Vermilion and Sunset Rockfishes
Stock Assessment Review (STAR) Panel Report

Virtual Online Meeting

July 26-30, 2021

Participants

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Overview

A Stock Assessment Review (STAR) panel was convened virtually on July 23-27, 2021, through the Ring Central platform to review draft stock assessments for the cryptic-species pair of vermilion rockfish (*Sebastes miniatus*) and sunset rockfish (*Sebastes crocotulus*), under the Pacific Fishery Management Council's (PFMC) Terms of Reference for the Groundfish and Coastal Pelagic Species Stock Assessment Review Process for 2021-2022 (PFMC, December 2020). These two species cannot be easily discriminated in the field through physical characteristics and were only discovered through the use of genetic methods (Hyde 2007, Hyde et al. 2008); thus, they were assessed as a complex where they co-occur in California. Though the vermilion/sunset rockfish complex, historically referred to nominally as "vermilion rockfish" range from Prince William Sound, Alaska, to central Baja California (Love et al. 2002), true vermilion rockfish are most common from central Oregon to Punta Baja, Mexico (Hyde et al. 2008), while sunset rockfish are primarily distributed south of Point Conception, California (Hyde 2008 and Budrick 2016). In addition to latitudinal differences in distribution, their depth distributions differ. The nominal "vermilion rockfish" including both species have been found at depths of 6 m to 436 m (Love et al. 2002), they primarily occur in depths of 50 m to 150 m (Hyde and Vetter 2009), with true vermilion rockfish residing in shallower depths (<100 m) than their sibling species, sunset rockfish (Hyde et al. 2008 and Budrick 2016). Further complicating population structure, is the presence of three additional populations within vermilion rockfish apart from sunset rockfish, identified in Hyde and Vetter (2009) and Budrick (2016). The California assessment was stratified at Point Conception to address cryptic species considerations and differences in length composition data, while further stratification at the state level captures differences in exploitation during the historical and contemporary period, as well as addressing some of the considerations around population structure.

Drs. E.J. Dick and Melissa Monk of Southwest Fisheries Science Center (SWFSC) presented assessments of the area south of Point Conception and north of Point Conception within California, respectively. These areas within California were assessed separately due to the prevalence of sunset rockfish south of Point Conception. Dr. Jason Cope of Northwest Fisheries Science Center (NWFSC) assessed the stock in Oregon and Washington 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. In combination, these four assessment areas covered the full range of the species within the groundfish Fishery Management Plan (FMP).

Previous attempts at a full assessment in 2005 and data-moderate assessment in 2013 were unsuccessful or incomplete, and thus not used in management. The current OFL contributions are based on the Depletion-Based Stock Reduction Analysis (DB-SRA) analysis implemented in 2010. The 2021 assessments are fully integrated length and age-structured bench-mark assessments conducted in Stock Synthesis (SS Version 3.30.17.00) using catch, length, age, and index data from fishery dependent and independent sources. Natural mortality was the primary axis of uncertainty for all stocks, though steepness contributed to a bi-variate axis south of Point Conception. Strong recent recruitment has bolstered the population contributing to the increased status observed in the assessments. While strong recruitment has likely contributed to the increased catch observed in each state in recent years, liberalization of fishing regulations with rebuilding of cowcod in 2019 and the continued progress in rebuilding yelloweye rockfish may also be driving the increase. Despite recent high catch events, all stocks are above target biomass (>40% of unfished spawning stock output).

Summary of Data and Assessment Models

Model complexity decreased from south to north as fewer data sources were available and sample sizes declined with distance from the center of their primary distribution in central/southern California. This is consistent with the diminishing relative abundance with latitude as fewer species and populations contribute to aggregate abundance with latitude. A summary of the management reference points and parameters across assessments are provided in Table 1.

Table 1. Parameters and management reference points across vermilion/sunset rockfish assessment areas. Values in standard text are estimated and those in italics are fixed. The *M*_male for southern California is fixed at the estimated value of *M*_female using the offset approach. The L_inf Male and VonBert_K_Male are estimated as offsets from the female parameters.

Model Parameters	**Southern California**	**Northern California**	**Oregon**	**Washington**
*M*_female	0.130	0.086	0.080	0.085
L_inf Female	55.378	55.184	57.184	57.106
VonBert_K_Fem	0.156	0.147	0.146	0.093
*M*_male	*0.130*	0.080	0.073	0.087
L_inf Male	-0.062	49.940	54.193	54.240
VonBert_K_Male	0.137	0.199	0.180	0.109
LN(R0)	6.697	6.041	2.793	0.908
h	0.730	*0.720*	*0.720*	*0.720*
sigma_R	*0.500*	*0.500*	*0.600*	*0.600*
RecrDev_1998	-0.434	0.566	1.758	-0.049
RecrDev_1999	1.353	1.139	0.759	0.520
RecrDev_2000	0.678	0.476	-0.383	1.370
RecrDev_2015	0.030	-0.215	1.738	-0.177
RecrDev_2016	0.895	1.472	-0.324	-0.044
Derived Parameters				
B0	978	1145	29	3
FracUnfished (2021)	48%	43%	73%	56%
OFL_FSPR (2021)	169.3	149.0	13.0	0.9
MSY_SPRproxy	148.3	139.0	8.0	0.8

Southern California Model

Waters off California were split into two separate stock assessments stratified at Point Conception (34°27' N lat.), which is supported by genetic analyses. The occurrence of vermilion and sunset rockfishes diminishes in northern California, with a small percentage of catch, biomass, and data occurring north of latitude 40° 10' N lat. The California/Oregon border was chosen as the northern boundary for the northern California stock assessment to maintain consistent data collection, history of exploitation and recent management by state within the California assessments.

Vermilion rockfish (*Sebastes miniatus*) and sunset rockfish (*S. crocotulus*) are a cryptic species pair that cannot be distinguished with certainty based on external characteristics. Genetic studies have recently identified these two species with sunset rockfish inhabiting deeper waters mostly distributed south of Point Conception. There are ongoing genetic sampling programs to investigate differences between the species including distribution. This report will simply refer to these two species as vermilion rockfish, and management considerations for the two species are discussed below.

Commercial and recreational fisheries have encountered vermilion rockfish since before 1980 in significant numbers. A variety of regulatory measures have been used to manage vermilion rockfish along with other rockfish species. These include cumulative trip limits or bag limits, seasonal and area closures, depth limits, and gear restrictions. A number of closed areas have been implemented including the Cowcod Conservation Areas (CCA) in southern California, rockfish conservation areas (RCA) coastwide, and marine protected areas (MPA) statewide.

Fishery-independent data sources include the coastwide West Coast Bottom Trawl Survey (WCGBTS), Northwest Fisheries Science Center (NWFSC) hook-and-line survey, the California Department of Fish and Wildlife CPFV Survey, and various smaller surveys associated with research projects. Age and length data are commonly available from these surveys, and standardized relative indices of abundance are created for some. Data from other fishery-independent sources were considered but contained few observations of vermilion rockfish given their association with rocky habitat.

Fishery-dependent data sources include catch estimates from 1875-2020, allocated among three commercial fleets (hook-and-line, trawl, and net gears) and four recreational fleets (party/charter and private/rental boats, each with an associated discard 'fleet'). Two abundance indices were derived from party/charter catch rate data, and one from the private/rental data. Fishery-dependent length composition data used in the model came from commercial hook-and-line and net gears, as well as both recreational boat modes. Insufficient age data were available from the fishery, and these were not used in the model.

Most samples of biological information are available from the recent few decades. The West Coast Groundfish Bottom Trawl Survey (WCGBTS) and the NWFSC hook-and-line survey are the two fishery independent surveys with a considerable number of samples of vermilion rockfish. Length, age, maturity, and weight samples were used to create estimates of biological parameters, some of which were estimated in the stock assessments. Maturity, fecundity, and weight-length relationships were estimated from all available samples and the parameters were fixed at the same values for each California stock assessment. Growth parameters were sometimes fixed, or externally estimated parameters were used as initial parameters in the assessment models. Figure 1 shows the data sources in the southern California stock assessment along with years of availability.

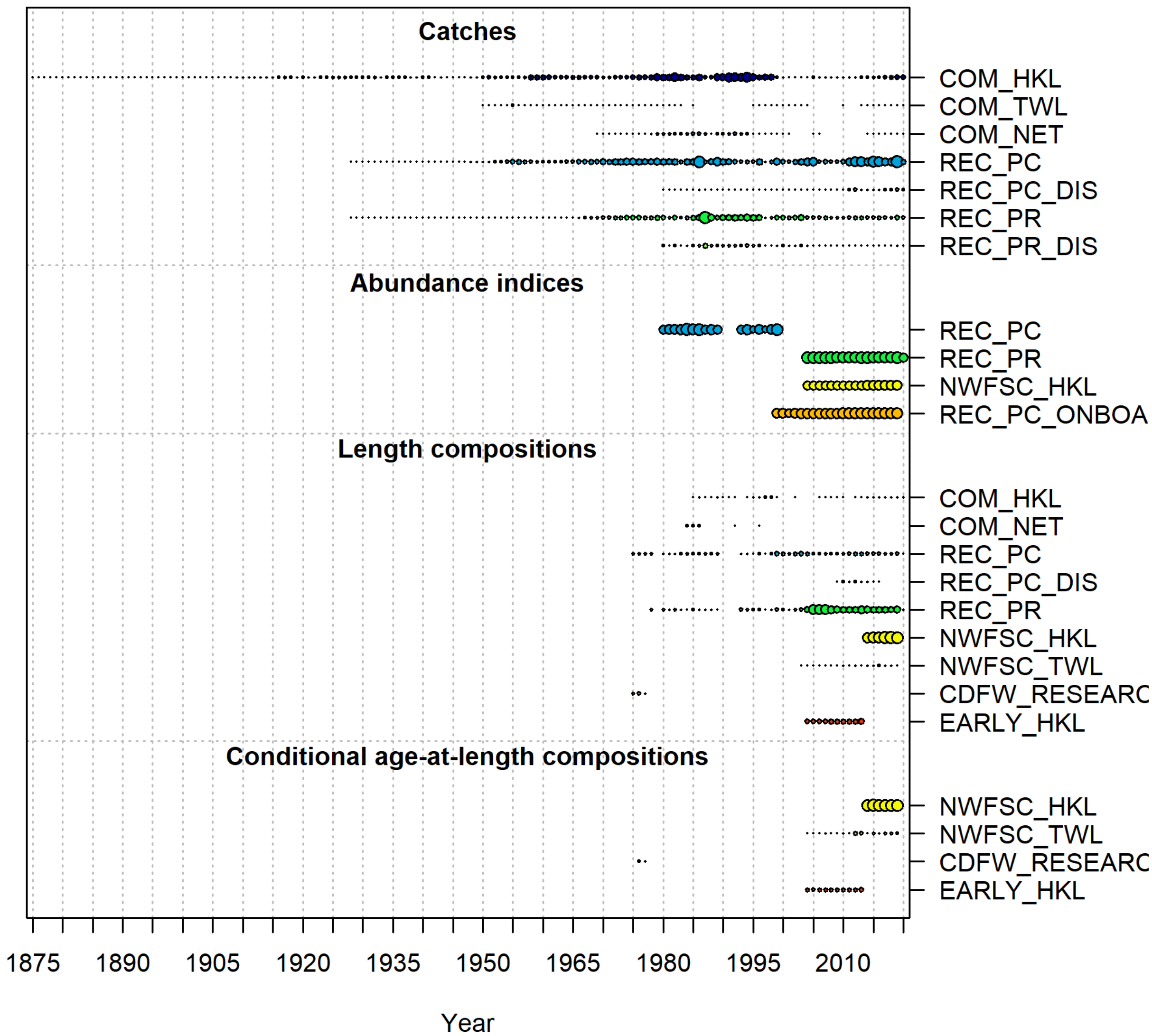


Figure 1. Summary of data sources used in the southern California stock assessment. Circles indicate the years that data were available, and the size of the circle is relative to the amount of data used.

Specific information to inform natural mortality outside of the stock assessment model is limited. Therefore, a diffuse prior distribution was created assuming a maximum age of 54, using the methods described by Hamel (2015). A prior for steepness was developed from a meta-analysis of past rockfish assessments, providing a mean value of 0.72, which was assumed when not estimating steepness.

The stock assessment model was conducted in Stock Synthesis version 3.30.17.00 and started in 1875 at equilibrium. Recruitment deviations were estimated in the years 1965–2020. The pre-STAR base model estimated 112 parameters with a time-block in 2001 for some selectivity patterns and steepness fixed at 0.72. Female natural mortality was estimated, and male natural mortality was fixed to be equal to the estimated value for females.

Two suggestions from the STAR panel were incorporated into the final base model. These were 1) implement a time-block in 2017 to represent changes in selectivity for the commercial hook-and-line fishery resulting from regulatory changes, and 2) estimate steepness. These changes improved the overall fits to data and incorporated exogenous information about the hook-and-line commercial fishery. The estimated value for steepness was 0.73, very close to the prior mean. The population trajectory changed slightly compared to the pre-STAR base model and is predicted to decline starting around 1950 to a low point slightly below the minimum stock size threshold in the late 1990s and then followed by stock size increasing to above the management target in the current year.

The STAR panel agreed that the southern California vermilion/sunset rockfish stock assessment should be classified as category 2 due to the co-occurrence of cryptic species that cannot currently be separately assessed. Due to depth differences of the adults of these two species and depth regulations that have been in place, it is likely that the two species have experienced different exploitation levels. The sigma from the updated base assessment model was 0.258, which is less than the default sigma for category 2 of 1.0. The Panel recommended that the next assessment of this stock be a full assessment because new research will be completed, additional data will be available, and this is the first full assessment for vermilion and sunset rockfishes.

Northern California Model

The extent of and abundance of sunset rockfish stock north of Point Conception is considered to be limited based on previous studies (Hyde 2008; Budrick 2016), although current genetic research efforts are underway to further examine latitudinal differences. The northern model represents the stock from Point Conception to the Oregon/California border.

The northern California stock also used the same version of Stock Synthesis as the southern California stock. Major data elements included commercial and recreational catch, commercial lengths, recreational length compositions and indices, as well as fishery-independent surveys. The West Coast Groundfish Bottom Trawl Survey, the Abrams thesis data, and SWFSC Groundfish Ecology Cruise data were used for both age and length compositions. The California Collaborative Fisheries Research Program (CCFRP) provided a fishery-independent index of abundance and length composition data. The CCFRP is a hook-and-line survey that monitors groundfish populations at pairs sites inside and outside MPAs along the California Coast.

A number of recreational fishery-dependent indices were included in the assessment. These included the Marine Recreational Fisheries Statistical Survey (MRFSS) era recreational party/charter boat dockside index, the CDFW recreational private/rental boat dockside index, and three surveys representing at-sea observations of the party/charter boat fleet (Deb Wilson-

Vandenberg's survey, CDFW's onboard program and Cal Poly's survey). Time frames for these and other important data sources can be found in Figure 2.

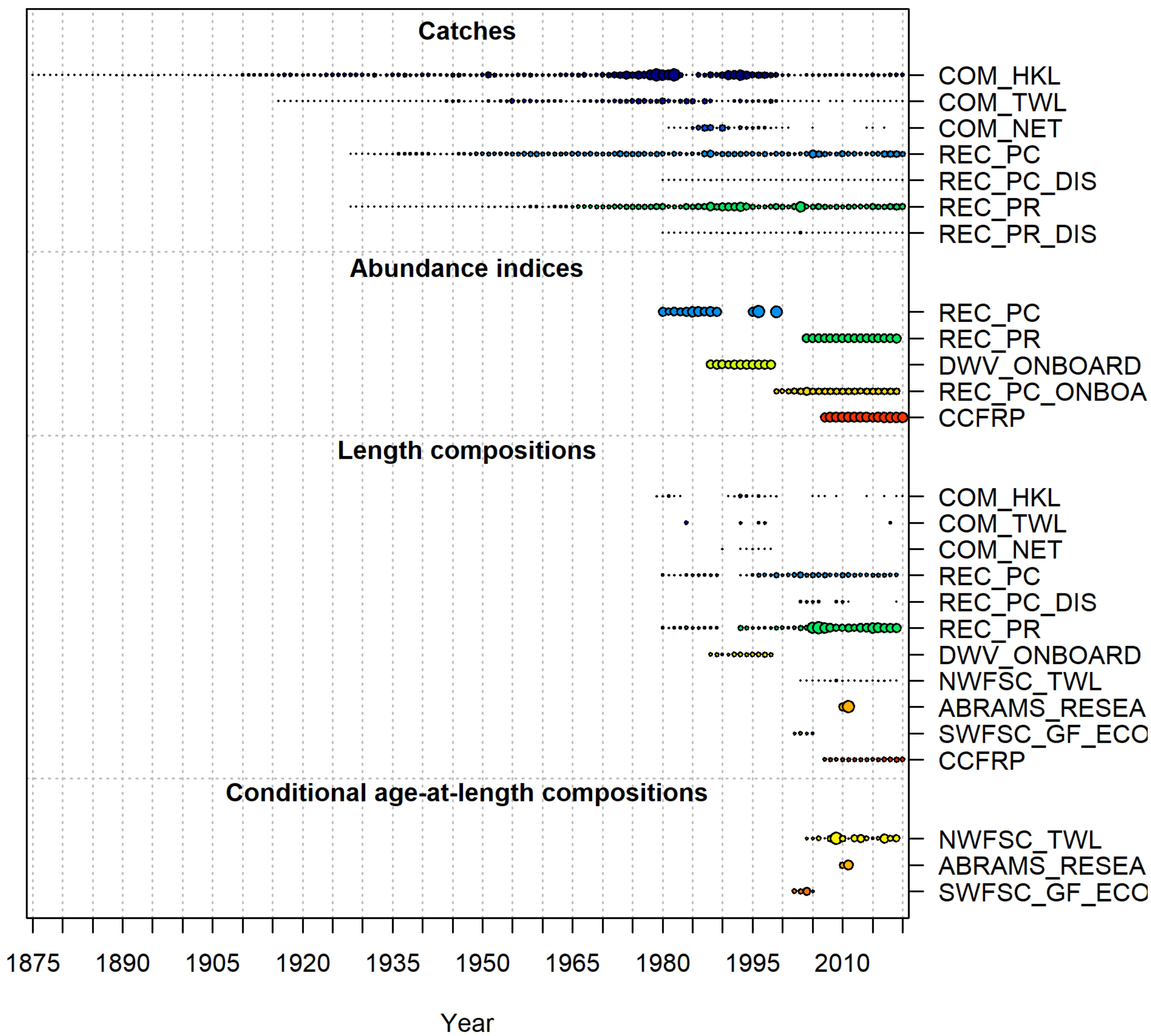


Figure 2. Summary of data sources used in the northern California stock assessment. Circles indicate the years that data were available, and the size of the circle is relative to the amount of data used.

The model started in 1875 and assumed an unfished state prior to that year. Ages were from 0-70+ and included four fishery-dependent abundance indices and one fishery-independent index. Length composition data were available from both recreational and commercial landings, as well as from the surveys. Age composition data in the final model were from fishery-independent sources only. The final model was Francis weighted.

A total of 115 parameters were estimated in the pre-STAR base model. The model was configured to estimate growth using the Schnute parameterization of the von Bertalanffy growth curve for females and males and natural mortality was also estimated for both sexes. A Beverton-Holt stock-recruitment relationship was assumed, with steepness fixed at 0.72, the mean of the prior distribution. Three time blocks were used for the recreational fleets in the pre-STAR base; 1875-2001, 2002-2016, and 2017-2020, to capture significant changes in the recreational regulations history and noticeable changes in length composition data. A full list of parameters, priors, and other information can be found in the assessment report Table 9.

Results from the assessment can be found in the assessment report. It should be noted that after discussion in Request 6 (see below), the STAT proposed a modifications to the pre-STAR base that included 1) the time block on the CCFRP index in 2017 after the survey was expanded from central California to the entire California coast, as explored in Request 1, 2) CCFRP length compositions re-weighted to reflect the weighting used in the index, and 3) removed the last year of the PR dockside index of abundance (2020) due to sampling constraints during COVID. The final base model was approved by both the STAT and the Panel.

Stock status in 2021 is approximately near target levels (42.7%), although the 95% confidence interval indicates that the stock status ranges from the minimum stock size threshold to above target. The STAR panel agreed that the northern California vermilion/sunset rockfish stock assessment should be classified as category 2 due to the potential presence of the cryptic species sunset rockfish and additional populations within vermilion rockfish that cannot currently be separately assessed. The sigma from the updated base assessment model was 0.246, which is less than the default sigma for category 2 stocks of 1.0. The Panel recommended that the next assessment of this stock be a full assessment given the ongoing genetic research, and this being the first full assessment for vermilion and sunset rockfishes.

Oregon Model

The assessment of vermilion rockfish (*Sebastes miniatus*) off Oregon using data through 2020 was conducted separately from California and Washington. This stock is north of the core biogeographic range of vermilion rockfish and subject to a different management and exploitation history. Vermilion rockfish have been caught mainly by hook and line gear in commercial and recreational fisheries. Commercial catches increased in the late 1960s peaking in the 1980s and have since decreased. Recreational catches started to increase in the 1980s and have been well above the commercial catch in recent years.

The Oregon stock assessment was conducted using the age-structured model Stock Synthesis (version 3.30.16). Model structure included two fleets (commercial and recreational). In common with the California and Washington assessments, life history parameters were sex-specific (i.e., a two-sex model) with natural mortality, growth parameters and recruitment deviations estimated. The model covers the years 1892 to 2020, with a 12-year forecast beginning in 2021. The assessment uses all available landings data, length, and conditional age-at-length composition data for both fisheries (Figure 3). The model uses ageing error matrices to incorporate ageing imprecision. There is one standardized index of abundance based on the recreational fishery catch and effort. This stock assessment does not explicitly incorporate trophic interactions, habitat factors or environmental factors into the assessment model.

In the model, the weight-at-length, maturity-at-length, fecundity-at-length, the Beverton-Holt stock-recruitment steepness value and recruitment variability are fixed. The important estimated values are the initial population scale ($ln(R_0)$), natural mortality and growth for each sex, asymptotic selectivity, and recruitment deviations. The base model was tuned to account for the weighting of the length and age data and estimated index variances, as well as the specification of recruitment variance and recruitment bias adjustments. Derived quantities include the time series of spawning biomass, age and size structure, and current and projected future stock status. Uncertainty is evaluated through estimates of parameter uncertainty and sensitivity analyses to consider alternative models and configurations. A base model was selected that best fit the observed data, met the desire to capture the central tendency across those sources of uncertainty, ensured model realism and tractability, and promoted robustness to potential model misspecification.

Productivity of the stock is reported as spawning output in millions of eggs because fecundity is nonlinearly related to body female weight. The estimated spawning output at the beginning of 2021 was 73% (approximate 95% percent confidence intervals: 48% to 98%). Overall, spawning output declined with increasing catch 1960s-1990s, even dropping below the target relative stock size to reach a minimum in 1994 before recovering. The largest of the estimated recruitment pulses since the mid-1990s supported by the data, caused a sharp increase in spawning output through the mid-2010s, followed by another decline. The minimum relative stock status of 34% of unfished levels is estimated to have occurred in 1995. Currently the stock is estimated well above the management target of $SB_{40\%}$ in 2021 and is estimated to have remained above the target since 2000.

Trends in fishing intensity (1 - SPR) largely mirrored that of landings until the 1990s when recruitment pulses overcame the catches to lower overall fishing intensity. Fishing intensity over the past decade has ranged between 0.27 and 0.51 and remains near target F_{MSY} proxy harvest rate. The population size has been decreasing toward the target over the past few years.

Reference points were calculated using the estimated selectivities and catch distributions among fleets in 2020. Sustainable total yield using an $SPR_{50\%}$ is 7.95 mt and the spawning output at 40% unfished stock ($SO_{40\%}$ calculated using $SPR_{50\%}$) was 13.04 million eggs.

The last ten years of the vermilion component acceptable biological catch (ABC) and annual catch limit (ACL) of the Minor Shelf Rockfish North Complex has been set below the overfishing limit (OFL). The vermilion rockfish component OFL for this complex has been exceeded by the Oregon removals in the most recent 4 years.

The model-estimated uncertainty around the 2021 spawning biomass was σ = 0.27 and the uncertainty around the OFL was σ = 0.31. This will underestimate overall uncertainty because some uncertainty associated with fixed parameters (e.g., stock recruitment steepness) and the model structure are unaccounted for. The results are most sensitive to estimated natural mortality (M). Independent research on natural mortality as well as continuing collection of age-length data will help reduce uncertainty in the assessment.

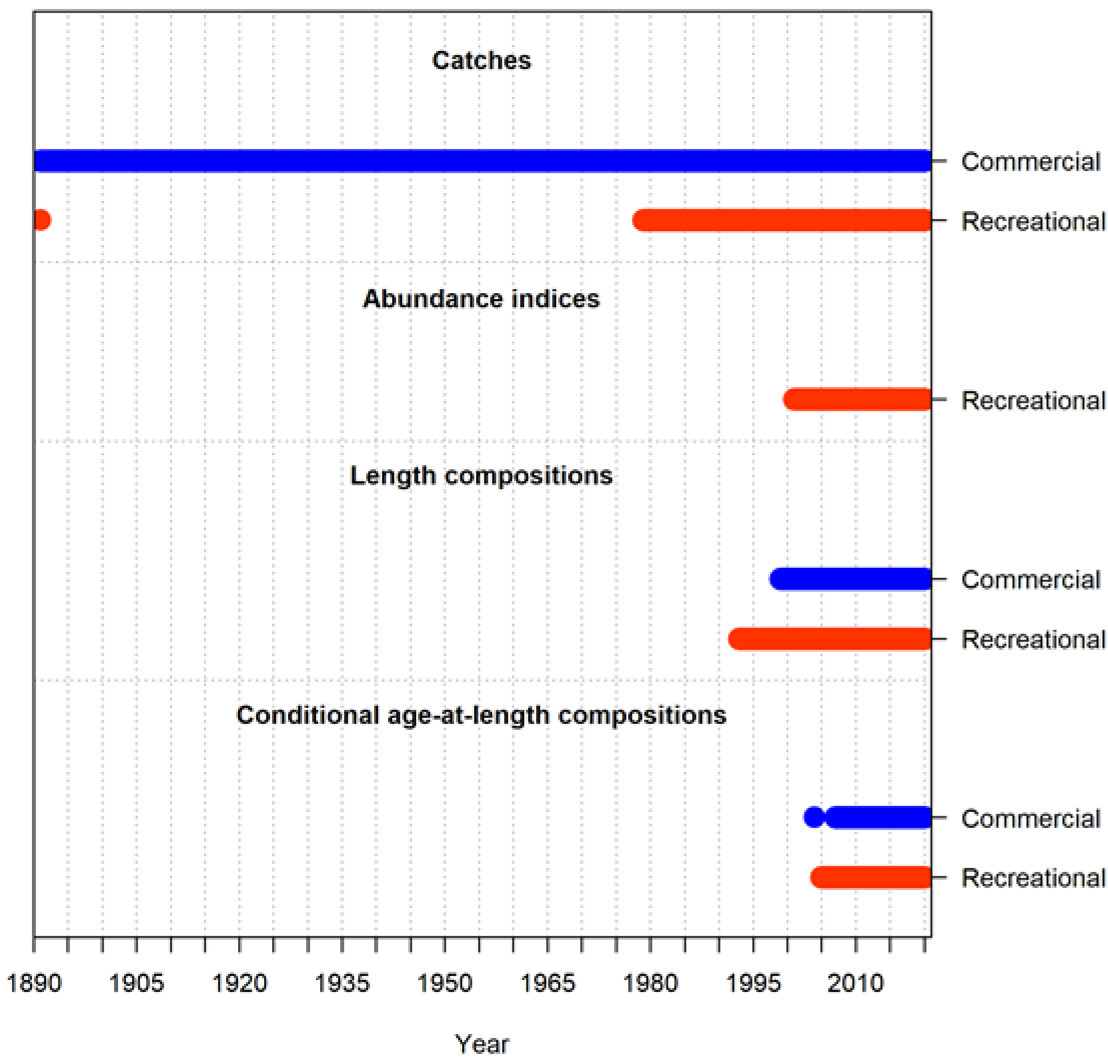


Figure 3. Summary of data sources used in the base model.

Washington Model

The state of Washington is near the northern edge of the distribution of vermilion rockfish, and they are considered relatively rare and are not specifically targeted, limiting the data available to assess the stock. The landings have been primarily composed of recreational catch over the time series and commercial landings were historically exceedingly low. The nearshore waters where they are most frequently encountered have been closed to commercial hook and line fishing since 1995 and trawl since 1999. As a result, the commercial and recreational catch were combined into a single fleet for parsimony, modeled over the years 1949-2020. Historical catch for the recreational fishery from before 1979 was approximated using bycatch relative to black rockfish, though the model was relatively insensitive to the magnitude of landings. Only catch, length and age data were available and conditional age-at-length was derived from the available data (Figure 4). Length and age data were available for multiple years, though there was some paucity in availability and low sample sizes, due to rarity and the minimum sample size of 10 individuals. This assessment does not incorporate environmental factors into the assessment model.

Additional data and parameters included weight-at-length, maturity-at-length, fecundity-at-length, information on natural mortality and steepness (*h*) fixed at the 2017 Thorson-Dorn rockfish prior of 0.72, recruitment variability ($\sigma_R = 0.6$) as well as ageing error. 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. Natural mortality was estimated using the recreational ages and the Natural Mortality Tool, applying Hamel (2015) and Then et al. (2015) based on expected mortality rates given longevity of 54 years for both males and females. These methods resulted in a final composite *M* distribution based on four empirical estimators, yielding a median value of 0.1 and the estimated *M* was 0.085 for females and 0.087 for males. Estimated values included initial population scale (lnR_0), sex-specific natural mortality, growth, asymptotic selectivity, and recruitment deviations. The model was tuned to account for length and age data as well as recruitment variance and recruitment bias adjustment. The derived quantities included spawning output (in millions of eggs), age and size structure and current and projected stock status. Length at 50% maturity was estimated at 39.4 cm (Hannah and Kautizi 2012) and fecundity at length was based on research by Dick et al (2017). Selectivity was fixed to be asymptotic and specified with a double normal parameterization. Uncertainty was explored using sensitivity analyses including data treatment and weighting, specification of life history parameters, selectivity, and recruitment.

Though recruitment information was weak for this model, informative recruitments started in the 1980s and peaked in the early 2000s, with highs in 1995-1996, 1999-2000, 2006 and 2011. Both natural mortality (with a lognormal prior), selectivity and growth parameters were estimated, while weight-at-length, maturity-at-length, fecundity-at-length, steepness (*h*) and recruitment variance were fixed. Convergence was achieved as evidenced by inverting the Hessian, reasonable parameter values and acceptable fits to the data and jittering was conducted to ensure a global optimum was reached. Francis weighting methods were used in the base model, though the Dirichlet-Multinomial, McAllister-Iannelli and no data weighting were explored as sensitivities. Additional sensitivities were conducted for data removal, catch histories, length treatment, ageing error, fixing life history parameters (*M*, growth, and recruitment), fecundity proportional to weight and domed steepness. Likelihood profiles for lnR_0 support a value of 0.91 and increased values of stock status toward unfished at higher values, while those for *h* showed little sensitivity of stock scale or relative stock status. Sensitivities to natural mortality assumptions were explored using likelihood profiling. The major axis of uncertainty was natural mortality, and likelihood profiles indicate a large range of *M* values (0.06 to 0.12) are supported primarily by the length and age data, with higher values resulting in higher biomass and relative stock status. There is a visible retrospective pattern, which may be related to model misspecification or availability of data reflecting recent recruitment that diminish as years are removed.

The resulting base model balanced parsimony, realism, and robustness to potential model misspecification. The results indicate the stock never dropped below target biomass throughout the time series and fishing intensity has fluctuated near the target F_{MSY} proxy harvest rate. The stock was determined to be healthy with a stock status of 56% in 2021. Recent fishing intensity (1-SPR) has been near or above the harvest rate limit in the early 1990s and late 2010s. Overall the model resulted in estimates of stock status with wide confidence bounds given the low annual sample sizes and paucity of data at the northern extent of the species range in Washington. As a result, the Panel assigned the stock to category 2 despite the lack of population structure considerations related to either cryptic-species or population structure at the northern extent of the range where only one of the vermilion rockfish clusters is prevalent. The uncertainty around the OFL was σ = 0.76, which is greater than the category 1 sigma of 0.5, thus the sigma of 1.0 associated category 2 was deemed more appropriate.

The panel recommends the Washington vermilion rockfish assessment as the best available science and considers it a suitable basis for management decisions. The panel also recommends that the next assessment be a full assessment to allow complete evaluation of uncertainties and alternative model structure. 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 meeting.

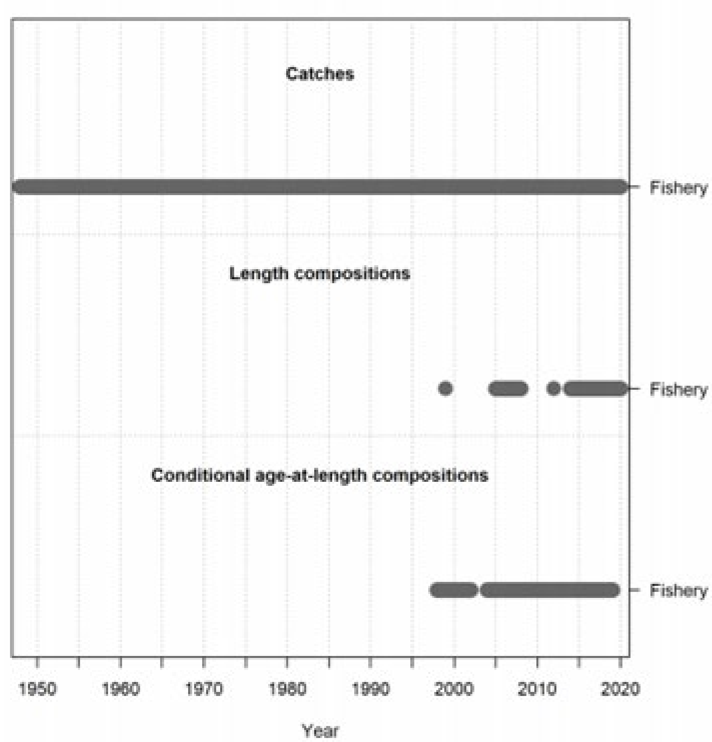


Figure 4. Summary of the sources and temporal availability of data used in the base model.

Requests by the STAR Panel and Responses by the STAT for the Southern California Assessment

Request No. 1: Implement a selectivity time block for the COM_HKL fishery starting in 2017 through present.

Rationale: Management changes allowing fishing in deeper depths may have changed the composition of catches from that point on.

STAT Response: The pre-STAR base model was modified to add a second time block pattern (1875-2001, 2002-2016, 2017-present). This pattern was applied to the commercial hook-and-line fleet (COM_HKL), while keeping the assumption of asymptotic selectivity in the base model. Two new selectivity parameters were estimated ('peak' and 'ascending width') for years after 2016. The revised model was run, one iteration of Francis weighting was applied, and the model was re-run with updated weights and produced no warnings. Figures and tables below compare the pre-STAR base model to the revised model with updated weights.

The revised model produced better fits to the COM_HKL length compositions from 2017-2020 (Figure 5). The new time block captured the shift to larger sizes after 2016 and resulted in a doubling of the Francis weight estimated for the COM_HKL length composition data (from 0.3 to 0.6 based on one iteration).

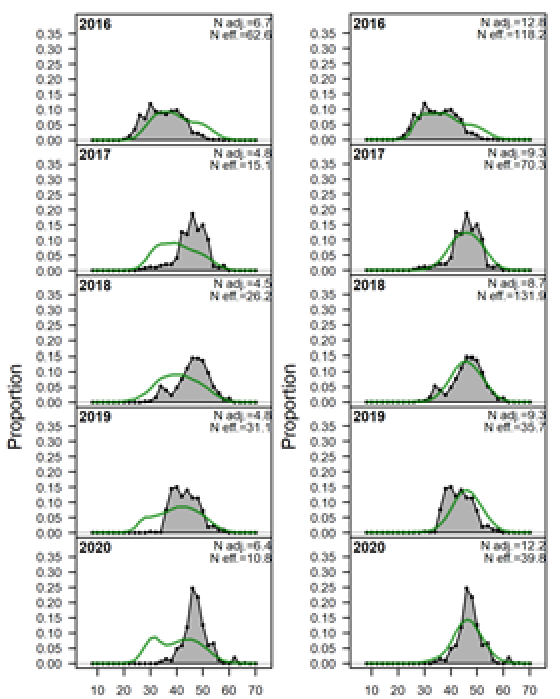


Figure 5. Fits to length composition data from the commercial hook-and-line fleet using the pre-STAR base model (left column), and a model with a time blocking pattern that allows selectivity to change after 2016 (right column).

Estimated selectivity in the new model for the COM_HKL fleet after 2016 is similar to the pre-2002 estimates (Figure 6). Peak selectivity from 1875-2001 changed very little relative to the base model (from 51 cm to 52 cm). Peak selectivity after 2001 in the pre-STAR base was 35 cm (2002-present), while the new estimates were 30 cm (2002-2016) and 50 cm (2017-present). The revised model resulted in slightly lower estimates of spawning output, and a very small reduction in relative stock size (Figure 7).

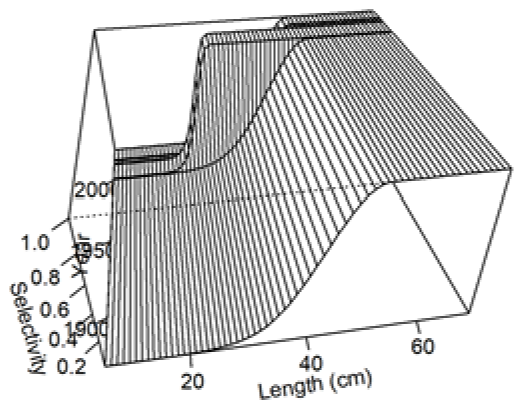


Figure 6. Time-varying selectivity for the commercial hook-and-line fleet using time blocks of 1875-2001, 2002-2016, and 2017-present.

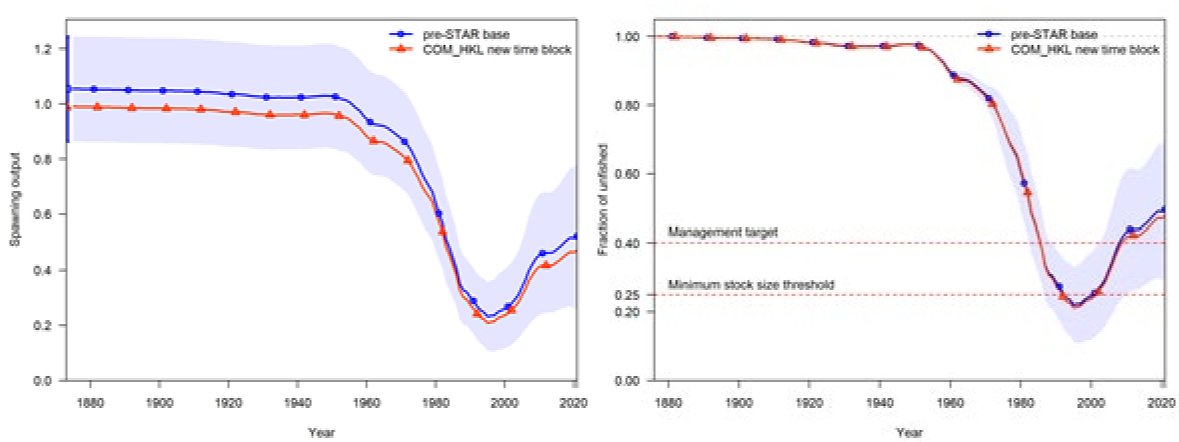


Figure 7. Changes to spawning output and relative spawning output associated with the new time block for the commercial hook-and-line fleet after 2016. Revised results are based on one iteration of Francis weights.

Panel Response: The panel agreed with the STAT that the addition of a time-block on the COM_HKL fleet in 2017 was useful because it improved fits to the length compositions and the newly estimated selectivity was as expected given opportunities in deeper water since 2017. The panel supported adding this to a revised base model.

Request No. 2: Turn on estimation of early recruitment deviations from the start year of the model to one year before the current defined main period in the base model. Tune the bias adjustment ramp, if possible. Compare the uncertainty intervals of the SSB and depletion to the base model. Also compare the pattern of estimated recruitment deviations.

Rationale: To examine how the estimation of these early, uninformed recruitment deviations affect the estimation of uncertainty and the recruitment patterns in the 1970s to see if these early recruitment deviations account for model misspecification.

STAT Response: The pre-STAR base model was modified to allow for estimation of early recruitment deviations for the period 1875-1964 (90 additional parameters, penalized given $\boldsymbol{\sigma}_R$ = 0.5). Relative to the pre-STAR base model, estimates of uncertainty in spawning output and relative spawning output increased prior to about 1980 (Figure 8). There was no effect on estimated recruitment deviations after 1964 (the 'main' period), and only minor changes in deviations prior to the main period (Figure 9). The estimated bias adjustment based on the new model called for a linear ramp from 1912 to 2018 (Figure 10). Given that there was no change in recruitment deviations during the main period (1965-2020), and estimates of uncertainty in recent decades were unaffected, the STAT concluded that, in this case, estimation of early recruitment deviations was unnecessary.

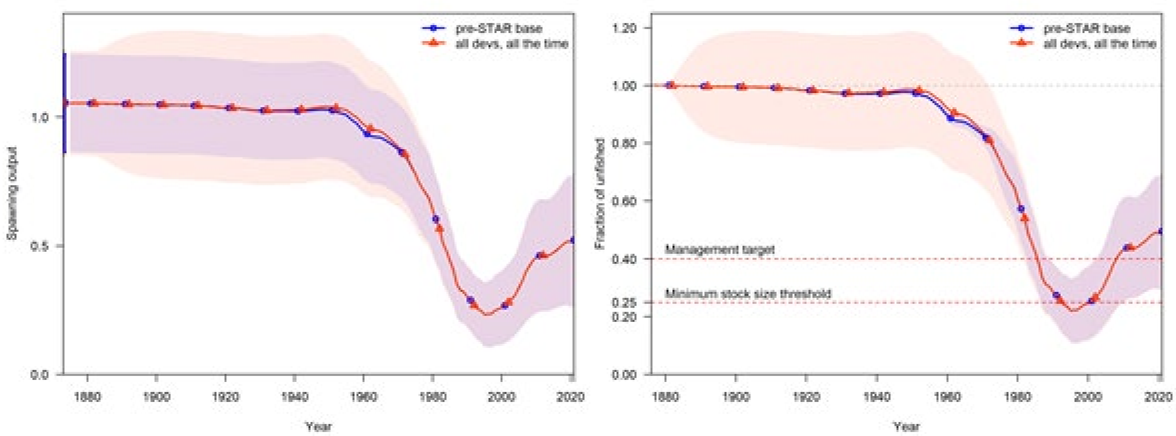


Figure 8. Comparison of spawning output (left) and relative spawning output (right) between the pre-STAR base model and a model that estimated recruitment deviations for the entire time period (1875-2020).

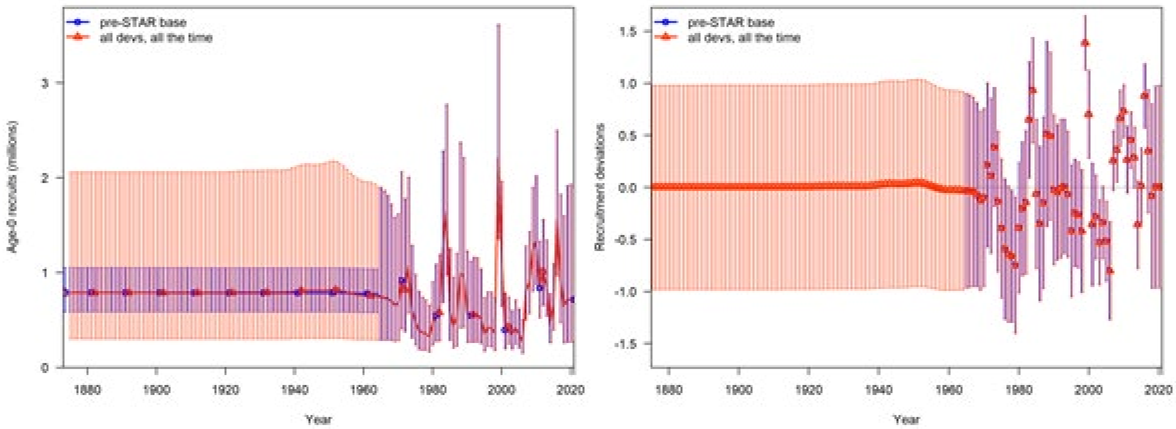


Figure 9. Comparison of recruitment time series (left) and recruitment deviations (right) with 95% uncertainty intervals from the pre-STAR base model and a model with deviations estimated in all years.

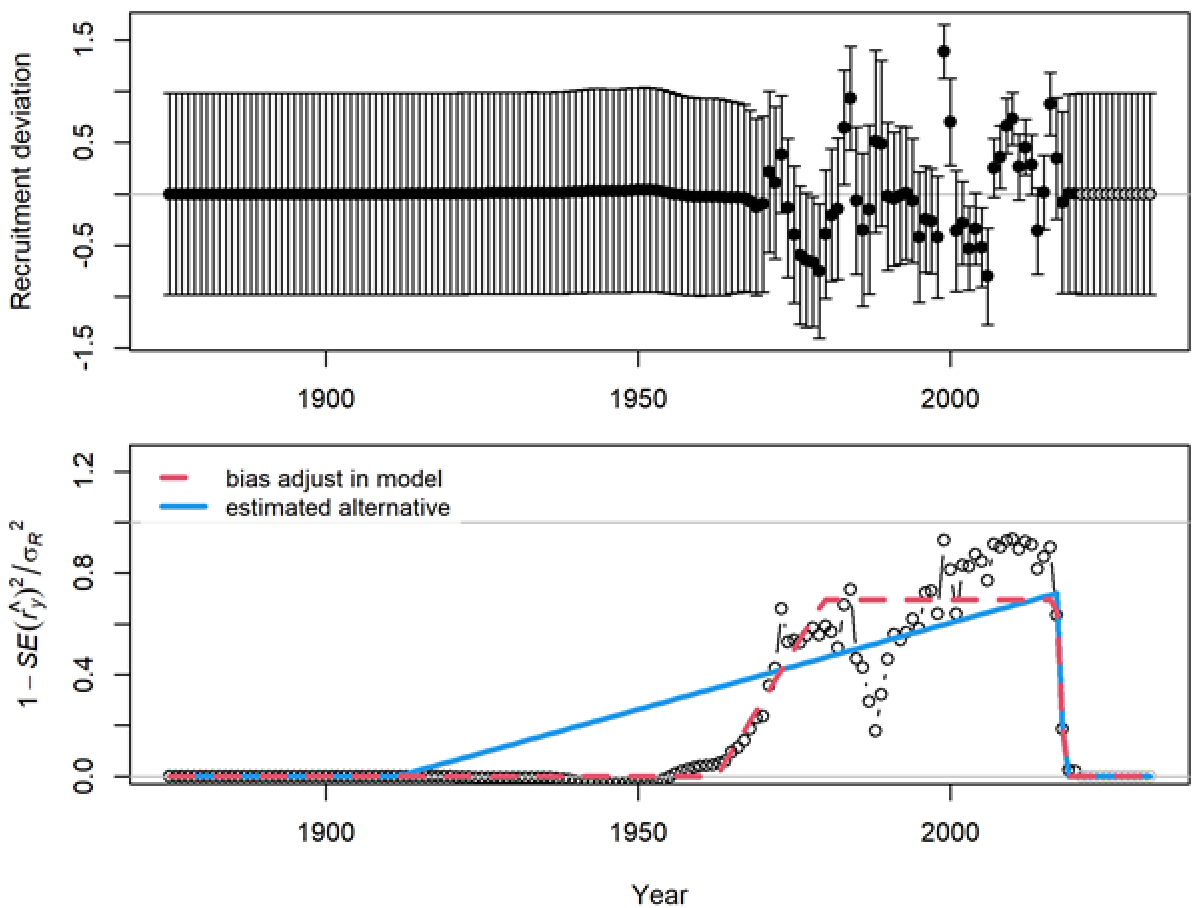


Figure 10. Estimated bias ramp from the pre-STAR base model modified to estimate 'early' recruitment deviations back to 1875.

Panel Response: The panel agrees with the STAT that the estimated spawning output trajectory is minimally affected when estimating early recruitment deviations from the start of the model. However, the estimated uncertainty of the spawning output from the beginning year to 1980 was larger and there was an appropriate level of uncertainty in the historical estimated fraction of unfished spawning output. This is expected and it is unrealistic that there is no uncertainty in the estimated fraction of unfished spawning output for nearly the first 100 years of this model. Recruitment deviations are assigned a variance ($\boldsymbol{\sigma}_R$) and penalized in the likelihood, thus will be estimated at zero when there is no information to inform them, but the *a priori* variability in recruitment will be carried through into the derived quantities. Fixing these recruitments ignores that variability and implies that the age structure was actually at equilibrium before fishing began. The Panel realizes that this has little to no effect on recent parameter estimates and derived quantities, is a parsimonious approach, and is unlikely to change management advice, and therefore accepts a base model without estimating early recruitment deviations. However, the Panel suggests that estimating early recruitment deviations be a discussion topic for the end of the year process review and for consideration for the next iteration of best practices guidelines for groundfish stock assessments for the PFMC.

Request No. 3: Fit strongly to the HKL survey index. This should be done by reducing the influence of the other indices by reducing their likelihood contribution with lambdas. The selectivities for the fishery-dependent catches should be fixed as estimated in the current base model.

Rationale: Only one abundance index appears to be well fitted. This sensitivity will provide results when the model is forced to these fishery independent data as well as it can in contrast to when the other indices are included.

STAT Response: A model run was conducted during which all selectivity parameters for fleets other than the NWFSC hook-and-line survey were fixed at the base model values, the ExtraSE parameter for the REC_PR index was turned off, and all lambdas for non-HLK survey data types were set equal to zero. The peak selectivity parameter for the HKL survey (2014-present) hit the upper bound of 60, so the bound was adjusted upward to 69 and the model was rerun without producing any warnings (no parameters on bounds, gradient sufficiently small, etc.).

Results based on fitting only to the NWFSC HKL survey included similar scale, mortality, and growth parameters with peak selectivity for the later period (2014-present) shifted to 67 cm with a wider ascending width. Unsurprisingly, the fit to the NWFSC HLK index improved and fits to the other indices degraded, and annual recruitment strength was estimated only for years with data from survey (Figure 11). The stock was estimated to be in a more depleted state relative to the previous base, at roughly 35% of unfished biomass, with significantly higher uncertainty (Figure 12; default shaded areas in plots are based on normal approximations in arithmetic space, and therefore not constrained to positive values).

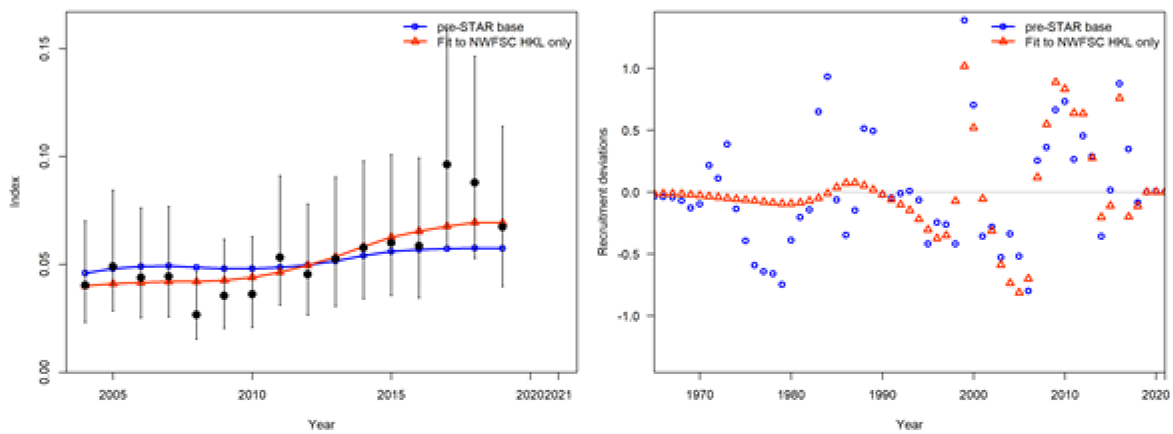


Figure 11. Comparison of fits to the NWFSC HKL index (left) and estimated recruitment deviations (right) for the pre-STAR base model and a model fit only to NWFSC HKL survey data.

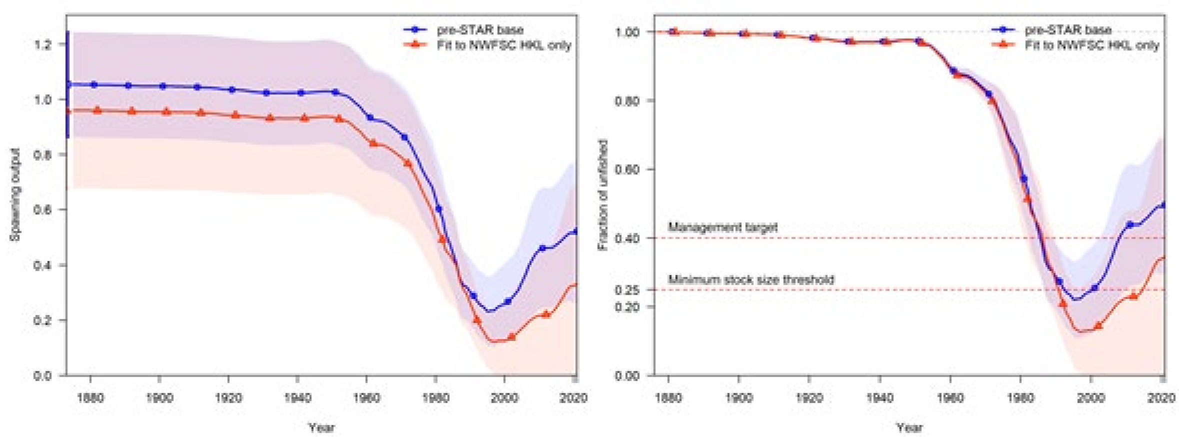


Figure 12. Comparison of spawning output (left) and relative spawning output (right) for the pre-STAR base and a model fit only to NWFSC HKL survey data.

Panel Response: The Panel appreciates the STAT investigating the information content of the hook and line survey. Many parameters estimates and the overall trend in spawning biomass were similar to the pre-STAR base model, but M was estimated at a smaller value (0.1198), and the initial spawning output was less, causing a lower fraction of unfished spawning output in 2021 given the same historical catches. Although the hook and line survey index was fit better, there was still a pattern of misfitting, especially in 2017 and 2018. The Panel concluded that the hook and line survey was not in major conflict with other data sources and the integration of all data was useful. The hook and line survey appears to be an important source of fishery-independent data for vermilion and sunset rockfishes in southern California and it would be worth holding a workshop to discuss methods for incorporating existing hook and line surveys in rockfish stock assessments and improving them for the future.

Request No. 4: Run the first three requests with steepness estimated.

Rationale: To evaluate the effect of estimating steepness.

STAT Response: Model fits for requests 1-3, now with steepness estimated, are compared to the pre-STAR base model (also with steepness estimated) in Figure 13. Steepness estimates for the four model runs are 0.777, 0.731, 0.778, and 0.728 (same order as figure legend).

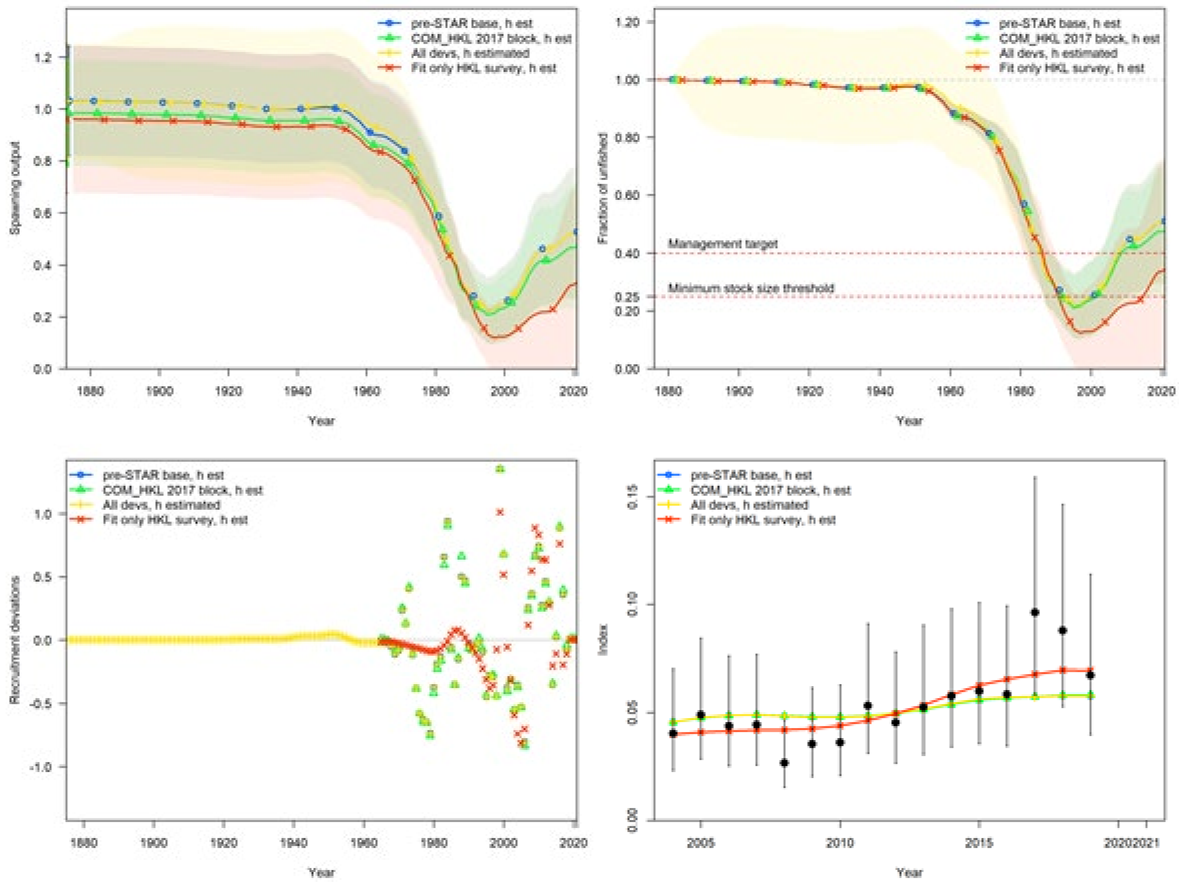


Figure 13. Alternative model runs with steepness estimated (pre-STAR base, and Requests 1-3), comparing spawning output (top left), relative spawning output (top right), recruitment deviations (bottom left), and fit to the NWFSC HKL index (bottom right).

Panel Response: The Panel noted that steepness was estimated to be in the 0.7 to 0.8 range in all of these models, and the addition of a time block in 2017 on the selectivity for the COM_HKL fleet resulted in a decrease in the estimated steepness from 0.777 to 0.731. The estimates of *M* were similar to the pre-STAR base model with steepness fixed at 0.72. The data appear to contain information about steepness, which may be a result of data available informing year class strengths before, during, and after the stock was at its lowest values in the late 1990s. The hook and line survey, in particular, began in 2004 when vermilion recruited in 1999 were five years old and has provided samples of many year classes for 16 years while the stock was increasing from below 20% of unfished spawning output. The STAT recommended estimating steepness in the base model and the Panel concurred.

Request No. 5: Examine length-dependent natural mortality using the Lorenzen M option in SS. Use the age of 10 years as the reference age. Use the time block of 2017 for the COM_HKL fishery and estimate steepness in the new base model.

Rationale: There is the potential for *M* to vary with length given the greater potential for natural mortality at smaller size. This request will help determine whether length-varying *M* has an impact on model parameters and results. This request is also needed to evaluate the effect of estimating steepness.

STAT Response: The model from request 1, with steepness estimated, was used as a baseline. A model using the Lorenzen (length-dependent) natural mortality function was fit for comparison to the assumption of constant *M* (no reweighting). A reference age of 10 was specified. Differences in growth between the sexes produced very minor differences in natural mortality at age under the Lorenzen model (Figure 14), declining to a value slightly below the estimated constant value of 0.129 for ages above 15 years. Care should be taken when comparing reported point estimates of *M* between the baseline (constant *M*) model and the Lorenzen *M* model (value depends on the reference age). The STAT noted that male and female *M* were equal at the reference age (male offset = 0), so a model with greater differences in growth may be sensitive to the choice of reference age if the male offset is fixed at 0. *M* at age 10 under the Lorenzen model is 0.14 yr-1.

Total likelihood increased by 1.94 under the Lorenzen assumption, with no change in the number of parameters. Higher natural mortality rates for younger (smaller) fish are offset by increased estimates of unfished recruitment (Table 2, Figure 15). Also, growth for males (but not females) was slower with length-dependent *M* (Table 2). Spawning output (absolute and relative) and recruitment deviations are similar under both models (Figure 15).

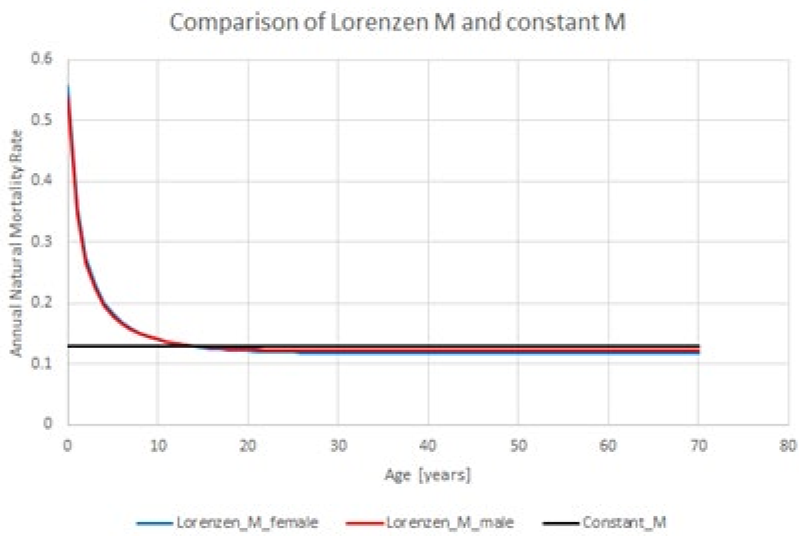


Figure 14. Estimated natural mortality at age using Lorenzen *M* and constant *M* options in Stock Synthesis (male *M* offset fixed at zero). Reference age in the Lorenzen model was set equal to 10 years.

Table 2. Comparison of likelihood components, select parameters, and derived quantities for models with constant *M* (Request 1, *h* estimated) and Lorenzen *M* (reference age = 10). Note that male *M* and growth parameters are parameterized as exponential offsets (male = female * exp(offset)).

Label	Request 1, h estimated	Same w/ Lorenzen M
N.Parms	115	115
TOTAL	1043.27	1045.21
Survey	-41.51	-42.31
Length_comp	357.17	359.09
Age_comp	726.81	727.96
Recruitment	0.65	0.20
Parm_priors	0.16	0.27
NatM_Lorenzen_Fem_GP_1	NA	0.140
NatM_Lorenzen_Mal_GP_1	NA	0
NatM_uniform_Fem_GP_1	0.129	NA
NatM_uniform_Mal_GP_1	0	NA
L_at_Amin_Fem_GP_1	8.5	8.5
L_at_Amax_Fem_GP_1	55.4	55.2
VonBert_K_Fem_GP_1	0.156	0.157
CV_young_Fem_GP_1	0.089	0.090
CV_old_Fem_GP_1	0.077	0.078
L_at_Amax_Mal_GP_1	-0.062	-0.056
VonBert_K_Mal_GP_1	0.136	0.108
CV_old_Mal_GP_1	-0.285	-0.307
SR_LN(R0)	6.69	7.51
SR_BH_steep	0.731	0.739
Q_extraSD_REC_PR(6)	0.138	0.133
Bratio_2021	0.480	0.519
SSB_unfished	984.8	911.9
Totbio_unfished	6280.2	6167.0
Recr_unfished	801.0	1830.5
Dead_Catch_SPR	147.8	152.7
OFLCatch_2023	165.3	177.6

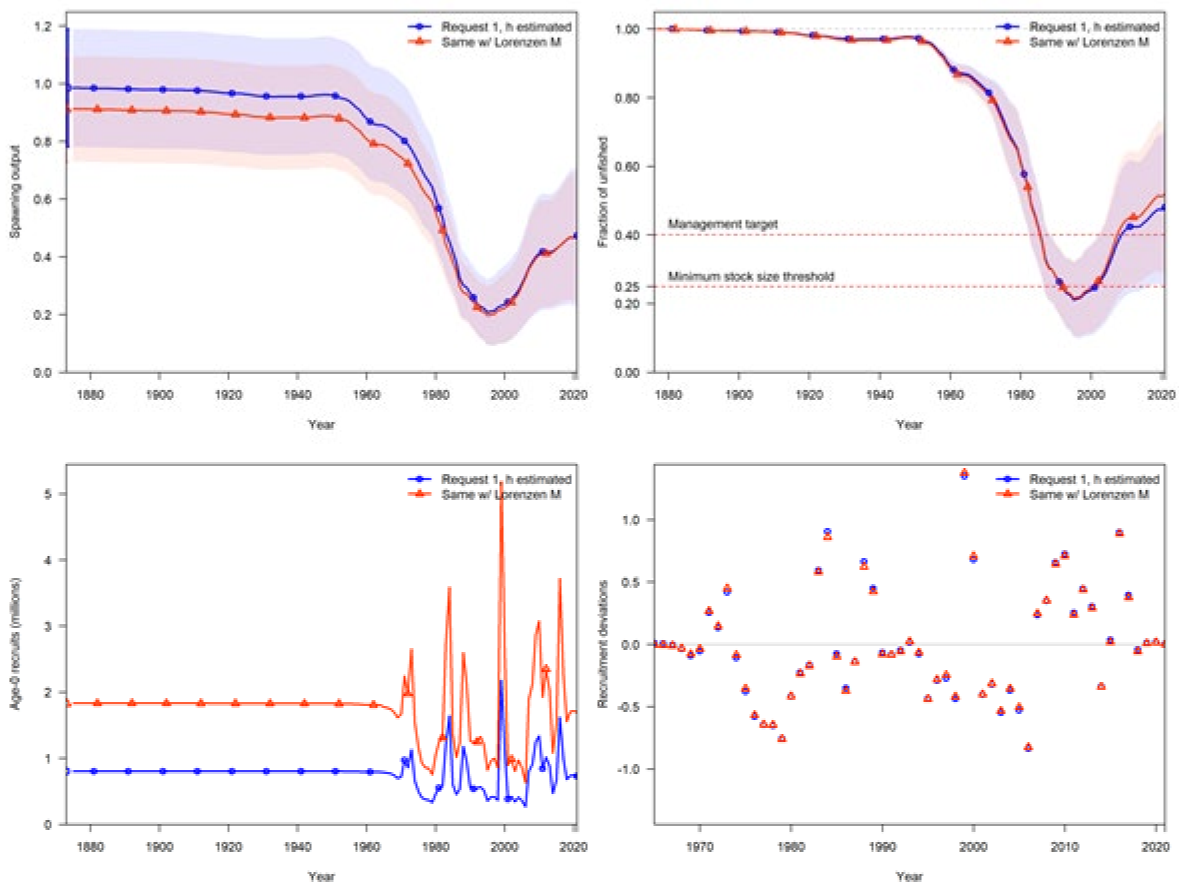


Figure 15. Time series of spawning output (upper left), relative spawning output (upper right), recruitment (lower left), and recruitment deviations (lower right) for a model with constant *M* (Request 1, *h* estimated) and Lorenzen *M*. Higher mortality rates at younger ages are largely offset by scaling up recruitment.

Panel Response: The Panel appreciated this analysis, especially the insights into differences between male and female natural mortality at age even when an offset is used to set them equal, but growth differs. It appears that estimating *M* with a Lorenzen parameterization did not result in better fits to the data overall, and simply rescaling the size of the stock to account for the higher mortality at young ages was sufficient to fit the data with minimal effects on the estimates of older fish and spawning output. Models incorporating fisheries and surveys that select a wide range of sizes and ages would be affected more by modifying *M* at young ages or smaller lengths. Changes to the trawl survey fits and selectivity were not specifically investigated but the selectivity was constrained to avoid optimization issues, thus it wouldn't be expected to change much. The Panel did not request additional investigations given that the survey is one data source of many, fits the data reasonably well and likely has little effect overall.

Request No. 6: Explore a bivariate decision table structure across the log-likelihoods of M and h using the new base model. Use the following catch streams: default harvest control rule (sigma = 1.0, P* = 0.45), P* = 0.4, and constant catch under an MSY (F_{MSY} of 50% SPR). Also report the model-specific sigma for the new base model (based on the estimated 2021 OFL).

Rationale: Natural mortality and steepness are the major axes of uncertainty and this structure appears to be a good one for the decision table since these estimates directly affect estimation of OFLs. The catch streams appeared to be within a reasonable range. The model-specific sigma is needed to ensure it is lower than the proxy for a category 2 stock of 1.0.

STAT Response: The STAT provided projections for the base model using four different catch streams: the harvest control rule predicting an OFL which was reduced based on a P* of 0.45 and a category 2 sigma of 1.0, the harvest control rule predicting an OFL which was reduced based on a P* of 0.40 and a category 2 sigma of 1.0, and constant catches equal to the equilibrium yield using an $F_{SPR} = 50\%$ with and without a buffer based on a P* of 0.45 and a category 2 sigma of 1.0. Projections for the low and high scenarios were unavailable during the STAR panel due to the time needed to determine these states from the bivariate likelihood profile. Complete decision tables will be presented in the post-STAR version of the assessment.

Panel Response: The STAT and the Panel agreed that natural mortality and steepness were the major axes of uncertainty and a decision table was constructed from the bivariate likelihood of these two parameters. It is useful to think of uncertainty in this way because the combination of these two parameters represent productivity. The decision table columns (representing the 12.5%, 50%, and 87.5% percentiles of the bivariate likelihood) were determined by calculating likelihood values for a grid with fixed *M* and *h* values and choosing the widest range of OFL and depletion estimates that were within 1.386 units of the minimum negative log-likelihood. Profiling over just *M* produced a wide range of OFL values but including steepness as well increased that range and provided an important parameter in the determination of reference points. This was a similar approach to what was done for the 2017 blue/deacon rockfish assessments. The resulting *M* and *h* values for the low productivity case were 0.1125 and 0.675, respectively. The resulting *M* and *h* values for the high productivity case were 0.1475 and 0.875, respectively.

The revised base model estimated steepness and included a time block on the commercial hook-and-line fleet in 2017, which is a better representation of the current changes in fishery selectivity due to recent changes in management and this was carried into the projections. Given the occurrence of two cryptic species, vermilion and sunset rockfishes, this is recommended to be a category 2 assessment. The Panel agreed that this is the best available science for the management of vermilion and sunset rockfishes.

The Panel and STAT discussed appropriate catch streams with the GMT and GAP representatives and it was noted that it is difficult to provide catch streams for a stock that is managed within a complex. The catch streams used an expected mortality in 2021 and 2022 of 211 mt for each year, which were provided by the GMT. Later years in the projections assumed full attainment of the ABC/ACL. Four catch scenarios were evaluated in the decision table. First, the harvest control rule was used to predict an OFL which was reduced based on a P* of 0.45 and a category 2 sigma of 1.0. Second, the harvest control rule was used to predict an OFL which was reduced based on a P* of 0.40 and a category 2 sigma of 1.0, to add additional precaution. Finally, constant catches equal to the equilibrium yield using an $F_{SPR = 50\%}$ fishing mortality rate were used with and without a buffer based on a P* of 0.45 and a category 2 sigma of 1.0. It was noted that attainment has been high, exceeding the OFL contribution for the stock, and that catch streams lower than recent catches may be constraining.

The Panel discussed whether the next assessment should be an update or a full assessment. The Panel agreed that these assessments were thorough, complete, and represent the best scientific information available. Although an update would be reasonable in the future, the Panel recommends a full assessment the next time this stock is assessed because the stock is near target and there have been recent changes in management. Additionally, this is the first full assessment, attainment is likely to be reached or exceeded, and more data will be available from fisheries and surveys. Stock structure is a major uncertainty and research is currently being conducted that will inform stock structure and assessment structure in the future. It was also noted that vermilion/sunset rockfish catches make up a considerable proportion of the complex ACL, making them an important component sustaining the fishery.

The Panel agreed that a summary table containing reference points from each stock assessment and summed over the pertinent stock assessment results for each management area (north and south of 40°10' N lat.) would help inform the coastwide management of vermilion and sunset rockfish. The method described section 11.10 of the northern California assessment provides updated methods for estimating the proportion of stock north and south of 40°10' N lat., near Cape Mendocino. The Panel agreed that the new method accounting for habitat area and relative abundance resulting in 4.4% of the stock to the north was an improvement on the previous method based on historical catch and constitutes the preferred method.

The base model projections showed an increase in the stock status for the first seven years of the projections for all catch levels. The P* = 0.40 projections continued to increase through the twelve year period while the others decreased slightly near the end of the projection. The Panel concluded that applying a buffer to the MSY proxy yield catch projections was a management decision, thus both were provided.

Conducting projections when inputting numbers of fish when catch limits are specified in metric tons was discussed. The STAT converted the biomass to numbers based on the current estimated biology and age structure from the assessment model, which was a time-consuming process that matched very closely, but not exactly, when converting back to biomass. The GMT representative suggested that they may be able to provide catch levels in numbers if that would be helpful. The Panel concluded that this topic should be discussed at the stock assessment review since it applies to any assessment that inputs mortality in numbers for projections.

The Panel viewed the decision table with projections for the base model only. The low and high scenarios were unavailable. Predicted catches beyond 2022 were less than the GMT supplied catch of 211 mt for 2021 and 2022. The projected population increased throughout the projection period for the P* catch streams and increased for 6 to 8 years for the MSY catch streams before stabilizing and slightly decreasing. All projections using these catch streams for the base model remained above the management target.

Additional Explorations by the STAT:

Recruitment deviation patterns: The STAT provided an investigation of the cause of the low recruitment pattern in the late 1970s and early 1980s, noting that this low pattern was inconsistent with the estimates from other southern and northern rockfish species. Estimated recruitment patterns were mostly consistent after 1985 for bocaccio, chilipepper, shortbelly, and southern California vermilion rockfishes (Figure 16).

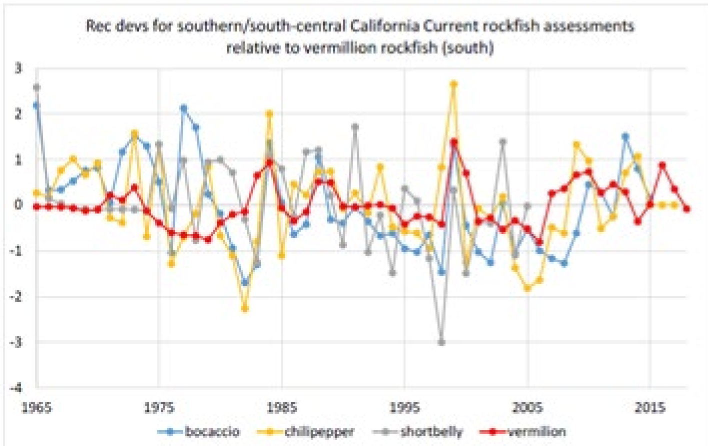
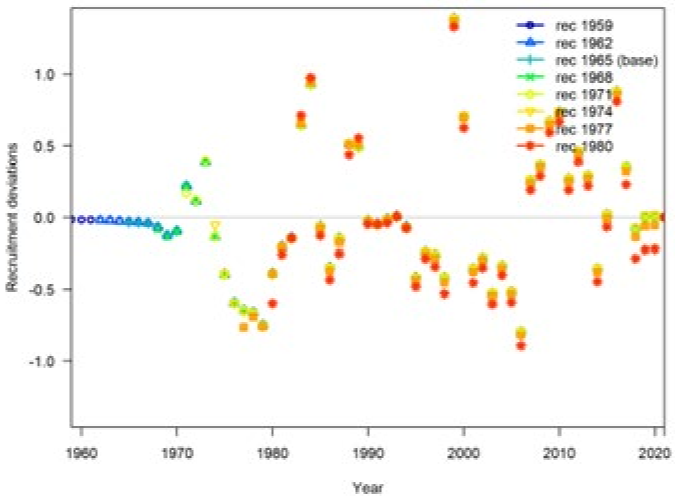


Figure 16. Estimated recruitment deviations for bocaccio rockfish, chilipepper rockfish, shortbelly rockfish, and vermilion rockfish (southern California).

Changing the first year that recruitment deviations were estimated had little effect on the pattern of estimated recruitment deviations, and it was noted that the largest change in fits were to the REC_PC fleet (Figure 17), indicating that this fleet is the most informative data for the late 1970s and early 1980s.



start rec devs year	1959	1962	1965	1968	1971	1974	1977	1980
N.Parms	118	115	112	109	106	103	100	97
TOTAL	1036.4	1036.4	1036.4	1036.7	1037.5	1038.8	1043.8	1058.5
Survey	-42.9	-42.9	-42.9	-42.8	-42.7	-43.2	-41.0	-37.3
PC Rec Index	5.9	5.9	5.9	5.9	6.1	5.6	7.7	11.0
Length_comp	349.7	349.6	349.6	349.6	349.6	351.5	353.5	364.0
H&L Length_comp	33.6	33.6	33.6	33.6	33.6	33.6	33.7	34.8
PC Rec Length_comp	60.0	60.0	59.9	59.9	60.0	61.4	63.6	71.6
Age_comp	729.2	729.2	729.2	729.2	729.4	729.0	729.2	730.4
Recruitment	0.3	0.2	0.3	0.6	1.1	1.5	2.0	1.2
Parm_priors	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3

Figure 17: Estimated recruitment deviations for vermilion rockfish south of Point Conception with different first year for estimates (left). The change in negative log likelihood for different data sources with different starting years for estimating recruitment deviation (right).

The length compositions for the REC_PC fleet showed a lack of small fish from 1980 through 1983 (Figure 18), and the fits degraded when starting estimated recruitment deviations in 1980 (Figure 19). Omitting these four length compositions in the model brought the low 1970s recruitment deviations closer to zero but were still estimated to be negative (Figure 19). Additionally, dropping the first three years of the REC_PC index (1980-1982) had a minor effect (Figure 19). Therefore, there is likely some signal of low 1970s recruitment in other data sets.

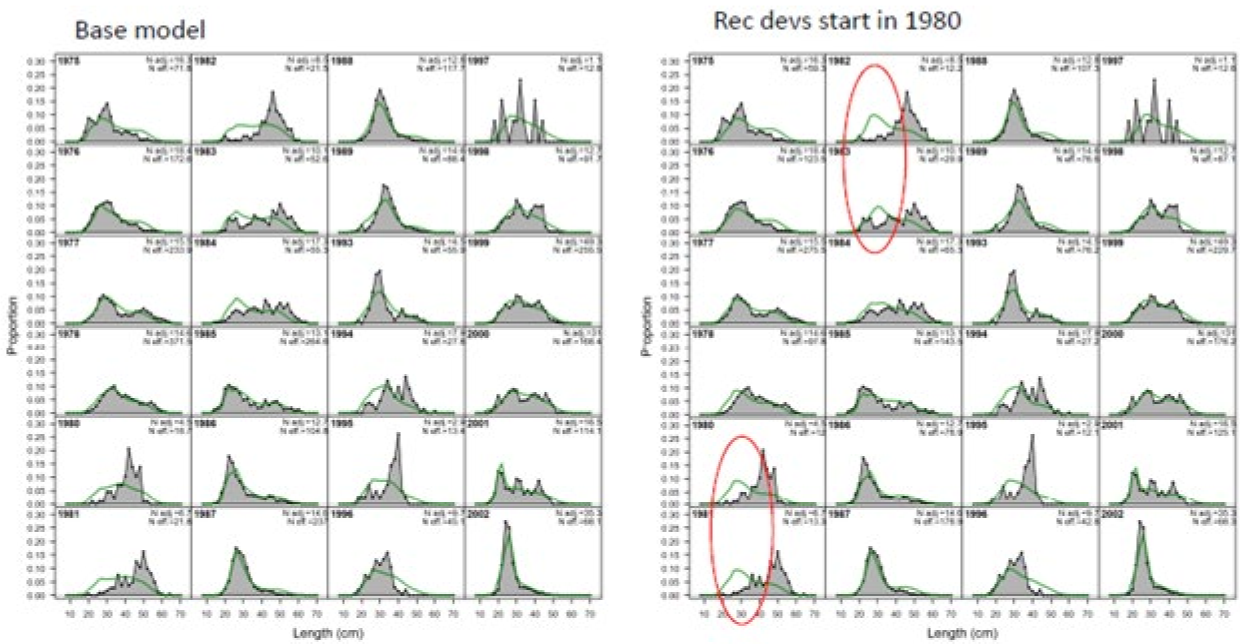


Figure 18: Fits to REC_PC length compositions in the pre-STAR base model (left) and the model with estimated recruitment deviations starting in 1980 (right).

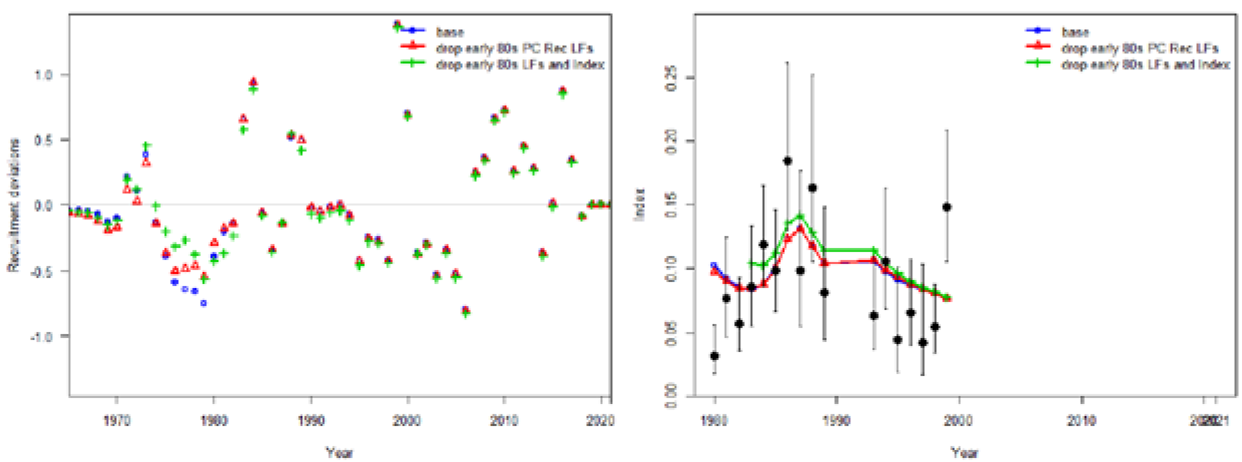


Figure 19: Estimated recruitment deviations and fits to the REC_PC index for the pre-STAR base model, a model omitting the REC_PC length compositions in 1980-1983, and additionally omitting the first three REC_PC index values.

Overall, the pattern of low recruitment in the late 1970s and early 1980s is inconsistent with estimates for other rockfish species, but there appears to be some evidence in the data to support these low estimates for vermilion rockfish.

Panel Response: The Panel was very appreciative of this additional analysis and agrees with the STAT there is some evidence of low recruitment in the late 1970s and early 1980s. It is common for assessment models to estimate a period of low recruitment immediately before data become informative, but the data from the REC_PC fleet contains information for this time period and is consistent across a number of years.

Requests by the STAR Panel and Responses by the STAT for the Northern California Assessment

Request No. 1: Introduce a time block for the CCFRP survey before and after the expansion of the survey in 2017. Reweight after implementing the time block.

Rationale: The index is not fitting the later time frame well after addition of sample locations resulting in a pattern of residuals at larger lengths. The expansion of sampling to include additional sites in central and northern California might have resulted in the observed pattern. Examination of the site level data may inform which locations are contributing to differences in patterns observed.

STAT Response: The model was re-weighted once after adding the time block (2007-2016, 2017-2020), with five additional estimated selectivity parameters. The selectivity during all time blocks remained domed-shaped (Figure 20). The time block provides a better fit to the length composition data (Figure 21), but a poorer fit to the index (Table 3; Figure 22). The new model does not fit well to the last few years of the index that indicates the increase in relative abundance. The selectivity looks as you would expect with a shift in the peak selectivity at larger fish. There were no substantial changes to the recruitment deviations (Figure 23). The stock status changes even though the model cannot reconcile the steep increase at the end of the time series (Figure 24).

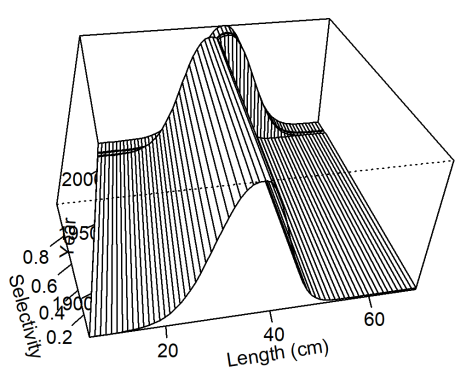


Figure 20. Length-based selectivities for the CCFRP survey with the addition of a time block in 2017 showing dome-shaped selectivities for both periods (2007-2016 and 2017-2020).

Table 3. Likelihood components, parameter estimates and derived quantities from the with and without the addition of a time block in 2017 for the CCFRP survey.

Label	Request 1	Request 1 unweighted	Base model
N.Parms	120	120	115
TOTAL	1006.15	901.455	910.571
Survey	-51.9608	-58.86	-55.121
Length_comp	387.383	366.44	370.792
Age_comp	658.663	583.514	581.647
Recruitment	11.881	10.2021	13.1288
Parm_priors	0.179081	0.148011	0.116238
NatM_uniform_Fem_GP_1	0.0859826	0.086808	0.0885519
L_at_Amin_Fem_GP_1	7.76483	7.71116	7.78639
L_at_Amax_Fem_GP_1	55.2084	55.2777	55.3827
VonBert_K_Fem_GP_1	0.146439	0.146654	0.145296
CV_young_Fem_GP_1	0.0978746	0.095123	0.0963105
CV_old_Fem_GP_1	0.0744815	0.075373	0.074967
NatM_uniform_Mal_GP_1	0.0807127	0.082548	0.0841389
L_at_Amin_Mal_GP_1	5.94712	5.97848	6.02528
L_at_Amax_Mal_GP_1	49.8432	49.8635	49.896
VonBert_K_Mal_GP_1	0.20028	0.199717	0.198787
CV_young_Mal_GP_1	0.0767468	0.07518	0.075516
SR_LN(R0)	6.04855	6.0398	6.07196
Size_DblN_peak_CCFRP(13)	**41.8588**	**37.2081**	**39.4572**
Size_DblN_ascend_se_CCFRP(13)	**4.78289**	**4.5244**	**5.1675**
Size_DblN_descend_se_CCFRP(13)	**4.42532**	**7.92799**	**4.03865**
Size_DblN_end_logit_CCFRP(13)	**-8.6452**	**-5.30497**	**-8**
Size_DblN_peak_CCFRP(13)_BLK2repl_1875	**37.989**	**38.1127**	NA
Size_DblN_ascend_se_CCFRP(13)_BLK2repl_1875	**4.78438**	**4.97153**	NA
Size_DblN_descend_se_CCFRP(13)_BLK2repl_1875	**3.56054**	**3.4859**	NA
Size_DblN_end_logit_CCFRP(13)_BLK2repl_1875	**-4.22019**	**-4.08711**	NA

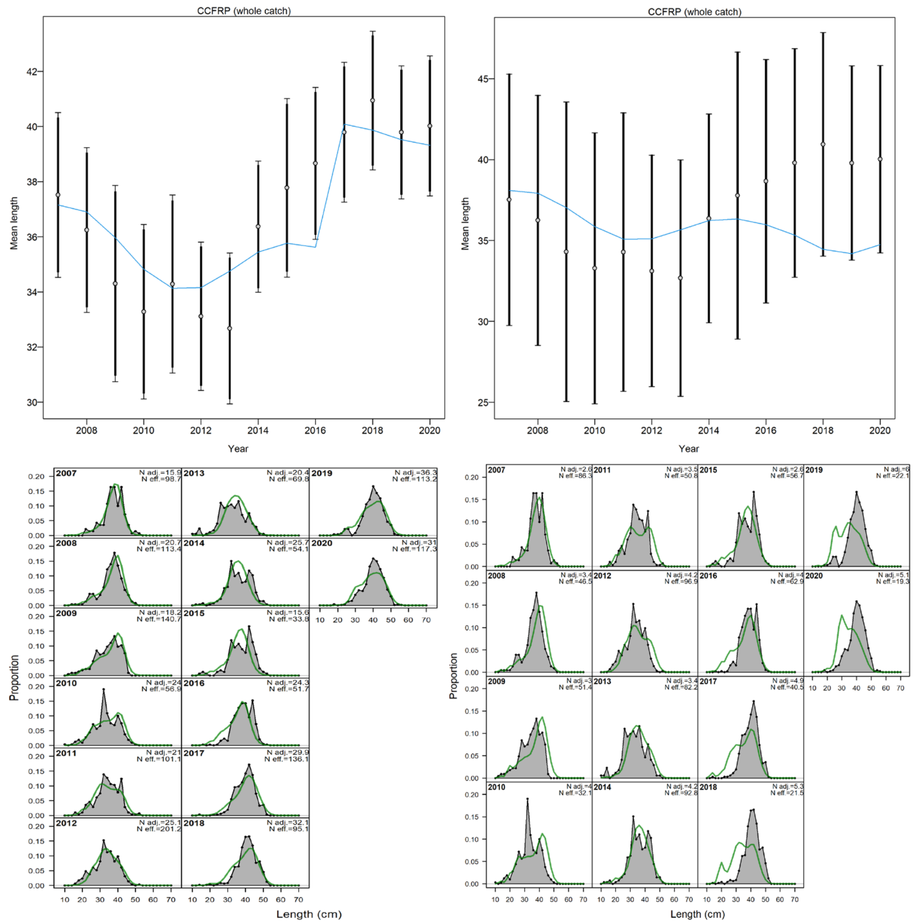


Figure 21. Fits to CCFRP survey length compositions with and without the addition of a time block in 2017 (left and right panels, respectively).

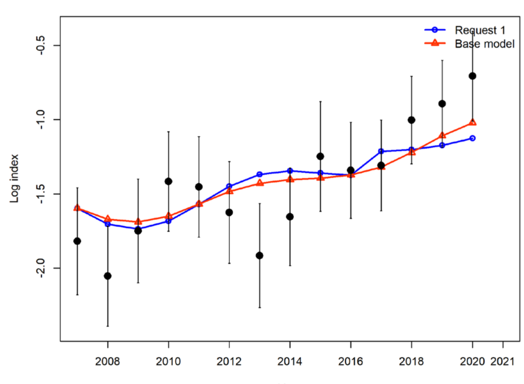


Figure 22. A comparison of model fits to the CCFRP survey index with and without the addition of a time block in 2017.

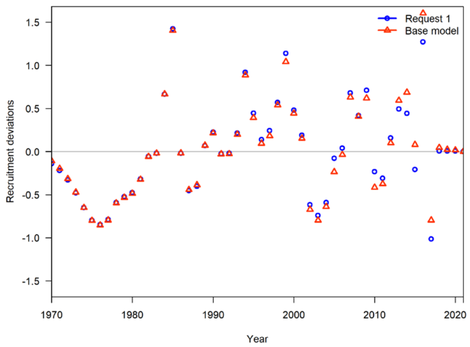


Figure 23. Estimated recruitment deviations with and without a time block added in 2017 for the CCFRP survey index.

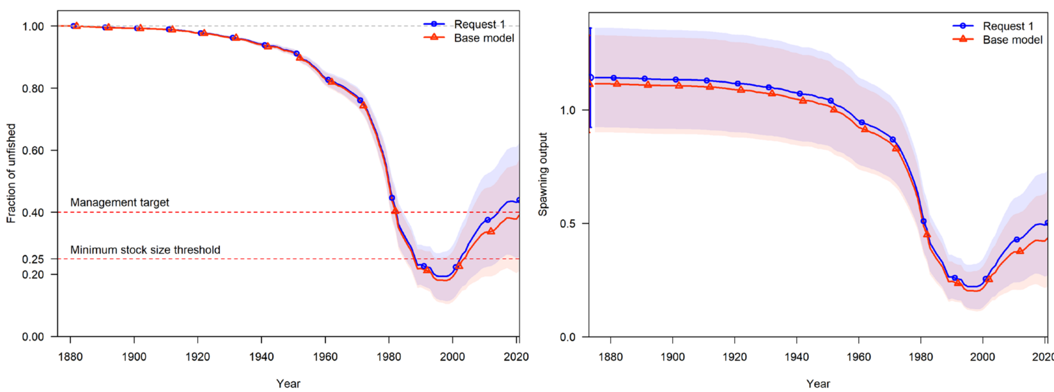


Figure 24. The time series of relative biomass (left panel) and spawning stock biomass (right panel) with and without a time block added in 2017 for the CCFRP survey index.

Panel Response: The Panel noted the STAT's response that the increase in those five parameters improved the fit to the length compositions but worsened the fit to the overall index. Fits to the later time period were improved. The Panel found that this was a difficult issue, as changes in the survey's footprint impact not only selectivity, but also availability. After much discussion, it was decided to discard the time block but to make a further request (Request 5) to examine the issue more fully. Additionally, a research recommendation was also made during these deliberations (See below).

Request No. 2: Implement a selectivity time block for the COM_HKL fishery starting in 2017 or 2018 through present.

Rationale: Management changes allowing fishing in deeper depths may have changed the composition of catches from that point on.

STAT Response: The time block was added in 2017 (1875-2016, 2017-2020), estimating two additional parameters (the peak and ascending limb) and the selectivity pattern remained asymptotic (Figure 25). The inseason regulations changed in July 2017, providing enough time during that year for additional access to depths. The model was re-weighted once after adding the time block. The time block has no effect on management quantities, spawning output (Figure 26), or recruitment deviations (Figure 27). There are few length compositions available for this later time period.

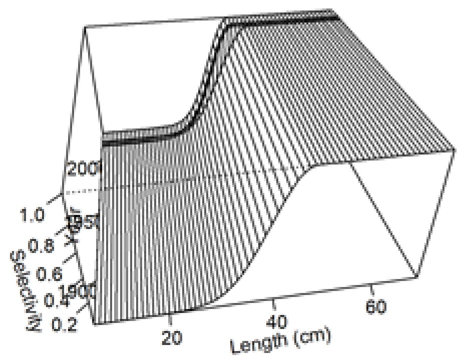


Figure 25. Selectivities estimated for the COM_HKL fishery with a time block added in 2017.

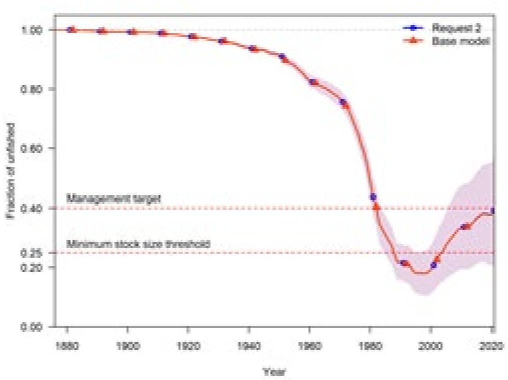


Figure 26. The time series of spawning stock biomass with and without a time block added in 2017 for the COM_HKL fishery.

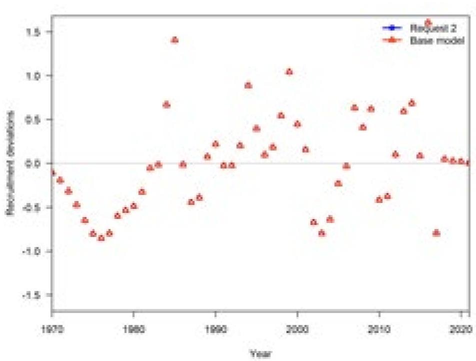


Figure 27. Estimated recruitment deviations with and without a time block added in 2017 for the COM_HKL fishery.

Panel Response: The Panel noted that the STAT had completed this request fully. After some discussion it appeared that adding in the time block for the hook and line fishery didn't change the model results. The Panel then had a lengthy discussion on the appropriateness of adding in selectivity blocks when there were management changes but no real tangible selectivity changes in the model. It was noted by some members that models may lag the management changes; meaning that a few more years may be needed to see the full extent of those management changes on selectivity. Such a block may also be very useful for projections. However, it was also suggested that small time blocks at the end of a time series results in some model diagnostics (i.e., retrospective analysis) becoming difficult to interpret. Additionally, the issue of parsimony was raised, in that adding time blocks increases complexity and parameters. The Panel came to consensus that, while a time block is not needed currently from 2017-2020 in the hook and line fishery, such a selectivity block could be important in either a future update or benchmark given the potential importance of this change in management.

Request No. 3: Drop the 2020 recreational PR index values from the analysis.

Rationale: Sampling protocols changed dramatically during the COVID pandemic preventing speciation of retained catch resulting in unaccounted encounters. This single year was likely influencing the overall weight of the index in the assessment.

STAT Response: There are no sampler examined unidentified rockfish (species = RFGEN or NOXXX) in the PR1 data after 2018. Sampling in 2020 was quartered, but the percent of vermilion observed in the total observed catch is very similar (Table 4). The index just slightly changes when 2020 is removed. The overall pattern is identical (Figure 28). The index just slightly changes when 2020 is removed (Figure 29). The overall pattern is identical and the fit to the index does not improve. The NLL changes by less than 1 and there are very few discernible changes to the model (for the re-weighted model vs. the base model) (Table 5).

Table 4. The percent of positive samples of vermilion rockfish in the PR data by year, 2004-2020.

Positive samples of vermilion in the PR data

Year	% vermilion
2004	0.12
2005	0.10
2006	0.11
2007	0.10
2008	0.07
2009	0.07
2010	0.09
2011	0.09
2012	0.08
2013	0.09
2014	0.08
2015	0.09
2016	0.10
2017	0.09
2018	0.09
2019	0.10
2020	0.10

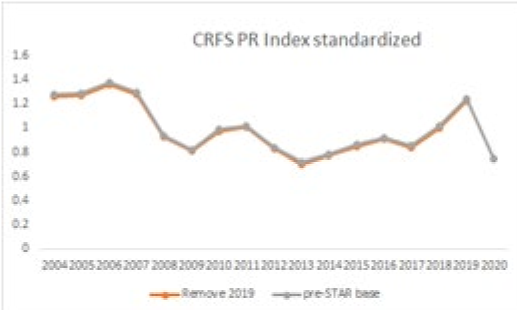


Figure 28. The standardized CRFS PR index with and without the inclusion of 2020 data.

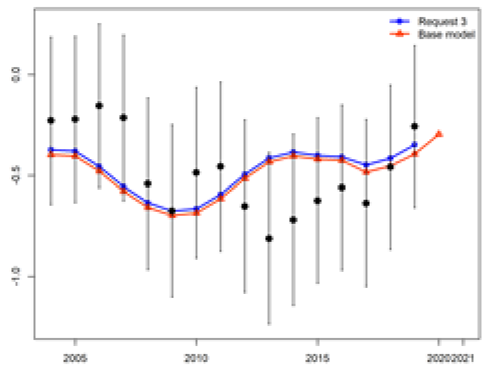


Figure 29. The fit to the CRFS PR index with and without the inclusion of 2020 data.

Table 5. Likelihood components, parameter estimates and derived quantities with and without the inclusion of 2020 data.

Label	Request 3	Base model
N.Parms	115	115
TOTAL	909.851	910.571
Survey	-56.6994	-55.121
Length_comp	371.131	370.792
Age_comp	581.654	581.647
Recruitment	13.6391	13.1288
Parm_priors	0.118463	0.116238
Q_extraSD_REC_PR(6)	0.163289	0.184216
Size_DblN_peak_REC_PR(6)_BLK1repl_1875	34.4208	34.4333
Size_DblN_peak_REC_PR(6)_BLK1repl_2002	36.5705	36.5857
Size_DblN_ascend_se_REC_PR(6)_BLK1repl_1875	4.26478	4.26535
Size_DblN_ascend_se_REC_PR(6)_BLK1repl_2002	4.09297	4.09567
Size_DblN_descend_se_REC_PR(6)_BLK1repl_1875	2.67675	2.65335
Size_DblN_descend_se_REC_PR(6)_BLK1repl_2002	5.3311	5.37641
Size_DblN_end_logit_REC_PR(6)_BLK1repl_1875	-0.313154	-0.290178
Size_DblN_end_logit_REC_PR(6)_BLK1repl_2002	-1.72719	-1.74581

Panel Response: The Panel agreed with the STAT's conclusion that dropping 2020 did little to improve the fit to the index, nor did it change the model results. After discussion with the STAT, the Panel formulated Request 7 to examine unidentified fish back to 2004.

Request No. 4: Provide a plot of recruitment deviation estimates for the M sensitivities, as was provided for the leave one out sensitivities.

Rationale: The equilibrium age-structure is a product of *M*, and recruitment deviations may alter the early age structure to account for misspecification. This will allow for the examination of the correlation between *M* and early recruitment deviation patterns.

STAT Response: Recruitment deviations for the natural mortality (*M*) profile are provided (Figure 30). Lower natural mortality rates resulted in lower recruitment deviations in the 1970s and increased deviations in the 1990s-2000s. There is a sum to zero constraint on recruitment deviations. The estimates of relative biomass and spawning stock biomass are sensitive to natural mortality assumptions (Figure 31).

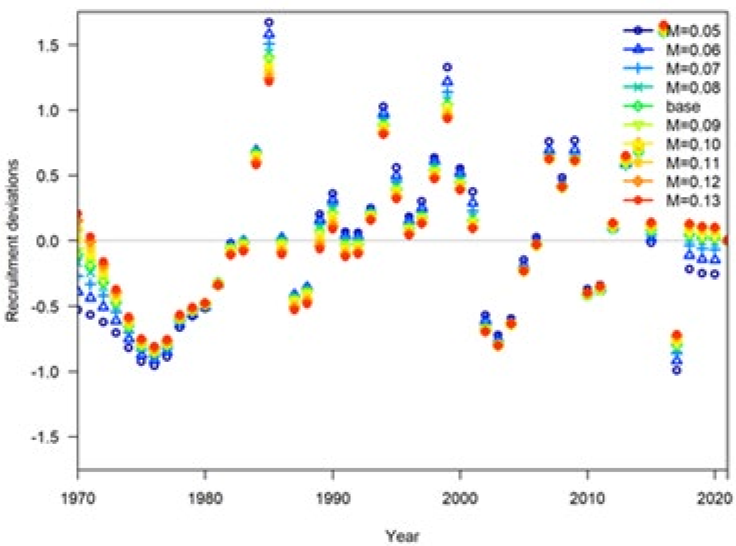


Figure 30. Recruitment deviations across a range of natural mortalities for vermilion rockfish in northern California.

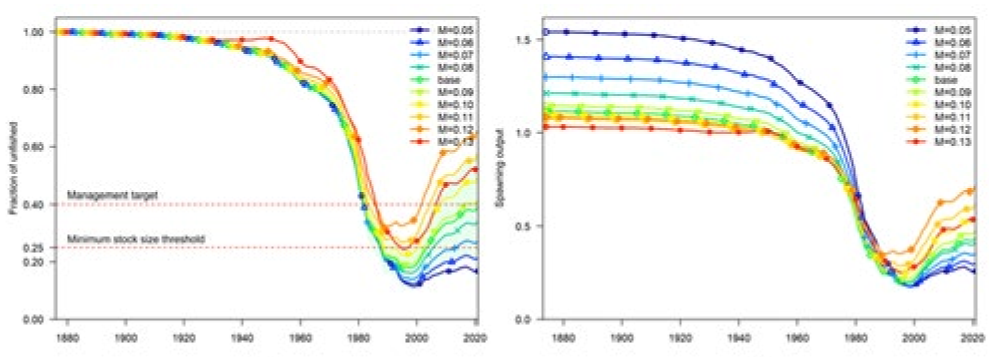


Figure 31. Estimated relative biomass (left panel) and spawning biomass (right panel) of vermilion rockfish in northern California across a range of natural mortality values.

Panel Response: After discussion the Panel agreed with the STAT that the sensitivity to natural mortality was as expected. There were no significant changes to the pattern of estimated recruitment deviations and there seemed to be little asymmetry. The Panel concluded that this was not a fruitful avenue for further exploration.

Request No. 5: Exclude the new sites added in 2017 from the CCFRP index and rerun the model and evaluate the resulting model fit.

Rationale: The fit of the model deviates from the index in the later years of the time series consistent with the expansion of the survey northward with additional sites. The requested analysis will provide an indication of the ability of the model to fit the resulting index when the new sites are omitted.

STAT Response: The index of abundance was constrained to the four areas sampled consistently since 2007 by MLML and Cal Poly (Figure 32). The spatial extent of this index represents Point Conception to Ano Nuevo. A Bayesian negative binomial area-weighted index was developed, giving 20% weight to the MPAs. The length composition data were also constrained to the areas within the new index. The trend in the index (Figure 32), estimated relative spawning biomass, and estimated spawning biomass (Figure 33) are the same without the newer sampling areas, and the increasing trend is still strongest inside the MPAs. The model was iteratively weighted using Francis weighting. The likelihood components and key model parameters between the model run from Request 5 (reweighted once) and the base model are provided in Table 6. Fits to the length composition data from CCFRP and annual mean length under Request 5 with only the core sites are provided in Figure 33 and Figure 34, respectively.

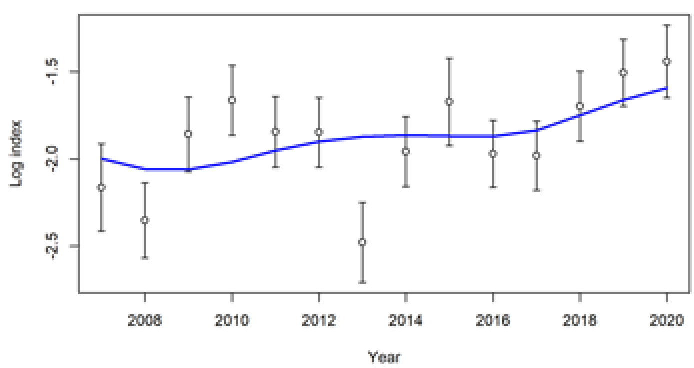


Figure 32. Fit to the CCFRP index when only the four core sites in central California are included.

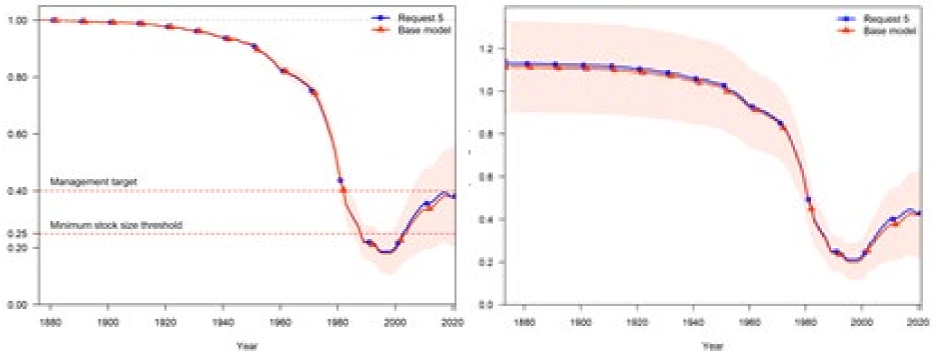


Figure 32. Estimated relative biomass (left panel) and spawning biomass (right panel) of vermilion rockfish in northern California with and without the inclusion of the new sites added to the CCFRP survey in 2017.

Table 6. Likelihood components and key model parameters between the model run from Request 5 (reweighted once) and the base model.

Label	Request 5	Base model
N.Parms	115	115
TOTAL	939.569	910.571
Survey	-45.7184	-55.121
Length_comp	386.27	370.792
Age_comp	587.299	581.647
Recruitment	11.5533	13.1288
Parm_priors	0.156562	0.116238
NatM_uniform_Fem_GP_1	0.086359	0.088552
NatM_uniform_Mal_GP_1	0.082168	0.084139
SR_LN(R0)	6.03162	6.07196
Q_extraSD_REC_PR(6)	0.164755	0.184216
Size_DblN_peak_NWFSC_TWL(9)	16.3303	16.3386
Size_DblN_ascend_se_NWFSC_TWL(9)	1.00394	1.00431
Size_DblN_end_logit_NWFSC_TWL(9)	-0.33078	-0.18546
Size_DblN_peak_CCFRP(13)	40.5479	39.4572
Size_DblN_ascend_se_CCFRP(13)	5.59765	5.1675
Size_DblN_descend_se_CCFRP(13)	3.50945	4.03865
SSB_unfished	1130.31	1114.67
Totbio_unfished	6278.3	6264.57
Recr_unfished	416.391	433.531
Dead_Catch_SPR	135.915	140.884
OFLCatch_2021	132.215	147.794

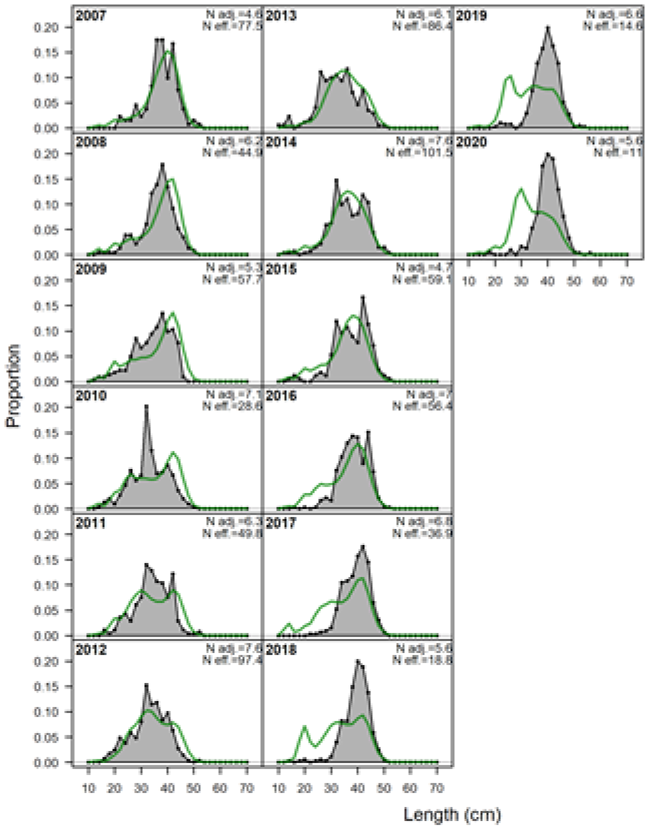


Figure 33. Fits to the length composition data from the model run from Request 5, limiting length data to the four core sites in central California.

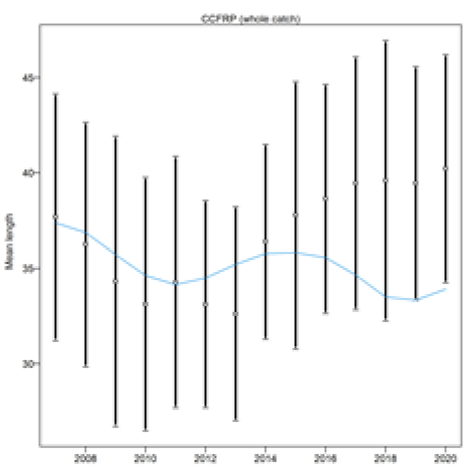


Figure 34. Mean lengths from the CCFRP survey from the model run with Request 5, constraining the index to only the four core central California areas.

Panel Response: The Panel agreed with the conclusion that dropping the new areas surveyed did not seem to improve the base model overall. Based on the discussions, the STAT proposed Request 6 to use a similar method to what was employed with the NWFSC hook and line survey in southern California to the CCFRP survey. The Panel agreed that this would be a good way to move forward in evaluating this issue.

Request No. 6: Provide a model structure treating the CCFRP index by employing methods analogous to the HKL survey index treatment in the southern California model (i.e., add a separate fleet for the later years and use that selectivity for the entire time series) with and without reweighting.

Rationale: The fit of the model deviates from the index in the later years of the time series consistent with the expansion of the survey northward with additional sites. The requested analysis will provide an indication of the ability of the model to fit the resulting index with the proposed model structure.

STAT Response: The STAT did not retain an unweighted model. The unweighted model had an NLL much larger than the weighted model. An additional fleet was added to the model and fundamentally changed the base model. The Francis weighted model for Request 6 is compared to the weighted base model. The index did not fit as well in the model with an early CCFRP fleet (Table 7; Figure 34). However, as with the time block in 2017, the end year relative biomass is higher with the CCFRP survey split into two fleets (Figure 35). Fits to mean length are improved over the base model, as well as fits to length composition data. The STAT does not recommend that the results from this request be incorporated in the base model.

Table 7. Likelihood components, parameter estimates and derived quantities with and without a separate fleet for the later years of the CCFRP index.

Label	Request 6	Base model
N.Parms	120	115
TOTAL	958.711	910.571
Survey	-43.5801	-55.121
Length_comp	399.269	370.792
Age_comp	590.649	581.647
Recruitment	12.2057	13.1288
Parm_priors	0.15642	0.116238
NatM_uniform_Fem_GP_1	0.087114	0.0885519
NatM_uniform_Mal_GP_1	0.081671	0.0841389
SR_LN(R0)	6.05768	6.07196
Q_extraSD_REC_PR(6)	0.226581	0.184216
Size_DblN_peak_CCFRP(13)	42.9179	39.4572
Size_DblN_ascend_se_CCFRP(13)	4.57064	5.1675
Size_DblN_descend_se_CCFRP(13)	3.68308	4.03865
Size_DblN_end_logit_CCFRP(13)	-9.06988	-8
Size_DblN_peak_EARLY_CCFRP(14)	38.4517	NA
Size_DblN_top_logit_EARLY_CCFRP(14)	-9	NA
Size_DblN_ascend_se_EARLY_CCFRP(14)	4.94407	NA
Size_DblN_descend_se_EARLY_CCFRP(14)	3.82026	NA
Size_DblN_start_logit_EARLY_CCFRP(14)	-10	NA
Size_DblN_end_logit_EARLY_CCFRP(14)	-8.10577	NA

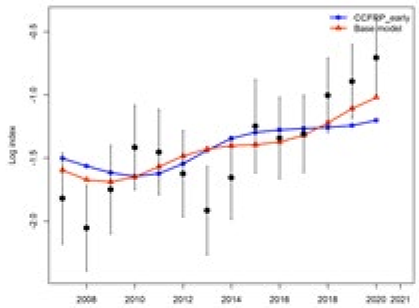


Figure 34. The fit to the CCFRP index with and without a separate fleet for the later years of the index.

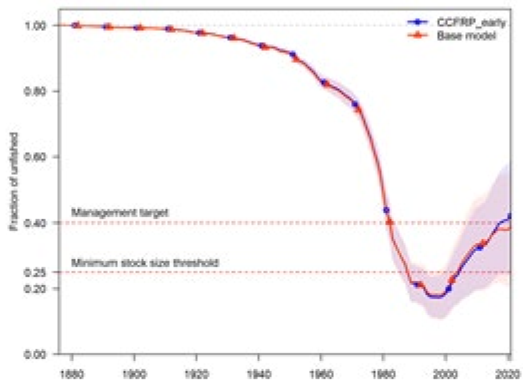


Figure 35. Relative spawning biomass of vermilion rockfish with and without a separate fleet for the later years of the CCFRP index.

Panel Response: The Panel agreed with the conclusions of the STAT that this change improved the fits to mean length as well as the length composition data. The Panel noted that this slightly increased stock status from the precautionary zone to slightly greater than target biomass in the terminal year, as well as the natural mortality, but concluded that this was an improvement over the pre-STAR base model for this region. The proposed changes to the base model were accepted by both the STAT and Panel.

Request No. 7: Evaluate the number of unidentified rockfish (RFGEN) reported from 2004-2020 in RecFIN north and south of Point Conception.

Rationale: To evaluate the potential effect of the COVID pandemic on sampling protocols that may have resulted in under-reporting of vermilion rockfish and poor fits to the PR index.

STAT Response: The STAT only readily had access to data back to 2015, which should be sufficient to look at the issue. The proportion of angler reported of unknown species was higher in 2020 both north and south of Point Conception. A table with the number of trips sampled by year is available in the response to Request 3.

Panel Response: The Panel noted that there was a large increase in the number of unidentified fish in angler reported catch in 2020 (Table 8). Based on this finding, the STAT and the Panel concluded that 2020 should be dropped from the PR index as proposed and evaluated in Request 3.

Table 8. Number of species identified north and south of Point Conception by state samplers vs. reported by anglers.

		SPECIES IDENTIFIED		SPECIES UNKNOWN	
Area	YEAR	Sampler examined	Angler reported	Sampler examined	Angler reported
North of Conception	2015	90931	33252	10	3159
	2016	71298	14415	25	1408
	2017	73476	26955	17	1408
	2018	69016	20537	31	1345
	2019	72554	20619	0	522
	2020	14065	56155	0	14468
South of Conception	2015	19915	25642	175	2113
	2016	14908	18232	53	3435
	2017	17301	21731	197	3832
	2018	17475	17607	62	2873
	2019	22605	22357	0	2164
	2020	2680	22029	0	8671

Request No. 8: Explore a decision table structure across the log-likelihood of M using the new base model. Use the following catch streams: default harvest control rule under a category 2 designation (sigma = 1.0, P* = 0.45), P* = 0.4, and constant catch under an MSY (F_{MSY} of 50% SPR). Also report the model-specific sigma for the new base model (based on the estimated 2021 OFL).

Rationale: Natural mortality is the major axis of uncertainty and this structure appears to be a good one for the decision table since these estimates directly affect estimation of OFLs. The catch streams appeared to be within a reasonable range. The model-specific sigma is needed to ensure it is lower than the proxy for a category 2 stock of 1.0.

STAT Response: The STAT provided projections for the base model using four different catch streams: the harvest control rule predicting an OFL which was reduced based on a P* of 0.45 and a category 2 sigma of 1.0, the harvest control rule predicting an OFL which was reduced based on a P* of 0.40 and a category 2 sigma of 1.0, and constant catches equal to the equilibrium yield using an F_{SPR} = 50% with and without a buffer based on a P* of 0.45 and a category 2 sigma of 1.0. Projections for the low and high scenarios were unavailable during the STAR panel due to the time needed to determine these states. A complete decision table is presented in the post-STAR version of the assessment.

Panel Response: The Panel concluded that this request was completed satisfactorily. Natural mortality appeared to be the best metric for capturing the uncertainty associated with various management responses. Likewise, the projection of catches appeared to be appropriate. The Panel also noted that the choice of high and low states of nature (Female *M* equal to 0.0769, 0.0856, and 0.0956, for the lower state of nature, base model, and higher state of nature, respectively) were appropriate as outlined in the Terms of Reference and Best Practices Guidelines for the 2021 STAR panel reviews.

After much deliberation, the Panel recommended that the northern California stock should be considered a Category 2 stock. Important considerations regarding this recommendation include the uncertainty in the stock structure with the potential presence of sunset rockfish and additional population structure in vermilion rockfish that constitute an unknown a portion of both the removals and the estimates of stock size, as well as the overall size of the uncertainty bounds surrounding the estimates of depletion in the terminal year. The Panel also recommended that the next stock assessment should not be an update, but rather a full assessment given that ongoing genetic research and additional improvements to data available may change how sunset/vermilion rockfish stocks in the region are assessed.

Requests by the STAR Panel and Responses by the STAT for the Oregon Assessment

Request No. 1: Provide the length composition Pearson residuals when weighting using the McAllister-Ianelli approach.

Rationale: This will provide a look at the Pearson residuals to determine if they are of reasonable size and will provide a more detailed look at the effects of weighting the compositions.

STAT Response:
The requested residuals are in Figure 36 and the resulting time series of derived outputs for each model is provided in Figure 37.

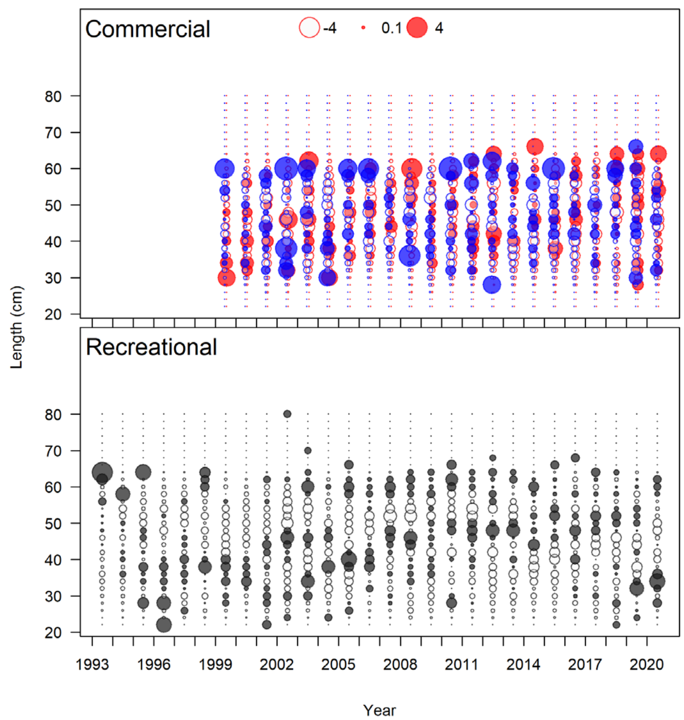


Figure 36. Pearson residuals for each fleet. Maximum Value = 5.12 (compared to 6.45 in reference model).

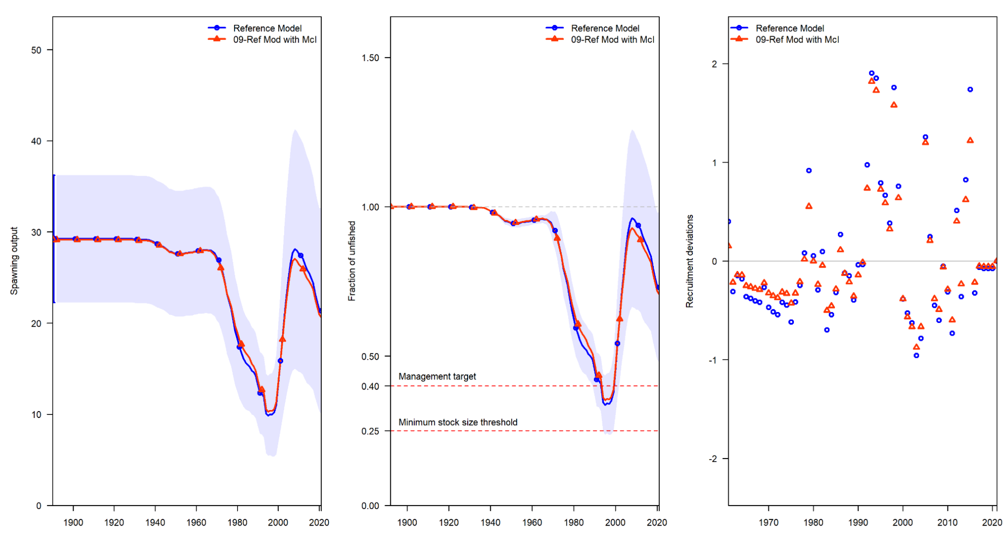


Figure 37. Time series of select derived outputs of McAllister & Ianelli data weighting versus Francis (Reference model).

Panel Response: It was noted that the maximum length composition Pearson residual was reduced from 6.45 (Francis weighting) to 5.12 (MacAllister-Ianelli weighting), but residuals remained relatively high because the sample size was small and bin width was not necessarily ideal for the commercial fishery, although results were better for the recreational fleet data. Higher residuals may also be due to growth error or selectivity. There was only a small effect on recruitment deviates, which might be expected to be most sensitive to the interpretation of length composition data. The same general pattern in recruitment deviates (i.e., they initially decrease and then adjust as information from the data become available) is present in both weightings, but the sensitivity run has a slightly lower variance. The Panel believed that the results seem robust to the choice of alternative weighting.

Request No. 2: Turn on estimation of early recruitment deviations from the start year of the model to one year before the current defined main period in the base model. Tune the bias adjustment ramp, if possible. Compare the uncertainty intervals of the SSB and depletion to the base model. Also compare the pattern of estimated recruitment deviations.

Rationale: To examine how the estimation of these early, uninformed recruitment deviations affect the estimation of uncertainty and the recruitment patterns in the 1970s and see if these early recruitment deviations account for model misspecification.

STAT Response: Figure 38 shows the model estimating all years of recruitment compared to the reference model. The biggest difference is the larger amount of uncertainty in relative stock status when estimating early years of recruitment.

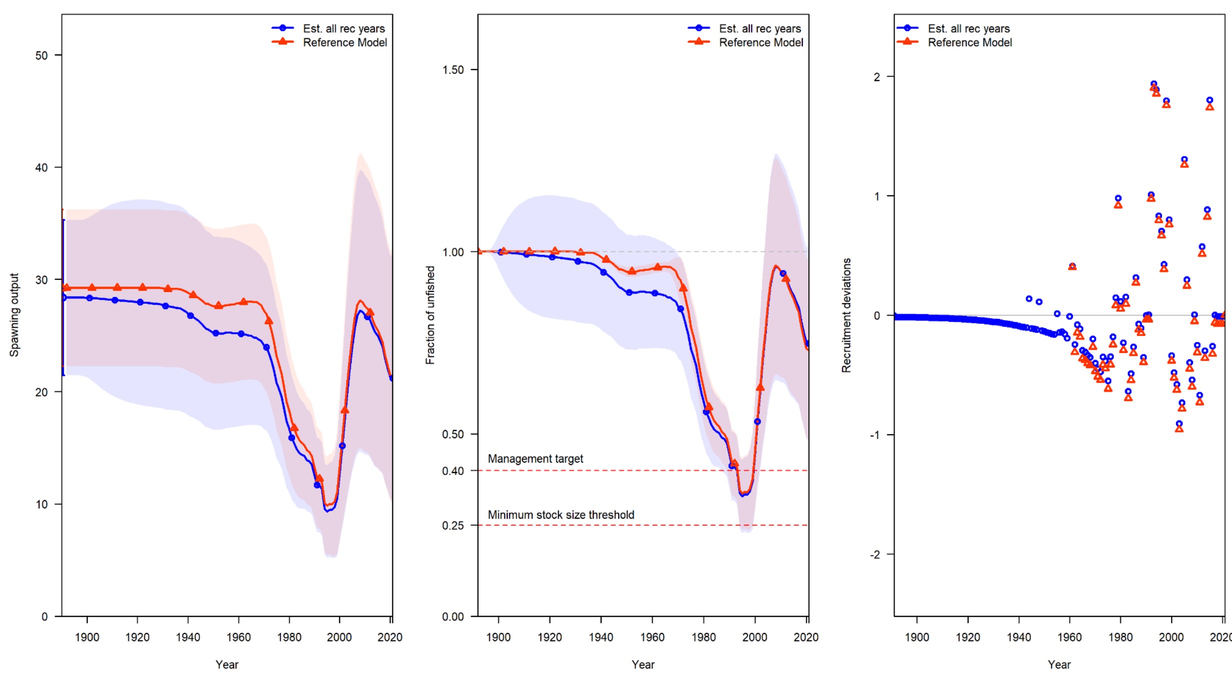


Figure 38. Time series of derived model outputs the reference model to a model estimating recruitment in all years.

Panel Response: The initial recruitment deviations clearly affected the early period biomass and indicated greater uncertainty in the initial level of depletion, increasing the error on stock size. Small changes in the recruitment deviates was explained by the greater flexibility available to the model fitting the length compositions. Catches in the early time period were very low and there is little information in this period. The objective was to capture uncertainty in recruitment and account for the stock not necessarily being at equilibrium.

It was argued that the additional parameters and complexity resulted in little benefit when determining current stock status and was only useful in that it characterized the uncertainty of stock size in the early period when there is little information. It was noted that the model runtime could increase significantly with this approach. Therefore, because the impact on the most recent status was small, it was agreed to add this run as a sensitivity rather than use it as the new reference model. It was recommended that this could be a standard consideration for future assessments, to check the impact of the initial fixed recruitment on the age structure before the recruitment deviates begin. This might be particularly important for longer lived species and led to Requests #5 and #6.

Request No. 3: Implement a time block in 2004 for the length compositions and allow the model to freely estimate selectivity.

Rationale: Seasonal depth restrictions were implemented in 2004 which may affect compositional data.

STAT Response: A small amount of dome-shaped selectivity was estimated in the recreational fishery from 2004 to present (Figure 39 and Figure 40), leading to an AIC improvement of -3.6 units. It was noted that if a randomly chosen year (in this case, 2001) was used for the block, the AIC improvement is -16 units. Overall, there was very little change in the derived outputs and the time series of derived quantities measuring scale, status, and productivity, as well as model uncertainty (Figure 41).

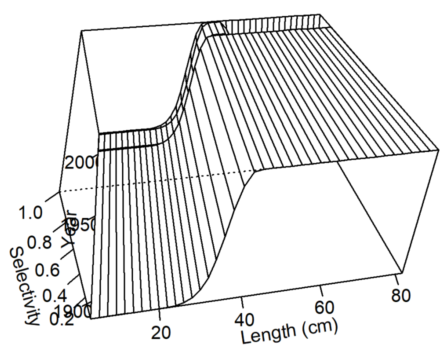


Figure 39. Selectivity blocks with dome-shaped selectivity from 2004 onward.

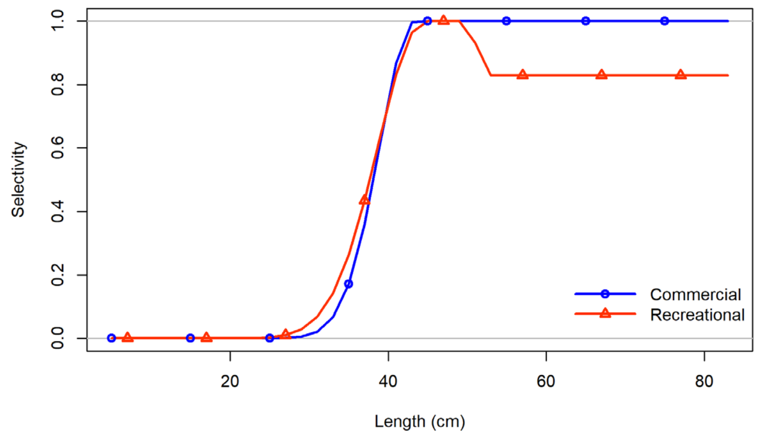


Figure 40. Dome-shaped recreational fishery selectivity for years 2004-2020.

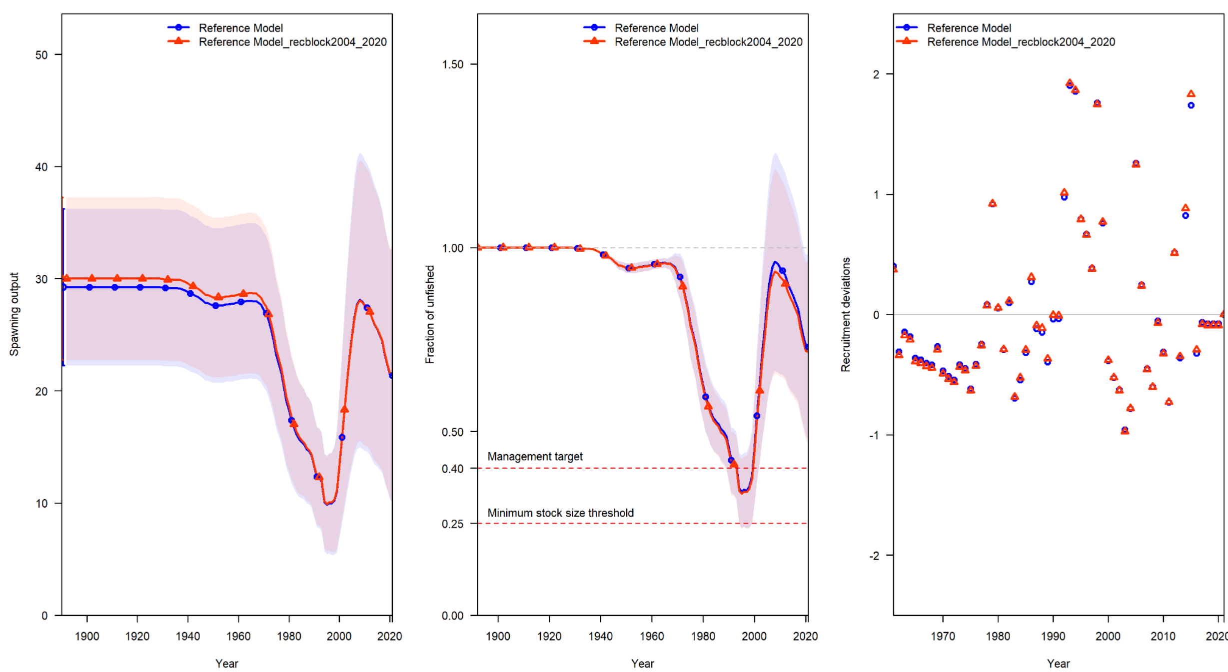


Figure 41. Time series of derived quantities comparing the reference model to one with a selectivity block starting in 2004.

In addition to the above, the STAT decided to evaluate an alternative ORBS abundance index which included winter trip data, which had previously been filtered out (Figure 42). This would also indicate how sensitive results might be to seasonal changes (Figure 43). The new index was fitted in stock assessment (Figure 44).

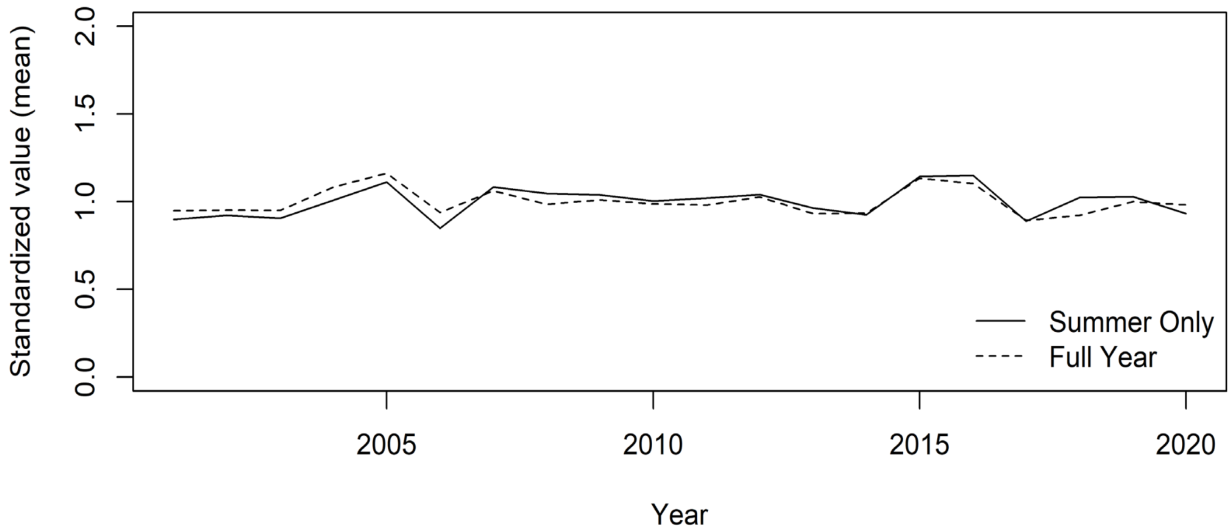


Figure 42. Standardized index without (Summer only) and with the winter trip data (Full year).

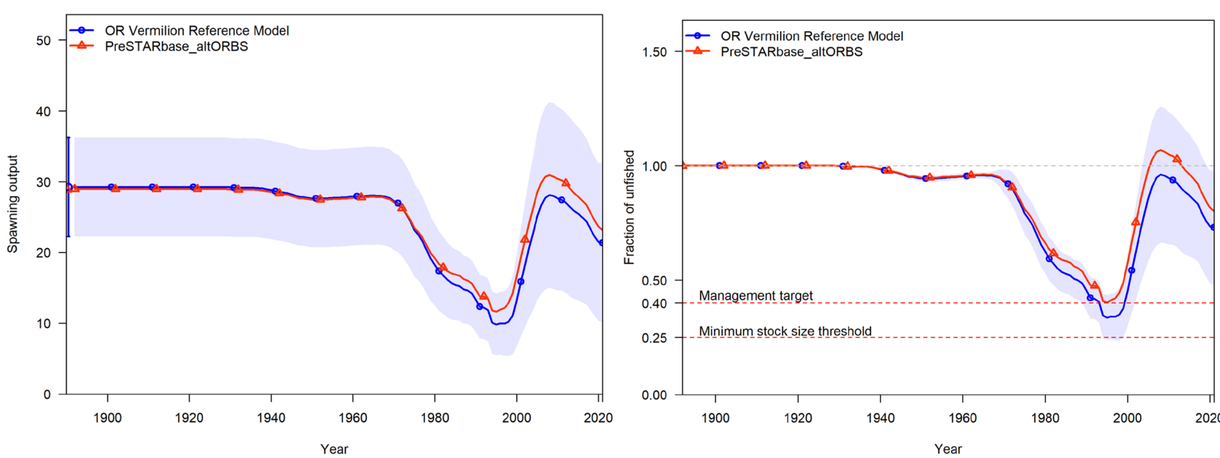


Figure 43. Stock assessment results (spawning output in millions of eggs and fraction of unfished) with the Summer only index (base model) and Full year index (alt-ORBS).

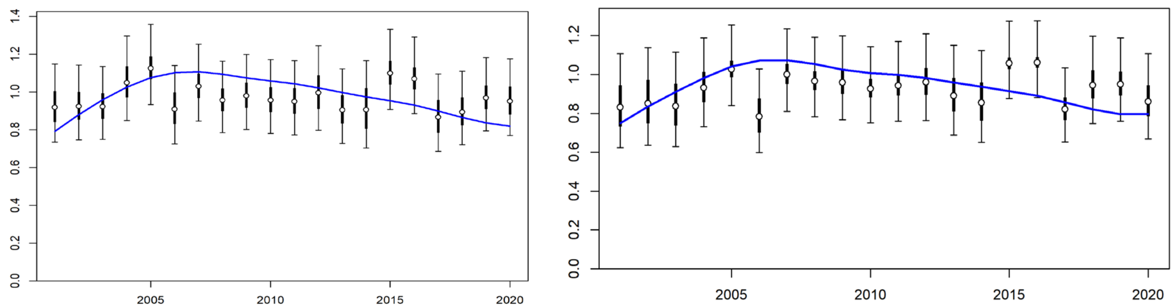


Figure 44. Index fits in the base model for "Summer only" (left) and the full year new index (right).

The STAT concluded that the alternative standardized index was very similar to the base model index. The standardized GLM diagnostics were also generally similar, but perhaps slightly worse. The alternative made only a small difference to results and these were more optimistic. Originally, removing the winter trips was to focus the data on the relevant fishery and was not based on any model diagnostics.

Panel Response: There was a small effect from the blocking with the selectivity exhibiting a slight degree of a dome shape while the AIC improved slightly. The additional double sided normal selectivity adds 3 parameters to the model. The STAT, as an additional test, had tried setting selectivity blocks at alternative points in time that had no justification and, in some cases, got better fits than this, implying the statistical improvement did not necessarily support this particular selectivity block. Overall, the block made little difference to results and reduced parsimony. However, it was noted that the selectivity favored some domed response if the model was allowed to estimate it.

As the fisheries are allowed to return to deeper water, one might expect larger fish to be caught. This may increase selectivity for larger fish at least for a short period in the recreational fishery. Selectivity may also change as management is encouraging the exploitation of different species over time and fishermen are interested in new resources for their novelty and higher catch rates in waters long closed to fishing.

Another factor that could affect the fishery is that since 2015 the number of angler trips per year has increased from 75,000 to over 100,000. Mean lengths have gone up for both recreational and commercial fleets, which may suggest recent increases in abundance and/or a change in selectivity given access to more of the adult biomass in deeper depths with the rebuilding of constraining overfished stocks. There are 5 MPAs with variable possible effects on fishing, which together make up about 10% of the Oregon territorial sea within 3 nm. They are distributed along the coast but limited to shallow areas. It was thought that they have had little or no effect on this fishery.

While the effect of applying a selectivity block based on management changes appeared small in this case, it was worth examining. The slightly dome-shaped selectivity would be used in projections, and there is also a strong seasonal effect, so it could be important. Possible changes in selectivity increase unmodelled uncertainty in projections. Based on the limited impact in these results, it was recommended that this run be retained as a sensitivity. An alternative means of accounting for the split-depth season would be to model the composition data for each season as separate fleets with representative selectivities. The issue should be further pursued under research and data needs, accounting for seasonal and management effects and possible different effects on different fleets.

The Panel agreed that the alternative "all year" index produced minor changes to the abundance index fit and stock status. Overall model log-likelihood was lower for this index, with poorer fit to length-age, but better fits to the index and length data. The panel agreed to include the alternative index as another sensitivity.

Request No. 4: Set the last four years of recruitment deviations into a post-main recruitment period (late era) and provide comparisons of SSB, depletion, and recruitment deviation estimates to the pre-STAR base model.

Rationale: This should not affect the fits to the model or change the historical estimates but will likely have a small effect on longer-term projections.

STAT Response: Figure 45 provides the comparison, showing the last four years with zero recruitment deviation, and slight change that did not change the results of the base model in estimating current stock quantities, but could alter projections. For this reason, the model with zero deviations in the last four years was used in projections.

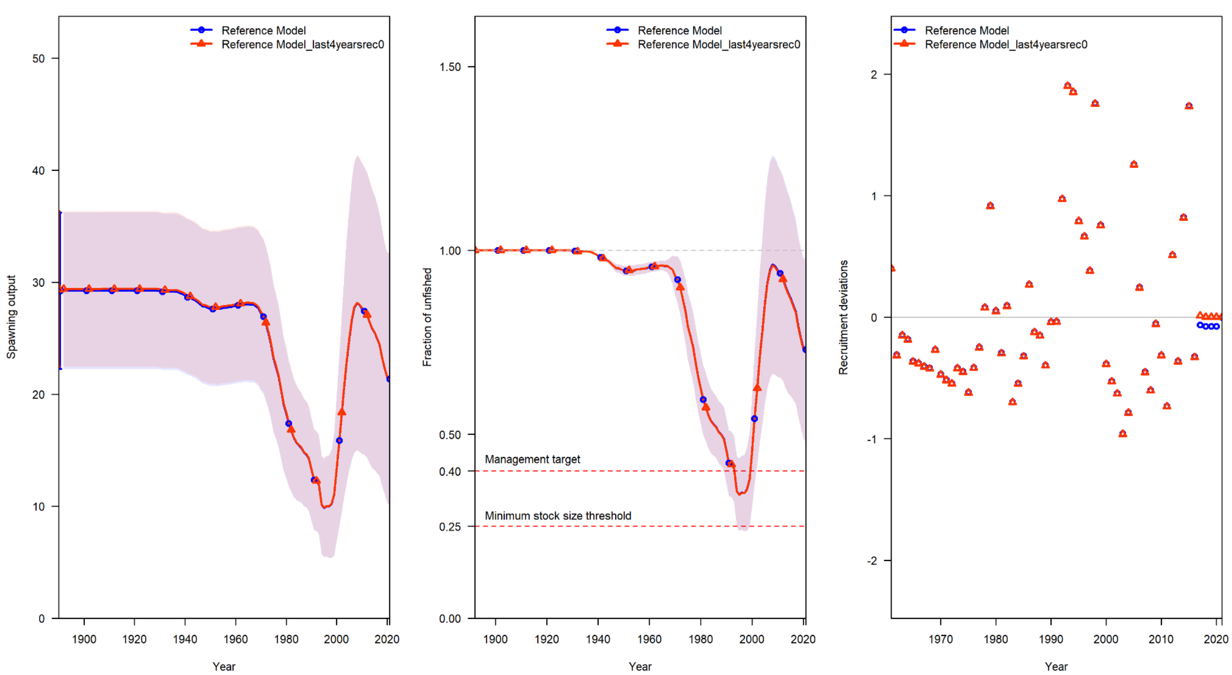


Figure 45. Time series of derived quantities for the reference model versus a model setting the last four recruitment deviations to zero.

Panel Response: The Panel agreed that this resulted in no significant changes but forced recruitment deviations to zero. This could slightly affect projections. It was recommended that this be used for projections because it reduced the effect of potential bias from the uniformed last four years of recruitment deviations. The STAT and Panel agreed to make this change for the reference model.

Request No. 5: Provide the reference points for the run with recruitment deviations estimated from the start of the model. Include confidence intervals.

Rationale: To more fully examine the full time series of recruitment deviations.

STAT Response: The requested reference points and confidence intervals are provided in Table 9.

Table 9. Reference points table comparing the reference model and the model estimating all recruitment years.

	Reference Model			All recruitment years	
	Estimate	Interval		Estimate	Interval
Unfished Spawning Output	29.2	22.2–36.3		28.4	21.4–35.4
Unfished Age 3+ Biomass (mt)	354.4	278.7–430.1		342.7	269.4–416.1
Unfished Recruitment (R0)	16.3	8.5–24.1		14.9	7.5–22.2
Spawning Output (2021)	21.4	10.1–32.7		21.2	10.2–32.2
Fraction Unfished (2021)	0.73	0.48–0.98		0.75	0.48–1.02
Reference Points Based SB40%					
Proxy Spawning Output SB40%	11.7	8.9–14.5		11.4	8.6–14.1
SPR Resulting in SB40%	0.458	0.458–0.458		0.458	0.458–0.458
Exploitation Rate Resulting in SB40%	0.061	0.050–0.071		0.059	0.048–0.070
Yield with SPR Based On SB40% (mt)	8.3	5.6–11.1		7.8	5.2–10.5
Reference Points Based on SPR Proxy for MSY					
Proxy Spawning Output (SPR50)	13	9.9–16.2		12.7	9.6–15.8
SPR50	0.5	-		0.5	-
Exploitation Rate Corresponding to SPR50	0.052	0.043–0.061		0.051	0.041–0.060
Yield with SPR50 at SB SPR (mt)	7.9	5.3–10.6		7.5	4.9–10.0
Reference Points Based on Estimated MSY Values					
Spawning Output at MSY (SB MSY)	8	6.3–9.8		7.8	6.1–9.6
SPR MSY	0.346	0.338–0.353		0.346	0.338–0.355
Exploitation Rate Corresponding to SPR MSY	0.091	0.075–0.107		0.088	0.072–0.105
MSY (mt)	8.8	5.9–11.8		8.3	5.5–11.1

Panel Response: Following from Request 2, the small differences in the reference point estimates confirmed that fitting the recruitment deviates to the initial period does not seem to make much difference compared to the reference model. This supports retaining the current reference model. The extended recruitment deviation model should be retained as a sensitivity.

Request No. 6: Provide the model-specific sigmas for the reference model and the model with the extended time series of recruitment deviations.

Rationale: To determine if sigma changes with the additional recruitment deviations.

STAT Response: The OFL sigma for the reference model is 0.314. The OFL sigma for the model estimating all recruitment years is 0.312.

Panel Response: Following from Request 2, the panel noted that the OFL sigmas were almost identical, again confirming little net difference in the expected advice from the difference models.

Request No. 7: Explore a decision table structure across the log-likelihood of M using the base model. Use the following catch streams: default harvest control rule under a category 1 designation (sigma = 0.5, P* = 0.45), P* = 0.4, and constant catch under an MSY (F_{MSY} of 50% SPR).

Rationale: Natural mortality is the major axis of uncertainty and this structure appears to be a good one for the decision table since these estimates directly affect estimation of OFLs. The catch streams appeared to be within a reasonable range.

STAT response: The STAT provided projections for the base model using four different catch streams: the harvest control rule predicting an OFL which was reduced based on a P* of 0.45 and a category 2 sigma of 1.0, the harvest control rule predicting an OFL which was reduced based on a P* of 0.40 and a category 2 sigma of 1.0, and constant catches equal to the equilibrium yield using an F_{SPR} = 50% with and without a buffer based on a P* of 0.45 and a category 2 sigma of 1.0. A complete decision table is presented in the post-STAR version of the assessment. The decision table columns representing the appropriate *M* values from the likelihood were determined by fitting a parabola to the likelihood values over *M* and interpolating 0.66 units away from the maximum, corresponding to the 12.5%, 50%, and 87.5% quantiles.

Panel Response: The STAT and the Panel agreed that natural mortality was the most important axis of uncertainty for the decision table. Except for the small adjustment to the four most recent recruitment deviates, the base model was unchanged from the pre-STAR assessment, and was used in the projections reflected in the decision table.

The Panel recommends this as a Category 1 assessment given the range of data utilized, the sample sizes for the composition data including length-age data and the favorable model diagnostics. Although there is some uncertainty about population structure, sunset rockfishes are not likely to be found in Oregon and the catches are expected to be made up primarily of one of the populations of vermilion rockfish at this latitude (Budrick 2016). The default sigma value of 0.5 associated with the Category 1 designation was used in buffer estimation, which is greater than the estimated sigma in the OFL of 0.31.

The Panel and STAT discussed appropriate catch streams with the GMT and GAP representatives. The catch scenarios used the expected mortality in 2021 and 2022 provided by the GMT and assumed full attainment for the remainder of the years. Three catch scenarios were evaluated including 1.) using the harvest control rule to predict an OFL which was reduced based on a P* of 0.45 and a category 1 sigma of 0.5, 2.) the harvest control rule was used to predict an OFL which was reduced based on a P* of 0.40 and a category 1 sigma of 0.5 to add additional precaution and 3.) constant catches equal to the equilibrium yield using an F_{SPR}=50%. It was noted that recent catches have exceeded the catch streams assumed in the projections.

The Panel discussed whether the next assessment should be an update or a full assessment. The Panel agreed that these assessments were thorough, complete, and the best available science. However, the Panel recommends a full assessment the next time this stock is assessed because this is the first full assessment, there have been recent changes in management, attainment is likely to be reached, and more data will become available from fisheries and surveys. It was also noted that vermilion/sunset rockfish catches make up a considerable proportion of the ACL of the Complex. The full assessment framework will provide the flexibility to implement innovations that are not afforded under an update. Additionally, stock structure is a major uncertainty and research is currently being undertaken that will inform stock structure and assessment structure in the future. Conducting full assessments for all vermilion rockfish stocks will also provide for useful comparison across assessments.

Requests by the STAR Panel and Responses by the STAT for the Washington Assessment

Request 1: Provide variance estimates or PSE, if possible, of annual catches from 2002-2020.

Rationale: Removals are a vital part of the data inputs and vermilion are rarely encountered in WA. Capturing the uncertainty of those removals can help to understand the overall uncertainty in the model.

STAT Response: The requested catch uncertainty measures are provided in Table 10 and show no discernible increase in the 2019 uncertainty compared to other years. Table 10 shows the increase in Pacific halibut catches in recent years.

Table 10. Estimated number of vermilion rockfish, variance, and coefficient of variation (CV) for retained and released fish from 2002-2020.

	Catches			Releases		
Year	Total	Variance	CV	Total	Variance	CV
2002	147	530	16%	23	85	40%
2003	109	631	23%			
2004	95	230	16%	48	105	21%
2005	192	456	11%	93	220	16%
2006	228	791	12%	208	2128	22%
2007	497	9898	20%	166	582	15%
2008	294	901	10%	128	321	14%
2009	163	294	11%	278	11180	38%
2010	382	4846	18%	192	1230	18%
2011	518	2316	9%	305	1477	13%
2012	422	1314	9%	222	642	11%
2013	538	4986	13%	450	1692	9%
2014	534	2781	10%	408	1961	11%
2015	673	4019	9%	452	1817	9%
2016	416	2095	11%	444	2839	12%
2017	491	2334	10%	424	3352	14%
2018	609	3651	10%	257	1413	15%
2019	1284	26419	13%	418	4147	15%
2020	230	2170	20%	153	1341	24%

Table 11. Coastal Washington recreational Pacific halibut catch 2000-2019.

Year	Columbia Catch Area 1	South Coast Catch Area 2	North Coast Catch Areas 3-4
2000	370	1,980	4,286
2001	387	2,085	5,752
2002	347	1,644	5,219
2003	327	2,482	5,576
2004	447	3,455	5,627
2005	518	2,981	5,046
2006	693	2,377	4,562
2007	585	2,017	3,136
2008	667	2,375	4,408
2009	391	2,328	4,841
2010	428	2,259	5,438
2011	480	2,613	4,931
2012	350	2,588	5,130
2013	292	2,664	5,387
2014	540	2,465	6,064
2015	590	2,557	5,247
2016	702	2,543	6,003
2017	949	3,835	5,683
2018	931	3,258	6,365
2019	1,082	4,138	8,011

Panel Response: The elevated vermilion rockfish catch estimates in 2019 observed in Table 10 resulted in further consideration of the factors contributing to the increase. The variance in 2019 was higher than in other years, but proportional to the higher estimates, while the CV of 13% was not inconsistent with other years. The Pacific halibut catch estimates were provided for perspective given the increase in the number of all depth Pacific halibut fishing days in 2019, which may have contributed to higher catch of vermilion rockfish. Plotting vermilion rockfish catch with Pacific halibut catches, showed some correlation in Areas 3 and 4 where most vermilion rockfish in Washington are caught, but there was no relationship across the whole state, in part due to low abundance in the south. The large increase in vermilion rockfish catch in 2019 resulted in estimates nearly double the previous year and was out of proportion with the increase in the Pacific halibut catch in Table 11, which may indicate other management effects such as the liberalization of depth limits and additional lingcod opportunities contributed to the increase. Estimates were elevated across states in 2019, possibly as a result of recent recruitment of the 2016 year class to the fishery given gear selectivity. There appears to be a combination of regulatory liberalization and recruitment contributing to the elevated catch estimates in 2019 rather than sampling error, bias, or artifacts of estimation methods. Thus, there is no support for augmenting or supplanting the values, as they are likely representative. If further liberalization of the fishery is considered, vermilion rockfish catch may increase as well.

Request No. 2: Provide SB, SB/B0, and estimated recruitment deviation plots for fixed M values (female and male equal) of 0.06, 0.08, 0.10, and 0.12.

Rationale: Natural mortality is one of the largest sources of uncertainty in the model and when estimating *M*, the uncertainty is also estimated but is currently an assumed normal distribution based on the inverse of the Hessian. Looking more specifically at this uncertainty with fixed *M* values may provide insight into the asymmetry of uncertainty that is more realistic.

STAT Response: Figure 46 with all requested scenarios and Figure 47 excluding the $M = 0.12$ scenario to better show the scale, highlight the asymmetric pattern in uncertainty in the natural mortality scenarios.

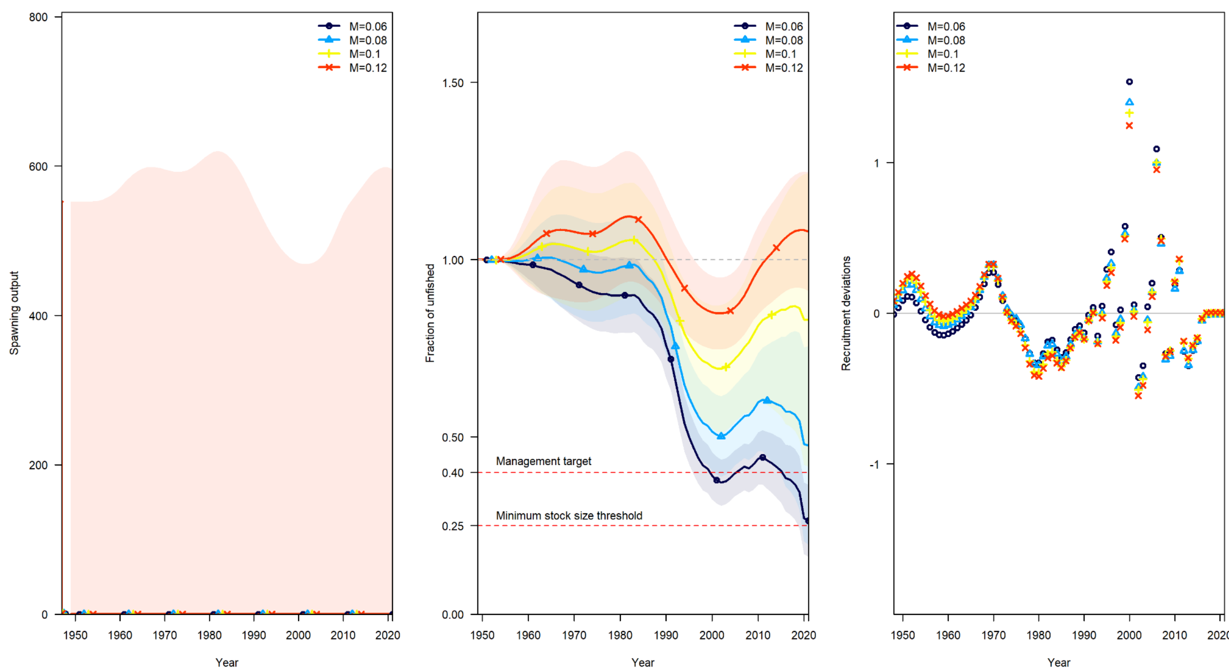


Figure 46. Time series of derived quantities across the four requested natural mortality scenarios.

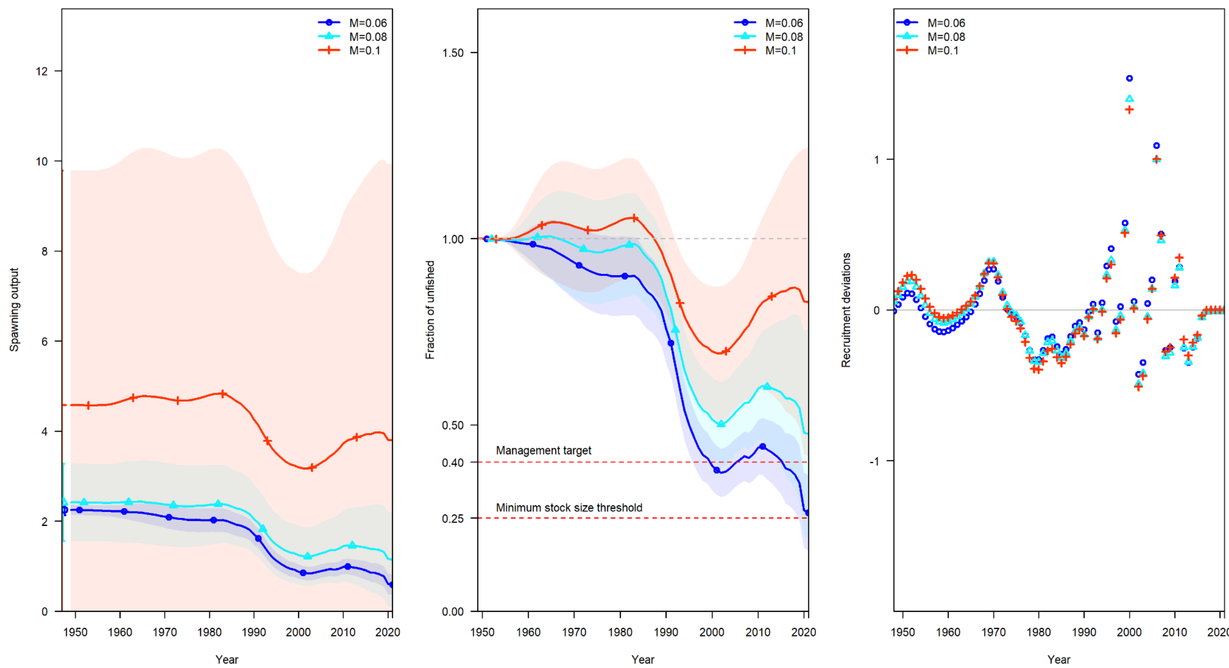


Figure 47. Time series of derived quantities excluding the *M* = 0.12 natural mortality scenarios.

Panel Response: The sensitivity analysis evaluated *M* from 0.6 to 0.12 to better understand the effect on model outcomes. Above *M* of 1.2, the assessment scale inflates unreasonably resulting in uncertainty bounds including unfished levels, the model cannot determine R_0 and thus inflates variance to an unrealistic level. While there is assumed symmetric error about the base model over time, there is asymmetry in the results of the terminal year depletion with increasing *M*, resulting in skew at higher values, while more proximate values are observed at the lower range of *M* values. Asymptotic uncertainty indicates that there is a lower probability of being more depleted across the major axis of uncertainty *M*. The reference model captures much of the uncertainty, but not the asymmetric distribution of depletion outcomes and resulting uncertainty.

The asymmetry appears to be across assessments with a single reference model, which does not capture the asymmetry. A Bayesian assessment with asymptotic variances or MLE derived ensemble models would account for some of the asymmetry in an intermodal representation that is not captured by the reference model itself. Ensemble models may provide a better overall reference model.

Request No. 3: Examine length-dependent natural mortality using the Lorenzen M option in SS. Use the age at 50% maturity as the reference age.

Rationale: There is potential for *M* to vary with age given the greater potential for natural mortality at smaller size. This request will help determine whether age-varying *M* has an impact on model parameters and results.

STAT Response: The Lorenzen *M* was estimated with an age at 50% maturity at 10 years set as the reference age selected (Figure 48, Table 12). Age- or length-specific mortality and the invariant form used in the base model results in similar outcomes for spawning biomass and relative depletion (Figure 49).

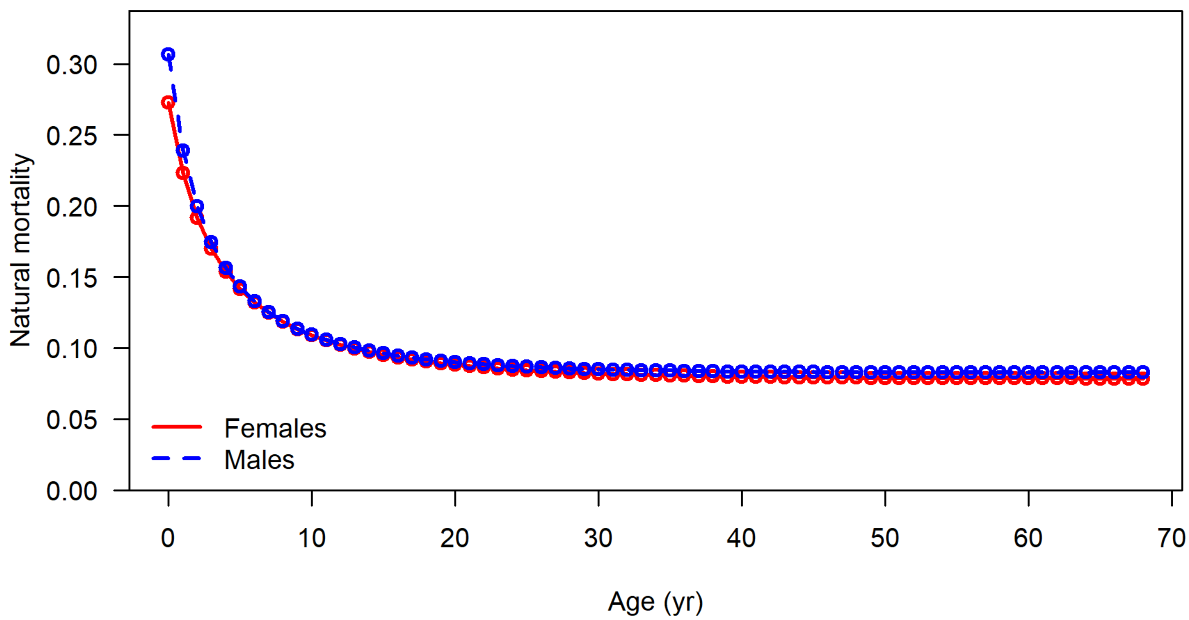


Figure 48. Lorenzen *M* for males and females with age.

Table 12. Age- and sex-specific *M* values using the SS implementation of the Lorenzen model.

Age	Females	Males	Age	Females	Males
0	0.273	0.306	31	0.082	0.085
1	0.223	0.239	32	0.081	0.084
2	0.192	0.200	33	0.081	0.084
3	0.170	0.174	34	0.081	0.084
4	0.154	0.156	35	0.081	0.084
5	0.142	0.143	36	0.080	0.084
6	0.132	0.133	37	0.080	0.084
7	0.125	0.125	38	0.080	0.084
8	0.118	0.119	39	0.080	0.083
9	0.113	0.114	40	0.080	0.083
10	0.109	0.109	41	0.080	0.083
11	0.105	0.106	42	0.080	0.083
12	0.102	0.103	43	0.079	0.083
13	0.099	0.100	44	0.079	0.083
14	0.097	0.098	45	0.079	0.083
15	0.095	0.096	46	0.079	0.083
16	0.093	0.095	47	0.079	0.083
17	0.092	0.093	48	0.079	0.083
18	0.090	0.092	49	0.079	0.083
19	0.089	0.091	50	0.079	0.083
20	0.088	0.090	51	0.079	0.083
21	0.087	0.089	52	0.079	0.083
22	0.086	0.088	53	0.079	0.083
23	0.086	0.088	54	0.079	0.083
24	0.085	0.087	55	0.079	0.083
25	0.084	0.087	56	0.079	0.083
26	0.084	0.086	57	0.079	0.083
27	0.083	0.086	58	0.079	0.083
28	0.083	0.086	59	0.079	0.083
29	0.082	0.085	60	0.079	0.083
30	0.082	0.085	61	0.079	0.083

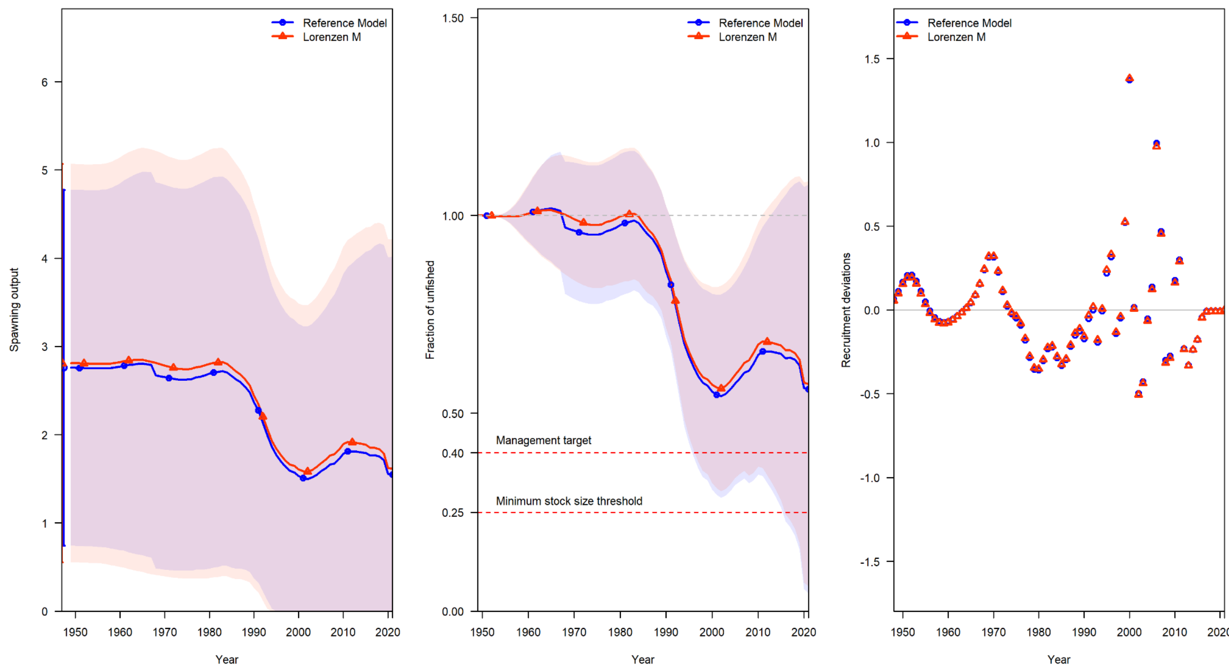


Figure 49. Time series of derived quantities for the reference model compared to the model using the Lorenzen *M* method.

Panel Response: By the time cohorts are selected by the gear, they are reaching the minimum of the natural mortality, as small fish are not selected until *M* is below 0.1, explaining some of the lack of difference in results for spawning output and depletion in Figure 49. If they were exploited earlier as juveniles, the Lorenzen *M* accounting for higher mortality for smaller/younger fish might have more of an influence on the outcomes. While it may be more realistic to use the Lorenzen *M*, it does not make much difference given the age of first exploitation. Given when the fish recruit to the fishery, there may be less of a concern, but for other stocks it may be a consideration. Use of the Lorenzen model might be more pertinent for stocks exploited at a younger age. Review of R_0 values to evaluate reasonable values is recommended if a Lorenzen model is implemented as there may be a shift in R_0 and increased scale of recruitment in order to balance take and recruitment.

Request No. 4: Implement a time block in 2007 for the length compositions and allow the model to freely estimate selectivity. Explore an additional time block in 2019 to present.

Rationale: Seasonal depth restrictions were implemented in 2007 which may affect compositional data. Liberalization of depth restrictions in 2019 may also have affected compositional data and catches.

STAT Response: Attempts were made to add time blocks to the WA recreational fishery time series, but each of these failed to find a reasonable model. This was determined by unreasonably high $\ln(R_0)$ values (>17) and significant dome-shaped selectivity (Figure 50), which presumes a good portion of individuals are cryptic right after maturity and presents an undetermined population size. An additional 50 jitter runs (jitter = 0.15 and 0.1) also failed to achieve a reasonable model (Figure R4b). The extension of adding an additional block in 2019 made no change in behavior and gave similar outrageous results. The two models produced worse AIC values (+2 and +10 AIC units respectively) compared to the base model, so the additional parameters did not improve the overall model fit but produced unrealistic scale estimates.

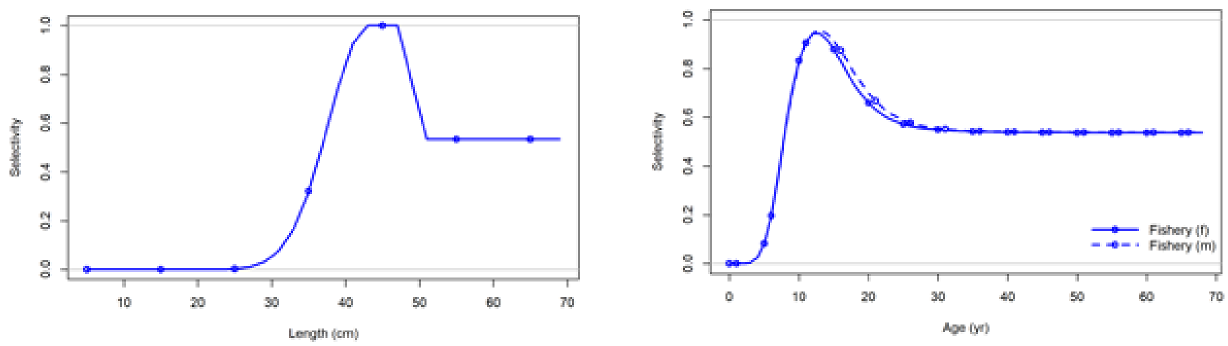


Figure 50. Length- and age-based selectivity when adding a block in 2006.

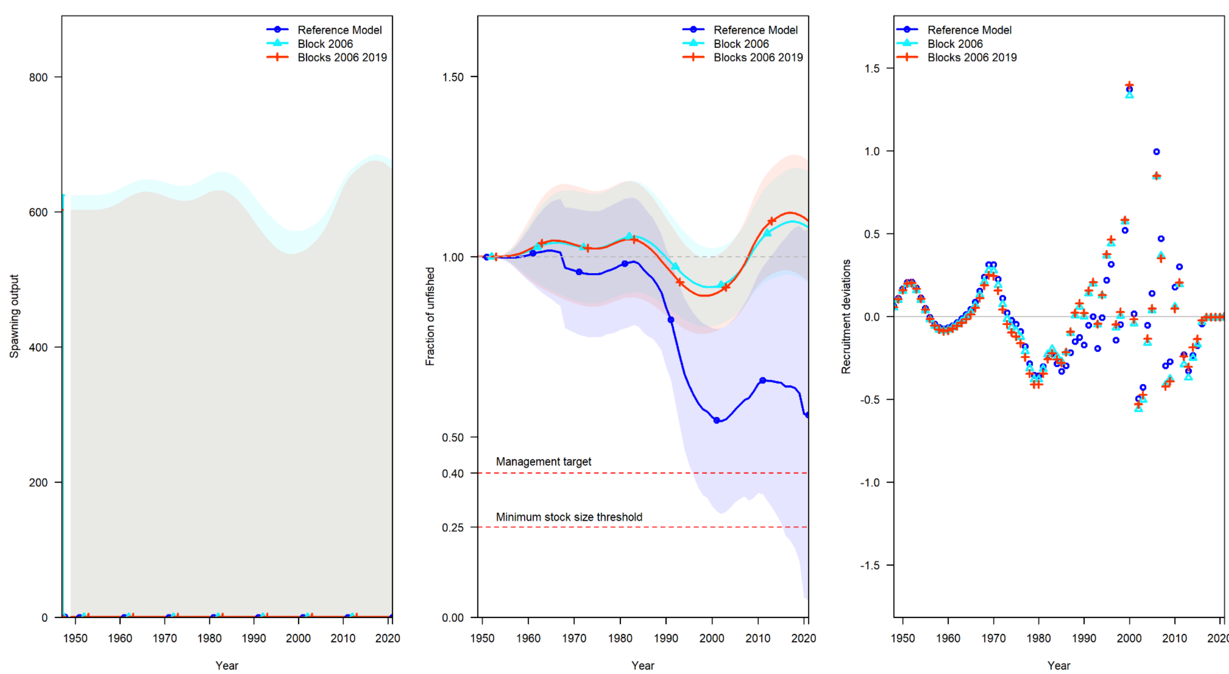


Figure 51. Comparison of spawning output, relative stock size and recruitment deviations with the reference model, time blocking in 2006 and time blocking in 2006 and 2019.

Panel Response: Given the lack of improvement to model fit and unreasonable ln(R_0) values, the STAT and the Panel agreed that time blocking should not be implemented.

Request No. 5: Explore a decision table structure across the log-likelihood of M using the base model. Use the following catch streams: default harvest control rule under a category 2 designation (sigma = 1.0, P* = 0.45), P* = 0.4, and constant catch under an MSY (FMSY of 50% SPR).

Rationale: Natural mortality is the major axis of uncertainty and this structure appears to be a good one for the decision table since these estimates directly affect estimation of OFLs. The catch streams appeared to be within a reasonable range.

STAT Response: The STAT provided projections for the base model using four different catch streams: the harvest control rule predicting an OFL which was reduced based on a P* of 0.45 and a category 2 sigma of 1.0, the harvest control rule predicting an OFL which was reduced based on a P* of 0.40 and a category 2 sigma of 1.0, and constant catches equal to the equilibrium yield using an F_{SPR} = 50% with and without a buffer based on a P* of 0.45 and a category 2 sigma of 1.0. A complete decision table is presented in the post-STAR version of the assessment. The decision table columns representing the appropriate *M* values from the likelihood were determined by fitting a parabola to the likelihood values over *M* and interpolating 0.66 units away from the maximum, corresponding to the 12.5%, 50%, and 87.5% quantiles.

Panel Response: The STAT and the Panel agreed that natural mortality was the major axis of uncertainty for the decision table. The decision table columns representing the appropriate *M* values from the likelihood were determined by fitting a parabola to the likelihood values over *M* and calculating values that were 0.66 units away from the optimum, corresponding to the 12.5%, 50%, and 87.5% quantiles.

The base model was unchanged from the pre-STAR assessment and was used in the projections reflected in the decision table. Given the likely absence of sunset rockfishes and prevalence of the northernmost population of vermilion rockfish identified in Budrick (2016) and Hyde (2009), cryptic species/population considerations were not a factor in category determination. The Panel and STAT agreed this should be a category 2 assessment given the assessment for this stock segment is in the northern edge of the range of the stock contributing to the low sample sizes for composition data relied upon in the assessment, paucity of this data across the time series and resulting broad uncertainty bounds in the terminal year depletion. The default sigma value of 1 associated with the category 2 designation was used in buffer estimation, which was greater than the estimated sigma for the OFL of 0.76.

The Panel and STAT discussed appropriate catch streams with the GMT and GAP representatives. The catch streams used expected mortality in 2021 and 2022 provided by the GMT, then assumed full attainment for later years. Three catch scenarios were evaluated including 1.) using the harvest control rule was used to predict an OFL which was reduced based on a P* of 0.45 and a category 2 sigma of 1.0, 2.) the harvest control rule was used to predict an OFL which was reduced based on a P* of 0.40 and a category 2 sigma of 1.0, to add additional precaution and 3.) constant catches equal to the equilibrium yield using an FSPR=50%. It was noted that attainment has been higher than the catch streams assumed under full attainment.

The Panel discussed whether the next assessment should be an update or a full assessment. The Panel agreed that these assessments were thorough, complete, and the best available science. Although an update would be reasonable in the future, the Panel recommends a full assessment the next time this stock is assessed because there have been recent changes in management, this is the first full assessment, attainment is likely to be reached or exceeded, and more data is anticipated to be available from fisheries and surveys. Additionally, stock structure is a major uncertainty and research is currently being done that will inform stock structure and assessment structure in the future. Conducting full assessments for all stocks also provides the benefit of synergistic evaluation of considerations across assessments, resulting in broader consideration of identified issues in the course of the deliberations of each. The full assessment framework will provide the flexibility to implement innovations that are not afforded under an update. It was also noted that vermilion catches make up a considerable proportion of the complex ACL.

The Panel agreed that a summary table containing reference points from each stock assessment and summed over the pertinent stock assessment results for each management area would help inform the coastwide management of vermilion and sunset rockfishes.

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

The base models for each assessment area reflect a balance of parsimony and reality achieved through investigation of model runs considering model structure, data and parameter treatment, estimation phasing, and jittered starting values. While natural mortality was identified as the major axis of uncertainty in all the assessment areas, the assessment south of Point Conception California incorporated a bivariate matrix approach to reflect uncertainty in both natural mortality and steepness.

There is tension between length and age data as shown in the likelihood profiles. The length data suggest lower natural mortality when compared to the length data which suggest higher natural mortality. This can be an issue, as changes in the relative weights for each of these data sources can dramatically change the natural mortality, and hence productivity and stock size. Descriptions of the various sensitivities and likelihood profiles used to evaluate uncertainties in each assessment are provided below, as well as a description of how the major axis of uncertainty was evaluated relative to the base model in decision tables.

Southern California Model

The post-STAR base model estimated steepness and modelled a change in selectivity for the commercial hook-and-line fleet in 2017. These sources of variability and uncertainty were in addition to the pre-STAR treatment of parameters and temporal variability. Many sensitivities were conducted by the STAT to explore uncertainty in the pre-STAR base model, and some of those were repeated with the post-STAR base model (see Request 4 for the southern California stock assessment). Likelihood profiles were run for natural mortality, steepness, and R0.

The model was robust to the sensitivities that were performed. An analysis dropping data from a single fleet showed that no single data source was extremely influential, although dropping either of the recreational fleets (REC_PC or REC_PR) reduced the stock status for a more depleted stock but remained above the management target in 2021. Removing the hook-and-line survey resulted in a slightly higher spawning output, but similar depletion. Halving or doubling the historical catches had expected results but applying different proportions on the species comps historically showed uncertain historical estimates of spawning output. Likelihood profiles showed that natural mortality was a major source of uncertainty and was defined as one axis of uncertainty along with steepness.

Estimating steepness in the post-STAR base model incorporates that uncertainty directly into the estimates, thus providing a more complete estimate of total uncertainty. However, there are some sources of uncertainty that are not modelled. For example, differences in the life-histories and exploitation of vermilion and sunset rockfish adds a considerable uncertainty to the model. Additionally, the connection with vermilion and sunset rockfishes in Mexican waters was not considered in this stock assessment. These additional uncertainties lead to a category 2 recommendation for this stock.

Northern California Model

A multitude of sensitivity analyses were conducted for the northern California model. These included the "Drop one" (where fleets were removed one at a time from the model), estimation of steepness rather than fixing it at the prior, starting recruitment deviations five years earlier or later than the base model, using the McAllister-Ianelli data weighting scheme rather than the Francis method, and mirroring recreational discard selectivity to retained fleets (PC or PR) rather than fitting to discard length comps. Additional sensitivities included fixing M using the observed maximum age (80 years), setting all length selectivities as a two-parameter asymptotic curve, setting all selectivities as a four-parameter domed shaped relationship, and using a Ricker stock recruitment relationship. A retrospective analysis was also conducted, where the terminal year of the assessment was sequentially removed from the model for 5 years.

Likelihood profiles and sensitivities were also run across other parameters. Natural mortality varied from 0.05 to 0.13 in 0.01 increments. Steepness also varied from 0.3 to 0.9 in 0.1 increments. And likewise, $ln(R0)$ also varied from 5.7 to 6.4 in 0.1 increments. Uncertainty in the historical catches was also explored by halving or doubling the pre-1980 catches.

From all these analyses, it appeared that the base model was relativity robust. Removal of the recreational party charter fleet, using McAllister-Ianelli weights, and setting natural mortality to the max observed age, had the largest effects but did not result in changes to stock status, nor were they outside the uncertainty interval. The retrospective analysis showed no pattern.

Likelihood profiling for natural mortality, steepness, and $ln(R0)$ indicated that the model was most sensitive to natural mortality, as expected. Like other models in the region, there was a tension in the likelihood profiles, with length data pushing the model to lower natural mortalities, while age and abundance data were pushing in the opposite direction. This contradictory to the southern California mode where age data rather than the length data pushed the model to lower natural mortalities. The reason for this difference between north and south of Point Conception remains uncertain.

Oregon Model

Uncertainty estimates for the important outputs were obtained from asymptotic standard errors estimated using the inverted Hessian matrix from the fit. This estimate relies on relatively informative data sets to estimate the variance well and ensure that the parameter error distribution is approximately Gaussian. There was evidence that some parameter confidence intervals would not be symmetric as assumed. In addition, a ten-year retrospective analysis was conducted by running the model and sequentially removing one year of data each time.

Likelihood profiles were conducted for $ln(R0)$, steepness (h), female and male natural mortality (M) values separately and varying together, female and male maximum length (L_∞), female and male growth coefficient (k), female and male variability of size at maximum age. In addition, joint profiles over L_∞ and k (that maintains their correlation structure) were done for females and males separately.

A wide range of sensitivity model runs were completed. Twelve alternative data treatments were explored consisting of removing different data groups (i.e., weighting specific data to zero), where the groups were the catches, length, length-age and indices, alternative weighting data schemes, including alternative CARE ageing error, and alternative treatment of sex-ratio for the commercial length data. Seventeen alternative model specifications were explored based around fixing various life history parameters (natural mortality, growth and stock-recruitment parameters), and setting fecundity proportional to weight and estimating a dome-shaped selectivity.

These uncertainty evaluations suggested that the results from the base model are relatively robust despite the uncertainties. They identified natural mortality as the most important uncertainty affecting estimates of productivity and the future outcomes from future fishing scenarios.

Washington Model

The model is described in the summary section above and final parameters used in the base model are provided in Table 13. Sensitivities conducted include data removal, catch histories, length treatment, ageing error, fixing life history parameters (M, growth, and recruitment), Lorenzen age-based M, fecundity proportional to weight and domed steepness. Data removal selectivities were analyzed with various combinations of length, catch and age data with and without estimating recruitment. Sensitivity to catch history was evaluated using minimum and maximum assumptions and inclusion and exclusion of outlier values. Francis weighting methods were used in the base model, though the Dirichlet-Multinomial, Mc Allister-Iannelli and no weighting were explored as sensitivities. Ageing error was evaluated for the results of the CARE exchange. Likelihood profiles for ln R_0 support a value of 0.91 and increased values of stock status toward unfished at higher values, while those for h showed little sensitivity of stock scale or relative stock status.

The major axis of uncertainty was M and likelihood profiling over various levels of M identified a range of 0.6 to 1.2, with higher values resulting in higher biomass and relative stock status. Evaluation of spawning output and stock status across M values identified asymmetric uncertainty in the outcomes with greater uncertainty at higher M. Alternative models to bracket uncertainty were based on the 12.5% and 87.5% quantiles around the final year spawning biomass. Values for female M were chosen so that model estimates of final year spawning output matched the 12.5% and 87.5% quantiles.

Table 13. Parameters used in the base model of vermilion rockfish in the Washington model.

Parameter	Value	Phase	Bounds	Status	Prior (Exp.Val, SD)
NatM p 1 Fem GP 1	0.085	3	OK	0.0129347	Log Norm (-2.30259, 0.438)
L at Amin Fem GP 1	1.968	3	OK	3.70137	None
L at Amax Fem GP 1	57.106	3	OK	1.01762	None
VonBert K Fem GP 1	0.093	3	OK	0.00850602	None
CV young Fem GP 1	0.090	3	OK	0.0265344	None
CV old Fem GP 1	0.053	3	OK	0.00664901	None
Wtlen 1 Fem GP 1	0.000	-99	-	-	None
Wtlen 2 Fem GP 1	3.100	-99	-	-	None
Mat50% Fem GP 1	39.400	-99	-	-	None
Mat slope Fem GP 1	-0.342	-99	-	-	None
Eggs scalar Fem GP 1	0.000	-3	-	-	None
Eggs exp len Fem GP 1	3.548	-3	-	-	None
NatM p 1 Mal GP 1	0.087	3	OK	0.0134205	Log Norm (-2.30259, 0.438)
L at Amin Mal GP 1	-2.671	3	OK	4.76078	None
L at Amax Mal GP 1	54.240	3	OK	0.687875	None
VonBert K Mal GP 1	0.109	3	OK	0.00906197	None
CV young Mal GP 1	0.149	3	OK	0.0402358	None
CV old Mal GP 1	0.037	3	LO	0.00760099	None
Wtlen 1 Mal GP 1	0.000	-99	-	-	None
Wtlen 2 Mal GP 1	2.960	-99	-	-	None
CohortGrowDev	1.000	-1	-	-	None
FracFemale GP 1	0.500	-99	-	-	None
SR LN(R0)	0.908	1	OK	0.612927	None
SR BH steep	0.720	-1	-	-	None
SR sigmaR	0.600	-6	-	-	None
SR regime	0.000	-99	-	-	None
SR autocorr	0.000	-99	-	-	None
Early InitAge 1	0.060	3	act	0.615948	dev (NA, NA)
Main RecrDev 1949	0.107	1	act	0.627134	dev (NA, NA)

Technical Merits of the Assessment

The technical merits common to all assessments are provided below, with stock specific merits to follow.

All the available data were used in the stock assessment. A wide range of available data were examined and data from each region was only excluded on the basis that it was not relevant (i.e., contained no information) to the population dynamics of vermilion rockfish.

By incorporating age/length and in some cases indices of abundance in an integrated length/age-based assessment, the results of these assessments represent improved knowledge of the status of the stock and sustainable harvest levels compared to the previous data-poor assessments.

The STAT teams explored many alternative models, including Bayesian models, within the Stock Synthesis framework. These alternative modelling approaches were not presented in detail but 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. Widening the approaches used to assess these stocks improved the quality of the assessment overall and indicated potential solutions to some problems, such as the asymmetric uncertainty estimate of stock size and modelling recruitment deviations when little information is available to support non-zero values.

The approaches to index standardization are rigorous, making use of generalized linear mixed models to include all significant covariates that might be related to vermilion rockfish catchability. Alternative Bayesian GLM standardization models were explored to check whether indices were robust. Full information was available on the model fits and diagnostics.

Southern California Model

The southern California stock assessment model is a technically sound model that was robust to many of the uncertainties examined. Many sources of data were used in the model, and no major conflicts between those data sources were identified. The fishery-independent data included the hook-and-line survey with a time-series of abundance, length, and age data starting in 2004. This survey is an important data source for vermilion and sunset rockfish and recently expanded into the Cowcod Conservation Areas to supply representative sampling in these areas closed to fishing. Observer data collected onboard recreational vessels supplies high resolution data for the recreational fisheries; continued monitoring of commercial fisheries has allowed for the model to incorporate important changes in management.

The varied, yet consistent data sources allowed for the estimation of M and h, which is not common in groundfish stock assessments. The hook-and-line survey began when the stock was near a low point and has collected data while the stock has been increasing. This perspective on recruitment before and after the smallest stock size likely contributes to the ability to estimate both parameters.

Northern California Model

Like with the other areas, the northern California stock assessment had many merits in how it was conducted, and in the data used. Chiefly there is a good amount of high-resolution on-board observer data for the recreational fleet. This allows for good monitoring of the fishery dynamics and an excellent ability to capture management changes and the effect on selectivity.

Additionally, the STAT ran a multitude of sensitivity analyses. These highlighted the model's behavior under a variety of formulations and potential states of nature. While this work allowed for a good discussion of the uncertainty around parameters like natural mortality, it did highlight how these sensitivities impacted the model. In furtherance of that goal of defining uncertainty, the range of sensitivities allowed for a full exploration of the axis of uncertainty and allows for a more robust definition of how that uncertainty translates to management goals.

Oregon Model

Oregon fishery age data proved to be particularly important to the estimation of natural mortality, which is the most important source of uncertainty in the current assessment. There were 896 commercial age samples available from 2004 and 2007 – 2020 and 1,180 recreational age samples available from 2005–2020, primarily from the southern Oregon coast. These data were important in fitting the model and highly informative on growth and mortality parameters. In addition, bias and imprecision in ageing was quantified and integrated as a source of variability into the stock assessment by estimating the ageing error matrix. This was carried out by estimating the ageing error matrices for commercial and recreational fisheries respectively using within reader comparisons (n = 181 for commercial; n = 237 for recreational), representing a significant proportion of the available age samples.

Washington Model

Despite the low sample sizes and paucity of length and age data in the Washington assessment, the STAT was able to construct a relatively robust model, structured such that it accounts for many potential sources of uncertainty. In addition, the proportion of fish for which both length and age were available for use in ageing and estimation of conditional age-at-length made good use of the available encountered specimens to the benefit of the model. Sampling efforts to obtain additional samples will be of continued benefit to future assessments.

Technical Deficiencies of the Assessment

The technical deficiencies common to all assessments are provided below, with stock specific deficiencies to follow.

Management depth restrictions (and other management interventions) potentially interfere with monitoring information where there is strong reliance on fishery-dependent composition data and indices. This applies mainly to the Oregon and Washington stock assessments which do not have fishery independent surveys. A survey can ignore management interventions or be adjusted to account for them, whereas a fishery dependent index will be affected directly. Management interventions have largely been directed at other species, such as yelloweye rockfish, but impact on recreational trips that also catch vermilion and sunset rockfish. While corrections such as adjusting the standardization model or introducing separate time blocks into the stock assessment address this problem, the uncertainties in the results are greatly increased.

While efforts were made to identify ecosystem considerations such as trophic relationships and environmental drivers of recruitment, there was not a 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.

Southern California Model

The southern California model has few technical deficiencies, but two were identified. First, the inability to easily distinguish between the two cryptic species and to accurately split historical and current catches into the two cryptic species add a considerable uncertainty to the results. The two species show differences in depth preferences as adults, and with potential different life histories as well as depth closures to the fisheries, there are likely to be different effects of exploitation on these two species. At this time, there is no clear way to avoid this deficiency, but upcoming research may provide more insight into the distribution and identification of the two species. Second, there was a lack of age data from commercial and recreational fisheries. All age data are from fishery-independent sources, with the majority of observations sampled from the hook-and-line survey.

Northern California Model

In addition to the general issues mentioned above, there was a lack of age data to inform the northern California model. Age data is likely to be important in the northern model as it contrasts with the length data that tends to pull the model to lower natural mortality. Better ageing information may help to resolve this tension between data sources.

Given the discussion during the request phase of the review, it was clear that the model simply wasn't fitting the most recent years of the Private/Rental index. While the cause is uncertain, the issue highlights the difficulty in relying on fishery dependent indices alone (see below). This can be particularly problematic during projections, as this lack of fit is likely to get worse over time unless rectified.

The lack of a fishery-independent index in this area was also troubling. While fishery dependent indices are sufficient, having a fishery independent index removes some of the issues of changing fishing behavior as well as management changes that can affect a fishery dependent index. These management changes result in even more complexity to a model's structure as it requires time blocks to account for these changes. Likewise changing spatial management also affects these fishery dependent indices, changing not only selectivity, but also availability.

An increase in the number of unidentified rockfish was also noted during the review of the northern California model. While apparently the result of COVID-19 restrictions on sampling, the effect of unidentified catch should be more fully explored. Even if only prevalent in 2020, given the resumption of length data collection in 2021, these data are likely to affect any model update or full assessment in the years to come.

Many of these issues are not exclusive to the northern stock model, but occur in varying degrees of importance across all, if not most, of the stock areas examined by the Panel. As with other areas, these simply could not be addressed in the time allotted for this review. To address these issues, a number of research recommendations were made which have some ability to decrease these uncertainties if addressed.

Oregon Model

There are no fishery independent indices for the Oregon stock assessment. Fishery dependent indices are potentially affected by gear and operational changes and management interventions, which may be corrected through standardization models, but may still substantially add uncertainty. In addition, fishery independent indices are obtained following good scientific survey principles, which are robust and can collect additional information to detect and account for effects such as ecosystem change, which can aid in modelling the population dynamics.

Washington Model

To some extent the relative dearth of ages and lengths is inevitable given that the species is relatively rare at these latitudes. The limited data directly contributed to the wide confidence bounds on estimates of stock status making this a category 2 stock assessment. The lack of indices of abundance and especially fishery independent indices, limits selectivity options for the remaining fleets and its absence prevents representation of the relative abundance in the assessment. Unfortunately, the relatively rarity of the species at this latitude makes it unlikely that a survey could be developed to provide additional length/age data or a representative index of abundance for this stock, even if focused on primary habitat. This technical deficiency is likely to persist.

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 STATs regarding STAR Panel recommendations.

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

The ORBS index for the Oregon model was filtered to only use summer months. The GMT had concerns about only using summer months due to there being seasonal depth restrictions during those same months since 2007, possibly preventing anglers from accessing the entire depth/area of the stock. The STAT Team examined this by using full years of data which showed minimal differences in the model outputs. The issue was addressed to the GMT's satisfaction.

Regarding recreational removal assumptions for the current and following year (i.e., for 2021 assessments, the projections for 2021 and 2022) in all models, the GMT questioned if the STAT would prefer the projections be provided in numbers of fish when possible (e.g., for Washington recreational projections). Providing projections in the preferred unit will help reduce the potential for error each time the projections get converted from numbers of fish to metric tons for GMT projections and then back to numbers of fish for the assessments. However, the GMT notes that some states may not be able to provide recreational projections in numbers of fish because their respective models estimate projections in metric tons.

Unresolved Problems and Major Uncertainties

The unresolved problems and major uncertainties common to all assessments are provided below, with stock specific ones to follow.

The stratification of assessment areas along the coast was based on consideration of population structure identified in genetic analyses, differences in historical exploitation, disparate geographic availability of data sources and state specific regulation histories to mitigate the catch of overfished species affecting catch of co-occurring stocks like vermilion and sunset rockfish. The Panel discussed the potential for alternative stratifications such as north and south of Cape Mendocino depending on the results of future analysis of population structure under the Saltonstall/Kennedy grant discussed in the assessment south of Point Conception, to better understand the distribution of sunset rockfish, potential for hybridization and resolve considerations surrounding population structure apparent in vermilion rockfish. A more regional approach might allow for greater efficiency gained by fewer assessment areas, while accounting for key differences.

Natural mortality remains the primary axis of uncertainty across assessment areas. Additional collection of lengths and otoliths from across the range of the stock and ageing existing structures from the hook and line survey may help reduce uncertainty in the future.

Southern California Model

The presence of two cryptic species and the connection with Mexican waters are two unresolved uncertainties in the southern California model. These will require additional research and coordination to resolve, noting that research is currently planned to investigate the two cryptic species. One of the cryptic species may be more susceptible to harvesting or may be unequally affected by past fishing, depending on life-history traits and management regulations. Potential stock structure with Mexican waters should be investigated to determine if the abundance and fishing in that area is affecting the population in southern California.

The major uncertainties in this stock assessment were estimates of natural mortality, steepness, and the stock boundary with northern California. Natural mortality was estimated at a higher value than other area-specific stock assessments for vermilion, and male natural mortality was fixed equal to female M. Steepness was estimated at a value near the median of the prior distribution, but likelihood profiles showed that values above 0.9 were likely. These two parameters were used to define alternative states of nature representing uncertainty in productivity. The stock boundary with northern California was defined as Point Conception, which is a boundary separating different ocean conditions. Estimates of natural mortality were much lower in the northern California stock assessment, and it would be useful to investigate if there is a latitudinal cline in natural mortality, a sudden shift in natural mortality associated with a boundary, or if the different estimates are an artefact of the data.

Northern California Model

The northern California model was not fitting the end of the time period for the Private/Rental index. The cause for this lack of fit is not well understood, despite numerous requests to examine this behavior. As outlined elsewhere, this can be problematic particularly for projections as it adds yet another layer of uncertainty. Unless addressed, this lack of fit could become even more problematic for future updates or full assessments.

As mentioned above in the overview, the connectedness and stock boundaries issues are particularly acute for the northern California area. How this stock is related to the stock south of Point Conception, as well the connectedness of the northern California stock assessment area to the Oregon area is not very clear.

Another unresolved issue is how the model estimates natural mortality. Despite being in close proximity to the southern California assessment area, the northern California model estimates a rather different natural mortality (Table 1). Given the uncertainty in the connectedness of the southern and northern California assessments, it is unresolved as to why each model is estimating such a different natural mortality, despite having a similar steepness.

Oregon Model

No information was available on last four recruitment deviations, which increases uncertainty of short-term projections because the biomass associated with these deviations is included in biomass projections. This is a common problem in assessments based on length and age data from larger, older individuals. Depending on how quickly they contribute to spawning output, the inability to estimate the abundance of these juveniles will make short term projections more uncertain. This might only be resolved through the capture of smaller fish, perhaps through a fishery independent survey.

Washington Model

There was some asymmetry in uncertainty given the more optimistic results of sensitivities, indicating the population may be larger than the base model would suggest.

Very wide uncertainty bounds around spawning output and depletion, contributed to the recommended category 2 designation. This is related to the amount and paucity of data available. Given the assessment area is at the edge of the range limiting sampling opportunities, this may be a persistent issue contributing to a continued application of a greater scientific uncertainty buffer in the future.

Recommendations for Future Research and Data Collection

The recommendations for future research and data collection common to all assessments are provided below, with stock specific ones to follow. High or low priority is indicated for each.

There is a need for a coastwide hook and line surveys to provide indices of abundance and associated biological sampling, contributing representative data in untrawlable habitats. This could be achieved through expansion of the current NWFSC Hook and Line Survey. (High Priority)

Additional age and length data would be beneficial in all assessment areas. This need was particularly acute in the California assessments where sample sizes were relatively low given removals. (High Priority)

The panel expressed support for additional genetic studies like the Saltonstall/Kennedy research mentioned in the California assessments or other additional research to further investigate population structure, evaluate the distribution of the cryptic species and populations, the potential for hybridization and identify physical characteristics associated with each species/population to allow definitive identification in the field would be beneficial. In addition, collection of species/population specific life history information such as growth and age of maturation as well as evaluation of length/age compositions for differential recruitment, would determine if there are disparate demographic trajectories or whether commonalities make differentiating between them less critical. In addition, whole individuals should be retained for further examination to identify characteristics associated with the genotype of species/populations that can be used in the field to discriminate between them easily and definitively. (High Priority)

While the Committee of Age Reading Experts inter-lab exchange and estimation of ageing error resulted in excessive variation in ageing results, the Panel is supportive of efforts to provide better resolution of ageing error through inter-lab ageing efforts. Age data are important for the estimation of natural mortality, which was found to be an important source of uncertainty across all four vermilion/sunset rockfish stock assessments. (High Priority)

MPAs provide a useful contrast to exploited areas where species are sufficiently sedentary that they can be considered to represent lightly exploited or unfished population components. These areas become useful for research, possibly providing improved estimates of fish density, catch rates and longevity for unexploited populations, as well as on fish ecology and species interactions. Collection of additional data from within MPAs from CCFRP or ROV surveys will provide representative data across the entire population to complement data collected in areas open to fishing, to better represent the stock as a whole (High Priority)

Examine the available tools to more fully account for abrupt changes in the footprint of the fishery or survey as a result of management action. These tools may include (but are not limited to), treating the “new” and “old” surveys as completely separate (aka breaking the survey), using selectivity blocks, or spatial/temporal modeling approaches. This avenue is important for many fishery-independent and -dependent indices, as they are subjected to numerous spatial management changes which in turn can affect the comparability of the data collected. Additional efforts are needed to investigate how fishery selectivity changes with management actions and how best to address the effects of management changes on length composition and indices. (High Priority)

Expanding the California Collaborative Fisheries Research Program from the current 120 ft depth or starting similar surveys that sample in deeper waters outside, if not inside MPAs and other closed areas to encompass the full depth distribution of vermilion and sunset rockfish or other shallow shelf rockfish species would provide valuable data for future assessments. (High Priority)

The Panel expressed support for ROV surveys in deeper depths than the current surveys focused in depths less than 100 meters to encompass the full distribution of the vermilion and sunset rockfish and other shallower distributed shelf rockfish species both inside and outside of areas closed to fishing i.e., CCA, RCA and MPA. The density estimates from the ROV survey can be combined with seafloor mapping to estimate biomass. Higher resolution seafloor mapping in deeper depths would also be beneficial though lower resolution data is available. The ROV survey also provides length compositions. (Low Priority)

The WCGBT survey contains useful information for the many rockfish species, including vermilion and sunset rockfish which are associated with rocky habitat. The data from this survey typically contain observations of the smallest fish compared to other data sources. Future research to examine how the data from this survey may be used in assessments of rockfish species that are not commonly encountered by trawl gear would help to inform best practices for future rockfish assessments. (Low Priority)

A management strategy evaluation (MSE) focused on the effectiveness of single or combined species assessment models when assessing a complex of species would inform risks associated with the current management framework and provide management guidance. (Low Priority)

Additional effort to resolve uncertainties in historical catch reconstructions would improve estimates of the scale of assessments and provide more representative removal estimates. (Low Priority)

There is some question whether it is more efficient or accurate to use of numbers of fish vs. biomass as an input for projections in the first two years (2021-2022) provided by the GMT providing predicted catch in decision tables. The projected mortality in metric tons is converted to numbers using the solver developed by Chantel Wetzel, though this can result in minor deviations given the rounding error in conversions using selectivities for each fleet. This may be a topic for further discussion at the Stock Assessment Process Review for which advice can be developed for the Accepted Practices document to provide clarity in future assessments. (Low Priority)

Additional fish tagging experiments may improve estimates of movement, mortality, and growth. (Low Priority)

Investigate ways to better incorporate recreational discards into assessments, possibly using some of the methods currently used to model commercial discards. (Low Priority)

Examine how to better account for asymmetric uncertainty through use of Bayesian frameworks such as SIR or ensemble models to capture asymmetry. Current models are not properly weighting the various models, given the distribution of the outcomes at the tails across values for M. Simple MCMC runs would provide an idea of what the asymmetry in uncertainty looks like. An ensemble of multiple M values would allow evaluation of various models and capture the asymmetry. Alternatively integrating across uncertainties at various levels of M could be done in a Bayesian method. The Bayesian methods in an ensemble likelihood to approximate uncertainty might provide results in a shorter time frame than MCMC, while accounting for asymmetry. A Bayesian approach to sensitivities would allow more integration across models to inform weighting of likely scenarios and capture uncertainty across models. (Low Priority)

Southern California Model

There is currently a very small amount of fishery-dependent age data collected in southern California such that none were included in the southern California stock assessment. Increasing these samples would improve the model and would maintain age data if fishery-independent surveys were unable to. (High Priority)

The hook-and-line survey is a very important and informative source of data for the southern California stock assessment. The survey expanded into the Cowcod Conservation Areas (CCAs) in 2014, supplying observations from areas closed to fishing, and thus providing improved monitoring of vermilion, sunset, and other rockfishes. The stock assessment modelled this survey as two distinct fleets, although fit to the entire index time-series using the selectivity of the fleet representing the expanded survey. As noted above, additional research into methods to standardize the hook-and line survey index and use the length and age data would improve this and other stock assessments. Potential topics are the use of statistical models to account for hook saturation, spatio-temporal models to predict observations from stations not observed in a particular year and to incorporate the CCAs into the entire time-series, the similarities with other hook-and-line fishery-independent surveys along the west coast, and the potential to expand the current hook-and-line survey into other areas of the west coast. (High Priority)

Northern California Model

Connectedness of this stock with southern California is an unresolved uncertainty as outlined in the STAT report and elsewhere in this report. Further studies on larval/juvenile/adult movement via tagging or other methods are warranted. Additionally, population substructure investigations, particularly north and south of Cape Mendocino are also recommended. (High Priority)

As outlined in this report, the northern California model is not fitting the most recent years of the Private/Rental recreational index very well. Further examination of this issue is recommended including spatial-temporal analysis to understand this lack of fit. (High Priority)

Development of a fishery independent index is a priority for this region. This could involve expansion of the CCFRP across depths and latitudes or expansion of the NWFSC Hook and Line Survey northward. Due to changes in both management and fishing behavior, fishery dependent indices may be difficult to apply to this region, requiring changes in selectivity, and other complex analysis. Use of a standard fishery independent index will remove some of this uncertainty and complexity, as it has in the southern California assessment. Documentation using a fishery independent design could also help to highlight climate change impacts in this area as well as being a springboard for future investigations of the stock's biology. (High Priority)

Oregon Model

Given that results are most sensitive to natural mortality, methods to improve the prior for M might be considered. The current prior favors a higher natural mortality than was estimated in the model. Improved estimates of natural mortality might be obtained from age composition of unexploited areas (MPAs), tagging, increasing age samples from catches and computer simulation studies. (High Priority)

Further investigate the Stephens-MacCall method for sub-setting data used in indices. The Stephens-MacCall method may not be fully appropriate for subsetting trip data in some cases and may not account for all information available. For the Oregon ORBS index, the filtering removed around 90% of all trips and 10% of positive trips where vermilion was caught. This may not be the most efficient use of the data, particularly as data are limited in this case. Therefore, it would be worth considering alternative ways to identify and estimate one or more unobserved latent categorical variables that might be used to define not only which trips to include in the abundance index estimation, but also in a Bayesian standardization model. (High Priority)

Carry out research to improve the understanding of functional maturity. The primary measure of recruitment used in the assessment is spawning output (SO) which estimates million eggs produced. Because fecundity increases relative to fish weight, this is considered a more appropriate measure. However, fecundity also changes over time with physiological behaviors such as delayed maturity, skipped spawning and atresia. Research on vermilion and sunset rockfish maturity and fecundity could lead to changes in the measure of spawning output and more accurate estimates of stock productivity. (Low Priority)

Develop a Bayesian approach to stock assessment of vermilion and sunset rockfish, particularly for stocks where available data are limited. Capturing and reporting the uncertainty is an important part of stock assessment. Both Oregon and Washington rely on less data for these assessments, and small data sets often lead to higher uncertainty. The Bayesian approach is the best way to estimate uncertainty, and models for the smaller datasets could be developed more easily than the larger to evaluate a Bayesian approach. Bayesian models are more complex to fit because they attempt to map out the whole probability density (prior and likelihood) rather than just find a maximum point. However, this also allows greater simplification by integrating across uncertainty to produce final statistics summarizing the results while fully encapsulating the uncertainty. (Low Priority)

Washington Model

Very wide uncertainty bounds around spawning output and depletion, contributed to the category 2 designation. This is related to the low sample size and paucity of data available as a result of low encounter rates at the edge of the species range. Additional data collection efforts that would improve sample size or capitalize on increased encounters would help address the wide confidence bounds and increase the potential for a category 1 designation. (High Priority)

An in-depth historical catch reconstruction conducted for the 2015 black rockfish assessment allowed bycatch rates with vermilion rockfish to be estimated from the well sampled recent period to be applied to years in the past when estimates were not available to approximate catch, though correlations were weak between species. The more pelagic habits of black rockfish and high density sometimes prevent hooks from reaching the seafloor, which may contribute to the poor correlations. Use of the minimum and maximum catch ratio were used to address uncertainties in the catch histories. The catch has been sufficiently low that the model is insensitive to the past catch, but examination of bycatch relationships for co-occurring demersal species such as copper or quillback rockfish may be more ideal. (Low Priority)

Further evaluation of the results of the CARE otolith ageing exchange may help explain very disparate results reflected in the ageing error matrix, which did not allow model convergence. The error in Washington lab age reads were higher than other labs. Sample size at age is worth examining to see if poor ageing of a few larger individuals might be contributing disproportionate to the ageing error. (Low Priority)

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