Cowcod
Stock Assessment Review (STAR) Panel Report

NOAA Fisheries, Southwest Fisheries Science Center
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July 22-26, 2019

Participants

Panel Members

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Todd Phillips, Pacific Fishery Management Council representative

Overview

The Stock Assessment Review (STAR) Panel met in Santa Cruz, California during the 22nd-26th of July 2019 to review a draft stock assessment of cowcod (*Sebastes levis*) in the Southern California Bight (SCB) prepared by the cowcod stock assessment team (STAT). Dr. Owen Hamel (Panel Chair) welcomed participants, and reviewed the Pacific Fishery Management Council's (PFMC) *Terms of Reference for Groundfish and Coastal Pelagic Species Stock Assessments* (PFMC 2019), and discussed logistics for the meeting. Dr. Chantel Wetzel agreed to serve as rapporteur.

The draft assessment document and extensive background material (previous assessments, previous STAR Panel reports, etc.) were provided (via the PFMC FTP site) to the Panel two weeks in advance of the Panel meeting. The FTP site was also used for common access to all presentation material and the additional model runs that were conducted during the course of the Panel meeting.

The cowcod stock assessment was conducted using Stock Synthesis 3 (version 3.30.13), with the model time period beginning in 1900 and ending in 2018. The model is based on the assumption of a single distinct stock in the waters off of the Southern California Bight, from the U.S.-Mexico border to Point Conception, although the STAT very clearly recognizes that the stock assumption is very likely violated due to some degree of connectivity with stocks north and south of this area.

The Panel concluded that this cowcod assessment was based on the best available data; the new assessment results constitute the best available information on stock status, and are suitable to serve as the basis for fishery management decisions and stock status determinations. The Panel commends the STAT for their excellent presentations, well-written and complete documentation, their willingness to respond to the Panel's requests for additional analyses.

Summary of Data and Assessment Models

The STAT provided detailed presentations on available data and the main assessment approach.

The pre-STAR draft assessment included two fisheries (commercial and recreational) and seven indices of abundance based on fishery-independent surveys, including two from the NWFSC Hook and Line survey, a 2002 Submersible survey, and a 2012 remotely operated vehicle (ROV) survey, which serves as an absolute abundance index.

Commercial landings prior to 1969 are based on a reconstruction conducted for the 2007 cowcod stock assessment (Dick et al., 2007), 1969-1983 landings based on fish ticket data and species composition of landings in 1984-1986, and 1984-2018 landings on fish ticket data and contemporaneous species compositions. Historical discard is assumed not present due to value of cowcod, while the West Coast Groundfish Observer Program Groundfish Expanded Mortality Multiyear report was used for total mortality estimates for 2002-2017, with 2001 and 2018 extrapolated.

Recreational landings from 1928-1980 and based on a reconstruction (Ralston et al. 2010), 1981-2004 landings largely based on MRFSS estimates, and 2005-2018 from CRFS estimates. MRFSS and CRFS estimates were obtained from RecFIN.

Length data was included from the recreational fishery (only in the 1970s), and from the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS), sanitation, and NWFSC Hook-and-Line surveys. Other sources of length data (e.g., commercial fisheries, 1980s recreational) were considered but not used. Ages were included as conditional age-at length data (primarily for use in estimating growth, as recruitment was assumed deterministic from the spawner-recruit curve), and available from the recreational fishery (in the 1970s), commercial fisheries (in the 1980s), the NWFSC WCGBTS and NWFSC Hook-and-Line survey.

The natural mortality rate was estimated with a prior based on a maximum age of 55 (Hamel prior; median = 0.098), while steepness was fixed at the prior mean of 0.72 as the data did not appear to inform steepness. Selectivity was asymptotic for most fleets, with the exception of the NWFSC WCGBTS and the sanitation surveys, which caught smaller fish and were essentially logistic from larger to smaller fish, and the Recreational fishery, which had a peak in selectivity around 40 cm. Selectivity for the NWFSC Hook-and-Line survey was domed from 2004-2013, and asymptotic from 2014-2018 to account for the expansion into the cowcod conservation areas (CCAs), which had larger average sizes of cowcod. Inadequate information was available to estimate recruitment deviations, and therefore these are assumed to be deterministic from the spawner-recruit curve.

Requests by the STAR Panel and Responses by the STAT

The pre-STAR draft document was very complete. This allowed for an efficient and effective review that could quickly identify the most important questions and allocate review time accordingly. The STAT team provided thorough responses to all requests.

Request 1: Develop a catch curve for (outside) NWFSC Hook-and-Line survey and compare to historic commercial catch curve from bias-corrected ages.

Rationale*:* It seems from catch curves that the value of M cannot be as high as estimated given the structure of the model

Response: The STAT had previously estimated a catch curve Z value using the bias corrected ages from the Butler 1999 assessment. The estimated slope, the Z value, was 0.060. For comparison, a catch curve was estimated using the NWFSC Hook-and-Line data from outside the CCA (Figure 1). The estimated Z value using these data was 0.145, much higher than the Z value based on the Butler ages. The STAT team noted that the results are a bit counter-intuitive. Reducing the catch curve for the NWFSC Hook-and-Line data to cover only fish between 16 and 25 in age, the resulting Z is 0.084. The STAT team expressed some concern that the model is estimating the stock to be more productive than it is (through values of both steepness and natural mortality) which is impacting the rate of decline and the recent rate of increase in the stock. However, without the ability to estimate recruitment deviations, and the potential for dome-shaped selectivity the hook and line survey, the values from the hook and line survey have the potential to be overestimating Z.

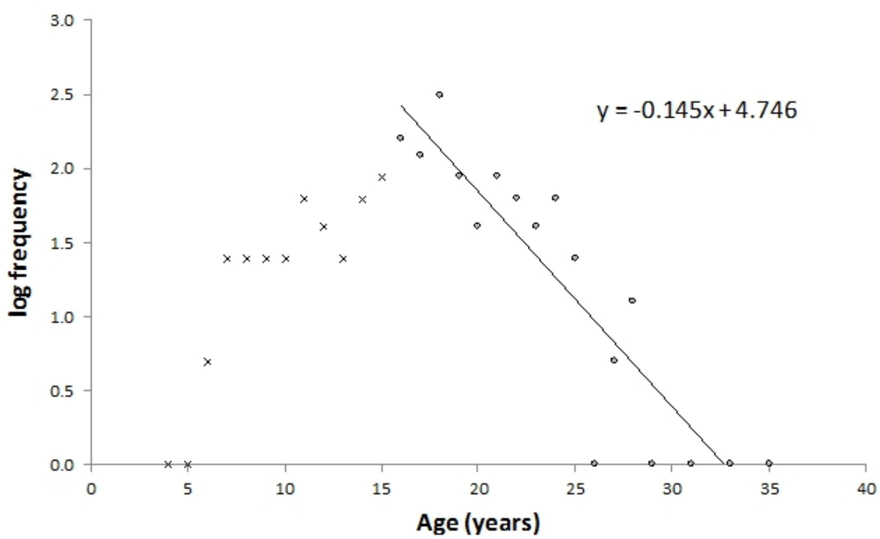

Figure 1. Catch curve analysis for the NWFSC Hook-and-Line survey age data.

Request 2: Rerun base model with two blocks of growth split at 1995 or as STAT determines appropriate.

Rationale*:* To assess whether the different growth patterns over the time period can improve the fit to the age-comp data.

Response: Exploring an early and late block on growth resulted in slightly lower spawning output in the early period but a larger spawning output in recent year, relative to the pre-STAR base model, with the stock nearing unfished in 2019 (Figure 2). The estimate of natural mortality increased marginally to 0.092 from 0.085. A larger difference was seen in estimates of Lmin, Lmax, and *k*, between the early and late periods. Blocking growth improved the overall model fit (lower NLL) through a better fit in the age data. However, the estimates of growth are confounded with potential changes in selectivity, recruitment deviations, and other life-history parameters. The constant growth model is preferable due to the confounding of growth and selectivity from a modeling perspective, and it is best to address the uncertainty in growth though crudely through different levels of constant growth, in the sensitivity analysis.

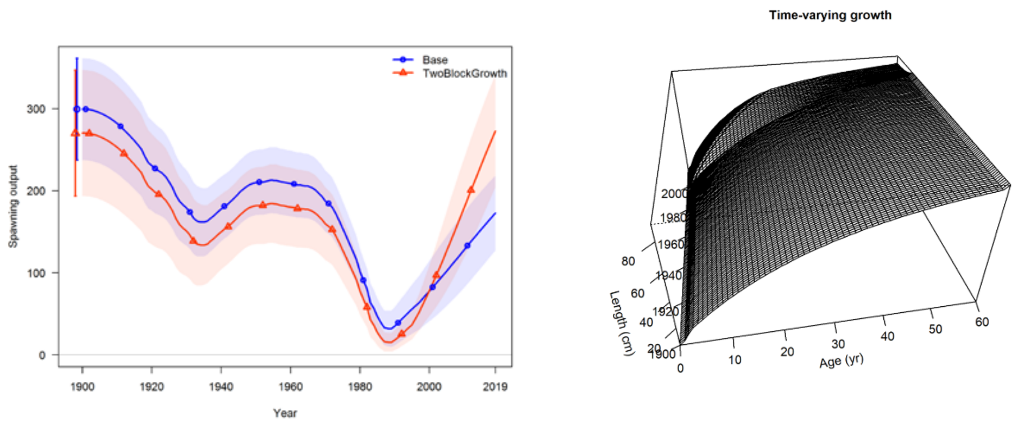

Figure 2. The estimated spawning biomass output based on two estimated growth curves compared to the base model (left panel, pre-2000 and post) and the estimated time-varying growth (right panel).

Request 3: Conduct a retrospective back to 2011. Also, do this retrospective dropping the ROV survey data point. In both cases, remove inside CCA NWFSC Hook-and-Line survey.

Rationale*:* To see the dependence of the ROV survey.

Response: Comparing the model when the ROV survey is included or excluded, in both cases with the Hook-and-Line data from inside the CCA removed, resulted in similar estimates of spawning output (Figure 3). The retrospective run with the ROV datum included did not result in a pattern as data years were removed. The 2011 retrospective run where the ROV datum was removed did result in a visible increase in the uncertainty estimate, implying that this datum point is contributing to the certainty in the scale in the population, but far less so to the scale itself. The retrospective run where the ROV datum is removed from the current pre-STAR base model resulted in a similar stable retrospective pattern.

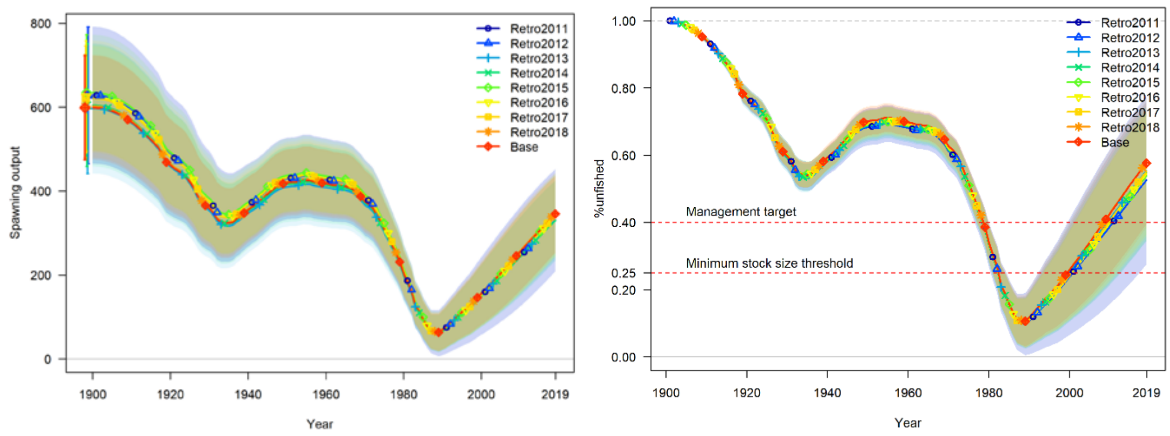

Figure 3. Retrospective pattern in spawning output (left panel) and the relative spawning output (right panel) when yearly data are removed.

Request 4: Fix growth at external estimate and turn all ages into marginal ages. Set Lambda for lengths and ages at 0.5 for fleet with both lengths and ages. Reweight. Also, plot marginals when you fit to the conditionals.

Rationale*:* Explore the impact of how the age data is treated in the model (conditional or marginal) on R_0 and M and the overall time series estimate.

Response: The spawning output trajectory was similar between the pre-STAR base model and this run with growth fixed at external values (Figure 4-left panel). However, the log(R_0) was estimated at a different value between these runs. The run that fixed growth parameters at the external estimated values resulted in a lower estimate in log(R_0) (Figure 4-right panel). The estimate of natural mortality declined to 0.077 from the 0.085 in the pre-STAR base model. Essentially, fish grow faster and live longer using the external growth estimates with a reduction in R_0 compensating for the increased productivity. Overall, the trajectories of the models with the two approaches to treating age data were quite similar in terms of spawning output and productivity.

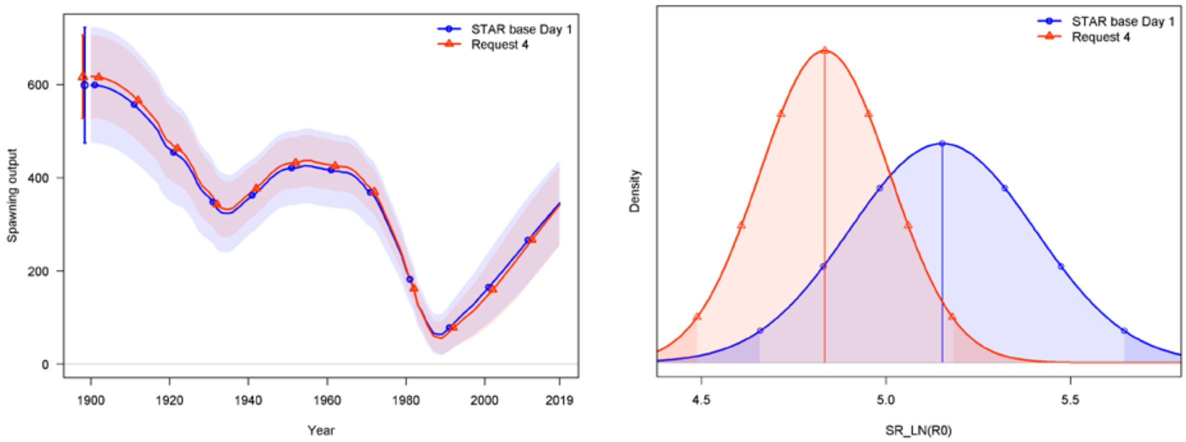

Figure 4. Comparison of the estimated spawning output between externally or internally estimating the growth parameters (left panel) and the difference in the estimated log(R_0) between the two approaches (right panel).

Request 5: Allow the model to estimate annual recruitment deviations starting in 2001. Complete for base model and for model from request 4 (above).

<u>Rationale</u>*:* There may be adequate information to inform recruitment strengths in more recent years.

<u>Response</u>: The STAT team estimated a main period of recruitment between 2003 – 2015, with early deviations starting in 1993 where the parameters were fixed at external estimates (Table 1 and Figure 5, Model4). The STAT team also presented the pre-STAR base model which internally estimated growth with the same set-up for estimation of recruitment deviations (Table 1 and Figure 5, Estimated1). In both models recruitment variation (sigmaR) was set equal to 0.40. The model with annual recruitment deviations estimated a large positive deviation in 2009. The STAT team noted that allowing the model to estimate recent recruitment deviations resulted in a lower estimate of natural mortality of 0.074, but a larger *k*, compared to the pre-STAR base model. Overall this suggest that there is little evidence that year class strength can be estimated reliably, at least not until growth can be better resolved.

Table 1. Comparison of the estimated parameters between the pre-STAR base model, that model with estimated recruit deviations, and the model structure from request 4 with recruitment deviations.

Label	Base	RecrDevsEstimated1	RecrDevsEstimatedModel4
Female M	0.085	0.082	0.074
Steepness	0.72	0.72	0.72
lnR0	5.153	5.091	4.761
Total biomass (mt)	4144.02	4194.87	4135.26
Depletion	0.577	0.57	0.563
SPR ratio	1	1	1
Female Lmin	19.965	20.016	19.614
Female Lmax	73.846	74.092	79.444
Female K	0.053	0.052	0.073

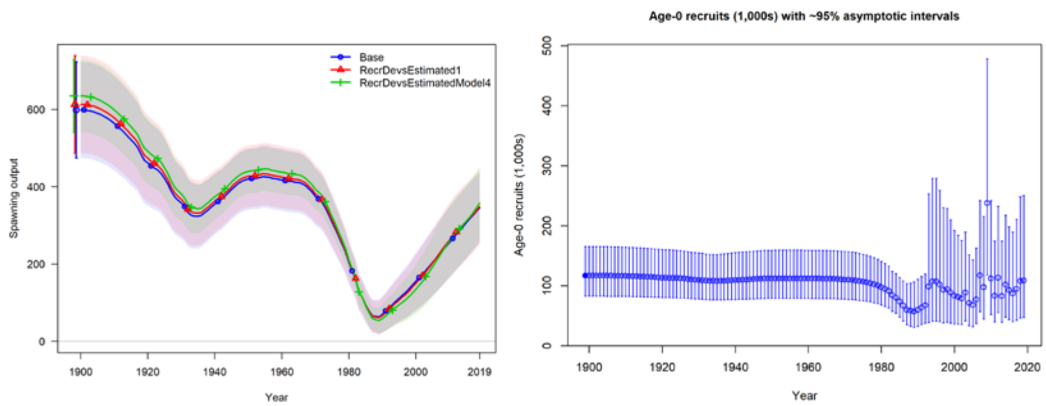

Figure 5. Comparison of the estimated spawning output trajectories (left panel) and the annual estimated recruitment deviations from Model 4 (right panel).

Request 6: Use the Francis-weighting approach for 3 iterations and compare result with harmonic mean weighting approach for 3 iterations and the Dirichlet approaches. Provide table of final weights.

<u>Rationale</u>*:* To examine interactions between data weighting approaches, estimation of growth, and estimates of biomass.

<u>Response</u>: The Dirichlet weights went to 1 and the model did not converge. The McAllister-Ianelli harmonic mean data weighting approach wanted to up-weight the recreational length samples but was capped at 1 because the input sample size was equal to the number of fish. The Francis weighting with multiple iterations had 3 fleets for which weights did not appear to be converging (Recreational, NWFSC WCGBTS, and the NWFSC Hook-and-Line ages). The weighting approaches resulted in similar population trajectories and growth estimates, however, the internally estimated growth rate parameter, *k*, was lower in all models compared to the external estimate based on the data (Table 2). The model parameters are largely insensitive to the weighting method used.

Table 2. Comparison of estimated parameters based on the alternative data weighting methods.

Parameter	pre-STAR base	Francis x3	MI x3	Dirichlet-Multinomial
NatM_p_1_Fem_GP_1	0.084514	0.084651	0.087714	0.086598
L_at_Amin_Fem_GP_1	19.9654	20.0589	19.4637	19.521
L_at_Amax_Fem_GP_1	73.8461	73.5107	76.0385	75.6077
VonBert_K_Fem_GP_1	0.052649	0.04341	0.050874	0.053044
CV_young_Fem_GP_1	0.171793	0.182174	0.174796	0.174112
CV_old_Fem_GP_1	0.075653	0.068188	0.077824	0.077063
SR_LN(R0)	5.15292	5.25277	5.14934	5.12136
SR_BH_steep	0.72	0.72	0.72	0.72
Bratio_2019	0.577234	0.592511	0.557932	0.54803
SSB_unfished	598.394	611.224	593.907	593.133

Request 7: Contact John Wallace and check for any interaction between the inside and outside NWFSC Hook-and-Line indices.

Rationale*:* Single index would be preferable from the assessment perspective.

Response: The STAT contacted J. Wallace (NWFSC) to inquire about interactions between the inside and outside hook-and-line indices. Mr. Wallace indicated that he had not evaluated interactions between year and location (inside/outside).

The STAT used the NWFSC Hook-and-Line survey data from 2014-2018 to test for an interaction between year and location (inside/outside CCA). Some sites did not catch a cowcod over the period 2014-2018, and these were excluded from further analyses. Prior to fitting a model, the STAT plotted the proportion positive by year and location (Figure 6).

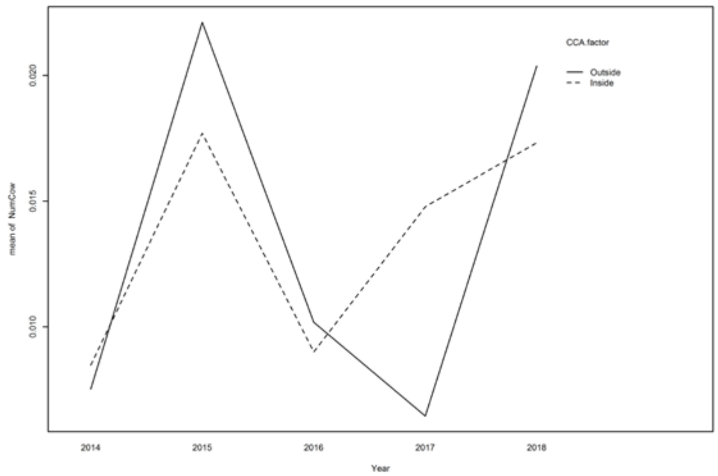

Figure 6. The proportion of positive hooks from the NWFSC Hook-and-Line survey, by year and location (inside/outside the CCAs). Sampling within the CCA began in 2014, so previous years of the survey are not shown.

Next, a binomial GLM was fitted to the data with covariates identical to the index in the draft assessment. Another GLM was fitted with a categorical covariate for location (inside/outside CCA), as well as an interaction term between the Year covariate and location. Specifically, the binomial GLM was fit using the glm() function in R:

```
NumCow ~ Year + CCA.factor + Year:CCA.factor + Vessel + SiteName +
         DropNum + HookNum + poly(Depth.m, 2)
```

The STAT team found small significance to this potential interaction term (AIC and BIC have opposite weak support for this interaction term). Given the weak evidence of an interaction, it is likely that a more parsimonious model that treated the two indices as a single index representative of the whole population should reduce uncertainty.

Request 8: Combine inside and outside comps in the indices for NWFSC Hook-and-Line survey and add a time block in selectivity to account for recent years.

<u>Rationale</u>*:* More realistic way to treat the information from the NWFSC Hook-and-Line survey

<u>Response</u>: The STAT realized after the request was made that an additive effect for CCA is confounded with site effects in the model, as each site can only occur inside or outside the CCAs. The STAT considers model structures for the NWFSC Hook-and-Line index a priority for future research, as this survey targets cowcod (untrawlable) habitat and provides useful information about growth. Hierarchical structures for the linear predictor should be evaluated, e.g. allowing sites to be nested within areas (inside/outside CCA).

To account for possible changes in selectivity with the addition of sites inside the CCA, a time block was added to the base model, retaining both indices (inside and outside) as they were in the base model. A time block was defined for the period 2014-2018. Another difference was the use of 3-

parameter selectivity curves for both time periods, allowing for domed shapes and estimating size at peak selectivity, the slope of the ascending limb, and the slope of the descending limb. The “-999” option was used for terminal selectivity, estimating this quantity based on the decay rate of the (estimated) descending limb.

Major differences between this model and the base include much slower growth and larger asymptotic size, to the point that the size distribution of older fish is truncated. Natural mortality decreases relative to the pre-STAR base (estimated M=0.067 vs. 0.085), and spawning output increases by roughly a third. Stock status declined from roughly 60% to 50% of unfished in 2019. The model with dome-shaped selectivity assumes larger, older fish are present, but not selected in the survey, whereas the model with asymptotic selectivity assumes that larger fish have not survived.

Request 8a: Analyze the entire set of NWFSC Hook-and-Line data using site effect as a proxy for inside vs outside CCA. Maintain time block with asymptotic selectivity in second time block allowing for dome-shaped selectivity in the first time block.

Rational: This will address the intent of Request 8 above, despite the inability to fit the index model to inside vs outside explicitly.

Response to the amended request: A revised NWFSC Hook-and-Line index was fit to the complete data set (including sites inside and outside the CCA). Stepwise AIC model selection identified a model with Year, Site, and Hook Number effects as the best model. Although there is evidence of changes in mean depth fished at some sites across years (Figure 7), depth fished at most sites is consistent over time. The AIC difference for depth (squared) was less than 2, after accounting for site, and therefore depth (and depth^2) was excluded as a factor in developing the final index.

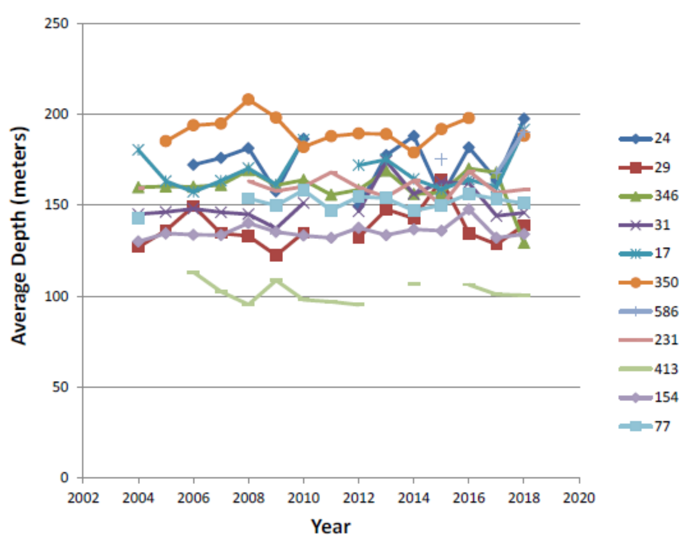

Figure 7. Changes in mean depth fished by site across years (variability among individual drops will be greater).

The revised index is similar to the previous ‘outside CCA’ index (Figure 8), with smaller log-scale standard errors, due in part to the inclusion of additional data from 2014-2018.

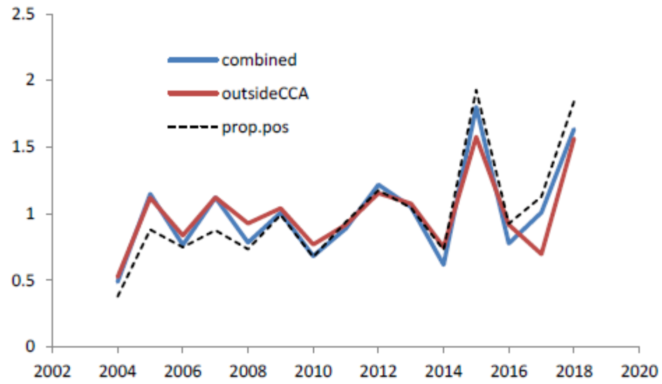

Figure 8. Revised NWFSC Hook-and-Line index (blue line) compared to the outside CCA index from the pre-STAR base model (red line) and annual proportions of positive tows (dashed black line; no standardization for site and hook numbers effects).

The model was fit to the new, combined NWFSC Hook-and-Line index, with selectivity forced to be asymptotic in the 2014-2018 time block. Unfished spawning output increases while current spawning output levels remain similar, resulting in a slightly more depleted stock in terms of relative spawning output (Figure 9). The model with the combined NWFSC Hook-and-Line index and asymptotic selectivity in the 2014-2018 time period has similar growth to the pre-STAR base, and does not result in truncated length distributions for the older fish as was seen in Request 8.

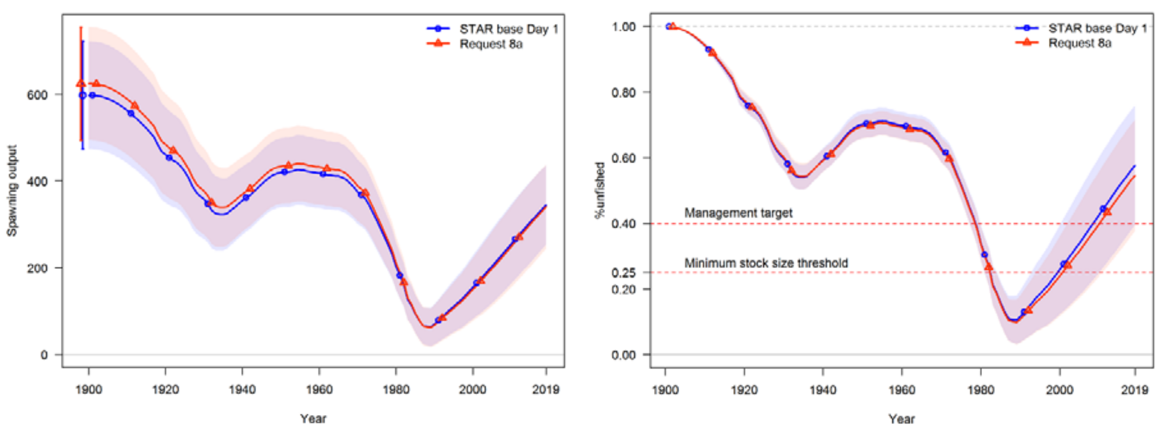

Figure 9. Comparison of spawning output trajectory (left panel) and the relative spawning output (right panel).

Estimates of growth parameters show values for *k* (0.053 in the pre-STAR base versus 0.050) and smaller size at age 35 that are similar to the pre-STAR base. The estimate of natural mortality decreased slightly relative to the pre-STAR base model (0.085 vs. 0.081).

There was concern from the STAR panel regarding the decision to model two periods of selectivity. The index is being modeled as one continuous process (inside and outside), but adding a selectivity block indicates that there are two processes are being modeled despite the single index calculation. However, the data does seem to support this change in selectivity when composition data from all years are included given that there is a higher proportion of larger fish from the CCA samples compared to the earlier years with data just from outside the CCA. This was further investigated under request 13.

Request 9: Turn off prior on submersible survey q

Rationale*:* The STAR panel is interested in the influence of the prior on the estimate of q and the overall assessment. .

Response: The pre-STAR base model estimates a catchability parameter (q) with a prior distribution developed during the STAR panel for the 2005 cowcod assessment. This quantity represents the proportion of cowcod biomass inside the CCAs, relative to the entire Southern California Bight.

The effect of the prior was evaluated by comparing the 'float' option in Stock Synthesis rather than estimating a parameter for q. The float option calculates an analytical solution for q. Given the large uncertainty in the prior, removing it had a minor effect on stock depletion in 2019 (3.6% change), and affected estimates of natural mortality in the third decimal place (0.0845 in the pre-STAR base versus 0.0868). The catchability estimate with a prior (red triangle at 0.45, Figure 10) was shifted toward the prior mode relative to the analytical solution (blue triangle at 0.37, Figure 10). The estimate of q without the prior made a small difference in the overall model, and the negative log-likelihood between models were similar with the largest difference arising from the prior likelihood contribution. In regard to the estimated trajectory this change only slightly altered the recovery trajectory in recent years (rather than shifting the whole time-series either up or down).

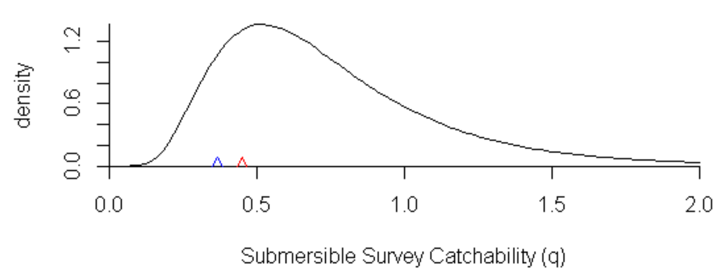

Figure 10. Comparison of the value of q between using a prior on q (red triangle) versus the analytical solution of q without a prior (blue triangle).

Request 10: Develop prior for submersible survey q based on the proportion of biomass inside the CCA relative to the total area estimated from the ROV survey.

Rationale*:* This is the best information we have on the proportion inside the CCA and would provide a more appropriate and informative prior than the one currently used.

Response: The prior for catchability for the SWFSC submersible survey used in the pre-STAR base model is based on an analysis of CPFV logbook CPUE from 1990 to 2000 (see Piner et al. 2005 for details). An index of abundance based on the logbook data was rejected during the 2013 cowcod assessment because catch rates were sensitive to alternative methods for determining effective effort for cowcod. The SWFSC ROV survey provides a direct estimate of the proportion of cowcod biomass inside and outside the CCAs in 2012. Use of these data to inform a prior for catchability assumes that the relative distribution of biomass was the same in 2002 when the submersible survey was conducted.

Using the model-based abundance estimate for the SWFSC ROV Survey, posterior draws (10^5) of biomass estimates for strata inside the CCAs were summed and divided by the sum of posterior draws in all strata (inside and outside the CCAs). This produced a distribution for the ratio of biomass inside the CCAs to total biomass in the SCB (solid black line, Figure 11). A lognormal distribution with the same mean and variance (dashed black line, Figure 11) is used as an alternative prior for the catchability coefficient for the SWFSC submersible survey. The original prior (red line, Figure 11) is less precise and more skewed, with a larger mean but a smaller mode than the prior derived from the ROV survey.

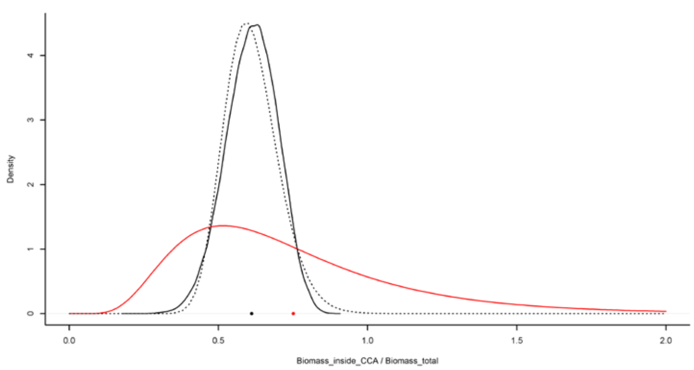

Figure 11. Comparison of q priors for the SWFSC 2002 submersible survey. The red line is the original prior, with a mean of 0.751 (red circle). The solid black line is the posterior density (mean = 0.61, black circle) for catchability derived from the SWFSC 2012 ROV survey. The dashed black line is a lognormal approximation of the posterior with the same mean and log-scale standard deviation.

Parameter estimates, derived quantities, and likelihood components were similar for the model with the submersible survey catchability with and without the original prior and the estimate based on the revised prior (i.e. derived from ROV survey). Stock status in 2019 based on the revised catchability prior is 53.9%, or 3.8% lower than the base and 7.4% lower than the estimate without a prior (i.e. effectively removing the submersible survey, Figure 12). The STAT supports this new approach for defining the prior on q for the submersible survey.

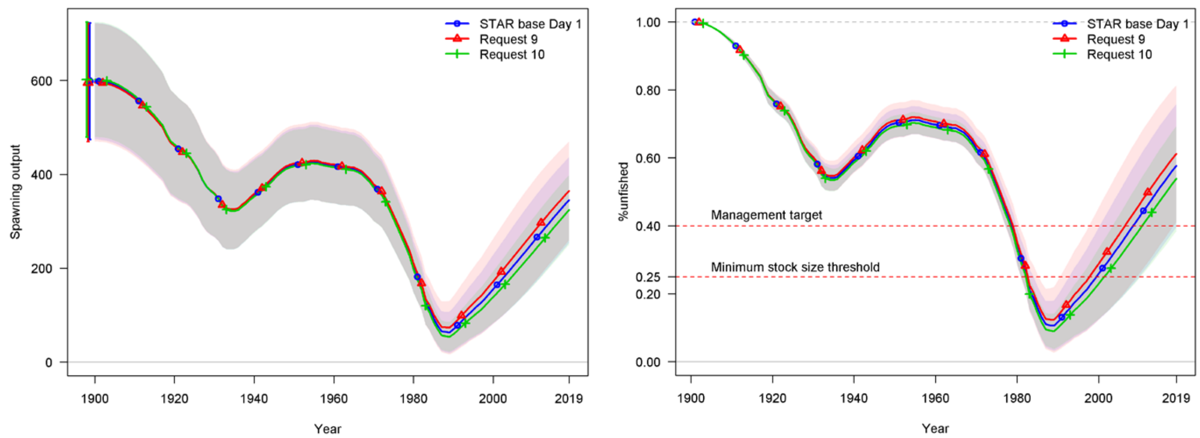

Figure 12. Comparison of the estimated spawning output (left panel) and relative spawning output (right panel) for three alternative priors on catchability for the SWFSC submersible survey. Request 10 uses the prior derived from the SWFSC ROV survey biomass estimates inside and outside the CCA.

Request 11: Conduct a series of drop 1 out as well as include only 1 index (and associated composition data) at a time sensitivities, in contrast to previous sensitivities which dropped only compositional data.

Rationale*:* To check the influence of each individual index data source.

Response: The model was relatively insensitive to dropping a single index at a time (Figure 13). Dropping either the CalCOFI (slower recovery trajectory) or the submersible indices (faster recovery trajectory) resulted in the largest differences. For the 1 index at a time sensitivities (Figure 14), the unfished spawning output is estimated much lower but a faster increase in recent years when only using the NWFSC WCGBTS, NWFSC Hook-and-Line, or CalCOFI indices due to higher estimates of natural mortality. Fits to only the NWFSC WCGBTS and Hook-and-Line survey indices did not meet the convergence (gradient) threshold. In these single index runs, growth was fixed at the full model estimates due to the lack of data to estimate growth in most of these sensitivities. The STAT team reported that, given that steepness is fixed, the model estimates of M and R_0 adjust in each run to result in a stock trajectory that fits both the ROV and submersible data points. This at least partially explains the high correlation between M and R_0 parameters in the model. The STAT team showed a run where only the submersible index was used which was a single parameter model, R_0, with M and q fixed. This run fits the submersible perfectly, but also is fitting the ROV data point (as a ghost fleet). Additionally, the visual fits to the other indices (as ghost fleets) are relatively similar to the full base model with M and growth estimated as well.

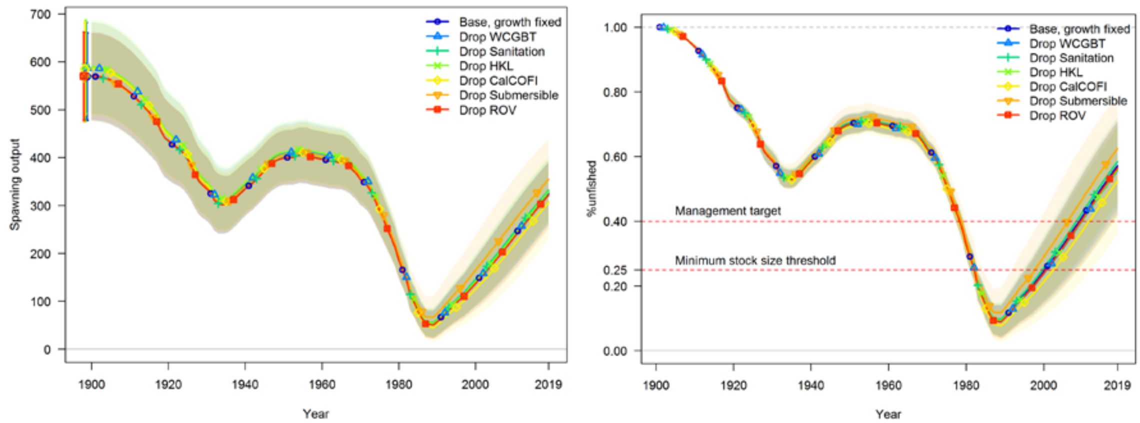

Figure 13. Estimates of spawning output (left panel) and the relative spawning output based on the drop-one analysis.

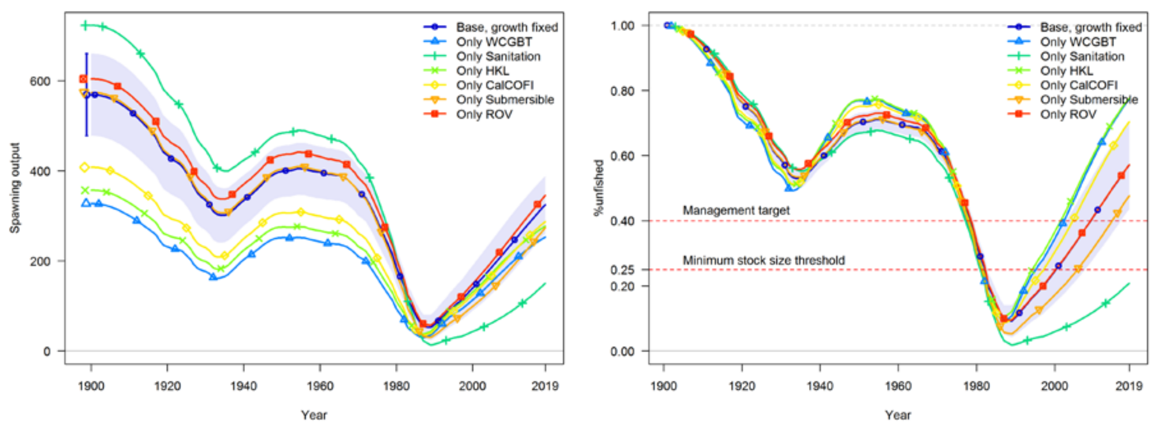

Figure 14. Estimates of spawning output (left panel) and the relative spawning output based on the include-only-1 analysis.

Request 12: Create the “Piner plot” for R_0 across the index likelihood components.

<u>Rationale</u>*:* This plot will provide information about the influence of each index on the estimated scale of the population.

<u>Response</u>: The majority of the information in the estimation of log(R_0) is coming from the ROV and the CalCOFI surveys. Each survey is supporting values of log(R_0) that range between 5-5.5 (Figure 15).

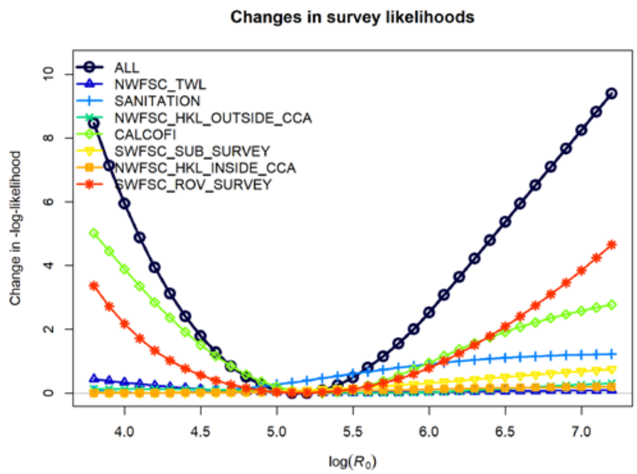

Figure 15. Contribution to the estimated log(R0) value based on the change in the log-likelihood across the survey indices included in the cowcod assessment.

Request 13: Remove composition data prior to 2014 from the combined NWFSC Hook-and-Line survey comps and put in a new dummy fleet. Also, remove time block on NWFSC Hook-and-Line selectivity.

<u>Rationale</u>*:* NWFSC Hook-and-Line survey index as developed should have a single selectivity over entire time period. However, do not want to lose information on lengths and ages from earlier portion.

<u>Response</u>: The selectivity for the 2014-2018 period was set at asymptotic reaching full selectivity at approximately 75 cm while the early comp fleet assumed a dome-shaped selectivity peaking at slightly smaller sizes (Figure 16 left panel). This adjustment to the treatment of the data resulted in a similar trajectory to the previous model with only a minor change in unfished spawning output (Figure 16 right panel). This treatment seems to be a better compromise than the pre-STAR-base model where the survey is treated as two separate indices.

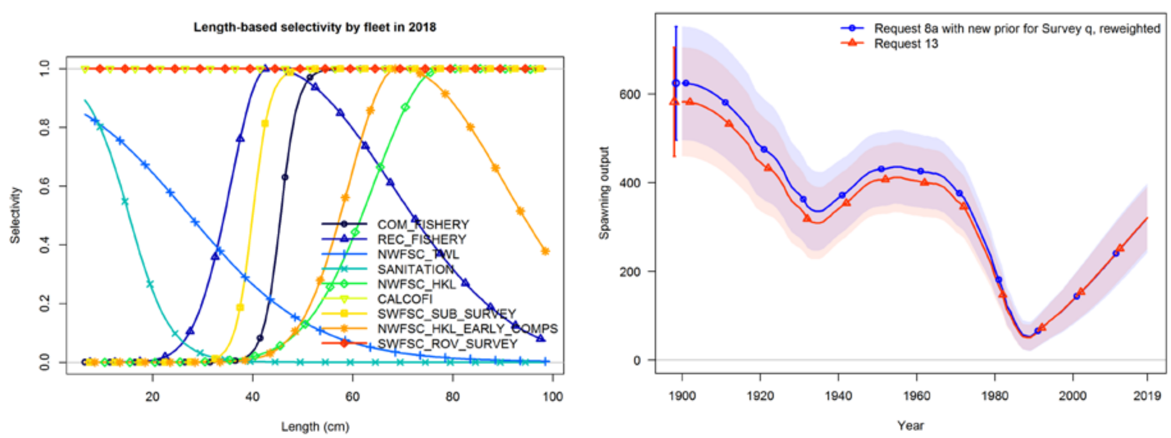

Figure 16. The estimated selectivity (left panel) between the early NWFS Hook-and-Line survey with only outside CCA data (orange line) and the late NWFSC Hook-and-Line survey (green line) which included length data collected inside and outside the CCA. Comparison of the estimated spawning output between the model with the revised treatment of q for the submersible survey (labeled Request 8a) and with the single NWFSC Hook-and-Line index with asymptotic selectivity (right panel).

Request 14: For CalCOFI index, replicate the index representing a ~20yr time period and place at 5yr intervals, i.e. remove the 1986 point and replace with identical values at 1979, 1984, 1989, and 1994. Use the average SE across all the other points.

Rationale*:* The current point at 1986 currently represents 19 years whereas the other super years represent 5 years. Thus this point is currently underweighted.

Response: The STAT team recalculated the index and input this in to the model from request 13. This change in the treatment of the CalCOFI data only resulted in a minor change to the spawning output. The model estimates a similar fit to the new index relative to the fits from previous model runs, but from a process perspective it is the more reasonable approach.

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

The post-STAR base model is a single area, single-growth morph, one-sex model, with deterministic recruitment with catches starting in 1900, and steepness fixed at 0.72 (the mean of the prior). Ages were included as individual years classes from age-0 to age-60+ years as a plus group, while population lengths were included as 1 cm bins from 6 to 98 cm. Growth and natural mortality were estimated with a prior on natural mortality based on a maximum age of 55. Two fishing fleets were defined: commercial and recreational. Six survey indices (including one absolute abundance estimate) were included: a sanitation survey, the NWFSC WCGBTS, the NWFSC Hook-and-Line survey, CalCOFI (with a more regular super year interval than in the pre-STAR model), the SWFSC submersible, and the SWFSC ROV survey. The ROV survey was given a fixed catchability coefficient (*q*) of 1, while a prior based on the ROV survey was placed on *q* for the submersible survey, which was conducted entirely within the CCAs. The conditional age-at-length compositional data were used for all age data sources: commercial, recreational, NWFSC WCGBTS, and the NWFSC Hook-and-Line. Length- and age-composition data were tuned using the Francis weighting approach.

The STAT team presented a preliminary decision table run where the uncertainty in natural mortality and the selectivity peak for the commercial fleet were explored. The low state of nature set commercial length at 50% selectivity ($L_{50\%}$) at 35 cm with an M of 0.055 (the value of M used in the previous assessment) and the high state of nature at a selectivity of 55 cm with M = 0.098 (the median of the Hamel prior on M given a maximum age of 55). The base model assumed a commercial fleet length at 50% selectivity of 45.6 cm, equal to the maturity ogive, and estimated M = 0.088.

The STAR and STAT agreed that creating a decision table based on these values provided the right amount of contrast across stock size, status, and the OFL values to reflect the uncertainty in the assessment. The GMT representative, Melissa Mandrup, provided the STAT team with catch projection values for 2019 and 2020. There was additional discussion concerning the implications of which fleet (commercial, recreational) would be the source of removal in the future years, with the fishery re-opening, and how the STAT team should allocate the projected ABC removals in the forecast years among fleets.

Technical Merits of the Assessment

The assessment makes use of the latest version of Stock Synthesis (SS v.3.30.13). This modelling framework can make use of a variety of disparate data and is particularly useful when time series data are discontinuous or where there are intermittent observations on length or age. It is therefore an appropriate choice for the assessment.

The assessment applied the full abilities of SS given the data available for cowcod. The model data and alternative model structures were thoroughly explored and the base model was well justified. Full sets of diagnostics were made available. The STAT was fully responsive to requests from the STAR panel.

Technical Deficiencies of the Assessment

Overall, there were no serious technical deficiencies with the assessment. Although the differences in the external versus the internal estimates of growth were of concern, given the lack of composition data for cowcod, the treatment of these data and internal estimation of growth was justified.

The model was not able to estimate recruitment deviations and cannot therefore fully capture annual changes in stock size and contributes to poor fits to some data components. The lack of fit will reduce the reliability of asymptotic variance estimates.

The fecundity of cowcod is not well known and there is uncertainty as to the number of broods individual females produce. In this new assessment fecundity estimates were revised and led to a major change in the scale of the estimated spawning output. However, this issue is not fully resolved.

Areas of Disagreement Regarding STAR Panel Recommendations

Among STAR Panel members (including GAP, GMT, and PFMC representatives):

None.

Between the STAR Panel and the STAT Team:

None.

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

None.

Unresolved Problems and Major Uncertainties

The major issue and uncertainty associated with the cowcod assessment is the lack of data, particularly age data, adequate to estimate recruitment deviations.

The STAR panel recommends that this assessment be considered a Category 2 assessment for purposes of management.

The next assessment should be a full if any of the following are true: There are substantial additional data in terms of fishery length and age compositions, a new visual survey, or from the WCGBTS following expanded into the CCAs, or the SSC determines that the assessment is sufficiently "stale" that a new full is needed. Otherwise, the assessment may be updated.

Recommendations for Future Research and Data Collection

Specific recommendations for the next cowcod assessment:

1. Evaluating how to structure the NWFSC Hook-and-Line survey index given its expansion into the CCA, also independent analysis of information content in NWFSC Hook-and-Line survey.
2. There are a number of improved data collections that would be beneficial to the next assessment of cowcod.
    a. Continue to conduct the NWFSC Hook-and-Line survey which was an important source of fishery independent data for cowcod.
    b. Having multiple absolute abundance observations for cowcod from visual survey are important to understanding the stock size and status of the stock.
    c. Given the lack of biological data for cowcod, it is critical to improve and expand collection of length and age data for fishery and fishery independent data sources.
    d. The majority of ages available for cowcod were read by a single age reader. As data collection increases having additional age double reads and age validation information would be beneficial.
    e. Rockfish species, particularly in southern California waters, have been observed to produce multiple broods within a single year. Collecting biological data to better understand the potential fecundity for cowcod across size and is important to understanding the reproductive potential of the population
3. The WCGBTS provides some abundance information for smaller cowcod. Adding sampling within the CCA while continuing with a sampling intensity of over 700 cells per year (a four-vessel survey, as opposed to the two-vessel survey conducted in 2019) would provide improved information on the abundance of these size and age classes.

4. Increased spatiotemporal sampling around Pt. Conception would aid in identifying stock boundaries.

General recommendations for all assessments:

1. Continued and improved data collection for West Coast groundfish stocks. The NWFSC Hook-and-Line survey offers important data on species that may be infrequently encountered by the NWFSC WCGBTS. Expanding the WCGBTS into the CCAs would improve index and compositional information for a number of stocks in the Southern California Bight.
2. Work with Mexico to get information on the densities and compositions of stocks in their waters, in particular in areas directly south of the California-Mexico border, would improve our understanding of ranges, dynamics and status of stocks which extend into Mexico.
3. Examine uncertainties around historical catch data and methods for incorporating into the assessment.
4. Explore alternate stock recruitment relationships.

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