2023 Rebuilding analysis for quillback rockfish (*Sebastes maliger*) in U.S. waters off the coast of California based on the 2021 stock assessment

by
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Summary

This rebuilding analysis is for the population of quillback rockfish (*Sebastes maliger*) in waters off California, and is based on the 2021 stock assessment for California (Langseth et al. 2021). The 2021 assessment estimated the California quillback rockfish population to be at 14% of the unexploited equilibrium spawning output at the start of 2021. This rebuilding analysis compares the results of applying a suite of potential management strategies to California quillback rockfish for 2025 and beyond based on updated catch values in 2021–2024 as provided by the Groundfish Management Team (GMT). This rebuilding analysis uses the standard suite of management strategies as described in the rebuilding Terms of Reference (TOR; PFMC (2022)), along with five SPR strategies ranging from SPR = 0.50 to SPR = 0.90 in increments of 0.10 and two additional SPR strategies at SPR = 0.55 and SPR = 0.65.

The results of the analysis show that the value for T_{MIN}, the median year for rebuilding to the target level in the absence of fishing since the year of declaration (2025), was 2045. The estimated generation time for quillback rockfish was 26 years. In conjunction with T_{MIN} and the mean generation time, T_{MAX} was estimated to be 2071. An SPR = 0.582 harvest rate leads to a 50% probability of recovery by T_{MID} where T_{MID} was 2058, an intermediate year between T_{MIN} and T_{MAX}.

1 Introduction

The 2021 stock assessment of quillback rockfish (*Sebastes maliger*) in California waters estimated that the California population of quillback rockfish in 2021 was below the Minimum Stock Size Threshold (MSST), which is 25% of unfished spawning output for rockfish stocks (Langseth et al. 2021). The California population was estimated to have declined below MSST starting in 1992, reached it lowest values in the mid-1990s, increased to near the MSST in the 2000s and early 2010s, and declined in recent years.

A draft rebuilding analysis was developed in 2021 based on the results of the 2021 assessment (Langseth and Wetzel 2022), and was used to inform catch levels (i.e. ACLs) for 2023–2024 using an SPR = 0.55. Subsequently, it was determined that quillback rockfish was defined in the Groundfish Fishery Management Plan (FMP) as a coastwide stock, so quillback rockfish in California waters did not meet the criteria for an overfished declaration and a rebuilding plan was not required. Since the 2021 assessment, Amendment 31 to the FMP was approved by the Pacific Fishery Management Council in June 2023, recommending that quillback rockfish along the U.S. west coast be defined as three separate stocks corresponding to waters off Washington, Oregon, and California (NMFS 2023). The recommended change to the FMP was adopted in November 2023 and the quillback rockfish stock off California was declared overfished in December 2023, necessitating an updated rebuilding analysis.

Given the assumed levels of depletion for quillback rockfish in California waters and the need for rebuilding, a range of alternative rebuilding strategies were examined and are described in this report. This analysis contains updated estimates for removals of quillback rockfish in California waters in 2021–2024, and applies the alternative rebuilding strategies starting in 2025.

2 Overview of the 2021 stock assessment

The 2021 assessments of quillback rockfish assessed the stock as three separate populations along the U.S. west coast: Washington, Oregon, and California. These were the first assessments of quillback rockfish that used catch and length composition data to inform model estimates around stock size and status. The 2021 assessments were conducted using Stock Synthesis (Methot and Wetzel 2013). The previous assessment of quillback rockfish, conducted in 2010, was a coastwide assessment modeled using Depletion-Based Stock Reduction Analysis (DB-SRA) to provide estimates of coastwide overfishing limits (OFLs) based on catch data and biological information (Dick and MacCall 2010). DB-SRA is a catch-only method and does not assess overfished status; the 2010 assessment assumed that current depletion was distributed around the management target of 40%. The 2010 assessment found there was a 52% chance that quillback rockfish was experiencing overfishing, as recent coastwide catch of quillback rockfish slightly exceeded the median coastwide OFL estimate at the time. Recent catches of quillback rockfish for the current assessment also exceed the annual catch limit (ACL) contributions for the species in all modeled areas. Estimates of depletion in 2021 for the populations off Washington and Oregon were above the MSST threshold, but the estimate of depletion for the population off California was 14% (Langseth et al. 2021).

California quillback rockfish was assessed using a single-sex model with coastwide life history parameters combined across sexes (Langseth et al. 2021). Life history parameters were estimated externally and then fixed within the model. Natural mortality and steepness were both fixed, at the median and mean of the priors, respectively. Annual recruitment deviations were estimated within the base model. The model for quillback rockfish in California waters included two fishing fleets, a commercial and a recreational fleet. The

majority of the removals and length composition data arose from the recreational fleet. Recreational removals peaked in the late 1970s and early 1980s, with two years of large catches in 1984 and 1993. Removals declined sharply in 1994, but increased to levels similar to the late 1970s and early 1980s during the mid 2000s and again in recent years. Commercial removals peaked in the mid to late 1990s, with one year of exceptionally large catches in 1991. Removals declined through the mid 2010s, but increased in recent years. Selectivity for the commercial and recreational fleets was specified to be asymptotic. The assessment model decision table explored uncertainty around stock size and status using lower ($M = 0.0464$ yr^{-1}) and higher ($M = 0.0744$ yr^{-1}) natural mortality (M) values relative to the base model ($M = 0.057$ yr^{-1}).

Sensitivities to modeling choices, catch history, and parameter values were explored and showed general support for the base model estimates of stock status and depletion. Sensitivities to the von Bertalanffy growth coefficient (k, whether estimated on its own or along with L_∞) and natural mortality showed that model estimates of depletion were sensitive to these parameter choices.

3 Management performance under rebuilding

No rebuilding plan exists for quillback rockfish in waters off the coast of California.

4 Rebuilding calculations

This rebuilding analysis was conducted in August and September, 2023 using software developed by A. Punt (version 3.12j, December 2021). The input file for the analysis is provided in Appendix A. The steps followed were:

1. Define how equilibrium spawning output (SB_0) will be calculated.
2. Define how future recruitment will be generated.
3. Define the biological information on which future projections will be based.
4. Define the fishery selectivity and allocation to be applied during rebuilding.
5. Decide how to include uncertainty in input parameters from the stock assessment in the rebuilding analysis.
6. Identification and analysis of alternative harvest strategies for rebuilding.

4.1 Definition of Equilibrium Spawning Output

The equilibrium spawning output (SB_0) used in this rebuilding analysis is calculated via the stock-recruitment, growth, maturity, and fecundity relationships from the 2021 assessment in order to be consistent with assessment model results. Equilibrium spawning output was estimated to be 55.08 millions of eggs in the assessment model, which dictates a rebuilding relative spawning output target ($SB_{40\%}$) of 22.035 millions of eggs (Table 1). Estimates of spawning output presented in this report are female spawning output only.

4.2 Generation of future recruitment

The estimated parameters of the stock recruitment relationship including the unexploited equilibrium recruitment ($\ln(R_0) = 3.168$), steepness ($h = 0.72$), and degree of recruitment variability ($\sigma_R = 0.60$) from the 2021 assessment were used to generate future recruitments in the rebuilding analysis.

4.3 Population biology

The biological parameters used for the rebuilding analysis were based on the values from the 2021 assessment. Biological parameters in the assessment were aggregated across sex and constant across time. The rebuilding analysis was based on a single sex model.

4.4 Fishery selectivity, and removal allocations

The selectivity used in the rebuilding analysis was obtained from the 2021 assessment. Selectivity in the assessment model was constant across time for each fishing fleet. The relative allocation of catch among fleets in the rebuilding analysis was informed using the relative fishing mortality from the assessment averaged over recent years (2017–2019). This choice provides some consistency between recent model results and forecasts from the rebuilding analysis, accounting for the unique dynamics in 2020 caused by the COVID-19 pandemic.

Removals for 2021–2024 were entered as fixed values within the analysis and were provided by the Groundfish Management Team (GMT). Removals in these years were allocated among fleets to approximate the fleet-specific values as provided by the GMT and were not based on relative fishery mortality from 2017–2019.

4.5 Inclusion of uncertainty

Model and parameter uncertainty is included in the rebuilding analysis via 1,000 random simulations of stochastic future recruitment strengths and integration over alternative low ($M = 0.0464$ yr^{-1}) and high ($M = 0.0744$ yr^{-1}) states of nature for values of natural mortality (M). Other potential states of nature were explored for the assessment, including for low and high $\ln(R_0)$ and high and low L_∞, but alternative values of natural mortality encapsulated a slightly wider range of depletion estimates compared to the other states of natures. The base model was given 50% of the weight (500 simulations) and each alternative natural mortality state of nature was given 25% of the weight (250 simulations).

4.6 Alternate rebuilding strategies analyzed

Assuming that a constant rate of harvest will be applied throughout a rebuilding period, the basis for rebuilding alternatives can be divided into two approaches: 1) strategies based on selection of a constant harvest rate (SPR rate), or 2) strategies based on selection of a target year for 50% probability of recovery. This rebuilding analysis presents the following alternate strategies, which are a combination of those specified in Section 2.5 of the rebuilding Terms of Reference (TOR; PFMC (2022)) and additional strategies. The additional strategies are based on the selection of a SPR harvest rate, and rebuilding by a selected target year T_{MID}.

1. Eliminate all harvest, F = 0, starting in the next management cycle, 2025, the same as setting a constant SPR harvest rate of 1.0.

2. Apply the harvest rate that would generate the ACL contributions specified for the current year (i.e., the latest year specified in regulations).
3. Apply a range of SPR values:
   (a) SPR = 0.50,
   (b) SPR = 0.55
   (c) SPR = 0.60,
   (d) SPR = 0.65,
   (e) SPR = 0.70,
   (f) SPR = 0.80, and
   (g) SPR = 0.90.
4. Apply SPR harvest rates that are estimated to lead to a 50% probability of recovery by alternative target years:
   (a) by T_{MAX} from the current cycle, and
   (b) by T_{MID} from the current cycle, which is the year midway between T_{MIN} and T_{MAX}.
5. Apply the default harvest policy based on the 40:10 harvest control rule with time-varying sigma (σ = 1.0 as the basis for the time-varying sigmas with a cap at the category 3 value of $\sigma = 2.0$) and $P^* = 0.45$.
6. Apply the ABC harvest rate with time-varying sigma ($\sigma = 1.0$ as the basis for the time-varying sigmas with a cap at the category 3 value of $\sigma = 2.0$) and $P^* = 0.45$.

The estimated removal in 2025 from applying an SPR of 0.5 was smaller than the 2024 ACL contributions (1.93 mt) for quillback rockfish in California waters. This implies that an SPR rate of below 0.5 would be needed to achieve the current ACL contributions, so results from this strategy (strategy 2 above) are not provided in this report. The SPR harvest rate to achieve a 50% probability of recovery by T_{MAX} from the current cycle was 0.5015, essentially equal to that of the SPR = 0.5 strategy. Consequently, results fom the T_{MAX} strategy (strategy 4a above) are not presented in this report.

No current rebuilding plan exists for quillback rockfish in California waters so the alternatives related to the results of a previous rebuilding plan as specified in Section 2.5 of the rebuilding TOR could not be done. These include:

- Apply the spawning potential ratio or relevant harvest control run in the current rebuilding plan (strategy 3 in TOR).
- Apply the harvest rate that is estimated to lead to a 50% probability of recovery by the current T_{TARGET} (strategy 4 in TOR).
- Apply the harvest rate that is estimated to lead to a 50% probability of recovery by the T_{MAX} from the previous cycle (strategy 6 in TOR).

All of the above rebuilding strategies were conducted assuming removals of 15.58 mt in 2021, 18.11 mt in 2022, 11.12 mt in 2023, and 10.62 mt in 2024, as recommended by the GMT.

5 Results

5.1 Rebuilding reference points

Reference points calculated based on this rebuilding analysis are given in Table 1. The minimum time required for rebuilding, T_{MIN}, with no fishing (F=0) starting in 2025 was estimated to be 20 years, corresponding to the stock being rebuilt by 2045, assuming the default removals for 2021–2024. The mean generation time was estimated to be 26 years. The maximum time allowed for rebuilding, T_{MAX}, is defined as the T_{MIN} plus the mean generation time for stocks that require more than 10 years to rebuild. Quillback rockfish was unable to rebuild within 10 years so the estimated T_{MAX} was 2071. T_{TARGET} and SPR_{TARGET} are not specified because no rebuilding plan for quillback rockfish exists so these values have not been set via the Council's process.

A rebuilding strategy is presented below that includes a rebuilding target year termed T_{MID}, which equals 2058 and is the mid-point between T_{MIN} and T_{MAX}. The Council may opt to select a T_{TARGET} earlier or later than this T_{MID} value based on fishery, economic, or other factors.

5.2 Alternative harvest policy projections

Summary results from the rebuilding analysis are presented in Table 2. Within Table 2, estimated catch values for 2025–2026 from the rebuilding analysis are labeled as ACL values. Detailed results for all runs are presented in Tables 3–6 and Figures 1–4. This rebuilding analysis reports results for quillback rockfish in California waters, and catches can be partitioned to the northern (49.6%) and southern (50.4%) management units using the values described in Appendix A of the 2021 stock assessment (Langseth et al. 2021).

The target rebuilding year based on the various rebuilding strategies ranged from 2045–2072 (Table 2). The probability of rebuilding by year steadily increased across the alternative SPR values with full rebuilding (reaching a probability of greater than 50%) by 2072 when the lowest SPR of 0.50 was applied (Table 3 and Figure 1). Note, however, that this year is beyond the year associated with T_{MAX}. The recommended removals in 2025, the first year of rebuilding, ranged between 0 – 1.51 mt across strategies excluding the no-harvest strategy (Table 4). Zero catches were observed for the first two years under the 40-10 strategy because spawning output relative to unfished spawning output was below the 10% limit through 2026. The recommended removals slowly increased by year during the rebuilding period (Figure 2). The estimated overfishing limits (OFLs) for each rebuilding alternative are given in Table 5. The change in spawning output by year relative to the spawning output target, 40% of unfished, under each of the alternatives are shown by year in Table 6 and Figure 3.

6 Acknowledgements

Thank you to the Groundfish Management Team for providing catch estimates for 2021–2024. Owen Hamel (NOAA) provided assistance in understanding and applying the rebuilder program for this cycle, and Chantel Wetzel (NOAA) provided comments on drafts of the analysis.

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8 Tables

8.1 Rebuilding reference points and policy projections

Table 1: Summary of the rebuilding reference points.

Quantity	2021 Assessment Values
SB_0 (millions of eggs)	55.08
$SB_{40\%}$ (millions of eggs)	22.03
SB_{2021} (millions of eggs)	7.75
Year rebuilding begins	2025
Current year	2021
T_{MIN}	2045
Mean generation time (years)	26
T_{MAX}	2071
T_{MID}	2058
$T_{F=0}$	2045
T_{TARGET}	TBD
SPR_{TARGET}	TBD
Current SPR (2021)	0.1

Table 2: Results of rebuilding strategies based on alternative SPR targets for 50 percent probability of recovery based on the assumed removals for 2021–2024. SPR for the ABC and 40-10 strategies is provided as a dash (-) because these strategies do not have a constant SPR value.

Quantity	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2021 Assumed Removals (mt)	15.58	15.58	15.58	15.58	15.58	15.58	15.58	15.58	15.58	15.58	15.58
2022 Assumed Removals (mt)	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11
2023 Assumed Removals (mt)	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12
2024 Assumed Removals (mt)	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62
2025 ACL (mt)	1.51	1.26	1.05	0.86	0.69	0.41	0.19	1.12	0	0	1.3
2026 ACL (mt)	1.76	1.47	1.23	1.01	0.82	0.49	0.22	1.31	0	0	1.5
SPR	0.5	0.55	0.6	0.65	0.7	0.8	0.9	0.58	1	-	-
T_{TARGET}	2072	2062	2057	2053	2051	2048	2046	2058	2045	2056	2060
T_{MAX}	2071	2071	2071	2071	2071	2071	2071	2071	2071	2071	2071
Probability of recovery by T_{MAX}	0.494	0.694	0.809	0.878	0.928	0.979	0.999	0.777	0.999	0.845	0.736

8.2 Rebuilding time series

Table 3: Probability of recovery by year for rebuilding strategies. Probabilities represent the proportion of simulations that reach the target biomass by the specified year.

Year	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2030	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000
2031	0.000	0.001	0.001	0.001	0.001	0.003	0.004	0.001	0.005	0.001	0.001
2032	0.001	0.001	0.001	0.002	0.003	0.008	0.012	0.001	0.018	0.001	0.001
2033	0.001	0.001	0.003	0.006	0.009	0.019	0.037	0.002	0.053	0.003	0.001
2034	0.002	0.003	0.010	0.016	0.027	0.045	0.072	0.007	0.106	0.009	0.004
2035	0.005	0.013	0.018	0.034	0.046	0.073	0.122	0.015	0.172	0.018	0.013
2036	0.010	0.020	0.031	0.047	0.060	0.113	0.159	0.028	0.204	0.031	0.022
2037	0.016	0.026	0.037	0.059	0.083	0.148	0.196	0.032	0.223	0.035	0.028
2038	0.020	0.031	0.054	0.081	0.114	0.173	0.223	0.045	0.243	0.050	0.033
2039	0.024	0.039	0.068	0.103	0.137	0.199	0.240	0.058	0.257	0.063	0.045
2040	0.027	0.051	0.082	0.118	0.158	0.230	0.255	0.073	0.284	0.078	0.062
2041	0.032	0.064	0.098	0.145	0.186	0.256	0.292	0.085	0.329	0.092	0.077
2042	0.042	0.076	0.118	0.166	0.220	0.281	0.333	0.102	0.380	0.119	0.086
2043	0.050	0.095	0.132	0.197	0.244	0.317	0.378	0.120	0.430	0.134	0.108
2044	0.063	0.105	0.154	0.222	0.276	0.354	0.427	0.136	0.489	0.160	0.120
2045	0.072	0.123	0.185	0.258	0.309	0.397	0.468	0.152	0.562	0.188	0.134
2046	0.080	0.137	0.213	0.285	0.349	0.440	0.538	0.185	0.612	0.219	0.156
2047	0.091	0.155	0.237	0.319	0.379	0.486	0.592	0.203	0.658	0.256	0.178
2048	0.105	0.170	0.270	0.346	0.410	0.545	0.628	0.235	0.702	0.292	0.202
2049	0.122	0.193	0.299	0.376	0.456	0.584	0.671	0.265	0.724	0.322	0.231
2050	0.131	0.218	0.325	0.413	0.497	0.617	0.701	0.286	0.734	0.347	0.264
2051	0.146	0.245	0.347	0.452	0.532	0.657	0.719	0.321	0.740	0.383	0.283
2052	0.166	0.269	0.382	0.482	0.561	0.688	0.732	0.338	0.744	0.415	0.308
2053	0.175	0.290	0.419	0.509	0.593	0.704	0.740	0.371	0.749	0.446	0.336
2054	0.185	0.320	0.450	0.540	0.634	0.723	0.745	0.405	0.761	0.472	0.370
2055	0.213	0.346	0.474	0.577	0.657	0.730	0.755	0.428	0.778	0.493	0.395
2056	0.230	0.370	0.496	0.609	0.677	0.738	0.770	0.455	0.797	0.527	0.421
2057	0.249	0.399	0.523	0.632	0.701	0.750	0.786	0.479	0.824	0.561	0.449

Table 3: Probability of recovery by year for rebuilding strategies. Probabilities represent the proportion of simulations that reach the target biomass by the specified year. (*continued)*

Year	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2058	0.268	0.425	0.561	0.655	0.716	0.764	0.803	0.500	0.848	0.585	0.472
2059	0.290	0.445	0.589	0.672	0.728	0.783	0.829	0.533	0.876	0.606	0.495
2060	0.307	0.473	0.613	0.691	0.739	0.796	0.851	0.566	0.903	0.631	0.524
2061	0.328	0.498	0.639	0.709	0.754	0.818	0.884	0.591	0.921	0.656	0.555
2062	0.339	0.520	0.655	0.730	0.769	0.841	0.907	0.617	0.943	0.676	0.576
2063	0.358	0.546	0.670	0.745	0.784	0.864	0.921	0.635	0.959	0.699	0.605
2064	0.378	0.567	0.690	0.760	0.800	0.893	0.941	0.652	0.967	0.719	0.620
2065	0.397	0.588	0.715	0.775	0.825	0.909	0.952	0.679	0.980	0.745	0.633
2066	0.410	0.602	0.728	0.792	0.850	0.929	0.960	0.700	0.989	0.763	0.661
2067	0.428	0.628	0.744	0.813	0.872	0.941	0.972	0.709	0.994	0.784	0.682
2068	0.449	0.648	0.754	0.830	0.883	0.951	0.985	0.724	0.998	0.809	0.694
2069	0.465	0.663	0.773	0.850	0.900	0.961	0.993	0.735	0.999	0.820	0.712
2070	0.480	0.677	0.797	0.865	0.911	0.969	0.995	0.751	0.999	0.828	0.723
2071	0.494	0.694	0.809	0.878	0.928	0.979	0.999	0.777	0.999	0.845	0.736

Table 4: Catches (mt) by year for rebuilding strategies. Catches in 2021–2024 for all strategies were set at values recommended by the Groundfish Management Team.

Year	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2021	15.58	15.58	15.58	15.58	15.58	15.58	15.58	15.58	15.58	15.58	15.58
2022	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11	18.11
2023	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12
2024	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62	10.62
2025	1.51	1.26	1.05	0.86	0.69	0.41	0.19	1.12	0.00	0.00	1.30
2026	1.76	1.47	1.23	1.01	0.82	0.49	0.22	1.31	0.00	0.00	1.50
2027	1.99	1.68	1.41	1.16	0.95	0.57	0.26	1.50	0.00	0.04	1.69
2028	2.21	1.88	1.58	1.31	1.07	0.65	0.30	1.68	0.00	0.43	1.87
2029	2.42	2.06	1.74	1.45	1.18	0.72	0.33	1.85	0.00	0.77	2.03
2030	2.60	2.23	1.89	1.58	1.29	0.79	0.37	2.01	0.00	1.07	2.18
2031	2.77	2.38	2.03	1.70	1.40	0.86	0.40	2.15	0.00	1.34	2.31
2032	2.94	2.53	2.16	1.82	1.50	0.93	0.43	2.30	0.00	1.59	2.44
2033	3.10	2.69	2.31	1.95	1.61	1.01	0.47	2.45	0.00	1.84	2.57
2034	3.26	2.83	2.43	2.06	1.71	1.07	0.50	2.58	0.00	2.04	2.68
2035	3.43	2.99	2.58	2.19	1.82	1.14	0.54	2.73	0.00	2.27	2.81
2036	3.60	3.15	2.72	2.32	1.93	1.22	0.58	2.88	0.00	2.51	2.96
2037	3.75	3.30	2.86	2.44	2.04	1.29	0.61	3.02	0.00	2.74	3.10
2038	3.92	3.45	3.00	2.57	2.15	1.36	0.65	3.17	0.00	2.96	3.25
2039	4.08	3.60	3.14	2.69	2.26	1.44	0.69	3.31	0.00	3.18	3.40
2040	4.22	3.74	3.27	2.81	2.36	1.51	0.72	3.44	0.00	3.39	3.53
2041	4.39	3.90	3.42	2.94	2.47	1.59	0.76	3.59	0.00	3.60	3.69
2042	4.56	4.07	3.57	3.07	2.59	1.67	0.80	3.75	0.00	3.81	3.85
2043	4.70	4.19	3.69	3.19	2.70	1.74	0.84	3.87	0.00	4.01	3.97
2044	4.87	4.36	3.84	3.32	2.81	1.81	0.88	4.03	0.00	4.23	4.14
2045	5.03	4.50	3.98	3.44	2.91	1.89	0.92	4.17	0.00	4.41	4.28
2046	5.19	4.66	4.12	3.57	3.04	1.97	0.96	4.32	0.00	4.62	4.43
2047	5.34	4.81	4.26	3.70	3.14	2.05	1.00	4.46	0.00	4.80	4.58
2048	5.47	4.93	4.38	3.82	3.25	2.12	1.03	4.58	0.00	4.94	4.70
2049	5.64	5.09	4.52	3.93	3.35	2.19	1.07	4.73	0.00	5.11	4.86
2050	5.73	5.19	4.62	4.03	3.44	2.26	1.11	4.83	0.00	5.26	4.95
2051	5.84	5.29	4.71	4.12	3.53	2.31	1.14	4.93	0.00	5.38	5.05
2052	5.96	5.42	4.83	4.23	3.61	2.38	1.17	5.05	0.00	5.50	5.17
2053	6.06	5.53	4.95	4.33	3.70	2.45	1.20	5.16	0.00	5.60	5.29
2054	6.17	5.62	5.03	4.42	3.78	2.50	1.23	5.25	0.00	5.73	5.38
2055	6.26	5.71	5.10	4.48	3.85	2.56	1.26	5.32	0.00	5.82	5.46
2056	6.37	5.82	5.21	4.58	3.93	2.61	1.29	5.43	0.00	5.94	5.57
2057	6.46	5.91	5.30	4.65	4.01	2.66	1.32	5.52	0.00	6.03	5.67
2058	6.56	6.00	5.38	4.74	4.07	2.71	1.34	5.62	0.00	6.12	5.75

Table 4: Catches (mt) by year for rebuilding strategies. Catches in 2021–2024 for all strategies were set at values recommended by the Groundfish Management Team. (*continued)*

Year	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2059	6.66	6.08	5.48	4.83	4.15	2.77	1.37	5.71	0.00	6.18	5.84
2060	6.76	6.20	5.57	4.91	4.22	2.82	1.40	5.80	0.00	6.26	5.95
2061	6.79	6.24	5.63	4.96	4.28	2.87	1.43	5.86	0.00	6.28	6.00
2062	6.85	6.29	5.66	5.01	4.33	2.90	1.45	5.90	0.00	6.34	6.04
2063	6.92	6.37	5.74	5.07	4.38	2.94	1.46	5.98	0.00	6.39	6.13
2064	6.98	6.41	5.80	5.13	4.43	2.98	1.49	6.03	0.00	6.42	6.17
2065	7.05	6.49	5.86	5.19	4.49	3.02	1.51	6.10	0.00	6.49	6.25
2066	7.09	6.53	5.92	5.24	4.54	3.05	1.53	6.15	0.00	6.52	6.29
2067	7.16	6.59	5.96	5.28	4.58	3.08	1.54	6.20	0.00	6.58	6.35
2068	7.18	6.63	6.00	5.34	4.62	3.11	1.56	6.24	0.00	6.63	6.39
2069	7.23	6.67	6.04	5.35	4.64	3.14	1.58	6.27	0.00	6.65	6.42
2070	7.29	6.73	6.11	5.41	4.69	3.17	1.59	6.35	0.00	6.70	6.50
2071	7.32	6.76	6.14	5.45	4.72	3.20	1.61	6.38	0.00	6.71	6.53

Table 5: OFLs (mt) by year for rebuilding strategies.

Year	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2021	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34	2.34
2022	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
2023	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41
2024	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
2025	1.51	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52
2026	1.76	1.77	1.78	1.78	1.79	1.80	1.80	1.77	1.81	1.81	1.77
2027	1.99	2.02	2.03	2.06	2.07	2.09	2.12	2.03	2.13	2.13	2.01
2028	2.21	2.24	2.28	2.30	2.33	2.38	2.41	2.27	2.44	2.44	2.24
2029	2.42	2.47	2.51	2.55	2.58	2.64	2.69	2.49	2.74	2.71	2.46
2030	2.60	2.67	2.73	2.78	2.82	2.91	2.97	2.70	3.03	2.97	2.67
2031	2.77	2.85	2.93	2.99	3.05	3.16	3.23	2.90	3.31	3.21	2.85
2032	2.94	3.04	3.13	3.20	3.28	3.40	3.51	3.09	3.60	3.45	3.04
2033	3.10	3.23	3.33	3.43	3.52	3.67	3.80	3.30	3.91	3.67	3.23
2034	3.26	3.39	3.52	3.63	3.73	3.91	4.06	3.48	4.19	3.90	3.40
2035	3.43	3.59	3.73	3.86	3.97	4.18	4.36	3.68	4.51	4.13	3.60
2036	3.60	3.78	3.93	4.09	4.22	4.46	4.65	3.88	4.82	4.36	3.80
2037	3.75	3.96	4.14	4.31	4.45	4.72	4.95	4.07	5.15	4.56	3.98
2038	3.92	4.14	4.34	4.52	4.69	4.99	5.23	4.27	5.46	4.78	4.18
2039	4.08	4.32	4.54	4.74	4.92	5.26	5.54	4.46	5.78	4.97	4.37
2040	4.22	4.49	4.73	4.95	5.15	5.51	5.84	4.64	6.11	5.17	4.54
2041	4.39	4.67	4.94	5.18	5.40	5.80	6.13	4.85	6.44	5.39	4.74
2042	4.56	4.87	5.15	5.41	5.66	6.11	6.48	5.05	6.83	5.58	4.95
2043	4.70	5.03	5.33	5.62	5.89	6.36	6.77	5.22	7.15	5.77	5.10
2044	4.87	5.22	5.55	5.85	6.13	6.63	7.08	5.44	7.47	5.99	5.32
2045	5.03	5.40	5.75	6.05	6.35	6.89	7.38	5.62	7.80	6.14	5.50
2046	5.19	5.59	5.95	6.30	6.63	7.19	7.70	5.82	8.16	6.35	5.69
2047	5.34	5.76	6.16	6.53	6.86	7.47	8.02	6.02	8.51	6.52	5.89
2048	5.47	5.91	6.32	6.72	7.08	7.72	8.32	6.18	8.86	6.67	6.04
2049	5.64	6.11	6.53	6.93	7.30	8.01	8.61	6.38	9.16	6.84	6.25
2050	5.73	6.22	6.67	7.10	7.51	8.25	8.91	6.50	9.50	6.97	6.36
2051	5.84	6.34	6.81	7.26	7.70	8.44	9.16	6.65	9.77	7.07	6.49
2052	5.96	6.49	6.98	7.44	7.89	8.70	9.42	6.80	10.08	7.19	6.65
2053	6.06	6.62	7.15	7.63	8.07	8.93	9.69	6.95	10.39	7.30	6.80
2054	6.17	6.74	7.28	7.78	8.25	9.15	9.95	7.08	10.67	7.42	6.92
2055	6.26	6.84	7.38	7.89	8.39	9.34	10.18	7.17	10.94	7.49	7.02
2056	6.37	6.97	7.53	8.07	8.59	9.52	10.40	7.33	11.17	7.63	7.16
2057	6.46	7.08	7.65	8.19	8.74	9.72	10.62	7.44	11.41	7.75	7.29
2058	6.56	7.19	7.78	8.34	8.88	9.88	10.82	7.57	11.66	7.87	7.39
2059	6.66	7.29	7.92	8.51	9.06	10.10	11.05	7.69	11.90	7.96	7.51

Table 5: OFLs (mt) by year for rebuilding strategies. (*continued)*

Year	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2060	6.76	7.42	8.06	8.65	9.22	10.28	11.27	7.83	12.19	8.05	7.65
2061	6.79	7.47	8.12	8.74	9.33	10.48	11.49	7.89	12.42	8.08	7.71
2062	6.85	7.53	8.17	8.82	9.45	10.58	11.65	7.96	12.61	8.16	7.76
2063	6.92	7.62	8.29	8.93	9.56	10.72	11.77	8.06	12.81	8.21	7.88
2064	6.98	7.67	8.38	9.04	9.67	10.87	11.98	8.11	13.01	8.25	7.93
2065	7.05	7.78	8.47	9.14	9.79	11.02	12.15	8.23	13.19	8.34	8.03
2066	7.09	7.83	8.55	9.23	9.90	11.13	12.30	8.29	13.38	8.38	8.08
2067	7.16	7.89	8.61	9.31	9.99	11.23	12.43	8.35	13.52	8.46	8.16
2068	7.18	7.94	8.68	9.41	10.08	11.38	12.56	8.42	13.69	8.52	8.21
2069	7.23	7.98	8.73	9.42	10.13	11.48	12.70	8.46	13.83	8.55	8.25
2070	7.29	8.06	8.83	9.52	10.23	11.56	12.81	8.56	13.97	8.61	8.35
2071	7.32	8.10	8.87	9.59	10.31	11.67	12.94	8.60	14.11	8.62	8.39

Table 6: Spawning output relative to the 40 percent of unfished spawning output target by year for rebuilding strategies.

Year	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2021	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2022	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
2023	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
2024	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
2025	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
2026	0.20	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
2027	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.24	0.25	0.25	0.24
2028	0.27	0.27	0.28	0.28	0.28	0.29	0.29	0.28	0.30	0.30	0.27
2029	0.30	0.30	0.31	0.32	0.32	0.33	0.33	0.31	0.34	0.34	0.30
2030	0.32	0.33	0.34	0.35	0.35	0.36	0.37	0.34	0.38	0.37	0.33
2031	0.35	0.36	0.37	0.38	0.39	0.40	0.41	0.37	0.42	0.41	0.36
2032	0.37	0.38	0.40	0.41	0.42	0.43	0.45	0.39	0.46	0.44	0.38
2033	0.39	0.41	0.42	0.44	0.45	0.47	0.49	0.42	0.50	0.47	0.41
2034	0.41	0.43	0.45	0.47	0.48	0.51	0.53	0.45	0.54	0.50	0.44
2035	0.44	0.46	0.48	0.49	0.51	0.54	0.56	0.47	0.58	0.53	0.46
2036	0.46	0.48	0.51	0.53	0.54	0.58	0.60	0.50	0.63	0.56	0.49
2037	0.48	0.51	0.53	0.56	0.58	0.61	0.64	0.52	0.67	0.59	0.51
2038	0.50	0.53	0.56	0.59	0.61	0.65	0.69	0.55	0.72	0.62	0.54
2039	0.52	0.56	0.59	0.62	0.64	0.69	0.73	0.58	0.76	0.65	0.56
2040	0.55	0.58	0.61	0.65	0.67	0.72	0.77	0.60	0.81	0.68	0.59
2041	0.56	0.60	0.64	0.67	0.71	0.76	0.81	0.63	0.85	0.70	0.61
2042	0.59	0.63	0.67	0.70	0.74	0.80	0.85	0.65	0.90	0.73	0.64
2043	0.61	0.66	0.70	0.74	0.77	0.84	0.90	0.68	0.95	0.76	0.67
2044	0.63	0.68	0.72	0.76	0.81	0.88	0.94	0.71	1.00	0.78	0.69
2045	0.65	0.70	0.75	0.80	0.84	0.91	0.98	0.73	1.04	0.81	0.72
2046	0.67	0.72	0.78	0.82	0.87	0.95	1.02	0.76	1.09	0.83	0.74
2047	0.69	0.75	0.80	0.86	0.90	0.99	1.07	0.78	1.14	0.85	0.76
2048	0.71	0.77	0.83	0.88	0.94	1.03	1.11	0.81	1.19	0.88	0.79
2049	0.73	0.79	0.85	0.91	0.96	1.07	1.15	0.83	1.23	0.89	0.81
2050	0.75	0.81	0.88	0.94	1.00	1.10	1.19	0.86	1.28	0.92	0.83
2051	0.76	0.83	0.90	0.96	1.02	1.14	1.24	0.87	1.32	0.93	0.85
2052	0.77	0.85	0.92	0.98	1.05	1.16	1.27	0.89	1.36	0.95	0.87
2053	0.79	0.86	0.94	1.00	1.07	1.19	1.30	0.91	1.40	0.96	0.89
2054	0.80	0.88	0.96	1.03	1.10	1.22	1.34	0.93	1.44	0.97	0.91
2055	0.82	0.90	0.98	1.05	1.12	1.26	1.38	0.95	1.48	0.99	0.92
2056	0.83	0.91	0.99	1.07	1.14	1.28	1.40	0.96	1.52	1.00	0.94
2057	0.84	0.92	1.01	1.09	1.17	1.31	1.44	0.98	1.56	1.02	0.96
2058	0.85	0.94	1.03	1.11	1.19	1.33	1.47	1.00	1.59	1.03	0.97

Table 6: Spawning output relative to the 40 percent of unfished spawning output target by year for rebuilding strategies. (*continued)*

Year	SPR= .500	SPR= .550	SPR= .600	SPR= .650	SPR= .700	SPR= .800	SPR= .900	Yr= T_{MID}	F=0	40-10 rule	ABC Rule
2059	0.87	0.96	1.04	1.12	1.20	1.36	1.49	1.01	1.62	1.05	0.99
2060	0.88	0.97	1.06	1.15	1.23	1.38	1.53	1.03	1.66	1.06	1.00
2061	0.89	0.98	1.07	1.16	1.25	1.41	1.56	1.04	1.69	1.07	1.01
2062	0.89	0.99	1.09	1.18	1.26	1.43	1.58	1.05	1.72	1.08	1.03
2063	0.90	1.00	1.10	1.19	1.28	1.45	1.60	1.06	1.75	1.09	1.04
2064	0.91	1.01	1.11	1.20	1.30	1.47	1.63	1.07	1.78	1.09	1.05
2065	0.92	1.02	1.12	1.22	1.31	1.49	1.65	1.09	1.81	1.10	1.06
2066	0.93	1.03	1.13	1.23	1.32	1.50	1.68	1.09	1.83	1.11	1.07
2067	0.94	1.04	1.14	1.24	1.34	1.52	1.69	1.11	1.85	1.12	1.08
2068	0.94	1.05	1.15	1.25	1.35	1.54	1.71	1.12	1.88	1.13	1.09
2069	0.95	1.06	1.16	1.27	1.37	1.55	1.73	1.13	1.89	1.14	1.10
2070	0.96	1.07	1.17	1.28	1.38	1.57	1.75	1.14	1.92	1.14	1.11
2071	0.96	1.08	1.18	1.29	1.39	1.58	1.77	1.14	1.94	1.15	1.12

9 Figures

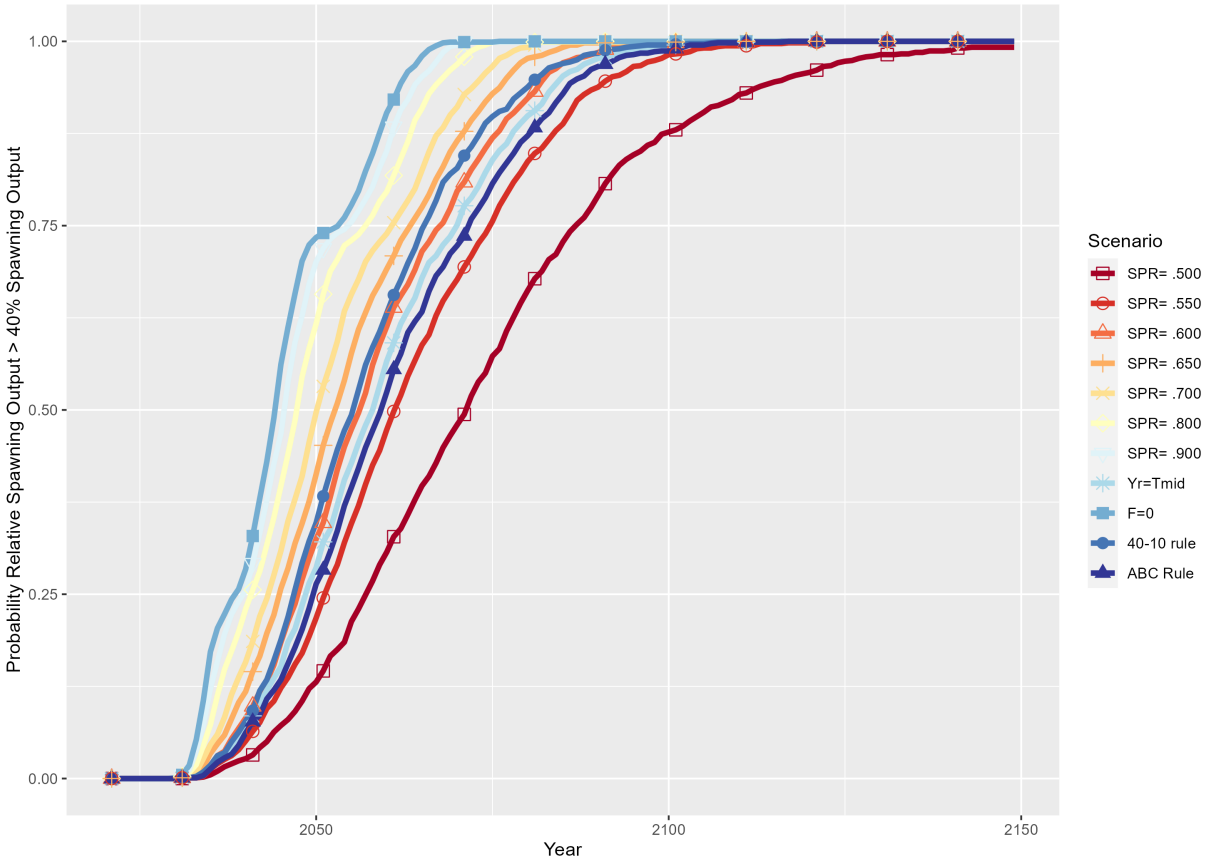

Figure 1: Probability of rebuilding by year for the alternative rebuilding strategies.

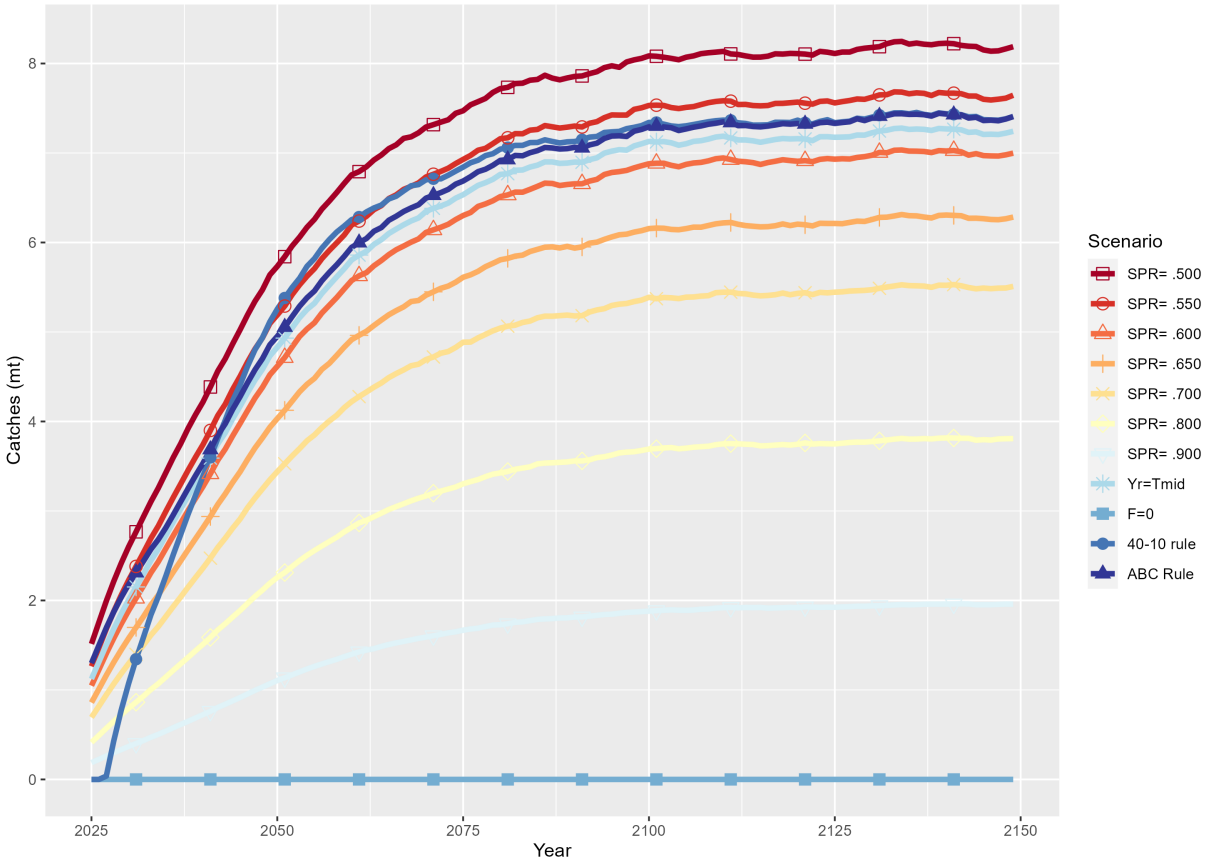

Figure 2: Catches (mt) by year, starting in 2025, for the alternative rebuilding strategies.

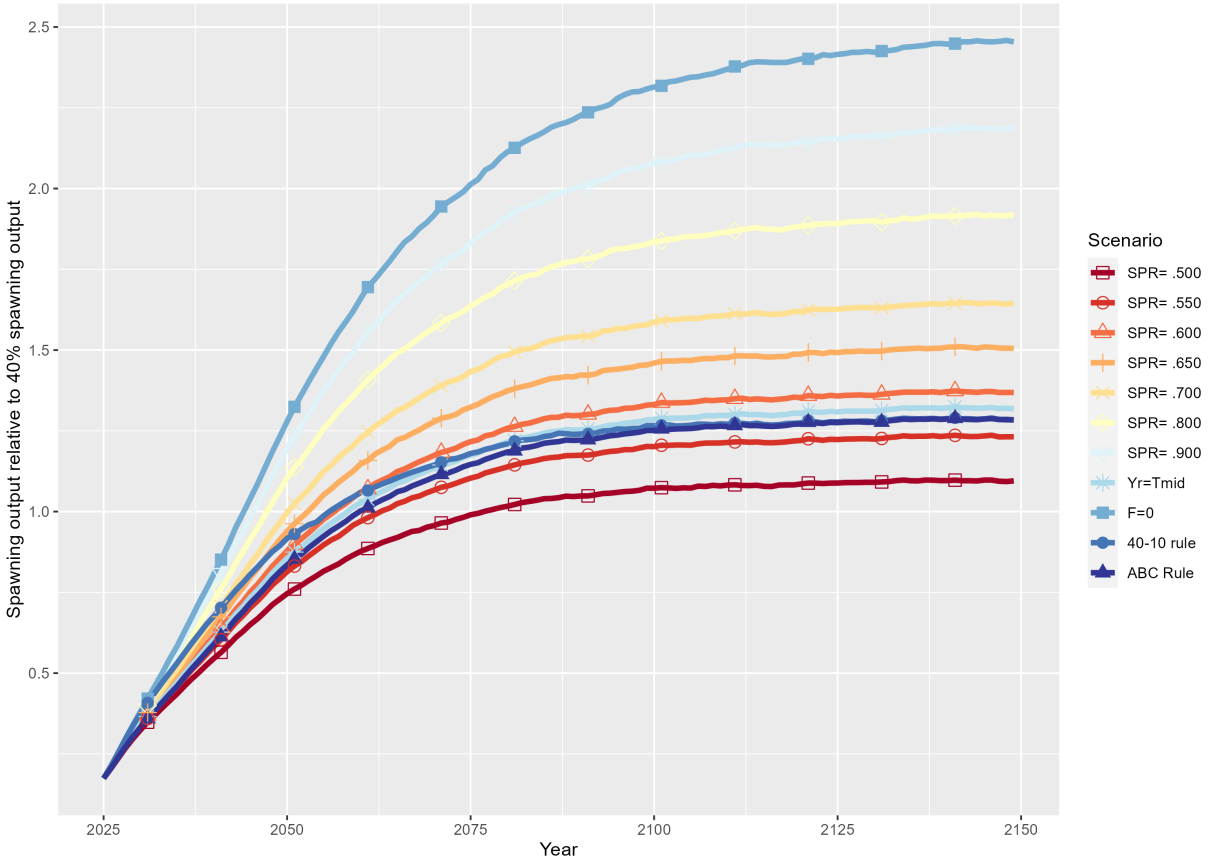

Figure 3: Spawning output relative to the management target of 40 percent of unfished spawning output by year, starting in 2025, for the alternative rebuilding strategies.

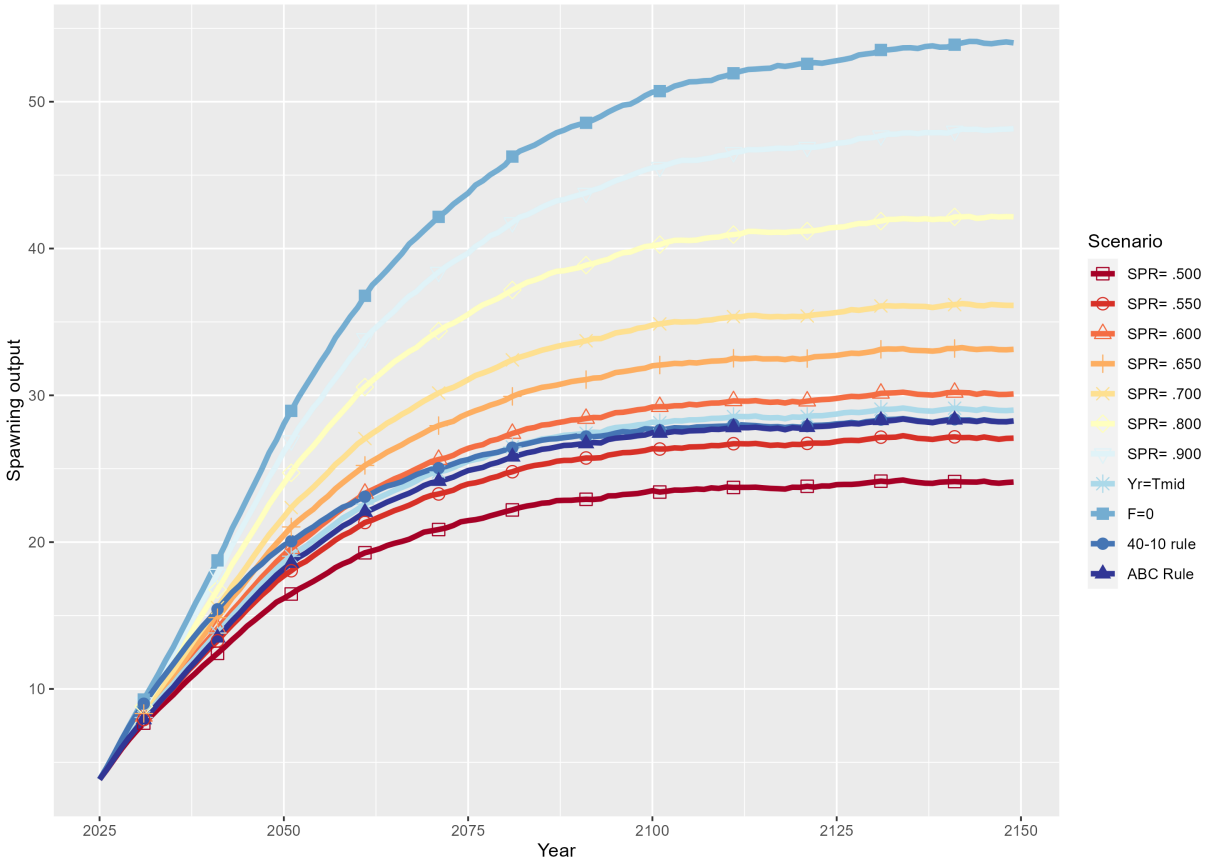

Figure 4: Spawning output by year, starting in 2025, for the alternative rebuilding strategies.

10 Appendix

10.1 Appendix A: Rebuilder data file

The rebuild.dat file used for the base rebuilding analysis is provided below. Note that to achieve the SPR = 0.5 and SPR = 0.55 strategies, the option "Constrain catches by the ABC" had to be set to 2 (no).

#Title, #runnumber: 1 2021_ca_quillback.dat 2021_ca_quillback.ctl 186.851 55.0825 7.74523 StartTime: Tue Aug 22 10:46:00 2023
2023_ca_quillback_rebuild.dat
Number of sexes
1
Age range to consider (minimum age; maximum age)
0 90
Number of fleets
2
First year of projection (Yinit)
2021
First Year of rebuilding period (Ydecl)
2025
Number of simulations
1000
Maximum number of years
200
Conduct projections with multiple starting values (0=No;else yes)
1
Number of parameter vectors
4
Is the maximum age a plus-group (1=Yes;2=No)
1
Generate future recruitments using historical recruitments (1) historical recruits/spawner (2) or a stock-recruitment (3)
3
Constant fishing mortality (1) or constant Catch (2) projections
1
Fishing mortality based on SPR (1) or actual rate (2)
1
Pre-specify the year of recovery (or -1) to ignore
-1
Fecundity-at-age
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 #runnumber: 1 2021_ca_quillback.dat 2021_ca_quillback.ctl 186.851 55.0825 7.74523
 0 9.89949e-11 2.18758e-07 7.86107e-05 0.00456528 0.0346351 0.0881909 0.142498 0.189883 0.230676 0.266017 0.296652 0.323085 0.345739 0.36502 0.381327 0.395044 0.406529 0.416109 0.424074 0.430679 0.436145 0.44066 0.444385 0.447453 0.449979 0.452057 0.453764 0.455167 0.456319 0.457265 0.45804 0.458677 0.459199 0.459628 0.459979 0.460267 0.460503 0.460696 0.460855 0.460985 0.461092 0.461179 0.461251 0.461309 0.461358 0.461397 0.461429 0.461456 0.461478 0.461495 0.46151 0.461522 0.461532 0.46154 0.461546 0.461552 0.461556 0.46156 0.461563 0.461565 0.461567 0.461569 0.46157 0.461571 0.461572 0.461573 0.461573 0.461574 0.461574 0.461575 0.461575 0.461575 0.461575 0.461575 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 0.461576 #female fecundity; weighted by N in year Y_init across morphs and areas
Age specific selectivity and weight adjusted for discard and discard mortality

#wt and selex for gender,fleet: 1 1 CA_Commercial
0.00574978 0.0486353 0.136511 0.276475 0.439279 0.605177 0.761886 0.903422 1.02827 1.13726
1.23189 1.3136 1.38373 1.44353 1.49419 1.53687 1.57267 1.60255 1.62743 1.64807 1.66517 1.67929
1.69095 1.70056 1.70847 1.71498 1.72033 1.72472 1.72833 1.7313 1.73373 1.73573 1.73736 1.73871
1.73981 1.74071 1.74145 1.74206 1.74255 1.74296 1.7433 1.74357 1.74379 1.74398 1.74413 1.74425
1.74435 1.74444 1.74451 1.74456 1.74461 1.74464 1.74468 1.7447 1.74472 1.74474 1.74475 1.74476
1.74477 1.74478 1.74479 1.74479 1.7448 1.7448 1.7448 1.7448 1.74481 1.74481 1.74481 1.74481
1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481
1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481 1.74481
0 0.000159582 0.00601452 0.0387019 0.124871 0.261771 0.417281 0.559169 0.671823 0.754299
0.812333 0.85267 0.880818 0.900706 0.914988 0.92542 0.933166 0.939005 0.943464 0.94691 0.949599
0.951714 0.95339 0.954726 0.955796 0.956657 0.957351 0.957913 0.958368 0.958738 0.959039
0.959285 0.959485 0.959648 0.959782 0.959891 0.95998 0.960053 0.960113 0.960162 0.960202
0.960235 0.960262 0.960284 0.960302 0.960316 0.960328 0.960338 0.960346 0.960353 0.960359
0.960363 0.960367 0.96037 0.960372 0.960374 0.960376 0.960377 0.960378 0.960379 0.96038
0.960381 0.960381 0.960381 0.960382 0.960382 0.960382 0.960382 0.960383 0.960383 0.960383
0.960383 0.960383 0.960383 0.960383 0.960383 0.960383 0.960383 0.960383 0.960383 0.960383
0.960383 0.960383 0.960383 0.960383 0.960383 0.960383 0.960383 0.960383 0.960383 0.960383
#wt and selex for gender,fleet: 1 2 CA_Recreational
0.00574978 0.0500613 0.145659 0.283826 0.431291 0.571775 0.704477 0.832183 0.953376 1.06496
1.16487 1.25245 1.32805 1.39256 1.44715 1.49304 1.53143 1.56342 1.58998 1.61199 1.63018 1.6452
1.65758 1.66777 1.67616 1.68306 1.68872 1.69338 1.6972 1.70033 1.7029 1.70501 1.70675 1.70816
1.70933 1.71028 1.71107 1.71171 1.71223 1.71266 1.71302 1.71331 1.71354 1.71374 1.7139 1.71403
1.71414 1.71422 1.71429 1.71435 1.7144 1.71444 1.71447 1.7145 1.71452 1.71454 1.71456 1.71457
1.71458 1.71459 1.71459 1.7146 1.7146 1.71461 1.71461 1.71461 1.71461 1.71461 1.71462 1.71462
1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462
1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462 1.71462
0 0.000109105 0.0106751 0.108381 0.362012 0.645194 0.829796 0.920509 0.961011 0.979251
0.987929 0.992357 0.994781 0.996196 0.99707 0.997637 0.998019 0.998287 0.998478 0.99862
0.998725 0.998806 0.998868 0.998917 0.998955 0.998985 0.999009 0.999029 0.999044 0.999057
0.999067 0.999075 0.999082 0.999087 0.999092 0.999096 0.999098 0.999101 0.999103 0.999105
0.999106 0.999107 0.999108 0.999109 0.999109 0.99911 0.99911 0.99911 0.999111 0.999111 0.999111
0.999111 0.999111 0.999111 0.999111 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112
0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112
0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112
0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112 0.999112
Sex ratio correction
1
M and current age-structure in year Yinit: 2021
gender = 1
0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057
0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057
0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057
0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057
0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057 0.057
0.057 0.057 0.057 0.057 0.057 0.057 0.057
14.99 14.907 14.8959 14.3886 9.13974 6.29549 4.10207 3.39404 3.69397 5.1358 8.14285 3.09089
1.77532 1.39555 1.31755 1.53111 2.31191 1.71558 1.0567 0.753646 0.684649 0.644916 4.67619

0.579787 0.455629 1.96667 0.395632 0.675561 0.295006 0.28124 0.190102 0.0699603 0.0427322
0.0253098 0.0475211 0.010198 0.00842008 0.00510449 0.00302489 0.00213938 0.00184772
0.00146248 0.00104786 0.000801277 0.000869866 0.000770569 0.000676152 0.000590255
0.000526188 0.000477005 0.000436447 0.00040186 0.000371292 0.000344156 0.000320067
0.000298477 0.000279003 0.000261271 0.000245105 0.00023019 0.000216476 0.000203941
0.000192428 0.000181814 0.000171865 0.000162483 0.000153521 0.000144957 0.000136845
0.000129252 0.000122146 0.000115469 0.000109189 0.000103264 9.76234e-05 9.23198e-05 8.73025e-
05 8.25448e-05 7.80416e-05 7.37711e-05 6.97141e-05 6.58643e-05 6.74125e-05 6.34827e-05
5.97992e-05 5.63447e-05 5.31047e-05 5.00617e-05 4.72008e-05 4.451e-05 0.000751828
Age-structure at Ydeclare= 2021
14.99 14.907 14.8959 14.3886 9.13974 6.29549 4.10207 3.39404 3.69397 5.1358 8.14285 3.09089
1.77532 1.39555 1.31755 1.53111 2.31191 1.71558 1.0567 0.753646 0.684649 0.644916 4.67619
0.579787 0.455629 1.96667 0.395632 0.675561 0.295006 0.28124 0.190102 0.0699603 0.0427322
0.0253098 0.0475211 0.010198 0.00842008 0.00510449 0.00302489 0.00213938 0.00184772
0.00146248 0.00104786 0.000801277 0.000869866 0.000770569 0.000676152 0.000590255
0.000526188 0.000477005 0.000436447 0.00040186 0.000371292 0.000344156 0.000320067
0.000298477 0.000279003 0.000261271 0.000245105 0.00023019 0.000216476 0.000203941
0.000192428 0.000181814 0.000171865 0.000162483 0.000153521 0.000144957 0.000136845
0.000129252 0.000122146 0.000115469 0.000109189 0.000103264 9.76234e-05 9.23198e-05 8.73025e-
05 8.25448e-05 7.80416e-05 7.37711e-05 6.97141e-05 6.58643e-05 6.74125e-05 6.34827e-05
5.97992e-05 5.63447e-05 5.31047e-05 5.00617e-05 4.72008e-05 4.451e-05 0.000751828
Year for Tmin Age-structure (set to Ydecl by SS)
2021
recruitment and biomass
Number of historical assessment years
107
Historical data
year recruitment spawner in B0 in R project in R/S project
1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932
1933 1934 1935 1936 1937 1938 1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950
1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967 1968
1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 #years
(with first value representing R0)
23.765 23.7692 23.7691 23.769 23.7686 23.7685 23.7684 23.7683 23.7682 23.7682 23.7681 23.7678
23.7675 23.7668 23.766 23.7649 23.7633 23.7612 23.7593 23.7574 23.7554 23.7526 23.7498 23.747
23.744 21.8368 21.7533 21.667 21.5795 21.4893 21.3926 21.2854 21.1729 21.0659 20.9517 20.8363
20.7173 20.5927 20.4656 20.3361 20.2011 20.0651 19.9274 19.788 19.6386 19.489 19.3357 19.1773
19.0086 18.8248 18.6296 18.4088 18.1641 17.8919 17.5929 17.2706 16.9331 16.6221 16.38 16.3328
16.5568 16.6346 16.4721 13.1049 14.397 16.6331 17.4852 16.7819 19.3378 25.7431 31.5045 25.9837
75.3229 23.1642 21.9488 21.0873 36.4782 36.1002 26.0683 42.5871 18.4807 70.5026 13.0214 13.6614
92.166 10.6782 9.56958 8.86081 10.446 14.5013 17.1114 10.0627 7.71078 7.24907 8.16213 12.5027
28.471 15.1661 9.05616 6.8555 6.87191 9.00158 11.6862 17.1017 16.6951 15.7814 14.99 #recruits;
first value is R0 (virgin)
55.0825 55.0825 55.0806 55.0767 55.0676 55.0659 55.0636 55.0601 55.0579 55.058 55.0564 55.0484
55.0408 55.0253 55.0049 54.9783 54.9417 54.8919 54.8458 54.8009 54.7534 54.6884 54.6208 54.5542
54.484 54.4249 54.3598 54.2959 54.2684 54.2355 54.0976 53.7508 53.3363 53.1538 52.8353 52.554

52.2541 51.892 51.5599 51.2671 50.9053 50.5543 50.1747 49.7952 49.2249 48.7778 48.394 48.0906
47.7636 47.3224 46.9488 46.3758 45.7502 45.0618 44.3682 43.6168 42.6266 41.7542 40.5348 39.2364
37.8214 36.4337 34.8724 33.2472 31.7036 30.0996 28.4088 27.9795 27.5406 22.7322 21.3651 20.2601
19.1308 19.0528 19.6005 19.2763 18.5412 11.8539 9.92412 7.11651 5.80869 5.84697 5.87699 5.28747
5.55544 6.02042 6.82146 7.38913 8.75693 9.75132 11.7634 12.8471 12.8958 11.9253 11.6594 11.8037
12.2726 12.3877 12.0442 12.1297 12.3019 11.9952 11.7369 11.0625 10.1863 8.77933 7.74523 #spbio;
first value is SSB_virgin (virgin)
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 # in Bzero
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 # in R project
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 # in R/S project
Number of years with pre-specified catches
4
catches for years with pre-specified catches go next
2021 15.58
2022 18.11
2023 11.12
2024 10.62
Number of future recruitments to override
0
Process for overiding (-1 for average otherwise index in data list)
Which probability to product detailed results for (1=0.5; 2=0.6; etc.)
3
Steepness sigma-R Auto-correlation
0.72 0.6 0
Target SPR rate (FMSY Proxy); manually change to SPR_MSY if not using SPR_target
0.5
Discount rate (for cumulative catch)
0.1
Truncate the series when 0.4B0 is reached (1=Yes)
0
Set F to FMSY once 0.4B0 is reached (1=Yes)
0
Maximum possible F for projection (-1 to set to FMSY)
-1
Defintion of recovery (1=now only;2=now or before)
2
Projection type
11
Definition of the 40-10 rule
10 40
Sigma Assessment Error (Base, Year1, Slope, MaxSigma)
1.0 2022 0.075 2.0
Pstar
0.45
Constrain catches by the ABC (1=yes; 2=no)

1
Implementation Error (0=no; 1=lognormal; 2=uniform)
0
Parameters of Implementation Error
1 0.3
Calculate coefficients of variation (1=Yes)
0
Number of replicates to use
10
Random number seed
-99004
File with multiple parameter vectors
rebuild_m_2023.SSO
User-specific projection (1=Yes); Output replaced (1->9)
0 5
Catches and Fs (Year; 1/2/3 (F or C or SPR); value); Final row is -1
2025 1 1
-1 -1 -1
Fixed catch project (1=Yes); Output replaced (1->9); Approach (-1=Read in else 1-9)
0 2 -1
(48a) Special catch options [switch (1 = Yes, 0 = No), Emsy, distribution, buffer, option to replace]
0 0.18 1.00 1.00 0 6
(48b) B1Target
150000
Split of Fs
2021 0.354 0.646
2022 0.525 0.475
2023 0.734 0.266
2024 0.746 0.254
2025 0.275016
 0.724984
-1 1 1
Yrs to define T_target for projection type 4 (a.k.a. 5 pre-specified inputs)
0.5 0.6 0.7 0.8 0.9
Year for probability of recovery
2030 2031 2041 2046 2051 2056 2061 2065
Time varying weight-at-age (1=Yes;0=No)
0
File with time series of weight-at-age data
none
Use bisection (0) or linear interpolation (1)
1
Target Depletion
0.4
CV of implementation error
0