Southeast Data, Assessment, and Review

Update assessment to SEDAR 21

HMS Dusky Shark

Addendum and Post-Review Updates

September 2016

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This addendum documents changes that were introduced to the HMS Dusky Shark stock assessment after the Stock Assessment Report (SAR) was made available at the end of July 2016. The addendum also incorporates answers to questions raised in the two internal NOAA peer reviews that were conducted during August 2016 and made available at the end of August 2016.

1 Revisions

1.1 The Bottom Longline Program (BLLOP) index of relative abundance

In the original standardization of this index (SAR page 6), the time series was truncated to include up to the year 2013. The reason for this truncation was that in 2013 HMS implemented changes to the Shark Research Fishery that included the implementation of the regional dusky shark bycatch cap, followed in 2014 by the allocation to the North Carolina region, an area known for higher dusky shark interactions in previous years, of more dead dusky shark quota so that fishing could continue. However, in order to still allow fishing, all vessels fishing in the North Carolina or South Atlantic region were limited to one main set with the soak time not to exceed 3 hours. This regulation resulted in high dusky shark catch per unit effort for many hauls in 2014, which led to the Generalized Linear Model (GLM) not converging, and the ensuing truncation of the series. The resulting standardized index showed a high peak in 2012, followed by a nadir in 2013 (Figure 1).

After the release of the SAR, the analytical team was informed that the peak in 2012 and the ensuing low value in 2013 were likely not reflective of real abundance, but that instead they reflected the fact that fishing was allowed inside the HMS Bottom Longline Closed Area in 2012 and disallowed in 2013. There had thus been management changes introduced that invalidated the use of a single series. As a result, a new GLM was conducted and made available to the analytical team, consisting of two series: 1) an index for the non-research shark fishery from 1994 to 2007 and 2) an index for the shark-research fishery only from 2008 to 2015 (Figure 2).

The analytical team proceeded to re-run the assessment for the five alternate states of nature with the BLLOP series split into two so that the assessment now included six indices of relative abundance: VIMS LL, LPS, NELL, PLLOP, and the two BLLOP series.

1.2 Results

1.2.1. Measures of Overall Model Fit

The only substantial change with respect to the SAR was that the additional variance for the non-research BLLOP index (1994-2007) was now of the same magnitude as for the LPS index and thus negligible, indicating lower levels of process error and a better fit (Table 1 and Figure 3).

The fit to the research BLLOP index (2008-2015) and the fits to the remaining three indices remained poor (Figure 3).

1.2.2. Parameter Estimates and Associated Measures of Uncertainty

A list of model parameters is presented in Table 1. The table includes predicted parameter values with associated standard deviations (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 described elsewhere in section 2 of the SAR and are not included in this table.

1.2.3. Evaluation of Uncertainty

SDs for predicted parameters (Table 1) and the associated coefficients of variation (CVs) for derived stock status (Table 2) were based on the asymptotic standard errors of the parameter estimates obtained from the Hessian matrix, as described in the SAR. .Posterior distributions based on profile likelihoods were obtained for several benchmarks (Figure 4), as described in the SAR. The distribution for relative spawning stock fecundity (SSF_{2015}/SSF_0) is fairly wide, but most of the density is concentrated between 0.05 and 0.30, indicating substantial depletion (i.e. 70 – 95%). In contrast, posterior distributions for spawning stock fecundity relative to MSY and MSST levels (SSF_{2015}/SSF_{MSY} and SSF_{2015}/SSF_{MSST}, respectively) were much tighter, and indicated that relative spawning stock fecundity in 2015 was between ca. 51 and 54% of MSST levels. The posterior for apical fishing mortality relative to MSY levels (F_{2015}/F_{MSY}) showed most of the density was now less than 2 and some of the density was below 1, indicating a lower degree of overfishing compared to the SAR (Figure 4). Likelihood profiling for the other four alternative states of nature also indicated that posterior distributions for SSF_{2015}/SSF_{MSST} were tight, with spawning stock fecundity ranging from ca. 0.42 to 0.72 of MSST levels overall. Posterior distributions for F_{2015}/F_{MSY} were also tight and indicated that fishing mortality in 2015 was above that corresponding to MSY levels, albeit greatly reduced compared to the SAR results (Figure 5).

Results of the five plausible states of nature are summarized in Table 2. Estimates of spawning stock fecundity relative to unfished equilibrium (SSF_{2015}/SSF_0) ranged from 0.12 (High Productivity scenario) to 0.30 (Low Productivity scenario). Estimates of spawning stock fecundity at MSY relative to unfished equilibrium (SSF_{MSY}/SSF_0) ranged from 0.29 to 0.47.

1.2.4. Benchmarks/Reference Points

Benchmarks and MSY reference points for the five plausible states of nature scenarios are summarized in Table 2. Estimates of biomass-related benchmarks, defined here as spawning stock fecundity relative to MSY and MSST, ranged from 0.41 to 0.64 for SSF_{2015}/SSF_{MSY}, and 0.44 to 0.69 for SSF_{2015}/SSF_{MSST}. All five scenarios thus resulted in the same conclusion that the stock was overfished, as in the SAR.

The estimates of current (2015) apical fishing mortality relative to MSY (F_{2015}/F_{MSY}) in all the runs were very uncertain (CV = 1.16 – 1.37) but generally lower than in the SAR and always lower than those from the SEDAR 21 stock assessment (Table 3).

The base run indicated that the stock first became overfished in 2001 ($SSF_{2001} < SSF_{MSST}$; Figure 6) compared to 2003 in the SAR. The base model also estimated that overfishing started occurring in 1988 ($F_{1988} > F_{MSY}$) compared to 1984 in the SAR and has occurred ever since (Figure 7).

Figure 8 shows the estimated time series of relative spawning stock fecundity, apical fishing mortality rates, spawning stock fecundity in relation to MSY levels, and fishing mortality rates in relation to MSY levels obtained for the five alternative states of nature (Base, High *M*, U-Shaped *M*, High Productivity, and Low Productivity). Figure 9 is a phase plot summarizing stock status in the terminal year obtained from SEDAR 21, the SAR, and this addendum for the five alternative states of nature. Overfishing stock status as reported in this addendum has improved substantially since SEDAR 21 was conducted and also compared to the SAR (see also Table 3).

1.2.5. Projections

Results of projections are summarized in Table 4 and Figure 10 (base run only). The target year for rebuilding ($Year_{rebuild}$) ranged from 2044 to 2164 depending on the plausible state of nature for the projection scenario (Base, High *M*, U-shaped *M*, High Productivity, and Low Productivity). Projections under all scenarios still suggested that fishing mortality would need to be reduced in order to meet rebuilding targets. Since removals are generally not known for this stock, this would most likely need to be accomplished using effort reductions.

Table 5 shows the reductions in current *F* (for 2015) that would be required to achieve rebuilding with a 70% and 50% probability by $Year_{rebuild}$ based on the results of this addendum compared to those from the SAR and the SEDAR 21 stock assessment. The range of required reductions in *F* was 47-97% and 47-91% in the SEDAR 21 stock assessment and SAR, or a median value of 81% and 69%, respectively, with a 70% probability of stock rebuilding. In contrast, the range in this addendum was 39-93% or a median value of 53%. With a 50% probability of stock rebuilding, the range of required reductions in *F* was 42-90% and 26-83% in the SEDAR 21 stock assessment and SAR, or a median value of 65% and 61%, respectively, whereas the range in this addendum was 24-80% or a median value of 35%.

2 Addressing Internal NOAA Peer Reviews

2.1 Review by C.A. Tribuzio

The reviewer had no major issues with the assessment, found that all ToRs had been adequately addressed, and offered no specific recommendations for additional work. One comment made under ToR 6 was that "this update demonstrated that both the fishery dependent and independent indices may not sample the full population well, for example dome shaped selectivity of the LPS".

In response to this comment, it is true that some of the indices do not sample the entire population either because of gear selectivity (e.g., bite-offs in certain fisheries like those represented by the LPS and PLLOP indices) or because some segments of the population may not be available to the gear (e.g., the VIMS LL index capturing mostly juveniles).

2.2 Review by L. Brooks

The reviewer had no major issues with the assessment, found that all ToRs had been adequately addressed, but had several comments, which we address next.

<u>ToRs 1 and 2</u> (1. Evaluate whether the assessment updated all data inputs (to 2015) used in the SEDAR 21 base run and the four plausible states of nature identified in the SEDAR 21 peer review; 2. Evaluate whether the assessment documented any changes or corrections made to the input datasets, if applicable, and provided updated input data tables).

Comment: The reviewer commented that "For the LPS index, there were substantial differences in the updated index in 1988 and 1993 (Fig 2.3), although I did not see any explanation or hypotheses offered to explain the difference in these 2 years".

Response: The LPS index was made available to the analysts with indications that the code with which the index standardization was run had experienced some improvements since the SEDAR 21 index was developed. No other changes were introduced as the same exact model (same factors, new data) used in SEDAR 21 was run for this update.

<u>ToR 4 (</u>Evaluate whether the age-structured catch-free production model used was configured properly and used consistent with the approach and structure used in SEDAR 21).

Comment : The reviewer made the observation that "I note that no recruitment deviations were estimated for the stock recruit curve, meaning that the Beverton-Holt function was fit exactly. As there are no recruitment indices, it is not expected that recruitment deviations could be estimated. Furthermore, one would not expect a lot of process error for this life history type. Nevertheless, it was noted that the estimate of pup survival was higher than the prior, and the resulting productivity was higher than typically expected for this life history (p25). While this observation led to sensitivity analysis with alternative natural mortality scenarios (which are good hypotheses), it may also be that the pup survival rate estimate is confounded with a small but inestimable amount of process error in the S-R relationship. I note that there are sensitivity analyses to bound higher and lower productivity rates, so this is simply an observation on my part, and I am not recommending any additional runs."

Response: We fully agree with the reviewer. The lack of recruitment indices precluded estimation of recruitment deviations. The increased pup (age-0) survival estimated by the model compared to the hypothesized values reflected in the prior distribution do suggest, as noted by the reviewer, that the stock-recruitment relationship would have included some process error that we were unable to account for in the current implementation of the ASCFM. The increased pup survival and resulting increased productivity are also likely the result of the model attempting to compensate, within the limits set by the input biological parameters, for rapid increases in abundance suggested by some of the indices.

ToR 5 (Evaluate whether the assessment provided updated parameter estimates and measures of uncertainty, updated estimates of stock status and management benchmarks (*e.g.*,*Fcurrent/FMSY*, *SSBcurrent/SSBMSY*, *SSBcurrent/SSBMSST*, *MFMT*), and updated projections of future stock status, as conducted in SEDAR 21)

Comment: The reviewer commented that "It would be useful to see the uncertainty in the estimates of the time series of derived parameters (Tables 3.3, 3.4, and 3.7). Also, it was mentioned that the catch scalar was highly uncertain, but it would be good to know what the CV was on that parameter."

Response: We agree it would have been useful, but in its current implementation, the ADMB code for the ASCFM only includes uncertainty (CVs) for the terminal year (2015) of all management benchmark time series (Rec/Rec_0, N/N_0, B/B_0, SSF/SSF_0, F, F/F_{MSY}, SSF/SSF_{MSY}, SSF/SSF_{MSST}). We will expand the code in future implementations (as this was only an update) to include computation of CVs for all these quantities.

Regarding the catch scalar, indeed it was highly uncertain, with a CV>>1 (because the variance term used in the likelihood, σ^2_c, was set to a very large value of 2,000,000 so that the catch data only affected estimation of the catch scalar). This further suggests that projections based on catch-based removals should not be considered since they were themselves based on the catch scalar.

Tables

Table 1. List of parameters estimated in the base run of the dusky shark stock assessment for this addendum. The list includes predicted parameter values with associated standard deviations (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. Fishing mortality was modeled as an auto-correlated random walk so they are not 'full' parameters and thus not presented here. SDs for predicted parameters were based on the asymptotic standard errors of the parameter estimates obtained from the Hessian matrix, as described in the SAR..

	Predicted					Prior pdf		
Parameter/Input name	Value	SD	Initial	Min	Max	Type	Value	SD(CV)
Pup (age-0) survival	8.93E-01	2.56E-01	8.14E-01	5.00E-01	9.90E-01	lognormal	0.814	(0.3)
Catchability coefficient LPS index	3.12E-01	6.07E-02	2.20E-02	1.00E-04	1.00E+01	constant	0	1
Catchability coefficient BLLOP non-research index (1994-2007)	1.44E-01	3.90E-02	3.20E-02	1.00E-04	1.00E+01	constant	0	1
Catchability coefficient BLLOP research index (2008-2015)	1.55E-01	5.97E-02	3.20E-02	1.00E-04	1.00E+01	constant	0	1
Catchability coefficient VIMS LL index	1.51E-01	3.84E-02	7.41E-02	1.00E-04	1.00E+01	constant	0	1
Catchability coefficient NELL index	9.42E-02	5.72E-02	1.20E-02	1.00E-04	1.00E+01	constant	0	1
Catchability coefficient PLLOP index	1.50E-01	4.35E-02	1.70E+00	1.00E-04	2.00E+01	constant	0	1
Historic effort/F relationship	7.19E-03	8.99E-03	0.1	1.00E-13	0.7	constant	0	(0.5)
Additional variance LPS index	7.15E-08	1.01E-04	4.00E-01	0	2	constant	0	0.1
Additional variance BLLOP non-research index (1994-2007)	3.97E-08	5.62E-05	4.00E-01	0	2	constant	0	0.1
Additional variance BLLOP research index (2008-2015)	3.64E-01	3.47E-01	4.00E-01	0	2	constant	0	0.1
Additional variance VIMS LL index	7.65E-01	3.20E-01	4.00E-01	0	2	constant	0	0.1
Additional variance NELL index	2.00E+00	1.87E-03	4.00E-01	0	2	constant	0	0.1
Additional variance PLLOP index	6.96E-01	2.96E-01	4.00E-01	0	2	constant	0	0.1
Depletion in 1975	9.70E-01	3.70E-02	0.83	0	∞	lognormal	0.83	(0.202)

Table 2. Summary of stock status results obtained from the dusky shark stock assessment for this addendum for the five scenarios reflective of plausible states of nature (Base, High *M*, U-Shaped *M*, High Productivity, and Low Productivity). Coefficients of variation (CVs) for derived stock status were based on the asymptotic standard errors of the parameter estimates obtained from the Hessian matrix, as described in the SAR.

	Base		High M		U-shaped *M*		High productivity		Low productivity	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
F_{MSY}	0.025	0.066	0.012	0.064	0.015	0.062	0.039	0.058	0.005	0.065
SSF_{MSY}/SSF_0	0.36	0.18	0.44	0.50	0.43	0.46	0.29	0.08	0.47	0.07
SSF_{2015}/SSF_0	0.18	0.41	0.23	0.32	0.27	0.33	0.12	0.50	0.30	0.33
SSF_{2015}/SSF_{MSST}	0.54	0.50	0.57	0.69	0.66	0.66	0.44	0.51	0.69	0.33
SSF_{2015}/SSF_{MSY}	0.50	0.50	0.53	0.69	0.62	0.66	0.41	0.51	0.64	0.33
F_{2015}/F_{MSY}	1.12	1.29	1.45	1.36	1.08	1.36	1.18	1.16	2.92	1.37
Pup survival	0.89	0.29	0.89	0.30	0.92	0.30	0.97	NA	0.51	NA
Steepness	0.51	0.14	0.31	0.21	0.32	0.20	0.71	NA	0.25	NA

Table 3. Summary of stock status results obtained from the dusky shark stock assessment for this addendum (green highlights) compared to those from the SAR (grey highlights) and the SEDAR 21 stock assessment (yellow highlights) for the five scenarios reflective of plausible states of nature (Base, High *M*, U-Shaped *M*, High Productivity, and Low Productivity).

	Base			High *M*			U-shaped *M*			High productivity			Low productivity		
	Est (2 BLLOP)	Est (Update)	Est (SEDAR 21)	Est (2 BLLOP)	Est (Update)	Est (SEDAR 21)	Est (2 BLLOP)	Est (Update)	Est (SEDAR 21)	Est (2 BLLOP)	Est (Update)	Est (SEDAR 21)	Est (2 BLLOP)	Est (Update)	Est (SEDAR 21)
F_{MSY}	0.025	0.035	0.035	0.012	0.017	0.017	0.015	0.019	0.019	0.039	0.054	0.054	0.005	0.007	0.007
SSF_{MSY}/SSF_0	0.36	0.35	0.35	0.44	0.43	0.43	0.43	0.43	0.43	0.29	0.28	0.28	0.47	0.47	0.47
$SSF_{terminal}/SSF_0$	0.18	0.19	0.15	0.23	0.26	0.18	0.27	0.29	0.17	0.12	0.14	0.13	0.30	0.32	0.23
$SSF_{terminal}/SSF_{MSST}$	0.54	0.58	0.47	0.57	0.66	0.45	0.66	0.72	0.44	0.44	0.52	0.49	0.69	0.73	0.53
$SSF_{terminal}/SSF_{MSY}$	0.50	0.54	0.44	0.53	0.61	0.42	0.62	0.67	0.41	0.41	0.49	0.45	0.64	0.68	0.50
$F_{terminal}/F_{MSY}$	1.12	2.02	1.59	1.45	1.44	2.01	1.08	0.99	1.39	1.18	2.48	1.49	2.92	3.04	4.35
Pup survival	0.89	0.88	0.89	0.89	0.93	0.95	0.92	0.94	0.96	0.97	0.97	0.97	0.51	0.51	0.51
Steepness	0.51	0.51	0.51	0.31	0.32	0.32	0.32	0.32	0.32	0.71	0.71	0.71	0.25	0.25	0.25

Table 4. Summary of projection results obtained for the dusky shark stock assessment for this addendum for the five scenarios reflective of plausible states of nature (Base, High *M*, U-Shaped *M*, High Productivity, and Low Productivity).See SAR for definitions of YearF=0p70, $Year_{rebuild}$, *F*-$Year_{rebuild}$, and TAC-$Year_{rebuild}$. Total allowable catch (TAC) is total annual removals in lb dressed weight.

	Terminal conditions					*F* -$Year_{rebuild}$		TAC-$Year_{rebuild}$ (lb dressed weight)	
Scenario	F_{2015}	F_{2015}/F_{MSY}	SSF_{2015}/SSF_{MSY}	YearF=0p70	$Year_{rebuild}$	P50	P70	P50	P70
Base	0.028	1.12	0.50	2053	2093	0.020	0.017	32413	24188
High *M*	0.017	1.45	0.53	2097	2137	0.007	0.004	18984	10956
U-shaped *M*	0.017	1.08	0.62	2067	2107	0.011	0.008	27346	17711
High Prod	0.046	1.18	0.41	2044	2084	0.035	0.032	47400	36101
Low Prod	0.015	2.92	0.64	2164	2204	0.003	0.001	7117	3507

Table 5. Reductions in fishing mortality rate (or effort as a proxy) that would be required to achieve rebuilding with a 70% and 50% probability by $Year_{rebuild}$ based on the results of this addendum compared to those form the SAR and the SEDAR 21 stock assessment. for the five scenarios reflective of plausible states of nature (Base, High *M*, U-Shaped *M*, High Productivity, and Low Productivity).

	Required reductions in F to achieve rebuilding in $Year_{rebuild}$ with a 70% probability			Required reductions in F to achieve rebuilding in $Year_{rebuild}$ with a 50% probability		
Scenario	2011 assessment	2016 assessment	2016 assessment (addendum)	2011 assessment	2016 assessment	2016 assessment (addendum)
Base	62%	67%	39%	54%	61%	29%
High *M*	85%	71%	76%	71%	54%	59%
U-shaped *M*	81%	47%	53%	65%	26%	35%
High Prod	47%	69%	30%	42%	65%	24%
Low Prod	97%	91%	93%	90%	83%	80%

Figures

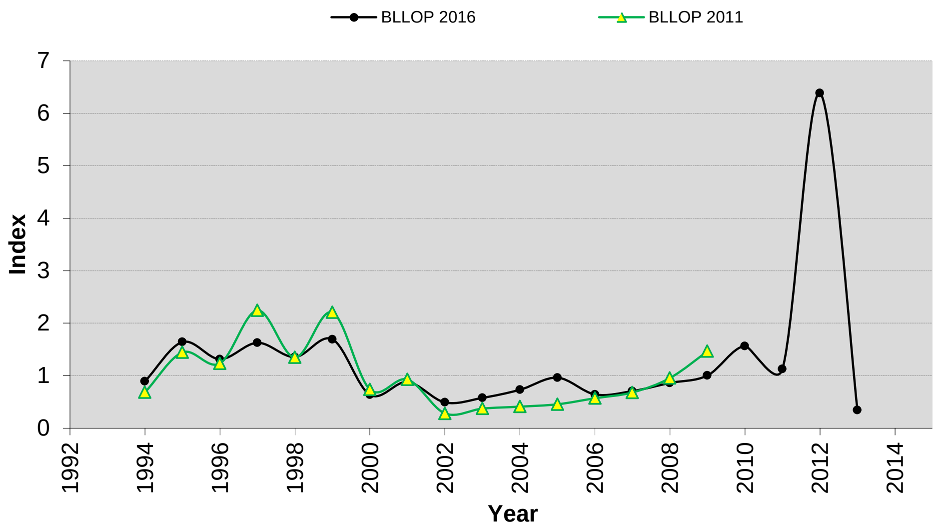


Figure 1. Bottom Longline Observer Program (BLLOP) index of relative abundance used in the preceding SEDAR 21 assessment (BLLOP 2011) vs. that used in the 2016 SAR (BLLOP 2016).

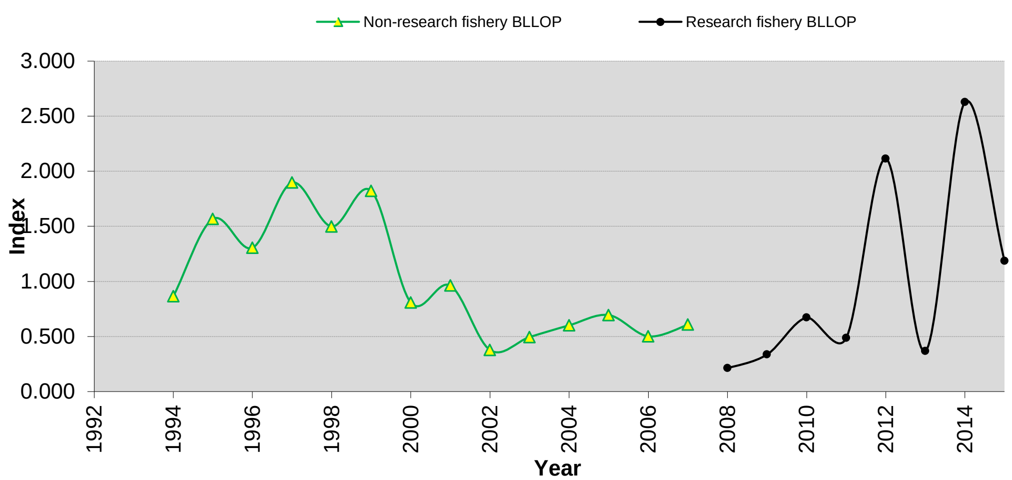
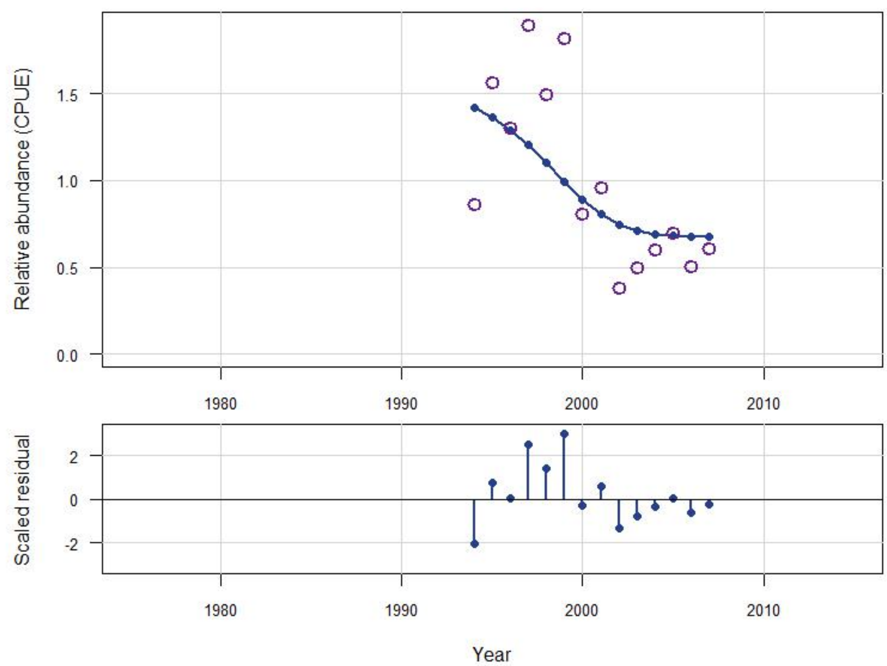


Figure 2. Bottom Longline Observer Program (BLLOP) indices obtained after splitting the original series into a non-research fishery index (1994-2007) and a research fishery index (2008-2015) and used in this addendum.

A. BLLOP Non-research fishery



B. BLLOP research fishery

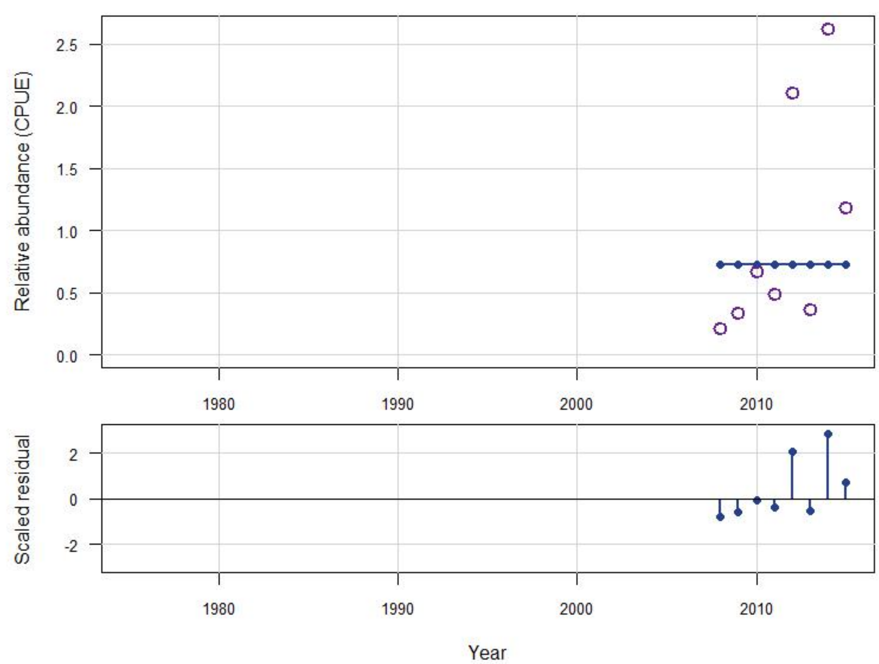
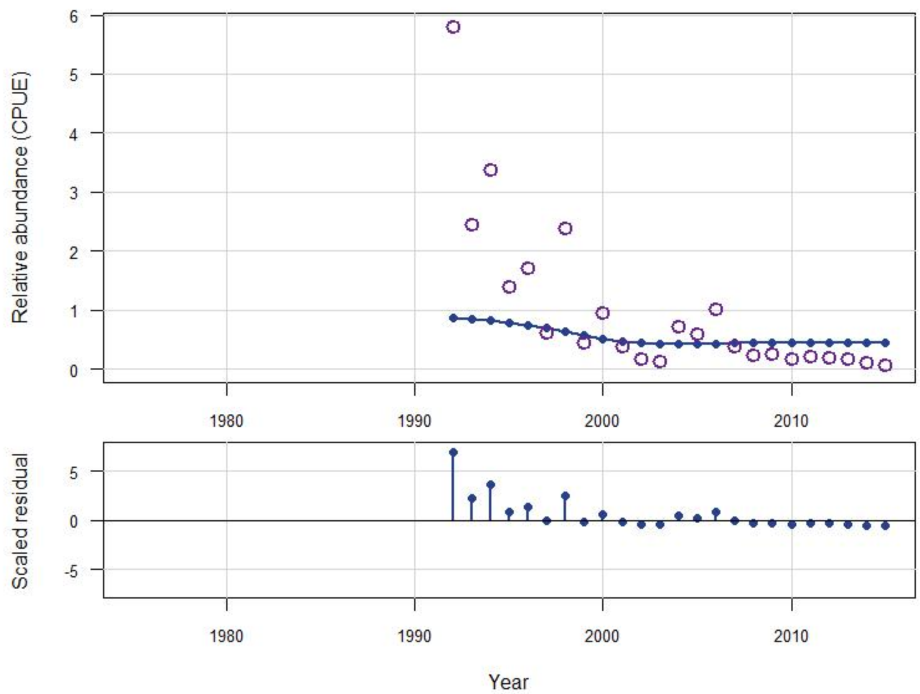


Figure 3. Fits to indices obtained from the base run of the dusky shark stock assessment for this addendum. The line with solid circles denotes ASCFM predictions, while open circles denote observed values. Bottom panels give scaled residuals.

C. PLLOP



D. LPS

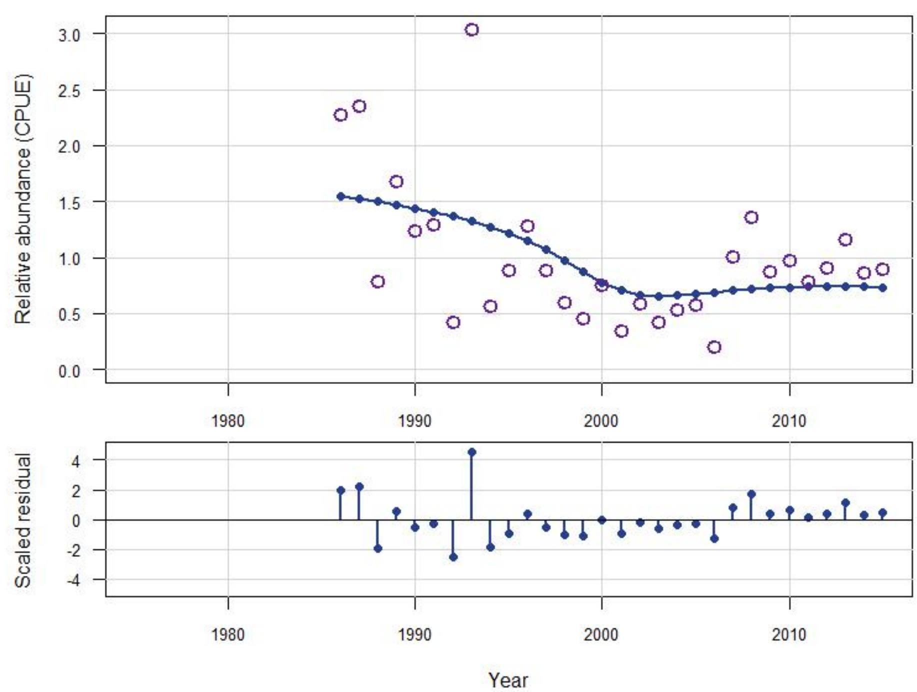
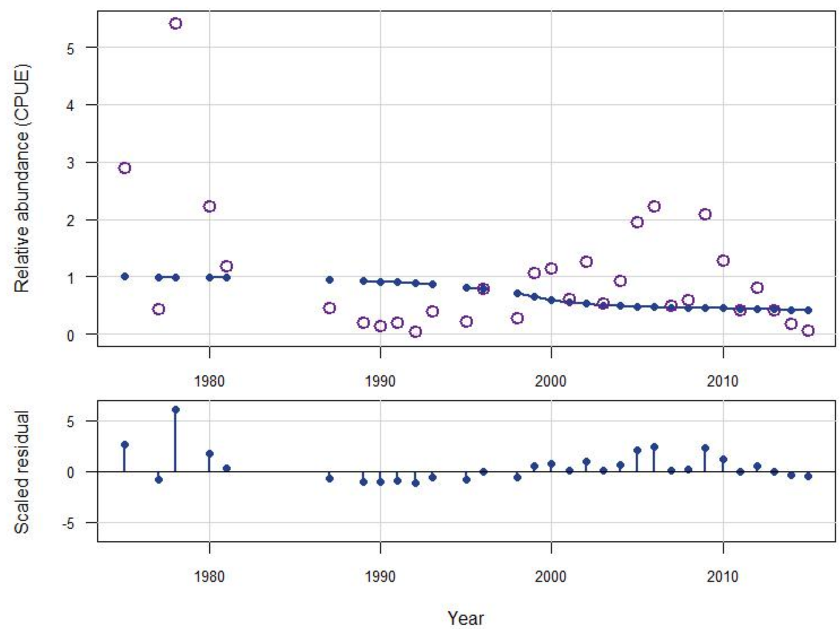


Figure 3**.** Fits to indices for the base run (continued).

E. VIMS LL



F. NELL

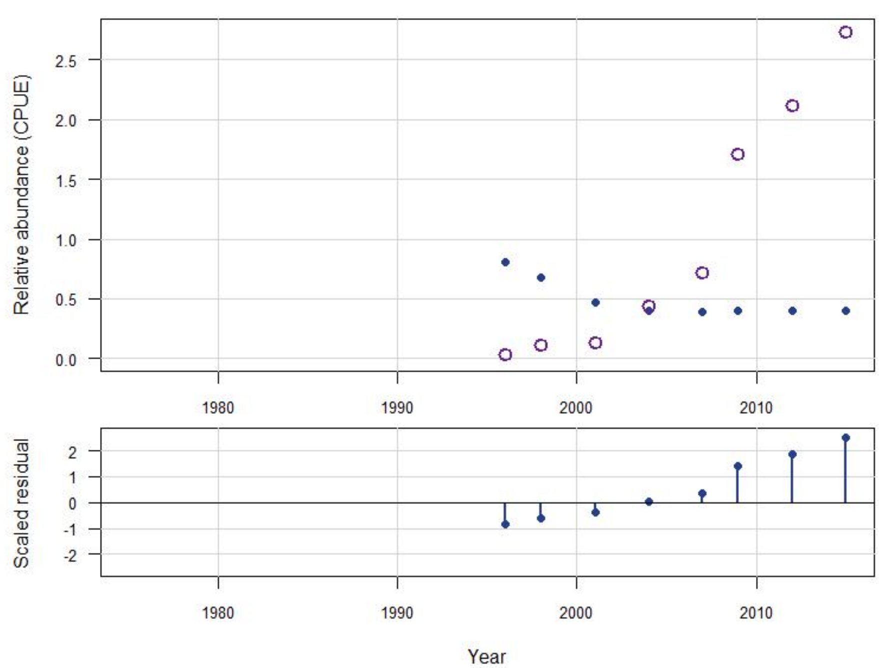


Figure 3. Fits to indices for the base run (continued).

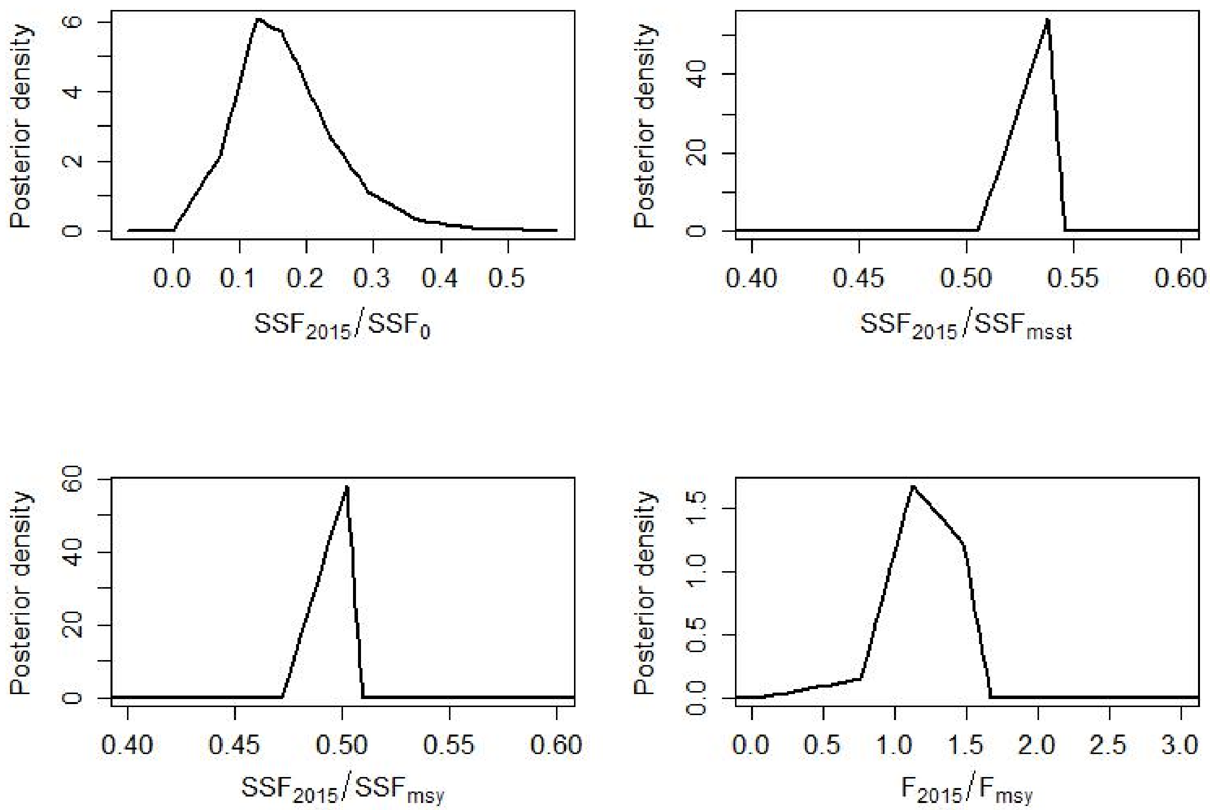


Figure 4. Estimated posterior distributions for stock status relative to management benchmarks obtained from the base run of the dusky shark stock assessment for this addendum.

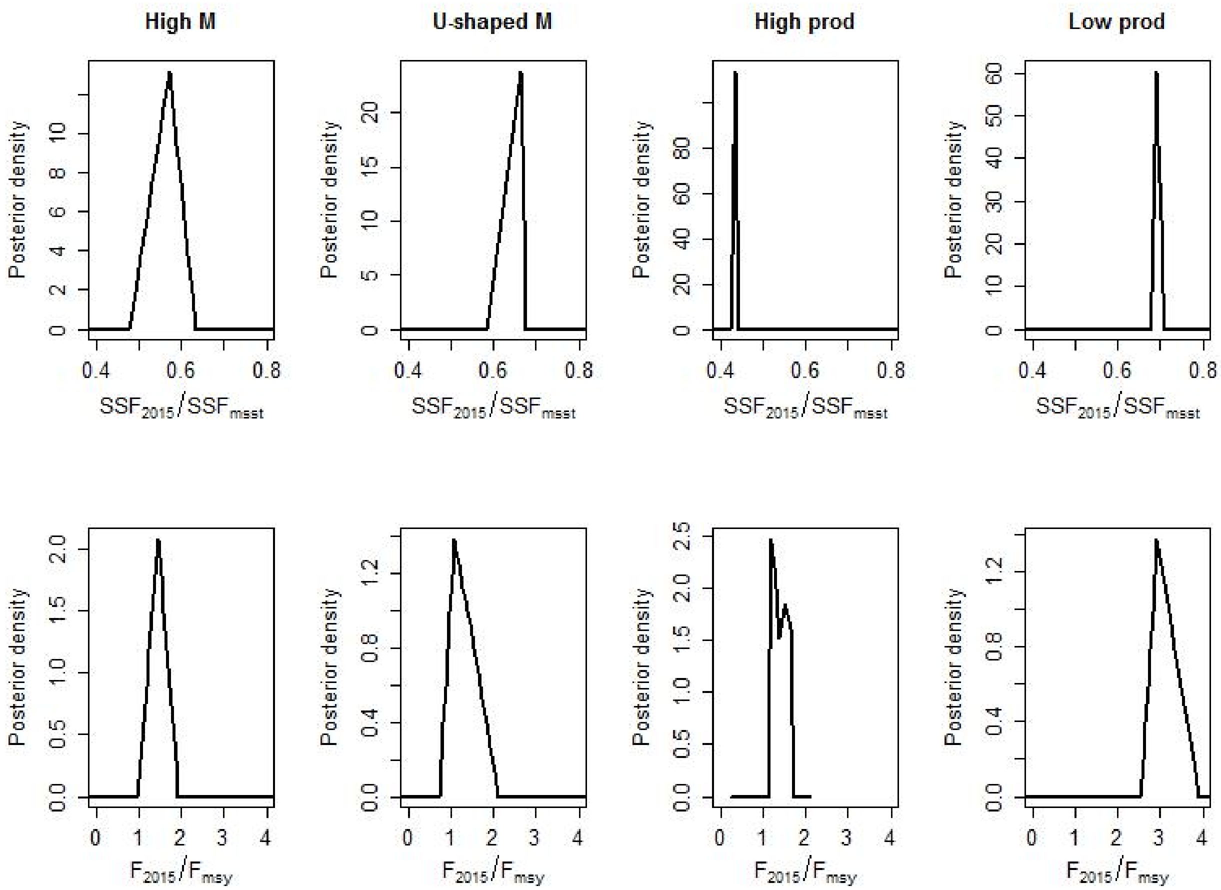


Figure 5. Estimated posterior distributions for stock status relative to management benchmarks (top panels: SSF_{2015}/SSF_{MSST}; lower panels: F_{2015}/F_{MSY}) obtained from the dusky shark stock assessment for this addendum for four additional scenarios reflective of plausible states of nature (High *M*, U-Shaped *M*, High Productivity, and Low Productivity).

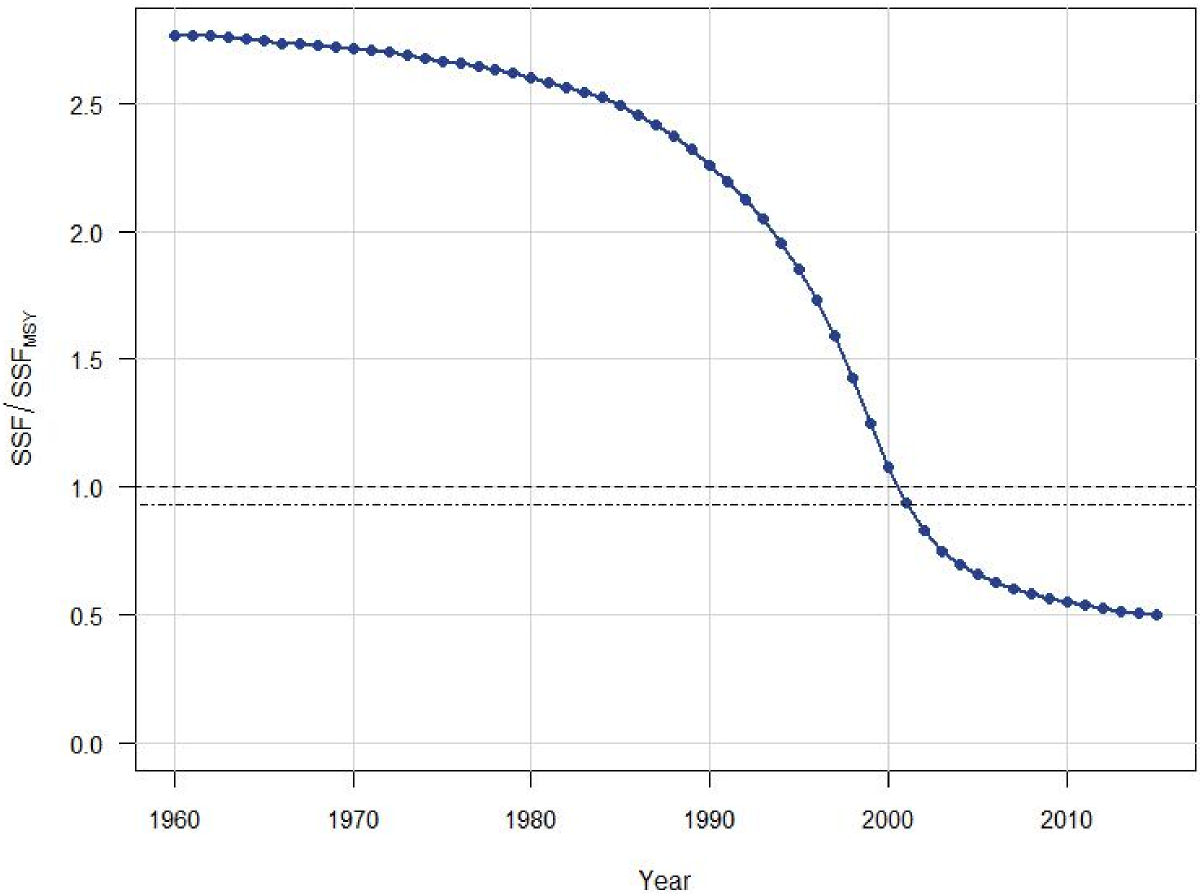


Figure 6. Spawning stock fecundity relative to MSY levels (horizontal dashed line) over time obtained from the base run of the dusky shark stock assessment for this addendum. The lower horizontal dot-dash line indicates the MSST level.

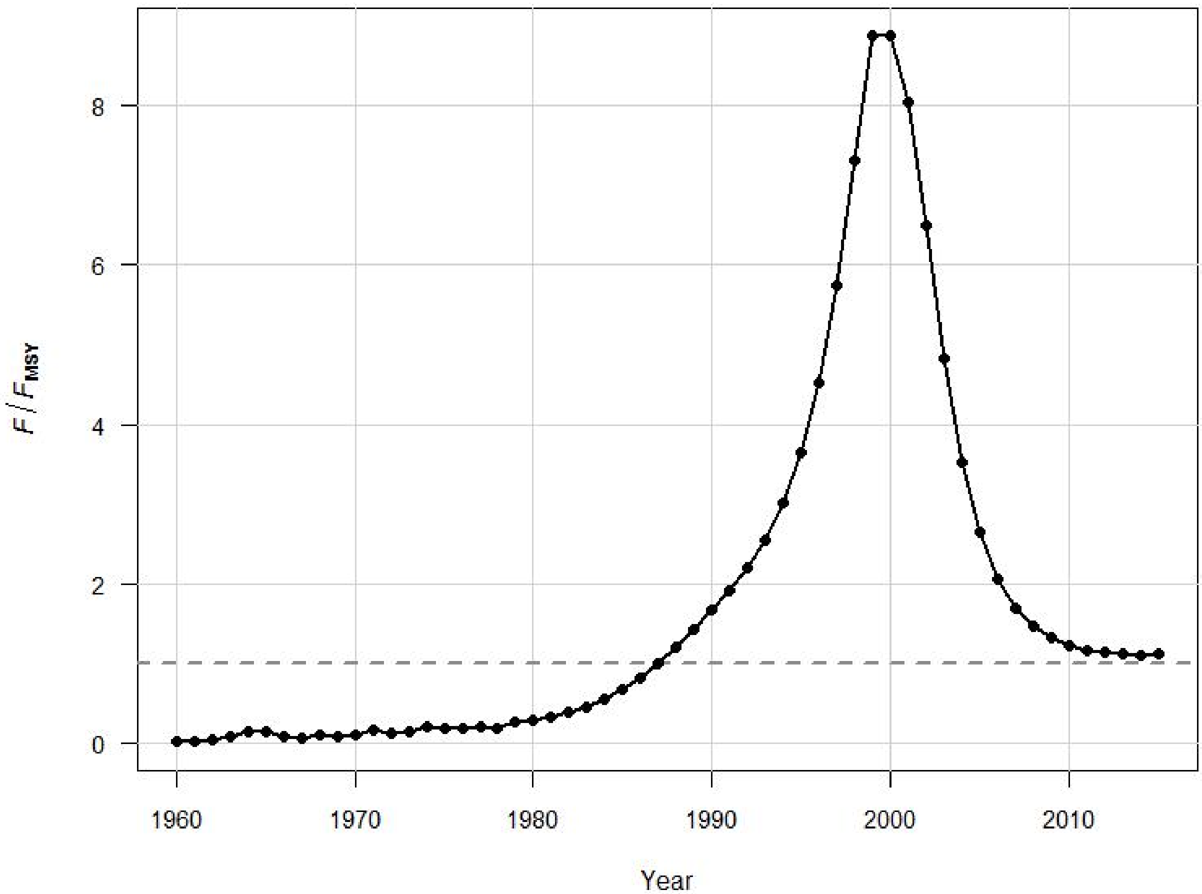


Figure 7. Apical fishing mortality relative to MSY levels obtained from the base run of the dusky shark stock assessment for this addendum, indicating that overfishing has been occurring since 1988.

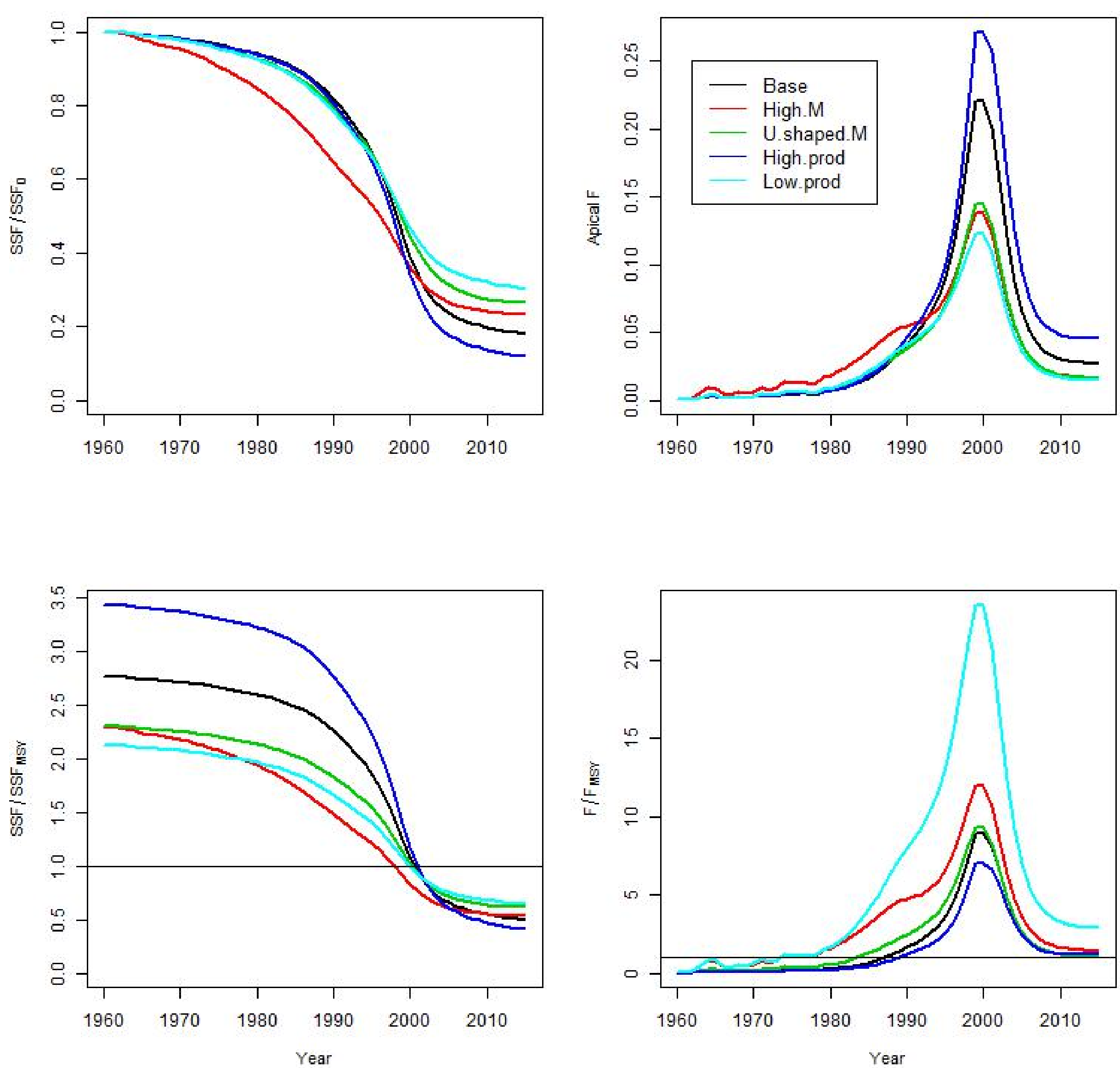


Figure 8. Estimated time series of relative spawning stock fecundity, apical fishing mortality rates, spawning stock fecundity in relation to MSY levels, and fishing mortality rates in relation to MSY levels obtained from the dusky shark stock assessment for this addendum for the five scenarios reflective of plausible states of nature (Base, High *M*, U-Shaped *M*, High Productivity, and Low Productivity).

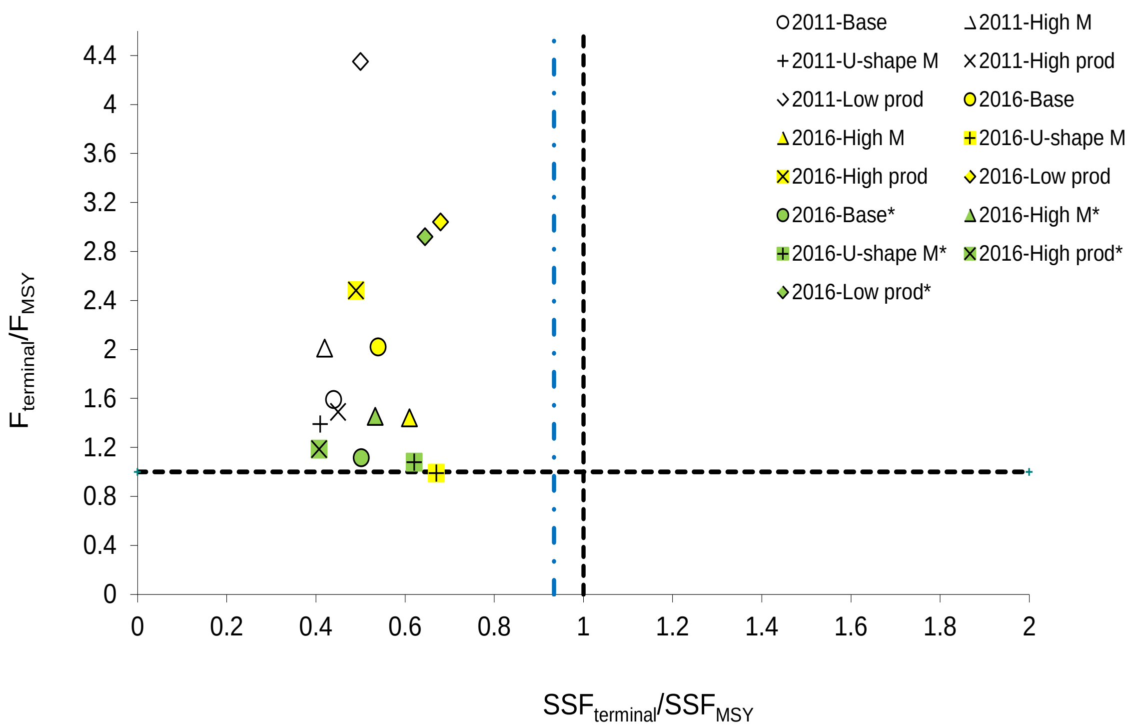


Figure 9. A phase plot summarizing stock status of dusky sharks in the terminal year from SEDAR 21 (2009, open symbols), the SAR update (2015, yellow symbols), and for this addendum (2015, green symbols) for the five scenarios reflective of plausible states of nature (Base, High *M*, U-Shaped *M*, High Productivity, and Low Productivity). For clarity we only show the overfished reference point (relative to SSF_{MSST}) for the addendum base run (vertical dot-dashed line), with points to the left of the line indicating the stock was estimated to be

overfished ($SSF_{terminal} < SSF_{MSST}$). Points above the horizontal black line indicate overfishing is estimated to have occurred ($F_{terminal} > F_{MSY}$).

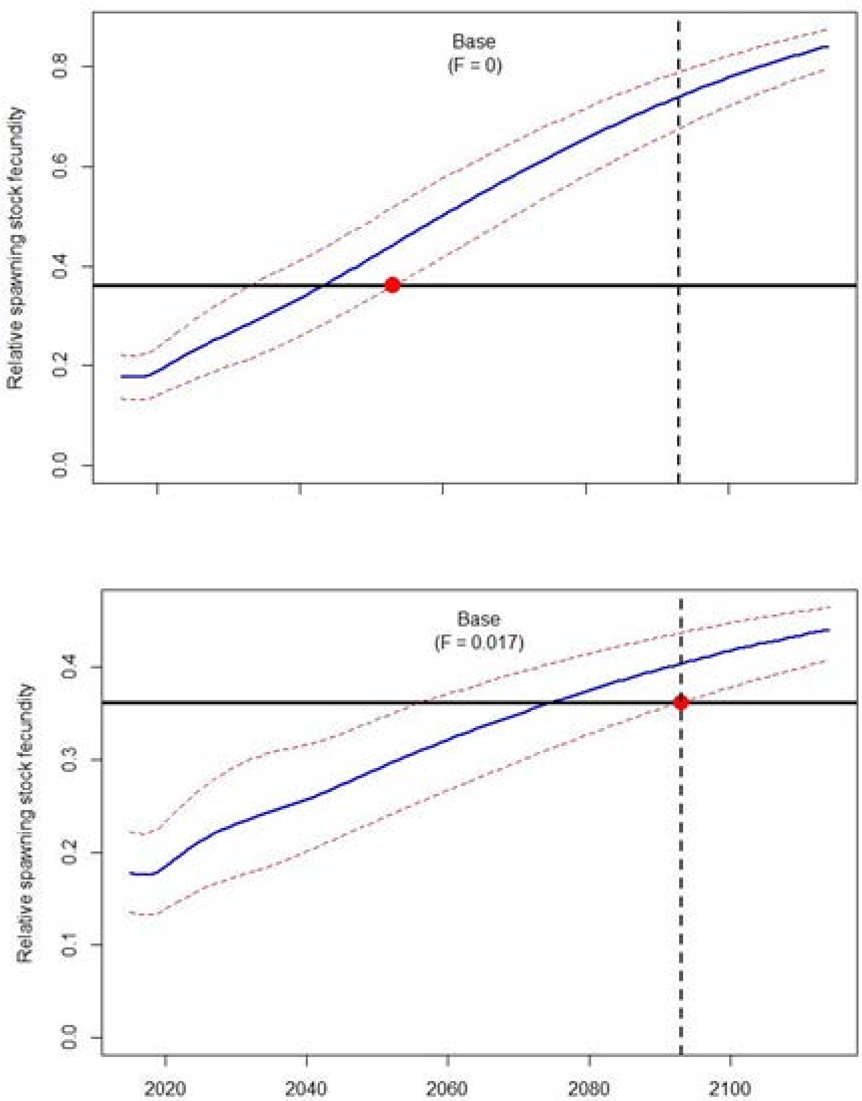


Figure 10. Projections for the base scenario for this addendum; Median (blue line), 30th, and 70th percentiles (red dashed lines) of relative spawning stock fecundity (SSF_t/SSF_0) obtained from 10,000 bootstrap replicates. Rebuilding to relative SSF_{MSY} (SSF_{MSY}/SSF_0; horizontal solid black line) under zero fishing mortality (F = 0) is achieved with 70% probability in year 2053 ($YearF{=}0_{p70}$, solid red circle in upper panel). Rebuilding with 70% probability by 2093 ($Year_{rebuild} = YearF{=}0_{p70} + 40$; vertical dashed black line) is achieved with a constant fishing mortality F = 0.017 (solid red circle in lower panel).