SEDAR

Southeast Data, Assessment, and Review

Update assessment to SEDAR 29

HMS Gulf of Mexico Blacktip Shark

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1. INTRODUCTION

1.1. TERMS OF REFERENCE

1. Update the approved Gulf of Mexico blacktip shark base SSASPM model and alternative model configurations reflective of plausible states of nature identified in the SEDAR 29 SAR and post-review document with data through 2016.

2. Document any changes, corrections, or additions to model and input datasets (including indices or life history data) and provide updated input data tables.

3. Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks.

4. 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 stock is overfished, then utilize projections to determine:

   - Year in which F=0 results in a 70% probability of rebuilding (Year $F=0_{p70}$)
   - Target rebuilding year ($Year_{rebuild}$).
     - o Year $F=0_{p70}$ if Year $F=0_{p70} \leq 10$ years, or
     - o Year $F=0_{p70}$ + 1 generation time if Year $F=0_{p70} > 10$ years
   - F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$

     Fixed level or removals (TAC) allowing rebuilding of stock with 50% and 70% probability

   B) If stock is undergoing overfishing, then utilize projections to determine:

   - $F=F_{reduce}$ (different reductions in F that should end overfishing with a 50% and 70% probability)

   C) If stock is neither overfished nor undergoing overfishing, then utilize projections to determine:

   - The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P* = 0.3 approach).

   D) If data-limitations preclude classic projections (i.e. A, B, and C above), explore alternate projection models to provide management advice.

5. Develop a stock assessment update report to address these TORS and fully document the input data and results of the stock assessment update.

NOTE: The intent of update assessments is to expedite appraisals of stock status by using only the methods and data sets used in the base model and approved during the preceding SEDAR assessment of that stock. Accordingly, it is not the intent of this update to resolve any outstanding issues identified in the initial SEDAR 29 assessment. However, because the post-review document identified several scenarios, in addition to the base run, as plausible states of nature, we will not limit the updated analyses to the base scenario only. Similarly, if new data become available we will endeavor to include them to the fullest extent possible allowed in the timeframe of this assessment update.

2. DATA REVIEW

The SEDAR 29 CIE reviewers identified six scenarios, including the base run, as plausible states of nature. Therefore, we updated the analyses for all six scenarios reflective of plausible states of nature identified and approved in the preceding SEDAR 29 assessment.

Catch and CPUE indices used for SEDAR 29 included data up to 2010. For this update, all catch and CPUE data were updated up to 2016 (six new years of data). Below we briefly describe the main changes introduced to the input datasets, followed by a more in depth description in the relevant section:

- Indices of relative abundance: the PC+MML+MS gillnet index used in SEDAR 29 is now called GULFSPAN Gillnet and includes additional data from two gillnet surveys in northwest Florida and Mississippi; the BLLOP bottom longline index used in SEDAR 29 was split into two series (BLLOP NR and BLLOP RES) to reflect changes in management that resulted from the introduction of the research fishery starting in 2008; the MS+MS-LA+AL longline index used in SEDAR 29 is now called MS+LA+AL+TX Longline, includes additional data from the Louisiana and Texas SEAMAP bottom longline programs started in 2012 and 2011, respectively, and the index now starts in 2006 (vs. 2004 in SEDAR 29) because of the exclusion of the Mississippi hand line survey data, which were excluded because of methodological differences with the other surveys

- Life history: a new growth curve incorporating additional samples was developed and the updated parameters used in turn to update the values of instantaneous natural mortality, M, used for input into the stock assessment model

2.1. CATCHES

2.1.1. Commercial catches

Total commercial catches were computed, as in SEDAR 29, as the sum of commercial landings, dead commercial discards, and post-release live discard mortality (**Table 2.6.1a**; **Figure 2.7.1 top**).

2.1.1.1. Commercial landings

Commercial landings were updated with six new years of data, 2011-2016. Landings for 2011-2012 come from GULFFIN; landings for 2013-2016 come from the maximum of GULFFIN and the eDealer database (which starts in 2013). Since the landings are in weight and the assessment used numbers, as in SEDAR 29, average weights from the Bottom Longline Observer Program (BLLOP) were used to transform weights into numbers. Average weights were obtained by back-transforming observed lengths into weights using the weight-length relationship listed in **Table 2.5.2** of the SEDAR 29 Stock Assessment Report (SAR) and **Table 2.6.5** of this update document.

2.1.1.2. Dead commercial discards

Commercial dead discards used in SEDAR 29 were estimated using the number of hooks from the logbook bottom longline dataset and observed discard rates per hook from the bottom longline observer program for 1993-2010. Dead discards were estimated for 2011-2016 in the same manner. Note that for 2008-2016, when the shark research fishery has been operating, the number of hooks corresponding to shark research trips was subtracted from the total number of hooks reported in the logbook dataset. Total discards for 2008-2016 were calculated as the sum of the estimated discards in the shark bottom longline fishery (non-research portion) and the total observed discards in the shark research fishery. See Carlson et al. (2018a) for details on the estimation procedure.

2.1.1.3. Commercial post-release live discard mortality

As in SEDAR 29, a post-release live discard mortality rate of 31% was used to account for the observed proportion of animals released alive from the BLLOP that are likely to die.

2.1.2. Recreational catches

Total recreational catches were computed, as in SEDAR 29, as the sum of recreational landings and dead discards, and post-release live discard mortality.

2.1.2.1. Recreational landings and dead discards

Recreational landings and dead discards were computed as in SEDAR 29 as the sum of fish killed or kept as seen by the interviewer ("A") and the number of fish killed or kept reported to the interviewer by the angler ("B1") from the Marine Recreational Fishery Statistics Program (MRFSS) for 1981-2003, or the Marine Recreational Information Program (MRIP) for 2004-2016, the Headboat Survey (1986-2016; now known as the Southeast Region Headboat Survey or SRHS), and the Texas Parks and Wildlife Department (TPWD; 1983-2016).

There was an unusually large value of 104,494 sharks reported in MRIP for 2013. Upon closer inspection, 83,161 of those sharks corresponded to the state of Mississippi for wave 4 (July-August). Although the estimate was based on 440 interviews, only 2 of the interviewees reported harvest, but that harvest was the sum of the catch by three anglers and was high, therefore inflating the total estimate when multiplied by the total effort in that stratum. As a result, we opted to subtract the 83,161 sharks from the estimate of 104,494 and then add the geometric mean of the surrounding years (2,923 and 1,168) resulting in an estimated 23,181sharks.

2.1.2.2. Recreational post-release live discard mortality

The post-release live discard mortality rate for hook and line fisheries used in SEDAR 29 was 10%. We slightly modified that rate and used a new value of 9.7% reported in Whitney el al. (2017) to calculate the number of sharks released alive reported by the fisher ("B2" in MRFSS/MRIP) that are likely to die.

2.1.3. Mexican catches

For context, previous assessments have assumed that Mexican catches of blacktip shark corresponded to 50% of the sum of small fish ("cazones") caught in the states of Tamaulipas and Veracruz. This percentage was used to take account of the potential mixing of U.S. and Mexican stocks in Mexican fishing grounds and these two states were selected because they are thought to include catches of blacktip sharks that cross into Mexican waters.

Data from Veracruz and Tamaulipas, covering the period 2001-2010, were used as in SEDAR 29 to produce estimates of the proportion that blacktip sharks make up in the "cazones" or small shark landings (19.7% for both states), as well as average weights of blacktip sharks landed (7.48 kg whole weight for Tamaulipas and 11.91 kg ww for Veracruz), for the period 2001-2016. For 1981-2000, the proportions used came from Castillo et al. (1998; 32.1% for Tamaulipas, 25% for Veracruz). The only data that were updated were thus the landings of "cazones" for 2011-2016 in the states of Tamaulipas and Veracruz, which were extracted from the official Mexican fisheries statistics for 2011-2014 ("Anuarios Estadísticos de Pesca" published by SAGARPA; available online from https://www.gob.mx/conapesca/documentos/anuario-estadistico-de-acuacultura-y-pesca). For 2015-2016, only preliminary, unpublished landings were available from SAGARPA, but since CONAPESCA also has its own database, called SIPESCA, estimates for 2015-2016 were computed as the average of landings reported in the SAGARPA and SIPESCA databases (J. L. Castillo, Instituto Nacional de la Pesca (INAPESCA), pers. comm. to E. Cortes).

In previous assessments, illegal Mexican catches were also considered based on interdictions of Mexican boats in Texas waters by the U.S. Coast Guard. We updated the information for 2011-2016 making the same assumptions as in previous assessments (25 sharks/boat; 50% of incursions are fishery-related; 80% of those incursions used gillnets that would catch coastal sharks; 33% of sharks were blacktips) using new data on incursions, interceptions, and interdictions provided by the U.S. Coast Guard.

2.1.4. Menhaden discards

Estimates of dead discards in the menhaden purse seine fishery were obtained as in previous assessments using the number of vessels operating in the fishery in 2011-2016. See SEDAR29-WP-08 for details.

2.1.5. Catches in weight

At the request of the Highly Migratory Species (HMS) Management Division we also developed catches in weight (**Table 2.6.1b; Figure 2.7.1 bottom**) to facilitate conversions between numbers and weight. The intermediate steps for obtaining catch in weight (lb, dw=dressed weight) were as follows. Commercial landings are already provided in weight, but dead discards from the bottom longline fishery were estimated in number so average weights from the BLLOP were used to convert numbers into weight. These same average weights were used to convert estimated number of live post release mortality estimates into weight. For recreational catches, estimates of A+B1 catches are now also available in weight (lb ww=whole weight). Since sharks released alive (B2s) are only available in numbers, we used the ratio of the weight to the number of A+B1 sharks as average weight to multiply B2 catches in numbers and obtain B2 catches in weight. All transformations of ww to dw used a factor of 2.0 (i.e., ww=2dw). For Mexican catches, the original fisheries statistics from SAGARPA already report catches in weight (t ww), so they were expressed in lb dw. There is almost no size information to help guide conversion of numbers into weight for the menhaden fishery discards. However, the original De Silva et al. (2001) paper from which these estimates are ultimately derived mentions one 100-cm TL blacktip shark being observed, which would correspond to a weight of 6.58 lb dw, thus this was used as average weight to transform numbers into weight. When expressed in weight compared to numbers, it becomes apparent that the commercial fishery catches larger animals than the Mexican and especially the recreational fishery (**Figure 2.7.1**).

2.2. SELECTIVITIES

No changes were introduced to the data or methodology for length compositions, age compositions, or selectivity previously identified and approved for GOM blacktip sharks during SEDAR 29. Briefly, age composition data were not available and length composition data were not input directly into the model. However, length composition data were used to generate age-frequency distributions through an age-length key. The age-frequency distributions produced were then used to estimate selectivity curves externally to the stock assessment model. Two types of selectivity curves were used:

Logistic:

$$s = \frac{1}{1 + e^{-\left(\frac{a - a_{50}}{b}\right)}}$$

where a_{50} is the median selectivity age (inflection point) and b is the slope.

Double logistic:

$$s = \frac{\frac{1}{1 + e^{-\left(\frac{a - a_{50}}{b}\right)}} \times \left(1 - \frac{1}{1 + e^{-\left(\frac{a - c_{50}}{d}\right)}}\right)}{\max\left(\frac{1}{1 + e^{-\left(\frac{a - a_{50}}{b}\right)}} \times \left(1 - \frac{1}{1 + e^{-\left(\frac{a - c_{50}}{d}\right)}}\right)\right)}$$

where a_{50} and c_{50} are the ascending and descending inflection points, and b and d are the ascending and descending slopes, respectively.

Selectivities to the catches and indices were assigned as follows:

Catches:

Commercial+unreported—Logistic curve, with age at full selectivity of 7 (selectivity curve corresponding to the BLLOP index).

Recreational—A dome-shaped selectivity curve (double exponential) with age 1 being fully selected and only the descending right limb of the curve represented.

Mexican—Same as the recreational selectivity, but with slightly higher selectivity at age.

Menhaden fishery discards—A constant selectivity of 1 was assumed as in SEDAR 29 (expressed in logistic form).

Indices of relative abundance:

GULFSPAN Gillnet (called PC+MML+MS gillnet in SEDAR 29)—In recognition that this composite index consisted of gillnet surveys predominantly catching juvenile sharks, a dome-shaped selectivity curve (double exponential) was assumed, with age 1 being fully selected and only the descending right limb of the curve represented.

BLLOP NR and BLLOP RES (called BLLOP in SEDAR 29)—A logistic curve with age at full selectivity of 7 was fitted to these two bottom longline series. Both indices cover the same fishery: BLLOP NR is the non-research fishery (1994-2007) and BLLOP RES is the research fishery (2008-2016).

NMFS LL SE (bottom longline)—Logistic curve, but with the ascending portion of the curve prior to the inflection point covering the younger age classes substantially more than the BLLOP curve. The age at full selectivity was 4.

ENP (hook and line)—Also recognizing that this was a predominantly juvenile shark survey, a double exponential curve was assumed with age at full selectivity of 1 followed by a descending right limb steeper than that of the GULFSPAN gillnet index, which also caught some older animals.

TEXAS Gillnet—Fully selected age was also 1, but older animals were also represented in the sample, thus a double exponential curve covering older age classes than the ENP and GULFSPAN gillnet curves was assumed.

MS+LA+AL+TX Longline (called MS+MS-LA+AL longline in SEDAR 29)—As above, but the sample covered even older animals, thus a double exponential curve with the least slope was assigned.

All selectivities used in the assessment are summarized in **Table 2.6.2** and **Figure 2.7.2**.

2.3. INDICES OF RELATIVE ABUNDANCE

The indices of relative abundance described above (GULFSPAN Gillnet, BLLOP NR, BLLOP RES, NMFS LL SE, ENP, TEXAS Gillnet, and MS+LA+AL+TX Longline), were identified and approved during the preceding SEDAR 29 assessment, and were updated here (**Table 2.6.3**; **Figure 2.7.3**), with the following modifications:

1) the PC+MML+MS gillnet index used in SEDAR 29 is now called GULFSPAN Gillnet and includes additional data from the Florida State University Coastal Marine Laboratory gillnet survey (2009-2016) and University of Southern Mississippi-Sport Fish surveys (2011-2016) (Carlson et al. 2018b);

2) the BLLOP bottom longline index used in SEDAR 29 was split into two series (BLLOP NR and BLLOP RES) to reflect changes in management that resulted from the introduction of the research fishery starting in 2008 (Carlson et al. 2018c);

3) the MS+MS-LA+AL longline combined index used in SEDAR 29 is now called MS+LA+AL+TX Longline and includes additional data from the Louisiana and Texas SEAMAP bottom longline programs that were started in 2012 and 2011, respectively. The index now starts in 2006 (vs. 2004 in SEDAR 29) because of the exclusion of the Mississippi hand line survey data, which were dropped because of methodological differences in hook size, number of hooks deployed, bait type, and length of longline deployed compared with the other surveys, which led the authors of the standardization to remove these data (Hoffmayer et al. 2018)

The GULFSPAN Gillnet (Carlson et al. 2018b), NMFS LL SE (Pollack et al. 2018), TEXAS Gillnet (Carlson and Fisher 2018), and MS+LA+AL+TX Longline (Hoffmayer et al. 2018) indices are fishery independent, whereas the BLLOP NR, BLLOP RES (Carlson et al. 2018c), and ENP (Carlson and Osborne 2018) are fishery dependent (the first two, commercial, and the third, recreational). The updated indices were standardized using the same GLM techniques identified and approved for each index during the preceding SEDAR 29 assessment, with data updated to 2016. The updated indices were used in the scenarios reflective of plausible states of nature as described in section 3 of this report.

Figure 2.7.4 shows each updated index superimposed on the index used for SEDAR 29 (ending in 2010). All updated indices tracked their corresponding index from SEDAR 29 fairly well, in particular the ENP index, and showed strong interannual variation in some cases (e.g., BLLOP RES in 2001-2002, 2010-2012; TEXAS Gillnet in 2011-2015; MS+LA+AL+TX Longline in 2014-2016). The updated TEXAS Gillnet and MS+LA+AL+TX Longline indices showed increasing tendencies since 2010, the NMFS LL SE and BLLOP RES indices showed decreasing tendencies since 2010, and the GULFSPAN Gillnet and ENP showed generally flat trends since 2010.

2.4. LIFE HISTORY INPUTS

A new growth curve incorporating 256 additional samples became available for this update (Deacy et al. 2018). The updated von Bertalanffy growth function parameters were subsequently used to update the values of instantaneous natural mortality, *M*, used for input into SSASPM. No other changes were introduced to the input life history data or methodology previously identified and approved for GOM blacktip sharks in SEDAR 29. The life history inputs used in this update are presented in **Table 2.6.4**. These include age and growth parameters, sex ratio, reproductive frequency, fecundity at age, month of pupping, a maternity ogive, and natural mortality at age (*M*). In SEDAR 29, age-specific values of *M* were estimated through several life history invariant methods commonly used for sharks, including Hoenig's (1983), Pauly's (1980), Chen and Watanabe's (1989), Peterson and Wroblewski's (1984), and Lorenzen's (1996) methods. For this update the two first methods were updated with the newer t_{max}-based and growth-based estimators developed by Then et al. (2015). To ensure positive population growth rates and emulate a compensatory density-dependent response in the absence of fishing, the maximum value of the five methods was taken. For reproduction, the proportion of females in maternal condition, rather than the proportion of mature females, was used as a more realistic measure of reproductive output because the latter does not account for the time it takes for a female to become pregnant and produce offspring after it reaches maturity (Walker 2005).

The SSASPM uses most life history characteristics as constant inputs and others are estimated parameters, which are given priors and initial values, as described below in section 3 of this report.

2.5. REFERENCES

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2.6. TABLES

Table 2.6.1a. Catches of Gulf of Mexico blacktip shark by fleet in numbers. Catches are separated into four fisheries: commercial + unreported catches, recreational catches, Mexican catches, and menhaden fishery discards.

Year	Com+Unrep	Recreational	Mexican	Menhaden discards
1981	7261	62576	64247	17495
1982	7261	82710	36156	17933
1983	7844	29064	37550	17714
1984	10712	30579	53258	17714
1985	9950	61468	43762	15964
1986	71435	162585	40073	15746
1987	69772	75117	42142	16402
1988	140261	129143	46239	15964
1989	144784	101637	54320	16839
1990	76851	95468	63659	16402
1991	81034	122534	48262	12684
1992	93187	77786	52856	11153
1993	66661	60274	61613	11372
1994	62028	55361	56715	12028
1995	84805	50199	47730	11372
1996	64741	72919	52332	11153
1997	46814	67634	35968	11372
1998	63798	90150	36589	10935
1999	52823	31677	26662	12028
2000	49888	94745	25838	10279
2001	39943	50093	18707	9622
2002	31968	48185	20545	9404
2003	69315	43998	17300	9185
2004	43732	47246	21086	9404
2005	33375	40526	20947	9404
2006	55073	52990	11491	8966
2007	46276	29830	11264	8966
2008	14439	18325	11595	8966
2009	14909	21801	13989	8966
2010	21541	35814	19482	8966
2011	16477	22895	11533	8966
2012	16161	43489	13556	8092
2013	20023	46391	16941	7654
2014	13722	16560	15355	6779
2015	22687	19533	12760	6779
2016	14159	13565	3872	6779

Table 2.6.1.b. Catches of Gulf of Mexico blacktip shark by fleet in weight (lb dressed weight). Catches are separated into four fisheries: commercial + unreported catches, recreational catches, Mexican catches, and menhaden fishery discards.

Year	Com+Unrep	Recreational	Mexican	Menhaden discards
1981	174269	368694	1165138	115119
1982	174269	487327	730135	117997
1983	188256	137481	771995	116558
1984	257097	177363	1127279	116558
1985	238805	337307	838585	105046
1986	1714436	708413	762099	103607
1987	1674533	311781	774248	107924
1988	3366256	627951	848026	105046
1989	3474810	453373	1023879	110802
1990	1844435	329275	1177799	107924
1991	1944808	410742	912023	83461
1992	2236499	291543	987547	73389
1993	1599853	340652	1165609	74828
1994	1204213	234170	1058420	79144
1995	1509661	210089	905821	74828
1996	1281542	262504	1001467	73389
1997	1169345	276802	771142	74828
1998	1670280	291941	702726	71950
1999	1587207	212496	514909	79144
2000	1520085	746531	474968	67633
2001	1234201	264261	353091	63316
2002	972288	331571	378420	61877
2003	1441011	509523	309443	60438
2004	1028650	401916	364600	61877
2005	951283	305736	388487	61877
2006	1258323	524157	221062	58999
2007	1085464	223910	213896	58999
2008	402317	129306	213679	58999
2009	448250	149735	256892	58999
2010	635808	187118	348965	58999
2011	379131	124878	201301	58999
2012	424391	298544	240388	53243
2013	553225	1149651	304883	50365
2014	443489	208348	282950	44609
2015	637966	188125	233354	44609
2016	422633	117431	71113	44609

Table 2.6.2. Selectivity curves for catches and indices of relative abundance. Parameters are ascending inflection point (a_{50}), ascending slope (b), descending inflection point (c_{50}), descending slope (d), and maximum selectivity (*max(sel)*).

Series	Scenario	Selectivity	a_{50}	b	c_{50}	d	max(sel)
CATCHES							
Commercial + unreported	Base	Logistic	4.41	0.59			
Recreational	Base	Double exponential	0.02	0.2	0.1	2.8	0.42
Mexican	Base	Double exponential	0.02	0.2	1	3	0.50
Menhaden discards	Base	Logistic	-120	0.2			
INDICES OF ABUNDANCE							
GULFSPAN Gillnet	Base	Double exponential	0.02	0.2	0.1	1.5	0.35
BLLOP NR	Base	Logistic	4.41	0.59			
BLLOP RES	Base	Logistic	4.41	0.59			
NMFS LL SE	Base	Logistic	1.03	0.59			
ENP	Base	Double exponential	0.02	0.10	0.10	1.00	0.29
TEXAS Gillnet	Base	Double exponential	0.02	0.10	1	2	0.50
MS+LA+AL+TX longline	Base	Double exponential	0.01	0.1	0.1	3	0.43

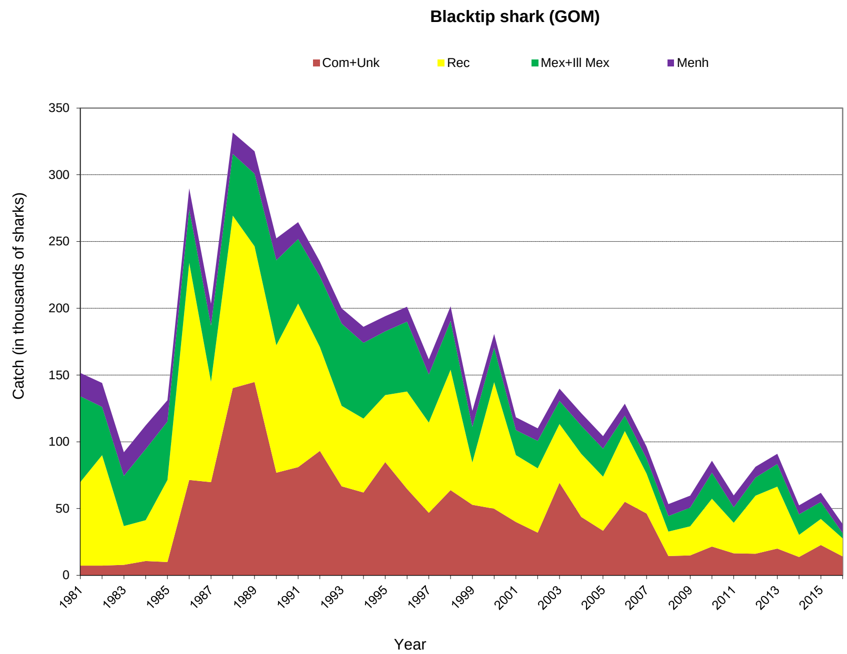
Table 2.6.3. Updated standardized indices of relative abundance used in the assessment update (scaled by the mean).

YEAR	GULFSPAN GN	BLLOP NR	BLLOP RES	NMFS LLSE	ENP	TEXAS GN	MS+LA+AL+TX LL
1981	-	-	-	-	-	-	-
1982	-	-	-	-	-	1.434	-
1983	-	-	-	-	0.910	0.585	-
1984	-	-	-	-	1.250	0.434	-
1985	-	-	-	-	0.992	0.320	-
1986	-	-	-	-	1.018	1.540	-
1987	-	-	-	-	1.509	1.059	-
1988	-	-	-	-	1.730	0.679	-
1989	-	-	-	-	0.834	0.472	-
1990	-	-	-	-	1.350	0.993	-
1991	-	-	-	-	0.865	0.000	-
1992	-	-	-	-	1.619	0.138	-
1993	-	-	-	-	0.811	0.302	-
1994	-	0.122	-	-	1.361	0.380	-
1995	0.529	0.320	-	0.585	1.051	0.578	-
1996	0.464	0.271	-	0.466	1.412	0.779	-
1997	0.498	0.239	-	0.374	1.345	0.228	-
1998	0.729	0.806	-	-	0.913	0.338	-
1999	0.818	0.708	-	0.358	0.851	0.601	-
2000	1.219	-	-	1.560	1.114	0.496	-
2001	1.100	0.015	-	0.850	0.765	0.312	-
2002	0.917	1.873	-	1.409	0.721	0.866	-
2003	0.776	1.864	-	2.358	0.995	0.681	-
2004	1.554	2.332	-	1.289	0.888	1.459	-
2005	1.206	0.929	-	1.445	0.726	1.099	-
2006	1.050	1.726	-	1.165	0.586	1.360	0.900
2007	1.454	1.795	-	0.800	0.783	0.582	0.528
2008	0.983	-	1.255	0.529	0.825	1.267	0.760
2009	0.757	-	0.953	1.378	0.734	1.106	0.815
2010	0.952	-	1.223	1.671	0.868	1.113	0.847
2011	0.966	-	2.352	0.710	1.079	0.996	0.368
2012	1.350	-	0.658	0.850	0.709	2.319	1.339
2013	1.334	-	0.981	0.648	1.085	4.307	1.367
2014	1.402	-	0.566	0.738	0.811	2.517	0.970
2015	1.063	-	0.430	1.444	0.610	1.659	2.111
2016	0.879	-	0.582	0.374	0.880	-	0.995

Table 2.6.4. Life history inputs used in the assessment update (all these quantities are treated as constants in the model). Shaded cells denote quantities that changed with respect to SEDAR 29 inputs.

Age	Proportion maternal	M	Fecundity	
1	0.029	0.206	1.541	
2	0.042	0.203	1.620	
3	0.061	0.186	1.698	
4	0.087	0.173	1.777	
5	0.123	0.164	1.855	
6	0.170	0.158	1.934	
7	0.232	0.152	2.013	
8	0.307	0.148	2.091	
9	0.394	0.145	2.170	
10	0.489	0.142	2.248	
11	0.584	0.140	2.327	
12	0.674	0.138	2.406	
13	0.752	0.136	2.484	
14	0.817	0.135	2.563	
15	0.868	0.134	2.641	
16	0.906	0.133	2.720	
17	0.934	0.132	2.799	
18	0.954	0.132	2.877	
Sex ratio:		1:1		
Reproductive frequency:		2 yr		
Pupping month:		May		
Age vs litter size relation:		pups = 0.1572*age + 2.9248		
L_{inf}		156.18	cm FL	
k		0.162		
t_0		-2.928		
Weight vs length relation:		$W=0.00001L^{3.0549}$		

2.7. FIGURES



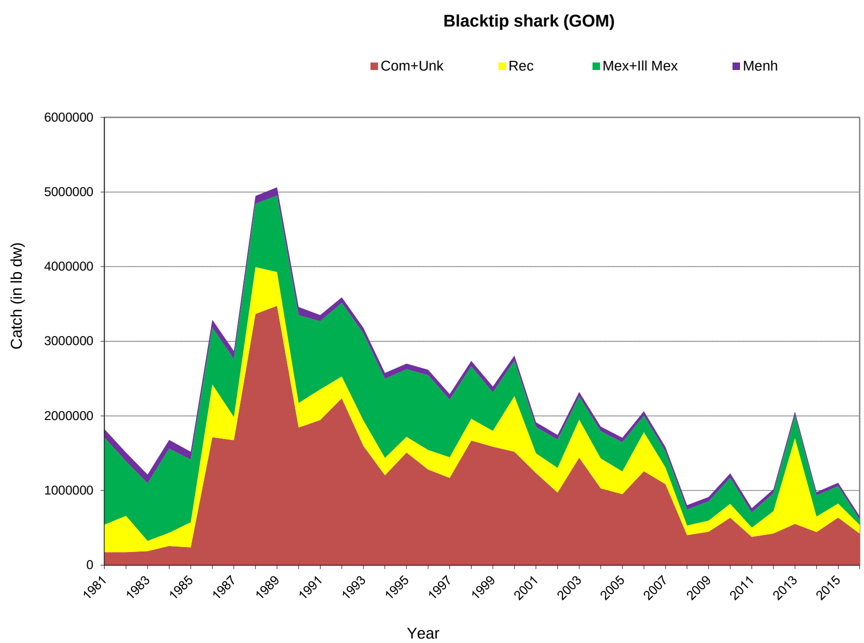
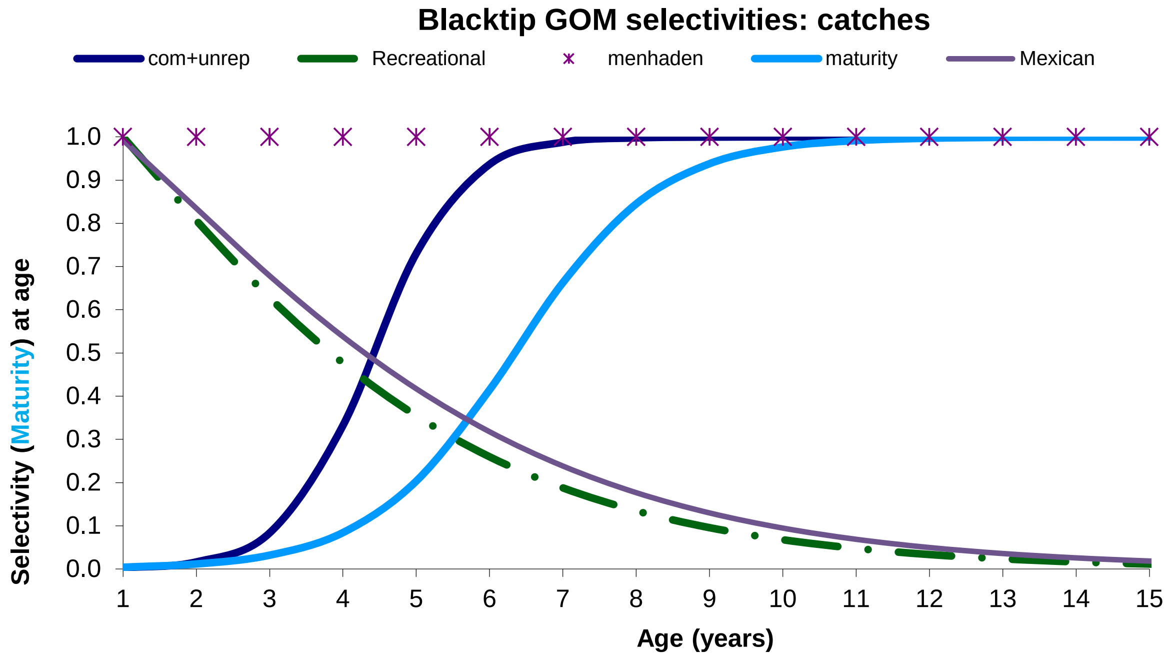


Figure 2.7.1. Catches of Gulf of Mexico blacktip shark by fleet in numbers (top) and weight (lb, dw=dressed weight; bottom). Catches are separated into four fisheries: commercial + unreported catches, recreational catches, Mexican catches, and menhaden fishery discards.



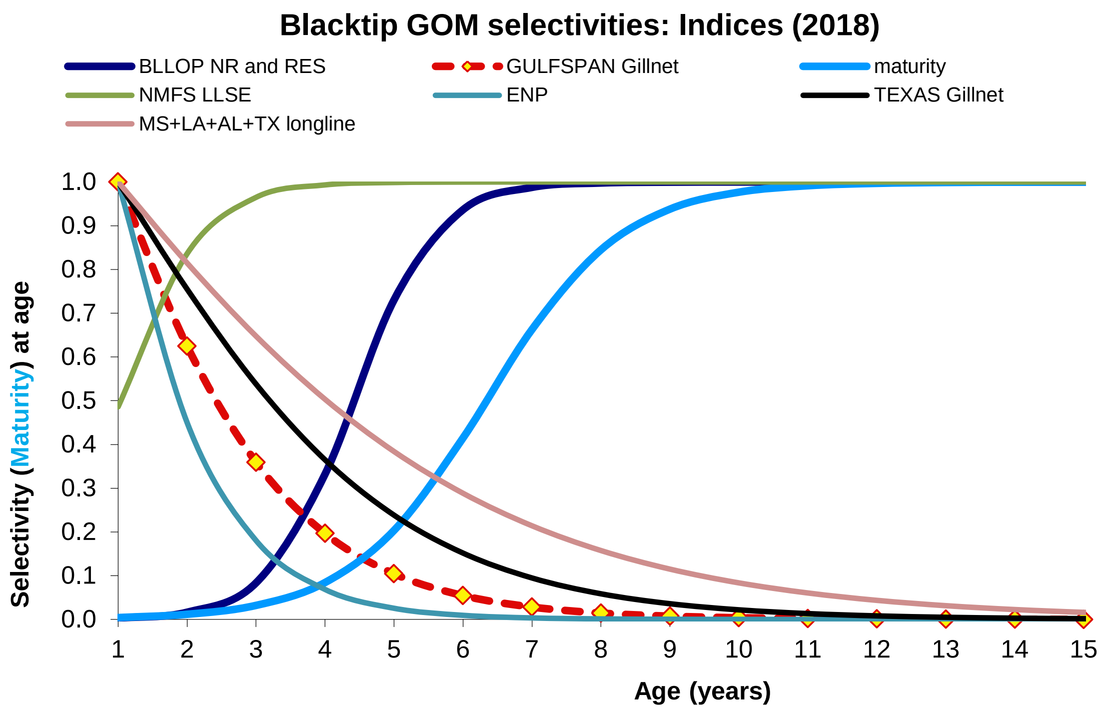


Figure 2.7.2. Selectivity curves for catches (top) and indices of relative abundance (bottom) used in the assessment update. The maturity ogive for GOM blacktip shark is added for reference.

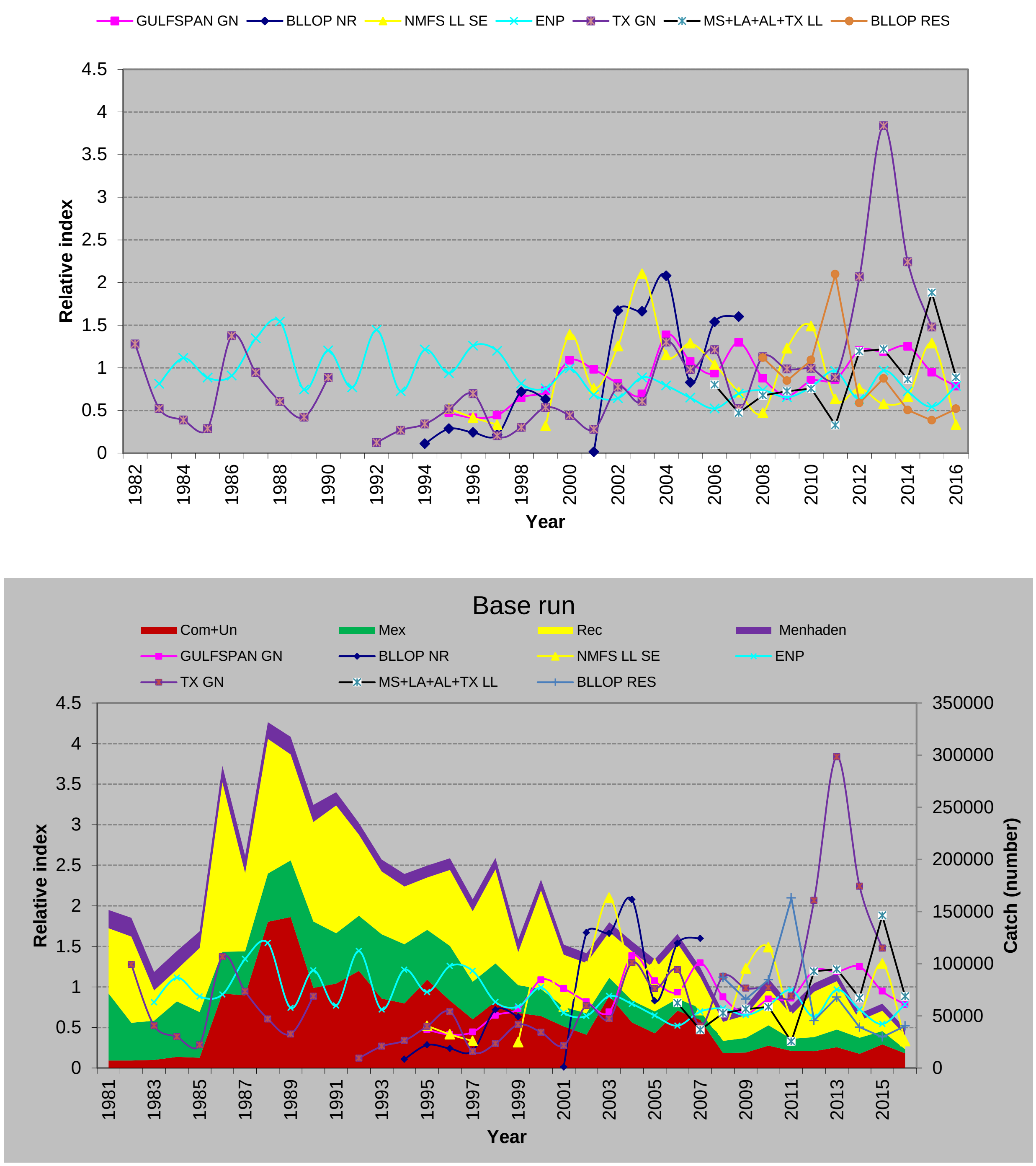


Figure 2.7.3. Updated indices of relative abundance used for the base run (top panel). All indices are statistically standardized and scaled (divided by their respective mean and a global mean for overlapping years for plotting purposes). Same indices superimposed on catches (bottom panel).

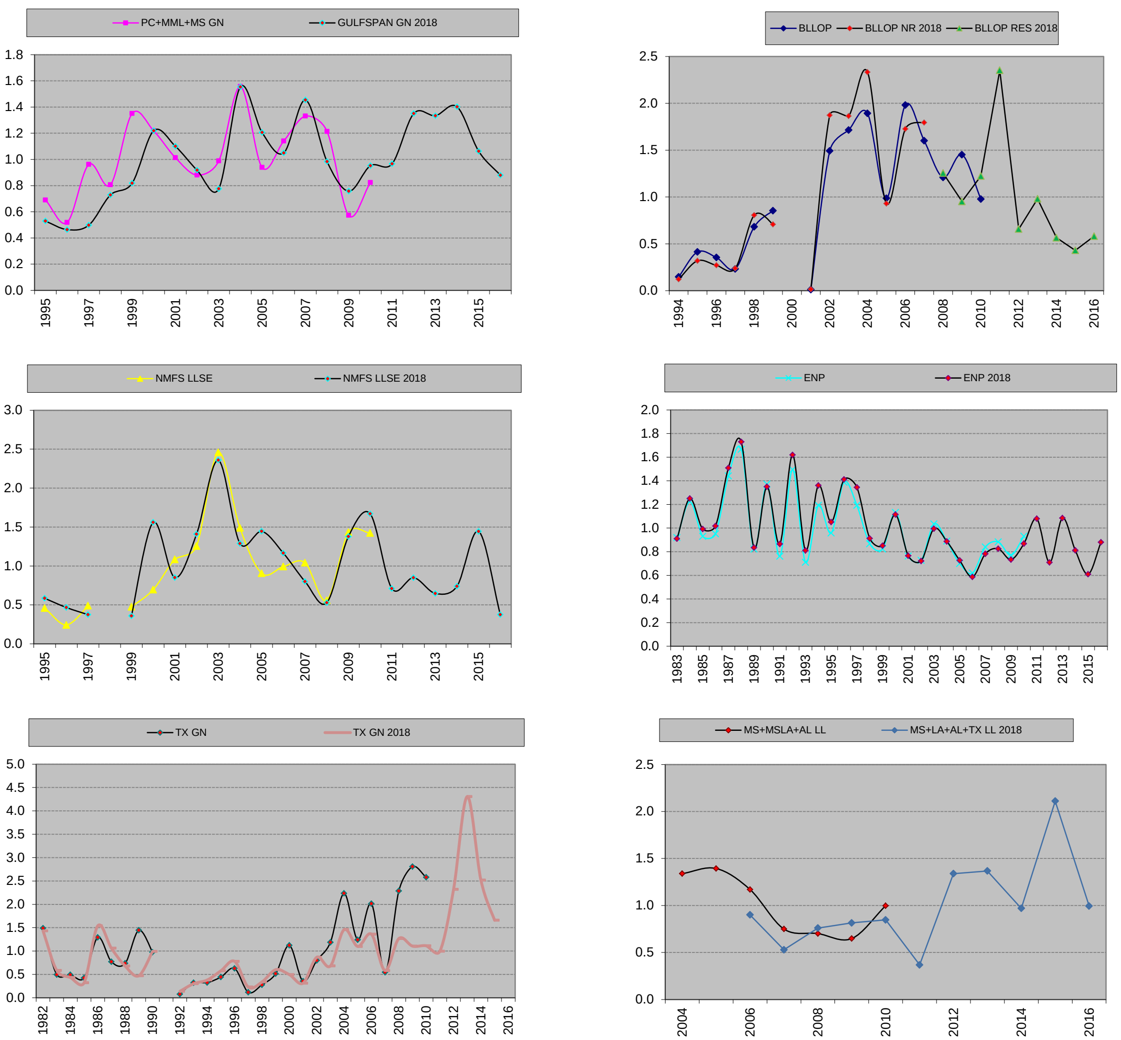


Figure 2.7.4. Indices of relative abundance for GOM blacktip shark used in the preceding SEDAR 29 assessment vs. those used in this assessment update (2018). From top to bottom and left to right: GULFSPAN Gillnet, BLLOP NR+BLLOP RES, NMFS LL SE, ENP, TEXAS Gillnet, and MS+LA+AL+TX Longline. All indices are scaled (divided by the mean of overlapping years).

3. STOCK ASSESSMENT MODEL AND RESULTS

3.1. ASSESSMENT METHOD

3.1.1. State Space Age-Structured Production Model (SSASPM) Description

To derive numbers at age for the first model year, one must define a year when the stock could be considered to be at virgin conditions. The current update assessment set the year of virgin conditions at 1981 (as in the previous assessment, SEDAR 29).

Population Dynamics

The dynamics of the model are described below, and are extracted (and/or modified) from Porch (2002). The model begins with the population at unexploited conditions, where the age structure is given by

(1) $$N_{a,y=1,m=1} = \begin{cases} R_0 & a = 1 \\ R_0 \exp\left(-\sum_{j=1}^{a-1} M_j\right) & 1 < a < A \\ \dfrac{R_0 \exp\left(-\sum_{j=1}^{A-1} M_j\right)}{1 - \exp(-M_A)} & a = A \end{cases},$$

where $N_{a,y=1,m=1}$ is the number of sharks in each age class in the first model year (y=1), in the first month (m=1), M_j is natural mortality at age, A is the plus-group age, and recruitment (R) is assumed to occur at age 1.

The stock-recruit relationship was assumed to be a Beverton-Holt function, which was parameterized in terms of the maximum lifetime reproductive rate, α:

(2) $$R = \frac{R_0 S \alpha}{1 + (\alpha - 1)S} .$$

In (2), R_0 is virgin number of recruits (age-1 pups) and S is spawners or "spawning production" (units are number of mature adult females times pup production at age). The parameter α is calculated as:

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

where p_a is pup-production at age a, m_a is maternity at age a, and M_a is natural mortality at age a. The first term in (3) 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).

The time period from the first model year (y_1) to the last model year (y_T) is divided into a historic and a modern period (mod), where y_i for i<mod are historic years, and modern years are y_i for which mod $\leq i \leq T$. The historic period is characterized by having relatively fewer data compared to the modern period. The manner in which effort is estimated depends on the period modeled. In the historic period, effort is estimated as either a constant (4a) or a linear trend (4b)

(4a) $$f_{y,i} = b_0 \qquad \text{(constant effort)}$$

or

(4b) $$f_{y,i} = b_0 + \frac{(f_{y=\mathrm{mod},i} - b_0)}{(y_{\mathrm{mod}} - 1)} f_{y=\mathrm{mod},i} \qquad \text{(linear effort),}$$

where $f_{y,i}$ is annual fleet-specific effort, b_0 is the intercept, and $f_{y=mod,i}$ is a fleet-specific constant. As in SEDAR 29, no historic period was considered in this model implementation for GOM blacktip shark.

In the modern period, fleet-specific effort is estimated as a constant with annual deviations assumed to be independent and lognormally distributed random variables, which are assumed to follow a first-order lognormal autoregressive process:

(5) $$\begin{aligned} f_{y=\mathrm{mod},i} &= f_i \exp(\delta_{y,i}) \\ \delta_{y,i} &= \rho_i \delta_{y-1,i} + \eta_{y,i} \quad . \\ \eta_{y,i} &\sim N(0, \sigma_i) \end{aligned}$$

where ρ_i are the autocorrelation coefficients and the $\eta_{y,i}$ are normal random variables with mean of 0 and standard deviation σ_i.

From the virgin age structure defined in (1), abundance at the beginning of subsequent months is calculated by

(6) $$N_{a,y,m+1} = N_{a,y,m} e^{-M_a \delta} - \sum_i C_{a,y,m,i} \quad ,$$

where δ is the fraction of the year (m/12) and $C_{a,y,m,i}$ is the catch in numbers of fleet i. The monthly catch by fleet is assumed to occur sequentially as a pulse at the end of the month, after natural mortality:

(7) $$C_{a,y,m,i} = F_{a,y,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad ,$$

where τ_i is the duration of the fishing season for fleet i. Catch in weight is computed by multiplying (7) by $w_{a,y}$, where weight at age for the plus-group is updated based on the average age of the plus-group.

The fishing mortality rate, F, is separated into fleet-specific components representing age-specific relative-vulnerability, v, annual effort expended, f, and an annual catchability coefficient, q:

(8) $$F_{a,y,i} = q_{y,i} f_{y,i} v_{a,i} \quad .$$

Catchability is the fraction of the most vulnerable age class taken per unit of effort. The relative vulnerability would incorporate such factors as gear selectivity, and the fraction of the stock exposed to the fishery. For this model application to GOM blacktip sharks, both vulnerability and catchability were assumed to be constant over years.

Catch per unit effort (CPUE) or fishery abundance surveys are modeled as though the observations were made just before the catch of the fleet with the corresponding index, i:

(9) $$I_{y,m,i} = q_{y,i} \sum_a v_{a,i} \left(N_{a,y,m} e^{-M_a \delta} - \sum_{k=1}^{i-1} C_{a,y,m,k} \right) \frac{\delta}{\tau_i} \quad .$$

Equation (9) provides an index in numbers; the corresponding CPUE in weight is computed by multiplying $v_{a,i}$ in (9) by $w_{a,y}$.

State space implementation

In general, process errors in the state variables and observation errors in the data variables can be modeled as a first-order autoregressive model:

(10) $$\begin{aligned} g_{t+1} &= E[g_{t+1}] e^{\varepsilon_{t+1}} \\ \varepsilon_{t+1} &= \rho \varepsilon_t + \eta_{t+1} \end{aligned} \quad .$$

In (10), g is a given state or observation variable, η is a normally distributed random error with mean=0 and standard deviation σ_g, and ρ is the correlation coefficient. *E[g]* is the deterministic expectation. When g refers to data, then g_t is the observed quantity, but when g refers to a state variable, then those g terms are estimated parameters. Both effort and recruitment in the modern period are treated in this fashion with ρ = 0.5 for effort and for ρ = 0 for recruitment, respectively.

The variances for process and observation errors (σ_g) are parameterized as multiples of an overall model coefficient of variation (CV):

$$\text{(11a)} \quad \sigma_g = \ln\left[(\lambda_g CV)^2 + 1\right]$$

$$\text{(11b)} \quad \sigma_g = \ln\left[(\omega_{i,y}\lambda_g CV)^2 + 1\right] \quad .$$

The term λ_g is a variable-specific multiplier of the overall model CV. For catch series and indices (eq 11b), the additional term, $\omega_{i,y}$, is the weight applied to individual points within those series. Given the SEDAR 29 AP decision to use ranks of indices as a weighting scheme for the baseline run, the $\omega_{i,y}$ represent those rank weightings (e.g. $\omega_{i,y}$=1 for all points in the NMFS LL SE series) and the same λ_g was applied to all indices.

Additional model specifications

Individual points within catch and index series can be assigned different weights, based either on estimated precision or expert opinion. As the SEDAR 29 CIE reviewers recommended, all catches were assigned the same weight (1 or no weight) and indices were weighted by an assigned rank.

One further model specification was the degree to which the model-predicted values matched catches vs. indices. An overall model CV is estimated (see equations 11a and 11b), and multiples (λ_g) of this overall CV can be specified separately for catches, indices, and effort (see Porch 2002). All catch series were assigned the same CV multiple, all indices were assigned a single same CV multiple, and all effort series were also assigned a single CV multiple.

Relatively more confidence was placed in the catch series compared to the indices. Placing less certainty in the indices relative to the catch is justified because of the lack of a consistent signal and interannual variability in the indices, which resulted in poorer fits or parameter estimates hitting boundaries likely because the model could not reconcile those conflicting indices. As in SEDAR 29, the CV multipliers were thus fixed at 5 (indices), 1 (catches), and 2 (effort).

3.1.2. Parameter Estimation

Parameters were estimated by minimizing the objective function (the negative log joint posterior density function) using AD Model Builder software (Otter Research, Ltd. 2004). The (log) joint posterior distribution was specified up to a proportionality constant and included log likelihood components for observed data (Λ_1), process error components (Λ_2), and prior distribution components (Λ_3). The total objective function was then given by $\Lambda = \Lambda_1 + \Lambda_2 + \Lambda_3$, with each component as described below.

Observed data log likelihood—The observed data log likelihoods were specified as lognormal, but included a number of variance terms that could be estimated or fixed to allow for a wide range of choices for how to fit the data. The objective function takes the sum of the negative log likelihood contributions from indices, catches, and effort. The indices contribution is provided by

$$(12) \qquad \Lambda_1 = 0.5\sum_i \sum_y \sum_m \frac{(\log(I_{i,y,m}) - \log(\tilde{I}_{i,y,m}))^2}{\sigma^2_{i,y}} + \log(\sigma^2_{i,y}),$$

where $I_{i,m,y}$ and $\tilde{I}_{i,m,y}$ give observed and predicted indices, respectively, and

$$(13) \qquad \sigma^2_{i,y} = \log(1 + \mathrm{CV}^2{}_{i,y}).$$

The catch and effort contributions have the same form. The term $\mathrm{CV}_{i,y}$ gives the assigned rank along with index *i* in year *y*.

Process errors—Process errors for effort and recruitment deviations made a contribution to the objective function. The contributions for effort and recruitment deviations (ρ = 0.5 for effort and for ρ = 0 for recruitment, respectively) are given by

$$(14) \quad \Lambda_2 = 0.5 \sum_{1982 \le y \le 2016} \frac{\left(\varepsilon_{ey} - \rho_e \varepsilon_{ey-1}\right)^2}{\sigma_e + (y-1)\log \sigma_e}$$

Prior distributions—The model started in 1981 and ended in 2016. Estimated model parameters were pup (age-0) survival, virgin recruitment (R_0), catchability coefficients associated with catches and indices, fleet-specific effort, fleet-specific effort annual deviation and recruitment annual deviation. Virgin recruitment was given a uniform prior distribution ranging from $1.00\text{x}10^5$ to $1.00\text{x}10^7$ individuals, whereas pup survival was given an informative lognormal prior with median=0.76 (mean=0.79, mode=0.69), a CV of 0.3, and bounded between 0.50 and 0.99. The mean value for pup survival was obtained using life-history invariant methods (see section 2.4). Fleet-specific effort annual deviations were assumed to be independent and lognormally distributed random variables with mean=0, SD of 1, and bounded between -7 and 7 on an arithmetic scale. Recruitment annual deviations were assumed to be independent and lognormally distributed random variables with mean=0, CV of 0.01, and bounded between -0.05 and 0.05.

The total contribution for prior distributions to the objective function was then

$$(15) \qquad \Lambda_3 = \log(p(e^{-M_0})) + \log(p(R_0)) + \sum_i \log(p(q_i)) + \sum_i \log(p(e_i))$$

A list of estimated model parameters is presented in **Table 3.5.1**. The table includes predicted parameter values and their associated SDs from SSASPM, initial parameter values, minimum and maximum values a parameter could take, and prior densities assigned to parameters.

3.1.3. Uncertainty and Measures of Precision

Initial model runs were made by maximizing the joint posterior (minimizing the negative of the objective function) using AD Model Builder software (Otter Research Ltd. 2004). Subsequent runs attempted to better quantify uncertainty by estimating marginal posterior distributions for key assessment parameters. We used the "likelihood profiling" procedure in AD Model Builder, which attempts to directly integrate the joint likelihood function. This procedure was used to quantify uncertainty in terminal stock status, terminal fishing mortality, and productivity parameters for the base run and the six plausible alternative states of nature referred to in the TORs for this update.

More specifically, the SEDAR 29 CIE review identified seven scenarios, including the base run, as plausible states of nature (see the SEDAR 29 HMS Gulf of Mexico Blacktip Shark SAR and Post-Review Updates and Projections document). For this update, uncertainty in data inputs and model configuration was examined through the updated analysis of the seven scenarios reflective of plausible states of nature previously identified and approved following the review of the SEDAR 29 assessment: (1) base; (2) low catch; (3) high catch; (4) low productivity; (5) high productivity; (6) lognormal prior on R_0; and (7) using the NMFS LL SE index only. These sensitivities consisted of the following:

1. Base scenario—The base scenario as described above.

2 and 3. Low and high catch scenarios—Same as the base run, but using a low and high catch scenario, respectively. The low and high catch series were constructed in an attempt to encapsulate the uncertainty in the magnitude of the catches, which had been recommended by previous CIE reviewers. This was done by introducing variability in the commercial, recreational, and Mexican catch data streams as follows. Commercial landings are reported in weight (not estimated), but then converted into numbers by using average weights from animals observed in the shark bottom longline observer program. Thus, the only way to incorporate uncertainty in this catch stream is in the average weights used for conversion from weight to numbers. Lower and upper 95% confidence limits (CLs) of those average weights were computed and used to produce high and low commercial landings scenarios, respectively. Additionally, the base run assumed a post-release live discard mortality rate of 31% for

commercial bottom longline gear; the AP in SEDAR 29 also recommended 19% and 73% as low and high values, which were used in the low and high catch scenarios, respectively. For recreational catches, lower and upper 95% CLs of the estimates of sharks landed and discarded dead in MRFSS/MRIP (A+B1) were computed in SEDAR 29 as well as lower and upper 95% CLs for MRFSS/MRIP estimates of sharks released alive (B2s). However, upon closer inspection during this update the estimates generated in SEDAR 29 did not seem to encompass a large enough range of variability. For this update, we used the CVs reported for A, B1 and B2 catches to express the low and high catch scenarios as ±1 SD. Additionally, the base run assumed a post-release live discard mortality rate of 9.7% for hook and line gear and it was recommended that values of 9.7% and 19% be used for the low and high catch scenarios, respectively, for this update (Courtney 2018). These values were used as multipliers for the estimated B2s. For Mexican catches, the base run assumed that 50% of blacktip sharks landed in the states of Tamaulipas and Veracruz belonged to the U.S. stock; in SEDAR 29 the AP recommended 25% and 75% as alternative values to use in the low and high catch scenarios, respectively. Additionally, the 95% CLs of the average weights of blacktip sharks landed in the states of Tamaulipas (mean=7.48 kg ww; LCL=6.42; UCL=8.53) and Veracruz (mean=11.91 kg ww; LCL=10.64; UCL=13.18) generated for SEDAR 29 were used to produce low and high Mexican catches. No measures of uncertainty were available for unreported commercial catches or for the menhaden fishery. The low and high catch scenarios are given in **Tables 3.5.2** and **3.5.3** and depicted in relation to the baseline catches in **Figure 3.6.1**.

<u>4 and 5. Low and high productivity scenarios</u>—Same as the base run, but using a low and high productivity scenario, respectively. As in SEDAR 29, to incorporate variability in productivity (while ensuring that it remained within biologically credible limits), lower and upper 95% CLs of the three new von Bertalanffy growth function parameters given in Deacy et al. (2018) were obtained: L_∞ (mean=156.2 cm FL; LCL=151.9; UCL=160.4), k (mean=0.162 yr^{-1}; LCL=0.142; UCL=0.181); t_0 (mean=-2.93; LCL=-3.20; UCL=-2.65). The new VBGF parameter estimates in turn yielded a new set of natural mortality (*M*) values through the five life history invariant methods. Additionally, 95% CLs were also computed for the litter size vs. maternal age linear relationship (slope: mean=0.157; LCL=0.068; UCL=0.247; intercept: mean=2.925; LCL=1.998; UCL=3.852) (**Table 3.5.4**).

<u>6. Lognormal prior on R_0</u>—Same as the base run, but using an informative lognormal prior for virgin recruitment (with median=$1\text{x}10^6$, a CV of 0.3, and bounded between $1\text{x}10^5$ and $1\text{x}10^7$).

<u>7. NMFS LL SE index</u>—Same as the base run, but using only the NMFS LL SE survey as an index of relative abundance.

3.1.4. Benchmark/Reference points methods

Benchmarks included estimates of spawning stock fecundity, fishing mortality and abundance for year 2016 (SSF_{2016}, F_{2016}, N_{2016}), reference points based on *MSY* (SSF_{MSY}, SSF_{MSST}, F_{MSY},), current status relative to SSF_{MSY} and/or SSF_{MSST}, and F_{MSY} levels, and depletion estimates (current status relative to virgin levels). *SSF* at the minimum spawning stock threshold (*MSST*) is calculated as (1-$\overline{M}_a$)*SSF_{MSY}. Age-independent natural mortality ($\overline{M}_a$) is defined as mean age-specific natural mortality for ages 1-18. In addition, a phase plot was provided and trajectories for SSF_{year}, SSF_{year}/SSF_{MSY}, F_{year} and SSF_{year}/SSF_{MSY} were plotted.

The estimate of generation time is 11.2 years, and was calculated as:

(16)
$$GenTime = \frac{\sum_i i f_i \prod_{j=1}^{i-1} s_j}{\sum_i f_i \prod_{j=1}^{i-1} s_j}$$

where *i* is age, f_i is the product of (fecundity at age) x (maturity at age), and s_j is survival at age. Maximum age used in the calculations was 18 years. This generation time corresponds to the mean age of parents of offspring produced by a cohort over its lifetime (ν_1; Caswell 2001); other formulae for calculating generation time gave similar estimates (*T*: time required by the population to increase by R_0=10.2; A: mean age of parents of offspring in a stable age distribution=9.2; Caswell 2001).

3.1.5. Projection methods

Projections were conducted for a subset of SSASPM model configurations representative of the range of uncertainty in data inputs and model configuration examined in the GOM blacktip shark stock assessment. The projection approach utilized Monte Carlo bootstrapping at alternative fixed landings levels to compute the probability that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce *MSY* (SSF_{MSY}), Pr($SSF_t > SSF_{MSY}$), and the probability that fishing mortality (F_t) will exceed the level of *F* that will produce *MSY* (F_{MSY}), Pr($F_t > F_{MSY}$), for a given projection year (2017 – 2046) and a given fixed level of total annual removals due to fishing (1,000s).

Projection methods followed those developed during SEDAR 21 for an age-structured catch-free model (ASCFM) applied to HMS dusky sharks (NMFS 2011), during SEDAR 29 for a SSASPM model applied to HMS blacktip sharks (NMFS 2012a, 2012b), as modified during SEDAR 34 for a SSASPM model applied to HMS Atlantic sharpnose and bonnethead sharks (NMFS 2013a, 2013b). Projections were governed with the same set of population dynamics equations as the original assessment model (see section 3.1.1 of this report), but allowed for uncertainty in initial conditions at the beginning of the time series (2016) as well as in underlying productivity. Projections were run using Monte Carlo bootstrap simulation, where initial numbers (N_{2016}^{boot}) and fishing mortality (F_{2016}^{boot}) were sampled from a bivariate normal distribution. Pup survival at low biomass ($e^{-M_0}{}_{2016}^{boot}$) and equilibrium recruitment ($R_0{}_{2016}^{boot}$) were sampled from a second bivariate normal distribution. Expectations were equivalent to posterior modes from SSASPM, and the standard deviations and covariance values were obtained from the Hessian approximation of the variance-covariance matrix at the posterior mode. The bivariate normal approximation was chosen because it reduced the probability of selecting values of the different parameters that were unlikely to have generated the data. A separate bivariate distribution was chosen for $e^{-M_0}{}_{2016}^{boot}$ and $R_0{}_{2016}^{boot}$ to more adequately simulate recruitment variability in the projections (e.g., see section 3.1.3 of this report, equations 2 and 3), as described below.

The first full projection year was 2017, and projections were run until the year 2046 (30 years). As a result, the projection interval included multiple generations (generation time is cf., 11.2 years; see section 3.1.4 of this report, equation 16). Projections were implemented with current fishing mortality F_{2016}^{boot} during the first three full projection years (2017, 2018, 2019), and then with the fishing mortality rate evaluated for the projection scenario during the remaining years (2020 – 2046). Projections used the same selectivity as used in the ending year (2016) of SSASPM. Thus, the anticipated allocation of effort within the fishery (between fleets) was assumed to remain the same as that in 2016. A given fixed level of total annual removals due to fishing represented catch (in 1,000s) from all fleets combined.

All projections used 10,000 Monte Carlo bootstrap simulations. Each projection was summarized with respect to the projected distribution in the mature spawning stock fecundity (*SSF*) and the fishing mortality rate (*F*) for each projection year (*t*). Moments of the distribution were summarized each year using quantiles, with the median used for the central tendency, and the 30th and 70th percentiles used as the lower and upper ranges, respectively. For a given year (2017 – 2046) and a given fixed level of total annual removals, the $\Pr(SSF_t > SSF_{\mathrm{MSY}})$ was calculated as $1 - \Pr\left(SSF_t \le SSF_{\mathrm{MSY}}\right)$, where $\Pr\left(SSF_t \le SSF_{\mathrm{MSY}}\right)$ was calculated as the cumulative relative frequency of $(SSF_{t,boot} \le SSF_{MSY})$ = (cumulative frequency)/(sample size). Analogously, for a given year (2017 – 2046) and a given fixed level of total annual removals, the $\Pr(F_t > F_{\mathrm{MSY}})$ was calculated as $1 - \Pr\left(F_t \le F_{\mathrm{MSY}}\right)$, where $\Pr\left(F_t \le F_{\mathrm{MSY}}\right)$ was calculated as the cumulative relative frequency of $(F_{t,boot} \le F_{MSY})$ = (cumulative frequency)/(sample size). All projections were conducted with R statistical software (R Core Team 2018). See Appendix 3.7 for more details.

3.2. RESULTS

3.2.1. Measures of Overall Model Fit

Catches were fit 5 times better than indices and thus were fit very well (**Figure 3.6.2**). The model appeared to have trouble reconciling the conflicting trends and oscillations within and among some of the indices of abundance and compromised with a flat fit. As a result, some of the indices were poorly fit, particularly the BLLOP NR series, which decreased to a value close to zero in 2001 (with a very large residual) after no observations in 2000, and then immediately increased to a high value in 2002 (**Figure 3.6.3**). Since the SEDAR 29 terminal year (2010), the GULFSPAN gillnet, BLLOP NR, BLLOP RES, NMFS LLSE and the MS+LA+MS+AL+TX longline indices showed slightly increasing tendencies (**Figure 3.6.3**), the GULFSPAN gillnet index and the MS+LA+MS+AL+TX longline indices had a large decrease in the terminal year of data of this assessment update, 2016, and the ENP and TEXAS gillnet indices were generally flat (**Figure 3.6.3**) despite catches having decreased since approximately 1990 (**Figure 3.6.2**). In general, the poor fit to some of the indices is caused in part by high interannual variability that does not seem to be compatible with the life history of the species, suggesting that the statistical standardization of the indices done externally to the model may not have included all factors that help explain relative abundance.

3.2.2. Parameter Estimates and Associated Measures of Uncertainty

A list of model parameters is presented in **Table 3.5.1**. The table includes predicted parameter values with associated SDs, initial parameter values, minimum and maximum allowed values, and prior density functions assigned to parameters. The predicted parameter values are within the range of the minimum and maximum allowed values except some annual recruitment deviation and effort deviation values. The jitter test confirmed that varying the initial values of some of the estimated parameters individually or simultaneously from within their allowable ranges, did not affect results during SEDAR 29.

3.2.3. Stock Abundance at Age and Recruitment

Predicted relative stock abundance at age is presented in **Figure 3.6.4**. The first four age classes made up almost 50% of the population in any given year. The SSASPM does not model age 0s and thus no predicted age-0 recruits are produced, only the estimated virgin number of age-1 recruits (see Section 3.1.1).

3.2.4. Total Stock Abundance and Spawning Stock Fecundity

Predicted abundance and spawning stock fecundity (numbers x proportion mature x fecundity in numbers) are presented in **Table 3.5.5** and **Figure 3.6.5**. Both trajectories show some depletion from 1981 to about 2000, followed by a stabilization (and a slight uptake in the last decade or so of data), which generally correspond to decreased catches, effort and F in the past decade as well as increasing tendencies for some of the indices in those years.

3.2.5. Fishery Selectivity

As explained in Section 2.2 and shown in **Table 2.6.2** and **Figure 2.7.2**, selectivities are estimated externally to the model and a functional form input for each fleet and index. In **Figure 2.7.2** one can see that most fleets fully select for immature animals, and that many of the indices include immature animals too.

3.2.6. Fishing Mortality

Predicted total and fleet-specific instantaneous apical fishing mortality rates are presented in **Table 3.5.6** and **Figure 3.6.6**. Fishing mortality was generally higher for all fleets prior to the mid-1990s, but never approached the estimated F_{MSY} of 0.056. The commercial and recreational fleets, followed by the Mexican fleet, accounted for most of total F. The contribution of the menhaden fishery fleet to total F was minimal. Fishing mortality was lower in the past decade or so in accordance with decreased effort and catches during that period.

3.2.7. Stock-Recruitment Parameters

The predicted virgin recruitment (R_0; number of age 1 pups) was ca. 6.07×10^6 animals (**Table 3.5.7**). The predicted steepness was 0.47 and the maximum lifetime reproductive rate was 3.49 (**Table 3.5.7**), values in line with the life history of this species (Brooks et al. 2010). The estimated pup (age-0) survival was 0.80 (**Table 3.5.7**).

3.2.8. Evaluation of Uncertainty

Posterior distributions for several model parameters of interest were obtained through likelihood profiling. Prior and posterior distributions for pup survival and virgin recruitment are shown in **Figure 3.6.7**. There appeared to be information in the data since the posteriors for these two parameters were different from the priors. The mode for the posterior of pup survival was estimated at a higher value than the prior mode, whereas the posterior for virgin recruitment of pups was informative in contrast to its diffuse uniform prior (**Figure 3.6.7**).

Posterior distributions were also obtained for several benchmarks (**Figure 3.6.8**). The distribution for SSF_{2016}/SSF_0 is fairly wide, but most of the density is concentrated between 0.7 and 1.0, indicating a slight depletion (i.e. 0-30%) (**Figure 3.6.8**). In contrast, posterior distributions for SSF_{2016}/SSF_{MSY} and SSF_{2016}/SSF_{MSST} were much tighter, and indicated that spawning fecundity in 2016 was about 2.7 times and 3.2 times higher than *MSY* and *MSST* levels, respectively (**Figure 3.6.8**). The posterior distribution for F_{2016}/F_{MSY} was about 0.024 (i.e. fishing mortality in 2016 was only about 2.4% the *MSY* level) (**Figure 3.6.8**).

Results of the base and the five additional scenarios reflective of plausible states of nature are summarized in **Table 3.5.8** (note: because the Hessian approximation to the numerically maximized posterior surface for the NMFS LL SE scenario (sensitivity #7) could not estimate parameter standard deviations , the results of this scenario were not reliable and were not included in this report). Estimates of SSF_{MSY} and SSF_{MSST} ranged from 1.75×10^6 to 1.38×10^7 and from 1.48×10^6 to 1.17×10^7, respectively. Estimates of spawning stock fecundity benchmarks ranged from 2.15 to 2.76 for SSF_{2016}/SSF_{MSY}, 2.56 to 3.25 for SSF_{2016}/SSF_{MSST}, and 0.63 to 0.99 for SSF_{2016}/SSF_0. Estimates of F_{MSY} ranged from 0.016 to 0.108. Estimates of the fishing mortality benchmark ranged from 0.014 to 0.120 for F_{2016}/F_{MSY}. Assuming an informative, lognormal distribution for R_0 resulted in the least optimistic stock status of all scenarios explored, with pup survival hitting the upper bound, indicating that the parameters we considered may not have been biologically reasonable (**Table 3.5.8**). Considering catches lower than those in the base run resulted in the most optimistic stock status of all scenarios explored (**Table 3.5.8**). Considering catches higher than those in the base run changed stock status very little (**Table 3.5.8**). Assuming lower stock productivity resulted in a more pessimistic status, with virgin recruitment (R_0) hitting the upper bound, indicating that the parameters we considered may not have been biologically reasonable (**Table 3.5.8**). The high productivity scenario also resulted in a more pessimistic status than the base run, with SSF_{2016} and SSF_{MSST} values being 4.2-fold and 3.9-fold smaller than in the base run and F_{MSY} and F_{2016} values being about two- and nine-fold larger than in the base run, respectively. All six scenarios (base and five alternative states of nature) resulted in the same conclusion that the stock was not overfished (i.e. $SSF_{2016} > SSF_{MSST}$) and overfishing was not occurring (i.e. $F_{2016} < F_{MSY}$), providing evidence that stock status determination based on estimated SSF_{MSST} and point estimated F_{MSY} is robust to changes in catch, productivity and prior distribution of R_0.

We also performed "likelihood profiling" for the five alternative states of nature. Posterior probability distributions for SSF_{2016}/SSF_{MSST} were tight and indicated that spawning stock fecundity in 2016 was well above that corresponding to SSF_{MSST} levels (i.e. with mass well above 1.0) (**Figure 3.6.9**). Posterior distributions for F_{2016}/F_{MSY} were also tight and indicated that fishing mortality in 2016 was well below that corresponding to F_{MSY} levels (i.e. with mass well below 1.0) (**Figure 3.6.9**).

3.2.9. Benchmarks/Reference Points

As described above, benchmarks and *MSY* reference points for the base and the five additional scenarios reflective of plausible states of nature are summarized in **Table 3.5.8** (and depicted in **Figures 3.6.10** and **3.6.11)**. Detailed information for the base run is summarized in **Tables 3.5.7** and **3.5.9**. As noted, all runs clearly indicated that the stock was not overfished and overfishing currently was not occurring (**Table 3.5.8; Figures 3.6.10** and **3.6.11**). The high and low catch runs estimated a status close to that of the base run, with the deviations coming from the high and low productivity, and lognormal distribution for R_0 scenarios (**Table 3.5.8; Figures 3.6.10** and **3.6.11**). The estimates of current (2016) apical fishing mortality relative to *MSY* (F_{2016}/F_{MSY}) in the base, high and low catch runs were very uncertain (CV >1; **Table 3.5.8**), but as discussed above, posterior distributions for the six runs all indicated that overfishing currently was not occurring (**Figures 3.6.8** and **3.6.9**). All runs estimated that the stock had never been overfished and overfishing only had occurred for the high productivity and lognormal distribution for R_0 scenarios some years during 1985-1992 (**Figure 3.6.11**). These conclusions thus generally agree with those from SEDAR 29 (2012) (**Table 3.5.10**; see Discussion).

3.2.10. Projections

A summary of projection model results is presented for the base model configuration and model sensitivities (**Tables 3.5.11 and 3.5.12**). Projection results provide examples from 10,000 Monte Carlo projections of a given fixed level of total annual removals due to fishing (1,000s of sharks) which resulted in both the $\Pr(SSF_t > SSF_{MSY}) \geq 70\%$ and $\Pr(F_t > F_{MSY}) \leq 30\%$ during the years 2017 – 2046). Projections were completed for the baseline SSASPM configuration (Ranked CPUE Weighting) and selected SSASPM model sensitivity analyses (Low Catch, High Catch, Low Productivity, High Productivity, and Lognormal Prior on R_0).

The $\Pr(SSF_t > SSF_{\text{MSY}})$ was summarized for the last ten projection years (2037 – 2046) and each fixed level of total annual removals due to fishing (**Table 3.5.13**). Fixed removals that resulted in $\Pr(SSF_t > SSF_{MSY}) \geq 70\%$ represented at most a 30% probability of exceeding SSF_{MSY} and were highlighted in green. Fixed removals that resulted in $70\% > \Pr(SSF_t > SSF_{MSY}) \geq 50\%$ represented more than a 30% probability of exceeding SSF_{MSY} but less than or equal to a 50% probability of exceeding SSF_{MSY} and were highlighted in yellow. Fixed removals that resulted in $\Pr(SSF_t > SSF_{MSY}) < 50\%$ represented more than a 50% probability of exceeding SSF_{MSY} and were highlighted in red.

The $\Pr(F_t > F_{\text{MSY}})$ was summarized for the last ten projection years (2037 – 2046) and each fixed level of total annual removals due to fishing (**Table 3.5.14**). Fixed landings that resulted in $\Pr(F_t > F_{MSY}) \leq 30\%$ represented at most a 30% probability of exceeding F_{MSY} and were highlighted in green. Fixed landings that resulted in $30\% < \Pr(F_t > F_{MSY}) \leq 50\%$ represented more than a 30%

probability of exceeding F_{MSY} but less than or equal to a 50% probability of exceeding F_{MSY} and were highlighted in yellow. Fixed landings that resulted in $Pr(F_t > F_{MSY}) > 50\%$ represented more than a 50% probability of exceeding F_{MSY} and were highlighted in red.

The 30th percentile of $SSF_{t,boot}/SSF_{MSY}$ was summarized for each projection year (2017 – 2046) and each fixed level of total annual removals due to fishing (**Figure 3.6.12**). The 30th percentiles of $SSF_{t,boot}/SSF_{MSY}$ represent the 70% probability of maintaining $SSF_{t,boot}$ above SSF_{MSY} for a given level of fixed removals and a given year.

The 70th percentile of $F_{t,boot}/F_{MSY}$ was summarized for each projection year (2017 – 2046) and each fixed level of total annual removals due to fishing (**Figure 3.6.13**). The 70th percentiles of $F_{t,boot}/F_{MSY}$ represent the 30% probability of $F_{t,boot}$ exceeding F_{MSY} for a given level of fixed removals and a given year.

Frequency distributions (**Figure 3.6.14**) and correlations (**Figure 3.6.15**) were provided from 10,000 Monte Carlo simulations (random draws) from a bivariate normal distribution for initial numbers (N_{2016}^{boot}) and fishing mortality (F_{2016}^{boot}) and a second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2016}^{boot}$) and equilibrium recruitment ($R_0{}_{2016}^{boot}$) for each projection scenario.

3.3. DISCUSSION

As was the case for the previously completed SEDAR 29 GOM blacktip assessment, an issue of concern regarding the indices of relative abundance is that many show interannual variability that does not seem to be compatible with the life history of the species, suggesting that the GLMs used to standardize the indices do not include all factors to help track relative abundance. Also, inconsistent signals likely lead to tensions among the different indices when fitting the model, which proposes an abundance trend that represents a compromise solution attempting to accommodate the sometimes different trends displayed by the indices. However, the model cannot ultimately distinguish which of the trends in abundance is most likely to represent reality. The SEDAR 29 AP identified ranks as the preferred way of weighting the indices prior to fitting the model in an effort to avoid bias, and also to avoid the model from being arbitrarily driven by more precise indices (with lower CVs), which may be reflective of larger sample size but not necessarily track real relative abundance. The scenario consisting of the NEFS LL SE index only was explored, but we could not estimate parameter standard deviations based on a Hessian approximation to the numerically maximized posterior surface and therefore we deemed the results of this scenario were not reliable and we did not consider them in our evaluations.

Considering the multiple sources of uncertainty that were examined through state of nature analyses, it can be concluded that the assessment provided a consistent picture of stock status. Exploring the uncertainty associated with catches revealed that while the model responded to different catch levels, the outcome was not significantly affected. Consideration of uncertainty in biological parameters, explored through the high and low productivity, and lognormal distribution for R_0 scenarios, had a larger effect on model results, but did not alter stock status predictions. The low productivity scenario in particular revealed that the model is sensitive to the life history inputs and that considering values of life history parameters representative of very low productivity for this stock can lead to boundary solutions for some estimated parameters.

Despite the differences between the inputs used in SEDAR 29 (2012) and this assessment update, stock status did not change substantially, although the magnitude of some of the estimated parameters varied significantly (**Table 3.5.10**). The current base model estimated substantially higher virgin recruitment than the 2012 assessment (6.07 x10^6 vs. 3.98 x10^6). Spawning stock fecundity in 2016 was higher than estimated for 2010 in the 2012 assessment (2.55x10^7 vs. 1.53x10^7), and the estimate of *MSY* for the current base model (8.46x10^5 sharks) was also higher than the 2012 assessment estimate (6.31x10^5 sharks). Differences between the 2012 (SEDAR 29) and this assessment update include: there are now seven indices of relative abundance in the base run (vs. six indices in 2012); all indices were re-analyzed and include six more years of data; recruitment annual deviation process error was assumed to be an independent and lognormally distributed random variable with mean=0, a CV of 0.01, and bounded between -0.05 and 0.05 (vs. no process error in 2012); there are new biological parameters, including a new von Bertalanffy growth curve with a slower growth coefficient K=0.162 (vs. 0.187), and there are new estimates of natural mortality at age (ranging from 0.206 to 0.132 vs. 0.226 to 0.134). Projections were conducted with a similar methodology to those conducted in 2012 for SEDAR 29 (Appendix 3.7).

We recognize, as was noted in SEDAR 29, that the estimation of selectivities externally to the model may not be ideal and may not have captured the uncertainty associated with the sample size used to fit age-length curves, the computation of the age-length key, and subsequent transformation of lengths into ages to produce age-frequency distributions to which selectivity curves were fitted or assigned. SSASPM cannot accommodate length composition data but can accept age composition data as input. However, SEDAR 29 attempts at estimating selectivity within the model through the use of available age compositions (obtained from length compositions through the age-length key) were unsuccessful and thus, as in SEDAR 29 implementations of the model, selectivities had to be estimated externally to the model in the current update. If representative length composition data from the different surveys and programs become available in the future, we hope to use a length-based, age-structured model (e.g. Stock Synthesis). We also note that the age-length key should be improved with the addition of more samples, especially corresponding to the largest/oldest segments of the stock.

Based on the similar results obtained in the present and 2012 assessments, it appears that the combination of a relatively productive stock, limited catches especially in recent years, and stable indices of relative abundance, makes this stock of blacktip sharks in the Gulf of Mexico resilient to overfishing. With the present allocation of effort among fishing sectors, projection results indicated that the stock appears to be capable of supporting total annual removals due to fishing from 2.00x10^5 to 1.20x10^6 sharks depending on the scenario (i.e. with both the Pr(SSF_t > SSF_{MSY}) ≥ 70% and Pr(F_t > F_{MSY}) ≤ 30% during the years 2017 – 2046).

3.4. REFERENCES

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3.5. TABLES

Table 3.5.1. List of parameters estimated in SSASPM for GOM blacktip shark (base run). The list includes predicted parameter values with associated SDs, initial parameter values, minimum and maximum allowed values, and prior density functions assigned to parameters. Priors designated as constant were estimated as such; parameters that were held fixed (not estimated) are not included in this table. All SD estimates are based on a Hessian approximation to the numerically maximized posterior surface.

	Predicted					Prior pdf			
	Value	SD	Initial	Min	Max	Type	Value	SD (CV)	Status
Virgin recruitment	6.07E+06	1.54E+07	1.00E+06	1.00E+05	1.00E+07	uniform	-	-	estimated
Pup (age-0) survival	8.01E-01	2.44E-01	7.60E-01	5.00E-01	9.90E-01	lognormal	0.76	(0.3)	estimated
Catchability coefficient GULFSPAN GN index	8.92E-08	2.32E-07	3.11E+04	1.00E-10	6.22E-03	constant	-	-	estimated
Catchability coefficient BLLOP NR index	3.05E-08	8.24E-08	1.17E+04	1.00E-10	6.22E-03	constant	-	-	estimated
Catchability coefficient BLLOP RES index	4.53E-08	1.21E-07	1.17E+04	1.00E-10	6.22E-03	constant	-	-	estimated
Catchability coefficient NMFS LL SE index	2.85E-08	7.56E-08	7.01E+04	1.00E-10	6.22E-03	constant	-	-	estimated
Catchability coefficient EPN index	1.16E-07	3.01E-07	1.56E+04	1.00E-10	6.22E-03	constant	-	-	estimated
Catchability coefficient TEXAS GN index	4.61E-08	1.20E-07	4.25E+04	1.00E-10	6.22E-03	constant	-	-	estimated
Catchability coefficient G. MSLAALTX LL index	5.76E-08	1.51E-07	1.17E+04	1.00E-10	6.22E-03	constant	-	-	estimated
Catchability coefficient Com+Unrep catch series	1.63E-03	4.64E-03	2.18E+03	1.00E-10	6.22E-02	constant	-	-	estimated
Catchability coefficient Recreational catch series	1.63E-03	4.55E-03	3.53E+03	1.00E-10	6.22E-02	constant	-	-	estimated
Catchability coefficient Mexican catch series	1.11E-03	3.10E-03	3.53E+03	1.00E-10	6.22E-02	constant	-	-	estimated
Catchability coefficient Menhaden discards catch series	1.30E-03	3.66E-03	3.74E+03	1.00E-10	6.22E-02	constant	-	-	estimated
Modern effort Com+Unrep fleet	1.00E+00	2.94E-01	1.00E+00	2.00E-01	9.91E+01	lognormal	1.0	(0.3)	estimated
Modern effort Recreational fleet	2.00E+00	5.87E-01	2.00E+00	1.00E-01	9.91E+01	lognormal	2.0	(0.3)	estimated
Modern effort Mexican fleet	1.50E+00	4.40E-01	1.50E+00	1.00E-01	9.91E+01	lognormal	1.5	(0.3)	estimated
Modern effort Menhaden discards fleet	2.50E-01	7.33E-02	2.50E-01	1.00E-01	9.91E+01	lognormal	0.25	(0.3)	estimated
Overall variance	-7.63E-02	3.67E-03	-2.00E-01	-2.00E-01	-1.00E-02	constant	-	-	estimated
Recruitment deviation in 1981	2.40E-02	3.94E-01	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1982	2.26E-02	3.59E-01	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1983	-5.00E-02	1.49E-02	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1984	-5.00E-02	7.25E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1985	-4.29E-02	3.41E-01	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated

Recruitment deviation in 1986	3.44E-02	3.57E-01	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1986	-4.54E-02	3.22E-01	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1988	-5.00E-02	3.16E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1989	-5.00E-02	9.34E-04	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1990	-5.00E-02	5.47E-04	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1991	-5.00E-02	1.40E-04	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1992	-5.00E-02	1.48E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1993	-5.00E-02	2.62E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1994	-5.00E-02	6.25E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1995	-5.00E-02	8.41E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1996	-5.00E-02	1.17E-02	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1997	-4.36E-02	3.18E-01	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1998	5.00E-02	3.45E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 1999	5.00E-02	1.37E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2000	5.00E-02	9.23E-04	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2001	5.00E-02	1.22E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2002	5.00E-02	8.90E-04	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2003	5.00E-02	1.02E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2004	5.00E-02	1.02E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2005	5.00E-02	1.06E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2006	5.00E-02	5.42E-04	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2007	5.00E-02	8.18E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2008	5.00E-02	4.51E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2009	5.00E-02	3.78E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2010	5.00E-02	4.03E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2011	5.00E-02	2.78E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2012	5.00E-02	1.50E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2013	5.00E-02	1.83E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2014	5.00E-02	1.20E-03	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Recruitment deviation in 2015	4.21E-02	3.15E-01	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated

Recruitment deviation in 2016	-4.99E-02	3.34E-02	0.00E+00	-5.00E-02	5.00E-02	lognormal	0	(0.01)	estimated
Effort deviation for Com+Unrep fleet in 1981	-1.49E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1982	-1.49E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1983	-1.41E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1984	-1.10E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1985	-1.17E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1986	7.99E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1986	7.92E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1988	1.50E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1989	1.54E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1990	9.18E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1991	9.77E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1992	1.12E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1993	7.98E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1994	7.33E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1995	1.05E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1996	7.84E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1997	4.65E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1998	7.74E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 1999	5.90E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2000	5.32E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2001	3.07E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2002	7.75E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2003	8.34E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2004	3.71E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2005	9.54E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2006	5.85E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2007	4.06E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2008	-7.58E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2009	-7.34E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated

Effort deviation for Com+Unrep fleet in 2010	-3.75E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2011	-6.45E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2012	-6.69E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2013	-4.61E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2014	-8.38E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2015	-3.44E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Com+Unrep fleet in 2016	-8.14E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1981	2.31E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1982	5.05E-01	1.06E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1983	-5.10E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1984	-4.45E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1985	2.60E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1986	1.21E+00	1.06E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1986	4.60E-01	1.06E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1988	1.01E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1989	7.85E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1990	7.31E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1991	9.85E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1992	5.33E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1993	2.80E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1994	1.96E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1995	1.00E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1996	4.73E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1997	3.98E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1998	6.46E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 1999	-4.12E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2000	6.56E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2001	1.85E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2002	-2.80E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2003	-1.22E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated

Effort deviation for Recreational fleet in 2004	-5.35E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2005	-2.06E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2006	5.73E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2007	-5.16E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2008	-1.00E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2009	-8.33E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2010	-3.42E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2011	-7.85E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2012	-1.51E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2013	-8.87E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2014	-1.11E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2015	-9.53E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Recreational fleet in 2016	-1.28E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1981	8.50E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1982	2.80E-01	1.06E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1983	3.39E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1984	7.02E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1985	5.16E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1986	4.11E-01	1.06E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1986	4.76E-01	1.06E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1988	5.82E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1989	7.54E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1990	9.20E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1991	6.51E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1992	7.43E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1993	8.98E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1994	8.17E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1995	6.47E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1996	7.39E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1997	3.66E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated

Effort deviation for Mexican fleet in 1998	3.49E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 1999	1.17E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2000	-3.50E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2001	-3.65E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2002	-2.80E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2003	-4.54E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2004	-2.60E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2005	-2.70E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2006	-8.68E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2007	-8.91E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2008	-8.64E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2009	-6.79E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2010	-3.52E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2011	-8.74E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2012	-7.16E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2013	-4.95E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2014	-5.95E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2015	-7.82E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Mexican fleet in 2016	-1.94E+00	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1981	3.95E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1982	4.21E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1983	4.20E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1984	4.28E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1985	3.31E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1986	3.14E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1986	3.65E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1988	3.49E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1989	4.12E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1990	3.94E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1991	1.45E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated

Effort deviation for Menhaden discards fleet in 1992	2.28E-02	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1993	4.66E-02	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1994	1.06E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1995	5.37E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1996	3.78E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1997	5.86E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1998	6.85E-03	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 1999	8.99E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2000	-7.48E-02	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2001	-1.48E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2002	-1.78E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2003	-2.07E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2004	-1.88E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2005	-1.93E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2006	-2.44E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2007	-2.47E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2008	-2.52E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2009	-2.56E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2010	-2.59E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2011	-2.63E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2012	-3.68E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2013	-4.27E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2014	-5.51E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2015	-5.53E-01	1.05E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated
Effort deviation for Menhaden discards fleet in 2016	-5.41E-01	1.04E+00	0.00E+00	-7.00E+00	7.00E+00	lognormal	0	1	estimated

Table 3.5.2. Catch of GOM blacktip shark used in the low catch state of nature. Catches are by fleet in numbers.

Year	Com+Unrep	Recreational	Mexican	Menhaden discards
1981	7261	62576	64247	17495
1982	7261	82710	36156	17933
1983	7844	29064	37550	17714
1984	10712	30579	53258	17714
1985	9950	61468	43762	15964
1986	71435	162585	40073	15746
1987	69772	75117	42142	16402
1988	140261	129143	46239	15964
1989	144784	101637	54320	16839
1990	76851	95468	63659	16402
1991	81034	122534	48262	12684
1992	93187	77786	52856	11153
1993	66661	60274	61613	11372
1994	62028	55361	56715	12028
1995	84805	50199	47730	11372
1996	64741	72919	52332	11153
1997	46814	67634	35968	11372
1998	63798	90150	36589	10935
1999	52823	31677	26662	12028
2000	49888	94745	25838	10279
2001	39943	50093	18707	9622
2002	31968	48185	20545	9404
2003	69315	43998	17300	9185
2004	43732	47246	21086	9404
2005	33375	40526	20947	9404
2006	55073	52990	11491	8966
2007	46276	29830	11264	8966
2008	14439	18325	11595	8966
2009	14909	21801	13989	8966
2010	21541	35814	19482	8966
2011	16477	22895	11533	8966
2012	16161	43489	13556	8092
2013	20023	46391	16941	7654
2014	13722	16560	15355	6779
2015	22687	19533	12760	6779
2016	14159	13565	3872	6779

Table 3.5.3. Catch of GOM blacktip shark used in the high catch state of nature. Catches are by fleet in numbers.

Year	Com+Unrep	Recreational	Mexican	Menhaden discards
1981	7261	114247	111432	17495
1982	7261	108584	62200	17933
1983	7844	69036	64507	17714
1984	10712	62067	91269	17714
1985	9950	87701	75595	15964
1986	71435	233461	69263	15746
1987	69772	103769	73024	16402
1988	140261	167446	80133	15964
1989	144784	134858	93949	16839
1990	76851	135895	110252	16402
1991	81034	224625	83454	12684
1992	93187	112097	91477	11153
1993	67114	90963	106533	11372
1994	67888	89126	98163	12028
1995	89221	71733	82508	11372
1996	69462	111461	90408	11153
1997	49406	97775	61572	11372
1998	66670	141954	63194	10935
1999	54411	44327	46029	12028
2000	50801	141522	44487	10279
2001	40200	90629	31935	9622
2002	32976	77434	35200	9404
2003	71492	93182	29664	9185
2004	45019	78143	36092	9404
2005	34868	64459	36226	9404
2006	56276	106962	19810	8966
2007	48317	51341	19423	8966
2008	15023	33187	20060	8966
2009	15820	38208	24198	8966
2010	22829	65484	33794	8966
2011	17856	39633	19997	8966
2012	17253	77114	23490	8092
2013	20975	89462	29287	7654
2014	14719	28407	26507	6779
2015	24034	38828	22004	6779
2016	14837	22377	6583	6779

Table 3.5.4. Values of age-specific *M*, fecundity, von Bertalanffy growth function parameters, and maternal vs. litter size relationships used in the low and high productivity states of nature. Shaded cells denote quantities that changed with respect to SEDAR 29 inputs.

	Low productivity		High productivity	
Age	M	Fecundity	M	Fecundity
1	0.312	1.033	0.157	2.049
2	0.272	1.067	0.137	2.172
3	0.174	1.101	0.124	2.296
4	0.174	1.135	0.115	2.419
5	0.174	1.169	0.109	2.542
6	0.174	1.202	0.104	2.666
7	0.174	1.236	0.101	2.789
8	0.174	1.270	0.098	2.912
9	0.174	1.304	0.095	3.035
10	0.174	1.338	0.093	3.159
11	0.174	1.372	0.091	3.282
12	0.174	1.406	0.090	3.405
13	0.174	1.440	0.089	3.529
14	0.174	1.474	0.088	3.652
15	0.174	1.508	0.087	3.775
16	0.174	1.542	0.086	3.898
17	0.174	1.575	0.086	4.022
18	0.174	1.609	0.085	4.145
Growth parameters				
Linf	151.90		160.45	
k	0.14		0.18	
to	-3.20		-2.65	
Age vs litter size relationship				
slope	0.068		0.247	
intercept	1.998		3.852	

Table 3.5.5. Predicted abundance (*N*) and spawning stock fecundity (*SSF*) from SSASPM for GOM blacktip shark (base run).

Year	N	SSF
1981	3.94E+07	2.65E+07
1982	3.94E+07	2.65E+07
1983	3.89E+07	2.64E+07
1984	3.86E+07	2.64E+07
1985	3.83E+07	2.63E+07
1986	3.86E+07	2.62E+07
1987	3.81E+07	2.60E+07
1988	3.78E+07	2.58E+07
1989	3.74E+07	2.56E+07
1990	3.70E+07	2.54E+07
1991	3.68E+07	2.52E+07
1992	3.65E+07	2.50E+07
1993	3.64E+07	2.48E+07
1994	3.62E+07	2.46E+07
1995	3.61E+07	2.45E+07
1996	3.60E+07	2.43E+07
1997	3.59E+07	2.42E+07
1998	3.64E+07	2.41E+07
1999	3.68E+07	2.40E+07
2000	3.71E+07	2.39E+07
2001	3.74E+07	2.39E+07
2002	3.76E+07	2.39E+07
2003	3.78E+07	2.39E+07
2004	3.80E+07	2.39E+07
2005	3.81E+07	2.40E+07
2006	3.83E+07	2.41E+07
2007	3.84E+07	2.42E+07
2008	3.86E+07	2.43E+07
2009	3.87E+07	2.45E+07
2010	3.89E+07	2.46E+07
2011	3.90E+07	2.48E+07
2012	3.91E+07	2.49E+07
2013	3.93E+07	2.51E+07
2014	3.93E+07	2.53E+07
2015	3.94E+07	2.54E+07
2016	3.90E+07	2.55E+07

Table 3.5.6. Estimated total and fleet-specific apical instantaneous fishing mortality rates by year from SSASPM for GOM blacktip shark (base run).

Year	TotalF	Fleet-specific F			
		ComUnrep	Recreational	Mexican	Menhaden Disc
1981	0.0084	0.0004	0.0041	0.0039	0.0005
1982	0.0080	0.0004	0.0054	0.0022	0.0005
1983	0.0047	0.0004	0.0020	0.0023	0.0005
1984	0.0059	0.0005	0.0021	0.0033	0.0005
1985	0.0074	0.0005	0.0042	0.0028	0.0005
1986	0.0137	0.0036	0.0109	0.0025	0.0004
1987	0.0082	0.0036	0.0051	0.0027	0.0005
1988	0.0123	0.0073	0.0089	0.0030	0.0005
1989	0.0111	0.0076	0.0071	0.0035	0.0005
1990	0.0113	0.0041	0.0067	0.0042	0.0005
1991	0.0122	0.0043	0.0087	0.0032	0.0004
1992	0.0093	0.0050	0.0055	0.0035	0.0003
1993	0.0087	0.0036	0.0043	0.0041	0.0003
1994	0.0080	0.0034	0.0040	0.0038	0.0004
1995	0.0071	0.0046	0.0036	0.0032	0.0003
1996	0.0090	0.0036	0.0052	0.0035	0.0003
1997	0.0075	0.0026	0.0048	0.0024	0.0003
1998	0.0088	0.0035	0.0062	0.0024	0.0003
1999	0.0042	0.0029	0.0022	0.0017	0.0004
2000	0.0081	0.0028	0.0063	0.0016	0.0003
2001	0.0047	0.0022	0.0033	0.0012	0.0003
2002	0.0047	0.0018	0.0032	0.0013	0.0003
2003	0.0048	0.0037	0.0029	0.0011	0.0003
2004	0.0046	0.0024	0.0031	0.0013	0.0003
2005	0.0042	0.0018	0.0026	0.0013	0.0003
2006	0.0044	0.0029	0.0034	0.0007	0.0003
2007	0.0033	0.0024	0.0019	0.0007	0.0003
2008	0.0021	0.0008	0.0012	0.0007	0.0003
2009	0.0025	0.0008	0.0014	0.0008	0.0003
2010	0.0037	0.0011	0.0023	0.0012	0.0003
2011	0.0024	0.0009	0.0015	0.0007	0.0003
2012	0.0038	0.0008	0.0028	0.0008	0.0002
2013	0.0042	0.0010	0.0030	0.0010	0.0002
2014	0.0022	0.0007	0.0011	0.0009	0.0002
2015	0.0022	0.0012	0.0013	0.0008	0.0002
2016	0.0013	0.0007	0.0009	0.0002	0.0002

Table 3.5.7. Summary of results from SSASPM for GOM blacktip shark (base run). AICc is the Akaike Information Criterion for small sample sizes, which converges to the AIC statistic as the number of data points gets large. *SSF* is spawning stock fecundity (sum of number at age times pup production at age). *SSF* at the minimum spawning stock size threshold (*MSST*) is calculated as $(1-\overline{M}_a)*SSF_{MSY}$. Age-independent natural mortality ($\overline{M}_a$) is defined as mean age-specific natural mortality for ages 1-18. *MSY* is expressed in numbers. SPR_{msy}/SPR_0 is the ratio of pups per recruit with fishing mortality at F_{MSY} to pups per recruit with $F = 0$. *N* is total abundance. R_0 is the number of age-1 pups at virgin conditions. The value of steepness is for the assumed Beverton-Holt stock-recruit relationship. All estimates of CV are based on the numerical Hessian evaluated at the posterior mode.

	Base	
	Est	CV
AICc	1361.94	NA
Objective function	40.25	NA
SSF_{2016}/SSF_{msy}	2.68	0.33
SSF_{2016}/SSF_{msst}	3.16	0.33
$\overline{M}_a$	0.153	NA
F_{2016}/F_{msy}	0.024	2.60
MSY	8.46E+05	2.46
SPR_{msy}/SPR_0	0.54	0.09
F_{msy}	0.0560	NA
SSF_{msy}	9.53E+06	2.50
SSF_{msst}	8.07E+06	2.50
F_{2016}	0.0013	2.60
SSF_{2016}	2.55E+07	2.68
N_{2016}	3.90E+07	2.62
SSF_{2016}/SSF_0	0.96	0.16
R_0	6.07E+06	2.53
Pup-survival	0.80	0.30
alpha	3.49	NA
steepness	0.47	NA
SSF_0	2.65E+07	2.53
SSF_{msy}/SSF_0	0.36	0.28

Table 3.5.8 Summary of stock status results from base and five additional scenarios reflective of plausible states of nature (High catch, Low catch, High Productivity, Low Productivity and Prior R_0; see section 3.1.3 of this report for definition of each scenario) runs for GOM blacktip shark. *SSF* is spawning stock fecundity (sum of number at age times pup production at age). *SSF* at the minimum spawning stock size threshold (*MSST*) is calculated as $(1-\overline{M}_a)*SSF_{MSY}$. Age-independent natural mortality ($\overline{M}_a$) is defined as mean age-specific natural mortality for ages 1-18. *MSY* is expressed in numbers. *N* is total abundance. R_0 is the number of age-1 pups at virgin conditions. All estimates of CV are based on the numerical Hessian evaluated at the posterior mode. Note: estimated R_0 hits the upper bound for the low productivity scenario and estimated pup-survival hits the upper bound for the lognormal distribution for R_0 scenario.

	Base		High catch		Low catch		High productivity		Low productivity		Prior R_0	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
SSF_{2016}/SSF_{msy}	2.68	0.33	2.70	0.45	2.76	0.23	2.61	0.31	2.15	0.83	2.17	0.21
SSF_{2016}/SSF_{msst}	3.16	0.33	3.18	0.45	3.25	0.23	2.90	0.31	2.64	0.83	2.56	0.21
$\overline{M}_a$	0.153	NA	0.153	NA	0.153	NA	0.102	NA	0.187	NA	0.153	NA
F_{2016}/F_{msy}	0.024	2.60	0.027	3.89	0.014	1.65	0.110	0.61	0.059	0.16	0.120	0.32
MSY	8.46E+05	2.46	9.99E+05	3.63	1.16E+06	1.60	2.06E+05	0.48	3.32E+05	0.83	1.94E+05	0.23
F_{msy}	0.0560	NA	0.0720	NA	0.0500	NA	0.1080	NA	0.0160	NA	0.0630	NA
SSF_{msy}	9.53E+06	2.50	1.02E+07	3.69	1.38E+07	1.59	2.33E+06	0.62	7.17E+06	0.83	1.75E+06	0.32
SSF_{msst}	8.07E+06	2.50	8.61E+06	3.69	1.17E+07	1.59	2.09E+06	0.62	5.83E+06	0.83	1.48E+06	0.32
F_{2016}	0.0013	2.60	0.0019	3.89	0.0007	1.65	0.0119	0.61	0.0009	0.16	0.0075	0.32
SSF_{2016}	2.55E+07	2.68	2.74E+07	4.05	3.81E+07	1.66	6.06E+06	0.81	1.54E+07	0.06	3.79E+06	0.33
N_{2016}	3.90E+07	2.62	4.20E+07	3.94	5.76E+07	1.64	4.93E+06	0.66	5.14E+07	0.06	6.55E+06	0.29
SSF_{2016}/SSF_0	0.96	0.16	0.95	0.28	0.99	0.06	0.63	0.30	0.97	0.06	0.72	0.11
R_0	6.07E+06	2.53	6.61E+06	3.76	8.84E+06	1.60	6.26E+05	0.51	1.00E+07	0.00	1.20E+06	0.23
Pup-survival	0.80	0.30	0.81	0.35	0.79	0.29	0.86	0.30	0.88	0.28	0.99	0.01

Table 3.5.9. Estimated temporal trends in stock status from SSASPM for GOM blacktip shark (base run) for apical fishing mortality relative to *MSY* levels (F/F_{MSY}) and spawning stock fecundity relative to *MSY* and *MSST* levels (SSF/SSF_{MSY} and SSF/SSF_{MSST}, respectively).

Year	F/F_{msy}	SSF/SSF_{msy}	SSF/SSF_{msst}
1981	0.150	2.78	3.28
1982	0.143	2.78	3.28
1983	0.085	2.77	3.27
1984	0.105	2.77	3.27
1985	0.132	2.76	3.26
1986	0.245	2.75	3.25
1987	0.147	2.73	3.23
1988	0.220	2.71	3.20
1989	0.198	2.69	3.17
1990	0.202	2.66	3.14
1991	0.218	2.64	3.12
1992	0.166	2.62	3.10
1993	0.155	2.60	3.07
1994	0.143	2.59	3.05
1995	0.126	2.57	3.03
1996	0.160	2.55	3.01
1997	0.135	2.54	3.00
1998	0.158	2.53	2.98
1999	0.075	2.52	2.97
2000	0.145	2.51	2.96
2001	0.084	2.51	2.96
2002	0.083	2.51	2.96
2003	0.087	2.51	2.96
2004	0.082	2.51	2.96
2005	0.074	2.52	2.97
2006	0.078	2.53	2.98
2007	0.058	2.54	2.99
2008	0.038	2.55	3.01
2009	0.045	2.57	3.03
2010	0.066	2.58	3.05
2011	0.043	2.60	3.07
2012	0.068	2.62	3.09
2013	0.075	2.63	3.11
2014	0.039	2.65	3.13
2015	0.039	2.67	3.15
2016	0.024	2.68	3.16

Table 3.5.10. Summary of stock status results from the current assessment update base run (2018) and the SEDAR 29 base (2012) run for GOM blacktip shark. *SSF* is spawning stock fecundity (sum of number at age times pup production at age). *SSF* at the minimum spawning stock size threshold (*MSST*) is calculated as (1-$\overline{M}_a$)*SSF_{MSY}. Age-independent natural mortality ($\overline{M}_a$) is defined as mean age-specific natural mortality for ages 1-18. *MSY* is expressed in numbers. *N* is total abundance. R_0 is the number of age-1 pups at virgin conditions. All estimates of CV are based on the numerical Hessian evaluated at the posterior mode.

	2018 Base		2012 Base	
	Est	CV	Est	CV
$SSFcur/SSF_{msy}$	2.68	0.33	2.62	0.53
$SSFcur/SSF_{msst}$	3.16	0.33	3.10	0.53
$\overline{M}_a$	0.153	NA	0.154	NA
F_{2016}/F_{msy}	0.024	2.60	0.074	2.97
MSY	8.46E+05	2.46	6.31E+05	2.65
F_{msy}	0.0560	NA	0.0840	NA
SSF_{msy}	9.53E+06	2.50	5.83E+06	2.70
SSF_{msst}	8.07E+06	2.50	4.93E+06	2.70
Fcur	0.0013	2.60	0.0062	2.97
SSFcur	2.55E+07	2.68	1.53E+07	3.16
Ncur	3.90E+07	2.62	2.38E+07	3.02
$SSFcur/SSF_0$	0.96	0.16	0.90	0.33
R_0	6.07E+06	2.53	3.98E+06	2.84
Pup-survival	0.80	0.30	0.84	0.40

Table 3.5.11. Stock projection information.

Projection information	Value
First projection year	2017
End projection year	2046 (30 years) (One generation is cf., 11 years)
Interim projection years at current fishing mortality rate	2017, 2018, 2019 (3 years)
Projection criteria (Iteratively solve for annual fishing mortality at a fixed level of total removals due to fishing)	Fixed removals (2020-2046)
Alternative levels	Fixed removals (1000s)
1	0
2	100
3	200
4	300
5	400
6	500
7	600
8	700
9	800
10	900
11	1000
12	1100
13	1200
14	1300
15	1400
16	1500
17	1600
18	1700
19	1800
20	1900
21	2000

Table 3.5.12. A summary of projection model results is presented for the base model configuration and model sensitivities. Projection results provide examples from 10,000 Monte Carlo projections of a given fixed level of total annual removals due to fishing (1,000s of sharks) which resulted in both the Pr($SSF_t > SSF_{MSY}$) ≥ 70% and Pr($F_t > F_{MSY}$) ≤ 30% during the years 2017 – 2046).

Projection scenario	Model configuration	Example of fixed removals (1000s)
1	Baseline, Ranked CPUE Weighting	800
2	Sensitivity, Low Catch	1200
3	Sensitivity, High Catch	1000
4	Sensitivity, Low Productivity	400
5	Sensitivity, High Productivity	200
6	Lognormal Prior R0	200

Table 3.5.13. Probabilities from 10,000 Monte Carlo bootstrap projections that spawning stock fecundity (SSF_t) will exceed the level of SSF that will produce *MSY* (SSF_{MSY}), Pr($SSF_t > SSF_{MSY}$), for a given year (2037 – 2046) and a given fixed removals level (1,000s); Green Pr ≥ 70%, Yellow 70% > Pr ≥ 50%, Red Pr < 50%.

Panel A. Projection Scenario-1 (Baseline, Ranked CPUE Weighting).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	0.92	0.93	0.93	0.93	0.94	0.94	0.94	0.95	0.95	0.95
2	100	0.91	0.91	0.92	0.92	0.92	0.92	0.93	0.93	0.93	0.93
3	200	0.89	0.89	0.90	0.90	0.90	0.90	0.91	0.91	0.91	0.92
4	300	0.87	0.88	0.88	0.88	0.88	0.89	0.89	0.89	0.89	0.90
5	400	0.86	0.86	0.87	0.87	0.87	0.87	0.88	0.88	0.88	0.88
6	500	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.86
7	600	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
8	700	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.80	0.81	0.80
9	800	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.77	0.77	0.77
10	900	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.74	0.74	0.74
11	1000	0.74	0.73	0.73	0.72	0.72	0.71	0.71	0.70	0.70	0.69
12	1100	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.67	0.66	0.65
13	1200	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.60	0.59
14	1300	0.66	0.65	0.64	0.63	0.62	0.60	0.59	0.58	0.56	0.54
15	1400	0.63	0.61	0.59	0.58	0.56	0.54	0.52	0.50	0.48	0.45
16	1500	0.61	0.59	0.57	0.55	0.53	0.51	0.48	0.45	0.43	0.39
17	1600	0.56	0.53	0.51	0.49	0.46	0.43	0.40	0.37	0.33	0.29
18	1700	0.52	0.50	0.47	0.44	0.40	0.37	0.33	0.29	0.25	0.20
19	1800	0.48	0.45	0.42	0.39	0.35	0.30	0.26	0.21	0.16	0.10
20	1900	0.44	0.40	0.37	0.32	0.27	0.23	0.17	0.12	0.07	0.03
21	2000	0.41	0.36	0.32	0.27	0.22	0.16	0.11	0.05	0.02	0.01

Panel B. Projection Scenario-2 (Sensitivity, Low Catch).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	0.93	0.93	0.94	0.94	0.95	0.95	0.95	0.95	0.96	0.96
2	100	0.93	0.93	0.93	0.94	0.94	0.94	0.94	0.95	0.95	0.95
3	200	0.91	0.91	0.92	0.92	0.92	0.92	0.93	0.93	0.93	0.94
4	300	0.90	0.91	0.91	0.91	0.92	0.92	0.92	0.92	0.92	0.93
5	400	0.89	0.89	0.90	0.90	0.90	0.90	0.91	0.91	0.91	0.92
6	500	0.88	0.89	0.89	0.89	0.89	0.90	0.90	0.90	0.90	0.90
7	600	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.88	0.89
8	700	0.86	0.87	0.87	0.87	0.87	0.87	0.88	0.88	0.88	0.88
9	800	0.84	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
10	900	0.83	0.83	0.83	0.83	0.84	0.83	0.83	0.84	0.84	0.84
11	1000	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
12	1100	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.79
13	1200	0.79	0.79	0.78	0.78	0.78	0.78	0.77	0.77	0.77	0.77
14	1300	0.77	0.77	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.74
15	1400	0.76	0.75	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.72
16	1500	0.73	0.72	0.72	0.71	0.71	0.70	0.69	0.69	0.68	0.67
17	1600	0.71	0.70	0.69	0.69	0.68	0.67	0.66	0.65	0.64	0.63
18	1700	0.69	0.68	0.67	0.66	0.65	0.64	0.63	0.62	0.61	0.59
19	1800	0.67	0.66	0.65	0.64	0.62	0.61	0.59	0.58	0.56	0.54
20	1900	0.65	0.64	0.62	0.61	0.59	0.57	0.55	0.54	0.51	0.49
21	2000	0.64	0.62	0.60	0.59	0.56	0.54	0.52	0.50	0.47	0.45

Panel C. Projection Scenario-3 (Sensitivity, High Catch).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	0.91	0.92	0.92	0.92	0.93	0.93	0.93	0.93	0.94	0.94
2	100	0.89	0.90	0.90	0.90	0.91	0.91	0.91	0.91	0.92	0.92
3	200	0.89	0.89	0.89	0.90	0.90	0.90	0.90	0.91	0.91	0.91
4	300	0.87	0.88	0.88	0.88	0.88	0.89	0.89	0.89	0.89	0.89
5	400	0.87	0.87	0.87	0.87	0.87	0.87	0.88	0.88	0.88	0.88
6	500	0.85	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
7	600	0.83	0.83	0.83	0.83	0.83	0.83	0.84	0.84	0.84	0.84
8	700	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
9	800	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
10	900	0.78	0.78	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.76
11	1000	0.77	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.74	0.74
12	1100	0.75	0.75	0.74	0.74	0.73	0.73	0.72	0.72	0.72	0.71
13	1200	0.72	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.67	0.66
14	1300	0.70	0.69	0.68	0.67	0.66	0.66	0.65	0.64	0.63	0.62
15	1400	0.67	0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.59	0.57
16	1500	0.66	0.65	0.64	0.62	0.61	0.60	0.59	0.57	0.56	0.54
17	1600	0.64	0.63	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.50
18	1700	0.61	0.60	0.58	0.56	0.54	0.52	0.50	0.48	0.45	0.42
19	1800	0.59	0.57	0.55	0.52	0.50	0.48	0.45	0.43	0.40	0.36
20	1900	0.56	0.54	0.52	0.49	0.46	0.43	0.40	0.37	0.33	0.29
21	2000	0.53	0.51	0.48	0.45	0.41	0.38	0.34	0.30	0.26	0.21

Panel D. Projection Scenario-4 (Sensitivity, Low Productivity).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	300	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99
5	400	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99
6	500	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.98
7	600	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96
8	700	0.99	0.99	0.99	0.98	0.98	0.97	0.97	0.96	0.95	0.94
9	800	0.99	0.98	0.98	0.97	0.97	0.95	0.94	0.92	0.90	0.88
10	900	0.98	0.98	0.97	0.96	0.94	0.92	0.90	0.87	0.83	0.79
11	1000	0.97	0.96	0.94	0.92	0.89	0.85	0.80	0.75	0.69	0.63
12	1100	0.95	0.92	0.89	0.85	0.80	0.74	0.65	0.56	0.47	0.38
13	1200	0.91	0.87	0.82	0.74	0.65	0.55	0.43	0.32	0.22	0.14
14	1300	0.85	0.78	0.68	0.57	0.44	0.31	0.20	0.11	0.05	0.02
15	1400	0.74	0.62	0.47	0.34	0.20	0.10	0.04	0.01	0.00	0.00
16	1500	0.57	0.41	0.24	0.12	0.05	0.01	0.00	0.00	0.00	0.00
17	1600	0.37	0.20	0.09	0.03	0.01	0.00	0.00	0.00	0.00	0.00
18	1700	0.17	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	1800	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	1900	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Panel E. Projection Scenario-5 (Sensitivity, High Productivity).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
2	100	0.95	0.96	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.97
3	200	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.84	0.84	0.83
4	300	0.59	0.55	0.51	0.48	0.44	0.40	0.35	0.31	0.26	0.21
5	400	0.19	0.12	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.00
6	500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	600	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	800	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	1600	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	1700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	1800	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	1900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Panel F. Projection Scenario-6 (Sensitivity, Lognormal Prior R_0).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	200	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95
4	300	0.71	0.67	0.62	0.57	0.51	0.46	0.39	0.32	0.25	0.19
5	400	0.11	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
6	500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	600	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	800	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	1000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1300	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	1500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	1600	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	1700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	1800	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	1900	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.5.14. Probabilities from 10,000 Monte Carlo bootstrap projections that fishing mortality (F_t) will exceed the level of F that will produce *MSY* (F_{MSY}), Pr($F_t > F_{MSY}$), for a given year (2037 – 2046) and a given fixed removals level (1,000s); Green Pr ≤ 30%, Yellow 30% > Pr ≤ 50%, Red Pr > 50%.

Panel A. Projection Scenario-1 (Baseline, Ranked CPUE Weighting).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01
2	100	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3	200	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
4	300	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
5	400	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
6	500	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
7	600	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13
8	700	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17
9	800	0.21	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.22
10	900	0.27	0.28	0.28	0.28	0.29	0.29	0.29	0.30	0.30	0.31
11	1000	0.35	0.36	0.37	0.37	0.38	0.39	0.40	0.41	0.42	0.43
12	1100	0.46	0.47	0.49	0.50	0.52	0.54	0.57	0.59	0.61	0.64
13	1200	0.60	0.63	0.66	0.69	0.73	0.77	0.81	0.85	0.89	0.94
14	1300	0.78	0.83	0.88	0.92	0.96	0.98	0.99	0.99	0.99	0.99
15	1400	0.96	0.98	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00
16	1500	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	1600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	1700	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	1800	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Panel B. Projection Scenario-2 (Sensitivity, Low Catch).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	0.00	<=0.01	<=0.01	<=0.01
2	100	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
3	200	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
4	300	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
5	400	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
6	500	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
7	600	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
8	700	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
9	800	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.10
10	900	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
11	1000	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17
12	1100	0.19	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20	0.20
13	1200	0.23	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.26	0.26
14	1300	0.28	0.29	0.29	0.30	0.30	0.31	0.31	0.32	0.32	0.33
15	1400	0.34	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.42	0.43
16	1500	0.43	0.44	0.46	0.48	0.49	0.51	0.53	0.55	0.57	0.60
17	1600	0.52	0.54	0.56	0.59	0.62	0.65	0.68	0.71	0.74	0.78
18	1700	0.64	0.67	0.71	0.74	0.78	0.82	0.87	0.92	0.96	0.99
19	1800	0.78	0.82	0.86	0.92	0.95	0.98	0.99	0.99	1.00	1.00
20	1900	0.92	0.96	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00
21	2000	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Panel C. Projection Scenario-3 (Sensitivity, High Catch).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	<=0.01	0.00	0.00	<=0.01	<=0.01	0.00	0.00	0.00	0.00	0.00
2	100	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3	200	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
4	300	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
5	400	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07
6	500	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
7	600	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12
8	700	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
9	800	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18
10	900	0.21	0.21	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.23
11	1000	0.25	0.26	0.26	0.26	0.27	0.27	0.27	0.28	0.28	0.29
12	1100	0.31	0.31	0.32	0.32	0.33	0.33	0.34	0.35	0.35	0.36
13	1200	0.39	0.40	0.41	0.42	0.43	0.44	0.45	0.46	0.48	0.49
14	1300	0.48	0.50	0.51	0.53	0.55	0.57	0.59	0.61	0.64	0.67
15	1400	0.61	0.63	0.66	0.69	0.72	0.76	0.79	0.83	0.87	0.92
16	1500	0.73	0.78	0.82	0.87	0.91	0.95	0.97	0.98	0.99	0.99
17	1600	0.91	0.94	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.99
18	1700	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00
19	1800	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
20	1900	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00
21	2000	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Panel D. Projection Scenario-4 (Sensitivity, Low Productivity).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01
2	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	300	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5	400	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.05	0.06
6	500	0.18	0.21	0.24	0.28	0.31	0.34	0.38	0.43	0.47	0.51
7	600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	700	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	800	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	1400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	1500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	1600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	1700	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	1800	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Panel E. Projection Scenario-5 (Sensitivity, High Productivity).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	<=0.01	<=0.01	<=0.01	<=0.01	0.00	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01
2	100	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3	200	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17
4	300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	700	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	800	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	1400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	1500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	1600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	1700	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	1800	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Panel F. Projection Scenario-6 (Sensitivity, Lognormal Prior R_0).

Fixed Harvest	1,000s	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1	0	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01	<=0.01
2	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	200	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
4	300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	700	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	800	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	1000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	1100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	1200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
14	1300	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15	1400	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
16	1500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
17	1600	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
18	1700	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
19	1800	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	1900	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

3.6. FIGURES

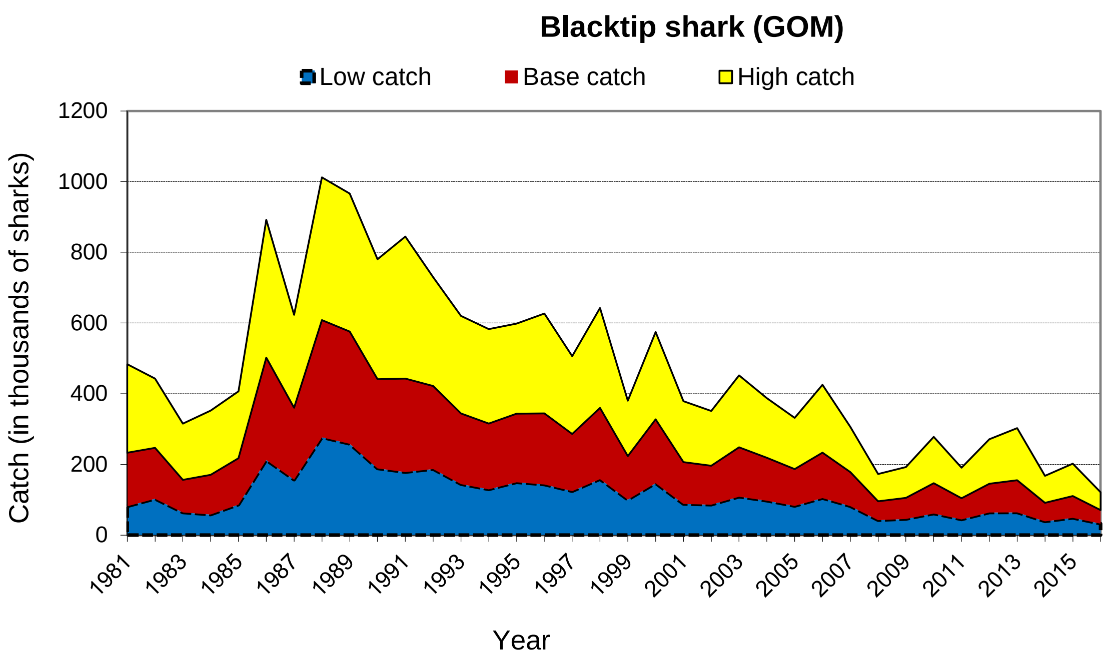
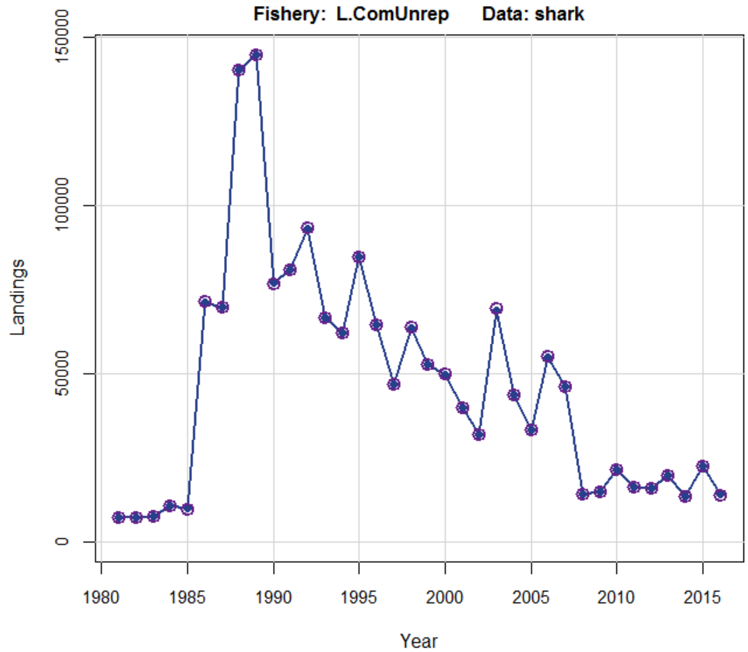


Figure 3.6.1. Catch estimates for GOM blacktip shark used in the low and high catch states of nature compared to the catch used in the base run.

A. Com+Unrep



B. Recreational

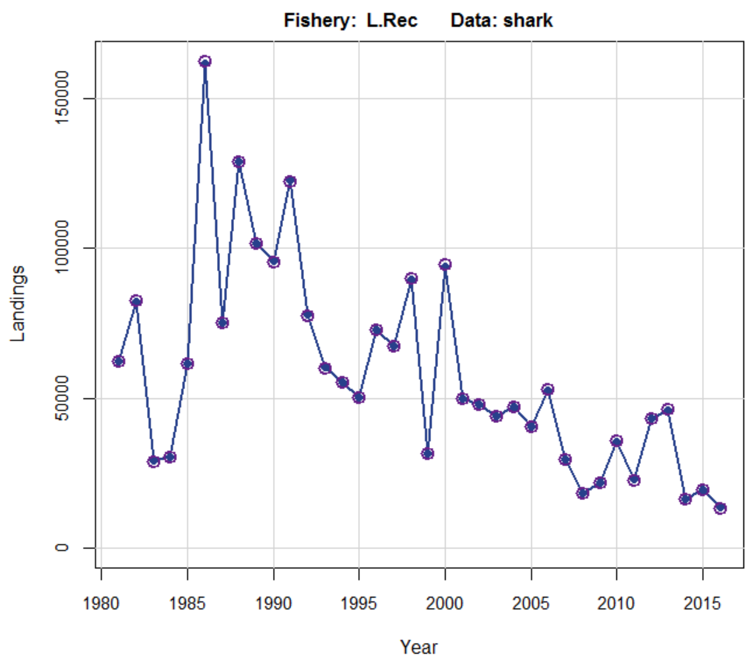
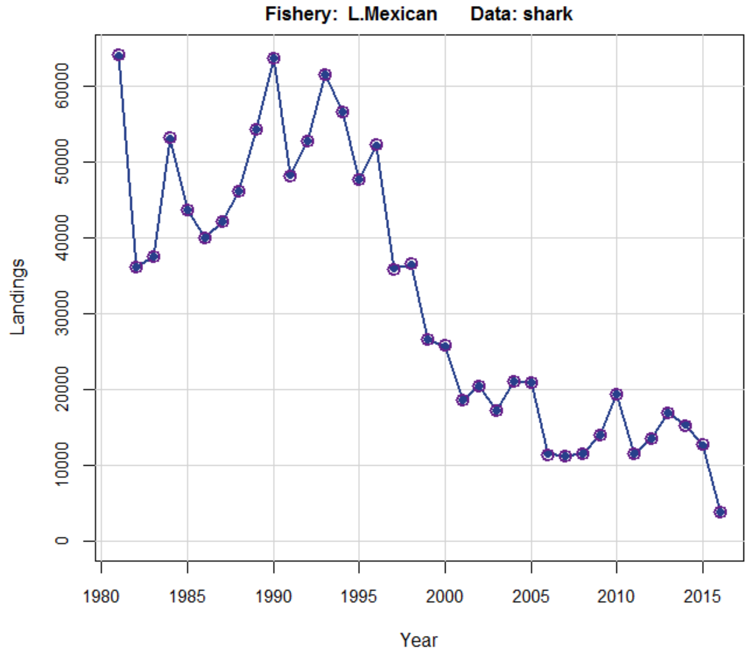


Figure 3.6.2. Predicted fits to catch from SSASPM for GOM blacktip shark (base run). The line with solid circles denotes SSASPM predictions, while open circles denote observed values.

C. Mexican



D. Menhaden discards

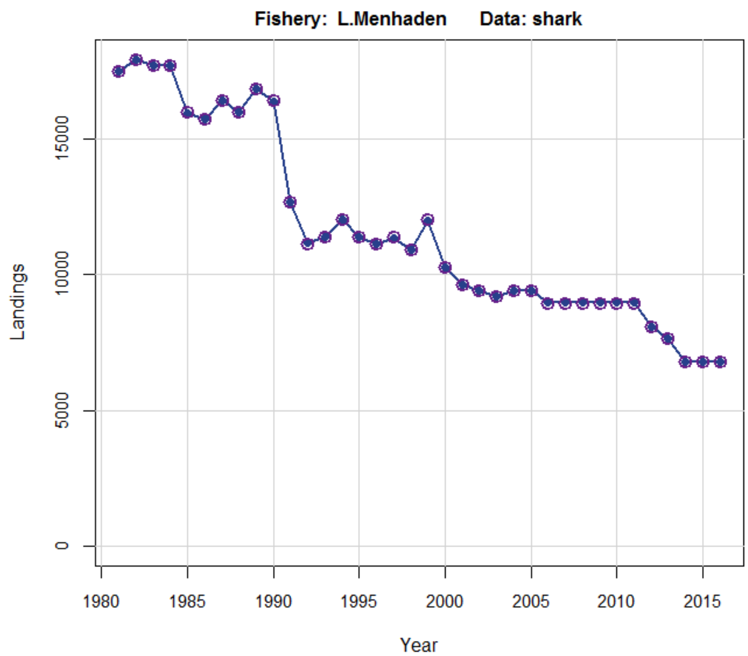
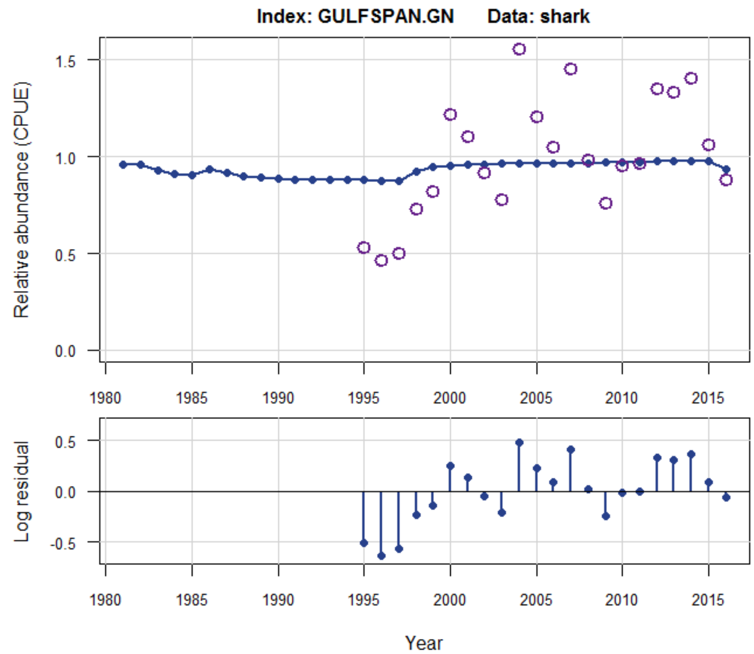


Figure 3.6.2. Predicted fits to catch for the base run (continued).

A. GULFSPAN GN



B. BLLOP NR

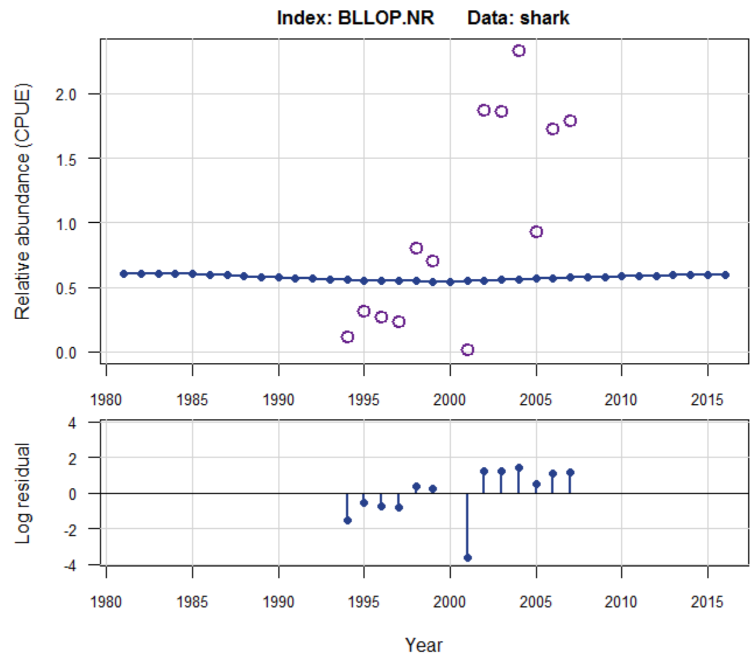
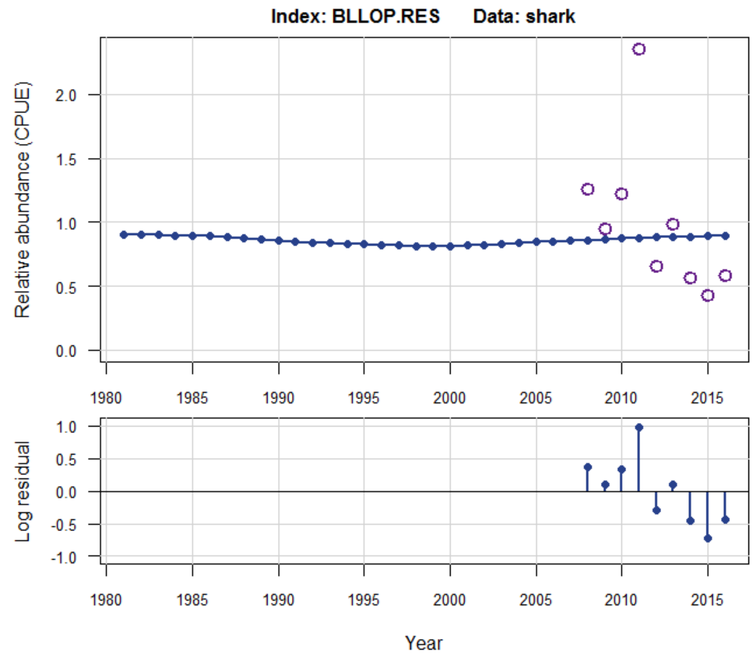


Figure 3.6.3. Fits to indices from SSASPM for GOM blacktip shark (base run). The line with solid circles denotes SSASPM predictions, while open circles denote observed values. Bottom panels give scaled residuals.

C. BLLOP RES



D. NMFS LL SE

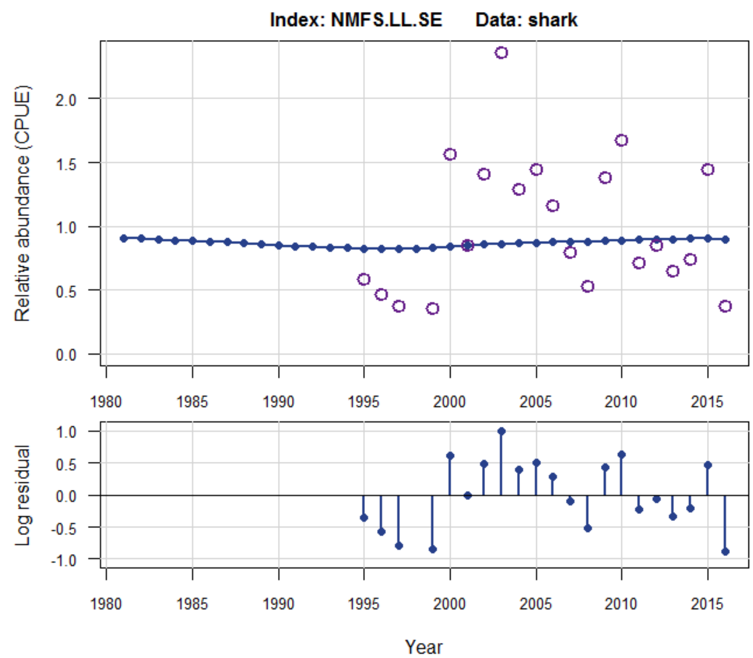
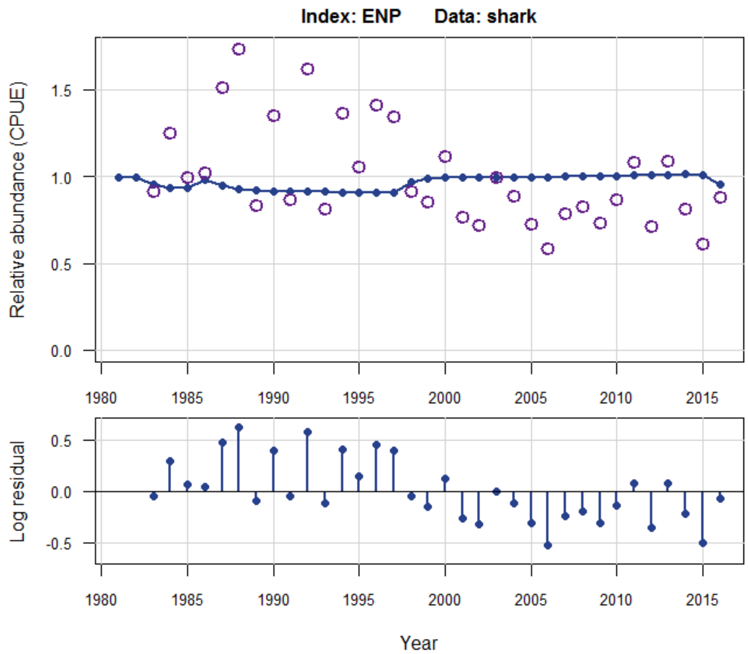


Figure 3.6.3. Fits to indices for the base run (continued).

E. ENP



F. TEXAS GN

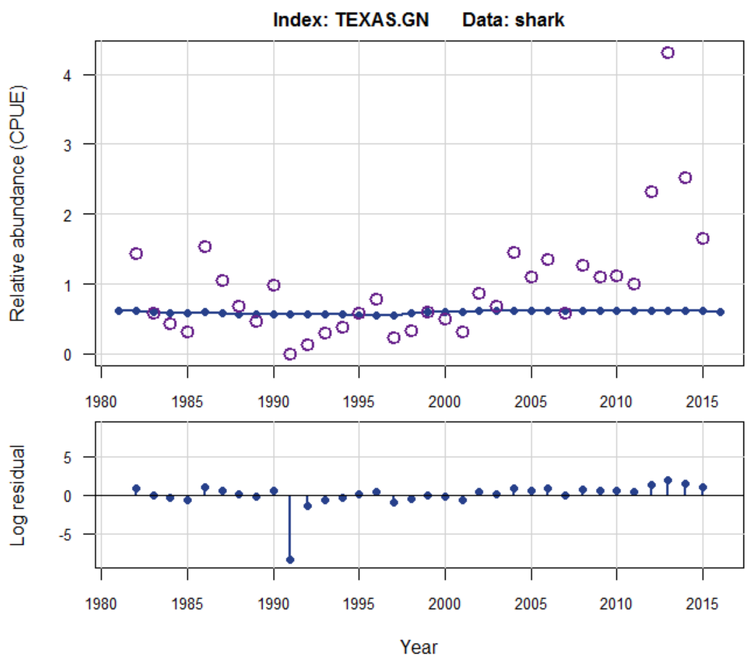


Figure 3.6.3. Fits to indices for the base run (continued).

G. MS+LA+AL+TX LL

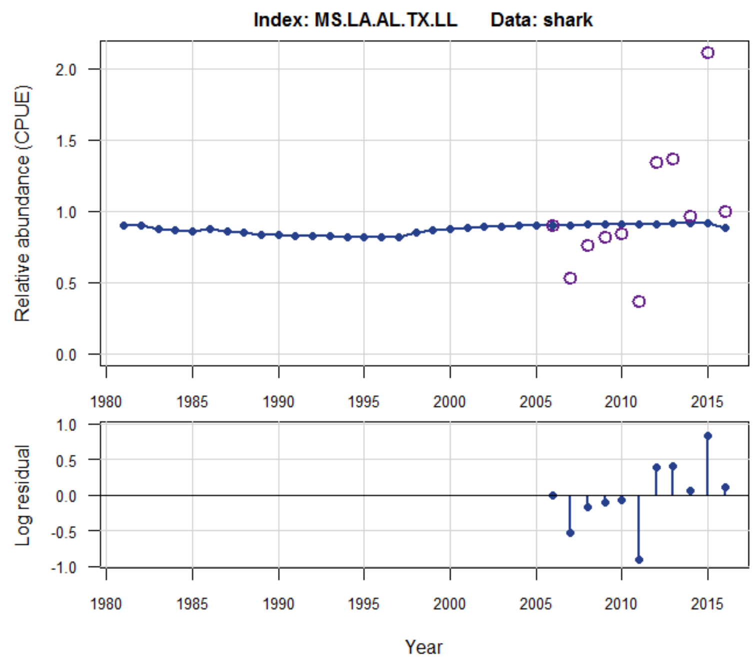


Figure 3.6.3. Fits to indices for the base run (continued).

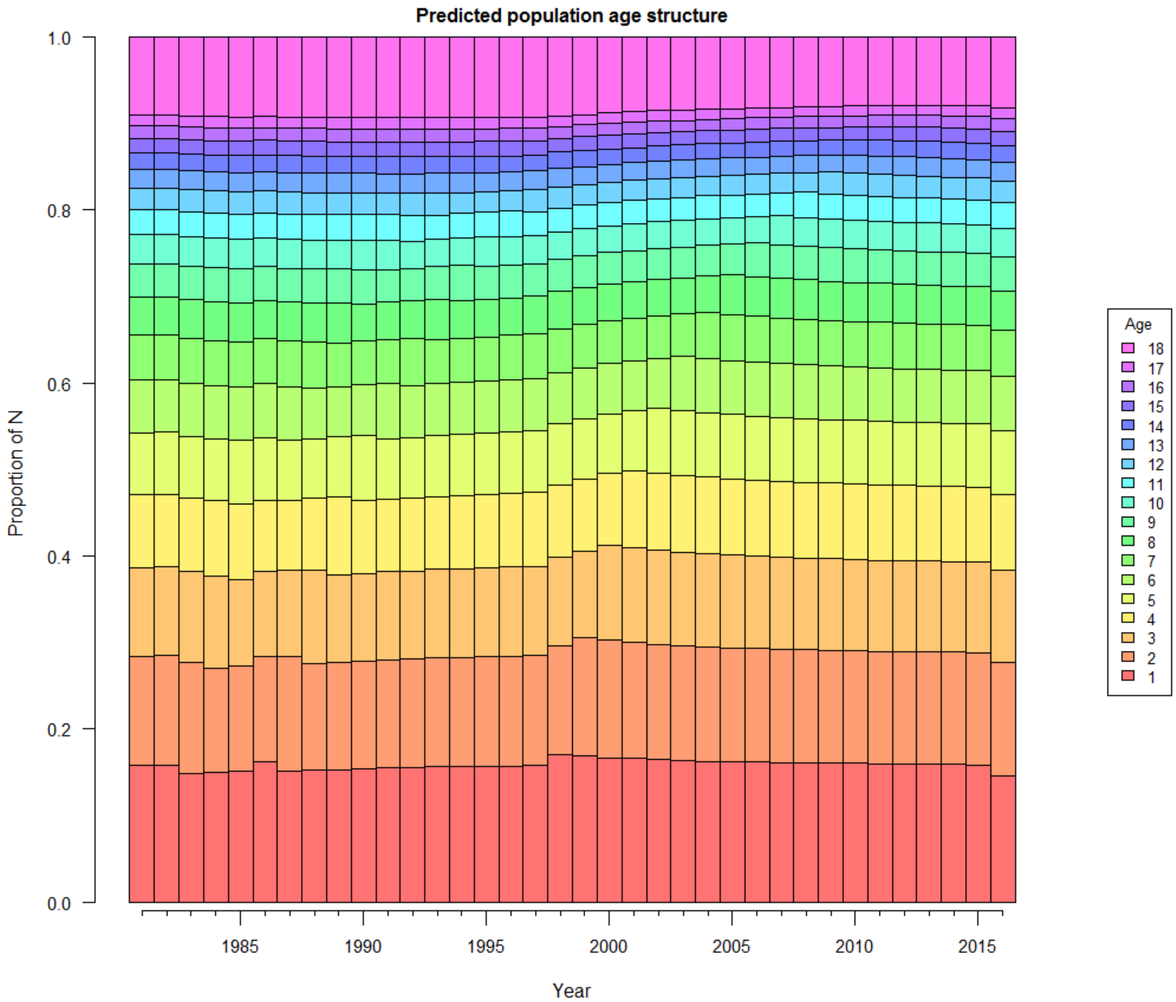


Figure 3.6.4. Predicted relative abundance at age from SSASPM for GOM blacktip shark (base run).

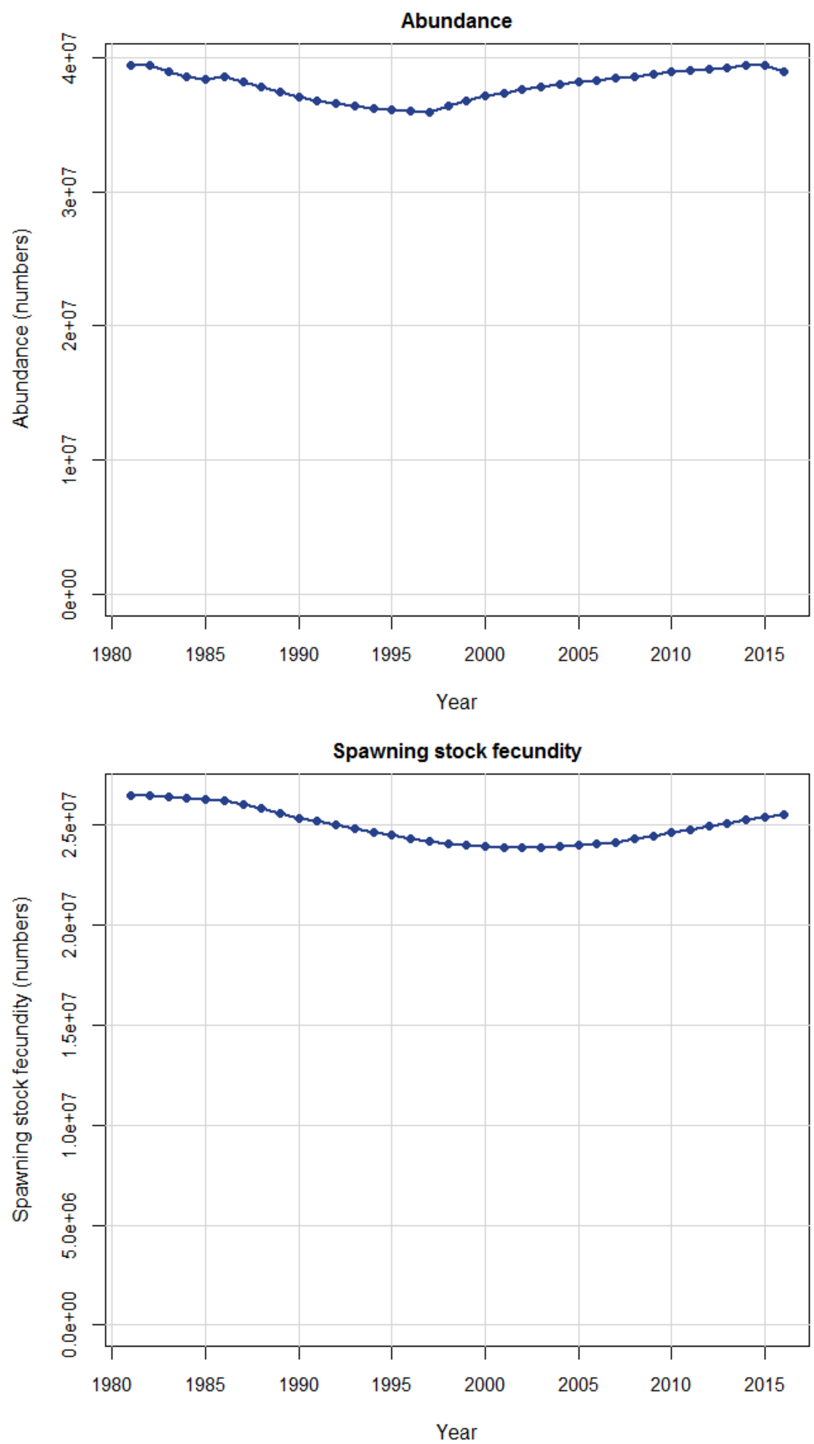


Figure 3.6.5. Predicted abundance and spawning stock fecundity trajectories from SSASPM for GOM blacktip shark (base run).

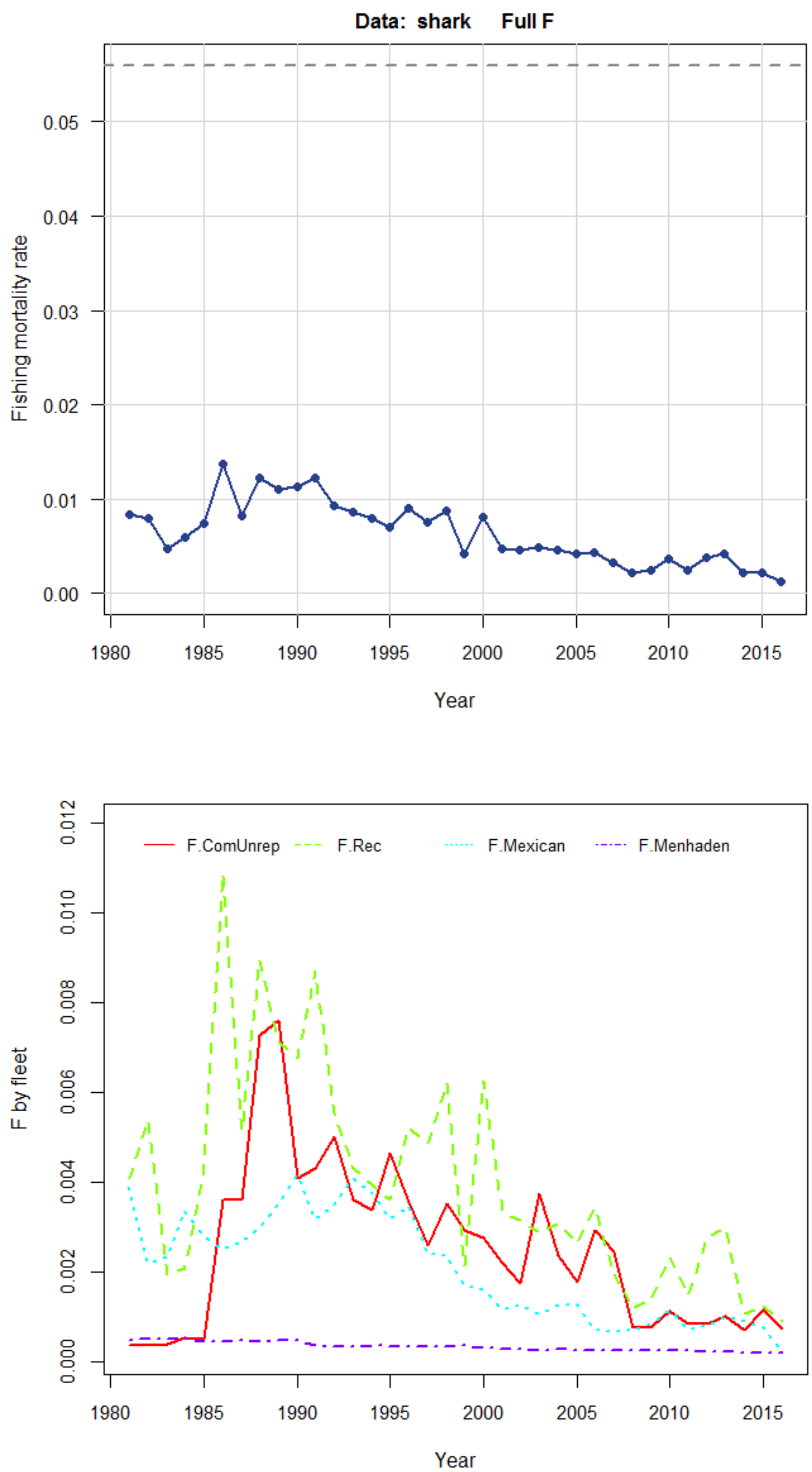
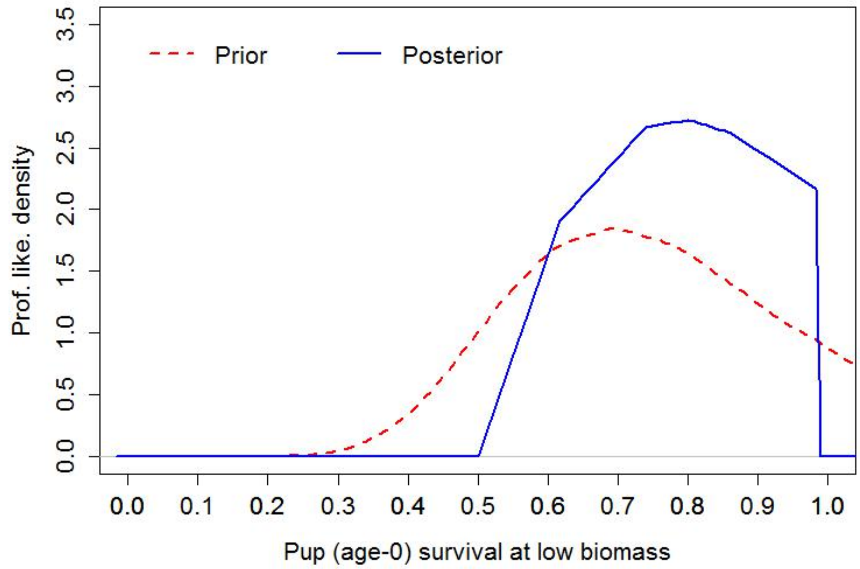


Figure 3.6.6. Estimated total (top) and fleet-specific (bottom) apical instantaneous fishing mortality rates from SSASPM for GOM blacktip shark (base run). This represents the fishing mortality level on the most vulnerable age class. The dashed line in the top panel indicates F_{MSY} (0.056)



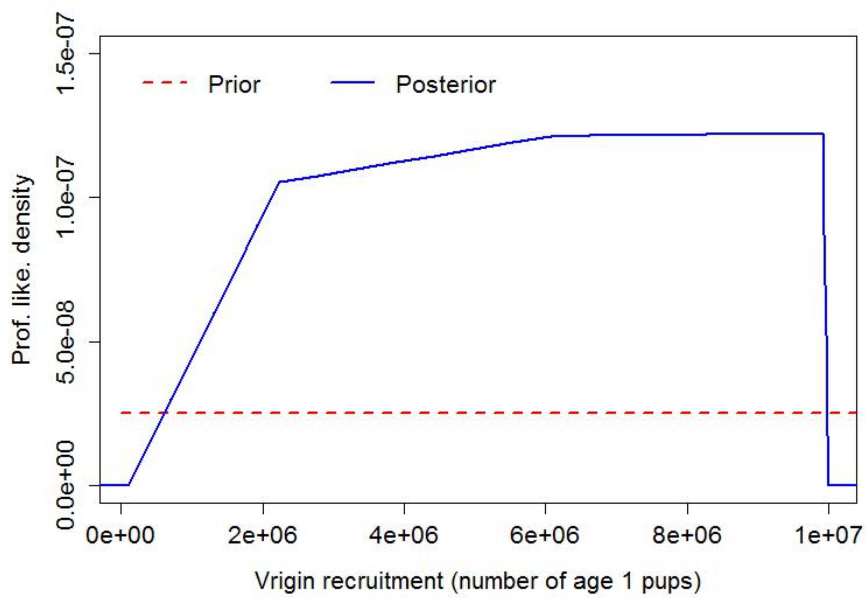


Figure 3.6.7. Profile likelihoods for pup survival and virgin recruitment from SSASPM for GOM blacktip shark (base run).

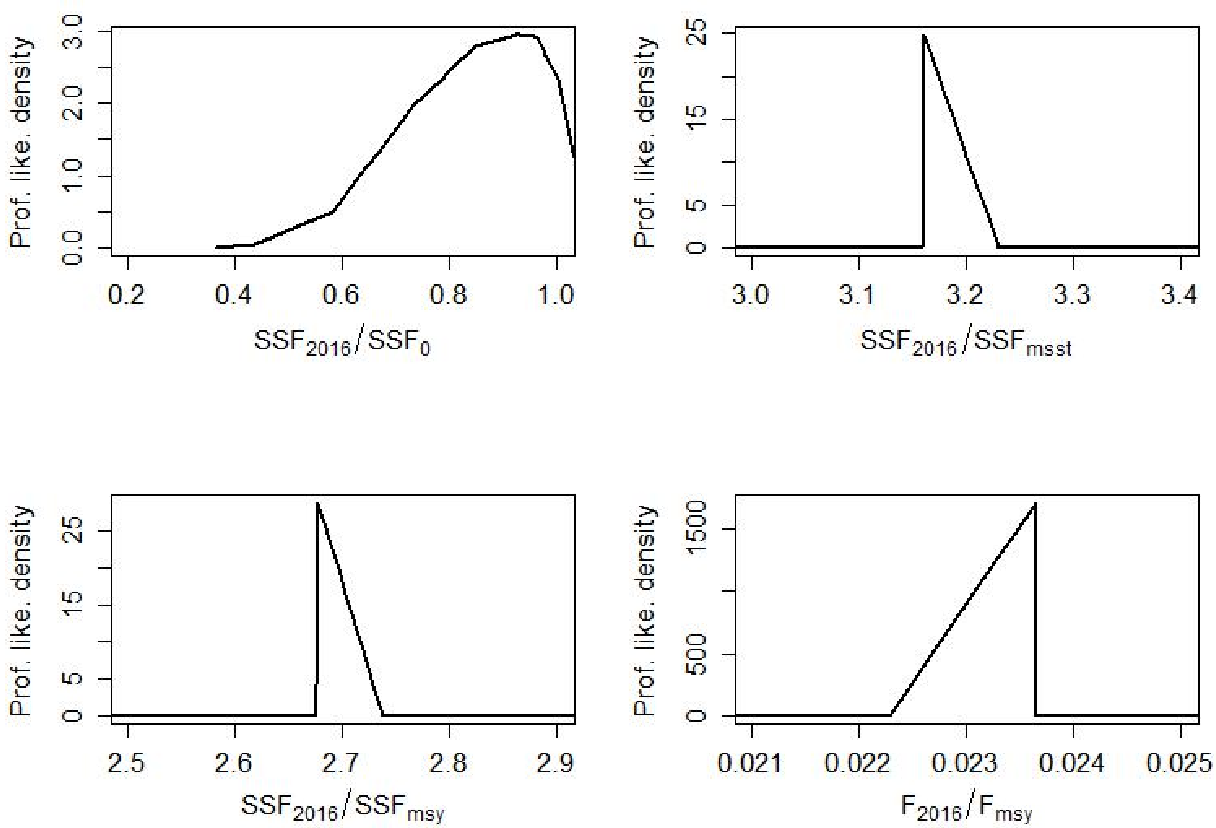


Figure 3.6.8. Estimated posterior distributions for stock status relative to management benchmarks from SSASPM for GOM blacktip shark (base run).

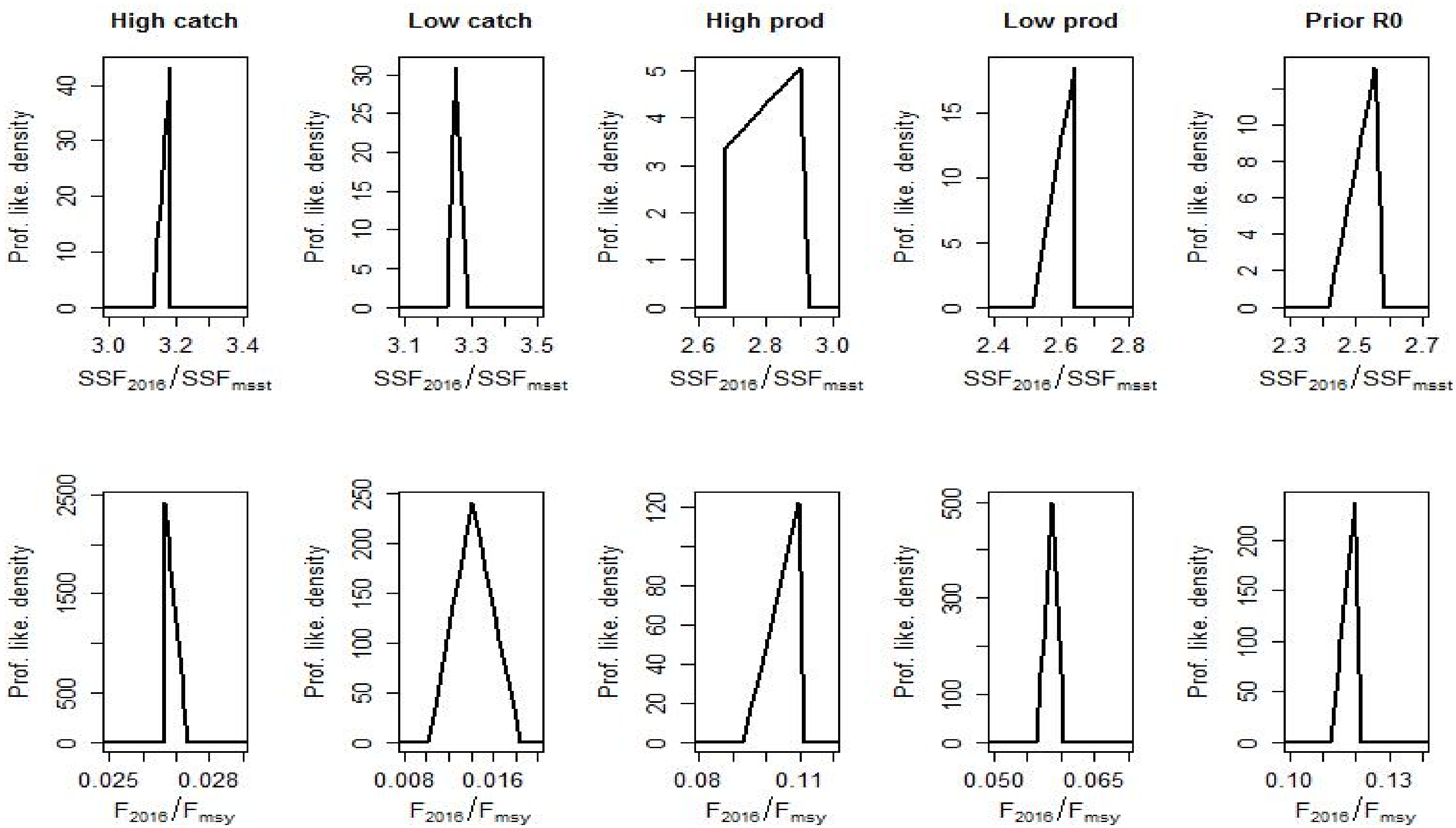


Figure 3.6.9. Estimated posterior distributions for stock status relative to management benchmarks (top panels: SSF_{2016}/SSF_{MSST}; lower panels: F_{2016}/F_{MSY}) from SSASPM for GOM blacktip shark for five additional scenarios reflective of plausible states of nature (High catch, Low catch, High Productivity, Low Productivity, and Prior for R_0; see section 3.1.3 of this report for definitions of each scenario).

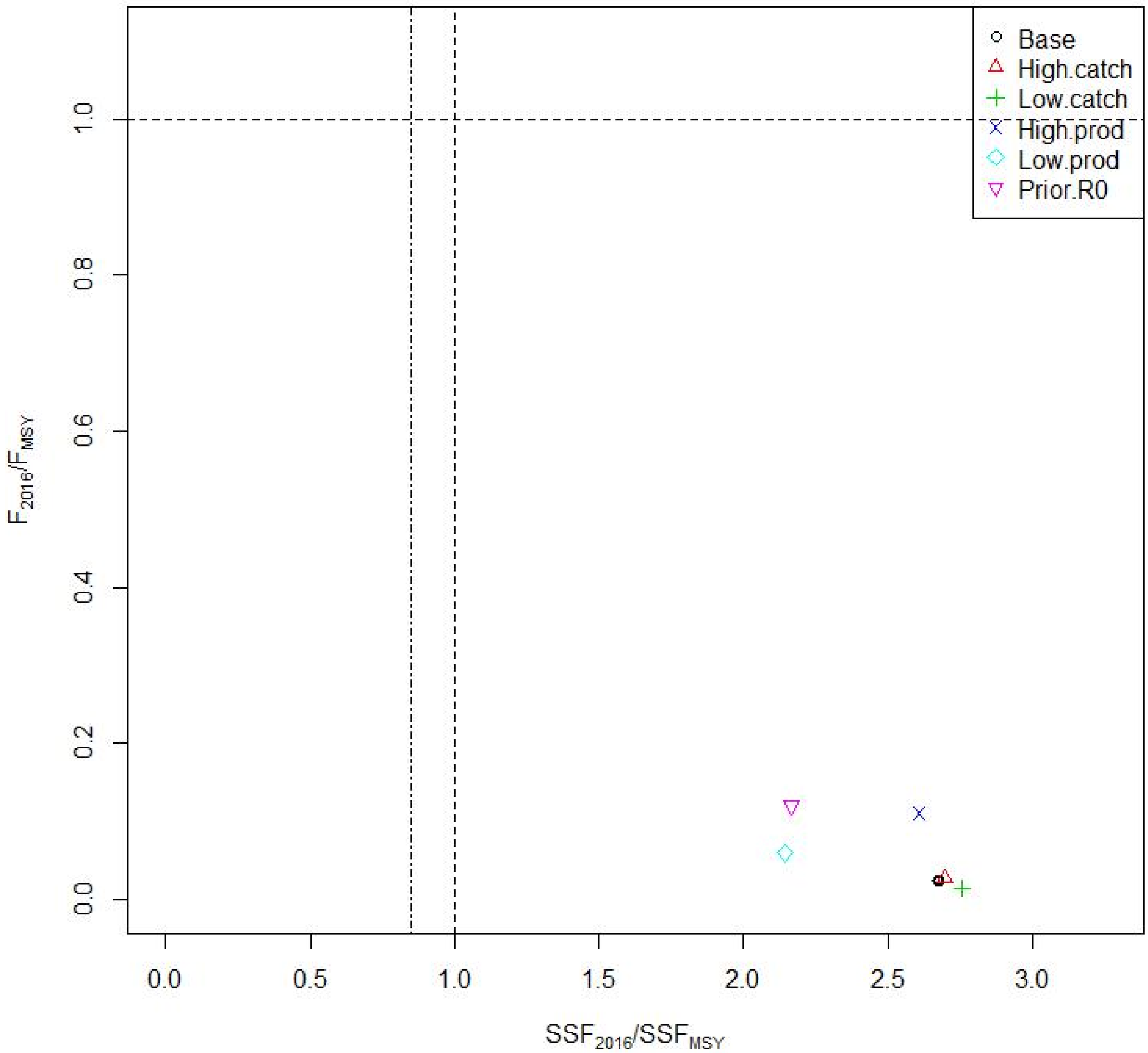


Figure 3.6.10. A phase plot summarizing stock status of blacktip sharks in the terminal year (2016) from SSASPM for GOM blacktip shark for the base and five additional scenarios reflective of plausible states of nature (Base, High catch, Low catch, High Productivity, Low Productivity, and Prior R_0; see section 3.1.3 of this report for definitions of each scenario). For clarity we only show the overfished reference point (relative to SSF_{MSST}) for the base run of this assessment update (horizontal dot-dashed line). None of the runs estimated an overfished status ($SSF_{2016} < SSF_{MSST}$, no points to the left of the dot-dashed vertical bar) or that overfishing was occurring ($F_{2016} > F_{MSY}$, no points above the horizontal black line).

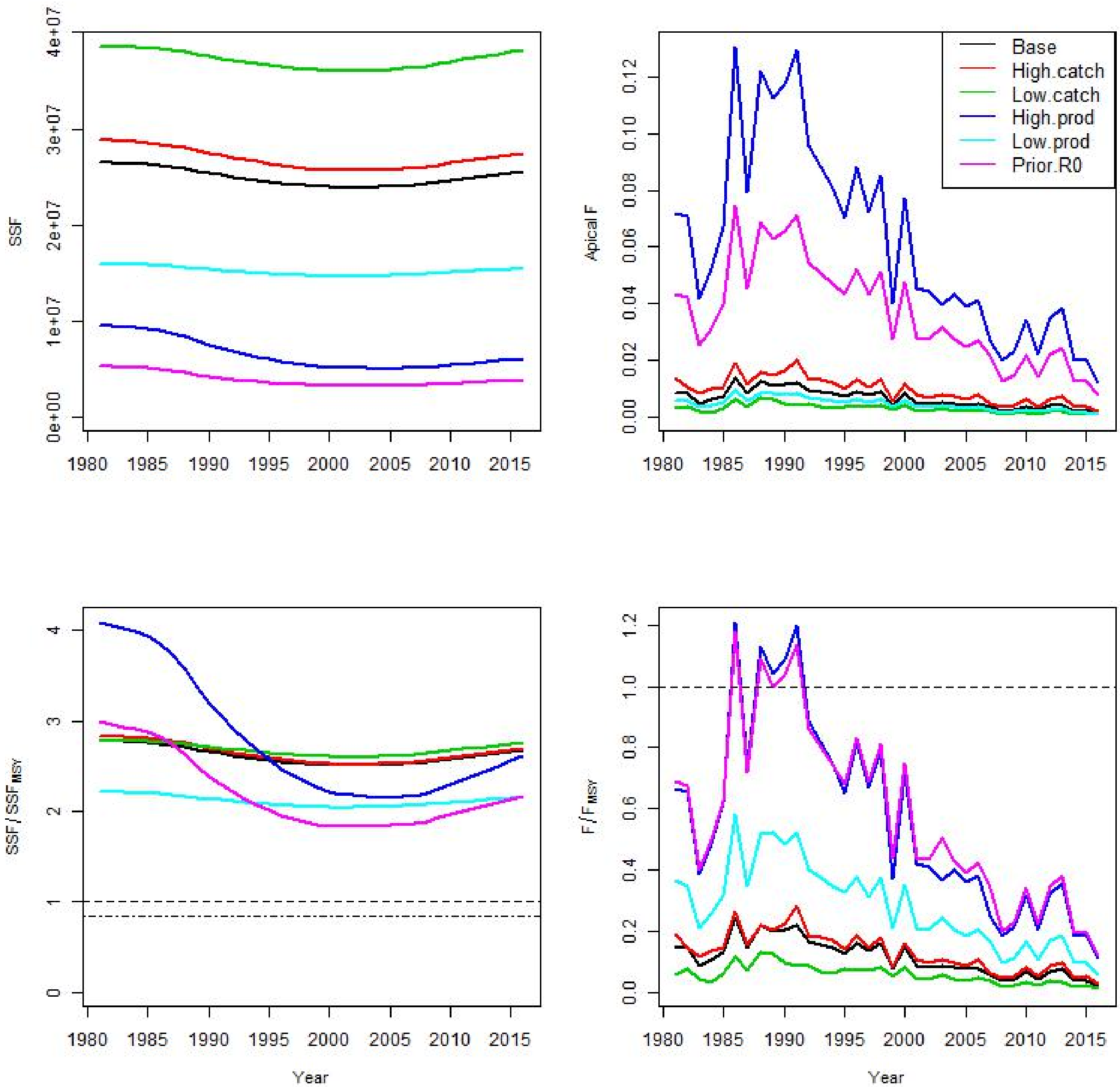
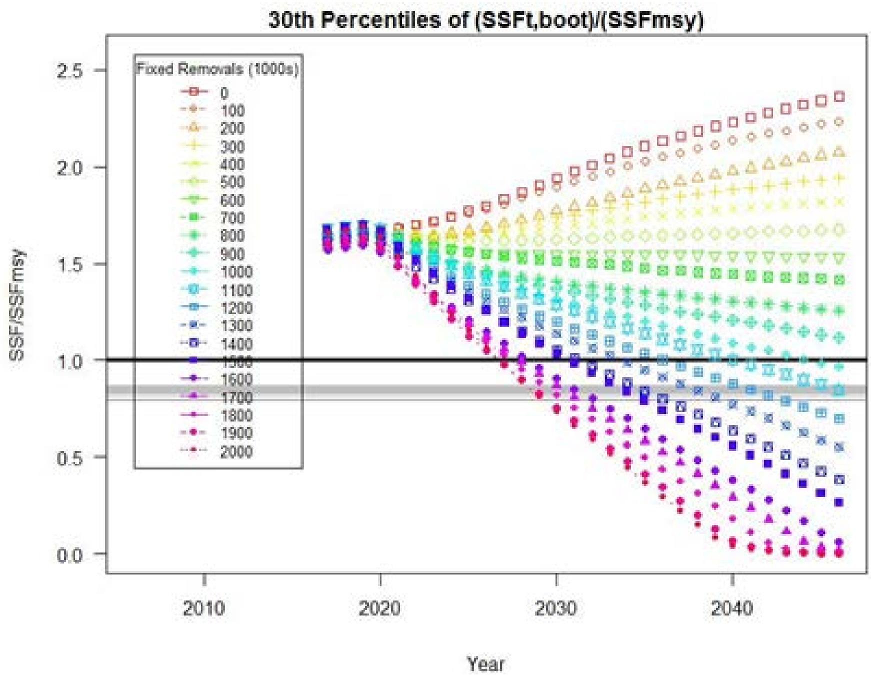


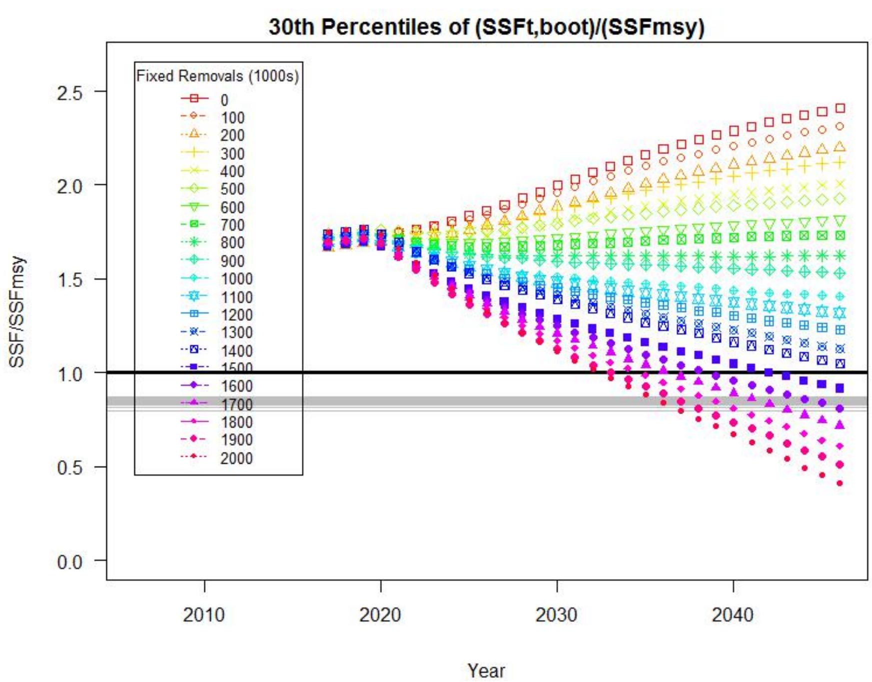
Figure 3.6.11. Estimated time series of spawning stock fecundity, apical fishing mortality rates, spawning stock fecundity in relation to *MSY* levels, and fishing mortality rates in relation to *MSY* levels from SSASPM for GOM blacktip shark for the base and five additional scenarios reflective of plausible states of nature (Base, High catch, Low catch, High Productivity, Low Productivity and Prior R_0 see section 3.1.3 of this report for definitions of each scenario). For clarity we only show the overfished reference point (relative to SSF_{MSST}) for the base run of this assessment update (horizontal dot-dashed line), with points below the line indicating the stock was estimated to be overfished ($SSF_{2016} < SSF_{MSST}$).

Figure 3.6.12. The 30th percentiles of $SSF_{t,boot}/SSF_{MSY}$ (2017 – 2046) represent the 70% probability of maintaining $SSF_{t,}$ above SSF_{MSY} from 10,000 Monte Carlo bootstrap projections for a given level of fixed removals (in 1000s) and a given year. Gray horizontal lines indicate approximate location relative to SSF_{MSST}.

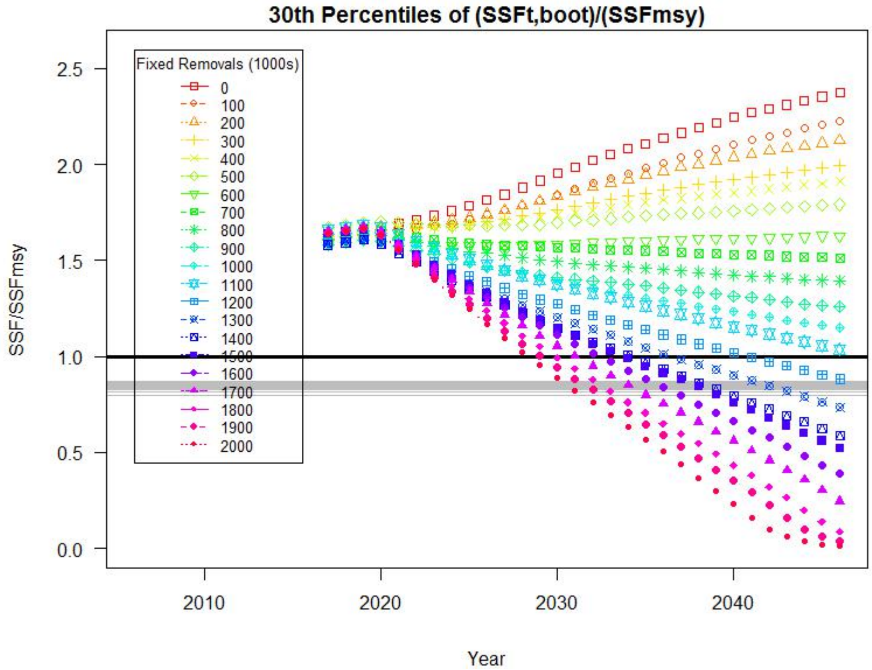
Panel A. Projection Scenario-1 (Baseline, Ranked CPUE Weighting).



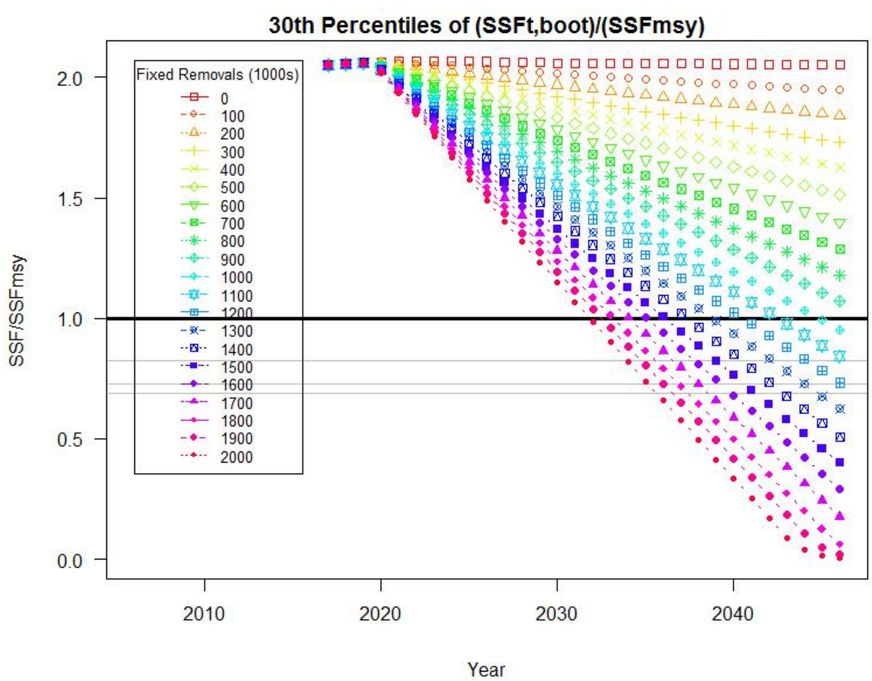
Panel B. Projection Scenario-2 (Sensitivity, Low Catch).



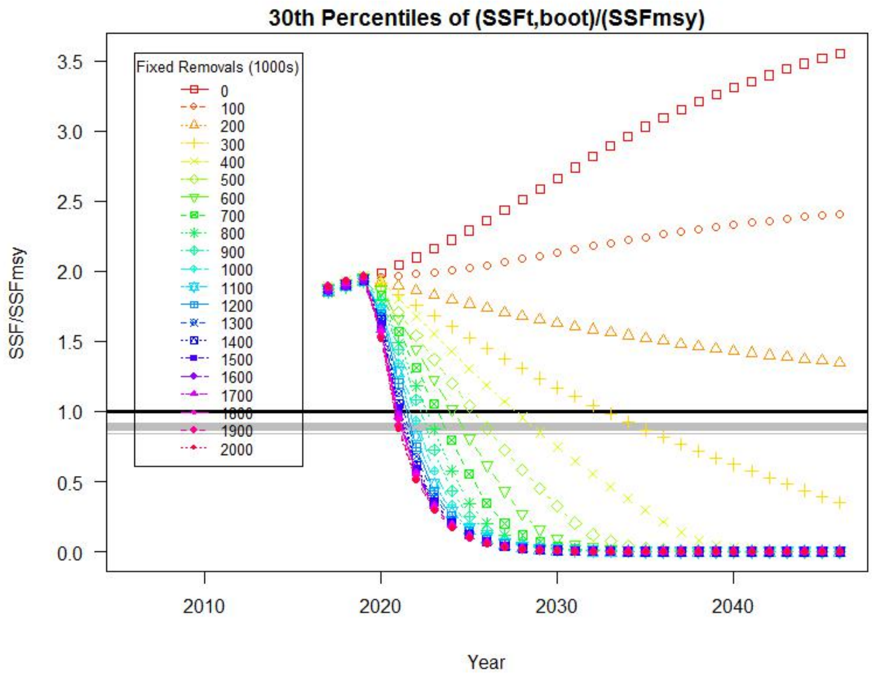
Panel C. Projection Scenario-3 (Sensitivity, High Catch).



Panel D. Projection Scenario-4 (Sensitivity, Low Productivity).



Panel E. Projection Scenario-5 (Sensitivity, High Productivity).



Panel F. Projection Scenario-6 (Sensitivity, Lognormal Prior R_0).

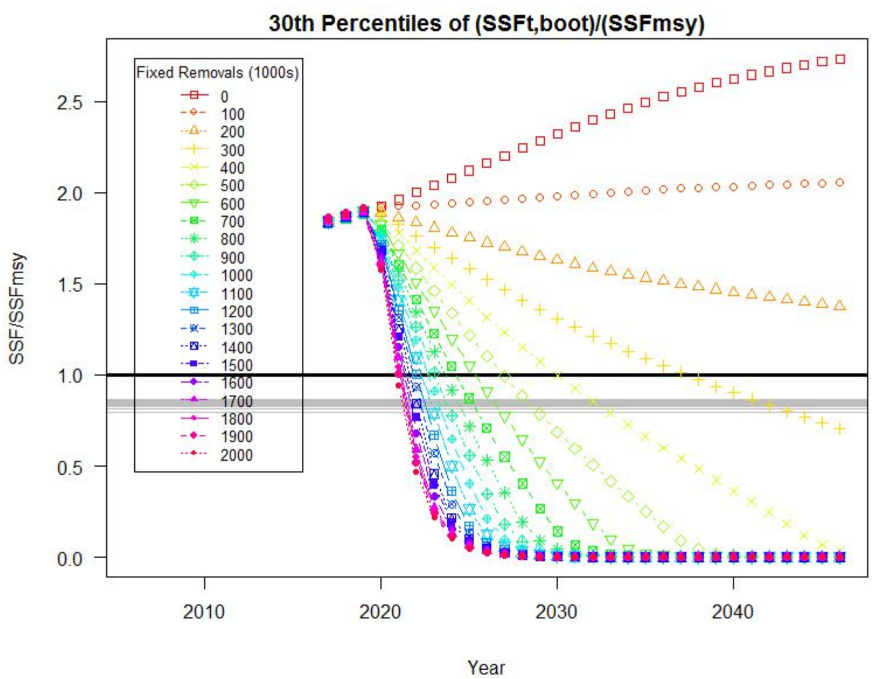
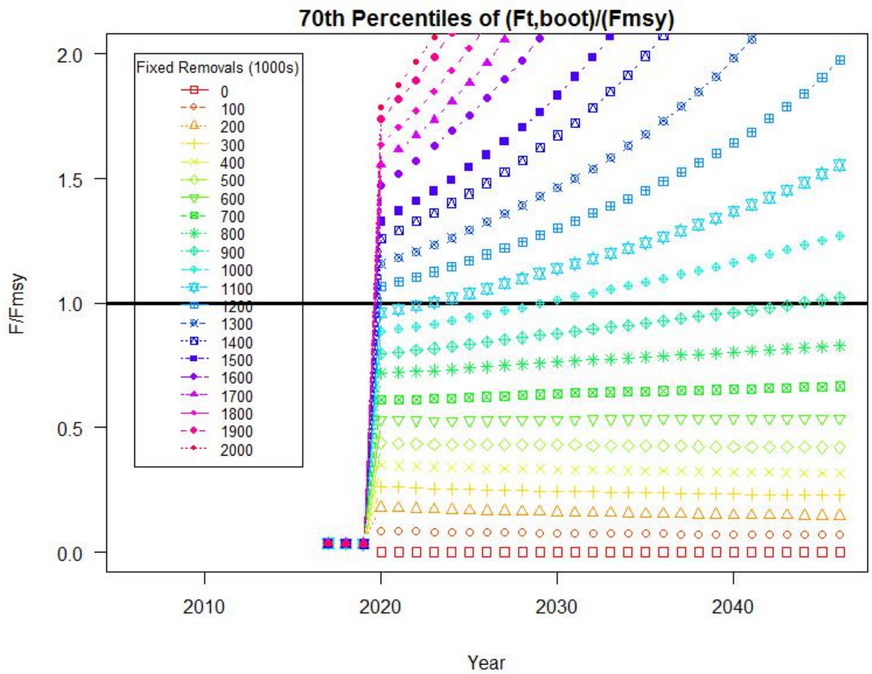
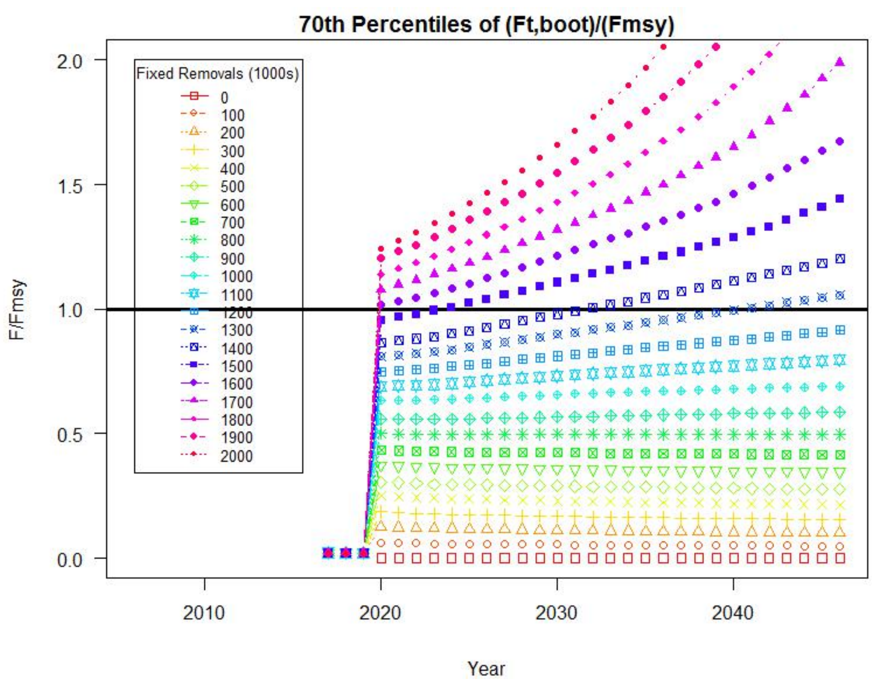


Figure 3.6.13. The 70th percentiles of $F_{t,boot}/F_{MSY}$ (2017 – 2046) represent the 30% probability of $F_{t,boot}$ exceeding F_{MSY} for a given level of fixed removals (in 1000s) and a given year.

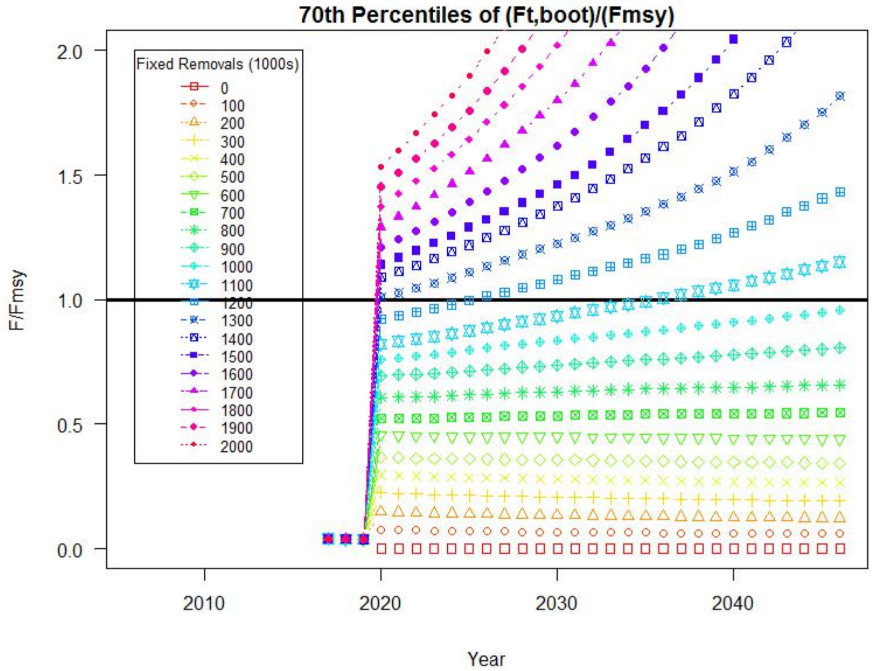
Panel A. Projection Scenario-1 (Baseline, Ranked CPUE Weighting).



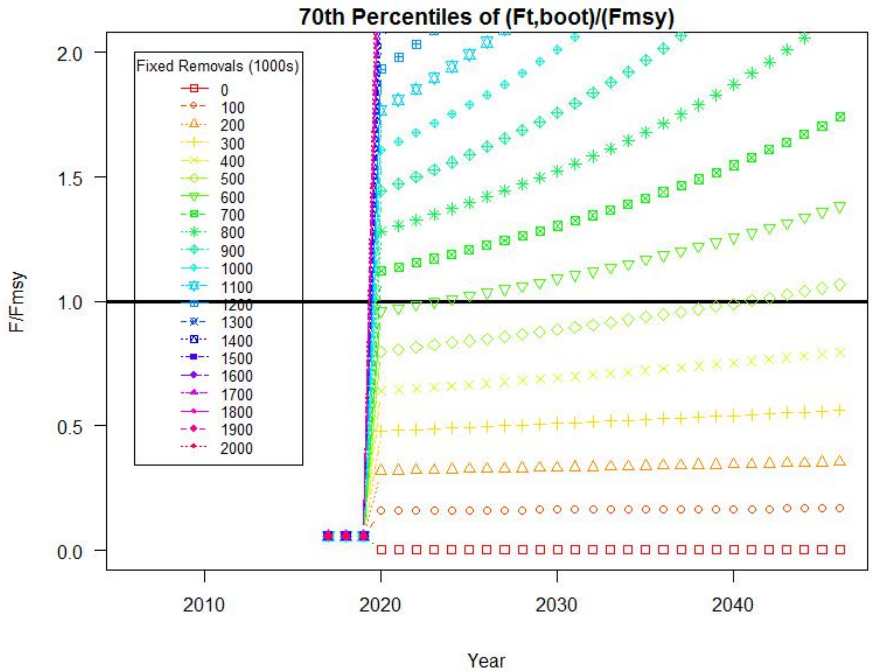
Panel B. Projection Scenario-2 (Sensitivity, Low Catch).



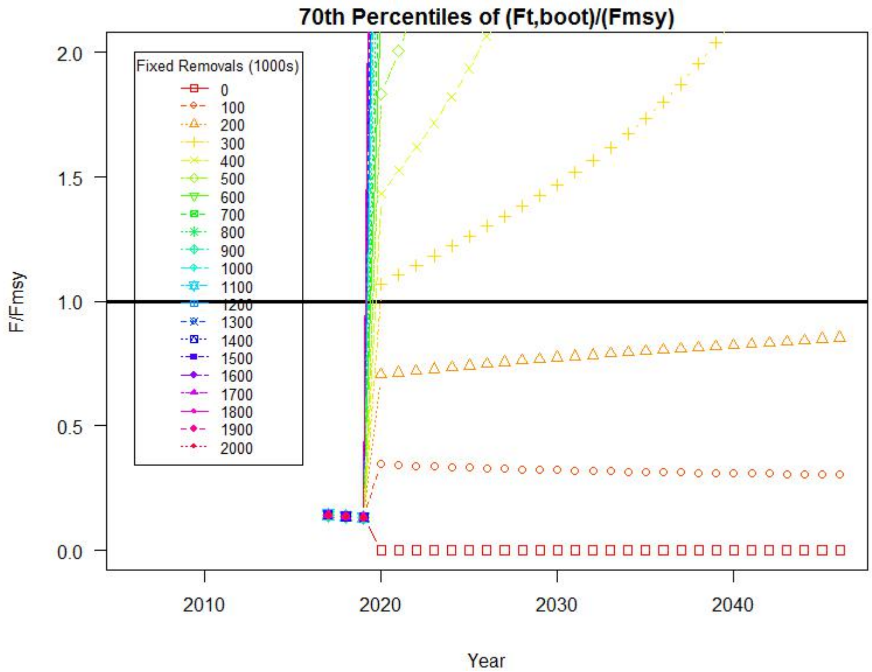
Panel C. Projection Scenario-3 (Sensitivity, High Catch).



Panel D. Projection Scenario-4 (Sensitivity, Low Productivity).



Panel E. Projection Scenario-5 (Sensitivity, High Productivity).



Panel F. Projection Scenario-6 (Sensitivity, Lognormal Prior R_0).

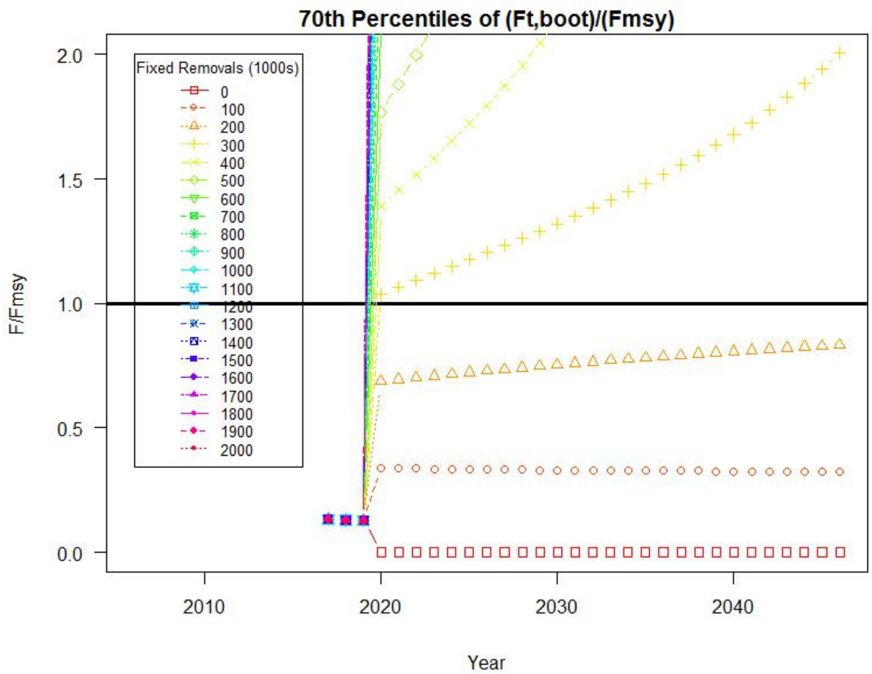
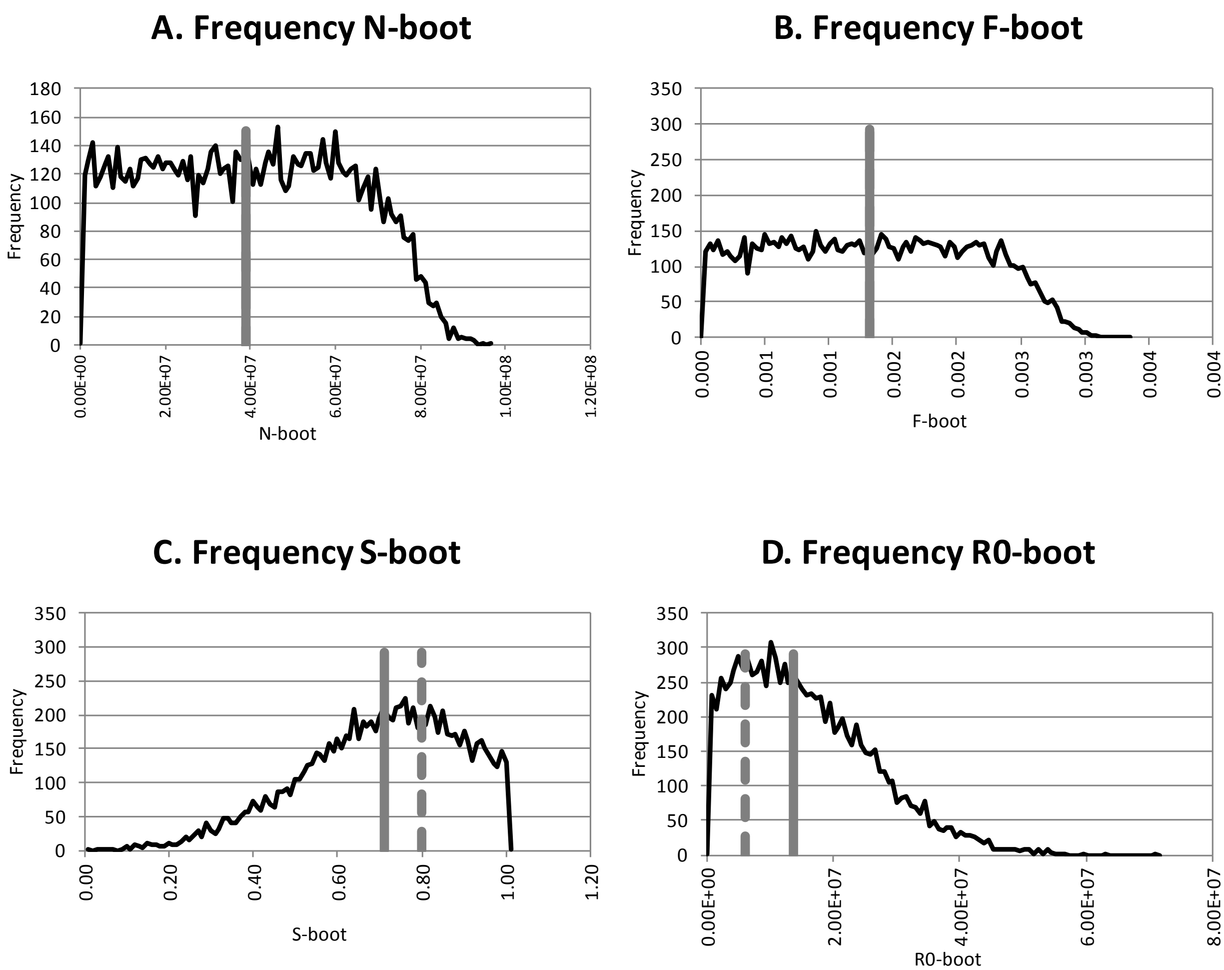
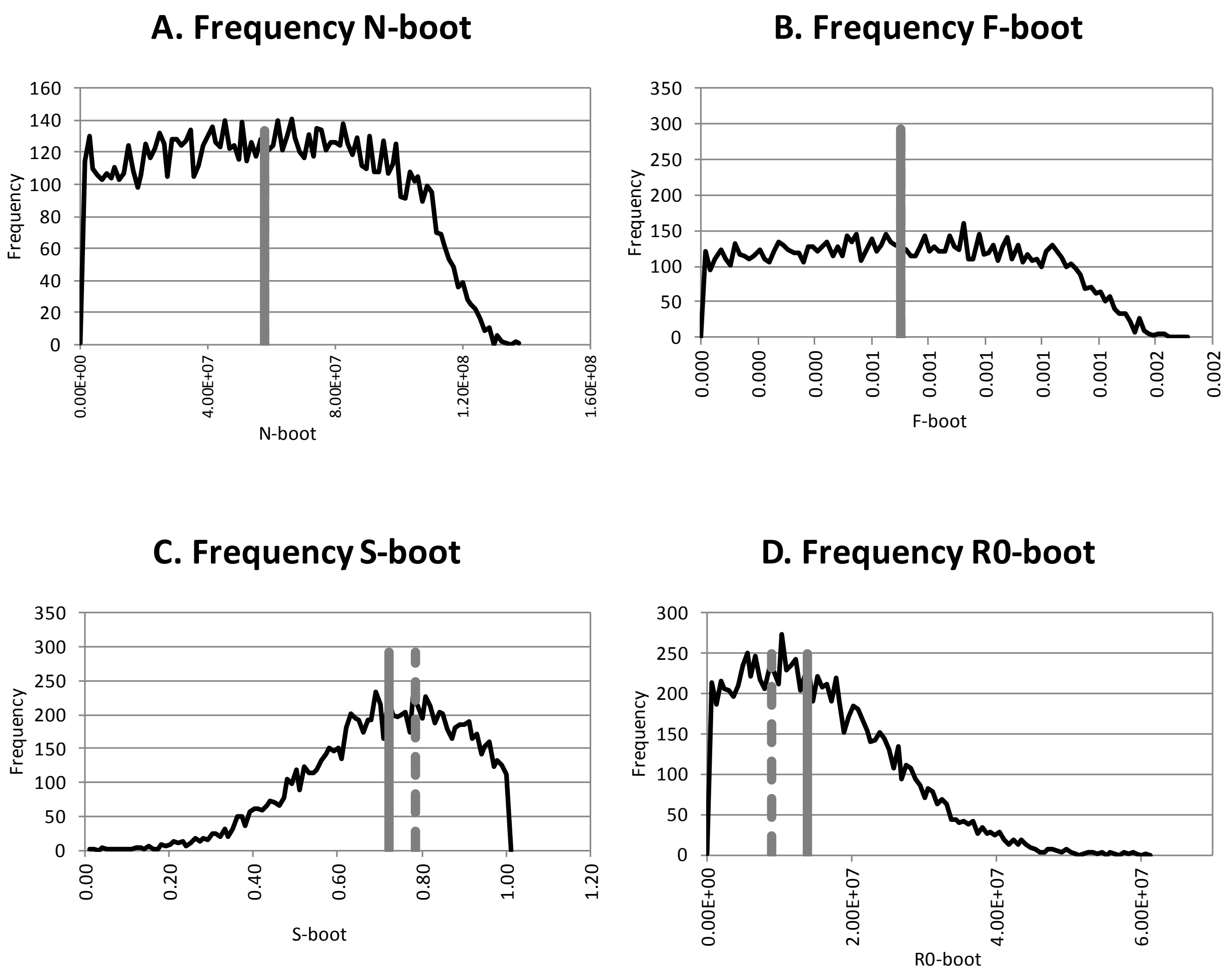


Figure 3.6.14. Frequency distributions from 10,000 Monte Carlo simulations (random draws obtained for projections) from a bivariate normal distribution for initial numbers (N_{2016}^{boot}) and fishing mortality (F_{2016}^{boot}) and a second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2016}^{boot}$) and equilibrium recruitment ($R_0{}_{2016}^{boot}$); median of the bootstrapped parameter value distribution (solid line); and the original SSASPM parameter value estimate (dashed line, unless overlapping solid line).

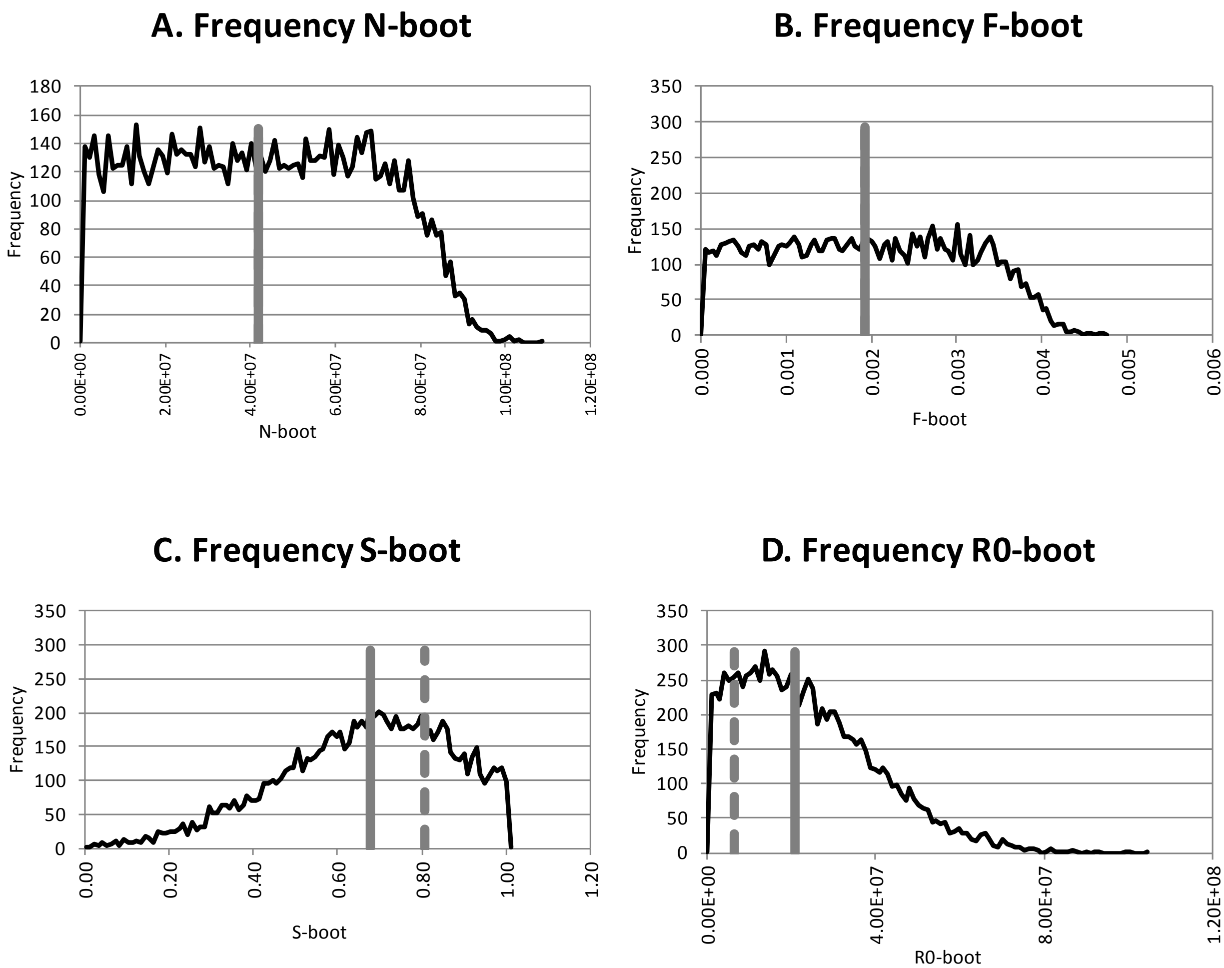
Panel A. Projection Scenario-1 (Baseline, Ranked CPUE Weighting).



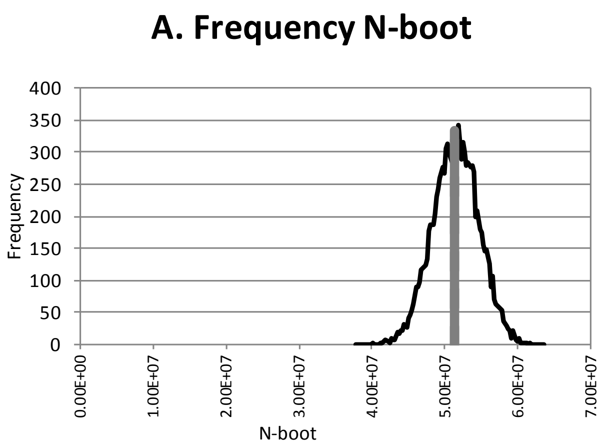
Panel B. Projection Scenario-2 (Sensitivity, Low Catch).

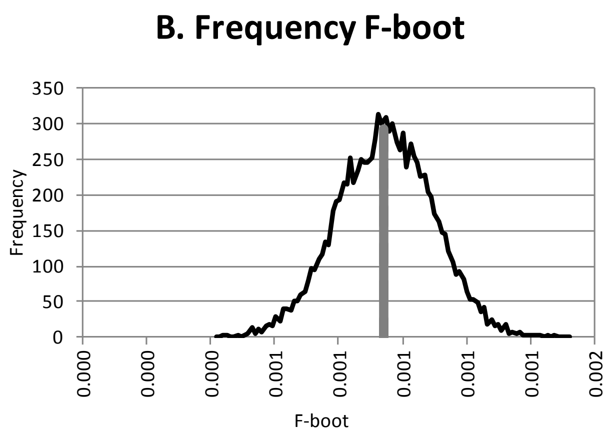


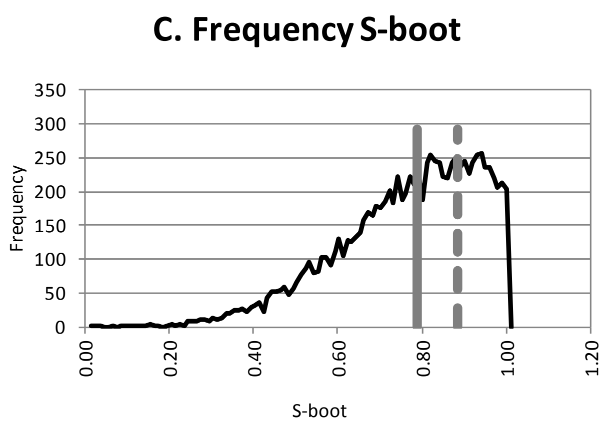
Panel C. Projection Scenario-3 (Sensitivity, High Catch).

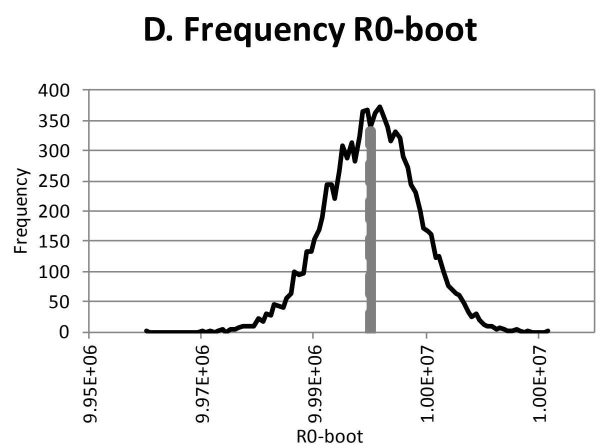


Panel D. Projection Scenario-4 (Sensitivity, Low Productivity).

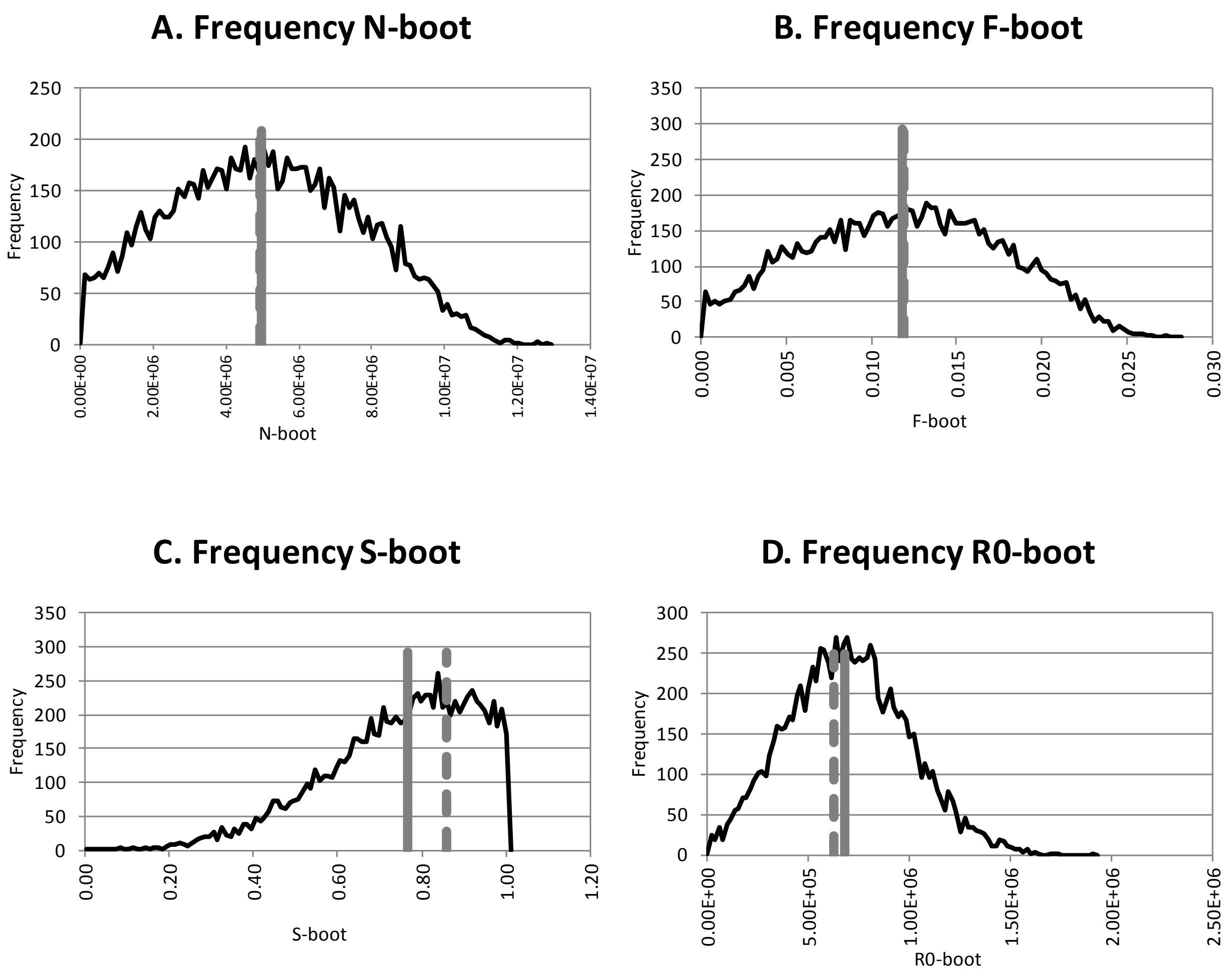








Panel E. Projection Scenario-5 (Sensitivity, High Productivity).



Panel F. Projection Scenario-6 (Sensitivity, Lognormal Prior R_0).

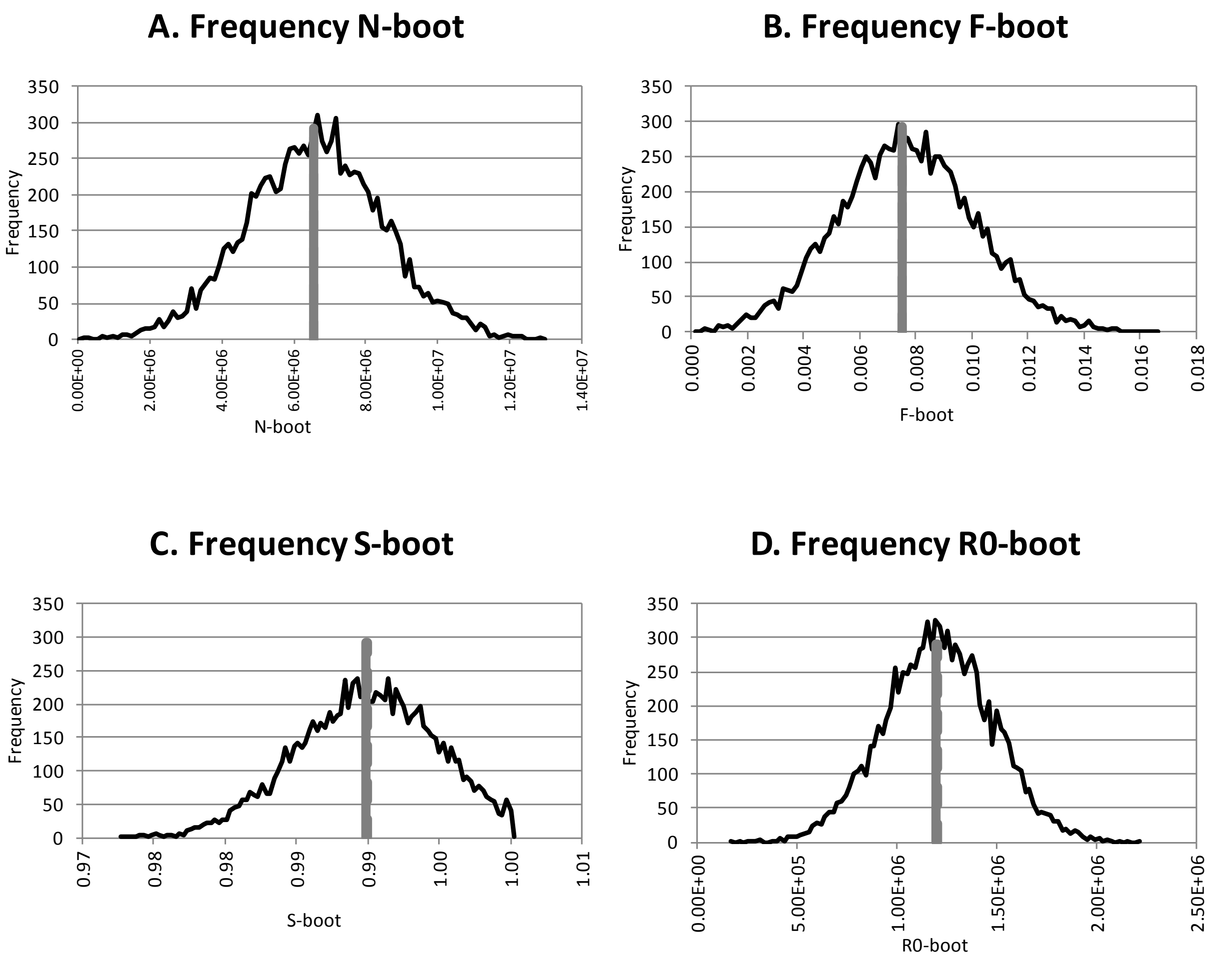
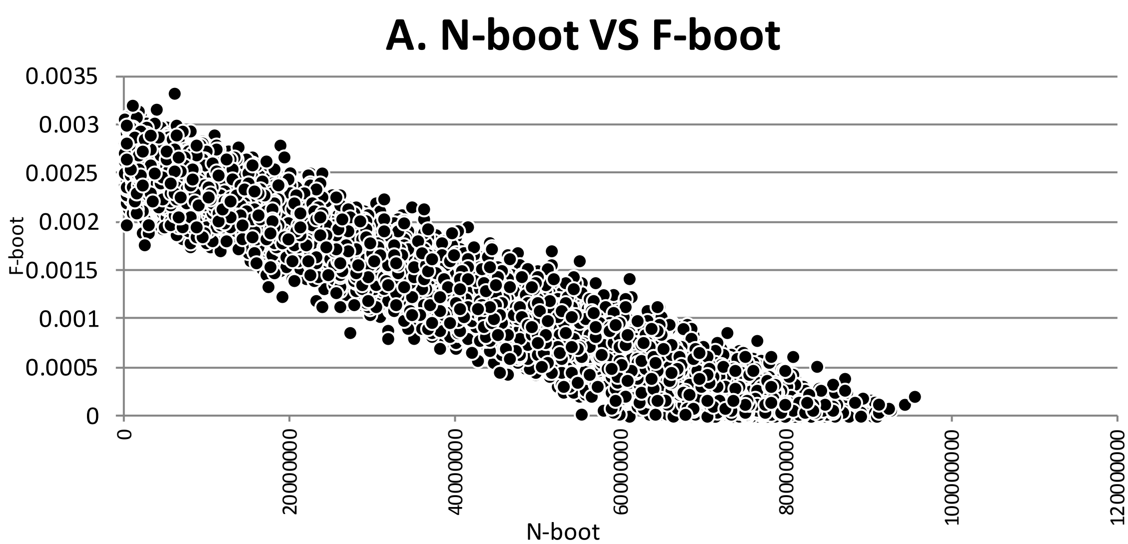
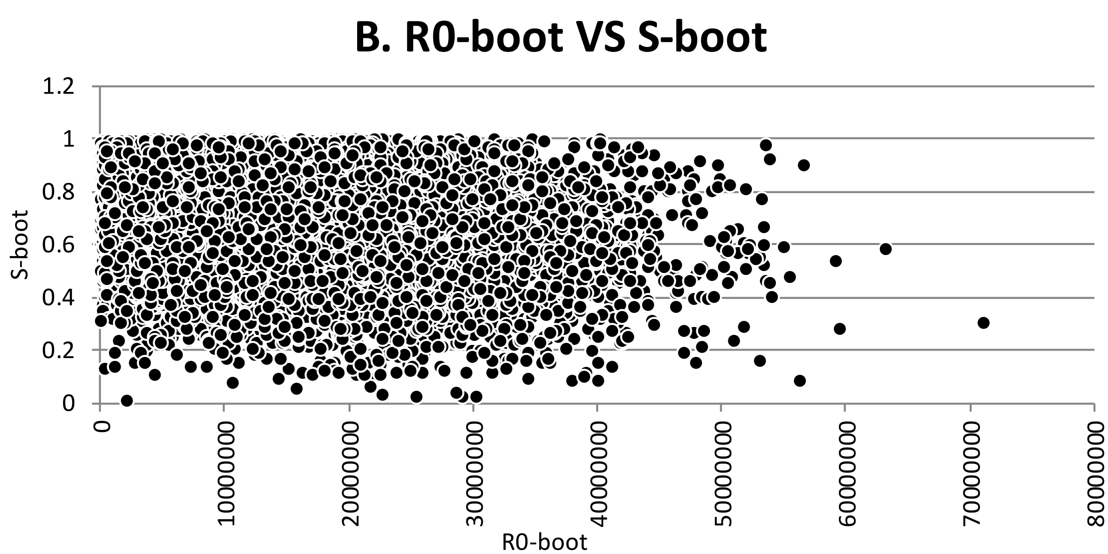


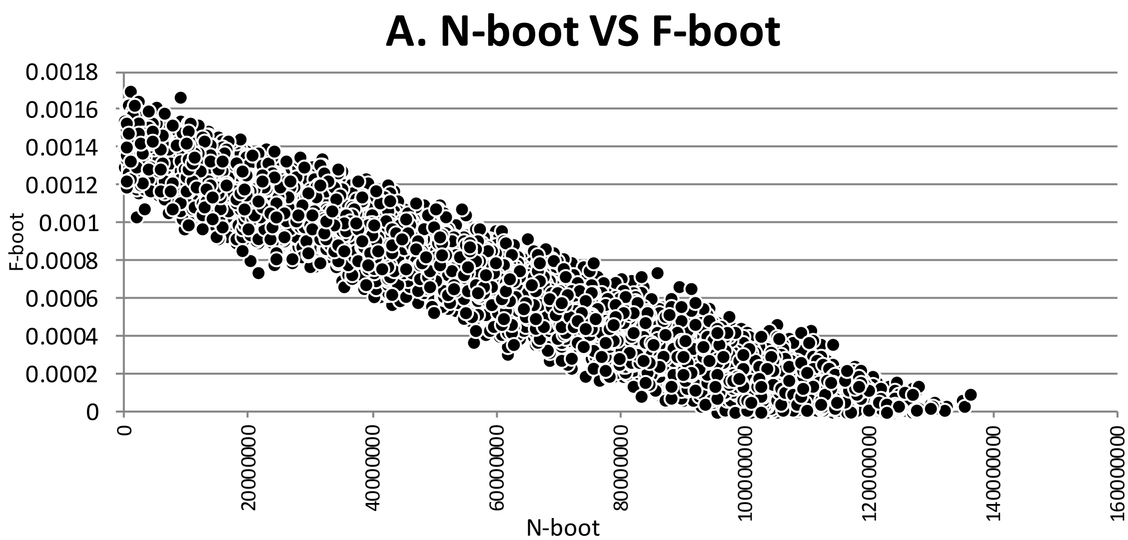
Figure 3.6.17. Correlations from 10,000 Monte Carlo simulations (random draws obtained for projections) from a bivariate normal distribution for initial numbers (N_{2016}^{boot}) and fishing mortality (F_{2016}^{boot}) and a second bivariate normal distribution for pup survival at low biomass ($e^{-M_0}{}_{2016}^{boot}$) and equilibrium recruitment ($R_0{}_{2016}^{boot}$).

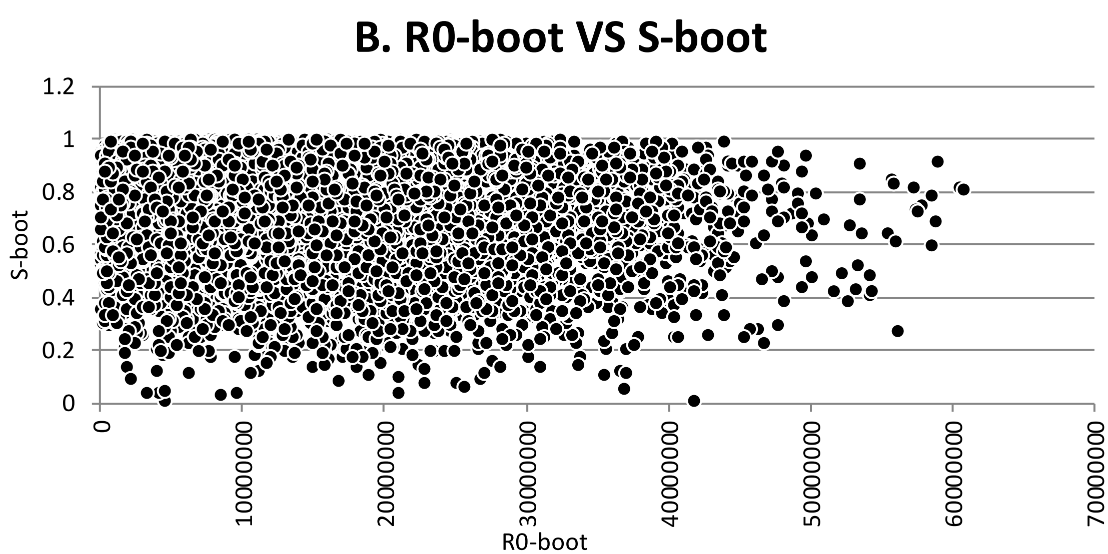
Panel A. Projection Scenario-1 (Baseline, Ranked CPUE Weighting).



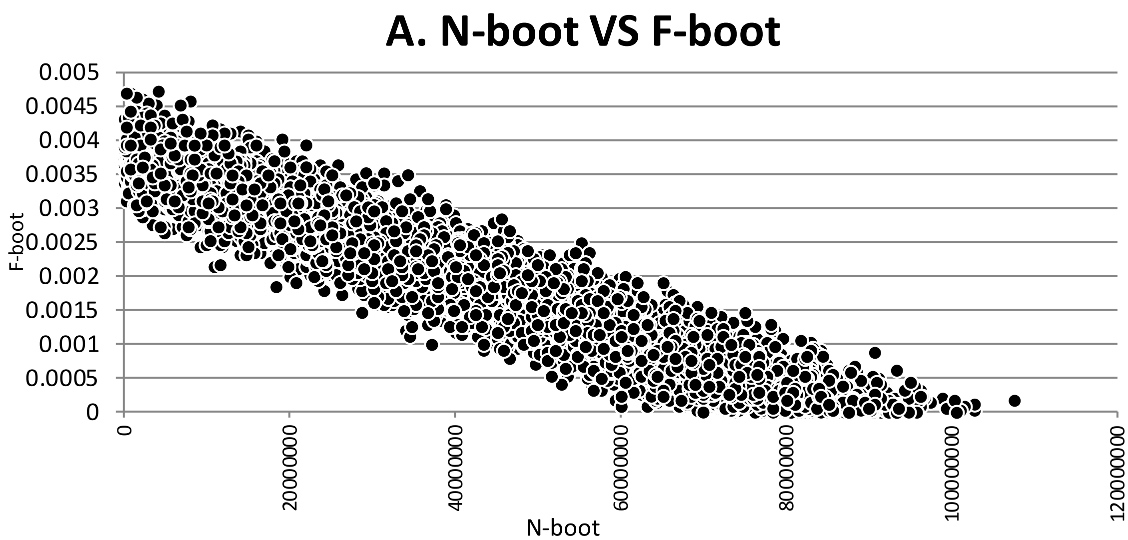


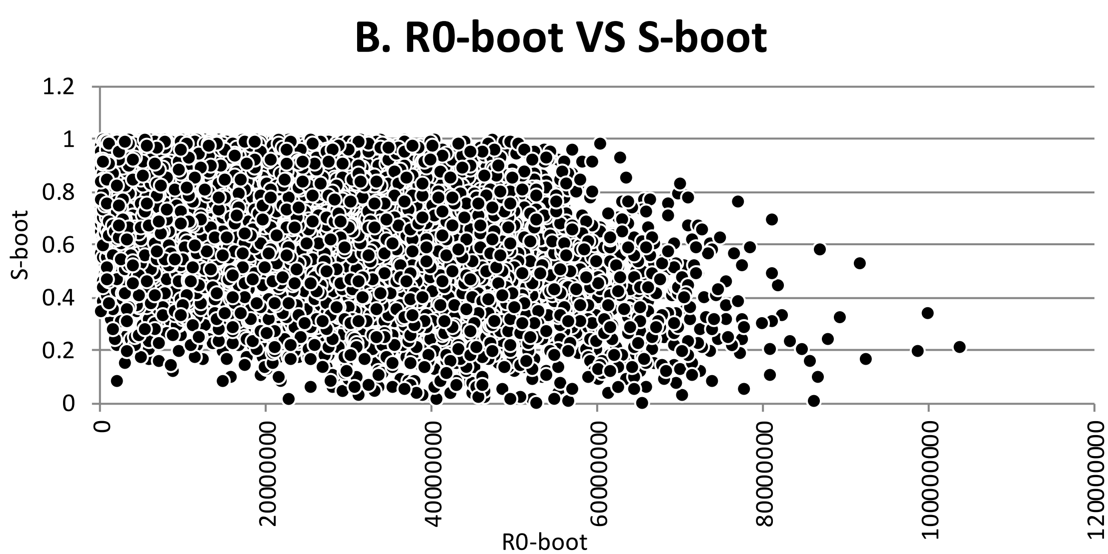
Panel B. Projection Scenario-2 (Sensitivity, Low Catch).



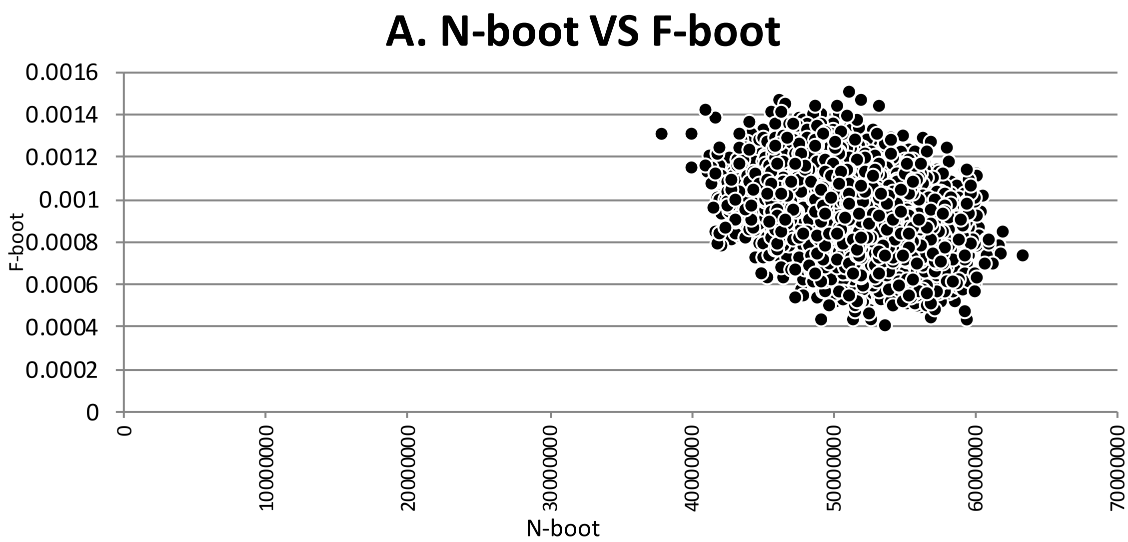


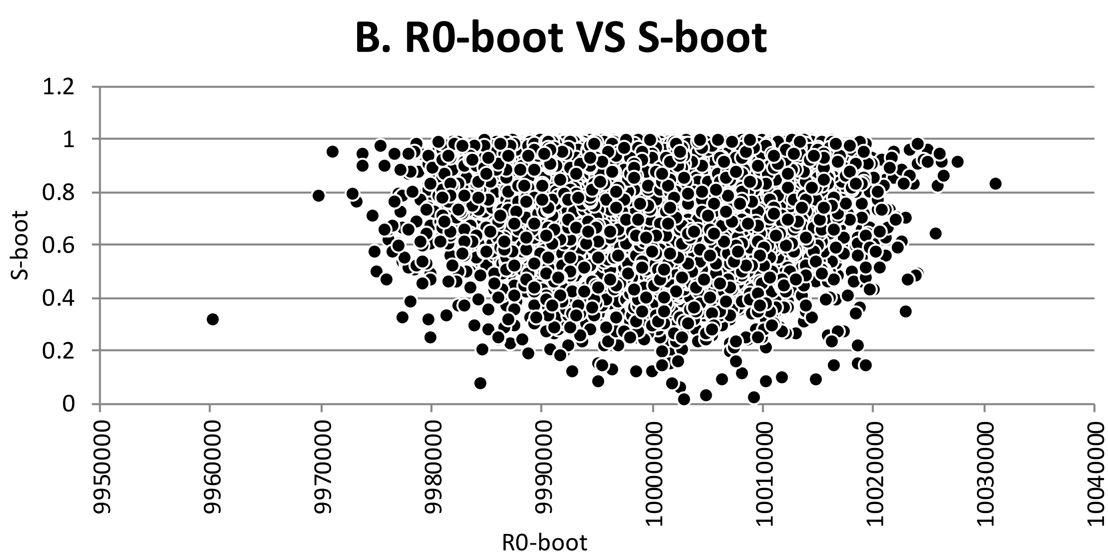
Panel C. Projection Scenario-3 (Sensitivity, High Catch).



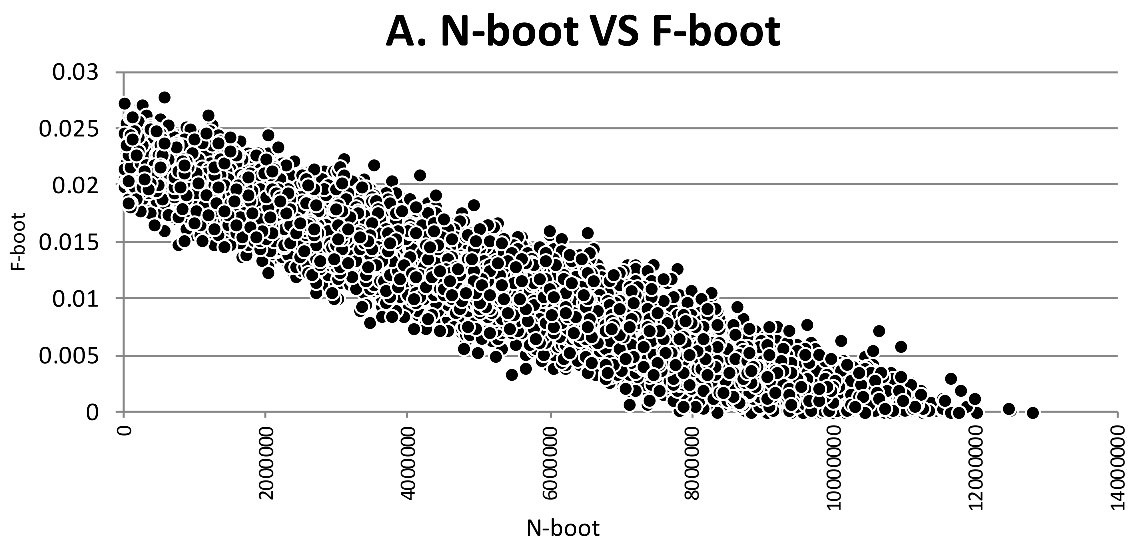


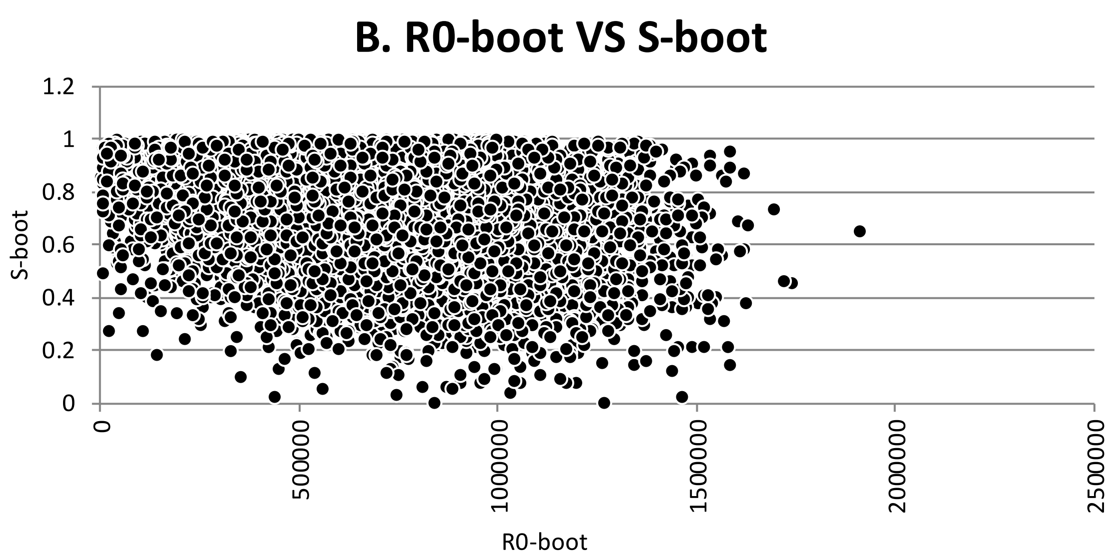
Panel D. Projection Scenario-4 (Sensitivity, Low Productivity).



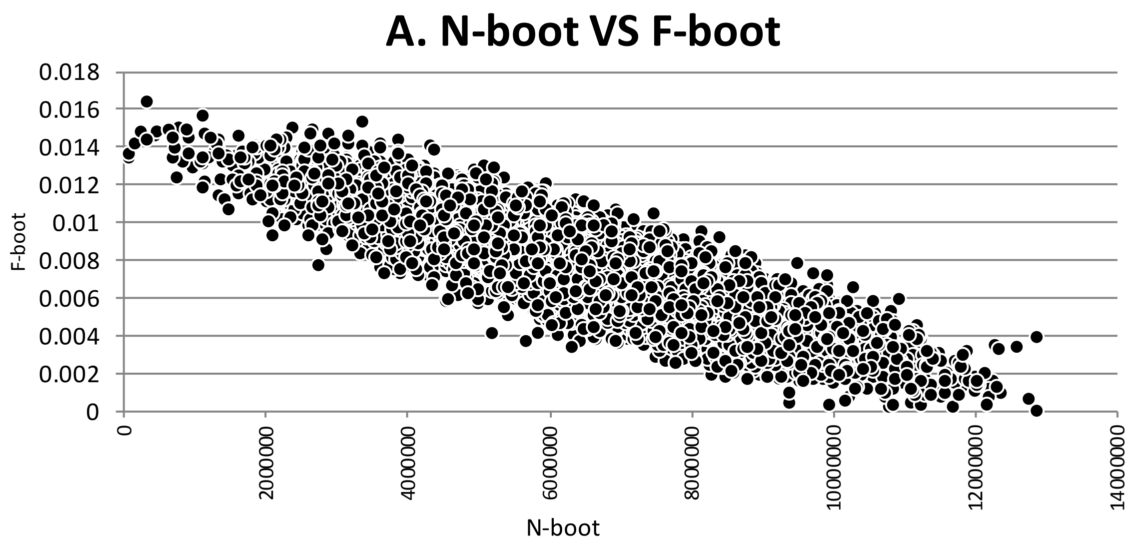


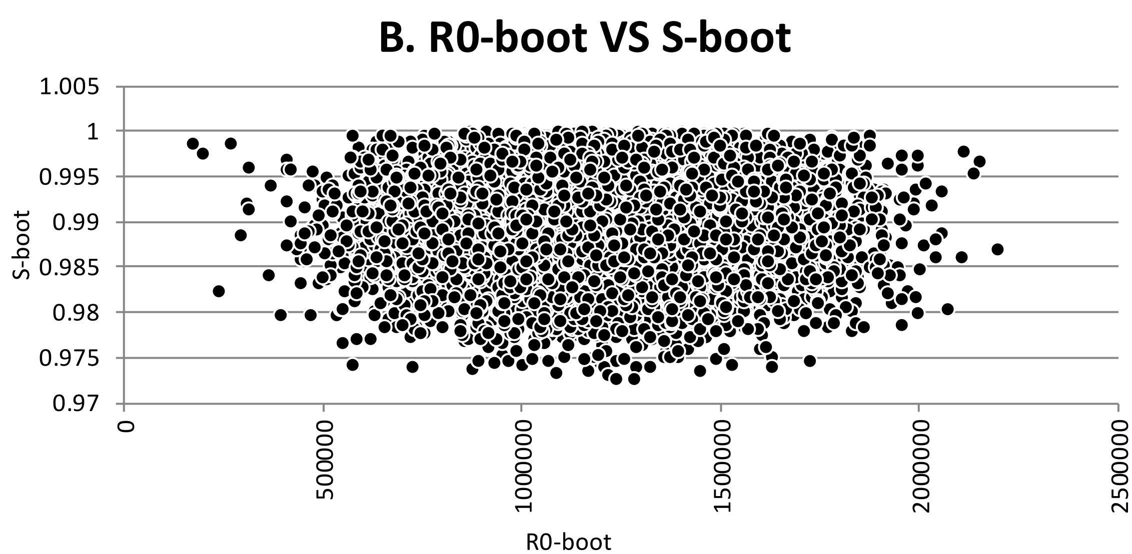
Panel E. Projection Scenario-5 (Sensitivity, High Productivity).





Panel F. Projection Scenario-6 (Sensitivity, Lognormal Prior R_0).





3.7. APPENDIX

The projection approach used here was developed based on discussions held during a workshop to investigate P* statistical analysis techniques for use in age-structured stock assessments of domestic U.S. shark stocks managed under the Highly Migratory Species (HMS) Fisheries Management Plan (FMP) (P* workshop, NOAA/NMFS, Panama City Laboratory, June 11-13, 2013). During the workshop, several shortcuts to published probabilistic P* approaches being implemented (or evaluated) within the framework of the Southeast Data, Assessment, and Review (SEDAR) process were discussed (e.g., Prager and Shertzer 2010, Shertzer et al. 2010). Preliminary analyses with empirical data from comparative model runs indicated that results from some of the shortcuts were comparable to those obtained from published probabilistic P* approaches. However, when the technical merits of each P* shortcut were discussed within the context of application to an existing HMS shark dataset and age-structured stock assessment model (SSASPM, NMFS 2012a), it became apparent that the distribution of F_{limit} (F_{MSY} for HMS domestic shark stocks) may be poorly characterized in the existing HMS domestic shark age structured stock assessment model (SSASPM, NMFS 2012a). Consequently, within the context of application to the existing HMS age-structured stock assessment model (SSASPM, e.g., NMFS 2012a), typical P* approaches may not adequately characterize uncertainty in the distribution of F_{limit}. In contrast, alternative probabilistic projection approaches were also discussed at the workshop, including short-term (~5 to 10 year) projections at fixed harvest levels similar to those used by the International Commission for the Conservation of Atlantic Tunas (ICCAT) Standing Committee on Research and Statistics (SCRS) in their Kobe II tables (e.g., SCRS BFT Stock Assessment Meeting Report 2012; their Tables 16-18, and their figures 36-38). It was noted at the workshop, that probabilistic projections at fixed harvest levels did not require estimates of uncertainty for F_{MSY} and accommodated multiple year lags at fixed harvest levels. It was also noted at the workshop that probabilistic projections at fixed harvest levels could be utilized to provide a buffer based on a pre-specified acceptable probability of overfishing (e.g., P* = 0.3; <0.5). Consequently, it was suggested at the workshop that within the context of application to the existing HMS domestic shark age structured stock assessment model (SSASPM, e.g., NMFS 2012a), probabilistic projections at fixed harvest levels may provide a proxy to a typical P* approach. However, conclusions regarding alternative probabilistic projection approaches should be interpreted cautiously because they were not verified during the P* workshop with empirical data or comparative model runs.

Following the P* workshop, a short-term (~5 to 10 year) probabilistic projection approach at fixed harvest levels was implemented in R statistical software. Projection methods were based on those developed during SEDAR 21 for an age-structured catch-free model (ASCFM) applied to HMS dusky sharks (NMFS 2011), and during SEDAR 29 for a SSASPM model applied to HMS blacktip sharks (NMFS 2012a, 2012b), except that the following modifications were made during SEDAR 34 (NMFS 2013a, 2013b) to the existing HMS domestic shark projection methodology based on recommendations made during the P* workshop.

During the P* workshop, it was noted that the existing HMS domestic shark projection methodology (e.g., NMFS 2012b) may not adequately characterize recruitment variability in HMS domestic shark stocks. For example, the 30th and 70th percentiles appeared to narrow over time (e.g., NMFS 2012b; their Figures 2.1-2.7), a result consistent with projections converging towards equilibrium in the absence of recruitment variability. As a result, the following changes to the existing HMS domestic shark projection methodology (e.g., NMFS 2012b) were implemented during SEDAR 34 (NMFS 2013a, 2013b), based on recommendations made at the P* workshop to more adequately characterize recruitment variability: 1) Remove pup survival at low biomass (e^{-M_0}) from the existing multivariate normal distribution with F and N; 2) Model F and N together in a new bivariate normal distribution; 3) Add uncertainty in equilibrium recruitment, R_0, to the projections; 4) Model uncertainty in R_0 and e^{-M_0} together in a new, but separate, bivariate normal distribution. The same approach was used here except that uncertainty in F and R_0 was removed from the projections in in order to be consistent with the projection methodology previously implemented in SEDAR 29 for this stock (NMFS 2012a, 2012b). Large uncertainty in R_0 in some model configurations also resulted in an implausibly large range of uncertainty in projected spawning biomass in some preliminary projections. . Uncertainty in F was not assumed for fixed removals scenarios.

Two more changes to the projection methodology were implemented during SEDAR 34 (NMFS 2013a, 2013b) and also adopted here. First, during preliminary SEDAR 34 projection runs, it was noted that very high fixed levels of total annual removals due to fishing resulted in Pr($SSF_t > SSF_{MSY}$) = 70%, and Pr($F_t > F_{MSY}$) = 30% from 10,000 Monte Carlo bootstrap projections for short-term projections (~5 to 10 years). However, a review of diagnostic output plots indicated that for many of the same runs there was a high probability (e.g., 70%) that projected stock size would decline (Pr($SSF_t > SSF_{MSY}$) < 30%) over a longer projection period (e.g., 30 years). In contrast, during preliminary SEDAR 34 projection runs, more moderate fixed levels of total annual removals due to fishing resulted in Pr($SSF_t > SSF_{MSY}$) = 70%, and Pr($F_t > F_{MSY}$) = 30% from 10,000 Monte Carlo bootstrap projections for longer term projections (30 years). The more moderate fixed levels of total annual removals due to fishing resulted in relatively more stable population trajectories over time (30 years). Consequently, results were presented in SEDAR 34 (NMFS 2013a, 2013b) for longer-term (30 years) rather than short-term (~5 to 10 years) probabilistic projections, and summarized for the last ten years of the projection scenarios. The same approach was implemented here and was consistent with the projection methodology previously implemented in SEDAR 29 for this stock (NMFS 2012a, 2012b).

Second, results were presented in SEDAR 34 (NMFS 2013a, 2013b) for projections at a given fixed level of total annual removals due to fishing in numbers (1000s) rather than in weight. The same approach was implemented here.

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