SEDAR 34

HMS Atlantic Sharpnose and Bonnethead Sharks

Post-Review Updates

December 2013

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This document addresses the CIE peer reviews of the SEDAR 34 HMS Atlantic sharpnose and bonnethead shark stock assessment reports (here forth referred to as SARs). The document thus includes additional details on model configuration and functioning, equations, and clarification on several issues raised by the reviewers as well as some additional analyses recommended by the reviewers. Our responses address the comments and recommendations listed by each reviewer under the relevant Term of Reference (ToR). Since the two assessments shared most of the same issues, we will address them for both species combined unless otherwise specified. We thank the reviewers for their thorough reviews and helpful suggestions for future work.

1. Reviews

1.1. Addressing Review of CIE reviewer Robin Cook

The main issue from this reviewer was the lack of variability in the CPUE values used to raise effort to generate total shrimp bycatch, which in the reviewer's view led to a biased time series of bycatch that casts doubt on the assessed stock status relative to reference points. A secondary concern was that the assessment model used, SSASPM, was overly complex for the data that were available for the assessment and thus the reviewer recommended using a simpler model developed by Brooks et al. (2010) as an additional sensitivity test, which would also avoid the problems associated with the shrimp bycatch estimates since the Brooks et al. model does not use catches. Next we address these main points along with other comments (summarized by us) under each relevant ToR.

ToR 1: Evaluate the data used in the assessment

<u>Issues</u>: (1) Estimates of uncertainty (e.g., variance) associated with the mean CPUE and the stratification of the effort data used in the derivation of the shrimp bycatch series should have been provided and used; (2) Variances for the recreational catch estimates could have been provided too; (3) The analysis of the hierarchical index of abundance should provide estimates of both process and measurement error associated with the surveys to illustrate the uncertainties in the indices associated with these two elements; (4) Fleet selectivity is estimated externally from the model as they appear not to be estimable within it; (5) It is noteworthy that the abundance indices, while numerous, do not show a high degree of consistency and this in itself is indicative of uncertainty in the assessment.

Responses: (1) To address the lack of variability around the mean CPUE values for 2009-2011 and determine whether these biased estimates affect assessment results, we used the Panel-recommended approach 2 with observer program data only to calculate the 2009-2011 mean and 95% CIs for observed season/area/depth-specific shrimp bycatch CPUE. Annual shrimp bycatch estimates with corresponding 95% CIs for Atlantic sharpnose and bonnethead sharks in the Gulf of Mexico were then computed based on the 2009-2011 mean and 95% CIs for observed season/area/depth-specific CPUE, year/season/area/depth-specific shrimp effort, and year-specific net per vessel (NPV) (**Figure 1**). See **Appendix 1** for a detailed description of the steps involved in the calculation.

We then used the updated historic shrimp bycatch estimates for 1950-1971 (see Response to Issue 3 in ToR1 for reviewer Apostolaki) in conjunction with the 95% CIs derived above for the modern period in

1972-2011 to produce low and high catch runs for both Atlantic sharpnose and bonnethead sharks (**Figures 2 and 3**). Note that the low catch run for bonnethead (**Figure 3**) yielded a catch stream that was not plausible given the large magnitude of the shrimp bycatch in the historic period but the low estimated bycatch in the modern period (**Figure 3**, top panel). Results indicated more and less optimistic stock status predictions when considering lower and higher catches, respectively, than in the base run for both Atlantic sharpnose and bonnethead sharks (**Tables 1 and 2**). The status relative to reference points did not change, with both species considered to be in a not overfished status and overfishing not occurring. Stock status with respect to the overfished condition for bonnethead shark in the high catch scenario was closer to the reference point than in the base run (1.07 vs. 1.27), but still considerably above the reference point of $(1\text{-}M)SSF_{MSY}$ or 0.78.

2) Given the overwhelming magnitude of the shrimp bycatch compared to the remaining catch streams used in the assessment, the alternate catch scenario we ran in the assessments (low catch run) only considered lower shrimp bycatch and we did not investigate variability in the recreational catch estimates (typically included in low and high catch scenarios in other SEDAR assessments) because we felt the influence of the recreational series on results would be minimal.

(3) Measurement (observation) error for each index of relative abundance is assumed to be captured in the previous standardization (via the CVs associated with each annual index value). The process error associated with each index is given in **Figure 4**.

(4) Although SSASPM can in theory estimate selectivities for both indices of relative abundance and fisheries (fleets) when age compositions are available, the general lack of such data is the reason why selectivities were fixed, i.e., they were not estimated by the model but rather fitted externally to the model based on age frequency distributions obtained from length frequency distributions. This procedure, while not ideal, as recognized in several parts of the SAR (sections 3.1.2.2. and 3.3), was the only one available given early unsuccessful attempts at estimating selectivities within the model based on the few and incomplete age compositions available. We also recognize that the ad-hoc approach used to estimate selectivities relies on the assumption of constant recruitment and F. If this modeling platform continues to be used in the future, the sensitivity of the model to changes in fleet and index selectivities will have to be more fully explored.

(5) Yes, this situation is routinely encountered in shark stock assessments and it adds to overall uncertainty. Conflicting trends in relative abundance indices often lead to tensions in the assessment model, which attempts to reconcile them by fitting a flat tendency. Since these are the data inputs agreed upon by the assessment panel, our only other option is to examine the effect of using different subsets of indices (e.g., decreasing vs. increasing indices) on assessments results, as well as the use of the hierarchical index (which combines all indices into a single series). See also response to Issue 2 in ToR2 for reviewer Rice.

ToR 2: Evaluate the methods used to assess the stock, taking into account the available data

<u>Issues</u>: (1) Would have liked to see more sensitivity runs to assess the effect of parameter specification on results, in particular how sensitive the model is to the choice of CV and autocorrelation in the recruitment

series; (2) The availability of length-frequency data appears to be very limited and it is difficult to tell whether the length-to-age-to-selectivity conversions are realistic; (3) Given the data limitations and assumptions required by SSASPM, it would have been good to use a simpler model, at least for exploratory purposes.

Responses: (1) In general we limit the number of sensitivity runs to those identified by the assessment panel given the relatively limited amount of time available, already high number of sensitivity runs identified, and time required for each individual run when calculating profile likelihoods. We also conducted a limited jitter test to verify that model results are not overly sensitive to the initial parameter values specified. See response to Issue 3 in ToR3 regarding recruitment.

(2) Available length data were indeed limited for bonnethead shark, but sample sizes for some of the surveys were actually quite high for Atlantic sharpnose shark (see Appendix 2 in SARs). See also response to Issue 4 in ToR1 above.

(3) We were constrained to using SSASPM because this was the model accepted and used in the previous assessment (SEDAR 13) and the current assessment was a standard assessment (not a benchmark where new models can be introduced). We have been exploring the use of other models, specifically SS3 (Methot and Wetzel 2013), to estimate length-based selectivities within the model, and track sex-structured population dynamics. However, use of this even more complex model will also require making multiple assumptions. In other assessments we also explored using simpler models (e.g., the Bayesian surplus production model) for comparison with SSASPM. As suggested by the reviewer, we used the Brooks et al. (2010) method with the hierarchical index to provide an additional perspective on stock status (see ToR7 below).

ToR3: Evaluate the assessment findings

<u>Issues:</u> (1) For bonnethead shark, sensitivity runs tend to show most evaluations of stock status as being not overfished, but many are close to the threshold; (2) For both stocks, given the uncertainty in the shrimp bycatch data and potential impact on the assessment, not confident that stock is not overfished; (3) The Beverton-Holt stock-recruit relationship given in Equation (2) of the SAR and the process error in recruitment (described by equation (14) described by a first-order autoregressive process were not structurally related because annual recruitment deviations were not estimated.

Responses: (1) Since the threshold is (1-M)B_{MSY}, most runs were actually well above the threshold (MSST in Table 3.5.17 of bonnethead shark SAR) with the probability of the stock not being overfished in those runs ranging from 79 to 97%.

(2) The main reason why the reviewer did not feel confident about accepting that the stock is not overfished and overfishing is not occurring is the potential impact on assessment results of considering uncertainty in the shrimp bycatch series. This was addressed in the response to Issue 1 in ToR1 above and since results indicated that stock status remained unchanged, the implication is that the reviewer’s misgivings would be alleviated.

(3) Equation (2) is the re-parameterized Beverton-Holt relationship. Equation (14) refers to the process error in recruitment. They are structurally related through equation (14) where the term E[g+1] is the deterministic expectation of recruitment estimated from equation (2). Although SSASPM can introduce process error in recruitment through the autocorrelation coefficient ρ and a normal random deviate, η with a mean of 0 and a given variance, we did not estimate recruitment deviations because the model became unstable. The only process error included was in effort deviations (see equation 18 in Atlantic sharpnose shark SAR for contributions to objective function). However, variability in recruitment is still introduced in equation (2) through the priors in the biological parameters R_0 (virgin recruitment) and S_0 (pup survival) through α (the maximum lifetime reproductive rate).

ToR4: Evaluate the stock projections, rebuilding timeframes, and generation times

Issues: (1) Consider projections models where future effort is considered as the control variable; (2) Long-term projections are fraught with uncertainties; (3) Skeptical about probabilities associated with reference points

Responses: (1) The request to consider projection models where future effort is considered as the control variable is consistent with assessment panel recommendations, which include the following: Add a projection scenario that includes trends in shrimp effort; Explore alternative probability distributions for parameter uncertainty in fishing mortality and pup survival; Explore a more nuanced approach to modeling selectivity at age and fishing mortality separately by fleet in the projections; Explore the effect of changing effort over time. In particular, the assessment panel also noted that some existing scenarios result in very different stock sizes which would likely affect the age composition of the projected population and the resulting distribution of catch among fleets – based on each fleet's selectivity, but this is not currently captured in the projections.

However, one member of the assessment panel pointed out that the goal of these projections (virtually all projection analyses for that matter) is to explore a stock's response to particular management strategies as a means of providing guidance for setting quotas. The assessment panel member also noted that since the management of sharks is not formally tied to the shrimp fishery dynamics, it seems unnecessary to simulate/guess about the trajectory of future shrimp effort within the projections.

(2) This reviewer noted that "any projections beyond a decade are fraught with uncertainties and should be regarded only as illustrative of what might happen. When the projection reaches a condition where all the population has been generated from within the model (as opposed to measurements taken in the base year) the result is entirely driven by model assumptions and are likely to be unreliable."

This is a valid critique of the current projection methodology, which could be addressed in more detail in future assessments, in consultation with the assessment panel and HMS, in order to be more explicit about the apparent tradeoff between projection uncertainty and projection duration. The original objective of the projections was to assess how the population would behave in the near future (~5 to 10 years) at alternative fixed harvest levels. However, during preliminary projection model runs with short-term projections (~5 to 10 years), it was noted that very high fixed levels of total annual removals due to fishing were required to achieve $Pr(SSF_t > SSF_{MSY}) = 70\%$, and $Pr(F_t > F_{MSY}) = 30\%$ with short-term projections (~5 to 10 years). A review of diagnostic output plots from the same preliminary model runs also indicated that the projected stock size would then have declined dramatically ($Pr(SSF_t > SSF_{MSY}) <$ 30%) over a longer projection period (e.g., 30 years).

In contrast, for longer term projections (30 years), more moderate fixed levels of total annual removals due to fishing were required to achieve $Pr(SSF_t > SSF_{MSY}) = 70\%$ and $Pr(F_t > F_{MSY}) = 30\%$ from 10,000 Monte Carlo bootstrap projections. The more moderate fixed levels of total annual removals due to fishing also resulted in relatively more stable population trajectories over time which appeared to approximate equilibrium by the end of the projection period (30 years). Consequently, results were presented to the assessment panel for longer-term (30 years) rather short-term (~5 to 10 years) probabilistic projections. The final projection duration, 30 years, was chosen to be consistent with the projection duration from SEDAR 29 for a SSASPM model applied to HMS blacktip sharks. However, the apparent tradeoff between projection duration and projection uncertainty was neither investigated nor discussed by the assessment panel.

(3) This reviewer correctly noted that only two principal sources of uncertainty were considered in the current projection methods, the error distributions associated with the initial conditions and model uncertainty as expressed by the sensitivity scenarios. However, this reviewer also believed that the true assessment uncertainties were much larger than those reflected in the chosen sensitivity scenarios, especially in relation to the shrimp fishery bycatch. This reviewer also noted that the effects of uncertainty about the length-age conversions and the resultant fleet selectivity functions were not accounted for explicitly in the assessment nor, as a result, in the projections. This reviewer also noted that over long time horizons, these errors could accumulate and have a major impact on the stock trajectory. As a result, while this reviewer supported the view that the projections offered an insight into possible stock trajectories, he was quite skeptical of the probabilities associated with the reference points which appeared to be too heavily dependent on the model estimates of fishing mortality, which are likely to be highly uncertain.

This is also a valid critique of the current projection methodology, which could be addressed in more detail in future assessments. One approach to investigate the probabilities associated with projections in future assessments could be to compare the reference points obtained from the current projection methodology with those obtained from other probabilistic approaches (e.g., alternative P* approaches; Caddy and McGarvey 1996; Prager et al. 2003; Prager and Shertzer 2010; Shertzer et al. 2008, 2010; Ralston et al. 2011).

ToR5: Consider how uncertainties in the assessment, and their potential consequences, are addressed

<u>Issues:</u> (1) Explore model uncertainty with substantially different model; (2) Sensitivity test drawing random vectors of catch from a multivariate lognormal pdf based on measurement error of the catch.

Responses: (1) We explored using the Brooks et al. (2010) method as recommended by the reviewer. See response in ToR7.

(2) Interesting, but this sensitivity test is beyond the scope of the current assessment. Uncertainty in catches is generally investigated through low and high catch scenarios that incorporate uncertainty in

catch estimates. In the current assessments, only a low (shrimp bycatch) catch scenario was initially explored owing to the large magnitude of that series compared to the other commercial and recreational catches. See response to Issue 2 in ToR1.

ToR6: Consider the research recommendations provided and make any additional recommendations or prioritizations warranted

Issues: (1) Use an assessment model that is more closely designed around the available data; (2) If shrimp bycatch cannot be estimated with any precision, it might be better to treat these catches as unknown and use the effort data directly; also better to describe the population in terms of length rather than age.

Responses: (1) See response to Issue 3 in ToR2 regarding the use of SS3 or another length-based, age-structured model, and the use of the Brooks et al. (2010) model.

(2) SSASPM should in theory be able to accommodate a missing catch series if the corresponding effort series is available. However, a partial catch series would still have to be imputed to estimate catchability for that fleet. In our case, we imputed the uncertain shrimp bycatch series (but see response to Issue 1 in ToR1 regarding incorporation of uncertainty through low and high bycatch scenarios), estimated a constant value of effort for the shrimp fleet in the historic period, and incorporated process error in effort in the modern period by estimating annual deviations. If we continue to use this modeling platform in the future, we will more fully explore the input options for catch and effort series.

Regarding use of length data, this is indeed a shortcoming of SSASPM and the reason why we want to explore length-based, age-structured models.

ToR7: Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment

Issues: (1) Use a simpler model (Brooks et al. 2010) with the hierarchical index of relative abundance (Conn 2010) as additional sensitivity test.

Responses: (1) The Brooks et al. (2010) model was used. However, this method at present only provides information on stock status relative to the overfished condition (not relative to overfishing).

This method requires a number of life history parameters to calculate several key quantities, specifically SPR_{MER}, which is the SPR at Maximum Excess Recruitment, and the ratio S_{MER}/S_0, which is the depletion of spawners and recruits corresponding to MER (in the Beverton-Holt stock-recruit model). Both of these quantities can be expressed as function of the maximum lifetime reproductive rate:

$$\alpha = e^{-M_0}\left[\left(\sum_{a=1}^{A-1} p_a m_a \prod_{j=1}^{a-1} e^{-M_a}\right) + \frac{p_A m_A}{1-e^{-M_A}} e^{-M_A}\right] = e^{-M_0}\varphi_0$$

where p_a is pup-production at age a, m_a is maturity at age a, and M_a is natural mortality at age a. The first term on the right side of the equation is pup survival at low population density (Myers et al. 1999). Thus, α is virgin spawners per recruit (φ_0) scaled by the slope at the origin (pup-survival) and is obtained from the "demographic gamer" spreadsheets using the required life history inputs.

Once these quantities have been obtained, we need an index of abundance, $I(t)$, to determine stock status. Since the index typically does not extend back in time to virgin conditions it can be scaled as follows. First it can be normalized by the value in the first year: $I'(t) = \frac{I(t)}{I(t=1)}$

Then alternative hypotheses as to the level of depletion (d) can be formulated:

$$d = \frac{I(t=1)}{I(unfished)}$$

I' can thus be rescaled to obtain a relative index of depletion, D, such that:

$$D(t) = dI'(t) = \frac{I(t)}{I(t=1)} \frac{I(t=1)}{I(unfished)}$$

The final step is to compare $D(t)$ with the level of depletion at MER to determine stock status relative to the overfished criterion:

$$\frac{D(t=current)}{S_{MER}/S_0} = \frac{I(t=current)/I(unfished)}{S_{MER}/S_0} < p$$

The overfished threshold is a proportion of p, which should be the greater of 0.5 or (1-M) (Restrepo et al. 1998).

As recommended by the reviewer, we used the hierarchical index of relative abundance to obtain $I'(t)$ and then explored several hypotheses about the level of depletion at the beginning of that index (d), also computing d_{crit}, or the level of initial depletion required for the stock status to become overfished. We used the values of the first and last years from the hierarchical index for Atlantic sharpnose (1.05 and 1.33; Table 3.5.8 of the SAR) and bonnethead shark (2.12 and 0.80; Table 3.5.8 of the SAR) and computed additional hierarchical indices for the Atlantic sharpnose shark in the GOM (7 indices) and Atlantic (10 indices), and for the bonnethead shark in the GOM (4 indices) and ATL (5 indices). **Figures 5 and 6** show the hierarchical indices for each stock of Atlantic sharpnose and bonnethead shark, respectively.

Based on the life history inputs identified in the assessment and using a relative index of depletion ($D(t)$) that assumed an initial level of depletion of 0.80 (i.e., the stock was reduced by 20% in the first year of the index relative to its virgin level), results indicated that none of the stocks (Atlantic sharpnose shark single stock or disaggregated into a Gulf of Mexico and an Atlantic stock and bonnethead shark single stock or disaggregated into a Gulf of Mexico and an Atlantic stock) were overfished (**Table 3**). Further, we found that the single Atlantic sharpnose shark stock would have had to be depleted to 11% of its virgin size in 1972 for the stock to become overfished (25% of its virgin size in 1972 and 6% of its virgin size in 1993 for the Gulf of Mexico and Atlantic stocks, respectively). For bonnethead shark, the single stock would have had to be depleted to 49% of its virgin size in 1972 for the stock to become overfished (64% of its virgin size in 1972 and 10% of its virgin size in 1989 for the Gulf of Mexico and Atlantic stocks, respectively). These results indicate that the Atlantic sharpnose shark stocks are thus very unlikely to be overfished, but the single bonnethead stock, and especially a Gulf of Mexico stock, would be less unlikely to be overfished if we find reasonable that the stock had decreased by about one third of its size from its virgin state to 1972.

1.2. Addressing Review of CIE reviewer Panayiota Apostolaki

The main issue from this reviewer was that the bonnethead shark assessment should not have been conducted as a single stock given the evidence for the existence of two separate stocks in the Gulf of Mexico and the South Atlantic. Secondary concerns were that the shrimp bycatch series had not been updated for the historical period (1950-1971) and that the continuity run for the bonnethead might have used incorrect values for shrimp bycatch for 2006-2011. Next we address these main points along with other comments (summarized by us) under each relevant ToR.

ToR 1: Evaluate the data used in the assessment

<u>Issues</u>: (1) Bonnethead sharks should have been assessed as two separate stocks; (2) Present different model estimates of natural mortality; (3) Present methodology for shrimp bycatch estimation prior to 1972 and revisit values currently used or explain adoption of previous values; (4) Correct values of shrimp bycatch for bonnethead for the period 2006-2011 (continuity analysis); (5) Inconsistencies in the selectivity patterns adopted for each fleet; (6) Fail to understand the logic behind the calculation of catches in weight

Responses: (1) The decision to run a single stock assessment for bonnethead shark was a procedural issue because the type of assessment undertaken (standard assessment) does not include consideration of additional stocks or new assessment models in the process. Given this critical limitation, the assessment panel, although not unanimously, decide to proceed with a single stock assessment in the interest of providing management advice. While this is not the best scientific outcome, it represents a pragmatic choice until separate stock assessments can be considered that fully examine the whole range of data available for the two stocks in the Gulf of Mexico and the South Atlantic.

(2) Apparently the “ATSH (BH)_demographic gamer_2013” spreadsheets were not uploaded to the SEDAR ftp site for the reviewers to examine in time. This gamer is intended in part to provide an easy interface to evaluate the effect of multiple biological inputs, such as maximum age, age at maturity, von Bertalanffy growth function parameters, and size on estimates of *M* and resulting population parameters of interest (maximum rate of increase, generation times, etc.) obtained through a straightforward life table approach. A brief description of the life history invariant methods used to generate estimates of *M* (all of which can be found in the literature) was included in the last paragraph of section 3.1.2.4 (page 71;

Atlantic sharpnose SAR). Varying the value in cell P4 of the demographic gamer allows one to see the effect of considering different methods or sets of methods on estimates of *M* (expressed as annual survival in column S). The reason for choosing option (4) (maximum of Hoenig's, Chen and Watanabe's, Peterson and Wroblewski's, and Lorenzen's methods) is to attempt to emulate a density-dependent response for exploited conditions, which these stocks are likely to be undergoing.

(3) The methodology used to derive estimates of shark bycatch in the shrimp trawl fishery for the historic period (1950-1971) was not revisited in the current assessment because new estimates of shark bycatch were only produced for 1972-2011 and new estimates of shrimp catch, which are also used in the procedure, were not updated for the period 2006-2011. However, as the reviewer partially points out, the method used the mean ratio of annual shark to shrimp catch for the modern period (1972-2005 in SEDAR 13) to raise shrimp catches and obtain shark bycatch for the historic period (1950-1971). We thus obtained updated shrimp catches for the GOM and SA for 2006-2011 and, using the new values of shark catches for the modern period derived in the current assessment, updated the mean ratio for shrimp to shark catches in the modern period (1972-2011) and back-calculated shark catches for the historic period (1950-1971; **Figure 7**). This eliminated the break in shark bycatch observed in the transition from the historic (1971) to the modern (1972) period, as noted by the reviewer (**Figures 8 and 9**).

The change in the historic shark shrimp bycatch series had little effect on results and stock status did not vary with respect to the baseline run (**Tables 1 and 2**).

(4) The values of bonnethead shark bycatch in the shrimp trawl fishery for 2006-2011 used in the continuity analysis were not the mean of the 2003-2005 values as stated in Table 2.5.1 This was indeed a cut-and-paste error (the values used for those years were the estimates obtained through WinBUGS) that carried through the continuity run. Therefore we corrected those values (the correct value was 260,904 sharks) and re-ran the continuity analysis for bonnethead (this error only affected bonnethead, not Atlantic sharpnose). This change made the status relative to the biomass reference point a little worse (SSF_{2011}/SSF_{MSY} decreased from 1.01 to 0.90; but MSST=0.74) and the status related to the fishing mortality rate a little better (F_{2011}/F_{MSY} decreased from 1.37 to 1.25; **Table 2**).

(5) The reviewer felt that there was inconsistency in the assignment of selectivity curves to each fishing fleet/index, citing for example that the selectivity assigned to the SEAMAP-SA index was the same as for the GADNR-Trawl index for sharpnose shark but not for bonnethead. The reason for what the reviewer interpreted as inconsistencies is that each selectivity curve was assigned based on the age-frequency distribution, obtained from the corresponding length-frequency distribution, for each fleet/survey and species. The age-frequency distributions for each fleet and index of relative abundance are shown in Appendix 2 of the SARs. Examination of these histograms reveals that in the example given by the reviewer, SEAMAP-SA and GADNR Trawl have a fully selected age of 3 for sharpnose, but ages 5 and 1, respectively, for bonnethead.

(6) The calculation of catches in weight responds to a specific request from the HMS Management Division for possible quota calculations after the assessment and involves a considerable number of assumptions. Indeed, the assessment is run in numbers and weight is not needed. Regarding the specific steps, the reviewer seems to have misunderstood what was done. Average weights (back-transformed from lengths, which is what is measured by observers) from observer programs were used whenever available as they represent the best available source. For the example of the recreational catches the

reviewer cites, there was no information at all on average weights prior to 1981 because the recreational surveys did not yet exist (in the historic period, 1950-1980), and average weights were computed as the mean of the year-specific ratios of catches in weight to catches in numbers for the modern period (1981-2011) mainly because there are few animals that are measured in the recreational surveys, with some years having no observations at all.

ToR 2: Evaluate the methods used to assess the stock, taking into account the available data

Issues: (1) Formula used to calculate catches each month; (2) Gender-specific parameters; (3) CV multipliers; (4) Simulation of fish of age 0; (5) pdf for effort deviation; (6) Weight of catches and MSY calculations

Response: (1) The reviewer asked whether the catch equation removed catches for months when a given fleet did not operate. The answer is "no". The equation only removes catches for the months of the year when each fleet is active. The SSASPM code uses the equation $C_{a,y,\mathrm{j},i} = F_{a,y,i} N_{a,y,\mathrm{j}+1}$, where *a* is age, *y* is year, *j* is month, and *i* is the fleet, only for those months (*j*) of the year (*y*) when fleet (*i*) operates. In the SSASPM code:

```
for (y=1; y<=nyears; y++)  {

 for (a=1; a<=nages; a++) {

  for (int j=1; j<=nsteps; j++)  {

   for (series=1; series<=n_series; series++) {

    if(series<=n_catch_series && catch_pdf(series)>0 && j>=catch_first(series) &&
j<=catch_last(series)) {

    catch_by_age = f(a,y,series)*n(a,y,j+1);
```

(2) SSASPM is not a sex-structured model. This can be viewed as a limitation given the availability of sex-specific biological information for both species and the reason why we hope to move to another modeling platform (e.g., SS3) in the future to incorporate sex-specific population dynamics.

(3) The CV multipliers (observation error variance scalars) for indices, catch, and effort were fixed at 3,1,1 for sharpnose and 1,1,1 for bonnethead following the values used for SEDAR 13 in 2007. We did explore the effect of changing the value for the index CV multiplier from 3 to 1 for sharpnose, finding that results were not affected but the fit to the shrimp bycatch series was slightly worse and F_{2011} was estimated more imprecisely (see page 77 of Atlantic sharpnose shark SAR for a discussion). See also response to Issue 1 in ToR2 for reviewer Rice below.

(4) The model does not track age 0 fish because the stock-recruit relationship includes survival to age 1 (recruitment is assumed to occur at age 1). While this represents a big advantage because recruitment is directly related to stock fecundity, making use of the best biological information available, age 0 fish are

not explicitly modeled and thus catches of age 0 fish are not accounted directly for as mentioned by the reviewer.

(5) Process errors for effort deviations make a contribution to the overall likelihood as penalized (weighted) squared deviations (cf. ATSH SAR Eq. 18). The overall likelihood is maximized when individual annual deviations follow a first-order lognormal autoregressive process, unless strongly influenced by the data. However, the individual annual effort deviations can attain negative values.

For example, negative annual effort deviations are estimated for years with no reported catch as well as for years with relatively low reported catch. In particular, the annual effort deviation for the commercial bottom longline (Com BLL) fleet in 1972, on the log scale, was -8.000 (ATSH SAR Table 3.5.6). The resulting annual effort deviation on the natural scale would be the exp(-8.000) = 0.000335463 (ATSH SAR Eq 5). Modern effort for the Com BLL fleet is estimated to be 0.000011 (ATSH SAR Table 3.5.6). As a result, the annual effort for the commercial bottom longline (Com BLL) fleet in 1972, on the natural scale would be 0.000011 * 0.000335463 = $3.69\text{x}10^{-09}$ (ATSH SAR Eq 5).

(6) We want to clarify that SSASPM estimates MSY in weight, as given by formulae (11) to (13) (page 75 of the Atlantic sharpnose shark SAR). Catch in weight in SSASPM is calculated by summing catch in weight over all fleets combined (equation 9). However, because SSF is in numbers, MSY is also expressed in numbers in the summary tables of results (Tables 3.5.17 to 3.5.20 in the Atlantic sharpnose shark SAR). First, SSASPM maximizes yield per recruit in weight to obtain F_{MSY} using a single selectivity which is calculated as the combined selectivity for all the fleets. Then, we calculate catch at MSY in numbers corresponding to F at MSY obtained from SSASPM as:

$$F_{a,MSY} = s_a F_{MSY}$$

$$Z_{a,MSY} = F_{a,MSY} + M_a$$

$$C_{MSY} = \sum_a N_{a,MSY} \frac{F_{a,MSY}}{Z_{a,MSY}} \left(1 - e^{-Z_{a,MSY}}\right)$$

where,

F_{MSY} is the F at MSY obtained from SSASPM

s_a is the combined selectivity at age for all the fleets, calculated from $F_{a,endyr} = s_a F_{endyr}$ exactly as in SSASPM and as described below,

M_a is natural mortality at age,

$N_{a,MSY}$ is the numbers at age under assumed constant recruitment at MSY, R_{MSY}, subject to M_a and $F_{a,MSY}$ and calculated as:

$$N_{a,MSY}=\begin{cases} R_{MSY}, & a=1 \\ R_{MSY}e^{-\sum_{j=1}^{a-1}(Z_{j,MSY})}, & 1<a<A_{max} \\ \dfrac{R_{MSY}e^{-\sum_{a=1}^{A_{max}-1}(Z_{a,MSY})}}{\left(1-e^{-Z_{A_{max,MSY}}}\right)}, & a=A_{max} \end{cases}$$

The combined selectivity at age for all the fleets, s_a, is calculated from $F_{a,endyr}=s_aF_{endyr}$ exactly as in SSASPM as:

Step 1: in shark_spasm.tpl s_latest(a)=total_catch(a,nyears)/average_n(a,nyears) = C_a/average_N_a = F_ay = sel_a*F_y

$$F_{a,endyr}\approx C_{a,endyr}/\bar{N}_{a,endyr},$$

where $\bar{N}_{a,endyr}$ is the average numbers at age in the end year, $\bar{N}_{a,endyr}=\sum_{m=1}^{12}N_{a,m,endyr}/12$.

Step 2: in shark_spasm.tpl Fcurrent=max(s_latest) = max F_ay = max (sel_a)*F_y = 1*F_y = F_y (assuming max(sel_a)=1.0

$$F_{endyr}=\max\left(F_{a,endyr}\right)$$

Step 3: In the sd_phase of shark_spasm.tpl, s_equilibrium=s_latest => s_equilibrium = F_ay = sel_a*F_y, while

Step 4: In the last_phase of the sd_phase of shark_spasm.tpl, s_latest = s_latest/Fcurrent => s_latest= F_ay/ F_y = sel_a*F_y/ F_y = sel_a

$$s_a=F_{a,endyr}/F_{endyr}$$

ToR3: Evaluate the assessment findings

<u>Issues:</u> (1) For bonnethead shark, model run using “Atlantic biology” is inconclusive

(1) The "Atlantic biology" scenario was intended to explore the effect of considering the biological characteristics of the Atlantic stock but using all other inputs, including catch and CPUE data, corresponding to the two (GOM + ATL) stocks combined. This run predicted that the stock would be overfished with overfishing occurring. Given the procedural issues that precluded consideration of two separate stocks under SEDAR 34 (see response to Issue 1 in ToR1), this represented a good faith alternative to try to characterize uncertainty in biological parameters.

ToR4: Evaluate the stock projections, rebuilding timeframes, and generation times

Issues: (1) Does the projected stock reach equilibrium within the projection horizon?; (2) Incorporation of uncertainty in calculations ("Some further analysis would be recommended to provide an insight as to how successful using the two bivariate distribution was in reducing the risk of selecting values of the variables that have not generated the data" and "a way to do this is to start the projection from 1950 instead of 2011 using the catch data already available for the period 1950-2011. In this case a bivariate distribution for current stock size and fishing mortality will not be needed and any combinations of the other two parameters that are not realistic (e.g. leads to stock extinction before 2011, etc.) would also be excluded"; (3) Low catch sensitivity scenario

Responses: (1) The objective of the projections was to assess how the population will behave in the near future. The final projection duration, 30 years, was chosen to be consistent with the projection duration from SEDAR 29 for a SSASPM model applied to HMS blacktip sharks. The evidence for the 30 year projection to reach a state that approximated equilibrium was based on the observed behavior of the 30th percentile of SSFt,boot/ SSF_{MSY} which appeared to approach an asymptote in some model configurations at low fixed removals levels. Formal conditions were not included in the projection model to confirm that is the case for any of the combinations of biological parameters and exploitation levels considered. See also response 2 in ToR4 for reviewer Cook.

(2) Projections were run using Monte Carlo bootstrap simulation, where initial numbers (N_{2011}^{boot}) and fishing mortality (F_{2011}^{boot}) were sampled from a bivariate normal distribution. Pup survival at low biomass ($e^{-M_0}{}_{2011}^{boot}$) and equilibrium recruitment ($R_{0\,2011}^{boot}$) were sampled from a second bivariate normal distribution. Further analysis was conducted here to provide an insight as to how successful using the two bivariate distributions was in reducing the risk of selecting values of the variables that have not generated the data.

First, frequency distributions were obtained and plotted for the base model configurations from the Atlantic sharpnose and bonnethead projections (ATSH SAR Table 3.5.23, Projection Scenario-1 Baseline, Inverse CV Weighting; and BH SAR Table 3.5.19, Projection Scenario-1 Baseline, Inverse CV Weighting, respectively). Frequency distributions were obtained from the original 10,000 Monte Carlo bootstrap simulations (random draws) from the bivariate normal distribution for initial numbers (N_{2011}^{boot}) and fishing mortality (F_{2011}^{boot}), and the second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2011}^{boot}$) and equilibrium recruitment ($R_{0\,2011}^{boot}$).

The frequency distributions were plotted for a given level of fixed removals (1,000s) (e.g., 2750, ATSH SAR Table 3.5.24; and e.g., 550 BH SAR Table 3.5.20) along with the corresponding parameter estimates from SSASPM (dashed lines) and the medians of the 10,000 Monte Carlo bootstrap simulations for each parameter (solid lines) (**Figures 10 and 11**). The resulting frequency plots indicated that frequency distributions of the 10,000 Monte Carlo bootstrap simulations were informative (i.e. not uniform) and consistent with the parameter values estimated in SSASPM (**Figures 10 and 11**).

Second, the same parameter values from the 10,000 Monte Carlo bootstrap replicates were plotted against each other from the bivariate normal distribution for initial numbers (N_{2011}^{boot}) and fishing mortality (F_{2011}^{boot}), and the second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2011}^{boot}$) and equilibrium recruitment ($R_{0\,2011}^{boot}$). The expectation was that values of the variables that did not generate the data would be unlikely in the bootstrap replicates. For example, for the standard deviation of the estimated parameters x and y (s_x and s_y, respectively) along with the estimated correlation coefficient *r* obtained from SSASPM, the variance-covariance matrix of *x* and *y* used to generate parameter values in R with a bivariate normal distribution is defined as:

$$\begin{bmatrix} s_x^2 & \mathrm{cov}(x,y) \\ \mathrm{cov}(x,y) & s_y^2 \end{bmatrix}, \text{where } \mathrm{cov}(x,y) = r\sqrt{s_x^2 s_y^2}$$, (Crawley 2007; The R Book, p. 237).

Bootstrap results were plotted for the same given level of fixed removals (1,000s) from the Atlantic sharpnose and bonnethead projections above (e.g., 2750, ATSH SAR Table 3.5.24; and e.g., 550 BH SAR Table 3.5.20).

For the base model configuration from the Atlantic sharpnose projections (Projection Scenario-1 Baseline, Inverse CV Weighting; ATSH SAR Tables 3.5.23 and 3.5.24), the estimated correlation coefficients *r* obtained from SSASPM for initial numbers (N_{2011}) and fishing mortality (F_{2011}), and for pup survival at low biomass (e^{-M_0}) and equilibrium recruitment (R_0), were -0.1238, and -0.4772, respectively. Bootstrap results indicated that both low and high values of F_{2011}^{boot} (F-boot) were likely to occur with any value of N_{2011}^{boot} (N-boot), consistent with the low correlation coefficient between N_{2011} and F_{2011} (**Figure 12, Panel A**). In contrast, low values of $e^{-M_0}{}_{2011}^{boot}$ (S-boot) were unlikely to occur with low values of $R_{0\,2011}^{boot}$ (R0-boot), consistent with the relatively higher correlation coefficient between e^{-M_0} and R_0 (**Figure 12, Panel B**).

For the base model configuration from the bonnethead projections (Projection Scenario-1 Baseline, Inverse CV Weighting ; BH SAR Tables 3.5.19 and 3.5.20), the estimated correlation coefficients *r* obtained from SSASPM for initial numbers (N_{2011}) and fishing mortality (F_{2011}), and for pup survival at low biomass (e^{-M_0}) and equilibrium recruitment (R_0), were -0.3866, and -0.5354, respectively.

Bootstrap results indicated low values of F_{2011}^{boot} (F-boot) were relatively less likely to occur than high values of F_{2011}^{boot} with low values of N_{2011}^{boot} (N-boot), consistent with the relatively higher correlation coefficient between N_{2011} and F_{2011} (**Figure 13, Panel A**). Similarly, low values of $e^{-M_0}{}_{2011}^{boot}$ (S-boot) were unlikely likely to occur with low values of $R_{0\,2011}^{boot}$ (R-boot), consistent with the higher correlation coefficient between e^{-M_0} and R_0 (**Figure 13, Panel B**).

Regarding the second point (Starting the projections in 1950), we note that for the fixed harvest projection scenarios, F_{proj} is currently found numerically from the fixed harvest level (each bootstrap in each projection year) with projections starting in 2011. The recommendation to start the projections in 1950 instead of 2011 using the catch data already available for the period 1950-2011, presumably in a manner similar to that of a sampling importance re-sampling (SIR) algorithm, could provide a useful alternative to this approach for evaluation in future assessments.

We also note the current projection code already includes a historical period (e.g., 1950-2011). Historical calculations are currently used as a projection model diagnostic, for example to ensure that retrospective SSF and F match those estimated in SSPASM. Examples of the historical calculations (1950-2011, calculated from the projection code without including parameter uncertainty) are provided here from the Atlantic sharpnose and bonnethead base projections for the given level of fixed removals (1,000s) described above (e.g., 2750, ATSH SAR Table 3.5.24; and e.g., 550 BH SAR Table 3.5.20) (**Figures 14-15**).

(3) The justification for considering the shark bycatch in the shrimp trawl fishery used in the baseline run as a high catch scenario is that the values generated (either the stratified nominal estimates recommended by the assessment panel or the WinBUGS model-generated estimates first presented in document SEDAR34-WP-18) were of much higher magnitude than the estimates generated also with WinBUGS for SEDAR 13 in 2007. However, in responding to reviewer's Cook request for considering uncertainty in the estimated shrimp bycatch series (Issue 1 in ToR1 for that reviewer), we developed low and high catch runs that address this concern and show that predicted stock status does not vary with respect to the baseline run.

ToR6: Consider the research recommendations provided and make any additional recommendations or prioritizations warranted

Issues: Research recommendations include (1) Run separate stock assessments for GOM and ATL stocks; (2) Increase precision of shrimp bycatch estimates; (3) Identify additional factors that could improve explanatory power of standardization models of CPUE; (4) Data collection to support improved calculation of gear selectivity; (5) Improve estimates of post-release mortality

Responses: These are all good recommendations, most of which apply not only to the two species assessed under SEDAR 34. Some will be specifically addressed in future assessments of these species (1, 2), explored as time permits (3, 4), or investigated through research activities if funds become available (5).

ToR7: Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment

<u>Issues:</u> (1) Gender-specific and age-0 model; (2) Projection model

Responses: (1) See response to Issue 2 in ToR2, but essentially we are planning on using another modeling platform (e.g., SS3) that will allow us to incorporate sex-structured population dynamics and model age-0 fish, among other improvements.

(2) Improvements to the projection model are contemplated as future work (see responses to ToR4).

1.3.Addressing Review of CIE reviewer Joel Rice

The main issue from this reviewer was also that the bonnethead shark assessment should have not been conducted as a single stock given the evidence for the existence of two separate stocks in the Gulf of Mexico and the South Atlantic. Next we address these main points along with other comments (summarized by us) under each relevant ToR.

ToR 1: Evaluate the data used in the assessment

<u>Issues</u>: Stock units: (1) Bonnethead sharks should have been assessed as two separate stocks in the GOM and ATL; (2) Alternatively, a single stock assessment model considering two regions with different life history traits should have been conducted; Life history parameters: (3) Reservations about how age and length data were used to derive selectivities, better to include length data and a growth model or age-length key in the assessment model; Abundance indices: (4) No summary of the discussion regarding weighting of indices was provided; Length and age data: (5) Conversion of lengths into ages is problematic, recommend that length data not be converted into ages unless age-length key is available for appropriate temporal-spatial strata; (6) Apparent temporal trends in length data are obscured by use of single selectivity curve for each fishery

Responses: (1) As already explained under ToR1 for reviewer Apostolaki, and explicitly stated by this reviewer at the bottom of page 5 of his review, “the stocks were assessed as one stock based on the desire for actionable management advice and the fact that consideration of multiple stocks was beyond the terms of reference for the assessment”.

(2) Similarly, the type of assessment undertaken (standard assessment) did not include consideration of a new modeling platform (e.g., SS3) that would have allowed us to consider a two-region model.

(3) As explained in responses to Issue 4 in ToR1 and Issue 2 in ToR2 for reviewer Cook, the procedure to derive selectivities is an ad-hoc approach given the data limitations and the fact that SSASPM cannot use length data directly. We opted to transform length into ages directly through the growth curve in the current assessment because previous reviews of other assessments that also used SSASPM had expressed concern at the use of age-length keys. Indeed, both approaches (back-transformation through the growth curve and age-length key) have clear shortcomings (see section 3.1.2.2 of the Atlantic sharpnose shark SAR on pages 67-68 for a discussion). Additionally, once age-frequency distributions were obtained we had to approximate selectivity curves "by eye" when fitting a double exponential curve to be consistent with the algorithm used. The intent is to use another modeling platform in the future that allows for direct use of length data as well as fitting of selectivities within the model (e.g., SS3).

(4) This comment pertains to the data portion of the report (section 2) and should be addressed by the relevant rapporteur. There is a brief description of the rationale used for ranking the indices at the bottom of page 41 and summarized positive and negative aspects for each series in Table 2.5.4 of the Atlantic sharpnose shark SAR.

(5) This has been addressed in item (3) above and we just add that a single age-length key for each stock is available (not available for multiple spatio-temporal strata).

(6) SSASPM does not contemplate changes in selectivity patterns through time.

ToR 2: Evaluate the methods used to assess the stock, taking into account the available data

Issues: (1) Overall CV multipliers; (2) Inclusion of conflicting trends will force the model towards non-optimal solutions

Response: (1) This was already addressed in the response to Issue 3 in ToR2 for reviewer Apostolaki. We will add that the use of a CV multiplier of 3 for indices for Atlantic sharpnose shark is unrelated to the weighting scheme used to weight each individual index (see equations 15a and 15b on page 76 of the Atlantic sharpnose shark SAR). In other words, the $w_{i,y}$ terms can take the value of 1 (equal weighting), 1/CV (inverse CV weighting) or 1/rank (rank weighting), but the values used for the λ_g terms (CV multipliers) are unrelated to the $w_{i,y}$ terms. The language used in SEDAR 13 in 2007 and quoted by the reviewer may have misled him. As reported earlier, we explored the effect of changing the value for the index CV multiplier from 3 to 1 for sharpnose, finding that results were not affected but the fit to the shrimp bycatch series was slightly worse and F_{2011} was estimated more imprecisely (see page 77 of the Atlantic sharpnose shark SAR for a discussion). We also add that residual plots are available under the predicted fit to each index in the figures showing fits to the indices.

(2) By definition, SSASPM will find the optimal solution between conflicting trends within the framework of a penalized maximum likelihood (minimizing the negative log likelihood of all components included in the likelihood). Since we do not know which of the conflicting trends, if any, reflects the true population trajectory over time, the optimal solution between conflicting trends is considered the best model fit.

ToR3: Evaluate the assessment findings

Issues: (1) F (selectivity) on age-0 individuals;

(1) This was also addressed in the response to Issue 4 in ToR2 for reviewer Apostolaki. The model starts at age 1.

ToR5: Consider how uncertainties in the assessment, and their potential consequences, are addressed

Issues: (1) Future sensitivity analyses should include more than one change to the assessment at a time

Responses: (1) We sympathize with this comment but note that factorial approaches to sensitivity analysis imply a multiplicative amount of computing time, making it impractical especially when running likelihood profiling or MCMC.

ToR6: Consider the research recommendations provided and make any additional recommendations or prioritizations warranted

Issues: (1) run sex-structured, length-based model that allows fitting of selectivities internally to the model

Responses: As mentioned in several parts of this document, we plan on using a length-based, sex- and age-structured model (e.g., SS3) for the next benchmark assessment of these species.

ToR7: Provide guidance on key improvements in data or modeling approaches which should be considered when scheduling the next assessment

Issues: (1) Explore models that do not require assumption that population is at virgin levels at beginning of model; (2) Simulation tests (Management Strategy Evaluation); (3) Fit model to each relative abundance index at a time

Responses: (1) We plan on exploring this further in the future when using another modeling platform (e.g., SS3). We also explored this in part by using the Brooks et al. (2010) model, in which we calculated the value of d_{crit}, the level of initial depletion required for the stock status to become overfished. See response to ToR7 for reviewer Cook.

(2) Use of MSE is also envisaged but will require additional time and resources that are not currently available.

(3) See response to ToR5 above.

References cited

Brooks, E.N., J.E. Powers, and E. Cortés. 2010. Analytic reference points for age-structured models: application to data-poor fisheries. ICES J. Mar. Sci. 67:165-175.

Caddy, J. F. and R. McGarvey. 1996. Targets or Limits for Management of Fisheries? North American Journal of Fisheries Management 16:479-487.

Crawley, M. J. 2007. The R book. West Sussex, England, John Wiley & Sons Ltd. 942 p.

Methot, R.D. and C.R. Wetzel. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fish. Res. 142:86-99.

Myers, R.A., K.G. Bowen, and N.J. Barrowman. 1999. Maximum reproductive rate of fish at low population sizes. Can. J. Fish. Aquat. Sci. 56:2404-2419.

Prager, M. H., Porch, C. E., Shertzer, K. W., and J. F. Caddy. 2003. Targets and limits for management of fisheries: A simple probability-based approach. North American Journal of Fisheries Management 23:349-361.

Prager, M. H., and K. W. Shertzer. 2010. Deriving acceptable biological catch from the overfishing limit: Implications for assessment models. North American Journal of Fisheries Management 30:289-294.

Ralston, S., Punt, A. E., Hamel, O. S., DeVore, J. D. and R. J. Conser, 2011. A meta-analytic approach to quantifying scientific uncertainty in stock assessments. Fishery Bulletin 109(2): 217-231.

Restrepo, V. R., Thompson, G. G., Mace, P. M., Gabriel, W. L., Low, L. L., MacCall, A. D., Methot, R. D., Powers, J. E., Taylor, B. L., Wade, P. R., and Witzig, J. F. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO, 54 pp.

Shertzer, K. W., Prager, M. H., and E. H. Williams. 2008. A probability-based approach to setting annual catch levels. Fishery Bulletin 106:225-232.

Shertzer, K. W., Prager, M. H., and E. H. Williams. 2010. Probabilistic approaches to setting acceptable biological catch and annual catch targets for multiple years: Reconciling methodology with national standards guidelines. Marine and Coastal Fisheries 2:451-458.

Appendix 1.

Approach 2:

$Annual\_NZCT\_CPUE\_A2_{[yr,sea, ar, dp]}$ =
$exp\{average[ln(NZCT\_CPUE_{[yr, sea, ar, dp]})] + 0.5*var(ln(NZCT\_CPUE_{[yr, sea, ar, dp]}))\}$ (Step1a)

$Annual\_All\_Tow\_CPUE\_A2_{[yr,sea, ar, dp]}$ =
$Annual\_NZCT\_CPUE\_A2_{[yr,sea, ar, dp]}*Percent\_of\_NZCT_{[yr, sea, ar, dp]}$
(Step1b)

$Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}$ =
$Mean(Annual\_All\_Tow\_CPUE\_A2_{[yr, sea, ar, dp]})$
(Step2a)
where yr = 2009, 2010 and 2011

$Lower\_95\%\_CI\_Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}$ =
$Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}$ -
$1.96*Standard\_Error\_of\_Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}$
(Step2b)

$Upper\_95\%\_CI\_Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}$ =
$Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}$ +
$1.96*Standard\_Error\_of\_Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}$
(Step2c)

$Obs\_Bycatch\_A2_{[yr, sea, ar, dp]}$ =
$Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]}*effort_{[yr, sea, ar, dp]}*npv_{[yr]}$
(Step3a)
where yr = 1972 - 2011

$Lower\_95\%\_CI\_Obs\_Bycatch\_A2_{[yr, sea, ar, dp]}$ =
$Lower\_95\%\_CI\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]} *effort_{[yr, sea, ar, dp]}*npv_{[yr]}$

(Step3b)
where yr = 1972 - 2011

$Upper\_95\%\_CI\_Obs\_Bycatch\_A2_{[yr, sea, ar, dp]}$ =
$Upper\_95\%\_CI\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2_{[sea, ar, dp]} *effort_{[yr, sea, ar, dp]}*npv_{[yr]}$

(Step3c)
where yr = 1972 - 2011

$Obs\_Bycatch\_A2_{[yr]} = sum(Observed\_Bycatch\_A2_{[yr, sea, ar, dp]})$ (Step4a)

$$\text{Lower\_95\%\_CI\_Obs\_Bycatch\_A2}_{[yr]} = \text{sum}(\text{Lower 95\%\_CI\_Observed\_Bycatch\_A2}_{[yr,\ sea,\ ar,\ dp]}) \quad \text{(Step4b)}$$

$$\text{Upper\_95\%\_CI\_Obs\_Bycatch\_A2}_{[yr]} = \text{sum}(\text{Upper 95\%\_CI\_Observed\_Bycatch\_A2}_{[yr,\ sea,\ ar,\ dp]}) \quad \text{(Step4c)}$$

$\text{Annual\_NZCT\_CPUE\_A2}_{[yr,sea,\ ar,\ dp]}$ is the observed annual non-zero-catch-tow year/season/area/depth-specific CPUE estimated with approach 2,

$\text{NZCT\_CPUE}_{[yr,\ sea,\ ar,\ dp]}$ is the observed non-zero-catch-tow year/season/area/depth-specific CPUE,

$\text{Annual\_All\_Tow\_CPUE\_A2}_{[yr,\ sea,\ ar,\ dp]}$ is the observed annual all-tow year/season/area/depth-specific CPUE,

$\text{Percent\_of\_NZCT}_{[yr,\ sea,\ ar,\ dp]}$ is the observed year/season/area/depth-specific percent of non-zero-catch tows,

$\text{Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2}_{[sea,\ ar,\ dp]}$ is the mean of 2009-2011 season/area/depth-specific CPUE,

$\text{Lower\_95\%\_CI\_Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2}_{[sea,\ ar,\ dp]}$ is the lower bound of 95% confidence interval of the mean of 2009-2011 season/area/depth-specific CPUE,

$\text{Upper\_95\%\_CI\_Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2}_{[sea,\ ar,\ dp]}$ is the upper bound of 95% confidence interval of the mean of 2009-2011 season/area/depth-specific CPUE,

$\text{Standard\_Error\_of\_Mean\_2009\_2011\_Annual\_All\_Tow\_CPUE\_A2}_{[sea,\ ar,\ dp]}$ is the standard error of the mean of 2009-2011 season/area/depth-specific CPUE,

$\text{Obs\_Bycatch\_A2}_{[yr,\ sea,\ ar,\ dp]}$ is the observed year/season/area/depth-specific bycatch,

$\text{effort}_{[yr,\ sea,\ ar,\ dp]}$ is year/season/area/depth-specific effort,

$\text{npv}_{[yr]\ i}$ is year-specific nets per vessel,

$\text{Lower\_95\%\_CI\_Obs\_Bycatch\_A2}_{[yr,\ sea,\ ar,\ dp]}$ is the lower bound of 95% confidence interval of the observed year/season/area/depth-specific bycatch,

$\text{Upper\_95\%\_CI\_Obs\_Bycatch\_A2}_{[yr,\ sea,\ ar,\ dp]}$ is the upper bound of 95% confidence interval of the observed year/season/area/depth-specific bycatch,

$\text{Obs\_Bycatch\_A2}_{[yr]}$ is the observed annual bycatch,

$Lower\_95\%\_CI\_Obs\_Bycatch\_A2_{[yr]}$ is the lower bound of 95% confidence interval of the observed annual bycatch,

$Upper\_95\%\_CI\_Obs\_Bycatch\_A2_{[yr]}$ is the upper bound of 95% confidence interval of the observed annual bycatch.

Table 1. Summary of results for additional runs conducted for this revision of the Atlantic sharpnose shark stock assessment. All runs used inverse CV weighting. R_0 is the number of age-1 pups at virgin conditions. SSF is spawning stock fecundity (sum of number at age times pup production at age). MSY is expressed in numbers. AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large. Runs include: low and high catch scenarios; altered historic period shrimp bycatch.

	Base (inv CV)		Low catch		High catch		Changed historic bycatch	
	Est	CV	Est	CV	Est	CV	Est	CV
AICc	3702.31		3699.67		3704.80		3701.74	
Objective function	1482.91		1481.59		1484.16		1482.63	
SSF_{2011}/SSF_{MSY}	**1.73**	0.41	**1.94**	0.85	**1.46**	0.38	**1.71**	0.40
F_{2011}/F_{MSY}	**0.34**	2.02	**0.25**	1.73	**0.47**	2.23	**0.33**	2.01
N_{2011}/N_{MSY}	1.52	---	1.63	---	1.33	---	1.51	---
MSY	3.06.E+06	---	1.01.E+06	---	4.75.E+06	---	3.14.E+06	---
SPR_{MSY}	0.45	0.19	0.46	0.46	0.43	0.13	0.46	0.18
F_{MSY}	0.377	---	0.260	---	0.413	---	0.365	---
SSF_{MSY}	1.75.E+07	---	6.55.E+06	---	2.55.E+07	---	1.88.E+07	---
N_{MSY}	1.90.E+07	---	7.17.E+06	---	2.79.E+07	---	2.02.E+07	---
F_{2011}	0.128	2.02	0.065	1.73	0.194	2.23	0.120	2.01
SSF_{2011}	3.03.E+07	0.31	1.27.E+07	0.43	3.70.E+07	0.34	3.23.E+07	0.29
N_{2011}	2.89.E+07	---	1.17.E+07	---	3.72.E+07	---	3.06.E+07	---
SSF_{2011}/SSF_0	0.55	0.22	0.63	0.20	0.45	0.29	0.55	0.22
B_{2011}/B_0	0.53	0.22	0.60	0.18	0.44	0.31	0.53	0.22
R0	9.37.E+06	0.16	3.39.E+06	0.26	1.40.E+07	0.14	9.92.E+06	0.15
Pup-survival	0.89	0.27	0.83	0.28	0.95	0.26	0.84	0.27
alpha	5.28	---	4.90	---	5.60	---	5.01	---
steepness	0.57	---	0.55	---	0.58	---	0.56	---
SSF_0	5.55.E+07	0.16	2.01.E+07	0.26	8.27.E+07	0.14	5.88.E+07	0.15
SSF_{MSY}/SSF_0	0.32	---	0.33	---	0.31	---	0.32	---
$Nmat_{MSY}$	8.77.E+06	---	3.33.E+06	---	1.27.E+07	---	9.44.E+06	---

Table 2. Summary of results for additional runs conducted for this revision of the bonnethead shark stock assessment. All runs used inverse CV weighting. R_0 is the number of age-1 pups at virgin conditions. SSF is spawning stock fecundity (sum of number at age times pup production at age). MSY is expressed in numbers. AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large. Runs include: low and high catch scenarios; altered historic period shrimp bycatch; corrected continuity run.

	Base (inv CV)		Low catch		High catch		Changed historic bycatch		Continuity		Corrected continuity	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
AICc	3363.98		3370.02		3365.17		3364.09		4059.78		4060.33	
Objective function	1293.94		1296.96		1294.53		1293.99		1551.88		1552.16	
SSF_{2011}/SSF_{MSY}	**1.27**	0.53	**2.12**	0.22	**1.07**	0.45	**1.30**	0.52	**1.01**	0.40	**0.90**	0.32
F_{2011}/F_{MSY}	**0.50**	0.71	**0.40**	0.71	**0.51**	0.72	**0.48**	0.70	**1.37**	0.75	**1.25**	0.32
N_{2011}/N_{MSY}	1.16	---	1.54		1.05		1.18		0.76	---	0.71	---
MSY	5.89.E+05	---	1.99.E+05		1.02.E+06		6.03.E+05		4.79.E+05	---	4.83.E+05	---
SPR_{MSY}	0.39	0.31	0.41	0.05	0.38	0.24	0.39	0.30	0.53	0.01	0.53	0.30
F_{MSY}	0.202	---	0.191		0.256		0.200		0.351	---	0.353	---
SSF_{MSY}	4.77.E+06	---	2.08.E+06		7.57.E+06		4.99.E+06		1.55.E+06	---	1.55.E+06	---
N_{MSY}	4.20.E+06	---	1.90.E+06		6.61.E+06		4.36.E+06		1.53.E+06	---	1.54.E+06	---
F_{2011}	0.101	0.71	0.076	0.71	0.131	0.72	0.096	0.70	0.480	0.75	0.442	0.19
SSF_{2011}	6.07.E+06	0.43	4.39.E+06	0.53	8.12.E+06	0.36	6.48.E+06	0.40	1.56.E+06	0.62	1.40.E+06	0.15
N_{2011}	4.89.E+06	---	2.92.E+06		6.96.E+06		5.15.E+06		1.17.E+06	---	1.09.E+06	---
SSF_{2011}/SSF_0	0.38	0.32	0.67	0.18	0.31	0.31	0.39	0.31	0.36	0.38	0.32	0.29
B_{2011}/B_0	0.39	0.29	0.65	0.17	0.33	0.28	0.40	0.28	0.34	0.38	0.31	0.28
R0	1.79.E+06	0.16	7.40.E+05	0.35	2.93.E+06	0.13	1.86.E+06	0.15	9.78.E+05	0.27	9.86.E+05	0.12
Pup-survival	0.88	0.23	0.79	0.24	0.92	0.22	0.86	0.23	0.79	0.24	0.80	0.14
alpha	7.88	---	7.07		8.22		7.66		3.56	---	3.59	---
steepness	0.66	---	0.64		0.67		0.66		0.47	---	0.47	---
SSF_0	1.60.E+07	0.16	6.61.E+06	0.35	2.62.E+07	0.13	1.66.E+07	0.15	4.38.E+06	0.27	4.42.E+06	0.22
SSF_{MSY}/SSF_0	0.30	---	0.32		0.29		0.30		0.35	---	0.35	---
$Nmat_{MSY}$	9.62.E+05	---	4.11.E+05		1.53.E+06		1.01.E+06		6.95.E+05	---	6.98.E+05	---

Table 3. Analytical predictions of overfished status based on the Brooks et al. (2010) method.

					Sa					d	d_{crit}				
Species	Stock	Ro	So	α	Min	Max	SPR_{MER}	S_{MER}/So	I(t)/I(t=1)	I(t=1)/Ivirgin	I(t=1)/Ivirgin	Dt	M	Ratio	Status
Atlantic sharpnose	GOM+ATL	6.68	0.79	5.42	0.4	0.79	0.43	0.30	1.267	0.80	0.11	1.013	0.519	7.01	not overfished
Atlantic sharpnose	GOM	3.45	0.66	2.30	0.51	0.79	0.66	0.40	0.890	0.80	0.25	0.712	0.431	3.14	not overfished
Atlantic sharpnose	ATL	4.48	0.79	3.58	0.46	0.79	0.53	0.35	2.841	0.80	0.06	2.273	0.470	12.40	not overfished
Bonnethead	GOM+ATL	6.55	0.79	5.16	0.56	0.80	0.44	0.31	0.376	0.80	0.49	0.301	0.386	1.60	not overfished
Bonnethead	GOM	4.28	0.66	2.86	0.62	0.80	0.59	0.37	0.377	0.80	0.64	0.302	0.342	1.24	not overfished
Bonnethead	ATL	3.25	0.79	2.54	0.58	0.82	0.63	0.39	2.432	0.80	0.10	1.946	0.357	7.85	not overfished

R_0 is virgin spawners per recruit (net reproductive rate)

S_0 is pup survival at low densities

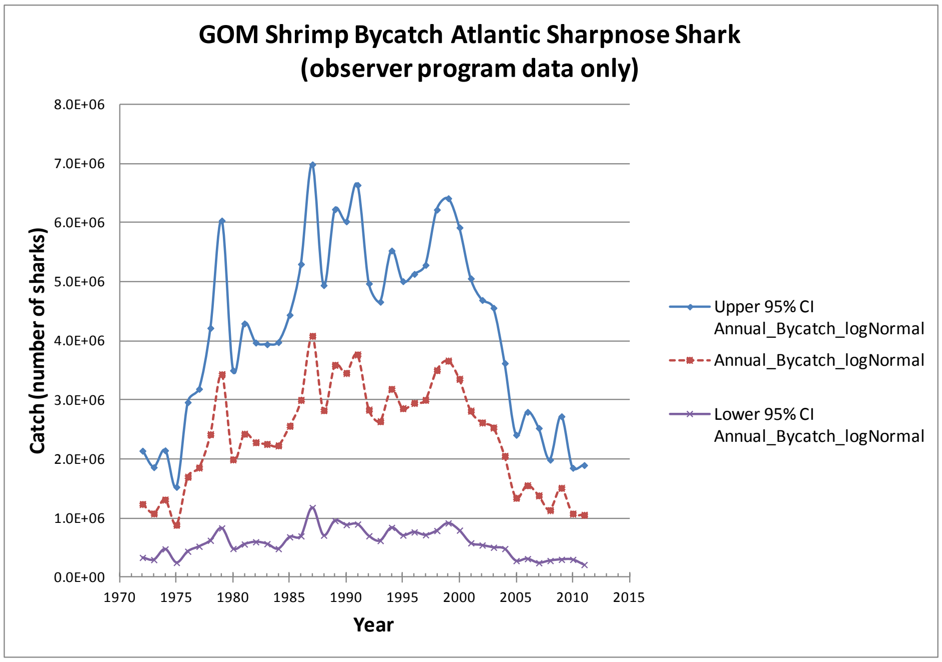
S_a is annual survival

M is the mean of the minimum and maximum values of annual survivorship, from ages 1 to max, expressed as mortality

d_{crit} is the initial value of depletion that will result in the stock being overfished in 2011.

Ratio is the quotient of D_t and S_{MER}/S_0 multiplied by 1-M

Figure 1. Estimates of shrimp bycatch for 1972-2011 in the Gulf of Mexico obtained when considering variability (95% CIs) around the mean CPUE for 2009-2011: Atlantic sharpnose shark (top panel); bonnethead shark (bottom panel).



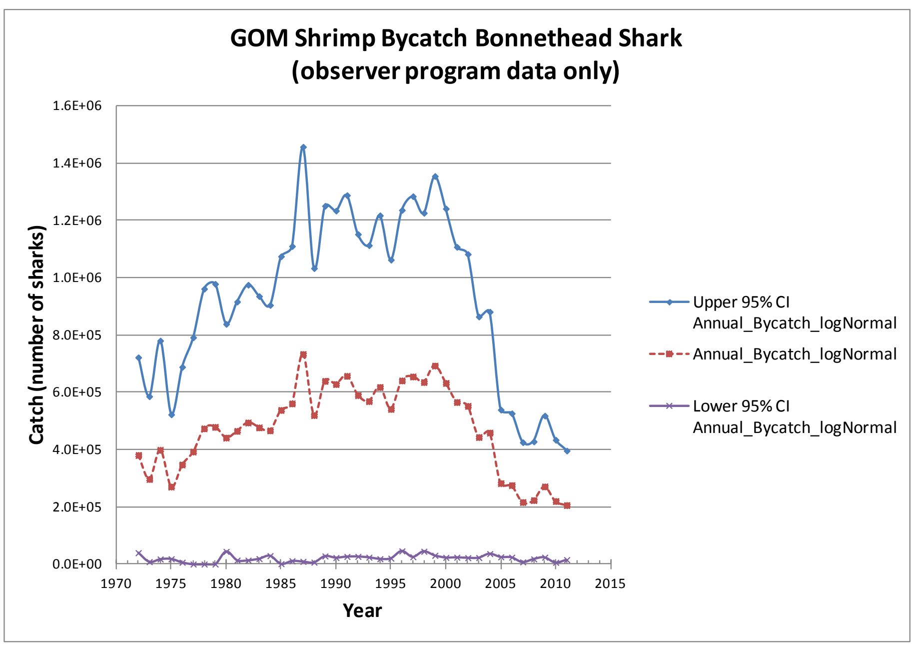
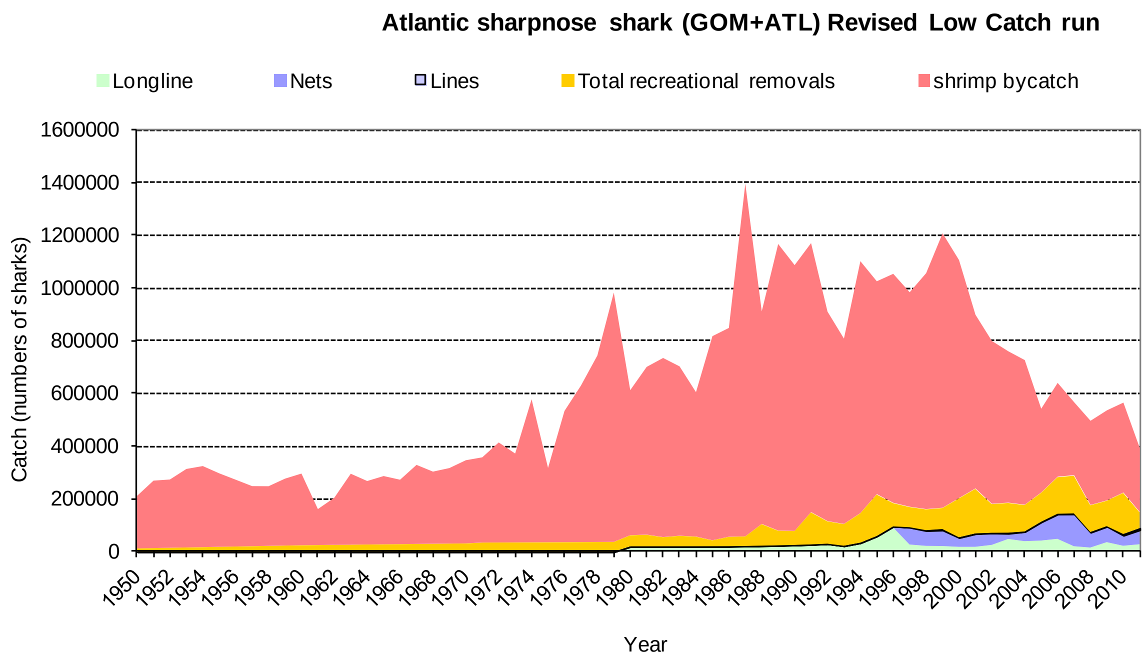


Figure 2. Low (top panel) and high (bottom panel) catch runs for Atlantic sharpnose shark. Note the different scale on the Y-axis.



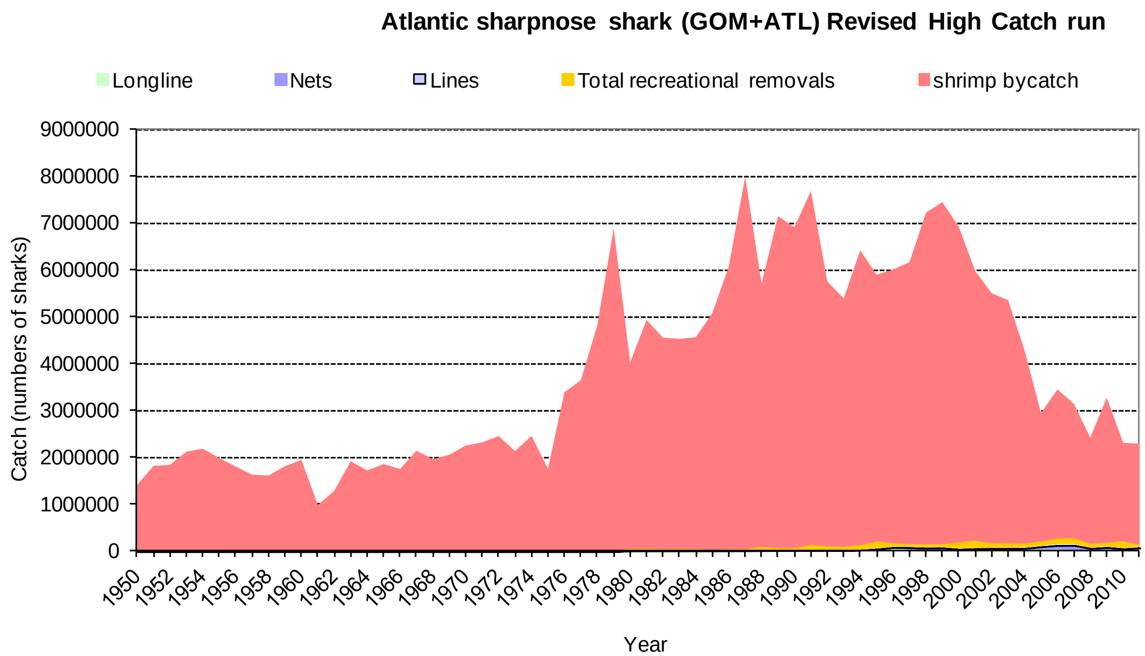
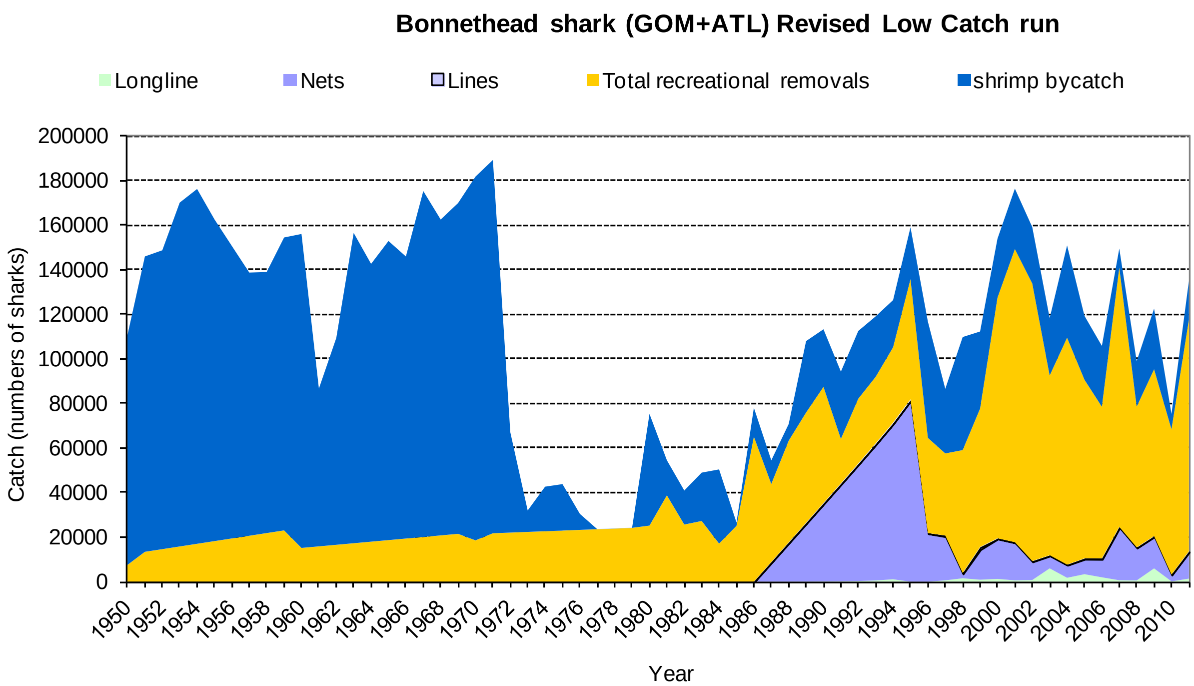


Figure 3. Low (top panel) and high (bottom panel) catch runs for bonnethead shark. Note the different scale on the Y-axis.



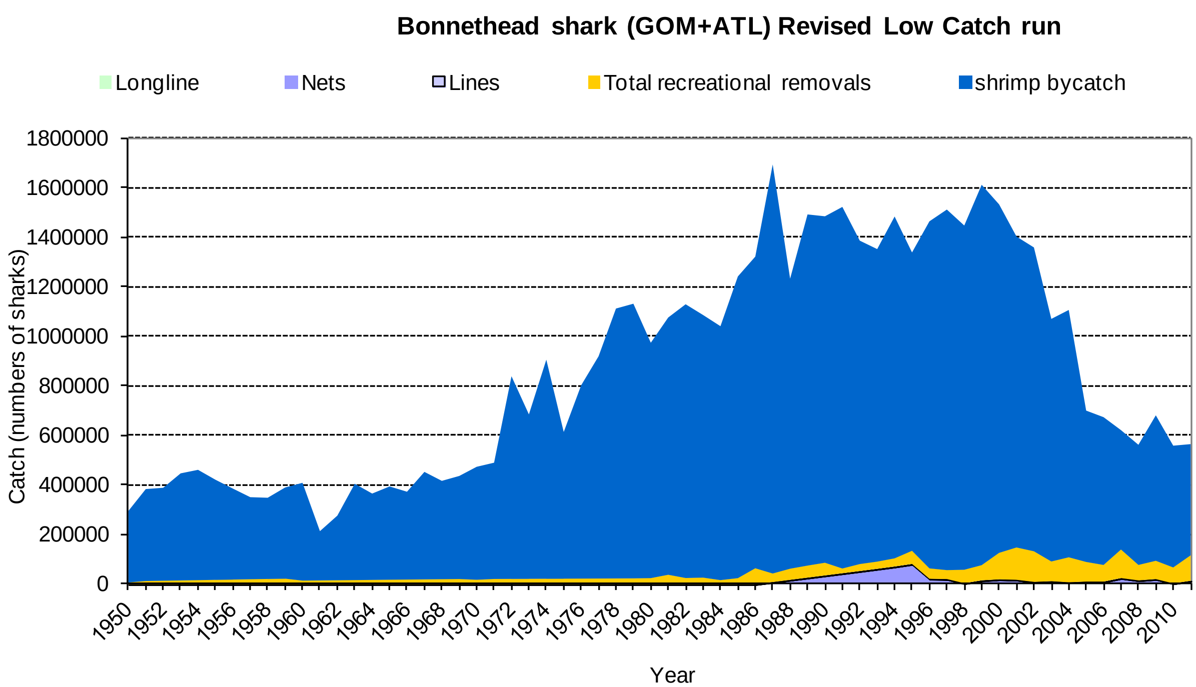


Figure 4. Process error estimated for the individual indices of relative abundance used in the hierarchical analysis. Top panel is for Atlantic sharpnose shark (indices from left to right are PCLL, ATL Coastspan LL, GOM Comb LL, BLLOP, SEAMAP-SA, GOM Comb GN, VALL, NMFS LL SE, SC Coastspan GN, SCDNR RD LL Early, GA-SCDNR RD LL Late, SEAMAP GOM ES, SEAMAP GOM EF, UNCLL, and GADNR Trawl); bottom panel is for bonnethead shark (indices from left to right are GOM Comb LL, SCDNR Trammel Net, ENP, SEAMAP-SA, Texas GN, SC Coastspan GN, ATL Coastspan LL, SEAMAP GOM EF, and GADNR Trawl).

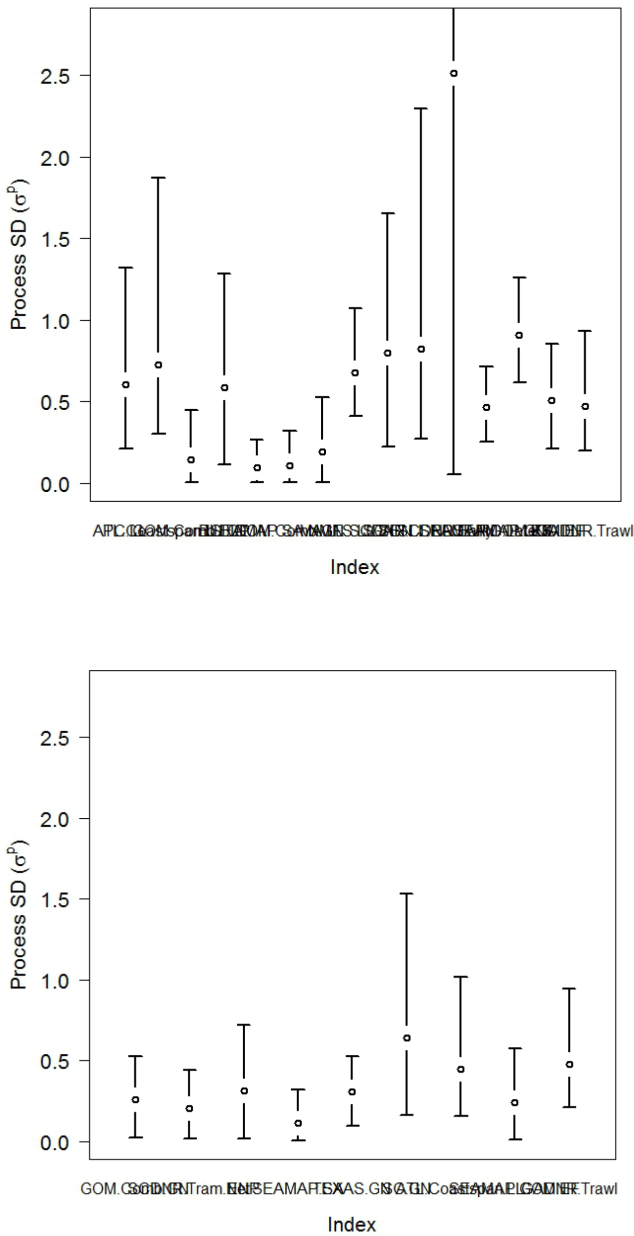


Figure 5. Hierarchical indices of relative abundance for Atlantic sharpnose shark: single combined stock (top panel), Gulf of Mexico stock (middle panel), and South Atlantic stock (bottom panel). Vertical bars are ± 1 CV.

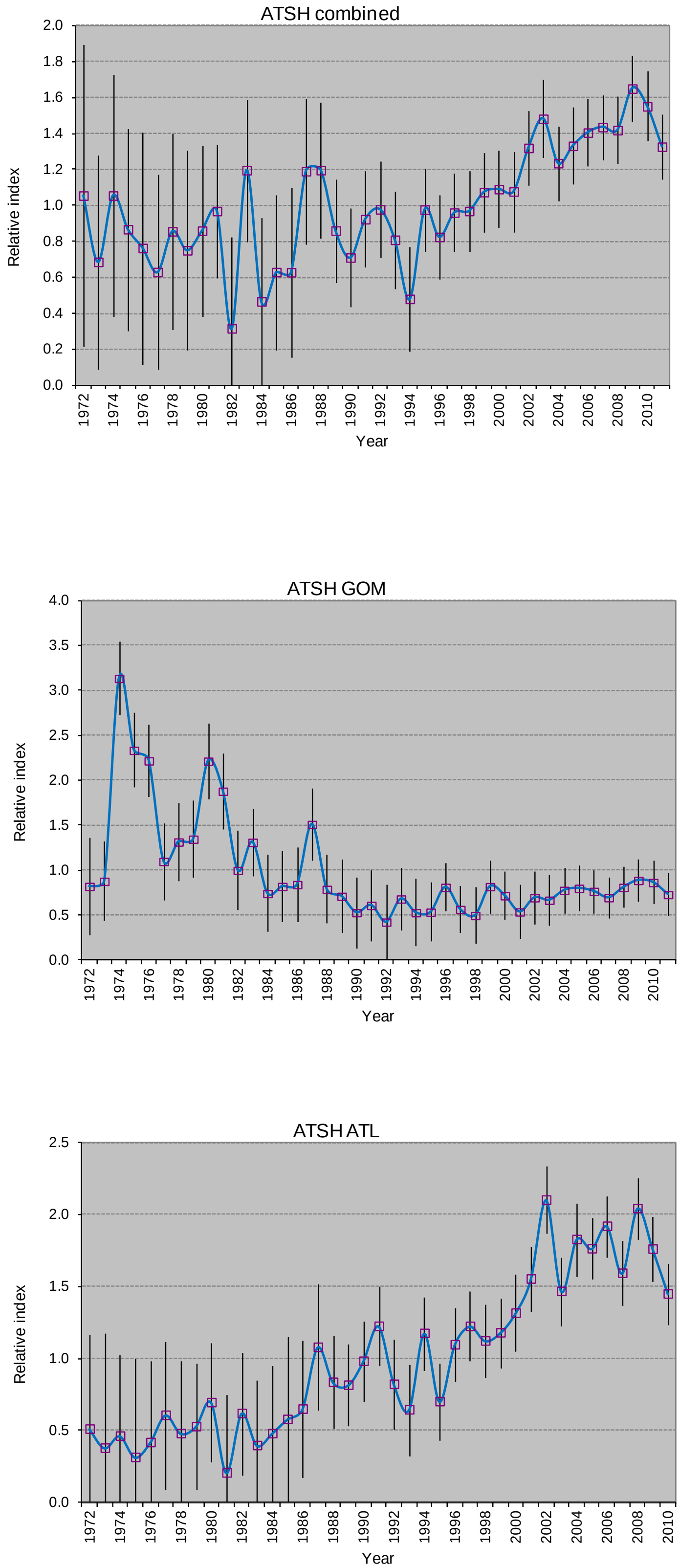


Figure 6. Hierarchical indices of relative abundance for bonnethead shark: single combined stock (top panel), Gulf of Mexico stock (middle panel), and South Atlantic stock (bottom panel). Vertical bars are ± 1 CV.

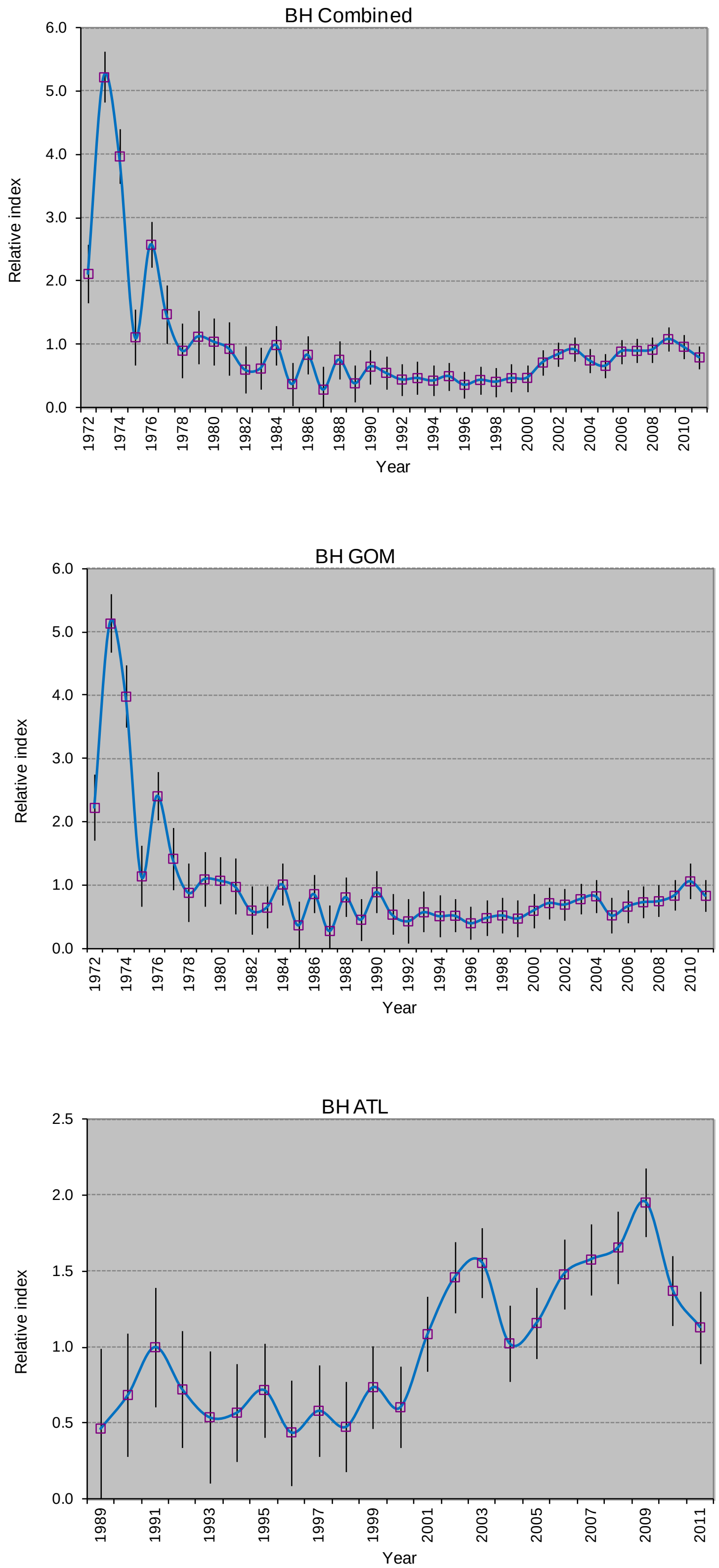


Figure 7. Updated estimates of shark bycatch in the shrimp trawl fishery in the historic period (1950-1971) compared to the values used in the baseline run: Atlantic sharpnose shark (top panel), bonnethead shark (bottom panel).

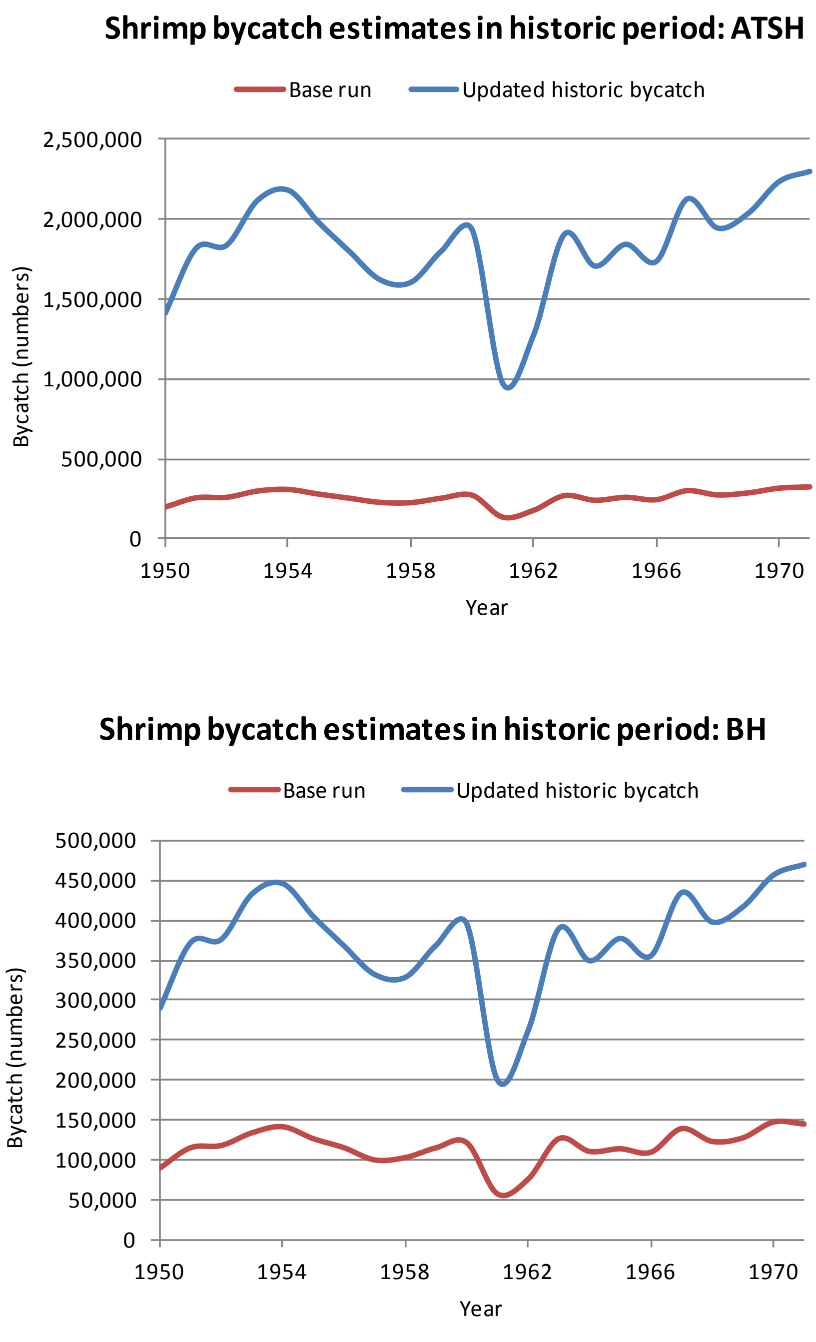
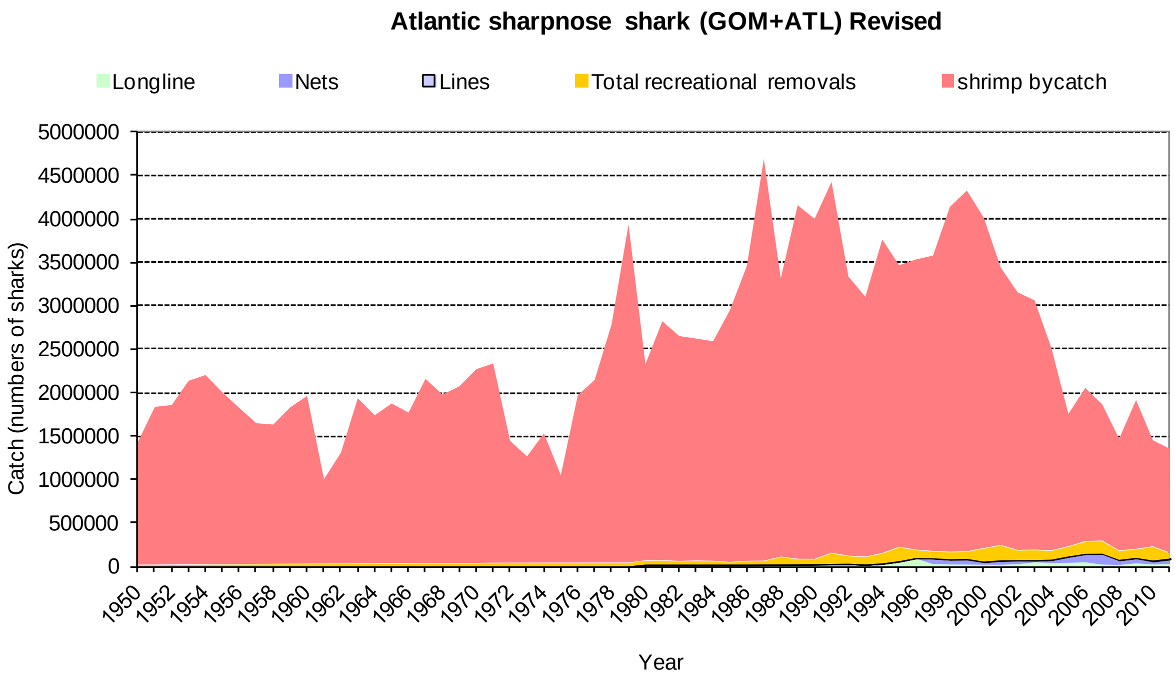


Figure 8. Catches of Atlantic sharpnose shark by fleet showing updated shrimp bycatch in the historic period (top panel) compared to values used in the baseline run (bottom panel).



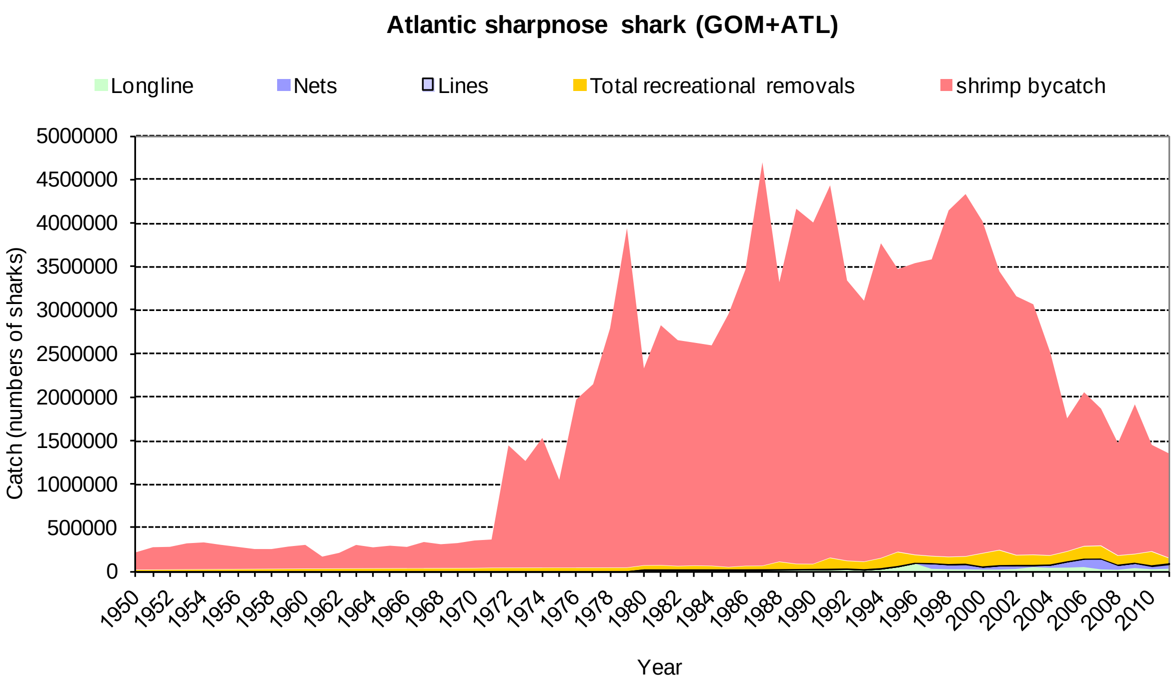
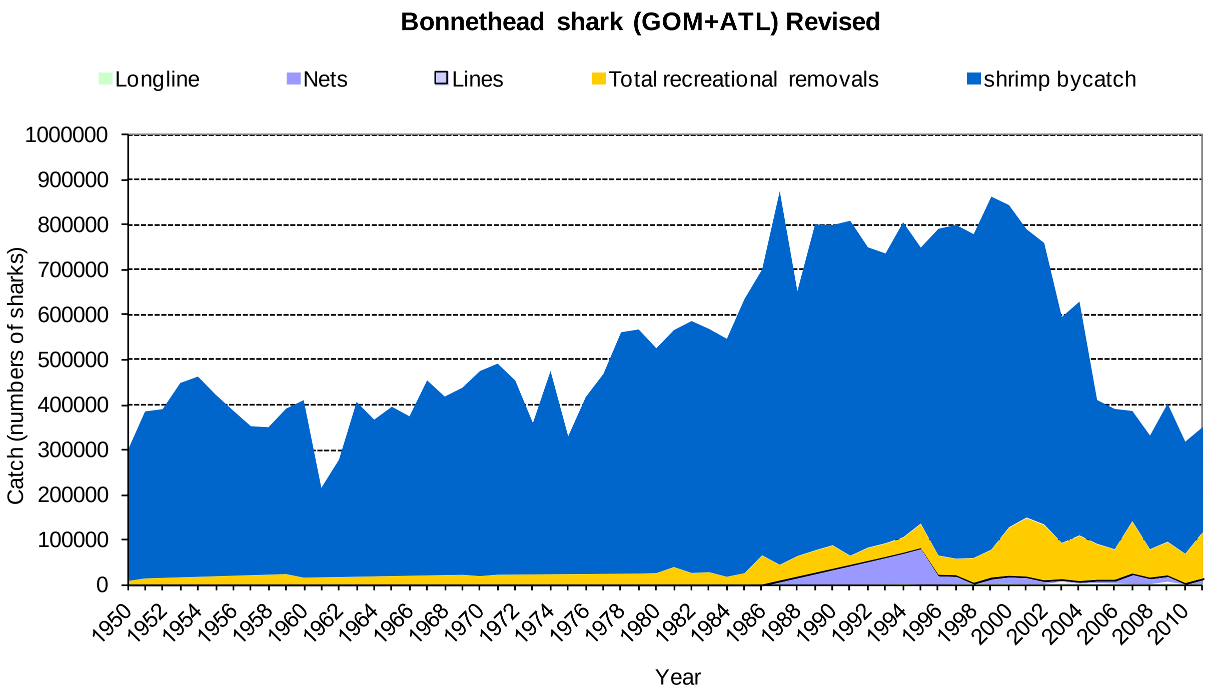


Figure 9. Catches of bonnethead shark by fleet showing updated shrimp bycatch in the historic period (top panel) compared to values used in the baseline run (bottom panel).



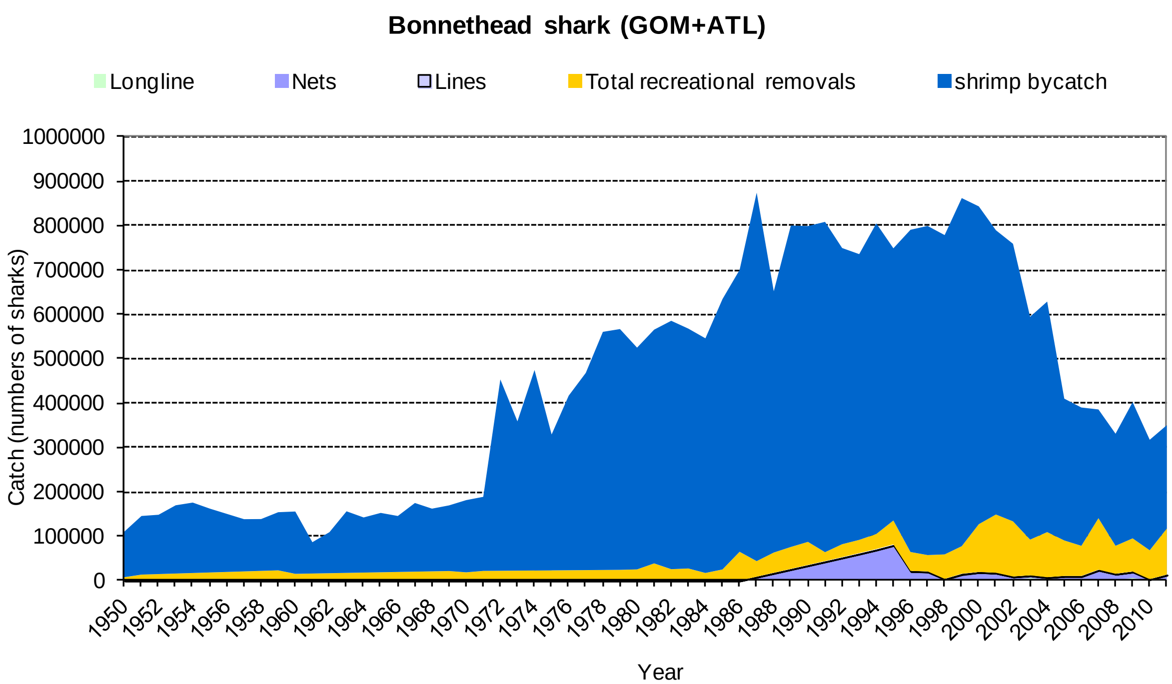


Figure 10. Frequency distributions for the base model configuration from the Atlantic sharpnose projections (ATSH SAR Table 3.5.23, Projection Scenario-1 Baseline, Inverse CV Weighting) for the fixed removals level (1,000s) of 2750 (ATSH SAR Table 3.5.24) were obtained from the original 10,000 Monte Carlo bootstrap simulations (random draws) from the bivariate normal distribution for initial numbers (N_{2011}^{boot},N-boot) and fishing mortality (F_{2011}^{boot},F-boot), and the second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2011}^{boot}$,S-boot) and equilibrium recruitment ($R_{0\,2011}^{boot}$,R0-boot), along with the corresponding parameter estimates from SSASPM (dashed lines) and the medians of the 10,000 Monte Carlo bootstrap simulations for each parameter (solid lines).

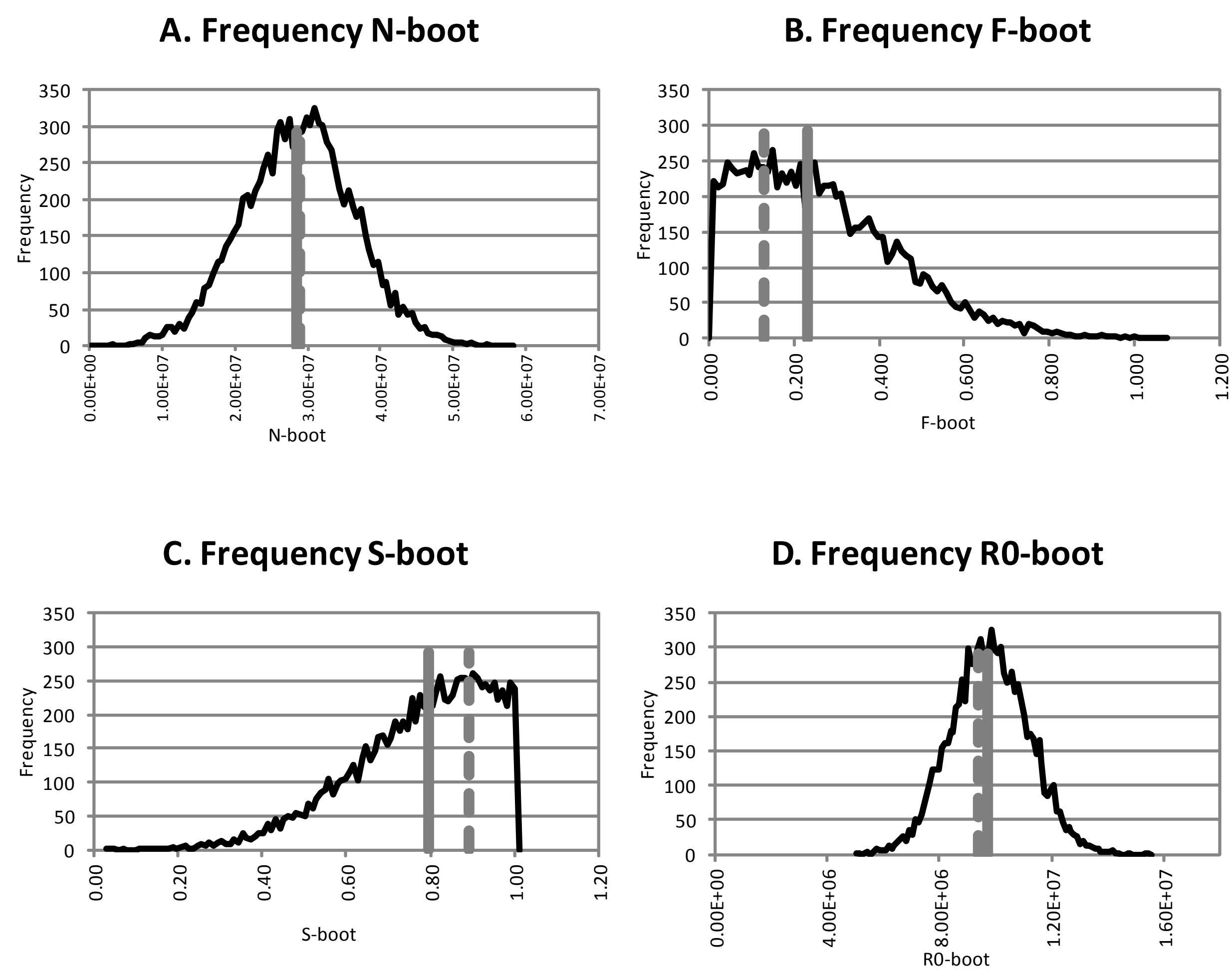


Figure 11. Frequency distributions for the base model configuration from the bonnethead projections (BH SAR Table 3.5.19, Projection Scenario-1 Baseline, Inverse CV Weighting) for the fixed removals level (1,000s) of 550 (BH SAR Table 3.5.20) were obtained from the original 10,000 Monte Carlo bootstrap simulations (random draws) from the bivariate normal distribution for initial numbers (N_{2011}^{boot}, N-boot) and fishing mortality (F_{2011}^{boot}, F-boot), and the second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2011}^{boot}$, S-boot) and equilibrium recruitment ($R_{0\,2011}^{boot}$, R0-boot), along with the corresponding parameter estimates from SSASPM (dashed lines) and the medians of the 10,000 Monte Carlo bootstrap simulations for each parameter (solid lines).

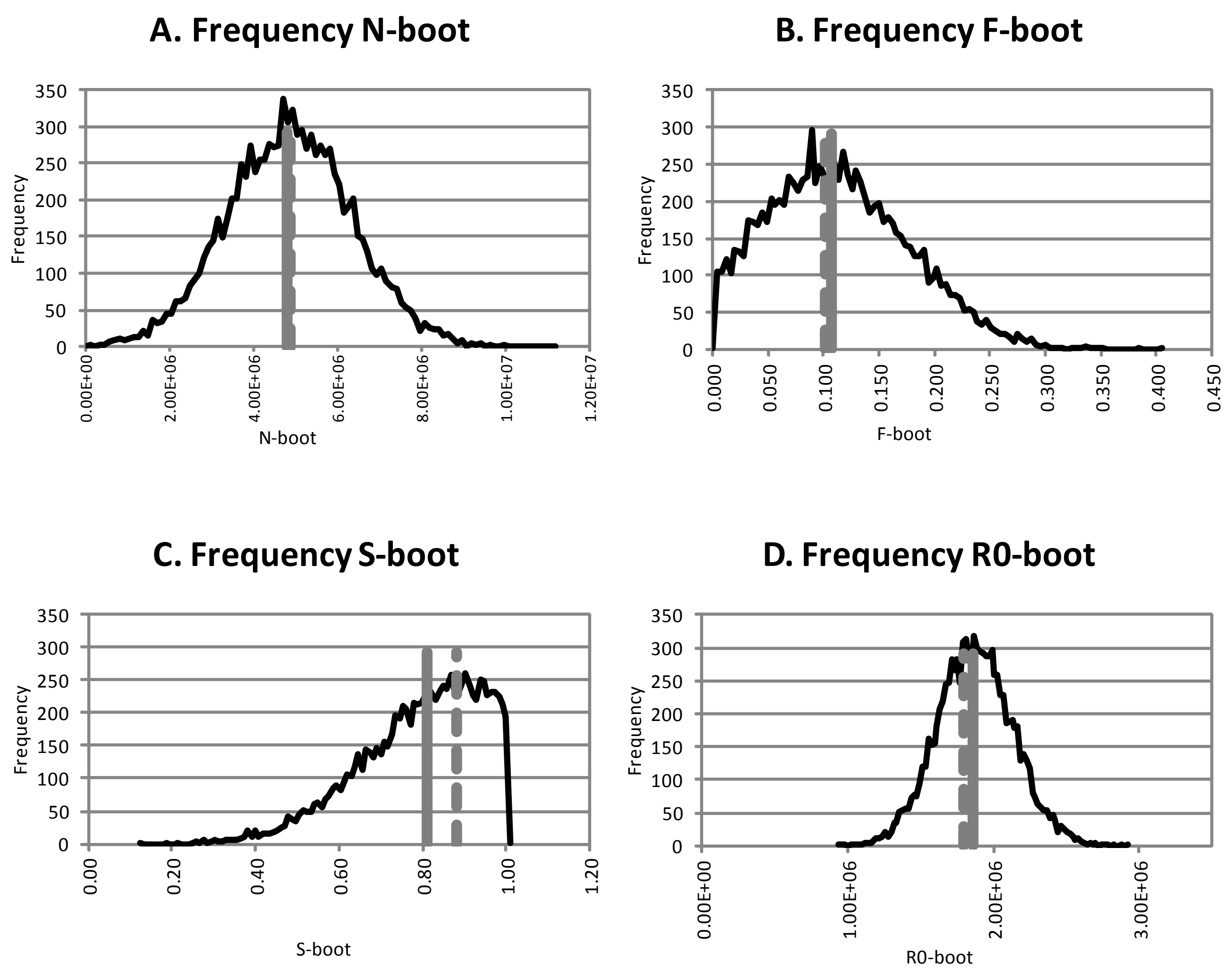
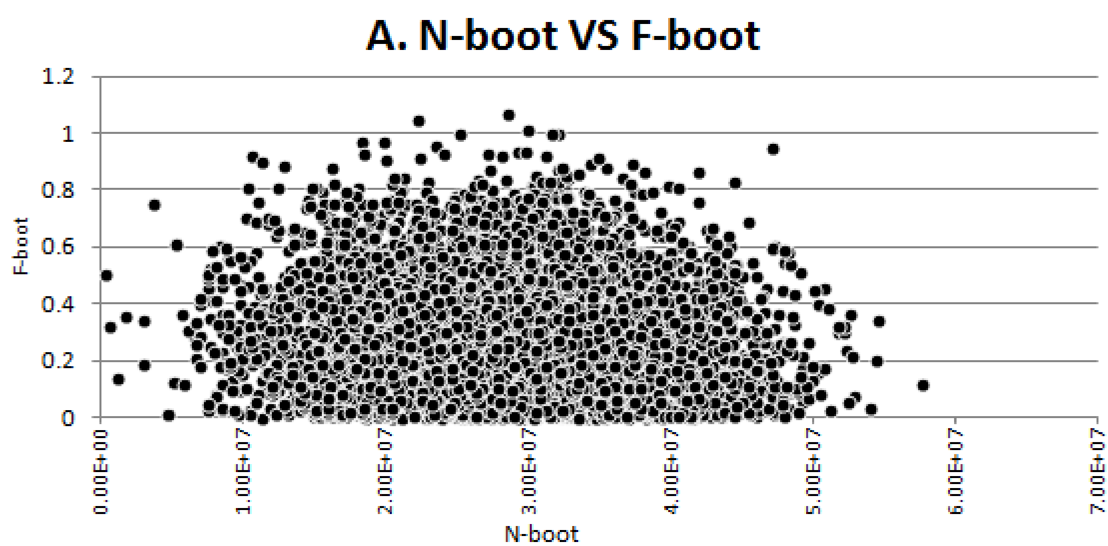


Figure 12. The parameter values form 10,000 Monte Carlo bootstrap replicates were plotted against each other from the bivariate normal distribution for initial numbers (N_{2011}^{boot}, N-boot) and fishing mortality (F_{2011}^{boot} , F-boot), and the second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2011}^{boot}$, S-boot) and equilibrium recruitment ($R_{0\,2011}^{boot}$, R0-boot) for the base model configuration from the Atlantic sharpnose projections (Projection Scenario-1 Baseline, Inverse CV Weighting; ATSH SAR Tables 3.5.23 and 3.5.24) for the fixed removals level (1,000s) of 2750.



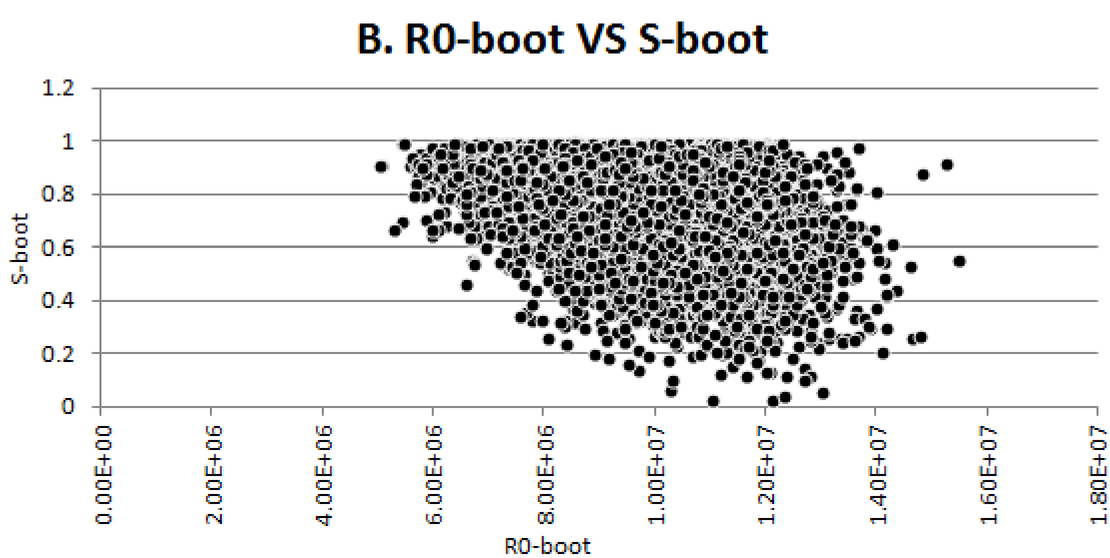
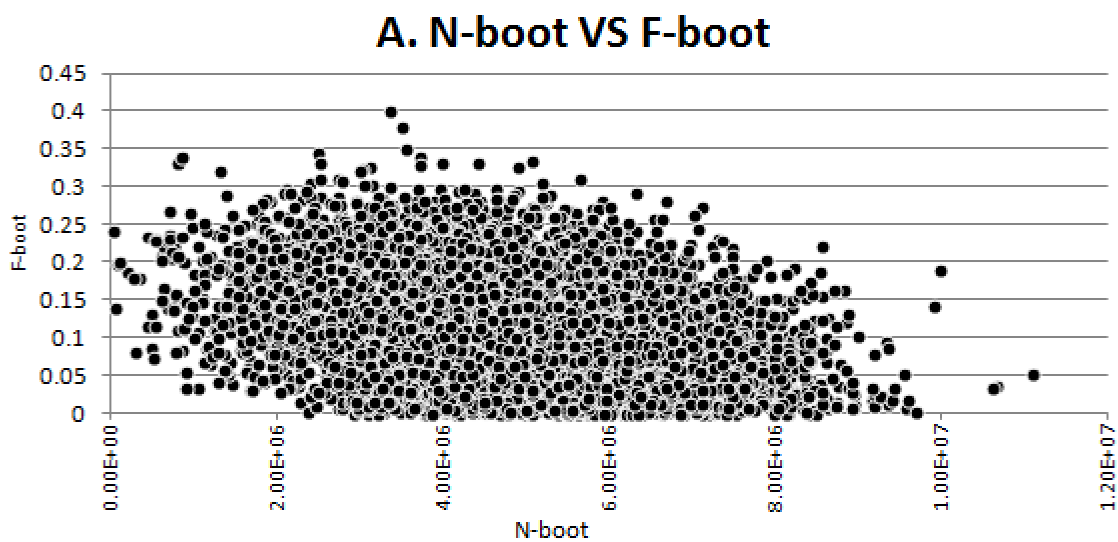


Figure 13. The parameter values form 10,000 Monte Carlo bootstrap replicates were plotted against each other from the bivariate normal distribution for initial numbers (N_{2011}^{boot}, N-boot) and fishing mortality (F_{2011}^{boot}, F-boot), and the second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2011}^{boot}$, S-boot) and equilibrium recruitment ($R_{0\,2011}^{boot}$, R0-boot) for the base model configuration from the bonnethead projections (Projection Scenario-1 Baseline, Inverse CV Weighting; BH SAR Tables 3.5.19 and 3.5.20) for the fixed removals level (1,000s) of 550.



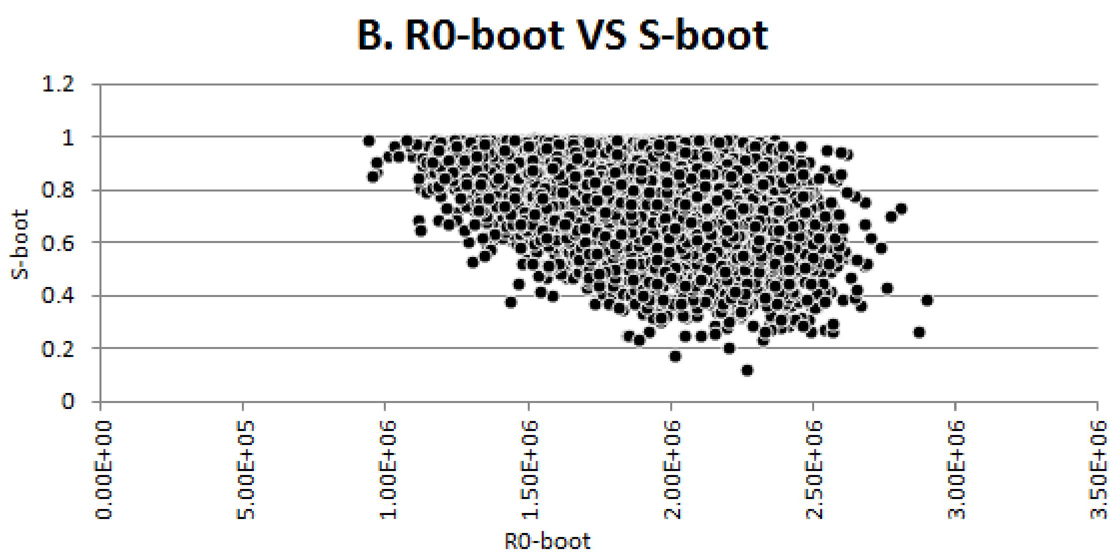


Figure 14. Retrospective projection (1950-2011) at the estimated annual fishing mortality rates from SSASPM, calculated from the projection code without including parameter uncertainty, interim projections at current fishing mortality rate (2012-2014), and the median, 30th and 70th percentiles of $SSF_{t,boot}/SSF_{MSY}$ and $F_{t,boot}/F_{MSY}$ (2015 – 2041) for the base model configuration from the Atlantic sharpnose projections (ATSH SAR Table 3.5.23, Projection Scenario-1 Baseline, Inverse CV Weighting) for fixed removals level (1,000s) of 2750 (L.try=12) (ATSH SAR Table 3.5.24); The 30th percentile of $SSF_{t,boot}/ SSF_{MSY}$ represents the 70% probability of maintaining SSF_t above SSF_{MSY} (solid black line, Panel A) from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041); The 70th percentile of $F_{t,boot}/ F_{MSY}$ represents the 30% probability of F_t exceeding F_{MSY} (solid black line, Panel B) from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).

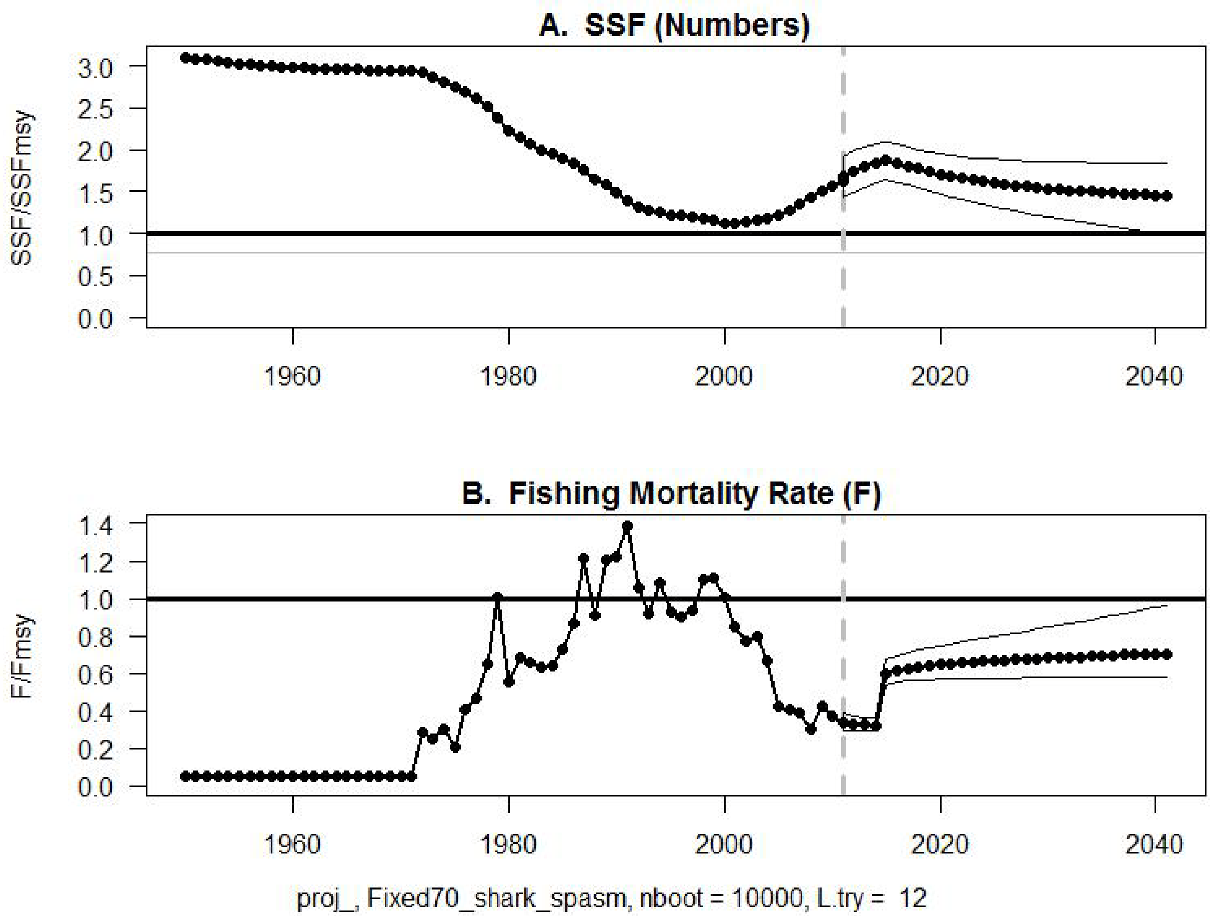


Figure 15. Retrospective projection (1950-2011) at the estimated annual fishing mortality rates from SSASPM calculated from the projection code without including parameter uncertainty, interim projections at current fishing mortality rate (2012-2014), and the median, 30th and 70th percentiles of $SSF_{t,boot}/SSF_{MSY}$ and $F_{t,boot}/F_{MSY}$ (2015 – 2041) for the base model configuration from the bonnethead projections (BH SAR Table 3.5.19, Projection Scenario-1 Baseline, Inverse CV Weighting) for fixed removals level (1,000s) of 550 (BH SAR Table 3.5.20); The 30th percentile of $SSF_{t,boot}$/ SSF_{MSY} represents the 70% probability of maintaining SSFt, above SSFMSY (solid black line, Panel A) from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041); The 70th percentile of $F_{t,boot}$/ F_{MSY} represents the 30% probability of F_t exceeding F_{MSY} (solid black line, Panel B) from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year (2015 – 2041).