MLE vs. MCMC

- Comparisons of MLE and MCMC status and projection results using the alternative fixed TAC limit approach are available from the SEDAR 54 domestic **sandbar shark** stock assessment update (Anon. 2017a; Anon. 2018a) and from the recent ICCAT North Atlantic **shortfin mako** projections update provided in SEDAR 65 RD14 (Courtney and Rice 2020).

- Anonymous. 2017a. HMS sandbar shark. SEDAR 54 stock assessment report. October 2017. SEDAR, 4055 Faber Place Drive, Suite 201 North Charleston, SC 29405. Available: https://sedarweb.org/docs/sar/S54_Final_SAR_with_exec_summary.pdf (Accessed September 2020).
- Anonymous. 2018a. HMS sandbar shark post-review updates. SEDAR 54. February 2018. SEDAR, 4055 Faber Place Drive, Suite 201 North Charleston, SC 29405. Available: http://sedarweb.org/docs/postsedar/Post_Review_Updates_SEDAR_2054_Final_22Feb2018.pdf (Accessed September 2020).
- Courtney, D. and J. Rice. 2020. Example of a Stock Synthesis projection approach at alternative fixed total allowable catch (TAC) limits implemented for three previously completed North Atlantic shortfin mako Stock Synthesis model runs. SCRS/2019/082. Collect. Vol. Sci. Pap. ICCAT, 76(10):78-114. Available: https://www.iccat.int/en/pubs_CVSP.html (Accessed September 2020).

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Sandbar shark stock status
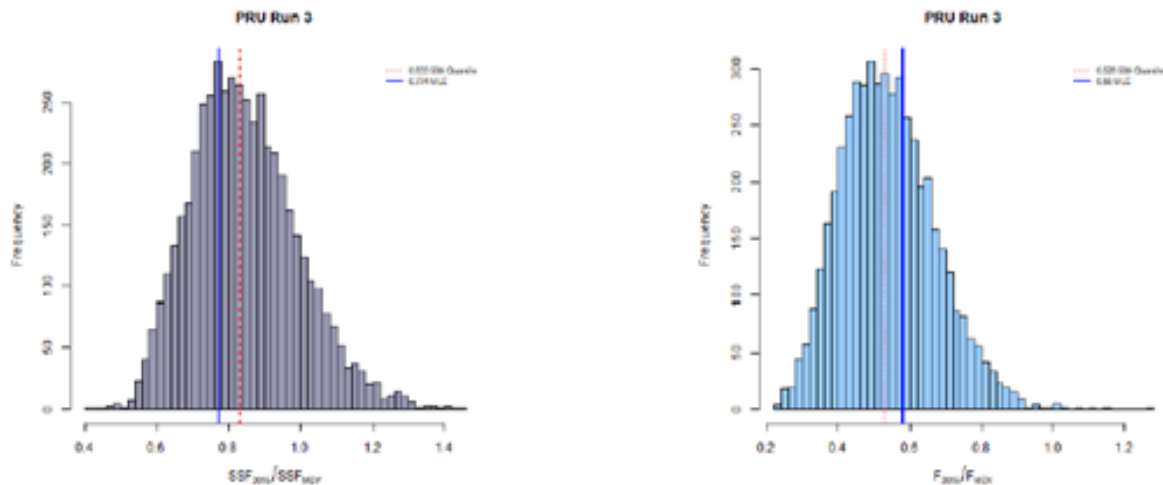
SSF/SSF_{MSY} F/F_{MSY}

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).
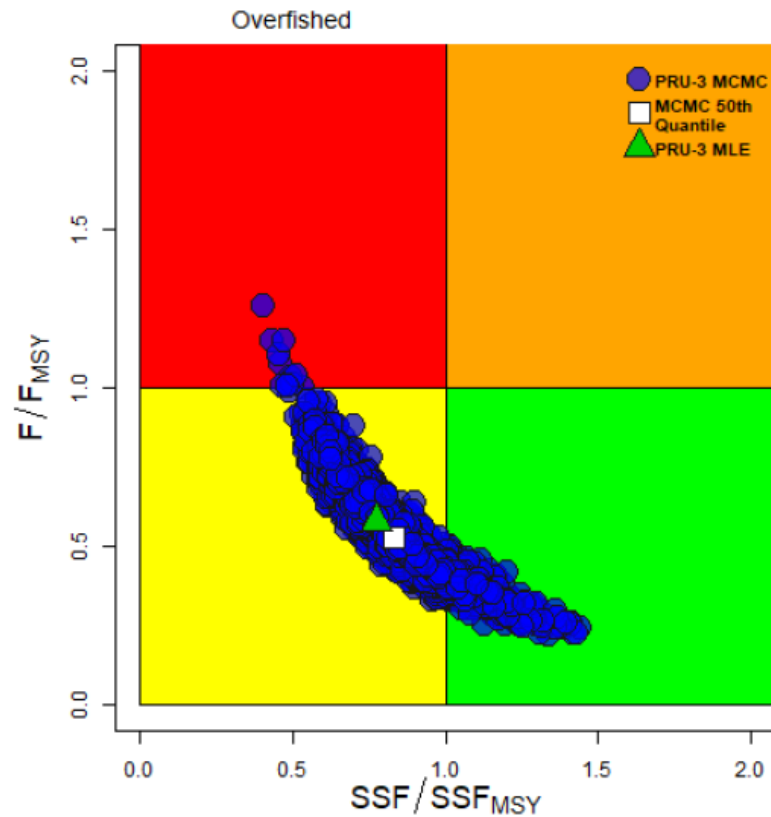
Sandbar shark stock status

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).
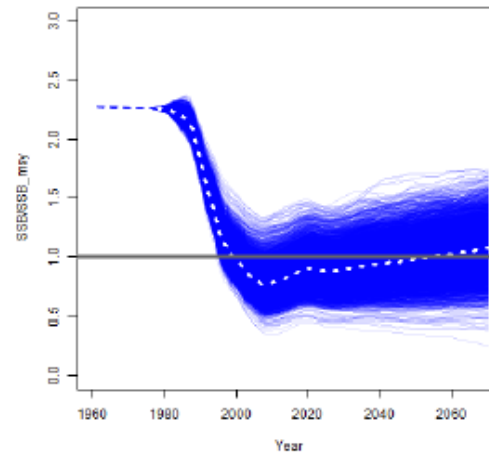
Sandbar shark projections

MLE
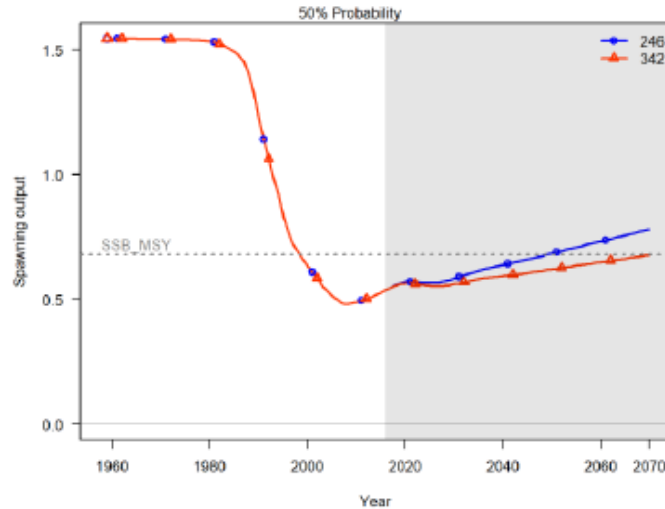
MCMC

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.

Sandbar shark projections

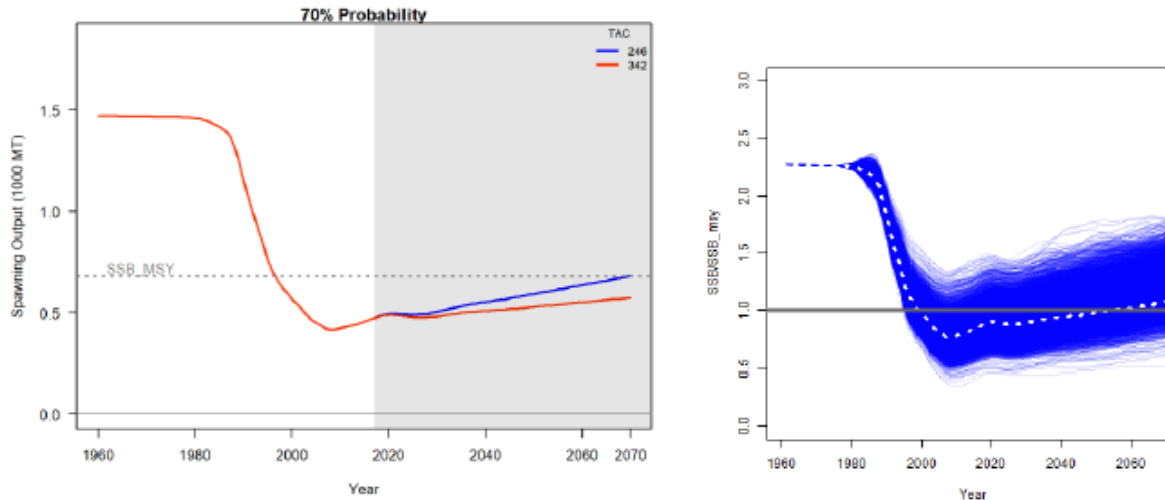MLE   MCMC

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.

Sandbar shark projections: conclusions

- The standard MLE projection approach is consistent with projection approaches used in the past for HMS stocks.

- 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 slightly exceeded $SSF/SSF_{MSY}=1$ in the rebuilding year, which is due to the slight non-normality of the MCMC estimates of SSF/SSF_{MSY}, and should be interpreted with caution. In this case, MLE projections would produce slightly more conservative results.

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Shortfin mako projections

- Model run time for MCMC projections currently limits the number of model runs which can be evaluated using MCMC. In order to reduce run time, two maximum likelihood estimation (MLE) approaches based on a normal and a lognormal distribution, respectively, were also explored to obtain approximate probabilities for $F/F_{MSY} < 1$ and $SSF/SSF_{MSY} > 1$ during the projection period.

- Annual probabilities were calculated using the cumulative normal distribution in R statistical software (R Core Team 2018). Calculations used the Stock Synthesis ADMB output for the parameter estimate (mode) and standard deviation (std) of the derived quantities F/F_{MSY} and SSF/SSF_{MSY}. Cumulative probabilities of $F/F_{MSY} < 1$ and $SSF/SSF_{MSY} > 1$ were calculated analogously to a normal distribution confidence interval (CI) as the proportion of a normal distribution (X%) at the distance x*std from the mode (X% CI = mode ± x*std) for each year of the projection period. A lognormal distribution in F/F_{MSY} and SSF/SSF_{MSY} was also evaluated.

Shortfin mako projections

TAC (t) allowing P >= 50% of achieving given status in projection year (2070)

	Run 1		Run 2		Run 3	
	$P(F<F_{MSY})$	$P(SSF>SSF_{MSY})$	$P(F<F_{MSY})$	$P(SSF>SSF_{MSY})$	$P(F<F_{MSY})$	$P(SSF>SSF_{MSY})$
MCMC	1000	800	900	800	700	0
MLE (normal)	900	800	900	600	600	0
MLE (lognormal)	900	800	900	600	600	0

- In general, the MLE probabilities of $F<F_{MSY}$ and $SSF>SSF_{MSY}$ were slightly lower than those from MCMC for all fixed TAC levels, similar to the SEDAR 54 Sandbar

- The MLE probabilities of $F<F_{MSY}$ and $SSF>SSF_{MSY}$ for the normal approximation were very similar to those from the lognormal approximation