Black Rockfish
Stock Assessment Review (STAR) Panel Report

National Oceanic and Atmospheric Administration
Southwest Fisheries Science Center
Santa Cruz Laboratory and Online
110 McAllister Way
Santa Cruz, CA 95060

July 10-14, 2023

Participants

STAR Panel Members

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Martin Dorn, University of Washington
Yong Chen, Center for Independent Experts
Joseph Powers, Center for Independent Experts

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Marlene A. Bellman, Pacific Fishery Management Council representative

Overview

A Stock Assessment Review (STAR) panel was convened on July 10-14, 2023 at the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center in Santa Cruz, California, to review draft stock assessments for black rockfish (*Sebastes melanops*) in Washington, Oregon and California, under the Pacific Fishery Management Council's (PFMC) Terms of Reference for the Groundfish Stock Assessment Review Process for 2023-2024 (PFMC, June 2022). There was an online participation option for STAT members unable to attend in person and to allow for public comment.

Black rockfish are found from the southern Bering Sea and Aleutian Islands to northern Baja California, but are most abundant from Kodiak, Alaska to northern California in depths to 360 m (1200 ft) though they are most commonly found in less than 73 m (240 ft) (Love 2002). Genetic studies have not identified strong genetic structure along the coast, though some degree of differentiation has been identified off of Cape Blanco, Oregon (Lotterhos et al 2014) and between Alaska and the contiguous West Coast of the U.S. (Hess 2023) and between Garibaldi Oregon and Monterey, California (Sivasundar and Palumbi 2010). Despite some evidence of genetic structure along the California coast (Hess 2023), tagging studies by CCFRP presented by the STAT show long distance movement across boundaries identified in genetic studies.

Assessments were structured at state boundaries as well Point Arena, California (Figure 1). Dr. Jason Cope of the Northwest Fisheries Science Center (NWFSC) assessed the stock in Washington and Oregon separately due to the disparate distribution of the primary rocky reef habitat in the south and north of each state, as well as the differing history of exploitation and management. Dr. E.J. Dick of the Southwest Fisheries Science Center (SWFSC) presented assessments of the area north and south of Point Conception within California. These areas within California were assessed separately due to differences in mean length, abundance trends, and exploitation histories observed in each area. In combination, these four assessment areas covered the full range of the black rockfish within the Pacific Coast Groundfish Fishery Management Plan (FMP).

The previous full assessments of Washington, Oregon and California in 2015 were used in management, though there was considerable uncertainty, especially in the Oregon assessment, regarding the overall scale of the stock. The current overfishing limit (OFL) contributions are based on the results of the 2015 stock assessments. The 2023 assessments are fully integrated length and age-structured bench-mark assessments conducted in Stock Synthesis (SS Version 3.30.21.00) using catch, length, age and index data from fishery dependent and independent sources.

In Washington, the primary axis of uncertainty was the log of unfished recruitment (lnR0) associated with the 12.5 and 87.5 percentile of the current spawning output. For the Oregon assessment, the primary axis of uncertainty involved the treatment of the acoustic-visual survey (AV) catchability (q). The upper state of nature used the pre-STAR reference model that forced the model trajectory through an AVq of 1.8, considered by the STAT as the largest plausible value and the lower state of nature from a freely-estimated AVq with the model including length composition data, presenting a more pessimistic model outcome. For both California models, the primary axis of uncertainty was female natural mortality (M), described by a lognormal distribution with median equal to the posterior mode of the northern base model (0.21 yr^{-1}) with log-scale standard deviation equivalent to the prior (0.31). Lower and upper states of nature were defined as the 12.5 and 87.5 percentiles of this distribution, though steepness was also considered for a potential bi-variate axis of uncertainty.

Management measures put in place in the 1990s and 2000s to reduce exploitation rates as well as strong recruitment around 2000, then again in 2008 and 2010 have bolstered the population contributing to the increased status observed over the last two decades in each of the assessments, though recent recruitment has appeared to weaken and a downward trend is emerging in California. While strong recruitment has likely contributed to the moderate catch observed in each state in recent years, longer seasons with the rebuilding of canary rockfish in 2015 and progress in rebuilding yelloweye rockfish are also contributing to recent catch. Access to deeper depths than the primary depth distribution of black rockfish has resumed in some areas, and may reduce future catch to greater or lesser extent among states. All stocks are either in the precautionary zone (25-40% of unfished spawning stock output) or slightly above target biomass (>40% of unfished spawning stock output). A summary of the management reference points and parameters across assessments are provided in Table 1.

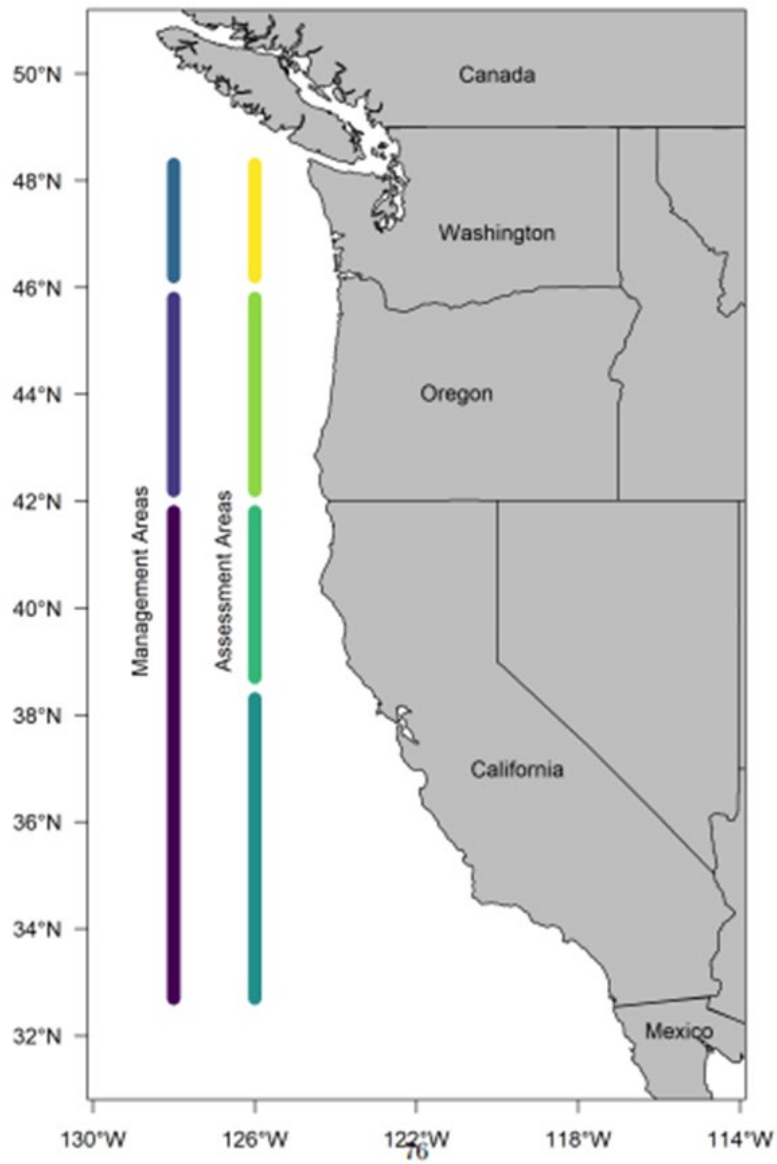


Figure 1. Assessment areas for black rockfish in 2023.

Table 1. Parameters and management reference points across black rockfish assessment areas. Values in standard text are estimated and those in italics are fixed. The natural mortality parameters for Central California are fixed at the estimated values from the northern California model (the assessment with the majority of available age data).

Model Parameters	Washington	Oregon	Northern California	Central California
M_female	*0.17*	*0.19*	*0.210*	*0.210*
L_inf Female	*52.73*	*51.00*	*57.073*	*57.577*
VonBert_K_Fem	*0.12*	*0.182*	*0.148*	*0.145*
M_male	*0.152*	*0.17*	*0.200*	*0.200*
L_inf Male	*47.65*	*46.04*	*47.762*	*50.542*
VonBert_K_Male	*0.14*	*0.220*	*0.202*	*0.186*
LN(R0)	7.58	8.104	7.718	6.473
h	*0.72*	*0.72*	*0.72*	*0.72*
sigma_R	*0.6*	*0.6*	*0.6*	*0.6*
Derived Parameters				
B0	943.88	1445.09	1126	324
FracUnfished (2023)	45%	43%	36%	42%
OFL_FSPR (2023)	266.12	372.05	204	48.5
MSY_SPRproxy	275.88	406.67	265	65

Washington Model

Summary of Data and Assessment Models

Black rockfish have historically been caught in the recreational, non-trawl and trawl fisheries in Washington. The nearshore waters where they are most frequently encountered have been closed to commercial hook and line fishing since 1995 and trawl fishing since 1999. The catch in the recreational fishery increased in the 1980s and is currently the primary contributor, with negligible bycatch in the commercial fisheries. The assessment included data from trawl, non-trawl and recreational fleets, six abundance indices, length composition data from fisheries and surveys and conditional age-at-length composition from the commercial and recreational fisheries from 1940-2022 (Figure 2).

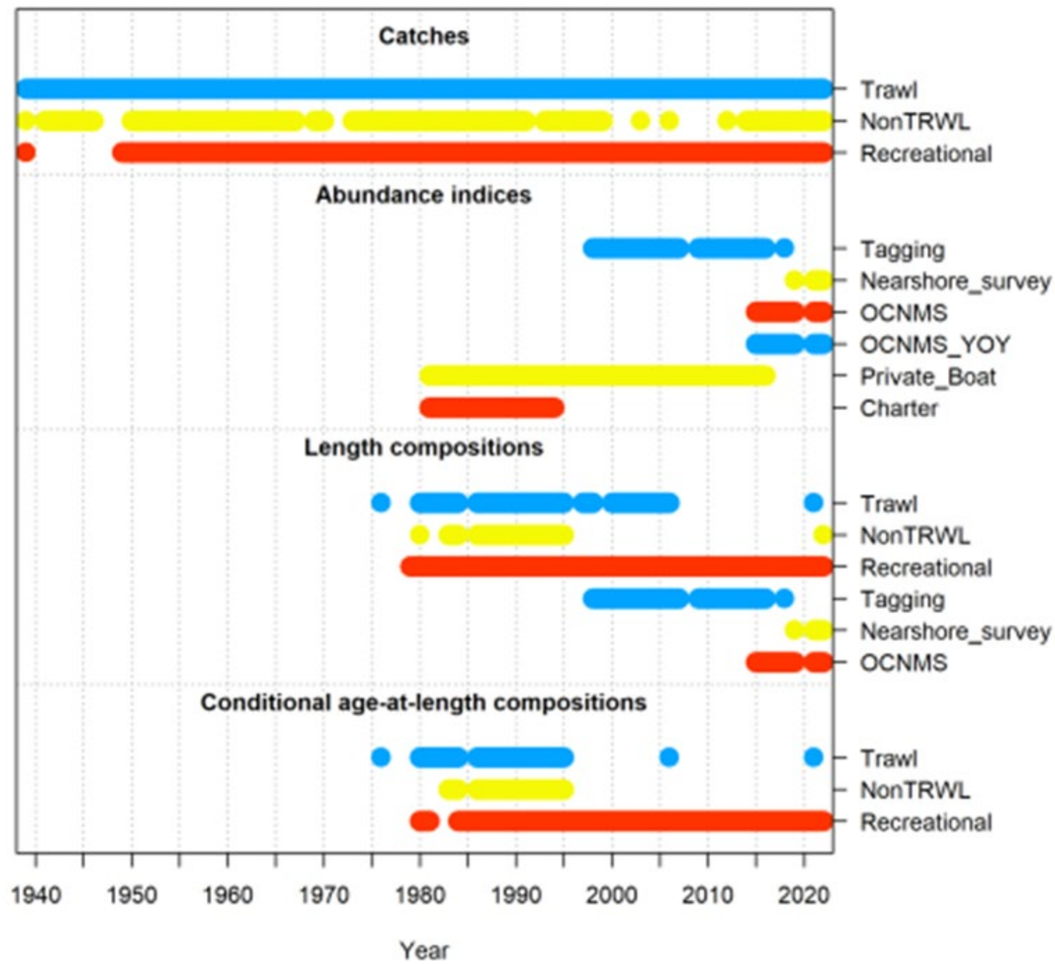


Figure 2. Summary of the sources and temporal availability of data used in the base model.

Commercial landings of black rockfish prior to 2006 when species-specific sorting requirements were put in place, were sorted into mixed-species market categories, though species composition sampling was not implemented until 2000, thus parsing historical landings from grouped market categories presented uncertainty in the historical catch. In addition, fish caught in the trawl fishery off of Washington by vessels fishing out of Astoria, Oregon presented uncertainty in the commercial catch time series. Analysis of samples collected from 1976-1993 by Oregon Department of Fish and Wildlife (ODFW) estimated 98.6% of trawl landings in Astoria were caught off of Washington, which was applied to all trawl landings in Oregon's Columbia River District ports prior to 1976 assuming 3-4% were black rockfish pre-1981 and 1981-1986, with 65-100% of estimated black rockfish landed in these ports accounted for in Washington's catch history. Conversely, Washington Department of Fish and Wildlife (WDFW) estimated catch harvested off of Oregon but landed in Washington were less than 1 mt per year from 1971-2014, which is relatively negligible. Thus all landings to Washington ports were assumed to have originated from waters off of Washington. A revised catch reconstruction was also provided for the recreational fishery.

The primary source of fishery-independent length and age data for Washington black rockfish is the recreational fishery from 1979-2022. The largest fish were observed in the commercial trawl fishery, followed by the non-trawl fishery, with the smallest fish observed in the recreational fishery. The data were stratified by fishery and sex. Data from WDFW's Ocean Sampling Program provides data on catch and effort used to provide an index of abundance for 1981 to 2022 using a delta-GLM approach. The data for the private fleet and charter fleets provided two separate indices. Bag limit and depth restriction changes were addressed as covariates in addition to year, month and area for the private fleet providing an index for 1981 to 2016, since large bag limit restrictions were put in effect in 2017 affecting comparability to the earlier time series. The charter index included year, month, area, daily bag limit and depth restrictions as covariates, providing a time series from 1981-1994, given the reduction to 10 fish in 1995.

The assessment included two fishery-independent data sources. The Black Rockfish Tagging Program conducted from 1981-2022 and nearshore survey data from 2018 to 2022 provide lengths and an index of abundance. The tagging program provides data on releases off the central coast of Washington in Marine Area 2 after 1998 until 2010 when it was expanded the length of the coastline, until it was terminated in 2014. A coastwide rod-and-reel survey was initiated in 2019 targeting semi-pelagic rockfish at 125 fixed stations, with five anglers deploying two shrimp files over rocky habitat at the station three times. A combined index was considered given the similarity in data types, but the two surveys were treated separately in the base mode given a change in the trajectory between the two surveys. A hurdle negative binomial regression model was used to generate indices of abundance for both data sets, with the tagging data filtered to include only sites within 1 km of the central coast tagging in Region 2 where data was consistently sampled. Apart from the aforementioned indices, the Olympic Coast National Sanctuary (OCNMS) provided SCUBA strip surveys for adult and young of year fish <10 cm interpreted as an index of recruitment.

The precipitous decrease in old females after age 20 compared to males still found into their 30s and 40s presents an uncertainty as to whether the older females were not available (i.e. hide'em) or that female natural mortality was appreciably higher (i.e. kill'em), presumably due to increased reproductive stress. The latter was believed most plausible and in past assessments, addressed this through a ramp in natural mortality for females. The Natural Mortality Tool from applying Hamel and Cope (2022) longevity-based estimator examining expected mortality for varying maximum ages was explored for this assessment. In the end, this assessment fixed natural mortality to the values of 0.17 for females and 0.152 for males from the last assessment, as those were still deemed reasonable estimates given potential longevity.

Females reached a greater maximum age than males, thus the model was structured for two sexes, with natural mortality and growth parameters estimated along with recruitment. Sex-specific growth parameters were estimated external to the model. The parameter t_0 was fixed in the base model since estimation led to extremely high current biomass values, while L infinity and k were estimated. Ageing error was addressed using matrices developed by Punt et al. (2008) to calculate bias and precision in age reads among age readers. Additional data and parameters included weight-at-length, maturity-at-length, fecundity-at-length, and steepness (h) fixed at the 2017 Thorson-Dorn rockfish prior of 0.72, recruitment variability ($\boldsymbol{\sigma}_R$ = 0.6), as well as ageing error.

Functional maturity was estimated to account for abortive maturation, skipped spawning and follicular atresia as opposed to biological maturity only considering physiological development. The functional maturity relationship was fit using a flexible spline using data from collaborative sampling with ODFW, WDFW, Oregon State University (OSU), and NWFSC to estimate the L50% for functional maturity accounting for declines from the asymptote from skipped spawning in the maturity ogive. Fecundity at length was based on research by Dick et al. (2017).

Two ageing error matrices were used to incorporate ageing imprecision. Fixed parameterizations of weight-at-length, maturity-at-length and fecundity-at-length, a Beverton-Holt stock-recruitment steepness value and recruitment variability were incorporated into the model. The model included sex-specific life history (two-sex model) with natural mortality fixed at estimates from the previous assessment, and most growth and recruitment parameters were estimated. In addition, parameters for initial population scale ($ln\mathrm{R}_0$), selectivity for each fishery and survey, and added survey variance were estimated. The base model was tuned by weighting length and age data, index variances and recruitment bias adjustments. The time series of spawning biomass, age and size structure, and current and 12 year projected future stock status were derived from the model.

Five primary likelihood components were examined including fits to survey indices of abundance, length composition samples, age composition samples, penalties on recruitment deviations and prior distribution penalties. Model configurations for data types, parameter treatments, phasing of parameter estimation, data weighting and exploration of local vs. global minima were examined. Exploration of sensitivities to estimate or fix M, growth parameters for each sex, the stock-recruitment relationship, catchability for each survey, selectivity parameters, as well as estimating or assuming constant recruitment, exploring logistic and dome-shaped selectivity, and estimating additional survey variance were all undertaken. No priors were estimated except female L_∞. Length-at-maturity, fecundity-weight, and length-weight relationships, steepness and recruitment variance were all fixed. Convergence was achieved as evidenced by inverting the Hessian, reasonable parameter values, and acceptable fits to the data. Jittering was conducted to ensure a global optimum was reached. No strong retrospective pattern was observed.

Parameter estimation uncertainty is used to determine within model uncertainty while among model uncertainty was explored through sensitivity analyses of data treatment and weighting assumptions and sensitivity to life history parameters, selectivity, recruitment and survey catchability. Selectivities for all fisheries were estimated as logistic even if dome-shaped selectivity was an option. More contrast was observed in the age data than the length data, with the age data indicating a more pessimistic outcome. The dockside private fleet index of abundance had the longest time series and was best fit showing an increasing trend, while the dockside charter fleet index showed a negative trend. The tagging study and nearshore survey showed poor overall fits. The OCNMS adult dive survey was not well fit, though the young-of-the-year (YOY) survey shows concurrence with the reference model. Sensitivity analyses were conducted for data treatments, life history parameters and data weighting specification of life history parameters and selectivity. Estimated values included initial population scale (lnR_0), growth, asymptotic selectivity, and recruitment deviations. The derived quantities included spawning output, age and size structure and current and projected stock status.

The reference model that best fit the observed data and balanced the central tendency across sources of uncertainty, ensured model realism and tractability, and promoted robustness to potential model misspecification was selected. The panel recommends the Washington black rockfish assessment as the best available science and considers it a suitable basis for management decisions. The panel applauds the STAT team for thorough evaluation of the uncertainties and clear presentation of modeling considerations in the documentation and at the STAR panel meeting.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: Compare functional maturity by year to evaluate possible temporal variation. Fit the curve and represent the L50 estimates, provide by year.

Rationale: Functional maturity is likely to respond to changes in biotic and abiotic environments, implying that it may vary over time. A comparison over time would help us understand possible temporal variability and improve the estimation of spawning output in the stock assessment.

STAT Response: We compared functional maturity by year to evaluate temporal variation. Functional maturity status observations (0 = immature and 1 = mature, n = 644) were fitted in a multiple logistic regression model with length and year (glm function, family = binomial, link = “logit”). The estimated model parameters were used to calculate length at 50% maturity by year ($L_{50\%}$; Table 2) and maturity ogives by year (Figure 3). The delta method was used to calculate 95% confidence intervals for estimated $L_{50\%}$ in the logistic regression.

We found that maturity varied year-to-year. The $L_{50\%}$ value provided for the assessment falls central to the range of $L_{50\%}$ values by year and is consistent with the $L_{50\%}$ values estimated for years with the highest sample sizes. In the future, more research is needed to explore potential drivers of time-varying maturity, such as ecosystem and population dynamics, for Black Rockfish and other species in the California Current ecosystem.

Table 2. Estimated functional length at 50% maturity ($L_{50\%}$), 95% CI, and sample size (*n*) by year (logistic regression).

Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**All samples**
$L_{50\%}$	44.09	40.95	39.35	42.78	38.25	40.16	38.57	40.36
95% CI	42.27, 45.91	40.27, 41.63	38.72, 39.99	41.28, 44.28	36.72, 39.78	39.47, 40.85	37.75, 39.38	39.89, 40.83
n	50	150	157	32	28	133	94	644

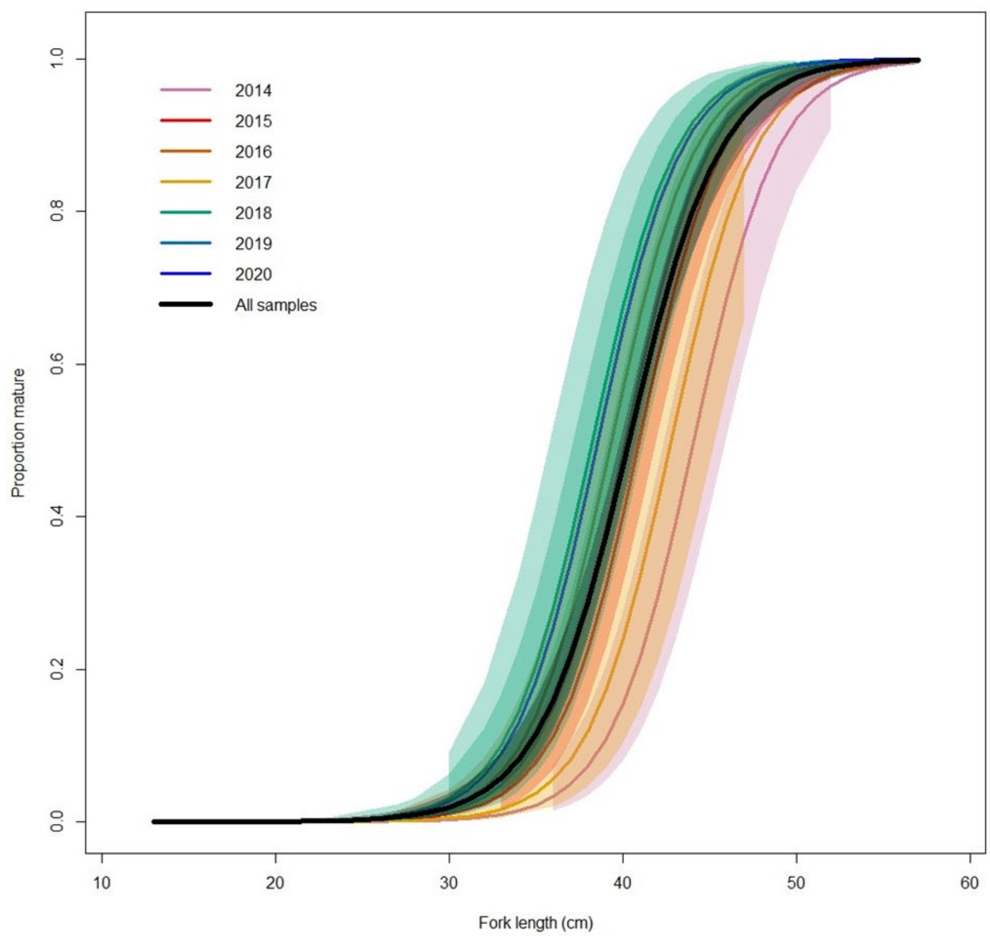


Figure 3. Functional maturity ogives by year. Functional maturity ogives and 95% CI are color-coded by year, with the functional maturity estimated with data from all years in black.

Panel Conclusion: Interannual variation is present in the results, though sample sizes may be somewhat limited. The underlying drivers of the patterns observed would need to be better understood before accounting for them in future modeling efforts. The time period encompassed the “warm blob” phenomenon that is anomalous and deviates from the range of typical variation. The panel expresses support for additional research into functional maturity and variation with time/environmental drivers.

Request No. 2: Attempt to estimate natural mortality (*M*) and steepness (*h*) concurrently, given the potential interactions and plot relationship. For steepness, between 0.3 and 1.0 with a reference at 0.72. For *M*, use the lower and upper end.

Rationale: The sensitivity analyses included in the current stock assessment only change *M* or *h* at once. However, *M* and *h* tend to be highly correlated. An examination of LL (log likelihood) values under a varying M and h (over a reasonable range) would help us understand how they interact and how they may influence the assessment of population dynamics.

STAT Response: Steepness is not estimable (*h* estimated at 1), and it was deemed the estimated *M* values (female *M* = 0.143; male *M* = 0.115) are very low. These are both true when attempting to estimate both parameters together (Figure 4). The likelihood profile outputs when estimating natural mortality shows how biomass goes down, relative stock status increases (Figure 5), and how natural mortality is negatively correlated with steepness (Figure 6).

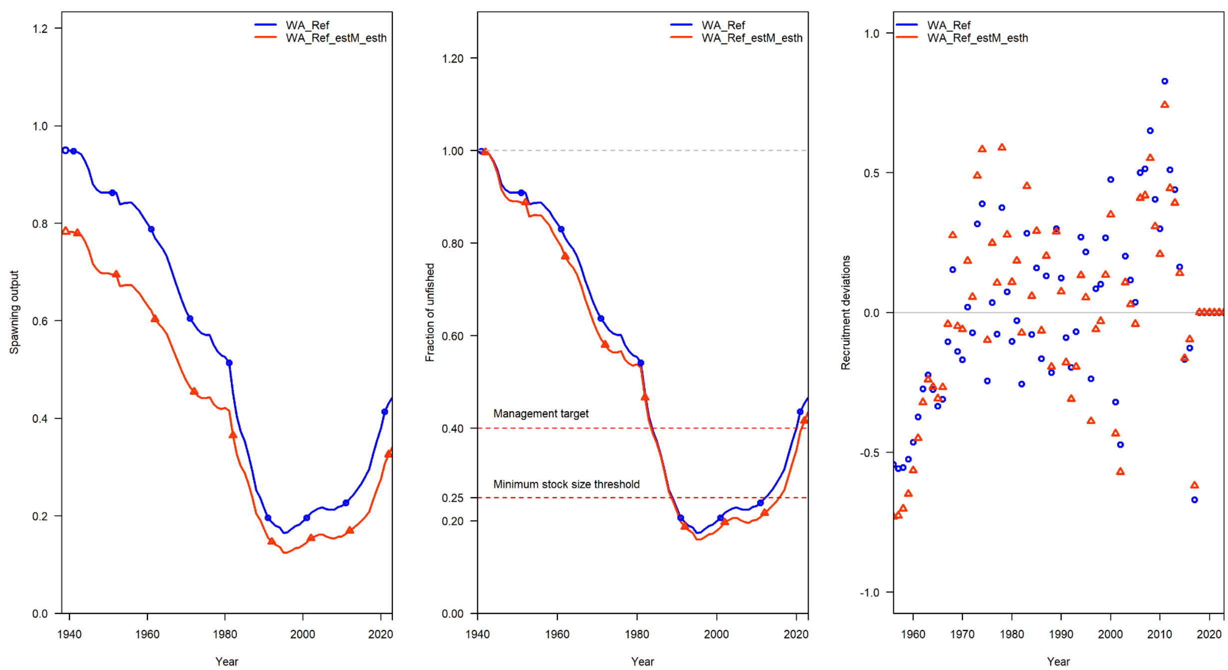


Figure 4. Comparison of spawning output, relative stock status, and recruitment deviations when estimating both *M* and *h* compared to the reference model that fixes both.

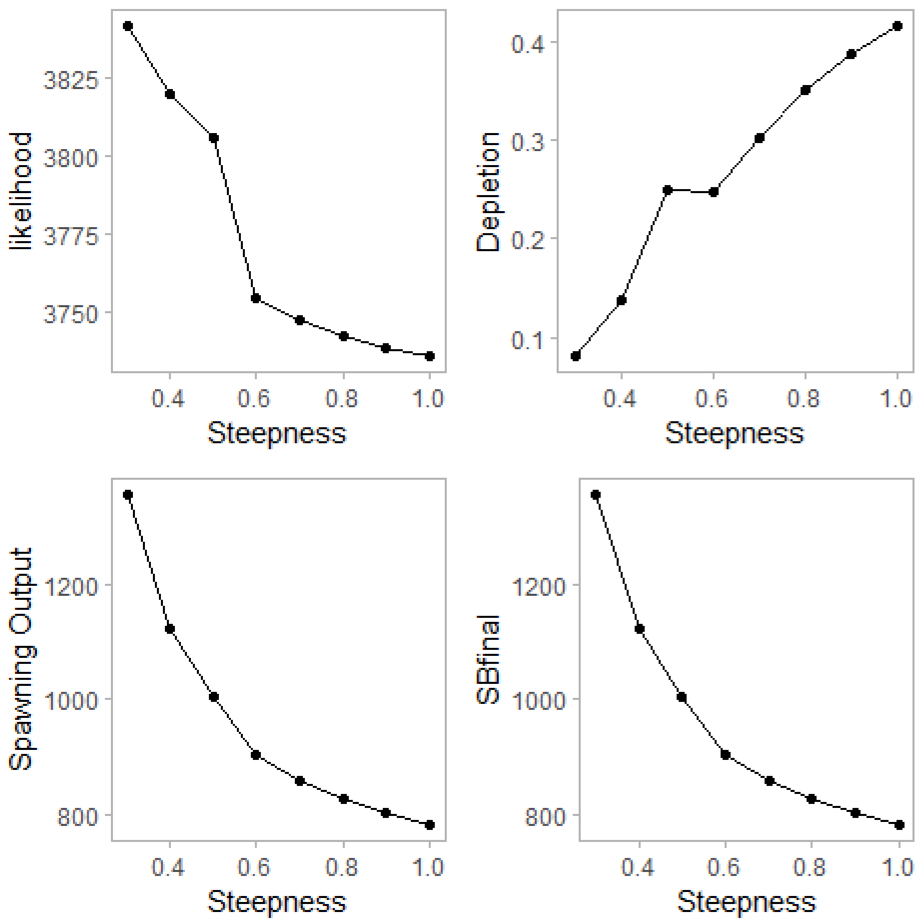


Figure 5. Likelihood profile and derived model outputs when profiling across steepness while estimating sex-specific *M*.

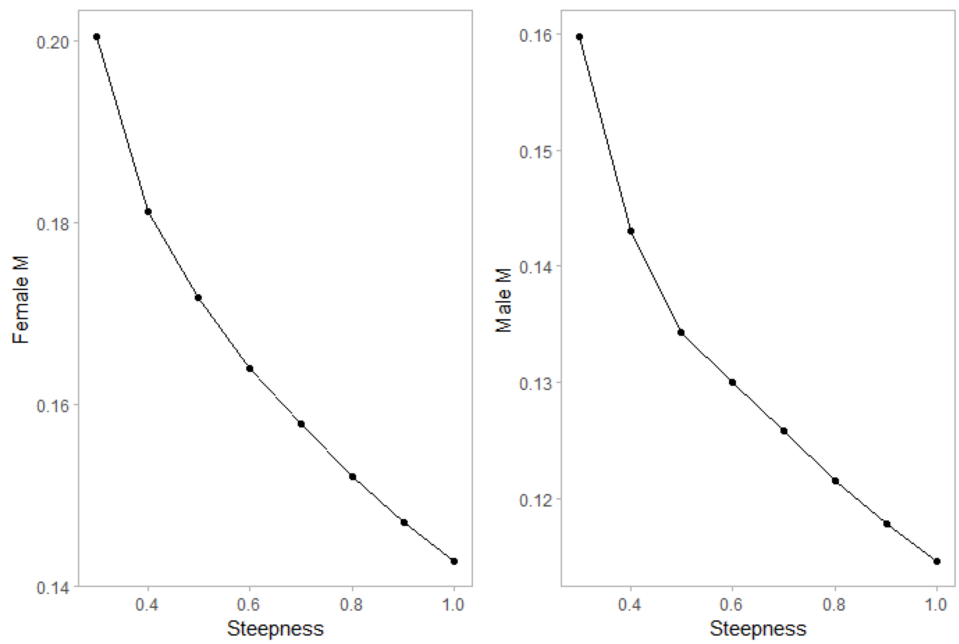


Figure 6. Estimating values for female and male *M* when profiling over steepness.

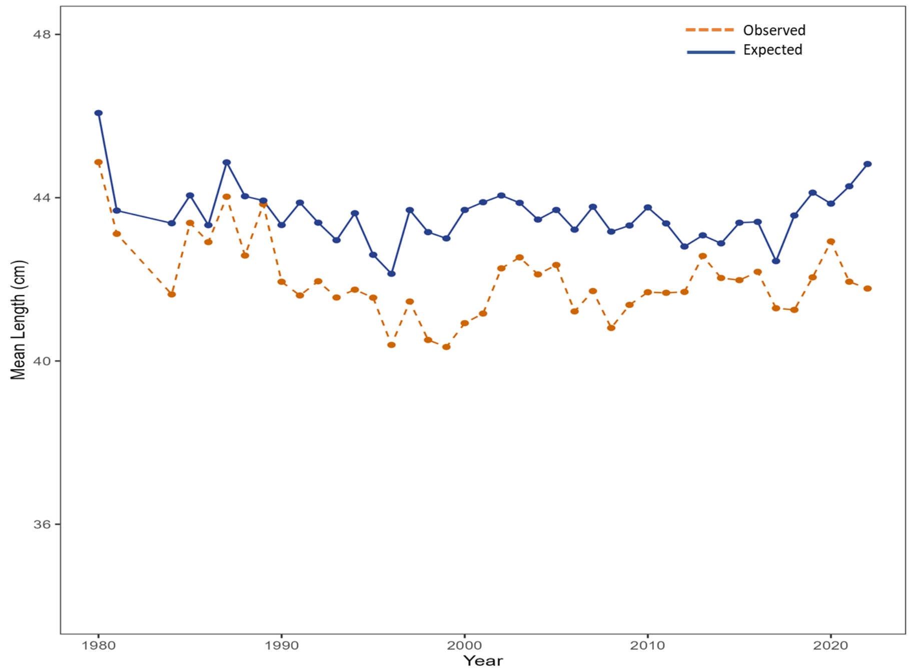
Panel Conclusion: Natural mortality is inversely related to steepness, and affected scale and depletion. The result is consistent with expectation.

Request No. 3: Compare variation over time in mean length estimated from mean age and see if it is declining as seen in the length data.

Rationale: The age composition should be consistent with the length composition data, which should show similar temporal trends if the samples are representative. Most of the ages are coming from the charter boat fleet in Area 2.

STAT Response: Mean ages are available both as observed (input) and expected (model fit). Each type of mean age by year was converted to a length value ("mean length") using the von Bertalanffy growth function parameters used in the reference model to estimate length from age. Figure 7 shows those "mean" lengths by year for each use of the age data.

Females



Males

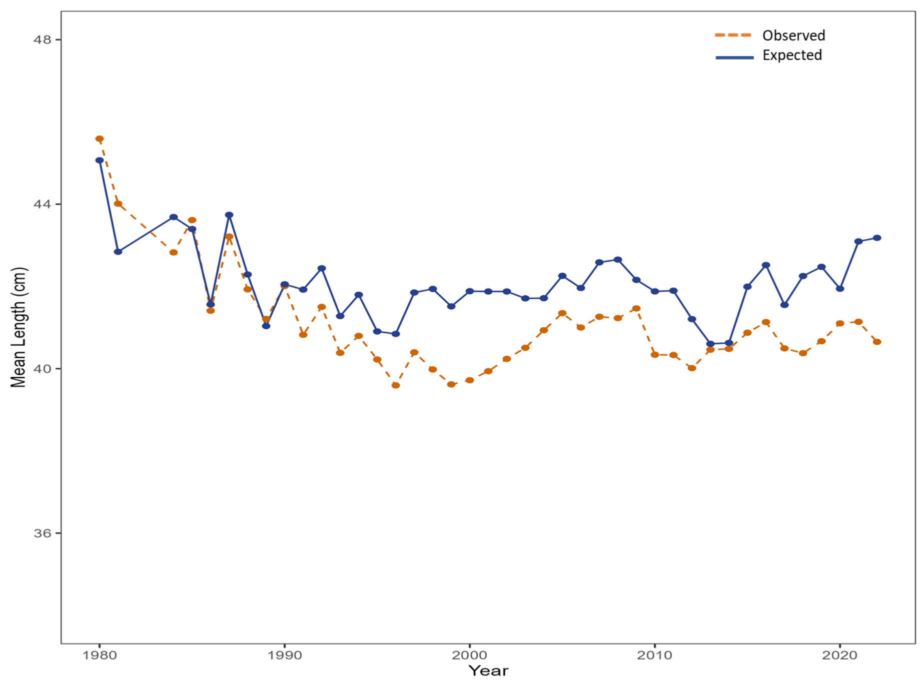


Figure 7. Expected and observed mean length coming from the expected and observed mean ages from the reference model for females (top panel) and males (bottom panel).

Panel Conclusion: Deviation of the observed and expected mean length derived from the length data indicate there are differences between the lengths and the lengths from age data. The initial decline is observed in both observed lengths and expected lengths from mean age resulting in consistent patterns.

Request No. 4: Show the retrospective pattern for recruitment.

Rationale: Recruitment estimation for recent years is critically important in projection. It is important to understand their possible retrospective errors.

STAT Response: Figure 8 shows the recruitment retrospective pattern**.**

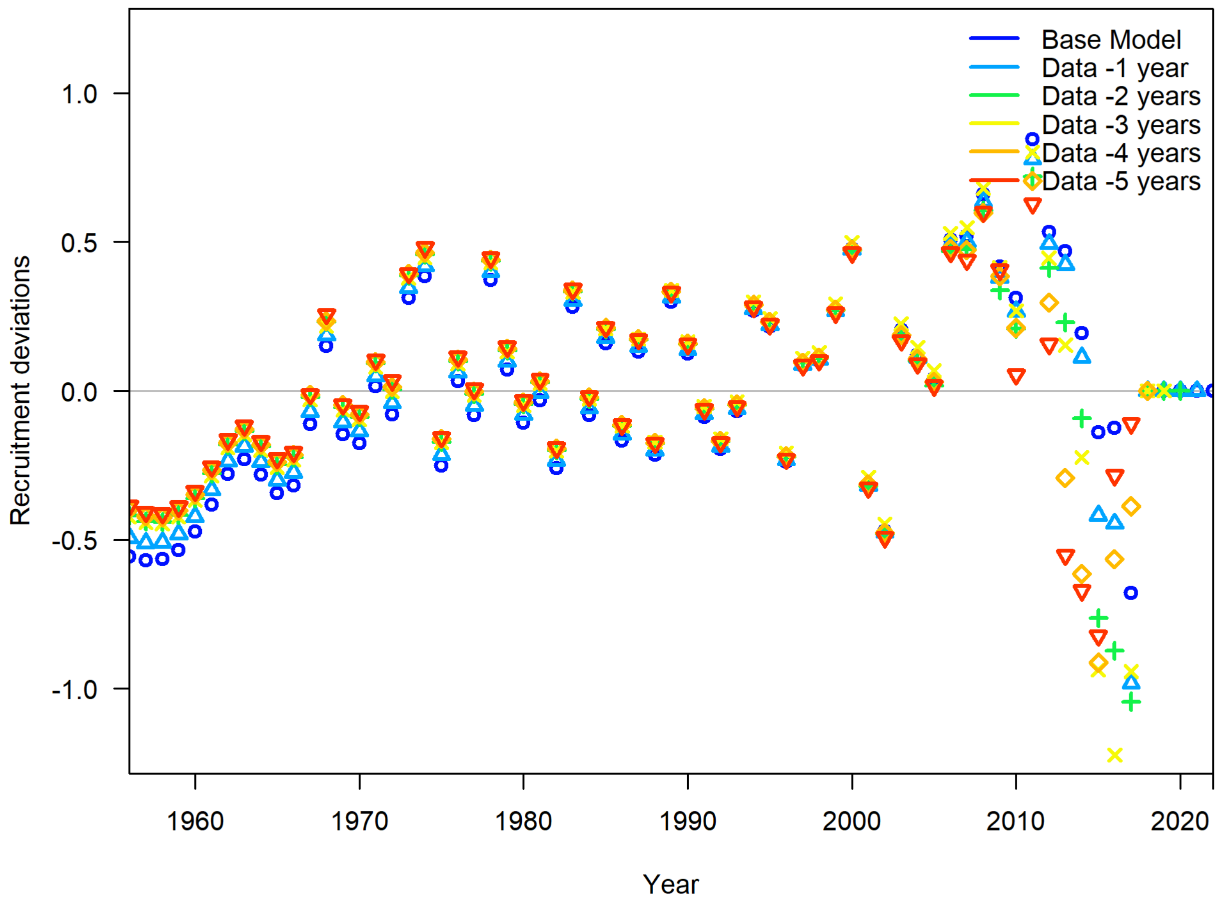


Figure 8. Recruitment deviations for the 5 year data peel in the retrospective analysis.

Panel Conclusion: Peeling back beyond three years begins to remove data sources not available in the earlier time series resulting in increased deviations. This plot should be included in future assessments.

Request No. 5: Please include clarification regarding the Mohns rho results and what they represent; over a 5 year average as stated in the TOR. Provide a plot to show relative error in ending biomass consistent with best practices described in Legault (2009).

Rationale: There are multiple options for calculating Mohns rho in r4ss and thus it is important to understand the mechanism being used. Retrospective error is a particular type of uncertainty and it is important to understand any bias.

STAT Response:
Mohn's Rho:

SSB	-0.174
Recruitment	0.034
Fraction unfished	-0.113

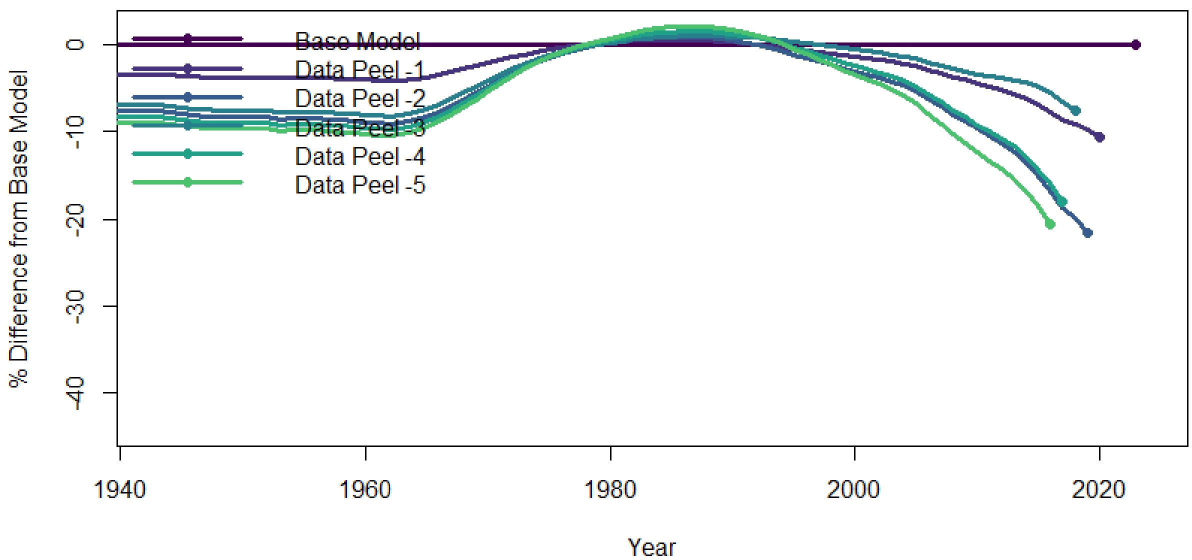


Figure 9. Relative error (Mohn's rho) for each data peel in the retrospective analysis.

Panel Conclusion: This level of retrospective error is within a reasonable range and not a major concern for the assessment. This type of plot should be included in all assessments.

Request No. 6: Provide a model run for comparison to the base model where the additional variance option is turned off for all surveys.

Rationale: To examine the effect of additional variance on overall model results, given the guidance to be sparing in the use of this option.

STAT Response: Comparison is provided in Figure 10. Fits to the private boat index, as well as the very small variance inputted into the model for that index (thus justifying additional variance), are shown in Figure 11.

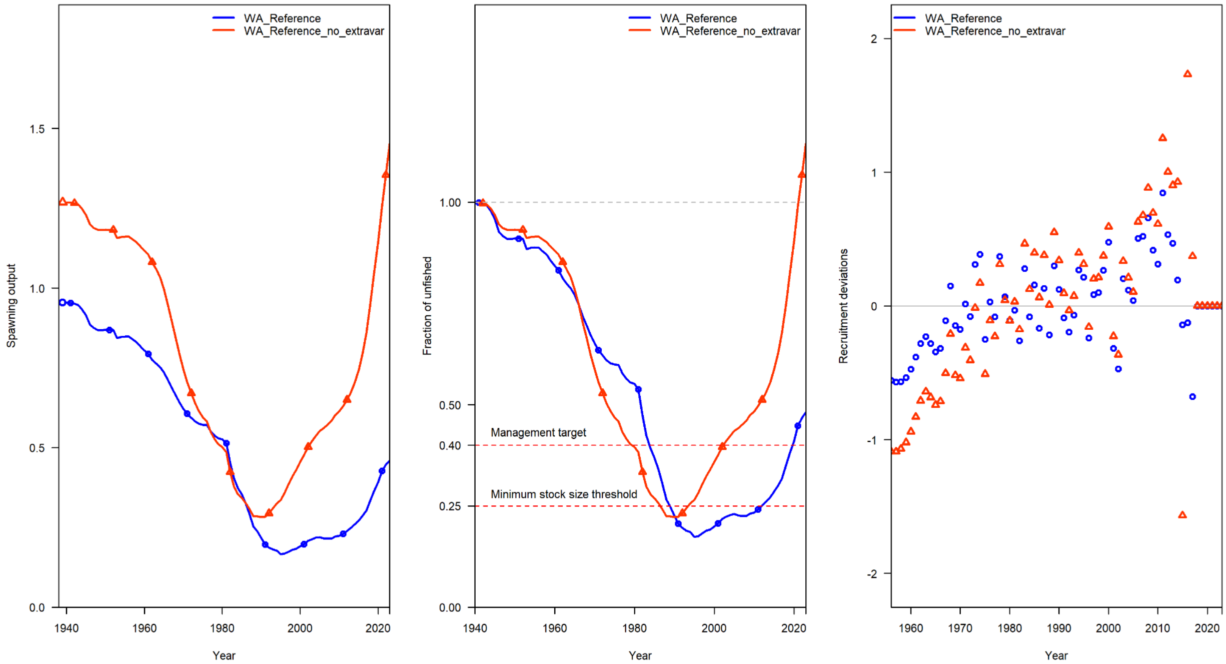


Figure 10. Comparison of spawning output, relative stock status, and recruitment deviations when no additional variance is added to the index uncertainties compared to the reference model that fixes both.

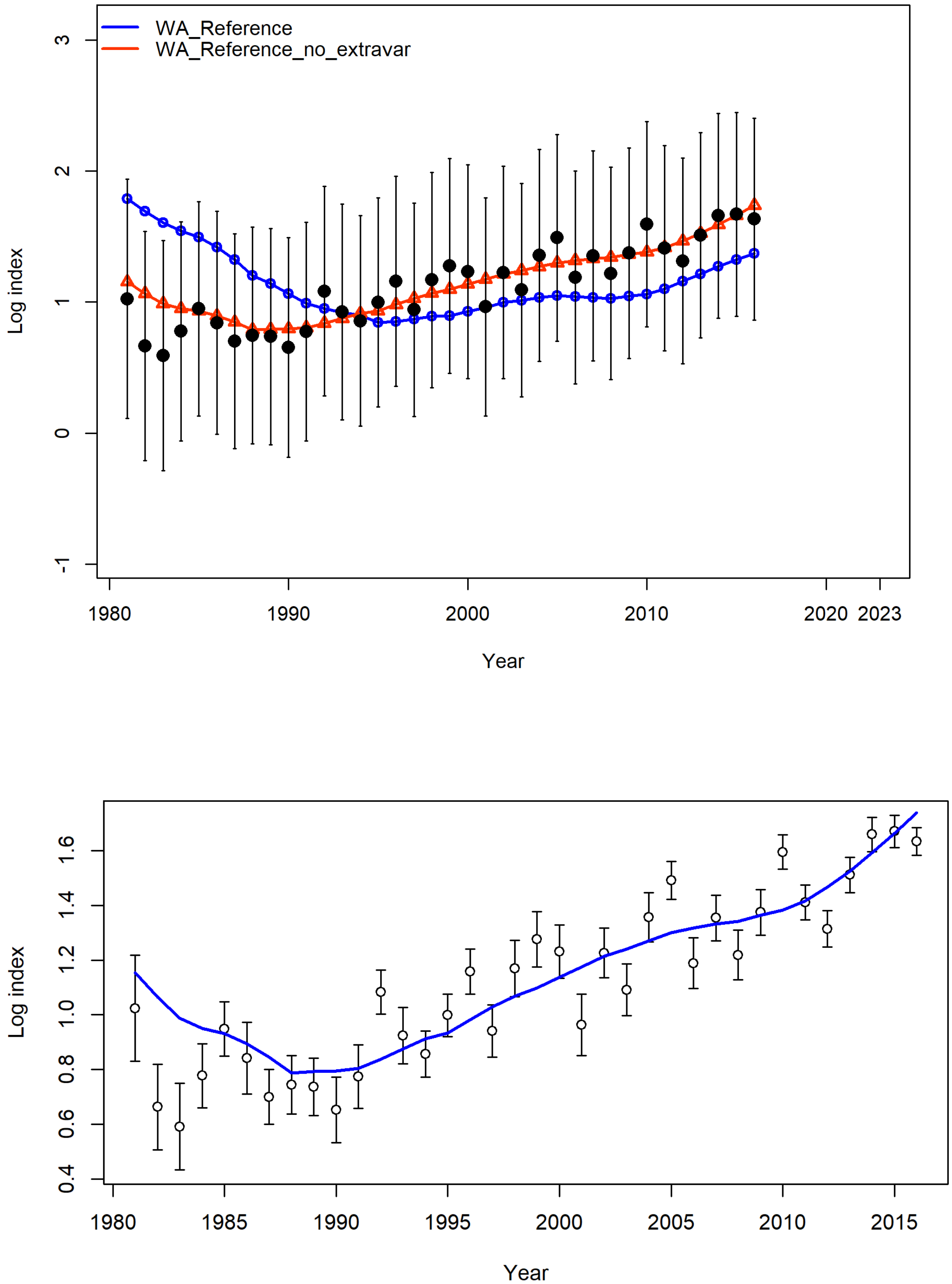


Figure 11. Fit to the private boat fleet index with and without additional variance. Without added variance, the input CVs (coefficient of variation) are very low (<5%; bottom panel).

Panel Conclusion: Turning off the additional variances greatly increased the spawning output and percent unfished relative to the reference model. Recruitment patterns were still similar. The more aggressive upward trend in the private boat index with unreasonably low variance gave more weight to the index with a more positive trend. Adding additional variance reduced the fit to the private boat index and others. It is not clear which index to turn off extra variance. The increasing trend in the depletion during the period of highest exploitation makes the resulting trend implausible. One by one addition of variance may be the most pragmatic approach to future exploration rather than turning extra variance off.

Request No. 7: Conduct a likelihood profile over natural mortality with all growth parameters estimated.

Rationale: To explore the tension between the length data and age data when attempting to estimate natural mortality.

STAT Response:

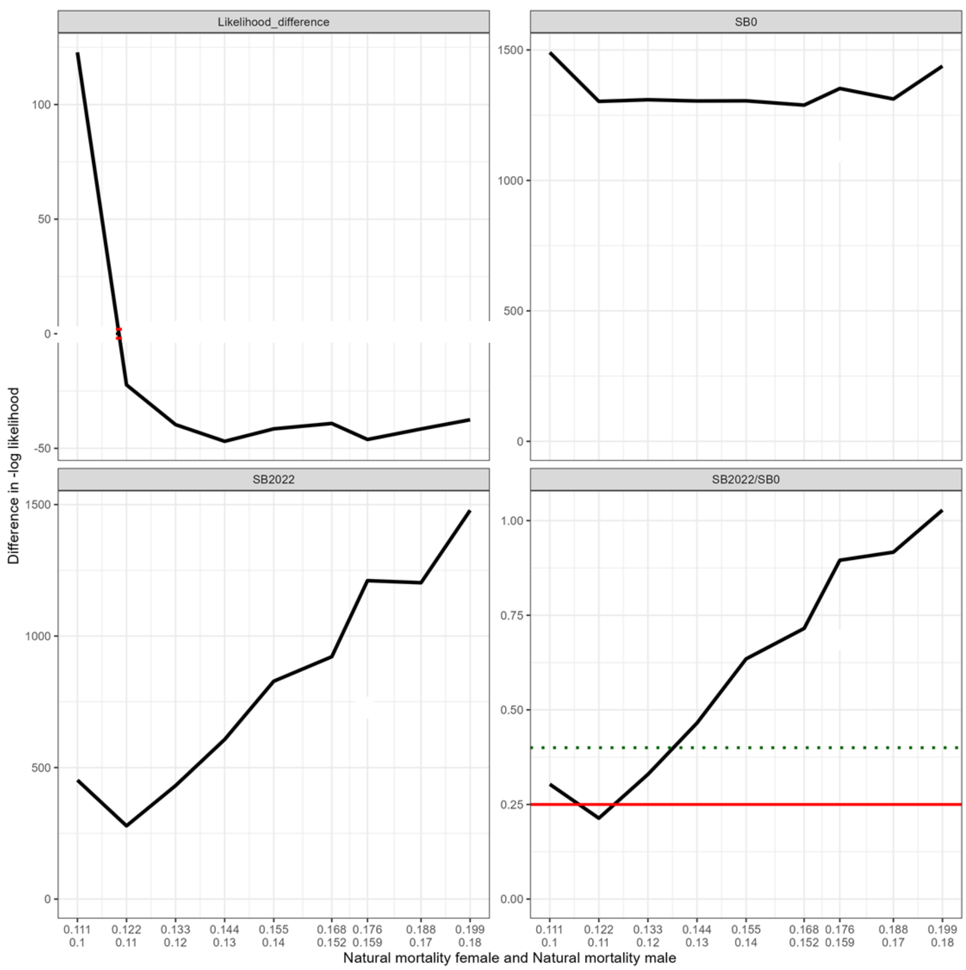
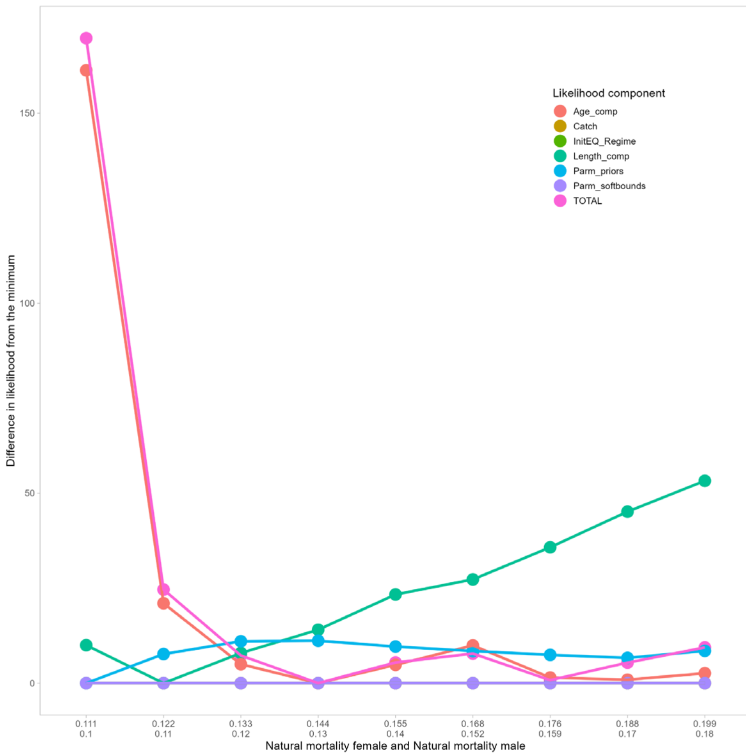
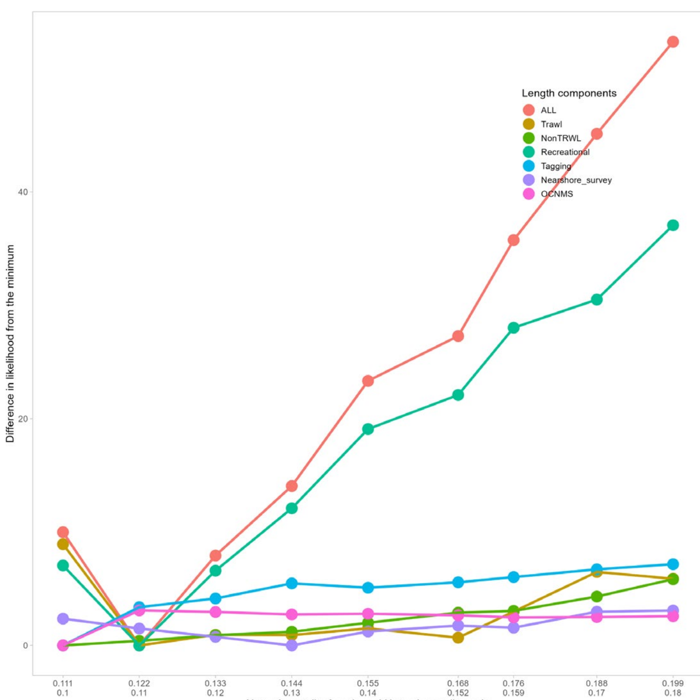


Figure 12. Likelihood profile over sex-specific natural mortality when all growth is estimated.


Likelihood component
Age_comp
Catch
InitEQ_Regime
Length_comp
Parm_priors
Parm_softbounds
TOTAL
Difference in likelihood from the minimum
0
50
100
150
0.111 0.1
0.122 0.11
0.133 0.12
0.144 0.13
0.155 0.14
0.168 0.152
0.176 0.159
0.188 0.17
0.199 0.18
Natural mortality female and Natural mortality male


Length components
ALL
Trawl
NonTRWL
Recreational
Tagging
Nearshore_survey
OCNMS
Difference in likelihood from the minimum
0
20
40
0.111 0.1
0.122 0.11
0.133 0.12
0.144 0.13
0.155 0.14
0.168 0.152
0.176 0.159
0.188 0.17
0.199 0.18
Natural mortality female and Natural mortality male

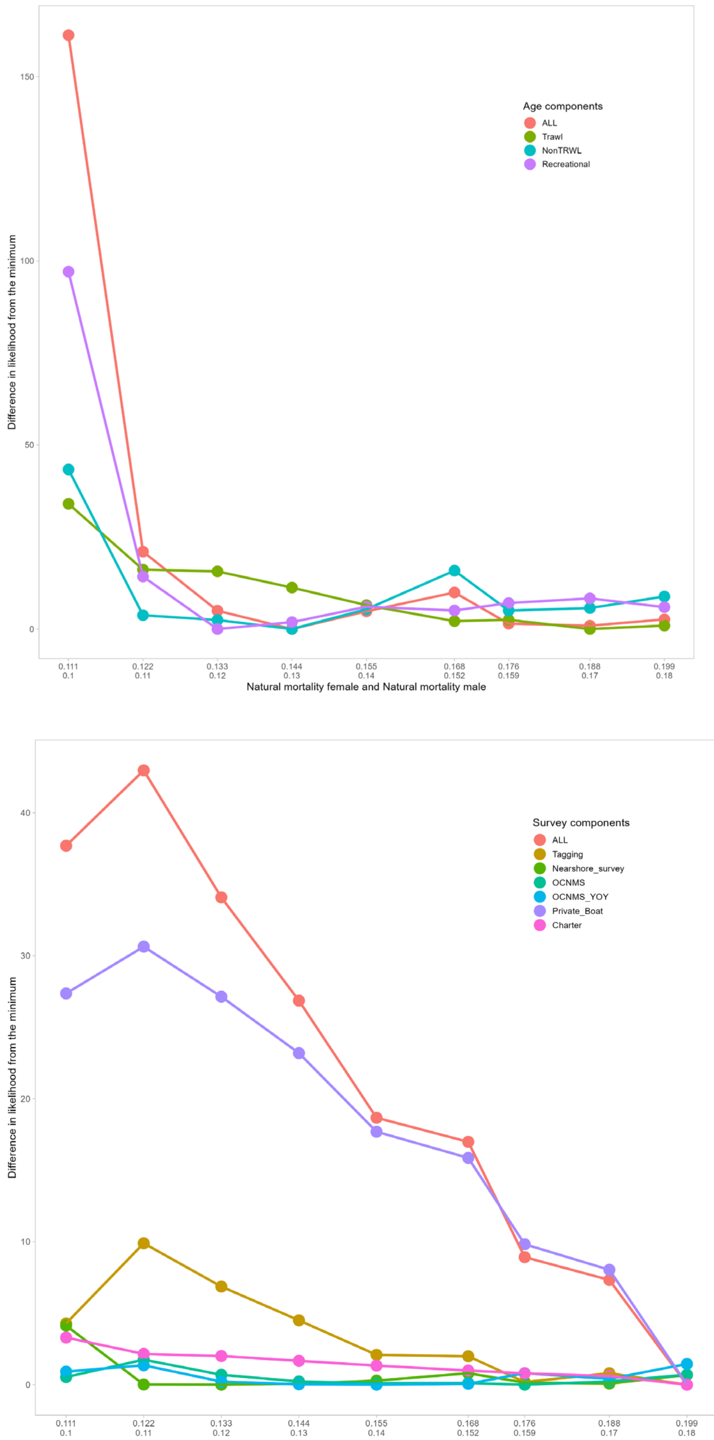


Figure 13. Likelihood component profiles (top panel all component; second to top are length components, second to bottom are age components; bottom panel are index components) across sex-specific natural mortality values when all growth parameters are estimated.

Panel Conclusion: There were very large gradients and lack of model convergence. Indices fit best at natural mortality rates that were considered implausible. The model with estimated growth parameters becomes unstable suggesting that the current approach to modeling growth was appropriate.

Request No. 8: Provide a sensitivity analysis comparing the results of the sexes as separate (Option 2) or combined (Option 3) in stock synthesis and overlay the results for depletion, scale and recruitment. Identify any notable changes to the fits to model data.

Rationale: To evaluate the implications of the alternative settings for the results of the assessment.

STAT Response: Larger increase when using sex = 3 option, but within uncertainty of the current model.

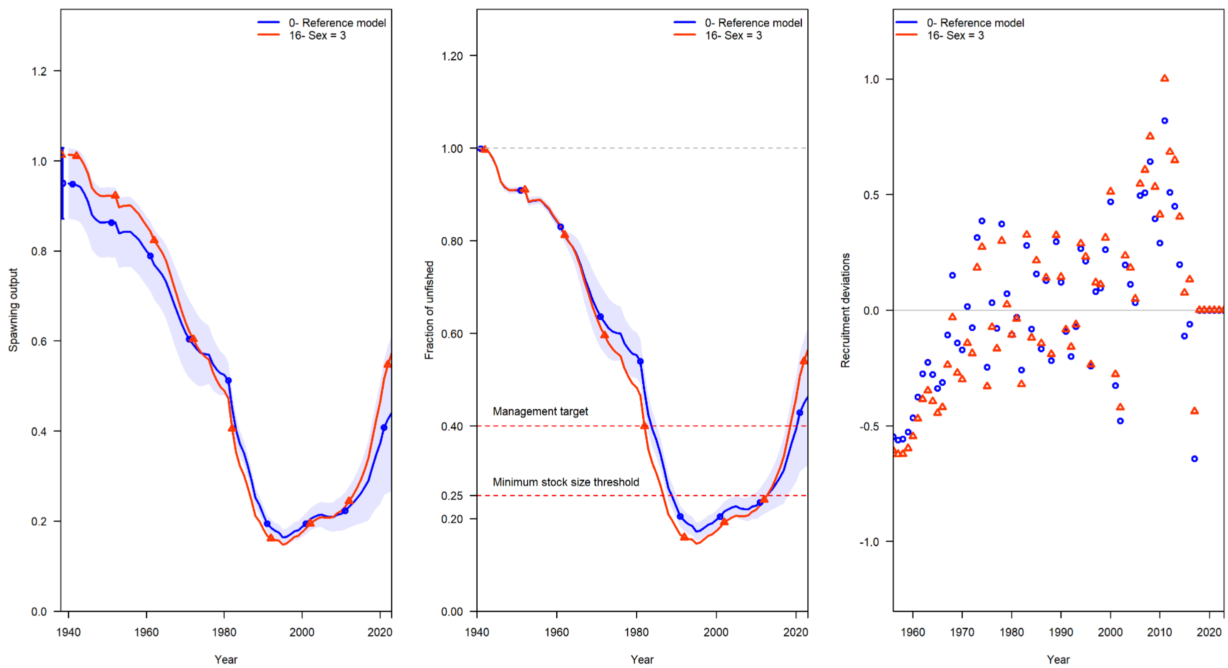


Figure 14. Comparison of spawning output, relative stock status, and recruitment deviations when using the sex = 3 option compared to the reference model that fixes both.

Panel Conclusion: The two settings resulted in similar trends, though the terminal year biomass and depletion were higher for Option 3. The panel does not recommend changing the reference model to reflect Option 3. There are a variety of ways that these options are utilized in different stock assessments on the U.S. West Coast, but there is no general guidance about which approach is best and in what circumstances. The Panel appreciates the STAT response and concludes that the approach in the current model is acceptable.

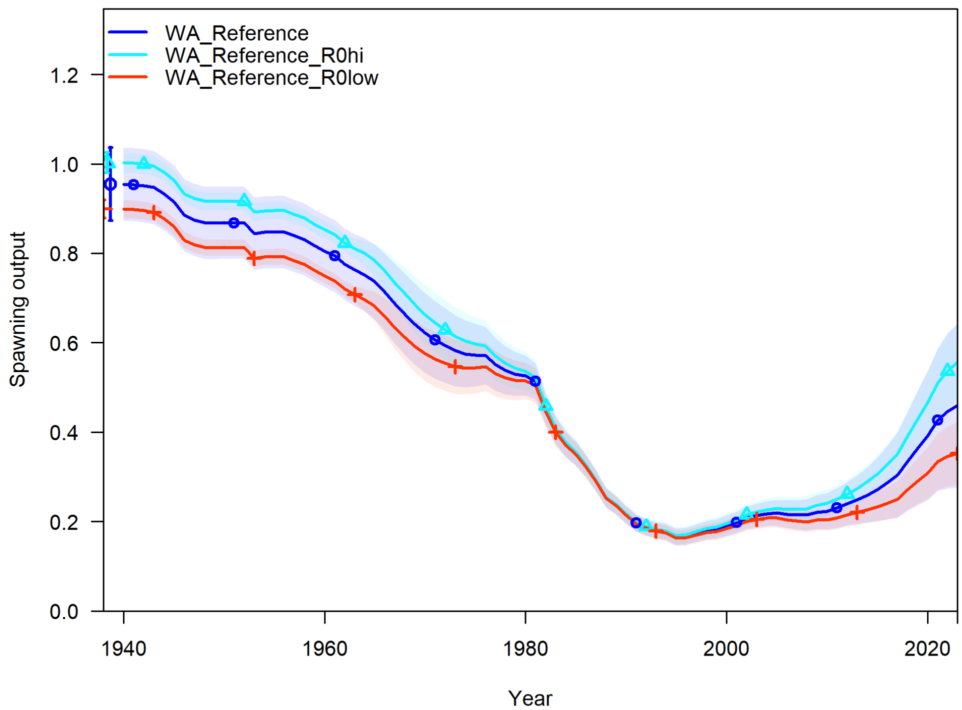
Request No. 9: For possible states of nature, obtain the current year (2023) spawning output for the high and low states of nature given by the base model mean plus or minus 1.15 standard deviations (i.e., the 12.5th and 87.5th percentiles). Search across fixed values of lnR0 to attain the current year spawning output values for the high and low states of nature.

Rationale: To examine a potential basis for bracketing uncertainty in the base model for the states of nature table.

STAT Response: The mean and standard deviation of the spawning output was used to calculate the 12.5th and 87.5th values using the following code:

qnorm(c(0.125,0.5,0.875),459.677,93.604)

Those states of nature and the reference model are included in the below comparison plots:



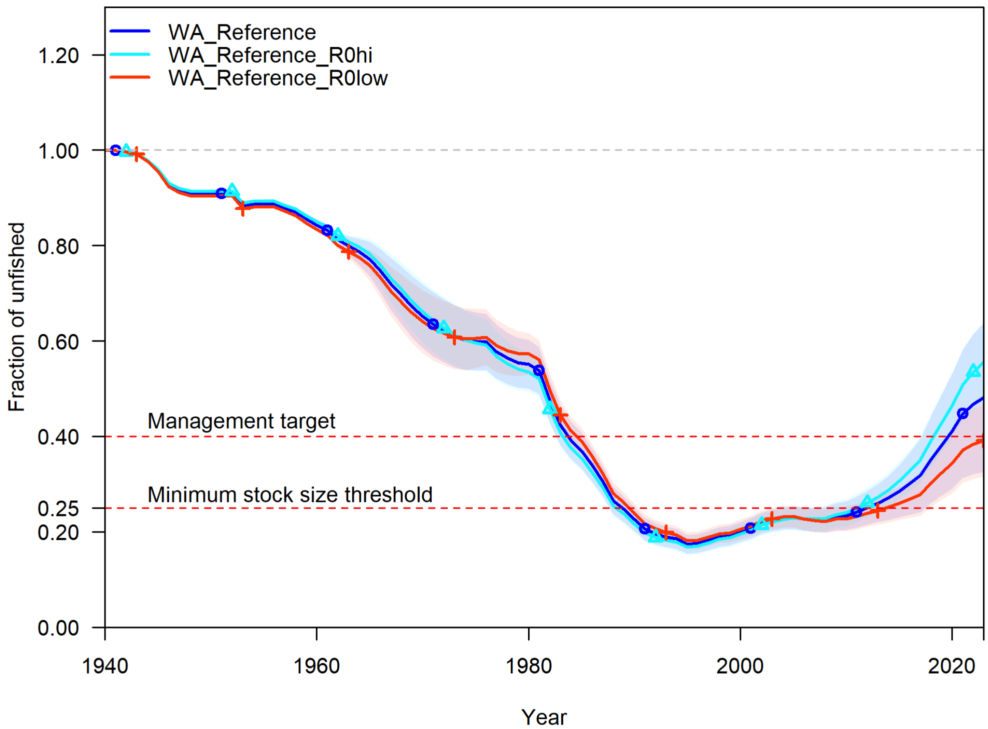


Figure 16. Comparison of spawning output (top panel) and relative stock status (bottom panel) of the three proposed states of nature.

Panel Conclusion: The states of nature identified provide a sufficient contrast to capture the uncertainty in the assessment.

Description of the Base Model and Alternative Models used to Bracket Uncertainty

Although many uncertainties were examined, the base model was unchanged during the course of the panel. A search was conducted across fixed values of *lnR0* to attain the current year spawning output values for the high and low states of nature. Spawning output for the high and low states of nature given by the base model mean plus or minus 1.15 standard deviations (i.e., the 12.5th and 87.5th percentiles) were provided in Request No. 9.

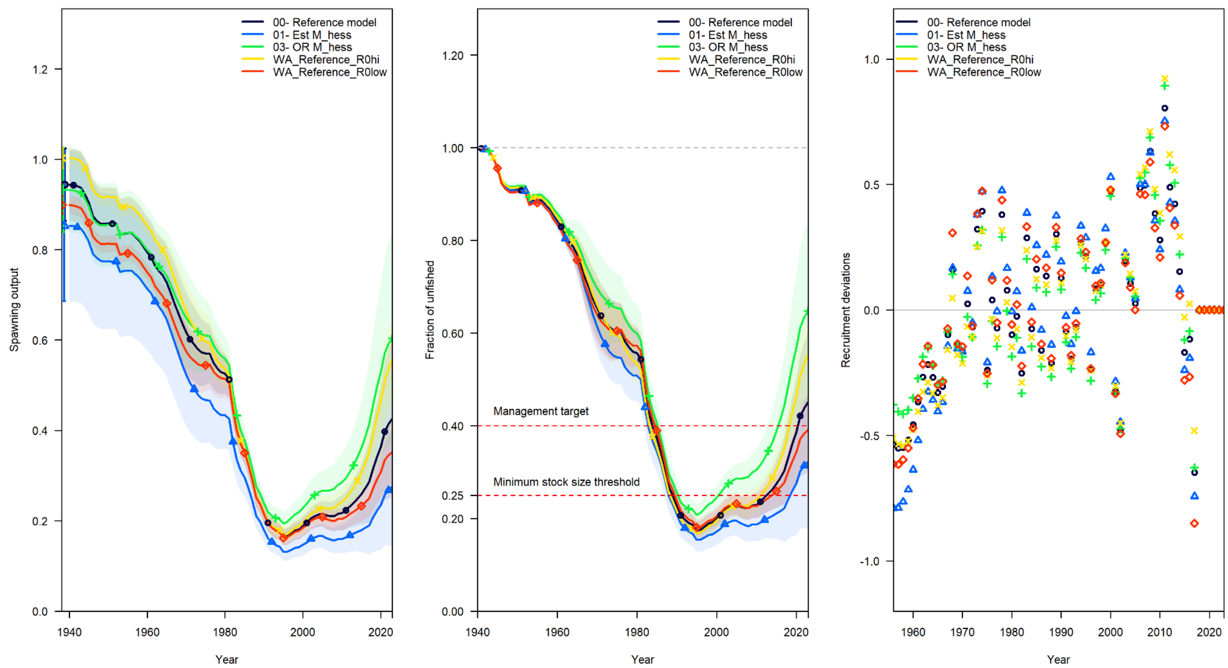


Figure 18. Comparison of spawning output, relative stock status, and recruitment deviations of the proposed states of nature pre- (blue and green) and post-STAR panel (red and yellow).

Technical Merits of the Assessment

The Black Rockfish Tagging Program conducted from 1981-2022 and nearshore survey data from 2018 to 2022 provide length data and an index of abundance. Though the time series for the Black Rockfish Tagging Program was terminated in 2014, the rod-and-reel survey may continue to provide data from 125 fixed stations. Substantial age and length data are available from the commercial and recreational fishery with associated sex data. These data provided the highest contributions to total likelihood (3760), age first (3091) and length second (657). Efforts were made to quantify the black rockfish caught in the trawl fishery off of southern Washington by vessels fishing out of Astoria, Oregon, which presented an uncertainty in the previous commercial catch history.

All available data sources were examined for use in the assessment leaving less impetus to conduct a full assessment to incorporate additional data sources in the future making it amenable to an update assessment. This provides efficiencies for providing current information to inform fishery management. Functional maturity was estimated to account for abortive maturation, skipped spawning and follicular atresia as opposed to biological maturity only considering physiological development. The assessment is very thorough and was carefully done, with a full set of sensitivity runs and model diagnostics that greatly assisted the STAR panel in model evaluation.

Technical Deficiencies of the Assessment

The assessment lacks a long-term statewide survey given the relatively short duration of the statewide nearshore rod-and-reel survey and the limited spatial coverage of the tagging program, though strides have been made to incorporate existing data in indices of abundance. The statewide nearshore survey will become more valuable as the time series is extended. Efforts were made to identify ecosystem considerations such as trophic relationships and environmental drivers of recruitment, but there was no direct effort to identify or account for them in the context of the model. Efforts to understand the drivers of strong year classes may lead to their integration in future assessments. Functional maturity only in the last decade during a period of extreme variability and further examination of the conditions affecting variation observed in sensitivity analyses may be beneficial.

Areas of Disagreement Regarding STAR Panel Recommendations

Among STAR Panel members (including GAP, GMT, and PFMC representatives): There were no areas of disagreement between STAR Panel members and representatives regarding STAR Panel recommendations.

Between the STAR Panel and the STAT Team: There were no areas of disagreement between STAR Panel members and the STAT Team regarding STAR Panel recommendations.

Management, Data, or Fishery Issues raised by the GMT or GAP Representatives During the STAR Panel Meeting

No issues were raised by the GMT or GAP representatives during the STAR Panel meeting.

Unresolved Problems and Major Uncertainties

The greatest uncertainty identified in the assessment is in the life history values, especially longevity and natural mortality. The treatment of sex-specific M is a remaining source of uncertainty, as estimated values were very low for both sexes compared to those derived from observed ages in the population and values used in the base model from the 2015 assessment.

The composition of market categories in the historical trawl catch reconstruction remains an uncertainty. There were conflicts between ages which provided a more pessimistic perspective and length data that are more optimistic present some unresolved tension in the model. The lack of coherence in the biological data, despite large sample sizes, can also make interpreting the population dynamics difficult, though current stock status does seem to be robust to this data.

Recommendations for Future Research and Data Collection

The panel supports the recommendations provided in the pre-STAR draft assessment (reproduced below).

1. Continue to develop the nearshore fishery-independent survey, as the other available surveys provide weak information for the trend in the population.
2. Improve understanding of broader ecosystem considerations within the context of Black Rockfish (and other nearshore species) management.
3. Evaluate and develop linkages between black rockfish population dynamics and environmental, oceanographic, and climate variables. In particular, develop multi-scale models (e.g., species distribution models) that can evaluate spatial patterns (e.g., multi-use areas or closures to fishing) and climate impacts (e.g., growth or distribution shifts) for vulnerable nearshore species. Utilize the growing body of ecosystem information available for the California Current Large Marine Ecosystem, as exemplified in the PFMC Integrated Ecosystem Assessment (IEA) report.
4. Continue work on the investigation into the movement, behavior or mortality of older (> age 10) females to further reconcile their absence in fisheries data. In particular, conduct genetics studies on fish observed off of the continental shelf (middle of the gyre and at sea mounts) to determine their association with the nearshore stocks.
5. Continue to build evidence for appropriate natural mortality values for females and males. This will help resolve the extent to which dome-shaped age-based selectivity may be occurring for each.
6. Design and conduct research studies to better understand the trade-offs revealed in this assessment between black rockfish biology and population scale that seem to be at odds. If discrepancies cannot be uncovered, evaluate management procedures that are as robust as can be to this trade-off.
7. Conduct early life history studies that provide a better understanding of the ecology and habitats of black rockfish from settlement to age-1.

The STAR panel supports the following additional recommendations for future research and data collection.

1. Simulation studies, meta-analyses across species or other research to examine circumstances in which options for treatment sex data for composition data are preferable under Option 1 or 2 treating them as separate or Option 3 treating them as combined. Such studies should aim to provide criteria for their application to inform guidance in the PFMC's Groundfish Terms of Reference and Accepted Practices documents.

2. Further evaluation of temporal and spatial variability in biological and functional maturity may facilitate accounting for uncertainty or help account for trends and identify drivers. Data informing the functional maturity ogive were collected during a period of extreme variability in ocean conditions and further examination of the drivers of variability observed may prove beneficial.
3. Compare trends in abundance and patterns of recruitment across species to examine commonalities, differences and their causes may help inform accounting for environmental determinants.
4. Account for variance in catch history to help reflect the full degree of uncertainty in the assessment.
5. Re-examine methods to generate estimates of abundance from the WDFW Tagging Program using approaches used for similar data sets from analogous studies in Oregon.

Recommendation for Next Assessment, Assessment Category, and Sigma

The panel agreed that the next assessment could be an update given the lack of major uncertainties that are likely to be resolved through a full assessment and the current model includes all available data sources.

The panel recommends the assessment be assigned to Category 1b given availability of fishery dependent indices of abundance, while the stock recruitment curve was not sufficiently well defined to estimate steepness. The associated default sigma value 0.5 is recommended, as the sigma value (the ln-scale coefficient of variation for OFL in the first projection year (2023), measuring scientific uncertainty) from the final base model was lower at 0.19.

Oregon Model

Summary of Data and Assessment Models

The assessment model for Oregon black rockfish integrates data and information from multiple sources into the stock synthesis modeling framework. The model is informed by catch data from two commercial fleets and two recreational fleets, six abundance indices, five sets of length composition data, and three sets of conditional age-at-length compositions. The model uses multiple ageing error matrices to incorporate ageing imprecision. It utilizes fixed parameters for weight-at-length, maturity-at-length, fecundity-at-length, the Beverton-Holt stock-recruitment steepness value, and recruitment variability. Life history parameters were sex-specific (i.e., a two-sex model) with natural mortality fixed at external estimates, and growth and recruitment deviation parameters estimated. Additional parameters that were estimated include initial population scale ($lnR0$), selectivity for each fishery and survey, and extra survey variance.

The primary likelihood components in the model were survey indices, length compositions, conditional age-at-length data, and marginal ages (included but not fit in initial model configurations). The base model was tuned to account for the weighting of the length and age data using the Francis method, and additional variances were estimated for indices, as well as the specification of the recruitment bias adjustments. Derived quantities include, among other things, the time series of spawning output, age and size structure, and current and projected future stock status. The model covers the years 1892 to 2022, with a 12 year forecast beginning in 2023.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: Provide separate index trends for marine reserve and comparison areas. Run the comparison area index in the model to examine whether the model is able to fit the comparison area index better than the original combined index.

Rationale: The treatment (marine reserve vs comparison area) was a significant variable in the index normalization and further examination of trends in marine reserves and comparison areas will help inform whether only comparison sites should be included given the lack of habitat-based weighting and the low proportion of habitat in marine reserves in total. Exploration of the fit to the comparison area index will indicate whether it has improved compared to the combined index.

STAT Response: Index trends among the combined, marine reserve (MR) only, and comparison areas (CA) only are shown in Figure 19. Each index has a slightly different set of covariates included in the final model. The length compositions were kept the same as the combined model for all runs.

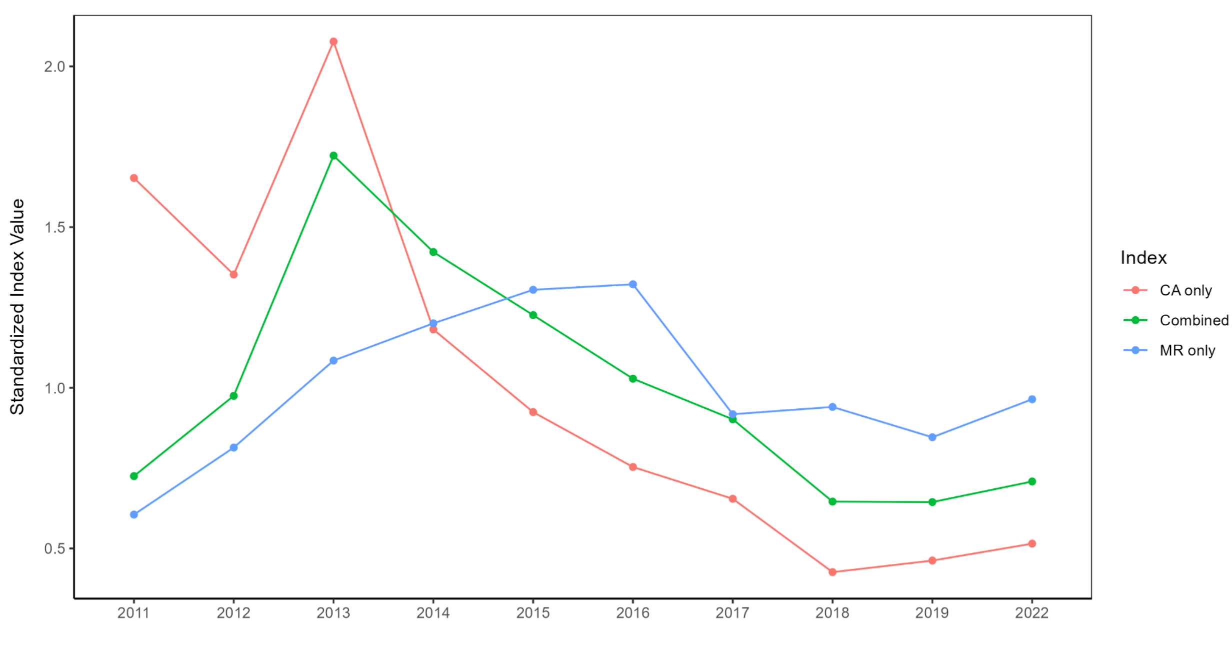


Figure 19. Marine reserve index treatments using reserve (MR) or comparison (CA) sites compared to the index used in the reference model.

The reference model was re-run with both the CA only and the MR only (Figure 20). There was no difference observed in the spawning output or relative stock status. The MR only index appeared to be fit better than the other two index versions (no additional SD required; Figure 21). However, the logSEs from the MR only index were larger than the other two versions (smaller sample size).

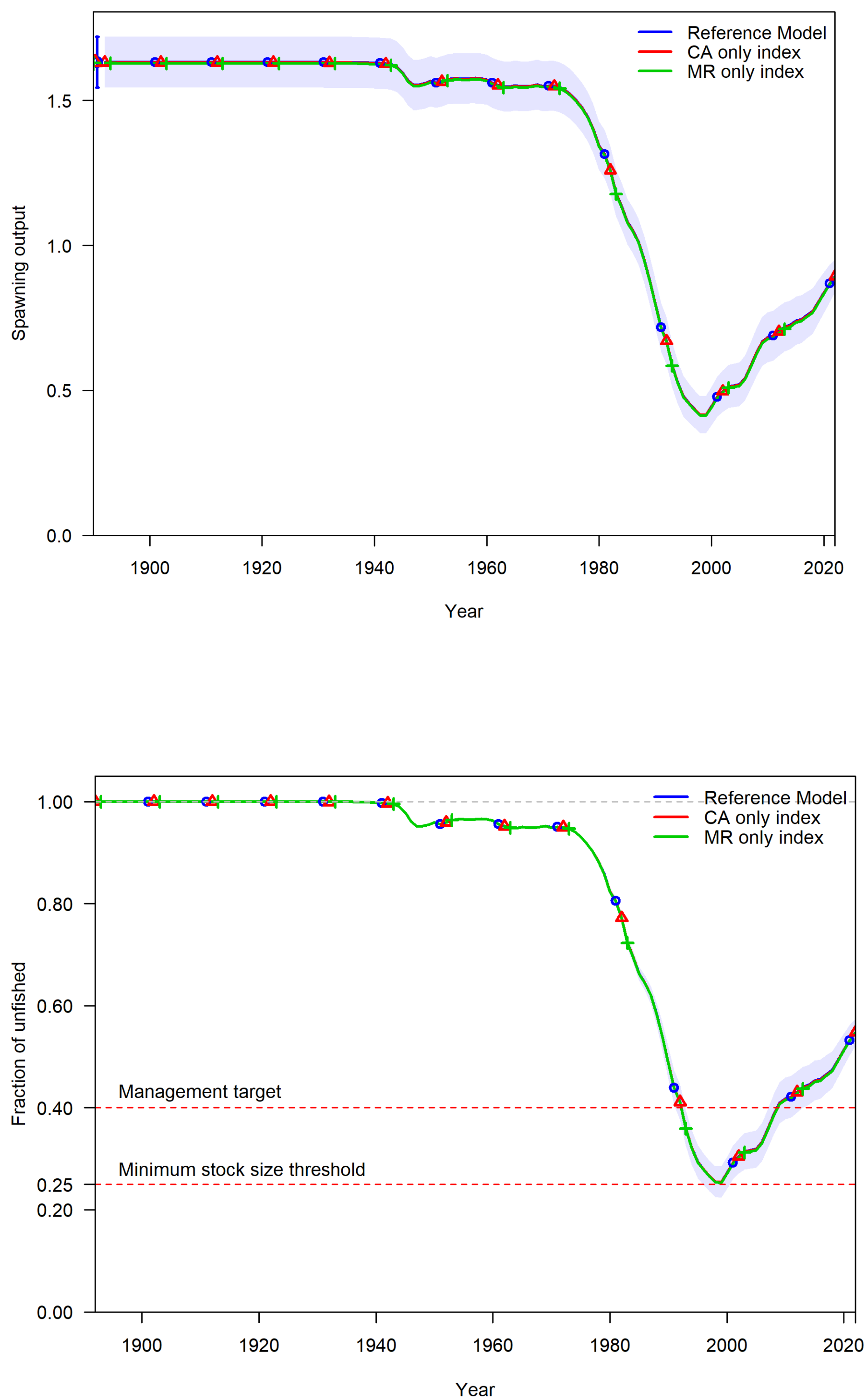


Figure 20. Comparison of spawning output (top panel) and relative stock size (bottom panel) for the different treatments of the MR index.

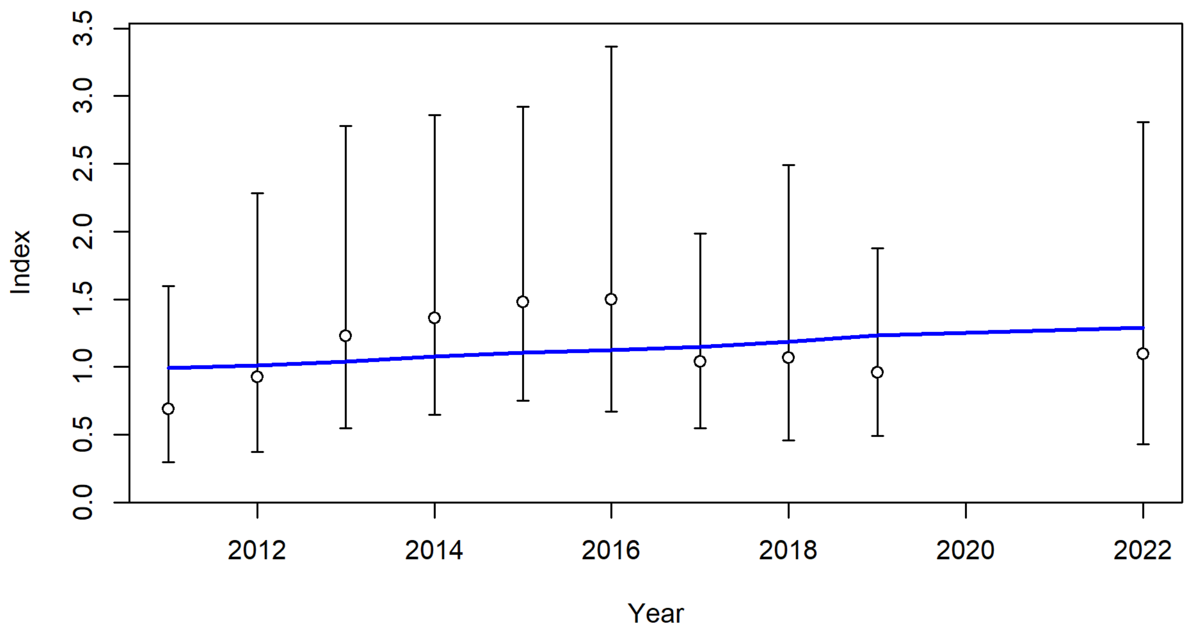


Figure 21. Model fit to the MR only index version.

Panel Conclusion: Include sensitivities in the documentation for this index in the revised post-STAR draft assessment. These surveys are designed to monitor local abundance around marine reserves and may not provide a reliable index at the population level. The Panel accepts use of the index in the base model although it does not appear informative in the assessment at present. Use of habitat-based weighting for sites inside and outside the marine reserve should be considered for future assessments. As a research recommendation, evaluate whether the survey could be modified to be more useful for stock assessment.

Request No. 2: Re-estimate abundance based on each of the four target strength relationship proxies and use the results for incorporation in the SS model and estimate the acoustic-visual (AV) survey catchability (*q*) from each. This request can be given lower priority to balance workload.

Rationale: This will help evaluate the variance in abundance estimates from target strength proxies and potential implications for AV*q* from each of the proxies.

STAT Response: The differences in target strengths across the four methods (studies) are minimal, leading to small changes in estimates of abundance and associated CVs (Table Request 2). These in turn have little change in the overall spawning output and stock status trajectories (Figure 22; top and middle panels) compared to the sensitivity model that also estimates q but uses the average target strength. All models that estimate *q* result in a downward shift in spawning output management metrics, relative to the reference model, and produce a *q* for the AV survey greater than 3 (Table 3). An AV survey *q* over 3 equates to a tagging *q* of near to or greater than 0.5, which has previously been deemed implausibly high (Mop-up panel report from 2015 assessment - "The inference that half of the available black rockfish stock is to be found off of Newport [*q* near 0.5], which is the literal interpretation of the model result, was found to be implausible by both the STAT and the Panel."). The reference model relates to a tagging *q* of approximately 0.3 (further work on the relationship between tagging *q* and AV*q* may become available during this meeting pending time). High AV survey *q*'s (~3) do not correspond well with the 2021 AV survey biomass estimate distribution (Figure 22; bottom panel). The reference model fixes AV*q* at 1.8.

Table 3: Relevant metrics for different target strength values used in calculating the AV survey 2021 biomass estimate. The reference model uses what amounts to an average of the four candidate target strengths from previous studies. For comparison, the reference model fixes ***q*** at ln(0.6) or a value of 1.82 on a linear (standard) scale.

Method	Target Strength (b_{20})	Biomass Estimate	CV	q (when estimated)
Hwang 2015	-69.01	14073.1	0.436	3.49
Gauthier and Rose 2002	-68.7	13550.9	0.445	3.36
Gauthier and Rose 2001	-68.1	12640.0	0.464	3.13
Kang and Hwang 2003	-67.7	12099.1	0.478	3.00
Average (reference model)	-68.38	13045.6	0.455	3.23

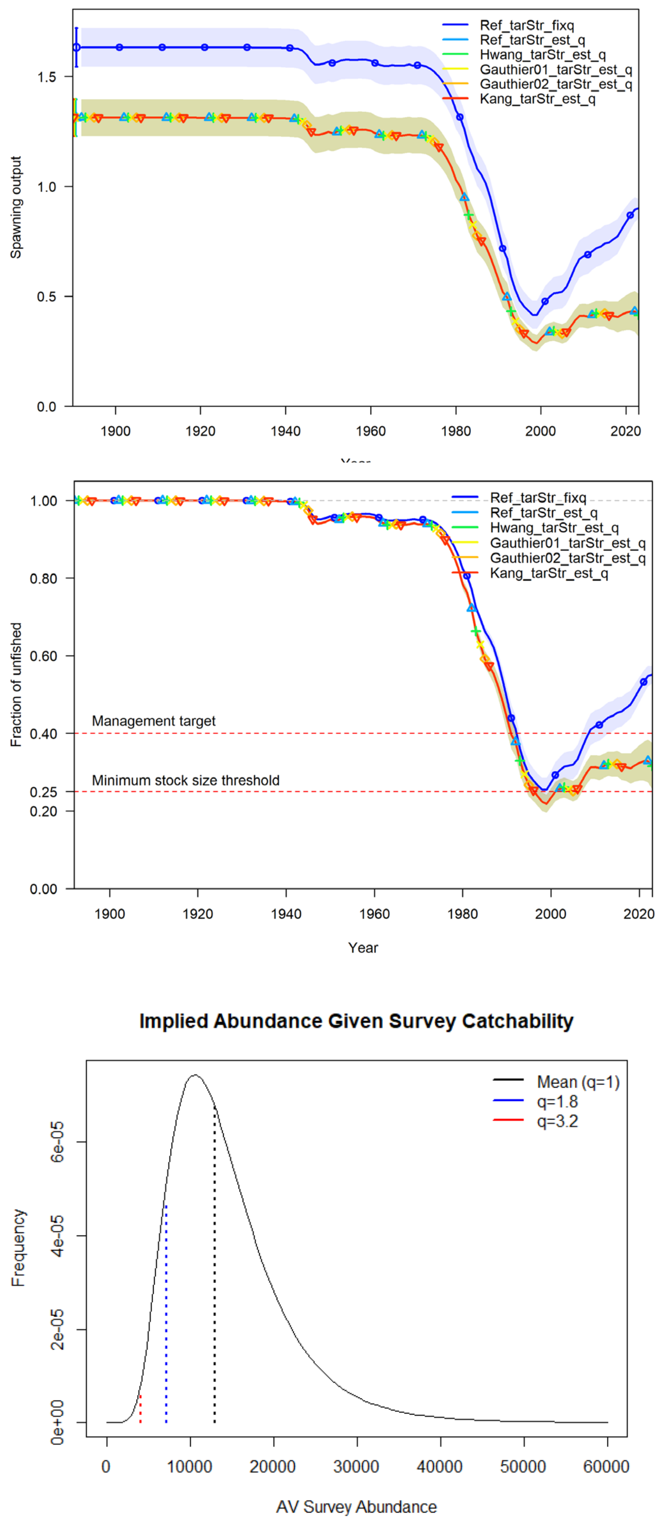


Figure 22: The time series of spawning output (top) and relative spawning output (or depletion; middle) for the reference model that uses the average target strength (Ref_tarStr_fixq), the sensitivity model that uses the reference model target strength but estimates *q* (Ref_tarStr_est_q),

and four additional model runs (Hwang, Gauthier01, Gauthier02, and Kang) that utilize the biomass (and associated CV) estimates for specific target strength estimates (i.e., not averaged). The bottom panel shows the implied abundance given different model values of catchability (dotted lines) relative to the lognormal distribution for the 2021 AV survey abundance estimate.

Panel Conclusion: Alternative target strength proxies for black rockfish are a source of assessment uncertainty, but do not appear to be a major source. Efforts should be made in the future to estimate target strength for the AV survey to replace proxies and calibrate the acoustic system in situ.

Request No. 3: Generate pairwise plots (and calculate correlation coefficients) for all the abundance indices, for years which overlap.

Rationale: The consistency of various abundance indices are evaluated graphically in the report. Pairwise comparison of all abundance indices can provide a more quantitative evaluation of consistency of abundance indices.

STAT Response: The requested plot was developed and is shown below (Figure 23). The ocean, MPA, and tag indices correspond more so than the non-trawl index. The indices have not been rescaled as is shown in the assessment document Figure 20, because consistent rescaling of indices doesn't matter for visualizing these summary metrics.

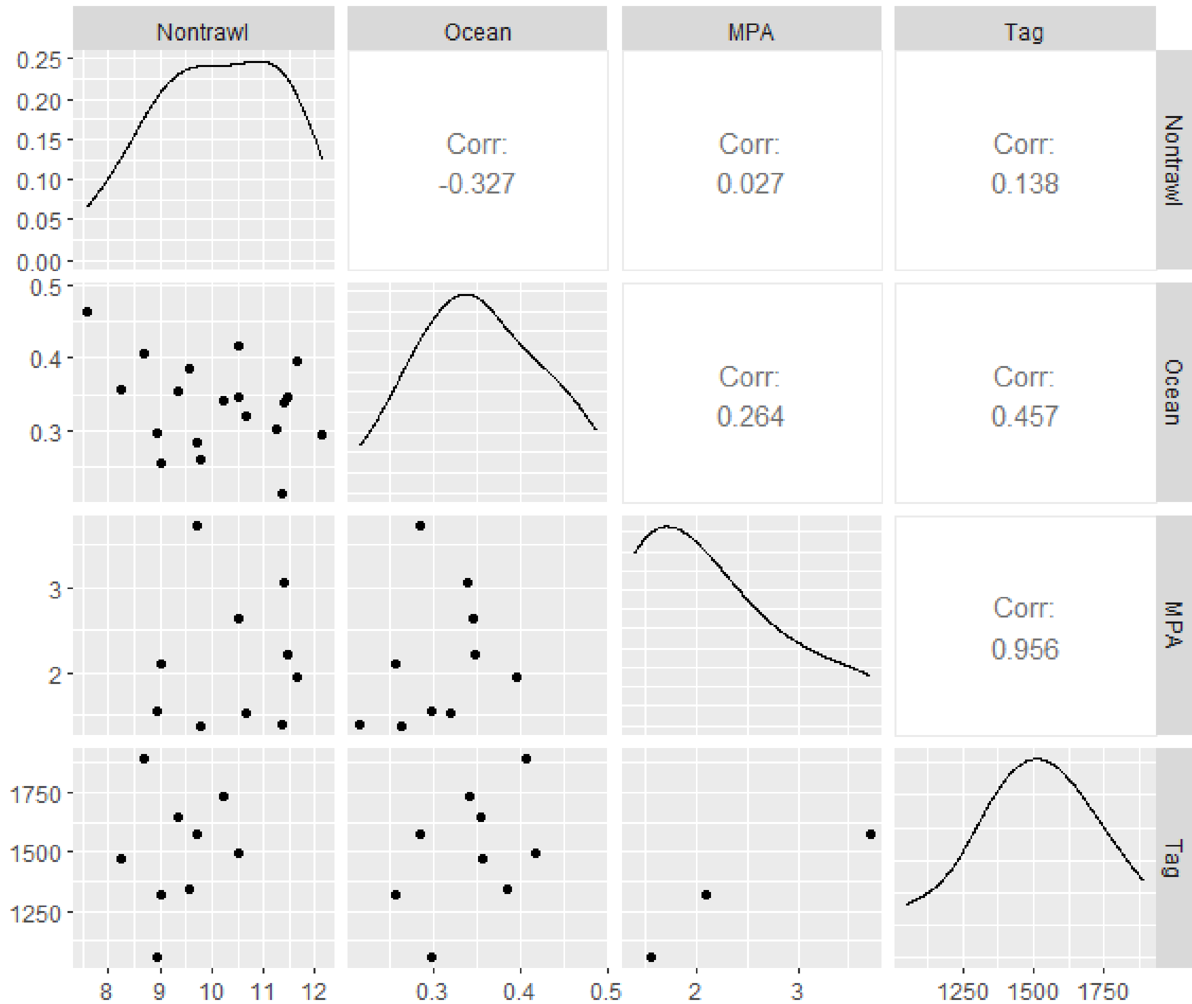


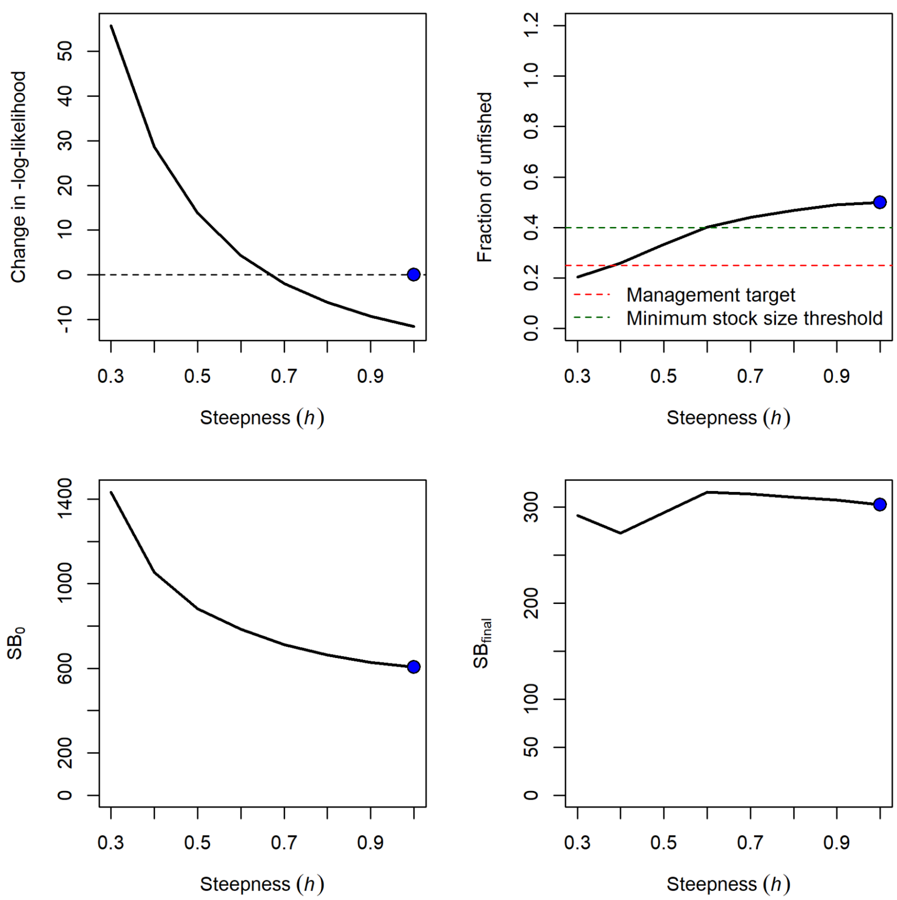
Figure 23: Generalized pairs plot for the four overlapping time series indices of abundance: non-trawl, ocean, MPA, and tag. The number of points in the pairs plots (below the diagonal) represent the pairwise sample sizes. Also shown are within index density plots (on the diagonal) and among index statistical correlations (above the diagonal). The indices presented here have not been rescaled.

Panel Conclusion: The indices available for the assessment are not highly correlated suggesting they are not tracking a common and consistent trend. This is a useful plot to include in future assessments with multiple indices.

Request No. 4: Attempt to estimate natural mortality (*M*) and steepness (*h*) concurrently, given the potential interactions and plot relationship. Provide a steepness profile, while estimating *M* for females and males.

Rationale: The sensitivity analyses included in the current stock assessment only change *M* or *h* individually. However, *M* and *h* tend to be highly correlated. An examination of LL (log likelihood) values under a varying *M* and *h* (over a reasonable range) would help us understand how they interact and how they may influence the assessment of population dynamics.

STAT Response:



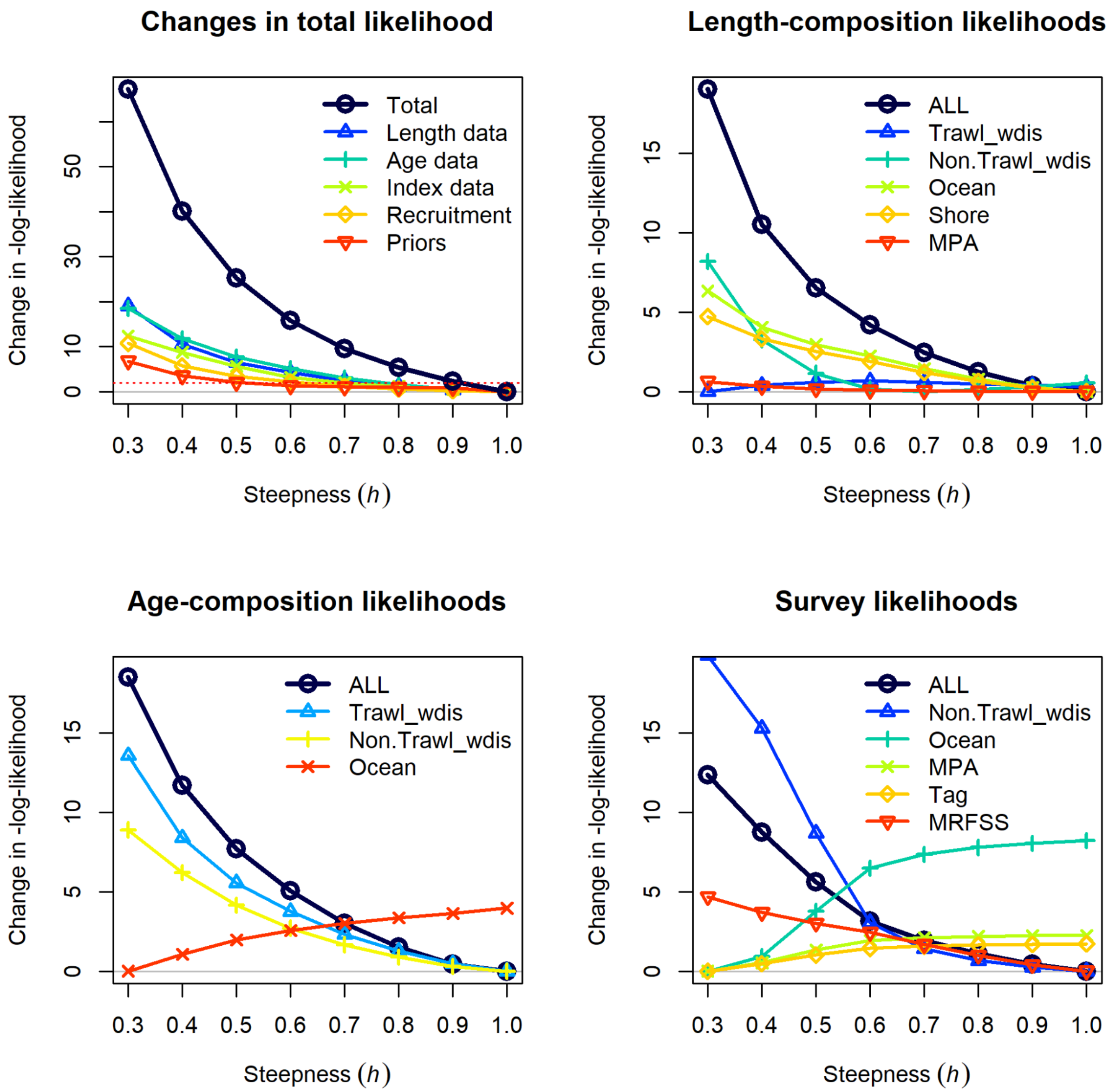


Figure 24. Likelihood profile (top panel) and component profiles (bottom panel) and derived model outputs when profiling across steepness while estimating sex-specific *M*.

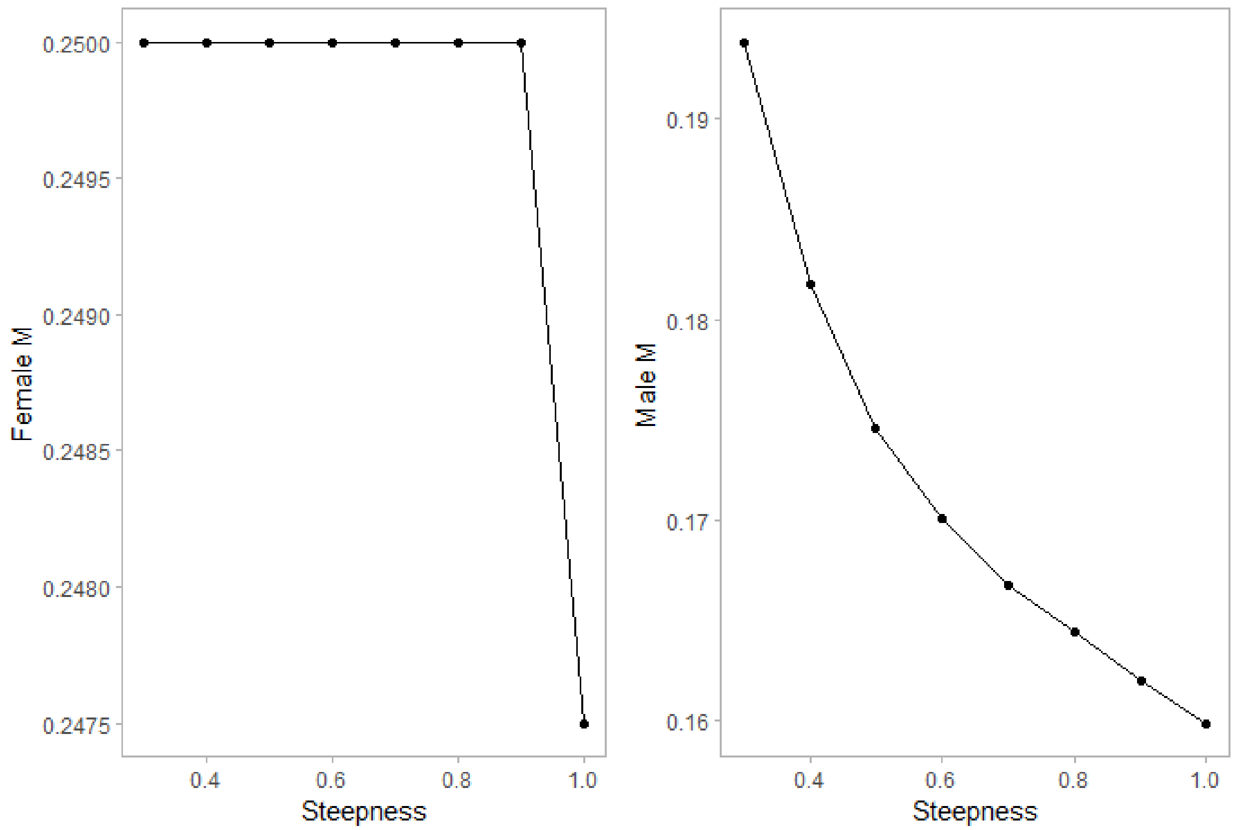


Figure 25. Estimating values for female and male *M* when profiling over steepness.

Panel Conclusion: The best fitting models indicate high steepness. As was anticipated, there is an inverse relationship between *M* and steepness. The Female *M* went to the upper bound in all cases except steepness = 1.0. The Panel concluded that the data are insufficient to estimate *M* and steepness in the model, justifying the approach used in the assessment.

Request No. 5: Provide results for models with all length data given weight (lambda) of 0.5 and 0.25 relative to the base model. This model should have the acoustic-visual survey catchability freely estimated.

Rationale: Since there is a different signal in the age and length data, this will allow a further evaluation of the impact of the large quantity of length data used in the assessment.

STAT Response: The following plot provides a comparison for requests 5 & 6.
The *q* values estimates for each scenario are:
Length lambda = 0.5: AV*q* = 2.9
Length lambda = 0.25: AV*q* = 2.7

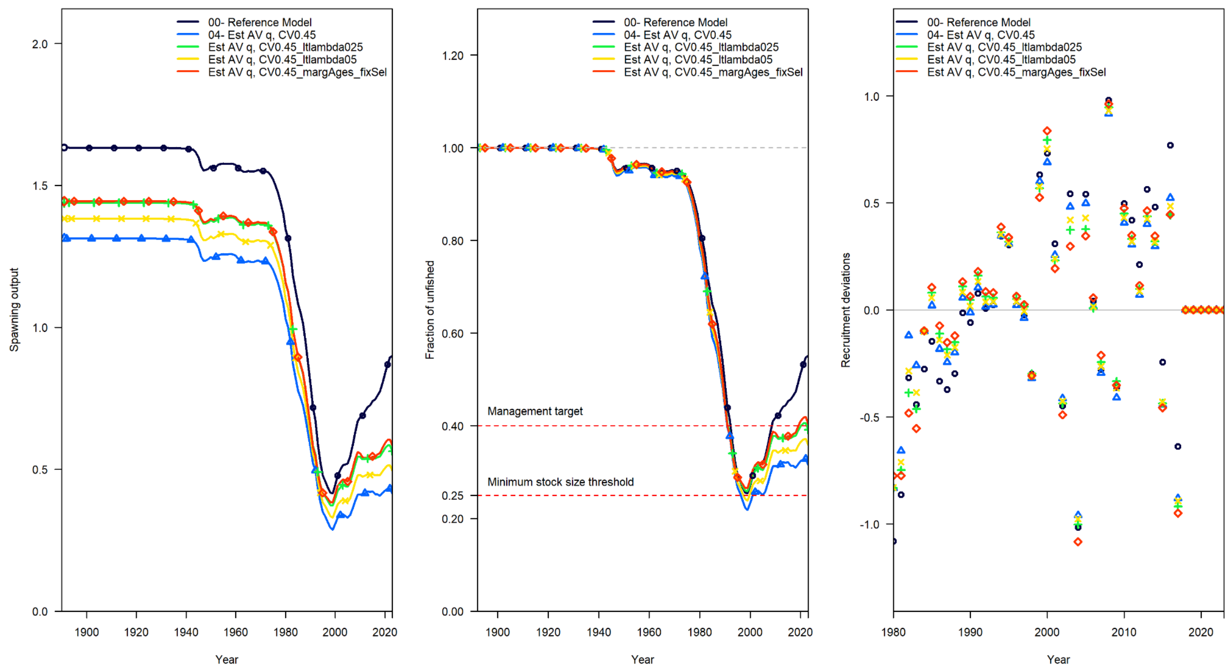


Figure 26. Comparison of spawning output, relative stock status, and recruitment deviations different treatments of length composition lambdas or use of marginal ages after fixing the selectivities based on fits to the length compositions.

Panel Conclusion: See panel conclusions for Request No. 6 below.

Request No. 6: In an initial model run, estimate the length-based selectivity with acoustic survey *q* freely estimated (lower state of nature). In a follow-up run, fix selectivity patterns and incorporate the marginal age composition data.

Rationale: To further explore the impact of length composition data on the assessment.

STAT Response: Figure 26 provides a comparison for requests 5 & 6.

The *q* values for the fixed selectivity, no lengths, marginal and conditional ages is AV*q* = 2.6. Reference model length likelihood component: 492.509.

Estimate AV*q* with CV 45% length likelihood component: 471.472

The difference in length fits are statistically significant, but do not change the overall fits by eye much. In general, the lowering of length lambdas fits the ages better and increasing stock status.

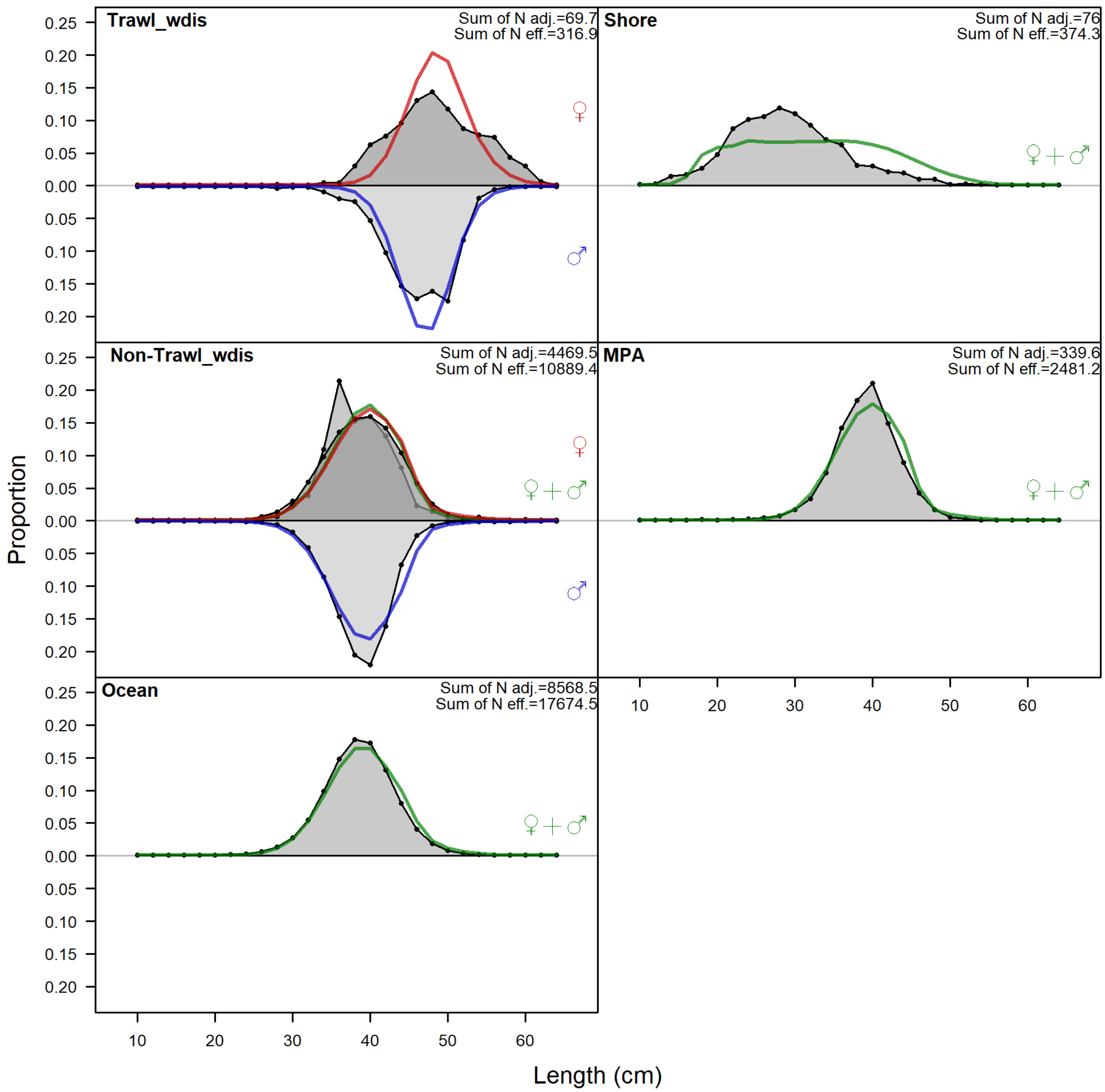


Figure 27. Passive fits to the length data (i.e., not included in the total likelihood) for the model that excludes length compositions and uses marginal ages, but assumes the selectivities of the length-based model.

Panel Conclusion: Successively reducing the lambda on the length data had the effect of allowing other data to have a greater influence on model results and led to increases in scale and a greater upward trend in recent years, more consistent with the reference model. Lower emphasis on lengths did not appreciably degrade fits to length composition data sets. Including marginal ages with fixed selectivity had an almost identical effect of reducing lambda to 0.25, suggesting that this approach would be a viable alternative that has the same result as downweighting the length data.

Request No. 7: For the Ocean Recreational Boat Survey (ORBS) dockside survey, provide time series plots of the management changes including bag limit changes, angler hours within a trip, percent of trips at or above the boat limit.

Rationale: To evaluate the utility of this index for use in the assessment.

STAT Response: Figure 28 is provided to show the daily bag limits for black rockfish over time, the total trip hours (after adjusting for travel time) and the annual proportion of trips that were at or above the boat catch limits. These graphs were developed from the filtered dataset used for the index.

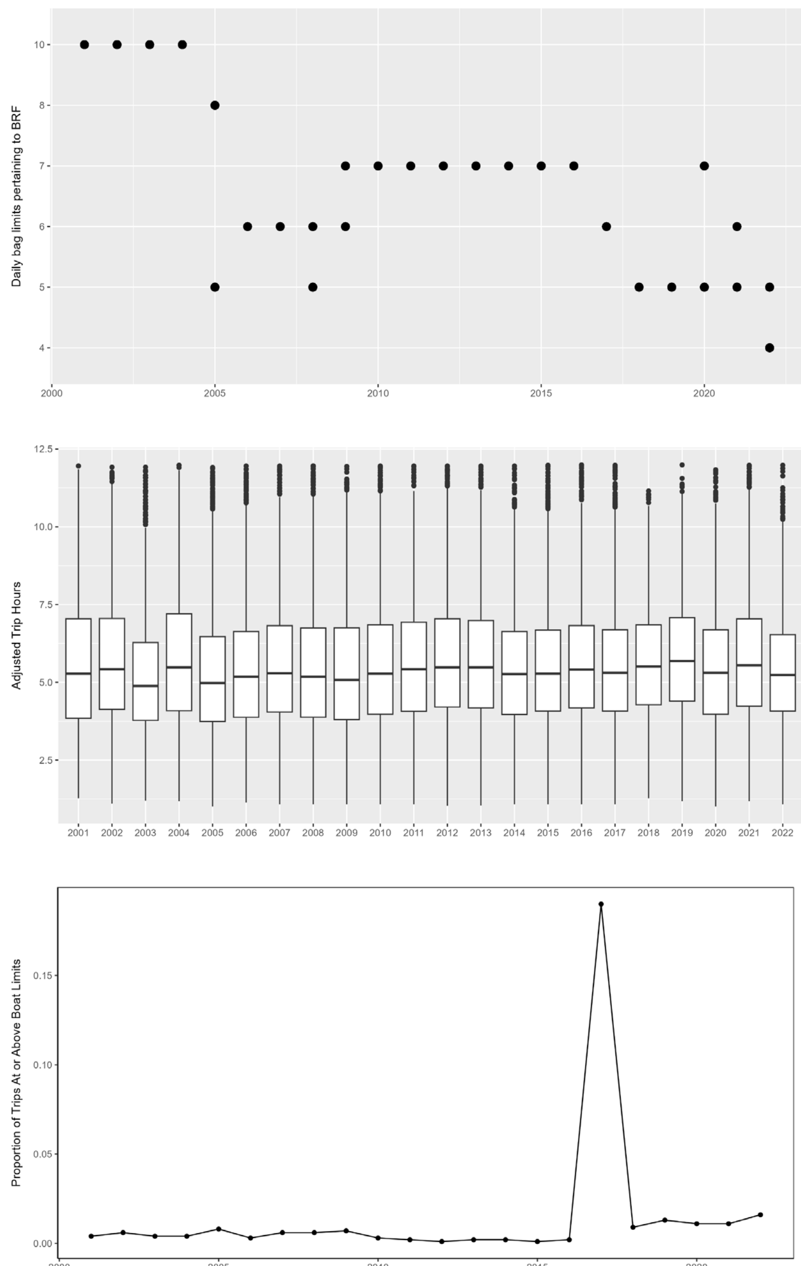


Figure 28. Bag limits over time in Oregon (top panel), total trip hours (after adjusting for travel time; middle panel) and the annual proportion of trips (bottom panel).

Panel Conclusion: Bag limits have varied over time as part of the active management of the stock by ODFW and have generally decreased over time. However, trip hours have remained remarkably consistent. The percent of trips at or above the boat bag limit is low, but has increased slightly over time (except for one outlier). The panel concluded that the index is unlikely to be compromised by the bag limits and should remain in the base model.

Request No. 8: Please provide confidence interval estimates for the fixed *q* from the AV survey used in the reference model.

Rationale: To quantify the variance in the *q* used in the reference model.

STAT Response: This was a difficult request since *q* was fixed at 1.8 so the 95 percent confidence intervals (CI) were calculated by using the standard deviation of the population estimate and applying that to the *q*. However, the 1.8 was selected by a discussion of the STAT with the survey team about where they would feel comfortable so applying the confidence interval was a bit arbitrary.

q	95 CI
1.8	0.65-2.95

Panel Conclusion: This approach cannot capture the real variability but serves to give a sense of the higher and lower values that could be considered as somewhat plausible.

Request No. 9: Provide a model run with lambda = 0.1 weighting of lengths, with AV*q* freely estimated.

Rationale: To explore weighting schemes that bring AV*q* to more plausible levels when estimated.

STAT Response:
Figure 29 compares the requested lamba value on lengths of 0.1 with the previous request of 0.25, and 0.5. All of these are compared to the middle and low states of nature as presented in the draft stock assessment.

A slight increase in the population scale and status was observed. The associate AV*q* values with the downweighted lengths are:

Length lambda	AV*q*
0.1	2.59
0.25	2.71
0.5	2.92

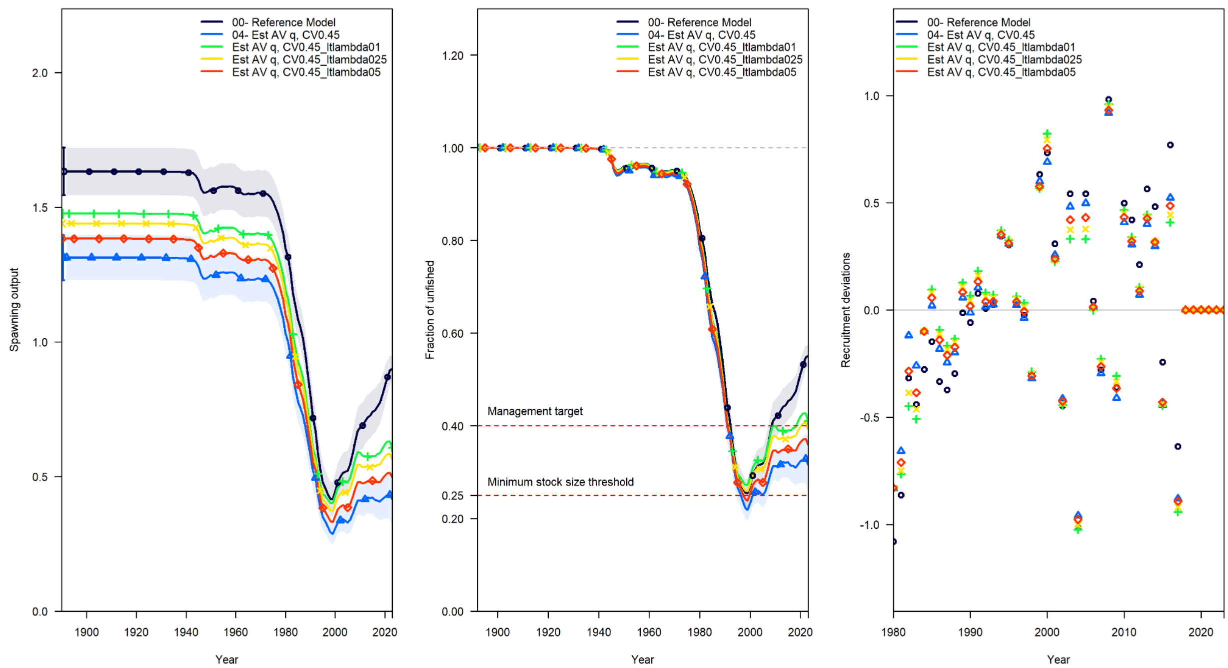


Figure 29. Comparison of spawning output, relative stock status, and recruitment deviations different treatments of length composition lambdas.

Panel Conclusion: There is little benefit to further reducing the lambda on the length data. A lambda of 0.25 seemed to be the most appropriate if this approach is adopted for the final assessment.

Request No. 10: Increase the weighting on the AV survey with *q* fixed at 1.0, and increase lambda to 5, 10, and 25 (explore other values if this does not give an adequate response). Find the equivalent weighting for an implied *q* of 1.8 (pinned value in the original reference model). Report the implied *q* for each model run.

Rationale: To explore weighting schemes that bring AV*q* to more plausible levels when estimated.

STAT Response: The below model compares the requested lambda values of 5, 10, and 25 for the acoustic visual survey. All of these are compared to the middle and low states of nature as presented in the draft stock assessment.

The upweighting of the acoustic-visual data shows the predicted behavior of successively greater increase in the population. The variance estimates from the reference model and the lamba of 25 model are essentially the same.

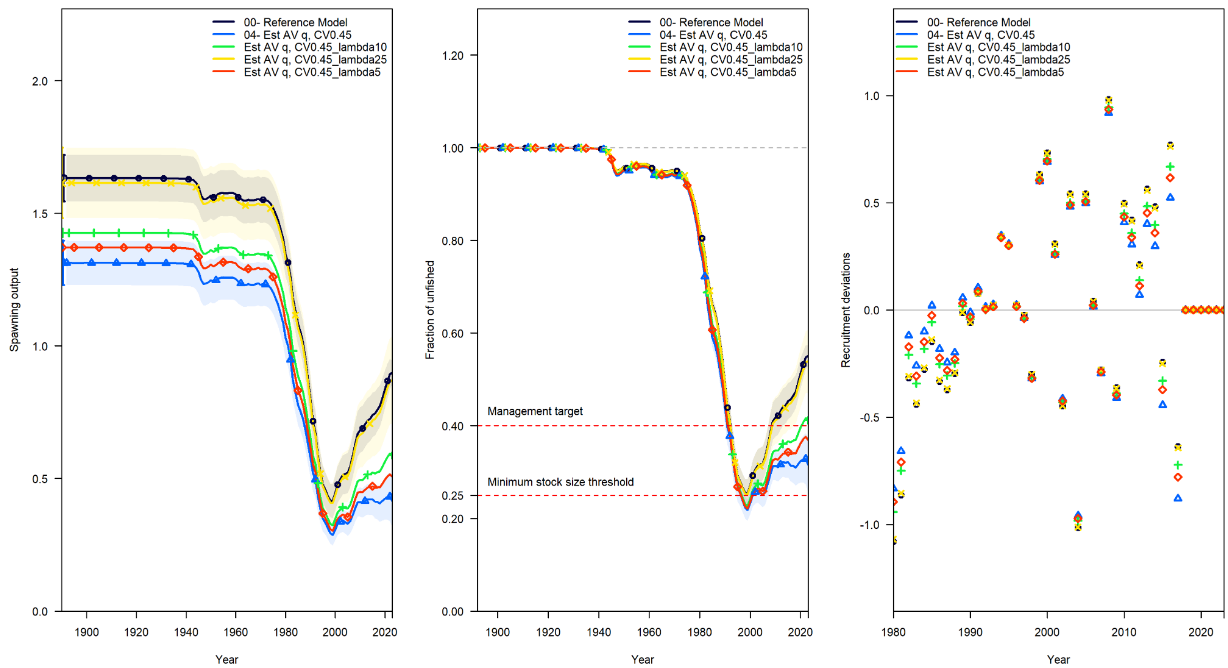


Figure 30. Comparison of spawning output, relative stock status, and recruitment deviations different treatments of survey lambdas, which are upweighted.

The following table provides the associated realized catchability value (realized *q*) for each lambda used to upweight the AV survey.

Lt lambda	AV*q*
5	2.79
10	2.50
25	1.71

Panel Conclusion: Setting lambdas for the acoustic visual survey is a viable alternative approach to achieving a more plausible fit to the acoustic survey. Downweighting length data also provides comparable results.

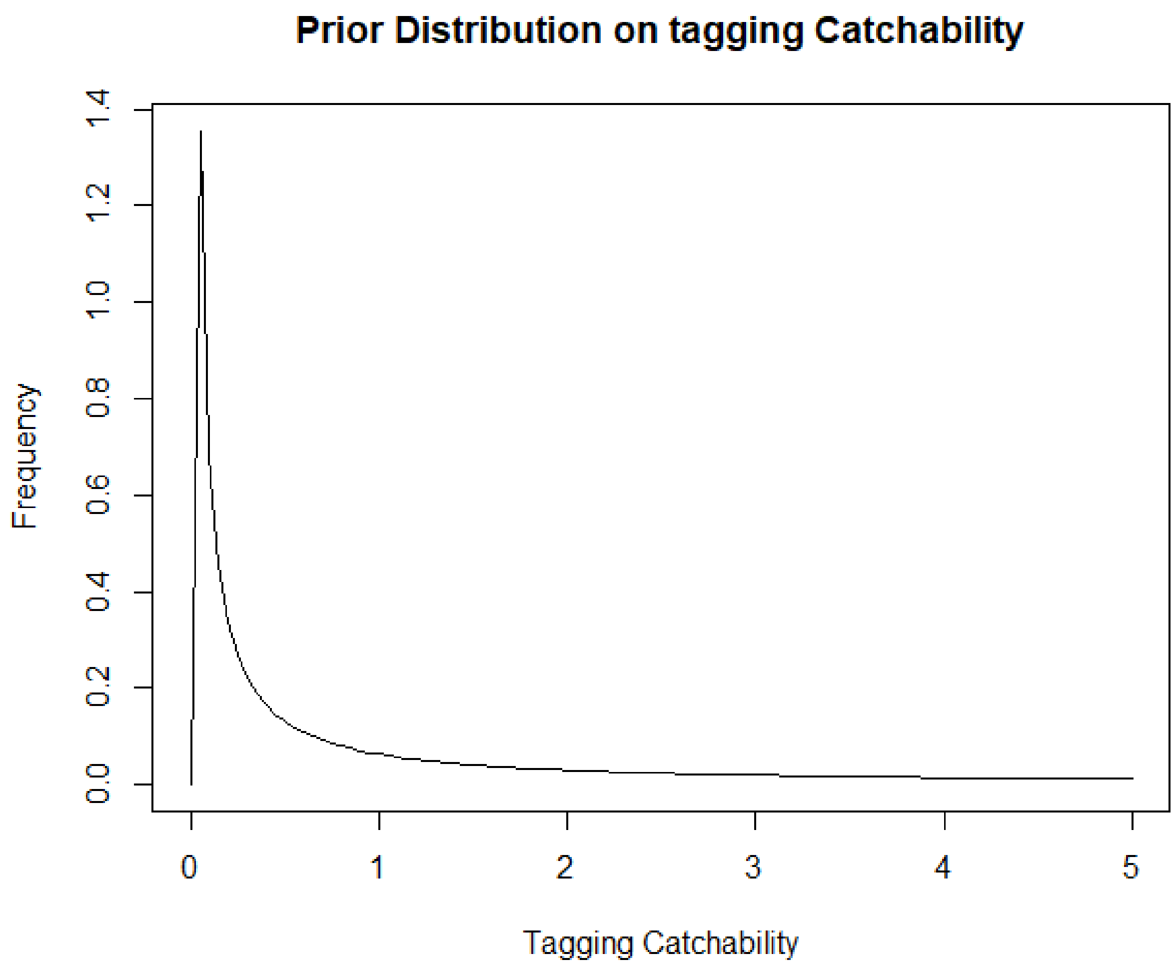
Request No. 11: Explore a model with an informative q for the passive integrated transponder (PIT) tag survey using the ratio of biomass in the area of the tagging study to the overall biomass for the AV survey. The uncertainty in this ratio from the AV survey should be used to specify the prior variance for the PIT tag survey. Include this prior in both the models where the AV*q* is fixed at 1.0 and freely estimated with a CV of 0.45 in both cases.

Rationale: To identify a more reasonable *q* for the PIT tagging index.

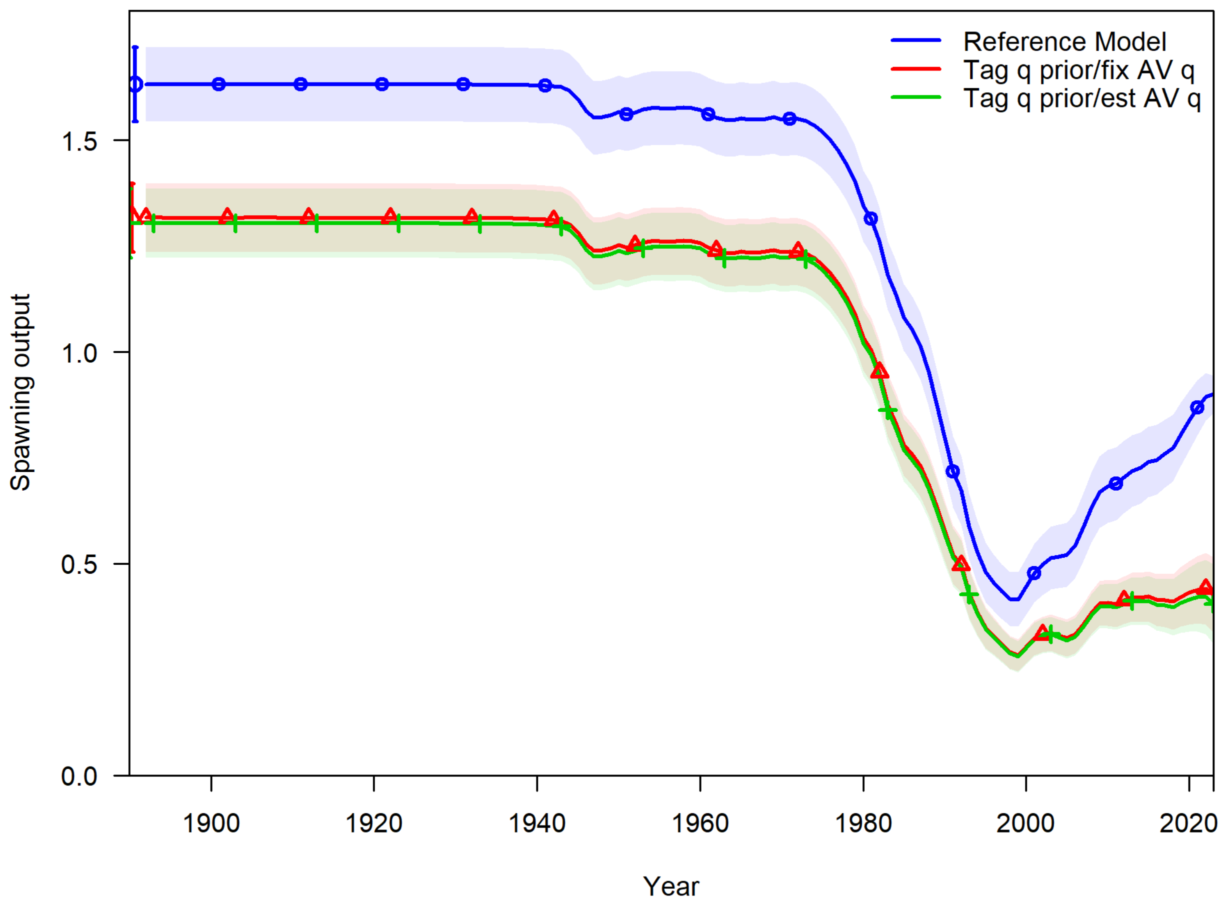
STAT Response: The provided model runs are shown in Table 4, and the associated spawning output based management metrics are shown in Figures 31-33.

Table 4. Catchability for tagging and AV survey index data sources for different model configurations. A lognormal distribution assumption was considered for the tagging prior: ln(0.097,0.568).

Model	Tag *q*	AV*q*	Extra SD Tag *q*
Reference model (tag *q* analytical, AV *q* fixed)	0.31	1.82	0.16
Tag *q* prior (ln), AV fix *q*=1 with CV=0.45	1.08	1.0	0.84
Tag *q* prior (ln), AV est *q* with CV=0.45	1.08	3.28	0.83
Tag *q* prior (ln), AV fix *q*=1 with CV=0.45, No Extra Variance on tag *q*	1.08	1	NA
Tag q prior (ln), AV est *q* with CV=0.45, No Extra Variance on tag *q*	1	6.05	NA



Prior Distribution on tagging Catchability
Frequency
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
1
2
3
4
5
Tagging Catchability



Reference Model
Tag q prior/fix AV q
Tag q prior/est AV q
Spawning output
0.0
0.5
1.0
1.5
1900
1920
1940
1960
1980
2000
2020
Year

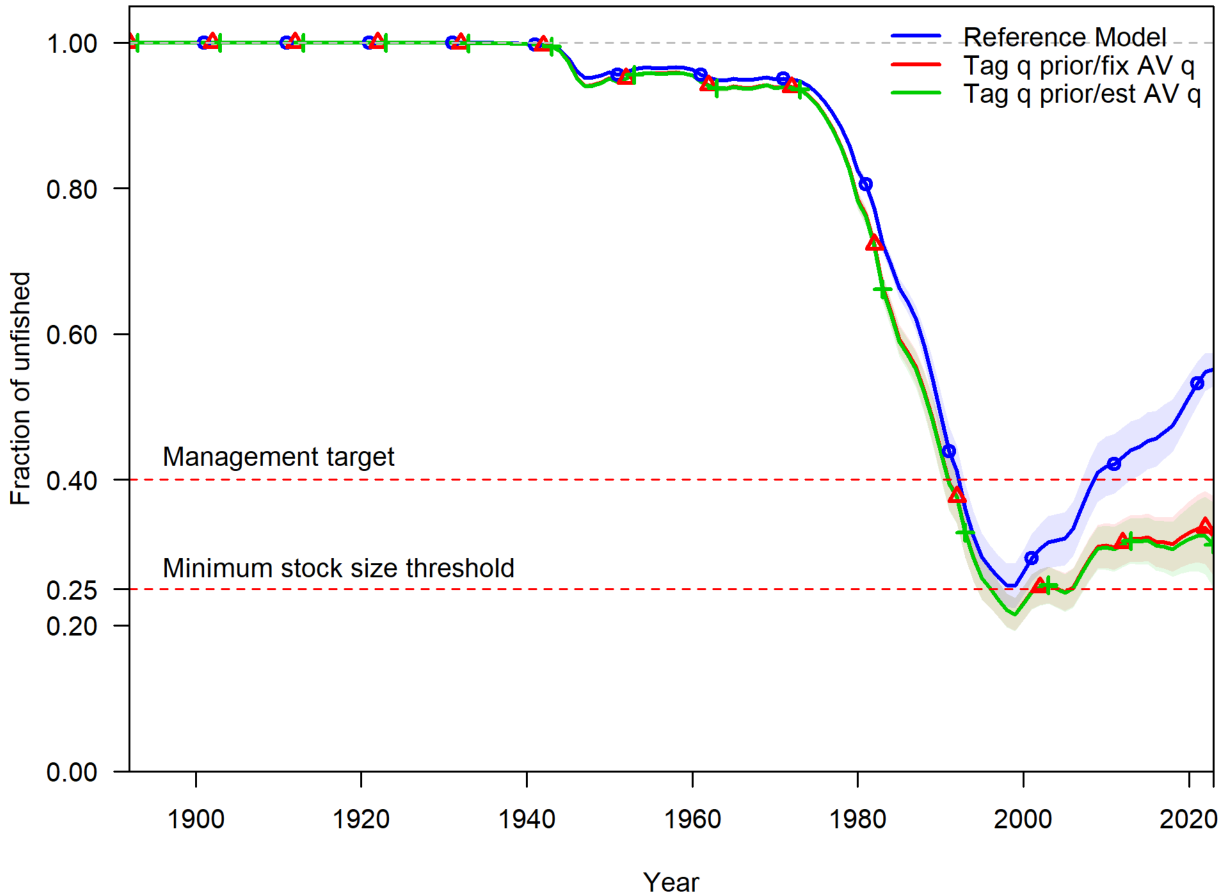


Figure Request 31: A lognormal prior on tagging q was developed (top panel) per the request and used in two alternative model runs (one with the AV*q* fixed at 1 and one with AV*q* estimated; See Table Request 11). Spawning output (middle panel) and stock status (lower panel) were compared for these model runs and the reference model.

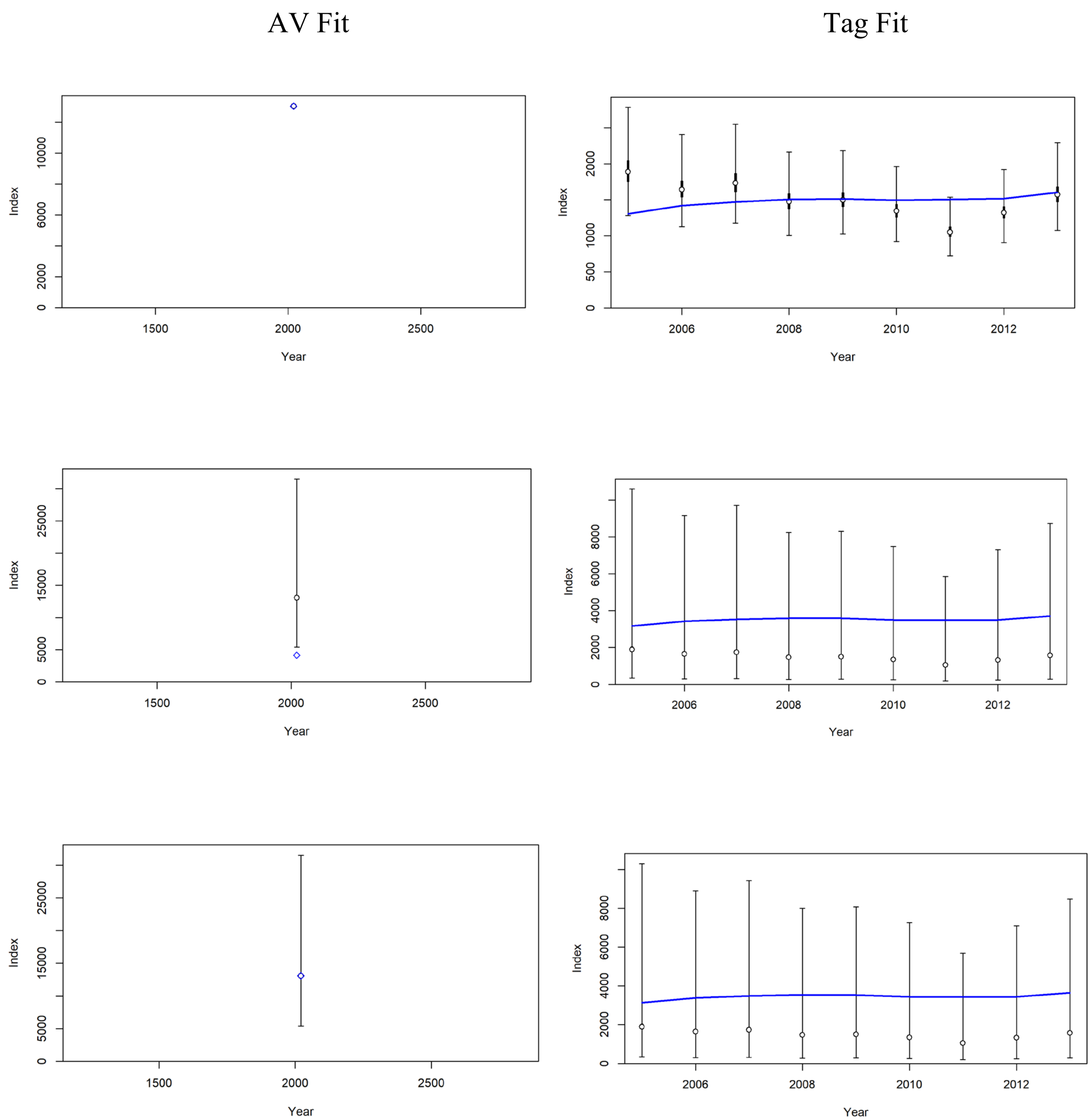
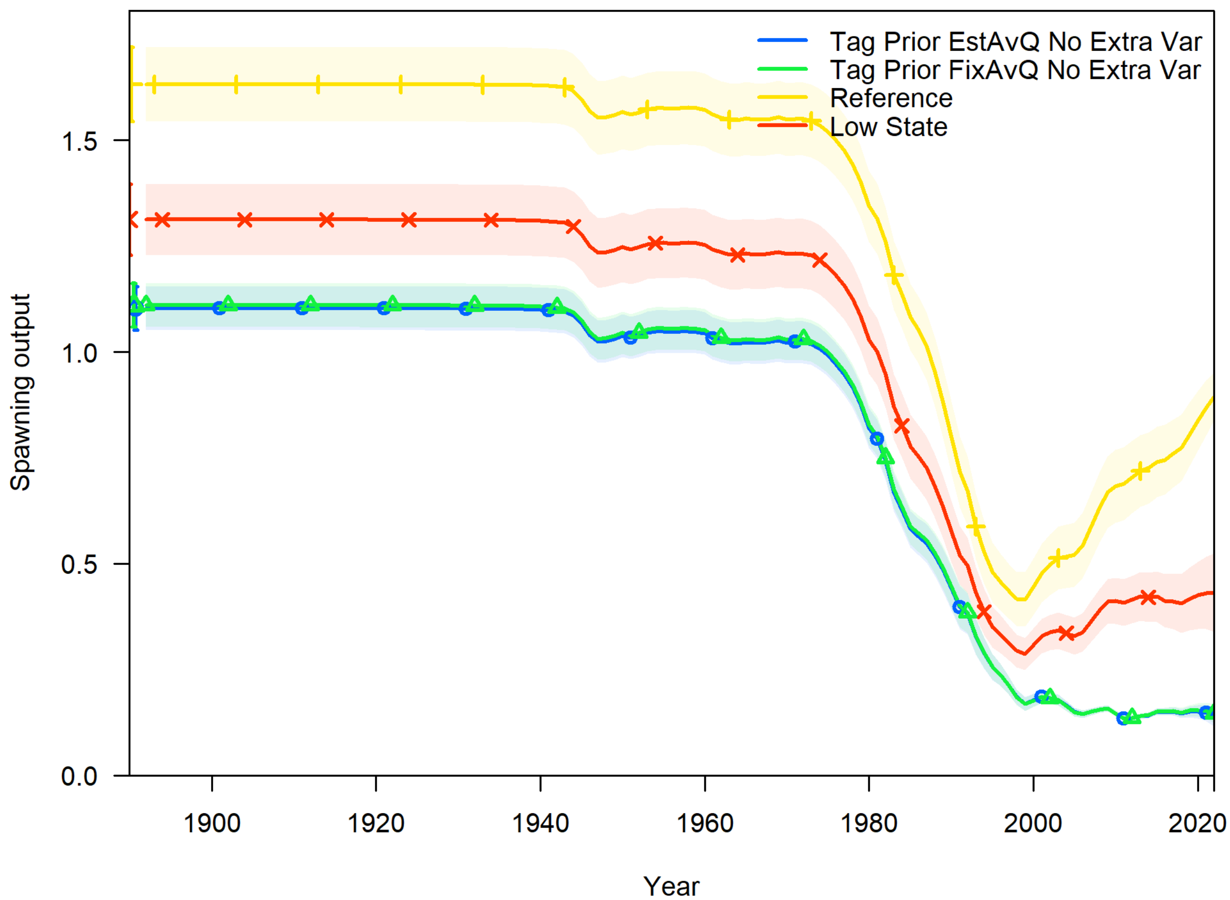
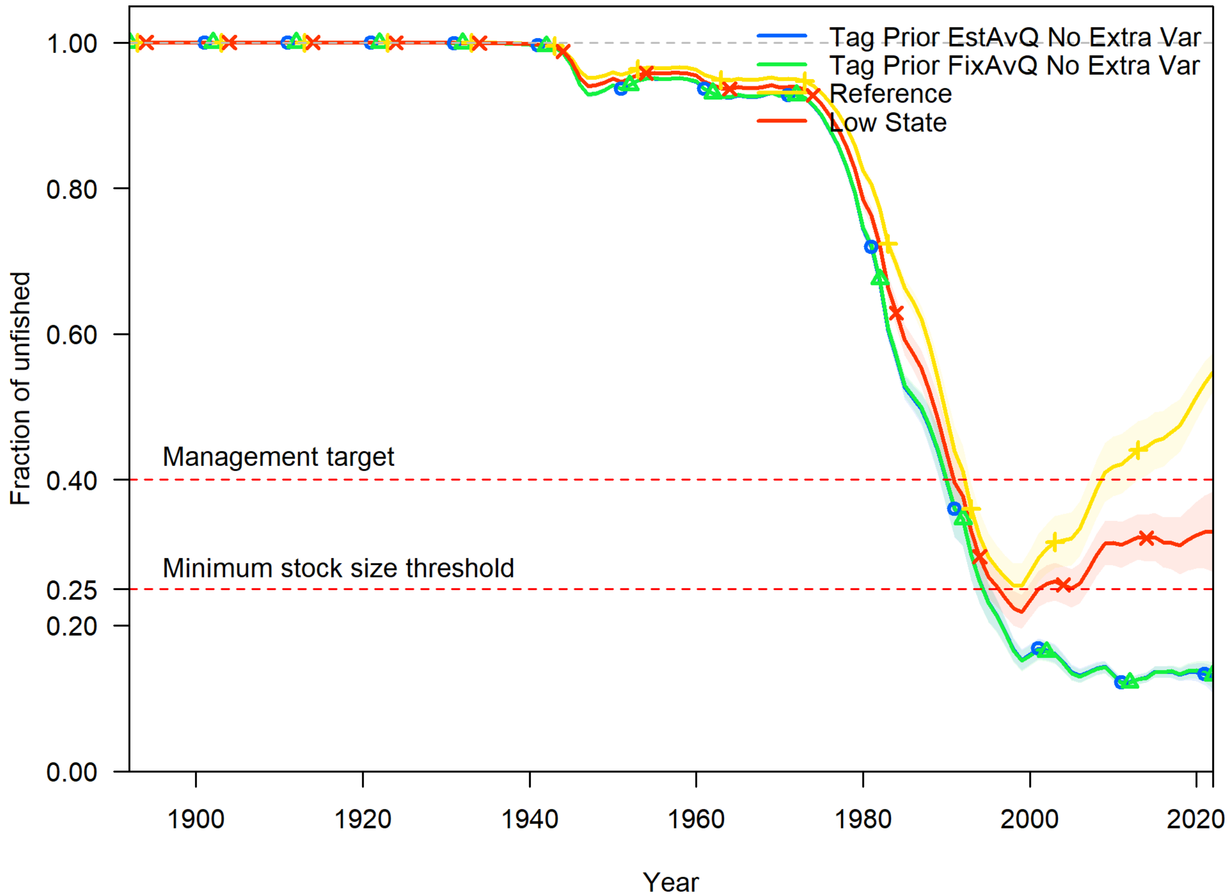


Figure 32: Plots of fits to the AV survey (left) and tagging data (right) for the reference model (top), the tagging prior model that fixes AVq (middle), and the tagging prior model that estimates AVq (bottom).


Tag Prior EstAvQ No Extra Var
Tag Prior FixAvQ No Extra Var
Reference
Low State
Spawning output
0.0
0.5
1.0
1.5
Year
1900
1920
1940
1960
1980
2000
2020



Tag Prior EstAvQ No Extra Var
Tag Prior FixAvQ No Extra Var
Reference
Low State
Management target
Minimum stock size threshold
Fraction of unfished
1.00
0.80
0.60
0.40
0.25
0.20
0.00
1900
1920
1940
1960
1980
2000
2020
Year

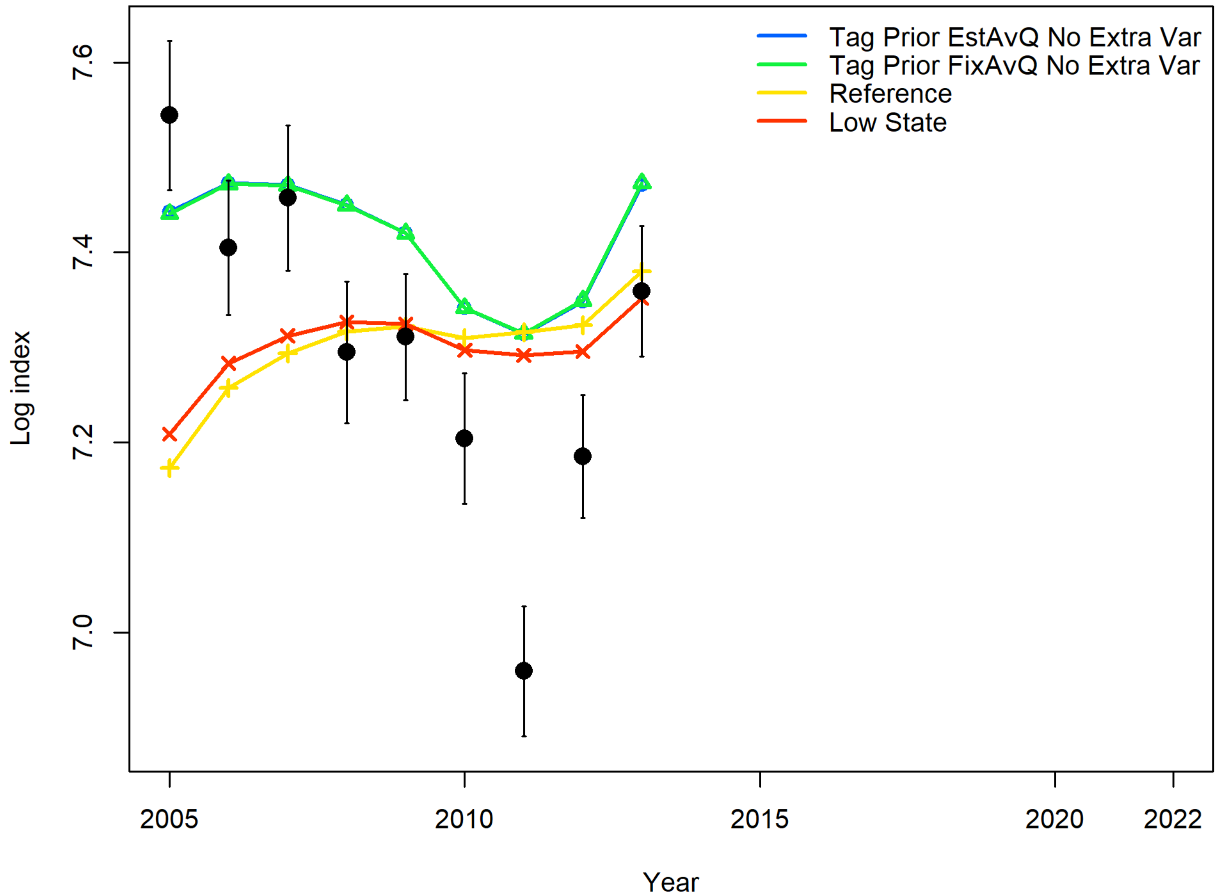


Figure Request 33: Spawning output (top panel) and stock status (middle panel) were compared for these model runs and the reference model. In these plots no extra variance was added to the tag *q*.

Panel Conclusion: Inclusion of the PIT tag survey with a weak but informative prior gave results contrary to what the STAT and STAR Panel had anticipated. The stock shows a much lower stock trajectory than for the reference model, and overall poor fit to the PIT tag index trend. Additional model runs are needed to understand model behavior. There was insufficient time to explore these issues during the STAR panel meeting, and the Panel agreed to defer this to a research recommendation.

Request No. 12: Provide the criteria (if any) to treat the sexes as separate (Option 2) or combined (Option 3) in length composition and conditional age data in stock synthesis and provide a justification for the method selected for the reference model.

Rationale: The panel wants to understand the basis for the current reference model settings and data format and the implications to the assessment. There was public comment on this issue. An email from Rick Methot (developer of the Stock Synthesis (SS) assessment approach) indicated that there was no general guidance on acceptable or best practices for treating sex as separate or combined.

STAT Response: There are no clear or explicit criteria used to choose between sex option 3 and 1 and 2. Time varying sex ratio is a complex mixture of many things such as selectivity, exploitation, and life history. Entering the model as separate sex composition does not discourage the model from altering or tracking the sex ratio, but it does not use what could be information content in the sampled lengths for it. It is less common practice to use non-combined vectors of sexes (i.e., options 1 and 2) for conditional ages. Using a combined sex vector (option 3) for lengths is more common. There is no hard guidance on this, and neither is wrong or right. The next request shows, for this particular assessment, the sensitivity to entering data in these two forms.

Panel Conclusion: The panel thanks the STAT for this information, and developed Request No. 13 to explore further.

Request No. 13: Provide a sensitivity analysis comparing the results of the sexes as separate (Option 2) or combined (Option 3) in stock synthesis and overlay the results for depletion, scale and recruitment. Identify any notable changes to the fits to model data. If possible, compare predicted and observed sex ratio for major data inputs.

Rationale: To evaluate the implications of the alternative settings for the results of the assessment.

STAT Response: Figure 34 provides the spawning output (scale), relative spawning output, and recruitment patterns for the following models:

- Reference Model("middle state of nature")
    - Ref Mod Sex=3_Lt: Use sex=3 option for lengths only
    - Ref Mod Sex=3_CAAL: Use sex=3 option for conditional ages only
    - Ref Mod Sex=3_Lt_CAAL: Use sex=3 option for lengths and conditional ages

- Est AV q, CV0.45 ("low state of nature")
    - Est AV q, CV0.45 Sex3_Lt: Use sex=3 option for lengths only
    - Est AV q, CV0.45 Sex3_CAAL: Use sex=3 option for conditional ages only
    - Est AV q, CV0.45 Sex3_Lt_CAAL: Use sex=3 option for lengths and conditional ages

Additionally, a model was run that estimated *M* using option sex=3 or the reference model version. Both estimate female *M* very high (0.25), but the sex=3 model estimates estimate male *M* very high (*M* = 0.235). The reference model estimates male *M* at 0.18 (not far from the 0.17 used in the model).

Figure 35 shows fits to the non-trawl survey, one of the few fishery-dependent surveys fit by the model. The fits degrade when using option sex=3.

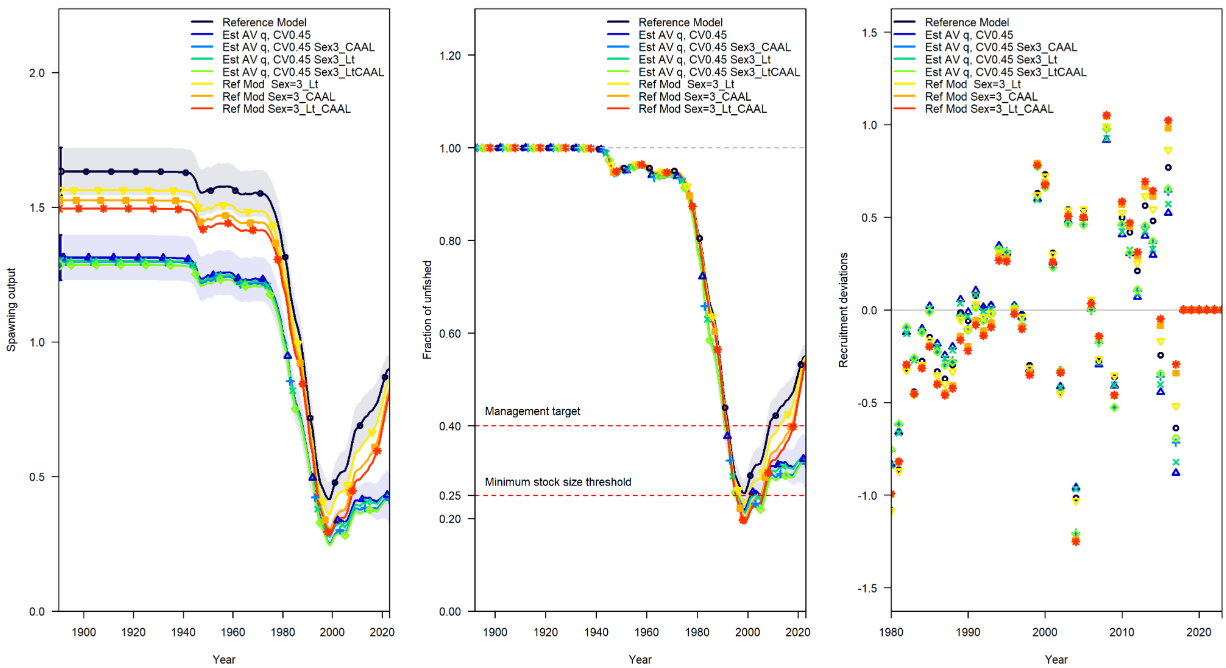


Figure 34. Comparison of spawning output, relative stock status, and recruitment deviations different treatments of sex ratio in the biological compositions.

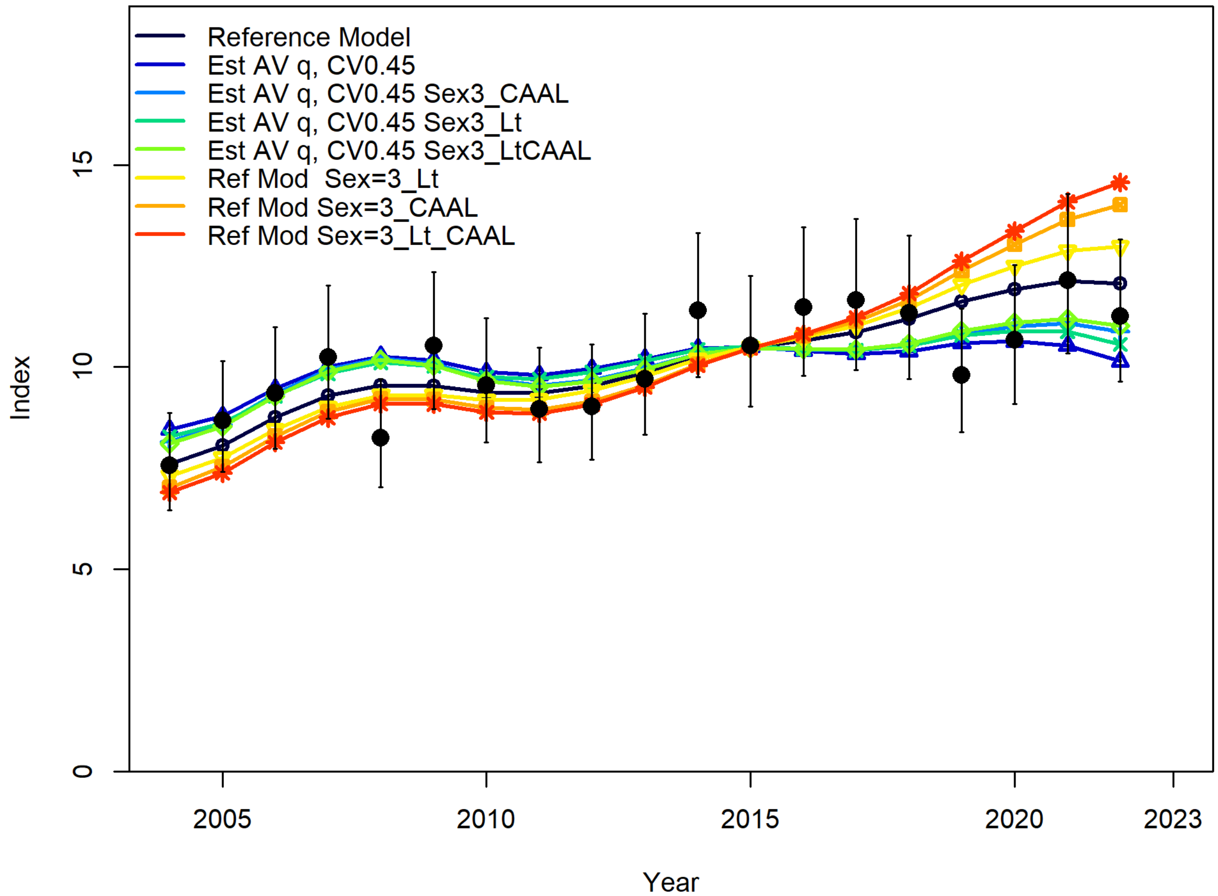


Figure 35. Fits to the non-trawl survey for the different treatments of sex ratio in the biological data.

Panel Conclusion: There are a variety of ways that these options are utilized in different stock assessments on the U.S. West Coast, but there is no consistent approach, nor is there general guidance about which approach is best and in what circumstances. The Panel appreciates the STAT response and concludes that the approach in the current model is acceptable.

Request No. 14: Provide a run with a weight of 0.25 on length composition and 5 and 10 on the AV survey and estimate AV*q*. Compare results to the base model.

Rationale: To upweight the value of the statewide AV survey relative to weights and estimate the resulting *q* value to explore a possible new base model.

STAT Response: See response for Request No. 15 below.

Panel Conclusion: See conclusion for Request No. 15 below.

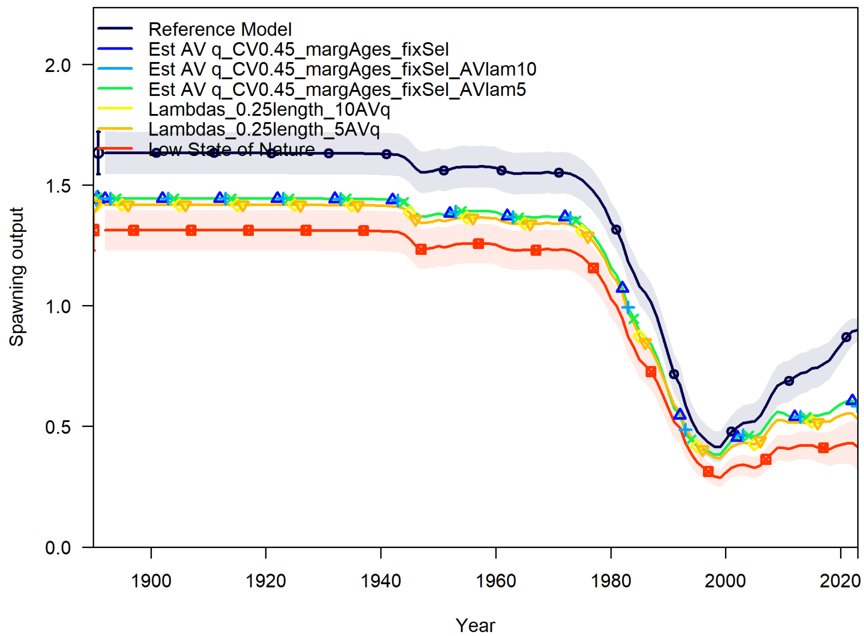
Request No. 15: Fix selectivity in the lengths as done in Request No. 6 and upweight the AV survey to 5 and 10.

Rationale: To explore an alternative method to upweight the statewide AV survey relative to lengths and determine whether it provides an AV*q* within a more reasonable range.

STAT Response to No. 14 and 15: Below are comparisons for the following models as requested in Request No. 14 and 15:

- Reference Model
- Low State of Nature
- Est AV *q*_CV0.45_margAges_fixSel: Fix selectivity to lengths, add marginal ages
- Est AV *q*_CV0.45_margAges_fixSel_AVlam5: as above, but increase AV lambda to 5
- Est AV *q*_CV0.45_margAges_fixSel_AVlam10: as above, but increase AV lambda to 10
- Est AV *q*_CV0.45_Lambdas_0.25length_5AV: decrease length lambdas to 0.25, increase AV to 5
- Est AV *q*_CV0.45_Lambdas_0.25length_10AV: as above but AV lambda to 10

Figure 36 provides the comparison plots for the above treatments. AV*q* values were 2.64 (fix length selectivity) 2.83 (downweight lengths).



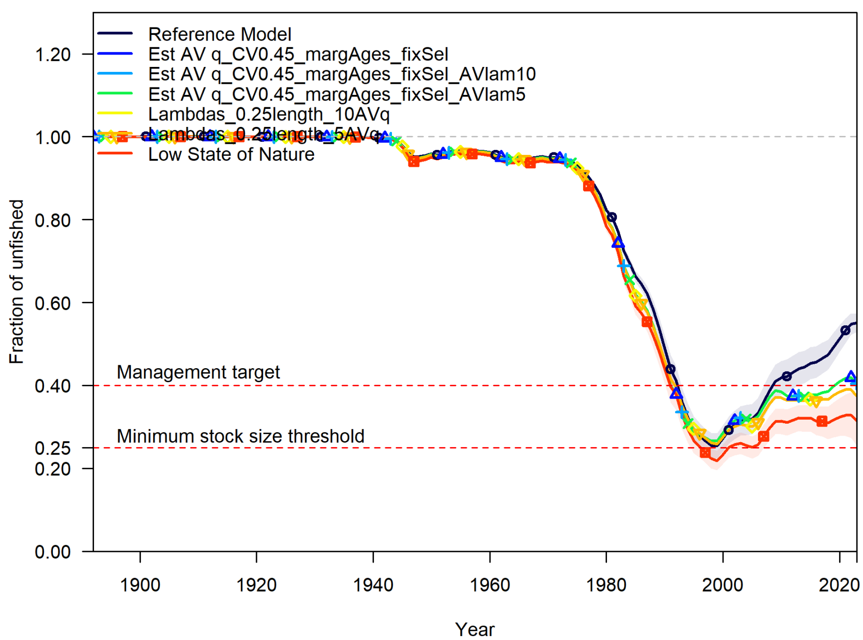


Figure 36. Spawning output (top panel) and relative spawning output (bottom panel) for different treatments of AV and length composition lambdas.

Panel Conclusion: Models in which additional lambda weights of 5 and 10 for the AV survey did not appreciably alter the model outcomes relative to models without these features but included lower lambda values for the length data or were fit to marginal ages. This suggests that models upweighting the acoustic survey are not particularly useful in providing alternatives for consideration for a base model or an alternative state of nature. The panel had extensive discussion on the relative merits of models that downweight the length data versus fitting marginal ages. Although both approaches gave nearly identical results, the STAR panel regarded the approach of fitting marginal ages to be more defensible as a technical approach to reduce the influence of the length data and avoids the subjectivity of selecting a value for lambda. Therefore, a new base model was proposed by the Panel where length selectivity is estimated in an initial run, then fixed and marginal ages are added for a final run. The STAT agreed that the Panel's recommendation be adopted as a new base model.

Description of the Base Model and Alternative Models used to Bracket Uncertainty

The base model is similar to the pre-STAR base model except that length selectivities are estimated in an initial model run and then fixed, and marginal age data are added to likelihood and the model is rerun. This approach reduced the importance of the length data in the assessment and increased the importance of the acoustic-visual survey (it gives comparable results to assigning a weight (lambda) of 0.25 to length data, or, alternatively, a lambda of 10 to acoustic-visual estimate). Although this approach resulted in an improved fit to the acoustic-visual survey estimate, the fit to this index remained relatively poor.

To bracket uncertainty, the Panel focused on alternative treatments of the acoustic-visual survey estimate, which the Panel considered to be the overriding dimension of uncertainty for the Oregon black rockfish assessment. The high state of nature was given by a model that pinned the acoustic-visual catchability (q) to 1.8 by reducing the CV of the survey to a small value. This model was the original base model in the pre-STAR draft assessment. The lower state of nature was given by a model in which the acoustic-survey catchability is freely estimated, essentially ignoring the information content of the survey.

Technical Merits of the Assessment

There is a large quantity of length and age data available for the assessment. There are a considerable number of indices available to inform the assessment, including several based on long-term monitoring of the fishery. In addition, there are several fishery-independent surveys available, including a recent acoustic-visual survey that, at least in theory, provides an absolute measure of abundance. The assessment incorporated estimates of functional maturity that took into account skipped spawning, which was considered an improvement over estimates of physiological maturity, as is usually done. The assessment is very thorough and was carefully done. There was a full set of sensitivity runs and model diagnostics that greatly assisted the STAR panel in model evaluation.

Technical Deficiencies of the Assessment

Only one acoustic visual survey estimate is available because the full survey has been conducted only once. Additional acoustic-visual surveys are needed to address this deficiency. The reliability of the acoustic-visual survey could be improved by in-situ transducer calibration, and use of a species-specific target strength for black rockfish. Information on functional maturity is only available in the last decade, which has been a period of extreme environmental variation in Oregon waters. It is unclear how representative these estimates are of the long-term average. While several long-term fishery-dependent indices are available, in general, they do not appear to be highly informative about the assessment.

Areas of Disagreement Regarding STAR Panel Recommendations

Among STAR Panel members (including GAP, GMT, and PFMC representatives): There were no areas of disagreement between STAR Panel members and representatives regarding STAR Panel recommendations.

Between the STAR Panel and the STAT Team: There were no areas of disagreement between STAR Panel members and the STAT Team regarding STAR Panel recommendations.

Management, Data, or Fishery Issues raised by the GMT or GAP Representatives During the STAR Panel Meeting

No issues were raised by the GMT or GAP representatives during the STAR Panel meeting.

Unresolved Problems and Major Uncertainties

A critical issue in the current assessment is the different signal given by the biological data (primarily length data) and the recent fishery-independent surveys of absolute abundance. Reliance on the length data would indicate that the stock is considerably below management target, while the acoustic-visual survey estimate, considered as an absolute estimate of abundance, indicates the stock is 3-4 times more abundant and above the management target. The large amount of length data available for the assessment has a strong influence on model results, which may be inappropriate given their limited information content. How to appropriately weight the length data in these circumstances is an unresolved problem. In addition, it is difficult to know how much emphasis is appropriate to give the single acoustic-visual survey estimate, which provides an extremely valuable fishery-independent estimate of absolute abundance, but is subject to large estimation uncertainty and consists of a single data point.

Recommendations for Future Research and Data Collection

The panel supports the recommendations provided in the pre-STAR draft assessment (reproduced below).

1. Continue work on the investigation into the movement, and behavior or mortality of older (> age 10) females to further reconcile their absence in fisheries data.
2. Conduct population genetics studies on fish observed off of the continental shelf (middle of the gyre and at sea mounts) to determine their association with the nearshore stocks.
3. Continue to build evidence for appropriate natural mortality values for females and males.
4. Improved historical catch reconstructions. Specifically, the historic trawl fishery catches (pre-1987) in particular require particular attention. A synoptic catch reconstruction is recommended, where states work together to resolve cross-boundary state catch issues as well as standardize the approach to catch recommendations to the extent possible.
5. Stock structure for black rockfish is a complicated topic that needs further analysis. How this is determined (e.g., exploitation history, genetics, life history variability, biogeography, etc.) and what this means for management units needs to be further refined. This is a general issue for all nearshore stocks that likely have significant and small-scale stock structure among and within states, but limited data collections to support small-scale management.
6. Continue acoustic-visual fisheries independent coastwide survey to develop a time series. Further refine the survey by addressing the recommendations of the SSC methodology review from 2022. Examine the potential of using spatial modeling to reduce the uncertainty in the population estimates from the acoustic-visual fisheries independent coastwide survey.
7. Reconcile contradictory signals in the black rockfish biology versus the population scale.
8. Better understand the ecology and habitats of black rockfish from settlement to age 4. Further development of surveys aimed specifically at recruitment or settlement rates of nearshore species, such as OSU's Standard Monitoring Units for the Recruitment of Fishes (SMURF) collections, that are not frequently encountered in offshore federal age-0 surveys is needed.

The STAR panel supports the following additional recommendations for future research and data collection.

1. With respect to the STAT's recommendation No. 6 above on the acoustic-visual survey, the Panel recommends that the survey team focus on improving the survey estimates by a) obtaining a target strength estimate for black rockfish, b) developing a method for in-situ transducer calibration, and c) improving backscatter identification using visual surveys and other methods as appropriate. Concentrating on the echo integration component of the survey seems warranted given that methods are well developed and widely used, and it is regarded as a reliable and robust acoustic survey technique.
2. Develop additional capacities in stock synthesis to model marine reserves (i.e., closed to fishing) and areas that are open to fishing.

3. Explore tradeoffs between the different options to fitting sex-specific composition data in stock synthesis and develop recommendations for acceptable practices.
4. Using acoustic visual survey data to develop an informative prior for the PIT tag survey was considered during the STAR panel meeting, but there was insufficient time to fully explore this approach. Future assessments should continue to develop and evaluate this approach.
5. Continue to collect functional maturity information and evaluate the role of geography, environmental forcing, and density dependence on functional maturity estimates for black rockfish.

Recommendation for Next Assessment, Assessment Category, and Sigma

The next assessment for Oregon black rockfish should be a full assessment to further address the conflict between the biological data and acoustic-visual survey estimates, particularly if additional acoustic-visual surveys are conducted. This assessment is considered to be a Category 1b assessment since it is an age-length structured assessment with a fishery-independent survey, but steepness could not be estimated.

The sigma value (the ln-scale coefficient of variation for OFL in the first projection year (2025), measuring scientific uncertainty) from the final base model was 0.10, which is less than the default sigma value (0.5) recommended by the Council's Scientific and Statistical Committee for Category 1 stocks.

Northern California Model

Summary of Data and Assessment Model

Two separate assessments were conducted on California black rockfish with data separated between Northern California (north of Point Arena, 38°57′30” N. lat.) and Central California (south of Point Arena). The northern California assessment is based on multiple data sources including commercial and recreational catches, size samples from both fishery and survey platforms, ageing data and a suite of indices of abundance, including both catch-per-unit-effort (CPUEs) from fisheries data and fishery-independent surveys. The temporal availability of these data sources are given in Figure 3**.**

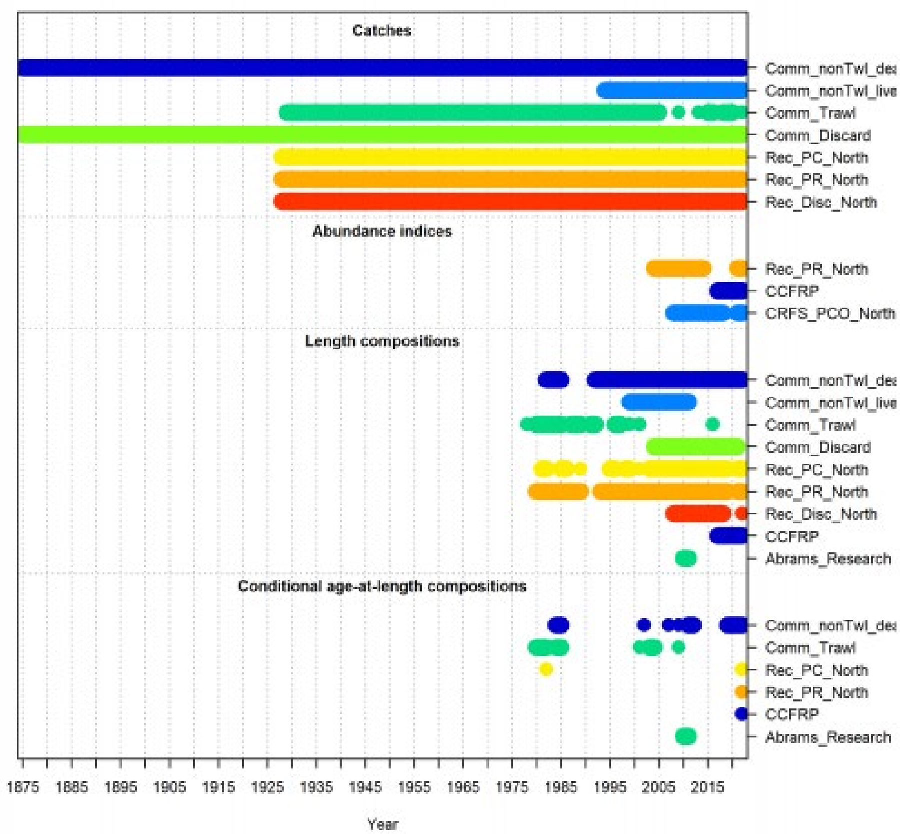


Figure 37. Availability and sources of input data for the northern California black rockfish assessment.

Black rockfish are taken by recreational and commercial fleets in California, but northern recreational fisheries have accounted for the majority of statewide removals in recent decades. Within the recreational sector, landings are dominated by the "boat modes" i.e., private/rental (PR) boats and party/charter (PC or Commercial Passenger Fishing Vessels (CPFV)) with relatively minor contributions from shore-based fishing modes. Until 1943, the great majority of rockfish landings in California (~95%) were taken by longline gear. Black rockfish became a component of the commercial live-fish fishery that developed in the early 1990s. In recent years, black rockfish landed alive have accounted for about 50% of the commercial catch in weight.

The northern California black rockfish assessment is structured as a single, sex-disaggregated population, spanning U.S. waters from the Oregon/California border south to Point Arena, California. The assessment model has an annual time step covering the period 1875 to 2022 and assumes an unfished equilibrium population prior to 1875. Population dynamics are modeled for ages 0 through 50, with age-50 being the plus age group. Size bins were set every 1 cm from 5 to 70 cm, and data bins were set every 2 cm from 8 to 60 cm. The model is conditioned on catch from two sectors (commercial and recreational) divided among six fleets (three commercial and two recreational) plus two discard "fleets", one for each sector. Additionally, there were three time series of relative abundance indices available, two being fishery-dependent from the recreational sector and the other being a fishery-independent survey. None of these surveys were initiated before 2002 and none had a continuous series in annual data over the time period 2003-2022. Size and age composition data include lengths and ages from 1972-2022 and ages with intermittent gaps in each data type.

The recreational sector is divided into two main fleets according to fishing type (CPFV or private boat) and catch type (retained or discarded). All recreational shore modes were combined with the private boat fleet due to their small contribution to overall catch. Discarded catch (CPFV and private boats combined) was modeled as a separate fleet due to differences in size composition relative to retained catch, and a lack of sufficient data in an appropriate format to explicitly model retention. The commercial sector was represented by three fleets. Two "non-trawl" fleets, representing primarily hook-and-line and longline gear types but including other minor gears, were defined for 'live' and 'dead' conditions. Other commercial fleets include a trawl fleet, and a fleet for discarded catch which represented discarded dead catch from both non-trawl and trawl fleets.

The northern California black rockfish model was structured using several fixed/prior-constrained parameters. A prior distribution was specified for the estimated female natural mortality parameter with a median of M = 0.154 and a log-scale standard deviation of 0.31, with male mortality estimated as an exponential offset with a flat prior. Parameters of sex-specific von Bertalanffy growth equations were either estimated (length at age 20, k, and CVs of length at age 20) or fixed (5-cm length at age 0 and a CV of 10% for length at age 0). Weight-length, maturity, and fecundity relationships were estimated external to the model or taken from values reported in the literature. A Beverton-Holt stock recruitment relationship was assumed, using a fixed steepness of 0.72 and a fixed sigma R = 0.6 with lognormal deviations being fitted from 1963-2022. Various fleet selectivity patterns were explored with the pre-STAR Panel recommendation being a suite of both domed and logistic selectivities. Francis weights were applied to the composition data with a maximum weight of 1, and additive variance was estimated for the PR recreational index. Otherwise, no further weighting was done.

Within model uncertainty is explicitly included in this assessment by parameter estimation uncertainty, while among model uncertainty is explored through sensitivity analyses addressing alternative input assumptions such as data treatment and weighted, and model specification sensitivity to the treatment of life history parameters, selectivity, and recruitment. While the updated assessment uses all available data, uncertainty remains regarding outcomes and management quantities.

As with most assessments, the value of steepness remains a source of uncertainty that has not been resolved through assessment modeling. The uncertainty in the prior for natural mortality (log-scale SD of 0.31) was used to obtain possible upper and lower states of nature. This uncertainty was centered on the point estimate of the base model (0.21) and was defined at the 12.5 and 87.5 percentile of the distribution for lower and upper states of nature.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: Generate pairwise plots (and calculate correlation coefficients) for all the abundance indices, for years which overlap.

Rationale: The consistency of various abundance indices are evaluated graphically in the report. Pairwise comparison of all abundance indices can provide a more quantitative evaluation of consistency of abundance indices.

STAT Response: The requested plots are shown below. Index combinations were separated into fishery-dependent, fishery-independent, and young of the year (YOY) survey categories because insufficient overlap among years prohibited all possible combinations (see Fig. 4 of the stock assessment document for the temporal extent of each index). Fishery-dependent indices (CRFS_PR and CRFS_PCO) were positively correlated. Fishery-independent indices (CCFRP and PISCO) showed weak or no correlation ($p > 0.1$) over the 5-year period that they overlap. The YOY surveys (RREAS and SWFSC_YOY) were strongly positively correlated ($p < 0.05$). The PISCO and YOY surveys were not included in the base model.

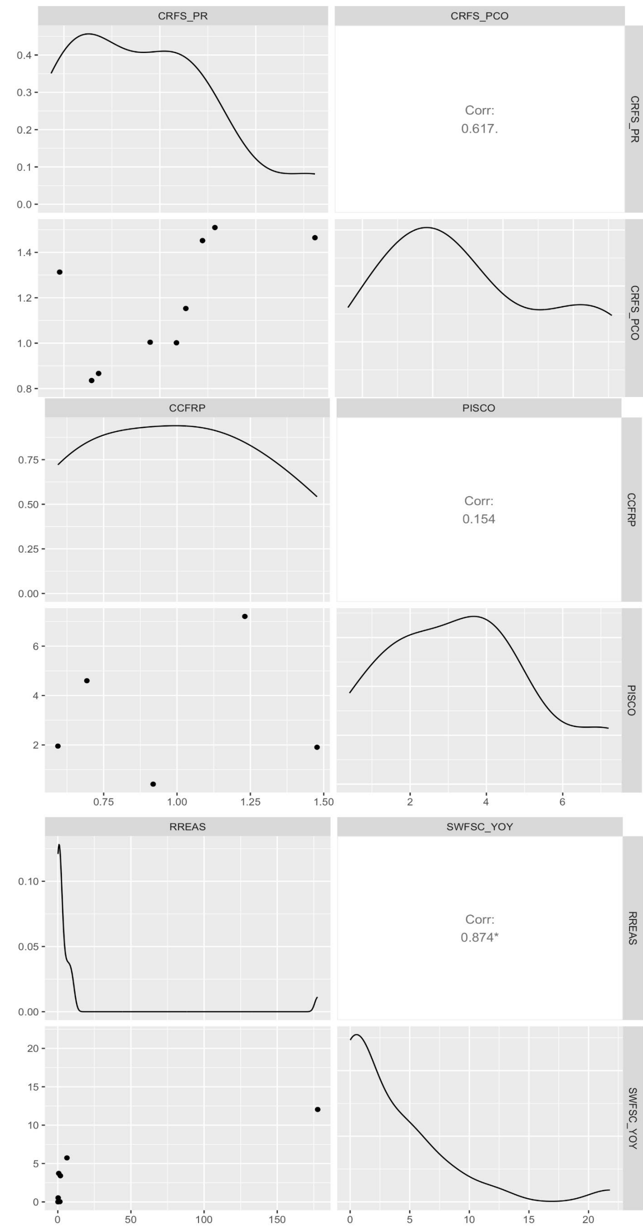


Figure 38: Pairwise comparisons of abundance indices considered for the northern California assessment. Correlation coefficients (numbers) and p values (*** < 0.001, ** < 0.01, * < 0.05, and . < 0.10) are shown in the upper right quadrants, data points are shown in the lower left quadrants, and kernel densities are shown along the diagonals. A minimum of five overlapping years was required for inclusion. CRFS_PR: dockside private/rental recreational fishing boats; CRFS PCO: party/charter onboard observers; CCFRP: California Collaborative Fisheries Research Program; PISCO: Partnership for the Interdisciplinary Study of Coastal Oceans; RREAS: NMFS SWFSC's Rockfish Recruitment and Ecosystem Assessment Survey; SWFSC_YOY: NMFS SWFSC's young of the year SCUBA survey.

Panel Conclusion: The moderate correlation between the fishery dependent indices suggests some consistency with each other. This may indicate a potential for both indices to inform the model on population trends. The weak relationship between two fishery-independent survey indices may result from the two programs capturing different components of the targeted population.

Request No. 2: Plot natural mortality (*M*) as a function of steepness (*h*), given the potential interactions (data from Tables 44 and 45). Provide a steepness profile, while estimating *M* for females and males.

Rationale: *M* and *h* tend to be highly correlated. An examination of LL (log likelihood) values under a varying *M* and *h* (over a reasonable range) would help us understand how they interact and how they may influence the assessment of population dynamics.

STAT Response: Based on a profile over the Beverton-Holt steepness parameter from 0.25 to 0.95 in increments of 0.05, natural mortality for females declined from slightly more than 0.3 to slightly less than 0.2. The estimated offset for males remained fairly constant across all values of steepness.

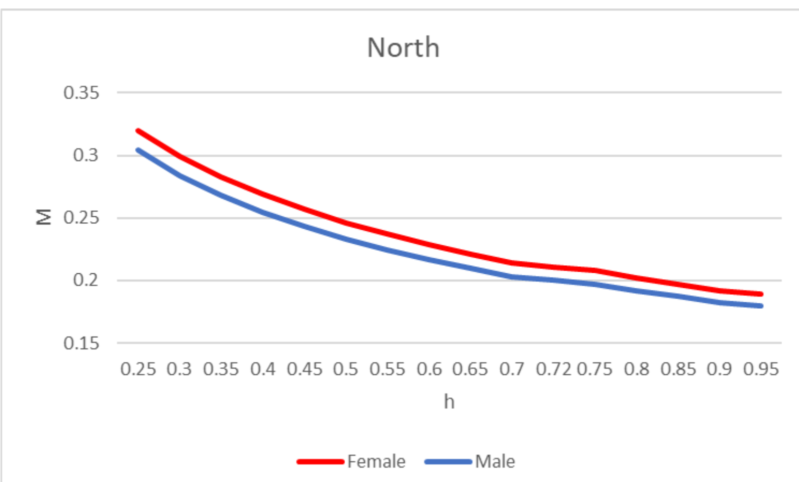


Figure 39. Estimated values of female and male natural mortality (*M*) as a function of the Beverton-Holt steepness parameter (*h*).

Panel Conclusion: This exercise demonstrates the inverse relationship between steepness and natural mortality rate. Both measure aspects of the underlying productivity of the stock, but the model requires constraints (priors) on one (or both) in order to estimate the other. This inherent relationship should be considered when defining axes of uncertainty.

Request No. 3: Update the ageing error data to include the errors for before 2015 since only those for after 2015 were applied and plot results relative to the reference base model.

Rationale: Ageing error matrices were developed for two time periods, but only the errors from after 2015 were included. This will better reflect the ageing errors in each period.

STAT Response: The addition of a new ageing error matrix for pre-2015 age data (excluding Abrams age estimates that were produced for this assessment) had very little effect on model likelihoods and estimated parameters changed very little. Small changes to estimated recruitment deviations were evident in the early part of the time series, but this had little impact on time series of spawning output or recruitment (Figure 40), or estimated parameter values (Table 5).

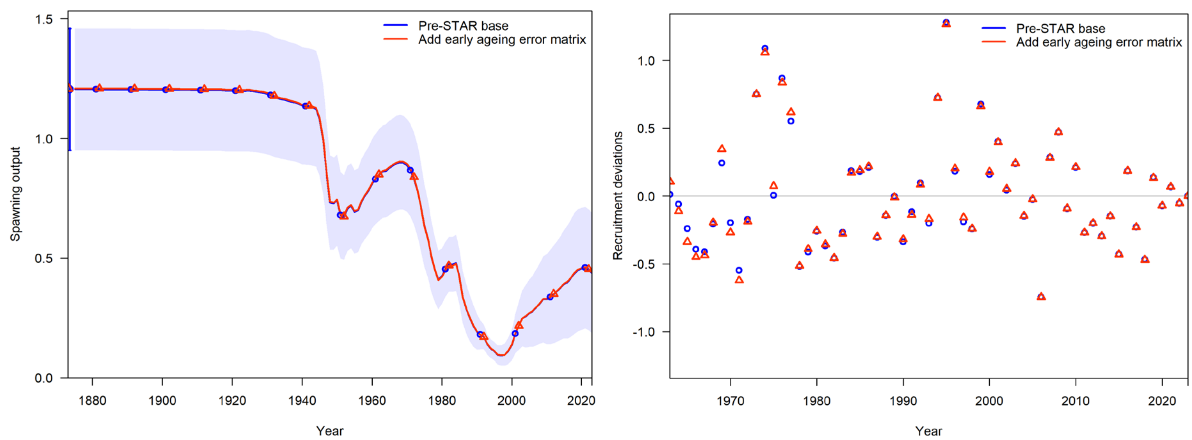


Figure 40. Comparison of estimated time series of spawning output (billions of eggs) and recruitment deviations from the pre-STAR base model and a revised model using the correct pre-2015 ageing error matrix.

Table 5. Number of estimated parameters, likelihood values, and parameter estimates for the northern California models evaluated in request 3.

Quantity	Pre-STAR base	Add early ageing error matrix
N.Parms	98	98
TOTAL	1106.27	1105.25
Survey	-29.9739	-29.9719
Length_comp	366.71	367.543
Age_comp	773.604	771.501
Recruitment	-4.58365	-4.3299
Parm_priors	0.517137	0.505673
NatM_uniform_Fem_GP_1	0.211457	0.210716
L_at_Amax_Fem_GP_1	54.4938	54.4408
VonBert_K_Fem_GP_1	0.147691	0.148211
CV_old_Fem_GP_1	0.0816563	0.0836846

NatM_uniform_Mal_GP_1	-0.0533557	-0.052892
L_at_Amax_Mal_GP_1	-0.147081	-0.146587
VonBert_K_Mal_GP_1	0.311759	0.311706
CV_old_Mal_GP_1	-0.319049	-0.334481
SR_LN(R0)	7.72829	7.72042
Q_extraSD_Rec_PR_North(6)	0.0878346	0.0878631

Panel Conclusion: Additional data on aging error represents an informational improvement that should be included in the assessment. The net difference in model spawning output is small. Nevertheless, the new data on aging error should be implemented into the new reference model.

Request No. 4: Provide a sensitivity analysis fitting functional maturity with a spline in addition to the logistic curve applied in the assessment.

Rationale: A spline was fit to data in the Oregon and Washington assessments and the Panel would like the STAT to provide comparable results for California.

STAT Response: Estimates of maturity at length (2-cm length bins up to 64 cm) from the Washington/Oregon models were used to interpolate maturity at length following the population length bin structure in the California model (1-cm bins, 4-70 cm). Estimates from 64-70 cm were based on linear extrapolation of the curve's descending limb (Figure 41).

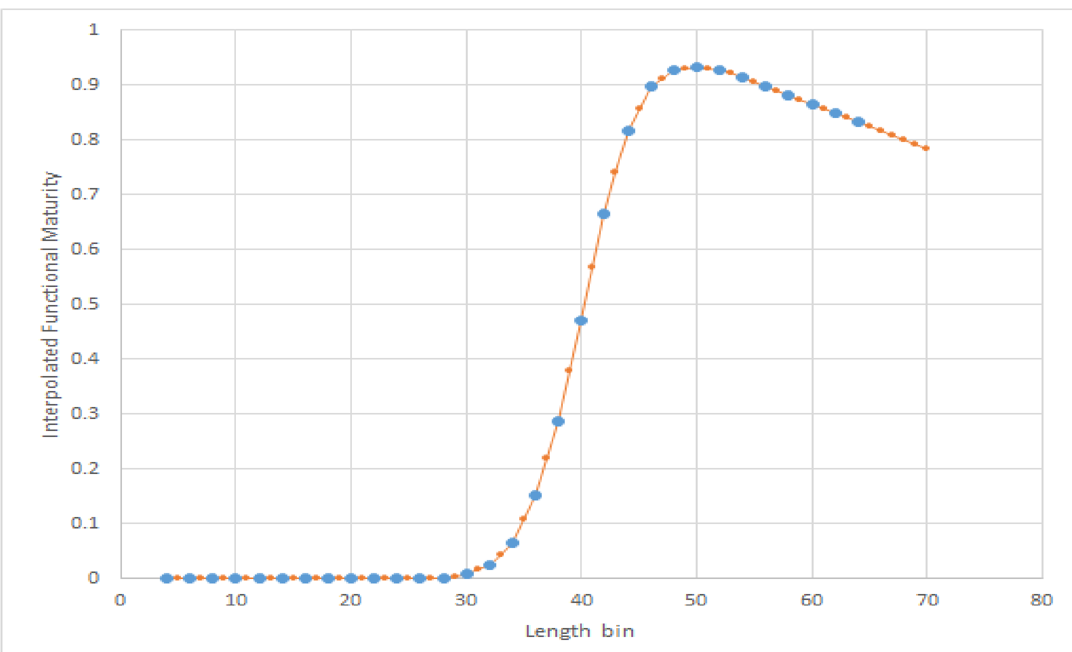


Figure 41: Spline model for functional maturity used in request number 4. Blue points are the estimates used in the Washington/Oregon models, and the orange line and points are the interpolated and extrapolated values used in the sensitivity run.

Use of the interpolated functional maturity relationship scaled the spawning output relative to the logistic model for functional maturity, but it did not change relative spawning output significantly (Figure 42).

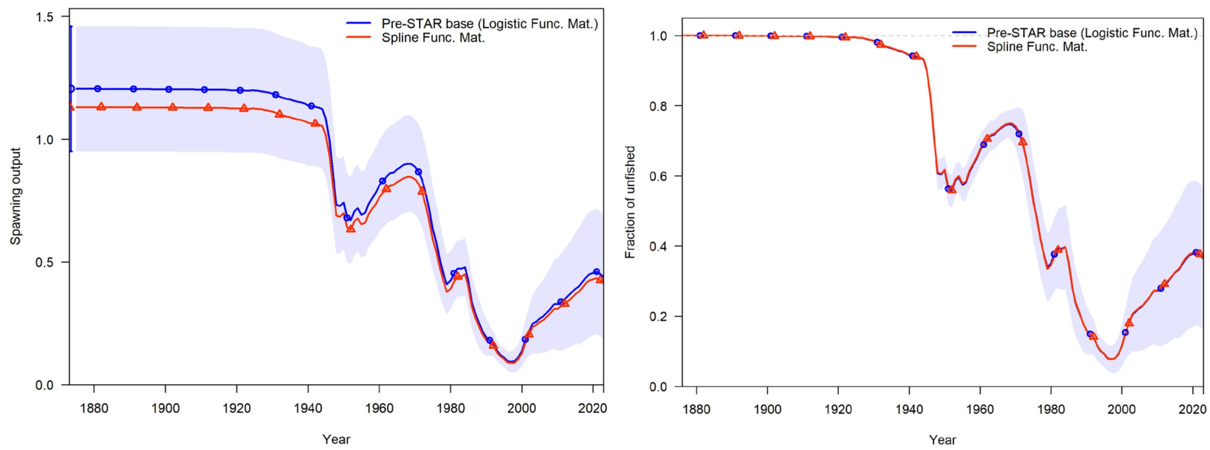


Figure 42. Effect of changing the functional maturity relationship (from a logistic model to a spline model) on time series of spawning output (billions of eggs) and spawning output relative to unfished spawning output.

Early recruitment deviations changed slightly, but other estimated model parameters and derived quantities did not change significantly (Figure 43).

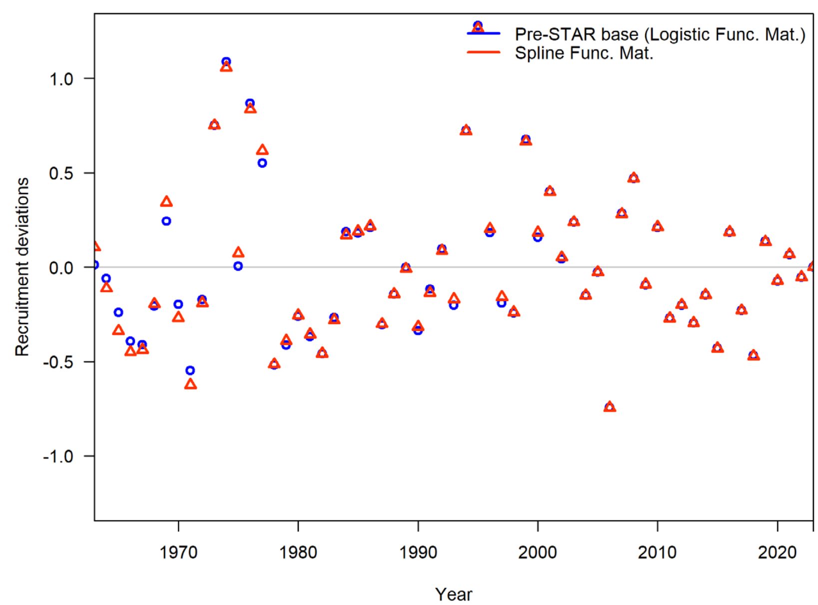


Figure 43. Effect of changing the functional maturity relationship (from a logistic model to a spline model) on estimated annual recruitment deviations.

Panel Conclusion: Improvements to the maturity ogive were made to the Oregon and Washington assessments that include a spline model where maturity declines slightly at large sizes. Thus, egg production shifts slightly compared to the logistic curve. Impacts on the assessment are minimal when the spline model is used instead of the logistic curve. The spline model should be used in a new reference model so that a consistent approach is applied across all assessments.

Request No. 5: Provide a model run that mirrors selectivity for non-trawl dead and non-trawl live fisheries.

Rationale: The Oregon assessment concluded that these fisheries could be combined. This model run would evaluate the effect of a similar assumption on the northern California assessment.

STAT Response: Mirroring commercial Non-Trawl live selectivity to the logistic selectivity of the dead category (Figure 44) results in small changes in estimated recruitment deviations from the 1980's-mid 1990's (decreases early, and increases around the 1990's; Figure 45).

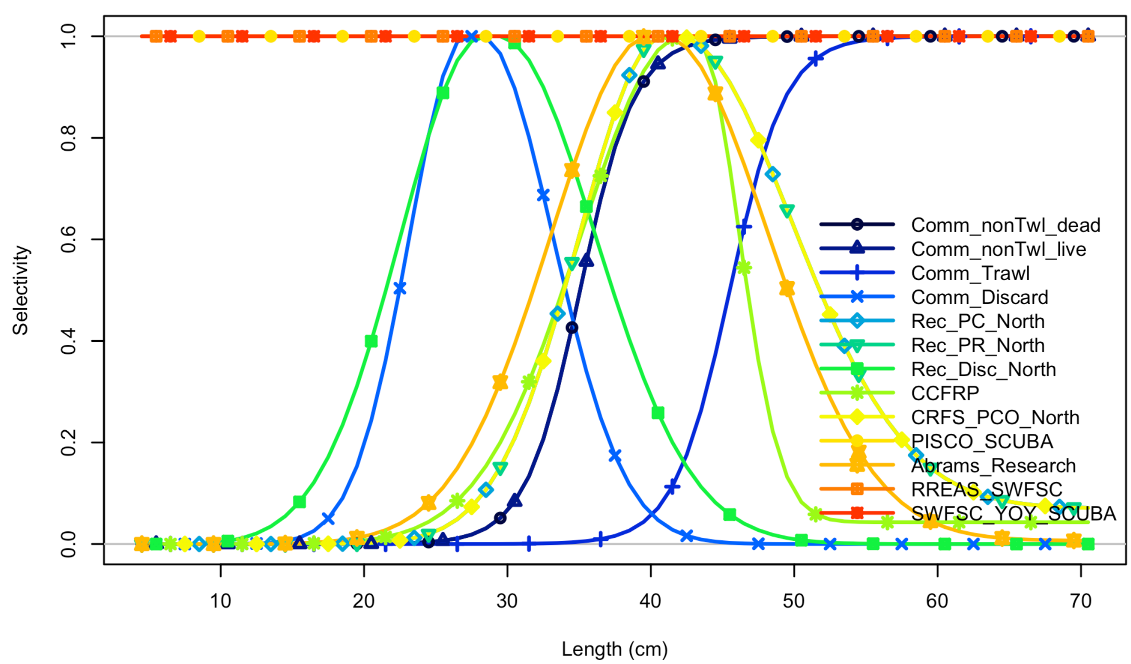


Figure 44. Length-based selectivity curves from the requested model run, with "mirrored" (equivalent) functional forms for the commercial non-trawl dead (Comm_nonTwl_dead) and live fisheries (Comm_nonTwl_live).

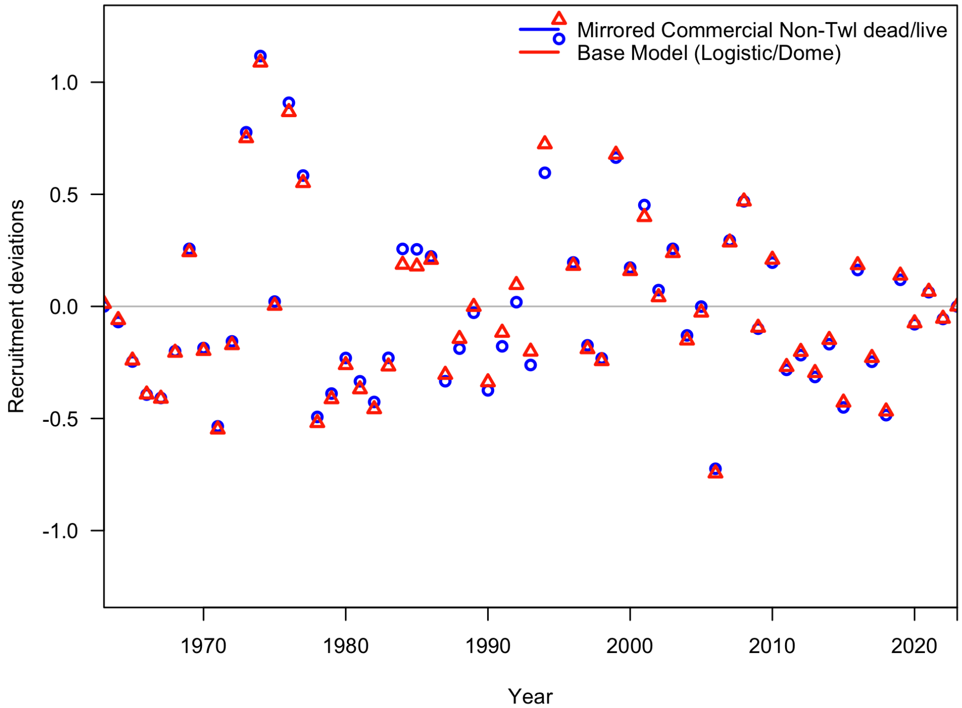


Figure 45. Changes in estimated recruitment deviations resulting from "mirrored" (equivalent) functional forms for the commercial non-trawl dead (Comm_nonTwl_dead) and live fisheries (Comm_nonTwl_live).

The mirrored model has three fewer parameters and NLL increases by 11.6 points as compared with the base model; other estimated model parameters and derived quantities did not change significantly (Figure 46).

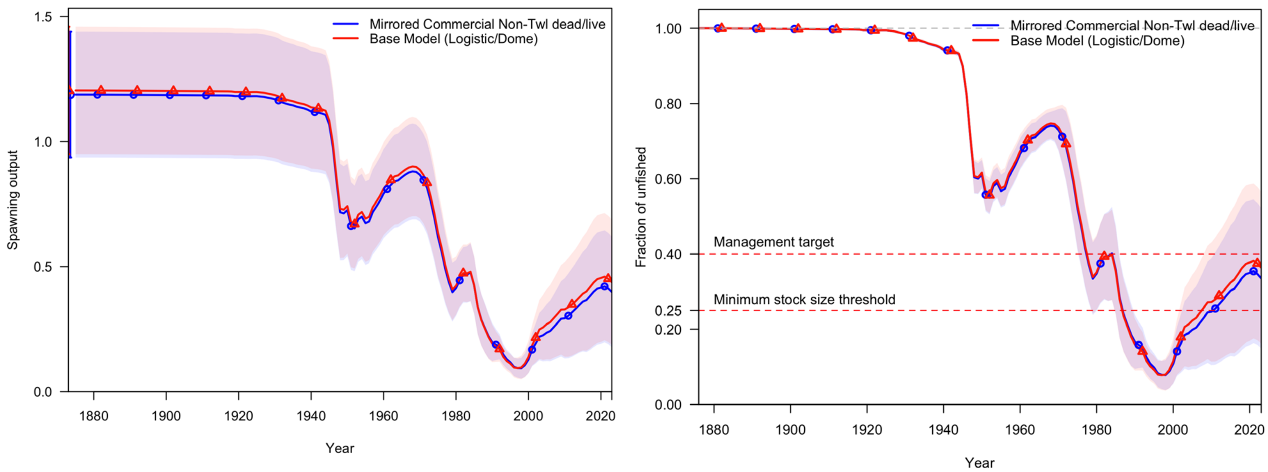


Figure 46. Comparison of time series of spawning output (billions of eggs) and relative spawning output from the pre-STAR base model and a revised model with mirrored selectivity for the live and dead non-trawl fleets.

Panel Conclusion: This request was an exploration of an alternative structure for selectivity of these "fleets". The effect on model outcomes was minimal and the statistical justification was not very strong. Therefore, the reference model should not be changed by using this alternative.

Request No. 6: Provide documentation for the data selection criteria for the private/rental boat (PR) dockside index.

Rationale: Selection criteria are intended to extract records that are likely to be informative about black rockfish abundance trends and panel members wanted to better understand how this was done.

STAT Response: The PR dockside data used to generate indices of abundance were selected using the following criteria:

- Excluded data from CRFS districts 1-2
- Removed data from 2015-2020 due to sub-bag limits for black rockfish
- Removed data with angler-reported distance from shore >3 nm
- Retained only hook and line gear (troll targets other species and has 1/10th the catch rate)
- Kept data from May-October (few samples in other months, especially in north)
- Kept trips with primary trip types 'rockfish genus','bottomfish (groundfish)', and 'lingcod'

Table 6. Mean CPUE, number of trips landing black rockfish (tripsWithTarget), number of trips that did not land a black rockfish (tripsWOTarget), total number of trips, and percentage of total

trips that landed a black rockfish (percentpos), by angler-reported primary target (prim1Common) and CRFS district number (districts 5 & 6 represent northern California).

prim1Common	district	MeanCPUE	tripsWithTarget	tripsWOTarget	totalTrips	percentpos
bottomfish (groundfish)	3	0.016	1	30	31	3%
bottomfish (groundfish)	4	3.017	11	5	16	69%
bottomfish (groundfish)	5	1.804	793	498	1291	61%
bottomfish (groundfish)	6	3.909	7380	1401	8781	84%
lingcod	3	0.277	196	672	868	23%
lingcod	4	0.665	87	162	249	35%
lingcod	5	1.196	58	47	105	55%
lingcod	6	2.192	325	168	493	66%
rockfish genus	3	0.434	3930	11357	15287	26%
rockfish genus	4	1.346	5138	4271	9409	55%
rockfish genus	5	1.367	1156	843	1999	58%
rockfish genus	6	4.311	3783	417	4200	90%

- From the set of trips with these primary targets, we retained trips with the same secondary targets (i.e. excluding secondary targets such as halibut, crab, or salmon), or with an unknown secondary target.
- The effects of target species on catch rate were explored in the development of the index standardization model.

Panel Conclusion: Information was provided indicating the selection criteria, particularly on "targeting" definition including primary and secondary targets. No further suggestions or comments.

Request No. 7: Please include clarification regarding the Mohns rho results and what they represent; over a 5 year average as stated in the TOR. Provide a plot to show relative error in ending biomass consistent with best practices described in Legault 2009.

Rationale: The values will be useful in assessing the retrospective pattern. There are multiple options for calculating Mohn's rho in r4ss and thus it is important to understand the mechanism being used. Retrospective error is a particular type of uncertainty and it is important to understand any bias.

STAT Response: Mohn's rho values based on a 5-year peel were -0.188 for spawning output, 0.086 for recruitment, and 0.246 for exploitation rate. This was calculated using the r4ss function "SSmohnsrho," dividing the reported cumulative value by the number of retrospective years (5).

Plots are provided below for time series of spawning output, recruitment, and exploitation rate (Figure 47) and percent change relative to the base model (Figure 48). Removal of the last 1-5 years of data tends to lead to lower estimates of spawning output (back to ~1990, generally not exceeding 20%), higher exploitation rates, and higher recent recruitments. Differences in recent recruitment predictions occur primarily because predictions revert back to the mean of the stock-recruit curve as data are removed.

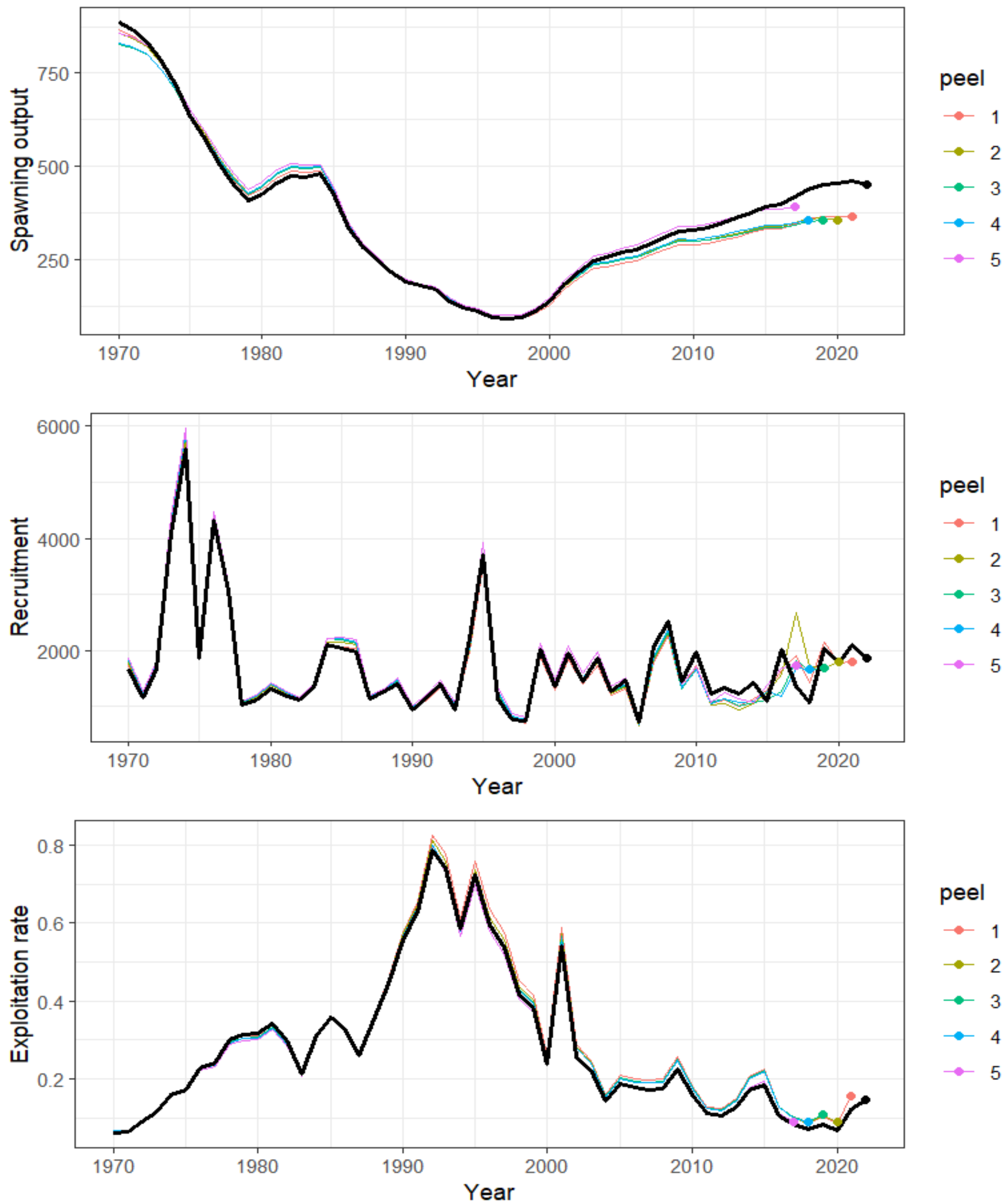


Figure 47. Time series of spawning output (billions of eggs; top panel), recruitment (1000s of age-0 fish; middle panel), and exploitation rate (catch divided by age 8+ biomass; bottom panel) for retrospective runs removing 1-5 years of data from the northern California black rockfish model. Black line shows results from the pre-STAR base model, for reference.

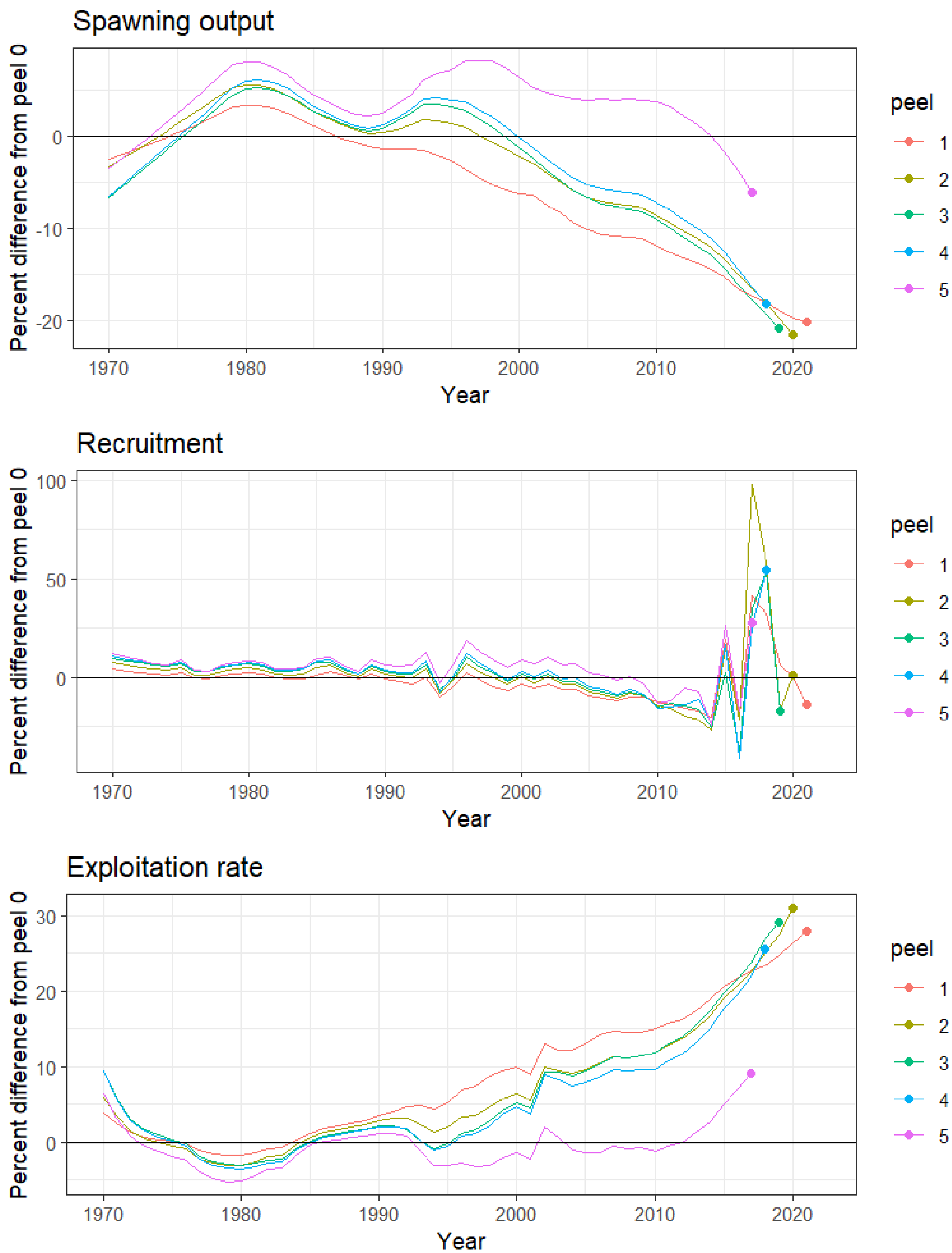


Figure 48. Time series of change in spawning output (billions of eggs; top panel), recruitment (1000s of age-0 fish; middle panel), and exploitation rate (catch divided by age 8+ biomass; bottom panel) for retrospective runs removing 1-5 years of data, relative to the northern California pre-STAR black rockfish model.

Panel Conclusion: This request provided the Panel with a diagnostic on the effects of retrospective patterns. One thing to note is that with 5 year peels, an index is eliminated. This distorts the outcomes somewhat. Generally, the Panel had no further recommendations, but noted that this exploration should be considered in the future.

Request No. 8: Provide squid plots showing the age at which recruitment is first detected in the fishery and fishery dependent studies, using the new base model and an updated model including the RREAS and SCUBA young of year surveys.

Rationale: To identify how long it takes for recruitment to be detected in the data from the fisheries or non-young of year surveys. This will help inform how much potential benefit there is for early indications of recent recruitments from the inclusion of the RREAS and SCUBA survey young of year surveys in the assessment. This model will be considered as a potential base model.

STAT Response: The STAT was unable to complete this request during the review. Preliminary results of the analysis were completed for the central area model, but as noted in the request document for that model, long run times in combination with many possible model configurations made it impossible to fully develop a response.

Panel Conclusion: The analysis from the Central California assessment area demonstrates that the RREAS and SCUBA young of year surveys may have potential to inform future recruitment in the projection. However, the STAT did not have time to fully explore incorporation of these data sets in the reference model, including evaluating model diagnostics to ensure the appropriate use of the information. The panel finds such plots to be useful for evaluating whether a recruitment index would be valuable to include in the assessment, and recommends they be included in future black rockfish assessments and other assessments that consider the use of recruitment indices.

Request No. 9: Incorporate the ageing error prior to 2015 and spline fit to the functional maturity to provide a revised reference model.

Rationale: To implement the conclusions of Request No. 4 (the ageing error prior to 2015) and Request No. 5 (functional maturity fit with a flexible spline), which improved the base model.

STAT Response: The corrected ageing error matrix and spline model for functional maturity were included in the model, and Francis weights updated (little change in weights). As noted in the request to revise the maturity relationship, spawning output was slightly scaled upwards, but relative spawning output remained very similar over time (see figures below).

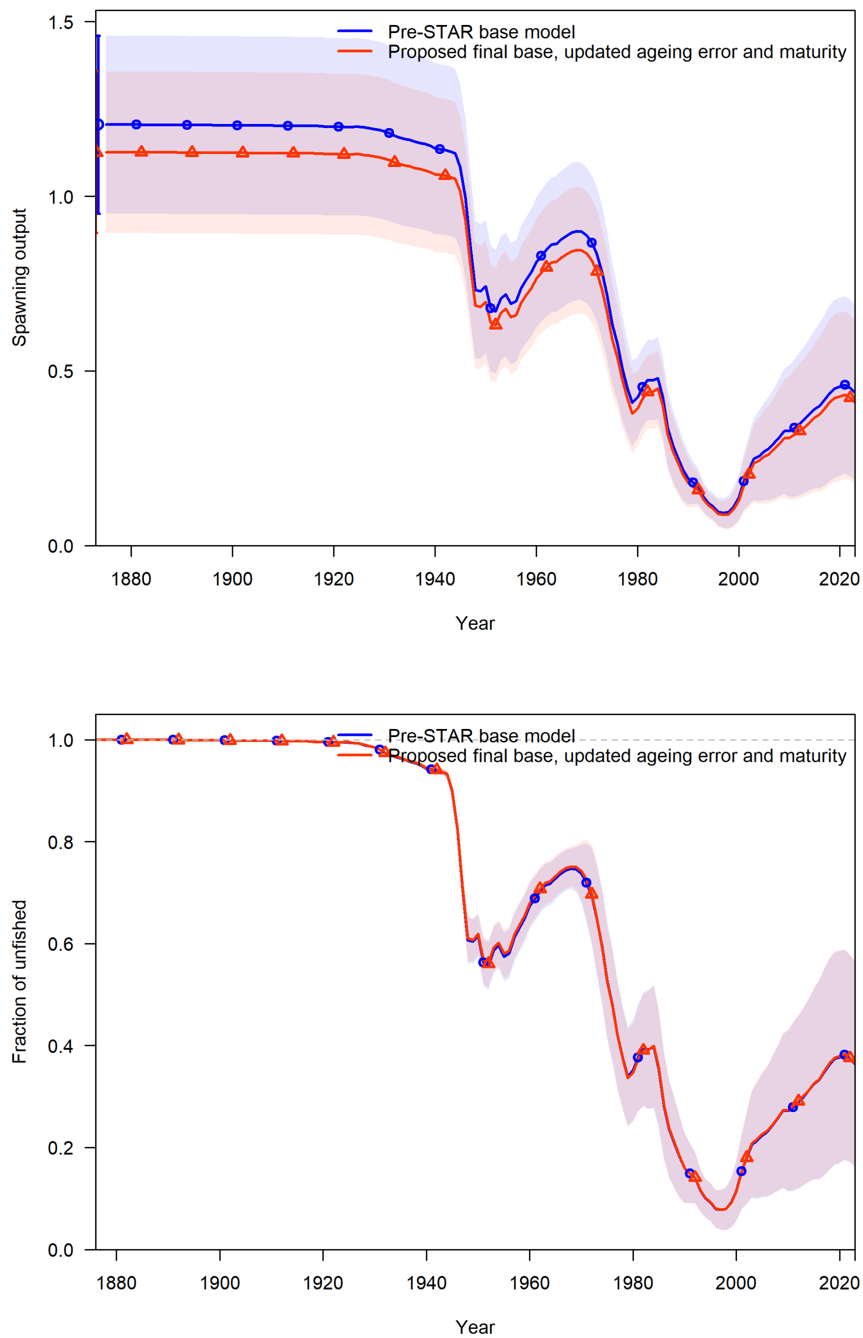


Figure 49. Comparison of the pre- and post-STAR base models' estimated time series of spawning output (billions of eggs; top panel) and relative spawning output (spawning output / unfished spawning output; bottom panel).

Model likelihoods, parameter estimates, and derived quantities are similar between the pre-STAR base and the updated model (Table 7). Further details of the updated model were presented to the panel using the r4ss html output.

Table 7. Number of estimated parameters, likelihood values, parameter estimates, and derived quantities for the pre- and post-STAR northern California base models.

Label	Pre-STAR base model	Proposed final base, updated ageing error and maturity
N.Parms	98	98
TOTAL	1106.27	1080.47
Survey	-29.9739	-30.0399
Length_comp	366.71	365.653
Age_comp	773.604	748.844
Recruitment	-4.58365	-4.48439
Parm_priors	0.517137	0.498684
NatM_uniform_Fem_GP_1	0.211457	0.21026
L_at_Amax_Fem_GP_1	54.4938	54.3987
VonBert_K_Fem_GP_1	0.147691	0.148452
CV_old_Fem_GP_1	0.0816563	0.0834932
NatM_uniform_Mal_GP_1	-0.0533557	-0.050796
L_at_Amax_Mal_GP_1	-0.147081	-0.145894
VonBert_K_Mal_GP_1	0.311759	0.309366
CV_old_Mal_GP_1	-0.319049	-0.329013
SR_LN(R0)	7.72829	7.7183
Q_extraSD_Rec_PR_North(6)	0.0878346	0.0877788
Size_inflection_Comm_nonTwl_dead(1)	35.9278	35.9117
Size_95%width_Comm_nonTwl_dead(1)	5.85885	5.85588
Size_DblN_peak_Comm_nonTwl_live(2)	36.2324	36.2334
Size_DblN_ascend_se_Comm_nonTwl_live(2)	3.09347	3.09416
Size_DblN_descend_se_Comm_nonTwl_live(2)	5.68353	5.67865
Size_inflection_Comm_Trawl(3)	45.4269	45.3946
Size_95%width_Comm_Trawl(3)	5.68759	5.67484
Size_DblN_peak_Comm_Discard(4)	27.1087	27.1041
Size_DblN_ascend_se_Comm_Discard(4)	3.42201	3.42218
Size_DblN_descend_se_Comm_Discard(4)	3.90851	3.90775
Size_DblN_peak_Rec_PC_North(5)	40.8067	40.7959
Size_DblN_ascend_se_Rec_PC_North(5)	4.20983	4.2097
Size_DblN_descend_se_Rec_PC_North(5)	4.75464	4.75971
Size_DblN_end_logit_Rec_PC_North(5)	-2.69513	-2.73716
Size_DblN_peak_Rec_Disc_North(7)	28.3864	28.3708
Size_DblN_ascend_se_Rec_Disc_North(7)	4.20435	4.2038
Size_DblN_descend_se_Rec_Disc_North(7)	4.51076	4.51057
Size_DblN_peak_CCFRP(8)	42.1655	42.1661
Size_DblN_ascend_se_CCFRP(8)	4.59475	4.59644
Size_DblN_descend_se_CCFRP(8)	2.80511	2.80592
Size_DblN_end_logit_CCFRP(8)	-3.17849	-3.18391
Size_DblN_peak_Abrams_Research(11)	39.8806	39.8553
Size_DblN_ascend_se_Abrams_Research(11)	4.52931	4.5296
Size_DblN_descend_se_Abrams_Research(11)	4.55167	4.5564
Size_DblN_peak_Rec_PC_North(5)_BLK1repl_1875	34.2142	34.1981
Size_DblN_ascend_se_Rec_PC_North(5)_BLK1repl_1875	3.86314	3.86098
Bratio_2023	0.36359	0.364302
SSB_unfished	1205.06	1126.05
Totbio_unfished	6573.23	6569.59
Recr_unfished	2271.71	2249.13
Dead_Catch_SPR	265.141	265.453
OFLCatch_2023	203.162	203.852

Panel Conclusion: The request was to provide the model run using the updated recommendations for the new reference model. The Panel and the STAT agreed that this new reference model should form the basis for scientific advice going forward to the SSC.

Request No. 10: Generate a bivariate steepness and natural mortality plot (similar to Request No. 3 for central California), provide the 75% confidence region for both the northern and central models.

Rationale: To provide a potential basis for selecting a combination of steepness and natural mortality for a decision table.

STAT Response: The STAT completed bivariate profiles over a range of natural mortality values (0.08-0.30) representing roughly a 95% interval based on the lognormal prior distribution, and steepness values from 0.25 to 0.95. Heat maps showing the NLL, depletion, proxy MSY, and 2023 OFL were provided to the panel showing approximate 75% confidence regions around the minimum based on a chi-square distribution with 2 degrees of freedom (Figure 50). The base model is on the border of the bivariate 75% chi-squared interval. Steepness values of ~0.3 and less are implausible given the proxy $F_{SPR50\%}$ harvest rate, as indicated by long-term equilibrium yields equal to zero (Figure 50, lower left panel).

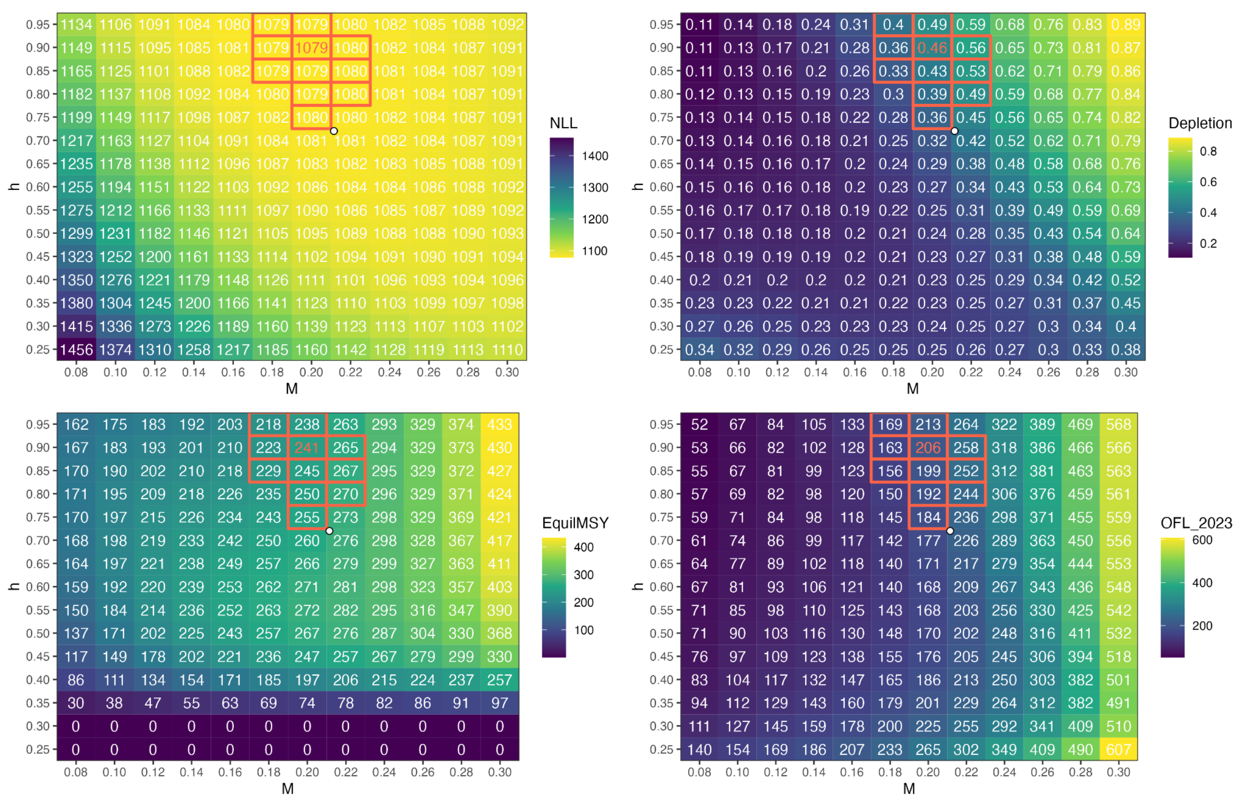


Figure 50. Bivariate profile over steepness and female natural mortality, plotting NLL, Depletion, Equilibrium proxy MSY, and OFL in 2023. The white point is the base model.

Numbers in red are values at the NLL minimum. Parameter combinations outlined in red are within the bivariate 75% chi-squared interval of the NLL minimum. Numbers within the plots are rounded for readability.

The bivariate profile plot with the 95% chi-squared interval is provided below for comparison (Figure 51). The base model falls within the 95% chi-squared interval.

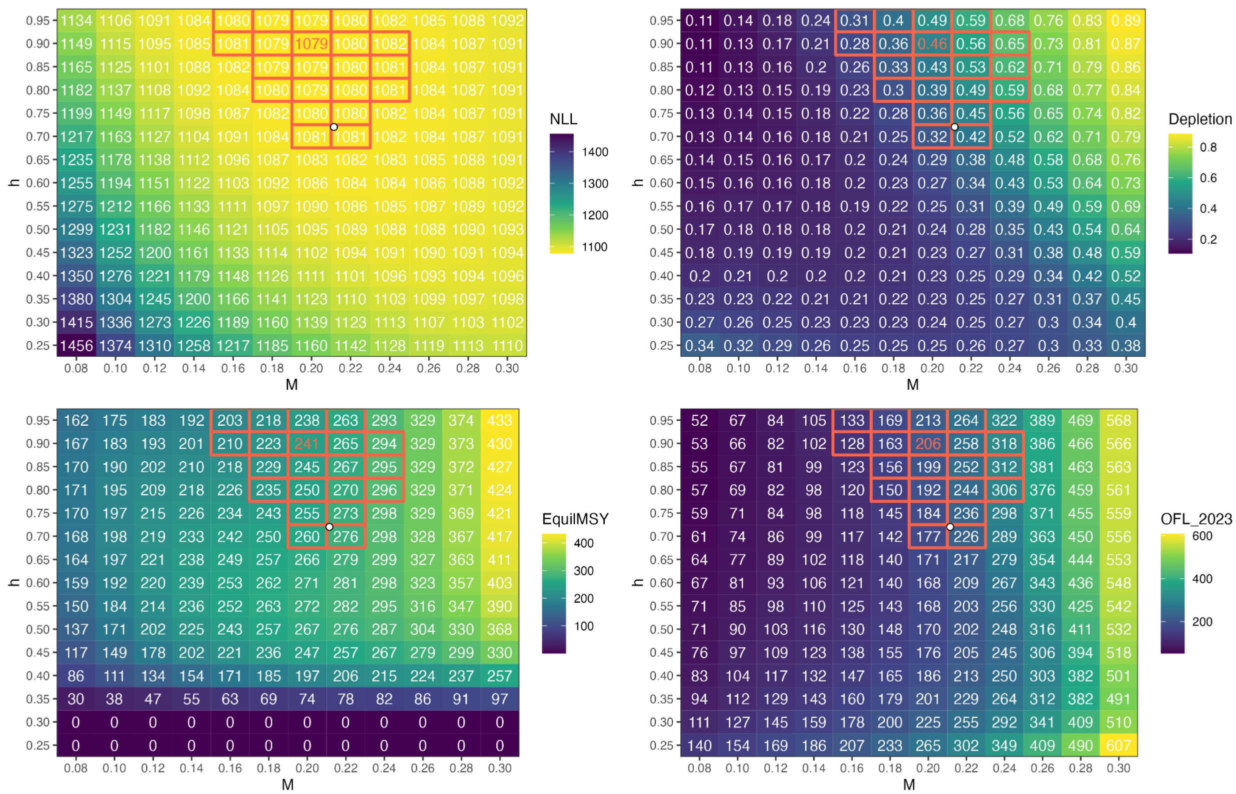


Figure 51. Bivariate profile over steepness and female natural mortality, plotting NLL, Depletion, Equilibrium MSY, and OFL. The white point is the base model. Parameter combinations outlined in red are within the bivariate 95% chi-squared interval of the NLL minimum.

Panel Conclusion: The response to this request included tables with the 95% confidence region as well as those with the 75% originally requested. The results indicate the relationship of the estimates of *h* and *M* in the fitting (NLL) and in the subsequent outcomes (depletion, OFL and MSY). However, the Panel agreed that the range at 75% did not capture all the uncertainty inherent in the assessment and, therefore, suggested further examinations using percentiles of the *M* prior (see Request No. 11 below).

Request No. 11: Use the uncertainty in the prior for natural mortality to obtain possible upper and lower states of nature. Center this uncertainty on the point estimate of the base model and use the *M* at the 12.5 and 87.5 percentile of the distribution for lower and upper states of nature.

Rationale: To provide a potential basis for selecting natural mortality values for a decision table.

STAT Response: The northern area model estimates female natural mortality (0.2103 yr^{-1}) and male natural mortality (0.1998 yr^{-1}). The log-scale standard deviation of the prior for *M* is 0.31. The point estimates of M for the high and low states of nature were calculated as $\exp\{\log_e(0.2103) +/- 0.31*1.15\}$, where 1.15 is the z-score corresponding to a two-tailed 75% interval in log space (i.e. plus or minus 1.15 standard deviations from the point estimate). The resulting values of *M* in arithmetic space for the high and low states of nature are 0.300 and 0.147, respectively.

Estimates of unfished spawning output (Figure 52) are scaled upward under the assumption that *M* = 0.147 (the 'low' state of nature), and downward with *M* = 0.300 (the 'high' state of nature). Trends in spawning output also show greater declines under the low-*M* scenario (Figure 53), suggesting a larger, less productive stock, and the opposite is seen for the high-*M* scenario (smaller, more productive stock).

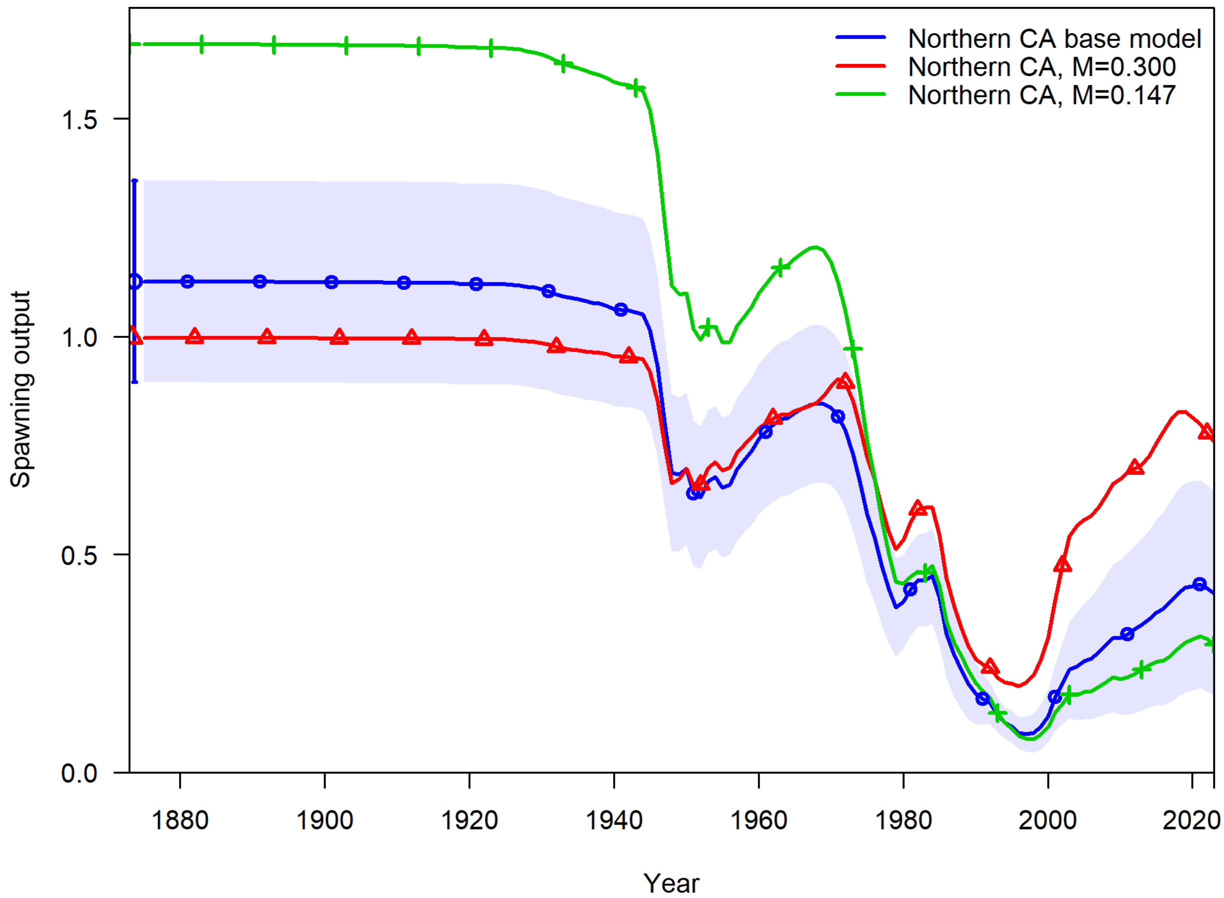


Figure 52. Comparison of spawning output time series (billions of eggs) for alternative states of nature described under request 11.

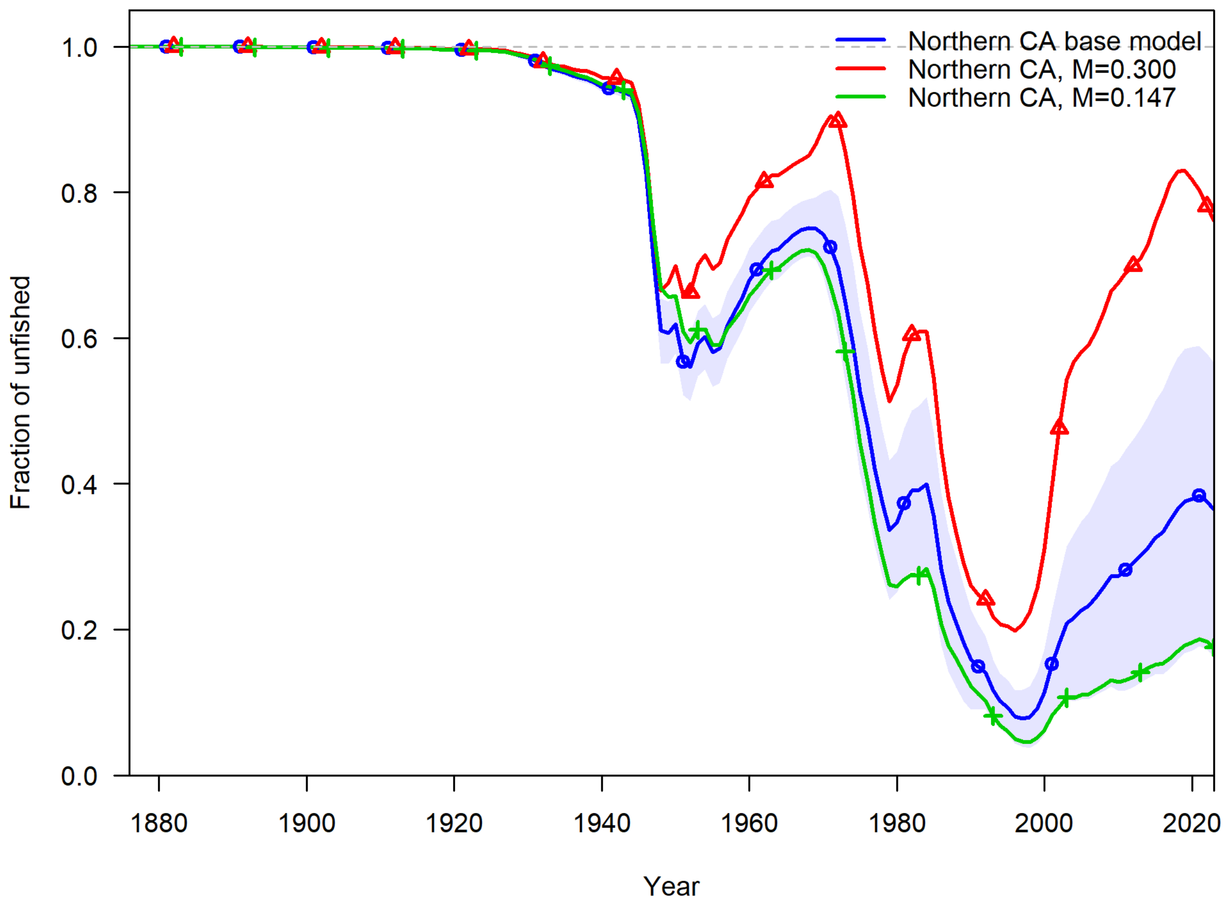


Figure 53. Comparison of relative spawning output time series (scaled relative to unfished spawning output) for alternative states of nature described under request 11.

The patterns in estimated recruitment deviations change over the modeled time period, with the high-*M* model producing the most positive deviations in the mid- to late-1960s, but more negative deviations in other time periods (Figure 54). Similar shifts over time are apparent for the other two models, but overall variation in estimated recruitment deviations is well within the range of uncertainty of the base model.

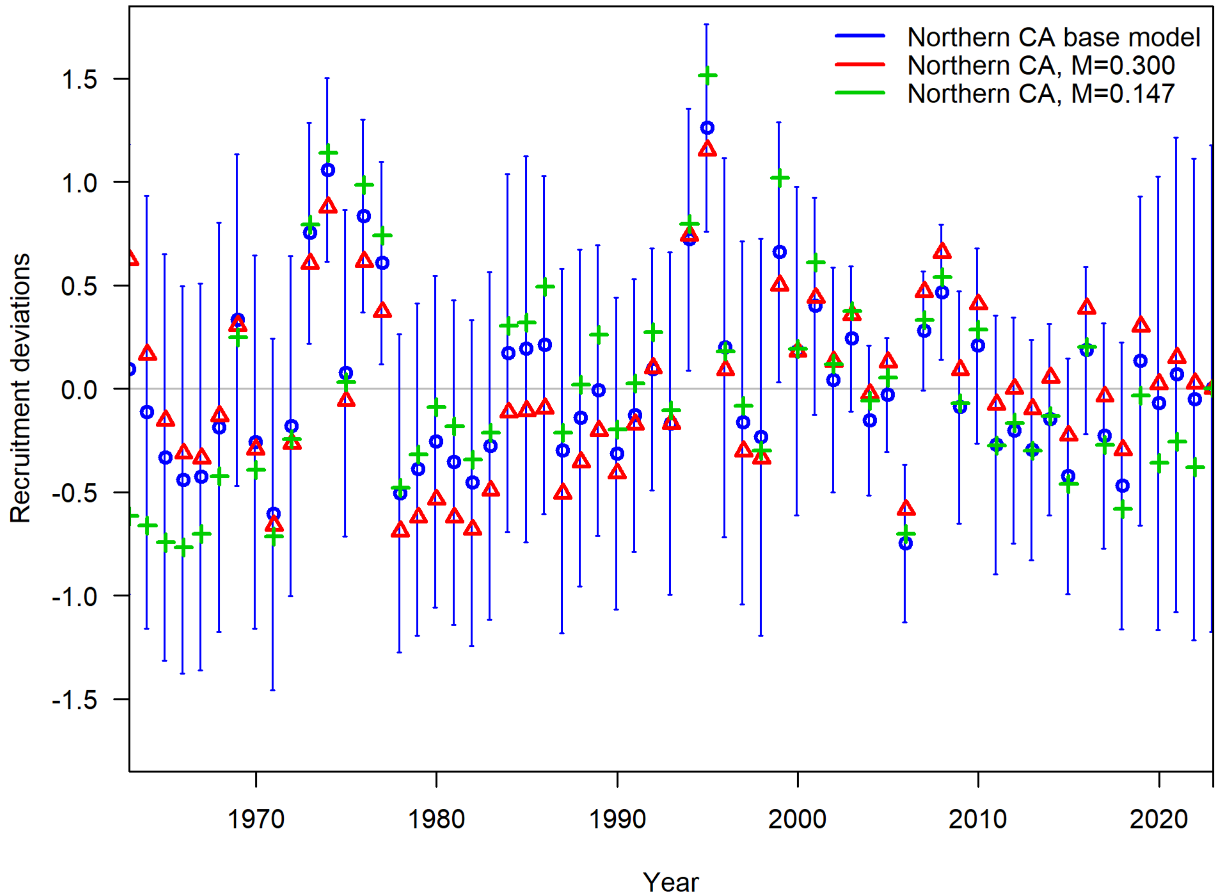


Figure 54. Comparison of recruitment deviations over time for alternative states of nature described under request 11.

For the northern area model, the reported 'sigma' (log-space uncertainty around the OFL value for the first forecast year, i.e. 2023) is 0.274.

Table 8. Number of estimated parameters, likelihood values, parameter estimates, and derived quantities for the three alternative states of nature described in request 11.

Label	Northern, base	North, M=0.300	North, M=0.147
N.Parms	98	97	97
TOTAL	1080.5	1090.9	1096.2
Survey	-30.0	-29.3	-30.3
Length_comp	365.7	369.2	366.7
Age_comp	748.8	752.5	757.1
Recruitment	-4.5	-3.7	2.8
Parm_priors	0.5	2.3	0.0
NatM_uniform_Fem_GP_1	0.210	0.300	0.147
L_at_Amax_Fem_GP_1	54.399	54.249	54.142
VonBert_K_Fem_GP_1	0.148	0.148	0.151
CV_old_Fem_GP_1	0.083	0.083	0.087

NatM_uniform_Mal_GP_1	-0.051	-0.062	-0.003
L_at_Amax_Mal_GP_1	-0.146	-0.143	-0.142
VonBert_K_Mal_GP_1	0.309	0.294	0.307
CV_old_Mal_GP_1	-0.329	-0.314	-0.365
SR_LN(R0)	7.718	8.768	7.151
Q_extraSD_Rec_PR_North(6)	0.088	0.083	0.086
Size_inflection_Comm_nonTwl_dead(1)	35.91	36.31	35.50
Size_95%width_Comm_nonTwl_dead(1)	5.86	5.89	5.75
Size_DblN_peak_Comm_nonTwl_live(2)	36.23	36.54	36.02
Size_DblN_ascend_se_Comm_nonTwl_live(2)	3.09	3.12	3.07
Size_DblN_descend_se_Comm_nonTwl_live(2)	5.68	5.80	5.76
Size_inflection_Comm_Trawl(3)	45.39	45.67	44.69
Size_95%width_Comm_Trawl(3)	5.67	5.66	5.52
Size_DblN_peak_Comm_Discard(4)	27.10	27.42	26.90
Size_DblN_ascend_se_Comm_Discard(4)	3.42	3.42	3.43
Size_DblN_descend_se_Comm_Discard(4)	3.91	3.95	3.89
Size_DblN_peak_Rec_PC_North(5)	40.80	41.52	40.63
Size_DblN_ascend_se_Rec_PC_North(5)	4.21	4.23	4.23
Size_DblN_descend_se_Rec_PC_North(5)	4.76	4.82	4.70
Size_DblN_end_logit_Rec_PC_North(5)	-2.74	-2.21	-3.00
Size_DblN_peak_Rec_Disc_North(7)	28.37	29.06	27.89
Size_DblN_ascend_se_Rec_Disc_North(7)	4.20	4.21	4.21
Size_DblN_descend_se_Rec_Disc_North(7)	4.51	4.55	4.53
Size_DblN_peak_CCFRP(8)	42.17	42.78	41.95
Size_DblN_ascend_se_CCFRP(8)	4.60	4.57	4.64
Size_DblN_descend_se_CCFRP(8)	2.81	2.59	2.87
Size_DblN_end_logit_CCFRP(8)	-3.18	-2.74	-3.43
Size_DblN_peak_Abrams_Research(11)	39.86	40.56	39.65
Size_DblN_ascend_se_Abrams_Research(11)	4.53	4.52	4.55
Size_DblN_descend_se_Abrams_Research(11)	4.56	4.59	4.51
Size_DblN_peak_Rec_PC_North(5)_BLK1repl_1875	34.20	34.73	33.79
Size_DblN_ascend_se_Rec_PC_North(5)_BLK1repl_1875	3.86	3.87	3.86
Bratio_2023	0.364	0.760	0.176
SSB_unfished	1126	997	1671
Totbio_unfished	6570	8656	7299
Recr_unfished	2249	6423	1276
Dead_Catch_SPR	265	419	234
OFLCatch_2023	204	557	105

Panel Conclusion: This response includes the model runs using the updated reference model and the upper and lower states of nature recommended by the STAR panel for use in the decision tables.

Description of the Base Model and Alternative Models used to Bracket Uncertainty

Proposals for base models were presented in the draft assessment document for the northern California black rockfish assessment area. The STAR Panel explored alternatives to these formulations as noted in the analytical requests above. At the STAR Panel's suggestion, the model was rerun with the spline maturity function and updated ageing error matrix. This modification was accepted by the STAR Panel as an appropriate adjustment to the draft base model and the updated base model to be carried forward in subsequent final assessments.

Similar to other rockfish assessments, the STAR Panel recommended that the upper and lower states of nature be defined based on the uncertainty in natural mortality. That range in uncertainty was centered on the point estimate of the base model and with the range as being the 12.5 and 87.5 percentiles of the distribution for lower and upper states of nature.

Technical Merits of the Assessment

This assessment for northern California black rockfish improved upon 2015 by the inclusion of additional data from the ensuing years, the introduction of new data streams and the review/revision of biological parameters. Of particular importance was the separation of the assessment into two area-specific assessments of northern and central California.

A wide range of available data collected in the fishery-dependent and fishery-independent monitoring programs were examined. Historical information was carefully evaluated for their quality and quantity before they were included in the assessment. A well-defined protocol was developed and followed in the CPUE standardization.

Incorporating age/length and indices of abundance from various sources including both fishery-dependent and fishery-independent programs in an integrated length/based assessment allow for a comprehensive evaluation of fish stock dynamics, leading to an improved understanding of the status of the stock and sustainable harvest levels that were robust to many uncertainties.

The STAT teams explored many alternative models with different configurations and parameterizations within the Stock Synthesis framework. These alternative models indicated that the STAT were reviewing and developing options to improve stock assessments in the future as well as check the robustness of the current approach being used for management advice. Exploring alternative model configurations and approaches used to assess these stocks improved the quality of the assessment overall and indicated potential solutions to some problems, such as uncertainty estimates of spawning output and exploitation.

Technical Deficiencies of the Assessment

The STAT provided CPUE standardization modeling information including variable selection, data filtering, and modeling diagnostics. However, the effectiveness of the CPUE standardization to remove factors other than stock abundance was not carefully evaluated and may affect how the indices should be used in stock assessment models. The STAR Panel did not have the opportunity to do a thorough review of CPUE standardization due the inherent limitations of a one-week STAR panel meeting on four different area models. There is a concern that primary or secondary trip targets may be too loosely applied to effectively filter out the non-informative data.

As with most assessments, major uncertainties lie with the parameters steepness and natural mortality. These parameters were primarily constrained by a prior (M) or a fixed value (h) provided by the SSC's Terms of Reference. While the impacts of these choices were evaluated through likelihood profiling, there remains uncertainty in some joint interactions of the choices of these parameters.

The current assessment assumes that the northern California area is closed with no immigration/immigration, which does not reflect the observed movement in tagging studies.

Historical data on functional maturity and fecundity are lacking which translates into the inherent uncertainty in spawning output and in the stock-recruitment relationship.

Catch estimates were essentially assumed to be without error. This is unlikely to be the case, especially for the historical catches. Additionally, since all of the age/length/index data were collected subsequent to the year 2000, all of the stock declines prior to that time are driven by the uncertain catches and prior perceptions of M and h.

There is a lack of explicit consideration of ecosystem dynamics (e.g., climate change) in the stock assessment.

Areas of Disagreement Regarding STAR Panel Recommendations

Among STAR Panel members (including GAP, GMT, and PFMC representatives): There were no areas of disagreement between STAR Panel members and representatives regarding STAR Panel recommendations.

Between the STAR Panel and the STAT Team: There were no areas of disagreement between STAR Panel members and the STAT Team regarding STAR Panel recommendations.

Management, Data, or Fishery Issues raised by the GMT or GAP Representatives During the STAR Panel Meeting

No issues were raised by the GMT or GAP representatives during the STAR Panel meeting.

Unresolved Problems and Major Uncertainties

There is conflicting evidence and limited information with which to evaluate black rockfish stock structure, especially off California. Much of what we know about the habitat associations and ecological role of black rockfish come from Oregon, Washington, and Alaska.

Attempts to investigate recruitment indices (RREAS, SWFSC SCUBA) for the fleets-as-areas model configuration were not successful, and there was not enough time to evaluate area-specific indices prior to the STAR panel document deadline (although they have been developed).

The fishery-independent abundance indices are of short duration and insufficient precision to provide much information on recent trends in abundance in the recent years in the northern assessment. Thus, the indices such as CCFRP need to mature to provide better catchability estimates as the abundance in the assessment area increases.

Further research is needed to explain skewed sex ratios among older individuals in the population.

Recommendations for Future Research and Data Collection

The panel supports the recommendations provided in the pre-STAR draft assessment (reproduced below).

1. There is conflicting evidence and limited information with which to evaluate black rockfish stock structure, especially off California. Future research on larval dispersal, life history traits, adult movement, and genetics south of the California-Oregon border would improve inputs for stock assessments and provide support for the spatiotemporal scale that is most appropriate for modeling black rockfish. Specifically, information about growth, maturity, and mortality north and south of Point Arena would further justify the separation of black rockfish at this location. Further genetic evaluation regarding the extent to which Point Arena may serve as a barrier to gene flow would also be valuable for this stock.
2. Specific estimates of larval dispersal and movement rates at various life stages would further our understanding about connectivity among the three West Coast stocks of black rockfish. Although most black rockfish show moderate to high site fidelity and some degree of homing, a notable proportion of fish appear to cross stock boundaries. Additional research on the directions and distances that black rockfish move in northern California and southern Oregon would help elucidate the degree of intergenerational exchange across this particular stock boundary.
3. Finally, much of what we know about the habitat associations and ecological role of black rockfish come from Oregon, Washington, and Alaska. Research that is specific to central and northern California is needed to fully understand variation in black rockfish life history, population structure, and trophic positioning.
4. Exploration of multiple-area models for the stock is recommended when sufficient data are available to parameterize movement within the model. Directional movement between areas (south to north, as observed in the CCFRP movement data) may partially explain sustained differences in size and age composition throughout the state.
5. Attempts to investigate recruitment indices (RREAS, SWFSC SCUBA) for the fleets-as-

areas model configuration were not successful, and there was not enough time to evaluate area-specific indices prior to the STAR panel document deadline (although they have been developed). Future assessments may benefit from an analysis of these recruitment indices representing sub-areas defined in this assessment.

6. Further research is also needed to explain skewed sex ratios among older individuals in the population. This assessment assumes that size-dependent selectivity is equal for both sexes, and does not consider alternative hypotheses such as sex- or age-specific selectivity or age-dependent natural mortality, both of which could also explain, in whole or in part, the reduced fraction of older females in the data.

The STAR panel supports the following additional recommendations for future research and data collection.

1. Inclusion of ecosystem consideration to evaluate possible shifts in productivity and environments and how such changes may influence fish life history, population dynamics, phenology of movement, distributions, and fisheries.
2. Continue the current tagging study to better understand the movement and spatial distribution of black rockfish in California.
3. Exploration and development of a spatially explicit model (e.g., 2-box model) to integrate the assessment of the northern and central California assessment areas accounting for migration rates between assessment areas using data from CCFRP and other tagging efforts.
4. Conducting habitat modeling to better understand spatio-temporal dynamics of black rockfish suitable habitats and how the changes may influence the existing monitoring programs and stock assessment.
5. Development of functional maturity-length relationships using the data collected in the central California assessment area.

Recommendation for Next Assessment, Assessment Category, and Sigma

The STAR panel concluded that this assessment should be classified as Category 1b, based on the criteria of availability of fishery independent indices and the lack of an estimable stock-recruitment relationship. Additionally, the Panel recommends the next assessment be a full assessment because 1) given large uncertainty associated with movement and that the current assessments represent the first time that California was separated into two sub-area models; 2) recruitment indices are just now becoming available and 3) there is a need to develop California-specific functional maturity relationships.

A sigma was calculated for the northern California assessment based on the range of *M*'s from the prior and its value was 0.5736. However, this sigma was not based on the assessment model uncertainty, as noted above. Therefore, the Panel recommended the default sigma value (the ln-scale coefficient of variation for OFL in the first projection year (2025) be 0.5 which is not inconsistent with the 0.5736 derived from the *M* uncertainty.

Central California Model

Summary of Data and Assessment Models

The central California black rockfish assessment is structured as a single, sex-disaggregated population, spanning U.S. waters from the US/Mexico border to Point Arena, California (38°57′30" N. lat.). Black rockfish are rare south of Point Conception (34°27′ N. lat.), so the central California model focuses on the region between Point Conception and Point Arena. The assessment model has an annual time step covering the period 1875 to 2022 and assumes an unfished equilibrium population prior to 1875. Population dynamics are modeled for ages 0 through 50, with age-50 being the plus age group. Size bins were set every 1 cm from 5 to 70 cm, and data bins were set every 2 cm from 8 to 60 cm. The model is conditioned on catch from two sectors (commercial and recreational) divided among six fleets, and is informed by four time series of relative abundance (one fishery-independent survey, one CPUE index from a shore-based recreational sampling program, and two CPUE indices from onboard CPFV observer programs operating over different time periods). Size and age composition data include lengths from 1959-2022 and ages from 1980-2022, with intermittent gaps in each data type.

Recruitment is assumed to be related to spawning output via the Beverton-Holt stock recruitment relationship with log-normally distributed, bias corrected process error. Growth was modeled across a range of ages from 0 through 50. All catches were assumed to be known with high precision (log-scale standard error of 0.05).

Fleets were specified for recreational and commercial sectors. While the previous assessment combined all recreational fishing modes and catch types (retained or discarded) into a single fleet, the recreational sector is divided into two main fleets according to fishing type (Commercial Passenger Fishing Vessels [CPFV, referred to as party/charter [PC]] or private/rental boat [PR]) and catch type (retained or discarded). All recreational shore modes were combined with the private boat fleet due to their small contribution to overall catch. Discarded catch (CPFV and private boats combined) was modeled as a separate fleet due to differences in size composition relative to retained catch, and a lack of sufficient data in an appropriate format to explicitly model retention.

The commercial sector was represented by three fleets. A single "non-trawl" fleets representing primarily hook-and-line and longline gear types, but including other minor gears, included both 'live' and 'dead' conditions, as samples of live fish were too small to warrant a separate fleet. Other commercial fleets include a trawl fleet, and a fleet for discarded catch which represented discarded dead catch from both non-trawl and trawl fleets. Fleet selectivity was allowed to be dome-shaped for all commercial fleets. Sensitivity to these selectivity assumptions were explored during model development and relative to the base model. The time-series of data used in the central California model are summarized in Figure 55.

In this assessment, there was no clear reason to down-weight (or up-weight) particular data sources relative to each other (apart from the application of Francis weights to the composition data and additive variances to some indices), so all likelihood components were assumed to have equal emphasis (λ=1) in the base case model.

A prior distribution was specified for male and female natural mortality following a meta-analytic approach. A lognormal prior for natural mortality was applied when estimating female natural mortality (log-scale mean = -1.86895, standard deviation = 0.31), and male natural mortality was modeled as an exponential offset with no explicit prior. A beta prior (mean = 0.72, SD = 0.16) was applied to the Beverton-Holt stock recruitment curve, but this parameter was fixed at the prior mean in the base model. The steepness prior was originally developed from a west coast groundfish meta-analysis (Dorn 2002), has been periodically updated, and is provided by the PFMC SSC. Since most available age data is from north of Point Arena, natural mortality parameters in the central area base model are fixed at the values estimated in the northern area for both females and males (exponential offset from females).

Likelihood components that were minimized in the overall fitting procedure include fleet-specific catch, length composition, and conditional age-at-length composition and also survey, recruitment deviate, parameter prior, and parameter soft-bound components.

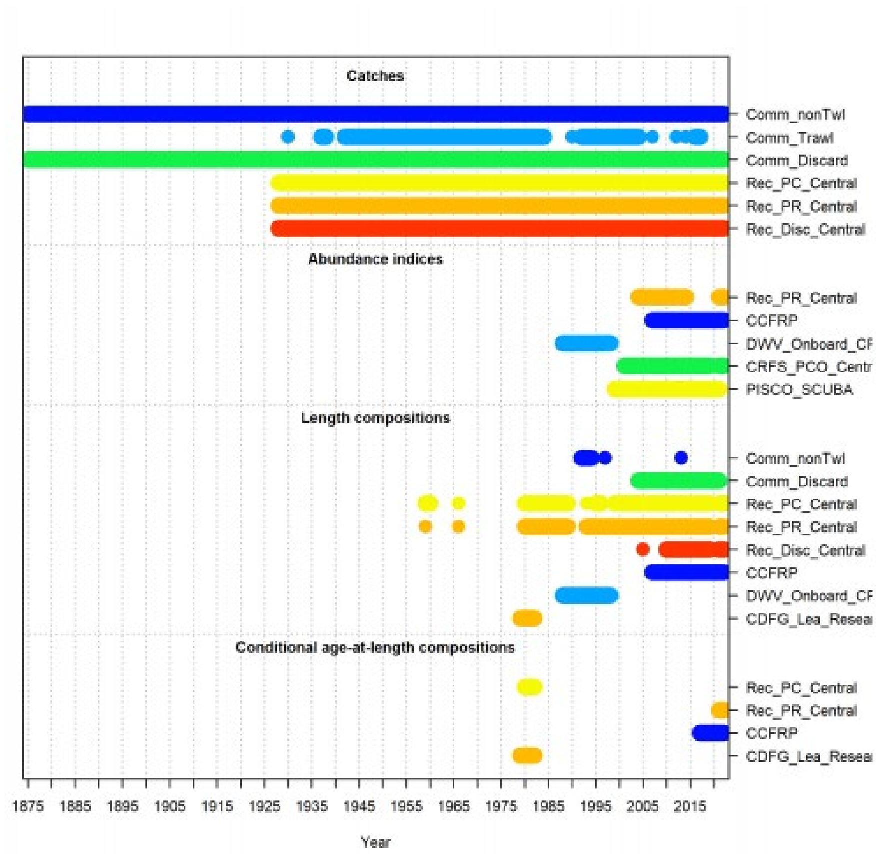


Figure 55. Availability and sources of input data for the central California black rockfish assessment.

Within model uncertainty is explicitly included in this assessment by parameter estimation uncertainty, while among model uncertainty is explored through sensitivity analyses addressing alternative input assumptions such as data treatment and weighting, and model specification sensitivity to the treatment of life history parameters, selectivity, and recruitment. While the updated assessment uses all available data, uncertainty remains regarding outcomes and management quantities.

As with most assessments the value of natural mortality and steepness remain a source of uncertainty that has not been resolved through assessment modeling. The uncertainty in the prior for natural mortality (log-scale SD of 0.31) was used to obtain possible upper and lower states of nature. This uncertainty was centered on the point estimate of the base model (0.21) and was defined at the 12.5 and 87.5 percentile of the distribution for lower and upper states of nature.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: Evaluate sensitivity of historical average weights by using a ten-year average of the earliest available MRFSS data rather than the specific estimates from publications.

Rationale: Changes in the estimate of early removals could impact the overall stock trajectory.

STAT Response: Average weights of retained fish in the historical recreational fishery were estimated using the mean weight from data collected 1980-1989 (MRFSS era) in central California. This increased the mean weights by roughly 0.2 kg in each mode relative to the pre-STAR base model (Figure 56). No change was made to the northern area estimate of 1.26 kg.

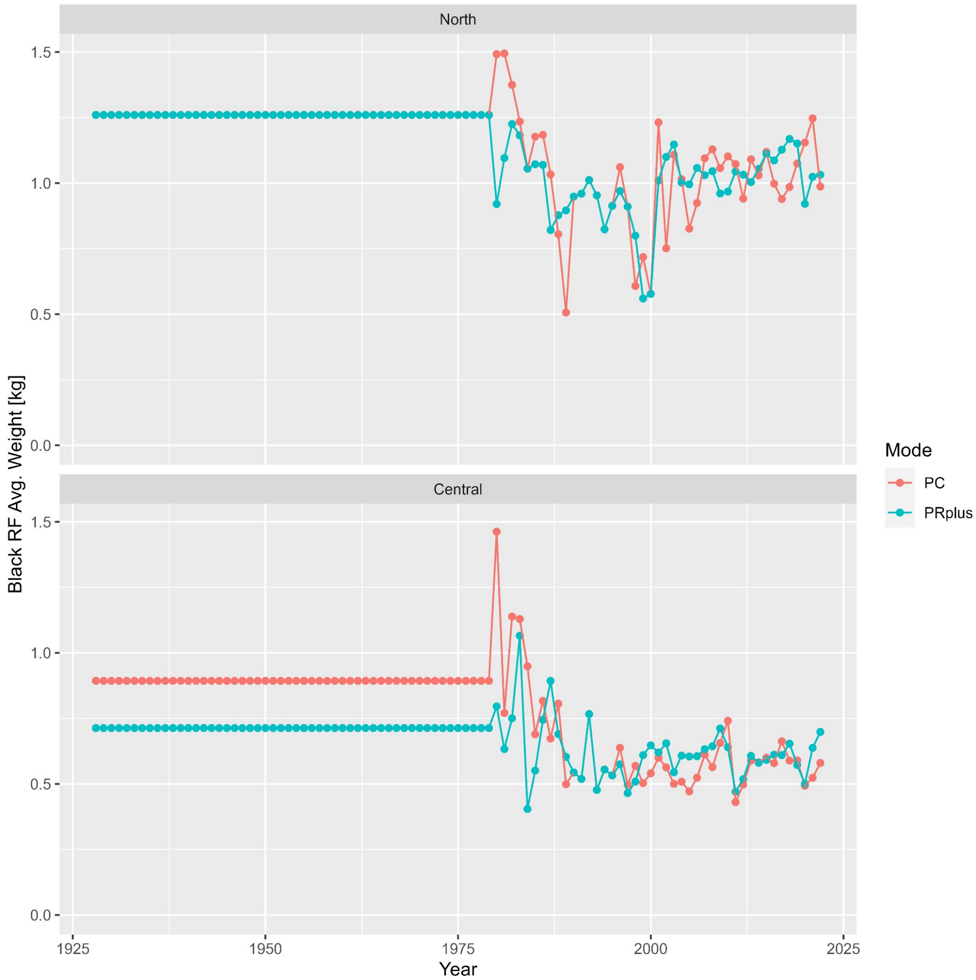


Figure 56. Mean weight (kg) of black rockfish by area, year, and mode. Modifications to the assumed mean weight in years prior to 1980 are illustrated in the lower panel.

As noted in the assessment document, data from a study by Miller and Gotshall (1965) suggest that average fish weight in the late 1950s and early 1960s was roughly 0.72 kg for party/charter (PC) mode and 0.54 kg for private/rental (PR) mode (see Table 13 in the pre-STAR draft assessment document for sample sizes by mode and year). These estimates differ from those based on MRFSS data from 1980-1989 (shown in red, below), which suggest that the PC mode average weight was closer to 0.89 kg and the PR mode was near 0.71 kg. It's not clear which of these estimates is a better representation of average fish weights for the historical catch time series (Figure 57).

Average recreational weights [kg] in the pre-STAR base model:

Area	Mode	retained.avg.wgt
Central	PC	0.7193192
Central	PRplus	0.5356403
North	PC	1.2600000
North	PRplus	1.2600000

Average recreational weights based on 10-year average of most recent years in central area:

```
   Area   Mode retained.avg.wgt
Central     PC        0.8934083
Central PRplus        0.7132623
  North     PC        1.2600000
  North PRplus        1.260000
```

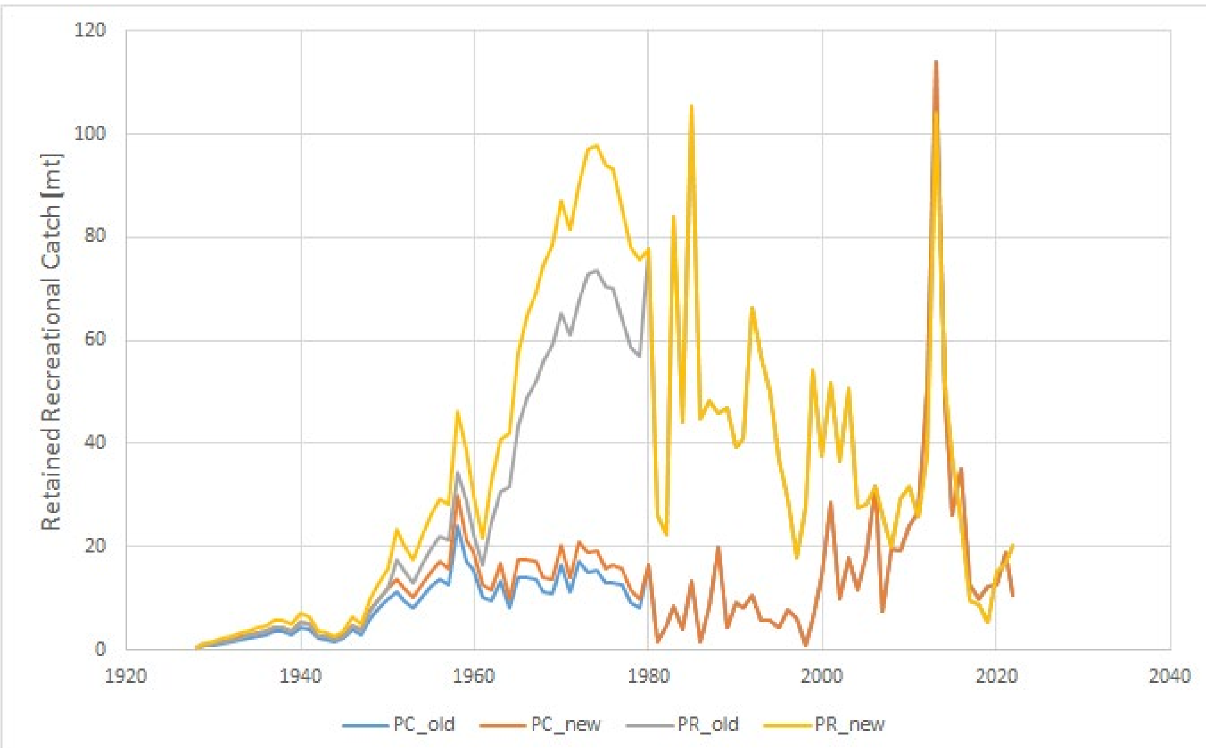


Figure 57. Time series of retained recreational catch (metric tons) using alternative average weight estimates. “PC_old” refers to the pre-STAR base model catch estimate for the PC mode, and “PC_new” refers to the catches based on the MRFSS average weights (with similar labels for the PR mode).

Time series of spawning output and relative spawning output were not strongly affected by the change to assumed average weight in the pre-1980 recreational catch (Figure 58). Since there was no change to catch in numbers, and discards were based on catch in numbers and discard average weights, there was no change to the time series of discarded catch.

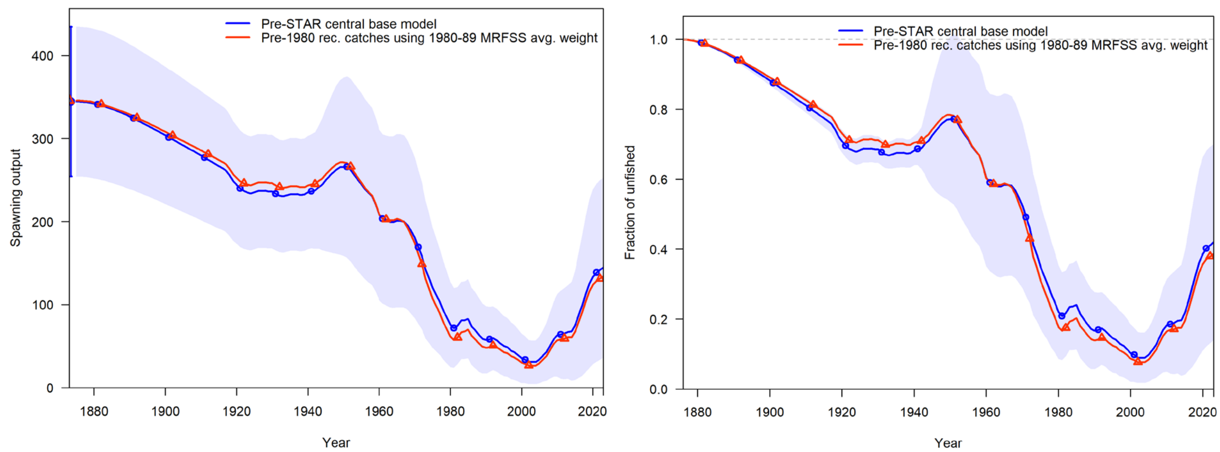


Figure 58. Time series of spawning output (billions of eggs) and spawning output relative to unfished levels, shown for the pre-STAR base model and a model with historical recreational catches derived from average weights over the period 1980-1989.

Panel Conclusion: Using average recreational weights based on a 10-year average of most recent years in the central area, this slightly increases party/charter (PC) and private/rental (PR) catches in the central area, but has small impacts on the estimation of spawning output and exploitation rate. Considering the reasonably large sample sizes in Miller and Gotshall (1965), the Panel supports the use of the historical average weight for the PC and PR catch estimation for the reference model. More research may be needed to better quantify the historical catch data.

Request No. 2: Generate pairwise plots (and calculate correlation coefficients) for all the abundance indices, for years which overlap.

Rationale: The consistency of various abundance indices are evaluated graphically in the report. Pairwise comparison of all abundance indices can provide a more quantitative evaluation of consistency of abundance indices.

STAT Response: Index combinations were separated into fishery-dependent, combined fishery-dependent and -independent, and young of the year (YOY) survey categories because insufficient overlap among years prohibited all possible combinations (see Fig. 5 of the stock assessment document for the temporal extent of each index). There were significant, positive correlations between CRFS_PR and CRFS_PCO, CRFS_PR and CCFRP, CRFS_PR and PISCO, and CRFS_PCO and CCFRP (Figure 59) . CRFS_PCO and PISCO and CCFRP and PISCO showed weak or no correlation ($p > 0.1$). The relationship between MRFSS and Onboard_CPFV is unclear (negative but nonsignificant, $p > 0.1$). The YOY surveys (RREAS and SWFSC_YOY) showed weak or no correlation ($p > 0.1$). The PISCO survey was not included in the pre-STAR base model.

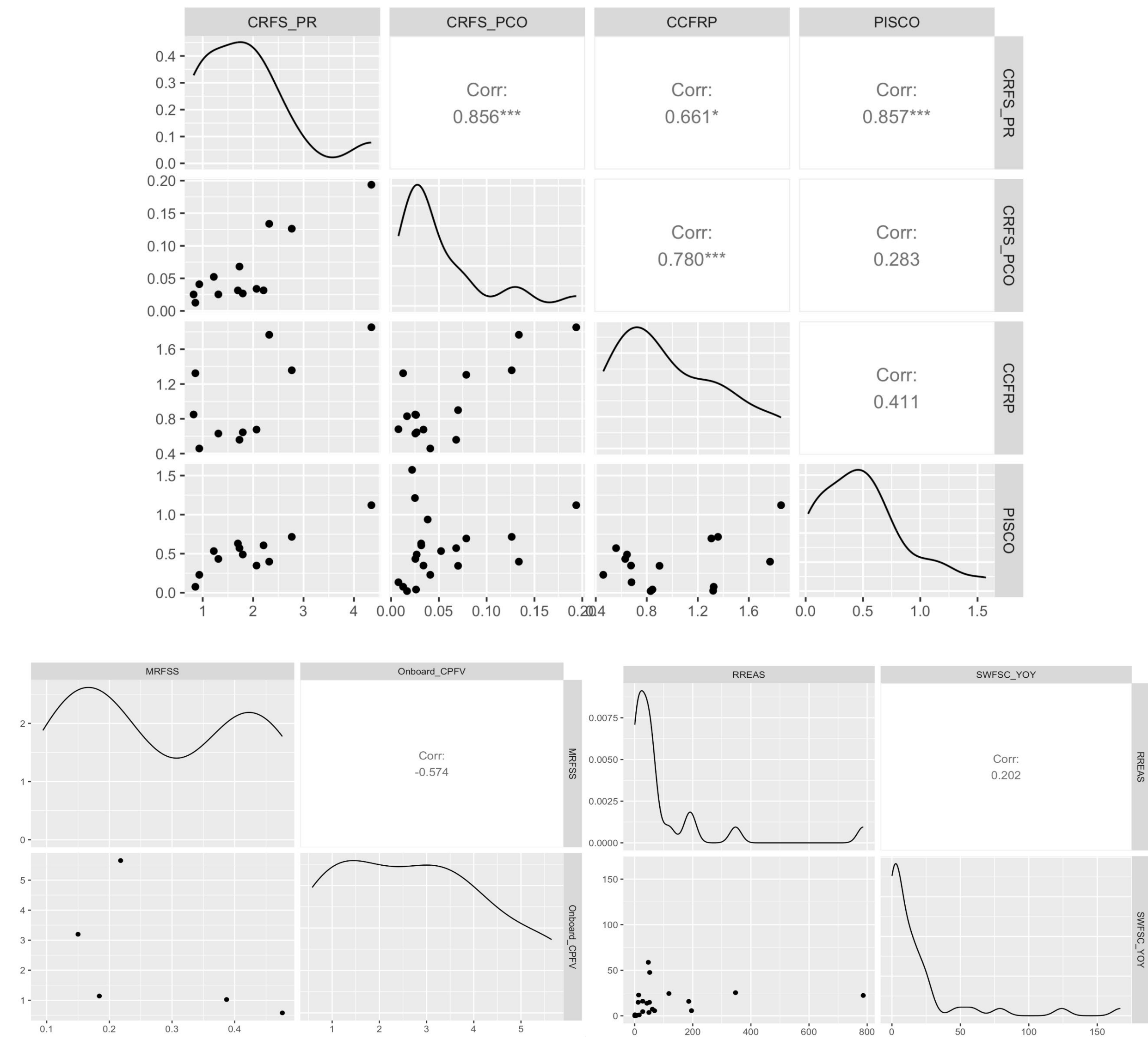


Figure 59. Pairwise comparisons of abundance indices, central California (CRFS Districts 3 and 4). Correlation coefficients (numbers) and p values (*** < 0.001, ** < 0.01, * < 0.05, and . < 0.10) are shown in the upper right quadrants, data points are shown in the lower left quadrants, and kernel densities are shown along the diagonals. A minimum of five overlapping years was required for inclusion. CRFS_PR: private/rental recreational fishing boats; CRFS PCO: party/charter operations; CCFRP: California Collaborative Fisheries Research Program; PISCO: Partnership for the Interdisciplinary Study of Coastal Oceans; MRFSS: Marine Recreational Fisheries Statistics Survey; Onboard_CPFV: Commercial Passenger Fishing Vessel Observer Program; RREAS: NMFS SWFSC's Rockfish Recruitment and Ecosystem Assessment Survey; SWFSC_YOY: NMFS SWFSC's young of the year SCUBA survey.

Panel Conclusion: The generally positive correlations between abundance indices suggest that there are consistent temporal patterns in the fishery-dependent and fishery-independent abundance indices for this stock. This result supports inclusion of these indices in the assessment.

Request No. 3: Estimate and plot natural mortality (*M*) as a function of steepness (*h*), given the potential interactions, for females and males.

Rationale: *M* and *h* tend to be highly correlated. An examination of LL (log likelihood) values under a varying *M* and *h* (over a reasonable range) would help us understand how they interact and how they may influence the assessment of population dynamics.

STAT Response: Profiles were initially approximated from the bivariate profile over *M* and *h*, by minimizing the NLL value with regard to *M* for each *h*. Subsequently, a profile over steepness was completed with female *M* estimated in each run. As expected, these produce similar results, and each demonstrates a negative relationship between *h* and *M*, so that as *h* increases *M* decreases (Figures 60 and 61, Table 9).

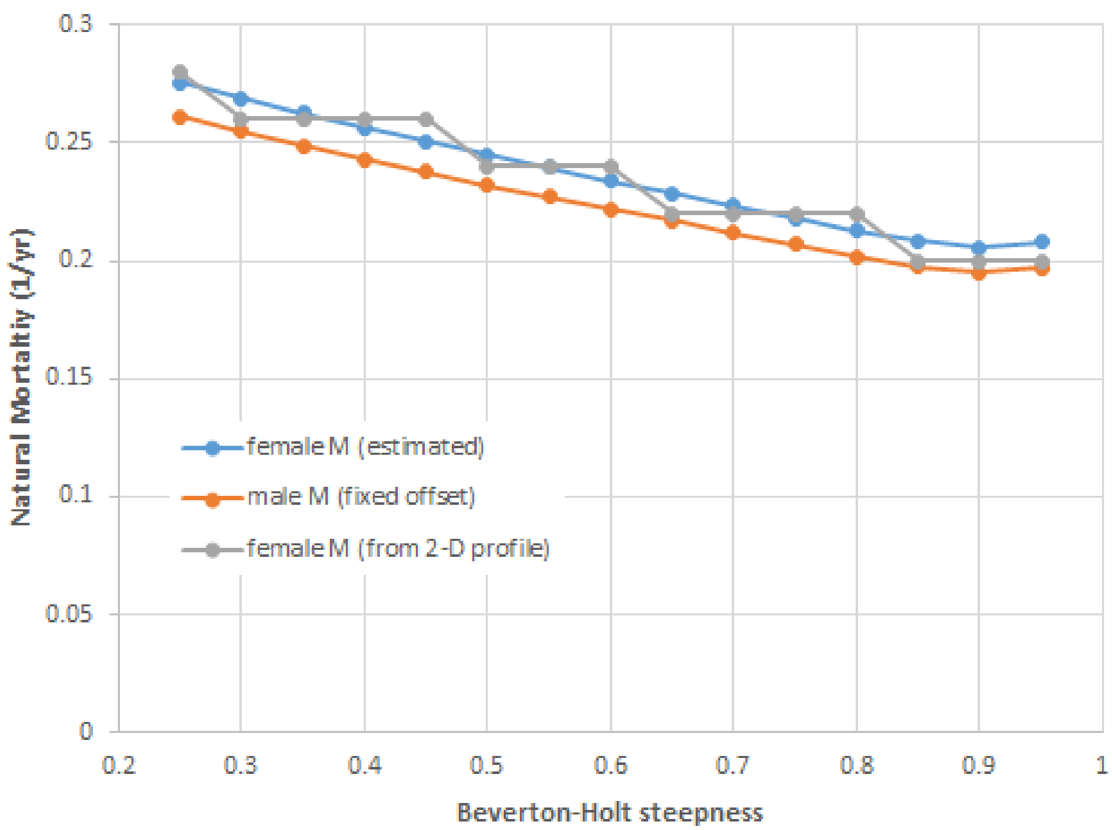


Figure 60. Natural mortality for females and males as a function of steepness in the central California model. The male offset was fixed at the value estimated in the northern model.

Table 9. Estimates of female natural mortality conditioned on alternative fixed values of steepness in the central California model.

h	$\widehat{M}\|h$ from 2-D profile	$\widehat{M}\|h$ (M estimated)	NLL
0.25	0.28	0.275	533.813
0.3	0.26	0.269	531.044
0.35	0.26	0.262	529.009
0.4	0.26	0.256	527.487
0.45	0.26	0.250	526.34
0.5	0.24	0.245	525.328
0.55	0.24	0.239	524.912
0.6	0.24	0.234	524.021
0.65	0.22	0.229	523.659
0.7	0.22	0.223	523.357
0.75	0.22	0.218	523.273
0.8	0.22	0.213	523.417
0.85	0.20	0.208	523.752
0.90	0.2	0.206	524.303
0.95	0.2	0.208	525.221

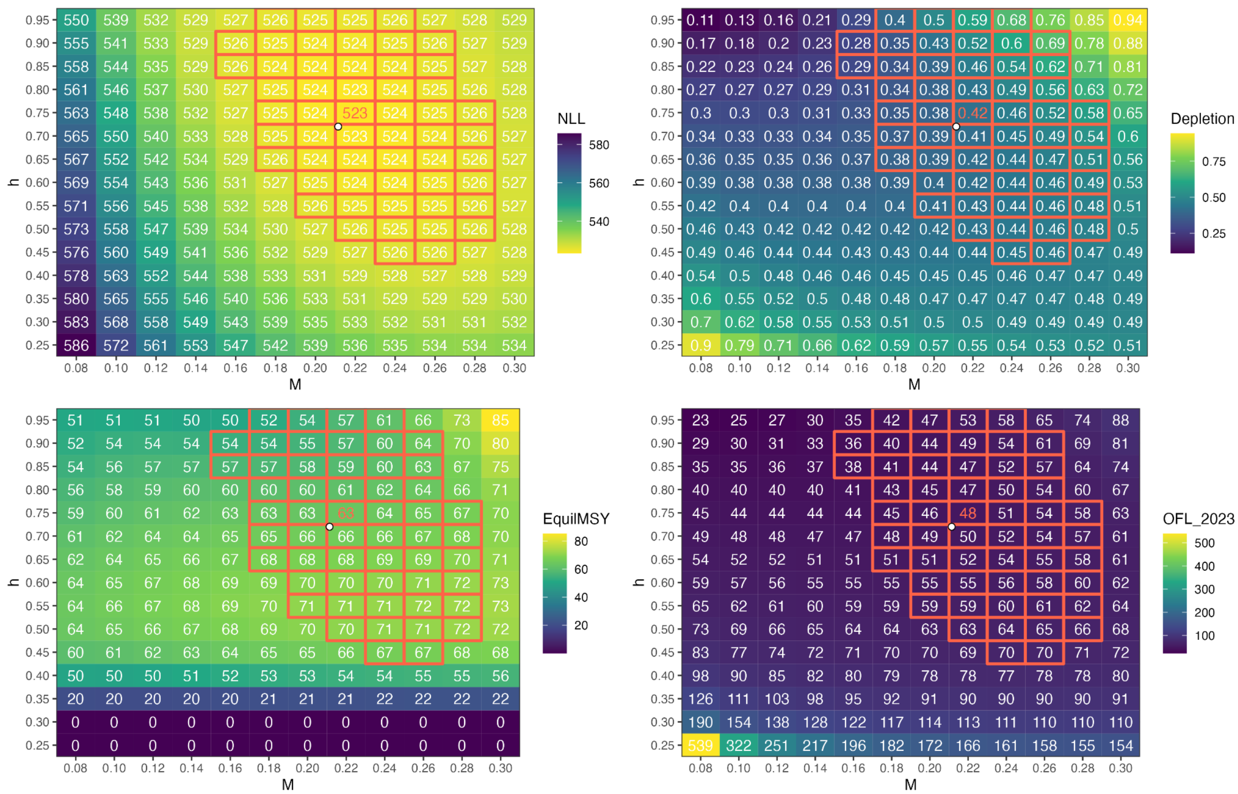


Figure 61. Bivariate profile over steepness and female natural mortality, plotting NLL, Depletion, Equilibrium proxy MSY, and OFL. The white point is the base model. Numbers in red are values at the NLL minimum. Parameter combinations outlined in red are within the bivariate 95% chi-squared interval of the NLL minimum. The base model is close to the minimum and falls within the 95% chi-squared interval. Numbers within the plots are rounded for readability.

Panel Conclusion: Natural mortality *M* and steepness *h* are negatively correlated as expected. Surprisingly the maximum likelihood estimates (MLE) of steepness and *M* are relatively close to the fixed values used in the reference assessment model. The bivariate profile plots may be useful to inform the determination of the states of nature.

Request No. 4: Update the ageing error data to include the errors before 2015 since only those after 2015 were applied and plot results relative to the reference base model.

Rationale: Ageing error matrices were developed for two time periods, but only the errors from after 2015 were included. This will better reflect the ageing errors in each period.

STAT Response: Correcting the ageing error matrix for the pre-2015 data had little effect on spawning output or relative spawning output, relative to the pre-STAR base model (Figure 62).

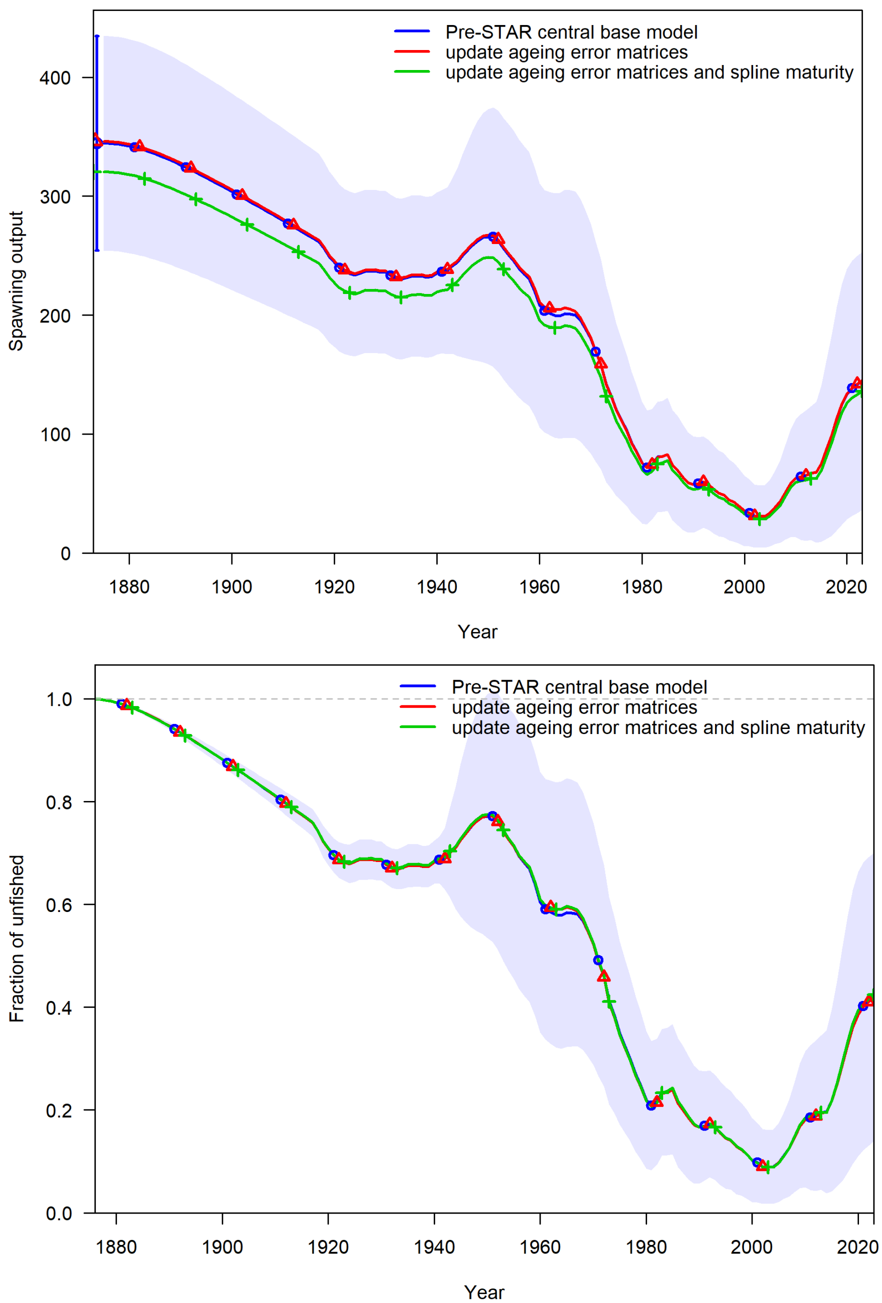


Figure 62. Comparison of spawning output (billions of eggs, upper panel) and relative spawning output (lower panel) time series from the pre-STAR base model and models with updated ageing error matrices and a spline model for the maturity at length relationship.

Panel Conclusion: The Panel supports the use of the corrected ageing error matrix for the pre-2015 data in the post-STAR base model. Additional data on aging error represents an informational improvement that should be included in the assessment. The net difference in model spawning output is small. Nevertheless, the new data on aging error should be implemented into an updated base model.

Request No. 5: Provide a sensitivity analysis fitting functional maturity with a spline in addition to the logistic curve applied in the assessment.

Rationale: A spline was fit to data in the Oregon and Washington assessments and the Panel would like the STAT to provide comparable results for California.

STAT Response: Updating the functional maturity relationship from the logistic model in the pre-STAR base to the spline model increased the scale of spawning output, but did not significantly change the time series of relative spawning output (Figure 62), estimated parameters, or fits to the data. This is likely due to the fact that the functional maturity logistic model was already in the pre-STAR base model, and few fish in the central model get large enough to be affected by the descending limb of the spline model.

Panel Conclusion: The Panel supports the use of spline functional maturity in the post-STAR reference model. Panel encourages the development of functional maturity estimates for the central assessment area. As shown in the study in Oregon, interannual variation is present in the functional maturity. The panel supports additional research into functional maturity and variation with time/environmental drivers in the central California assessment area. The spline model should be used in an updated reference model so that a consistent approach is applied across all assessments.

Request No. 6: Provide the Mohn's rho values from the retrospective analysis. Provide a plot to show relative error in spawning output as suggested in the best practice guideline outlined in Legault (2009). In addition, provide relative error plots for exploitation rate, and recruitment.

Rationale: The values will be useful in assessing the retrospective pattern. There are multiple options for calculating Mohn's rho in r4ss and thus it is important to understand the mechanism being used. Retrospective error is a particular type of uncertainty and it is important to understand any bias.

STAT Response: Mohn's rho values based on a 5-year peel were -0.036 for spawning output, 0.311 for recruitment, and 0.062 for exploitation rate. This was calculated using the r4ss function "SSmohnsrho," dividing the reported cumulative value by the number of retrospective years (5).

Plots are provided below for the time series of spawning output, recruitment, and exploitation rate (Figure 63) and percent change relative to the base model (Figure 64). Removal of the last 1-5 years of data tends to lead to lower estimates of spawning output (back to ~1980, generally not exceeding 20%), higher exploitation rates, and higher recent recruitments. Differences in recent recruitment predictions occur primarily because predictions revert back to the mean of the stock-recruit curve as data are removed.

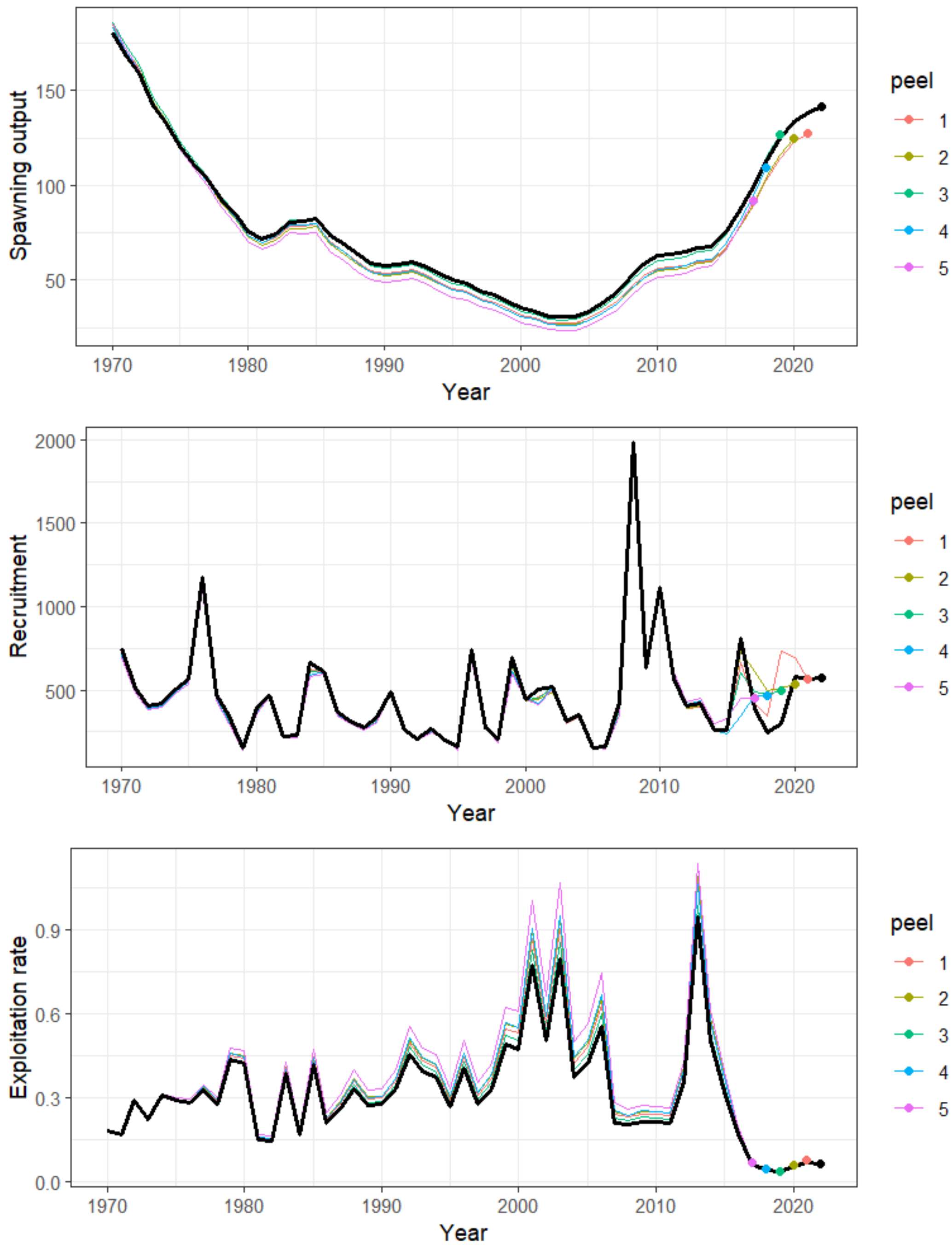


Figure 63. Time series of spawning output (billions of eggs; top panel), recruitment (1000s of age-0 fish; middle panel), and exploitation rate (catch divided by age 8+ biomass; bottom panel) for retrospective runs removing 1-5 years of data from the central California black rockfish model. Black line shows results from the pre-STAR base model, for reference.

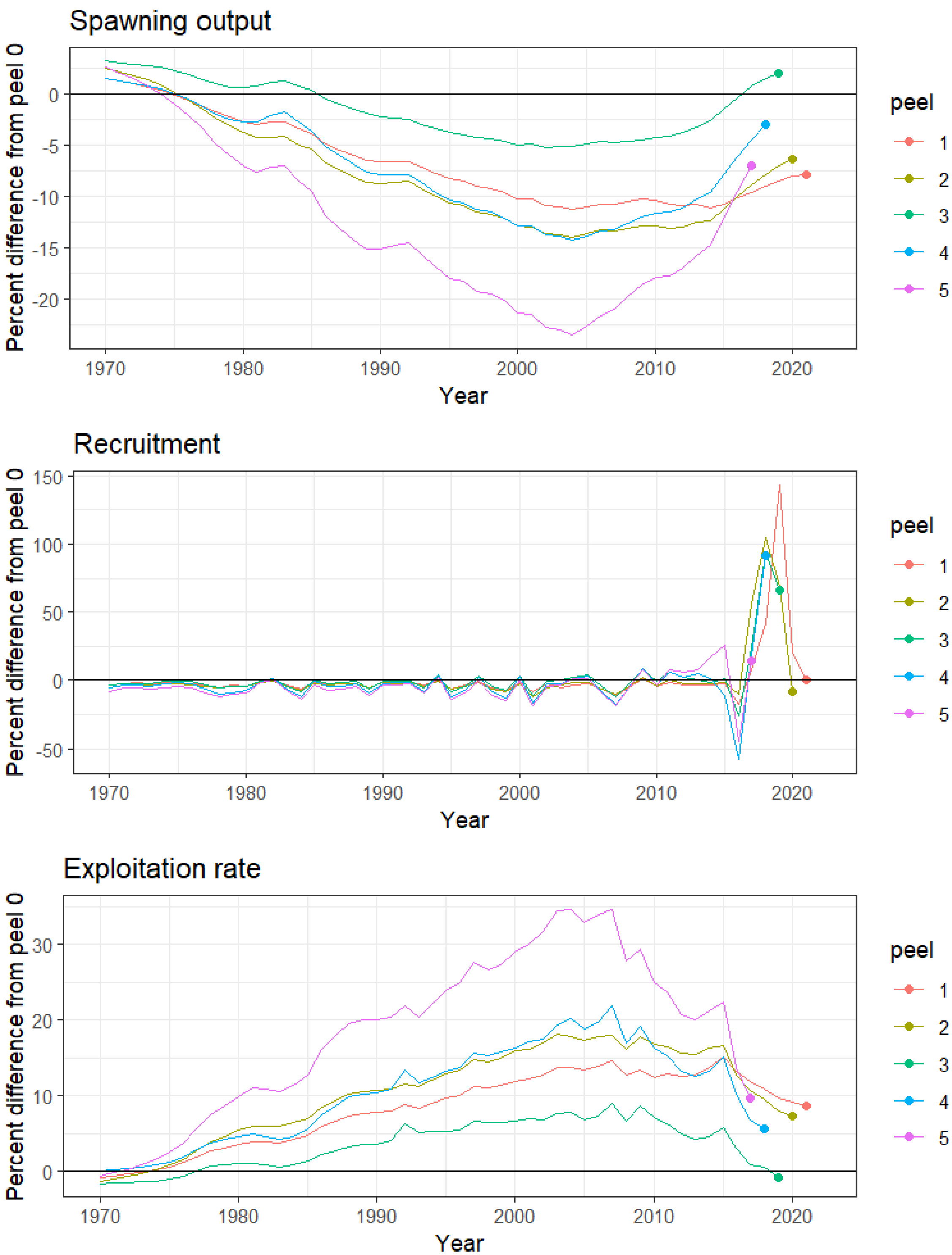


Figure 64. Time series of change in spawning output (billions of eggs; top panel), recruitment (1000s of age-0 fish; middle panel), and exploitation rate (catch divided by age 8+ biomass; bottom panel) for retrospective runs removing 1-5 years of data, relative to the central California pre-STAR black rockfish model.

Panel Conclusion: Retrospective patterns do not appear to be an issue for spawning output and the exploitation estimates in this assessment. The retrospective pattern for recruitment is large but it is unclear if this represents a systematic bias since it may just reflect the lack of information on recruitment in the ending year of the stock assessment. Generally, the Panel had no further recommendations, but noted that this exploration should be considered in the future.

Request No. *7*: Conduct a sensitivity run with dome-shaped selectivities being replaced with asymptotic selectivities (except for CCFRP that was mainly in shallow water and Lea et al. data) while having *M* estimated.

Rationale: It is hypothesized that the lack of large/old individuals in this stock resulted from large/old fishes moving out to the northern area. This hypothesis is supported by tagging study, although more data are probably still needed to continue testing this hypothesis. It is less likely that the lack of large/old fish resulted from poor selectivity for the large/old black rockfish. Thus, selectivities are more likely to follow logistic functions. The loss of large/old fish due to movement may be captured by having *M* estimated. Thus, *M* would be representing natural mortality and emigration.

STAT Response: All fleets were set to asymptotic except for the discard fleets and CCFRP survey (Figure 65). Female natural mortality was allowed to be estimated with a fixed male offset. Female natural mortality was estimated much higher than the prior and female Lmax increased dramatically (Figure 66). Spawning output was decreased substantially across the time series. Ending stock status is just below the minimum threshold (Figure 67). Early recruitment deviations became more positive, resulting in a shift toward more negative deviations in later years, possibly due to the sum-to-zero constraint on deviations (Figure 68).

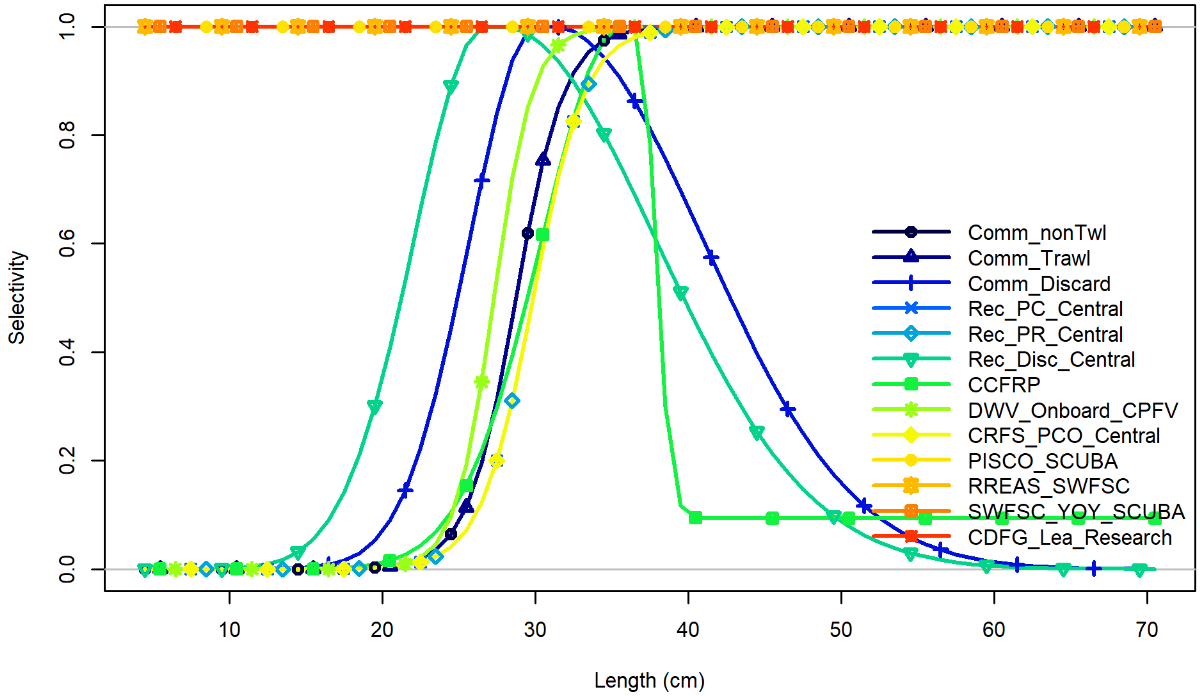


Figure 65. Selectivity at length for fleets in the central California model, forcing asymptotic relationships for all fleets except the discard fleets and the CCFRP survey, per request 7.

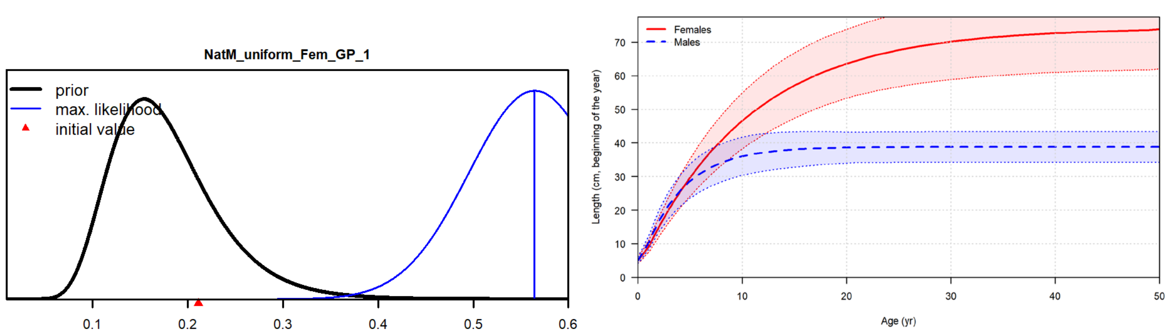


Figure 66. Comparison of prior for natural mortality and estimated value when forcing asymptotic selectivity curves as described in request 8 (left panel). Estimates of length at age for females and males under the same assumption (right panel).

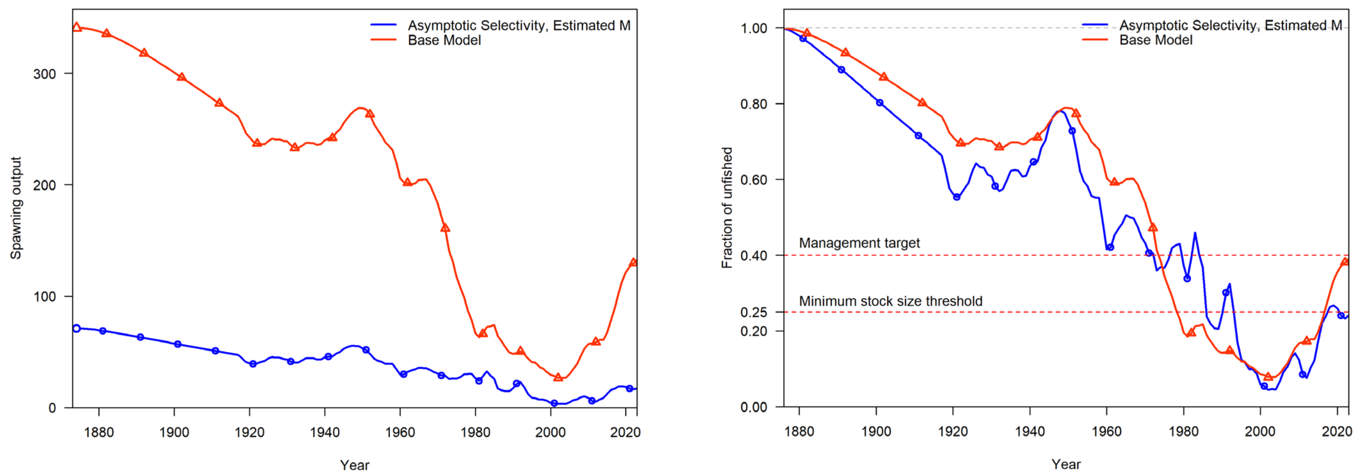


Figure 67. Comparison of a model forcing asymptotic selectivity at length relationships for all fleets except the discard fleets and the CCFRP survey, per request 7, and the pre-STAR base model.

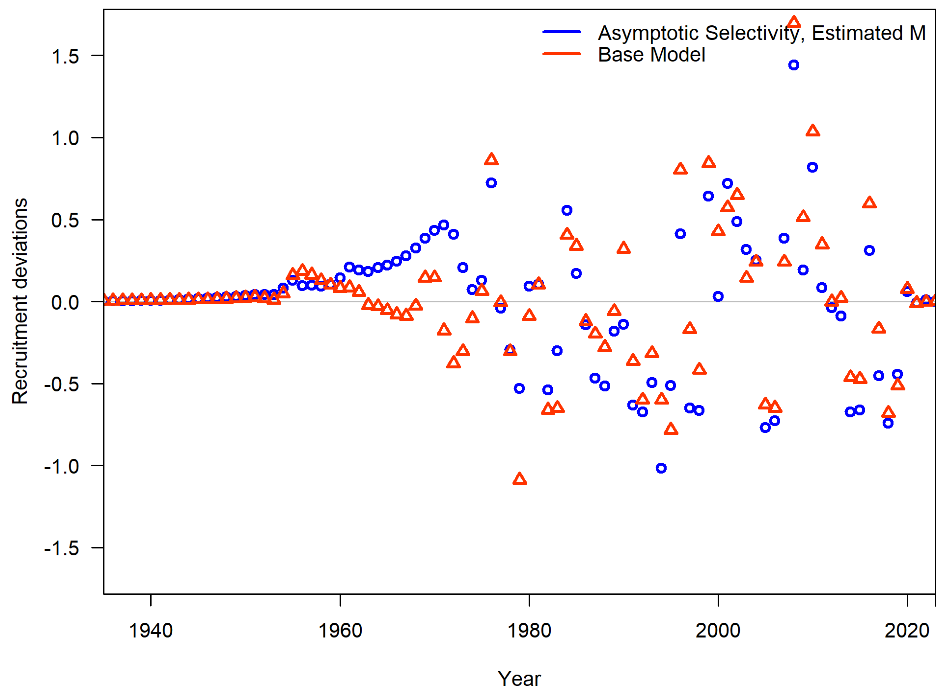


Figure 68. Estimated recruitment deviations in the central California model, forcing asymptotic relationships for all fleets except the discard fleets and the CCFRP survey, per request 7, and allowing dome-shaped selectivity, as in the pre-STAR base model.

Panel Conclusion: Changing selectivity has large impacts on the estimation of *M* (much higher) and other parameters (e.g., Lmax which becomes biologically unrealistic). It is not plausible to use logistical selectivity in the current assessment, but logistic selectivity may be considered in a future assessment when a spatially explicit model (e.g., 2-box model) linking the northern and central assessment areas through migration rates from CCFRP or other tagging data sources is developed for future stock assessment.

Request No. 8: Provide squid plots showing the age at which recruitment is first detected in the fishery and fishery-dependent studies, using the base model and a model including the RREAS and SCUBA young of year surveys.

Rationale: To identify how long it takes for recruitment to be detected in the data from the fisheries or non-young of year surveys. This will help inform how much potential benefit there is for early indications of recent recruitments from the inclusion of the RREAS and SCUBA survey young of year surveys in the assessment.

STAT Response: The STAT was unable to complete the request, as the number of possible combinations of YOY index configurations and run times made it impossible to fully analyze the impact of including these data sets in a base model. However, we present preliminary results for the central area, with and without inclusion of the YOY indices (RREAS and SWFSC SCUBA), estimating an additive variance parameter for the SCUBA survey.

As noted during earlier discussions with the panel, black rockfish are infrequently encountered by the RREAS survey, and the majority of encounters have occurred off central California. Since the adult population is larger in the northern part of the state, further research is needed to understand dispersal patterns, timing of parturition and settlement, and other factors that may influence spatiotemporal patterns of abundance for black rockfish pelagic juveniles.

The figures below were generated using the r4ss function "SSplotRetroRecruits." The analysis uses retrospective runs (12 runs were completed for the figures below, based on the typical forecast length for PFMC assessments), and the figures illustrate how estimates of recruitment deviations stabilize over time with the addition of new data each year. Since recent recruitments are often not well informed by composition data, the number of years it takes for deviations to stabilize can be interpreted as the lag between each model's ending year and a stable estimate of recruitment, given the data. For the central California model, the lag appears to be in the range of 4-6 years, roughly (Figures 69 and 70). The deviation for 2011 is unique in that it does not begin at zero (Figure 69), and the STAT needs to investigate this further.

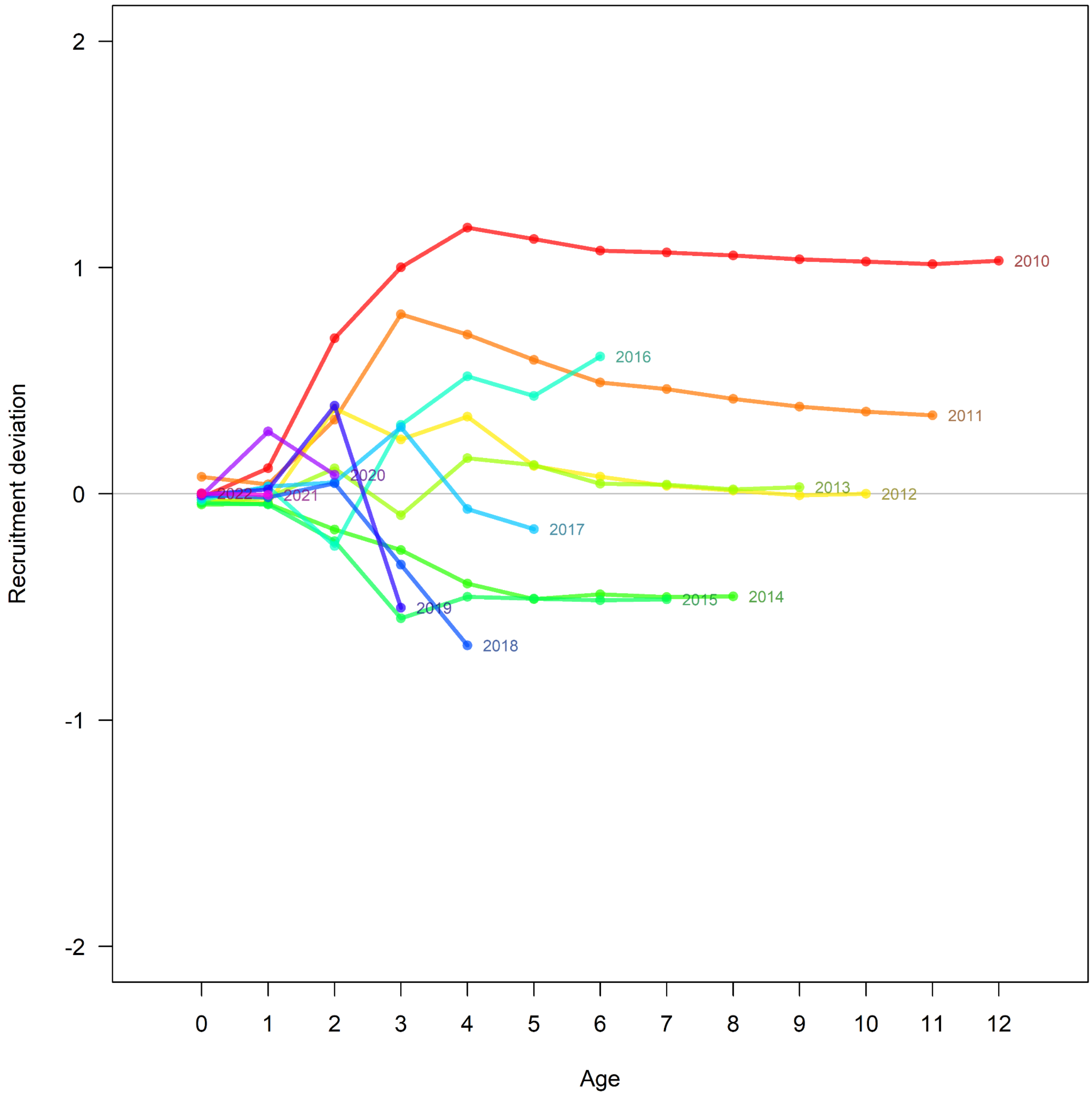


Figure 69. Retrospective analysis of recruitment deviations ('squid plot') for the central California model. 'Age' is the end year of each retrospective peel minus the year of the estimated deviation, e.g. the base model ends in 2022, so the maximum 'age' of the 2010 deviation in the retrospective analysis is 12.

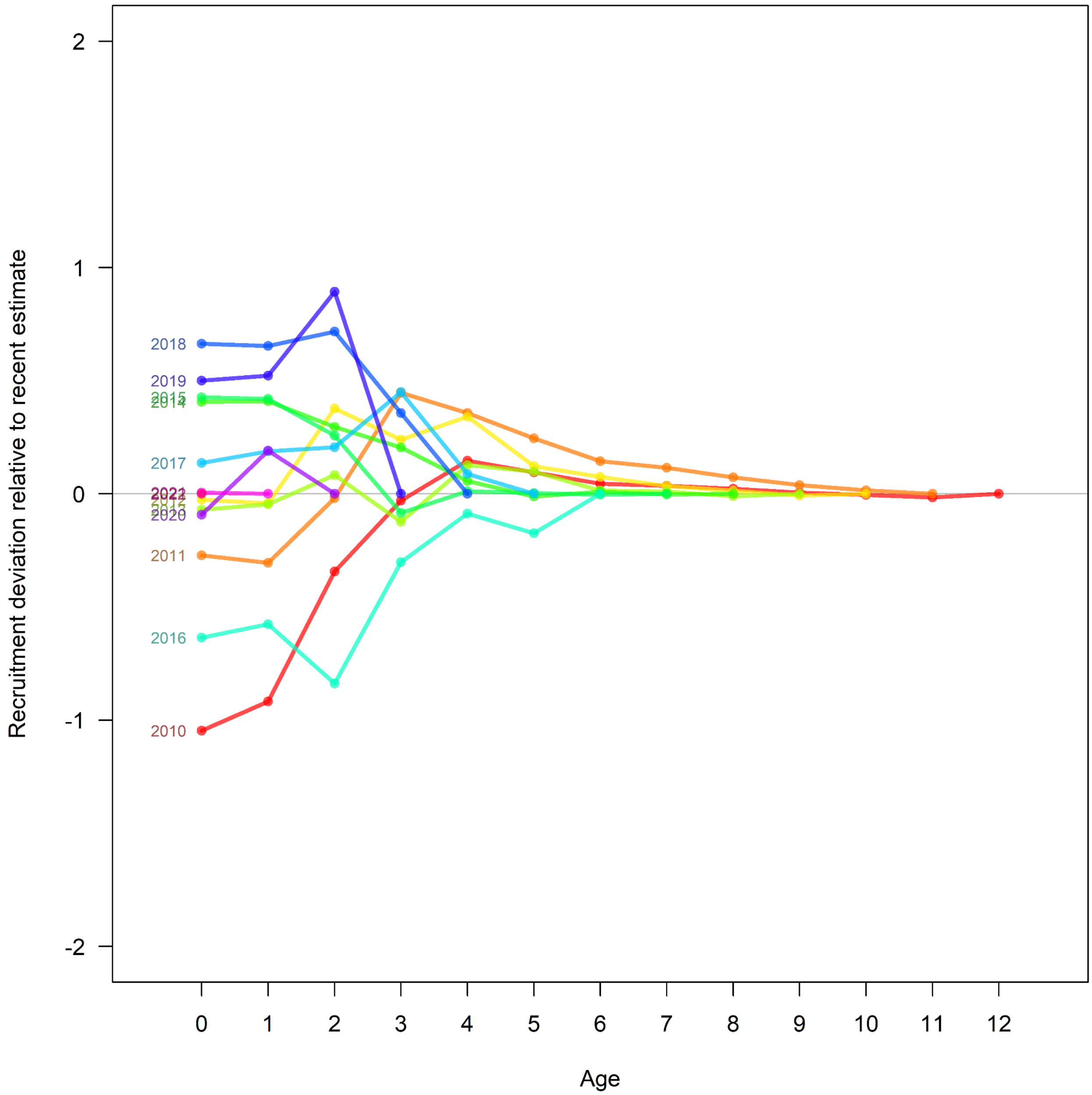


Figure 70. Retrospective analysis of recruitment deviations for the central California model, scaled relative to the most recent recruitment estimate. Convergence of the deviations is represented by the values approaching zero along the vertical axis.

A model that included the YOY abundance indices, as described above, appears to provide information sooner about the strength of recruitment in some years (e.g. 2014, 2015, 2016, and 2018; Figures 71 and 72). However, in other years (2010 and 2011) the initial estimates are slightly negative with inclusion of the indices, but ultimately stabilize at positive values as information improves over time.

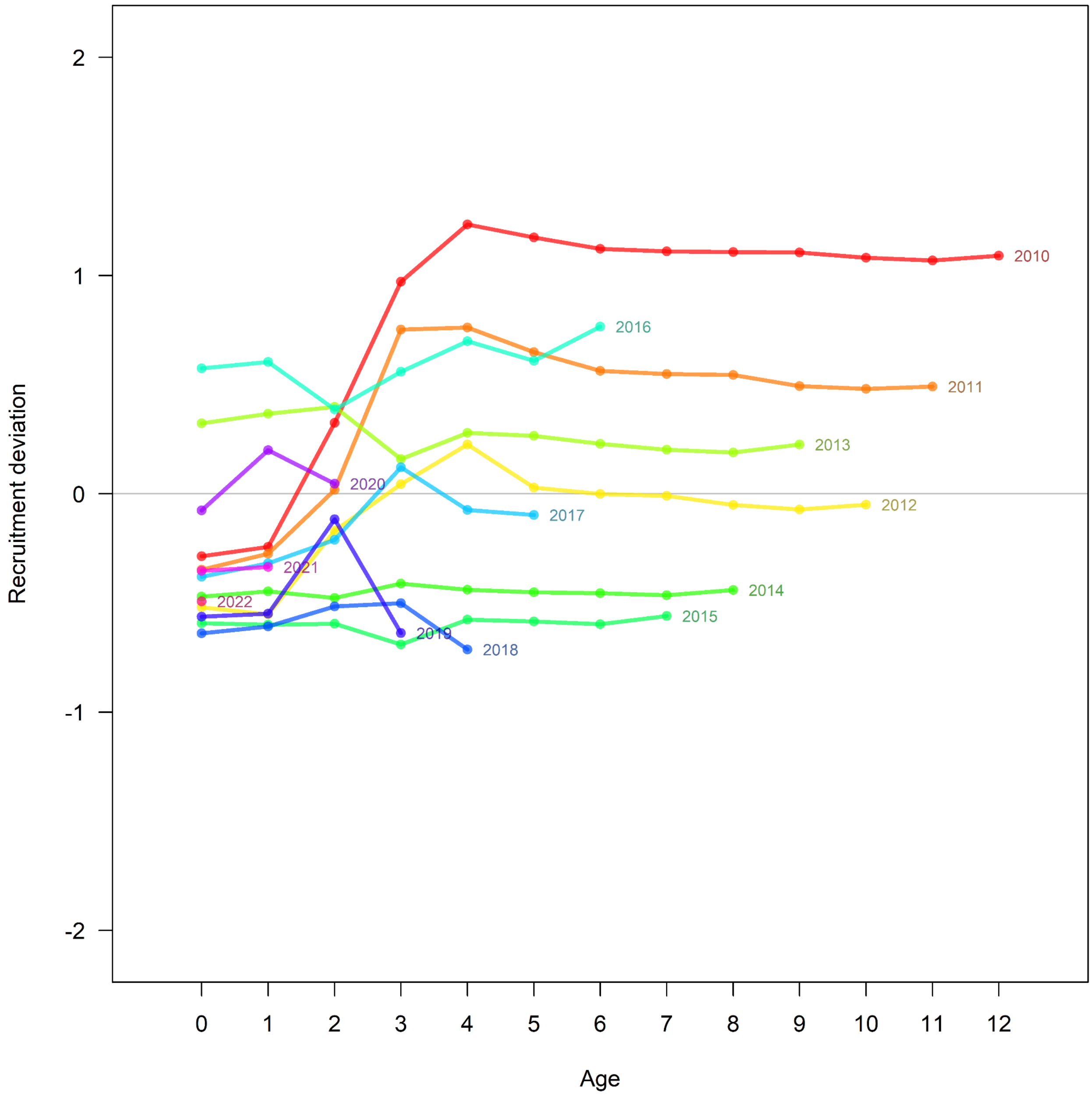


Figure 71. Effect of adding YOY abundance indices to a retrospective analysis of recruitment deviations ('squid plot') for the central California model. 'Age' is the end year of each retrospective peel minus the year of the estimated deviation, e.g. the base model ends in 2022, so the maximum 'age' of the 2010 deviation in the retrospective analysis is 12.

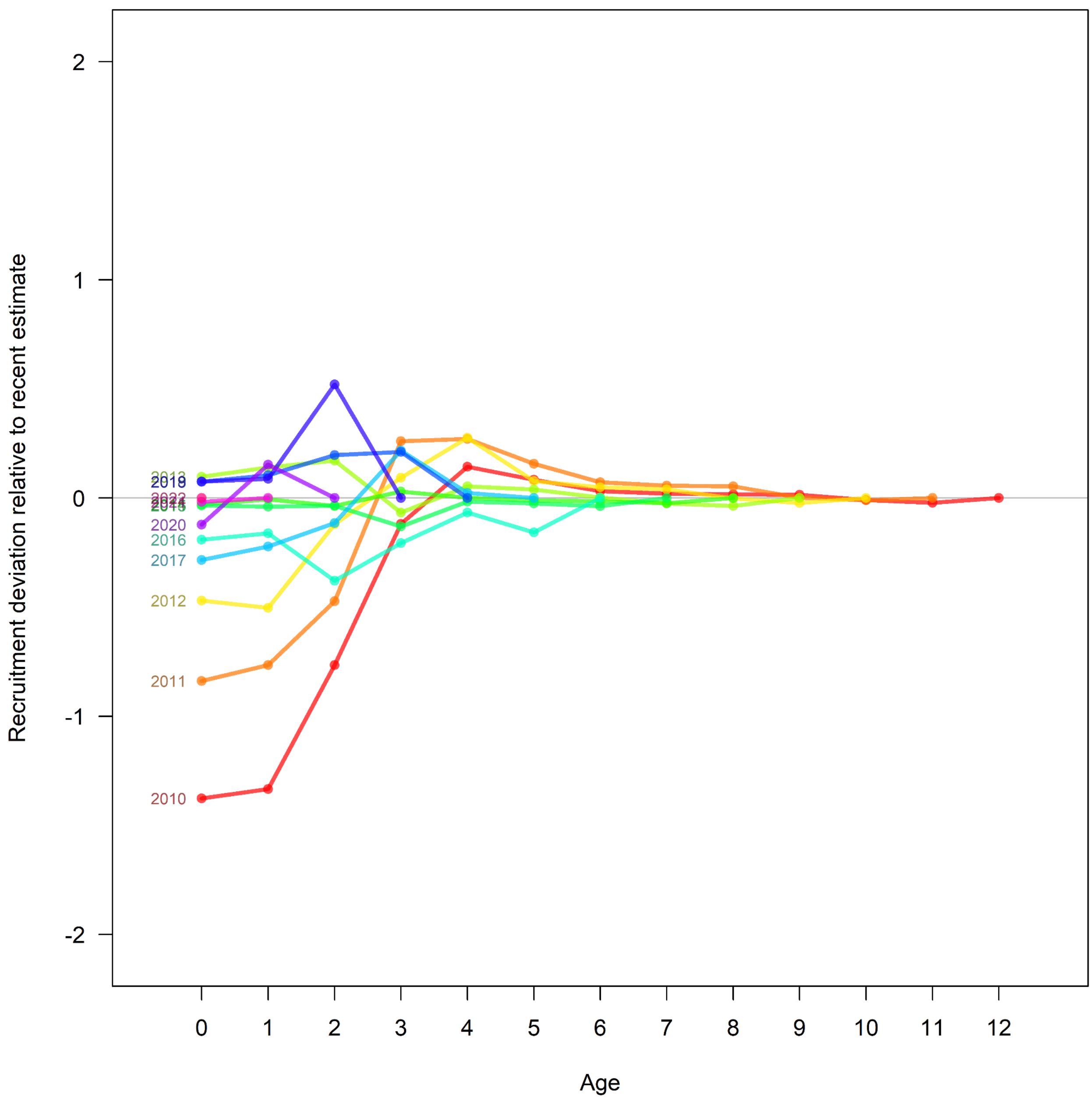


Figure 72. Retrospective analysis of recruitment deviations for the central California model fit with YOY abundance indices, scaled relative to the most recent recruitment estimate. Convergence of the deviations is represented by the values approaching zero along the vertical axis.

Panel Conclusion: This analysis shows that the RREAS and SCUBA young of year surveys may have potential to inform future recruitment in the projection. However, the STAT did not have time to fully explore incorporation of these data sets in the reference model, including evaluating model diagnostics to ensure the appropriate use of the information. These data should be considered in future stock assessments.

Request No. 9: Incorporate the ageing error prior to 2015 and spline fit to the functional maturity to provide a revised base model.

Rationale: To implement the conclusions of Request No. 4 (the ageing error prior to 2015) and Request No. 5 (functional maturity fit with a flexible spline), which improved the base model.

STAT Response: The corrected ageing error matrix and spline model for functional maturity were included in the model, and Francis weights updated (little change in weights). As noted in the request to revise the maturity relationship, spawning output was slightly scaled upwards, but relative spawning output remained very similar over time (Figures 73 and 74).

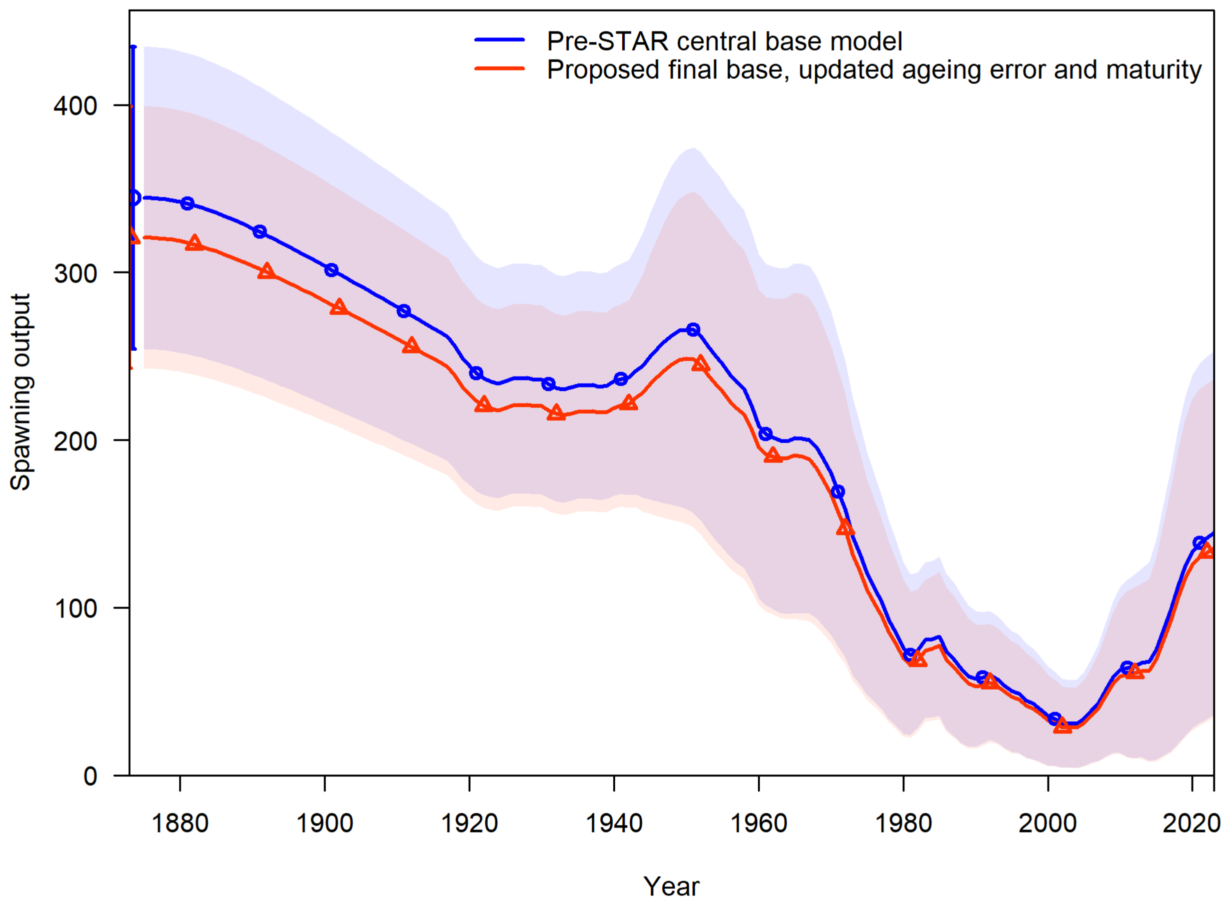


Figure 73. Time series of spawning output (billions of eggs) comparing the pre-STAR base model to a revised model with updated ageing error matrices and a spline function for maturity at length.

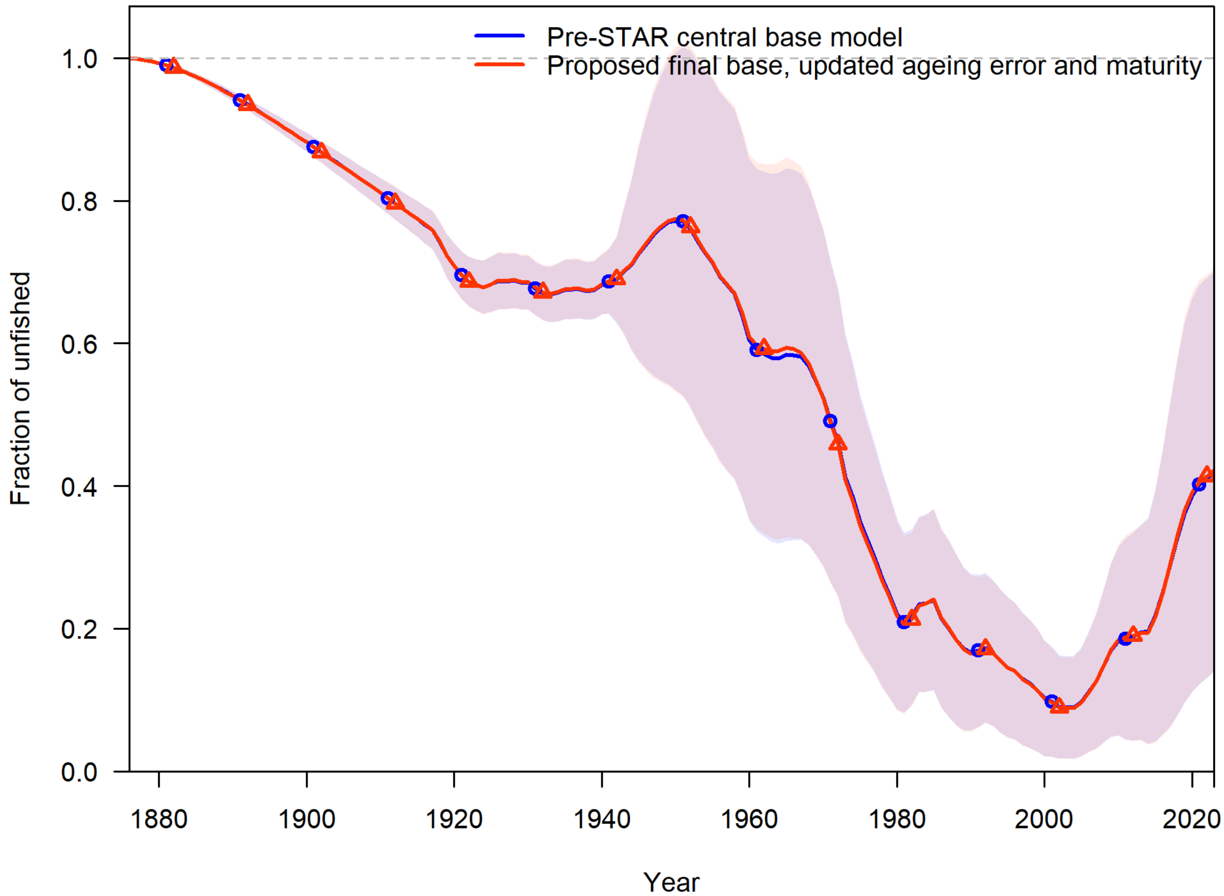


Figure 74. Time series of relative spawning output comparing the pre-STAR base model to a revised model with updated ageing error matrices and a spline function for maturity at length.

Model likelihoods, parameter estimates, and derived quantities are similar between the pre-STAR base and the updated model in Request No. 9 (Table 10). Further details of the updated model will be presented using the r4ss html output.

Table 10. Number of estimated parameters, likelihood values, parameter estimates, and derived quantities from the pre-STAR and revised (post-STAR) models.

Label	**Pre-STAR central base model**	**Proposed final base, updated ageing error and maturity**
N.Parms	118	118
TOTAL	523.4	520.5
Survey	20.6	20.6
Length_comp	319.3	319.2
Age_comp	180.8	178.1
Recruitment	2.1	2.1
Parm_priors	0.5	0.5
NatM_uniform_Fem_GP_1	0.211	0.210
L_at_Amax_Fem_GP_1	54.651	54.671

VonBert_K_Fem_GP_1	0.145	0.145
NatM_uniform_Mal_GP_1	-0.053	-0.051
L_at_Amax_Mal_GP_1	-0.100	-0.101
VonBert_K_Mal_GP_1	0.246	0.248
SR_LN(R0)	6.479	6.473
Q_extraSD_Rec_PR_Central(5)	0.378	0.378
Size_DblN_peak_Comm_nonTwl(1)	29.96	29.94
Size_DblN_ascend_se_Comm_nonTwl(1)	2.81	2.81
Size_DblN_descend_se_Comm_nonTwl(1)	4.50	4.53
Size_DblN_end_logit_Comm_nonTwl(1)	-1.32	-1.34
Size_DblN_peak_Comm_Discard(3)	27.50	27.50
Size_DblN_ascend_se_Comm_Discard(3)	3.43	3.43
Size_DblN_descend_se_Comm_Discard(3)	3.97	3.97
Size_DblN_peak_Rec_PC_Central(4)	32.99	32.99
Size_DblN_ascend_se_Rec_PC_Central(4)	3.52	3.52
Size_DblN_descend_se_Rec_PC_Central(4)	2.06	2.06
Size_DblN_end_logit_Rec_PC_Central(4)	-2.05	-2.05
Size_DblN_peak_Rec_Disc_Central(6)	24.28	24.28
Size_DblN_ascend_se_Rec_Disc_Central(6)	3.59	3.59
Size_DblN_descend_se_Rec_Disc_Central(6)	4.23	4.23
Size_DblN_peak_CCFRP(7)	32.81	32.81
Size_DblN_ascend_se_CCFRP(7)	4.01	4.01
Size_DblN_descend_se_CCFRP(7)	2.17	2.17
Size_DblN_end_logit_CCFRP(7)	-4.67	-4.67
Size_DblN_peak_DWV_Onboard_CPFV(8)	29.38	29.38
Size_DblN_ascend_se_DWV_Onboard_CPFV(8)	2.72	2.72
Size_DblN_descend_se_DWV_Onboard_CPFV(8)	3.08	3.08
Size_DblN_end_logit_DWV_Onboard_CPFV(8)	-1.25	-1.25
Bratio_2023	0.420	0.421
SSB_unfished	344.5	324.1
Totbio_unfished	1952.2	1959.5
Recr_unfished	651.0	647.6
Dead_Catch_SPR	64.8	64.9
OFLCatch_2023	48.5	48.5

Panel Conclusion: The Panel supports the use of the corrected ageing error matrix and spline model for functional maturity in the post-STAR base model with the Francis weights being updated.

Request No. 10: For the bivariate steepness and natural mortality plot (see Request No. 3), provide the 75% confidence region for both the northern and central California models.

Rationale: To provide a potential basis for selecting a combination of steepness and natural mortality for a decision table.

STAT Response: The STAT completed the request, which shows that the base model with fixed M and h is close to the minimum and falls within the 75% chi-squared interval (Figure 75). A figure with 95% chi-square intervals was also produced for comparison (Figure 76).

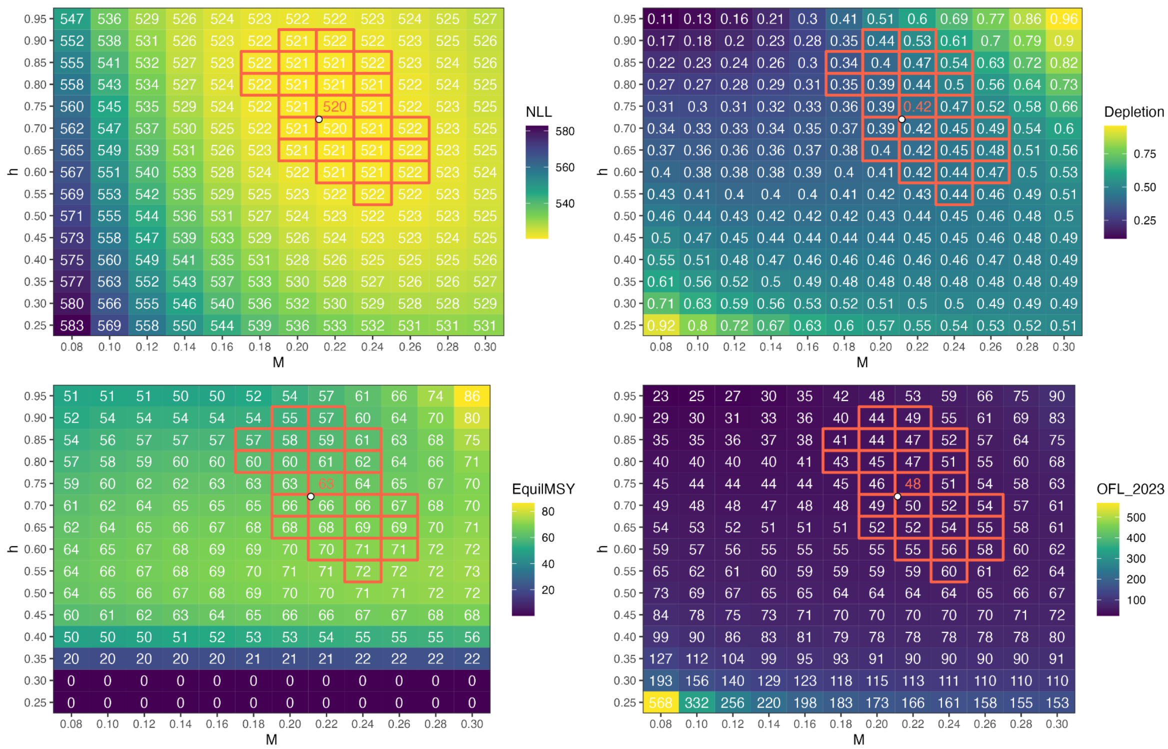


Figure 75. Bivariate profile over steepness and female natural mortality, plotting NLL (top left), Depletion (top right), Equilibrium MSY (bottom left), and OFL (bottom right). The white point is the base model. Numbers in red are values at the NLL minimum. Parameter combinations outlined in red are within the bivariate 75% chi-squared interval of the NLL minimum. Numbers within the plots are rounded for readability.

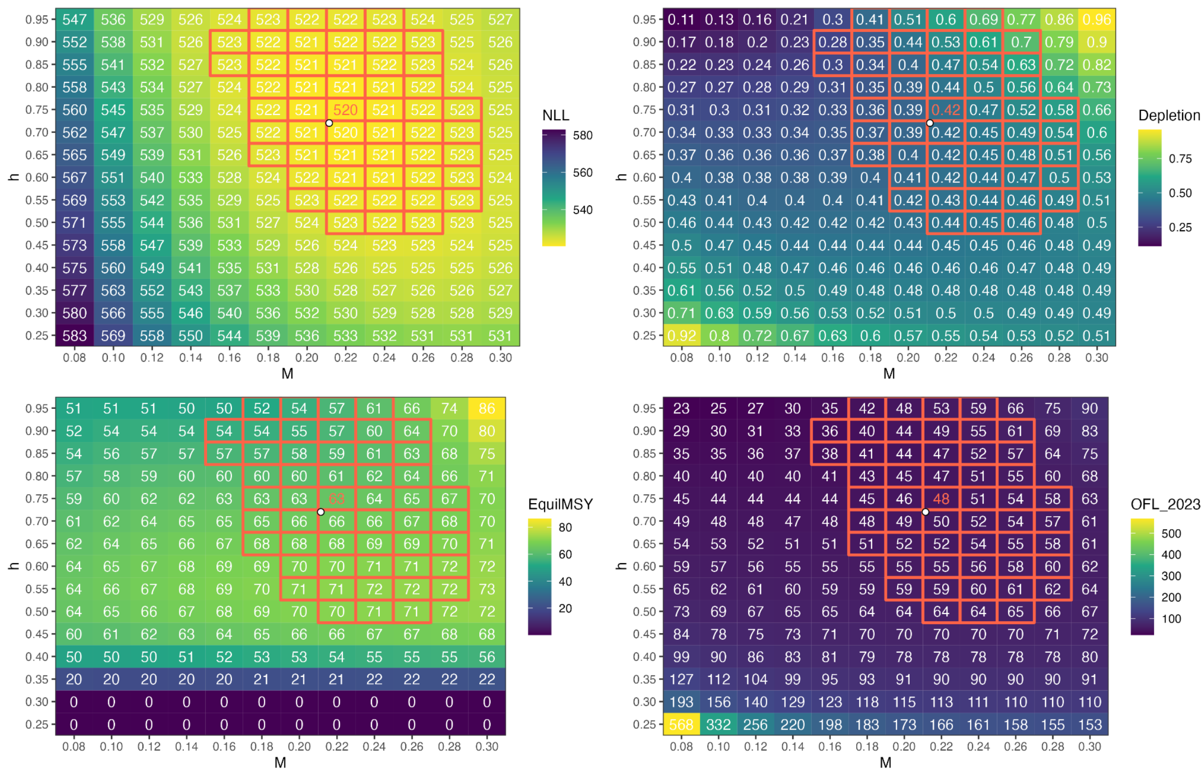


Figure 76. Bivariate profile over steepness and female natural mortality, plotting NLL (top left), Depletion (top right), Equilibrium MSY (bottom left), and OFL (bottom right). The white point is the base model. Numbers in red are values at the NLL minimum. Parameter combinations outlined in red are within the bivariate 95% chi-squared interval of the NLL minimum. Numbers within the plots are rounded for readability.

Panel Conclusion: The Panel requested that the bivariate steepness and natural mortality plot be modified to provide the 75% confidence region for both the northern and central models, which may provide a basis for selecting a combination of steepness and natural mortality for a decision table. However, the contrast in the *M* and *h* values within the 75% confidence region was not sufficiently broad to provide a suitable set of alternatives. Instead, the Panel suggests to use the uncertainty in the prior for natural mortality only to obtain possible upper and lower states of nature (see Request No. 11).

Request No. 11: Use the uncertainty in the prior for natural mortality to obtain possible upper and lower states of nature. Center this uncertainty on the point estimate of the base model and use the *M* at the 12.5 and 87.5 percentile of the distribution for lower and upper states of nature.

Rationale: To provide a potential basis for selecting natural mortality values for a decision table.

STAT Response: The central area model has female natural mortality fixed at the value estimated in the northern area model (0.2103 yr^{-1}) and also fixes the offset for male natural mortality at the estimate of the northern area model (male M=0.1998 yr^{-1}). The log-scale standard deviation of the prior for *M* is 0.31. The point estimates of *M* for the high and low states of nature were calculated as exp{$\log_e$(0.2103) +/- 0.31*1.15}, where 1.15 is the z-score corresponding to a two-tailed 75% interval in log space (i.e. plus or minus 1.15 standard deviations from the point estimate). The resulting values of *M* in arithmetic space for the high and low states of nature are 0.300 and 0.147, respectively.

Estimated time series of spawning output are scaled upward under the assumption that *M* = 0.147 (the 'low' state of nature), and downward with *M* = 0.300 (the 'high' state of nature). Estimated unfished spawning output varies more than recent estimates (Figure 77), and on a relative scale the low state is well within the base model's range of uncertainty while the high state is at the upper edge of that range in recent years (Figure 78).

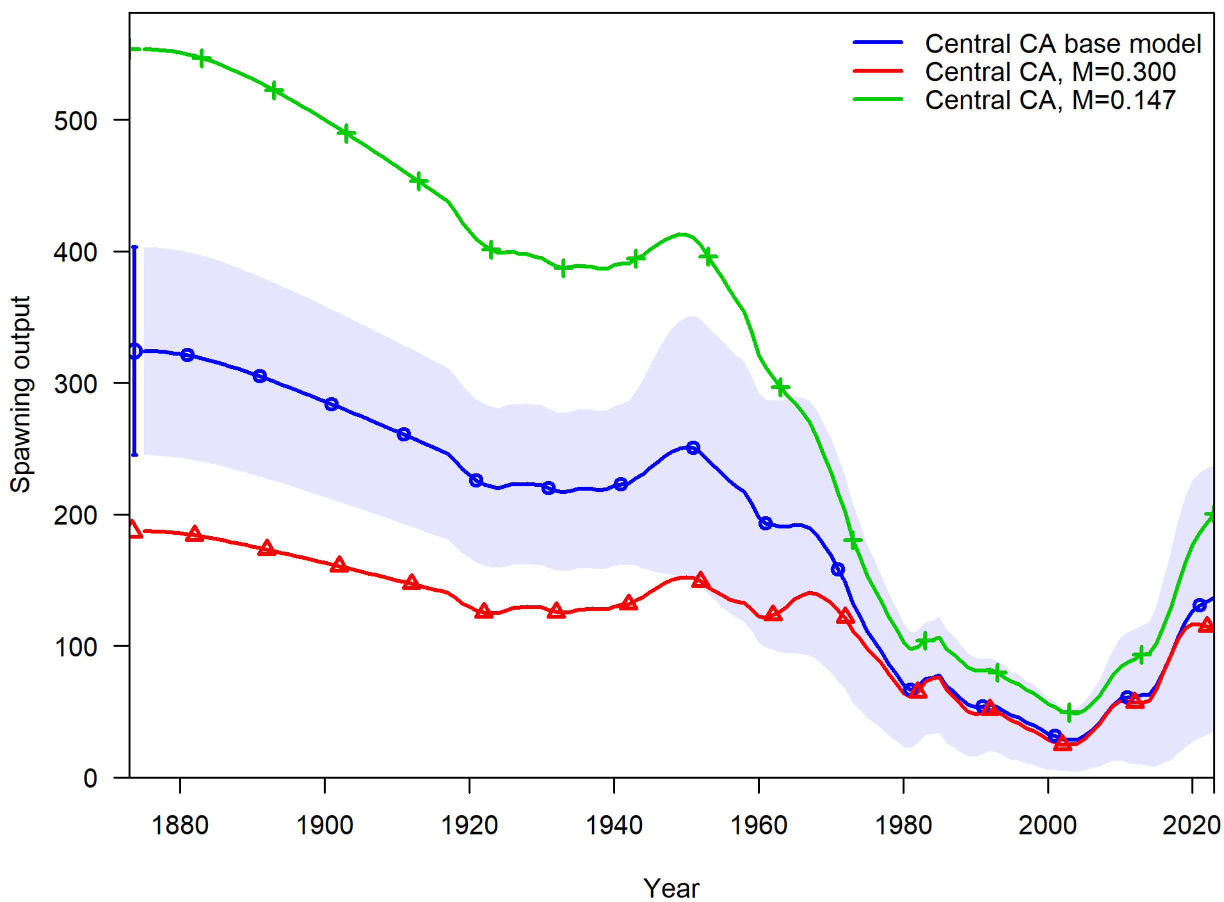


Figure 77. Comparison of spawning output time series (billions of eggs) for alternative *M* values (states of nature) for the central California post-STAR base model.

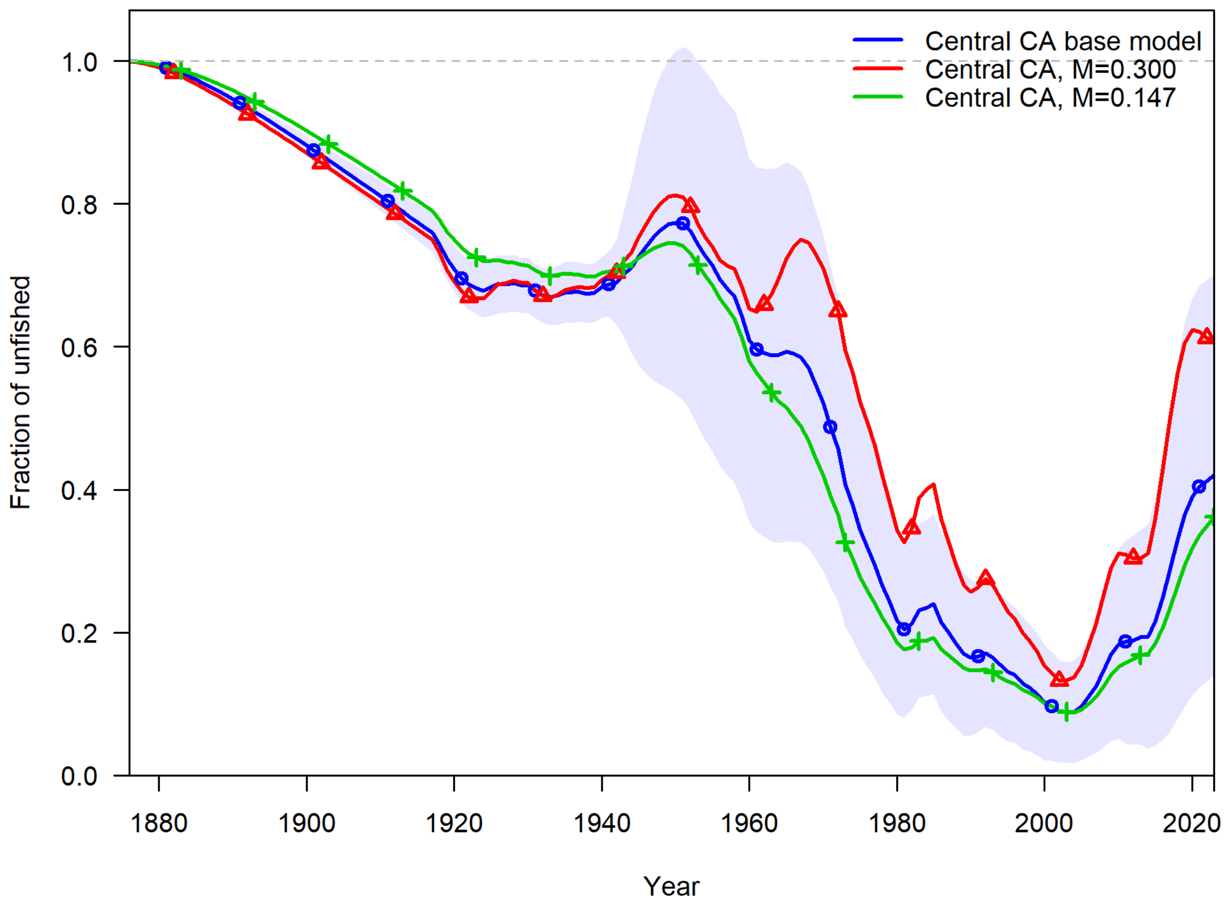


Figure 78. Comparison of relative spawning output time series (relative to unfished spawning output) for alternative *M* values (states of nature) for the central California post-STAR base model.

The pattern of scaling relative to the base model holds for the early recruitment deviations, while more recent estimates are less affected (Figure 79).

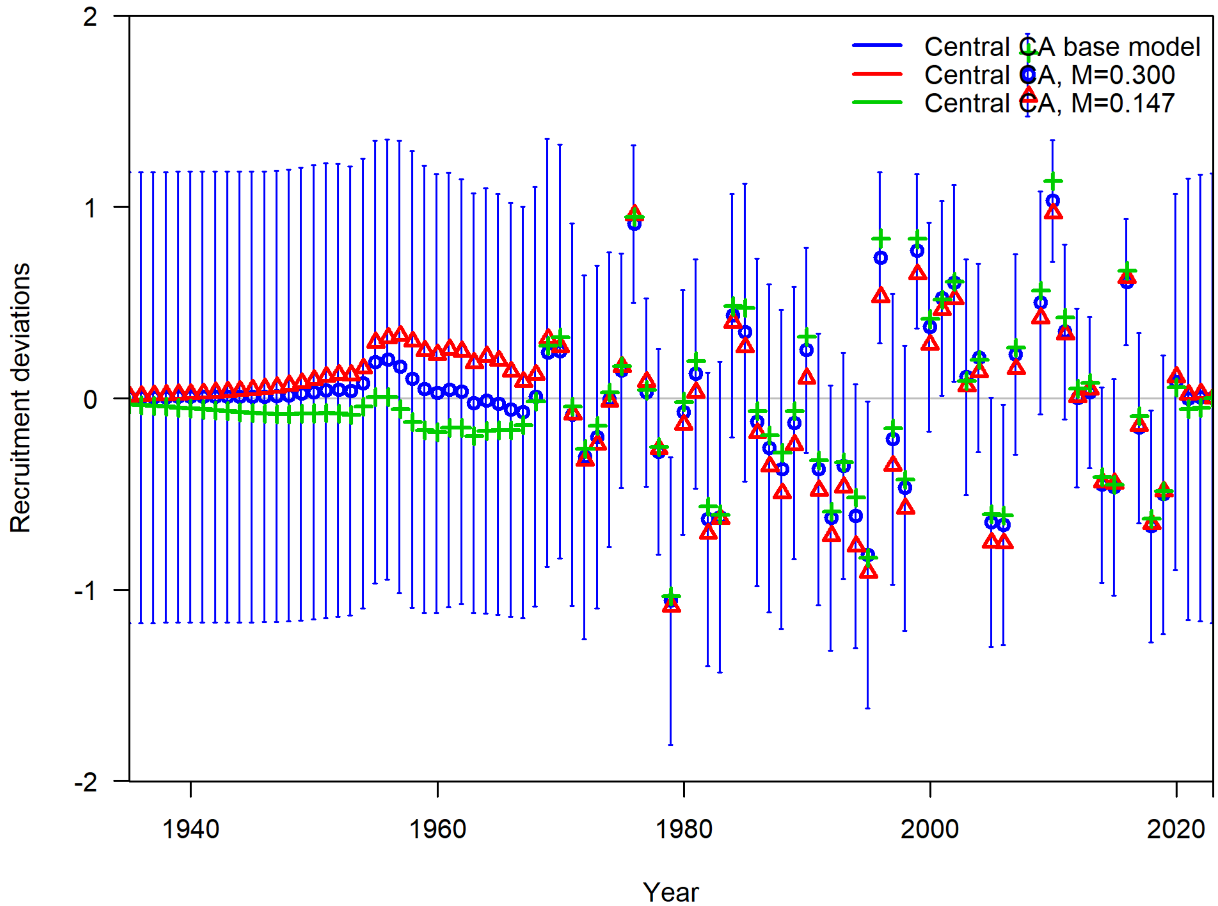


Figure 79. Comparison of estimated recruitment deviations given alternative *M* values (states of nature) for the central California post-STAR base model.

For the central California model, the reported 'sigma' (log-space uncertainty around the OFL value for the first forecast year) is 0.254.

Table 11. Number of estimated parameters, likelihood values, parameter estimates, and derived quantities for the three alternative states of nature in the central California model, as described in request 11.

Label	**Central, base**	**Central, M=0.300**	**Central, M=0.147**
N.Parms	118	118	118
TOTAL	520.484	524.917	527.597
Survey	20.6343	17.5095	22.1225
Length_comp	319.157	319.714	322.546
Age_comp	178.095	181.866	179.565
Recruitment	2.09745	3.52576	3.35007
Parm_priors	0.498516	2.3007	0.0121744
NatM_uniform_Fem_GP_1	0.21026	0.3	0.147

L_at_Amax_Fem_GP_1	54.6712	55.9329	53.4577
VonBert_K_Fem_GP_1	0.144782	0.137387	0.152801
L_at_Amax_Mal_GP_1	-0.10082	-0.116921	-0.0893332
VonBert_K_Mal_GP_1	0.24799	0.278353	0.225275
SR_LN(R0)	6.47327	7.02112	6.11101
Q_extraSD_Rec_PR_Central(5)	0.377881	0.362366	0.377306
Size_DblN_peak_Comm_nonTwl(1)	29.9412	30.056	29.5288
Size_DblN_ascend_se_Comm_nonTwl(1)	2.81086	2.81972	2.71577
Size_DblN_descend_se_Comm_nonTwl(1)	4.52856	4.79617	4.34205
Size_DblN_end_logit_Comm_nonTwl(1)	-1.33925	-1.61883	-1.37348
Size_DblN_peak_Comm_Discard(3)	27.4959	27.7505	27.2327
Size_DblN_ascend_se_Comm_Discard(3)	3.4325	3.42739	3.4279
Size_DblN_descend_se_Comm_Discard(3)	3.97451	4.0256	3.90991
Size_DblN_peak_Rec_PC_Central(4)	32.993	33.2072	32.7007
Size_DblN_ascend_se_Rec_PC_Central(4)	3.51636	3.51827	3.50563
Size_DblN_descend_se_Rec_PC_Central(4)	2.05918	1.85688	2.2639
Size_DblN_end_logit_Rec_PC_Central(4)	-2.04922	-1.74457	-2.44505
Size_DblN_peak_Rec_Disc_Central(6)	24.2756	24.6617	23.9039
Size_DblN_ascend_se_Rec_Disc_Central(6)	3.58767	3.59827	3.5665
Size_DblN_descend_se_Rec_Disc_Central(6)	4.2343	4.27171	4.19077
Size_DblN_peak_CCFRP(7)	32.8079	33.027	32.5214
Size_DblN_ascend_se_CCFRP(7)	4.00553	3.99054	4.01249
Size_DblN_descend_se_CCFRP(7)	2.16916	2.09659	2.25166
Size_DblN_end_logit_CCFRP(7)	-4.67126	-4.32086	-5.08348
Size_DblN_peak_DWV_Onboard_CPFV(8)	29.3786	29.5837	28.967
Size_DblN_ascend_se_DWV_Onboard_CPFV(8)	2.71895	2.76686	2.61836
Size_DblN_descend_se_DWV_Onboard_CPFV(8)	3.08284	2.82761	3.39622
Size_DblN_end_logit_DWV_Onboard_CPFV(8)	-1.2525	-0.863897	-1.85692
Bratio_2023	0.420579	0.608575	0.361595
SSB_unfished	324.133	187.23	553.927
Totbio_unfished	1959.46	1554.2	2733.35
Recr_unfished	647.6	1120.04	450.793
Dead_Catch_SPR	64.8502	70.0031	63.827
OFLCatch_2023	48.4745	62.1215	46.0443

Panel Conclusion: The states of nature identified by this approach (M = 0.147, 0.300) provide a sufficient contrast to capture the uncertainty in the assessment.

Description of the Base Model and Alternative Models used to Bracket Uncertainty

Proposals for base models were presented in the draft assessment document for the central California black rockfish assessment area. The STAR Panel explored alternatives to these formulations as noted in the analytical requests above. The model for the central California assessment area was rerun with the spline maturity function and updated ageing error matrix. This modification was accepted by the STAR Panel as an appropriate adjustment to the draft base model and the updated base model is to be carried forward in subsequent post-STAR revised assessments.

The uncertainty in the prior for natural mortality was used to obtain possible upper and lower states of nature for the central California black rockfish assessment area. This uncertainty was centered on the point estimate of the northern base model and was defined at the 12.5 and 87.5 percentile of the distribution for lower and upper states of nature.

Technical Merits of the Assessment

A wide range of available data collected in the fishery-dependent and fishery-independent monitoring programs were examined. Historical information was carefully evaluated for their quality and quantity before they were included in the assessment. A well defined protocol was developed and followed in the CPUE standardization.

Incorporating age/length data and indices of abundance from various sources including both fishery-dependent and fishery-independent programs in an integrated length/based assessment allow for a comprehensive evaluation of fish stock dynamics, leading to an improved understanding of the status of the stock and sustainable harvest levels.

The STAT team explored many alternative models with different configurations and parameterizations within the Stock Synthesis framework. These alternative models indicated that the STAT were reviewing and developing options to improve stock assessments in the future as well as check the robustness of the current approach being used for management advice. Exploring alternative model configurations and approaches used to assess these stocks improved the quality of the assessment overall and indicated potential solutions to some problems, such as uncertainty estimates of spawning output, exploitation and recruitment.

The STAT team evaluated life history and fishery-dependent and fishery-independent data collected along the coast of California and proposed a finer spatial scale stock assessment for black rockfish in California. The newly defined two assessment areas improve the stock assessment and reduce the uncertainty compared with the 2015 assessment.

Technical Deficiencies of the Assessment

The STAT provided CPUE standardization modeling information including variable selection, data filtering, and modeling diagnostics. However, the effectiveness of the CPUE standardization to remove factors other than stock abundance was not carefully evaluated and may affect how the indices should be used in stock assessment models. The STAR Panel did not have the opportunity to do a thorough review of CPUE standardization due the inherent limitations of a one-week STAR panel meeting. There is a concern that primary or secondary trip targets may be too loosely applied to effectively filter out the non-informative data.

There is a need to better quantify uncertainties from different model structures that represent plausible fisheries population dynamics. Ensemble modeling approaches may be considered in future to quantify the uncertainty in stock assessment models.

The current assessment assumes that the central California assessment area is closed with no immigration/immigration, which does not reflect the observed movement in tagging studies.

There is no historical functional maturity information available. Recent years of data were used in estimating historical spawning output, which might introduce additional uncertainty given functional maturity is likely to vary with biotic and abiotic environmental conditions.

There is a lack of explicit consideration of ecosystem dynamics (e.g., climate change) in the stock assessment.

Areas of Disagreement Regarding STAR Panel Recommendations

Among STAR Panel members (including GAP, GMT, and PFMC representatives): There were no areas of disagreement between STAR Panel members and representatives regarding STAR Panel recommendations.

Between the STAR Panel and the STAT Team: There were no areas of disagreement between STAR Panel members and the STAT Team regarding STAR Panel recommendations.

Management, Data, or Fishery Issues raised by the GMT or GAP Representatives During the STAR Panel Meeting

No issues were raised by the GMT or GAP representatives during the STAR Panel meeting.

Unresolved Problems and Major Uncertainties

Black rockfish in the assessment areas north and south of Point Arena, California were assessed as separate non-mixing stocks, but there is likely larval or juvenile dispersal and movement of adult black rockfish between the two stock areas. Existing tagging studies have shown northward movement of adult black rockfish between the northern and central assessment areas. Dispersal and movement rates are not well known. Improved understanding of northward movement of black rockfish is needed to support the development of spatially explicit modeling for a coastal-wide integrated California stock assessment (e.g., 2-box models or other spatially explicit stock assessment models considering regional differences as well as northward movement of adult black rockfish).

Lack of understanding of missing large/old black rockfish in the surveys and fisheries is a source of major uncertainty in stock assessment. This may result from high natural mortality, emigration out of the central stock area, and/or failure of monitoring programs in catching them during the surveys and fisheries. During the review, the lack of large/old individuals in this stock was hypothesized resulting from large/old fishes moving out to the northern area. This hypothesis is supported by tagging study, although more data are probably still needed to continue testing this hypothesis. It is less likely that the lack of large/old fish resulted from poor selectivity for the large/old black rockfish, given all the monitoring programs and commercial and recreational fisheries. Thus, selectivities are more likely to follow logistic functions. The loss of large/old fish due to movement may be captured by having M estimated. Thus, M would be representing natural mortality and emigration. A sensitivity run was conducted (Request No. 7) with dome-shaped selectivities being replaced with asymptotic selectivities to evaluate selectivities (except for CCFRP that was mainly in shallow water and Lea et al. data) while having M estimated. In this sensitivity run (Request No. 7), female natural mortality was allowed to be estimated with a fixed male offset. Female natural mortality was estimated much higher than the prior. Spawning output decreased substantially across the time series. Ending stock status is just below the minimum threshold. Female Lmax increased dramatically with the estimated values biologically unrealistic. More studies are needed to continue exploring the causes of lacking large/old females.

Some historical data may be problematic (e.g., average weight estimates early in the time series), which might result in additional biases in estimating catch.

Functional maturity data were borrowed from Orgean and Washington stock areas. However, the functional maturity-length relationships are likely to differ among the areas, and the use of functional relationships derived from the data collected in other areas may introduce additional uncertainties.

Recommendations for Future Research and Data Collection

The panel supports the recommendations provided in the pre-STAR draft assessment (reproduced below).

1. There is conflicting evidence and limited information with which to evaluate black rockfish stock structure, especially off California. Future research on larval dispersal, life history traits, adult movement, and genetics south of the California-Oregon border would improve inputs for stock assessments and provide support for the spatiotemporal scale that is most appropriate for modeling black rockfish. Specifically, information about growth, maturity, and mortality north and south of Point Arena would further justify the separation of black rockfish at this location. Further genetic evaluation regarding the extent to which Point Arena may serve as a barrier to gene flow would also be valuable for this stock.
2. Specific estimates of larval dispersal and movement rates at various life stages would further our understanding about connectivity among the three West Coast stocks of black rockfish. Although most black rockfish show moderate to high site fidelity and some degree of homing, a notable proportion of fish appear to cross stock boundaries. Additional research on the directions and distances that black rockfish move in northern California and southern Oregon would help elucidate the degree of intergenerational exchange across this particular stock boundary.
3. Finally, much of what we know about the habitat associations and ecological role of black rockfish come from Oregon, Washington, and Alaska. Research that is specific to central

and northern California is needed to fully understand variation in black rockfish life history, population structure, and trophic positioning.

4. Exploration of multiple-area models for the stock is recommended when sufficient data are available to parameterize movement within the model. Directional movement between areas (south to north, as observed in the CCFRP movement data) may partially explain sustained differences in size and age composition throughout the state.
5. Attempts to investigate recruitment indices (RREAS, SWFSC SCUBA) for the fleets-as-areas model configuration were not successful, and there was not enough time to evaluate area-specific indices prior to the STAR panel document deadline (although they have been developed). Future assessments may benefit from an analysis of these recruitment indices representing sub-areas defined in this assessment.
6. Further research is also needed to explain skewed sex ratios among older individuals in the population. This assessment assumes that size-dependent selectivity is equal for both sexes, and does not consider alternative hypotheses such as sex- or age-specific selectivity or age-dependent natural mortality, both of which could also explain, in whole or in part, the reduced fraction of older females in the data.

The STAR panel supports the following additional recommendations for future research and data collection.

1. Inclusion of ecosystem consideration to evaluate possible shifts in productivity and environments and how such changes may influence fish life history, population dynamics, phenology of movement, distributions, and fisheries.
2. Continue the current tagging study to better understand the movement and spatial distribution of black rockfish in California.
3. Exploration and development of a spatially explicit model (e.g., 2-box model) to integrate the assessment of the northern and central California assessment areas with migration rates informed from tagging studies.
4. Conducting habitat modeling to better understand spatio-temporal dynamics of black rockfish suitable habitats and how the changes may influence the existing monitoring programs and stock assessment.
5. Development of functional maturity-length relationships using the data collected in the central California assessment area.

Recommendation for Next Assessment, Assessment Category, and Sigma

Given large uncertainty associated with movement and some key life history parameters (e.g., functional maturity and natural mortality), the STAR Panel concluded that the next assessment should be a full assessment to better address these issues. Based on the criteria defined, the STAR Panel classified the central California assessment area as Category 1b.

The sigma value estimated for the central California assessment area (log-space uncertainty around the OFL value for the first forecast year) is 0.254, much lower than the default sigma of 0.5 for Category 1b. The Panel recommends that the default sigma value of 0.5 be used.

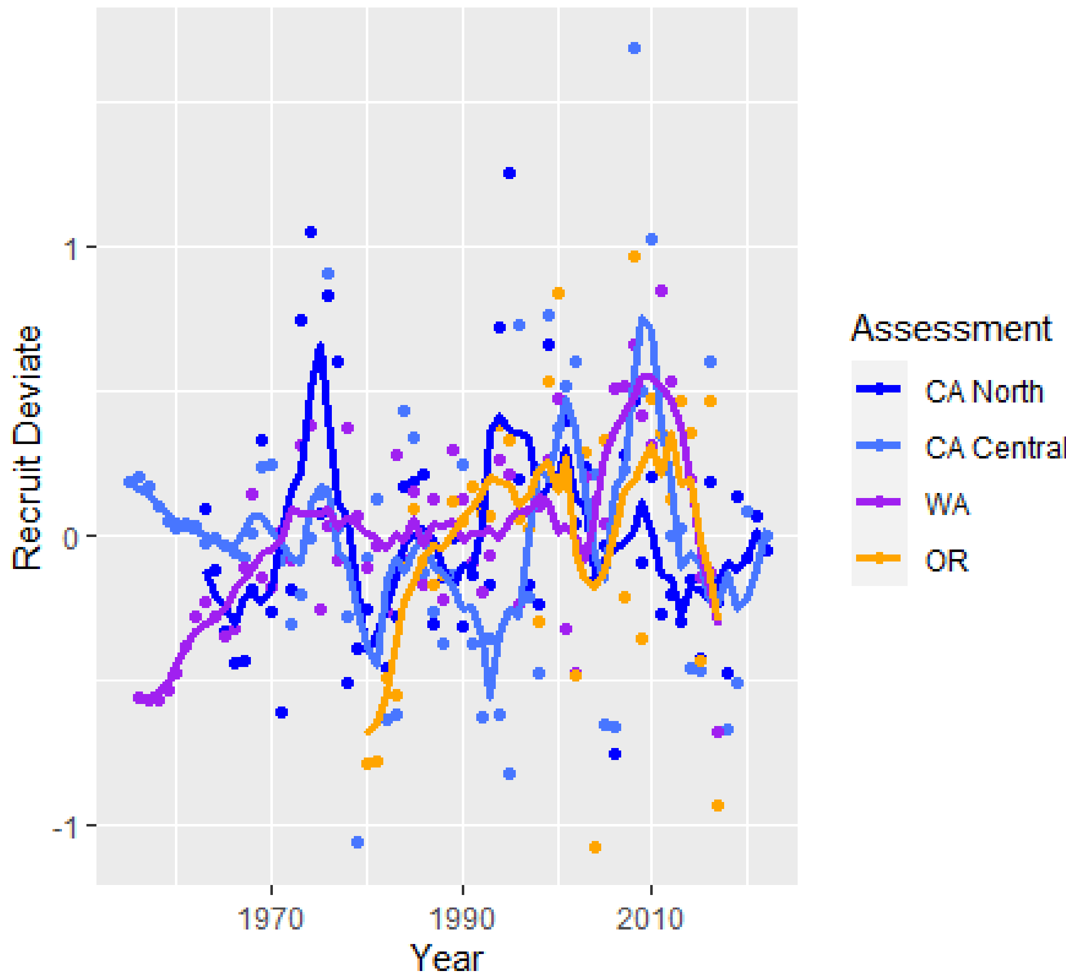
Consistency of Trends Across Assessment Areas

The panel made Request 10 below to examine the degree of consistency among assessment areas. The coherent patterns lend credibility to the ability of the models to capture trends in depletion and recruitment.

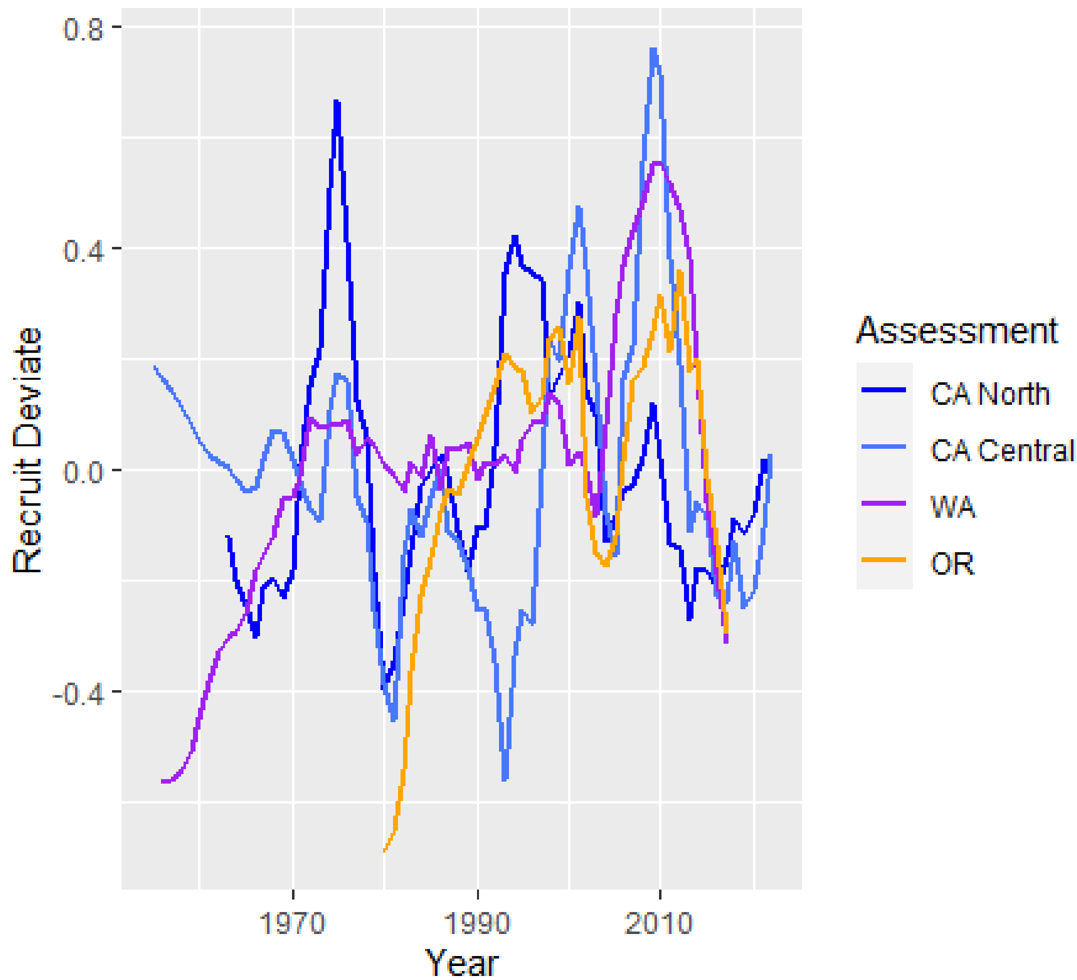
Request No. 10: Compare temporal patterns of recruitment deviation for all assessments (Washington, Oregon, northern California, central California) by plotting a five-year running average to the temporal trend and plotting on a common relative axis. The five-year average should be calculated by averaging the two previous years, the target year, and the two subsequent years except at the beginning and end of the time series where the running average is based on a smaller set of years. Provide a pairs plot showing bivariate plots of recruitment deviations for all stock (include correlation coefficients). In addition, provide a plot of relative depletion for the final assessment models for each stock (Washington, Oregon, northern California, central California).

Rationale: Consistency across assessments lends support for all assessments when they have experienced similar patterns of environmental and human forcing.

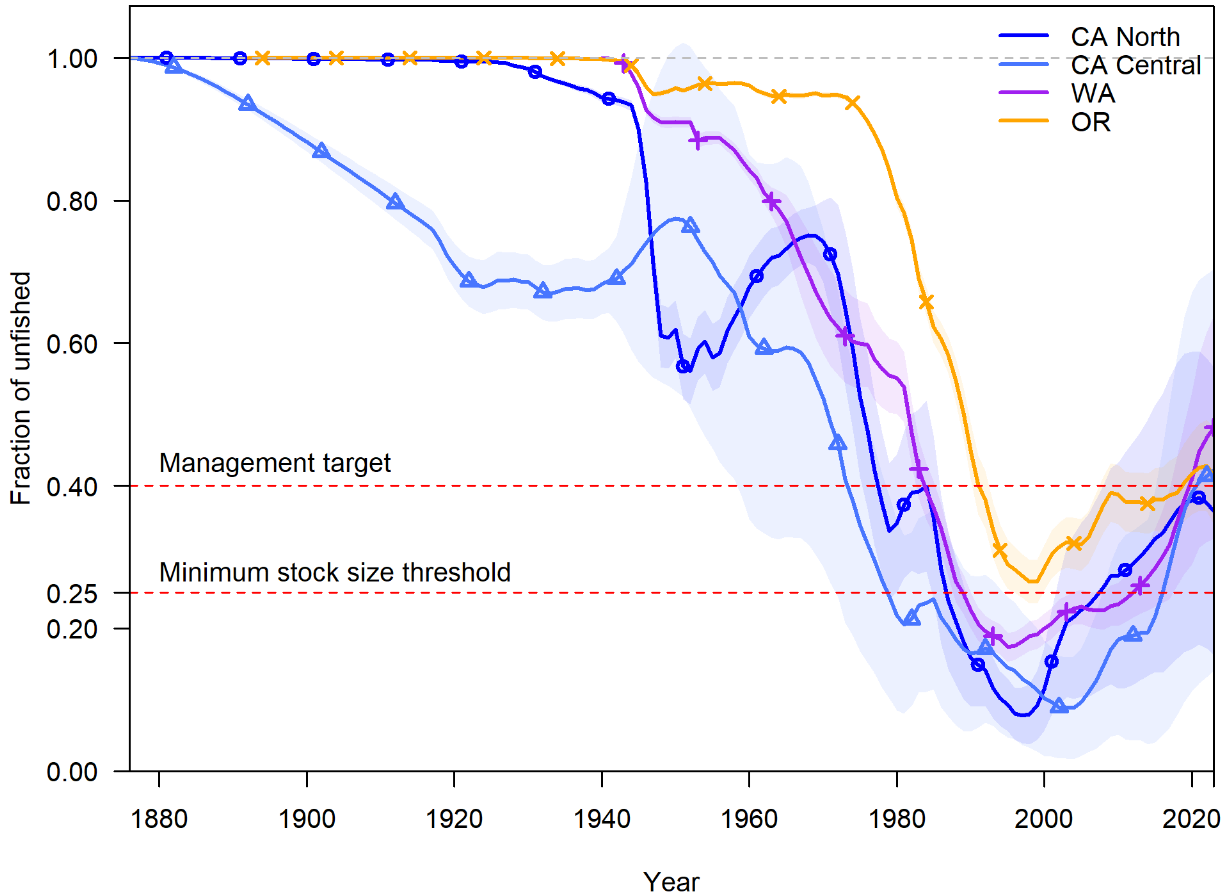
STAT Response: The following figures show the main period recruitment deviates by assessment area with (top) and without (upper middle) data points overlaid on the 5-year moving average (lines) for each. After that (lower middle) is a comparison of the relative depletion for all assessments. Lastly, a pairs plot is shown (bottom) to highlight the similarity in recruitment deviations among each of the four assessment areas. Overall, smoothed (5-yr moving average) trends in recruitment deviations were variable across assessments, but general trends were somewhat consistent among areas from 2000 to 2015. The general trend in stock status (depletion) over time has also been relatively consistent across assessments. Oregon recruitment deviations were correlated with northern California and Washington (as well as but less so with central California). Lowest correlations were between Washinton and the California areas.



Recruit Deviate
1
0
-1
1970
1990
2010
Year
Assessment
CA North
CA Central
WA
OR



0.8
0.4
0.0
-0.4
Recruit Deviate
1970
1990
2010
Year
Assessment
CA North
CA Central
WA
OR



CA North
CA Central
WA
OR
1.00
0.80
0.60
0.40
0.25
0.20
0.00
Fraction of unfished
Management target
Minimum stock size threshold
1880
1900
1920
1940
1960
1980
2000
2020
Year

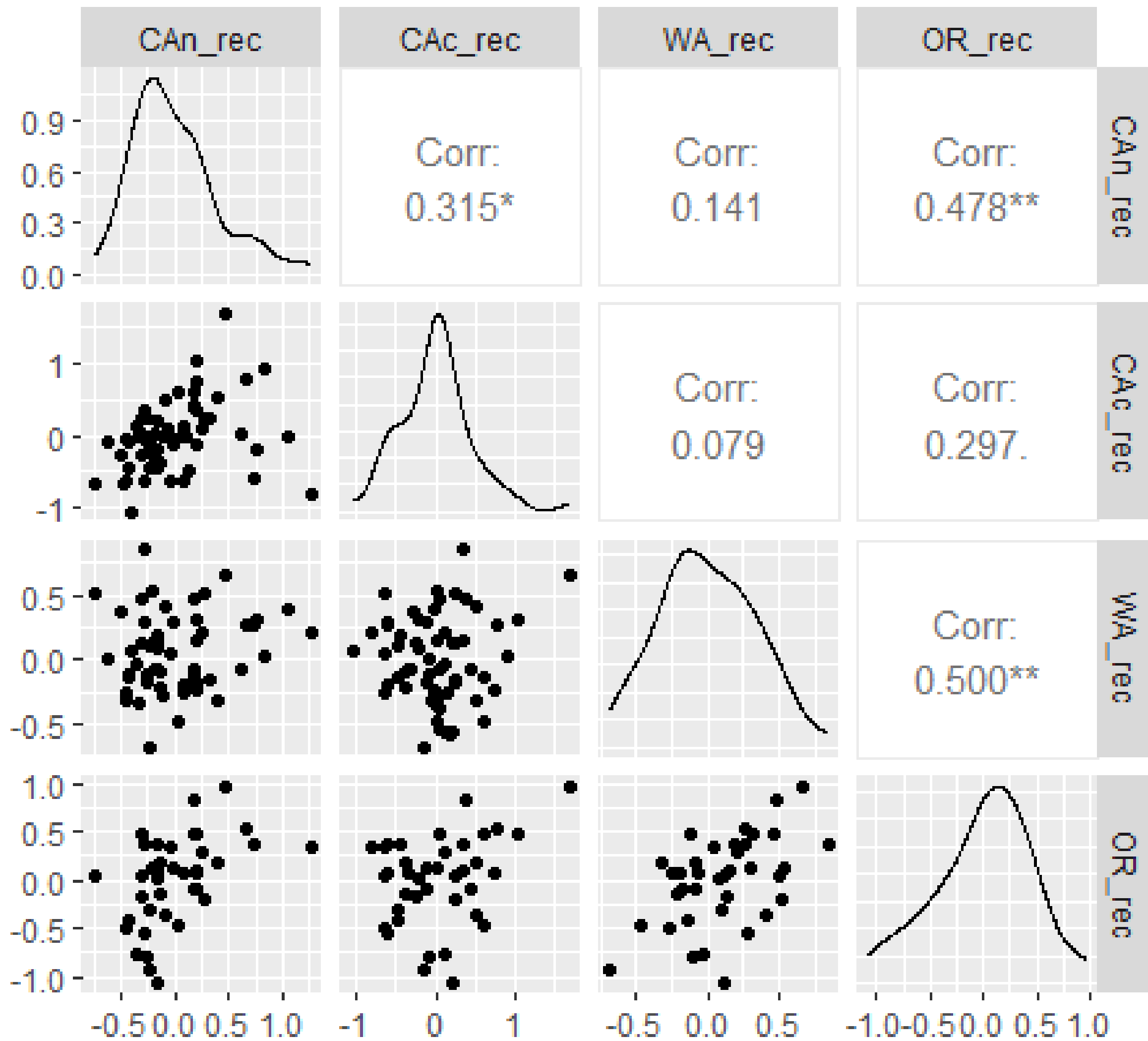


Figure 80. Main period recruitment deviates by assessment area with (top) and without (upper middle) data points overlaid on the 5-year moving average (lines) for each. Comparison of the relative depletion for all assessments (lower middle). Pairs plot (bottom) highlighting the similarity in recruitment deviations among each of the four assessment areas.

Panel Conclusion: Recruitment deviations are generally consistent between assessment regions. The five-year average appears to be a reasonable moving window to smooth trends. All depletion patterns appear roughly consistent though the timing of the declines and later increases are slightly different. There were some significant correlations in the recruitment trends in the bivariate plots within California, between California and Oregon and between Oregon and Washington. The correlation degrades from north to south becoming lower and less significant. All the adjacent stock pairwise correlations are significant, while none of the non-adjacent stock correlations are. This suggests similar environmental forcing in recruitment regionally but not necessarily coastwide. The running average recruitment plots indicated that all the stocks experienced high recruitment around 2010 to varying degrees, which partially explains the recent shared increase.

The consistency in results lends support to the assessment results as they provide similar patterns despite resulting from disparate data sources. In the future, comparisons for other assessments that are coastwide with area specific assessment models would be beneficial.

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