

Memorandum

To: John Boreman, Chair, Mid-Atlantic Fisheries Management Council SSC
From: Thomas Miller, Chair, Blueline Tilefish Working Group, MAFMC SSC
Date: March 22, 2016
Re: Proposed BLT Subcommittee Report

Introduction (Including Term of Reference and brief statement of purpose)

Blueline tilefish (*Caulolatilus microps*) is a deep water fish in the family Malacanthidae that is distributed along the US Atlantic and Gulf of Mexico coasts. Based on the historical distribution of commercial and recreational catches, the species has been managed as two separate stocks: a south Atlantic stock and a Gulf of Mexico stock. The status of the stock in the south Atlantic was determined by a stock assessment overseen by the South Atlantic Fishery Management Council (Southeast Data Assessment and Review, 2013). This SEDAR 32 assessment considered the status of the stock based on catches northward of the Florida Keys. However, on February 25, 2015, based on concerns of increasing catches of blueline tilefish in waters off of Virginia, the Mid-Atlantic Fishery Management Council (MAFMC) voted to request emergency action by the National Marine Fisheries Service to restrict commercial and recreational catches of blueline tilefish in the Mid-Atlantic. Subsequently, on April 15, 2015 the MAFMC voted to develop of measures for the long term management of blueline tilefish in the Mid-Atlantic. Based on this action, the Council held five scoping meetings from 1-6 June 2015 to obtain stakeholder input. Based on this input, the MAFMC endorsed development of a range of alternative management actions in October 2015.

The MAFMC requested its Scientific and Statistical Committee (SSC) form a working group to evaluate knowledge of the status of blueline tilefish in Mid-Atlantic waters. The working group was given the following term of reference:

TOR #1. Review data-poor approaches that can (or cannot) be used for developing an ABC for Blueline Tilefish north of NC. Based on the review, the SSC will then determine what data-poor method is most suitable to use.

This document summarizes the working group's results regarding development of ABCs for blueline tilefish in the Mid-Atlantic that were presented for consideration by the whole SSC at its March 15-16, 2016 SSC meeting.

The SSC working group appointed to review the approaches on data-poor approaches to establish catch advice for blueline tilefish is comprised of Thomas Miller (Working Group Chair, and Vice Chair MAFMC SSC), Michael Schmidtke (Old Dominion University), Cynthia Jones (MAFMC SSC), and David Tomberlin (MAFMC SSC).

Data Poor Approaches

Over the last decade, the MAFMC SSC has used a range of approaches identified in the Council's Risk Policy when confronted with its responsibility to make Allowable Biological Catch (ABC) determinations for data-poor stocks. Central to ABC decision making was whether or not an overfishing limit (OFL) could be defined for the stock. In cases where no OFL could be determined, the SSC relied on data from either fishery-independent surveys or from commercial catch time series to develop an ABC based on a constant catch procedure that sought to either maintain the stock or return the stock to a condition that was believed, based on the weight of evidence, to be sustainable. In cases where determining an OFL was possible, the SSC provided an ABC recommendation based on the current stock biomass relative to the target biomass and an empirically determined level of uncertainty in the estimated OFL.

Because of their ubiquity worldwide, approaches to estimating sustainable fishery management procedures for data poor stocks have received considerable attention. Determining the performance of proposed management procedures **for data poor stocks** has been a central challenge limiting their applicability. However, application of management strategy evaluation (MSE) simulations has substantially advanced our understanding of the performance of alternative management procedures (e.g., Geromont and Butterworth, 2015). Based on these evaluations a data limited method tool box (DLMTool) was developed by Carruthers et al. (2014a). **Application of the DLMTool is a two-step process. In the first step, DLMTool evaluates the performance of 47 different fishery management procedures in an operating model of a simulated fishery, which is parameterized using only life history parameters from the species under consideration.** Many of the 47 different management procedures are alternative "flavors" of the same approach, only with slightly different parameterizations. The management procedures are evaluated against a set of user defined performance measures in a closed loop MSE that projects a population forward under a defined management procedure by sampling from distributions of biological, fishery and observation processes. The MSE assumes perfect implementation of each management procedure. From the output of the MSE, the management procedures that **meet or exceed a priori performance objectives are identified. In the second stage, DLMTool uses the observed catch history and the life history parameters to provide catch advice based on the selected management procedures.**

The first stage in the DLMTool approach is a management strategy evaluation based on the analysis of an operating model that is parameterized to represent what is known about the biology of the stock and characteristics of a fishing fleet and the sampling uncertainty

associated with the species under consideration. Importantly, this first stage does not use any information from observed catches.

Details of the operating model are given in Caruthers et al (2014b), and are only summarized here. The operating model is parameterized by three components: the stock, the fleet, the observations, which together represent what is known about the biology of the stock and characterize the performance of possible fishery fleets and sampling uncertainty of the species under consideration.

The stock component of the operating model uses an age-structured model which is initialized using equilibrium assumptions regarding age and spatial structure. Specifically,

$$N_{y=1,a,r} = R_0 (e^{-\tilde{M}})^{a-1} d_r \quad \text{Eq. 1}$$

where y , a , and r are indices of year, age and region. R_0 is the virgin recruitment. In cases where R_0 is poorly known, the value of R_0 used is selected to ensure the largest catch observed in the time series can be removed without generating negative abundances. As a result of defining R_0 as a scalar, all yield calculations are expressed in terms of relative yield, because the actual values of yield cannot be calculated. M is the natural mortality rate, and any parameter indicated with an accented \sim implies that its value is drawn from a uniform distribution with specified bounds for each simulation. d is the proportion of the stock in each region. In this way, each simulation of the model starts with a potentially different equilibrium abundance of fish.

In each subsequent year of the simulation the population generates recruitment, is fished and moves.

Recruitment was defined using a Beverton-Holt stock recruitment relationship defined as

$N_{y+1,a=1,r} = \exp\left(P_{y,a,r} - \frac{\tilde{\sigma}_{proc}^2}{2}\right) \frac{0.8R_0\tilde{h}SSB_{y,r}}{0.2SSB_0(1-\tilde{h}) + (\tilde{h}-0.2)SSB_{y,r}}$	Eq. 2
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where P is a process error term ($\sim N(0, \tilde{\sigma}_{proc})$), h is the steepness, $SSB_{y,r}$ is the spawning stock biomass in in year y and in region r , and SSB_0 is the virgin spawning biomass.

The numbers at age are converted to weight at age via a von Bertalanffy growth equation (parameters sampled stochastically from a specified uniform distribution) and an allometric length-weight relationship (parameters sampled stochastically from a specified uniform distribution). The spawning stock biomass is defined by a user-defined maturity schedule. Thus, recruitment in each year is a random process determined as the interaction of stochastic draws from uniform distributions representing process error, steepness, von Bertalanffy growth parameters, allometric coefficients, and maturation rates.

The abundance of older age classes ($a > 1$) is governed by a catch equation:

$N_{y,a,r} = (N_{y-1,a-1,r} - C_{y-1,a-1,r}) \exp(-\tilde{M})$	Eq. 3
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where $C_{y,a,r}$ is a year-specific, age-specific, region-specific catch. Catch is calculated in the model based on a flexible double normal vulnerability function and a fishing mortality rate $F_{y,a}$:

$C_{y,a,r} = N_{y,a,r} (1 - \exp(-\omega_a p_{y,r} R_r F_{y,a}))$	Eq. 4
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Where ω_a is the age-specific vulnerability, $p_{y,r}$ is the proportion of effort in the region and R_r represents the size of potential refuges. The fishing mortality rate F is itself a function of a stochastic fishing effort \tilde{E}_y . Fishing effort in each year is calculated as the product of a stochastic catchability term (\tilde{q}) and a stochastic random walk process (defined by the user) which allows effort to change from year to year. The random walk in effort can be characterized as increasing, decreasing, or stable, based on user inputs. Importantly, the specific simulated catches taken can be limited by application of any of 47 management procedures.

Movement among regions occurs after recruitment and catch, and is specified by a region-specific movement probability. For our application to blueline tilefish we did not identify any regional differences or any spatial refuges.

Analysts also define desirable performance measures for the fishery, such as the probability of overfishing (POF), the probability of the stock biomass being greater than MSY , etc. These performance measures are used to gauge how effective each of the management procedures are in meeting predetermined objectives for the fishery. Performance measures generated by DLMTTool were designed specifically to reflect requirements of the Magnuson Stevens Fishery Conservation and Management Act (MSA) to prevent overfishing, to avoid becoming overfished and to produce sustainable yields to benefit the nation (Carruthers et al., 2014a). The probability of overfishing in each simulation was calculated as the fraction of projected years in which $F > F_{MSY}$, averaged over all simulations. Similarly, the probability of being overfished was calculated by accumulating the number of years when $B < 0.5B_{MSY}$ in each simulation and then averaging over all simulations. DLMTTool also calculates relative yield, based on the yield in the last five years of each simulation, compared to the yield produced by application of the constant F fishing policy that produces the highest catch in the last five years for the particular suite of input variables.

In the second step of the application, DLMTTool applies specified management procedures (in this case, those that meet a priori MSE performance measures) using the actual data streams available for the species. Each management procedure is parameterized stochastically using observed catches and random draws of key life history input parameters required by each selected management procedure to yield a distribution of the ABC for each method. Often

multiple management procedures are shown to meet the performance measures set as objectives in the first stage of the analysis. In its application of the DLMTTool to recommend an ABC for black sea bass, the SSC recommended an ABC based on the average of the median values of all the management procedures that met the performance measures in the MSE.

The DLMTTool was used for the first time by the SSC in developing its ABC recommendation for black sea bass in 2015, based on an analysis by McNamee et al (2015). In its review of the McNamee et al. report, a sub-committee of the SSC noted that as applied in the McNamee et al. (2015), DLMTTool conflated the two approaches to establishing ABCs identified in the MAFMC's Risk Policy regarding the ability to estimate an OFL (Miller et al., 2015). In considering the application of DLMTTool to blue line tilefish, the SSC recommend maintaining a clear distinction between those DL management procedures that estimate OFL and those that provide an estimate of ABC. The reasoning for the distinction is that OFL-based reference points and ABC-based reference points estimate different things, and failing to recognize this difference will increase the uncertainty in any recommended ABC. An additional advantage of maintaining the distinction between OFL- and ABC-based reference points is that the two categories of reference points may provide an additional empirical check on the reliability of each because OFL estimates should be greater than the ABC estimates.

Application of DLMTTool to Blueline Tilefish

The SSC working group applied DLMTTool to blueline tilefish in the mid-Atlantic. We did not define regional differences spatially, or define any refuges from fishing. In this way, the DLMTTool is modeling a single uniform population subunit.

A) Inputs

A) 1. Performance measures

We considered three categories of performance measures: probability of overfishing, probability of being overfished ($BMSY < 0.5$) and relative yield. Following interpretation of MSA National Guideline 1, we considered acceptable only those management procedures that resulted in a probability of overfishing < 0.5 and a probability of being overfished ($50\% B_{MSY}$) < 0.5 . Additionally, the work group sought policies that maintained sufficient yield to support a viable fishery. We defined acceptable management procedures as those that supported relative yields in the range of 30-100%.

We note that these definitions are less conservative than those used in the application of DLMTTool to black sea bass which defined acceptable management procedures as those that met the following criteria: $P(\text{overfishing}) < 0.3$, $P(10\% BMSY) < 0.2$ and relative yield $> 50\%$.

A) 2. Life history data

Parameter inputs were derived from a study of life history for blueline tilefish predominantly from the Norfolk Canyon by researchers at the Center for Quantitative Fisheries Ecology at Old Dominion University (ODU). The ODU data were collected from 2009-2014, primarily by donations of carcasses from recreational anglers through the Virginia Marine Resources Commission's Marine Sportfish Collection Program, but also through purchases of commercial catches and research collections aboard recreational charter and head boat vessels. Researchers collected data on the length, weight, sex and maturity status of each fish and removed otoliths for subsequent ageing (n=2293). These data were supplemented by data provided by the NMFS, based on collections in the same region from 2007-2008 (n=146). Of these combined data, 84% of samples came from the recreational fishery, 2% from commercial, and 14% from research collections.

Procedures standard to the Age and Growth Laboratory at ODU were used to age blueline tilefish and estimate life history parameters (<http://www.odu.edu/sci/research/cqfe/research/ageing-lab>). Briefly, aging was attempted for all ODU samples collected from 2009-2011 (n=983), while only a subsample of 2012 data and no samples from 2013-2014 were aged. Von Bertalanffy parameters and coefficients of variation (CV) were estimated by a non-linear least squares (LS) regression of ages and total lengths (TL; cm) from the combined NMFS and ODU data. As most of the NMFS data and some of the ODU data only contained forked lengths, these were converted to TL by a conversion factor estimated through linear LS regression of ODU and NMFS data with both measurements (n=2031). Parameters and CVs for the weight (kg)-TL relationship were estimated by non-linear LS regression of a subset of the ODU data that included both measurements (n=220).

Length at 50% maturity was estimated as halfway between the TLs of the smallest mature female and the only immature female from the ODU data. Length at first capture was the smallest observed TL from the combined NMFS and ODU data. Length at full selection was the mode of TLs from the combined NMFS and ODU data. Numbers caught at length were from all of the combined NMFS and ODU data, separated by year and into 1 cm TL bins.

The maximum age for blueline tilefish in the Mid-Atlantic was defined as the maximum observed age for the combined NMFS and ODU data. An estimate of natural mortality (M) was developed as the mean of the Alverson-Carney (1975), Hoenig (1983), and Pauly (1980) estimators. The environmental temperature used in these methods was the average of bottom temperatures for areas in which blueline tilefish were captured during ODU research cruises in 2013.

All life history parameters used in subsequent model are provided in Table 1.

Parameter	Value (\pm SD)
Von Bertalanffy Growth Parameters	
k	0.098 \pm 0.0050
Linf (cm)	92.63 \pm 1.76
T0	-0.37 \pm 0.20
Length-Weight Relationship	
a	0.00000222 \pm 0.000000377
b	3.39 \pm 0.41
Maturity and Selectivity	
TL at 50% maturity	33
Length at first capture	26
Natural Mortality	0.13 \pm 0.047 (Alverson-Carney M=0.086, Hoenig M= 0.12, Pauly M=0.20)

Table 1. Life history parameters for blueline tilefish in the Mid-Atlantic

A) 2. Removals

Information on removals of blueline tilefish in Mid-Atlantic waters were derived from a report by Jason Didden (MAFMC Staff, February 23, 2016). Available commercial data and recreational data on removals were combined. The recreational data were developed from a series of surveys and interviews with charter boat and headboat operators and individual private anglers with expert knowledge of fishing for tilefish in the Mid-Atlantic. Recreational numbers were converted to weights by multiplying them by the weight (1.657 kg) corresponding to the average TL (53.9 cm) of the combined NMFS and ODU data. The estimates of removals of blueline tilefish are provided in Table 2.

Table 2. Total removals of blueline tilefish in Mid-Atlantic waters. Recreational catches include a six-fold correction for under-reporting in charter and headboat removals, and 2% discard mortality in the commercial fishery. Values highlighted in yellow are estimates for the recreational removals in 1999-2002, based on reported recreational removals in 2003-2006.

Year	BLT Caught (pounds)			BLT Caught (kg)		
	Commercial	Recreational	Total	Commercial	Recreational	Total
1999	33.33	786.30	819.64	15.12	356.66	371.78
2000	2470.71	786.30	3257.01	1120.69	356.66	1477.36
2001	944.44	786.30	1730.75	428.39	356.66	785.05
2002	307.07	786.30	1093.37	139.28	356.66	495.95
2003	6274.24	786.30	7060.55	2845.95	356.66	3202.61
2004	7406.06	786.30	8192.36	3359.33	356.66	3715.99
2005	4205.56	786.30	4991.86	1907.61	356.66	2264.27
2006	28437.37	786.30	29223.68	12898.98	356.66	13255.64
2007	26095.45	24186.03	50281.48	11836.70	10970.60	22807.30
2008	7881.38	6860.30	14741.69	3574.94	3111.78	6686.72
2009	39205.05	27118.72	66323.77	17783.11	12300.84	30083.96
2010	7439.39	14639.75	22079.14	3374.45	6640.48	10014.93
2011	17670.20	31841.29	49511.49	8015.07	14442.97	22458.04
2012	41268.18	67869.29	109137.47	18718.93	30784.99	49503.92
2013	33610.61	90578.99	124189.60	15245.51	41085.94	56331.45
2014	204017.17	122531.27	326548.44	92540.63	55579.25	148119.88
2015	74380.81	143013.16	217393.97	33738.57	64869.68	98608.25

B) DLMTTool specification

The operating model (OM) within DLMTTool is specified by three classes of parameters: stock – which defines the biology of the species, fleet – which defines the parameters of the fishery, and observation – which defines levels of uncertainty and bias in observed data. All modeling was conducted using the DLMTTool package v 3.1 in R. The model code is provided in Appendix 1.

B) 1. DLM Stock Definition

The DLM stock definition for blueline tilefish was based on a re-parameterization of Porgy stock provided in the R package. The following data definitions were used:

Table 3. The values (or ranges) and definitions of parameters used to define the blueline tilefish stock class in DLMTool. Values determined directly from mid-Atlantic samples are shown in blue shading

Parameter	Value or Range	Definition
blStock@maxage	40	Maximum age – Table 1
blStock@Ro	500,000	Unfished recruitment (kg), arbitrarily set based on highest observed catch
blStock@M	0.086-0.20	Range based on estimate M from Table 1
blStock@Msd	0-0.36	Estimated coefficient of variation (CV) of M as CV of Alverson-Carney, Hoenig, and Pauly estimates from Table 1
blStock@Mgrad	-0.2 – 0.2	Range of annual rate of change of M – reasonable value
blStock@h	0.7 – 0.9	Steepness of the stock-recruitment relationship, based on SEDAR 32 value of 0.84
blStock@Srel	1	Beverton-Holt stock recruitment definition
blStock@Linf	87.63 - 97.63	Range of von Bertalanffy Linf parameter (cm), based on Table 1
blStokc@vbK	0.048 – 0.148	Range of von Bertalanffy k parameter, based on Table 1
blStock@vbt0	-0.47 - -0.27	Range of von Bertalanffy t0 parameter, based on Table 1
bkStock@Ksd	0-0.051	Range of CV of K, based on Table 1
blStock@Kgrad	-0.2 – 0.2	Range of annual rate of change of K – reasonable value
blStock@Linfsd	0-0.019	Range of CV of Linf, based on Table 1
blStock@Linggrad	-0.25 – 0.25	Range of annual rate of change of Linf – reasonable value
blStock@recgrad	-10 – 10	Rate of change in lognormal recruitment deviations – reasonable value
blStock@AC	0.1 - 0.9	Autocorrelation in recruitment – reasonable value
blStock@a	0.00000222	Intercept of length-weight relationship, based on Table 1
blStock@b	3.39	Intercept of length-weight relationship, based on Table 1
blStock@L50	30 – 50	Length at 50% maturity, based on Table 1
blStock@D	0 – 0.5	Depletion of stock – $B_{\text{current}} / B_{\text{MSY}}$ – reasonable value
blStokc@Size_area_1	0.8 – 0.99	Relative area of exploitable region – reasonable value (high values indicate no marine reserve)
blStock@Frac_area_1	0.8 – 0.99	Fraction of Area1 occupied – reasonable value
blStock@Prob_staying	0.8 – 0.99	Probability of individuals staying in area 1
blStock@Source	Table 1	

bIStockPerr	0.5 – 0.8	Extent of inter-annual variability in log normal recruitments – reasonable value
bIStock@L50_95	11 – 20	Growth increment (cm) between length at 50% maturity and 95% maturity - lower bound: difference between input L50 and L50 from SEDAR 32 (44), upper: reasonable value

The growth parameters used in the this application of DLMTool are substantially different to those used in the South Atlantic stock assessment for blueline tilefish (Southeast Data Assessment and Review, 2013). Specifically, the L_{inf} for the mid-Atlantic is approximately 50% larger than for the south Atlantic, and the mid-Atlantic k value is about half that of the south Atlantic value.

The steepness parameter was based on the results of the south Atlantic assessment. The age-structured model used in the south Atlantic assessment could not estimate h reliably, and the assessment team agreed on a fixed value of $h=0.84$. In our application we bracketed this fixed value using values $0.7 < h < 0.9$. This range matches well those estimated by Shertzer and Conn (2012). The coefficient of variation of M was lower than the $CV(M)=0.5$ recommended by MacCall (2009) but was calculated based on the three different indirect methods of estimating M .

B) 2. DLM Fleet Definition

The FLEET component of the operating model defines how effort changes within and between simulations. Effort is used in DLMTool to force fishing mortality rates and ultimately removals. Fishing effort in these simulations is modeled as a random walk. The pattern of the inter-annual change is driven by variance terms that specify the degree of autocorrelation and the scale in interannual variation. As result, the definition of the generic fleet can produce effort time series in individual simulations that vary considerably. DLMTool offers ways to filter this variance to consider effort simulations that reflect only patterns of increasing effort, patterns of relatively constant effort, or patterns of decreasing effort.

The FLEET class allows also specification of the duration of the historical simulation.

For the application of DLMTool to blueline tilefish, we explored the performance of management procedures using a generic fleet, a constant effort fleet and an increasing effort fleet.

B) 3. DLM Observation Definition

Because of the lack of information available from both fishery dependent and fishery-independent time series, we adopt the generic imprecise and biased observation model in our observation model.

C) Results

Preliminary modeling indicated that 14 management procedures could be developed from the data available for blueline tilefish in the Mid-Atlantic (Table 4).

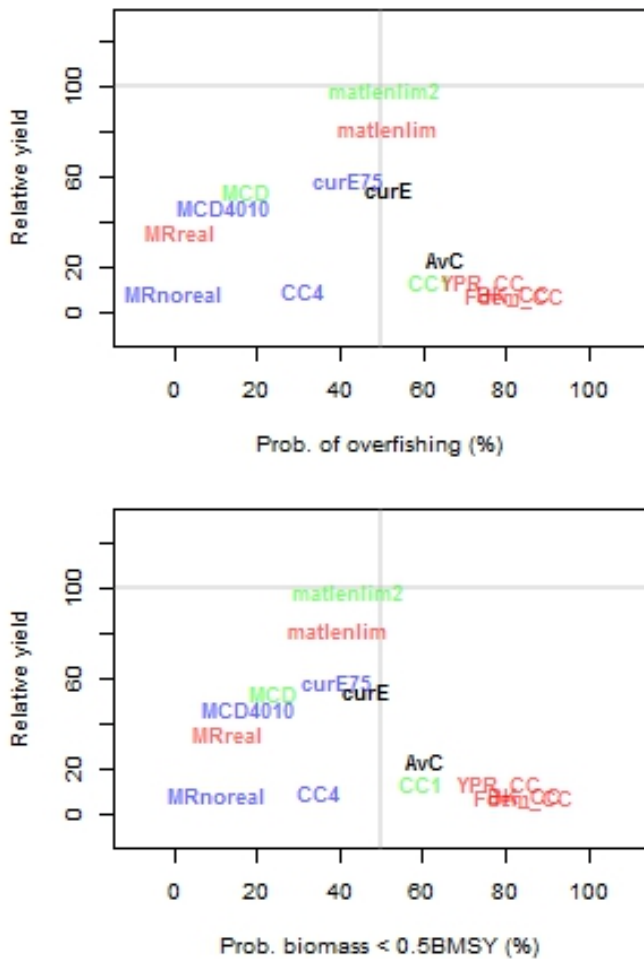


Figure 1. Performance of 14 management procedures for blueline tilefish in a DLMTool operating model with a generic fleet and an imprecise and biased observation model. The dashed blue box indicates zones of acceptable performance. A) Performance of management procedures against a priori performance measures reflecting overfishing and yield and B) Performance of management procedures against a priori performance measures reflecting the likelihood of becoming overfished and yield

The results from the MSE for the generic fleet are presented in Figure 1. There was considerable variability in the performance of the 14 different management procedures – with some producing unacceptably high risks of overfishing (i.e., AvC has POF > 50%). Others, produced unacceptably low yields for the fishery (e.g., CC1 – based on the average of the last five years, produces a relative yield << 30%). The full diagnostics of the other standard plots from DLMTool are provided in Appendix 2.

Based on performance measures determined before simulations were conducted (i.e., a $P(\text{overfishing}) < 50\%$, $P(\text{overfished}) < 50\%$ and relative yields between 30 – 100%), six management procedures were selected for further evaluation: matlenlim, matlenlim2, curE, cure75 and MCD, MCD4010. Although these six could be defined as performing well in the operating model, **only the MCD and the MCD4010 management procedure could be defined based on the available data, and would lead to management measures that could be implemented.** For example, the

working group recognized that management procedures that rely on adjusting the selectivity of the fishery would be almost impossible to regulate, as would management procedures relying on controlling fishing effort in what is largely a recreational fishery.

Table 4. Management procedures that could be estimated for blueline tilefish in the Mid-Atlantic based on data currently available. We note that MRnoreal and MRreal are spatial management tools and were not considered further.

Abbreviation in DLMTool	Management Procedure
AvC	Average catch
BK_CC	Catch curve based estimate of F and FMSY from Beddington and Kirkwood (2005)
CC1	Average catch in last t years
CC4	30% of average catch in last t years
curE	Constant fishing effort – set at the final year of the historical simulations
curE75	Constant fishing effort – set at the 75% of the final year of the historical simulations
Fdem_CC	Life history based MSY estimate derived from catch curve (McAllister et al., 2001)
Matlenlim	An input control in which selectivity at length is set to maturity at length to protect reproductive potential.
Matlenlim2	An input control in which selectivity at length is set slightly higher than maturity at length to protect reproductive potential.
MCD	Simple catch depletion method
MCD4010	Simple catch depletion method that employs the 40-10 harvest rule
MRnoreal	A spatial management procedure in which a marine reserve is set up in area 1, but does not reallocate fishing effort – not considered further
MRreal	A spatial management procedure in which a marine reserve is set up in area 1, but reallocates fishing effort – not considered further
YPR_CC	A catch-curve based yield-per-recruit analysis

We also ran simulations employing increasing and constant effort scenarios (Fig. 2). The same management procedures, MCD and MCD4010, were the only realistically implementable procedures that met the *a priori* selected performance measures (POF < 50%, P(overfished) < 50% and relative yield 30% < yield < 100%) under either effort scenario. Therefore, we saw that in the case of blueline tilefish, altering effort scenarios has no impact on the choice of management strategies used for further analyses.

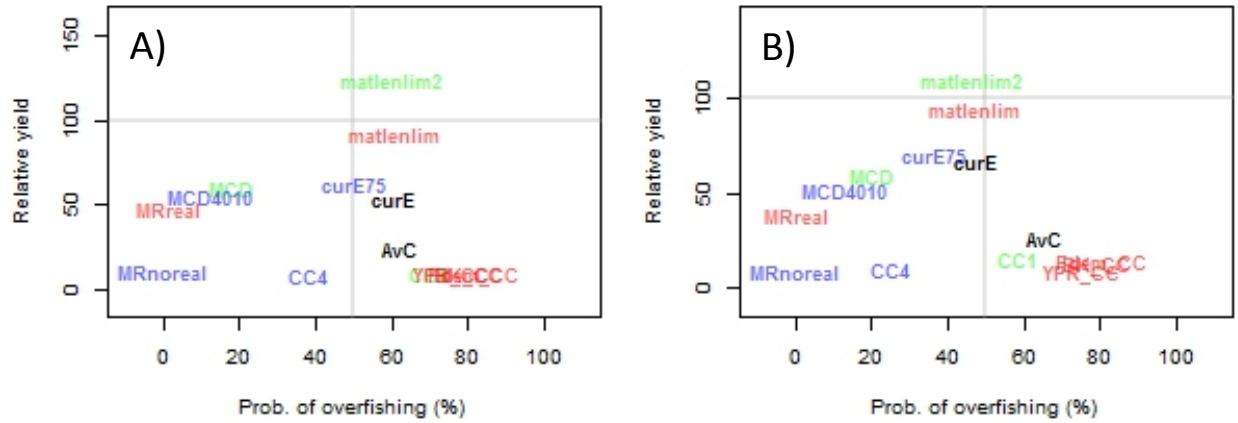


Figure 2. Performance of 14 management procedures for blueline tilefish in a DLMTTool operating model with fleets exhibiting increasing effort (A) and constant effort (B) and an imprecise and biased observation model.

ABC Recommendation

The blueline tilefish working group recommends developing an ABC based on the MCD and the MCD4010 management procedure which performed acceptably well in simulation studies with the generic fleet and the increasing fleet. Available data were used to generate 1000 stochastic estimations of the MCD and MDC4010 management procedure for blueline tilefish. The MCD and MCD4010 management procedure yielded a wide range of ABCs with the observed uncertainty in parameters for the blueline tilefish (Figure 3).

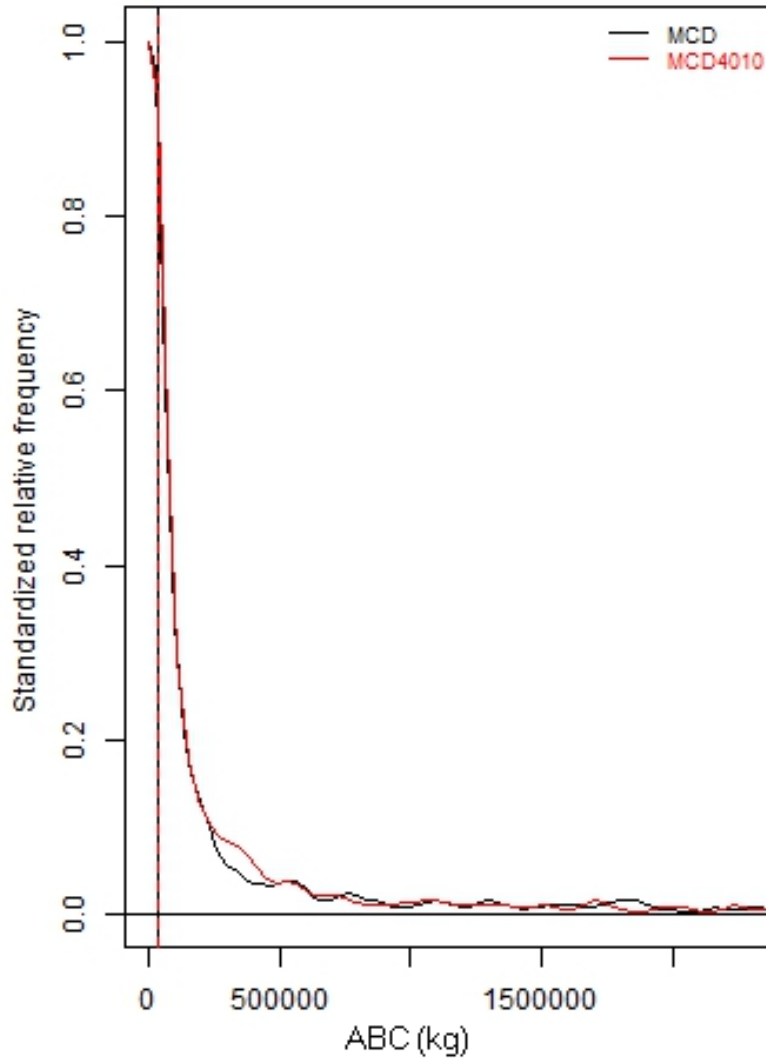


Figure 3. Distributions of ABC values for blueline tilefish using 1000 realizations of the MCD and MCD4010 management procedure.

Table 5. Quantiles of the distribution of the MCD and MCD4010 management procedures applied to Mid-Atlantic blue line tilefish

Quantile	MCD	MCD4010
0%	5	16
25%	5972	6672
50%	35,128	38,746
75%	217,990	204,242
100%	86,745,400	25,719,959

The quantiles of the distribution of the ABCs are provided in Table 4. The minimum ABCs in 1000 stochastic simulations of real parameters was 5 kg, the maximum was 86,745,400 kg for the MCD management procedure.

The SSC blueline tilefish working group recommend an ABC calculated as the average of the median ABCs calculated from the

MCD and MCD 4010 management procedures. The suggested ABC is 36,937 kg = 81,432 lbs (Table 6).

For comparison, Table 6 also provides averages for removals for different time periods, and including or excluding the high landings in 2014 which promoted concern from the Council over substantial increases in commercial landings.

Table 2. Comparison of catch levels developed from the observed blueline tilefish catches using different approaches

Approach	Full time period	Excluding 2014
DLMTool	36,937 kg = 81,432 lbs	
Average (1999-2015)	36,805kg = 81,141 lbs	29,848kg = 65,803 lbs
Average(2011-2014)	78,110 kg = 172,204 lbs	60,608kg = 133,618 lbs

Literature Cited

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Appendix 1

The R code used for the simulations

```
#####  
##  Blueline tilefish DLMtool  
##  
##  
##Authors: Mike Schmidtke (mschmidt@odu.edu)  
##  Tom Miller (miller@umces.edu)  
##  
## Date: 03/15/2016  
#####  
  
#####  
# Housekeeping  
  
rm(list=ls(all=TRUE))  
graphics.off()  
cls <- function() cat(rep("\n",100)); cls()  
library(grDevices)  
  
#####  
#Directories  
  
indirectory="C:/Users/Mike/Documents/Blueline_DLM/"  
outdirectory="C:/Users/Mike/Documents/Blueline_DLM_Output/"  
  
#####  
#Core Processes to initiate DLMtool Analysis  
  
library(DLMtool)  
for(i in 1:length(DLMdat))assign(DLMdat[[i]]@Name,DLMdat[[i]])  
sfInit(parallel=TRUE, cpus=4)  
sfExportAll()  
#set.seed(1)  
memory.limit(size=8000) #Increase memory usage so figures can be created (if necessary)  
  
#####  
#Read in data  
  
inFile<-paste(indirectory,"MidAtl_blueline_tilefish.csv",sep="")  
MidAtl_BLT=new('DLM_data',inFile)  
summary(MidAtl_BLT)  
  
#####  
#Inspection of MPs for stock  
  
Can(MidAtl_BLT) #Usable MPs from data available
```

```

#Cant(MidAtl_BLT) #Non-usable
#Needed(MidAtl_BLT) #What data are needed to make non-usable, usable
MPs=c("BK_ML","Fdem_ML",Can(MidAtl_BLT)[Can(MidAtl_BLT)!="BK_ML" & Can(MidAtl_BLT)!="Fdem_ML"])
#Store usable MPs
MPs

#####
#Define our stock, info of source next to each parameter

blstock<-Porgy #default stock from which parameter values will be changed

blstock@Name<-MidAtl_BLT@Name #Stock name
blstock@maxage<-MidAtl_BLT@MaxAge #Max age from input file, observation by ODU
blstock@R0<-500000 #Unfished recruitment; arbitrary, set it at value higher than highest catch value
blstock@M<-c(0.086,0.200) #Range of M values; Range of observed M values from Alverson-Carney, Hoenig, and
#Pauly estimators
blstock@Msd<-c(0, MidAtl_BLT@CV_Mort)#Interannual variation in M, expressed as CV, used CV of Alverson-
#Carney, Hoenig, and Pauly estimates
blstock@Mgrad<-c(-0.2, 0.2) #Temporal change in M expressed as a percent, reasonable est
blstock@h<-c(0.7,0.9) #Steepness of stock-recruit relationship, 0.84 from SEDAR 32
blstock@SRrel<-1 #Stock-recruit relationship, set to Beverton-Holt=1, Ricker is 2
blstock@Linf<-c(MidAtl_BLT@vbLinf-5, MidAtl_BLT@vbLinf+5) #Input von Bertalanffy Linf parameter (cm) +/-5,
#obs ODU
blstock@K<-c(MidAtl_BLT@vbK-.05, MidAtl_BLT@vbK+.05) #Input von Bertalanffy K parameter +/-0.5, obs ODU
blstock@t0<-c(MidAtl_BLT@vbt0-.1, MidAtl_BLT@vbt0+.1) #Input von Bertalanffy t0 parameter +/-0.1, obs ODU
blstock@Ksd<-c(0, MidAtl_BLT@CV_vbK) #Interannual variability in K parameter, obs ODU
blstock@Kgrad<-c(-0.2,0.2) #Temporal trend in K parameter, expressed as percent, reasonable est
blstock@Linfsd<-c(0, MidAtl_BLT@CV_vbLinf) #Interannual variability in Linf param, obs ODU
blstock@Linfgrad<-c(-0.25,0.25) #Mean temporal trend in Linf param, bounded by reasonable est
blstock@recgrad<-c(-10,10) #Mean temporal trend in lognormal recruitment deviations, reasonable est
blstock@AC<-c(0.1, 0.9) #Autocorrelation in recruitment deviations  $rec(t)=AC*rec(t-1)+(1-AC)*\sigma(t)$ ,
#reasonable est
blstock@a<- MidAtl_BLT@wla #Length-weight parameter alpha, obs ODU
blstock@b<- MidAtl_BLT@wlb #Length-weight parameter beta, obs ODU
blstock@L50<-c(30,50) #Length at 50% maturity (33 cm), obs ODU
blstock@D<-c(0,0.5) #Depletion, Bcurr/Bunfished, reasonable estimate
blstock@Size_area_1<-c(0.8, 0.99) #Relative area of exploitable region, reasonable est (high values indicate no
#marine reserve)
blstock@Frac_area_1<-c(0.8, 0.99) #Fraction of area_1 occupied, reasonable est
blstock@Prob_staying<-c(0.8, 0.99) #The probability of individuals in area 1 remaining in area 1 over the course of
#one year
blstock@Source<-"ODU, NMFS, SEDAR 32, reasonable estimates"
blstock@Perr <-c(0.5,0.8) #Extent of inter-annual log-normal recruitment variability (sigma R), reasonable est
blstock@L50_95<-c(11,20) #Length increment from 50 to 95% maturity; lower: difference between input L50 and
#L50 from SEDAR 32 (44), upper: reasonable est

#####
#Simulation Preferences

```

```

#Number of reps for TAC estimation
      TACn=1000

#Fleet
      BLTFleet<-Generic_fleet #Generic
#      BLTFleet<-Generic_IncE #Increasing effort
#      BLTFleet<-Generic_FlatE #Constant effort

#####
#Define Operating Model

OM<-new('OM', blstock, BLTFleet, Imprecise_Biased)

#####
#Run MSE

BLTMSE<-runMSE(OM, MPs, nsim=1000, reps=200, proyears=50, interval=5)

#####
#Plot MSE Results

jpeg(filename = paste(outdirectory,"Tplot_",BLTFleet@Name,".jpg",sep=""), width = 640, height = 480,
      units = "px", pointsize = 12, quality = 400, bg = "white",
      res = NA, restoreConsole = FALSE)
Tplot(BLTMSE)

dev.off()
graphics.off()

jpeg(filename = paste(outdirectory,"Pplot_",BLTFleet@Name,".jpg",sep=""), width = 640, height = 480,
      units = "px", pointsize = 12, quality = 400, bg = "white",
      res = NA, restoreConsole = FALSE)
Pplot(BLTMSE)

dev.off()
graphics.off()

jpeg(filename = paste(outdirectory,"Kplot_",BLTFleet@Name,".jpg",sep=""), width = 640, height = 480,
      units = "px", pointsize = 12, quality = 400, bg = "white",
      res = NA, restoreConsole = FALSE)
Kplot(BLTMSE)

dev.off()
graphics.off()

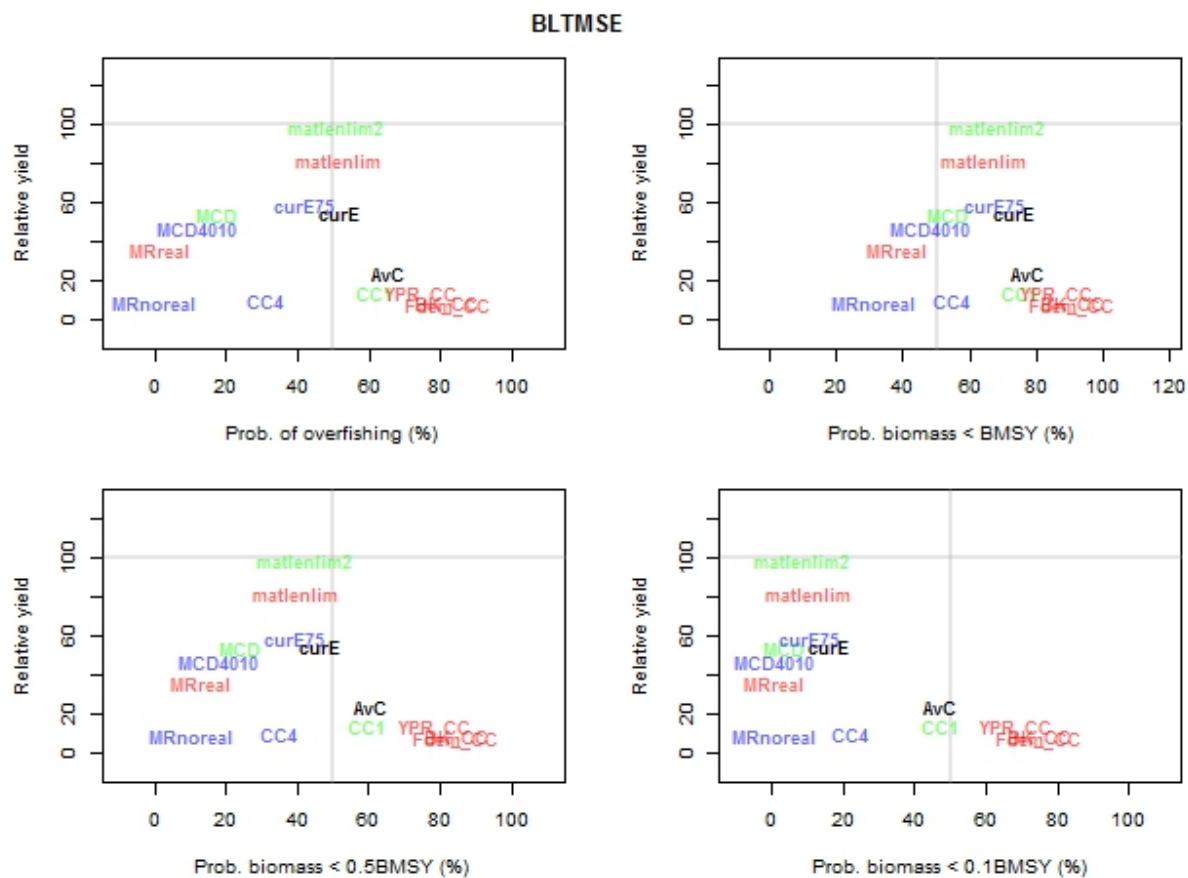
Results<-summary(BLTMSE)
outfile=paste(outdirectory,"MSE_Results_",BLTFleet@Name,".csv",sep="")
write.matrix(Results,file=outfile,sep=",")

```

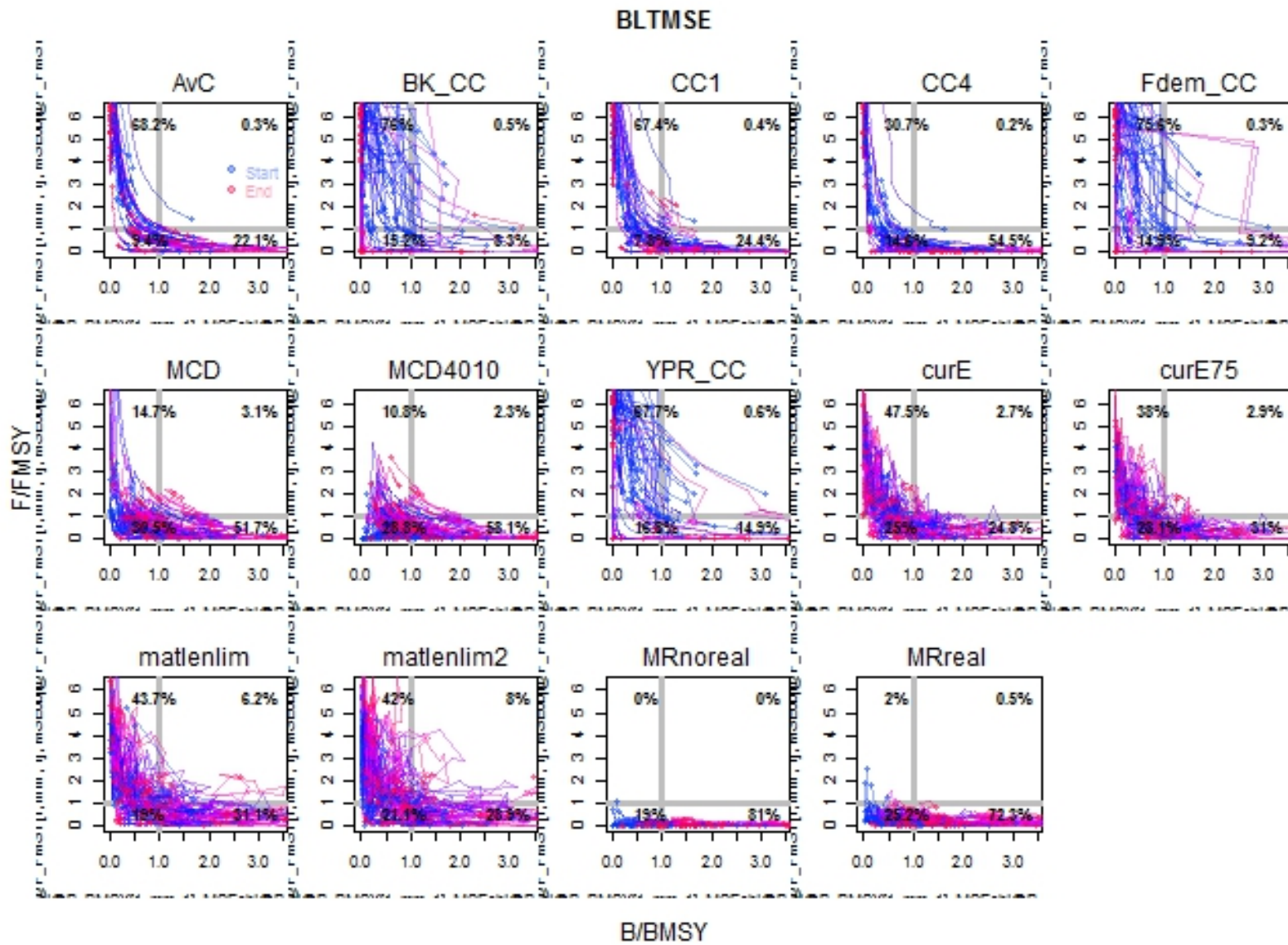
Results

```
#####  
#TAC for MPs with .3*MSY<Yield<MSY and POF<0.6  
  
Targetted<-subset(Results, Results$POF<50 & Results$Yield>30 & Results$Yield<100)  
MPselected<-Targetted[,1]  
  
BLTReal=TAC(MidAtl_BLT, MPselected, reps=TACn)  
  
#####  
#Calculate and Print TAC quantiles and estimates  
  
TACs<-t(as.data.frame(BLTReal@TAC))  
colnames(TACs)<-BLTReal@MPs  
row.names(TACs)<-seq(1:TACn)  
  
TAC.quant=matrix(NA,nrow=5,ncol=length(TACs[1,])+1)  
colnames(TAC.quant)=c("Quantile",BLTReal@MPs)  
for(i in 1:length(TACs[1,])){#i=1  
TAC.quant[,1]=c("0%","25%","50%","75%","100%")  
TAC.quant[,i+1]=quantile(na.omit(TACs[,i]))  
}  
  
outfile=paste(outdirectory,"TAC_Results_",BLTFleet@Name,".csv",sep="")  
write.matrix(TACs,file=outfile,sep=",")  
  
outfile=paste(outdirectory,"TAC_Quantile_",BLTFleet@Name,".csv",sep="")  
write.matrix(TAC.quant,file=outfile,sep=",")  
  
#####  
#Plot TAC and OFL  
jpeg(filename = paste(outdirectory,BLTFleet@Name,"_TAC_Plot.jpg",sep=""), width = 640, height = 480,  
units = "px", pointsize = 12, quality = 400, bg = "white",  
res = NA, restoreConsole = FALSE)  
  
plot(BLTReal)  
  
jpeg(filename = paste(outdirectory,BLTFleet@Name,"_OFL_Plot.jpg",sep=""), width = 640, height = 480,  
units = "px", pointsize = 12, quality = 400, bg = "white",  
res = NA, restoreConsole = FALSE)  
  
plotOFL(BLTReal)  
  
dev.off()  
graphics.off()  
sfStop()
```

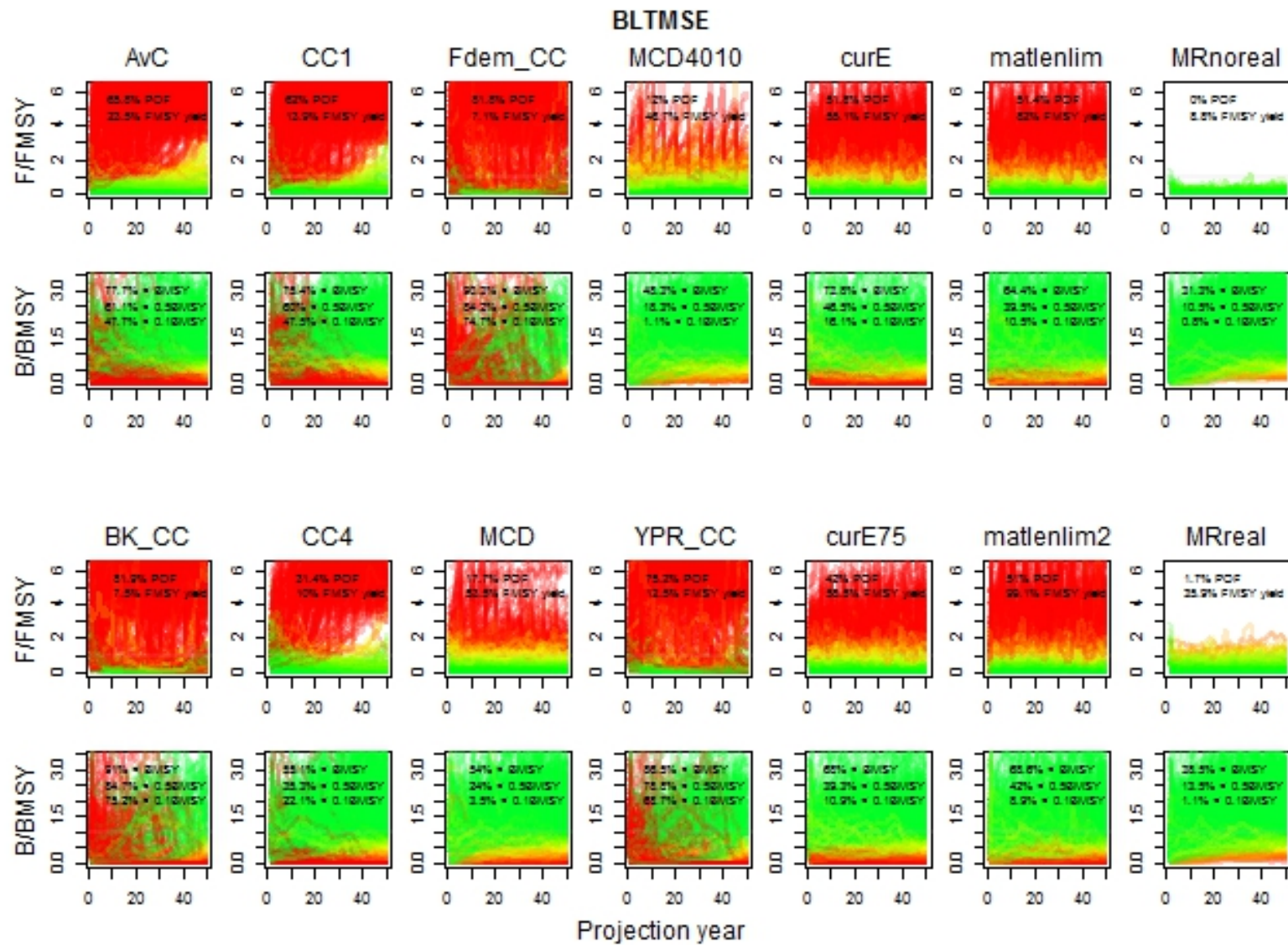
Appendix 2. Diagnostic plots from the DLMTool OM for blueline tilefish with a generic fleet.



Appendix 2, Figure 1. Trade-off plot for blueline tilefish OM with a generic fleet



Appendix 2, Figure 2. Time series projects of F/F_{MSY} and B/B_{MSY} for the blueline tilefish OM with a generic fleet



Appendix 2, Figure 3. A projection plot of $F/FMSY$ and $B/BMSY$ for the blueline tilefish OM with a generic fleet