Rebuilding analysis for copper rockfish (*Sebastes caurinus*) in

U.S. waters off the coast of California south of Point Conception based on the 2021 stock assessment

by Chantel R. Wetzel1

1Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112

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# Summary

This rebuilding analysis is for the stock of copper rockfish (*Sebastes caurinus*) in waters off California, south of Point Conception. The analysis is based on the 2021 stock assessment. The 2021 assessment model estimated the copper rockfish south of Point Conception to be at 18% of the unexploited equilibrium spawning output at the beginning of 2021. This rebuilding analysis compares the results of applying a suite of potential management actions to the stock for 2023 and beyond.

The results of the analysis show that the value for TMIN, the median year for rebuilding to the target level in the absence of fishing since the year of declaration (2023), is 2035. The estimated generation time for copper rockfish was estimated to be 17 years. In conjunction with TMIN and the mean generation time TMAX to be 2052. The SPR = 0.586 harvest rate generates a 50% probability of recovery by TMID where TMID was set equal to 2043, between TMIN and TMAX.

# Introduction

The 2021 assessment of copper rockfish south of Point Conception documented that the stock had declined below the Minimum Stock Size Threshold (MSST), 25% for rockfish stocks, for the first time during the mid 1980s, increased above the MSST briefly between 2010-2016, but had fallen back below the MSST starting in 2017 (Wetzel et al. 2021). Given the assumed productivity of stock combined with the longevity of copper rockfish a range of alternative rebuilding approaches were examined with rebuilding ranging from 2035 to 2052 based on various SPR harvest rates from 0.5 to 1

# Overview of the 2021 stock assessment

The 2021 assessment of copper rockfish assessed the stock as four separate sub-stocks along the U.S. west coast: south of Point Conception in California, north of Point Conception in California, Oregon, and Washington. This was the first assessment of copper rockfish conducted within Stock Synthesis that used catch and length composition data to inform model estimates around stock size and status. The previous assessment of copper rockfish conducted in 2013 was modeled using Extended Depletion-Based Stock Reduction Analysis (XDB-SRA), a delay-difference model, using catch, catch-per-unit-effort data, and prior distributions around biological parameters (Cope et al. 2013). The 2013 assessment estimated the stock at 76% of unfished spawning output based on fits to catch-per-unit-effort and updated parameter distribution around biology (i.e., the posterior distributions). During model bridging between the 2013 to the 2021 assessment model, the large downward shift in estimated stock status in the new assessment was identified to be driven by the inclusion of the length data which implied a low relative stock size in recent years (Wetzel et al. 2021).

The model for the area south of Point Conception in California was modeled as two fishing fleets, a commercial and an recreational fleet, along with one survey fleet, the Northwest Fisheries Science Center Hook and Line Survey (NWFSC HKL Survey). The majority of the removals and length composition data arose from the recreational fleet. Total removals of copper rockfish south of Point Concpetion peaked in the late 1970s and early 1980s, decreased from the late 1980s to mid-2000s but had high annual variability, and then increased in recent years. The stock was modeled using Stock Synthesis as a two-sex age-structured model. Area specific length-at-age and fecundity-at-length for the copper rockfish stock south of Point Conception were estimated externally and then fixed within the model. Natural mortality and steepness were both fixed at the median or mean of the priors. The selectivity of both the commercial and recreational fishery were estimated to be domed-shape with the NWFSC HKL Survey selectivity fixed to be asymptotic.

# Management performance under rebuilding

This is the first rebuilding plan for copper rockfish off the coast of California south of Point

Conception.

# Rebuilding calculations

This rebuilding analysis was conducted using software developed by A. Punt (version 3.12h, August 2021). The steps followed were:

* + Define how equilibrium spawning output (SB0) will be calculated.
  + Define how future recruitment will be generated.
  + Define the fishery selectivity and allocation to be applied during rebuilding.
  + Decide how to include uncertainty in input parameters from the stock assessment in the rebuilding analysis.
  + Calculate rebuilding reference points from the most current assessment results
    - Calculate the projected year in which the stock would rebuild with a 50% probability if all future fishing mortality was eliminated (TF=0).
    - Calculate the projected year for a 50% probability of rebuilding from the year in which the stock was first declared overfished (TMIN).
    - Calculate the mean generation time.
    - Calculate the maximum allowable rebuilding time (TMAX).
  + Identification and analysis of alternative harvest strategies for rebuilding.

## Definition of Equilibrium Spawning Output

The equilibrium spawning output (SB0) used in this rebuilding analysis is calculated via the stock-recruitment relationship in order to be consistent with assessment model results. This level was estimated to be 233.04 millions of eggs in the base case assessment model, which dictates a rebuilding relative spawning output target (SB40%) of 93.22 millions of eggs (Table [1](#_bookmark16)).

## Generation of future recruitment

The estimated parameters of the stock recruitment relationship (unexploited equilibrium recruitment [natural log of 𝑅0], and steepness [ℎ]) were used to generate future recruitments in the rebuilding analysis. The 2021 assessment model did not estimate annual recruit- ment deviations but uncertainty around future recruitments was generated by assuming a recruitment variability of 𝜎𝑅 = 0.60.

## Fishery selectivity and allocation

The selectivity and weight-at-age used in the rebuilding analysis were obtained from 2021 assessment. The relative allocation of catch among fleets in this rebuilding analysis was informed using the relative fishing mortality averaged over recent years (2015-2019).

## Inclusion of uncertainty

Uncertainty was included in this rebuilding analysis via 1,200 random simulations of stochastic future recruitment strengths and integration over the three states of nature across stock size, log(𝑅0). The base model was given 50% of the weight and each alternative state of nature was given 25% of the weight.

## Rebuilding reference points

Two alternative rebuilding scenarios were explored. The first set the 2021 and 2022 ACL removals at 90.8 mt and 88.9 mt, respectively, based on values provided by the Pacific Fishery Management Council Groundfish Management Team. The second analysis explored the impact on the rebuilding plan if removals in 2021 and 2022 were reduced to 50 mt for both years. The following reference points reported below are based on assumed full removals of

90.8 and 88.9 mt in 2021 and 2022. The reference points based on assuming lower removals in 2021 and 2022 are presented as sensitivities later in the results section.

All reference points calculated based on this rebuilding analysis are given in Table [1](#_bookmark16). The minimum time required for rebuilding, TMIN, with no fishing (F=0) starting in 2023 was estimated to be 12 years, corresponding to the stock being rebuilt by 2035, assuming the default removals for 2021 and 2022. The mean generation time was estimated to be 17 years. The maximum time allowed for rebuilding, TMAX, is defined as the TMIN plus the mean generation time for stocks that require more than 10 years to rebuild. Copper rockfish was unable to rebuild within 10 years so the estimated TMAX was 2052.

TTARGET, SPRTARGET and PMAX are not specified since this is the first rebuilding plan for copper rockfish and these values have not been set via the Pacific Fishery Management Council (Council) process. A rebuilding strategy is presented below based on rebuilding target year termed TMID which is set at 2043, mid-value between TMIN and TMAX, along with the associated SPRMID. The Council may opt to select a TTARGET earlier or later than this TMID value based on fishery, economic, or other factors.

## Alternate rebuilding strategies

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 selection of a TTARGET (year for 50% probability of recovery). This rebuilding analysis presents the following alternate strategies spread among the approaches based on the selection of a SPR harvest rate or rebuilding by a selected target year:

* + - Apply a range of SPR values: 0.55, 0.60, 0.65, 0.70, and 0.75
    - Eliminate all harvest, F = 0, beginning in the next management cycle, 2023, the same as setting a constant SPR harvest rate of 1.0.
    - Apply the ACL based on the 40:10 harvest control rule.
    - Apply the ABC with time-varying 𝜎.
    - Apply SPR harvest rates that are estimated to lead to a 50% probability of recovery by alternative target years: TMID, TMAX, and other years between TMIN and TMAX

All of the above rebuilding strategies were conducted assuming removals of 90.8 mt and 88.9 mt in 2021 and 2022. A sensitivity examining the impact of reducing removals in 2021 and 2022 to 50 mt was conducted on a subset of the alternative fixed SPR harvest rate alternative listed above.

# Results

Summary results from the rebuilding alternatives assuming removals of 90.8 and 88.9 mt are presented in Table [2](#_bookmark17). Summaries of the additional alternative based on reduced removals in 2021 and 2022 are presented in Table [3](#_bookmark18) and rebuilding alternatives based on various target years are presented in Table [4](#_bookmark19).

The target rebuilding year based on the range of pre-specified SPR values between 0.55 - 0.75 ranged from 2036 - 2046 (Table [2](#_bookmark17)). The probability of rebuilding by year steadily increased across the alternative SPR values with full rebuilding by 2046 when the lowest SPR of 0.55 was applied (Table [5](#_bookmark21) and Figure [1](#_bookmark31)). The recommended removals in 2023, the first year of rebuilding, were low ranging between 8.91 - 18.66 mt across alternative SPR values (Table [6](#_bookmark22)) with the recommended removals slowly increasing by year during the rebuilding period (Figure [2](#_bookmark32)). The change in spawning output by year under each of the alternative SPR values are shown by year in Table [7](#_bookmark23) and Figure [3](#_bookmark34)).

The “ABC Rule” projections were based on the adopted rockfish SPR target of 0.50 combined with a time-varying 𝜎 and category 2 𝑃 ∗. The stock was estimated to rebuild by year 2052 with a proability of 0.523 (Table [2](#_bookmark17)). Rebuilding by TMID, 2043, was achieved using a SPR value of 0.586 (Table [2](#_bookmark17)) with a 0.887 probability of rebuilding by TMAX, 2052 (Table [5](#_bookmark21)).

Reducing the assumed removals in 2021 and 2022 had only a limited impact on the estimated rebuilding by SPR rate (Table [3](#_bookmark18)). Reducing the removals in 2021 and 2022 decreased the minimum time for rebuilding (TMIN) to 2033, two years earlier compared to the initial rebuilding alternatives. The reduction of the TMIN resulted in a decrease in the TMAX to 2050. The probability of rebuilding, ACLs, and spawning outputs by year are shown in Tables [8](#_bookmark25) - [10](#_bookmark26).

The final alternative rebuilding analysis that examined a range of specific rebuilding target years (Table [4](#_bookmark19)) generally fell within alternatives explored in the initial analysis (Table [2](#_bookmark17)) but provided additional granularity to see potential rebuilding timelines. The probability of rebuilding, ACLs, and spawning output by year are shown in Tables [11](#_bookmark28) - [13](#_bookmark29)

# Acknowledgments

Thank you to Andre Punt for quickly updating the rebuilder program to apply time-varying

𝜎 for the Acceptable Biological Catch scenarios and thank you for his assistance and guidance on application of the rebuilding program.

# References

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Wetzel, C. R., Brian J. Langseth, Jason M Cope, and John Budrick. 2021. “The Status of Copper Rockfish (*Sebastes Caurinus*) in U.S. Waters Off the Coast of California South of Point Conception in 2021 Using Catch and Length Data.” Pacific Fishery Management Council, Portland, Oregon.

# Tables

## Rebuilding reference points and summary of alternatives

**Table 1:** Summary of the rebuilding reference points.

Parameter 2021

Assessment Values

SB0 (millions of eggs) 233.04

SB40% (millions of eggs) 93.22

SB2021 (millions of eggs) 42.28

Year rebuilding begins 2023

Current year 2021

Tmin 2035

Mean generation time (years) 17

Tmax 2052

Pmax TBD

Ttarget TBD

SPRtarget TBD

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**Table 2:** Results of rebuilding alternatives based on selection of an SPR target or year for 50 percent probability of recovery based on the assumed removals for 2021-22.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | SPR= | SPR= | SPR= | SPR= | SPR= | Yr=Tmid | F=0 | 40-10 | ABC |
| .550 | .600 | .650 | .700 | .750 |  |  | rule | Rule |
| 2021 Assumed Removals (mt) | 90.8 | 90.8 | 90.8 | 90.8 | 90.8 | 90.8 | 90.8 | 90.8 | 90.8 |
| 2022 Assumed Removals (mt) | 88.9 | 88.9 | 88.9 | 88.9 | 88.9 | 88.9 | 88.9 | 88.9 | 88.9 |
| 2023 ACL (mt) | 18.66 | 15.9 | 13.39 | 11.06 | 8.91 | 16.66 | 0 | 8.57 | 21.68 |
| 2024 ACL (mt) | 20.89 | 17.96 | 15.24 | 12.68 | 10.28 | 18.77 | 0 | 11.15 | 24.04 |
| SPR | 0.55 | 0.6 | 0.65 | 0.7 | 0.75 | 0.586 | 1 | 0.758 | 0.5 |
| Ttarget | 2046 | 2042 | 2039 | 2037 | 2036 | 2043 | 2033 | 2041 | 2052 |
| Tmax | 2052 | 2052 | 2052 | 2052 | 2052 | 2052 | 2052 | 2052 | 2052 |
| Probability of recovery by Tmax | 0.77 | 0.918 | 0.973 | 0.993 | 0.999 | 0.887 | 1 | 0.923 | 0.523 |

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**Table 3:** Results of rebuilding alternatives based on alternative SPR targets resulting in 50 percent probability of recovery by the target year listed based on the assumed removals for 2021-22.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | SPR= | SPR= | SPR= | SPR= | SPR= | Yr=Tmid | F=0 | 40-10 | ABC |
|  | .550 | .600 | .650 | .700 | .750 |  |  | rule | Rule |
| 2021 Assumed Removals (mt) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 2022 Assumed Removals (mt) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 2023 ACL (mt) | 23.61 | 20.13 | 16.94 | 14.01 | 11.28 | 22.78 | 0 | 14.6 | 27.43 |
| 2024 ACL (mt) | 25.24 | 21.7 | 18.42 | 15.33 | 12.43 | 24.4 | 0 | 17.25 | 29.04 |
| SPR | 0.55 | 0.6 | 0.65 | 0.7 | 0.75 | 0.562 | 1 | 0.69 | 0.5 |
| Ttarget | 2043 | 2039 | 2037 | 2035 | 2034 | 2042 | 2031 | 2039 | 2049 |
| Tmax | 2050 | 2050 | 2050 | 2050 | 2050 | 2050 | 2050 | 2050 | 2050 |
| Probability of recovery by Tmax | 0.787 | 0.932 | 0.979 | 0.996 | 0.999 | 0.825 | 1 | 0.93 | 0.533 |

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**Table 4:** Results of rebuilding alternatives based on alternative target rebuilding years based on 50 percent probability of recovery.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Yr = 2036.0 | Yr = 2040.0 | Yr = 2044.0 | Yr = 2048.0 | Yr = 2052.0 |
| 2021 Assumed Removals (mt) | 90.8 | 90.8 | 90.8 | 90.8 | 90.8 |
| 2022 Assumed Removals (mt) | 88.9 | 88.9 | 88.9 | 88.9 | 88.9 |
| 2023 ACL (mt) | 9.29 | 14.48 | 17.91 | 19.08 | 21.98 |
| 2024 ACL (mt) | 10.71 | 16.42 | 20.1 | 21.33 | 24.35 |
| SPR | 0.741 | 0.628 | 0.563 | 0.543 | 0.495 |
| Ttarget | 2036 | 2040 | 2044 | 2046 | 2052 |
| Tmax | 2052 | 2052 | 2052 | 2052 | 2052 |
| Probability of recovery by Tmax | 0.999 | 0.953 | 0.826 | 0.738 | 0.5 |

## Rebuilding alternative time series

**Table 5:** Probability of recovery by year for rebuilding SPR alternatives assuming removals of 90.8 and 88.9 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | SPR= | SPR= | SPR= | SPR= | SPR= | Yr=Tmid | F=0 | 40-10 | ABC |
|  | .550 | .600 | .650 | .700 | .750 |  |  | rule | Rule |
| 2021 | 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 |
| 2023 | 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 |
| 2025 | 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 |
| 2027 | 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 |
| 2029 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.004 | 0.000 | 0.000 |
| 2030 | 0.001 | 0.001 | 0.002 | 0.002 | 0.004 | 0.001 | 0.047 | 0.002 | 0.000 |
| 2031 | 0.002 | 0.002 | 0.008 | 0.012 | 0.022 | 0.002 | 0.196 | 0.006 | 0.001 |
| 2032 | 0.003 | 0.010 | 0.020 | 0.040 | 0.070 | 0.007 | 0.414 | 0.018 | 0.002 |
| 2033 | 0.011 | 0.025 | 0.053 | 0.092 | 0.145 | 0.018 | 0.627 | 0.045 | 0.003 |
| 2034 | 0.022 | 0.051 | 0.102 | 0.170 | 0.267 | 0.042 | 0.805 | 0.081 | 0.008 |
| 2035 | 0.038 | 0.091 | 0.169 | 0.274 | 0.394 | 0.074 | 0.898 | 0.136 | 0.018 |
| 2036 | 0.067 | 0.142 | 0.252 | 0.378 | 0.525 | 0.122 | 0.953 | 0.208 | 0.023 |
| 2037 | 0.107 | 0.209 | 0.328 | 0.500 | 0.644 | 0.169 | 0.983 | 0.262 | 0.039 |
| 2038 | 0.146 | 0.271 | 0.428 | 0.590 | 0.738 | 0.234 | 0.989 | 0.333 | 0.058 |
| 2039 | 0.184 | 0.335 | 0.508 | 0.686 | 0.817 | 0.292 | 0.997 | 0.406 | 0.092 |
| 2040 | 0.238 | 0.400 | 0.605 | 0.762 | 0.881 | 0.346 | 0.998 | 0.484 | 0.120 |
| 2041 | 0.282 | 0.476 | 0.676 | 0.827 | 0.918 | 0.424 | 0.999 | 0.548 | 0.146 |
| 2042 | 0.338 | 0.536 | 0.739 | 0.877 | 0.948 | 0.485 | 1.000 | 0.604 | 0.181 |
| 2043 | 0.390 | 0.607 | 0.781 | 0.909 | 0.964 | 0.537 | 1.000 | 0.676 | 0.212 |
| 2044 | 0.441 | 0.658 | 0.837 | 0.937 | 0.977 | 0.602 | 1.000 | 0.718 | 0.248 |
| 2045 | 0.496 | 0.703 | 0.866 | 0.953 | 0.984 | 0.653 | 1.000 | 0.758 | 0.281 |
| 2046 | 0.538 | 0.748 | 0.897 | 0.968 | 0.990 | 0.697 | 1.000 | 0.795 | 0.311 |
| 2047 | 0.574 | 0.783 | 0.920 | 0.973 | 0.993 | 0.740 | 1.000 | 0.823 | 0.342 |
| 2048 | 0.622 | 0.821 | 0.940 | 0.982 | 0.995 | 0.770 | 1.000 | 0.850 | 0.378 |
| 2049 | 0.666 | 0.851 | 0.954 | 0.988 | 0.997 | 0.802 | 1.000 | 0.883 | 0.415 |
| 2050 | 0.700 | 0.882 | 0.960 | 0.989 | 0.998 | 0.843 | 1.000 | 0.900 | 0.452 |
| 2051 | 0.738 | 0.901 | 0.966 | 0.993 | 0.999 | 0.867 | 1.000 | 0.917 | 0.488 |
| 2052 | 0.770 | 0.918 | 0.973 | 0.993 | 0.999 | 0.887 | 1.000 | 0.923 | 0.522 |
| 2053 | 0.802 | 0.931 | 0.980 | 0.993 | 1.000 | 0.906 | 1.000 | 0.936 | 0.551 |
| 2054 | 0.822 | 0.942 | 0.983 | 0.997 | 1.000 | 0.921 | 1.000 | 0.947 | 0.578 |
| 2055 | 0.839 | 0.948 | 0.988 | 0.998 | 1.000 | 0.927 | 1.000 | 0.953 | 0.606 |

**Table 6:** ACLs (mt) by year for rebuilding SPR alternatives assuming removals of 90.8 and

88.9 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | SPR= | SPR= | SPR= | SPR= | SPR= | Yr=Tmid | F=0 | 40-10 | ABC |
|  | .550 | .600 | .650 | .700 | .750 |  |  | rule | Rule |
| 2021 | 90.80 | 90.80 | 90.80 | 90.80 | 90.80 | 90.80 | 90.8 | 90.80 | 90.80 |
| 2022 | 88.90 | 88.90 | 88.90 | 88.90 | 88.90 | 88.90 | 88.9 | 88.90 | 88.90 |
| 2023 | 18.66 | 15.90 | 13.39 | 11.06 | 8.91 | 16.66 | 0.0 | 8.57 | 21.68 |
| 2024 | 20.89 | 17.96 | 15.24 | 12.68 | 10.28 | 18.77 | 0.0 | 11.15 | 24.04 |
| 2025 | 22.74 | 19.71 | 16.83 | 14.10 | 11.49 | 20.55 | 0.0 | 13.99 | 25.97 |
| 2026 | 24.21 | 21.10 | 18.12 | 15.26 | 12.50 | 21.97 | 0.0 | 16.71 | 27.45 |
| 2027 | 25.59 | 22.41 | 19.32 | 16.33 | 13.44 | 23.31 | 0.0 | 19.28 | 28.87 |
| 2028 | 26.73 | 23.50 | 20.38 | 17.30 | 14.29 | 24.40 | 0.0 | 21.50 | 30.00 |
| 2029 | 27.74 | 24.51 | 21.28 | 18.10 | 14.99 | 25.41 | 0.0 | 23.31 | 31.03 |
| 2030 | 28.69 | 25.43 | 22.18 | 18.95 | 15.71 | 26.34 | 0.0 | 25.00 | 31.97 |
| 2031 | 29.64 | 26.36 | 23.07 | 19.76 | 16.45 | 27.29 | 0.0 | 26.44 | 32.87 |
| 2032 | 30.63 | 27.32 | 23.97 | 20.55 | 17.14 | 28.28 | 0.0 | 27.71 | 33.83 |
| 2033 | 31.53 | 28.23 | 24.82 | 21.36 | 17.87 | 29.19 | 0.0 | 29.06 | 34.79 |
| 2034 | 32.63 | 29.24 | 25.76 | 22.18 | 18.56 | 30.21 | 0.0 | 30.22 | 35.83 |
| 2035 | 33.51 | 30.14 | 26.59 | 22.96 | 19.23 | 31.08 | 0.0 | 31.30 | 36.72 |
| 2036 | 34.15 | 30.73 | 27.18 | 23.51 | 19.74 | 31.70 | 0.0 | 32.26 | 37.32 |
| 2037 | 34.71 | 31.25 | 27.71 | 23.97 | 20.17 | 32.25 | 0.0 | 33.33 | 37.90 |
| 2038 | 35.49 | 32.05 | 28.41 | 24.64 | 20.73 | 33.05 | 0.0 | 34.43 | 38.68 |
| 2039 | 36.16 | 32.74 | 29.05 | 25.23 | 21.25 | 33.74 | 0.0 | 36.25 | 39.35 |
| 2040 | 36.67 | 33.19 | 29.50 | 25.69 | 21.67 | 34.21 | 0.0 | 38.96 | 39.92 |
| 2041 | 37.46 | 33.96 | 30.20 | 26.31 | 22.20 | 35.00 | 0.0 | 40.90 | 40.70 |
| 2042 | 38.12 | 34.61 | 30.82 | 26.83 | 22.66 | 35.65 | 0.0 | 42.94 | 41.32 |
| 2043 | 38.64 | 35.07 | 31.25 | 27.19 | 23.01 | 36.10 | 0.0 | 44.65 | 41.84 |
| 2044 | 39.03 | 35.45 | 31.66 | 27.59 | 23.34 | 36.50 | 0.0 | 45.25 | 42.11 |
| 2045 | 39.29 | 35.77 | 31.95 | 27.87 | 23.58 | 36.81 | 0.0 | 45.61 | 42.49 |
| 2046 | 39.47 | 35.91 | 32.09 | 28.01 | 23.73 | 36.95 | 0.0 | 46.10 | 42.63 |
| 2047 | 40.20 | 36.61 | 32.72 | 28.51 | 24.12 | 37.69 | 0.0 | 46.31 | 43.35 |
| 2048 | 40.64 | 37.00 | 33.06 | 28.85 | 24.43 | 38.05 | 0.0 | 46.53 | 43.90 |
| 2049 | 40.74 | 37.15 | 33.23 | 29.05 | 24.59 | 38.18 | 0.0 | 46.89 | 43.99 |
| 2050 | 41.09 | 37.50 | 33.52 | 29.32 | 24.86 | 38.56 | 0.0 | 47.29 | 44.30 |
| 2051 | 41.22 | 37.67 | 33.73 | 29.50 | 25.03 | 38.71 | 0.0 | 47.35 | 44.39 |
| 2052 | 41.29 | 37.67 | 33.74 | 29.50 | 25.02 | 38.74 | 0.0 | 47.00 | 44.51 |
| 2053 | 41.56 | 37.94 | 33.97 | 29.71 | 25.22 | 39.03 | 0.0 | 46.89 | 44.66 |
| 2054 | 41.56 | 37.94 | 34.03 | 29.77 | 25.25 | 39.00 | 0.0 | 47.12 | 44.71 |
| 2055 | 42.20 | 38.50 | 34.47 | 30.18 | 25.55 | 39.60 | 0.0 | 47.44 | 45.46 |

**Table 7:** Spawning output by year for rebuilding SPR alternatives assuming removals of

90.8 and 88.9 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | SPR= | SPR= | SPR= | SPR= | SPR= | Yr=Tmid | F=0 | 40-10 | ABC |
|  | .550 | .600 | .650 | .700 | .750 |  |  | rule | Rule |
| 2021 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 |
| 2022 | 38.97 | 38.97 | 38.97 | 38.97 | 38.97 | 38.97 | 38.97 | 38.97 | 38.97 |
| 2023 | 35.28 | 35.28 | 35.28 | 35.28 | 35.28 | 35.28 | 35.28 | 35.28 | 35.28 |
| 2024 | 37.11 | 37.34 | 37.56 | 37.76 | 37.94 | 37.28 | 38.69 | 37.97 | 36.85 |
| 2025 | 39.62 | 40.16 | 40.65 | 41.11 | 41.54 | 40.01 | 43.33 | 41.50 | 39.04 |
| 2026 | 42.63 | 43.53 | 44.37 | 45.15 | 45.89 | 43.28 | 49.04 | 45.62 | 41.65 |
| 2027 | 45.84 | 47.15 | 48.38 | 49.55 | 50.65 | 46.79 | 55.43 | 49.95 | 44.43 |
| 2028 | 49.07 | 50.84 | 52.51 | 54.07 | 55.55 | 50.35 | 62.15 | 54.23 | 47.20 |
| 2029 | 52.42 | 54.63 | 56.73 | 58.75 | 60.63 | 54.02 | 69.18 | 58.45 | 50.08 |
| 2030 | 55.72 | 58.39 | 60.93 | 63.36 | 65.75 | 57.65 | 76.44 | 62.55 | 52.89 |
| 2031 | 58.78 | 61.91 | 64.94 | 67.84 | 70.64 | 61.04 | 83.52 | 66.24 | 55.45 |
| 2032 | 61.76 | 65.42 | 68.94 | 72.28 | 75.52 | 64.39 | 90.56 | 69.77 | 57.97 |
| 2033 | 64.71 | 68.81 | 72.76 | 76.63 | 80.40 | 67.65 | 97.62 | 73.29 | 60.48 |
| 2034 | 67.46 | 72.02 | 76.42 | 80.71 | 84.87 | 70.74 | 104.32 | 76.54 | 62.77 |
| 2035 | 70.28 | 75.30 | 80.20 | 84.98 | 89.56 | 73.89 | 111.38 | 79.64 | 65.11 |
| 2036 | 72.92 | 78.41 | 83.76 | 88.95 | 94.15 | 76.88 | 118.30 | 82.53 | 67.39 |
| 2037 | 75.62 | 81.70 | 87.46 | 93.18 | 98.75 | 79.96 | 125.00 | 85.58 | 69.71 |
| 2038 | 78.12 | 84.43 | 90.63 | 96.74 | 102.70 | 82.62 | 131.29 | 87.99 | 71.65 |
| 2039 | 79.96 | 86.69 | 93.29 | 99.84 | 106.22 | 84.79 | 137.05 | 89.94 | 73.10 |
| 2040 | 81.89 | 89.11 | 96.19 | 103.09 | 109.92 | 87.08 | 142.58 | 91.92 | 74.60 |
| 2041 | 84.47 | 92.00 | 99.47 | 106.72 | 113.90 | 89.85 | 148.56 | 93.42 | 76.76 |
| 2042 | 86.50 | 94.45 | 102.23 | 109.99 | 117.55 | 92.22 | 154.24 | 94.62 | 78.43 |
| 2043 | 88.37 | 96.58 | 104.77 | 112.82 | 120.66 | 94.29 | 159.16 | 95.56 | 80.04 |
| 2044 | 90.23 | 98.78 | 107.26 | 115.69 | 124.01 | 96.39 | 164.27 | 96.71 | 81.50 |
| 2045 | 92.47 | 101.37 | 110.11 | 118.92 | 127.64 | 98.84 | 169.10 | 97.51 | 83.50 |
| 2046 | 94.15 | 103.40 | 112.49 | 121.58 | 130.54 | 100.81 | 174.16 | 98.03 | 84.91 |
| 2047 | 95.84 | 105.34 | 114.70 | 124.02 | 133.18 | 102.65 | 178.46 | 98.80 | 86.25 |
| 2048 | 96.88 | 106.66 | 116.35 | 126.14 | 135.79 | 103.91 | 182.30 | 99.23 | 87.07 |
| 2049 | 98.40 | 108.35 | 118.16 | 127.92 | 137.69 | 105.52 | 185.37 | 99.74 | 88.28 |
| 2050 | 100.02 | 110.07 | 120.12 | 130.17 | 140.12 | 107.21 | 188.80 | 100.11 | 89.78 |
| 2051 | 100.87 | 111.24 | 121.58 | 131.98 | 142.32 | 108.38 | 192.78 | 101.02 | 90.43 |
| 2052 | 101.80 | 112.49 | 123.02 | 133.66 | 144.05 | 109.44 | 195.79 | 101.40 | 91.16 |
| 2053 | 103.09 | 113.75 | 124.57 | 135.28 | 146.01 | 110.71 | 198.49 | 101.89 | 92.23 |
| 2054 | 103.98 | 115.00 | 125.86 | 136.74 | 147.65 | 111.90 | 200.67 | 101.65 | 92.92 |
| 2055 | 104.39 | 115.44 | 126.55 | 137.55 | 148.56 | 112.36 | 202.53 | 101.97 | 93.23 |

## Rebuilding alternative time series with reduced removals for 2021 and 2022

**Table 8:** Probability of recovery by year for rebuilding SPR alternatives assuming removals of 50 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | SPR= | SPR= | SPR= | SPR= | SPR= | Yr=Tmid | F=0 | 40-10 | ABC |
|  | .550 | .600 | .650 | .700 | .750 |  |  | rule | Rule |
| 2021 | 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 |
| 2023 | 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 |
| 2025 | 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 |
| 2027 | 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 | 0.002 | 0.000 | 0.000 |
| 2029 | 0.000 | 0.001 | 0.002 | 0.002 | 0.004 | 0.000 | 0.058 | 0.002 | 0.000 |
| 2030 | 0.002 | 0.004 | 0.007 | 0.014 | 0.032 | 0.002 | 0.283 | 0.007 | 0.001 |
| 2031 | 0.009 | 0.016 | 0.035 | 0.068 | 0.102 | 0.010 | 0.569 | 0.024 | 0.002 |
| 2032 | 0.019 | 0.045 | 0.088 | 0.145 | 0.238 | 0.022 | 0.787 | 0.059 | 0.007 |
| 2033 | 0.045 | 0.090 | 0.156 | 0.267 | 0.393 | 0.055 | 0.902 | 0.106 | 0.013 |
| 2034 | 0.077 | 0.153 | 0.259 | 0.392 | 0.537 | 0.089 | 0.960 | 0.171 | 0.029 |
| 2035 | 0.116 | 0.222 | 0.356 | 0.512 | 0.665 | 0.130 | 0.983 | 0.250 | 0.047 |
| 2036 | 0.161 | 0.291 | 0.458 | 0.622 | 0.749 | 0.196 | 0.994 | 0.322 | 0.070 |
| 2037 | 0.216 | 0.366 | 0.546 | 0.706 | 0.843 | 0.248 | 0.998 | 0.407 | 0.105 |
| 2038 | 0.269 | 0.446 | 0.624 | 0.782 | 0.899 | 0.301 | 1.000 | 0.482 | 0.133 |
| 2039 | 0.318 | 0.512 | 0.703 | 0.857 | 0.935 | 0.353 | 1.000 | 0.545 | 0.162 |
| 2040 | 0.362 | 0.584 | 0.766 | 0.892 | 0.958 | 0.414 | 1.000 | 0.620 | 0.196 |
| 2041 | 0.428 | 0.649 | 0.816 | 0.923 | 0.971 | 0.474 | 1.000 | 0.669 | 0.232 |
| 2042 | 0.478 | 0.702 | 0.857 | 0.948 | 0.981 | 0.526 | 1.000 | 0.727 | 0.273 |
| 2043 | 0.520 | 0.742 | 0.893 | 0.962 | 0.988 | 0.574 | 1.000 | 0.757 | 0.307 |
| 2044 | 0.572 | 0.781 | 0.917 | 0.974 | 0.993 | 0.623 | 1.000 | 0.801 | 0.342 |
| 2045 | 0.614 | 0.818 | 0.936 | 0.980 | 0.995 | 0.667 | 1.000 | 0.828 | 0.377 |
| 2046 | 0.658 | 0.849 | 0.951 | 0.987 | 0.995 | 0.699 | 1.000 | 0.857 | 0.407 |
| 2047 | 0.692 | 0.869 | 0.963 | 0.990 | 0.997 | 0.737 | 1.000 | 0.873 | 0.450 |
| 2048 | 0.727 | 0.893 | 0.968 | 0.993 | 0.998 | 0.762 | 1.000 | 0.892 | 0.472 |
| 2049 | 0.758 | 0.917 | 0.974 | 0.994 | 0.998 | 0.790 | 1.000 | 0.917 | 0.505 |
| 2050 | 0.787 | 0.932 | 0.979 | 0.996 | 0.999 | 0.825 | 1.000 | 0.930 | 0.533 |
| 2051 | 0.812 | 0.940 | 0.983 | 0.997 | 0.999 | 0.856 | 1.000 | 0.938 | 0.567 |
| 2052 | 0.843 | 0.946 | 0.988 | 0.997 | 1.000 | 0.872 | 1.000 | 0.947 | 0.591 |
| 2053 | 0.857 | 0.958 | 0.990 | 0.998 | 1.000 | 0.886 | 1.000 | 0.956 | 0.623 |
| 2054 | 0.877 | 0.963 | 0.992 | 0.999 | 1.000 | 0.900 | 1.000 | 0.963 | 0.647 |
| 2055 | 0.891 | 0.968 | 0.992 | 1.000 | 1.000 | 0.917 | 1.000 | 0.968 | 0.678 |

**Table 9:** ACLs (mt) by year for rebuilding SPR alternatives assuming removals of 50 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | SPR= | SPR= | SPR= | SPR= | SPR= | Yr=Tmid | F=0 | 40-10 | ABC |
|  | .550 | .600 | .650 | .700 | .750 |  |  | rule | Rule |
| 2021 | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | 50 | 50.00 | 50.00 |
| 2022 | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | 50.00 | 50 | 50.00 | 50.00 |
| 2023 | 23.61 | 20.13 | 16.94 | 14.01 | 11.28 | 22.78 | 0 | 14.60 | 27.43 |
| 2024 | 25.24 | 21.70 | 18.42 | 15.33 | 12.43 | 24.40 | 0 | 17.25 | 29.04 |
| 2025 | 26.46 | 22.93 | 19.59 | 16.41 | 13.38 | 25.63 | 0 | 19.65 | 30.20 |
| 2026 | 27.53 | 23.99 | 20.60 | 17.34 | 14.21 | 26.71 | 0 | 21.78 | 31.22 |
| 2027 | 28.71 | 25.14 | 21.69 | 18.33 | 15.06 | 27.88 | 0 | 23.77 | 32.41 |
| 2028 | 29.70 | 26.09 | 22.64 | 19.21 | 15.84 | 28.86 | 0 | 25.54 | 33.37 |
| 2029 | 30.66 | 27.04 | 23.50 | 20.00 | 16.54 | 29.84 | 0 | 26.97 | 34.32 |
| 2030 | 31.50 | 27.90 | 24.32 | 20.77 | 17.23 | 30.65 | 0 | 28.38 | 35.12 |
| 2031 | 32.36 | 28.78 | 25.17 | 21.56 | 17.93 | 31.53 | 0 | 29.52 | 35.86 |
| 2032 | 33.20 | 29.61 | 25.96 | 22.28 | 18.55 | 32.37 | 0 | 30.45 | 36.69 |
| 2033 | 33.99 | 30.38 | 26.70 | 22.97 | 19.19 | 33.16 | 0 | 31.68 | 37.48 |
| 2034 | 34.83 | 31.21 | 27.47 | 23.66 | 19.80 | 34.00 | 0 | 32.56 | 38.31 |
| 2035 | 35.61 | 32.01 | 28.27 | 24.38 | 20.42 | 34.79 | 0 | 33.52 | 39.06 |
| 2036 | 36.16 | 32.50 | 28.72 | 24.83 | 20.84 | 35.33 | 0 | 34.43 | 39.56 |
| 2037 | 36.49 | 32.91 | 29.13 | 25.16 | 21.15 | 35.69 | 0 | 36.34 | 39.90 |
| 2038 | 37.27 | 33.60 | 29.75 | 25.81 | 21.71 | 36.48 | 0 | 38.85 | 40.69 |
| 2039 | 37.81 | 34.15 | 30.31 | 26.30 | 22.15 | 37.01 | 0 | 40.78 | 41.17 |
| 2040 | 38.18 | 34.50 | 30.67 | 26.66 | 22.50 | 37.35 | 0 | 42.67 | 41.60 |
| 2041 | 38.88 | 35.18 | 31.28 | 27.19 | 22.95 | 38.04 | 0 | 43.94 | 42.22 |
| 2042 | 39.45 | 35.76 | 31.82 | 27.71 | 23.38 | 38.57 | 0 | 45.27 | 42.79 |
| 2043 | 39.88 | 36.13 | 32.16 | 27.99 | 23.66 | 39.03 | 0 | 45.81 | 43.21 |
| 2044 | 40.08 | 36.42 | 32.49 | 28.31 | 23.95 | 39.31 | 0 | 46.28 | 43.40 |
| 2045 | 40.34 | 36.65 | 32.73 | 28.56 | 24.12 | 39.52 | 0 | 46.30 | 43.61 |
| 2046 | 40.41 | 36.75 | 32.82 | 28.62 | 24.24 | 39.59 | 0 | 46.57 | 43.71 |
| 2047 | 41.10 | 37.37 | 33.39 | 29.08 | 24.61 | 40.28 | 0 | 46.69 | 44.38 |
| 2048 | 41.47 | 37.73 | 33.69 | 29.38 | 24.86 | 40.64 | 0 | 46.91 | 44.80 |
| 2049 | 41.49 | 37.85 | 33.85 | 29.55 | 25.02 | 40.69 | 0 | 47.32 | 44.82 |
| 2050 | 41.78 | 38.15 | 34.06 | 29.79 | 25.24 | 41.02 | 0 | 47.49 | 45.12 |
| 2051 | 41.90 | 38.24 | 34.23 | 29.93 | 25.37 | 41.08 | 0 | 47.44 | 45.16 |
| 2052 | 41.87 | 38.19 | 34.17 | 29.88 | 25.34 | 41.06 | 0 | 47.22 | 45.14 |
| 2053 | 42.12 | 38.43 | 34.39 | 30.06 | 25.52 | 41.31 | 0 | 47.10 | 45.28 |
| 2054 | 42.03 | 38.40 | 34.40 | 30.11 | 25.51 | 41.24 | 0 | 47.29 | 45.25 |
| 2055 | 42.69 | 38.89 | 34.84 | 30.48 | 25.79 | 41.85 | 0 | 47.61 | 45.99 |

**Table 10:** Spawning output by year for rebuilding SPR alternatives assuming removals of 50 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | SPR= | SPR= | SPR= | SPR= | SPR= | Yr=Tmid | F=0 | 40-10 | ABC |
|  | .550 | .600 | .650 | .700 | .750 |  |  | rule | Rule |
| 2021 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 |
| 2022 | 42.45 | 42.45 | 42.45 | 42.45 | 42.45 | 42.45 | 42.45 | 42.45 | 42.45 |
| 2023 | 42.91 | 42.91 | 42.91 | 42.91 | 42.91 | 42.91 | 42.91 | 42.91 | 42.91 |
| 2024 | 45.70 | 46.00 | 46.27 | 46.53 | 46.76 | 45.77 | 47.74 | 46.47 | 45.36 |
| 2025 | 48.77 | 49.45 | 50.08 | 50.66 | 51.20 | 48.93 | 53.49 | 50.43 | 48.03 |
| 2026 | 51.93 | 53.05 | 54.09 | 55.06 | 55.98 | 52.20 | 59.89 | 54.49 | 50.73 |
| 2027 | 55.05 | 56.64 | 58.13 | 59.54 | 60.87 | 55.43 | 66.64 | 58.47 | 53.35 |
| 2028 | 58.08 | 60.15 | 62.13 | 64.01 | 65.77 | 58.56 | 73.55 | 62.26 | 55.87 |
| 2029 | 61.25 | 63.82 | 66.27 | 68.60 | 70.81 | 61.84 | 80.71 | 66.09 | 58.54 |
| 2030 | 64.36 | 67.46 | 70.35 | 73.18 | 75.86 | 65.08 | 88.01 | 69.81 | 61.12 |
| 2031 | 67.21 | 70.78 | 74.22 | 77.50 | 80.66 | 68.06 | 95.10 | 73.10 | 63.48 |
| 2032 | 69.93 | 73.99 | 77.88 | 81.65 | 85.30 | 70.87 | 102.16 | 76.30 | 65.66 |
| 2033 | 72.70 | 77.26 | 81.70 | 85.94 | 90.10 | 73.76 | 109.11 | 79.47 | 67.96 |
| 2034 | 75.15 | 80.19 | 85.06 | 89.75 | 94.32 | 76.31 | 115.67 | 82.24 | 70.01 |
| 2035 | 77.59 | 83.06 | 88.41 | 93.61 | 98.61 | 78.86 | 122.39 | 85.05 | 71.95 |
| 2036 | 80.07 | 85.94 | 91.74 | 97.40 | 102.91 | 81.44 | 128.92 | 87.62 | 73.97 |
| 2037 | 82.34 | 88.82 | 95.14 | 101.20 | 107.22 | 83.84 | 135.58 | 90.20 | 75.82 |
| 2038 | 84.38 | 91.21 | 97.94 | 104.44 | 110.85 | 85.99 | 141.43 | 92.05 | 77.51 |
| 2039 | 86.12 | 93.29 | 100.30 | 107.12 | 114.01 | 87.76 | 146.73 | 93.04 | 78.80 |
| 2040 | 87.70 | 95.36 | 102.79 | 110.07 | 117.37 | 89.47 | 151.98 | 94.49 | 79.93 |
| 2041 | 89.93 | 97.87 | 105.59 | 113.31 | 120.95 | 91.75 | 157.14 | 95.47 | 81.86 |
| 2042 | 91.66 | 100.00 | 108.19 | 116.27 | 124.21 | 93.59 | 162.61 | 96.10 | 83.22 |
| 2043 | 93.21 | 101.80 | 110.23 | 118.65 | 126.92 | 95.21 | 166.95 | 97.10 | 84.54 |
| 2044 | 94.72 | 103.67 | 112.59 | 121.31 | 129.82 | 96.77 | 171.72 | 98.03 | 85.73 |
| 2045 | 96.79 | 106.01 | 115.13 | 124.19 | 133.06 | 98.97 | 176.18 | 98.52 | 87.40 |
| 2046 | 98.22 | 107.78 | 117.11 | 126.52 | 135.77 | 100.44 | 180.74 | 99.17 | 88.67 |
| 2047 | 99.60 | 109.29 | 119.01 | 128.60 | 138.11 | 101.82 | 184.78 | 99.84 | 89.69 |
| 2048 | 100.26 | 110.36 | 120.24 | 130.26 | 140.19 | 102.60 | 187.99 | 100.18 | 90.30 |
| 2049 | 101.58 | 111.82 | 121.87 | 131.98 | 141.98 | 103.95 | 190.64 | 100.56 | 91.30 |
| 2050 | 102.99 | 113.33 | 123.57 | 133.82 | 143.97 | 105.37 | 193.86 | 100.78 | 92.54 |
| 2051 | 103.71 | 114.40 | 124.92 | 135.36 | 146.02 | 106.20 | 197.40 | 101.49 | 93.09 |
| 2052 | 104.53 | 115.31 | 126.17 | 136.90 | 147.57 | 107.02 | 200.17 | 101.72 | 93.66 |
| 2053 | 105.51 | 116.49 | 127.44 | 138.29 | 149.13 | 108.05 | 202.48 | 102.35 | 94.45 |
| 2054 | 106.28 | 117.44 | 128.49 | 139.56 | 150.47 | 108.87 | 204.39 | 102.23 | 94.98 |
| 2055 | 106.52 | 117.79 | 129.00 | 140.10 | 151.17 | 109.16 | 206.04 | 102.24 | 95.28 |

## Rebuilding alternative time series for target rebuilding years

**Table 11:** The probabilty of rebuilding by year for alternative rebuilding target years assuming removals of 90.8 and 88.9 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Yr = 2036.0 | Yr = 2040.0 | Yr = 2044.0 | Yr = 2048.0 | Yr = 2052.0 |
| 2021 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2022 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2023 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2024 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2025 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2026 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2027 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2028 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2029 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2030 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2031 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2032 | 0.06 | 0.01 | 0.00 | 0.00 | 0.00 |
| 2033 | 0.14 | 0.04 | 0.01 | 0.01 | 0.00 |
| 2034 | 0.25 | 0.08 | 0.03 | 0.02 | 0.01 |
| 2035 | 0.37 | 0.13 | 0.05 | 0.03 | 0.02 |
| 2036 | 0.50 | 0.20 | 0.08 | 0.06 | 0.02 |
| 2037 | 0.62 | 0.27 | 0.13 | 0.09 | 0.03 |
| 2038 | 0.71 | 0.35 | 0.17 | 0.13 | 0.05 |
| 2039 | 0.80 | 0.42 | 0.22 | 0.17 | 0.08 |
| 2040 | 0.87 | 0.50 | 0.28 | 0.22 | 0.11 |
| 2041 | 0.90 | 0.58 | 0.33 | 0.26 | 0.14 |
| 2042 | 0.94 | 0.65 | 0.40 | 0.31 | 0.17 |
| 2043 | 0.96 | 0.71 | 0.45 | 0.37 | 0.20 |
| 2044 | 0.97 | 0.76 | 0.50 | 0.41 | 0.23 |
| 2045 | 0.98 | 0.80 | 0.55 | 0.47 | 0.26 |
| 2046 | 0.99 | 0.84 | 0.60 | 0.51 | 0.29 |
| 2047 | 0.99 | 0.87 | 0.64 | 0.55 | 0.32 |
| 2048 | 0.99 | 0.90 | 0.68 | 0.59 | 0.35 |
| 2049 | 1.00 | 0.92 | 0.72 | 0.63 | 0.39 |
| 2050 | 1.00 | 0.94 | 0.76 | 0.66 | 0.43 |
| 2051 | 1.00 | 0.94 | 0.79 | 0.70 | 0.46 |
| 2052 | 1.00 | 0.95 | 0.83 | 0.74 | 0.50 |
| 2053 | 1.00 | 0.96 | 0.84 | 0.77 | 0.52 |
| 2054 | 1.00 | 0.97 | 0.87 | 0.80 | 0.55 |
| 2055 | 1.00 | 0.98 | 0.89 | 0.82 | 0.58 |

**Table 12:** ACLs (mt) by year for alternative rebuilding target years assuming removals of

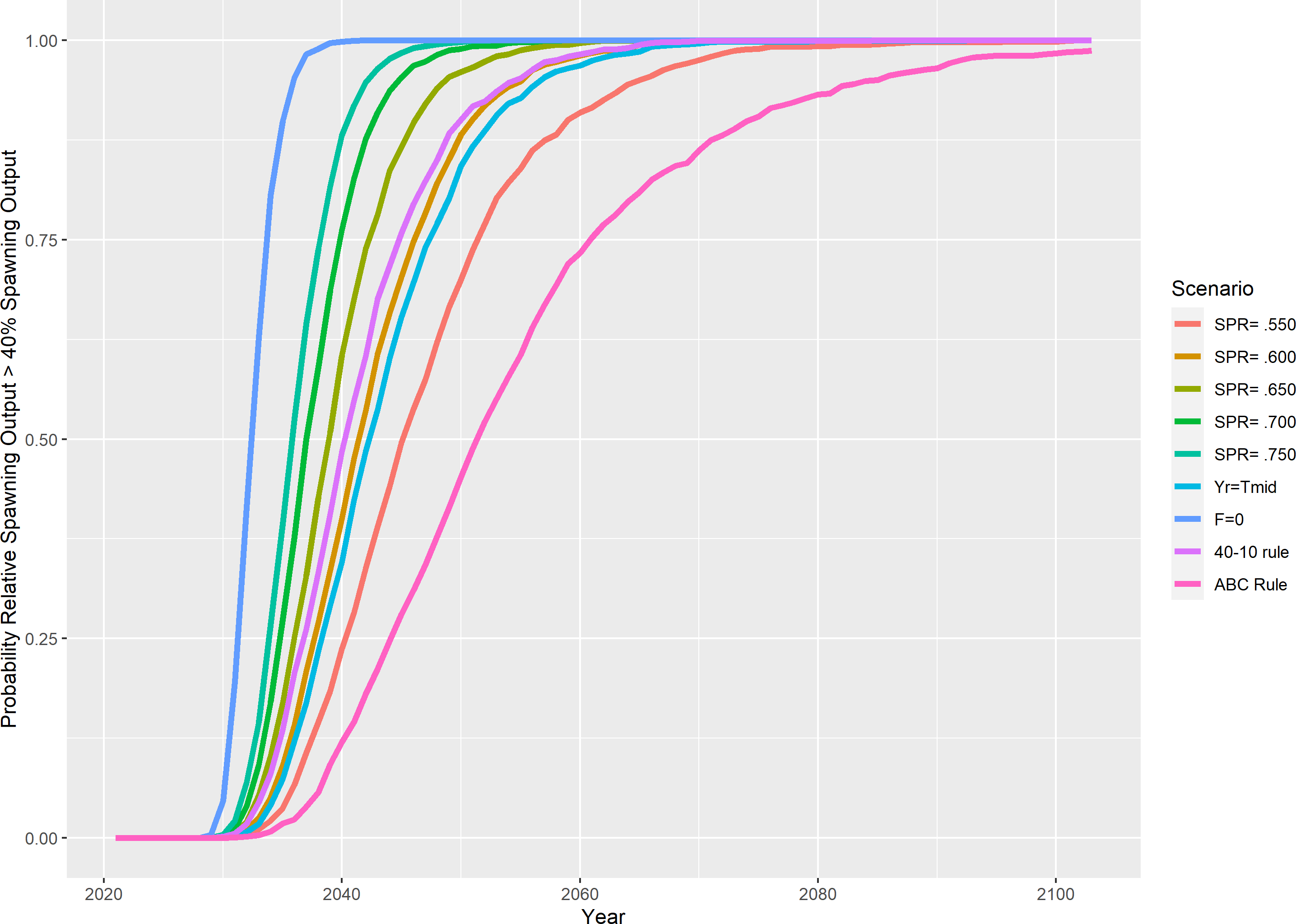
90.8 and 88.9 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Yr = 2036.0 | Yr = 2040.0 | Yr = 2044.0 | Yr = 2048.0 | Yr = 2052.0 |
| 2021 | 90.80 | 90.80 | 90.80 | 90.80 | 90.80 |
| 2022 | 88.90 | 88.90 | 88.90 | 88.90 | 88.90 |
| 2023 | 9.29 | 14.48 | 17.91 | 19.08 | 21.98 |
| 2024 | 10.71 | 16.42 | 20.10 | 21.33 | 24.35 |
| 2025 | 11.96 | 18.09 | 21.93 | 23.20 | 26.28 |
| 2026 | 13.00 | 19.43 | 23.38 | 24.67 | 27.76 |
| 2027 | 13.96 | 20.68 | 24.75 | 26.07 | 29.19 |
| 2028 | 14.84 | 21.76 | 25.88 | 27.21 | 30.31 |
| 2029 | 15.56 | 22.71 | 26.88 | 28.22 | 31.35 |
| 2030 | 16.29 | 23.62 | 27.83 | 29.17 | 32.28 |
| 2031 | 17.05 | 24.53 | 28.80 | 30.12 | 33.18 |
| 2032 | 17.76 | 25.47 | 29.76 | 31.10 | 34.12 |
| 2033 | 18.52 | 26.35 | 30.66 | 32.01 | 35.09 |
| 2034 | 19.22 | 27.30 | 31.74 | 33.11 | 36.13 |
| 2035 | 19.92 | 28.16 | 32.64 | 34.01 | 37.02 |
| 2036 | 20.44 | 28.75 | 33.28 | 34.63 | 37.61 |
| 2037 | 20.87 | 29.31 | 33.84 | 35.20 | 38.17 |
| 2038 | 21.46 | 30.05 | 34.63 | 35.99 | 38.97 |
| 2039 | 21.98 | 30.72 | 35.28 | 36.65 | 39.62 |
| 2040 | 22.42 | 31.14 | 35.78 | 37.16 | 40.22 |
| 2041 | 22.95 | 31.89 | 36.61 | 37.95 | 41.00 |
| 2042 | 23.43 | 32.52 | 37.23 | 38.59 | 41.62 |
| 2043 | 23.79 | 32.99 | 37.74 | 39.15 | 42.13 |
| 2044 | 24.13 | 33.40 | 38.13 | 39.52 | 42.41 |
| 2045 | 24.38 | 33.69 | 38.43 | 39.78 | 42.76 |
| 2046 | 24.52 | 33.82 | 38.57 | 39.97 | 42.92 |
| 2047 | 24.93 | 34.49 | 39.34 | 40.67 | 43.65 |
| 2048 | 25.26 | 34.86 | 39.71 | 41.14 | 44.17 |
| 2049 | 25.42 | 35.05 | 39.85 | 41.25 | 44.28 |
| 2050 | 25.69 | 35.31 | 40.18 | 41.62 | 44.59 |
| 2051 | 25.86 | 35.53 | 40.31 | 41.71 | 44.67 |
| 2052 | 25.85 | 35.52 | 40.39 | 41.77 | 44.80 |
| 2053 | 26.06 | 35.77 | 40.66 | 42.03 | 44.92 |
| 2054 | 26.09 | 35.83 | 40.67 | 42.05 | 44.98 |
| 2055 | 26.41 | 36.30 | 41.29 | 42.71 | 45.75 |

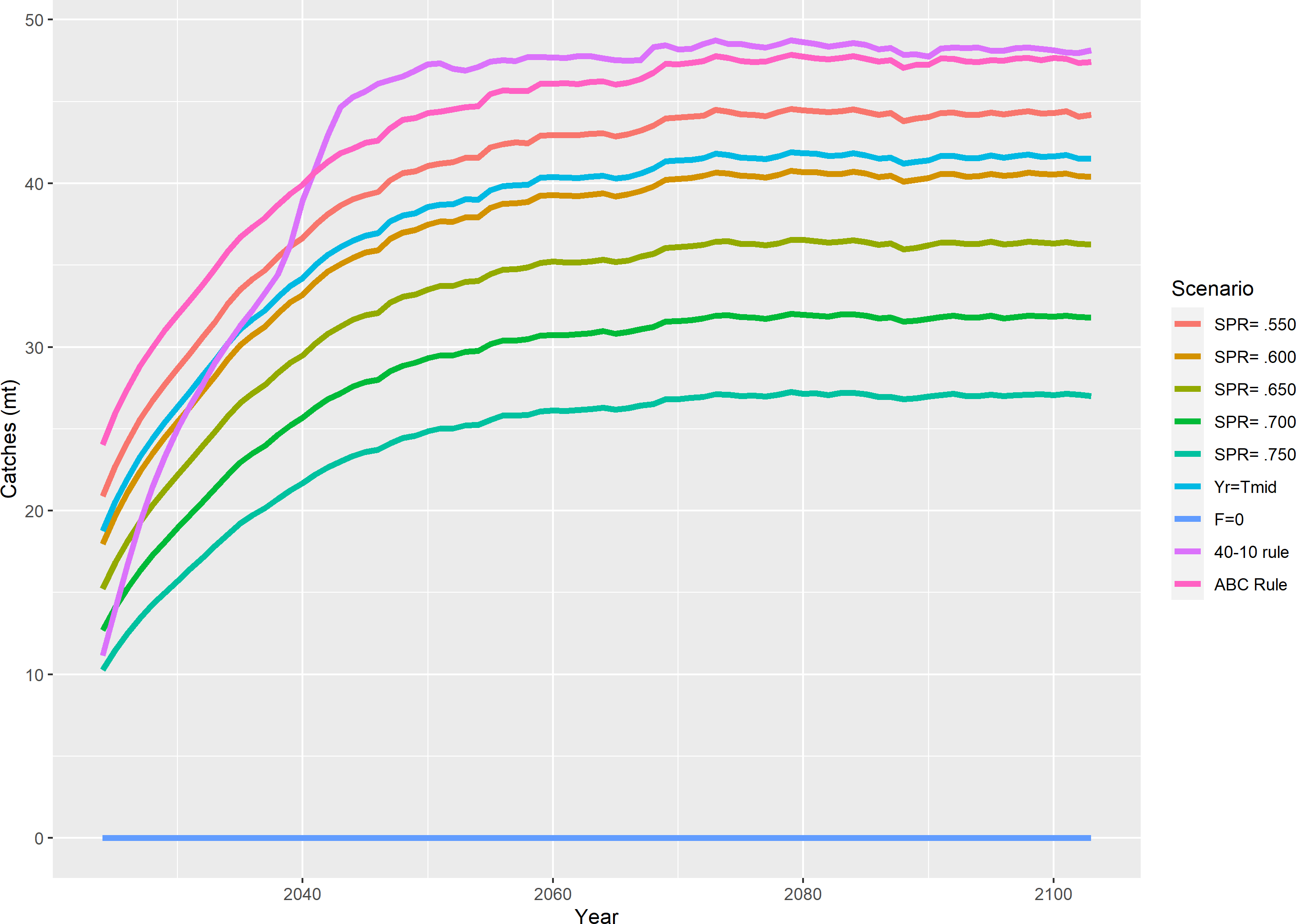
**Table 13:** Spawning output by year for alternative rebuilding target years assuming removals of 90.8 and 88.9 mt in 2021 and 2022, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Yr = 2036.0 | Yr = 2040.0 | Yr = 2044.0 | Yr = 2048.0 | Yr = 2052.0 |
| 2021 | 42.28 | 42.28 | 42.28 | 42.28 | 42.28 |
| 2022 | 38.97 | 38.97 | 38.97 | 38.97 | 38.97 |
| 2023 | 35.28 | 35.28 | 35.28 | 35.28 | 35.28 |
| 2024 | 37.91 | 37.47 | 37.17 | 37.07 | 36.83 |
| 2025 | 41.46 | 40.44 | 39.77 | 39.54 | 38.98 |
| 2026 | 45.76 | 44.00 | 42.87 | 42.49 | 41.56 |
| 2027 | 50.45 | 47.84 | 46.19 | 45.64 | 44.29 |
| 2028 | 55.29 | 51.78 | 49.54 | 48.81 | 47.01 |
| 2029 | 60.29 | 55.80 | 53.01 | 52.09 | 49.85 |
| 2030 | 65.31 | 59.82 | 56.44 | 55.31 | 52.62 |
| 2031 | 70.13 | 63.61 | 59.61 | 58.31 | 55.12 |
| 2032 | 74.93 | 67.40 | 62.73 | 61.22 | 57.59 |
| 2033 | 79.73 | 71.01 | 65.78 | 64.10 | 60.07 |
| 2034 | 84.11 | 74.48 | 68.67 | 66.78 | 62.32 |
| 2035 | 88.74 | 78.03 | 71.60 | 69.52 | 64.60 |
| 2036 | 93.21 | 81.44 | 74.38 | 72.13 | 66.85 |
| 2037 | 97.76 | 84.92 | 77.14 | 74.79 | 69.14 |
| 2038 | 101.61 | 87.89 | 79.74 | 77.19 | 71.03 |
| 2039 | 105.05 | 90.37 | 81.75 | 78.97 | 72.45 |
| 2040 | 108.65 | 93.05 | 83.79 | 80.83 | 73.90 |
| 2041 | 112.59 | 96.19 | 86.43 | 83.35 | 76.03 |
| 2042 | 116.18 | 98.81 | 88.59 | 85.33 | 77.66 |
| 2043 | 119.17 | 101.10 | 90.53 | 87.16 | 79.24 |
| 2044 | 122.49 | 103.49 | 92.48 | 88.97 | 80.65 |
| 2045 | 126.07 | 106.26 | 94.80 | 91.15 | 82.64 |
| 2046 | 128.91 | 108.48 | 96.59 | 92.79 | 84.03 |
| 2047 | 131.50 | 110.57 | 98.33 | 94.45 | 85.34 |
| 2048 | 134.06 | 112.00 | 99.42 | 95.44 | 86.11 |
| 2049 | 135.90 | 113.79 | 100.98 | 96.95 | 87.33 |
| 2050 | 138.33 | 115.66 | 102.64 | 98.51 | 88.81 |
| 2051 | 140.41 | 117.04 | 103.64 | 99.36 | 89.46 |
| 2052 | 142.13 | 118.41 | 104.58 | 100.24 | 90.14 |
| 2053 | 144.06 | 119.79 | 105.86 | 101.54 | 91.17 |
| 2054 | 145.66 | 121.03 | 106.88 | 102.37 | 91.86 |
| 2055 | 146.52 | 121.68 | 107.29 | 102.76 | 92.15 |

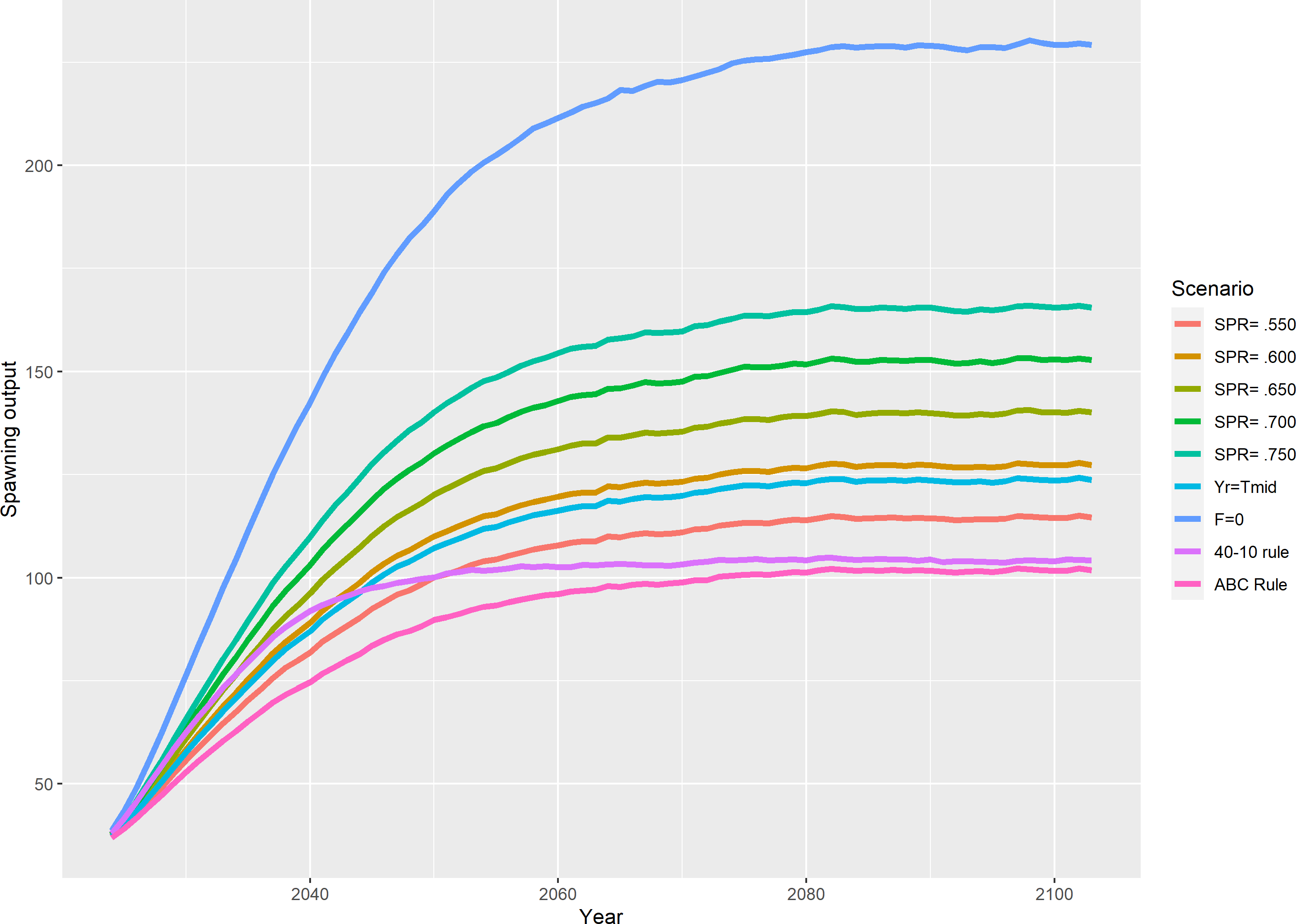
# Figures



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



**Figure 2:** ACLs (mt) by year for alternative rebuilding strategies.



**Figure 3:** Spawning output by year for alternative rebuilding strategies.