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Extension of the MSE simulations to 50 years for testing the NAFO Precautionary Approach Framework (NAFO-PAF) for Divs. 3NO Witch Flounder stock case-study

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Abstract

In June 2024, the outcome from Management Strategy Evaluation (MSE) with 25 years of simulation for the 3NO Witch Flounder Stock to assess the provisional precautionary approach framework (PAF) was presented in the NAFO Scientific Council (SC) meeting. The PAF aims to minimize the risk of stock depletion, rebuild biomass to sustainable levels, and maintain average catches at maximum sustainable yield (MSY). Initial simulations showed borderline results for achieving a risk of less than 30% of stock falling below $B_{trigger}$. Subsequently, the SC recommended to extend the simulation period 50 years. The extended simulations passed the performance statistic of having low risk of falling below $B_{trigger}$. The stock biomass increases into the Healthy Zone, with approximately 35% of simulations reaching above B_{msy}. However, the goal of maintaining biomass above B_{msy} consistently was not met.

Introduction

At the NAFO Scientific Council (SC) meeting in June 2024, a Management Strategy Evaluation (MSE) with 25 years of simulation was conducted for the 3NO Witch Flounder Stock to evaluate the performance of the provisional precautionary approach framework (PAF) (**Varkey et al., 2024**). The key objectives of the PAF are to have a low risk of stock biomass (B) depletion (i.e., B<B_{lim}), to rebuild B to the level associated with maximum sustainable yield (B_{msy}), to maintain stocks above B_{msy} more often than not, and to maintain average catches approximately at MSY in the long-term (**NAFO, 2022**, **2024**). In the simulations, the objective of less than 30% risk of the stock being below $B_{trigger}$ (i.e. low risk of being in the cautious zone) showed borderline results for passing or failing the performance statistic. At the inter-sessional meeting in July 2024, the NAFO SC recommended running a longer simulation to allow the population to stabilize and then report on the performance of the PAF. This document is an extension of the simulations (**Varkey et al., 2024**) to 50 years. Three runs were conducted using the lower, middle and upper leaf F following the leaf shape in the PAF (Figure 1).

Methods

The stock is currently assessed using a Bayesian Surplus Production (BSP) model (**Maddock Parsons et al., 2022**, **2024**) and is understood to be in the Cautious Zone (Figure 2). The 2022 accepted BSP model (**Maddock Parsons et al., 2022**), which was the most recent accepted assessment model for the stock at the time of testing, was used as the operating model (OM) for the MSE work. For testing the PAF, the MSE applies the PA 'leaf' structure to determine the TAC advice for the stock in the simulation. This stock is assessed every two years and advice for the next 2-year is provided. In the MSE implementation too, the assessment frequency of two years is maintained, and at every assessment, advice based on the PA is provided (based on projections from the assessment) for two years.

Key steps of the MSE are as follows:

1. Operating model: The operating model is initialized using the BSP model and process and observation uncertainty from the fitted BSP model is carried forward using 350 threads in the projections. Catch advice is available till year 2024 and these values are used to calculate F (ratio of catch over biomass) in the initial years. PA implementation in the simulations begins in 2025.

2. Observation model: New data are generated for Canadian spring and autumn survey and provided to the assessment process within the simulations to mimic the process with real data and assessments for this NAFO stock.

3. Application of the PA leaf formulation: The PA implementation process begins in the current year 2024 (using data upto 2023). The assessment model is run within each simulation wherein catch advice is generated for 2025. Projections from this assessment is also used to generate catch advice for 2026 as there will be no new assessment for this stock in 2025 NAFO SC meeting.

Full details of the MSE simulation set-up with equations are available in Varkey et al. (**2024**).

Results and Discussion

Simulations were re-run for 50 years because the initial 25 years period was not sufficient to reach stability. Biomass across all the leaves trajectory is projected to increase into the Healthy Zone (Figure 3). After extending to 50 years, approximately 35% of the simulations reach above B_{msy}. This is an increase from the previous results, where simulation run for 25 years showed only 15 to 20% simulation reached above B_{msy}; however, the performance statistic of getting the biomass above B_{msy} more often than not is not met in either case. As expected, the projections using the lower leaf trajectory performs better for biomass trends. The yields approach MSY towards the end of the simulation (Figure 4). During a large portion of the simulation, the stock is in the Healthy Zone and most F values are evaluated to remain at F_{target} with 27 to 29% exceeding F_{lim} (Figure 5). F_{lim} is exceeded due to the process and observation errors and lag in implementation. To elaborate on implementation, at an assessment in year 'y', data up to the year 'y-1' are used to provide catch advice for year 'y+1'. Further, assessment frequency for the Witch Flounder stock is every two years, so catch advice is also provided for year 'y+2' based on projections from the assessment in year 'y'.

The Witch Flounder simulations indicate that, in general, the PAF achieves most of the established objectives. As noted previously, when the PAF is implemented, there is an increase in F from current levels in all the three leaf trajectories (F scenarios) examined. In the short term, there is an abrupt increase in F and TAC from current levels, especially in the upper leaf trajectory. Based on the observations on TAC variability, we suggest that the PA leaf shape should be informed by the current position of the stock on the PA map in order to reduce the abrupt changes to catch advice upon implementation of PA. For the Witch Flounder stock, if the leaf is set to pass through the current stock position, then the 'leaf' trajectory would be closest to the lower leaf (Figure 2).

References

Maddock Parsons, D., Rideout, R., and Rogers, B. (2022). An assessment of the witch flounder resource in NAFO divisions 3NO. *NAFO SCR Doc*, *22/014*.

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NAFO. (2022). Achieving NAFO convention objectives with a precautionary approach framework precautionary approach working group (PA-WG) october 2021. *NAFO SCS Doc*, *22/02*. **https://www.nafo.int/Portals/0/PDFs/sc/2022/scs22-02.pdf**

NAFO. (2024). Report of the NAFO precautionary approach working group (PA-WG) april 2024. *NAFO SCS Doc*, *24/05*. **https://www.nafo.int/Portals/0/PDFs/sc/2024/scs24-05.pdf**

Varkey, D. A., Kumar, R., Gullage, N., and Maddock-Parsons, D. (2024). Management strategy evaluation (MSE) of witch flounder in divs. 3NO to test the proposed NAFO precautionary approach framework (NAFO-PAF). *NAFO SCR Doc*, *24/045*.

Tables

Table 1. Reference points for 3NO Witch Flounder stock based on the NAFO SC assessment accepted in June 2022

Blim	Bmsy	Btarget	Fmsy	Ftarget	MSY
18.15	60.49	45.37	0.062	0.053	3.78

Figures

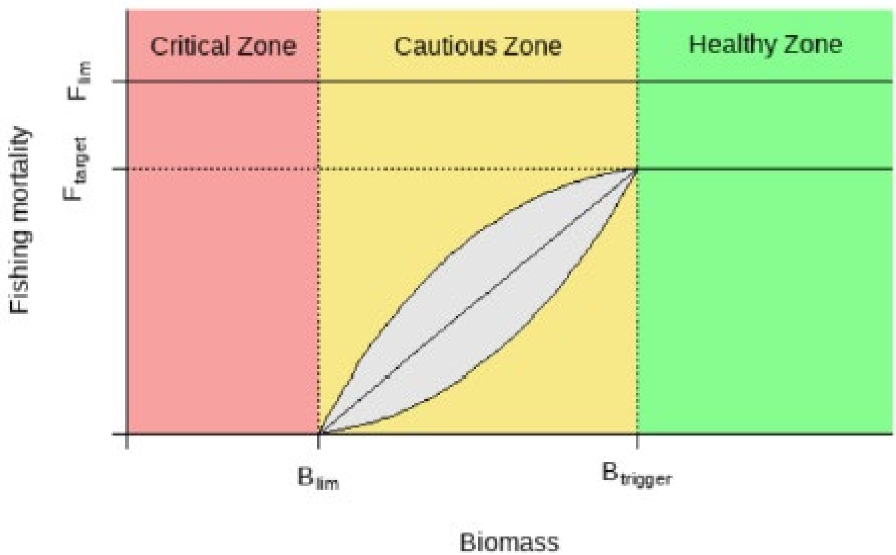

Figure 1. The NAFO Precautionary Approach Leaf shape. In the healthy zone, F is set to Ftarget which is a level below Flim. In the cautious zone, the F is determined based on the grey shaded leaf area.

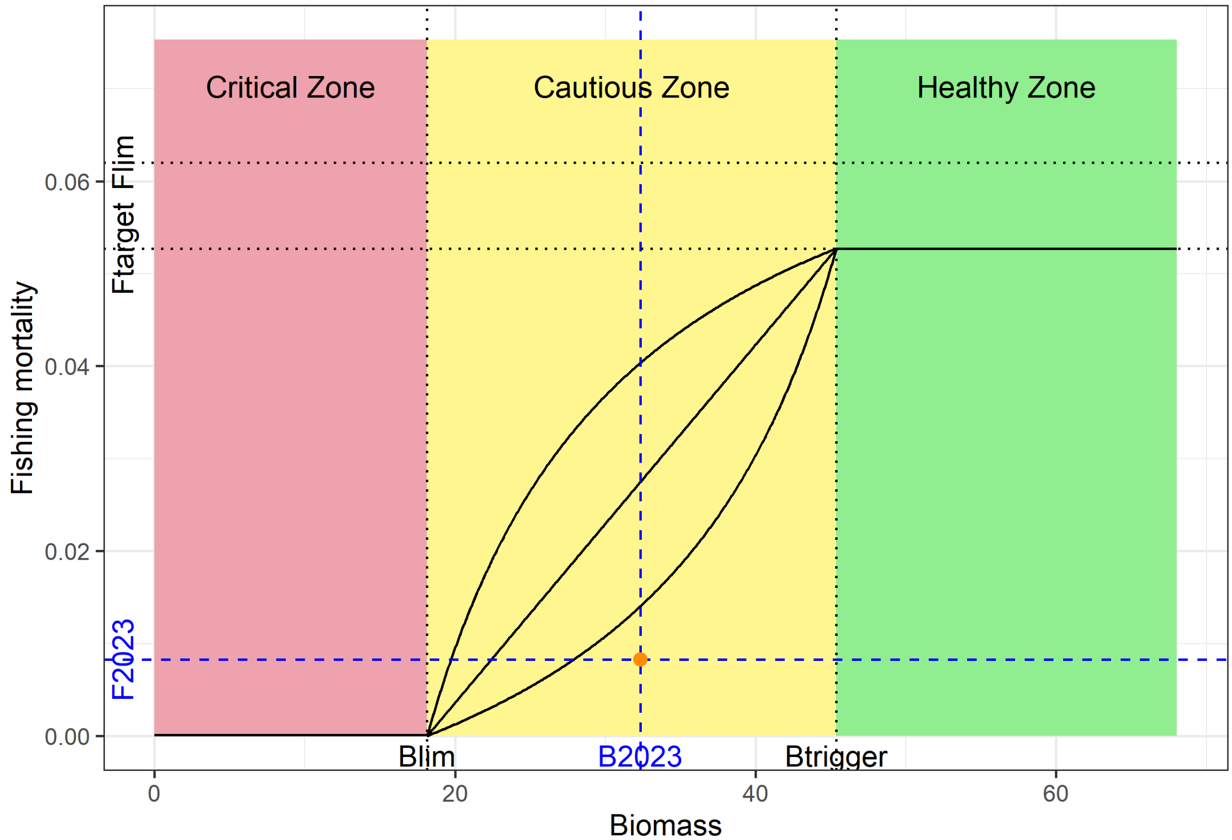

Figure 2. Position of the Witch Flounder stock on the PA map. The position is based on the biomass and F levels for 2023; Reference points: Blim=18.15, Btrigger=45.37, Bmsy=60.49, Fmsy=0.062, Ftarget=0.0527.

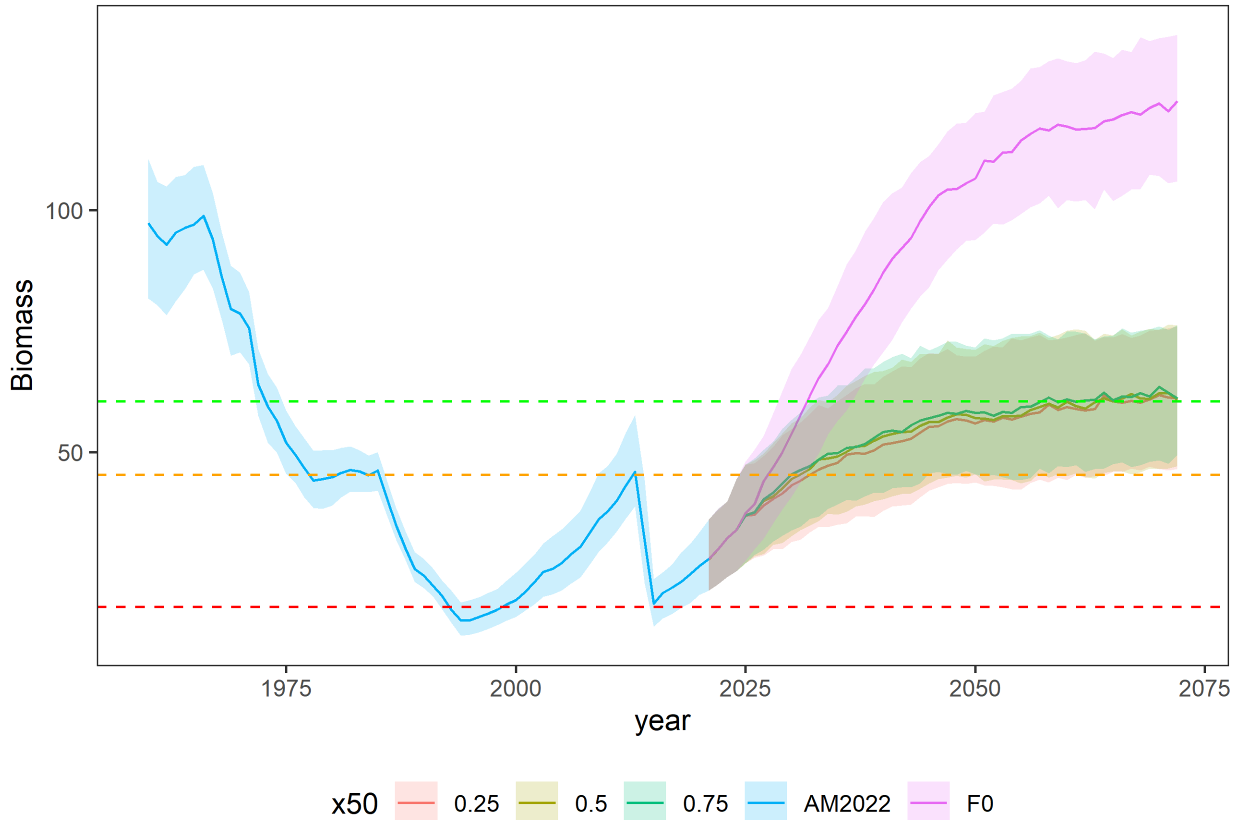

Figure 3. Median and 75% CIs for stock biomass under the three PA leaf trends and under no fishing (for comparison). The dotted lines indicate Blim (red),Btrigger (orange) and Bmsy (green) for the stock.

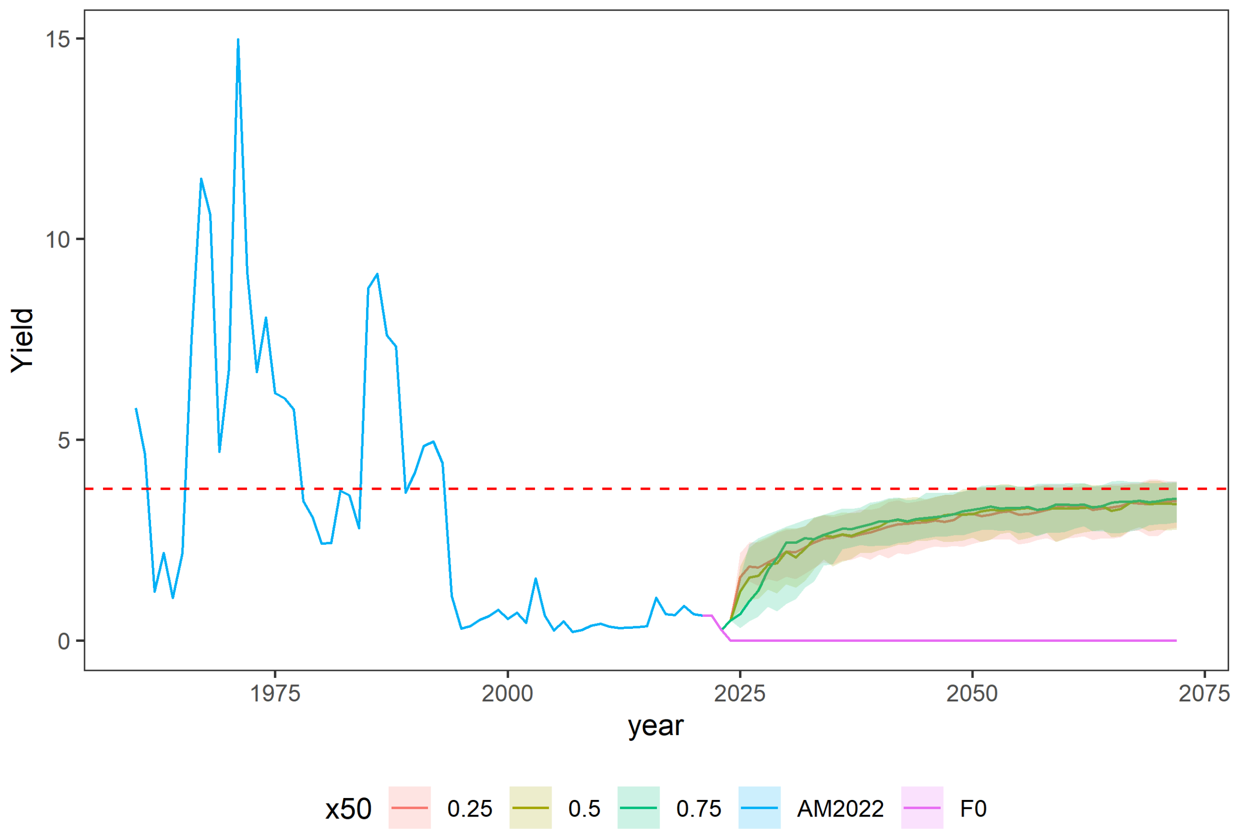

Figure 4. Median and 75% CIs for yield levels under the three PA leaf trends and under no fishing (for comparison). The dotted line shows MSY for the stock.

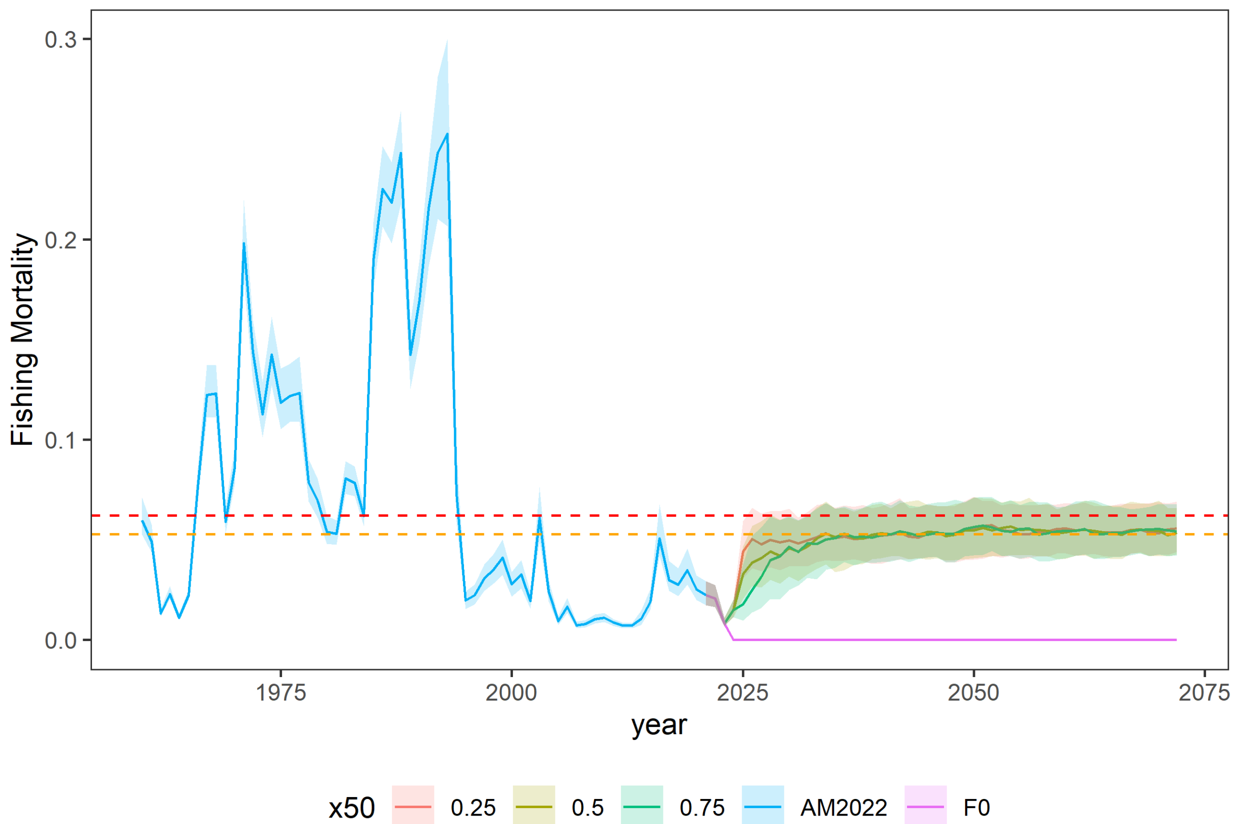

Figure 5. Median and 75% CIs for stock F levels under the three PA leaf trends and under no fishing (for comparison). The dotted lines indicate Ftarget (yellow), and Fmsy (red) for the stock.

Appendix Performance metrics

Fourteen Performance Metrics (PMs) were tested for the 3NO witch flounder 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

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

Most performance metrics 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 all HCRs achieved a low risk of being below $B_{trigger}$ *(2)*, but no HCRs maintained B_{MSY} *(3)* or rebuilt 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)*, although some only just passed this objective (e.g., short-term growth for the F_{upper} HCR). The absolute *(9)* and extra *(11)* times to recovery objectives do not have criteria for success, but values are very similar across all HCRs. A similar trend to absolute recovery time occurs for the relative time to recovery *(10)*, but only the F_{lower} HCR passed the objective. The median inter-annual variability in TAC *(13)* passed the objective for all HCRs. Catch of maximum recovery *(14)* does not have an assigned success criterion, but all HCRs have similar levels of average relative catches.

Table 2. Performance Metrics for each HCR for the 3NO Witch Flounder MSE.

Description	Performance Metric	OM	F_{lower}	F_{linear}	F_{upper}	F = 0
Very low risk of stock depletion	$Prop(B < B_{lim})$	WF	0.000	0.000	0.000	0.000
Risk of stock falling below $B_{trigger}$	$Prop(B < B_{trigger})$	WF	0.188	0.229	0.260	0.062
Maintain stocks above B_{MSY} more often than not	$Prop(B > B_{MSY})$	WF	**0.354**	**0.375**	**0.333**	0.833
Very low risk of overfishing	$Prop(F < F_{MSY})$	WF	0.729	0.729	0.708	1.000
Rebuild stocks to the vicinity of B_{MSY}	$Prop(\bar{\mu}(B_{(T-10):T}) > B_{trigger})$	WF	**0.740**	**0.716**	**0.689**	0.986
Monitor short term growth	$Prop(B_{t=5} > B_{t=1})$	WF	0.820	0.805	0.780	0.949

Description	Performance Metric	OM	F_{lower}	F_{linear}	F_{upper}	F = 0
Monitor medium term growth	$Prop(B_{t=15} > B_{t=1})$	WF	0.886	0.877	0.840	0.971
Monitor long term growth	$Prop(B_{t=25} > B_{t=1})$	WF	0.894	0.900	0.877	0.983
Time to recovery (absolute)	$Count_t(B \rightarrow B_{trigger})$	WF	5	5	6	4
Time to recovery (relative)	$\frac{Count_t^{F=HCR}(B \rightarrow B_{trigger})}{Count_t^{F=0}(B \rightarrow B_{trigger})}$	WF	1.200	**1.333**	**1.500**	1.000
Time to recovery (additional years)	$Count_t^{F=HCR}(B \rightarrow B_{trigger}) - Count_t^{F=0}(B \rightarrow B_{trigger})$	WF	1	1	2	0
Maintain approximately MSY catches in the long-term	$Prop(0.8 \geq \frac{Median(C_{(T-10):T})}{MSY} < 1.2)$	WF	**0.471**	**0.476**	**0.429**	**0.000**
Measure the inter-annual TAC variation	$\frac{Median(\mid C_{t+1} - C_t \mid)}{C_t}$	WF	0.052	0.051	0.047	-
Catch during the maximum recovery window	$\frac{\Sigma_{1:tmax}(C_t/MSY)}{t_{max}}$	WF	0.755	0.759	0.757	0.000