Canary Rockfish
Stock Assessment Review (STAR) Panel Report

National Oceanic and Atmospheric Administration
Northwest Fisheries Science Center
Auditorium and Online
2725 Montlake Boulevard E
Seattle, WA 98112

July 24-28, 2023

Participants

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Overview

A Stock Assessment Review Panel (STAR) met July 24-28, 2023, in-person at the Northwest Fisheries Science Center Auditorium with a remote participation option to facilitate public comment and participation for those unable to travel to Seattle, WA. In addition to a full benchmark assessment for the Canary Rockfish resource off the coasts of Washington, Oregon and California, the panel also reviewed an assessment for Petrale Sole. The panel operated under the Pacific Fishery Management Council's (PFMC) Terms of Reference for the Groundfish and Coastal Pelagic Species Stock Assessment Review Process for 2023-2024. Dr. Brian Langseth and Dr. Kiva Oken of the Northwest Fisheries Science Center presented the canary rockfish assessment.

The 2023 assessment was a fully integrated age-structured benchmark assessment conducted in Stock Synthesis (SS Version 3.30.21.00) using catch, length, age, and index data from fishery dependent and independent sources. The 2015 assessment was similar, but estimated spatial allocations of recruitment by state, whereas the 2023 model estimates recruitment coastwide. Natural mortality (M) was the primary axis of uncertainty for the stock, although M acts as a lever which reflects uncertainty in other parameters which were fixed such as steepness. Based on this assessment, the point estimate of 2023 spawning output relative to equilibrium spawning output with no fishing was below the target of 40% of the unfished spawning stock output.

Summary of Data and Assessment Models

The status of canary rockfish (*Sebastes pinniger*) off the U.S. coast of Washington, Oregon and California was assessed assuming a single coast-wide stock. There is currently no genetic evidence suggesting distinct biological stocks of canary rockfish off these U.S. states and, thus, this stock of canary rockfish was modeled as a single coastwide population. Additionally, this assessment does not account for populations located in Canadian or Mexican waters and assumes that these northern and southern populations do not contribute to nor take from this population. While canary rockfish were modeled as a single population, spatial aspects were addressed through geographic separation of data sources/fleets where possible.

Canary rockfish are caught in both commercial and recreational fisheries off the U.S. coast of Washington, Oregon and California, with the majority of catches coming from commercial sources. The rockfish fishery developed off California late in the 19th century and was catching an average of almost 2,500 metric tons per year (across species) over the period 1916-1940. The northern rockfish fishery developed later, becoming established during the early 1940s, at which time canary rockfish catches increased considerably. Canary rockfish catches dropped somewhat following the war, and were generally stable from the 1950s to the 1960s. In 1977, when the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) was enacted, the large foreign-dominated rockfish fishery catches that had developed since the late 1960s were replaced by the domestic trawl fishery. The trawl fishery peaked for canary rockfish in the early 1980s and subsequently decreased after the establishment of strict management restrictions starting in the mid-1990s. Beginning in the 2000s the recreational and non-trawl fisheries took a larger proportion of total catch of canary rockfish. In 2015, catches of canary rockfish increased somewhat due to relaxation of regulations where current catches are predominantly trawl, though there is a sizable recreational component of landings, as well (Figure 1).

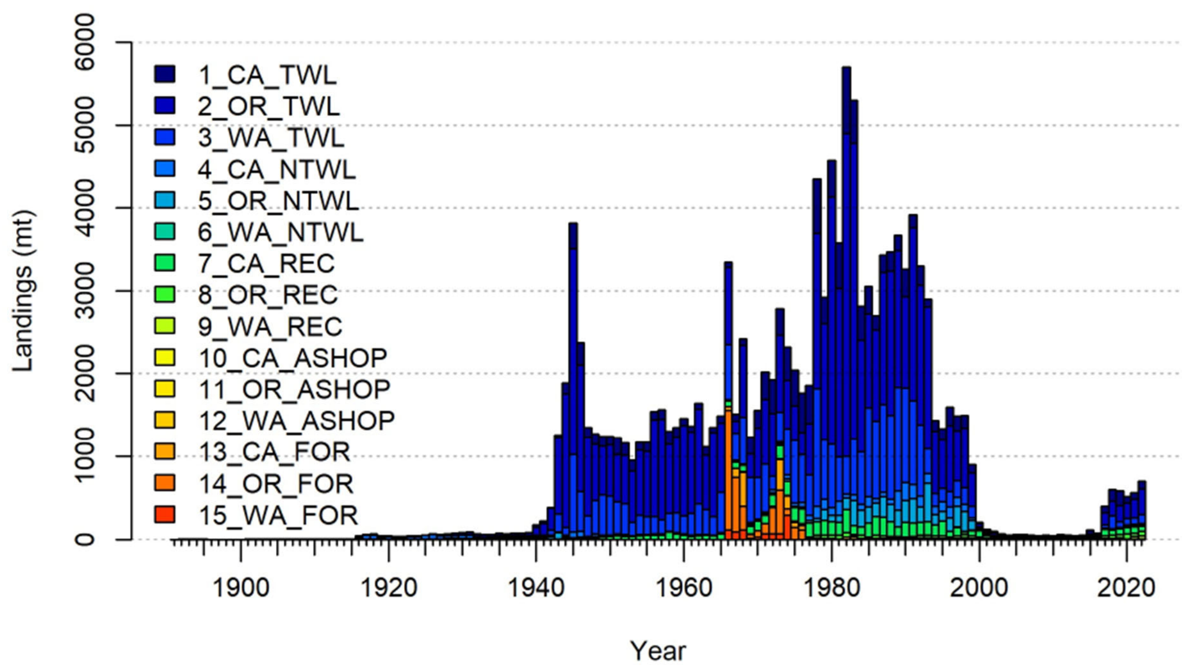

Figure 1: Catches of canary rockfish over full assessment period by fleet

Canary rockfish was most recently assessed in 2015 using an age-structured population model that allowed for spatial differences in recruitment deviations and depletion by state. The current assessment uses an areas-as-fleets approach to account for different sizes and ages of fish available in each state, but returns to a coastwide population model configuration.

The assessment model is a two-sex age-structured model operating on an annual time step covering the period 1892 to 2022 assuming an unfished equilibrium population prior to 1892. The assessment includes updated catches from five fleets (commercial trawl, non-trawl, foreign, and at-sea hake, and recreational), each of which is divided across three states; fishery-independent indices from the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS), AFSC/NWFSC West Coast Triennial Shelf Survey (Triennial Survey), and a pre-recruit survey; and age and length data from the fishery and the WCGBTS and Triennial Survey. It extends all of these data sets from the previous assessment through 2022, and also includes any updates to previously used data (Figure 2).

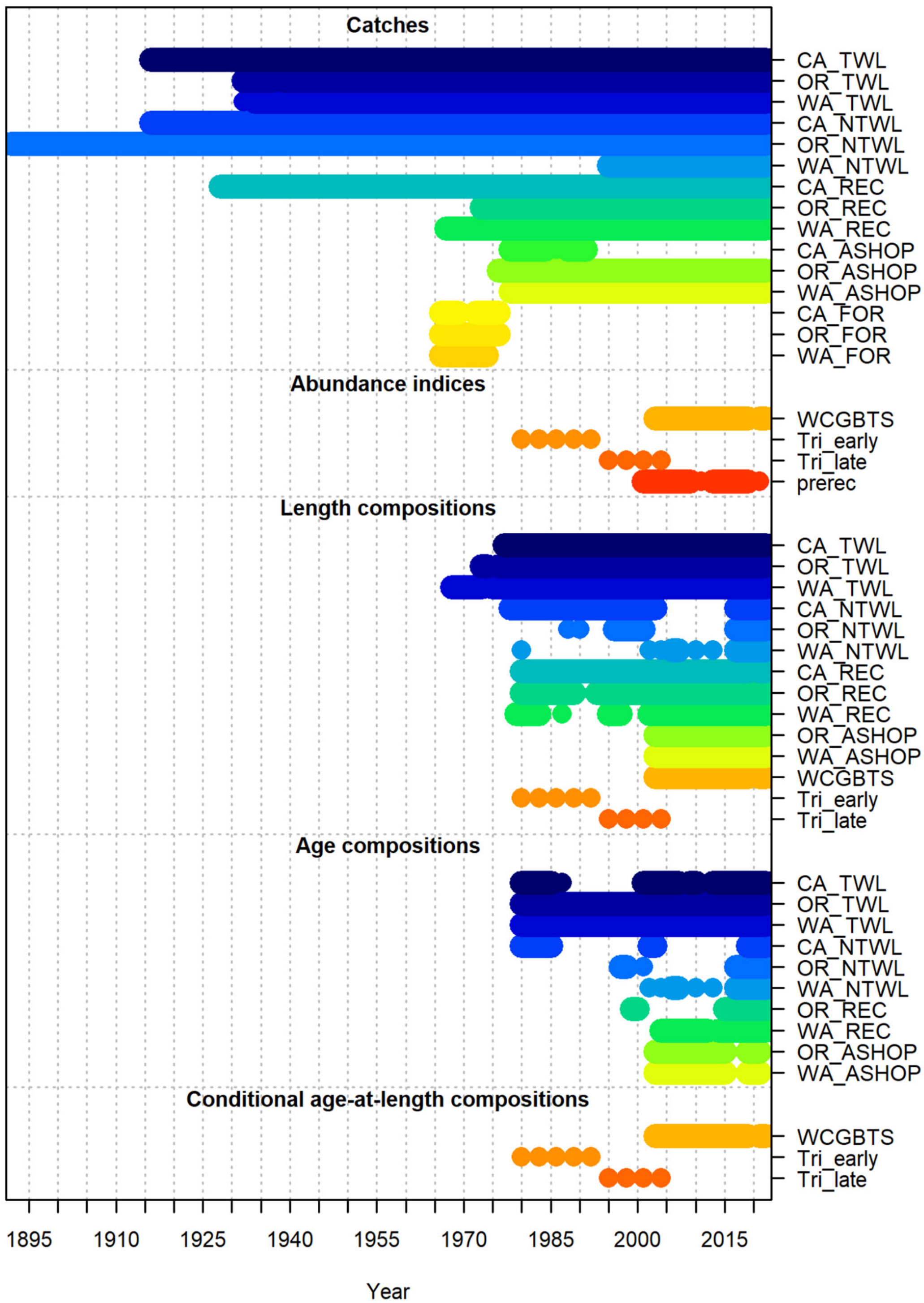

Figure 2. Availability and sources of input data for Canary Rockfish assessments.

Parameters for sex-specific von Bertalanffy growth and recruitment deviations are estimated. The assumed recruitment model was Beverton-Holt stock-recruit function with a fixed steepness (h=0.72) and sigmaR=0.5. In addition, this assessment includes an updated maturity curve based on newly analyzed ovaries and updated biological relationships for fecundity. Natural mortality was modeled as age-invariant, with male M fixed at the prior (as in the previous assessment) and female estimated. The model estimated selectivities by sex within time blocks thought appropriate for each fleet.

Model uncertainty is explicitly included in this assessment by parameter estimation uncertainty. Model specification uncertainty is explored through sensitivity analyses addressing alternative input assumptions such as data treatment and weighting, and treatment of life history parameters, selectivity, and recruitment. Base models were selected that best fit the observed data while balancing the desire to capture the central tendency across sources of uncertainty, ensure model realism and tractability, and promote robustness to potential model mis-specification.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: Include into a new model all age data that were inadvertently omitted from the draft base model provided to the panel. Provide the fits to the updated model.

In the model including the new age data, explore different selectivity blocking options for the WA recreational fishery, for a.) amalgamating the most recent block with the one just prior and b.) by mirroring selectivity in the final block to the earliest block. If these lead to similar high correlation problems with other fleets, explore a.) similar time blocking options for those fleets, or, b.) fixing selectivity at the estimated values. Present diagnostic comparisons of different model options, including the table of likelihood components.

Rationale: This would allow the inclusion into the model of all age data that were originally intended to be in the model. The selectivity exploration would allow exploration of concerns that the STAT found high correlation among selectivity parameters.

STAT Response: The STAT provided numerous slides and a full set of r4ss graphics showing the additional model runs and fits.

When combining mid and late blocks, high correlation between the early WA recreational ascending limb of the selectivity curve and the early WA recreational peak appeared. Combining all WA recreational blocks sent some selectivity estimates to their bounds so this was not considered further. Other solutions offered were reweighting just the WA recreational length and age comps (a preferred approach) or fixing the early WA recreational ascending limb (the most convenient approach). Model fits were similar, but OR non-trawl (NTWL) selectivity curve parameters then had the highest correlation (0.94). The STAT suggested that additional reweighting could be done for OR recreational or for all data sets.

When combining early and late blocks, high correlation among recent OR NTWL peak, descending, and sex-dependent descending limbs of the selectivity curve appeared. A suggested solution was to combine early and late blocks for OR NTWL. After reweighting, the maximum correlation was 0.94 (selectivity for the Triennial survey). Reweighting makes direct comparisons challenging but the likelihood was poorer compared with a full-blocking model with similar weights. This model still has some high correlation among selectivity parameters, estimated different male growth (faster growing and smaller sizes, which was more similar to external estimates), and suggested a faster increase in spawning output in recent years with some increase of recruitment deviations.

The STAT suggested combining (mirroring) selectivity blocks for the early and late periods for OR NTWL and WA recreational because this approach matched dynamics in the fleets better than combining middle and late blocks. The STAT also suggested that it might be a useful area of future research to look at alternatives to double-normal selectivity parameterisations to reduce the number of parameters and potentially reduce correlations.

Panel conclusion: None of the approaches explored was free from correlation issues but the panel agreed with the STAT's suggestion to combine (mirror) early and late blocks for WA recreational and OR NTWL and to re-weight the model. This would be a good candidate to be a new working base model.

The panel agreed with the STAT's suggestion for future research into alternatives to double-normal selectivity parameterizations.

Request No. 2: Provide a series of sensitivity runs that explore the consequences of a.) dropping out each abundance index in turn, and b.) upweighting all the abundance indices using a lambda of 10 as a diagnostic to examine the influence of data weighting choices on estimates of depletion.

Rationale: Given the apparent sensitivity of the model to re-weighting the data inputs, the panel would like to be assured that there are no plausible data weighting scenarios that would lead to very low estimates of depletion, as well as to understand the influence of the early triennial index data.

STAT Response: This request was done on the pre-STAR panel base model. Upweighting all abundance indices (lambda = 10) had only little impact on the model estimates of depletion. Dropping indices other than the Triennial survey had slightly more impact on estimated depletion, but excluding the Triennial survey was very influential and took spawning output to a very low level in about 2000 and led to a more pessimistic estimate of current spawning output at or just below the minimum stock size threshold (Figure 3).

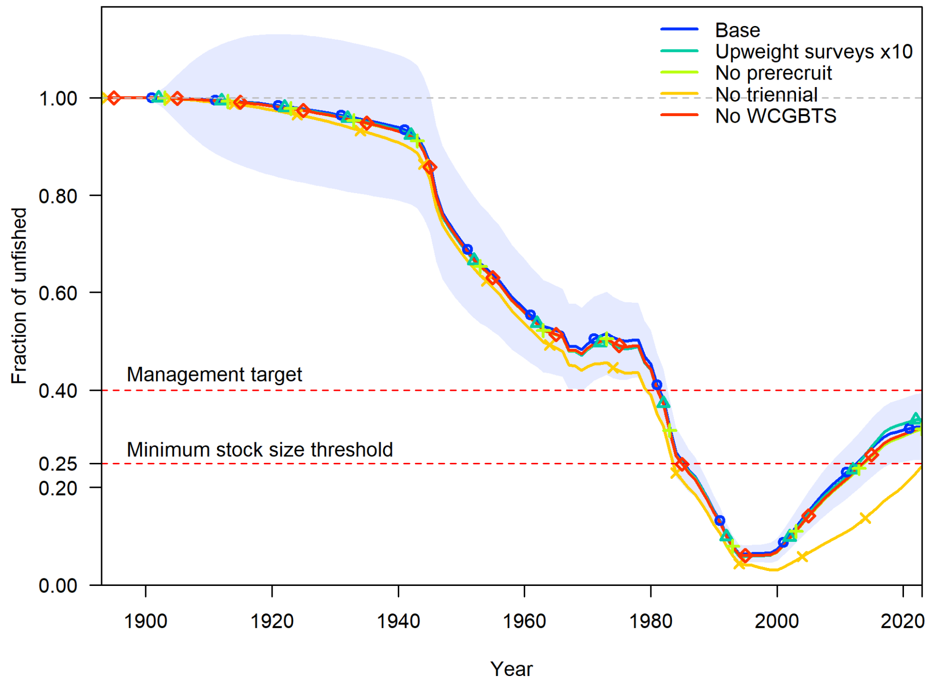

Figure 3: Estimates of depletion for models not including each of the abundance indices in turn, and a model upweighting all the abundance indices using a lambda of 10.

Panel conclusion: The panel agreed that there was no rationale for giving very low weight to the Triennial survey or for dropping it from the model altogether. A model excluding the Triennial survey was the only one that led to estimated current spawning output being close to the minimum stock size threshold so the panel is confident that, for the working base model, there are no plausible data weighting scenarios that would lead to point estimates of current depletion below the minimum stock size threshold.

Request No. 3: Present a.) the estimated selectivity curves when M is fixed at the same value for the two sexes, b.) the corresponding selectivity curves by age.

Rationale: The Panel has seen selectivity curves by length but not by age and the Panel is trying to understand the trade-offs between M for males and females and counterintuitive patterns in selectivity shapes for males and females.

STAT Response: This request was done on pre-STAR panel model runs. When males and females had the same (fixed) M, male selectivity was still more domed than female selectivity. Analysis suggested that the growth relationship was not resulting in a different pattern with age selectivity. Domeness in male age-selectivity was derived from length data. Female selectivity became slightly more domed when M was fixed than when M was estimated (Figures 4 to 7).

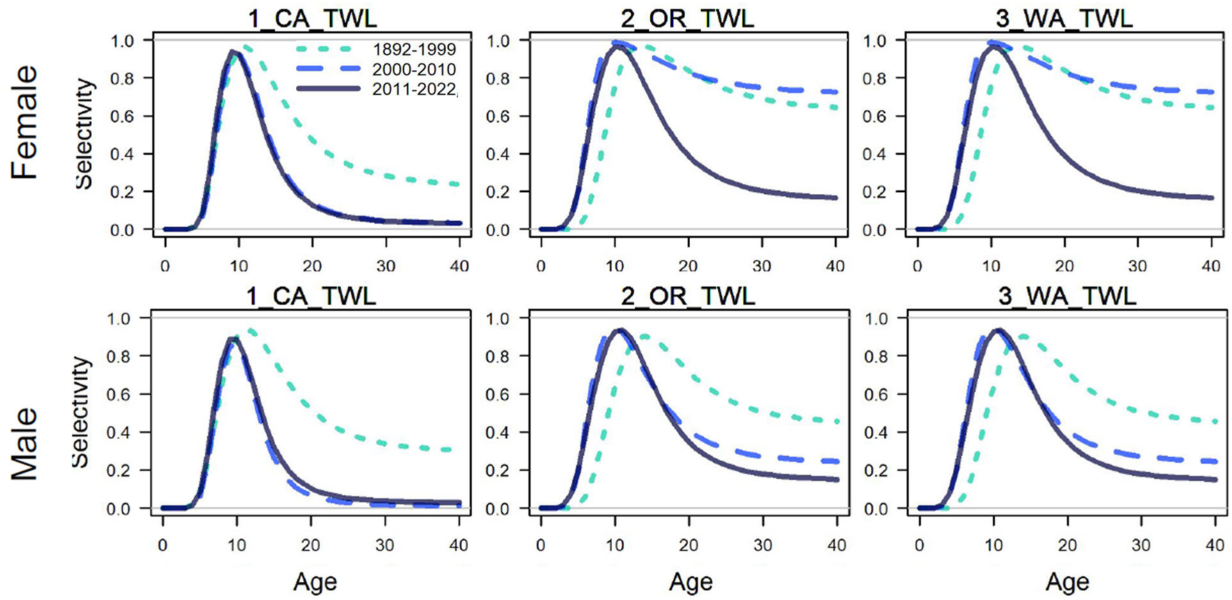

Figure 4: Estimated age-based selectivity curves for trawl fisheries from a model where males and females had the same fixed value of M.

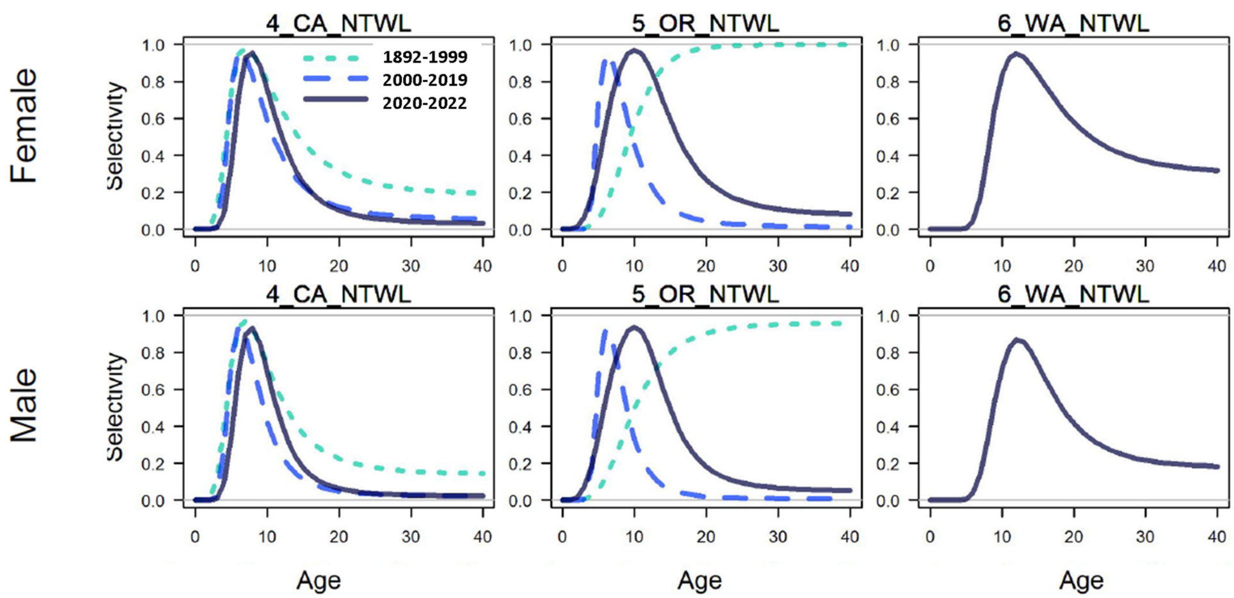

Figure 5: Estimated age-based selectivity curves for non-trawl fisheries from a model where males and females had the same fixed value of M. If only one curve is included for a fleet it is applied over all years.

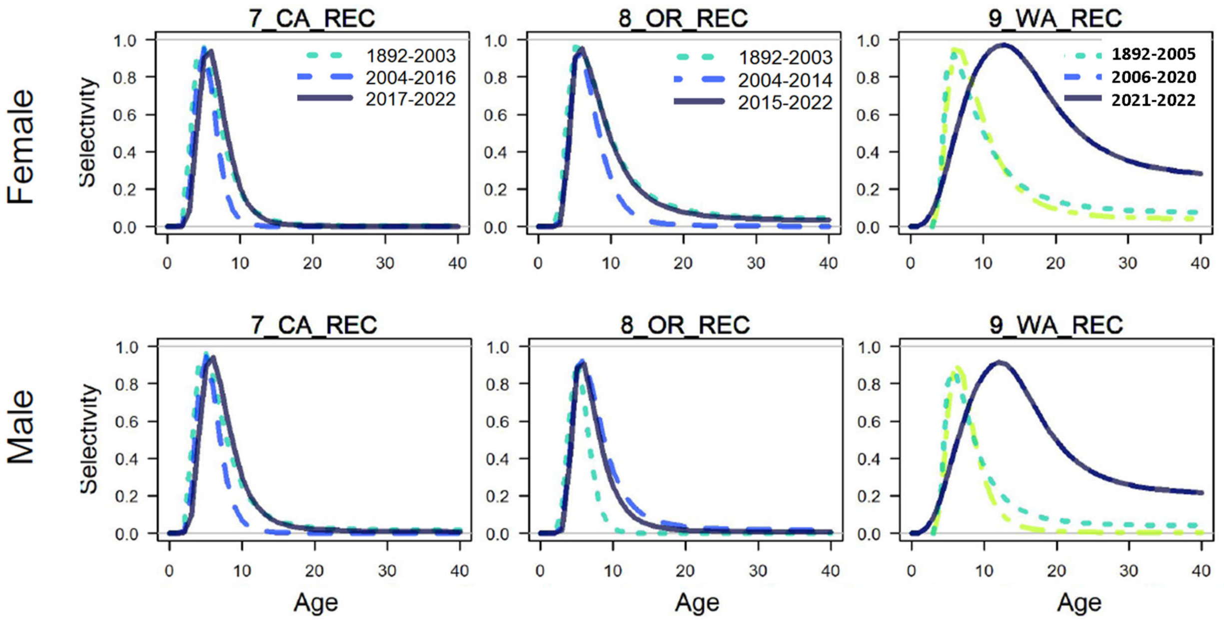

Figure 6: Estimated age-based selectivity curves for recreational fisheries from a model where males and females had the same fixed value of M.

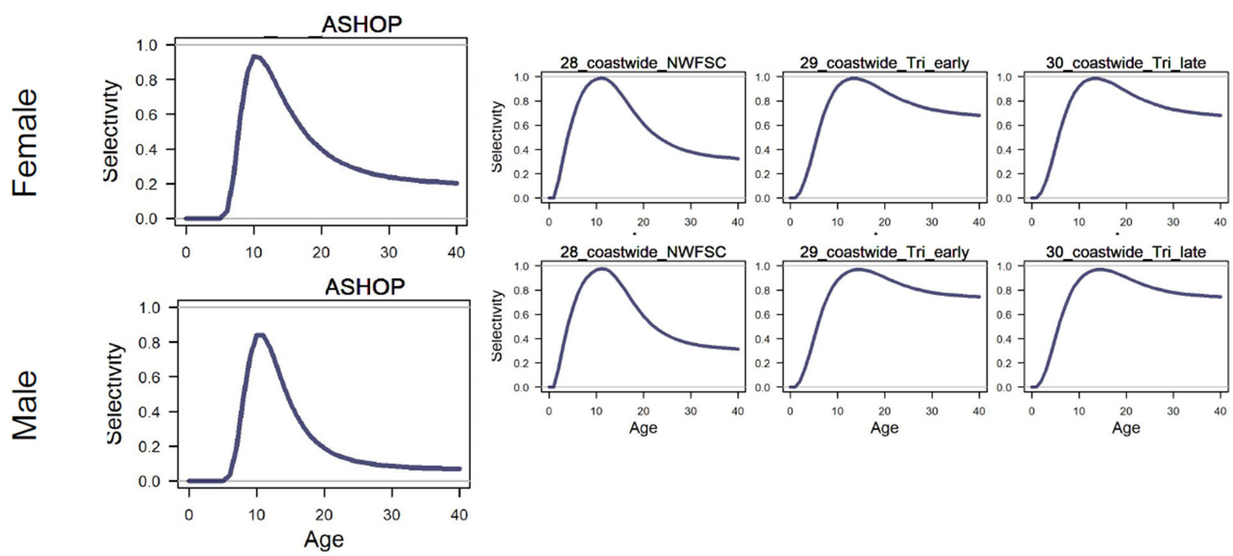

Figure 7: Estimated age-based selectivity curves for the At Sea Hake Observer Program (ASHOP) and surveys, from a model where males and females had the same fixed value of M. A single selectivity curve is applied over all years for each of these fleets.

Panel conclusion: The panel agreed that no changes to the treatment of natural mortality in the model were warranted.

Request No. 4: Present standard retrospective plots, including depletion, spawning output, recruitment and recruitment deviations, as well as recruitment deviation estimates over time (aka, squid plots) using the STAT choice of draft base model from Request No. 1.

Rationale: The Panel has not yet had a chance to examine the retrospectives for the revised base model.

STAT Response: The model including all age data showed some retrospective bias in un-fished spawning output. Recruitment deviations over the last ~20 years showed a lot of variability in retrospectives, likely because most of the age data come from the last 5 years (Figure 8).

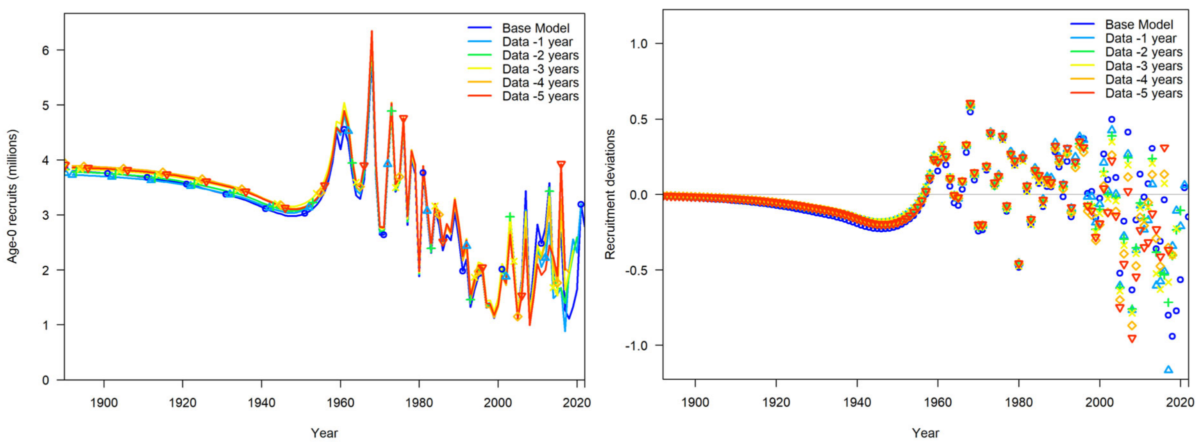

Figure 8: Estimates of recruitment and recruitment deviations from retrospective runs based on a model that combined (mirrored) early and late selectivity blocks for WA recreational and OR Non-trawl.

Panel conclusion: The panel noted that the high variability in recruitment in the retrospectives was expected given that a high proportion of the contemporary age data come from the most recent years.

Request No. 5: Present standard profiles a.) with recruitment deviations turned off, and b.) using sigmaR of 0.4 to 1.0, incrementing by 0.1.

Rationale: The Panel would like to determine the impact of different values of sigmaR on the stock assessment.

STAT Response: This request was done on the pre-STAR panel base model. Increasing sigmaR substantially affected the model, especially recruitment since ~2003 and estimates of current spawning output. Very high levels of sigmaR (> 0.8) suggested very low recent recruitment and estimates of current spawning output below the minimum stock size threshold and decreasing (Figures 9 to 11).

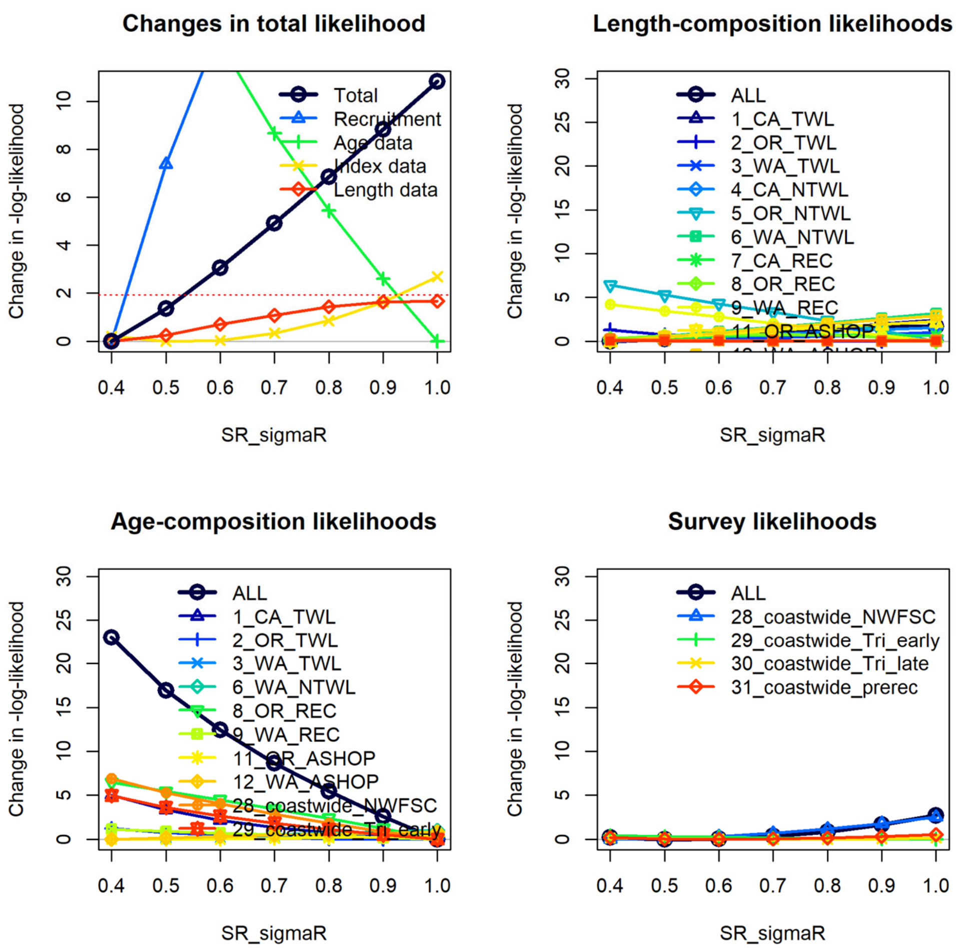

Figure 9: Likelihood profiles for a model with no recruitment deviations and models with deviations constrained by different fixed values for sigmaR. The base model has a fixed sigmaR of 0.5.

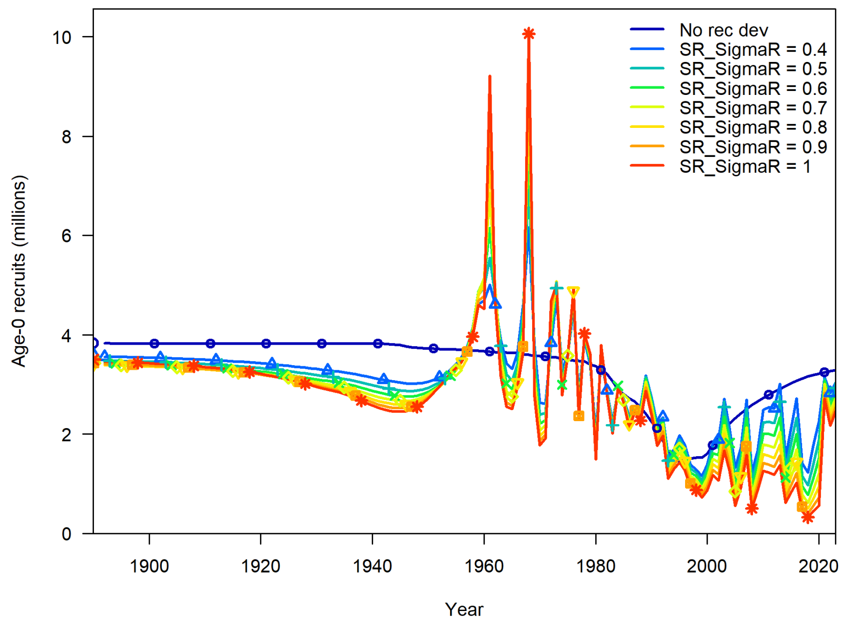

Figure 10: Estimates of annual recruitment for a model with no recruitment deviations and models with deviations constrained by different fixed values for sigmaR. The base model has a fixed sigmaR of 0.5.

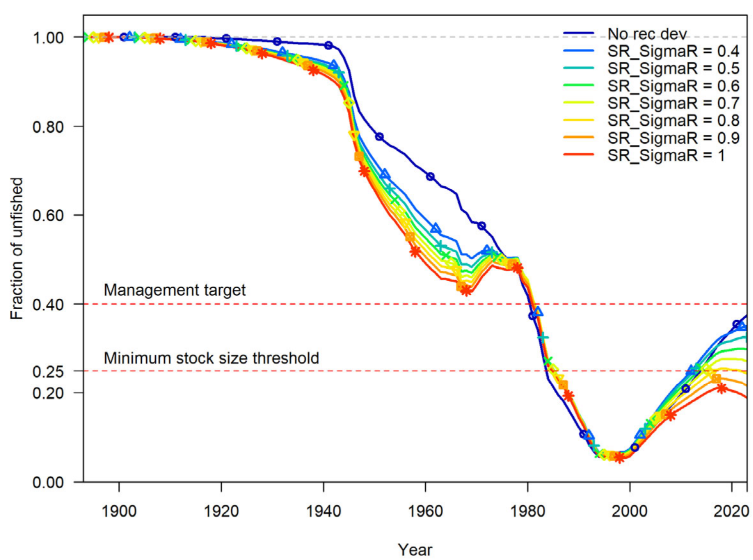

Figure 11: Estimates of depletion for a model with no recruitment deviations and models with deviations constrained by different fixed values for sigmaR. The base model has a fixed sigmaR of 0.5.

Panel conclusion: The panel agreed that this was a very useful diagnostic but that a model with a very high sigmaR was not realistic and should not be considered as a base case. If models providing more flexibility for recruitment were required, using very high values for sigmaR was probably not the best approach, and quite a lot of work would be required to develop and weight such a model. The panel did not see any reason to change the fixed sigmaR in the model.

Request No. 6: Jitter the models associated with the new age data and option 2b given by the STAT in response to Request No. 1 (recent WA recreational and OR Non-Trawl selectivities mirrored to the early time period, re-weighted). Present the results of the jitter analyses and the r4SS plots of any models with a better likelihood than the base.

Rationale: The panel would like to understand the stability of the two most plausible base cases.

STAT Response: The jitter analyses indicate that models with lower likelihoods can be found under both circumstances. The best jittered model for the model with new age data (model 1) has a very similar trajectory to the model before the jitter. Jittering the model from option 2b found many models with lower likelihood values. The model with the lowest likelihood had a lower estimate of initial spawning output but similar estimates of recent spawning output, and was overall similar to the model before the jitter. There remained some high correlations for the best jittered model for option 2b (around 0.96).

During these runs it was found that the model for option 2b had also unintentionally mirrored the late and early selectivity blocks for the CA Non-Trawl fleet. A model was run on the best jittered model where those blocks were allowed to be estimated separately. Results for that analysis are described in response to request 10.

Panel conclusion: The Panel had a provisional preference for the best-jittered version of model 2b given the lower (though still high) correlations, its simplified structure, and that no parameter bounds were reached during jittering. A decision was deferred pending evaluation of whether correlations in Model 1 remained high. This was being explored by the STAT at this time (see Request No. 9 below).

Request No. 7: Provide estimates of the male-skewed sex ratio by state for the two west coast trawl surveys, similar to the figures provided on slide 17 of the canary rockfish part 1 presentation.

Rationale: To evaluate whether there are latitudinal trends in the divergent sex ratios for older fish.

STAT Response: The survey sees younger canary rockfish in California relative to Oregon and Washington. However, there is not a major difference across states in how the sex ratio changes with age, given the age range observed in each state (Figure 12).

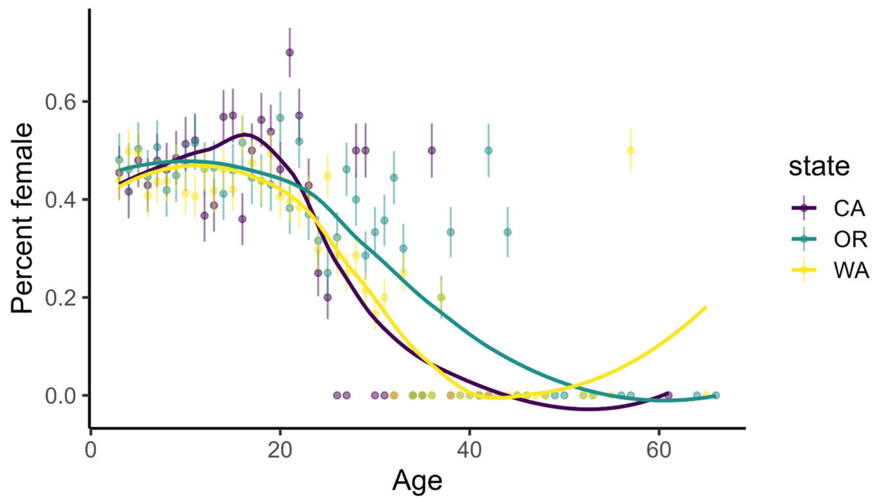

Figure 12: Estimated sex ratio by state from the trawl survey

Panel conclusion: The panel agreed there were no major differences across states in how the sex ratio changes with age.

Request No. 8: Provide a time series of estimated catches against input catch values for the model sensitivity run that included greater uncertainty in historical catches. Run a new model with uncertainty increased to 0.2 for years before 1980 to assess model behavior and provide similar plots.

Rationale: This is an example of an assessment where there is a need to improve catch histories and to assess the impacts on the model of doing so.

STAT Response: This request was done on the pre-STAR panel base model. The model estimates catch to be the same as the input catch whether the standard error (SE) is 0.1 or 0.2. However, models with different SEs on catch had different trajectories and different optimized negative log-likelihoods suggesting increasing catch SE leads to numerical instability (Figure 13). The catch SE feature in stock synthesis and its impact on models is not well-understood.

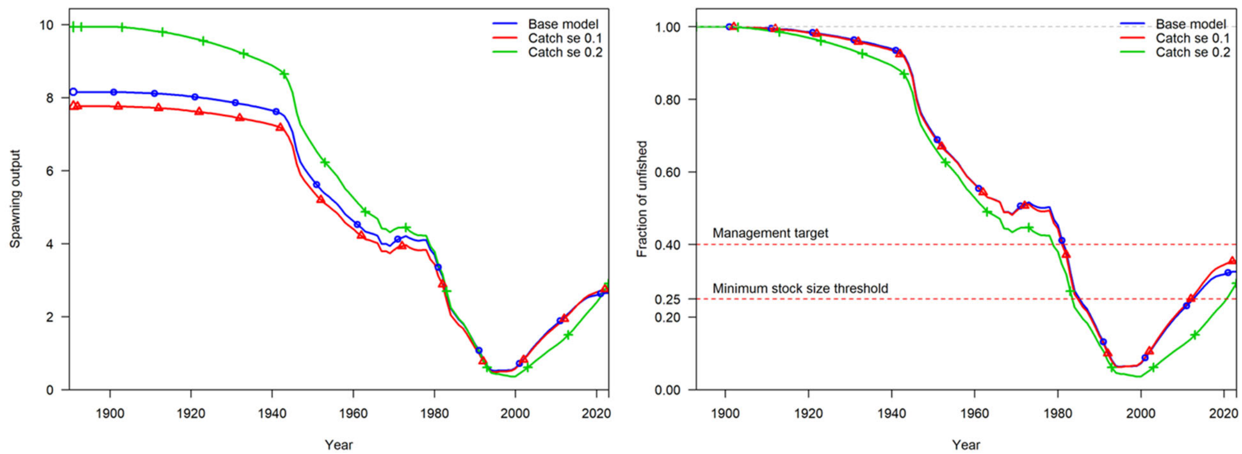

Figure 13: Trajectories of spawning output and depletion for sensitivity runs where the standard error feature for catches was implemented using settings of 0.1 and 0.2. These runs had lower likelihoods than the working base model.

Panel conclusion: The panel agrees that the catch SE feature in Stock Synthesis and its impact on models is not well-understood. Further exploration of problems with catch histories would probably be better achieved using sensitivity runs with different catch histories. Future modeling platforms would benefit from improved and well documented methods for evaluating uncertainties in catch history.

Request No. 9: Provide the Hessian matrix and correlations from the best jittered model from Model 1 (see Request No. 6, all age data included with the original blocking structure for WA recreational, OR Non-Trawl and CA Non-Trawl).

Rationale: To assess whether the correlations in Model 1 remain high after the Hessian has been examined.

STAT Response: The r4ss plots with the Hessian for Model 1 were added to the github website. The highest magnitude correlations for the jittered model changed from the last WA Recreational selectivity time block to the last OR Non-Trawl selectivity time block, but remained high and were not reduced as a consequence of the jitter analysis. The STAT does not recommend this as a candidate base model.

Panel conclusion: The panel agrees with the STAT that this should not be considered as a base model.

Request No. 10: Provide the results of the best jittered Model 2b (see Request No. 6) with CA Non-Trawl early and late period not combined. Provide a jitter analysis of the best-fitting model.

Rationale: This is for consideration as the final reference model.

STAT response: When resplitting the CA non-trawl early and late blocks from the best jittered model 2b, the model diagnostics indicated that the ascending limb for selectivity for the OR Non-Trawl fleet was near its lower bound. Two options were pursued to resolve this: a) fixing the ascending limb estimate at its bound, and b) reweighting the model one iteration. Both options resulted in models without parameters on bounds, but option b (reweighting) was preferred as it was more in line with the original process done for Request 6, resulted in a visually better fitting model (likelihoods were not comparable due to reweighting), and did not suggest additional reweighting was needed. The model with one additional reweighting iteration was chosen for jittering and 50 runs were done using the same jitter fraction as previous analyses (0.05). Jittering found that no models had lower negative log-likelihoods, while 10 iterations returned to the best fitting model. Results from the best fitting model were provided to the panel. The STAT recommends this model be the revised base model.

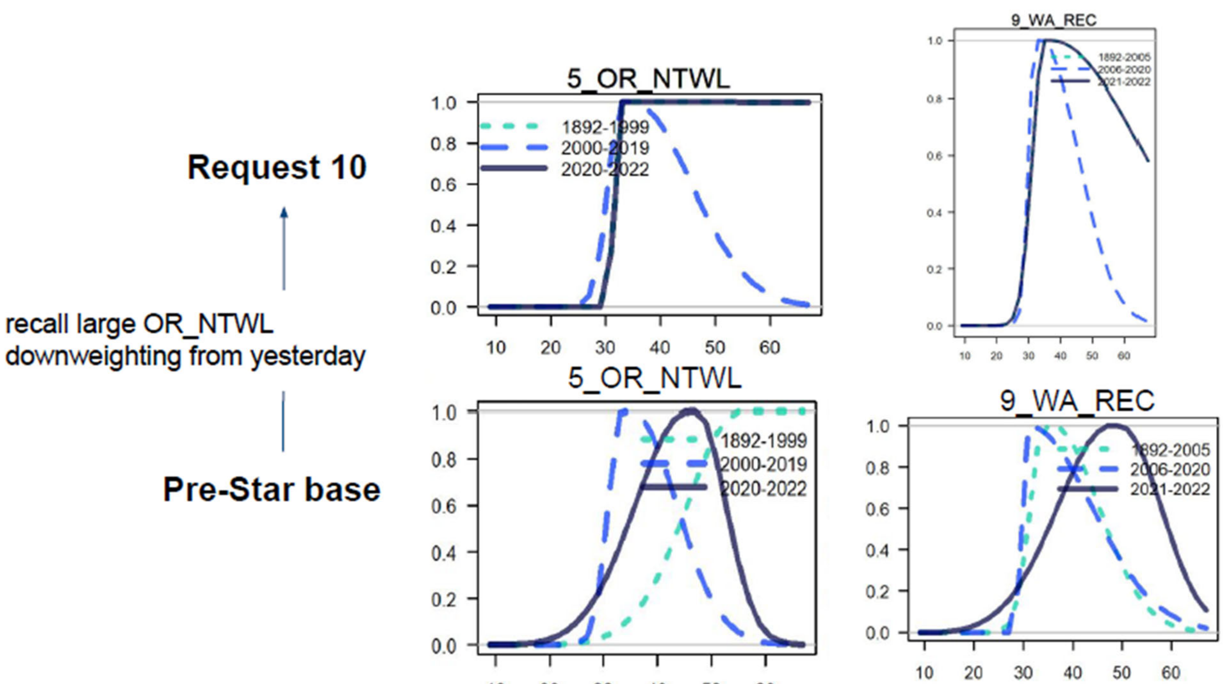

Figure 14: Estimates of female selectivity curves in OR Non-trawl and WA recreational fisheries in the pre-STAR model and model 2b (where early and late blocks for these fleets are mirrored, then the model is re-weighted).

Panel conclusion: The panel agreed that this model with the added age data (re-splitting CA Non-Trawl and reweighting, after mirroring recent OR Non-Trawl & WA Recreational selectivities to the early period, and reweighting) be adopted as the revised base model. Updated selectivity curves for females in the Oregon non-trawl and Washington recreational fleets are shown in Figure 14.

Request No. 11: Provide likelihood profiles over male and female M for the candidate final reference model from Request No. 10.

Rationale: The panel may consider this as an axis of uncertainty.

STAT response: Compared with the pre-STAR base model, the likelihood profiles show less influence of OR Non-Trawl lengths on the likelihood profile (Figure 15). The STAT notes this model has much lower weights for these data than the pre-STAR base model (0.083 vs. 1.67). The male M profile is minimized at a higher natural mortality rate, largely due to length data.

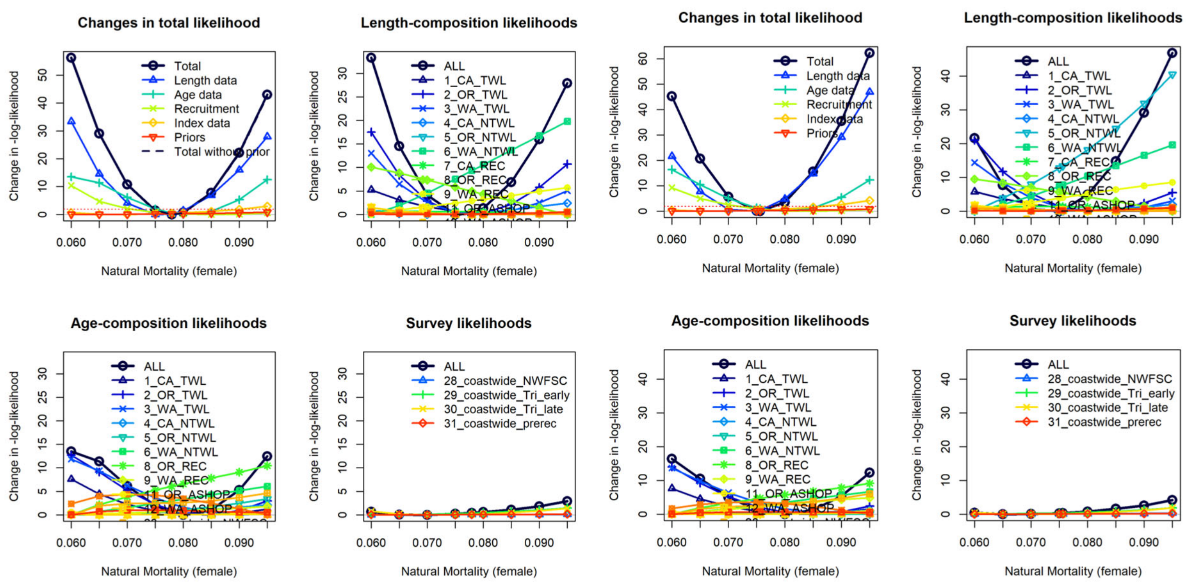

Figure 15: Likelihood profiles for the pre-STAR model (left four panels) and model 2b including all age data and OR Non-trawl and WA recreational selectivities mirrored between early and late blocks, then the model is re-weighted (right four panels).

Panel conclusion: The panel agreed that the lower weight for the OR Non-Trawl length composition data appeared to be appropriate given the small proportion of the catch represented by these data and the revised likelihood profiles. There were no indicators in the profiles or the revised fits that raised concerns about adopting this as the final reference model.

Request No. 12: Using the candidate final reference model (from Request No. 10), provide sensitivity runs with different structural assumptions for M as follows: single M fixed at the prior; a break for female M with higher mortality starting at age 12 (~ 50% age at maturity); a break for female M with higher mortality starting at age 20 (~ the age at which the sex ratio can be seen to change); a ramp for female M between age 6 and age 14; a model run in which the sex offsets for selectivity are all removed. Provide plots of spawning output and depletion over time and a table of equilibrium MSY and current depletion compared across models.

Rationale: The panel may consider a subset of these alternatives as an axis of uncertainty. These potential structural model alternatives that lead to the states of nature were largely informed by structural differences in the 2015 assessment.

STAT Response: Sensitivity runs showed similar dynamics to the pre-STAR base model with the exception of the model without sex-dependent selectivity (Figure 16). The run without sex-dependent selectivity resulted in a female M estimate of 0.055 (lower than the prior for male) which the STAT considers less probable for consideration as a plausible axis of uncertainty. The estimates of female M from other sensitivity runs were as follows: for the ramp between ages 6–14, female M started at the male M and increased to M = 0.0934; for the break at age 20, female M started at the male M and increased to M = 0.162.

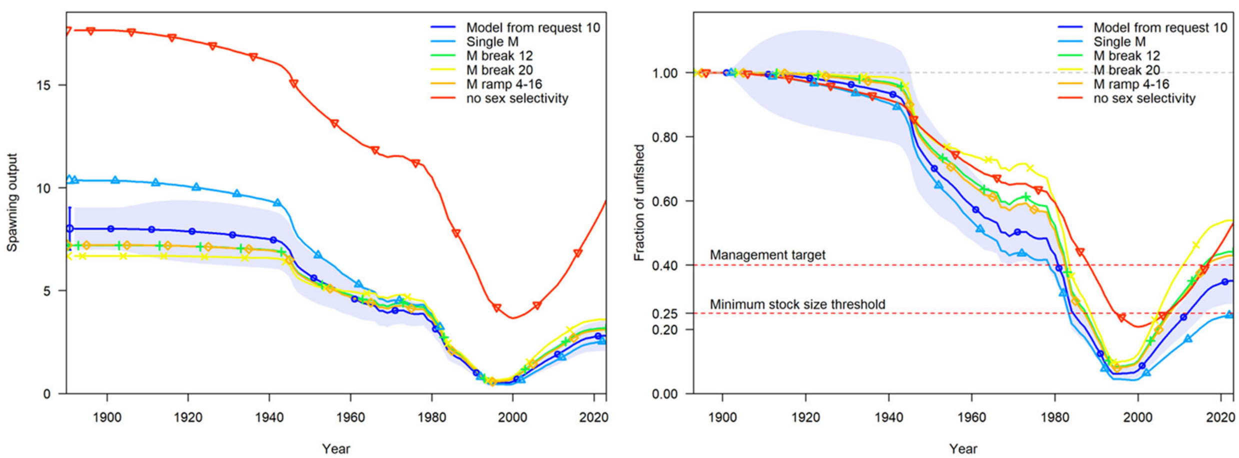

Figure 16: Trajectories of spawning output (left) and depletion (right) for variations of the final reference model with different structural treatment of female natural mortality, M, and no differences in selectivity by sex were assumed.

Panel conclusion: After a detailed discussion of the Terms of Reference, the panel considered structural uncertainty in the treatment of natural mortality for females to be a good candidate for an axis of uncertainty. Models using a single M as the lower state of nature and a ramp of female M between ages 6 and 14 as the higher state of nature were selected.

Request No. 13: Provide the values associated with the 12.5% and 87.5% percentiles of the distribution of spawning output in the terminal year based on the model estimated asymptotic uncertainty. Provide values for the high and low states of nature in the terminal year in terms of spawning output for comparison.

Rationale: The panel would like to understand the variability in states of nature based on the Terms of Reference guidelines relative to those selected as structural choices for female M.

STAT Response: This request was done using the candidate final reference model (from Request No. 10) and sensitivity runs from request 12. The 75% confidence interval of 2023 spawning output in the base model is wider than the range of 2023 spawning output in the proposed low and high states of nature (Table 1). The difference between the low and high states of nature approximately matches a 50% confidence interval for current spawning output.

Table 1: Confidence intervals for current spawning output from the final reference model compared with the range of current spawning output from the low and high states of nature.

	CI Bounds: 2023 spawning output based on 75% confidence interval of base model	**CI Bounds**: 2023 spawning output based on 50% confidence interval of base model	**States of nature**: 2023 spawning output based on structural states of nature
Low	2364	2548	2523
Base	2809		
High	3254	3070	3098

Panel conclusion: The panel noted that the range of current spawning output from the low and high states of nature runs was substantially narrower than the 75% confidence interval for current spawning output from the final reference model. However, the range of depletion from the low and high states of nature runs was wider than the 95% confidence interval for current depletion from the final reference model. This led to some uncertainty about whether the states of nature were sufficiently disparate. Some additional guidance in the Terms of Reference on methods of selecting states of nature and on the rationale and intended use / interpretation of the results would be very helpful for future STAR panels.

Request No. 14: Provide an initial decision table based on the states of nature from Request No. 12, specifically the single M scenario (low state of nature) and the M ramp scenario for females (high state of nature), and the default harvest control rules, assuming a P* = 0.45. Also include an alternative of P* = 0.4. Provide a revised figure of the spawning output and depletion time series.

Rationale: These elements form an adequate range of options for the decision table that is a starting point for management consideration.

STAT Response: The simplified figure, a figure showing projections of these quantities, preliminary decision tables and a proposed projection table for the post-STAR draft assessment were provided (Figure 17 and 18, Tables 2 to 4).

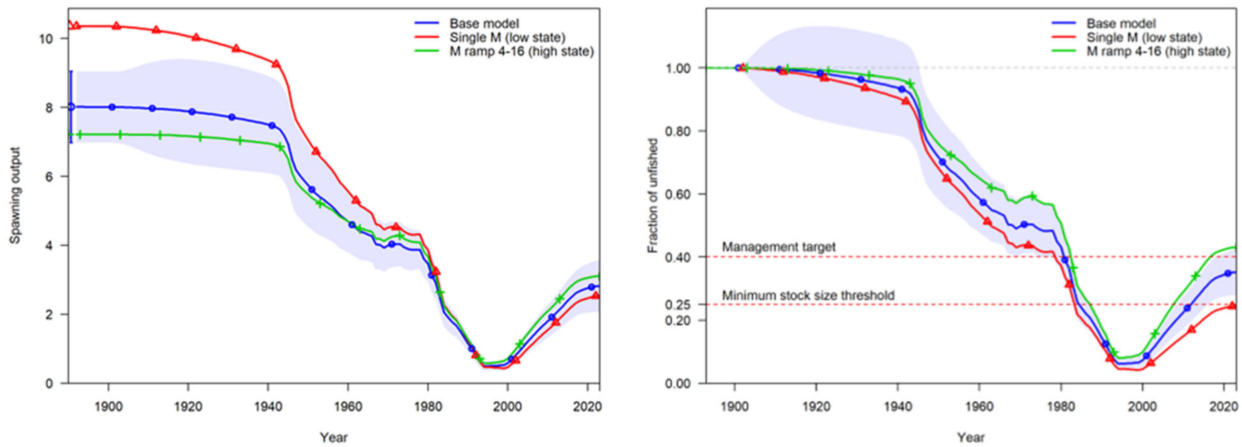

Figure 17: Trajectories of spawning output (left) and depletion (right) for the final reference model and low and high states of nature.

Table 2: Preliminary decision table with P* = 0.45

Year	Catch	Low Spawn (M fixed)	Low Frac (M fixed)	Base Spawn	Base Frac	High Spawn (M ramp)	High Frac (M ramp)
2023	863	2523.1	0.244	2808.87	0.351	3098.08	0.43
2024	860	2494.43	0.241	2782.56	0.347	3068.81	0.426
2025	571	2449.39	0.237	2739.4	0.342	3021.7	0.419
2026	573	2420.81	0.234	2709.94	0.338	2986.12	0.414
2027	584	2383.86	0.23	2670.26	0.333	2938.59	0.407
2028	601	2343.21	0.226	2625.73	0.328	2885.43	0.4
2029	623	2305.7	0.223	2584.62	0.323	2836.83	0.393
2030	648	2279.22	0.22	2556.58	0.319	2804.6	0.389
2031	674	2269.97	0.219	2548.98	0.318	2797.59	0.388
2032	700	2280.56	0.22	2564.13	0.32	2817.93	0.391
2033	726	2309.81	0.223	2599.27	0.325	2860.65	0.397
2034	749	2354.31	0.227	2649.08	0.331	2917.64	0.405

Table 3: Preliminary decision table with P* = 0.40

Year	Catch	Low Spawn (M fixed)	Low Frac (M fixed)	Base Spawn	Base Frac	High Spawn (M ramp)	High Frac (M ramp)
2023	863	2523.1	0.244	2808.87	0.351	3098.08	0.43
2024	860	2494.43	0.241	2782.56	0.347	3068.81	0.426
2025	533	2449.39	0.237	2739.4	0.342	3021.7	0.419
2026	533	2424.82	0.234	2713.76	0.339	2989.89	0.415
2027	542	2392.15	0.231	2678.11	0.334	2946.34	0.409
2028	558	2355.98	0.228	2637.77	0.329	2897.29	0.402
2029	577	2323.21	0.224	2601.05	0.325	2853.02	0.396
2030	598	2301.84	0.222	2577.72	0.322	2825.45	0.392
2031	621	2298.39	0.222	2575.43	0.322	2823.73	0.392
2032	645	2315.69	0.224	2596.64	0.324	2850.17	0.395
2033	667	2352.54	0.227	2638.56	0.329	2899.7	0.402
2034	686	2405.68	0.232	2695.91	0.337	2964.22	0.411

Table 4: The STAT's proposed projection table for the post-STAR draft assessment based on the final reference model and P*=0.45

Table 22: Projections of estimated OFL (mt), ABC (mt), resulting ACLs (mt) based on 40-10 rule and applied buffers, and estimated spawning output in millions of eggs, and spawning output relative to unfished for 2025-2034, with assumed removals in 2023 and 2024 based on recommended values from the Groundfish Management Team.

Year	Adopted OFL (mt)	Adopted ABC (mt)	Adopted ACL (mt)	Assumed removals (mt)	OFL (mt)	Buffer	ABC	ACL	Spawning Output	Fraction Unfished
2023	1413	1284	1284	863.16					2808.87	0.35
2024	1401	1267	1267	860.19					2782.56	0.35
2025					646.93	0.935	604.88	571.28	2739.40	0.34
2026					654.71	0.930	608.88	572.51	2709.94	0.34
2027					674.29	0.926	624.39	583.52	2670.26	0.33
2028					703.06	0.922	648.22	601.48	2625.73	0.33
2029					737.31	0.917	676.11	623.09	2584.62	0.32
2030					773.77	0.913	706.45	647.92	2556.58	0.32
2031					809.71	0.909	736.03	674.16	2548.98	0.32
2032					843.09	0.904	762.15	699.96	2564.13	0.32
2033					872.65	0.900	785.38	725.64	2599.27	0.32
2034					897.79	0.896	804.42	749.34	2649.08	0.33

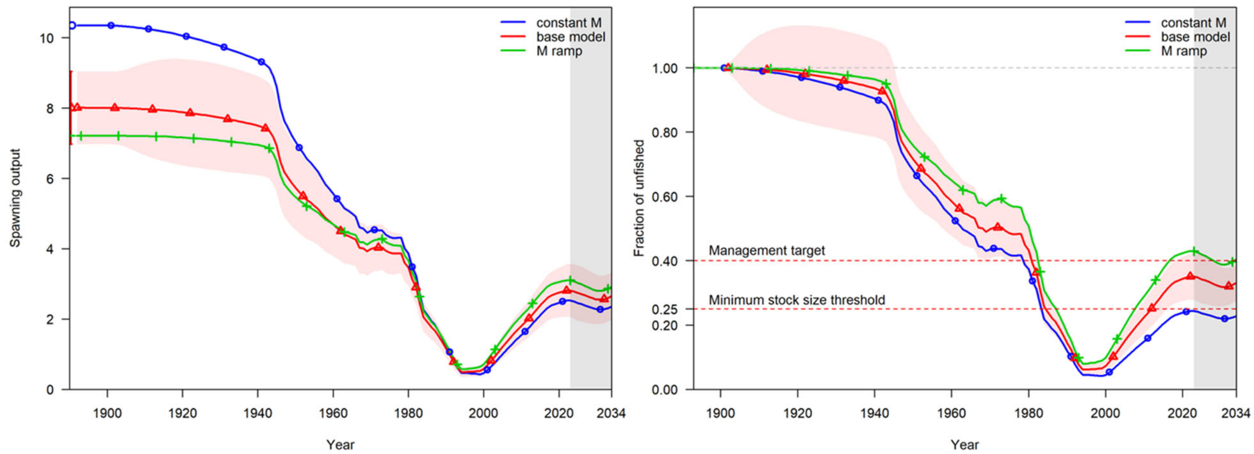

Figure 18: Trajectories and projections (gray shaded areas) of spawning output (left) and depletion (right) for the final reference model and low and high states of nature.

Panel conclusion: The panel agreed that the additional figures were useful and the preliminary decision tables could be used, pending final confirmation by the STAT. The panel also agreed that the draft projection table should be included in the post-STAR draft assessment document.

Request No. 15: In the post-STAR draft assessment, provide an additional sensitivity run where projections assume low recruitment averaged over the years 2014–2019 and catches are hard-wired from the revised base model.

Rationale: This provides an alternative perspective should poor recruitment occur in the near future and potential implications for projections used in fishery management.

STAT Response: The additional sensitivity run will be included in the post-STAR draft assessment.

Panel conclusion: The panel suggests this will be useful for understanding the likely consequences of poor future recruitment.

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

Proposals for base models were presented in the draft assessment documents for canary rockfish. The STAR Panel explored alternatives to these formulations as noted in the analytical requests above. At the STAR Panel's suggestion, the model was rerun with the missing age data and the best jittered Model 2b (after mirroring recent OR Non-Trawl & WA Recreational selectivities to the early period, and reweighting) with CA Non-Trawl early and late period not combined and applying one additional iteration of reweighting (see Request 10). This modification was accepted by the STAR Panel as an appropriate adjustment to the draft base model and thus, this updated base model is to be carried forward in the subsequent post-STAR assessment.

Similar to other rockfish assessments, the STAR Panel recommended that the upper and lower states of nature be defined based on the uncertainty in natural mortality. That range in uncertainty was centered on the point estimate of the base model and with the lower end of the range being defined by a model run with the single M over both sexes set at the prior (see response to Request 12) and the upper end of the range from a model run with a ramp for female M between age 6 and age 14 (also, see Request 12). The upper end scenario mimics the M vector used in the 2015 assessment. The lower end scenario, a single M for both sexes, reflects a low productivity state of nature for this stock.

Technical Merits of the Assessment

A number of technical merits were demonstrated in the canary rockfish stock assessment, as mentioned below.

All data available at the appropriate (e.g, coastwide) spatial scale were used in the stock assessment. A wide range of available data were examined and data was only excluded on the basis that it was not relevant (i.e., contained no information) to the population dynamics of canary rockfish, or that it was too localized in space (e.g, there were many state-specific indices for smaller scale recreational fisheries or localized surveys that were not used). The results of this assessment represent improved knowledge of the status of the stock and sustainable harvest levels compared to the previous assessments.

The STAT teams explored many alternative models, within the Stock Synthesis framework. These alternative modeling 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 the stock improved the quality of the assessment overall and indicated potential solutions to some problems, such as uncertainty in estimates of stock size and modeling recruitment deviations.

Technical Deficiencies of the Assessment

The Panel found no technical deficiencies in the assessment modeling. However, the assessment remains deficient in the data available. For example, as denoted in Figures 1 and 2, canary rockfish experienced a lengthy period of significant catches prior to 1980 during which few data were collected other than catch data. Thus, the perceptions of the dynamics in that time period are being driven by strong constraints imposed by fixing steepness and implementing a prior on natural mortality. Additionally, the abundance indices since 2000 are relatively short term. Thus, the assessment relies heavily on recent length and aging data to inform estimates of year-class strength and scale (R_0).

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 GMT asked the STAT why the non-trawl length selectivity curves included a time block for 2020-2022 and whether 2017-2022 was considered as an alternative, given that canary rockfish was declared rebuilt in 2015, resulting in ACLs that nearly tripled between 2016 and 2017. The STAT response was that there was not enough data between 2000 and 2017 to include a time block between those years and chose to include 2018-2020 to that period. . The STAT ultimately combined the early and late non-trawl selectivity curves for the OR+WA fleet in the base model, so using 2020 instead of 2017 made sense to the GMT given the reduction in spatial restrictions in 2021. Non-trawl trip limits also increased from 300 lbs. to 3,000 lbs. per bimonthly period in 2020. The GMT was satisfied with the STAT's response.

The GMT and GAP also note the value in collecting non-trawl commercial fishery dependent data from larger and older fish and support the continued improvement of sampling and observer coverage for that fleet. The GMT and GAP also support the STAT's research recommendation #2 to explore coastwide hook and line fishery-independent indices given the low encounter rates of canary rockfish in the WCGBTS.

Unresolved Problems and Major Uncertainties

As with many rockfish assessments, the canary rockfish natural mortality rate and the stock-recruitment relationship remain the major uncertainty in understanding the stock's current and potential productivity.

There is limited information with which to evaluate canary rockfish stock structure beyond the US West Coast areas used in this assessment.

The abundance indices are of insufficient precision to provide much information on trends in abundance in recent years. Thus, the indices need to mature to provide better catchability estimates as the stock increases. This is particularly an issue for long-lived species like canary rockfish.

Further research is needed to explain skewed sex ratios among older individuals in the population. Specifically, there is an apparent absence of older females in many data sets, and more importantly a lack of clarity in how to account for this in the structure of the model.

Despite considerable improvement of the parameterization of selectivity in this model compared with the previous assessment, there is remaining evidence of high correlations among selectivity parameters. Simplification of fleet structure and selectivity should be considered in the next full assessment.

Recommendations for Future Research and Data Collection

The STAT provided a list of seven research activities which are summarized below. The Panel supports the STAT's list and, generally, the priorities that the STAT assigned. However, there are several additional research directions the Panel wishes to support which are added at the end of this section.

1. Continued research into the mechanism leading to skewed sex ratios and empirical studies to estimate natural mortality rates. This remains a critical uncertainty for canary rockfish assessments, as well as other species of rockfish along the U.S. West Coast. Further research to understand the mechanism by which skewed sex ratios occur would be beneficial for understanding the potential of canary rockfish recovery. (High)

2. The WCGBTS has low encounter rates with canary rockfish in part because it has limited access to rocky habitat. There is a need for non-trawl coast-wide fishery-independent surveys to improve abundance indices. This might mean an expansion of the Hook and Line Survey into more northern waters, or taking advantage of developments in model-based index standardization to integrate multiple similar overlapping fishery-independent non-trawl sampling programs that have occurred over smaller spatial and temporal scales than the WCGBTS. This also has the potential to provide biological data in a variety of habitats and across latitudinal gradients. (Medium)

3. Similar to recommendations 1 and 2, other biological relationships can be updated to better understand dynamics for canary rockfish. Few samples of canary rockfish are available to inform estimates of fecundity. Fecundity for canary rockfish was based on a genus level relationship. Greater species-specific information on canary rockfish fecundity would ensure that biological relationships better reflect individual species dynamics should they differ from other species in their genus. (Medium)

4. This assessment model does not include any ecosystem or climate considerations, but canary rockfish are considered highly vulnerable and highly exposed to climate change. To date, most research has relied on non-mechanistic basin-scale indices that may not be reliable predictors of how environmental conditions will impact productivity in the future. In addition,

the lack of correspondence between recruitment deviations estimated in this assessment and in British Columbia is concerning, as recruitment deviations are often used as response variables to understand environmental drivers of productivity. We recommend further research into environmental drivers of canary rockfish productivity to understand how future and past climate change impact both short-term and long-term changes in productivity. Doing this research in a multispecies manner across groundfish species, particularly those with similar life histories, may lead to more statistical power to gain new insight. (Medium)

5. Further exploration of differences in spatial and non-spatial modeling structure, stability, and results. The structure of canary rockfish stock assessments has varied over time. The 2015 assessment added population structure so as to more explicitly describe potential regional differences in depletion. For this assessment we return to a coastwide model for reasons explained previously. Although the 2015 model showed little difference in results between a spatial and coastwide model, which is also supported through bridging analyses both before and after data weighting, balancing spatial explorations of differences in exploitation, movement, or biological patterns with the realities of model complexity and stability within the time frame of production stock assessments is challenging. Given that this issue could apply to other species in addition to canary rockfish we suggest the possibility of establishing a process by which research-based assessments can be done to explore these issues, similar to the research track process on the east coast of the U.S. (Medium)

6. Research to inform understanding of movement rates for a spatial model, as well as improve estimates of natural mortality. Large scale movement patterns for canary rockfish are generally unknown. Even a small number of tagging samples collected intermittently can improve model estimates. Any method that determines both the extent and direction of movement would be useful; the method need not be limited to tagging. (Low)

7. Ageing error matrices were not updated from the 2015 assessment. Revision of the ageing error matrices, incorporating the new aged canary rockfish data and utilizing new analytical methods are topics for future research. Potential bias in ageing of old canary rockfish based on bomb-radiocarbon data should also be considered in these analyses. (Low)

The Panel also recommends the following:

8. Explore selectivity parameterization using asymptotic selectivity at length and domed selectivity at age to potentially capture dynamics related to male-skewed sex-ratio and sex dependent selectivity.

9. There is a need to better understand changes over time in predation mortality on canary rockfish, given large changes in biomass of known or likely predators of canary rockfish (e.g., lingcod, hake). This could be initially explored using existing databases and published information. Additional information could be developed using ecosystem models or genetic analyses of gut contents.

10. With respect to the first STAT research recommendation, related to skewed age distributions, the Panel would suggest that a comprehensive literature review and/or additional development of models to explore the potential mechanisms for greater mortality with age (or

simply higher natural mortality more generally) for female canary rockfish be initiated. This could include an evaluation of bioenergetics models or state dependent models to better understand and quantify the trade-offs between growth and reproduction for rockfish.

11. With respect to the first STAT research recommendation, consider whether additional sampling or potentially cooperative research with the Washington or Oregon fixed gear fleets to better sample age structure for canary rockfish could be informative.

12. Evaluate and explore additional sources of relative abundance information from either commercial fixed gear fisheries or other fixed gear surveys in the California Current.

13. If available, historical age structures (otoliths) that were surface read and not used in this assessment should be read using contemporary methods to better inform historical population structure within the model.

14. Given the uncertainty and apparent declines in Canary recruitment deviations in recent years, monitoring of the pre-recruit survey index in between assessments for Canary rockfish is recommended. Additional explorations of how best to incorporate the pre-recruit index into rockfish stock assessments should be done.

Recommendation for whether next assessment would be a full or update assessment and basis for recommendation and category

The STAR panel recommends that this assessment should be classified as Category 1b, based on the criteria of availability of fishery independent indices and the lack of an estimable stock-recruitment relationship (e.g., steepness is fixed). When estimated internally, the estimated value is not tremendously different from the point estimate of the steepness prior (estimated value of 0.835 in the pre-star base), although there are concerns that this value approaches implausibly high levels. The Panel notes that 1) the current assessment represents a coastwide recruitment model for the three states as opposed to the 2015 model which, although also assumed a coastwide recruitment model, allocated spatial recruitment by state; and 2) there were revisions in the M and steepness characterizations compared to 2015. The Panel recommends that there is little benefit in conducting a full assessment unless new data or research indicate a need to reconsider the treatment of natural mortality or steepness in this model, in which case the next assessment should be an update.

Recommended sigma value and basis of recommendation

The sigma value (the ln-scale coefficient of variation for OFL2023, measuring scientific uncertainty) from the final base model was 0.145 for canary rockfish, which is less than the default sigma value recommended by the Council's Scientific and Statistical Committee for category 1 stocks (0.5). The STAR Panel recommends using the default sigma value for catch projections for Canary Rockfish.

Acknowledgements

The STAR Panel thanks the Stock Assessment Team, the PFMC advisory body representatives and staff, and all of the meeting participants for contributing to a productive review.