Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Pacific Region
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Science Response 2023/003

RECOVERY POTENTIAL ASSESSMENT FOR YELLOWEYE ROCKFISH (*SEBASTES RUBERRIMUS*) IN BRITISH COLUMBIA

Context

The *Species at Risk Act (SARA)* recommends several actions to be undertaken by Fisheries and Oceans Canada (DFO) if an aquatic species is assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as *Threatened, Endangered, or Extirpated*. Scientific information on status, threats and limiting factors, and the recovery potential is used to support mitigation planning and actions. This information is typically compiled in a Recovery Potential Assessment (RPA) that is reviewed in a Canadian Science Advice Secretariat process and may be used to support a listing decision. Currently, this species is listed as *Threatened* by COSEWIC, and *Special Concern* in Schedule 1 of *SARA*.

There has been a substantial amount of work recently conducted for both the inside and outside Yelloweye Rockfish Designatable Units (DUs). As such, much of the information normally provided in the RPA has already been compiled in reviewed and recently published CSAS documents. In lieu of repeating this information, the RPA elements for which there is new content is provided in this Science Response, and readers are directed to the appropriate document(s) for information within applicable elements described elsewhere. The information provided here largely reflects the *Recovery Targets* content, with some additional updated information relevant for other RPA elements.

This Science Response Report results from the regional peer review of October 11, 2022 on the Recovery Potential Assessment for Yelloweye Rockfish (*Sebastes ruberrimus*) in British Columbia.

Background

Species Information

Scientific name: *Sebastes ruberrimus* (Cramer 1895)

Common name: English - Yelloweye Rockfish

French - sébastes aux yeux jaunes

Other names: Red Snapper (misnomer), Rock Cod (misnomer)

Table 1. COSEWIC status for the two Yelloweye Rockfish DUs (COSEWIC 2020).

Designatable Unit (DU)	**COSEWIC Status**	**Reason for Designation**
Yelloweye Rockfish (*Sebastes ruberrimus*) — Inside DU (IYE)	Threatened	This species is slow growing and late-maturing, with a generation time of ~38 years. These life-history traits entail they are susceptible to overfishing. Recent analyses have suggested that there has been a dramatic drop in abundance over the last 100 years.
Yelloweye Rockfish (*Sebastes ruberrimus*) — Outside DU (OYE)	Threatened	This species is slow growing and late-maturing, with a generation time of ~38 years. These life-history traits entail they are susceptible to overfishing. Recent analyses have suggested that there has been a dramatic drop in abundance over the last 100 years.

Listing and Recovery Background

There are two recognized DUs for Yelloweye Rockfish (YE) in British Columbia. The inside DU corresponds to the population occupying the eastern waters in Queen Charlotte Strait, the Broughton Archipelago and the Salish Sea. The outside DU comprises the outer coastal waters off the west coast of Vancouver Island, central coast, and north coast/Haida Gwaii. COSEWIC last assessed both DUs in 2020 (COSEWIC 2020), which resulted in a change in status from *Special Concern* (COSEWIC 2008) to *Threatened*.

Previous assessments conducted by Yamanaka et al. (2011, 2018) found that the inside and outside DUs were below their Limit Reference Points (LRPs). This finding triggered the development of Rebuilding Plans using DFO's Guidance for the development of rebuilding plans under the Precautionary Approach Framework: Growing stocks out of the critical zone policy (DFO 2013) to increase stock biomass. The respective Rebuilding Plan evaluations were published by Cox et al. (2020) and Haggarty et al. (2022*)* with their corresponding Science Advisory Reports (DFO 2020a, b). Management Procedures (MPs) intended to increase stock biomass were evaluated in the Rebuilding Plan analyses using closed-loop simulations. These analyses follow the MP Framework approach described by Anderson et al. (2021).

For the inside YE DU (or stock) (IYE), 34 data-limited MPs were evaluated in their ability to meet the proposed principal objective of rebuilding the stock above the LRP (40% of the biomass at Maximum Sustainable Yield [40% B_{MSY}]) over 1.5 generations (56 years) with at least a 95% (19 times out of 20) probability of success. MP performance was also evaluated for two additional conservation metrics based on an LRP of 40% B_{MSY} and Upper Stock Reference (USR) of 80% B_{MSY}, three average-catch objectives, and one catch-variability objective. Natural mortality, selectivity, and historical catch were identified as major sources of uncertainty. Uncertainty in these parameters was accounted for by evaluating performance of the MPs across six alternative Operating Model (OMs) scenarios with different assumptions. Four OMs, representing the most important and plausible uncertainties, were allocated to a "reference set"; two OMs, representing a broader range of uncertainties, were allocated to a "robustness set" (Table 2; see Section 4.1 in Haggarty et al. [2022] for description of OMs).

Table 2. Operating Models and set type for the Inside Yelloweye Rockfish stock analysis. M = natural mortality, HBLL = hard bottom long-line survey, CV = coefficient of variation. Please see the IYE Rebuilding Plan and Appendices for full descriptions and parameter values used in the OMs.

OM Scenario name	Description	Set type
(1) Base	Sets the baseline conditions for setting parameter values and what data sources are included.	Reference
(2) Low catch	Tests model sensitivity to the assumption of large unreported commercial catch from 1986-2005. The stock reduction analysis (SRA) was fit to the nominal catch data; used 2x the nominal catch data in the Base OM.	Reference
(3) Episodic recruitment	Addresses concern that large cohorts are not adequately modeled by the lognormal recruitment deviations in the Base OM. Assumes an extreme recruitment event occurs once every 38 years (1 generation).	Reference
(4) Estimate HBLL selectivity	Limited age samples from the HBLL research surveys make it hard to estimate selectivity. Here, selectivity is estimated by the SRA, while it is fixed in the other OMs.	Reference
(A) Low M	Lower values of natural mortality used in this OM.	Robustness
(B) High HBLL CV	Considers that the future HBLL index may be less precise than assumed in other OMs, and use a higher standard deviation from the index residuals in OM 1.	Robustness

None of the reference set OMs estimated the median stock biomass to be below the LRP in 2019. Differences in estimates of IYE stock status between the current OMs and previous assessment were attributable to model structure choices. Closed-loop simulation screened out MPs that did not meet basic performance criteria, resulting in five remaining candidate MPs: two annual constant-catch MPs (10 and 15 tonnes), and three MPs that adjust the total allowable catch (TAC) based on a survey index of abundance. All five final MPs met the principal performance metric with greater than 98% probability (49 times out of 50), across all four OM reference set scenarios.

For the outside YE DU (or stock) (OYE), alternative data scenarios produced a wide range of estimated stock status, as well as biological and management parameters, from which four representative operating model (OM) scenarios were selected for simulation testing of MPs. These four OMs were selected to address uncertainty in the commercial catch reconstruction, the lack of fishery-independent survey data prior to the 1990s, and different priors used to estimate natural mortality and the stock-recruitment steepness parameter. Upper and lower bounds of commercial catch, a model start year of 1918 or 1960, and two priors on natural mortality were evaluated (Table 3).

Environmental factors can affect natural mortality rates and productivity (estimated by the stock-recruitment steepness parameter). While natural mortality is a key parameter in understanding fish population dynamics, it is often confounded with fishing mortality, productivity parameters, and the scale of the population. Likewise, productivity is also difficult to estimate. As such, the

OMs attempt to address underlying uncertainty in natural mortality and productivity by modeling both parameters within the OM, in lieu of understanding the mechanistic relationship between environmental factors and natural mortality and steepness.

Table 3. Operating Models for the Outside Yelloweye Rockfish stock analysis. Please see the OYE Rebuilding Plan for full descriptions and parameter values used in the OMs. OMs were developed for a northern and southern region and then combined to compute coastwide estimates.

OM Scenario name	Description
Base	Base case that includes a 1918 model start year and upper bound for reconstructed commercial catch, and the least informative prior on natural mortality.
OM2	Uses a 1960 model start year and lower bound for reconstructed commercial catch, and the same prior on natural mortality as in the Base scenario.
OM3	Uses a 1960 model start year and the reconstructed commercial catch, with a lower mean prior than the Base scenario.
OM4	Uses the 1918 model start year and lower bound of reconstructed commercial catch, and the same prior on natural mortality as in the Base scenario.
Weighted	The 4 OMs were averaged using a weighting of 50% for the base model and 16.67% for the alternative OMs.

The candidate MPs evaluated included three different assessment methods:

1. a catch-at-age assessment model (caa),
2. a surplus production assessment model (sp), and
3. an empirical rule using survey index trends (idx).

The three assessment methods were used in combination with different harvest control rules or implementation error scenarios to create a set of candidate MPs that were simulation-tested for each of the four operating model scenarios for the outside North and South areas independently. In total, 13 MPs were evaluated (two sp MPs, four caa MPs, and seven idx MPs). Additional MPs for the OYE stock have been evaluated in an addition to Cox et al. (2020). These new MPs include two index-based MPs that use a 3-year or 5-year moving average from the Hard Bottom Longline Survey (HBLL) index, a fishing at MSY (F_{MSY}) MP, and a ‘no fishing’ MP. The intent is to continue to apply these MPs as part of the rebuilding strategies and Recovery Potential Assessment process as much as possible, knowing that scientific advice evolves over time. A peer review process is planned to evaluate the OYE MPs in 2023.

The OMs and MPs illustrate a range of management options and plausible states of nature. Simulations of MP performance for setting future OYE TACs generally showed robust performance relative to the objectives described above, across the range of operating model scenarios. The operating model scenarios, including the combined weighted OM showed that OYE is currently above the LRP of 40% B_{MSY} coast-wide with a probability ranging from (99.7%

to 100%) even though OYE biomass declined rapidly by 49% - 71% in the North, and by 57% - 79% in the South over the past two OYE generations.

Analysis and Response

Content for each element is summarized below. The content for each element may be provided in full, may be partially provided that includes updates on data gaps and/or uncertainties, or the reader may be directed to previously published documents that detail the content needed to satisfy the element. Document references are provided with the relevant section number(s) listed in square brackets.

Links for Reference Documents

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021)
- Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: biology, distribution and abundance trends (Keppel and Olsen 2019)
- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020)
- Evaluation of potential rebuilding strategies for Outside Yelloweye Rockfish (*Sebastes ruberrimus*) in British Columbia (Cox et al. 2020)
- Evaluation of potential rebuilding strategies for Inside Yelloweye Rockfish (*Sebastes ruberrimus*) in British Columbia (Haggarty et al. 2022)

Biology, Abundance, Distribution and Life History Parameters

Element 1: Summary of Yelloweye Rockfish biology

The content for this element can be found in the following documents:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [4.1]
- Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: biology, distribution and abundance trends (Keppel and Olsen 2019) [3]
- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020) [1; 4]
- Evaluation of Potential Rebuilding Strategies for Outside Yelloweye Rockfish in British Columbia (Cox et al. 2020) [1]
- Evaluation of Potential Rebuilding Strategies for Inside Yelloweye Rockfish in British Columbia (Haggarty et al. 2022) [1]

Element 2: Distribution, number of populations and abundance trajectory

For a discussion of the distribution and number of populations please see:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [4.2]

- Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: biology, distribution and abundance trends (Keppel and Olsen 2019) [1.4; 2.1; 2.2]
- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020) [2; 5]

Abundance trends and trajectories are presented in:

- Evaluation of Potential Rebuilding Strategies for Outside Yelloweye Rockfish in British Columbia (Cox et al. 2020) [2.3]
- Evaluation of Potential Rebuilding Strategies for Inside Yelloweye Rockfish in British Columbia (Haggarty et al. 2022) [2.4]

Element 3: Life-history parameters for Yelloweye Rockfish

The content for this element can be found in the following documents:

- Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: biology, distribution and abundance trends (Keppel and Olsen 2019) [3]
- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020) [4.1]
- Evaluation of Potential Rebuilding Strategies for Outside Yelloweye Rockfish in British Columbia (Cox et al. 2020) [2.2]
- Evaluation of Potential Rebuilding Strategies for Inside Yelloweye Rockfish in British Columbia (Haggarty et al. 2022) [2.3]

Habitat and Residence Requirements

Element 4: Habitat properties needed by Yelloweye Rockfish to complete its life-cycle

General information regarding habitat needs can be found in the following documents:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [4.3.1; 5.3.2]
- Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: biology, distribution and abundance trends (Keppel and Olsen 2019) [2.3]
- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020) [3]

Element 5: Provide information on the spatial extent of the areas in Yelloweye Rockfish's distribution that are likely to have these habitat properties

The content for this element can be found in the following documents:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [5.3]
- Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: biology, distribution and abundance trends (Keppel and Olsen 2019) [2.2; 2.3.2; 2.4]

- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020) [3]

Element 6: Quantify the presence and extent of spatial configuration constraints, if any, such as connectivity, barriers to access, etc.

The content for this element can be found in the following documents:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [5.3.1]
- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020) [5.3]

Element 7: Evaluate to what extent the concept of residence applies to the species, and if so, describe the species' residence

Residence is defined by SARA as "a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" (DFO 2015). YE exhibit internal fertilization, and larvae disperse into the water column for an extended pelagic larval duration phase after parturition. Once they have settled into adult habitat, some Yelloweye Rockfish exhibit high site fidelity with small home ranges, but some individuals may move farther (Hannah and Rankin 2011). The concept of residence, however, does not apply.

Threats and Limiting Factors to the Survival and Recovery of Yelloweye Rockfish

Element 8: Assess and prioritize the threats to the survival and recovery of Yelloweye Rockfish

Some of the content for this element can be found in the following documents:

- Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: biology, distribution and abundance trends (Keppel and Olsen 2019) [6]
- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020) [6]
- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [5.1]

The primary threat identified for YE is overfishing. Fishing mortality increased through the 1980s and reached its highest level in the 1990s. It is highly unlikely that fishing rates will ever return to those historic highs in the short or medium term. Given that YE persisted through this period of high exploitation, it is unlikely that fishing pressure alone under the current management plan poses a risk to the survival of YE.

Climate change presents possible but unknown threats to YE. In a recent study English et al. (2022) suggest that changes in temperature and/or dissolved oxygen have resulted in redistributions of fish populations in British Columbia that may result in novel ecological and fisheries interactions. Species with high site fidelity, such as YE and other rockfishes, are more likely to experience environmental effects at finer spatial scales, which can be difficult to detect. The longevity of YE and many rockfishes also entails that monitoring over longer periods of time is needed to detect strong effects of climate change on populations. Of the 38 Canadian groundfish species included in the analysis, YE were the species identified to be most at risk of population declines due to local temperature warming. As such, climate change may present novel threats to YE, however, the mechanisms underlying these threats remain largely unknown.

Element 9: Identify the activities most likely to threaten (i.e., damage or destroy) the habitat properties identified in elements 4-5 and provide information on the extent and consequences of these activities

The content for this element can be found in the following document:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [5.2.3]

Element 10: Assess any natural factors that will limit the survival and recovery of the Yelloweye Rockfish

The content for this element can be found in the following documents:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [4.3.2]
- Pre-COSEWIC review of Yelloweye Rockfish (*Sebastes ruberrimus*) along the Pacific coast of Canada: biology, distribution and abundance trends (Keppel and Olsen 2019) [6.3]
- COSEWIC Assessment and Status Report on the Yelloweye Rockfish (*Sebastes ruberrimus*), Pacific Ocean outside waters population and Pacific Ocean inside waters population, in Canada (COSEWIC 2020) [6]

Element 11: Discuss the potential ecological impacts of the threats identified in element 8 to the target species and other co-occurring species. List the possible benefits and disadvantages to the target species and other co-occurring species that may occur if the threats are abated. Identify existing monitoring efforts for the target species and other co-occurring species associated with each of the threats, and identify any knowledge gaps

The content for this element can be found in the following documents:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [5.2.1; 7.1; 7.2; 7.3]

Recovery Targets

Element 12: Propose candidate abundance and distribution targets for recovery

Under the Fish Stocks provisions in the *Fisheries Act*, Rebuilding Plans are required for stocks found to be below their limit reference point (LRP). While not prescribed under the Precautionary Approach, commonly used default reference points include 40% B_{MSY} and 80% B_{MSY} for the LRP and upper stock reference (USR), respectively. Rebuilding Plans were developed for the outside and inside YE stocks using these two B_{MSY}-based reference points (defined as the probability of being above the LRP or USR at the end of 1.5 generations, i.e., 56 years into the projection). The rebuilding target should be set at a level that is far enough above the LRP to have a high probability of the stock being above it, taking uncertainties into account and so that there is a low probability of falling below the LRP in the short to medium term (DFO 2021).

As such, the working objectives of the Rebuilding Plans were to identify management procedures that will grow the OYE and IYE stocks above the LRP (40% B_{MSY}) with high probability (95%) within 1.5 – 2 generations, and to ensure the stocks do not fall below the LRP in the medium term. These working objectives, however, do not reflect official rebuilding or recovery targets for YE, which do not yet exist. Guidance for writing Rebuilding Plans under the Fish Stock provisions in the 2019 revisions to the *Fisheries Act* (Guidelines for writing rebuilding plans per the Fish Stocks Provisions and A Fishery Decision-making Framework Incorporating the Precautionary Approach) states that rebuilding targets should not be treated as a target reference point (TRP), but is intended to signal the transition from the Rebuilding Plan to the standard fisheries management processes, as the stock approaches or exceeds the USR or a specified TRP. A potential candidate rebuilding or recovery target suggested for YE may be between 60% – 80% B_{MSY}.

Provisional Recovery Targets

In accordance with Section 37 of the *Species at Risk Act* (SARA), a recovery strategy must be prepared for species listed as extirpated, endangered or threatened in Schedule 1 of SARA. Within the SARA recovery strategies, population and distribution objectives for the species are developed with the support of advice provided by DFO Science through the Recovery Potential Assessment (RPA) process regarding candidate abundance and distribution targets for recovery. If there are few guidelines on the recovery target, then presumably, the recovery target should be the population level at which the species is no longer considered endangered or threatened. These determinations can be based on population trends, such as population declines at certain thresholds (e.g., 30%, 50%, or 70%) over a specified time period (see COSEWIC criteria A descriptions).

Projections from the MP Framework could be used to inform a recovery target and evaluate when, and at what population size, these metrics are reduced. Similar to the rebuilding target analysis, a recovery target needs to also define the probability and timeline at which the target should be met.

Recovery Targets for YE are currently undefined; however, milestones under the Fish Stock provisions, such as the rebuilding target, or reference points (LRP and USR) may serve as preliminary benchmarks until an official recovery target is defined. These management points can help facilitate the transitions between special concern, threatened, and not-at-risk status designations.

Rebuilding Plan Considerations for Rebuilding and Recovery Targets

The MP Framework was used for YE to identify procedures that would meet conservation objectives associated with rebuilding. The primary performance measure used in the rebuilding analysis was the probability that the stock is above the LRP in 1.5 generations (56 years). As a result, the analyses implicitly identified the LRP as the performance goal, along with achieving that goal in the associated timeframe (56 years) and with a probability for exceeding that goal (management procedures needed to meet this performance metric with at least 95% probability). For IYE, operating models were developed with the intention of testing dynamic management procedures that would be responsive to data and meet the conservation objectives with high probability. No determination on the ability for operating models to sufficiently represent the true stock dynamics were made, i.e., no individual operating model may be a sufficient representation of current stock dynamics and likely would not pass peer review if presented as a single best model stock assessment. For OYE, operating models and management procedures were also evaluated in their ability to meet the provisional rebuilding goal of growing the stock above the LRP with high probability. The OMs for the OYE analysis are used to explore differences in the reconstructed commercial catch (upper and lower bounds), a model start year of 1918 or 1960, and different priors on estimating natural mortality. A single, weighted model combines the four OMs.

While the rebuilding target should be determined a priori according to policy, the results of the rebuilding analyses may be evaluated post-hoc to determine whether alternative rebuilding targets would be sensible for the dynamics of both YE stocks.

In Element 13, we show population trajectories using a suite of potential rebuilding and recovery targets that span 40% to 160% of B_{MSY}. We also show population trajectories with reference to the 30%, 50%, and 70% COSEWIC decline criteria. For IYE, we evaluated the probability of meeting the potential rebuilding and recovery target within 1.5 generations (56 years) for three management procedures (MPs): no fishing, a constant catch of 15 tonnes (t) annually, and a fixed F_{MSY}-based fishing policy. F_{MSY} is the maximum allowable removal rate (RR) according to the Precautionary Approach (PA) and UN Fish Stocks Agreement, and 15 t is the annual total catch prescribed by management. For OYE, we evaluated the probability of the 30%, 50%, and 70% declines for four MPs: no fishing, two hard bottom longline survey index MPs, and a perfect information F_{MSY} MP.

The different MPs may reflect possible management options that could be implemented under different legislative tools, dependent on a decision to list or not list Yelloweye Rockfish under the *Species at Risk Act* (SARA).

Element 13: Project expected population trajectories over a scientifically reasonable time frame (minimum of 10 years), and trajectories over time to the potential recovery target(s), given current Yelloweye Rockfish population dynamics parameters

Population trajectories for IYE and OYE are provided in their respective Rebuilding Plan Analyses. The stock trajectories are projected over different operating models under a suite of management procedures, which results in different trajectories over the projection period.

Inside Yelloweye Rockfish Stock

The analysis for IYE that was developed in advance of the Fish Stocks Provisions guidance, uses a high probability of being above the LRP as the conservation goal, and shows that the stocks are presently above the LRP, and that multiple management procedures will maintain the IYE stock above the LRP (or even above the USR) for the projection time-series of 1.5 generations into the future.

The probability that the 2019 spawning biomass is above the LRP and the USR ranges from 93% - 98% and 37% - 71% across the reference OMs, respectively (Figure 1).

	LRP	USR
(1) Base	0.98	0.71
(2) Low catch	0.93	0.61
(3) Episodic recruitment	0.98	0.71
(4) Estimate HBLL selectivity	0.93	0.37
(A) Low M	0.44	0.04
(B) High HBLL CV	0.98	0.71

Figure 1. Estimated probability that the 2019 IYE spawning biomass is above the LRP and USR (40% B_{MSY} and 80% B_{MSY}, respectively) across the four reference and two robustness operating models.

Across the suite of reference OMs, at the end of the projection period (1.5 generations into the future) the range of probabilities that the stock remains above the 40% B_{MSY} LRP and the 80% B_{MSY} USR vary across the suite of reference OMs and MPs. The analysis shows that the stock will remain above the LRP with a 98% – 99+% probability, and above the USR with a 92% – 99+% probability (Figure 2).

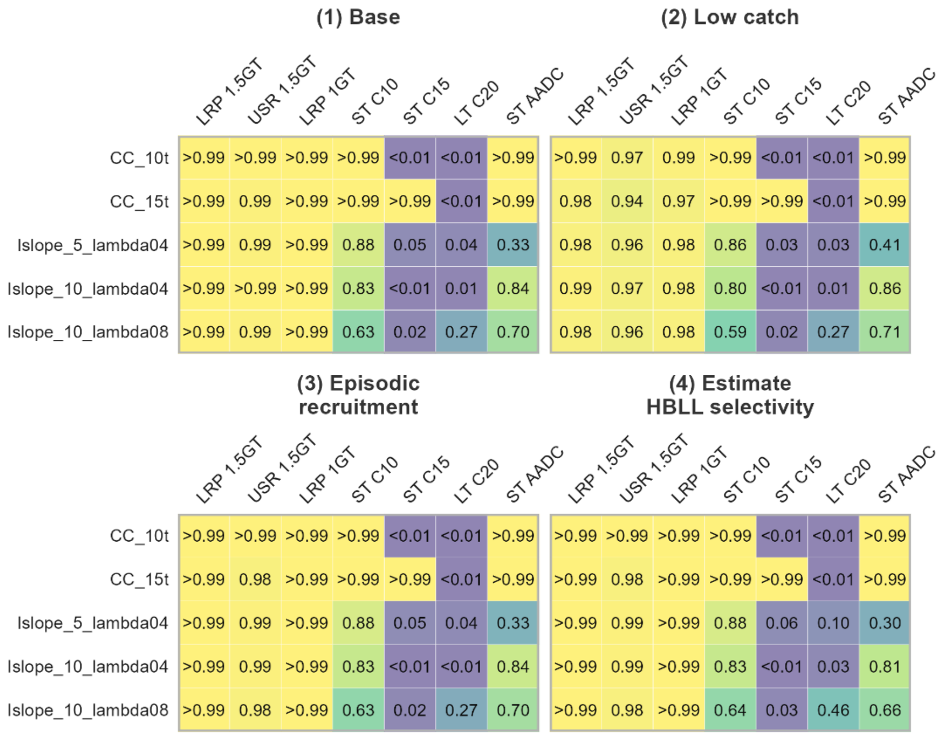

Figure 2. The probability that the different objectives (columns) for IYE are met at the end of the 1.5 generation projection period with each management procedure for each of the four reference operating models. Objectives: probability that the stock is above the LRP after 1.5 generations (LRP 1.5GT), probability that the stock is above the USR after 1.5 generations (USR 1.5GT), probability that the stock is above the LRP after 1 generations (LRP 1GT), probability that the stock is above the USR after 1 generations (USR 1GT), probability of average annual catch meeting 10 tonnes for first 10 years (ST C10), probability of average annual catch of meeting 15 tonnes for first 10 years (ST C15), probability of average annual catch meeting 20 tonnes after 1 GT (year 38 of the projection period, LT C20), probability that the absolute average deviation in annual catch for 2020-2029 is less than that for 2012-2019 (ST AADC). Management Procedures: constant catch of 10 tonnes (CC_10t), constant catch of 15 tonnes (CC_15t), catch is adjusted using linear regression within a time period (e.g., 5 or 10 years) to achieve a constant abundance index, and different values for the lambda parameter are used (the three "Islope" MPs).

In order to project the population trajectory with respect to the COSEWIC decline criteria, we evaluated the probability of at least 30%, 50%, and 70% decline for the same three management procedures as the rebuilding target exercise, over 100 future projection years (the minimum between a century and three generations). With no fishing, the probability of population decline steadily decreases over time (Figure 3). The probability of decline is less than < 50% by 2075 in almost all situations (1.5 generations after the start of the projections), except for the probability of 30% decline in the low *M* operating model. With the 15 t management procedure, these probabilities also decrease over time although at a slower rate than with no fishing (Figure 4). The probability of decline is less than < 50% by 2075 in almost all scenarios except in the low *M* operating model, which assumes the stock is less productive.

With the fishing at F_{MSY} MP, the probability of a 70% decline decreases gradually over time and is less than 50% by 2075, but the probability of a 30% and 50% decline remains high until the end of the current century (Figure 5). These results are likely a result of high biomass inferred from the conditioning of operating models. Fishing at F_{MSY} would result in a windfall of catches and reduce biomass in the projections. Figure 6 reports the probability of decline after 1.5 generations for each operating model, and Figure 7 reports the probability of decline after 1.5 generations averaged across the operating models.

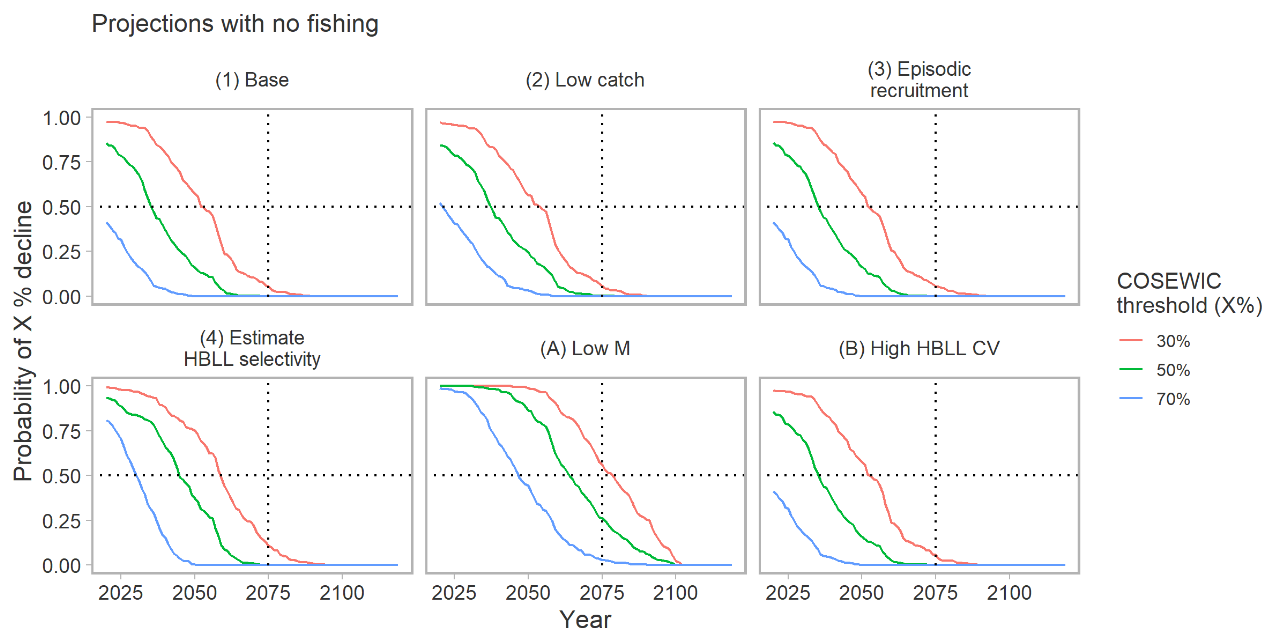

Figure 3. With no fishing, the annual probability of IYE population decline from projections over 100 years in six operating models. The vertical dotted line indicates 2075 (1.5 generations from the start of the projection) and the horizontal dotted line indicates 50% probability.

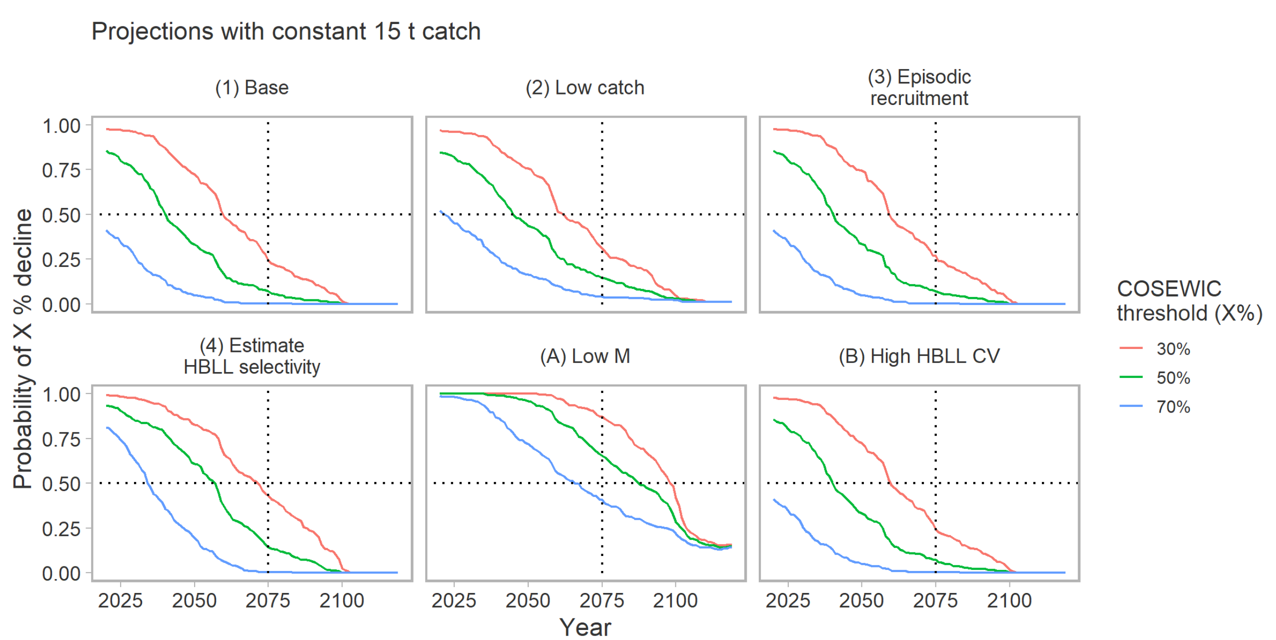

Figure 4. With annual 15 tonnes catch, the annual probability of IYE population decline from projections over 100 years in six operating models. The vertical dotted line indicates 2075 (1.5 generations from the start of the projection) and the horizontal dotted line indicates 50% probability.

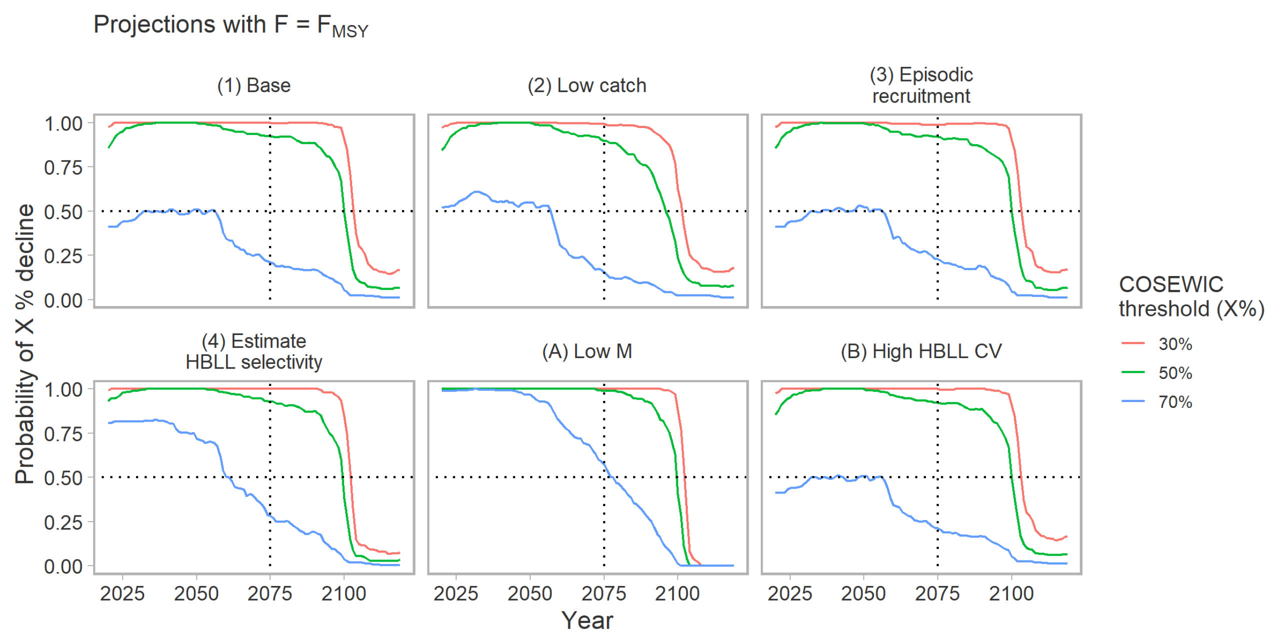

Figure 5. With a fixed F_{MSY} fishing policy, the annual probability of IYE population decline from projections over 100 years in six operating models. The vertical dotted line indicates 2075 (1.5 generations from the start of the projection) and the horizontal dotted line indicates 50% probability.

	(1) Base			(2) Low catch			(3) Episodic recruitment		
	30% decline	50% decline	70% decline	30% decline	50% decline	70% decline	30% decline	50% decline	70% decline
No fishing	0.06	<0.01	<0.01	0.06	<0.01	<0.01	0.06	<0.01	<0.01
CC_15t	0.24	0.07	<0.01	0.31	0.14	0.04	0.27	0.07	<0.01
FMSY	>0.99	0.92	0.21	0.99	0.90	0.15	0.99	0.92	0.23

	(4) Estimate HBLL selectivity			(A) Low M			(B) High HBLL CV		
	30% decline	50% decline	70% decline	30% decline	50% decline	70% decline	30% decline	50% decline	70% decline
No fishing	0.11	<0.01	<0.01	0.56	0.26	0.03	0.06	<0.01	<0.01
CC_15t	0.43	0.14	<0.01	0.87	0.65	0.41	0.24	0.07	<0.01
FMSY	>0.99	0.93	0.28	>0.99	0.99	0.57	>0.99	0.92	0.21

Figure 6. The COSEWIC decline criteria, showing the probability that by the end of the 1.5 generation projection period the IYE stock has declined by 70%, 50%, and 30% of B_0. Management procedures: constant catch of 15 tonnes (CC_15t), fishing rate of F_{MSY} (F_{MSY}).

	30% decline	50% decline	70% decline
No fishing	0.07	<0.01	<0.01
CC_15t	0.31	0.11	0.01
FMSY	>0.99	0.92	0.22

Figure 7. The COSEWIC decline criteria, showing the probability that by the end of the 1.5 generation projection period the IYE stock has declined by 70%, 50%, and 30% of B_0. Each probability is averaged across the four reference operating models, and shown for three management procedures: no fishing, constant catch of 15 tonnes (CC_15t), fishing rate of F_{MSY} (F_{MSY}).

For the COSEWIC decline Criterion E, there is a >99% probability that the biomass remains above 2% and 5% of B_0 (Figure 8).

	2% B0	5% B0
NFref	>0.99	>0.99
Islope_5_lambda04	>0.99	>0.99
Islope_10_lambda08	>0.99	>0.99
Islope_10_lambda04	>0.99	>0.99
CC_10t	>0.99	>0.99
CC_15t	>0.99	>0.99

Figure 8. COSEWIC extinction criterion E, showing the probability that the IYE stock remains above 2% and 5% of B_0 at the end of the 1.5 generation projection period for each management procedure averaged over the four reference operating models. The two thresholds of 2% and 5% of B_0 were chosen to illustrate the extremely low probability of extinction. Management Procedures: constant catch of 10 tonnes (CC_10t), constant catch of 15 tonnes (CC_15t), catch is adjusted using linear regression within a time period to achieve a constant abundance index, and different values for the lambda parameter are used (the three "Islope" MPs).

We also present the population trajectories in terms of candidate rebuilding targets that range from 40% to 160 % of B_{MSY}. These trajectories are shown for each operating model with a management procedure of no fishing (Figure 9), constant catch of 15 tonnes (Figure 10), and fishing at F_{MSY} (Figure 11). The probabilities at the end of 1.5 generations are summarized for each operating model in Figure 12, and averaged over operating models in Figure 13.

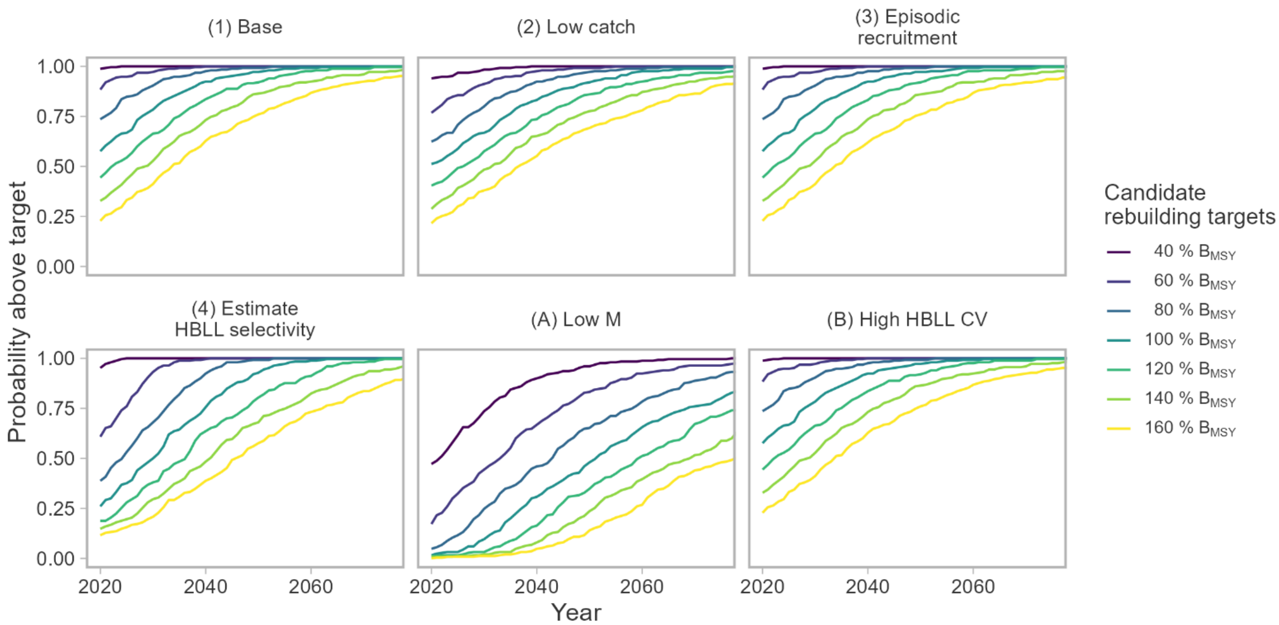

Figure 9. Probability of exceeding candidate rebuilding targets under the no fishing management procedure for each operating model for IYE.

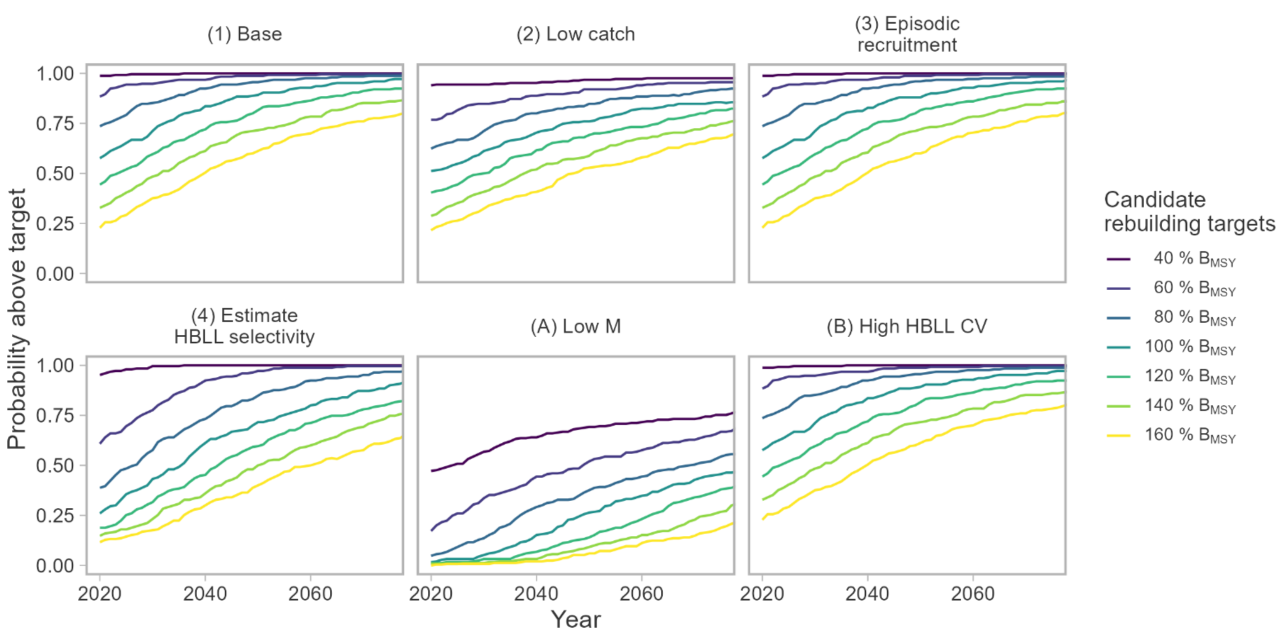

Figure 10. Probability of exceeding candidate rebuilding targets under the constant catch of 15 tonnes management procedure for each operating model for IYE.

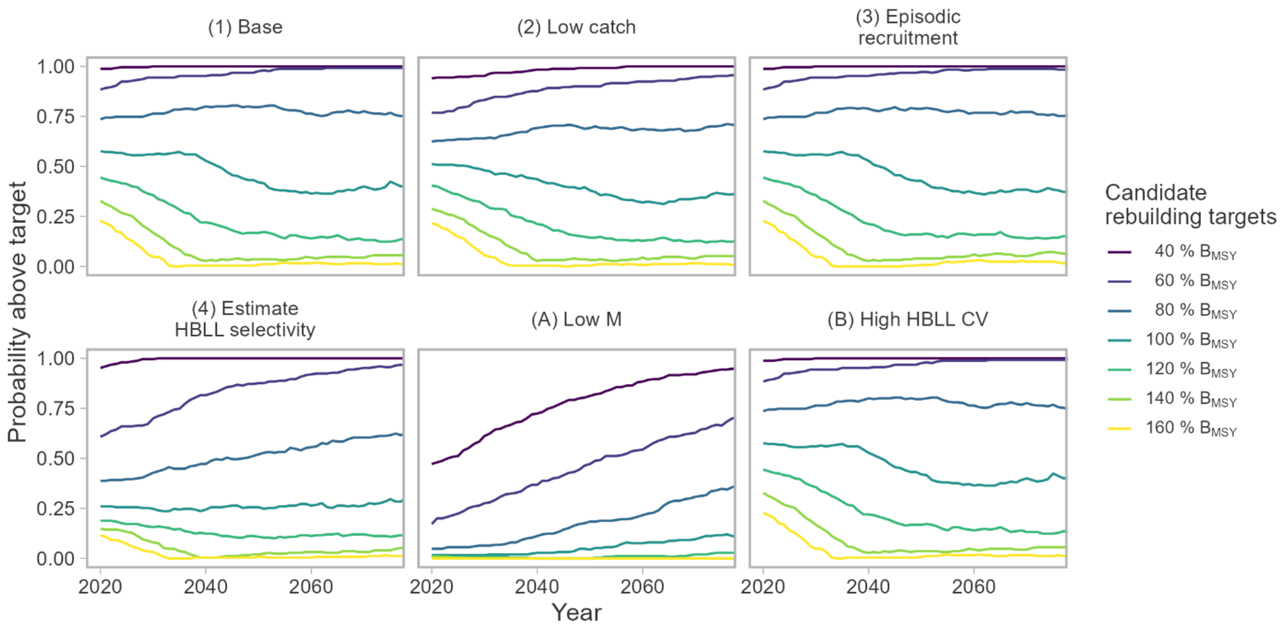

Figure 11. Probability of exceeding candidate rebuilding targets under the F_{MSY} management procedure for each operating model for IYE.

(1) Base

	40% BMSY	60% BMSY	80% BMSY	100% BMSY	120% BMSY	140% BMSY	160% BMSY
No fishing	>0.99	>0.99	>0.99	>0.99	>0.99	0.98	0.94
CC_15t	>0.99	>0.99	0.99	0.97	0.92	0.86	0.78
FMSY	>0.99	0.99	0.77	0.42	0.12	0.06	0.01

(2) Low catch

	40% BMSY	60% BMSY	80% BMSY	100% BMSY	120% BMSY	140% BMSY	160% BMSY
No fishing	>0.99	>0.99	>0.99	0.99	0.97	0.94	0.91
CC_15t	0.98	0.96	0.92	0.86	0.82	0.75	0.68
FMSY	>0.99	0.95	0.70	0.36	0.13	0.05	0.01

(3) Episodic recruitment

	40% BMSY	60% BMSY	80% BMSY	100% BMSY	120% BMSY	140% BMSY	160% BMSY
No fishing	>0.99	>0.99	>0.99	>0.99	>0.99	0.97	0.94
CC_15t	>0.99	>0.99	0.98	0.96	0.92	0.85	0.79
FMSY	>0.99	0.99	0.76	0.38	0.14	0.07	0.02

(4) Estimate HBLL selectivity

	40% BMSY	60% BMSY	80% BMSY	100% BMSY	120% BMSY	140% BMSY	160% BMSY
No fishing	>0.99	>0.99	>0.99	>0.99	>0.99	0.94	0.88
CC_15t	>0.99	>0.99	0.97	0.90	0.81	0.75	0.62
FMSY	>0.99	0.96	0.62	0.30	0.11	0.04	0.01

(A) Low M

	40% BMSY	60% BMSY	80% BMSY	100% BMSY	120% BMSY	140% BMSY	160% BMSY
No fishing	>0.99	0.96	0.92	0.80	0.72	0.59	0.48
CC_15t	0.75	0.67	0.54	0.46	0.38	0.27	0.19
FMSY	0.94	0.66	0.35	0.12	0.03	<0.01	<0.01

(B) High HBLL CV

	40% BMSY	60% BMSY	80% BMSY	100% BMSY	120% BMSY	140% BMSY	160% BMSY
No fishing	>0.99	>0.99	>0.99	>0.99	>0.99	0.98	0.94
CC_15t	>0.99	>0.99	0.99	0.97	0.92	0.86	0.78
FMSY	>0.99	0.99	0.77	0.42	0.12	0.06	0.01

Figure 12. Probability of exceeding the proposed rebuilding targets at the end of the 1.5 generation projection for the three management procedures for each operating model for IYE.

	40% BMSY	60% BMSY	80% BMSY	100% BMSY	120% BMSY	140% BMSY	160% BMSY
No fishing	>0.99	>0.99	>0.99	>0.99	0.99	0.96	0.92
CC_15t	0.99	0.99	0.96	0.92	0.87	0.80	0.72
FMSY	>0.99	0.97	0.71	0.37	0.13	0.06	0.01

Figure 13. Probability of exceeding the proposed rebuilding targets at the end of the1.5 generation projection for the three management procedures averaged over the reference operating models for IYE.

Outside Yelloweye Rockfish Stock

Across the four OMs for OYE, the analyses found that there is a high probability (>99%) of the stock remaining above the LRP of 40% B_{MSY} over the 1.5 generations for the 13 MPs published in Cox et al. (2020) (Table 4), and for the four MPs (two HBLL index MPs, perfect info for F_{MSY}, and no fishing) of the additional work to the rebuilding strategies. This was found for both the North and South Management Units, as well as for the single coastwide stock (Table 5). The probabilities of exceeding other proposed potential rebuilding and recovery targets (60% - 160% B_{MSY}) are also shown in Table 5 for the additional four MPs.

The four additional MPs were also evaluated with the COSEWIC decline criteria of 30%, 50%, and 70% declines for a 100-year period for the North and South Management Units, and the coastwide stock. After 1.5 generations (beginning in 2023), a 14-15% probability of experiencing a 30% decline was observed for the two HBLL survey index MPs. No MP produced a probability greater than 1% of observing a 50% or 70% decline after 1.5 generations (Table 6). The probability of observing these declines in any 100-year period is shown for the North and South stocks for the two HBLL survey index MPs, the perfect info F_{MSY} MP, and the no fishing MP in Figures 14 - 17. The probabilities shown correspond to the probability of the decline at the end of the 100 years from the start year. For example, the probability shown for 1960 is the probability of the decline observed 100 years from the start year, which would be 2059. The magnitude of decline (30%, 50%, and 70%) corresponds to COSEWIC Criteria A for different status assignments. These figures show the importance of start year for illustrating the effect of start year on the observable decline in the following 100 years, and for illustrating the low risk of further decline given the suite of management procedures for the 100 years beginning in the early 2020s.

Table 4. Results for the MPs tested in Cox et al. (2020). The probability of biomass exceeding the LRP is shown for the terminal year (1.5 generations) of the projection (2076), and in the short term (by year 2029). The probabilities of meeting other Performance Measures include long-term biomass relative to B_0 and B_{MSY}. Here, we only show the results for the three base MPs from the different assessment methods, and a subset of catch Performance Measures. Readers are directed to Table 12 and Table 13 in Cox et al. (2020) for the full set of results. The results are shown for the North and South Management Units separately.

Region	MP	$P(B_{2076})$>LRP	$P(B_{2029})$>LRP	B_{2076}/B_0	B_{2076}/B_{MSY}
North	sp	1	0	0.55	1.89
	caa	1	0.48	0.36	1.25
	idx	1	0.43	0.43	1.48
South	sp	1	0	0.42	1.45
	caa	1	0.45	0.31	1.07
	idx	1	0.05	0.56	1.9

Table 5. Probability of exceeding different biomass thresholds between LRP (40% B_{MSY}), USR (80% B_{MSY}), and 160% B_{MSY} over 1.5 generations (59 years) for Outside Yelloweye for different management procedures (MPs, updated work that is in prep). Probabilities are calculated as the weighted average over 4 operating models for north, south, and coastwide (CW). The projection starts in 2023.

Stock	MP	40% B_{MSY}	60% B_{MSY}	80% B_{MSY}	100% B_{MSY}	120% B_{MSY}	140% B_{MSY}	160% B_{MSY}
North								
	2023 3YR MOV HBLL index	1	1	0.76	0.50	0.17	0	0
	2023 5YR MOV HBLL index	1	1	0.77	0.50	0.19	0.01	0
	Perfect Info F_{MSY}	1	1	0.91	0.65	0.04	0.01	0
	No Fishing	1	1	1	1	1	1	1
South								
	2023 3YR MOV HBLL index	1	0.96	0.74	0.52	0.22	0.01	0
	2023 5YR MOV HBLL index	1	0.97	0.75	0.52	0.20	0.01	0
	Perfect Info F_{MSY}	1	1	0.92	0.66	0.06	0	0
	No Fishing	1	1	1	1	1	1	1
CW								
	2023 3YR MOV HBLL index	1	1	0.88	0.50	0.29	0.02	0
	2023 5YR MOV HBLL index	1	1	0.87	0.50	0.29	0.02	0
	Perfect Info F_{MSY}	1	1	1	0.65	0.05	0.01	0
	No Fishing	1	1	1	1	1	1	1

Table 6. Probability of 30%, 50%, and 70% decline after 1.5 generations (59 years) for Outside Yelloweye for different management procedures (MPs). Probabilities are calculated as the weighted average over 4 operating models for north, south, and coastwide. The projection starts in year 2023.

Stock	MP	30% decline	50% decline	70% decline
North				
	2023 3YR MOV HBLL index	0.05	0	0
	2023 5YR MOV HBLL index	0.06	0	0
	Perfect Info F_{MSY}	0	0	0
	No Fishing	0	0	0
South				
	2023 3YR MOV HBLL index	0.15	0	0
	2023 5YR MOV HBLL index	0.13	0	0
	Perfect Info F_{MSY}	0	0	0
	No Fishing	0	0	0
Coastwide				
	2023 3YR MOV HBLL index	0.14	0	0
	2023 5YR MOV HBLL index	0.16	0	0
	Perfect Info F_{MSY}	0	0	0
	No Fishing	0	0	0

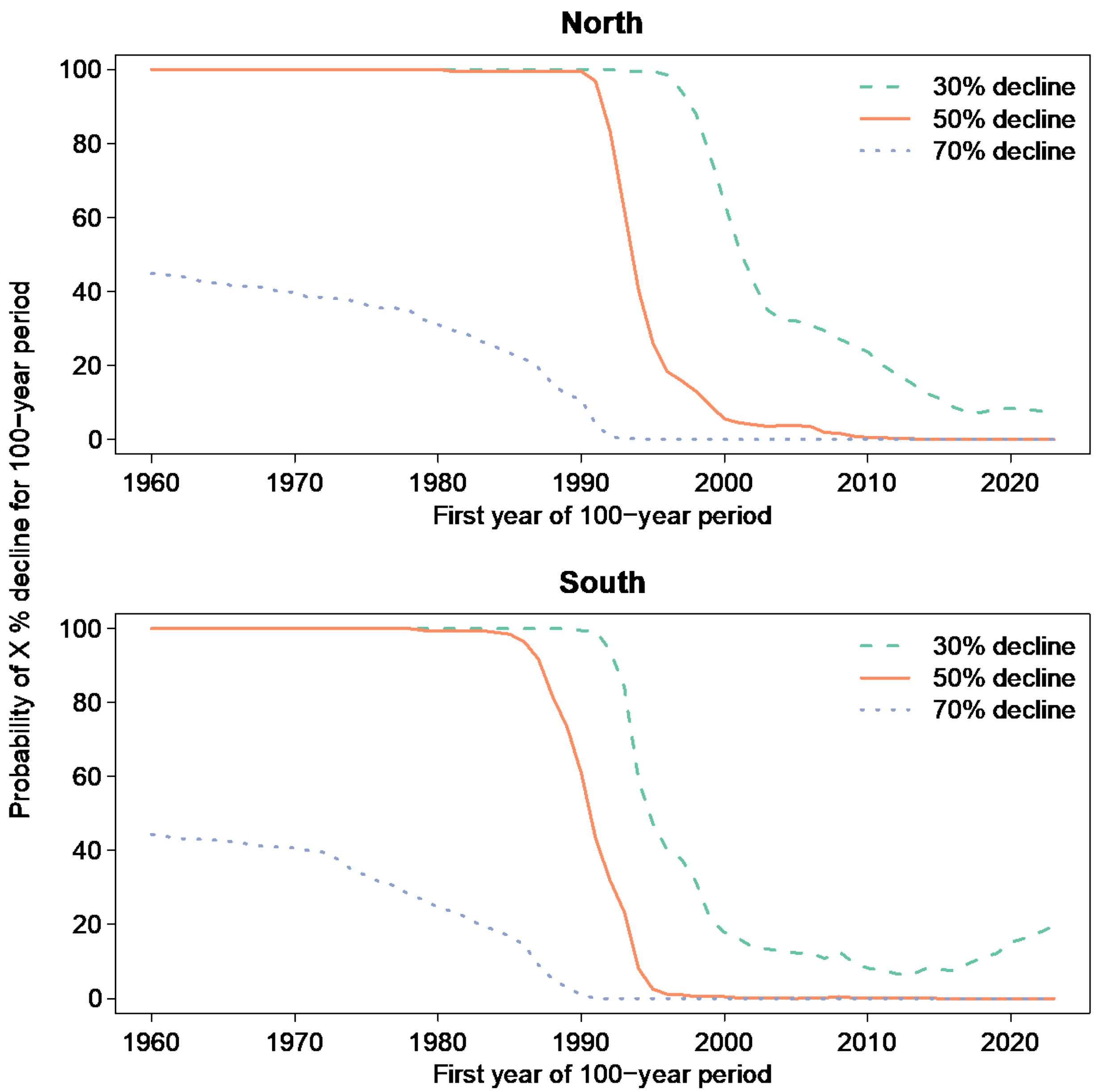

Figure 14. Probability of OYE 30%, 50%, and 70% declines for HBLL 3-year MOV index MP for 100-year periods ranging from 1960-2059 to 2023-2122. Projection years using the HBLL index MP run from 2023-2122. Probabilities are calculated as the weighted average over 4 operating models for north and south.

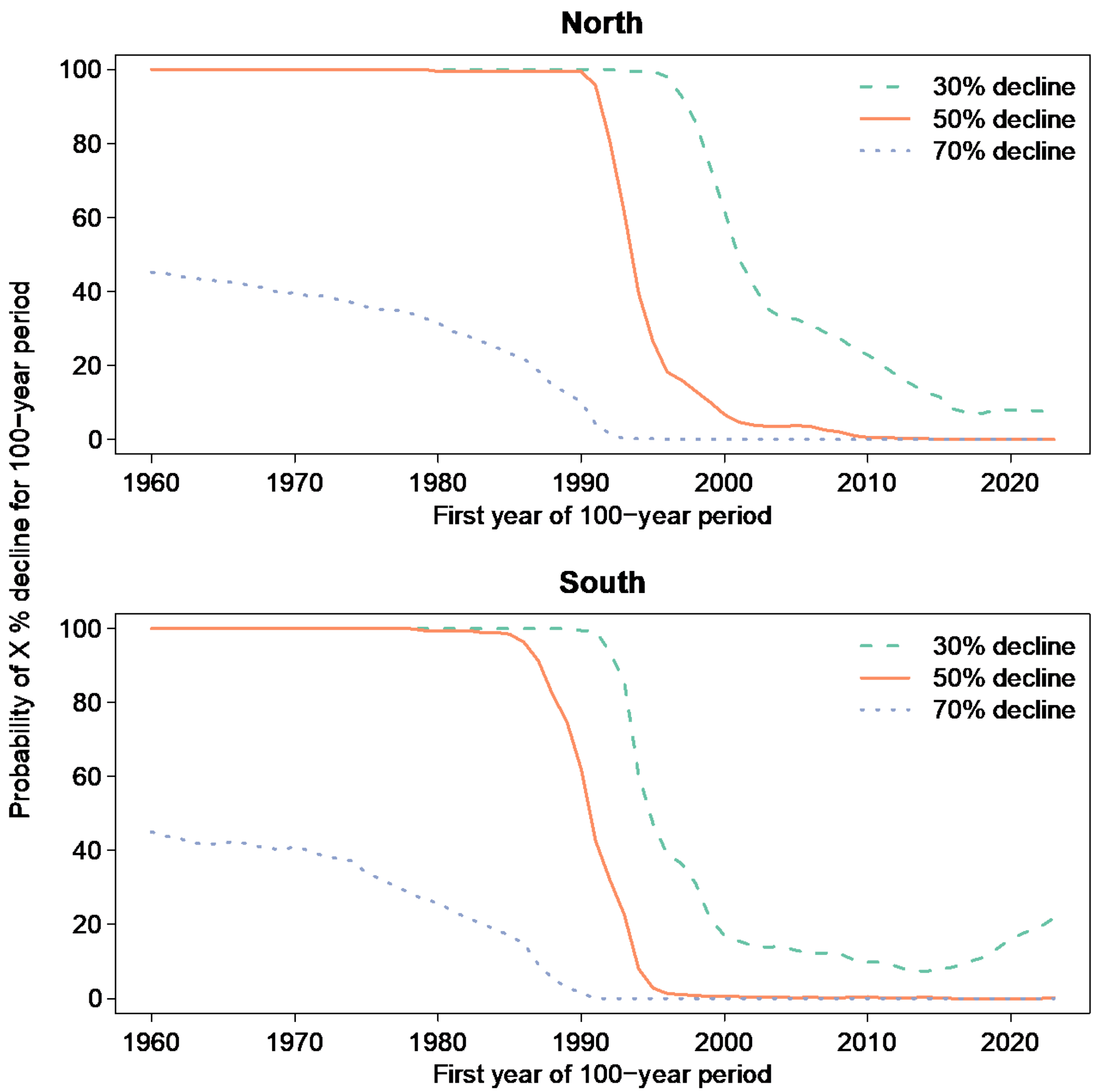

Figure 15. Probability of OYE 30%, 50%, and 70% declines for HBLL 5-year MOV index MP for 100-year periods ranging from 1960-2059 to 2023-2122. Projection years using the HBLL index MP run from 2023-2122. Probabilities are calculated as the weighted average over 4 operating models for north and south.

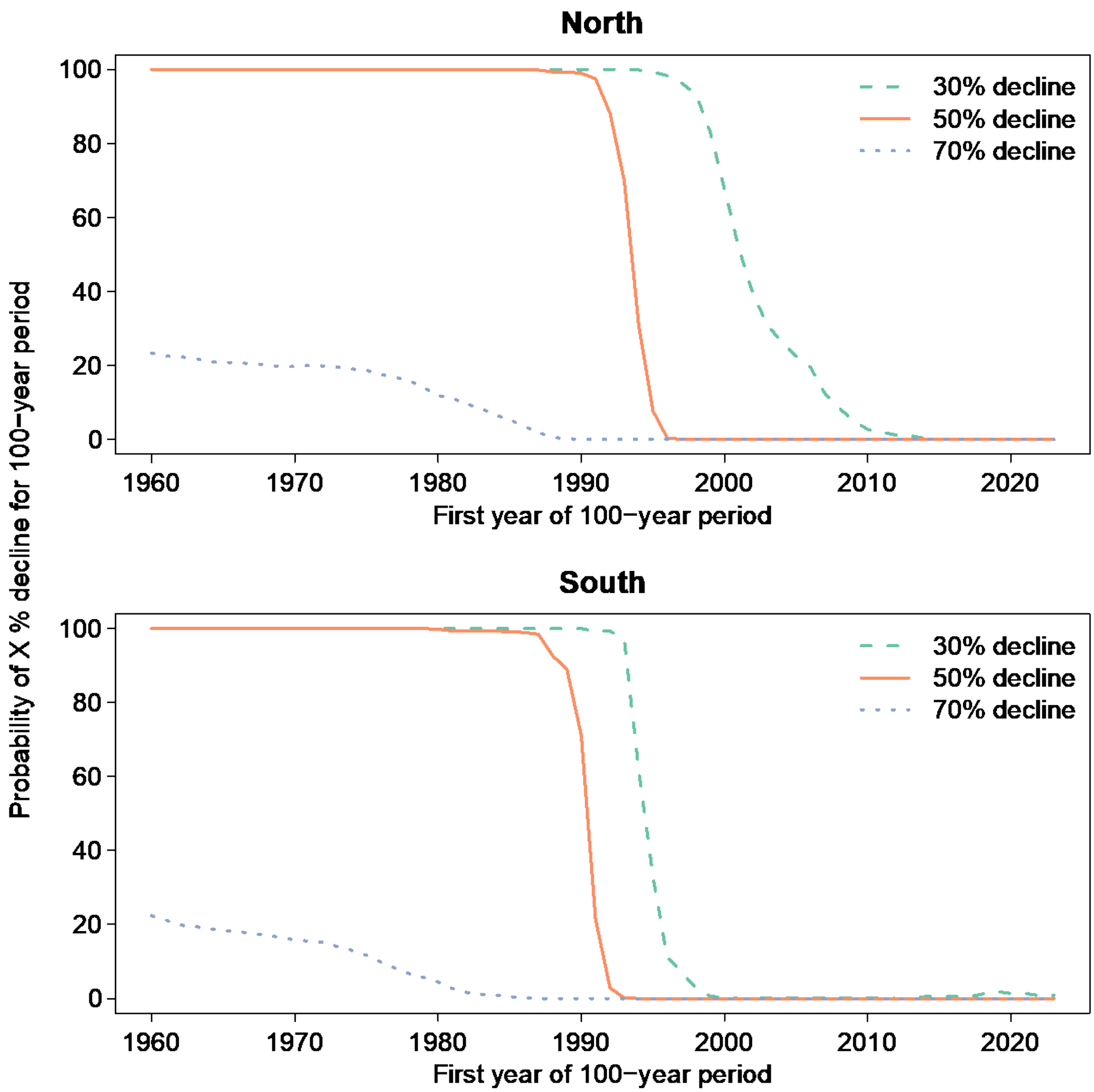

Figure 16. Probability of OYE 30%, 50%, and 70% declines for a hypothetical 'Perfect Information' MP fishing at F_{MSY} for 100-year periods ranging from 1960-2059 to 2023-2122. Projection years using the F_{MSY} MP run from 2023-2122. Probabilities are calculated as the weighted average over 4 operating models for north and south.

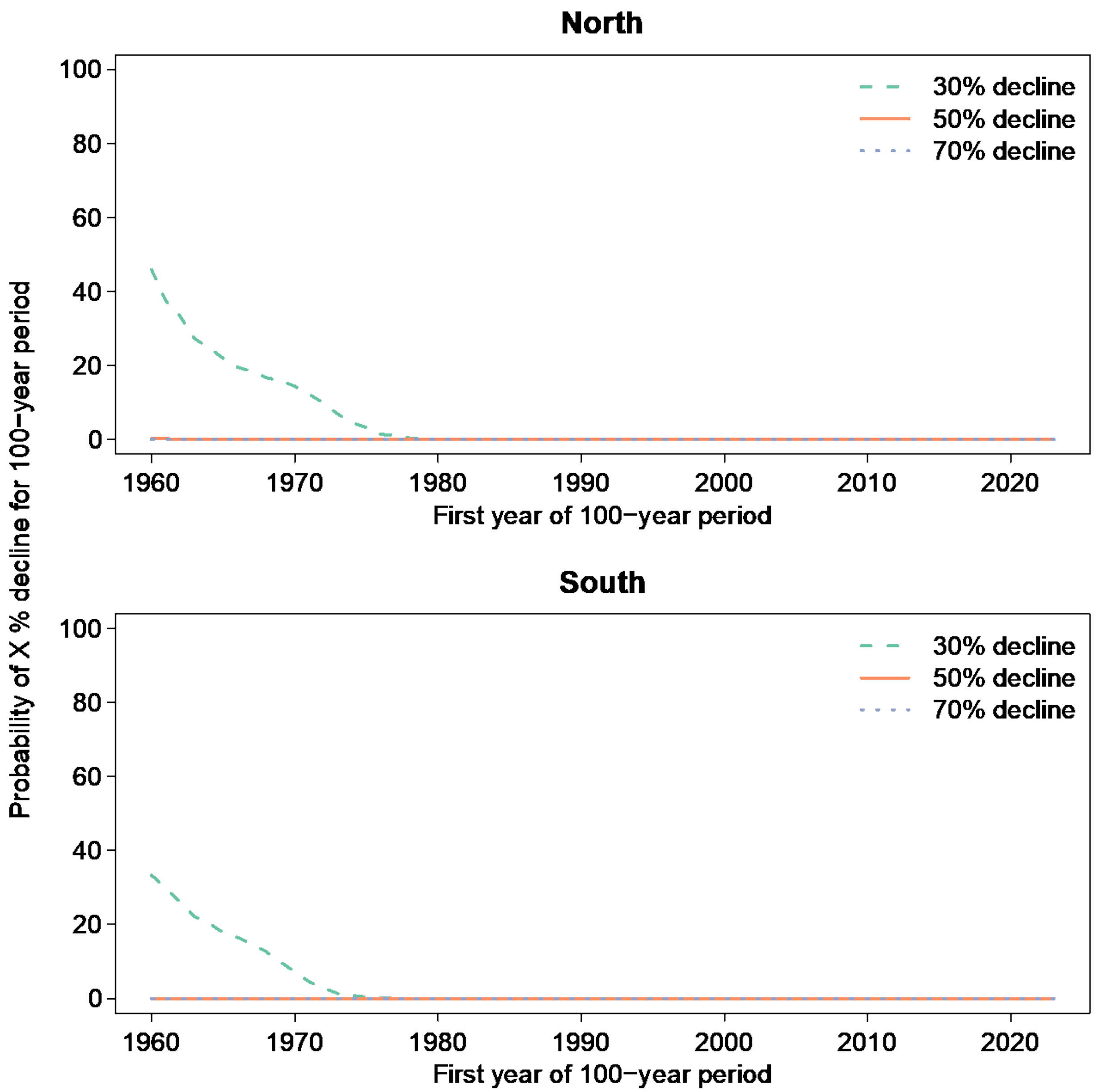

Figure 17. Probability of OYE 30%, 50%, and 70% declines for a no fishing MP for 100-year periods ranging from 1960-2059 to 2023-2122. Projection years using the no fishing MP run from 2023-2122. Probabilities are calculated as the weighted average over 4 operating models for north and south.

Element 14: Provide advice on the degree to which supply of suitable habitat meets the demands of the species both at present and when the species reaches the potential recovery target(s) identified in element 12

There is ample adequate habitat for both the outside and inside YE stocks to meet the proposed recovery targets as both stocks have already been assessed above their respective LRPs. The Extent of Occurrence and Area of Occupancy that were calculated in Keppel and Olsen (2019), summarized over a 2 km x 2 km grid were 14,267 km², and 3,956 km² for IYE and 108,035 km² and 49,924 km² for OYE respectively. A new model using integrated data from DFO trawl and longline surveys (Thompson et al. 2022) is also shown to depict the extent of Yelloweye Rockfish habitat available in BC (Figure 18).

Furthermore, in 2001, DFO implemented a four-prong Rockfish Conservation Strategy that included designating a series of protected areas prohibiting bottom fishing. The process of identifying these protected areas was carried out between 2002 and 2006, which included discussions with stakeholders and interested parties to identify preliminary areas, the overlay of rockfish catch data to assess areas with medium-high value for rockfish, and finally a 100x100 m^2 spatial model of habitat to identify areas of high relief that represent high quality rockfish habitat. In total, an estimated 15% of rockfish habitat on the outside and 28% on the inside were protected in a series of 164 Rockfish Conservation Areas (RCAs) comprising 4,800 km^2 (Yamanaka and Logan 2010).

A recent Science Response (DFO 2019) provides updated information on rockfish habitat within the RCAs. Additional modeling of rocky reefs at 5x5 m^2 and 20x20 m^2 resolutions, eelgrass, kelp and glass sponge reefs is described that further elucidates the rockfish habitat contained in the RCAs. The total rockfish habitat that is protected within RCAs is approximately 1,254 km^2, which is ~26% of the total RCA area.

Additional protected areas include provincial conservancies, the Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs MPA, Gwaii Haanas National Marine Conservation Area, SG̲aan K̲inghlas-Bowie Seamount MPA, and the Scott Islands Marine National Wildlife Area. The total area protected by these additional areas is 1,941 km^2, which increases the amount of protected rockfish habitat from 1,254 km^2 to 2,134 km^2. Provincial jurisdictions, however, cannot prohibit angling in ocean waters (which is under federal jurisdiction), but do add to the amount of additional rockfish habitat located in federally protected areas and increases the total habitat protected to 2,134 km^2 (DFO 2019) (Figure 18).

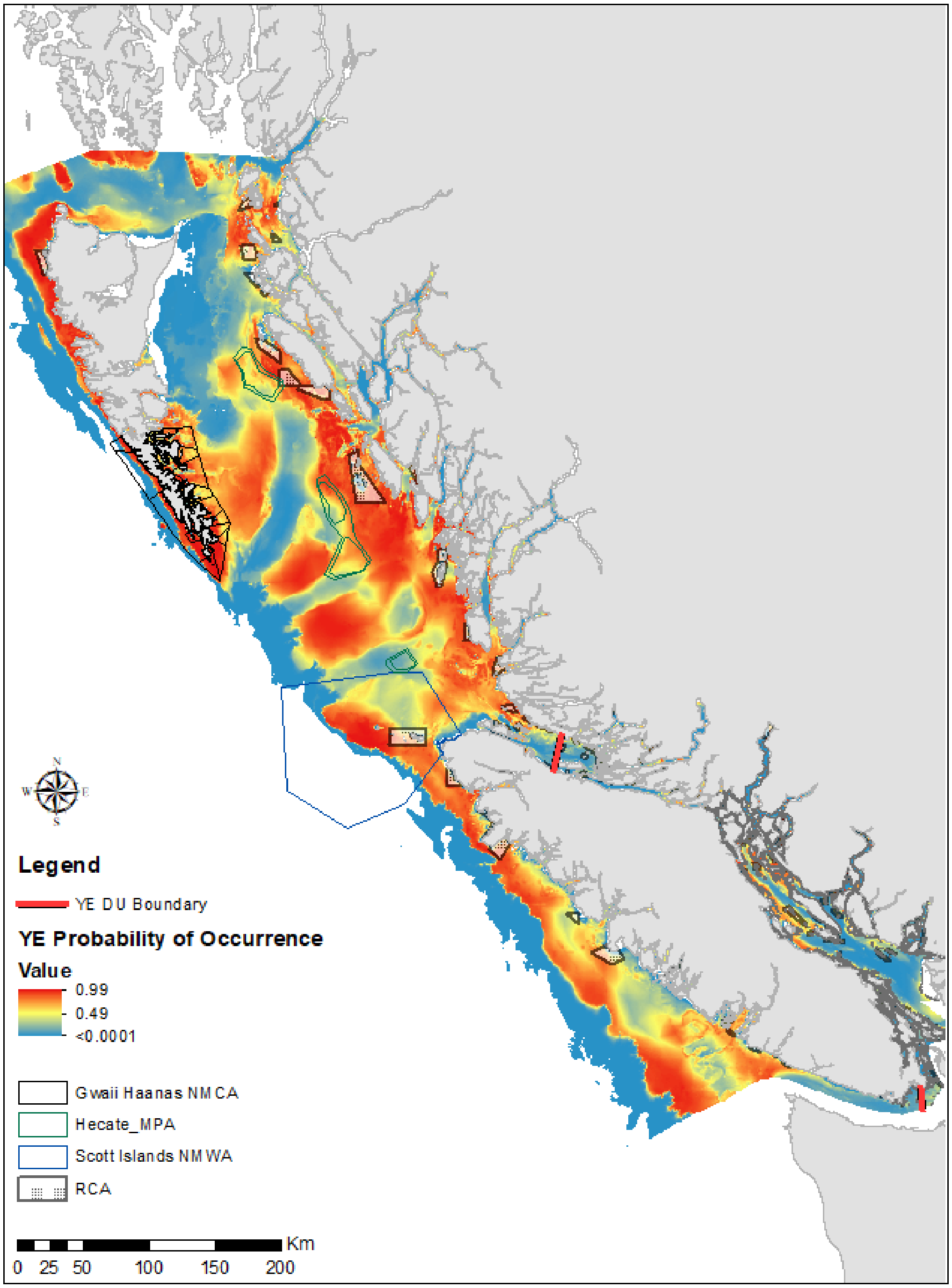

Figure 18. Yelloweye Rockfish Probability of Occurrence modeled from Groundfish Synoptic Trawl Survey and Hard Bottom Longline Survey data of both Designatable Units (DUs). RCAs and MPAs (Gwaii Haanas National Marine Conservation Area, Hecate Strait Queen Charlotte Strait Glass Sponge Reef Marine Protected Area and the Scott Island National Marine Wildlife Area) protecting Yelloweye Rockfish are also shown (with the exception of SGaan Kinghlas-Bowie Seamount Marine Protected Area).

Element 15: Assess the probability that the potential recovery target(s) can be achieved under current rates of population dynamics parameters, and how that probability would vary with different mortality (especially lower) and productivity (especially higher) parameters

The most recent analyses for IYE and OYE demonstrate that the stocks have a high probability of being above their LRPs of 40% B_{MSY}. Across the reference operating models for IYE and OYE, the probability of being above the LRP is >93% and >99%, respectively. The Rebuilding Plan evaluations (Cox et al. 2020, Haggarty et al. 2022) show how different proposed management procedures maintain the stock above the LRP for the projection period beyond 2050, corresponding to 1.5 generations (56 years). Figures and tables shown above in Element 13 present the probability of being above recovery targets ranging from 40% to 160% of B_{MSY}. No fishing scenarios are shown in Element 13 to illustrate how eliminating the primary threat to YE would affect abundance trends.

Scenarios for Mitigation of Threats and Alternatives to Activities

Element 16: Develop an inventory of feasible mitigation measures and reasonable alternatives to the activities that are threats to the species and its habitat (as identified in elements 8 and 10)

The Inshore Rockfish Conservation Strategy (Yamanaka and Logan 2010) is the primary roadmap that outlines mitigating actions for the recovery of YE and other inshore rockfish species. The Strategy was developed in 2001, outlining four broad components:

1. develop a comprehensive catch monitoring process,
2. drastic reductions in fishing mortality,
3. close areas to fishing, and
4. improve stock assessment and monitoring.

Current specifics on how these actions are being implemented can be found in the YE Management Plan:

- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021) [7]

Element 17: Develop an inventory of activities that could increase the productivity or survivorship parameters (as identified in elements 3 and 15)

As is common for marine fishes, there are few feasible activities that can increase YE stock productivity. Based on MPA theory, however, as size and age structure in protected areas stabilize and larger, older and more productive fish become more abundant, larvae will be exported to bolster fished populations (Marshall et al. 2019). This theory is one of the rationales behind the establishment of the Rockfish Conservation Areas.

Element 18: If current habitat supply may be insufficient to achieve recovery targets (see element 14), provide advice on the feasibility of restoring the habitat to higher values. Advice must be provided in the context of all available options for achieving abundance and distribution targets

Sufficient habitat exists as YE persisted through a period of high exploitation rates, and are currently above the LRP. Additionally, there are no feasible activities that can increase YE habitat supply on any meaningful scale (refer back to Element 14 and Figure 18).

Element 19: Estimate the reduction in mortality rate expected by each of the mitigation measures or alternatives in element 16 and the increase in productivity or survivorship associated with each measure in element 17

The primary threat of fishing is highly controlled through the management plan. There is no monitoring data from the RCAs that can be used to quantitatively estimate how potential differences in size and age-structure of YE within the RCAs may be disproportionately contributing to increased productivity of the IYE and OYE stocks, or to what extent the RCAs are reducing fishing mortality rates of the stocks.

Element 20: Project expected population trajectory (and uncertainties) over a scientifically reasonable time frame and to the time of reaching recovery targets, given mortality rates and productivities associated with the specific measures identified for exploration in element 19. Include those that provide as high a probability of survivorship and recovery as possible for biologically realistic parameter values

The content for this element can be found in the following documents:

- Evaluation of Potential Rebuilding Strategies for Outside Yelloweye Rockfish in British Columbia (Cox et al. 2020) [2.2; 2.3; 2.4]
- Evaluation of Potential Rebuilding Strategies for Inside Yelloweye Rockfish in British Columbia (Haggarty et al. 2022) [6]

Element 21: Recommend parameter values for population productivity and starting mortality rates and, where necessary, specialized features of population models that would be required to allow exploration of additional scenarios as part of the assessment of economic, social, and cultural impacts in support of the listing process

The content for this element can be found in the following documents:

- Evaluation of Potential Rebuilding Strategies for Outside Yelloweye Rockfish in British Columbia (Cox et al. 2020)
- Evaluation of Potential Rebuilding Strategies for Inside Yelloweye Rockfish in British Columbia (Haggarty et al. 2022)

Allowable Harm Assessment

Element 22: Evaluate maximum human-induced mortality and habitat destruction that the species can sustain without jeopardizing its survival or recovery

As per the Fish Stocks Provisions under the *Fisheries Act,* LRPs have been established that represent thresholds below which the stock may suffer “serious harm”. Both the IYE and OYE stocks have the current LRP set at 40% B_{MSY}. The 2019 spawning biomass for the IYE has an average 96% probability (values averaged across reference OMs) of being greater than the LRP. Similarly, for the OYE stock, the average (values averaged across the OMs) probability of the recent (2018) spawning biomass exceeding the LRP is >99%. The Rebuilding Plans have identified MPs that will achieve growing the stock above their respective LRPs with high probability in the 1.5 generations timeline. This also includes an MP that has the fishing mortality rate set at a value to achieve B_{MSY}. This fishing rate (F_{MSY}) represents the likely upper bound.

Additional content for this element can be found in the following documents:

- Evaluation of Potential Rebuilding Strategies for Outside Yelloweye Rockfish in British Columbia (Cox et al. 2020)
- Evaluation of Potential Rebuilding Strategies for Inside Yelloweye Rockfish in British Columbia (Haggarty et al. 2022)
- Management Plan for the Yelloweye Rockfish (*Sebastes ruberrimus*) in Canada (DFO 2021)

Conclusions

A significant amount of analysis on YE stock dynamics has been recently published in the form of Rebuilding Plans (Cox et al. 2020, Haggarty et al. 2022). Here, we present a Recovery Potential Assessment (RPA) that references this significant amount of work conducted for the Rebuilding Plans, the COSEWIC assessment, and the *Management Plan for the Yelloweye Rockfish*. We have presented some additional results specific for this RPA that are not presented in previously published reports (mostly presented in Element 13). The Rebuilding Plan analyses show that there is a high probability that both YE stocks are above the LRP of 40% B_{MSY}. This differs from previous analyses that found YE stocks to be below their LRPs. Much of this discrepancy can be attributed to the previous use of surplus production models (Yamanaka et al. 2011, 2018), and the use of age-structured models in the Rebuilding Plans.

The current Rebuilding Plan evaluations (Cox et al. 2021, Haggarty et al. 2022) also differ in approach from previous stock assessments by using a closed-loop simulation approach that is part of a Management Strategy Evaluation, i.e., the Management Procedure (MP) Framework for groundfish. The MP Framework approach differs from the single best approach by evaluating the efficacy of management procedures across different types of uncertainty, rather than attempting to describe the state of nature. In this vein, any single operating model contained within a MP Framework analysis would likely not be sufficient itself for a stock assessment.

The MP Framework approach focuses on the efficacy of different management procedures given the suite of uncertainties. Several management procedures have been evaluated to assess their ability to achieve fishery and conservation objectives. Both YE stocks are predicted to remain above their LRPs with high probability under several MPs and across the suite of different operating models. Accounting for environmental effects on population dynamics is difficult for long-lived and widely distributed marine fishes. Mechanistically modelling these effects is not feasible yet for many species, however, environmental effects can be broadly addressed within the MP Framework by creating OMs spanning a range of natural mortality and productivities, as well as with OMs that include more extreme recruitment events. While the OMs for the IYE and OYE Rebuilding Plans do include variation in the prior distributions for natural mortality and steepness, additional OMs that address other possible effects of the environment on population dynamics should be considered.

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Regional Director
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November 30, 2022

Sources of Information

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