Stock Assessment Review (STAR) Panel for Chilipepper Rockfish
Southwest Fisheries Science Center Auditorium, NOAA
110 McAllister Way | Santa Cruz CA 95060

June 23-27, 2025

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Overview
The Stock Assessment Review (STAR) Panel for chilipepper rockfish (*Sebastes goodei*) was held at the NOAA's SWFSC in Santa Cruz, CA on June 23-27, 2025. The meeting was hosted by the Pacific Fishery Management Council (PFMC) and followed the Terms of Reference for the Groundfish Stock Assessment Review Process for 2025-2026 (TOR) and Accepted Practices Guidelines for Groundfish Stock Assessments in 2025 and 2026. Chilipepper rockfish are retained in commercial and recreational fisheries, with most landings commonly north of Point Conception. Recreational catches have increased in recent years due to nearshore fishing closures that shifted fishing effort into deeper waters.

The 2025 full (benchmark) assessment was conducted by E.J. Dick (SWFSC), John Field (SWFC), Nicholas Grunloh (University of California, Santa Cruz), and Tanya Rogers (SWFSC). This assessment follows catch-only projections in 2023 (Wetzel 2023), a catch-only update to correct errors in historical catch estimates in 2017 (Field 2017), and an update assessment in 2015 (Field et al. 2015). The last benchmark assessment was conducted in 2007 (Field 2007). The 2025 model estimates a decrease in spawning output from the 1980s to the early 2000s, when the stock was estimated to be below the minimum stock size threshold (MSST). Since the early 2000s, the stock was estimated to have undergone considerable increases in spawning output and was estimated well above the management target in the terminal year.

Discussions during the STAR Panel centered around data weighting procedures, improving spatiotemporal models used to develop indices of abundance, improving model fits to composition data and indices of abundance, estimating additive variance for indices of abundance, evaluating fleet-specific assumptions about selectivity, and considering effects of a sum-to-zero constraint on recruitment deviations. The STAR Panel and STAT agreed on a revised base model from the pre-STAR version as best scientific information available. The Panel identified several areas for future research, many of which are not unique to the chilipepper rockfish assessment.

Summary of Data and Assessment Models

The 2025 benchmark assessment for chilipepper rockfish was performed using an integrated age-structured assessment model (single area, sex-disaggregated) in Stock Synthesis (SS3 v3.30.23.1).

Input Data

- Eight (8) catch data streams: hook-and-line fleet north of Point Conception (NoCA_HKL), hook-and-line fleet south of Point Conception (SoCA_HKL), trawl fleet from California (CA_TWL), commercial fleet from Washington and Oregon (OR_WA_Comm; mostly trawl), net gear from California (CA_NET), recreational fleet north of Point Conception (NoCA_OR_WA_Rec; includes Oregon and Washington), recreational fleet south of Point Conception (SoCA_Rec), and trawl discard fleet (TWL_discard; mostly California).
- Four (4) abundance indices: West Coast Groundfish Bottom Trawl Survey (WCGBTS; WCGBT_Survey), Alaska Fisheries Science Center (AFSC) & NWFSC West Coast Triennial Shelf Survey (Triennial_Survey), recruitment index from the CalCOFI survey (CalCOFI_survey), young-of-the-year (YOY) index from the Rockfish Recruitment and Ecosystem Assessment Survey (RREAS; RREAS_YOY_Survey).
- Ten (10) fleets with length composition data: sourced from the commercial and bottom trawl survey fleets mentioned above.
- Seven (7) fleets with conditional-age-at-length (CAAL) data: commercial and survey fleets.

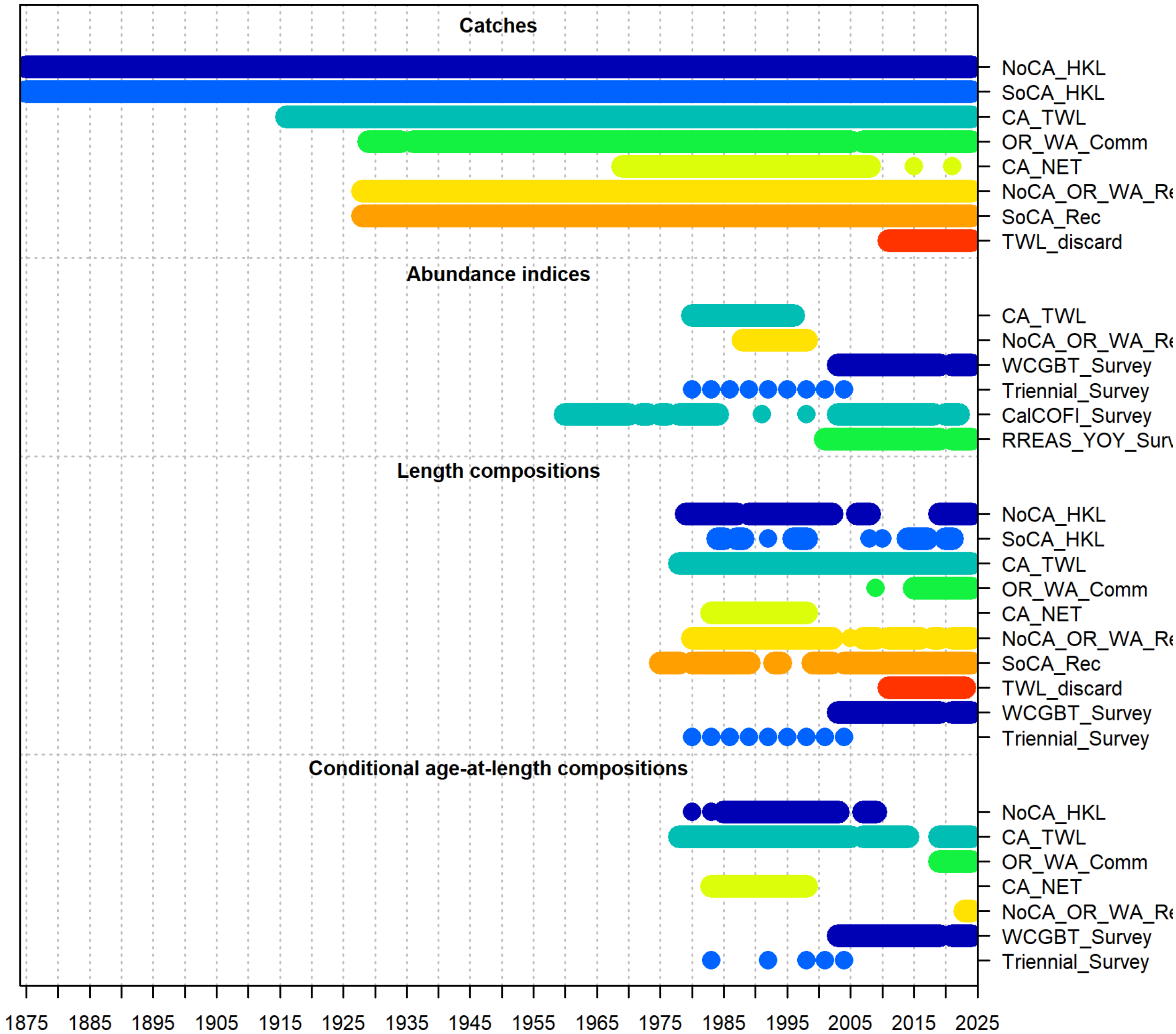


Figure 1. Input data by year and fleet, organized by type (catches, abundance indices, length compositions, and conditional age-at-length compositions).

Model Specifications

- The assessment period began in 1875 with a linear interpolation of catches from 1875 to 1916, when the first annual catch record was available. The stock was assumed to be unfished and in equilibrium condition in 1875.
- The model included ages 0 yr (recruits) to 35 yr (plus group) with a step size of 1 yr and lengths 7 cm (mid-year size at age 0) to 60 cm (plus group) with a step size of 1 cm. Age data were binned in 1 year increments from 1 to 60 yr. Length data were binned in 2 cm increments from 8 to 60 cm.
- Growth was internally estimated using the Schnute parameterization of the von Bertalanffy growth model. L_0 was fixed at 7.3 cm. Remaining growth parameters were estimated internally. Growth was assumed to be sex-specific and time-invariant. Time-varying growth was examined as a sensitivity.
- Ageing error was estimated externally.
- A lognormal prior for female natural mortality (*M*) with a median of 0.154 and a log-standard deviation of 0.31 was based on the Hamel and Cope (2022) prior and A_{max} equal to 35 yr. Male *M* was modeled as an exponential offset from female *M*.
- The length-weight relationship was estimated externally as: $W = 8.41443 \times 10^{-6} L^{3.13495}$ for females and $W = 6.93782 \times 10^{-6} L^{3.202012}$ for males.
- Length-at-maturity was estimated externally using a logistic curve with $L_{50\%}$ = 24.4 cm and a slope of -0.27.
- Fecundity was estimated externally and updated from the 2015 assessment to account for size-dependent multiple brooding. The length-fecundity relationship was estimated as: $F = 5.6822 \times 10^{-8} L^{4.1773}$
- The sex ratio at birth (female to male) was fixed at 0.5.
- Recruitment dynamics were assumed to follow the Beverton-Holt stock-recruit relationship with steepness (*h*) fixed at the mean of a beta prior (0.72) with σ = 0.16. Recruitment deviations were estimated from 1968 to 2024, with the main recruitment estimation period being between 1968 and 2024) and σ_R fixed at 1.0. The model used a sum-to-zero constraint for recruitment deviations (modified from the pre-STAR base).
- Selectivities for the commercial and recreational fleets were length-based, included time blocks, and allowed for dome-shaped curves in the pre-STAR base model. Several selectivity curves (NoCA_HKL, CA_TWL, CA_NET, NoCA_OR_WA_Rec) were changed to asymptotic for the final base model based on the results of MCMC diagnostics. Selectivities for the WCGBTS and Triennial survey remained asymptotic with the same properties as in the pre-STAR base model.
- Two parameters with standard errors greater than MLE estimates (“CV_old_Mal_GP_1” and “Size_DblN_ascend_se_SoCA_HKL(2)”) were fixed at MLE values to stabilize the model.
- CalCOFI and RREAS indices estimated additive variance in the pre-STAR base model. Additional variance for the RREAS index was fixed so that the total standard error averaged across all years equaled the input σ_R value.

Description of the Alternative Models used to Bracket Uncertainty in the Decision Table

The final base model was similar to the pre-STAR base model, with the following revisions:

- changing some selectivities from dome-shaped to asymptotic,
- re-estimating the WCGBTS index to account for depth effects,
- fixing additive variances for the RREAS indices such that standard errors for all years averaged to the input sigma-R value (σ_R = 1.0),
- including a sum-to-zero constraint for recruitment deviations, and
- fixing two parameters (“CV_old_Mal_GP_1” and “Size_DblN_ascend_se_SoCA_HKL(2)”) to stabilize the model given standard errors that exceeded MLE estimates.

Many parameters that are typically used as the axis of uncertainty (e.g., natural mortality, *M*) were estimated in the base model. Thus, those sources of uncertainty were at least partially captured in the base model. Steepness (*h*) for the Beverton-Holt stock-recruitment relationship was fixed at the prior mean of 0.72 (a value derived from a meta-analysis based on maximum age). As such, the uncertainty surrounding steepness was not well captured in the base model. Following further analyses on the influence of *M* (e.g., bivariate likelihood profiles presented in response to Request 17), steepness was identified as the most appropriate axis of uncertainty. This was because different values resulted in considerable differences in estimated spawning biomass. The fixed value was also greater than the value used in the previous assessment. Therefore, the MLE for steepness when estimated (h = 0.38) was used for the low state of nature. This value was less than the 12.5th percentile of the assumed prior distribution. Steepness for the high state of nature (h = 0.97) was chosen from a recent study that approximates steepness based on life history characteristics (Beyer, in prep; following the approach of Mangel et al. 2010). These high and low values for steepness cover a wide range of structural uncertainty.

Following consultation with the GAP and GMT advisors, the Panel requested plots and tables that included 12-year projections assuming full attainment of the model-predicted ACL and constant catch at the predicted MSY value (2,114 t). These plots were very useful for comparing projections at different states of nature.

Technical Merits of the Assessment

The Panel found several technical merits:

- This assessment includes the best scientific information available to inform the model. Many new and updated data sources were included compared to the 2017 catch-only-update and the STAT uses the current best practices for model specifications.
- The young-of-the-year (YOY) RREAS index is informative of recruitment and has the potential to improve forecast skill.
- The initial modeling work that investigated time-varying growth was excellent.
- A wide range of sensitivity analyses were performed to identify sources of uncertainty (e.g., input data, model structure).
- “Problematic” or unstable parameters were identified via MCMC runs. The Panel highly recommends continued use of MCMC diagnostics for future assessments. However, MCMC runs cannot currently be performed for models that include a sum-to-zero constraint for recruitment deviations.
- Model fits to data were generally good.
- Estimated uncertainty seems appropriate given the ratio of fixed to estimated parameters, with at least one major fixed parameter serving as a key axis of uncertainty.

Technical Deficiencies of the Assessment

The Panel found the following deficiencies in the assessment:

- Despite several attempts, the STAT was unable to improve model fit to early portions of the WCGBTS index (2004 to 2007). Further evaluation is recommended.
- Despite several attempts to improve model fit to mean age data from the CA_TWL fleet between the mid1980s and 2000s, the model continued to underpredict mean ages. Possible changes in gear type (e.g., popularization of ‘rockhopper’ gear) in the mid-1980s and 1990s were identified but there was inadequate information to propose specific time blocking for selectivity. Further evaluation of this issue is recommended.
- The Panel recommends further consideration of a) the effect of selectivity by modifying the likelihood function and b) the possibility for changes in selectivity over time, as identified in the assessment model.
- Including a depth effect for the Triennial survey index was not investigated due to time constraints. Further evaluation is recommended.
- There were some potential concerns about weighting of composition data and abundance indices, which may alter stock trajectory and status.
- There was a relatively strong retrospective pattern, though it primarily presented as iterative decreases in strength of the 2013 year-class when removing additional years of data. This

implies that the model tends to overestimate biomass and stock status in the terminal year until this year-class is clearly defined and/or fished down.

- The final base model showed estimation instability that required fixing two parameters.

Recommended Sigma Value

The Panel recommends a Category 1b designation for this assessment (default sigma = 0.5). The age-structured model includes compositional data that sufficiently resolve year-class strength and growth characteristics, and trends are informed by fishery-independent indices. The model estimates sigma at 0.2284 (log scale) for the 2025 OFL. This is less than the default sigma for a Category 1b stock, thus the recommended sigma is 0.5.

Recommended Next Assessment Type

The Panel recommends that the next assessment be an update. If, however, new information leads to better guidance about using the sum-to-zero constraint on recruitment deviations (and how reference points and projections are made when the constraint is not used), a full (benchmark) assessment may be more appropriate. If altering the sum-to-zero constraint can be addressed without a full assessment, an update is still recommended.

Areas of Disagreement between STAR Panel and STATs or among STAR Panel

There were no disagreements within the Panel or between the Panel and the STAT. Several technical issues were constructively discussed, which led to a revised base model that was amicably agreed upon.

Management, Data, or Fishery Issues

The GMT and GAP advisors appreciated the opportunity to participate in the STAR Panel for chilipepper rockfish. The GMT advisor noted the utility of additional alternative catch projections based on constant catch at the MSY proxy yield. The OFLs predicted from this assessment were more than two times greater than current catches, which is why projections with the predicted MSY value were used for a second decision table. Given recent fishery performance, it is unlikely that the higher 2025 annual catch limit (ACL) will be fully attained.

Industry representatives have expressed concern that the WCGBTS may underestimate abundance for chilipepper rockfish, in part due to its limited access to rocky habitat and the semi-pelagic behavior of this species, which often occupies higher positions in the water column. The GMT and GAP recognize the need to improve fishery-independent indices of abundance through expanded or alternative survey methodologies. One potential approach could include extending the spatial coverage of existing hook-and-line surveys into more northern areas or taking advantage of developments in model-based index standardization to integrate multiple non-trawl fishery-independent sampling programs that have occurred over smaller spatial and temporal scales compared to the WCGBTS.

Expanding non-trawl survey coverage would also support the collection of biological data across a wider range of habitats and latitudinal gradients. The GMT and GAP recommend considering the application of acoustic or midwater trawl surveys to sample rocky reef habitats for semi-pelagic species such as widow, canary, chilipepper, and yellowtail rockfishes. These methods may provide more appropriate biomass estimates or abundance indices for species that were not well represented in bottom trawl surveys. Additionally, the use of environmental DNA (eDNA) in conjunction with acoustic surveys may offer opportunities to develop more species-specific indices, potentially improving precision in future assessments.

Unresolved Problems and Major Uncertainties
The Panel identified the following remaining uncertainties for this assessment:

- Historical catch reconstructions are subject to uncertainty stemming from issues with species identification and the spatiotemporal extent of data collection, highlighting the need for uncertainty estimates comparable to those used for model-based indices.
- Although results provided in an appendix to the stock assessment suggested the presence of time-varying growth, sensitivity analyses indicated minimal influences on model results. Thus, the model assumed that growth is time-invariant. Analyses of time-varying growth in the model were limited to variation in the parameter ‘k’ from the von Bertalanffy growth function. Temporal variation in L_∞ (potentially correlated with k) may have a greater effect on model results.
- Abnormal sex-specific sizes and ages should be evaluated further (e.g., by revisiting original datasheets, examining otolith morphology, or reviewing archived biological samples) to resolve uncertainties about notable outliers.
- Model fit to the WCGTS index, particularly in the early part of the time series, warrants further investigation, including additional work on index standardization.
- Further evaluation is needed regarding the inclusion of a depth effect in the Triennial survey index.
- Likelihood profiles indicate that input data were informative for estimating natural mortality (*M*) but not steepness (*h*).
- There is uncertainty in mean productivity estimates when applying a sum-to-zero constraint on recruitment deviation, potentially due to inaccurate assumptions about the stock-recruitment relationship.
- Estimation of selectivity and associated time blocking remain difficult for this assessment.

Recommendations for Future Research and Data Collection
The Panel identified the following research recommendations for this assessment:

- Additional biological research on skip spawning, functional maturity, and environmentally driven variation in brooding frequency is needed to improve estimates of fecundity.
- Further exploration of cohort and density-dependent effects at the assemblage level (particularly for co-occurring species like bocaccio, yellowtail, and widow rockfishes) may increase our understanding about variation in growth rates for chilipepper rockfish.
- A better understanding about the portion of the population in Mexican waters may be supported by habitat suitability mapping.
- A small number of ages derived from FT-NIRS were included using a unique ageing error matrix, yet model selection did not indicate a bias between FT-NIRS and traditional ageing methods. Visual inspection suggests a consistent bias toward younger FT-NIRS ages for older fish. This may reflect limitations in the bias structures available in the ageing error software, supporting an improved understanding about differences between FT-NIRS and traditional break-and-burn ages.
- Further development of the spatiotemporal models would improve index standardization. This may include the use of barrier meshes to account for geographic barriers and unique coastline features. Residual diagnostics should be evaluated by depth, especially for demersal species, to decide whether to include a depth effect in the model (even when including anisotropy to account for variables like depth).
- Selectivity estimation remains a challenge for this assessment due to complex and changing management measures. Further investigation into time-blocking and/or a more structured spatiotemporal modeling (e.g. by length groups or age) approach could clarify how to incorporate management and gear changes in future models by indicating which size/age might be affected by such changes.
- Continued research on density-independent effects on YOY survival, especially for integration into future risk tables. This includes developing an inshore-offshore index for the southern population and exploring moving average approaches to link the "minty-spicy" temperature index to recruitment dynamics.

- Prioritize completion of analysis of the historic CalCOFI data from central California to expand the time series for future assessments.
- A better understanding about predator-prey dynamics would improve our understanding about time-varying natural mortality.

The Panel identified the following research recommendations for groundfish stock assessments (in general):

- Appropriately weighting length and age compositions remains a challenge but identifying maximum input sample sizes based on expected observation uncertainty and down-weighting accordingly is a practical method. A bootstrapping approach to identifying maximum sample sizes (Hulson et al. 2023; Hulson and Williams 2024) may improve upon existing methods. The Panel recommends exploring different approaches to data weighting for West Coast groundfish assessments.
- More complete documentation about the configuration of spatiotemporal models used to develop based indices of abundance would benefit the review process. This includes identifying the family (distribution and link) used, justification for the inclusion and treatment of spatial and spatiotemporal terms, and assumptions about (an)isotropy. For nonlinear effects, descriptions of the smooth terms (e.g., basis spline, tensor product, tensor product interaction), smooth class (e.g., thin plate regression, cubic regression, Gaussian process), constraints on the number of knots, and method used for parameter estimation (e.g., GCV, REML) should be included.
- Analysts should explore the use of smoothers for model-based indices of abundance when nonlinear relationships are anticipated (as opposed to including both linear and squared terms to approximate nonlinearity). Exploration of alternative distributions and link functions (e.g., Poisson-link Gamma) and modeling densities or catch rates as numerical or biomass responses with effort as an offset (rather than CPUE) are recommended, whenever possible. Caution should be used when predicting outside the range of any covariate used in model fitting.
- Historical catch reconstructions should be accompanied by uncertainty estimates. This will facilitate running sensitivity analyses on catch histories.
- It is becoming increasingly common for Stock Synthesis to allow free estimation of recruitment deviations in the main recruitment estimation period, thus not imposing a sum-to-zero constraint on those deviations. This is done because of an issue within ADMB and MCMC sampling. When recruitment deviations in the main recruitment estimation period do not average to a value that is close to zero, it implies a different mean recruitment than is being used to calculate reference points and projections. This introduces inconsistencies between the period that is most informative and the time periods with little information. With the help of the STAT, it became apparent that assuming steepness greater than model-based estimate results in greater differences in mean recruitment deviations (from the main recruitment estimation period) from zero. The Panel was uncertain why the sum-to-zero constraint is not recommended or about the inconsistencies that result from not using the constraint. One way forward would be to investigate how mean recruitment deviations change when steepness is incorrectly specified. Further investigation into whether bias correction is appropriate when not using a sum-to-zero constraint on recruitment deviations would be helpful. MCMC runs cannot be performed for models that include a sum-to-zero constraint for recruitment deviations.
- A paper is in review that describes methods to interpret one-step ahead (OSA) residuals in stock assessments (Stewart and Monnahan, in prep), with applicable code for use in Stock Synthesis. OSA residuals should be considered for future West Coast stock assessments to aid in weighting of different data sources and interpreting potential issues associated with the data weighting procedures used.

STAR Panel Requests, Rationale, and Summary of STAT Responses

1 - Request
Explore whether a flexible 2D selectivity parameterization improves model fit to age data from the California trawl fleet. Plot the fit to mean age and mean length using this run. Please also present Pearson residual plots for each.

1 - Rationale
Given the poor fit to mean ages (~ 10 yr fish) and high selectivity of 25 to 30 cm fish from the mid-1980s to 2000s, changes in sex-specific selectivity may be having an effect. If this run improves the fits to mean age and mean length, an alternative selectivity parameterization or time block structure may be considered.

1 - STAT Response
The pre-STAR base model was modified to use the "2D-AR" length-based selectivity function in Stock Synthesis for the California trawl fleet (1978-2024). The standard deviation of the selectivity deviations was fixed at 1. The model was not re-tuned to compare likelihood components. The estimated parameters of the underlying logistic selectivity curve (from which year- and size-specific deviations are estimated) were 32.19 cm for the inflection point and 6.57 cm for the "95% width" parameter (i.e., the difference between the mean and the 95th percentile of the logistic curve). Deviations were estimated for each year and population bin (Fig. 1A), resulting in ~1360 parameters. The change to a more flexible selectivity curve did not visibly improve fits to mean age (Fig. 1B) and the age composition likelihood component increased from 2002.35 to 2006.22, suggesting a slight degradation of fit to age data. The length composition likelihood decreased from 569.09 for the pre-STAR base model to 531.01 for the model with a more flexible length-based selectivity curve. Given the addition of over 1,300 deviation parameters, an improved fit to the length composition data is not surprising. Visually, the change in overall fit to the length data is subtle, with noticeable improvements from 1978 to 1983 (Fig. 1C). Pearson residuals for the conditional age-at-length (CAAL) data showed some reduction in residual size for large males (Fig. 1D and Fig. 1E), though patterns observed in the pre-STAR base model persisted. Pearson residuals for the length composition data (Fig. 1F) show larger extreme deviations when using 2D selectivity, suggesting that the improvement in fit (i.e., decrease in likelihood) is spread across multiple length bins and years. Changes in scale for the residual plots make visual comparison difficult. The STAT plotted the $\log_{10}$ absolute value of the Pearson residuals from each model against each other, grouped by sex (Fig. 1G) and length bin (Fig. 1H). These suggest that improved model fit using the 2D selectivity is driven by better fits to large males.

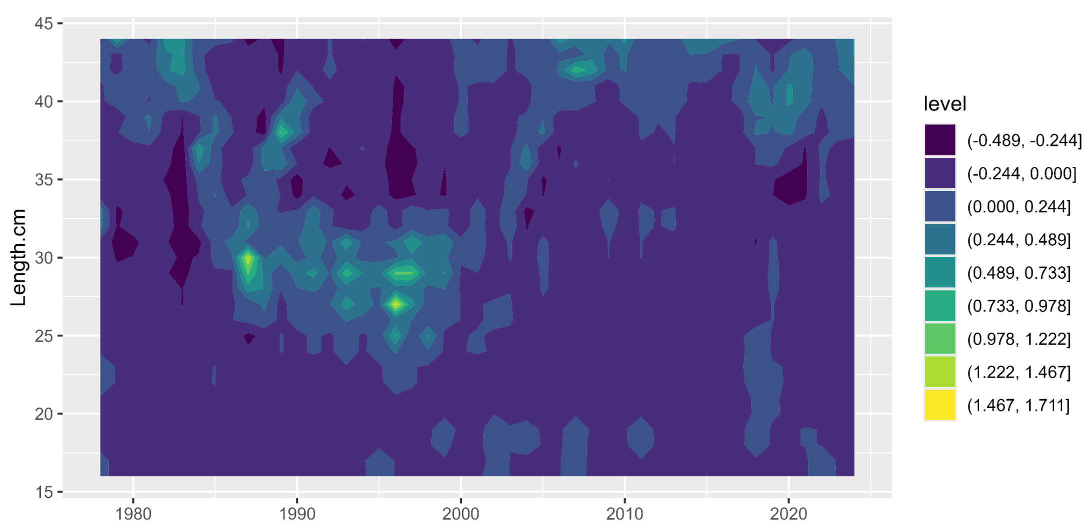


Figure 1A. Contour plot of deviations when estimating a logistic selectivity for the California trawl fleet.

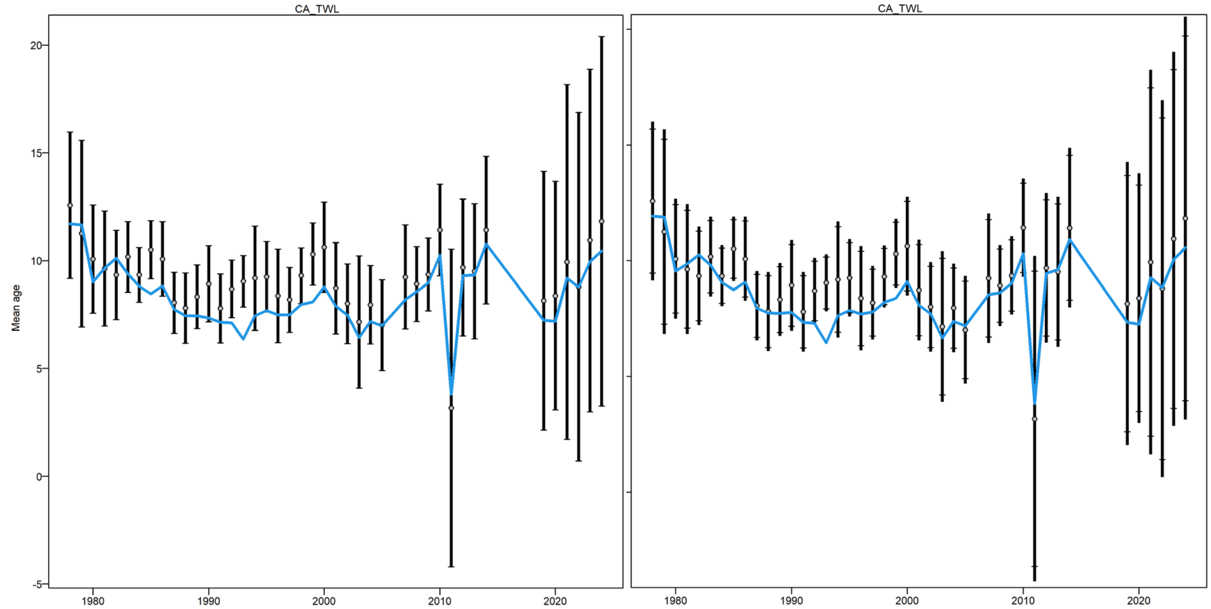


Figure 1B. Observed mean age (points) with 95% confidence intervals based on tuned sample sizes and model predictions of mean age (blue line) for the California trawl fleet. Results from the pre-STAR base model tuned using Francis weights (left) and the model using 2D-AR selectivity for the trawl fleet and the same Francis weights as the pre-STAR base model (i.e., not re-tuned; right) are shown.

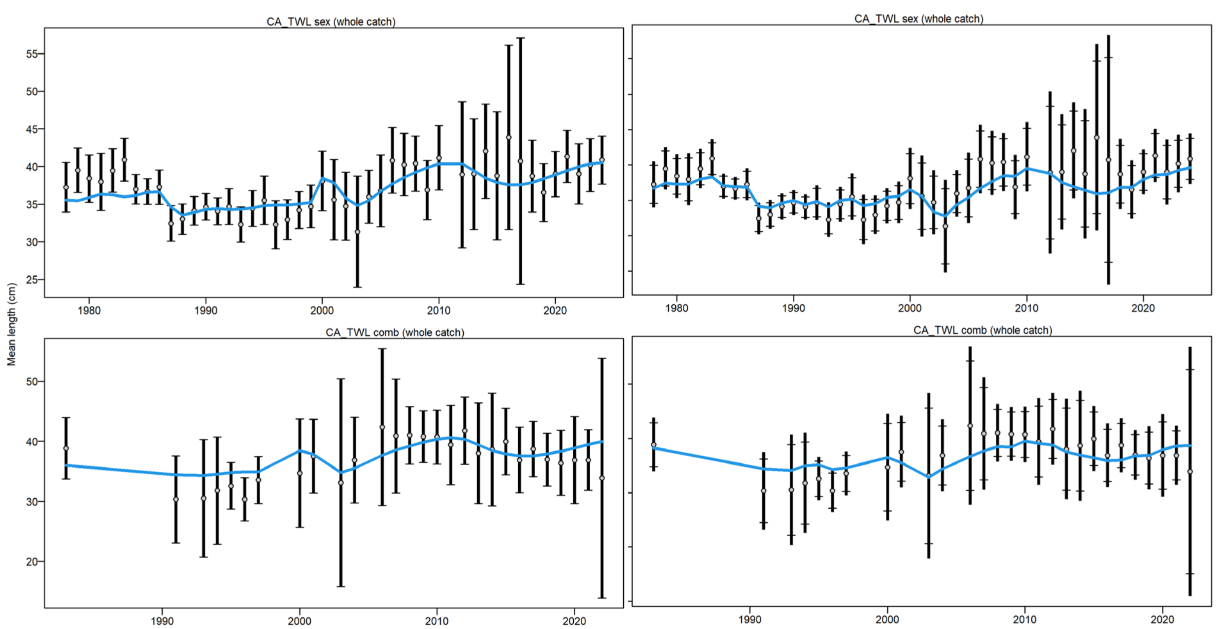


Figure 1C. Observed mean length (points) with 95% confidence intervals based on tuned sample sizes and to model predictions of mean length (blue line) for the California trawl fleet. Results from the pre-STAR base model tuned using Francis weights (left) and the model using 2D-AR selectivity for the trawl fleet using the same Francis weights as the pre-STAR base model (i.e., not re-tuned; right) for sexed (top) and unsexed (bottom) fish are shown. Note differences in the range of the axes.

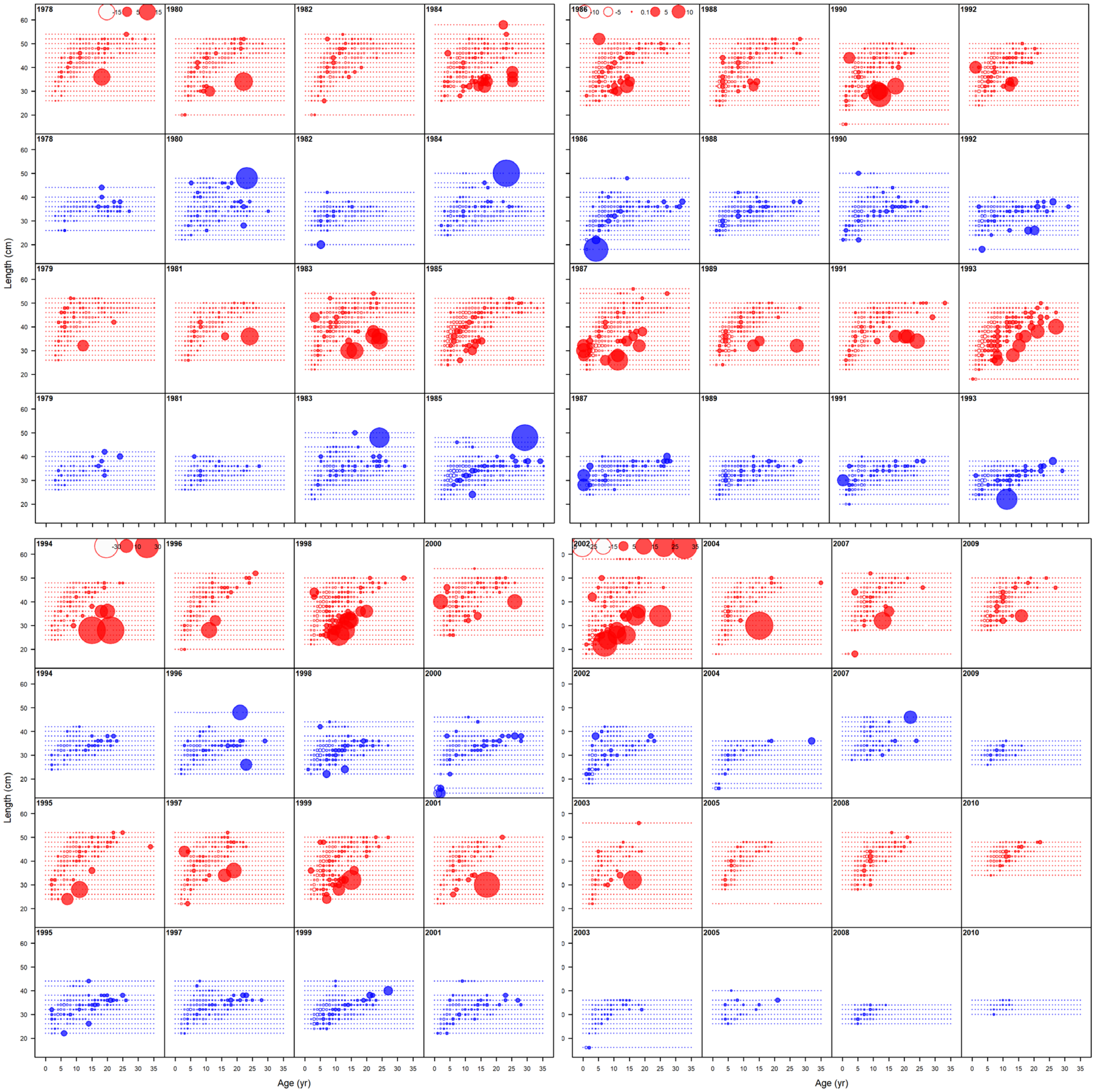


Figure 1D. Pearson residuals for conditional age-at-length data from the California trawl fleet (1978-2010). Length-based selectivity was modeled using the 2D-AR option in Stock Synthesis.

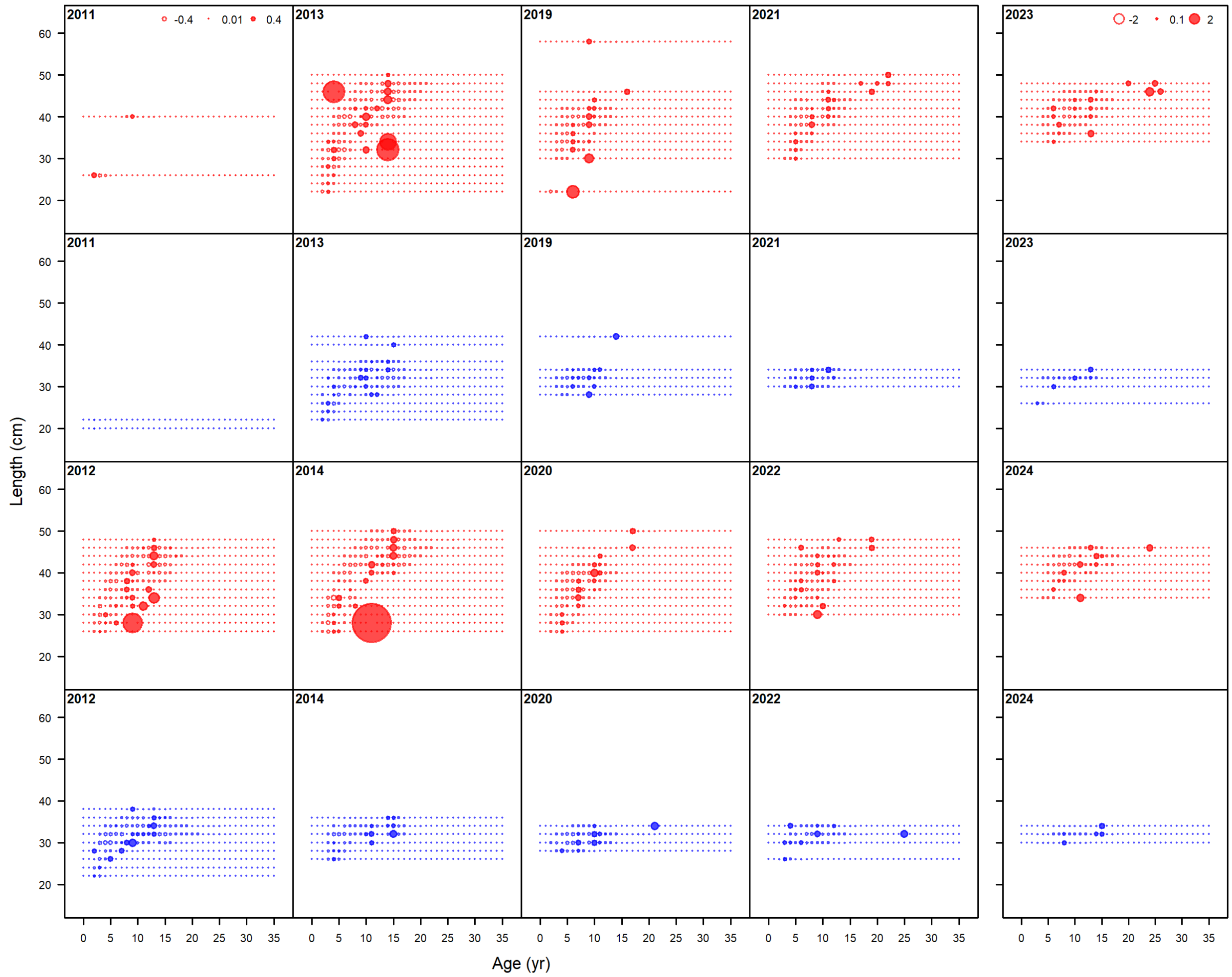


Figure 1E. Pearson residuals for conditional age-at-length data from the California trawl fleet (2011-2024). Length-based selectivity was modeled using the 2D-AR option in Stock Synthesis.

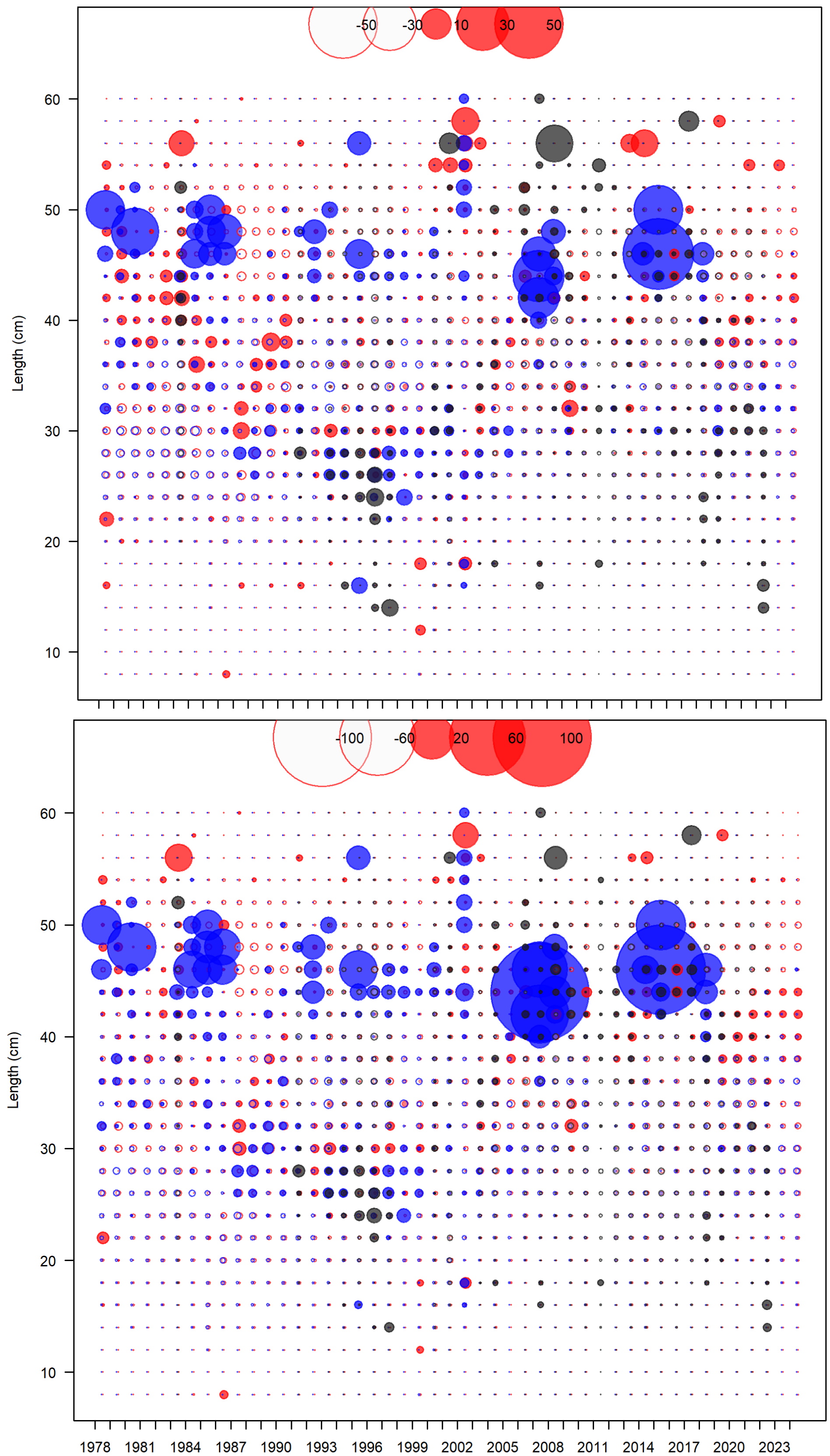


Figure 1F. Pearson residuals for length composition data from the California trawl fleet (1978-2024). Length-based selectivity was modeled using time-blocks from the pre-STAR base model (top) and the 2D-AR option in Stock Synthesis (bottom).

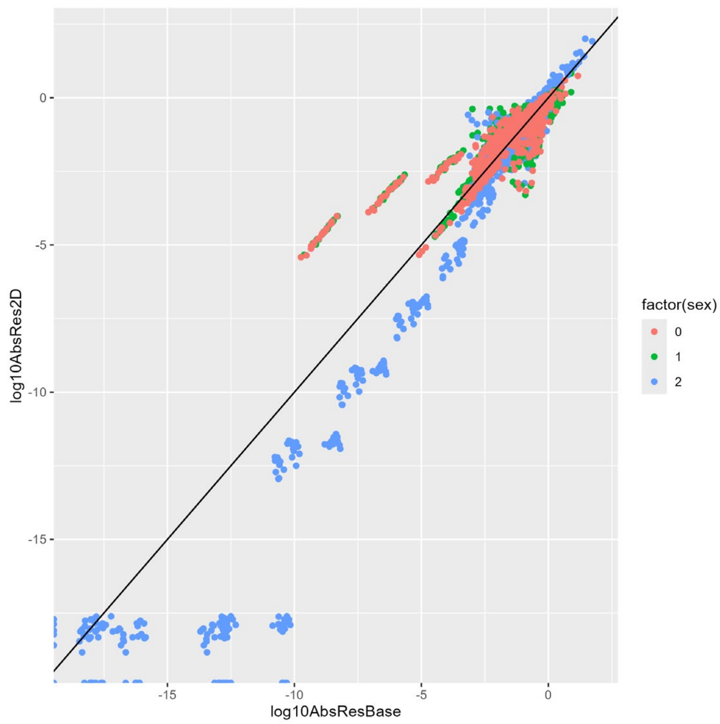


Figure 1G. Log-scale absolute Pearson residuals from the pre-STAR base model (x-axis) compared to log-scale absolute Pearson residuals from the model with flexible (2D) selectivity (y-axis). The 2D selectivity model has smaller residuals for males (sex=2) and some larger residuals for unsexed fish (sex=0) and females (sex=1).

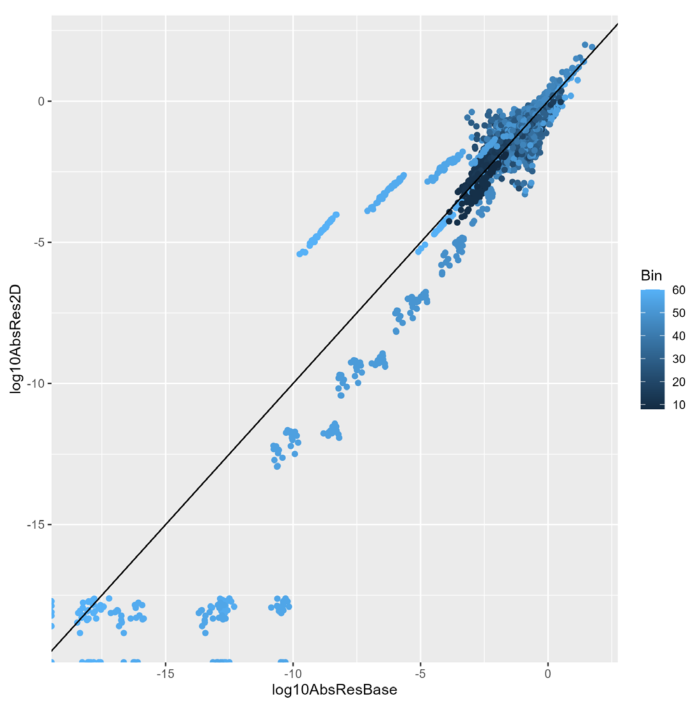


Figure 1H. Log-scale absolute Pearson residuals from the pre-STAR base model (x-axis) compared to log-scale absolute Pearson residuals from the model with flexible (2D) selectivity (y-axis). The 2D selectivity model has smaller residuals for larger males (sex=2) and some larger residuals for very large, unsexed fish (sex=0) and females (sex=1).

1 - Panel Conclusion
A freely estimated, time-varying selectivity with many deviation parameters (2D) did not improve the general fits to mean age. There was minor improvement to fits to mean length. There were a few larger residuals with the 2D selectivity model, especially for larger males, which were similar to those from the pre-STAR base model. The 2D selectivity model slightly reduced residuals for larger males, though residuals were still large and model fit worsened slightly for some female and unsexed fish. Thus, the Panel does not recommend proceeding with 2D selectivity.

There was some discussion about changes in gear type (e.g., popularization of 'rockhopper' roller gear) in the mid-1980s and 1990s (to explain patterns in Fig. 1A) but there was inadequate information to propose specific time blocking at this time.

2 - Request
Run a sensitivity analysis by replacing dome-shaped selectivity with asymptotic selectivity for the commercial fleets that showed estimation issues with the descending limb parameter based on the MCMC analysis. Plot spawning output, fraction unfished, and recruitment deviations compared to estimates from the pre-STAR base model.

2 - Rationale
The parameters for the descending limb were not well-defined based on the MCMC analysis. Additionally, asymptotic selectivity would simplify the model. If overall fits and predictions do not change with asymptotic selectivity, that would support a more parsimonious model.

2 - STAT Response
MCMC diagnostics of the pre-STAR base model showed that the descending scale parameter of the double-normal (DN) dome-shaped selectivities in the NoCA_HKL, SoCA_HK, CA_TWL, CA_NET, and NoCA_OR_WA_Rec fleets appeared to have improper posteriors (Fig. 2A). Each of these fleets were given asymptotic sigmoidal selectivity by fixing the final selectivity of the DN to inv.logit(10) = 0.9999546 and fixing the descending scale to produce a two-parameter sigmoid, with estimated parameters at the DN peak and the DN ascending scale. Time blocks in the model were preserved, allowing for changes in the 'peak' and 'ascending scale' parameters. Separate model runs were constructed to separately fit asymptotic selectivities for each of the above-mentioned fleets. A final model is shown fitting all of the above fleets jointly with asymptotic selectivities. Spawning output, fraction unfished, and recruitment deviations were mostly indistinguishable from pre-STAR base model estimates (Fig. 2B and Fig. 2C). The only model to show even slight differences in recruitment deviations is the model with only asymptotic selectivity in the CA_NET fleet.

Most models resulted in nearly identical likelihoods (Table 2), though the CA_NET only model shows the greatest increase in negative log-likelihood (NLL). The model with all asymptotic selectivities has four NLL points greater than the pre-STAR base model but it also saves four parameters and therefore seems to be a parsimonious option that doesn't substantively change results as compared with the pre-STAR base model. The weak identifiability of the dome-shaped selectivities of the pre-STAR base model likely indicates that there is little to no information in the data to inform the descending scale parameters (Fig. 2D). This illustrates the utility of MCMC diagnostics, as the asymptotic standard errors for the descending limb parameters suggested greater precision and would not have revealed this source of model instability.

Table 2. Negative log-likelihood values for each of the fit models. Likelihood components are in the rows.

	NoDome All	NoDomeCA_NET	NoDome SoCA_HKL	NoDome CA_TWL	NoDome NoCA_OR_WA_Rec	NoDome NoCA_HKL	pre-STAR base
N.Parms	109	113	113	113	113	113	114
TOTAL	2624.18	2626.11	2621.95	2622.39	2620.82	2620.51	**2620.26**
Survey	24.2567	**24.1734**	24.5525	24.3505	24.4258	24.4998	24.5754
Length_comp	570.567	571.97	570.691	569.718	568.723	**568.564**	569.086
Age_comp	2004.83	2006.28	2002.38	2003.88	2003.37	2003.19	**2002.35**
Recruitment	24.4337	**23.5844**	24.2486	24.3614	24.2309	24.1945	24.1847

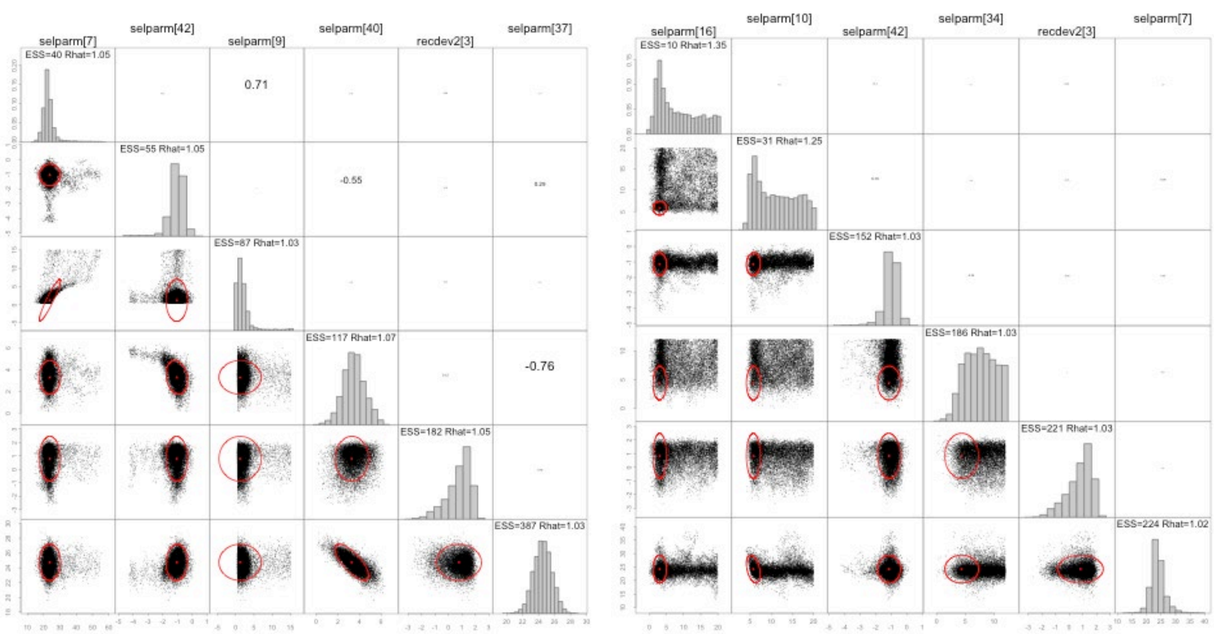


Figure 2A. Pairwise scatterplots and histograms of the slowest converging parameters from the MCMC diagnostics for the pre-STAR base model (left) and all asymptotic selectivity model (right). Although convergence is not perfect, asymptotic selectivities largely remove the improper posteriors present in the pre-STAR base model.

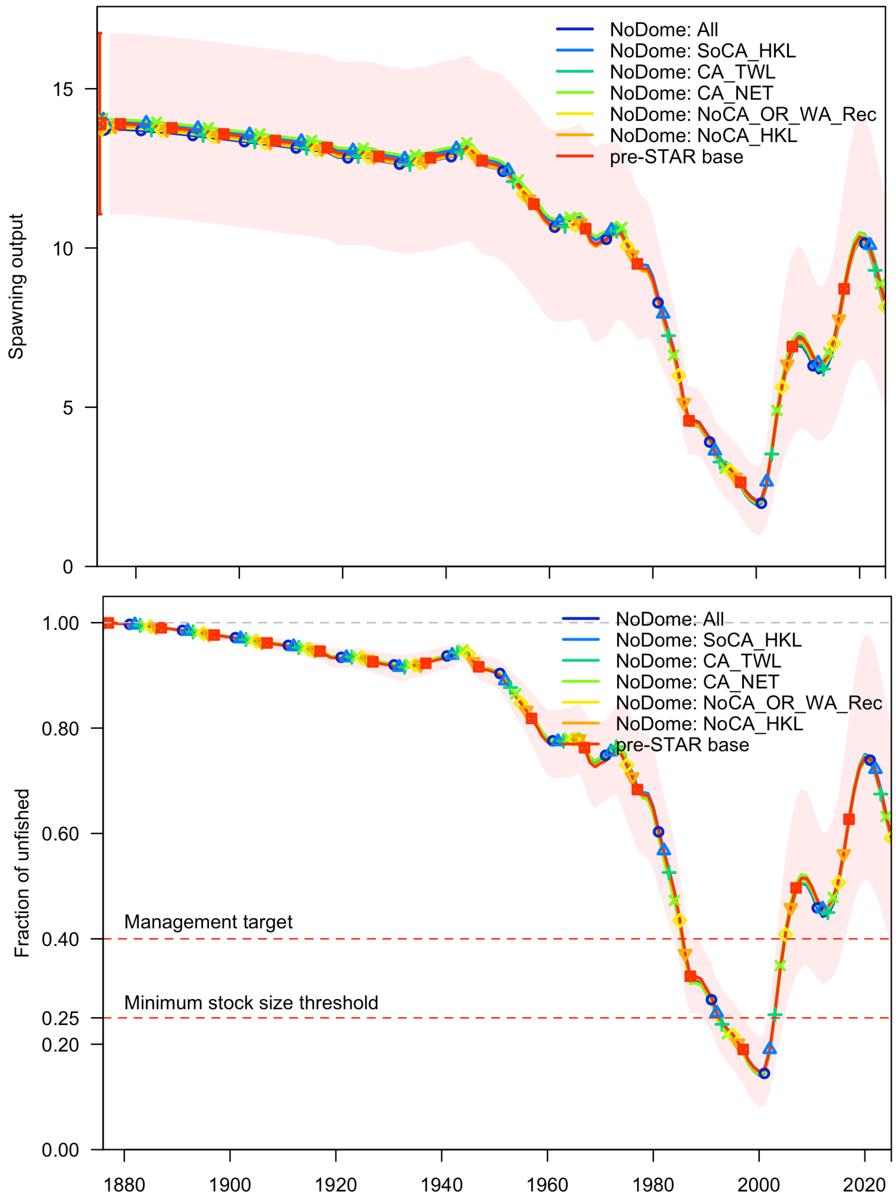


Figure 2B. Spawning output and fraction unfished when replacing dome-shaped selectivities with asymptotic selectivities. Estimates from the pre-STAR base model are also shown.

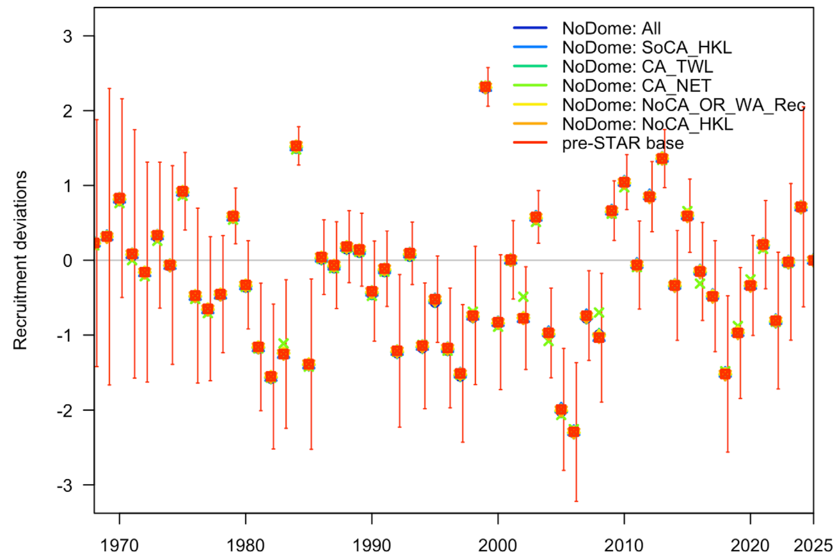


Figure 2C. Recruitment deviations when replacing dome-shaped selectivities with asymptotic selectivities. Estimates from the pre-STAR base model are also shown.

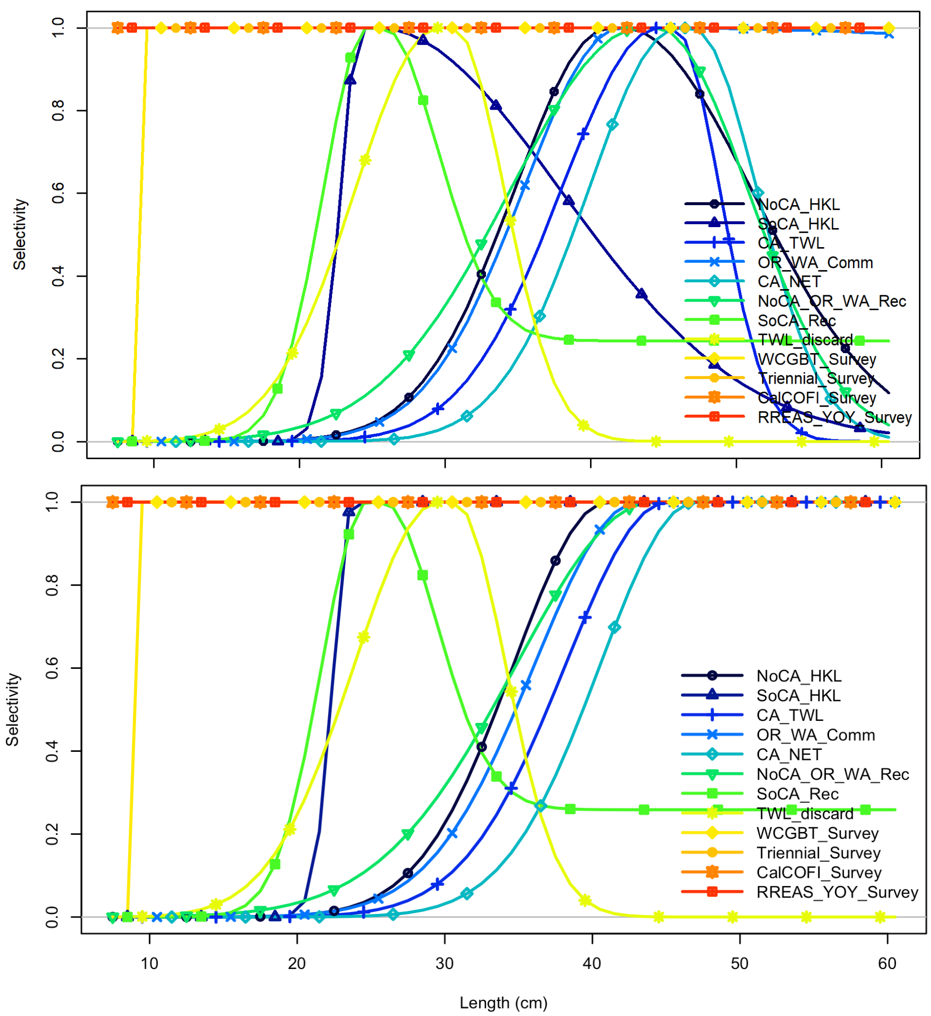


Figure 2D. Fits to pre-STAR base model dome selectivities (top) as compared with the fit asymptotic selectivities (bottom).

2 - Panel Conclusion
The new base model should update selectivity from dome-shaped to asymptotic for all commercial fleets, except for the southern California recreational and trawl discard fleets in defining a new base model. This is supported by a more parsimonious model showing an insignificant increase in the likelihood (approximately 4 units of likelihood resulting from a reduction of 5 parameters).

3 - Request
Re-compute the West Coast Groundfish Bottom Trawl Survey (WCGBTS) index by including a depth effect (WCGBTS_depth). Compare the current WCGBTS index and WCGBTS_depth index in a single plot with confidence intervals.

3 - Rationale
Depth is an important habitat variable for rockfish species. Although the spatial model can capture much of the depth effects (via anisotropy and a spatial field), previous work (Johnson et al. 2019) has shown that including depth can improve model performance.

3 - STAT Response
The STAT received preliminary model runs from Chantel Wetzel and Eric Ward (NWFSC), which led to further investigation as part of Request 12.

3 - Panel Conclusion
Discussion about responses to Request 3 resulted in a new request (see Request 12).

4 - Request
Calculate the mean of the recruitment deviations from the main recruitment estimation period in the pre-STAR base model. Present results from a run with the sum-to-zero constraint for recruitment deviations. Provide a table with the parameters for these two runs along with the sensitivity that fixes recruitment deviations to zero. Please include reference points and plot dynamic B_0.

4 - Rationale
The sum-to-zero constraint for recruitment deviations ensures that reference points are consistent with the assumptions of the model. Without this constraint, reference points implied by the main recruitment estimation period may differ considerably from the reported reference points. This request will provide insight into the magnitude of this potential discrepancy.

4 - STAT Response
The mean of the main period recruitment deviations (1968-2024) in the pre-STAR base model is -0.24498. This model was modified by setting the “Do Recruitment Deviations” option to “Deviation Vector” (option 1), which imposes a sum-to-zero constraint on the recruitment deviations. An initial run was completed without ‘tuning’ the model, so likelihood components could be compared directly to the pre-STAR base model. A subsequent model run adjusted the bias ramp and tuned Francis weights using the same methods applied to the pre-STAR base model. Finally, a model using the pre-STAR base model (with Triennial survey ages added) and no recruitment deviations was run without tuning.

Compared to the pre-STAR base model, models with a sum-to-zero constraint on recruitment deviations have a lower estimate of initial spawning output and similar end-year estimates of spawning output. Therefore, relative spawning output (i.e., fraction unfished) is higher (less depleted relative to unfished levels) in models with the sum-to-zero constraint (Fig. 4A). Recruitment deviations without a sum-to-zero constraint have a negative offset relative to the constrained deviations, resulting in a higher estimate of unfished equilibrium recruitment (R_0; Fig. 4B). Estimates of long-term sustainable yield from the pre-STAR base model are approximately

2500 mt, whereas estimates from models with the sum-to-zero constraint are approximately 2000 mt (similar to the previous assessment, which also used a sum-to-zero constraint). Likelihood components, estimated parameter values, and derived quantities from the four models are provided in Table 4. Estimates of natural mortality are lower for females, with a larger offset for males, in the models with a sum-to-zero constraint. All models assume a steepness of 0.72.

Models with sum-to-zero constraints and the pre-STAR base model include a bias adjustment following the methods of Methot and Taylor (2011). Methot and Taylor (2011) estimated deviations using a sum-to-zero constraint, so it is unclear to the STAT whether the bias adjustment is appropriate for the pre-STAR base model and other models that are fit using maximum likelihood without a sum-to-zero constraint. Posterior distributions for log R_0, based on the diagnostic MCMC runs that did not use a sum-to-zero constraint, suggest a value between 10 and 11, with a mode near 10.3 (Fig. 4C). The log R_0 value estimated by the pre-STAR base model without a sum-to-zero constraint and with a bias correction is 10.24. The log R_0 values estimated by models with a sum-to-zero constraint are slightly below 10.

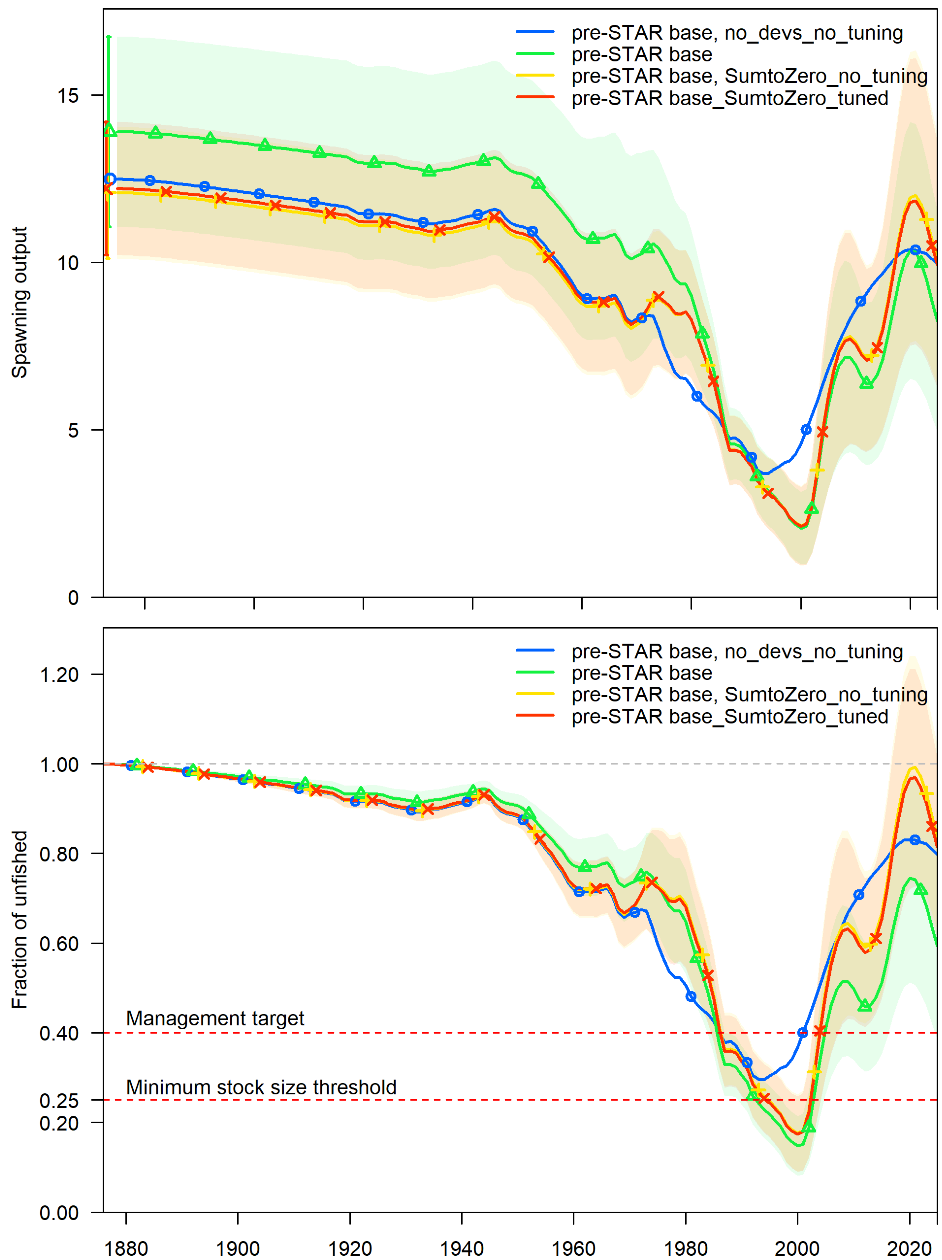


Figure 4A. Spawning output (top) and fraction unfished (bottom) for models with and without a sum-to-zero constraint imposed on recruitment deviations.

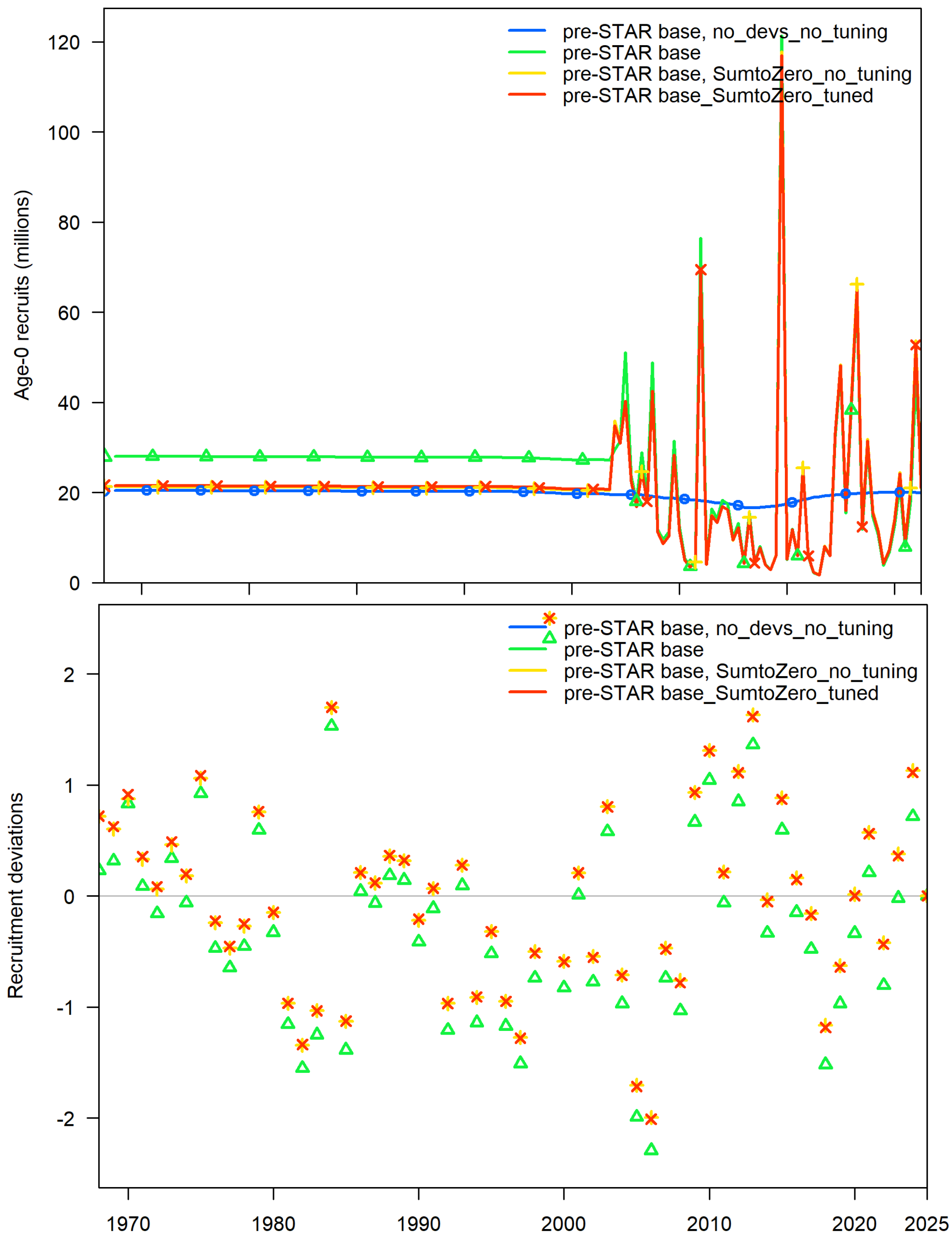


Figure 4B. Age-0 recruits (top) and recruitment deviations from the spawner-recruit curve (bottom) for models with and without a sum-to-zero constraint imposed on recruitment deviations.

Table 4. Comparison of likelihood components, parameter estimates, and derived quantities from models with and without recruitment deviations, as well as unconstrained or 'sum-to-zero' recruitment deviations.

Label	pre-STAR base, no_devs_no_tuning	pre-STAR base	pre-STAR base, SumtoZero_no_tuning	pre-STAR base, SumtoZero_tuned
N.Parms	45	114	114	114
TOTAL	3119.280	2620.260	2623.630	2628.760
Survey	47.220	24.575	29.211	28.844
Length_comp	667.444	569.086	569.314	569.318
Age_comp	2404.610	2002.350	2003.130	2008.480
Recruitment	0.000	24.185	21.961	22.102
Parm_priors	0.000	0.053	0.007	0.008
NatM_uniform_Fem_GP_1	0.155	0.171	0.160	0.160
L_at_Amax_Fem_GP_1	48.574	48.169	48.223	48.234
VonBert_K_Fem_GP_1	0.189	0.194	0.194	0.193
CV_young_Fem_GP_1	0.102	0.108	0.109	0.110
CV_old_Fem_GP_1	0.034	0.038	0.037	0.037
NatM_uniform_Mal_GP_1	0.271	0.266	0.291	0.291
L_at_Amax_Mal_GP_1	-0.353	-0.333	-0.333	-0.334
VonBert_K_Mal_GP_1	0.610	0.540	0.542	0.543
CV_young_Mal_GP_1	-0.131	0.203	0.198	0.195
CV_old_Mal_GP_1	0.665	0.112	0.118	0.117
SR_LN(R0)	9.924	10.240	9.964	9.976
Q_extraSD_CalCOFI_Survey(11)	0.421	0.313	0.368	0.363
Q_extraSD_RREAS_YOY_Survey(12)	1.740	1.234	1.217	1.219
Size_DblN_peak_NoCA_HKL(1)	42.278	41.254	41.202	41.222
Size_DblN_ascend_se_NoCA_HKL(1)	4.452	4.438	4.438	4.440
Size_DblN_descend_se_NoCA_HKL(1)	4.270	5.042	4.960	4.943
Size_DblN_peak_SoCA_HKL(2)	24.218	24.245	24.220	24.209
Size_DblN_ascend_se_SoCA_HKL(2)	1.415	1.403	1.392	1.387
Size_DblN_descend_se_SoCA_HKL(2)	5.779	5.766	5.725	5.723
Size_DblN_peak_CA_TWL(3)	44.110	44.699	44.520	44.512
Size_DblN_ascend_se_CA_TWL(3)	4.494	4.512	4.505	4.505
Size_DblN_descend_se_CA_TWL(3)	2.874	2.987	2.983	2.981
Size_DblN_peak_OR_WA_Comm(4)	39.771	42.043	41.527	41.492
Size_DblN_ascend_se_OR_WA_Comm(4)	4.135	4.496	4.447	4.444
Size_DblN_peak_CA_NET(5)	46.184	45.969	45.927	45.919
Size_DblN_ascend_se_CA_NET(5)	4.289	4.321	4.320	4.319
Size_DblN_descend_se_CA_NET(5)	3.949	3.686	3.655	3.642
Size_DblN_peak_NoCA_OR_WA_Rec(6)	44.908	43.503	43.339	43.333
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.117	5.099	5.094	5.093
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	3.589	4.373	4.318	4.299
Size_DblN_peak_SoCA_Rec(7)	24.536	24.673	24.628	24.626
Size_DblN_ascend_se_SoCA_Rec(7)	2.973	2.920	2.910	2.909
Size_DblN_descend_se_SoCA_Rec(7)	3.160	3.352	3.397	3.400
Size_DblN_end_logit_SoCA_Rec(7)	-0.700	-1.135	-1.186	-1.189
Size_DblN_peak_TWL_discard(8)	29.509	29.501	29.457	29.453
Size_DblN_ascend_se_TWL_discard(8)	4.325	4.173	4.170	4.170
Size_DblN_descend_se_TWL_discard(8)	3.321	3.203	3.208	3.208
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	49.997	50.291	50.412	50.357
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	3.970	4.053	4.062	4.057
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	49.777	47.563	47.511	47.506
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.814	4.734	4.736	4.735
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	36.345	33.490	33.421	33.422
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.792	3.213	3.201	3.201
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	32.168	30.454	30.488	30.482
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	4.059	3.712	3.723	3.722
Bratio_2025	0.798	0.593	0.836	0.813
SSB_unfished	12484	13904	12081	12203
Totbio_unfished	52519	60831	51324	51833
Recr_unfished	20422	27998	21247	21493
Dead_Catch_SPR	1960	2494	2000	2022
OFLCatch_2025	3087	2834	3200	3143

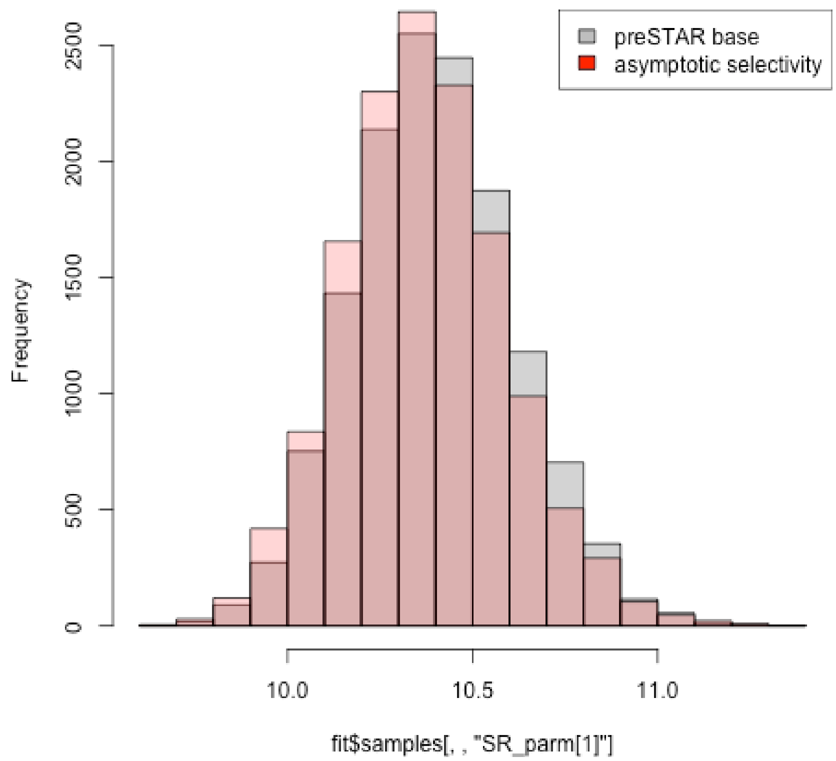


Figure 4C. Posterior distributions for unfished equilibrium recruitment from diagnostic MCMC runs. Recruitment deviations were not subject to the sum-to-zero constraint in either run.

4 - Panel Conclusion
The Panel and STAT discussed this at length without coming to a conclusion. Therefore, a new request was made to further investigate effects of using a sum-to-zero constraint on recruitment deviations (see Request 13). The Panel agreed that estimation of the requested dynamic B_0 was no longer required.

5 - Request
Replot fits to the CalCOFI index of spawning output without confidence intervals.

5 - Rationale
This will enable additional scope for interpretation of model fit to the time series. Including the confidence intervals compresses the y-axis.

5 - STAT Response
The requested figure without confidence intervals was provided (Fig. 5A).

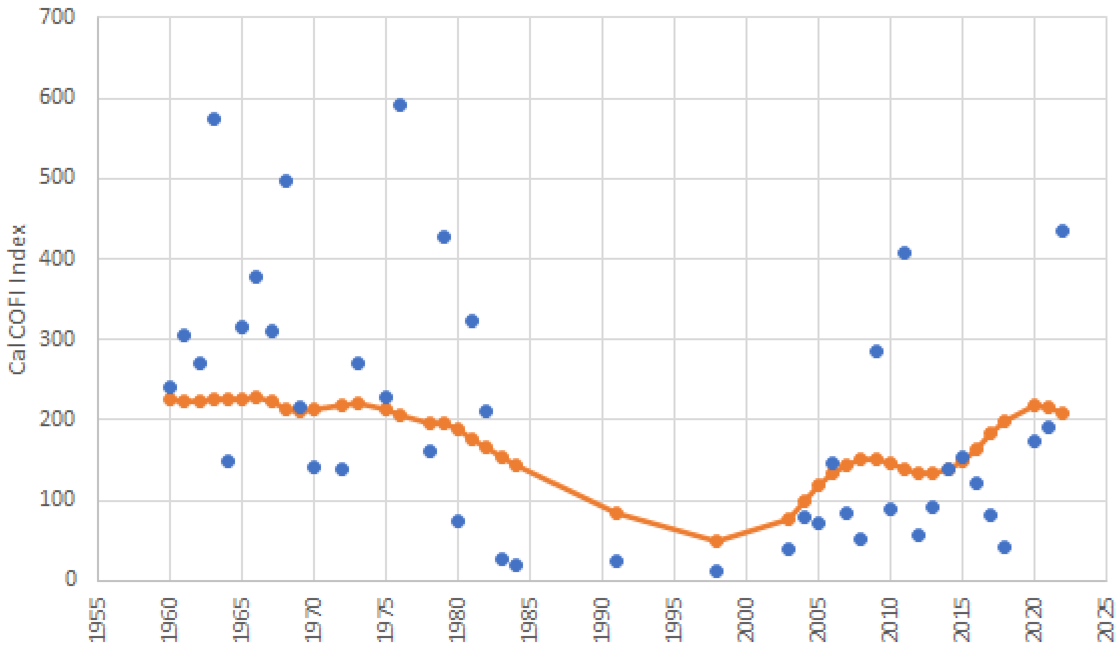


Figure 5A. CalCOFI index of spawning output (blue points) and pre-STAR base model fit to the index (orange points and interpolated line). Confidence intervals were excluded for illustrative purposes.

5 - Panel Conclusion
This plot clarifies the model fit to this index.

6 - Request
Run an additional sensitivity that replaces the coastwide CalCOFI index with the southern CaCOFI index without the early (1950s) estimates. Please plot fits without confidence intervals and investigate why the terminal years in the coastwide index are increasing when regional indices are decreasing.

6 - Rationale
Including the coastwide CalCOFI index increases stock status, whereas separately including central and southern CalCOFI indices decreases stock status. This sensitivity will inform the effects of spatial and spatiotemporal extent of the CalCOFI index on stock status.

6 - STAT Response
The STAT inadvertently used the shorter southern CalCOFI index instead of the central CalCOFI index for sensitivity runs. Corrected and additional runs are now a bit more intuitive (Fig. 6A). With the correct data, the central CalCOFI model is less depleted in the terminal year than the pre-STAR base model (all data but only years with data from both regions) and the southern CalCOFI index model is more depleted. The “CalCOFI Short south” model is slightly more depleted than the southern model with all data, which is consistent with the observation that the first decade of data (i.e., the 1950s) have low index values that would presumably scale down the fraction unfished. Including data from all years and regions is still nearly identical to the pre-STAR base model.

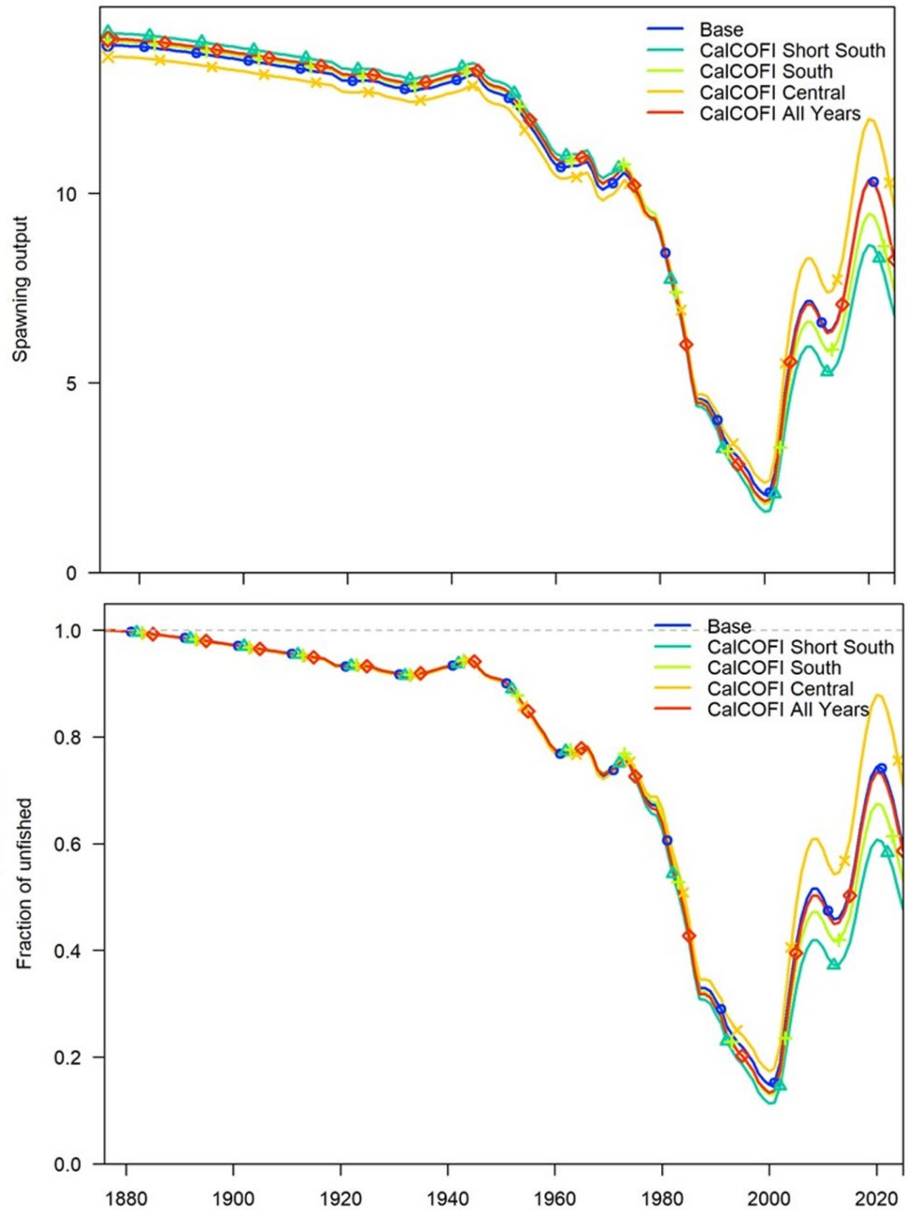


Figure 6A. Spawning output (top) and fraction unfished (bottom) from the pre-STAR base model, and models that included: a) CalCOFI central, b) CalCOFI south, c) CalCOFI "short" south (starting in 1960), and all CalCOFI data (years and areas).

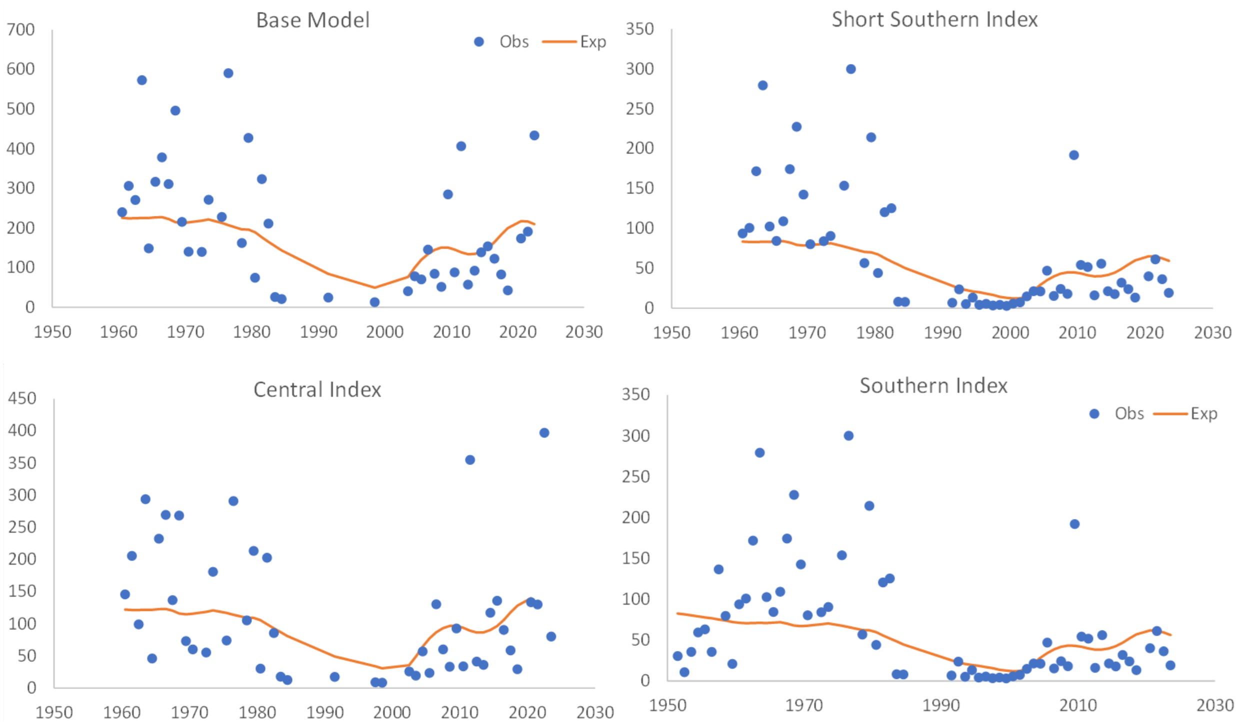


Figure 6B. Model fits (lines) to CalCOFI indices of relative spawning output (arithmetic scale without error bars) for the pre-STAR base model and models that included: a) CalCOFI central, b) CalCOFI south, c) CalCOFI “short” south (starting in 1960), and all CalCOFI data (years and areas).

6 - Panel Conclusion
The odd terminal year discrepancies were resolved and the influence of the different regional components of the CalCOFI index on model results are now more understandable.

7 - Request
Run an additional sensitivity that estimates additive variance for the WCGBTS index.

7 - Rationale
Although there is some justification for estimating additive variance for the CalCOFI index, justification for not estimating additive variance for the WCGBTS is missing. Additive variance may be warranted given poor fit during the early portion of the time series and high q.

7 - STAT Response
The additive variance (“extraSD”) for the WCGBTS was estimated at 0.145, which slightly reduces the influence of the WCGBTS index. This change had little effect on the time series of spawning output but resulted in a slightly poorer fit to the early years of the index (Fig. 7A). The STAT would prefer not to down weight the index but rather search for alternative model configurations that improve fit.

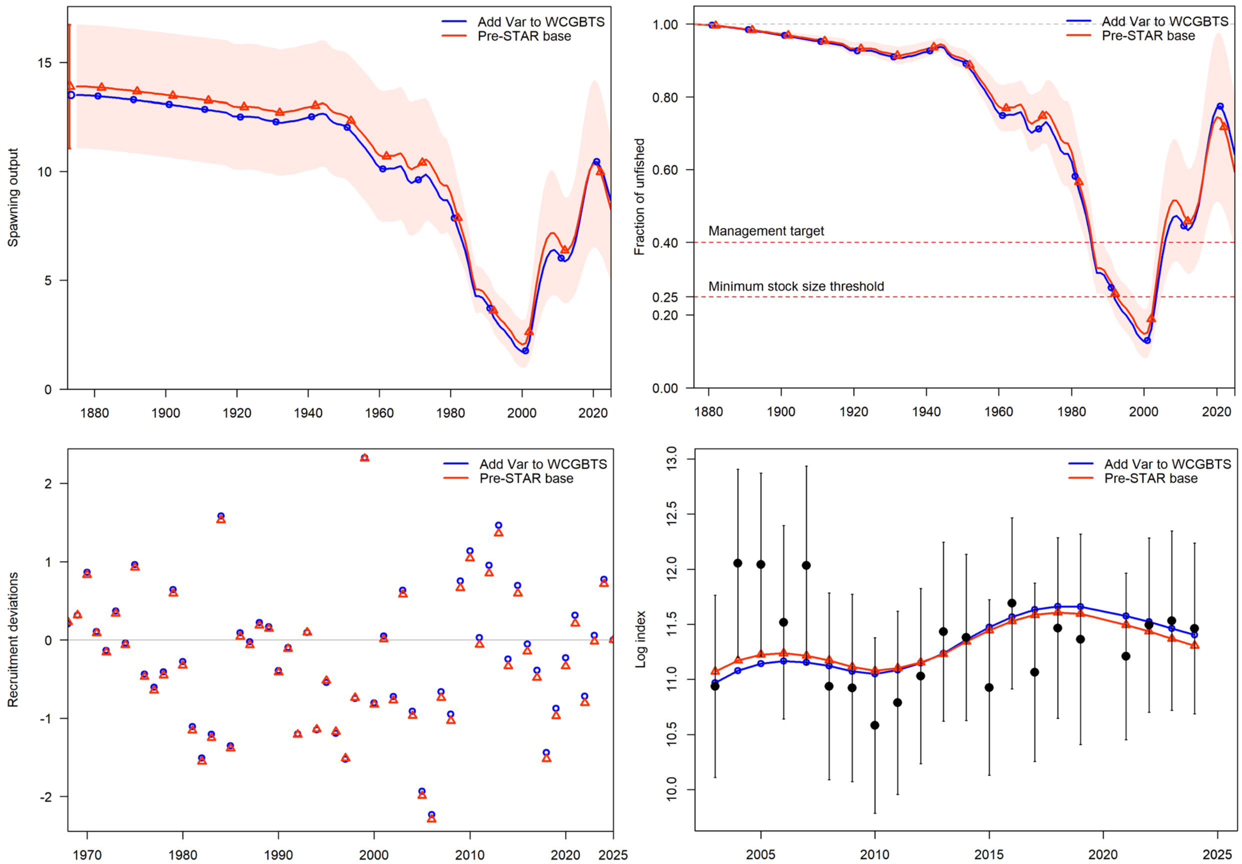


Figure 7A. Spawning output (top left), fraction unfished (top right), recruitment deviations (bottom left), and log-scale fits to the WCGBTS index (bottom left) for the pre-STAR base model and a model that estimates additive variance for the WCGBTS index.

7 - Panel Conclusion

The STAT should explore including a depth effect in the model used to estimate the WCGBTS index (see Request 3) before making a conclusion about estimating additive variance (see Request 12). The Panel agreed that estimation of the requested lnQ was no longer required.

8 - Request

Provide two runs that down-weight all length composition data and age composition by a factor of 2 and 10 using the input sample multiplier (from the final Francis tuned multipliers). Present Pearson residuals for the commercial CA trawl fleet and fits to all fishery-independent indices compared to the pre-STAR base model.

8 - Rationale

It is possible that the composition data are over-weighted.

8 - STAT Response

Two models were run with Francis weights from the pre-STAR base model divided by 2 and 10 (Table 8A). Down weighting the composition data resulted in a more depleted stock and less variable recruitment deviations (Fig. 8).

Table 8. Francis weights from the pre-STAR base model, a model with pre-STAR base model weights divided by 2, and a model with pre-STAR base model weights divided by 10.

Fleet	Component	Pre-STAR base	Weights / 2	Weights / 10
NoCA_HKL	Lengths	0.54034	0.27017	0.054034
SoCA_HKL	Lengths	2.43888	1.21944	0.243888
CA_TWL	Lengths	0.23845	0.119225	0.023845
OR_WA_Comm	Lengths	0.09089	0.045445	0.009089
CA_NET	Lengths	0.41067	0.205335	0.041067
NoCA_OR_WA_Re	Lengths	0.383	0.1915	0.0383
SoCA_Rec	Lengths	0.17159	0.085795	0.017159
TWL_discard	Lengths	0.0205	0.01025	0.00205
WCGBT_Survey	Lengths	0.03578	0.01789	0.003578
Triennial_Survey	Lengths	0.05515	0.027575	0.005515
NoCA_HKL	Ages	0.02971	0.014855	0.002971
CA_TWL	Ages	0.01572	0.00786	0.001572
OR_WA_Comm	Ages	1	0.5	0.1
CA_NET	Ages	0.06535	0.032675	0.006535
NoCA_OR_WA_Re	Ages	1	0.5	0.1
WCGBT_Survey	Ages	0.09373	0.046865	0.009373
Triennial_Survey	Ages	0.06838	0.03419	0.006838

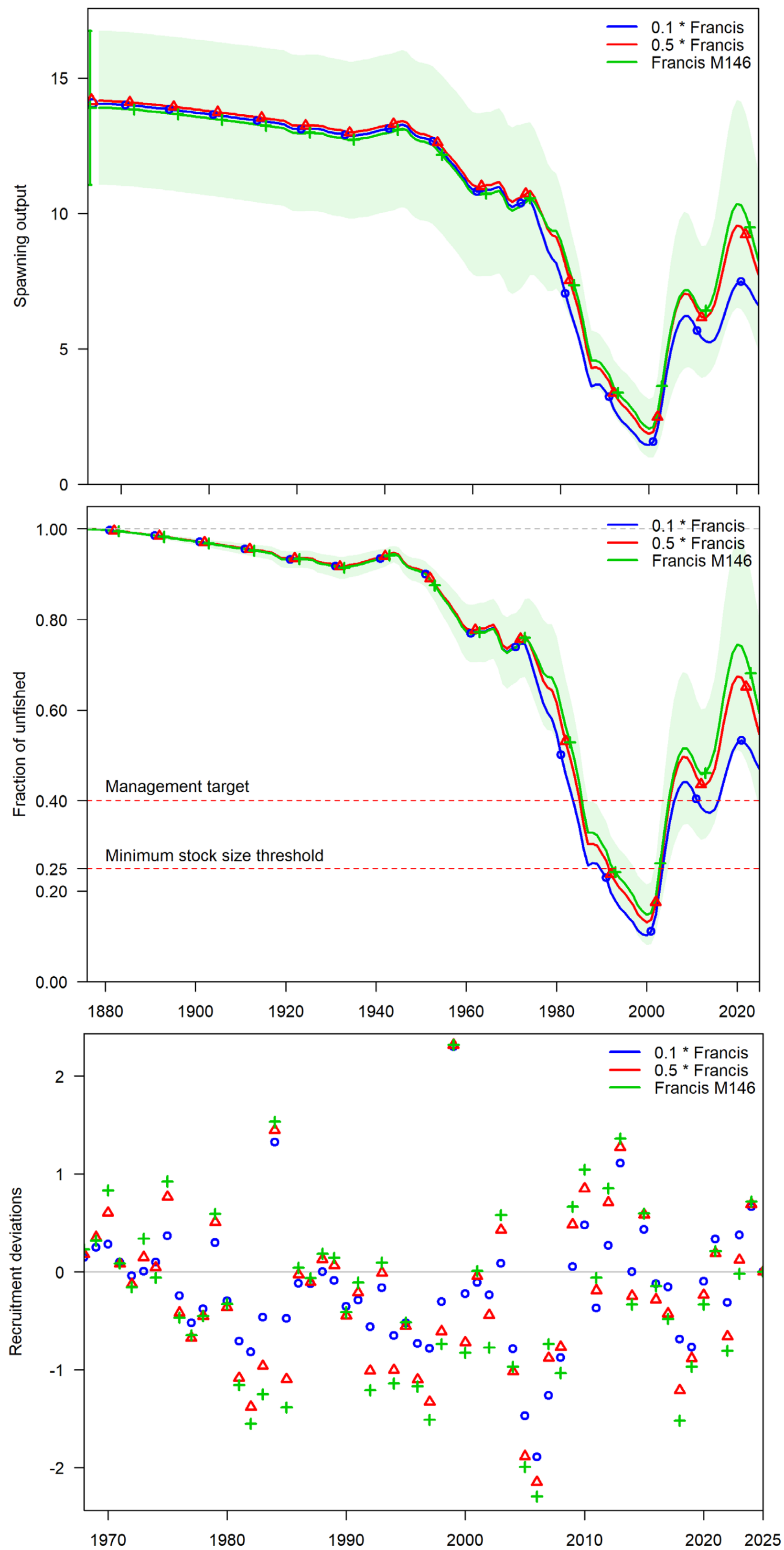


Figure 8. Spawning output (top), fraction unfished (middle), and recruitment deviations (bottom) using Francis weights from the pre-STAR base model, a model with pre-STAR base model weights divided by 2, and a model with pre-STAR base model weights divided by 10.

8 - Panel Conclusion
Down weighting length composition data seems to decrease recruitment deviations and allow other data to change the stock trajectory and stock status. This suggests that there may be some over-weighting of composition data in the pre-STAR base model. The STAT did not have time to show the Pearson residuals and fits to the fishery-independent indices. The Panel acknowledges that responses to other requests should be prioritized first.

9 - Request
Present length-fecundity relationships that depict the variability given different environment regimes alongside the assumed length-fecundity relationship used in the pre-STAR base model. Conduct sensitivities using these alternative length-fecundity relationships with *M* fixed at the value from the pre-STAR base model. Plot spawning output, fraction unfished, and recruitment deviations compared to estimates from the pre-STAR base model.

9 - Rationale
These results will help to characterize the uncertainty in fecundity estimates under varying environmental conditions and could be used to identify an appropriate axis of uncertainty.

9 - STAT Response
The STAT ran the pre-STAR base model with the highest and the lowest length-fecundity relationships (b parameters only, given $F = aL^b$) from the Beyer et al. (2024; Fig. 9A). The STAT ran high and low fecundity scenarios with *M* estimated (as in the pre-STAR base model) and fixed at the pre-STAR base model estimate. The results dramatically scaled estimates of larval production but had only a modest influence on relative abundance (i.e., depletion or fraction unfished; Fig. 9B). *M* changed only trivially in the low fecundity model, with *M* estimated from 0.1706 to 0.17089. *M* changed more substantively for the high fecundity model, with *M* estimated from 0.1706 to 0.1772. This reflected the increase in age 3+ biomass.

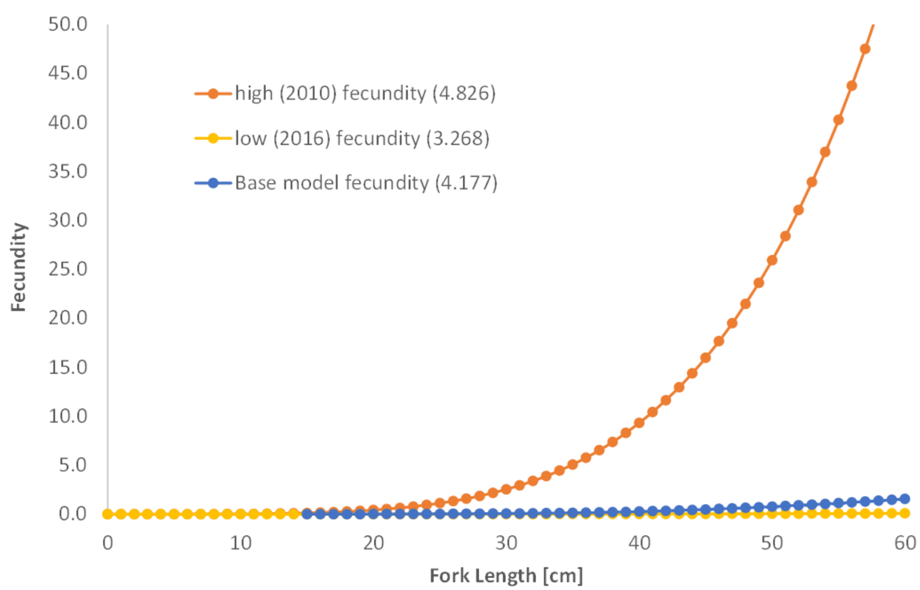


Figure 9A. Alternative length-fecundity relationships used to account for effects of different environmental conditions on stock productivity (i.e., by modifying the exponent for multiple brooding).

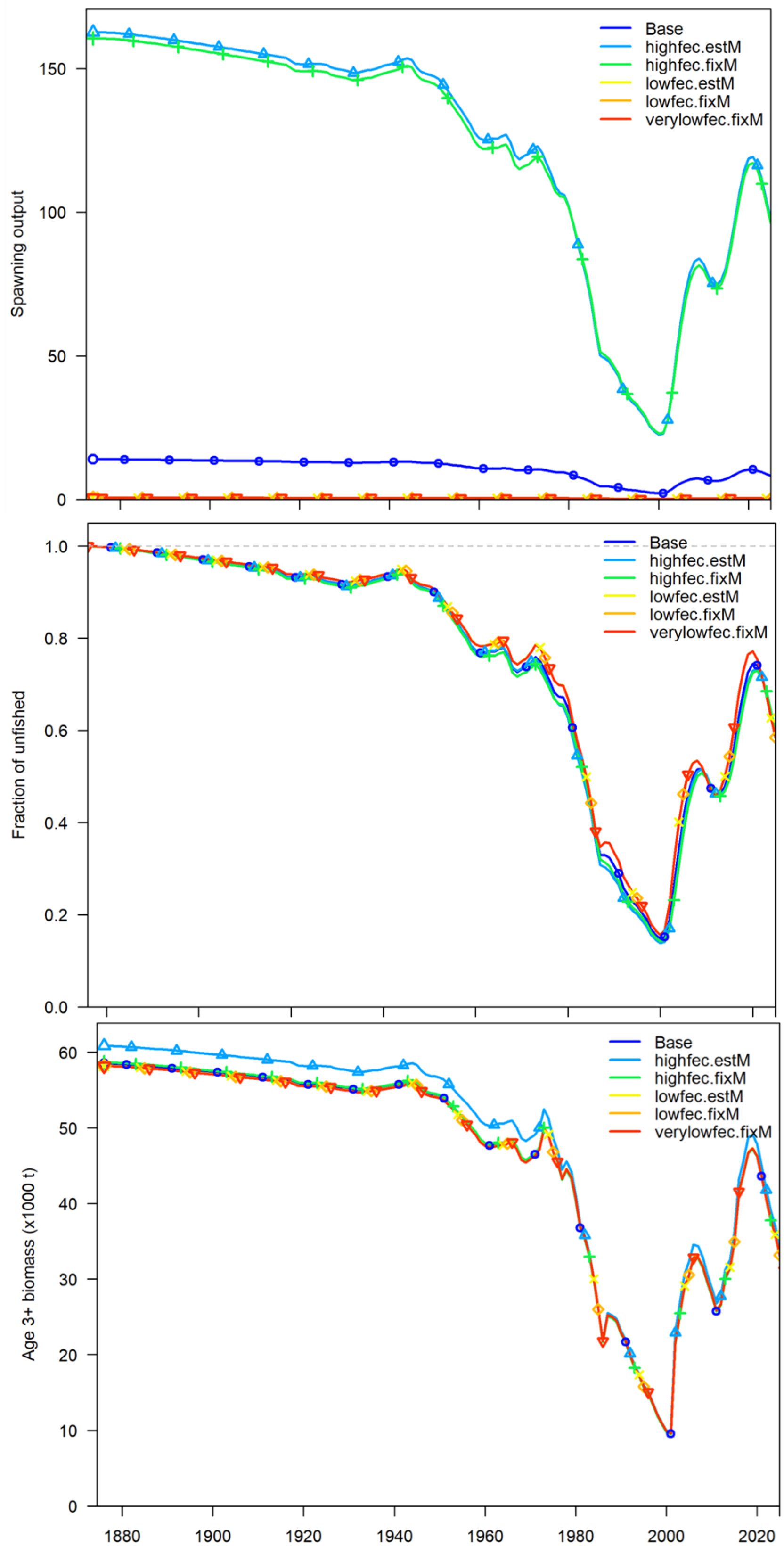


Figure 9B. Spawning output (top), fraction unfished (middle), and age 3+ biomass (bottom) from the suite of models with alternative length-fecundity relationships.

9 - Panel Conclusion

These results were very useful to understand how variability in fecundity translates to uncertainty in stock status. It appears that variability in fecundity has a minor effect on model uncertainty.

10 - Request
Create a squid plot using a 15-year retrospective analysis. This should include recruitment deviation on the y-axis and age on the x-axis, showing the age at which estimated recruitment begins to be informed by data.

10 - Rationale
There are a few large year classes that are important to the stock trajectory, one of which is from 2013. It will be beneficial to understand how long it takes to generate reasonable estimates of recruitment, whether low or high.

10 - STAT Response
The STAT ran 15-year retrospective analyses with and without the Rockfish Recruitment and Ecosystem Assessment Survey (RREAS) index (Fig. 10). The difference was surprisingly small. After a bit more investigation, it appears that there is quite a bit of information for age 0 and 1 yr fish from the WCGBTS. The combination of tuning the RREAS index and not tuning the WCGBTS index essentially upweights the trawl data. The STAT completed several additional runs with the WCGBTS index tuned and the RREAS index upweighted to better understand how each index is informing near-term recruitments. The STAT explored other options to better understand the relative influence of the two indices on early recruitment deviations. This included tuning the WCGBTS (which was untuned in pre-STAR base model) to slightly reduce its estimate of recruitment and decreased tuning of the RREAS index.

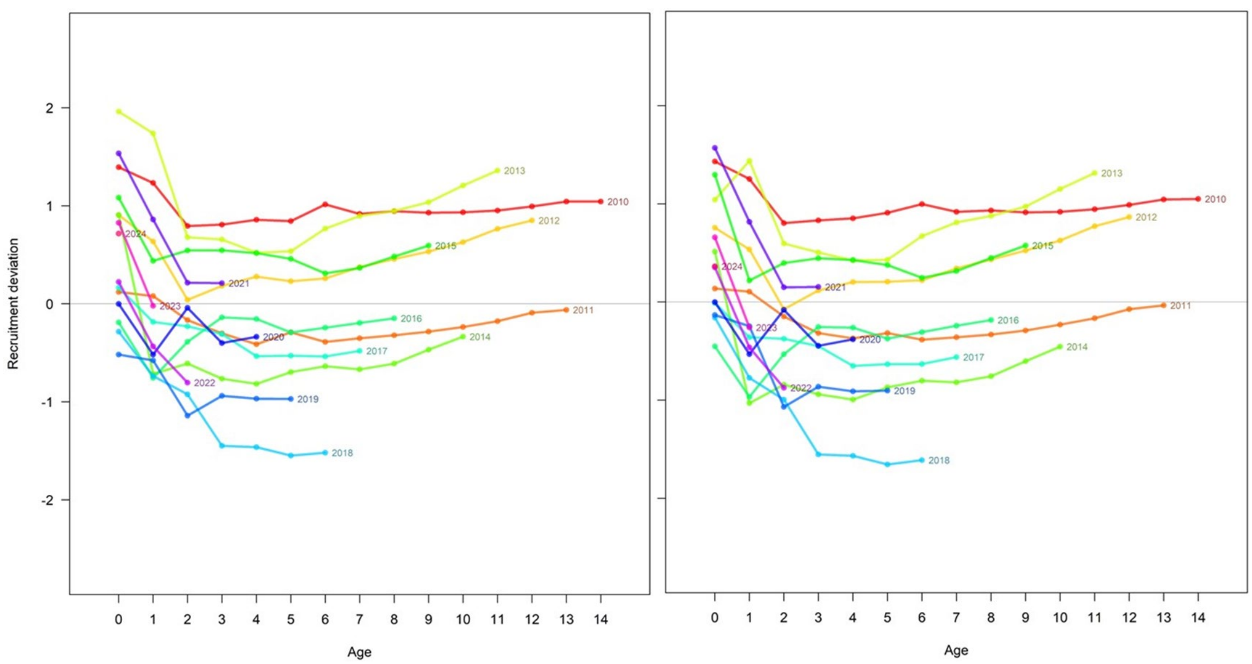


Figure 10. Squid diagnostic plots from the pre-STAR base model with a 15-year retrospective with (left) and without (right) the RREAS pelagic young-of-the-year index.

10 - Panel Conclusion
These plots show the importance of the WCGBTS index in predicting year class strength and that it provides information when the cohort was age 0 yr. Although the RREAS was appropriately weighted and included additive variance, the outcome was that this index had very little weight and virtually no influence on model results. The RREAS index became appropriately more influential when either removing the additive variance or when down weighting the WCGBTS index. There was concern that the strength of a cohort at age 0 yr was estimated above average and tended to be reduced as the cohort aged in the pre-STAR base model. The Panel realizes that changes to the pre-STAR base model from other requests could modify these conclusions, so there may be a need to revise these figures as part of future requests.

11 - Request
Estimate steepness with and without the sum-to-zero constraint on recruitment deviations. Please use the revised model based on conclusions from earlier requests and calculate the mean of the recruitment deviations from the main recruitment estimation period. Plot spawning output, fraction unfished, age-0 recruits, and recruitment deviations. Please provide a table showing the parameters with reference points, including the SPR proxy for yield.

11 - Rationale
The mean recruitment deviations from the main recruitment estimation period was < 0 without a sum-to-zero constraint. The pre-STAR base model, which fixed steepness at 0.72, may be attempting to reduce recruitment during this period, which included years with low predicted spawning biomass. Reduced recruitment could result from reduced spawning biomass.

11 - STAT Response
The revised base model (i.e., pre-STAR base with asymptotic selectivity curves for fleets with poor MCMC diagnostics in the descending scale parameter; “M160”) was used to complete this request. Estimates of steepness were lower than the prior mean in both runs, resulting in a more depleted stock status. When steepness is estimated, the change in model scale and trend is less pronounced between models with and without the sum-to-zero constraint for recruitment deviations (Fig. 11A) compared to models with steepness fixed at the prior mean of 0.72 (Fig. 11B). When steepness is estimated, the mean recruitment deviation without a sum-to-zero constraint is -0.14. With the constraint, the mean is near zero ($7x10^{-8}$), as expected. By fixing steepness at a value that is slightly less consistent with the data (i.e., h = 0.72), the simple deviations are scaled down to best fit the data, decreasing productivity and increasing estimates of R_0 and M (Table 11; Fig. 11B).

The current model does not have a precise estimate of steepness (see bivariate likelihood profile over steepness and female M in the main document). The STAT therefore recommends that the assessment continue to fix steepness at 0.72. The current accepted practices also recommend that the Methot and Taylor (2011) method be applied to reduce bias in estimates of unfished equilibrium recruitment. However, that method was developed using the sum-to-zero constraint (“deviation vector” option) in Stock Synthesis. Therefore, the STAT recommends that a revised base model be constructed that a) continues to fix steepness at 0.72, b) continues to use the bias adjustment, and c) enforces a sum-to-zero constraint on recruitment deviations.

Given that the model is sensitive to the treatment of recruitment deviations (sum-to-zero or unconstrained), the STAT recommends that a new assessment be conducted if future research clarifies the preferred approach to estimating recruitment deviations, whether bias adjustment is needed when using maximum likelihood without a sum-to-zero constraint, and the type of deviation vector that gives unbiased parameter estimates when using MCMC. From the results of this analysis, it appears that assumptions about steepness also need to be considered as part of future research recommendations.

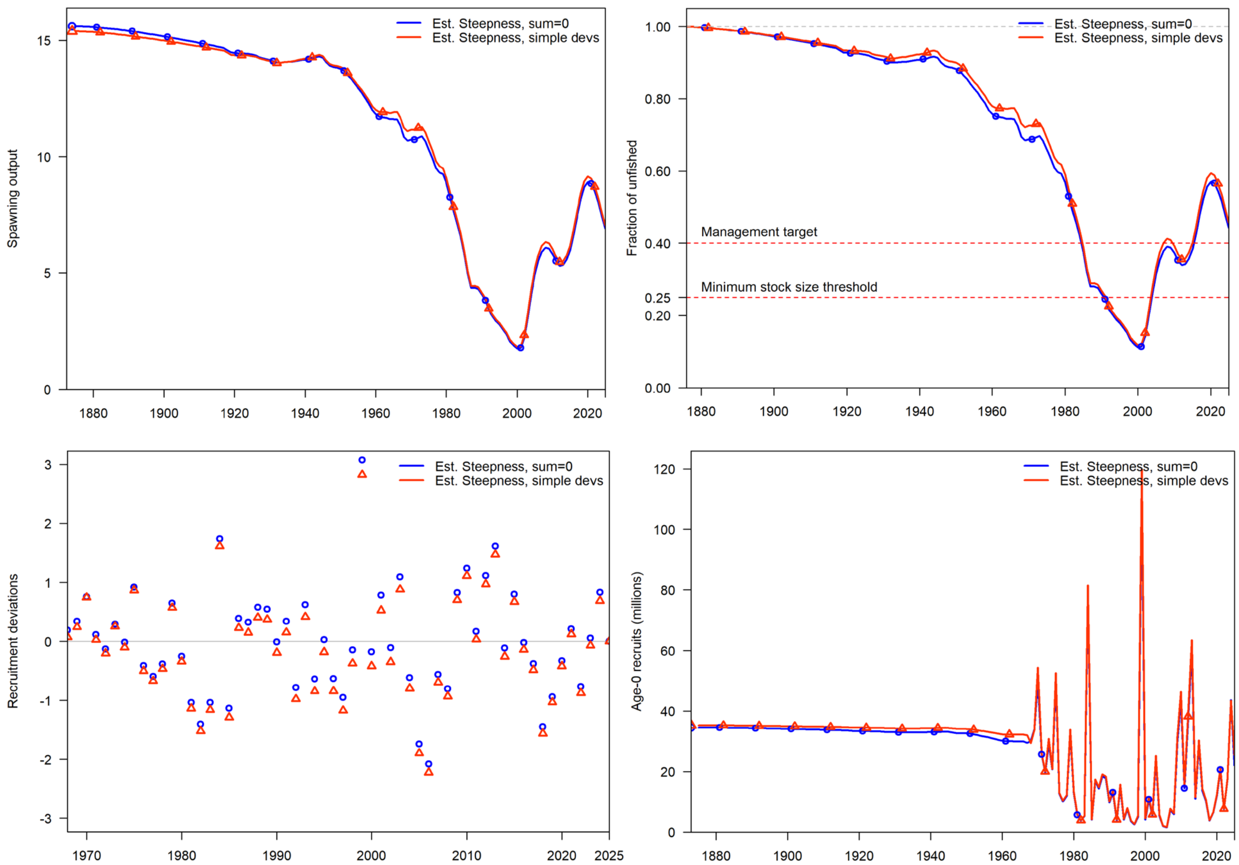


Figure 11A. Spawning output (top left), fraction unfished (top right), recruitment deviations (bottom left), and age-0 recruits (bottom right) for models with steepness estimated and either unconstrained recruitment deviations (red lines and points) or a sum-to-zero constraint on recruitment deviations (blue lines and points).

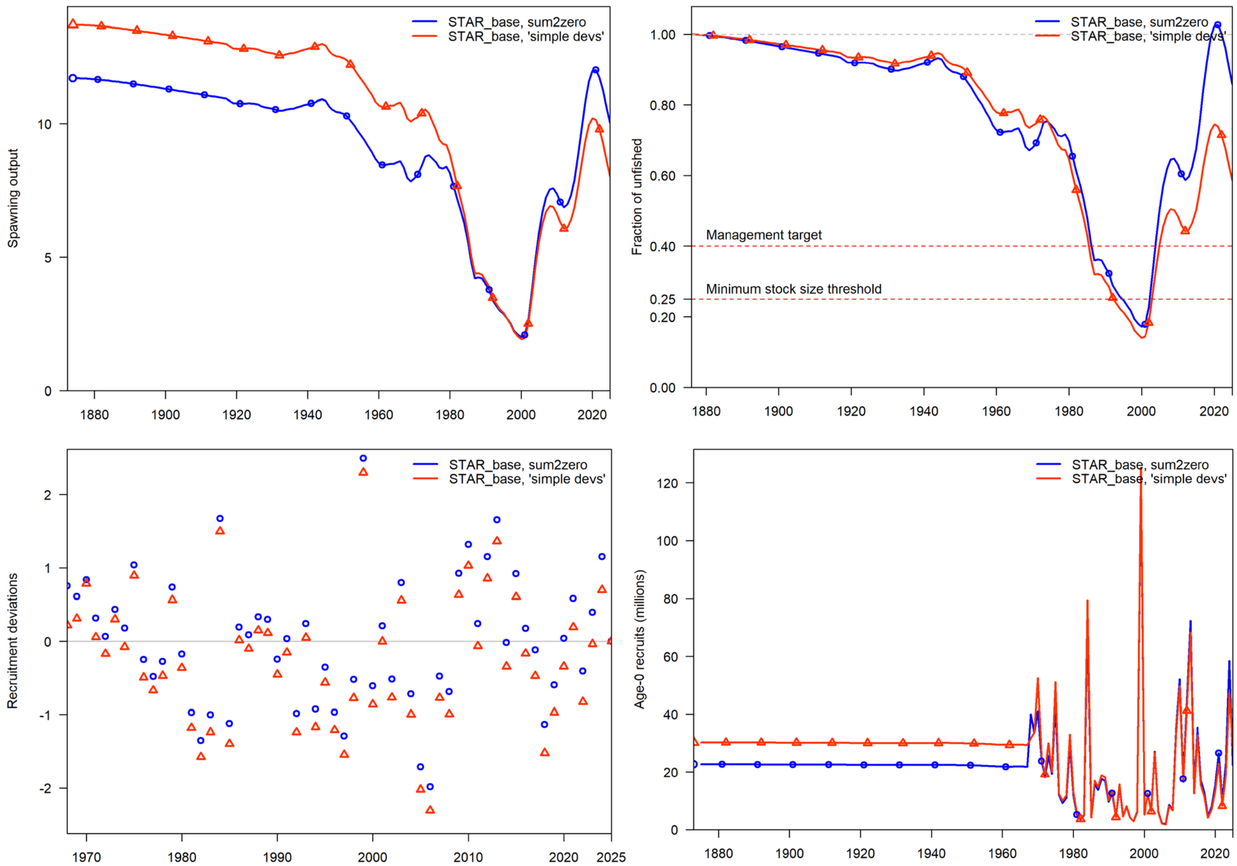


Figure 11B. Spawning output (top left), fraction unfished (top right), recruitment deviations (bottom left), and age-0 recruits (bottom right) for models with steepness fixed at the prior mean of 0.72 and either unconstrained recruitment deviations (red lines and points) or a sum-to-zero constraint on recruitment deviations (blue lines and points).

Table 11. Likelihood components, parameter estimates, and derived quantities from models with steepness fixed or estimated and recruitment deviations either unconstrained or with a sum-to-zero constraint.

Label	STAR_base, sum2zero	STAR_base, simple devs	Est. Steepness, sum2zero	Est. Steepness, simple devs
N.Parms	109	109	110	110
TOTAL	2625.350	2621.330	2620.330	2619.620
Survey	29.383	24.307	22.831	22.724
Length_comp	572.553	572.015	572.476	572.356
Age_comp	2001.450	2000.480	1999.830	1999.750
Recruitment	21.928	24.425	23.155	23.498
Parm_priors	0.030	0.096	2.035	1.289
NatM_uniform_Fem_GP_1	0.166	0.177	0.177	0.180
L_at_Amax_Fem_GP_1	47.887	47.860	47.852	47.848
VonBert_K_Fem_GP_1	0.197	0.197	0.197	0.197
CV_young_Fem_GP_1	0.105	0.105	0.104	0.104
CV_old_Fem_GP_1	0.039	0.039	0.039	0.039
NatM_uniform_Mal_GP_1	0.263	0.241	0.241	0.235
L_at_Amax_Mal_GP_1	-0.329	-0.329	-0.328	-0.329
VonBert_K_Mal_GP_1	0.528	0.528	0.528	0.528
CV_young_Mal_GP_1	0.234	0.235	0.236	0.236
CV_old_Mal_GP_1	0.101	0.100	0.098	0.099
SR_LN(R0)	10.027	10.314	10.450	10.471
SR_BH_steep	0.720	0.720	0.355	0.436
Q_extraSD_CalCOFI_Survey(11)	0.369	0.310	0.291	0.292
Q_extraSD_RREAS_YOY_Survey(12)	1.210	1.230	1.227	1.233
Size_DblN_peak_NoCA_HKL(1)	40.931	41.080	41.117	41.119
Size_DblN_ascend_se_NoCA_HKL(1)	4.393	4.405	4.412	4.409
Size_DblN_peak_SoCA_HKL(2)	23.720	23.788	23.802	23.817
Size_DblN_ascend_se_SoCA_HKL(2)	1.155	1.195	1.203	1.212
Size_DblN_peak_CA_TWL(3)	44.864	45.102	45.191	45.218
Size_DblN_ascend_se_CA_TWL(3)	4.554	4.563	4.570	4.570
Size_DblN_peak_OR_WA_Comm(4)	42.470	43.109	43.312	43.424
Size_DblN_ascend_se_OR_WA_Comm(4)	4.538	4.600	4.618	4.628
Size_DblN_peak_CA_NET(5)	46.982	46.979	46.999	46.976
Size_DblN_ascend_se_CA_NET(5)	4.425	4.420	4.422	4.419
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.836	44.110	44.233	44.248
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.132	5.145	5.154	5.152
Size_DblN_peak_SoCA_Rec(7)	24.698	24.731	24.749	24.754
Size_DblN_ascend_se_SoCA_Rec(7)	2.929	2.936	2.939	2.940
Size_DblN_descend_se_SoCA_Rec(7)	3.317	3.278	3.267	3.260
Size_DblN_end_logit_SoCA_Rec(7)	-1.094	-1.049	-1.033	-1.025
Size_DblN_peak_TWL_discard(8)	29.531	29.572	29.603	29.606
Size_DblN_ascend_se_TWL_discard(8)	4.178	4.181	4.183	4.183
Size_DblN_descend_se_TWL_discard(8)	3.199	3.194	3.188	3.188
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.711	51.396	51.317	51.276
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.166	4.141	4.135	4.132
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	48.816	48.776	48.825	48.772
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.822	4.814	4.819	4.813
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.818	33.920	33.905	33.930
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.295	3.315	3.313	3.317
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.698	30.648	30.616	30.609
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.755	3.742	3.737	3.734
Bratio_2025	0.858	0.587	0.443	0.456
SSB_unfished	11695	13702	15608	15395
Totbio_unfished	51221	61698	70333	69920
Recr_unfished	22633	30156	34542	35271
Dead_Catch_SPR	2089	2633	570	1772
OFLCatch_2025	3663	3160	2742	2838

11 - Panel Conclusion
The Panel generally agrees with the proposed way forward, which is to consider best practices of using bias correction for recruitment deviations and modelling recruitment deviations along with a steepness fixed at the mean of the prior. It is uncertain whether the bias correction method is appropriate without a sum-to-zero constraint on recruitment deviations. It was noted that when estimating steepness, the difference between constraining recruitment deviations or not was much smaller than when fixing steepness at a larger value. This topic deserves further research.

12 - Request
Predict the WCGBTS index with depth as a covariate and assuming isotropy (all other model configurations unchanged). If a suitable alternative index (as determined by the STAT) is identified, please run a revised base model using this index. Please include information about how the depth effect was modeled and show the marginal effect of depth.

12 - Rationale
An initial WGCBTS index with depth as a covariate (from Request 3) showed large differences in scale and wider confidence intervals compared to the pre-STAR base model index. The analysis was preliminary and changes to the index model setting should be explored further.

12 - STAT Response
Further investigation revealed an incorrect sign in the scaled depth range of the prediction grid. Thus, the model was extrapolating to unobserved depth values, leading to the large difference in scale, high uncertainty, and different trends. This issue was corrected in the new index.

Depth was standardized and included as a quadratic covariate for the binomial and positive models. Isotropy was assumed, as requested. The model was configured as follows:

```
newfit1 <- sdmTMB(formula = catch_weight ~
             0 + fyear + pass_scaled + depth_scaled + depth_scaled_squared,
                      data = data_truncated,
                      mesh = mesh,
                      time = "year",
                      family = delta_lognormal(type="standard"),
                      spatial = "on",
                      spatiotemporal = list("iid", "off"),
                      share_range = TRUE,
                      offset = log(data_truncated$effort),
                      anisotropy = FALSE)
```

The relationship between model residuals and depth was explored for a) the original model without depth and assuming anisotropy, b) the original model without anisotropy, and c) the new model with depth and assuming isotropy (Fig. 12A). Models without depth showed a relationship between the residuals and depth, particularly for the positive component of the delta model. This suggests that anisotropy does not account for depth effects and that depth is informative.

The new index (using correct scaled depth values) had a similar trend and variance estimate as the original index but was somewhat lower in scale (abundances ~15% smaller when including a depth effect; Fig. 12B).

Marginal effects could not be produced as this required regenerating the mesh and the STAT did not have information about the parameters used to generate the original. As a substitute, the STAT computed the conditional effect of depth by predicting biomass across the range of observed depths at the mean latitude and longitude of the prediction grid for the first year of the survey (Fig. 12C). This shows a peak in biomass around 200 m, with few fish observed at the shallowest depths and deeper than 350 m.

The revised base model was run with this new index without re-tuning (Fig. 12D). Catchability (q) for the revised index was 1.84, compared to a value > 2 for the model without depth. Fits to the survey component and total likelihood improved more than two likelihood points with no change in the number of parameters (Table 12), suggesting a better fit when depth was included. The model fit to the index with depth effects did not require tuning, as the Francis weights were unchanged to the third decimal place.

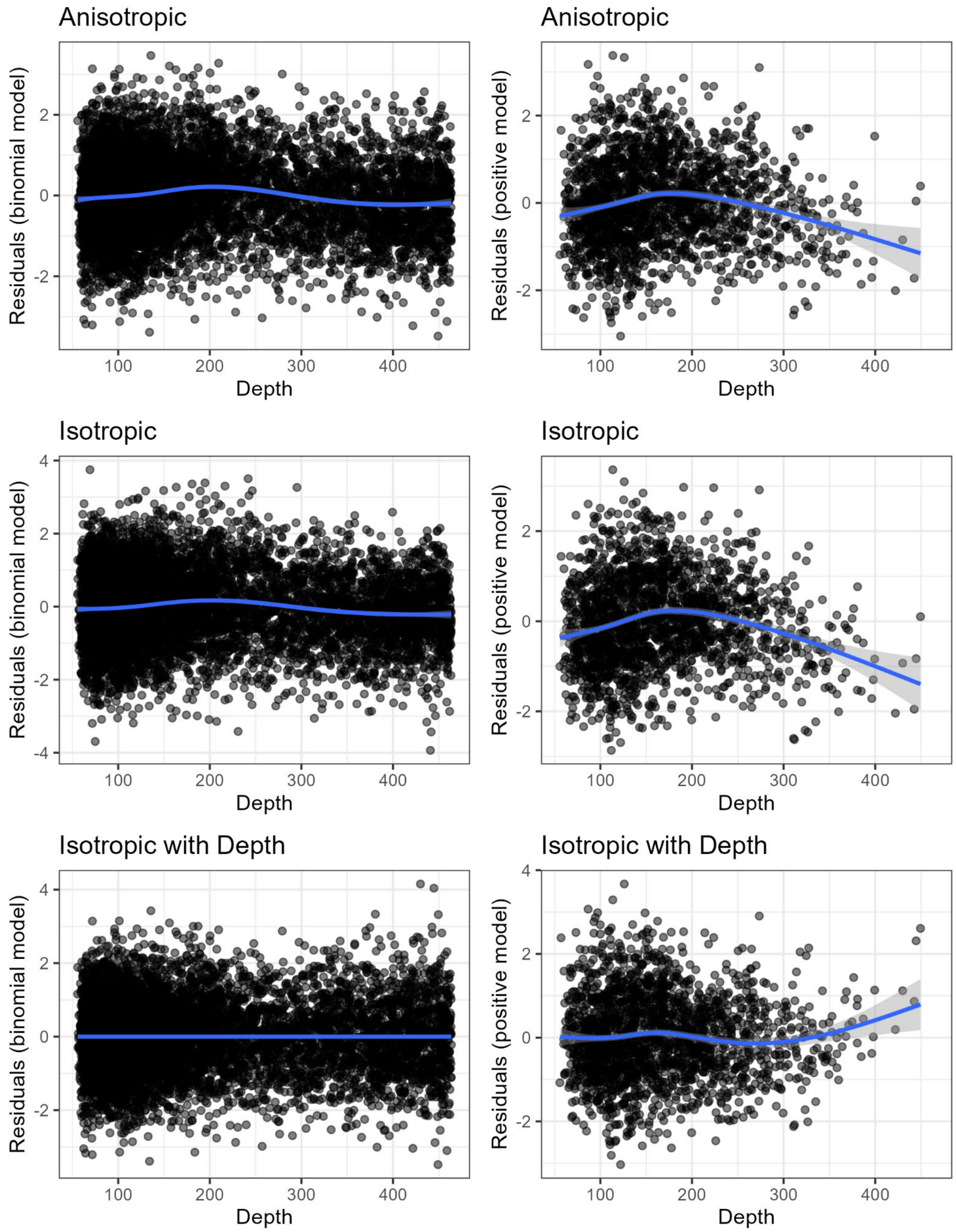


Figure 12A. Model residuals for the original WCGBTS index model that assumed anisotropy and did not include a depth effect (top), a revised WCGBTS index model that assumed isotropy (middle), and a revised WCGBTS index model that assumed isotropy and included a depth effect (bottom). Binomial (left) and positive (right) models are shown.

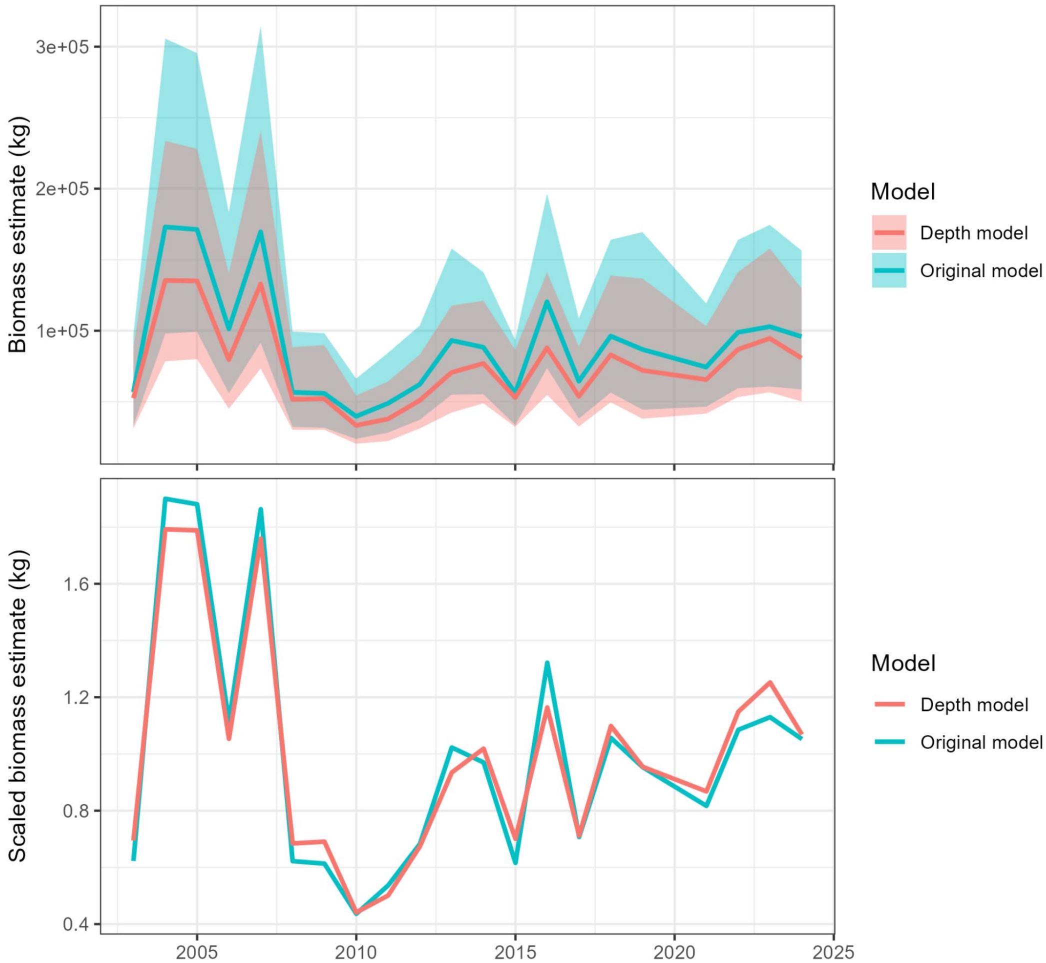


Figure 12B. The original WCGBTS index and a revised WCGBTS index that includes depth as a covariate and assumes isotropy (top). Biomass estimates were also scaled using their respective means (bottom).

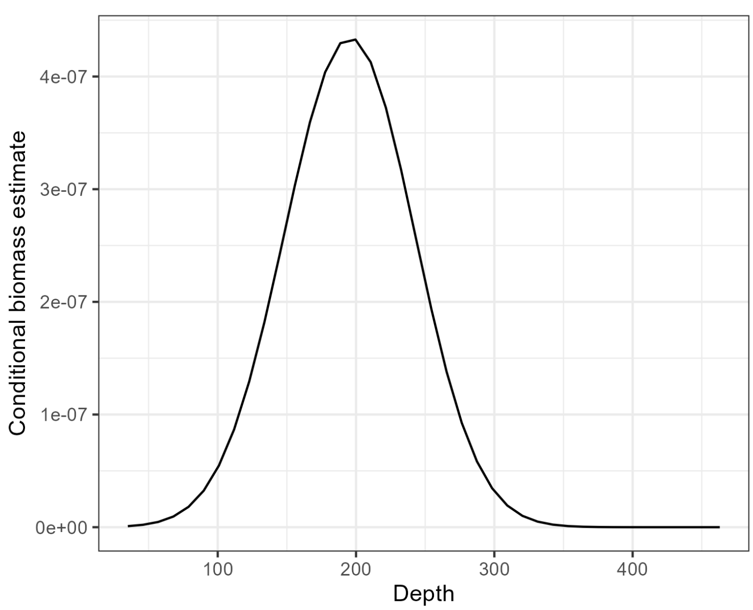


Figure 12C. Conditional effect of depth on biomass (link scale) using the WCGBTS index model. Predicted biomass densities are shown across the full range of observed depths, assuming the mean latitude and longitude of the prediction grid during the first year of the survey.

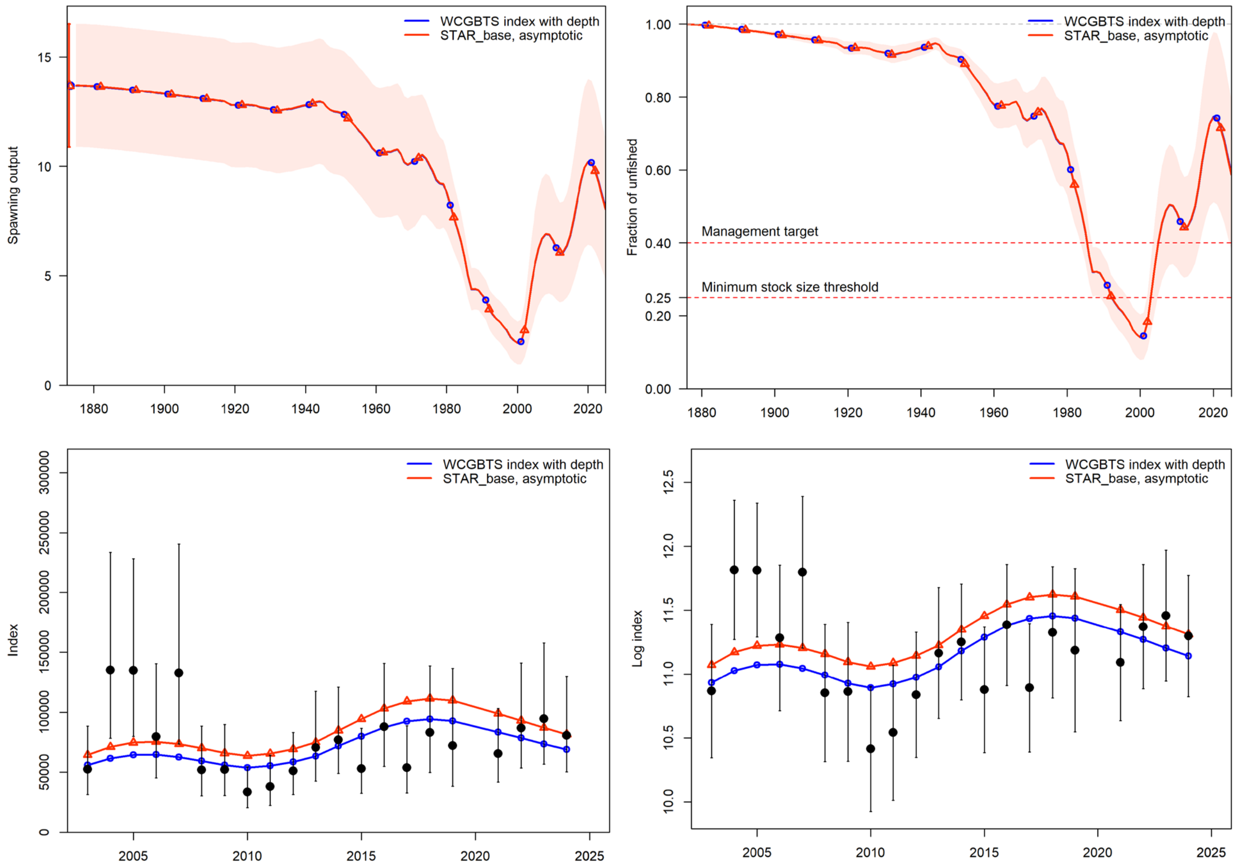


Figure 12D. Spawning output (top left), fraction unfished (top right), model fits to data (arithmetic scale) on the index (bottom left) and log scale (bottom right). Note that fits are not comparable due to a change in index scale when adding depth effect.

Table 12. Likelihood components, parameter estimates, and derived quantities for models fit to WCGBTS indices with and without a depth effect.

Label	WCGBTS index with depth	STAR_base, asymptotic
N.Parms	109	109
TOTAL	2618.920	2621.330
Survey	21.805	24.307
Length_comp	572.090	572.015
Age_comp	2000.530	2000.480
Recruitment	24.400	24.425
Parm_priors	0.093	0.096
NatM_uniform_Fem_GP_1	0.176	0.177
L_at_Amax_Fem_GP_1	47.861	47.860
VonBert_K_Fem_GP_1	0.197	0.197
CV_young_Fem_GP_1	0.105	0.105
CV_old_Fem_GP_1	0.039	0.039
NatM_uniform_Mal_GP_1	0.241	0.241
L_at_Amax_Mal_GP_1	-0.329	-0.329
VonBert_K_Mal_GP_1	0.528	0.528
CV_young_Mal_GP_1	0.235	0.235
CV_old_Mal_GP_1	0.100	0.100
SR_LN(R0)	10.309	10.314
Q_extraSD_CalCOFI_Survey(11)	0.310	0.310
Q_extraSD_RREAS_YOY_Survey(12)	1.224	1.230
Size_DblN_peak_NoCA_HKL(1)	41.088	41.080
Size_DblN_ascend_se_NoCA_HKL(1)	4.406	4.405
Size_DblN_peak_SoCA_HKL(2)	23.803	23.788
Size_DblN_ascend_se_SoCA_HKL(2)	1.203	1.195
Size_DblN_peak_CA_TWL(3)	45.106	45.102
Size_DblN_ascend_se_CA_TWL(3)	4.564	4.563
Size_DblN_peak_OR_WA_Comm(4)	43.154	43.109
Size_DblN_ascend_se_OR_WA_Comm(4)	4.602	4.600
Size_DblN_peak_CA_NET(5)	46.981	46.979
Size_DblN_ascend_se_CA_NET(5)	4.420	4.420
Size_DblN_peak_NoCA_OR_WA_Rec(6)	44.140	44.110
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.147	5.145
Size_DblN_peak_SoCA_Rec(7)	24.734	24.731
Size_DblN_ascend_se_SoCA_Rec(7)	2.936	2.936
Size_DblN_descend_se_SoCA_Rec(7)	3.278	3.278
Size_DblN_end_logit_SoCA_Rec(7)	-1.050	-1.049
Size_DblN_peak_TWL_discard(8)	29.586	29.572
Size_DblN_ascend_se_TWL_discard(8)	4.181	4.181
Size_DblN_descend_se_TWL_discard(8)	3.191	3.194
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.389	51.396
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.140	4.141
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	48.777	48.776
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.814	4.814
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.915	33.920
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.314	3.315
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.642	30.648
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.741	3.742
Bratio_2025	0.591	0.587
SSB_unfished	13694	13702
Totbio_unfished	61608	61698
Recr_unfished	30000	30156
Dead_Catch_SPR	2626	2633
OFLCatch_2025	3178	3160

12 - Panel Conclusion
Proceed with the new WCGBTS index that accounts for depth and assumes isotropy.

13 - Request
Estimate the peak and ascending variance parameters for selectivity of the WCGBTS and Triennial survey. Use the quick MCMC algorithm to determine how well these parameters are estimated and what reasonable values may be. Keep these survey selectivities as asymptotic and use the assumptions for commercial selectivities as in the "No Dome: All" run (Request 2).

13 - Rationale
The selectivities for these trawl surveys were not estimated in the pre-STAR base model. Forcing many of the commercial selectivities to be asymptotic (as done for Request 2) may improve the ability to estimate survey selectivities.

13 - STAT Response
Using the asymptotic selectivity base model established in Request 2, asymptotic selectivity was added for the WCGBTS and Triennial survey. The ascending scale and peak parameters were estimated using the double normal functional form with the other parameters fixed as asymptotic.

Selparm[55] and selparm[57] are the Triennial peak and ascending scale parameters, respectively. The Triennial survey selectivities are poorly estimated, with posterior modes against parameter bounds and a substantial tail in the peak parameter (Fig. 13A). Triennial parameter MLEs are not well reflected in the posteriors. Selparm[51] and selparm[49] are WCGBTS ascending scale and peak, respectively. The WCGBTS selectivity parameters display some multimodality (Fig. 13A). Multimodality is evidence of a nearby local mode but the prominent mode seems well defined and reasonably well captured by the MLE estimates.

Fitted end-year selectivities with asymptotic selectivities for the WCGBTS and Triennial survey are provided (Fig. 13B). A small improvement to marginal length composition fit at small sizes resulted from fitting the WCGBTS selectivity (Fig. 13C).

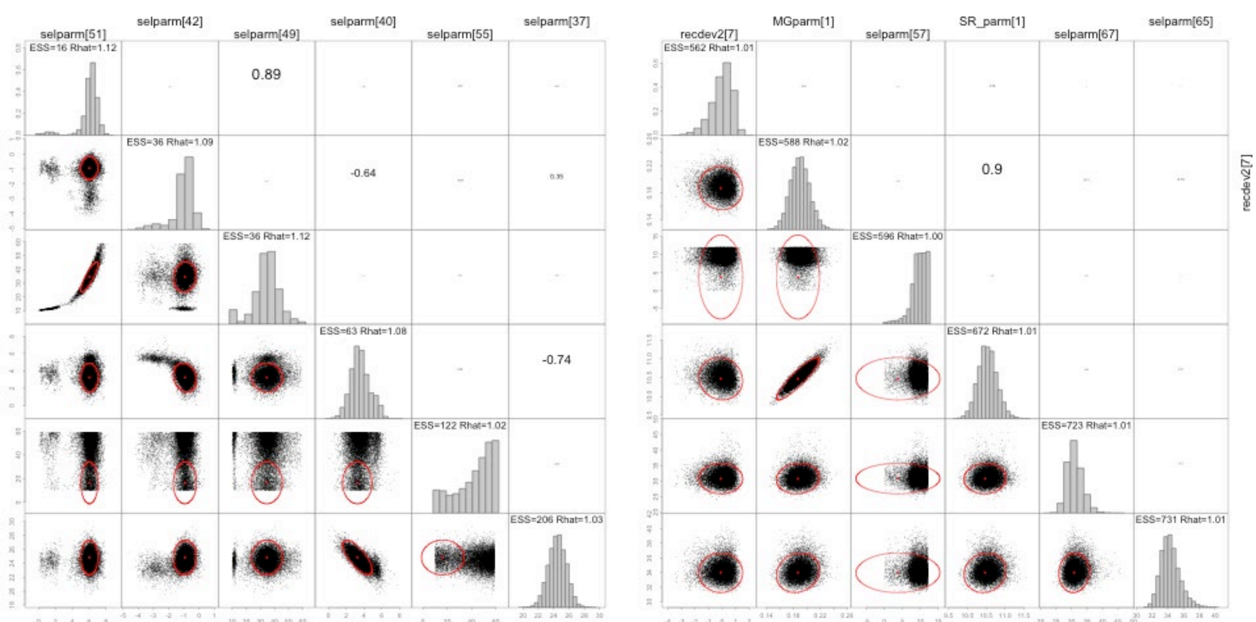


Figure 13A. Bivariate scatter plots and histograms of estimated selectivity parameters for the WCGBTS and Triennial survey, based on Request 13. Selparm[55] and selparm[57] are the Triennial peak and ascending scale parameters, respectively. Selparm[51] and selparm[49] are WCGBTS ascending scale and peak, respectively.

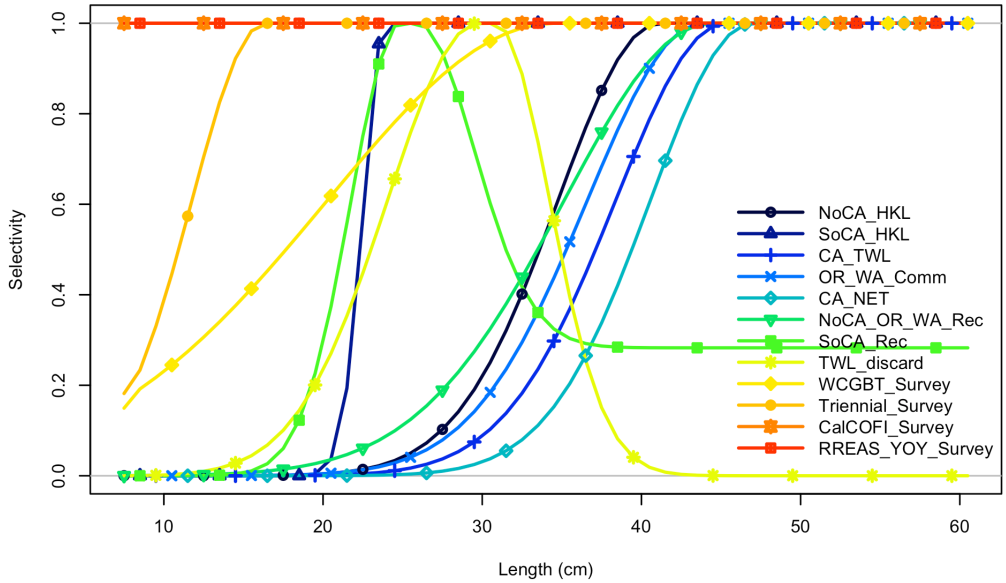


Figure 13B. Fitted end-year selectivities with asymptotic selectivities for the WCGBTS and Triennial survey.

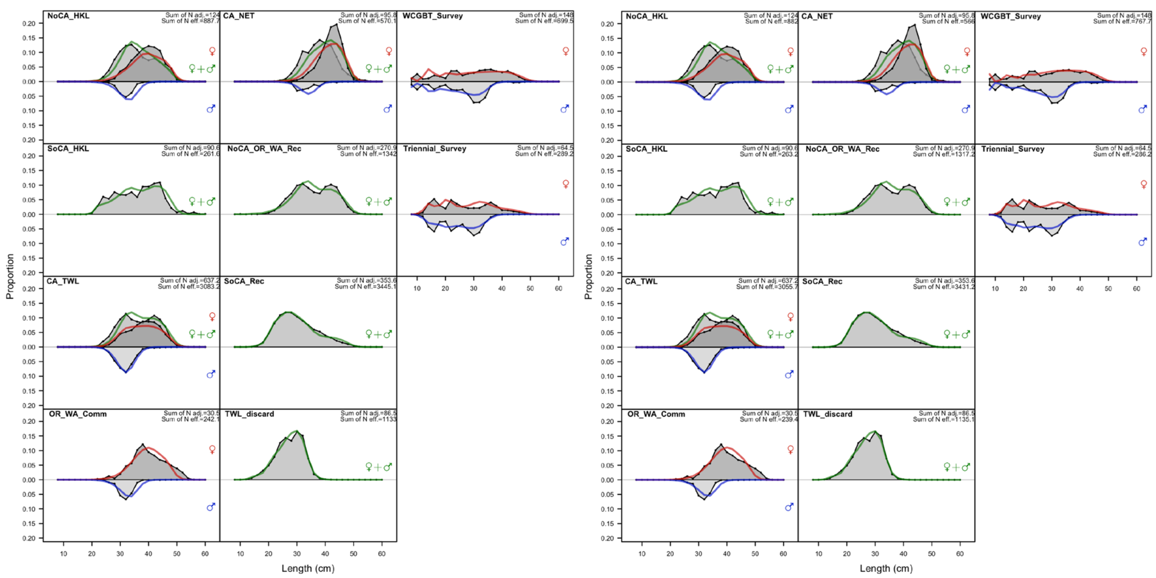


Figure 13C. Fits to marginal length compositions using the asymptotic base model (left) and with the added asymptotic selectivities for the WCGBTS and Triennial survey (right).

13 - Panel Conclusion

The Panel appreciates the work done by the STAT. The MCMC run is very informative and shows that there may be some multimodality in the selectivity parameter estimates. This request prompted Request 16 (evaluating predicted spatial fields).

14 - Request
Examine catch rates in early years (2004 to 2007) of the WCGBTS and compare those to catch rates in later years (2008 to 2024) . This may include creating bubble plots of raw catch rates, identifying the locations and magnitude of the 10 highest catch rates each year, and presenting depth-stratified proportions of zero catch.

14 - Rationale
The early years of the WCGBTS show high index values that are not well represented by the model. A better understanding about spatial distributions of catch will help determine how likely these years are to reflect overall stock abundance.

14 - STAT Response
The STAT worked with GIS analyst, Rebecca Miller (UCSC), to update plots that were initially developed for the 2015 assessment update. These plots show WCGBTS catch rates for the entire California coast (i.e., the region of greatest abundance; Fig. 14A) and for central California (Fig. 14B) during two time periods: 2004 to 2007 and 2008 to 2024. The highest catches are most frequently close to the shelf break (between 125 and 275 m depth), particularly in regions where the continental slope is steep. The results do not suggest substantive changes in the distribution of high and low catches between these two time periods, although this is difficult to discern from the figure alone. A provisional table of the total number of WCGBTS tows, the number of tows positive for chilipepper rockfish, and the year-specific mean CPUE by depth bin between 34 and 42 N is provided (Table 14A). A provisional table showing the year, location, and CPUE of the top 15 catches from the WCGBTS are also provided (Table 14B).

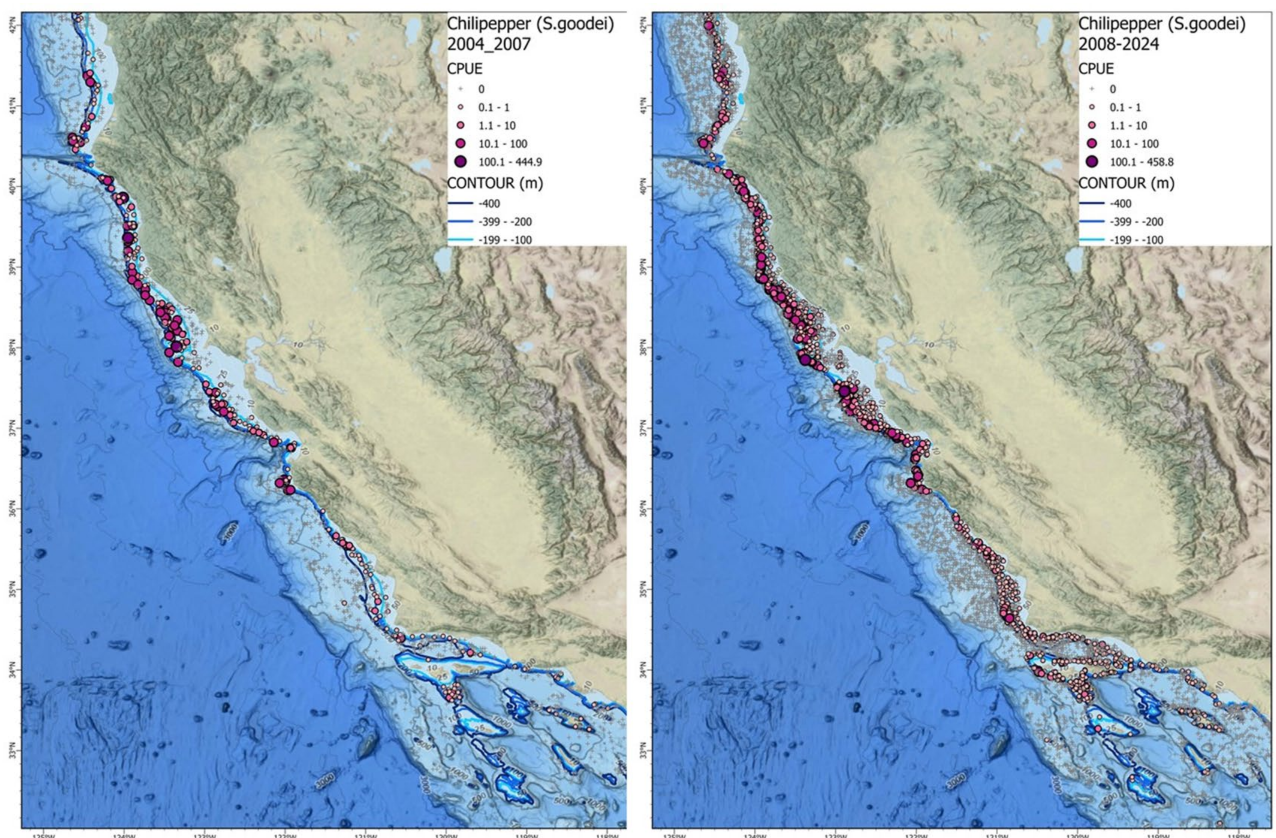


Figure 14A. WCGBTS catch-per-unit-effort (CPUE) from 2004 to 2007 (left) and 2008 to 2024 (right) along the California coast. Depth contours (100, 200 and 400m) are shown.

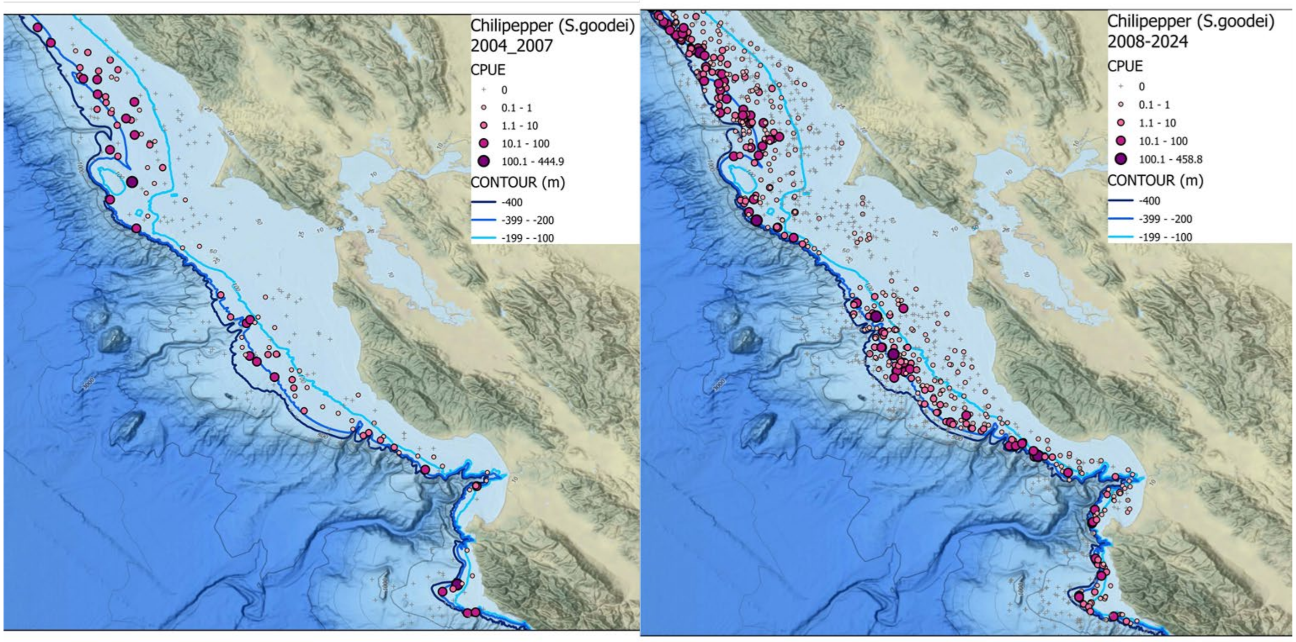


Figure 14B. WCGBTS catch-per-unit-effort (CPUE; kg per ha) from 2004 to 2007 (left) and 2008 to 2024 (right) off central California. Depth contours (100, 200 and 400m) are shown.

Table 14A. Percent positive tows, mean CPUE (kg per ha) per tow, and the number of tows conducted by the WCGBTS. Summarized data were constrained to the area of highest density, between 34 and 42 N, excluding waters off Oregon, Washington, and southern California.

year	% pos 50-125 m	mean cpue pos 50-125m	# tows	% pos 125-275 m	mean cpue pos 125-275m	# tows	% pos 275-550m	mean cpue pos 275-550	# tows
2003	38.18%	0.01	55	83.33%	11.78	54	18.03%	0.02	61
2004	48.33%	0.70	60	75.61%	10.26	41	8.33%	0.00	36
2005	33.72%	5.57	86	76.92%	6.75	52	3.28%	0.01	61
2006	26.23%	2.93	61	69.57%	6.25	46	3.28%	0.02	61
2007	18.18%	0.40	66	66.04%	7.36	53	8.20%	0.00	61
2008	28.40%	0.28	81	72.73%	5.51	44	6.49%	0.02	77
2009	24.18%	0.19	91	58.62%	2.26	58	13.04%	0.14	69
2010	32.94%	0.06	85	73.44%	1.04	64	8.45%	0.03	71
2011	18.52%	0.06	81	77.05%	5.19	61	5.08%	0.01	59
2012	36.73%	0.11	98	85.45%	4.77	55	8.45%	0.26	71
2013	65.52%	1.76	58	90.24%	3.03	41	13.16%	0.02	38
2014	49.37%	0.27	79	77.97%	9.99	59	16.42%	0.01	67
2015	27.47%	0.07	91	74.47%	4.13	47	17.81%	0.38	73
2016	35.21%	0.69	71	88.52%	9.32	61	4.11%	0.05	73
2017	30.95%	0.20	84	74.51%	4.83	51	13.70%	0.34	73
2018	31.25%	0.30	80	68.52%	14.53	54	10.00%	0.01	70
2019	29.41%	0.02	34	73.17%	9.22	41	3.03%	0.00	33
2021	53.61%	0.52	97	68.42%	4.71	57	11.11%	0.37	63
2022	45.35%	0.35	86	73.47%	3.21	49	5.33%	0.01	75
2023	32.10%	0.40	81	71.70%	4.34	53	10.67%	0.11	75
2024	45.00%	0.59	80	81.48%	9.70	54	12.96%	0.07	54

Table 14B. Year, location, depth, and raw CPUE (kg per ha) of the 15 highest catches of chilipepper rockfish from the WCGBTS between 2003 and 2024.

year	cpue	longitude	latitude	depth
2014	458.78	-123.93	38.87	265
2005	444.86	-124.01	39.86	114
2003	257.61	-123.46	38.10	174
2018	193.78	-123.81	38.72	255
2018	168.31	-123.61	38.53	168
2006	167.84	-123.35	38.01	112
2019	153.89	-122.23	36.89	145
2011	147.42	-122.89	37.46	150
2004	128.41	-122.01	36.35	133
2007	118.87	-123.95	39.36	180
2024	115.79	-122.89	37.46	150
2022	115.00	-124.69	42.51	126
2024	111.64	-123.38	37.85	153
2021	107.96	-122.82	37.30	158
2006	99.62	-123.44	37.94	142

14 - Panel Conclusion
The Panel appreciates the work done by the STAT. Plots of the raw data cannot, however, explain higher catches from 2004 to 2007 (i.e., the distribution was much more contracted in spatial range, the overall mean did not seem consistently higher in these years, and fish were found in shallow waters during this time). This issue will be further explored for Request 16.

15 - Request
Estimate the WCGBTS peak and ascending variance selectivity parameters starting the MLE optimization routine at 35 and 6, respectively. Fix the Triennial survey peak selectivity parameter at 58 and the ascending limb parameter at 10 (or a different value if 10 presents any issues). Present the r4ss output and compare likelihoods to the revised base model. Please also try a run that estimates the WCGBTS peak and ascending limb and removes the Triennial survey index, length data, and age data (e.g., setting lambdas to zero).

15 - Rationale
The MCMC analysis supported shallower (slower ascending) survey selectivities with a peak at ≥ 30 cm and a small mode at steeper selectivity with a smaller peak. This request will improve our understanding about the uncertainty across these two scenarios.

15 - STAT Response
The pre-STAR base model with asymptotic selectivities and unconstrained recruitment deviations was used as the starting point for this request. The first part of the request, with estimated parameters for the WCGBTS and fixed parameters for the Triennial survey, produced WCGBTS selectivity estimates that were consistent with the ‘mode’ of the MCMC reported in Request 13 (Fig. 15A; Table 15). The fixed parameter estimates for the Triennial survey (chosen by visual inspection of the MCMC results in Request 13) produced a curve very similar to the curve in the pre-STAR base model, where only age-0 fish are excluded and all other ages have selectivity equal to one. The STAT views this as support for a simple selectivity curve in the Triennial survey and suggests keeping the original curve (i.e., selectivity = 1 for age-1+ fish). The STAT modified the request slightly, adding an age-based selectivity that set selectivity=0 for age-0 fish, as the length-based selectivity curve requested by the Panel predicted a large number of age-0 fish that were not seen by the survey (see r4ss output for aggregated length compositions). Fits to lengths from the WCGBTS were ultimately degraded by the estimated

curve relative to the original pre-STAR base model, as determined by an increase of approximately 4 points in the negative log likelihood component (Table 15). There was minor improvement in fit to the WCGBTS index, as seen by a - 0.6 change in the survey component.

For the second part of the request, the model from part 1 was modified to remove all data types from the Triennial survey. This had no effect on estimated selectivity curves for the remaining fleets (Fig. 15B). Comparison plots of the three runs (base model with asymptotic selectivities, part 1 of this request, and part 2 of this request) show that the estimated stock scale is affected by removal of the Triennial survey, shifting recruitment deviations toward more negative values and shifting R_0 toward more positive values to offset that effect. A similar but much smaller effect is associated with the changes to survey selectivity in part 1 of this request, relative to the pre-STAR base model.

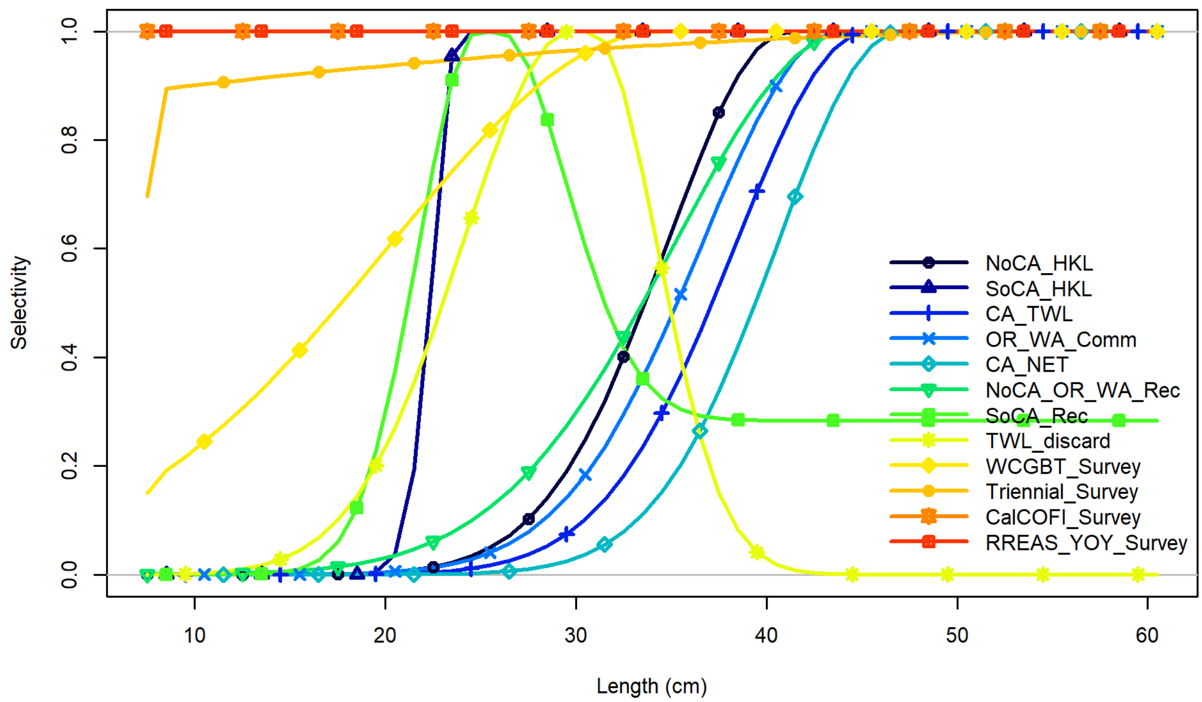


Figure 15A. End-year selectivity curves from the pre-STAR base model with estimated peak and ascending width parameters for the WCGBTS, and fixed selectivity parameters for the Triennial survey.

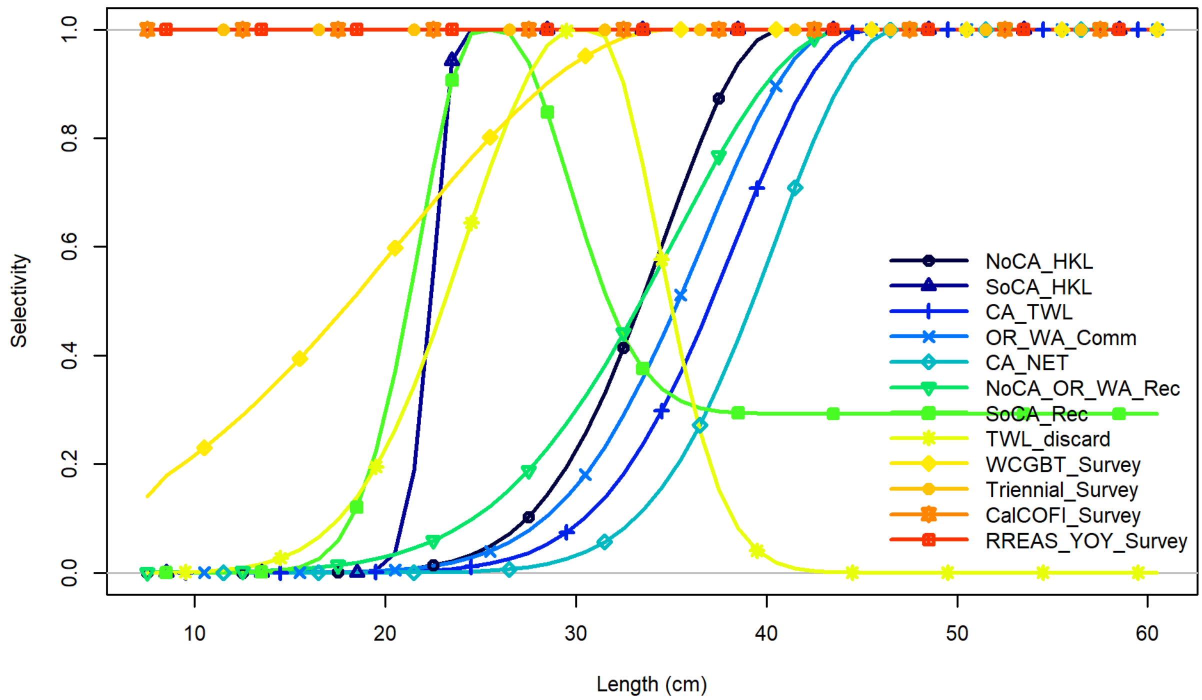


Figure 15B. End-year selectivity curves from the pre-STAR base model with estimated peak and ascending width parameters for the WCGBTS, and the Triennial survey removed from the model.

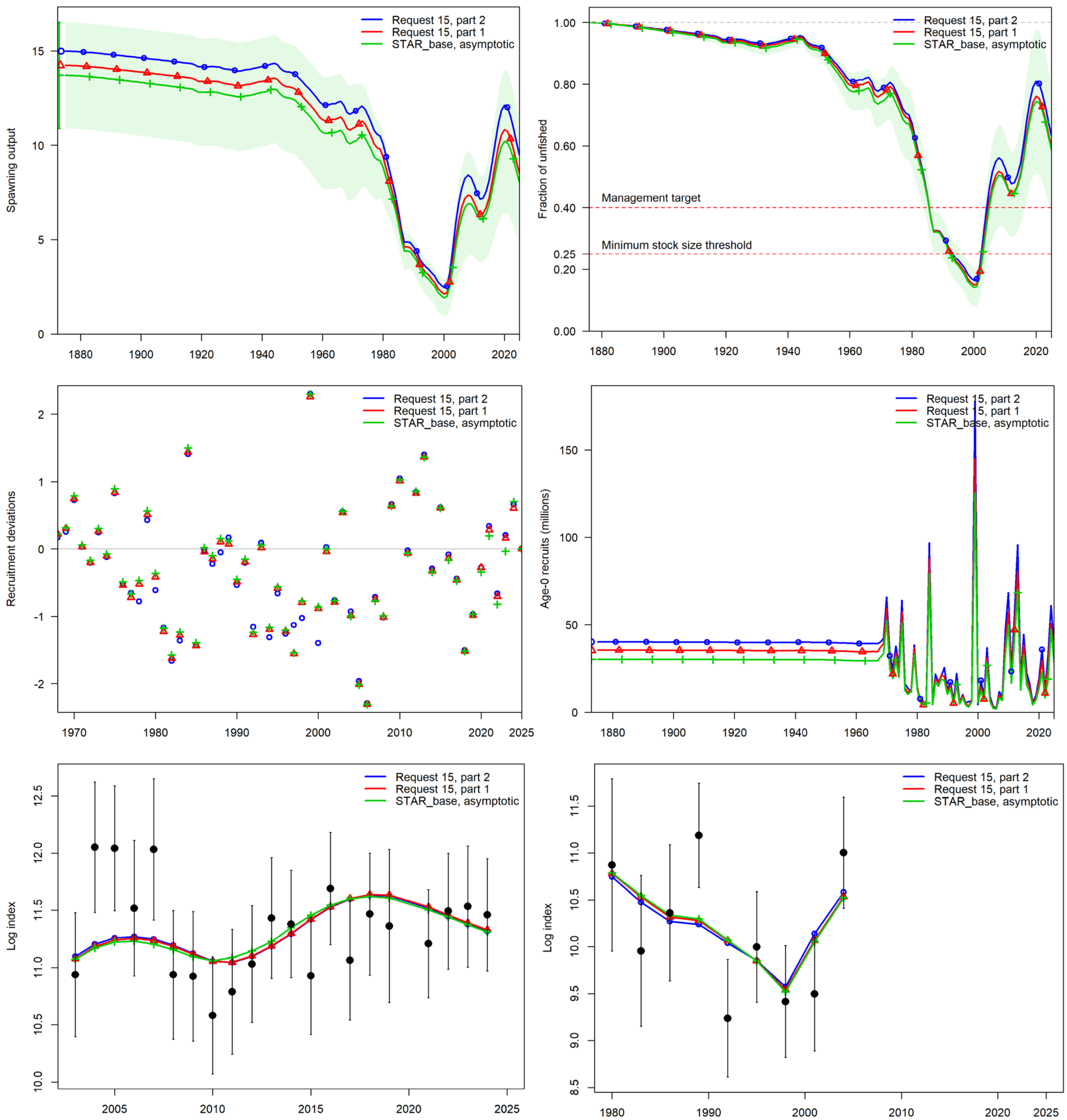


Figure 15C. Spawning output (top left), fraction unfished (top right), recruitment deviations (middle left), age-0 recruits (middle right), log-scale fits to the WCGBTS (bottom left), and log-scale fits to the Triennial survey (bottom right). “Fit” to the Triennial survey index for part 2 is implied with lambda set to zero.

Table 15. Likelihood components, estimated parameters, and derived quantities associated with altering selectivity parameters for the WCGBTS and Triennial survey.

Label	Request 15, part 2	Request 15, part 1	STAR_base, asymptotic
N.Parms	111	111	109
TOTAL	2504.080	2623.980	2621.330
Survey	20.881	23.745	24.307
Length_comp	547.765	576.047	572.015
Age_comp	1910.190	1999.490	2000.480
Recruitment	24.978	24.495	24.425
Parm_priors	0.262	0.191	0.096
NatM_uniform_Fem_GP_1	0.193	0.187	0.177
L_at_Amax_Fem_GP_1	47.948	47.890	47.860
VonBert_K_Fem_GP_1	0.195	0.196	0.197
CV_young_Fem_GP_1	0.106	0.105	0.105
CV_old_Fem_GP_1	0.038	0.039	0.039
NatM_uniform_Mal_GP_1	0.211	0.221	0.241
L_at_Amax_Mal_GP_1	-0.332	-0.329	-0.329
VonBert_K_Mal_GP_1	0.515	0.522	0.528
CV_young_Mal_GP_1	0.283	0.241	0.235
CV_old_Mal_GP_1	0.098	0.099	0.100
SR_LN(R0)	10.598	10.474	10.314
Q_extraSD_CalCOFI_Survey(11)	0.319	0.311	0.310
Q_extraSD_RREAS_YOY_Survey(12)	1.219	1.221	1.230
Size_DblN_peak_NoCA_HKL(1)	40.742	41.136	41.080
Size_DblN_ascend_se_NoCA_HKL(1)	4.345	4.401	4.405
Size_DblN_peak_SoCA_HKL(2)	23.962	23.906	23.788
Size_DblN_ascend_se_SoCA_HKL(2)	1.289	1.259	1.195
Size_DblN_peak_CA_TWL(3)	45.243	45.296	45.102
Size_DblN_ascend_se_CA_TWL(3)	4.557	4.565	4.563
Size_DblN_peak_OR_WA_Comm(4)	43.881	43.833	43.109
Size_DblN_ascend_se_OR_WA_Comm(4)	4.651	4.654	4.600
Size_DblN_peak_CA_NET(5)	46.794	46.973	46.979
Size_DblN_ascend_se_CA_NET(5)	4.400	4.414	4.420
Size_DblN_peak_NoCA_OR_WA_Rec(6)	44.128	44.372	44.110
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.108	5.140	5.145
Size_DblN_peak_SoCA_Rec(7)	24.873	24.844	24.731
Size_DblN_ascend_se_SoCA_Rec(7)	2.956	2.954	2.936
Size_DblN_descend_se_SoCA_Rec(7)	3.282	3.249	3.278
Size_DblN_end_logit_SoCA_Rec(7)	-0.884	-0.929	-1.049
Size_DblN_peak_TWL_discard(8)	29.887	29.757	29.572
Size_DblN_ascend_se_TWL_discard(8)	4.190	4.185	4.181
Size_DblN_descend_se_TWL_discard(8)	3.126	3.158	3.194
Size_DblN_peak_WCGBT_Survey(9)	35.007	34.585	NA
Size_DblN_top_logit_WCGBT_Survey(9)	-6.000	-6.000	NA
Size_DblN_ascend_se_WCGBT_Survey(9)	6.013	6.022	NA
Size_DblN_descend_se_WCGBT_Survey(9)	7.000	7.000	NA
Size_DblN_start_logit_WCGBT_Survey(9)	-999.000	-999.000	NA
Size_DblN_end_logit_WCGBT_Survey(9)	10.000	10.000	NA
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.194	51.365	51.396
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.122	4.135	4.141
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	48.393	48.771	48.776
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.775	4.806	4.814
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.940	33.997	33.920
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.299	3.322	3.315
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.960	30.791	30.648
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.775	3.757	3.742
Size_DblN_peak_Triennial_Survey(10)	NA	58.000	NA
Size_DblN_top_logit_Triennial_Survey(10)	NA	-6.000	NA
Size_DblN_ascend_se_Triennial_Survey(10)	NA	10.000	NA
Size_DblN_descend_se_Triennial_Survey(10)	NA	7.000	NA
Size_DblN_start_logit_Triennial_Survey(10)	NA	-999.000	NA
Size_DblN_end_logit_Triennial_Survey(10)	NA	10.000	NA
SizeSel=1_BinLo_WCGBT_Survey(9)	NA	NA	3.000
SizeSel=1_BinHi_WCGBT_Survey(9)	NA	NA	54.000
Bratio_2025	0.633	0.597	0.587
SSB_unfished	14983	14233	13702
Totbio_unfished	70061	65718	61698
Recr_unfished	40069	35386	30156
Dead_Catch_SPR	3198	2927	2633
OFLCatch_2025	4170	3613	3160

15 - Panel Conclusion
The likelihood when estimating WCGBTS selectivity was slightly higher than when fixing parameters to produce a knife-edge selectivity. The MCMC results from Request 13 were likely not fully converged on a parameter space that was correlated with two similar peaks. The assumed (fixed) selectivity for the Triennial survey based on MCMC results from Request 13 was essentially the same as the pre-STAR base model. The Panel does not see sufficient reason to remove the Triennial survey given some influence on the model. The Panel supports assumptions about survey selectivity that were made in the pre-STAR base model.

16 - Request
Plot estimated spatial and spatiotemporal fields for both components of the delta-lognormal model used for the WCGBTS index. The spatiotemporal field will only be available for the presence-absence model. The STAT can choose which years to present if there are too many plots but please provide a justification for specific time frame used. Please focus on evaluating differences between the early (2004 to 2007) and late (after 2008) periods to understand the reason for relatively high index values from 2004 to 2007. Please also present values for the estimated "year" effect.

16 - Rationale
The raw data presented as part of Request 14 was informative but cannot explain higher catches from 2004 to 2007 (i.e., the distribution was much more contracted in spatial range, the overall mean did not seem consistently higher in these years, and fish were found in shallow waters during this time). Thus, the impact of these observations on the WCGBTS index standardization model requires further examination into the estimated spatiotemporal field, which is the only component of the model that can vary in time and space.

16 - STAT Response
Plots of the 'year' effects (Fig. 16A and Fig. 16B), spatial random fields for the binomial and positive models (Fig. 16D), the spatiotemporal random field for the binomial model (Fig. 16E), and the 'non-random fields' that correspond to the depth effect plotted over space (Fig. 16F) are shown below. It appears that the index is driven primarily by the fixed year effect in the positive model, which resembles the raw geometric mean of the positive catch data. The spatiotemporal random field in the binomial model (and the binomial model in general) does not appear to be contributing as much to overall trends. Predictions for central California for two 'high years' (i.e., 2004 and 2005) and two 'low years' (i.e., 2010 and 2011) show higher values in the 'high years', although the difference is more pronounced in the positive model (Fig. 16G).

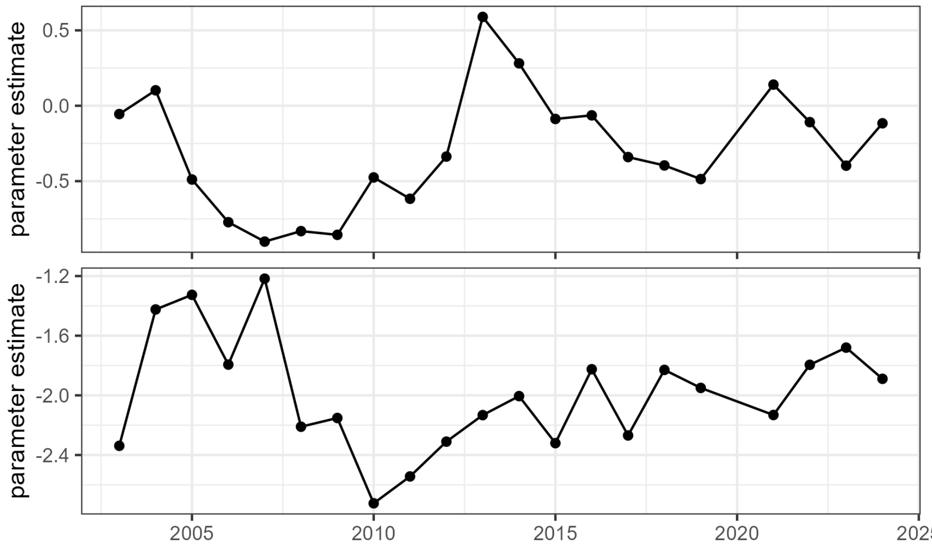


Figure 16A. Parameter estimates for the year effect from the binomial (top) and positive (bottom) components of the WCGBTS index model. Values are on the link scale.

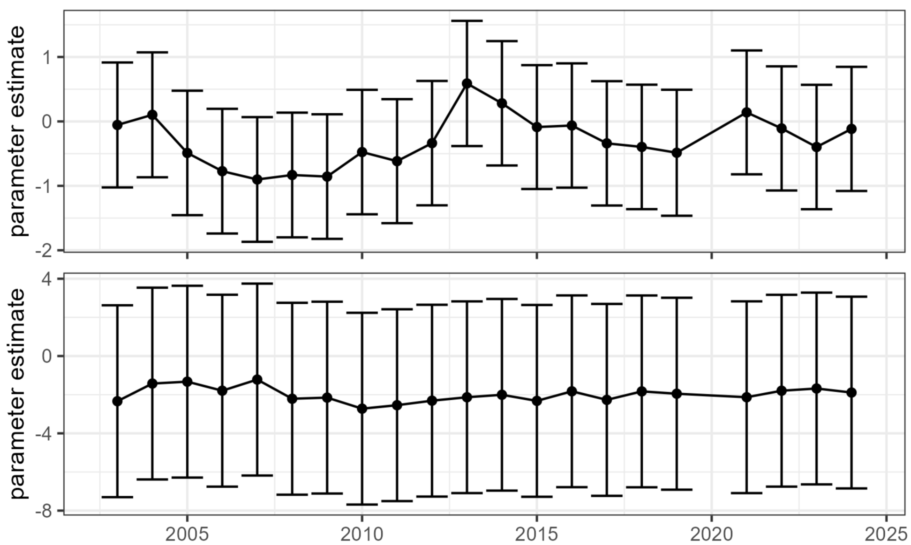


Figure 16B. Parameter estimates for the year effect from the binomial (top) and positive (bottom) components of the WCGBTS index model, with standard errors. The resemblance of the positive model coefficients is obscured when error bars are included.

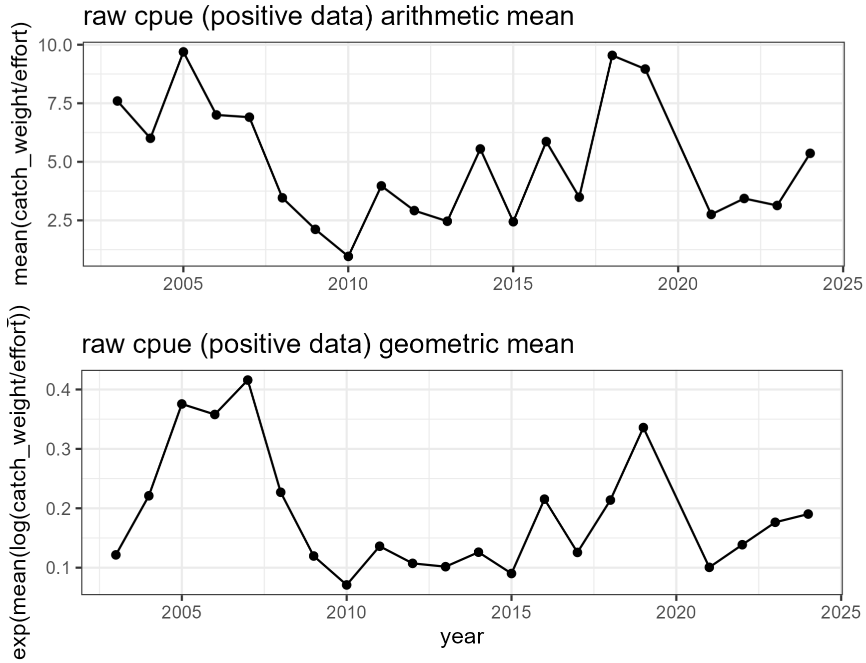


Figure 16C. Arithmetic (top) and geometric (bottom) mean catch-per-unit-effort (CPUE, kg per ha) from the WCGBTS index.

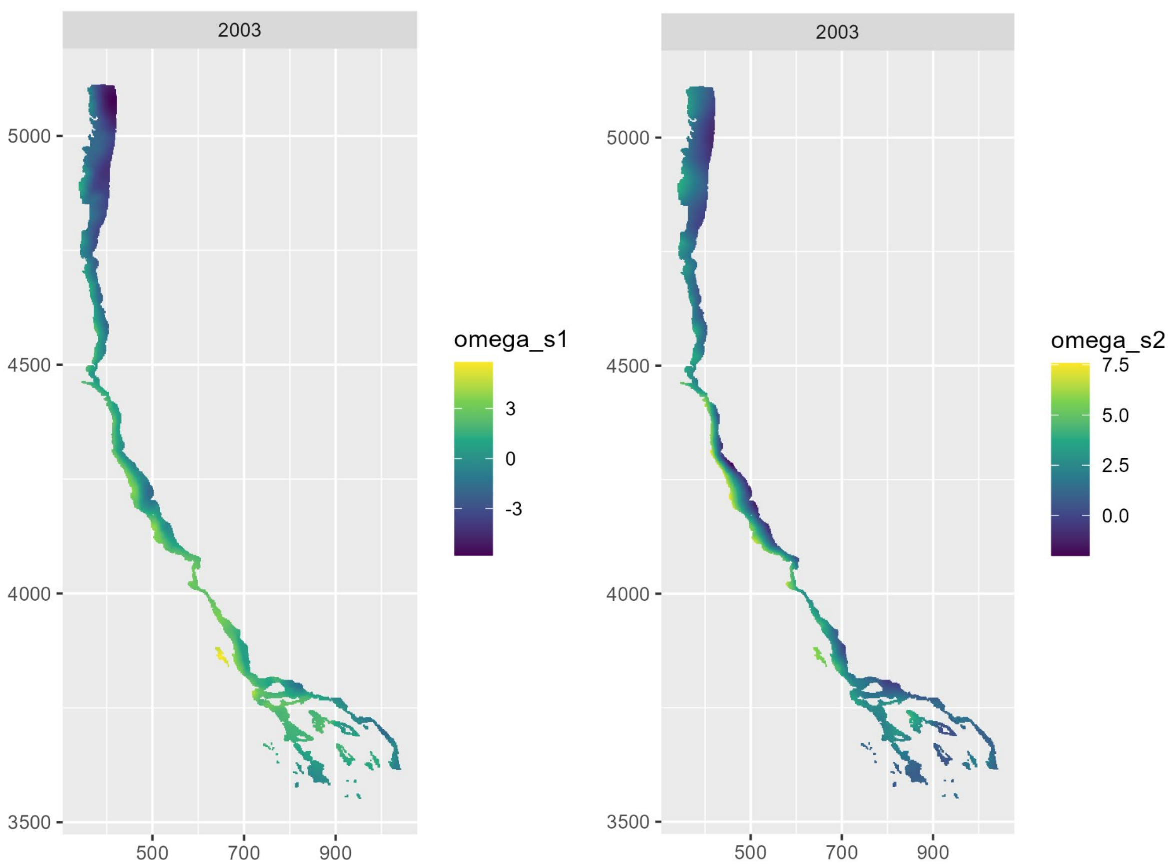


Figure 16D. Spatial random fields for the binomial (left) and positive (right) components of the WCGBTS index model. The spatial random field is shown for 2003, though the effect does not vary by year. Values are on the link scale.

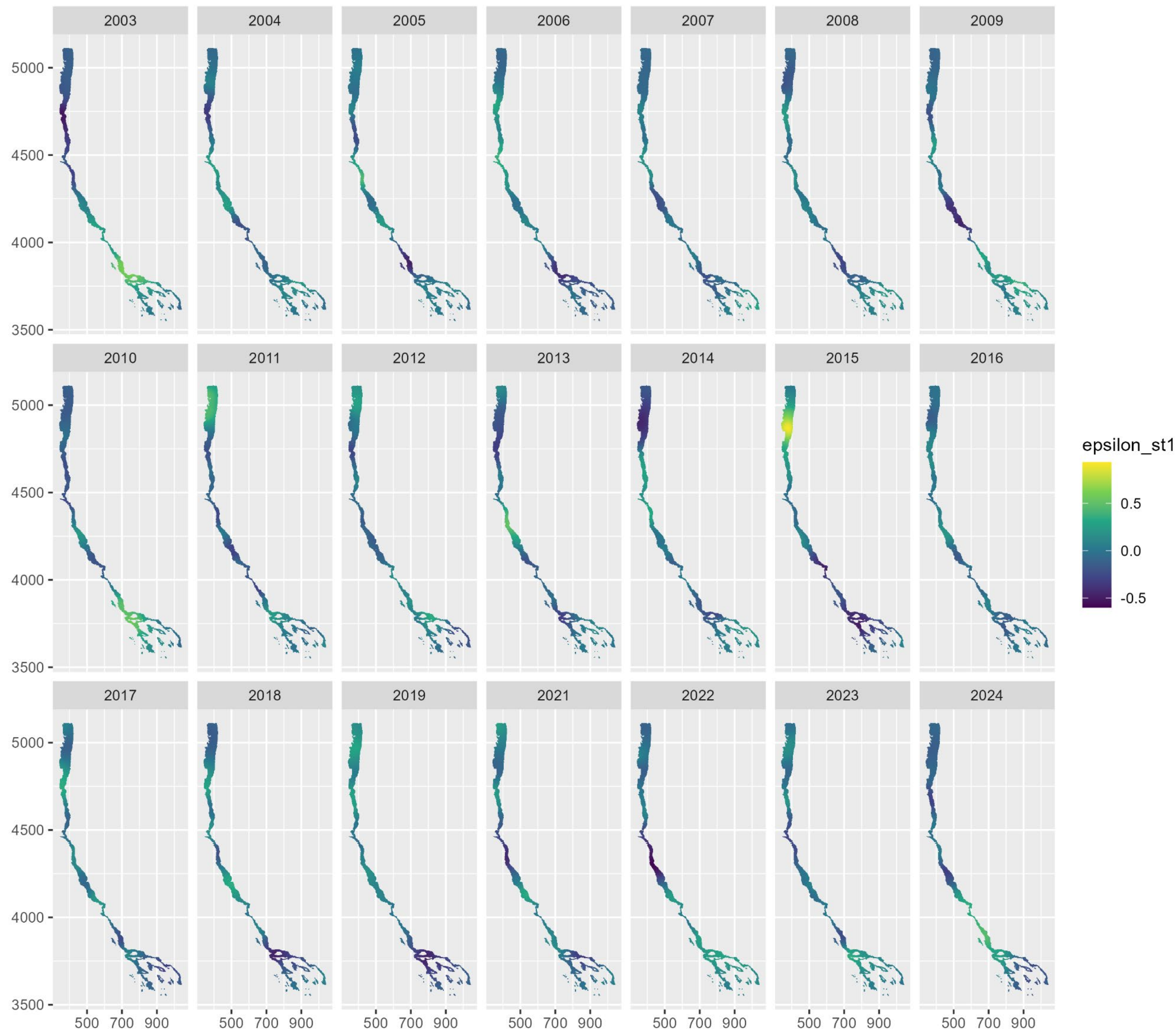


Figure 16E. Spatiotemporal random fields for the binomial component of the WCGBTS index model by year. Values are on the link scale.

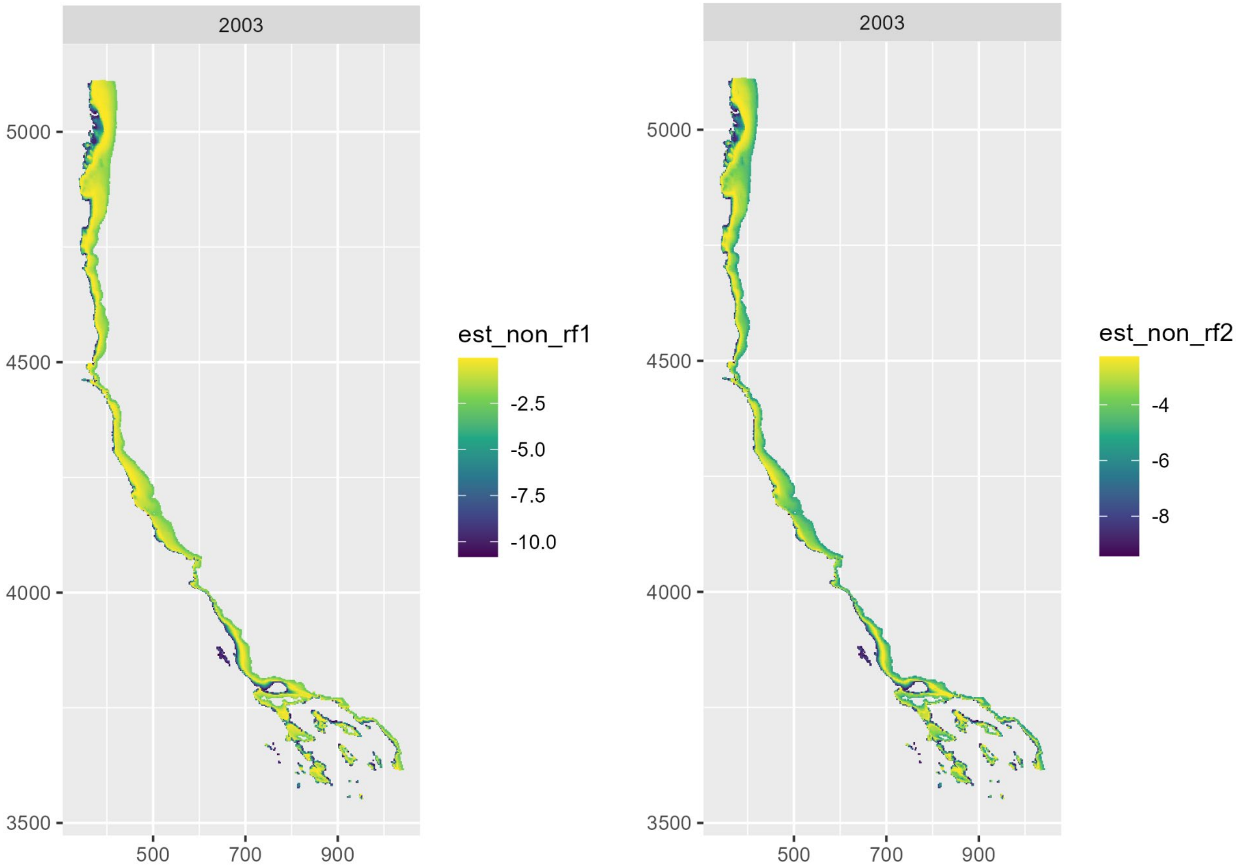


Figure 16F. Non-random fields for the binomial (left) and positive (right) components of the WCGBTS index model. The non-random field is shown for 2003, though the effect does not vary by year. Values are on the link scale.

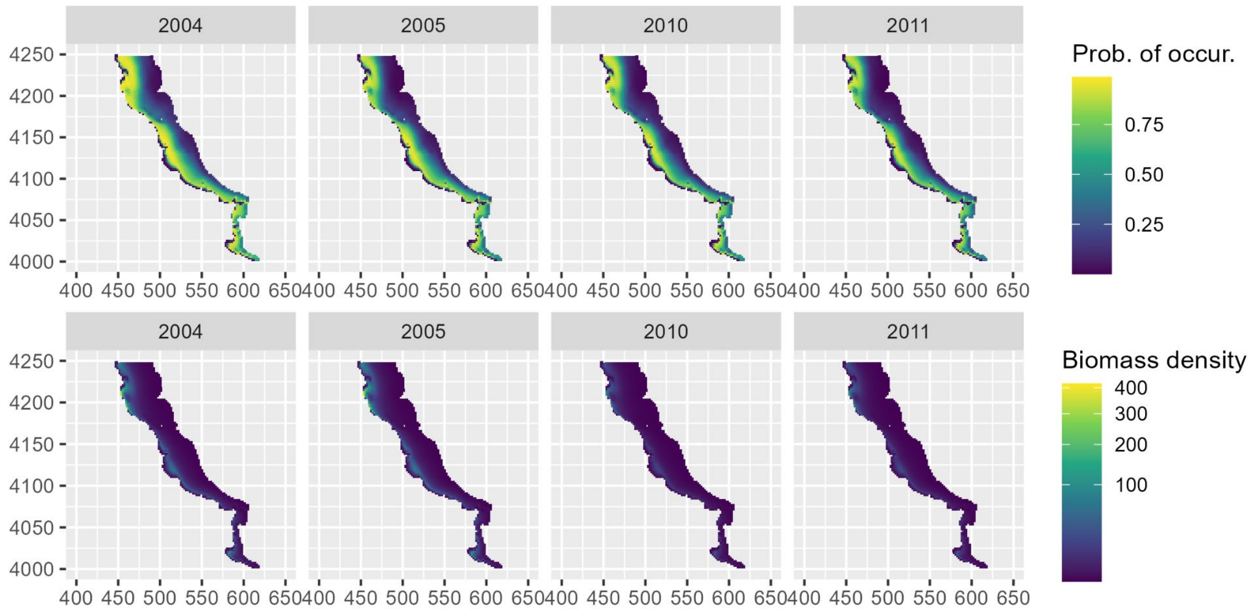


Figure 16G. Predictions from the WCGBTS index model for two 'high years' (i.e., 2004 and 2005) and two 'low years' (i.e., 2010 and 2011). The binomial (top) and positive (bottom) components are shown for central California only. Values are on the response scale.

16 - Panel Conclusion
The Panel appreciates this detailed investigation to identify differences in biomass density.

17 - Request
Run a model with asymptotic commercial and northern recreational selectivities, recruitment deviations with the sum-to-zero constraint, recruitment bias correction tuned, the WCGBTS index that includes a depth effect with assumed isotropy, including additive variance for the RREAS index (fixed to the value of sigma R such that total standard error across all years averages to 1.0), and estimated or fixed selectivity for the WCGBTS and Triennial survey determined by the STAT. Please tune this model, as it will be examined as a potential revised base model.

17 - Rationale
The STAT has provided many investigations, sensitivities, and responses to requests that support revising the pre-STAR base model as described in this request. Request 2 supported asymptotic commercial selectivity. Requests 4 and 11 support the sum-to-zero constraint on recruitment deviations. Request 12 identified the utility of including a depth effect for the WCGBTS spatiotemporal model. Request 10 supported additive variance estimates for the RREAS index. Request 13 examined different survey selectivities, which are pending as part of Request 15. The Panel encourages the STAT to provide their recommendations for survey selectivity.

17 - STAT Response
The STAT constructed a model with the previously mentioned asymptotic selectivity curves, a sum-to-zero constraint on recruitment deviations, steepness fixed at 0.72, a revised WCGBTS index, an additive variance parameter for the RREAS index that was fixed so total mean logSE = sigmaR (1.0), and trawl survey selectivities fixed at 1 for 9.5+ cm fish for the WCGBTS and fixed at 1 for age 1+ fish for the Triennial survey. The model was less stable than the pre-STAR base model, with multiple minima in the region of the best identified solution. Attempts to estimate the Hessian for the best available solution after tuning the composition data failed. In an effort to stabilize the model, the STAT examined the parameter standard errors from a previous run and identified two parameters with standard errors greater than the MLE: the ascending limb of

selectivity for the southern California hook-and-line fleet and the male offset for the CV of length at age 20 yr (Table 17A).

The STAT fixed the “CV_old_Mal_GP_1” parameter at 0.1, fixed the “Size_DblN_ascend_se_SoCA_HKL(2)” parameter at 1.2, and re-estimated and tuned the model. This change appeared to stabilize the model, as evidenced by rapid convergence of the Francis tuning algorithm, successful estimation of the Hessian, and use of the “-hess_step” option to minimize the final gradient. The tuned model was used for a “jitter” analysis of 100 runs with “jitter fraction” of 0.2. The jitter analysis did not find a smaller NLL value than the proposed base model and 97 of the 100 runs found the same solution (NLL = 2633.05). This is evidence (but not proof) that the optimizer has found a global solution. It also suggests that fixing the two parameters resolved issues with convergence. Given that the new model enforces a sum-to-zero constraint, it is unclear to the STAT if the use of MCMC diagnostics to further diagnose the issue is appropriate.

Reference points from the proposed base model suggest a less depleted but smaller stock than the pre-STAR base model (Table 17B and 17C). This is largely attributed to the change from unconstrained recruitment deviations to including the sum-to-zero constraint while fixing steepness at a value greater than the estimated value (as described in Request 11; Fig. 17A and Fig. 17B). Equilibrium sustainable yields under the proposed base model are similar to those estimated in the previous assessment (Field 2017). In that assessment, the yield based on an $SPR_{50\%}$ harvest rate and applied to the equilibrium biomass at that rate was 2042 mt, compared to 2114 mt in the proposed base model (Table 17B).

Despite having a smaller stock scale, the proposed base model estimates larger recruitments in recent years, which reflects increased influence of the RREAS index. The additive variance (“extraSD”) parameter in the proposed base model is fixed at 0.683, compared to 1.23 when freely estimated.

Likelihood profiles for the Beverton-Holt steepness parameter are provided (Fig. 17C, Fig. 17D, and Table 17D). Likelihood profiles for female natural mortality (*M*; Fig. 17E, Fig. 17F, and Table 17E) and log of unfished recruitment (log R_0) are also provided (Fig. 17G, Fig. 17H, and Table 17F). Note that steepness values ≤ 0.3 are inconsistent with the $F_{SPR=50\%}$ proxy harvest rate, as indicated by an equilibrium yield (“Dead_Catch_SPR”) of zero (Table 17D). When estimated in the proposed final base model, steepness is 0.383. Some likelihood components (e.g., several sources of age data and the WCBTS index) exhibit bi-modality.

The STAT was curious about how unconstrained recruitment deviations would affect likelihood profiles for *h* and/or *M*. A comparison of bivariate likelihood profiles for *h* and *M* from the pre-STAR base model and the proposed final base model is shown in Fig. 17I. The proposed final base model includes other changes, as noted above in Request 11, that result in recruitment deviation estimates that are more negative when steepness is fixed at 0.72. Without a sum-to-zero constraint on recruitment deviations, the model can maintain a similar fit across a wider range of steepness values.

Table 17A. Method used to identify potentially problematic parameters. Grey highlights represent parameters with standard errors greater than the maximum likelihood estimate.

Parameter	Value	Parm_StDev	Parm_StDev/Value
NatM_uniform_Fem_GP_1	0.166	0.012	0.07
L_at_Amax_Fem_GP_1	47.924	0.213	0.00
VonBert_K_Fem_GP_1	0.196	0.003	0.02
CV_young_Fem_GP_1	0.105	0.004	0.04
CV_old_Fem_GP_1	0.038	0.003	0.08
NatM_uniform_Mal_GP_1	0.251	0.044	0.18
L_at_Amax_Mal_GP_1	-0.325	0.009	-0.03
VonBert_K_Mal_GP_1	0.510	0.036	0.07
CV_young_Mal_GP_1	0.213	0.067	0.32
CV_old_Mal_GP_1	0.104	0.170	1.63
SR_LN(R0)	10.049	0.189	0.02
Q_extraSD_CalCOFI_Survey(11)	0.364	0.082	0.22
Size_DblN_peak_NoCA_HKL(1)	40.677	2.315	0.06
Size_DblN_ascend_se_NoCA_HKL(1)	4.382	0.324	0.07
Size_DblN_peak_SoCA_HKL(2)	23.828	2.504	0.11
Size_DblN_ascend_se_SoCA_HKL(2)	1.208	2.199	1.82
Size_DblN_peak_CA_TWL(3)	44.921	1.672	0.04
Size_DblN_ascend_se_CA_TWL(3)	4.556	0.208	0.05
Size_DblN_peak_OR_WA_Comm(4)	43.111	6.340	0.15
Size_DblN_ascend_se_OR_WA_Comm(4)	4.592	0.844	0.18
Size_DblN_peak_CA_NET(5)	46.829	1.756	0.04
Size_DblN_ascend_se_CA_NET(5)	4.422	0.220	0.05
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.810	2.473	0.06
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.138	0.231	0.05
Size_DblN_peak_SoCA_Rec(7)	24.768	1.023	0.04
Size_DblN_ascend_se_SoCA_Rec(7)	2.937	0.363	0.12
Size_DblN_descend_se_SoCA_Rec(7)	3.270	0.645	0.20
Size_DblN_end_logit_SoCA_Rec(7)	-1.107	0.303	-0.27
Size_DblN_peak_TWL_discard(8)	29.520	1.585	0.05
Size_DblN_ascend_se_TWL_discard(8)	4.153	0.376	0.09
Size_DblN_descend_se_TWL_discard(8)	3.201	0.600	0.19
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.733	5.167	0.10
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.163	0.616	0.15
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	48.483	4.369	0.09
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.811	0.436	0.09
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.658	1.255	0.04
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.268	0.352	0.11
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.798	2.075	0.07
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.767	0.464	0.12

Table 17B. Reference points from the proposed final base model.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output (billions of eggs)	11,922	10,006	13,839
Unfished Age 3+ Biomass (mt)	50,121	41,265	58,976
Unfished Recruitment (R0, 1000s)	22,734	14,697	30,770
Spawning Output (2025, billions of eggs)	9,925	6,263	13,587
Fraction Unfished (2025)	0.832	0.628	1.037
Reference Points Based SB40%			
Proxy Spawning Output SB40%	4,769	4,002	5,536
SPR Resulting in SB40%	0.458	0.458	0.458
Exploitation Rate Resulting in SB40%	0.089	0.080	0.098
Yield with SPR Based On SB40% (mt)	2,230	1,672	2,787
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Output (SPR50)	5,319	4,464	6,174
SPR50	0.5	--	--
Exploitation Rate Corresponding to SPR50	0.077	0.070	0.085
Yield with SPR50 at SB SPR (mt)	2,114	1,588	2,639
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY (SB MSY)	3,056	2,563	3,548
SPR MSY	0.329	0.323	0.334
Exploitation Rate Corresponding to SPR MSY	0.136	0.121	0.151
MSY (mt)	2,421	1,807	3,035

Table 17C. Likelihood components, parameter estimates, and derived quantities from the proposed final base model and the model with unconstrained recruitment deviations (and other changes, as noted above). Three parameters (outlined in black) were fixed in the proposed base model.

Label	proposed final base	STAR_base, asymptotic
N.Parms	106	109
TOTAL	2633.050	2621.330
Survey	29.272	24.307
Length_comp	569.289	572.015
Age_comp	2011.060	2000.480
Recruitment	23.397	24.425
Parm_priors	0.025	0.096
NatM_uniform_Fem_GP_1	0.165	0.177
L_at_Amax_Fem_GP_1	47.901	47.860
VonBert_K_Fem_GP_1	0.197	0.197
CV_young_Fem_GP_1	0.105	0.105
CV_old_Fem_GP_1	0.039	0.039
NatM_uniform_Mal_GP_1	0.266	0.241
L_at_Amax_Mal_GP_1	-0.328	-0.329
VonBert_K_Mal_GP_1	0.526	0.528
CV_young_Mal_GP_1	0.236	0.235
CV_old_Mal_GP_1	0.1	0.100
SR_LN(R0)	10.032	10.314
Q_extraSD_CalCOFI_Survey(11)	0.355	0.310
Q_extraSD_RREAS_YOY_Survey(12)	0.683	1.230
Size_DblN_peak_NoCA_HKL(1)	40.974	41.080
Size_DblN_ascend_se_NoCA_HKL(1)	4.399	4.405
Size_DblN_peak_SoCA_HKL(2)	23.799	23.788
Size_DblN_ascend_se_SoCA_HKL(2)	1.2	1.195
Size_DblN_peak_CA_TWL(3)	44.904	45.102
Size_DblN_ascend_se_CA_TWL(3)	4.556	4.563
Size_DblN_peak_OR_WA_Comm(4)	42.753	43.109
Size_DblN_ascend_se_OR_WA_Comm(4)	4.559	4.600
Size_DblN_peak_CA_NET(5)	46.991	46.979
Size_DblN_ascend_se_CA_NET(5)	4.426	4.420
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.894	44.110
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.136	5.145
Size_DblN_peak_SoCA_Rec(7)	24.708	24.731
Size_DblN_ascend_se_SoCA_Rec(7)	2.924	2.936
Size_DblN_descend_se_SoCA_Rec(7)	3.318	3.278
Size_DblN_end_logit_SoCA_Rec(7)	-1.112	-1.049
Size_DblN_peak_TWL_discard(8)	29.552	29.572
Size_DblN_ascend_se_TWL_discard(8)	4.167	4.181
Size_DblN_descend_se_TWL_discard(8)	3.193	3.194
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.604	51.396
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.157	4.141
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	48.830	48.776
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.824	4.814
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.792	33.920
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.290	3.315
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.678	30.648
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.752	3.742
Bratio_2025	0.832	0.587
SSB_unfished	11922	13702
Totbio_unfished	52043	61698
Recr_unfished	22734	30156
Dead_Catch_SPR	2114	2633
OFLCatch_2025	3617	3160

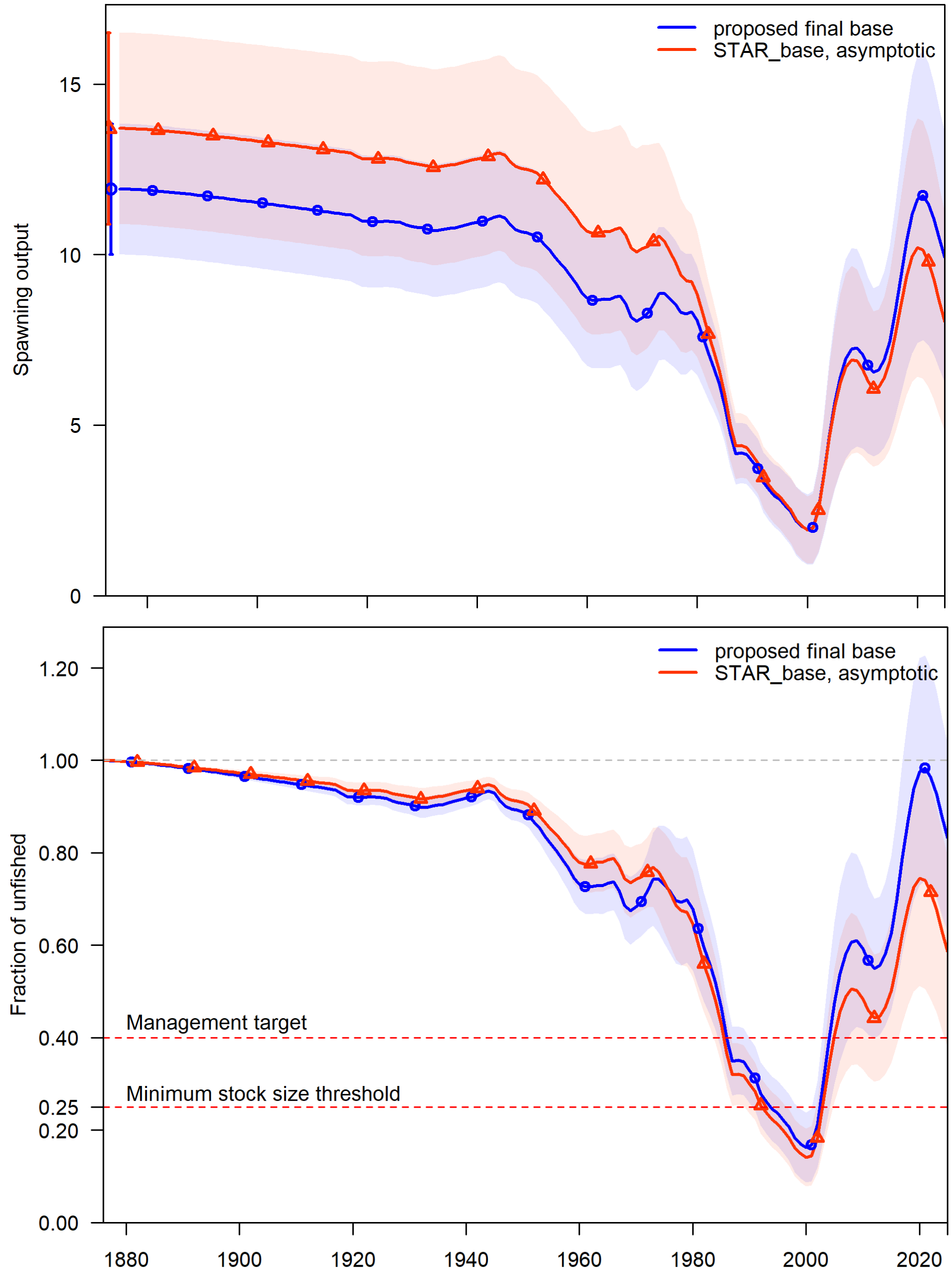


Figure 17A. Spawning output (top) and fraction unfished (bottom) from the model with unconstrained recruitment deviations (red) and the proposed final base model with sum-to-zero deviations and other changes as described in the request (blue). Shaded areas represent 95% asymptotic confidence intervals.

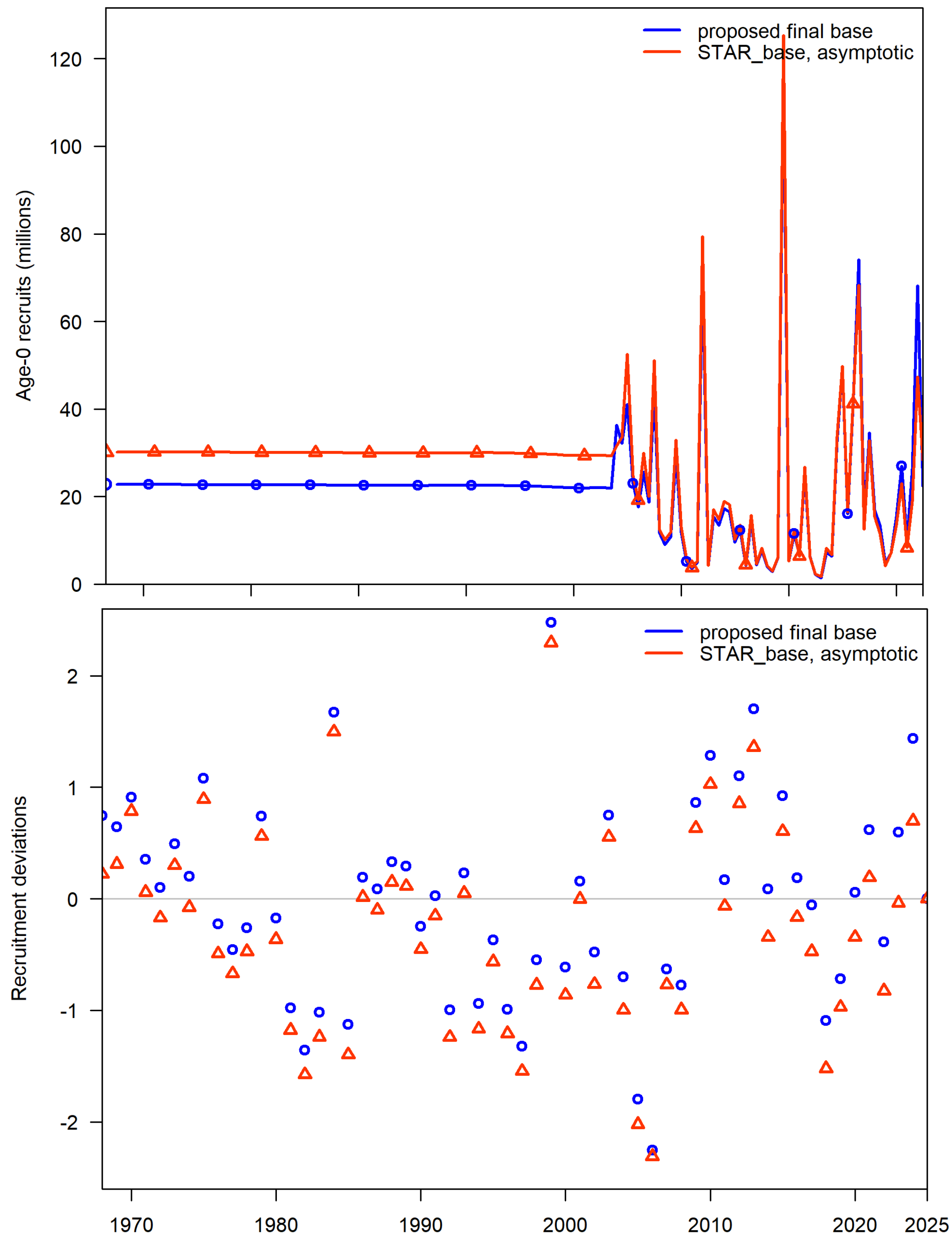


Figure 17B. Age-0 recruits (top) and recruitment deviations (bottom) from the model with unconstrained recruitment deviations (red) and the proposed final base model with a sum-to-zero constraint on recruitment deviations and other changes as described in the request (blue). Shaded areas represent 95% asymptotic confidence intervals.

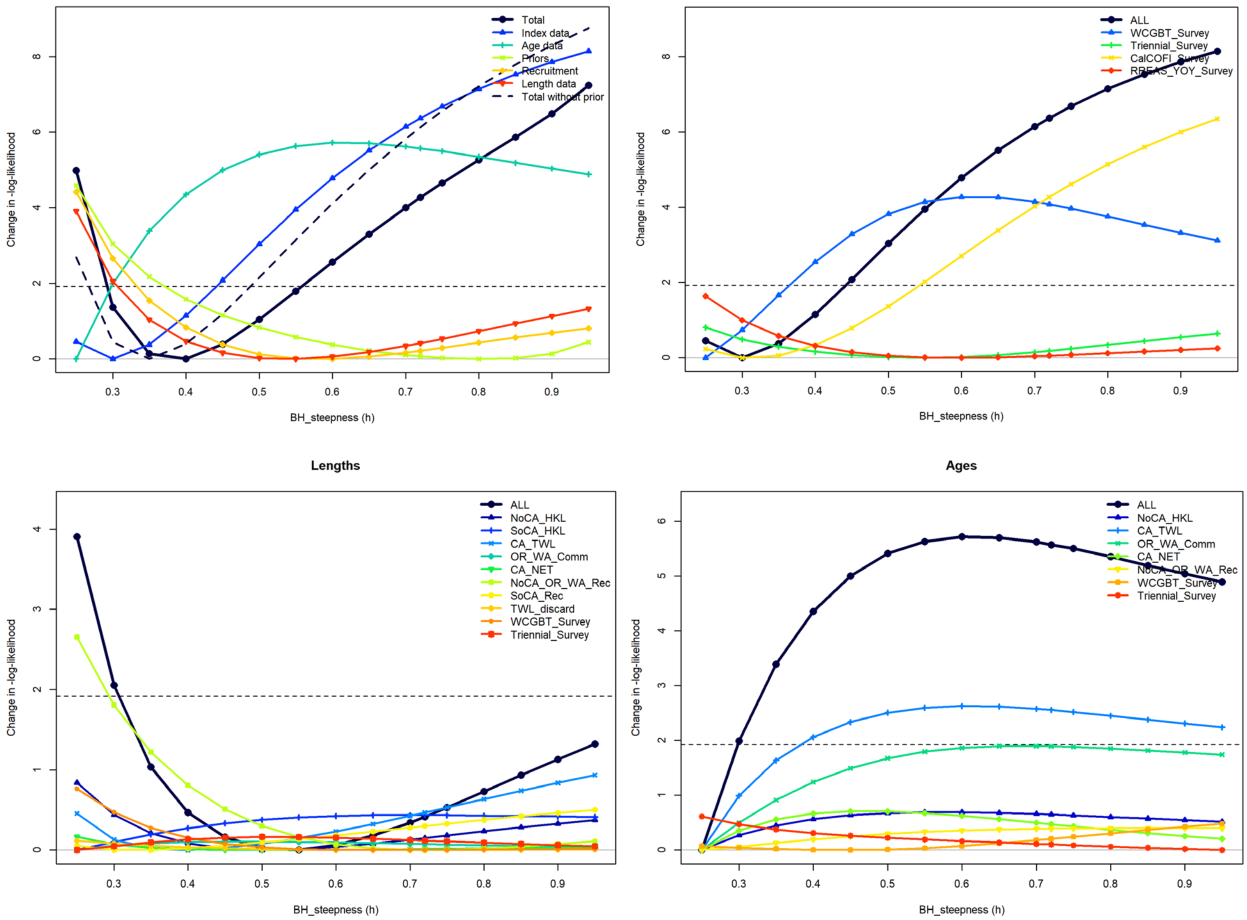


Figure 17C. Likelihood profiles over the Beverton-Holt steepness parameter organized by data type (top left), fleets with indices (top right), fleets with length composition data (bottom left), and fleets with age composition data (bottom left). Components or fleets that show little change over the range of parameter values were excluded.

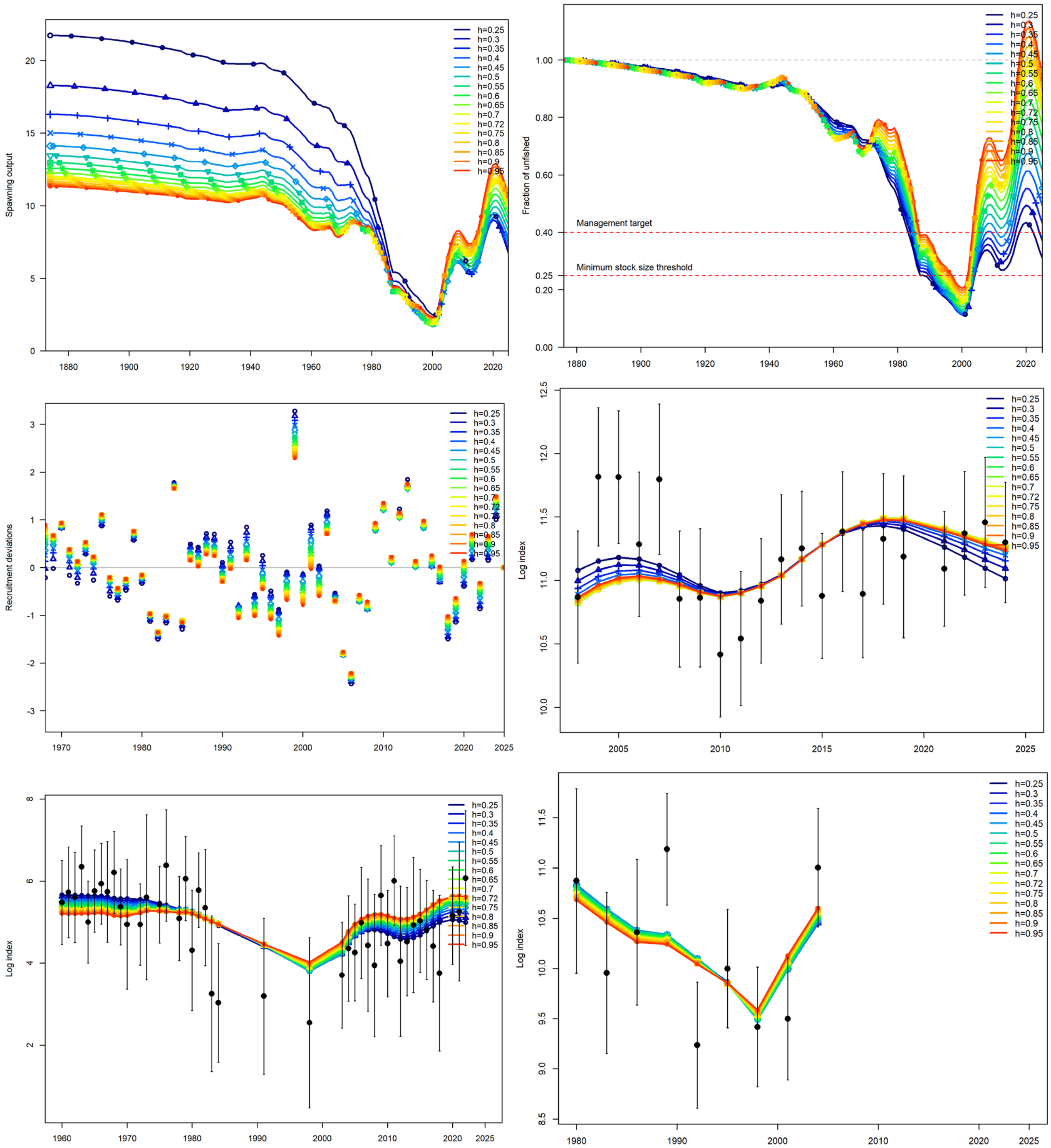


Figure 17D. Likelihood profiles for the Beverton-Holt steepness parameter (*h*). Spawning output (top left), fraction unfished (top right), recruitment deviations (middle left), log-scale fit to WCGBTS index (middle right), log-scale fit to CalCOFI index (bottom left), and log-scale fit to Triennial survey (bottom right) are shown.

Table 17D. Likelihood components, parameter values, and derived quantities from a likelihood profile for steepness.

Label	h=0.3	h=0.35	h=0.4	h=0.45	h=0.5	h=0.55	h=0.6	h=0.65	h=0.7	h=0.72	h=0.75	h=0.8	h=0.85	h=0.9	h=0.95
N.Parms	106	106	106	106	106	106	106	106	106	106	106	106	106	106	106
TOTAL	2630.15	2628.92	2628.78	2629.17	2629.82	2630.57	2631.34	2632.08	2632.78	2633.05	2633.44	2634.05	2634.65	2635.27	2636.02
Survey	22.901	23.276	24.048	24.979	25.939	26.852	27.683	28.414	29.046	29.272	29.585	30.043	30.431	30.762	31.046
Length_comp	570.928	569.911	569.343	569.037	568.899	568.875	568.935	569.055	569.216	569.289	569.403	569.603	569.807	570.007	570.199
Age_comp	2007.48	2008.88	2009.84	2010.49	2010.90	2011.12	2011.21	2011.19	2011.11	2011.06	2010.99	2010.84	2010.68	2010.53	2010.38
Recruitment	25.838	24.725	24.010	23.561	23.306	23.192	23.182	23.243	23.348	23.398	23.476	23.612	23.745	23.872	23.989
Parm_priors	3.000	2.125	1.536	1.108	0.782	0.528	0.328	0.174	0.059	0.025	-0.015	-0.046	-0.022	0.090	0.398
NatM_uniform_Fem_GP_1	0.189	0.180	0.174	0.169	0.166	0.165	0.164	0.164	0.165	0.165	0.166	0.167	0.168	0.169	0.170
L_at_Amax_Fem_GP_1	47.859	47.865	47.872	47.878	47.884	47.889	47.893	47.897	47.900	47.901	47.902	47.904	47.906	47.908	47.909
VonBert_K_Fem_GP_1	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197	0.197
CV_young_Fem_GP_1	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
CV_old_Fem_GP_1	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
NatM_uniform_Mal_GP_1	0.217	0.235	0.248	0.258	0.264	0.268	0.269	0.268	0.267	0.266	0.264	0.262	0.259	0.256	0.254
L_at_Amax_Mal_GP_1	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328	-0.328
VonBert_K_Mal_GP_1	0.526	0.526	0.527	0.527	0.527	0.527	0.527	0.527	0.526	0.526	0.526	0.526	0.526	0.526	0.526
CV_young_Mal_GP_1	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.236	0.236	0.236	0.236	0.235	0.235	0.235	0.235
SR_LN(R0)	10.751	10.528	10.366	10.249	10.166	10.108	10.070	10.047	10.034	10.032	10.029	10.029	10.032	10.037	10.042
SR_BH_steep	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.72	0.75	0.8	0.85	0.9	0.95
Q_extraSD_CalCOFI_Survey(11)	0.289	0.289	0.293	0.299	0.308	0.318	0.329	0.340	0.351	0.355	0.361	0.370	0.378	0.385	0.391
Size_DblN_peak_NoCA_HKL(1)	40.929	41.079	41.146	41.168	41.160	41.133	41.094	41.047	40.995	40.974	40.942	40.889	40.839	40.791	40.747
Size_DblN_ascend_se_NoCA_HKL(1)	4.387	4.407	4.417	4.421	4.421	4.419	4.414	4.408	4.402	4.399	4.395	4.389	4.382	4.377	4.371
Size_DblN_peak_SoCA_HKL(2)	23.864	23.843	23.827	23.816	23.808	23.803	23.800	23.799	23.799	23.799	23.800	23.802	23.803	23.805	23.807
Size_DblN_peak_CA_TWL(3)	45.343	45.258	45.178	45.107	45.048	45.000	44.962	44.933	44.911	44.904	44.896	44.884	44.875	44.869	44.864
Size_DblN_ascend_se_CA_TWL(3)	4.573	4.572	4.569	4.567	4.564	4.562	4.560	4.558	4.557	4.556	4.556	4.555	4.555	4.554	4.554
Size_DblN_peak_OR_WA_Comm(4)	44.496	43.912	43.460	43.206	43.018	42.890	42.811	42.768	42.753	42.752	42.757	42.772	42.794	42.820	42.846
Size_DblN_ascend_se_OR_WA_Comm(4)	4.721	4.668	4.625	4.602	4.585	4.573	4.566	4.561	4.560	4.559	4.560	4.561	4.563	4.565	4.567
Size_DblN_peak_CA_NET(5)	46.849	46.953	47.009	47.038	47.048	47.045	47.034	47.018	46.999	46.991	46.978	46.958	46.937	46.918	46.900
Size_DblN_ascend_se_CA_NET(5)	4.410	4.419	4.424	4.427	4.428	4.429	4.428	4.427	4.426	4.426	4.425	4.423	4.422	4.421	4.419
Size_DblN_peak_NoCA_OR_WA_Rec(6)	44.318	44.294	44.233	44.164	44.097	44.037	43.986	43.943	43.907	43.894	43.877	43.852	43.832	43.814	43.798
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.150	5.154	5.154	5.152	5.150	5.147	5.143	5.140	5.137	5.136	5.135	5.132	5.130	5.128	5.126
Size_DblN_peak_SoCA_Rec(7)	24.799	24.773	24.753	24.737	24.725	24.717	24.711	24.709	24.708	24.708	24.708	24.710	24.711	24.713	24.715
Size_DblN_ascend_se_SoCA_Rec(7)	2.940	2.936	2.932	2.930	2.927	2.926	2.925	2.924	2.924	2.924	2.924	2.924	2.924	2.924	2.924
Size_DblN_descend_se_SoCA_Rec(7)	3.237	3.259	3.277	3.291	3.301	3.309	3.314	3.317	3.318	3.318	3.318	3.318	3.317	3.316	3.315
Size_DblN_end_logit_SoCA_Rec(7)	-1.006	-1.035	-1.060	-1.078	-1.092	-1.101	-1.107	-1.110	-1.112	-1.112	-1.112	-1.111	-1.110	-1.108	-1.107
Size_DblN_peak_TWL_discard(8)	29.679	29.645	29.617	29.595	29.579	29.567	29.559	29.555	29.553	29.552	29.552	29.553	29.554	29.556	29.558
Size_DblN_ascend_se_TWL_discard(8)	4.172	4.172	4.171	4.170	4.170	4.169	4.168	4.168	4.167	4.167	4.167	4.166	4.166	4.166	4.165
Size_DblN_descend_se_TWL_discard(8)	3.175	3.179	3.183	3.186	3.188	3.190	3.192	3.192	3.193	3.193	3.193	3.193	3.193	3.193	3.193
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.074	51.188	51.277	51.349	51.409	51.461	51.507	51.551	51.590	51.605	51.623	51.649	51.671	51.688	51.702
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.116	4.125	4.132	4.137	4.142	4.146	4.149	4.153	4.156	4.157	4.158	4.160	4.162	4.163	4.164
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	48.511	48.723	48.843	48.906	48.932	48.931	48.913	48.882	48.845	48.830	48.805	48.764	48.723	48.684	48.648
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.794	4.811	4.821	4.827	4.830	4.831	4.830	4.828	4.825	4.824	4.823	4.820	4.817	4.814	4.811
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.900	33.890	33.868	33.846	33.828	33.814	33.805	33.798	33.793	33.791	33.789	33.786	33.783	33.780	33.777
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.306	3.308	3.306	3.303	3.300	3.297	3.295	3.292	3.291	3.290	3.289	3.287	3.285	3.284	3.282
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.598	30.600	30.600	30.604	30.611	30.622	30.636	30.653	30.671	30.678	30.689	30.706	30.723	30.738	30.752
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.728	3.733	3.736	3.738	3.741	3.743	3.746	3.748	3.751	3.752	3.753	3.755	3.757	3.759	3.761
Bratio_2025	0.371	0.432	0.493	0.555	0.615	0.672	0.726	0.774	0.817	0.832	0.854	0.885	0.912	0.934	0.952
SSB_unfished	18271	16285	15002	14108	13453	12953	12563	12254	12007	11922	11809	11649	11521	11417	11332
Totbio_unfished	84990	73957	66957	62221	58881	56460	54678	53353	52365	52044	51627	51076	50663	50353	50121
Recr_unfished	46656	37329	31756	28249	25990	24536	23625	23084	22797	22734	22681	22675	22740	22847	22979
Dead_Catch_SPR	0	479	1266	1614	1796	1905	1981	2042	2094	2114	2142	2186	2226	2265	2300
OFLCatch_2025	2929	2865	2883	2953	3056	3178	3309	3442	3568	3617	3686	3792	3887	3971	4045

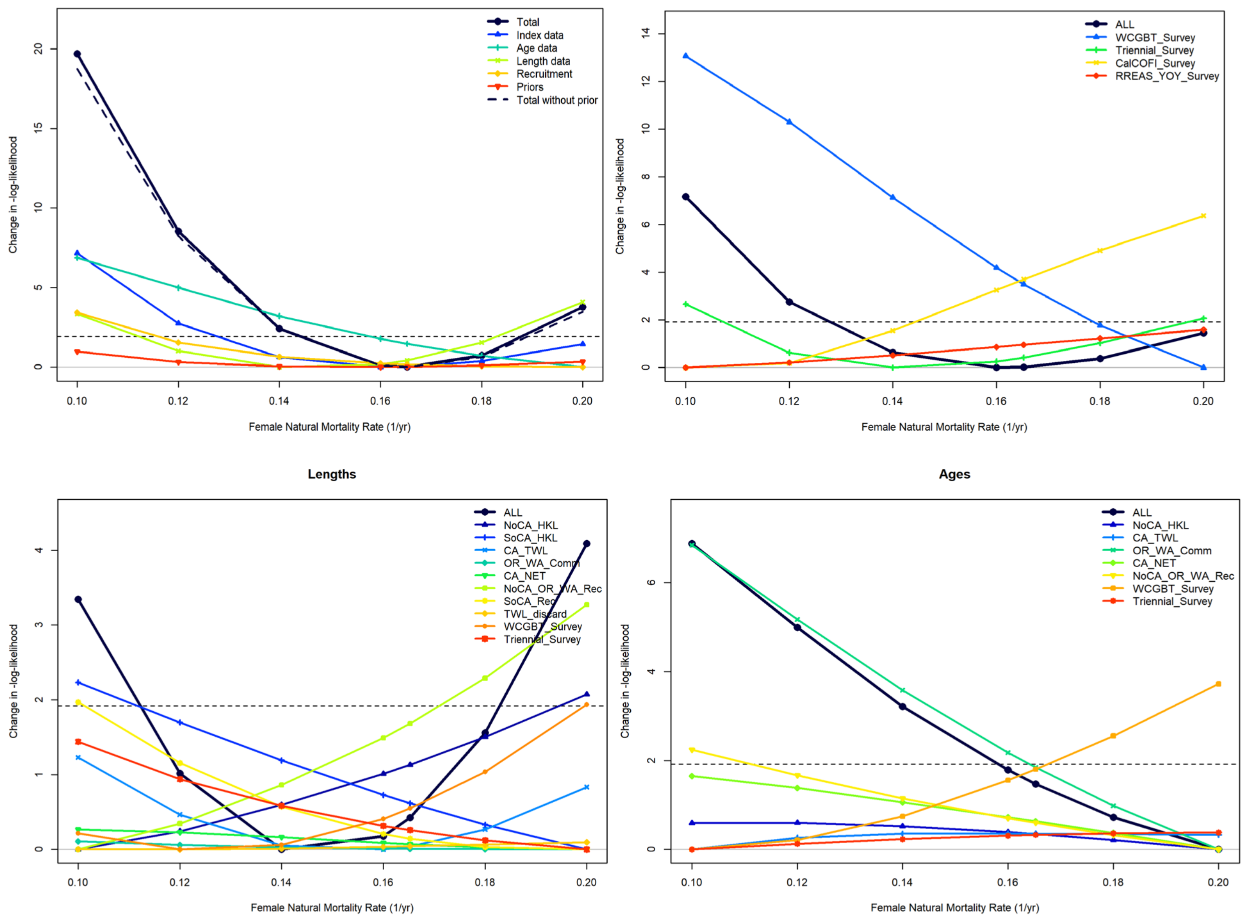


Figure 17E. Likelihood profiles over the female natural mortality (*M*) parameter organized by data type (top left), fleets with indices (top right), fleets with length composition data (bottom left), and fleets with age composition data (bottom left). Components or fleets that show little change over the range of parameter values were excluded.

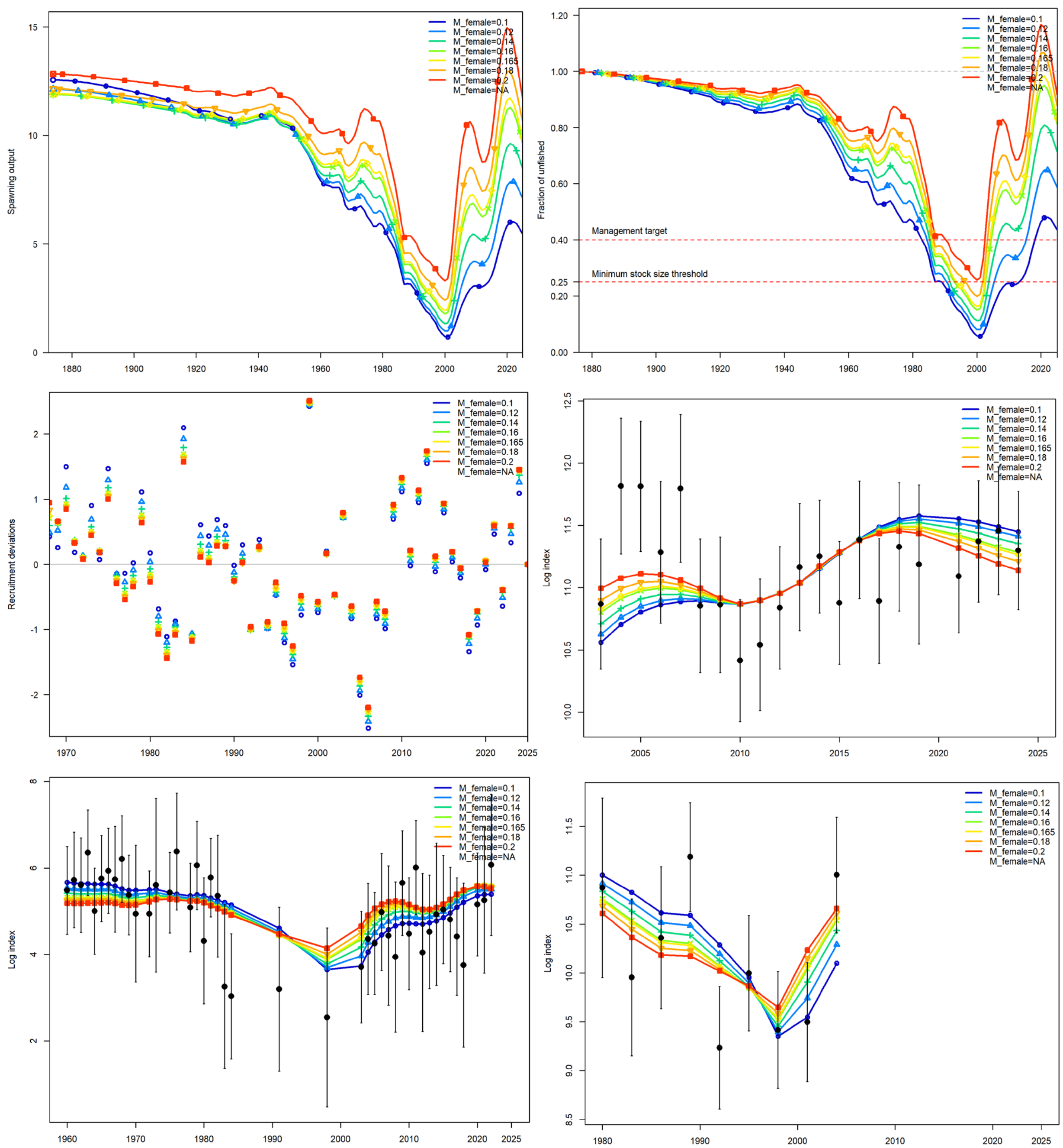


Figure 17F. Likelihood profiles for the female natural mortality (*M*) parameter. Spawning output (top left), fraction unfished (top right), recruitment deviations (middle left), log-scale fit to WCGBTS index (middle right), log-scale fit to CalCOFI index (bottom left), and log-scale fit to Triennial survey (bottom right) are shown.

Table 17E. Likelihood components, parameter values, and derived quantities from a likelihood profile over female natural mortality (*M*). *M* = 0.165 for the proposed base model.

Label	M_female=0.1	M_female=0.12	M_female=0.14	M_female=0.16	M_female=0.165	M_female=0.18	M_female=0.2
N.Parms	106	106	106	106	106	106	106
TOTAL	2652.75	2641.59	2635.48	2633.15	2633.05	2633.78	2636.84
Survey	36.425	32.014	29.893	29.257	29.272	29.631	30.717
Length_comp	572.210	569.880	568.864	569.040	569.289	570.424	572.955
Age_comp	2016.47	2014.58	2012.80	2011.38	2011.06	2010.31	2009.59
Recruitment	26.663	24.790	23.879	23.460	23.398	23.288	23.232
Parm_priors	0.978	0.329	0.049	0.007	0.025	0.124	0.350
NatM_uniform_Fem_GP_1	0.100	0.120	0.140	0.160	0.165	0.180	0.200
L_at_Amax_Fem_GP_1	47.861	47.884	47.896	47.900	47.901	47.901	47.899
VonBert_K_Fem_GP_1	0.199	0.198	0.198	0.197	0.197	0.197	0.196
CV_young_Fem_GP_1	0.106	0.105	0.105	0.105	0.105	0.105	0.105
CV_old_Fem_GP_1	0.038	0.038	0.038	0.039	0.039	0.039	0.039
NatM_uniform_Mal_GP_1	0.516	0.418	0.342	0.280	0.266	0.228	0.184
L_at_Amax_Mal_GP_1	-0.323	-0.325	-0.327	-0.328	-0.328	-0.329	-0.330
VonBert_K_Mal_GP_1	0.522	0.523	0.525	0.526	0.526	0.527	0.528
CV_young_Mal_GP_1	0.238	0.238	0.238	0.236	0.236	0.235	0.234
SR_LN(R0)	9.125	9.419	9.693	9.961	10.032	10.232	10.518
Q_extraSD_CalCOFI_Survey(11)	0.292	0.296	0.319	0.347	0.355	0.376	0.402
Size_DblN_peak_NoCA_HKL(1)	40.325	40.624	40.817	40.950	40.974	41.019	41.033
Size_DblN_ascend_se_NoCA_HKL(1)	4.393	4.405	4.406	4.401	4.399	4.391	4.377
Size_DblN_peak_SoCA_HKL(2)	23.594	23.656	23.719	23.783	23.799	23.845	23.907
Size_DblN_peak_CA_TWL(3)	44.168	44.339	44.577	44.833	44.904	45.114	45.411
Size_DblN_ascend_se_CA_TWL(3)	4.575	4.562	4.558	4.556	4.556	4.558	4.561
Size_DblN_peak_OR_WA_Comm(4)	40.435	40.979	41.658	42.481	42.753	43.558	45.263
Size_DblN_ascend_se_OR_WA_Comm(4)	4.392	4.425	4.473	4.537	4.559	4.625	4.773
Size_DblN_peak_CA_NET(5)	47.112	47.073	47.034	47.001	46.991	46.960	46.906
Size_DblN_ascend_se_CA_NET(5)	4.476	4.459	4.443	4.429	4.426	4.416	4.402
Size_DblN_peak_NoCA_OR_WA_Rec(6)	42.067	42.702	43.254	43.769	43.894	44.244	44.678
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.088	5.109	5.123	5.134	5.136	5.142	5.147
Size_DblN_peak_SoCA_Rec(7)	24.340	24.461	24.576	24.681	24.708	24.783	24.880
Size_DblN_ascend_se_SoCA_Rec(7)	2.850	2.876	2.899	2.919	2.924	2.938	2.955
Size_DblN_descend_se_SoCA_Rec(7)	3.529	3.473	3.409	3.338	3.318	3.261	3.182
Size_DblN_end_logit_SoCA_Rec(7)	-1.540	-1.407	-1.275	-1.145	-1.112	-1.019	-0.894
Size_DblN_peak_TWL_discard(8)	29.102	29.238	29.379	29.515	29.552	29.659	29.801
Size_DblN_ascend_se_TWL_discard(8)	4.151	4.155	4.160	4.165	4.167	4.171	4.177
Size_DblN_descend_se_TWL_discard(8)	3.233	3.223	3.210	3.197	3.193	3.181	3.164
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.277	51.321	51.428	51.564	51.604	51.709	51.830
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.148	4.147	4.151	4.155	4.157	4.160	4.163
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	48.716	48.767	48.796	48.825	48.829	48.832	48.812
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.869	4.854	4.840	4.827	4.824	4.815	4.801
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.110	33.300	33.473	33.727	33.792	33.962	34.168
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.169	3.202	3.229	3.278	3.290	3.319	3.352
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.057	30.210	30.393	30.612	30.678	30.871	31.152
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.684	3.699	3.719	3.744	3.752	3.775	3.809
Bratio_2025	0.435	0.587	0.715	0.812	0.832	0.878	0.916
SSB_unfished	12550	12131	11895	11883	11922	12150	12825
Totbio_unfished	45401	46545	48345	51111	52044	55274	61682
Recr_unfished	9184	12317	16210	21189	22734	27781	36982
Dead_Catch_SPR	1263	1486	1734	2026	2114	2392	2885
OFLCatch_2025	1180	1831	2567	3385	3617	4317	5457

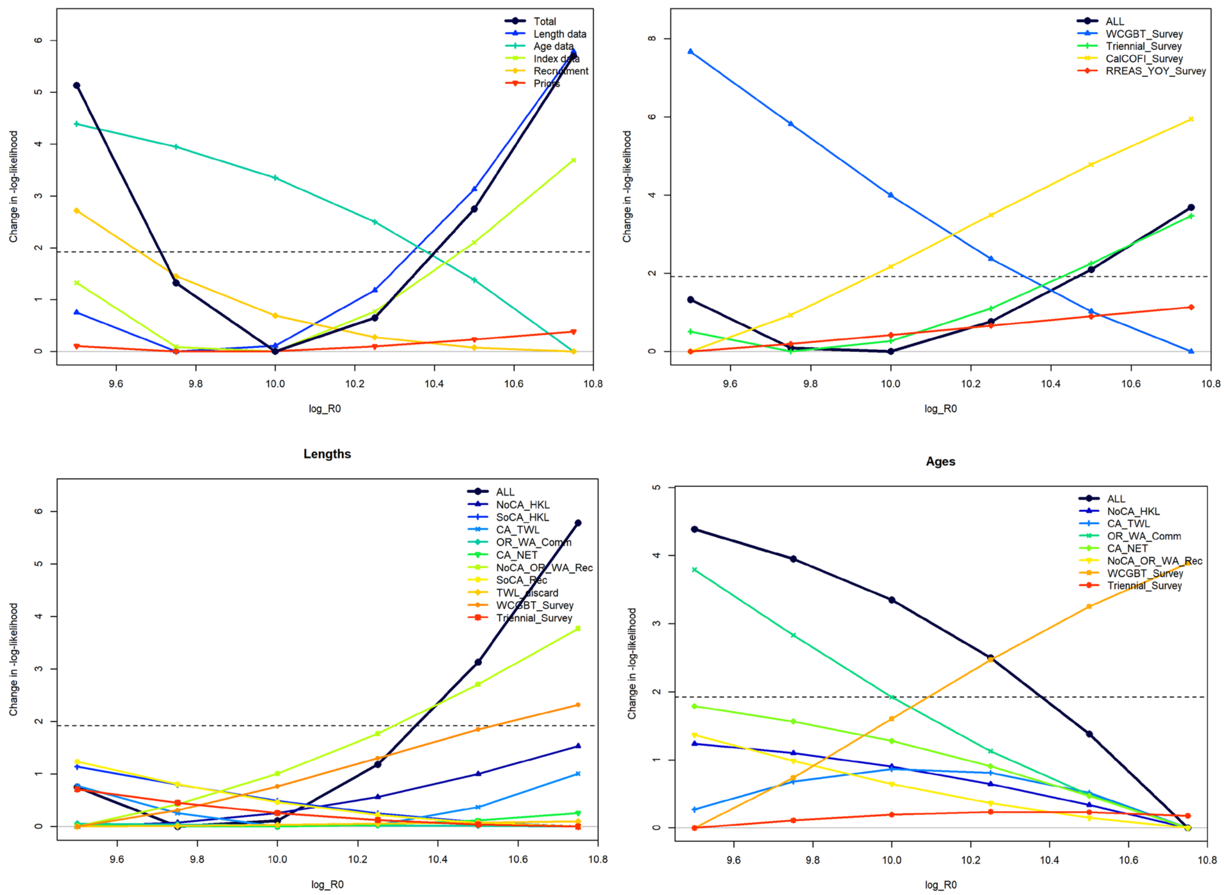


Figure 17G. Likelihood profiles over the log of unfished recruitment (log R_0) parameter organized by data type (top left), fleets with indices (top right), fleets with length composition data (bottom left), and fleets with age composition data (bottom left). Components or fleets that show little change over the range of parameter values were excluded.

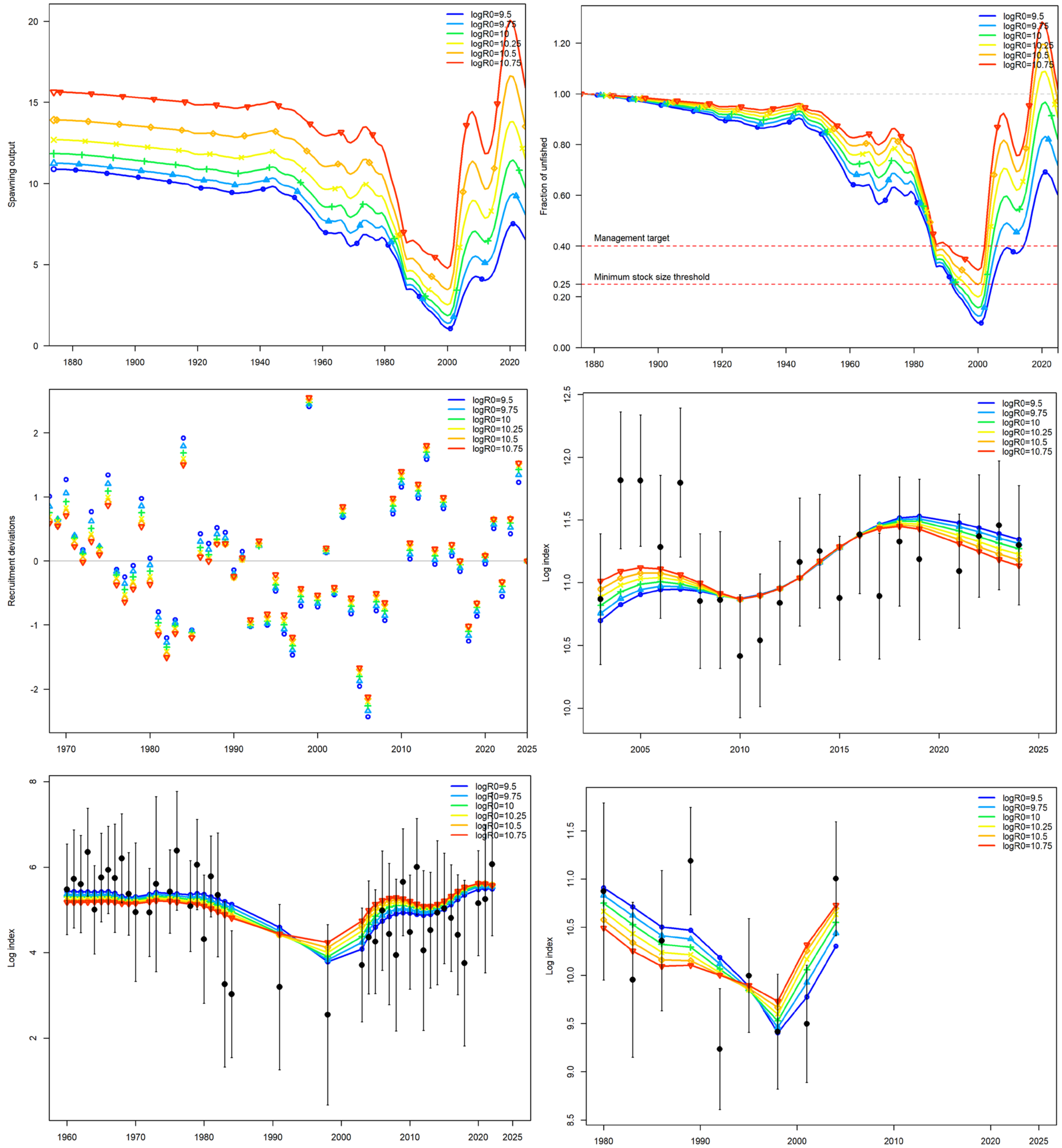


Figure 17H. Likelihood profiles for the log of unfished recruitment (log R_0) parameter. Spawning output (top left), fraction unfished (top right), recruitment deviations (middle left), log-scale fit to WCGBTS index (middle right), log-scale fit to CalCOFI index (bottom left), and log-scale fit to Triennial survey (bottom right) are shown.

Table 17F. Likelihood components, parameter values, and derived quantities from a likelihood profile over log R_0.

Label	logR0=9.5	logR0=9.75	logR0=10	logR0=10.25	logR0=10.5	logR0=10.75
N.Parms	106	106	106	106	106	106
TOTAL	2638.20	2634.39	2633.07	2633.72	2635.82	2638.77
Survey	30.541	29.307	29.216	29.986	31.318	32.907
Length_comp	569.843	569.091	569.205	570.272	572.219	574.874
Age_comp	2012.20	2011.76	2011.16	2010.31	2009.19	2007.81
Recruitment	25.490	24.226	23.466	23.050	22.851	22.773
Parm_priors	0.116	0.008	0.017	0.105	0.240	0.393
NatM_uniform_Fem_GP_1	0.133	0.148	0.163	0.178	0.191	0.203
L_at_Amax_Fem_GP_1	47.912	47.907	47.901	47.898	47.898	47.901
VonBert_K_Fem_GP_1	0.198	0.197	0.197	0.197	0.196	0.196
CV_young_Fem_GP_1	0.106	0.105	0.105	0.105	0.105	0.105
CV_old_Fem_GP_1	0.038	0.038	0.039	0.039	0.039	0.039
NatM_uniform_Mal_GP_1	0.362	0.313	0.271	0.235	0.206	0.182
L_at_Amax_Mal_GP_1	-0.326	-0.327	-0.328	-0.329	-0.329	-0.329
VonBert_K_Mal_GP_1	0.526	0.526	0.526	0.526	0.525	0.524
CV_young_Mal_GP_1	0.236	0.236	0.236	0.236	0.236	0.236
SR_LN(R0)	9.500	9.750	10.000	10.250	10.500	10.750
Q_extraSD_CalCOFI_Survey(11)	0.312	0.330	0.352	0.376	0.399	0.420
Size_DblN_peak_NoCA_HKL(1)	40.926	40.991	40.982	40.862	40.626	40.290
Size_DblN_ascend_se_NoCA_HKL(1)	4.430	4.419	4.402	4.375	4.337	4.292
Size_DblN_peak_SoCA_HKL(2)	23.695	23.744	23.793	23.839	23.879	23.912
Size_DblN_peak_CA_TWL(3)	44.611	44.736	44.885	45.036	45.169	45.266
Size_DblN_ascend_se_CA_TWL(3)	4.569	4.561	4.557	4.555	4.554	4.554
Size_DblN_peak_OR_WA_Comm(4)	41.566	42.074	42.664	43.362	44.190	45.115
Size_DblN_ascend_se_OR_WA_Comm(4)	4.474	4.509	4.552	4.608	4.679	4.759
Size_DblN_peak_CA_NET(5)	47.167	47.095	47.005	46.880	46.715	46.514
Size_DblN_ascend_se_CA_NET(5)	4.456	4.442	4.428	4.412	4.397	4.381
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.343	43.624	43.867	44.046	44.131	44.102
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.143	5.141	5.137	5.130	5.120	5.106
Size_DblN_peak_SoCA_Rec(7)	24.543	24.621	24.698	24.772	24.836	24.889
Size_DblN_ascend_se_SoCA_Rec(7)	2.894	2.908	2.922	2.935	2.946	2.955
Size_DblN_descend_se_SoCA_Rec(7)	3.407	3.369	3.324	3.277	3.234	3.199
Size_DblN_end_logit_SoCA_Rec(7)	-1.322	-1.222	-1.124	-1.034	-0.957	-0.898
Size_DblN_peak_TWL_discard(8)	29.300	29.421	29.537	29.651	29.747	29.822
Size_DblN_ascend_se_TWL_discard(8)	4.156	4.161	4.166	4.171	4.174	4.176
Size_DblN_descend_se_TWL_discard(8)	3.220	3.208	3.195	3.180	3.167	3.156
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.846	51.722	51.617	51.509	51.403	51.283
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.183	4.170	4.158	4.147	4.137	4.128
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	49.115	48.999	48.853	48.637	48.389	48.128
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.869	4.848	4.827	4.803	4.780	4.761
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.381	33.556	33.770	33.911	33.975	33.957
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.213	3.244	3.286	3.309	3.314	3.302
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.446	30.547	30.663	30.776	30.877	30.952
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.730	3.739	3.750	3.761	3.770	3.774
Bratio_2025	0.601	0.717	0.821	0.906	0.972	1.017
SSB_unfished	10867	11247	11831	12688	13909	15634
Totbio_unfished	43340	46831	51376	57344	65206	75658
Recr_unfished	13360	17154	22027	28283	36316	46630
Dead_Catch_SPR	1494	1753	2069	2460	2952	3581
OFLCatch_2025	1876	2600	3491	4573	5877	7448

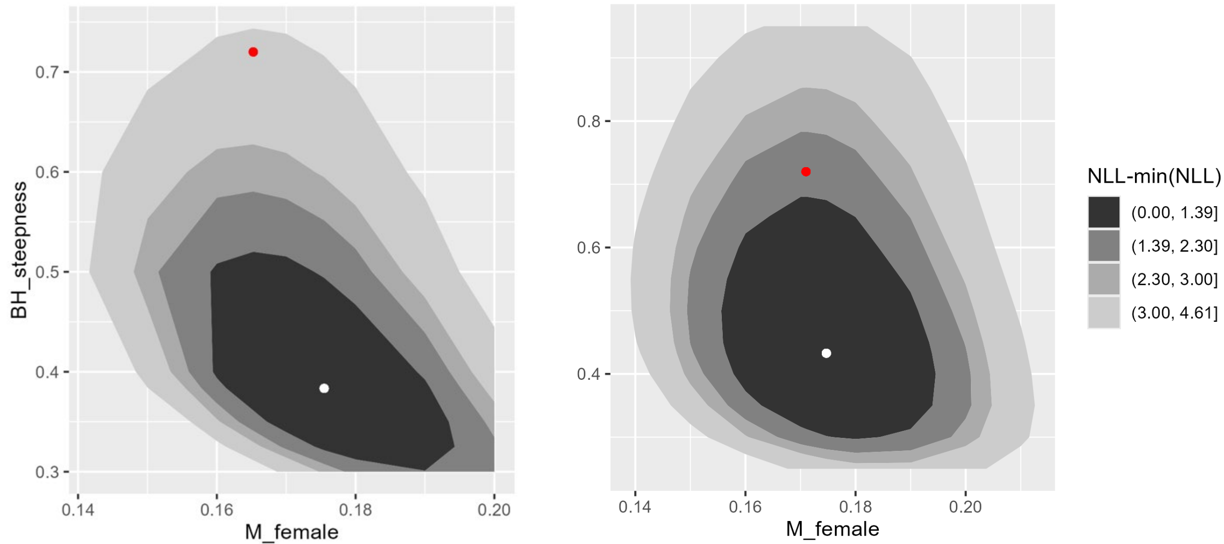


Figure 17l. Bivariate likelihood profiles for Beverton-Holt steepness (*h*) and female natural mortality (*M*) from the proposed base model (left) with a sum-to-zero constraint on recruitment deviations and the pre-STAR base model with unconstrained recruitment deviations (right). White points indicate the minimum NLL and red points indicate the base model for each model run. Contours represent 75%, 90%, 95%, and 99% bivariate confidence regions.

17 - Panel Conclusion

These results are informative and there are no concerns for the proposed final base model. The Panel noted that steepness values changed equilibrium values but also had an effect (although relatively small) on the recent spawning output, whereas the range of natural mortality values mostly affected recent spawning output (and thus OFL). The likelihood for steepness was useful to inform low and high states of nature for decision tables, along with additional sources of uncertainty (see Request 18).

18 - Request

Provide a decision table using steepness (*h*) as the primary axis of uncertainty (low *h* = 0.38, high *h* = 0.97), with the decision table based on the catch time series reflecting full attainment (=ACL) as required by the TOR and alternative catch projections based on constant catch at the MSY proxy yield (2114 t) to bracket the range of catch alternatives in the decision table. If possible, plot spawning output, fraction unfished, age 3+ biomass (t), and relative fishing intensity (1-SPR)/(1-SPR_50%) with management reference points (where appropriate). Please provide this in the post-STAR assessment document and to the STAR Panel, if possible, for inclusion in the STAR Panel report. These outputs are necessary to satisfy the Terms of Reference.

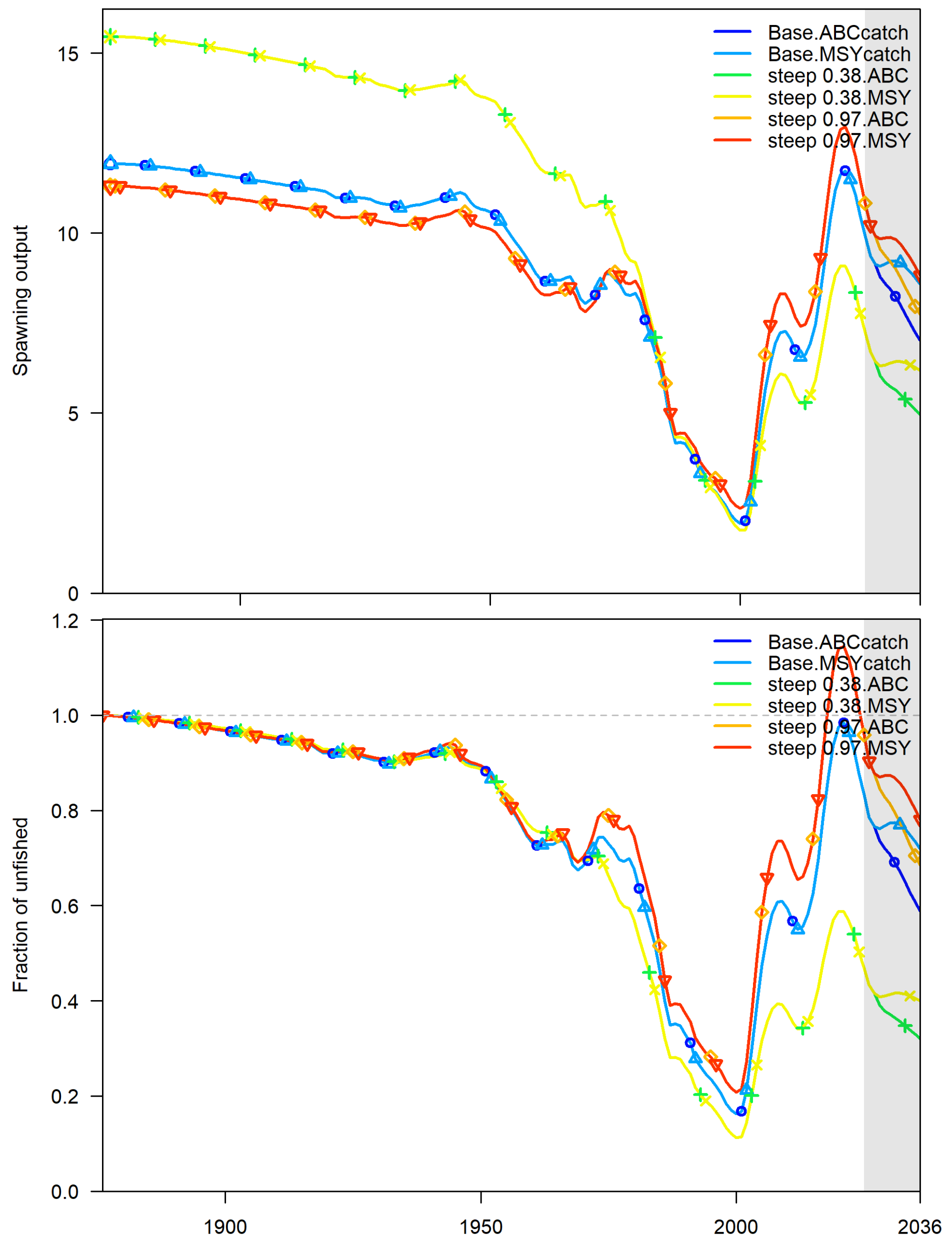
18 - Rationale

A few possible options for the axis of uncertainty were considered. However, it quickly became clear that the most appropriate axis of uncertainty was the Beverton-Holt steepness parameter (*h*). The low value of *h* (0.38) was based on the model estimate of steepness and the high value of *h* (0.97) was based on an estimate from Beyer et al. (in prep).

18 - STAT Response

Runs with the three states of nature were conducted: the proposed final base model with a fixed steepness of 0.72, a high state of nature with steepness 0.97, and a low state of nature with steepness 0.38. The two catch streams used were the equilibrium MSY estimate from the base model (2114 t) and the ABC catch stream from the base model (in which 2027 ABC is 3211 t and the 2036 ABC is 2431 t). Catch apportionments were identical to those used for the 2025-

2026 forecasts. Estimated stock trajectories are shown as Fig. 18A. For all projections, spawning output and depletion estimates decline over the course of the 12 year projection (2025-2036). Declines accelerated in the ABC catch streams relative to the equilibrium MSY catch streams for each state of nature. The models that assume high steepness start closer to the estimated unfished level (approximately 95% of the unfished level in 2025) and decline less rapidly than the base model and models with low steepness. The only scenario where spawning output declines below target levels is the low steepness model combined with ABC catches, which suggests that depletion could decline to approximately 32% by 2036.



Figures 18A. Model estimates and 2025-2036 projections for: a) the base model (*h* = 0.72), b) high state of nature (*h* = 0.97), and c) low state of nature (*h* = 0.38). Equilibrium MSY (2114 t) and the ABC catch stream (ABC_{2027} = 3211 t and ABC_{2036} = 2431 t) from the base model represent the basis for catch projections in each state of nature.

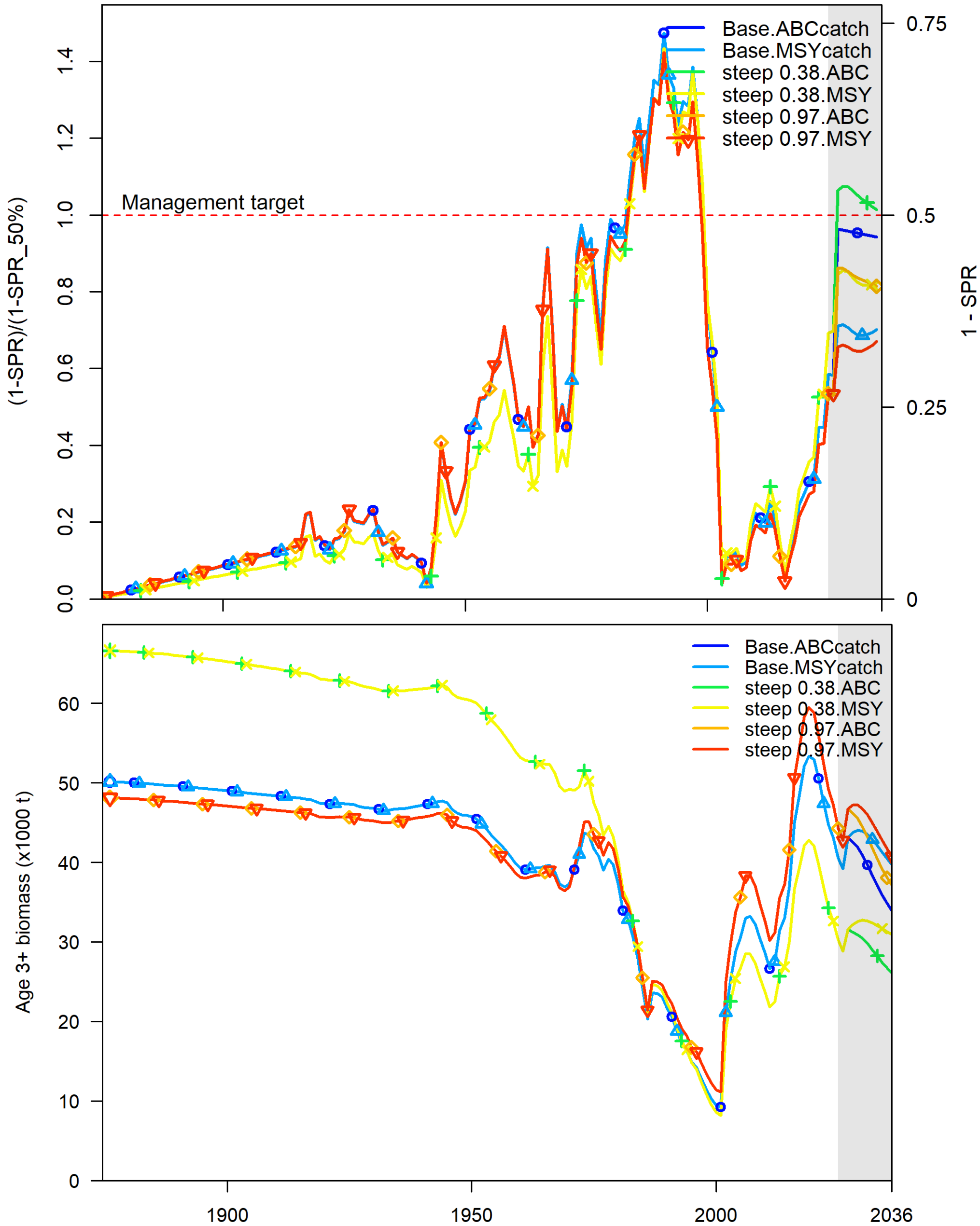


Figure 18B. Model estimates and projections for relative SPR (top) and age 3+ biomass (bottom) for: a) the base model (*h* = 0.72), b) high state of nature (*h* = 0.97), and c) low state of nature (*h* = 0.38). Equilibrium MSY (2114 t) and the ABC catch stream (ABC_{2027} = 3211 t and ABC_{2036} = 2431 t) from the base model represent the basis for the two catch projections in each state of nature.

Table 18. Depletion estimates associated with model projections from the base model (*h* = 0.72), the high state of nature (*h* = 0.97), and the low state of nature (*h* = 0.38) under alternative removal assumptions (equilibrium MSY and the ABC catch stream) for the 2027-2036 time period. Removal assumptions for 2025-2026 are based on existing ABC values.

	MSY catch	low steepness	base model	high steepnesss
2025	1599	46.89%	83.25%	95.87%
2026	1522	43.38%	78.58%	90.35%
2027	2114	41.64%	76.61%	87.83%
2028	2114	40.84%	76.14%	87.02%
2029	2114	40.98%	76.73%	87.26%
2030	2114	41.35%	77.31%	87.37%
2031	2114	41.61%	77.43%	86.91%
2032	2114	41.63%	77.00%	85.83%
2033	2114	41.41%	76.09%	84.22%
2034	2114	41.02%	74.84%	82.28%
2035	2114	40.53%	73.41%	80.17%
2036	2114	40.01%	71.90%	78.05%
	base ABC catch	low steepness	base model	high steepnesss
2025	1599	46.89%	83.25%	95.87%
2026	1522	43.38%	78.58%	90.35%
2027	3211	41.64%	76.61%	87.83%
2028	3086	39.09%	73.63%	84.57%
2029	3010	37.87%	72.11%	82.89%
2030	2960	37.17%	70.77%	81.44%
2031	2901	36.51%	69.13%	79.68%
2032	2821	35.72%	67.16%	77.54%
2033	2725	34.81%	64.97%	75.15%
2034	2621	33.85%	62.76%	72.74%
2035	2525	32.94%	60.69%	70.47%
2036	2439	32.10%	58.83%	68.45%

18 - Panel Conclusion

The Panel thanks the STAT for their timely provision of these model outputs.

Acknowledgments

The Panel would like to thank the STAT for their attention to detail, scientific rigor, and commitment to transparency throughout the development and review of this stock assessment. Their collaborative efforts and responsiveness to reviewer requests, in conjunction with actively engaged GMT and GAP advisors, provides a sound foundation for sustainable fisheries management. The Panel is also appreciative of the public feedback that was communicated throughout the review. The Panel thanks Council staff for their technical support and ongoing guidance on the administrative aspects of this process.

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