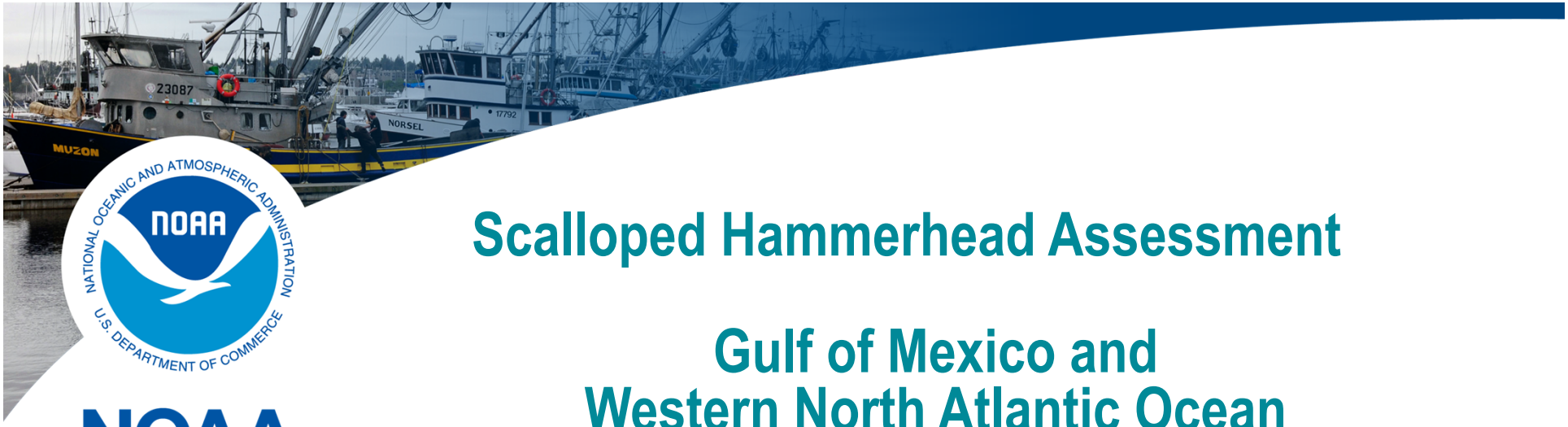


NOAA FISHERIES

SEFSC

Scalloped Hammerhead Assessment

Gulf of Mexico and Western North Atlantic Ocean

Reference Case Stock Synthesis Model

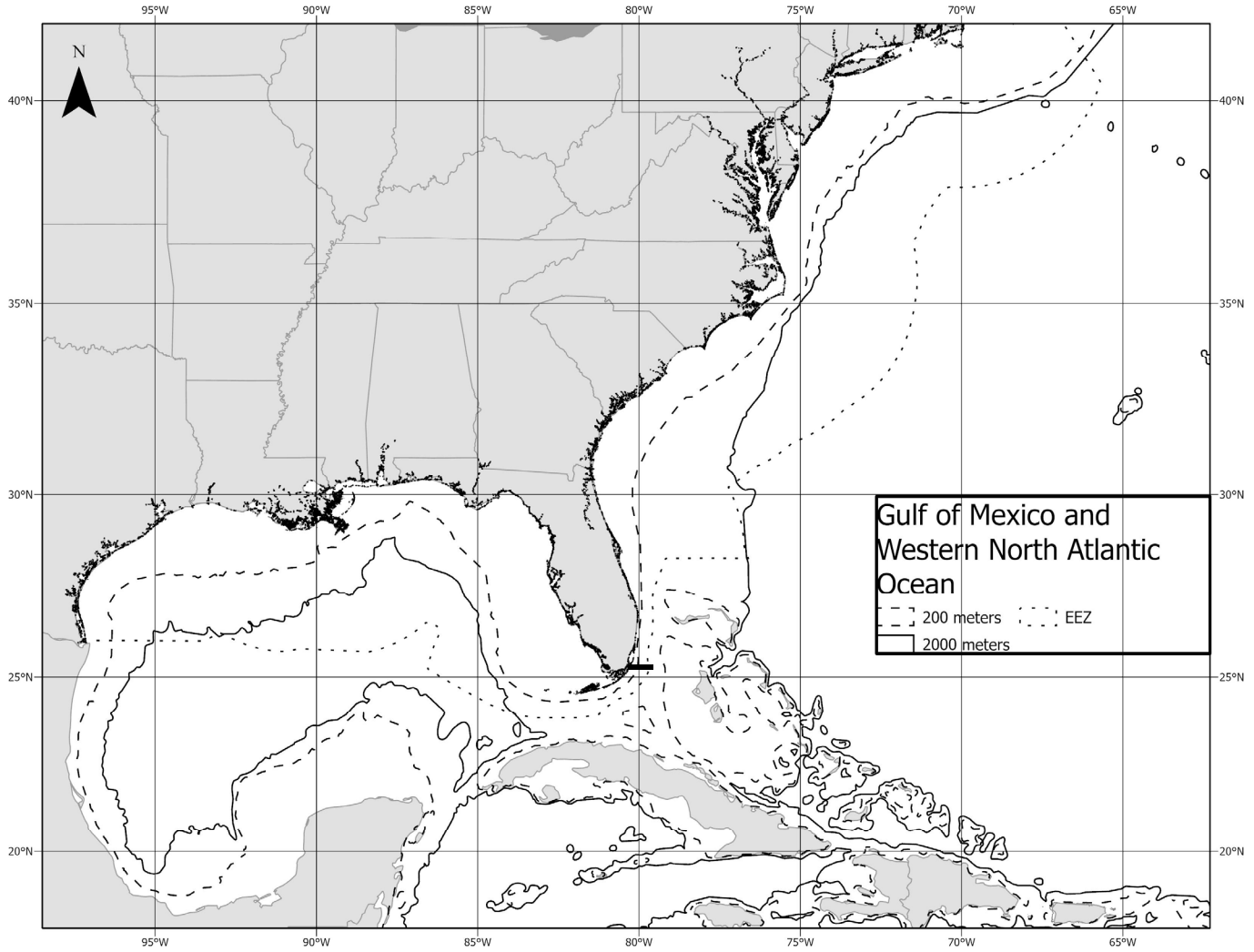
SEDAR 77 (Review Workshop)

August 28 – September 1, 2023

Outline

- Scalloped Hammerhead Assessment – Assessment Process
  - Gulf of Mexico and Western North Atlantic Ocean
- Statement addressing each term of reference
- Data review and update
- Stock assessment reference case model
  - Data
  - Configuration
  - Results
  - Diagnostics
  - Benchmarks and reference points
  - Projections
  - Examples of ABC reductions from projected OFL

Gulf of Mexico and Western North Atlantic Ocean



Assessment Process Final Report Discussion and Decisions

1.5 Statement addressing each term of reference

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks: Scalloped Hammerhead Shark

Section III: Assessment Report

June 2023

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Assessment Process Final Report
Statement addressing each term of reference

- *1. Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.*

- The data used in the assessment are summarized in Section 2 (Data Review and Update). Vital rates (steepness and natural mortality) are obtained from SEDAR77-AW04 (Cortés 2022) developed from life history data provided in the Data Workshop.

Assessment Process Final Report
Statement addressing each term of reference

- *2. Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations (if necessary) for each model considered.*

- Stock Synthesis is implemented as the population assessment model based on its compatibility with the available data and its use in several previous shark stock assessments as summarized in Section 3.1. Input data are provided in Section 3.2 (Data Sources). Model configuration is described in Section 3.3 (Model Configuration and Equations).

Assessment Process Final Report
Statement addressing each term of reference

- *2. Develop population assessment models, continued.*

- Stock Synthesis is implemented as the population assessment model based on its compatibility with the available data and its use in several previous shark stock assessments as summarized in Section 3.1. Input data are provided in Section 3.2 (Data Sources). Model configuration is described in Section 3.3 (Model Configuration and Equations).

- *3. Identify preferred model approach if applicable.*
- See the statement addressing TOR 2.

Assessment Process Final Report
Statement addressing each term of reference

- *4. Provide preliminary estimates of stock population parameters:*
  - *a. Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.*
  - *b. Include appropriate measures of precision for parameter estimates.*
- Preliminary stock population parameters are provided in Section 4 (Results).
- Precision of estimated and derived parameters is obtained from Stock Synthesis AD-Model Builder (ADMB) output as the asymptotic parameter standard deviations (SD) at the converged solution (Fournier et al. 2011) as described in Section 3.3.1.11 (Uncertainty and Measures of Precision).

Assessment Process Final Report
Statement addressing each term of reference

- *5. Characterize uncertainty in the assessment and estimated values, if possible.*
  - *a. Consider uncertainty in input data, modeling approach, and model configuration.*

- In response to the presence of a cryptic hammerhead species in the Atlantic region (Carolina hammerhead), the Stock ID Process recommended conducting sensitivity analyses to the scalloped hammerhead assessment for data inputs separately by geographic region for the GOM and the ATL.

Assessment Process Final Report
Statement addressing each term of reference

- *5. Characterize uncertainty, continued.*
- Two sensitivity analyses were implemented in Stock Synthesis, one for the Gulf of Mexico (GOM) and the other for the Atlantic (ATL).
  - Stock Synthesis models were fit to data inputs provided separately in the GOM and ATL
  - Catch:
    - Section 2.1.4 Sensitivity Analyses; Section 3.2.1.4 Sensitivity Analyses for Catches
  - Indices of abundance:
    - Section 2.2.2 Sensitivity Analyses; Section 3.2.1 Indices of Abundance Sensitivity Analyses
  - Length composition:
    - Section 2.4.1 Sensitivity Analyses; Section 3.2.4.1 Length Composition Sensitivity Analyses
  - Life history:
    - Section 2.3.2 Sensitivity Analyses and Section 3.2.3.1 Life History Analyses

Assessment Process Final Report
Statement addressing each term of reference

- *5. Characterize uncertainty, continued.*
- Two sensitivity analyses were completed, one for the Gulf of Mexico (GOM) and the other for the Atlantic (ATL).
  - Results of the GOM and ATL sensitivity analyses are provided in Section 3.4.4 Sensitivity Analyses (see Section 3.11 **Appendix 3.B** and see Section 3.12 **Appendix 3.C**).
  - However, both sensitivity analysis model configurations failed to pass multiple convergence criteria.
  - A hypothesis provided for the lack of model convergence is that the limited data in both the GOM or the ATL model configurations may not be sufficiently informative to estimate the absolute scale (size) of the population, catchability, and selectivity simultaneously.

Assessment Process Final Report
Statement addressing each term of reference

- *5. Characterize uncertainty, continued.*
  - *b. Consider and include other sources of uncertainty as appropriate for this assessment.*

- Other sensitivity analyses were not conducted due to time constraints.

Assessment Process Final Report
Statement addressing each term of reference

- *5. Characterize uncertainty, continued.*
  - *c. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.*

- Diagnostic results implemented for the Stock Synthesis GOM+ATL continuity analysis model configuration are provided in Section 3.4.5 Diagnostics (see Section 3.14 **Appendix 3.D)**. .

Assessment Process Final Report
Statement addressing each term of reference

- *6. Provide preliminary estimates of population benchmarks or management criteria consistent with available FMPs and amendments, proposed FMPs and amendments, other ongoing or proposed management programs, and the National Standards.*
  - *a. Evaluate existing or proposed management criteria as specified in the management summary.*
  - *b. Recommend and define proxy values when necessary, and provide appropriate justification.*
- Preliminary estimates of population benchmarks are provided in Section 3.4.6 (Benchmarks and Reference Points).

Assessment Process Final Report
Statement addressing each term of reference

- *7. Recommend preliminary stock status relative to management benchmarks or alternative data-poor approaches if necessary.*
- The Stock Synthesis reference case (GOM + ATL) model configuration**, defined here as a provisional base model configuration**, predicted that the stock was not overfished (SSF2019 > MSST) and that the stock was not experiencing overfishing (*F*2019 > *F*MSY) in the terminal year of the assessment (see Section 3.4.6 Benchmarks and Reference Points; see **Tables 3.10** and **3.11**; and see **Figures 3.9** and **3.10**).

Assessment Process Final Report
Statement addressing each term of reference

- *8. Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability density functions for reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.*
- A multivariate log-normal Monte-Carlo approach (MVLN; Winker et al 2019; e.g., Walter and Winker 2020) was applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration to estimate uncertainty about the stock status as described in Section 3.13 (**Appendix 3.D)**.

Assessment Process Final Report
Statement addressing each term of reference

- *9. Project future stock conditions and develop rebuilding schedules, if warranted. Provide the estimated generation time for the stock. Stock projections shall be developed in accordance with the following:*

a. *If the preliminary stock status is overfished, then utilize projections to determine:*
   i. *Year in which F=0 results in a 70% probability of rebuilding (Year $F{=}0_{p70}$).*
   ii. *Target rebuilding year ($Year_{rebuild}$).*
      1. *Year $F{=}0_{p70}$ if Year $F{=}0_{p70} \leq 10$ years, or*
      2. *Year $F{=}0_{p70}$ + 1 generation time if Year $F{=}0_{p70} > 10$ years.*
   iii. *F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$.*
   iv. *Fixed level of removals allowing rebuilding of stock with 50% and 70% probability.*

Assessment Process Final Report
Statement addressing each term of reference

- *9. Project future stock conditions, continued.*

b. *If the preliminary stock status is determined to be undergoing overfishing, then utilize projections to determine:*
   i. *$F=F_{reduce}$ (different reductions in F that should end overfishing with a 50% and 70% probability).*

c. *If the preliminary stock status is determined to be neither overfished nor undergoing overfishing, then utilize projections to determine:*
   i. *The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P* = 0.3 approach), and/or*
   ii. *The constant catch associated with a 70% probability of overfishing not occurring and the stock not being overfished.*

d. *If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.*

Assessment Process Final Report
Statement addressing each term of reference

- *9. Project future stock conditions, continued.*

- Examples of projected fishery removals at the overfishing limit (OFL) were obtained for the Stock Synthesis reference case (GOM + ATL) model configuration as described in Sections 3.3.1.14, 3.4.7, and 3.14 (**Appendix 3.E)**.
- Examples of projected OFL during the years 2020 – 2025 were obtained from Stock Synthesis projections at F_{MSY} based on the underlying population dynamics assumed during the projection period as described in Sections 3.4.7 and 3.14.

Assessment Process Final Report
Statement addressing each term of reference

- *11. Provide recommendations for future research and data collection. Emphasize items that will improve future assessment capabilities and reliability. Consider data, monitoring, and assessment needs.*
- See Section 3.6 (Recommendations for Future Research and Data Collection).

- *12. Complete an Assessment Workshop Report in accordance with project schedule deadlines.*
- The Assessment Workshop Report was completed in accordance with project schedule deadlines.

Break - DATA REVIEW AND UPDATE

- DC_SEDAR_77_RW_01_Assessment_History_v3(8_27_2023).pdf
- DC_SEDAR_77_RW_02_Scalloped_HH_Stock_ID_v2(08_27_2023).pdf
- DC_SEDAR_77_RW_03_Hammerhead_PRM_v2(08_27_2023).pdf
- DC_SEDAR_77_RW_04_Scalloped_HH_Catches_v2(08_27_2023).pdf

Assessment Process Final Report Discussion and Decisions

2. DATA REVIEW AND UPDATE

SEDAR

Southeast Data, Assessment, and Review

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HMS Hammerhead Sharks: Scalloped Hammerhead Shark

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Assessment Process Final Report
Discussion and Decisions

- 2.1.1 Total Commercial Catch
- Total commercial catches of scalloped hammerheads were obtained for the period 1981 – 2019 from the SEDAR 77 DW Report (their section 3, Tables 36, 38, and 40) in pounds dressed weight (lb dw), converted to kilograms whole weight (kg ww) using conversion ratios obtained from the DW for each data source (Pers. Comm. E. Cortés, July 2022; **Table 2.1**) and entered in Stock Synthesis in units of metric tons (where one mt = 1,000 kg; **Table 2.1**).

Assessment Process Final Report Discussion and Decisions

- 2.1.1 Total Commercial Catch

11.8260= 18757 (lb dw) x 1.39 (lb ww:ld dw) x 0.453592 (kg:lb) x 0.0001 (mt:kg)
where
18757 (lb dw)is obtained from SEDAR 77 DW Report (their section 3, Table 36)

2.5 Tables

Table 2.1. Total commercial catches of scalloped hammerheads in weight (mt ww) adapted from SEDAR 77 DW Report (their section 3, Tables 36, 38, and 40) using conversion ratios obtained from the DW for each data source (Pers. Comm. E. Cortés, July 2022).

A. Areas Combined (GOM + ATL)

Year	Bottom longline (total catch)	Gillnet (total catch)	Hook and line + hand line (total catch)	Pelagic longline (dead discards)
1981	0.0000	0.0000	0.0000	0.0000
1982	12.6696	2.9262	0.0553	10.4877
2016	11.8260	13.7074	10.8603	48.1910
2017	17.4460	30.9052	1.9842	73.8634
2018	13.1444	8.3638	11.1679	20.6635
2019	7.7864	10.2231	0.1293	9.9001
lb ww : lb dw	1.39	1.39	1.39	2.02

Assessment Process Final Report
Discussion and Decisions

- 2.1.2 Total Recreational Catch
- Total recreational catches of scalloped hammerheads were obtained for the period 1981 – 2019 from the SEDAR 77 DW Report (their section 3, Tables 37, 39, and 41) in numbers (thousands; **Table 2.2**). Recreational catches were obtained as the sum of type A (number of fish killed or kept seen by the interviewer) plus type B1 (number of fish killed or kept reported to the interviewer by the angler). Recreational live post-release mortality (LPRM) was obtained as type B2 (number of fish released alive reported by the fisher) multiplied by the assumed post-release mortality rate.

Assessment Process Final Report Discussion and Decisions

- 2.1.2 Total Recreational Catch

Table 2.2. Total recreational catches of scalloped hammerheads in numbers (thousands of individuals) adapted from SEDAR 77 DW Report (their section 3, Tables 37, 39, and 41). Recreational catch (AB1) is type A (number of fish killed or kept seen by the interviewer) plus type B1 (number of fish killed or kept reported to the interviewer by the angler). Recreational LPRM is type B2 (number of fish released alive reported by the fisher) multiplied by the assumed post-release mortality rate.

	Areas combined (GOM + ATL)		Gulf of Mexico (GOM)		Atlantic (ATL)	
Year	Recreational AB1 (1000s)	Recreational LPRM (1000s)	Recreational AB1 (1000s)	Recreational LPRM (1000s)	Recreational AB1 (1000s)	Recreational LPRM (1000s)
1981	23.6410	22.8979	2.1019	0.2551	25.2492	26.0038
1982	23.6410	22.8979	2.1019	0.2551	25.2492	26.0038
2016	0.1932	2.9880	0.0384	0.3775	0.0887	3.6302
2017	0.0389	2.4954	0.0342	0.4962	0.0040	2.8450
2018	0.0389	2.4954	0.0342	0.4962	0.0040	2.8450
2019	0.0389	2.4954	0.0342	0.4962	0.0040	2.8450

Assessment Process Final Report
Discussion and Decisions

- 2.1.3 Commercial Discards
- Commercial discards were included in the reference case total commercial catches of scalloped hammerheads obtained for the period 1981 – 2019 from the SEDAR 77 DW Report (their section 3, Tables 36, 38, and 40) and reported here in (**Table 2.1**).

Assessment Process Final Report
Discussion and Decisions

- **2.2 Indices of Abundance**
- 2.2.1 Indices of Abundance Recommended by the DW
- All indices of abundance recommended by the DW for use in the stock assessment model are described in the DW report and the associated DW working papers and are summarized here in **Tables 2.3** and **2.4**. Unless noted otherwise below, all indices were standardized using generalized linear models in a two-step delta-lognormal approach that modeled the proportion of positive catch with a binomial error distribution separately from the positive catch, which was modeled using a lognormal distribution as described in the associated DW working papers identified below. The SEDAR77 DW papers identified [in] **Tables 2.3** and **2.4** are referenced in the first section of the DW (List of Data Workshop Working Papers).

Assessment Process Final Report Discussion and Decisions

- 2.2.1 Indices of Abundance Recommended by the DW

Table 2.3. Recommended indices of abundance for Age 1+ scalloped hammerhead including index name, the value of catch per unit effort, and SEDAR document number (adapted from SEDAR 77 DW Report, their section 4, Tables 5, 6, and 7); CV is the coefficient of variation for the annual index value; Years with missing values (corresponding to either zero catches, no CV, or no sampling, ns) were excluded from the assessment.

A. Areas Combined (GOM+ATL)

	Pelagic Longline Observer Program SEDAR77-DW08 Sharks per 1000 hooks		Shark Bottom Longline Observer Program SEDAR77-DW12 Sharks per 10000 hooks		Shark Research Fishery SEDAR77-DW12 Sharks per 10000 hooks		FSU Longline SEDAR77-DW14 Sharks per 100 hook-hrs		SEFSC MS Bottom Longline SEDAR77-DW24 Sharks per 100 hook-hrs	
Year	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1992	0.174	0.741								
1993	0.062	0.565								
1994	0.045	0.645	5.867	0.430						
1995	0.039	0.629	8.990	0.419					0.081	0.337
1996	0.014	1.231	9.030	0.398					0.052	0.438
1997	0.070	0.729	9.015	0.503					0.063	0.310
1998	0.077	0.880	12.811	0.452					ns	
1999	0.018	1.066	3.266	0.714					0.050	0.339
2000	0.017	0.772	0.281	1.596					0.071	0.247
2001	0.052	0.807	12.125	0.447					0.115	0.219
2002	0.017	1.319	16.468	0.390					0.093	0.177
2003	0.038	0.785	20.271	0.343					0.154	0.209
2004	0.035	0.772	16.563	0.378					0.056	0.312
2005	0.040	0.642	6.975	0.509					0.112	0.475
2006	0.050	0.777	25.205	0.405					0.060	0.358
2007	0.049	0.591	15.530	0.562					0.088	0.327
2008	0.073	0.497			4.129	0.773			0.095	0.372
2009	0.101	0.449			65.590	0.331			0.129	0.268
2010	0.084	0.488			46.926	0.328			0.142	0.242
2011	0.054	0.481			58.507	0.325	0.003	0.333	0.066	0.269
2012	0.101	0.471			90.500	0.374	ns		0.060	0.358
2013	0.046	0.458			53.035	0.396	ns		0.061	0.312
2014	0.038	0.551			68.047	0.358	0.001	1.147	0.079	0.337
2015	0.039	0.516			99.944	0.371	0.006	0.468	0.157	0.219
2016	0.041	0.521			68.444	0.360	0.004	0.777	0.094	0.295
2017	0.073	0.523			89.840	0.361	0.009	0.271	0.126	0.243
2018	0.033	0.688			42.589	0.395	0.003	0.656	0.094	0.275
2019	0.015	0.918			44.341	0.387	0.002	0.796	0.118	0.294

Assessment Process Final Report Discussion and Decisions

- 2.2.1 Indices of Abundance Recommended by the DW

Table 2.4. Recommended indices of abundance for Age 0 scalloped hammerhead including index name, the value of catch per unit effort, and SEDAR document number (adapted from SEDAR 77 DW Report, their section 4, Table 9). Years with missing values (corresponding to either zero catches, no CV, or no sampling, ns) were excluded from the assessment.

	TXPWD-Gillnet SEDAR77 DW-16 Gulf of Mexico Sharks per net per hour		GULFSPAN SEDAR77 DW-17 Gulf of Mexico Sharks per net per hour		COASTSPAN - LL SEDAR77-DW-30 Atlantic Sharks per 100 hook hours		SCCOASTGN - LONG SEDAR77-DW-31 Atlantic Sharks per net hour		SCCOASTGN - SHORT SEDAR77 DW-32 Atlantic Sharks per net hour	
Year	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1982	0.00033									
1983	0.00042	0.912								
1984	0.00000									
1985	0.00015									
1986	0.00035	0.732								
1987	0.00000									
1988	0.00050	0.618								
1989	0.00012									
1990	0.00090	0.603								
1991	0.00053	0.749								
1992	0.00000									
1993	0.00032	0.819								
1994	0.00027	0.848								
1995	0.00010	1.165								
1996	0.00093	0.536	0.009	0.294						
1997	0.00172	0.666	0.016	0.461						
1998	0.00031	0.842	0.002	0.548						
1999	0.00021	0.781	0.091	0.312						
2000	0.00048	0.589	0.156	0.253						
2001	0.00150	0.603	0.148	0.302			1.2498	0.4793		
2002	0.00033	0.822	0.15	0.166			0.7881	0.5178		
2003	0.00183	0.577	0.102	0.181			2.7417	0.4496		
2004	0.00075	0.689	0.07	0.227			0.5413	1.4316		
2005	0.00254	0.517	0.048	0.373	5.464	0.529	0.6254	0.5384		
2006	0.00069	0.630	0.079	0.22	8.119	0.416	0.9807	1.0179		
2007	0.00079	0.778	0.168	0.171	1.976	1.128	1.9521	0.5328	0.1709	0.4233
2008	0.00075	0.703	0.172	0.189	1.730	1.165	1.3839	0.7066	0.2857	0.5813
2009	0.00095	0.560	0.163	0.2	3.482	0.654	7.2980	1.3825	0.0000	
2010	0.00213	0.598	0.208	0.211	9.376	0.327	2.2974	0.8537	0.1135	0.5813
2011	0.00091	0.563	0.159	0.201	3.876	0.372	1.4874	0.5401	0.1129	0.3072
2012	0.00124	0.540	0.093	0.217	1.907	0.469	8.1799	0.5273	0.1155	0.3072
2013	0.00484	0.428	0.129	0.215	2.052	0.427	4.0580	0.4515	0.0897	0.4233
2014	0.00198	0.477	0.141	0.207	2.443	0.548	2.2039	0.6955	0.0000	
2015	0.00283	0.565	0.068	0.252	1.158	0.554	0.9686	0.6158	0.0199	0.5813
2016	0.00191	0.590	0.124	0.235	1.899	0.419	1.6754	0.5384	0.0978	0.3507
2017	0.00041	0.775	0.184	0.2	1.123	0.519	6.8082	0.3406	0.0000	
2018	0.00482	0.499	0.21	0.225	0.738	0.565	3.7252	0.5473	0.0000	
2019	0.00248	0.514	0.176	0.265	1.029	1.175	3.3050	0.4230	0.0208	0.5813

Assessment Process Final Report Discussion and Decisions

- 2.2.1 Indices of Abundance Recommended by the DW

During the assessment we identified two types of geographic distribution in the CPUE coverage
1. those indices that cover primarily age - 0 (sample estuaries and coastal bays where primarily age-0 sharks are encountered)
2. Those indices that cover other life stages (sample generally waters for offshore where older sharks are encountered and age-0 sharks are not)

For those indices that cover primarily age - 0, we limited the sharks included in the CPUE index to those assumed to be age-0 based on size at capture (cant remember the size cutoff)

those are the indices you are referring to and are listed in Table 2.4

Assessment Process Final Report Discussion and Decisions

- **2.3 Life History Inputs**
- Life history data used in the stock assessment model were obtained directly from the DW report (Data Workshop Report Section 2 Life History, their Tables 1 and 6) and were unchanged for use in the scalloped hammerhead stock assessment unless noted otherwise below.

Assessment Process Final Report
Discussion and Decisions

- **2.3 Life History Inputs**
- 2.3.1 Estimates of Vital Rates
- Assessment document SEDAR77-AW04 (Cortés 2022) developed vital rates and population dynamics parameters including Beverton-Holt stock-recruitment steepness (*h*) and natural mortality based on biological information provided in the Data Workshop Report.
- **For the combined regions (GOM + ATL), the median steepness value (0.69)**, along with approximate lower and upper confidence limits computed as the 2.5th and 97.5th percentiles (LCL = 0.44 and UCL = 0.87) obtained from Monte Carlo simulation of vital rates with a Leslie matrix approach were recommended by the author for use in the Stock Synthesis base, low, and high productivity states of nature sensitivity analyses, respectively (Cortés 2022, his Table 8, Panel A; Pers. Comm. E. Cortés, July 2022).

Assessment Process Final Report
Discussion and Decisions

- **2.3 Life History Inputs**
- 2.3.1 Estimates of Vital Rates, continued.
- **Mean estimates of instantaneous natural mortality rates (yr-1) were obtained from six life-history invariant estimators** (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022) for use in the reference case Stock Synthesis model (areas combined GOM+ATL; **Table 2.5 Panel A**).

Assessment Process Final Report Discussion and Decisions

- 2.3.1 Estimates of Vital Rates. continued.

Table 2.5. Mean estimates of instantaneous natural mortality rates (yr^{-1}) for use in the reference case Stock Synthesis model obtained with six life-history invariant estimators used in the Euler-Lotka and Leslie matrix approaches, and estimates for use in sensitivity analyses obtained with the Dureuil et al. (2021) method; Adapted from the estimation of vital rates for scalloped hammerhead in the assessment document SEDAR77-AW04 (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022).

A. Areas Combined (GOM+ATL)

	Mean of 6 life-history invariant methods		Dureuil et al. (2021) length-based method	
Age	Female (Mean of 6)	Male (Mean of 6)	Female (Dureuil et al. 2021)	Male (Dureuil et al. 2021)
0	0.184	0.193	0.353	0.385
1	0.164	0.171	0.258	0.275
46	0.116	0.124	0.066	0.070
47	0.116	0.124	0.066	0.070
48	0.116	0.124	0.066	0.070
49	0.116		0.066	
50	0.116		0.065	
Average	0.123		0.093	

Assessment Process Final Report
Discussion and Decisions

- **2.4 Length Composition Data**
- A review of the available length composition data is provided in the Data Workshop Report (Section 6. Length Composition). Length composition data sets used in the Stock Synthesis stock assessment model(s) are discussed in more detail below in Section 3.

Assessment Process Final Report Discussion and Decisions

3. Stock Assessment Model (Data)

SEDAR

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Assessment Process Final Report
Stock Assessment Reference Case Model

- **3.1 Overview**
- Stock Synthesis (version 3.30.15.00; Methot et al. 2020) was implemented here using an areas as fleets approach by including multiple fleets within a spatially-aggregated assessment model (e.g., Hurtado-Ferro et al. 2014; Punt et al. 2014).

Assessment Process Final Report
Stock Assessment Reference Case Model

- 3.2.1 Catch
- 3.2.1.1. Total Commercial Catch

Total commercial catches during the years 1981 – 2019 were obtained from **Table 2.1** above. Commercial catches were entered in Stock Synthesis in metric tons (one mt = 1,000 kg) aggregated into "fleets" (F1 – F3, and F6) as described in **Table 3.1**:

F1 (Com-BLL) = Bottom longline (1981 – 2019);
F2 (Com-GN) = Gillnet (1981 – 2019);
F3 (Com-PLL) = Pelagic longline discard (1981 – 2019); and
F6 (Com-Other-Kept) = Hook and line plus hand line (1981 – 2019) as described below.

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- 3.2.1 Catch
- 3.2.1.2. Total Recreational Catch

Total recreational catches during the years 1981 – 2019 were obtained from **Table 2.2 above**. Recreational catch and recreational post-release mortality, PRM, were entered in Stock Synthesis in numbers (thousands) aggregated into "fleets" (F4 and F5) described in **Table 3.1**:

F4 (Recreational catch) = Recreational (A+B1) (1981 – 2019); and

F5 (Recreational PRM) = Recreational (B2 PRM) (1981 – 2019), as described below.

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Stock Assessment Reference Case Model

- 3.2.1 Catch
- 3.2.1.3. Commercial Discards

Commercial discards were included in the total commercial catches of scalloped hammerheads obtained for the period 1981 – 2019 from the SEDAR 77 DW Report (their section 3, Tables 36, 38, and 40) as described above and in **Table 2.1**.

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Stock Assessment Reference Case Model

- 3.2.2 Indices of Abundance and Catchability
- Indices of relative abundance during the years 1982 – 2019 were obtained from **Tables 2.3** and **2.4** above. Indices of relative abundance were input in Stock Synthesis (**Table 3.1**) as either population "surveys" (S1 – S5; all-ages in the sampled population, generally obtained offshore and generally not including age-0 individuals) or surveys of "recruits" (R1 – R5; age-0 in the sampled population, generally obtained from near-shore bays or estuaries and further limited within analyses to include only age-0 data):

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Stock Assessment Reference Case Model

- 3.2.2 Indices of Abundance, continued.

S1 (PLL-Obs) = Pelagic longline observer program (1992 – 2019);
S2 (Shark-BLL-Obs) = Bottom longline fishery observer program (1994 – 2007);
S3 (Shark-BLL-Res) = Shark bottom longline research fishery (2008 – 2019);
S4 (FSU-BLLS) = FSU bottom longline survey (2011 – 2019);
S5 (SEFSC-BLLS) = NMFS SEFSC bottom longline survey (1995 – 2019);
R1 (TXPWD-GNS) = Texas Parks and Wild. Dep. gillnet survey (age-0, 1982 – 2019);
R2 (GULFSPAN-GNS) = GULFSPAN gillnet survey (age-0, 1996 – 2019);
R3 (COASTSPAN-BLLS) = (COASTSPAN) bottom longline survey (age-0, 2005 – 2019);
R4 (COASTSPAN-LGNS) = COASTSPAN long-gillnet survey (age-0, 2001-2019); and
R5 (COASTSPAN-SGNS) = COASTSPAN short-gillnet survey (age-0, 2007 – 2019) as described below.

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- 3.2.2 Indices of Abundance, continued.
- The ten indices of relative abundance were recommended by the Index Working Group of the Data Workshop for use in a base model configuration. The annual indices of relative abundance and their associated annual coefficients of variation (CVs) were obtained from both fisheries-dependent observer programs (S1 – S3) and fisheries-independent scientific surveys (S4, S5, R1 – R5) as described in **Tables 2.3 and 2.4** above.
- All "surveys" were input in Stock Synthesis as indices of relative abundance and assumed to have log-normally distributed annual error input as sqrt(ln(1+CV^2)), which is approximated by the annual CVs provided for each index as described in **Tables 2.3 and 2.4** above and then modified by data weighting described below.

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Stock Assessment Reference Case Model

- 3.2.2 Catchability (q)
- Indices of relative abundance were assumed to be proportional to available biomass at the middle of the calendar year, with constant catchability (*q*) (Methot and Wetzel 2013).
- For indices without time blocks, the median unbiased analytical solution for *q* was obtained from Stock Synthesis by setting *q* equal to a constant scaling factor (Methot et al. 2020).

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- 3.2.2 Catchability (q), was estimated with time blocks for some fleets
- Index S2 (Shark-BLL-OBS)
  - 1981 – 1996; 1997 – 2004 [main years]; and 2005 – 2007.
- Index S3 (Shark-BLL-Res)
  - 2008; 2009 – 2017 [main years]; and 2018 – 2019.
- The time blocks were adapted from those previously implemented for both length and catchability in the relatively more data rich SEDAR 65 Atlantic blacktip shark stock assessment (Anonymous. 2020).
- An assumption made in SEDAR 77 was that time blocks implemented for fits to length composition and catchability data in SEDAR 65 resulted from poor fits to length data over time caused by factors not accounted for directly in the modelled population dynamics (e.g., management changes or other external factors not accounted for in the [SEDAR 65] population dynamics model).

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Stock Assessment Reference Case Model

- 3.2.2 Catchability (q), continued.
- Another assumption made in SEDAR 77 was that similar factors (e.g., management changes or other external factors not accounted for in the [SEDAR 65] population dynamics model) probably affected length composition data collected in both SEDAR 65 and SEDAR 77.
- Consequently, time blocks developed [for] fits to length composition data in the relatively more data rich SEDAR 65 stock assessment were be adapted here for use in the relatively more data poor SEDAR 77 stock assessment (E.g., Punt et al. 2011, 2020).
- **Generally, if time blocks are required to improve fits to length comp, then they are also added to catchability.**

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Stock Assessment Reference Case Model

- 3.2.3 Life History Data
- Life history data were obtained from the Data Workshop Report (Their Section 2 Life History Table 1) for use in the reference case Stock Synthesis model (areas combined GOM+ATL).
- In addition, the assessment document SEDAR77-AW04 (Cortés 2022) developed vital rates and population dynamics parameters including Beverton-Holt stock-recruitment steepness (*h*=***0.69***) and natural mortality based on biological information provided in the Data Workshop Report.
- Mean estimates of instantaneous natural mortality rates (yr-1) were obtained from six life-history invariant estimators (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022) for use in the reference case Stock Synthesis model (areas combined GOM+ATL; **Table 2.5 Panel A**).

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- 3.2.4 Length Composition Data
- The available length composition data are summarized in the Data Workshop Report (Their Section 6. Length Composition). For use in Stock Synthesis, the commercial and recreational gear types were aggregated into six 'fleets' (F1 – F6) with similar length composition as described in **Tables 3.1** and **3.2**. This approach is consistent with previous Atlantic HMS SEDAR stock assessments conducted in Stock Synthesis for both the Atlantic smooth dogfish shark (Anon. 2015) and the Atlantic blacktip shark (Anon. 2020). Fishery-independent length composition data were also provided for several fishery independent scientific surveys as described in **Tables 3.1** and **3.2**.

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Stock Assessment Reference Case Model

- 3.2.4 Length Composition Data, continued.
- Total sample size differs in some cases between the Data Workshop Report (Their Section 6. Length Composition) and **Table 3.2** because length data in **Table 3.2** were limited to the years with catch and survey data included for the Stock Synthesis reference case (GOM + ATL) model configuration (**Table 3.1)**.
- Fits to length composition data by fleet and survey are provided in the assessment model results section.

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- 3.2.4 Length Composition Data, continued.
- A minimum annual sample size of 20 to 30 measured individuals was implemented for the Stock Synthesis reference case (GOM + ATL) model configuration (**Table 3.2**).
- A minimum sample size was implemented in an effort to insure that the annual length composition data entered in the stock assessment model were representative of the annual distributions in length captured by each fleet and survey.

Assessment Process Final Report
Stock Assessment Reference Case Model

- **3.3 Model Configuration and Equations**
- 3.3.1.6. Selectivity
- The Stock Synthesis double normal selectivity function (Stock Synthesis selectivity pattern 24; Methot et al. 2020) was implemented (**Table 3.5**) in the Stock Synthesis reference case (GOM + ATL) model configuration and fit to the available length composition data (35 – 250+ cm FL with a 10 cm data bin width) based on a review of the available length composition data described in the Data Workshop Report Section 6 Length Composition, and summarized here in **Tables 3.1** and **3.2)**.

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Stock Assessment Reference Case Model

- **3.3 Model Configuration and Equations**
- 3.3.1.6. Selectivity
- Sex-specific selectivity was implemented for fleets with sufficient sex-specific length composition data (F1, F3, S4, and S5; **Tables 3.2 and 3.5**). Sex-specific selectivity was implemented as a parameter offset to the double normal selectivity (Methot et al. 2020).

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- 3.3.1.6. Selectivity, continued.

Table 3.5 Number of estimated parameters (numbers within parentheses) in the Stock Synthesis reference case (GOM + ATL) model configuration.

Fleet	Fleet name	Proposed selectivity pattern	Implemented selectivity pattern	Sex	Time block(s)	Number of selectivity parameters	Number of catchability parameters	Sub-total of parameters	Sub-total of estimated parameters
1	F1 (Com-BLL)	Logistic	Logistic	Sex specific	Sel. (peak, ascend)[1]	19 (6)	0 (0)	19	(6)
2	F2 (Com-GN)	Double normal	Double normal	Combined sex	Sel. (peak)[2]	7 (3)	0 (0)	7	(3)
3	F3 (Com-PLL)	Logistic	Logistic	Sex specific		11(3)	0 (0)	11	(3)
4	F4 (Rec)	Double normal	Double normal	Combined sex	Sel. (end)[3]	7 (1)	0 (0)	7	(1)
5	F5 (Rec-RPM)		Mirror F4	Mirror F4	Mirror F4	0 (0)	0 (0)	0	(0)
6	F6 (Com-Other-Kept)		Mirror F4	Mirror F4	Mirror F4	0 (0)	0 (0)	0	(0)
7	S1 (PLL-Obs)		Mirror F3	Mirror F3		0 (0)	1 (0)	1	(0)
8	S2 (Shark-BLL-Obs)		Mirror F1	Mirror F1	Catchability[4]	0 (0)	3 (3)	3	(3)
9	S3 (Shark-BLL-Res)		Mirror F1	Mirror F1	Catchability[5]	0 (0)	3 (3)	3	(3)
10	S4 (FSU-BLLS)	Logistic	Logistic	Sex specific		11(2)	1 (0)	12	(2)
11	S5 (SEFSC-BLLS)	Logistic	Logistic	Sex specific		11(3)	1 (0)	12	(3)
12	R1 (TXPWD-GNS)	Double normal	Double normal	Combined sex		6 (2)	1 (0)	7	(2)
13	R2 (GULFSPAN-GNS)	Double normal	Double normal	Combined sex		6 (1)	1 (0)	7	(1)
14	R3 (COASTSPAN-BLLS)	Double normal	Double normal	Combined sex		6 (1)	1 (0)	7	(1)
15	R4 (COASTSPAN-LGNS)	Double normal	Double normal	Combined sex		6 (1)	1 (0)	7	(1)
16	R5 (COASTSPAN-SGNS)	Double normal	Mirror R4	Mirror R4		0 (0)	1 (0)	1	(0)
						Total (selectivity, catchability)		104	(29)
	Other estimated parameters								
	ln(R_0)								(1)
	Recruitment deviations					1988 – 2019			(32)
	Forecast rec. dev.					2020 – 2029			(10)
						Grand total			(72)

[1] Time blocks in selectivity for F1 (1981 – 1996, 1997 – 2004, 2005 – 2008, 2009 – 2017 [main years], and 2018 – 2019; adapted from SEDAR 65 blacktip).
[2] Time blocks in selectivity for F2 (1981 – 2006, and 2007 – 2019 [main years]; adapted from SEDAR 65 blacktip).
[3] Time blocks in selectivity for F4 (1981 – 1999, and 2000 – 2019 [main years]; adapted from SEDAR 65 blacktip).
[4] Time blocks in catchability for S2 (1981 – 1996, 1997 – 2004 [main years], and 2005 – 2007; adapted from SEDAR 65 blacktip).
[5] Time blocks in catchability for S3 (2008, 2009 – 2017 [main years], and 2018 – 2019; adapted from SEDAR 65 blacktip).

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- 3.3.1.6. Selectivity, continued.
- Initial selectivity parameter values were obtained by fitting the double normal selectivity curve by eye to the available length composition data separately for each fleet with the SELEX24 helper spreadsheet.1
- If any individual selectivity parameter could not be estimated in Stock Synthesis, e.g., based on poor model diagnostics, then the electivity parameter was fixed at the value obtained externally with the SELEX24 helper spreadsheet by setting initial values equal to those obtained with the SELEX24 helper spreadsheet.
- This approach allowed for either asymptotic selectivity (logistic) or dome-shaped selectivity to be implemented consistent with selectivity parameter values obtained externally to the model with the SELEX24 helper spreadsheet while allowing a limited number of selectivity parameters to be estimated for each data set base on the limited available length composition data and the resulting model diagnostics for fit to data.

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- 3.3.1.6. Selectivity, continued.
- Asymptotic (logistic) selectivity was proposed during the Assessment Process webinars for fleets that capture the largest sharks F1 (Com-BLL), F3 (Com-PLL), S4 (FSU-BLL), and S5 (SEFSC-BLLS) (**Table 3.5**).
- An examination of the available fishery-dependent length composition data obtained from observer programs identified a high proportion of large **male** sharks (> size at maturity) in both F1 and F3.
- Similarly, an examination of the available fishery-independent length composition data identified a high proportion of large **male** sharks (> size at maturity) in both S4 and S5 (e.g., as described in the Data Workshop Report, their Section 6 Length Composition and their Figure 12).

Break - Data Workshop Report, their Section 6

Combined Gulf of Mexico and Atlantic Ocean Regions

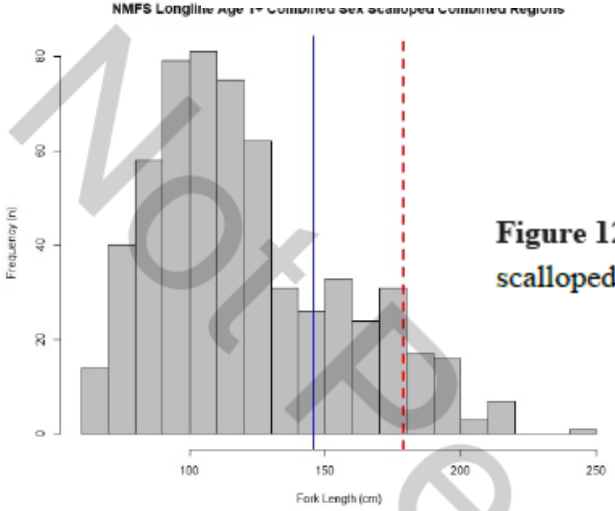
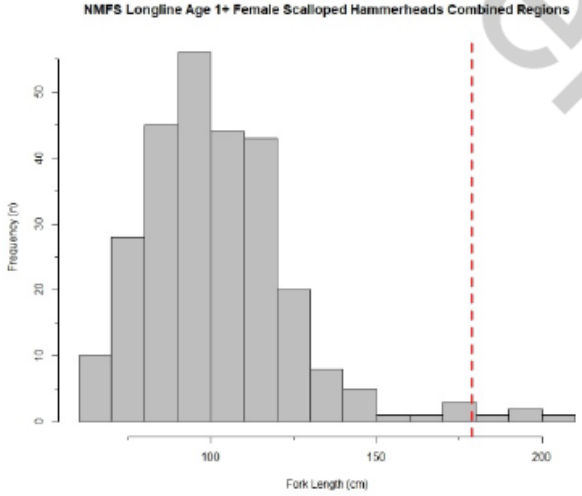
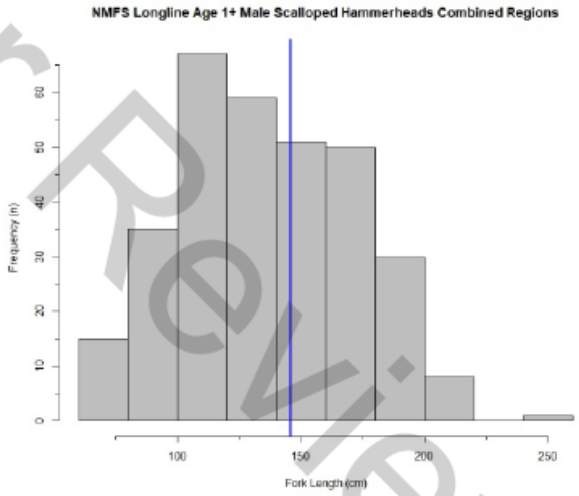


Figure 12. Fishery-independent bottom longline survey length composition data for Age 1+ scalloped hammerheads for the combined Gulf of Mexico and Atlantic Ocean regions.





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Stock Assessment Reference Case Model

- 3.3.1.6. Selectivity, continued.
- Preliminary model runs resulted in a large number of poorly estimated selectivity parameters (i.e., large gradient >1.00*10-04 or CV > 50%, highly correlated > 0.95 or un-correlated < 0.01, or estimated at a boundary condition).
- Consequently, the number of estimated selectivity parameters was reduced by identifying and removing (or reformulating) poorly estimated selectivity parameters.
- Poorly estimated selectivity time block parameters were fixed to their values obtained during the time block with the most data [main years].
- Similarly, poorly estimated sex-specific offset parameter values were fixed to their estimated values obtained for the other sex in the same fleet.
- If neither of these options were available, poorly estimated selectivity parameters were fixed at their initial values obtained from the fit to length composition data obtained externally to the model with the SELEX24 helper spreadsheet, as described above.

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- 3.3.1.7. Data Weighting
- A Francis (2011) two-stage data weighting approach was implemented in the Stock Synthesis reference case (GOM + ATL) model configuration.
- In stage one, a minimum average standard error, SE on the natural log scale, was imposed in Stock Synthesis for each CPUE series. The minimum SE was based on the residual variance obtained from a simple smoother fit to each CPUE series, on the natural log scale, outside the model (Francis 2011; Lee et al. 2014a, 2014b).
- In stage two, the effective sample size (Effn) of each length composition data set was obtained from the residuals of the Stock Synthesis model fit to each length composition data set using either the Francis (2011) or the McAllister and Ianelli (1997) harmonic mean data weighting methods. The Francis (2011) and McAllister and Ianelli (1997) data weighting methods are reviewed in Francis (2017) and Punt (2017). Data weighting philosophies in fisheries stock assessment models are discussed in Punt et al. (2014).

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- 3.3.1.8. Recruitment Deviation
- The parameter representing the standard deviation in recruitment, σR, was not adjusted from the initial value of 0.28, and was also consistent with the RMSE of recruitment variability obtained from the Stock Synthesis report file for the main recruitment deviation period (0.19, 1998 – 2017).
- **Alternative sigma R (0.25** 1998 – 2017**) obtained from r4ss**

```
$sigma_R_info
           period N_devs SD_of_devs Var_of_devs   mean_SE mean_SEsquared sqrt_sum_of_components SD_of_devs_over_sigma_R
1            Main     20  0.1949548  0.03800739 0.1631242     0.02720569              0.2553685              0.6886357
2      Early+Main     30  0.2407115  0.05794202 0.1826067     0.03474302              0.3044422              0.8502611
3 Early+Main+Late     32  0.2379015  0.05659713 0.1826182     0.03466224              0.3020917              0.8403355
  sqrt_sum_over_sigma_R alternative_sigma_R
1             0.9020339           0.2553685
2             1.0753760           0.3044422
3             1.0670733           0.3020917
```

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- 3.3.1.8. Recruitment Deviation Bias Adjustment Ramp
- The expected recruitments require a bias adjustment so that the resulting recruitment level on the standard scale is mean unbiased (Methot and Taylor 2011). The years chosen for bias adjustment, and the maximum bias adjustment parameter value were obtained from Stock Synthesis output with the program r4ss from the R package r4ss (Taylor et al. 2020):

```
1982.5   #_last_yr_nobias_adj_in_MPD; begin of ramp
2000.9   #_first_yr_fullbias_adj_in_MPD; begin of plateau
2018.8   #_last_yr_fullbias_adj_in_MPD
   2020  #_end_yr_for_ramp_in_MPD
 0.6718  #_max_bias_adj_in_MPD
```

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- 3.3.1.10. Model convergence and diagnostics
- Model convergence was based on whether or not the Hessian matrix inverted (i.e., the matrix of second derivatives of the likelihood with respect to the parameters, from which the asymptotic standard error of the parameter estimates is derived).
- Other convergence diagnostics were also evaluated. Excessive CVs on estimated quantities (>> 50 %) or a large final gradient (>1.00*10-04) were indicative of poorly estimated parameters.
- The correlation matrix was also examined for highly correlated (> 0.95) and un-correlated (< 0.01) parameters, which were assumed to be non-informative and an indication of over parameterization.

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Stock Assessment Reference Case Model

- 3.3.1.10. Model convergence, continued.
- Parameters estimated at a bound were a diagnostic for poorly estimated parameters (or poorly specified model structure).
- Poor fits to CPUE or length composition data along with patterns in Pearson's residuals of fits to CPUE or length composition data were diagnostics for problems with fitting the available data resulting from poorly estimated parameters or poorly specified model structure.

Assessment Process Final Report Discussion and Decisions

3. Stock Assessment Reference Case Model (Results)

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks: Scalloped Hammerhead Shark

Section III: Assessment Report

June 2023

SEDAR

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Stock Assessment Reference Case Model

- 3.4.1 Measures of Overall Model Fit
- 3.4.1.1. Model Convergence and Diagnostics
- The Hessian matrix inverted and, consequently, was assumed to be positive definite. However, the maximum gradient (3.61*10-4, Late_RecrDev_2019; **Table 3.7**) along with the gradients of several other estimated parameters (**Table 3.7**) were relatively larger than expected at a converged solution (>1.00*10-04). Similarly, CVs of several estimated catchability and selectivity parameters were also relatively larger than expected at a converged solution (> 50 %; **Table 3.7**), and the CV of one estimated selectivity parameter was much larger (>> 50 %; **Table 3.7**) than expected at a converged solution. However, the very large CV resulted from division with a value near zero (-0.02), which highlights the limited utility of evaluating parameters CVs as a convergence diagnostic. No parameters were estimated above the maximum correlation threshold *(cormax = 0.95)* or below the minimum correlation threshold (*cormin* = 0.01), and no parameters were estimated on a boundary condition.

Break - Reference Case Model Fits
Presentation Adapted from Assessment Webinar 7

- **3.8 Tables**
- **Table 3.1 …**

DC_SEDAR_77_RW_05_01_Adapted_Assess_Web_7_Ref_Case_Model_(1_24_2023).pdf

Scalloped and Carolina Hammerheads (Mixed Species Complex) Base Model Development

(GOM + ATL) Continuity Analysis Model Configuration and Model Fits

SEDAR 77 (Assessment Webinar VII)

January 24, 2023

Tables and Figures

References

SEDAR. 2020. SEDAR 65 Atlantic Blacktip Shark Stock Assessment Report. SEDAR, North Charleston SC. 438 pp. available online at: http://sedarweb.org/sedar-65

Assessment Process Final Report Discussion and Decisions

3. Stock Assessment Reference Case Model (Diagnostics)

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks: Scalloped Hammerhead Shark

Section III: Assessment Report

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Stock Assessment Reference Case Model

- 3.4.5 Diagnostics
- Diagnostic results implemented for the Stock Synthesis GOM+ATL continuity analysis model configuration are provided and discussed in Section 3.14 **Appendix 3.D**.

Assessment Process Final Report
Stock Assessment Reference Case Model

- **3.13 Appendix 3.D Diagnostics Implemented for the Stock Synthesis (GOM + ATL) Continuity Analysis Model Configuration**
- 3.D.1. Introduction
- Multiple diagnostics (Carvalho et al. 2021; **Tables 3.D.1** and **Table 3.D.2;** e.g., Courtney et al. 2020) were implemented for the Stock Synthesis (GOM + ATL) continuity analysis model configuration, as described below.
- .

Break - Reference Case Model Diagnostics Presentation Adapted from Assessment Webinar 9

DC_SEDAR_77_RW_05_02_Adapted_Web_9_Ref_Case_Diagnostics_v1(03_20_2023).pdf

Assessment Process Final Report Discussion and Decisions

3. Stock Assessment Reference Case Model
(Benchmarks and Reference Points **)**

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks: Scalloped Hammerhead Shark

Section III: Assessment Report

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Assessment Process Final Report
Stock Assessment Reference Case Model

- 3.4.6 Benchmarks and Reference Points
- Results obtained for the Stock Synthesis reference case (GOM + ATL) model configuration predicted that the combined GOM + ATL stock was not overfished (SSF2019 > MSST) and that the stock was not experiencing overfishing (*F*2019 > *F*MSY) in the terminal year of the assessment (**Tables 3.10** and **3.11; Figures 3.9** and **3.10**).
- In contrast, results obtained for the Stock Synthesis reference case (GOM + ATL) model configuration predicted that the combined GOM + ATL stock had experienced overfishing, annual total *F* > *F*MSY, during some years of the assessment: 1981 – 1985, 1990 – 1995, and 2003 – 2005 (**Table 3.10**; **Figures 3.9** and **3.10**).

Assessment Process Final Report
Stock Assessment Reference Case Model

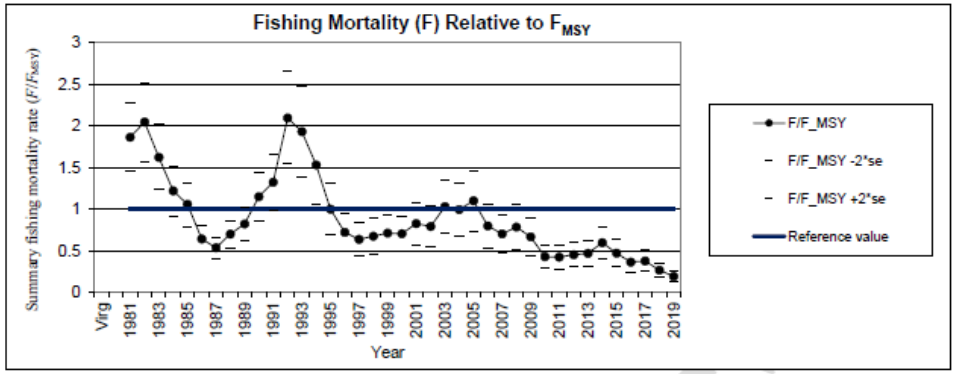
- 3.4.6 Benchmarks and Reference Points

Table 3.11 Summary of benchmark and reference point results obtained for the Stock Synthesis reference case (GOM + ATL) model configuration. Benchmarks are provided for spawning stock fecundity, SSF, and the summary fishing mortality, F, calculated as the total fishing mortality rate experienced by the population (F=Z-M) for the terminal year of the assessment (SSF_{2019}, and F_{2019}). Benchmarks are reported relative to equilibrium MSY reference points (SSF_{MSY}, and F_{MSY}) and to the Minimum Stock Size Threshold, MSST = $\left(1-\bar{M}_a\right)$*SSF_{MSY}, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of M used in the assessment model configuration (**Table 2.5**). Unfished equilibrium levels for SSF and recruitment (SSF_0, R_0) are estimated at the start year of the assessment (1981). Stock and fishery status are summarized relative to the benchmarks and reference points as described above in Sections 3.3.1.13 and 3.4.6.

	Provisional base model configuration	
Parameters	72	
Objective function	894.3	
Gradient	3.61E-04	
$\bar{M}_a$	0.123	
$(1-\bar{M}_a)$	0.877	
Steepness	0.69	
	Est	CV
SSF_{2019}	228	21%
F_{2019}	0.009	---
R_{2019}	73	22%
SSF_0	617	9%
R_0	73	9%
MSY	244	9%
SSF_{MSY}	181	9%
F_{MSY}	0.048	4%
SSF_{2019}/SSF_{MSY}	1.259	13%
F_{2019}/F_{MSY}	0.194	16%
MSST	159	---
$SSF_{2019}/MSST$	1.436	---
Stock status	$SSF_{2019} > MSST$	
Fishery status	$F_{2019} < F_{MSY}$	

Assessment Process Final Report
Stock Assessment Reference Case Model

- 3.4.6 Benchmarks and Reference Points



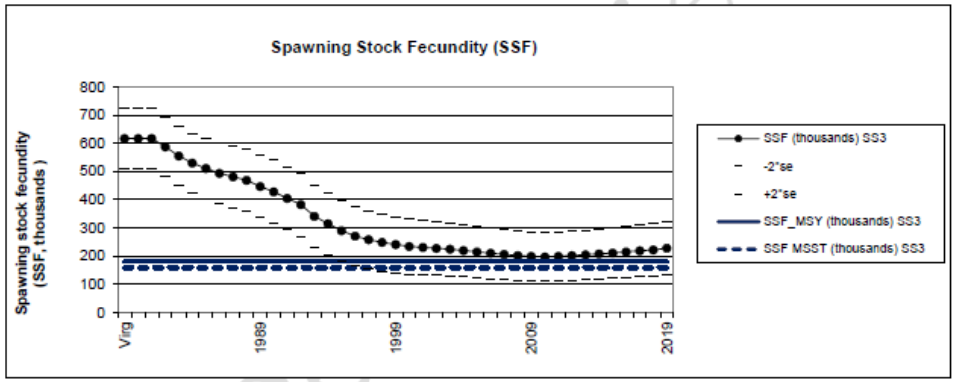


Figure 3.9. Summary fishing mortality (F) relative to F_{MSY} (upper panel) and spawning stock fecundity (SSF) (lower panel) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; Summary fishing mortality, F, is calculated as the total fishing mortality rate experienced by the population (F=Z-M) obtained from Stock Synthesis output on an annual basis; Error bars are the 95% asymptotic standard errors, ± 1.96*SE, for F_Y/F_{MSY} and SSF_Y obtained from Stock Synthesis output. MSST (lower Panel) is $\left(1-\bar{M}_a\right)$*SSF_{MSY}, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of M used in the provisional base model configuration (0.123, **Table 2.5**, panel A).

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Stock Assessment Reference Case Model

- 3.4.6 Benchmarks and Reference Points

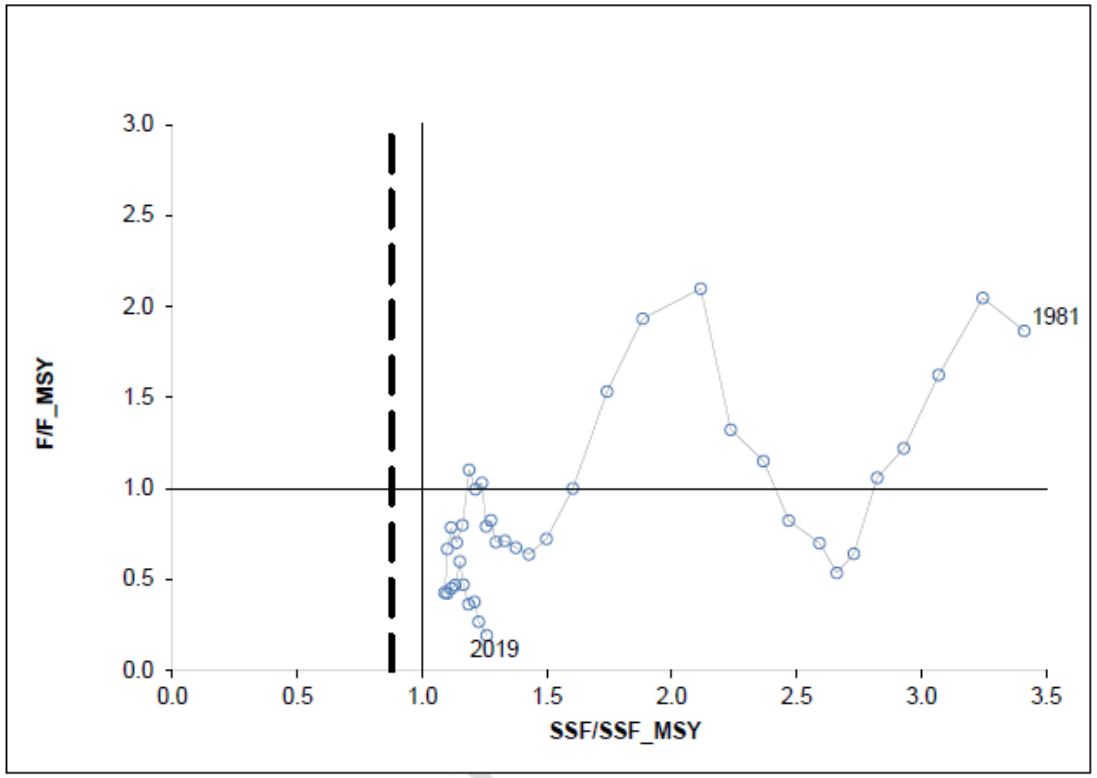

Figure 3.10. Phase plot of the relative spawning stock fecundity (SSF) and relative fishing mortality (F) trajectories by year from 1981 to 2019 obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; The dotted horizontal and vertical lines indicate F_{MSY} and SSF_{MSY}. The dashed vertical line indicates $MSST = (1-\bar{M}_a) * SSF_{MSY}$, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of M used in the provisional base model configuration (**Tables 2.5 and 3.11**).

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3. Stock Assessment Reference Case Model
(Projections)

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Stock Assessment Reference Case Model

- 3.4.7 Projections
- Examples of projected fishery removals at the overfishing limit (OFL) were obtained for the Stock Synthesis reference case (GOM + ATL) model configuration as described in Section 3.14 (**Appendix 3.E)**.

- Examples of projected OFL during the years 2020 – 2025 were obtained from Stock Synthesis projections at F_{MSY} based on the underlying population dynamics assumed during the projection period as described in **Appendix 3.E**.
-

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- 3.4.7 Projections
- *OFL Projections in Biomass*
- Examples of projected fishery removals in biomass (mt) at the overfishing limit (OFL) were obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM (**Figure 3.E.1** and **Table 3.E.3**).
- Projected OFL (mt) was adjusted for expected average annual fishery removals during the gap years 2020, 2021, and 2022 (OFL Adj-1; **Figure 3.E.1** and Table **3.E.3**).

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- 3.4.7 Projections
- *OFL Projections in Biomass*

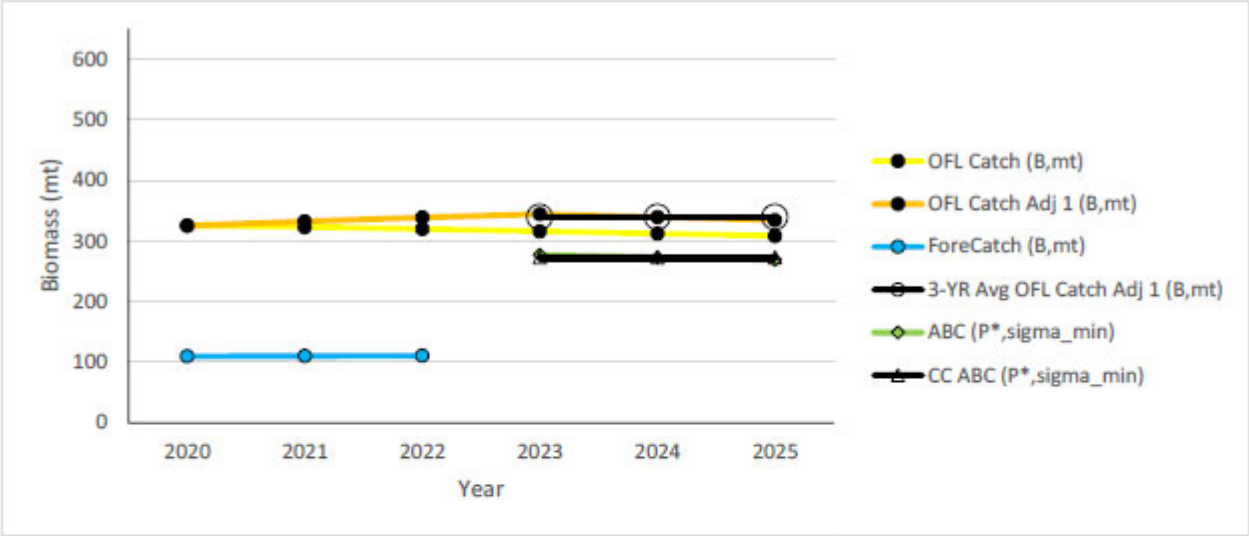

Figure 3.E.1. Preliminary annual ABC (mt) during the years 2023, 2024, and 2025 (green line with diamond markers) was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (OFL Adj catch) using the ABC/OFL map (ABC = 80.4% of OFL); Average annual OFL (mt) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (Avg. OFL 2023-2025 = 339.54 mt); CC ABC is the average annual ABC (mt) during the years 2023, 2024, and 2025 (Avg. ABC 2023-2025 = 273.13 mt) was obtained using the ABC/OFL map (ABC = 80.4% of OFL); P* and sigma_min as described above and in **Table 3.E.5**.

Assessment Process Final Report
Stock Assessment Reference Case Model

- 3.4.7 Projections
- *OFL Projections in Biomass*

Table 3.E.3. Preliminary projected fishery removals in weight (mt) at the overfishing limit (OFL) obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM; Projected OFL (mt) was adjusted (OFL Adj-1) for the expected average annual fishery removals input in projections during gap years 2020, 2021, and 2022 (Tables **3.E.1** and **3.E.2**).

Year	OFL Catch (B, mt)	OFL Catch Adj 1 (B, mt)	ForeCatch (B, mt)
2020	325.380	325.380	109.944
2021	323.063	332.501	110.379
2022	319.868	338.830	110.842
2023	316.120	344.448	344.448
2024	312.249	339.543	339.543
2025	308.489	334.626	334.626
2026	304.854	329.852	329.852
2027	301.321	325.217	325.216
2028	297.915	320.697	320.697
2029	294.675	316.299	316.299

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Stock Assessment Reference Case Model

- 3.4.7 Projections
- *OFL Projections in Biomass*

Color Code

Blue: Projected fishery removals in biomass (mt) obtained from Stock Synthesis (forecast_report.ss loop 3) based on the commercial removal (mt) and recreational catch plus PRM (1000s) input in Stock Synthesis projections during the gap years 2020, 2021, 2022 (forecast.ss).

Yellow: Projected fishery removals in biomass (mt) for commercial and recreational catch plus PRM obtained from Stock Synthesis projections (forecast_report.ss loop 1) at F_MSY based on the underlying population dynamics assumed during the projection period.

Orange: Projected OFL (mt) adjusted for input commercial landings (mt) and input recreational catch plus PRM (1000s) during the years 2020, 2021, 2022 obtained from Stock Synthesis projections (forecast_report.ss loop 1) (forecast_report.ss loop 1). [Projected OFL Adj-1 (B, mt) is provided as OFLCatch in the report.ss management quantities section along with the standard error of the estimates obtained from the Hessian].

Green: Projected fishery removals in biomass (mt) include both the removals input in Stock Synthesis projections during the years 2020, 2021, 2022 (blue), and OFL adjusted for the input removals during the years 2023+ (orange). [Projected Fishery Removals (B, mt) is provided as ForeCatch in the report.ss management quantities section along with the standard error of the estimates obtained from the Hessian].

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Stock Assessment Reference Case Model

- 3.4.7 Projections
- *OFL Projections in Numbers*
- Examples of projected fishery removals in numbers (1000s of individuals) at the overfishing limit (OFL) were obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM (**Figure 3.E.2** and **Table 3.E.4**).
- Projected OFL (mt) was adjusted for expected average annual fishery removals during the gap years 2020, 2021, and 2022 (OFL Adj-1; **Figure 3.E.2** and **Table 3.E.4**).

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- 3.4.7 Projections
- *OFL Projections in Numbers*

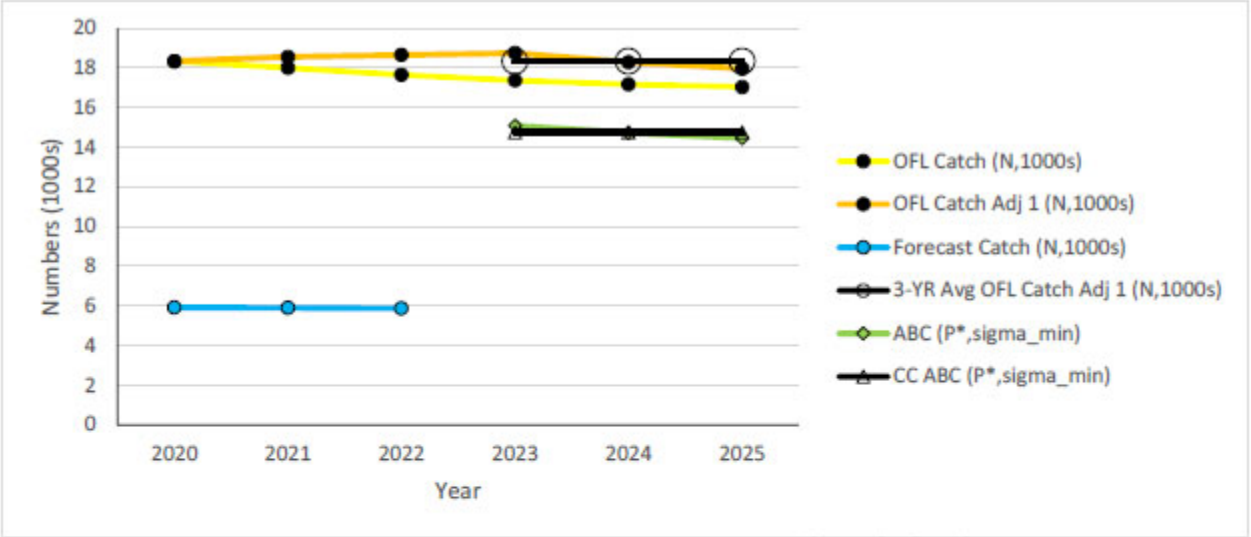

Figure 3.E.2. Preliminary annual ABC (1000s) during the years 2023, 2024, and 2025 (green line with diamond markers) was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (OFL Adj catch) using the ABC/OFL map (ABC = 80.4% of OFL); Average annual OFL (1000s) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (Avg. OFL 2023-2025 = 18.33, 1000s, black line with open black circle markers); Average annual ABC (1000s) during the years 2023, 2024, and 2025 (Avg. ABC 2023-2025 = 14.71, 1000s, black line with open black triangle markers) was obtained using the ABC/OFL map (ABC = 80.4% of OFL); OFL Catch Adj, ForeCatch, P*, and sigma_min as described above and in **Table 3.E.6**.

Assessment Process Final Report
Stock Assessment Reference Case Model

- 3.4.7 Projections
- *OFL Projections in Numbers*

Table 3.E.4. Preliminary projected fishery removals in numbers (1000s) at the overfishing limit (OFL) obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM; Projected OFL (1000s) was adjusted (OFL Adj-1) for the expected average annual fishery removals input in projections during gap years 2020, 2021, and 2022 (**Tables 3.E.1** and **3.E.2**); Color code as described in **Table 3.E.3**.

Year	OFL Catch (N,1000s)	OFL Catch Adj 1 (N,1000s)	Forecast Catch (N,1000s)
2020	18.33	18.33	5.90
2021	18.00	18.55	5.89
2022	17.64	18.65	5.86
2023	17.36	18.74	18.74
2024	17.16	18.28	18.28
2025	17.03	17.96	17.96
2026	16.94	17.74	17.74
2027	16.87	17.58	17.58
2028	16.81	17.46	17.46
2029	16.77	17.36	17.36

Assessment Process Final Report Discussion and Decisions

3. Stock Assessment Reference Case Model
(Examples of ABC Reductions from Projected OFL)

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- 3.4.7 Projections
- Examples of ABC reductions from OFL were obtained for the Stock Synthesis reference case (GOM + ATL) model configuration and are described in Sections 3.3.1.14 and 3.14 (**Appendix 3.E)**.

- Examples of average annual ABC during the years 2023, 2024, and 2025 were obtained by using an ABC/OFL map (ABC = 80.4% of average OFL; Courtney and Rice 2023), where average OFL was computed as the average of projected annual OFL obtained during the years 2023, 2024, and 2025, as described in **Appendix 3.E**.

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- 3.4.7 Projections
- *Example ABC Reduction from OFL Projections in Biomass*
- An example of the average annual ABC (mt) during the years 2023, 2024, and 2025 (273.13 mt) was obtained for the Stock Synthesis reference case (GOM + ATL) model configuration using the ABC/OFL map (ABC = 80.4% of average OFL), where average OFL in biomass was computed as the average of projected annual OFL obtained during the years 2023, 2024, and 2025 (Avg. OFL 2023 – 2025 = 339.54 mt).

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- 3.4.7 Projections
  - *Example ABC Reduction from OFL Projections in Biomass*

Table 3.E.5. Preliminary annual ABC (mt) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (OFL Adj catch) using the ABC/OFL map (ABC = 80.4% of OFL); Average annual OFL (mt) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (Avg. OFL 2023-2025 = 339.54 mt); Average annual ABC (mt) during the years 2023, 2024, and 2025 (Avg. ABC 2023-2025 = 273.13 mt) was obtained using the ABC/OFL map (ABC = 80.4% of OFL); Color code as described in **Table 3.E.3**.

A. Example ABC/OFL Ratio

Parameter	Value
P*	0.3
Lognormal sigma_min	0.415

Map	ABC (P*,sigma_min)
Example ABC/OFL Ratio[1]	0.804

[1]Where, 0.804 = LOGNORM.INV(0.3,0,0.415)

B. Example ABC Reduction from OFL Projections in Biomass

Year	OFL Adj catch (mt)	ABC (mt)	Map (ABC/OFL)
2023	344.45	277.08	0.804
2024	339.54	273.14	0.804
2025	334.63	269.18	0.804
Avg. 2023-2025	339.54	273.13	0.804

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- 3.4.7 Projections
- *Example ABC Reduction from OFL Projections in Numbers*
- An example of the average annual ABC (1000s of individuals) during the years 2023, 2024, and 2025 (14.74, 1000s) was obtained for the Stock Synthesis reference case (GOM + ATL) model configuration using the ABC/OFL map (ABC = 80.4% of average OFL), where average OFL in numbers was computed as the average of projected annual OFL obtained during the years 2023, 2024, and 2025 (Avg. OFL 2023 – 2025 = 18.33, 1000s).

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- 3.4.7 Projections
  - *Example ABC Reduction from OFL Projections in Numbers*

Table 3.E.6. Preliminary annual ABC (1000s) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (OFL Adj catch) using the ABC/OFL map (ABC = 80.4% of OFL); Average annual OFL (1000s) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (Avg. OFL 2023-2025 = 18.33, 1000s); Average annual ABC (1000s) during the years 2023, 2024, and 2025 (Avg. ABC 2023-2025 = 14.71, 1000s) was obtained using the ABC/OFL map (ABC = 80.4% of OFL); Color code as described in **Table 3.E.3**.

A. Example ABC/OFL Ratio

Parameter	Value
P*	0.3
Lognormal sigma_min	0.415

Map	ABC (P*,sigma_min)
Example ABC/OFL Ratio[1]	0.804

[1]Where, 0.804 = LOGNORM.INV(0.3,0,0.415)

B. Example ABC Reduction from OFL Projections in Numbers

Year	OFL Adj catch (1000s)	ABC (1000s)	Map (ABC/OFL)
2023	18.74	15.07	0.80
2024	18.28	14.71	0.80
2025	17.96	14.45	0.80
Avg. 2023-2025	18.33	14.74	0.80