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Reference points and MSE simulation of Div. 3M Cod for testing performance of NAFO provisional 'leaf' PA framework

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Abstract

The NAFO Precautionary Approach Framework (PAF) is essential for sustainably managing fishery resources in the Convention Area, aiming to maintain or rebuild stocks while minimizing risks to biological productivity. At the NAFO Scientific Council (SC) meeting in June 2024, an Management Strategy Evaluation (MSE) was conducted on the NAFO 3M cod stock to evaluate the performance of the provisional PAF. The simulation employed Reference points (RPs) derived from the Equilibrium analysis approach. The results indicated that the stock stabilized in the Cautious Zone of the proposed PAF, raising concerns that the RPs used might be too high. Consequently, the SC recommended estimating new RPs using a "simulation approach" and repeating the analysis with these updated RPs. This report assesses the effectiveness of the proposed NAFO 'leaf' PAF with the new simulation-based RPs in MSE with the 2023 3M cod Bayesian Statistical Catch-at-Age (BSCAA) assessment model as an Operating model (OM). The MSE results using new RPs based on the last 3 years' average life history characteristics (LHC) indicate that the stock is close to B_trigger, and the three leaf trajectories return F levels close to F_target. Therefore, performance is similar across all the three trajectories tested. In all cases, the stock stabilized within the Healthy Zone over the 25-year simulation period and yields approach MSY. In the initial years of PA implementation, the F levels are not much different from the current F applied to the stock. On the other hand, using new RPs based on the full time-series average LHC, the stock remains in the Cautious Zone. However, the lower leaf and linear or mid leaf trajectories showed growth from the current level. This is because RP estimates are higher when based on the full time-series LHC, indicating different productivity and fishery patterns in the recent period compared to its average historical productivity. The difference in MSE results under the two RPs highlights the importance of robust RPs estimation for PAF functionality, especially when stock dynamics are non-stationary.

Introduction

The NAFO Precautionary Approach Framework (PAF) aims to maintain or rebuild depleted fish stocks to minimize the risk of impaired biological productivity. The NAFO PA working group (PAWG) proposed a PA 'leaf' framework (Figure 1) following several years of review of multiple options (NAFO, 2022a, 2022c, 2022b, 2023). Three possible leaf width options ('Wide', 'mid', and 'narrow') were proposed based on the biomass levels within the 'Cautious' Zone where the F on the stock would be half of F_{target}. Mathematical details about PA 'leaf' framework can be found in NAFO (2024).

To assess the approved PAF, stock "specific testing" using MSE simulations was carried out on two stocks: 3M cod (Kumar et al., 2024) and 3NO Witch Flounder (Varkey et al., 2024). The PAWG observed that the narrow option closely resembled the linear model, while the wide option could cause sharp changes in the curve, potentially leading to significant fluctuations in TAC. The PAWG, therefore, recommended the 'mid' (option 2) to be applied in the specific testing examples, where the 'leaf' argument x50=0.25 for the upper leaf and x50=0.75 for the upper leaf (NAFO, 2024).

1. **Wide**: $X_{50}^{\text{up}} = 0.1, X_{50}^{\text{low}} = 0.9$
2. **Mid**: $X_{50}^{\text{up}} = 0.25, X_{50}^{\text{low}} = 0.75$
3. **Narrow**: $X_{50}^{\text{up}} = 0.4, X_{50}^{\text{low}} = 0.6$

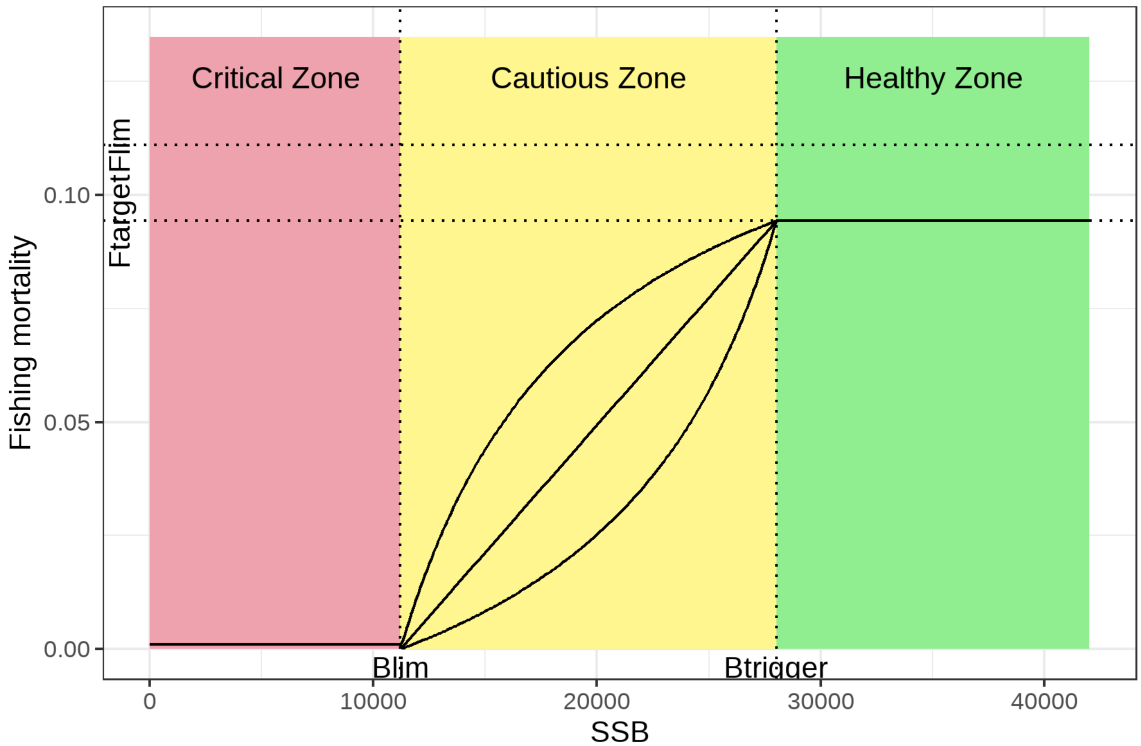

Figure 1. The 'the mid-width leafs' PA Framework to be tested for 3M cod. Overlaying reference points are calculated using the simulation approach, assuming an average 3-year LHC and a Beverton-Holt SR model with a fixed steepness value of 0.70.

At the NAFO Scientific Council (SC) meeting in June 2024, an MSE was conducted on the NAFO 3M cod stock to evaluate the performance of the provisional PAF. The simulation employed RPs derived from the Equilibrium analysis approach (**Gullage et al., 2024a**). The results indicated that the stock stabilized in the Cautious Zone, raising concerns that the RPs used might be too high. Consequently, the SC recommended estimating new RPs using a simulation approach and repeating the analysis with these updated RPs. Here, we present the RPs estimated using different approaches and updated MSE outputs based on simulation-based RPs. For reference, the MSE is based on the OM of the 3M cod BSCAA model, which was approved at the NAFO SC meeting in June 2023 (**Garrido et al., 2023**). Complete details and equations for the implementation of the MSE for the 3M cod model can be found in Kumar et al. (**2024**).

Methods

Fisheries Reference Points

We have utilized three approaches to estimate the fisheries reference points:

1. Equilibrium Analysis Approach

Equilibrium analysis approach aims to identify sustainable levels of fish stock and harvest rates to ensure long-term population stability. The approach involves balancing recruitment and mortality (due to fishing and natural causes) to find a stable state where the spawning stock biomass (SSB) remains constant over time. The mathematical details of this approach can be found in (**Gullage et al., 2024b**). In summary, to determine fishing reference points using equilibrium analysis, we follow a systematic approach. First, the Spawner Per Recruit (SPR) and Yield Per Recruit (YPR) are calculated under a specific fishing mortality rate (F), using life history characteristics (LHC) such as selectivity, maturity, natural mortality, stock weight, and catch weight. Next, stock-recruitment (SR) models, specifically the Beverton and Holt (BH) and Ricker models, are fitted to historical data to estimate parameters describing the relationship between spawning biomass and recruitment. Note that as per the recommendation of SC, steepness parameter (h) for SR relation were kept fixed at 0.7 while estimating the other parameter, $R0$ (unfished recruitment), of SR model. Then, the equilibrium spawning stock biomass ($SSBeq$) for a given fishing level is calculated by finding the point where the rate of new recruits matches the spawner biomass adjusted for SPR. By combining YPR and recruitment at $SSBeq$, the equilibrium yield is estimated. Optimization techniques are used to find the fishing mortality rate (F_{msy}) that maximizes equilibrium yield, determining the Maximum Sustainable Yield (MSY) and the spawning stock biomass at MSY (B_{msy}).

Based on the recommendation of NAFO SC June 2024 meeting, the reference points were calculated under two assumptions of LHC: (1) the average of the last 3 years for selectivity, maturity, natural mortality, stock-weight, and catch-weight, and (2) the average of the entire time-series of these LHC characteristics. The SR parameter, especially $R0$, changes under different assumptions of LHC. The reference points (F_{msy}, MSY, B_{msy}) calculations were performed separately for the Beverton-Holt and Ricker SR models (**Gullage et al., 2024b**).

2. Simulation Approach

This approach involves simulating from an operating model (OM) under the same assumptions of life history characteristics (LHC) and stock-recruitment (SR) relationship as in the Equilibrium Analysis, using both the 3-year average and the full time-series average of LHC. The OM is projected for 50 years across a range of fishing mortality (F) levels from 0 to 0.5, with increments of 0.001. The simulations utilize 350 randomly selected threads of LHC derived from the posterior of the 2023 Bayesian SCAA model, which incorporates data up to 2022. The optimal fishing mortality rate, F_{msy}, is identified by finding the level that yields the maximum median yield (MSY) in the terminal year. The corresponding spawning stock biomass at F_{msy} is B_{msy}.

3. SPR 30%

The existing or current approach of determining Flim, the fishing mortality rate at which the Spawner Per Recruit (SPR) is reduced to 30% of the SPR achieved under no fishing (F=0), involves identifying the level of fishing mortality that results in this specific reduction in SPR, thereby establishing a limit to prevent overfishing and ensure sustainable fish populations.

Table 1. Estimating fisheries Reference Points (RPs) using various methods for 3M Cod. RPs shown in red were used in MSE analysis.

Methods	LHC	SR	SPR0	Fmsy	Ftarget	msy	Bmsy	Blim	Btrigger	logR0	h
Eq. Analysis	3-yr	BH	0.801	0.112	0.095	14,035	37,627	11,288	28,220	11.923	0.7
Eq. Analysis	3-yr	RK	0.801	0.100	0.085	13,805	40,955	12,287	30,716	11.670	0.7
Eq. Analysis	full-TS	BH	1.227	0.179	0.152	17,504	70,287	21,086	52,715	12.053	0.7
Eq. Analysis	full-TS	RK	1.227	0.168	0.143	15,321	65,467	19,640	49,100	11.680	0.7
Simulation	3-yr	BH	0.801	0.111	0.094	13,922	37,358	11,207	28,019	11.923	0.7
Simulation	3-yr	RK	0.801	0.097	0.082	13,682	41,653	12,496	31,240	11.670	0.7
Simulation	full-TS	BH	1.227	0.177	0.150	17,355	70,382	21,115	52,786	12.053	0.7
Simulation	full-TS	RK	1.227	0.167	0.142	15,204	65,179	19,554	48,884	11.680	0.7
SPR30%	3-yr	NA	0.800	0.155	0.132		48,488	14,546	36,366	NA	
SPR30%	full-TS	NA	0.887	0.264	0.224		48,488	14,546	36,366	NA	

MSE implementation

A Bayesian statistical catch-at-age model (BSCAA) is used to assess the cod stock in NAFO Division 3M. The Operating Model (OM) used for the MSE simulations is based on the latest assessment completed in 2023, incorporating data up to 2022. More information about the assessment model can be found in **Garrido et al. (2023)**. The population is simulated forward assuming a three-year average for life history characteristics: maturity-at-age, selectivity-at-age, stock-weight, and catch-weight. Natural mortality (M) at age is time-invariant in the BSCAA and this M is used in the simulations. The PA 'leaf' is applied to calculate catch-advice in the simulations, and the performance of stock biomass, F, and yield outputs are evaluated using performance metrics. Complete details on MSE implementation is provided in (**Kumar et al., 2024**); this work is an update of the MSE simulations with new reference points.

Results

Both the equilibrium and simulation-based methods yield similar reference point estimates (Table 1); the primary difference lies in the length of the time-series used for calculating average LHC. The RP estimates are consistently higher across approaches when using the average of the full time series LHC compared to a 3-year average.

The MSE outcome from simulation-based RPs using 3 years average LHC for both the SRR types showed the stock reaching the Healthy Zone (Figures 2, Figures 3). At the beginning of the simulation, the stock is at the border of the Healthy Zone. During the simulation, biomass increases well into the Healthy Zone. Ftarget seems to be a reasonable estimate as it supports the growth of the stock well into the Healthy Zone. F-levels at the beginning of PA implementation are not much different from the current F applied to the stock (Figures 6, Figures 7) ; and hence, there is not much variability in short-term yields. The fishery yields approach MSY towards the end of the simulation (Figures 8, Figures 9).

Since the current stock is at the border of the 'Healthy' Zone at the beginning of the simulation and remains in that zone throughout the simulation, it was not possible to compare the different 'leaf' options. Performance metrics for 3M cod do not vary much between PA 'leaf' options, and this result is consistent across both the Beverton-Holt and Ricker based OMs. There are slight differences between the 'leaf' options for some metrics, and these disparities are a result of random processes in the simulations. Although overall results are similar for both SRRs, the simulations using the Ricker SRR have slightly better performance metrics than the BH for the risk of falling below Btrigger, risk of overfishing, growth metrics, and recovery catches.

The MSE outcome from simulation-based RPs using full-time series average LHC, showed the stock remaining in the Cautious zone (Figure 12). Only the linear and the lower leaf show stock growth. F levels stayed close to current F levels in the upper leaf but decreased in both the lower and linear leaf (Figure 13), and the catches stabilized at levels below the MSY (Figure 14).

More results are in the section on performance metrics, see "Appendix: Performance Statistics".

Discussion

The findings underline several key points about the effectiveness of the proposed PAF and the importance of RPs estimation. The RPs define the boundaries of different stock status zones (Healthy, Cautious, and Critical) of PAF. The RPs estimation and MSE simulations showed that the under current conditions (3-year LHC), the stock is less productive, and fishery patterns are different than indicated by historical full time-series averages. In the second scenario, using new reference points based on the full time-series average LHC, the stock remains in the Cautious Zone due to higher Ftarget levels and the Healthy Zone boundary being set at a higher SSB. These results emphasize the importance of robust reference point estimation for the effective functioning of the PAF, especially when there are concerns about non-stationarity in stock dynamics.

Acknowledgements

We sincerely thank Karen Dwyer, Section Head, GF, NL Region, for providing the opportunity and time to undertake the PA simulation work. We are also grateful to NAFO PAWG for their invaluable advice throughout this project. Additionally, we appreciate the IT support from DFO HPC, particularly Robert Ma, whose assistance was crucial in ensuring the timely completion of the simulation work.

Figures

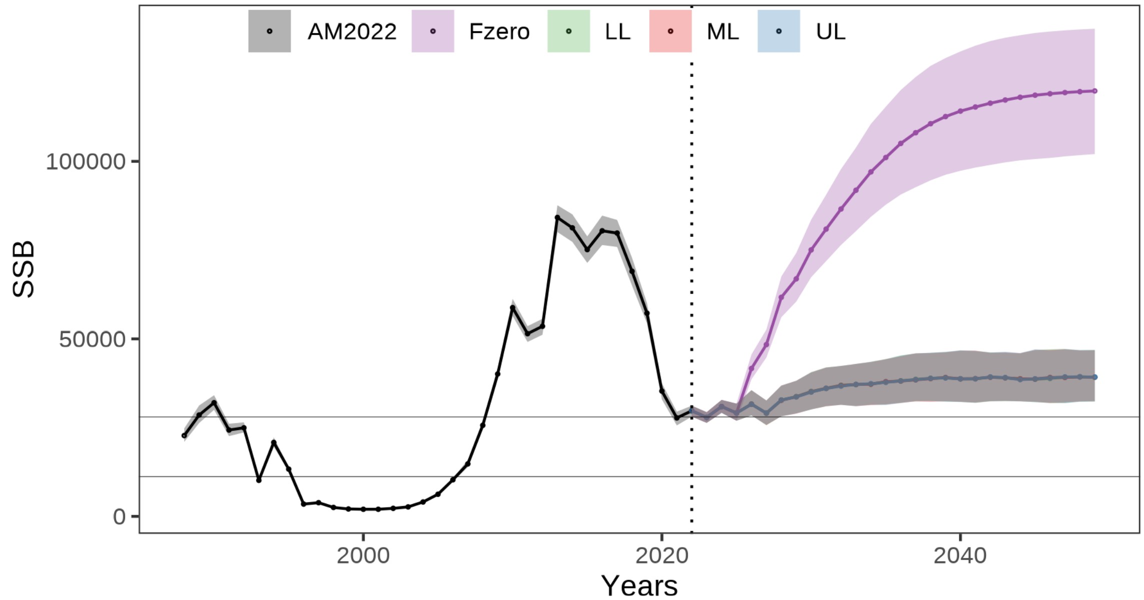

Figure 2. 25-year 3M cod MSE simulation output for SSB under the assumption of BH SR relationship. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero. The area between the two horizontal lines is the Cautious Zone.

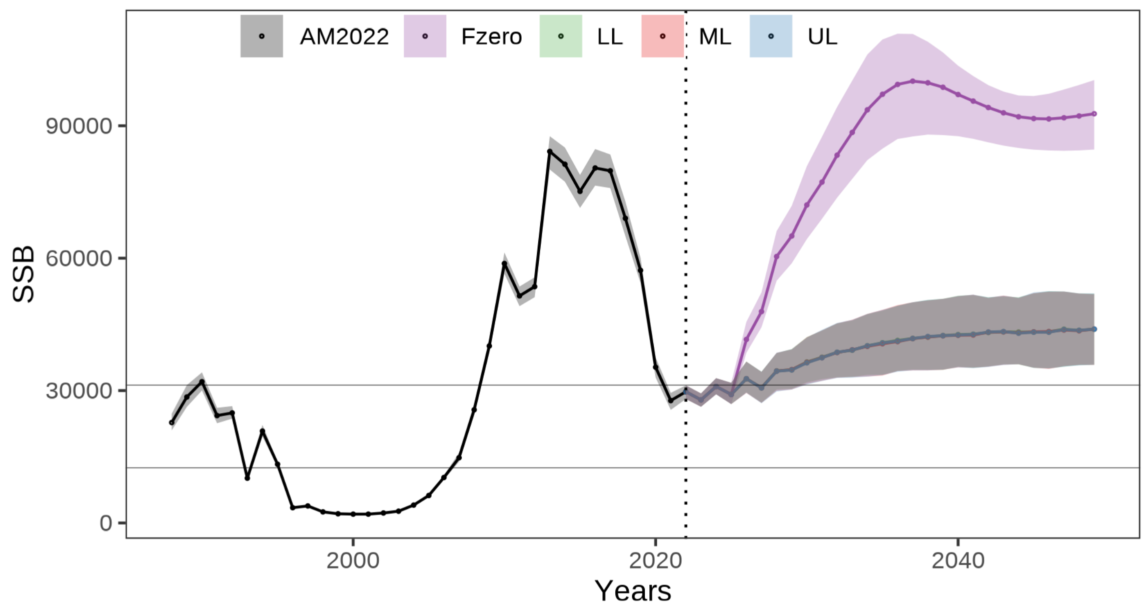

Figure 3. 25-year 3M cod MSE simulation output for SSB under the assumption of Ricker SR relationship. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero. The area between the two horizontal lines is the Cautious Zone.

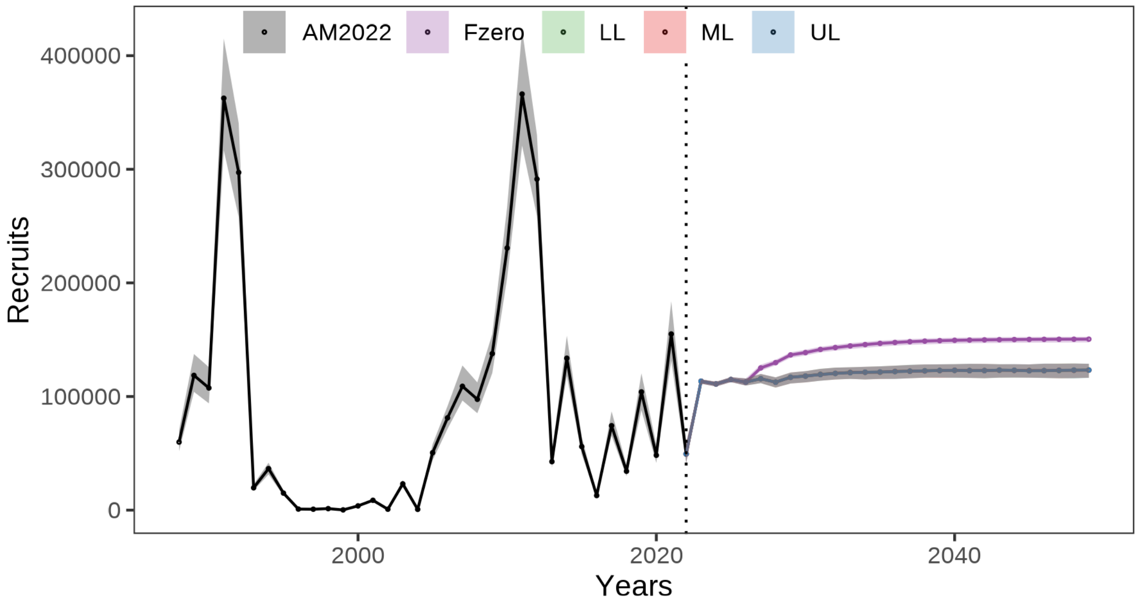

Figure 4. 25-year 3M cod MSE simulation output for Recruitments under the assumption of BH SR relationship. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero.

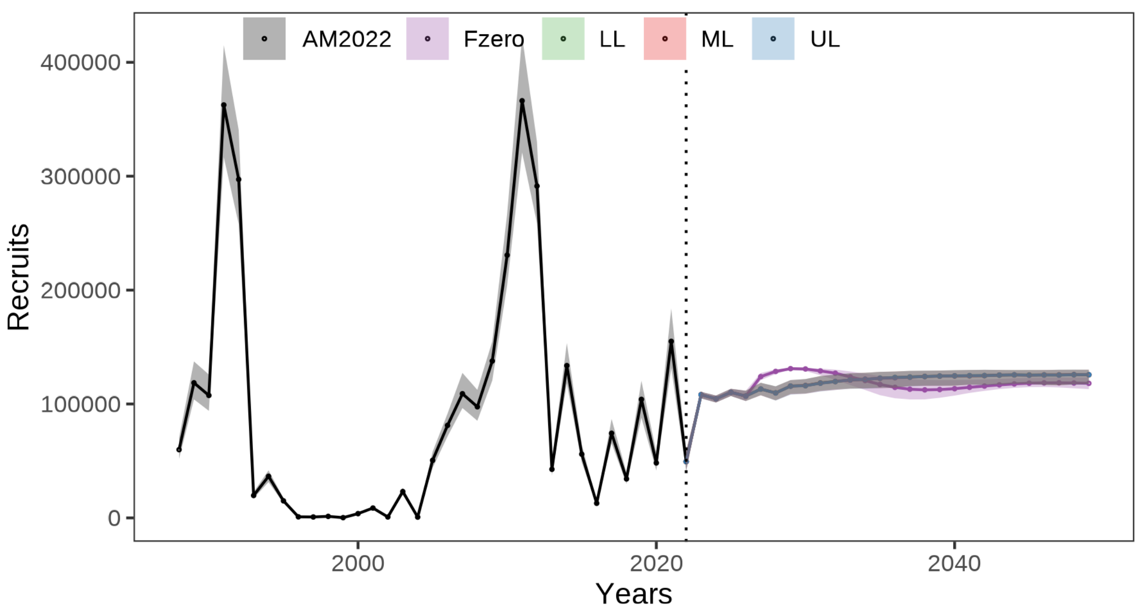

Figure 5. 25-year 3M cod MSE simulation output for Recruitments under the assumption of Ricker SR relationship. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero.

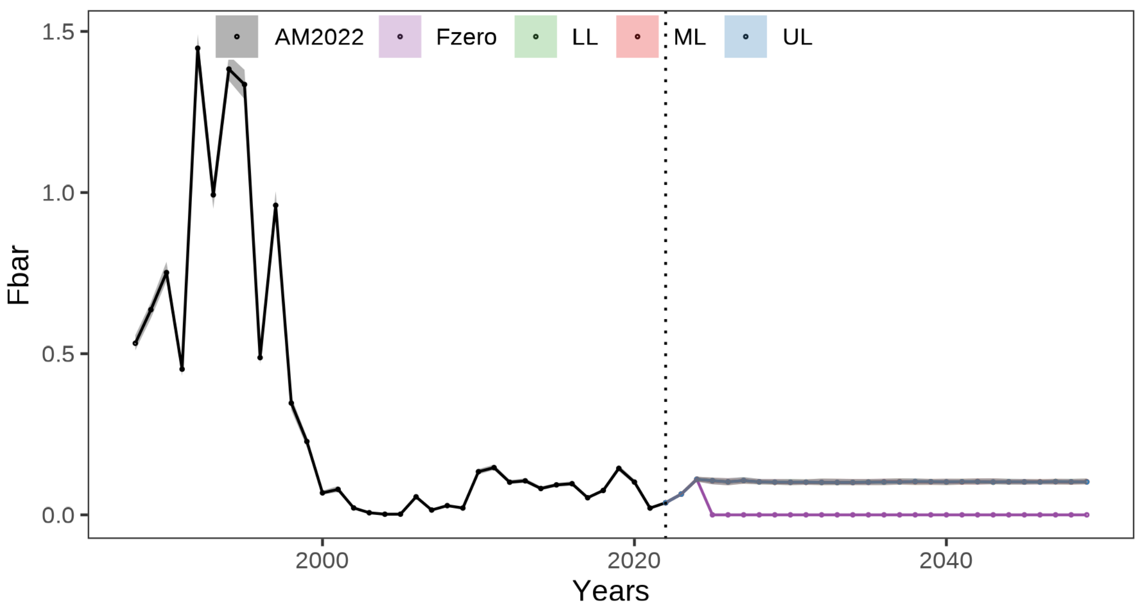

Figure 6. 25-year 3M cod MSE simulation output for Fbar under the assumption of BH SR relationship. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero.

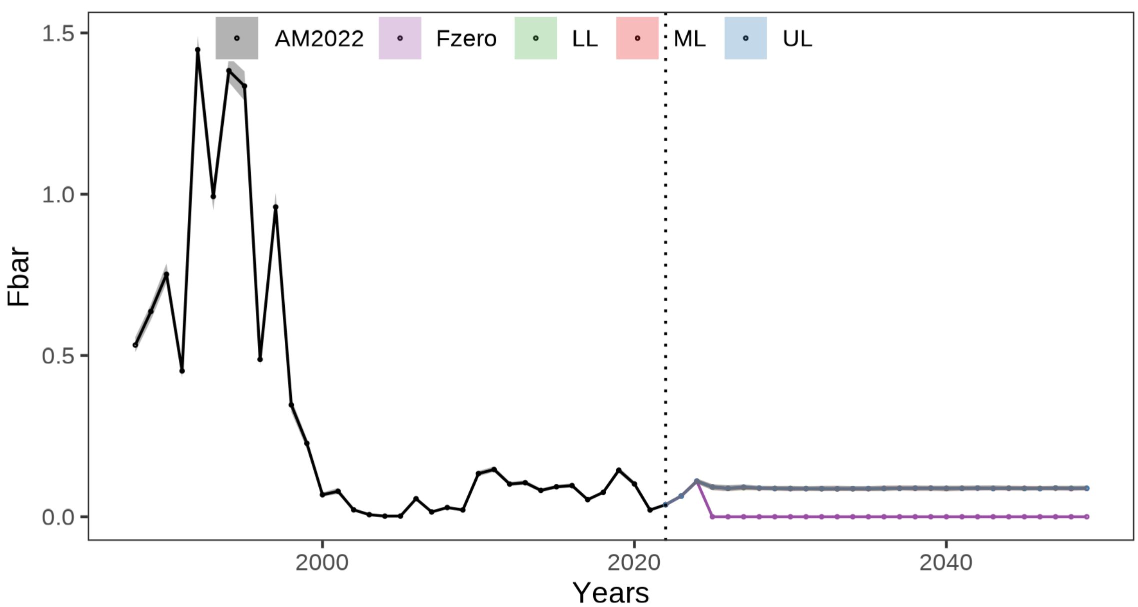

Figure 7. 25-year 3M cod MSE simulation output for Fbar under the assumption of Ricker SR. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero.

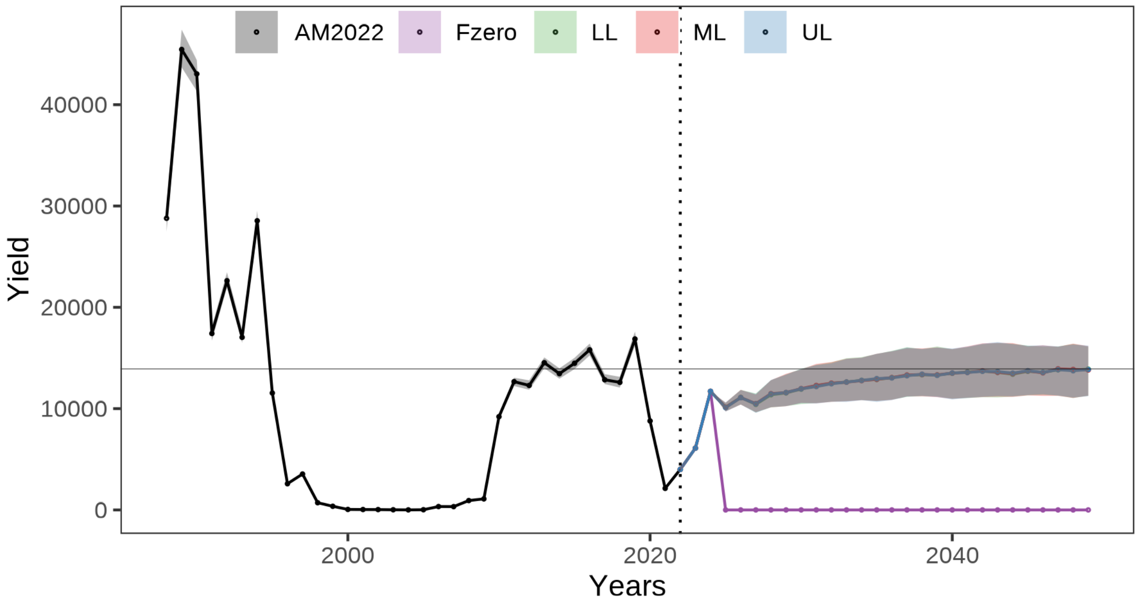

Figure 8. 25-year 3M cod MSE simulation output for Yield under the assumption of BH SR. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero. The horizontal line represents MSY.

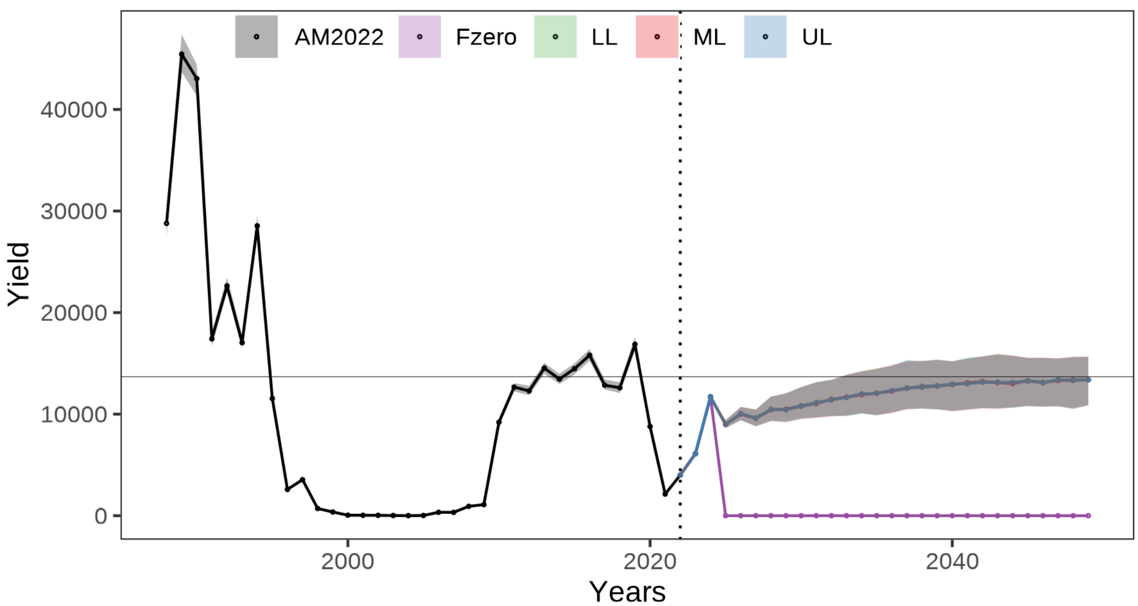

Figure 9. 25-year 3M cod MSE simulation output for Yield under the assumption of Ricker SR relationship. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero.The horizontal line represents MSY.

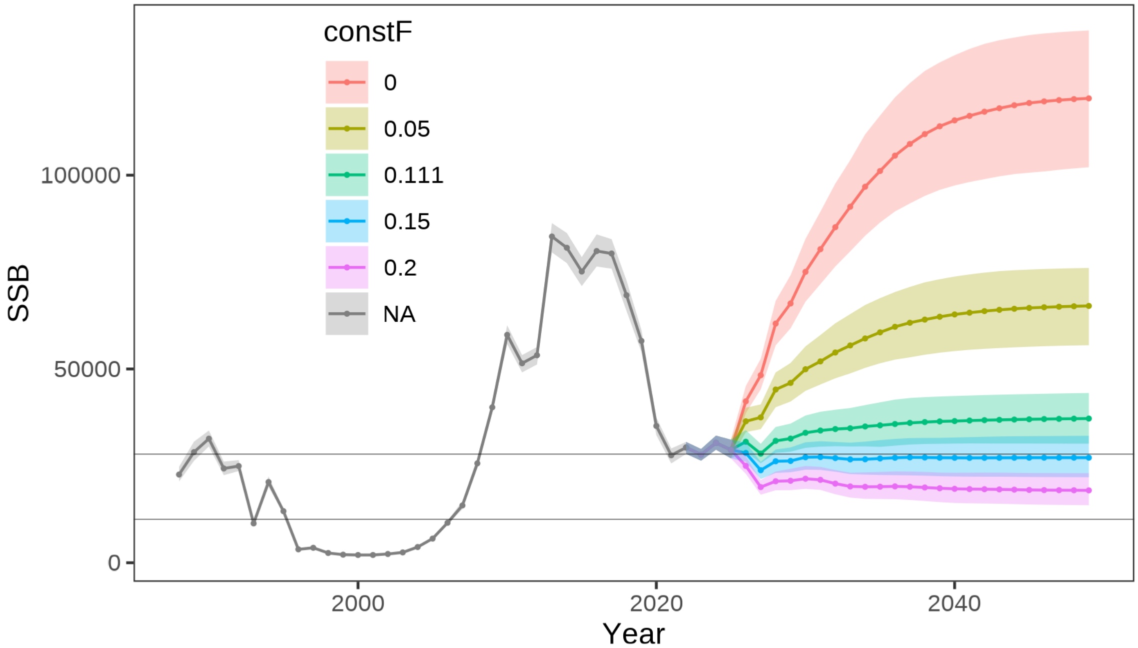

Figure 10. 25-year 3M cod simulation at a range of constant F levels for SSB under Beverton-Holt stock-recruitment relationship. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model.

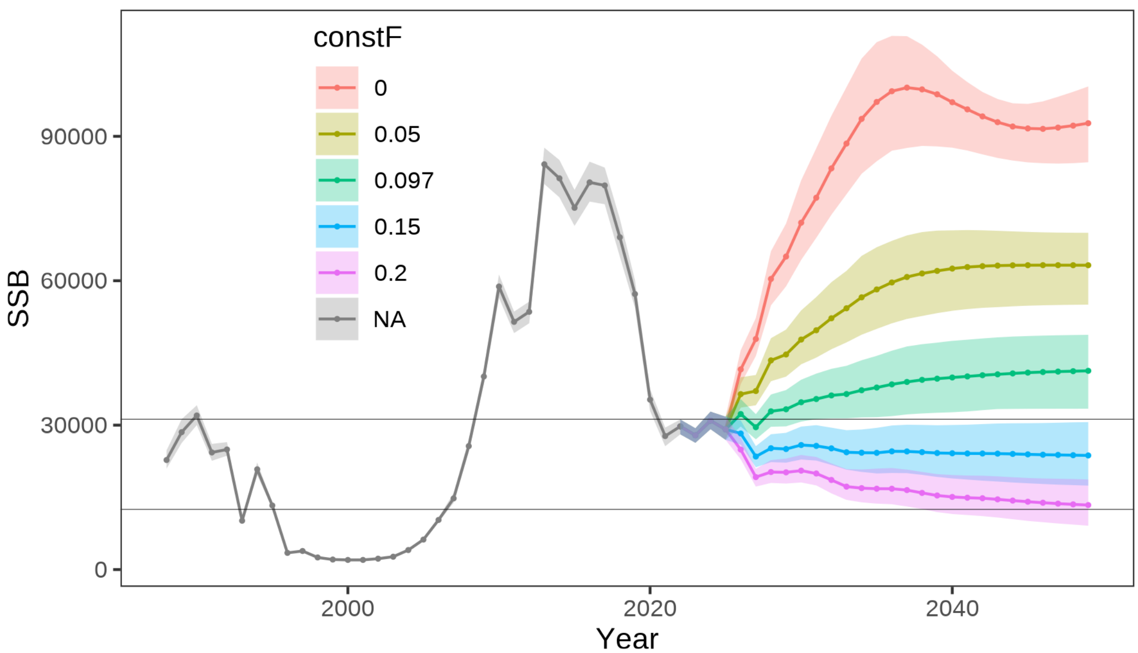

Figure 11. 25-year 3M cod simulation at a range of constant F levels for SSB under Ricker stock-recruitment relationship. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model.

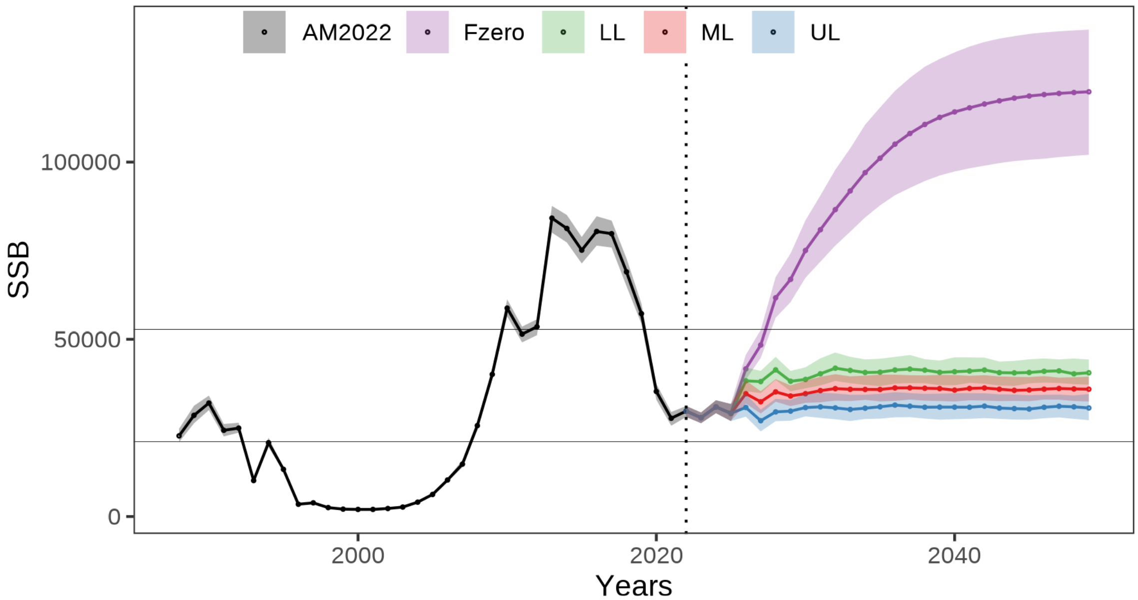

Figure 12. 25-year 3M cod MSE simulation output for SSB under the assumption of BH SR relationship and reference points based on full time-series average of LHC. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero. The area between the two horizontal lines is the Cautious Zone.

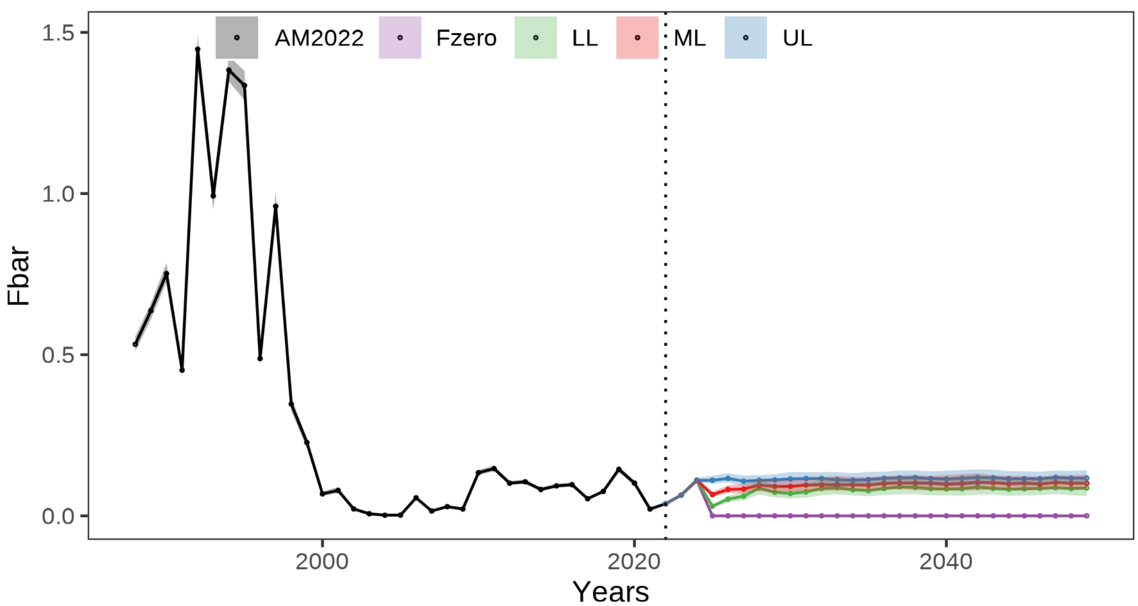

Figure 13. 25-year 3M cod MSE simulation output for Fbar under the assumption of BH SR relationship and reference points based on full time-series average of LHC. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero.

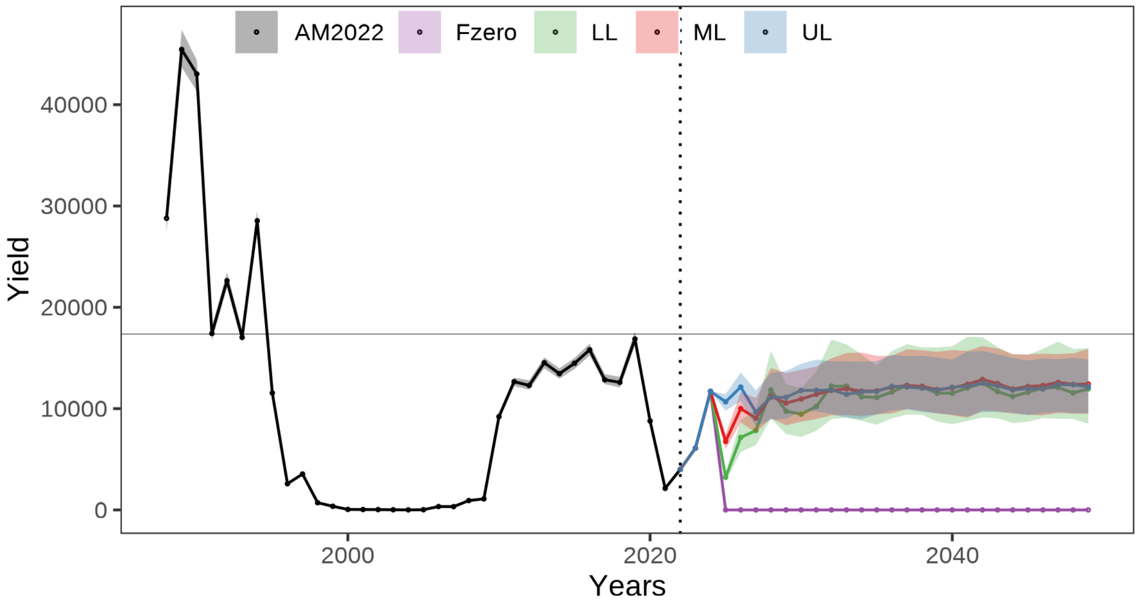

Figure 14. 25-year 3M cod MSE simulation output for Yield under the assumption of BH SR and reference points based on full time-series average of LHC. Median CI is calculation using 350 iterations. The estimate upto 2022 (shown in black) is from 2023 assessment model. LL denotes the lower leaf, ML the middle leaf, and UL the upper leaf. Fzero is a projection from the OM with F set to zero.The horizontal line represents MSY.

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Appendix: Performance Statistics

Fourteen performance Metrics (PMs) were tested for the 3M cod MSE, each with their own criterion to determine objective success or failure. PMs were derived for all HCRs, including the $F = 0$ run, to determine how each HCR performed. Below is a brief list of the PMs:

(1) Very low risk of stock depletion

$$Prop(B < B_{lim}) \leq 0.10$$

(2) Risk of stock falling below$B_{trigger}$

$$Prop\left(B < B_{trigger}\right) \leq 0.30$$

(3) Maintain stocks above B_{MSY}

$$Prop(B > B_{MSY}) \geq 0.75$$

(4) Low risk of overfishing

$$Prop(F < F_{MSY}) \geq 0.70$$

(5) Rebuild stocks to the vicinity of B_{MSY}

$$Prop\left(\bar{\mu}\left(B_{(T-10):T}\right) > B_{trigger}\right) \geq 0.80$$

(6) Monitor short term growth

$$Prop(B_{t=5} > B_{t=1}) \geq 0.75$$

(7) Monitor medium term growth

$$Prop(B_{t=15} > B_{t=1}) \geq 0.75$$

(8) Monitor medium term growth

$$Prop(B_{t=25} > B_{t=1}) \geq 0.75$$

(9) Absolute time to recovery

$$Count_t\left(B \to B_{trigger}\right)$$

(10) Relative time to recovery

$$\frac{Count_t^{F=HCR}\left(B \to B_{trigger}\right)}{Count_t^{F=0}\left(B \to B_{trigger}\right)} \leq 1.2$$

(11) Extra time to recovery

$$Count_t^{F=HCR}\left(B \to B_{trigger}\right) - Count_t^{F=0}\left(B \to B_{trigger}\right)$$

(12) Maintain approximately MSY catches in the long-term

$$Prop\left(0.8 \geq \frac{Median\left(C_{(T-10):T}\right)}{MSY} < 1.2\right) \geq 0.80$$

(13) Measure the inter-annual TAC variation

$$Median\left(\frac{|C_{t+1} - C_t|}{C_t}\right) \leq 0.20$$

(14) Catch during the maximum recovery window

$$\frac{\sum_{1:t_{max}} C_t \,/MSY}{t_{max}}$$

All performance metrics (PMs) passed their respective criterion for success regardless of which HCR was used. All HCRs (i.e., F_{upper}, F_{linear}, and F_{lower}) had a very low risk of stock depletion *(1)* and a low risk of being below $B_{trigger}$ *(2)*. All HCRs were unable to maintain B_{MSY} *(3)*, but allHCRS were able to rebuild to B_{MSY} *(5)*. All HCRs had a low risk of overfishing *(4)*, but no HCRs maintained a long-term catch close to MSY *(12)*. All HCRs achieved growth in the short- *(6)*, medium- *(7)*, or long-term *(8)*. The absolute *(9)* and extra *(11)* times to recovery does not have criteria for objective success, but values are consistent across HCRs. All HCRs pass the objective for relative time to recovery *(10)*. The median inter-annual variability in TAC *(13)* passed the objective only for all HCRs, and the relative catch of maximum recovery *(14)* does not have an assigned success criterion, but all HCRs perform consistently. Trajectories for simulations using either the Bevertone-Holt and Ricker stock-recruit relationships perform consistently, and SRR selection does not impact overall trajectory or performance.

Table 2. Performance Metrics for each HCR for the 3M cod BH OM.

Description	Performance Metric	OM	F_{lower}	F_{linear}	F_{upper}	F = 0
Very low risk of stock depletion	$Prop(B < B_{lim})$	BH	0.000	0.000	0.000	0.000
Risk of stock falling below $B_{trigger}$	$Prop(B < B_{trigger})$	BH	0.040	0.040	0.040	0.000
Maintain stocks above B_{MSY} more often than not	$Prop(B > B_{MSY})$	BH	**0.480**	**0.480**	**0.480**	0.960
Low risk of overfishing	$Prop(F < F_{MSY})$	BH	0.760	0.760	0.760	1.000
Rebuild stocks to the vicinity of B_{MSY}	$Prop(\bar{\mu}(B_{(T-10):T}) > B_{trigger})$	BH	0.877	0.877	0.874	1.000
Monitor short term growth	$Prop(B_{t=5} > B_{t=1})$	BH	0.763	0.757	0.757	1.000
Monitor medium term growth	$Prop(B_{t=15} > B_{t=1})$	BH	0.823	0.817	0.811	1.000
Monitor long term growth	$Prop(B_{t=25} > B_{t=1})$	BH	0.817	0.817	0.817	1.000
Time to recovery (absolute)	$Count_t(B \rightarrow B_{trigger})$	BH	1	1	1	1
Time to recovery (relative)	$\frac{Count_t^{F=HCR}(B \rightarrow B_{trigger})}{Count_t^{F=0}(B \rightarrow B_{trigger})}$	BH	1.0	1.0	1.0	1.0
Time to recovery (additional years)	$Count_t^{F=HCR}(B \rightarrow B_{trigger}) - Count_t^{F=0}(B \rightarrow B_{trigger})$	BH	0	0	0	0
Maintain approximately MSY catches in the long-term	$Prop(0.8 \geq \frac{Median(C_{(T-10):T})}{MSY} < 1.2)$	BH	**0.574**	**0.571**	**0.580**	**0.000**
Measure the inter-annual TAC variation	$\frac{Median(\mid C_{t+1} - C_t \mid)}{C_t}$	BH	0.056	0.055	0.054	-
Catch during the maximum recovery window	$\frac{\Sigma_{1:tmax}(C_t/MSY)}{t_{max}}$	BH	0.917	0.916	0.917	0.000

Table 3. Performance Metrics for each HCR for the 3M cod RK OM.

Description	Performance Metric	OM	F_{lower}	F_{linear}	F_{upper}	F = 0
Very low risk of stock depletion	$Prop(B < B_{lim})$	RK	0.000	0.000	0.000	0.000
Risk of stock falling below $B_{trigger}$	$Prop(B < B_{trigger})$	RK	0.080	0.080	0.080	0.040
Maintain stocks above B_{MSY} more often than not	$Prop(B > B_{MSY})$	RK	**0.480**	**0.480**	**0.500**	0.960
Low risk of overfishing	$Prop(F < F_{MSY})$	RK	0.840	0.840	0.840	1.000
Rebuild stocks to the vicinity of B_{MSY}	$Prop(\bar{\mu}(B_{(T-10):T}) > B_{trigger})$	RK	0.877	0.869	0.863	1.000
Monitor short term growth	$Prop(B_{t=5} > B_{t=1})$	RK	0.860	0.846	0.840	1.000
Monitor medium term growth	$Prop(B_{t=15} > B_{t=1})$	RK	0.900	0.889	0.880	1.000
Monitor long term growth	$Prop(B_{t=25} > B_{t=1})$	RK	0.923	0.903	0.891	1.000
Time to recovery (absolute)	$Count_t(B \rightarrow B_{trigger})$	RK	2	2	2	2
Time to recovery (relative)	$\frac{Count_t^{F=HCR}(B \rightarrow B_{trigger})}{Count_t^{F=0}(B \rightarrow B_{trigger})}$	RK	1.0	1.0	1.0	1.0
Time to recovery (additional years)	$Count_t^{F=HCR}(B \rightarrow B_{trigger}) - Count_t^{F=0}(B \rightarrow B_{trigger})$	RK	0	0	0	0
Maintain approximately MSY catches in the long-term	$Prop(0.8 \geq \frac{Median(C_{(T-10):T})}{MSY} < 1.2)$	RK	**0.577**	**0.574**	**0.577**	**0.000**
Measure the inter-annual TAC variation	$\frac{Median(\mid C_{t+1} - C_t \mid)}{C_t}$	RK	0.055	0.054	0.053	-
Catch during the maximum recovery window	$\frac{\Sigma_{1:tmax}(C_t/MSY)}{t_{max}}$	RK	0.873	0.873	0.873	0.000