Atlantic Blacknose 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

Results showed that the stock was overfished (SSF_{2009}/SSF_{MSY} of 0.43 to 0.64, all below MSST) and therefore subject to rebuilding. The base model estimated an overfished stock and that overfishing was still occurring at a level similar to that when the stocks were treated as a single unit. Current F values over all sensitivities also indicated that the stock was subject to overfishing (F_{2009}/F_{MSY} of 3.26 to 22.53).

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	0.20
F_{2009} (per year)	Apical Fishing mortality in 2009	0.38
F_{MSY} (per year)	Fishing Mortality at MSY	0.08
N_{MSY} (numbers)	Abundance at MSY	153,709
SSF_{2009} (numbers)	Spawning stock fecundity** in 2009	58,049
SSF_{MSY} (numbers)	Spawning Stock Fecundity at MSY	96,809
MSST (numbers)	(1-M)*SSF_{MSY}	77,447
MFMT (per year)	F_{MSY}	0.08
MSY (numbers)	Maximum Sustainable Yield	24,495
F_{Target} (per year)	75%F_{MSY}	0.06
Biomass Status	SSF_{2009}/MSST	0.75
Exploitation Status	F_{2009}/F_{MSY}	5.02

* Values presented are from the Review Workshop 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 working group concluded that blacknose sharks inhabiting the U.S. waters of the western North Atlantic Ocean (including the Gulf of Mexico) should be considered two separate stocks; one in the U.S. waters of the western North Atlantic Ocean (referred to in the document as South Atlantic Bight) and one in the Gulf of Mexico.
- Since SEDAR 13, tagging efforts have increased and there is still a lack of exchange between the Gulf of Mexico and South Atlantic Bight.
- While genetic information still doesn't not provide data to discriminate distinct stocks, the continued lack of exchange between the two basins and the difference in reproductive cycle (1 year vs. 2 year) led the group to conclude that the stocks should be split.

Stock Life History

- There are currently no natural mortality estimates for blacknose shark available based on direct empirical data.
- It was determined that the *maximum* of the four life history invariant methods for estimating natural mortality discussed at the Data Workshop (Hoenig [1983], Chen and Watanabe [1989], Peterson and Wroblewski [1984], and Lorenzen [1996]), be used as the estimate of M.
- Due to the low sample sizes of younger individuals in the growth model from the South Atlantic Bight and larger animals from the Gulf of Mexico, the working group chose to adopt the combined growth model to describe both areas.
- Observed maximum age of blacknose sharks is 14.5 years for females and 20.5 years for males. The working group agreed that it was reasonable to assume a maximum age of 20.5 years for females as well.
- The reproductive periodicity in the Gulf of Mexico is considered to be annual while the periodicity is considered biennial in the South Atlantic Bight.
- A litter size of 5 should be adopted for both regions. This value represents the median of all data available on blacknose shark fecundity.

Assessment Methods

The state-space, age-structured production model (ASPM) was used as the primary assessment modeling approach. The ASPM has been used extensively for assessing shark stocks domestically (including the sandbar and blacknose sharks) and under the auspices of ICCAT since 2002. 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 length and age compositions if available).

- The year of virgin conditions was set to 1950
- The stock-recruit relationship was assumed to be a Beverton-Holt function

- The base case model configuration downweighted the catches for certain periods, giving them ½ of the weight of catches in more recent years, on the rationale that they were either estimated or generally less well known.
- One further model specification is the degree to which the model-predicted values matched catches versus indices. Given that the estimated stock status did not vary much based on the alternate weighting between catch and indices, it was decided to proceed by placing relatively more confidence in the catch series.

Assessment Data

- Commercial landings were decomposed into three separate gears: bottom longlines, nets, and lines, by taking the product of the annual landing estimates and the proportional gear composition for the South Atlantic
- Annual recreational catch estimates are the sum of estimates reported in the MRFSS (fish landed [A] and discarded dead [B1]), and Headboat survey (fish landed).
- Dead discards from the commercial shark bottom longline fishery are estimated using the annual dead discard percentage observed in the Shark Bottom Longline Observer Program in the South Atlantic multiplied by the annual commercial landings of blacknose sharks caught on longlines in the South Atlantic.
- Dead discards from the commercial shrimp trawl fishery in the South Atlantic are included. The pre-TED and post-TED series were imputed as a single series into the model to address poor-fit issues
- 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 Index WG of the DW recommended the use of seven indices: four fishery-independent series (NMFS LL SE, SCDNR Historical Red drum longline, GADNR Red drum longline, and UNC longline) and three fishery-dependent series (the BLLOP and DGNOP commercial observer program indices and the CFL Gillnet logbook-based commercial index), all of which were standardized by the respective authors through GLM techniques
- Life history inputs to the model include age and growth, as well as several parameters associated with reproduction, including sex ratio, reproductive frequency, fecundity at age, maturity at age, and month of pupping, and natural mortality.

Catch Trends

- Catches of blacknose shark in the US south Atlantic were dominated by catches from the gillnet fishery, followed by the commercial bottom longline and the shrimp fishery bycatch.
- The gillnet fishery is the dominant fishery in the south Atlantic, but large sporadic catches of blacknose shark have been recorded in the recreational fishery as well.

Fishing Mortality Trends

- Fishing mortality started low and progressively increased until the peak in 1994, which again corresponded to the decline in catches from 1994 to 1995 and a matching peak in effort and F in the commercial gillnet fleet in 1994.
- After 1995, fishing mortality and effort oscillated but were more in line with the corresponding catches in each fleet.
- Total fishing mortality did not exceed the estimated F_{MSY} of 0.074 until 1993, after which it remained above F_{MSY}.
- Fishing mortality was dominated by the shrimp fleet until 1994, after which the commercial gillnet fleet dominated

Stock Abundance and Biomass Trends

- All model trajectories show very little depletion until 1987, corresponding to low catches, effort and estimated F in the historic and early modern period.
- Coinciding with progressively increasing catches, effort and F until the mid-1990s, all trajectories declined more steeply from about 1988 to 1994, followed by a precipitous decline from 1994 to 1995. This decline coincides with the sharp decline in catches from 1994 to 1995.
- After the mid-1990s, the rate of decline decelerates despite the increase in catches possibly in response to the lack of a clear trend in most indices in those years.
- The first three age classes made up about 50% of the population in any given year and mean age by year varied little (min=4.4, max=7.0).
- The age distribution in 1995 and 1996 appeared disrupted, with proportionally more age-1 animals in the population in those years and thereafter than in the preceding 1950-1994 period.

Projections

- Projections for blacknose shark only vary for biomass and fishing mortality in the F-based scenarios.
- The target year for rebuilding ranged between 2033 and 2086 depending on the state of nature of the stock.
- Most scenarios suggested that fishing mortality needed to be reduced by about an order of magnitude in order to meet rebuilding targets.
- The low productivity scenario was the most extreme, and was meant more to bookend the states of nature on the lower end of the life history spectrum.
- Projections of the high productivity scenario suggested that a reduction of fishing mortality of about 82% percent would be sufficient to rebuild the stock to MSY levels within the projected rebuilding time frame.

Scientific Uncertainty

- 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. Eight alternative runs, along with retrospective analyses were also examined.
- The reviewers identified four additional sensitivity analyses to provide verification that the results of the assessment were robust to assumptions about underlying stock productivity and assumed level of removals.
- 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 sharks suggesting that the GLMs used to standardize the indices did not include all factors to help track relative abundance or that the spatial scope of sampling is too limited to allow for precise inference about stock-wide trends.
- The uncertainty associated with biological parameters was only investigated through the scenario with a U-shaped natural mortality curve and resulted in a much higher degree of overfishing.
- The estimation of selectivities externally to the model 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.

Significant Assessment Modifications

The Review Panel modified the Base run put forth by the Assessment Panel. The modification entailed that the UNC series is fit less well by use of a weight in the data input.

Sources of Information

All information was copied directly or generated from the information available in the final Stock Assessment Report for SEDAR 21: HMS Atlantic Blacknose 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 Process Report*)

Age	Proportion mature	M
1	0.0000	0.2089
2	0.0005	0.2089
3	0.0099	0.2089
4	0.1751	0.2089
5	0.8191	0.2089
6	0.9897	0.2051
7	0.9995	0.2009
8	1.0000	0.1979
9	1.0000	0.1957
10	1.0000	0.1941
11	1.0000	0.1930
12	1.0000	0.1922
13	1.0000	0.1915
14	1.0000	0.1911
15	1.00000	0.19076
16	1.00000	0.19051
17	1.00000	0.19033
18	1.00000	0.19019
19	1.00000	0.19009
20	1.00000	0.19002

Sex ratio:	1:1
Reproductive frequency:	2 yr
Fecundity:	5 pups
Pupping month:	June
L_{inf}	104.3 cm FL
k	0.3
t_0	-1.71
Weight vs length relation:	$W=0.00000165L^{3.34}$

Table 3: Catches of blacknose shark by fleet in numbers. Catches are separated into six fisheries: commercial longline, commercial gillnet, commercial lines, recreational, shrimp bycatch, and commercial bottom longline discards. The value in red (nets, 1995) indicates a change introduced with respect to what was reported in the SEDAR21 DW Report. (*Table 2.1 from the Assessment Process Report*)

Year	Commercial landings			Recreational	Shrimp	Bottom LL
	Bottom longlines	Nets	Lines		bycatch	discards
1950	0	0	0	0	1567	0
1951	0	0	0	0	1671	0
1952	0	0	1	0	1773	0
1953	0	0	1	0	1873	0
1954	0	0	1	0	1971	0
1955	0	0	2	0	2067	0
1956	0	0	2	0	2162	0
1957	0	0	2	0	2254	0
1958	0	0	3	0	2345	0
1959	0	0	3	0	2434	0
1960	0	0	4	0	3128	0
1961	0	0	4	0	2215	0
1962	0	0	4	0	2667	0
1963	0	0	5	0	3014	0
1964	0	0	5	0	3231	0
1965	0	0	5	0	2832	0
1966	0	0	6	0	2659	0
1967	0	0	6	0	3082	0
1968	0	0	6	0	3137	0
1969	0	0	7	0	3628	0
1970	0	0	7	0	3039	0
1971	0	0	7	0	3110	0
1972	0	0	8	0	4569	0
1973	0	0	8	0	3888	0
1974	0	0	8	0	3536	0
1975	0	0	9	0	2876	0
1976	0	0	9	0	3108	0
1977	0	0	9	0	3287	0
1978	0	0	10	0	3690	0
1979	0	0	10	0	3605	0
1980	0	0	11	0	2101	0
1981	397	0	11	0	2536	120
1982	794	0	11	0	2387	239
1983	1191	0	12	119	2174	359
1984	1587	0	12	844	2239	479
1985	4096	0	12	172	2036	599
1986	4916	0	13	0	2144	718
1987	5735	1144	13	59	2082	838
1988	6554	2288	13	4668	1682	958
1989	7374	3433	14	0	1693	1077
1990	8193	4577	14	2400	1956	1197
1991	9012	5721	14	8	2236	1317

1992	9831	6865	15	551	2249	1437
1993	10651	8010	15	0	2126	1556
1994	11470	9154	15	170	1963	1676
1995	5434	11838	0	0	2021	564
1996	6125	14573	763	1	2188	156
1997	14082	26004	45	1	2493	580
1998	5617	14428	20	974	2548	0
1999	5458	20685	29	733	2375	637
2000	10249	32154	0	3346	2335	9318
2001	4177	28525	15	31	2535	2517
2002	3071	18340	124	537	2846	3071
2003	7358	12482	85	709	2258	2453
2004	3958	7942	34	30	2047	1319
2005	612	12208	254	0	1501	184
2006	2736	11498	14	476	1279	456
2007	705	12035	77	3368	1137	163
2008	3963	19097	139	2	863	90
2009	9792	19292	146	1070	1025	0

Table 4: Estimated total and fleet-specific instantaneous fishing mortality rates by year. (*Table 3.9 from the Assessment Process Report*)

Year	Total F	Fleet-specific F					
		Com-BLL	Com-GN	Com-L	Rec	Shrimp	BLL-Disc
1950	0.003	2.9624E-07	4.4109E-07	2.19E-07	2.768E-07	0.0029667	2.962E-07
1951	0.009	2.9624E-07	4.4109E-07	1.152E-06	2.776E-07	0.0088394	2.962E-07
1952	0.015	2.9624E-07	4.4109E-07	2.086E-06	2.785E-07	0.014712	2.962E-07
1953	0.021	2.9624E-07	4.4109E-07	3.019E-06	2.793E-07	0.0205846	2.962E-07
1954	0.026	2.9624E-07	4.4109E-07	3.952E-06	2.801E-07	0.0264573	2.962E-07
1955	0.032	2.9624E-07	4.4109E-07	4.885E-06	2.81E-07	0.0323314	2.962E-07
1956	0.038	2.9624E-07	4.4109E-07	5.819E-06	2.818E-07	0.0382019	2.962E-07
1957	0.044	2.9624E-07	4.4109E-07	6.752E-06	2.827E-07	0.0440755	2.962E-07
1958	0.050	2.9624E-07	4.4109E-07	7.685E-06	2.835E-07	0.049949	2.962E-07
1959	0.056	2.9624E-07	4.4109E-07	8.618E-06	2.843E-07	0.0558195	2.962E-07
1960	0.062	2.9624E-07	4.4109E-07	9.552E-06	2.852E-07	0.0616931	2.962E-07
1961	0.068	2.9624E-07	4.4109E-07	1.049E-05	2.86E-07	0.0675666	2.962E-07
1962	0.073	2.9624E-07	4.4109E-07	1.142E-05	2.869E-07	0.0734371	2.962E-07
1963	0.079	2.9624E-07	4.4109E-07	1.235E-05	2.877E-07	0.0793107	2.962E-07
1964	0.085	2.9624E-07	4.4109E-07	1.329E-05	2.885E-07	0.0851842	2.962E-07
1965	0.091	2.9624E-07	4.4109E-07	1.422E-05	2.894E-07	0.0910577	2.962E-07
1966	0.097	2.9624E-07	4.4109E-07	1.515E-05	2.902E-07	0.0969283	2.962E-07
1967	0.103	2.9624E-07	4.4109E-07	1.608E-05	2.911E-07	0.1028018	2.962E-07
1968	0.109	2.9624E-07	4.4109E-07	1.702E-05	2.919E-07	0.1086753	2.962E-07
1969	0.115	2.9624E-07	4.4109E-07	1.795E-05	2.927E-07	0.1145459	2.962E-07
1970	0.120	2.9624E-07	4.4109E-07	1.888E-05	2.936E-07	0.1204194	2.962E-07
1971	0.126	2.9624E-07	4.4109E-07	1.982E-05	2.944E-07	0.1262929	2.962E-07
1972	0.132	3.0907E-07	4.60712E-07	2.075E-05	2.953E-07	0.1321635	3.09E-07
1973	0.103	3.0997E-07	4.60978E-07	2.386E-05	2.984E-07	0.1032873	3.099E-07
1974	0.094	3.1037E-07	4.60302E-07	2.389E-05	2.988E-07	0.0939316	3.103E-07
1975	0.076	3.1054E-07	4.59094E-07	2.689E-05	2.989E-07	0.0762271	3.105E-07
1976	0.083	3.1029E-07	4.57998E-07	2.687E-05	2.987E-07	0.0827029	3.103E-07
1977	0.088	3.1038E-07	4.58008E-07	2.689E-05	2.988E-07	0.0877703	3.104E-07
1978	0.099	3.1072E-07	4.58828E-07	2.991E-05	2.992E-07	0.098948	3.107E-07
1979	0.097	3.1136E-07	4.59944E-07	2.997E-05	2.998E-07	0.0966735	3.113E-07
1980	0.056	3.125E-07	4.59401E-07	3.3E-05	3.001E-07	0.0557176	3.124E-07
1981	0.069	0.00123633	4.57834E-07	3.295E-05	2.995E-07	0.0675007	0.0003731
1982	0.067	0.00248481	4.57578E-07	3.298E-05	3E-07	0.063536	0.0007453
1983	0.063	0.00374771	4.57865E-07	3.607E-05	0.0003576	0.0578962	0.0011234
1984	0.069	0.00503307	4.59053E-07	3.622E-05	0.0025533	0.0598201	0.0015073
1985	0.063	0.00635376	4.60558E-07	3.644E-05	0.0005222	0.05445	0.0018981
1986	0.068	0.00769433	4.63221E-07	3.967E-05	3.055E-07	0.0575936	0.0022895
1987	0.078	0.00909269	0.009789167	4.004E-05	0.0001817	0.0563649	0.0027001
1988	0.095	0.01067493	0.020311999	4.092E-05	0.014939	0.0458795	0.0031659
1989	0.095	0.01240549	0.031749148	4.526E-05	3.238E-07	0.0468324	0.003658
1990	0.126	0.01426379	0.044308711	4.66E-05	0.0080575	0.0552591	0.0041972
1991	0.144	0.01638271	0.058247736	4.836E-05	2.765E-05	0.0645699	0.0048003
1992	0.166	0.0187643	0.073541645	5.401E-05	0.0019868	0.0665627	0.0054764
1993	0.181	0.0212489	0.089123327	5.672E-05	3.786E-07	0.0645909	0.00622
1994	0.203	0.02395189	0.109435326	5.993E-05	0.0006793	0.0618369	0.007078

1995	0.177	0.02400751	0.085088373	4.203E-07	4.202E-07	0.0650554	0.0024779
1996	0.204	0.02799709	0.09846107	0.0033411	4.379E-06	0.0738896	0.0007144
1997	0.334	0.06675254	0.175797006	0.000215	4.782E-06	0.0882109	0.0028922
1998	0.213	0.02782712	0.090805923	0.000103	0.0049401	0.0892297	5.416E-07
1999	0.242	0.02716786	0.11900042	0.0001548	0.0038555	0.0885705	0.0035184
2000	0.405	0.05294096	0.189110306	5.952E-07	0.018679	0.0940215	0.0499481
2001	0.370	0.0275593	0.212674847	0.0001012	0.0002092	0.1124811	0.0172508
2002	0.365	0.02276006	0.175858452	0.0009091	0.0039218	0.1388551	0.0230667
2003	0.334	0.05878575	0.134740837	0.0006769	0.0056287	0.1133771	0.0203453
2004	0.228	0.03258309	0.079299135	0.0002815	0.0002483	0.1041893	0.0113011
2005	0.198	0.00524053	0.107684115	0.0020979	8.323E-07	0.0816781	0.001602
2006	0.205	0.02294342	0.103413618	0.0001188	0.0039959	0.0706862	0.004029
2007	0.206	0.00633192	0.106997968	0.0006699	0.027349	0.0634431	0.0014943
2008	0.262	0.03603702	0.173369889	0.0012717	1.835E-05	0.0506802	0.0008677
2009	0.421	0.10571916	0.23882012	0.0015068	0.011049	0.0640605	1.093E-06

Table 5: Predicted abundance (numbers), total biomass (kg), and spawning stock fecundity (numbers) of blacknose shark for the base run. (*Table 3.8 from the Assessment Process Report*)

Year	N	SSF	B
1950	460560	257894	2211819
1951	460457	257894	2211571
1952	460168	257893	2210777
1953	459727	257876	2209368
1954	459165	257787	2207338
1955	458493	257588	2204701
1956	457714	257284	2201464
1957	456837	256904	2197698
1958	455868	256455	2193420
1959	454814	255942	2188637
1960	453683	255372	2183415
1961	452480	254746	2177769
1962	451212	254068	2171733
1963	449885	253346	2165358
1964	448503	252580	2158650
1965	447066	251773	2151620
1966	445588	250932	2144341
1967	444065	250058	2136798
1968	442504	249152	2129024
1969	440907	248220	2121039
1970	439278	247262	2112864
1971	437619	246281	2104505
1972	435933	245280	2095995
1973	434219	244256	2087310
1974	433610	243217	2081214
1975	433258	242175	2076743
1976	433385	241272	2074421
1977	433134	240881	2072355
1978	432703	240769	2070239
1979	431966	240836	2067358
1980	431450	240741	2064653
1981	432353	240460	2065295
1982	432160	239658	2062891
1983	431514	238715	2058266
1984	430417	237873	2050944
1985	428136	236076	2037181
1986	426295	234454	2025589
1987	424086	232721	2012649
1988	419592	230104	1989689
1989	408940	223058	1931478
1990	400976	217985	1891020
1991	388426	209869	1826286
1992	376064	202491	1764621
1993	361332	193401	1689587
1994	345707	183507	1609464
1995	328018	172286	1519024
1996	316874	163448	1456967

1997	303095	154334	1385897
1998	273327	138269	1240129
1999	264690	130661	1189079
2000	252447	122841	1128577
2001	220328	104826	968096
2002	201373	95860	884109
2003	187333	87303	816078
2004	174106	78147	745872
2005	170277	74610	725351
2006	167976	74478	719728
2007	164255	73698	701842
2008	160370	72120	681761
2009	152057	68365	644442

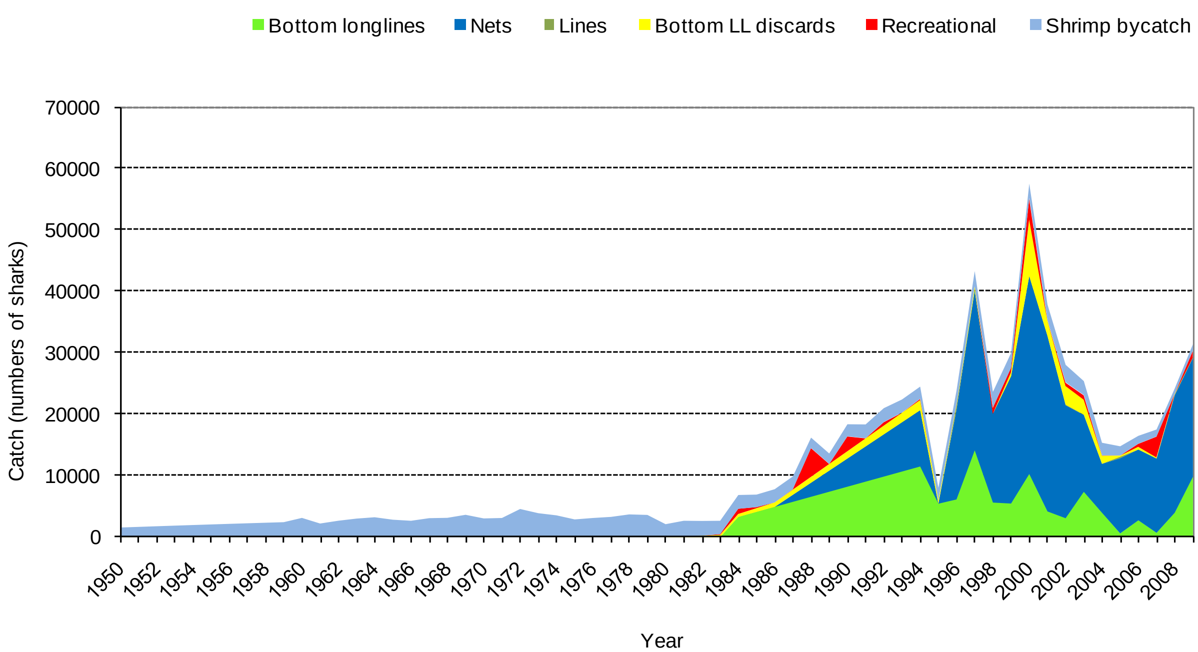

Figure 1: Catches of blacknose shark by fleet. Catches are separated into six fisheries: commercial longline, commercial gillnet, commercial lines, recreational, shrimp bycatch, and commercial bottom longline discards. The commercial lines series is not visible in the figures due to its small magnitude. (*Figure 2.1 from the Assessment Process Report*)

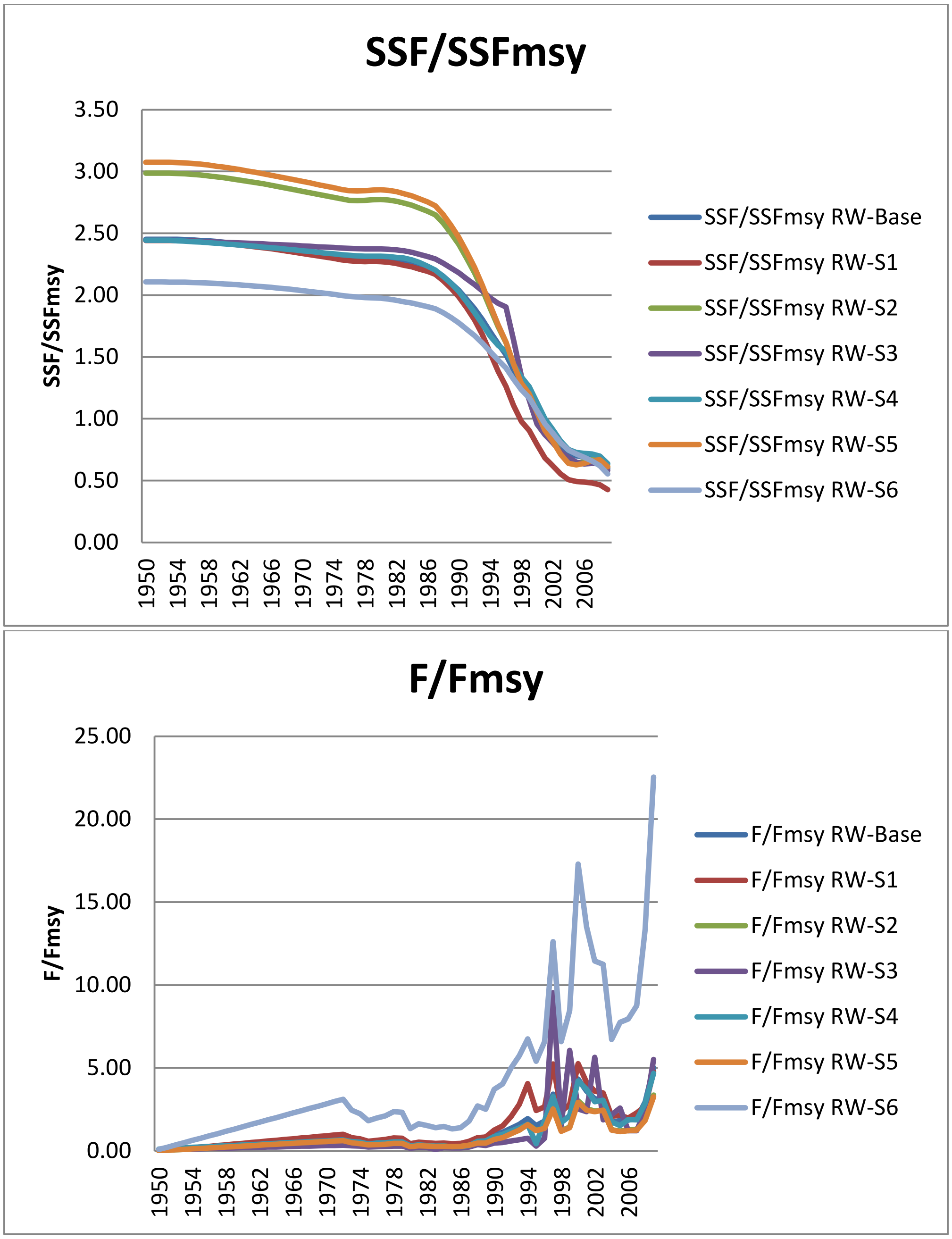

Figure 2 Scenarios selected to explore the range of model outputs for blacknose shark at the Review Workshop. Base and six others are shown below: RW-1 inv-CV weighting, RW-2 1-yr reproductive cycle, RW-3 modified high catch, RW-4 modified low catch, RW-5 high productivity, and RW-6 low productivity. Two time series trajectories are shown: relative biomass, and relative fishing mortality. (*Figure 2 from the Addendum*)

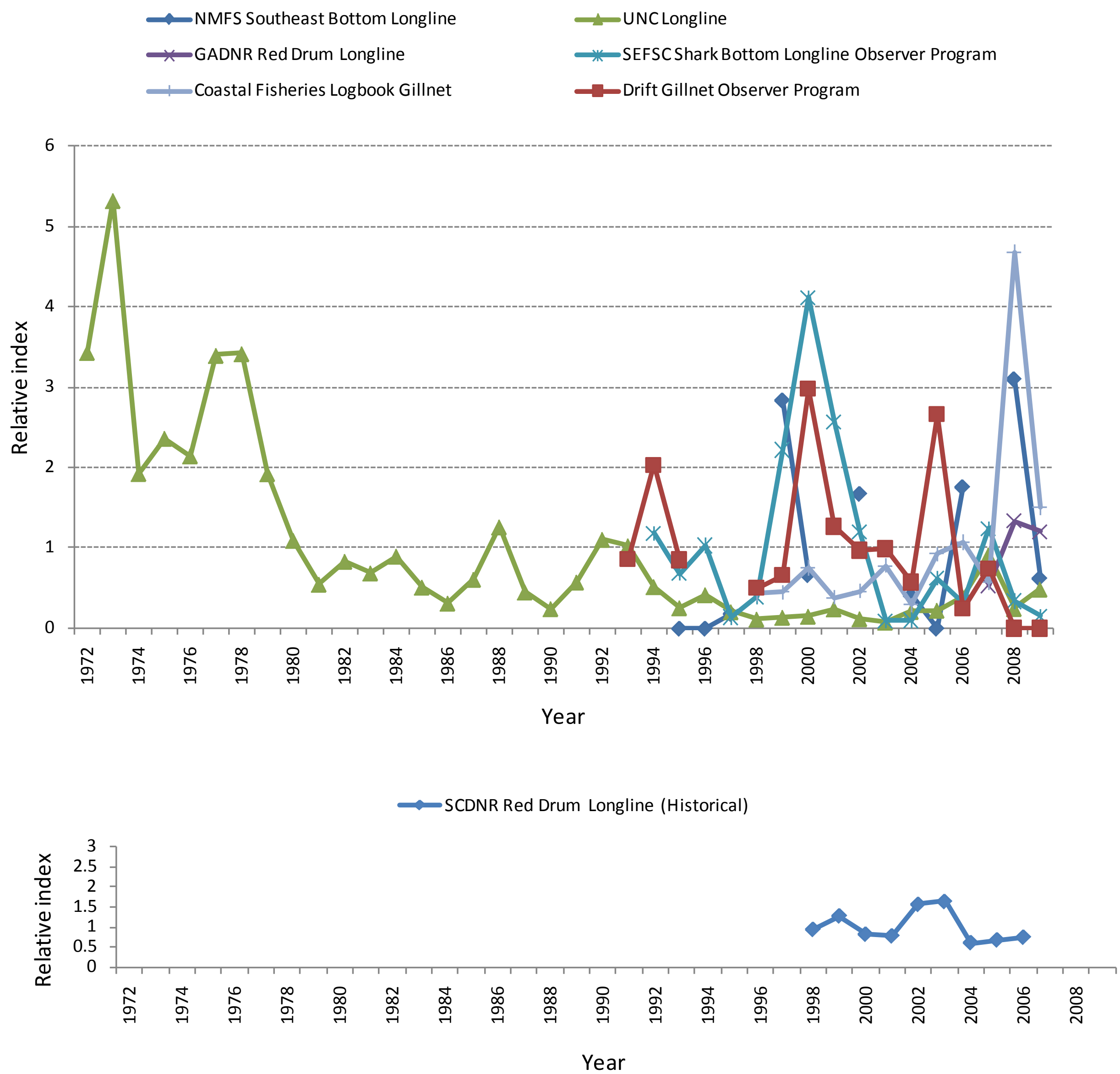

Figure 3: Indices of relative abundance used for the baseline scenario. All indices are statistically standardized and scaled (divided by their respective mean and a global mean for overlapping years for plotting purposes). The SCDNR Historic red drum series is shown separately in the lower panel because there were no years of overlap with the other series to be displayed on the same scale. Note that the earliest series starts in 1972. *(Figure 2.4 from the Assessment Process Report*)

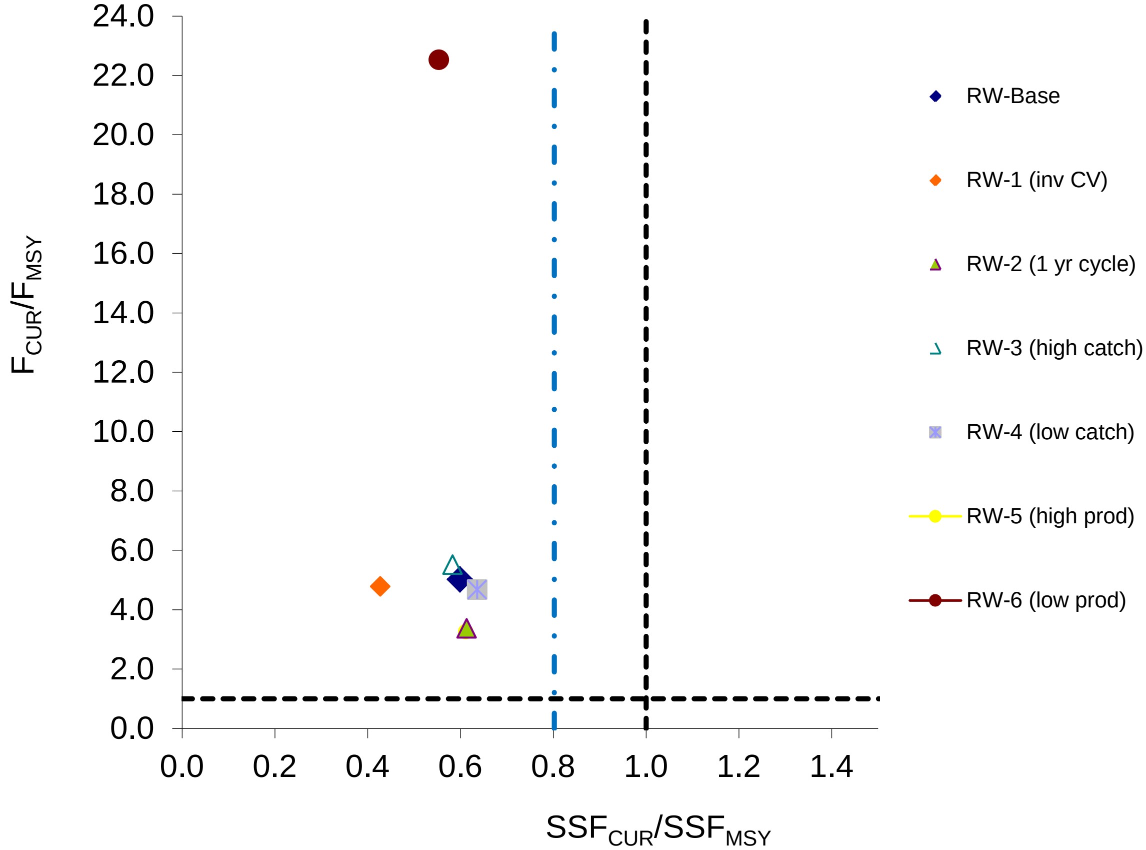

Figure 4: Phase plot summarizing stock status in 2009 for the seven scenarios selected to explore the range of model outputs for Atlantic blacknose shark at the Review Workshop. Base and six others are shown below: RW-1 inv-CV weighting, RW-2 1-yr reproductive cycle, RW-3 modified high catch, RW-4 modified low catch, RW-5 high productivity, and RW-6 low productivity. (*Figure 1 from the Addendum*)

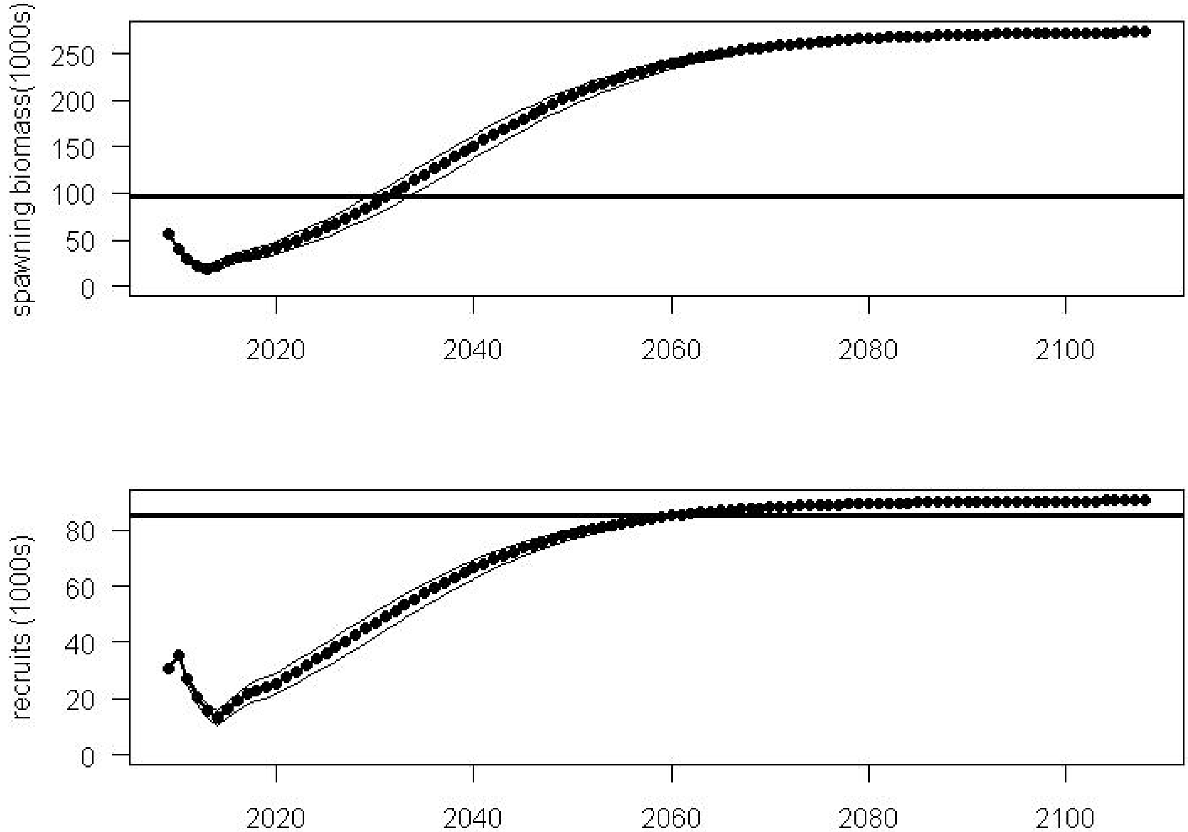

Figure 5: Base model projections for the spawning stock fecundity and recruitment estimates for the Frebuild 70 scenario. Frebuild70 is the fishing mortality permitted in order to attain a 70% probability of recovery by the rebuilding year. The heavy dotted line is the median and the thin lines are the 70% and 30% quantiles. The solid horizontal line is the SSFmsy or the Rmsy. Where the horizontal line is absent for recruitment, the projection does not reach the Rmsy during the projection time period. (*Figure 3 from the Addendum*)

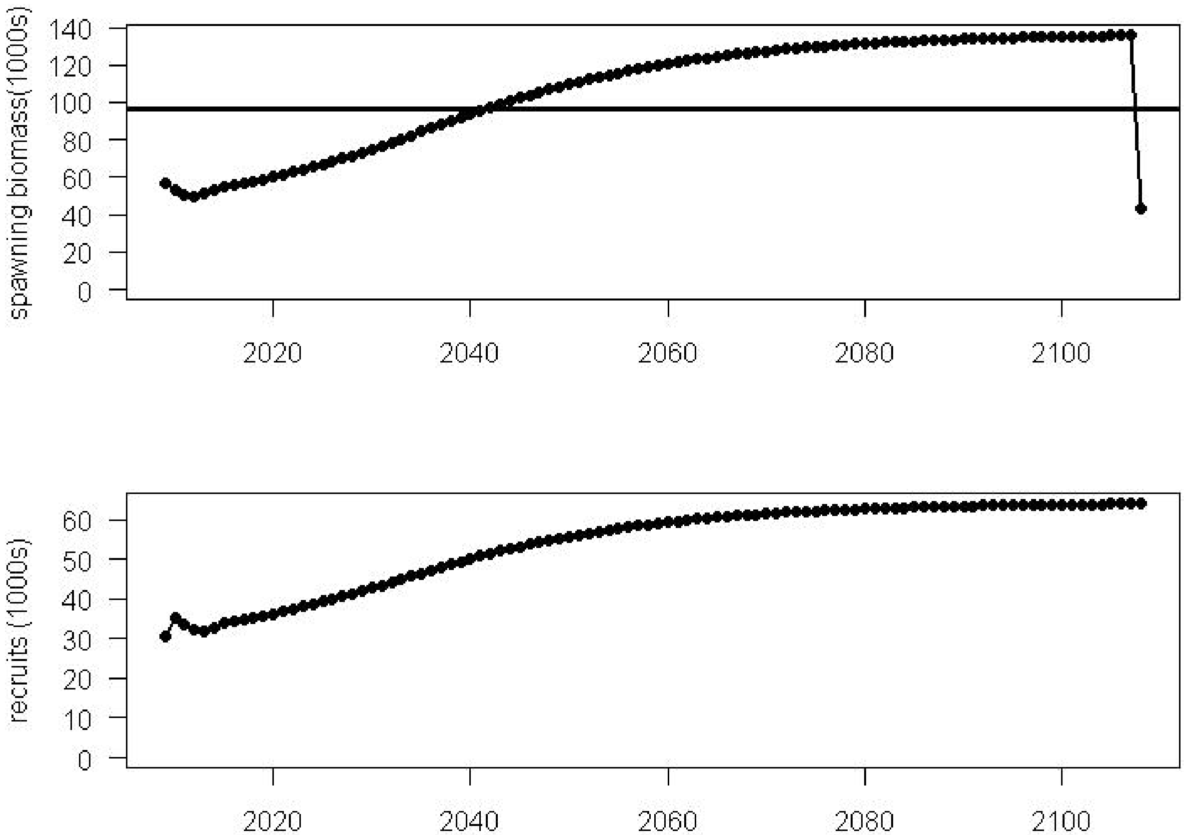

Figure 6: Base model projections for the spawning stock fecundity and recruitment estimates for the TACrebuild70 scenario under the base case model assumptions. The TACrebuild 70 is the total allowable catch permitted to attain recovery by the rebuilding year. The heavy dotted line is the median and the thin lines are the 70% and 30% quantiles. The solid horizontal line is the SSFmsy or the Rmsy. Where the horizontal line is absent for recruitment, the projection does not reach the Rmsy during the projection time period. (*Figure 4 from the Addendum*)