2019 REPORT OF THE 2019 ICCAT WORKING GROUP ON STOCK ASSESSMENT METHODS MEETING (WGSAM)

(*Madrid, Spain, 8-12 April 2019*)

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

1. Opening, adoption of agenda and meeting arrangements

The meeting was held at the ICCAT Secretariat in Madrid, April 8 to 12, 2019. Dr. Michael Schirripa (USA), the Working Group ("the Group") rapporteur and meeting Chair, opened the meeting and welcomed participants. Mr. Camille Jean Pierre Manel (ICCAT Executive Secretary) welcomed the participants and highlighted the importance of the issues to be discussed by the Group aiming the work of the different SCRS Species Groups and the requests made by the Commission. The Chair proceeded to review the Agenda, which was adopted with some changes (**Appendix 1**).

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

Sections	Rapporteur
Items 1, 10	A. Kimoto
Item 2	V. Ortiz de Zárate, C. Palma
Item 3	K. Gillespie
Item 4	G. Melvin, H. Arrizabalaga
Item 5	M. Pons, H. Winker
Item 6	A. Kimoto, M. Otriz
Item 7	T. Frédou
Item 8	T. Frédou
Item 9	M. Schirripa

2. Score Card on Fisheries Data Availability

Since 2010, the Secretariat together with various ICCAT CPC scientists, have continuously worked in the improvement of the SCRS catalogues adopted by the Commission in 2011 ("para. 9i)" of *Resolution by ICCAT to standardize the presentation of scientific information in the SCRS annual Report and in Working Group Detail Reports* [Res. 11-14]. Up to 2016, the SCRS catalogues were summaries of fisheries data (Task I/II) availability, with a focus on the major ICCAT species (10 tuna and tuna-like species, and, 3 major sharks). However, to fully accomplish the ICCAT Resolution [11-14], the catalogues required a quantitative indicator (score) for a given species/stock across a time period.

After 2016, preliminary score estimations were presented by the Secretariat to the SCRS. The SCRS, following a Subcommitee Statistics (SC-STAT) recommendation, requested the Group to evaluate in 2019 the scorecard methodology presented by the Secretariat at the 2018 SCRS annual meeting.

Document SCRS/2019/045 presented an improved version of that methodology, generalised to be used across all ICCAT species and for any arbitrary time period (after 1950). A deterministic score function was chosen to estimate quantitative scores for 26 species-stock combinations (10 major tuna and tuna-like species, and three major sharks). For each one of the 26 cases, the scores were obtained for various time series/scenarios (10, 15, 20, 25, 30, and 35 years), covering all the Task I and Task II data available in ICCAT between 1950 and 2017. The scorecard can contain scores of one of more time series for those 26 species/stock combinations.

The Group congratulated the leadership of the Secretariat in accomplishing this task requested by the SCRS and the Commission, and acknowledged its importance and potential usage in ICCAT (SCRS and other reports, MSE framework, indicator for data improvement plans, etc.). The Secretariat noted that these scores reflect only "data availability" and not "data quality". The Group agreed and recommended that the quality control on fisheries data should be made independently using specialised procedures.

Finally, the Group adopted the scorecard methodology, and proposed a standard format with three time periods (10, 20 and 30 year) for the 26 main species/stock (**Table 1**), maintaining however the current 30 years for the presenting the SCRS catalogues. The Group also supported the ongoing work of the Secretariat in enlarging the scorecards to small tuna and possibly other species.

3. CPUE standardization/incorporation of oceanographic and environmental changes into the assessment process

This agenda item included one presentation and a brief discussion on swordfish movement data obtained from pop-up satellite archival tags (PSAT).

Presentation SCRS/P/2019/017 introduced a species distribution model (SDM) using a habitat suitability framework using swordfish as a case study. The model integrates ocean depth, annual average estimated total zooplankton, temperature, oxygen by depth, latitude and longitude, month and year. Model predictions and general distributions of North Atlantic swordfish catches, conventional tags, PSAT tracks, and observer data are used as criteria for the inclusion and treatment of variables. The preliminary formulation predicts the north-south seasonal migration in the North Atlantic but also predicts high abundance in areas of low swordfish catch. The author noted the potential use of this model for habitat suitability based CPUE standardization and as an input in a longline fishing simulator.

The Group acknowledged the effort for the development of this model. It was noted that some of catch patterns used to validate the model require re-examination and error checking against the ICCAT Task II spatial fishing data. It was suggested that feeding and spawning migration/movements by life stage should be taken into account. The author noted that modeling by life stage and sex was the ideal approach, however, this is very analytically demanding and beyond the scope of current model development. There was discussion on whether it was appropriate to introduce a migration function into the model or if movement should instead be an emergent property based on habitat suitability. The author noted that development of modeling tools such as visualization is complete and the focus is now on populating the model with appropriate environmental, trophic and species affinity curves. The author further noted that a number of projects are planned using the SDM, including a process for estimating time-area closures for by-catch minimization, and CPUE standardization for target and by-catch species for longline fisheries.

The Group discussed use and sharing of swordfish PSAT data. Those with data were encouraged to contribute data to a password protected ICCAT swordfish PSAT OwnCloud site. Unless otherwise agreed, only those contributing data should have access to the site and permission to use the tagging data. It was noted that outputs using tagging data are considered a collective effort among tagging data contributors and this should be reflected in those documents (e.g. through authorship).

4. Harvest Control Rules, Limit Reference points and Management Strategy Evaluation (MSE)

Document SCRS/2019/059 provided an analytical approach for diagnostics of parameters estimation in MSE. The paper provided a mathematical approach to diagnostics of parameters estimation quality. This approach provided the foundation of mathematical theory of parametric dependence of uncertainty. This theory shows how the distribution of parameter estimation errors depends on the parameters themselves and the process error. The structure of this distribution is completely determined by the behavior of the deterministic solution near the true value of the parameters. The paper presents explicit formulas for mathematical expectation and correlation functions of parameter estimates. Although evident in the equations, several members of the Group requested for future work a numerical example of how the approach would be used and the actual outputs.

Presentation SCRS/P/2019/019 provided an update on the current status and progress of the northern Albacore MSE. A peer review of the northern albacore MSE, including the operating models (OMs), management procedures, performance indicators and code was conducted in 2018. The peer review (Sculley, 2019) concluded that the Northern Albacore MSE is scientifically sound and robust to major sources of uncertainty. However, the review recommended to: further check the behavior of some models; to improve communication of results and to separate the OMs into a reference set and robustness tests. For 2019, the North Albacore Species Group will further characterize the indicators identified by the SCRS in 2018 to detect exceptional circumstances, address recommendations from the peer review and prepare a single consolidated report.

The Group was provided with a brief summary of albacore Harvest Control Rules (HCRs) and exceptional circumstances over the last several years by the rapporteur of Albacore Species Group. ICCAT Rec. [17-04] requested that the SCRS develop criteria for identifying exceptional circumstances. The SCRS was also requested to test some variants of the adopted HCR identified in the Rec. [17-04] (e.g., lower TAC limits, and alternative maximum/minimum TAC change regimes). It was anticipated that the Commission would review the interim HCR with the view of adopting a long-term HCR in 2020. In the response to the Commission (Section 19.7 in Anon. 2019), two principles that would signal the possibility of exceptional circumstances were identified: 1) when there is evidence that the stock is in a state not previously considered to be plausible in the context of the MSE and/or; 2) when there is evidence that the data required to apply the HCR are not available or are no longer appropriate. The Committee adopted a table that identifies a list of indicators that could be used to judge whether exceptional circumstances exist.

The development of the North Atlantic Swordfish (N-SWO) MSE started in 2018, with the initial development of the framework to use in the conditioning of the operating model (OM). At its 2018 inter-sessional meeting, the Swordfish (SWO) Species Group defined a list of factors that were identified as the ones with more uncertainty associated during the last stock assessment (2017) and that should be addressed within the MSE framework. The 2018 N-SWO MSE work was mostly devoted to some initial OM development trials using a grid approach for some of the main factors.

The N-SWO MSE work is scheduled for 2019 with a Call for Tenders. The objectives for 2019 are mostly related with the continuation of the OM development, mainly to include and address the factors previously identified by the SWO Species Group, as well as to continue work on model validation.

The road map for N-SWO MSE development adopted by the SCRS in 2018 planned for a continuation of the OM development, begin testing Management Procedures, and conducting an independent peer review of the code. However, given the limited development of the current OM, as well as limited funding available for 2019, the priority for this year will be restricted to only continue the OM development and validation. Accordingly, the MSE roadmap for N-SWO will likely have to be further revised by the SCRS plenary, to reflect those changes.

The SCRS involvement in Atlantic bluefin tuna (BFT) MSE essentially began in 2015 with Rec. [15-07], although there was some activity prior to this period. Between 2016 and 2017 there were a number of meetings to discuss the approach and to develop the MSE framework. (Core Modelling Group, Joint tRFMO MSE, intersessional and Science/Manager Dialogue). The original schedule anticipated an MSE framework providing interim bluefin tuna advice for 2020. However, the process was delayed due to the requirement to conduct full assessment in 2017 and other issues. In 2018 April, at the Bluefin tuna MSE Intersessional meeting it was recognized the complexity of the process and the SCRS recommended to the Commission a more realistic schedule for completing the MSE process to provide interim bluefin tuna advice for 2021. Although the road map has been approved, the schedule may have to be revised again given recent technical and data issues.

Three meetings were undertaken in 2019 (to date) to progress the bluefin tuna MSE: a bluefin tuna MSE Technical Group meeting in February, a bluefin tuna Working Group meeting (mid-February) and a Panel 2 meeting in early March. The objectives for the latter two meetings were to review and approve operating models (OMs), to make progress and advice on Candidate Management Procedures (CMPs) and to identify Key Performance Indicators. The intent was to present the results to Panel 2 and get feedback on MSE progress and the CMP's, as well as identify some Operational Management Objectives. Unfortunately, a serious coding error was uncovered (and fixed) that limited progress on the overall MSE approach.

Additional errors on the input data were detected at the bluefin tuna Working Group meeting that needed to be corrected before much of the quantitative work could continue. Activities such as the conditioning OMs and review of CMP's were delayed until the July Bluefin tuna MSE Technical Group meeting. Managers must be made aware that there is a risk the MSE work will not be completed in time to provide TAC advice for 2021, and, if an assessment is needed in 2020, the MSE process will be further delayed/slowed by assessment work. A recommendation on whether to proceed with MSE for 2021 TAC advice or revert to a stock assessment in 2020 shall be made at the SCRS Plenary in September 2019.

The SCRS is expected to recommend that CMPs include an option where catch is reduced to zero to illustrate the upper bound on the extent to which the status and safety management objectives can be achieved under the most extreme case of closing the fishery. In addition, it was stressed that while the management implications of east-west mixing remain unquantified, scientific evidence indicates mixing does occur. It is important that Panel 2 recognizes this east-west mixing of bluefin has implications for both stocks, and that a TAC set for the west area may impact the eastern population and vice versa.

There was no presentation on the report of the joint tRFMO MSE Working Group meeting and the Group focused on the MSE glossary. The Group agreed to adopt the joint tRFMO MSE WG glossary of terms used in MSE to provide a common bases across organizations. It was also recommended that any suggested changes or additions to the glossary were to be made by ICCAT/SCRS they should be presented and reviewed by the Group and the SCRS plenary, then submitted to the joint tRFMO MSE Working Group via the ICCAT representatives.

The Group reviewed the progress on MSE for albacore, swordfish and bluefin tuna and explored options for moving forward. Consideration was also given to the Commission's recommendation to focus on bluefin tuna MSE and to slow down the MSE processes for the other species, except albacore for which there is already an interim HCR in place and further specific work is requested in Rec. [17-04]. This was interpreted as meaning to reduce effort and to continue working at a slower pace, but not to stop the remaining MSEs. The activities associated with MSE were discussed in two broad categories: species specific MSE's and the overall MSE process.

The Group was presented with an option to reassign funding intended for the northern albacore and North Atlantic swordfish MSE efforts. Given the limited resources available for albacore and swordfish, the Group recommended that the current funds budgeted for the northern albacore and swordfish MSE work should remain devoted to the work on those specific MSE efforts as was initially intended. That is, to complete the tasks identified in the peer review report for albacore, and for swordfish toward further development of OM as recommended by the Swordfish Species Group.

The Group supported the concept of an Independent Peer Review (IPR) of the overall ICCAT MSE approach/framework for all species. This was considered to be a major undertaking and likely take several months to complete. The overall review should be completed by a team of 1-3 reviewers independent of ICCAT, first to review what has been done to date for each of the 3 species currently under MSE development. The Independent Peer Review should consider evaluating all aspects of the MSE process and recommend improvements. Thereafter the reviewers should design a generic framework for development of MSE in ICCAT in conjunction with ICCAT species representatives involved in MSE. The species specific ICCAT representatives would include the Species Group rapporteurs and someone active in the MSE process.

5. Characterizing uncertainty in stock assessment results

A key stock assessment output for management advice within tuna RFMOs is the Kobe phase plot and the Kobe2 strategy matrix (K2SM). Both require translating the estimated uncertainty about the stock status into probabilistic statements. The key quantities of interest are the ratios spawning stock biomass (SSB) and fishing mortality (F) relative to their reference values SBB_{MSY} and F_{MSY} that will lead or maintain the stock at levels that can produce the Maximum Sustainable Yield (MSY), respectively. In integrated age-structured stock assessment models, such as Stock Synthesis (SS), the uncertainty about the individual quantities (e.g. MSY) can be directly approximated based on standard error estimates derived from the variance-covariance matrix using the delta method. However, due to the inherently correlated nature of

SSB/SSB_{MSY} and F/F_{MSY} it is not straight forward to estimate uncertainty of both quantities simultaneously. Currently used approaches to do so include: i) the use of large grids comprising model runs with alternative parameterizations to capture structural uncertainty, ii) bootstrap and iii) Markov chain Monte Carlo (MCMC) methods to estimate the within model uncertainty. However, these methods are computationally intense and time consuming, which renders them as challenging tasks to complete during typically time-constrained stock assessment meetings.

To address this, SCRS/P/2019/020 presented the main results and underlying concepts by Walter *et al*. (2019), which introduced an approach to estimate uncertainty of the stock status using a multivariate normal distribution (MVN) that accounts for the inherent covariance between F/F_{MSY} and SSB/SSB_{MSY}. Walter *et al*. (2019) provided two case studies to compare the MVN approach with SS3 bootstrapping and MCMC routine. The first example used the medium-sized SS3 assessment model grid from the 2018 Atlantic bigeye tuna assessment to compare structural uncertainty approximation from MVN with the SS3 bootstrapping routine for constructing the Kobe phase plot and the K2SM. The second example compared the within-model uncertainty estimates from MVN approach in conjunction with the delta-method to the SS3 MCMC routine for constructing the K2SM using SS3 base case model run from the 2018 Blue marlin stock assessment (Anon. 2018a). Results showed that MVN method provides a reasonable approximation of the uncertainty estimates from bootstrap and MCMC, indicating that MVN could work in principle for estimating both structural uncertainty within medium-sized grids and within-model uncertainty. The major advantage of the MVN approach over the bootstrap and MCMC routines is that it reduces the computing time from several days to minutes.

The Group suggested that the MVN method provides a promising solution that would allow producing the Kobe phase plot and K2SM in time for adoption of the stock assessment report. This could also be a method to combine output from multiple modelling platforms, but care must be taken that important differences between models are adequately reported and not lost in the presentation. The Group recommended that more comparisons between MVN and MCMC and bootstrap approaches should be conducted before adopting the MVN as the sole method of choice.

The Group discussed options of how to combine and present uncertainty on future stock status projections. Kimoto and Ortiz (2019) was presented as background information. The Group noticed that the deterministic approach forwards projections under alternative quotas (chicken feet plot) is still appropriate for inclusion in the assessment report. For construction of the K2SM the Group recommended that additional projection posteriors to be provided for preparing the diagnostic plots proposed in Kimoto and Ortiz (2019). The Group noted that these routines may not always converge adequately, which can produce unrealistic or even negative values in the projections of the future stock status. To visualize those problems, Kimoto and Ortiz (2019) suggests graphical checks and diagnostics on the projection results that the Group recommend should be presented, together with the K2SM (**Appendix 5**).

6. Review of stock assessment software catalogue

The Group discussed and considered the newly proposed software JABBA ("Just Another Bayesian Biomass Assessment"). The Secretariat presented the materials for the inclusion of JABBA into the ICCAT stock assessment software catalogue (ICCAT software catalogue), comprising documentation, source codes, user's manual, vignette, and references. JABBA has been widely applied in stock assessments of highly migratory species (sharks, tuna, and billfishes) around the world. JABBA is published as a peer-reviewed open-access publication (Winker *et al*., 2018) and distributed through the global open-source platform GitHub and is accessible free at https://github.com/JABBAmodel. After reviewing, the Group fully agreed to include JABBA in ICCAT software catalogue.

The Secretariat reported that the current ICCAT software catalogue in GitHub has been reorganized by following suggestions by the 2018 ICCAT Working Group on Stock Assessment Meeting (WGSAM) (https://github.com/ICCAT/software/wiki) (Anon. 2018b): all links are now up to date and point to the developers most recent versions of each model, and stock assessment software and generic diagnostics and graphical tools are now clearly separated. There was a comment that the former format of having a list of direct links to the software webpages on software the ICCAT webpage was preferred because the list of ICCAT software can be captured easily and the GitHub is not always friendly to non-users. It was also

commented that GitHub has advantages for effective version control of software to allow scientists to reproduce particular stock assessment and projection results used for the management recommendations, and to maintain all results of ICCAT stock assessments for transparency in science. The Group requested to add the list of software with its link to the current webpage for the ICCAT software catalogue (https://www.iccat.int/en/AssessCatalog.html), while maintaining the GitHub site.

The archiving of the stock assessment results was discussed. The Group recognized the importance that all stock assessment and projection results should be reproducible. It was recommended to create a table of the stock assessment(s) used for the management recommendations by species with the year, the accepted stock assessment models and the version of the software for the latest assessment. The Group also recommended to archive the results during the assessment meeting and to provide them to the Secretariat. The results will reside at the Secretariat with the correct version of the software. It was suggested to keep those data as R objects that can reduce the size of the files and are easily readable. It was requested updating the GitHub site with the version of software used for the latest assessments when possible.

The Group continues to recommend using principally the stock assessment models in the ICCAT software catalogue for providing management advices. This should not restrict or discourage efforts of exploring applications or other methods in the individual Species Group. The Species Groups are encouraged to submit the new stock assessment models for the review to the ICCAT software catalogue.

Lastly, the Group discussed the current process for accepting and completing the inclusion of a given assessment software for the ICCAT software catalogue. Of the current ICCAT software catalogue, there are 5 models (ASPIC, VPA2Box, Stock Synthesis, mpb, and JABBA) that have completed the general request from the SCRS for being included in the list including; code, user's guide, simulation test, examples of use for tuna species and testing by external scientist (e.g. no the model developer). Then there are currently 2 models into the process (FLXSA, and SAM) for which partial request has been provided. It was suggested to add the information on the status of completeness for review of the ICCAT software catalogue in the web page. The Group previously noted that any stock assessment software should be simulation tested, and recommended to form a study group to facilitate the simulation testing. It was noted that the evaluations done by other scientific groups could be considered (e.g. evaluation of JABBA from the US methods technical Working Group).

7. Data Limited Methods: Theory and Assumptions

A general discussion about data limited methods was undergone, four methods were highlighted and presented in more details to the Group: two length-based methods and two catch-based methods (**Table 2**).

Length-based methods

Length based spawning potential ratio (LBSPR) (Hordyk *et al*., 2015a). SPR in an exploited population is a function of the ratio of fishing mortality to natural mortality (F/M), and the two life history ratios M/k and Lm/L_∞; k is the von Bertalanffy growth coefficient, Lm is the size of maturity and $L\infty$ is asymptotic size (Hordyk *et al*., 2015b). The inputs to LBSPR are: M/k, L_∞, the variability of length-at-age (CVL_∞), which is normally assumed to be around 10%; and length at maturity specified in terms of L_{50} and L_{95} (the size at which 50% and 95% of a population matures). Given the assumed values for the M/k and L_∞ parameters and length composition data from an exploited stock, the LBSPR model uses maximum likelihood methods to estimate the selectivity ogive, which is assumed to be a logistic curve defined by the selectivity-at-length parameters S_{50} and S_{95}, and the relative fishing mortality (F/M), and these are used to calculate SPR (Hordyk *et al*., 2015). Estimates of SPR are primarily determined by the length of fish relative to L_{50} and L_∞. If a reasonable proportion of fish in a sample attain sizes approaching L_∞a high estimate of SPR will be derived. LBSPR is an equilibrium based method with the following assumptions: i) asymptotic selectivity, ii) growth is adequately described by the von Bertalanffy equation, iii) a single growth curve can be used to describe both sexes which have equal catchability, iv) length at-age is normally distributed, v) rates of natural mortality are constant across adult age classes, vi) recruitment is constant over time, and vii) growth rates remain constant across the cohorts within a stock (Hordyk *et al*., 2015). This method can be implemented in R using the LBSPR package (Hordyk, 2017).

Presentation SCRS/P/2019/023 provided an overview of the concepts of the new Length-Based Bayesian approach (LBB; Froese *et al*., 2018a) to estimate stock status in data limited situations. LBB requires no input in addition to length frequency data, but provides the user option to specify priors for the estimable parameter's asymptotic length (L_∞), length at first capture (Lc) and relative natural mortality (M/k). In addition, the relative fishing mortality (F/M) is estimated as means over the age range represented in the length-frequency sample. With these parameters as input, standard fisheries equations can be used to estimate depletion or current exploited biomass relative to unexploited biomass (B/B_0). In addition, these parameters allow the estimation of the length at first capture that would maximize catch and biomass for the given fishing effort (Lc_opt; Froese *et al*., 2016), and estimation of a proxy for the relative biomass capable of producing maximum sustainable yields (B_{MSY}/B_0). Relative biomass estimates of LBB were not significantly different from the "true" values in simulated data and similar to independent estimates from full stock assessments. The most recent version of LBB includes an additional user option to account the "pile-up" effect size bins when sampling is likely to occur continuous throughout the year (Froese *et al*., 2018b). However, it was also discussed that the pile-up correction is likely to introduce a negative bias when sampling mostly occurs during a specific month or season.

Worked examples of LBB for the small tuna case study examples in Pons *et al*. (2019) were shared and discussed with the Group. Applications of LBB to these selected small tuna stocks show that performs similar to LBSPR (Hordyk *et al*., 2015 and 2016).

The Group discussed that just like other length-based methods LBB will perform poorly if the input size data are not representative of the length composition of the exploited phase of the stock or if the selectivity diverges strongly from the assumed logistic selectivity.

Catch-based methods

Catch-MSY (Martell and Froese, 2013) is a stock reduction analysis approach with a Schaefer biomass dynamic model. As input data, it requires a time series of removals, prior ranges of the population rate of increase (r) and carrying capacity (K), and possible ranges of relative stock sizes in the final year of the time series. Probable ranges for r and K are filtered with a Monte Carlo approach to detect 'viable' r-K pairs. A parameter pair is considered 'viable' if the corresponding biomass trajectories calculated with a production model are compatible with the observed catches, so that the population abundance never falls below 0, and is compatible with prior estimates of relative biomass (i.e., stock depletion; Martell and Froese, 2013). The r-K pairs are drawn from uniform prior distributions and the Bernoulli distribution is used as the likelihood function for accepting each r-K pair. Catch-MSY method can be implemented in R using the package "fishmethods" (Nelson, 2017).

Presentation SCRS/P/2019/022 provided an overview of the concepts of the data poor, catch-only method CMSY by Froese *et al*. (2017). CMSY estimates fisheries reference points (MSY, F_{MSY}, B_{MSY}) as well as relative stock size (B/B_{MSY}) and exploitation (F/F_{MSY}) from catch data and broad priors for resilience or productivity (r) and for stock status (B/K) at the beginning and the end of the time series. Part of the CMSY package is an advanced Bayesian state-space implementation of the Schaefer surplus production model (BSM). A number differences to the Catch-MSY method (Martell and Froese, 2013) were highlighted and discussed.

The Group noted that (1) CMSY extends Catch-MSY by placing stronger emphasis on B_t/B_{MSY} and F_t/F_{MSY} estimates, (2) CMSY explicitly incorporates process error, (3) CMSY uses a newly developed Monte-Carlo filter (not the SIR algorithm) that fixes emerging systematic biases of Catch-MSY, (4) previous uniform depletion priors are now approximated with lognormal distributions, (5) CMSY has an inbuilt piece-wise "hockey-stick" to prevent over-estimating of rebuilding potential at very low abundance $B<0.25B_0$. Worked examples of CMSY applications were shown for Mediterranean albacore, North Atlantic shortfin mako and Atlantic white marlin. These were discussed not only in the context of data poor assessment applications but also as a potential diagnostic for identifying conflicts between catch and catch-per-unit-effort (CPUE) indices, given the stock's productivity, when compared to models fitted to CPUE, such as the inbuilt Bayesian State-Space Surplus Production Schaefer Model or the assessment model JABBA (Winker *et al*., 2018).

The Group recognized that to estimate stock status for any species with length-based methods, the length distribution should come from the gear that is more representative of the length distribution of the exploitable population. It also noted that catch-based methods are highly sensitive to the completeness (unreported historical data) of catch data and therefore will not perform well on small tuna species.

8. Data Limited Methods of stock assessment

Two scientific documents were presented on Data Limited Methods. Document SCRS/2019/063 presented an exploration of data-limited assessment methods for small tunas species. In this work, 6 small scombrids stocks were assessed using 2 catch-based models (Depletion Based Stock Reduction Analysis –DBSRA– and Simple Stock Synthesis –SSS), 2 length-based models (Length Based Spawning Potential Ratio –LBSPR– and Length based Integrated Mixed Effects –LIME) and one that combines both data-sets, catch and length data (LIME_Catch). The authors found there was a high uncertainty in the estimation of stock status and they are highly sensitive to input parameters suggesting that more sensitivity analysis should be carried out. Close loop simulation studies such a as Management Strategy Evaluation should be considered to determine the most feasible management procedures to implement for each stock considering current parameters, data and model uncertainties.

The Group recognized that the observed increase in catch for most of the small tuna species is due to an increase in catch reporting by the CPCs. The Group suggested that given the uncertainty around catch reports for these species, the small tuna Species Group should explore: (1) using catch reconstructions (e.g. Sea Around Us project) as an input for catch-based models; and (2) using the catch scorecards to select the most appropriate period of the catch time series available in ICCAT where the reporting was more stable.

Document SCRS/2019/041 presented a preliminary exercise of on Management Strategy Evaluation (MSE) using the DLMtool toolkit to test the performance of a variety of Management Procedures (MPs) for the northwest Atlantic wahoo. In this analysis, nine MPs were selected to be included in the MSE run in order to evaluate the performance of each one and its effectiveness for management advice. The chosen MPs were based on catch ("AvC","CC1","SPMSY" and "DBSRA"), length ("LBSPR","minlenLopt1" and "matlenlim"), and fishing effort controls ("curE" and "curE75"). The preliminary results show that catch-based methods were the most acceptable with respect to the pre-established threshold values for the performance metrics. However, length-based MP might be more appropriate or most of the small tuna species.

The Group noted that an MSE approach is a good option in a data limited framework (e.g. 'dlmtools' application), but the MSE simulation approach are somehow lacking in depth understanding by many groups. The Group recognized that training capacity is needed in both, data-limited assessments methods and MSE for data poor stocks. Such methods could be applied to other Species Groups such as sharks or billfishes.

9. Recommendations

With financial implications

1. The Group recognized that several of the Species Groups are in "data limited" situations, as well as the lack of stock assessment capacity. Thus, the Group recommends that a series of Data Limited Workshops be conducted to specifically address the needs of ICCAT. These workshops should have long-term benefits for the Species Group and cover the various aspects of conducting reliable stock assessment, such as data requirements, collection, model implementation, etc.

2. The Group agreed that the swordfish Species Distribution Model was a useful tool and recommended that it should be continued through the WGSAM Work Plan. The Group recommended that funding be made available to continue this work by a cooperative effort between the WGSAM and an independent expert. The products of this work should support the ongoing development of the Longline Simulator which will significantly increase the utility of the simulator in providing the means to investigate CPUE standardization and develop best practices for it.

3. In the response to the Commission's request for an MSE Independent Peer Review (IPR), the Group recommended that the SCRS creates a panel of one to three reviewers independent of ICCAT to be formed to review the entire process and effectiveness of the ICCAT MSE process to date. The products of this IPR would be a review of past and current practices, recommendations for improvements and a subsequent design of a generalized framework for the MSE process suited to the ICCAT process. To facilitate this review it was recommended that appropriate representatives from the Species Group should be consulted to help facilitate the review.

Without financial implications

1. The Group recognized the importance of the scorecard and SCRS catalogues as useful instruments for tracking fisheries data availability and improvements over time. The Group recommended that ICCAT CPCs should use these tools to revise/complement their data and that the error in the catch be given careful consideration in stock assessment and management advice development. It is recommended that the proper place to report the scorecard with three time series (10, 20, and 30 years) of all stocks is in the report of the Sub-committee of Statistics.

2. The Group recommended that the current funds budgeted for the northern albacore and swordfish MSE work should remain devoted to the work on those specific MSE efforts as was initially intended.

3. The Group recommended that an analysis be conducted based on comparing past ICCAT (or other tRFMOs) assessments using Monte Carlo Markov Chain (MCMC) analysis or bootstrapping techniques to the multi-variate normal (MVN) methods presented during this meeting so that a determination can be made as to whether the MVN method is an effective and reliable option for producing equivalent results in a more efficient and timely manner.

4. The Group emphasized the importance of properly recording the stock assessment results and the software used to provide management advice so that the advice is reproducible. In this regard, the Group strongly recommends that the version of the software used be explicit in the stock assessment meeting report and that any software used to create management advice is provided to the Secretariat by the end of the assessment meeting for archiving. The responsibility of this task is that of the Species Group Rapporteur.

5. The Group recommends that more data limited methods should be explored for data-poor stocks including assessment methods and MSE. The Group acknowledges that collection of catch data for small tuna species can be challenging (partial catch reporting, unreported by-catch, catches from national small-scale fisheries that do not report to ICCAT). Therefore, the Group recommends that more effort should be devoted to data collection for Task II catch and effort and Task II size for these data poor stocks.

6. Recognizing the importance of scientifically sound CPUE analysis in the stock assessment process, the Group reiterates its recommendation for the use of the previously published WGSAM CPUE evaluation table be used during each stock assessment.

Work Plan Items

1. Complete the swordfish Species Distribution Model as a stand-alone model as well as to add a simulated directed fishery to the Longline Simulator tool.
2. Continue to make progress on CPUE level of aggregation study.
3. Continue work on problems associated with use of localized CPUE and/or Shifting Distributions.
4. A comparison study of MCMC and bootstrapping to MVN techniques to characterize stock assessment uncertainty.
5. A document outlining the recommended standard diagnostics for stock assessment models.
6. Options paper for stock assessment software use and inclusion into the ICCAT software catalogue.

10. Adoption of the report and closure

The report was adopted during the meeting. The meeting was adjourned.

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Table 1. Scorecard for the 26 main species/stock with 3 time series (10, 20, and 30 years) ending in 2017 (final year).

SCORECARD on Task I/II availability for the main ICCAT fisheries (final year: 2017)									
				SCORES (by time series)			N. flag fisheries ranked		
FisheryID	Spc. Group	Species	Species/stock	10 yr (2008-2017)	20 yr (1998-2017)	30 yr (1988-2017)	10 yr (2008-2017)	20 yr (1998-2017)	30 yr (1988-2017)
1	Temperate	ALB	ALB-N stock	7.77	7.13	7.05	12	14	12
2			ALB-S stock	5.81	6.01	5.49	10	9	10
3			ALB-M stock	5.75	2.82	1.89	6	9	12
4		BFT	BFT-E stock (ATE region)	9.32	6.63	5.71	6	9	10
5			BFT-E stock (MED region)	5.87	4.15	3.12	18	21	29
6			BFT-W stock	9.76	8.77	8.49	7	8	9
7	Tropicals	BET	BET-A stock (AT + MD)	8.09	7.29	6.49	26	27	27
8		YFT	YFT-E region	8.79	7.47	6.46	16	21	24
9			YFT-W region	5.00	4.73	4.36	23	25	26
10		SKJ	SKJ-E stock	8.62	7.86	7.05	15	17	18
11			SKJ-W stock	4.61	4.60	4.37	3	4	5
12	SWO & billfish	SWO	SWO-N stock	8.75	8.41	7.48	10	11	12
13			SWO-S stock	6.83	7.22	6.52	11	10	11
14			SWO-M stock	6.51	4.89	3.90	9	10	12
15		BUM	BUM-A stock (AT + MD)	3.84	4.02	4.11	28	28	29
16		WHM	WHM-A stock (AT + MD)	5.23	5.21	5.08	16	18	18
17		SAI	SAI-E stock	3.92	3.61	2.93	10	12	14
18			SAI-W stock	4.18	3.74	3.62	13	16	18
19		SPF	SPF-E stock	5.25	4.70	2.03	3	4	3
20			SPF-W stock	4.00	4.00	3.37	6	6	6
21	Major sharks	BSH	BSH-N region	6.58	4.58	3.30	3	4	5
22			BSH-S region	6.91	5.40	3.70	7	6	6
23		POR	POR-N region	3.30	2.16	1.24	13	11	8
24			POR-S region	2.85	1.58	0.93	4	4	5
25		SMA	SMA-N region	5.80	3.52	2.47	7	6	5
26			SMA-S region	7.32	5.50	3.25	7	8	7

Table 2. Data-limited assessment techniques discussed at this meeting. Techniques include length-based, catch-based, and an integrated catch and length-based method. Methods vary in their input requirements, outputs and assumptions.

Type	Method	Data requirements and outputs	Supporting documents	Notes
Length based	LBSPR (Hordyk *et al.*, 2015a). Length-base spawning potential ratio	Inputs: lengths/length frequency (single or multi-year); life history (maturity, growth, M/k ratio) Outputs: Spawning potential ratio; F/M ratio; selectivity ogive	https://cran.r-project.org/web/packages/LBSPR/vignettes/LBSPR.html	Assumes logistic selectivity; best used with data containing wide range of sizes; available as simulation model
	LBB (Froese *et al.*, 2018a). Length-based Bayesian biomass estimation	Inputs: Length Frequencies (single or multi-year); Optionally: life history priors (L_∞, M/k) Outputs: Ratios B/B_{MSY} and F/M, selectivity	http://oceanrep.geomar.de/43182/7/LBB_UserGuide_1.zip	Assumes stock equilibrium; logistic selectivity; von Bertalanffy growth function; representative of the length composition of the exploited phase of the stock.
Length and/or catch based	LIME (Rudd and Thorson, 2017). Length-based integrated mixed effects model	Inputs: lengths/length frequency; life history (maturity, growth, M and length-weight relationship) Outputs: Spawning potential ratio; F; selectivity ogive and recruitment deviations	https://github.com/merrillrudd/LIME	Assumes logistic selectivity; best used with data containing wide range of sizes; includes recruitment and F variability. Can include catch and index of abundance
Catch based	Catch-MSY (Martell and Froese, 2013)	Inputs: catch series; priors K, r and prior on B/B_0 Outputs: MSY, F_{MSY}, B_{MSY}	https://cran.r-project.org/web/packages/fishmethods/fishmethods.pdf	Assumes a logistic population growth model (Schaefer); the input range for r is representative of the plausible stock's productivity; some degree of knowledge about the exploitation history
	CMSY (Froese *et al.*, 2017)	Inputs: catch series; priors r and prior on B/B_0 (at least one) Outputs: B, B/B_{MSY}, F/F_{MSY}, MSY	http://oceanrep.geomar.de/33076/21/UserGuideNew.zip	Assumes a logistic population growth model (Schaefer); the input range for r is representative of the plausible stock's productivity; some degree of knowledge about the exploitation history
	Depletion Based Stock Reduction Analysis, DBSRA (Dick and McCall, 2011)	Inputs: catch series; Age at maturity and priors F_{MSY}/M, B_{MSY}/B_0, M and B/B_0 Outputs: B, B/B_{MSY}	https://cran.r-project.org/web/packages/fishmethods/fishmethods.pdf	Assumes a logistic population growth with a delay difference model, selectivity equal to maturity ogive
	Simple Stock Synthesis (SSS, Cope, 2013)	Inputs: catch series; growth and reproductive parameters, priors h, M and B/B_0 Outputs: B, B/B_{MSY}, SPR and other derived quantities	https://github.com/shcaba/SSS	Age structured model, stock recruitment relationship could be Beverton-Holt or Ricker

Appendix 1

Agenda

1. Opening, adoption of agenda and meeting arrangements
2. Score Card on Fisheries Data Availability
3. CPUE standardization/incorporation of oceanographic and environmental changes into the assessment process
4. Harvest Control Rules, Limit Reference points and Management Strategy Evaluation (MSE)
5. Characterizing uncertainty in stock assessment results
6. Review of stock assessment software catalogue
7. Data Limited Methods: Theory and Assumptions
8. Data Limited Methods of stock assessment
9. Recommendations
10. Adoption of the report and closure

Appendix 2

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Appendix 3

List of Papers and Presentations

Number	Title	Authors
SCRS/2019/041	Application of the DLM tool kit: small tunas case study	Mourato B., Pons M., Lucena-Frédou F., and Frédou T.
SCRS/2019/045	Global scores on Task-I and Task-II data availability by species and stock, for the major ICCAT managed species	Palma C., Mayor C., Taylor N.G., Schirripa M., and Diaz G.
SCRS/2019/059	Analytical approach for diagnostic of parameters estimation in management strategy evaluation	Mikhaylov A.
SCRS/2019/063	Exploration of length-based and catch-based data limited methods for small tunas	Pons M., Lucena-Frédou F., Frédou T., and Mourato B.

SCRS/P/2019/017	Progress Towards a Swordfish Species Distribution Model Based on Habitat: A Work in Progress	Schirripa, M.J., Forrestal F., and Phillip Goodyear C.P.,
SCRS/P/2019/019	Summary of North albacore MSE	Arrizabalaga H.
SCRS/P/2019/020	The Multivariate Normal (MVN) approach to capture uncertainty about the stock status within a two dimensional Kobe-framework	Winker H.
SCRS/P/2019/022	CMSY is not Catch-MSY: ICCAT assessment applications	Winker H., and Mourato B.
SCRS/P/2019/023	LBB: Length-Based Bayesian Estimator	Winker H.

Appendix 4

SCRS Document and Presentations Abstracts as provided by the authors

SCRS/2019/041 - This paper presents a preliminary exercise of Management Strategy Evaluation (MSE) using the DLMtool toolkit to test the performance of a variety of management procedures (MPs) for the Northwest Atlantic wahoo. In this analysis, nine management procedures (MP) were selected to be included in the MSE run in order to evaluate the performance of each MP and its effectiveness for management advice. The chosen MPs were based on catch ("AvC","CC1","SPMSY" and "DBSRA"), length ("LBSPR","minlenLopt1" and "matlenlim"), and fishing effort controls ("curE" and "curE75"). Our preliminary results show that catch-based methods are the most acceptable with respect to the pre-established threshold values for the performance metrics. Simulations of the length-based and fishing effort control methods did not present satisfactory results with respect to the annual variability in yield and probability of spawning biomass being higher than spawning biomass at maximum sustainable yield. However, results must be interpreted with caution given the high uncertainty in the parametrization of the operating model, which might be strongly influence the performance of MPs.

SCRS/2019/045 - This study presents an improved version of the methodology used by the Secretariat to obtain global scores on fisheries statistics (Task I and Task II data) availability. A deterministic score function was adopted to estimate quantitative scores for 26 species-stock combinations (10 major tuna & tuna like species, and 3 major sharks), the global scorecard on fisheries data availability. For each one of the 26 cases, the scores were obtained for various time series/scenarios (10, 15, 20, 25, 30, and 35 years), covering all the Task I/II data available in ICCAT between 1950 and 2017. For all the 26 cases, the retrospective results show an increasing trend of the scores, with an overall convergence tendency (all scenarios) to higher scores on the last decade. Overall, larger time series (≥25 years) tend to be more stable (lower variability) however more pessimistic (lower scores), while smaller time series (<25 years) show higher variability (more unstable) and are more optimistic. Also observed is that, with higher data completeness/homogeneity levels (recent decade), the scores obtained in all the scenarios tend to converge to a unique value. The scenarios recommended for the global scorecard are 25 or 30 years.

SCRS/2019/059 - The problems of diagnostics of parameter estimation within the framework of management strategy evaluation are discussed. The observations are generated by stochastic differential equation. The dependence of the error distribution on the model parameters, noise level, and duration of observation are investigated in general case. An example of an exactly solvable model is built up.

SCRS/2019/063 - For most of the small scombrids species, such as small tunas, mackerels and bonitos, data are insufficient to perform traditional stock assessments despite their economic importance in many small-scale fisheries. Thus, most of these fisheries remain unassessed and their exploitation status is unknown. In such data-limited situations two main quantitative approaches, based on data availability, can be used to assess exploitation status: catch-based model, when only catch data exist, or length-based models, when only information of the length composition of the catch is available. In this study, we estimated the exploitation status of 6 small scombrids stocks in the Atlantic Ocean using 2 catch-based models (Depletion Based Stock Reduction Analysis –DBSRA– and Simple Stock Synthesis –SSS), 2 length-based models (Length Based Spawning Potential Ratio –LBSPR– and Length-based Integrated Mixed Effects –LIME) and one that combines both data-sets (LIME_Catch). We found that there is high uncertainty in the estimation of stock status by these models and, since they are highly sensitive to input parameters, more sensitivity analysis should be done before drawing conclusions about stock status. We suggest moving to close loop simulations studies (i.e. Management Strategy Evaluation) to determine the most feasible management procedures to implement for each stock considering current parameters, data and model uncertainties.

SCRS/P/2019/017 - A presentation of the progress of the swordfish Species Distribution Model was provided to the Group. The presentation demonstrated the data management and analysis tools that have been developed to date. Environmental data that has been formatted for use in the model now include dissolved oxygen, temperature, and small plankton chlorophyll and zooplankton carbon by depth, year and month, 1948-2019. Programs have also been developed that can easily lag the environmental data by any number of months either forward or backwards. The framework is in place now such that the habitat model development is ready to implement and move forward. Results to date are only preliminary but encouraging. Ground trothing of the models are being carried out by comparing model results to landings, conventional tagging, PSAT tagging tracks and fishery observer data. The next challenges for the modeling

effort are to describe with greater accuracy the affinity curves associated with each of the environmental data and improving the graphics of model results. Furthermore, methods of comparing model results to landings that are more numerical should be investigated. Once the swordfish model is deemed satisfactory it will be added to the Longline Simulator to represent a directed fishery with blue marlin as a bycatch species.

SCRS/P/2019/019 - This presentation summarizes the progress regarding the albacore tuna MSE framework. In 2017, the ICCAT Commission adopted an interim Harvest Control Rule (HCR) for North Atlantic albacore (Rec. 17-04), which represents the first HCR adopted in the history of ICCAT. This HCR imposes an FTARGET = 0.8 BMSY, a BTHRESHOLD = BMSY, a BLIM=0.4BMSY and an FMIN=0.1FMSY, with a maximum TAC of 50,000 t and a maximum TAC change of 20% when BCURR>BTHRESHOLD. Recommendation 17-04 also requested the SCRS to pursue an independent peer review during 2018, to develop criteria for the identification of exceptional circumstances, and to test several variants of the interim HCR, with a view to adopt a long term HCR in 2020. During 2018, the Committee was able to complete the peer review. On the exceptional circumstances, the Committee has come up with a generic set of indicators that would be useful to determine if exceptional circumstances exist. The albacore Species Group has slightly adapted these to the North Atlantic albacore case. Moreover, the Committee evaluated some of the variants to the interim HCR, as requested by the Commission, and the outcomes of these evaluations are reflected in the Executive Summary. The main priority for 2019 is to address the recommendations identified by the external peer reviewer to improve the MSE framework, in anticipation to adopting a long term HCR in 2020. In addition, there is a need to characterize the indicators to identify exceptional circumstances and produce a single consolidated report.

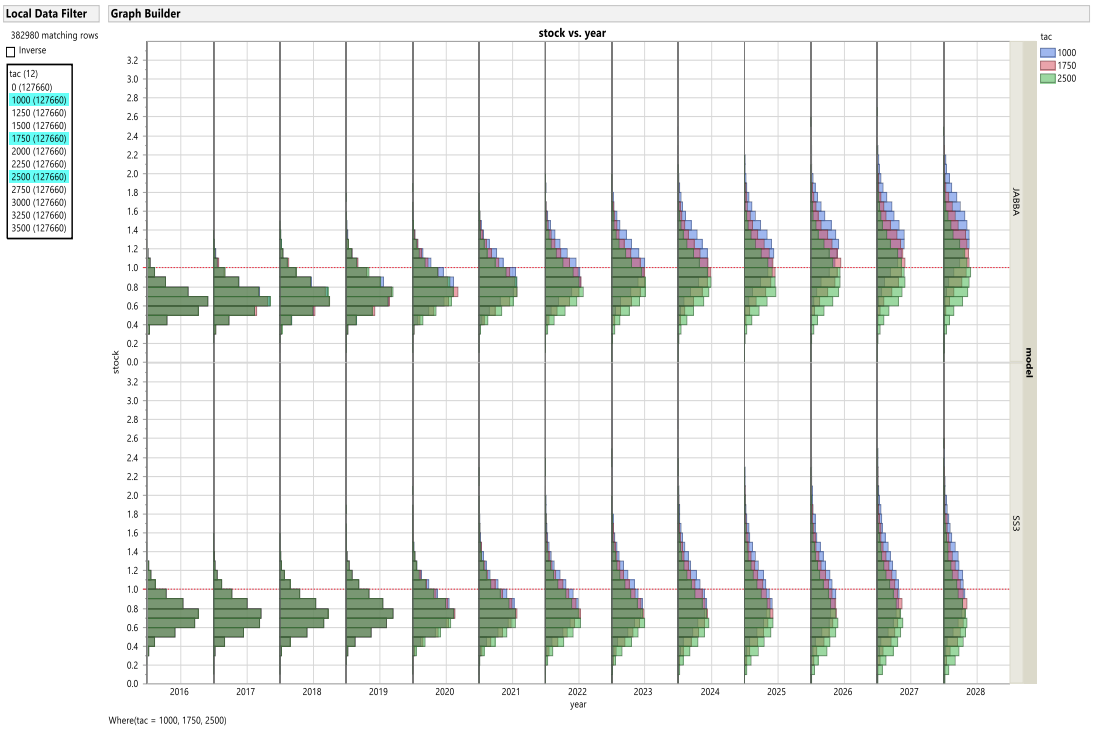
SCRS/P/2019/020 -A key stock assessment output for management advice within tuna RFMOs are the Kobe phase and the Kobe projection matrix, which both to translate the estimated uncertainty about the stock status (present and future) into probabilistic statements. There are several approaches to quantify uncertainty age-structured stock assessment models, such as Stock Synthesis (SS3). These include the use of so large grids of model runs with alternatives parameterizations to capture structural uncertainty as well as bootstrap and MCMC methods to estimate the within model uncertainty. However, these methods are computationally intense and time consuming, which renders them challenging to complete during time-constrained stock assessment meetings. This contribution presents a new, rapid approach to estimate uncertainty about the stock status from a multivariate normal approximation (MVN), which has been shown to work in principle for estimating both structural uncertainty within medium-sized grids and within-model uncertainty (SCRS/2018/162). A conceptual framework to extend the MVN approach for capturing both structural and within-model uncertainty simultaneously is proposed.

SCRS/P/2019/022 - This presentation provides an overview of the concepts of the Catch-only method CMSY by Froese et al. (2017) based on worked examples for Mediterranean Albacore, North Atlantic shortfin mako and Atlantic White marlin. CMSY is a Monte-Carlo method that advances the Catch-MSY method (Martell and Froese, 2013) by addressing biased estimation of unexploited stock size and productivity, and adding estimation of biomass and exploitation rates. Part of the CMSY package is an advanced Bayesian state-space implementation of the Schaefer surplus production model (BSM), which allows direct comparison between the catch-only CMSY and the BSM fitted to, for example, to short and fragmented abundance data.

SCRS/P/2019/023 - This presentation provides an overview of the concepts of the new Length-Based Bayesian approach (LBB; Froese et al., 2018) to estimate stock status in data limited situations. LBB works for species that growth throughout their lives, such as most commercial fish and invertebrates, and requires no input in addition to length frequency data. LBB has been tested against simulated data and formal stock assessment estimates. Applications of LBB to selected small tuna stocks show that performs similar to other length-based methods. However, just like other length-based methods, LBB will perform poorly if the input size data are not representative of the length composition of the exploited phase of the stock.

Appendix 5

Example of additional diagnostic for stochastic projections



Histogram of B/B_{MSY} by year, constant catch scenario, and stock assessment method. The plots shows the histograms for the projections scenarios of constant catch of 1000, 1750 and 2500 t by each assessment model in the 2018 BUM assessment (Figure 2 in Kimoto and Ortiz, 2019).