SEDAR 54

HMS Sandbar Shark

Post-Review Updates

February 2018

Background

This document addresses the CIE peer reviews of the SEDAR 54 HMS Sandbar shark stock assessment report (here forth referred to as SAR). The document includes responses to comments and issues raised by the three reviewers. Our responses address the comments and recommendations listed by each reviewer under the relevant Term of Reference (ToR) where we believe a response is needed. We thank the reviewers for their thorough reviews and helpful suggestions for future work.

An important issue that became apparent based on many of the reviewers' comments is that the Reviewers' TORs or their SOW did not specify clearly that SEDAR 54 was a *standard* assessment. The aim of the assessment was thus to update all the data inputs used previously for SEDAR 21, except when new information had become available, such as the new Florida Coastspan survey, or modifications had to be introduced to the input data to reflect new knowledge or changes that occurred since SEDAR 21 (e.g., the new growth curve, splitting the BLLOP index into two indices, or merging the old GA and SC Coastspan indices into a single SEAMAP SE index that also incorporated data from FL). Therefore the current assessment did not contemplate in-depth changes or a re-evaluation of all data inputs as is done in a *benchmark* assessment. In particular, reconsideration of the catch reconstruction assumptions or identification of different catch series, re-evaluation of the appropriateness of the abundance indices, or examination and incorporation of tagging data were beyond the scope of this standard assessment. This was specified in the assessment TORs (point 2) but perhaps was not made clear enough.

1. Reviews

1.1. Addressing Review of CIE reviewer Noel Cadigan

ToR 2: Evaluate the data used in the assessment

Issues: 1) Uncertainty in the landings was not quantified; 2) magnitude of catches outside the US EEZ; 3) uncertainty with recent catch data, specifically include Mexican catches in 2014-2015 to assess their magnitude; 4) censored catch approach to account for unknown catches; 5) new estimates of natural mortality (M) at age were up to 30% different from those in SEDAR 21; 6) new growth function; 7) maturity ogive based on lengths; 8) proportion of maternal females; 9) effect of hook saturation on indices of abundance based on longlines; 10) different methods for statistical standardization of indices of abundance; 11) different treatment of effort in two studies and within a study; 12) reliability of species identification; 13) removal of 1998 and 1999 values in Coastspan SE index; 14) hierarchical cluster analysis using Spearman rank vs. Pearson correlation matrices; 15) lack of explanation of how variance of length at age in growth curves was considered; and 16) use of tagging data to estimate M.

Responses: (1) As stated in the Background section of the current document, the assessment used the same catch series as previously used in SEDAR 21, updated to 2015 and incorporating any changes in estimates that may have occurred since SEDAR 21. SEDAR 21 explored uncertainty in the catches by considering a low and high catch scenario that incorporated some of the potential variability in the catch series in the more recent period (1981-2010), but not in the early period (1960-1980) because the magnitude of the catches was assumed to be very low in the early period. These scenarios were not included in the current assessment for the reasons explained under ToR 6 (1) below.

(2) The magnitude of the catches outside of the US EEZ is unknown but believed to be small, with the exception of the Mexican catches. For example, there are no reported catches of sandbar sharks in Puerto Rico or the U.S. Virgin Islands according to the Atlantic Coastal Cooperative Statistics Program (ACCSP) or eDealer data sources.

(3) We disaggregated the “Recreational + Mexican” catches into recreational and Mexican components to allow assessment of their magnitude (Table 1; Figure 1). Mexican catches in numbers accounted for about 1/3 of the total catches in 2014 and 2015 and 50% and 43% of the total catches in weight in 2014 and 2015, respectively. Catches used in the assessment were all in weight, except for the menhaden fishery discards. We now provide catches both in weight and numbers to facilitate conversion between the two. Note the numerous assumptions.

(4) We will explore the use of the censored catch approach in the future to account for unknown catches and associated uncertainty.

(5) The new estimates of natural mortality (M) at age were calculated using five life history invariant estimators (Chen and Watanabe [1989], Lorenzen [1996], Peterson and Wroblewski [1984],and the revised versions of Hoenig [1983] and Pauly [1980] developed by Then et al. [2015]). Only the new Then et al. estimators varied with respect to those used in SEDAR 21. M was computed by taking the minimum of the M estimates at age to approximate a maximum density-dependent response and the intrinsic rate of increase, r_{max}. Using the outputs from a life table/Leslie matrix approach steepness is also derived analytically based on the maximum lifetime reproductive rate ($\hat{\alpha}$), which is the product of SPR_0 and S_0 (pup survival) (Brooks et al. 2010). Given that the M estimators use von Bertalanffy growth function parameters, lifespan, and mass to compute M and that the growth curve and lifespan were updated based on additional data, M at age changed with respect to SEDAR 21. Since the life history information used for

SEDAR 54 is considered to be better than that used for SEDAR 21, the current M estimates should also be considered more reliable.

(6) The new growth function was not developed by the stock assessment analysts, but the reviewer offers some valid points about the “updated + Hale and Baremore” vs. “updated” curves, which will be transmitted to the authors of the document. Nevertheless, the current growth curve should be considered the most reliable because it includes more data points.

(7) The reviewer correctly notes the difference between the age-based maturity ogive used in the assessment and the length-based maturity ogive presented in document SEDAR54-WP-01. The decision to use the old age-based ogive responded to a technical aspect of SS3 and the fact that, as the reviewer notes, lengths would have to be transformed into ages through the growth curve with the corresponding loss of information. Using the length-based ogive would result in a slightly more productive stock, but since we already explored the effect of changing stock productivity in the low and high productivity scenarios and found that it did not greatly influence the assessment results we conclude that this change also would not substantially affect results.

(8) The proportion of maternal females was incorporated into the assessment by allowing for a one year (12 month) gestation period before the females can reproduce after becoming mature.

(9) The reviewer is correct in that the effect of hook saturation is typically not accounted for in standardization of indices of abundance based on longlines. This is partially due to the fact that the information required (percent of hooks with no catch and with no catch or bait), at least for commercial fisheries, is typically not available from observer or logbook programs. Nevertheless, this is a methodological recommendation that can affect all fish species caught on longlines and of general interest to SEDAR assessments, particularly for fishery-independent surveys (e.g., Rodgveller et al. 2008).

(10, 11) Different model selection methods were used in statistical standardization of indices of abundance; and effort was treated differently in two studies and within a study. Both of these are also technical issues of interest to all SEDAR assessments in general, and will be better addressed at a SEDAR benchmark assessment or methods workshop.

(12) Reliability of species identification: species ID is much less of an issue for sandbar sharks than for other species, such as dusky or silky sharks. Scientific observers on commercial boats and scientists on fishery-independent surveys are trained to identify them; identification in recreational fisheries is more problematic, but NMFS regularly organizes ID workshops and has produced field guides to aid in identification. Thus, species ID for this species can generally be considered reliable.

(13) The 1998 and 1999 values in the Coastspan SE index of abundance were removed by the analyst who standardized the index because those years were pilot years, survey coverage was very limited, and the methodology had not yet been standardized.

(14) The intent of implementing the hierarchical cluster analysis was to determine if the base case model results would be sensitive to alternative CPUE groupings. All indices used in the

base run were previously vetted in SEDAR 21 and included in the SEDAR 54 standard assessment base model by default. However, it was noted that some CPUE indices appeared to have conflicting trends. In other previous shark assessments using simpler models, sensitivity to conflicting CPUE indices had sometimes been evaluated either by fitting one CPUE at a time within the model, or by removing one CPUE at a time from the model fit. This can be a time-consuming process for complex modeling approaches such as SS3 and results from this approach are difficult to present concisely. Moreover, the range of uncertainty would likely be even greater had we fitted the model with one CPUE series at a time or removing one at a time. The main reason for using the grouping method was to attempt to characterize the plausible range of uncertainty and to address the potentially problematic issue of conflicting indices. The hierarchical cluster analysis was thus useful in identifying a major axis of uncertainty in assessment model results, indicated by groupings of different CPUE trends.

The reviewer replicated the hierarchical cluster analysis with the Pearson correlation coefficient used in the assessment and reanalyzed the analysis using the non-parametric Spearman rank correlation coefficient (Spearman's rho), on the basis that Spearman rank provides a more robust measure of association. The two methods resulted in different groupings. However, whether or not one method is preferred over another is debatable, and may depend upon the context of the analysis and other factors such as sample size, which was not evaluated and is a research question that is beyond the scope of a standard assessment. The selection of indices of abundance via a correlation metric is complicated by the fact that the CPUE series in question have different sample sizes and only partially overlap, or only overlap in one or two years (resulting in a sample size of 0, 1, or 2). These small sample sizes could affect the response of each method differently, and not really be related to how correlated the series are to each other. The results of the methods might not be that different if CPUE series with small sample size (overlapping years) were removed from the analysis. Given the fact that this was not a benchmark assessment, research into these topics was beyond the scope of this assessment. The major difference between the hierarchical cluster analysis with the Spearman rank correlation and the Pearson correlation is to treat CPUEs as either ranking data (Spearman rank) or interval/ratio data (Pearson). Since the hierarchical cluster analysis with the Spearman rank correlation treats CPUEs as ranking data, this grouping method is invariant to one-to-one transformations of the indices and is more robust in this sense. However, as a rule of thumb, if the data satisfy the statistical assumptions, the parametric methods are more powerful than their non-parametric counterparts. Consequently, while it may be informative to compare the alternative approaches for grouping CPUE series more formally in a future benchmark or research track assessment, this comparison was not done for this assessment.

Within the context of the current assessment, the groupings obtained from both methods are expected to provide similar sensitivity analysis results. The Spearman rank correlation analysis would add S2 (BLLOP 1), S6 (COASTSPAN NE LL) and S1 (LPS) to the "POS-1" CPUE group. S2 (BLLOP 1) had already been included in the "POS-1" CPUE group because the Assessment Panel felt that it helped extend the available time series to the period where the majority of the fishing effort occurred. However, S2 (BLLOP 1), S6 (COASTSPAN NE LL) and S1 (LPS) were all negatively correlated with one CPUE index within the "POS-1" CPUE group (S4–VA LL; SEDAR 54 WP06, their Figure 4). Consequently, adding them to the "POS-1" CPUE group would be expected to reduce the contrast among the resulting CPUE groupings obtained with the cluster analysis and in turn reduce the major axis of uncertainty in assessment model sensitivity analysis results. Consequently, sensitivity analysis results based on Spearman's rank correlation would be expected to fall within the range of those already identified in the assessment by the base run and the sensitivity analyses, although this was not explicitly evaluated.

Other CPUE groupings are also possible. For example, CIE reviewer John Neilson (this assessment review) indicated that he would like to have seen a model run that included only the two longest-running series, LPS (S1) and VA LL (S4), in order to reduce noise in the reconstruction of the population by the inclusion of the other CPUE series. However, both LPS (S1) and VA LL (S4) appear to closely follow the smoothed overall trend obtained from all CPUE series combined (SEDAR 54 WP06, their Figure 1). Consequently, sensitivity analysis results based on grouping LPS (S1) and VA LL (S4) would be expected to fall within the range of those already identified in the assessment by the base run, which included all of the CPUE series, although this was not explicitly evaluated. Other, more formal approaches have also been previously developed to combine noisy CPUE series (E.g., Conn 2010; Peterson et al 2017). Some of these approaches have been evaluated in previous HMS SEDAR assessments, but they were not implemented here because it was beyond the scope of a standard assessment.

CIE reviewer John Neilson (this assessment review) also indicated that he would like to have seen more progress on the SEDAR 21 recommendation to implement a power analysis of the ability of these CPUE surveys to detect changes in population abundance of sandbar sharks. It may be informative to compare this approach to the alternative approaches discussed above for grouping CPUE series in a future benchmark or research track assessment. However, this is a research question that is beyond the scope of the current standard assessment.

In all, the hierarchical cluster analysis used to identify potential subgroups of indices represented a first effort to determine alternate states of nature. However, this can only be considered an exploratory analysis allowed by the type of assessment undertaken— a standard assessment in this case—in which there was limited time to address methodological issues beyond those already explored and vetted in SEDAR 21.

(15) The variance of length at age in growth curves was considered in the assessment. Sex-specific CV values were initially set for age 0 and the age at L_{INF}, based on the empirical age at length derived from a combined dataset of age and length measurements. The CV for age 0 sharks was then iteratively increased until it included the smallest sharks in the age sample. This was done under the assumption that the CV was biased low due to low sample sizes in the very young and very old age classes, and that the 95% confidence interval around the growth curve should include the smallest and largest observed individuals.

(16) Use of tagging data to potentially estimate M, another methodological recommendation, will indeed be very helpful and hopefully can be explored for the next sandbar shark benchmark stock assessment, but was beyond the scope of this standard assessment as explained in the Background section above.

ToR 3: Evaluate the methods used to assess the stock, taking into account the available data
<u>Issues</u>: 1) Stock assessment is parameterized in terms of virgin biomass and catch histories are reconstructed to year of virgin biomass; 2) Reason for combining recreational and Mexican catches; 3) Reason why only F2 and F4 fisheries had asymptotic selectivities and most index selectivities were dome shaped; 4) Use of weightings (input CVs) for indices.

Responses: (1) SEDAR 21 used a state-space, age-structured production model (SSASPM), which requires that the model start at virgin conditions, i.e., SSASPM could not estimate initial depletion. For that reason, catches were reconstructed to the year believed to represent unexploited conditions, 1960, based on the collective knowledge of the SEDAR 21 Assessment Panel. The approach used in the current assessment, which used SS3, was to replicate SSASPM results using the same data inputs and then to update all those inputs with data that had become available since SEDAR 21. This is the reason why we used the same catch series as in SEDAR 21, starting in 1960 and ending in 2015 (vs. 2010 in SEDAR 21). Starting the model later (i.e. just prior to the expansion of the directed fishery) was investigated; however, estimating the additional parameters associated with the initial depletion introduced more variability in the model. For these reasons the model was run over the time frame of available data.

(2) As explained above, we kept the same data series as in SEDAR 21. The decision to combine recreational and Mexican catches dates back to SEDAR 11 (2006) and was taken by the SEDAR 11 Assessment Panel based on the belief that the two series shared the same selectivity pattern. This assumption should probably be revisited in the next benchmark assessment for sandbar shark.

(3) The double normal (dome shaped selectivity) is the preferred selectivity for implementation in SS3; where length data were available this selectivity was used to model the fishery selectivity. The South Atlantic commercial fishery (F2) was chosen to be asymptotic to prevent the model from estimating cryptic biomass that was never encountered by the main commercial fisheries (F1 and F2). Of the two fisheries F2 was chosen to have asymptotic selectivity because the length compositions from that fleet were slightly larger. The menhaden trawl fishery (F4) is assumed to catch every sandbar shark encountered and thus had constant, asymptotic selectivity (=1) over all length classes.

(4) The input CV values associated with the point estimates for individual CPUE series were entered at the values calculated from the individual standardizations (i.e. we used what was delivered). As part of the model fitting process a lowess line was fit to the CPUE data, and the CVs of the residuals from that fit were used in the stock assessment model. This is equivalent to saying that the stock assessment model should be expected to fit these data as well as the smoother. This approach is recommended on p. 1132 of Francis (2011).

ToR 4: Evaluate the assessment findings
<u>Issues</u>: 1) Provide estimated selectivity curves; 2) sample size multipliers for length compositions; 3) convergence diagnostics for SS3

Responses:
(1) The fits of the estimated length compositions to the length composition by fleet for the base case model configuration were provided in Figure 3.2.6. The estimated selectivity parameters were provided in Table 3.2.3 along with all the estimated parameters, and again as a comparison to the MCMC output in Table 3.2.11. Nevertheless, we include a separate table (Table 2, this document) with the full parameterization of the selectivity curves. See the SS3 manual for the formulation of the selectivity functions.

(2) Initial model fitting included the use of the raw sample sizes and, as an interim measure, sample sizes down-weighted by an equal scalar (0.2 in this case). Final sample size weights were determined via the Francis (2011) method, see Annex 1 of this report for details on the total number of length records, the effective sample size, and the sensitivity of the results to alternative weightings.

(3) The reviewer noted that some of the initial values were very close to the estimated values, and was correct in supposing that the initial values were derived from the preliminary model runs. The use of previously estimated values as a starting point is a common practice that facilitates the computation of the maximum likelihood estimate because the initial values are close to the MLEs. Phase alternation runs were not attempted; jitter analysis was completed in the model fitting stage but is not commonly reported. Model diagnostics in the form of MCMC runs and estimated parameters are presented in Table 3.2.11, which shows close adherence of the MLE to the MCMC 50th quantile. The final gradient was 0.00445866, estimates of model parameters are presented along with the bounds (Table 3.2.3) and no estimates were on the bounds.

ToR 5: Evaluate the stock projections, rebuilding timeframes, and generation times
Issues: 1) Results comparing projections from the base and sensitivity runs were not presented; 2) A range in M larger than 10% should have been considered in the high and low productivity scenarios and a range of steepness values should have been considered too; 3) Investigate sensitivity to alternative reasonable weighting of the length compositions

Responses: (1) This is not correct as projections were run for the base and two alternate states of nature (POS and NEG CPUE indices) with the default (base) productivity only because productivity was found to have a small effect on stock status results. This was explained on page 37 of the SAR.

(2) See response to ToR 2 (5) for estimates of M used in the current assessment. The low and high productivity scenarios not only incorporated a ± 10% change in M at age, but also a change in first year (pup) survival, a reproductive cycle of 2 vs. 3 years, and constant fecundity vs. using an increasing relationship with age. Therefore we felt that a plausible range of productivity values had been incorporated into the sensitivity scenarios. Since steepness can be considered a proxy for productivity, the low and high productivity scenarios also represent low and high steepness scenarios (ranging from 0.22 to 0.39).

(3) The length compositions are given weights based on their effective sample size, and then weighted based on the Francis method (Francis 2011). The effective sample size for this project

was the number of sets made. There was an error in the computation of the effective sample sizes for S3 BLLOP 2 which led to lower values, which were then adjusted higher with a sample size multiplier. Other reasonable weighting schemes that have been used in other assessments include all equal and low, and no weights given at all. Recognizing these facts we conducted alternative model runs using an updated sample size with no weights, sample size weighting of 0.2 across all fleets and surveys, and the Francis (2011) method as outlined in the SAR (see **Annex 1** for a complete description of methods and updated results.)

ToR 6: Consider how uncertainties in the assessment, and their potential consequences, are addressed
Issues: 1) Low and high catch scenarios were not considered as a sensitivity; 2) Assign informative priors (derived from life-history experts) to M and steepness; 3) a sensitivity where the F1 and F3 fleets had also asymptotic selectivities should have been conducted; 4) a robust cluster analysis would have provided a different grouping of indices and thus a different sensitivity

Responses: (1) We agree that we should have explained why low and high catch scenario sensitivities were not conducted in the current assessment to quantify uncertainty in catches. The reason was that the assessment used all data series in weight, except for the menhaden fishery discards (F4). Commercial landings (F1 and F2) are originally collected in weight and are census-like, therefore there is no measure of uncertainty associated with them. Mexican landings (F3) are also available in weight and are also “exact”, with no measure of precision reported either in the official statistics. The recreational catches (landings + dead discards; F3) are estimates and reported in both numbers and weight, but only the variances of the estimates in numbers are reported. The menhaden fishery discards (F4) are truly “back-of-the-envelope” estimates and have no measure of uncertainty.

(2) Developing and assigning informative priors to M and steepness may be a useful research topic for future assessments conducted within Stock Synthesis. However, M and steepness are confounded with other estimated parameters in the model and consequently their estimation within an integrated model is an ongoing area of research and outside the scope of a standard assessment. Our approach in this assessment was analogous to that used in previous HMS SEDAR assessments conducted with SSASPM, namely to fix natural mortality and productivity parameters within the assessment, then develop a plausible range for these fixed parameter values based on the most recently available scientific literature (presumably derived from the life-history experts), and then include them together in sensitivity analyses as plausible states of nature. As explained in ToR 5 (2), we used a range of M and steepness values (together) in the low and high productivity scenarios.

(3) Length composition data from fleet F3 do not support the use of an asymptotic selectivity because the length composition data is in general much smaller than the maximum observed size classes. The use of the asymptotic selectivity on one of the main fisheries was justified because we did not want the model to estimate a cryptic biomass of large sharks that could potentially skew model results. The selectivity for F1 was well fit and unimodal, therefore the choice of a double normal for this fishery was appropriate.

(4) We agree that the two methods resulted in different groupings. However, whether or not one method is preferred over another is debatable, and may depend upon the context of the analysis. See response to ToR 2 (14).

ToR 7: Research recommendations
Good research recommendations were provided by the reviewer, many of which can be explored in the next full benchmark stock assessment.

1.2. Addressing Review of CIE reviewer Jean-Jacques Maguire

ToR 2: Evaluate the data used in the assessment
Issues: 1) Magnitude of catches of same stock of sandbar shark in Caribbean; 2) reporting on data uncertainties; 3) use of a single commercial fleet for the two regions prior to 1991; 4) showing recreational and Mexican catches separately; 5) standardization method for VIMS LL index; 6) use of different approaches for index standardization; 7) SS3 being fit to aggregated length compositions; 8) indicate what numbers in each cell in Figure 3.2.2 are; and 9) indices do not all cover the same size/age range.

Responses: (1) As explained in ToR 2 (2) for reviewer Cadigan, the magnitude of the catches outside of the US EEZ is unknown but believed to be small, with the exception of the Mexican catches. The only Caribbean catches the analysts had access to for this assessment were from Puerto Rico and the U.S. Virgin islands and there were no sandbar sharks reported.

(2) As explained in the Background section and for reviewer Cadigan, treatment of data uncertainties was very limited because the datasets had been vetted in SEDAR 21 and this assessment was a standard assessment, which does not contemplate in-depth re-evaluation of the input datasets.

(3) Again, the same catch series as in SEDAR 21 were used for this assessment and re-formulating the catch series, with the associated model structural changes this would imply was not contemplated for this assessment. This recommendation can be considered when the next benchmark assessment takes place and all input datasets and model configurations are fully evaluated.

(4) The recreational and Mexican catch series were split (see response in ToR 2 (3) for reviewer Cadigan) and it can be seen that the 2014 and 2015 Mexican catches were the mean of the 2011-2013 catches.

(5) The standardization for the VIMS longline index was done by a member of the Assessment Panel, not the stock assessment analysts, but it used the same methodology as in the document presented in SEDAR 21 (SEDAR21-DW-18).

(6) The use of different statistical approaches for index standardization responds to the individual analyst's preferences. Although some may be more preferable than others, all methods were

vetted by the Assessment Panel in SEDAR 21. This is also a methodological issue of general interest to all SEDAR assessments.

(7) Although only the plots for aggregated length compositions were shown in the SAR, length compositions were fit annually for each index and fishery in SS3.

(8) Figure 3.2.2 shows the available length frequency data by fishery and CPUE series, aggregated across years, used in the base case model configuration. The numbers in the figure reflect the adjusted input sample size, where the adjustment is the variance adjustment based on the Francis method. The "effN" is calculated from the comparison of the observed and expected proportions and is independent of the input sample size. The "effN" is also used in the McAllister and Ianelli tuning method, which was not applied in this analysis. Note that the text in Table 3.2.2 of the SAR refers to the N as the “Effective Sample Size used in Model”, however this table shows the N prior to the implementation of the minimum sample size, which is the reason for the incongruity.

(9) We agree that the indices represent different segments of the stock. However, our expectation is that the effect on the reconstructed population dynamics is accounted for in Stock Synthesis by applying the corresponding selectivity curves before fitting each CPUE index separately within the model likelihood.

ToR 3: Evaluate the methods used to assess the stock, taking into account the available data
Issues: 1) Selectivity was assumed to be time invariant but management changes over time may indicate otherwise; 2) fits to the indices in current assessment are equally poor as those in SEDAR 21

Responses: (1) Although management did change over the assessment period, the selectivity was relatively well fit to the individual fleet length composition data. Of the four fishing fleets that management regulations may have affected, only the commercial longline fleets had sufficient length composition data from before and after the 2008 closure of the fishery, and the length composition data was similar across both time periods.

(2) There are indices that are only partially fit, and fits of individual indices in the assessment that are poor. As noted in the assessment this is because there are conflicting trends in some of the CPUE series, especially in the later years. As the assessment noted, the base case model was implemented as closely as possible to the previous assessment, which used all CPUE series to model the population. Noting different trends in the CPUE series, the SAR included results of the hierarchal cluster analysis carried out to group CPUE series, which provided alternative groupings of CPUE series. See response to reviewer Cadigan (TOR 2 point 14).

ToR 4: Evaluate the assessment findings
Issues: (1) Presentation of assessment outputs online; 2) lack of basis in the report to choose which model run is more reflective of true stock trends; 3) there is not an informative stock-recruitment relationship because the curve does not reach an asymptote

Responses: (1) This is a good recommendation for the SEFSC and SEDAR. A spreadsheet summarizing all the data inputs used to be prepared for benchmarks assessments, but all outputs are not typically made available, although the code for the stock assessment model is provided to the reviewers.

(2) The idea behind considering the two alternate states of nature (POS and NEG) in addition to the base run identified in SEDAR 21 was to attempt to characterize the plausible range of uncertainty associated with including potentially conflicting CPUE indices within the assessment model (see also response to ToR 2 (14) for reviewer Cadigan). The indices of abundance used in the base run were all vetted in SEDAR 21 but nevertheless contained conflicting trends, which led to a poor fit. Because the base case model results were sensitive to alternative CPUE groupings identified with the hierarchical cluster analysis, the CPUE groupings were carried forward as plausible alternate states of nature and their implications for management advice were evaluated with projections along with the other plausible states of nature. However, because the alternative states of nature are essentially sensitivity analyses for the base model run, less time was spent by the analysts on the development of each individual alternative state of nature model run than on the base model run. For example, it was noted that the "POS" run had the highest uncertainty in overfished status but the lowest in overfishing status of the three runs, did not include the CPUEs that tracked the smallest animals, but included the CPUEs of the main fisheries and surveys that track the older, mature segment of the stock. In contrast, the NEG run had the lowest uncertainty in overfished status but the highest in overfishing status of the three runs, included indices that track the smallest animals in the stock, but did not include indices that track the mature segment of the stock, the main commercial fisheries, or the longest running and more geographically complete surveys. In comparison, the base run had intermediate uncertainty in both overfished and overfishing status and included all indices.

(3) See response to ToR 3 (3) for reviewer Neilson below, additionally note that the stock recruit relationship is extremely informative because we:

1. Assume that there is a stock recruit relationship and define it as a Beverton-Holt
2. Fix steepness of the Beverton-Holt (BH), which defines the shape of the curve for various levels of depletion based on the well understood life history of the stock (compared to say a teleost)
3. Allow recruitment deviations around the stock recruitment curve, and
4. Constrain stock recruitment deviations based on a fixed sigma_r value (fixed at 0.18) associated with a reasonable range around the curve.

In this assessment, the relatively low steepness value of the recruitment curve was determined analytically, based on life history invariant methods and the life history for this species, which is fairly well studied. The shape of a BH curve that would be expected for a less productive stock (relatively low steepness) does not have an asymptote at unfished equilibrium spawning stock size (Quinn and Deriso 1999 see figure 3.1 therein). Plotting the approximate BH curve resulting from the sandbar assessment parameter values using the equation in Quinn and Deriso (1999, page 88 eq 3.6, BH_R=(BH_alpha*BH_S)/(1+BH_beta*BH_S)) results in the same curve presented in this analysis. In comparison, the shape of a BH curve that would be expected for a more highly productive stock (relatively higher steepness) would increase more rapidly at low stock size and approach an asymptote at unfished equilibrium (Quinn and Deriso 1999 see figure

3.1 therein). In contrast, an uninformative stock recruit relationship would have a steepness of 1 (which would be a flat recruitment curve for any depletion level) or have no recruitment relationship (as with random recruitment deviates as in some NPFMC rockfish models).

It is true though that the length frequency information is less informative about recruitment cycles than in other teleost (i.e. tuna) fisheries that often have clearly defined recruitment modes visible in the length composition.

ToR 7: Research recommendations
Good research recommendations were provided by the reviewer, many of which can be explored in the next full benchmark stock assessment.

1.3. Addressing Review of CIE reviewer John Neilson

ToR 1: Evaluate the data used in the assessment (following the reviewer's numbering which does not match that in the original ToRs)
<u>Issues</u>: 1) absence of a description of the biology of the species; 2) provision of better background on factors included in CPUE standardization and documentation in working papers; 3) non-inclusion of 2016 data in the assessment; 4) pattern in REC+MEX catch series ramping up from 1978 to 1983; 5) change in average weight of sharks in that catch series over the same period; 6) 1983 peak in catch in numbers; 7) reconciling different peaks in catch in numbers or weight; 8) catches in Mexican states and stock area, including Central America; 9) indices not covering period of rapid development and heavy exploitation of the fishery; 10) power analysis of CPUE series; and 11) scenario with LPS and VALL indices only.

Responses: (1) and (2) See comment on Background section. This is only done in a benchmark assessment; these are procedural issues.

(3) Final landings data for a given year are typically not available till April-June of the following year. Since this assessment started in January 2017, 2016 data were thus not available and the final year of data was 2015.

(4) This is an artifact related to the catch reconstruction strategy adopted in SEDAR 21 for years 1960-1980 (see Table 1); essentially values for 1960-1974 for all series except the menhaden fishery discards were based on an assumed linear increase and values for 1975-1980, on an assumed exponential increase to the first available year of values for the REC, MEX, and commercial catch data series.

(5) and (7) The peak in numbers in Figure 2.1 of the SAR corresponds to small fish in the recreational fishery whereas the peak in weight in Figure 2.2 corresponds to larger fish in the commercial fishery.

(6) This peak comes from the MRFSS recreational fisheries survey; in other assessments similar peaks were handled by taking the geometric mean of the surrounding years but this approach was not followed in SEDAR 21 and thus not reconsidered in the current assessment.

(8) The two Mexican states considered, Tamaulipas and Veracruz, are those closest to Texas and it was considered (dating back to SEDAR 11 and the 2002 Large Coastal Shark stock assessment) that sandbar sharks estimated to have been caught in these states all came from the U.S. since there are no known nursery grounds of sandbar sharks in the Mexican Gulf of Mexico. The stock area considered for this and previous assessments of sandbar sharks contemplated only U.S. waters and inclusion of Mexican catches was a recognition that the unit stock may extend beyond the U.S. No information on catches from the Caribbean (see response to ToR 2 (2) for reviewer Cadigan) or from Central America were available, let alone indices of abundance. The SEDAR 21 Data Workshop report (page 20) stated that "after considering the available data, the working group decided that sandbar sharks inhabiting the waters of the western North Atlantic Ocean (including the Gulf of Mexico) should be considered a single stock. Genetic data indicate no significant differentiation between the Gulf of Mexico and western North Atlantic Ocean (Heist et al. 1995, Heist and Gold 1999) and tag-recapture data showed a high frequency of movements between basins (SEDAR21-DW-38)." So for all practical purposes the stock assessment is limited to sandbar sharks in U.S. waters. Consideration of a different stock definition will have to be undertaken at the next benchmark stock assessment, although if the stock is indeed found to extend into Mexican, Caribbean, and Central American waters, the assessment may not even be feasible since there are no agreements with nations from these areas for collaborative stock assessments and management and information from these areas will be very poor.

(9) We agree with this.

(10) This is an issue for consideration in a full benchmark assessment. See also response to ToR 2 (14) for reviewer Cadigan.

(11) See response for reviewer Cadigan ToR 2 (14).

ToR 2: Evaluate the methods used to assess the stock taking into account the available data
Issues: (1) The decision to include all eleven indices in the base case is questionable.

Responses: (1) See comment on Background section. The current assessment used all eleven indices because this was the base model configuration vetted in SEDAR 21 and the purpose of the current assessment was to update the base model but not to re-evaluate the adequateness of each individual index of abundance. The conflicting trends in the indices were addressed by exploring the two alternative states of nature (POS and NEG), which represent two separate hypotheses about the trend of the stock.

ToR 3: Evaluate the assessment findings
Issues: 1) The authors appear to support the base case findings compared with the two alternative CPUE groupings, but there is rather limited support for this conclusion; (2) absence of any index covering the more southern range of distribution; (3) the stock-recruitment relationship is not informative

Responses: (1) See response to ToR 4 (2) for reviewer Maguire.

(2) See response to ToR 1 (8) above.

(3) The reviewer argued that the stock-recruit relationship was not informative on the basis that the reproductive biology of the stock was not well understood and that he did not understand the statement that “annual recruitment deviates from the recruitment relationship were estimated, but constrained to reflect the limited scope for compensation given the estimates of fecundity”. While it is true that uncertainty remains about a biennial vs. triennial reproductive cycle in this population, the stock-recruitment relationship of this and other shark species is much stronger than those of teleosts and the reason why it was constrained to not deviate much from a direct relationship. Regardless of a 2- or 3-year reproductive cycle the biology of this species is constrained by its annual fecundity. See also response to ToR 4 (3) for reviewer Maguire.

ToR 4: Evaluate the stock projections, rebuilding timeframes, and generation times
<u>Issues</u>: 1) Unsure that the range of productivity scenarios developed reflected the uncertainty in the range of reproductive output

Responses: (1) The range of productivity did reflect the uncertainty in the range of reproductive output as it considered the 2 vs. 3 year reproductive cycle, constant vs. increasing fecundity, and varying steepness. See also response to ToR 5 (2) for reviewer Cadigan.

ToR 5: Consider how uncertainties in the assessment, and their potential consequences, are addressed
<u>Issues</u>: 1) S54-WP-06 indicated that combining multiple conflicting indices into a stock assessment is ill advised yet the base case model did precisely that.

Responses: (1) The recognition of the potential problem of combining indices with conflicting trends is precisely what led to the consideration of the two alternate states of nature, or different CPUE groupings. An in-depth reconsideration of the adequateness of each individual index of abundance would have only been possible during a benchmark assessment, but since the current assessment was a standard assessment, the base case run was maintained as such.

ToR 6: Research recommendations
There are several useful research recommendations by the reviewer, such as a compilation of information on movement and migration provided by archival satellite tags that can be considered in the next full benchmark stock assessment. Others, such as starting a new index of abundance covering the Caribbean Sea is not very realistic because it is not practically feasible. The same can be said for developing an index of abundance in Mexican waters of the southern Gulf of Mexico, which was attempted back in the late 1990s-early 2000s, but abandoned due to many insurmountable logistical difficulties. An index for the U.S. recreational fishery was developed for SEDAR 21 (S21-DW11), but it was not recommended for use by the authors because of changing reporting issues with unidentified carcharhinid sharks that likely biased the index developed for sandbar sharks.

ToR 8: Provide guidance on key improvements in data or modeling approaches

Issues: 1) Review and evaluate the highly uncertain Mexican removals; 2) follow ICCAT best practices for evaluation and comparison of abundance indices

Responses: (1) Mexican removals have been incorporated into U.S. shark stock assessments since the 2002 Large Coastal Shark stock assessment. They are highly uncertain because of the lack of species-specific catch monitoring for sharks in that country, which makes any reconstruction be based on rough numbers and numerous assumptions. Characterization of Mexican removals in these assessments should thus be considered a good faith effort to include likely removals of sandbar sharks belonging to a U.S. stock by Mexican fishermen and also responds to concerns long expressed by the U.S. commercial fishing industry.

(2) We thank the reviewer for pointing this out, but such best practices already exist (SEDAR Procedures Workshop 1. Abundance indices workshop: developing protocols for submission of abundance indices to the SEDAR process, Miami, FL, Oct-14-17, 2008) and actually pre-date those developed by ICCAT, which were based in part on them. The reason, as explained many times throughout this document, why the indices were not re-evaluated is because this is only done in a benchmark assessment.

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Table 1. Catches of sandbar sharks in numbers (top) and round weight (lb rw; bottom). For all series, except Menhaden discards, values for 1960-1974 were based on an assumed linear increase and values for 1975-1980, on an assumed exponential increase. For menhaden, 1960-1980 values are the mean for the years with data (1981-2015). *Commercial landings* for 1981-1985 were originally in numbers and were transformed into weight using the average weight from the bottom longline observer program (BLLOP) for the first three years of data (1994-1996). For 1986-2015, landings were originally in dressed weight (lb dw) and were transformed into numbers by using average weights from the BLLOP. Note that for 1986-1993, the average weight used was the mean for the first 3 years of data from the BLLOP (1994-1996). *Recreational catches* (sum of MRFSS/MRIP, Headboat, and Texas Parks and Wildlife Department) are available both in numbers and weight since 1981. *Mexican landings* for 1981-1999 were originally derived in numbers and were grandfathered in from SEDAR 21 and previous assessments. Since 2000 they are available in tons from the official CONAPESCA fishery statistics. *Menhaden fishery discards* original estimates were in numbers. No size information was given for 13 sandbar sharks observed in the fishery (De Silva et al. 2001). Assuming the same size distribution as for dusky sharks (see their Figure 3), the mean interval size is 100 cm TL, which when transformed into weight is ca. 15 lb round weight.

Table 1. Continued, catches of sandbar sharks in numbers.

Year	Com + Un (GOM)	Com + Un (SA)	REC + MEX	REC	MEX	Menhaden disc
1960	59	25	65			469
1961	119	51	129			469
1962	178	76	194			469
1963	237	102	259			469
1964	297	127	323			469
1965	356	152	388			469
1966	415	178	453			469
1967	475	203	517			469
1968	534	228	582			469
1969	593	254	647			469
1970	653	279	711			469
1971	712	305	776			469
1972	771	330	841			469
1973	831	355	905			469
1974	890	381	970			469
1975	949	406	1035			469
1976	969	414	1035			469
1977	1033	442	1042			469
1978	1236	529	1234			469
1979	1807	773	6366			469
1980	3018	1291	56090			469
1981	4650	1990		111964	10065	696
1982	4650	1990		32127	11822	713
1983	5024	2149		335591	11126	705
1984	6861	2936		53914	11708	705
1985	6373	2727		75214	7910	635
1986	18908	6918		122654	9368	626
1987	54132	19851		33914	6962	653
1988	78241	46440		70117	9142	635
1989	104839	55874		23904	8346	670
1990	87469	34971		53018	10738	653
1991	88900	7781		28142	9063	505
1992	69488	31105		30006	9675	444
1993	45201	26777		22434	9080	452
1994	86311	39963		12485	8762	479
1995	49038	35360		22677	9892	452
1996	32126	33419		37798	10732	444
1997	21190	20275		35089	8364	452
1998	32264	30391		33164	7208	435
1999	18087	35212		18522	7976	479
2000	16781	20544		9498	7035	409
2001	26185	21998		30514	6414	383
2002	27572	28788		6994	5025	374
2003	23663	21567		4691	4327	365
2004	18472	20667		4226	4232	374
2005	14109	19265		1654	4425	374
2006	22096	20022		1187	4646	357
2007	6068	10845		6418	4078	357
2008	668	1485		4421	2572	357
2009	2705	1281		7162	2372	357
2010	1914	907		3076	3183	357
2011	2323	1100		1325	1987	357
2012	1148	544		903	2548	322
2013	827	1031		1803	2415	305
2014	836	1809		1935	2316	270
2015	511	2916		1256	2316	270

Table 1. Continued, catches of sandbar sharks in round weight (lb rw).

Year	Com + Un (GOM)	Com + Un (SA)	REC + MEX	REC	MEX	Menhaden disc
1960	1706	730	23			7130
1961	3411	1459	47			7130
1962	5117	2189	70			7130
1963	6822	2919	94			7130
1964	8528	3649	117			7130
1965	10234	4378	141			7130
1966	11939	5108	164			7130
1967	13645	5838	188			7130
1968	15351	6568	211			7130
1969	17056	7297	235			7130
1970	18762	8027	258			7130
1971	20467	8757	282			7130
1972	22173	9487	305			7130
1973	23879	10216	329			7130
1974	25584	10946	352			7130
1975	27290	11676	376			7130
1976	38726	16569	1683			7130
1977	54955	23512	7545			7130
1978	77985	33365	33813			7130
1979	110666	47347	151541			7130
1980	157042	67189	679160			7130
1981	222854	95346		1275754	1768029	10579
1982	222854	95346		301703	2076665	10844
1983	240742	103000		2150129	1954405	10711
1984	328810	140678		596478	2056640	10711
1985	305417	130670		753648	1389479	9653
1986	906657	331748		1178908	1645593	9521
1987	2595647	951976		363426	1222953	9918
1988	3751280	2226262		798806	1605894	9653
1989	5026903	2678802		230308	1466067	10182
1990	4194398	1677034		434663	1886249	9918
1991	4263137	373136		266432	1592016	7670
1992	3332287	1491637		240546	1699521	6744
1993	2167613	1284084		182129	1595003	6876
1994	4457324	2063819		108749	1539143	7273
1995	2432649	1754122		173492	1737640	6876
1996	1365842	1420773		431776	1885195	6744
1997	911985	872596		274025	1469229	6876
1998	1069426	1007343		313248	1266165	6612
1999	816315	1589178		149913	1401073	7273
2000	961151	1176696		79215	543220	6215
2001	1336967	1123169		212558	509011	5819
2002	1628331	1700102		48154	399266	5686
2003	1337509	1219039		45516	343510	5554
2004	988116	1105506		42789	336768	5686
2005	877933	1198814		19676	349456	5686
2006	1260251	1141955		21921	363982	5422
2007	374373	669129		78432	322762	5422
2008	45640	101532		78231	208687	5422
2009	185972	88098		64917	191194	5422
2010	123447	58479		26093	255890	5422
2011	156090	73942		16811	158464	5422
2012	77237	36589		19479	203564	4893
2013	58278	59218		22281	197378	4628
2014	52893	114491		12140	186469	4099
2015	74008	156547		15418	186469	4099

Table 2. The fits of the estimated length compositions to the length composition by fleet for the base case model configuration from the SEDAR 54 SAR. The number of estimated selectivity parameters varies based on the selectivity type and availability of sex specific length data. See the SS3 manual for the formulation of the selectivity functions.

Fleet Name	Fleet or Survey #	Selectivity Type	Sex Specific	Sex Offset	PEAK	TOP	ASC-WIDTH	DSC-WIDTH	INIT	FINAL	Peak Offset	ASC Offset	DSC Offset	Final Offset	Scale Offset
Commercial GOM	F1	Double Normal	Yes	Male from Female	149.4	-10.0	5.5	5.6	-999	-999	4.0	0.7	-0.6	0.0	0.7
Recreational & Mexican	F3	Double Normal	No	NA	55.1	-10.0	0.0	7.2	-15	-999	NA	NA	NA	NA	NA
LPS	S1	Double Normal	No	NA	155.5	-10.0	7.3	14.6	-999	-999	NA	NA	NA	NA	NA
BLLOP_1	S2	Double Normal	Yes	Female From Male	155.5	-10.0	7.9	5.0	-999	-999	4.0	-0.1	-0.6	0.0	1.0
BLLOP_2	S3	Double Normal	Yes	Male from Female	158.2	-10.0	6.7	6.7	-999	-999	4.2	-0.1	-0.6	0.0	0.7
VA_LL	S4	Double Normal	No	NA	45.0	-10.0	-9.4	8.7	-999	-999	NA	NA	NA	NA	NA
NMFS_LLSE	S5	Double Normal	Yes	Male from Female	161.8	-10.0	7.1	5.6	-999	-999	-6.2	-0.7	-0.8	0.0	0.7
CST_NE_LL	S6	Double Normal	Yes	Male from Female	57.0	-10.0	-8.0	7.6	-999	-999	5.4	10.9	-0.8	0.0	1.1
NMFS_NE	S7	Double Normal	Yes	Female From Male	132.7	-10.0	8.0	6.3	-999	-999	0.0	-1.0	1.0	0.0	2.3
PLLOP	S8	Double Normal	Yes	Male from Female	147.3	-10.0	6.5	6.0	-999	-999	4.0	-0.4	-1.2	0.0	1.4
SCDNR_RedDr	S10	Double Normal	Yes	Male from Female	92.9	-10.0	6.0	6.0	-999	-999	4.0	1.6	-0.3	0.0	0.6
SEAMAP_LL_SE	S11	Double Normal	Yes	Male from Female	93.6	-10.0	6.1	8.0	-999	-999	4.2	-0.4	-0.3	0.0	1.2

Fleet Name	Fleet or Survey #	Selectivity Type	CODE	GRAD_Lo	GRAD_HI	KNOT_1	KNOT_2	KNOT_2	KNOT_4	KNOT_5	VAL_1	VAL_2	VAL_3	VAL_4	VAL_5
COASTSPAN_SE_LL	S9	Cubic Spline	0	0.004	-0.003	45	55	65	80	85	3.36	2.54	2.00	-1.05	-4.40

Fleet Name	Fleet or Survey #	Selectivity Type		Inflection	Width
Commercial SA	F2	Logistic	No	93.63	29.72
Menhaden	F4	Logistic	No	45.67	1.00

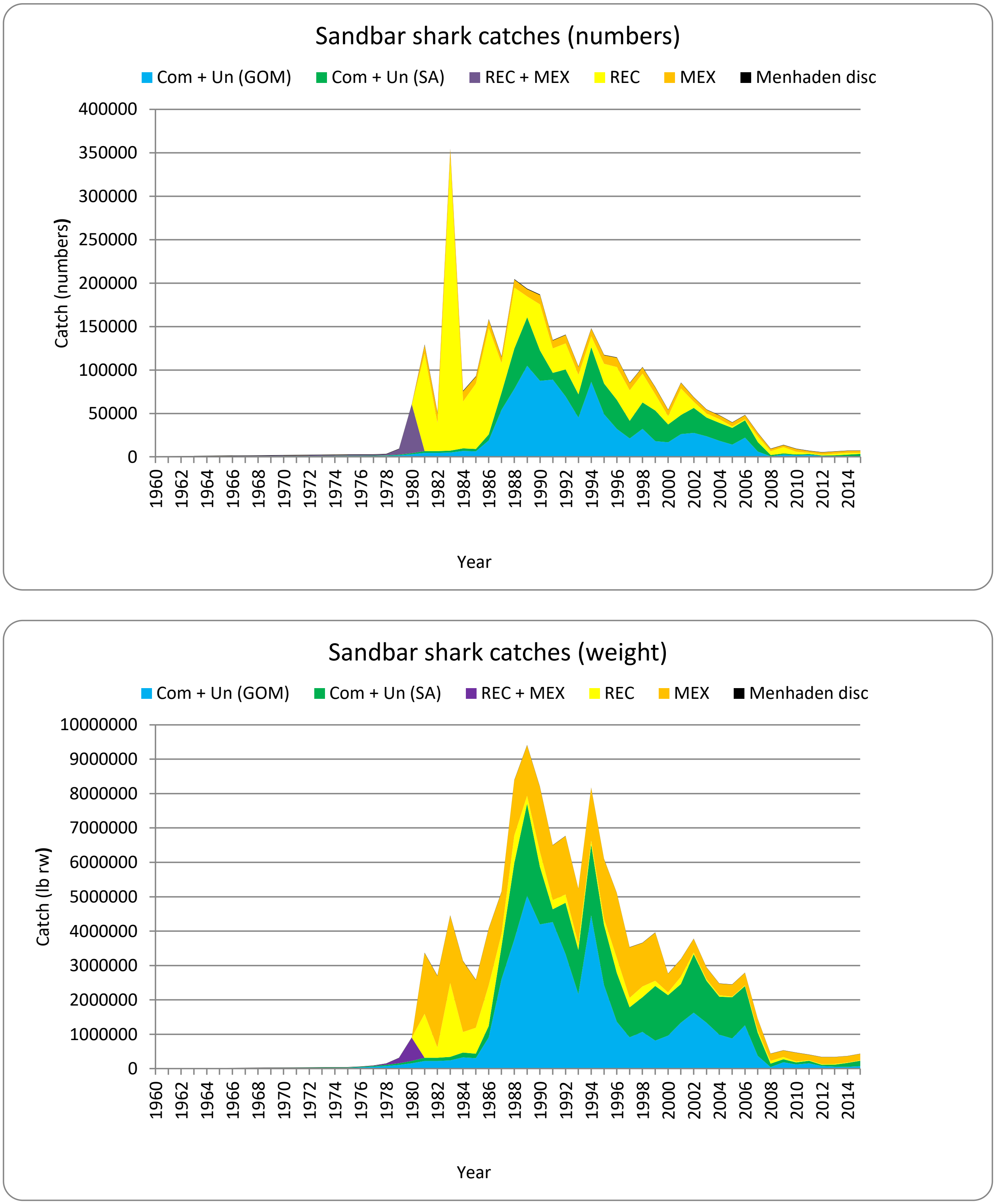

Figure 1. Catches of sandbar sharks in numbers (top panel) and weight (bottom panel).

Post Review Update. Annex 1.

The purpose of this annex is to present the changes introduced to the base case model run arising from comments made by CIE reviewer Cadigan (ToR 5(3)). In checking the data inputs for the model, errors in interpretation of the raw data were discovered. In particular, a number of the individual sets, clustered in only a few months of the dataset, from the observer database, had non-unique set identification numbers. These non-unique identification numbers led to incorrect sample size calculations. The observer data set informed both commercial fisheries (F1 and F2) as well as the bottom longline survey. This error resulted in lower numbers of effective sample size inputs for these datasets. The corrected data is presented as Table A1 (Table 3.2.2 in the SAR), and is expanded to show the total number of records, the number of records after a minimum annual sample size (of 33) was applied, as was done for the SAR, the total effective sample size (number of sets), the effective sample size after the minimum annual sample size was applied, and the effective sample size used in the model after re-weighting based on the Francis (2011) method.

Based on the revised effective sample size calculations, three additional model runs were completed:

1) Model run PRU-1: No length composition weighting
2) Model run PRU-2: All length composition weights at 0.2
3) Model run PRU-3: Same as the base model run from SEDAR 54 SAR, except that the initial length composition effective sample sizes were corrected. As in the SAR the length composition weighting was based on the Francis (2011) iterative re-weighting method.

Results of these model runs are presented below, in comparison to the base case run from SEDAR 54 (Table A2 and Figure A1). Results of the post review update runs without length composition weighting (PRU-1) and with all weights at 0.2 (PRU-2) should be considered diagnostic because they are intermediate runs used to illustrate the effect of no weighting (PRU-1) and an ad-hoc weighting scheme (PRU-2). The results of the run with the length composition weights based on the Francis (2011) method, PRU-3, should be considered an update to the base case model that takes into account the comments from the CIE reviewer. Reference points for the base case model configuration from the SEDAR 54, along with the intermediate models and the updated base case model using revised sample size estimates and model weights as explained above are presented in Table A2. Relevant tables and figures from the updated bases case model (run PRU-3) are produced below (Tables A3 to A9; Figures A1 to A13).

From these updated model runs, we conclude, as expected, that model results are sensitive to data weighting. This result is expected because there is conflicting information within the data provided to the assessment (i.e., conflicting trends were identified in CPUE possibly resulting in conflicting information between CPUE and length composition data in the model). One approach for dealing with conflicting data in an integrated stock assessment model has been to "down-weight" conflicting CPUE or length composition data (as identified by its poor fit in the model or its effect of the fit to other data) by arbitrarily reducing its input sample size. An alternative approach, used here for the base model run and the updated base model run, PRU-3, is to "right-weight" the CPUE and length composition data used in the model based on the effective sample size estimated from the model fit to the data using the Francis iterative re-weighting approach. The goal of this approach is to reduce the influence of data which is most in conflict with model fits to all of the data by iteratively re-weighting data input sample size to equal that estimated within the fitted model.

Iterative re-weighting methods can also be sensitive to the initial sample size provided for each data component, as observed here for the base model run compared to the updated base model run PRU-3. Consequently, it is important to provide the best initial effective sample size estimate as possible for compositional data, for example based on a plausible approximation of the effective sample size such as the number of sets from which lengths were measured. In contrast, the number of individuals measured is generally not a good estimate of effective sample size for length composition data because fish (and presumably sharks) of the same size tend to school together. Unfortunately, estimates of effective sample size for compositional data, such as the number of sets or trips, are not routinely provided to the analyst, which can to lead to errors interpreting the data, as discovered for this addendum. In the future, it is recommended that the data providers develop effective sample size estimates for their own compositional data and provide these estimates along with the raw data to SEDAR for review prior to use within the model.

Given that model results were known to be sensitive to data weighting, a sensitivity analysis to the corrected range of initial sample sizes for compositional data was provided in this addendum. Model results based on the corrected range of initial sample sizes and "right-weighting" the CPUE and length composition data using the Francis iterative re-weighting approach (the updated base model run PRU-3) are directly comparable to those obtained from the base model run of the assessment, except for corrections made to the input sample sizes, and are thus recommended for use in management advice.

Given that model results are known to be sensitive to data weighting when there are conflicting data, as in the current assessment, it may be important in future SEDAR assessments to routinely include sensitivity analyses to data weighting, e.g., by including a range of initial sample sizes for compositional data (either determined from the data or calculated post-hoc by the analyst) along with the use of alternative iterative re-weighting methodologies (e.g., those of both Francis 2011 and McAllister and Ianelli 1997; e.g., as reviewed by Punt 2017) along with the other types of sensitivity analyses routinely conducted within SEDAR stock assessments.

Projections based on the PRU-3 model were carried out using the forecast module internal to SS3 via the maximum likelihood estimates (MLE) and also via MCMC analysis. Both MLE and MCMC projections were carried out at a level of constant TACs (see main SAR for explanation) that would allow stock rebuilding by 2070 with a 50% and 70% probability based on the MLE projections. The MLE projections (Figures A12 and A13 left panel) use uncertainty associated with the MLE parameter estimates calculated internally to SS3 using the inverse Hessian method in the maximum likelihood estimation, which is then propagated into the variance of derived quantities, such as the fishing mortality intensity that would produce MSY, and forecasts of stock abundance and future yield for a given total allowable catch (TAC). MCMC projections with Stock Synthesis (Figures A12 and A13 right panel) included MCMC uncertainty in estimated parameters (see table A9). The standard MLE projection approach is consistent with projection approaches used in the past for HMS stocks. MCMC projections are presented here only for comparison with the MLE projections, and to show variability of stock status under TACs selected using the standard projection approach. Details on the projections are in section 3.2.10 and 3.4 of the SAR. The MCMC projections indicated that the TAC (based on the MLE projections) that would allow stock rebuilding by 2070 with a 50% or 70% probability may reasonably be expected to slightly exceed $SSF/SSF_{MSY}=1$ in the rebuilding year, which is due to the non-normality of the MCMC estimates of SSF/SSF_{MSY}, and should be interpreted with caution.

In all, projections based on the revised effective sample size and length composition weights based on the Francis (2011) method (Table A3) indicate that a TAC of 246 mt (whole weight) would achieve a 70% chance of rebuilding in 2070.

TABLES

Table A1 (update of SEDAR 54 SAR Table 3.2.2). Details on the number of length records, the number of length records where the annual sample size was larger than the minimum sample size (of 33), the Total (effective) Sample Size, the initial effective Sample Size where the annual sample size was larger than the minimum sample size, the sample size multiplier, and the resulting effective sample size input in the Stock Synthesis updated base case model configuration.

Number	Name	Number of Records	Number of Records where annual sample size was greater than minimum sample size	Sex Specific Records	Total Sample Size	Initial Sample Size where annual Sample size was greater than minimum sample size	Sample Size Multiplyer	Effective Sample Size Used in Model
1	F1_COM_GOM	14634	14634	Yes	5720	5720	0.06	362
2	F2_COM_SA	31385	31385	Yes	17142	17142	0.03	539
3	F3_RecMEX	604	334	No	156	56	0.86	41
4	F4_MEN_DSC	NA	NA	NA	NA	NA	1	NA
5	S1_LPS	236	167	No	114	67	0.50	28
6	S2_BLLOP_1	24862	24862	Yes	21821	21821	0.01	306
7	S3_BLLOP_2	21157	21157	Yes	888	888	0.32	284
8	S4_VA_LL	6488	6380	Yes	872	840	0.12	103
9	S5_NMFS_LLSE	1045	1005	Yes	550	516	0.38	163
10	S6_CST_NE_LL	1084	1069	Yes	385	374	0.36	124
11	S7_NMFS_NE	5122	5122	Yes	333	333	0.10	38
12	S8_PLLOP	256	177	Yes	76	28	0.95	27
13	S9_COASTSPAN_SE_LL	1539	1515	Yes	592	575	1.50	864
14	S10_SCDNR_RedDr	516	493	Yes	203	194	0.13	17
15	S11_SEAMAP_LL_SE	842	842	Yes	515	515	0.37	188

TABLE A2 (update of SEDAR 54 SAR Table 3.2.8). Reference points for base case model configuration from SEDAR 54, along with intermediate models using revised sample size estimates and model weights as explained above. Stock status in 2015 relative to MSY based reference points is in the grey shaded rows. Bold text indicates updated base case model configuration (PRU-3).

	SEDAR 54 BASE	PRU-1	PRU-2	**PRU-3**
Catch2015/MSY	0.47	1.05	0.61	**0.45**
MSY	417	187	321	**435**
B_0	97218	41064	71225	**99769**
B_{MSY}	42778	18175	31422	**43952**
SSF_0	1505	636	1103	**1545**
SSF_{MSY}	662	281	487	**681**
SSF_{2015}/SSF_{MSY}	0.60	0.31	0.75	**0.77**
F_{MSY}	0.07	0.07	0.07	**0.07**
F_{2015}/F_{MSY}	0.75	4.50	0.86	**0.58**
SSF_{2015}	397	87	366	**527**
F_{2015}	0.05	0.33	0.06	**0.04**
Total Biomass 2015	29665	4764	24323	**37620**
MSST	579	246	425	**595**

Table A3 . (update of SEDAR 54 SAR Table 3.2.10**)**. Projections based on TAC levels (in mt whole weight) from MLE projections. For the base case updated with revised sample sizes and sample size weightings (model run PRU-3) as used in the SEDAR 54 SAR, projections were implemented with constant TAC allowing rebuilding of stock by 2070 with 50% and 70% probability (TOR 4A).

Model Run	Probability of Rebuilding by Year Rebuild	Year Rebuild	TAC Based on MLE Projections	50th Quantile (of $SSF_{YR\_rebuild}/SSF_{MSY}$) based on MCMC Projections
Model run PRU-3	70%	2070	246	1.212
Model run PRU-3	50%	2070	342	1.069

Table A4 (update of SEDAR 54 SAR Table 3.2.9). Estimated stock status based on MCMC analysis for the updated base case model configuration (PRU-3 Updated Base). Values shown are the probabilities of being in that particular quadrant of the phase (Kobe) plot: red (overfished and overfishing); orange (not overfished but overfishing); yellow (overfished but no overfishing); green (not overfished and no overfishing).

	Quadrant			
	1	**2**	**3**	**4**
PRU-3 Updated Base	**0.2%**	**0.00%**	**85.0%**	**14.8%**

Table A5. (update of SEDAR 54 SAR Table 3.2.3). List of parameters estimated in SS3 for sandbar shark (updated base run). The list includes (columns from left to right) the parameter labels, the predicted parameter value, the minimum, maximum and initial value for the parameter, the parameter standard deviation, the prior type if applicable, the prior value (if applicable) and the prior standard deviation if applicable. Parameters that were held fixed (not estimated) are not included in this table.

Label	Value	Min	Max	Init	Parm_StDev	PR_type	Prior	Pr_SD
SR_LN(R0)	6.30	3	10	6.27	0.09	No_prior	NA	NA
SizeSel_1P_1_F1_COM_GOM	150.47	35	259	150.90	1.74	No_prior	NA	NA
SizeSel_1P_3_F1_COM_GOM	5.65	-15	15	5.96	0.21	No_prior	NA	NA
SizeSel_1P_4_F1_COM_GOM	5.61	-15	15	5.51	0.23	No_prior	NA	NA
SzSel_1Male_Ascend_F1_COM_GOM	0.57	-15	15	-0.05	0.21	No_prior	NA	NA
SzSel_1Male_Scale_F1_COM_GOM	0.88	-15	15	1.34	0.13	No_prior	NA	NA
SizeSel_2P_1_F2_COM_SA	92.45	1	200	94.68	3.08	No_prior	NA	NA
SizeSel_2P_2_F2_COM_SA	30.54	1	100	31.03	4.93	No_prior	NA	NA
SizeSel_3P_1_F3_RecMEX	55.19	35	259	55.03	0.70	Normal	55	1
SizeSel_3P_2_F3_RecMEX	-10.00	-15	15	-10.00	1.00	Normal	-10	1
SizeSel_5P_1_S1_LPS	160.19	35	259	155.50	23.02	No_prior	NA	NA
SizeSel_5P_3_S1_LPS	7.35	-15	15	7.31	0.91	No_prior	NA	NA
SizeSel_5P_4_S1_LPS	14.41	-15	15	14.62	14.81	No_prior	NA	NA
SizeSel_8P_1_S4_VA_LL	41.26	35	258	41.27	0.98	No_prior	NA	NA
SizeSel_8P_3_S4_VA_LL	-5.06	-15	15	-8.52	44.76	No_prior	NA	NA
SizeSel_9P_1_S5_NMFS_LLSE	162.15	35	259	156.52	5.59	No_prior	NA	NA
SizeSel_9P_3_S5_NMFS_LLSE	7.17	-15	15	6.91	0.28	No_prior	NA	NA
SizeSel_9P_4_S5_NMFS_LLSE	5.61	-15	15	5.88	0.74	No_prior	NA	NA
SzSel_9Male_Peak_S5_NMFS_LLSE	-6.13	-20	200	3.00	7.13	No_prior	NA	NA
SzSel_9Male_Ascend_S5_NMFS_LLSE	-0.68	-15	15	-0.14	0.46	No_prior	NA	NA
SzSel_9Male_Descend_S5_NMFS_LLSE	-0.83	-15	15	-0.60	1.12	No_prior	NA	NA
SzSel_9Male_Scale_S5_NMFS_LLSE	0.76	-15	15	0.67	0.16	No_prior	NA	NA
SizeSel_10P_1_S6_CST_NE_LL	57.07	35	258	70.82	2.60	No_prior	NA	NA
SizeSel_10P_3_S6_CST_NE_LL	-5.52	-15	15	6.07	94.12	No_prior	NA	NA
SizeSel_10P_4_S6_CST_NE_LL	7.56	-15	15	6.92	0.22	No_prior	NA	NA

Table A5 continued.

Label	Value	Min	Max	Init	Parm_StDev	PR_type	Prior	Pr_SD
SzSel_10Male_Peak_S6_CST_NE_LL	5.33	-20	200	4.21	3.70	No_prior	NA	NA
SzSel_10Male_Ascend_S6_CST_NE_LL	8.41	-15	15	-0.12	94.13	No_prior	NA	NA
SzSel_10Male_Descend_S6_CST_NE_LL	-0.78	-15	15	-0.60	0.34	No_prior	NA	NA
SzSel_10Male_Scale_S6_CST_NE_LL	1.08	-15	15	1.00	0.25	No_prior	NA	NA
SizeSel_11P_1_S7_NMFS_NE	134.16	35	259	129.64	12.78	No_prior	NA	NA
SizeSel_11P_3_S7_NMFS_NE	8.09	-15	15	7.90	0.62	No_prior	NA	NA
SizeSel_11P_4_S7_NMFS_NE	6.33	-15	15	6.66	1.04	No_prior	NA	NA
SzSel_11Fem_Scale_S7_NMFS_NE	2.32	-15	15	2.22	0.87	No_prior	NA	NA
SizeSel_12P_1_S8_PLLOP	147.59	35	259	146.63	6.28	No_prior	NA	NA
SizeSel_12P_3_S8_PLLOP	6.59	-15	15	6.70	0.72	No_prior	NA	NA
SzSel_12Male_Ascend_S8_PLLOP	-0.45	-15	15	-0.14	0.85	No_prior	NA	NA
SzSel_12Male_Descend_S8_PLLOP	-1.21	-15	15	-0.60	1.27	No_prior	NA	NA
SzSel_12Male_Scale_S8_PLLOP	1.49	-15	15	1.07	0.76	No_prior	NA	NA
SizeSpline_Val_1_S9_COASTSPAN_SE_LL_13	3.36	-5	5	1.24	0.42	No_prior	NA	NA
SizeSpline_Val_2_S9_COASTSPAN_SE_LL_13	2.55	-5	5	1.00	0.42	No_prior	NA	NA
SizeSpline_Val_3_S9_COASTSPAN_SE_LL_13	2.01	-5	5	-0.69	0.41	No_prior	NA	NA
SizeSpline_Val_4_S9_COASTSPAN_SE_LL_13	-1.04	-5	5	2.06	0.25	No_prior	NA	NA
SizeSel_14P_1_S10_SCDNR_RedDr	92.36	35	259	86.71	5.60	No_prior	NA	NA
SzSel_14Male_Ascend_S10_SCDNR_RedDr	1.59	-15	15	1.07	1.24	No_prior	NA	NA
SzSel_14Male_Descend_S10_SCDNR_RedDr	-0.40	-15	15	1.08	1.84	No_prior	NA	NA
SzSel_14Male_Scale_S10_SCDNR_RedDr	0.60	-15	15	0.79	0.35	Sym_Beta	4	50
SizeSel_15P_1_S11_SEAMAP_LL_SE	93.90	35	258	95.74	3.06	No_prior	NA	NA
SizeSel_15P_4_S11_SEAMAP_LL_SE	7.94	-15	15	8.09	0.28	No_prior	NA	NA
SzSel_15Male_Ascend_S11_SEAMAP_LL_SE	-0.35	-15	15	-0.12	0.44	No_prior	NA	NA
SzSel_15Male_Descend_S11_SEAMAP_LL_SE	-0.26	-15	15	-0.60	0.34	No_prior	NA	NA
SzSel_15Male_Scale_S11_SEAMAP_LL_SE	1.17	-15	15	1.16	0.22	No_prior	NA	NA

TABLE A6. (update of SEDAR 54 SAR Table 3.2.4). Estimated recruitment deviations in the updated base case model configuration.

Label	Value	Parm_StDev
Early_RecrDev_1970	-0.01878	0.17832
Early_RecrDev_1971	-0.01969	0.17822
Early_RecrDev_1972	-0.01931	0.17816
Early_RecrDev_1973	-0.01805	0.17809
Early_RecrDev_1974	-0.02039	0.17782
Early_RecrDev_1975	-0.01439	0.17797
Early_RecrDev_1976	-0.01067	0.17848
Early_RecrDev_1977	-0.00264	0.17909
Early_RecrDev_1978	0.01648	0.18025
Early_RecrDev_1979	0.02774	0.18055
Main_RecrDev_1980	0.02085	0.17954
Main_RecrDev_1981	0.01590	0.17963
Main_RecrDev_1982	0.01170	0.18015
Main_RecrDev_1983	0.02641	0.17961
Main_RecrDev_1984	0.01520	0.17992
Main_RecrDev_1985	-0.00073	0.17801
Main_RecrDev_1986	0.00942	0.17788
Main_RecrDev_1987	0.01700	0.17826
Main_RecrDev_1988	0.00798	0.17670
Main_RecrDev_1989	-0.02533	0.17385
Main_RecrDev_1990	-0.05532	0.17086
Main_RecrDev_1991	-0.05410	0.17024
Main_RecrDev_1992	-0.03480	0.16991
Main_RecrDev_1993	0.02070	0.17444
Main_RecrDev_1994	0.10840	0.18032
Main_RecrDev_1995	0.17842	0.18458
Main_RecrDev_1996	0.27186	0.19062
Main_RecrDev_1997	0.24669	0.18680
Main_RecrDev_1998	0.12786	0.17649
Main_RecrDev_1999	0.03661	0.17304
Main_RecrDev_2000	-0.08378	0.16650
Main_RecrDev_2001	-0.07805	0.16531
Main_RecrDev_2002	-0.05940	0.16860
Main_RecrDev_2003	0.08830	0.16843
Main_RecrDev_2004	0.04935	0.17298
Main_RecrDev_2005	0.34426	0.16951
Main_RecrDev_2006	0.21908	0.17408
Main_RecrDev_2007	0.11204	0.16823
Main_RecrDev_2008	0.02746	0.16196
Main_RecrDev_2009	-0.19572	0.16328
Main_RecrDev_2010	-0.06344	0.15904

Table A6 Continued

Label	Value	Parm_StDev
Main_RecrDev_2011	-0.14510	0.16151
Main_RecrDev_2012	-0.03919	0.15618
Main_RecrDev_2013	-0.04099	0.15998
Main_RecrDev_2014	0.00198	0.15828
Main_RecrDev_2015	-0.09317	0.16273

Table A7 (update of SEDAR 54 SAR Table 3.2.5)**.** Estimated total biomass (in whole weight, mt), spawning stock fecundity (1000s) and recruits (1000s) in the updated base case model.

Year	Total Biomass	Spawning Stock Fecundity	Recruits
1960	99769	1545	547
1961	99756	1545	547
1962	99741	1544	547
1963	99726	1544	547
1964	99710	1544	547
1965	99694	1544	547
1966	99676	1543	547
1967	99658	1543	547
1968	99639	1543	547
1969	99620	1542	547
1970	99578	1542	536
1971	99518	1541	536
1972	99439	1541	536
1973	99347	1541	537
1974	99241	1540	535
1975	99134	1540	538
1976	99031	1539	540
1977	98938	1539	544
1978	98865	1538	555
1979	98804	1536	561
1980	98667	1534	556
1981	98138	1531	553
1982	95827	1524	549
1983	93711	1516	556
1984	90228	1505	547
1985	87441	1491	535
1986	85022	1477	538
1987	81838	1451	536
1988	78431	1402	520
1989	73525	1324	486
1990	68367	1226	449
1991	63815	1141	429
1992	60200	1063	418
1993	56653	985	419
1994	54055	921	436
1995	50323	832	436
1996	47814	770	452
1997	45804	725	421
1998	44544	693	361
1999	43164	663	319

Table A7 continued.

Year	Total Biomass	Spawning Stock Fecundity	Recruits
2000	41514	634	273
2001	40495	610	267
2002	39260	585	263
2003	37910	556	292
2004	37021	533	272
2005	36610	516	356
2006	36316	501	306
2007	35884	485	268
2008	36008	481	245
2009	36424	485	197
2010	36705	490	227
2011	36881	496	211
2012	37056	502	237
2013	37244	509	239
2014	37451	517	253
2015	37620	527	233

Table A8 (update of SEDAR 54 SAR Table 3.2.6). Estimated fishing mortality by fleet, with total fishing mortality and F/F_{MSY}.

Year	F1_COM_GOM	F2_COM_SA	F3_RecMEX	F4_MEN_DSC	F_Total	F/F_{MSY}
1960	0	0	0	0.0001	0	0.002
1961	0.0001	0	0	0.0001	0	0.003
1962	0.0001	0	0	0.0001	0	0.003
1963	0.0001	0	0	0.0001	0	0.003
1964	0.0001	0	0	0.0001	0	0.004
1965	0.0002	0	0	0.0001	0	0.004
1966	0.0002	0	0	0.0001	0	0.005
1967	0.0002	0	0	0.0001	0	0.005
1968	0.0002	0	0	0.0001	0	0.006
1969	0.0003	0	0	0.0001	0	0.006
1970	0.0003	0	0	0.0001	0	0.006
1971	0.0003	0	0	0.0001	0	0.007
1972	0.0003	0	0	0.0001	0.001	0.007
1973	0.0004	0.0001	0	0.0001	0.001	0.008
1974	0.0004	0.0001	0	0.0001	0.001	0.008
1975	0.0004	0.0001	0	0.0001	0.001	0.009
1976	0.0006	0.0001	0.0001	0.0001	0.001	0.013
1977	0.0008	0.0001	0.0006	0.0001	0.002	0.023
1978	0.0012	0.0002	0.0025	0.0001	0.004	0.056
1979	0.0016	0.0002	0.0112	0.0001	0.013	0.186
1980	0.0023	0.0003	0.0505	0.0001	0.053	0.749
1981	0.0034	0.0005	0.2388	0.0002	0.243	3.414
1982	0.0034	0.0005	0.2011	0.0002	0.205	2.885
1983	0.0038	0.0005	0.3758	0.0002	0.38	5.346
1984	0.0053	0.0008	0.2604	0.0002	0.267	3.75
1985	0.0051	0.0007	0.2144	0.0002	0.221	3.1
1986	0.016	0.0019	0.2876	0.0002	0.306	4.298
1987	0.0484	0.0058	0.162	0.0002	0.216	3.043
1988	0.0753	0.0143	0.2466	0.0002	0.336	4.73
1989	0.1101	0.0185	0.179	0.0003	0.308	4.328
1990	0.0999	0.0125	0.2563	0.0003	0.369	5.187
1991	0.109	0.003	0.217	0.0002	0.329	4.626
1992	0.0905	0.0126	0.2372	0.0002	0.34	4.786
1993	0.062	0.0114	0.225	0.0002	0.299	4.198
1994	0.1356	0.0196	0.2109	0.0002	0.366	5.149
1995	0.079	0.0178	0.2466	0.0002	0.344	4.83
1996	0.0465	0.0152	0.3027	0.0002	0.365	5.124
1997	0.0321	0.0097	0.2316	0.0002	0.274	3.846
1998	0.0386	0.0115	0.2168	0.0002	0.267	3.755
1999	0.0303	0.0187	0.2269	0.0003	0.276	3.881

Table A8 Continued.

Year	F1_COM_GOM	F2_COM_SA	F3_RecMEX	F4_MEN_DSC	F_Total	F/F_{MSY}
2000	0.0364	0.0142	0.0972	0.0002	0.148	2.082
2001	0.0516	0.014	0.1175	0.0002	0.183	2.576
2002	0.0644	0.0219	0.0754	0.0002	0.162	2.276
2003	0.0542	0.0162	0.065	0.0002	0.136	1.906
2004	0.0407	0.015	0.063	0.0002	0.119	1.672
2005	0.0367	0.0165	0.0574	0.0002	0.111	1.559
2006	0.0535	0.016	0.058	0.0002	0.128	1.795
2007	0.016	0.0094	0.0609	0.0002	0.086	1.216
2008	0.0019	0.0014	0.0451	0.0002	0.049	0.684
2009	0.0076	0.0012	0.0431	0.0002	0.052	0.733
2010	0.0049	0.0008	0.0499	0.0002	0.056	0.785
2011	0.006	0.001	0.0323	0.0002	0.04	0.556
2012	0.0029	0.0005	0.0414	0.0002	0.045	0.633
2013	0.0022	0.0008	0.0405	0.0002	0.044	0.614
2014	0.002	0.0015	0.0358	0.0002	0.04	0.555
2015	0.0028	0.0021	0.0362	0.0002	0.041	0.58

Table A 9. (update of SEDAR 54 SAR Table 3.2.11). Comparison of MLE estimates and the 50th quantile of the MCMC estimates.

Label	MLE Estimate	MCMC 50th Quantile
SR_LN(R0)	6.305	6.337
SizeSel_1P_1_F1_COM_GOM	150.473	150.328
SizeSel_1P_3_F1_COM_GOM	5.648	5.651
SizeSel_1P_4_F1_COM_GOM	5.614	5.635
SzSel_1Male_Ascend_F1_COM_GOM	0.573	0.561
SzSel_1Male_Scale_F1_COM_GOM	0.879	0.891
SizeSel_2P_1_F2_COM_SA	92.455	92.583
SizeSel_2P_2_F2_COM_SA	30.536	31.443
SizeSel_3P_1_F3_RecMEX	55.190	55.105
SizeSel_3P_2_F3_RecMEX	-9.998	-10.014
SizeSel_5P_1_S1_LPS	160.188	188.405
SizeSel_5P_3_S1_LPS	7.349	8.235
SizeSel_5P_4_S1_LPS	14.412	10.428
SizeSel_8P_1_S4_VA_LL	41.263	43.489
SizeSel_8P_3_S4_VA_LL	-5.061	-1.748
SizeSel_9P_1_S5_NMFS_LLSE	162.154	162.764
SizeSel_9P_3_S5_NMFS_LLSE	7.170	7.219
SizeSel_9P_4_S5_NMFS_LLSE	5.611	5.664
SzSel_9Male_Peak_S5_NMFS_LLSE	-6.126	-6.546
SzSel_9Male_Ascend_S5_NMFS_LLSE	-0.681	-0.693
SzSel_9Male_Descend_S5_NMFS_LLSE	-0.832	-0.881
SzSel_9Male_Scale_S5_NMFS_LLSE	0.765	0.780
SizeSel_10P_1_S6_CST_NE_LL	57.069	56.908
SizeSel_10P_3_S6_CST_NE_LL	-5.520	-2.264
SizeSel_10P_4_S6_CST_NE_LL	7.556	7.579
SzSel_10Male_Peak_S6_CST_NE_LL	5.328	6.281
SzSel_10Male_Ascend_S6_CST_NE_LL	8.412	5.685
SzSel_10Male_Descend_S6_CST_NE_LL	-0.781	-0.909
SzSel_10Male_Scale_S6_CST_NE_LL	1.077	1.138
SizeSel_11P_1_S7_NMFS_NE	134.156	135.205
SizeSel_11P_3_S7_NMFS_NE	8.088	8.214
SizeSel_11P_4_S7_NMFS_NE	6.330	6.490
SzSel_11Fem_Scale_S7_NMFS_NE	2.320	2.611
SizeSel_12P_1_S8_PLLOP	147.593	151.251
SizeSel_12P_3_S8_PLLOP	6.593	7.072
SzSel_12Male_Ascend_S8_PLLOP	-0.446	-0.574
SzSel_12Male_Descend_S8_PLLOP	-1.209	-1.898

Table A9 Continued

Label	MLE Estimate	MCMC 50th Quantile
SzSel_12Male_Scale_S8_PLLOP	1.494	1.942
SizeSpline_Val_1_S9_COASTSPAN_SE_LL_13	3.361	3.432
SizeSpline_Val_2_S9_COASTSPAN_SE_LL_13	2.548	2.606
SizeSpline_Val_3_S9_COASTSPAN_SE_LL_13	2.006	2.069
SizeSpline_Val_4_S9_COASTSPAN_SE_LL_13	-1.041	-1.012
SizeSel_14P_1_S10_SCDNR_RedDr	92.358	93.711
SzSel_14Male_Ascend_S10_SCDNR_RedDr	1.585	6.428
SzSel_14Male_Descend_S10_SCDNR_RedDr	-0.401	-0.057
SzSel_14Male_Scale_S10_SCDNR_RedDr	0.596	0.539
SizeSel_15P_1_S11_SEAMAP_LL_SE	93.903	93.209
SizeSel_15P_4_S11_SEAMAP_LL_SE	7.940	7.990
SzSel_15Male_Ascend_S11_SEAMAP_LL_SE	-0.347	-0.427
SzSel_15Male_Descend_S11_SEAMAP_LL_SE	-0.262	-0.263
SzSel_15Male_Scale_S11_SEAMAP_LL_SE	1.174	1.195

FIGURES

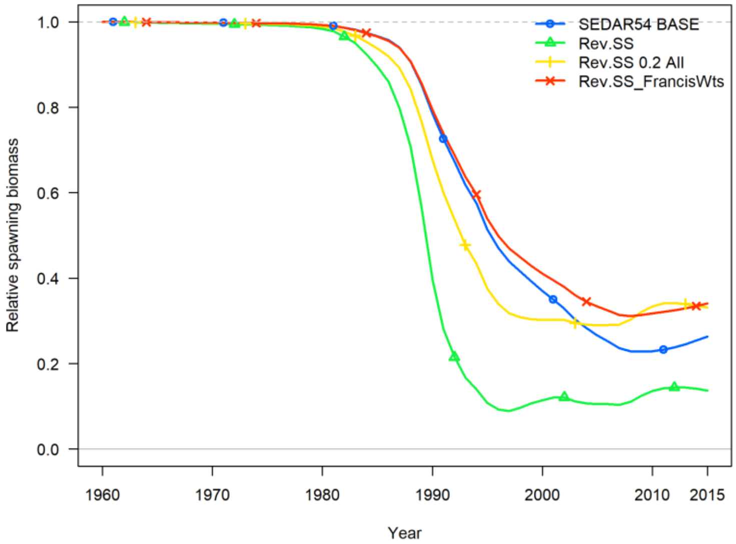

Figure A1. Relative spawning biomass for the SEDAR 54 Base case (blue line, SEDAR54 Base), the SEDAR 54 base case model with revised sample size (green line denoted Rev.SS, i.e. no length composition weighting), all length composition weights at 0.2 (yellow line, denoted Rev.SS 0.2 all), and length composition weights based on the Francis (2011) method (red line, denoted Rev.SS_FancisWts) (Rev.SS, Rev,SS 0.2 All, Rev.SS Franciswts are defined above as PRU-1, PRU-2, and PRU-3, respectively).

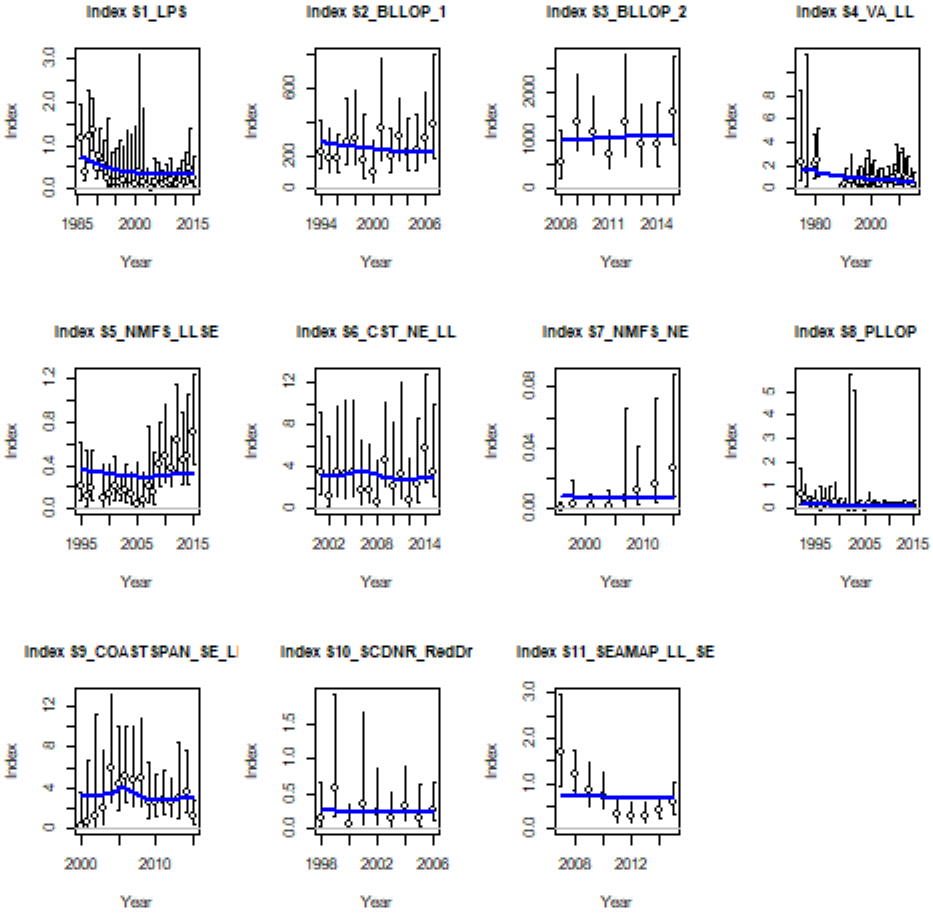

Figure A2. (Figure 3.2.3 in the SAR) Fits of the predicted relative abundance trends (blue lines) to the observed relative abundance trends and uncertainty intervals based on input CVs by fleet for the updated base case model configuration.

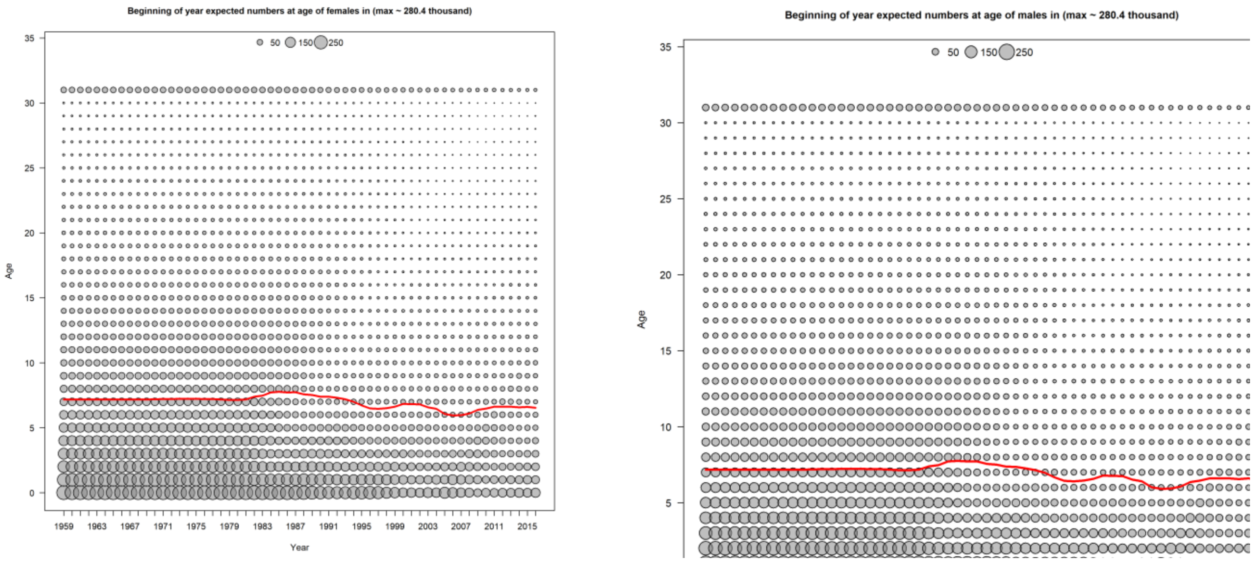

Figure A3 (Figure 3.2.4 in the SAR) Estimated numbers at age of female (left panel) and male (right panel) by year for the updated base case model configuration.

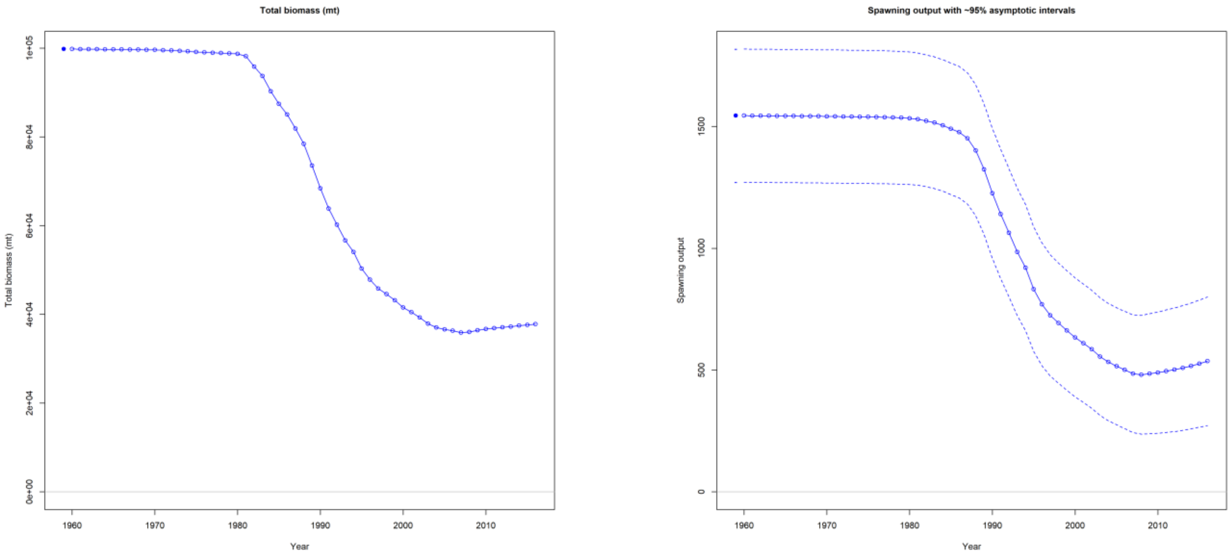

Figure A4. (Figure 3.2.5 in the SAR) Estimated total biomass (left panel) and spawning output (SSF, right panel) by year for the updated base case model configuration.

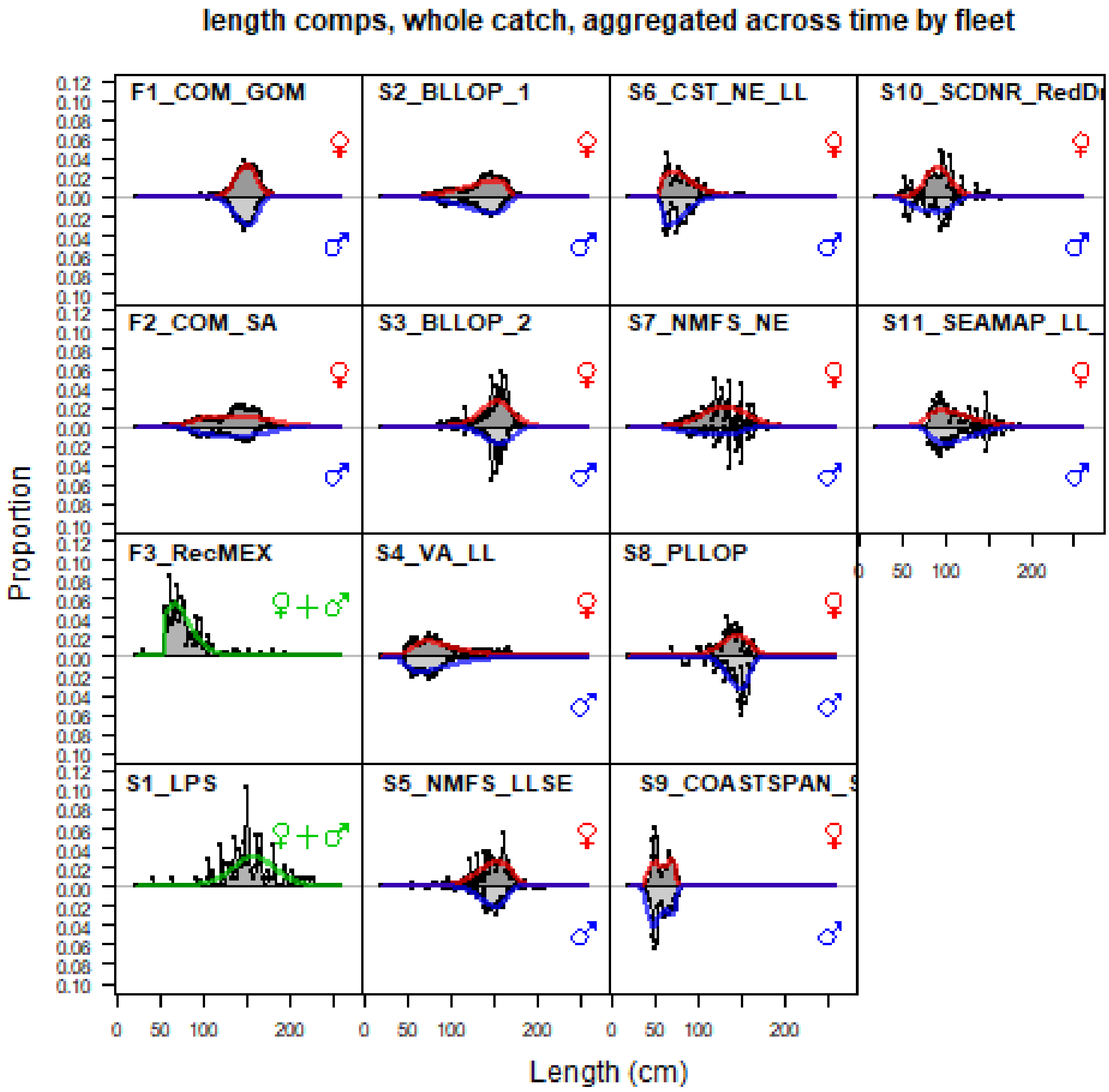

Figure A5. (Figure 3.2.6 in the SAR). Fits of the predicted length compositions (red: females; blue: males; green: combined sexes) to the observed length composition (grey histograms) by fleet for the updated base case model configuration. Where possible the sex specific selectivity was estimated. For sex specific length compositions (all except F3 and S1) the top half of each panel shows the female length composition and estimated fit, while the bottom shows the male length compositions and corresponding fits.

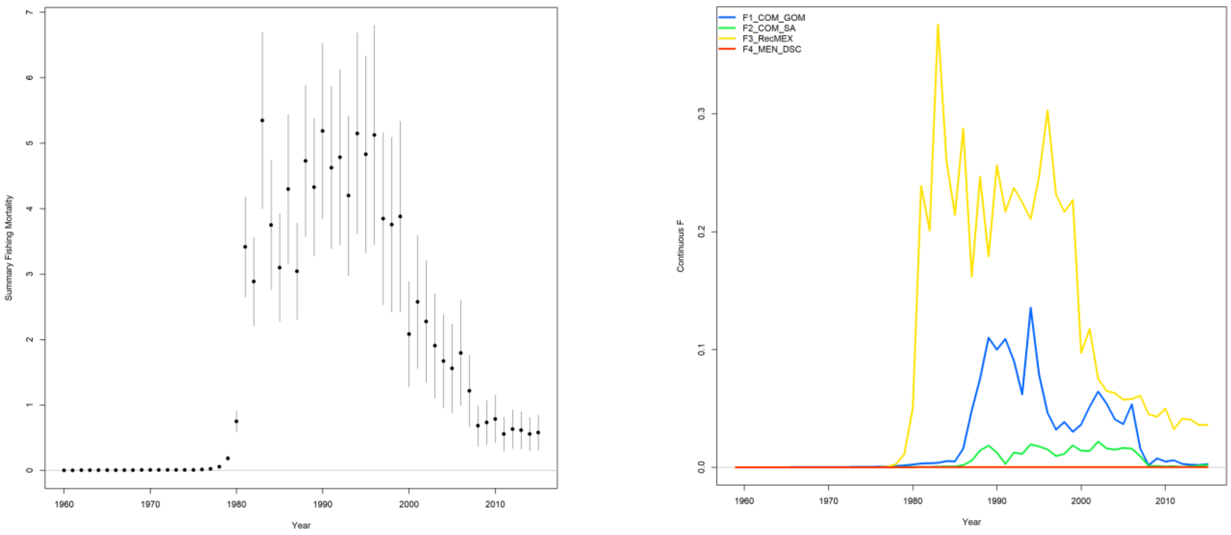

Figure A6. (Figure 3.2.7 in the SAR)**.** Estimated F/F$_{MSY}$ (left panel) and fleet specific (right panel) fishing mortality by year for the updated base case model configuration.

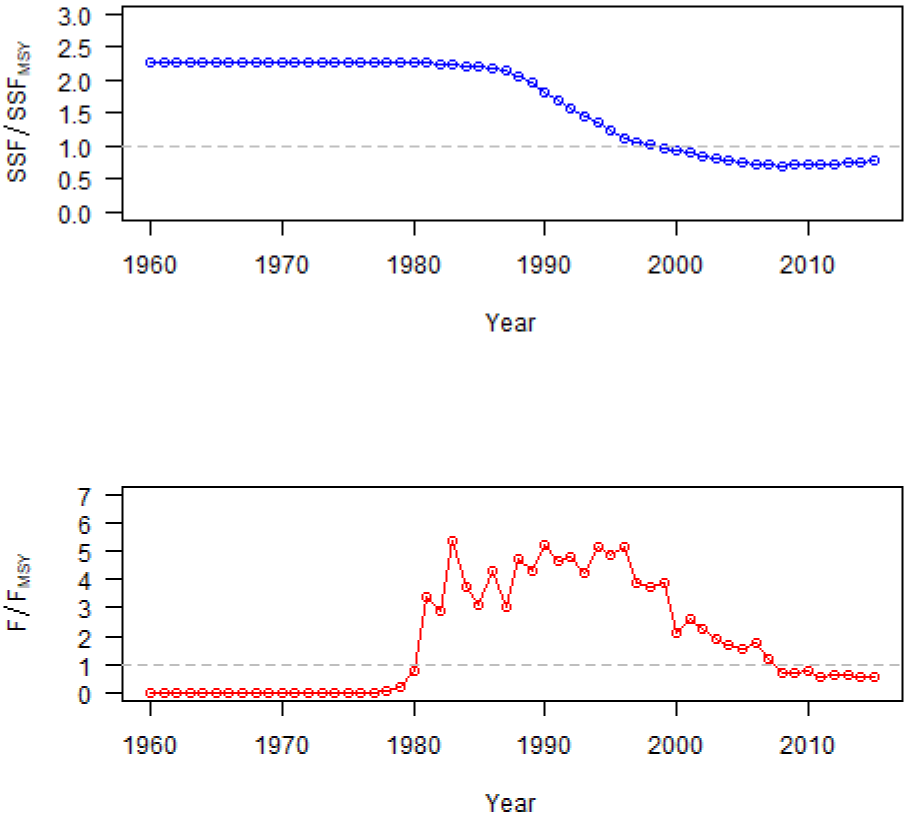

Figure A7 (Figure 3.2.8 in the SAR). Time series of stock status parameters F/F$_{MSY}$ and SSF/SSF$_{MSY}$ for the updated base case model configuration.

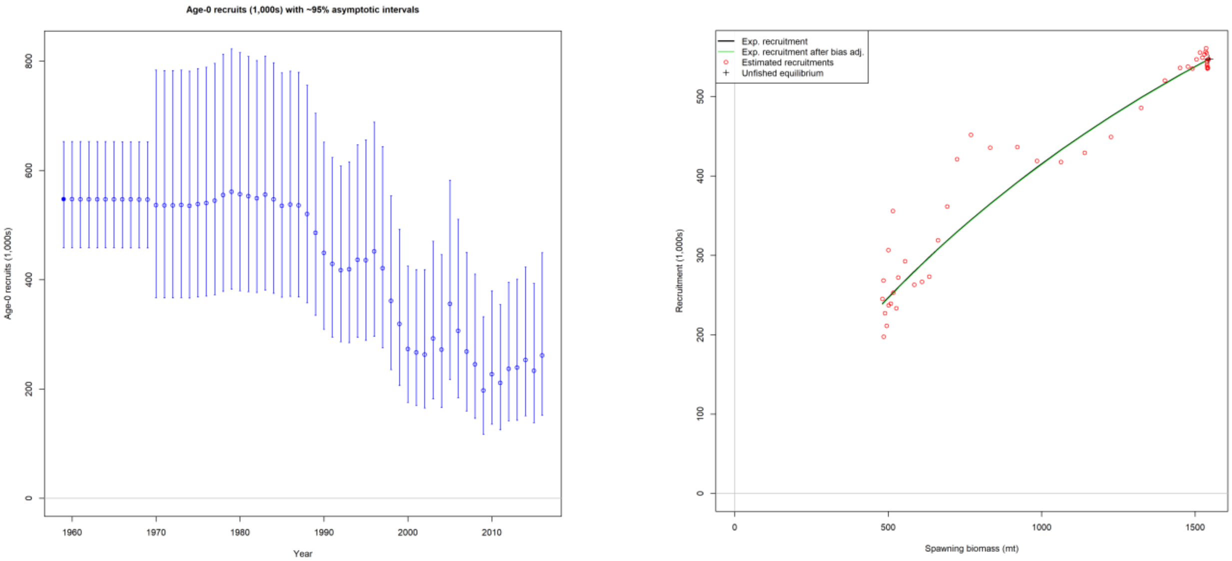

Figure A8. (Figure 3.2.9 in the SAR). Estimated annual recruits (left panel) and estimated stock recruitment relationship (right panel) with annual recruitment deviates (red circles in right panel) by year for the updated base case model configuration.

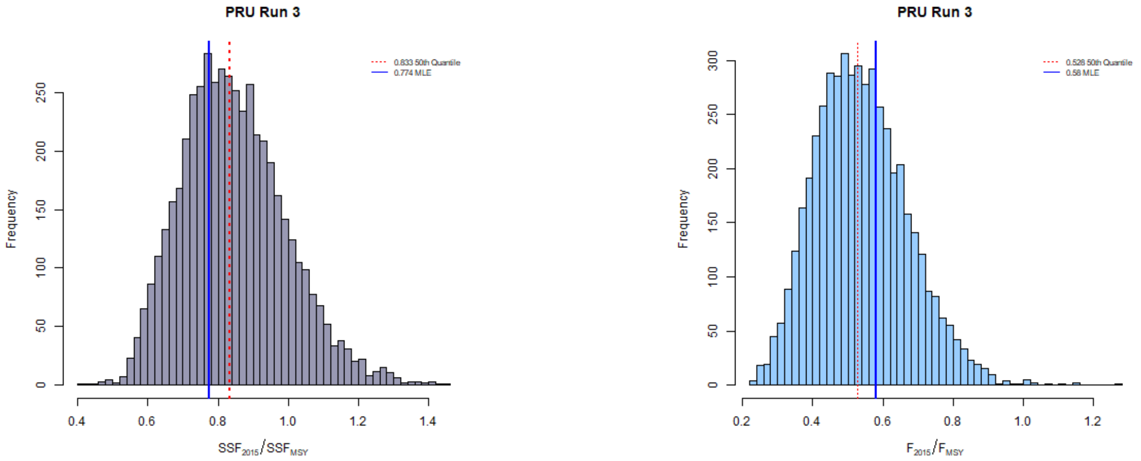

Figure A9 (Figure 3.2.11. in the SAR). Estimated spawning output in 2015 relative to MSY (SSF_{2015}/SSF_{MSY}, left panel) and estimated total fishing mortality in 2015 relative to MSY (F_{2015}/F_{MSY}, right panel) for the updated base case model configuration, comparing the maximum likelihood estimate (MLE blue line in both panels) obtained from Stock Synthesis and the 50th quantile (stippled red line in both panels) obtained from MCMC analysis (histograms in both panels).

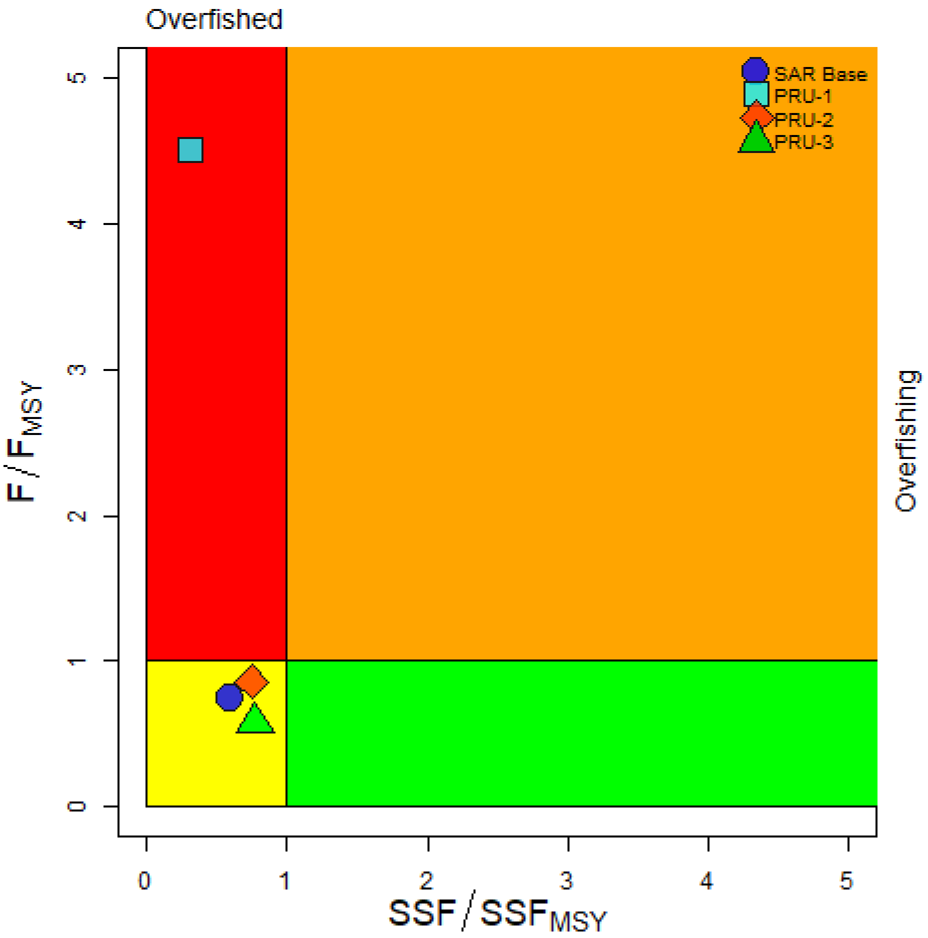

Figure A10. Estimated stock status based on estimated spawning output in 2015 relative to MSY (SSF/SSF$_{MSY}$, x-axis) and estimated total fishing mortality in 2015 relative to MSY (F/F$_{MSY}$, y-axis) for the SEDAR 54 SAR base case, and each of the 3 post review update runs (PRU-1, PRU-2, PRU-3) as defined in the text above.

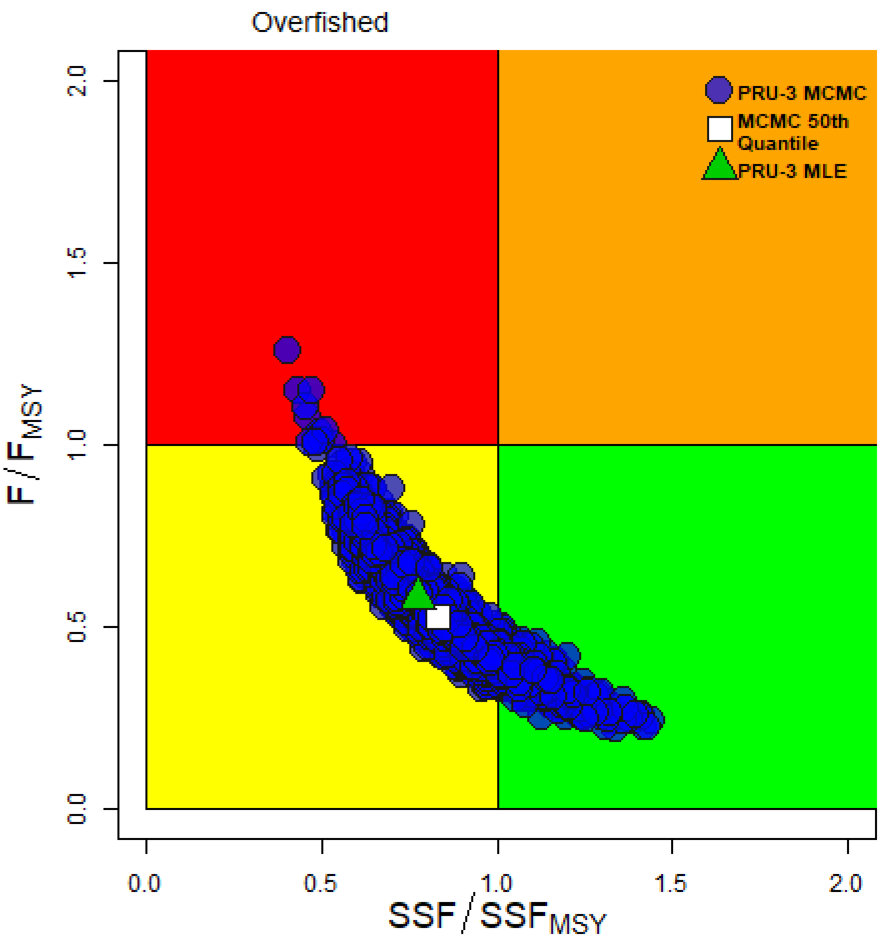

Figure A11. Estimated stock status based on estimated spawning output in 2015 relative to MSY (SSF/SSF_{MSY}, x-axis) and estimated total fishing mortality in 2015 relative to MSY (F/F_{MSY}, y-axis) for the updated base case (green triangle, PRU-3) MLE, MCMC estimates based on PRU-3 (PRU-3 MCMC, blue circles) and the 50th quantile of the MCMC runs (white square, MCMC 50th Quantile).

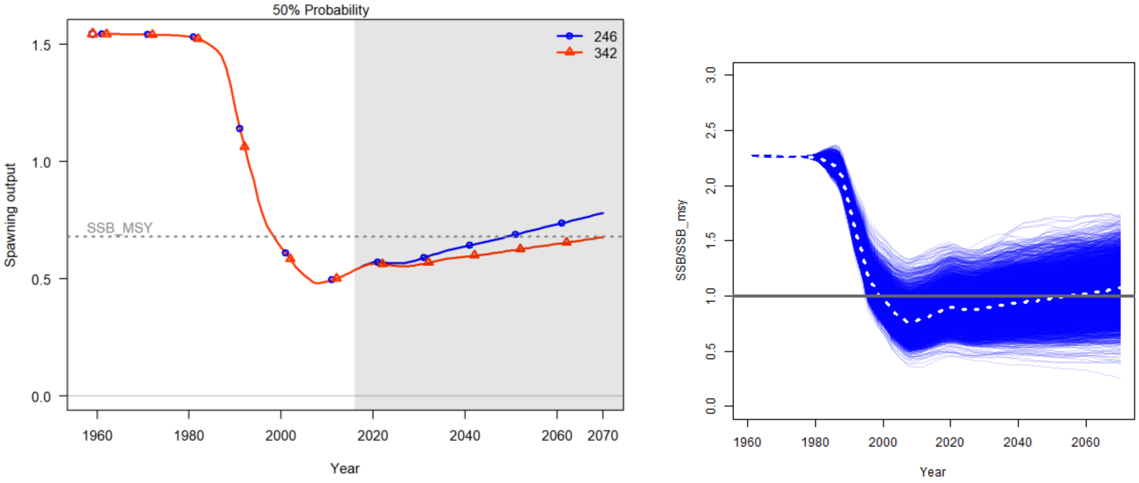

Figure A12. Updated base case projections of spawning output (SSF in millions, left panel) indicating that a constant TAC of 342 mt (whole weight) would allow stock rebuilding by 2070 with a 50% probability (red line left panel; the blue line in the left panel identifies a constant TAC of 246 mt whole weight). For comparison, the updated base case MCMC projections at a constant TAC of 342 mt are provided for SSF/SSF$_{MSY}$ (right panel). The blue lines indicate individual MCMC runs and the stippled line in the right panel represents the 50th quantile of the runs.

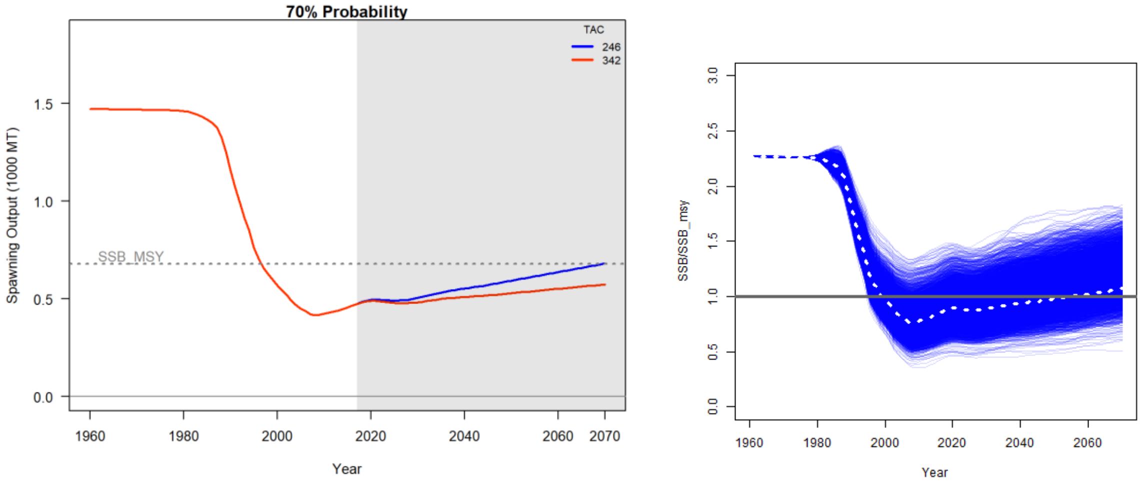

Figure A13. Updated base case projections of spawning output (SSF in millions, left panel) indicating that a constant TAC of 246 mt (whole weight) would allow stock rebuilding by 2070 with a 70% probability (blue line left panel; the red line in the left panel identifies a constant TAC of 342 mt whole weight). For comparison, the updated base case MCMC projections at a constant TAC of 246 mt are provided for SSF/SSF_{MSY} (right panel). The blue lines indicate individual MCMC runs and the stippled line in right panel represents the lower 30th quantile of the runs.

ANNEX 1 Literature Cited

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 1124-1138.

McAllister, M. K. and J. N. Ianelli. 1997. Bayesian stock assessment using catch-age data and the sampling - Importance resampling algorithm." Canadian Journal of Fisheries and Aquatic Sciences 54: 284-300.

Punt, A. E. 2017. Some insights into data weighting in integrated stock assessments. Fisheries Research: 192: 52-65. http://dx.doi.org/10.1016/j.fishres.2015.12.006.