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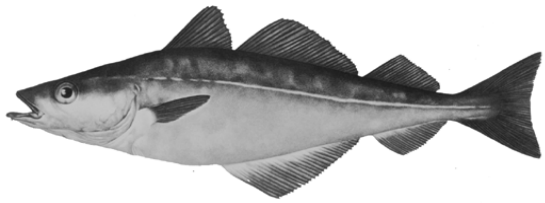
Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2023/037

WESTERN COMPONENT (4Xopqrs5) POLLOCK MANAGEMENT STRATEGY EVALUATION, STOCK STATUS, AND ADVICE



*Pollock (*Pollachius virens*)*

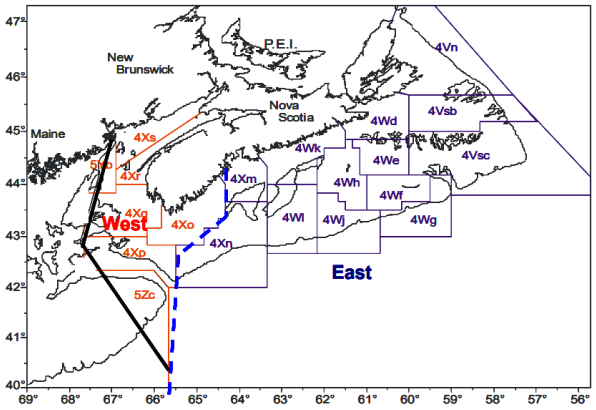


Figure 1. Canadian Pollock assessment unit showing the Western (4Xopqrs5) and Eastern Components (4VW+4Xmn). Dashed blue line separates Western and Eastern Components; solid line is the Canada/USA international boundary.

Context:

*In the western Atlantic, Pollock (*Pollachius virens*) are found from southwestern Greenland to Cape Hatteras, North Carolina. Important Canadian fisheries for Pollock occur on the Scotian Shelf, eastern Georges Bank, and the Bay of Fundy using primarily otter trawl and gillnets, but also handlines and longlines. In the Maritimes Region, two management areas are in place for Pollock within the NAFO Divisions 4VWX5 management unit: 4VW and 4X5 (Canadian waters only).*

A detailed evaluation of Pollock stock structure in 2003 indicated that Pollock in 4VWX5 are represented by two population components: a slower-growing Eastern Component including Divisions 4V and 4W, as well as unit areas 4Xm and 4Xn; and a faster-growing Western Component including 4Xopqrs and Canadian portions of NAFO Division 5 (Figure 1). An analytical assessment has been conducted for the Western Component, while the Eastern Component has been monitored solely with survey indices. The last analytical assessment providing management advice on Western Component Pollock was completed in 2009, followed by a Management Strategy Evaluation (MSE) in 2011.

In 2021, a review of the original MSE was initiated in concurrence with revision of the analytical assessment framework established in 2004. The current report summarizes the conclusions of the new assessment framework, the revised components of the MSE and applies the chosen Management Procedure to provide advice for the 2023/2024 fishing year. This document also outlines the intended assessment schedule for Western Component Pollock, protocols for exceptional circumstance, and future research recommendations that could help address the greatest uncertainties for this stock.

This Science Advisory Report is from the February 17th, 2023, regional peer review on the Assessment of Stock Status for Western Component Pollock and Harvest Control Rule. Additional publications from

this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Pollock (*Pollachius virens*) are a semi-pelagic gadid species found in the North Atlantic and are harvested as part of a multi-species groundfish fishery in the Maritimes Region.
- In the multi-species groundfish fishery, fishing effort on Pollock appears to have shifted primarily to catching Pollock as a bycatch species in some areas (e.g., 4Xmn), while remaining a directed species in others (e.g., 4Xpq).
- The population model accepted for this Management Strategy Evaluation (MSE) review shows alternating periods of high and low recruitment for Western Component Pollock throughout the time series. The stock is currently undergoing a period of low recruitment, with an annual average of 4.7 million recruits since 2016.
- The Limit Reference Point for Western Component Pollock was defined as 0.2 of the unfished biomass (B_0; 14,350 mt) and the maximum removal rate (F_{lim}) for a stock in the Healthy zone was defined as the fishing mortality rate that results in 40% of the spawning biomass per recruit in an unfished state ($F_{40\%SPR}$; 0.187) under the most recent levels of natural mortality. The Upper Stock Reference point was defined as 0.32 B_0 (22,960 mt).
- The three-year running geometric mean of the survey biomass, adjusted for catchability to the gear, is 22,331 mt, placing the stock in the Cautious zone.
- Based on the available estimate of population biomass and the application of the selected Management Procedure, the advice for Western Component Pollock for fishing year 2023-2024 is 3,609 mt. This represents an increase of 5.9% from the previous fishing year's total allowable catch (TAC) and is equivalent to a fishing mortality rate (F) of 0.176.
- Although Science has not provided catch advice for the 4Xmn portion of the Western Component Management Unit, it is recommended that the removal of any Eastern Component TAC be limited to the areas occupied by Eastern Component Pollock to avoid exceeding F for the rest of the Western Component Management Unit.
- Throughout the review of the Pollock MSE, a number of uncertainties have been identified. They are summarized in this report to frame the results of the MSE and to provide guidance for future research related to Western Component Pollock.

INTRODUCTION

Biology

Pollock (*Pollachius virens*) are a semi-pelagic gadid species found in the North Atlantic, ranging from North Carolina to southwestern Greenland. Its life history involves broadly distributed offshore spawning throughout late fall and early winter, a pelagic larval phase, recruitment to coastal waters, and offshore migration as they mature. In addition to aggregating by size, Pollock exhibit strong schooling behaviour that, in combination with its semi-pelagic nature, can make it difficult to monitor using conventional bottom-trawl survey gear. Within NAFO Divisions 4VWX5, the Pollock population is thought to be comprised of a Western Component (unit areas 4Xopqrs+5Yb+5Zc) and an Eastern Component (unit areas 4Xmn+4VW), driven primarily by a persistent growth difference between the two (Neilson et al. 2003, Andrushchenko, I., Martin, R.,

et al. in prep[1]). Growth for both components slowed down substantially beginning with the 2011 year class; though the Eastern Component has been exhibiting a gradual slow down since the 1970s (Andrushchenko, I., Martin, R., et al. in prep[1]). The mechanistic relationship for this shift is not currently known.

The preferred temperature range of Pollock varies by life stage, but there appears to be evidence of a lower limit of 4 ºC and a consistent upper limit of 11 ºC, particularly for adult Pollock (Carruthers et al. 2003, Collette and Klein-MacPhee 2002, Cargnelli et al. 1999). Spawning of Pollock is known to have a very defined temperature aspect, starting when waters cool in late fall (8–10 ºC) and peaking in early winter (5–6 ºC; McGlade et al. 1993). Sexual maturation occurs between the ages of 2 and 6, with 50% maturity occurring between the ages 3 and 4. Pollock are relatively long-lived species, reaching a maximum age of 23 years and a length of 116 cm in the 1980s.

Given a fairly defined temporal preference for Pollock, increasing water temperatures across the Scotian Shelf, Bay of Fundy, and Georges Bank may be starting to play an increasingly important role in Pollock distribution and spawning, particularly where temperatures approach the 11 ºC limit. Core habitat work showed that Jordan Basin, Georges Basin, the Northeast Channel, and some strata surrounding LaHave Basin recur as preferred Pollock habitat in recent years. This differs from the core habitat observed earlier in the time series that consisted of various banks along the Scotian Shelf (Andrushchenko, I., Martin, R., et al. in prep[1]).

In general, Pollock have experienced a shift from a piscivorous to an invertebrate-based diet, indicating that squid and shrimp are becoming more instrumental in the diet of Western Component (WC) Pollock, replacing fish species that were more integral in the past (Andrushchenko, I., Martin, R., et al. in prep[1]). Predators for Pollock vary by life stage and include Monkfish, dogfish, Silver Hake, redfish, Atlantic Cod, seals, and other Pollock. In addition, fishermen have noted species like Silver Hake being a strong competitor to Pollock (pers. comm., Scotia Fundy Groundfish Advisory Committee). Various trends in predator species may result in shifts in predation pressures on juvenile and adult Pollock, with likely implications on the stationarity of population dynamics for this species over time. Although mechanistic relationships for both diet preferences and predation have been identified for Pollock, data limitations plague attempts to incorporate some of the most basic trophic links into the assessment model, particularly in terms of prey interactions.

Fishery

Pollock are harvested as part of a multi-species groundfish fishery in the Maritimes Region that has evolved over time with various management measures and restructuring of large scale operators impacting how the fishery is carried out. Pollock are harvested by both mobile and fixed gear, reaching commercial size at age three and fully selected by age 5.

Currently, there is a directed fishery for Pollock in 4X5, and licence holders targeting other groundfish stocks (i.e., redfish, Silver Hake, Haddock, and halibut) must retain Pollock as bycatch. Within NAFO Divisions 4X5Y, Pollock appears to have shifted primarily to a bycatch species in some areas (e.g., 4Xmn), while remaining a directed species in others (e.g., 4Xpq). During Pollock directed effort, the predominant bycatch species are White Hake and Atlantic Cod for both mobile and fixed gear, with Haddock and redfish also being caught as bycatch by mobile gear (Andrushchenko, I., Martin, R., et al. in prep[1]).

[1] Andrushchenko, I., Martin, R., Doherty, P. Debertin, A., McCurdy, Q., MacEachern, E., Clark, D. and C. Clark. In Prep. Western Component Pollock – Data Inputs. Can. Sci. Advis. Sec. Res. Doc.

Historically, landings of Pollock reached 40,000 mt and were harvested equally between Eastern and Western Component areas. However, after the mid-1990s, removals of Pollock from the Eastern Component all but disappeared, while those from the Western Component decreased to below 10,000 mt (Figure 2). Since the inception of the 2011 Management Strategy Evaluation (MSE), catches of Western Component Pollock have remained below 4,500 mt.

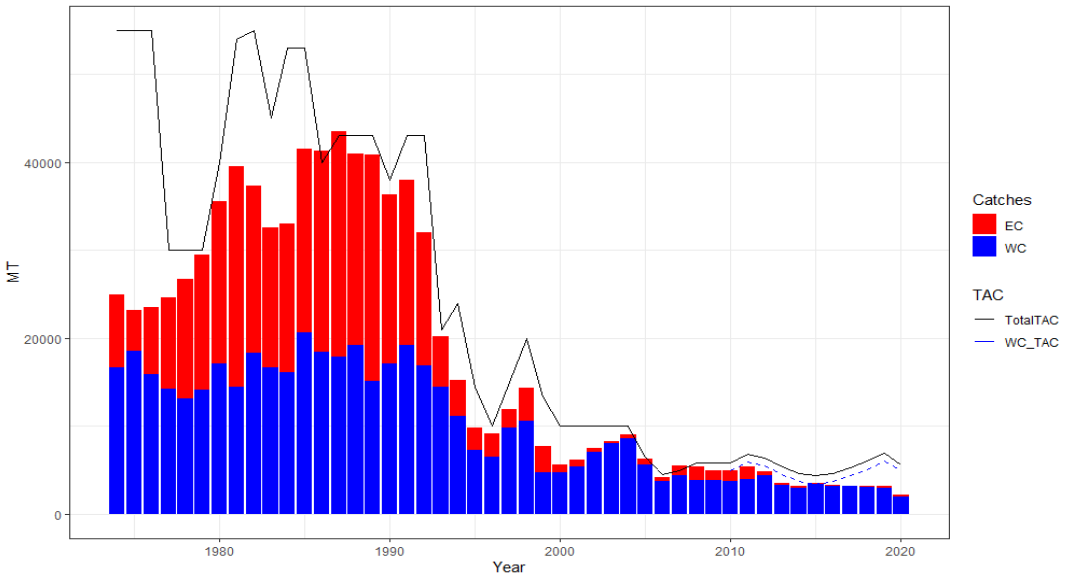


Figure 2. Canadian catches of Pollock from Eastern (red bars) and Western (blue bars) components for fishing year (April 1st – March 31st). Black line indicates combined quota for both components. Dashed blue line indicates the quota for just the Western Component (management unit), starting in the 2010 fishing year (April 1st 2010 – March 31st 2011).

The Western and Eastern Component Pollock stocks are treated separately for assessment purposes, with unit areas 4Xmn attributed to Eastern Component. However, the fishery is managed based on a split where 4Xmn is attributed to the Western Component. The current MSE deals with providing advice for the Western Component as defined by the assessment delineation only.

ASSESSMENT

The 2022 modeling framework accepted a Statistical Catch-at-Age population model where natural mortality is estimated in three temporal blocks for ages 5+ (1994–2000, 2000–2010, and 2011–2020; Andrushchenko, I., Yin, Y., et al. in prep[2]). The model is tuned to an age-disaggregated bottom trawl index of abundance and an age-disaggregated acoustic index of biomass from the Research Vessel (RV) survey; both indices cover the full Western Component assessment area, including eastern Georges Bank. This model was chosen based on the lower value of its objective function, good performance with respect to both a multi-year and annual retrospective analysis, and showed consistency with model-independent observations of selectivity, fishing mortality, and recruitment.

[2] Andrushchenko, I., Yin, Y., Clark, C.M., Martin, R.M. and Barrett, T.J. In Prep. Western Component Pollock MSE – Population Modeling, Operating Model Conditioning and Reference Points. Can. Sci. Advis. Sec. Res. Doc.

The accepted population model shows alternating periods of high and low recruitment for Western Component Pollock throughout the time series, with the stock currently undergoing a period of low recruitment with an annual average of 4.7 million recruits since 2016 (Figure 3). Fishing mortality seems to vary historically, with some of the highest levels reached in the early 2010s, and decreasing to 0.125 in recent years (Figure 3). Finally, spawning stock biomass has generally increased following periods of high recruitment and decreased following poor recruitment, with the most recent model estimate of spawning stock biomass in 2020 being 21,711 mt.

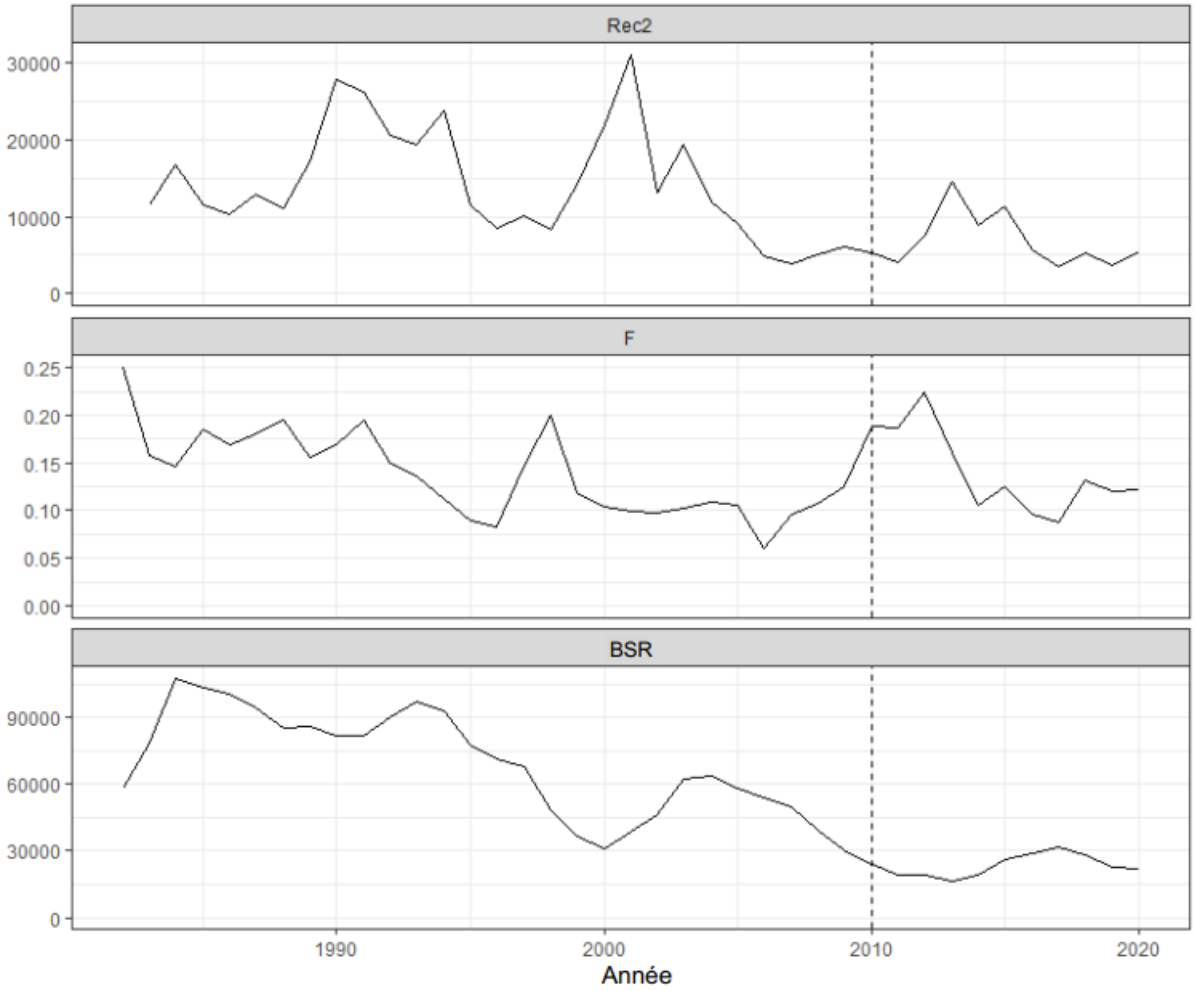


Figure 3. Age-2 recruitment (Rec2; thousands of fish), the fishing mortality (F) on ages 6 through 9, and spawning stock biomass (SSB; ages 4+) from Model J_M4B. Vertical dashed line indicates the inception of the Management Strategy Evaluation for this stock.

Various candidate Limit Reference Points (LRPs) and maximum removal rates (F_{lim}) were examined for this stock, calculated using both production-based and empirical-based approaches (Andrushchenko, I., Yin, Y., et al. in prep[2]). The LRP for Western Component Pollock was chosen as 0.2 of the unfished biomass (B_0; 14,350 mt) and the F_{lim} for a stock in the Healthy Zone was selected based on $F_{40\%SPR}$ (fishing mortality rate that results in 40% of the spawning biomass per recruit in an unfished state; 0.187) under the most recent levels of M. Simulation testing of various Upper Stock Reference points as control points in a Harvest Control Rule (HCR) was also carried out, resulting in the selection of 0.32 B_0 (22,960 mt) as the

Upper Stock Reference Point during a meeting of Scotia Fundy Groundfish Advisory Committee members, led by Fisheries and Oceans Canada (DFO) Resource Management on November 10, 2022.

MANAGEMENT STRATEGY EVALUATION

A defining characteristic of the MSE is the ability to test various Management Procedures (MPs) against evaluation metrics derived from the Management Objectives (MOs) across the uncertainty encompassed by various Operating Models (OMs). The MOs for the Western Component Pollock MSE were developed through various consultation processes led by Resource Management and are summarized in Table A2. In the case of Western Component Pollock, the reference set of OMs only contained two OMs that differed in how they project recruitment; OM #1 had a less informed variation on future recruitment, and OM #2 had a predicted oscillation in future recruitment (Andrushchenko, I., Yin, Y., et al. in prep[2]).

A total of seven candidate MPs were put forward for testing in the Western Component Pollock MSE. The detailed descriptions of each is provided in Table A1, with the MPs falling into three broad categories: slope-based (i.e., MPs 1 and 2), ramp-based (i.e., MPs 3, 4, and 5) and banded (i.e., MPs 6 and 7). Within these three broad categories, MPs can also be subdivided into those with an inter-annual limit on change (i.e., MPs 1, 2, 4, and 5) and those without a limit (i.e., MPs 3, 6, and 7). The scorecard summarizing the performance of each MP against each MO and accompanying evaluation metric are shown in the Appendix.

In general, the candidate MPs performed well across the provided objectives. However, MPs without a limit imposed on interannual change in Total Allowable Catch (TAC) tended to be more detrimental to the stock, given the high amount of observation error involved. As such, MP3, MP6, and MP7 were considered less precautionary than MP1, MP2, MP4, and MP5. Additionally, the difference between MP1 and MP2 lies in the limit on change in the critical zone, with MP1 allowing a change greater than 15% when the stock is nearing the LRP. Consequently, MP1, MP4, and MP5 were considered the most precautionary of the seven.

Following consultation on the MPs at the Scotia Fundy Groundfish Advisory Committee meeting on January 18th 2023, consensus was received from all participants on MP4 as the most appropriate option for application in the MSE to provide TAC advice. Therefore, the Department of Fisheries and Oceans Canada is proceeding with using MP4 for use as the Harvest Control Rule for Western Component Pollock.

Harvest Control Rule Application and Advice

The application of MP4 involves a ramp-based HCR where the harvest rate across the Cautious Zone increases gradually from 0.04 (Critical Zone) to 0.187 (Healthy Zone), with an interannual limit on change of 15% when in the Cautious Zone and a 20% limit on change when in the Healthy Zone. Change while in the Critical Zone is limited to 50%.

The population biomass for each year is estimated by adjusting a three-year geometric mean of all available bottom trawl and acoustic biomass values by the model-generated index-specific q; a value which is expected to change slightly each time the model is re-run. The q-adjusted (adjusted for catchability by the gear) population biomass determines the fishing mortality and accompanying TAC based on the ramp-based HCR described above.

The three-year running geometric mean of the q-adjusted survey biomass is 22,331 mt, placing the stock in the Cautious zone. Based on the available estimate of population biomass, the advice for Western Component Pollock for fishing year 2023-2024 is 3,609 mt. This represents

an increase of 5.9% from the previous fishing year's TAC and is equivalent to a fishing mortality (F) of 0.176. (LRP=14,350, USR=22,960;Figure 4). The 2021 bottom-trawl survey index is not currently available due to the absence of conversion factors, while the 2022 acoustic index has not yet been calculated.

Figure 4. Q-adjusted spawning stock biomass (SSB) from Acoustic (black) and Bottom Trawl (blue) surveys, with dots representing the annual points and the lines representing a three year geometric mean of each series. Asterisks identify years where the geometric mean is calculated on an incomplete dataset. Red, yellow and green bands delineate the Critical, Cautious and Healthy zones, respectively.

Currently, no mechanism exists for providing advice for the portion of Eastern Component Pollock that falls into unit area 4Xmn. Since the 2011 MSE, the 4Xmn portion of the Western Component Management Unit was assigned a constant TAC of 700 mt that could be caught anywhere in the 4X5 management unit. Although Science has not provided catch advice for the 4Xmn portion of the Western Component Management Unit, it is recommended that the removal of any Eastern Component TAC be limited to the areas occupied by Eastern Component Pollock to avoid exceeding F for the rest of the Western Component Management Unit. The substantial slowdown in growth experienced by Eastern Component Pollock since the 1970s indicates that the component is undergoing changes that are not being examined or monitored at this time.

Exceptional Circumstances and Assessment Cycle

The MSE assessment cycle is set to achieve a balance between workload and retaining confidence in the appropriateness of advice. Given the complexity of the MSE process, five levels of review are possible:

- Level 1: Annual provision of advice by updating the HCR with new survey data and generation of new TAC advice and stock status.

- Level 2: The model remains appropriate, but projections have very wide uncertainty after several years. This review updates the accepted model with the most recent data and generates new projections (two generations). The HCR is evaluated to ensure it continues to perform well.
- Level 3: A change in the fishery has occurred that may require a modified HCR; the understanding of stock dynamics has not changed. The accepted population model is updated with additional data, projected forward two generations, and both old and new HCRs are tested to see if modification is appropriate.
- Level 4: A change in the stock dynamics or understanding of the stock has occurred, namely the recruitment cycle is not consistent. If the recruitment cycle is not consistent with the predicted Autocorrelation Cycle, the model will be updated with additional data, modification of the appropriate projection of recruitment, and MPs re-tested.
- Level 5: A change in the stock dynamics or understanding of the stock has occurred, namely an evident change in growth, mortality, or fecundity, a full revision of the MSE and reference points is required. This is also triggered if the stock dynamics move outside of predicted bounds.

The MSE assessment cycle will be run with annual Level 1 reviews. After five years (2027), a Level 2 review will be conducted, and after ten years (2032) a Level 5 review will be conducted. During the annual Level 1 review, a check of exceptional circumstances will be conducted to determine if a Level 3, 4, or 5 review is required. If a review at these levels is triggered, the review would be conducted in the following year. The following are examples of exceptional circumstances that would trigger a higher level review:

- Evidence of major shifts in the fishery logistics, including in unit areas 4Xmn (Level 3)
- Evidence of a change in recruitment cycle for the stock (Level 4)
- Empirical evidence that growth has changed, in either direction (Level 5)
- Empirical evidence that the fecundity or spawning potential of the stock has changed. Examples of empirical evidence are shift in spawning timing, a change in age-at-maturity, etc. (Level 5)
- Evidence of a change in the natural mortality experienced by the stock (Level 5)
- Stock signals move outside of the predicted bounds (Level 5)
- The advice represents a notable increase in TAC while the stock is in the Critical Zone.

SOURCES OF UNCERTAINTY

Throughout the review of the Pollock MSE, a number of uncertainties have been identified. They are summarized in this report to frame the results of the MSE and to provide guidance for future research related to Western Component Pollock.

- The cause of the slower growth experienced by Western Component Pollock since the 2011 cohort remains unclear. Given that it appears to be tied to a cohort rather than a year, the cause is likely ecosystem-based, but no clear link could be established throughout the MSE process. Identification of a cause would help monitor the change and may help determine whether the change is permanent or reversible.
- The impact of slower growth on productivity of the stock is unknown.

- Recruitment of Western Component Pollock appears to exhibit a multi-year oscillatory tendency, caused by something other than the spawning stock biomass that produced it. Identifying a mechanistic relationship for spawning stock biomass-independent impacts on recruitment would help improve the predictive capacity of the models.
- The causes of temporal changes in natural mortality for Western Component Pollock are unknown.

In addition, the absence of survey points from the bottom-trawl survey in 2021 and acoustic survey in 2022 introduces additional uncertainty into the three-year geometric mean. Once available, any missing survey points would be incorporated into the time series. Finally, the validity of simulation testing is linked directly to the validity of the assumptions made in setting up the simulation. The various components of the Western Component Pollock MSE were built on assumptions around the biology, fishery, and environmental factors influencing Western Component Pollock, all of which are detailed in Andrushchenko, I., Martin, R., et al. (in prep)[1] and Andrushchenko, I., Yin, Y., et al. (in prep)[2].

CONCLUSIONS AND ADVICE

The three-year running geometric mean of the q-adjusted survey biomass is 22,331 mt, placing the stock in the Cautious zone (LRP=14,350, USR=22,960). Based on the available estimate of population biomass, the advice for Western Component Pollock for fishing year 2023-2024 is 3,609 mt. This represents an increase of 5.9% from the previous fishing year's TAC and is equivalent to F of 0.176.

Although Science has not provided catch advice for the 4Xmn portion of the Western Component Management Unit, it is recommended that the removal of any Eastern Component TAC be limited to the areas occupied by Eastern Component Pollock to avoid exceeding F for the rest of the Western Component Management Unit.

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Vascotto, Kris	Atlantic Groundfish Council
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SOURCES OF INFORMATION

This Science Advisory Report is from the February 17, 2023, regional peer review on the Assessment of Stock Status for Western Component Pollock and Harvest Control Rule. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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Neilson, J.D., Perley, P., Carruthers, E.H., Stobo, W., and Clark, D. 2003. Stock Structure of Pollock in NAFO Divs. 4VWX5Zc. Can. Sci. Advis. Sec. Res. Doc. 2003/045.

APPENDIX

Scorecard Report for 2022 Western Component Pollock Management Strategy Evaluation

The 2022 Management Strategy Evaluation (MSE) review produced a reference set of two Operating Models (OMs) and seven candidate Management Procedures (MPs) to be tested against approved Management Objectives (MOs) for Western Component Pollock. The performance of each MP was quantified using an evaluation metric derived from each MO, and the format of the final results was finalized at the third Pollock MSE Canadian Science Advisory Secretariat peer review meeting held on October 18–20, 2022. This report presents the final Scorecard results for each candidate MP.

Operating Models

Both OMs are conditions on the accepted model for Western Component Pollock (Model J_M4B). The difference between OMs is limited to how they project recruitment, with OM #1 having a less informed variation on future recruitment, and OM #2 having a predicted oscillation in future recruitment.

Candidate Management Procedures

Table A1. Description of each candidate management procedure (MP) for the 2022 Pollock Management Strategy Evaluation (MSE).

Name	Detailed Description	Short Hand Description	Type	Limit
MP1	Slope of last year's 3-year survey geometric mean and this year's 3-year geometric mean. Total Allowable Catch(TAC) advice is generated by applying the slope to last year's TAC, with a change limit of 15% or 250 mt, whichever is greater.	Survey Slope with 15% or 250 mt change limit.	Slope	Yes
MP2	Slope of last year's 3-year survey geometric mean and this year's 3-year geometric mean. TAC advice is generated by applying the slope to last year's TAC, with a change limit of 15%.	Survey Slope with 15% change limit.	Slope	Yes
MP3	Population biomass is q-adjusted this year's 3-year survey geometric mean, which determines the f based on a ramp harvest control rule with F=0.06 in critical zone and F=0.187 in healthy zone. TAC advice is generated based on the F and population biomass.	Ramp HCR (0.06–0.187) with no limit on change.	Ramp	No
MP4	Population biomass is q-adjusted this year's 3-year survey geometric mean, which determines the f based on a ramp harvest control rule, with F=0.04 in critical zone and F=0.187 in healthy zone. TAC advice is generated based on the F and population biomass, with a 15% limit on TAC change when in Cautious Zone and 20% limit on TAC change when in Healthy Zone.	Ramp HCR (0.04–0.187) with a 15% limit in Cautious and 20% limit in Healthy.	Ramp	Yes
MP5	Population biomass is q-adjusted this year's 3-year survey geometric mean, which determines the f based on a ramp harvest control rule, with F=0.06 in critical zone and F=0.187 in healthy zone. TAC advice is generated based on the F and population biomass, with a 15% limit on TAC change when in Cautious Zone and 20% limit on TAC change when in Healthy Zone.	Ramp HCR (0.06–0.187) with a 15% limit in Cautious and 20% limit in Healthy.	Ramp	Yes

Name	Detailed Description	Short Hand Description	Type	Limit
MP6	Population biomass is q-adjusted this year's 3-year survey geometric mean, which determines the TAC advice based on a 3-band TAC harvest control rule when in Cautious Zone, F=0.06 in Critical Zone and F=0.187 in Healthy Zone.	3-band HCR	Band	No
MP7	Population biomass is q-adjusted this year's 3-year survey geometric mean, which determines the TAC advice based on a 4-band TAC harvest control rule when in Cautious Zone, F=0.06 in Critical Zone and F=0.187 in Healthy Zone.	4-band HCR	Band	No

Management Objectives

Table A2. Approved Management Objectives and evaluation metrics for the 2022 Western Component Pollock Management Strategy Evaluation (MSE).

General intent	Aspirational objective	Measure	Probability	Time
Maintain the stock above the Limit Reference Point (LRP) and avoid fishery induced declines to below the LRP	Avoid fishery-induced decline of spawning biomass/abundance below LRP.	The probability of the Spawning biomass/abundance falling below the LRP.	Low (5-25%)	2 generations (between now and 12 years)
Adjust level of precaution depending on stock status (DFO SFF Table 1)	Promote stock growth to the Healthy Zone	Spawning biomass/abundance status and trend.	Probability of growth high at LRP (75%) to neutral (50%) at Upper Stock Reference (USR)	2 generation (between now and 12 years)
Provide stable inter-annual TACs (Industry)	Avoid large inter-annual changes in TAC (15%)	Average Number of years in each projection that interannual change in TAC exceeds 15%, in the short, medium and long terms	NA	2023-2030 2023-2036 2023-2045
Maintaining TAC above a certain level (Industry)	Maintaining TAC above a certain value (proposed 3000 mt)	Average Number of years in each projection that TAC exceeds 3000 mt in short, medium and long term	NA	2023-2030 2023-2036 2023-2045

Results

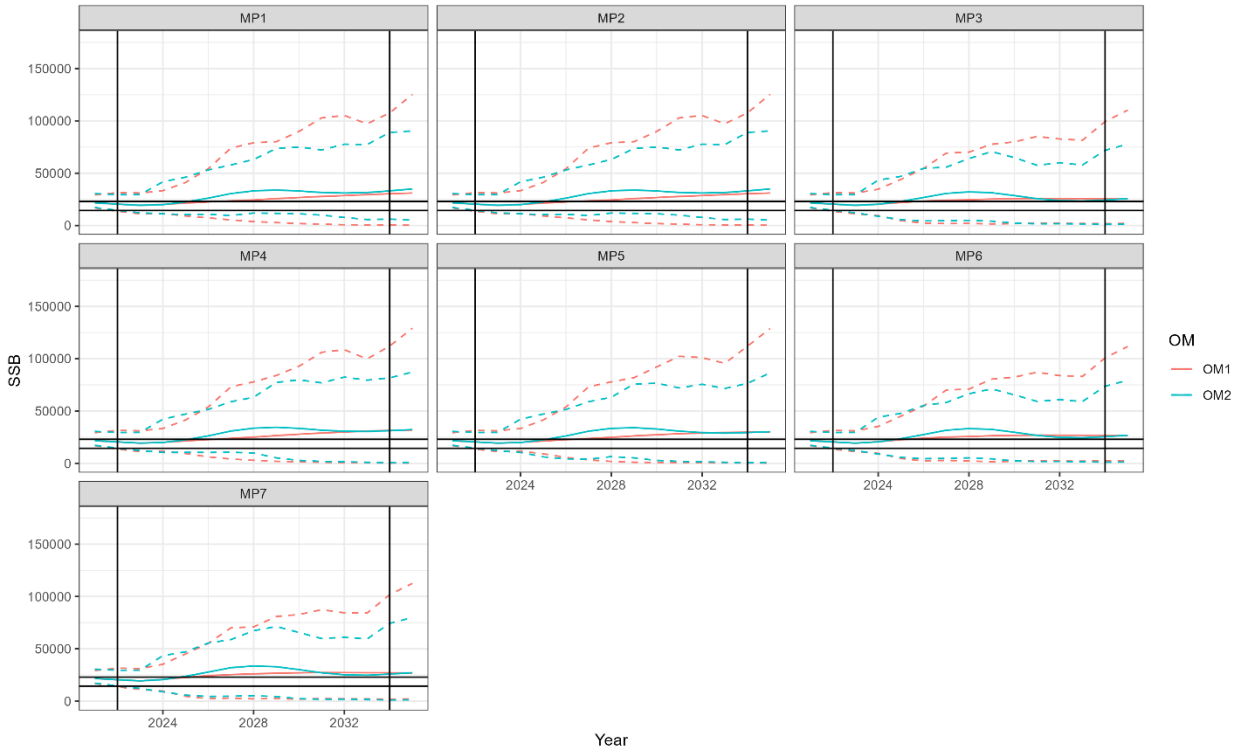

Figure A1. Projected Spawning Stock Biomass (SSB) across all Operating Model (OM; colours) and Management Procedure (MP; facets) combinations, with median (solid coloured line), maximum, and minimum (dashed coloured lines) of 1000 simulations. Horizontal black lines show the Limit Reference Point (LRP) and Upper Stock Reference (USR), while vertical black lines show the current year (2022) and the terminal year for biomass-based objectives (2034).

Objective 1: Avoid Fishery-Induced Decline of Spawning Biomass/Abundance Below the Limit Reference Point

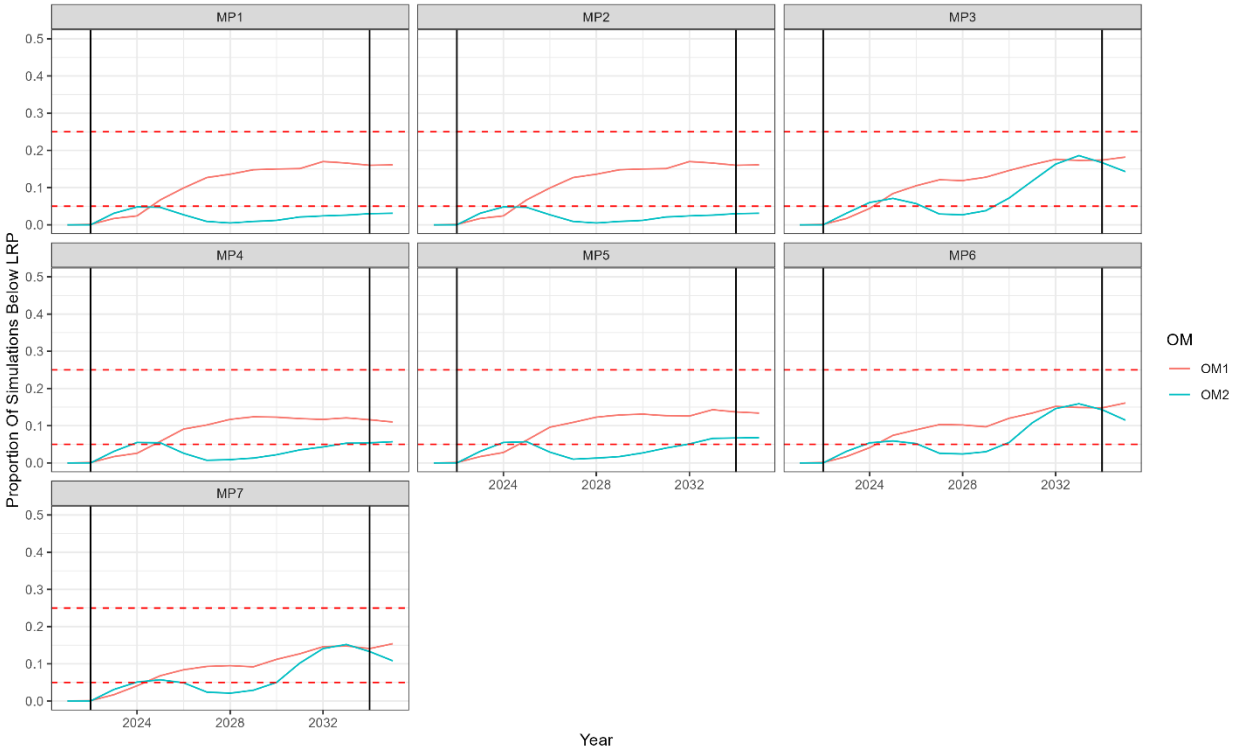

Figure A2. The proportion of simulations where Spawning Stock Biomass falls below the Limit Reference Point (LRP) across all OMs (colours) and MPs (facets). Horizontal dashed lines indicate the 5% and 25% thresholds. Vertical lines show current year (2022) and terminal year (2034).

Table A3. Proportion of simulations where Spawning Stock Biomass falls below the Limit Reference Point (LRP) across all OMs and MPs in the terminal year (2034).

MP	OM	PropBelowLRP
MP1	OM1	16.0%
MP1	OM2	3.0%
MP2	OM1	16.0%
MP2	OM2	3.0%
MP3	OM1	17.4%
MP3	OM2	16.7%
MP4	OM1	11.6%
MP4	OM2	5.4%
MP5	OM1	13.7%
MP5	OM2	6.7%
MP6	OM1	14.8%
MP6	OM2	14.3%
MP7	OM1	14.1%
MP7	OM2	13.3%

Objective 2: Promote Stock Growth to the Healthy Zone

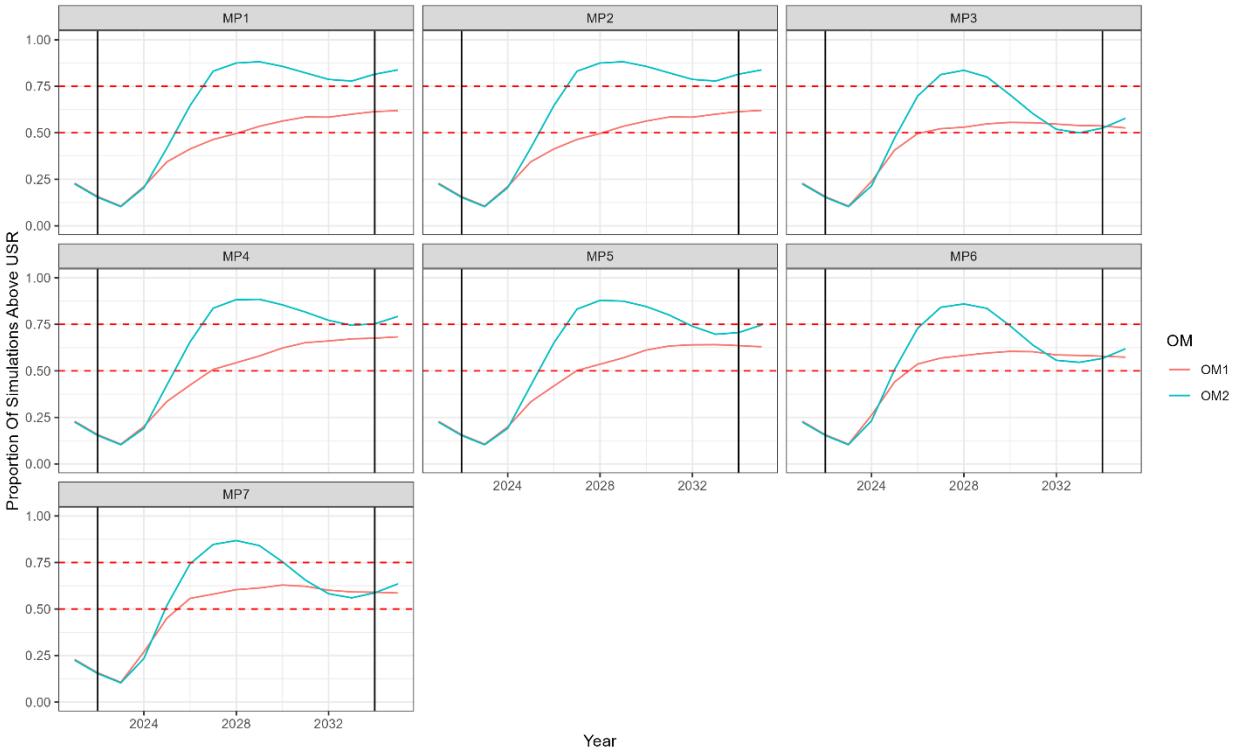

Figure A3. The proportion of simulations where Spawning Stock Biomass falls above the USR across all OMs (colours) and MPs (facets). Horizontal dashed lines indicate the 50% and 75% thresholds. Vertical lines show current year (2022) and terminal year (2034).

Table A4. Proportion of simulations where Spawning Stock Biomass falls above the USR across all OMs and MPs in the terminal year (2034).

MP	OM	PropAboveUSR
MP1	OM1	61.4%
MP1	OM2	81.5%
MP2	OM1	61.4%
MP2	OM2	81.5%
MP3	OM1	53.7%
MP3	OM2	52.5%
MP4	OM1	67.6%
MP4	OM2	75.3%
MP5	OM1	63.6%
MP5	OM2	70.6%
MP6	OM1	57.9%
MP6	OM2	56.7%
MP7	OM1	59.0%
MP7	OM2	58.7%

Objective 3: Avoid Large Inter-Annual Changes in Total Allowable Catch (15%)

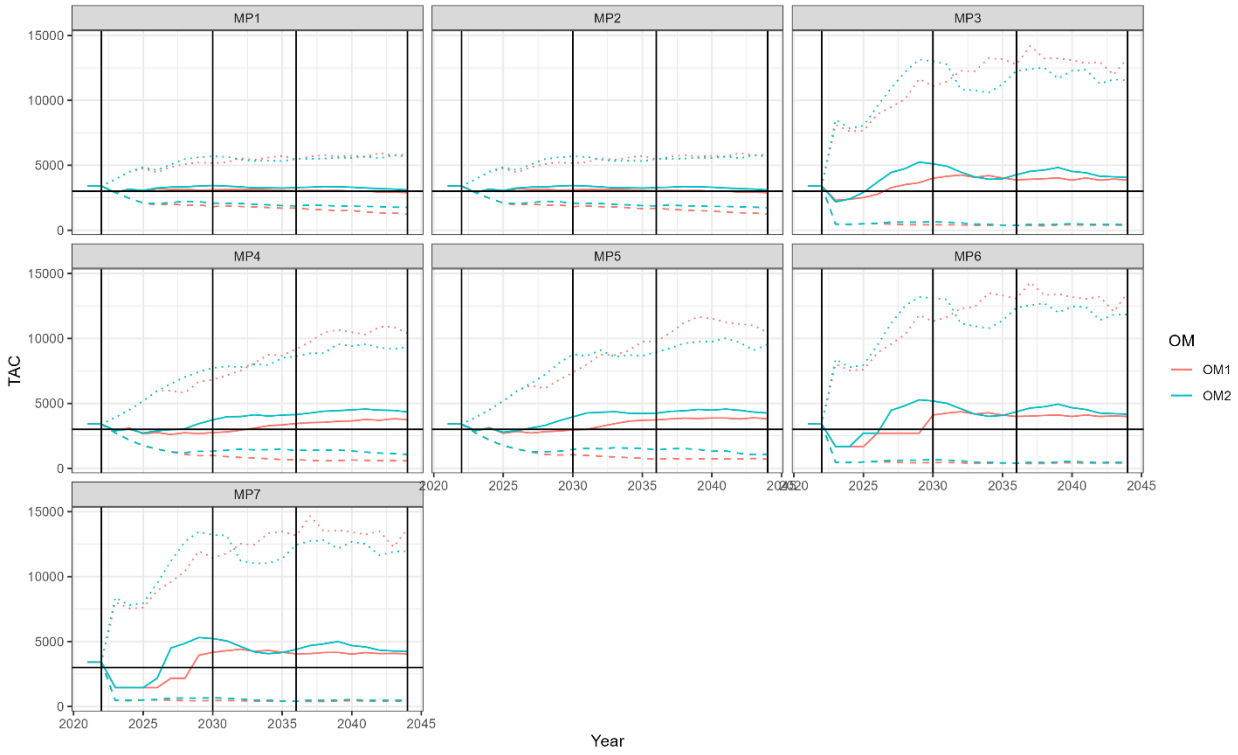

Figure A4. Projected TAC across all OM (colours) and MP (facets) combinations, with median (solid coloured line), max and minimum (dashed coloured lines) of 1000 simulations. Vertical black lines show the current year (2022), and the three terminal years for the objective (2030, 2036 and 2045).

Table A5. Average number of simulations in all years of each time period where the change in TAC exceeds 15%.

MP	OM	Long(2023-2045)	Med (2023-2036)	Short (2023-2030)
MP1	OM1	26.1%	15.7%	9.2%
MP1	OM2	25.1%	15.1%	9.0%
MP2	OM1	25.1%	15.5%	9.2%
MP2	OM2	24.8%	15.1%	9.0%
MP3	OM1	67.8%	41.5%	24.2%
MP3	OM2	67.9%	41.5%	24.0%
MP4	OM1	46.3%	28.3%	16.9%
MP4	OM2	46.6%	28.1%	16.2%
MP5	OM1	48.1%	29.2%	17.2%
MP5	OM2	48.3%	29.1%	16.7%
MP6	OM1	65.2%	40.1%	23.5%
MP6	OM2	65.4%	40.0%	23.3%
MP7	OM1	65.0%	40.0%	23.4%
MP7	OM2	65.3%	40.0%	23.2%

Objective 4: Maintaining Total Allowable Catch Above a Certain Value (proposed 3000 mt)

Table A6. Average number of simulations in all years of each time period where the TAC exceeds 3000mt.

MP	OM	Long(2023-2045)	Med (2023-2036)	Short (2023-2030)
MP1	OM1	78.3%	85.7%	75.0%
MP1	OM2	95.7%	92.9%	87.5%
MP2	OM1	78.3%	85.7%	75.0%
MP2	OM2	95.7%	92.9%	87.5%
MP3	OM1	82.6%	71.4%	50.0%
MP3	OM2	87.0%	78.6%	62.5%
MP4	OM1	60.9%	35.7%	25.0%
MP4	OM2	82.6%	71.4%	50.0%
MP5	OM1	65.2%	42.9%	25.0%
MP5	OM2	87.0%	78.6%	62.5%
MP6	OM1	69.6%	50.0%	12.5%
MP6	OM2	82.6%	71.4%	50.0%
MP7	OM1	73.9%	57.1%	25.0%
MP7	OM2	82.6%	71.4%	50.0%

Summary of Discussion at the Fourth Technical Meeting of the Pollock Management Strategy Evaluaton (Dec 19, 2022)

In general, the candidate MPs performed well across the provided objectives. However, MPs without a limit imposed on interannual change in Total Allowable Catch tended to result in a higher detriment to the stock, given the high amount of observation error for this stock. As such, MP3, MP6 and MP7 are considered less precautionary than MP1, MP2, MP4, and MP5.

Additionally, the difference between MP1 and MP2 lies in the limit on change in the critical zone, with MP1 allowing a greater change than 15% when the stock is nearing the Limit Reference Point. Consequently, the most precautionary MPs are MP1, MP4, and MP5.

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