Stock Assessment Review (STAR) Panel Report for Copper Rockfish in California, Rex Sole, and Shortspine Thornyhead

National Oceanic and Atmospheric Administration
Northwest Fisheries Science Center
Auditorium and Online
2725 Montlake Boulevard E
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June 5-9, 2023

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Copper Rockfish in California

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Copper Rockfish in California

Overview

A Stock Assessment Review (STAR) Panel met June 5-9, 2023, in-person at the Northwest Fisheries Science Center (NWFSC) Auditorium with a remote participation option to facilitate public comment for those unable to travel to Seattle, WA. In addition to full benchmark assessments for copper rockfish in California, the panel also reviewed data-moderate assessments for rex sole and shortspine thornyhead. The panel operated under the Pacific Fishery Management Council's (PFMC) Terms of Reference (TOR) for the Groundfish Stock Assessment Review Process for 2023-2024.

Length-based data-moderate assessments were conducted in 2021 for copper rockfish off the U.S. West Coast. The population was assessed regionally with four separate population models for Washington, Oregon, and south and north of Point Conception in California. Only the stock off the coast of California is being assessed in 2023, as full benchmark assessments with two sub-area models split at Point Conception (34°27′ N. lat.).

Summary of Data and Assessment Models

The recreational fishery in California is the primary source of mortality for copper rockfish where private/rental (PR) vessels are the primary source of historical removals across the state. Catches by commercial passenger fishing vessels (CPFV) ramped up between the 1960s to the 1980s across the state. In recent years, the recreational removals north of Point Conception have been split between CPFV and PR vessels. In contrast, the CPFV fleet south of Point Conception is the primary source of mortality for copper rockfish.

The stock of copper rockfish in waters off California was assessed using two sub-area models that captured distinct dynamics split north and south of Point Conception, 34°27′ N. lat. The estimated dynamics for each assessed sub-area are described here along with the combined stock status for the California stock. This assessment does not account for populations located in Mexican waters or other areas off the U.S. West Coast and assumes that these southern and northern populations do not contribute to nor take from the population being assessed here.

These assessments use Stock Synthesis 3 (version 3.30.21.00). Each assessment model is a two-sex age-structured model operating on an annual time step covering the period 1916 to 2022, with a twelve-year projection, and assumes an unfished population prior to 1916. Population dynamics are modeled for ages 0 through 50, with age 50 being the accumulator age. The model is conditioned on catch from two sectors, commercial and recreational, divided among four fleets, and is informed by both fishery-dependent and fishery-independent indices of abundance. The sub-area models are fit to length composition data from fishery-independent and fishery-dependent sources, as well as age compositions as marginals or conditioned on length. Discards from the commercial and recreational fleets were estimated externally and added to landings to represent total catch. The commercial fishery is subdivided based on the landed condition of copper rockfish, live or dead. The recreational fishery is split into two fleets, a CPFV and PR boat modes where the PR fleet includes very minimal catch from manmade and beach/bank modes. The model also incorporates an updated length-based maturity schedule and externally estimated length-weight relationship and fecundity-at-length function. The assessment fixes values for natural mortality of females and males at the median of the prior (0.108 yr^{-1}) and estimates sex-specific growth parameters. Year-class strength is estimated as deviations from Beverton-Holt stock-recruitment relationship beginning in 1965 in the south and in 1970 north of Point Conception. Steepness of the Beverton-Holt stock-recruitment relationship is fixed at the mean of the prior, 0.72. All the data sources included in each sub-area model for copper rockfish in California have been re-evaluated for these assessments, including improvements and updates in the data (and associated analyses) that were used in the previous assessments (Figure 1). New data types and sources were included in these assessments compared to the 2021 assessments which included a limited scope of data types and sources. The primary fishery-independent survey for West Coast groundfish, the Northwest Fisheries Science Center (NWFSC) West Coast Groundfish Bottom Trawl (WCGBT) survey does not sample rocky habitats where most copper rockfish are found, and thus does not provide a robust index of abundance. An alternative survey, the California Collaborative Fisheries Research Program (CCFRP) Hook and Line survey, provides a reasonable signal for copper rockfish, including relative abundance and demographic structure inside and outside a number of Marine Protected Areas (MPAs). The CCFRP Hook and Line survey data (indices, lengths, and ages) have been included in other nearshore assessments in the past (e.g., vermilion/sunset rockfishes). The NWFSC Hook and Line survey provides the longest fishery-independent time series south of Point Conception (2004-2022) along with annual lengths and ages. These assessments also include fishery-dependent indices of abundance from the CRFS CPFV and PR fleets, north and south of Point Conception, that were not included in the 2021 assessments. Finally, this is the first assessment to include age composition data to support estimates of growth and population dynamics within the base models.

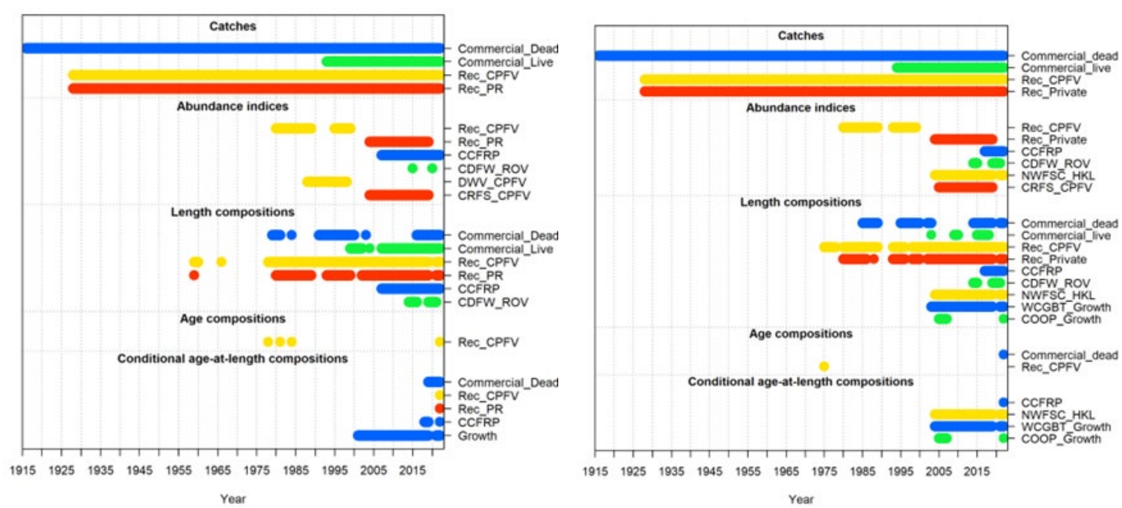


Figure 1. Availability and sources of input data for copper rockfish assessments: Left panel north of Point Conception, CA and right panel south of Point Conception, CA.

Within model uncertainty is explicitly included in this assessment by parameter estimation uncertainty, while among model uncertainty is explored through sensitivity analyses addressing alternative input assumptions such as data treatment and weighted, and model specification sensitivity to the treatment of life history parameters, selectivity, and recruitment. While the updated assessment uses all available data, uncertainty remains regarding outcomes and management quantities. As with most assessments the value of natural mortality and steepness remain a source of uncertainty that has not been resolved through assessment modeling. Thus, steepness is used as the defining index of the state of nature in subsequent decision tables and status determination criteria. Base models were selected that best fit the observed data while concomitantly balancing the desire to capture the central tendency across those sources of uncertainty, ensure model realism and tractability, and promote robustness to potential model mis-specification.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: Provide maturity data on Figure 44 (or table).

Rationale: To demonstrate model fit with observed data.

STAT Response: During the additional plotting of maturity, the STAT found errors in the latitude values of samples provided from the NWFSC Hook and Line (HKL) survey data that we previously assumed were from the area between Point Conception and Point Arguello. However, the Set IDs between the NWFSC Hook and Line survey do not match the Set ID in the maturity data file for any of the data spot-checked. This reduces the number of available samples for the north to four. The STAT re-estimated the maturity for north and south of Point Conception. The updated values are presented in the following tables and figures.

The available data for maturity includes 112 copper rockfish samples, three of which were fish that were functionally mature (Table 1). The estimate of length at 50% maturity is the same for the southern model as California as a whole with the available data.

Table 1. Sample sizes of copper rockfish by model sub-area when all NWFSC hook and line survey data are assigned to southern California.

Area	Functionally Immature	Functionally Mature
North of Pt. Conception	1	3
South of Pt. Conception	32	76

Table 2. Sample sizes for copper rockfish by survey and model sub-area.

Area	NWFSC HKL survey	NWFSC WCGBT
North of Pt. Conception	0	4
South of Pt. Conception	94	14

Table 3. Model results for length at 50% maturity and 95% confidence interval for all data combined and split by area for samples from September and October only.

Sample size	Length at 50% mature	Standard Error	2.50%	97.50%	Model
112	34.04586	0.759584	32.5571	35.53462	All data
4	31.532	23501.585	-46030.727	46094	North only
108	34.04563	23501.585	32.551	35.54	South only

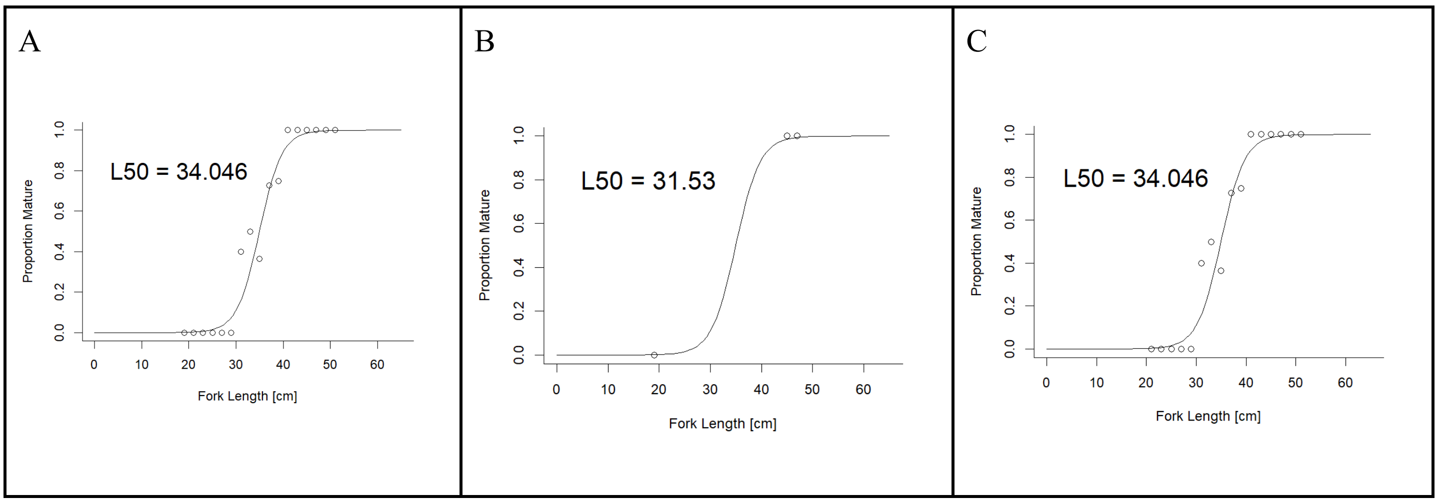


Figure 2. Data and the fitted maturity ogive for all data from September and October for all data (A), the north only (B) and the south only (C) from the updated data assigning all NWFSC hook and line data to southern California.

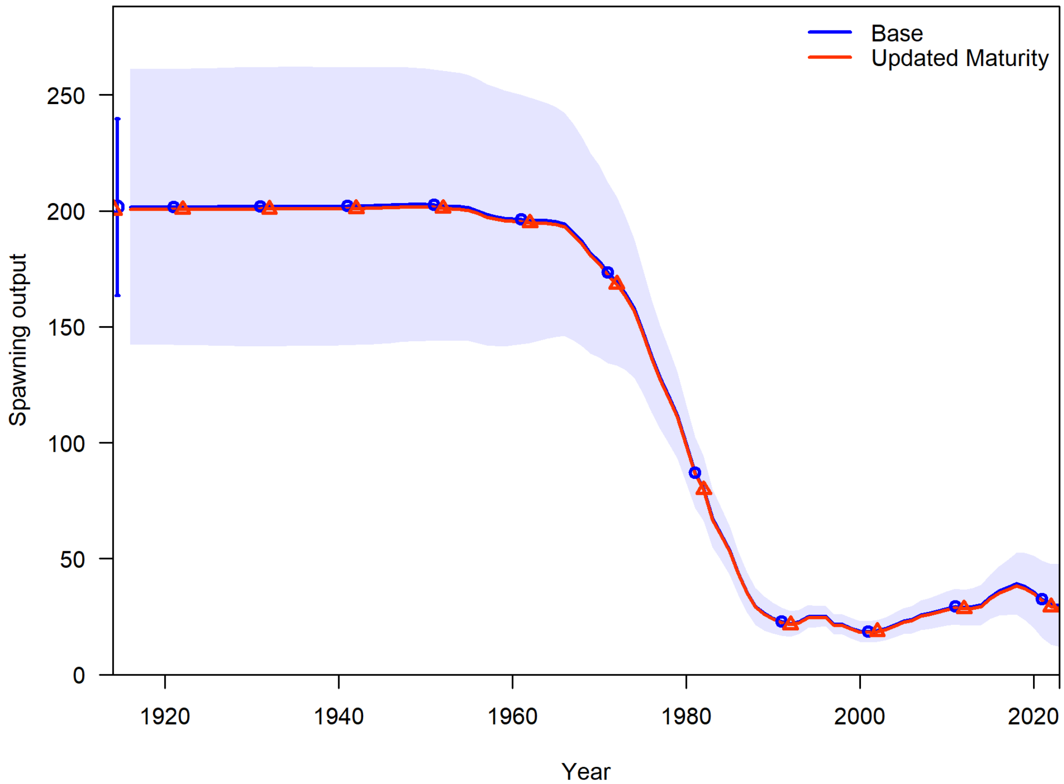


Figure 3. Estimated spawning output for the sub-area model south of Point Conception with the maturity estimates from the base model and the revised estimate presented above.

Panel conclusion: The rationale for this request was to explore the fits to the observed data and to understand the relationships. The STAT response assisted in the understanding of the model-data fits. Results did not suggest any changes to the base model.

Request No. 2: Provide a sensitivity to an alternative selectivity for the Northern stock growth fleet by changing the age at full selectivity at age 6 and greater.

Rationale: The growth fleet may be influential on the stock assessment as being informative to the estimates of growth parameters. Selectivity determines which ages may be observed in the conditional ages-at-length. The growth fleet in the South model, although it is composed of different data sources, has an implied estimated age selectivity peaking around age 8, which is greater than the assumed peak at age 1 in the North growth fleet.

STAT Response: Age-based selectivity for the growth fleet in the sub-area north of Point Conception was fixed to have a selectivity equal to 1 for ages 6+. The estimated spawning output and the fraction unfished were highly similar to the estimates from the base model.

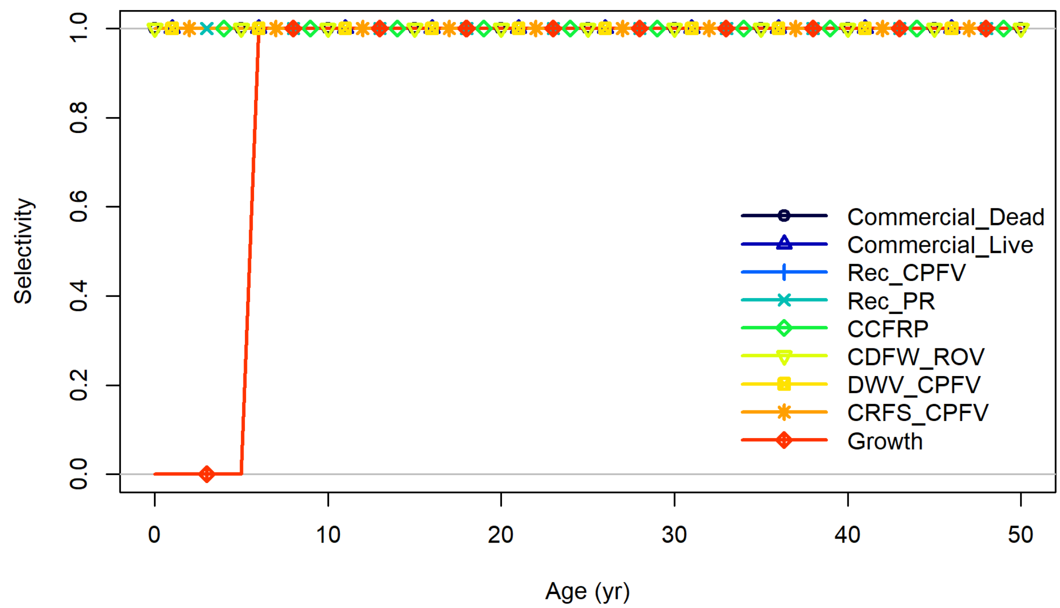


Figure 4. Fixed selectivity for the growth fleet in the sub-area model north of Point Conception

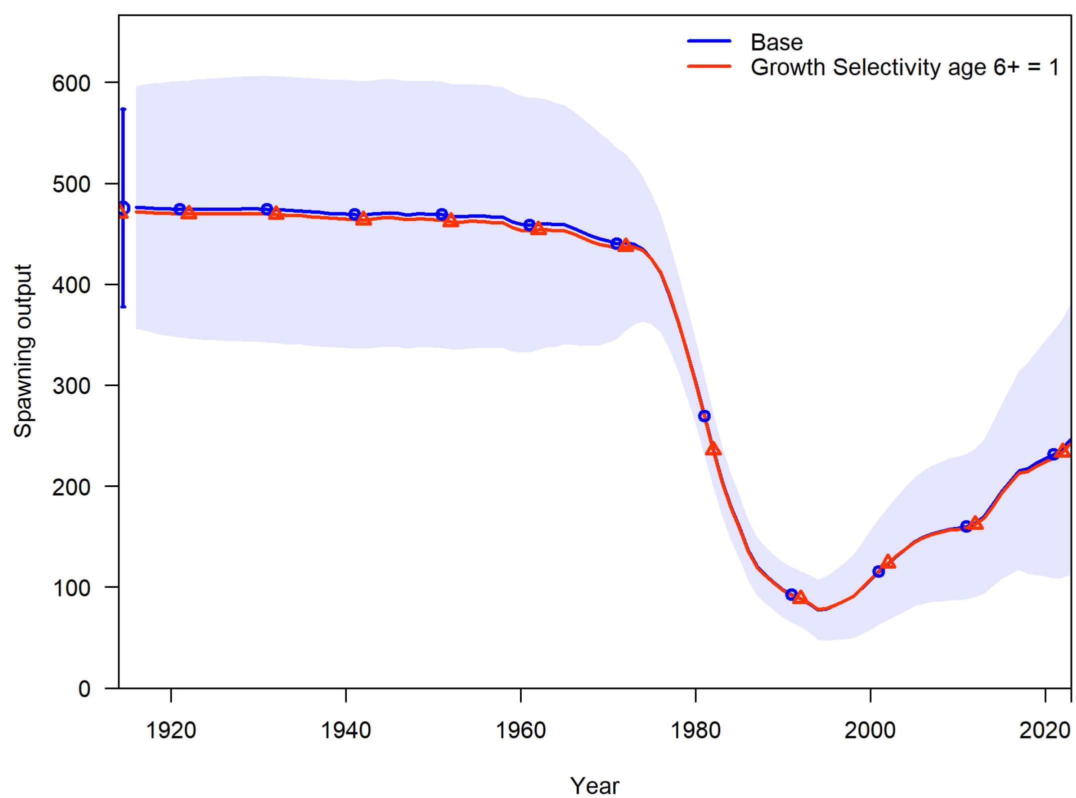


Figure 5. Comparison in the estimated spawning output between the base model and the growth selectivity sensitivity for the sub-area model north of Point Conception.

Table 4. Estimates of the growth parameters for the base model and the growth selectivity for the sub-area north of Point Conception.

	$L_{age=20}$ (F)	$L_{age=20}$ (M)	k (F)	k (M)	$CV_{age=2}$ (F)	$CV_{age=2}$ (M)	$CV_{age=20}$ (F)	$CV_{age=20}$ (M)
Base	48.31	46.50	0.153	0.195	0.157	0.157	0.074	0.073
Selex 6+	48.08	46.84	0.169	0.195	0.077	0.094	0.074	0.079

Panel conclusion: The rationale for this request was to explore the fits to the observed data and to understand the relationships. The STAT response assisted in the understanding of the model-data fits. Results did not suggest any changes to the base model.

Request No. 3: For both sub-areas, provide profiles for SigmaR, use plotting functions in panel format to review results, using a 0.1 step size from 0.1 to 1.

Rationale: Explore a potential improvement in model fit for data sources.

STAT Response: A profile over sigmaR was conducted for each sub-area model. The initial profile between 0.1 - 1.0 indicated that the model range did not appear to bookend values resulting in the lowest negative-loglikelihood (NLL) (i.e., NLL minimized at the upper bound of 1.0). Hence, a larger range of sigmaR values were explored: 0.10 - 1.50 that included the highest sigmaR values assumed in other West Coast groundfish assessments (e.g., sablefish 1.40 and Pacific hake 1.40). Plots of the NLL by data type are shown below for each sub-area.

<u>North of Point Conception</u>

The best fit to the data was achieved with a sigmaR value of 1.0 (NLL 1004.61) which was -7.49 NLL units below the base model (NLL 1012.10). No sigmaR profiled across were within 1.92 NLL units from the base model. The change in NLL across values of sigmaR is primarily due to changes in fits to the age data where the age data is best fit with the largest values of sigmaR of 1.50. However, there is a trade-off in fits to the data at larger values of sigmaR where there is a minimal degradation in the fit to the length and survey data and the penalty in fits to the recruitment NLL increases with high values of sigmaR.

An alternative model for the sub-area north of Point Conception was run using a sigmaR value of 1.0, higher than the fixed value in the base model (0.50). The estimates of spawning output in the model where sigmaR was fixed at 1.0 was lower across the time series relative to the base model and estimating a more depleted population relative to the base model. The estimates of annual recruitment deviation for the model with the higher fixed sigmaR does estimate move extreme deviations relative to the base model, particularly in the final years of the model. The tuning value recommended for the model that assumed sigmaR of 1.0 was 0.69.

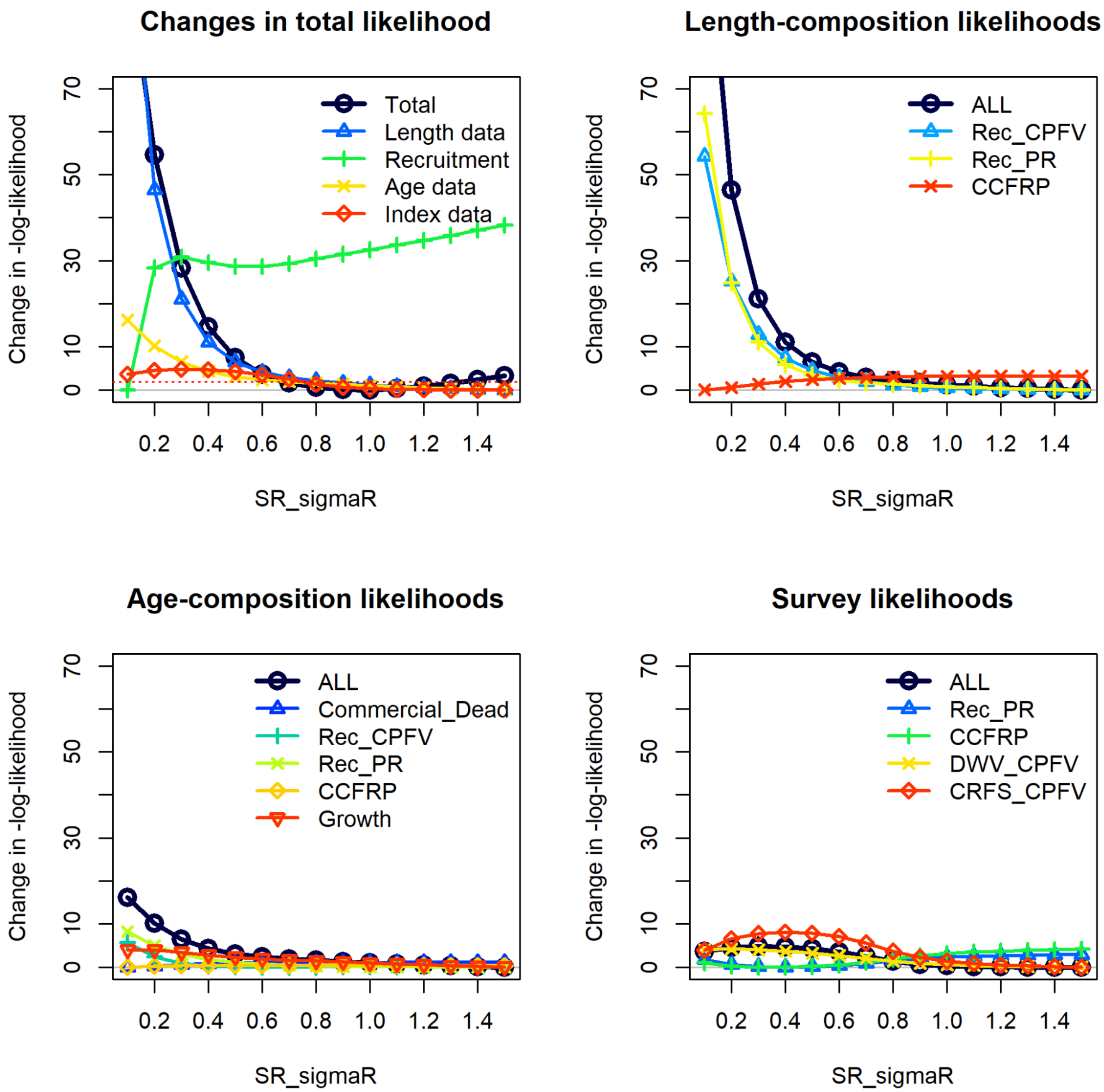


Figure 6. Profile across sigmaR for the sub-area north of Point Conception.

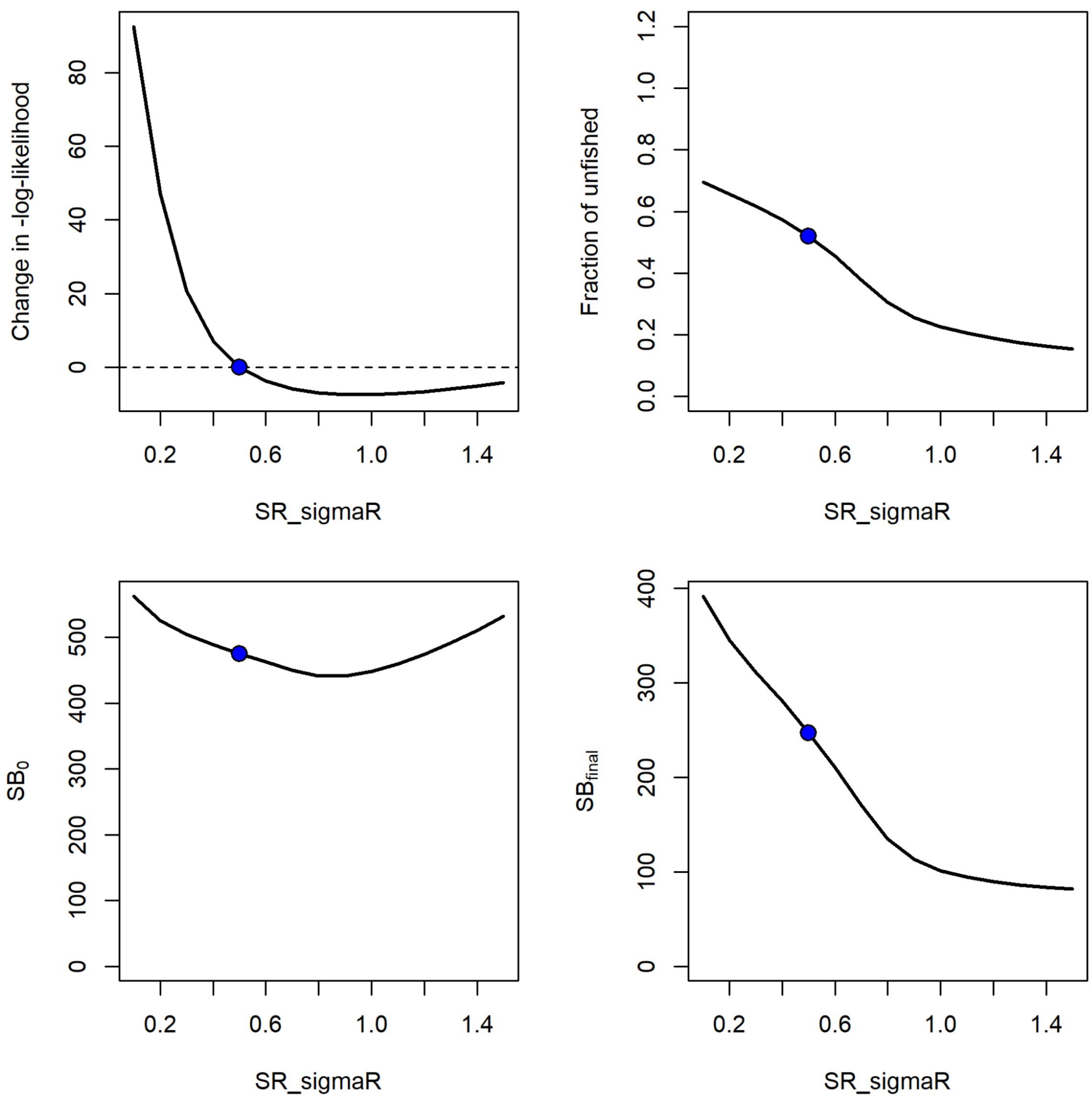


Figure 7. Change in the total negative log-likelihood for the sub-area north of Point Conception and how values of fraction unfished, unfished spawning output (SB0), and spawning output in the final model year (SB2013) change across values of sigmaR.

Table 5. Change in the total negative log-likelihood (NLL) and the negative log-likelihood from specific data types across values of sigmaR for the sub-area model north of Point Conception.

	0.1	0.2	0.3	0.4	Base Model 0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
Total NLL	1104.72	1059.18	1032.87	1019.26	1012.10	1008.28	1006.23	1005.14	1004.65	1004.61	1004.90	1005.43	1006.14	1006.97	1007.91
Survey	-39.82	-38.92	-38.63	-38.79	-39.22	-39.92	-40.93	-42.08	-42.82	-43.17	-43.33	-43.41	-43.44	-43.45	-43.45
Discard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Length	514.65	445.87	420.50	410.49	405.91	403.55	402.26	401.53	400.99	400.55	400.20	399.92	399.70	399.53	399.40
Age	653.00	646.97	643.28	641.10	639.85	639.10	638.66	638.36	638.06	637.77	637.50	637.27	637.08	636.92	636.78
Recr.	-23.11	5.26	7.72	6.45	5.57	5.55	6.24	7.34	8.43	9.47	10.53	11.64	12.79	13.98	15.18
Forecast	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prior	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Param.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diff	92.62	47.08	20.77	7.16	0.00	-3.82	-5.87	-6.96	-7.45	-7.49	-7.20	-6.67	-5.96	-5.13	-4.19

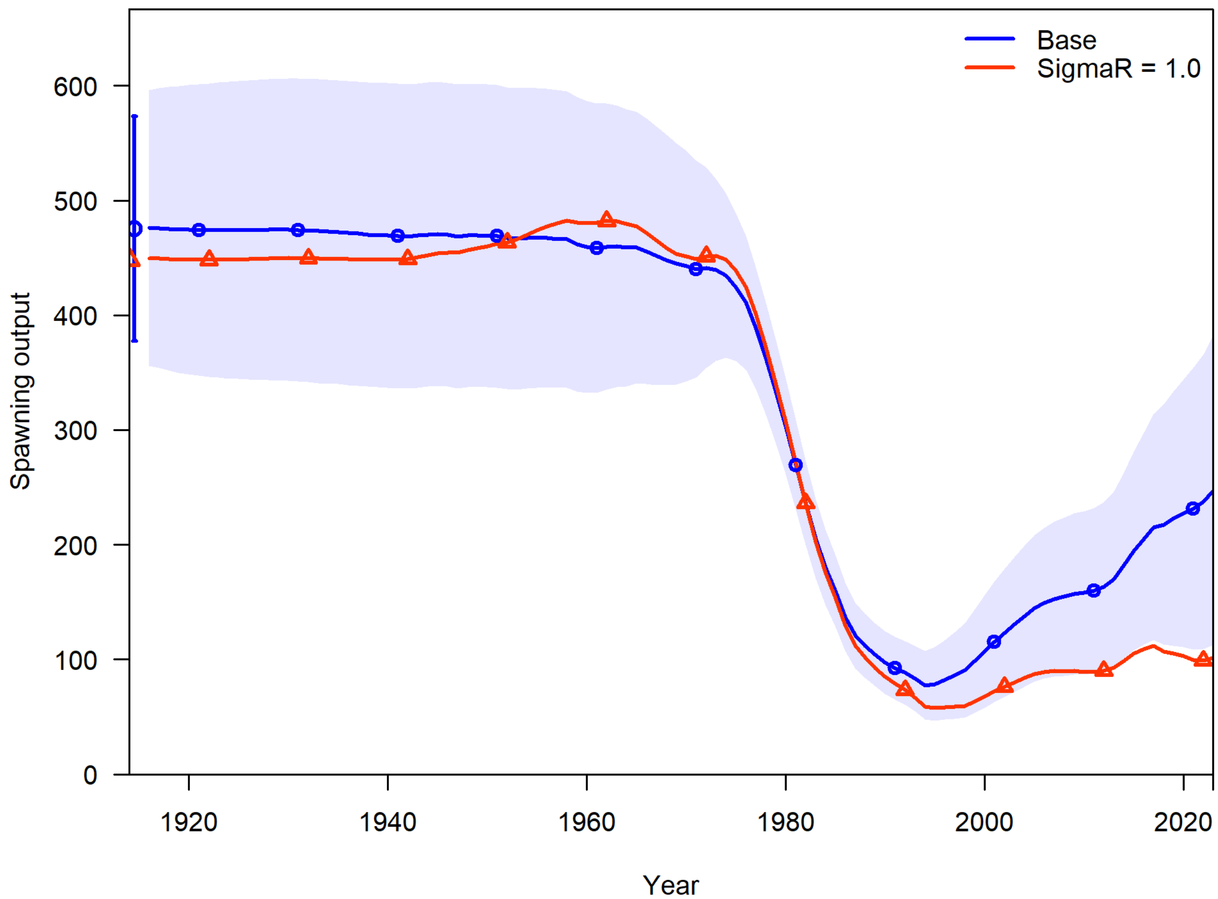


Figure 8. Sensitivity to the estimated spawning output for the sub-area north of Point Conception between the base model and a model where sigmaR is fixed at 1.0.

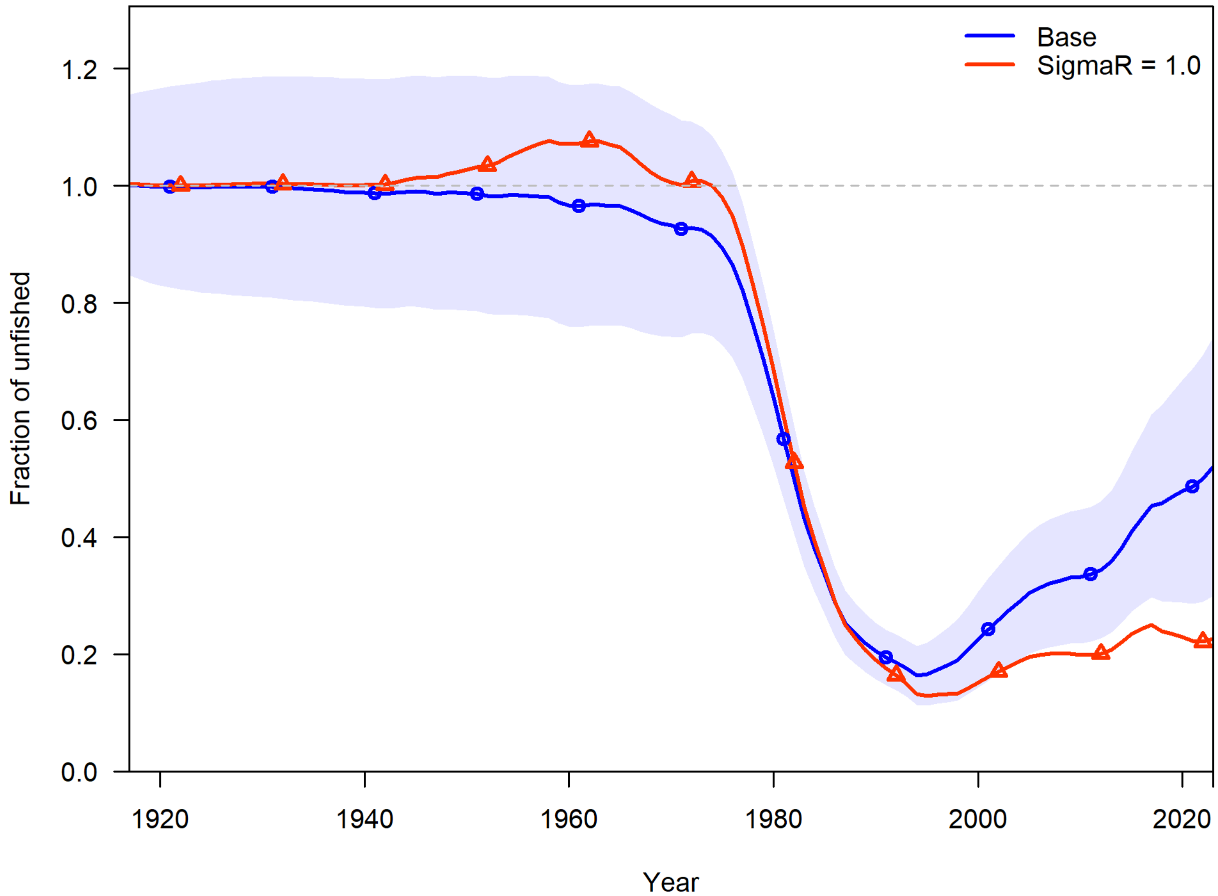


Figure 9. Sensitivity to the estimated fraction unfished for the sub-area north of Point Conception between the base model and a model where sigmaR is fixed at 1.0.

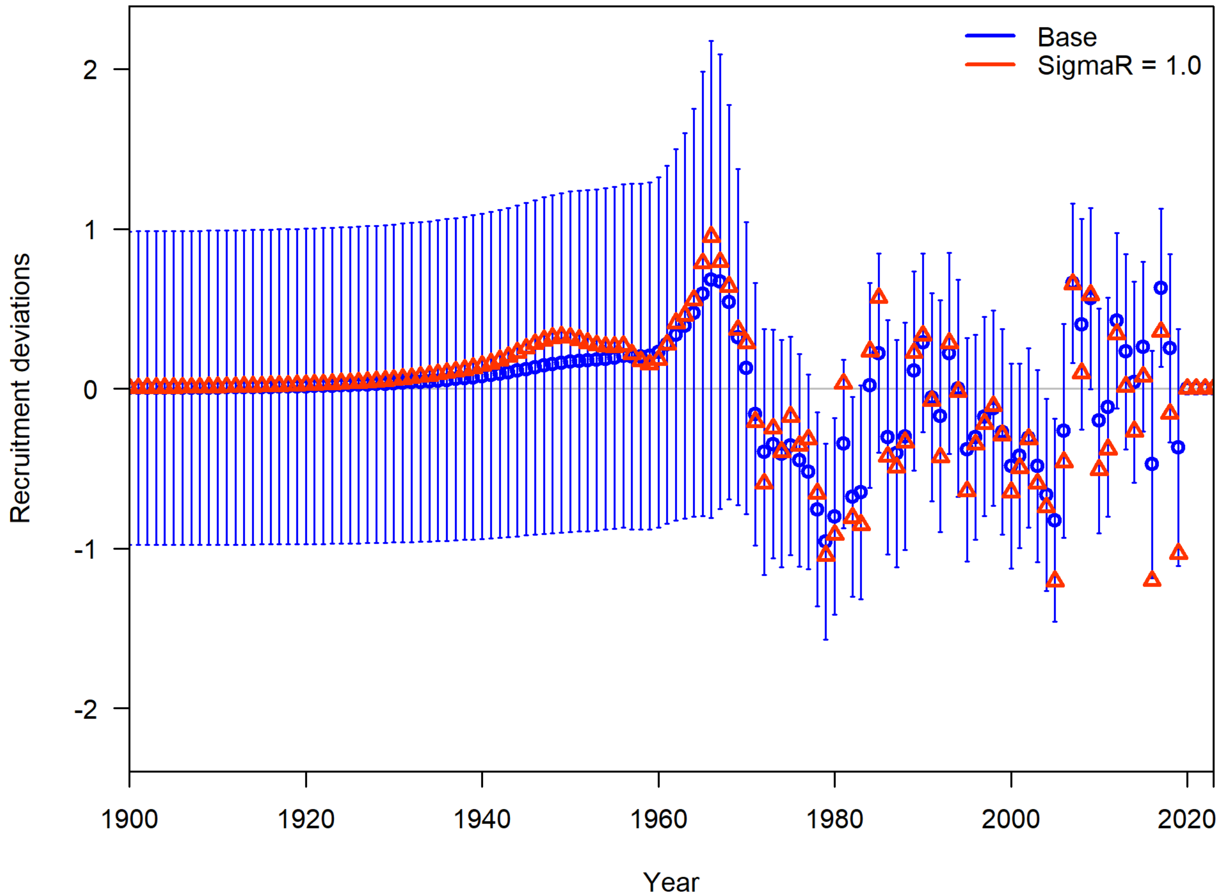


Figure 10. Sensitivity to the estimated annual recruitment deviations for the sub-area north of Point Conception between the base model and a model where sigmaR is fixed at 1.0.

<u>South of Point Conception</u>

The best fit to the data was achieved with a sigmaR value of 0.80 (NLL 2830.5) which was 1.7 NLL units below the base model (NLL 2832.2). SigmaR values between 0.60-1.2 were within 1.92 NLL units from the base model. The change in NLL across values of sigmaR is primarily due to changes in fits to the age data where the age data is best fit with the largest values of sigmaR of 1.50. However, there is a trade-off in fits to the data at larger values of sigmaR where there is a minimal degradation in the fit to the length and survey data and the penalty in fits to the recruitment NLL increases with high values of sigmaR (Table 5).

An alternative model for the sub-area south of Point Conception was run using a sigmaR value of 0.80, higher than the fixed value in the base model (0.60). The estimates of spawning output and the fraction unfished for the model with a higher sigmaR value was highly similar to the estimates from the base model. The estimates of annual recruitment deviation for the model with the higher fixed sigmaR does estimate marginally move extreme deviations relative to the base model. The tuning value recommended for the model that assumed sigmaR of 0.80 was 0.80.

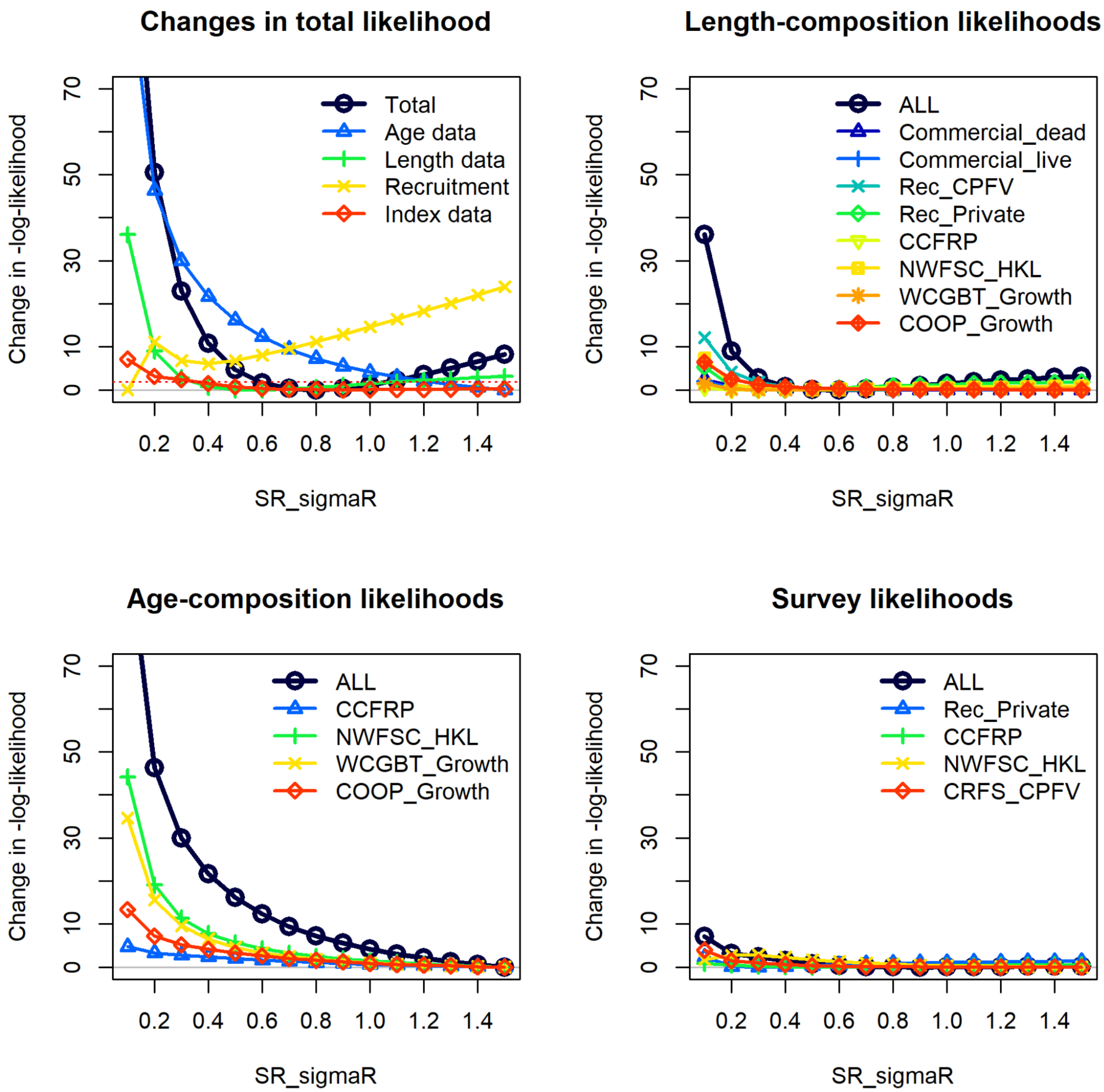


Figure 11. Profile across sigmaR for the sub-area south of Point Conception.

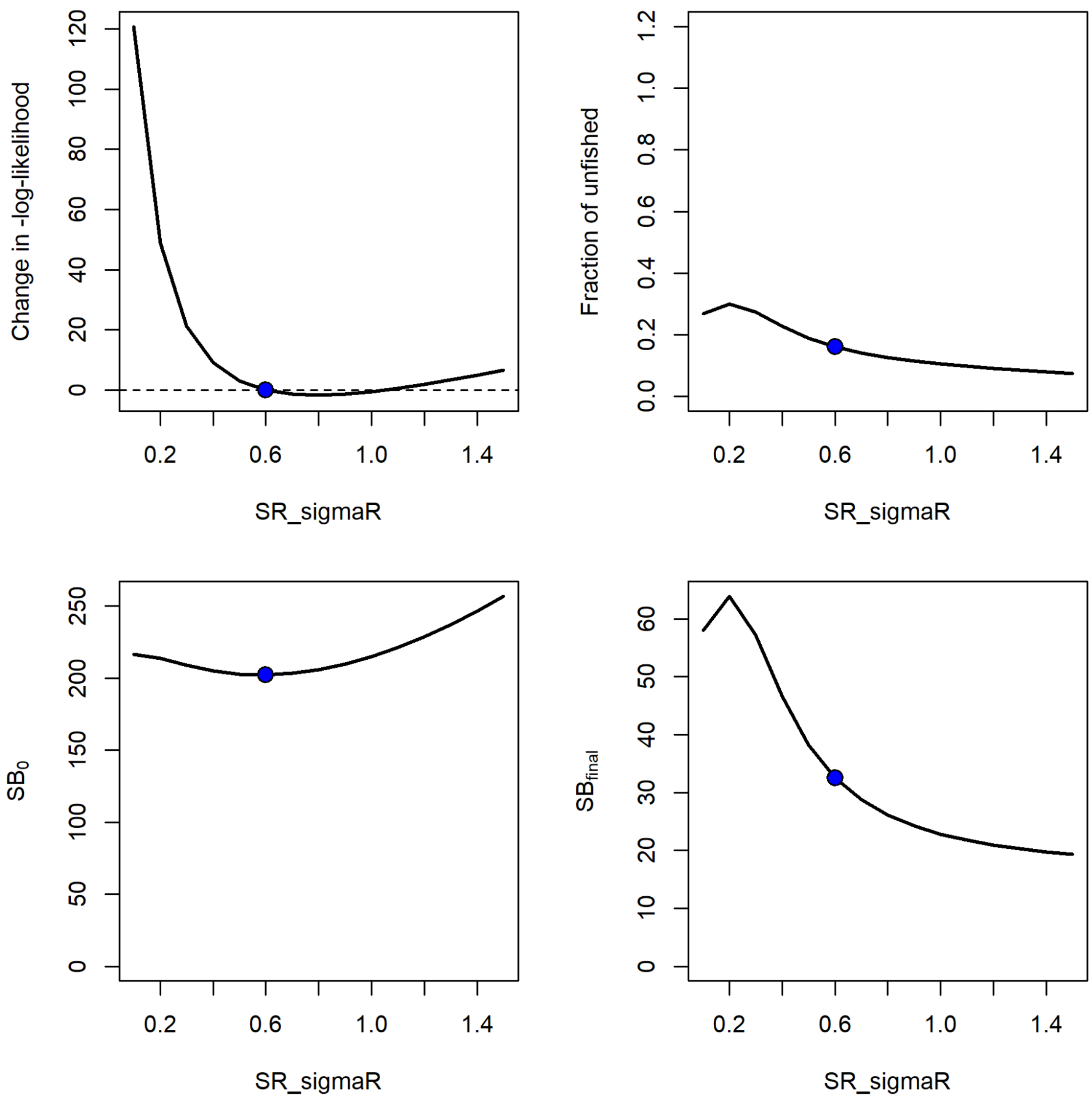


Figure 12. Change in the total negative log-likihood for the sub-area south of Point Conception and how values of fraction unfished, unfished spawning output (SB0), and spawning output in the final model year (SBfinal) change across values of sigmaR.

Table 6. Change in the total negative log-likelihood (NLL) and the negative log-likelihood from specific data types across values of sigmaR for the sub-area model south of Point Conception.

	0.1	0.2	0.3	0.4	0.5	Base Model 0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
Total NLL	2953.0	2881.1	2853.4	2841.3	2835.2	2832.2	2830.9	2830.5	2830.9	2831.7	2832.8	2834.1	2835.5	2837.1	2838.8
Survey	-26.6	-30.5	-31.3	-32.2	-33.0	-33.4	-33.6	-33.7	-33.7	-33.7	-33.7	-33.6	-33.6	-33.5	-33.5
Discard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Length	575.0	548.0	541.8	539.6	539.0	538.9	539.2	539.6	540.0	540.4	540.8	541.1	541.5	541.8	542.1
Age	2406.7	2354.5	2338.2	2329.8	2324.4	2320.5	2317.6	2315.4	2313.7	2312.3	2311.2	2310.3	2309.5	2308.8	2308.2
Recr.	-2.7	8.5	4.2	3.4	4.2	5.4	6.9	8.5	10.2	12.0	13.8	15.6	17.5	19.4	21.3
Forecast	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prior	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Param.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diff.	120.8	48.9	21.3	9.1	3.0	0.0	-1.3	-1.7	-1.3	-0.5	0.6	1.9	3.3	4.9	6.6

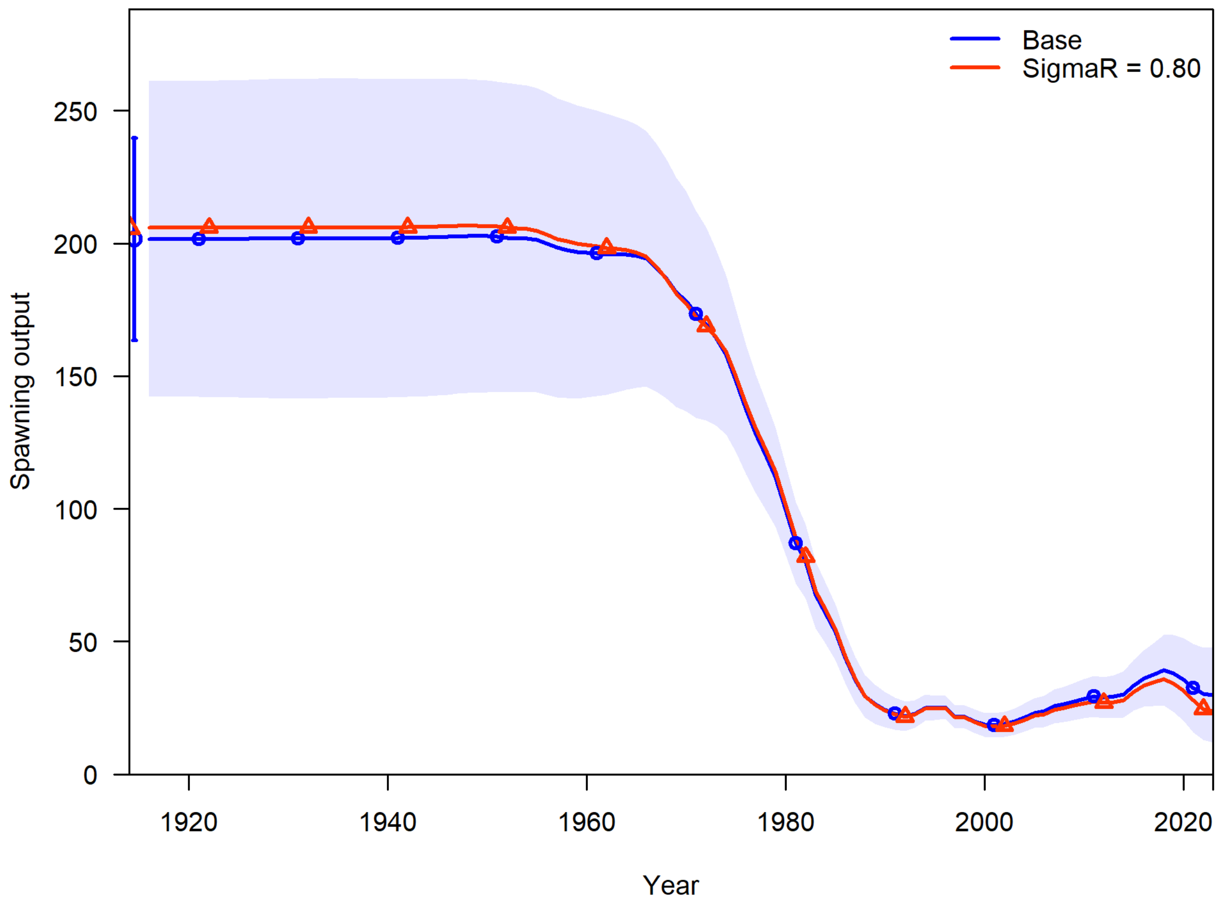


Figure 13. Sensitivity to the estimated spawning output for the sub-area south of Point Conception between the base model (sigmaR = 0.60) and a model where sigmaR is fixed at 0.80.

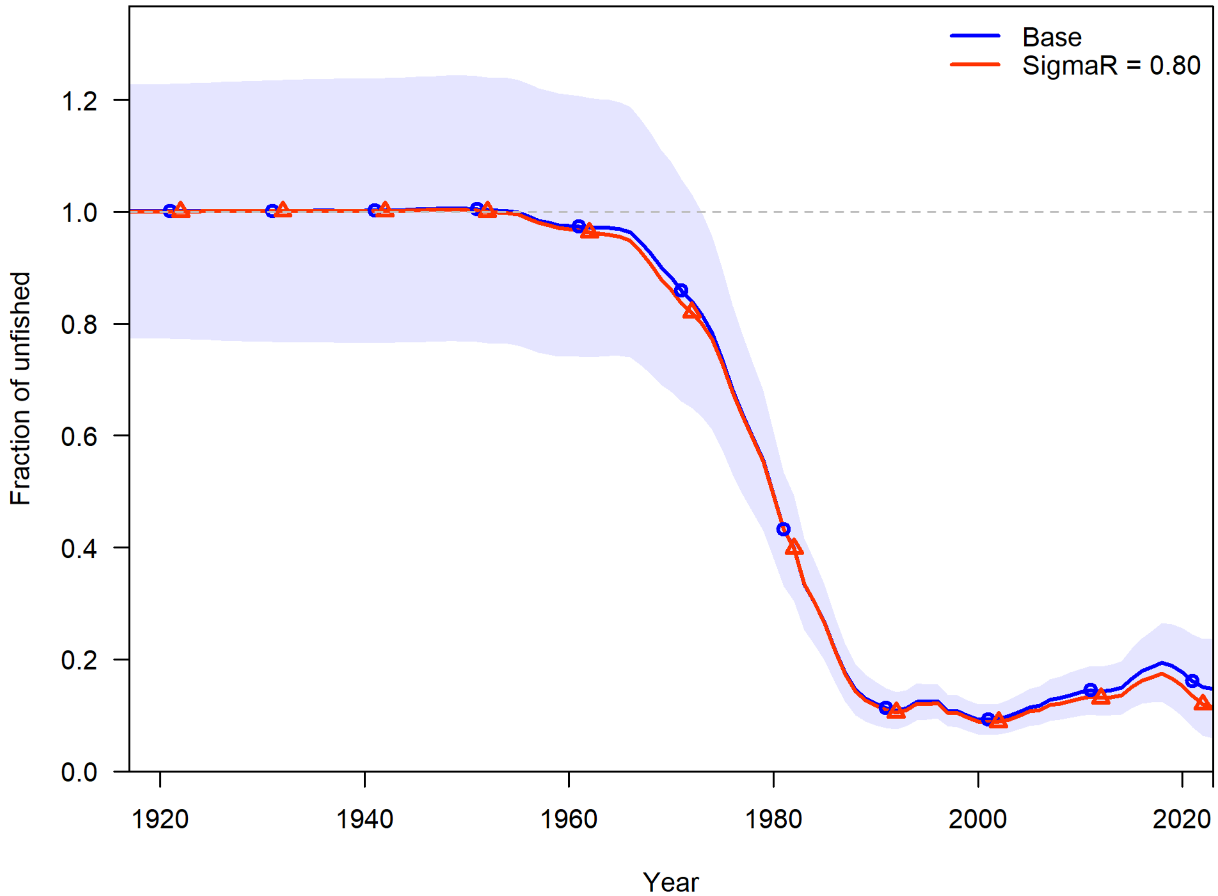


Figure 14. Sensitivity to the estimated fraction unfished for the sub-area south of Point Conception between the base model (sigmaR = 0.60) and a model where sigmaR is fixed at 0.80.

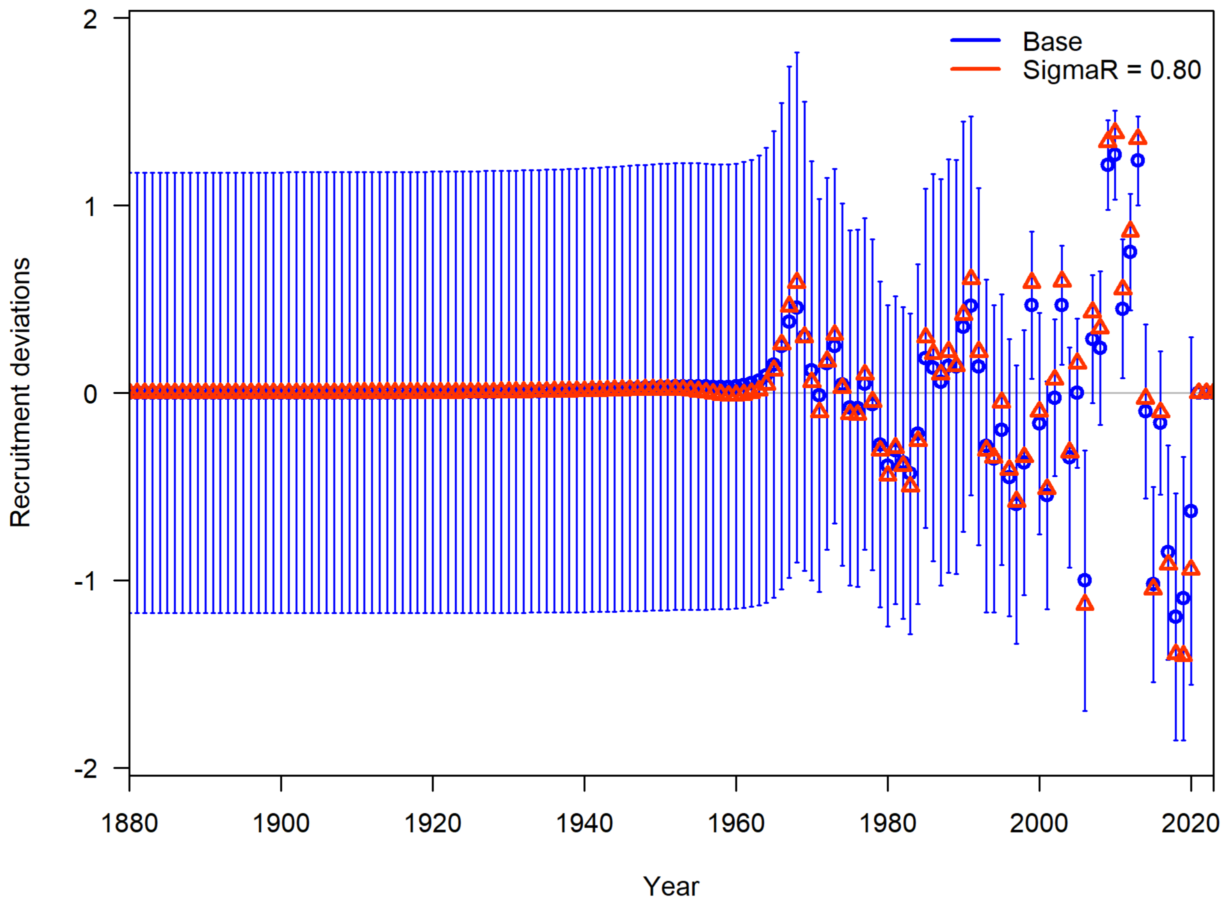


Figure 15. Sensitivity to the estimated annual recruitment deviations for the sub-area south of Point Conception between the base model (sigmaR = 0.60) and a model where sigmaR is fixed at 0.80.

Panel conclusion: The rationale for this request was to explore the fits to the observed data and to understand the relationships. The STAT response assisted in the understanding of the model-data fits. Results did not suggest any changes to the base model.

Request No. 4: Estimate two time blocks for catchability (2007-2016 and 2017-2022; same as current selectivity) in the CCFRP index of abundance in the North model.

Rationale: The latter period appeared to be underfit. The survey expanded with additional sampling sites and shifted further north. This will assist in understanding how the survey expansion may need to be accounted for.

STAT Response: After the discussion with the STAR panel regarding Request 4, the STAT realized that the float parameter for q on the CCFRP index needed to be estimated and not solved analytically. Please disregard the STAT's response to Request 4.

Panel conclusion: The panel replaced request 4 with request 5.

Request No. 5: Update Day 1 (1st Round) Request 4 using an estimated parameter for catchability with a time block starting in 2017 and re-weight using prior methods.

Rationale: This represents an improved method to estimate catchability using time blocks.

STAT Response: The base model for north of Point Conception was rerun with the *q* parameter estimated (not as a float) with a time block for the CCFRP survey with a blocking period of 2007-2016 and 2017-2022. The time block functional form was set to 1 (additive parameter) and the model was re-weighted once using the same data weighting methods as the base model. A summary of the estimated *q* and change in the negative log-likelihood is provided below. Adding a time-block in catchability for the CCFRP survey results in a better fit to the later years (2017-2022) when the survey expanded across the northern California coast. The resulting time series has a slight decline in the estimated unfished spawning output, spawning output in 2023, and a slightly more depleted population relative to the base model. A time-block has not previously been used on *q* for assessments utilizing the CCFRP data, and the time-block for catchability to capture the expansion of the survey in 2017 was discussed during the SSC's review of methods for hook and line surveys (Agenda Item G.4.a Supp SSC GF Subcom Rpt 1, Sept 2022).

Table 7. The catchability and added variance parameters for the north of Point Conception base model and the sensitivity with a time-block on catchability for the CCFRP survey.

Parameter	Base Model	Request 5
CCFRP Catchability (*q*)	4.64e-05	4.34e-05
Time-Varying q	-	6.46e-05
Added Variance	0.221	0.184

Table 8. The total negative log-likelihood, likelihood components and parameters for the base model and Request 5 model north of Point Conception with a time-varying block on catchability for the CCFRP survey. Fixed parameters (natural mortality, steepness, and the length at Amin) are not shown in the table.

	Base Model	Request 5
Total Likelihood	1012.11	1013.76
Survey Likelihood	-39.2202	-42.4913
Length Likelihood	405.907	403.077
Age Likelihood	639.846	647.097
Recruitment Likelihood	5.57054	6.07023
Forecast Recruitment Likelihood	0	0
Parameter Priors Likelihood	0.00231881	0.00231881
log(R0)	6.31901	6.28073
SB Virgin	475.329	456.047
SB 2023	247.113	208.739
Fraction Unfished 2023	0.519877	0.457715
Total Yield - SPR 50	121.19	116.464
Length at Amax - Female	48.3132	48.2891
Von Bert. k - Female	0.153411	0.15294
CV young - Female	0.156597	0.156651
CV old - Female	0.0738092	0.0737291
Length at Amax - Male	46.4995	46.4817
Von Bert. k - Male	0.194784	0.194151
CV young - Male	0.156659	0.156688
CV old - Male	0.0725049	0.0727298

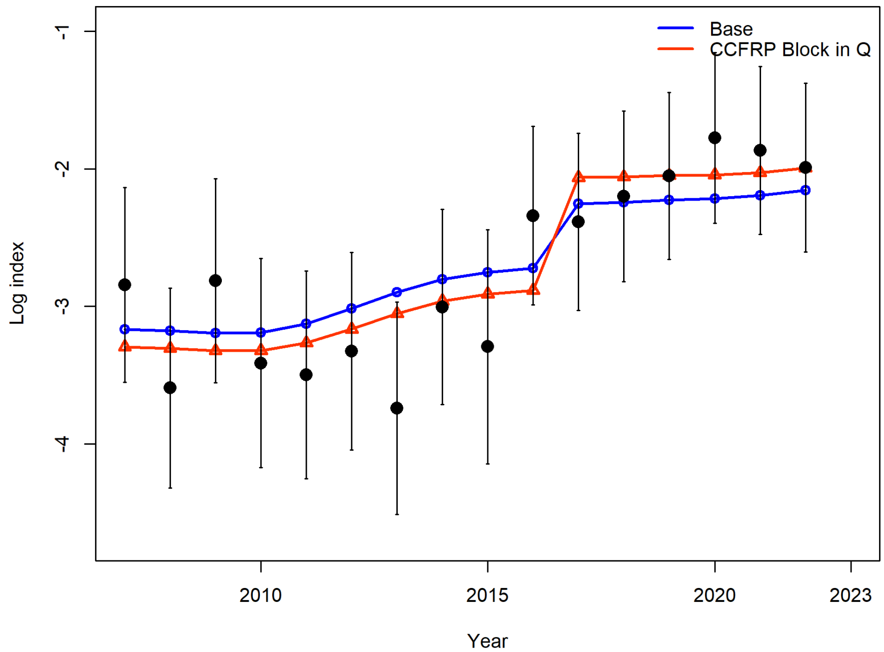


Figure 16. The fit to the CCFRP index of abundance in log-scale for the north of Point Conception base model and the sensitivity model that includes a time-block in catchability for the survey.

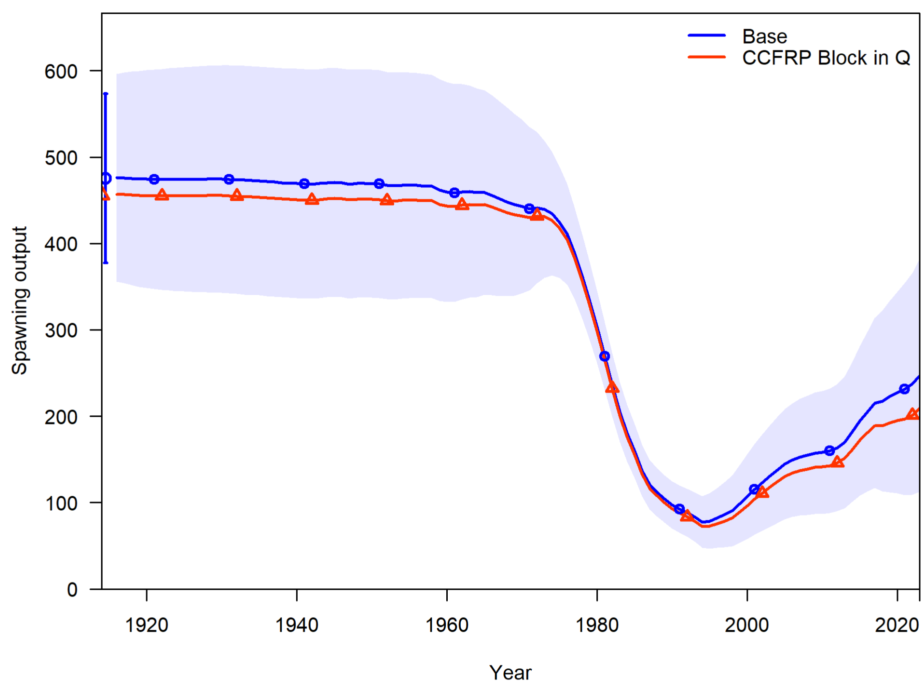
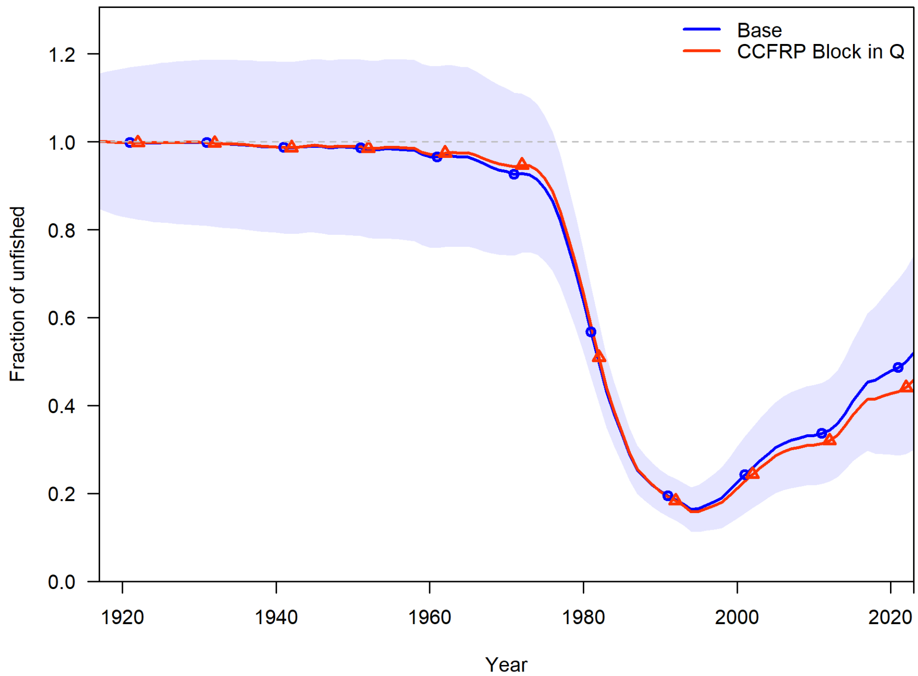


Figure 17. The estimated spawning output for the base model and the sensitivity model that includes a time-block in catchability for the CCFRP survey.



Figures 18. The estimated fraction unfished for the north of Point Conception base model and the sensitivity model that includes a time-block in catchability for the CCFRP survey.

Panel conclusion: Given these results, the Panel recommends that the time-blocking parameterization be carried forward in the base model.

Request No. 6: Add columns to Table 2 from the errata document into the final assessment documents showing the assessment area contributions north and south of Point Conception to the statewide OFL and ABC values for all projected years.

Rationale: The Council's copper rockfish stock definition preliminary preferred alternative (PPA) is two stocks delineated at 42° N. lat.. The STAT has indicated that the results of the two California assessment areas will be combined to produce one decision table to inform a single stock status determination off the coast of California under the assumption that the PPA is selected as the final preferred alternative (FPA). During the 2025-2026 harvest specifications process, management measures may be designed to address the different assessment area outcomes, and therefore, knowing the contribution to the overfishing limit (OFL)/acceptable biological catch (ABC) will be needed.

STAT Response: Below is a proposed table structure to include in the assessment documents. The methodology to determine the allocation of the northern California management quantities to north of 40° 10′ N. latitude follows the same methods used in the 2021 vermilion and sunset rockfish complex assessment (Monk et al. 2021; Dick et al. 2021). We used the 2016-2019 data from the California Department of Fish and Wildlife (CDFW) California Recreational Fisheries Survey (CRFS) private and rental boat fishing (PR) data, which is the only survey with large sample sizes north of San Francisco and excluded 2020-2022 due to pauses in sampling. We modeled catch-per-unit-effort (CPUE) (as copper rockfish per angler trip) using a Bayesian negative binomial regression with sub-region defined as CRFS districts and pooled data across years 2016-2019. Including the sub-region covariate reduced AIC by 1486 points relative to the null (intercept-only) model. When CPUE is multiplied by the percentage of rocky substrate north of 40° 10′ N. latitude, the expected percentage of the stock that occurs north of Cape Mendocino is 5.86% (Table 9).

Table 9. Estimates of the catch-per-unit-effort (CPUE), area and percent rocky habitat by northern California CRFS district, and the estimates of relative abundance by region.

Northern California CRFS District (south to north)	CPUE	Area of rocky substrate (km2)	Percent of rocky substrate	CPUE*Fraction of rocky substrate	Relative Abundance
Central	0.438	272.707	32.30%	0.142	29.71%
Bay	0.857	271.279	32.10%	0.275	57.53%
Wine	0.202	136.937	16.20%	0.033	6.90%
Redwood	0.142	164.193	19.40%	0.028	**5.86%**

Table 10. The estimated overfishing limit (OFL), acceptable biological catch (ABC), annual catch limit (ACL), spawning output (SO) in billions of eggs, and fraction unfished for copper rockfish across California (CA) and the estimated proportion of the ACL to allocate north and south of the 40° 10′ N. lat. management line.

Year	Assumed Removals	OFL (CA)	ABC (CA)	ACL (CA)	SO (CA)	Fraction Unfished (CA)	ACL CA South of 40° 10′ N. lat.	ACL CA North of 40° 10′ N. lat.
2023	91.5	-	-	-	240.8	0.366	-	-
2024	94.7	-	-	-	245.9	0.374	-	-
2025	-	143.5	134.1	131.9	250.6	0.381	124.1	7.7
2026	-	145.2	135.0	133.0	252.0	0.383	125.2	7.8
2027	-	146.8	136.0	134.2	253.6	0.385	126.4	7.9
2028	-	148.3	136.7	135.3	255.3	0.388	127.4	7.9
2029	-	149.5	137.1	136.0	257.2	0.391	128.0	8.0
2030	-	150.5	137.4	136.7	259.2	0.394	128.7	8.0
2031	-	151.5	137.7	137.3	261.2	0.397	129.3	8.0
2032	-	152.3	137.7	137.7	263.1	0.400	129.6	8.1
2033	-	153.2	137.8	137.8	265.0	0.403	129.8	8.1
2034	-	154.0	138.0	138.0	266.8	0.405	129.9	8.1

A proposed decision table for copper rockfish in California has been compiled using steepness (*h*) to develop low and high states of nature. The low and high state of nature was set-up using sub-area model specific *h* values. The sub-area north of Point Conception applied values of *h* of: 0.655, 0.72, and 0.859. The sub-area south of Point Conception applied values of *h* of: 0.54, 0.72, and 0.929. The proposed decision table assumes full ACL removal during the projection period. The catch is set equal to the ACL with a P* of 0.45 and sigma of 0.50 for both sub-area models.

Table 11. Decision table for copper rockfish in California assuming full annual catch limit (ACL) removal. The removal values in 2023 and 2024 were set equal to the adopted ACLs.

			Low *h*		Base *h*		High *h*	
	Year	Catch	Spawning Output	Fraction Unfished	Spawning Output	Fraction Unfished	Spawning Output	Fraction Unfished
ACL	*2023*	*91.5*	*176.2*	*0.255*	*240.8*	*0.366*	*337.3*	*0.533*
	2024	*94.7*	*178.2*	*0.258*	*245.9*	*0.374*	*345.7*	*0.546*
	2025	131.9	180.2	0.261	250.6	0.381	352.9	0.558
	2026	133.0	179.2	0.260	252.0	0.383	355.8	0.562
	2027	134.2	178.7	0.259	253.6	0.385	358.0	0.565
	2028	135.3	178.6	0.259	255.3	0.388	359.6	0.568
	2029	136.0	178.7	0.259	257.2	0.391	360.9	0.570
	2030	136.7	179.0	0.259	259.2	0.394	362.0	0.572
	2031	137.3	179.4	0.260	261.2	0.397	362.8	0.573
	2032	137.7	179.6	0.260	263.1	0.400	363.5	0.574
	2033	137.8	179.8	0.260	265.0	0.403	364.1	0.575
	2034	138.0	179.9	0.261	266.8	0.405	364.6	0.576

Panel conclusion: The Panel accepts this approach for developing decision tables.

Request No. 7: Use the default harvest control rule of P* value of 0.45 in the base model run with all states of nature, as well as runs with alternative P* values of 0.4 and 0.35. Assume full ACL attainment under each P* alternative run. The results of this request would be included in the Revised Draft Assessment (post-STAR panel).

Rationale: The P* value of 0.45 is the default value for copper rockfish. Exploration of alternative P* values of 0.4 and 0.35 would take into account the different assessment area outcomes by providing additional buffers and provide the Council with options for consideration later this year. The potential harvest limits for copper rockfish may be constraining to the fishery and full attainment is a reasonable expectation.

STAT Response: This will be included in the Revised Draft Assessment (post-STAR panel).

Panel conclusion: The Panel accepts this approach for inclusion in the decision tables.

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

Proposals for base models were presented in the draft assessment documents for north and south copper rockfish. The STAR Panel explored alternatives to these formulations as noted in the analytical requests above. Of particular interest was request 5 in which two time blocks for catchability were estimated (2007-2016 and 2017-2022; same as current selectivity) in the CCFRP index of abundance in the north model. The reasons for this exploration were that the latter period appeared to be underfit. The survey expanded with additional sampling sites and shifted further north. Estimating catchability in time blocks was designed to address this deficiency.

The model for north of Point Conception was rerun with the *q* parameter estimated (not as a float) with a time block for the CCFRP survey with a blocking period of 2007-2016 and 2017-2022. The time block functional form was set to 1 (additive parameter) and the model was re-weighted once using the same data weighting methods as the base model. A summary of the estimated *q* and change in the negative log-likelihood is provided below. Adding a time-block in catchability for the CCFRP survey results in a better fit to the later years (2017-2022) when the survey expanded across the northern California coast. The resulting time series has a slight decline in the estimated unfished spawning output, spawning output in 2023, and a slightly more depleted population relative to the base model. A time-block has not previously been used on *q* for assessments utilizing the CCFRP data, and the time-block for catchability to capture the expansion of the survey in 2017 was discussed during the SSC's review of methods for hook and line surveys (Agenda Item G.4.a Supp SSC GF Subcom Rpt 1, Sept 2022). This modification was accepted by the STAR Panel as an appropriate adjustment to the base model and the updated base model is to be carried forward in subsequent final assessments.

The major axes of uncertainty for copper rockfish were based on low and high spawning output. Values of steepness (h) were chosen so that model estimates of final year spawning output matched the 12.5% and 87.5% quantiles of the base model estimate in 2023. For the northern model, h_{lo}=0.637 and h_{hi} = 0.892. For the southern model h_{lo}=0.637 and h_{hi} = 0.93.

Recommended sigma value and basis of recommendation

The sigma value (the ln-scale coefficient of variation for SB2023, measuring scientific uncertainty) from the final base model was 0.30 in the northern model and 0.28 in the southern model, which is less than the default sigma value recommended by the Council's Scientific and Statistical Committee for Category 1 stocks (0.5). The STAR Panel recommends using the default sigma value for catch projections for copper rockfish in California.

Technical Merits of the Assessment

A number of technical merits were common to both north and south copper rockfish in California assessments, as mentioned below.

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

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

The STAT teams explored many alternative models, within the Stock Synthesis framework. These alternative modeling approaches were not presented in detail but indicated that the STAT were reviewing and developing options to improve stock assessments in the future as well as check the robustness of the current approach being used for management advice. Widening the approaches used to assess these stocks improved the quality of the assessment overall and indicated potential solutions to some problems, such as uncertainty estimates of stock size and modeling recruitment deviations.

Technical Deficiencies of the Assessment

Ageing data and growth estimates remain a weakness in the ability of the assessment to provide precise estimates. Additionally, understanding of the CCFRP survey and the factors that influence it are important components of the assessment process which might be improved by both collection of additional data and by alternative model formulations (as exemplified by time-blocking).

The Panel only superficially reviewed the model-based survey index standardization, by comparing design-based versus model-based estimates. However, details of the standardization may impact how the indices should be used in stock assessment models.

Areas of Disagreement Regarding STAR Panel Recommendations

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

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

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

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

Unresolved Problems and Major Uncertainties

Copper rockfish in the sub-areas north and south of Point Conception are being assessed as separate non-mixing sub-populations, but there is likely larval or juvenile dispersal, and potentially some adult movement among these areas. Dispersal and movement rates are not well known. Improved understanding around the dispersal rates of copper rockfish across California, particularly around Point Conception, are needed to support spatial modeling of the stock.

Age data are limited and consequently growth estimates are uncertain and the available age data contains insufficient information to reliably estimate natural mortality. There is some tension among limited data sources and types inferred by the likelihood profiles, with age data suggesting a higher natural mortality rate and length data suggesting a lower value, particularly for the area north of Point Conception. Conflicting signals in the information between length and age data is commonly encountered for many U.S. West Coast groundfish stock assessments. The mechanisms driving these differences are uncertain.

Each of the sub-area models estimates high recruitment events over the most recent decade, especially relative to previous time periods. The base model for the sub-area north of Point Conception estimated overall lower variation in recruitment relative to the model south of Point Conception. Oceanographic conditions likely drive periods of either poor or above average recruitment, particularly for rockfish species. However, it is unclear what conditions may be contributing to the differing levels of recruitment variation across the California coast.

Recommendations for Future Research and Data Collection

The panel supports the recommendations provided in the pre-STAR draft assessment (reproduced below). Additionally, with respect to recommendation No. 2, the Panel recommends considering the implications of management on each sub-area and how to present these to managers. There is uncertainty in catch estimates, and more so for historic periods and when interpolations are used to fill in catches for some years. This uncertainty was not quantified and provided to the Panel. There is an important need for STATs to provide information on the quality of the annual catch estimates, and more specifically to quantify the uncertainty in these estimates. This technical deficiency is common to all assessments reviewed by this Panel.

1. The NWFSC Hook and Line survey is the only long-term fishery-independent survey in rocky (untrawlable) habitat in the Southern California Bight. Efforts should continue to explore how best to model hook and line catch data to develop indices of abundance. We also recommend evaluating how to structure the NWFSC Hook and Line survey index, given its expansion into the cowcod conservation areas (CCAs) and increase in sites within designated marine protected areas (MPAs), and independent analysis of information content in NWFSC Hook and Line survey across observed species. Finally, increased spatiotemporal sampling around Point Conception would aid in identifying stock boundaries.

2. The assessment area south of Point Conception appears to have a mixture of observations from areas experiencing variable fishing mortality. In the region there are likely a mixture of areas: open access rocky reefs that are close to port that are heavily fished, open access rocky reefs that are inaccessible via day-trips that are fished but likely at lower levels, and rocky reefs that fall within MPAs. A spatially-explicit assessment model may be able to capture this complexity but will require data (indices of abundance and composition data) from each of the regions.

3. Future nearshore assessments would greatly benefit from additional CDFW remotely operated vehicle (ROV) surveys which could increase the power of these data to inform assessments.

4. There are very limited age data for copper rockfish across California arising from fishery dependent sources. Establishing regular collections of otoliths from the recreational fishery, a large source of mortality, would support future assessments and would improve the understanding of the population structure and life history of copper rockfish.

5. There is limited information for copper rockfish on maturity and fecundity and the variability of these parameters with increasing latitude. The NWFSC WCGBT and Hook and Line surveys provided the only available information on the maturity ogive and the timing of these surveys does not overlap with the expected peak spawning season. The Southwest Fisheries Science Center has egg samples from a total of ten copper rockfish, which is too few to draw conclusions regarding fecundity.

6. Some of the PR mode recreational data that should be available via the Recreational Fisheries Information Network (RecFIN) were found to contain information in that database inconsistent with datasheets available from CDFW. There is also a question if length data collected by the Deb Wilson-Vandenberg onboard observer survey is duplicated within RecFIN and attributed to Marine Recreational Fisheries Statistics Survey (MRFSS) dockside samples of the CPFV fleet.

7. The interpreted substrate data for the areas north of Point Conception within state waters is incomplete. Additional data needs include high resolution interpreted substrate maps for areas outside of state waters. The available interpreted bathymetry data from south of Point Conception is incomplete within state waters around the northern and southern Channel Islands. This poses a challenge for estimating available rocky substrate both by district and also inside and outside closed areas.

8. The genetic stock structure of copper rockfish warrants further investigation to ensure appropriate management of copper rockfish along the U.S. West Coast.

9. The Marine Recreational Fisheries Statistics Survey (MRFSS) index was excluded from both California assessment models. The standardized trends in abundance were marked by extreme peaks in the data throughout the time series that the STAT did not think represented the data. Additional investigations of the MRFSS dataset could help resolve some of the issues.

10. Additional research on the effect of the MPA network on copper rockfish and other nearshore rockfish species needs to be conducted. The trend inside the MPAs in northern California exhibited an increasing trend compared to outside the MPAs, similar to what was observed during the 2021 assessment of vermilion rockfish. However, the trends inside MPAs south of Point Conception varied by location with a number of sites showing no increase in abundance or declining trends.

11. Further investigations of other available fishery-independent data such as the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) kelp forest index would benefit future assessments of nearshore species, including copper rockfish.

12. Larval and smaller young-of-the-year copper rockfish can only be identified with certainty genetically. Existing sources of data (California Cooperative Oceanic Fisheries Investigations [CalCOFI] and Standard Monitoring Units for the Recruitment of Fishes [SMURFs]) where

genetic samples can be analyzed would provide key information to inform spawning output estimates for copper rockfish.

13. Continue to improve historical catch reconstructions, including attempting to quantify uncertainty with these and other historical data.

14. Existing catch estimates within the Recreational Fisheries Information Network (RecFIN) that are currently assigned only to "rockfish, general" should be investigated to determine if these removals can be assigned to specific-species.

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

If the next assessment occurs within 4-years, an update assessment would be appropriate.

The Panel supports designating the copper rockfish in California assessment as Category 1.

Acknowledgements

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

References

Monk, M.H., E.J. Dick, J.C. Field, E.M. Saas, T.L. Rogers. 2021. The status of Vermilion Rockfish (*Sebastes miniatus*) and Sunset Rockfish (*Sebastes crocotulus*) in U.S. waters off the coast of California north of Point Conception in 2021. Pacific Fisheries Management Council, Portland, Oregon.

Dick, E.J., M.H. Monk, T.L. Rogers, J.C. Field, E.M. Saas. 2021. The status of Vermilion Rockfish (*Sebastes miniatus*) and Sunset Rockfish (*Sebastes crocotulus*) in U.S. waters off the coast of California south of Point Conception in 2021. Pacific Fisheries Management Council, Portland, Oregon.

Rex Sole

Overview

A Stock Assessment Review (STAR) Panel met June 5-9, 2023, in-person at the Northwest Fisheries Science Center Auditorium with a remote participation option to facilitate public comment for those unable to travel to Seattle, WA. In addition to a data-moderate assessment for rex sole, the panel also reviewed two full benchmark assessments for copper rockfish in California and a data-moderate assessment for shortspine thornyhead. The panel operated under the Pacific Fishery Management Council's (PFMC) Terms of Reference (TOR) for the Groundfish Stock Assessment Review Process for 2023-2024.

Rex sole was last assessed in 2013 using extended Simple Stock Synthesis, a data-moderate assessment method, and incorporated removals (landings and discards not distinguished) and indices of abundance from fishery-independent trawl surveys. The assessment fixed most life history parameters, and estimated posterior distributions for sex-specific natural mortality, steepness, and relative stock status in 2013 using Sampling-Importance Resampling based on the fits to the index of abundance data. The 2013 assessment estimated the stock to be at approximately 80% of virgin biomass.

Summary of Data and Assessment Models

The assessment for the single stock of rex sole applies to the West Coast of the United States (U.S.) from the U.S.-Canada border to the U.S.-Mexico border. All data sources included in the base model for rex sole were re-evaluated for this assessment, including improvements in the data and associated analyses. A single fishery was modeled with landings starting in 1916, length compositions of landings since 2003 (none in 2021), discard rates from 2002 through 2021, and discard mean weights from 2002 through 2021 (Figure 18). For the catch data, this assessment included a newly available catch reconstruction for Washington landings from 1948-1980 and an updated catch reconstruction from Oregon for 1929-1980. Abundance indices were calculated using Species Distribution Models with (sdmTMB) (Anderson et al. 2022).

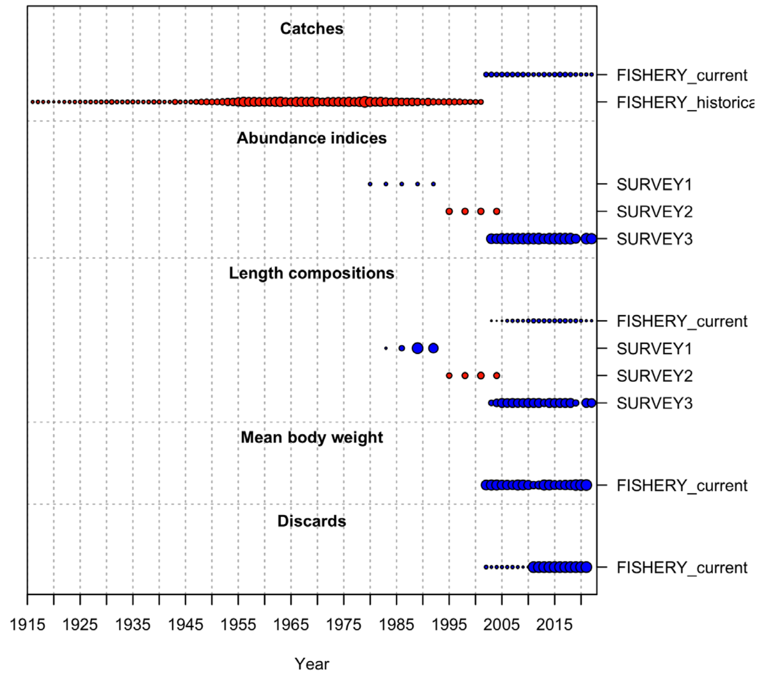


Figure 18: Data sources and years used in the U.S. West Coast rex sole stock assessment. Circle size is proportional to the amount (catches) or precision.

The definition of fishing fleets changed in this assessment relative to the 2013 assessment. Two fishing fleets are now defined in the model: one historical coastwide fishery (removals from 1916-2001 including landings and discards) and one current coastwide fishery (landings and discards modeled separately for 2002-2022). This change was made to facilitate the inclusion of discard data from the West Coast Groundfish Observer Program (WCGOP), which began collecting data in 2002.

Biological parameters and relationships were determined from published literature and recent data collections. Maturity and fecundity parameters were updated to U.S. West Coast-specific parameter values (Hosie and Horton 1977), rather than using parameter values from studies conducted in Alaska, as was done in the last stock assessment. The length-weight relationship was estimated externally using data from 2007 to 2022 (with the exception of 2020 due to no survey in that year) collected by the West Coast Groundfish Bottom Trawl Survey (WCGBTS). Age data from the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS) were used to estimate sex-specific growth curves for U.S. West Coast rex sole using 620 age-length observations collected from the years 2007 to 2019. The otoliths were sampled to represent a wide range of lengths and thus preferentially sampled small and large fish. The majority of these data came from the years 2017-2019. Earlier years were used to fill in ages for the smallest and largest lengths. Natural mortality was determined from the median of the Hamel and Cope (2022) prior using a maximum age of 29, which was consistent with the literature and the 2013 assessment (although one fish from the WCGBTS was aged at 33 years old).

The stock assessment for rex sole used Stock Synthesis version 3.30.21 and estimated R_0, selectivity, retention, extra standard error for the early and late Triennial surveys, and recruitment deviations. All life history parameters were fixed in the pre-STAR base model. The assessment was classified as a data moderate Category 2 assessment, meaning that age data are encouraged to be used externally to inform parameter values (see page 33 of the TOR).

Fits to the data were poor in the pre-STAR assessment and the catchability (*q*) for the WCGBTS was fixed at 3 because it was estimated at a value greater than 19. Patterns in residuals were observed in the fits to the WCGBTS index and in the Pearson residuals for the fits to the WCGBTS length compositions (Figure 19). The predicted length comps overpredicted the proportion of large fish and underpredicted the proportion of small fish.

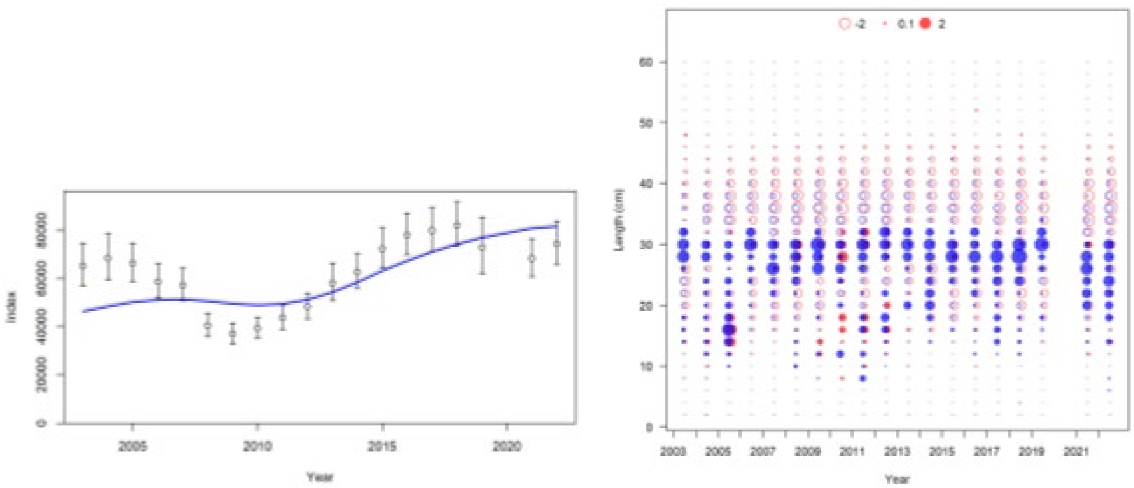


Figure 19: Fit to index data for the West Coast Groundfish Bottom Trawl Survey (left) and Pearson residuals for length composition from the West Coast Groundfish Bottom Trawl Survey (right) for males (blue) and females (red). Closed bubbles are positive residuals (observed > predicted) and open bubbles are negative residuals (observed < predicted).

The estimated spawning output trajectory declined slowly from 1916 to the mid-1950's, and then declined quickly to below the management target (25% of unfished spawning output) in the late 1970's, and further declined to a level below the minimum stock size threshold (10% of unfished spawning output) in the early 1990's. Since 2000, the spawning output has increased rapidly with a short stable period from 2007 to 2011. The spawning output in 2023 was estimated at 76.5% of unfished spawning output. Fishing intensity (i.e., spawning potential ratio [SPR]) was above target in the 1980's and 1990's, but declined to less than 50% of the target in recent years.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: STAT will update the latitudinal strata for the WCGBTS length compositions to the correct latitudinal strata, as is outlined in Appendix B of the pre-STAR assessment document. STAT will also update the Washington historical catch reconstruction as outlined in Appendix B of the pre-STAR assessment document to remove double-counted catches.

Rationale: Incorporate the strata by sampling design and updated information on historical catch.

STAT Response: Starting from the pre-STAR base model presented in the assessment document draft and presented to the Panel, the STAT developed two models sequentially. In the first model (Figure 20; red line), length compositions were updated following advice to use a latitudinal split at 34.5° N, rather than 42°N. In the second model (Figure 20; green line), catch data were updated to fix the issue of double-counting WA landings during 1956-1980. The model with updated latitudinal strata was almost identical to the base model, which reflected very minor differences in the updated length composition data. The model with updated catch was also very similar to the base model, with no significant effects on derived quantities and fits. The second model (green line in Figure 20) was used as the base model for subsequent requests.

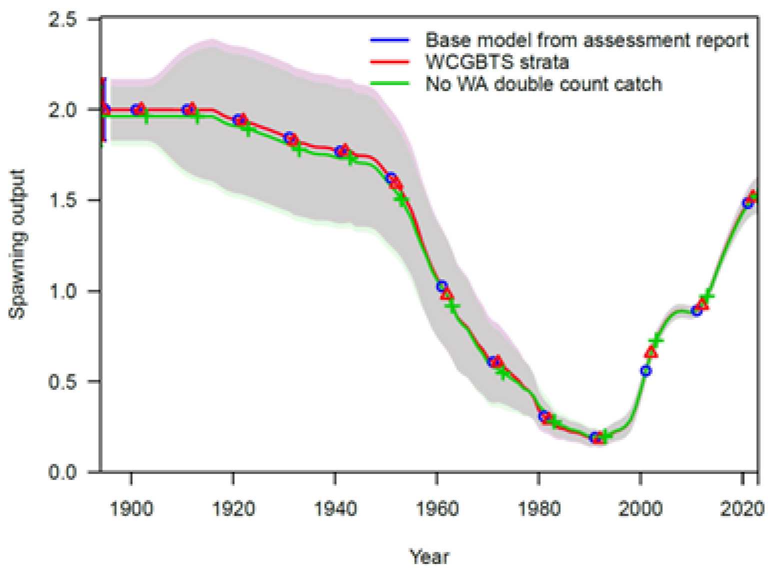


Figure 20. Spawning output from the prior pre-STAR base model, the model with updated WCGBTS strata for length compositions, and model with updated catch. The green line is the new base model used for following requests.

Panel conclusion: The Panel agreed with the STAT to include these updates.

Request No. 2: Provide two separate graphics with the fitted growth curve for males and females, with data.

Rationale: To examine the fits more closely by sex.

STAT Response: Male and female observations were plotted separately to allow for a closer examination of the fitted growth curve (Figure 21). When considering Request No. 5 below, we also plotted the distribution and median-lengths-by-sex of the aged fish and all fish (Figure 22). The median length for aged females was higher by 2.5 cm than the median for all lengths and the median length for aged males was lower by 3.5 cm. This difference is consistent with sub-sampling the fish by length for ages to be better able to estimate the L1 and L2 parameters, but may have introduced bias into our estimation of growth outside the model (Figure 22).

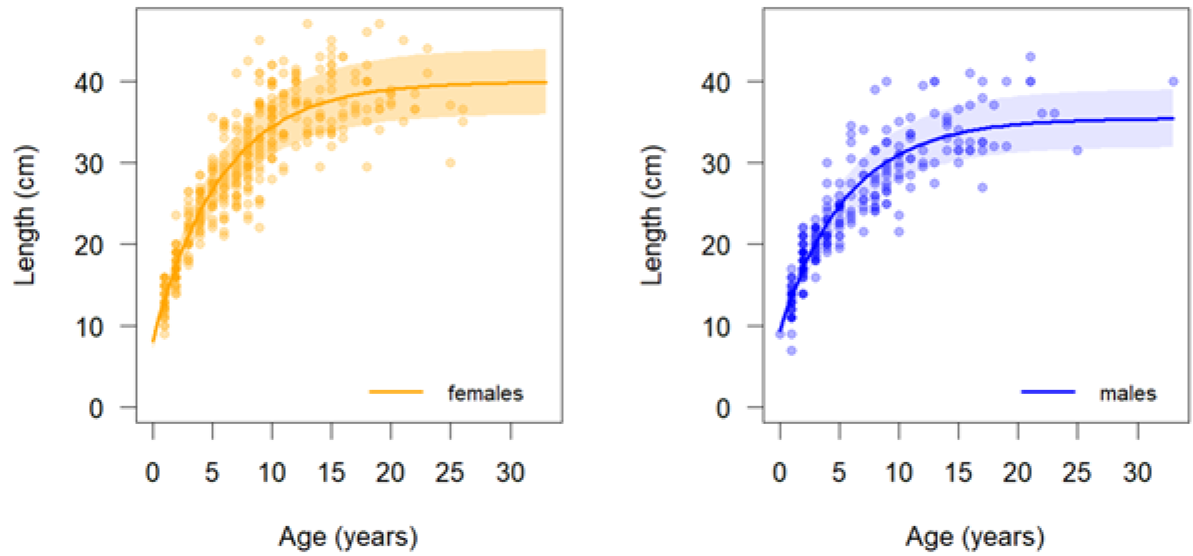


Figure 21. Sex-specific growth curves fit external to the assessment model using data from the WCGBTS. Female n = 370, male n = 250. Shaded areas represent +/- 10% length-at-age used in growth sensitivities.

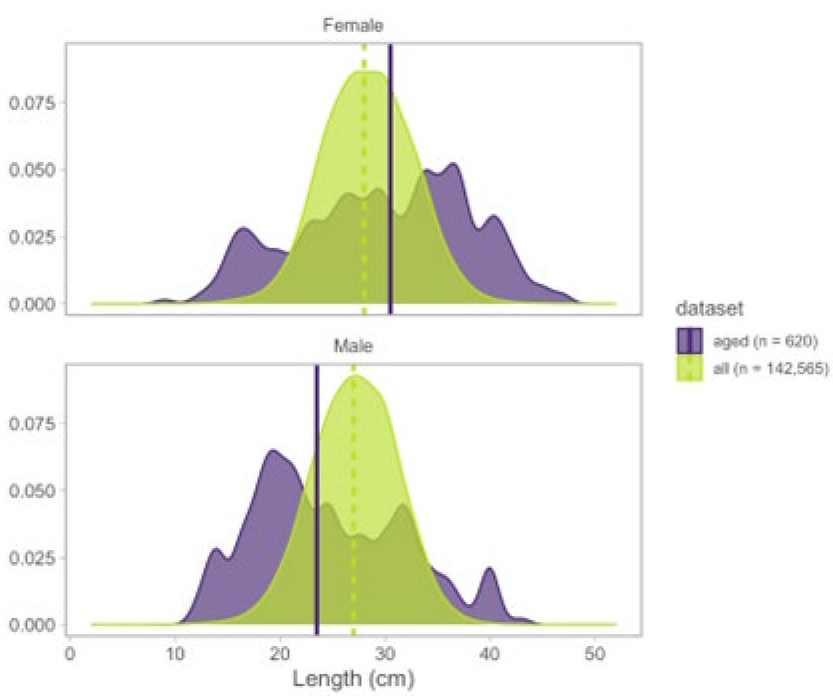


Figure 22. Lengths for all WCGBTS samples (yellow) and for fish sub-sampled for aging (purple) of females (top) and males (bottom). Vertical lines represent median length. Aged fish n = 620; all WCGBTS length n = 142,565.

Panel Conclusion: The Panel appreciated seeing the fits for each sex and the extra analysis the STAT provided looking at the range of lengths sampled for each sex. The Panel remains concerned about potential bias in the estimates of growth given preferential sampling of large and small fish.

Request No. 3: Estimate dome-shaped selectivity for the fisheries, Triennial early, and Triennial Late fleets. Force asymptotic selectivity for the WCBTS and estimate catchability using the 'float' option. Include these options in further requests.

Rationale: The 'top' parameter in the control file for the Triennial Late fleet was fixed at 15, which would probably not allow for dome-shaped selectivity regardless of any other parameter values. The fishery may be dome-shaped given the spatial footprint of the fisheries. It may be useful to estimate the final parameter to allow for some selectivity at the largest ages. We leave it to the STAT to determine the best parameterizations. For future requests, it would be useful to have these possibly be dome-shaped while investigating the influence of the WCGBTS.

STAT Response: The STAT updated the size selectivity parameters to reflect the requested selectivities (dome-shaped selectivity for all fleets except for the WCGBTS), and estimated q using the "float" option. For the fishery, which has sex-specific selectivity curves, three different parameterizations were explored. The first parameterization was the "base case", which fixed parameter 2 (the width of the plateau) to -15, estimated parameters 1, 3, and 4, and set parameters 5 and 6 to -99 to ignore these parameters and have the right half of the selectivity curve represented by parameters 3 and 4, and estimated only the first two male offset parameters (thus, allowing the left half of the male selectivity curve to vary from the female selectivity curve, but forcing the right half of the male selectivity curve [which is controlled by parameters 3 and 4] to mimic that of the female selectivity curve). The second parameterization was the same as the "base case", but with parameter 2 estimated. The third parameterization was the same as the "base case", but allowed male offset parameters 3 and 4 to be estimated, thereby freeing the male fishery selectivity from the previously mentioned constraints.

The estimated selectivity curves for the fishery are quite different, with the fishery selectivity being essentially asymptotic in the "base case" parameterization (Figure 23, 24, 25). For the base case, WCGBTS q was estimated to be 15.1, and a Hessian matrix was estimated; for the other two parameterizations, WCGBTS q was above 30 and no Hessian matrix was estimated. Fits to the WCGBTS index were very similar, but fits to the WCGBTS length composition data were much better for the two other models than in the "base case" (Figure 26, 27, 28).

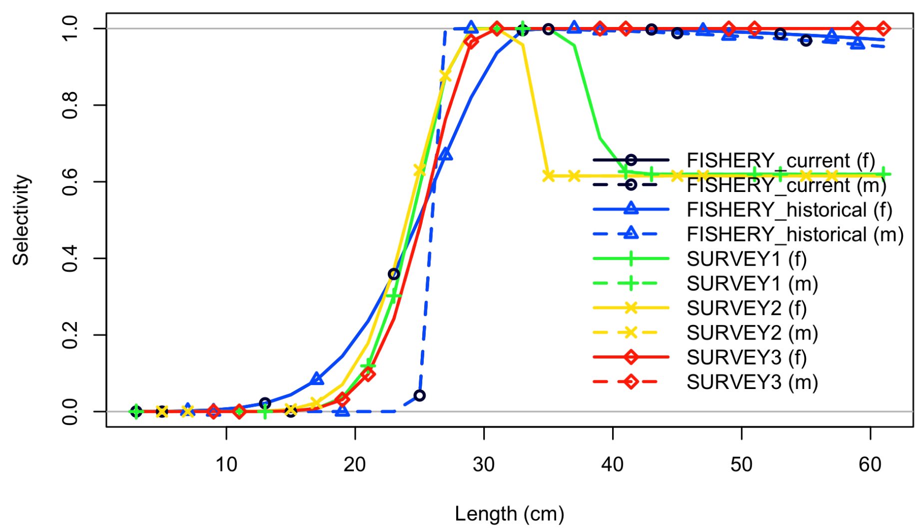


Figure 23. “Base case” estimated selectivity curves for STAR panel request 3 (dome-shaped selectivity for all fleets except WCGBTS).

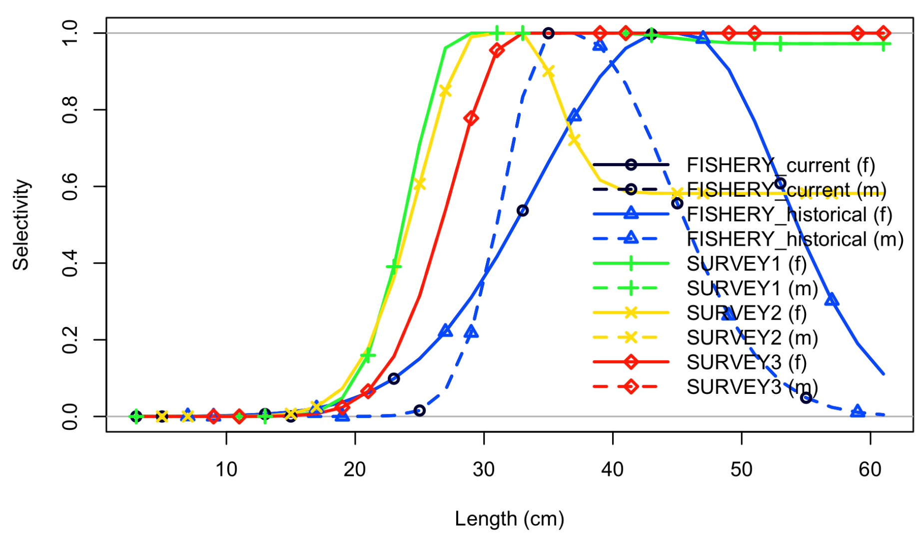


Figure 24. Estimated selectivity curves, with fishery parameter 2 estimated for STAR panel request 3 (dome-shaped selectivity for all fleets except WCGBTS).

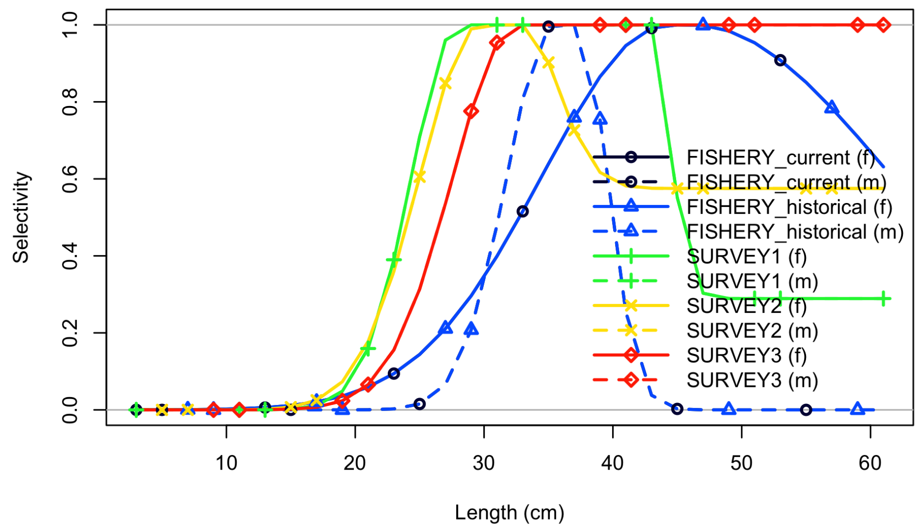


Figure 25. Estimated selectivity curves, with male offset parameters 3 and 4 estimated for STAR panel request 3 (dome-shaped selectivity for all fleets except WCGBTS).

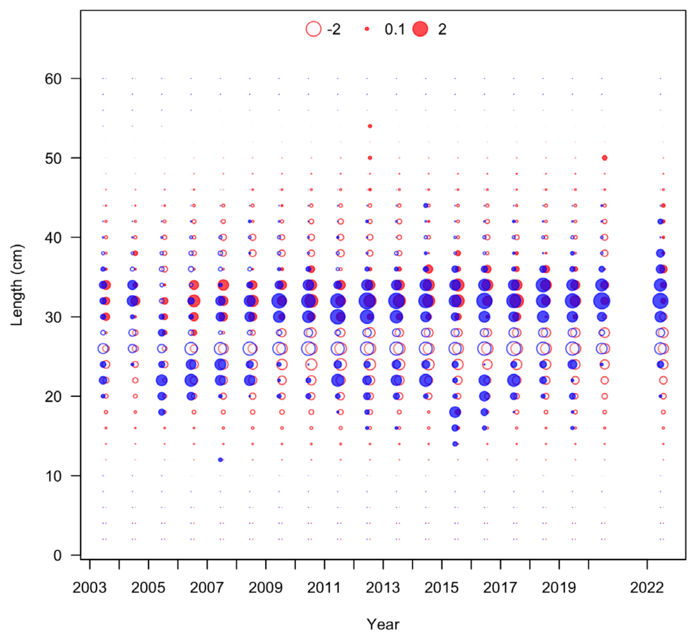


Figure 26. “Base case” model Pearson residuals for the WCGBTS for males (blue) and females (red) for STAR panel request 3 (dome-shaped selectivity for all fleets except WCGBTS). Closed bubbles are positive residuals and open bubbles are negative residuals.

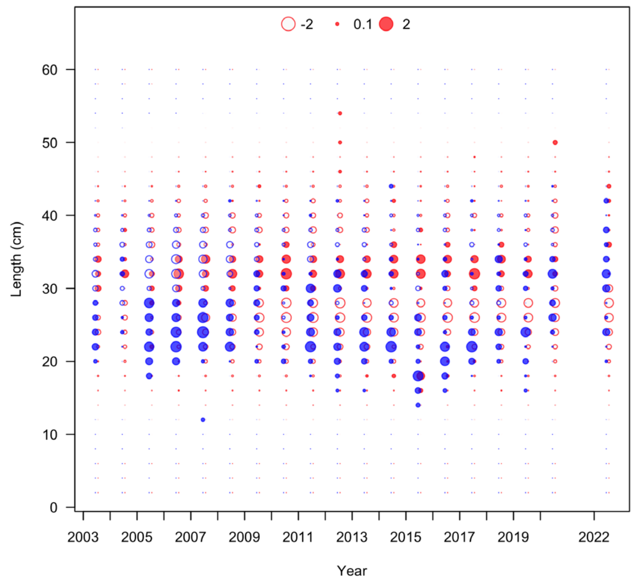


Figure 27. For the model with fishery selectivity parameter 2 estimated, Pearson residuals for the WCGBTS for males (blue) and females (red) for STAR panel request 3 (dome-shaped selectivity for all fleets except WCGBTS). Closed bubbles are positive residuals and open bubbles are negative residuals.

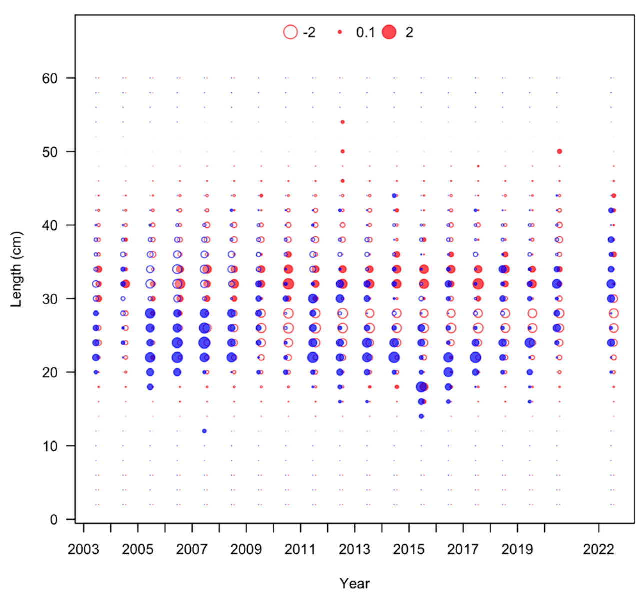


Figure 28. For the model with fishery male offset selectivity parameters 3 and 4 estimated, Pearson residuals for the WCGBTS for males (blue) and females (red) for STAR panel request 3 (dome-shaped selectivity for all fleets except WCGBTS). Closed bubbles are positive residuals and open bubbles are negative residuals.

Panel conclusion: There was a slight improvement to the length composition residuals, but the concerns of fits to the WCGBTS still exist.

Request No. 4: Estimate dome-shaped selectivity for all fleets and estimate catchability using the 'float' option.

Rationale: A pattern in residuals of overfitting all length compositions was observed. One potential solution is dome-shaped selectivity, noting that there are other potential solutions as well.

STAT Response: The STAT updated the size selectivity parameters to reflect the requested selectivities (dome-shaped selectivity for all fleets), and estimated q using the "float" option. For the fishery, which has sex-specific selectivity curves, three different parameterizations were explored. The first parameterization was the "base case", which fixed parameter 2 (the width of the plateau) to -15, estimated parameters 1, 3, and 4, and set parameters 5 and 6 to -99 to ignore these parameters and have the right half of the selectivity curve represented by parameters 3 and 4, and estimated only the first two male offset parameters (thus, allowing the left half of the male selectivity curve to vary from the female selectivity curve, but forcing the right half of the male selectivity curve [which is controlled by parameters 3 and 4] to mimic that of the female selectivity curve). The second parameterization was the same as the "base case", but with parameter 2 estimated. The third parameterization was the same as the "base case", but allowed male offset parameters 3 and 4 to be estimated, thereby freeing the male fishery selectivity from the previously mentioned constraints.

The estimated selectivity curves are quite similar for the "base case" and for the model with the male offset parameters estimated (Figure 29, 31), but for the model with parameter 2 estimated, the male and female selectivities for the fishery are essentially flipped (Figure 30). This resulted in much worse fits to the length compositions for the model with parameter 2 estimated (Figure 33) than for the other two models (Figure 32, 34), which were very similar. A Hessian matrix was estimated for all three models that had all fleets dome-shaped selectivity, and q was estimated to be 6.75, 4.42, and 6.01 for the "base case", parameter 2 estimated, and male offset parameters estimated models, respectively. The population trajectories and fits to the WCGBTS index were similar across all three models.

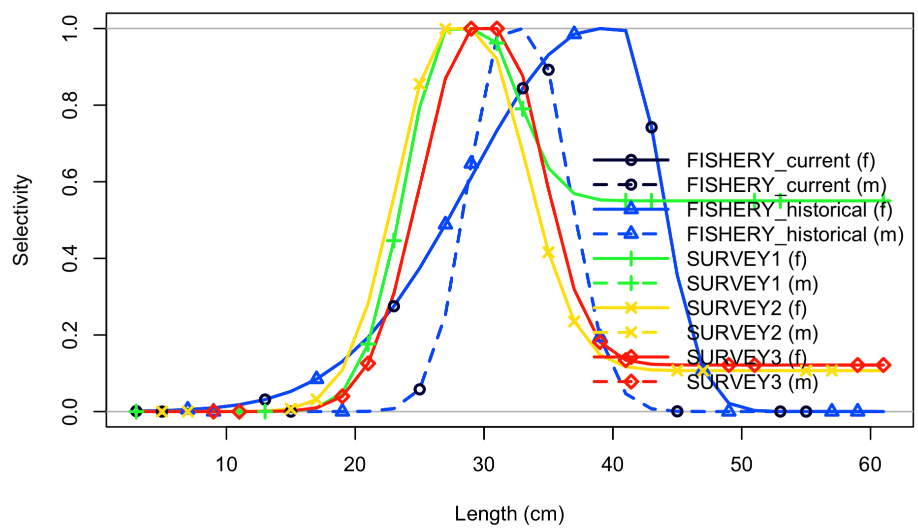


Figure 29. "Base case" estimated selectivity curves for STAR panel request 4 (dome-shaped selectivity for all fleets).

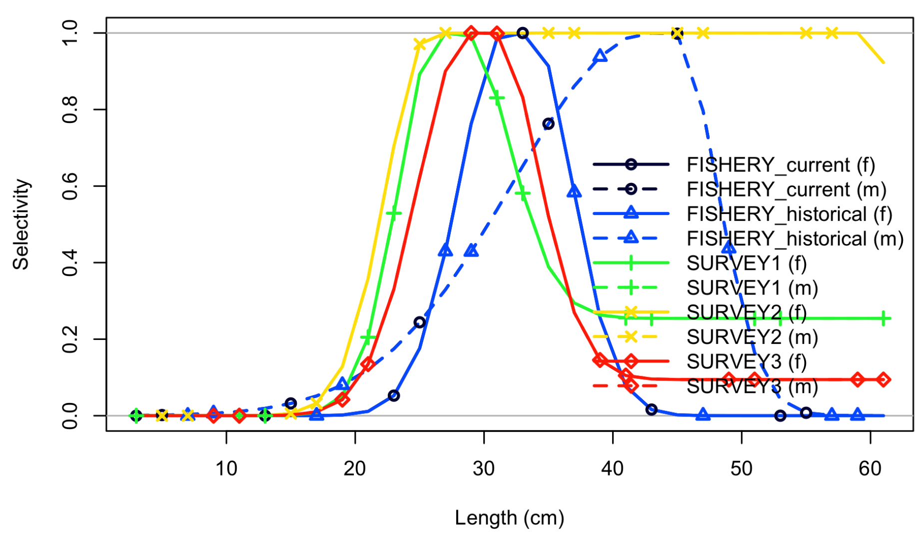


Figure 30. Estimated selectivity curves, with fishery parameter 2 estimated for STAR panel request 4 (dome-shaped selectivity for all fleets).

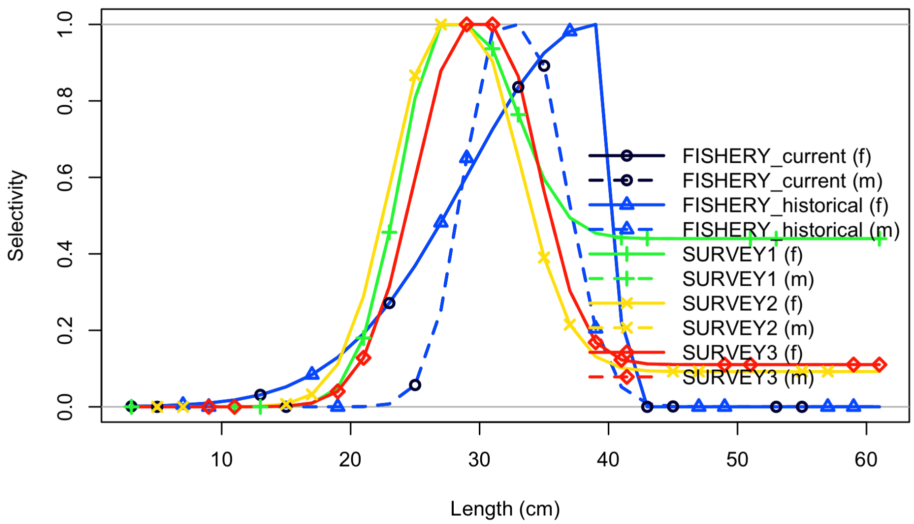


Figure 31. Estimated selectivity curves, with male offset parameters 3 and 4 estimated for STAR panel request 4 (dome-shaped selectivity for all fleets).

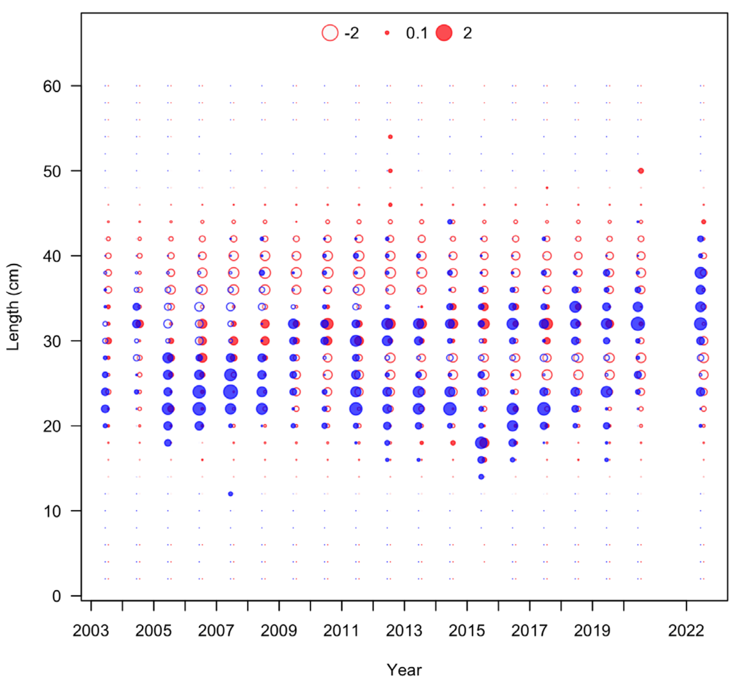


Figure 32. "Base case" model Pearson residuals for the WCGBTS for males (blue) and females (red) for STAR panel request 4 (dome-shaped selectivity for all fleets). Closed bubbles are positive residuals and open bubbles are negative residuals.

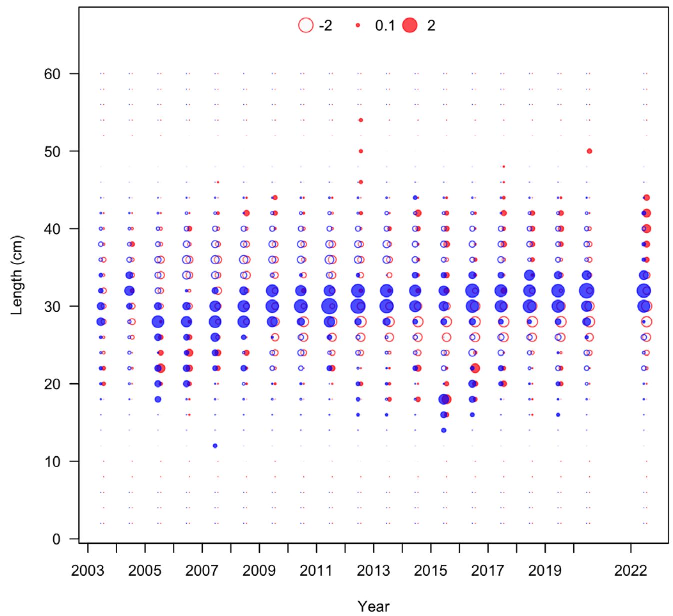


Figure 33. For the model with fishery selectivity parameter 2 estimated, Pearson residuals for the WCGBTS for males (blue) and females (red) for STAR panel request 4 (dome-shaped selectivity for all fleets). Closed bubbles are positive residuals and open bubbles are negative residuals.

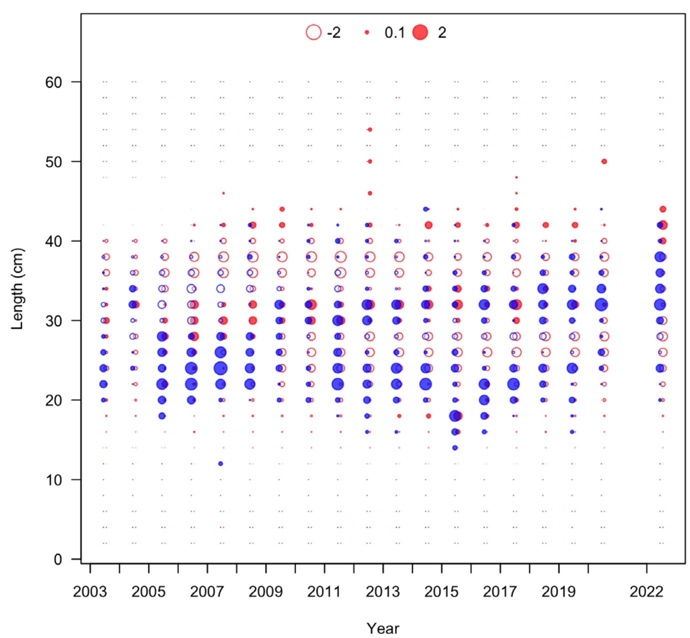


Figure 34. For the model with fishery male offset selectivity parameters 3 and 4 estimated, Pearson residuals for the WCGBTS for males (blue) and females (red) for STAR panel request 4 (dome-

shaped selectivity for all fleets). Closed bubbles are positive residuals and open bubbles are negative residuals.

Panel conclusion: The pattern in the Pearson residuals for the length comps were slightly improved with dome-shaped selectivity for all fleets. However, the Panel questioned why the WCGBTS would have dome-shaped selectivity when it likely covers the offshore extent of rex sole.

Request No. 5: Fit female and male growth curves in the assessment model using conditional age-at-length from the WCGBTS (e.g. the same data that were used for the external analysis). Assume that ages are known without error. Perform two runs as specified in requests 3 and 4 above: one with asymptotic selectivity for the WCGBTS, and another estimating dome-shaped selectivity for the WCGBTS (in later phases). Estimate dome-shaped selectivity for all other fleets.

Rationale: Length-stratified sampling of ages along with external estimation of growth and not accounting for selectivity may produce biased estimates of growth parameters. Estimating growth in the assessment may alleviate these concerns and produce different parameter estimates that may improve fits to data. However, it is not expected that estimating growth internal to the assessment model would be considered as a base model, but be used to inform the growth curve used in the base model.

STAT Response: The STAT incorporated conditional age-at-length data from the WCGBTS into the model and estimated growth internally. This analysis was done on models developed to address requests 3 and 4: dome-shaped selectivities for all fleets and for all fleets except WCGBTS. Both models with internally estimated growth curves have poor fit to the available age-length data when the growth curves were estimated externally, with both internally estimated curves being estimated lower (Figure 35). When estimating growth internally, all fleet selectivities are nearing asymptotic selectivity and the selectivity curves are similar between the 2 growth estimated models (Figure 36, 37). WCGBTS as dome was functionally asymptotic, which explains the very similar growth curves. The internally estimated growth curves may fit the true U.S. West Coast rex sole age-length relationship better than external estimates because the available age data are biased toward longer females and shorter males due to the length-stratified subsampling of otoliths selected for ageing compared to lengths of all rex sole collected by the WCGBTS.

Length composition fits of both internally estimated growth models are very similar and thus reported only in Figure 38. Length composition fits are improved from the base model. Age composition fits are rather poor given the low sample size, but acceptable in 2017, 2018 and 2019, when we have more than 80 sampled fish (Figure 39).

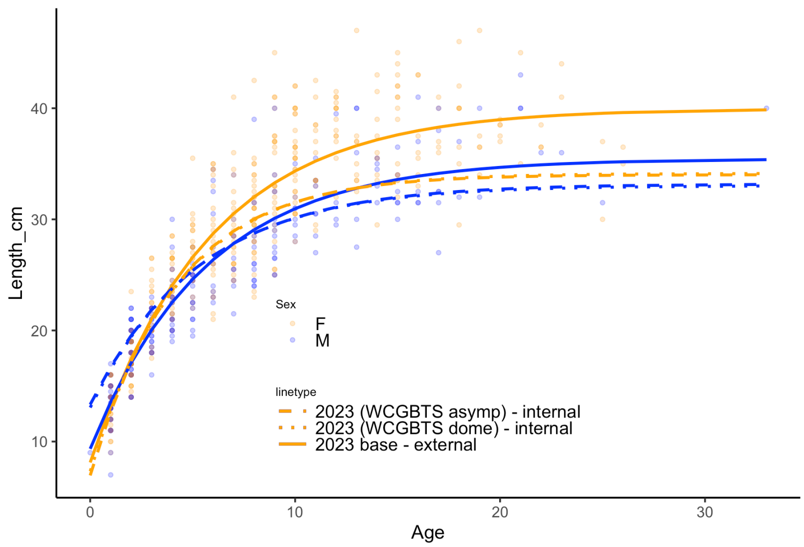


Figure 35. Growth curves estimated within the model (dashed lines) and externally (solid lines). Females in orange, males in blue.

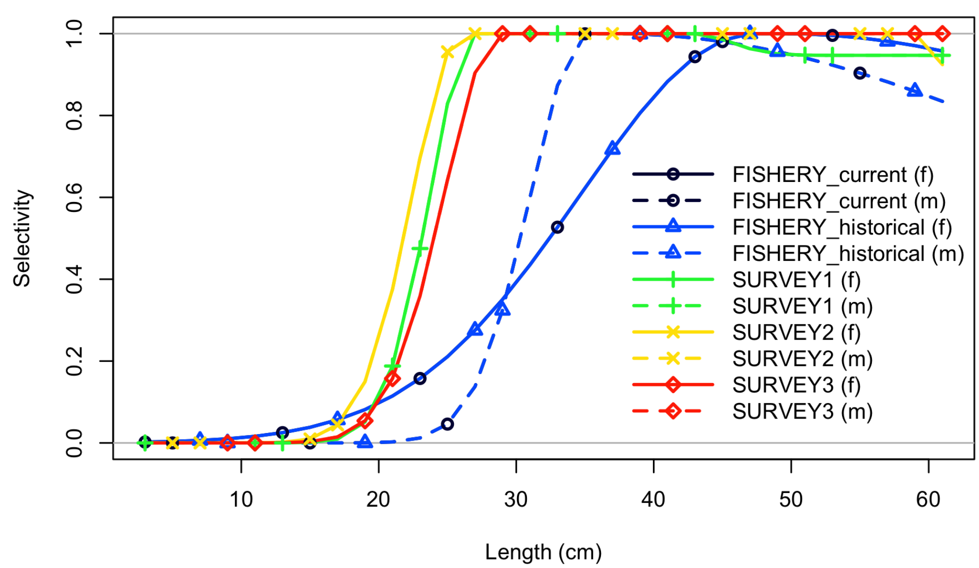


Figure 36. Selectivity of the internally estimated growth with all fleets dome-shaped fixed plateau except the WCGBTS, which is fixed to asymptotic.

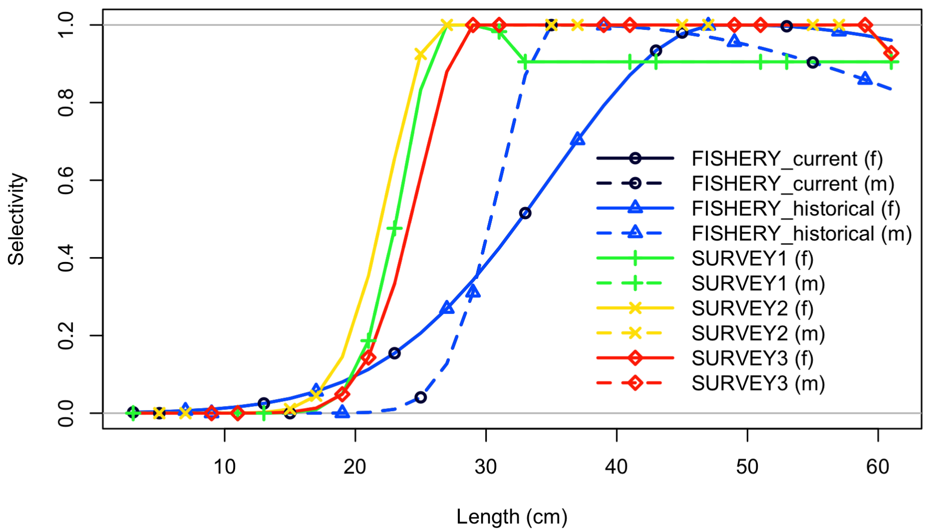


Figure 37. Selectivity of the internally estimated growth with all fleets dome-shaped fixed plateau including the WCGBTS. Note the similarities in selectivities between Figure 36 and 37. The WCGBTS dome shaped selectivity is essentially asymptotic.

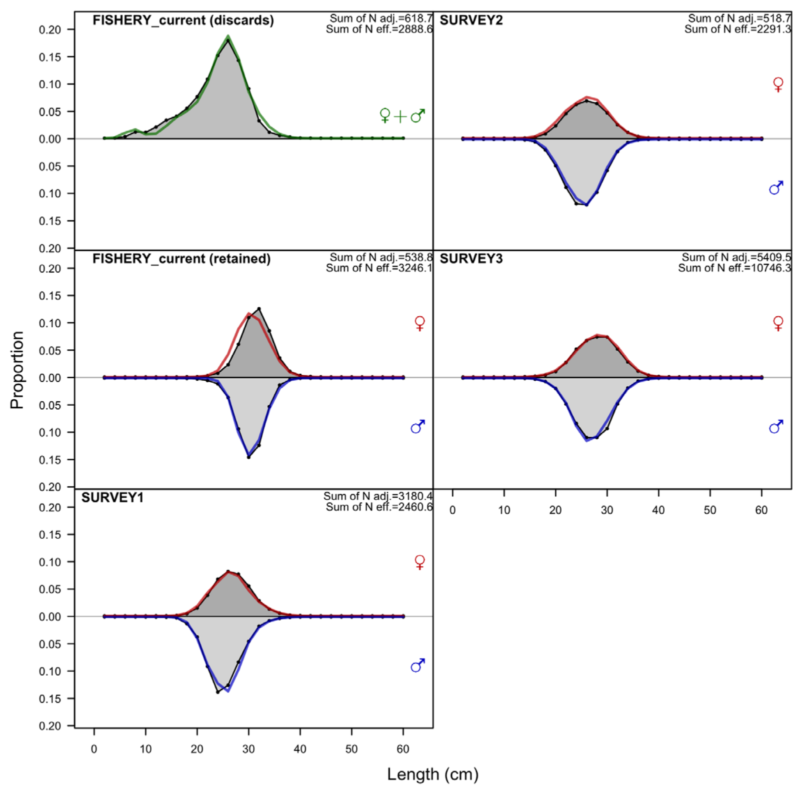


Figure 38. Length compositions where all selectivities were dome shaped except WCGBTS and growth was estimated internal to the model.

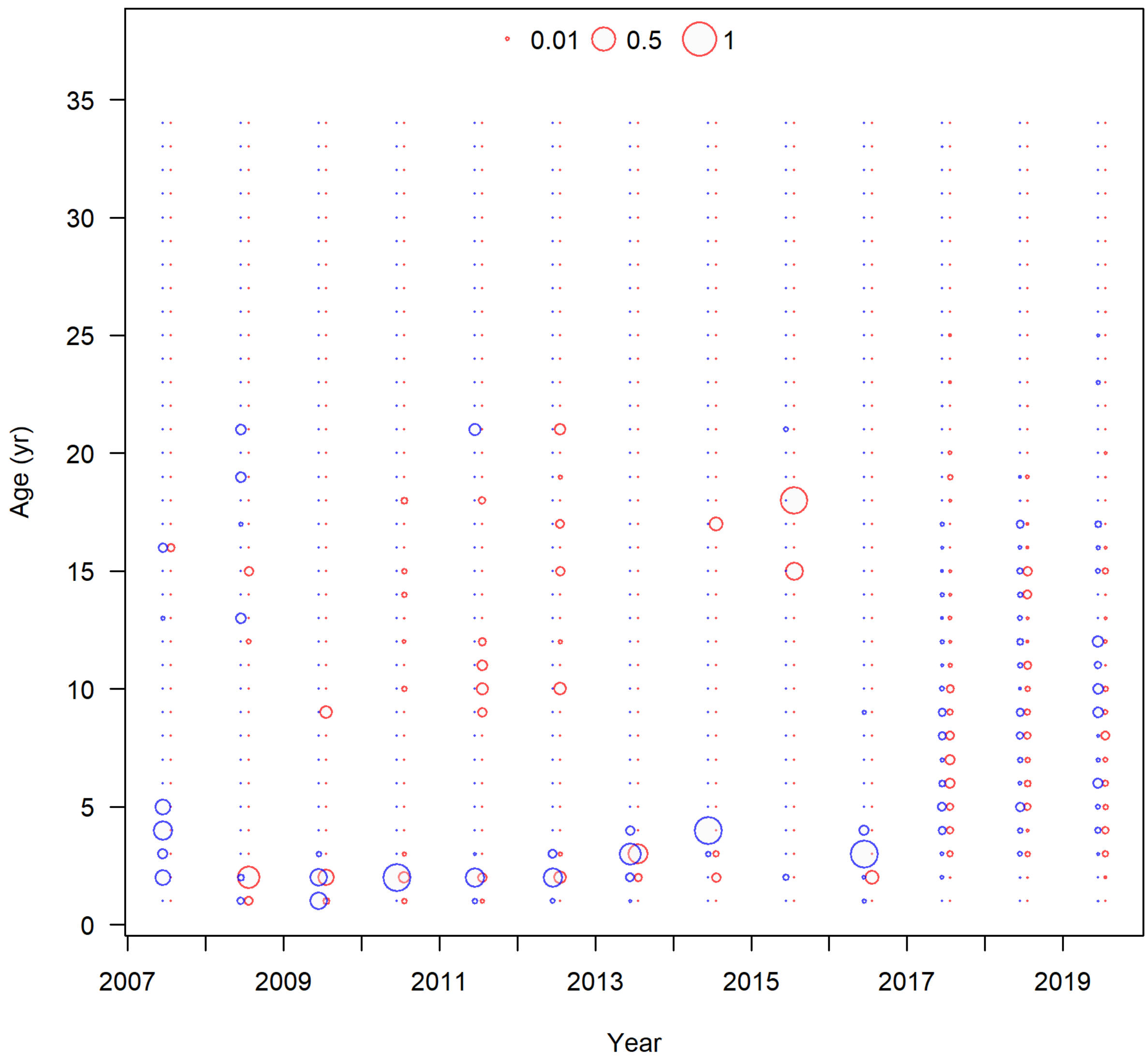


Figure 39. Age composition fits of the internally estimated growth model.

Panel conclusion: The estimates of growth changed in the direction expected (e.g. lower Linf; Perreault et al. 2020) given preferential sampling, selectivity was estimated nearly asymptotic, fits to the survey index were improved with a catchability below 4.0, and fits to the length comps improved (see Figure 38). The Panel agreed that the estimation of growth in the model was useful and provides a better assessment model. Subsequent model runs fixing growth at these estimates were not satisfactory due to lack of convergence, indicating that including the age data in the model was helpful.

Request No. 6: Investigate whether a higher sigmaR can improve fits to the WCGBTS indices and length compositions. Apply to the best alternative(s) from prior requests.

Rationale: Improved fitting may be good but requires panel review.

STAT Response: STAT used the model developed in STAR panel request No. 4 to explore different fixed values of sigmaR. Three different sigmaR values were investigated, 0.45, 0.55, and 0.65. There was a marginal decrease in the log-likelihood when sigmaR was fixed at 0.45 (Table 13). In each scenario, increased sigmaR led to a lower stock status (Figure 40). Increased sigmaR did not improve fits to WCGBTS index or length compositions (Figures 41, 42).

Table 13. Likelihood values for models where all fleets had dome-shaped selectivity. Models varied in the fixed value of sigmaR (0.4, 0.45, 0.55, 0.65 from left to right).

Label	**est.dome.all.fleets**	**est.dome.all.fleets.sigmaR0.45**	**est.dome.all.fleets.sigmaR0.55**	**est.dome.all.fleets.sigmaR0.65**
TOTAL_like	83.3444	83.1887	83.6133	196.308
Recr_Virgin_millions	53.5796	51.988	50.279	46.1017
SR_LN(R0)	10.8889	10.8588	10.8253	10.7386

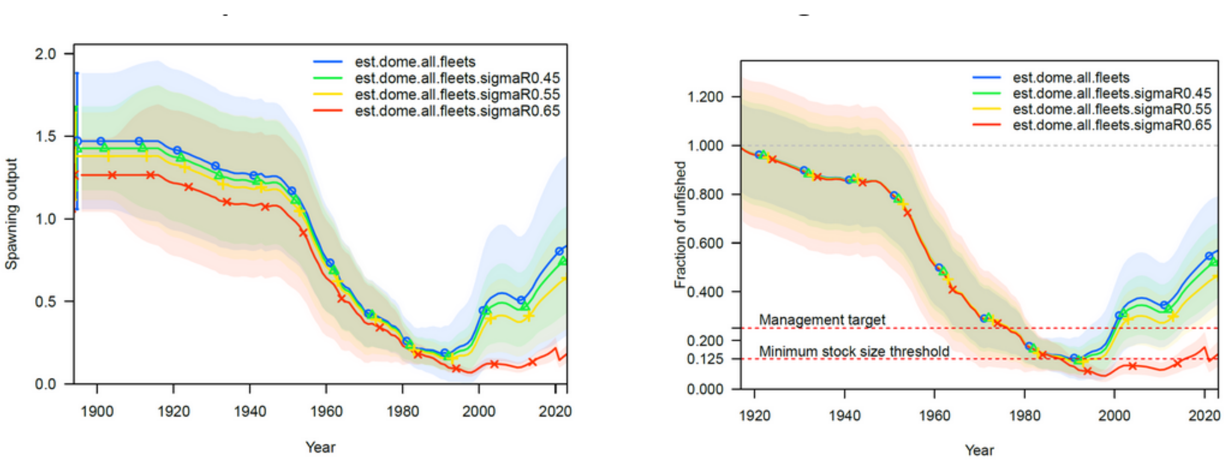


Figure 40. Spawning output and fraction of unfished for sensitivity runs exploring increased values of sigmaR.

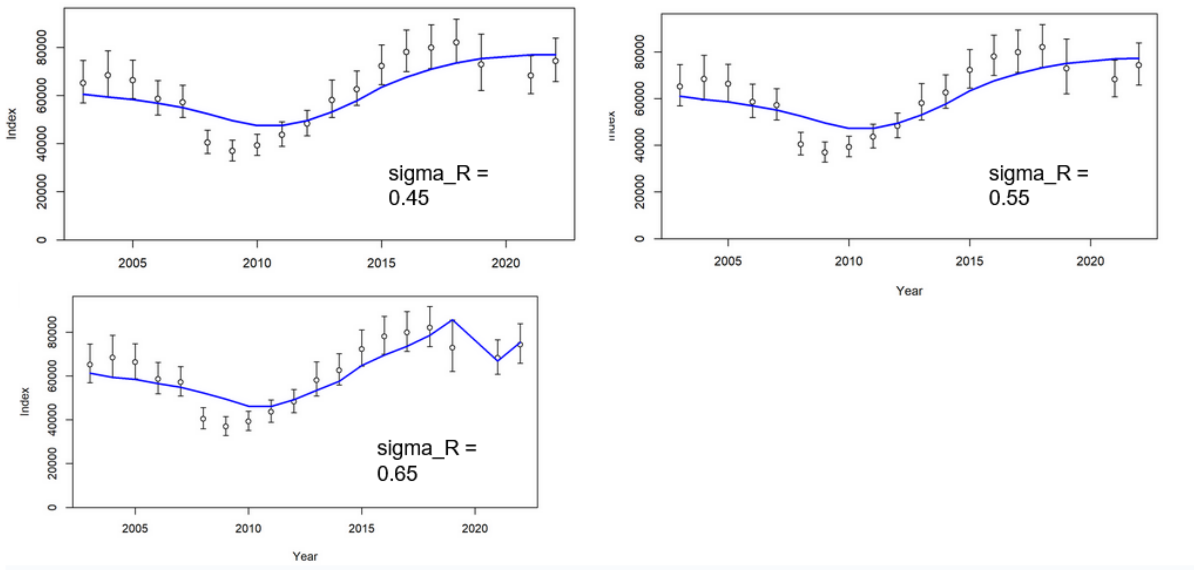


Figure 41. WCGBTS index fit for the three sensitivity runs exploring increased sigmaR values.

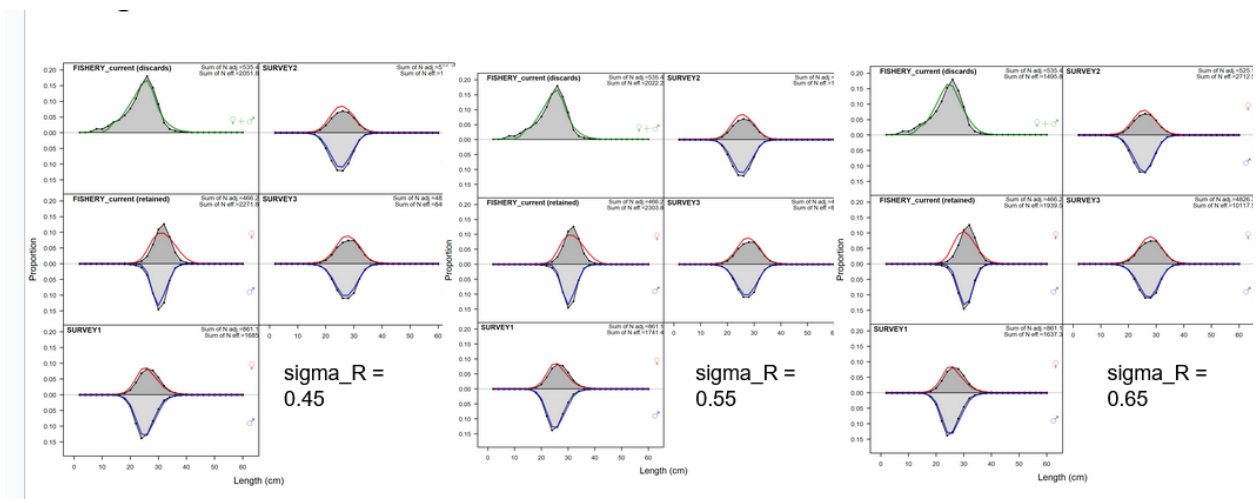


Figure 42. WCGBTS length composition fits for sensitivity runs exploring different sigmaR values.

Panel conclusion: This model supported a sigmaR near 0.4 and increasing sigmaR either did not improve the assessment model or resulted in patterns of estimated quantities that were unexpected.

Request No. 7: Perform reweighting of the models from Request No. 5 with conditional age-at-length data (CAAL) and internally estimated growth for two selectivity assumptions, 1) estimating dome-shaped selectivity for all fleets and 2) fixing selectivity asymptotic for all fleets. Reweight the data according to best practices and provide details of how the different data sources were weighted. Determine sigmaR using current best practices and present the root mean square error (RMSE) table for recruitment periods reported in r4ss output. Present fits to length compositions and index data, the estimated growth curves, and time-series trajectories. Please provide the model files and present any other interesting aspects to the STAR panel.

Rationale: There are some patterns in recruitment that would be worthwhile to examine and determine if there are any changes to recruitment estimates given changes to the base model. One concern is the recent period of low estimated recruitment, and whether that is being influenced by modeling assumptions. Examination of the specifications of recruitment is warranted.

STAT Response: Reweighting was performed after the addition of the CAAL data, and the model was fit with both selectivity assumptions (i.e., all fleets dome-shaped selectivity, and all fleets asymptotic selectivity). Reweighting was performed using Francis weighting in the tune_comps() function in r4ss. Data weights are provided in Table 14, and gave the most weight to length compositions from the early Triennial survey and the age compositions from the WCGBTS. The sigmaR tables are provided in Table 15 (for the all dome-shaped selectivity option) and in Table 16 (for the all asymptotic selectivity option); based on these results, we updated sigmaR to be 0.6 for the all asymptotic selectivity run, but kept sigmaR at 0.4 for the all dome-shaped selectivity run. The selectivity curves for the all dome-shaped selectivity run and all asymptotic selectivity run are shown in Figure 43 and Figure 44, respectively. The selectivity curves for both model runs appeared reasonable (Figure 43, 44).

Table 14. Data weights from Francis weighting, used for both selectivity options.

Data type	Fleet	Value
Length compositions	Fishery (current)	0.050633
Length compositions	Triennial (early)	1.41774
Length compositions	Triennial (late)	0.147707
Length compositions	WCGBTS	0.234541
Age compositions	WCGBTS	1.63867

Table 15. SigmaR info table for the all dome-shaped selectivity option.

Period	N_devs	SD_of_devs	Var_of_devs	mean_SE	mean_SEsquared	sqrt_sum_of_components	SD_of_devs_over_sigma_R	sqrt_sum_over_sigma_R	alternative_sigma_R
Main	43	0.329	0.109	0.230	0.060	0.410	0.824	1.025	0.410
Early+Main	121	0.196	0.196	0.337	0.122	0.401	0.491	1.002	0.401
Early+Main+Late	123	0.195	0.195	0.338	0.123	0.401	0.487	1.002	0.401

Table 16. SigmaR info table for the all asymptotic selectivity option.

Period	N_devs	SD_of_devs	Var_of_devs	mean_SE	mean_SEsquared	sqrt_sum_of_components	SD_of_devs_over_sigma_R	sqrt_sum_over_sigma_R	alternative_sigma_R
Main	43	0.599	0.359	0	0	0.599	1.499	1.499	0.599
Early+Main	121	0.614	0.377	0	0	0.614	1.535	1.535	0.614
Early+Main+Late	123	0.609	0.371	0	0	0.609	1.523	1.523	0.609

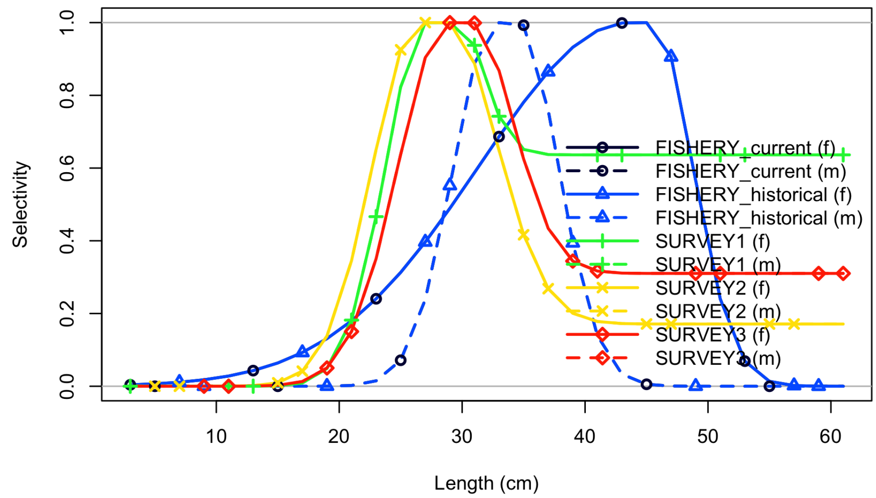


Figure 43. Estimated selectivity curves, for the model with selectivity for all fleets set to be dome-shaped.

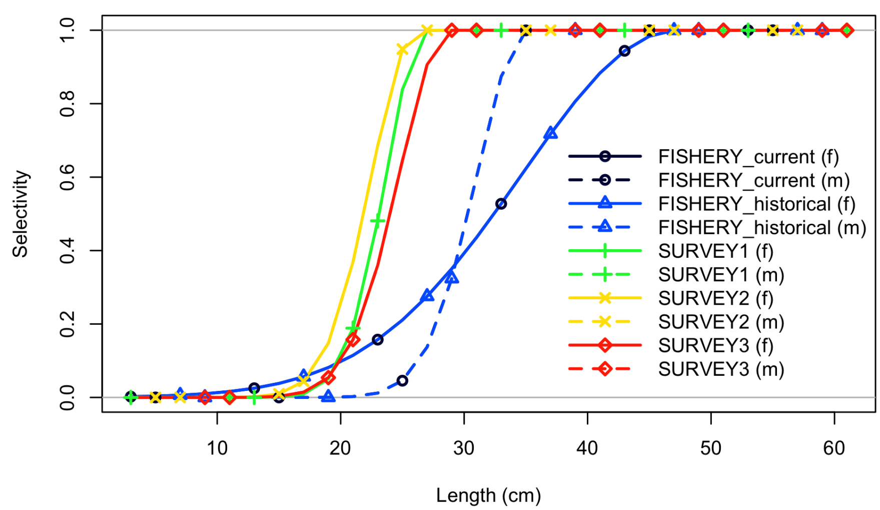


Figure 44. Estimated selectivity curves, for the model with selectivity for all fleets set to be asymptotic.

For the model run with all fleets with dome-shaped selectivity, the model produced a Hessian matrix and estimated the value of q to be 3.67. The model run with all fleets with all asymptotic selectivity also produced a Hessian and estimated a q value of 3.98. The population trajectories appear similar between the two models, but the scale is slightly larger for the all dome-shaped selectivity model (Figure 45, 46). The estimated growth curves for the two models were fairly similar (Figure 47, 48). Fits to both the WCGBTS index (Figure 49, 50) and length compositions (Figure 51, 52) were similar.

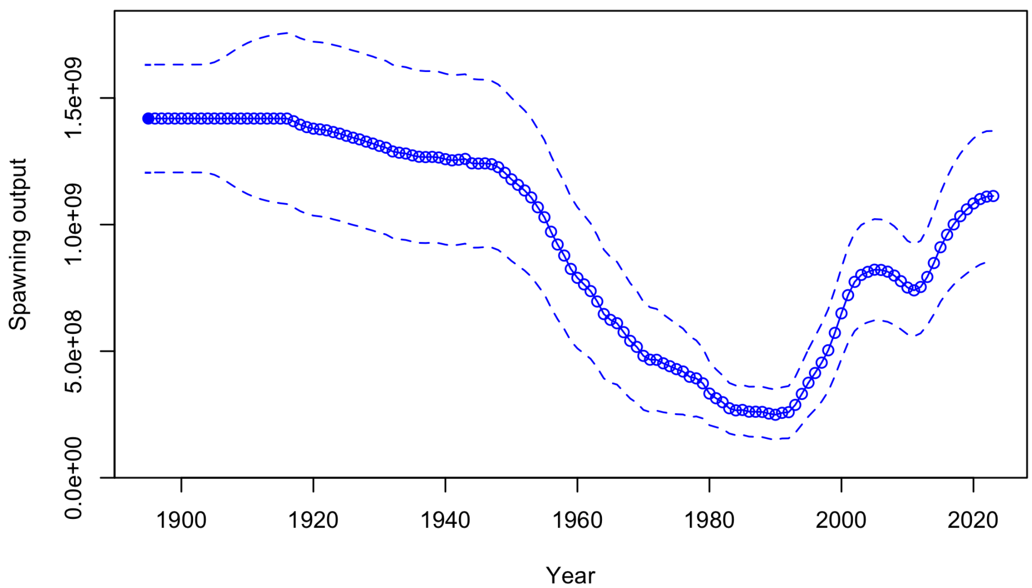


Figure 45. Time series of spawning output, for the model with selectivity for all fleets estimated to be dome-shaped.

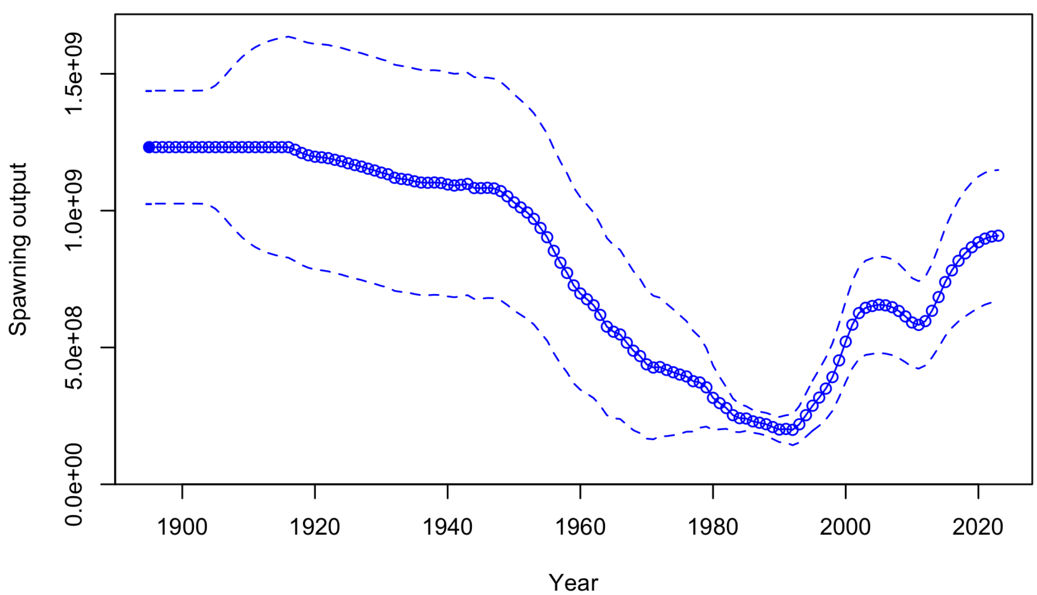


Figure 46. Time series of spawning output, for the model with selectivity for all fleets estimated to be asymptotic.

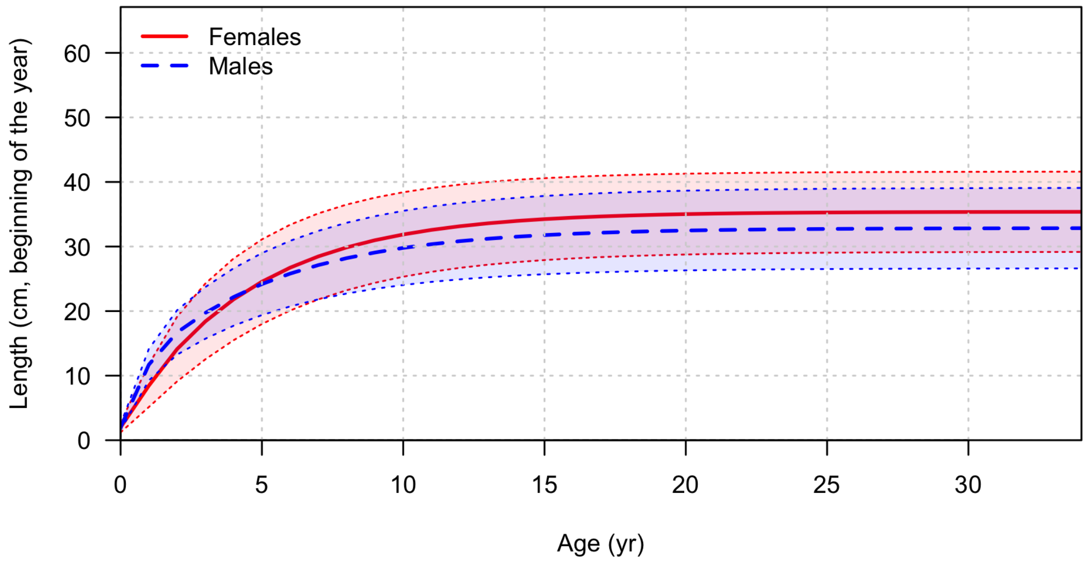


Figure 47. The growth curve estimated within the model when selectivity for all fleets was fixed to be dome-shaped.

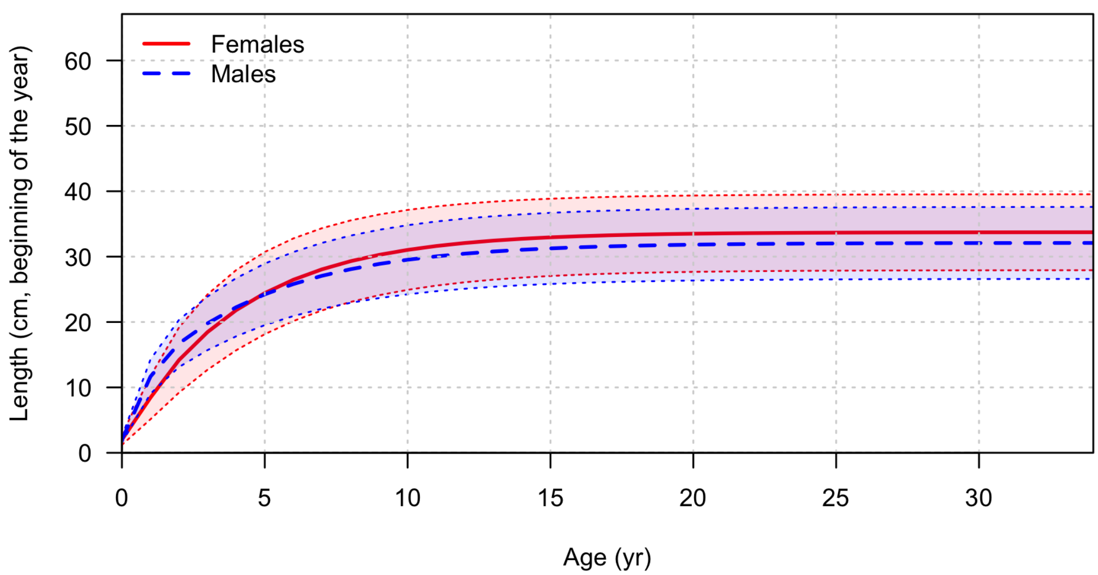


Figure 48. The growth curve estimated within the model when selectivity for all fleets was fixed to be asymptotic.

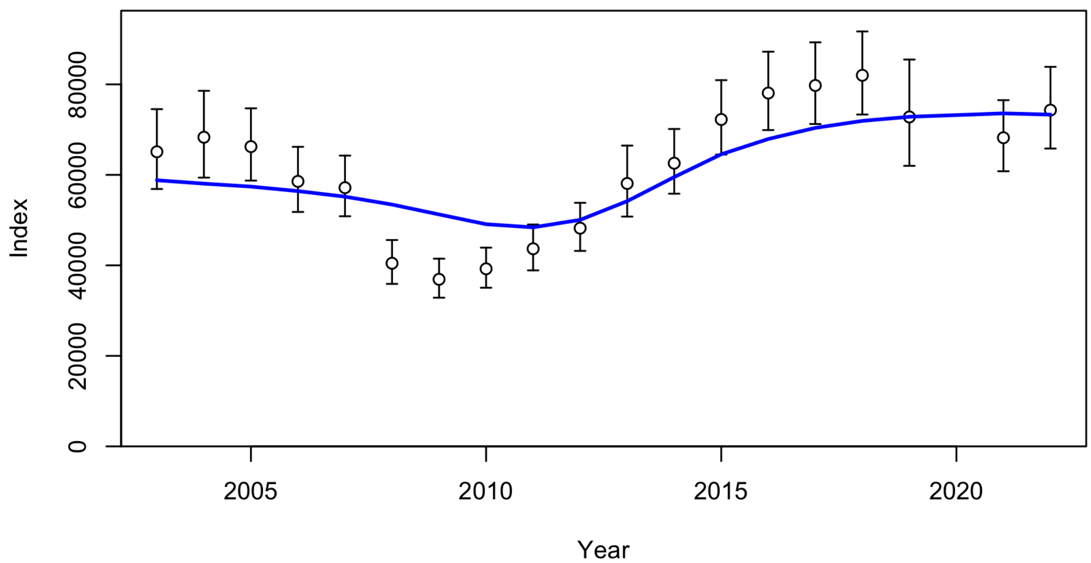


Figure 49. Fit to the WCGBTS for the model with selectivity fixed to be dome-shaped for all fleets.

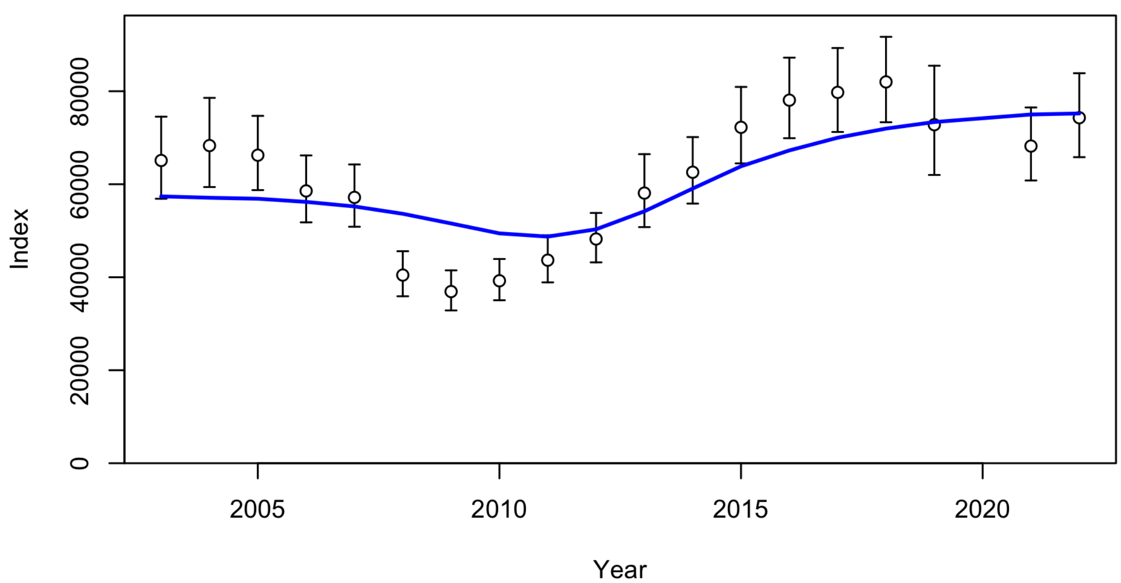


Figure 50. Fit to the WCGBTS for the model with selectivity fixed to be asymptotic for all fleets.

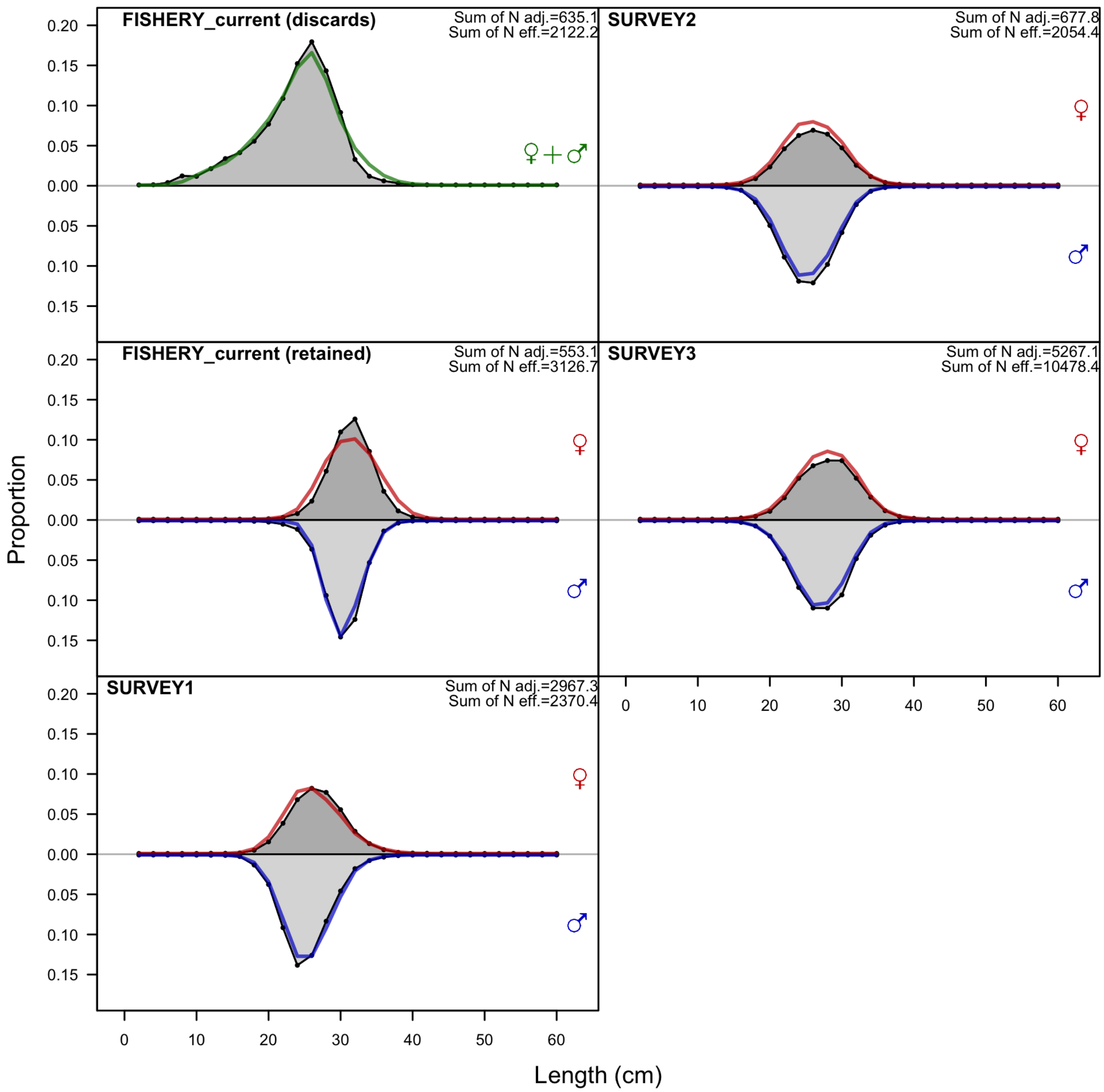


Figure 51. Fit to length compositions from all fleets with selectivity fixed to be dome-shaped for all fleets.

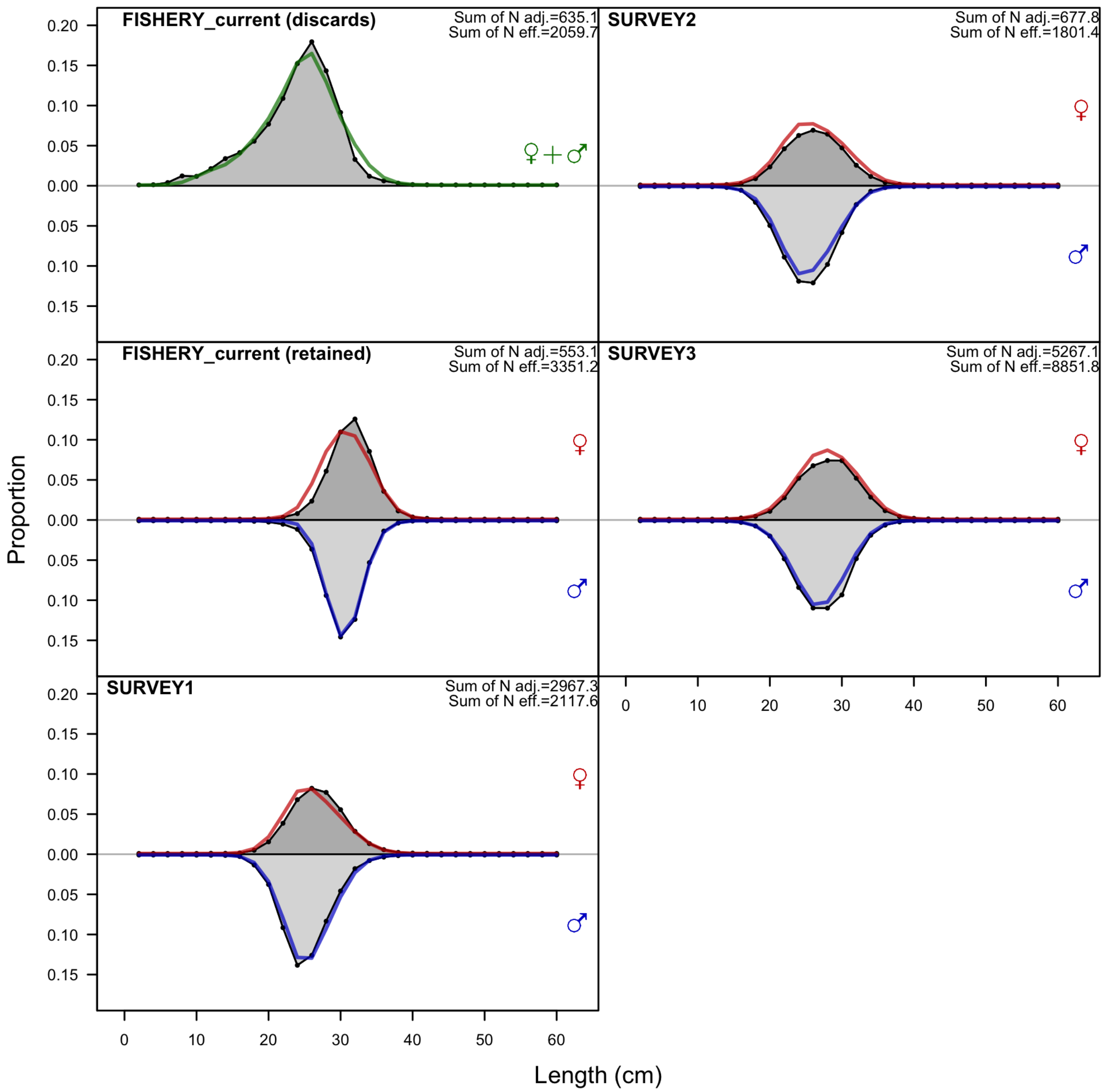


Figure 52. Fit to length compositions from all fleets with selectivity fixed to be asymptotic for all fleets.

Based on these comparisons, the STAT determined that the all-asymptotic selectivity model was preferred to the all-dome shaped selectivity model, as the STAT believed that it was not realistic that all fleets have dome-shaped selectivity (especially for the WCGBTS), and with less parameters estimated, the all-asymptotic selectivity model appeared more stable.

Panel conclusion: The Panel noticed that the newly added age data were being upweighted from the input sample sizes and that the run with asymptotic selectivity supported a sigmaR near 0.6 which is higher than the sigmaR with dome-shaped selectivity. The Panel agreed with the STAT that asymptotic selectivity was the preferred approach.

Request No. 8: Choosing the best performing model from Request No. 7, perform a jitter analysis to confirm convergence, and then provide preliminary likelihood profiles on *M*, *h*, and R0. Finally, perform a 5-year retrospective analysis.

Rationale: This model may potentially replace the base model, and a full exploration is necessary for the STAR panel.

STAT Response: The STAT has chosen the model with all asymptotic selectivity for all fleets as the best-performing model from Request No. 7. This is because the all-dome model had a high gradient. The all-dome model also estimated a more domed selectivity curve for the Late Triennial than the Early Triennial, which we believe to be unrealistic given the depths each survey sampled. We have performed a preliminary jitter with 0.10, preliminary likelihood profiles, and 5-year retrospective analysis on the all-asymptotic model. The preliminary jitter did not find a better model. The preliminary likelihood profile for steepness (Figure 53) indicated that a higher value of steepness was preferred. The changes in likelihood associated with a higher steepness value were not significant (Figure 54), however. The profile for R0 indicated that the preferred model had the lowest log-likelihood (Figure 55, 56), with a value of log(R0) = 11.1. The natural mortality profile recommended a lower value, around 0.1 (Figure 57, 58), which corresponds to a maximum age 54 years. This is likely not biologically reasonable. The oldest aged rex sole in the data was 33 years. The majority of rex sole were younger than 30 years.

While there is no consistent trend in the retrospective, there is some difference between runs. We ran the retrospective for 6 years to explore the changes in stock scale and status after the majority of age data has been removed (terminal year 2016). It is expected that with the majority of the age data collected in 2017 and 2018, the model would be sensitive to the removal of these years (Figure 59). The variability between retrospective runs and between models may be explained by general instability in the model. We have attempted to address this instability by fixing the young female cv on growth to be 0.1, the same value as both the cv for the old females and for the young males. Previously, this value was on the bound of 0.2. We are open to other options.

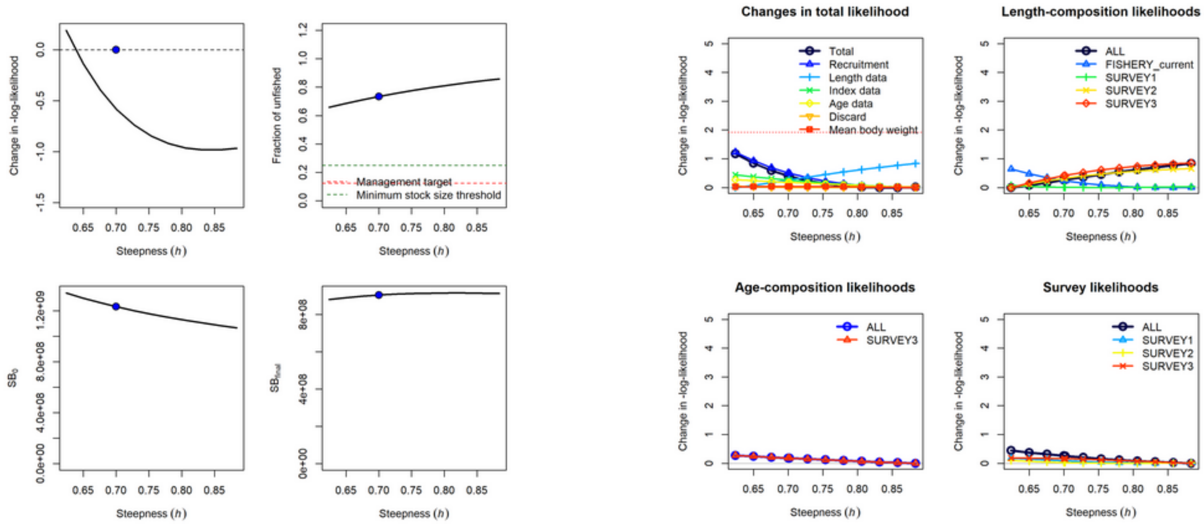


Figure 53. Preliminary likelihood profile for steepness.

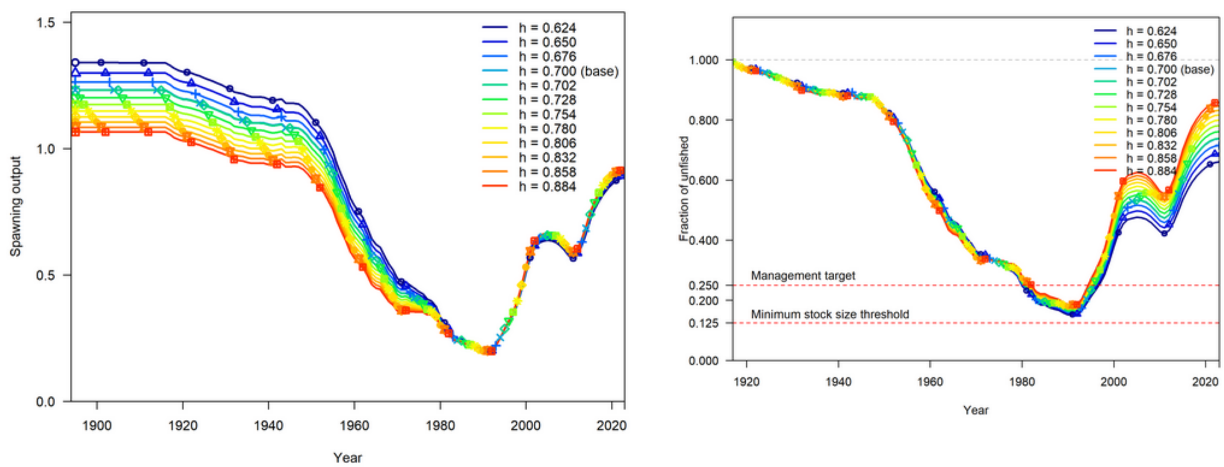


Figure 54. Spawning output and fraction unfished trajectories for the preliminary steepness likelihood profile.

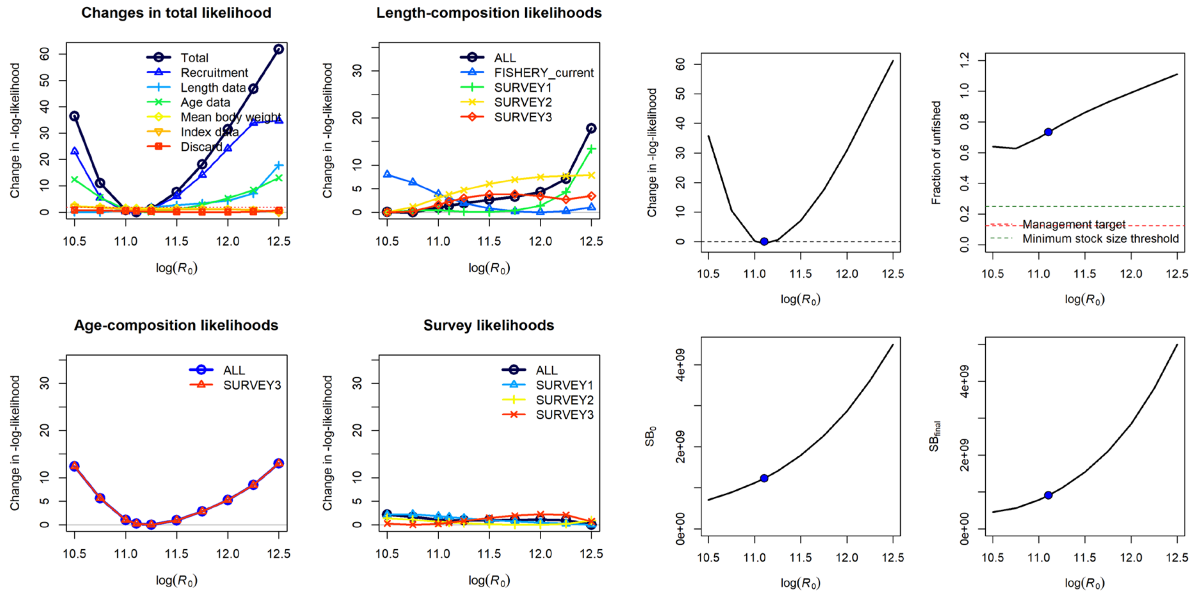


Figure 55. Preliminary likelihood profile for R0.

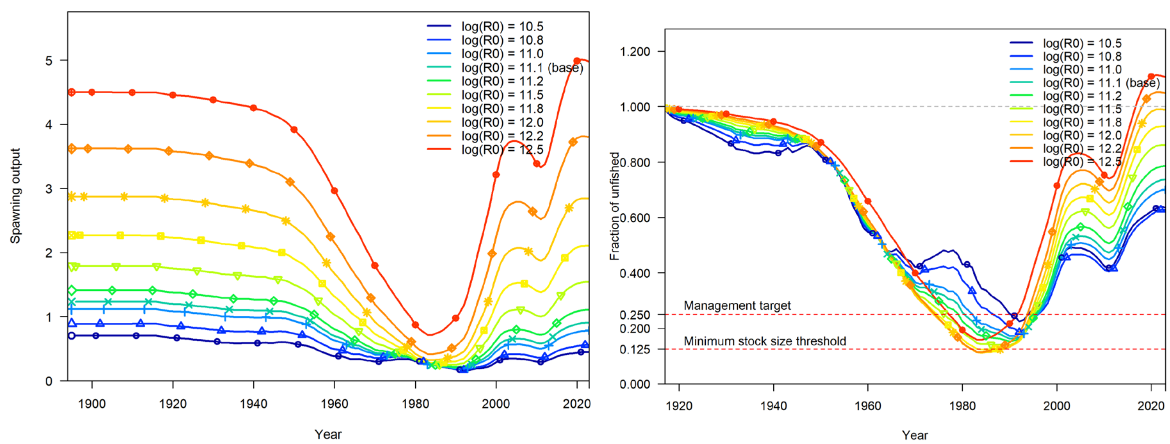


Figure 56. Spawning output and fraction unfished trajectories for the preliminary R0 likelihood profile.

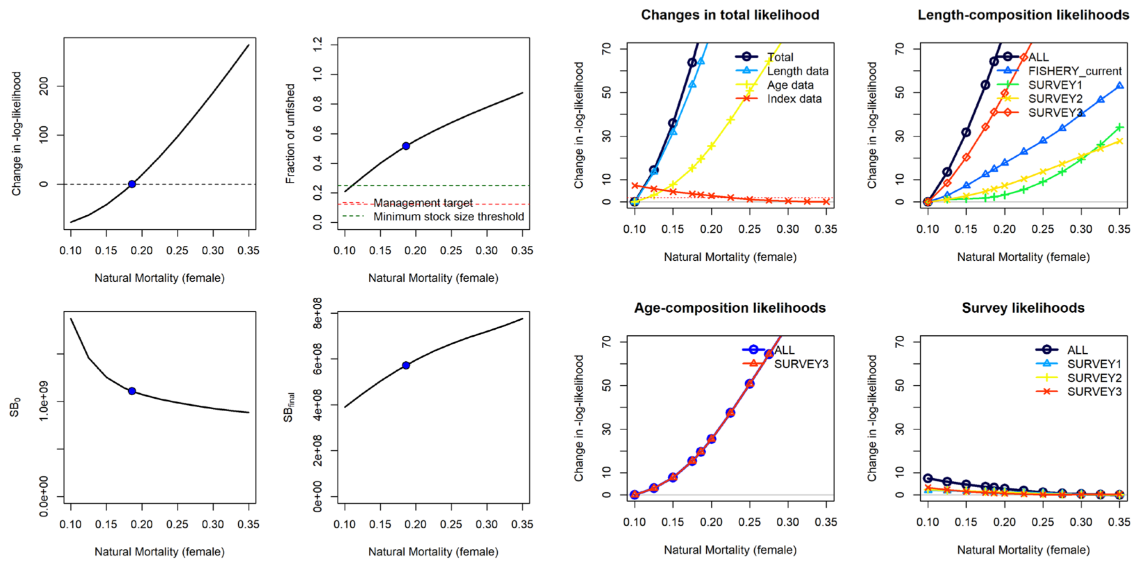


Figure 57. Preliminary likelihood profile for natural mortality.

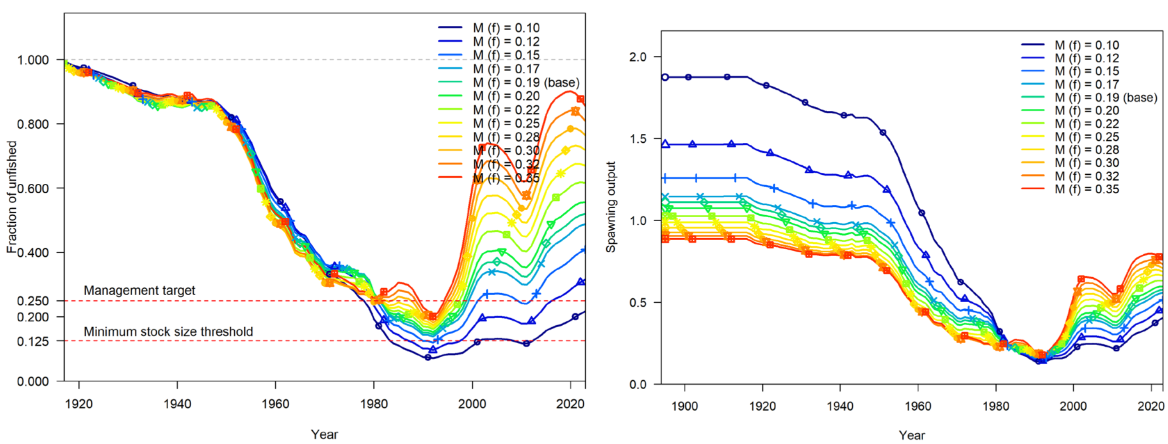


Figure 58. Spawning output and fraction unfished trajectories for the preliminary natural mortality likelihood profile.

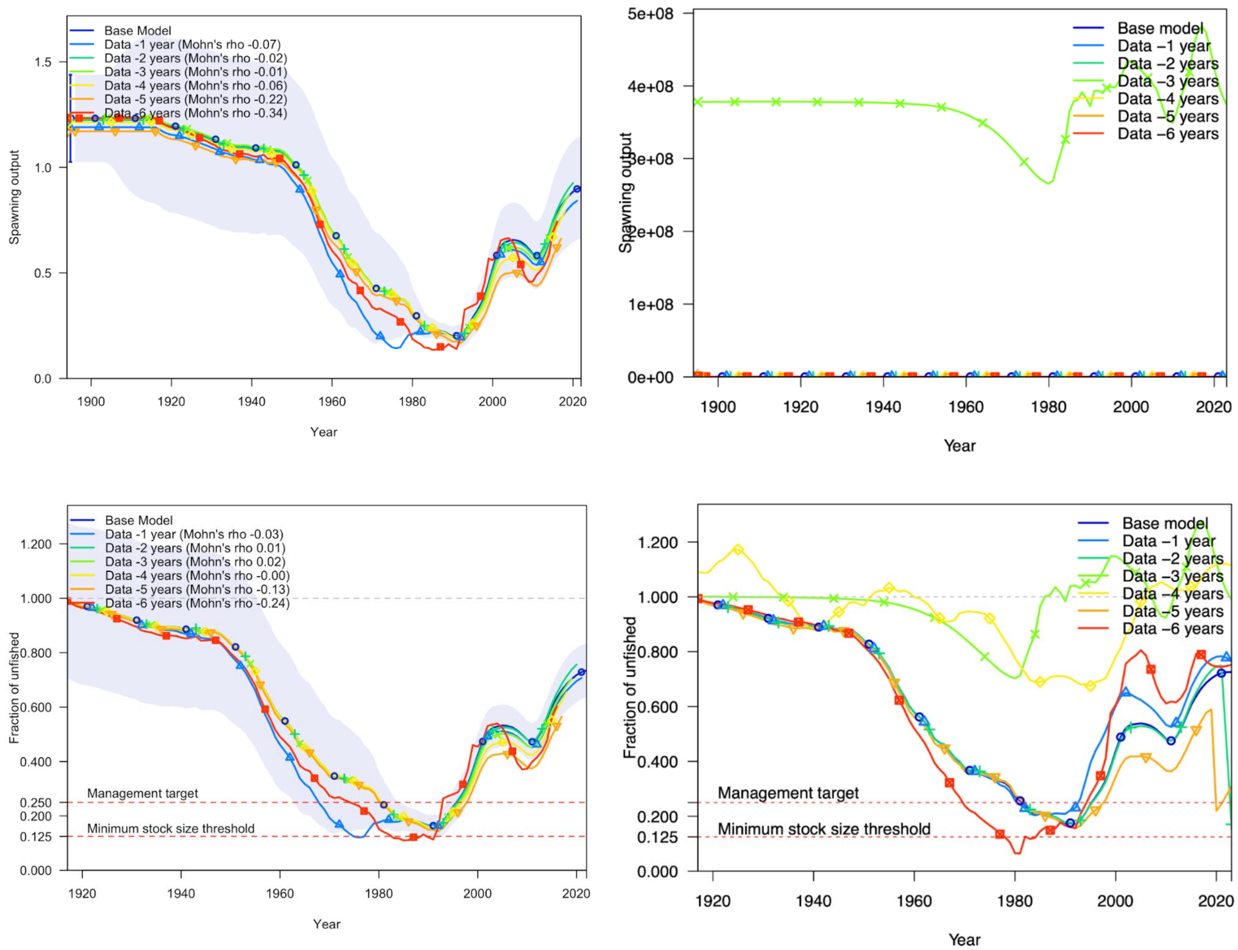


Figure 59: Two runs of the six-year retrospective analysis for the best-performing model from Request No. 7 - all asymptotic selectivity for all fleets.

Panel conclusion: Natural mortality appears to have the largest effect on the estimated spawning output. There was considerable discussion about the retrospective patterns and instability in convergence. Guided by advice from other SS users, the Panel suggested making sure that the jitter was not on when conducting retrospective analyses.

Request No. 9: Modify the pre-STAR base model in the following ways: 1) update latitudinal strata for the WCGBTS analysis of length compositions, 2) update the Washington historical catch reconstruction, 3) the addition of age-at-length data, 4) internally estimate growth parameters, 5) force all fleets to be asymptotic, 6) fix steepness at 0.8, and 7) re-evaluate data weights, and 8) retune sigmaR starting at 0.6. If a steepness of 0.8 results in an unsatisfactory/unstable model, maintain steepness at 0.7. Provide a retrospective analysis and likelihood profiles on *M*, R0, and *h*.

Rationale: The Panel found that the above updates from the pre-STAR base model improved fits to the length composition data, reduced bias in the growth estimates, maintained an *a priori* assumption that the WCGBTS has asymptotic selectivity, and alleviates concerns of a large estimate of catchability. All models presented showed signs of instability, thus the Panel refers to the STAT to determine if changing steepness results in a more unstable (and inferior) model.

STAT Response: The STAT team modified the pre-STAR base model performing sequentially steps 1-5. The resulting model used a steepness of 0.7. Steepness was then set to 0.8 as requested in step 6. However, likelihood values of the resulting model showed that total likelihood was not appreciably improved. For this reason, the STAT team decided to keep $h = 0.7$. Data sources were weighted following best practices with Francis weighting, which meant reducing the weight for the age composition data for the WCGBTS survey from 1.6 to 1 (step 7). This led to an unviable model with a high final gradient of 0.0068. Spawning output trajectory was unreasonably high and length composition fits deteriorated. For these reasons, Francis weights were reverted back to the values used during steps 1-6. SigmaR was then tuned down from 0.6 to 0.5 following indications from the tuning algorithm in SS3 (step 8). Trajectories of spawning output and relative spawning output from the resulting model are shown in Figure 60.

Table 16. Likelihood and parameter estimates for steepness "sensitivity analysis".

Label	Steepness = 0.7	Steepness = 0.8
TOTAL_like	896.913	896.873
Survey_like	1.443	0.839
Length_comp_like	261.059	260.946
Age_comp_like	780.969	780.197
Parm_priors_like	0.578	0.578
Recr_Virgin_millions	63.528	64.798
SR_LN(R0)	11.059	11.079
SR_BH_steep	0.700	0.700
NatM_uniform_Fem_GP_1	0.186	0.186
NatM_uniform_Mal_GP_1	0.186	0.186
L_at_Amax_Fem_GP_1	33.753	33.743
L_at_Amax_Mal_GP_1	32.077	32.092
VonBert_K_Fem_GP_1	0.246	0.247
VonBert_K_Mal_GP_1	0.225	0.224
SSB_Virgin_thousand_mt	1175510.000	1198990.000
Bratio_2023	0.768	0.752
SPRratio_2022	0.193	0.194

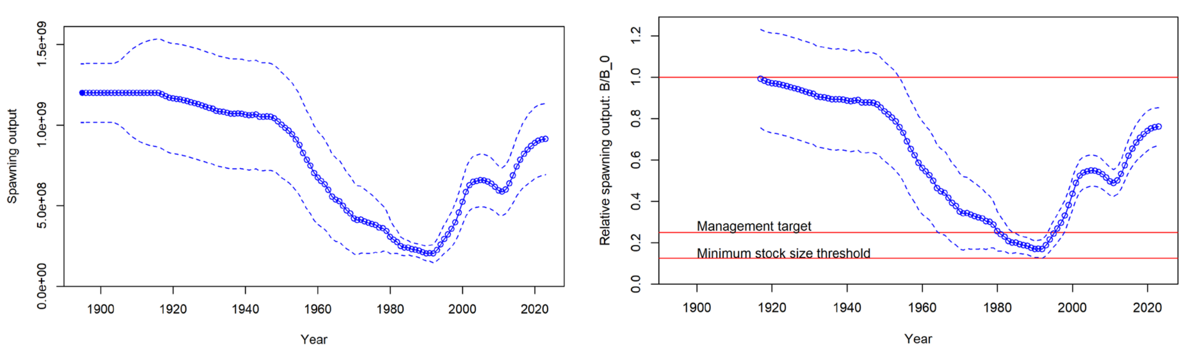


Figure 60. Trajectories from the proposed model for the 2023 rex sole assessment.

A retrospective analysis was performed on the resulting model (Figure 61). For this retrospective analysis, the parameter jitter_fraction was set to 0 in the starter.ss file. This step showed increasing changes to model trajectories as more years of data were removed, in particular when the bulk of the age data was removed. Likelihood profiles were run for *h*, R0, and *M*. The likelihood profile for h showed no appreciable difference in log likelihood from values of 0.7 to 0.85 (Figure 62). The profile over log(R0) indicated that the base model had the lowest log likelihood value of 11.1 (Figure 63). The *M* profile indicated the model preferred a lower value of *M*, around 0.1 (Figure 64). This value of *M* is likely unrealistic, as flatfish are believed to live between 20 and 30 years. The length and age data have the largest impact on the likelihood of *M*. *M* will be used as an axis of uncertainty for management decision tables.

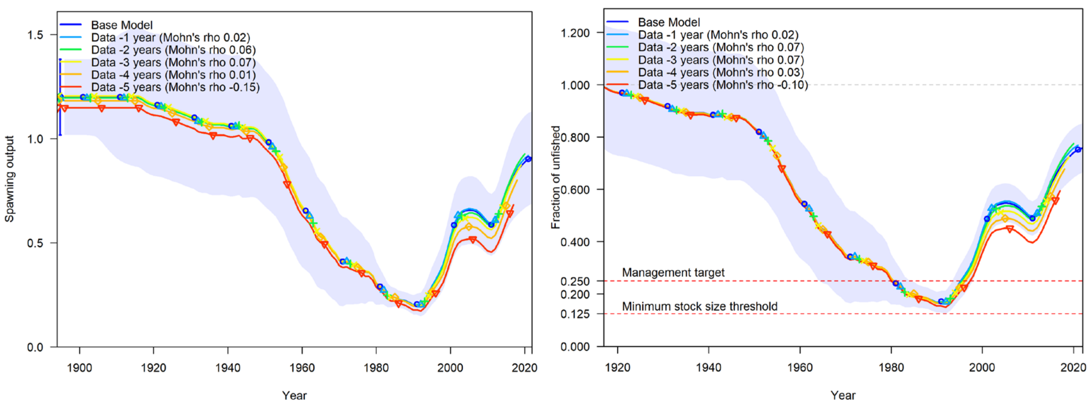


Figure 61. Retrospective analysis for the proposed model.

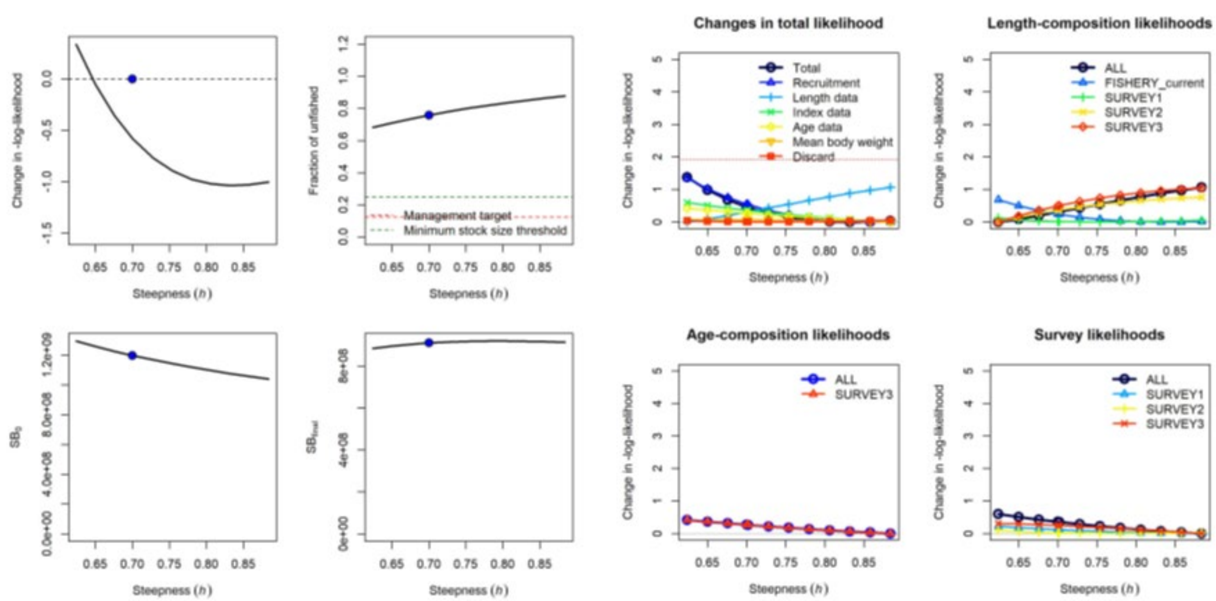


Figure 62. Likelihood profile for *h*.

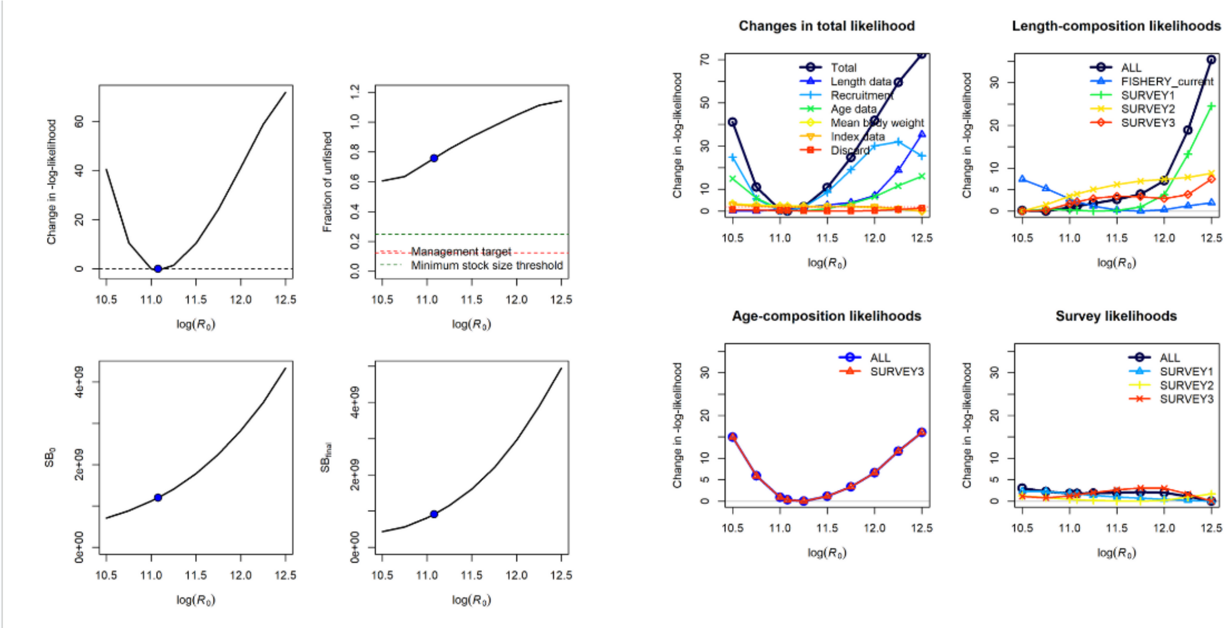


Figure 63. Likelihood profile for R0.

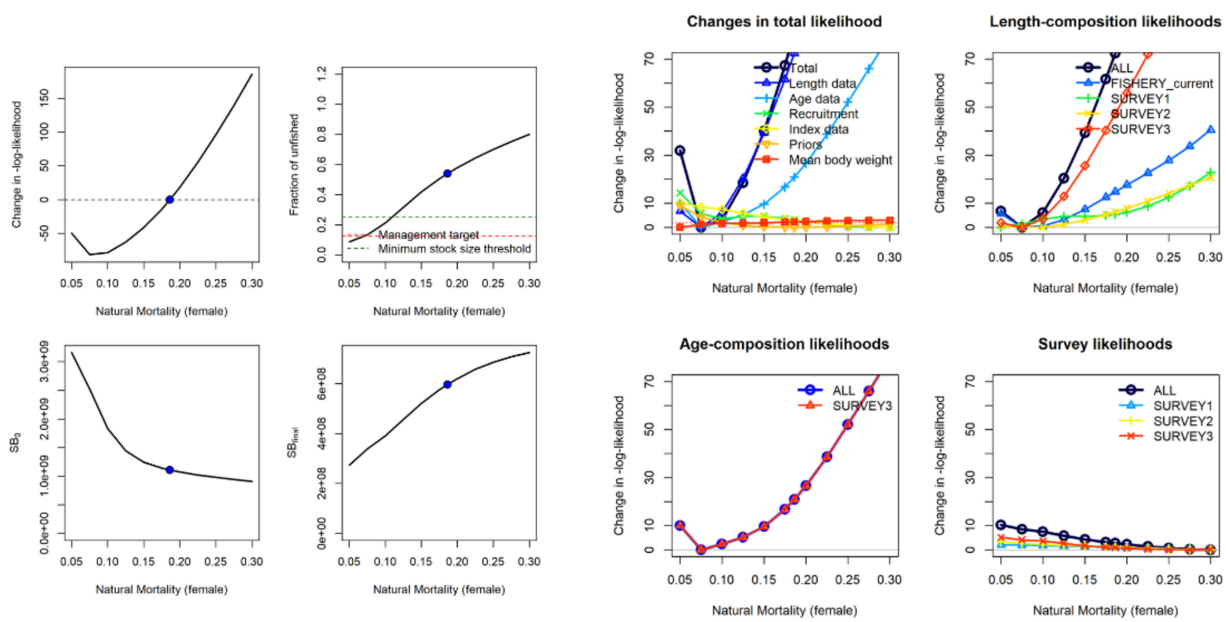


Figure 64. Likelihood profile for *M*.

A jitter with a fraction of 0.10 was run on the resulting model (*h*=0.70, sigmaR=0.5) and found no significantly better model (Figure 65). The lower negative log-likelihoods (NLL) found are only lower by 0.001. These lower NLL models are only different in their estimated recruitment deviations. Given the small difference, which may be due to rounding error, we move on to Request No. 10 with the original resulting model.

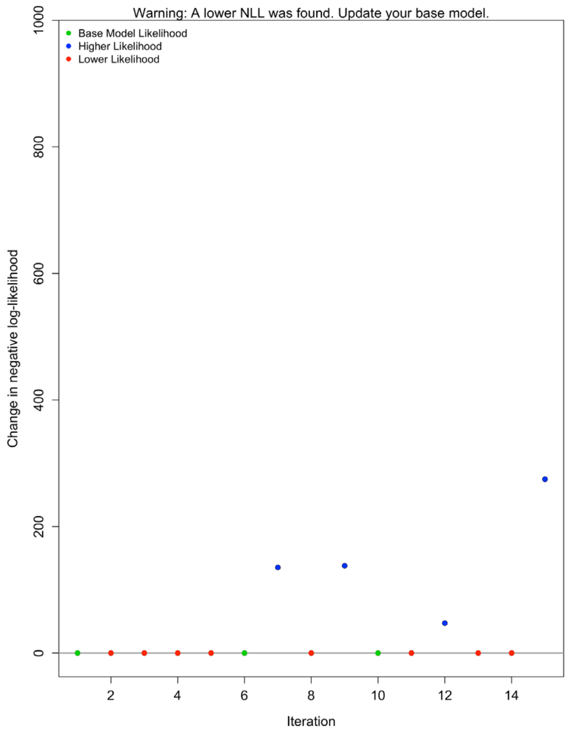


Figure 65. Jitter of 0.10 of the resulting model (*h*=0.70, sigmaR=0.5) finds no significantly better model. Models with lower likelihoods are better by 0.001. We find it unnecessary to use these models and continue with the resulting model.

Panel conclusion: The Panel agreed that these models were an improvement over the pre-STAR base model, but disagreed with the STAT that a steepness of 0.7 was a preferred steepness value. The fits to the index and age data slightly improved with a steepness of 0.8, as seen in the likelihood profiles, and the median of the current accepted prior for steepness of U.S. West Coast flatfish is 0.8. However, these improvements were insignificant regarding fits to data and the STAT suggested that the model was less stable with a steepness of 0.8. Given that model evaluations have been completed using a steepness of 0.7 and performing the model runs for a steepness of 0.8 would take a considerable amount of the time, the Panel agreed that a steepness of 0.7 is satisfactory for this assessment, is captured in the uncertainty, and other values should be considered in the future.

Request No. 10: Using the model from Request No. 9, determine values of natural mortality (*M*) that would correspond to the 12.5% and 87.5% percentiles of the 2023 overfishing limit (OFL) estimate from this new base model. Create the same plot for 2023 spawning output using these *M* values determined from the 2023 OFL uncertainty. Also report the standard deviation of the 2023 OFL estimate (e.g. empirical sigma).

Rationale: Natural mortality is a reasonable axis of uncertainty, even though lower values are supported.

STAT Response: A search was conducted over values of natural mortality (*M*) to find those that produced a trajectory where the OFL estimate fell in the 12.5% and 87.5% percentiles of the 2023 OFL estimate, resulting in *M* values of 0.175 (for the 12.5%) and 0.210 (for the 87.5%). The spawning output in 2023 for the two alternative values of *M* fell within the 95% confidence interval (Figure 66), but just outside of the 95% confidence for fraction of unfished (Figure 67). The plot of 2023 spawning output in the three states of nature is provided in Figure 68.

The standard deviation of the 2023 OFL estimate was 0.124.

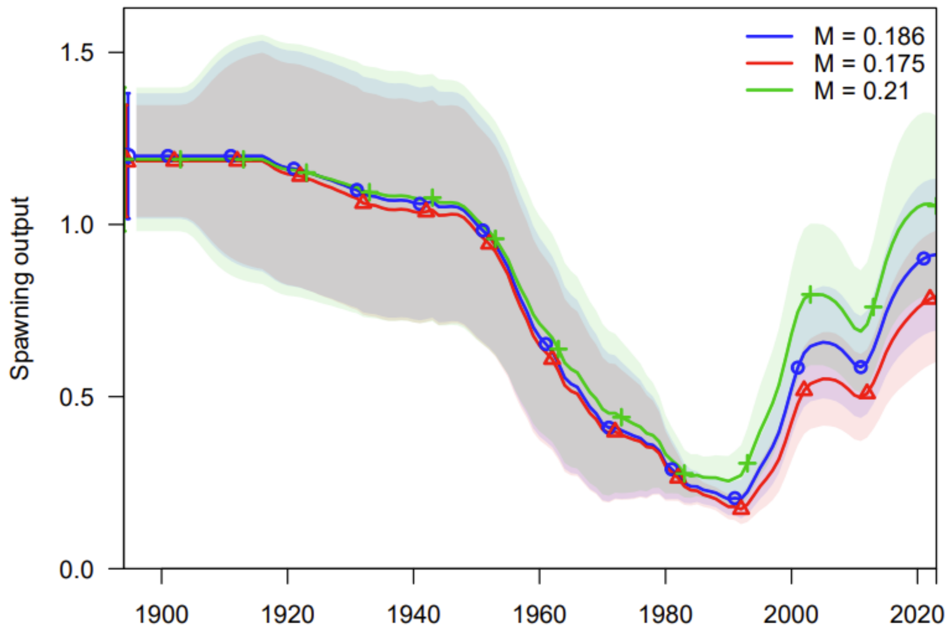


Figure 66. Spawning output trajectory in the modeled period for the three values of *M* selected to create the decision table.

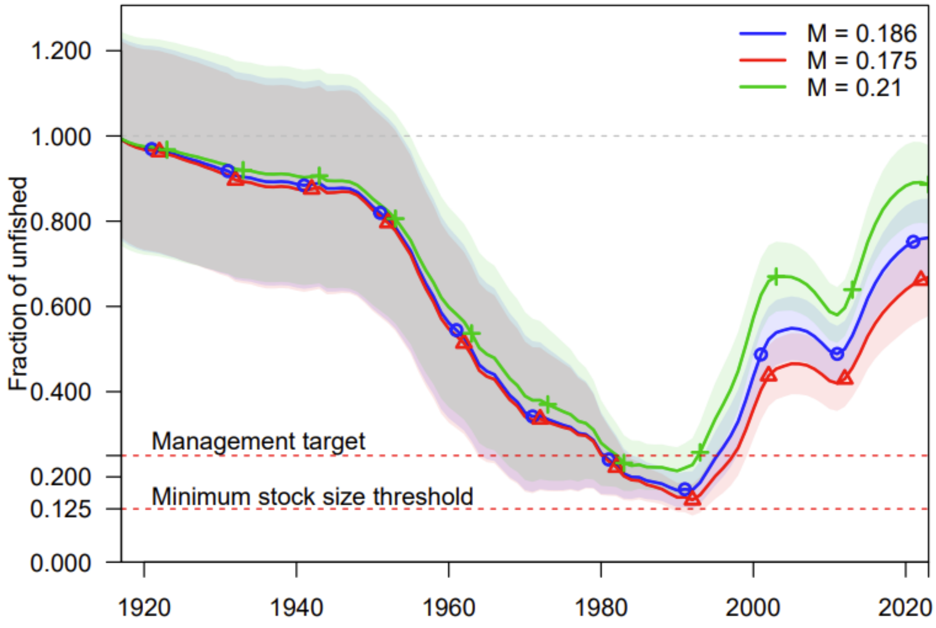


Figure 67. Fraction unfished trajectory in the modeled period for the three values of *M* selected to create the decision table.

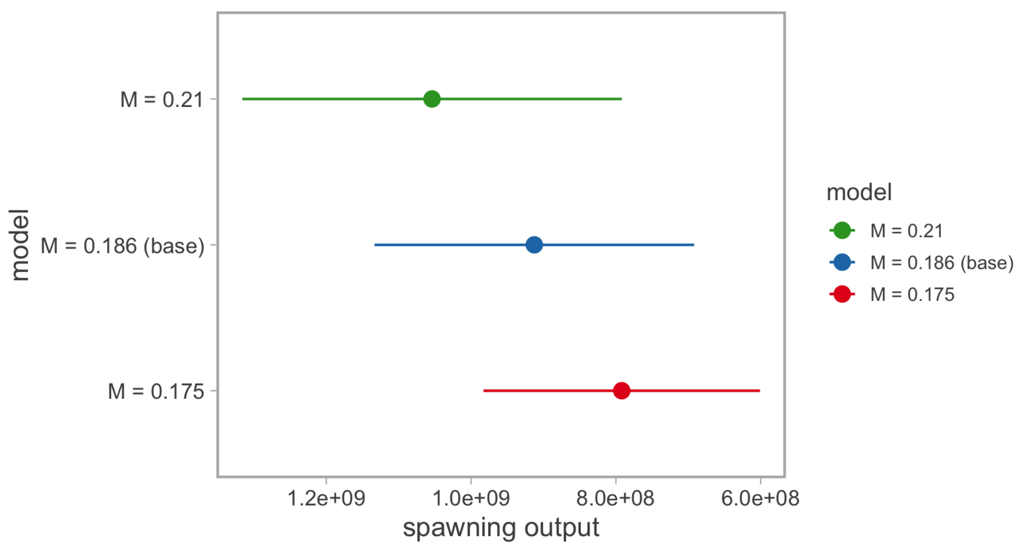


Figure 68. The spawning output for 2023 for the model with base natural mortality (*M*=0.186) and the natural mortalities that result in the 12.5% (*M* = 0.175) and 87.5% (*M* = 0.210) percentiles of the estimate of OFL in the base model in 2023.

Panel conclusion: These values of *M* are useful to define the states of nature and provide a reasonable range for projections.

***Request No. 11*:** Use the default harvest control rule for rex sole (P* of 0.4 and sigma=1.0) in the base model run with all states of nature, as well as an alternative run with a P* of 0.45, with ABC=ACL full removal under both alternative model runs.

Rationale: The Council has continued to adopt a P* value of 0.4 for rex sole since the last time it was assessed with a data moderate assessment. The GMT requests analyzing an alternative P* value of 0.45 to provide the Council with options for consideration later this year. Although catches are likely to remain well below the ACL, setting removals equal to the ABC allows the trawl fleet the greatest flexibility in the event of future expansion.

STAT Response: The decision tables are provided below in Tables 17 and 18. The population trajectory in the projection period for P* = 0.4 is shown in Figure 69.

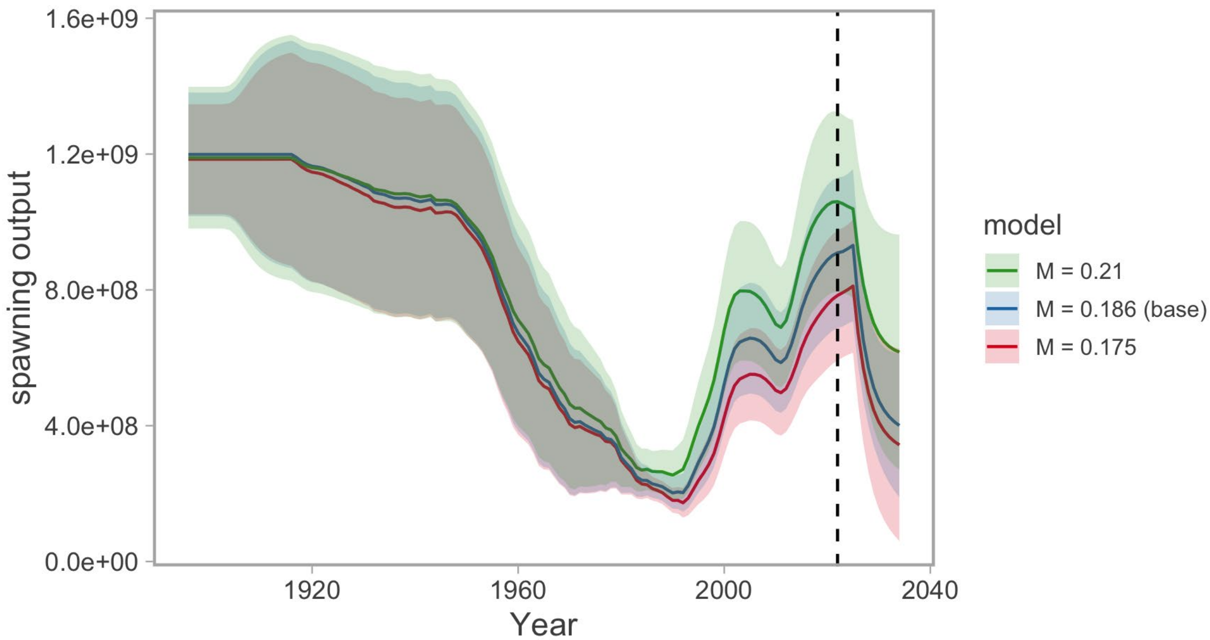


Figure 69: Spawning stock biomass (including projection to 2034 with P* = 0.4 and with ABC=ACL full removal) for the model with base natural mortality (*M*=0.186) and the natural mortalities that result in the 12.5% (*M* = 0.175) and 87.5% (*M* = 0.210) percentiles of the estimate of OFL in the base model in 2023.

Table 17. Decision table summary of 10 year projections beginning in 2025 for alternative states of nature based on an axis of uncertainty about female natural mortality for the base model. Columns range over low, mid, and high states of nature and rows range over a catch level assumption of full ACL attainment at a P* of 0.4 for 2025-2034.

		M = 0.175		M = 0.186		M = 0.210	
Year	Catch	Spawning Output (millions)	Fraction unfished	Spawning Output (millions)	Fraction unfished	Spawning Output (millions)	Fraction unfished
2023	447	792	0.669	913	0.761	1054	0.886
2024	447	801	0.676	915	0.764	1046	0.879
2025	3967	811	0.685	920	0.767	1039	0.873
2026	3310	671	0.566	783	0.653	909	0.764
2027	2850	570	0.481	684	0.570	815	0.685
2028	2527	497	0.420	613	0.511	749	0.629
2029	2305	446	0.377	563	0.470	702	0.590
2030	2147	411	0.347	528	0.441	670	0.564
2031	2032	386	0.326	504	0.421	649	0.545
2032	1942	367	0.310	487	0.407	634	0.533
2033	1869	354	0.299	475	0.396	623	0.524
2034	1810	343	0.290	467	0.389	617	0.519

Table 18. Decision table summary of 10 year projections beginning in 2025 for alternative states of nature based on an axis of uncertainty about female natural mortality for the base model. Columns range over low, mid, and high states of nature and rows range over a catch level assumption of full ACL attainment at a P* of 0.45 for 2025-2034.

		M = 0.175		M = 0.186		M = 0.210	
Year	Catch	Spawning Output (millions)	Fraction unfished	Spawning Output (millions)	Fraction unfished	Spawning Output (millions)	Fraction unfished
2023	447	792	0.669	913	0.761	1054	0.886
2024	447	801	0.676	915	0.764	1046	0.879
2025	4550	811	0.685	920	0.767	1039	0.873
2026	3719	646	0.545	759	0.633	888	0.747
2027	3153	529	0.446	645	0.538	781	0.657
2028	2769	447	0.377	565	0.471	707	0.594
2029	2510	390	0.329	510	0.425	655	0.551
2030	2334	351	0.296	471	0.393	620	0.522
2031	2212	323	0.273	445	0.371	597	0.502
2032	2119	302	0.255	425	0.355	580	0.488
2033	2044	285	0.241	411	0.343	568	0.478
2034	1983	271	0.229	400	0.333	560	0.471

Panel conclusion: The Panel accepts this approach to construct decision tables for inclusion in the Revised Draft Assessment (post-STAR panel).

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

The base model supported by the STAR panel has some significant differences from the pre-STAR base model. This includes some updates to the data (Request No. 1), the addition of conditional age-at-length data and internal estimation of growth (Request No. 5), forcing all fleets to have asymptotic selectivity, a steepness of 0.7, and a sigmaR of 0.5 (see Request No. 9 for a summary). This model emerged after the exploration of various attempts to improve the fits to the data, reduce the estimated value of catchability for the WCGBTS index, and provide a converged model. Exploring dome-shaped selectivity also improved the fits to the data and reduced catchability for the WCGBTS index, but it was not expected that the WCGBTS would have dome-shaped selectivity given that it covers the majority of the range of U.S. West Coast rex sole. Addressing the potential bias in estimating growth externally with length preferential sampling of ages (see Perreault et al. 2020) was a more parsimonious and supported route to pursue that resulted in asymptotic selectivity ogives.

Being defined as a Category 2 data moderate assessment, the terms of reference discourage the use of age data in the assessment, but support using age data external to the assessment model to estimate necessary parameters (see Section 1 and 9 of the PFMC Terms of Reference for the Groundfish Stock Assessment Review Process for 2023-2024). However, the concern over the likely bias in the estimated growth curve and the greatly improved fits to the data support using the age data internally in this assessment to estimate growth parameters and led the Panel to support using the conditional age-at-length data in this stock assessment to assist with the estimation of growth parameters. The Panel felt that this was a significant improvement to the model, fixing the growth parameters at the internally estimated values and removing the conditional age-at-length data resulted in poor behavior, and because the assessment was fully reviewed at this STAR panel, it was warranted to keep the age data in the model.

Natural mortality was defined as the axis of uncertainty because changes in the fixed value of M resulted in significant changes in the spawning output, and because the specification of M using maximum age is uncertain. Natural mortality values of 0.175 and 0.210 were chosen to represent the 12.5% and 87.5% percentiles of the estimated 2023 OFL.

Recommended sigma value and basis of recommendation

The value for sigma calculated from the assessment is 0.124, which is less than the default sigma for a Category 2 stock, which is 1.0. Therefore, a sigma of 1.0 is recommended.

Technical Merits of the Assessment

This assessment for U.S. West Coast rex sole is a considerable improvement compared to the previous stock assessment completed in 2013. Additional data, exploration, and flexibility of the modeling choices provide improved management advice. This assessment model includes U.S. West Coast specific life history estimates, predicts discards in recent years, and estimates recruitment deviations throughout the time-series. Internally estimating growth greatly improved the fits of this model to data and resulted in a robust model to many sensitivities.

A new use of data was model-based survey index standardization using the sdmTMB package, which is described in the STAT draft assessment. Model-based index standardization is a common practice in U.S. West Coast groundfish stock assessments. In particular, a single Triennial Survey index time series was produced that accounted for the increase of the maximum depth (from 366 m to 500 m) of this survey from 1995 onward. This is a merit because splitting the survey series reduces the stock trend.

Technical Deficiencies of the Assessment

The updated assessment uses all available data but uncertainty remains regarding the appropriate value of steepness (h) to use. The data used are not informative of steepness, and fits to the data are not significantly improved at higher values. The median of the steepness prior for flatfish on the West Coast of the U.S. is 0.8, and the steepness used in this assessment model is 0.7, based on early investigations during development of the pre-STAR base model. Even though the value of steepness has a small effect on the fit to the data and the estimated spawning output, it has a larger consequence on the determination of reference points and projections.

Age data were added to the assessment during the STAR panel and have not been fully investigated as part of this assessment and review process. No aging error matrix is available because reader error has yet to be fully explored for this species and double reads were not available. However, estimating growth using these data greatly improved the fits to data and expectations of the model. Additional age data with proper analysis and exploration would improve this assessment in the future.

The Panel only superficially reviewed the model-based survey index standardization, by comparing design-based versus model-based estimates. However, details of the standardization may impact how the indices should be used in stock assessment models.

Areas of Disagreement Regarding STAR Panel Recommendations

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

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

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

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

Unresolved Problems and Major Uncertainties

The higher than expected estimate of catchability for the WCGBTS (nearly 4) is a concern in this assessment. The prediction of the WCGBTS index provides annual estimates of biomass appropriately scaled to match the scale of the stock assessment. With an accurate estimate of selectivity, the catchability would be expected to be near 1. However, as seen with other flatfish assessments on the U.S. West Coast, catchability may be greater than 1 for various reasons. The catchability for this survey in the 2019 petrale sole assessment was near 3 and was justified because the bridles of the trawl gear likely herd flatfish into the wings of the net, and the door spread is approximately three times the wing spread, noting that wing spread is used to calculate the index. The fit to the index was improved when compared to the pre-STAR base model, but still showed patterns in the residuals.

The indices of abundance were estimated using a spatial model in the package sdmTMB (Anderson et al. 2022). This is the accepted method for analysis of survey data, but the Panel did not have the time to investigate these analyses in detail. The panel noticed that for rex sole, the estimates from sdmTMB were higher than the design-based estimates and the pattern in the final years also differed between the two. The higher scale of the sdmTMB estimates may contribute to a high estimated catchability.

Likelihood profiles for natural mortality supported a value smaller than the fixed input natural mortality determined from the median of the prior using a maximum age of 29 (M=0.186). The length and newly added age data supported a lower M below 0.10 which would correspond to a maximum age much greater than observed for rex sole. This was in contrast to larger values of natural mortality supported in the pre-STAR assessment model. The Panel was unsure why smaller values of M were supported by the data when asymptotic selectivity was used because invoking dome-shaped selectivity would result in even smaller values of M. Some model misspecification is still present and one possible explanation is that growth may not be correct, even with the age-at-length data providing information to estimate growth.

Recommendations for Future Research and Data Collection

The panel supports the recommendations provided in the pre-STAR draft assessment (reproduced below). The Panel notes that while q ultimately was estimated within the model at a value that is reasonable, q is still larger (~4) than for other flatfish assessments and remains highly uncertain. In addition, determining an appropriate range of natural mortality is another area of uncertainty for rex sole. The value of natural mortality used in the assessment was determined from a maximum age that came from the published literature. The post-STAR assessment model supported much lower values of M than the value it was fixed at, but seemed unreasonable given the current understanding of the life history of rex sole and other U.S. West Coast flatfish. An improved understanding of natural mortality will help identify model misspecification. Increased availability of ages for the next rex sole assessment is necessary. Many otoliths are collected from the WCGBTS and are available to be read. Having these data available would better inform biological parameters and the assessment outcomes. Development of an aging error matrix would be a key outcome of this as well. There is uncertainty in catch estimates, and more so for historic periods and when interpolations are used to fill in catches for some years. This uncertainty was not quantified and provided to the Panel. There is an important need for STATs to provide information on the quality of the annual catch estimates, and more specifically to quantify the uncertainty in these estimates. This technical deficiency is common to all assessments reviewed by this Panel.

1. Limited historical discard data (rate and length compositions) led to unstable models when assuming a single fishery fleet. This was circumvented by splitting the fleet into historical and current fleets, and hard-wiring the discard into the historical fleet to avoid estimating discard rates prior to 2002. Further information on historical discards would be beneficial for future rex sole assessments.

2. Updated biological research of rex sole specifically along the U.S. West Coast would be instrumental. This assessment used improved estimates of growth, maturity, and fecundity parameters for U.S. West Coast rex sole compared to the last assessment. However, the maturity and fecundity assumptions are based on a single study from the 1960s and 1970s, which had limited spatial coverage (Oregon only) and a small sample size for the length-fecundity relationship (Hosie and Horton 1977). Gonads are collected in good numbers from the WCGBTS, but none have been processed for maturity.

3. Catchability is an ongoing concern and major source of uncertainty in the model.

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

The assessment model for rex sole estimates current stock status much higher than the management target and even though age data were included, this remains a Category 2 assessment. A limited amount of age data was included in this model and additional age data would likely be very helpful. If additional age data are available, this assessment may be a Category 1 and should be a full assessment the next time it is considered.

Acknowledgements

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

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Shortspine Thornyhead

Overview

A Stock Assessment Review (STAR) Panel met June 5-9, 2023, in-person at the Northwest Fisheries Science Center Auditorium with a remote participation option to facilitate public comment for those unable to travel to Seattle, WA. In addition to a data-moderate assessment for shortspine thornyhead, the panel reviewed two full benchmark assessments for copper rockfish in California and a data-moderate assessment for rex sole. The panel operated under the Pacific Fishery Management Council's (PFMC) Terms of Reference (TOR) for the Groundfish Stock Assessment Review Process for 2023-2024.

Beginning in 1989, both shortspine and longspine thornyhead species were managed as part of a Dover sole-thornyhead-sablefish complex. In 1991, the Pacific Fishery Management Council adopted separate ABC levels for thornyheads and catch limits were imposed on the thornyhead complex, under the Pacific Coast Groundfish Fishery Management Plan. The most recent assessment for shortspine thornyhead was a data-moderate assessment conducted in 2013. Stock status was determined to be above the management target and catches did not attain the full management limits, so reassessment of thornyheads has not been a higher priority.

Summary of Data and Assessment Models

Data were divided into three fishery fleets: North trawl (the waters off Washington and Oregon), South trawl (the waters off California), and coastwide Non-trawl, and three survey fleets: the Alaska Fisheries Science Center (AFSC)/NWFSC West Coast Triennial Shelf Survey (Triennial Survey) from 1980-2004, which was divided into early (pre-1995) and late period (post-1995) to account for a change in depth-sampling, and the NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS), from 2003-2022.

Most data used in the 2013 assessment were updated for this assessment, including length compositions from all fishing and survey fleets, indices of abundance derived from new geostatistical analyses, discard rates from both a 1980s observer study (Pikitch et al. 1988) and the current WCGOP, historical catch data from Washington, Oregon, and California, and all reported catches from 1981-2022. The only data taken from the previous assessment without reanalysis were discard rates from the Enhanced Data Collection Project (EDCP) study in the 1990s.

New maturity analyses of samples collected in the WCGBTS in 2011, 2013, 2014, 2016 and 2018 were available for this assessment. The larger number and better spatial coverage of these samples allowed the use of statistical modeling to better understand the spatial variation in the proportion of females spawning. This assessment also assumes a new fecundity relationship, in which fecundity is modeled as a power function of length. New growth curves were estimated, using data from Butler (1995), which were similar to the curves assumed in the 2005 and 2013 assessments. In the previous assessment, a Beverton-Holt stock recruitment relationship was assumed and steepness (h) was fixed at 0.60. This assessment fixed steepness at 0.72, as recommended by Thorson et al. (2019). Natural mortality (M) was also slightly updated, from 0.0505 in the 2013 assessment, to be fixed at 0.04.

This assessment uses Stock Synthesis 3 (version 3.30.21) and estimated 180 parameters. The log of the unfished equilibrium recruitment, $ln(R0)$, controls the scale of the population and annual deviations around the stock-recruit curve (135 parameters) allow for more uncertainty in the population trajectory. In addition, 43 selectivity and retention parameters for the three fishery fleets and three surveys allowed for estimation of annual length compositions and discards rates. Two catchability parameters were analytically computed from the data, and one additional parameter, representing additional variability in the early Triennial survey, was directly estimated by the model.

Requests by the STAR Panel and Responses by the STAT

Request No. 1: Provide a table of all sensitivities presented on Tuesday June 6 in the format of Table 10 in the rex sole draft assessment. This includes the addition of the at-sea hake observer program (ASHOP) catch stream.

Rationale: A table of sensitivities with pertinent values is useful to understand the details and consequences of each sensitivity.

STAT Response: A table of parameter and likelihood estimates was generated for all relevant sensitivity analyses (Table 19). This table contains the updated Bratio and SPRratio to reflect estimates from the terminal year. The at-sea hake catch stream sensitivity analysis is presented under Landings as "ASHOP Landings." The ASHOP Landings, rel + sel blocks, and Updated W-L sensitivity analyses will be integrated into the base model as suggested in Request No. 6. The table will be added to the Revised Draft Assessment (post-STAR panel).

Table 19. Comparison of parameter and likelihood estimates across sensitivity analyses.

		Biology					Landings			Surveys					Retention + Selectivity		
Label	Base	Low Growth	High Growth	2013 Maturity	Intermediate Maturity	Updated W-L	Imputed Landings	2013 Landings	ASHOP Landings	LogNorm Error MBI	DBI	MBI Depth-cov.	+ Slope Survey	WCGBTS extra SD	all retention blocks	all selectivity blocks	ret + sel blocks
TOTAL_like	536.643	544.202	530.747	536.587	536.643	537.799	536.308	535.813	537.167	538.556	524.366	533.769	927.277	534.944	262.913	518.113	242.448
Survey_like	-48.598	-44.260	-53.352	-48.639	-48.607	-48.465	-48.690	-49.003	-48.458	-41.834	-54.331	-46.958	-64.145	-45.554	-48.676	-50.657	-50.072
Length_comp_like	270.396	269.085	283.699	270.417	270.409	270.513	270.292	270.614	270.404	269.516	269.253	269.737	563.371	269.445	269.964	260.666	257.076
Parm_priors_like	1.572	1.637	1.552	1.573	1.572	1.579	1.576	1.580	1.570	1.569	1.597	1.587	1.557	1.555	4.680	3.769	6.729
Recr_Virgin_millions	11.550	16.495	7.225	11.540	11.547	11.580	11.667	11.879	11.692	10.703	10.301	10.761	10.056	10.793	11.549	13.409	13.048
SR_LN(R0)	9.354	9.711	8.885	9.354	9.354	9.357	9.364	9.383	9.367	9.278	9.240	9.284	9.216	9.287	9.354	9.504	9.476
SR_BH_steep	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
NatM_break_1_Fem_GP_1	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
NatM_break_2_Fem_GP_1	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
NatM_break_1_Mal_GP_1	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
NatM_break_2_Mal_GP_1	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
L_at_Amax_Fem_GP_1	73.608	66.247	92.010	73.608	73.608	73.608	73.608	73.608	73.608	73.608	73.608	73.608	73.608	73.608	73.608	73.608	73.608
L_at_Amax_Mal_GP_1	66.073	59.466	82.591	66.073	66.073	66.073	66.073	66.073	66.073	66.073	66.073	66.073	66.073	66.073	66.073	66.073	66.073
VonBert_K_Fem_GP_1	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
VonBert_K_Mal_GP_1	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
SSB_Virgin_thousand_mt	20.332	18.477	29.637	21.797	21.416	20.384	20.537	20.911	20.581	18.841	18.134	18.943	17.701	19.000	20.330	23.604	22.969
Bratio_2023	0.407	0.458	0.372	0.430	0.420	0.409	0.398	0.395	0.409	0.382	0.368	0.380	0.352	0.388	0.398	0.402	0.372
SPRratio_2022	0.636	0.506	0.803	0.609	0.618	0.635	0.635	0.628	0.886	0.724	0.771	0.721	0.836	0.711	0.651	0.627	0.688

Panel conclusion: The table provided was acceptable.

Request No. 2: Display the residuals of the fitted length-weight relationship. Provide the fitted curve and standardized residuals in log space.

Rationale: This will allow for the panel to examine the fit and evaluate the fit.

STAT Response: Plotting the linear fit to length-weight data in log space (Figure 70) as well as the standardized residuals from the fit (Figure 71) shows high variability in smaller fish, which is likely causing the poor overall fit. It is typically more difficult to get accurate weights of smaller fish at sea. In addition, all fish less than 16 cm were unsexed, and the base model assigned a 50/50 ratio of males and females to these unsexed fish (Figure 72a). Therefore, we eliminated data for fish less than 16 cm (2.77 in log space; Figure 72b). The removal of fish less than 16 cm improved the fit to the length-weight data (Figure 73) compared to the fit used in the base model which included these smaller fish (Figure 74). We updated the length-weight coefficients from this improved fit, and ran a sensitivity with the updated coefficients (Table 20). Model results were insensitive to the change in weight-length coefficients (Figure 75). Due to the improved fit from the length-weight curve after removing fish less than 16 cm, updated length-weight coefficients from this sensitivity will be incorporated into the new base model.

Table 20. Length-weight coefficients (alpha, beta) from the base model and the sensitivity model where fish less than 16 cm were removed.

Sex	**Model**	**alpha**	**beta**
Female	Base W-L	6.71E-6	3.17
Female	Updated W-L (sensitivity)	4.86E-6	3.26
Male	Base W-L	6.49E-6	3.18
Male	Updated W-L (sensitivity)	4.96E-6	3.25

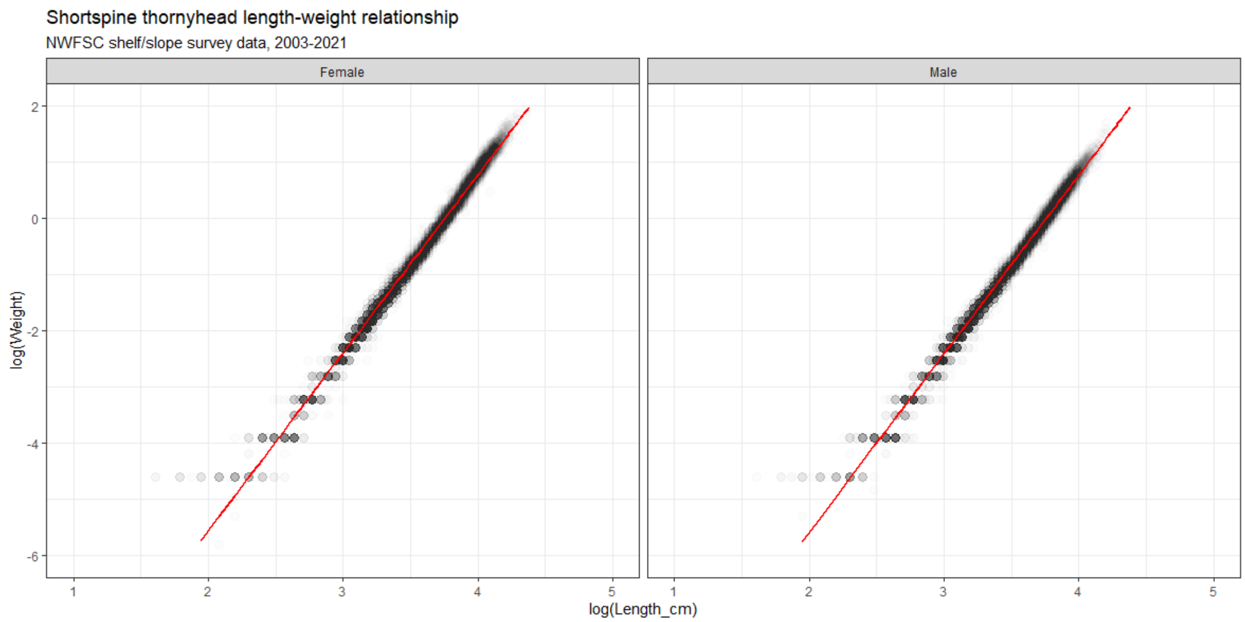

Figure 70. Fit to length-weight data in log space for Females (left) and Males.

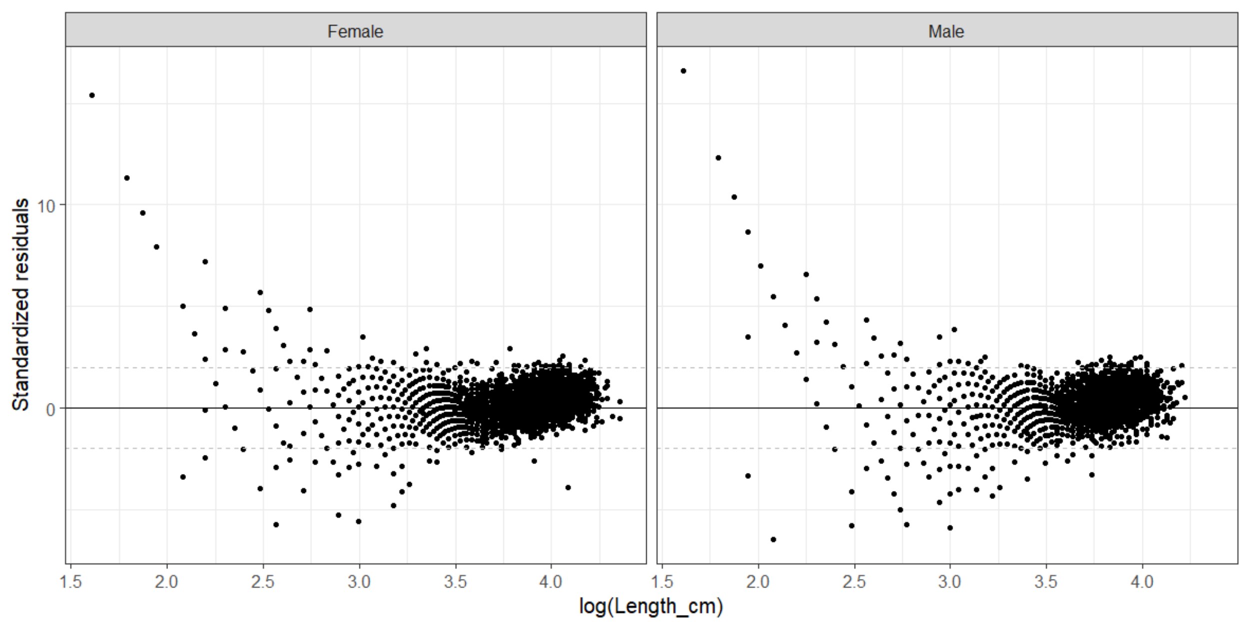

Figure 71. Standardized residuals for fit to length-weight data for Females (left) and Males (right).

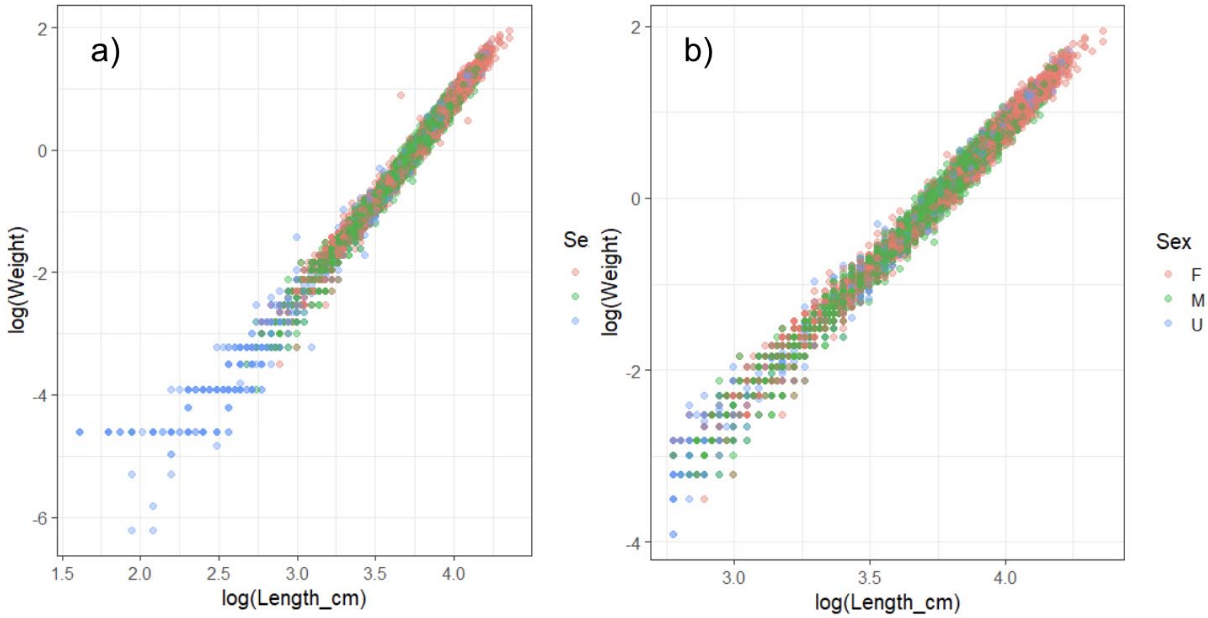

Figure 72. Fit to length-weight data in log space color coded by sex for a) all data and b) fish less than 16 cm removed.

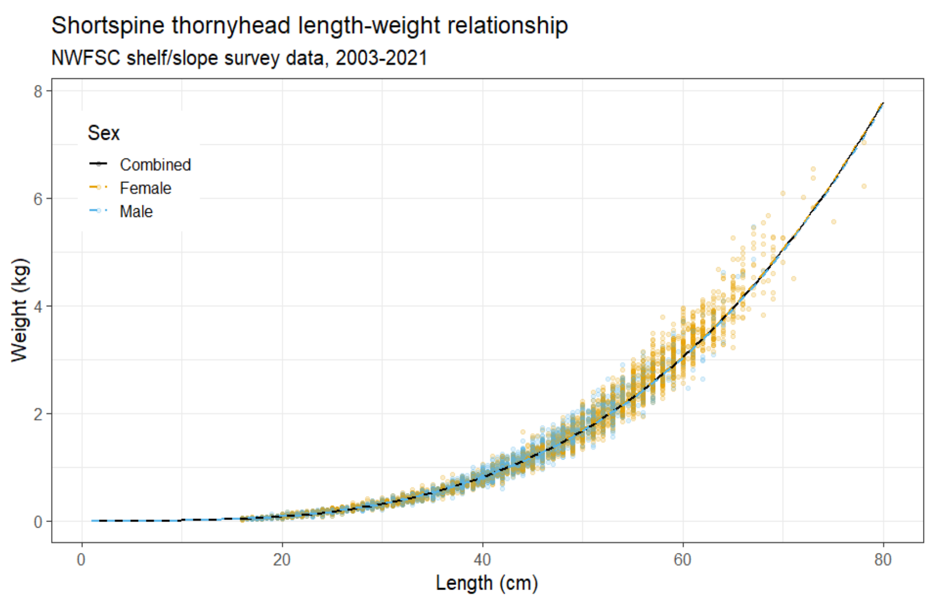

Figure 73. Fit to length-weight data after removal of fish less than 16 cm.

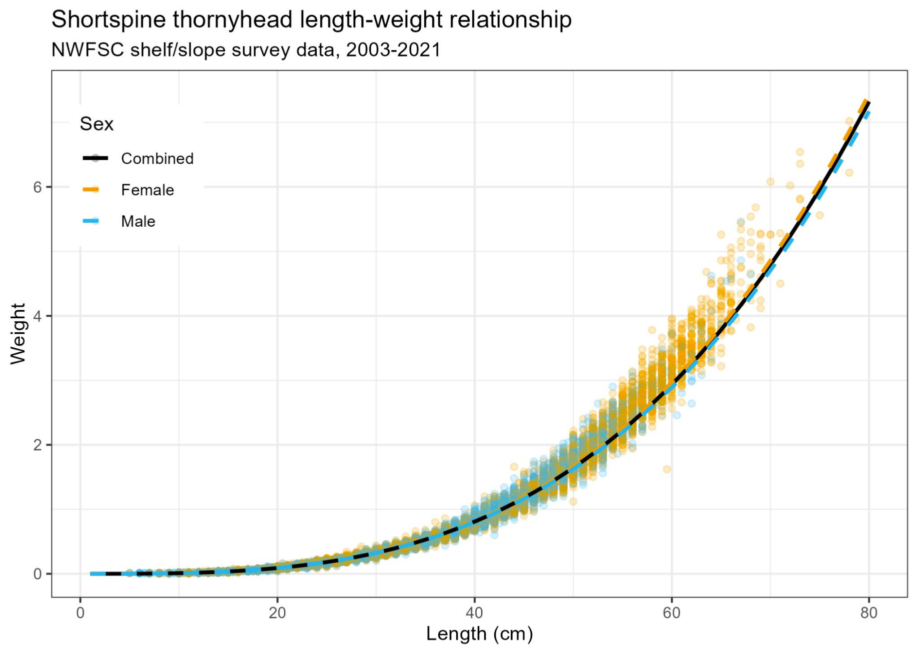

Figure 74. Fit to length-weight data used in the base model.

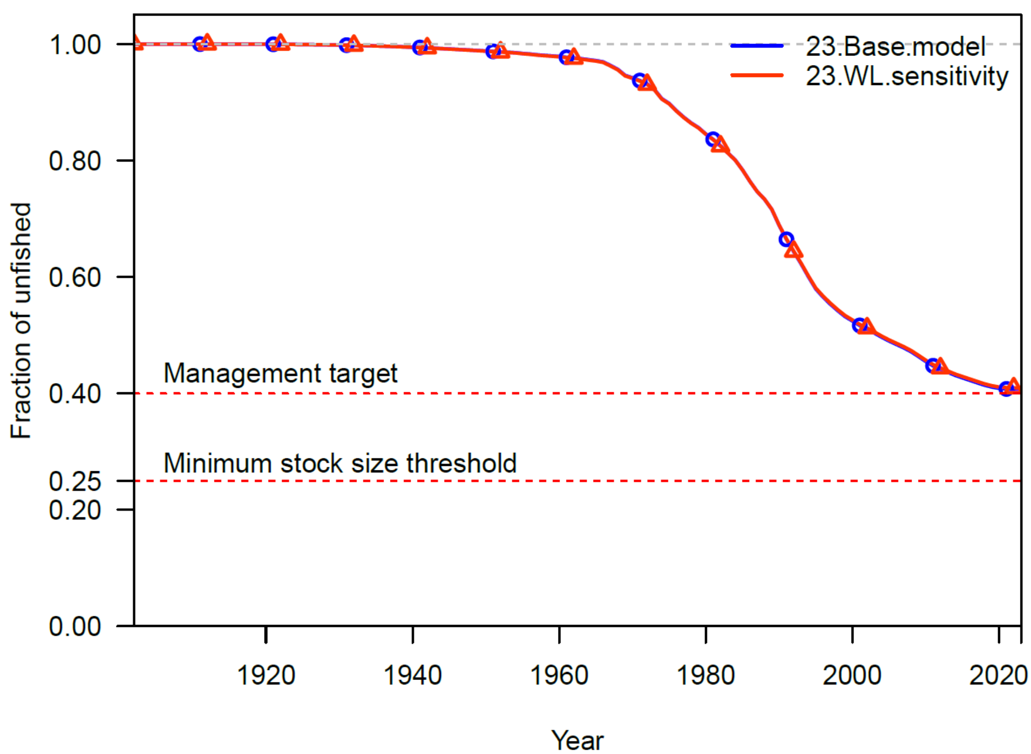

Figure 75. Fraction unfished from model results comparing base model to a sensitivity which used new length-weight coefficients from length-weight relationship after fish less than 16 cm were removed.

Panel conclusion: The Panel agreed with the decision to remove all shortspine thornyheads less than 16 cm for fitting the weight-length curve. The updated length-weight relationship with individuals less than 16 cm removed resulted in an improved fit and should be included in the new base model.

Request No. 3: Provide two sensitivity runs with *M*=0.045 and *M*=0.05, reported in the format requested in Request No. 1. Additionally, show the fits to survey indices and all length comps.

Rationale: Natural mortality may improve the fits to some data sources. These larger values are supported by the likelihood profile (realizing there is little information in the data to estimate *M*), past assessments, and uncertainty in maximum age. The value of 0.03 used in the Gulf of Alaska (GOA) shortspine thornyhead assessment was determined using the Hoenig (1983) method with a max-age around 100 to 115. The current Hamel and Cope method (2022) is consistent with an *M* higher than 0.04 when assuming a maximum age between these values.

STAT Response: The STAT team provides two sensitivities setting values of *M*=0.045, associated with a maximum age of ~120 and supported by the likelihood profiles, and *M*=0.05, associated with a maximum age of 108.

The changes in the fraction of unfished biomass were as expected, where a higher value for M resulted in a lower fraction of unfished. In the base model, the fraction of unfished was 40.7%, for *M*=0.045, the fraction of unfished was 41.9%, and for *M*=0.05, the fraction of unfished was 43.3% (Figure 76). *M* also impacts the SPR ratio, whereas *M* increases, which in turn decreases the relative fishing intensity decreases (Figure 77). There was a slight improvement to the likelihood when *M* was fixed at 0.045 but fits to length composition data (primarily from the Triennial 2 survey) were slightly degraded (Table 19). Increasing *M* led to minimal improvement to fits to Triennial 2 length compositions, as well as a slightly better fit to the Triennial survey index (Figure 78), there were no significant changes, and the model fits to the WCGBTS continue to miss the last two years (Figure 78).

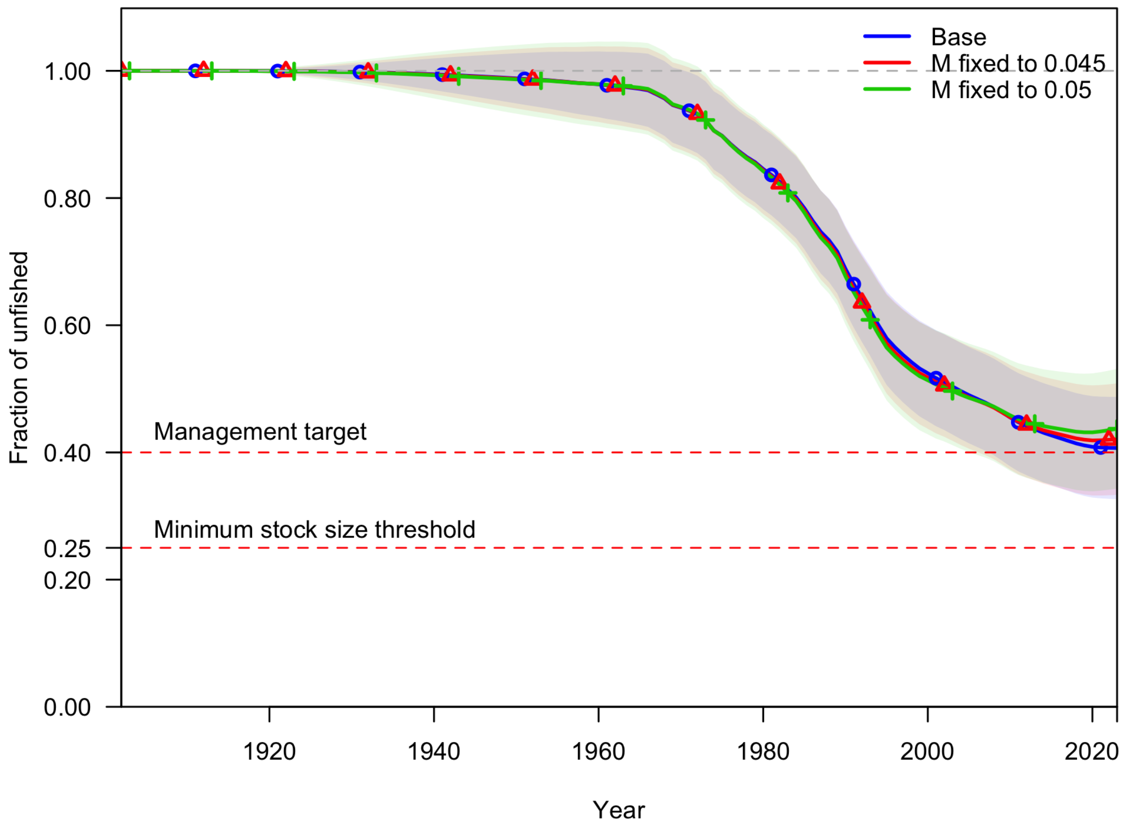

Figure 76: Fraction of unfished biomass for the base model (blue), natural mortality fixed at 0.045 (red), and 0.05 (green).

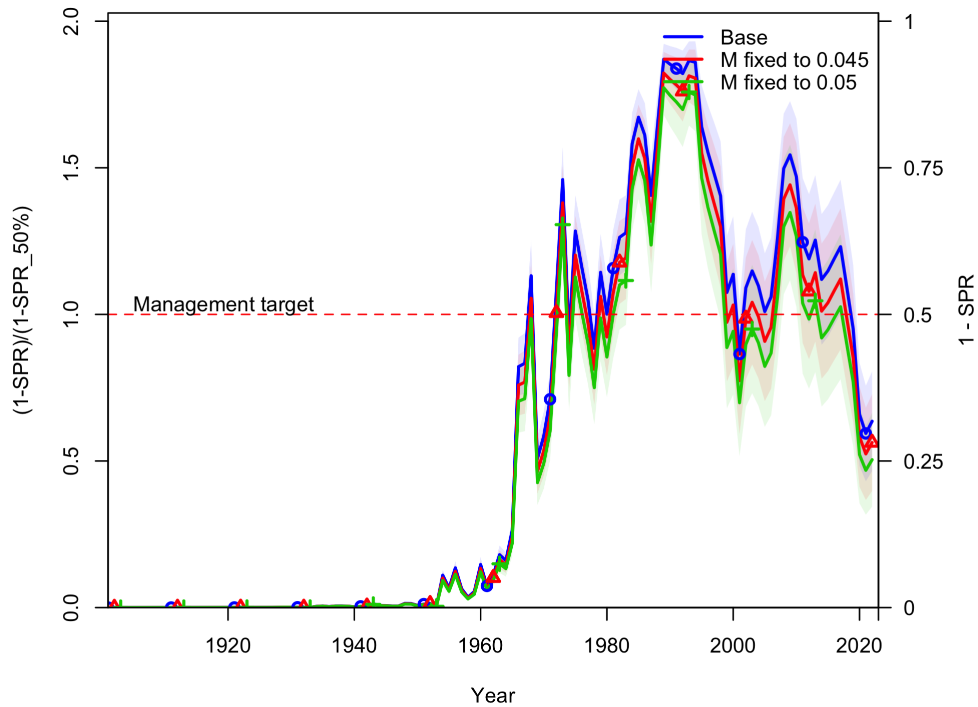

Figure 77: Relative fishing pressure for the base model (blue), natural mortality fixed at 0.045 (red), and 0.05 (green).

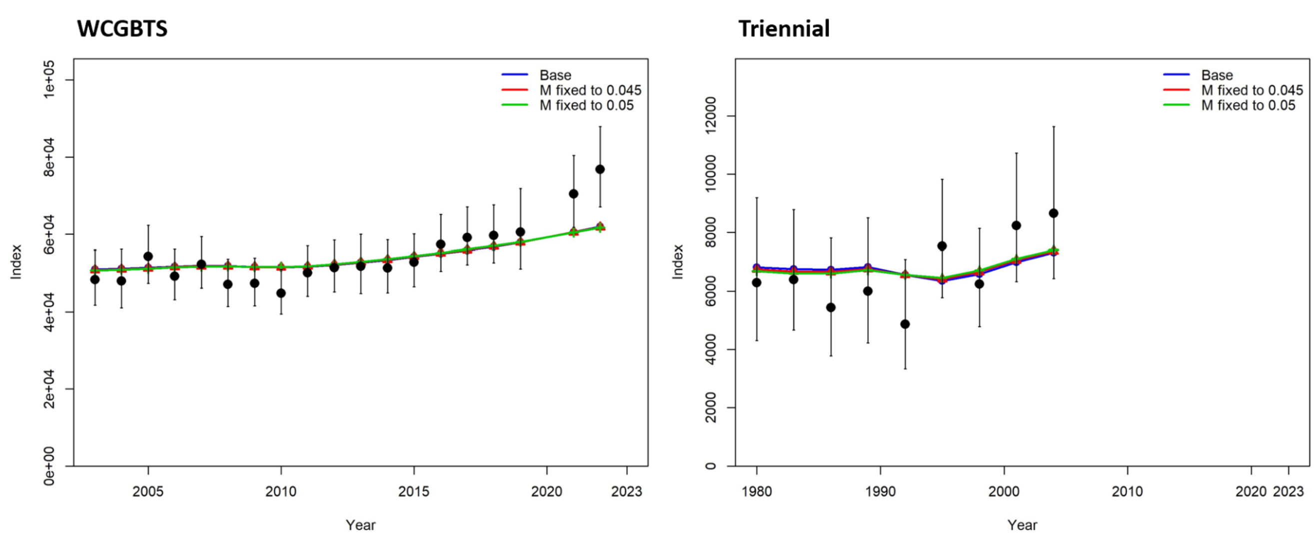

Figure 78: Fits to survey indices for the WCGBTS (left) and the Triennial (right) from the base model (blue), with natural mortality fixed at 0.045 (red), and 0.05 (green).

Panel conclusion: These results did not indicate a need to change the base model formulation.

Request No. 4: Provide sensitivities investigating early time blocks for retention with the goal of improving the fits to discard rates and discard length comps in the 1980's. This should include defining an appropriate block for the period prior to 1990's and estimating the asymptote parameter (potentially below 1). Show fits to all length comps and discard rates. Define the blocks such that the discard data in the 1980's are informing discards for those years, earlier years, and possibly later years, at the discretion of the STAT.

Rationale: Discarding practices before management changes since the 1990's appear to be different than recent years. The discard rates were underfit and the predicted length comps underfit larger sized fish. Creating a time block for this early period and adjusting the asymptote may improve these fits.

STAT Response: The combination of blocks requested by the panel was included in our sensitivity analyses so we compared the model with and without asymptote parameters being estimated (below 1).

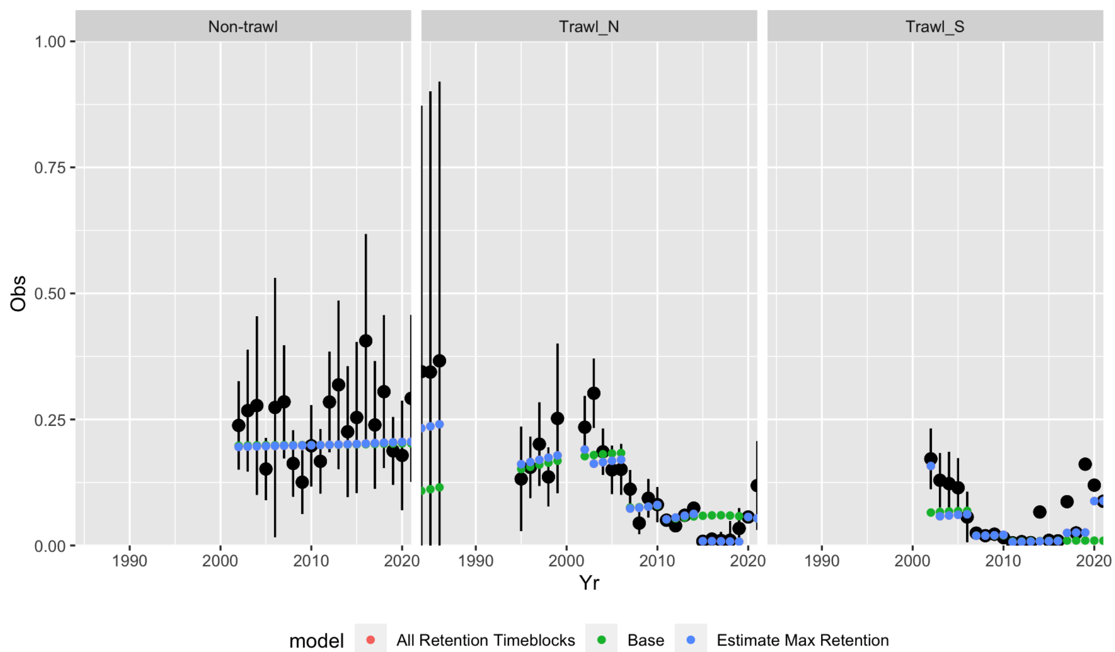

Figure 79. Discard rates with model estimates.

Panel conclusion: Time blocks model led to improved fitting of the early Pititch et al. (1988) data and the Panel agreed this should be included in the base model. This model has a likelihood that is 200 units better. Estimating the maximum retention is not necessary given the length comps do not indicate discarding of large fish.

Request No. 5: Present the model results for sensitivity runs that have been completed, including M=0.045, M=0.05, low growth, and high growth. This should be an interactive presentation of the r4ss plots.

Rationale: There are some details of these runs that would be useful to examine. For example, do any fit the last two years of the WCGBTS better, or do they show improved patterns of recruitment compared to the base model. This interactive evaluation will help inform any potential changes to the pre-STAR base model.

STAT Response: Model results for sensitivity runs for low mortality (*M*=0.045) and high mortality (*M*=0.05) as well as low and high growth were presented.

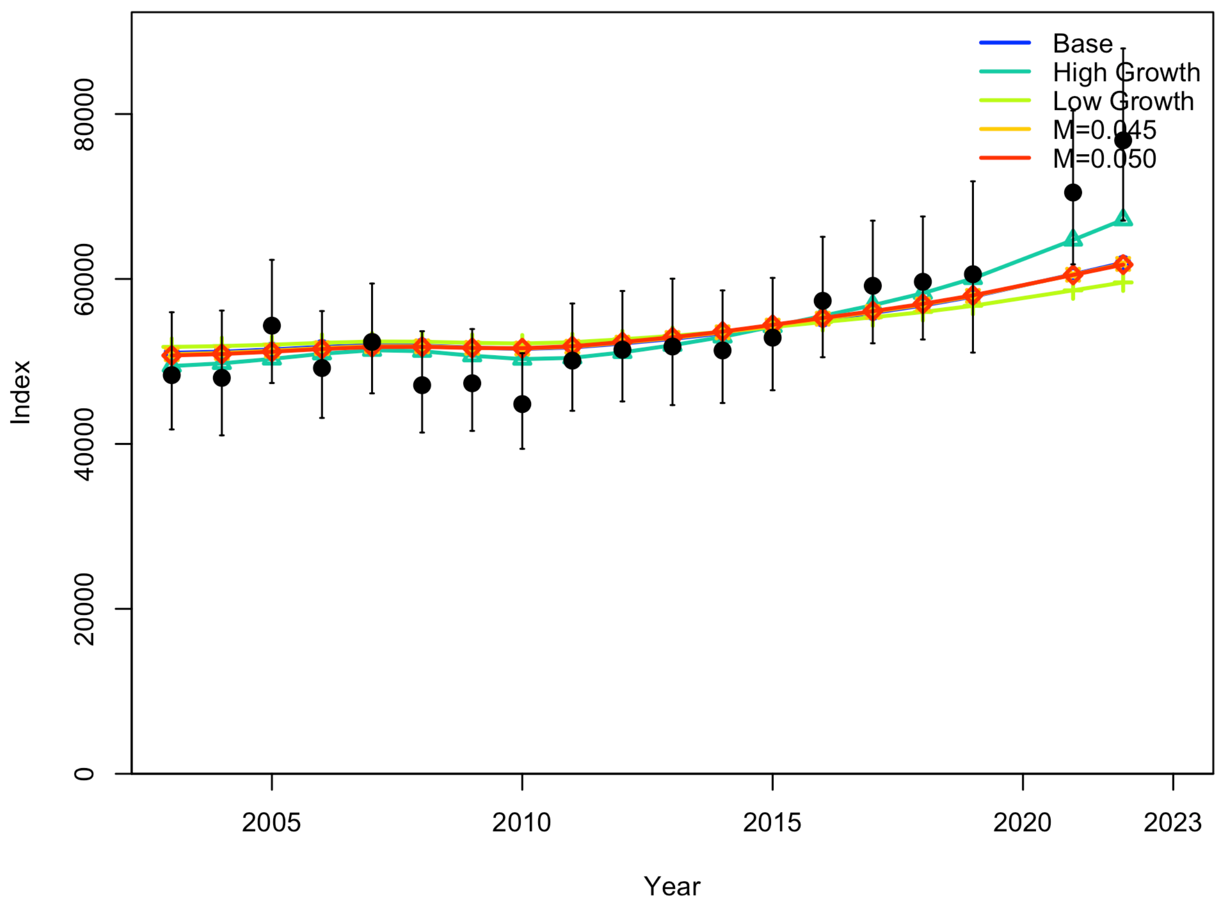

Figure 80. Model fit to the WCGBTS index for the pre-STAR base model (*M*=0.04) and alternative models with growth 25% greater than the base case (*M*=0.40), growth 10% less than the base case (*M*=0.40), *M*=0.045 (base growth) and *M*=0.05 (and base growth).

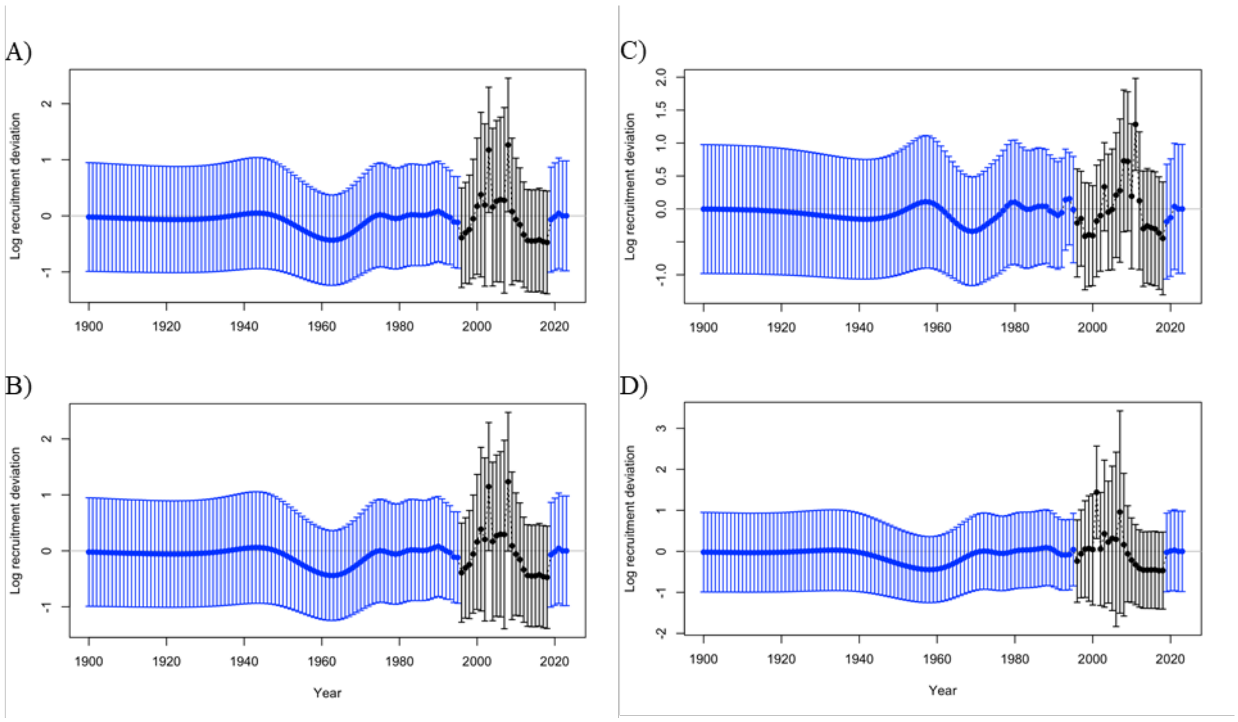

Figure 81. Recruitment deviations for alternative models with A) M=0.045 (base growth), B) M=0.05 (and base growth), C) growth 25% greater than the base case (M=0.40), and D) growth 10% less than the base case (M=0.40).

Panel conclusion: These sensitivity runs did not indicate an improved model formulation.

Request No. 6: Display the exact time blocks for retention and selectivity. Present the years for each block (selectivity and retention) and plot of selectivity/retention/keep curves for each combination of retention/selectivity block. This run will include the at-sea hake data and the updated weight-length estimates. Provide model files (e.g. SS files and plots) for this updated run.

Rationale: There has been an extensive and thorough analysis of time blocks on retention and selectivity (much appreciated) and it would be useful to see the exact specifications and understand how discards are being estimated throughout the entire time-series. The Panel needs a complete description of the model and any changes.

STAT Response: Figures have been created for the retention and selectivity time blocks and curves. For both the North and South Trawl, historical retention timeblocks end in 1989, Ret1 ranges between 1989 - 2007, and Ret2 between 2007 - 2011. Ret3 and Ret4 differ slightly between the North and South Trawl. Ret3 is 2011 - 2015 for the North Trawl and 2011 - 2017 for the South Trawl. Ret 4 is 2015 - 2019 for the North Trawl and 2017 - 2019 for the South Trawl. Ret 5 ranges from 2019 - present for both trawls.

The selectivity timeblocks are the same between North and South Trawl. Historical selectivity ends in 2003, Sel1 ranges from 2003 - 2011, and Sel2 ranges from 2011 to present.

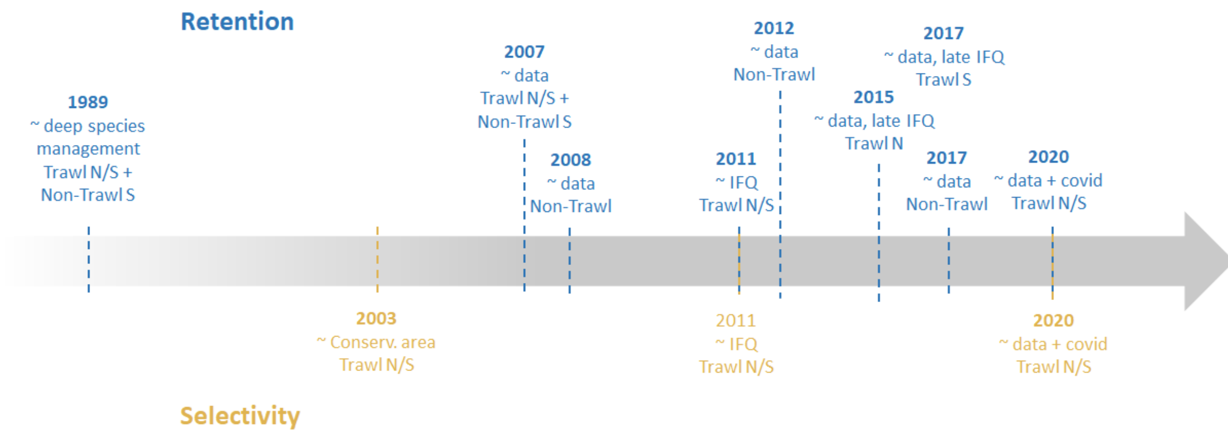

Figure 82. Timeline of all retention (blue) and selectivity (yellow) blocks and their associated rationale.

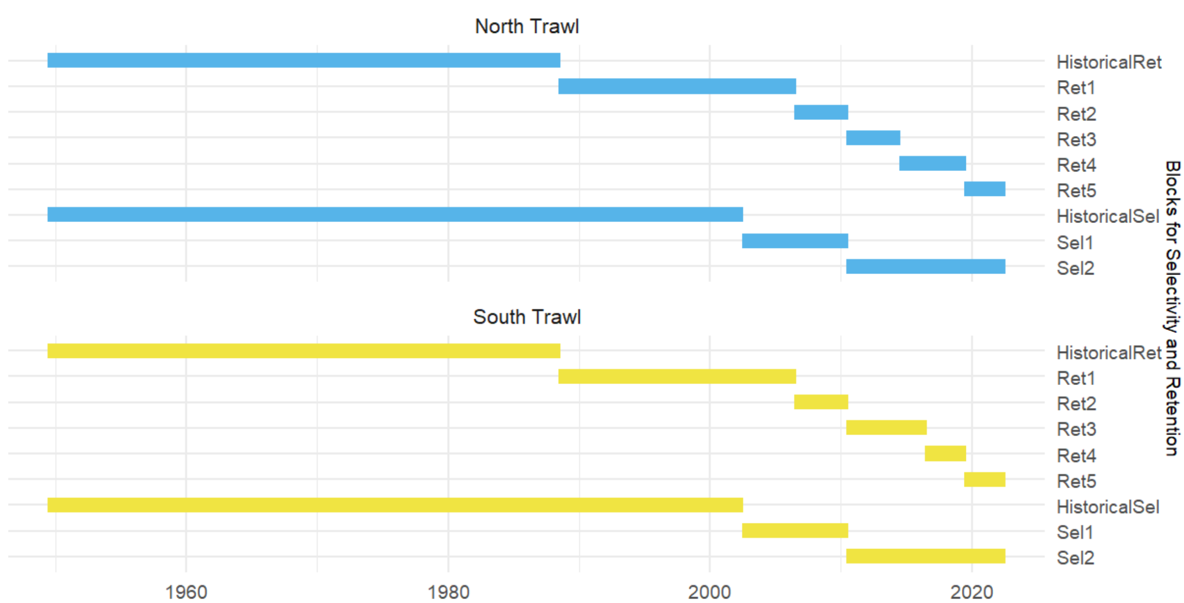

Figure 83. Timeline showing all retention and selectivity blocks for the North (blue) and South (yellow) Trawl.

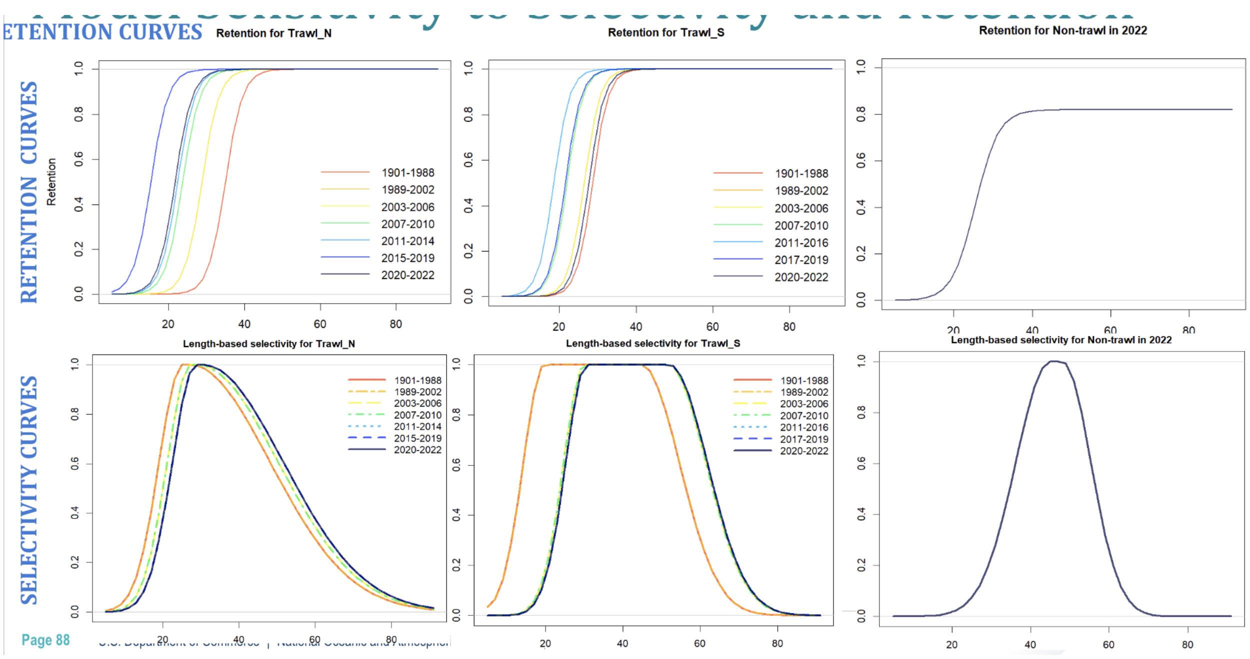

Figure 84. Retention (top row) and selectivity (bottom row) curves for the North (left), South (middle), and Non-(right) Trawl Fishery.

Panel conclusion: These figures clarified the location of time-blocks as well as the selectivity and retention in each time-block.

Request No. 7: Examine predicted recruitment and recruitment deviations for the model with the updated time blocks from Request No. 4 and the at-sea hake catches included (Request No. 1). Show the estimates, the asymptotic standard error estimates, and the bias correction figure from r4ss. Examine alternative bias correction ramps (e.g. reduce the maximum bias correction) and alternative definitions of the main period (e.g. end main period in 2012), as the STAT feels appropriate. Relate recruitment estimates to the updated index of small shortspine thornyhead presented in the 2023 PFMC ecosystem status report (page 18; https://www.pcouncil.org/documents/2023/02/h-1-a-cciea-team-report-1-electronic-only-2022-2023-california-current-ecosystem-status-report-and-appendices.pdf/).

Rationale: There are some patterns in recruitment that would be worthwhile to examine and determine if there are any changes to recruitment estimates given changes to the base model. One concern is the recent period of low estimated recruitment, and whether that is being influenced by modeling assumptions. Examination of the specifications of recruitment is warranted.

STAT Response: Three alternative models were estimated in response to the STAR panel's Request No. 7: a model with a maximum bias correction of 0.3, a model for which the main period of recruitment ends in 2012, and a model that removes the constraint that the sum of recruitment deviations equal zero. The maximum recruitment deviation bias correction presented in the base model was 0.75. Based on the Panel's request for a lower maximum bias correction, a sensitivity analysis was run with a maximum bias correction of 0.3 (Figure 85). Figure 86 illustrates the updated recruitment deviations under this alternative maximum bias adjustment, which appear to have minimal impact to the base model.

In the base model, the main recruitment period ends in 2018. At the panel's request, a sensitivity analysis was conducted that changed the end of the main recruitment period to 2012. This modification resulted in lower deviations from log-zero in recent years as shown in Figure 87 as compared to the base model. Limiting the main recruitment period resulted in an increase to the high in recruitment in 2011 that was previously noted in the base model.

In the base model, deviations from log recruitment are constrained to zero during the main period. Based on the STAR Panel's discussion surrounding the recruitment deviations, a sensitivity analysis was conducted that removed that constraint. Figure 88 illustrates that the magnitude of the recruitment deviations for recent years were substantially reduced under this sensitivity analysis. Deviations in the late 1990s were marginally reduced as well. It is also noted that without a constraint in the log recruitment deviations, the sum of recruitment deviations across the entire time series (including time periods outside of the main period) was indistinguishable from zero. The fits to the WCGBTS biomass index were slightly higher without constraining recruitment deviations to sum to zero, and this model just touched the confidence intervals of the two terminal years (Figure 89).

The STAT could access the updated version of the index of small shortspine thornyhead (method based on Tolimieri et al, 2020; Tolimieri, pers. comm.). While there are no significant correlations between this index and the recruitment estimates from the base model, it is clear from a visual diagnostic and regime-shift detection (Rodionov's methodology; see Figure 90), that there is a transition to a lower recruitment period in the early- mid- 2010s. The time lag between the transition observed in the abundance index and the estimated recruitment should reflect recruitment changes for the earliest detectable cohort in the survey (~ 2 years-old).

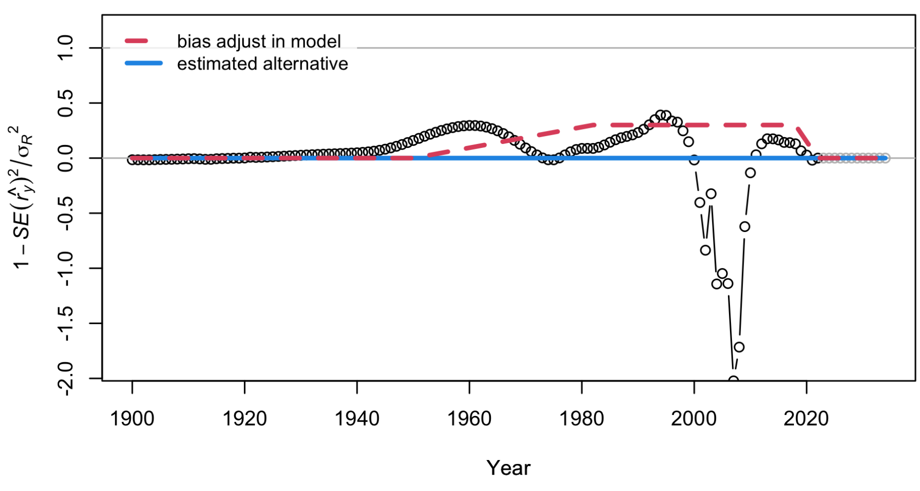

Figure 85. Recruitment deviation bias adjustment with a maximum bias adjustment of 0.3.

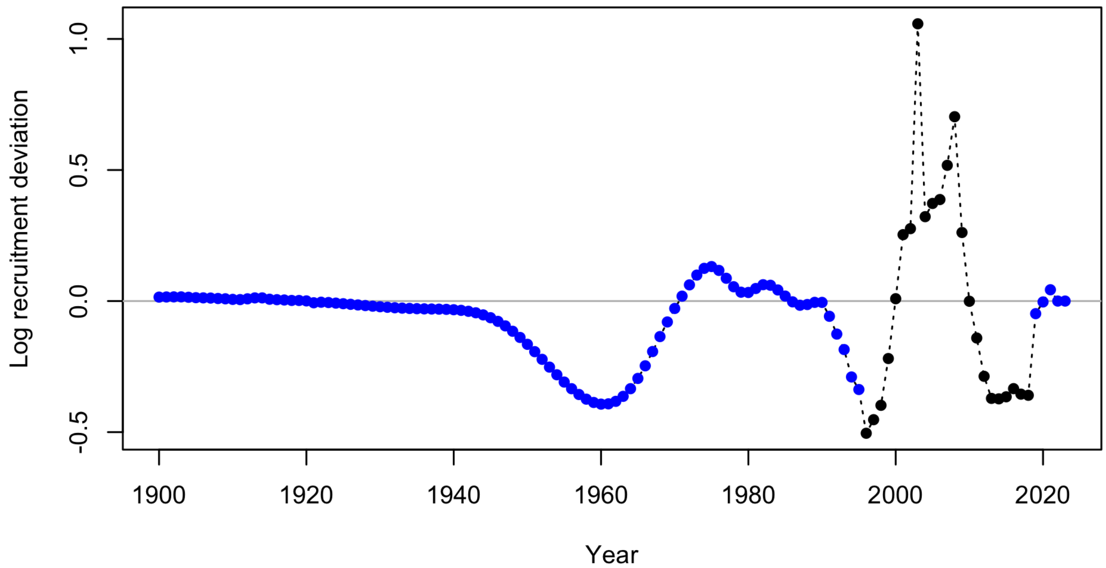

Figure 86. Recruitment deviation when maximum recruitment deviation bias adjustment of 0.3

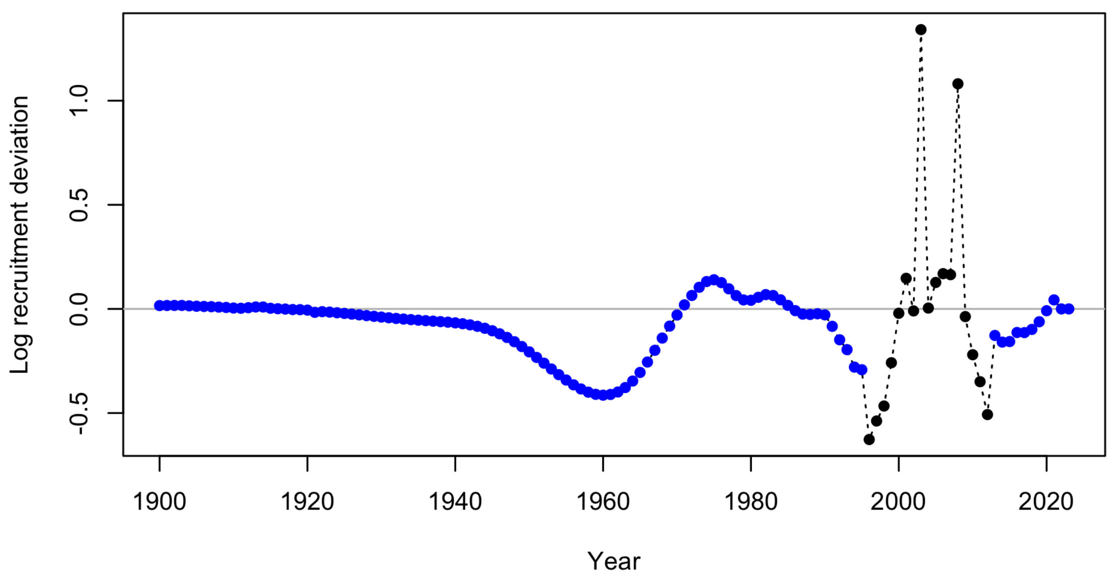

Figure 87. Recruitment deviations when the main recruitment period is years 1996-2012.

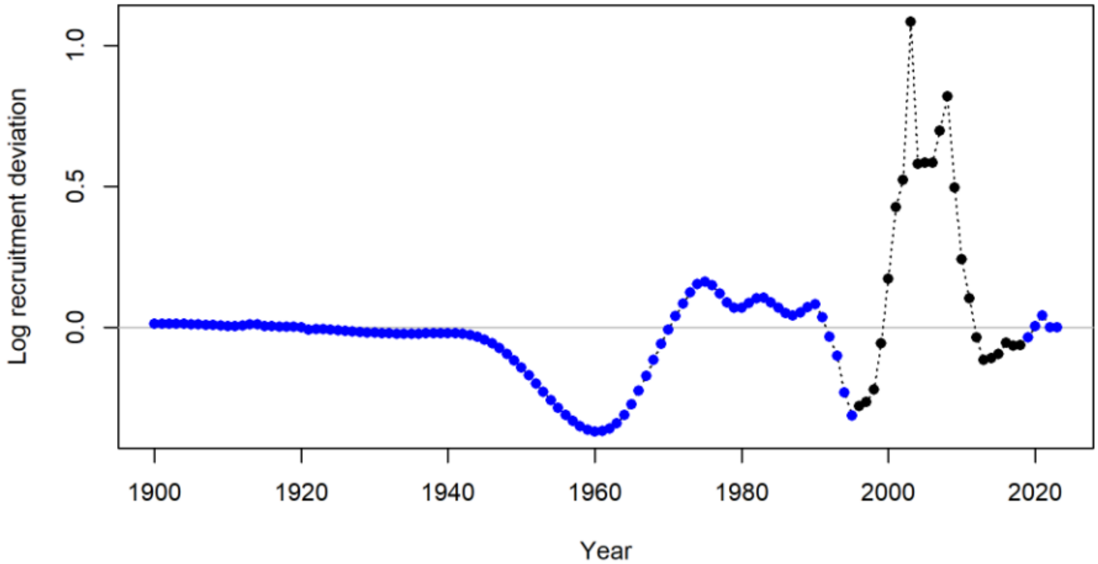

Figure 88. Recruitment deviations without constraining recruitment deviations to sum to zero.

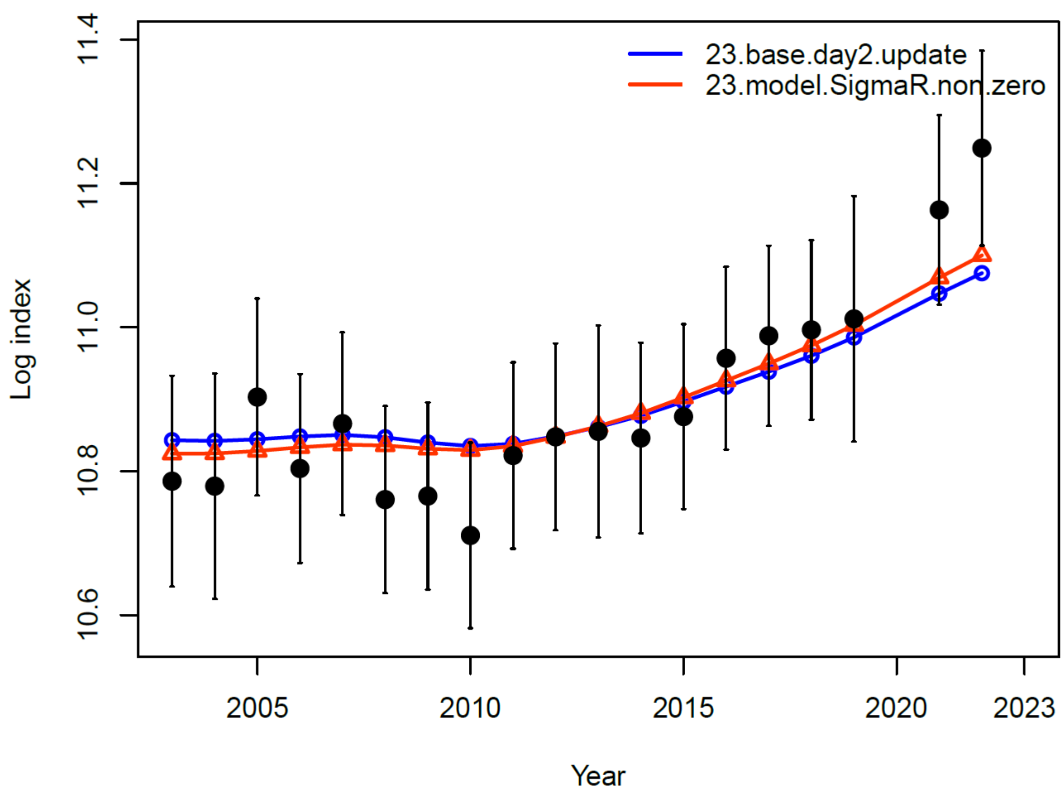

Figure 89. Biomass Index without constraining recruitment deviations to sum to zero.

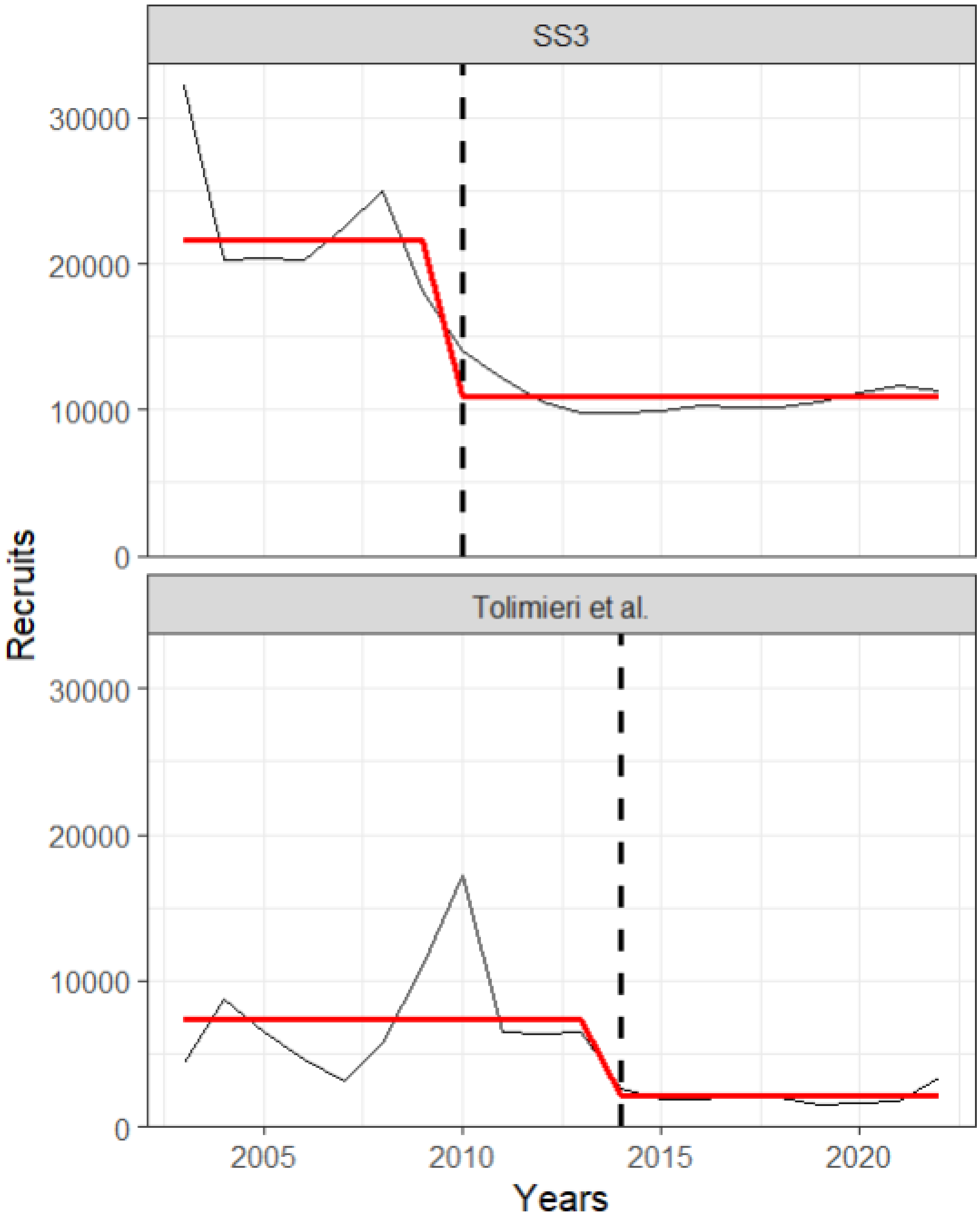

Figure 90. Comparison of the recruitment estimated by SS3 and the abundance index of small shortspine thornyhead from Tolimieri et al. (2020).

Panel conclusion: The recent period of low model recruitment in recent years is consistent with the survey index of small shortspine thornyhead noting that the data used to develop the survey index of small shortspine thornyhead are included in the length compositions in the assessment. Additionally, a maximum bias correction of 0.3 on the recruitment deviations is preferable based on current best practices.

Request No. 8: Provide a run with the main period of recruitment starting at the start year of the model and ending in 2018, with the constraint that the recruitment deviations sum to zero. Maintain the maximum of the bias adjustment at 0.75, as in the pre-STAR base model. Compare this to the estimated recruitment time-series from a run with the main period defined as in the pre-STAR base but with the constraint that the deviations sum to zero removed.

Rationale: Given a short time-period of main recruits and the potential for long periods of low or high recruitment, it may be best practice to not enforce a constraint to sum to zero or to extend the length of the period with the constraint such that deviations would be expected to have an average of zero. When deviations do not sum to zero, there is the potential that the average recruitment from the stock recruit curve could differ in the historical and projection periods.

STAT Response: In response to the panel's Request No. 8, an additional sensitivity model has been completed that extends the main recruitment period to the first model year of 1901. Figure 91 compares this sensitivity analysis with the last sensitivity analysis from Request No. 7 (i.e., a sensitivity that removes the constraint that recruitment deviations sum to zero but leaves the main recruitment period the same as in the base model). There are no apparent differences in recruitment deviations between these two sensitivities. The main recruitment period for the new base model will incorporate this change, resulting in a new base model presented in the subsequent requests.

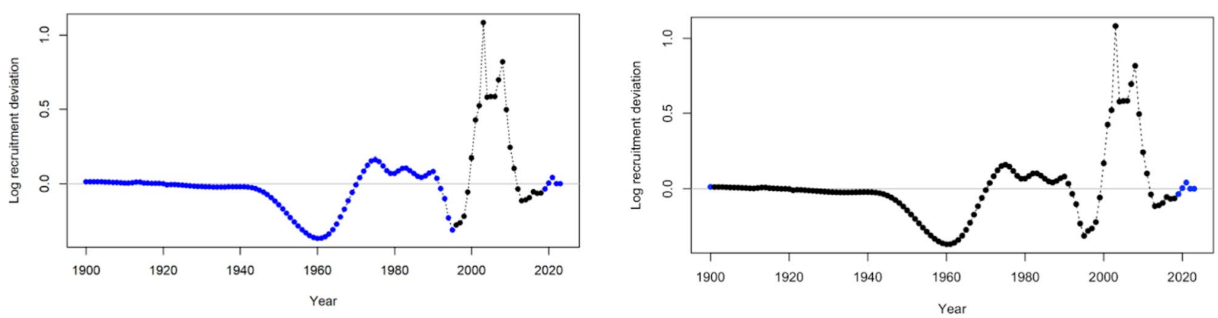

Figure 91: Left: Base model with no restriction on recruitment deviations. Right: Main recruitment period set to years 1901-2018 with the restriction that recruitment deviations sum to 0.

Panel conclusion: The Panel agreed that the sum to zero constraint over the full model time-period produced the same results as the no sum constraint run, and the sum to zero constraint over the full time-period is the preferred option. The Panel concludes that this is the preferred option, with the bias correction ramp max at 0.3.

Request No. 9: Modify the pre-STAR base model in the following ways: 1) inclusion of at-sea hake catches, 2) updated selectivity and retention blocks resulting from Request No. 4, 3) updated weight-length parameters from Request No. 2, 4) main period of recruitment deviations specified as 1901-2018, and 5) the maximum bias correction for recruitment deviations at 0.3. Using this model, determine values of natural mortality (*M*) that would correspond to the 12.5% and 87.5% percentiles of the 2023 OFL estimate from this new base model. Create the same plot for 2023 spawning output using these *M* values determined from the 2023 OFL uncertainty. Uncertainty for the base model is necessary, but uncertainty for the alternate states of nature are not necessary for this request. Also report the calculated sigma value determined from the 2023 OFL.

Rationale: The STAR panel came to the conclusion that these elements provide an improved stock assessment. Natural mortality is a reasonable axis of uncertainty because the values that would satisfy the requirements for the states of nature are within a reasonable range of natural mortality values.

STAT Response: The base model was updated (with uncertainty) to include at-sea hake catches, selectivity and retention blocks, and updated weight-length parameters, with the main recruitment period specified as 1901-2018, and a maximum bias correction for recruitment set at 0.3. Figure 92 illustrates the two values of natural mortality (*M*) that corresponded to the approximate 12.5% and 87.5% percentiles of the posterior lognormal distribution of the OFL estimate. These high and low natural mortality values serve as the alternative states for the model in the forecast. Models were run (without uncertainty) for both the low state of nature (*M* was fixed at 0.03) and in the high state of nature, *M* was fixed at 0.05 (Figure 92).

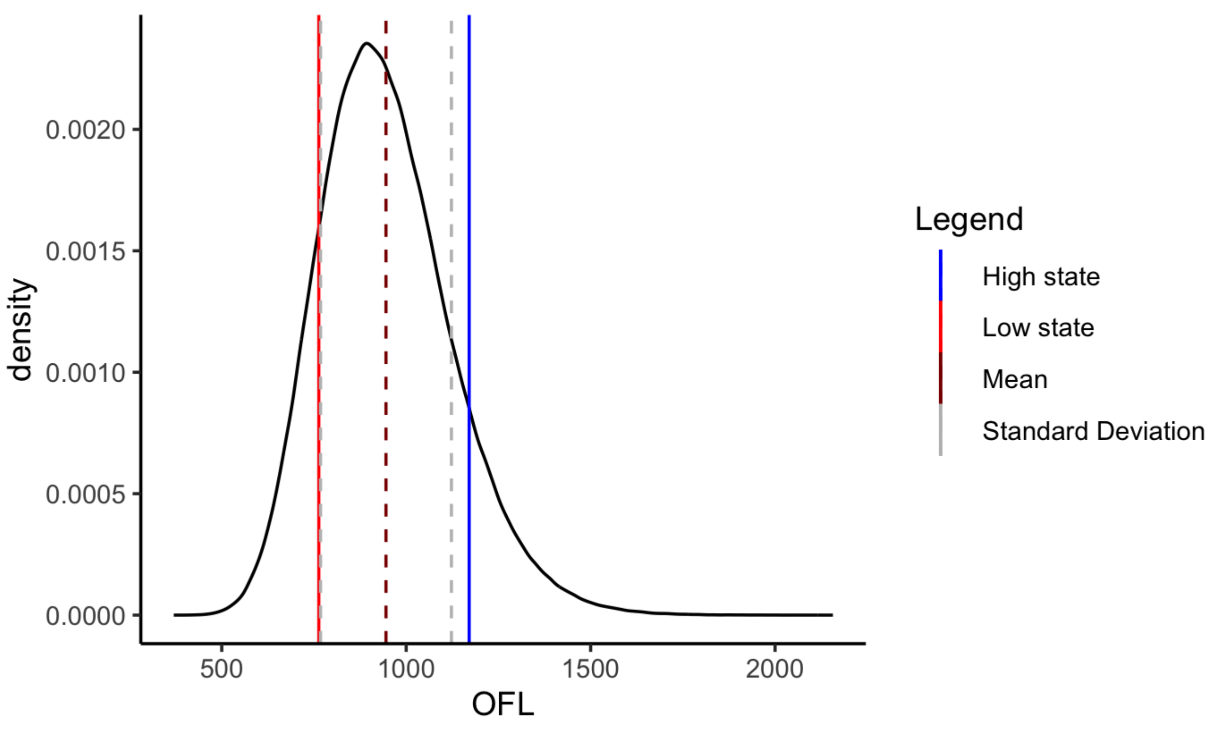

Figure 92. Probability distribution of OFL (lognormal) showing the OFL values corresponding with our low (red) and high (blue) states of nature.

Panel conclusion: The panel concluded that this was the preferred model, and represented the best available information to evaluate the status of shortspine thornyhead.

Request No. 10: Use the default harvest control rule for shortspine thornyhead (P* of 0.4 and a sigma of 1.0) in the base model run with all states of nature (from Request No. 9), as well as an alternative run with a P* of 0.45, with ABC=ACL full attainment under both alternative model runs.

Rationale: The Council has continued to adopt a P* value of 0.4 for shortspine thornyhead since the last time it was assessed with a full benchmark assessment. The GMT requests analyzing an alternative P* value of 0.45 to provide the Council with options for consideration later this year. The projected ACLs are comparable to what the Groundfish Management Team (GMT) predicted for catch projections for 2023-2024. This may become a constraining species to the trawl fleet. Due to increases in sablefish ACLs over the next few years, the trawl fleet that targets DTS (Dover/Thornyhead/Sablefish) may expand to whatever the ACL is, so full attainment is a reasonable expectation.

STAT Response: Six models were explored, considering P* values of 0.4 and 0.45 for both the high and low states of nature (*M* values). All models, including base models specified for each P*, were forecasted for 12 years. Results are provided in Figure 93 (P*=0.4), Figure 94 (P*=0.45), and in Table 21. Note that there was an error in the catch stream calculations, and this will be updated in the Revised Draft Assessment document (post-STAR panel), as requested by the panel. The low and high states of nature for *M* lead to fractions of 2034 unfished biomass higher (out of the uncertainty envelope) and very similar to the base model, respectively. These patterns are consistent with those observed during the sensitivity analysis, which highlighted that the lowest fraction of unfished biomass in 2023 was reached for the base model. Note that while the projections of high and low states of nature reflect a higher spawning biomass when compared to the base model, the fraction of unfished biomass indicate that the trends for low and high states of nature do behave as expected for assumptions of high vs low stock productivity, where the base model fraction of unfished falls in between the low and high states of nature in the terminal year of projections (Figures 93, 94).

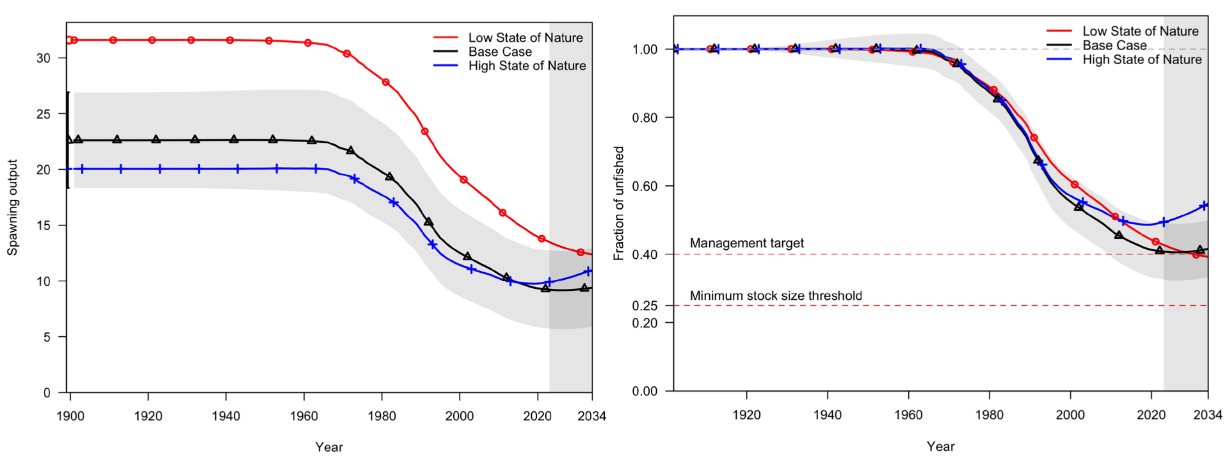

Figure 93. Comparison of the predicted trends in the spawning output and fraction of unfished biomass for the base model and the low and high states of nature of natural mortality, including projections, under P*=0.4. Forecast period is highlighted in gray. Note that the catch streams will be updated in the Revised Draft Assessment document (post-STAR panel).

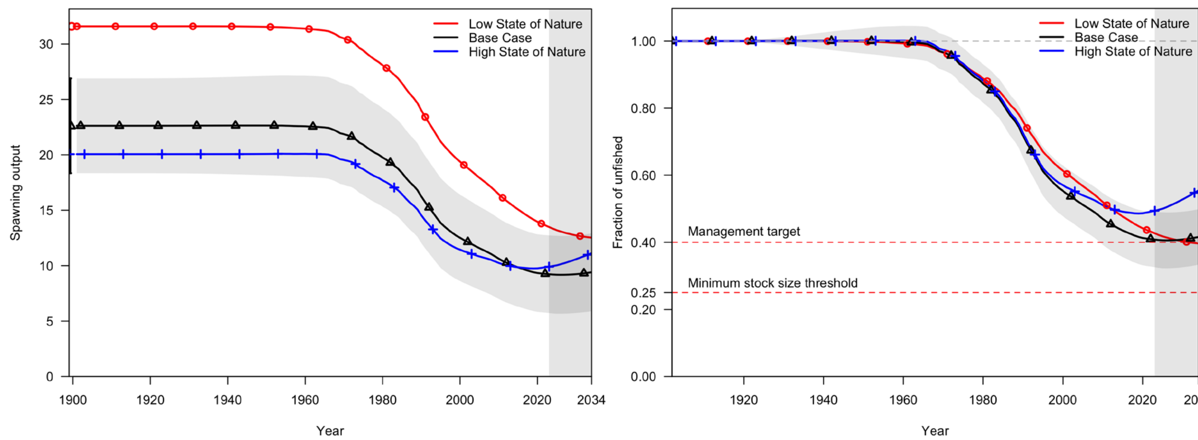

Figure 94. Comparison of the predicted trends in the spawning output and fraction of unfished biomass for the base model and the low and high states of nature of natural mortality, including projections, under P*=0.45. Forecast period is highlighted in gray. Note that the catch streams will be updated in the final assessment document.

Table 21. Decision table showing the low state of nature (*M*=0.03), the base model (*M*=0.04), and the high state of nature (*M*=0.05) for two P* options, 0.4, (standard for shortspine thornyhead) and 0.45.

			Low State of Nature		**Base State of Nature**		**High State of Nature**	
	Yr	**Catch (mt)**	**SO**	**Depletion**	**SO**	**Depletion**	**SO**	**Depletion**
P*=0.40	2023	756	13,485	0.426	9,229	0.408	9,907	0.494
	2024	756	13,334	0.422	9,200	0.407	9,965	0.497
	2025	755	13,194	0.418	9,181	0.406	10,032	0.500
	2026	756	13,064	0.414	9,171	0.405	10,110	0.504
	2027	757	12,943	0.410	9,171	0.405	10,196	0.508
	2028	758	12,832	0.406	9,178	0.406	10,289	0.513
	2029	758	12,729	0.403	9,193	0.406	10,389	0.180
	2030	757	12,636	0.400	9,216	0.407	10,494	0.523
	2031	756	12,551	0.397	9,245	0.409	10,604	0.529
	2032	753	12,474	0.395	9,280	0.410	10,718	0.534
	2033	750	12,405	0.393	9,321	0.412	10,834	0.540
	2034	747	12,344	0.391	9,366	0.414	10,952	0.546
P*=0.45	2023	756	13,485	0.427	9,229	0.408	9,907	0.494
	2024	756	13,334	0.422	9,200	0.407	9,965	0.497
	2025	866	13,194	0.418	9,181	0.406	10,032	0.500
	2026	874	13,056	0.413	9,164	0.405	10,103	0.504
	2027	883	12,927	0.409	9,155	0.405	10,180	0.508
	2028	891	12,806	0.405	9,153	0.405	10,264	0.512
	2029	897	12,693	0.402	9,158	0.405	10,354	0.516
	2030	903	12,588	0.398	9,170	0.405	10,449	0.521
	2031	909	12,491	0.395	9,187	0.406	10,548	0.526
	2032	913	12,401	0.393	9,210	0.407	10,650	0.531
	2033	916	12,317	0.390	9,237	0.408	10,753	0.536
	2034	919	12,240	0.387	9,268	0.410	10,858	0.541

Panel conclusion: The Panel notes that the catch stream in Table 4 is incorrect but accepts this approach for developing the decision tables. The corrected decision table will be included in the Revised Draft Assessment (post-STAR panel).

Request No. 11: The GMT requests that the STAT provide a table in the Revised Draft Assessment (post-STAR panel) document similar to Table xiv in the copper rockfish assessment. This table can be a modification of the existing Table 7 in the draft shortspine thornyhead document, or a new table.

Rationale: Historically the STAT has provided a table in the assessment document that includes current specifications cycle OFL/ABC and contains projected catches as provided by the GMT, as well as projected OFL/ABC values for management cycles out to 10 years.

Example from Copper rockfish in California pre-STAR draft assessment (Executive Summary):

Table xiv: The estimated OFL, ABC, buffer, spawning output in billions of eggs across California, and relative spawning outut by year.

Year	Adopted OFL (mt)	Adopted ABC (mt)	Assumed Catch (mt)	OFL (mt)	ABC (mt)	Buffer	Spawning Output	Relative Spawning Ouptut
2023	116.4	91.5	91.5	-	-	-	289.74	0.421
2024	121.3	94.7	94.7	-	-	-	297.76	0.433
2025	-	-	-	172.7	161.5	0.935	304.99	0.443
2026	-	-	-	172.4	160.3	0.93	305.40	0.444
2027	-	-	-	171.9	159.2	0.926	305.18	0.444
2028	-	-	-	171.3	157.9	0.922	304.55	0.443
2029	-	-	-	170.5	156.4	0.917	303.66	0.442
2030	-	-	-	169.8	155	0.913	302.68	0.440
2031	-	-	-	169.1	153.7	0.909	301.67	0.439
2032	-	-	-	168.4	152.2	0.904	300.67	0.437
2033	-	-	-	167.8	151	0.9	299.76	0.436
2034	-	-	-	167.4	149.9	0.896	298.94	0.435

STAT Response: The table specified above (Table 21 in Request No. 10) will be included in the revised post-STAR panel assessment document in the format of Table xiv in the current Copper rockfish assessment.

Panel conclusion: The Panel accepts this approach for inclusion in the decision tables.

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

The pre-STAR base model was modified by inclusion of at-sea hake catches, updated selectivity and retention blocks resulting from Request No. 4, updated weight-length parameters from Request No. 2, specifying the main period of recruitment deviations from 1901-2018, and adjusting the maximum bias correction for recruitment deviations to 0.3. This resulted in a model that had improved fit to the WCGBTS index and length comps.

Natural mortality was defined as the axis of uncertainty because changes in the fixed value of *M* resulted in significant changes in the spawning output, and because the specification of *M* using maximum age is uncertain. Natural mortality values of 0.03 and 0.05 were chosen to represent the 12.5% and 87.5% percentiles of the estimated 2023 OFL.

The alternative models do not fully bracket the range of spawning output or fraction of unfished biomass in the expected manner but response in the projection period follows the Panels expectation. Under the base case, the fraction of unfished biomass is expected to remain flat throughout the projection period in contrast to increasing or decreasing trends under the high or low states of nature, respectively.

Recommended sigma value and basis of recommendation

The value for sigma calculated from the assessment is 0.18, which is less than the default sigma for a Category 2 stock, which is 1.0. Therefore, a sigma of 1.0 is recommended.

Technical Merits of the Assessment

The STAR panel commends the STAT for their systematic and thorough documentation of the assessment data and model specifications, and their documentation of assessment model diagnostics and sensitivity analyses.

Technical merits of the assessment model can be summarized as a size-structured model that integrates all relevant data about the productivity dynamics for the shortspine thornyhead stock as a whole. Model fit diagnostics were good overall, as were model convergence diagnostics.

The single stock structure assumption seemed reasonable, or there were no compelling reasons to treat populations as substocks. However, this is also a source of uncertainty (see below).

All available data were considered for use in the stock assessment. Data that were excluded from the assessment model were explicitly explored during the development of the stock assessment or have not changed since their past exploration in a previous shortspine thornyhead stock assessment. In some cases, the inclusion of excluded data sources were explored through sensitivity analyses.

A long time-series (1901-2022) of estimates of fishery landings and discards have been constructed for the shortspine thornyhead stock assessment. This has been improved since the last assessment by using historical state catch reconstructions instead of previous analyses that imputed historical shortspine thornyhead catch as a fixed proportion of sablefish catch. The accuracy of estimates of landings and discards has improved over time. This is a merit but is also a source of uncertainty (see below).

A new use of data was model-based survey index standardization using the sdmTMB package, which is described in the pre-STAR draft assessment. Model-based index standardization is a common practice in U.S. West Coast groundfish stock assessments. In particular, a single Triennial Survey index time series was produced that accounted for the increase of the maximum depth (from 366 m to 500 m) of this survey since 1995 onward. This is a merit because splitting survey series reduces the stock trend information.

Another new data source included in this assessment are the histological maturity samples from the WCGBTS survey in 2011, 2013, 2014, 2016 and 2018.

Technical Deficiencies of the Assessment

There is insufficient age data and high uncertainty associated with the ages used.

Data that were excluded from the assessment model were not described by the STAT.

The Panel only superficially reviewed the model-based survey index standardization, by comparing design-based versus model-based estimates. However, details of the standardization may impact how the indices should be used in stock assessment models.

Areas of Disagreement Regarding STAR Panel Recommendations

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

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

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

Prior to the STAR Panel review, the GMT noted differences in some catch streams between downloads made by the STAT team and GMT. The STAT team indicated that while not all fishery data sources were made available to them prior to the pre-STAR panel draft document deadline, the post-STAR panel assessment document would include all fishery sources of mortality for shortspine thornyhead. The willingness of the STAT team to reconcile differences and update portions of the catch streams was appreciated.

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

Unresolved Problems and Major Uncertainties

Major uncertainties in the model are centered around uncertainty in biological processes including growth, maturity, and mortality. The absence of reliable ageing methods for shortspine thornyhead, particularly, makes it difficult to estimate growth and natural mortality.

The assessment does not include age composition data; there is no production ageing of thornyheads for the U.S. West Coast (or Alaska). The assessment model used external estimates of a Von Bertalanffy growth curve based on the Butler research age dataset. The ages in these data were averaged from two age-readers. Nonetheless, there will still be ageing error in the averages. It was also not described how fish were selected for aging or whether they were representative of the overall stock. Age measurement errors and sampling methods are both sources of bias in Von Bertalanffy parameter estimates.

The WCGBTS model-based indices generally followed the design-based trends (see Figure 9 in the pre-STAR draft assessment); however, the 2021 and 2022 model-based indices are substantially higher than the design-based indices. Confidence intervals for the model-based indices do not cover the 2021 design-based index, and barely cover the 2022 index. The assessment model could not fit the last two model-based indices which was a concern for the Review Panel. It is a source of uncertainty why there is such a difference in design- and model-based indices in 2021 and 2022.

The Panel agreed that shortspine thornyhead along the Pacific coast could be assessed as a single stock, but recognized that there is a lack of information of recruitment dynamics (e.g., larval transport) that may indicate functional substock structure. These fish do not move much and may be territorial which are attributes that can contribute to substock structure.

There is uncertainty in catch estimates, and more so for historic periods and when interpolations are used to fill in catches for some years. This uncertainty was not quantified and provided to the Panel. There is an important need for STATs to provide information on the quality of the annual catch estimates, and more specifically to quantify the uncertainty in these estimates. This technical deficiency is common to all assessments reviewed by this Panel.

Recommendations for Future Research and Data Collection

The panel supports the recommendations provided in the pre-STAR draft assessment (reproduced below). With respect to maturity (No. 3 below), the Panel notes that maturity predictions were derived from a Bernoulli GLM fit to functional maturity data from the WCGBTS samples. The GLM model included covariate effects for fish length, latitude, latitude squared, depth and depth squared. For the 2023 assessment, a single curve for the coastwide population assessment of shortspine thornyhead was derived by setting the latitude and depth at the values of the center of gravity (using number of fish as a weighing factor) of the population sampled by the WCGBTS. A better approach is to derive a density-weighted average maturity ogive across the stock domain, with density approximated via catches from the WCGBTS. In addition to further research into aging methods (No. 1 below), the Panel suggests the use of an Errors in Variables approach to fit the Butler growth data (e.g., Dey et al. 2019).

1. Research into aging methods and availability of reliable age data would be valuable for future stock assessments. Otoliths have been collected in good quantities from the NWFSC survey, but there is currently no validated aging method for shortspine thornyhead.

2. Additional investigation into growth patterns would provide valuable information for future population projections. We acknowledge that additional work on aging shortspine thornyhead would be required to make such additional growth research possible.

3. More investigation into maturity of shortspine thornyhead is necessary to understand the patterns in maturity observed in WCGBTS samples.

4. Information on possible migration of shortspine thornyheads would be valuable for understanding stock dynamics. Analysis of trace elements and stable isotopes in shortspine otoliths may provide valuable information on the extent of potential migrations. Possible connections between migration and maturity could likewise be explored.

5. A greater understanding of the connection between thornyheads and bottom type could be used to refine the indices of abundance. Thornyheads are very well sampled in trawlable habitat, but the extrapolation of density to a survey stratum could be improved by accounting for the proportion of different bottom types within a stratum and the relative density of thornyheads within each bottom type.

6. Additional investigation into spatial stock structure could be valuable for determining whether future assessments should develop a spatial assessment model, or if shortspine thornyhead should be assessed at distinct spatial scales in the future.

7. Further research into the Dirichilet-Multinmoial (DMN) data-weighting method for length-composition data is needed for integration with length-based data-moderate assessments like shortspine thornyhead. The DMN method has not, to date, been thoroughly simulation tested with length-composition data, and an attempted sensitivity analysis performed for the 2023 assessment failed to converge entirely. This is a general research need, and is widely applicable to many data-moderate or length-based assessments, not just shortspine thornyhead.

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

The Panel supports this assessment as a Category 2 designation. If no new age data become available, an update assessment would be appropriate.

Acknowledgements

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

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