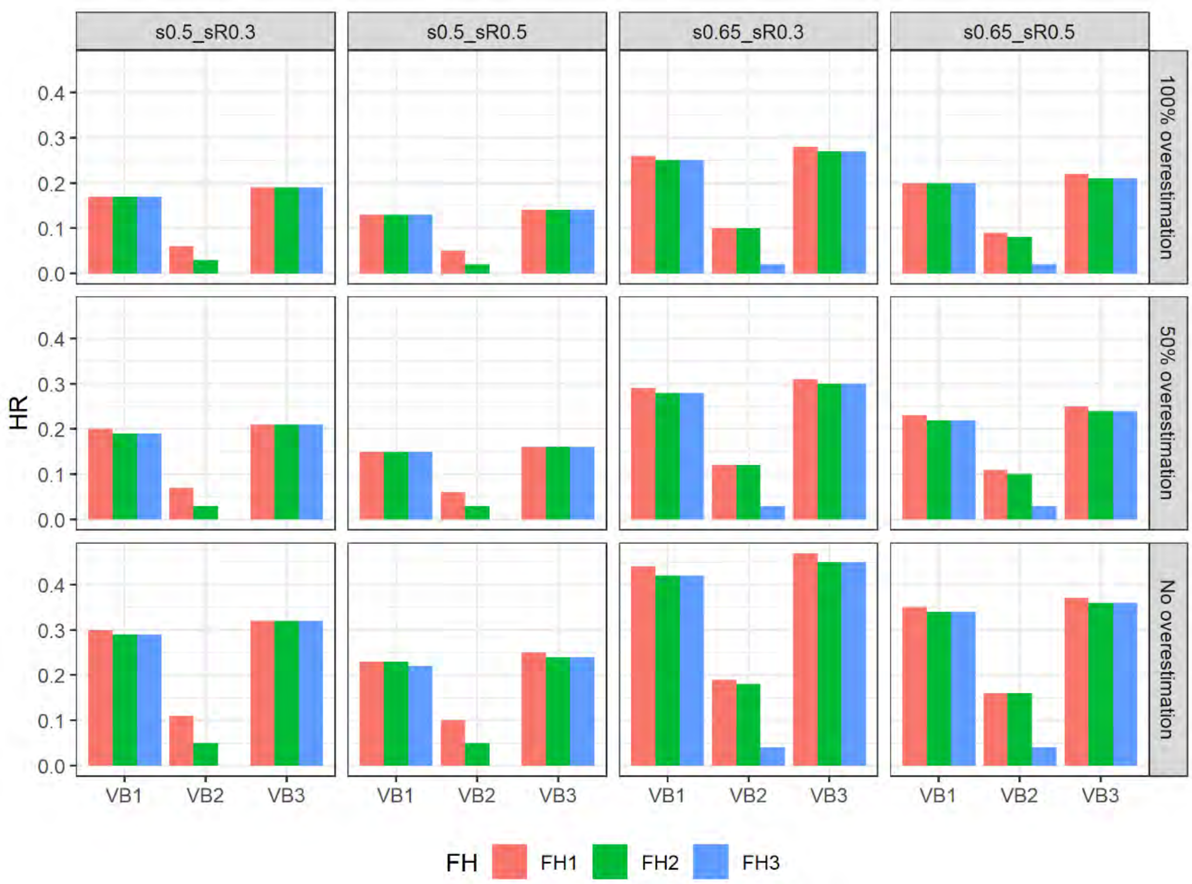

Figure 3.1.7. The maximum precautionary harvest rate (i.e. the maximum harvest rate for at least one of the risk statistics to be <5%) under a range of different life histories (columns), survey catchabilities (rows) and fishing histories (colours). For ease of visualisation, only results from OMs with the first length-weight parameter combination are plotted, while the main text summarises results from all OMs.

Harvest rates of 10%, 20%, 30% and 40% were applied in conjunction with a biomass safeguard (I_{stat}) to the 12 primary OMs (i.e. the life histories highlighted green in Table 3.1.1 with all three fishing histories and up to 50% overestimation of survey biomass), but resulted in only slight reductions of risk for higher harvest rates. Reference point updates were not modelled here (i.e. I_{stat} was set at the beginning of the projection period based on the historic index) but would likely decrease the effectiveness of biomass safeguards further as a high harvest rate would decrease biomass resulting in lower index observations and therefore lowering of the biomass safeguard.

3.1.4.3 Comparison of select HCRs

Table 3.1.2 shows all performance statistics for the life history considered by WKDLSSLS2 to be most representative for sprat in 7.de (with the growth and length–weight parameters highlighted green in Table 3.1.1, a steepness of 0.65 and recruitment variability of 0.5) with each of the three fishing histories while Figure 3.1.8 summarises yield against risk for the 12 primary OMs. Table 3.1.2 shows the 1o2 rule with 20% uncertainty cap (used to provide advice for 2021) to be the least precautionary HCR and the only one with a non-zero probability of collapse (up to 48% under FH2). A 20% harvest rate resulted in some of the highest medium- and long-term yields whist remaining precautionary for the more resilient life histories (and with a maximum long-term risk of 15% for the less resilient life histories). The 1o2 rule with 80% uncertainty cap and biomass safeguard was the most precautionary of the 1o2 rules, with long-term risks <5% for all but the least resilient life histories (s=0.5 and σ_R=0.3) under the most extreme fishing history (FH3), but also with some reductions in yield.

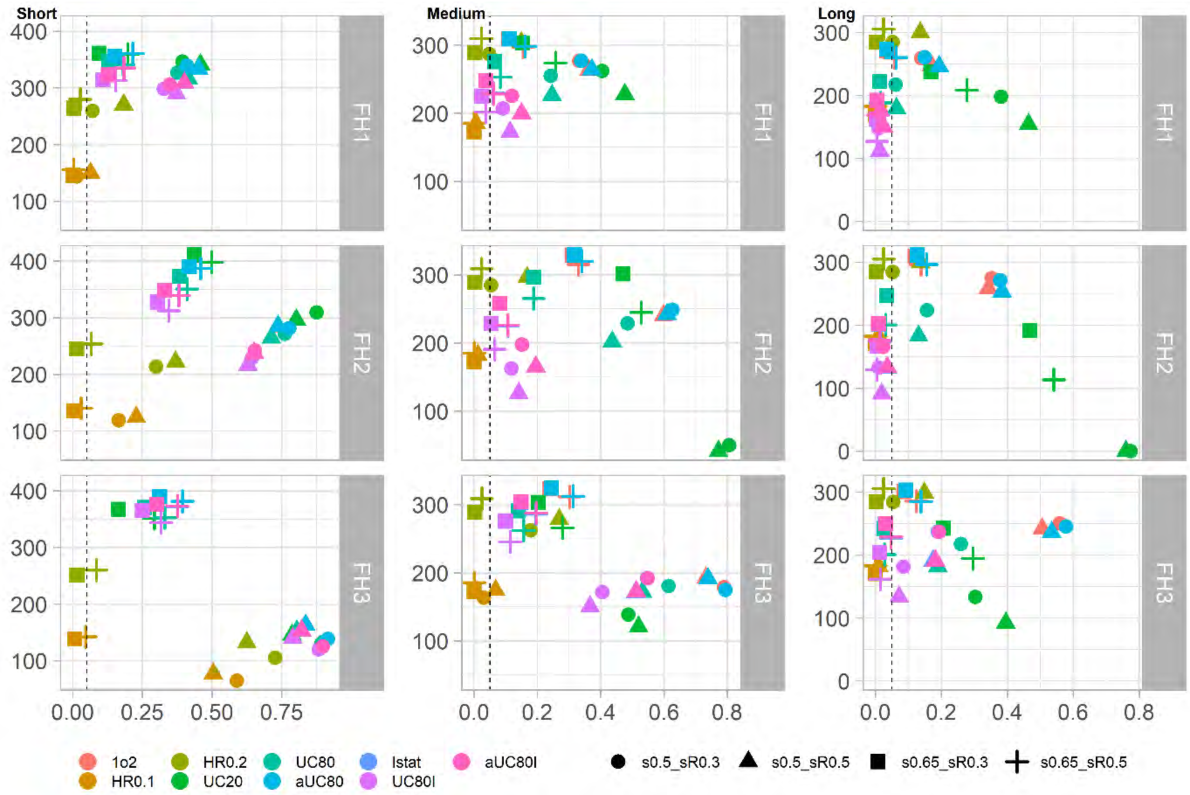

Figure 3.1.8. Short- medium- and long-term plots of yield against risk for select HCRs: 1o2 rule (1o2), 10% harvest rate (HR0.1), 20% harvest rate (HR0.2), 1o2 rule with 20% uncertainty cap (UC20), 1o2 rule with 80% uncertainty cap (UC80), 1o2 rule with 80% asymmetric uncertainty cap (aUC80), 1o2 rule with biomass safeguard (Istat), 1o2 rule with 80% uncertainty cap and biomass safeguard (UC80I) and 1o2 rule with 80% asymmetric uncertainty cap and biomass safeguard (aUC80I).

Table 3.1.2. Performance statistics for select HCRs applied to the life history WKDLSSLS2 considered to be the most representative for sprat in 7.de (the growth and length–weight parameters highlighted green in Table 3.1.1 with a steepness of 0.65 and recruitment variability of 0.5) and for each of the three fishing histories (FH1 top, FH2 middle and FH3 bottom respectively). HCRs are ranked according to long-term risk, with the columns showing short (s), medium (m) and long-term (l) risk. Risks >5% are highlighted in red and yields are coloured according to magnitude. 1o2 rule (1o2), 10% harvest rate (HR0.1), 20% harvest rate (HR0.2), 1o2 rule with 20% uncertainty cap (UC20), 1o2 rule with 80% uncertainty cap (UC80), 1o2 rule with 80% asymmetric uncertainty cap (aUC80), 1o2 rule with biomass safeguard (Istat), 1o2 rule with 80% uncertainty cap and biomass safe guard (UC80I) and 1o2 rule with 80% asymmetric uncertainty cap and biomass safeguard (aUC80I).

	Risk			Depletion (20% Bvirgin)			Depletion (40% Bvirgin)			Collapse	Yield			SSB			F			ICV		
	s	m	l	s	m	l	s	m	l		s	m	l	s	m	l	s	m	l	s	m	l
HR0.1	0.003	0.000	0.000	0.000	0.000	0.000	0.031	0.005	0.008	0.000	155	186	183	729	796	793	0.155	0.172	0.169	0.491	0.378	0.365
UC80I	0.154	0.037	0.005	0.052	0.012	0.001	0.310	0.088	0.014	0.000	313	202	127	538	718	850	0.438	0.215	0.114	0.397	0.374	0.319
Istat	0.183	0.060	0.008	0.068	0.021	0.002	0.340	0.128	0.029	0.000	335	230	169	514	674	790	0.488	0.262	0.159	0.460	0.474	0.363
aUC80I	0.184	0.061	0.008	0.068	0.022	0.002	0.340	0.128	0.029	0.000	335	228	169	514	673	790	0.488	0.260	0.159	0.460	0.474	0.363
UC80	0.181	0.083	0.015	0.070	0.034	0.004	0.344	0.163	0.040	0.000	341	253	188	516	636	769	0.493	0.293	0.182	0.368	0.379	0.335
HR0.2	0.027	0.023	0.025	0.002	0.001	0.001	0.123	0.113	0.109	0.000	280	310	305	602	621	624	0.328	0.351	0.345	0.442	0.435	0.421
1o2	0.215	0.155	0.057	0.092	0.065	0.020	0.381	0.275	0.123	0.000	361	297	260	496	560	649	0.537	0.398	0.291	0.415	0.492	0.414
aUC80	0.215	0.162	0.063	0.093	0.072	0.023	0.382	0.280	0.133	0.000	361	298	260	496	558	644	0.537	0.407	0.296	0.415	0.492	0.414
UC20	0.197	0.257	0.277	0.084	0.203	0.249	0.377	0.340	0.316	0.212	359	274	208	492	565	624	0.525	0.417	0.299	0.172	0.177	0.175

HR0.1	0.030	0.000	0.000	0.004	0.000	0.000	0.091	0.005	0.008	0.000	140	185	183	686	796	793	0.150	0.171	0.169	0.557	0.379	0.365
UC80I	0.344	0.065	0.005	0.154	0.023	0.002	0.504	0.123	0.017	0.000	312	191	129	430	701	853	0.555	0.210	0.114	0.439	0.386	0.319
aUC80I	0.381	0.107	0.013	0.178	0.046	0.004	0.535	0.184	0.042	0.000	339	226	176	413	642	780	0.625	0.281	0.169	0.494	0.519	0.365
Istat	0.380	0.106	0.014	0.177	0.046	0.004	0.535	0.184	0.043	0.000	339	225	174	413	644	780	0.625	0.281	0.167	0.494	0.519	0.365
HR0.2	0.067	0.024	0.025	0.010	0.001	0.001	0.193	0.113	0.109	0.000	254	309	305	567	620	624	0.315	0.351	0.345	0.523	0.435	0.421
UC80	0.410	0.188	0.031	0.222	0.103	0.012	0.566	0.290	0.069	0.000	351	265	201	395	563	738	0.695	0.356	0.212	0.394	0.411	0.347
1o2	0.458	0.330	0.138	0.244	0.184	0.060	0.606	0.466	0.242	0.000	387	315	296	374	449	579	0.783	0.536	0.387	0.431	0.562	0.465
aUC80	0.459	0.340	0.155	0.245	0.200	0.067	0.606	0.476	0.264	0.000	387	320	297	374	444	566	0.784	0.546	0.399	0.431	0.561	0.473
UC20	0.499	0.528	0.541	0.312	0.470	0.523	0.645	0.602	0.574	0.482	398	245	113	337	341	54	0.830	0.858	1.933	0.186	0.197	0.253

HR0.1	0.046	0.000	0.000	0.016	0.000	0.000	0.101	0.006	0.008	0.000	142	185	183	690	794	793	0.149	0.171	0.169	0.539	0.381	0.365
UC80I	0.317	0.114	0.015	0.151	0.048	0.005	0.473	0.195	0.039	0.000	344	245	161	444	627	794	0.576	0.293	0.159	0.399	0.395	0.329
HR0.2	0.084	0.024	0.025	0.025	0.001	0.001	0.194	0.113	0.109	0.000	260	309	305	572	619	624	0.313	0.351	0.345	0.490	0.436	0.421
UC80	0.330	0.157	0.028	0.166	0.078	0.009	0.482	0.256	0.065	0.000	352	262	201	442	583	741	0.592	0.348	0.200	0.383	0.399	0.344
aUC80I	0.375	0.196	0.047	0.192	0.098	0.019	0.534	0.303	0.101	0.000	373	288	229	409	551	693	0.662	0.395	0.239	0.489	0.549	0.398
Istat	0.375	0.195	0.047	0.191	0.098	0.018	0.534	0.301	0.100	0.000	372	286	227	409	551	696	0.661	0.396	0.236	0.489	0.549	0.397
1o2	0.394	0.302	0.124	0.206	0.171	0.053	0.544	0.429	0.222	0.000	381	311	285	403	469	588	0.683	0.507	0.365	0.468	0.538	0.453
aUC80	0.394	0.313	0.138	0.207	0.184	0.062	0.544	0.438	0.245	0.000	381	312	285	403	465	581	0.683	0.527	0.375	0.468	0.537	0.455
UC20	0.293	0.279	0.295	0.146	0.223	0.271	0.461	0.360	0.338	0.218	351	266	194	452	558	638	0.535	0.432	0.292	0.172	0.179	0.176

3.1.5 Conclusions

- The 1o2 rule with 20% uncertainty cap, used to provide advice for 2021, is not precautionary and resulted in high levels of risk and collapse.
- The 1-over-2 rule is more precautionary than the 2-over-3 rule, although additional mechanisms are required to reduce risks to <5%.
- A 20% constant harvest rate generated the highest yields whilst remaining precautionary for the most likely OMs (i.e. those with a steepness of 0.65). However, harvest rates applied to these simulated stocks may not translate directly to sprat in 7.de. While an attempt was made here to account for sensitivity to plausible life history parameters and survey catchability, the upcoming inter-benchmark should consider whether the uncertainties in these aspects are covered adequately by the MSE scenarios. It was suggested during the meeting that the parameterisation of recruitment may need further tuning (i.e. higher values of both steepness and recruitment variability).
- Biomass safeguards were shown to be ineffective when employing a fixed harvest rate.
- Harvest rates found to be precautionary in this study may not be precautionary when considering an annual advice schedule, due to lengthening of the time between observation and implementation of advice. If advice for sprat in 7.de is to remain on an annual schedule, it is recommended to simulation test harvest rates within a seasonal MSE with at least two time-steps per calendar year.
- An 80% symmetric uncertainty cap, preferably with biomass safeguard, performs well as a 'blind' rule when information of life history and survey catchability are lacking. However, this can result in reductions of catches due to the inability of the rule to take advice back to the previous level after hitting the lower cap.
- An 80% asymmetric uncertainty cap with biomass safeguard can prevent major losses of yield by allowing catches to return to past levels but may not be precautionary for less resilient or depleted stocks.

3.1.6 References

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3.2 Testing management advice procedures for short-lived category 3 data-limited stocks

Sánchez, S., Uriarte, A., Citores, L. and Ibaibarriaga, L.

3.2.1 Introduction

As a follow-up of the work conducted in WKDLSSLS (ICES, 2019), different variants of the current ICES advice rule for Category 3 short-lived stocks were evaluated. In particular, we focused on the performance of these trend-based harvest control rules (HCRs) including biomass safeguards and harvest rate (HR) limits. The evaluation was carried out for two types of short-lived stocks (anchovy-like -STK1- and sardine and sprat-like stocks -STK2-). The first ones, anchovy-like, are characterised by high natural mortality (with mean across ages 1–3 above 0.8), full maturity-at-age 1 and with high interannual variability. Whereas the second ones, sardine and sprat-like, are stocks with medium natural mortality, full maturity-at-age 2 and with halfway interannual variability. We used the management strategy evaluation approach (Punt *et al*., 2016) with FLBEIA software (García *et al*., 2017). The performance of various alternative harvest control rules was compared across a range of different settings such as changing the timing of the advice and the management calendar, using various levels of uncertainty caps and setting different biomass safeguard reference values. Present information forms part of a work that is currently in preparation to be submitted for publication (Sánchez *et al*., in prep.).

3.2.2 Material and methods

The biological operating model (OM) was an age-structured (ages 0–6^{+}) model in half-year steps. Spawning time was set at the beginning of the second semester (1st July) and therefore recruits (age 0 individuals) were entering the population on 1st July. The operating model was conditioned built on the life-history parameters of the stock type and a Beverton and Holt stock–recruitment model with steepness equal to 0.75 and virgin biomass equal to 100 000 tonnes without autocorrelation in residuals and standard deviation (σ_{REC}) at 0.75 was used to generate annual recruitments. The operating model worked in half-yearly steps and it was assumed that 50% of the catches occurred in each semester. The historical development of each stock was simulated for 30 years. Starting from a virgin population, each stock experienced a linear increasing exploitation during the first ten years up to a predefined level of fishing mortality (F_{target}) and was kept constant for the next 20 years at this level. The following levels of fishing mortality in the historical period were tested: (i) low fishing mortality, $F_{target} = 0.5 \cdot F_{MSYproxy}$; optimum fishing mortality, $F_{target} = F_{MSYproxy}$; or high fishing mortality, $F_{target} = 2 \cdot F_{MSYproxy}$. Variability in the historical fishing mortality level was included through a log-normal distribution with a coefficient of variation (CV_F) of 10%.

Regarding the reference points, the limit biomass (B_{lim}) was set as 20% of the virgin biomass B_0 and an F_{MSY} proxy was assumed at $F_{40\%B0}$.

Each year, an index of biomass at age 1+ (with catchability equal to 1) was observed, which followed a log-normal distribution with 25% coefficient of variation. Observations from the survey were assumed and simulated to start nine years prior to the start of the management period.

Within the management procedure, three alternative calendars were tested:

- Interim-year calendar. The management calendar was set from January to December and the index on 1st July informing on B1+ (biomass index of age 1 and older) in year y-1 was used to set the TAC from January to December in year (y+1). Lacking information on age

1 and 2 abundances in the TAC year, which would represent the largest part of the population for short-lived species.

- In-year calendar. The index on 1st July in year y on B1+ was used to set the TAC from July year y to June of the next year (y+1). Therefore, age 1 abundance was known during the second semester of year y, but not during the first half of year y+1.
- Full population knowledge. The TAC from January to December in year (y+1) was based on the B1+ index on 1st January of year (y+1). This is usually the case when a recruitment index is available (in the autumn of age 0 or in January itself of age 1). In this case, the index provides information on all the age classes that are going to be exploited.

Model free harvest control rules were tested, where the TAC was set based on the changes in the stock status based on the observed index. Rules of type n-over-m type were tested, where the TAC was calculated as:

$$TAC_{y+1} = TAC_y \frac{\frac{\sum_{i=l-n+1}^{l} I_i}{n}}{\frac{\sum_{i=l-(n+m)+1}^{l-m+1} I_i}{m}}.$$

where I_l is the last available index. For the in-year calendar $l = y$, for the interim year $l = y - 1$ and for the case where some indication of recruitment is available $l = y + 1$. Specifically, the 1-over-2 and the 2-over-3 rules were tested.

An alternative approach using geometric means instead of arithmetic ones was also tested, namely:

$$TAC_{y+1} = TAC_y \frac{\left(\prod_{i=l-n+1}^{l} I_i\right)^{\frac{1}{n}}}{\left(\prod_{i=l-(n+m)+1}^{l-m+1} I_i\right)^{\frac{1}{m}}}.$$

In the first simulation year, the reference TAC value was set using a mean of the last *m* historical years (for the n-over-m rule). Variants of these rules that were tested included:

i. the application of uncertainty caps, where following options were covered:

a) no uncertainty caps: UC(NA,NA);

b) symmetric uncertainty caps, with a maximum 20, 50 and 80% TAC change from previous year: UC(0.2, 0.2), UC(0.5, 0.5), UC(0.8, 0.8); and

c) asymmetric uncertainty cap: UC(0.8, 4).

ii. the use of a biomass safeguard, which reduces the advice by the multiplier $bsafe = min(1, I_l/I)$, with the following alternatives:

a) Imin : $I = min(I_{hist})$

b) Itrigger: $I = 1.4 \cdot min(I_{hist})$

c) Istat : $I = geometricMean(I_{hist}) \cdot e^{-1.645 \cdot sd(log(I_{hist}))}$

iii. HR limits: two optional limits were covered,

a) min: $min(HR_{hist}) < \frac{TAC}{I_y} < max(HR_{hist})$

b) min50: $mean(HR_{hist}) \cdot 0.5 < \frac{TAC}{I_y} < mean(HR_{hist}) \cdot 1.5$

Two additional HCRs were tested within the same simulation framework. Firstly, the *Islope1* proposed by Geromont and Butterworth (2015) and tested by Carruthers *et al*. (2016), computing new TACs as:

$$TAC_{y+1}^{ISlope1} = TAC_y(1 + \lambda s_y),$$

where, $\lambda = 0.4$, $thereferenceTACforthefirstsimulationyearisequal 0.8 \cdot \frac{\sum_{i=lasty-5}^{y-1} C_i}{5}$ (lasty being the last historical year before beginning of management) and s_y is the index slope (gradient of log-linear regression) for the most recent five years.

And secondly, constant harvest rates (*HRconst*) rules with different initial values, where new TACs were calculated as:

$$TAC_{y+1}^{HRconst} = refHR \cdot I_l,$$

where I_l is the last available abundance index and $refHR$ can take three different values; equal to the mean of most recent five years HRs, $refHR^0 = \frac{\sum_{i=lasthy-5}^{y-1} HR_i}{5}$, or a reduction of this value to $0.8 \cdot refHR^0$ or $0.75 \cdot refHR^0$.

The *HRconst* rules were also tested in combination with biomass safeguards, which in this case acted to reduce $refHR$ if a new biomass index value was falling below some reference point ($I_{trigger}$), and kept it at this lower value until a new reduction was needed:

$$refHR_y = \begin{cases} refHR_{y-1}, if I_y \geq I \\ refHR_{y-1} \cdot \frac{I_y}{I_{trigger}}, if I_y < I \end{cases}$$

where I values were the alternative biomass safeguards mentioned above.

No implementation error was simulated (i.e. total catches are assumed to be equal to the TAC set if the population tolerates it). Maximum allowed catches in numbers-at-age are capped at 90% of the population numbers-at-age. It was assumed that 50% of the TAC was taken each semester, but when the seasonal quota was not taken, it was reassigned to the next season within the same management calendar.

A thousand iterations of a 30-year projection period were run for each scenario. Two sources of uncertainty were introduced in the projection period through: (i) recruitment variability; and (ii) observation error of the biomass index used to set the TAC.

Performance statistics are basically relative yield (over MSY, mean catch/F_{MSY} proxy) and risks of falling below B_{lim} over the short (first five years of management), medium (years 6–10) and long term (years 20–30 of management).

3.2.3 Results

Regarding the **coupling in time between assessment, advice, and management**: Previous year results are confirmed, so that the shorter the lag between observations, advice, and management, the bigger the catches and the smaller are the risks. This means that the best management calendar is the full population advice followed by the in-year advice, which should always be preferred over the usual calendar (with an interim year) advice.

Regarding the use of the **geometric means instead of the arithmetic means in the trend-based HCRs** (Figure 3.2.3.1): The use of the geometric mean for a given trend rule results in higher risks than using the arithmetic mean (Figure 3.2.3.1). Increased risks are linked to increased relative yields in the short and medium terms, as a result of lesser reduction properties of the catch options of the rules based on the geometric mean. However, relative yields do not necessary increase the long-term (see for example the 1-over-2 rule with 20% symmetric uncertainty cap, red dots and triangles, that for sprat/sardine-like stocks exploited above F_{MSY} proxy have same relative yields with much higher risk when geometric mean is used). In addition, rule 2-over-3 results in higher risks levels for the same catch levels as the 1-over-2 rules, for any uncertainty cap level (Figure 3.2.3.1), which confirms that 1-over-2 outperforms 2-over-3 rules for these short-living species.

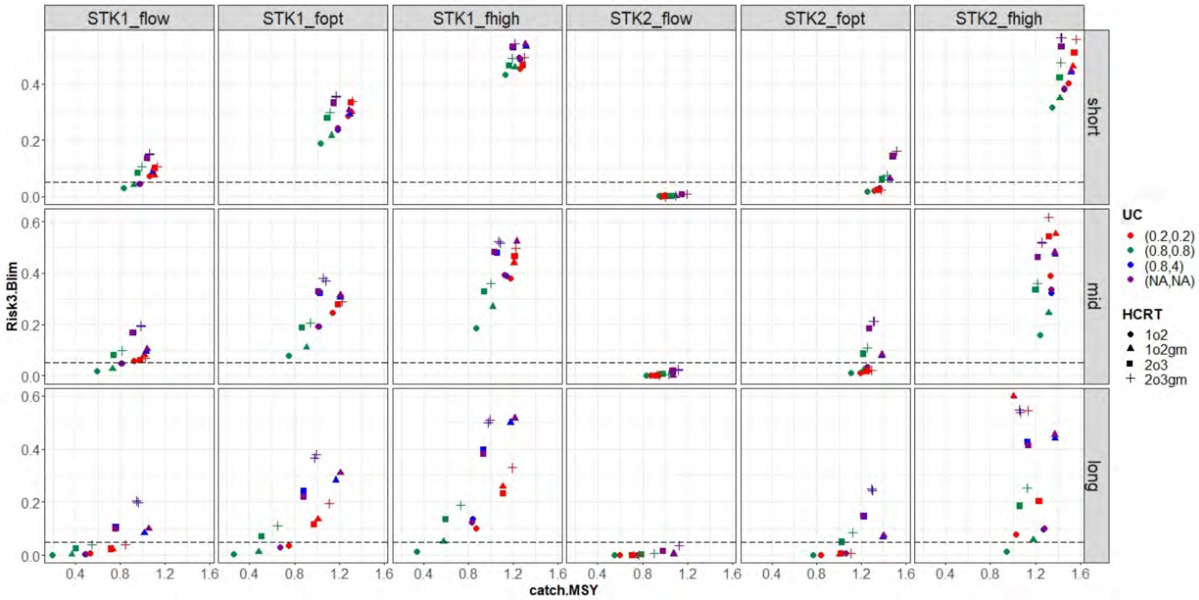

Figure 3.2.3.1. Risk3 (maximum probability of falling below B_{lim}) versus relative yields (catch/MSY) in the short (first five projection years - upper graphs), medium (next five projection years - middle graphs) and long-term (last ten projection years - bottom graphs) for each HCR (standard 1-over-2 and 2-over-3 rules and same rules with geometric means instead of arithmetic means, see right lower legend) combined with various uncertainty cap levels (see right upper legend). In columns, combination of stock-types and their historical fishing mortality levels (STK1 and STK2, correspond to anchovy-like and sardine/sprat-like stocks, respectively; and flow: Fhist=0.5*F_{MSY}, fopt: Fhist=F_{MSY} and fhigh: Fhist=2*F_{MSY}). Based on Sánchez *et al*. (in prep.)

Regarding the use of a **biomass safeguard** in the trend-based harvest control rule (Figure 3.2.3.2): The inclusion of a biomass safeguard in the rule remarkably reduces the risk in the medium and long terms by slightly reducing the relative yields for the stocks that have been historically exploited at or above F_{MSY}. The I_{stat} biomass safeguard is the one that leads to the smaller reduction in relative yields with similar benefits in the reduction of risks as I_{min}, whilst I_{trig} imply bigger loses in yield for very similar risks. Notably the major differences are driven by the uncertainty cap limits, whereby the symmetric UC(0.8,0.8) implies faster reduction of risks than the others (particularly clear in the medium term). Additionally, the biomass safeguard makes the UC(0.2,0.2) precautionary in the long term.

Regarding the inclusion of **HR stabilisers** applied to the rule, for the two stocks and for the different operating models, results indicate that these increased the risks and the relative yields. However, they have demonstrated to be inefficient, as they avoid the stock recovering to sustainable levels after being historically exploited at or above F_{MSY} (not shown).

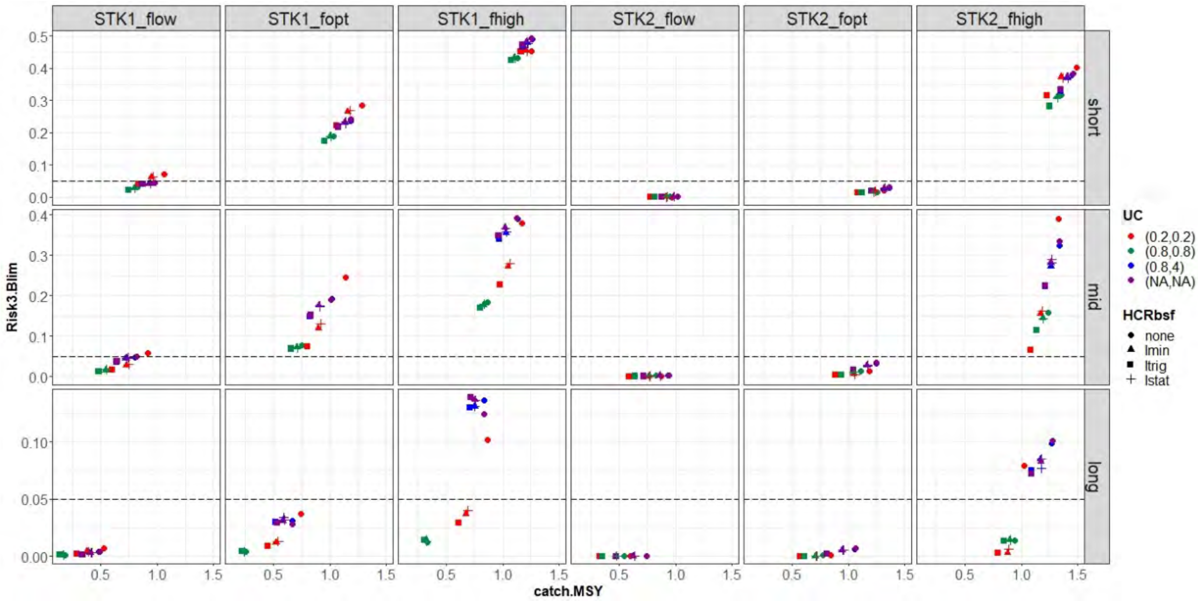

Figure 3.2.3.2. Risk3 (maximum probability of falling below B_{lim}) versus relative yields (catch/MSY) in the short (first five projection years - upper graphs), medium (next five projection years - middle graphs) and long-term (last ten projection years - bottom graphs) for the 1-over-2 rule combined with various uncertainty cap levels (see right upper legend) and biomass safeguards (see right lower legend). In columns, combination of stock-types and their historical fishing mortality levels (STK1 and STK2, correspond to anchovy-like and sardine/sprat like stocks, respectively; and flow: Fhist=0.5*F_{MSY}, fopt: Fhist=F_{MSY} and fhigh: Fhist=2*F_{MSY}). Based on Sánchez *et al*. (in prep.)

As a result of the former analysis, it is concluded that the best performing rules in terms of trade-offs between biological risks and relative yields in the long term are the 1-over-2 rule with 80% symmetric uncertainty cap both without or with biomass safeguard (based on I_{stat}) and the 1-over-2 rule with 20% symmetric uncertainty cap with I_{stat} biomass safeguard (Figure 3.2.3.3). However, due to the faster reduction properties of the levels of risks of the 1-over-2 rule with 80% symmetric uncertainty cap and with biomass safeguard, particularly noticeable in the medium term, this is to be preferred over the other rules for management purposes for stocks presumed to have been quite intensively exploited in the past. The 1-over-2 rule with 80% symmetric uncertainty cap and without any biomass safeguard gives the highest relative yields at acceptable risk levels for stocks that have been exploited at or below F_{MSY}, but differences are minor to when biomass safeguard is applied. The 1-over-2 rule calculated using the geometric mean of the indices and with symmetric 80% uncertainty cap has demonstrated to give higher yields, but it is not precautionary in the long term for stocks that have been historically exploited above F_{MSY}, though risks are very close to 0.05. The inclusion of a biomass safeguard could reduce the risks. However, this has not been tested yet in the present work.

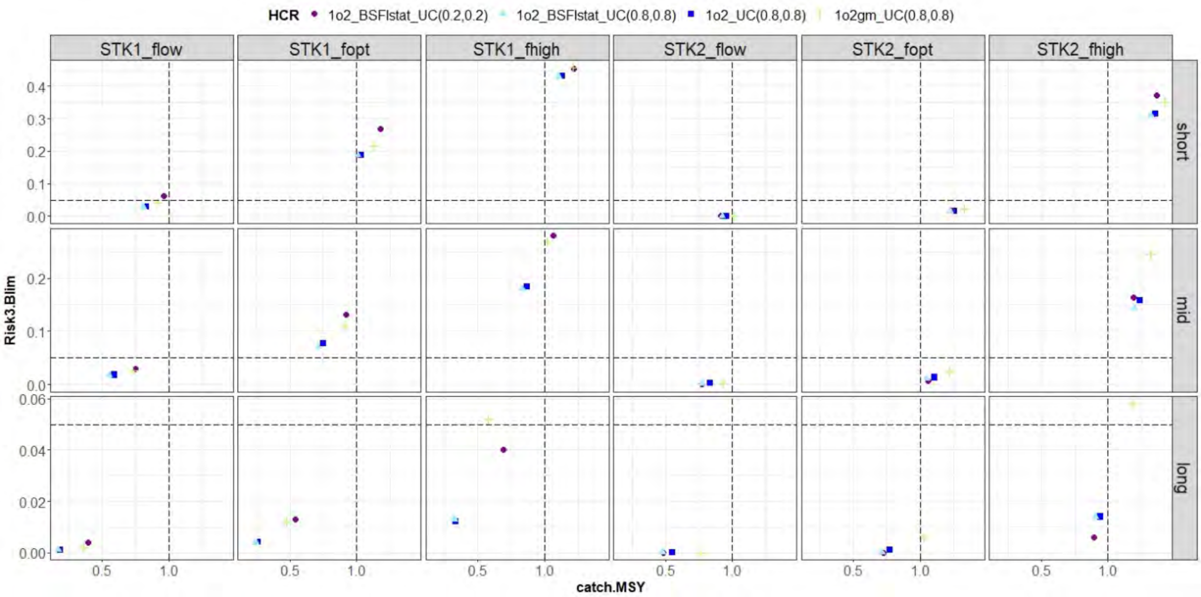

Figure 3.2.3.3. Risk3 (maximum probability of falling below B_{lim}) versus relative yields (catch/MSY) in the short (first five projection years - upper graphs), medium (next five projection years - middle graphs) and long-term (last ten projection years - bottom graphs) for a selection of HCRs and uncertainty cap levels (see right upper legend). In columns, combination of stock-types and their historical fishing mortality levels (STK1 and STK2, correspond to anchovy-like and sardine/sprat like stocks, respectively; and flow: Fhist=0.5*F_{MSY}, fopt: Fhist=F_{MSY} and fhigh: Fhist=2*F_{MSY}). Based on Sánchez *et al*. (in prep.)

Concerning the additional implemented rules, constant HR rules without any biomass safeguard keep constant risks and catches along the time not being able to decrease to precautionary levels in the cases where the starting point is at high risk For example, for anchovy-like stocks (STK1) with historical fishing mortality well above F_{MSY} (fhigh) the starting risks are around 0.5 and the constant HR rules keep it constant in the short, mid and long term (Figure 3.2.3.4), the same happens with the rest of stock status scenarios. With lower starting reference harvest rates (refHRs) lower risks are obtained.

The *ISlope1* rule is able to decrease risk and catches along time but it does it at a slower speed in comparison to 1-over-2 rules (Figure 3.2.3.4).

All results show that for stock lightly exploited in the past selected rules will imply unnecessary loses of catches, this implies that an initial evaluation of the historical exploitation level should be stablished to assess the need of applying a rule with reduction properties or just a stabilizer harvest rate rule (like a constant harvest rate).

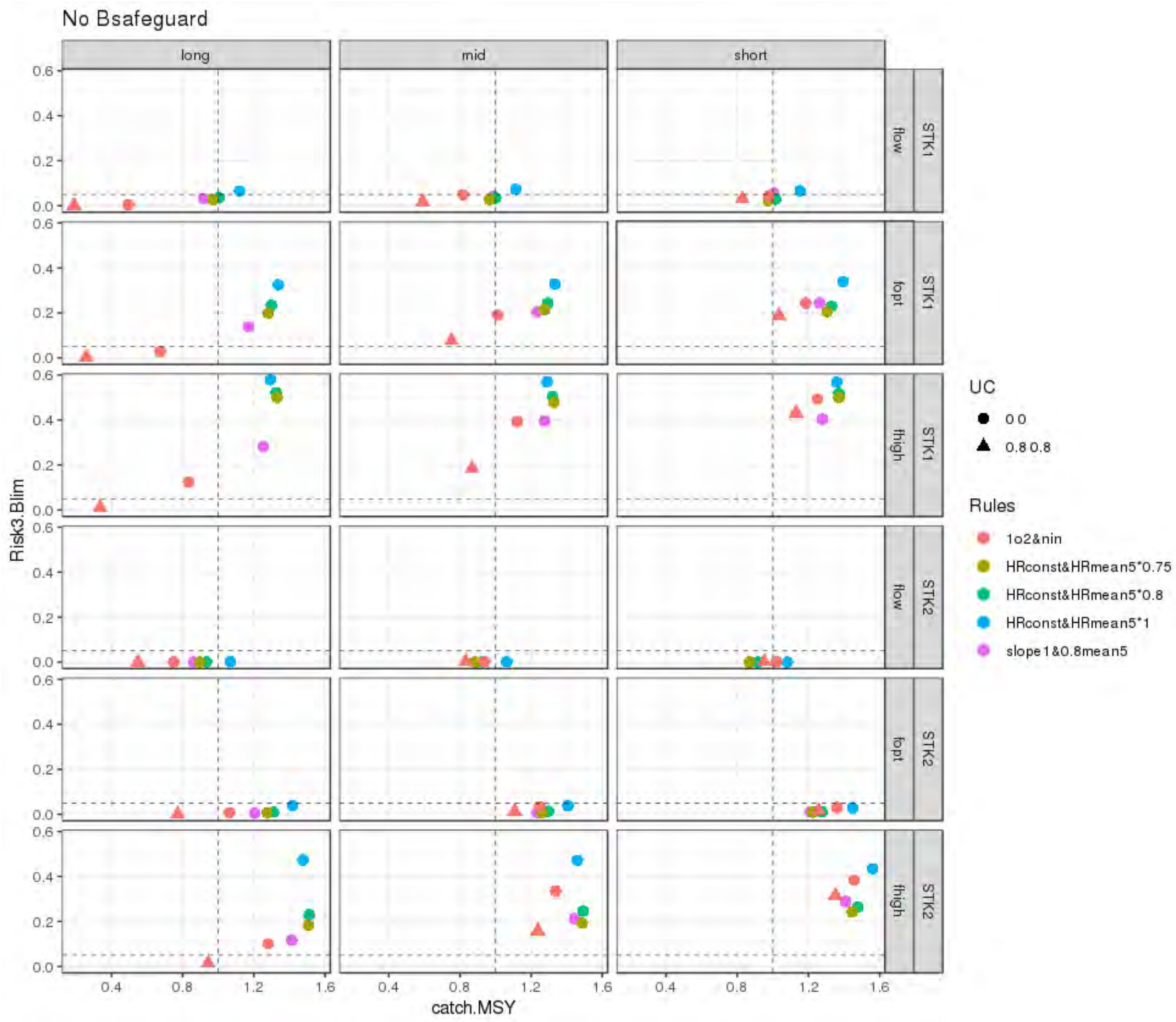

Figure 3.2.3.4. Risk3 of falling below Blim versus relative catch respect to MSY for alternative historical F levels (Flow: 0.5*FMSY, Fopt: FMSY and Fhigh: 2*FMSY), HCRs (red circle and triangle – 1o2 without uncertainty cap UC(0,0) and 1o2 with uncertainty cap UC(0.8,0.8); brown circle –constant HR with the starting refHR=0.75*historical HRmean(last 5 years); green circle –constant HR with the starting refHR=0.8*historical HRmean(last 5 years) without uncertainty cap; blue circle –constant HR with the starting refHR=historical HRmean(last 5 years) without uncertainty cap; pink circle –constant HR with the starting refTAC=0.8*historical Catch mean(last 5 years) without uncertainty cap, no biomass safeguards, stock types (STK1: anchovy-like; STK2: sardine-like), standard deviation for the recruitment= 0.75 and time frames (short: years 31–35; medium: years 36–40; and long term: years 51–60).

When combining constant HR with biomass safeguards, risk decreases along the time (Figure 3.2.3.5). For example, for anchovy-like stocks (STK1) with historical fishing mortality levels well above F_{MSY} (fhigh) the starting risk is around 0.45 in the short term and it decreases to around 0.37 in the long term, quite far from the low risk level (<0.05) that the 1-over-2 rule with UC(0.8,0.8) is able to reach. On the other hand, constant HRs keep higher level of catches. For low initial risk levels, they can show better performance as they do not reduce catches as much as the 1-over-2 does. Thus, the trade-off between catches and risk for these types of rules is very dependent on the initial stock status.

Moreover, the performance of constant HR rules may be affected by the survey catchability parameter and the CV of such survey index. The interaction between these two factors affecting survey index may require *ad hoc* tuning of the performance of the constant harvest rate rules devised to be applied to a particular stock and monitoring system. The performance of these rules also depends on the starting refHR, since lower starting refHRs imply lower risks. Therefore, the election of the refHR should also be tested.

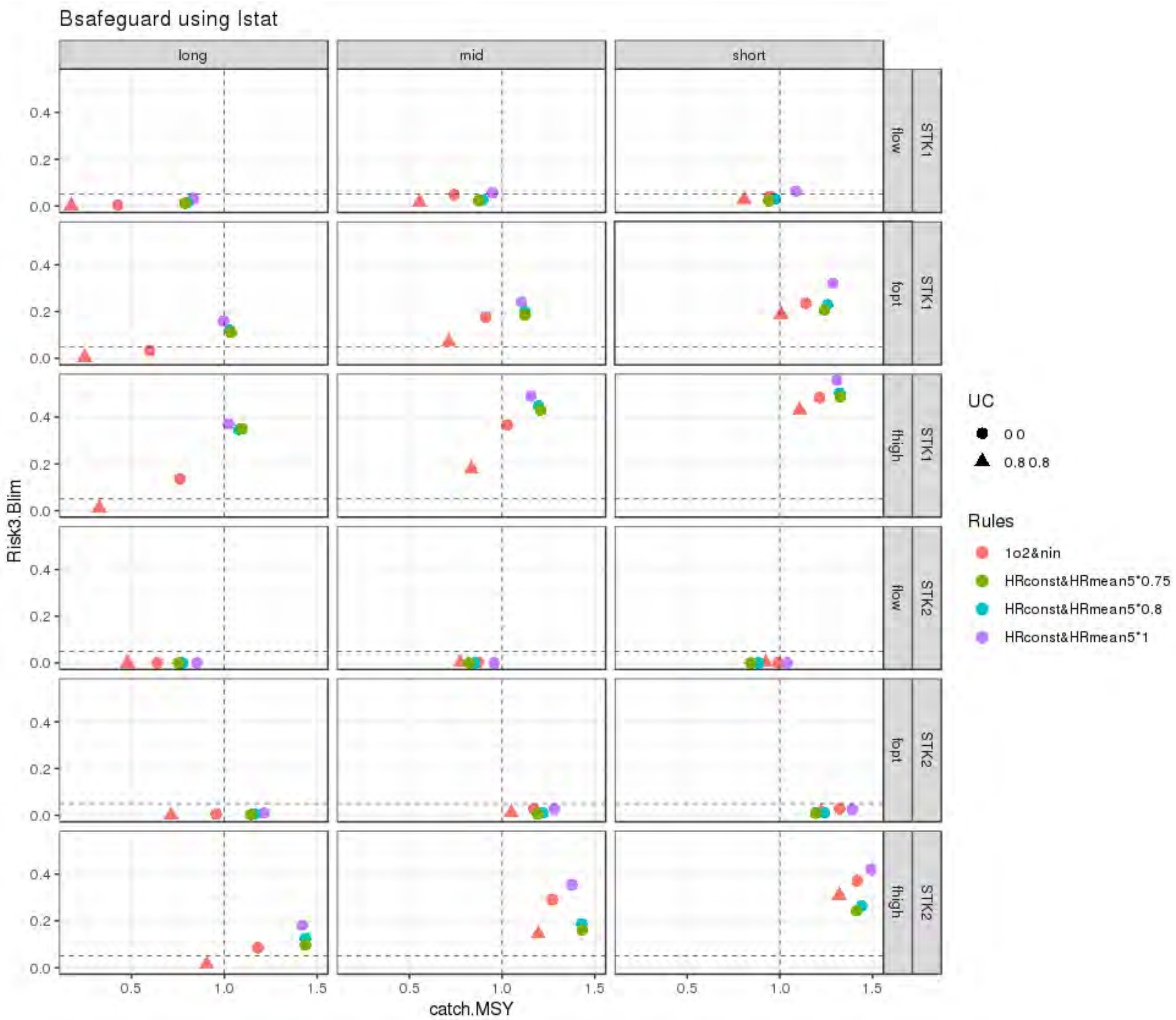

Figure 3.2.3.5. Risk3 of falling below Blim versus relative catch respect to MSY for alternative historical F levels (Flow: 0.5*FMSY, Fopt: FMSY and Fhigh: 2*FMSY), HCRs (red circle and triangle – 1o2 without uncertainty cap UC(0,0) and 1o2 with uncertainty cap UC(0.8,0.8); green circle –constant HR with the starting refHR=0.75*historical HRmean(last 5 years); blue circle –constant HR with the starting refHR=0.8*historical HRmean(last 5 years) without uncertainty cap; purple circle –constant HR with the starting refHR=historical HRmean(last 5 years) without uncertainty cap, biomass safeguard (I=Istat), stock types (STK1: anchovy-like; STK2: sardine-like), standard deviation for the recruitment= 0.75 and time frames (short: years 31–35; medium: years 36–40; and long term: years 51–60).

3.2.4 Conclusions

The main conclusions of this work are:

- The shorter the time-lag between the observed index and the application of the management advice, the bigger are the catches and the smaller are the biological risks. So, the best is full population advice, followed by in-year advice.
- Rule 1-over-2 result in better performance than the 2-over-3 rule for these short-living species, as the former results in higher risks levels for the same catch levels than the latter, at any uncertainty cap levels.

- Using the geometric mean instead of arithmetic mean when estimating the ratio of the indices means increase catch options and the risks in most of the cases. This results from the lesser reduction properties of the catch options of the rules based on the geometric mean.
- Biomass safeguards reduce the risks remarkably by slightly reducing yields for overexploited stocks in the medium term. Moreover, in the long term, it transforms the rules with 20% symmetric uncertainty cap as precautionary, while the reduction of risks is minor compared with the reduction in catches for the lower 80% uncertainty cap or without any uncertainty cap.
- Differences among the alternative biomass safeguards are small, being the I_{min} and I_{stat} biomass safeguard the ones that lead to the smaller reduction in relative yields. However, I_{stat} would be preferred due to its statistical properties.
- Setting harvest rate caps, increase the yields and the risks, and therefore worsen the performance of the trend rules applied to stocks at exploited at or above F_{MSY} proxy.
- According to our simulations constant HR rules keep constant risk and catches and are not able to move the stock to precautionary levels when starting from high-risk status.
- Constant HR rules combined with biomass safeguards can decrease risks, at a lower level than the 1-over-2 rule and can result in a better trade-off of catch vs. risks when starting from low risks. However, this is dependent on the initial stock status.
- Constant HR rules may be affected by the survey catchability parameter (in these simulations it was assumed to be correctly known) and the CV of the survey observations. The interaction between these two factors affecting survey index may require *ad hoc* tuning of the performance of the constant harvest rate rules devised to be applied to a particular stock and monitoring system.
- For stocks presumed to have been subject to a relevant exploitation level before management (at or above F_{MSY} levels) 1-over-2 rule with 80% symmetric uncertainty cap and with biomass safeguard is preferred to be applied for management due to the faster reduction of risks levels in the first ten years (medium term), than any other rule tested here. However, for stocks presumed to have been lightly exploited in the past other rules may show a better balance between catches and risks (as for instance a constant harvest rate with a biomass safeguard). Hence, an earlier assessment of the past of exploitation of the stock is very relevant to select the most suitable HCR for the management of such stock (as to prevent undue loses of catches for underexploited stocks).

3.2.5 Discussion and future work

So far we have tested trend based HCRs on stock abundance indicators (for instance a survey index) of the type n-over-m, which were coupled with maximum interannual allowable changes in the advice (by uncertainty cap levels, with lower and upper bounds) and with a biomass safeguard trigger alarm reduction factor. However, all the rules tested share the feature of being blind rules, not having and not leading necessarily to sustainable exploitation level of the stock, but inducing instead to a progressive reduction of catch options and risks (relative to the risk of dropping below B_{lim}). For this reason, these rules should always be considered provisional until achieving a better assessment of stock status and of sustainable harvest rates upon which to base improved management advice.

In addition, the rules have occasionally resulted in a too rigid behaviour for highly fluctuating stocks (as for the anchovy stock in 9.a-West). Namely, the trend rules smoothed so much the actual fluctuations of the stock that induced major interannual changes in harvest rates associated to the catch advice with rapid loses of catch opportunities at sudden stock outbursts. For that reason, ICES Working Group on Southern Horse Mackerel, Anchovy and Sardine

(WGHANSA) asked to WKDLSSLS-2 to explore the management of short-lived stocks based solely on a constant harvest rate.

Such recommendation of applying constant harvest rates (or gradually changing HR) for the management, could only be preliminary explored here.

Constant harvest rates were set at the mean of the last five years previous to the start of management with an initial precautionary buffer (PB at 1, 0.8, 0.75), but they resulted in keeping risks at the initial starting point of the management period (or reduced by the PB) without achieving any further reduction in the long term. These constant HR rules, if coupled with a biomass safeguard alarm (which would gradually reduce such harvest rate), reduce gradually risks but at a far lower rate than the preferred 1-over-2 rule with UC(0.8,0.8). In summary, constant harvest rate need to be selected carefully according to the characteristics of stock productivity and properties of the observation system (like bias and CV of the survey index), otherwise constant harvest rates just chosen from the recent exploitation levels in the fishery would act as blind rules as well (even if complemented with biomass safeguard factor) not necessarily being sustainable in the long term.

In both cases (i.e. for the trend based and for the constant harvest rate harvest control rules), having an initial assessment of the past exploitation level experienced by the population before starting the management would greatly help to select sustainable exploitation levels as to improve the trend rule with a target exploitation factor (F_{MSY} proxy/F_{obs}) or as to properly set a sustainable constant harvest rate, respectively.

In summary, main elements for improvements and future work will be:

- Getting an initial assessment of past exploitation levels exerted by the fishery before management starts as to get qualitative indication of F_{MSY} proxy or of a sustainable constant harvest rate. There are several assessment methods in literature which might be essayed (like SPiCT or others simply based on catch trajectories and trends), which could be coupled within the MSE of the current case studies. This would be also of utility to test if an initial PA buffer would be beneficial to start the application of any HCR in time.
- Ways of applying constant harvest rates complemented with biomass safeguard factors (either as just occasional -reversible- reduction or as permanent reduction factor).
- Searching for not blind rules but dynamic rules which can approach maximum sustainable harvest rates (as in Carruthers *et al.*, 2016).

3.2.6 References

Carruthers, T. R., Kell, L. T., Butterworth, D. D. S., Maunder, M. N., Geromont, H. F., Walters, C., McAllister, M. K., *et al*. 2016. Performance review of simple management procedures. ICES Journal of Marine Science, 73: 464-482.

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Geromont, H. F., and Butterworth, D. S. 2015. Generic management procedures for data-poor fisheries: forecasting with few data. ICES Journal of Marine Science, 72: 251–261.

ICES. 2019. Workshop on Data-limited Stocks of Short-Lived Species (WKDLSSLS). ICES Scientific Reports. 1:73. 166 pp. http://doi.org/10.17895/ices.pub.5549.

Punt, A. E., Butterworth, D. S., de Moor, C. L., De Oliveira, J. A. A., and Haddon, M. 2016. Management strategy evaluation: best practices. Fish and Fisheries, 17: 303–334.

3.3 Discussion and conclusions on abundance trend-based harvest control rules for guidelines on short-lived species, Uncertainty caps and Bsafeguards

Management calendar: The shorter the lag between assessment, advice and management the better the performance of all these rules (constant Harvest rate or Trend-based rules). The performance is optimised if based on an indication of the population (from surveys) just around the start of the management years, or with a shorter than a half year gap (in year advice). For lags of a year or more the performance of the rules worsens.

Rules 1o2 vs 2o3: For the OM considered in this section anchovy, sardine and sprat-like stocks, rules 1o2 outperform 2o3. When applied alone (without any UC or Bsafeguard) for the sprat 7.de-like stock, it is was shown that 1o2 rule is capable of reducing risk faster than the 2o3 reaching levels below 0.05 in the long term (at least for steepness at 0.65 under a sustainable historic fishing scenario) while the latter does not. In addition, the simulations on anchovy and sardine-like stocks show that even after combining these rules with symmetric and asymmetric uncertainty cap levels, rule 1-over-2 results in smaller risks levels for the same catch levels as the 2-over-3 rules given a common uncertainty cap level, which confirms that 1-over-2 outperforms 2-over-3 rules for these short-living species.

Uncertainty cap levels: for the sprat 7.de, it has been shown that the 1o2 rule results in the lowest long-term risks and, for most OMs, highest yields, when applying an 80% cap. The symmetric cap was more precautionary than the asymmetric cap, but also resulted in reductions of long-term yield. The application to anchovy and sardine-like stocks shows that the 1o2 rule with symmetric UC(0.8,0.8) implies faster reduction of risks than for the other UCs (particularly clear in the medium term), though at the expense of greater reductions of yield. The faster reduction of risks of the 80% symmetric uncertainty cap makes this one the most advisable one when actual exploitation is presumed to be high, or uncertain. For almost all OMs, the 1o2 rule with 20% cap was the least precautionary option.

Biomass safeguard: In all cases, applying a biomass safeguard to the 1o2 rule reduced risk, with risk($I_{trigger}$) < risk(I_{stat}) < risk(I_{lim}), though the actual reduction depends quite much on the operating models and the historical exploitation exerted over the population. In general, inclusion of the biomass safeguard remarkably reduces the risk in the medium and long terms by slightly reducing the relative yields for the stocks that have been historically exploited at or above F_{MSY}. I_{stat} is put forward for its application because of its robustness to the length of historical observations.

In general, application of both an uncertainty cap with a biomass safeguard (I_{stat}) to the 1o2 rule appears to perform better across all OMs and time-scales than either mechanism on its own. In many cases, applying a biomass safeguard with uncertainty cap is already highly noticeable in the medium term (in around ten years) for the reduction of risks it implies and furthermore reduces long-term risk to acceptable levels (<5%). The only exceptions occurred for the sprat in 7.de in cases with low steepness of s=0.5 and/or high levels of past exploitation under (FH3).

For short-lived stocks presumed to have been subject to a relevant exploitation level before management (at or above F_{MSY} levels) the 1-over-2 rule with 80% symmetric uncertainty cap and with biomass safeguard (I_{stat}) is the preferred option to be applied for their management, due to the faster reduction of risks levels in the first ten years (medium term), than any other rule tested here.

The 1-over-2 rule calculated using the geometric mean of the indices (instead of the arithmetic mean) and with symmetric 80% uncertainty cap has demonstrated to give higher yields, but it is not precautionary in the long term for stocks that have been historically exploited above F_{MSY}, though risks are very close to 0.05. The inclusion of a biomass safeguard could reduce the risks. However, this has not been yet been sufficiently tested in the present workshop.

Application of constant harvest rate rules can keep rather constant risks but are not able to move the stock towards precautionary levels when starting from high-risk status, therefore they require careful analysis of sustainable reference levels of harvest rates. It has been shown that taking the mean of recent HR from the fishery of the history (with some buffers) are not necessarily sustainable, as its performance would depend on the exploitation the fishery has exerted historically on the stock. These constant harvest rate rules when combined with biomass safeguards can decrease risks, at a lesser speed than the 1-over-2 rule; this can result in a better trade-off of catch vs. risks when starting from low risk levels, but this requires knowledge of the initial exploitation status.

The performance of a constant HR rule will depend upon stock life history, survey catchability and the CV of the survey observations. In principle the larger the steepness, intensity of growth, the larger can be the sustainable harvest rate, but this will have to change inversely to catchability and to the observation CV of the survey. The interaction between the stock characteristics and the factors affecting survey index may require *ad hoc* tunning of the performance of the constant harvest rate rules devised to be applied to a particular stock and monitoring system.

Global comparison of these rules, suggests when a careful tuning of a sustainable constant harvest rate can be made by taking into account the stock life history and catchability and CV of the observation index, then such constant harvest rate strategy will result in the higher sustainable catches for the standard allowable levels of risks (0.05). But if such a tuning is not achievable because of the poor knowledge of the life history or observation properties, then the WK recommends for short-lived small pelagic fish stocks the Trend rule 1-over-2 coupled with a symmetric Uncertainty Cap constraint of 80% and with Bsafeguard (I_{stat}), as it results in the faster reduction of risks levels in the first ten years (medium term), than any other rule tested here.

A caution: It should be noted that for stocks presumed to have been lightly exploited in the past other rules may show a better balance between catches and risks that the 1o2 UC(-0.8, 0.8) (as for instance a constant harvest rate at the mean of recent values with a biomass safeguard). Hence, an earlier assessment of the past of exploitation of the stock is very relevant to select the most suitable HCR for the management of such stock (as to prevent undue loses of catches for under-exploited stocks).

4 General conclusions

4.1 On Assessments and BRPs

- For short-lived stocks with sufficient long input dataseries (and with enough contrast of biomasses and production in the series) surplus production models will be applicable (can be fitted) and the advice can be formulated on the basis of F_{MSY} (rather than on constant catch at MSY), or preferably less than F_{MSY} (accounting for the strong fluctuations of these short-lived species). Such F_{MSY} rule would be most successful if applied to an assessment including an indicator of the biomass population just prior to the management calendar (and including the most of the harvestable population age classes). A year lag between assessment and management year would worsen the performance of the management for short-lived species and this should be evaluated in comparison with other potential MPs.
- During the workshop SPiCT assessments to Anchovy in 9.aSouth, Anchovy 9.aWest were performed, resulting in a satisfactory application to Anchovy in 9.aSouth, with estimates very similar to those provided by a Gadget model (a data-rich model used as basis of the current assessment). Results for Anchovy 9.aWest were still unacceptable, even after SPiCT experts made improvements. In addition, there were presentations on successful applications of Surplus production modelling to several Cephalopods populations.
- No alternative reference points definition for management were produced by WKDLSSLS2, apart from those already available from surplus production assessments.

4.2 On HCRs

- The time-lag between abundance index, advice and management should be minimized, this leads to select in-year advice, implying that the management year (i.e. TAC year) generally differs from the calendar year.
- For DLSSLS with a survey monitoring system, a constant Harvest rate strategy can be the best management procedure conditioned to a careful setting of such level according to a prior good knowledge on the distribution of potential catchability and CV of the survey. Definition of such constant harvest rate is to be made by MSE during inter benchmarks covering the main range of uncertainties on life history, catchabilities, CV of surveys, etc.).
  - A preliminary assessment of such constant HR has been made for the sprat in 7.de.
  - Other analysis have shown that just taking the mean of recent HR from the fishery of the history (with some buffers) are not necessarily sustainable as this would depend heavily on the exploitation the fishery has exerted historically on the stock.
  - The potential of this approach would also depend upon the observation error of the survey.
- When the knowledge on the catchability or on the uncertainties are so poor as to preclude the definition of constant harvest rates, then Trend based Harvest Control rules (according to the recent indications of biomass) can be applied, coupled preferably to some Uncertainty Cap constrains and to Biomass Safeguards, as follows:
  - The WK recommends for short-lived small pelagic fish stocks the Trend rule 1-over-2 coupled with a symmetric Uncertainty Cap constraint of 80% and with Bsafeguard (I_{stat}): The analysis shows that the Rule 1-over-2 UC(-0.8,0.8) with Bsafeguard (I_{stat})

allows decreasing the biological risks (of falling below B_{lim}) for anchovy, sardine and sprat-like stocks in the long term to around 0.05, or below, with moderate losses of catches in the medium term (particularly for the fully and overexploited stocks), but losses are more pronounced in the long term.

- Asymmetric Uncertainty caps: An 80% asymmetric (UC(-0.8, 4)) uncertainty cap with biomass safeguard can prevent losses of yield by allowing catches to return to past levels, but may not be precautionary for less resilient or for depleted stocks.
- 1-over-2 with a symmetric 20% uncertainty cap is not sustainable in the long term (implying risks well above 0.05 of falling below B_{lim}). Coupling of Biomass safeguard alarm improves largely its performance but without overcoming the former 1-over-2 rule with 80% symmetrical uncertainty cap and Biomass safeguard.
- The shorter the lag between assessment, advice and management the better the performance of all these rules (constant Harvest rate or Trend-based rules). The performance is optimised if based on an indication of the population (from surveys) just around the start of the management years, or with a shorter than a half year gap (in year advice). For lags of a year or more, the performance of the rules worsens.
- The risk reduction properties of this rule with time is due to the reductions of catches it implies, this means that:
    - The Trend rule should be considered a provisional HCR with the aim of achieving a better management system in about 10 years or earlier (for instance until next benchmark). Longer application may lead to major losses of catches to the fishery in the long term.
    - Lightly exploited fisheries would not obtain improved management by applying this rule, as it would imply reduction of catch options without having a need of reducing risks. To avoid such situations early assessment of the exploitation of the fisheries would be required.
- Clear management objectives including the timing to achieve them for the particular short-lived data-limited stock, would help to select the rule which may best accommodate to those objectives.
- There is trade-off between the reduction of risks and catches associated to the many Trend rules examined by WKDLSSLS2, upon which the election of the most suitable rule to the fishery of concern is to be made. This would be better made in consultancy with managers and stakeholders according to the objectives of the management.
- The work of WKDLSSLS is considered unfinished. Further research on the definition of optimal harvest control rules for data-limited short-lived stocks is ongoing. Therefore, the suggested either tuned constant harvest rate or the trend rule (1-over-2 with symmetrical 80% Ucap and biomass safeguard) should be taken as an interim (provisional) proposal while guidelines are refined in 2021.

5 Future directions of work for DLSSLS stocks

The work of WKDLSSLS is considered unfinished and a recommendation for a new workshop in 2021 is proposed. Several points of further research are put forward below:

- Further work on assessment methods of initial stock status relative to MSY with simpler analysis of historical catches, the abundance indices or from expert knowledge is of relevance.

Getting an initial assessment of past exploitation levels exerted by the fishery before management starts as to get qualitative indication of F_{MSY} proxy or of a sustainable constant harvest rate. There are several assessment methods in literature which might be essayed (like SPiCT or others simply based on catch trajectories and trends), which could be coupled within the MSE of the current case studies. This would be also of utility to test if an initial PA buffer would be beneficial to start the application of any HCR in time.

- Improved fitting with SPICT or other surplus production models will have to be made on a stock-by-stock basis accounting for their particular catch and abundance index trajectories.
- Testing alternative ways of applying the trend rules with uncertainty caps. For instance, testing the effect of shifting the uncertainty cap from symmetric 80% to no uncertainty cap in time after 8–10 years of application of the 80% UC. It is expected that more optimal UCs could be invented and tested (e.g. one allowing advice to return back up to previous fishing levels).
- Further work on applying constant or variant harvest rate strategies instead of the trend-based rules aligned with HCR 3.2.2 Catch rule based on applying an F_{proxy} (WKMSYCat34). Definition of constant Harvest rates and how they vary with assumed catchability and uncertainty (CV) of surveys and life-history assumptions, across modelling platforms.
- Testing alternative ways of applying constant harvest rates complemented with biomass safeguard factors: For instance, either as just occasional -reversible- reduction or as permanent reduction factor; Periodic updates of reference points for the Biomass safeguard
- Searching for not blind rules but dynamic rules which can approach maximum sustainable harvest rates (as in Carruthers *et al*., 2016).
- Reviewing literature on and doing simulation tests to determine if LT-MSEs may need to operate on sub-annual time-steps due to the short-lived, fast maturing nature of these stocks.

Annex 1: WKDLSSLS2 Workshop Agenda

WebEx meeting online 14–18 September 2020

Agenda

MONDAY	SEPTEMBER 14	
Time (Denmark)	**Presenters**	**Brief Presentation Description**
09:30	**None**	wellcome
10:00	**Plenary**	Introduction and adoption of the agendav(by the Chairs) Intoductory presentation on the following of ICES on ShortLived Data Limited stocks in 2020 (Sarah Miller)
11:30	**Margarita María Rincón Hidalgo (ICMAN) (CSIC)**	A comparison of Spict and Gadget estimates up to 2020, and the last advances in the Farfish-DLMtool
12:15	**Ruben H. Roa-Ureta (Consultant in Statistical Modeling, Marine Ecology and Fisheries)**	Stock assessment of the octopus fishery in Asturias, northern Spain
13:30	**Plenary**	**End of Plenary (time to work and write report)**

TUESDAY	SEPTEMBER 15	
Time (Denmark)	**Presenters**	**Brief Presentation Description**
09:30	**Mollie Brooks (DTU Aqua)**	Information on production curves regarding Fmsy compared to the escapement strategy HCR used for North Sea sprat
11:15	**Campbell C. Pert (Marine Scotland, Scottish Government)**	Working Towards A Sustainable Future – The Scottish Mallaig Sprat Fishery
12:30	**Sonia Sanchez et al. (AZTI)**	Revisting of the relative performance of the Trend-based HCR: Management advice procedures for short lived data limited stocks in ICES Category 3
14:00	**Plenary**	**End of Plenary (time to work and write report)**

WEDNESDAY	SEPTEMBER 16	
Time (Denmark)	**Presenters**	**Brief Presentation Description**
09:30	**Laura Wise and Susana Garrido (IPMA)**	Testing Harvest strategies with anchovy in 9aWest
11:15	**Plenary**	Discussion on Sanchez et al. Presentation on the revisiting the performance of trend based HCRs
12:00	**Nicola Walker (CEFAS)**	Management strategy evaluations for a simulated stock of sprat in 7.de
13:00	**Tobias K. Mildenberger (DTU Aqua)**	Simulating the ICES approach to data-limited fisheries management: The case study of Anchovy in the Bay of Biscay

THURSDAY	SEPTEMBER 17	
Time (Denmark)	**Presenters**	**Brief Presentation Description**
10:00	**Mollie and Andrés, Sarah**	Balance on index on contents of the report and pending issues for the meeting (other presentations…)
10:45	**Sonia Sanchez and L. Citores et al. (AZTI)**	Management advice procedures for short-lived data limited stocks in ICES Category 3 – additional rules
12:10	**Angela Larivain**	SPiCT trials assessment of Sepia officinalis in the English Channel (ICES divisions 27.7.d).
13:30	**BREAK**	Lunch time
15:00	**Plenary**	Common discussion on the applicability of the surplus production methods to short lived data limited stocks
17:30	**Plenary**	**End of Plenary**

FRIDAY	SEPTEMBER 18	
Time (Denmark)	**Presenters**	**Brief Presentation Description**
09:30	**Mollie and Andrés**	Balance on index on contents of the report and pending issues for the meeting (other presentations…)
10:00	**Nicola Walker (CEFAS)**	Some further testing Management strategy evaluations for a simulated stock of sprat in 7.de
10:45	**Sonia Sanchez and L. Citores et al. (AZTI)**	Some further Management procedures for short-lived data-limited stocks in ICES Category 3 – additional rules
11:30	**Plenary**	Common discussion on the advances on management procedures for short-lived data-limited stocks in ICES Category 3
12:30	**Breack**	
13:30	**Plenary**	Reading of the general conclusions of the workshop And fixing deadlines for reporting and future tasks Closing the meeting
14:30	**Plenary**	Final recommendation and Closing the meeting

Annex 2: WKDLSSLS2 List of Participants

Attendees to WKDLDSLS	Attending?	Country	Institute
Sarah Louise Millar' <sarah-louise.millar@ices.dk>	Yes	Denmark	International Council for the Exploration of the Seas (ICES)
Mollie Elisabeth Brooks <molbr@aqua.dtu.dk>	Yes	Denmark	Denmark's Technical University (DTU-Aqua)
Andrés Uriarte <auriarte@azti.es>	Yes	SPAIN	FUNDACION AZTI (Pasaia)
Tobias Mildenberger <tobm@aqua.dtu.dk>	Part time	Denmark	Denmark's Technical University (DTU-Aqua)
Alexandra (Xana) Silva <asilva@ipma.pt>	Part time	Portugal	Instituto Português do Mar e da Atmosfera (IPMA)
Susana Garrido <susana.garrido@ipma.pt>	Yes	Portugal	Instituto Português do Mar e da Atmosfera (IPMA)
Margarita Rincón Hidalgo <margarita.rincon@csic.es>	Yes	SPAIN	Instituto Español de Oceanografía (Cadiz) Spain
Sonia Sanchez <ssanchez@azti.es>	Yes	SPAIN	FUNDACION AZTI (Pasaia)
Leire Ibaibarriaga <libaibarriaga@azti.es>	Part time	SPAIN	FUNDACION AZTI (Sukarrieta)
Leire Citores <lcitores@azti.es>	Yes	SPAIN	FUNDACION AZTI (Pasaia)
Nicola Walker (CEFAS) <nicola.walker@cefas.co.uk>	Yes	UK	Cefas (UK)
Angela larivain<angela.larivain@unicaen.fr>	Yes	France	University of Caen (France)
Laura Wise IPMA <lwise@ipma.pt>	Yes	Portugal	Instituto Português do Mar e da Atmosfera (IPMA)
Pia Schuchert <pia.schuchert1@gmail.com>	Yes	Norhern Ireland	Agri-food and Biosciences Institute
Campbell Pert <Campbell.Pert@gov.scot>	Yes	Scotland	Marine Scotland Science
Ruben Roa Ureta <ruben.roa.ureta@mail.com>	Yes	Spain	Consultant in Statistical Modelling, Marine Ecology and Fisheries
Richard Nash (Cefas) <richard.nash@cefas.co.uk>	Part time	UK	Cefas

A picture of the Expert Group follows:

Annex 3: Minutes of WebEx meetings held in May and June 2020

Short Minutes of the WebEx meeting on 4 May 2020 on WKDLSSLS preparation

PROJECT	WKDLSSLS
DATE	04/05/2020
TIME	10:00–12:00
PLACE	WebEx
PARTICIPANTS	Andrés Uriarte, AZTI, Basque Country, Spain Mollie Brooks, DTU-Aqua, Denmark Pia Schuchert, Northern Ireland, UK Leire Ibaibarriaga, AZTI, Basque Country, Spain Angela Larivain, University of Caen, France Margarita Rincón, IEO, Spain Nicola Walker, Cefas, UK Sarah Millar, ICES, Denmark Campbell Pert, Marine Scotland, UK

Meeting objective: To prepare the works for WKLDLSSLS2

Items covered and notes during the meeting…

a) Updates on: a.1 the actual procedure for ICES advice on data-limited stock of short-lived species, a.2 what stocks are actually requiring this type of advice in ICES and a.3 what has happened with the sprat in 7.de this year 2020 and how has been the advised formulated? (and what discussion took place?).

Sarah Millar informed us that:

a.1 WKDLSSLS GUIDELINES for providing advice to DLSSLS were reviewed in WKLIFE9 (ICES, 2019... ICES Scientific Reports. 1:77, see page 111 of 138 pp). ACOM discussed them, were not yet adopted as they were considered provisional until this year. The work for providing advice is finished.

a.2 Stocks affected b: anchovy in Cadiz, sprat in the English Channel (7.de), cephalopods…

a.3 English Channel sprat in the herring WG:

i. There was a New person doing the assessment.
ii. They used the 1o2 rule, with the symmetric 20% uncertainty cap to provide advice for a calendar year, after a long discussion on the uncertainty cap to be applied, and having doubts whether our conclusions from WKDLSSLS1 applied equally to the calendar year as to the in-year advice.

iii. The conclusion for WKDLSSLS2 is that further work is needed to finalise the guidelines, and that WKDLSSLS2 has to evaluate and verify the properties of the HCRs for a normal calendar year advice.

iv. The EC was asked to change management to an interim year advice, but after some positive initial views, at the end they rejected the idea.

b) Quick overview to the ToRs. The ToRs were shown on the screen and briefly commented.

c) List of works we plan to do to cover the ToRS by attendees and collaborators to the WK (one or two slides to summarize you planned work would be welcome).

- ToR 1a: Further work on assessment methods of initial stock status relative to MSY with simpler analyses of historical catches, the abundance indices, or from expert knowledge where it is relevant.
  - AZTI: review simple approaches to give a first assessment to start the rule
- ToR 1b: Further testing of SPiCT advice rules for management for short-lived species. Evaluation of the performance of these rules either alone or in combination with uncertainty caps and biomass safeguards.
  - Mollie: continuation of last year work that was conditioned on North Sea sprat. Working with SPICT, a MSE conditioned to North Sea Sprat, for both in-year and calendar year…
  - Margarita for anchovy in 9.a southern component. She will work on SPiCT. She will try to apply gadget for the western component, but not for this year.
  - Angela Larivain will be working with SPICT and she might try also Biodyn.
  - Pia working on Irish Sea cod. They tried but SPICT did not work, because there was not enough contrast. They are trying DLMtoolkit. But they don't know how the work will evolve. WGCSE starting 6 May. Fast growth, mature at age 2, behaving like a short-lived species.

    http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/Fisheries%20Resources%20Steering%20Group/2019/WGCSE/01_WGCSE_2019.pdf

- ToR 2: Further explore the appropriateness of the management procedures currently in use for short-lived species by means of Long-Term Management Strategy Evaluations (LT-MSE). This will involve: a- Revisiting, if required, the advice rules proposed in WKDLSSLS 2019, b-Testing the effectiveness of the precautionary buffer, c- Further exploring the benefits of adding a biomass safeguard of minimum, d- Revisiting, if necessary, the suitability and magnitude of the uncertainty Cap, e- Testing constant or variable harvest rate strategies instead of the trend-based rules (aligned with HCR 3.2.2 Catch rule based on F_{proxy}–WKMSYCat34).
  - The work done last year has to be checked; Nicola and Mollie feel there are things to be checked.
  - Runs from last year should be there as a baseline for comparison.
  - Nicola is planning to work on:

  1. Asymmetric uncertainty cap: Nicola proposes to define the upper cap as the change needed to go back to the same number. Because otherwise, with the symmetric cap the catches continuously decrease.
  2. AZTI (Andres) also thinks along these lines of asymmetric uncertainty caps: UC(L, 1/(1-L))

What is the rate β needed to recover the catch to the same level after a reduction of L percent?

$$\beta(1 - L)Index = Index$$

$$\beta = \frac{1}{1 - L}$$

- Besides this: Nicola, AZTI and Mollie will also work on all the above issues in ToR 2.
- Campbell: They are working Spratt NW Scotland. They are trying to get MSC certification for Northwestern Scotland sprat, they are collecting data towards the assessment. Biological data: length distribution, some age readings, … just starting. Very small-scale fishery.

d) Overview of issues requiring some standardization for the MSE and HCRs we may want to test, so that results will be comparable as much as possible.

A list of points which may require such standardization (or pre agreement) was delivered in advance to the group. The items around the Management Procedure are the ones considered to require most standardization.

- Standardization of MSE works. Considerations of the group
  - Simulations: project forward for 25 years
  - Performance statistics periods:
    - Short: first five years: reasons to support this selection:

      1. Benchmarks every five years
      2. See the effect of the starting conditions and the initial exploitation rate

  - Medium: 6–15 years
  - Long: last ten years (16–25)
  - The results can be quite different depending on the period considered.
  - In principle, we agree that we will use the above, but if people find arguments to change it, there might be new proposals for the next meeting.
- Should we agree on the definition of F_{MSY} proxy and B_{lim}?
  - This might be relevant for comparison purposes
  - B_{lim} could be stock specific. If the rules are evaluated using different B_{lim} values for risk, we cannot compare the performance of the HCRs in absolute terms, but the comparison in relative terms among rules would still be valid.
  - Definition of stock collapse…
  - Comment Anna Rindorf and Mikael van Deurs are working on a simulation study showing that F_{MSY} is sometimes ill-defined for short-lived stocks, due to variability of productivity.

e) Logistics for the September meeting: Will we have a physical meeting or an online WebEx meeting in September? (Risks or suggestions from ICES? and participants?)

  - Next meeting in September:
    - ICES ASC has been cancelled.
    - No official guidelines for the meetings after June.
    - Options: meeting by correspondence or delay the physical meeting to November.
    - This meeting reports to WKLIFE, which is scheduled in October.
    - Therefore in principle the meeting will not be postponed, and it will be held if possible physically and if not, by video conference call.

- Future actions (ACC): each person writes a short paragraph with the workplan to Andrés to be included in the meeting minutes.
- We will organize another meeting at the end of June to present and discuss the work-plans of people in more detail.

Short Minutes of the WebEx meeting on 17 July 2020 on WKDLSSLS2 preparation

PROJECT	WKDLSSLS
DATE	16/07/2020
TIME	10:00–12:00
PLACE	WebEx
PARTICIPANTS	Andrés Uriarte, AZTI, Basque Country, Spain Mollie Brooks, DTU-Aqua, Denmark Laura Wise, IPMA, Portugal Fernando Ramos, IEO, Spain Pia Schuchert, Northern Ireland Nicola Walker, Cefas, UK Angela Larivain, University of Caen, France Sonia Sanchez, AZTI Basque Country, Spain Tobias Mildenberger, DTU-Aqua, Denmark

Meeting objective: To prepare the works for WKLDLSSLS2 for the September meeting

- Brief update on what has happened to the anchovy in 9.a this year (the other short-lived stock in category 3).
- Going through the minutes of our last meeting attached, and reviewing team by team, our plans of work, how far we have reached by now and if there are some changes in our plans.
- To see if there are some other standardizations we can still achieve in particular for B_{lim}, B_{MSY} and F_{MSY} by stock types…
- Look and discuss the preliminary results on the application of SPiCT to Common cuttle-fish by Angela Larivain (seeking for suggestions for improvements).

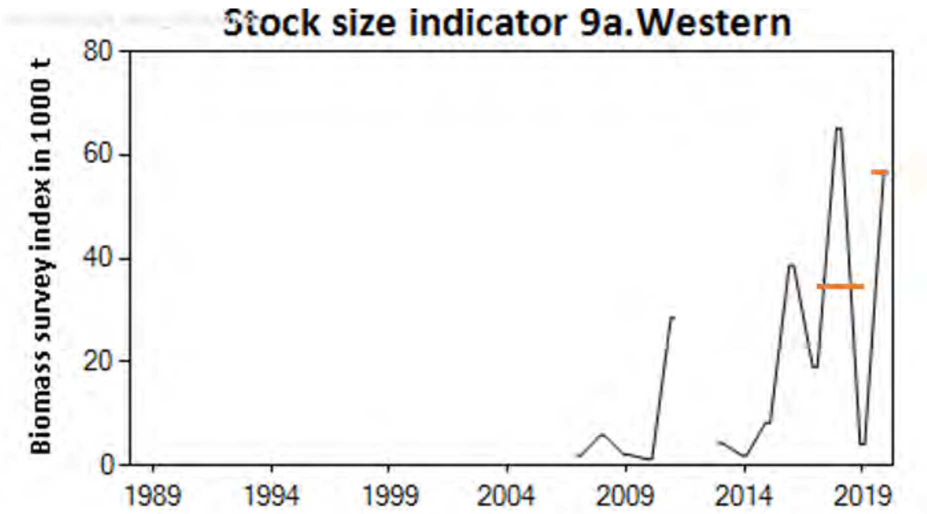
Items covered and notes during the meeting…

a) Update on the application of the ICES procedure for advice on data-limited stock of short-lived species to anchovy in 9.a this year.

Laura Wise informed to us that:

For anchovy in 9.a West: The WKDLSSLS GUIDELINES for providing advice to DLSSLS were followed as agreed in WKLIFE9 (ICES, 2019... ICES Scientific Reports. 1:77, see page 111 of 138pp). The interim year advice with a maximum of 80% interannual change (symmetrical un-certainty cap of 80%) was followed based on stock indicators directly provided by an acoustic survey (PELAGO+PELACUS survey). For the advice released in 2020 the PELACUS survey was inferred (PELAGO was used to infer the expected biomass for the PELACUS missing coverage, with a linear regression using the historical data (2007–2019) of PELAGO and PELACUS).

The trends for the surveys for the anchovy western area was:



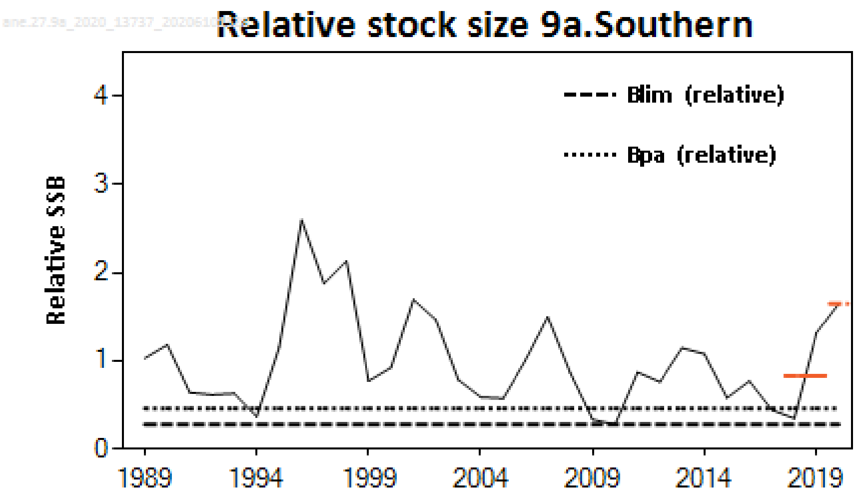
The estimate of anchovy abundance in 2020 over the mean of the previous two estimates was 1.63, therefore the 80% Ucap was not applied. This Resulted in an advice of 4347 tonnes.

The issue, which raised some debate in WGHANSA, was that in the advice for the period 2018/2019, corresponding to an acoustic biomass of 65 097 t, the catch option was of 13 308 t, while two years later for an acoustic biomass estimate of 56 526 in 2020 the catch advice was 4347 tonnes, which implies a strong reduction in harvest rates. This was explained by the strong reduction in the surveys estimates in 2019 (see the figure) required reducing 80% the catch options for the period 2019/2020 to 2662 tonnes, while the sharp increase in 2020 compared to mean of the two previous years cannot be as high as to compensate the sharp decrease of catch options in the former year. This implied a huge drop in harvest rates between these two consecutive years (63% in 2019 to 7% in 2020). This led WGHANSA to write a recommendation for WKDLSSLS2 to look for better procedures of providing advice for this data-limited stocks of short-lived species (DLSSLS) by allowing either greater uncertainty caps (such as being capable of restoring catch levels when sharp increases of the population occurs) or simply by applying harvest rates to the most recent biomass estimates from surveys.

The concrete recommendation is: "The group (WGHANSA) asks WKDLSSLS and WKLIFE to make a detailed analysis of HCRs based on fixed or gradually moving harvest rates applicable to the most recent population estimates for the provision of advice to this SLS category 3 stocks".

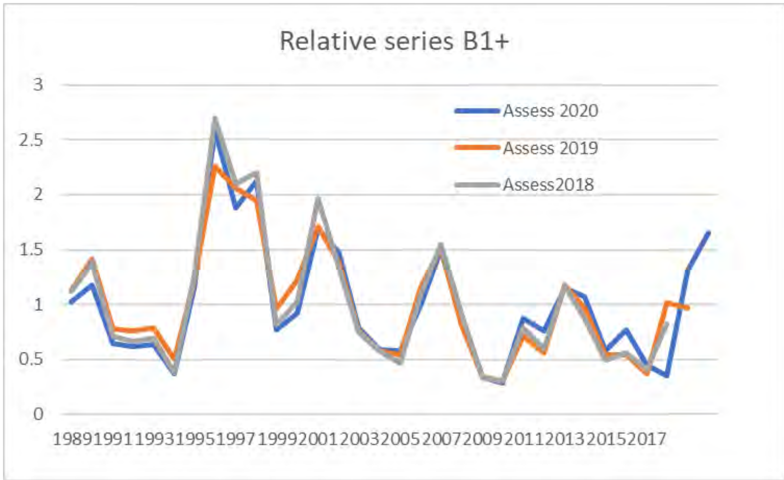
Regarding anchovy in 9.aSouth: The WKDLSSLS GUIDELINES for providing advice to DLSSLS were followed as agreed in WKLIFE9. The interim year advice with a maximum of 80% interannual change (symmetrical Uncertainty cap of 80%) was followed based on stock indicators produced by an Integrated assessment using Gadget based on several acoustic surveys (PELAGO+ECOCADIZ survey) and catches-at-age.

The overall tendencies allowed an increase of catches:



The Index ratio (A/B) was 1.98 and therefore the 80% Uncertainty Cap was applied.

A problem arose from the fact that the most recent assessment revised downward the biomass estimates in 2018:



As this 2018 biomass value is taken into account in the denominator of the one over two rule applied last year, but the value was different in last year from the value used this year, then it affects to the consistency of the application of the rule… This revision of recent past biomass estimates is something not yet taken into account in the evaluation of the performance of this HCR, and therefore it alters the functioning of the rule in an uncertain manner. The reason for this change was the new information input in the assessment regarding the age composition in the surveys and catches which has changed the perception of the recent stock biomass levels.

This problem again asked for a revision of the basis of formulating advice for this short-lived species, supporting the former recommendation on analysing the performance of basing the rules directly on harvest rates.

b) reviewing team by team, the progresses on our plans of work.

- Mollie and Tobias (DTU): continuation of last year work that was conditioned on North Sea sprat. Working with SPiCT, an MSE conditioned to North Sea Sprat, for both in-year and calendar year… Priority Modify existing NS Sprat MSE to run with

TACyear equal to calendar year (i.e. no in-year advice). (see more in the minutes of our past meeting report (meeting_wkdlssls2020_20200504.docx)

- Mollie: The work has suffered from some delay due to other commitments, but she is planning to essay it again, with more time in late August before the meeting …
- Tobias is working as usual with SPiCT and is addressing several improvements in the modelling to obtain greater reliability on the absolute levels of the assessment outputs and on better definition of the reference points from the assessment. He is also further including the 1o2 and 2o3 rules in addition to the biomass fraction rule standard of SPiCT (F based rule).
- Nicola Walker (Cefas) is going ahead with her plan of work: She will explore both the catch trend rules 1o2 and the Harvest Rates approaches, in addition she will consider asymmetric uncertainty caps (defining the upper cap as the change needed to go back to the same harvest rates as in the recent past) (or a bit lesser level), to avoid the continuous decline of harvest rates. She will also include the biomass safeguards and the precautionary buffer.
- Nicola was going slightly behind schedule too, hoping to further work this in July and late August and before the September meeting. She also mentioned that there will be an Inter-Benchmark on the English Chanel Sprat next February for which the results of the simulations for our Workshop will be highly relevant.
- Laura Wise (IPMA) will be testing Harvest Rate rules in collaboration with AZTI team for the dynamics of the western anchovy stock in Division 9.a. The work is pending to be launched in next weeks.
- Margarita Rincon and Fernando Ramos (IEO) will be working with application of SPiCT to the southern component of the anchovy in 9.a.
- Angela Larivain (Univ. Caen) has already been working with SPiCT (see last point of these minutes).
- Sonia Sanchez and Andrés Uriarte (AZTI) explained that they have already started working with the asymmetrical Uncertainty Caps, though the work is still in progress, while the work on harvest rates will launched probably in August.
- Pia Schubert (Northern Ireland) is working on Irish Sea cod (Fast growth, mature at age 2, behaving like a short-lived species). They are trying DLMtoolkit. They are testing the performance of the 2o3 rule for year Y+1 based on the Q1 (march) index of the IBTS(?) of year Y (and previous ones) on ages 1–3.

  She is also trying SPiCT.

Reminder: A Workshop on the application of SPiCT (initially foreseen for November 2020) will take place probably in January 2021…

Further references on this? (Tobias?)

c) Overview of issues requiring some standardization for the MSE and HCRs we may want to test, so that results will be as comparable as possible.

In the previous meeting we had agreed:

- Standardization of MSE: Simulations: project forward for 25 years.
- Performance statistics periods short, medium and long:
  - Short: first five years: reasons to support this selection: Benchmarks every five years and to see the effect of the starting conditions and the initial exploitation rate.
  - Medium: years 6–15.
  - Long: last ten years (16–25).

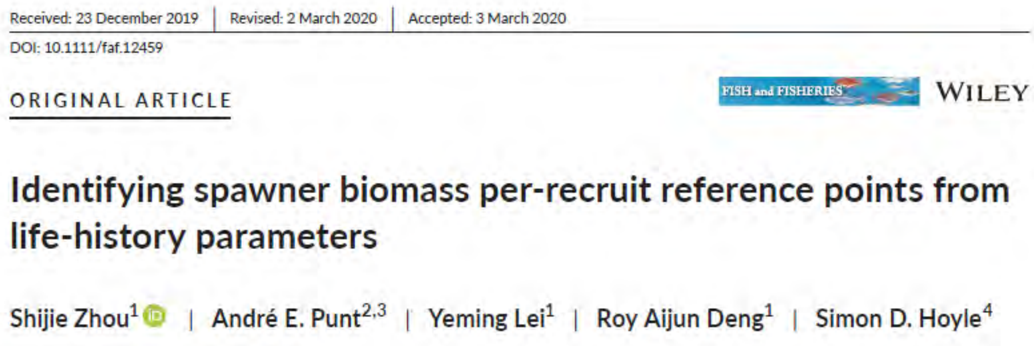
- In principle, we agree that we will use the above, but if people find arguments to change them, there might be new proposals for the next meeting.

New items for agreement:

Should we agree on the definition of F_{MSY} proxy and B_{lim}?

- It was agreed not to standardize the setting of B_{lim}…. B_{lim} could be stock-specific. If the rules are evaluated using different B_{lim} values for risk, we cannot compare the performance of the HCRs in absolute terms, but the comparison in relative terms among rules would still be valid.
- However, it was agreed to set common thresholds of Virgin Biomass (B_0) at 20%B_0 and at 40%B_0 as proxies of B_{lim} and B_{MSY}, though they will not be called B_{lim} or B_{MSY}… The idea is allowing direct comparison of the performance of any HCR in terms of probabilities (risks) of leading to biomasses below these thresholds. So that this can facilitate comparisons of the performance of the HCRs.
- On the definition of biomass reference points, it was mentioned that in the paper below there are explicit ad hoc suggestions for setting the B_{MSY} reference point:

  DOI: 10.1111/faf.12459



Received: 23 December 2019 | Revised: 2 March 2020 | Accepted: 3 March 2020

DOI: 10.1111/faf.12459

ORIGINAL ARTICLE

FISH and FISHERIES WILEY

Identifying spawner biomass per-recruit reference points from life-history parameters

Shijie Zhou[1] | André E. Punt[2,3] | Yeming Lei[1] | Roy Aijun Deng[1] | Simon D. Hoyle[4]

- Regarding indicators of fishing mortality sustainable values:
  - AZTI is setting them at F40%B_0.
  - Nicola is using the criteria that F/Z = 0.4 of Patterson, 1992.
  - In addition, the paper of Zhou *et al.*, 2012 suggests that he best model results in F_{MSY} = 0.87M (standard deviation (SD = 0.05) for teleosts.

We should not discard including these reference points for F in our analysis.

Zhou, S., Yin, S., Thorson, J. T., Smith, A. D. M., and Fuller, M. 2012. Linking fishing mortality reference points to life-history traits: An empirical study. Canadian Journal of Fisheries and Aquatic Sciences, 69(8), 1292–1301. https://doi.org/10.1139/f2012 -060.

  - There was no guidance on the definition of stock collapse, some people uses 0.1% of virgin SSB (Fischer *et al.*, 2020).
- Other Performance indicators: Given the difficulty of setting clear F_{MSY} other performance indicators can be very valuable such as:
  - Likelihood of stabilization of biomass // General tendencies of biomass in simulations.
  - Probability of reducing the risks to B_{lim} in time.
  - Initial Catches and Risks.
- Other issues requiring standardization for which some email exchange of proposals are expected to occur before the end of July are:

    - Concrete cases (values) of asymmetric uncertainty cap levels.
    - Biomass indicator buffer: Relative to what level? B_{loss} in the Indicator series? Or percentile 5% of past observations, or 10%? (notice that if we have ten years of past observations 10% equals the minimum past observed value), or 20%?
    - Precautionary buffer values? Just the Standard 20% PrecBuffer?
- Should our base cases correspond with SigmaR =0.75 / Steepness of 0.75 and a CV(survey) = 0.25 ???
- Other relevant issues were: Initial assessment of stock status (related or not to the Buffer application).

d) Angela Larivain showed SPiCT trial assessment of Common cuttlefish *Sepia officinalis* in the English Channel (7.d–7.e).

The assessment TRIAL 1 – without any priors on a Calendar year (With landings (1992–2019) + both commercial indices only (FR+UK)) seemed to have result in successful fitting… while the seasonal trial (2) had very uncertain results. And the third trial was unsuccessful (Run without any priors / Calendar year landings (1992–2019) + Commercial indices only (FR+UK) + CGFS_7d (1992–2019)).

Tobias pointed out that the Warning messages were not an issue of relevance… But point out the convenience of setting some priors since the beginning… They agreed to have some direct exchange of emails after the meeting.

e) Logistics for the September meeting:

- Our Next meeting is foreseen to take place from 14 to 18 September 2020 → ONLINE (ICES WebEx meeting).

In addition, Angela pointed out the convenience of inviting Ruben Roa to collaborate with WKDLSSLS2 after his interesting work while assessing the Octopus case studies in Asturias during the WGCEPH2020. The chairs endorsed her suggestion and Angela invited him to take part of this group short after the meeting (and he accepted).

Annex 4: Recommendations

Recommendation	For follow up by
It is recommended by WKDLSSLS that a new workshop on this subject (WKDLSSLS III) takes place next year, 20–24 September 2021 the ToRs of which should be discussed by ACOM at their November 2019 consultation meeting.	ACOM

Annex 5: List of Presentations

During the meeting a total of eleven presentations were made.

Authors	Presentation Title	Content
Sarah Millar (ICES)	WKDLSSLS 1 The aftermath	Current situation of ICES advice for DLSSLS in 2019/2020
Angela Larivain	SPiCT trials assessment of *Sepia officinalis* in the English Channel (ICES divisions 27.7.d).	summary of different assessment trials for the cuttlefish in the English Channel using SPiCT (annual Vs. quarterly landings inputs)
Ruben H. Roa-Ureta (Consultant in Statistical Modelling, Marine Ecology and Fisheries)	Spawning stock and recruitment of *Octopus vulgaris* in Asturias, Bay of Biscay	Stock assessment and advice for the octopus fishery in Asturias. A non-Bayesian hierarchical model built upon weekly data of catch, effort and mean weight for 20 years. A Shepherd stock–recruitment model was fitted with rather good precision, in addition to a Pella-Tomlinson surplus production model, both having immediate management applicability
Mollie Brooks (DTU Aqua)	Simulated production curves for North Sea sprat	information on production curves regarding F_{MSY} compared to the escapement strategy HCR used for North Sea sprat
Margarita María Rincón Hidalgo (IEO)	SPiCT vs Gadget Anchovy 9.aS, 2020	A comparison of SPiCT and Gadget estimates up to 2020
Laura Wise and Susana Garrido (IPMA)	Anchovy in 9.aWest component. Progress	A summary of recent management advice and essays on SPiCT and on Testing Harvest rate strategies with anchovy in 9.aWest
Campbell C. Pert (Marine Scotland, Scottish Government)	Working Towards A Sustainable Future – The Scottish Mallaig Sprat Fishery	an overview of a small fishery targeting sprats on Scotland's west coast and potential approaches to assessment and advice on sustainable catch levels
Tobias K. Mildenberger (DTU Aqua)	Simulating the ICES approach to data-limited fisheries management: The case study of Anchovy in the Bay of Biscay	comparing the performance of data-limited harvest control rules based on MSE parameterised according to the anchovy stock in the Bay of Biscay.
Sonia Sanchez *et al*. (AZTI)	Management advice procedures for short-lived data-limited stocks in ICES Category 3	Confirmation of previous years simulations on the relative performance of the HCR based on Trends from Abundance indicators, like T(1o2), T(1o3), T(1o5), T(2o3) with symmetrical and asymmetrical uncertainty cap constrained (lower and upper values) UC(L,U) and for different timings of the advice relative to the inputs availability

Authors	Presentation Title	Content
Sonia Sanchez *et al*. (AZTI)	Management advice procedures for short-lived data-limited stocks in ICES Category 3 – additional rules	Relevance of coupling to the former rules Biomass safeguards trigger alarms, harvest rates cap limits. Testing variants of the Trend rules based on Geometric means of the index series, and testing the performance of Constant harvest rate strategies and others
Nicola Walker (Cefas)	Management strategy evaluations for a simulated stock of sprat in 7.de	Testing catch rules (i.e. 1o2 and 2o3), constant harvest rates and variations of those rules with uncertainty caps and biomass safe guards

Annex 6: Working Document: Stock assessment trials for the cuttlefish (*Sepia officinalis*) in the English Channel (7.de) using SPiCT

Angela Larivain, UNICAEN, Normandie Université, Biologie des Organismes et Ecosystèmes Aquatiques BOREA (MNHN, UPMC, UCBN, CNRS-7208, IRID-207) CS 14032 Caen, France.

2.4. Stock assessment trials for the cuttlefish (*Sepia officinalis*) in the English Channel (7.de) using SPiCT

Angela Larivain

UNICAEN, Normandie Université, Biologie des Organismes et Ecosystèmes Aquatiques BOREA (MNHN, UPMC, UCBN, CNRS-7208, IRID-207) CS 14032 Caen, France.

Abstract

A serie of SPiCT models have been fitted to the cuttlefish 7.de stock, trying to develop appropriate and comparable methods to assess cephalopods stocks in the NE Atlantic waters. Yearly and quaterly catch inputs were used, testing different model features (*i.e.* index inputs – commercial Vs. surveys). Results of different outputs are presented with preliminary biological reference points (BRP) obtained according to the inputs.

1. SPiCT model (Surplus Production in Continuous Time)

SPiCt model fits a stochastic surplus production model in continuous time using the Pella-Tomlinson (1969) formulation, with parameter *n* controling the shape of the production curve (if equal to 2, Schaefer production curve). SPiCT is incorporating dynamics in both biomass and fisheries (process error) and observation error of both catches and biomass indices, allowing the estimation of three reference points proxies (MSY, B_{MSY}, F_{MSY}). The process error corresponds to the variability causes, not included in the model, while the observation error represents the difference between the measured biomass and the real biomass. Data requirement is not challenging as there is a need for only catch data and one or multiple biomass indices.

General SPiCT model description is available in Pedersen and Berg (2017) and technical guidelines to check before accepting an assessment, as a user guide, are available on GitHub (https://raw.githubusercontent.com/DTUAqua/spict/master/spict/inst/doc/spict_guidelines.pdf).

2. Data and different trials

In the English Channel, the cuttlefish is mainly exploited by France and UK (England, Wales and North Ireland) countries (WGCEPH reports). In this region, the species have a 2 years old life cycle with a fishing season assumed to start in July the year y untill June the year y+1, with seasonal migrations (offshore, in the central western channel part in the winter/coastal areas during spring-summer).

The SPiCT model was used to run stock assessment of Sepiidae stock (assuming mostly *Sepia officinalis*) in the English Channel area (ICES 7.de). Following last years SPiCT stock assessment exercises (WGCEPH, 2020 & WKDLSSLS1 this July), models and data have been updated, which included using updated and in certain cases corrected datasets; running a permuation of trials testing different versions of landings : (1) calendar year (Jan-Dec) [1992-2019] landings, (2) seasonal year (July-June) landings (Figure 1) - according to the fishing season of the species - and (3) quaterly landings, available for a shorter period [2000-2019] with default priors and different model settings.

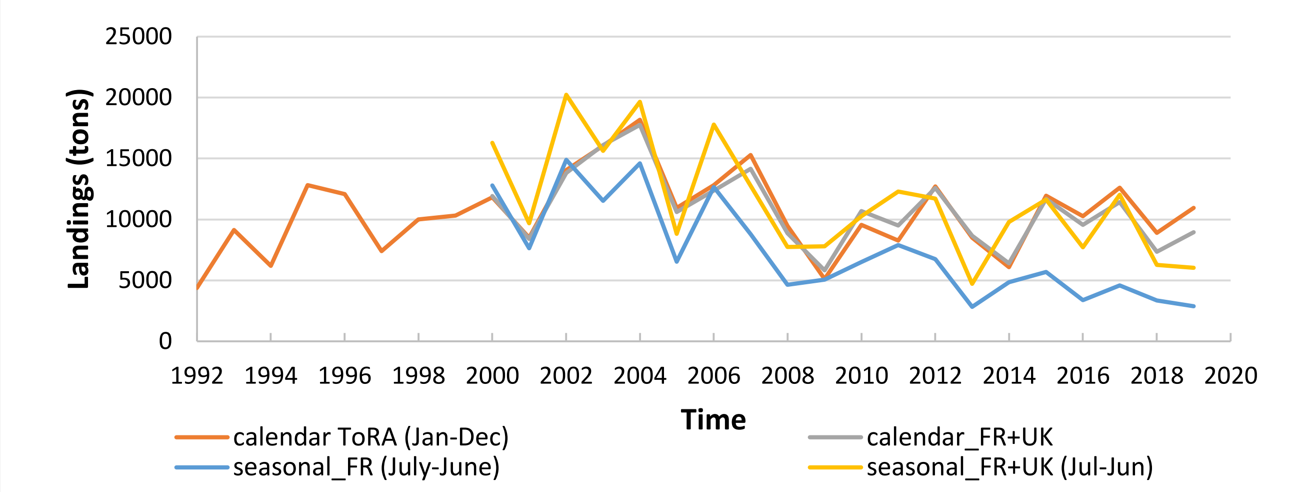


Figure 1. Calendar Vs. seasonal cuttlefish landings (tons) in the English Channel. The longest time serie is corresponding to each year DataCall realised during of the WGCEPH (ToRA).

Several models trials were run using a different set of catch data, allowing SPiCT to estimate the seasonal pattern of the fishing mortality when quaterly data were available. When the output was satisfaying enough according to the guidelines & Mildenberger (2019), the best models were selected based on following criteria:

- Successful model convergence – with no serious warnings or errors,
- A calculated order of magnitudes for relative biomass (B/B_{MSY}) and fishing mortality (F/F_{MSY}) between 0 and 2,
- Reasonable model diagnostics (*i.e.* no violation of model assumptions, avoiding auto-correlation)
- Reasonable retrospective plots (different trajectories should be inside the CI and be consistent between years)
- And if possible, the narrowest confidence intervals

2.1 Previous outputs (yearly catches) – presented in WKDLSSLS1

2.1.1 Scenario 1 – calendar landings (Jan-Dec)

Inputs: Default priors

Catches: calendar year landings [1992-2019]

Index : + yearly FR standardized lpue [1992-2019]

+ november UK lpue [2000-2019]

Considering all data together, residuals autocorrelation was present for some combinaition (**Annex 1**) and model did not reached convergence for others, when using surveys index together (**Annex 2**). However, when using commercial landings per unit effort available for FR and UK only, the model did converge (Figures 3, 4 & Table 1).

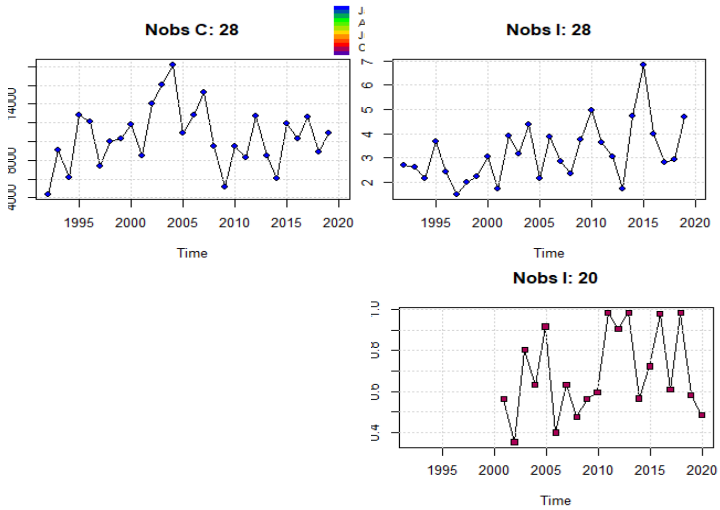


Figure 2. Summary of data inputs

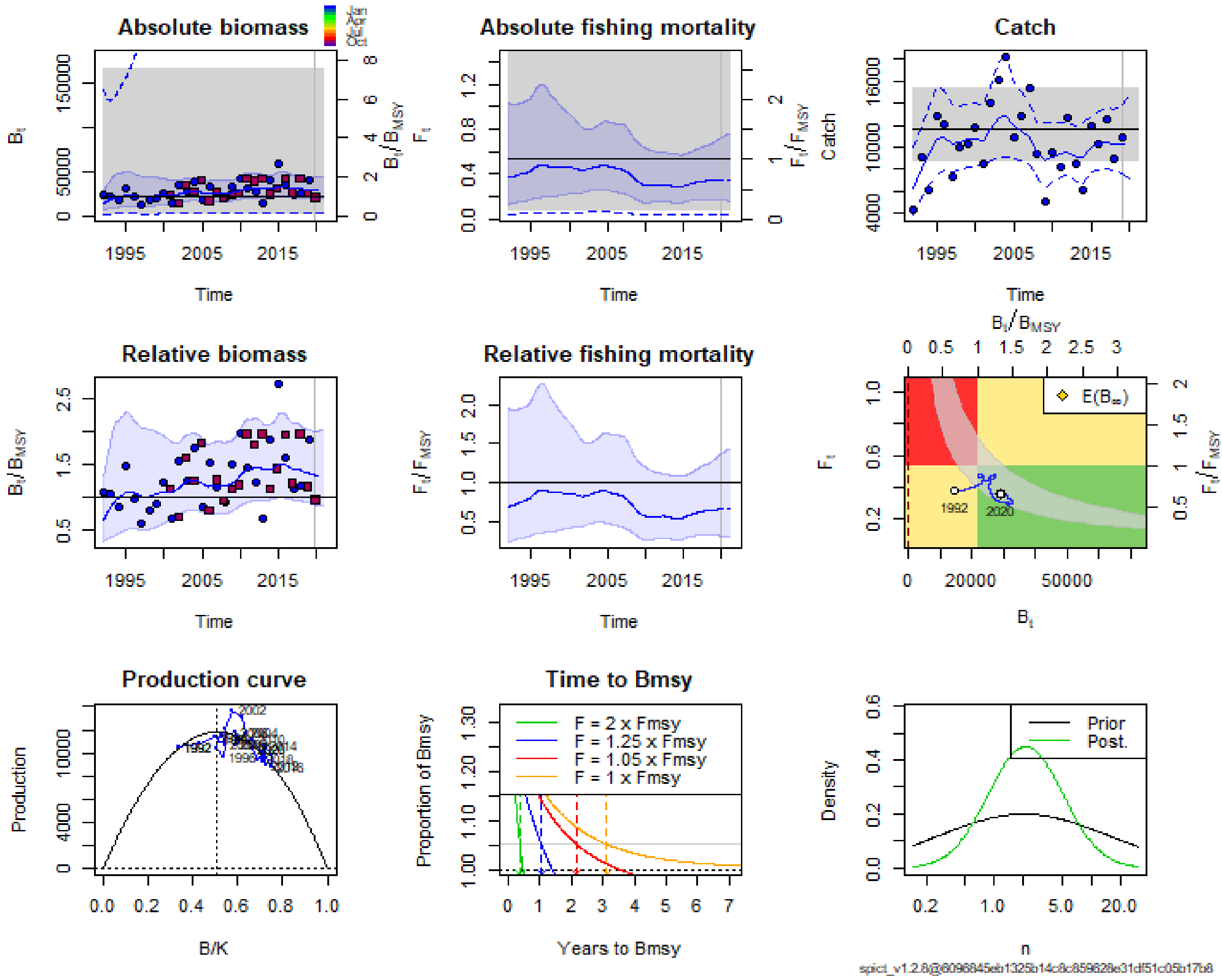


Figure 3. Summary of SPiCT stocks metrics for scenario 1

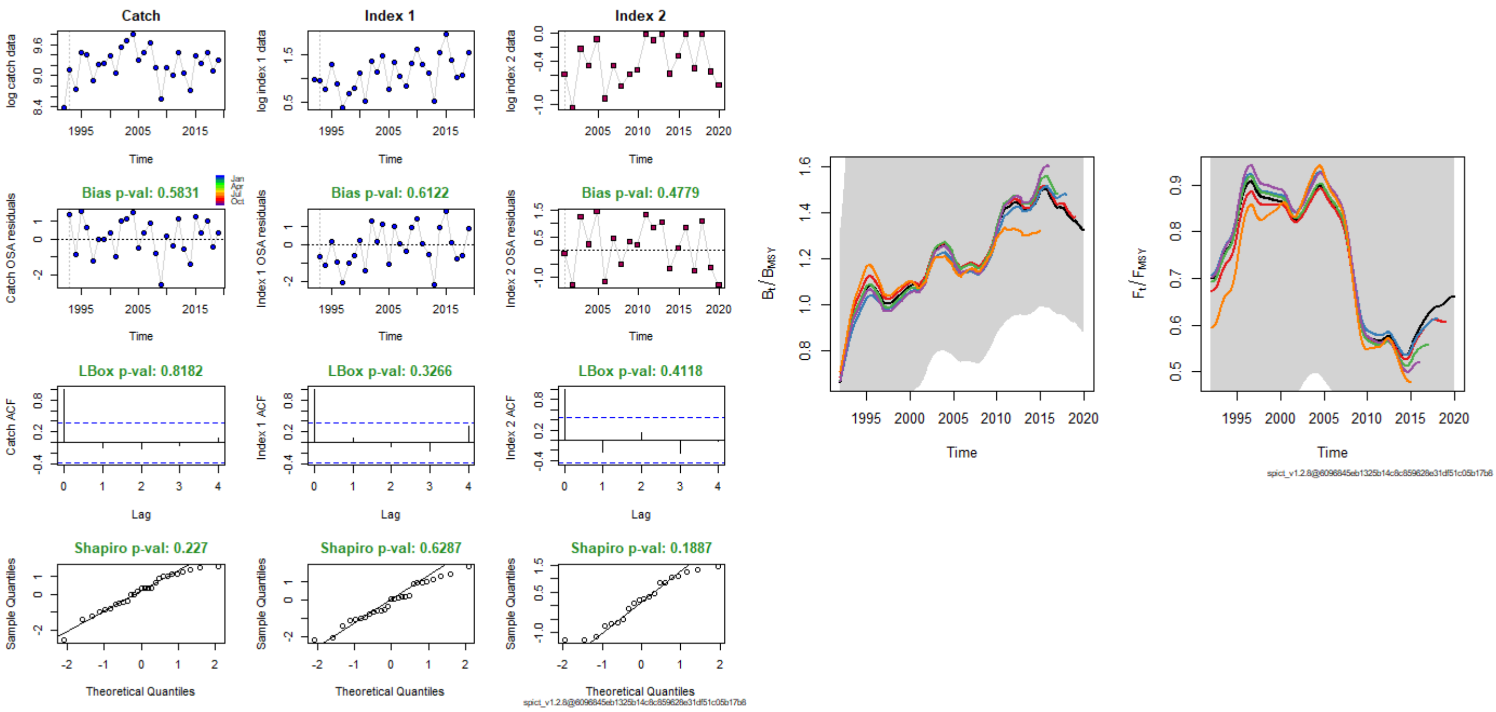


Figure 4. SPiCT residuals diagnostics (left) and 5 years retrospective of the relative biomass and fishing mortality (right) for scenario 1

2.1.2. Scenario 2 – seasonal landings (July-June)

Inputs: Default priors

Catches : seasonal year landings – FR+UK [July2000 – June 2019]

Index : + yearly FR standardized lpue [1992-2019]

+ november UK lpue [2000-2019]

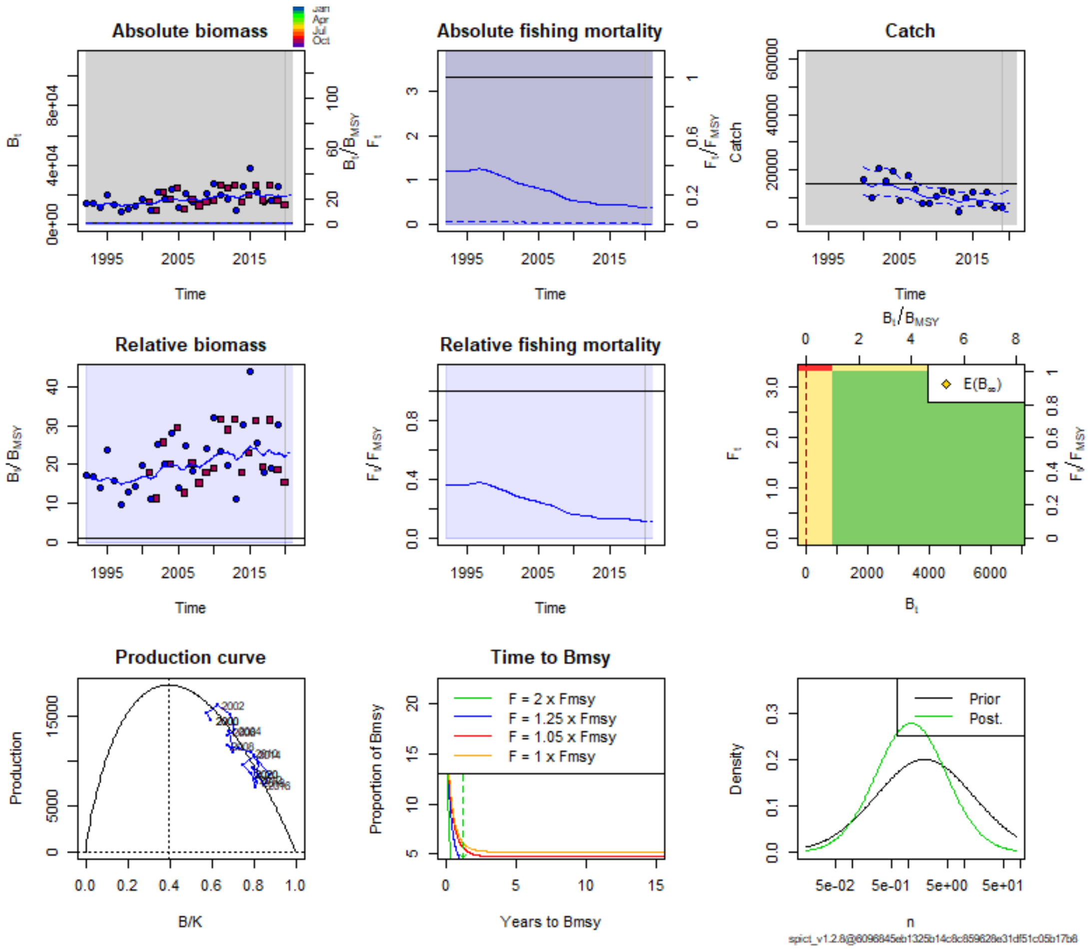


Figure 5. Summary of SPiCT stocks metrics for scenario 2

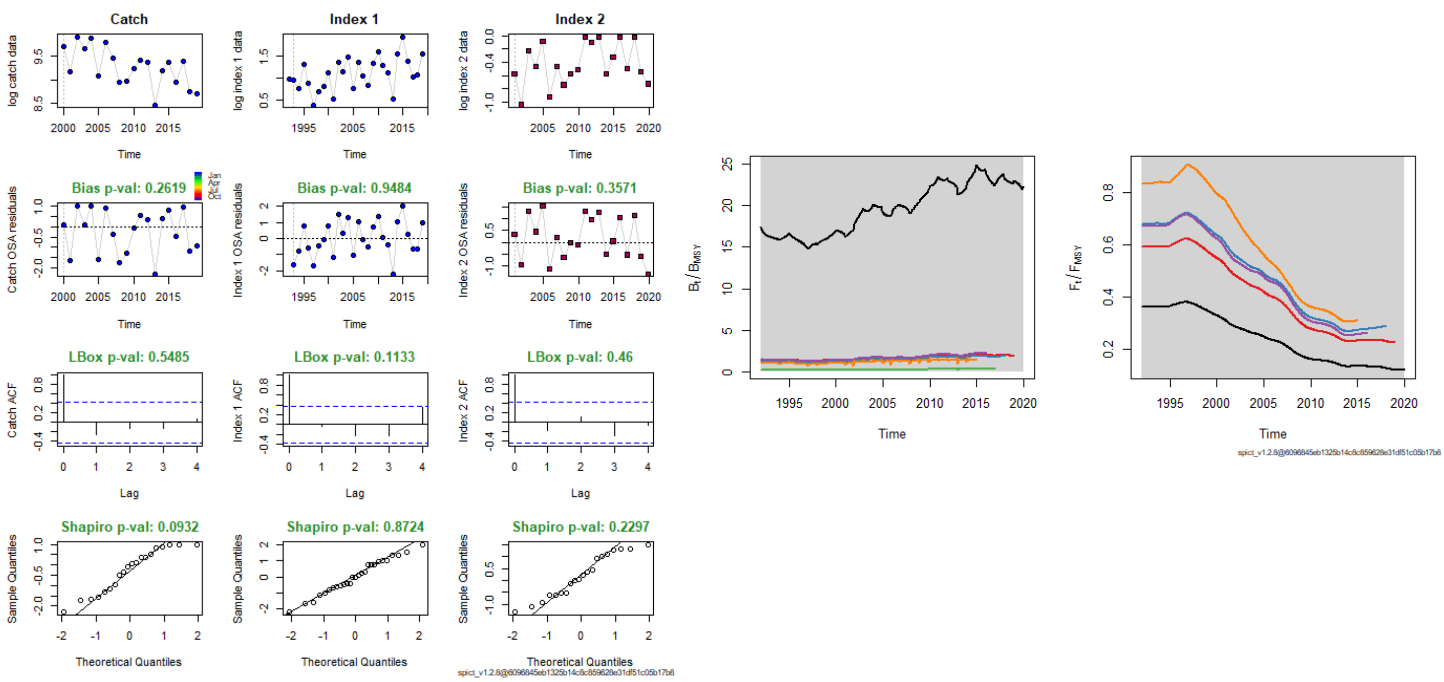


Figure 6. Residuals diagnostics plot (left) and 5 years retrospective (right) of the relative biomass and fishing mortality for the scenario 2

The fishing season compilation of the landings of cuttlefish (July year y – June year y+1), was not relevant when trying to assess the 7.de stock. Despite the apparently same signal (even far below the msy limit, with huge confidence intervals) given by the model's outputs (Fig. 5), the retrospective plots (Fig. 6) were not providing consistent performance.

2.2. Updated outputs (quaterly bases)

2.2.1. Scenario 3 – quaterly catches / quaterly FR lpue + surveys

Inputs: Default priors

Catches : Quaterly landings – FR+UK [July2000 – June 2019]
Index : + quaterly FR standardized lpue [2000-2019] #cut to the catch time-series
+ november UK lpue [2000-2019]
+ CGFS_7d (Sept/Oct) [2000-2019]
+ BTS7d (July) [2000-2017]

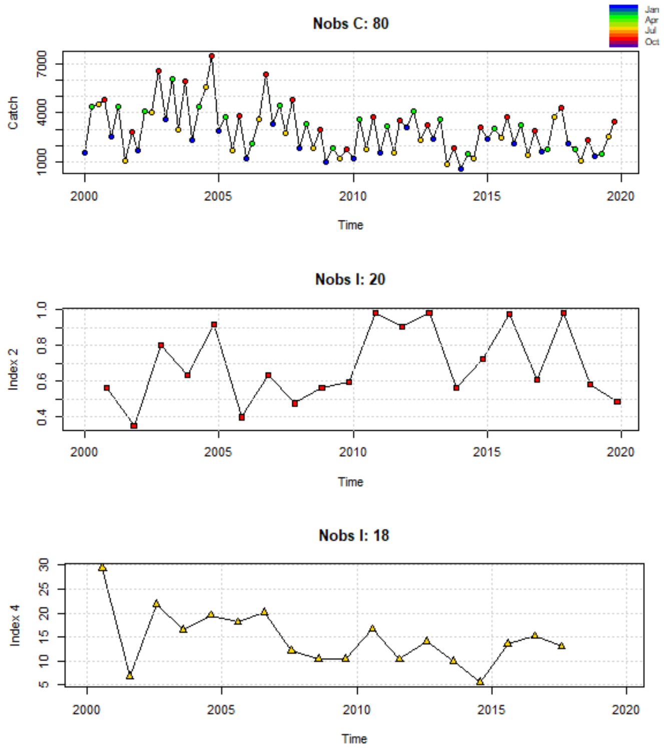


Figure 7. Summary of data inputs

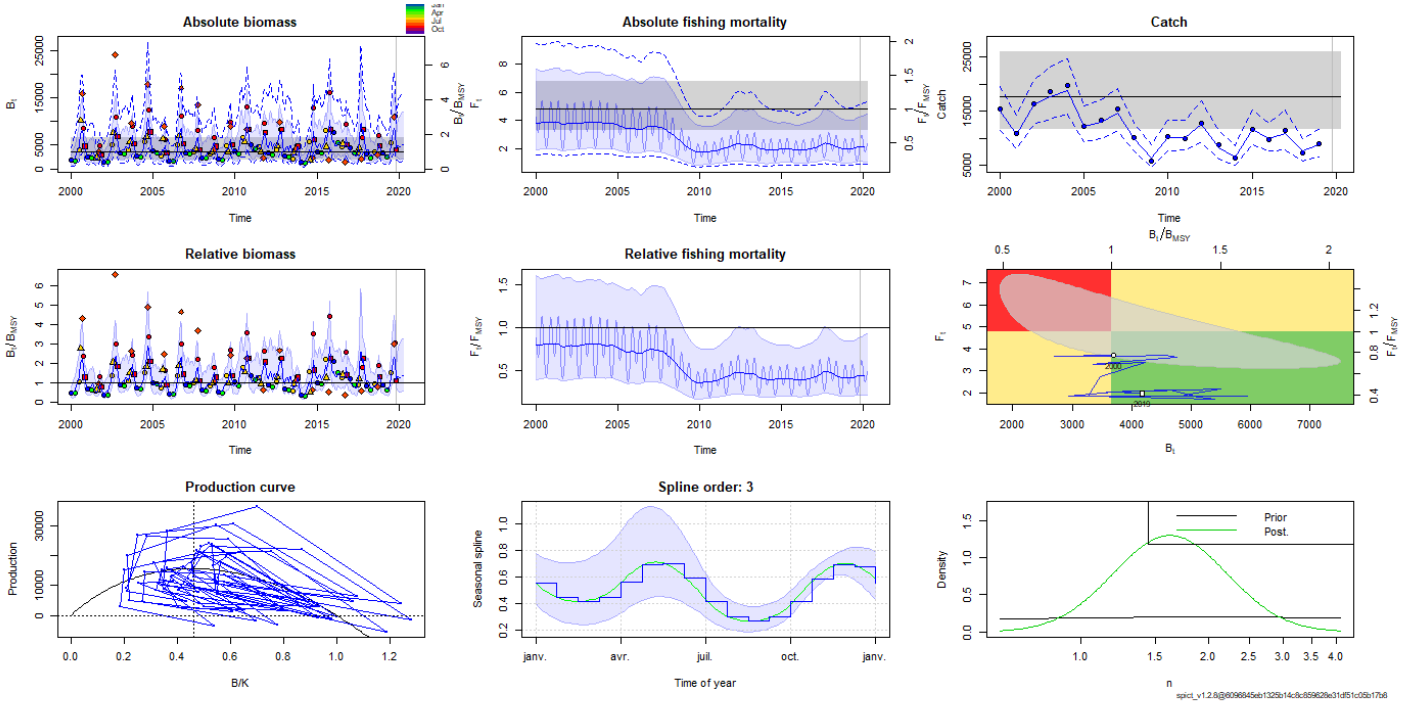


Figure 8. Summary of SPiCT stocks metrics for scenario 3

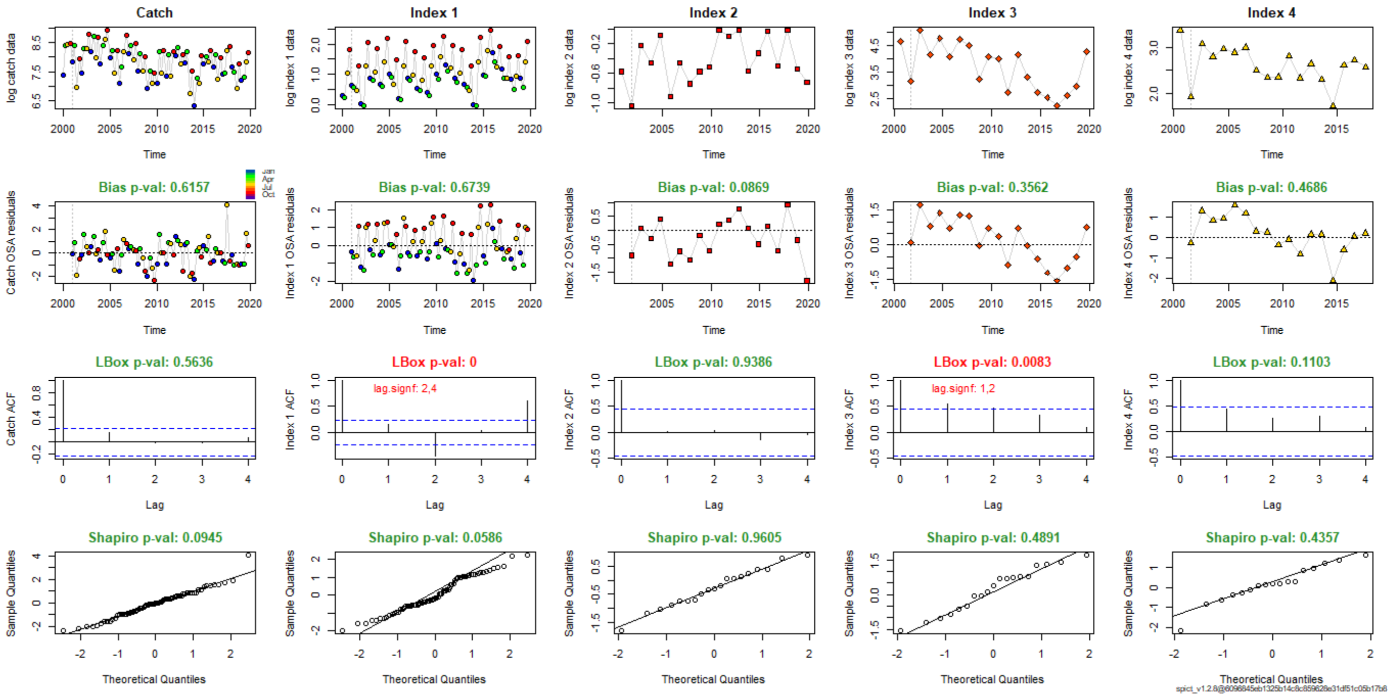


Figure 9. Residuals diagnostics for scenario 3

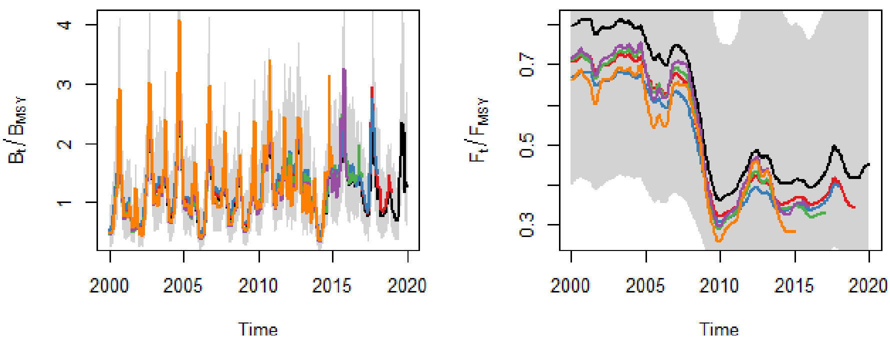


Figure 10. 5 years retrospective plots of relative biomass and fishing mortality for Scenario 3

2.2.2. Scenario 4 – quaterly catches / yearly index

Inputs: Default priors

Catches : Quaterly landings – FR+UK [July2000 – June 2019]

Index : + yearly FR standardized lpue [2000-2019]

+ november UK lpue [2000-2019]

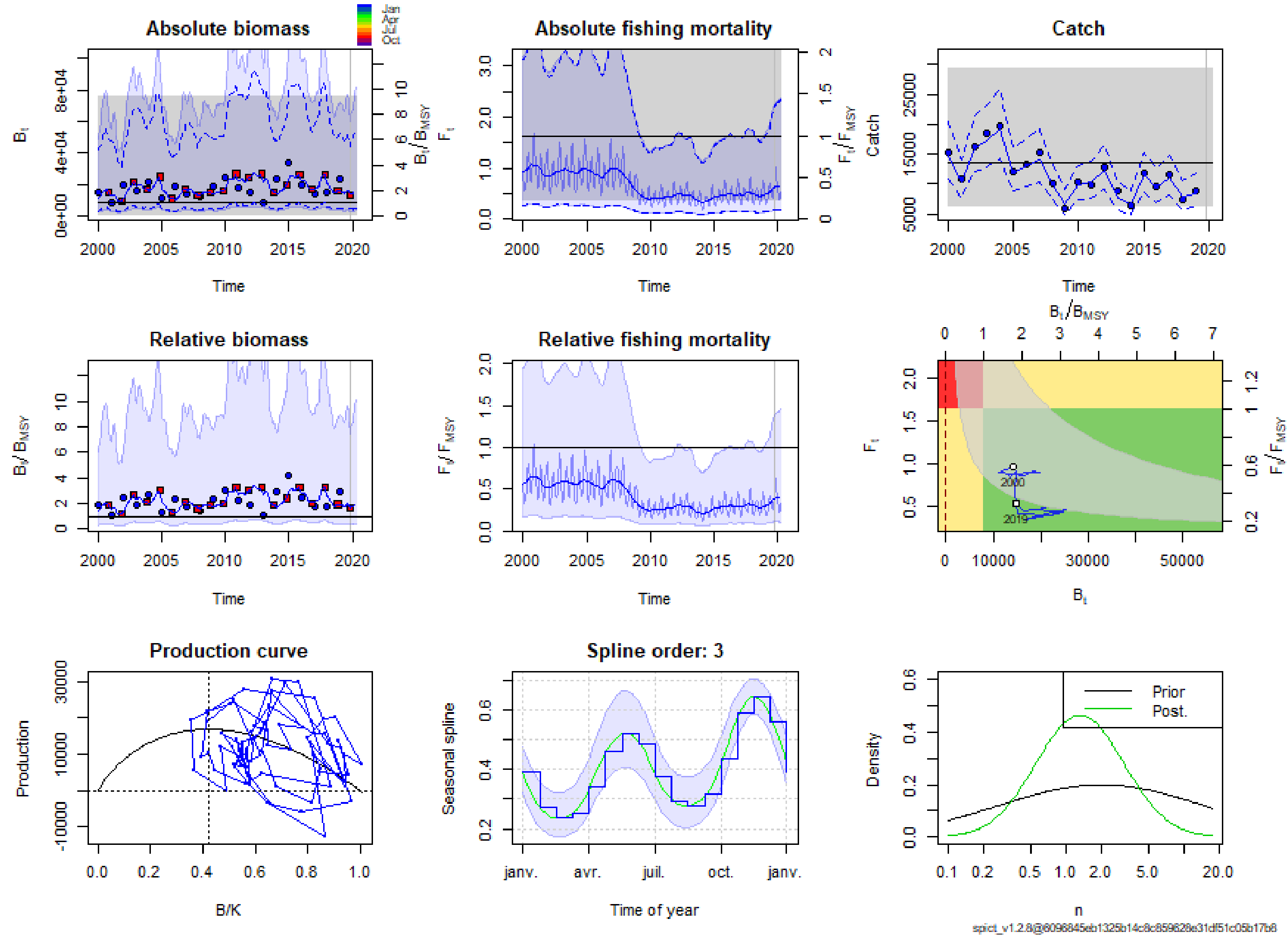


Figure 11. Summary of the stock metrics for scenario 4

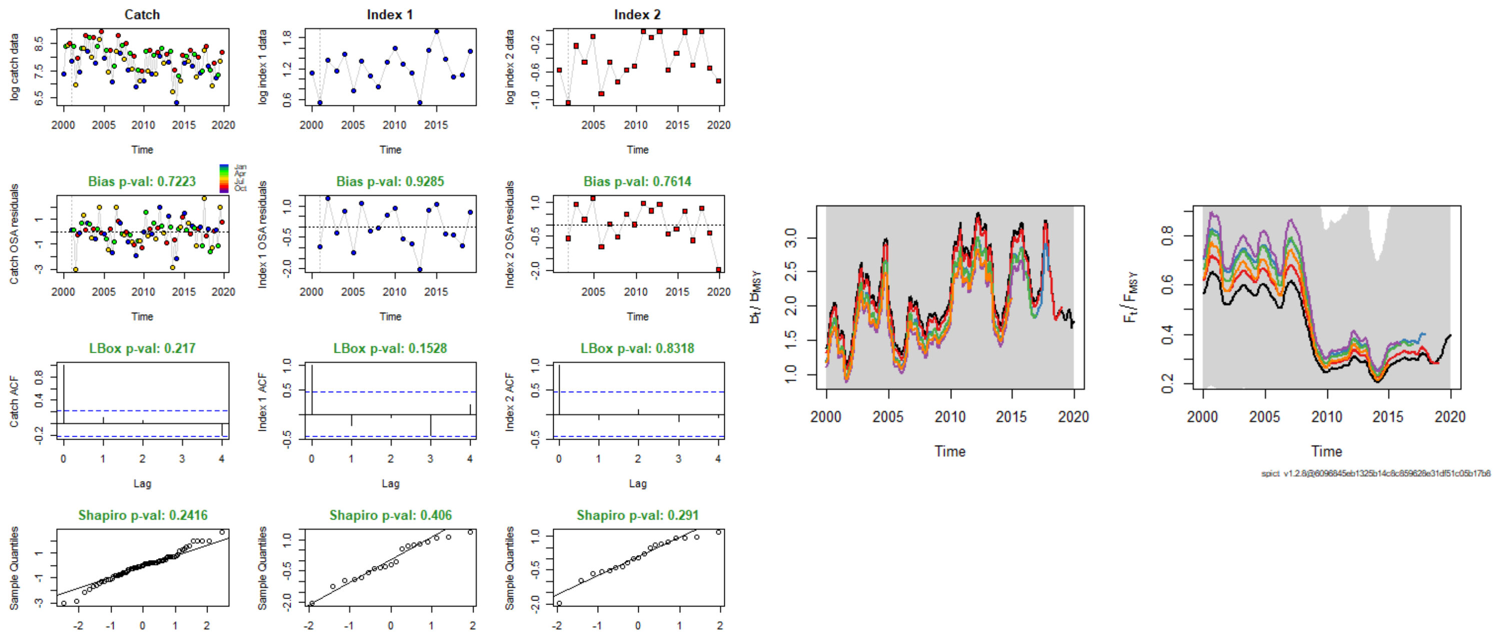


Figure 12. Residuals diagnostic (left) and 5 years retrospective plots (right) of relative biomass and fishing mortality for scenario 4

Tableau 1. Summary of the outputs parameters for the fourth *scenarii* using SPiCT. **α** the process errors of the inputed indices; **β** the observation error (difference between the measured biomass and the real biomass); **n** the shape of the production curve; **r** the intrinsic growth rate; **K** the carrying capacity of the stock; **sdb** the standard deviation of the biomass; both relative biomass and fishing mortality (respectively **B/Bmsy** and **F/Fmsy**) and the maximum sustainable yield **MSY**

Outputs parameters	Scenario 1	Scenario 2	Scenario 3	**Scenario 4**
α	3.143 [0.553 – 17.847] 2.539 [0.402 – 16.049]	0.319 [0.077 – 1.325] 0.326 [0.085 – 1.249]	0.253 [0.078-0.818] 0.072 [0.014-0.363] 0.667 [0.391-1.139] 0.240 [0.110-0.526]	0.930 [0.558-1.549] 0.147 [0.022-0.974]
β	1.894 [0.460 – 7.802]	1.749 [0.720 – 4.249]	0.774 [0.194-3.096]	0.853 [0.355-2.052]
n	2.098 [0.369 – 11.940]	0.688 [0.040 – 11.845]	1.624 [0.889-2.965]	1.320 [0.244-7.149]
r	1.117 [0.106 – 11.768]	5.438 [1.303 – 22.686]	6.843 [3.830-12.226]	1.971 [0.587-6.616]
K	43 544 [5 938 – 319 314]	7 674 [1 858 – 31 700]	8 086 [4 418-14 797]	26 915 [10 206-70 984]
sdb	0.107 [0.019 – 0.592]	0.764 [0.356 – 1.643]	1.193 [0.783-1.820]	0.474 [0.320-0.701]
B/Bmsy	1.324 [0.882 – 1.988]	2.593 [0.556 – 12.092]	1.174 [0.815-1.692]	1.684 [0.383-7.398]
F/Fmsy	0.661 [0.322 – 1.358]	0.172 [0.024 – 1 .238]	0.448 [0.226-0.889]	0.388 [0.109-1.386]
MSY	11 627 [8 780 – 15 399]	18 377 [10 060 – 33 572]	17 606 [11 895-26 060]	13 573 [6 262-29 420]

The stock of interest in the English Channel consists of the cuttlefish *Sepia officinalis*, mostly fished by FR and UK (80% of total landings). Initially, 5 indices series, variable in covered time were available (2 commercial/3 surveys): standardized LPUE index (kg/h) from french otter trawlers [1992-2019]; mean LPUE in november from english beam trawlers [2000-2019]; biomass index from the Channel Ground Fish Survey (CGFS) collected in September-October [1990-2019]; abundance index from the Bottom Trawl Survey (BTS) collected in July [1989-2017] and the abundance index from the South Western Beam Trawl Survey collected in quarter 1 each year (Q1SWBEAM) [2007-2018]. The index time-series were cut according to cover the catch/landings time-series.

Since 2012, the Q1SWBEAM, previously covering only the Western English Channel was extended to cover the Celtic Sea, so this index was removed from analyses. Convergence was obtained using both a subset of the annual Sepiidae landings dataseries between 1992 and 2019 (from WGCEPH ToRA) and quaterly *Sepia officinalis* landings, available since 2000 after SIH extraction and data treatment. CGFS and BTS surveys are covering the Eastern part of the English Channel (7.d division), and since 2015, following the vessel modication, the standardisation of CGFS serie leads to residuals autocorrelation to fix. For these reasons, also as cuttlefish (and cephalopods in general) are not targeting in surveys, the series was also removed from analyses. No adjusted priors was presented as the Scaheffer production curve (n=2) is not expected for such short-lived species and the less priors are setted, the better the outputs reliability.

Despite having slightly wide confidence intervals, the selected model specifications (scenario 4, Fig. 11, 12 and Table 1) produced the best results. The production curve followed a somewhat chaotic path but was shifted slightly to the left, which is expected in cephalopods.

The assessment suggest that the stock is in good condition (Fig. 11), as relative biomass > 1 and relative fishing mortality < 1 (Table 1) and is being exploted at sustainable levels. The average catch from the previous four years (10 670 ± 1 543 tons) was calculated to be smaller than the estimated stochastic MSY (13 573 tons) (Table 1). It should be noted that the model performed similarly well when using the annual landings with default priors, however quaterly landings inputs did estimate the seasonal pattern of the fishing mortality (Fig. 11, seasonal spline).

Retrospective plots showed the model provided consistent performance (Fig. 12 right). The model diagnostics (Fig. 12 left) produced satisfactory results with no evidence of autocorrelation or non-normality in the data.

The presented SPiCT models outputs of the selected ICES Area, 7.de are representative of the best model performances from a series of trials of varied data formats and model specifications. Using the raw fishing season landings data did not produce good model outputs, possibly due to the smoothed effect of this compilation. Furthermore, shortening the length of index data time series was a factor in trying to get model convergence or improvement, however, this could not solve for the large confidence intervals associated with relative fishing mortality in most models.

ANNEXES

Annex 1 – Commercial lpue and CGFS survey indices input

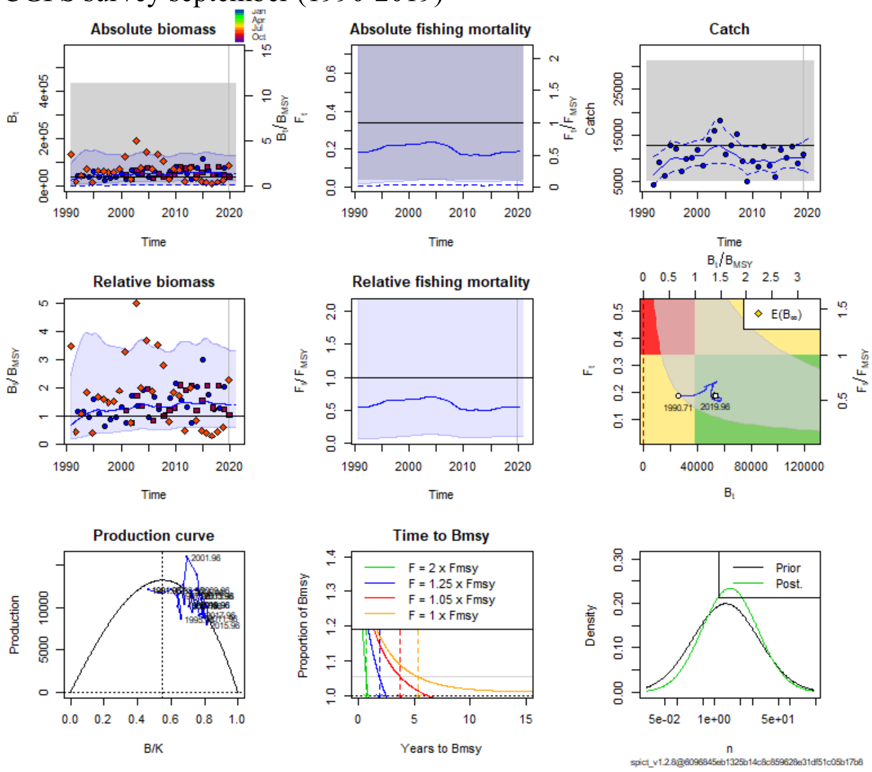
Model with commercial indices and surveys

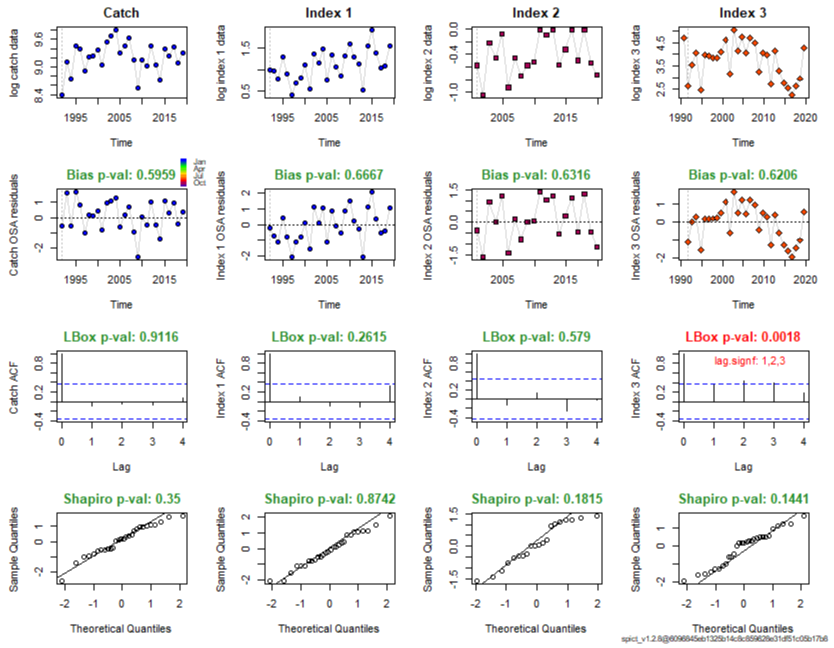
Inputs - > Catches: calendar landings from ToRA (1992-2019)

Index: - yearly std FR lpue (1992-2019)

- TBB_UK november (2000-2019)

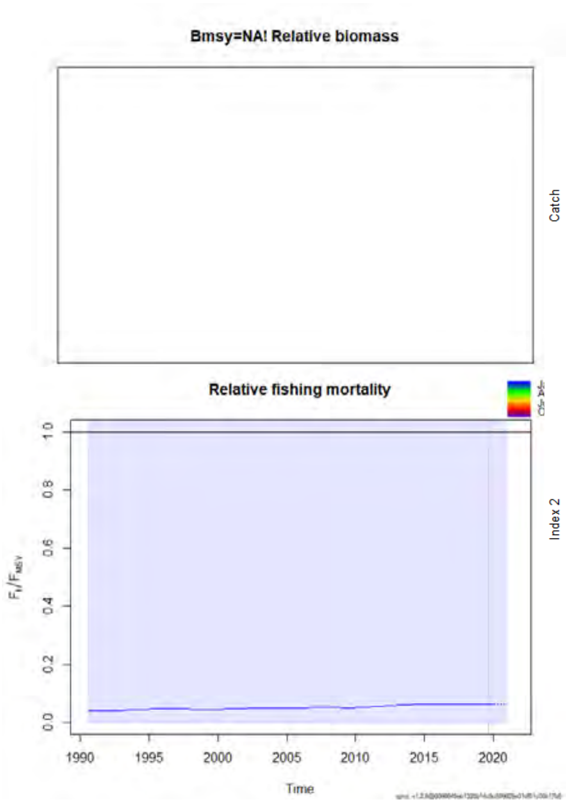
- CGFS survey september (1990-2019)

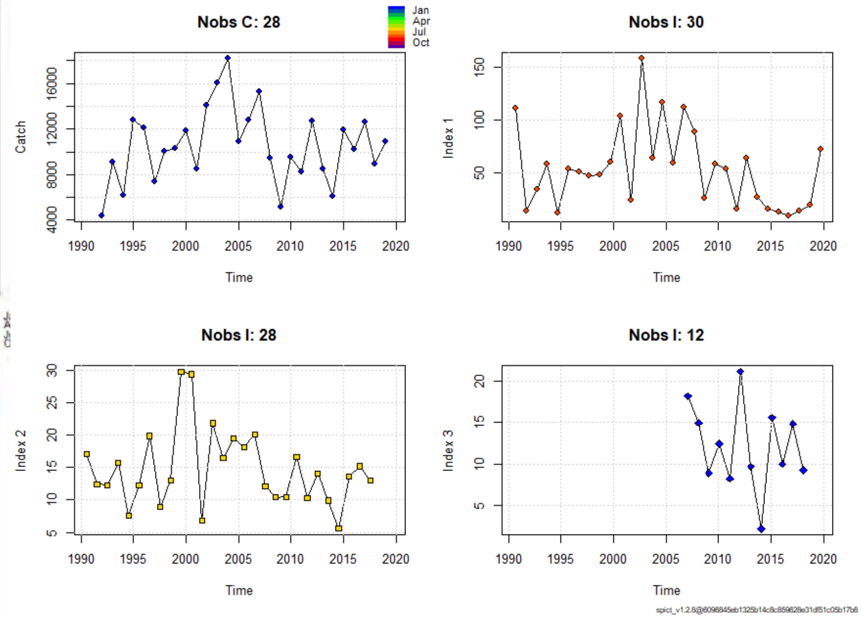




Annex 2 – Yearly landings input + 3 surveys indices in the English Channel: CGFS (division 7.d) [Sept. 1990 – 2019]; BTS7d [July 1990-2017]; Q1SWBEAM (UK) [March 2007-2018]

Q1SWBEAM index series was then not use cause of the survey realised in the western english channel but also Celtic sea, not about interest in this study and also the short time-series.





Annex 7: Working Document: A comparison between SPiCT and Gadget model estimates up to 2020 for anchovy 9.aSouth

Margarita Rincón, Fernando Ramos, Tobias Mildenberger and Alexandros Kokkalis

A comparison between SPiCt and Gadget model estimates up to 2020 for anchovy 9a South

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[b]*DTU Aqua*

Abstract

An SPiCt model has been fitted to anchovy 9a South data using catches biomass time series and PELAGO and ECOCADIZ survey indexes, available until 2020, testing different model features. Results of different scenarios will be presented and also a comparison with the current model used as basis for the assessment which is a Gadget model.

1. Model Description

SPiCt model fits an stochastic surplus production model in continuous time incorporating dynamics in both biomass and fisheries and observation error of both catches and biomass indices. The model has a general state-space form that can contain process and observation-error as well as state-space models that assume error-free catches (Pedersen and Berg, 2017).

The general SPiCT model description and all the options available can be found in Pedersen and Berg (2017), as well as a user guide available at `https://github.com/DTUAqua/spict/raw/master/spict/inst/doc/spict_manual.pdf`. The version of the model including seasonal productivity is described in detail in Mildenberger et al. (2020).

2. Data and priors

Quarterly catches time series from 1989 to the second quarter of 2020. For the first two quarters of year 2020, provisional catches estimations of Spanish (until May 18th) purse-seine fleet were used and catches for June were estimated as the **38%** of January to May catches based on historical records from 2009 to **2019**. There were not any catches for Portuguese purse-seine in these two quarters. ECOCADIZ and PELAGO acoustic survey biomass indexes were provided at the exact time of the year when the surveys were carried out. For ECOCADIZ that corresponds to March of 2004 and 2006, April of 2007, 2009, 2010, 2014-2019, and May of 2013, and for PELAGO to February of 1998, 2000-2002 and April of 2005-2010, 2013-2020. Data summary is presented in Figure 1.

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Email address: `margarita.rincon@ieo.es` (Margarita María Rincón)

Priors for parameters were set to default.

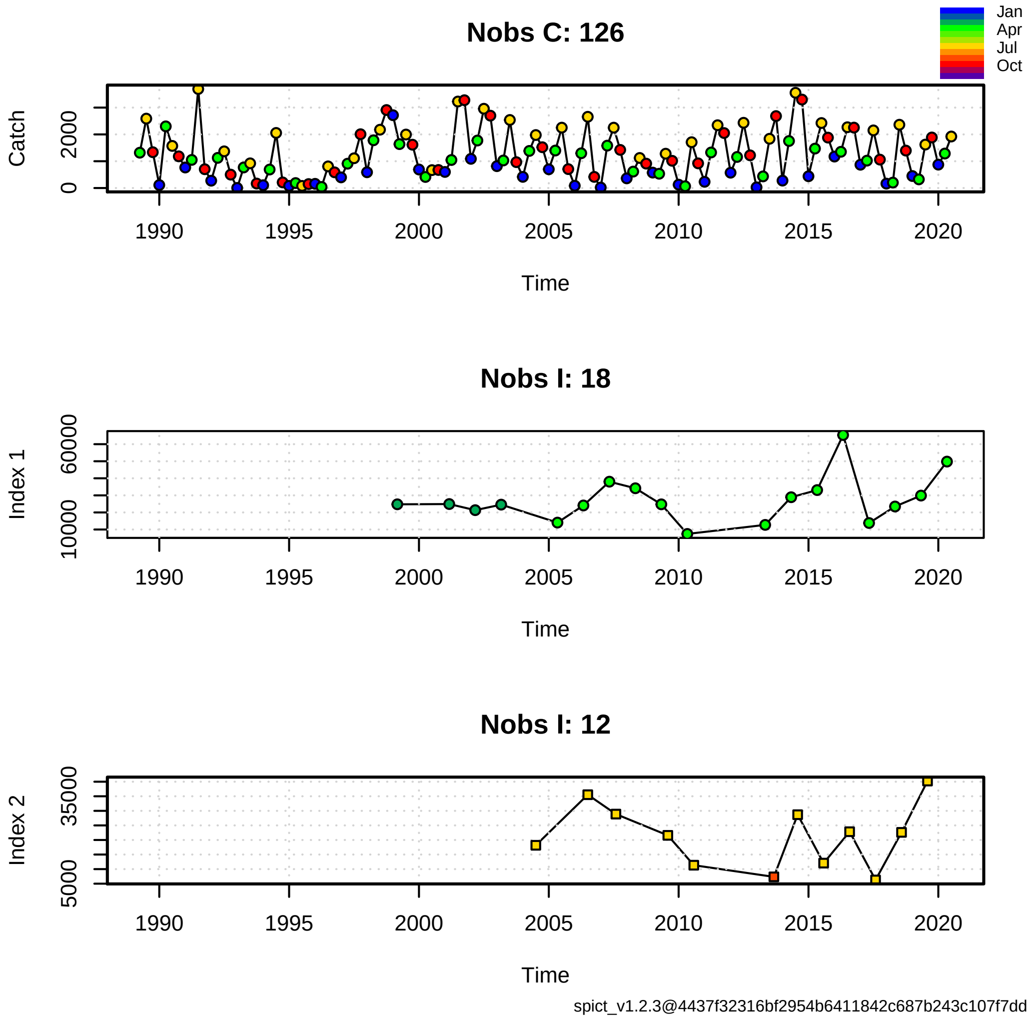

Figure 1: Summary of data used for the SPiCt model

3. Scenarios

Four different scenarios were tested, the first one with no seasonal productivity, the second one assuming seasonal productivity, the third one with no seasonal productivity and with time-varying growth and the last one with no seasonal productivity, no time-varying growth and with the data restricted to the 1999-2019 period where there is a more stable length distribution pattern.

4. Results

4.1. Scenario 1

Most important outputs for scenario 1 are displayed in figure 2. This scenario assumes no seasonal productivity, no time-varying growth and uses the whole data set available. Diagnostics are displayed in figure 3 and the following is the results summary:

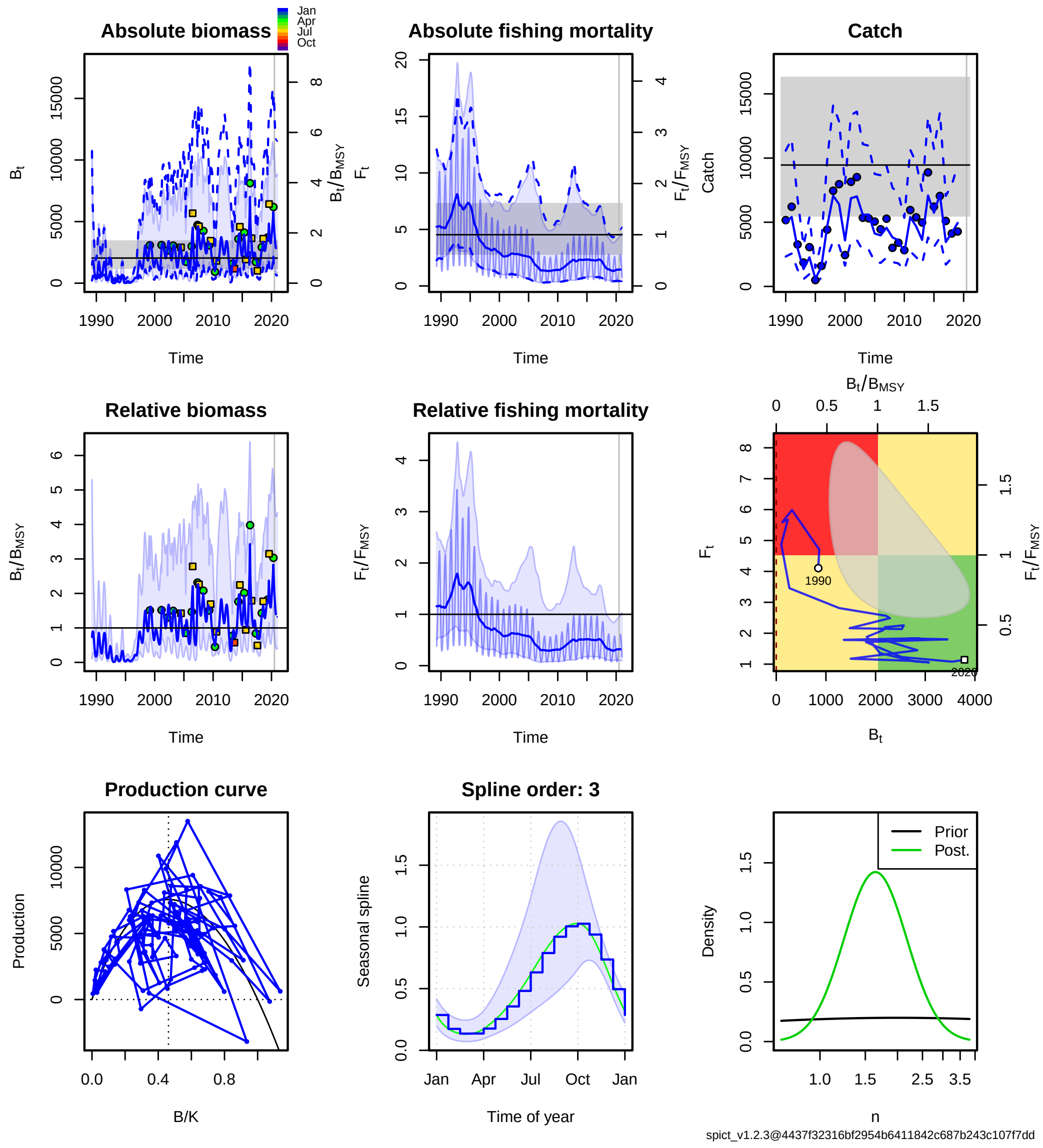

Figure 2: Summary of SPiCt results for scenario 1

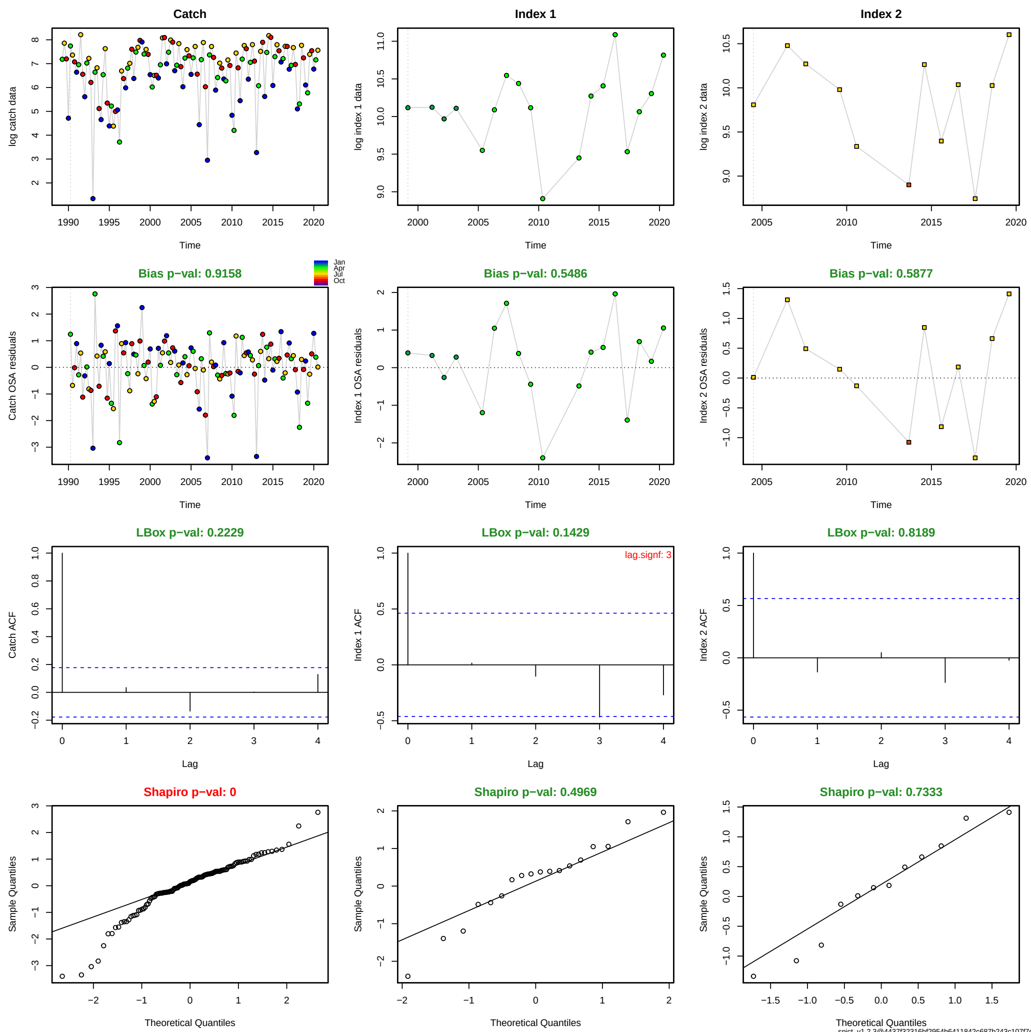

Figure 3: Summary of SPiCt diagnostics for scenario 1

4.2. Scenario 2

Most important outputs for scenario 2 are displayed in figure 4. This scenario assumes a seasonal productivity, no time-varying growth and uses the whole data set available. No diagnostics are available because of the lack of convergence, nevertheless, a plot on how the model estimates the seasonal productivity pattern is presented in figure 5. The following is the results summary:

```
null device
          1
```

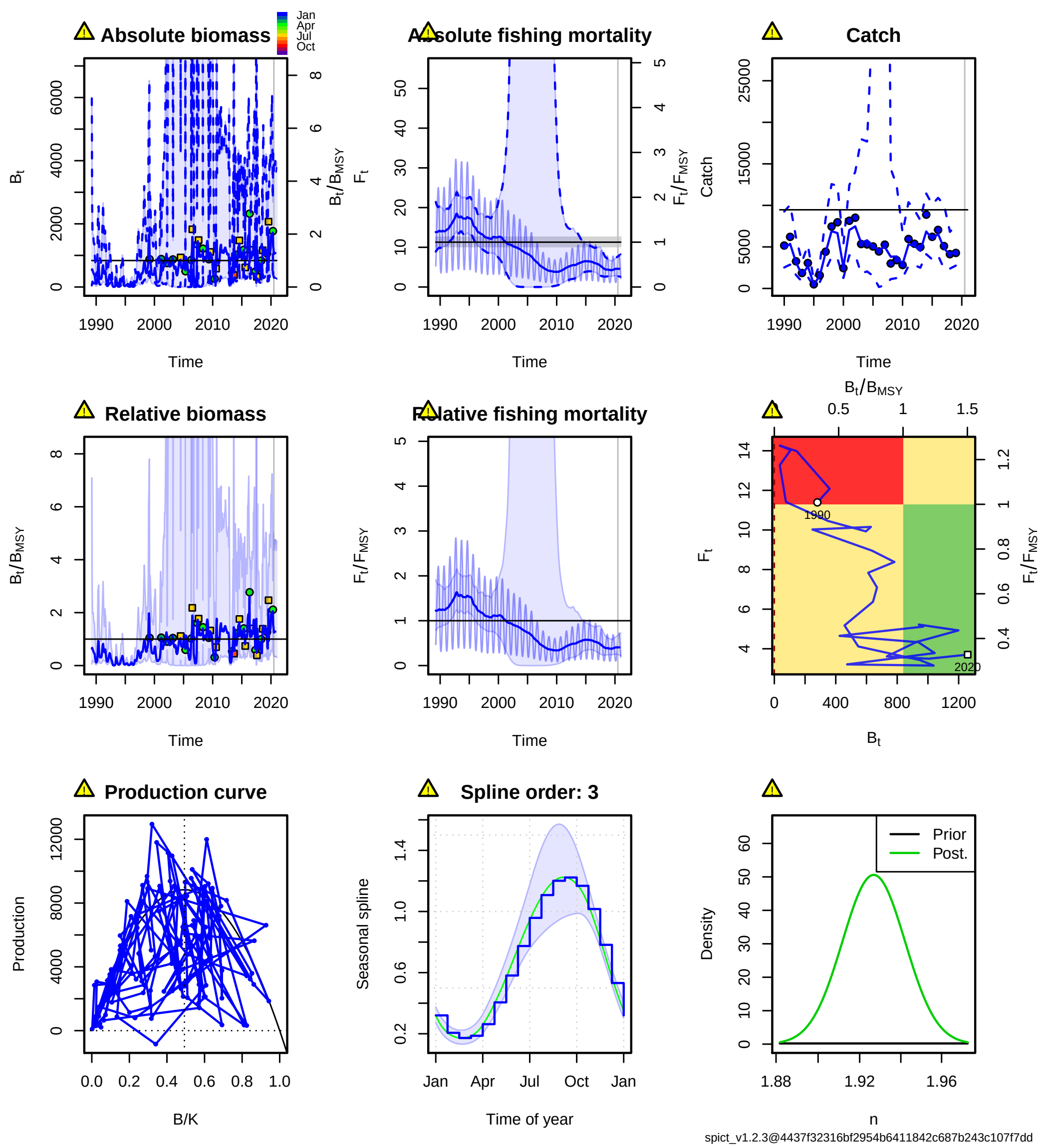

Figure 4: Summary of SPiCt results for scenario 2

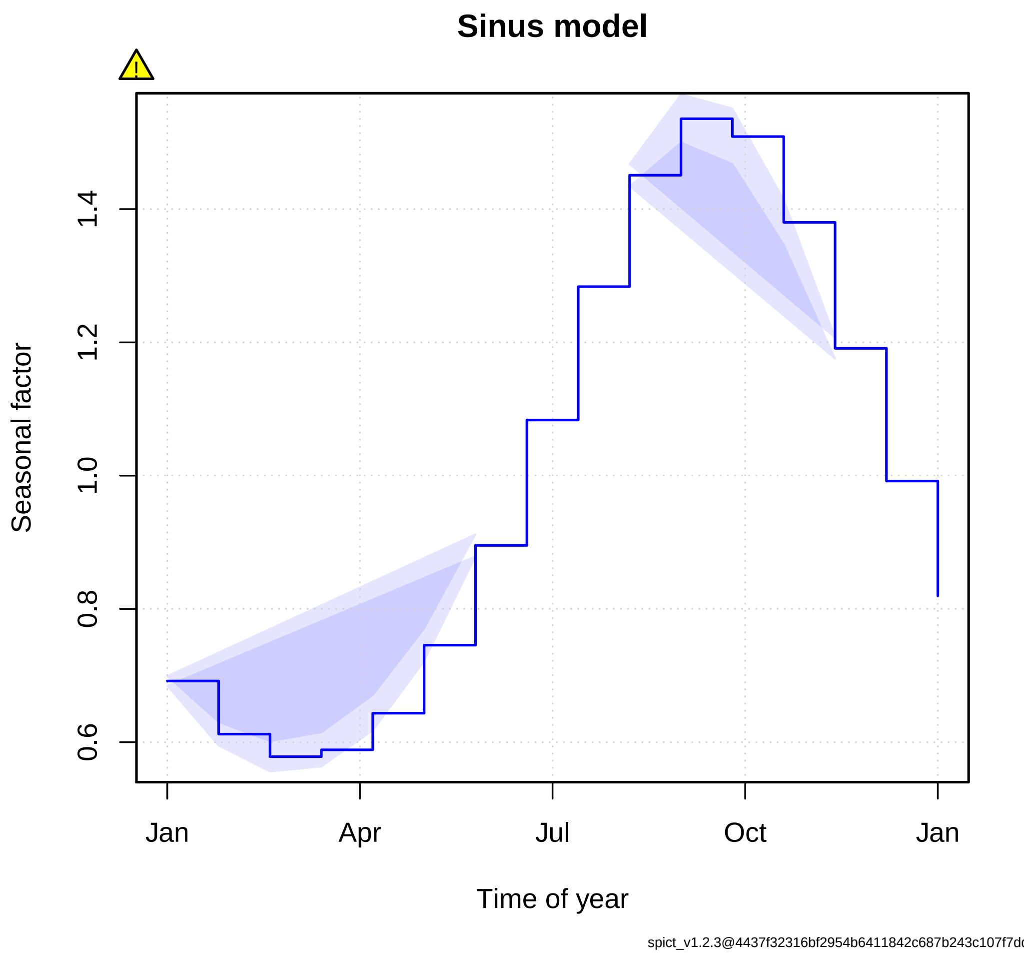

Figure 5: Estimation of the seasonal productivity pattern in scenario 2

4.3. Scenario 3

Most important outputs for scenario 3 are displayed in figures 6 and 7 . This scenario assumes no seasonal productivity, time-varying growth and uses the whole data set available. Diagnostics are displayed in figure 8 and the following is the results summary:

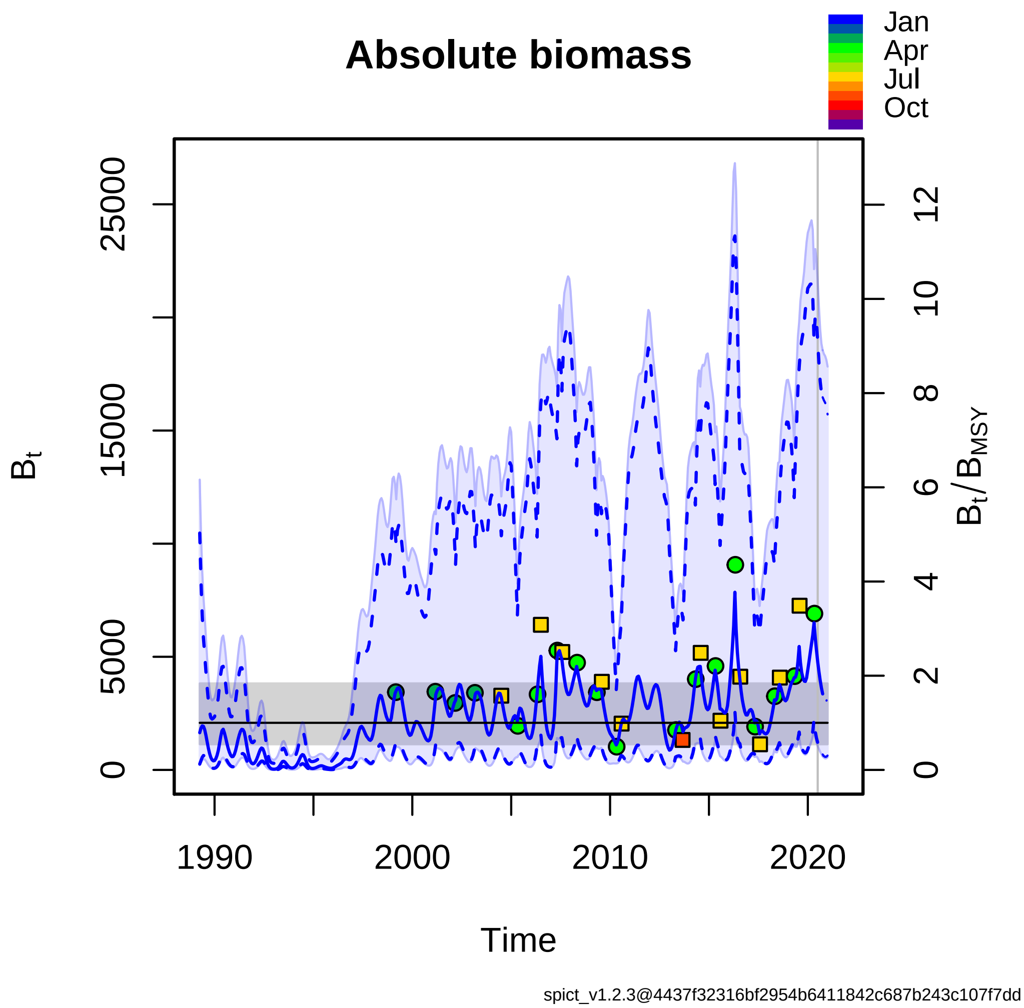

Figure 6: Summary of SPiCt results for scenario 3

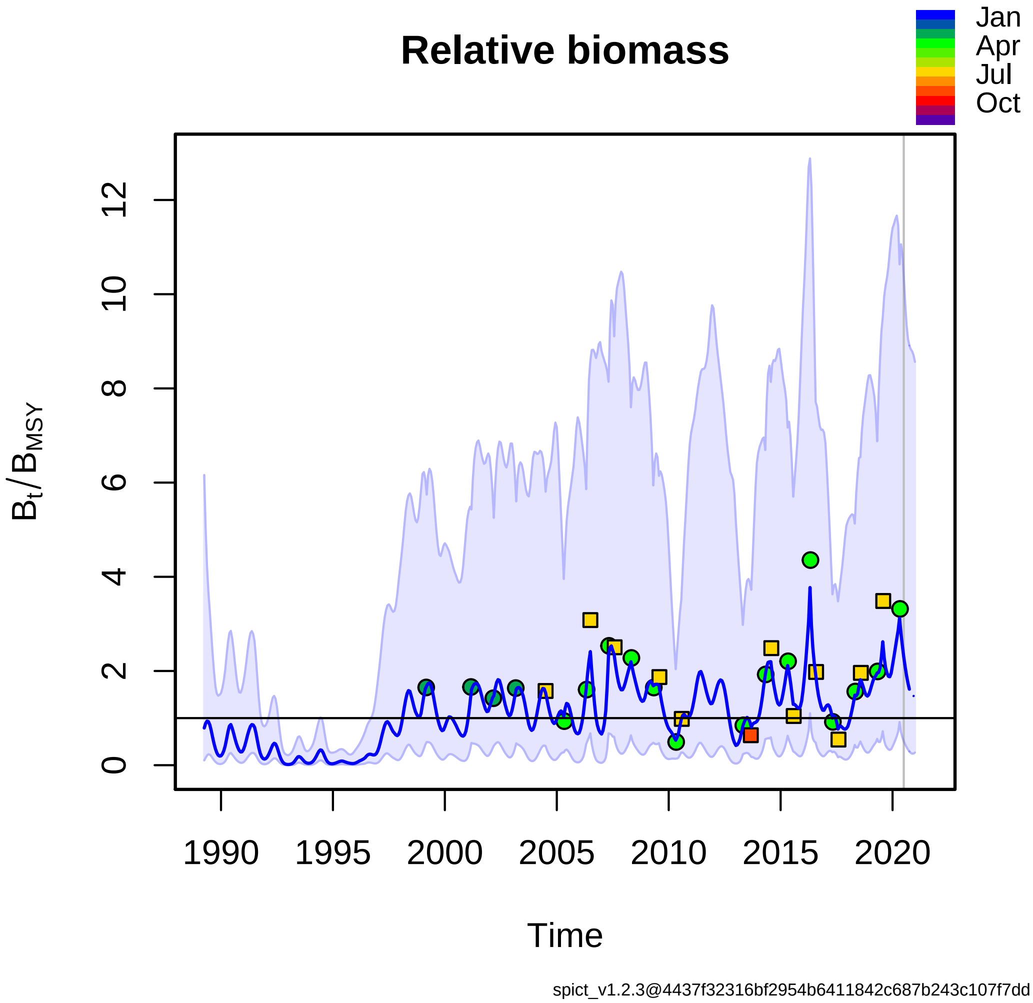

Figure 7: Summary of SPiCt results for scenario 3

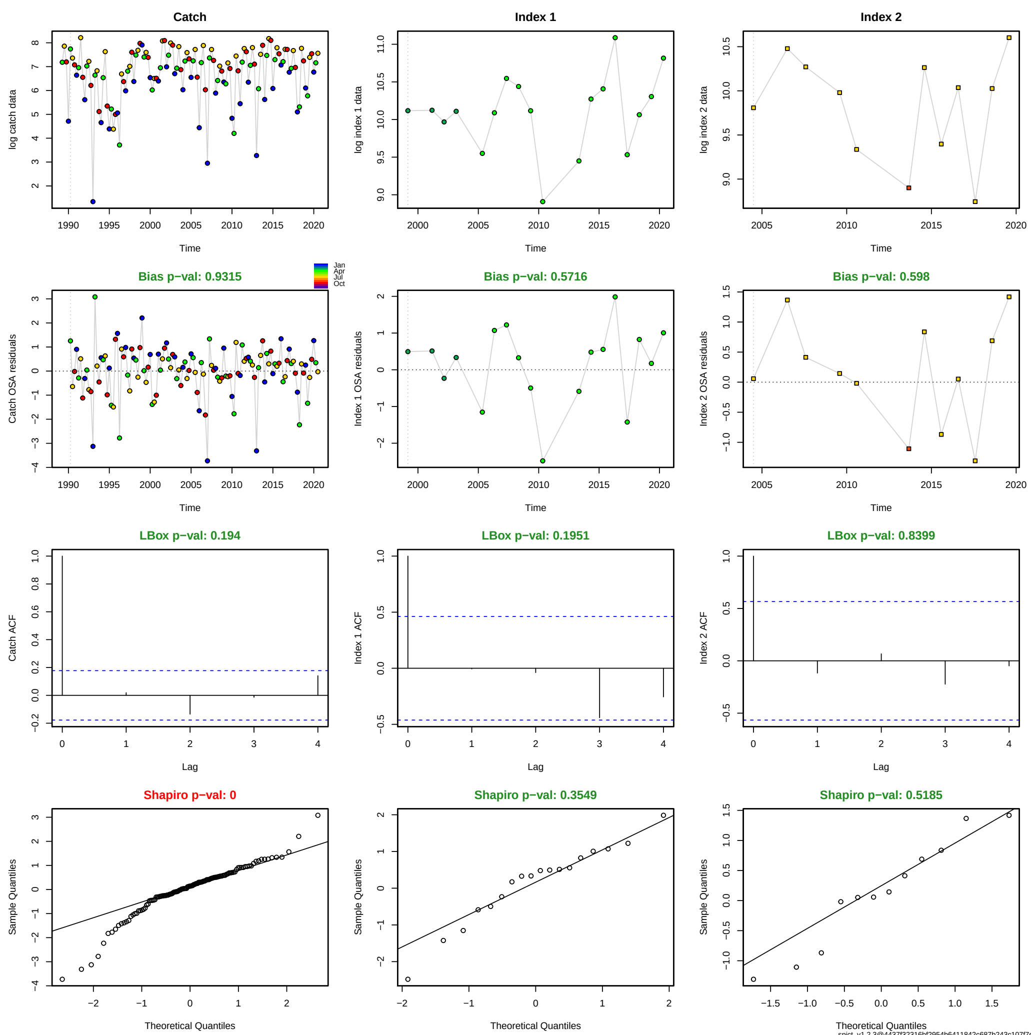

Figure 8: Summary of SPiCt diagnostics for scenario 3

4.4. Scenario 4

Most important outputs for scenario 4 are displayed in figure 9. This scenario assumes no seasonal productivity, no time-varying growth and uses a restricted dataset, with data only for the 1999-2019 period where there is a more stable length distribution pattern. Diagnostics are displayed in figure 10 and the following is the results summary:

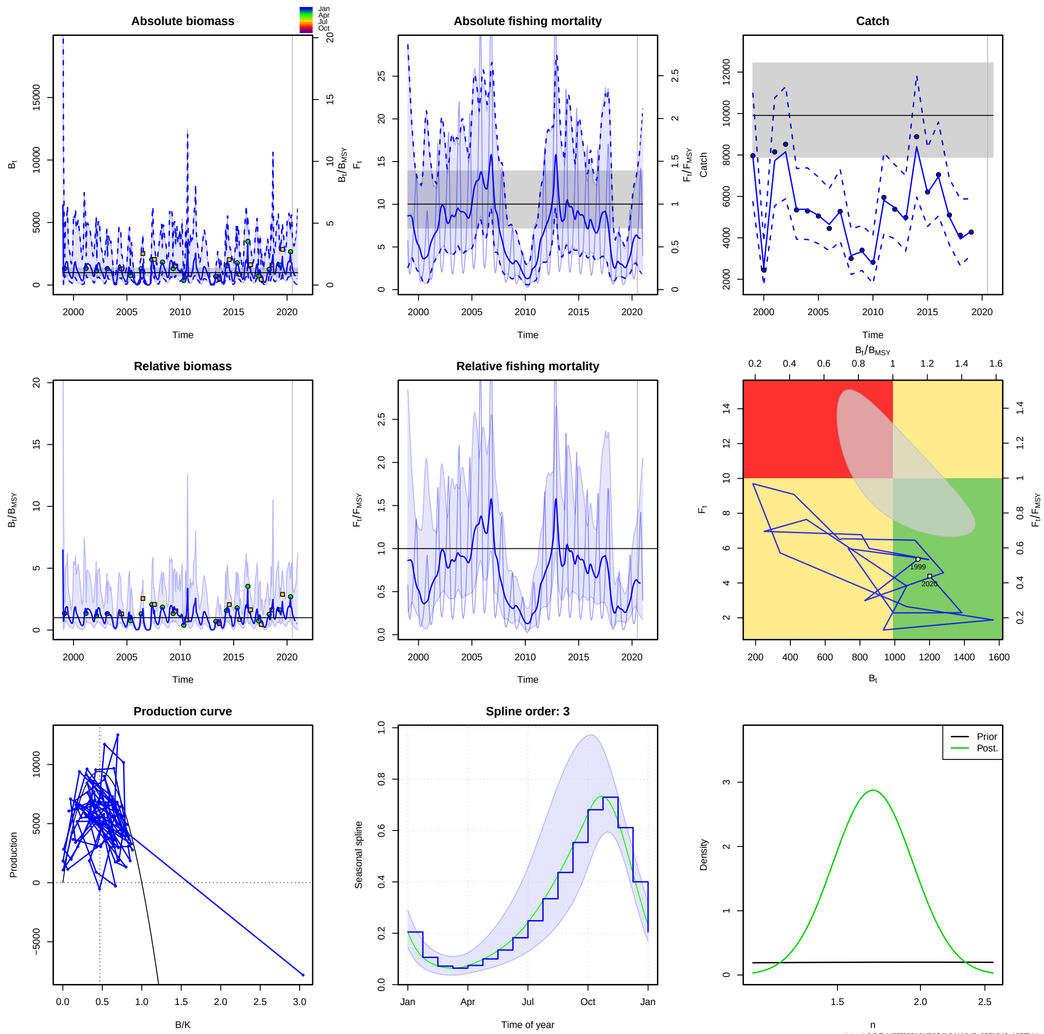

Figure 9: Summary of SPiCt results for scenario 4

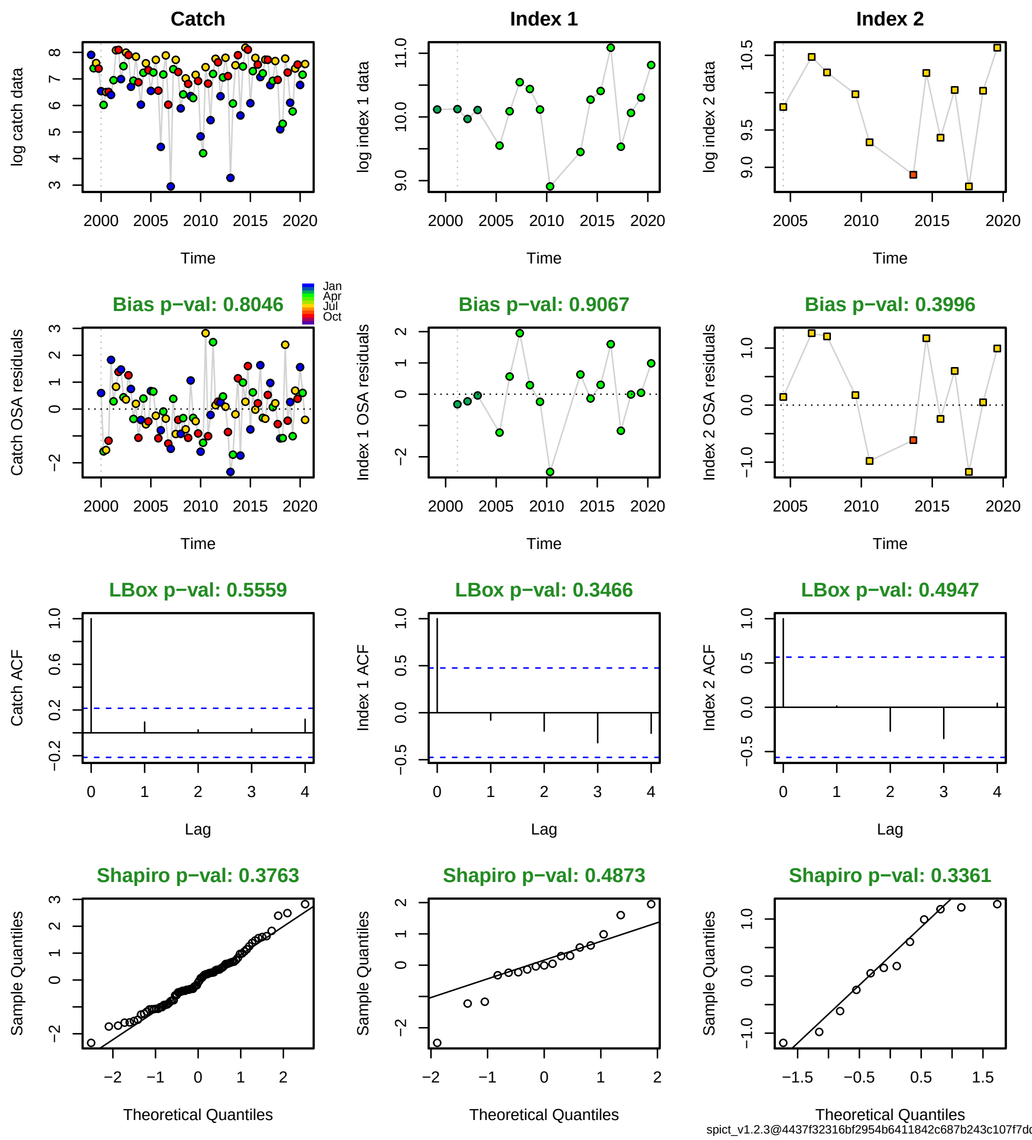

Figure 10: Summary of SPiCt diagnostics for scenario 4

5. Scenario 1 detailed model output

According to the previous plots, scenario 1 results are more consistent regarding uncertainty intervals and diagnostics, thus more detailed information about its output is presented

```
> summary(fit1)

Convergence: 0  MSG: relative convergence (4)
Objective function at optimum: 191.5553781
Euler time step (years):  1/16 or 0.0625
Nobs C: 126,  Nobs I1: 18,  Nobs I2: 12

Residual diagnostics (p-values)
   shapiro   bias    acf   LBox shapiro bias acf LBox
 C   0.0000 0.9158 0.1365 0.2229     ***    -   -    -
 I1  0.4969 0.5486 0.0474 0.1429       -    -   *    -
 I2  0.7333 0.5877 0.4134 0.8189       -    -   -    -

Priors
     logn  ~  dnorm[log(2), 2^2]
 logalpha  ~  dnorm[log(1), 2^2]
  logbeta  ~  dnorm[log(1), 2^2]

Model parameter estimates w 95% CI
            estimate        cilow        ciupp    log.est
 alpha1    0.1500161    0.0263926 8.526944e-01 -1.8970130
 alpha2    0.2581998    0.0691201 9.645113e-01 -1.3540214
 beta      1.9976305    0.8534965 4.675506e+00  0.6919617
 r         5.5785227    1.7461581 1.782193e+01  1.7189240
 rc        6.7973357    3.0766562 1.501753e+01  1.9165307
 rold      8.6976185    3.7445113 2.020252e+01  2.1630492
 m      7573.7985312 4864.6661430 1.179165e+04  8.9324500
 K      4825.5323587 2080.7202761 1.119120e+04  8.4816763
 q1        8.0511334    3.5635780 1.818979e+01  2.0858129
 q2        6.2595990    2.6129244 1.499568e+01  1.8341161
 n         1.6413851    0.9472899 2.844055e+00  0.4955404
 sdb       1.2003848    0.6501406 2.216326e+00  0.1826422
 sdf       0.3130694    0.1375802 7.124024e-01 -1.1613303
```

```
 sdi1      0.1800770    0.0363820 8.913131e-01 -1.7143708
 sdi2      0.3099392    0.1029656 9.329548e-01 -1.1713792
 sdc       0.6253970    0.4919972 7.949667e-01 -0.4693686
 phi1      0.0819407    0.0386710 1.736256e-01 -2.5017597
 phi2      0.3789405    0.1822619 7.878550e-01 -0.9703760
 phi3      1.0525103    0.4532576 2.444036e+00  0.0511781

Deterministic reference points (Drp)
          estimate       cilow        ciupp  log.est
 Bmsyd 2228.460941 1032.323330  4810.545322 7.709066
 Fmsyd    3.398668    1.538328     7.508764 1.223383
 MSYd  7573.798531 4864.666143 11791.646642 8.932450
Stochastic reference points (Srp)
          estimate       cilow        ciupp  log.est rel.diff.Drp
 Bmsys 2039.821232 1216.082810  3421.535627 7.620617  -0.09247855
 Fmsys    4.531853    2.822374     7.276742 1.511131   0.25004892
 MSYs  9457.933048 5493.907567 16282.126421 9.154609   0.19921208

States w 95% CI (inp$msytype: s)
                    estimate        cilow        ciupp    log.est
 B_2020.50      4069.6356451 1179.4259658 1.404237e+04  8.3113088
 F_2020.50         1.4445672    0.4326156 4.823622e+00  0.3678098
 B_2020.50/Bmsy    1.9950943    0.7929830 5.019529e+00  0.6906913
 F_2020.50/Fmsy    0.3187586    0.1070864 9.488324e-01 -1.1433211

Predictions w 95% CI (inp$msytype: s)
                  prediction       cilow        ciupp    log.est
 B_2020.75      2844.3262048 690.0175239 1.172462e+04  7.9530815
 F_2020.75         1.4438795   0.4171718 4.997433e+00  0.3673336
 B_2020.75/Bmsy    1.3943997   0.4571585 4.253121e+00  0.3324640
 F_2020.75/Fmsy    0.3186069   0.1029483 9.860323e-01 -1.1437973
 Catch_2020.75  1453.1820188 629.9886792 3.352025e+03  7.2815109
 E(B_inf)       3381.8325771          NA           NA  8.1261730
```

6. Comparison of harvestable biomass estimation obtained in scenario 1 with harvestable biomass estimated by Gadget

Figures 11 and 12 show model comparison estimates of absolute (in tonnes) and relative harvestable biomass at the end of the second quarter, respectively. The models used for this comparison are, the SPiCt scenario 1 and the Gadget model used in the latest anchovy 9a South assessment (Rincón et al., 2020). The data used for the SPiCt scenario was also the same used in this assessment. In Figure 11 it can be observed that the two models present different trends mostly before 2005 (the year when PELAGO survey starts).

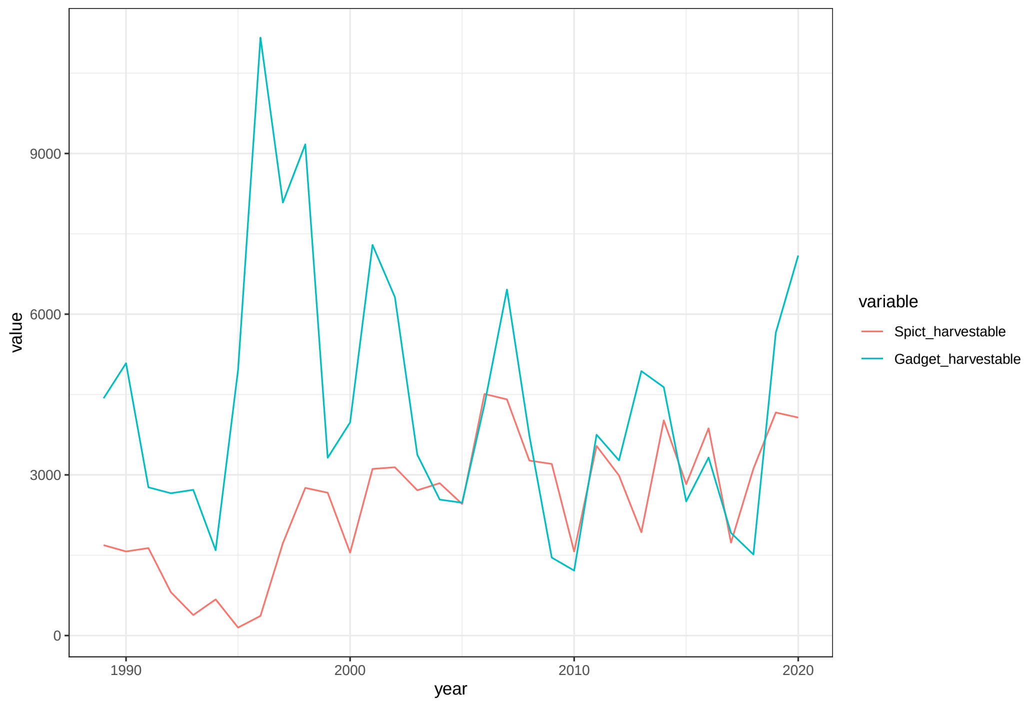

Figure 11: Comparison of absolute harvestable biomass estimates at the end of the second quarter of each year by Spict (scenario 1) and Gadget, pink and blue lines, respectively.

7. Acknowledgements

The research leading to these results is a contribution to project IMPRESS (RTI2018-099868-B-100), European Regional Development Fund (ERDF), Spanish Ministry of science, innovation and Universities-State Research Agency.

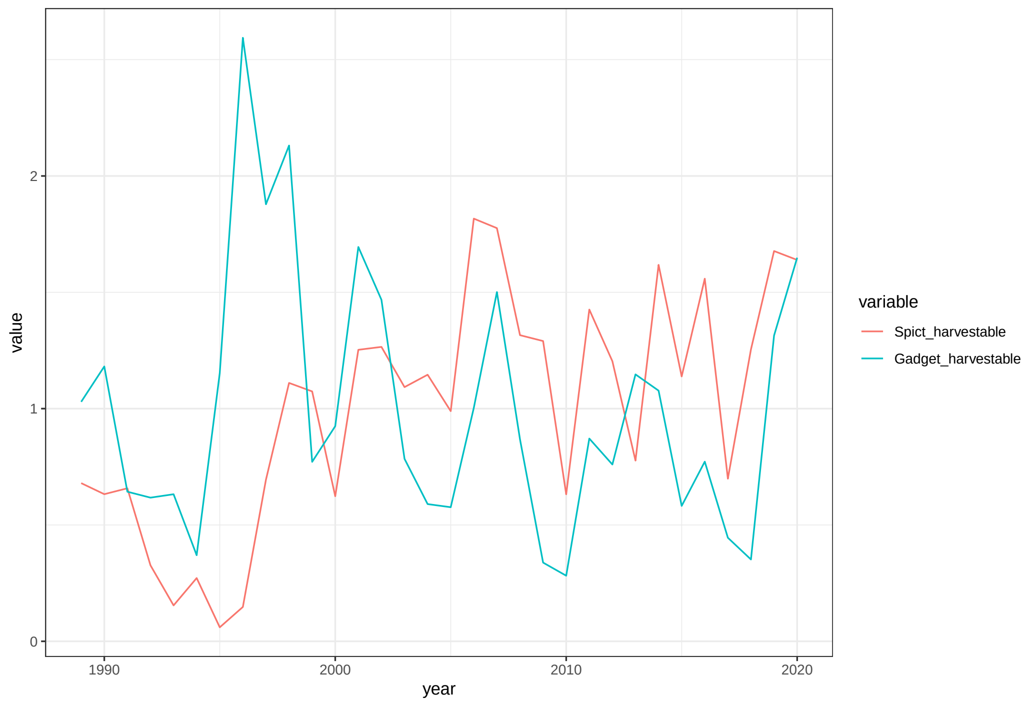

Figure 12: Comparison of relative harvestable biomass estimates at the end of the second quarter of each year by Spict (scenario 1) and Gadget, pink and blue lines, respectively.

8. References

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