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PRELIMINARY CLOSED-LOOP SIMULATION OF MANAGEMENT PROCEDURE PERFORMANCE FOR SOUTHERN SWORDFISH

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SUMMARY

We present some preliminary closed-loop simulations for South Atlantic swordfish. We condition an Operating Model using OpenMSE's Rapid Conditioning Model and using a joint multivariate prior for steepness derived from maturity, growth and natural mortality information from northern swordfish to integrate across the uncertainty in these quantities in a single operating model. Then we test data-moderate MPs similar to those used for the southern Swordfish stock assessment, including delay difference and surplus production models to illustrate their performance. The preliminary results show that most of these Candidate Management Procedures meet minimal satisficing criteria. If the tolerance for being below the limit reference is very small, then this criterion has strong discriminatory power. To be informative for management, this preliminary exercise would have to be expanded to include stock-specific priors, a broader set of operating models, and finalized quantitative objectives.

RÉSUMÉ

Nous présentons quelques simulations préliminaires en boucle fermée pour l'espadon de l'Atlantique Sud. Un modèle opérationnel a été conditionné en utilisant le modèle de conditionnement rapide d'OpenMSE et en utilisant une distribution a priori multivariée conjointe pour la pente dérivée des informations sur la maturité, la croissance et la mortalité naturelle de l'espadon du Nord afin d'intégrer l'incertitude de ces quantités dans un seul modèle opérationnel. Des MP à données modérées similaires à ceux utilisés pour l'évaluation du stock d'espadon du Sud ont ensuite été testés, y compris les modèles à différences retardées et de production excédentaire, afin d'illustrer leurs performances. Les résultats préliminaires montrent que la plupart de ces procédures de gestion potentielles répondent à des critères de « suffisfaisant » minimaux. Si la tolérance pour se situer en dessous de la référence limite est très faible, alors ce critère a un fort pouvoir discriminatoire. Afin d'apporter des informations à des fins de gestion, cet exercice préliminaire devrait être élargi pour inclure des distributions a priori spécifiques aux stocks, un ensemble plus large de modèles opérationnels et des objectifs quantitatifs finalisés.

RESUMEN

Se presentan algunas simulaciones preliminares de bucle cerrado para el pez espada del Atlántico sur. Se condiciona un modelo operativo utilizando el modelo de condicionamiento rápido de OpenMSE y utilizando una distribución previa multivariante conjunta para la inclinación derivada de la información de madurez, crecimiento y mortalidad natural del pez espada del norte con el fin de integrar la incertidumbre sobre estas cantidades en un único modelo operativo. A continuación, se probaron los MP de datos moderados similares a los utilizados para la evaluación de stock de pez espada del sur, incluidos los modelos de diferencia retardada y de producción excedente para ilustrar su desempeño. Los resultados preliminares muestran que la mayoría de estos procedimientos de ordenación candidatos cumplen los criterios mínimos de «satisfaciente». Si la tolerancia de estar por debajo del nivel de referencia límite es muy pequeña, este criterio tiene un fuerte poder discriminatorio. Para que resulte informativo para la ordenación, este ejercicio preliminar tendría que ampliarse para incluir las distribuciones previas especificas del stock, un conjunto más amplio de modelos operativos y objetivos cuantitativos finalizados.

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KEYWORDS

Mathematical models, Time series analysis, Variance analysis, Yield predictions, Fishery management, Computer programs, Tuna fisheries

1. Introduction

While the north Atlantic stock of swordfish, *Xiphais gladius*, is undergoing a full Management Strategy Evaluation or (MSE) (Smith 1993; De la Mare 1998; Deroba and Bence 2008; Punt et al. 2016), there has not been much work to validate the efficacy of MPs applied to the southern stock in practice. Closed-loop simulation permits examining management performance for a given set of Management Procedure (MP) without the more elaborate elicitation of objective and performance tuning of MPs that typically occur in some "full" MSEs. By engaging in smaller scale exploratory simulations, it is possible to illustrate performance for some MPs that are similar to those currently used for the southern swordfish stock.

2. Methods

We followed the seven basic steps outlined by (Punt et al. 2016) for the preliminary set of MSE simulations for south Atlantic swordfish.

2.1 Identification of the management objectives in concept and representation of these using quantitative performance statistics

The main management objectives in concept that we consider are those related to yield, stock status, and variability in effort. Performance statistics for yield, stock status, and variability are pretty standard for MSE (Hall et al. 1988; Punt et al. 2016; Forrest et al. 2018) and elsewhere in applied ecology (Mendelssohn 1980). For yield, we measure MP performance relative against a so-called reference yield. The reference yield is calculated by projecting the population forward in the OM with a fixed fishing mortality and optimizing for the fishing mortality that results in the highest long-term yield. It is usually close to MSY but unlike MSY, it is not an equilibrium value, but rather, it accounts for the impact of recruitment deviations in the simulations and other non-equilibrium dynamics (see the OpenMSE webpage for more details). Values of the reference yield performance statistic are reported in relative terms i.e., in fractions of the reference yield so that values near one correspond to nearly achieving the maximum yield possible.

There are no formal reference points or probability tolerances for southern swordfish, so we assumed a number of them for illustrative purposes. For a limit reference point, we explore the use of 0.40BMSY, as this has been adopted for use in northern SWO by Panel 4 (Rec 17-02) as well as for a general recommendation on the development of harvest control rules (Rec 15-07), northern albacore (Rec 17-04) and Atlantic bluefin tuna. Otherwise, the key performance statistics of interest are the probability of not overfishing (PNOF), the probability of being above BMSY (B100), the yield, and the average annual variability in yield (AAVY). The actual selection of MPs in practice will involve a much richer set of objectives and tradeoffs that we did not have the capacity to consider here. This might involve additional performance metrics, different time periods, and different probabilities associated with achieving the desired (or avoiding the undesired) outcomes.

2.2 Identification of a broad range of uncertainties to which the management strategy should be robust

For practical reasons, we limited our explorations of uncertainties to the input steepness, growth, mortality.

2.3 Development of a set of operating models which provide a mathematical representation of the system to be managed, including biological characteristics of the stock, the fisheries which intercept the modelled stock, and how data are collected from the system

We define a single OM using the R package OpenMSE. OMs are defined initially using a set of input parameters (Carruthers and Hordyk 2018); these parameters are described in SSWOOM.html (supplemental materials). For steepness and growth parameters, we use Taylor et al. 2022 simulated distributions of growth and steepness (Taylor et al. 2022) as custom parameters in the OMs for steepness, natural mortality, and the von Bertalanffy growth parameters; rather than the uniform distribution specified in initial OM, where for the number of simulations sampled is given by the number of iterations of the MSE, in this case 48. The initial OM was updated using the RCM function in the OpenMSE R package (See **Figure 1** for a schematic).

2.4 Selection of starting values for parameters in the operating models and quantifying parameter uncertainty

As a preliminary analysis of MP performance, limits on time reduced the range of uncertainty that we could consider practically. We borrowed operating model parameters extensively from northern SWO OMs but updated the stock status by fitting an age-structured model using OpenMSE's Rapid Conditioning Model (RCM). RCM fits an age-structured stochastic stock reduction model (Walters et al. 2006) to the data (catch, indices of abundance, and length composition data) and thus updates the original population dynamics parameters to reflect how the Stochastic Stock Reduction Analysis (SRA; Walters et al. 2006) updated the prior parameters defined in the input OM. Parameters updated by RCM include:

Unfished recruitment OM@R0, only if catch is provided.
Depletion OM@D
Recruitment autocorrelation OM@AC which is estimated post-hoc from the recruitment deviation estimates.
Annual recruitment deviations OM@cpars$Perr_y.

Historical recruitments are those estimated from the model, while future recruitment will be sampled with autocorrelation.

2.5 Identification of candidate MPs which could realistically be implemented for the system

Given that southern SWO has a tradition of model-based MPs, we only tested MPs that used an assessment model. MPs tested were in **Table 1** below with hyperlinks for more information.

2.6 Simulation of the application of each MP for each operating model

For the reference set, each MP was applied at the specified assessment interval (4 years). 48 iterations of each MP were used for testing. TACs determined by a given MP at a specific interval were applied for all years between assessment intervals. The overall schematic for the simulation framework is presented in **Figure 2**.

2.7 Summary and interpretation of the performance statistics

While there are no formal satisficing criteria (Miller and Shelton 2010) for southern SWO, we explore the effect of some minimum satisficing criteria to illustrate their potential use. Making some assumptions that the desire to be above BLIM, PLIM=90%, the desire to be above BMSY, PMSY=60%, the desire to avoid overfishing PNOF is 50%, and that the desire is to achieve 50% of the reference yield with a 50% chance so that the basic satisficing P_{crit} for MPs was:

P_{crit}=P(B_t>0.4B_{MSY})>90% & P(B_t>B_{MSY})>60% & P(F_t/F_{MSY}) >50% & P(C=0.5Cref>50%)

3. Results

3.1 Operating Model

The updated operating model is summarized in SouthernSWO_OM.html

3.2 MP testing results

Graphical representations of simulated stock trajectories are shown with line plots in **Figure 3**. These plots illustrate that even if the performance across all simulations is good, there will still be some interactions of the MP that result in FMSY being exceeded and lower stock status. This is important in that there is a still chance that some iterations will result in overexploitation even if the mean performance of MP is good.

The tradeoff plots (**Figure 4**) display the performance of MPs in terms of being above SSBMSY (y) and the probability of being above the limit reference point 0.40SSBMSY (y) in the left panel. As is expected, the probability of being above SSBMSY is positively correlated with the probability of being above 0.40SSMY (left panel). The right panel shows how the yield (y) declines as the conservation performance increases (x).

Given the minimal satisficing criteria defined here, a large proportion of the MPs failed (**Table 2**). The reason for the failure differed in each case (highlighted in red text). The criterion that had the most discrimination power in this particular exercise was P40. All MPs passed the BMSY criterion, but several of those MPs that it did not pass the safety (B40) criterion. For illustrative purposes we set this criterion to a high value, representing a scenario where decision makers choose to avoid a limit reference point with very high probability (90%). This was a made-up number but serves to illustrate the effect that variance (from process error, observation error, and estimation errors) in the MP can be an important factor in how MPs performance with high performance thresholder are chosen.

4. Discussion

This exercise shows that a small-scale closed-loop simulation can be set up to evaluation MP performance for the southern swordfish stock. But there is a great deal of work to do before it could be considered to inform management. Specifically, the following are needed:

1. develop the multivariate prior on steepness and the life history parameters to be specific to southern swordfish;
2. expand the operating model set to capture an alternative hypothesis for the stock;
3. finalized a set of quantitative objectives against which to measure performance.

In addition, Future MSE simulations could be improved by using SS model outputs (SCRS/2022/116) in the OM conditioning.

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Table 1. Summary of MPs tested for southern swordfish (hyperlinks provide for information).

MP	Description
DDSS_4010	A simple delay-difference assessment with UMSY and MSY as leading parameters that estimates EMSY using a time-series of catches and a relative abundance index.
DDSS_75MSY	A simple delay-difference assessment with UMSY and MSY as leading parameters that estimates EMSY using a time-series of catches and a relative abundance index.
DDSS_MSY	A simple delay-difference assessment with UMSY and MSY as leading parameters that estimates EMSY using a time-series of catches and a relative abundance index.
SCA_4010	The statistical catch-at-age model uses a time series of total catch (in weight), index, and catch-at-age observations, as well as information on weight, maturity, natural mortality at age with a 40:10 Harvest Control Rule
SCA_75MSY	The statistical catch-at-age model uses a time series of total catch (in weight), index, and catch-at-age observations, as well as information on weight, maturity, natural mortality at age applied with a 75%F_{MSY} harvest rate.
SCA_MSY	The statistical catch-at-age model uses a time series of total catch (in weight), index, and catch-at-age observations, as well as information on weight, maturity, natural mortality at age applied with a F_{MSY} harvest rate
SP_4010	A surplus production model with a TAC recommendation based on fishing with a 40-10 harvest control.
SP_75MSY	A surplus production model with a TAC recommendation based on fishing at 75% of FMSY.
SP_MSY	A surplus production model with a TAC recommendation based on fishing at FMSY, and default arguments for configuring
SSS_4010	Simple stock synthesis (terminal depletion fixed to 0.4) with a 40-10 control rule.
SSS_75MSY	Simple stock synthesis (terminal depletion fixed to 0.4) with a TAC recommendation based on fishing at 75% FMSY.
SSS_MSY	Simple stock synthesis (terminal depletion fixed to 0.4 in SSS) with a TAC recommendation based on fishing at FMSY.

Table 2. Mean MP long term performance.

MP	P40	P100	PNOF	Yield	Satisificed
DDSS_4010	0.91	0.94	0.75	0.63	TRUE
DDSS_75MSY	0.93	0.94	0.8	0.55	TRUE
DDSS_MSY	0.89	0.92	0.72	0.62	FALSE
SCA_4010	0.78	0.84	0.51	0.78	FALSE
SCA_75MSY	0.8	0.84	0.46	0.71	FALSE
SCA_MSY	0.71	0.79	0.32	0.78	FALSE
SP_4010	0.82	0.88	0.45	0.82	FALSE
SP_75MSY	0.9	0.95	0.6	0.74	TRUE
SP_MSY	0.81	0.86	0.41	0.8	FALSE
SSS_4010	0.98	0.99	0.9	0.47	FALSE
SSS_75MSY	0.98	0.99	0.89	0.54	TRUE
SSS_MSY	0.88	0.92	0.61	0.68	FALSE

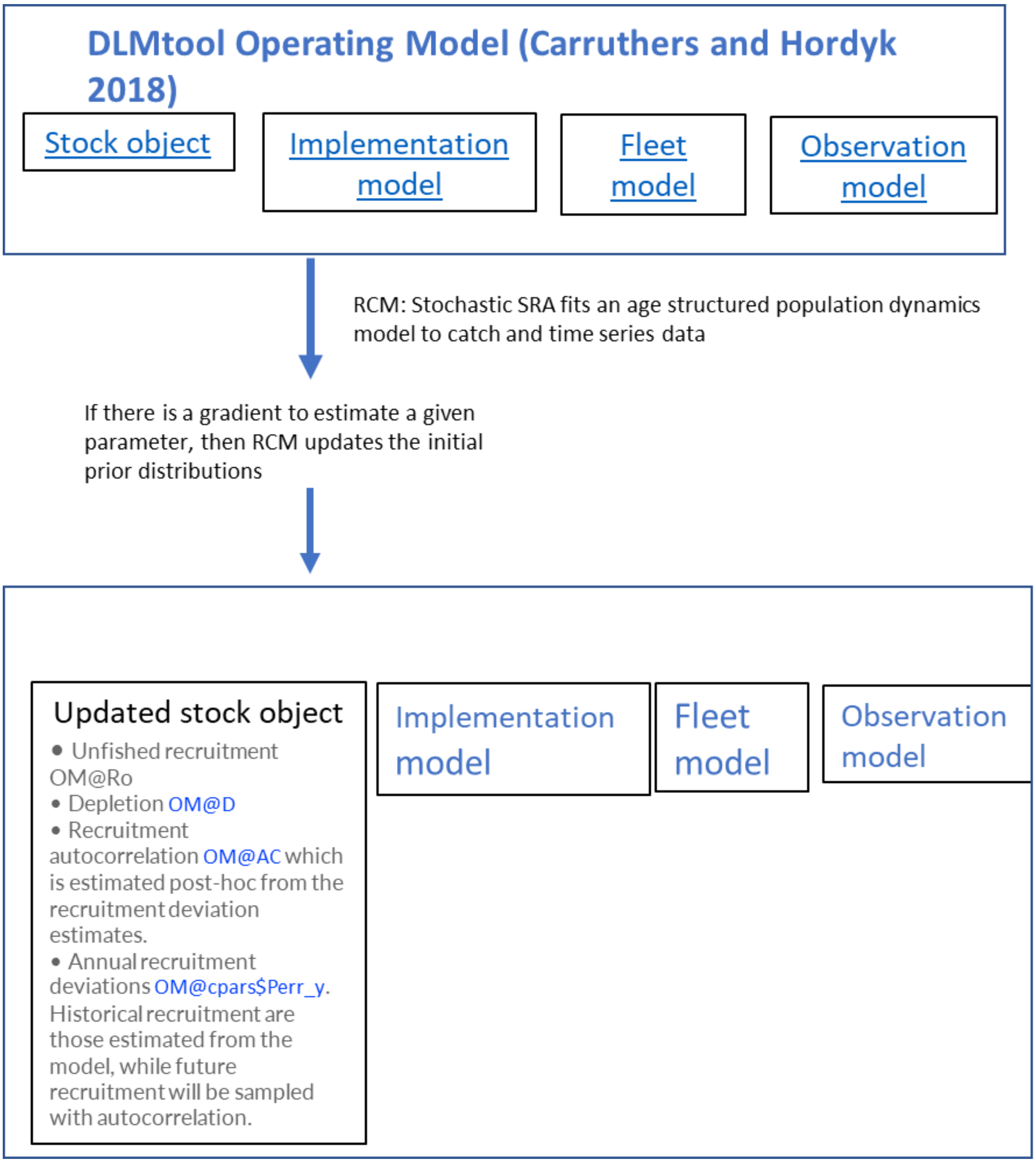

Figure 1. Schematic of the RCM fitting to update Operating Models.

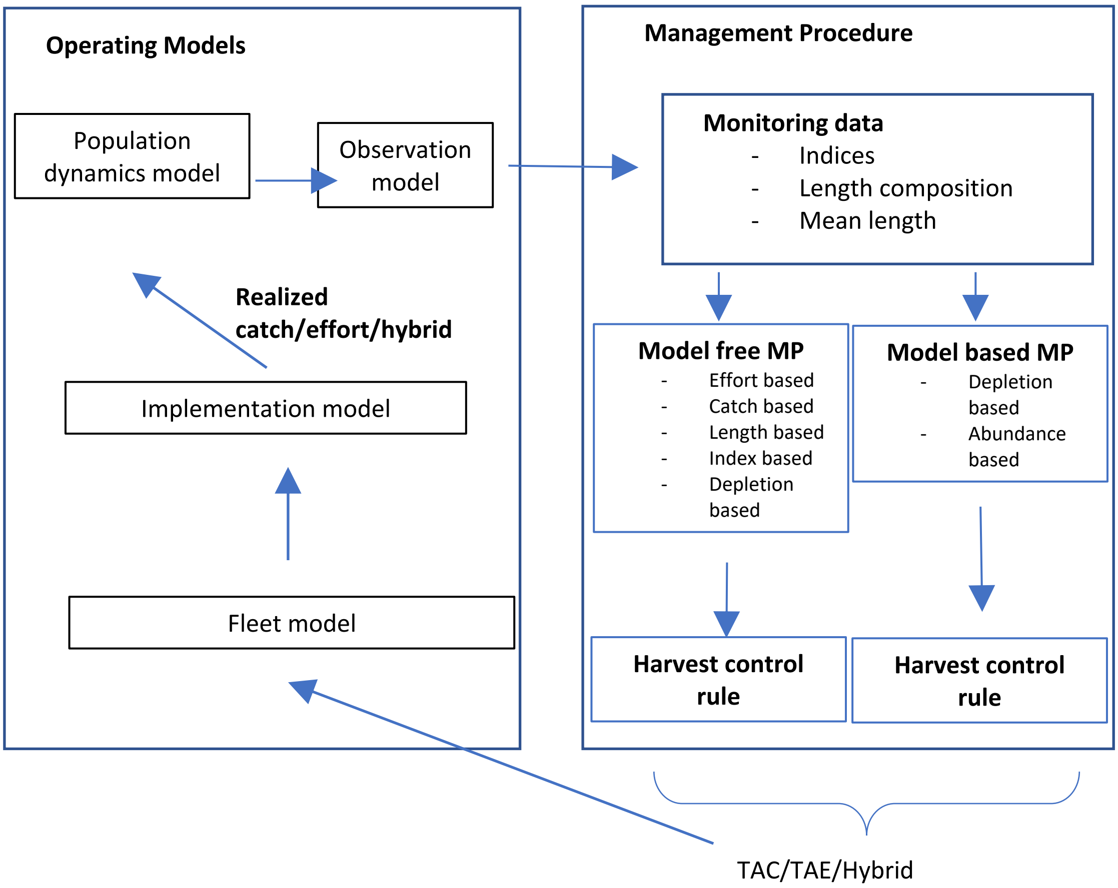

Figure 2. Schematic of closed-loop simulation scheme.

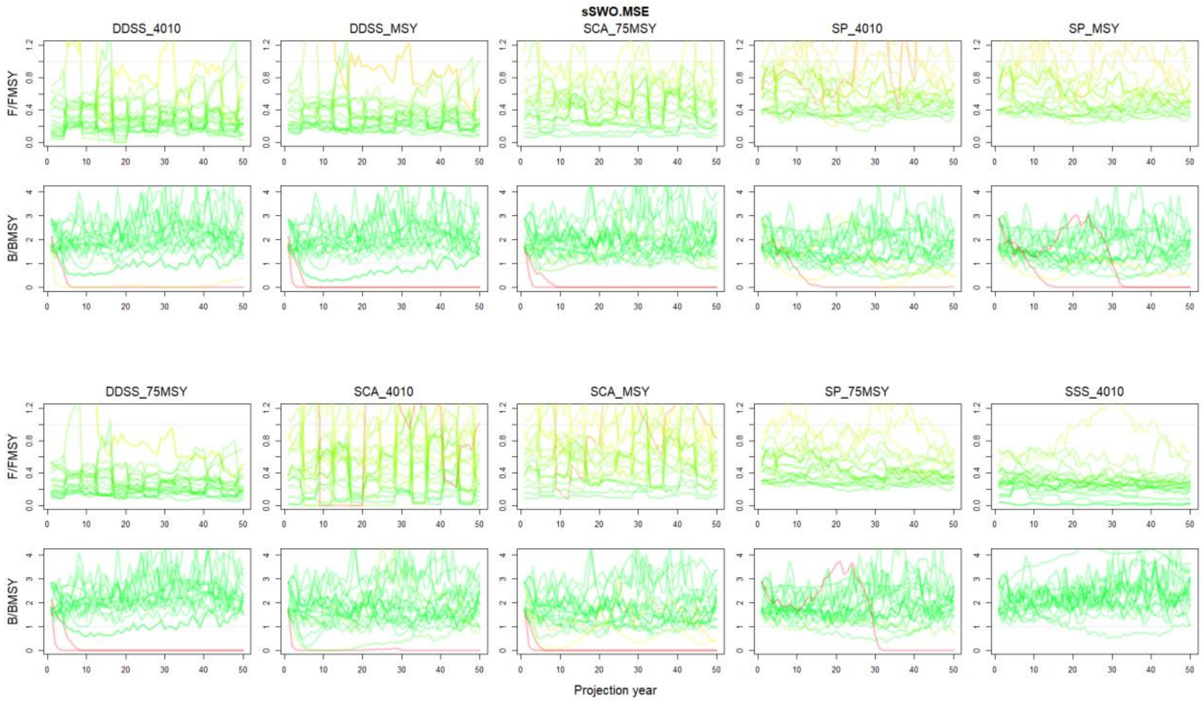

Figure 3. Line plots for MP performance for 10 MPs tested.

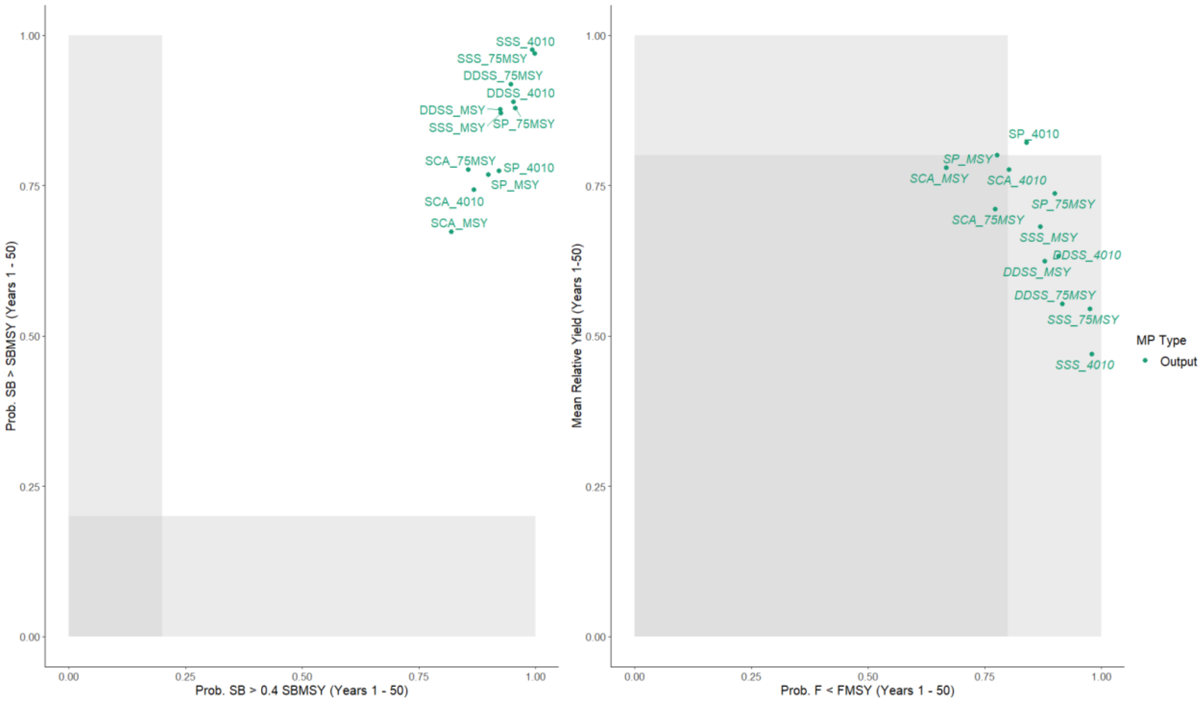

Figure 4. Tradeoff plot for all MPs tested.