# Memorandum

**To:** John Boreman, Chair, Mid-Atlantic Fisheries Management Council SSC

**From:** Thomas Miller, Chair, Blueline Tilefish Working Group, MAFMC SSC

**Date:** March 9, 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 in June 2015 to obtain initial stakeholder input, and the MAFMC endorsed development of a range of alternative management actions in October 2015 with action expected in April 2016.

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 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 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 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. (2014). The DLMTool evaluates the performance of 47 different fishery management procedures in an operating model which is parameterized to represent a particular species defined by a suite of biological and fisheries related parameters. Many of the 47 different management procedures are alternative "flavors" of the same approach, only with slightly different parameterizations. The selected 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 are determined to perform "best" are identified. The values of these "best" management procedures are then estimated based on the real data.

The DLMTool 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), DLMTool conflates the two approaches to establishing ABCs identified in the MAFMC's Risk Policy regarding the ability to estimate an OFL (Miller et al., 2015). Specifically, the SSC subcommittee noted that the mixing of these two categories of reference points leads to confusion in the application of the DLMTool to MAFMC managed species (Miller et al 2015).

In considering the application of DLMTool 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 DLMTool to Blueline Tilefish

The DLMTool applies a sequence of analyses to estimate a range of ABCs for a data poor stock. The first step is a management strategy evaluation based on the analysis of an operating model that is parameterized to represent what is known about the biology the stock, the performance of the fishery fleet and the observed sampling of the species under consideration. 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. The operating model is used to evaluate the likelihood that each of a number of possible management procedures meet performance measures. Based on this evaluation, a limited number of management procedures are considered further. We followed the precedent set for black sea bass by the MAMFC SSC of considering only management procedures that achieved a POF < 60%, and relative yields between 30 – 100%.

In the second step of the application of DLMTool, the limited number of management procedures are parameterized using the actual data streams available for the species. Each management procedure is parameterized stochastically using observed estimates of uncertainties to yield a distribution of the ABC for each method. In its application of the DLMTool 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.

## A) Data Inputs

### A) 1. 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, 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). An estimate of natural mortality (M) was developed as the mean of the Alverson-Carney (1975), Hoenig (1983), and Pauly (1980) estimators. The maximum age for blueline tilefish in the Mid-Atlantic was defined as the maximum observed age for the combined NMFS and ODU data. Environmental temperature was estimated as the average of bottom temperatures for areas in which blueline tilefish were captured during ODU research cruises in 2013.

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 age were from the NMFS data and ODU data collected from 2009-2011. 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. Numbers caught at length were from all of the combined NMFS and ODU data, separated by year and into 1 cm TL bins. Although recreational sampling often biases estimates of proportions at age towards larger fish, a relative lack of discards in the fishery could mitigate this bias. Additionally, these are the only data currently available that describe catch composition for blueline tilefish in this region.

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

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

| Parameter | Value (±SD) |
| --- | --- |
| | Von Bertalanffy Growth Parameters |
| k | 0.098 ± 0.0050 |
| Linf (cm) | 92.63± 1.76 |
| T0 | -0.37±0.20 |
| | Length-Weight Relationship |
| a | 0.00000101 ±0.000000172 |
| b | 3.39 ± 0.41 |
| | Maturity and Selectivity |
| TL at 50% maturity | 33 |
| Length at first capture | 26 |
| Natural Mortality | 0.1 |

**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 angers 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.*

| | BLT Caught (pounds) | | | BLT Caught (kg) | | |
|---|---|---|---|---|---|---|
| Year | 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) DLMTool specification

The operating model (OM) within DLMTool 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 DLMTool 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.*

| Parameter | Value or Range | Definition |
|---|---|---|
| blStock@maxage | 40 | Maximum age – Table 1 |
| blSotck@RO | 500,000 | Unfished recruitment (kg), arbitrarily set based on highest observed catch |
| blStock@M | 0.05-0.15 | Range based on estimate M from Table 1 |
| blStock@Msd | 0-.02 | Estimated standard deviation in M |
| 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 | 0-0.0050 | Range of standard deviation of K, based on Table 1 |
| blStock@Kgrad | -0.2 – 0.2 | Range of annual rate of change of K – reasonable value |
| blStock@Linfsd | 0-1.76 | Range of standard deviation of Linf, based on Table 1 |
| blStock@Lingfrad | -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 | 0.00000101 | 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 – $B_{current}$ / $B_{MSY}$ – 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 | |
| blStockPerr | 0.5 – 0.8 | Extent of inter-annual variability in log normal recruitments – reasonable value |
| blStokc@L50_95 | 11 – 20 | Growth increment (cm) between length at 50% maturity and Linf, based on Table 1 |

**B) 2. DLM Fleet Definition**

DLMTool has a range of fleet definitions that all specify how effort changes across the duration of the simulation. The FLEET class allows specification of the duration of the historical simulation, the inter-annual variation in F and the trend in F over time. Fishing effort in these simulations is modeled as a random walk – that is the fishing effort next year is a deviation from the fishing effort this year. Thus in the generic fleet definition, fishing effort in any one simulation could show either a noisy increase year after year, a noisy decrease year after years or any number of intermediate patterns. In contrast, the Constant Effort Fleet is defined such that the average level of effort over the course of each simulation is constant, but effort in any single year can vary. Similarly, the increasing effort simulation only allows simulations in which effort increases noisily year after year.

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 16 management procedures could be developed from the data available for blueline tilefish in the Mid-Atlantic (Table 4).

*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) |
| BK_ML | Length based catch curve 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) |
| Fdem_ML | Life history based MSY estimate derived from length-based 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 |
| SPSRA_ML | A surplus production equivalent of Depletion-Based Stock Reduction Analysis (Dick and MacCall, 2011) that uses a demographically derived prior for intrinsic rate of increase. A prior for depletion is calculated from a mean-length estimator. |
| YPR_CC | A catch-curve based yield-per-recruit analysis |

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 > 60%). 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.

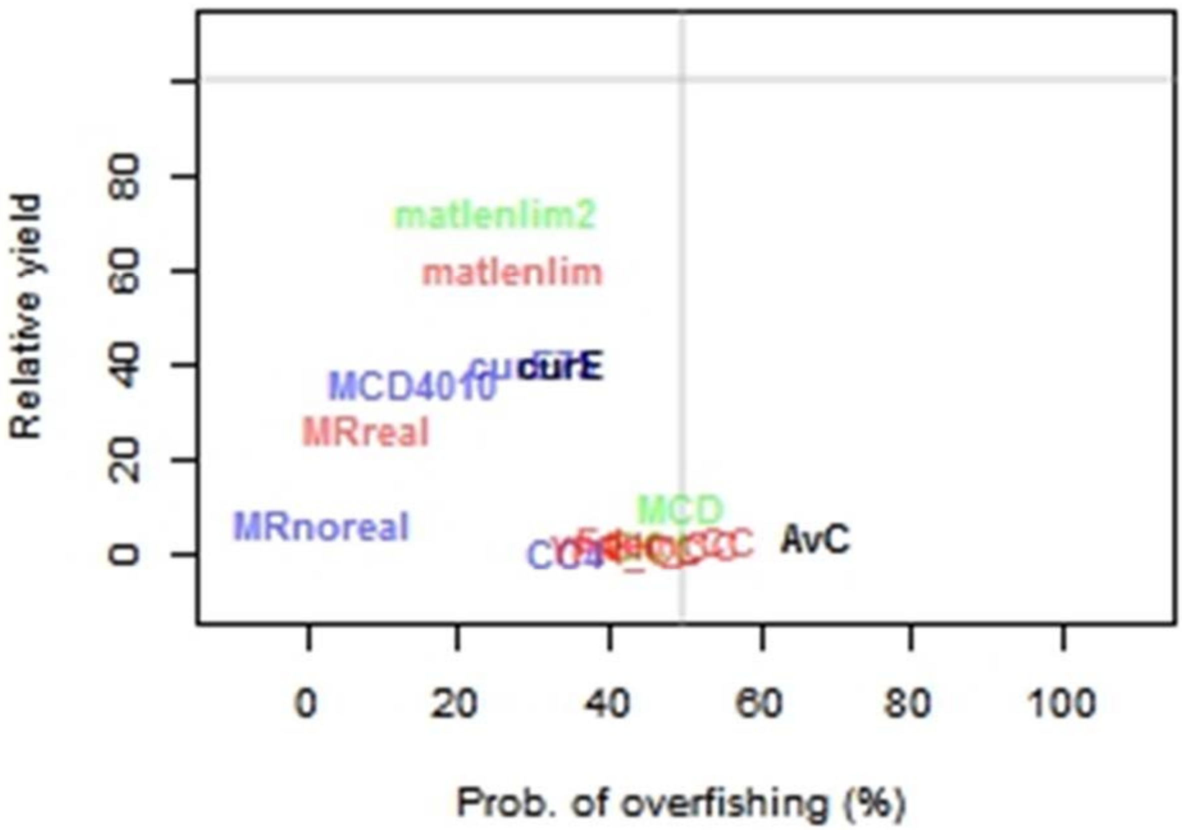


*Figure 1. Performance of 16 management procedures for blueline tilefish in a DLMTool operating model with a generic fleet and an imprecise and biased observation model.*

Based on performance measures determined before simulations were conducted (i.e., a POF < 60%, and relative yields between 30 – 100%.), five management procedures were selected for further evaluation: matlenlim, matlenlim2, curE, cure75 and MCD4010. Although these five could be defined as performing well in the operating model, only 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.

We also ran simulations employing an increasing effort scenario (Fig. 2). Only four management procedures (curE, curE75, matlenlim and matlenlim2) met the *a priori* selected performance measures (POF < 60%, relative yield 30% < yield , 100%). None of these performance measures could be parameterized with the data available for blueline tilefish. Full results for the increasing effort scenario are provided in Appendix 3.

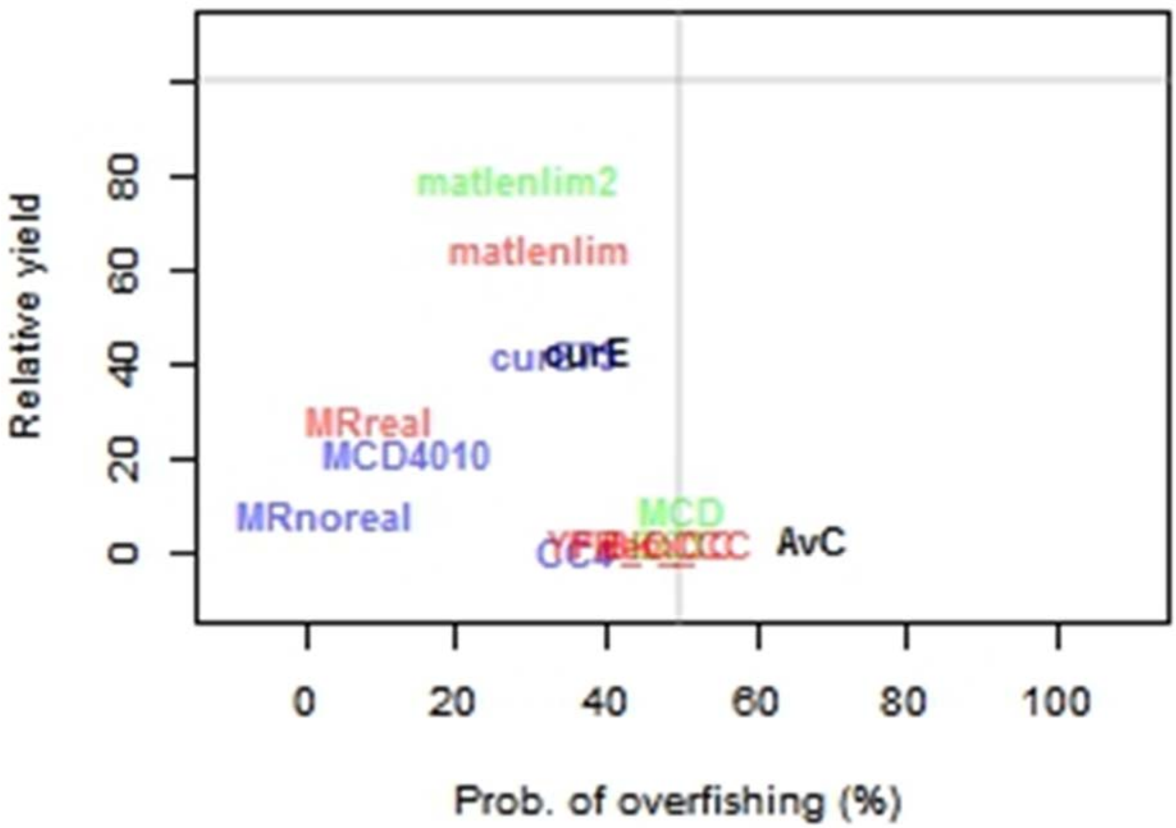


*Figure 2. Performance of 16 management procedures for blueline tilefish in a DLMTool operating model with a fleet exhibiting increasing effort and an imprecise and biased observation model.*

## ABC Recommendation

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

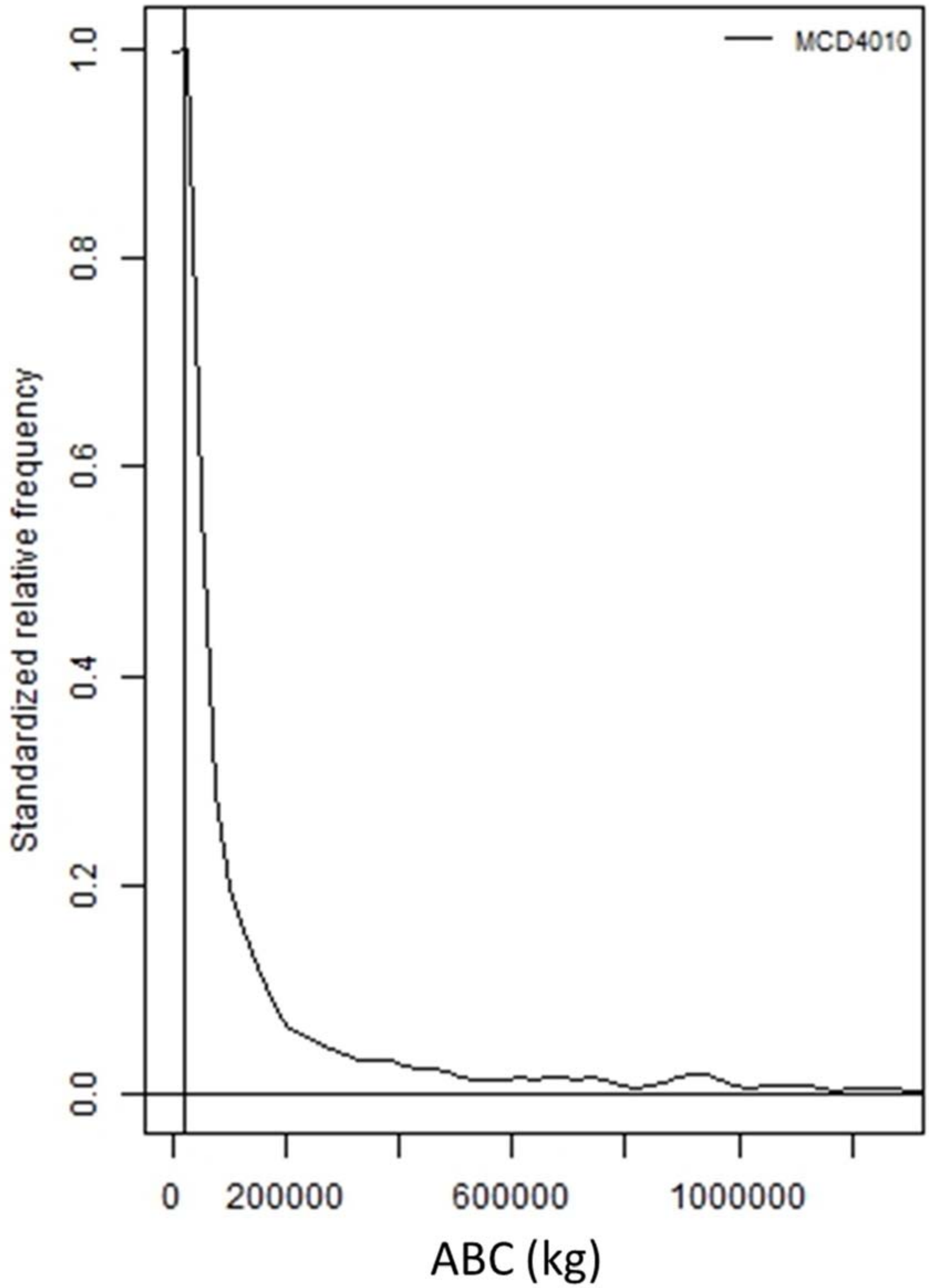


*Figure 3. Distribution of ABC values for blueline tilefish using 1000 realizations of the MCD4010 management procedure.*

The minimum ABC in 1000 stochastic simulations of real parameters was 1.55 kg, the maximum was 12,956,316 kg. The quantiles of the distribution were: 25% - 4,072 kg, median – 22,245 kg, 75% 127,967 kg.

The SSC blueline tilefish working group suggests an ABC of 22,245 kg =49,028 lbs. For comparison, the average estimated landings for the period 1999-2015 is 60,975 lbs, and the average for the last five years is 165,356 lbs.

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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:  03/06/2016
########################################################

########################################################
# Housekeeping

rm(list=ls(all=TRUE))
graphics.off()
cls <- function() cat(rep("\n",100)); cls()
library(grDevices)

########################################################
#Directories

indirectory="C:/Users/Tom Miller/My Documents/Admin/Councils/MAMFC/2016/March 15-
16/Blueline/"
outdirectory="C:/Users/Tom Miller/My Documents/Admin/Councils/MAMFC/2016/March 15-
16/Blueline/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=1)
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=Can(MidAtl_BLT) #Store usable 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(MidAtl_BLT@Mort-.05,MidAtl_BLT@Mort+.05)  #Input M +/- 0.5, obs ODU
blstock@Msd<-c(0, MidAtl_BLT@CV_Mort)#Interannual variation in M, expressed as CV, used reasonable estimate
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
```

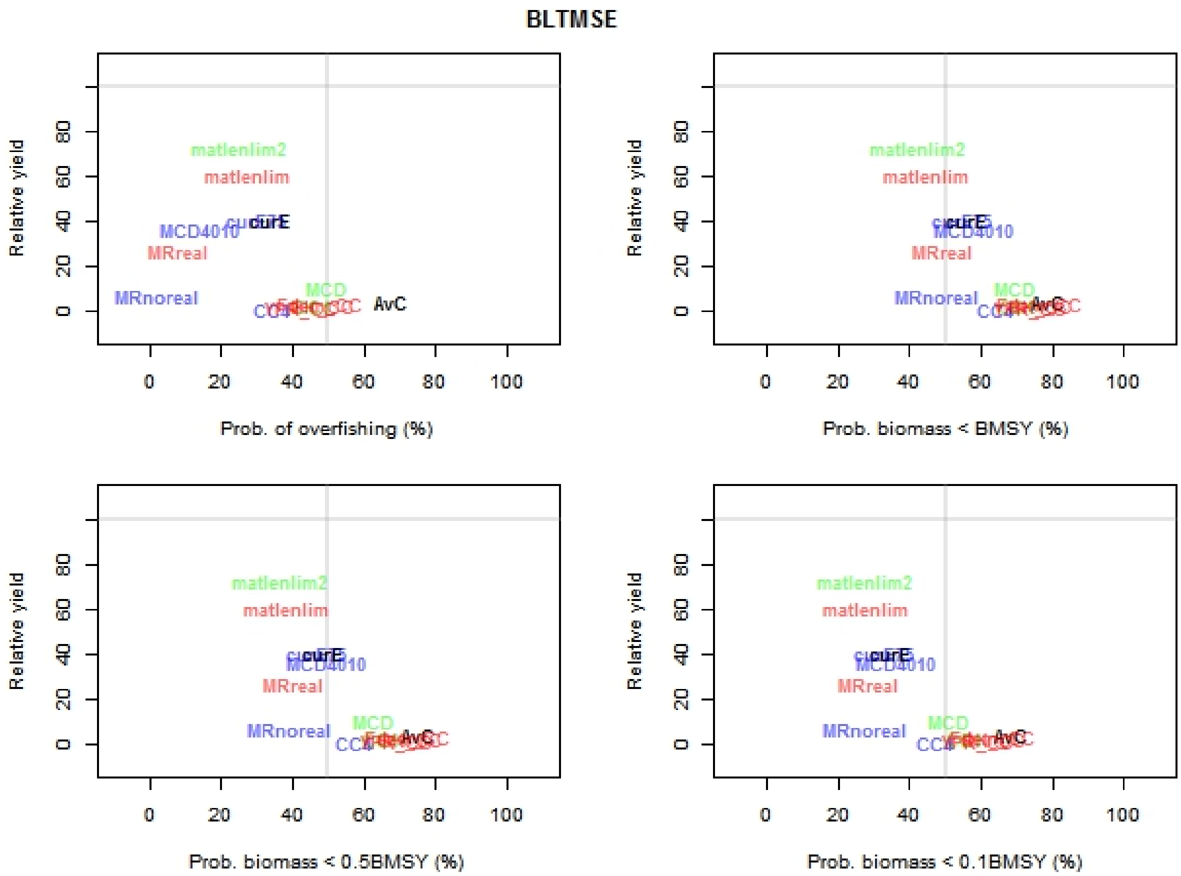
```
blstock@recgrad<-c(-10,10)  #Mean temporal trend in lognormal recruitment deviations, resonable est
blstock@AC<-c(0.1, 0.9)  #Autocorrelation in recruitment deviations rec(t)=AC*rec(t-1)+(1-AC)*sigma(t), reasonable est
blstock@a<- MidAtl_BLT@wla #Length-weight parameter alpha, obs ODU
blstock@b<- 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$POF<60 & Results$Yield>30 & Results$Yield<100)
MPselected<-Targetted[,1]
MPselected<-c('MCD4010')
```

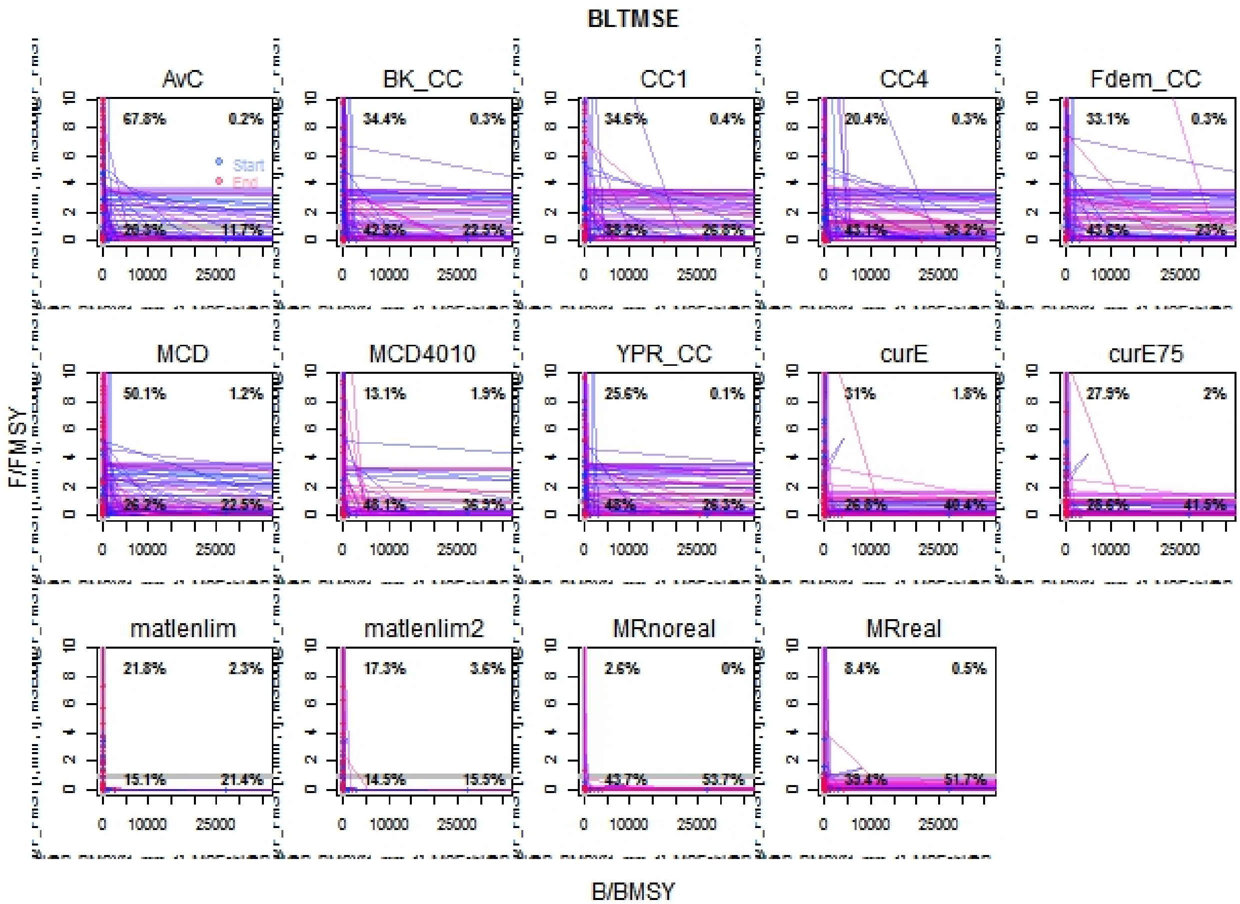
```
BLTReal=TAC(MidAtl_BLT, MPselected, reps=TACn)

###########################################################
#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,"TAC_Plot.jpg",BLTFleet@Name,sep=""), width = 640,
height = 480,
    units = "px", pointsize = 12, quality = 400, bg = "white",
    res = NA, restoreConsole = FALSE)

plot(BLTReal)

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

plotOFL(BLTReal)

dev.off()
graphics.off()
```

sfStop()

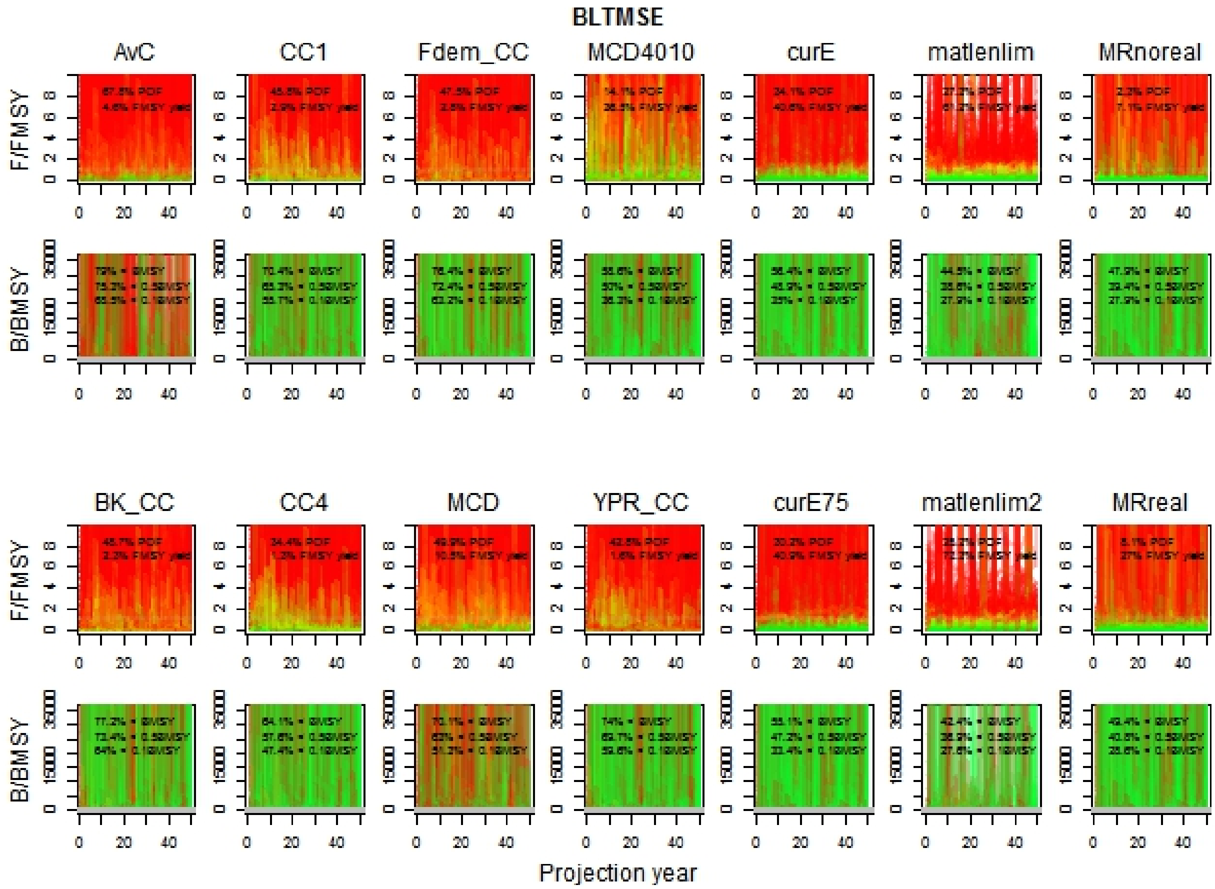
Appendix 2. Diagnostic plots from the DLMTool OM for blueline tilefish with a generic fleet.




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

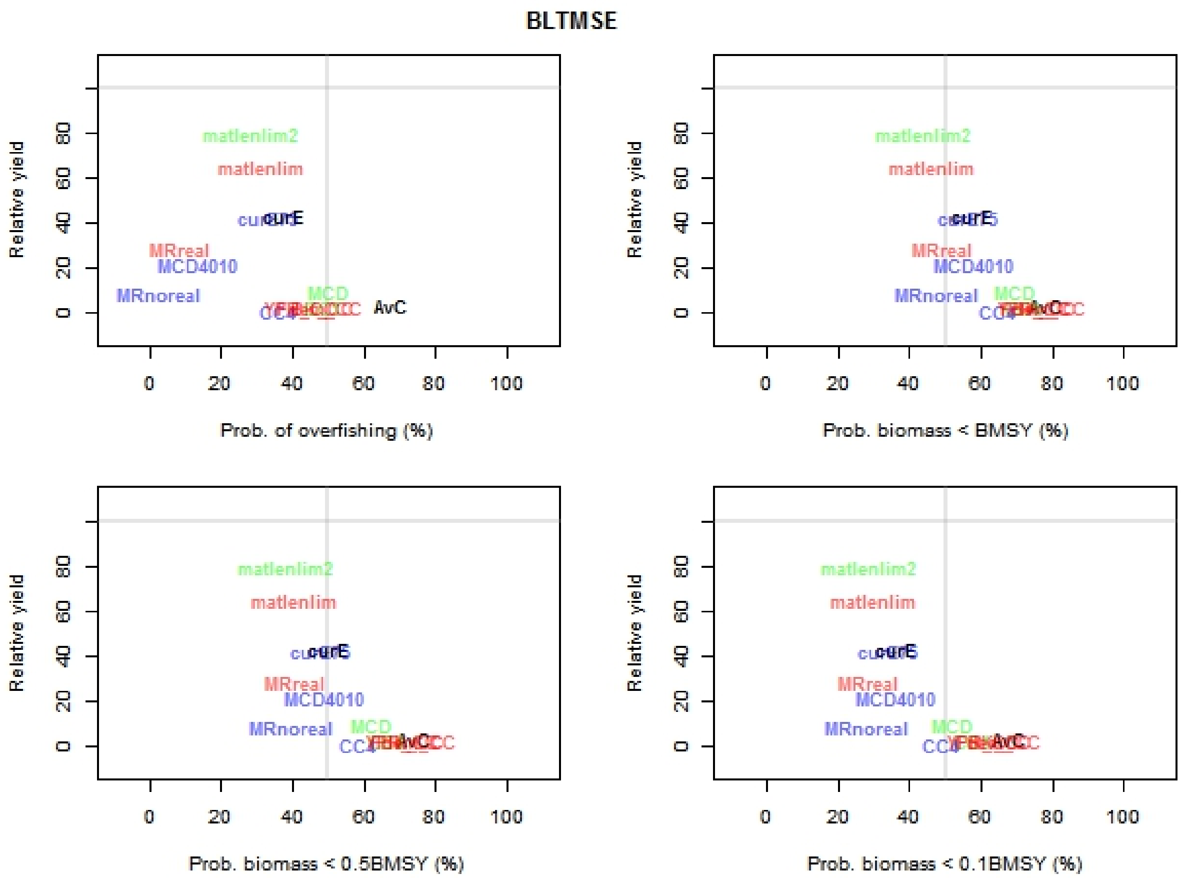



*Appendix 2, Figure 2. Time series projects of F/FMSY and B/BMSY for the blueline tilefish OM with a generic fleet*

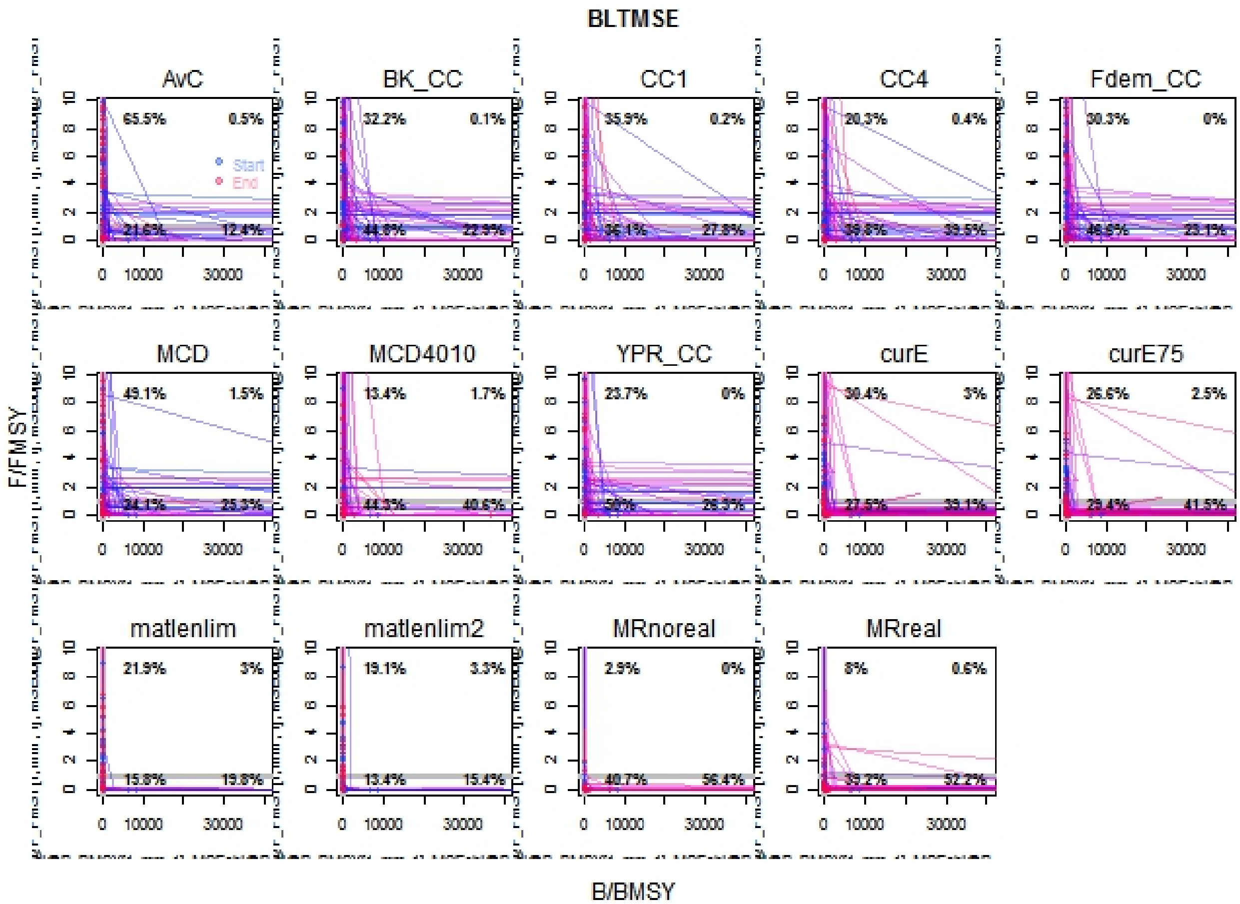



*Appendix 2, Figure 3. A projection plot of F/FMSY and B/BMSY for the blueline tilefish OM with a generic fleet*

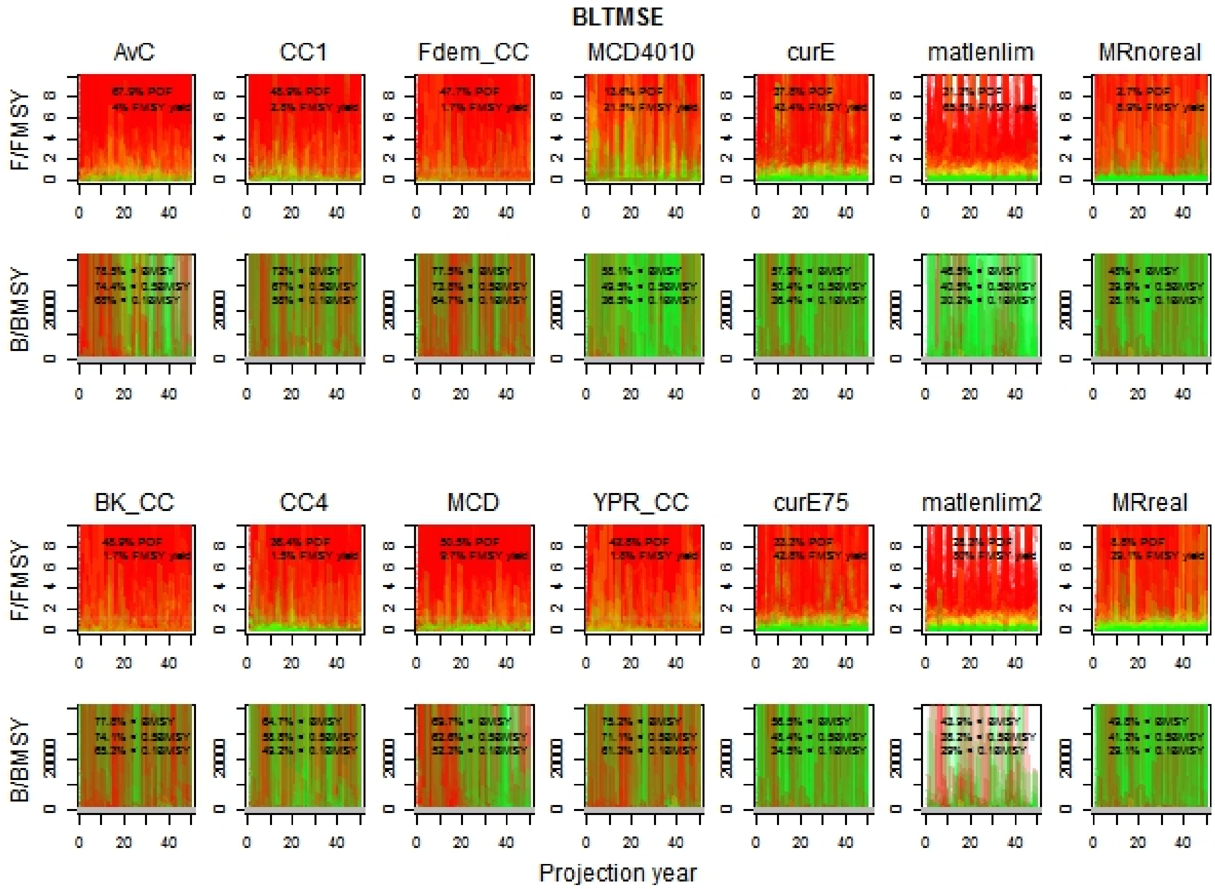
Appendix 3. Diagnostic plots from the DLMTool OM for blueline tilefish with a fleet exhibiting increasing effort




*Appendix 3, Figure 1 . Trade-off plot for blueline tilefish OM with a fleet exhibiting increasing effort*




*Appendix 3, Figure 2 Time series projects of F/FMSY and B/BMSY for the blueline tilefish OM with a fleet exhibiting increasing effort*




*Appendix 3, Figure 3 A projection plot of F/FMSY and B/BMSY for the blueline tilefish OM with a fleet exhibiting increasing effort*

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