SEDAR 21: SANDBAR SHARK ASSESSMENT SUMMARY

The Summary Report provides a broad but concise view of the salient aspects of the stock assessment. It recapitulates: (a) the information available to and prepared by the Data Workshop; (b) the application of those data, development and execution of one or more assessment models, and identification of the most reliable model configuration as the base run by the Assessment Process (AP); and (c) the findings and advice determined during the Review Workshop.

Stock Status and Determination Criteria

Assessment results showed that the stock was overfished and therefore subject to rebuilding. Current F values over most sensitivities indicated that the stock was not currently subject to overfishing (F_{2009}/F_{MSY} 0.29 to 0.93). However, the low productivity scenario indicated overfishing (F_{2009}/F_{MSY} of 2.62).

Table 1. Summary of stock status determination criteria.

Criteria	Recommended Values from SEDAR 21	
	Definition	Value*
M (Instantaneous natural mortality; per year)	Arithmetic mean of the age-specific values of M used for the baseline run	0.136
F_{2009} (per year)	Apical Fishing mortality in 2009	0.013
F_{MSY} (per year)	F_{MSY}	0.021
N_{MSY} (numbers)	Abundance at MSY	1,928,165
SSF_{2009} (numbers)	Spawning Stock Fecundity** in 2009	312,890
SSF_{MSY} (numbers)	Spawning Stock Fecundity at MSY	477,590
MSST (numbers)	$(1\text{-}M)SSF_{MSY}$	412,638
MFMT (per year)	F_{MSY}	0.021
MSY (numbers)	Maximum Sustainable Yield	160,643
F_{Target} (per year)	$75\%F_{MSY}$	0.016
Biomass Status	SSF_{2009}/SSF_{MSST}	0.76
Exploitation Status	F_{2009}/F_{MSY}	0.62

* Values presented are from the base model configuration but it is important to note that that the Review Panel recommended all runs in the addendum be considered equally plausible
** SSF is spawning stock fecundity (sum of number at age times pup production at age)

Stock Identification and Management Unit

After considering the available data, the Data Workshop Life History working group decided that sandbar sharks occurring in the U.S. waters of the western North Atlantic Ocean (including the

Gulf of Mexico) should be considered as a single stock. Genetic data indicate no significant differentiation between the Gulf of Mexico and western North Atlantic Ocean (thus gene flow likely occurs between the two areas) and tag-recapture data showed a high frequency of movements between basins.

Species Distribution:

The sandbar shark is a common inshore and offshore coastal-pelagic species that occurs in warm temperate and tropical waters mostly on the continental and insular shelves. In the western North Atlantic, it ranges from southern New England to the Caribbean and Gulf of Mexico to southern Brazil. The largest nursery area for sandbar sharks is reported to be in the Chesapeake Bay, with known smaller nursery areas along the east coast of the US in Delaware, Virginia, South Carolina, and Florida, and also in the Gulf of Mexico. Sandbar sharks are known to migrate large distances, with seasonal north-south migrations off the US eastern coast and into the Gulf of Mexico.

Stock Life History

- There are currently no natural mortality estimates for sandbar shark available based on direct empirical data, therefore the Data Workshop Panel concluded that the range of survivorship estimates at age to be used for priors were to be based on Peterson and Wroblewski and Lorenzen estimates without using the Lorenzen-Hoenig hybrid.
- A 2.5 year reproductive cycle was incorporated in the base model configuration, providing a balance between the biennial and triennial reproductive periods discussed.
- Given there is a positive relationship between maternal age and litter size, the Data Workshop Panel recommended using this relationship instead of an average litter size estimate for all age classes. The sex ratio of embryos was not significantly different from 1:1 for all data sources discussed.
- Three-parameter von Bertalanffy growth curves were fitted to male and female sandbar shark data separately and growth parameters were estimated as male $L\infty = 172.97 \pm 1.30$ cm FL, female $L\infty = 181.15 \pm 1.45$ cm FL, male $k = 0.15 \pm 0.005$, female $k = 0.12 \pm 0.004$, male $t_0 = -2.33 \pm 0.19$, and female $t_0 = -3.09 \pm 0.16$.
- The oldest aged sandbar shark was a 27 year old female.

Assessment Methods

The state-space, age-structured production model (ASPM) was used as the primary assessment modeling approach. The ASPM allows incorporation of many of the important biological (mortality, growth, reproduction) and fishery (selectivity, effort) processes in conjunction with observed catches and CPUE indices (and age compositions if available).

- The base case model configuration downweighted the historical catches (1960-1980), giving them ½ of the weight of catches from 1981-2009, on the rationale that they were less well known (as was done in the last assessment in 2006).
- The model started in 1960 and ended in 2009, with the historic period covering 1960-1980, and the modern period spanning 1981-2009.
- Estimated model parameters were pup (age-0) survival, virgin recruitment (R_0), catchability coefficients associated with catches and indices (q_i), and fleet-specific effort (e_i).
- Virgin recruitment was given a uniform prior distribution ranging from 1000 to 10 billion individuals, whereas pup survival was given an informative lognormal prior with median=0.81 (mean=0.85, mode=0.77), a CV of 0.3, and bounded between 0.50 and 0.99. The mean value for pup survival matched closely that derived using life-history based methods.

Assessment Data

- Commercial landings were split into a Gulf of Mexico and an Atlantic component.
- Recreational annual catch estimates are the sum of estimates reported in the MRFSS (fish landed [A] and discarded dead [B1]), Headboat survey (fish landed) and Texas Parks and Wildlife Department survey (fish landed).
- Catches of sandbar sharks caught in the states of Tamaulipas and Veracruz in Mexico, assumed to have come from the USA, were as reported in the previous assessment until 2000 and came from online fisheries statistics from Conapesca for 2001-2009.
- Eleven indices were included in the base assessment: eight fishery-independent series (VIMS LL, NELL, NMFS Coastspan age-1+ LL, GA Coastspan LL, SC Coastspan LL, SCDN Historic red drum LL, PCGN, and NMFS SE LL) and three fishery-dependent series (the commercial BLLOP and PLLOP observer indices and the recreational LPS).
- Length-frequency information from animals caught in scientific observer programs, recreational fishery surveys, and various fishery-independent surveys was used to generate age-frequency distributions through age-length keys.
- The life history inputs used in the assessment included age and growth, as well as several parameters associated with reproduction, including sex ratio, reproductive frequency, fecundity at age, maturity and maternity at age, and month of pupping, and natural mortality. The ASPM uses most life history characteristics as constants (inputs) and others are estimated parameters, which are given priors and initial values.

Catch Trends

- The commercial landings of sandbar sharks increased overall from 1981 to a peak in 1994 (126,300 sharks) and steadily declined thereafter.
- Although sandbar sharks were caught in a variety of different gear types, since 1987 the majority of landings occurred in longline and gillnet fisheries.

- Landings of sandbar sharks were reported in the North Atlantic (Maine to New Jersey), Mid-Atlantic (New Jersey to Virginia), South Atlantic (North Carolina to east coast of Florida) and Gulf of Mexico (west coast of Florida to Texas) regions.
- The majority of sandbar shark landings from 1987 to 2009 occurred in the Gulf of Mexico (53%) and in the South Atlantic (31%) regions with a minority of landings in the Mid-Atlantic (16%). Most landings were along the east and west coasts of Florida and in North Carolina.

Fishing Mortality Trends

Fishing mortality was very low in 1960-1981 in accordance with very reduced catches and effort during that period. Starting in 1982, fishing mortality widely oscillated but always exceeded the estimated F_{MSY} of 0.021. Fishing mortality dropped below F_{MSY} in 2008 and 2009 in accordance with reduced catches imposed by management and increasing trends of some of the indices.

Stock Abundance and Biomass Trends

- All trajectories show little depletion from 1960 to 1982 (a few years later for SSF), corresponding to very reduced catches, effort and estimated F in the historic period, and a marked decline until 2007, followed by stabilization until 2009.
- Decreasing biomass and abundance in 1983-2007 correspond to increased catches and possibly declining trends in the early years of some indices, whereas the stabilization in the last few years of data likely corresponds to reduced catches and increasing tendencies for some of the indices in those years.
- The first six age classes made up about 50% of the population in any given year and mean age by year varied very little (min=6.80, max=7.73).
- The ASPM does not model age 0s and thus no predicted age-0 recruits are produced, only the estimated virgin number of age-1 recruits. The predicted virgin recruitment (R_0; number of age 1 pups) was 563,000 animals.
- The predicted steepness was 0.29 and the maximum lifetime reproductive rate was 1.64. The estimated pup (age-0) survival was 0.84 (see next section for further discussion on pup survival).

Projections

A new projection methodology was used to better incorporate the uncertainties observed in the stock assessment model. The method uses a multivariate normal bootstrap around pup survival, fishing mortality and spawning stock biomass to project stock status under various fishing and catch scenarios.

- The target year for rebuilding ranged between 2047 and 2360 depending on the state of nature of the stock. When excluding the low productivity scenario (RW-4), which seems

unrealistic, the rebuilding year ranged between 2047 and 2083, thus it was lower than for the previous assessment (2070), except for S6 (3-yr cycle).

- All scenarios suggested that fishing mortality needed to be reduced with respect to the 2009 level to meet rebuilding targets with a 70% probability, except for scenarios RW-1(high catch) and RW-3(high productivity), likely due to the fact that these two scenarios modeled the stock as more productive.
- The TAC-based projections to meet rebuilding targets with 70% probability mirrored the general trends of the F-based projections. The three scenarios with higher inferred productivity (S5, RW-1, and RW-3) resulted in higher estimates than the current TAC.
- The results over all scenarios ranged from 168 to 522 mt whole weight (using a dressed to whole weight conversion ratio of 2.0) or 84 to 261 mt dressed weight.
- The low and high productivity scenarios were meant to encapsulate all the other scenarios by pushing the lower and upper bounds on the life history parameters. For projection purposes, both scenarios are unlikely to represent a true state of nature.

Scientific Uncertainty

- Uncertainty in parameter estimates was quantified by computing asymptotic standard errors for each parameter.
- Likelihood profiling was performed to examine posterior distributions for several model parameters and to provide probabilities of the stock being overfished and overfishing occurring.
- Uncertainty in data inputs and model configuration was examined through the use of sensitivity scenarios. Sixteen alternative runs, along with retrospective analyses were also examined.
- The reviewers identified four additional sensitivity analyses to run to provide verification that the results of the assessment were robust to assumptions about underlying stock productivity and assumed level of removals.
- Reviewers also requested that projections be run for several of the sensitivity runs, noting that the uncertainty will be underestimated if only one of several equally plausible “states of nature” is used for projection purposes.

Significant Assessment Modifications

The Review Panel requested four additional sensitivity runs but no significant changes to the base model configuration were required. Additionally, the Review Panel requested that projections be undertaken for sandbar stocks using a method similar to that applied to dusky shark. This differed from the ProBox2 methodology presented in the Assessment Workshop Report. This method was applied and results can be found in the Addendum of the Final Stock Assessment Report.

Sources of Information

All information was copied directly or generated from the information available in the final Stock Assessment Report for SEDAR 21: HMS Sandbar shark.

Table 2: Life history inputs used in the assessment. All these quantities are treated as constants in the model. (*Table 2.4 from the Assessment Workshop Report*)

Age	Proportion mature	Proportion maternal	M	Fecundity
1	0.00035	0.0024	0.15431	4.2488
2	0.00068	0.0036	0.15431	4.5079
3	0.00131	0.0054	0.15431	4.7670
4	0.00253	0.0082	0.15431	5.0261
5	0.00487	0.0124	0.15431	5.2852
6	0.00935	0.0186	0.15431	5.5443
7	0.01788	0.0279	0.15431	5.8034
8	0.03393	0.0417	0.15323	6.0625
9	0.06346	0.0618	0.14812	6.3216
10	0.11562	0.0908	0.13116	6.5807
11	0.20141	0.1313	0.13116	6.8398
12	0.32730	0.1863	0.13116	7.0989
13	0.48418	0.2575	0.13116	7.3580
14	0.64424	0.3443	0.13116	7.6171
15	0.77746	0.4430	0.13099	7.8762
16	0.87079	0.5464	0.12942	8.1353
17	0.92858	0.6460	0.12806	8.3944
18	0.96166	0.7343	0.12688	8.6535
19	0.97975	0.8071	0.12586	8.9126
20	0.98940	0.8637	0.12497	9.1717
21	0.99448	0.9057	0.12419	9.4308
22	0.99713	0.9356	0.12351	9.6899
23	0.99851	0.9566	0.12291	9.9490
24	0.99923	0.9709	0.12239	10.2081
25	0.99960	0.9806	0.12193	10.4672
26	0.99979	0.9871	0.12153	10.7263
27	0.99989	0.9914	0.12117	10.9854

Sex ratio at birth:	1:1
Reproductive frequency:	2.5 yr
Pupping month:	June
Age vs litter size relation:	pups = 0.2591*age + 3.9897
L_{inf}	181.15 cm FL
k	0.12
t_0	-2.33
Weight vs length relation:	$W=0.000010885L^{3.0124}$

Table 3: Catches of sandbar shark by fleet in numbers. Catches are separated into four fisheries: commercial landings + unreported commercial catches in the GOM, commercial landings + unreported commercial catches in the ATL, recreational + Mexican catches, and menhaden fishery discards. (*Table 2.1 from the Assessment Workshop Report*)

Year	Com+Un (GOM)	Com + Un (SA)	REC+MEX	Menhaden discards
1960	59	25	65	504
1961	119	51	129	504
1962	178	76	194	504
1963	237	102	259	504
1964	297	127	323	504
1965	356	152	388	504
1966	415	178	453	504
1967	475	203	517	504
1968	534	228	582	504
1969	593	254	647	504
1970	653	279	711	504
1971	712	305	776	504
1972	771	330	841	504
1973	831	355	905	504
1974	890	381	970	504
1975	949	406	1035	504
1976	969	414	1036	504
1977	1033	442	1079	504
1978	1236	529	2310	504
1979	1807	773	25366	504
1980	3018	1291	97983	504
1981	4650	1990	138933	696
1982	4650	1990	45401	713
1983	5024	2149	426979	705
1984	6861	2936	68135	705
1985	6373	2727	75593	635
1986	18908	6918	134151	626
1987	54132	19851	37438	653
1988	78241	46440	72789	635
1989	104839	55874	34532	670
1990	87469	34971	68479	653
1991	88900	7781	44428	505
1992	69488	31105	43450	444
1993	45201	26777	32922	452
1994	86311	39963	23411	486
1995	49038	35360	35206	445
1996	32126	33419	46817	444
1997	21190	20275	49315	452
1998	32264	30391	41846	435
1999	18087	35212	27329	479
2000	16781	20544	17794	409
2001	26185	21998	42127	383
2002	27572	28788	13062	374

2003	23663	21567	9252	365
2004	18472	20667	7395	374
2005	14109	19265	6126	374
2006	22096	20022	5059	374
2007	6068	10845	10638	374
2008	668	1485	7324	374
2009	2705	1281	7026	374

Table 4: Estimated total and fleet-specific instantaneous fishing mortality rates by year. (*Table 3.13 from the Assessment Workshop Report*)

Year	Total F	Fleet-specific F			
		Com+Un (GOM)	Com + Un (SA)	REC+MEX	Menhaden disc
1960	0.00016	0.00002	0.00001	0.00003	0.00013
1961	0.00030	0.00006	0.00004	0.00017	0.00013
1962	0.00044	0.00011	0.00006	0.00031	0.00013
1963	0.00058	0.00015	0.00009	0.00045	0.00013
1964	0.00072	0.00019	0.00011	0.00059	0.00013
1965	0.00086	0.00023	0.00014	0.00072	0.00013
1966	0.00101	0.00028	0.00017	0.00086	0.00013
1967	0.00115	0.00032	0.00019	0.00100	0.00013
1968	0.00129	0.00036	0.00022	0.00114	0.00013
1969	0.00143	0.00041	0.00024	0.00128	0.00013
1970	0.00157	0.00045	0.00027	0.00142	0.00013
1971	0.00171	0.00049	0.00029	0.00156	0.00013
1972	0.00185	0.00053	0.00032	0.00170	0.00013
1973	0.00200	0.00058	0.00034	0.00184	0.00013
1974	0.00214	0.00062	0.00037	0.00198	0.00013
1975	0.00228	0.00066	0.00039	0.00212	0.00013
1976	0.00242	0.00071	0.00042	0.00226	0.00013
1977	0.00256	0.00075	0.00045	0.00239	0.00013
1978	0.00270	0.00079	0.00047	0.00253	0.00013
1979	0.00284	0.00084	0.00050	0.00267	0.00013
1980	0.00299	0.00088	0.00052	0.00281	0.00013
1981	0.00319	0.00092	0.00055	0.00295	0.00019
1982	0.03147	0.00247	0.00147	0.03128	0.00019
1983	0.11148	0.00273	0.00161	0.11141	0.00019
1984	0.05108	0.00377	0.00221	0.05086	0.00020
1985	0.05654	0.00360	0.00210	0.05636	0.00018
1986	0.09998	0.01079	0.00537	0.09931	0.00018
1987	0.04807	0.03186	0.01597	0.02936	0.00020
1988	0.08935	0.04901	0.04001	0.05560	0.00020
1989	0.12463	0.07083	0.05332	0.02778	0.00022
1990	0.10083	0.06380	0.03662	0.05619	0.00022
1991	0.07743	0.06798	0.00910	0.03907	0.00018
1992	0.09286	0.05572	0.03682	0.04012	0.00017
1993	0.07254	0.03834	0.03394	0.03203	0.00018
1994	0.12910	0.07559	0.05302	0.02418	0.00020
1995	0.09653	0.04609	0.05009	0.03834	0.00020
1996	0.08070	0.03150	0.04885	0.05478	0.00021
1997	0.06348	0.02169	0.03068	0.06188	0.00022
1998	0.08074	0.03375	0.04663	0.05568	0.00023
1999	0.07637	0.02010	0.05586	0.03810	0.00026
2000	0.05355	0.01932	0.03394	0.02594	0.00023
2001	0.06846	0.03087	0.03723	0.06163	0.00022
2002	0.08490	0.03405	0.05049	0.02038	0.00023
2003	0.07068	0.03043	0.03993	0.01465	0.00023
2004	0.06467	0.02466	0.03970	0.01197	0.00024
2005	0.05830	0.01959	0.03840	0.01014	0.00025
2006	0.07207	0.03065	0.04107	0.00864	0.00026
2007	0.03205	0.00883	0.02293	0.01817	0.00026
2008	0.01323	0.00103	0.00326	0.01297	0.00026
2009	0.01305	0.00395	0.00275	0.01257	0.00027

Table 5: Predicted abundance (numbers), total biomass (kg), and spawning stock fecundity (numbers) of sandbar shark for the base run. (*Table 3.12 from Assessment Workshop Report*)

Year	N	B	SSF
1960	4,136,052	88,307,548	1,157,184
1961	4,135,480	88,294,090	1,157,010
1962	4,134,619	88,274,185	1,156,732
1963	4,133,523	88,249,192	1,156,395
1964	4,132,124	88,217,597	1,155,981
1965	4,130,510	88,180,897	1,155,490
1966	4,128,645	88,138,044	1,154,922
1967	4,126,575	88,089,966	1,154,274
1968	4,124,267	88,035,502	1,153,528
1969	4,121,738	87,975,820	1,152,724
1970	4,119,018	87,911,547	1,151,850
1971	4,116,115	87,842,350	1,150,900
1972	4,113,000	87,767,679	1,149,871
1973	4,109,733	87,689,191	1,148,772
1974	4,106,229	87,604,799	1,147,593
1975	4,102,552	87,516,177	1,146,338
1976	4,098,701	87,423,467	1,145,037
1977	4,094,689	87,326,255	1,143,642
1978	4,090,482	87,224,521	1,142,178
1979	4,086,122	87,119,246	1,140,667
1980	4,081,608	87,010,124	1,139,070
1981	4,076,893	86,896,459	1,137,423
1982	4,071,819	86,773,595	1,135,623
1983	4,025,192	86,137,310	1,130,645
1984	3,882,774	84,458,374	1,123,653
1985	3,834,516	83,300,472	1,115,474
1986	3,784,642	82,110,607	1,107,222
1987	3,671,804	79,837,404	1,086,772
1988	3,603,422	76,582,667	1,034,921
1989	3,442,693	71,293,576	946,597
1990	3,269,287	65,311,505	837,586
1991	3,088,063	60,884,602	758,891
1992	2,949,985	57,897,374	704,227
1993	2,805,026	54,684,577	644,964
1994	2,692,431	52,540,571	603,754
1995	2,530,868	48,700,128	536,991
1996	2,391,551	46,166,875	494,628
1997	2,259,984	44,116,196	464,346
1998	2,154,324	42,800,641	449,447
1999	2,041,650	40,720,368	425,258
2000	1,954,665	38,982,212	405,796
2001	1,894,891	37,912,155	397,026
2002	1,806,557	36,256,021	383,467
2003	1,740,611	34,525,532	365,366
2004	1,688,826	33,268,064	353,121
2005	1,645,191	32,247,512	343,206

2006	1,608,720	31,436,577	335,358
2007	1,565,308	30,383,263	323,068
2008	1,541,327	30,139,700	322,934
2009	1,539,102	30,431,026	330,902

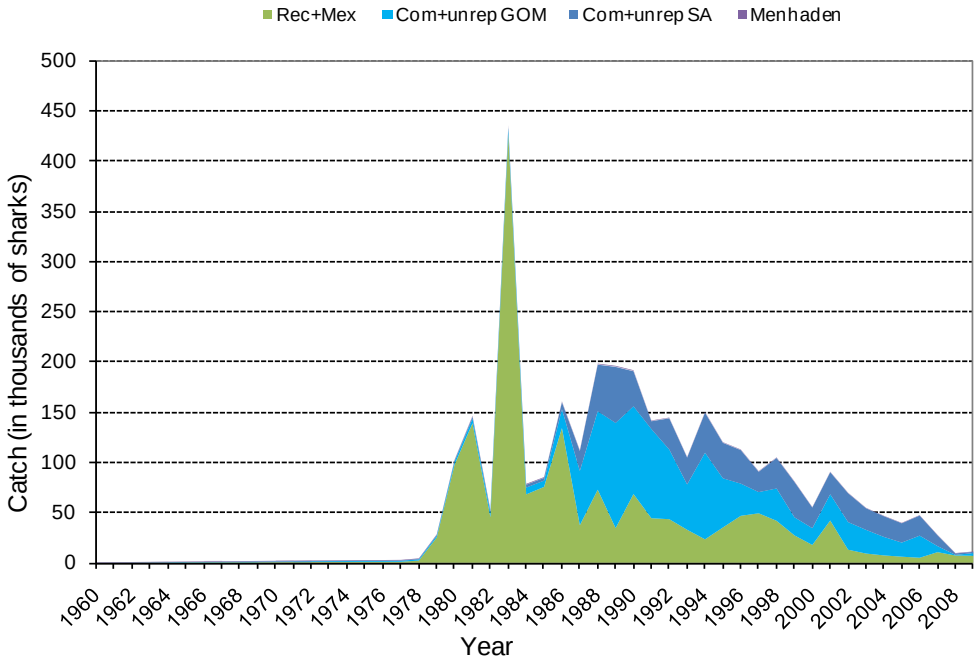

Figure 1: Catches of sandbar shark by fleet. Catches are separated into four fisheries: commercial landings + unreported commercial catches in the GOM, commercial landings + unreported commercial catches in the ATL, recreational + Mexican catches, and menhaden fishery discards (this last series does not show up in the figure due to its small magnitude). (*Figure 2.1 from the Assessment Workshop Report*)

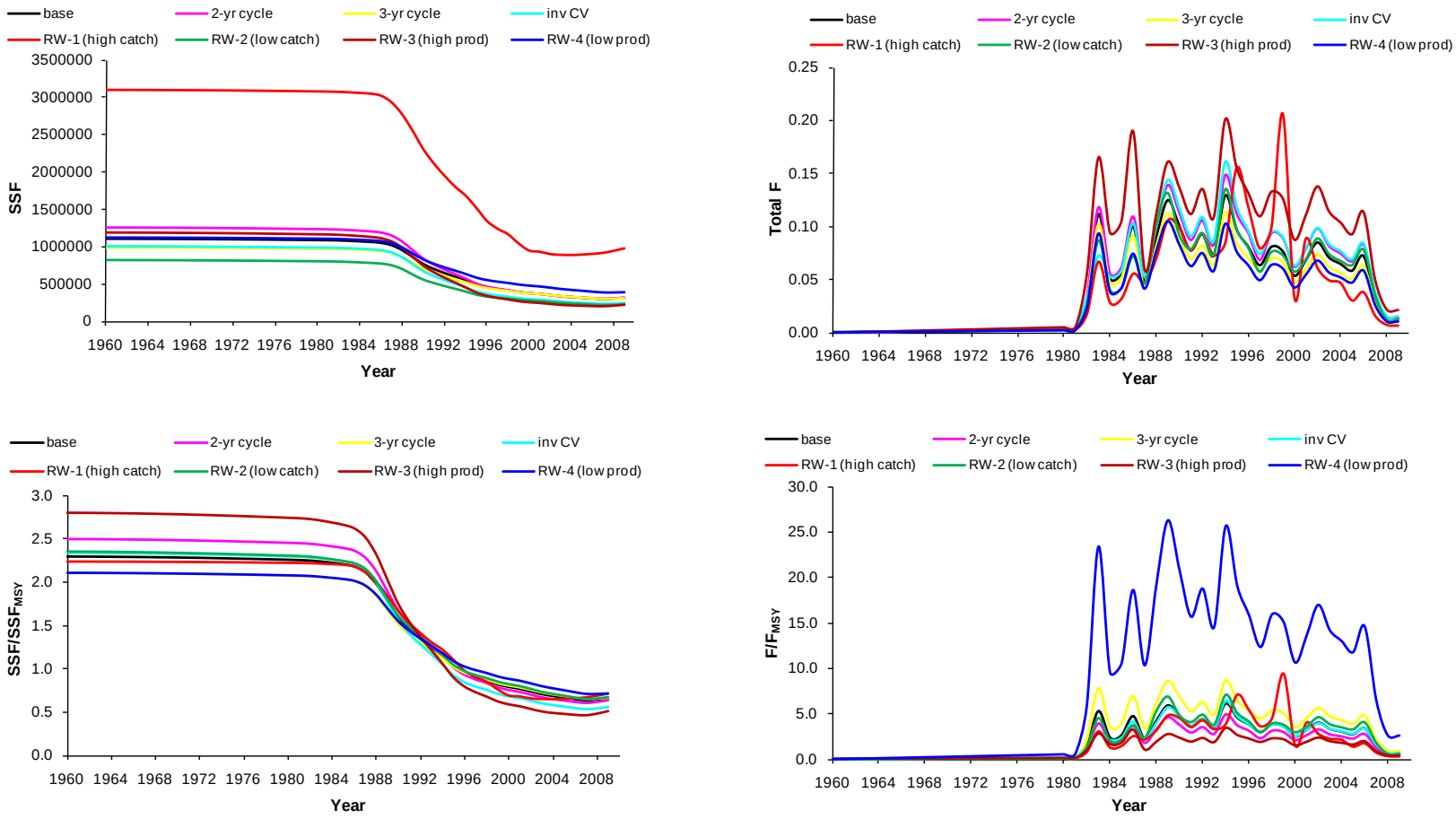

Figure 2: Scenarios selected to explore the range of model outputs for sandbar shark at the Review Workshop. Base is baseline scenario; S1 is inverse CV weighting; S5 is 2-year reproductive cycle; S6 is 3-year reproductive cycle; RW-1 (high catch) is modified high catch; RW-2 (low catch) is modified low catch; RW-3 (high prod) is high productivity; RW-4 (low prod) is low productivity. Four time series trajectories are shown: SSF (spawning stock fecundity; top left panel), total apical F (top right panel), relative biomass (bottom left panel), and relative fishing mortality (bottom right panel). (*Figure 6.2 in the Addendum*)

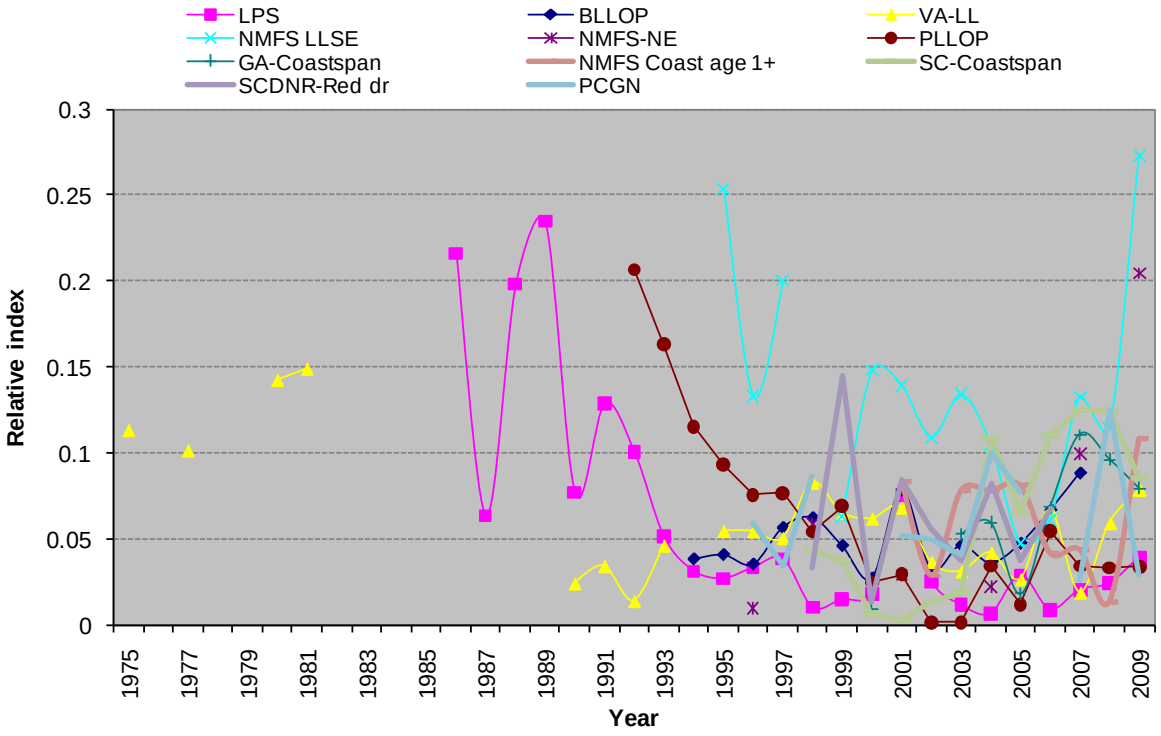

Figure 3: Indices of relative abundance used for the baseline scenario. All indices are statistically standardized and scaled (divided by their respective mean and a global mean for overlapping years for plotting purposes). (*Figure 2.8 from the Assessment Workshop Report*)

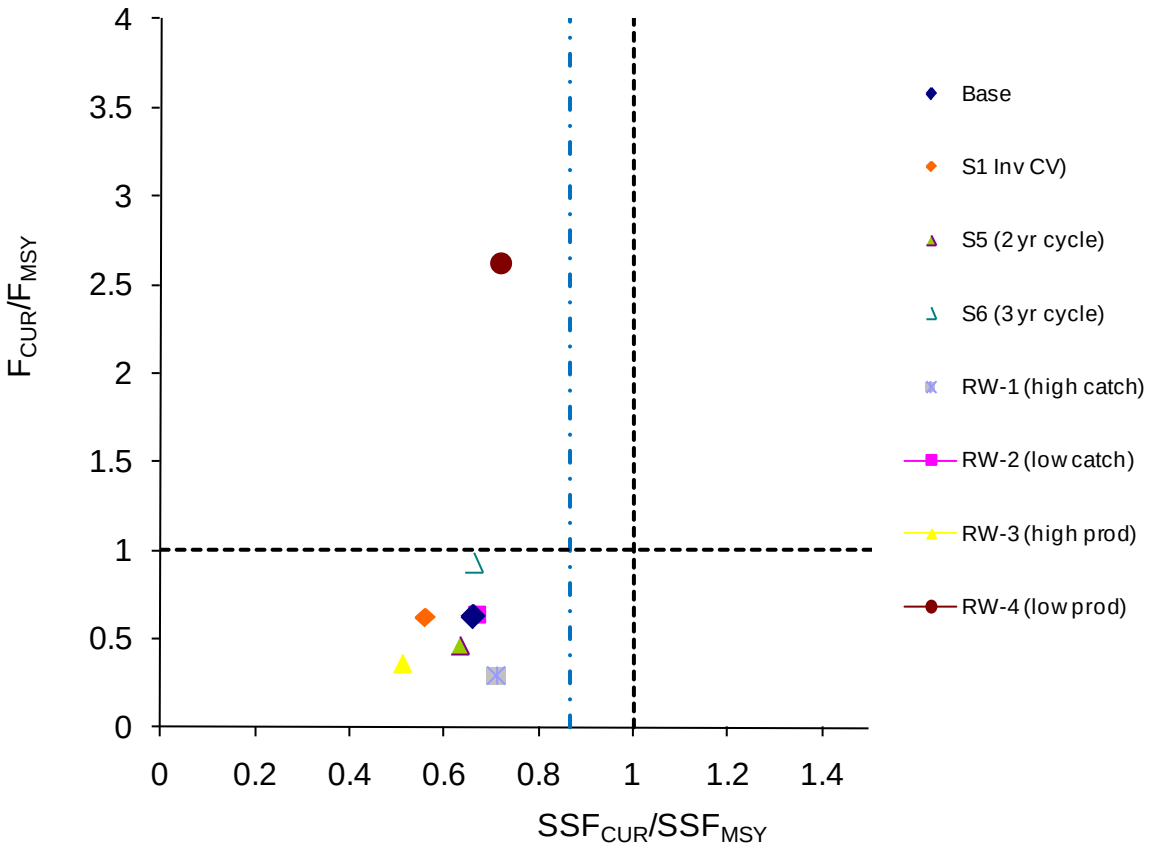

Figure 4: Phase plot summarizing stock status in 2009 for original base run and scenarios selected to explore the range of model outputs for sandbar shark at the Review Workshop. Base is baseline scenario; S1 is inverse CV weighting; S5 is 2-year reproductive cycle; S6 is 3-year reproductive cycle; RW-1 (high catch) is modified high catch; RW-2 (low catch) is modified low catch; RW-3 (high prod) is high productivity; RW-4 (low prod) is low productivity. The vertical dashed line denotes MSST ((1-M)*SSF_{MSY}) (*Figure 6.1 from the Addendum*)

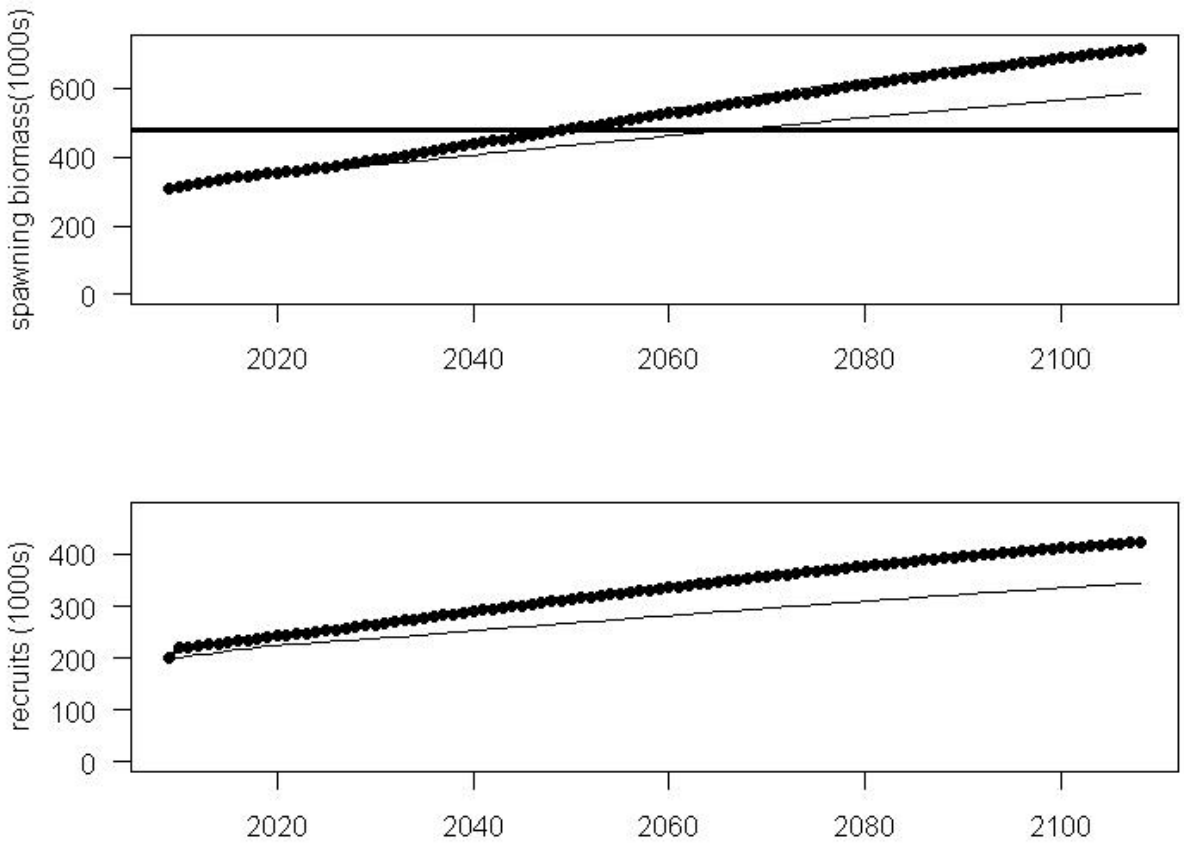

Figure 5: Base model projections. The top panel is the spawning stock fecundity and recruitment estimates for the Frebuild 70 scenario. Frebuild70 is the fishing mortality permitted in order to attain a 70% probability of recovery by the rebuilding year. The bottom panel is the spawning stock fecundity and recruitment estimates for the TACrebuild70 scenario under the base case model assumptions. The TACrebuild 70 is the total allowable catch permitted to attain recovery by the rebuilding year. The heavy dotted line is the median and the thin lines are the 70% and 30% quantiles. In this case the median and 70% quantiles overlap. The solid horizontal line is the SSFmsy or the Rmsy. Where the horizontal lines are absent for recruitment, the projection does not reach the Rmsy during the projection time period.

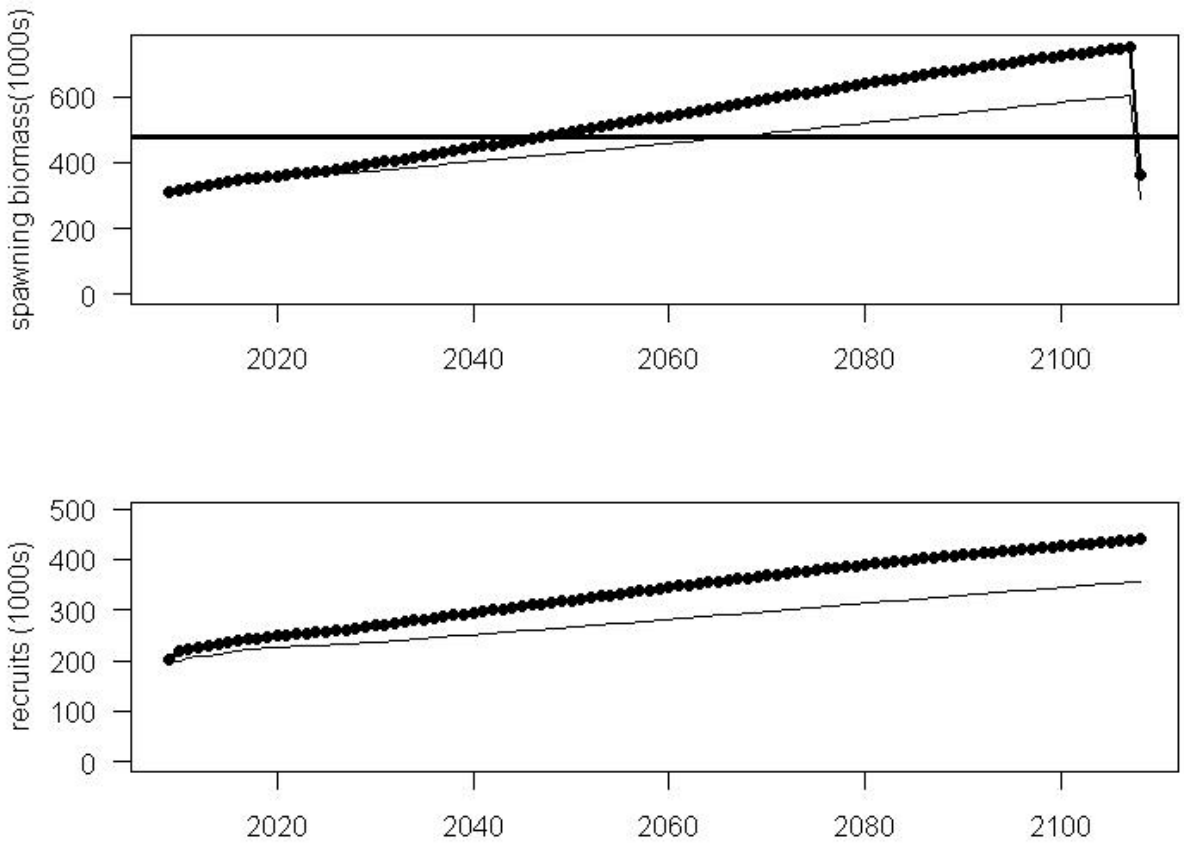

Figure 5. (Continued)