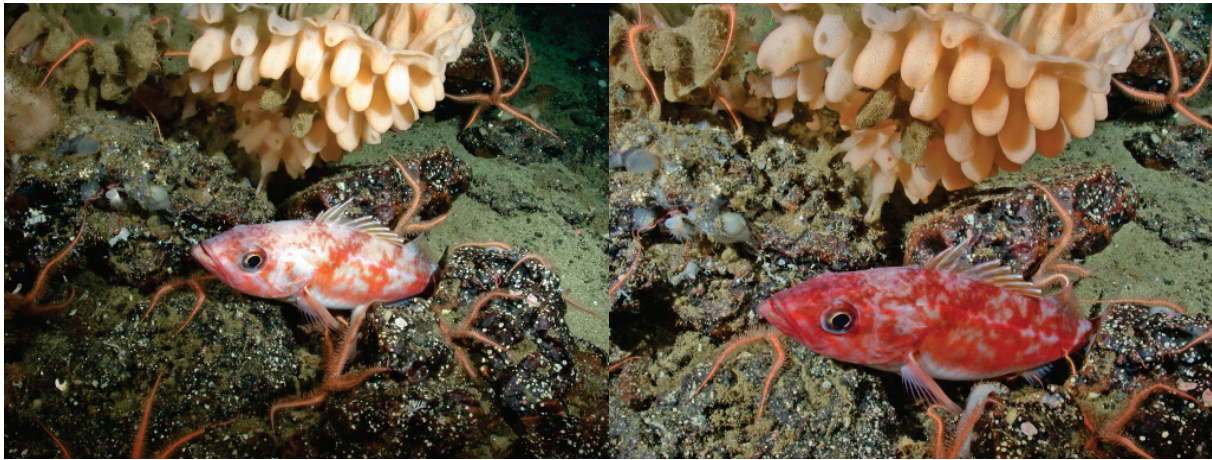


# The Status of Chilipepper Rockfish (*Sebastes goodei*) in U.S. Waters off California, Oregon, and Washington in 2025

July 28, 2025



E.J. Dick<sup>1,\*</sup>, John C. Field<sup>1</sup>, Nicholas Grunloh<sup>2,1</sup>, and Tanya Rogers<sup>1</sup>

<sup>1</sup> Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 110 McAllister Way, Santa Cruz, CA 95060

<sup>2</sup> University of California, Santa Cruz, Cooperative Institute for Marine, Earth, and Atmospheric Systems, 1156 High Street, Santa Cruz, CA 95064, USA

\* Corresponding author: [edward.dick@noaa.gov](mailto:edward.dick@noaa.gov)



U.S. Department of Commerce  
National Oceanic and Atmospheric Administration  
National Marine Fisheries Service  
Southwest Fisheries Science Center

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**Photo Credit:** NMFS SWFSC. *In:* Butler, J., M. Love, and T. Laidig. 2012. A Guide to the Rockfishes, Thornyheads, and Scorpionfishes of the Northeast Pacific. University of California Press.

Description from Butler et al. (2012; page xi): “*The ability to rapidly change color and pattern (often in just a few seconds) is most obvious in those species that routinely both swim in the water column and rest on the sea floor (e.g., bocaccio, chilipepper, halfbanded, shortbelly, squarespot, stripetail, and widow rockfishes). In these species, fish lying on, or adjacent to, substrate are heavily mottled, spotted, and blotched. That same individual swimming in the water column lacks most or all patterning and is often drab.*”

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## **Common Acronym Definitions:**

ABC: Acceptable Biological Catch

ACL: Annual Catch Limit

CAAL: Conditional age-at-length

CalCOFI: California Cooperative Oceanic Fisheries Investigations

CALCOM: California Cooperative Groundfish Survey Database

CDFW (formerly CDFG): California Department of Fish and Wildlife (formerly Fish and Game)

CI: Confidence Interval

CPFV: Commercial Passenger Fishing Vessel (aka “party” or “charter” boats, or “PC mode”)

CPUE: Catch-per-unit-effort

CRFS: California Recreational Fisheries Survey

GEMM: Groundfish Expanded Mortality Multiyear [report]

GMT: Groundfish Management Team of the PFMC

IFQ: Individual Fishing Quota

MRFSS: Marine Recreational Fisheries Statistics Survey

MSST: Minimum Stock Size Threshold (i.e., 25% of unfished spawning output for rockfishes)

MSY: Maximum Sustainable Yield

NMFS: National Marine Fisheries Service

NOAA: National Oceanic and Atmospheric Administration

NWFSC: Northwest Fisheries Science Center

ODFW: Oregon Department of Fish and Wildlife

OFL: Overfishing Limit

PacFIN: Pacific Fisheries Information Network

PFMC: Pacific Fishery Management Council

PR: Private/Rental recreational boat (aka private boat or “skiff”)

PSMFC: Pacific States Marine Fisheries Commission

RecFIN: Recreational Fisheries Information Network

RREAS: Rockfish Recruitment and Ecosystem Assessment Survey (NMFS, SWFSC)

SPR: Spawning Potential Ratio; the ratio of equilibrium spawning output under fished and unfished conditions

SSC: Scientific and Statistical Committee of the PFMC

STAR: Stock Assessment Review (Panel)

STAT: Stock Assessment Team

SWFSC: Southwest Fisheries Science Center

WCGBTS: West Coast Groundfish Bottom Trawl Survey

WCGOP: West Coast Groundfish Observer Program

WDFW: Washington Department of Fish and Wildlife

YOY: Young-of-the-year, i.e., age-0 fish



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## Executive Summary

### Stock

This assessment reports the status of the chilipepper rockfish (*Sebastes goodei*), also known simply as “chilipepper,” in U.S. waters off the coast of California, Oregon, and Washington. Although relatively few chilipepper are observed off the coast of Washington, landings from that state have been included in the analysis to facilitate coastwide management based on a single assessment model. Information about stock structure from genetic analyses and tagging studies is outdated and/or has insufficient sampling effort to detect evidence of reproductive isolation or movement patterns. Analyses conducted for this assessment suggest that patterns of adult growth (length-at-age) are similar across the assessed range. Most catches were taken by trawl gear in California, north of Point Conception (34° 27' N. lat.), following World War II until roughly the year 2000 when large-scale spatial closures went into effect. No data are available to inform trends in chilipepper abundance in Mexican waters. Based on these general findings, the population dynamics are modeled as a single, “coastwide” stock in U.S. waters from the U.S./Mexico border (roughly 32.5° N. latitude) to the U.S./Canada border (49° N. lat.).

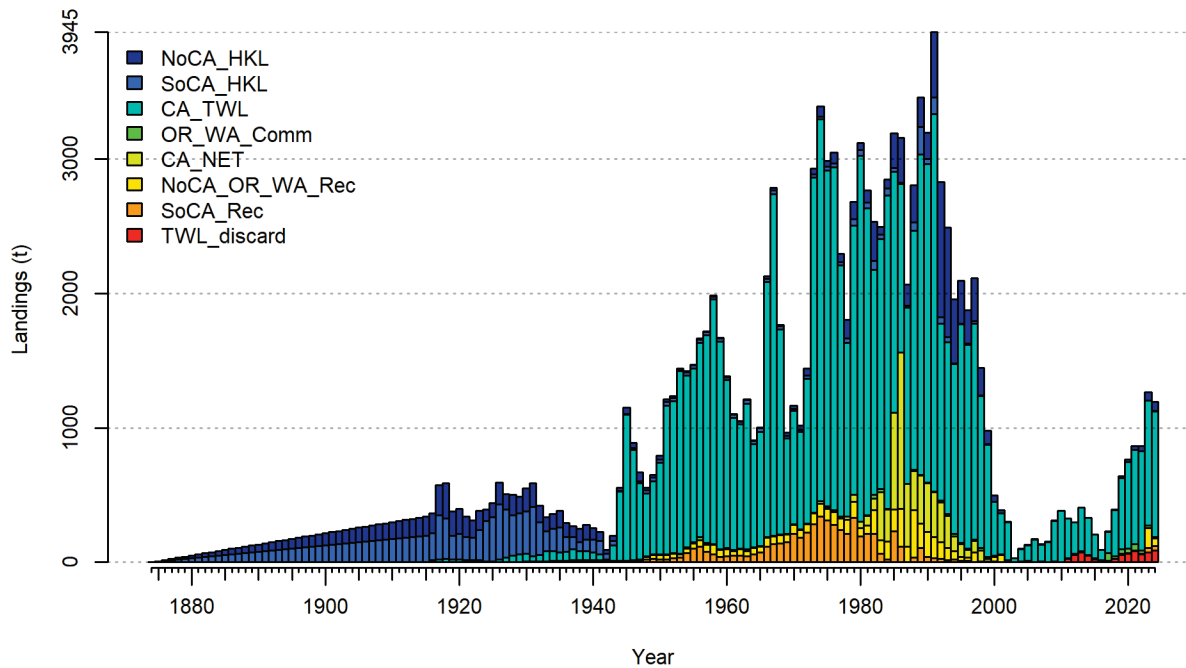
Chilipepper rockfish in U.S. waters are currently managed south of 40° 10' N. latitude (roughly Cape Mendocino, California) with a species-specific harvest specification. North of Cape Mendocino, chilipepper are a component stock in the PFMCC's northern shelf rockfish complex.

### Catches

Prior to World War II, chilipepper rockfish were landed primarily by commercial hook and line gears (the dominant gear type of the era), followed by an abrupt switch to trawl gears after the war (Figure a). Landings by hook and line gear types, as a fraction of total landings, increased during the 1980s and 1990s, as did landings by net gears, but have since declined. Significant declines in landings since the 2000s across all gears have been due to regulatory action in response to evidence of declining rockfish populations at the time. Recreational catches of chilipepper peaked around 1970, accounting for roughly 20% of total fishing mortality at that time. Since the war, the California trawl fleet has accounted for most landings in all but a few years. In recent years, the trawl fleet continues to be the dominant source of landings (Table a). Recent landings by commercial hook and line gears have represented less than 10% of trawl landings. Recreational landings increased dramatically in 2023 and 2024 due to closures of nearshore waters, resulting in increased fishing effort in depths inhabited by chilipepper rockfish, and direct targeting of the species in some areas. Despite this increase in recreational landings, the trawl fishery still accounted for over 80% of total fishing mortality (catch + dead discards) in 2023-2024.

**Table a.** Recent catches (mt) by fleet and total catch (mt) summed across fleets for the assessed region. HKL = hook and line, TWL = trawl, Comm. = all commercial gears, Rec. = recreational, and Pt. Conc. = Point Conception, CA.

| Year | North<br>CA<br>HKL | South<br>CA<br>HKL | CA<br>TWL | OR +<br>WA<br>Comm. | CA Net | Rec. N.<br>of Pt.<br>Conc. | Rec. S.<br>of Pt.<br>Conc. | TWL<br>discard | Total<br>Catch |
|------|--------------------|--------------------|-----------|---------------------|--------|----------------------------|----------------------------|----------------|----------------|
| 2015 | 0.9                | 0.2                | 176.1     | 1.8                 | 0.0    | 0.0                        | 5.8                        | 20.6           | 205.6          |
| 2016 | 0.4                | 0.1                | 76.6      | 4.6                 | 0.0    | 0.0                        | 5.4                        | 3.3            | 90.4           |
| 2017 | 2.7                | 0.2                | 157.4     | 56.7                | 0.0    | 0.1                        | 2.5                        | 10.5           | 230.2          |
| 2018 | 2.5                | 0.4                | 344.3     | 17.4                | 0.0    | 0.0                        | 2.0                        | 24.2           | 390.8          |
| 2019 | 13.7               | 0.3                | 530.6     | 34.8                | 0.0    | 0.1                        | 5.8                        | 55.7           | 641.1          |
| 2020 | 19.8               | 0.4                | 643.3     | 34.5                | 0.0    | 0.1                        | 1.6                        | 65.4           | 765.1          |
| 2021 | 27.1               | 1.3                | 700.7     | 46.1                | 0.1    | 0.2                        | 3.7                        | 83.0           | 862.2          |
| 2022 | 37.9               | 1.7                | 740.4     | 21.7                | 0.0    | 1.1                        | 3.6                        | 59.7           | 866.2          |
| 2023 | 59.9               | 2.2                | 928.1     | 18.0                | 0.0    | 146.1                      | 34.3                       | 74.2           | 1262.9         |
| 2024 | 66.2               | 3.3                | 936.0     | 8.9                 | 0.0    | 56.0                       | 35.8                       | 87.0           | 1193.2         |



**Figure a.** Estimated coastwide landings (mt) of chilipepper rockfish, 1875-2024, by model fleet. Discarded dead catch from the IFQ trawl fishery is modeled as a separate fleet to account for differences in size composition between retained and discarded catch, and due to the magnitude of discarded catch from the IFQ trawl fleet relative to other, non-trawl gears.



## Data and assessment

This is the first benchmark assessment of chilipepper rockfish since 2007. An update to that assessment was conducted in 2015, followed by a catch-only update to correct errors in historical landings in 2017. A catch-only projection based on the 2017 update was completed in 2023 (Wetzel 2023). Due to significant changes in best practices for assessments and available data sources since 2007, the stock assessment team re-analyzed all data sources used in the previous assessment, and updated the model structure to reflect current best practices.

The 2025 chilipepper model is structured as a single, sex-disaggregated population, spanning U.S. waters from Mexico to Canada. The model operates on an annual time step covering the period 1875 to 2024 (not including forecast years) and assumes an unfished equilibrium population prior to 1875. Although not explicitly spatial, the model defines some fishing fleets by gear, and others by gear and area. While this “fleets as areas” approach assumes population trends and biological characteristics are the same across the assessed area, it allows the size and age structure of catches to reflect area-specific fleets where appropriate. Population dynamics are modeled for ages 0 through 35, with age 35 being the accumulator age. Population length bins were defined every 1 cm from 7 to 60 cm, and data length bins were set every 2 cm from 8 to 60 cm. The model is conditioned on catch from two sectors (commercial and recreational) divided among eight fishing fleets. Four “survey” fleets represent fishery-independent time series of relative abundance: two fishery-independent trawl surveys, one ichthyoplankton survey of spawning output, and one index of age-0 recruitment. Size and age composition data include lengths from 1975-2024 and ages from 1978-2024, with intermittent gaps in each data type. Recruitment is assumed to be related to spawning output via the Beverton-Holt stock recruitment relationship with log-normally distributed, bias corrected process error. Growth was estimated within the model, informed largely by age composition data conditioned on length bins. All catch was assumed to be known with high precision (log-scale standard error of 0.05).

Fishing fleets were specified for both recreational and commercial sectors. While the previous assessment combined all recreational fishing modes and areas into a single fleet, we split the recreational sector into two main fleets according to area (north or south of Point Conception, CA), as suggested in the 2015 update assessment (Field et al. 2015). Dead recreational discards were combined with retained catch as they represent a small fraction of total fishing mortality. The commercial sector was represented by eight fleets. The primary commercial fleet in terms of landings is the California trawl fleet, which is modeled as two fleets representing retained catch and discarded catch. Two commercial fleets representing hook-and-line and longline gear types, were differentiated by area fished (waters off California, north and south of Point Conception). The commercial net fishery in California, with landings primarily during the 1980s and 1990s, was modeled as a separate fleet. Commercial landings north of California (almost entirely from Oregon) were summed across areas and gears and modeled as a single fleet, with trawl landings representing the majority of catch from that area.

Given that previous assessments differed with respect to time-varying treatments of selectivity and growth, the stock assessment team (STAT) made considerable efforts to evaluate alternative hypotheses using the most recent data and modeling framework. Although there was evidence of time-varying growth (see Appendix A by Nick Grunloh), sensitivity analyses did not find that changes in growth (specifically, the parameter  $k$  in the von Bertalanffy growth model) significantly affected estimated population dynamics over the modeled time period. Therefore, growth is assumed constant, or averaged over time, in the base model. To evaluate the effects of time-varying selectivity in the trawl fleet, a flexible (“2D”) selectivity option that allows for variation over size and time was compared to assumptions of constant selectivity and a simplified, time-blocking approach. The STAT concluded that the simpler, time-blocking approach captured a significant fraction of variation in size-based selectivity over time, while requiring fewer parameters than the 2D approach.

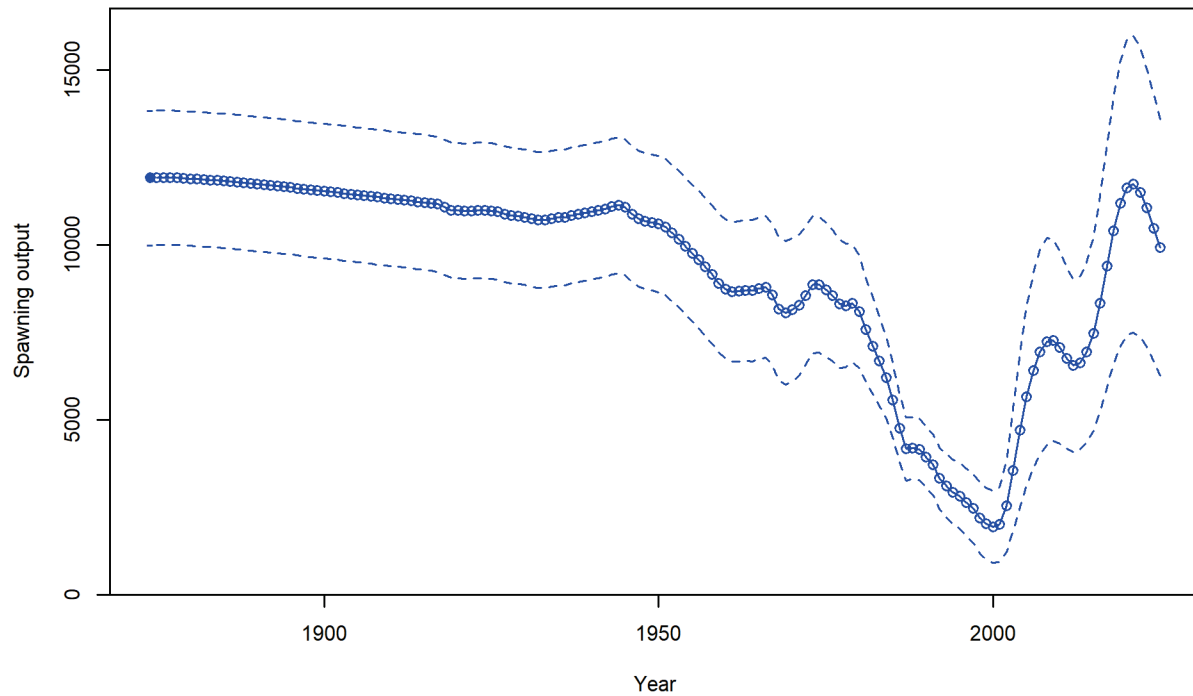
## Stock spawning output and dynamics

The last catch projection for chilipepper rockfish (Wetzel 2023) was based on a 2017 update of the 2007 benchmark assessment. The 2023 catch projection estimated spawning output to be at 74% of unfished levels in 2023. The current assessment estimates that relative spawning output (“depletion”) in 2023 was between 70% and 115% of the unfished equilibrium level, with a higher point estimate of 93% (Table b). Spawning output in 2025 is centered around 9.9 trillion eggs (~95% asymptotic interval: 6.3-13.6 trillion). Relative to the updated unfished level, the 2025 assessment estimates the stock to be above target biomass with high probability, with a point estimate for stock status of 83% of unfished spawning output in 2025. Although assessment uncertainty is likely underestimated (see Evaluation of Uncertainty in the main text), the current model produces a 95% confidence interval for depletion of 63% - 104% in 2025 (Table b).

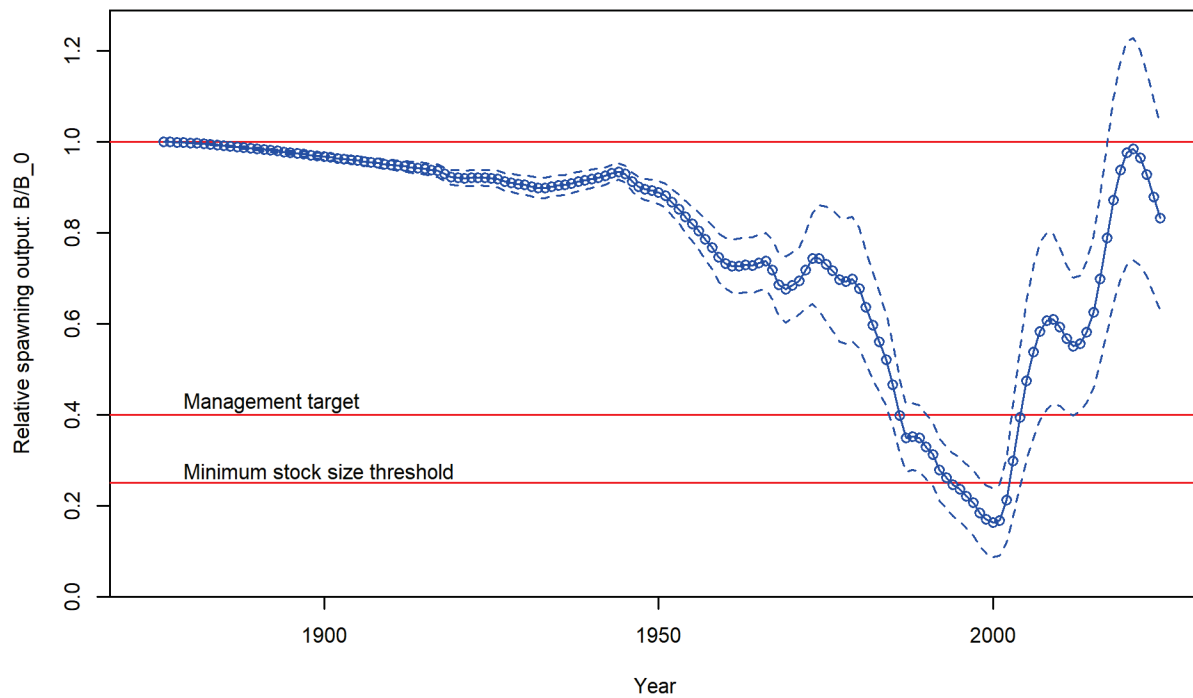
Estimates of historical chilipepper spawning output declined from unfished levels in the second half of the 19<sup>th</sup> century until about 2000 (Figure b, Figure c), after which multiple regulatory actions limiting catch of shelf rockfish species were put into place. Although chilipepper was never declared overfished, it is frequently caught with bocaccio (*Sebastes paucispinis*), which was declared overfished in 1999. Efforts to avoid bocaccio and other depleted rockfish stocks reduced fishing pressure on chilipepper. Estimates of increasing biomass after 2000 are driven by reduced fishing pressure, assumptions about average stock productivity, and evidence of a few very strong recruitment events.

Table b. Estimated recent trend in spawning output (billions of eggs) and the fraction unfished and the 95-percent intervals for the model area.

| Year | Spawning output | Lower Interval | Upper Interval | Fraction Unfished | Lower Interval | Upper Interval |
|------|-----------------|----------------|----------------|-------------------|----------------|----------------|
| 2015 | 7457            | 4678           | 10237          | 0.626             | 0.459          | 0.792          |
| 2016 | 8318            | 5225           | 11410          | 0.698             | 0.513          | 0.882          |
| 2017 | 9392            | 5924           | 12860          | 0.788             | 0.581          | 0.994          |
| 2018 | 10392           | 6580           | 14203          | 0.872             | 0.646          | 1.097          |
| 2019 | 11178           | 7106           | 15251          | 0.938             | 0.698          | 1.177          |
| 2020 | 11631           | 7414           | 15849          | 0.976             | 0.730          | 1.221          |
| 2021 | 11726           | 7491           | 15961          | 0.984             | 0.740          | 1.228          |
| 2022 | 11491           | 7351           | 15632          | 0.964             | 0.728          | 1.200          |
| 2023 | 11057           | 7076           | 15038          | 0.927             | 0.703          | 1.152          |
| 2024 | 10467           | 6654           | 14281          | 0.878             | 0.664          | 1.092          |
| 2025 | 9925            | 6263           | 13587          | 0.832             | 0.628          | 1.037          |



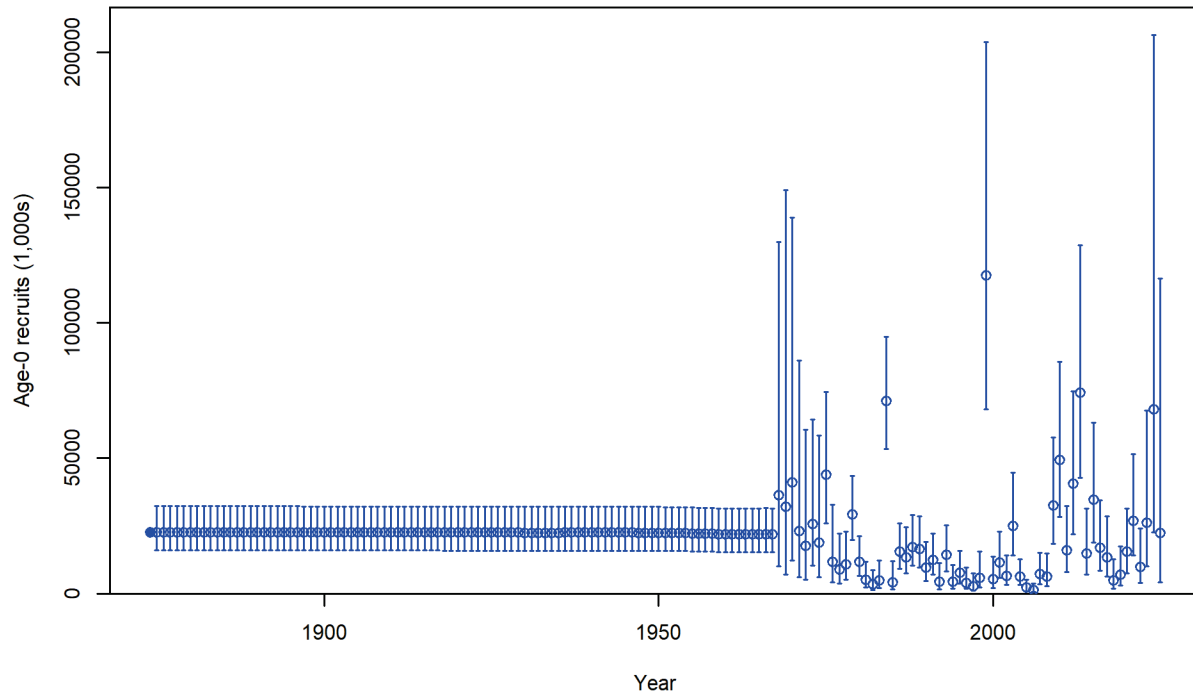
**Figure b.** Time series of estimated spawning output (trillions of eggs) for the 2025 chilipepper rockfish model. Area between the dashed lines represents the 95% asymptotic confidence interval.



**Figure c.** Spawning output relative to unfished spawning output chilipepper rockfish, 1875-2024, with 95% asymptotic confidence interval (dashed lines). The target level of spawning output (40% of unfished) and minimum stock size threshold (25% of unfished) are shown as horizontal lines for reference.

## Recruitment

Inter-annual recruitment variability is large for chilipepper rockfish, with one of the largest estimated recruitment events (1999) occurring around the time of minimum stock size. Average recruitment was based on a Beverton-Holt stock recruitment relationship with steepness fixed at 0.72 (the mean of the prior). The input value for the standard deviation of log-scale recruitment was 1.0. Recruitment patterns in the base model were largely consistent with previous update assessments, showing strong estimated recruitments in 1984, 1999, and 2013 (Figure d, Table c). The model's estimate of recruitment in 2024 is driven in part by the juvenile (RREAS) index. Until additional years of size and age data become available to verify the strength of the 2024 year class, the precision of this estimate will remain low and the strength of the 2024 year class should be interpreted with caution.



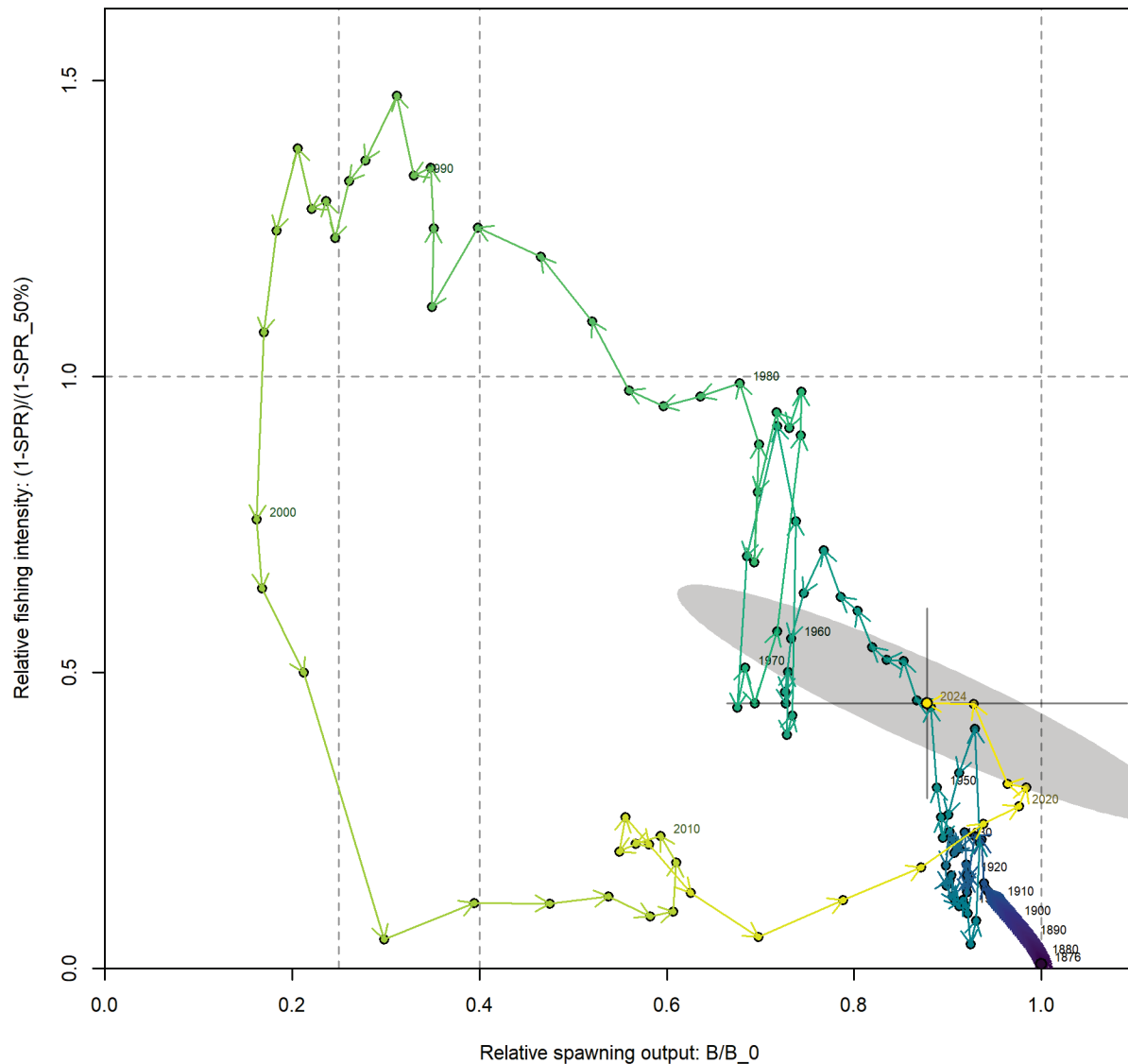
**Figure d.** Time series of estimated recruitment (1000's of age-0 fish) in the chilipepper base model.

**Table c.** Estimated recent trend in recruitment (1,000s) and recruitment deviations with 95 percent intervals for the model area. \* Recruitment in 2025 is equal to the stock-recruitment curve.

| Year  | Recruitment<br>(1,000s) | Lower<br>Interval | Upper<br>Interval | Recruitment<br>Deviations | Lower<br>Interval | Upper<br>Interval |
|-------|-------------------------|-------------------|-------------------|---------------------------|-------------------|-------------------|
| 2015  | 34600                   | 18951             | 63172             | 0.922                     | 0.492             | 1.351             |
| 2016  | 16900                   | 8301              | 34406             | 0.190                     | -0.400            | 0.779             |
| 2017  | 13443                   | 6331              | 28541             | -0.055                    | -0.706            | 0.596             |
| 2018  | 4819                    | 1831              | 12685             | -1.092                    | -2.022            | -0.162            |
| 2019  | 7063                    | 2854              | 17479             | -0.718                    | -1.569            | 0.134             |
| 2020  | 15418                   | 7550              | 31485             | 0.059                     | -0.549            | 0.667             |
| 2021  | 26998                   | 14146             | 51524             | 0.618                     | 0.104             | 1.133             |
| 2022  | 9842                    | 4022              | 24083             | -0.389                    | -1.225            | 0.448             |
| 2023  | 26252                   | 10191             | 67625             | 0.596                     | -0.307            | 1.500             |
| 2024  | 68168                   | 22524             | 206308            | 1.438                     | 0.324             | 2.552             |
| 2025* | 22297                   | 4271              | 116413            | 0                         | -1.960            | 1.960             |

## Exploitation status

Based on the best available historical catch reconstructions, exploitation rates of chilipepper rockfish exceeded target levels from the mid-1980s through the 1990s (Figure e). Exploitation rates since the 2000s have been well below target, with an increasing trend in recent years (Table d). Estimated spawning output dropped briefly below the MSST during the mid-1990s, but has exceeded target levels since the mid-2000s (Figure e).



**Figure e.** “Phase” plot illustrating the rate of fishing intensity relative to the target level (vertical axis) versus the annual spawning output relative to the unfished level (horizontal axis), 1875-2024. Uncertainty around estimates of relative spawning output and fishing intensity in 2024 is represented by the shaded ellipse and crosshairs around that point.

**Table d.** Estimated recent trend in fishing intensity relative to target,  $(1-SPR)/(1-SPR\ 50\%)$ . SPR is the spawning potential ratio in equilibrium given the exploitation rate, and uncertainty in this quantity is shown as 95% asymptotic confidence intervals. Exploitation rates (and 95% C.I.s) in this table assume exploitable biomass consists of age 3+ fish.

| Year | (1-SPR)/<br>(1-SPR 50%) | Lower Interval | Upper Interval | Exploitation Rate | Lower Interval | Upper Interval |
|------|-------------------------|----------------|----------------|-------------------|----------------|----------------|
| 2015 | 0.127                   | 0.071          | 0.183          | 0.006             | 0.003          | 0.008          |
| 2016 | 0.053                   | 0.029          | 0.077          | 0.002             | 0.001          | 0.003          |
| 2017 | 0.115                   | 0.064          | 0.165          | 0.005             | 0.003          | 0.007          |
| 2018 | 0.170                   | 0.098          | 0.242          | 0.008             | 0.005          | 0.010          |
| 2019 | 0.244                   | 0.144          | 0.343          | 0.012             | 0.007          | 0.017          |
| 2020 | 0.274                   | 0.165          | 0.384          | 0.014             | 0.009          | 0.020          |
| 2021 | 0.305                   | 0.186          | 0.425          | 0.017             | 0.011          | 0.023          |
| 2022 | 0.312                   | 0.191          | 0.433          | 0.018             | 0.012          | 0.025          |
| 2023 | 0.446                   | 0.286          | 0.606          | 0.028             | 0.018          | 0.039          |
| 2024 | 0.447                   | 0.287          | 0.608          | 0.028             | 0.017          | 0.038          |

## Ecosystem considerations

Chilipepper are reasonably well-sampled throughout their life history relative to most rockfishes, in larval surveys, pelagic juvenile young-of-the-year (YOY) surveys and bottom trawl surveys, and there is a considerable body of literature, in addition to the results of past stock assessments, on the dynamics and ecosystem interactions throughout these stages. Both larval and pelagic juvenile abundance, as well as estimates of year class strength from previous stock assessments, clearly indicate considerably interannual variability in recruitment, which is typically thought to be primarily a function of variable growth and mortality in late larval or early juvenile life history stages, which is in turn related to large-scale variability in environmental conditions (Field et al. 2010, Ralston et al. 2013, Schroeder et al. 2019). Past stock assessments have also identified interannual variability in growth, which analyses presented here also conclude as considerable (Appendix A), as well as a nontrivial amount of interannual variability in reproductive output in response to environmental conditions (Beyer et al. 2024). Consistent with research into drivers of interannual variability in pelagic YOY, variability growth and reproductive output has also been either shown or suggested to vary in response to environmental conditions, although the potential for density-dependent processes as contributing factors have been less thoroughly evaluated. Much of that information is more rigorously synthesized in analysis supporting the risk table (Section 4.3.1).

## Reference points

Management reference points for the coastwide stock (Table e) suggest that stock status is above target, with a point estimate of 83% of unfished spawning output in 2025 (95% asymptotic confidence interval: 63% - 104%). Long-term equilibrium yield based on Spawning Potential Ratio (SPR) proxy harvest rates is 2114 mt coastwide (95% asymptotic confidence interval: 1588 – 2639 mt), compared to 2230 mt based on the SB40% proxy and 2421 mt based on the peak of the yield curve given a Beverton-Holt stock-recruitment relationship with steepness fixed at 0.72. Exploitation rates represent catch as a fraction of age 3+ biomass.

**Table e.** Chilipepper base model reference points and 95% asymptotic intervals.

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

## Management performance

Chilipepper rockfish in U.S. waters are currently managed south of 40° 10' N. latitude (roughly Cape Mendocino, California) with a species-specific harvest specification. North of Cape Mendocino, chilipepper are a component stock in the PFMC's northern shelf rockfish complex. Total mortality estimates for chilipepper rockfish south of 40° 10' N. latitude have been well below the Annual Catch Limit since 2015 (Table f). Estimates of total mortality reported here are from the [Groundfish Expanded Mortality Multiyear \(GEMM\) report](#).

Previous assessments have allocated yield to these areas as follows: 93% to the southern area (species-level ACL), and 7% as a species-specific contribution to the OFL/ABC/ACL for the northern shelf rockfish complex. An analysis of biomass distribution over the past five years (2019-2024), based on the WCG BTS index created for this assessment, supports the same yield allocation. Extending the analysis to include all years of the survey (2003-2024) produces the same allocation estimate.

**Table f.** Evaluation of Management Performance for chilipepper rockfish. \* In this table, total mortality (mt) North of 40° 10' N. latitude is reported for chilipepper rockfish only, but since chilipepper is managed as part of a stock complex in this area, the OFL/ABC/ACL are defined for the complex as a whole. \* The Groundfish Expanded Mortality Multiyear (GEMM) report on total mortality for 2024 was not yet released when this assessment was prepared.

| <b>South of 40° 10' N. latitude (harvest specifications set for chilipepper alone)</b> |          |          |          |                      |
|----------------------------------------------------------------------------------------|----------|----------|----------|----------------------|
| Year                                                                                   | OFL (mt) | ABC (mt) | ACL (mt) | Total Mortality (mt) |
| 2015                                                                                   | 1703     | 1628     | 1628     | 204                  |
| 2016                                                                                   | 1694     | 1619     | 1619     | 92                   |
| 2017                                                                                   | 2727     | 2607     | 2607     | 128                  |
| 2018                                                                                   | 2623     | 2507     | 2507     | 299                  |
| 2019                                                                                   | 2652     | 2536     | 2536     | 413                  |
| 2020                                                                                   | 2521     | 2410     | 2410     | 665                  |
| 2021                                                                                   | 2571     | 2358     | 2358     | 749                  |
| 2022                                                                                   | 2474     | 2259     | 2259     | 814                  |
| 2023                                                                                   | 2401     | 2183     | 2183     | 1213                 |
| 2024                                                                                   | 2346     | 2121     | 2121     | *                    |

| <b>North of 40° 10' N. latitude (chilipepper is a component of the northern shelf rockfish complex)</b> |                                                 |          |          |                      |
|---------------------------------------------------------------------------------------------------------|-------------------------------------------------|----------|----------|----------------------|
| Year                                                                                                    | Shelf Rockfish Complex (harvest specifications) |          |          | Chilipepper          |
|                                                                                                         | OFL (mt)                                        | ABC (mt) | ACL (mt) | Total Mortality (mt) |
| 2015**                                                                                                  | 2209                                            | 1944     | 1944     | 7                    |
| 2016**                                                                                                  | 2218                                            | 1953     | 1953     | 10                   |
| 2017                                                                                                    | 2303                                            | 2049     | 2049     | 98                   |
| 2018                                                                                                    | 2302                                            | 2048     | 2048     | 105                  |
| 2019                                                                                                    | 2309                                            | 2054     | 2054     | 236                  |
| 2020                                                                                                    | 2302                                            | 2048     | 2048     | 110                  |
| 2021                                                                                                    | 1888                                            | 1511     | 1511     | 110                  |
| 2022                                                                                                    | 1821                                            | 1450     | 1450     | 62                   |
| 2023                                                                                                    | 1614                                            | 1283     | 1283     | 64                   |
| 2024                                                                                                    | 1610                                            | 1278     | 1278     | *                    |



## Unresolved problems and major uncertainties

- Likelihood profiles indicate that input data were informative for estimating natural mortality ( $M$ ) but not steepness ( $h$ ). The available data are only weakly informative about the steepness parameter ( $h$ ) of the assumed Beverton-Holt stock recruitment relationship, and model output is highly sensitive to this parameter. The base model fixes steepness at the mean of the prior probability distribution ( $h = 0.72$ ). When estimated, the parameter central tendency is much lower ( $h \sim 0.4$ , i.e., suggesting a less productive stock), despite the fact that the largest estimated recruitment (in 1999) occurred near the lowest biomass level.
- Skewed sex ratios observed in the catch may be caused by sex-specific natural mortality rates, sex-specific selectivity, or a combination of the two. The base model assumes that natural mortality rates vary by sex, and that selectivity is independent of sex.
- Future assessments would benefit from additional research into sources of chilipepper ageing error. The model's fit to the conditional age-at-length data displayed large, positive residuals for males at the upper edge of their size range in several year/fleet combinations. Large, positive residuals were also detected for females in some year/fleet combinations, with a greater-than-expected number of females that were older than expected, given their length. Sex-specific sizes and ages should be evaluated further (e.g., by revisiting original datasheets, examining otolith morphology, or reviewing archived biological samples) to resolve uncertainties about notable outliers.
- Although results provided in an appendix to the stock assessment suggested the presence of time-varying growth, sensitivity analyses indicated minimal influences on model results. Thus, the model assumed that growth is time-invariant. Analyses of time-varying growth in the model were limited to variation in the parameter 'k' from the von Bertalanffy growth function. Temporal variation in  $L_{\infty}$  (potentially correlated with k) may have a greater effect on model results.
- Model fit to the WCGTS index, particularly in the early part of the time series, warrants further investigation, including additional work on index standardization.
- Catchability ( $q$ ) estimates for trawl survey indices are counter-intuitive (i.e., near or greater than 1). Indices of abundance from these surveys are not used to inform absolute abundance, but additional research is needed to understand the scale implied by the model-based abundance estimates.
- Further evaluation is needed regarding the inclusion of a depth effect in the Triennial survey index, given that fits to the WCGTS were improved by inclusion of depth as a covariate.
- Historical catch reconstructions are subject to uncertainty stemming from issues with species identification and the spatiotemporal extent of data collection, highlighting the need for uncertainty estimates comparable to those used for model-based indices.
- There is uncertainty in mean productivity estimates when applying a sum-to-zero constraint on recruitment deviation, potentially due to inaccurate assumptions about the stock-recruitment relationship. See Appendix B, Requests #4 and #17 for additional details.
- Estimation of selectivity and associated time blocking remain difficult for this assessment.

## Decision table and harvest projections

Alternative states of nature defined by three values of the Beverton-Holt steepness parameter ( $h$ ) were identified during the STAR panel, representing uncertainty that was not accounted for by the base model. A “low-productivity” alternative ( $h=0.38$ ) and “high-productivity” alternative ( $h=0.97$ ) are presented in addition to the base model ( $h=0.72$ ). Population dynamics were forecast 12 years ahead for each state of nature, assuming two different catch projections requested during the STAR panel (Table g; see also Appendix B, Request 18). Catch projections for 2025-2026 and fleet allocations for 2027-2036 were provided for each area and fleet by representatives on the GMT. Yields associated with the Overfishing Limit (OFL), Acceptable Biological Catch (ABC), and the assumed buffer to account for scientific uncertainty in the ABC, are provided in Table h. Since spawning output is estimated to be above the management target (40% of unfished), Annual Catch Limits (ACLs) are equal to the ABC. Projections assume a relatively strong 2024 year class (see the “Recruitment” section of the Executive Summary).

**Table g.** 12-year projections (2025 – 2036) for chilipepper rockfish according to three alternative states of nature. Columns represent low, medium (base case), and high states of nature, and rows range over different assumed catch levels (the default harvest control rule, and constant catches equal to the MSY proxy). Spawning output units are billions of eggs.

|      | ACL=ABC<br>catch | Low Productivity<br>(steepness = 0.38) |                  | Base Model<br>(steepness = 0.72) |                  | High Productivity<br>(steepness = 0.97) |                  |
|------|------------------|----------------------------------------|------------------|----------------------------------|------------------|-----------------------------------------|------------------|
|      |                  | spawning<br>output                     | % of<br>unfished | spawning<br>output               | % of<br>unfished | spawning<br>output                      | % of<br>unfished |
| 2025 | 1599*            | 7247                                   | 46.9%            | 9925                             | 83.2%            | 10836                                   | 95.9%            |
| 2026 | 1522*            | 6704                                   | 43.4%            | 9369                             | 78.6%            | 10212                                   | 90.3%            |
| 2027 | 3211             | 6435                                   | 41.6%            | 9133                             | 76.6%            | 9927                                    | 87.8%            |
| 2028 | 3086             | 6041                                   | 39.1%            | 8778                             | 73.6%            | 9559                                    | 84.6%            |
| 2029 | 3010             | 5854                                   | 37.9%            | 8597                             | 72.1%            | 9369                                    | 82.9%            |
| 2030 | 2960             | 5744                                   | 37.2%            | 8437                             | 70.8%            | 9205                                    | 81.4%            |
| 2031 | 2901             | 5642                                   | 36.5%            | 8242                             | 69.1%            | 9006                                    | 79.7%            |
| 2032 | 2821             | 5520                                   | 35.7%            | 8006                             | 67.2%            | 8764                                    | 77.5%            |
| 2033 | 2725             | 5379                                   | 34.8%            | 7746                             | 65.0%            | 8494                                    | 75.2%            |
| 2034 | 2621             | 5232                                   | 33.9%            | 7483                             | 62.8%            | 8221                                    | 72.7%            |
| 2035 | 2525             | 5091                                   | 32.9%            | 7235                             | 60.7%            | 7965                                    | 70.5%            |
| 2036 | 2439             | 4962                                   | 32.1%            | 7014                             | 58.8%            | 7736                                    | 68.4%            |

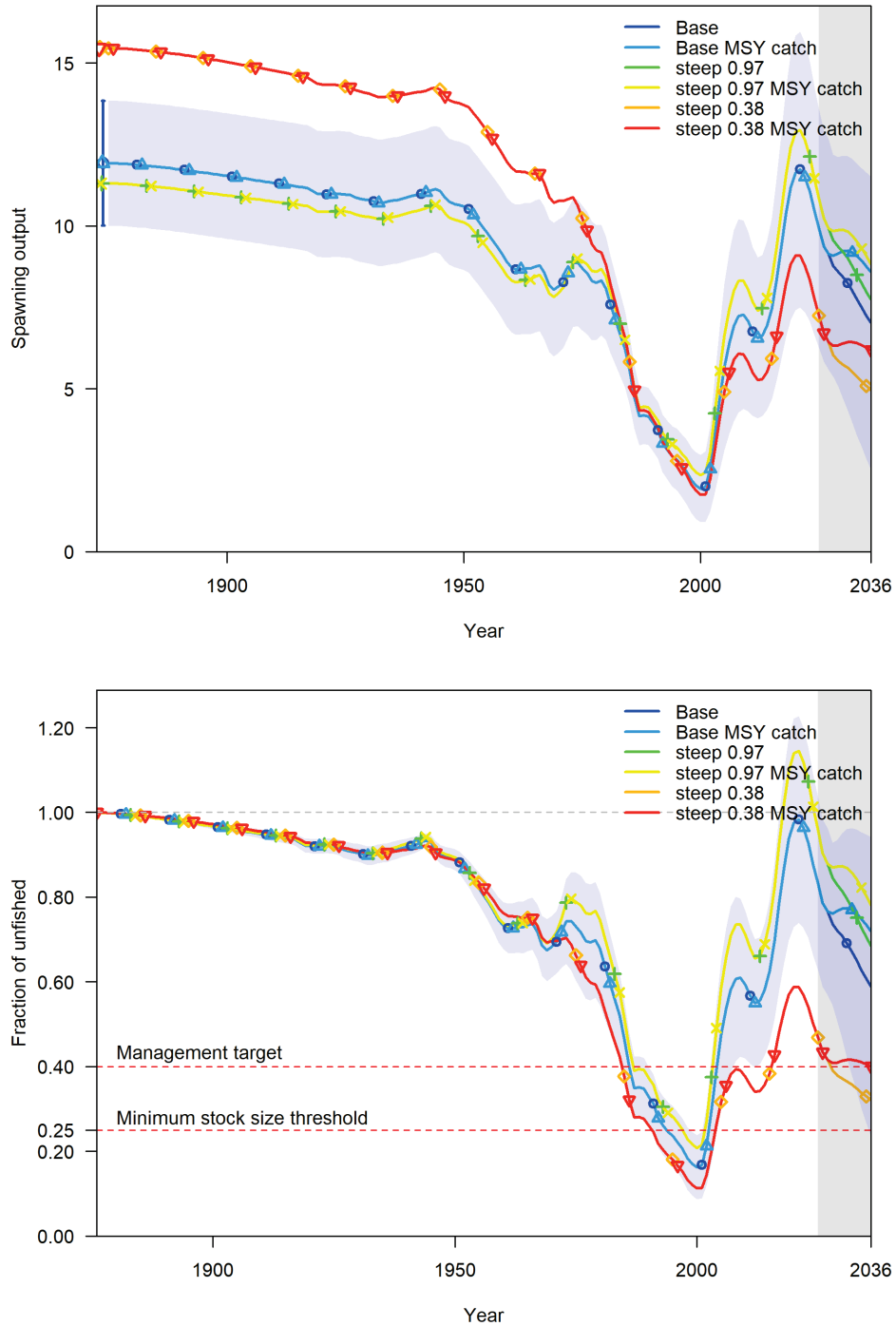
|      | SPR Proxy<br>MSY catch | spawning<br>output | % of<br>unfished | spawning<br>output | % of<br>unfished | spawning<br>output | % of<br>unfished |
|------|------------------------|--------------------|------------------|--------------------|------------------|--------------------|------------------|
|      |                        |                    |                  |                    |                  |                    |                  |
| 2025 | 1599*                  | 7247               | 46.9%            | 9925               | 83.2%            | 10836              | 95.9%            |
| 2026 | 1522*                  | 6704               | 43.4%            | 9369               | 78.6%            | 10212              | 90.3%            |
| 2027 | 2114                   | 6435               | 41.6%            | 9133               | 76.6%            | 9927               | 87.8%            |
| 2028 | 2114                   | 6312               | 40.8%            | 9078               | 76.1%            | 9835               | 87.0%            |
| 2029 | 2114                   | 6333               | 41.0%            | 9149               | 76.7%            | 9863               | 87.3%            |
| 2030 | 2114                   | 6391               | 41.4%            | 9217               | 77.3%            | 9875               | 87.4%            |
| 2031 | 2114                   | 6431               | 41.6%            | 9231               | 77.4%            | 9823               | 86.9%            |
| 2032 | 2114                   | 6434               | 41.6%            | 9180               | 77.0%            | 9701               | 85.8%            |
| 2033 | 2114                   | 6400               | 41.4%            | 9071               | 76.1%            | 9519               | 84.2%            |
| 2034 | 2114                   | 6339               | 41.0%            | 8923               | 74.8%            | 9300               | 82.3%            |
| 2035 | 2114                   | 6264               | 40.5%            | 8752               | 73.4%            | 9062               | 80.2%            |
| 2036 | 2114                   | 6184               | 40.0%            | 8572               | 71.9%            | 8821               | 78.0%            |

**Table h.** Projections of potential OFLs (mt), ABCs (mt), estimated spawning output (billions of eggs), and fraction unfished. Projections assume catches are equal to the ABC starting in 2027, and based on default values for a “category 1” assessment ( $\sigma=0.5$  and  $P_{star} = 0.45$ ). Catch estimates for 2025 and 2026 (1598.72 and 1521.61 mt, respectively) were provided by the Groundfish Management Team (GMT).

| Year | Predicted OFL (mt) | ABC (mt) | Buffer | Spawning output | Fraction Unfished |
|------|--------------------|----------|--------|-----------------|-------------------|
| 2025 | --                 | --       | --     | 9925            | 0.832             |
| 2026 | --                 | --       | --     | 9369            | 0.786             |
| 2027 | 3434.3             | 3211.1   | 0.935  | 9133            | 0.766             |
| 2028 | 3318.1             | 3085.8   | 0.930  | 8778            | 0.736             |
| 2029 | 3250.8             | 3010.3   | 0.926  | 8597            | 0.721             |
| 2030 | 3210.7             | 2960.2   | 0.922  | 8437            | 0.708             |
| 2031 | 3163.1             | 2900.5   | 0.917  | 8242            | 0.691             |
| 2032 | 3090.3             | 2821.4   | 0.913  | 8006            | 0.672             |
| 2033 | 2997.8             | 2725.0   | 0.909  | 7746            | 0.650             |
| 2034 | 2899.1             | 2620.8   | 0.904  | 7483            | 0.628             |
| 2035 | 2805.2             | 2524.7   | 0.900  | 7235            | 0.607             |
| 2036 | 2721.5             | 2438.5   | 0.896  | 7014            | 0.588             |

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

Because the stock is estimated to be above target biomass and all assumed 12-year catch alternatives are equal to or greater than MSY, projected stock status declines in every scenario outlined above, as fishing reduces the stock to target levels. Under the default harvest control rule, this ‘fishing down’ of the stock temporarily estimates yields greater than the estimated  $SPR=50\%$  proxy for Maximum Sustainable Yield (MSY), which the base model estimates as 2114 mt per year.



**Figure f.** Estimated 2025-2036 projections of spawning output in trillions of eggs (top panel, shaded area) and relative spawning output (“Fraction of unfished”; bottom panel, shaded area) for: a) the base model (Beverton-Holt “steepness” =  $h = 0.72$ ), b) a high-productivity alternative state of nature ( $h = 0.97$ ), and c) a low-productivity alternative state of nature ( $h = 0.38$ ). Catch projections under each state of nature include SPR Proxy MSY catches held constant at 2114 mt per year and the default rockfish harvest control rule catch stream (“ABC” in Table h) from the base model represent the alternative catch projections in each state of nature.

## Research and data needs

- Addressing the underlying productivity in the spawner-recruit relationship (“steepness”) remains a key research and data need for West Coast rockfish stocks. This model, like most West Coast rockfish models, continues to use the mean of the prior distribution from a meta-analysis, despite a suite of issues and concerns related to the inability to appropriately update that analysis.
- Among the ongoing efforts to better develop priors or other information to inform steepness include an effort to use a life-history based approach based on Mangel et al. (2010), in preparation as Beyer et al. (in prep), for which chilipepper are one of four species under evaluation. This approach suggests that steepness values considerably higher than that used in the meta-analysis are plausible, although the study needs to be completed and other considerations discussed before this work is ready for application, and the work would benefit from additional research into some of the life-history based relationships to better inform future implementation.
- Ongoing research provides strong insights into the environmental mechanisms related to variability in recruitment, as well as variability in growth and reproductive output. Such research should remain a high priority, particularly with respect to the potential to better inform forecasting.
- Further investigation of the relative importance of time-varying growth on chilipepper population dynamics is needed. Evidence suggests that growth variation is auto-correlated (possibly at multiple time scales; Appendix A), and methods to model this within the assessment may be needed, including correlations between growth parameters (e.g.,  $k$  and  $L_{\infty}$ ).
- Further exploration of cohort and density-dependent effects at the assemblage level (particularly for co-occurring species like bocaccio, yellowtail, and widow rockfishes) may increase our understanding about variation in growth rates for chilipepper rockfish.
- Prioritize completion of analysis of the historic CalCOFI data from central California to expand the time series for future assessments.
- Further development of the spatiotemporal models would improve index standardization. This may include the use of barrier meshes to account for geographic barriers and unique coastline features. Residual diagnostics should be evaluated by depth, especially for demersal species, to decide whether to include a depth effect in the model (even when including anisotropy to account for variables like depth).
- Examination of factors contributing to skewed sex ratios in the catch is needed, e.g., sex-specific natural mortality, selectivity, and/or discards.
- Age validation for chilipepper rockfish is needed. Standardization of ageing methods is also needed to minimize ageing error, including both “traditional” (break-and-burn) methods and ages derived from FT-NIRS (scanning and modeling).
- A small number of ages derived from FT-NIRS were included using a unique ageing error matrix, yet model selection did not indicate a bias between FT-NIRS and traditional ageing methods. Visual inspection suggests a consistent bias toward younger FT-NIRS ages for older fish. This may reflect limitations in the bias structures available in the ageing error software, supporting an improved understanding about differences between FT-NIRS and traditional break-and-burn ages.
- Selectivity estimation remains a challenge for this assessment due to complex and changing management measures. Further investigation into time-blocking and/or a more structured spatiotemporal modeling (e.g., by length groups or age) approach could clarify how to incorporate management and gear changes in future models by indicating which size/age might be affected by such changes.
- This assessment attempts to account for multiple brooding of larger, older female chilipepper with respect to larval production and reproductive output. However, both the spatial and temporal variability associated with this phenomenon could be better understood. An improved understanding of the environmental factors associated with variable reproductive output,

including multiple brooding, could also lead to an improved interpretation of the CalCOFI larval abundance time series, as it is likely that some of the high variance observed in that time series relates to interannual variability in reproductive output, relative to simple sampling variance alone. Additionally, ongoing efforts positively identify chilipepper larvae from the earliest part of the CalCOFI time series would greatly benefit the ability of that time series to inform the model.

- Additional biological research on skip spawning, functional maturity, and environmentally driven variation in brooding frequency is needed to improve estimates of fecundity.
- Although there is a reconstruction of historical rockfish landings for California waters, the current reconstruction does not explicitly account for the expansion of both fixed gear and trawl fisheries into deeper habitats, further from port, over time (as discussed in Miller et al. 2014 and the 2017 catch reconstruction review; PFMC 2017). Ongoing catch reconstruction efforts are also focused on efforts to quantify the uncertainty associated with both historical and recent catches (Grunloh et al. 2017), the completion of these efforts would better allow for this uncertainty to be accounted for in future assessment models.
- A better understanding about the portion of the population in Mexican waters may be supported by habitat suitability mapping.
- Continued research on density-independent effects on YOY survival, especially for integration into future risk tables. This includes developing an inshore-offshore index for the southern population and exploring moving average approaches to link the "minty-spicy" temperature index to recruitment dynamics.
- A better understanding about predator-prey dynamics would improve our understanding about time-varying natural mortality.
- If the at-sea hake fishery begins targeting hake in waters off California, and bycatch rates increase, collection of biological data (lengths, otoliths) from chilipepper will be useful for future assessments.

## Scientific uncertainty

The base model's estimate of the log-scale standard deviation ("sigma") of the overfishing limit (OFL) in 2025 is 0.2284. This is less than the Scientific and Statistical Committee's default value of  $\sigma = 0.5$  for a category 1 assessment, so harvest projections in this document assume an initial sigma of 0.5.

## Risk Table

For chilipepper, there is a considerable body of literature relating various aspects of productivity to environmental factors, including patterns of variability associated with adult growth and reproductive output, early larval dynamics (parturition timing, ocean transport and survival), through processes associated with pelagic juvenile growth, abundance and distribution. A common thread is that adult growth and reproductive output, larval condition and growth, and pelagic juvenile abundance, all appear to be greater during cool, high productivity ocean conditions, which are typically associated with a negative Pacific Decadal Oscillation (PDO) and/or positive North Pacific Gyre Oscillation (NPGO), and more specifically with a higher proportion of subarctic ("minty") rather than subtropical ("spicy") source waters occurring within the California Current Ecosystem. Further, euphausiid (krill) abundance, a key forage resource for all life history stages, are generally higher during these cooler environmental phases. Throughout 2024, summer and fall NPGO values were negative (indication of reduced southward transport), which would be consistent with poorer condition and lower reproductive output for chilipepper. However, for winter and spring of 2025, PDO values have been negative, and subsurface waters off of central California (35-37° N) have been among their "mintiest" (most subarctic) since 2015. The "minty" conditions are consistent with both greater pelagic juvenile abundance and recruitment based on the current assessment model (see section 4.3.1). Thus, most environmental information is consistent

with estimates of above average 2024 recruitment in the base model, as well as with an expectation of above average recruitment for the 2025 year class, which is not evaluated in the base model. See Table i for a summary of potential factors affecting stock productivity.

**Table i.** ‘Risk Table’ for chilipepper to document ecosystem and environmental factors potentially affecting stock productivity and uncertainty, or other concerns arising from the stock assessment. Level 1 is favorable, Level 2 is neutral, and Level 3 is unfavorable.

| Ecosystem and environmental conditions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Assessment data inputs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Assessment model fits and structural uncertainty                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Larval production and condition: Based on 2024- 2025 NPGO, may be neutral to unfavorable, but signals are somewhat mixed</p> <p>Recruitment: Index used in assessment. High diversity and abundance of the YOY groundfish assemblage community in 2024 consistent. Environmental conditions are favorable for 2025 (minty/subarctic), high preliminary survey catch rates. Overall, favorable for recruitment</p> <p>Prey: Most evidence suggests abundant forage, favorable conditions, positive</p> <p>Predators: Ongoing long-term increases in abundance, but no evidence of recent sharp increases, neutral</p> <p>Growth: Recent years potentially unfavorable in near term (based on autocorrelation in growth variability), neutral</p> | <p>Historically and currently among most important commercial species in California, catch reconstruction and recent catch data are reliable, favorable</p> <p>Robust age data to inform assessment, modest aging error concerns need resolution, neutral to favorable</p> <p>Robust information on reproductive ecology, but better data on functional maturity and role of multiple brooding would be helpful, neutral to favorable</p> <p>Several informative fishery independent indices that span life history stages, including larval production/spawning output (CalCOFI), settled juvenile and mature adult biomass (WCG BTS), and pelagic YOY abundance (RREAS), favorable</p> | <p>Good fits to age and length composition data. Generally good fits fishery-independent survey data, particularly in more recent years, favorable</p> <p>Several abundance indices help inform recent recruitment and population forecasts (e.g., WCG BTS, RREAS), favorable</p> <p>Selectivity functions are not always well behaved, unfavorable</p> <p>Evidence for time-varying growth in data, but growth assumed to be time-invariant within the model, neutral</p> <p>Likelihood profiles indicate that natural mortality is well informed, but steepness is not well informed. Steepness provides axis of uncertainty for decision table, neutral</p> |
| Level 1, favorable (medium agreement, robust evidence)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Level 1, favorable (high agreement, robust evidence)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Level 2, neutral (medium agreement, medium evidence)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

# 1 Introduction

## 1.1 Basic Information

Chilipepper rockfish (*Sebastes goodei*) are a mid-size, semi pelagic rockfish found primarily in shelf and shelf-break waters off California, where they have been among the most important commercial and recreational rockfish species in both historical and contemporary groundfish fisheries. They are described as “streamline” rockfish species, an elongate fish with reduced head spines, similar in appearance to both the more diminutive shortbelly rockfish (*S. jordani*) and the considerably larger bocaccio (*S. paucispinis*) (Love et al. 2002; Love 2011). The Latin name honors the 19th century ichthyologist George Brown Goode, who served the Smithsonian Institution and was also the United States Commissioner for Fish and Fisheries from 1887 to 1888. The common name was derived from the observation that long strings of these bright red fish resemble a string of drying chilis (Davis 1949). They have been one of the most important commercially targeted rockfishes in southern and central California waters since the 1880s, and are important component of recreational fisheries as well.

Chilipepper’s distribution is generally described as ranging from Queen Charlotte Sound in British Columbia to Bahia Magdalena in Baja California Sur (Westrheim 1965; Eschmeyer et al. 1983; Love et al. 2002). Historically, they were uncommon north of Cape Blanco (Oregon) and south of Punta Colnett (Baja California Norte), and past assessments have not included the minor catches north of Oregon nor south of the U.S./Mexico border. This assessment expands the spatial footprint of the stock to include Washington waters, consistent with the stock definition for chilipepper adopted by the PFMC. The region of greatest abundance and the historically highest catches have generally been between Point Conception and Cape Mendocino, California. Alverson et al. (1964) reported only trace catches of chilipepper rockfish in resource surveys conducted in the 1960s off Oregon and Washington, all of which was noted between approximately 200 and 300 fathoms. More recent survey data may indicate somewhat greater biomass in recent years off Oregon waters, and indeed recent catches have been considerably greater than historical catches for this region as well.

### 1.1.1 Stock structure

Wishard et al. (1980) conducted the only known genetic study of stock structure, from samples collected between 34° and 40° N. They concluded that chilipepper was unusual in its very low levels of allozyme variability, with no suggestion of population substructure. An extensive review of phylogenetic relationships among *Sebastes* found that chilipepper rockfish were most closely related to the two species with which they generally resemble morphologically; shortbelly rockfish (*S. jordani*) and bocaccio (*S. paucispinis*), with a lineage that dated back approximately 6 million years (Hyde and Vetter 2007). No substantive investigations into stock structure have been published since that time, however with respect to demographic considerations, Field and Ralston (2005) evaluated spatial patterns in recruitment variability based on regional catch at age models, and concluded that recruitment is largely synchronous throughout most of the range of chilipepper, between Cape Blanco and Point Conception. This suggests strong demographic connectivity, consistent with the suggestion of a single stock, although there were insufficient data to include recruitment estimates or trends south of Point Conception. Following the 2015 stock assessment, Solinger (2019) revised and updated that analysis with over a decade of newly available age data and reached similar conclusions.

Ralston et al. (1998) assessed chilipepper rockfish and defined the stock as the combined Eureka, Monterey, and Conception International North Pacific Fisheries Commission (INPFC) areas, i.e., U.S. waters south of roughly Cape Blanco, Oregon. Field (2007) extended the assessed area to include all of



Oregon. Although relatively few chilipepper are observed off the coast of Washington, landings from that state have been included in the current analysis to facilitate coastwide management based on a single assessment model. Information about stock structure from genetic analyses and tagging studies is outdated (e.g., Wishard et al. 1980) and/or has insufficient sampling effort to detect evidence of reproductive isolation or movement patterns. An analysis of rockfish evolution by Hyde and Vetter (2007) was able to detect cryptic speciation in what came to be known as vermilion and sunset rockfishes. They found no similar evidence for chilipepper, although the sampling design may not have been configured to address that question. Analyses conducted for this assessment suggest that patterns of adult growth (length-at-age) are similar across the assessed range. Most catches were taken by trawl gear in California, north of Point Conception (34° 27' N. lat.), following World War II and roughly until the year 2000 when large-scale spatial closures went into effect. No data are available to inform trends in chilipepper abundance in Mexican waters. Based on these general findings, and the observed synchrony in recruitment described above, the population dynamics are modeled as a single, “coastwide” stock in U.S. waters from the U.S./Mexico border (roughly 32.5° N. latitude) to the U.S./Canadian border (49° N. lat.).

## 1.2 Map

A map of the assessment area with selected coastal features is provided as Figure 1.

## 1.3 Life History

Chilipepper are part of a very speciose genus of rockfishes (*Sebastes*) in the California Current ecosystem, an ecosystem characterized by strong seasonal, interannual and interdecadal variability in ocean conditions and subsequent productivity of most important fishery species. Like all *Sebastes*, chilipepper are primitively viviparous and bear live young at parturition. While many exploited rockfishes have slow growth rates, are late to mature and have great longevity (many live to 100 years or more; Love et al. 2002, Berkeley et al. 2004), chilipepper generally have a “faster” life history; they mature between the ages of 2 and 4, have relatively fast growth rates, and reach a maximum age close to 35, although relatively few individuals older than 25 years are observed in age composition data.

Adult fish tend to be most abundant in large schools between 100 and 300 meters, often in midwater. Chilipepper are among the species of rockfish that can rapidly change color and pattern; when in midwater they are often solidly pigmented with brown on the back and pink on the flanks, but within seconds of settling on the seafloor they become darker and more blotched and patterned (Love 2011; Butler et al. 2012). Settled juveniles can be found in shallow water, but rapidly move to greater depths with size and age, and there are strong ontogenetic patterns throughout their life history, with larger and older individuals typically found at greater depths. While often found midwater, Love et al. (2002) describe the benthic habitat associations of adult chilipepper schools as including boulder fields and other high relief substrata, as well as occasionally low-relief cobblestones. Despite bocaccio being a known predator of chilipepper, the two species may co-occur in large semi-pelagic schools. They are rarely observed in visual surveys (ROV or submersible), being observed with far less frequency than species that have considerably lower abundance (such as cowcod, yellowtail rockfish or vermilion rockfish). One interesting anecdotal visual survey observation suggests that this could be due to differences in their response to threats. During a benthic survey using a manned submersible, a large mixed school of chilipepper and bocaccio was observed above rocky habitat ~10 m in front of the submersible. As the submersible approached, the bocaccio descended to the benthic habitat and were counted in the survey while the chilipepper rose into the water column above the submersible and were out of the transect.

## 1.4 Ecosystem Considerations

Chilipepper are well to reasonably well sampled throughout their life history; in larval surveys, pelagic juvenile young-of-the-year (YOY) surveys and bottom trawl surveys, and there is a considerable body of literature, in addition to the results of past stock assessments, on the dynamics and ecosystem interactions throughout these stages. Both larval and pelagic juvenile abundance, as well as estimates of year class strength from previous stock assessments, clearly indicate considerably interannual variability in recruitment, which is typically thought to be primarily a function of variable growth and mortality in late larval or early juvenile life history stages, which is in turn related to large-scale variability in environmental conditions (Field et al. 2010, Ralston et al. 2013, Schroeder et al. 2019). Past stock assessments have also identified interannual variability in growth, which analyses presented here also conclude as considerable (Appendix A), as well as a nontrivial amount of interannual variability in reproductive output in response to environmental conditions (Beyer et al. 2024). Consistent with research into drivers of interannual variability in pelagic YOY, variability growth and reproductive output has also been either shown or suggested to vary in response to variable environmental conditions, although the potential for density-dependent processes as contributing factors have been less thoroughly evaluated. Much of that information is more rigorously synthesized in analysis supporting the risk table (Section 4.3.1).

With respect to trophic interactions, adult chilipepper have been described as midwater foragers, with euphausiids, forage fishes (such as anchovies, Pacific hake, and mesopelagic fishes), and small squids among key prey items (Love et al. 2002). With respect to predation mortality, pelagic juvenile rockfishes of all species, including chilipepper, are among one of the most important forage taxa identified in a meta-analysis of predator food habits studies in the California Current. Key predators of pelagic juveniles including seabirds, salmon, lingcod, tunas and marine mammals (Szoboszlai et al. 2015, Warzybok et al. 2018). Adults are consumed by larger piscivorous fishes, such as bocaccio and lingcod, as well as marine mammals. Predation by Humboldt squid (*Dosidicus gigas*) was documented during a period of range expansion of that species between the early 2000s and approximately 2010, although adult rockfish were a relatively minor component of the diet during that period, the abundance of squid for several years was novel and predation on some prey items potentially substantial (Field et al. 2013).

## 1.5 Fishery Information

Chilipepper have historically been one of the most important rockfish species in California fisheries. In one of the earliest accounts, Jordan and Evermann (1898) described chilipepper as being “taken in abundance about the Coronados Islands, Santa Catalina, and the Cortez Banks.” Rockfish landings were far greater Southern California Bight in the early 20th century, and chilipepper were described as the “second most important rockfish in southern California rockfish fisheries” (after vermillion) by Walford (1930), and as “one of three leading Southern California species” (along with vermillion and bocaccio) by Roedel (1948).

In central California, chilipepper were also among the most important commercial targets for rockfish fisheries. Although there is relatively little data on the species composition of rockfish catches in those early years, Phillips (1939) reported on the species composition of rockfish from the Monterey wholesale fish markets between April 1937 and March 1938, in which 30.8% of the landings by weight were chilipepper rockfish (with 39.4% bocaccio and 7.9% yellowtail rockfish). Monterey Bay area ports were the most productive along the coast during that period, accounting for 51% of all landings between 1936 and 1940, with San Francisco accounting for another 20%. Catches and landings of rockfish in more northern California ports were minimal until the introduction of the balloon trawl fishery in the early

1940s, during the development of new markets for frozen rockfish by the military to support the war effort. After that development, trawl gear rapidly surpassed hook and line gear in accounting for most California rockfish landings, particularly in the northern ports of Eureka and Fort Bragg, where chilipepper made up a smaller fraction of the commercial catch (Scofield 1948, Phillips 1939).

Along the U.S. West Coast, rockfish landings increased sharply following the post-war period, with a transition from largely hook-and-line caught fish to largely trawl caught. A spike in foreign fishery landings took place during the 1960s and 1970s (Rogers 2003), followed by the more rapid development of the fishery by U.S. participants throughout the 1980s and 1990s, when catches of rockfish peaked. Within California waters, chilipepper continued to represent one of the most important commercial targets, often second only to bocaccio with respect to total landings. As documented in Miller et al. (2014), commercial fisheries landings were made from deeper water habitats, generally further from ports and exposed to more inclement weather, such that chilipepper became an even more important target for commercial fisheries during this period. During the period of more rigorous sampling of the species composition of rockfish market categories in California commercial fisheries, chilipepper catches tend to co-occur and be reported in chilipepper, bocaccio and mixed rockfish market categories, and chilipepper rockfish scored high on an index of reliability of landings estimates within these fisheries (Pearson et al. 2008). Landings began to decline throughout the 1990s in response to declines in abundance of many key target species, such as bocaccio and widow rockfish, and in response to the mandates to rebuild co-occurring populations during the late 1990s and early 2000s.

Recreational fishing effort in California for fishes other than big game fish such as tunas and salmon were relatively modest in California until about 1928, when Commercial Passenger Fishing Vessels (CPFVs) popularized recreational fishing (Croker 1940; Young 1969). Initially, most effort was in the waters of the Southern California Bight; however, party boat fisheries soon became popular in central California regions (particularly Monterey Bay area ports). Chilipepper were historically important in southern California recreational fisheries, but less so in central California fisheries due to their deeper depth distribution (Miller and Gotschall 1965). However, the importance of chilipepper in recreational catches from both regions increased over time, particularly in the CPFV fleets which were able to access more distant and deeper waters, such as Cordell Bank in central California. In this way, recreational fisheries mirrored the pattern observed in commercial fisheries, in which catches (and thus presumably effort) moved to deeper waters, generally further from ports and exposed to more inclement weather with time (Miller et al. 2014).

Miller and Gotshall (1965) and Ralston et al. (2010), among other sources provide more information about recreational rockfish fishery catch trends and species compositions (Ralston et al. 2010 is the source for historical recreational catches). In general, recreational catches have rarely represented more than 10% or so of the historical total catch. Since the late 1990s and early 2000s recreational catches have been minimal until very recently, as a result of spatial closures implemented to help rebuild co-occurring overfished stocks, such as bocaccio, cowcod and canary rockfishes. However, recreational fisheries catches have increased sharply in recent years as access to deeper habitats for recreational fishing has increased.

## **1.6 Summary of Management History and Performance**

Chilipepper rockfish in U.S. waters are currently managed south of 40° 10' N. latitude (roughly Cape Mendocino, California) with a species-specific harvest specification. North of Cape Mendocino, chilipepper are a component stock in the PFMC's northern shelf rockfish complex.

Prior to establishment of the U.S. EEZ in 1976, chilipepper were caught by domestic fleets from the late 1800s, with the addition of foreign and joint-venture fisheries starting in the 1960s (Rogers 2003). The Rockfish Conservation Area (RCA) closures to commercial fishing, and corresponding constraints on recreational fishing to exclude deeper waters (particularly in central California) dramatically reduced fishing opportunities for chilipepper rockfish starting in the early 2000s. Landings (or retention) are permitted in all existing fishing activities. For bottom trawl fishing, trip limits were constrained largely due to limits on bocaccio rockfish, at the time one of the shelf rockfish species declared overfished and a species that co-occurs with chilipepper. Trawl landings of chilipepper during this time tended to be greatest south of 40°10' during periods in which the seaward line of the RCA is set at 150 fm, although there were occasional catches of chilipepper shoreward of the RCA as well. As most of the chilipepper biomass is found in the core area of the RCAs, catches have been far lower than OFLs. Table 1 compares the OFL, ABC, and ACL for chilipepper south of Cape Mendocino to estimates of total mortality from the GEMM report.

Amendment 32 to the Pacific Coast Groundfish Fishery Management Plan re-opened sections of the non-trawl RCA and both the Cowcod Conservation Areas. This action provides access to about 4,600 square miles that had been closed for decades. In the Southern California Bight, the Cowcod Conservation areas were closed while smaller Groundfish Exclusion Areas were opened to protect critical habitat and deep-sea corals and sponges. New gears (e.g., non-bottom contact hook-and-line gear) have proven successful at targeting healthy stocks such as chilipepper and yellowtail rockfish, while avoiding impacted demersal species.

In addition to being affected by some of the above-mentioned spatial closures, recreational anglers in California have a daily bag and possession limit for the Rockfish-Cabazon-Greenling (RCG) species group, which includes Chilipepper Rockfish. In 1971, a 20-fish bag limit for rockfish was replaced with a 15-fish limit, after which the limit was reduced to 10 fish in 2000 and has remained the same since. Gear restrictions for sport fishermen were first implemented in 2000, allowing no more than one line with three hooks. The following year, the number of hooks per line was reduced from three to two, and this limit (one line, two hooks) is still in effect as of the time of writing. Current [seasonal restrictions](#) on recreational rockfish fishing vary by month, management area, depth, and species group.

## **1.7 Fisheries off Canada, Alaska, and/or Mexico**

Although chilipepper are abundant throughout most California waters, their relative abundance declines sharply in waters north of southern Oregon, and they are only rarely encountered in Canadian waters. Their abundance off Baja California Norte, Mexico, is also poorly described and no robust historical or recent landings estimates are available. Early CalCOFI larval abundance data suggests that there could have been a non-trivial biomass in this region during the 1950s and 1960s, however recent [IMOCECAL](#) (Investigaciones Mexicanas de la Corriente de California) data have not been evaluated to ascertain whether chilipepper remain a significant fraction of the rockfish community in this region. A better understanding about the portion of the population in Mexican waters may be supported by habitat suitability mapping.

## **2 Data**

The STAT presented an online overview of available data sources for the chilipepper rockfish assessment during the PFMC Data Workshop held on January 23, 2025. A graphical summary of data sources used in the base model is provided as Figure 2.

## 2.1 Fishery-dependent data

Fishery-dependent data were split into eight fleets, described below with abbreviations used in many figures and tables throughout this document.

1. Hook and line gears from California, north of Point Conception (“NoCA\_HKL”)
2. Hook and line gears from California, south of Point Conception (“SoCA\_HKL”)
3. Trawl gear types from California (“CA\_TWL”)
4. Commercial gears, combined, from Oregon and Washington (“OR\_WA\_Comm”)
5. Net gears from California (“CA\_NET”)
6. Recreational fishing (all types) north of Point Conception, including Oregon and Washington (“NoCA\_OR\_WA\_Rec”)
7. Recreational fishing (all types) south of Point Conception (“SoCA\_Rec”)
8. Trawl discard with mortality rates applied (“TWL\_discard”)

### 2.1.1 Landings

A summary of total removals is provided as Table 2 and Figure 3. Since WWII, the California trawl fleet has accounted for most removals in all but a few years. In recent years, the trawl fleet continues to be the dominant source of landings (Figure 4).

#### 2.1.1.1 Commercial

Commercial data sources used in the chilipepper assessment span the period 1916 – 2024, with an assumed linear ramp in catch from 1875 to the first year of available data (Table 2). This is consistent with reports of a developed rockfish fishery in California in 1875, going back as far as 1860, however there is considerable uncertainty in estimates of historical catch (Phillips, 1957). A comparison of coastwide landings used in the 2017 update shows very close agreement (Figure 5), which is reassuring because the STAT reconstructed the entire time series from original sources for this assessment.

Combined estimates of commercial chilipepper catch [mt] from Oregon and Washington amount to less than 1% of historical removals over the modeled time period. Oregon estimates were obtained from A. Whitman (ODFW, pers. comm.), and Washington estimates were obtained from PacFIN. All gears and areas were combined into a single commercial fleet north of the California/Oregon border.

Estimates of commercial landings [mt] in California are derived from two primary data sources: first, a cooperative port sampling program (California Cooperative Groundfish Survey, CCGS) that collects information including species composition (i.e. the proportion of species by weight landed in a sampling stratum) and biological data (lengths, sex, maturity, otoliths), and second landing receipts (sometimes called “fish tickets”) collected by CDFW that are a record of pounds landed in a given stratum. A map of CCGS port complexes is provided as Figure 6. Strata in California are defined by market category, year, quarter, gear group, port complex, and disposition (live or dead). Although many market categories are named after actual species, catch in each market category can consist of several species, and many species are landed across multiple market categories. This was especially true for rockfish catches prior to 2000 (Figure 7). Fishers have historically used rockfish market categories not only to sort catch by species, but also to sort catch according to price per pound, size, or other factors.

Species composition samples collected by CCGS port biologists are stored in the CALCOM database, and used to partition catch recorded in market categories to individual species. These “expanded” catches are

estimated in CALCOM and are also made available via PacFIN. PacFIN is a repository for commercial landings data since 1981, and California's estimated chilipepper catches from the database are nearly identical to those in CALCOM (Figure 8). CALCOM also contains estimated catches from 1978-1980.

Prior to 1981, a variety of sources were available to reconstruct chilipepper catches. Working backwards in time from 1980, these are:

- 1978-1980. CALCOM; the database containing CCGS port sample data (species compositions and biological data such as lengths and ages). Species composition sampling began in 1978 and has been applied to landing receipt data for this time period to estimate catches.
- 1969-1977. Species composition estimates from the earliest available samples (1978-1982, depending on available data in each region) were applied to landing receipts over this time period. We refer to these data as the "ratio estimates."
- 1966-1976. Catches by foreign countries as estimated by Rogers (2003). These were added to the California trawl fleet.
- 1948-1968. Estimates of catch from Oregon waters, landed in California (J. Field, SWFSC). These estimates were not part of the Ralston et al. (2010) catch reconstruction, and were added to the California trawl fleet.
- 1916-1968. Ralston et al. (2010) created a catch reconstruction for California, applying available species composition data to time series of total rockfish landings. These estimates are stratified by species, year, region, and course gear categories (trawl and non-trawl).
- 1875-1915. A linear ramp was used to represent catches leading up to the first year of the Ralston et al. commercial reconstruction.

### **2.1.1.2 Bycatch in the At-Sea Hake fishery**

This assessment is the first chilipepper assessment to include bycatch from the at-sea hake fishery (1966-2024). Estimated bycatch was unusually large in 1991 (Figure 9). Years with larger bycatch amounts correspond with a more southern distribution of fishing in that year (Figure 10). Regulations prohibit processing of catch south of 42 degrees N. latitude (the CA/OR border), but catcher vessels delivering to motherships can still fish south of 42 degrees if catch is delivered north of 42 degrees. If fishing south of 42 degrees becomes more common in the future, it is reasonable to expect chilipepper bycatch to increase. If that occurs, collection of biological data for chilipepper should be considered to aid future stock assessment efforts. To date, chilipepper biological data have not been collected by the observer program. Bycatch data were provided by Vanessa Tuttle (NMFS, NWFSC).

### **2.1.1.3 Recreational**

Estimates of recreational removals in this assessment span the period 1928 – 2024 (Figure 2). Estimates prior to 1980 are based on Ralston et al. (2010; see more details on historical recreational fisheries in section 1.5). Over the modeled period, recreational fleets have accounted for just under 8% of total removals (Table 2). Per recommendations outlined in the 2015 assessment, we define separate recreational fleets north and south of Point Conception, and explore time blocks for selectivity in each fleet to account for large-scale spatial closures. Recreational catch [mt] in Oregon and Washington makes up a small fraction of total recreational landings. Recreational landings [mt] from Oregon were provided by A. Whitman (ODFW).

From 1980-2003, the Marine Recreational Fisheries Statistics Survey (MRFSS) executed a dockside (angler intercept) sampling program in Washington, Oregon, and California. Data from this survey are

available from the Recreational Fisheries Information Network (RecFIN). RecFIN serves as a repository for recreational fishery data for California, Oregon, and Washington ([www.recfin.org](http://www.recfin.org)).

MRFSS was replaced with state-run sampling programs beginning January 1, 2004. For California, this marked the beginning of the California Recreational Fisheries Survey (CRFS). Among other improvements to MRFSS, CRFS provides higher sampling intensity, finer spatial resolution (6 districts vs. 2 regions), and onboard CPFV sampling (Figure 11).

Recreational landings were combined across “modes” (party/charter boats, private/rental boats) and districts/areas into two recreational fleets, north and south of Point Conception.

### **2.1.2 Discards**

Field (2007) and Ralston et al. (1998) noted that reports of commercial discards were historically a very small fraction of total landings. For example, Heimann and Miller (1960) reported a bycatch rate of approximately 0.8% for chilipepper from a bottom trawl fishery off Morro Bay, California between August 1957 and July 1958, and Heimann (1963) reported discard rates of approximately 0.4% for bottom trawls made between Pigeon Point and Point Sur, California in 1960. Consequently, we assumed that discards were negligible prior to implementation of large-scale closed areas and trip limits in the 2000s.

The STAT estimated commercial discard ratios (discard/landings) based on West Coast Groundfish Observer Program’s (WCGOP) Groundfish Expanded Mortality Multiyear (GEMM) report. Recent landings and discard estimates from the report (2019-2023) were used to estimate a trawl discard ratio (discard/landings) of roughly 0.09, for use in forecasting discards from the trawl discard fleet (Figure 12). WCGOP’s provides observer data on discarding practices across sectors since 2003. Length data from the observer program were used to estimate the size distribution of discarded catch. Discards prior to 2011 (the beginning of the trawl IFQ fishery) were combined with catches. Discards from 2011 to 2024 are modeled as a separate fleet to reflect changes in the size composition of the catch over time (see the next section on biological data).

Methods used to determine recreational discard mortality have changed significantly over time. Under MRFSS, catch estimates were stratified into sampler-examined retained catch (Type A), angler-reported dead discard and otherwise unavailable retained catch (Type B1), and angler-reported fish that were discarded live (Type B2). The reliability of angler-reported catch and disposition (live/dead) is unknown for this data set. Under CRFS, catch estimates since 2005 are adjusted to account for estimates of depth-dependent discard mortality. These methods have changed over time, as well. We use the CRFS estimates of total mortality from RecFIN without modification.

### **2.1.3 Biological data**

This section describes fishery-dependent length and age composition data used in the assessment. Descriptions of biological characteristics such as adult growth (length at age, weight at length), reproductive biology (maturity, fecundity), and estimates of natural mortality rates are found in the “Biological Parameters” section. Units for body length in all data sets were standardized to fork length in cm. Sample sizes for fishery-dependent length compositions (number of lengths, and number of samples/hauls/trips depending on the source) are provided in Table 3. Age composition sample sizes for fishery-dependent data sources are provided by fleet, year, and sex in Table 4.

Input sample sizes for lengths from California commercial fleets are equal to the number of port samples by year and fleet. Input sample sizes for the Oregon commercial fleet are based on Stewart and Hamel (2014), as implemented in the [pacfintools](#) R package. Trawl discard lengths from WCGOP use input sample sizes equal to the number of observed hauls. Recreational input sample sizes for length compositions represent the number of trips and are defined as observed trips for onboard observer data sources, or unique sample identifiers for dockside sampling programs (MRFSS and CRFS).

Length compositions for commercial catch in the model are “expanded” to represent a catch-weighted distribution of lengths by fleet, area, and year. Insufficient samples are available to develop length compositions for Washington (commercial or recreational). For Oregon, commercial length compositions (all gears combined) were provided by A. Whitman (ODFW), based on the [pacfintools](#) R package developed by the NWFSC. For the Oregon data, years with fewer than 100 fish sampled were excluded from the model.

Commercial length compositions for retained fish in California were expanded using the procedures developed for CALCOM. These expansions differ from the default approach used by the “[pacfintools](#)” package. Specifically, differences in mean length by market category (Figure 13) and port complex (Figure 14) are accounted for in the CALCOM expansion routine. The documentation for [pacfintools](#) indicates that default stratification is by state, gear, and year. To allow for variation in mean length across market category and port complex, and for consistency with previous stock assessments, the STAT used the length composition expansion routine from CALCOM, which stratifies by year, gear group, port complex, and market category. Stratification by landing disposition (live/dead) is also accounted for in CALCOM’s length expansion routine, but a negligible amount of chilipepper is landed live. Lengths for commercial discards were obtained from the WCGOP (Figure 15). Commercial length compositions by fleet, year, and size bin are shown in Figure 16.

Recreational length compositions (Figure 16) are unweighted in the base model. Based on CRFS methods for allocation of sampling effort, sample sizes should be roughly proportional to catch by stratum. However, this is untested, and may not be sufficient to capture differences in mean size across strata in unweighted comps. Standardized methods for catch-weighted length compositions from recreational fisheries are in preparation (E. Dick, SWFSC, and J. Edwards, PSMFC, pers. comm.). Sources of recreational length data include onboard observer programs in Southern California during the 1970s and 1980s (Collins and Crooke, unpublished report; Ally et al. 1991). The 1970s data extend the time series back before the beginning of the MRFSS sampling program. Length data from Ally et al. (1991) were used in place of MRFSS data from 1985-1989 in Southern California due to larger sample sizes. Another onboard observer program for CPFVs in the central California region collected length information from 1987-1998 (Monk et al. 2016). Sampling in this program was limited to Monterey Bay in 1987, but subsequent years included sampling across the core range for chilipepper, and were used in place of relatively limited MRFSS samples for the period 1988-1998 and, importantly, bridged the gaps in MRFSS sampling from 1990-1992 (all modes) and through 1995 in the northern California charter boat fleet. Starting in 2004, all recreational length composition data came from CDFW’s CRFS data via RecFIN.

All age data in the current assessment are modeled as conditional on length. Sample sizes are numbers of fish aged (Table 4). Some observed age/length combinations were clear errors and removed from the data. These are noted in the data file, and the original data record is commented out to help identify the change. A novel approach to age estimation (Helser et al. 2019; details below) was used in the current assessment for two years of recreational age structures (2023-2024) collected by CDFW. For chilipepper, the size compositions for the fish sampled for ages and the fish regularly sampled using the CRFS protocol were similar in those two years, and therefore the ages were included in the base model.



### *Age data from Fourier Transformed Near-Infrared Spectroscopy (FT-NIRS)*

Over the past five years, NOAA Fisheries has undertaken a strategic initiative to develop the methodology and application of using Fourier Transformed Near-Infrared Spectroscopy (FT-NIRS) as a more efficient, rapid and cost-effective means of developing age estimates to inform stock assessments. All seven NMFS science centers have been involved in the initiative, with an overarching goal of operationalizing the approach across NOAA ageing labs. In the fall of 2024, the PFMC SSC Groundfish Subcommittee conducted a review of the FT-NIRS methodology for use in fish age estimation for groundfish stock assessments of U.S. West Coast species. The review focused specifically on applications to sablefish, Pacific hake, and rougheye/blackspotted rockfish, however the review included presentations of analyses by the team of researchers at the Alaska Fishery Science Center (AFSC) who led the initiative and have been developing methods for species such as northern rockfish, walleye pollock, and Pacific cod in Alaskan waters.

As summarized in the SSC and GFSC reports from the methodology review (PFMC 2024), otoliths are exposed to near infrared light, and the absorbance profiles of the resulting spectra can be quantified using a spectrometer (Helser et al. 2019, Benson et al. 2024). Relating the absorbance profile to traditional age estimates (typically from break and burn methods) provides the basis for the age estimation, and although predictions to the observed data are subject to uncertainty, this uncertainty can be quantified. To provide the most robust age estimates from the spectral data, both the AFSC and NWFSC have developed “deep learning” methods to improve age predictions. Estimates developed for chilipepper were developed by John Wallace and Emily Wallingford (NWFSC) using a fully connected neural network (FCNN) modeling approach. During the review, concerns were raised regarding some bias in the FT-NIRS estimates, particularly for sablefish in which FT-NIRS tends to overpredict relative to traditional age estimates at younger ages (positive bias) and underpredict at older ages (negative bias). One contributing factor could be that there are typically fewer data from older fish available to include in the training models, thus there is more potential for bias or uncertainty for those ages. The review noted that effects of bias on the older ages in stock assessment outputs could be minimal when aggregated into the “plus group” of older ages within the stock assessment model.

The SSC concluded that sablefish and potentially chilipepper assessments during the 2025 assessment cycle could include a relatively small number of FT-NIRS age estimates, with sensitivity of assessment results provided to assess the effects of inclusion of these data. Many chilipepper were aged using traditional methods and scanned for FT-NIRS, with most of the scans taking place at the Santa Cruz lab. The NWFSC (John Wallace, pers. Com; <https://github.com/John-R-Wallace-NOAA/JRWTToolBox>) then developed a FCNN model for chilipepper based on 4816 reference ages (from traditional methods) and model estimates (Figure 17). Qualitatively and visually, the model does appear to exhibit some of the concerning characteristics that were noted earlier in models of age estimates from FT-NIRS relative to traditional age estimates for sablefish and rougheye/blackspotted rockfish, in that there was some indication of bias towards younger age estimation in the FCNN model. However, agreement was overall quite strong between the two estimates when all scanned data were considered, and the ageing error estimation program did not detect a clear bias in the FT-NIRS ages relative to the traditional ages. Between this observation, and the recognition that only a very small number of FT-NIRS ages are included in the base model (the 2004 triennial trawl survey, and 2023 and 2024 recreational fisheries, the latter of which exhibit dome-shaped selectivity with lower selectivity on larger, older fish), the STAT is comfortable using a small number of FT-NIRS based ages in the base model. Additional research, analysis and model development should take place before a larger number of FT-NIRS based age estimates are used in future assessments or updates.

### **2.1.4 Fishery-dependent abundance Indices**

Two fishery-dependent indices of abundance were included in previous stock assessments: an index developed from trawl logbook data, and a recreational CPUE index derived from onboard observer data. These are not included in the 2025 base model. Since it has been nearly 20 years since the last benchmark assessment, fishery-independent surveys such as the WCGBTS and the RREAS have developed informative, long-term, time series for chilipepper rockfish. See section 2.6 for a description of the trawl logbook index and recreational onboard observer index.

## **2.2 Fishery-Independent Data**

The 2025 chilipepper rockfish base model includes four fishery-independent data sources: the Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (WCGBTS), the Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey (Triennial Survey), the Southwest Fisheries Science Center California Cooperative Oceanic Fisheries Investigations (CalCOFI) ichthyoplankton survey, and the Southwest Fisheries Science Center Rockfish Recruitment and Ecosystem Assessment Survey (RREAS).

### **2.2.1 NWFSC West Coast Groundfish Bottom Trawl Survey**

The Northwest Fishery Science Center has conducted combined shelf and slope trawl surveys, the West Coast Groundfish Bottom Trawl Survey (WCGBTS) since 2003, based on a random-grid design from depths of 55 to 1280 meters. Additional details on this survey and design are available in the abundance and distribution reports by Keller et al. (2008), Keller et al. (2014) and Bradburn et al. (2011). The survey design typically relies on the use of four vessels per year, with some exceptions based on funding, covid and other impacts, which fish from north to south along the entire U.S. West Coast in two passes, one beginning in late May and the other beginning in early October. Each vessel is assigned to a roughly equal number of randomly selected grid cells, and the design is intended to account for vessel-specific differences in catchability.

Chilipepper rockfish are frequently encountered in this survey, occurring in approximately 13% of the sampled trawls (which extend to over 1200m, so the percentage of positive observations within the habitat range for the species is much greater). They are encountered throughout nearly the entire latitudinal range of the survey, and between the shallowest depths sampled to at least 464 meters of depth, but with a mean latitude of capture of approximately 38.4 N and a mean depth of 166 meters (Keller et al. 2014).

To develop a relative abundance index from this dataset, geostatistical models of biomass density were fit using Template Model Builder (TMB) (Kristensen et al. 2016, Anderson et al. 2022), as configured within the {indexwc} R package (Johnson et al. 2025), consistent with the accepted practices guidelines for West Coast groundfish stock assessments. A plot of the survey index is provided as Figure 18, and model diagnostics (quantile plots) are provided as Figure 19. Estimates of biomass were predicted using a grid based on available survey locations, and a map of the spatial residuals to the model fit is provided as Figure 20. The index suggests that the highest catch rates for the stock occurred between 2004 and 2008, with a steep drop following that peak and variable but consistent (slow) increase in abundance since that time.

During the STAR panel, the STAT plotted residuals from the geostatistical model against haul depth, revealing a pattern that suggested a peak in chilipepper density at intermediate depths (see Request 12 in Appendix B). The STAT found that inclusion of a depth covariate improved the fit of the geostatistical

model, regardless of whether the model assumed an isotropic or anisotropic spatial process. The relative trend changed only a small amount, but the index was better fit by the assessment model when the depth covariate was included, based on a reduction in the negative log likelihood of slightly more than 2 points (Figure 21). With the depth covariate, annual biomass estimates from geostatistical model were reduced by about 15%, on average, resulting in a survey catchability estimate that was more consistent, although still larger than expected, with the assessment estimates of vulnerable biomass ( $q=1.8$  with the depth covariate, vs.  $q=2.3$  without the depth covariate). The STAT recommends further research into assessment methods, as well as geostatistical modeling for trawl survey indices, with specific attention to estimation of population scale.

### **2.2.2 Alaska Fisheries Science Center/Northwest Fisheries Science Center West Coast Triennial Shelf Survey**

Until the development of the WCGBTS, a primary source of fishery independent information for most managed and assessed groundfish species along the U.S. West Coast was the triennial trawl survey conducted between 1977 and 2004 (Weinberg et al. 2002). The consensus from recent data workshops has been to exclude 1977 data, due to concerns related to differences in survey protocols, the depth distribution of the survey, and the number of bad performance tows and “waterhauls,” in which few benthic organisms were noted (Zimmermann et al. 2001).

In most early years of the triennial survey, the survey did not include a large fraction of chilipepper habitat; from 1980 through 1986 the survey only sampled to just south of the Gulf of the Farallones (San Francisco region, approximately 37° N) and did not sample the region of Monterey Bay and further south, where a considerable fraction of chilipepper biomass is found. From 1989-onward the survey extended to approximately Point Conception, CA (34.5 N), thus covering a larger fraction, albeit still not the entirety, of chilipepper habitat given the relatively high abundance in the waters throughout the Southern California Bight. A similar shift occurred in the depths sampled for this survey; between 1980 and 1995 the survey sampled depths from 55 to 366 meters (the 1977 did not sample as shallow, and the 1977 data are not used in this index), while from 1995 through 2004 the survey sampled depths between 55- and 500-meters depth. Subtle changes (several weeks) in the timing of some earlier surveys have led some analysts to treat the index from this survey as two separate time series. Due to the many other changes that could complicate this modest seasonal shift, the index was not modeled separately for the two time periods. Additional details regarding this survey, including the history of the transition between this survey and the ongoing West Coast Groundfish Bottom Trawl Survey, can be found in Keller et al. (2017).

To develop a relative abundance index from this dataset, geostatistical models of biomass density were fit using Template Model Builder (TMB) (Kristensen et al. 2016, Anderson et al. 2022), consistent with the accepted practices guidelines for West Coast groundfish stock assessments. A plot of the survey index is provided as Figure 22, model diagnostics are provided as Figure 23 and a map of the spatial residuals to the model fit is provided as Figure 24. There was insufficient time during the STAR panel to investigate depth covariates for the Triennial survey index as identified in the WCGBTS data (see Section 2.2.1), but the STAT recommends that future assessments evaluate depth covariates during development of indices of abundance from the Triennial survey as well.

### **2.2.3 Southwest Fisheries Science Center California Cooperative Oceanic Fisheries Investigations (CalCOFI) ichthyoplankton survey**

The California Cooperative Oceanic and Fisheries Investigations (CalCOFI) survey began in 1951, in order to help evaluate the oceanographic and ecosystem drivers of the decline in the California sardine population. The survey samples zooplankton and ichthyoplankton with a 505-um bongo net, which is a double-ring net system attached to a central frame and towed obliquely through the water column. Chilipepper are one of only several *Sebastes* species for which larvae are readily identifiable using morphometric methods (Moser et al. 1977, Moser et al. 2000), however the morphometric criteria for chilipepper were developed later than the criteria for other rockfishes such as shortbelly (*S. jordani*), bocaccio (*S. paucispinis*), and cowcod (*S. levis*); as larval chilipepper are harder to ID at younger ages. Older larvae (a week or so of age) are more likely to exhibit the conclusive features that allow species specific identification. Thus, until recently many of the historical collections did not identify chilipepper in initial plankton sorting efforts. Efforts to re-analyze those early samples, while maintaining analysis of ongoing collections, have been ongoing for the past two decades. Consequently, the current time series of historical data is considerably more spatially and temporally robust than it was for the 2007 chilipepper stock assessment (W. Watson, SWFSC, pers. comm.).

Although egg or larval abundance data from CalCOFI surveys are no longer directly used for stock assessments of coastal pelagic species, they have continued to be used in assessments of other groundfish species. Specifically, larval abundance data have been used in stock assessments of bocaccio since the mid-1990s through the most recent (Jacobson et al. 1996, MacCall 2003, He and Field 2017), as well as in cowcod stock assessments since 2002 (Butler et al. 2002, Dick and He 2019) and an assessment of shortbelly rockfish (Field et al. 2007). In all these examples, the assumption has always been that larval abundance reflects relative female spawning output, and selectivity of this dataset is mapped to this value within the model while accounting for size-dependent fecundity. Larval abundance data have also been used in assessments of California sheephead (Alonzo et al. 2004), and were found to be correlated with recruitment in the assessment of California halibut (Coates et al. 2025). Until recently, data from this survey were generally limited to species that can be morphologically identified, but with genetic identification (e.g., Thompson et al. 2017), there are increasing opportunities to extend the application of this dataset to other species. Identification of larvae from samples taken during the 1950s was identified as a research recommendation during the STAR panel review.

## Data

Tow data from the CalCOFI survey were obtained from 1951 to 2023. From Ed Webber (SWFSC) and William Watson (SWFSC) we also obtained data from a subset of these tows (846 tows from years 1992, 1994, 1996, 1998, 1999, 2002-2006) that had been recounted more accurately for chilipepper larvae, which we substituted for the existing counts.

For this analysis, we used only tow types C1 (CalCOFI One Meter Oblique Tow, 0.8 m<sup>2</sup> mouth area, 1-m diameter) and CB (CalCOFI Oblique Bongo Tow, 0.4 m<sup>2</sup> mouth area, 0.71-m diameter). We also excluded port (P) net side samples prior to 1997 due to use of a different mesh size. The mesh size for all remaining samples was either 0.55 or 0.505 microns.

For spatial subsetting, we excluded the nearshore SCCOOS stations, and included only tows between lines 60 and 93.3 (inclusive) and station  $\leq 80$ . This encompasses the primary CalCOFI sampling region off central and southern California, and excludes far offshore stations, where chilipepper larvae are unlikely to occur.

For temporal subsetting, we excluded years 1985 to 1990, as these samples had not been reliably sorted for chilipepper. We also excluded data from lines  $\leq 73.3$  (central region) for the years 1959 and earlier, as these samples had also not been reliably sorted for chilipepper. We also only included data collected from November to April, when most chilipepper larvae are expected in the plankton. For analysis, tows

from November and December were assigned to the following spawn year, and 365 was subtracted from their Julian sample dates.

Finally, if both net sides (S and P) were processed from the same tow, we averaged them. This resulted in a total sample size of 10,234 tows from 64 years (missing years: 1971, 1974, 1977, 1985, 1986, 1987, 1988, 1989, 1990). See Table 5 for a summary of the data filtering steps. Figure 25 shows the spatial and temporal coverage of all retained samples.

### *Model*

We modeled larval density (larvae\_10m2) using a spatial GLM with the package sdmTMB (Anderson et al. 2022). The model included Julian date (GAM smoother with  $k=4$ ) to account for seasonality (Figure 26), a spatial random field, and IID spatiotemporal random fields. Since there were 6 years (1952, 1983, 1993, 1995, 1997, 1999) with sampling but no detections of chilipepper, we modeled year effects using time-varying (random walk) intercepts rather than as fixed effects. This allowed us to retain these years, which are informative about abundance being relatively low (the fixed year effect model is unable to estimate an index and associated uncertainty for years with no positive catches). Prior testing indicates that for years with positive catches, there is little difference between these two model structures, and that for years without positive catches, the time-varying intercept model produces low index values of reasonable magnitude. A Tweedie error distribution was used, and found to be suitable from diagnostic plots (Figure 27).

Predictions were made to a grid of 74 standard CalCOFI stations (lines 60 to 93.3 and station  $\leq 80$ ) for Julian date 32 (around the peak of larval abundance). These predictions were summed to generate a coastwide index, with bias correction turned on (Figure 28, Figure 29). The same model was also used to generate regional (southern, central) indices (Figure 30), by summing together the predictions for just the central area stations (line  $< 76.7$ ) or southern area stations (line  $\geq 76.7$ ). For the regional indices, years were excluded post-hoc if a region had no sampling in that year (all values would be extrapolated). This only affected the central region.

## **2.2.4 Southwest Fisheries Science Center Rockfish Recruitment and Ecosystem Assessment Survey (RREAS)**

### *Data*

The Fishery Ecology Division of the Southwest Fishery Science Center has conducted a standardized pelagic juvenile trawl survey (the Rockfish Recruitment and Ecosystem Assessment Survey, RREAS) during May-June every year since 1983 (Ralston et al. 2013; Sakuma et al. 2016; Field et al. 2021). A primary purpose of the survey is to estimate the abundance of pelagic juvenile rockfishes (*Sebastes* spp.) and to develop indices of year-class strength for use in groundfish stock assessments on the U. S. West Coast. This is possible because the survey samples young-of-the-year rockfish when they are ~100 days old, an ontogenetic stage that occurs after year-class strength is established, but well before cohorts recruit to commercial and recreational fisheries. This survey has encountered tremendous interannual variability in the abundance of the species that are routinely indexed, as well as high apparent synchrony in abundance among the ten most frequently encountered species (Ralston et al. 2013, Schroeder et al. 2019). Past assessments have used data from this survey to provide indices of year-class strength (as relative age 0 abundance), including assessments for Canary rockfish (Langseth et al. 2023), Blue/Deacon Rockfish (Dick et al. 2018), Widow Rockfish (Adams et al. 2019), Bocaccio (He et al. 2015), Shortbelly Rockfish (Field et al. 2007) and Chilipepper Rockfish (Field 2015).

Historically (1983-2003), the survey was conducted between 36°30' and 38°20' N latitude (the 'core area' from approximately Carmel to just north of Point Reyes, CA). However, starting in 2004 the spatial coverage of the RREAS expanded to cover from the U.S./Mexico border to Cape Mendocino. Additionally, since 2001 data are available from comparable surveys conducted by the Pacific Whiting Conservation Cooperative (PWCC) and the NWFSC (2001-2009), which later evolved into the NWFSC "Pre-recruit" survey (2011-present) for waters off Oregon and Washington (Field et al. 2021). Coastwide data have revealed both spatial differences in species composition (e.g., north and south of Point Conception) and interannual shifts in the distribution of most pelagic juvenile rockfishes (Ralston and Stewart, 2013; Field et al. 2021). As the core area index seems to have failed to capture the magnitude of the 1999 year class for most stocks, the recommendations from the juvenile rockfish survey workshop held in 2005 were to use only the coastwide data (since 2001) for juvenile indices rather than the longer-term 'core area' indices unless a convincing case could be made otherwise. Here we used data from 2001 to 2024, the period for which we have coastwide coverage. On account of the COVID-19 pandemic, sampling in 2020 was very limited and restricted to the historical core area (Santora et al. 2021), so this year is excluded in all models. Note that in the years 2010 and 2012, sampling did not span the entire coastwide spatial domain, with data sparse or lacking from northern CA, OR, and WA. The year 2022 lacks sampling in northern CA. These years were included in the models for coastwide stocks (e.g., widow and chilipepper), but 2010 and 2012 were excluded for the yellowtail rockfish northern index. Assessors may want to consider a sensitivity with these years excluded, particularly for species with a more northern distribution. Catch per tow was adjusted to a common age of 100 days to account for interannual differences in age structure (Ralston et al. 2013), as has been done for prior assessment indices using this dataset.

Data from these surveys also supports process studies seeking to better understand the oceanographic processes leading to strong or weak year classes in adult groundfish populations. Survey data also provide insights into the drivers and consequences of climate-driven shifts in both the abundance and spatial distribution of other epipelagic micronekton, such as krill, coastal pelagic species, and mesopelagic fishes, as well as many of the seabirds and marine mammals that prey upon them. Such data are routinely reported in the CCIEA and other ecosystem status reports. More details about these research efforts can be found on the [project storymap page](#).

### *Model*

For the index model, we first examined species occurrence in samples across the entire survey domain. If there was evidence of a hard range boundary (e.g., the species was never observed south of Point Conception), then we excluded the regions where the species was never observed. Depending on the geographic scope of assessment, we may also have applied other geographic subsettings, e.g., only CA waters. If there were years in the final geographic domain with no or very sparse sampling, those years were also excluded.

Since catch (and sampling) varied over space and time, we modeled catch using a spatial GLM with the package sdmTMB (Anderson et al. 2022). The 100-day standardized catch per tow was modeled as a function of fixed year effects along with Julian date (GAM smoother with  $k=4$ ) to account for seasonality (Figure 31), a spatial random field, and IID spatiotemporal random fields. If there were years with sufficient sampling but where no fish of the focal species were caught, then we modeled year effects instead using time-varying (random walk) intercepts. This allowed us to retain these years, which are informative about abundance being relatively low (the fixed year effect model is unable to estimate an index and associated uncertainty for years with no positive catches). Prior testing indicates that for years with positive catches, there is little difference between these two model structures, and that for years without positive catches, the time-varying intercept model produces low index values of reasonable magnitude.

We fit the model using 3 different error structures: Tweedie, delta-lognormal, and delta-gamma. In all rockfish species examined so far, dharmas quantile residuals from model simulations suggested that Tweedie distribution was the best (Figure 32), so this is the model we proceeded with. The Tweedie model also best reproduced the observed proportion of zeros in the data based on simulations from the fitted model. For all species except yellowtail (see below), the Julian date effect showed a decline in catch towards the end of the sampling season, as juveniles begin to settle out of the water column.

For the index, predictions from the model were made for all active sample stations within the geographic domain, for the mean Julian date, for each year. Predictions were added together for each year to produce the index (Figure 33, Figure 34). Active stations are those regularly and consistently sampled, and are located on a semi-regular grid spanning the sampling region. Previous work has found that interpolating to a finer spatial grid has little impact on the resulting index.

Two indices were generated for chilipepper rockfish: One using data since 2001 (Figure 33, same as the other coastwide indices generated), and once using historical data back to 1984 (Figure 35, Figure 36; 1983 was excluded because no chilipepper were caught that year). For both time periods, a coastwide index was generated with no spatial subsetting (all data from CA, OR, and WA were used). For the index using the historical data, which before 2001 was only collected in central CA, this involved extrapolation to regions outside of central CA. For both models, there were no years with zero positive catches (excluding 2020 and 1983).

Recruitment of young fish to the population is known to vary both spatially and temporally for Chilipepper. See section 4.3.1 for a summary of factors affecting juvenile growth, survival and recruitment dynamics, including associated references.

## **2.2.5 Biological Data**

This section describes fishery-independent length and age composition data used in the assessment. Descriptions of biological characteristics such as adult growth (length at age, weight at length), reproductive biology (maturity, fecundity), and estimates of natural mortality rates are found in the “Biological Parameters” section.

Composition data from fishery-independent sources came from the Triennial Survey and the WCGBTS. Data from 1977 were excluded from the Triennial Survey due to known issues with that year, but in other years sample sizes were in the 1000s of fish (Table 6, Figure 37). Length compositions from the WCGBTS were available for all years from 2003-2024, with the exception of 2020 (Table 7, Figure 38). Age compositions were available for all years of the WCGBTS where there were length data, with sample sizes ranging from 349-873 ages per year (Table 8).

For the 2007 benchmark, it was reported that age data from the Triennial trawl survey were unavailable, as age estimates had been based on surface-read ages, rather than ages estimated using break and burn methods. However, prior to the 2015 update assessment, the SWFSC located age structures from several triennial survey years, specifically for 1983 (n=734), 1992 (n=246), 1998 (n=439) and 2001 (n=487). Additionally, age structures from the 2004 triennial survey were aged for this assessment using FT-NIRS methods (Table 8; also see section 2.1.3). Despite extensive efforts and searches in Alaska Fishery Science Center warehouses prior to the 2015 update, age structures from 1977, 1986, 1989 and 1995 triennial surveys could not be relocated.

## 2.3 Ageing Error

Within-reader estimates of precision for ages read for previous assessments were carried into this assessment (constant CV of 10%). For ages estimated in preparation for the 2025 assessment, the [AgeingError](#) software package (Punt et al. 2025) was used to evaluate between-reader bias and variability. Cross-reads between fish aged by D. Pearson (SWFSC, retired) and T. Johnson (NWFSC) were evaluated and found to be unbiased with a constant CV of roughly 24% (n=200). Analysis of age predictions from a Neural network model of FT-NIRS otolith scans (J. Wallace, NWFSC, retired) showed that a constant CV model with no bias was appropriate, although with greater variability (CV near 30%). However, see the research recommendation section for suggestions related to estimation of ageing error matrices for model-predicted ages.

## 2.4 Biological Parameters

### 2.4.1 Natural Mortality

Hamel (2015) developed a method for combining meta-analytic approaches to relating the natural mortality rate  $M$  to other life-history parameters such as longevity, size, growth rate and reproductive effort, to provide a prior on  $M$ . In that same issue of ICESJMS, Then et al. (2015), provided an updated data set of estimates of  $M$  and related life history parameters across many fish species, from which to develop an  $M$  estimator for fish species in general. They concluded by recommending  $M$  estimates be based on maximum age ( $A_{max}$ ) alone, based on an updated Hoenig non-linear least squares (nls) estimator  $M = 4.899A_{max}^{-0.916}$ . The approach of basing  $M$  priors on maximum age alone was one that was already being used for west coast rockfish assessments. However, in fitting the alternative model forms relating  $M$  to  $A_{max}$ , Then et al. did not consistently apply their transformation. In real space, one would expect substantial heteroscedasticity in both the observation and process error associated with the observed relationship of  $M$  to  $A_{max}$ . Therefore, it would be reasonable to fit all models under a log transformation. This was not done.

Revaluating the data used in Then et al. (2015) by fitting the one-parameter  $A_{max}$  model under a log-log transformation (such that the slope is forced to be -1 in the transformed space (as in Hamel 2015)), the point estimate for  $M$  is:

$$M = 5.4/A_{max}$$

Hamel and Cope (2022) further refined estimation of  $M$  by appropriately accounting for sources and of error in both  $A_{max}$  and  $M$ . They recommend a prior defined as a lognormal distribution with median  $5.4/A_{max}$ , as above, and log-scale standard deviation of 0.31.

The oldest chilipepper rockfish in California (the center of chilipepper rockfish distribution; source: CALCOM) was a 39-year-old female landed by a vessel using trawl gear in 2004 near Monterey, California. The next few oldest fish, a 35-year-old male and a few 34-year-old females have also been observed, any of which represent the 99.99% quantile within rounding error (n=53,847 ages). No older fish were observed in Oregon samples (max. age = 29), although sample sizes were small by comparison.

The prior for female natural mortality is defined as a lognormal with mean  $\ln(5.4/A_{max})$  and  $SE = 0.31$ . Using a female maximum age of 35 the point estimate and median of the prior is 0.154 (with a log-space value of -1.869). Natural mortality of males was modeled as an exponential offset with no explicit prior.



## **2.4.2 Growth**

### **2.4.2.1 Length at age**

For this assessment, an extensive analysis of adult growth (Appendix A) was conducted to evaluate spatio-temporal variation. The previous benchmark assessment (Field 2007) assumed that the growth coefficient ( $k$ ) of the von Bertalanffy model for length-at-age varied over time. We also found evidence of time-varying growth based on fits external to the stock assessment model, although time-varying selectivity could produce patterns in the data that are confounded with variation in growth.

The base model assumes constant growth, estimating parameters within the model. Alternative models with variable growth are evaluated as sensitivities, but not found to significantly alter the estimated dynamics. Currently, methods for reference point calculations are an active area of research for models with time-varying biology, and future assessments may wish to revisit the inclusion of time-varying growth. In particular, models with time-varying asymptotic size, perhaps correlated with  $k$  and exhibiting low-frequency variability, may have a greater influence on population dynamics.

### **2.4.2.2 Weight at length**

Revised estimates of chilipepper weight-at-length were calculated using data from the WCGBTS. There appears to have been an error in the calculation used for the previous assessments (Figure 39), but this has little effect as it is roughly equivalent to changing the (arbitrary) units of spawning output in the model. Estimates of biomass, yield, and depletion show little difference as a result of the change.

## **2.4.3 Maturity**

Maturity was updated for the 2015 update assessment (see Field et al. 2015 for details) based on the results of Beyer et al. (2015). Maturity status for that assessment was based on gross macroscopic evaluation, and future chilipepper assessments may consider revising the maturity relationship based on functionally mature fishes (Lefebvre and Field 2015). The 2025 assessment model uses the same estimates for maturity-at-length as in the 2015 assessment (Figure 40).

The 2007 assessment used macroscopic maturity estimates from over 10,000 fish sampled during port sampling or survey activities to develop maturity at length curves, and estimated that 50% of females matured at a length of 25.7 cm. For the 2015 update, a more comprehensive evaluation of maturity, based on both macroscopic and histological analysis, and including evaluations of regional variability, were conducted and described. In brief, in advance of the 2015 update, ovarian tissue samples from reproductive ecology and other investigations were processed histologically ( $n=565$ ) to inform macroscopic assignments of maturity, detect abortive maturation and atresia (mass resorption of developing oocytes), and determine if secondary broods (see fecundity discussion) may be identified at early or later stages than possible macroscopically.

Results are reported more comprehensively in Lefebvre et al. (2018), and there was considerable discussion on abortive maturation and atresia in the 2015 assessment and the 2018 publication. Regional variability in maturity was also explored, and we found that maturity estimates varied slightly by region, such that L50 and L95 were slightly greater (by 3 and 2 cm, respectively) in central California relative to southern California fish. Estimates obtained by temporally restricting samples to the period of peak ovarian development before peak parturition (September to January), when assignment of maturity based on macroscopic evaluation is most accurate, resulted in small a decrease (0.5 cm) in the length of 50% maturity, but also reduced the sample size. With respect to abortive maturation (mass resorption of developing oocytes), those studies found that females collected in September and October showed normal

development for the reproductive season, but that females collected in November and December, when the vast majority of mature females have vitellogenic (stage 3) or eyed larvae (stage 4), abortive maturation was found to be occurring in 92% of the fish identified macroscopically as stage 2 (pre-vitellogenesis, again most fish were stage 3 or 4). This suggests that these females were likely incapable of successfully producing a brood of larvae in the current spawning season.

To evaluate how sensitive maturity estimates were to these phenomena, maturity curves were re-estimated using the temporally restricted subsamples, such that females with stage 1 ovaries were considered immature, as were those with stage 2 ovaries from November – January. With the data we had at the time, we found that there was a negligible decrease in the combined and southern California L50 estimates, and a counter-intuitive modest increase in the central California L50. The most substantive change was an increase in L95 estimates for all areas (flattening the curve). Atresia was also frequently observed in smaller individuals, however most individuals generally displayed low (5% or less oocytes) or moderate (> 5–25% of oocytes) downregulation. Ultimately, the histological data were considered to be too sparse to rely on exclusively, and the 2015 assessment pooled the previously used historic macroscopic data with the recent data (from all regions) in order to update physiological maturity estimates. Consequently, the 2015 updated maturity curve estimated a slightly smaller size at maturity for female chilipepper (50% mature at 24.4 cm FL, 95% at 35.2 cm) than the 2007 model. We continue to use these parameters for the current benchmark, although future work should include additional data analysis in order to revisit the potential impacts of abortive maturation and atresia in developing a more robust functional maturity curve.

#### 2.4.4 Fecundity

This assessment assumes that fecundity ( $F$ ) is a power function of female body length ( $L$ ), based on the relationship,  $F = aL^b$ . Dick et al. (2017) conducted a meta-analysis of fecundity for the genus *Sebastes*, reporting values for  $b$  (3.790) and  $a$  ( $1.00579E-07$ ) for chilipepper rockfish. Since the exponent of the fecundity-length relationship is greater than the exponent of the fecundity-weight relationship, weight-specific fecundity (eggs or larvae per gram female body weight) also increases with size. These parameter values estimate fecundity in millions of eggs. Since Stock Synthesis tracks fish in 1000s, the reported values of spawning output are in billions of eggs.

Later research found that chilipepper rockfish can produce multiple broods in a year, and that the probability of occurrence is size-dependent (Lefebvre et al. 2018). Dick and He (2019) evaluated the sensitivity of cowcod population dynamics to multiple brooding by multiplying the “brood” fecundity-length relationship from Dick et al. (2017) by a factor of  $1+x$ , where  $x$  is the probability of a female producing a second brood, given body length, i.e.,  $1 + \text{Pr}\{\text{multiple brooding} \mid \text{length}\}$ . Since data for the prevalence of multiple brooding at length were not available for cowcod, Dick and He (2019) used estimated values for chilipepper as a proxy, but found that changes in  $M$  (when estimated) under alternative fecundity assumptions negated the effects.

Since data on multiple brooding at length are available for chilipepper, we approximated total annual fecundity (assuming at most 2 broods per female per year) using a fitted power function, following the methods used by Dick and He (2019; Figure 41). S. Beyer (AFSC) provided updated estimates of  $\text{Pr}\{\text{multiple brooding} \mid \text{length}\}$  that included the 2013-15 data from Lefebvre et al. (2018), and added data from 2016-2019 winter spawning seasons. We use estimates from central California only (excluding southern California), as this represents the central part of the chilipepper distribution. The adjustment for length-dependent multiple brooding probability increases the exponent of the fecundity-length relationship ( $b$ ) from roughly 3.8 to 4.2, accelerating the increase in weight-specific fecundity with increasing length.

## 2.5 Environmental and ecosystem data

Chilipepper are reasonably well sampled throughout their life history; in larval surveys, pelagic juvenile young-of-the-year (YOY) surveys and bottom trawl surveys, and there is a considerable body of literature, in addition to the results of past stock assessments, on the dynamics and ecosystem interactions throughout these stages. Both larval and pelagic juvenile abundance, as well as estimates of year class strength from previous stock assessments, clearly indicate considerably interannual variability in recruitment, which is typically thought to be primarily a function of variable growth and mortality in late larval or early juvenile life history stages, which is in turn related to large-scale variability in environmental conditions (Field et al. 2010, Ralston et al. 2013, Schroeder et al. 2019). Past stock assessments have also identified interannual variability in growth, which analyses presented here also conclude as considerable (Appendix A), as well as a nontrivial amount of interannual variability in reproductive output in response to environmental conditions (Beyer et al. 2024). Consistent with research into drivers of interannual variability in pelagic YOY, variability growth and reproductive output has also been either shown or suggested to vary in response to environmental conditions, although the potential for density-dependent processes as contributing factors have been less thoroughly evaluated. Much of that information is more rigorously synthesized in analyses supporting the risk table (Section 4.3.1).

With respect to trophic interactions, adult chilipepper have been described as midwater foragers, with euphausiids, forage fishes (such as anchovies, Pacific hake, and mesopelagic fishes), and small squids among key prey items (Love et al. 2002). With respect to predation mortality, pelagic juvenile rockfishes of all species, including chilipepper, are among one of the most important forage taxa identified in a meta-analysis of predator food habits studies in the California Current. Key predators of pelagic juveniles including seabirds, salmon, lingcod, tunas and marine mammals (Szoboszlai et al. 2015, Warzybok et al. 2018). Adults are consumed by larger piscivorous fishes, such as bocaccio and lingcod, as well as marine mammals. Predation by Humboldt squid (*Dosidicus gigas*) was documented during a period of range expansion of that species between the early 2000s and approximately 2010, although adult rockfish were a relatively minor component of the diet during that period, the abundance of squid for several years was novel and predation on some prey items potentially substantial (Field et al. 2013).

## 2.6 Data sources evaluated, but not used in the assessment

### Commercial Trawl Logbook Index

Ralston et al. (1998) noted that the previous assessment did not use the logbook data because chilipepper rockfish were not identified to species in the logbooks. Ralston et al. attempted to filter the data in a way that better represented catch rates of chilipepper. Specifically, they identified statistical blocks where most chilipepper rockfish were reported as caught, linking logbooks to port sample data by vessel and date. A subset of blocks, primarily between Monterey and Fort Bragg, was used for the analysis. The data were further subset to include only positive “rockfish” tows, and a linear model was fit to log-transformed catch rates (lbs./hour) of “rockfish” landed predominantly in the chilipepper/bocaccio rockfish market category. The proportion of total rockfish catch that was not either widow or splitnose was then assumed to represent the proportion of chilipepper rockfish, and estimated on a year and port basis. Finally, the model-based “rockfish” index was multiplied by these proportions to create the final index. Ralston et al. noted that the resulting “chilipepper” index declined more slowly than the “rockfish” index, because the importance (i.e., assumed proportion) of chilipepper in the catch increased over time. They found the precision of the index to be surprisingly high (CV=4%), and it was decided to adjust the CV upward to 10% for all years, although this was admittedly an ad-hoc adjustment. While the declining trend in the

index is qualitatively consistent with trends estimated from other data sources in the base model (Figure 42), the STAT chose to exclude the trawl logbook index due to the availability of long time series of fishery-independent data now available, and the strong assumptions made about species composition in the original index.

#### **Central California Onboard CPFV Observer Index, 1987-1998**

The CDFW (formerly CDFG) Central California Marine Sport Fish Project sampled the Northern and Central California CPFV fleet using onboard observers from 1987-1998. Observers recorded the total catch (kept and released fish) of a subset of anglers during each fishing drift. Catches from drifts occurring at a single CDFW fishing site were aggregated into a “fishing stop.” Each stop in the database is associated with the closest reef structure. Retained fish were measured at the end of the fishing day. Additional details about the survey design, data collected, spatial associations between fishing stops and reef habitat, and the structure of the relational database are described by Monk et al. (2016). This index is often referred to as the “Deb-Wilson Vandenberg” or simply “DWV” index.

As noted by Monk et al. (2016), samples in 1987 were only collected in Santa Cruz and Monterey counties, so this year is often excluded from the index. Further examination of the data revealed that over 90% of chilipepper observed were caught in less than 1% of the fishing stops, consistent with a species that is infrequently targeted by the recreational fleet. The index, as included in the previous assessment, is shown in Figure 43.

#### **CDFW Onboard CPFV Observer Index, 1999-2024**

A database of California onboard CPFV observer data now spanning the years 1999-2024 is described by Monk et al. (2014). Due to large-scale spatial closures over multiple decades, an index based on these data was not developed for chilipepper. The STAT recommends that future assessments revisit this data set if recreational anglers have continued access to depths in which chilipepper rockfish are more commonly encountered.

#### **MRFSS Dockside CPFV Index, 1980-1999**

Trip-level catch rate data (“Type 3 data”) from MRFSS dockside sampling of CPFVs were downloaded from the NMFS SWFSC. These data are derived from fish sampled in angler bags following completion of a trip, and were aggregated to the trip level using an algorithm developed by Braden Soper (University of California, Santa Cruz).

#### **NWFSC Southern California Shelf Rockfish Hook and Line Survey**

Age structures (40/year) from this survey were read to help inform analysis of spatial patterns in growth. As the survey represents only the southern portion of the stock, we did not use lengths or develop an index of abundance, as regional trends may introduce bias in a model for the coastwide stock. This data source should be considered for construction of an index and/or use of length information if a spatially-explicit model is developed for chilipepper, or if the survey expands to cover a greater portion of the population range.

### **3 Assessment Model**

### 3.1 History of Modeling Approaches Used for this Stock

The first assessment for chilipepper was developed by Henry (1985) using a cohort analysis, however this assessment did not result in a clear picture of stock status and was not used to inform management. The stock was re-assessed the following year (Henry 1986), using an age-structured deterministic population model to estimate MSY and equilibrium yields for two alternative models. The data used in that model included total catch (modeled as a single fishery), age and length data (from a relatively short time period), and triennial survey abundance point estimates from 1977- 1983. The results indicated that the stock was moderately exploited, with “good recent recruitment and the absence of apparent biological stress.” The author recommended an ABC of 3563 mt, set at the midpoint of two alternative estimates (the ABC was ultimately set by the PFMC at 3,600 mt). Note that “ABC” at the time was equivalent to what is known as the “OFL.”

Subsequently, Rogers and Bence (1993) conducted a length-based assessment using stock synthesis (Methot 1990) for which the modeled time period began in 1980. Their model included a triennial trawl survey index and a recreational CPUE index, as well as age and length data from commercial fisheries, and assuming estimates of natural mortality rate that ranged from 0.15 to 0.20. Rather than present a single base model, the authors provided a set of three models, in which the 1992 biomass ranged from 40,000 to 87,000 mt, and the equilibrium yield (based on the then proxy for FMSY of F35%) ranged from 3,941 to 6,729 mt. Their general conclusions were that the existing ABC of 3600 mt was sufficient to protect the fishery at the F<sub>35%</sub> level, and that raising the ABC above this level could be “somewhat optimistic.”

Ralston et al. (1998) provided the next assessment of chilipepper, using the stock synthesis age-structured model (Methot 2000) to estimate abundance for the combined Eureka, Monterey, and Conception INPFC areas. The initial year for the 1998 model was 1970, but the model assumed a starting biomass below the unfished equilibrium level, using estimated landings from 1960-69 to generate an initial equilibrium population in 1970. The 1998 model also did not include a stock-recruit relationship. Natural mortality rates were estimated to be 0.22 for females and 0.25 for males. The model assumed four distinct fisheries (trawl, hook-and-line, setnet and recreational), and included a CPUE index derived from the California commercial trawl logbook database, an index of abundance from the triennial trawl survey, and a time series of pelagic juvenile abundance. The 1998 assessment discussed apparently significant changes in mean size at age, which were raised as an important research question, but ultimately applied an approach utilizing time-varying selectivity to fit the length composition data. The 1998 assessment estimated an unfished spawning biomass of 58,500 mt, a 1997 biomass above target levels, and indicated that the exploitation rate had been below the target fishing mortality rate since 1993. Key sources of uncertainty included tension between the two key indices (the trawl logbook index and the triennial trawl survey indices), uncertainty in population projections due to high recruitment variability, and challenges associated with discerning changes in selectivity from changes in growth and size at age.

The 2007 stock assessment (Field 2008) was developed in Stock Synthesis II (SS2), the precursor to SS3, and included a newly developed catch reconstruction, with the catch history extended back to 1892. Fleet structure was identical to the previous Ralston et al. model, with commercial trawl, hook and line and setnet fleets, along with a recreational fleet. The 2007 model also included the trawl fishery CPUE index used in the 1998 assessment, along with a recreational fishery index based on CPFV observer data (1987-1998), the triennial trawl survey (1980-2004), the (then) newly initiated West Coast Groundfish Bottom Trawl Survey (WCGBTS), and an index of age 0 abundance from the Rockfish Recruitment and Ecosystem Assessment Survey. The model was well informed by age data from commercial fisheries, but with more limited survey age data, and all age data were treated as marginal age compositions, rather than conditional-age-at-length data. Steepness in the 2007 model was fixed at 0.57 based on the updated Dorn prior (Dorn 2002), natural mortality was fixed at 0.16 for females, 0.20 for males, and selectivity curves

were based on logistic curves for the trawl fishery, the hook and line fishery, and the two surveys, while the double-normal selectivity curve was used for both the setnet and recreational fisheries. Time varying growth was estimated internally in the model, implemented with time block offsets for the growth coefficient,  $K$ , using time period blocks that were informed by major shifts in the signal for the Pacific Decadal Oscillation.

The 2007 assessment estimated that exploitation rates had been high and spawning biomass had declined sharply through the late 1980s and 1990s, to roughly 26-29% of the unfished level between 1995 and 1999. However, sharp reductions in fishing mortality also began in the late 1990s, in response to rebuilding requirements for co-occurring species such as bocaccio and canary rockfish. These occurred in combination with an extremely strong recruitment event in 1999, a year in which most West Coast groundfish experienced strong recruitment (for chilipepper this remains the strongest estimated recruitment event for this population). This resulted in a rapid increase in abundance and spawning output, such that the 2007 estimate of relative spawning output (“depletion”) was 71% of the estimated unfished level. The model estimated an MSY proxy (harvest associated with an SPR of 50%) of 2099 tons.

The 2015 assessment update (Field et al. 2015) used an updated version of the Stock Synthesis model, updated historical catch estimates, updated maturity and fecundity relationships, and additional years of data for all fisheries and ongoing surveys. Most of these additions or changes resulted in only minor changes to model assumptions or fits, and model results were generally consistent with the 2007 assessment. However, concerns were raised regarding how time-varying growth was modeled in that assessment, based on the observation that when additional time blocks were added for growth variability in the recent time period, the model estimated unusually low growth rates. This raised concerns regarding the robustness of catch projections if growth was mis-parameterized. Ultimately the final model simply extended the duration of the terminal time block from the 2007 model to resolve this challenge, resulting in a terminal growth estimate slightly above the long term mean. The fact that marginal age contributions were used (rather than conditional age at length), coupled with the greater availability of age data for small individuals from fisheries independent surveys (which were limited in previous assessments), were likely contributing factors to these challenges. The update estimated a depletion in 2015 of 67%, and an equilibrium MSY from the SPR 50% proxy of 2115 metric tons.

Subsequent to the 2015 assessment update, errors were discovered to have taken place in the historical catch reconstruction. Consequently, in 2017 there was an additional “catch-only” update, in which only historical catches were updated. The revised historical (pre-1968) catches were reduced by about 18,550 mt, representing 30 percent of the total previously used for the period 1916-1968, leaving 44,194 mt of catches during that period. The resulting OFL estimates from the 2017 model were slightly greater than the corresponding estimates from the 2015 model, primarily because recent catches were less than previously assumed. Another catch only update was conducted in 2023 (Wetzel 2023) to update OFL and ACL values for upcoming management cycles.

The reported units of spawning output changed across assessments, but a comparison of age 1+ biomass (Figure 44) is possible going back to the assessment of Ralston et al. (1998).

### **3.2 Response to STAR Panel Recommendations from Previous Assessment**

The STAR Panel report from the 2007 chilipepper rockfish assessment had the following recommendations for future research and data collection.

The following were recommended for the next assessment:

- Reconstruct the chilipepper rockfish catch history using all available data including catch by gear and by region. The reconstruction should include an envelope of high and low values to set bounds for exploration of alternative catch histories. The Panel notes that the SWFSC has made significant progress in retrieving detailed historical landings data, which will facilitate catch reconstructions. As has been recommended previously by a variety of STAR Panels, the reconstruction of historical rockfish landings needs to be done comprehensively across all rockfish species to ensure efficiency and consistency.

STAT response: Historical catch reconstructions were specified as a Council priority shortly after the 2007 assessment, and revisions to the historical catch were made in later update assessments.

- Read chilipepper rockfish otoliths from the triennial and combination bottom trawl surveys to provide better data on the early stages of growth and possible time-variations in growth

STAT response: Only one year of chilipepper ages from the triennial survey, made available using FT-NIRS technology. Traditional (break-and-burn) ages are now available for most years from the WCGTBS (aka “combination” bottom trawl survey).

- Explore use of conditional age-at-length data rather than coupled age- and length-composition data

STAT response: Completed in the new assessment.

- Explore time-varying growth as influenced by environmental changes

STAT response: This was evaluated in later updates, but linkages to the PDO were unclear. An analysis of time-varying growth has been included as Appendix A of this assessment, but further research is needed regarding environmental drivers of time-varying growth.

- Explore possible spatial structuring of the data and model

STAT response: Although genetic analyses are lacking for chilipepper, there is no strong evidence of spatial differences in growth (see Appendix A). The data in the current assessment were partitioned into “fleets as areas” to account for spatial differences in selectivity.

- The next STAT should have full access to raw data from the NWFSC trawl survey

STAT response: No longer an issue.

Recommendations in 2007 “for the longer term” included:

- Age-validation of chilipepper rockfish should be pursued

STAT response: This recommendation is still outstanding, and the STAT also recommends this be done.

- Develop a fishery-independent time series using fixed sites and volunteer anglers who use standard protocols and are properly supervised

STAT response: This now exists south of Point Conception, but sampling does not extend into the central part of the chilipepper range. Other hook and line surveys have greater latitudinal coverage, but only sample nearshore waters not occupied by chilipepper rockfish.

- Establish a meta-database that provides a comprehensive overview of all relevant data sources and sufficient information to correctly interpret the data

STAT response: This has not been completed and will require coordination among several Federal and state agencies. The STAT also supports this recommendation.

- Establish an accessible database for rockfish catch histories by species, including envelopes of high and low values for each species to set bounds for exploration of alternative catch histories

STAT response: Significant progress has been made on historical catch reconstructions, except for recommended ‘envelopes’ of uncertainty.

- Relevant raw data, updated in a timely manner, should be readily accessible to assessment authors in on-line databases that are user-friendly

STAT response: Significant progress has been made, largely due to the efforts of PacFIN and RecFIN staff at the PSMFC.

- Develop comprehensive descriptive analyses of recreational fisheries and fleets to assist in interpretation of recreational CPUE and length-composition data

STAT response: Per the 2015 stock assessment recommendation, this assessment includes refinements to the structure of recreational fleets (e.g., separation of fleets north/south of Point Conception), length compositions dating back to 1975, and limited CAAL data from recent CDFW sampling efforts.

- Develop a concise set of documents that provide details of common data sources and methods used for analyzing the data to derive assessment model inputs

STAT response: Progress has been made on this request (e.g., metadata for databases, use of standardized R code), although additional documentation would be useful.

### **3.3 Model Structure and Assumptions**

#### **3.3.1 Key Base Model Changes from the Last Assessment**

- Beverton-Holt steepness parameter fixed at 0.72 versus 0.57
- Female and male natural mortality estimated versus fixed
- Revised priors for natural mortality and steepness
- Use of conditional age-at-length compositions rather than marginal age composition data
- Use of the CalCOFI ichthyoplankton survey data as an index of spawning output
- Growth rates (length at age) assumed to be constant, but are still estimated within the model
- Removal of fishery-dependent indices of abundance (trawl logbook and recreational indices)



- “Fleets as areas” approach for commercial hook & line fleets, recreational fishery, separation of California trawl and Oregon commercial fleets
- Included bycatch from the at-sea hake fishery
- Addition of trawl discard fleet to account for size differences in retained vs. discarded fish
- Revised fecundity-at-length relationship, with adjustments to account for size-dependent multiple brooding in chilipepper
- Revised weight-at-length relationship
- Applied recruitment bias adjustment following Methot and Taylor (2011) to reduce bias in estimate of initial biomass
- Increase in maximum age and length bins (“plus groups”)
- Updated ageing error matrices

### 3.3.2 Modeling Platform and Structure

The assessment is structured as a single, sex-disaggregated population model, spanning U.S. waters between the U.S./Mexico border to the U.S./Canada border. The model operates on an annual time step covering the period 1875 to 2024 (not including forecast years) and assumes an unfished equilibrium population prior to 1875. Population dynamics are modeled for ages 0 through 35, with age-35 being the accumulator age (‘plus group’). The maximum observed age was 34 for males and 39 for females. Population bins were set every 1 cm from 7 to 60 cm, and data bins were set every 2 cm from 8 to 60 cm. The model is conditioned on catch from two sectors (commercial and recreational) divided among eight fishing fleets, and is informed by three fishery-independent time series of relative abundance (two successive trawl surveys and an index of spawning output) and a fishery-independent index of age-0 recruitment. Size and age composition data include lengths from 1975-2024 and ages from 1978-2024, with intermittent gaps in each data type. Recruitment is assumed to be related to spawning output via the Beverton-Holt stock recruitment relationship with log-normally distributed, bias corrected process error. Growth was modeled across a range of ages from 0 through 35. All catches were assumed to be known with high precision (log-scale standard error of 0.05).

Fleets were specified for recreational and commercial sectors. While the previous assessment combined all recreational fishing modes and catch types (retained or discarded) into a single fleet, we split the recreational sector into two main fleets according to area fished (north or south of Point Conception, CA). All recreational modes were combined, and discarded recreational catch was added to landings. The commercial sector was represented by six fleets. Two commercial hook-and-line fleets were differentiated by area fished (north or south of Point Conception). The primary commercial fleet in terms of total removals is a California trawl fleet, modeled separate from a smaller, combined-gear, commercial fleet representing catch north of California (primarily in Oregon). Fleet selectivity was allowed to vary over time, mainly in response to large spatial closures around the turn of the century. Sensitivity to these selectivity assumptions were explored during model development and relative to the base model.

Age and length composition sample sizes were then tuned in the base assessment model using the Francis weighting method (Francis 2011). Weights were applied iteratively for each method until absolute changes in the multiplier were  $<0.01$  for all fleets. Variance adjustments were capped at a value of 1 for conditional age-at-length data, as these represent individual fish ages. Variance adjustments were allowed to exceed 1 for marginal length composition data, as length compositions had been down-weighted to partially account for misspecification of the multinomial distribution.

Data source weights (or emphasis factors) can also be specified in Stock Synthesis (i.e., “lambdas”). In this assessment, there was no clear reason to down-weight (or up-weight) data sources relative to each

other (apart from the application of Francis weights to the composition data and additive variances to some indices), so all likelihood components were assumed to have equal emphasis ( $\lambda=1$ ) in the base case model. Some data sources that were considered during model explorations, but ultimately rejected, were retained in the Stock Synthesis input data file and excluded from the likelihood by setting  $\lambda=0$  in the control file (i.e., the commercial trawl logbook index and the recreational onboard observer index). This allows the STAT to observe the implied fit to the data source without having it affect the estimation process.

A prior distribution was specified for male and female natural mortality following a meta-analytic approach (see section 2.4.1 for more details). A lognormal prior for natural mortality was applied when estimating female natural mortality (mean = -1.86895, standard deviation = 0.31), and male natural mortality was modeled as an exponential offset with no explicit prior. A beta prior (mean=0.72, SD=0.16) was applied when estimating steepness of the Beverton-Holt stock recruitment curve. The steepness prior was originally developed from a west coast groundfish meta-analysis (Dorn 2002), has been periodically updated, and is provided by the PFMCC SSC in each management cycle. In the base model, natural mortality parameters are estimated for both females and males (exponential offset from females), and steepness is fixed at the prior mean of 0.72.

This assessment used a recent version of Stock Synthesis 3 (version 3.30.23.1, optimized). The basic population dynamic equations used in Stock Synthesis 3 can be found in Methot and Wetzel (2013). The R package “r4ss” (Taylor et al. 2021) was used to visualize model output and greatly assisted with model development and evaluation.

### 3.3.3 Model Parameters

The population dynamics model has many parameters, some estimated using the available data and some fixed at values from external analyses and/or the available literature. Estimated and fixed parameter values in the base model, excluding recruitment deviations, are listed in Table 9 and Table 10. A total of 106 parameters were estimated in the base model, including 57 recruitment deviations and twelve forecast deviations.

Natural mortality was estimated for females and informed by a prior distribution, and estimated for males as an exponential offset with no prior (see section 2.4.1). The pre-STAR base model fixes the Beverton-Holt steepness parameter at 0.72, the mean of the prior distribution. Initial (equilibrium) recruitment was also estimated. Recruitment deviations from the stock-recruitment relationship were estimated in the base model from 1968 – 2024. Recruitment variation about the stock recruitment curve was fixed at 1.0, a value tuned to the estimated recruitment deviation RMSE plus a slight adjustment upward to account for unmeasured process error.

Time-invariant growth parameters were estimated for each sex (Brody growth coefficient ( $k$ ), lengths at age 20, and the CVs of length at age 0 and age 20) using the Schnute parameterization (Schnute 1981) of the von Bertalanffy growth function, where males were estimated as an exponential offset of female parameters. Length at age 0 for both sexes was fixed at 7.3 cm based on observations of settled YOY chilipepper rockfish around the month of July (see Appendix A for more details). The CV of the distribution of length-at-age,  $CV(L(a))$ , in the base model is defined by a linear interpolation between the lower and upper ages specified in the Schnute parameterization of von Bertalanffy growth. Weight at length parameters were fixed at values externally estimated from WCGTBS observations.

Selectivity for all fishing fleets was specified by variations of a 6-parameter “double-normal” function form in SS3. This form allows for logistic-like shapes, ‘domed’ shapes, and many other variations, but in all cases some of the 6 parameters were fixed or bypassed by options available in SS3. Time blocks were

included in the model to allow changes in selectivity when major regulatory changes occurred. These include a change in 1991 due to the sort requirement for bocaccio rockfish, a change in 2001 to account for establishment of the Cowcod Conservation Areas in Southern California, and a change in 2000 representing the overfished declaration for bocaccio rockfish. Regulations pertaining to bocaccio rockfish also affect chilipepper, as the two species are frequently caught together.

An additive variance parameter was estimated for the CalCOFI index. Fecundity has been shown to vary in time (Beyer et al. 2015), introducing additional uncertainty into an index designed to track parental biomass via spawning output. The RREAS index tracks cohort strength of pelagic juvenile rockfish, but realized recruitment to the adult population may still be affected by post-settlement, density dependent mortality. The additive variance parameter for this survey was fixed at 0.683, calculated from the input sigma-r value (1.0) minus the mean of annual input observation errors from the standardized index.

### **3.3.4 Key Assumptions and Structural Choices**

Major structural assumptions included fixing the steepness stock recruitment parameter and estimating sex-specific natural mortality parameters, but assuming sex-invariant selectivity parameters. This favors the hypothesis that higher natural mortality for males explains the skewed sex ratio at older ages in the catch. An alternative hypothesis is that males become less available to the fishing gear. The base model estimates male natural mortality as an offset to female natural mortality with no prior, as joint priors for female and male natural mortality parameters are not currently available (either directly estimated or as an offset). Due to the use of discard “fleets” rather than estimated retention curves, it was not possible to model the interaction between discarded catch and retained catch as a result of regulatory changes or time blocks on discard size compositions. However, discards make up a relatively small fraction of total removals for this species, and the discard length composition data seems to provide good information about the long-term average size of discarded catch, at least since the beginning of the trawl IFQ fishery. An advantage of including discard length compositions (rather than simply adding discarded catch to landings), is retaining potential information about recruitment given the smaller average size of discarded catch.

All age data in the model were entered using the conditional-age-at-length (CAAL) format. For each fleet, year, and sex, the proportion of observed ages in each length data bin are entered, improving estimation of growth and reducing correlations associated with fitting to both marginal lengths and marginal ages from the same fish.

### **3.3.5 Bridging Analysis**

The last benchmark assessment for chilipepper rockfish was almost 20 years ago. The PFMC terms of reference for update assessment requires that updates retain similar model structures to the last benchmark. As a result, many aspects of the previous model have changed (see partial list in section 3.3.1). In addition, most data sets were completely re-analyzed, and time series of existing data were extended through 2024 whenever possible.

For those reasons, complete tracking of changes since the last assessment is not practical. As described in the sensitivities section, changes in the Beverton-Holt steepness parameter and the estimated rates of natural mortality are not sufficient to account for estimated changes in population dynamics. Some factors can be ruled out. For example, estimated catches have remained very similar since the 2017 catch-only update assessment, and should therefore not significantly affect population dynamics or scale (Figure 5). Revised methods for estimation of the WCG BTS have changed the magnitude of relative biomass

estimates in early years of the index (Figure 21). Bias-correction to ensure mean-unbiased biomass estimates has become standard practice, following the method of Methot and Taylor (2011). The previous benchmark pre-dated that study, as a result all subsequent updates do not include a bias correction term in the likelihood. The choice of whether recruitment deviations should sum to zero (as they did in previous assessments) can also have an effect.

To compare patterns in scale and trend between the current base model and the 2017 catch-only update, we modified the pre-STAR base model to match the 2017 values of steepness, natural mortality (sex-dependent), weight-length, fecundity, recruitment configuration (devs sum to zero, no bias ramp), no CalCOFI index, fitting to fishery-dependent indices, and removing data after 2016. Despite having completely different likelihood weights (lambdas), fleet structure, marginal vs. conditional age-at-length compositions, revised fishery-independent indices, input variance adjustments, etc., the two models are very similar in scale and trend (Figure 45).

### 3.4 Base Model Results

#### 3.4.1 Parameter Estimates

A total of 106 parameters were estimated in the model, 57 of which were recruitment parameters, 27 were selectivity parameters, and 12 of which were forecast deviations. Model parameters were evaluated for stability and precision along likelihood profile gradients, by ensuring that no model parameters were up against a lower or upper bound, and had sufficiently low gradients (Table 9, Table 10). Parameter precision was also monitored by looking at asymptotic standard deviations to assess the variability associated with point estimates.

Estimates of length at age from the model (Figure 46) are consistent with external fits (Appendix A). The CV of length at age zero for females was typical (~10%) but variability in length at age 20 was best fit by a smaller value of roughly 4%. Male CVs of length at age were larger than their female counterparts, and the offset for the male CV at age 20 was poorly estimated (large SE) and ultimately fixed. The point estimate of natural mortality for females ( $M_{\text{female}} = 0.165 \text{ yr}^{-1}$ ) was generally consistent with both the prior distribution and fixed values used in previous stock assessments. Natural mortality for males was estimated as an exponential offset parameter (0.266), producing an estimate of male  $M = 0.216 \text{ yr}^{-1}$  (also like fixed values used in previous assessments).

Parameters of the Beverton-Holt stock recruitment relationship (Figure 47) included steepness (fixed at the prior mean of 0.72), estimated log-scale unfished recruitment ( $\log R_0 = 10.032$ ), and variability in recruitment deviations (Figure 48) was iteratively tuned to a value of 1.0, slightly larger than the standard deviation of the estimated log-scale recruitment deviations. Recruitment deviations were forced to sum to zero. The method of Methot and Taylor (2011) was used to estimate annual variation in bias correction factor (Figure 49).

Selectivity curves estimates for most fleets were asymptotic in the terminal year, with the exception of the trawl discard 'fleet' and the recreational fleet in Southern California (Figure 50). Fleets with time-blocked selectivity were often best fit by asymptotic curves in the early time periods and/or estimates of selectivity at large sizes were imprecise and fixed (Figure 51, Figure 52, Figure 53, Figure 54). Selectivity for the two trawl surveys were unstable, switching between domed shapes and asymptotic shapes that only excluded very small fish. The STAT found that simple selectivity curves based on a minimum length or age fit these data almost as well as more complicated functional forms, and had the advantage of being stable across a range of other parameter values. This assumption was tested during the STAR panel and

remained unchanged in the final base model. Selectivity for the CalCOFI index is tied to spawning output via the fecundity relationship, and the RREAS recruitment survey is configured to select only age-0 fish.

### **3.4.2 Fits to the Data**

Residuals to length composition and age composition fits to the model were explored during model development. In addition to information about regulatory changes, the identification of residual patterns helped to sort out which set of a priori selectivity time blocks were the most appropriate given the data. Alternative model configurations were also explored during model development to minimize residual trends.

Fits from the base model to time-aggregated length compositions, by fleet, show that the model can reproduce differences in observed lengths between sexes in most fleets (Figure 55). Fits to the sex-specific lengths from the California trawl fleet, the primary source of landings, are generally good, except for large positive residuals associated with large, male fish in several years (Figure 56). It's unclear whether this is due to model misspecification or errors in the data. Evidence of strong cohorts is visible in several fleets. A particularly large residual is evident in the fit to WCGBTS lengths (Figure 57; again, associated with an excess of large males).

For each fleet with composition data, we compared observed mean lengths summarized from the length data to predicted mean lengths, and mean ages from the CAAL data to predicted mean age (Figure 58 through Figure 67). Model predictions for the California trawl fleet were generally good for length compositions, although the model predicted younger mean ages than were observed for the period 1980-2000. Alternative selectivity parameterizations explored during the STAR panel did not improve fits to mean ages (see research recommendations).

Fits to abundance indices (both arithmetic- and log-scale) are shown in Figure 68 through Figure 71. The model was not able to fit three years (2004, 2005, and 2007) from the early period of the WCGBTS, despite investigation by the STAT and during the STAR panel. Inclusion of a depth effect in the index standardization model improved fit to the index by >2 NLL points, but ultimately the lack of fit was left as a research recommendation. Fits to the RREAS survey were among the best in the model, suggesting that the index is informative for estimation of recent recruitment strength. However, estimates of recent recruitment should be viewed with caution until age and length information become available to verify the size of recent year classes.

Model predictions are plotted against time series of relative abundance from the trawl logbook index (Figure 72) and recreational onboard observer index (Figure 73) for reference only. The base model was not fit to either fishery-dependent indices, although model predictions are not inconsistent with general declining trends in both indices.

### **3.4.3 Population Trajectory**

The base model's estimates of spawning output over time (in billions of eggs) show declines associated with the development of the trawl fleet following World War II through the 1990s (Figure 74). Spawning output is estimated to have fallen below the MSST, if only briefly, around the year 2000 (Figure 75). Significant reductions in catch in subsequent years have likely led to increases in stock size, although estimated rates of population increase are uncertain and driven in part by the assumed value of steepness in the stock-recruitment relationship.

Estimates of recruitment deviations are largely consistent with previous stock assessments for chilipepper, with the largest cohorts being estimated in 1984, 1999, and 2013 (Figure 76). The current assessment also estimates an above-average recruitment in 2024 based in part on the influence of the RREAS index of age-0 chilipepper. On average, recruitment was below average in the 1990s and 2000s, with the notable exception of 1999. Several above-average cohorts are estimated to have entered the population between 2009 and 2015, followed by a few years of lower-than-average recruitment.

Chilipepper rockfish spawning output was estimated to be 9.9 trillion eggs in 2025 (~95% asymptotic interval: 6.3-13.6; Table 11), which equates to a “depletion” level of 83% (~95% asymptotic interval: 63%-104%) in 2025. Depletion is a ratio of the estimated spawning output in a particular year relative to estimated unfished, equilibrium spawning output. Long-term, sustainable yield based on the proxy MSY harvest rate (SPR 50%) is 2114 mt (~95% asymptotic interval: 1588-2639). Time series of spawning output and other relevant population quantities are in Table 12.

## 3.5 Model Diagnostics

### 3.5.1 Convergence

Model convergence was checked during development of a base model by ensuring that

- The final gradient of the likelihood surface was less than 0.0001 (see ‘-hess\_step’, below)
- Parameters were checked to ensure that they were not hitting a minimum or maximum bound
- A search for a better minimum was conducted using jittered starting values (“jitter fraction” in r4ss function “jitter” set = 0.2). A total of 100 jittered runs were performed for the base model.
- A model run using the “-hess\_step” option was compared to the base model
- The base model was run using the -phase N option, starting the optimization in the N-th phase

No parameter estimates were near the bounds (min or max), and the gradient of the base model was effectively zero after using the “-hess\_step” command-line option. A comparison of likelihoods, parameter estimates, and derived quantities showed that results based on the -hess\_step run were indistinguishable from the base. Across all 100 jittered runs, the model found no minima lower than the base case likelihood (2633.05). Starting the model from different optimization phases had no effect on the final likelihood (Table 13).

### 3.5.2 Likelihood Profiles

Likelihood profiles were performed across three major sources of uncertainty: natural mortality (M), initial recruitment (R0), and steepness (h). An individual profile was completed for each data type (e.g., lengths, ages, indices) and parameter combination to derive the relative importance of each data set to parameter estimation. In addition, profiles for each data set within a data type (i.e., a “Piner” plot) were produced for each of the three parameters listed above.

The profile over log(R0) from 9.5 to 10.75 showed better fits to age data overall at larger sizes, but a univariate profile interval of roughly 9.7 to 10.4 (Figure 77, Table 14). The WCGBTS composition data (ages and lengths) were better fit by smaller values of R0, although the index was better fit by larger values.

Total NLL for the profile over female natural mortality (with male natural mortality estimated as an offset), favored values roughly between 0.14 and 0.19. The WCGBTS index was better fit by larger

female M values, while other data sources were either uninformative or showed lack of fit for only high values of female M (Figure 78, Table 15).

The profile over Beverton-Holt steepness ( $h$ ), shows that total NLL is minimized near 0.4, but values between 0.3 and roughly 0.55 are within the 95% univariate confidence interval. Age data and indices seem to have improved fits at lower steepness values, while length data and recruitment deviations are more consistent with intermediate values, although length and recruitment contain little information overall for this parameter (Figure 79, Table 16, Table 17).

A bivariate likelihood profile over steepness and female natural mortality reveals that steepness is not well estimated by the model, given the data, and that the prior mean ( $h=0.72$ ) falls outside the 95% bivariate confidence interval (Figure 80). Female natural mortality, on the other hand, seems to be relatively well informed, with a value in the range of 0.15 to 0.2, and generally consistent with the prior. The STAT noted that the use of a sum-to-zero constraint on the recruitment deviations changed the bivariate likelihood profile, relative to the pre-STAR base that did not enforce the constraint. Without a sum-to-zero constraint, the model can shift the mean recruitment to better fit the data if the value of steepness is fixed at a value that is otherwise inconsistent with the data. As observed in Request #4 (Appendix B), this is less of an issue when steepness is estimated in the model.

### 3.5.3 Sensitivity Analyses

We evaluated sensitivity of the base model to several alternative model structures and data set configurations. These included:

- A ‘drop-one’ approach to identify the impact of various sets of information on model outputs. Data were removed by fleet (i.e., all composition and trend data associated with a particular fleet)
- Comparison of model outputs using alternative weighting methods (‘Francis’ and ‘McAllister-Ianelli’)
- Inclusion of fishery-dependent data sources used in the last assessment, but not in the 2025 base model, and increasing the emphasis (likelihood component multiplier, or ‘lambda’) of the WCG BTS and/or CalCOFI index.
- Comparison of the base model (time-invariant growth) to models with annual deviations in the von Bertalanffy ‘ $k$ ’ parameter, or an index for multiplicative deviations in  $k$  based on externally estimated annual deviations in chilipepper length at age (Appendix A).
- Comparison of the base model (with time-blocked selectivity in the trawl fleet) to models with constant trawl selectivity and a flexible, semi-parametric selectivity function that varies over time and size (Xu et al. 2019)
- Assuming natural mortality was the same for both sexes
- Estimation of steepness and natural mortality (male and female)

Additional sensitivity analyses were conducted during the STAR panel. See Appendix B for details.

#### *“Drop-one” analysis*

We evaluated the influence of data associated with each survey fleet on model estimates by removing all data types (indices, lengths, and ages), one fleet at a time. Figure 81 shows model outputs (time series of spawning output, depletion and recruitment) when data from each survey fleet were sequentially removed from the model. In the case of the triennial and WCG BT surveys, this included the associated compositional (age and length) data, although for the WCG BT we also evaluated the sensitivity of only

removing the index and leaving the compositional data in the model, given the challenges in fitting the index combined with the importance of the age composition data in particular for informing growth.

The greatest changes among these sequential data removals were observed with the removal of the CalCOFI, the triennial and the WCGBTS data (Table 18). The removal of any one of these three sources resulted in a more optimistic estimate of relative abundance in very recent years. Removing each of these surveys also resulted in a modest increase in the estimated unfished spawning output. For the run without CalCOFI data, this was associated with a generally more optimistic perception of relative stock status, with a similar (but more modest) result for the run without the triennial trawl survey data. For the runs without the WCGBTS data, the results from both runs were of a considerably more pessimistic estimation of both spawning output and relative abundance between approximately 1970 and 2020, with the greatest differences observed in the years between approximately 2005 and 2015. The key driver of these differences is that recruitments estimated in the model without the survey data were generally far lower than those that included the data, particularly the strength of the 1999 year class, which was less than half as strong in the model without WCGBTS data as the base model. This general pattern held until 2013, when that pattern reversed, and can likely be explained by the paucity of compositional data (particularly age data) during the period in which fisheries landings and catch statistics were sparse. During this period the WCGBTS age and length data were extremely important to estimating recruitment and population trends. Thus, the inclusion of the survey data was associated with a near doubling of the estimated relative spawning output between approximately 2005 and 2015, although differences were less extreme between approximately 2015 and 2025. In nearly all of these cases, the sensitivities suggested that both spawning output, depletion and recruitment were within the estimated uncertainty of the base model, the exception being the very low relative abundance estimated for the 2005-2015 time period when WCGBTS data were excluded.

With respect to changes in parameter estimates, most changes were relatively modest. The most significant change was a fairly substantial increase in the estimated female natural mortality rate (from 0.165 to 0.178) when CalCOFI data were removed, this rate also increased to 0.172 with the removal of the triennial trawl survey data and indices. By contrast, with the removal of the WCGBTS data the natural mortality rate dropped from 0.165 to 0.151 (when all data were removed), and interestingly dropped even more significantly (to 0.140) when only the index data were removed. This suggests that both the relative abundance data and the age compositional data from this survey are highly informative with respect to natural mortality, which should be expected given the robust amount of age data available during an extended period for which fishing mortality was minimal.

Due to the poor fit for several of the early years of the WCGBTS index (specifically 2004-2007), and given that the “leave one out” sensitivity analysis suggested that the more influential indices on model results and stock status were the WCGBTS and the CalCOFI index, we also ran models in which those indices were upweighted (lambdas set to 10 rather than 1), to evaluate whether this could significantly improve the fits to the index, and how that would influence the model result. For the scenario in which the WCGBTS index was upweighted, the resulting spawning output, relative abundance (depletion) and recruitment estimates scaled upwards considerably for most of the time series, particularly during the mid-2000s when several of the survey years were underfit by the base model. Interestingly, the fit to the index improves very slightly, but still barely grazes the lower error bars for the 2004-2005 and 2007 survey index estimates (the 2006 data point is well fit), despite the model estimating that the stock was nearly at the unfished level during this time period. This was also associated with an increase in the magnitude of the 1999 recruitment event, as well as a substantial increase in the model estimated natural mortality rate (0.218 rather than 0.165 for females). However, the terminal depletion estimate did not vary by more than a percentage point from that of the base model (91% of the unfished level in 2025, relative to 83% in the base model). By contrast, when the CalCOFI index is upweighted, the model result is somewhat more pessimistic, with a downward scaling of abundance and recruitment and a considerably



more pessimistic ending depletion value (61% of unfished, rather than 83%). The estimated natural mortality rate for females is considerably lower (0.13) in this scenario as well. In both of these scenarios, the model results are well outside of the base model uncertainty bounds for a large fraction of the modeled time period, although in all cases the terminal abundance estimate is well above target levels.

#### *Evaluation of alternative data-weighting methods*

The base model adjusts the input sample sizes of composition data following Francis (2011; method TA1.8) to reduce the effects of known problems with the use of a multinomial likelihood in this context (overdispersion and correlation). Since input sample sizes for marginal length compositions represent the number of trips, hauls, or port samples (rather than the number of fish measured), the STAT allowed the iterative tuning procedure to “upweight” sample sizes for length data. However, since the input sample sizes for CAAL data are numbers of fish, the maximum ‘weight’ was capped at one, i.e., the ‘tuned’ input sample size could not exceed the number of fish actually aged. This cap was used for CAAL data from the combined commercial fleets off Oregon and Washington, as well as the combined recreational fleets north of Point Conception. Length composition data was ‘upweighted’ for only one fleet: the commercial hook-and-line fishery south of Point Conception. McAllister and Ianelli (“M.I.”; 1997) suggested an alternative approach to addressing the issues of overdispersion and correlation. A comparison of data weights for composition data using these two methods is in Table 19. Likelihoods between these two sensitivity analyses are not comparable due to the use of different data weights, but parameter estimates and associated derived quantities are shown in Table 20. The M.I. approach had larger weights for the composition data, on average, with the notable exception of the WCGBTS age data, for which the M.I. weight was almost 1/20<sup>th</sup> of the weight based on the Francis method. The M.I. approach also ‘upweighted’ three length data sets, compared to only one being upweighted using the Francis approach, and down weighted the two age data sets that were capped at one using the Francis approach. Spawning output estimates based on M.I. weights were generally smaller, but with a similar trend to the base model (Figure 82). Punt (2017) found that the M.I. method was inferior to Francis (2011), so the latter was used to tune initial sample sizes in the base model.

#### *Effect of including fishery-dependent abundance indices and changing survey emphasis factors*

We also explored the sensitivity of the model to the inclusion of data sources used in the 2007 benchmark and 2015 update assessments, but not included in this model, specifically the trawl fishery CPUE index and the central/northern California recreational fishery CPUE index (Figure 83, Table 21). As in these earlier assessments, the inclusion of the trawl fishery CPUE index results in a more optimistic estimation of abundance and relative stock status, while the recreational fishery CPUE results in a more pessimistic estimation. These results were associated with slight increases in the estimated female natural mortality rate (when trawl cpue included) and decreases (when the rec fishery CPUE was included), although the change was relatively modest (approximately 0.01 increase and decrease, respectively). When the two are both included, the resulting estimates are slightly more pessimistic, but much closer to the base model than the sensitivity with the recreational index alone. In all of these sensitivities, the model estimates of spawning output and depletion are well within the uncertainty bounds of the base model.

#### *Time-varying growth analysis*

As described in section 4.3.1, the previous benchmark and update assessments for chilipepper rockfish estimated variation in growth (length-at-age) over time. For this assessment, an analysis of spatio-temporal variation in growth from 1978 to 2024 was conducted external to the model (Appendix A). To evaluate model sensitivity to alternative specifications of time-varying growth, we compared models with 1) annual deviations in the von Bertalanffy ‘*k*’ parameter, 2) constant *k*, as in the pre-STAR base model, and 3) deviations in *k* linked to a multiplicative index estimated externally (Appendix A). Use of the

index was intended to invoke a pattern of variability consistent with chilipepper biology in terms of both amplitude and frequency. The STAT notes that this third approach would use the length-at-age data twice, and would therefore not be considered as a base model. The intent of this sensitivity is to evaluate the impact of time-varying growth on the population dynamics of chilipepper. The model with annual deviations in  $k$  (1978-2024, a period informed by composition data) had a large gradient ( $\sim 0.1$ ), even after attempts to start from alternative initial values. We therefore used the `-hess_step` option, reducing the gradient to nearly zero within the local minimum. Comparing results from the models with freely estimated annual deviations in  $k$ , deviations driven by the analysis from Appendix A, and constant  $k$  revealed similar trends in spawning output, depletion, and recruitment (Figure 84, Figure 85). Associated likelihood values (all runs used the pre-STAR base model data-weights), estimated parameters, and select derived quantities are provided as Table 22. The STAT recommends further research into this topic for future assessments. Models evaluated here are relatively simple, and only account for variability in a single parameter, although correlations between growth parameters (e.g.,  $k$  and asymptotic maximum size) are well-known and worthy of consideration. Trends and/or autocorrelation in time-varying growth may also have greater impacts on population dynamics than those demonstrated in this sensitivity analysis. This analysis was not repeated for the final (post-STAR) base model, as the methodology required further development, as noted above.

#### *Selectivity parameterization for the trawl fleet*

We compared the pre-STAR base model (with time-blocked selectivity in the trawl fleet, changing around the year 2000) to models with constant trawl selectivity and a flexible, semi-parametric selectivity function that varies over time and size (Xu et al. 2019). The time-blocked selectivity (base) model reduced the total NLL by over 26 points with the addition of 2 parameters and had little effect on the model results (Table 23, Figure 86). The flexible, “2D” approach by Xu et al. increased the total NLL due to the additional “`Parm_dev`” likelihood component, but fits to the lengths were (not surprisingly) improved. This approach adds over 1300 parameters to the model, but was included as a sensitivity to evaluate how a very flexible selectivity parameterization would affect model results. Deviations from the underlying logistic curve suggest a shift in selectivity around 2000, when large spatial closures were taking effect (Figure 87). Ultimately, the STAT chose the time-blocked approach as it showed improved fits to the data with a relatively parsimonious parameterization.

#### *Assumptions about natural mortality parameterization and Beverton-Holt steepness*

If the final base model is changed to assume that natural mortality is the same for both females and males (“saving” one parameter), it increases natural mortality to 0.22 (to account for ‘missing’ males) and increases the NLL by over 25 points, mainly due to degraded fits to the composition data (Table 24). Population scale with sex-invariant  $M$  is increased, and current stock status is slightly less depleted (Figure 88). If steepness is estimated, along with sex-specific  $M$  parameters, the estimates of female and male  $M$  increase slightly (Table 24).

### **3.5.4 Retrospective Analysis**

A retrospective analysis was conducted by sequentially removing up to 5 years of data from the base model starting with 2024. Sequential removal of the data produced mild retrospective patterns, with each ‘peel’ (successive removal of a single years’ data) estimating a lower unfished spawning output and a slightly lower fraction of unfished spawning output in the end year, relative to the base model (Figure 89). Mohn’s  $\rho$  values were calculated using the `r4ss` function “`SSmohnsrho`” (Table 25).

### 3.6 Unresolved Problems and Major Uncertainties

- Likelihood profiles indicate that input data were informative for estimating natural mortality ( $M$ ) but not steepness ( $h$ ). The available data are only weakly informative about the steepness parameter ( $h$ ) of the assumed Beverton-Holt stock recruitment relationship, and model output is highly sensitive to this parameter. The base model fixes steepness at the mean of the prior probability distribution ( $h = 0.72$ ). When estimated, the parameter central tendency is much lower ( $h \sim 0.4$ , i.e., suggesting a less productive stock), despite the fact that the largest estimated recruitment (in 1999) occurred near the lowest biomass level.
- Skewed sex ratios observed in the catch may be caused by sex-specific natural mortality rates, sex-specific selectivity, or a combination of the two. The base model assumes that natural mortality rates vary by sex, and that selectivity is independent of sex.
- Future assessments would benefit from additional research into sources of chilipepper ageing error. The model's fit to the conditional age-at-length data displayed large, positive residuals for males at the upper edge of their size range in several year/fleet combinations. Large, positive residuals were also detected for females in some year/fleet combinations, with a greater-than-expected number of females that were older than expected, given their length. Sex-specific sizes and ages should be evaluated further (e.g., by revisiting original datasheets, examining otolith morphology, or reviewing archived biological samples) to resolve uncertainties about notable outliers
- Although results provided in an appendix to the stock assessment suggested the presence of time-varying growth, sensitivity analyses indicated minimal influences on model results. Thus, the model assumed that growth is time-invariant. Analyses of time-varying growth in the model were limited to variation in the parameter ' $k$ ' from the von Bertalanffy growth function. Temporal variation in  $L_\infty$  (potentially correlated with  $k$ ) may have a greater effect on model results.
- Model fit to the WCGTS index, particularly in the early part of the time series, warrants further investigation, including additional work on index standardization.
- Catchability ( $q$ ) estimates for trawl survey indices are counter-intuitive (i.e., near or greater than 1). Indices of abundance from these surveys are not used to inform absolute abundance, but additional research is needed to understand the scale implied by the model-based abundance estimates.
- Further evaluation is needed regarding the inclusion of a depth effect in the Triennial survey index, given that fits to the WCGTS were improved by inclusion of depth as a covariate.
- Historical catch reconstructions are subject to uncertainty stemming from issues with species identification and the spatiotemporal extent of data collection, highlighting the need for uncertainty estimates comparable to those used for model-based indices.
- There is uncertainty in mean productivity estimates when applying a sum-to-zero constraint on recruitment deviation, potentially due to inaccurate assumptions about the stock-recruitment relationship. See Appendix B, Requests #4 and #17 for additional details.
- Estimation of selectivity and associated time blocking remain difficult for this assessment.

## 4 Management

### 4.1 Reference Points

Chilipepper rockfish spawning output was estimated to be 9.9 trillion eggs in 2025 (~95% asymptotic interval: 6.3 – 13.6; Table 11), which equates to a “depletion” level of 83% (~95% asymptotic interval: 63%-104%) in 2025. Depletion is a ratio of the estimated spawning output in a particular year relative to

estimated unfished, equilibrium spawning output. Long-term, sustainable yield based on the proxy MSY harvest rate (SPR 50%; Figure 90) is 2114 mt (~95% asymptotic interval: 1588-2639).

## 4.2 Harvest Projections and Decision Tables

Harvest projections assuming GMT-specified catches in 2025-2026, and ABC=ACL catches from 2027 onward are in Table 26.

Alternative states of nature defined by three values of the Beverton-Holt steepness parameter ( $h$ ) were identified during the STAR panel, representing uncertainty that was not accounted for by the base model. A “low-productivity” alternative ( $h=0.38$ ) and “high-productivity” alternative ( $h=0.97$ ) are presented in addition to the base model ( $h=0.72$ ). Population dynamics were forecast 12 years ahead for each state of nature, assuming two different catch projections requested during the STAR panel (; see also Appendix B, Request 18). Catch projections for 2025-2026 and fleet allocations for 2027-2036 were provided for each area and fleet by representatives on the GMT. Yields associated with the Overfishing Limit (OFL), Acceptable Biological Catch (ABC), and the assumed buffer to account for scientific uncertainty in the ABC, are provided in Table 27. Since spawning output is estimated to be above the management target (40% of unfished), Annual Catch Limits (ACLs) are equal to the ABC. Projections assume a relatively strong 2024 year class (see the “Recruitment” section of the Executive Summary).

## 4.3 Evaluation of Scientific Uncertainty

For the base model, the reported ‘sigma’ (log-scale uncertainty around the OFL value for the first forecast year, i.e., 2025; Ralston et al. 2011) is 0.232, less than the proxy value for category 1 stocks (0.5).

### 4.3.1 Risk Table information for Chilipepper rockfish

Contributions from John Field, Isaac Schroeder, Elliott Hazen and Jarrod Santora

#### *Summary*

To identify and evaluate environmental drivers of chilipepper (*Sebastes goodei*) recruitment and productivity, we evaluated what is known about drivers at important life history stages. For chilipepper, a common thread is that adult growth and reproductive output, larval condition and growth, pelagic juvenile abundance, all appear to be greater during cool, high productivity ocean conditions, which are typically associated with a negative Pacific Decadal Oscillation (PDO) and/or positive North Pacific Gyre Oscillation (NPGO), and more specifically in many cases with a higher proportion of subarctic (“minty”) rather than subtropical (“spicy”) source waters occurring within the California Current Ecosystem. Further, euphausiid (krill) populations, an important prey for both pelagic juveniles and adult life history stages, are generally higher during these cooler environmental phases. Herein, we provide an overview of the suite of environmental relationships that have been documented or suggested for this stock, with a focus on source-water variability as a key factor associated with both reproductive output and early life history survival (and thus subsequent recruitment), and review environmental influences among a wide range of life history stages of chilipepper.

In brief, throughout 2024, summer and fall NPGO values were negative (indication of reduced southward transport), which would be consistent with poorer condition and lower reproductive output for chilipepper. However, for winter and spring of 2025, PDO values have been negative, and subsurface waters off of central California (35-37° N) have been among their “mintiest” (most subarctic) since 2015.

The “minty” conditions are consistent with a greater fraction of subarctic waters, which are consistent with both greater pelagic juvenile abundance and recruitment based on the current assessment model. Thus, there is consistent environmental information to support the above average 2024 recruitment estimate in the base model, and to indicate that above average recruitment is also likely for the 2025 year class.

### *Primer on source-water variability and ocean modeling*

Building on the work of Schroeder et al. (2019), which documented the relationship as well as potential mechanisms between winter source-water variability and observed spring pelagic juvenile young-of-the-year (YOY) rockfish abundance for ten species of winter-spawning rockfishes, the risk table for chilipepper makes extensive use of the ‘spiciness index’ to evaluate environmental drivers of recruitment. The logic is that subsurface ocean conditions are characterized by spiciness, which is a variable that describes how temperature and salinity change in a way that maintains water density and captures variability while density remains constant (Flament 2002). In this way, spiciness provides an indication of a water mass's origins, with cool/fresh “minty” spice values being indicative of subarctic conditions (Pacific Subarctic Upper Waters), and warmer, saltier “spicy” values representing waters of subtropical origin (Pacific Equatorial Waters). More subarctic, or “minty” waters also tend to be higher in dissolved oxygen at their origin, relative to Pacific equatorial waters.

For this risk table synthesis, an ocean modeling reanalysis product (which also assimilates historical observations) was used to evaluate connections between contemporary estimates of spiciness and chilipepper recruitment. For a consistent monthly, spatial and depth resolved dataset of ocean temperature and salinity, the Glorys Global Ocean Physics Reanalysis (GLORYS12V1 product; <https://doi.org/10.48670/moi-00021>) was used for spiciness indices. Although validation efforts related to GLORYS estimates of spiciness are ongoing, there is evidence that GLORYS does capture fine scale oceanographic features in the California Current Ecosystem (Amaya et al. 2023). For individual months, monthly values were spatially averaged over 35-37° N over an area 250 to 500 km offshore. Correlations between depth-derived spiciness (surface-300 m) per month (from January-June) were calculated to evaluate the potential of spiciness as an indicator of both empirical YOY chilipepper abundance as well as recruitment estimates and recruitment deviations from the current stock assessment.

### *Spawning output and larval productivity and dynamics*

Like all *Sebastes* spp., relative fecundity (the number of eggs or larvae produced per unit of female body weight or length) increases with female size and age, and both this length-based fecundity and the probability of producing a second brood (which is greater in larger, older fish) are accounted for within the base assessment model (Lefebvre et al. 2018). Total reproductive output (larval production) at any given size or age is variable from year to year, and that bioenergetic trade-offs resulting from variable ocean conditions are key factors in year-to-year changes in reproductive investment (Harvey et al. 2011). Schroeder et al. (2019) hypothesized that in addition to being associated with more favorable recruitment conditions for late larval and early juvenile life history stages, source waters with subarctic origins could also influence reproduction of adult rockfish at depth of their habitats, consistent with the results of Beyer et al. (2024).

Beyer et al. (2024) report on interannual variability in the reproductive output of four species of rockfish, including chilipepper, spanning between the mid-1980s and 2019. Results suggest that both oceanographic conditions and female condition influenced the year-specific estimate of the slope parameter for the length-fecundity relationship, indicating larger fish with greater energetic reserves had disproportionately greater larval production, particularly when ocean conditions were cooler and more productive, with a greater proportion of subarctic source waters (Positive NPGO) during August-October,

prior to the spawning season (January-March). Total brood size declined from 30 to 51% during low fecundity years relative to the high fecundity years, a significant range but also a lower range than the single brooding species (yellowtail and widow rockfish). This suggests that the probability of producing a second (or more) brood is part of the means by which the multiple brooding species vary their reproductive output in response to environmental and bioenergetic dynamics (Lefebvre et al. 2018, Beyer et al. 2021). In short, these results also provide strong evidence for environmental and bioenergetic drivers of interannual variability in reproductive output (e.g., total larval production by spawning females). In the short term, these analyses would suggest that all else equal, larval production is likely to be lower than expected based on population abundance and demographics alone for the current (2025) brood year. However, the weak relationship between larval production and year class strength would suggest that factors associated with greater early life history survival and subsequent pelagic YOY abundance may be more important than those associated with reproductive output.

In addition to larval production, larval condition (generally inferred by larval size or otolith core width at parturition) can influence early survival and subsequent year class strength. Both maternal and environmental influences on larval condition are documented in rockfishes, although most research has focused on nearshore species. In one study, a maternal influence on oil globule volume for chilipepper was noted (Stafford et al. 2014), although the relationship was not statistically significant. A more recent study of pelagic larvae from CalCOFI collections evaluated spatial and temporal variability in otolith core width at extrusion (parturition), and found evidence of both maternal and environmental conditions on larval chilipepper condition, which were in turn related to early larval rockfish growth rate and survival (Fennie et al. 2024). Essentially, larval chilipepper rockfish growth rate during winter was related to source water variability within southern California the previous fall. Ongoing efforts are expanding these investigations to more rigorously compare larval and pelagic juvenile YOY otolith core widths and the extent to which these proxies for larval condition relate to both oceanographic conditions and subsequent estimates of recruitment from both the RREAS and the stock assessment recruitment estimates.

### *Juvenile growth, survival and recruitment dynamics*

Similar to the recent published work on larval otolith growth and survival rates (Fennie et al. 2024), otolith microstructure analyses are ongoing to quantify otolith width at birth, late larval and pelagic juvenile growth rates, and age to support development of year-specific YOY growth models. Integrating these metrics with environmental variables can enhance our understanding of mechanisms through which ocean conditions shape year-class strength. Similarly, quantifying variability in birthdate distributions of pelagic juveniles has confirmed substantial interannual variability in the timing of successful recruitment, such that greater pelagic juvenile abundance is associated with greater survival of individuals that undergo parturition earlier in the spawning season (Ralston et al. 2013).

An index of pelagic juvenile (young-of-the-year, YOY) chilipepper rockfish, derived from the RREAS data are included in the stock assessment, and suggest strong recruitment in 2024 (reflected in the base model). This year class strength might have otherwise been underpredicted if inferred by environmental conditions alone, given the near average spiciness values observed in Spring of 2024 (Schroeder et al. 2019, unpublished data). However, for winter and spring of 2025, PDO values have been negative, and subsurface (roughly 150-250 meters depth) offshore waters off of central California (35-37° N) have been among their “mintiest” (most subarctic) since 2015. As described above, spiciness gives an indication of a water mass's origins, with cool/fresh “minty” spice values indicative of subarctic conditions, and hot/salty “spicy” values of equatorial origin. The “minty” conditions are consistent with greater pelagic juvenile abundance of chilipepper and other winter-spawning rockfishes (Schroeder et al. 2019; Santora et al. 2021). In an evaluation of this index of spiciness with both the recruitment estimates and recruitment deviations estimated in this assessment for the 1993-2024 time period, there is also a strong correlation (Spearman rho=-0.71 to recruitment, -0.70 to recruitment deviations,  $p<0.01$ ), which would indicate that

the 2025 year class should be expected to be well above average (Figure 91, Figure 92). Interestingly, ocean conditions further north (e.g., north of Cape Mendocino) have been closer to long-term average levels, suggesting that oceanographic conditions may be less favorable for the northern stocks previously evaluated with respect to pelagic YOY indices (Schroeder et al. 2019), such as widow and yellowtail rockfish.

In addition to the species-specific index of YOY, a recent coastwide analysis of the pelagic groundfish community assemblage structure (Gasbarro et al. 2025) found that years of high productivity were associated with both high estimates of diversity, as well as different pelagic YOY assemblages relative to those seen predominantly in years of low productivity (Santora et al. 2021). Although Gasbarro et al. (2025) used data through 1990-2023, the analysis was updated using 2024 survey data, and the results suggest that in 2024 the abundance and diversity of groundfish was higher than it had been since the peak abundance levels of 2015 (Santora et al. 2017), and that this high abundance was associated with greater species richness and diversity throughout the range of the survey. Based on preliminary data from the RREAS 2025 survey, catch rates of pelagic juvenile chilipepper, as well as many groundfish species more generally, have been higher than the long-term average. This is consistent with the very “minty” (subarctic) waters observed for the winter and early spring of 2025 off of central California (35-37° N), and would suggest that above, to significantly above average recruitment conditions are likely for 2024 (as currently estimated in the model) and 2025 (not yet in the modeled period).

Indices of age 0 and 1 chilipepper (individuals 16 cm or smaller) from the West Coast Groundfish Bottom Trawl Survey (WCGBTS) have also been evaluated over both space and time (Tolimieri et al. 2020). In recent years (2021-2024), the relative abundance for fish in this age and size range showed values slightly above average for 2021 and 2022, consistent with a slightly above average recruitment in 2021 estimated in the base model, with slightly below average recruitment in 2023 and 2024. However, these data are already in the model as part of the WCGBTS index, and thus are not explicitly discussed in the risk table. The spatial distribution patterns and trends in this index are included here (Figure 93) for additional consideration.

### *Time-varying growth of adults*

Time varying growth has been suggested or documented for a number of groundfish species along the U.S. West Coast, such as Pacific hake, sablefish and many others (Stawitz et al. 2015, Johnson et al. 2025). For chilipepper, both the 2007 benchmark and 2015 update assessments included time varying growth, implemented through time blocks on offset parameters to the growth coefficient ( $K$ ) that were informed by the timing of significant shifts in the PDO, such that periods of more rapid growth were associated with negative PDO conditions (e.g., cool SST years). Time-varying growth was more rigorously revisited for the current assessment (see Appendix A), and indeed growth was observed to vary considerably over time, although the phenomena is not explicitly accounted for in the base model. The analysis indicates that periods of above and below average growth varied throughout the 1980s and 1990s, and growth conditions between approximately 2005 and 2009, and again between 2015 and 2017, were relatively poor. Those time periods were associated with unusual ocean conditions, including the large marine heatwave that took place between 2014 and 2016, however they also occurred in time periods that followed some of the strongest recruitment events estimated in the current assessment (1999 and 2013). This might suggest that density dependent processes could be important, which has also been suggested for other groundfish species. The observation of significant autocorrelation in the time-varying growth analysis could also reflect either, or both, some response to climate dynamics or some type of density-dependent process. If this cyclic pattern holds, it would suggest that a period of low growth may be observed in the relatively near future, however the pattern and the drivers are not well understood.

### *Trophic considerations*

With respect to trophic interactions, chilipepper are midwater foragers, with euphausiids, forage fishes (such as anchovies, Pacific hake, and mesopelagic fishes), and small squids among key prey items (Love et al. 2002). More recent food habits data from WCG BTS (123 fish between 2005-2008), although relatively sparse, are highly consistent with this generalization, with krill and small fishes (such as myctophids, juvenile Pacific hake, and other rockfishes) among the most frequently occurring prey, along with various cephalopods and other crustaceans. With respect to predation mortality, pelagic juvenile rockfishes of all species, including chilipepper, are among one of the most important forage taxa identified in a meta-analysis of predator food habits studies in the California Current. Key predators of pelagic juveniles include seabirds (e.g., common murre), salmon, lingcod, and other piscivorous fishes (Szoboszlai et al. 2015, Warzybok et al. 2018), while adults are also consumed by larger piscivorous fishes, such as bocaccio and lingcod, as well as marine mammals such as California sea lions. Most of these forage taxa have been at above average abundance for 2024, and although many predator populations have been increasing, most have been doing so at consistent rates over recent decades, suggesting modest potential for sharp, recent increases in predation mortality. Consequently, foraging conditions can be considered favorable, and predation mortality is considered neutral.

See for a summary of potential factors affecting stock productivity.

#### **4.4 Regional Management Considerations**

Chilipepper rockfish are managed south of Cape Mendocino with a species-specific OFL, ABC, and ACL. North of Cape Mendocino, chilipepper are part of the northern shelf rockfish complex. Allocation of OFL between these two areas in previous assessments assigned 93% of yield to the southern region, and the remaining 7% to the northern shelf rockfish complex. An analysis of biomass distribution over the past five years based on the WCG BTS for this assessment (2019-2024) supports the same yield allocation. Extending the analysis to include all years of the survey (2003-2024) produces the same allocation.

As noted earlier, if the at-sea hake fishery begins targeting hake in waters off California, and bycatch rates for chilipepper increase as a result, the collection of biological data (e.g., lengths, otoliths) from chilipepper will be useful for future assessments.

#### **4.5 Research and Data Needs**

##### **4.5.1 Progress since the last assessment**

The 2007 benchmark assessment (Field 2007) called for additional research on several topics. These included improvements to historical catch reconstructions, specifically a comprehensive reconstruction across all rockfish stocks rather than independent efforts. Significant progress was made by Ralston et al. (2010) and Karnowski et al. (2014) for California and Oregon. Estimates of uncertainty in historical landings are still needed. Maturity estimates were updated for the 2015 update assessment, and size-based fecundity estimates were updated by Dick et al. (2017) for brood-fecundity and Lefebvre et al (2018) for multiple-brooding. Ageing error, although still a priority, has been better quantified via several rounds of double-reads across labs and ageing experts. The current assessment includes an extensive analysis of time-varying growth (Appendix A), although methods to incorporate time-varying biology in stock assessments are still evolving. The 2007 assessment called for additional research into the effects of large-scale spatial closures (e.g., the RCAs and CCAs) on stock assessment results. The current assessment incorporates time-varying selectivity based on these closures, but additional research into this topic is still



needed. Lastly, the 2007 benchmark assessment called for analysis of trends south of Point Conception, identifying the CalCOFI survey as a potential source. This assessment includes the CalCOFI index of spawning output, using years in which samples were collected both south and north of Point Conception.

The 2015 update assessment echoed the concerns of the 2007 benchmark with respect to time-varying growth, and we have made progress on that front (Appendix A). Reproductive biology was also mentioned, and updated as the STAT has described in this assessment. The call for use of conditional age-at-length data has been answered, with the current model using CAAL compositions exclusively, and producing reasonable estimates of growth. Lastly, the RREAS survey was updated, included in the current assessment, and evaluated in the context of oceanographic conditions (section 4.3.1).

#### **4.5.2 Research and Data needs identified during in the current assessment**

- Addressing the underlying productivity in the spawner-recruit relationship (“steepness”) remains a key research and data need for West Coast rockfish stocks. This model, like most West Coast rockfish models, continues to use the mean of the prior distribution from a meta-analysis, despite a suite of issues and concerns related to the inability to appropriately update that analysis.
- Among the ongoing efforts to better develop priors or other information to inform steepness include an effort to use a life-history based approach based on Mangel et al. (2010), in preparation as Beyer et al. (in prep), for which chilipepper are one of four species under evaluation. This approach suggests that steepness values considerably higher than that used in the meta-analysis are plausible, although the study needs to be completed and other considerations discussed before this work is ready for application, and the work would benefit from additional research into some of the life-history based relationships to better inform future implementation.
- Ongoing research provides strong insights into the environmental mechanisms related to variability in recruitment, as well as variability in growth and reproductive output. Such research should remain a high priority, particularly with respect to the potential to better inform forecasting.
- Further investigation of the relative importance of time-varying growth on chilipepper population dynamics is needed. Evidence suggests that growth variation is auto-correlated (possibly at multiple time scales; Appendix A), and methods to model this within the assessment may be needed, including correlations between growth parameters (e.g.,  $k$  and  $L_{\infty}$ ).
- Further exploration of cohort and density-dependent effects at the assemblage level (particularly for co-occurring species like bocaccio, yellowtail, and widow rockfishes) may increase our understanding about variation in growth rates for chilipepper rockfish.
- Prioritize completion of analysis of the historic CalCOFI data from central California to expand the time series for future assessments.
- Further development of the spatiotemporal models would improve index standardization. This may include the use of barrier meshes to account for geographic barriers and unique coastline features. Residual diagnostics should be evaluated by depth, especially for demersal species, to decide whether to include a depth effect in the model (even when including anisotropy to account for variables like depth).
- Examination of factors contributing to skewed sex ratios in the catch is needed, e.g., sex-specific natural mortality, selectivity, and/or discards.
- Age validation for chilipepper rockfish is needed. Standardization of ageing methods is also needed to minimize ageing error, including both “traditional” (break-and-burn) methods and ages derived from FT-NIRS (scanning and modeling).
- A small number of ages derived from FT-NIRS were included using a unique ageing error matrix, yet model selection did not indicate a bias between FT-NIRS and traditional ageing methods. Visual inspection suggests a consistent bias toward younger FT-NIRS ages for older fish. This

may reflect limitations in the bias structures available in the ageing error software, supporting an improved understanding about differences between FT-NIRS and traditional break-and-burn ages.

- Selectivity estimation remains a challenge for this assessment due to complex and changing management measures. Further investigation into time-blocking and/or a more structured spatiotemporal modeling (e.g., by length groups or age) approach could clarify how to incorporate management and gear changes in future models by indicating which size/age might be affected by such changes.
- This assessment attempts to account for multiple brooding of larger, older female chilipepper with respect to larval production and reproductive output. However, both the spatial and temporal variability associated with this phenomenon could be better understood. An improved understanding of the environmental factors associated with variable reproductive output, including multiple brooding, could also lead to an improved interpretation of the CalCOFI larval abundance time series, as it is likely that some of the high variance observed in that time series relates to interannual variability in reproductive output, relative to simple sampling variance alone. Additionally, ongoing efforts to positively identify chilipepper larvae from the earliest part of the CalCOFI time series would greatly benefit the ability of that time series to inform the model.
- Additional biological research on skip spawning, functional maturity, and environmentally driven variation in brooding frequency is needed to improve estimates of fecundity.
- Although there is a reconstruction of historical rockfish landings for California waters, the current reconstruction does not explicitly account for the expansion of both fixed gear and trawl fisheries into deeper habitats, further from port, over time (as discussed in Miller et al. 2014 and the 2017 catch reconstruction review; PFMC 2017). Ongoing catch reconstruction efforts are also focused on efforts to quantify the uncertainty associated with both historical and recent catches (Grunloh et al. 2017), the completion of these efforts would better allow for this uncertainty to be accounted for in future assessment models.
- A better understanding about the portion of the population in Mexican waters may be supported by habitat suitability mapping.
- Continued research on density-independent effects on YOY survival, especially for integration into future risk tables. This includes developing an inshore-offshore index for the southern population and exploring moving average approaches to link the "minty-spicy" temperature index to recruitment dynamics.
- A better understanding about predator-prey dynamics would improve our understanding about time-varying natural mortality.
- If the at-sea hake fishery begins targeting hake in waters off California, and bycatch rates increase, collection of biological data (lengths, otoliths) from chilipepper will be useful for future assessments.

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## 6 References

- Adams, G.D., Kapur, M.S., McQuaw, K., Thurner, S., Hamel, O.S., Stephens, A. and Wetzel, C., 2019. Stock assessment update: status of widow rockfish (*Sebastes entomelas*) along the US West Coast in 2019. Pacific Fishery Management Council, Portland, OR.
- Ally, J.R.R., Ono, D.S., Read, R.B., and Wallace, M. 1991. Status of major southern California marine sport fish species with management recommendations, based on analyses of catch and size composition data collected on board commercial passenger fishing vessels from 1985 through 1987. Marine Resources Division Administrative Report No. 90-2 California Department of Fish and Game.
- Alonzo, S.H., M. Key, T. Ish, and A.D. MacCall. 2004. Status of the California sheephead (*Semicossyphus pulcher*) stock. California Department of Fish and Game.
- Alverson, D.L., A.T. Pruter and L.L. Ronholt. 1964. A study of demersal fishes and fisheries of the Northeastern Pacific Ocean. Institute of Fisheries, University of British Columbia: Vancouver, CA.
- Amaya, D. J., Alexander, M. A., Scott, J. D., and M.G. Jacox. 2023. An evaluation of high-resolution ocean reanalyses in the California current system. Progress in Oceanography, 210, 102951. <https://doi.org/10.1016/j.pocean.2022.102951>
- Anderson, S.C., Ward, E.J., English, P.A. and Barnett, L.A., 2022. sdmTMB: an R package for fast, flexible, and user-friendly generalized linear mixed effects models with spatial and spatiotemporal random fields. bioRxiv, pp.2022-03.
- Benson IM, Helser TE, and Barnett BK. 2024. Fourier transform near infrared spectroscopy of otoliths coupled with deep learning improves age prediction for long-lived northern rockfish. Fisheries Research. 278:107-116.
- Berkeley, S.A., Hixon, M.A., Larson, R.J. and Love, M.S., 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries 29(8), pp.23-32.

Beyer, S.G., Sogard, S.M., Harvey, C.J. and Field, J.C. 2015. Variability in rockfish (*Sebastes* spp.) fecundity: species contrasts, maternal size effects, and spatial differences. *Environmental Biology of Fishes*, 98, pp.81-100.

Beyer, S.G., Alonzo, S.H. and Sogard, S.M., 2021. Zero, one or more broods: reproductive plasticity in response to temperature, food, and body size in the live-bearing rosy rockfish *Sebastes rosaceus*. *Marine Ecology Progress Series* 669: 151-173. <https://doi.org/10.3354/meps13718>

Beyer, S.G., Sogard, S.M., Stafford, D.M., Kashef, N.S., Rodriguez, A., Alonzo, S.H. and Field, J.C., 2024. Shifting ocean conditions influence temporal variation in the fecundity of California Current rockfishes (*Sebastes* spp.). *Canadian Journal of Fisheries and Aquatic Sciences*, 81(6), pp.781-795. <https://doi.org/10.1139/cjfas-2023-0253>

Beyer, S., J.C. Field and M. Mangel. In preparation. Using the reproductive ecology of steepness to inform spawner-recruit dynamics: A case study of West Coast rockfishes (*Sebastes* spp.).

Bradburn, M.J., Keller, A.A., and Horness, B.H. 2011. The 2003 to 2008 US West Coast bottom trawl surveys of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, length, and age composition. US Department of Commerce, National Oceanic; Atmospheric Administration, National Marine Fisheries Service.

Butler, J. L., L. D. Jacobson and J.T. Barnes. 1999. Stock assessment of cowcod rockfish. In: Pacific Fishery Management Council. 1999. Appendix: Status of the Pacific Coast Groundfish Fishery through 1999 and recommended biological catches for 2000: Stock assessment and fishery evaluation. Pacific Fishery Management Council, Portland, OR.

Butler, J.L., M.S. Love and T.E. Laidig. 2012. A guide to the rockfishes, thornyheads and scorpionfishes of the Northeast Pacific. University of California Press: Berkeley.

Coates, J.H., Hicks, A., Valero, J., Meyer, K. 2025. The Status of California Halibut in U.S. Waters off Southern California in 2023. California Department of Fish & Wildlife. Available from: <https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=229693>

Collins, R.A., and Crooke, S.J. (n.d.). An evaluation of the commercial passenger fishing vessel record system and the results of sampling the Southern California catch for species and size composition, 1975-1978. Unpublished report.

Croaker, R.S. 1939. Three years of fisheries statistics on marine sport fishing in California. *Transactions of the American Fisheries Society* 69: 117-118.

Davis, J.C. 1949. Salt water fishing on the Pacific coast. A.S. Barnes and Co. New York.

Dick, E.J., Beyer, S., Mangel, M. and Ralston, S., 2017. A meta-analysis of fecundity in rockfishes (genus *Sebastes*). *Fisheries Research*, 187, pp.73-85.

Dick, E.J., Berger, A., Bizzarro, J., Bosley, K., Cope, J., Field, J., Glibert-Horvath, L., Grunloh, N., Ivens-Duran, M., Miller, R., Privitera-Johnson, K., and Rodomsky, B.T. 2018. The combined status of blue and deacon rockfishes in U.S. Waters off California and Oregon in 2017. Pacific Fishery Management Council, Portland, OR. <https://www.pcouncil.org/documents/2018/01/the-combined-status-of-blue-and-deacon-rockfishes-in-u-s-waters-off-california-and-oregon-in-2017.pdf>

Dick, E.J. and He, X. 2019. Status of Cowcod (*Sebastes levis*) in 2019. Pacific Fishery Management Council, Portland, OR. <https://www.pcouncil.org/documents/2019/10/status-of-cowcod-sebastes-levis-in-2019-october-24-2019.pdf>

Eschmeyer, W., E. Herald, Hammann. 1983. A field guide to Pacific Coast fishes of North America : from the Gulf of Alaska to Baja, California. Houghton Mifflin, Boston. 336 p.

Fennie, H.W., Ben-Aderet, N., Bograd, S.J., Kwan, G.T., Santora, J.A., Schroeder, I.D. and Thompson, A.R., 2024. Momma's larvae: Maternal oceanographic experience and larval size influence early survival of rockfishes. Fisheries Oceanography 33(2): e12658. <https://doi.org/10.1111/fog.12658>

Field, J.C. 2007. Status of the Chilipepper rockfish, *Sebastes goodei*, in 2007. In: Status of the Pacific Coast Groundfish Fishery Through 2007, Stock Assessment and Fishery Evaluation: Stock Assessments and Rebuilding Analyses. Portland, Oregon. <https://www.pcouncil.org/documents/2009/01/status-of-the-chilipepper-rockfish-sebastes-goodei-in-2007.pdf>

Field, J.C. and S. Ralston. 2005. Spatial variability in California Current rockfish recruitment events. Canadian Journal of Fisheries and Aquatic Sciences. 62:2199–2210.

Field, J.C., E.J. Dick, M. Key, M. Lowry, Y. Lucero, A. MacCall, D. Pearson, S. Ralston, W. Sydeman, and J. Thayer. 2007. Population dynamics of an unexploited rockfish, *Sebastes jordani*, in the California Current. pp 451-472 in J. Heifetz, J. Dicosimo, A.J. Gharrett, M.S. Love, V. M. O'connell and R.D. Stanley (editors) Proceedings of the Lowell-Wakefield Symposium on the Biology, Assessment and Management of North Pacific Rockfish. University of Alaska Sea Grant: Anchorage, Alaska

Field, J.C., MacCall, A.D., Bradley, R.W., and Sydeman, W.J. 2010. Estimating the impact of fishing on dependent predators: a case study in the California Current. Ecological Applications 20(8):2223-2236.

Field, J.C., Elliger, C., Baltz, K., Gillespie, G.E., Gilly, W.F., Ruiz-Cooley, R.I., Pearse, D., Stewart, J.S., Matsubu, W. and Walker, W.A., 2013. Foraging ecology and movement patterns of jumbo squid (*Dosidicus gigas*) in the California Current System. Deep Sea Research Part II: Topical Studies in Oceanography, 95, pp.37-51. <http://dx.doi.org/10.1016/j.dsr2.2012.09.006>

Field, J.C., S. Beyer and X. He. 2015. Status of the Chilipepper Rockfish, *Sebastes goodei*, in the California Current for 2015. Pacific Fishery Management Council Stock Assessment and Fishery Evaluation. Portland, Oregon. <https://www.pcouncil.org/documents/2016/06/status-of-the-chilipepper-rockfish-sebastes-goodei-in-the-california-current-for-2015.pdf>

Field, J.C., R.R. Miller, J.A. Santora, N. Tolimieri, M.A. Haltuch, R.D. Brodeur, T.D. Auth, E.J. Dick, M.H. Monk, K.M. Sakuma and B.K. Wells. 2021. Spatiotemporal patterns of variability in the abundance and distribution of winter-spawned pelagic juvenile rockfish in the California Current. PloS one 16(5):e0251638. <https://doi.org/10.1371/journal.pone.0251638>

Flament, P. 2002. A state variable for characterizing water masses and their diffusive stability: spiciness. Progress in Oceanography 54(1–4): 493–501. [https://doi.org/10.1016/s0079-6611\(02\)00065-4](https://doi.org/10.1016/s0079-6611(02)00065-4).

Francis, R. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 1124–1138.

Gasbarro, R., Santora, J.A., Cimino, M., Schonfeld, A., Bograd, S.J., Hazen, E.L., Wells, B.K. and J.C. Field. 2025. Composition and functional diversity of juvenile groundfish assemblages in the California Current. *Journal of Biogeography*. <https://doi.org/10.1111/jbi.15108>

Grunloh, N., Pearson, D., Dick, E.J., Field, J. and M. Mangel. 2017. Improving Catch Estimation Methods in Sparsely Sampled, Mixed Stock Fisheries. Unpublished report prepared for PFMF methodology review. <https://www.pcouncil.org/documents/2018/09/agenda-item-i-6-attachment-2.pdf/>

Hamel, O.S. 2015. A method for calculating a meta-analytical prior for the natural mortality rate using multiple life history correlates. *ICES Journal of Marine Science* 72(1): 62–69.  
doi:10.1093/icesjms/fsu131

Hamel, O. and Cope, J. 2022. Development and considerations for application of a longevity-based prior for the natural mortality rate. *Fisheries Research* 256: 106477.  
<https://doi.org/10.1016/j.fishres.2022.106477>.

Harvey, C., J.C. Field, S.G. Beyer and S.M. Sogard. 2011. Modeling growth and reproduction of chilipepper rockfish under variable environmental conditions. *Fishery Research* 109: 187-200.  
<https://doi.org/10.1016/j.fishres.2011.02.004>

He, X., J.C. Field, D.E. Pearson, L. Lefebvre and S. Lindley. 2015. Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2015. Pacific Fishery Management Council, Portland, OR. <https://www.pcouncil.org/documents/2016/05/status-of-bocaccio-sebastes-paucispinis-in-the-conception-monterey-and-eureka-inpfc-areas-for-2015-august-2015.pdf>

He, X., J.C. Field. 2018. Stock Assessment Update: Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2017. Pacific Fishery Management Council, Portland, OR. <https://www.pcouncil.org/documents/2017/02/stock-assessment-update-status-of-bocaccio-sebastes-paucispinis-in-the-conception-monterey-and-eureka-inpfc-areas-for-2017.pdf/>

Heimann, R.F.G. and D.J. Miller. 1960. The Morro Bay otter trawl and party boat fisheries August, 1957 to September, 1958. *California Department of Fish and Game* 46: 35-67.

Heimann, R.F.G. 1963. Trawling in the Monterey Bay Area, with special reference to catch composition. *California Department of Fish and Game* 49: 152-173.

Helser TE, Benson I, Erickson J, Healy J, Kastle C, and Short JA. 2019. A transformative approach to ageing fish otoliths using Fourier transform near infrared spectroscopy: a case study of eastern Bering Sea walleye pollock (*Gadus chalcogrammus*). *Canadian Journal of Fisheries and Aquatic Sciences*. 76(5):780-789.

Henry, F. D., Jr. 1985. A progress report on the status of chilipepper (*Sebastes goodei*) off California. In: Appendix to the Status of the Pacific Coast Groundfish Fishery through 1985 and Recommended Acceptable Biological Catches for 1986, Stock Assessment and Fishery Evaluation, Pacific Fishery Management Council, Portland, OR.

Henry, F. D., Jr. 1986. Status of the coastwide chilipepper (*Sebastes goodei*) fishery. In: Appendix to the Status of the Pacific Coast Groundfish Fishery through 1986 and Recommended Acceptable Biological Catches for 1987, Stock Assessment and Fishery Evaluation, Pacific Fishery Management Council, Portland, OR

- Hyde, J.R. and Vetter, R.D., 2007. The origin, evolution, and diversification of rockfishes of the genus *Sebastes* (Cuvier). *Molecular phylogenetics and evolution* 44(2): 790-811.  
<https://doi.org/10.1016/j.ympev.2006.12.026>
- Jacobson, L. D., S. Ralston, and A. D. MacCall. 1996. Historical larval abundance indices for bocaccio rockfish (*Sebastes paucispinus*) from CalCOFI data. NMFS SWFSC Administrative Report LJ-96-06.
- Johnson, K.F., A.M. Edwards, A.M. Berger, C.J. Grandin, and C.R. Wetzel. 2025. Status of the Pacific Hake (whiting) stock in U.S. and Canadian waters in 2025. Prepared by the Joint Technical Committee of the U.S. and Canada Pacific Hake/Whiting Agreement, National Marine Fisheries Service and Fisheries and Oceans Canada. 286 p.
- Jordan, D.S. and B.W. Evermann. 1898. The fishes of North and Middle America. *Bulletin of the U.S. National Museum* 47, pt. 2.
- Karnowski, M., V. Gertseva, and A. Stephens. 2014. Historical Reconstruction of Oregon's Commercial Fisheries Landings. Oregon Department of Fish and Wildlife Information Reports, Number 2014-02.  
[https://www.dfw.state.or.us/mrp/publications/docs/ODFW\\_Info\\_Rpt%202014-02\\_Historic\\_Reconstruction\\_Oregon\\_Commercial\\_Fish\\_Landings.pdf](https://www.dfw.state.or.us/mrp/publications/docs/ODFW_Info_Rpt%202014-02_Historic_Reconstruction_Oregon_Commercial_Fish_Landings.pdf)
- Keller, Aimee A. 2008. The 2005 U.S. West Coast bottom trawl survey of groundfish resources off Washington, Oregon, and California : estimates of distribution, abundance, and length composition.  
[https://repository.library.noaa.gov/view/noaa/3580/noaa\\_3580\\_DS1.pdf](https://repository.library.noaa.gov/view/noaa/3580/noaa_3580_DS1.pdf)
- Keller, A.A., Wakefield, W.W., Whitmire, C.E., Horness, B.H., Bellman, M.A. and Bosley, K.L., 2014. Distribution of demersal fishes along the US west coast (Canada to Mexico) in relation to spatial fishing closures (2003-2011). *Marine Ecology Progress Series* 501: 169-190.
- Keller, A.A., Wallace, J.R. and Methot, R.D. 2017. The northwest fisheries science Center's West coast Groundfish bottom trawl survey: History, design, and description. NOAA Technical Memorandum NMFS-NWFSC-136. <https://repository.library.noaa.gov/view/noaa/14179>
- Kristensen, K., Nielsen, A., Berg, C.W., Skaug, H.J., and Bell, B.M. 2016. TMB: Automatic Differentiation and Laplace Approximation. *Journal of Statistical Software* 70: 1–21.
- Langseth, B.J., K.L. Oken, A.D. Whitman, J.E. Budrick and T. Tsou. 2023. Status of Canary Rockfish (*Sebastes pinniger*) along the U.S. West Coast in 2023. Pacific Fishery Management Council, Portland, OR.
- Lefebvre, L.S. and Field, J.C. 2015. Reproductive Complexity in a Long-Lived Deepwater Fish, the Blackgill Rockfish. *Transactions of the American Fisheries Society*, 144: 383-399.  
<https://doi.org/10.1080/00028487.2014.1001039>
- Lefebvre, L.S., S.G. Beyer, D.M. Stafford, N.S. Kashef, E.J. Dick, S.M. Sogard and J.C. Field. 2018. Double or nothing: Plasticity in reproductive output in the chilipepper rockfish (*Sebastes goodei*). *Fisheries Research* 204: 258-268. <https://doi.org/10.1016/j.fishres.2018.03.002>
- Love, M.S., M. Yolkavich and L. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. University of California Press: Berkeley.



- Love, M.S., 2011. Certainly more than you want to know about the fishes of the Pacific Coast: a postmodern experience. Really Big Press: Santa Barbara. ISBN 978-0-9628725-6-3. 649 pp.
- MacCall, A. 2003. Status of Bocaccio off California in 2003. In: Status of the Pacific Coast Groundfish Fishery Through 2003, Stock Assessment and Fishery Evaluation: Stock Assessments and Rebuilding Analyses. Pacific Fishery Management Council, Portland, OR.
- Mangel, M., Brodziak, J. and DiNardo, G., 2010. Reproductive ecology and scientific inference of steepness: a fundamental metric of population dynamics and strategic fisheries management. *Fish and Fisheries*, 11(1), pp.89-104.
- McAllister, M. K., and J. N. Ianelli. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. *Canadian Journal of Fisheries and Aquatic Sciences* 54(2): 284–300.
- Methot, R.D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *Int. N. Pac. Fish. Comm. Bull.*:50:259-277.
- Methot, R.D. 2000. Technical description of the stock synthesis assessment program. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-43, 46 p.
- Methot, R D.Jr. and Taylor, I G. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. *Canadian Journal of Fisheries and Aquatic Sciences*. 68(10): 1744-1760. <https://doi.org/10.1139/f2011-092>
- Methot, R.D. and Wetzel, C. R. 2013. Stock Synthesis: a biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research* 142:86-99. <https://doi.org/10.1016/j.fishres.2012.10.012>
- Miller, R.R., J.C. Field, J. Santora, I. Schroeder, D.D. Huff, M. Key, D. Pearson and A.D. MacCall. 2014. A spatially distinct history of the development of California Groundfish Fisheries. *Public Library of Science (PLOS ONE)* 9:6: e99758. <https://doi.org/10.1371/journal.pone.0099758>.
- Miller, D.J. and D. Gotshall. 1965. Ocean sportfish catch and effort from Oregon to Point Arguello, California. *California Department of Fish and Game Fish Bulletin* 130. 135 p.
- Monk, M., Dick, E., and Pearson, D. 2014. Documentation of a relational database for the California Recreational Fisheries Survey Onboard Observer Sampling Program, 1999-2011. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-529. 107 p.
- Monk, M.H., Miller, R.R., Field, J., Dick, E.J., Wilson-Vandenberg, D., and Reilly, P. 2016. Documentation for California Department of Fish and Wildlife's Onboard Sampling of the Rockfish and Lingcod Commercial Passenger Fishing Vessel Industry in Northern and Central California (1987-1998) as a relational database. NOAA-TM-NMFS-SWFSC-558. doi:10.7289/V5/TM-SWFSC-558
- Moser, H.G., E.H. Ahlstrom and E.M. Sandknop. 1977. Guide to the identification of scorpionfish larvae (Family Scorpaenidae) in the eastern Pacific with comparative notes on species of *Sebastes* and *Helicolenus* from other oceans. NOAA Technical Report NMFS Circular 402; 71 pp.



Moser, H. G., R. L. Charter, W. Watson, D. A. Ambrose, J. L. Butler, S. R. Charter, and E. M. Sandknop. 2000. Abundance and distribution of rockfish (*Sebastes*) larvae in the Southern California Bight in relation to environmental conditions and fishery exploitation. CalCOFI Reports 41: 132-147.

Pacific Fishery Management Council (PFMC). 2017. Report of the Groundfish Historical Catch Reconstruction Workshop. Pacific Fishery Management Council, Portland, OR.  
[https://www.pcouncil.org/documents/2017/03/i2\\_att1\\_catch\\_reconstruction\\_workshop\\_report\\_mar2017b.pdf/](https://www.pcouncil.org/documents/2017/03/i2_att1_catch_reconstruction_workshop_report_mar2017b.pdf/)

Pacific Fishery Management Council (PFMC). 2024. Scientific and Statistical Committee Report on Methodology Review: Final Fishery Impact Model Review Topics and Stock Assessment Methodologies. <https://www.pcouncil.org/documents/2024/11/i-3-a-supplemental-ssc-report-1-scientific-and-statistical-committee-report-on-methodology-review-final-fishery-impact-model-review-topics-and-stock-assessment-methodologies.pdf>

Pearson, D.E., Erwin, B. and Key, M., 2008. Reliability of California's groundfish landing estimates from 1969-2006. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-431. <https://swfsc-publications.fisheries.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-431.pdf>

Phillips, J.B. 1939. The rockfish of the Monterey wholesale fish markets. California Fish and Game 25: 214-225.

Phillips, J. B. 1957. Rockfish review. In: The Marine Fish Catch of California For the Years 1955 and 1956 with Rockfish Review, State of California Department of Fish and Game, Fish Bulletin 105.

Punt, A.E., K.F. Johnson, I.G. Taylor and P. Burch. 2025. AgeingError: Estimating ageing error with 'TMB' from double reads. R package version 2.1.0, <https://pfmc-assessments.github.io/AgeingError/>

Ralston, S., D. Pearson and J. Reynolds. 1998. Status of the chilipepper rockfish in 1998. In Appendix to Status of the Pacific Coast Groundfish Fishery through 1998 and recommended acceptable biological catches for 1999. Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, Portland OR.

Ralston, S., D. Pearson, J. Field and M. Key. 2010. Documentation of the California commercial catch reconstruction project. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-461.

Ralston, S.D., A.E. Punt, O.S. Hamel, J.D. DeVore, and R.J. Conser. 2011. [A meta-analytic approach to quantifying scientific uncertainty in stock assessments](#). Fish. Bull. 109:217-231.

Ralston, S., K.M. Sakuma and J.C. Field. 2013. Interannual variation in pelagic juvenile rockfish abundance— going with the flow. Fisheries Oceanography 22:288–308. <https://doi.org/10.1111/fog.12022>

Ralston, S. and Stewart, I.J., 2013. Anomalous distributions of pelagic juvenile rockfish on the US west coast in 2005 and 2006. CalCOFI Rep, 54, pp.155-166.

Roedel, P.M. 1948. California Department of Fish and Game Fish Bulletin No. 68. Common Marine Fishes of California.

Rogers, J.B. 2003. Species allocation of *Sebastes* and *Sebastolobus* sp. caught by foreign countries from 1965 through 1976 off Washington, Oregon, and California, USA. NOAA Tech. Memo. NMFS-NWFSC-57.

Rogers, J. B., and J. R. Bence. 1993. Status of the chilipepper rockfish stock in 1993. In: Appendices to the status of the Pacific coast groundfish fishery through 1993 and recommended acceptable biological catches for 1994, Stock Assessment and Fishery Evaluation, Pacific Fishery Management Council, 2000 SW First Avenue, Suite 420, Portland, OR, 97201.

Sakuma, K.M., J.C. Field, N.J. Mantua, S. Ralston, B.B. Marinovic, and C.N. Carrion. 2016. Anomalous epipelagic micronekton assemblage patterns in the neritic waters of the California Current in spring 2015 during a period of extreme ocean conditions. *CalCOFI Reports* 57:163-183.

Santora, J.A., Hazen, E.L., Schroeder, I.D., Bograd, S.J., Sakuma, K.M. and Field, J.C., 2017. Impacts of ocean climate variability on biodiversity of pelagic forage species in an upwelling ecosystem. *Marine Ecology Progress Series* 580: 205-220. <https://www.int-res.com/abstracts/meps/v580/meps12278>

Santora, J.A., Schroeder, I.D., Bograd S.J., Chavez F., Cimino M., Fiechter J., Hazen E.L., Kavanaugh M.T., Messie M., Miller R.R., Sakuma K., Sydeman W.J., Wells B.K., Field J.C. 2021. Pelagic biodiversity, ecosystem function and services: an integrated observing and modeling approach. *Oceanography* 34:2: 16-37. <https://doi.org/10.5670/oceanog.2021.212>

Scofield, W.L. 1948. Trawling gear in California. California Department of Fish and Game Fish Bulletin 72.

Schroeder, I.D., J.A. Santora, S.J. Bograd, E.L. Hazen, K.M. Sakuma, A.M. Moore, C.A. Edwards, B.K. Wells and J.C. Field. 2019. Source water variability as a driver of rockfish recruitment in the California Current Ecosystem: implications for climate change and fisheries management. *Canadian Journal of Fisheries and Aquatic Sciences* 76: 950–960. <https://doi.org/10.1139/cjfas-2017-0480>

Solinger, L.K. 2019. Spatial variability in recruitment of chilipepper rockfish (*Sebastes goodei*) in the California Current system. MS Thesis. Humboldt State University. 152 pp.

Stafford, D.M., Sogard, S.M. and Berkeley, S.A., 2014. Maternal influence on timing of parturition, fecundity, and larval quality in three shelf rockfishes (*Sebastes* spp.). *Aquatic Biology* 21(1): 11-24. <https://doi.org/10.3354/ab00564>

Stawitz, C.C., Essington, T.E., Branch, T.A., Haltuch, M.A., Hollowed, A.B. and Spencer, P.D., 2015. A state-space approach for detecting growth variation and application to North Pacific groundfish. *Canadian Journal of Fisheries and Aquatic Sciences*, 72(9), pp.1316-1328

Szoboszlai, A.I., Thayer, J.A., Wood, S.A., Sydeman, W.J. and Koehn, L.E., 2015. Forage species in predator diets: synthesis of data from the California Current. *Ecological Informatics* 29: 45-56.

Taylor, I. G., Kathryn L. Doering, Kelli F. Johnson, Chantel R. Wetzel, Ian J. Stewart, 2021. Beyond visualizing catch-at-age models: Lessons learned from the r4ss package about software to support stock assessments, *Fisheries Research*, 239:105924. <https://doi.org/10.1016/j.fishres.2021.105924>

Then, A.Y., Hoenig, J.M., Hall, N.G., and Hewitt, D.A. 2015 (correction published in 2018). Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. *ICES Journal of Marine Science* 75(4): 1509. doi: 10.1093/icesjms/fsx199

Thompson, A.R., Chen, D.C., Guo, L.W., Hyde, J.R. and Watson, W., 2017. Larval abundances of rockfishes that were historically targeted by fishing increased over 16 years in association with a large marine protected area. *Royal Society open science*, 4(9), p.170639.

Tolimieri, N., Wallace, J. and Haltuch, M., 2020. Spatio-temporal patterns in juvenile habitat for 13 groundfishes in the California Current Ecosystem. *PLoS One*, 15(8), p.e0237996

Walford, L.A. 1930. California Department of Fish and Game Fish Bulletin No. 28. Handbook of Common Commercial and Game Fishes of California.

Warzybok, P., Santora, J.A., Ainley, D.G., Bradley, R.W., Field, J.C., Capitolo, P.J., Carle, R.D., Elliott, M., Beck, J.N., McChesney, G.J. and Hester, M.M., 2018. Prey switching and consumption by seabirds in the central California Current upwelling ecosystem: Implications for forage fish management. *Journal of Marine Systems*, 185, pp.25-39.

Weinberg, K.L., M.E. Wilkins, F.R. Shaw, and M. Zimmerman, M. 2002. The 2001 Pacific west coast bottom trawl survey of groundfish resources: estimates of distribution, abundance and length and age composition. NOAA Tech. Mem. NMFS-AFSC-128.

Westrheim, S.J. 1965. Northern range extensions for four species of rockfish (*Sebastes goodei*, *S. helvomaculatus*, *S. rubrivinctus*, and *S. zacentrus*) in the north Pacific Ocean. *Journal of the Fisheries Research Board of Canada* 22: 231-235.

Wetzel, C. 2023. Catch update for chilipepper rockfish (*Sebastes goodei*) off the U.S. West Coast. Pacific Fishery Management Council, Portland OR. <https://www.pcouncil.org/documents/2023/10/e-2-attachment-2-catch-update-for-chilipepper-rockfish-sebastes-goodei-off-the-u-s-west-coast.pdf/>

Wishard LN, FM Utter, and DR Gunderson. 1980. Stock separation of five rockfish species using naturally occurring biochemical genetic markers. *Marine Fisheries Review*. 49:64–73.

Xu, H. J.T. Thorson, R. D. Methot, and I. G. Taylor. 2019. A new semi-parametric method for autocorrelated age- and time-varying selectivity in age-structured assessment models. *Canadian Journal of Fisheries and Aquatic Sciences*. 76(2): 268-285. <https://doi.org/10.1139/cjfas-2017-0446>

Young, P.H. 1969. The California Partyboat Fishery 1947-1967. California Department of Fish and Game Fish Bulletin 145. 91 p.

Zimmerman, M., M. E. Wilkins, K. L. Weinberg, R, R, Lauth, and F. R. Shaw. 2001. Retrospective analysis of suspiciously small catches in the National Marine Fisheries Service West Coast Triennial Bottom Trawl Survey. AFSC Proc. Rep. 2001-03: 135p.

## 7 Auxiliary Files

*Files archived with the 2025 chilipepper assessment:*

Chili\_2025.ctf

Chili\_2025.dat

forecast.ss

Report.sso

starter.ss

Files with population numbers at age x year x sex (.csv format)

Folder containing plots and html files from the base model using the “r4ss” package

## 8 Tables

Table 1: Evaluation of Management Performance for chilipepper rockfish south of 40 10 N. latitude. North of this, chilipepper is managed as part of the shelf rockfish complex. Note that total mortality estimates reported here are for the entire coast, based on the Groundfish Expanded Mortality Multiyear (GEMM) report, and therefore an overestimate of total mortality in the southern area. The GEMM report estimate for 2024 was not yet released when this assessment was prepared. Previous assessments have allocated yield to these areas as follows: 93% to the southern area (species-level ACL), and 7% as a species-specific contribution to the OFL/ABC/ACL for the northern shelf rockfish complex

| Year | OFL (mt) | ABC (mt) | ACL (mt) | COASTWIDE            |
|------|----------|----------|----------|----------------------|
|      |          |          |          | Total Mortality (mt) |
| 2015 | 1703     | 1628     | 1628     | 210                  |
| 2016 | 1694     | 1619     | 1619     | 102                  |
| 2017 | 2727     | 2607     | 2607     | 225                  |
| 2018 | 2623     | 2507     | 2507     | 404                  |
| 2019 | 2652     | 2536     | 2536     | 649                  |
| 2020 | 2521     | 2410     | 2410     | 775                  |
| 2021 | 2571     | 2358     | 2358     | 859                  |
| 2022 | 2474     | 2259     | 2259     | 876                  |
| 2023 | 2401     | 2183     | 2183     | 1277                 |
| 2024 | 2346     | 2121     | 2121     | 1193.2*              |

\* Preliminary estimate based on 2025 assessment

Table 2: Total removals (mt) of chilipepper rockfish by year and fleet definition. See section 2.1 for fleet descriptions.

| Year | NoCA<br>HKL | SoCA<br>HKL | CA<br>TWL | OR_WA<br>Comm | CA<br>NET | NoCA<br>OR<br>WA Rec | SoCA<br>Rec | TWL<br>discard | Grand<br>Total |
|------|-------------|-------------|-----------|---------------|-----------|----------------------|-------------|----------------|----------------|
| 1875 | 3.4         | 4.9         | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 8.3            |
| 1876 | 6.8         | 9.7         | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 16.5           |
| 1877 | 10.3        | 14.6        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 24.8           |
| 1878 | 13.7        | 19.4        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 33.1           |
| 1879 | 17.1        | 24.3        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 41.4           |
| 1880 | 20.5        | 29.1        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 49.6           |
| 1881 | 24.0        | 34.0        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 57.9           |
| 1882 | 27.4        | 38.8        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 66.2           |
| 1883 | 30.8        | 43.7        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 74.4           |
| 1884 | 34.2        | 48.5        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 82.7           |
| 1885 | 37.6        | 53.4        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 91.0           |
| 1886 | 41.1        | 58.2        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 99.3           |
| 1887 | 44.5        | 63.1        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 107.5          |
| 1888 | 47.9        | 67.9        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 115.8          |
| 1889 | 51.3        | 72.8        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 124.1          |
| 1890 | 54.7        | 77.6        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 132.3          |
| 1891 | 58.2        | 82.5        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 140.6          |
| 1892 | 61.6        | 87.3        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 148.9          |
| 1893 | 65.0        | 92.2        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 157.2          |
| 1894 | 68.4        | 97.0        | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 165.4          |
| 1895 | 71.9        | 101.9       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 173.7          |
| 1896 | 75.3        | 106.7       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 182.0          |
| 1897 | 78.7        | 111.6       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 190.3          |
| 1898 | 82.1        | 116.4       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 198.5          |
| 1899 | 85.5        | 121.3       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 206.8          |
| 1900 | 89.0        | 126.1       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 215.1          |
| 1901 | 92.4        | 131.0       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 223.3          |
| 1902 | 95.8        | 135.8       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 231.6          |
| 1903 | 99.2        | 140.7       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 239.9          |
| 1904 | 102.6       | 145.5       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 248.2          |
| 1905 | 106.1       | 150.4       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 256.4          |
| 1906 | 109.5       | 155.2       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 264.7          |
| 1907 | 112.9       | 160.1       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 273.0          |
| 1908 | 116.3       | 164.9       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 281.2          |
| 1909 | 119.8       | 169.8       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 289.5          |
| 1910 | 123.2       | 174.6       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 297.8          |
| 1911 | 126.6       | 179.5       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 306.1          |
| 1912 | 130.0       | 184.3       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 314.3          |
| 1913 | 133.4       | 189.2       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 322.6          |
| 1914 | 136.9       | 194.0       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 330.9          |
| 1915 | 140.3       | 198.9       | 0.0       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 339.1          |
| 1916 | 143.7       | 203.7       | 14.4      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 361.8          |
| 1917 | 223.4       | 328.7       | 22.4      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 574.4          |
| 1918 | 262.3       | 299.4       | 26.2      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 588.0          |
| 1919 | 181.8       | 179.4       | 18.3      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 379.5          |
| 1920 | 185.5       | 194.8       | 18.6      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 398.9          |
| 1921 | 153.5       | 170.0       | 15.4      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 338.8          |
| 1922 | 131.8       | 167.3       | 13.2      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 312.4          |
| 1923 | 142.0       | 224.3       | 14.3      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 380.5          |
| 1924 | 82.0        | 299.9       | 8.2       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 390.1          |
| 1925 | 104.5       | 327.9       | 6.7       | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 439.1          |
| 1926 | 166.1       | 408.4       | 20.2      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 594.7          |
| 1927 | 118.0       | 353.5       | 36.9      | 0.0           | 0.0       | 0.0                  | 0.0         | 0.0            | 508.5          |
| 1928 | 150.9       | 301.0       | 47.4      | 0.0           | 0.0       | 1.5                  | 0.3         | 0.0            | 501.0          |
| 1929 | 125.3       | 302.3       | 56.0      | 0.0           | 0.0       | 2.9                  | 0.6         | 0.0            | 487.1          |

| Year | NoCA  | SoCA  | CA     | OR_WA | CA     | NoCA         | SoCA  | TWL     | Grand  |
|------|-------|-------|--------|-------|--------|--------------|-------|---------|--------|
|      | HKL   | HKL   | TWL    | Comm  | NET    | OR<br>WA Rec | Rec   | discard |        |
| 1930 | 170.9 | 315.7 | 58.6   | 0.0   | 0.0    | 3.3          | 0.8   | 0.0     | 549.4  |
| 1931 | 175.5 | 364.2 | 40.2   | 0.0   | 0.0    | 4.5          | 1.1   | 0.0     | 585.5  |
| 1932 | 123.0 | 243.7 | 47.8   | 0.0   | 0.0    | 5.6          | 1.4   | 0.0     | 421.5  |
| 1933 | 103.4 | 150.8 | 73.1   | 0.0   | 0.0    | 6.7          | 1.7   | 0.0     | 335.7  |
| 1934 | 106.6 | 170.0 | 70.5   | 0.0   | 0.0    | 7.8          | 1.9   | 0.0     | 356.8  |
| 1935 | 124.1 | 184.6 | 62.8   | 0.0   | 0.0    | 8.9          | 2.2   | 0.0     | 382.6  |
| 1936 | 101.9 | 109.4 | 66.7   | 0.0   | 0.0    | 10.0         | 2.2   | 0.0     | 290.2  |
| 1937 | 81.1  | 89.7  | 80.8   | 0.0   | 0.0    | 11.9         | 4.5   | 0.0     | 267.9  |
| 1938 | 103.7 | 63.7  | 68.2   | 0.1   | 0.0    | 11.7         | 3.8   | 0.0     | 251.1  |
| 1939 | 109.5 | 84.6  | 70.6   | 0.1   | 0.0    | 10.2         | 3.3   | 0.0     | 278.2  |
| 1940 | 86.1  | 95.7  | 55.8   | 0.2   | 0.0    | 14.7         | 2.1   | 0.0     | 254.6  |
| 1941 | 66.7  | 97.3  | 43.3   | 0.2   | 0.0    | 13.6         | 2.0   | 0.0     | 223.0  |
| 1942 | 30.3  | 43.3  | 11.2   | 0.3   | 0.0    | 7.2          | 1.0   | 0.0     | 93.3   |
| 1943 | 39.1  | 30.8  | 116.8  | 1.2   | 0.0    | 6.9          | 1.0   | 0.0     | 195.8  |
| 1944 | 27.6  | 4.2   | 515.6  | 2.0   | 0.0    | 5.7          | 0.8   | 0.0     | 556.0  |
| 1945 | 44.2  | 8.7   | 1084.5 | 2.5   | 0.0    | 7.6          | 1.1   | 0.0     | 1148.5 |
| 1946 | 38.2  | 16.4  | 817.3  | 1.8   | 0.0    | 13.0         | 1.9   | 0.0     | 888.5  |
| 1947 | 66.2  | 16.6  | 566.8  | 1.6   | 0.0    | 10.3         | 6.9   | 0.0     | 668.3  |
| 1948 | 20.0  | 23.9  | 465.5  | 3.2   | 0.0    | 20.5         | 20.2  | 0.0     | 553.3  |
| 1949 | 20.1  | 27.7  | 544.7  | 3.4   | 0.0    | 26.6         | 26.1  | 0.0     | 648.7  |
| 1950 | 28.7  | 24.0  | 684.1  | 2.2   | 0.0    | 32.4         | 22.4  | 0.0     | 793.8  |
| 1951 | 18.7  | 28.1  | 1107.6 | 3.1   | 0.0    | 37.0         | 18.9  | 0.0     | 1213.4 |
| 1952 | 14.5  | 20.6  | 1132.4 | 4.5   | 0.0    | 32.2         | 29.9  | 0.0     | 1234.1 |
| 1953 | 5.3   | 14.7  | 1357.7 | 2.6   | 0.0    | 27.5         | 32.3  | 0.0     | 1440.1 |
| 1954 | 9.8   | 21.0  | 1278.5 | 11.6  | 0.0    | 34.1         | 66.9  | 0.0     | 1421.9 |
| 1955 | 4.2   | 24.2  | 1291.8 | 10.6  | 0.0    | 40.7         | 99.7  | 0.0     | 1471.2 |
| 1956 | 6.1   | 26.2  | 1444.1 | 24.9  | 0.0    | 45.4         | 117.5 | 0.0     | 1664.1 |
| 1957 | 4.2   | 24.5  | 1545.0 | 13.4  | 0.0    | 52.4         | 77.8  | 0.0     | 1717.3 |
| 1958 | 7.7   | 20.7  | 1820.7 | 4.2   | 0.0    | 71.5         | 58.7  | 0.0     | 1983.4 |
| 1959 | 6.2   | 20.4  | 1545.0 | 3.9   | 0.0    | 56.3         | 37.5  | 0.0     | 1669.3 |
| 1960 | 9.9   | 22.3  | 1248.0 | 8.9   | 0.0    | 51.6         | 45.7  | 0.0     | 1386.3 |
| 1961 | 6.4   | 21.1  | 985.9  | 7.9   | 0.0    | 31.5         | 50.9  | 0.0     | 1103.8 |
| 1962 | 6.6   | 18.2  | 922.6  | 8.5   | 0.0    | 44.1         | 50.6  | 0.0     | 1050.6 |
| 1963 | 6.0   | 26.7  | 1082.1 | 18.0  | 0.0    | 36.5         | 43.5  | 0.0     | 1212.7 |
| 1964 | 2.7   | 22.3  | 767.4  | 7.7   | 0.0    | 48.3         | 56.8  | 0.0     | 905.1  |
| 1965 | 4.5   | 28.0  | 848.2  | 3.4   | 0.0    | 45.9         | 70.7  | 0.0     | 1000.7 |
| 1966 | 19.6  | 23.4  | 1899.6 | 3.0   | 0.0    | 66.7         | 116.6 | 0.0     | 2128.9 |
| 1967 | 19.9  | 28.3  | 2539.6 | 4.0   | 0.0    | 60.6         | 133.0 | 0.0     | 2785.4 |
| 1968 | 9.6   | 27.1  | 1525.4 | 2.6   | 0.0    | 63.9         | 138.5 | 0.0     | 1767.1 |
| 1969 | 19.7  | 20.9  | 708.5  | 2.6   | 2.9    | 57.4         | 150.2 | 0.0     | 962.2  |
| 1970 | 24.2  | 14.2  | 843.3  | 2.0   | 1.9    | 66.6         | 212.8 | 0.0     | 1164.9 |
| 1971 | 33.2  | 14.9  | 726.6  | 2.1   | 2.3    | 55.7         | 182.2 | 0.0     | 1016.9 |
| 1972 | 53.0  | 23.4  | 1077.9 | 1.1   | 2.1    | 61.4         | 222.8 | 0.0     | 1441.8 |
| 1973 | 45.5  | 21.5  | 2494.4 | 1.0   | 5.7    | 81.9         | 280.5 | 0.0     | 2930.3 |
| 1974 | 79.1  | 16.0  | 2843.2 | 0.9   | 15.4   | 96.5         | 341.0 | 0.0     | 3392.1 |
| 1975 | 46.3  | 24.8  | 2501.2 | 1.9   | 15.5   | 87.9         | 310.1 | 0.0     | 2987.7 |
| 1976 | 80.2  | 29.0  | 2548.4 | 1.3   | 14.1   | 94.5         | 278.5 | 0.0     | 3046.1 |
| 1977 | 63.2  | 21.8  | 1869.1 | 0.5   | 15.7   | 86.0         | 238.2 | 0.0     | 2294.4 |
| 1978 | 138.7 | 30.4  | 1293.1 | 0.6   | 25.8   | 102.1        | 211.6 | 0.0     | 1802.3 |
| 1979 | 131.4 | 45.2  | 2004.1 | 0.8   | 53.5   | 117.9        | 330.2 | 0.0     | 2683.1 |
| 1980 | 53.4  | 42.4  | 2720.1 | 2.6   | 45.4   | 64.4         | 191.5 | 0.0     | 3119.9 |
| 1981 | 87.9  | 44.9  | 2281.5 | 5.8   | 72.5   | 61.5         | 210.7 | 0.0     | 2764.8 |
| 1982 | 289.3 | 68.8  | 1671.2 | 28.2  | 85.4   | 179.1        | 210.0 | 0.0     | 2531.9 |
| 1983 | 56.8  | 35.0  | 1856.7 | 26.4  | 357.6  | 99.6         | 62.5  | 0.0     | 2494.6 |
| 1984 | 67.1  | 53.6  | 2334.5 | 3.1   | 236.0  | 136.6        | 19.0  | 0.0     | 2850.0 |
| 1985 | 256.7 | 28.1  | 1791.8 | 3.3   | 719.4  | 163.6        | 227.8 | 0.0     | 3190.8 |
| 1986 | 331.8 | 12.6  | 1251.8 | 2.3   | 1162.7 | 277.7        | 117.8 | 0.0     | 3156.6 |
| 1987 | 156.9 | 16.1  | 1311.5 | 0.8   | 465.1  | 114.3        | 3.0   | 0.0     | 2067.7 |
| 1988 | 274.8 | 64.1  | 1779.1 | 8.6   | 289.3  | 354.0        | 35.2  | 0.0     | 2805.0 |

| Year           | NoCA<br>HKL | SoCA<br>HKL | CA<br>TWL | OR_WA<br>Comm | CA<br>NET | NoCA<br>OR<br>WA Rec | SoCA<br>Rec | TWL<br>discard | Grand<br>Total |
|----------------|-------------|-------------|-----------|---------------|-----------|----------------------|-------------|----------------|----------------|
| 1989           | 218.4       | 208.0       | 2380.3    | 4.7           | 361.3     | 178.1                | 107.6       | 0.0            | 3458.4         |
| 1990           | 192.0       | 39.1        | 2370.1    | 3.1           | 364.5     | 184.8                | 40.2        | 0.0            | 3194.0         |
| 1991           | 489.3       | 120.5       | 2810.2    | 5.2           | 333.8     | 154.2                | 31.8        | 0.0            | 3945.1         |
| 1992           | 1005.9      | 46.5        | 1319.8    | 13.4          | 296.0     | 124.0                | 23.5        | 0.0            | 2829.1         |
| 1993           | 814.4       | 36.7        | 1280.2    | 9.9           | 238.8     | 93.0                 | 14.9        | 0.0            | 2487.9         |
| 1994           | 477.9       | 7.0         | 1261.8    | 19.0          | 107.7     | 62.4                 | 21.4        | 0.0            | 1957.1         |
| 1995           | 319.0       | 5.8         | 1624.5    | 10.0          | 93.6      | 31.8                 | 9.0         | 0.0            | 2093.7         |
| 1996           | 247.3       | 6.8         | 1518.4    | 9.9           | 57.7      | 20.6                 | 12.2        | 0.0            | 1873.0         |
| 1997           | 318.2       | 18.2        | 1608.0    | 11.0          | 82.9      | 72.8                 | 1.0         | 0.0            | 2112.3         |
| 1998           | 204.8       | 4.0         | 1131.9    | 19.9          | 77.6      | 1.0                  | 6.5         | 0.0            | 1445.8         |
| 1999           | 101.3       | 2.9         | 835.6     | 5.5           | 9.7       | 18.4                 | 6.1         | 0.0            | 979.5          |
| 2000           | 46.9        | 0.5         | 400.3     | 0.9           | 6.1       | 33.8                 | 7.8         | 0.0            | 496.4          |
| 2001           | 24.4        | 0.8         | 306.5     | 0.7           | 4.9       | 50.6                 | 1.3         | 0.0            | 389.2          |
| 2002           | 2.6         | 0.8         | 285.4     | 0.3           | 0.2       | 5.9                  | 7.0         | 0.0            | 302.2          |
| 2003           | 0.1         | 0.1         | 27.3      | 1.6           | 0.1       | 0.0                  | 0.3         | 0.0            | 29.5           |
| 2004           | 2.9         | 0.2         | 90.2      | 0.0           | 0.9       | 0.0                  | 6.0         | 0.0            | 100.2          |
| 2005           | 3.2         | 0.2         | 117.9     | 0.1           | 0.1       | 1.0                  | 7.8         | 0.0            | 130.3          |
| 2006           | 6.1         | 0.1         | 164.1     | 0.0           | 0.2       | 0.1                  | 1.6         | 0.0            | 172.2          |
| 2007           | 4.1         | 0.3         | 123.5     | 0.0           | 0.2       | 0.1                  | 6.6         | 0.0            | 134.9          |
| 2008           | 4.9         | 1.0         | 147.3     | 0.0           | 0.1       | 0.0                  | 2.9         | 0.0            | 156.2          |
| 2009           | 0.6         | 0.3         | 304.9     | 1.6           | 0.0       | 0.0                  | 2.1         | 0.0            | 309.5          |
| 2010           | 0.1         | 0.1         | 381.4     | 0.4           | 0.0       | 0.0                  | 2.8         | 0.0            | 384.9          |
| 2011           | 0.7         | 0.1         | 292.4     | 1.3           | 0.0       | 0.0                  | 5.3         | 25.3           | 325.1          |
| 2012           | 1.0         | 0.2         | 235.0     | 0.6           | 0.0       | 0.0                  | 7.7         | 54.4           | 298.9          |
| 2013           | 0.8         | 0.3         | 322.7     | 1.8           | 0.0       | 0.0                  | 7.2         | 74.1           | 407.0          |
| 2014           | 1.0         | 0.3         | 274.6     | 1.1           | 0.0       | 0.0                  | 7.9         | 47.0           | 331.9          |
| 2015           | 0.9         | 0.2         | 176.1     | 1.8           | 0.0       | 0.0                  | 5.8         | 20.6           | 205.6          |
| 2016           | 0.4         | 0.1         | 76.6      | 4.6           | 0.0       | 0.0                  | 5.4         | 3.3            | 90.4           |
| 2017           | 2.7         | 0.2         | 157.4     | 56.7          | 0.0       | 0.1                  | 2.5         | 10.5           | 230.2          |
| 2018           | 2.5         | 0.4         | 344.3     | 17.4          | 0.0       | 0.0                  | 2.0         | 24.2           | 390.8          |
| 2019           | 13.7        | 0.3         | 530.6     | 34.8          | 0.0       | 0.1                  | 5.8         | 55.7           | 641.1          |
| 2020           | 19.8        | 0.4         | 643.3     | 34.5          | 0.0       | 0.1                  | 1.6         | 65.4           | 765.1          |
| 2021           | 27.1        | 1.3         | 700.7     | 46.1          | 0.1       | 0.2                  | 3.7         | 83.0           | 862.2          |
| 2022           | 37.9        | 1.7         | 740.4     | 21.7          | 0.0       | 1.1                  | 3.6         | 59.7           | 866.2          |
| 2023           | 59.9        | 2.2         | 928.1     | 18.0          | 0.0       | 146.1                | 34.3        | 74.2           | 1262.9         |
| 2024           | 66.2        | 3.3         | 936.0     | 8.9           | 0.0       | 56.0                 | 35.8        | 87.0           | 1193.2         |
| Grand<br>Total | 13953.7     | 11657.7     | 92960.6   | 624.1         | 5624.7    | 4685.1               | 5639.2      | 684.4          | 135829.5       |
| % of<br>Total  | 10.3%       | 8.6%        | 68.4%     | 0.5%          | 4.1%      | 3.4%                 | 4.2%        | 0.5%           | 100%           |

Table 3: Length composition sample sizes for fishery fleets. See text for descriptions of sample sizes. See section 2.1.3 for details.

| Year | Commercial<br>No. CA HKL |         | Commercial<br>So. CA HKL |         | Commercial<br>CA Trawl |         | Commercial<br>Oregon |         | Commercial<br>CA Net |         | WCGOP<br>IFQ Trawl Discard |         | Recreational<br>No. CA, OR, WA |         | Recreational<br>So. CA |         |
|------|--------------------------|---------|--------------------------|---------|------------------------|---------|----------------------|---------|----------------------|---------|----------------------------|---------|--------------------------------|---------|------------------------|---------|
|      | Samp                     | Lengths | Samp                     | Lengths | Samp                   | Lengths | Samp                 | Lengths | Samp                 | Lengths | Hauls                      | Lengths | Trips                          | Lengths | Trips                  | Lengths |
| 1975 | 0                        | 0       | 0                        | 0       | 0                      | 0       | 0                    | 0       | 0                    | 0       | 0                          | 0       | 0                              | 0       | 106                    | 3258    |
| 1976 | 0                        | 0       | 0                        | 0       | 0                      | 0       | 0                    | 0       | 0                    | 0       | 0                          | 0       | 0                              | 0       | 178                    | 8875    |
| 1977 | 0                        | 0       | 0                        | 0       | 0                      | 0       | 0                    | 0       | 0                    | 0       | 0                          | 0       | 0                              | 0       | 111                    | 6524    |
| 1978 | 0                        | 0       | 0                        | 0       | 60                     | 1024    | 0                    | 0       | 0                    | 0       | 0                          | 0       | 0                              | 0       | 123                    | 8128    |
| 1979 | 10                       | 280     | 0                        | 0       | 70                     | 1628    | 0                    | 0       | 0                    | 0       | 0                          | 0       | 0                              | 0       | 0                      | 0       |
| 1980 | 4                        | 67      | 0                        | 0       | 60                     | 1027    | 0                    | 0       | 0                    | 0       | 0                          | 0       | 12                             | 180     | 22                     | 666     |
| 1981 | 4                        | 97      | 0                        | 0       | 41                     | 619     | 0                    | 0       | 0                    | 0       | 0                          | 0       | 5                              | 93      | 21                     | 768     |
| 1982 | 10                       | 211     | 0                        | 0       | 78                     | 1620    | 0                    | 0       | 0                    | 0       | 0                          | 0       | 8                              | 209     | 33                     | 522     |
| 1983 | 3                        | 58      | 0                        | 0       | 109                    | 2080    | 0                    | 0       | 11                   | 151     | 0                          | 0       | 9                              | 218     | 11                     | 451     |
| 1984 | 1                        | 17      | 5                        | 67      | 166                    | 4587    | 0                    | 0       | 24                   | 470     | 0                          | 0       | 16                             | 689     | 8                      | 108     |
| 1985 | 9                        | 275     | 4                        | 65      | 211                    | 6631    | 0                    | 0       | 34                   | 648     | 0                          | 0       | 28                             | 1792    | 50                     | 1651    |
| 1986 | 7                        | 170     | 3                        | 45      | 127                    | 3766    | 0                    | 0       | 26                   | 540     | 0                          | 0       | 23                             | 1971    | 43                     | 1777    |
| 1987 | 1                        | 26      | 5                        | 95      | 138                    | 4163    | 0                    | 0       | 23                   | 406     | 0                          | 0       | 19                             | 427     | 47                     | 4073    |
| 1988 | 0                        | 0       | 3                        | 100     | 144                    | 4441    | 0                    | 0       | 19                   | 330     | 0                          | 0       | 44                             | 4009    | 50                     | 3331    |
| 1989 | 1                        | 16      | 9                        | 210     | 128                    | 4328    | 0                    | 0       | 17                   | 402     | 0                          | 0       | 57                             | 3833    | 55                     | 4685    |
| 1990 | 2                        | 54      | 0                        | 0       | 150                    | 4804    | 0                    | 0       | 42                   | 722     | 0                          | 0       | 15                             | 608     | 0                      | 0       |
| 1991 | 39                       | 1799    | 0                        | 0       | 155                    | 7450    | 0                    | 0       | 19                   | 457     | 0                          | 0       | 14                             | 420     | 0                      | 0       |
| 1992 | 74                       | 2647    | 1                        | 14      | 85                     | 3697    | 0                    | 0       | 31                   | 795     | 0                          | 0       | 33                             | 1788    | 0                      | 0       |
| 1993 | 74                       | 3539    | 0                        | 0       | 92                     | 4480    | 0                    | 0       | 28                   | 974     | 0                          | 0       | 34                             | 2201    | 5                      | 28      |
| 1994 | 69                       | 3576    | 0                        | 0       | 89                     | 3640    | 0                    | 0       | 30                   | 860     | 0                          | 0       | 23                             | 1416    | 11                     | 79      |
| 1995 | 16                       | 705     | 0                        | 0       | 79                     | 3539    | 0                    | 0       | 26                   | 722     | 0                          | 0       | 14                             | 631     | 2                      | 16      |
| 1996 | 22                       | 1046    | 3                        | 42      | 92                     | 3262    | 0                    | 0       | 12                   | 315     | 0                          | 0       | 18                             | 734     | 7                      | 29      |
| 1997 | 29                       | 1252    | 5                        | 101     | 109                    | 4411    | 0                    | 0       | 11                   | 430     | 0                          | 0       | 19                             | 611     | 5                      | 7       |
| 1998 | 21                       | 810     | 3                        | 21      | 88                     | 2994    | 2                    | 82      | 7                    | 263     | 0                          | 0       | 9                              | 315     | 5                      | 17      |
| 1999 | 8                        | 410     | 0                        | 0       | 66                     | 2980    | 0                    | 0       | 0                    | 0       | 0                          | 0       | 5                              | 532     | 13                     | 68      |
| 2000 | 9                        | 364     | 0                        | 0       | 37                     | 1668    | 0                    | 0       | 0                    | 0       | 0                          | 0       | 5                              | 198     | 14                     | 95      |
| 2001 | 9                        | 395     | 0                        | 0       | 42                     | 2021    | 3                    | 56      | 0                    | 0       | 0                          | 0       | 4                              | 212     | 2                      | 89      |
| 2002 | 2                        | 63      | 0                        | 0       | 45                     | 1822    | 0                    | 0       | 0                    | 0       | 0                          | 0       | 4                              | 140     | 8                      | 98      |
| 2003 | 0                        | 0       | 0                        | 0       | 13                     | 565     | 1                    | 15      | 0                    | 0       | 0                          | 0       | 1                              | 2       | 0                      | 0       |
| 2004 | 0                        | 0       | 0                        | 0       | 42                     | 1712    | 0                    | 0       | 0                    | 0       | 0                          | 0       | 1                              | 1       | 49                     | 298     |
| 2005 | 0                        | 0       | 0                        | 0       | 15                     | 442     | 1                    | 30      | 1                    | 25      | 0                          | 0       | 2                              | 5       | 53                     | 288     |
| 2006 | 3                        | 70      | 0                        | 0       | 21                     | 634     | 0                    | 0       | 0                    | 0       | 49                         | 210     | 1                              | 1       | 61                     | 332     |
| 2007 | 5                        | 150     | 0                        | 0       | 26                     | 984     | 3                    | 3       | 0                    | 0       | 101                        | 440     | 5                              | 7       | 59                     | 482     |
| 2008 | 6                        | 118     | 2                        | 46      | 47                     | 1331    | 0                    | 0       | 0                    | 0       | 103                        | 445     | 5                              | 27      | 47                     | 276     |
| 2009 | 0                        | 0       | 0                        | 0       | 44                     | 1544    | 10                   | 224     | 0                    | 0       | 129                        | 547     | 2                              | 2       | 63                     | 231     |
| 2010 | 0                        | 0       | 1                        | 16      | 40                     | 1450    | 7                    | 77      | 0                    | 0       | 60                         | 247     | 1                              | 2       | 73                     | 356     |
| 2011 | 0                        | 0       | 0                        | 0       | 13                     | 556     | 4                    | 36      | 0                    | 0       | 196                        | 894     | 2                              | 2       | 85                     | 633     |
| 2012 | 0                        | 0       | 0                        | 0       | 29                     | 1249    | 8                    | 46      | 0                    | 0       | 261                        | 1216    | 5                              | 5       | 67                     | 703     |
| 2013 | 0                        | 0       | 0                        | 0       | 28                     | 1101    | 10                   | 42      | 0                    | 0       | 409                        | 1919    | 3                              | 11      | 75                     | 730     |
| 2014 | 0                        | 0       | 2                        | 53      | 38                     | 1344    | 11                   | 41      | 0                    | 0       | 577                        | 2658    | 2                              | 6       | 57                     | 663     |
| 2015 | 0                        | 0       | 3                        | 65      | 39                     | 1447    | 23                   | 162     | 0                    | 0       | 430                        | 1699    | 6                              | 15      | 35                     | 427     |
| 2016 | 0                        | 0       | 1                        | 11      | 33                     | 1387    | 12                   | 146     | 0                    | 0       | 153                        | 526     | 2                              | 2       | 39                     | 433     |
| 2017 | 0                        | 0       | 1                        | 14      | 33                     | 1260    | 35                   | 678     | 0                    | 0       | 135                        | 505     | 6                              | 13      | 42                     | 191     |
| 2018 | 0                        | 0       | 0                        | 0       | 64                     | 2995    | 48                   | 452     | 0                    | 0       | 288                        | 1229    | 5                              | 14      | 42                     | 231     |
| 2019 | 2                        | 72      | 0                        | 0       | 77                     | 4554    | 69                   | 645     | 0                    | 0       | 441                        | 1952    | 9                              | 14      | 51                     | 318     |
| 2020 | 1                        | 24      | 1                        | 12      | 87                     | 3692    | 20                   | 176     | 0                    | 0       | 334                        | 1504    | 0                              | 0       | 3                      | 54      |
| 2021 | 6                        | 195     | 1                        | 18      | 70                     | 2014    | 39                   | 310     | 0                    | 0       | 413                        | 1854    | 7                              | 17      | 20                     | 177     |
| 2022 | 6                        | 164     | 0                        | 0       | 32                     | 1495    | 35                   | 479     | 0                    | 0       | 402                        | 1742    | 21                             | 98      | 41                     | 208     |
| 2023 | 1                        | 11      | 1                        | 12      | 38                     | 1559    | 28                   | 379     | 0                    | 0       | 361                        | 1871    | 129                            | 3137    | 111                    | 999     |
| 2024 | 3                        | 50      | 3                        | 50      | 49                     | 2042    | 25                   | 261     | 0                    | 0       | 0                          | 0       | 58                             | 1029    | 102                    | 1322    |



Table 4: Age composition sample sizes (number of fish) for fishery-dependent sources by fleet, year, and sex.

| fleet name | year | females | males | unsexed | total | fleet name     | year | females | males | unsexed | total |
|------------|------|---------|-------|---------|-------|----------------|------|---------|-------|---------|-------|
| NoCA_HKL   | 1980 | 2       | 0     | 0       | 2     | CA_TWL         | 1999 | 1464    | 613   | 0       | 2077  |
| NoCA_HKL   | 1983 | 7       | 1     | 0       | 8     | CA_TWL         | 2000 | 707     | 288   | 0       | 995   |
| NoCA_HKL   | 1985 | 99      | 3     | 0       | 102   | CA_TWL         | 2001 | 448     | 318   | 0       | 766   |
| NoCA_HKL   | 1986 | 123     | 5     | 0       | 128   | CA_TWL         | 2002 | 729     | 294   | 0       | 1023  |
| NoCA_HKL   | 1987 | 14      | 3     | 0       | 17    | CA_TWL         | 2003 | 201     | 97    | 0       | 298   |
| NoCA_HKL   | 1988 | 4       | 1     | 0       | 5     | CA_TWL         | 2004 | 661     | 285   | 0       | 946   |
| NoCA_HKL   | 1989 | 9       | 0     | 0       | 9     | CA_TWL         | 2005 | 286     | 63    | 0       | 349   |
| NoCA_HKL   | 1990 | 12      | 3     | 0       | 15    | CA_TWL         | 2007 | 340     | 118   | 0       | 458   |
| NoCA_HKL   | 1991 | 285     | 132   | 0       | 417   | CA_TWL         | 2008 | 363     | 72    | 0       | 435   |
| NoCA_HKL   | 1992 | 582     | 163   | 0       | 745   | CA_TWL         | 2009 | 599     | 106   | 0       | 705   |
| NoCA_HKL   | 1993 | 369     | 63    | 0       | 432   | CA_TWL         | 2010 | 287     | 15    | 0       | 302   |
| NoCA_HKL   | 1994 | 199     | 26    | 0       | 225   | CA_TWL         | 2011 | 4       | 2     | 0       | 6     |
| NoCA_HKL   | 1995 | 185     | 64    | 0       | 249   | CA_TWL         | 2012 | 210     | 137   | 0       | 347   |
| NoCA_HKL   | 1996 | 125     | 39    | 0       | 164   | CA_TWL         | 2013 | 315     | 92    | 0       | 407   |
| NoCA_HKL   | 1997 | 198     | 10    | 0       | 208   | CA_TWL         | 2014 | 258     | 42    | 0       | 300   |
| NoCA_HKL   | 1998 | 263     | 59    | 0       | 322   | CA_TWL         | 2019 | 58      | 18    | 0       | 76    |
| NoCA_HKL   | 1999 | 147     | 18    | 0       | 165   | CA_TWL         | 2020 | 61      | 42    | 0       | 103   |
| NoCA_HKL   | 2000 | 117     | 44    | 0       | 161   | CA_TWL         | 2021 | 44      | 16    | 0       | 60    |
| NoCA_HKL   | 2001 | 73      | 55    | 0       | 128   | CA_TWL         | 2022 | 42      | 17    | 0       | 59    |
| NoCA_HKL   | 2002 | 10      | 28    | 0       | 38    | CA_TWL         | 2023 | 46      | 9     | 0       | 55    |
| NoCA_HKL   | 2003 | 3       | 0     | 0       | 3     | CA_TWL         | 2024 | 42      | 5     | 0       | 47    |
| NoCA_HKL   | 2007 | 46      | 2     | 0       | 48    | OR_WA_Comm     | 2019 | 33      | 7     | 0       | 40    |
| NoCA_HKL   | 2008 | 24      | 5     | 0       | 29    | OR_WA_Comm     | 2020 | 35      | 5     | 0       | 40    |
| NoCA_HKL   | 2009 | 1       | 0     | 0       | 1     | OR_WA_Comm     | 2021 | 36      | 4     | 0       | 40    |
| CA_TWL     | 1978 | 447     | 112   | 0       | 559   | OR_WA_Comm     | 2022 | 32      | 8     | 0       | 40    |
| CA_TWL     | 1979 | 270     | 60    | 0       | 330   | OR_WA_Comm     | 2023 | 34      | 6     | 0       | 40    |
| CA_TWL     | 1980 | 717     | 335   | 0       | 1052  | OR_WA_Comm     | 2024 | 35      | 5     | 0       | 40    |
| CA_TWL     | 1981 | 475     | 224   | 0       | 699   | CA_NET         | 1983 | 64      | 4     | 0       | 68    |
| CA_TWL     | 1982 | 825     | 392   | 0       | 1217  | CA_NET         | 1984 | 41      | 0     | 0       | 41    |
| CA_TWL     | 1983 | 1721    | 581   | 0       | 2302  | CA_NET         | 1985 | 218     | 46    | 0       | 264   |
| CA_TWL     | 1984 | 2539    | 1035  | 0       | 3574  | CA_NET         | 1986 | 358     | 53    | 0       | 411   |
| CA_TWL     | 1985 | 2126    | 1145  | 0       | 3271  | CA_NET         | 1987 | 328     | 38    | 0       | 366   |
| CA_TWL     | 1986 | 1285    | 712   | 0       | 1997  | CA_NET         | 1988 | 161     | 58    | 0       | 219   |
| CA_TWL     | 1987 | 1638    | 880   | 0       | 2518  | CA_NET         | 1989 | 273     | 41    | 0       | 314   |
| CA_TWL     | 1988 | 1472    | 938   | 0       | 2410  | CA_NET         | 1990 | 320     | 110   | 0       | 430   |
| CA_TWL     | 1989 | 1631    | 924   | 0       | 2555  | CA_NET         | 1991 | 74      | 22    | 0       | 96    |
| CA_TWL     | 1990 | 978     | 700   | 0       | 1678  | CA_NET         | 1992 | 317     | 85    | 0       | 402   |
| CA_TWL     | 1991 | 962     | 636   | 0       | 1598  | CA_NET         | 1993 | 158     | 29    | 0       | 187   |
| CA_TWL     | 1992 | 1363    | 714   | 0       | 2077  | CA_NET         | 1994 | 154     | 38    | 0       | 192   |
| CA_TWL     | 1993 | 1325    | 680   | 0       | 2005  | CA_NET         | 1995 | 59      | 1     | 0       | 60    |
| CA_TWL     | 1994 | 448     | 285   | 0       | 733   | CA_NET         | 1996 | 36      | 1     | 0       | 37    |
| CA_TWL     | 1995 | 895     | 502   | 0       | 1397  | CA_NET         | 1997 | 58      | 5     | 0       | 63    |
| CA_TWL     | 1996 | 455     | 343   | 0       | 798   | CA_NET         | 1998 | 85      | 8     | 0       | 93    |
| CA_TWL     | 1997 | 1095    | 618   | 0       | 1713  | NoCA_OR_WA_Rec | 2023 | 0       | 0     | 59      | 59    |
| CA_TWL     | 1998 | 1486    | 646   | 0       | 2132  | NoCA_OR_WA_Rec | 2024 | 0       | 0     | 48      | 48    |

Table 5: Description of data filtering steps and resulting sample sizes (number of tows and total count of chilipepper rockfish) used for the CalCOFI larval abundance index.

| Description                                                        | Number of Tows | Number of chilipepper |
|--------------------------------------------------------------------|----------------|-----------------------|
| All tows C1 and CB tows, excluding P net sides prior to 1997       | 46,496         | 3,251                 |
| Exclude SCOOS stations                                             | 45,969         | 3,251                 |
| Include only line $\geq$ 60 & line $\leq$ 93.3 & station $\leq$ 80 | 20,390         | 3,148                 |
| Exclude years 1985-1990                                            | 19,052         | 3,147                 |
| Excluded lines $\leq$ 73.3 for years 1959 and earlier              | 18,145         | 3,146                 |
| Include only months 11, 12, 1, 2, 3, 4                             | 10,846         | 3,023                 |
| Average S and P net sides for same tow                             | 10,234         | 2,917.5               |

Table 6: Length composition sample sizes for the triennial bottom trawl survey. Data from 1977 are not included in the 2025 stock assessment.

| year | sex_grouped | n_tows | n    | n_stewart_hamel | input_n |
|------|-------------|--------|------|-----------------|---------|
| 1977 | all         | 50     | 4806 | 121             | 121     |
| 1977 | sexed       | 50     | 4806 | 121             | 121     |
| 1977 | unsexed     | 0      | 0    | 0               | 0       |
| 1980 | all         | 12     | 1151 | 29              | 29      |
| 1980 | sexed       | 12     | 1151 | 29              | 29      |
| 1980 | unsexed     | 0      | 0    | 0               | 0       |
| 1983 | all         | 17     | 1526 | 41              | 41      |
| 1983 | sexed       | 17     | 1526 | 41              | 41      |
| 1983 | unsexed     | 0      | 0    | 0               | 0       |
| 1986 | all         | 14     | 1847 | 34              | 34      |
| 1986 | sexed       | 14     | 1847 | 34              | 34      |
| 1986 | unsexed     | 0      | 0    | 0               | 0       |
| 1989 | all         | 88     | 6798 | 213             | 213     |
| 1989 | sexed       | 88     | 6624 | 213             | 213     |
| 1989 | unsexed     | 3      | 174  | 7               | 7       |
| 1992 | all         | 53     | 3056 | 128             | 128     |
| 1992 | sexed       | 52     | 3055 | 126             | 126     |
| 1992 | unsexed     | 1      | 1    | 2               | 1       |
| 1995 | all         | 73     | 3985 | 177             | 177     |
| 1995 | sexed       | 73     | 3721 | 177             | 177     |
| 1995 | unsexed     | 3      | 264  | 7               | 7       |
| 1998 | all         | 81     | 3992 | 196             | 196     |
| 1998 | sexed       | 75     | 3668 | 182             | 182     |
| 1998 | unsexed     | 13     | 324  | 31              | 31      |
| 2001 | all         | 76     | 3151 | 184             | 184     |
| 2001 | sexed       | 73     | 3010 | 177             | 177     |
| 2001 | unsexed     | 5      | 141  | 12              | 12      |
| 2004 | all         | 88     | 4656 | 213             | 213     |
| 2004 | sexed       | 87     | 4537 | 211             | 211     |
| 2004 | unsexed     | 7      | 119  | 17              | 17      |

Table 7: Length composition sample sizes for WCGBTS survey.

| year | sex_grouped | n_tows | n    | n_stewart_hamel | input_n |
|------|-------------|--------|------|-----------------|---------|
| 2003 | all         | 82     | 2484 | 199             | 199     |
| 2003 | sexed       | 73     | 2348 | 177             | 177     |
| 2003 | unsexed     | 13     | 136  | 31              | 31      |
| 2004 | all         | 79     | 3283 | 191             | 191     |
| 2004 | sexed       | 77     | 3214 | 187             | 187     |
| 2004 | unsexed     | 7      | 69   | 17              | 17      |
| 2005 | all         | 86     | 3704 | 208             | 208     |
| 2005 | sexed       | 84     | 3576 | 204             | 204     |
| 2005 | unsexed     | 7      | 128  | 17              | 17      |
| 2006 | all         | 69     | 2679 | 167             | 167     |
| 2006 | sexed       | 68     | 2613 | 165             | 165     |
| 2006 | unsexed     | 1      | 66   | 2               | 2       |
| 2007 | all         | 68     | 2495 | 165             | 165     |
| 2007 | sexed       | 66     | 2472 | 160             | 160     |
| 2007 | unsexed     | 2      | 23   | 4               | 4       |
| 2008 | all         | 80     | 2209 | 194             | 194     |
| 2008 | sexed       | 80     | 2192 | 194             | 194     |
| 2008 | unsexed     | 4      | 17   | 9               | 9       |
| 2009 | all         | 77     | 2111 | 187             | 187     |
| 2009 | sexed       | 63     | 1753 | 153             | 153     |
| 2009 | unsexed     | 17     | 358  | 41              | 41      |
| 2010 | all         | 106    | 2091 | 257             | 257     |
| 2010 | sexed       | 94     | 1666 | 228             | 228     |
| 2010 | unsexed     | 25     | 425  | 60              | 60      |
| 2011 | all         | 81     | 1058 | 196             | 196     |
| 2011 | sexed       | 76     | 980  | 184             | 184     |
| 2011 | unsexed     | 10     | 78   | 24              | 24      |
| 2012 | all         | 100    | 1249 | 243             | 243     |
| 2012 | sexed       | 92     | 1117 | 223             | 223     |
| 2012 | unsexed     | 18     | 132  | 43              | 43      |
| 2013 | all         | 93     | 1083 | 225             | 225     |
| 2013 | sexed       | 77     | 890  | 187             | 187     |
| 2013 | unsexed     | 21     | 193  | 51              | 51      |
| 2014 | all         | 124    | 1728 | 301             | 301     |
| 2014 | sexed       | 116    | 1607 | 281             | 281     |
| 2014 | unsexed     | 18     | 121  | 43              | 43      |
| 2015 | all         | 102    | 1031 | 247             | 247     |
| 2015 | sexed       | 91     | 891  | 221             | 221     |
| 2015 | unsexed     | 16     | 140  | 38              | 38      |
| 2016 | all         | 111    | 1445 | 269             | 269     |
| 2016 | sexed       | 94     | 1176 | 228             | 228     |
| 2016 | unsexed     | 22     | 269  | 53              | 53      |
| 2017 | all         | 93     | 905  | 225             | 225     |
| 2017 | sexed       | 88     | 867  | 213             | 213     |
| 2017 | unsexed     | 8      | 38   | 19              | 19      |
| 2018 | all         | 93     | 985  | 225             | 225     |
| 2018 | sexed       | 92     | 978  | 223             | 223     |
| 2018 | unsexed     | 3      | 7    | 7               | 7       |
| 2019 | all         | 52     | 659  | 126             | 126     |
| 2019 | sexed       | 51     | 658  | 123             | 123     |
| 2019 | unsexed     | 1      | 1    | 2               | 1       |
| 2021 | all         | 126    | 1382 | 306             | 306     |
| 2021 | sexed       | 99     | 1021 | 240             | 240     |
| 2021 | unsexed     | 34     | 361  | 82              | 82      |
| 2022 | all         | 107    | 1167 | 260             | 260     |
| 2022 | sexed       | 101    | 1085 | 245             | 245     |
| 2022 | unsexed     | 14     | 82   | 34              | 34      |
| 2023 | all         | 92     | 1022 | 223             | 223     |
| 2023 | sexed       | 81     | 858  | 196             | 196     |
| 2023 | unsexed     | 18     | 164  | 43              | 43      |
| 2024 | all         | 108    | 1168 | 262             | 262     |
| 2024 | sexed       | 93     | 1018 | 225             | 225     |
| 2024 | unsexed     | 22     | 150  | 53              | 53      |

Table 8: Age composition sample sizes from fishery-independent surveys used in the base model. See text for details regarding allocation of small, unsexed fish to sexed compositions.

| Survey           | Year | Female | Male  | Unsexed | N   |
|------------------|------|--------|-------|---------|-----|
| WCGBT_Survey     | 2003 | 339.5  | 323.5 | 0       | 663 |
| WCGBT_Survey     | 2004 | 421.5  | 321.5 | 0       | 743 |
| WCGBT_Survey     | 2005 | 477.5  | 354.5 | 0       | 832 |
| WCGBT_Survey     | 2006 | 349    | 247   | 0       | 596 |
| WCGBT_Survey     | 2007 | 344    | 246   | 0       | 590 |
| WCGBT_Survey     | 2008 | 374.5  | 322.5 | 0       | 697 |
| WCGBT_Survey     | 2009 | 315.5  | 300.5 | 0       | 616 |
| WCGBT_Survey     | 2010 | 403    | 403   | 0       | 806 |
| WCGBT_Survey     | 2011 | 312    | 335   | 0       | 647 |
| WCGBT_Survey     | 2012 | 473    | 360   | 0       | 833 |
| WCGBT_Survey     | 2013 | 377.5  | 305.5 | 0       | 683 |
| WCGBT_Survey     | 2014 | 455    | 418   | 0       | 873 |
| WCGBT_Survey     | 2015 | 356.5  | 251.5 | 0       | 608 |
| WCGBT_Survey     | 2016 | 399    | 321   | 0       | 720 |
| WCGBT_Survey     | 2017 | 293    | 247   | 0       | 540 |
| WCGBT_Survey     | 2018 | 280.5  | 219.5 | 0       | 500 |
| WCGBT_Survey     | 2019 | 211.5  | 137.5 | 0       | 349 |
| WCGBT_Survey     | 2021 | 253    | 247   | 0       | 500 |
| WCGBT_Survey     | 2022 | 276    | 230   | 0       | 506 |
| WCGBT_Survey     | 2023 | 297    | 209   | 0       | 506 |
| WCGBT_Survey     | 2024 | 270    | 237   | 0       | 507 |
| Triennial_Survey | 1983 | 340    | 394   | 0       | 734 |
| Triennial_Survey | 1992 | 135    | 111   | 0       | 246 |
| Triennial_Survey | 1998 | 197    | 240   | 0       | 437 |
| Triennial_Survey | 2001 | 252    | 233   | 0       | 485 |
| Triennial_Survey | 2004 | 340    | 291   | 0       | 631 |

Table 9: Summary of base model parameters.

| Parameter                                                                          | Number<br>Estimated | Bounds<br>(low, high)        | Prior Distribution<br>(Mean, SD) - Type | Point<br>Estimate | Transformed<br>Value | Std. Err.<br>(Pt. Est.) |
|------------------------------------------------------------------------------------|---------------------|------------------------------|-----------------------------------------|-------------------|----------------------|-------------------------|
| <b>General Biology</b>                                                             |                     |                              |                                         |                   |                      |                         |
| Natural mortality ( $M$ ) - <i>female</i>                                          | 1                   | (0.01, 0.5)                  | (-1.869, 0.31) - Lognormal              | 0.165             |                      | 0.012                   |
| Nat. mortality ( $M$ ) - <i>male (offset)</i>                                      | 1                   | (-0.5, 1)                    | -                                       | 0.266             | 0.216                | 0.045                   |
| Ln ( $R_0$ )                                                                       | 1                   | (8, 13)                      | -                                       | 10.032            | 22733.6              | 0.180                   |
| Steepness ( $h$ )                                                                  | 0                   | (0.201, 0.999)               | (0.72, 0.16) - "Full Beta"              | 0.720             |                      | -                       |
| <b>Growth</b>                                                                      |                     |                              |                                         |                   |                      |                         |
| Length at age 0 - <i>female</i>                                                    | 0                   | (5, 15)                      | -                                       | 7.300             |                      | -                       |
| Length at age 20 - <i>female</i>                                                   | 1                   | (44, 52)                     | -                                       | 47.901            |                      | 0.219                   |
| von Bertalnaffy k - <i>female</i>                                                  | 1                   | (0.15, 0.25)                 | -                                       | 0.197             |                      | 0.003                   |
| CV(L(age 0)) - <i>female</i>                                                       | 0                   | (0.01, 0.2)                  | -                                       | 0.105             |                      | -                       |
| CV(L(age 20)) - <i>female</i>                                                      | 1                   | (0.01, 0.15)                 | -                                       | 0.039             |                      | 0.003                   |
| Length at age 0 - <i>male (offset)</i>                                             | 0                   | (-0.6, 0)                    | -                                       | 0.000             | 7.300                | -                       |
| Length at age 20 - <i>male (offset)</i>                                            | 1                   | (-0.8, 0)                    | -                                       | -0.328            | 34.497               | 0.008                   |
| von Bertalnaffy k - <i>male (offset)</i>                                           | 1                   | (0.2, 1)                     | -                                       | 0.526             | 0.333                | 0.031                   |
| CV(L(age 0)) - <i>male (offset)</i>                                                | 0                   | (-1, 1)                      | -                                       | 0.236             | 0.133                | -                       |
| CV(L(age 20)) - <i>male (offset)</i>                                               | 0                   | (-1, 2)                      | -                                       | 0.100             | 0.043                | -                       |
| <b>Indices</b>                                                                     |                     |                              |                                         |                   |                      |                         |
| Extra SD - CalCOFI                                                                 | 1                   | (0, 1)                       |                                         | 0.355             |                      | 0.081                   |
| Extra SD - RREAS                                                                   | 0                   | (0, 1)                       | -                                       | 0.683             |                      | -                       |
| <b>Recruitment Deviations</b>                                                      |                     |                              |                                         |                   |                      |                         |
| SD of log-scale rec devs (sigma-R)                                                 | 0                   | (0, 2)                       |                                         | 1.00              |                      | -                       |
| <u>Main Recruitment Deviation Parameters</u>                                       |                     |                              |                                         | Min               | Max                  | maxSE                   |
| 1968-2024                                                                          | 57                  | (-4, 4)                      | -                                       | -2.252            | 2.477                | 0.906                   |
| <b>Selectivity (see separate table)</b>                                            |                     |                              |                                         |                   |                      |                         |
| <b>Summary of model parameters (see separate table for selectivity parameters)</b> |                     |                              |                                         |                   |                      |                         |
| Number of parameters in model                                                      | 164                 |                              |                                         |                   |                      |                         |
| Number of estimated parameters                                                     | 106                 | (including 12 forecast devs) |                                         |                   |                      |                         |
| Number within 1% of bound                                                          | 0                   |                              |                                         |                   |                      |                         |

Table 10: Log-scale catchability coefficients ('LnQ'), additive variance parameters ('Q\_extraSD') and selectivity parameters from the base model. All catchability coefficients ('LnQ') are analytical estimates. LnQ values for the CA\_TWL and NoCA\_OR\_WA\_Rec fleets are shown for reference, but these indices are not included in the likelihood (see main text for details).

| Parameter Label in SS3 (fleet # in parentheses) | Value   | Estimated | Phase | Min   | Max  | Parm     | StDev |
|-------------------------------------------------|---------|-----------|-------|-------|------|----------|-------|
| LnQ_base_CA_TWL(3)                              | -4.994  | —         | -1    | -15   | 0    | —        | —     |
| LnQ_base_NoCA_OR_WA_Rec(6)                      | -12.637 | —         | -1    | -15   | 0    | —        | —     |
| LnQ_base_WCGBT_Survey(9)                        | 0.590   | —         | -1    | -15   | 3    | —        | —     |
| LnQ_base_Triennial_Survey(10)                   | 0.219   | —         | -1    | -15   | 3    | —        | —     |
| LnQ_base_CalCOFI_Survey(11)                     | -3.776  | —         | -1    | -15   | 0    | —        | —     |
| Q_extraSD_CalCOFI_Survey(11)                    | 0.355   | Yes       | 1     | 0     | 1    | 0.081    | —     |
| LnQ_base_RREAS_YOY_Survey(12)                   | -5.050  | —         | -1    | -15   | 0    | —        | —     |
| Q_extraSD_RREAS_YOY_Survey(12)                  | 0.683   | —         | -1    | 0     | 1    | —        | —     |
| Size_DblN_peak_NoCA_HKL(1)                      | 40.9735 | Yes       | 3     | 10    | 59   | 2.35091  | —     |
| Size_DblN_top_logit_NoCA_HKL(1)                 | -6      | —         | -3    | -10   | 10   | —        | —     |
| Size_DblN_ascend_se_NoCA_HKL(1)                 | 4.39925 | Yes       | 3     | 0.01  | 12   | 0.32016  | —     |
| Size_DblN_descend_se_NoCA_HKL(1)                | 7       | —         | -3    | 0.01  | 12   | —        | —     |
| Size_DblN_start_logit_NoCA_HKL(1)               | -999    | —         | -3    | -1000 | -998 | —        | —     |
| Size_DblN_end_logit_NoCA_HKL(1)                 | 10      | —         | -3    | -12   | 12   | —        | —     |
| Size_DblN_peak_SoCA_HKL(2)                      | 23.7993 | Yes       | 3     | 8.5   | 59.5 | 0.90849  | —     |
| Size_DblN_top_logit_SoCA_HKL(2)                 | -6      | —         | -3    | -10   | 10   | —        | —     |
| Size_DblN_ascend_se_SoCA_HKL(2)                 | 1.2     | —         | -3    | 0.5   | 15   | —        | —     |
| Size_DblN_descend_se_SoCA_HKL(2)                | 7       | —         | -3    | 0.01  | 12   | —        | —     |
| Size_DblN_start_logit_SoCA_HKL(2)               | -999    | —         | -3    | -1000 | -998 | —        | —     |
| Size_DblN_end_logit_SoCA_HKL(2)                 | 10      | —         | -3    | -12   | 12   | —        | —     |
| Size_DblN_peak_CA_TWL(3)                        | 44.9044 | Yes       | 3     | 10    | 59   | 1.66004  | —     |
| Size_DblN_top_logit_CA_TWL(3)                   | -6      | —         | -3    | -10   | 10   | —        | —     |
| Size_DblN_ascend_se_CA_TWL(3)                   | 4.55625 | Yes       | 3     | 0.01  | 12   | 0.206183 | —     |
| Size_DblN_descend_se_CA_TWL(3)                  | 7       | —         | -3    | 0.01  | 12   | —        | —     |
| Size_DblN_start_logit_CA_TWL(3)                 | -999    | —         | -3    | -1000 | -998 | —        | —     |
| Size_DblN_end_logit_CA_TWL(3)                   | 10      | —         | -3    | -12   | 12   | —        | —     |
| Size_DblN_peak_OR_WA_Comm(4)                    | 42.7525 | Yes       | 3     | 10    | 59   | 6.38687  | —     |
| Size_DblN_top_logit_OR_WA_Comm(4)               | -6      | —         | -3    | -10   | 10   | —        | —     |
| Size_DblN_ascend_se_OR_WA_Comm(4)               | 4.55947 | Yes       | 3     | 0.01  | 12   | 0.871433 | —     |
| Size_DblN_descend_se_OR_WA_Comm(4)              | 7       | —         | -3    | 0.01  | 12   | —        | —     |
| Size_DblN_start_logit_OR_WA_Comm(4)             | -999    | —         | -3    | -1000 | -998 | —        | —     |
| Size_DblN_end_logit_OR_WA_Comm(4)               | 10      | —         | -3    | -12   | 12   | —        | —     |
| Size_DblN_peak_CA_NET(5)                        | 46.9908 | Yes       | 3     | 10    | 59   | 1.7738   | —     |
| Size_DblN_top_logit_CA_NET(5)                   | -6      | —         | -3    | -10   | 10   | —        | —     |

| Parameter Label in SS3 (fleet # in parentheses) | Value    | Estimated | Phase | Min   | Max  | Parm     | StDev |
|-------------------------------------------------|----------|-----------|-------|-------|------|----------|-------|
| Size_DblN_ascend_se_CA_NET(5)                   | 4.42563  | Yes       | 3     | 0.01  | 12   | 0.217864 |       |
| Size_DblN_descend_se_CA_NET(5)                  | 7        | —         | -3    | 0.01  | 12   | —        |       |
| Size_DblN_start_logit_CA_NET(5)                 | -999     | —         | -3    | -1000 | -998 | —        |       |
| Size_DblN_end_logit_CA_NET(5)                   | 10       | —         | -3    | -12   | 12   | —        |       |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)                | 43.8942  | Yes       | 3     | 10    | 59   | 2.46261  |       |
| Size_DblN_top_logit_NoCA_OR_WA_Rec(6)           | -6       | —         | -3    | -10   | 10   | —        |       |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)           | 5.13617  | Yes       | 3     | 0.01  | 12   | 0.229126 |       |
| Size_DblN_descend_se_NoCA_OR_WA_Rec(6)          | 7        | —         | -3    | 0.01  | 12   | —        |       |
| Size_DblN_start_logit_NoCA_OR_WA_Rec(6)         | -999     | —         | -3    | -1000 | -998 | —        |       |
| Size_DblN_end_logit_NoCA_OR_WA_Rec(6)           | 10       | —         | -3    | -12   | 12   | —        |       |
| Size_DblN_peak_SoCA_Rec(7)                      | 24.7079  | Yes       | 3     | 8.5   | 50   | 1.02101  |       |
| Size_DblN_top_logit_SoCA_Rec(7)                 | -6       | —         | -3    | -10   | 10   | —        |       |
| Size_DblN_ascend_se_SoCA_Rec(7)                 | 2.92383  | Yes       | 3     | 0.5   | 10   | 0.364116 |       |
| Size_DblN_descend_se_SoCA_Rec(7)                | 3.31823  | Yes       | 3     | 0.01  | 8    | 0.64822  |       |
| Size_DblN_start_logit_SoCA_Rec(7)               | -10      | —         | -3    | -11   | -10  | —        |       |
| Size_DblN_end_logit_SoCA_Rec(7)                 | -1.11196 | Yes       | 3     | -12   | 12   | 0.302647 |       |
| Size_DblN_peak_TWL_discard(8)                   | 29.5523  | Yes       | 3     | 10    | 50   | 1.56611  |       |
| Size_DblN_top_logit_TWL_discard(8)              | -6       | —         | -3    | -10   | 10   | —        |       |
| Size_DblN_ascend_se_TWL_discard(8)              | 4.16685  | Yes       | 3     | 0.5   | 8    | 0.370267 |       |
| Size_DblN_descend_se_TWL_discard(8)             | 3.19313  | Yes       | 3     | 0.01  | 8    | 0.592072 |       |
| Size_DblN_start_logit_TWL_discard(8)            | -10      | —         | -3    | -11   | -10  | —        |       |
| Size_DblN_end_logit_TWL_discard(8)              | -10      | —         | -3    | -11   | -10  | —        |       |
| SizeSel=1_BinLo_WCGBT_Survey(9)                 | 3        | —         | -99   | 1     | 10   | —        |       |
| SizeSel=1_BinHi_WCGBT_Survey(9)                 | 54       | —         | -99   | 53    | 55   | —        |       |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875        | 51.6041  | Yes       | 3     | 10    | 59.5 | 5.09178  |       |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875   | 4.15685  | Yes       | 3     | 0.5   | 10   | 0.614889 |       |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875        | 48.8295  | Yes       | 3     | 8.5   | 59.5 | 5.08479  |       |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875   | 4.8242   | Yes       | 3     | 0.5   | 15   | 0.486629 |       |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875          | 33.7915  | Yes       | 3     | 10    | 59   | 1.12358  |       |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875     | 3.28981  | Yes       | 3     | 0.01  | 12   | 0.313352 |       |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875        | 30.6778  | Yes       | 3     | 8.5   | 50   | 2.07561  |       |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875   | 3.75181  | Yes       | 3     | 0.5   | 10   | 0.468246 |       |
| Size_DblN_descend_se_SoCA_Rec(7)_BLK2repl_1875  | 7        | —         | -3    | 0.01  | 8    | —        |       |
| Size_DblN_end_logit_SoCA_Rec(7)_BLK2repl_1875   | 10       | —         | -3    | -12   | 12   | —        |       |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875   | 3.73193  | Yes       | 3     | 0.5   | 10   | 0.454487 |       |
| Size_DblN_descend_se_SoCA_Rec(7)_BLK2repl_1875  | 7        | —         | -3    | 0.01  | 8    | —        |       |
| Size_DblN_end_logit_SoCA_Rec(7)_BLK2repl_1875   | 10       | —         | -3    | -12   | 12   | —        |       |

Table 11: Chilipepper base model reference points and 95% asymptotic intervals.

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



Table 12: Time series of population estimates from the base model. Spawning output is in billions of eggs.

| Year | Total<br>Biomass<br>(mt) | Spawning<br>output | Total<br>Biomass<br>Age 3+ (mt) | Fraction<br>Unfished | Age-0<br>Recruits<br>(1,000s) | Total<br>Mortality<br>(mt) | (1-SPR)/<br>(1-SPR50%) | Exploitation<br>Rate |
|------|--------------------------|--------------------|---------------------------------|----------------------|-------------------------------|----------------------------|------------------------|----------------------|
| 1875 | 52043                    | 11922              | 50121                           | 1                    | 22734                         | 8.27                       | 0.0033                 | 0.0002               |
| 1876 | 52036                    | 11920              | 50114                           | 1.000                | 22733                         | 16.54                      | 0.0066                 | 0.0003               |
| 1877 | 52022                    | 11915              | 50100                           | 0.999                | 22732                         | 24.82                      | 0.0099                 | 0.0005               |
| 1878 | 52003                    | 11908              | 50080                           | 0.999                | 22731                         | 33.09                      | 0.0132                 | 0.0007               |
| 1879 | 51978                    | 11899              | 50056                           | 0.998                | 22729                         | 41.36                      | 0.0165                 | 0.0008               |
| 1880 | 51949                    | 11889              | 50027                           | 0.997                | 22727                         | 49.63                      | 0.0198                 | 0.0010               |
| 1881 | 51916                    | 11878              | 49994                           | 0.996                | 22725                         | 57.90                      | 0.0231                 | 0.0012               |
| 1882 | 51879                    | 11865              | 49957                           | 0.995                | 22723                         | 66.18                      | 0.0264                 | 0.0013               |
| 1883 | 51839                    | 11851              | 49918                           | 0.994                | 22720                         | 74.45                      | 0.0296                 | 0.0015               |
| 1884 | 51797                    | 11836              | 49875                           | 0.993                | 22717                         | 82.72                      | 0.0329                 | 0.0017               |
| 1885 | 51752                    | 11820              | 49831                           | 0.991                | 22715                         | 90.99                      | 0.0362                 | 0.0018               |
| 1886 | 51705                    | 11804              | 49784                           | 0.990                | 22711                         | 99.26                      | 0.0395                 | 0.0020               |
| 1887 | 51656                    | 11787              | 49735                           | 0.989                | 22708                         | 107.53                     | 0.0427                 | 0.0022               |
| 1888 | 51605                    | 11769              | 49685                           | 0.987                | 22705                         | 115.81                     | 0.0460                 | 0.0023               |
| 1889 | 51553                    | 11751              | 49633                           | 0.986                | 22701                         | 124.08                     | 0.0493                 | 0.0025               |
| 1890 | 51499                    | 11733              | 49579                           | 0.984                | 22698                         | 132.35                     | 0.0526                 | 0.0027               |
| 1891 | 51445                    | 11714              | 49525                           | 0.982                | 22694                         | 140.62                     | 0.0559                 | 0.0028               |
| 1892 | 51389                    | 11694              | 49469                           | 0.981                | 22691                         | 148.89                     | 0.0591                 | 0.0030               |
| 1893 | 51332                    | 11675              | 49413                           | 0.979                | 22687                         | 157.17                     | 0.0624                 | 0.0032               |
| 1894 | 51274                    | 11655              | 49356                           | 0.978                | 22683                         | 165.44                     | 0.0657                 | 0.0034               |
| 1895 | 51216                    | 11635              | 49297                           | 0.976                | 22679                         | 173.71                     | 0.0690                 | 0.0035               |
| 1896 | 51157                    | 11614              | 49239                           | 0.974                | 22675                         | 181.98                     | 0.0723                 | 0.0037               |
| 1897 | 51097                    | 11594              | 49179                           | 0.972                | 22671                         | 190.25                     | 0.0756                 | 0.0039               |
| 1898 | 51037                    | 11573              | 49119                           | 0.971                | 22667                         | 198.52                     | 0.0788                 | 0.0040               |
| 1899 | 50976                    | 11552              | 49059                           | 0.969                | 22663                         | 206.80                     | 0.0821                 | 0.0042               |
| 1900 | 50915                    | 11531              | 48998                           | 0.967                | 22659                         | 215.07                     | 0.0854                 | 0.0044               |
| 1901 | 50853                    | 11510              | 48937                           | 0.965                | 22655                         | 223.34                     | 0.0887                 | 0.0046               |
| 1902 | 50791                    | 11489              | 48875                           | 0.964                | 22650                         | 231.61                     | 0.0920                 | 0.0047               |
| 1903 | 50729                    | 11467              | 48813                           | 0.962                | 22646                         | 239.88                     | 0.0953                 | 0.0049               |
| 1904 | 50666                    | 11446              | 48751                           | 0.960                | 22642                         | 248.16                     | 0.0986                 | 0.0051               |
| 1905 | 50603                    | 11424              | 48688                           | 0.958                | 22638                         | 256.43                     | 0.1019                 | 0.0053               |
| 1906 | 50540                    | 11403              | 48626                           | 0.956                | 22633                         | 264.70                     | 0.1052                 | 0.0054               |
| 1907 | 50477                    | 11381              | 48563                           | 0.955                | 22629                         | 272.97                     | 0.1085                 | 0.0056               |
| 1908 | 50414                    | 11360              | 48500                           | 0.953                | 22625                         | 281.24                     | 0.1118                 | 0.0058               |
| 1909 | 50350                    | 11338              | 48436                           | 0.951                | 22620                         | 289.51                     | 0.1152                 | 0.0060               |
| 1910 | 50286                    | 11316              | 48373                           | 0.949                | 22616                         | 297.79                     | 0.1185                 | 0.0062               |
| 1911 | 50222                    | 11294              | 48309                           | 0.947                | 22611                         | 306.06                     | 0.1218                 | 0.0063               |
| 1912 | 50158                    | 11272              | 48246                           | 0.945                | 22607                         | 314.33                     | 0.1251                 | 0.0065               |
| 1913 | 50094                    | 11250              | 48182                           | 0.944                | 22602                         | 322.60                     | 0.1284                 | 0.0067               |
| 1914 | 50029                    | 11229              | 48118                           | 0.942                | 22598                         | 330.87                     | 0.1317                 | 0.0069               |
| 1915 | 49965                    | 11207              | 48054                           | 0.940                | 22593                         | 339.15                     | 0.1350                 | 0.0071               |
| 1916 | 49900                    | 11185              | 47989                           | 0.938                | 22589                         | 361.85                     | 0.1436                 | 0.0075               |
| 1917 | 49822                    | 11159              | 47912                           | 0.936                | 22583                         | 574.44                     | 0.2177                 | 0.0120               |
| 1918 | 49564                    | 11072              | 47654                           | 0.929                | 22565                         | 587.98                     | 0.2233                 | 0.0123               |
| 1919 | 49323                    | 10989              | 47413                           | 0.922                | 22547                         | 379.50                     | 0.1523                 | 0.0080               |
| 1920 | 49294                    | 10978              | 47386                           | 0.921                | 22545                         | 398.94                     | 0.1597                 | 0.0084               |
| 1921 | 49251                    | 10964              | 47345                           | 0.920                | 22542                         | 338.85                     | 0.1379                 | 0.0072               |
| 1922 | 49267                    | 10970              | 47360                           | 0.920                | 22543                         | 312.35                     | 0.1280                 | 0.0066               |
| 1923 | 49304                    | 10983              | 47397                           | 0.921                | 22546                         | 380.49                     | 0.1535                 | 0.0080               |
| 1924 | 49275                    | 10976              | 47369                           | 0.921                | 22545                         | 390.11                     | 0.1580                 | 0.0082               |
| 1925 | 49238                    | 10966              | 47331                           | 0.920                | 22542                         | 439.11                     | 0.1759                 | 0.0093               |
| 1926 | 49161                    | 10942              | 47254                           | 0.918                | 22537                         | 594.68                     | 0.2301                 | 0.0126               |
| 1927 | 48953                    | 10873              | 47047                           | 0.912                | 22522                         | 508.48                     | 0.2020                 | 0.0108               |
| 1928 | 48843                    | 10838              | 46938                           | 0.909                | 22515                         | 501.04                     | 0.1994                 | 0.0107               |
| 1929 | 48752                    | 10809              | 46848                           | 0.907                | 22508                         | 487.09                     | 0.1952                 | 0.0104               |
| 1930 | 48683                    | 10787              | 46779                           | 0.905                | 22503                         | 549.39                     | 0.2172                 | 0.0117               |
| 1931 | 48566                    | 10749              | 46663                           | 0.902                | 22495                         | 585.51                     | 0.2307                 | 0.0125               |
| 1932 | 48430                    | 10704              | 46527                           | 0.898                | 22485                         | 421.51                     | 0.1729                 | 0.0091               |
| 1933 | 48454                    | 10713              | 46552                           | 0.899                | 22487                         | 335.66                     | 0.1398                 | 0.0072               |
| 1934 | 48551                    | 10749              | 46650                           | 0.902                | 22495                         | 356.80                     | 0.1476                 | 0.0076               |
| 1935 | 48619                    | 10775              | 46717                           | 0.904                | 22501                         | 382.57                     | 0.1570                 | 0.0082               |
| 1936 | 48656                    | 10789              | 46753                           | 0.905                | 22504                         | 290.15                     | 0.1211                 | 0.0062               |
| 1937 | 48770                    | 10830              | 46867                           | 0.908                | 22513                         | 267.88                     | 0.1117                 | 0.0057               |
| 1938 | 48891                    | 10874              | 46988                           | 0.912                | 22522                         | 251.11                     | 0.1046                 | 0.0053               |
| 1939 | 49014                    | 10917              | 47110                           | 0.916                | 22532                         | 278.24                     | 0.1148                 | 0.0059               |

| Year | Total<br>Biomass<br>(mt) | Spawning<br>output | Total<br>Biomass<br>Age 3+ (mt) | Fraction<br>Unfished | Age-0<br>Recruits<br>(1,000s) | Total<br>Mortality<br>(mt) | (1-SPR)/<br>(1-SPR50%) | Exploitation<br>Rate |
|------|--------------------------|--------------------|---------------------------------|----------------------|-------------------------------|----------------------------|------------------------|----------------------|
| 1940 | 49099                    | 10948              | 47194                           | 0.918                | 22538                         | 254.63                     | 0.1056                 | 0.0054               |
| 1941 | 49196                    | 10981              | 47291                           | 0.921                | 22546                         | 223.01                     | 0.0930                 | 0.0047               |
| 1942 | 49311                    | 11020              | 47405                           | 0.924                | 22554                         | 93.34                      | 0.0401                 | 0.0020               |
| 1943 | 49530                    | 11092              | 47623                           | 0.930                | 22569                         | 195.82                     | 0.0803                 | 0.0041               |
| 1944 | 49630                    | 11131              | 47723                           | 0.934                | 22577                         | 555.97                     | 0.2127                 | 0.0116               |
| 1945 | 49380                    | 11076              | 47472                           | 0.929                | 22566                         | 1148.52                    | 0.4044                 | 0.0242               |
| 1946 | 48596                    | 10869              | 46687                           | 0.912                | 22521                         | 888.53                     | 0.3300                 | 0.0190               |
| 1947 | 48121                    | 10738              | 46214                           | 0.901                | 22492                         | 668.33                     | 0.2590                 | 0.0145               |
| 1948 | 47900                    | 10669              | 45996                           | 0.895                | 22477                         | 553.29                     | 0.2202                 | 0.0120               |
| 1949 | 47811                    | 10639              | 45910                           | 0.892                | 22470                         | 648.65                     | 0.2547                 | 0.0141               |
| 1950 | 47648                    | 10591              | 45748                           | 0.888                | 22459                         | 793.84                     | 0.3055                 | 0.0174               |
| 1951 | 47368                    | 10511              | 45468                           | 0.882                | 22441                         | 1213.45                    | 0.4408                 | 0.0267               |
| 1952 | 46724                    | 10332              | 44825                           | 0.867                | 22398                         | 1234.08                    | 0.4528                 | 0.0275               |
| 1953 | 46117                    | 10161              | 44221                           | 0.852                | 22357                         | 1440.11                    | 0.5189                 | 0.0326               |
| 1954 | 45375                    | 9953               | 43483                           | 0.835                | 22304                         | 1421.86                    | 0.5214                 | 0.0327               |
| 1955 | 44721                    | 9764               | 42832                           | 0.819                | 22255                         | 1471.17                    | 0.5428                 | 0.0343               |
| 1956 | 44084                    | 9579               | 42199                           | 0.803                | 22206                         | 1664.09                    | 0.6040                 | 0.0394               |
| 1957 | 43330                    | 9363               | 41450                           | 0.785                | 22145                         | 1717.28                    | 0.6271                 | 0.0414               |
| 1958 | 42599                    | 9152               | 40723                           | 0.768                | 22084                         | 1983.42                    | 0.7058                 | 0.0487               |
| 1959 | 41692                    | 8893               | 39821                           | 0.746                | 22005                         | 1669.28                    | 0.6337                 | 0.0419               |
| 1960 | 41161                    | 8733               | 39296                           | 0.732                | 21954                         | 1386.30                    | 0.5566                 | 0.0353               |
| 1961 | 40950                    | 8659               | 39091                           | 0.726                | 21930                         | 1103.81                    | 0.4667                 | 0.0282               |
| 1962 | 41030                    | 8667               | 39174                           | 0.727                | 21933                         | 1050.57                    | 0.4476                 | 0.0268               |
| 1963 | 41160                    | 8694               | 39305                           | 0.729                | 21941                         | 1212.72                    | 0.5010                 | 0.0309               |
| 1964 | 41131                    | 8684               | 39276                           | 0.728                | 21938                         | 905.12                     | 0.3947                 | 0.0230               |
| 1965 | 41389                    | 8751               | 39534                           | 0.734                | 21960                         | 1000.66                    | 0.4266                 | 0.0253               |
| 1966 | 41537                    | 8793               | 39682                           | 0.738                | 21973                         | 2128.91                    | 0.7558                 | 0.0536               |
| 1967 | 40619                    | 8557               | 38762                           | 0.718                | 21896                         | 2785.37                    | 0.9155                 | 0.0719               |
| 1968 | 39236                    | 8169               | 37301                           | 0.685                | 36342                         | 1767.09                    | 0.6956                 | 0.0474               |
| 1969 | 39086                    | 8048               | 36909                           | 0.675                | 32104                         | 962.22                     | 0.4401                 | 0.0261               |
| 1970 | 40334                    | 8148               | 37315                           | 0.683                | 41008                         | 1164.93                    | 0.5078                 | 0.0312               |
| 1971 | 41892                    | 8273               | 39061                           | 0.694                | 23028                         | 1016.94                    | 0.4477                 | 0.0260               |
| 1972 | 44027                    | 8554               | 41023                           | 0.717                | 17606                         | 1441.80                    | 0.5694                 | 0.0351               |
| 1973 | 45556                    | 8857               | 43696                           | 0.743                | 25607                         | 2930.33                    | 0.9008                 | 0.0671               |
| 1974 | 45082                    | 8866               | 43438                           | 0.744                | 18716                         | 3392.06                    | 0.9744                 | 0.0781               |
| 1975 | 43883                    | 8709               | 41746                           | 0.730                | 43879                         | 2987.70                    | 0.9126                 | 0.0716               |
| 1976 | 42786                    | 8550               | 40773                           | 0.717                | 11612                         | 3046.09                    | 0.9396                 | 0.0747               |
| 1977 | 41916                    | 8308               | 38998                           | 0.697                | 8985                          | 2294.44                    | 0.8042                 | 0.0588               |
| 1978 | 41351                    | 8261               | 40423                           | 0.693                | 10781                         | 1802.31                    | 0.6861                 | 0.0446               |
| 1979 | 40598                    | 8329               | 39694                           | 0.699                | 29277                         | 2683.07                    | 0.8848                 | 0.0676               |
| 1980 | 38455                    | 8079               | 37194                           | 0.678                | 11722                         | 3119.87                    | 0.9887                 | 0.0839               |
| 1981 | 35947                    | 7583               | 33931                           | 0.636                | 5187                          | 2764.83                    | 0.9662                 | 0.0815               |
| 1982 | 33620                    | 7108               | 32795                           | 0.596                | 3512                          | 2531.92                    | 0.9500                 | 0.0772               |
| 1983 | 31124                    | 6672               | 30718                           | 0.560                | 4880                          | 2494.60                    | 0.9764                 | 0.0812               |
| 1984 | 28564                    | 6201               | 27871                           | 0.520                | 71154                         | 2849.96                    | 1.0926                 | 0.1023               |
| 1985 | 25867                    | 5551               | 24223                           | 0.466                | 4251                          | 3190.82                    | 1.2020                 | 0.1317               |
| 1986 | 24750                    | 4749               | 20286                           | 0.398                | 15415                         | 3156.62                    | 1.2517                 | 0.1556               |
| 1987 | 24228                    | 4160               | 23610                           | 0.349                | 13451                         | 2067.67                    | 1.1177                 | 0.0876               |
| 1988 | 24758                    | 4190               | 23482                           | 0.351                | 17228                         | 2804.96                    | 1.2499                 | 0.1195               |
| 1989 | 24331                    | 4150               | 23107                           | 0.348                | 16531                         | 3458.38                    | 1.3525                 | 0.1497               |
| 1990 | 23033                    | 3930               | 21631                           | 0.330                | 9493                          | 3193.96                    | 1.3394                 | 0.1477               |
| 1991 | 21800                    | 3719               | 20557                           | 0.312                | 12345                         | 3945.10                    | 1.4742                 | 0.1919               |
| 1992 | 19571                    | 3320               | 18744                           | 0.278                | 4292                          | 2829.08                    | 1.3647                 | 0.1509               |
| 1993 | 18223                    | 3108               | 17318                           | 0.261                | 14402                         | 2487.90                    | 1.3305                 | 0.1437               |
| 1994 | 16870                    | 2931               | 16319                           | 0.246                | 4386                          | 1957.08                    | 1.2338                 | 0.1199               |
| 1995 | 15927                    | 2819               | 14933                           | 0.236                | 7660                          | 2093.68                    | 1.2966                 | 0.1402               |
| 1996 | 14640                    | 2633               | 14210                           | 0.221                | 4030                          | 1872.97                    | 1.2826                 | 0.1318               |
| 1997 | 13409                    | 2459               | 12855                           | 0.206                | 2830                          | 2112.26                    | 1.3855                 | 0.1643               |
| 1998 | 11793                    | 2190               | 11464                           | 0.184                | 5875                          | 1445.75                    | 1.2459                 | 0.1261               |
| 1999 | 11277                    | 2028               | 10351                           | 0.170                | 117648                        | 979.48                     | 1.0740                 | 0.0946               |
| 2000 | 12029                    | 1934               | 9453                            | 0.162                | 5255                          | 496.38                     | 0.7584                 | 0.0525               |
| 2001 | 16520                    | 1999               | 9247                            | 0.168                | 11504                         | 389.17                     | 0.6421                 | 0.0421               |
| 2002 | 21690                    | 2531               | 21121                           | 0.212                | 6631                          | 302.16                     | 0.4991                 | 0.0143               |
| 2003 | 26233                    | 3552               | 25277                           | 0.298                | 25088                         | 29.49                      | 0.0484                 | 0.0012               |
| 2004 | 29720                    | 4702               | 28817                           | 0.394                | 6281                          | 100.17                     | 0.1099                 | 0.0035               |
| 2005 | 32183                    | 5661               | 30537                           | 0.475                | 2184                          | 130.27                     | 0.1089                 | 0.0043               |
| 2006 | 33429                    | 6409               | 33001                           | 0.538                | 1414                          | 172.21                     | 0.1208                 | 0.0052               |
| 2007 | 33434                    | 6942               | 33236                           | 0.582                | 7243                          | 134.89                     | 0.0872                 | 0.0041               |
| 2008 | 32489                    | 7236               | 32234                           | 0.607                | 6321                          | 156.21                     | 0.0955                 | 0.0048               |
| 2009 | 31135                    | 7270               | 30401                           | 0.610                | 32546                         | 309.50                     | 0.1787                 | 0.0102               |

| Year | Total<br>Biomass<br>(mt) | Spawning<br>output | Total<br>Biomass<br>Age 3+ (mt) | Fraction<br>Unfished | Age-0<br>Recruits<br>(1,000s) | Total<br>Mortality<br>(mt) | (1-SPR)/<br>(1-SPR50%) | Exploitation<br>Rate |
|------|--------------------------|--------------------|---------------------------------|----------------------|-------------------------------|----------------------------|------------------------|----------------------|
| 2010 | 29839                    | 7070               | 28580                           | 0.593                | 49301                         | 384.87                     | 0.2232                 | 0.0135               |
| 2011 | 29571                    | 6757               | 26597                           | 0.567                | 16093                         | 325.09                     | 0.2104                 | 0.0122               |
| 2012 | 31046                    | 6552               | 27545                           | 0.550                | 40535                         | 298.88                     | 0.1973                 | 0.0109               |
| 2013 | 33541                    | 6626               | 31407                           | 0.556                | 74126                         | 407.02                     | 0.2548                 | 0.0130               |
| 2014 | 36927                    | 6926               | 33015                           | 0.581                | 14853                         | 331.91                     | 0.2089                 | 0.0101               |
| 2015 | 41854                    | 7457               | 36908                           | 0.626                | 34600                         | 205.56                     | 0.1271                 | 0.0056               |
| 2016 | 46615                    | 8318               | 44980                           | 0.698                | 16900                         | 90.36                      | 0.0529                 | 0.0020               |
| 2017 | 50757                    | 9392               | 48277                           | 0.788                | 13443                         | 230.18                     | 0.1149                 | 0.0048               |
| 2018 | 53396                    | 10392              | 52098                           | 0.872                | 4819                          | 390.80                     | 0.1699                 | 0.0075               |
| 2019 | 54315                    | 11178              | 53374                           | 0.938                | 7063                          | 641.08                     | 0.2436                 | 0.0120               |
| 2020 | 53450                    | 11631              | 52942                           | 0.976                | 15418                         | 765.11                     | 0.2741                 | 0.0145               |
| 2021 | 51416                    | 11726              | 50554                           | 0.984                | 26998                         | 862.22                     | 0.3054                 | 0.0171               |
| 2022 | 48901                    | 11491              | 47412                           | 0.964                | 9842                          | 866.19                     | 0.3119                 | 0.0183               |
| 2023 | 46711                    | 11057              | 44752                           | 0.927                | 26252                         | 1262.86                    | 0.4460                 | 0.0282               |
| 2024 | 44605                    | 10467              | 43148                           | 0.878                | 68168                         | 1193.16                    | 0.4473                 | 0.0277               |
| 2025 | 43491                    | 9925               | 40513                           | 0.832                | 22297                         | 1598.72                    | 0.5847                 | 0.0395               |

[end of time series table]

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Table 13: Diagnostic results from starting the base model at different phases of the optimization routine.

| Estimation start phase | Neg. Log Likelihood | max. gradient | Used -hess_step? |
|------------------------|---------------------|---------------|------------------|
| 1 (base)               | 2633.05             | 0             | yes              |
| 2                      | 2633.05             | 1.04757e-03   | no               |
| 3                      | 2633.05             | 6.35030e-04   | no               |
| 4                      | 2633.05             | 3.72520e-03   | no               |
| 5                      | 2633.05             | 3.75120e-03   | no               |

Table 14: Likelihoods, estimated parameters, and select derived quantities from a likelihood profile over the natural mortality parameter for females (M). Male natural mortality was estimated in each run as an exponential offset, i.e. Male M = (Female M) \* exp(offset parameter).

| Label                                         | M_fem=<br>0.1 | M_fem=<br>0.12 | M_fem=<br>0.14 | M_fem=<br>0.16 | M_fem=<br>0.165 | M_fem=<br>0.18 | M_fem=<br>0.2 |
|-----------------------------------------------|---------------|----------------|----------------|----------------|-----------------|----------------|---------------|
| N.Parms                                       | 106           | 106            | 106            | 106            | 106             | 106            | 106           |
| TOTAL                                         | 2652.75       | 2641.59        | 2635.48        | 2633.15        | 2633.05         | 2633.78        | 2636.84       |
| Survey                                        | 36.425        | 32.014         | 29.893         | 29.257         | 29.272          | 29.631         | 30.717        |
| Length comp                                   | 572.210       | 569.880        | 568.864        | 569.040        | 569.289         | 570.424        | 572.955       |
| Age comp                                      | 2016.47       | 2014.58        | 2012.80        | 2011.38        | 2011.06         | 2010.31        | 2009.59       |
| Recruitment                                   | 26.663        | 24.790         | 23.879         | 23.460         | 23.398          | 23.288         | 23.232        |
| Parm_priors                                   | 0.978         | 0.329          | 0.049          | 0.007          | 0.025           | 0.124          | 0.350         |
| <b>NatM_uniform_Fem_GP_1</b>                  | <b>0.1</b>    | <b>0.12</b>    | <b>0.14</b>    | <b>0.16</b>    | <b>0.165249</b> | <b>0.18</b>    | <b>0.2</b>    |
| L_at_Amax_Fem_GP_1                            | 47.861        | 47.884         | 47.896         | 47.900         | 47.901          | 47.901         | 47.899        |
| VonBert_K_Fem_GP_1                            | 0.199         | 0.198          | 0.198          | 0.197          | 0.197           | 0.197          | 0.196         |
| CV_young_Fem_GP_1                             | 0.106         | 0.105          | 0.105          | 0.105          | 0.105           | 0.105          | 0.105         |
| CV_old_Fem_GP_1                               | 0.038         | 0.038          | 0.038          | 0.039          | 0.039           | 0.039          | 0.039         |
| <b>NatM_uniform_Mal_GP_1</b>                  | <b>0.516</b>  | <b>0.418</b>   | <b>0.342</b>   | <b>0.280</b>   | <b>0.266</b>    | <b>0.228</b>   | <b>0.184</b>  |
| L_at_Amax_Mal_GP_1                            | -0.323        | -0.325         | -0.327         | -0.328         | -0.328          | -0.329         | -0.330        |
| VonBert_K_Mal_GP_1                            | 0.522         | 0.523          | 0.525          | 0.526          | 0.526           | 0.527          | 0.528         |
| CV_young_Mal_GP_1                             | 0.238         | 0.238          | 0.238          | 0.236          | 0.236           | 0.235          | 0.234         |
| SR_LN(R0)                                     | 9.125         | 9.419          | 9.693          | 9.961          | 10.032          | 10.232         | 10.518        |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.292         | 0.296          | 0.319          | 0.347          | 0.355           | 0.376          | 0.402         |
| Size_DblN_peak_NoCA_HKL(1)                    | 40.325        | 40.624         | 40.817         | 40.950         | 40.974          | 41.019         | 41.033        |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 4.393         | 4.405          | 4.406          | 4.401          | 4.399           | 4.391          | 4.377         |
| Size_DblN_peak_SoCA_HKL(2)                    | 23.594        | 23.656         | 23.719         | 23.783         | 23.799          | 23.845         | 23.907        |
| Size_DblN_peak_CA_TWL(3)                      | 44.168        | 44.339         | 44.577         | 44.833         | 44.904          | 45.114         | 45.411        |
| Size_DblN_ascend_se_CA_TWL(3)                 | 4.575         | 4.562          | 4.558          | 4.556          | 4.556           | 4.558          | 4.561         |
| Size_DblN_peak_OR_WA_Comm(4)                  | 40.435        | 40.979         | 41.658         | 42.481         | 42.753          | 43.558         | 45.263        |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 4.392         | 4.425          | 4.473          | 4.537          | 4.559           | 4.625          | 4.773         |
| Size_DblN_peak_CA_NET(5)                      | 47.112        | 47.073         | 47.034         | 47.001         | 46.991          | 46.960         | 46.906        |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.476         | 4.459          | 4.443          | 4.429          | 4.426           | 4.416          | 4.402         |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 42.067        | 42.702         | 43.254         | 43.769         | 43.894          | 44.244         | 44.678        |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.088         | 5.109          | 5.123          | 5.134          | 5.136           | 5.142          | 5.147         |
| Size_DblN_peak_SoCA_Rec(7)                    | 24.340        | 24.461         | 24.576         | 24.681         | 24.708          | 24.783         | 24.880        |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 2.850         | 2.876          | 2.899          | 2.919          | 2.924           | 2.938          | 2.955         |
| Size_DblN_descend_se_SoCA_Rec(7)              | 3.529         | 3.473          | 3.409          | 3.338          | 3.318           | 3.261          | 3.182         |
| Size_DblN_end_logit_SoCA_Rec(7)               | -1.540        | -1.407         | -1.275         | -1.145         | -1.112          | -1.019         | -0.894        |
| Size_DblN_peak_TWL_discard(8)                 | 29.102        | 29.238         | 29.379         | 29.515         | 29.552          | 29.659         | 29.801        |
| Size_DblN_ascend_se_TWL_discard(8)            | 4.151         | 4.155          | 4.160          | 4.165          | 4.167           | 4.171          | 4.177         |
| Size_DblN_descend_se_TWL_discard(8)           | 3.233         | 3.223          | 3.210          | 3.197          | 3.193           | 3.181          | 3.164         |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.277        | 51.321         | 51.428         | 51.564         | 51.604          | 51.709         | 51.830        |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.148         | 4.147          | 4.151          | 4.155          | 4.157           | 4.160          | 4.163         |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 48.716        | 48.767         | 48.796         | 48.825         | 48.829          | 48.832         | 48.812        |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.869         | 4.854          | 4.840          | 4.827          | 4.824           | 4.815          | 4.801         |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 33.110        | 33.300         | 33.473         | 33.727         | 33.792          | 33.962         | 34.168        |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.169         | 3.202          | 3.229          | 3.278          | 3.290           | 3.319          | 3.352         |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.057        | 30.210         | 30.393         | 30.612         | 30.678          | 30.871         | 31.152        |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.684         | 3.699          | 3.719          | 3.744          | 3.752           | 3.775          | 3.809         |
| Bratio_2025                                   | 0.435         | 0.587          | 0.715          | 0.812          | 0.832           | 0.878          | 0.916         |
| SSB_unfished                                  | 12550         | 12131          | 11895          | 11883          | 11922           | 12150          | 12825         |
| Totbio_unfished                               | 45401         | 46545          | 48345          | 51111          | 52044           | 55274          | 61682         |
| Recr_unfished                                 | 9184          | 12317          | 16210          | 21189          | 22734           | 27781          | 36982         |
| Dead_Catch_SPR                                | 1263          | 1486           | 1734           | 2026           | 2114            | 2392           | 2885          |
| OFLCatch_2025                                 | 1180          | 1831           | 2567           | 3385           | 3617            | 4317           | 5457          |

Table 15: Likelihoods, estimated parameters, and select derived quantities from a likelihood profile over the logarithm (base  $e$ ) of unfished recruitment ('logR0') for age-0 fish.

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

Table 16: Likelihoods, estimated parameters, and select derived quantities from a likelihood profile over the Beverton-Holt steepness parameter (h), for values from 0.3-0.6. \*\* An equilibrium fishing mortality level associated with the proxy MSY harvest rate for rockfish ( $F_{SPR=50\%}$ ) is not possible with steepness values of 0.3 and lower, as equilibrium yield goes to zero between steepness values of 0.3 and 0.35.

| Label                                         | h=0.3      | h=0.35      | h=0.4      | h=0.45      | h=0.5      | h=0.55      | h=0.6      |
|-----------------------------------------------|------------|-------------|------------|-------------|------------|-------------|------------|
| N.Parms                                       | 106        | 106         | 106        | 106         | 106        | 106         | 106        |
| TOTAL                                         | 2630.15    | 2628.92     | 2628.78    | 2629.17     | 2629.82    | 2630.57     | 2631.34    |
| Survey                                        | 22.901     | 23.276      | 24.048     | 24.979      | 25.939     | 26.852      | 27.683     |
| Length comp                                   | 570.928    | 569.911     | 569.343    | 569.037     | 568.899    | 568.875     | 568.935    |
| Age_comp                                      | 2007.48    | 2008.88     | 2009.84    | 2010.49     | 2010.90    | 2011.12     | 2011.21    |
| Recruitment                                   | 25.838     | 24.725      | 24.010     | 23.561      | 23.306     | 23.192      | 23.182     |
| Parm priors                                   | 3.000      | 2.125       | 1.536      | 1.108       | 0.782      | 0.528       | 0.328      |
| NatM uniform Fem GP 1                         | 0.189      | 0.180       | 0.174      | 0.169       | 0.166      | 0.165       | 0.164      |
| L_at_Amax_Fem_GP_1                            | 47.859     | 47.865      | 47.872     | 47.878      | 47.884     | 47.889      | 47.893     |
| VonBert K Fem GP 1                            | 0.197      | 0.197       | 0.197      | 0.197       | 0.197      | 0.197       | 0.197      |
| CV_young_Fem_GP_1                             | 0.105      | 0.105       | 0.105      | 0.105       | 0.105      | 0.105       | 0.105      |
| CV_old_Fem_GP_1                               | 0.039      | 0.039       | 0.039      | 0.039       | 0.039      | 0.039       | 0.039      |
| NatM_uniform_Mal_GP_1                         | 0.217      | 0.235       | 0.248      | 0.258       | 0.264      | 0.268       | 0.269      |
| L_at_Amax_Mal_GP_1                            | -0.328     | -0.328      | -0.328     | -0.328      | -0.328     | -0.328      | -0.328     |
| VonBert K_Mal_GP_1                            | 0.526      | 0.526       | 0.527      | 0.527       | 0.527      | 0.527       | 0.527      |
| CV_young_Mal_GP_1                             | 0.237      | 0.237       | 0.237      | 0.237       | 0.237      | 0.237       | 0.237      |
| SR_LN(R0)                                     | 10.751     | 10.528      | 10.366     | 10.249      | 10.166     | 10.108      | 10.070     |
| <b>SR_BH_steep</b>                            | <b>0.3</b> | <b>0.35</b> | <b>0.4</b> | <b>0.45</b> | <b>0.5</b> | <b>0.55</b> | <b>0.6</b> |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.289      | 0.289       | 0.293      | 0.299       | 0.308      | 0.318       | 0.329      |
| Size_DblN_peak_NoCA_HKL(1)                    | 40.929     | 41.079      | 41.146     | 41.168      | 41.160     | 41.133      | 41.094     |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 4.387      | 4.407       | 4.417      | 4.421       | 4.421      | 4.419       | 4.414      |
| Size_DblN_peak_SoCA_HKL(2)                    | 23.864     | 23.843      | 23.827     | 23.816      | 23.808     | 23.803      | 23.800     |
| Size_DblN_peak_CA_TWL(3)                      | 45.343     | 45.258      | 45.178     | 45.107      | 45.048     | 45.000      | 44.962     |
| Size_DblN_ascend_se_CA_TWL(3)                 | 4.573      | 4.572       | 4.569      | 4.567       | 4.564      | 4.562       | 4.560      |
| Size_DblN_peak_OR_WA_Comm(4)                  | 44.496     | 43.912      | 43.460     | 43.206      | 43.018     | 42.890      | 42.811     |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 4.721      | 4.668       | 4.625      | 4.602       | 4.585      | 4.573       | 4.566      |
| Size_DblN_peak_CA_NET(5)                      | 46.849     | 46.953      | 47.009     | 47.038      | 47.048     | 47.045      | 47.034     |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.410      | 4.419       | 4.424      | 4.427       | 4.428      | 4.429       | 4.428      |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 44.318     | 44.294      | 44.233     | 44.164      | 44.097     | 44.037      | 43.986     |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.150      | 5.154       | 5.154      | 5.152       | 5.150      | 5.147       | 5.143      |
| Size_DblN_peak_SoCA_Rec(7)                    | 24.799     | 24.773      | 24.753     | 24.737      | 24.725     | 24.717      | 24.711     |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 2.940      | 2.936       | 2.932      | 2.930       | 2.927      | 2.926       | 2.925      |
| Size_DblN_descend_se_SoCA_Rec(7)              | 3.237      | 3.259       | 3.277      | 3.291       | 3.301      | 3.309       | 3.314      |
| Size_DblN_end_logit_SoCA_Rec(7)               | -1.006     | -1.035      | -1.060     | -1.078      | -1.092     | -1.101      | -1.107     |
| Size_DblN_peak_TWL_discard(8)                 | 29.679     | 29.645      | 29.617     | 29.595      | 29.579     | 29.567      | 29.559     |
| Size_DblN_ascend_se_TWL_discard(8)            | 4.172      | 4.172       | 4.171      | 4.170       | 4.170      | 4.169       | 4.168      |
| Size_DblN_descend_se_TWL_discard(8)           | 3.175      | 3.179       | 3.183      | 3.186       | 3.188      | 3.190       | 3.192      |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.074     | 51.188      | 51.277     | 51.349      | 51.409     | 51.461      | 51.507     |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.116      | 4.125       | 4.132      | 4.137       | 4.142      | 4.146       | 4.149      |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 48.511     | 48.723      | 48.843     | 48.906      | 48.932     | 48.931      | 48.913     |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.794      | 4.811       | 4.821      | 4.827       | 4.830      | 4.831       | 4.830      |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 33.900     | 33.890      | 33.868     | 33.846      | 33.828     | 33.814      | 33.805     |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.306      | 3.308       | 3.306      | 3.303       | 3.300      | 3.297       | 3.295      |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.598     | 30.600      | 30.600     | 30.604      | 30.611     | 30.622      | 30.636     |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.728      | 3.733       | 3.736      | 3.738       | 3.741      | 3.743       | 3.746      |
| Bratio_2025                                   | 0.371      | 0.432       | 0.493      | 0.555       | 0.615      | 0.672       | 0.726      |
| SSB_unfished                                  | 18271      | 16285       | 15002      | 14108       | 13453      | 12953       | 12563      |
| Totbio_unfished                               | 84990      | 73957       | 66957      | 62221       | 58881      | 56460       | 54678      |
| Recr_unfished                                 | 46656      | 37329       | 31756      | 28249       | 25990      | 24536       | 23625      |
| Dead_Catch_SPR                                | 0**        | 479         | 1266       | 1614        | 1796       | 1905        | 1981       |
| OFLCatch_2025                                 | 2929       | 2865        | 2883       | 2953        | 3056       | 3178        | 3309       |

Table 17: Likelihoods, estimated parameters, and select derived quantities from a likelihood profile over the Beverton-Holt steepness parameter (h), for values from 0.65-0.95.

| Label                                         | h=0.65      | h=0.7      | h=0.72      | h=0.75      | h=0.8      | h=0.85      | h=0.9      | h=0.95      |
|-----------------------------------------------|-------------|------------|-------------|-------------|------------|-------------|------------|-------------|
| N.Parms                                       | 106         | 106        | 106         | 106         | 106        | 106         | 106        | 106         |
| TOTAL                                         | 2632.0      | 2632.7     | 2633.0      | 2633.4      | 2634.0     | 2634.6      | 2635.2     | 2636.0      |
| Survey                                        | 8           | 8          | 5           | 4           | 5          | 5           | 7          | 2           |
| Length_comp                                   | 28.414      | 29.046     | 29.272      | 29.585      | 30.043     | 30.431      | 30.762     | 31.046      |
| Age_comp                                      | 569.06      | 569.22     | 569.29      | 569.40      | 569.60     | 569.81      | 570.01     | 570.20      |
| Recruitment                                   | 2011.1      | 2011.1     | 2011.0      | 2010.9      | 2010.8     | 2010.6      | 2010.5     | 2010.3      |
| Parm_priors                                   | 9           | 1          | 6           | 9           | 4          | 8           | 3          | 8           |
| NatM_uniform_Fem_GP_1                         | 23.243      | 23.348     | 23.398      | 23.476      | 23.612     | 23.745      | 23.872     | 23.989      |
| L_at_Amax_Fem_GP_1                            | 0.174       | 0.059      | 0.025       | -0.015      | -0.046     | -0.022      | 0.090      | 0.398       |
| VonBert_K_Fem_GP_1                            | 0.164       | 0.165      | 0.165       | 0.166       | 0.167      | 0.168       | 0.169      | 0.170       |
| CV_young_Fem_GP_1                             | 47.897      | 47.900     | 47.901      | 47.902      | 47.904     | 47.906      | 47.908     | 47.909      |
| CV_old_Fem_GP_1                               | 0.197       | 0.197      | 0.197       | 0.197       | 0.197      | 0.197       | 0.197      | 0.197       |
| NatM_uniform_Mal_GP_1                         | 0.105       | 0.105      | 0.105       | 0.105       | 0.105      | 0.105       | 0.105      | 0.105       |
| L_at_Amax_Mal_GP_1                            | 0.039       | 0.039      | 0.039       | 0.039       | 0.039      | 0.039       | 0.039      | 0.039       |
| VonBert_K_Mal_GP_1                            | 0.268       | 0.267      | 0.266       | 0.264       | 0.262      | 0.259       | 0.256      | 0.254       |
| CV_young_Mal_GP_1                             | -0.328      | -0.328     | -0.328      | -0.328      | -0.328     | -0.328      | -0.328     | -0.328      |
| SR_LN(R0)                                     | 0.527       | 0.526      | 0.526       | 0.526       | 0.526      | 0.526       | 0.526      | 0.526       |
| <b>SR_BH_steep</b>                            | 0.236       | 0.236      | 0.236       | 0.236       | 0.235      | 0.235       | 0.235      | 0.235       |
| Q_extraSD_CalCOFI_Survey(11)                  | 10.047      | 10.034     | 10.032      | 10.029      | 10.029     | 10.032      | 10.037     | 10.042      |
| Size_DblN_peak_NoCA_HKL(1)                    | <b>0.65</b> | <b>0.7</b> | <b>0.72</b> | <b>0.75</b> | <b>0.8</b> | <b>0.85</b> | <b>0.9</b> | <b>0.95</b> |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 0.340       | 0.351      | 0.355       | 0.361       | 0.370      | 0.378       | 0.385      | 0.391       |
| Size_DblN_peak_SoCA_HKL(2)                    | 41.047      | 40.995     | 40.974      | 40.942      | 40.889     | 40.839      | 40.791     | 40.747      |
| Size_DblN_peak_CA_TWL(3)                      | 4.408       | 4.402      | 4.399       | 4.395       | 4.389      | 4.382       | 4.377      | 4.371       |
| Size_DblN_ascend_se_CA_TWL(3)                 | 23.799      | 23.799     | 23.799      | 23.800      | 23.802     | 23.803      | 23.805     | 23.807      |
| Size_DblN_peak_OR_WA_Comm(4)                  | 44.933      | 44.911     | 44.904      | 44.896      | 44.884     | 44.875      | 44.869     | 44.864      |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 4.558       | 4.557      | 4.556       | 4.556       | 4.555      | 4.555       | 4.554      | 4.554       |
| Size_DblN_peak_CA_NET(5)                      | 42.768      | 42.753     | 42.752      | 42.757      | 42.772     | 42.794      | 42.820     | 42.846      |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.561       | 4.560      | 4.559       | 4.560       | 4.561      | 4.563       | 4.565      | 4.567       |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 47.018      | 46.999     | 46.991      | 46.978      | 46.958     | 46.937      | 46.918     | 46.900      |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 4.427       | 4.426      | 4.426       | 4.425       | 4.423      | 4.422       | 4.421      | 4.419       |
| Size_DblN_peak_SoCA_Rec(7)                    | 43.943      | 43.907     | 43.894      | 43.877      | 43.852     | 43.832      | 43.814     | 43.798      |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 5.140       | 5.137      | 5.136       | 5.135       | 5.132      | 5.130       | 5.128      | 5.126       |
| Size_DblN_peak_TWL_discard(8)                 | 24.709      | 24.708     | 24.708      | 24.708      | 24.710     | 24.711      | 24.713     | 24.715      |
| Size_DblN_ascend_se_TWL_discard(8)            | 2.924       | 2.924      | 2.924       | 2.924       | 2.924      | 2.924       | 2.924      | 2.924       |
| Size_DblN_end_logit_SoCA_Rec(7)               | 3.317       | 3.318      | 3.318       | 3.318       | 3.318      | 3.317       | 3.316      | 3.315       |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | -1.110      | -1.112     | -1.112      | -1.112      | -1.111     | -1.110      | -1.108     | -1.107      |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 29.555      | 29.553     | 29.552      | 29.552      | 29.553     | 29.554      | 29.556     | 29.558      |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 4.168       | 4.167      | 4.167       | 4.167       | 4.166      | 4.166       | 4.166      | 4.165       |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 3.192       | 3.193      | 3.193       | 3.193       | 3.193      | 3.193       | 3.193      | 3.193       |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 51.551      | 51.590     | 51.605      | 51.623      | 51.649     | 51.671      | 51.688     | 51.702      |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 4.153       | 4.156      | 4.157       | 4.158       | 4.160      | 4.162       | 4.163      | 4.164       |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 48.882      | 48.845     | 48.830      | 48.805      | 48.764     | 48.723      | 48.684     | 48.648      |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 4.828       | 4.825      | 4.824       | 4.823       | 4.820      | 4.817       | 4.814      | 4.811       |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 33.798      | 33.793     | 33.791      | 33.789      | 33.786     | 33.783      | 33.780     | 33.777      |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.292       | 3.291      | 3.290       | 3.289       | 3.287      | 3.285       | 3.284      | 3.282       |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.653      | 30.671     | 30.678      | 30.689      | 30.706     | 30.723      | 30.738     | 30.752      |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.748       | 3.751      | 3.752       | 3.753       | 3.755      | 3.757       | 3.759      | 3.761       |
| Bratio_2025                                   | 0.774       | 0.817      | 0.832       | 0.854       | 0.885      | 0.912       | 0.934      | 0.952       |
| SSB_unfished                                  | 12254       | 12007      | 11922       | 11809       | 11649      | 11521       | 11417      | 11332       |
| Totbio_unfished                               | 53353       | 52365      | 52044       | 51627       | 51076      | 50663       | 50353      | 50121       |
| Recr_unfished                                 | 23084       | 22797      | 22734       | 22681       | 22675      | 22740       | 22847      | 22979       |
| Dead_Catch_SPR                                | 2042        | 2094       | 2114        | 2142        | 2186       | 2226        | 2265       | 2300        |
| OFLCatch_2025                                 | 3442        | 3568       | 3617        | 3686        | 3792       | 3887        | 3971       | 4045        |

Table 18: Likelihoods, parameter estimates, and select derived quantiteis associated with “drop one” sensitivity analyses.

| Label                                         | Base    | No CalCOFI | No RREAS | No Triennial | No WCGBTS | No WCGBTS Index |
|-----------------------------------------------|---------|------------|----------|--------------|-----------|-----------------|
| N.Parms                                       | 106     | 106        | 106      | 106          | 106       | 106             |
| TOTAL                                         | 2633.05 | 2623.77    | 2606.21  | 2512.08      | 1702.02   | 2633.29         |
| Survey                                        | 29.27   | 20.63      | 5.32     | 26.83        | 29.74     | 31.07           |
| Length_comp                                   | 569.29  | 570.43     | 567.48   | 541.58       | 474.57    | 567.81          |
| Age_comp                                      | 2011.06 | 2008.50    | 2011.92  | 1919.94      | 1178.34   | 2008.99         |
| Recruitment                                   | 23.40   | 24.09      | 21.44    | 23.67        | 19.35     | 25.37           |
| Parm_priors                                   | 0.0245  | 0.1025     | 0.0396   | 0.0585       | 0.0019    | 0.0517          |
| NatM_uniform_Fem_GP_1                         | 0.165   | 0.178      | 0.168    | 0.172        | 0.151     | 0.140           |
| L_at_Amax_Fem_GP_1                            | 47.901  | 47.896     | 47.892   | 47.951       | 47.260    | 47.847          |
| VonBert_K_Fem_GP_1                            | 0.197   | 0.197      | 0.197    | 0.196        | 0.204     | 0.197           |
| CV_young_Fem_GP_1                             | 0.105   | 0.105      | 0.105    | 0.106        | 0.082     | 0.104           |
| CV_old_Fem_GP_1                               | 0.039   | 0.039      | 0.039    | 0.038        | 0.058     | 0.039           |
| NatM_uniform_Mal_GP_1                         | 0.266   | 0.237      | 0.259    | 0.252        | 0.267     | 0.329           |
| L_at_Amax_Mal_GP_1                            | -0.328  | -0.328     | -0.329   | -0.331       | -0.329    | -0.327          |
| VonBert_K_Mal_GP_1                            | 0.526   | 0.525      | 0.530    | 0.522        | 0.514     | 0.526           |
| CV_young_Mal_GP_1                             | 0.236   | 0.234      | 0.231    | 0.276        | 0.078     | 0.243           |
| SR_LN(R0)                                     | 10.032  | 10.221     | 10.066   | 10.153       | 9.965     | 9.751           |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.355   | 0.300      | 0.369    | 0.373        | 0.317     | 0.315           |
| Size_DblN_peak_NoCA_HKL(1)                    | 40.974  | 40.633     | 40.912   | 40.543       | 43.598    | 41.299          |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 4.399   | 4.352      | 4.389    | 4.339        | 4.629     | 4.458           |
| Size_DblN_peak_SoCA_HKL(2)                    | 23.799  | 23.818     | 23.750   | 23.818       | 24.423    | 23.831          |
| Size_DblN_peak_CA_TWL(3)                      | 44.904  | 44.900     | 44.840   | 44.828       | 46.328    | 45.234          |
| Size_DblN_ascend_se_CA_TWL(3)                 | 4.556   | 4.551      | 4.553    | 4.547        | 4.632     | 4.581           |
| Size_DblN_peak_OR_WA_Comm(4)                  | 42.753  | 43.111     | 42.347   | 42.752       | 57.154    | 43.224          |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 4.559   | 4.593      | 4.530    | 4.552        | 5.522     | 4.624           |
| Size_DblN_peak_CA_NET(5)                      | 46.991  | 46.867     | 46.962   | 46.808       | 48.258    | 47.162          |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.426   | 4.415      | 4.422    | 4.411        | 4.474     | 4.447           |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 43.894  | 43.822     | 43.824   | 43.657       | 47.345    | 43.924          |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.136   | 5.122      | 5.132    | 5.105        | 5.364     | 5.170           |
| Size_DblN_peak_SoCA_Rec(7)                    | 24.708  | 24.726     | 24.695   | 24.718       | 24.729    | 24.708          |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 2.924   | 2.926      | 2.935    | 2.922        | 2.933     | 2.923           |
| Size_DblN_descend_se_SoCA_Rec(7)              | 3.318   | 3.296      | 3.314    | 3.355        | 3.006     | 3.335           |
| Size_DblN_end_logit_SoCA_Rec(7)               | -1.112  | -1.093     | -1.083   | -1.079       | -0.990    | -1.100          |
| Size_DblN_peak_TWL_discard(8)                 | 29.552  | 29.561     | 29.520   | 29.669       | 29.475    | 29.555          |
| Size_DblN_ascend_se_TWL_discard(8)            | 4.167   | 4.164      | 4.184    | 4.175        | 4.081     | 4.172           |
| Size_DblN_descend_se_TWL_discard(8)           | 3.193   | 3.195      | 3.202    | 3.166        | 3.280     | 3.182           |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.604  | 51.642     | 51.666   | 51.414       | 51.783    | 51.291          |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.157   | 4.156      | 4.161    | 4.142        | 4.131     | 4.139           |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 48.830  | 48.599     | 48.796   | 48.417       | 55.594    | 49.091          |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.824   | 4.805      | 4.820    | 4.791        | 5.215     | 4.855           |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 33.792  | 33.860     | 33.847   | 33.768       | 36.317    | 33.565          |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.290   | 3.296      | 3.301    | 3.274        | 3.813     | 3.254           |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.678  | 30.853     | 30.725   | 30.851       | 31.132    | 30.340          |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.752   | 3.770      | 3.758    | 3.771        | 3.859     | 3.712           |
| Bratio_2025                                   | 0.832   | 0.927      | 0.833    | 0.903        | 0.964     | 0.878           |
| SSB_unfished                                  | 11922   | 12396      | 11859    | 12439        | 12943     | 12609           |
| Totbio_unfished                               | 52043   | 55946      | 52202    | 55048        | 55507     | 51514           |
| Recr_unfished                                 | 22734   | 27483      | 23518    | 25661        | 21265     | 17174           |
| Dead_Catch_SPR                                | 2114    | 2395       | 2147     | 2298         | 2111      | 1848            |
| OFLCatch_2025                                 | 3617    | 4502       | 3631     | 4238         | 4427      | 3413            |



Table 19: Multiplicative adjustments to input sample sizes for length and age composition using two alternative, iterative ‘tuning’ methods (Francis, 2011; McAllister and Ianelli 1997). Weights for CAAL data were not tuned higher than 1, as the input sample sizes represent individual fish.

| Fleet identifier | Data type | Tuned Francis Weight (base model) | Tuned M.I. Weight |
|------------------|-----------|-----------------------------------|-------------------|
| NoCA_HKL         | Lengths   | 0.549754                          | 1.275011          |
| SoCA_HKL         | Lengths   | 2.604632                          | 6.180662          |
| CA_TWL           | Lengths   | 0.229748                          | 0.601379          |
| OR_WA_Comm       | Lengths   | 0.091690                          | 0.372730          |
| CA_NET           | Lengths   | 0.427312                          | 1.747854          |
| NoCA_OR_WA_Rec   | Lengths   | 0.403535                          | 0.581049          |
| SoCA_Rec         | Lengths   | 0.162278                          | 0.696095          |
| TWL_discard      | Lengths   | 0.020526                          | 0.079056          |
| WCGBT_Survey     | Lengths   | 0.034620                          | 0.141923          |
| Triennial_Survey | Lengths   | 0.054124                          | 0.182039          |
| NoCA_HKL         | CAAL      | 0.029681                          | 0.153131          |
| CA_TWL           | CAAL      | 0.015459                          | 0.033899          |
| OR_WA_Comm       | CAAL      | 1.000000                          | 0.419436          |
| CA_NET           | CAAL      | 0.064954                          | 0.162369          |
| NoCA_OR_WA_Rec   | CAAL      | 1.000000                          | 0.565174          |
| WCGBT_Survey     | CAAL      | 0.095144                          | 0.004457          |
| Triennial_Survey | CAAL      | 0.068007                          | 0.167048          |

Table 20: Likelihoods (not comparable for this sensitivity analysis due to differences in data-weighting approach), parameter estimates, and select derived quantities using two alternative, iterative ‘tuning’ methods (Francis, 2011; McAllister and Ianelli 1997). Likelihoods and derived quantities are shaded

| Label                                         | McAllister-Ianelli weighting | Base; Francis weighting |
|-----------------------------------------------|------------------------------|-------------------------|
| N.Parms                                       | 106                          | 106                     |
| TOTAL                                         | 3623.83                      | 2633.05                 |
| Survey                                        | 36.23                        | 29.27                   |
| Length_comp                                   | 1654.71                      | 569.29                  |
| Age_comp                                      | 1910.96                      | 2011.06                 |
| Recruitment                                   | 21.93                        | 23.40                   |
| Parm_priors                                   | 0.0003                       | 0.0245                  |
| NatM_uniform_Fem_GP_1                         | 0.153                        | 0.165                   |
| L_at_Amax_Fem_GP_1                            | 47.096                       | 47.901                  |
| VonBert_K_Fem_GP_1                            | 0.204                        | 0.197                   |
| CV_young_Fem_GP_1                             | 0.100                        | 0.105                   |
| CV_old_Fem_GP_1                               | 0.048                        | 0.039                   |
| NatM_uniform_Mal_GP_1                         | 0.245                        | 0.266                   |
| L_at_Amax_Mal_GP_1                            | -0.318                       | -0.328                  |
| VonBert_K_Mal_GP_1                            | 0.473                        | 0.526                   |
| CV_young_Mal_GP_1                             | 0.143                        | 0.236                   |
| SR_LN(R0)                                     | 9.941                        | 10.032                  |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.356                        | 0.355                   |
| Size_DblN_peak_NoCA_HKL(1)                    | 42.056                       | 40.974                  |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 4.514                        | 4.399                   |
| Size_DblN_peak_SoCA_HKL(2)                    | 23.876                       | 23.799                  |
| Size_DblN_peak_CA_TWL(3)                      | 45.202                       | 44.904                  |
| Size_DblN_ascend_se_CA_TWL(3)                 | 4.609                        | 4.556                   |
| Size_DblN_peak_OR_WA_Comm(4)                  | 43.242                       | 42.753                  |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 4.591                        | 4.559                   |
| Size_DblN_peak_CA_NET(5)                      | 47.823                       | 46.991                  |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.479                        | 4.426                   |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 45.922                       | 43.894                  |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.289                        | 5.136                   |
| Size_DblN_peak_SoCA_Rec(7)                    | 24.554                       | 24.708                  |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 2.925                        | 2.924                   |
| Size_DblN_descend_se_SoCA_Rec(7)              | 3.218                        | 3.318                   |
| Size_DblN_end_logit_SoCA_Rec(7)               | -1.107                       | -1.112                  |
| Size_DblN_peak_TWL_discard(8)                 | 29.511                       | 29.552                  |
| Size_DblN_ascend_se_TWL_discard(8)            | 4.239                        | 4.167                   |
| Size_DblN_descend_se_TWL_discard(8)           | 3.248                        | 3.193                   |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | 53.431                       | 51.604                  |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.287                        | 4.157                   |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 54.947                       | 48.830                  |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 5.225                        | 4.824                   |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 34.507                       | 33.792                  |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.446                        | 3.290                   |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.609                       | 30.678                  |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.749                        | 3.752                   |
| Bratio_2025                                   | 0.795                        | 0.832                   |
| SSB_unfished                                  | 12156                        | 11922                   |
| Totbio_unfished                               | 53200                        | 52043                   |
| Recr_unfished                                 | 20765                        | 22734                   |
| Dead_Catch_SPR                                | 2054                         | 2114                    |
| OFLCatch_2025                                 | 3413                         | 3617                    |

Table 21: Likelihoods, parameter estimates, and select derived quantities associated with sensitivity runs where fishery-dependent indices from the previous assessment are included in the current base model, and where two fishery-independent indices are “upweighted” (lambda changed from 1 to 10).

| Label                                         | Base    | Add rec<br>CPUE | Add<br>trawl<br>CPUE | Add rec<br>and<br>trawl<br>CPUE | Upweight<br>CalCOFI | Upweight<br>WCGBTS |
|-----------------------------------------------|---------|-----------------|----------------------|---------------------------------|---------------------|--------------------|
| N.Parms                                       | 106     | 106             | 106                  | 106                             | 106                 | 106                |
| TOTAL                                         | 2633.05 | 2637.08         | 2621.66              | 2630.71                         | 2675.08             | 2525.81            |
| Survey                                        | 29.27   | 30.66           | 17.29                | 25.25                           | 58.87               | -99.49             |
| Length comp                                   | 569.29  | 571.54          | 570.46               | 571.22                          | 567.10              | 585.71             |
| Age comp                                      | 2011.06 | 2010.95         | 2010.75              | 2010.68                         | 2027.48             | 2014.79            |
| Recruitment                                   | 23.40   | 23.93           | 23.07                | 23.55                           | 21.48               | 24.18              |
| Parm_priors                                   | 0.025   | 0.001           | 0.081                | 0.001                           | 0.145               | 0.619              |
| NatM_uniform_Fem_GP_1                         | 0.165   | 0.152           | 0.175                | 0.156                           | 0.131               | 0.218              |
| L_at_Amax_Fem_GP_1                            | 47.901  | 47.871          | 47.911               | 47.882                          | 47.941              | 47.877             |
| VonBert_K_Fem_GP_1                            | 0.197   | 0.197           | 0.197                | 0.197                           | 0.196               | 0.197              |
| CV_young_Fem_GP_1                             | 0.105   | 0.105           | 0.105                | 0.105                           | 0.105               | 0.104              |
| CV_old_Fem_GP_1                               | 0.039   | 0.039           | 0.038                | 0.039                           | 0.038               | 0.039              |
| NatM_uniform_Mal_GP_1                         | 0.266   | 0.302           | 0.243                | 0.293                           | 0.362               | 0.149              |
| L_at_Amax_Mal_GP_1                            | -0.328  | -0.328          | -0.328               | -0.327                          | -0.328              | -0.330             |
| VonBert_K_Mal_GP_1                            | 0.526   | 0.528           | 0.523                | 0.524                           | 0.530               | 0.525              |
| CV_young_Mal_GP_1                             | 0.236   | 0.240           | 0.236                | 0.240                           | 0.237               | 0.231              |
| SR_LN(R0)                                     | 10.032  | 9.798           | 10.214               | 9.872                           | 9.641               | 10.838             |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.355   | 0.323           | 0.385                | 0.338                           | 0.281               | 0.421              |
| Size_DblN_peak_NoCA_HKL(1)                    | 40.974  | 41.114          | 40.323               | 40.549                          | 42.156              | 40.904             |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 4.399   | 4.422           | 4.329                | 4.370                           | 4.537               | 4.348              |
| Size_DblN_peak_SoCA_HKL(2)                    | 23.799  | 23.772          | 23.817               | 23.775                          | 23.726              | 23.957             |
| Size_DblN_peak_CA_TWL(3)                      | 44.904  | 45.029          | 44.807               | 44.853                          | 44.798              | 45.427             |
| Size_DblN_ascend_se_CA_TWL(3)                 | 4.556   | 4.557           | 4.555                | 4.555                           | 4.556               | 4.542              |
| Size_DblN_peak_OR_WA_Comm(4)                  | 42.753  | 42.441          | 43.024               | 42.406                          | 41.702              | 46.348             |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 4.559   | 4.537           | 4.583                | 4.534                           | 4.455               | 4.800              |
| Size_DblN_peak_CA_NET(5)                      | 46.991  | 46.983          | 46.983               | 47.125                          | 47.412              | 46.806             |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.426   | 4.437           | 4.426                | 4.450                           | 4.446               | 4.387              |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 43.894  | 43.892          | 43.863               | 43.443                          | 44.240              | 45.493             |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.136   | 5.168           | 5.123                | 5.133                           | 5.171               | 5.138              |
| Size_DblN_peak_SoCA_Rec(7)                    | 24.708  | 24.664          | 24.735               | 24.663                          | 24.616              | 25.077             |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 2.924   | 2.918           | 2.927                | 2.915                           | 2.913               | 2.997              |
| Size_DblN_descend_se_SoCA_Rec(7)              | 3.318   | 3.335           | 3.311                | 3.351                           | 3.371               | 3.112              |
| Size_DblN_end_logit_SoCA_Rec(7)               | -1.112  | -1.146          | -1.096               | -1.160                          | -1.220              | -0.791             |
| Size_DblN_peak_TWL_discard(8)                 | 29.552  | 29.501          | 29.585               | 29.503                          | 29.445              | 30.301             |
| Size_DblN_ascend_se_TWL_discard(8)            | 4.167   | 4.169           | 4.165                | 4.167                           | 4.162               | 4.181              |
| Size_DblN_descend_se_TWL_discard(8)           | 3.193   | 3.198           | 3.187                | 3.196                           | 3.207               | 3.076              |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.604  | 51.816          | 51.503               | 51.881                          | 50.864              | 51.878             |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.157   | 4.178           | 4.146                | 4.182                           | 4.110               | 4.162              |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 48.830  | 49.063          | 48.398               | 48.732                          | 49.215              | 48.688             |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.824   | 4.845           | 4.790                | 4.822                           | 4.839               | 4.782              |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 33.792  | 33.633          | 33.518               | 33.402                          | 33.714              | 34.305             |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.290   | 3.270           | 3.210                | 3.202                           | 3.288               | 3.366              |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.678  | 30.551          | 30.817               | 30.697                          | 30.035              | 31.393             |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.752   | 3.741           | 3.764                | 3.758                           | 3.671               | 3.835              |
| Bratio_2025                                   | 0.832   | 0.709           | 0.908                | 0.764                           | 0.591               | 0.911              |
| SSB_unfished                                  | 11922   | 11179           | 12736                | 11438                           | 12906               | 14555              |
| Totbio_unfished                               | 52043   | 47055           | 57049                | 48626                           | 51255               | 73574              |
| Recr_unfished                                 | 22734   | 17995           | 27291                | 19389                           | 15383               | 50912              |
| Dead_Catch_SPR                                | 2114    | 1798            | 2416                 | 1894                            | 1746                | 3688               |
| OFLCatch_2025                                 | 3617    | 2659            | 4458                 | 2988                            | 2204                | 7112               |

Table 22: Likelihoods, parameter estimates, and select derived quantities based on different assumptions of constant and time-varying growth (relative to pre-STAR base). Likelihoods and derived quantities are shaded.

| Label                                         | K devs fixed at<br>Appendix A estimates | Estimated annual<br>k deviations | Pre-STAR<br>base |
|-----------------------------------------------|-----------------------------------------|----------------------------------|------------------|
| N.Parms                                       | 115                                     | 161                              | 114              |
| TOTAL                                         | 2597.09                                 | 2401.00                          | 2597.98          |
| Survey                                        | 23.26                                   | 21.11                            | 24.51            |
| Length comp                                   | 576.11                                  | 538.57                           | 572.24           |
| Age comp                                      | 1972.35                                 | 1805.25                          | 1976.25          |
| Recruitment                                   | 24.36                                   | 24.62                            | 24.92            |
| Parm_priors                                   | 1.006                                   | 0.125                            | 0.055            |
| NatM_uniform_Fem_GP_1                         | 0.182                                   | 0.180                            | 0.171            |
| L_at_Amax_Fem_GP_1                            | 47.894                                  | 47.851                           | 48.190           |
| <b>VonBert_K_Fem_GP_1</b>                     | <b>0.199</b>                            | <b>0.215</b>                     | <b>0.194</b>     |
| CV_young_Fem_GP_1                             | 0.104                                   | 0.098                            | 0.110            |
| CV_old_Fem_GP_1                               | 0.040                                   | 0.036                            | 0.037            |
| NatM_uniform_Mal_GP_1                         | 0.211                                   | 0.207                            | 0.261            |
| L_at_Amax_Mal_GP_1                            | -0.351                                  | -0.341                           | -0.337           |
| <b>VonBert_K_Mal_GP_1</b>                     | <b>0.611</b>                            | <b>0.577</b>                     | <b>0.549</b>     |
| CV_young_Mal_GP_1                             | -0.146                                  | -0.100                           | 0.208            |
| CV_old_Mal_GP_1                               | 0.609                                   | 0.558                            | 0.148            |
| VonBert_K_Fem_GP_1_ENV_mult                   | 0.342                                   | NA                               | NA               |
| SR_LN(R0)                                     | 10.406                                  | 10.325                           | 10.248           |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.309                                   | 0.309                            | 0.313            |
| Q_extraSD_RREAS_YOY_Survey(12)                | 1.249                                   | 1.258                            | 1.233            |
| Size_DblN_peak_NoCA_HKL(1)                    | 41.489                                  | 43.464                           | 41.247           |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 4.399                                   | 4.492                            | 4.428            |
| Size_DblN_descend_se_NoCA_HKL(1)              | 5.578                                   | 6.470                            | 5.024            |
| Size_DblN_peak_SoCA_HKL(2)                    | 24.265                                  | 24.462                           | 24.245           |
| Size_DblN_ascend_se_SoCA_HKL(2)               | 1.374                                   | 1.522                            | 1.410            |
| Size_DblN_descend_se_SoCA_HKL(2)              | 6.034                                   | 5.933                            | 5.781            |
| Size_DblN_peak_CA_TWL(3)                      | 44.982                                  | 44.763                           | 44.673           |
| Size_DblN_ascend_se_CA_TWL(3)                 | 4.474                                   | 4.462                            | 4.502            |
| Size_DblN_descend_se_CA_TWL(3)                | 3.122                                   | 3.053                            | 2.985            |
| Size_DblN_peak_OR_WA_Comm(4)                  | 42.951                                  | 42.483                           | 41.925           |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 4.484                                   | 4.432                            | 4.476            |
| Size_DblN_peak_CA_NET(5)                      | 46.210                                  | 47.336                           | 45.868           |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.313                                   | 4.336                            | 4.307            |
| Size_DblN_descend_se_CA_NET(5)                | 4.290                                   | 8.896                            | 3.632            |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 44.769                                  | 45.889                           | 43.491           |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.143                                   | 5.169                            | 5.090            |
| Size_DblN_descend_se_NoCA_OR_WA_Rec(6)        | 4.888                                   | 4.687                            | 4.321            |
| Size_DblN_peak_SoCA_Rec(7)                    | 24.629                                  | 24.341                           | 24.645           |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 2.937                                   | 2.854                            | 2.913            |
| Size_DblN_descend_se_SoCA_Rec(7)              | 3.073                                   | 3.247                            | 3.365            |
| Size_DblN_end_logit_SoCA_Rec(7)               | -0.797                                  | -1.022                           | -1.108           |
| Size_DblN_peak_TWL_discard(8)                 | 30.055                                  | 29.968                           | 29.547           |
| Size_DblN_ascend_se_TWL_discard(8)            | 4.305                                   | 4.306                            | 4.182            |
| Size_DblN_descend_se_TWL_discard(8)           | 3.184                                   | 3.193                            | 3.200            |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.166                                  | 50.647                           | 50.237           |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.136                                   | 4.068                            | 4.050            |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 47.759                                  | 51.097                           | 47.410           |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.689                                   | 4.850                            | 4.717            |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 35.598                                  | 37.348                           | 33.585           |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.663                                   | 3.919                            | 3.234            |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 31.385                                  | 31.539                           | 30.581           |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.888                                   | 3.920                            | 3.732            |
| <b>VonBert_K_Fem_GP_1_dev_se</b>              | <b>NA</b>                               | <b>0.500</b>                     | <b>NA</b>        |
| <b>VonBert_K_Fem_GP_1_dev_autocorr</b>        | <b>NA</b>                               | <b>0.000</b>                     | <b>NA</b>        |
| Bratio_2025                                   | 0.603                                   | 0.588                            | 0.603            |
| SSB_unfished                                  | 14036                                   | 13710                            | 13945            |
| Totbio_unfished                               | 64717                                   | 62341                            | 61069            |
| Recr_unfished                                 | 33071                                   | 30485                            | 28215            |
| Dead_Catch_SPR                                | 2774                                    | 2636                             | 2509             |
| OFLCatch_2025                                 | 3431                                    | 3287                             | 2894             |

Table 23: Likelihoods, parameter estimates, and select derived quantities for alternative treatments of trawl selectivity in California. Likelihoods and derived quantities are shaded.

| Label                                         | Constant, asymptotic | Time-blocked | Flexible, 2D |
|-----------------------------------------------|----------------------|--------------|--------------|
| N.Parms                                       | 112                  | 114          | <b>1474</b>  |
| TOTAL                                         | 2624.360             | 2597.980     | 3832.740     |
| Survey                                        | 24.996               | 24.512       | 24.855       |
| Length_comp                                   | 588.294              | 572.241      | 528.587      |
| Age_comp                                      | 1986.700             | 1976.250     | 1978.840     |
| Recruitment                                   | 24.339               | 24.915       | 24.449       |
| Parm_priors                                   | 0.027                | 0.055        | 0.022        |
| Parm_devs                                     | 0.000                | 0.000        | 1275.980     |
| NatM uniform Fem GP 1                         | 0.166                | 0.171        | 0.165        |
| L at Amax Fem GP 1                            | 48.046               | 48.190       | 48.053       |
| VonBert K Fem GP 1                            | 0.195                | 0.194        | 0.195        |
| CV young Fem GP 1                             | 0.108                | 0.110        | 0.108        |
| CV old Fem GP 1                               | 0.037                | 0.037        | 0.037        |
| NatM uniform Mal GP 1                         | 0.283                | 0.261        | 0.283        |
| L at Amax Mal GP 1                            | -0.346               | -0.337       | -0.337       |
| VonBert K Mal GP 1                            | 0.580                | 0.549        | 0.556        |
| CV young Mal GP 1                             | 0.186                | 0.208        | 0.213        |
| CV old Mal GP 1                               | 0.275                | 0.148        | 0.166        |
| SR_LN(R0)                                     | 10.156               | 10.248       | 10.130       |
| Q_extraSD CalCOFI Survey(11)                  | 0.317                | 0.313        | 0.314        |
| Q_extraSD_RREAS_YOY_Survey(12)                | 1.249                | 1.233        | 1.242        |
| Size_DblN_peak_NoCA_HKL(1)                    | 41.857               | 41.247       | 41.544       |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 4.481                | 4.428        | 4.465        |
| Size_DblN_descend_se_NoCA_HKL(1)              | 5.587                | 5.024        | 5.678        |
| Size_DblN_peak_SoCA_HKL(2)                    | 24.216               | 24.245       | 24.199       |
| Size_DblN_ascend_se_SoCA_HKL(2)               | 1.401                | 1.410        | 1.385        |
| Size_DblN_descend_se_SoCA_HKL(2)              | 5.762                | 5.781        | 5.749        |
| Size_DblN_peak_CA_TWL(3)                      | 38.303               | 44.673       | NA           |
| Size_DblN_top_logit_CA_TWL(3)                 | -6.000               | -6.000       | NA           |
| Size_DblN_ascend_se_CA_TWL(3)                 | 4.095                | 4.502        | NA           |
| Size_DblN_descend_se_CA_TWL(3)                | 11.467               | 2.985        | NA           |
| Size_DblN_start_logit_CA_TWL(3)               | -10.000              | -10.000      | NA           |
| Size_DblN_end_logit_CA_TWL(3)                 | -999.000             | -999.000     | NA           |
| Size_DblN_peak_OR_WA_Comm(4)                  | 41.113               | 41.925       | 41.456       |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 4.380                | 4.476        | 4.431        |
| Size_DblN_peak_CA_NET(5)                      | 46.835               | 45.868       | 46.938       |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.381                | 4.307        | 4.405        |
| Size_DblN_descend_se_CA_NET(5)                | 4.795                | 3.632        | 4.984        |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 43.765               | 43.491       | 43.792       |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.101                | 5.090        | 5.119        |
| Size_DblN_descend_se_NoCA_OR_WA_Rec(6)        | 4.514                | 4.321        | 4.567        |
| Size_DblN_peak_SoCA_Rec(7)                    | 24.495               | 24.645       | 24.586       |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 2.881                | 2.913        | 2.902        |
| Size_DblN_descend_se_SoCA_Rec(7)              | 3.436                | 3.365        | 3.401        |
| Size_DblN_end_logit_SoCA_Rec(7)               | -1.121               | -1.108       | -1.150       |
| Size_DblN_peak_TWL_discard(8)                 | 29.595               | 29.547       | 29.509       |
| Size_DblN_ascend_se_TWL_discard(8)            | 4.214                | 4.182        | 4.190        |
| Size_DblN_descend_se_TWL_discard(8)           | 3.206                | 3.200        | 3.209        |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | 50.969               | 50.237       | 50.978       |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.105                | 4.050        | 4.092        |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 48.680               | 47.410       | 49.115       |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.780                | 4.717        | 4.836        |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.922               | 30.581       | 30.698       |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.796                | 3.732        | 3.754        |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | NA                   | 33.585       | NA           |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | NA                   | 3.234        | NA           |
| Size_DblN_descend_se_CA_TWL(3)_BLK3repl_1875  | NA                   | 19.000       | NA           |
| Size_inflection_CA_TWL(3)                     | NA                   | NA           | 31.672       |
| Size_95%width_CA_TWL(3)                       | NA                   | NA           | 6.257        |
| sigmasel_CA_TWL(3)_LEN(10)                    | NA                   | NA           | 1.000        |
| Bratio_2025                                   | 0.5925               | 0.6025       | 0.5851       |
| SSB_unfished                                  | 13487                | 13945        | 13333        |
| Totbio_unfished                               | 58072                | 61069        | 57435        |
| Recr_unfished                                 | 25756                | 28215        | 25095        |
| Dead_Catch_SPR                                | 2356                 | 2509         | 2306         |
| OFLCatch_2025                                 | 2566                 | 2894         | 2543         |

Table 24: Likelihoods, parameter estimates, and select derived quantities for alternative treatments of natural mortality ( $M$ ) and steepness ( $h$ ). Likelihoods and derived quantities are shaded. Note that variation in assumed values for  $h$  and  $M$  effect large changes in the estimated proxy for MSY under the default SPR 50% harvest rate (“Dead\_Catch\_SPR”).

| Label                                         | h = 0.72,<br>female M = male M | h = 0.72,<br>sex-specific M (base) | estimate h,<br>sex-specific<br>M |
|-----------------------------------------------|--------------------------------|------------------------------------|----------------------------------|
| N.Parms                                       | 105                            | 106                                | 107                              |
| TOTAL                                         | 2654.44                        | 2633.05                            | 2628.74                          |
| Survey                                        | 32.53                          | 29.27                              | 23.77                            |
| Length_comp                                   | 582.19                         | 569.29                             | 569.50                           |
| Age_comp                                      | 2016.01                        | 2011.06                            | 2009.56                          |
| Recruitment                                   | 23.06                          | 23.40                              | 24.21                            |
| Parm_priors                                   | 0.646                          | 0.025                              | 1.709                            |
| <b>NatM_uniform_Fem_GP_1</b>                  | <b>0.219</b>                   | <b>0.165</b>                       | <b>0.175</b>                     |
| L_at_Amax_Fem_GP_1                            | 47.650                         | 47.901                             | 47.870                           |
| VonBert_K_Fem_GP_1                            | 0.198                          | 0.197                              | 0.197                            |
| CV_young_Fem_GP_1                             | 0.102                          | 0.105                              | 0.105                            |
| CV_old_Fem_GP_1                               | 0.042                          | 0.039                              | 0.039                            |
| <b>NatM_uniform_Mal_GP_1</b>                  | <b>0.000</b>                   | <b>0.266</b>                       | <b>0.244</b>                     |
| L_at_Amax_Mal_GP_1                            | -0.338                         | -0.328                             | -0.328                           |
| VonBert_K_Mal_GP_1                            | 0.562                          | 0.526                              | 0.527                            |
| CV_young_Mal_GP_1                             | 0.221                          | 0.236                              | 0.237                            |
| SR_LN(R0)                                     | 10.755                         | 10.032                             | 10.414                           |
| <b>SR_BH_steep</b>                            | <b>0.720</b>                   | <b>0.720</b>                       | <b>0.383</b>                     |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.423                          | 0.355                              | 0.291                            |
| Size_DblN_peak_NoCA_HKL(1)                    | 44.271                         | 40.974                             | 41.130                           |
| Size_DblN_ascend_se_NoCA_HKL(1)               | 4.655                          | 4.399                              | 4.415                            |
| Size_DblN_peak_SoCA_HKL(2)                    | 23.936                         | 23.799                             | 23.832                           |
| Size_DblN_peak_CA_TWL(3)                      | 46.776                         | 44.904                             | 45.203                           |
| Size_DblN_ascend_se_CA_TWL(3)                 | 4.593                          | 4.556                              | 4.570                            |
| Size_DblN_peak_OR_WA_Comm(4)                  | 57.452                         | 42.753                             | 43.587                           |
| Size_DblN_ascend_se_OR_WA_Comm(4)             | 5.522                          | 4.559                              | 4.637                            |
| Size_DblN_peak_CA_NET(5)                      | 48.134                         | 46.991                             | 46.994                           |
| Size_DblN_ascend_se_CA_NET(5)                 | 4.417                          | 4.426                              | 4.422                            |
| Size_DblN_peak_NoCA_OR_WA_Rec(6)              | 48.886                         | 43.894                             | 44.255                           |
| Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.355                          | 5.136                              | 5.154                            |
| Size_DblN_peak_SoCA_Rec(7)                    | 24.870                         | 24.708                             | 24.759                           |
| Size_DblN_ascend_se_SoCA_Rec(7)               | 2.971                          | 2.924                              | 2.933                            |
| Size_DblN_descend_se_SoCA_Rec(7)              | 2.771                          | 3.318                              | 3.271                            |
| Size_DblN_end_logit_SoCA_Rec(7)               | -0.638                         | -1.112                             | -1.052                           |
| Size_DblN_peak_TWL_discard(8)                 | 29.536                         | 29.552                             | 29.626                           |
| Size_DblN_ascend_se_TWL_discard(8)            | 4.170                          | 4.167                              | 4.171                            |
| Size_DblN_descend_se_TWL_discard(8)           | 3.336                          | 3.193                              | 3.182                            |
| Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875      | 52.536                         | 51.604                             | 51.250                           |
| Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.155                          | 4.157                              | 4.130                            |
| Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875      | 56.635                         | 48.830                             | 48.811                           |
| Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 5.227                          | 4.824                              | 4.818                            |
| Size_DblN_peak_CA_TWL(3)_BLK3repl_1875        | 37.703                         | 33.792                             | 33.876                           |
| Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 4.035                          | 3.290                              | 3.307                            |
| Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875      | 32.052                         | 30.678                             | 30.600                           |
| Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.977                          | 3.752                              | 3.735                            |
| Bratio_2025                                   | 1.000                          | 0.832                              | 0.473                            |
| SSB_unfished                                  | 13006                          | 11922                              | 15373                            |
| Totbio_unfished                               | 72247                          | 52043                              | 68965                            |
| Recr_unfished                                 | 46848                          | 22734                              | 33316                            |
| <b>Dead_Catch_SPR</b>                         | <b>3547</b>                    | <b>2114</b>                        | <b>1077</b>                      |
| OFLCatch_2025                                 | 7733                           | 3617                               | 2870                             |

Table 25: Estimates of “Mohn’s rho” from the package r4ss, based on a 5-year retrospective analysis.

| Quantity            | value  |
|---------------------|--------|
| SSB                 | -0.550 |
| Rec                 | 4.652  |
| Bratio              | -0.492 |
| F                   | 0.691  |
| WoodHole_SSB.all    | -0.541 |
| WoodHole_Rec.all    | 2.281  |
| WoodHole_Bratio.all | -0.483 |
| WoodHole_F.all      | 0.705  |
| AFSC_Hurtado_SSB    | -0.110 |
| AFSC_Hurtado_Rec    | 0.930  |
| AFSC_Hurtado_F      | 0.138  |
| AFSC_Hurtado_Bratio | -0.098 |

Table 26: Projections of potential OFLs (mt), ABCs (mt), estimated spawning output (billions of eggs), and fraction unfished. Projections assume catches are equal to the ABC starting in 2027, and based on default values for a “category 1” assessment ( $\sigma=0.5$  and  $P_{star} = 0.45$ ). Catch estimates for 2025 and 2026 (1598.72 and 1521.61 mt, respectively) were provided by the Groundfish Management Team (GMT).

| Year | Predicted OFL (mt) | ABC (mt) | Buffer | Spawning output | Fraction Unfished |
|------|--------------------|----------|--------|-----------------|-------------------|
| 2025 | --                 | --       | --     | 9925            | 0.832             |
| 2026 | --                 | --       | --     | 9369            | 0.786             |
| 2027 | 3434.3             | 3211.1   | 0.935  | 9133            | 0.766             |
| 2028 | 3318.1             | 3085.8   | 0.930  | 8778            | 0.736             |
| 2029 | 3250.8             | 3010.3   | 0.926  | 8597            | 0.721             |
| 2030 | 3210.7             | 2960.2   | 0.922  | 8437            | 0.708             |
| 2031 | 3163.1             | 2900.5   | 0.917  | 8242            | 0.691             |
| 2032 | 3090.3             | 2821.4   | 0.913  | 8006            | 0.672             |
| 2033 | 2997.8             | 2725.0   | 0.909  | 7746            | 0.650             |
| 2034 | 2899.1             | 2620.8   | 0.904  | 7483            | 0.628             |
| 2035 | 2805.2             | 2524.7   | 0.900  | 7235            | 0.607             |
| 2036 | 2721.5             | 2438.5   | 0.896  | 7014            | 0.588             |

Table 27: 12-year projections (2025 – 2036) for chilipepper rockfish according to three alternative states of nature. Columns represent low, medium (base case), and high states of nature, and rows range over different assumed catch levels (the default harvest control rule, and constant catches equal to the MSY proxy). Spawning output units are billions of eggs.

|      | Low Productivity<br>(steepness = 0.38) |                    |                  | Base Model<br>(steepness = 0.72) |                  | High Productivity<br>(steepness = 0.97) |                  |
|------|----------------------------------------|--------------------|------------------|----------------------------------|------------------|-----------------------------------------|------------------|
|      | ACL=ABC<br>catch                       | spawning<br>output | % of<br>unfished | spawning<br>output               | % of<br>unfished | spawning<br>output                      | % of<br>unfished |
| 2025 | 1599*                                  | 7247               | 46.9%            | 9925                             | 83.2%            | 10836                                   | 95.9%            |
| 2026 | 1522*                                  | 6704               | 43.4%            | 9369                             | 78.6%            | 10212                                   | 90.3%            |
| 2027 | 3211                                   | 6435               | 41.6%            | 9133                             | 76.6%            | 9927                                    | 87.8%            |
| 2028 | 3086                                   | 6041               | 39.1%            | 8778                             | 73.6%            | 9559                                    | 84.6%            |
| 2029 | 3010                                   | 5854               | 37.9%            | 8597                             | 72.1%            | 9369                                    | 82.9%            |
| 2030 | 2960                                   | 5744               | 37.2%            | 8437                             | 70.8%            | 9205                                    | 81.4%            |
| 2031 | 2901                                   | 5642               | 36.5%            | 8242                             | 69.1%            | 9006                                    | 79.7%            |
| 2032 | 2821                                   | 5520               | 35.7%            | 8006                             | 67.2%            | 8764                                    | 77.5%            |
| 2033 | 2725                                   | 5379               | 34.8%            | 7746                             | 65.0%            | 8494                                    | 75.2%            |
| 2034 | 2621                                   | 5232               | 33.9%            | 7483                             | 62.8%            | 8221                                    | 72.7%            |
| 2035 | 2525                                   | 5091               | 32.9%            | 7235                             | 60.7%            | 7965                                    | 70.5%            |
| 2036 | 2439                                   | 4962               | 32.1%            | 7014                             | 58.8%            | 7736                                    | 68.4%            |
|      | SPR Proxy<br>MSY catch                 | spawning<br>output | % of<br>unfished | spawning<br>output               | % of<br>unfished | spawning<br>output                      | % of<br>unfished |
| 2025 | 1599*                                  | 7247               | 46.9%            | 9925                             | 83.2%            | 10836                                   | 95.9%            |
| 2026 | 1522*                                  | 6704               | 43.4%            | 9369                             | 78.6%            | 10212                                   | 90.3%            |
| 2027 | 2114                                   | 6435               | 41.6%            | 9133                             | 76.6%            | 9927                                    | 87.8%            |
| 2028 | 2114                                   | 6312               | 40.8%            | 9078                             | 76.1%            | 9835                                    | 87.0%            |
| 2029 | 2114                                   | 6333               | 41.0%            | 9149                             | 76.7%            | 9863                                    | 87.3%            |
| 2030 | 2114                                   | 6391               | 41.4%            | 9217                             | 77.3%            | 9875                                    | 87.4%            |
| 2031 | 2114                                   | 6431               | 41.6%            | 9231                             | 77.4%            | 9823                                    | 86.9%            |
| 2032 | 2114                                   | 6434               | 41.6%            | 9180                             | 77.0%            | 9701                                    | 85.8%            |
| 2033 | 2114                                   | 6400               | 41.4%            | 9071                             | 76.1%            | 9519                                    | 84.2%            |
| 2034 | 2114                                   | 6339               | 41.0%            | 8923                             | 74.8%            | 9300                                    | 82.3%            |
| 2035 | 2114                                   | 6264               | 40.5%            | 8752                             | 73.4%            | 9062                                    | 80.2%            |
| 2036 | 2114                                   | 6184               | 40.0%            | 8572                             | 71.9%            | 8821                                    | 78.0%            |



Table 28: ‘Risk Table’ for chilipepper to document ecosystem and environmental factors potentially affecting stock productivity and uncertainty, or other concerns arising from the stock assessment. Level 1 is favorable, Level 2 is neutral and Level 3 is unfavorable.

| Ecosystem and environmental conditions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Assessment data inputs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Assessment model fits and structural uncertainty                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>Larval production and condition: Based on 2024- 2025 NPGO, may be neutral to unfavorable, but signals are somewhat mixed</p> <p>Recruitment: Index used in assessment. High diversity and abundance of the YOY groundfish assemblage community in 2024 consistent. Environmental conditions are favorable for 2025 (minty/subarctic), high preliminary survey catch rates. Overall, favorable for recruitment</p> <p>Prey: Most evidence suggests abundant forage, favorable conditions, positive</p> <p>Predators: Ongoing long-term increases in abundance, but no evidence of recent sharp increases, neutral</p> <p>Growth: Recent years potentially unfavorable in near term (based on autocorrelation in growth variability), neutral</p> | <p>Historically and currently among most important commercial species in California, catch reconstruction and recent catch data are reliable, favorable</p> <p>Robust age data to inform assessment, modest aging error concerns need resolution, neutral to favorable</p> <p>Robust information on reproductive ecology, but better data on functional maturity and role of multiple brooding would be helpful, neutral to favorable</p> <p>Several informative fishery independent indices that span life history stages, including larval production/spawning output (CalCOFI), settled juvenile and mature adult biomass (WCGBTS), and pelagic YOY abundance (RREAS), favorable</p> | <p>Good fits to age and length composition data. Generally good fits fishery-independent survey data, particularly in more recent years, favorable</p> <p>Several abundance indices help inform recent recruitment and population forecasts (e.g., WCGBTS, RREAS), favorable</p> <p>Selectivity functions are not always well behaved, unfavorable</p> <p>Evidence for time-varying growth in data, but growth assumed to be time-invariant within the model, neutral</p> <p>Likelihood profiles indicate that natural mortality is well informed, but steepness is not well informed. Steepness provides axis of uncertainty for decision table, neutral</p> |
| Level 1, favorable (medium agreement, robust evidence)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Level 1, favorable (high agreement, robust evidence)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Level 2, neutral (medium agreement, medium evidence)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

## 9 Figures

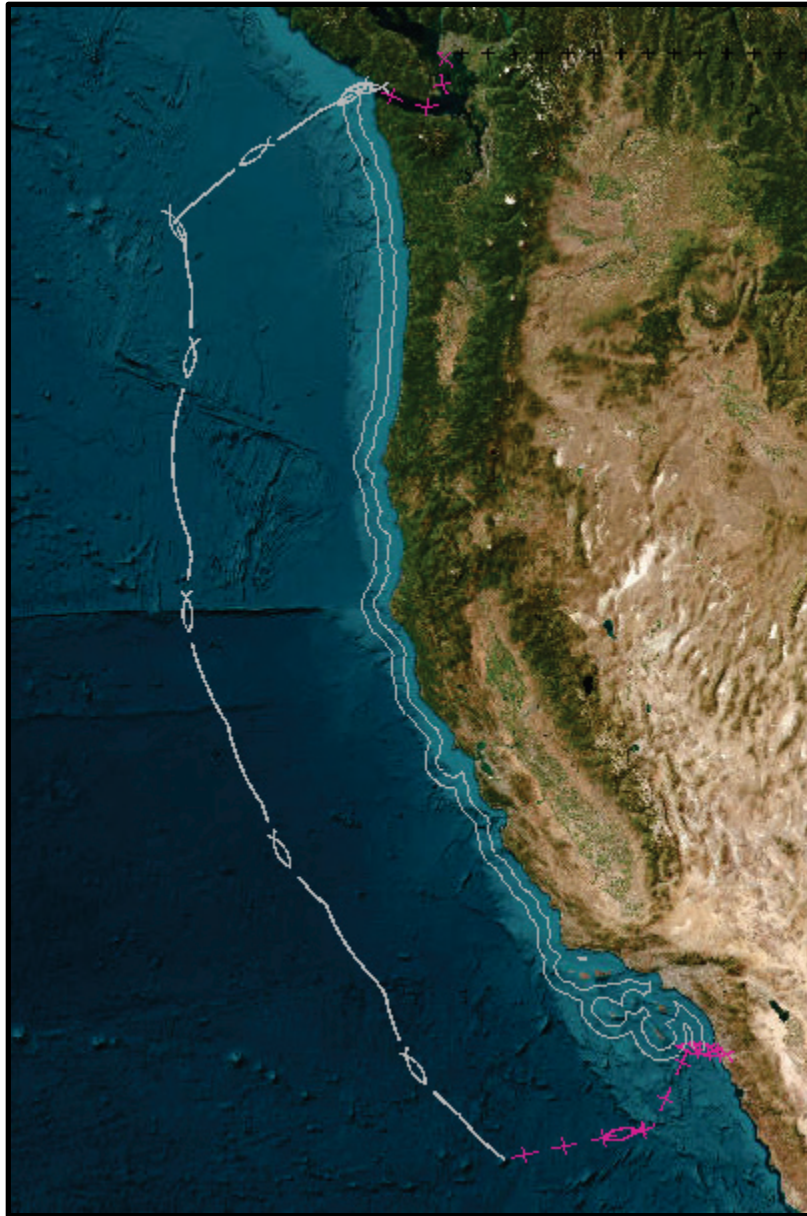


Figure 1: Map of the assessed area. Outlined region represents waters inside the U.S. Exclusive Economic Zone (EEZ) off the coasts of Washington, Oregon, and California. Source: NOAA U.S. Maritime Limits and Boundaries [Webmap](#).

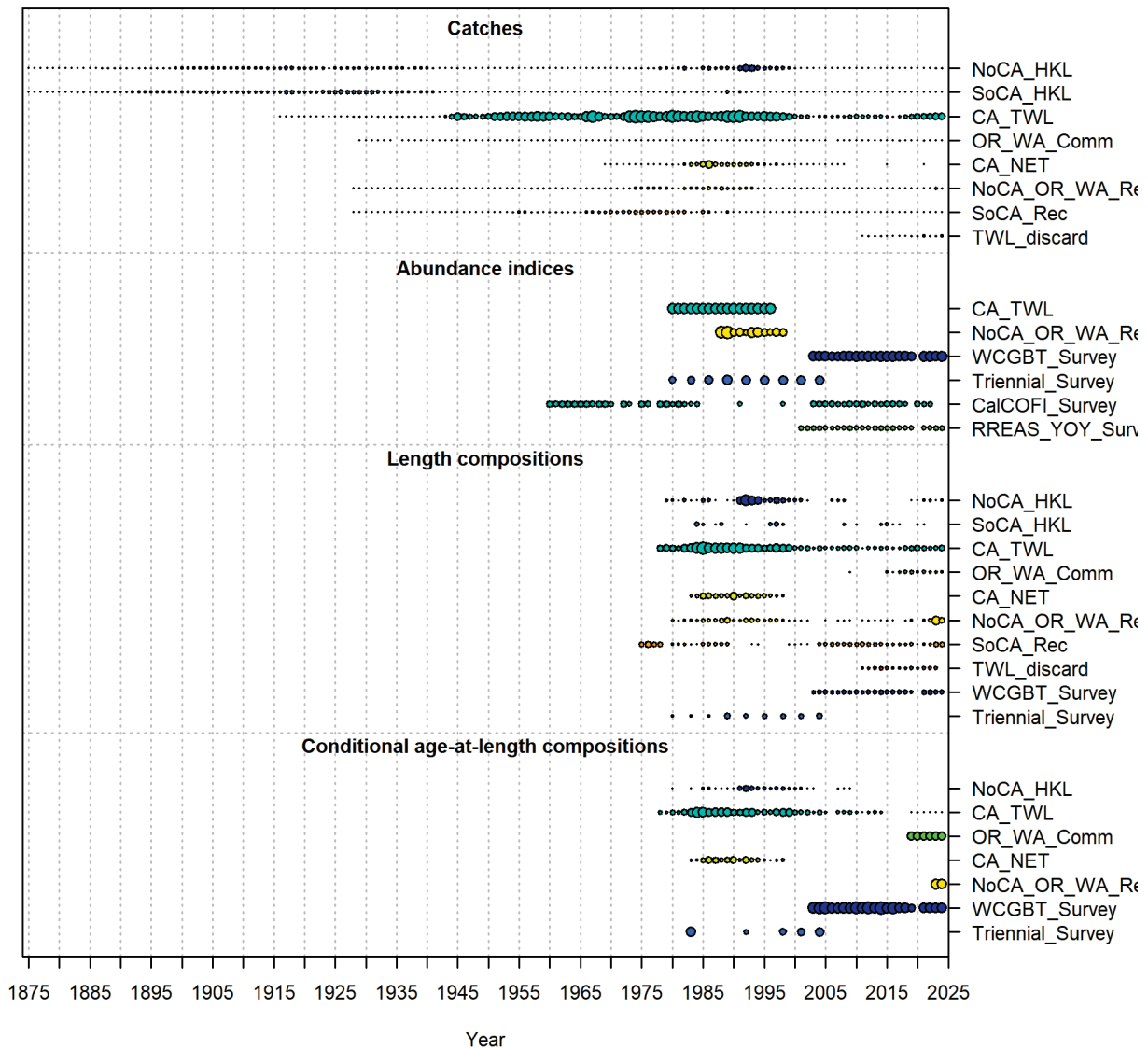


Figure 2: Summary of data sources by year, type, and fleet in the chilipepper base model. Two abundance indices (“CA\_TWL” and “NoCA\_OR\_WA\_Rec”) were in previous assessments, but are not included in the likelihood (i.e. not used to fit the 2025 model). Circle areas are relative and comparable only within a data type. Circle sizes are proportional to total catch for catches; to precision for indices; to total sample size for length compositions or conditional age-at-length observations.

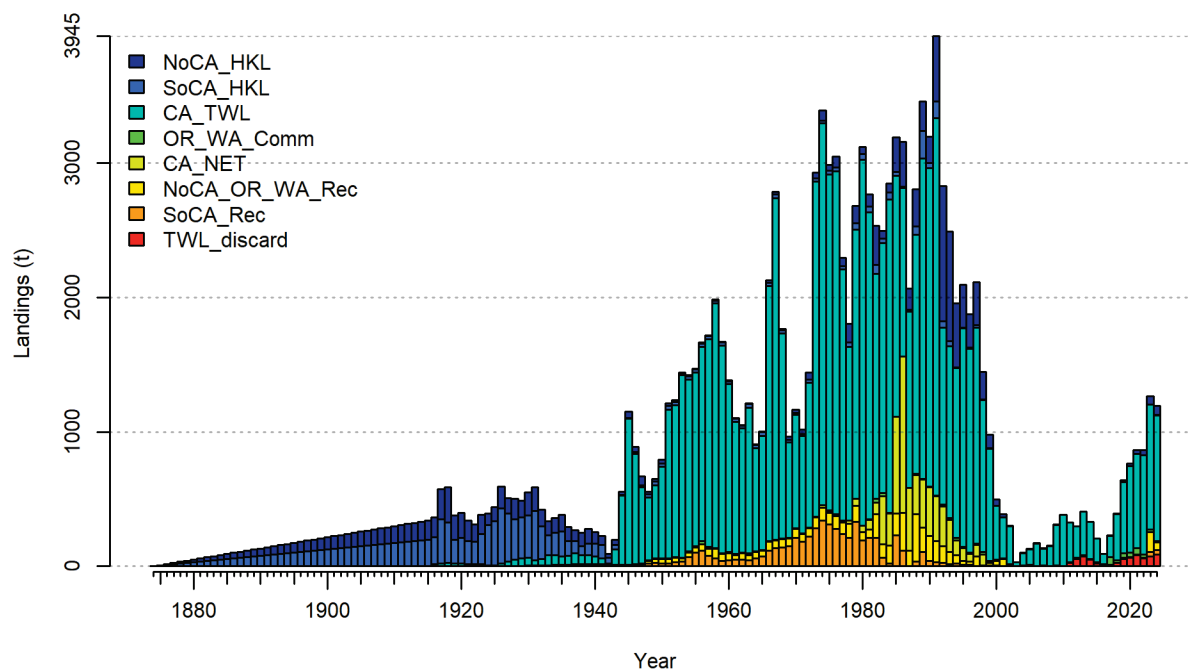


Figure 3: Total catch (mt) by fleet and year (including discards) used in the model. Values are stacked so bar height equals total removals in each year.

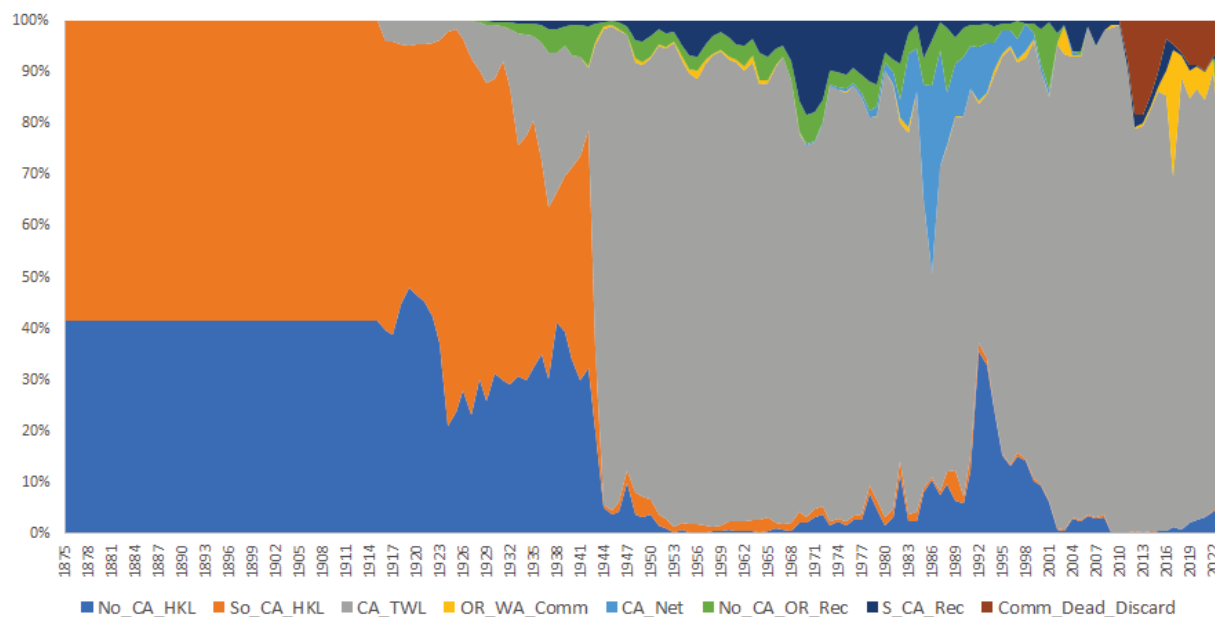


Figure 4: Percentage (vertical axis) of total annual catch by fleet (color) and year (horizontal axis).

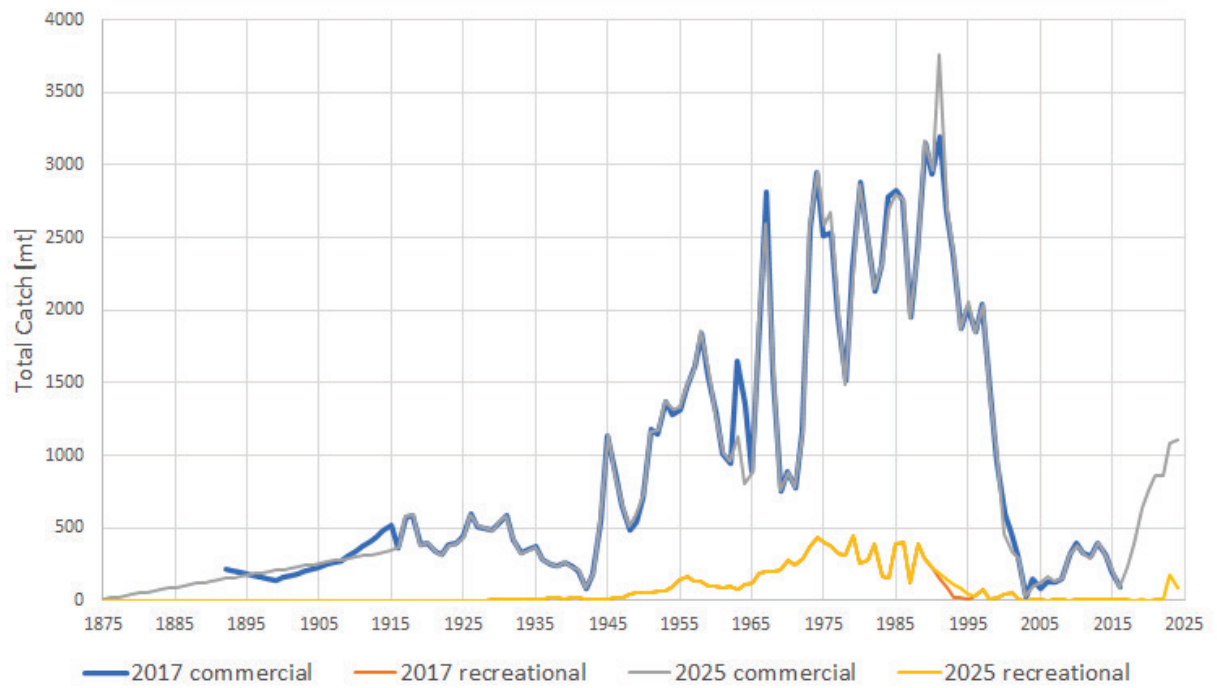


Figure 5: Comparison of catch estimates (mt) by year, sector (commercial or recreational), and assessment year.

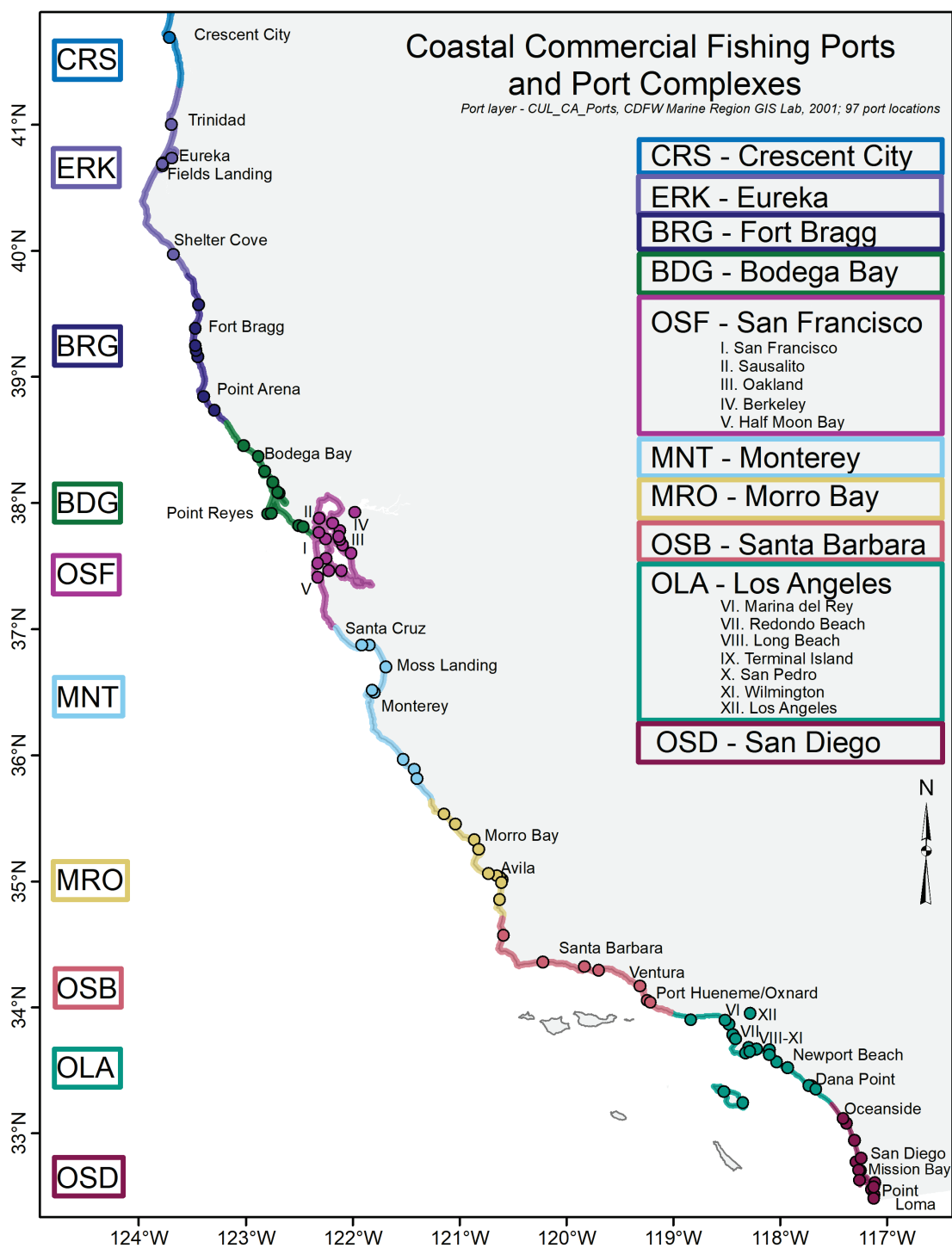


Figure 6: California commercial fishing ports and port complexes sampled by the California Cooperative Groundfish Survey (CCGS).

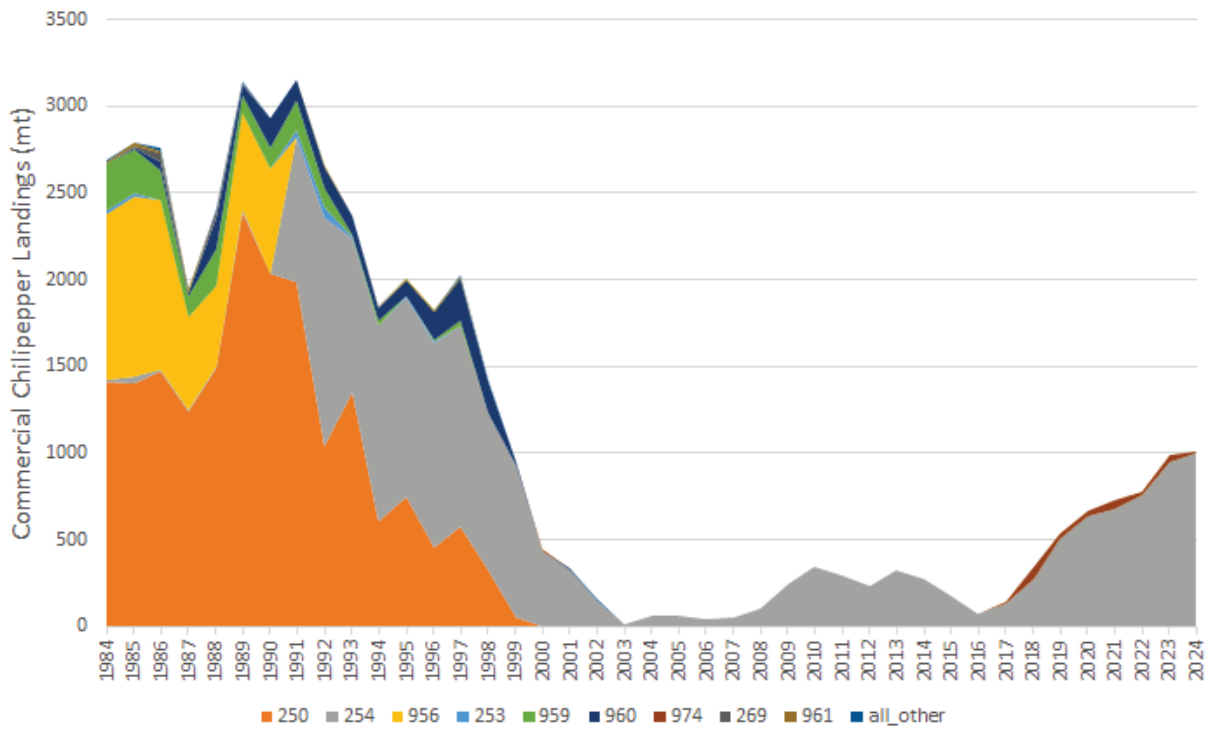


Figure 7: Chilepepper rockfish landings in California by market category and year. The nominal “chilepepper” market category is 254 (gray). Other market categories shown include 250 (Rockfish, unspecified), 956 (Rockfish, group bocaccio/chili), 253 (bocaccio), 959 (Rockfish, Group Red), 960 (Rockfish, Group Small), 974 (Rockfish, shelf), 269 (Rockfish, widow), and 961 (Rockfish, Group Rosefish).

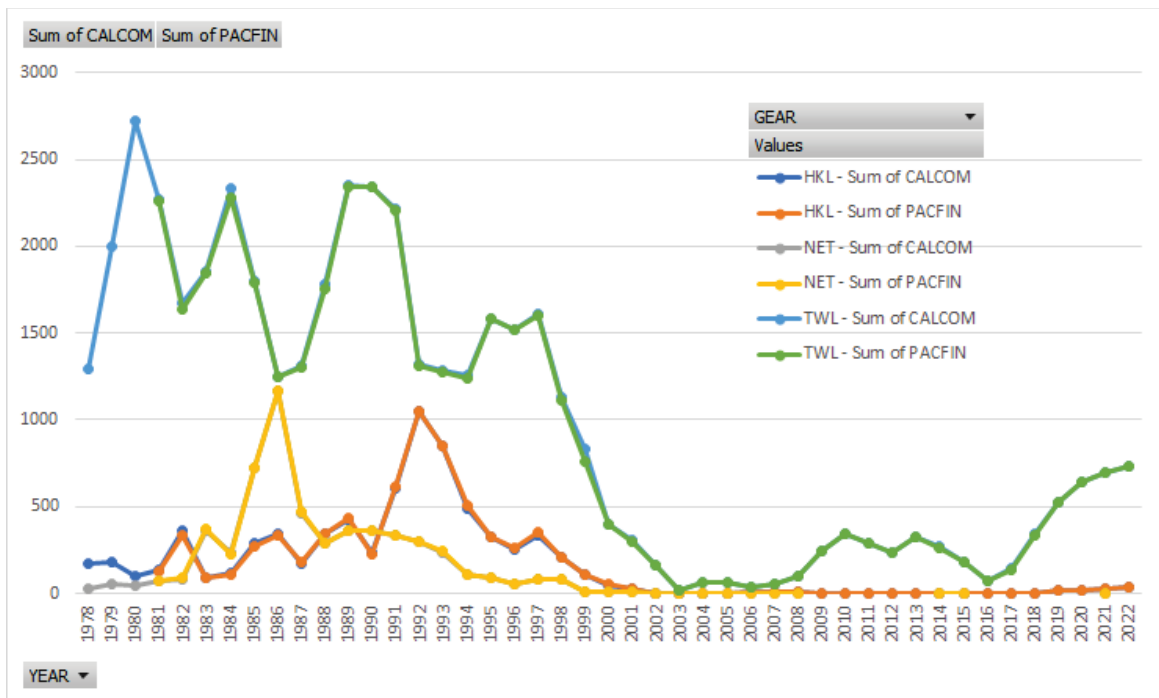


Figure 8: Comparison of catch estimates (vertical axis, in mt) by year, commercial gear group (HKL = hook and line, NET = net gears, TWL = trawl) and source database (CALCOM or PacFIN).

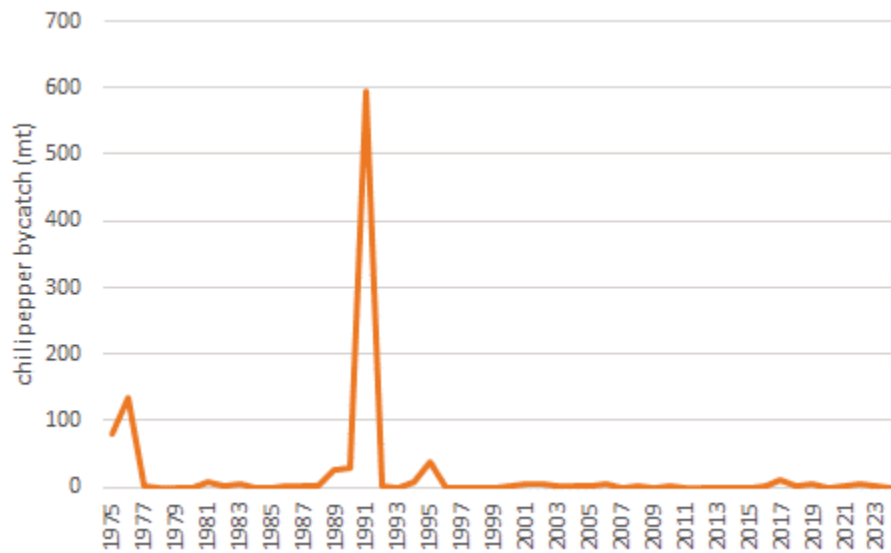


Figure 9: Chilipepper bycatch in the at-sea hake fishery.

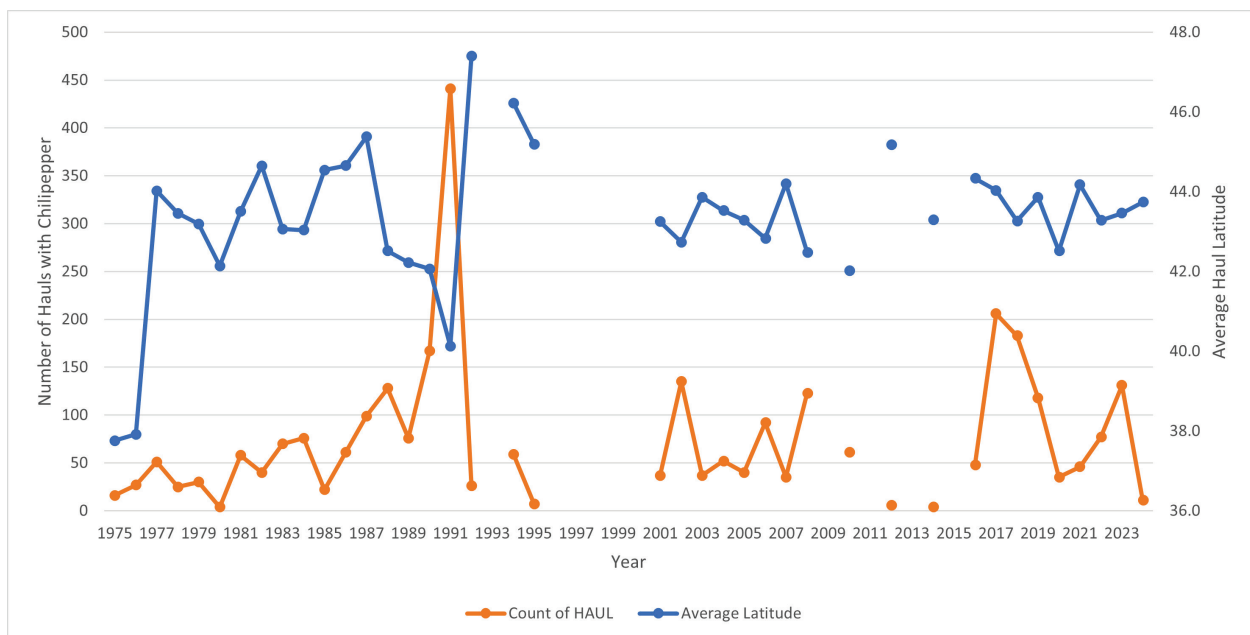


Figure 10: Annual number of observed hauls catching chilipepper rockfish and average latitude fished in the at-sea hake fishery. Years with increased chilipepper bycatch (both encounter rates and total bycatch in mt) correspond with fishing occurring south of 42 degrees N. latitude, on average.





Figure 11: Map of CRFS districts in California. Source: CDFW website.

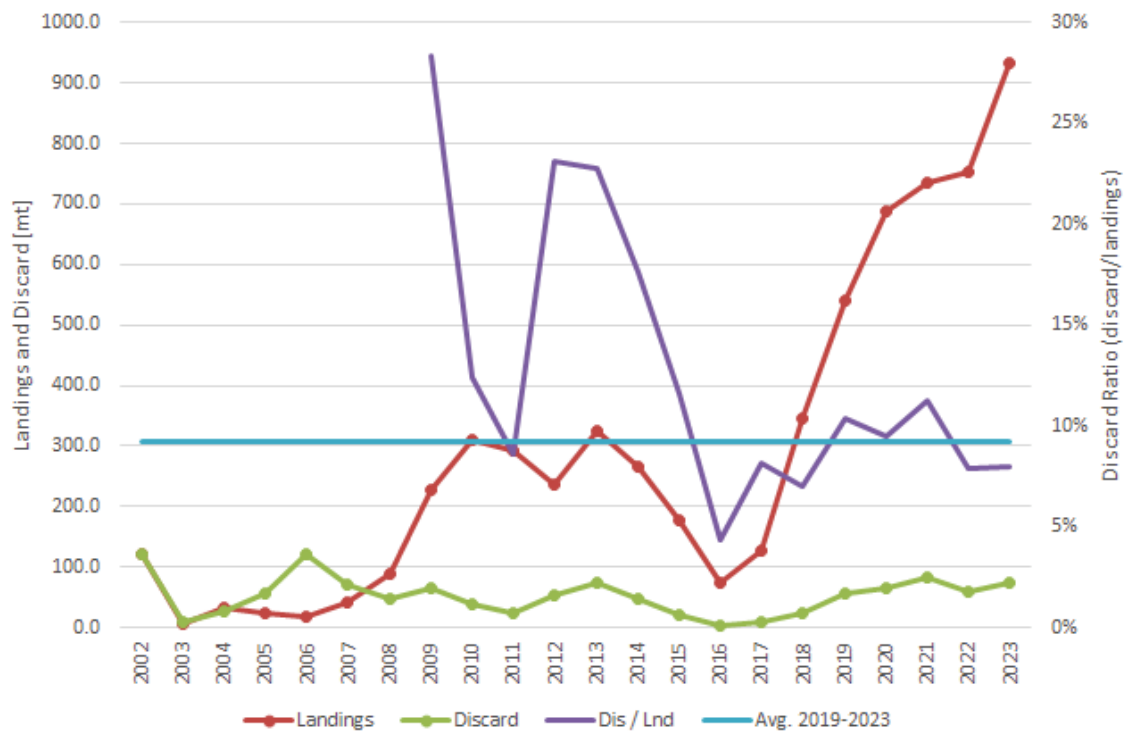


Figure 12: Landings and discards [mt] from all trawl sectors (combined) in the GEMM report. Large discard ratios in early years were driven by regulatory restrictions. Discards from 2019-2023 averaged 9% of landings by weight.

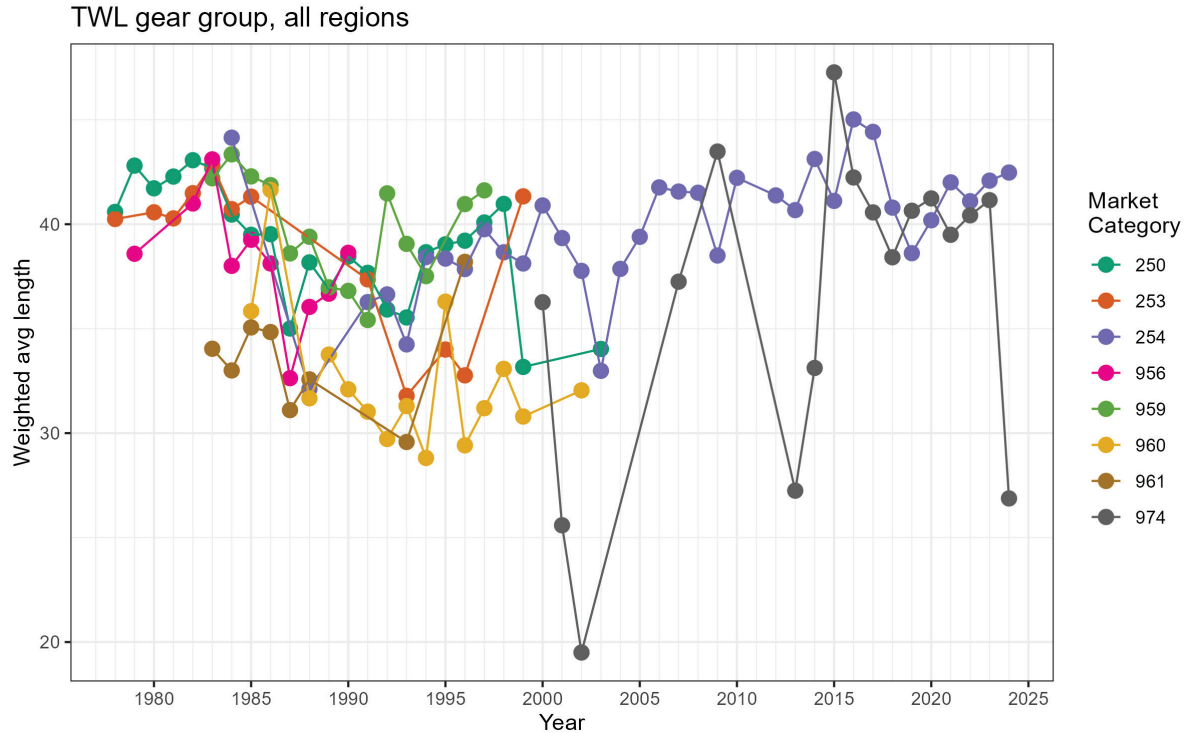


Figure 13: Catch-weighted differences in mean chilipepper fork length [cm] in California, all trawl gears combined, by year and market category.

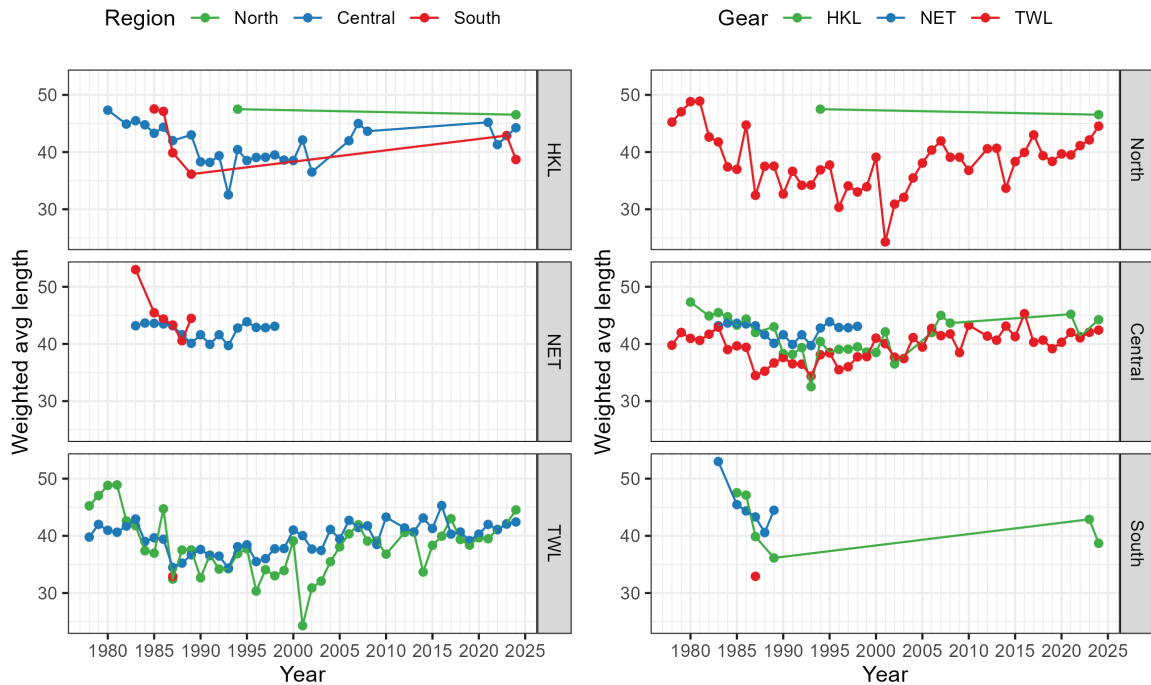


Figure 14: Differences in catch-weighted mean fork length [cm] in California, by year, gear, and region (North = Eureka and Crescent City port complexes, Central = Fort Bragg, Bodega Bay, San Francisco, Monterey, and Morro Bay port complexes, South = Santa Barbara, Los Angeles and San Diego port complexes).

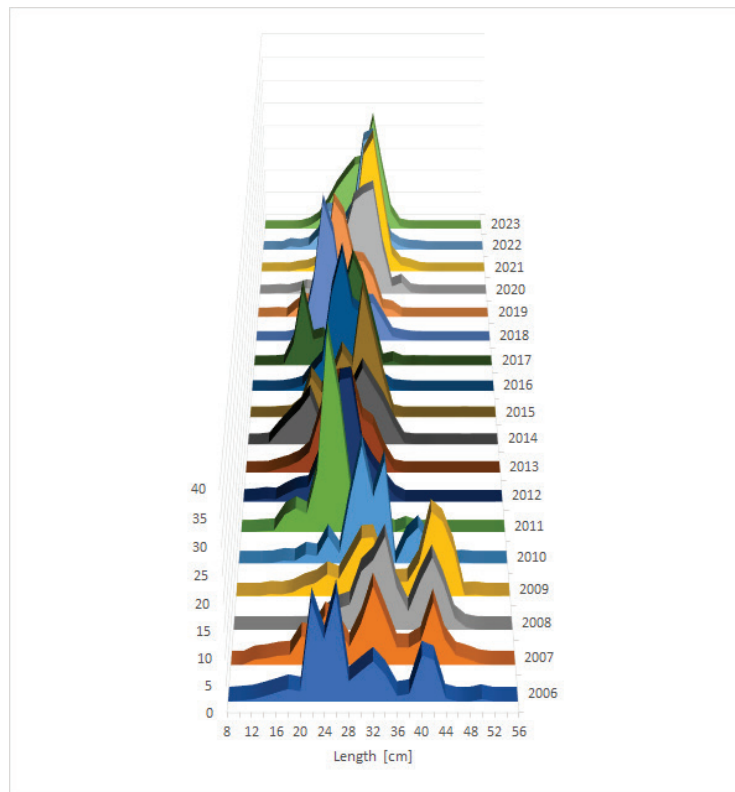


Figure 15: Percentage of lengthed fish (vertical axis) by length bin and year of discarded chilipepper in the trawl fleet, 2006-2023. Note the shift in 2011 at the beginning of the IFQ fishery. Source: WCGOP.

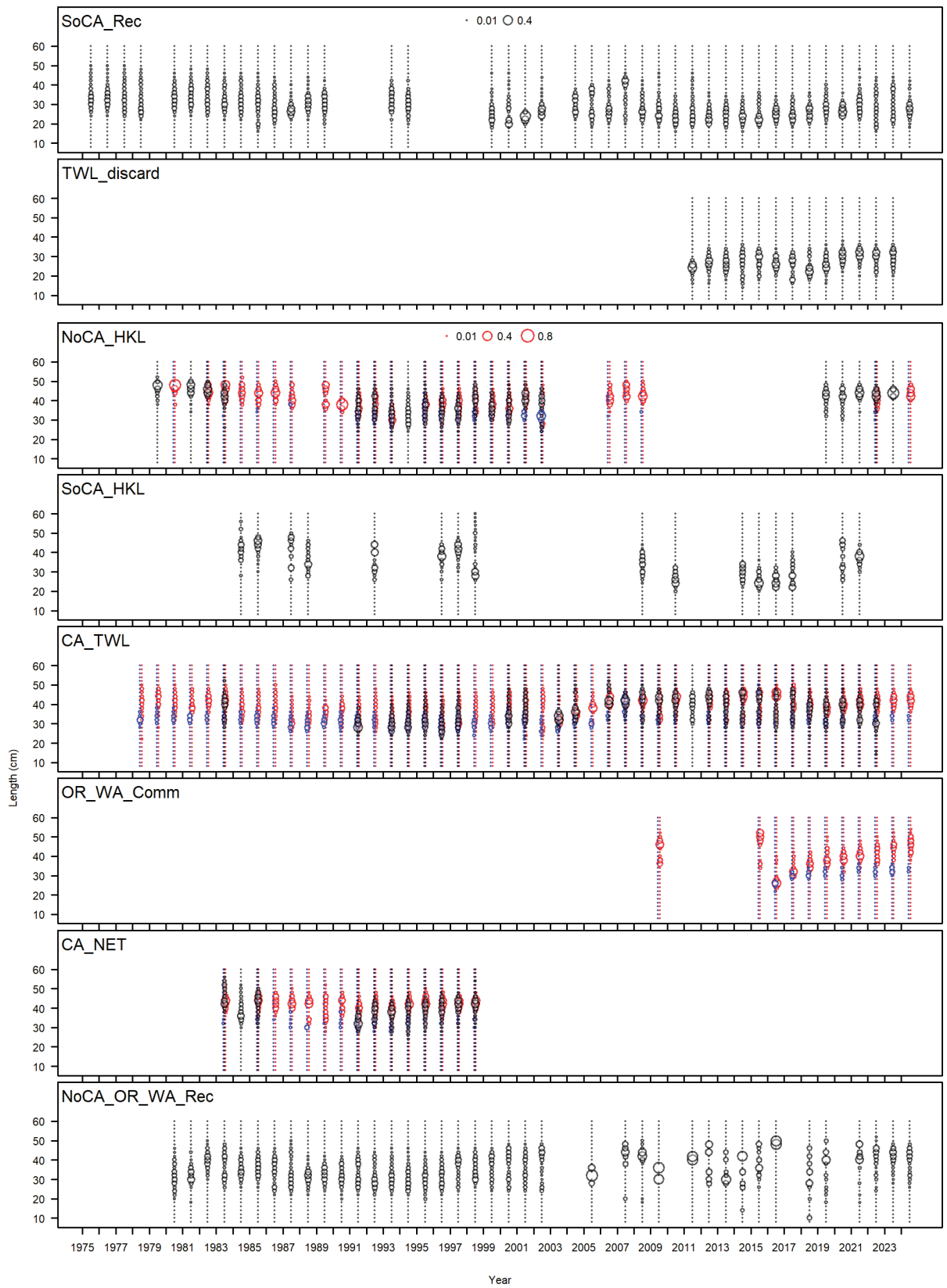


Figure 16: Length composition data from fishery fleets.

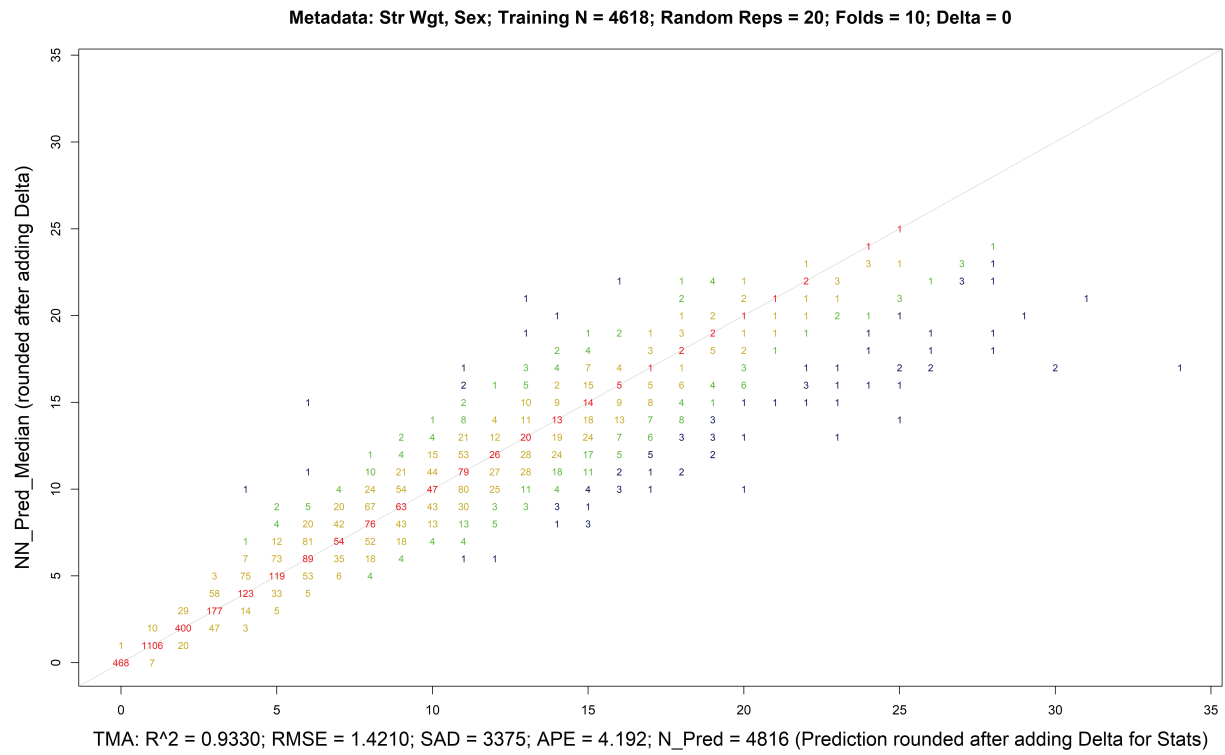


Figure 17: Traditional age estimates relative to the predictions for the training set of 4618 otoliths used to develop the Neural Network model. Results indicate a bias to younger estimates after approximately age 15.

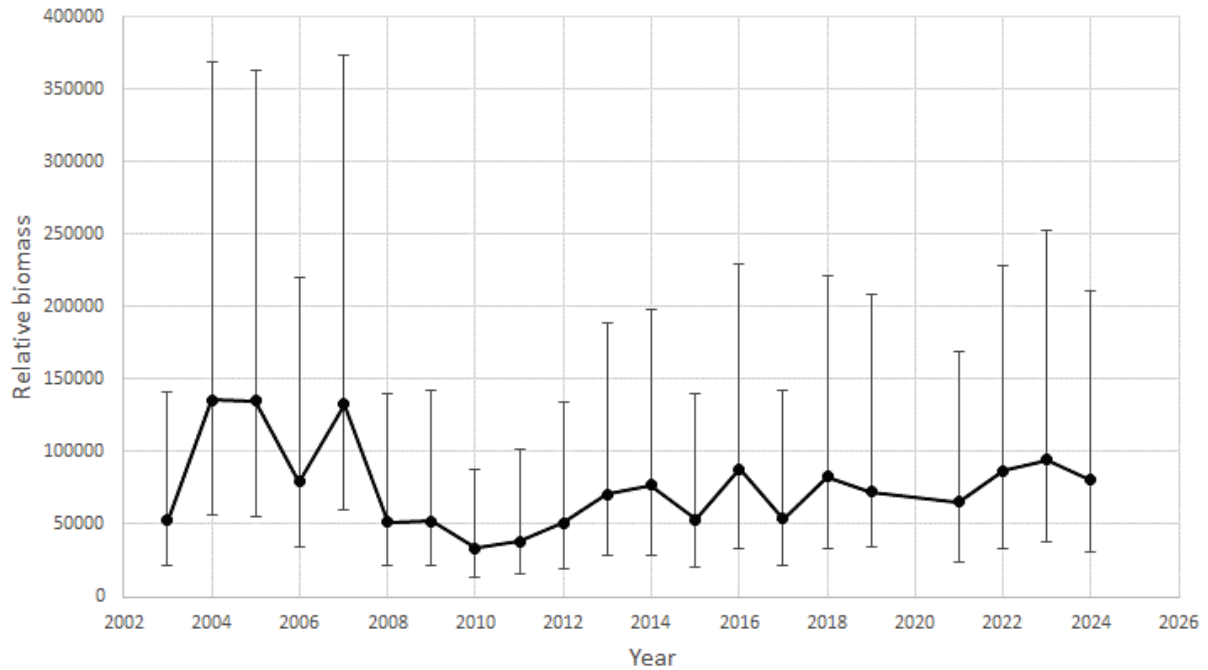


Figure 18: WCG BTS relative abundance index for chilipepper rockfish, updated to include depth effect. See STAR Panel request 12 in Appendix B. Error bars represent  $\pm 1$  S.E. assuming a lognormal distribution. Hauls from Washington were excluded due to a small number of positive observations.

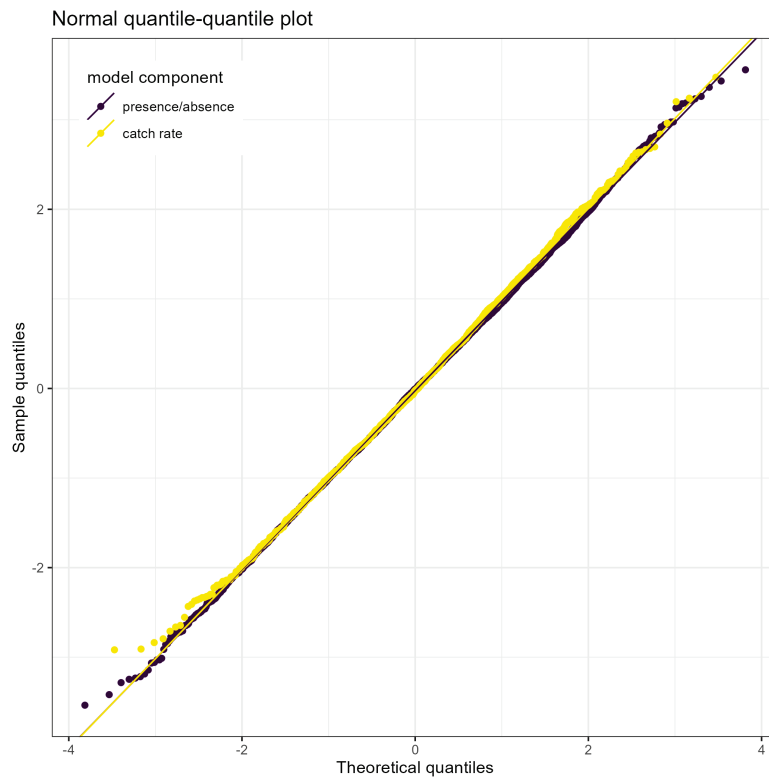


Figure 19: Quantile-quantile plot for component models (binomial and lognormal) of the WCG BTS relative abundance index for chilipepper rockfish.

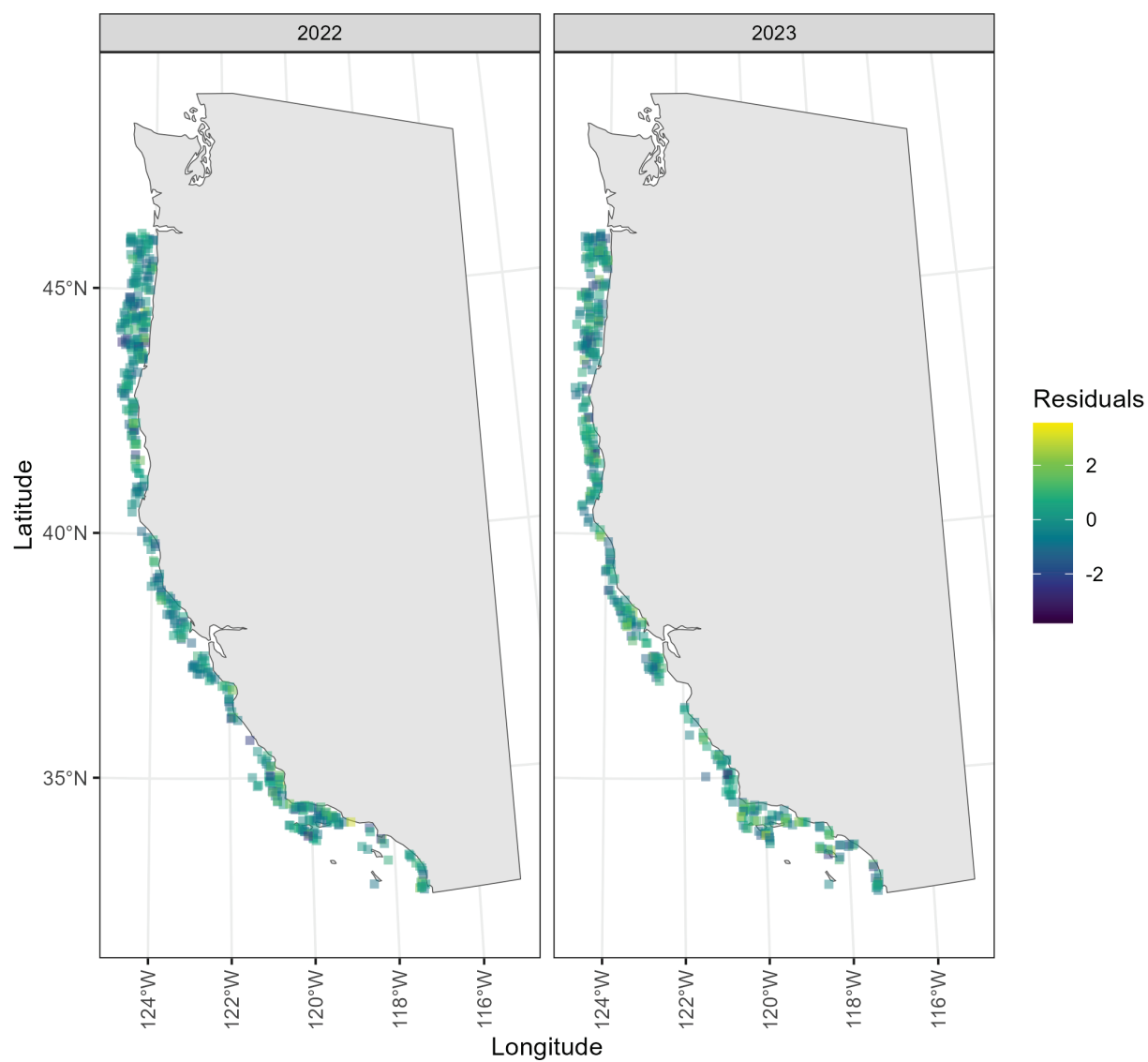


Figure 20: Map of residuals from the WCGBTS index used in the chilipepper rockfish assessment. Example shown is for 2022-2023.

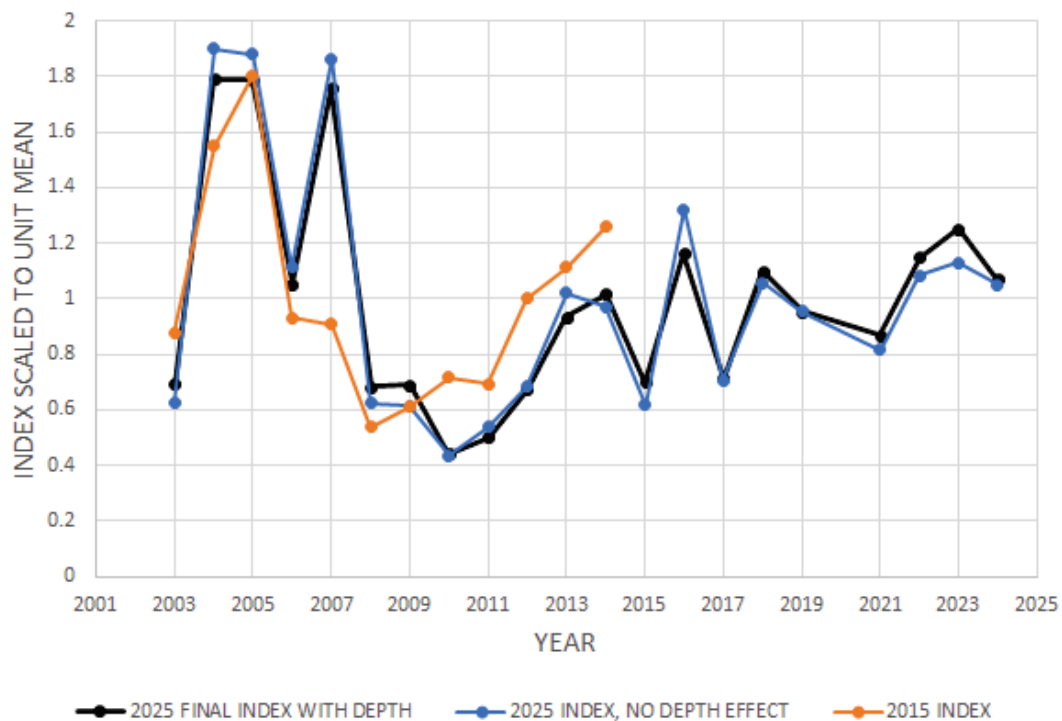


Figure 21: Comparison of WCGTBS indices from the 2015 and 2025 chilipepper stock assessments. The final index used in the 2025 assessment included a depth effect. Each index was rescaled to have a mean equal to 1 to facilitate comparison of trends.

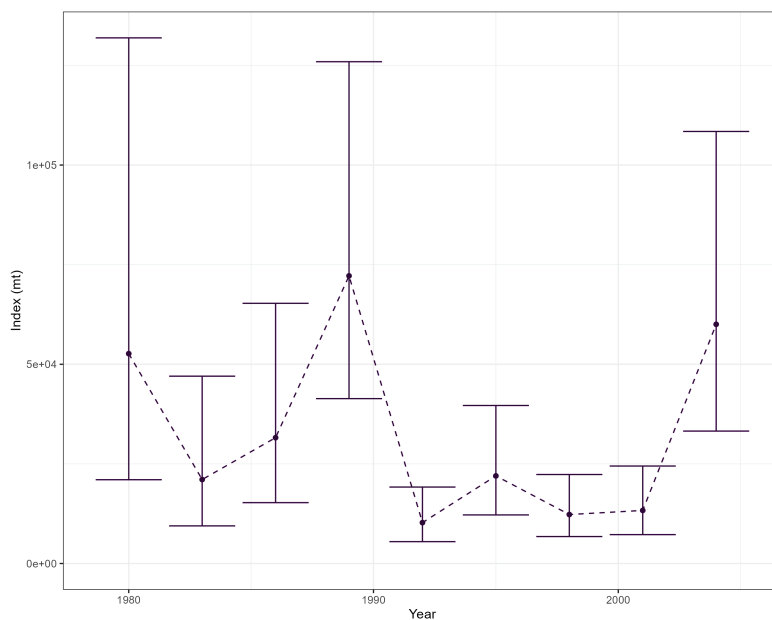


Figure 22: Triennial trawl survey relative abundance index for chilipepper rockfish. Error bars represent  $\pm 1$  S.E. assuming a lognormal distribution. Depth effects for the triennial survey were not explored due to insufficient time.



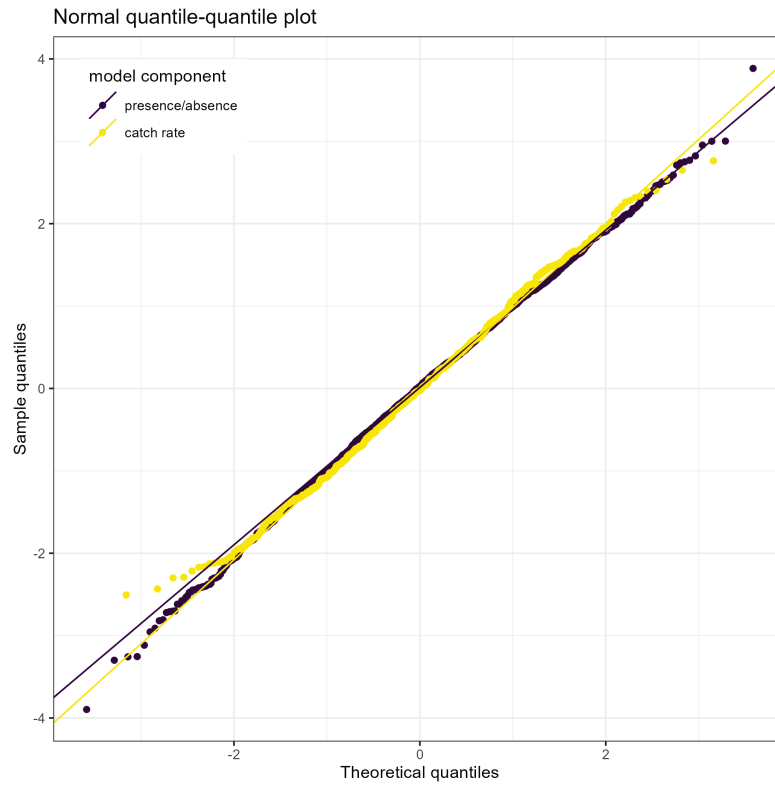


Figure 23: Quantile-quantile plot for component models (binomial and lognormal) of the Triennial trawl survey relative abundance index for chilipepper rockfish.

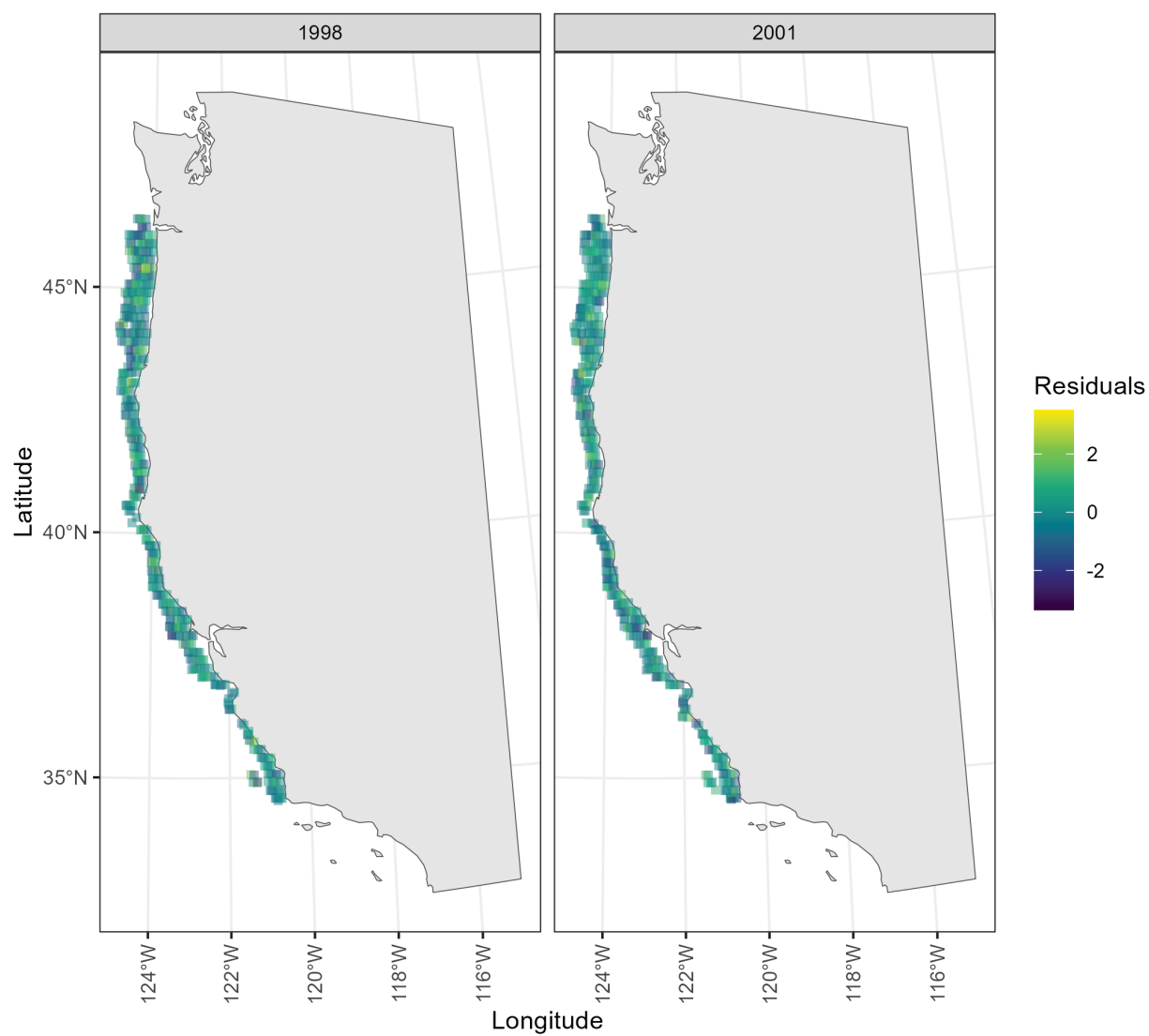


Figure 24: Map of residuals from the Triennial trawl survey index used in the chilipepper rockfish assessment. Example shown is for 1998 & 2001.

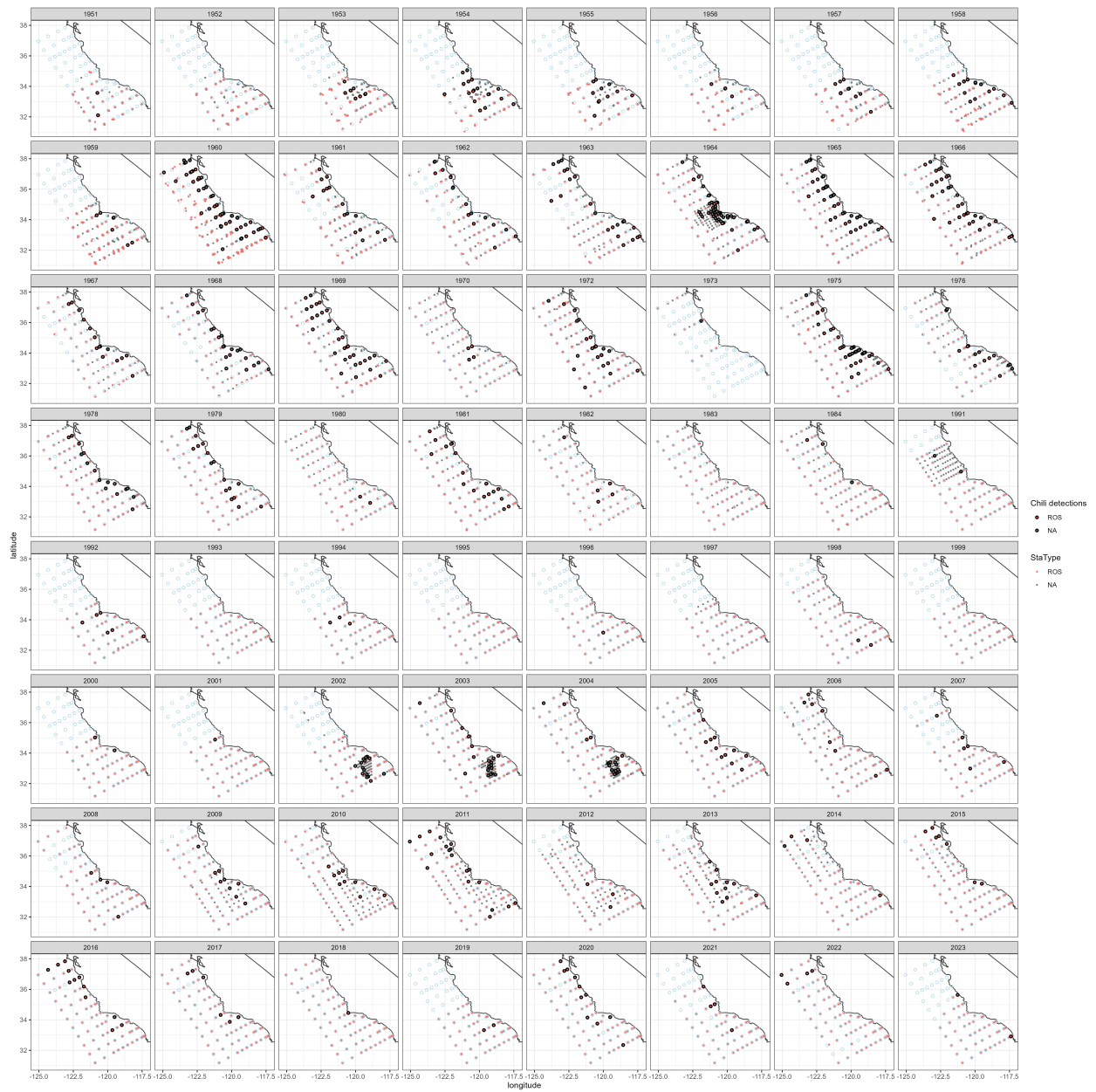


Figure 25: Spatial and temporal distribution of all CalCOFI tows retained for analysis. Light blue open circles are locations of the standard CalCOFI stations. Filled circles are tows, with color indicating whether they are at standard CalCOFI stations or other stations. The filled circles outlined in black are samples with a positive catch of chilipepper.

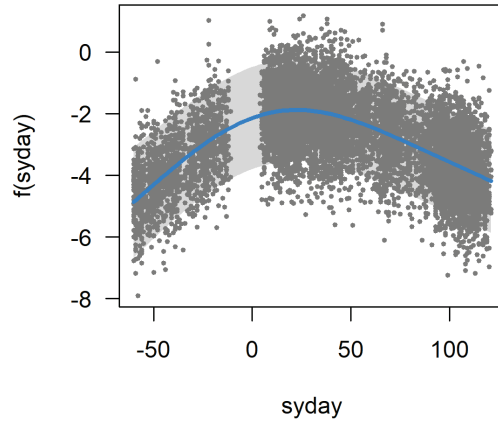


Figure 26: Conditional effect of Julian date (“syday”) on larval chilipepper rockfish density from the CalCOFI survey. Zero on the horizontal axis represents January 1, and negative values represent days in the previous year (as spawning spans winter months). Points are partial randomized quantile residuals, with a smooth function (blue line) illustrating the model prediction.

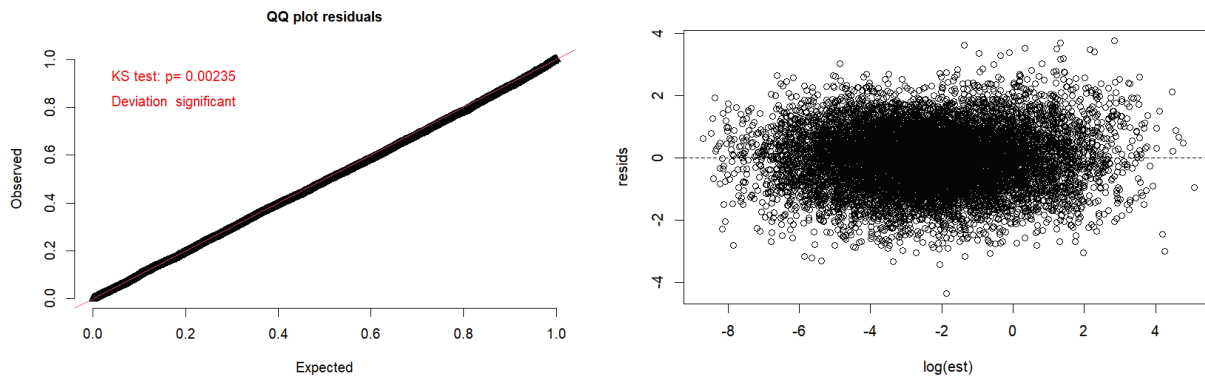


Figure 27: Diagnostic plots for the model of larval chilipepper rockfish from the CalCOFI survey. Q-Q plot for Dharma residuals based on 500 simulations, and plot of predicted values vs. residual. The KS normality test is often statistically significant when sample sizes are large, but there is not strong visual evidence of a meaningful deviation.

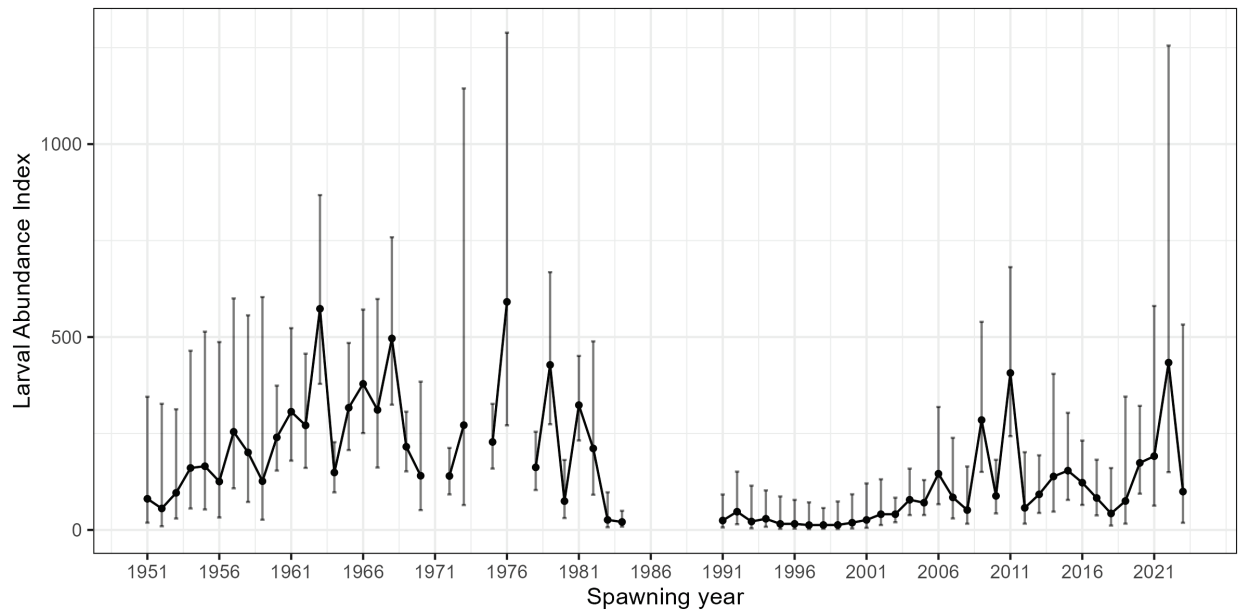


Figure 28: Relative abundance index for larval output of chilipepper rockfish from the CalCOFI survey. Error bars are 95% CI. Although all years are displayed here, years in which fewer than 10% of samples were taken north of Point Conception were excluded from the fitted index. See model fits to indices for final index.

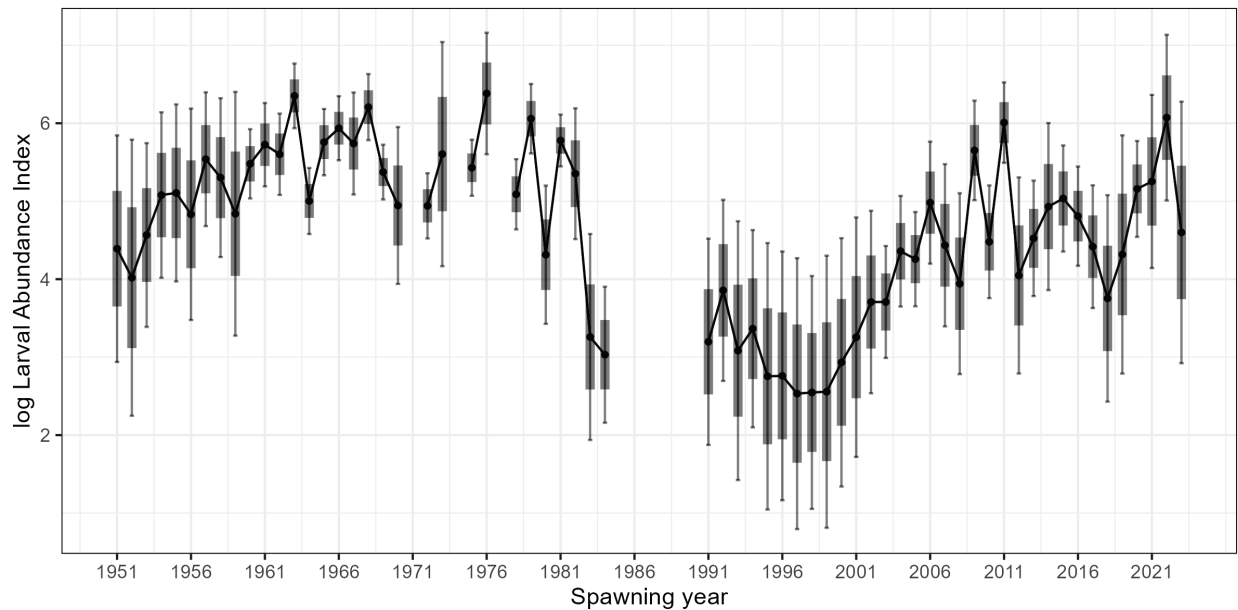


Figure 29: Log abundance index for larval output of chilipepper rockfish from the CalCOFI survey. Error bars are  $\pm 1$  SE (thick bars) and 95% CI (thin bars). Although all years are displayed here, years in which fewer than 10% of samples were taken north of Point Conception were excluded from the fitted index. See model fits to indices for final index.

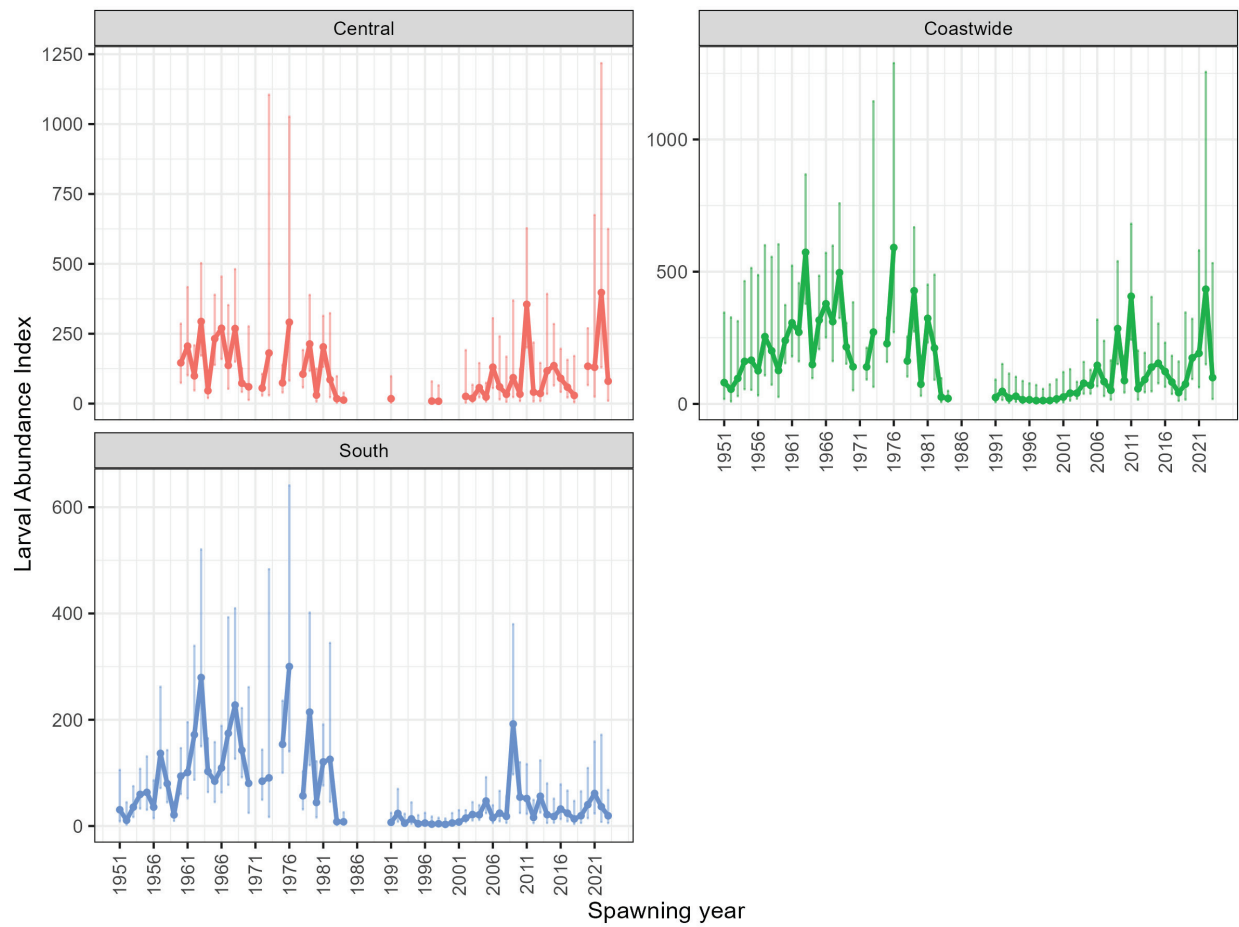


Figure 30: Relative abundance index for larval chilipepper rockfish from the CalCOFI survey, for coastwide (same as Figure 28), central, and south regions. Error bars are 95% CI. The index for the central region excludes years with no sampling in this region.

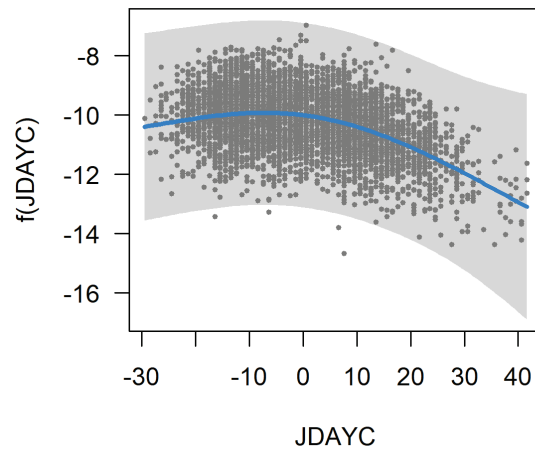


Figure 31: Effect of Julian date (centered by subtracting the mean) estimated in the RREAS index of age-0 recruits. Declines in density are expected over time due to settlement out of the pelagic juvenile stage. Points are partial randomized quantile residuals, with a smooth function (blue line) illustrating the model prediction.

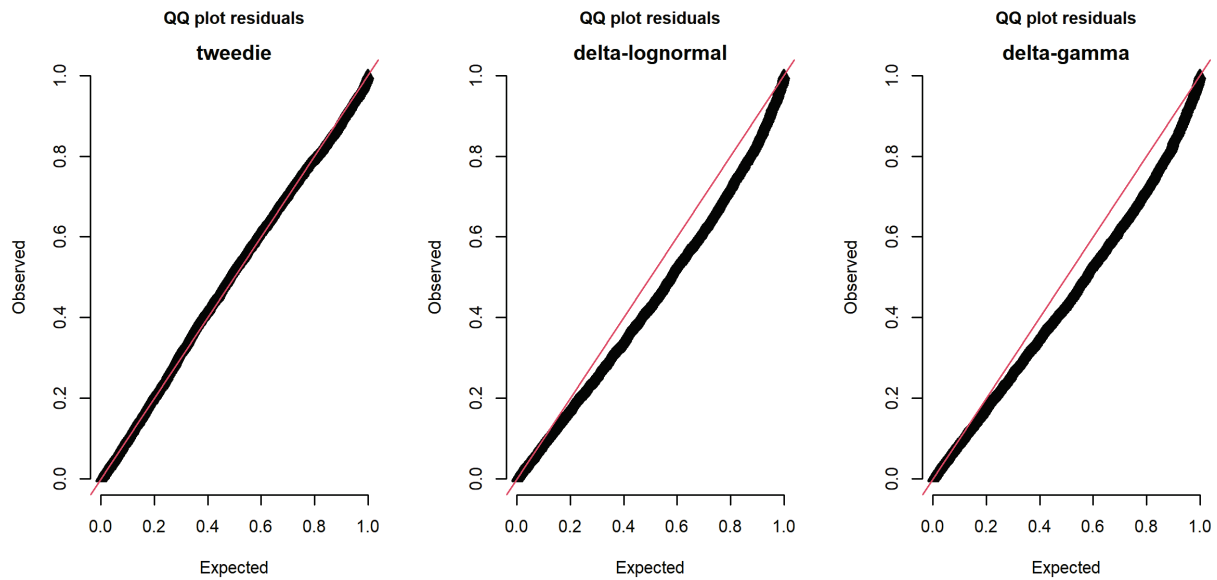


Figure 32: Evaluation of alternative distributional assumptions for the RREAS index of age-0 recruits.

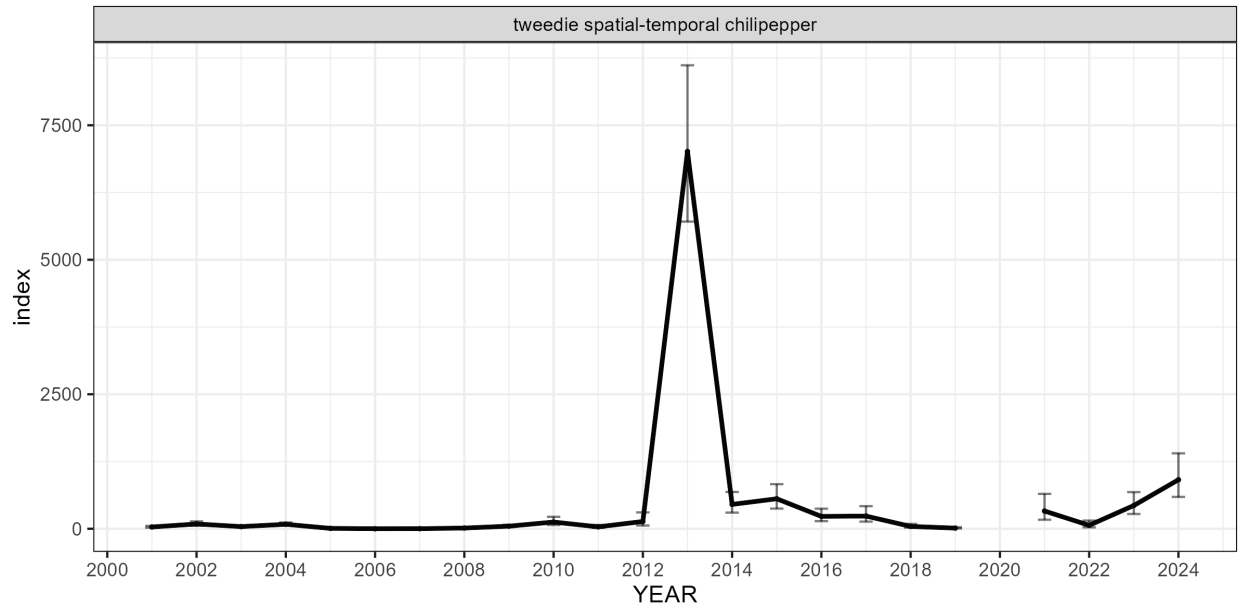


Figure 33: RREAS relative index of age-0 recruits for chilipepper rockfish, 2001-2024. Error bars are 95% CI.

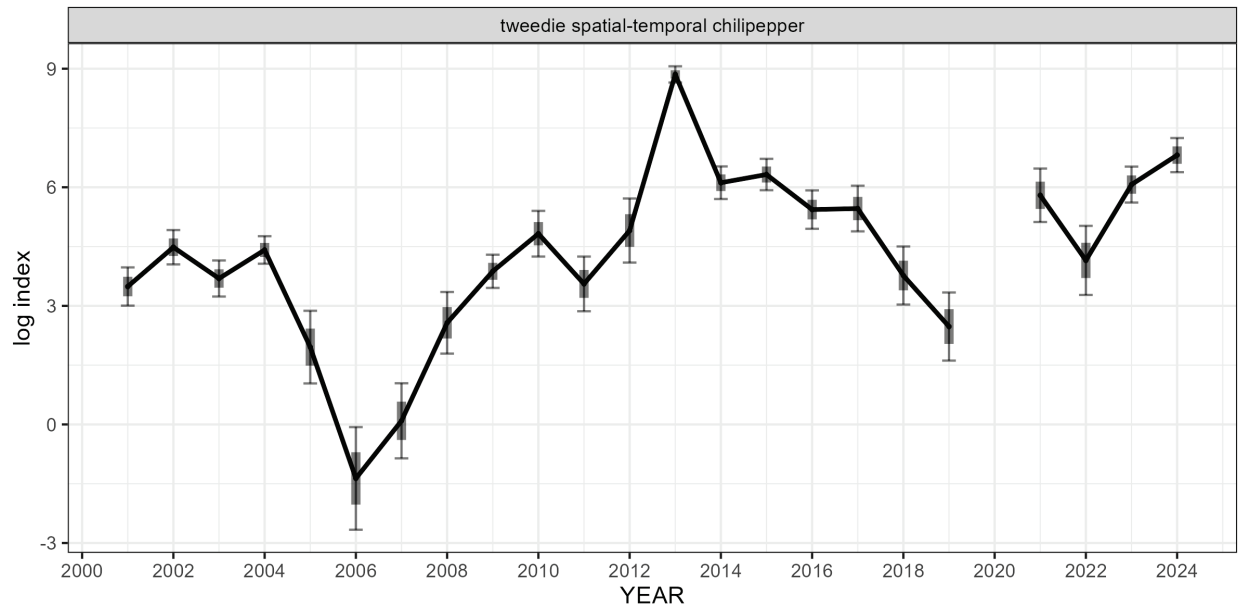


Figure 34: RREAS relative index (log scale) of age-0 recruits for chilipepper rockfish, 2001-2024. Error bars are 95% CI.



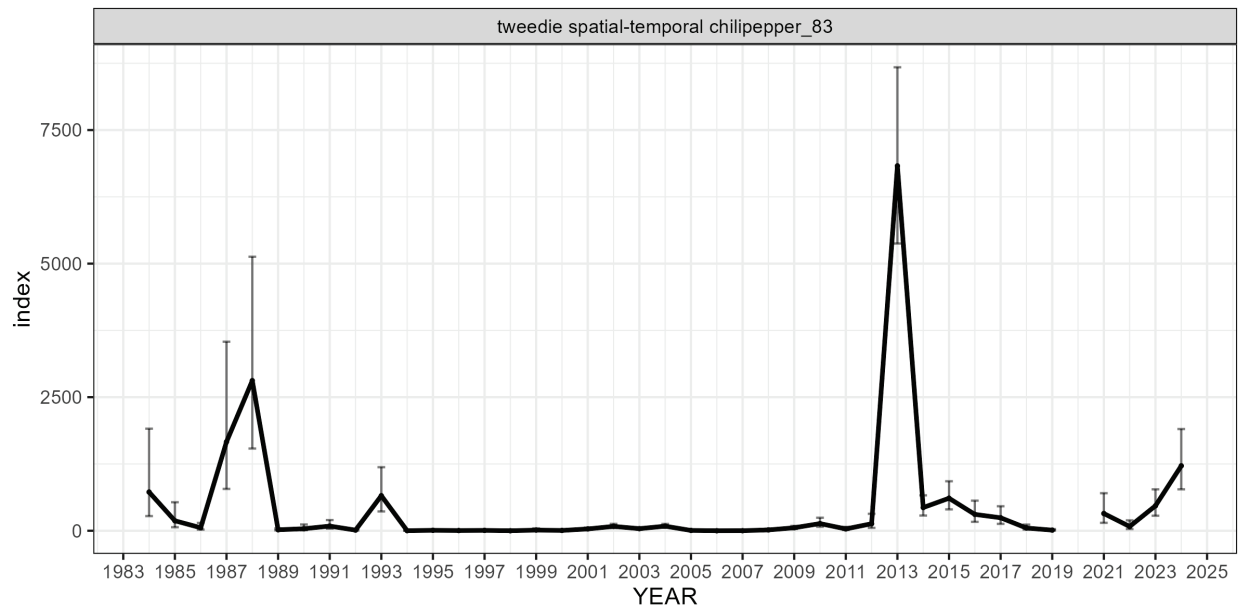


Figure 35: RREAS relative index of age-0 recruits for chilipepper rockfish, 1984-2024. Error bars are 95% CI.

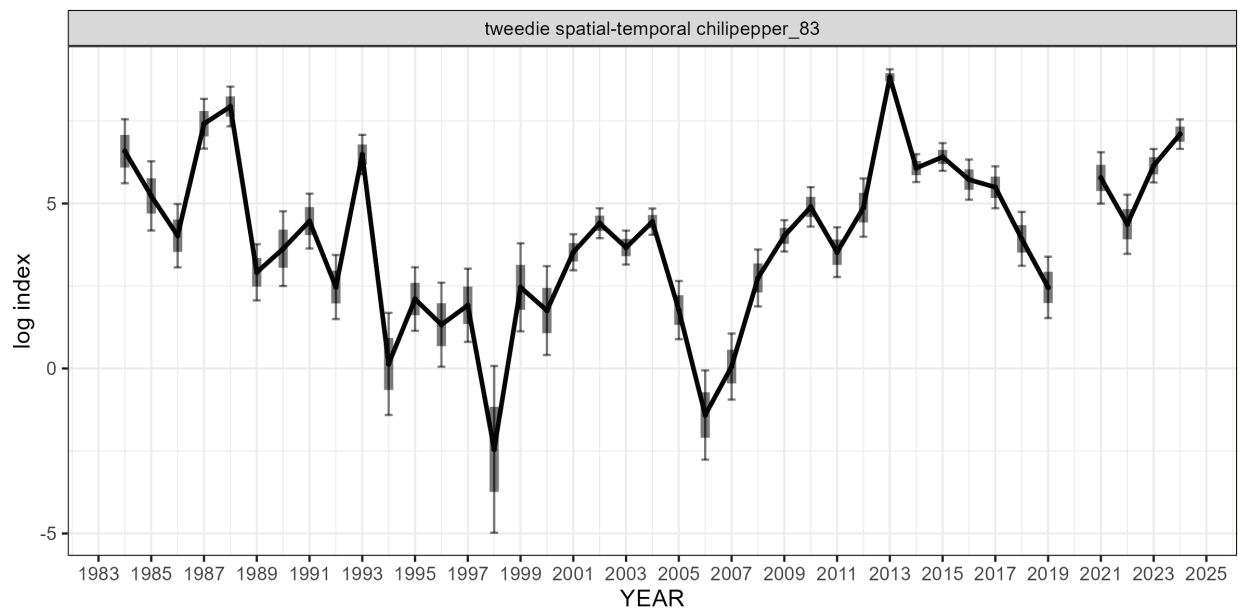


Figure 36: RREAS relative index (log scale) of age-0 recruits for chilipepper rockfish, 1984-2024. Error bars are 95% CI.

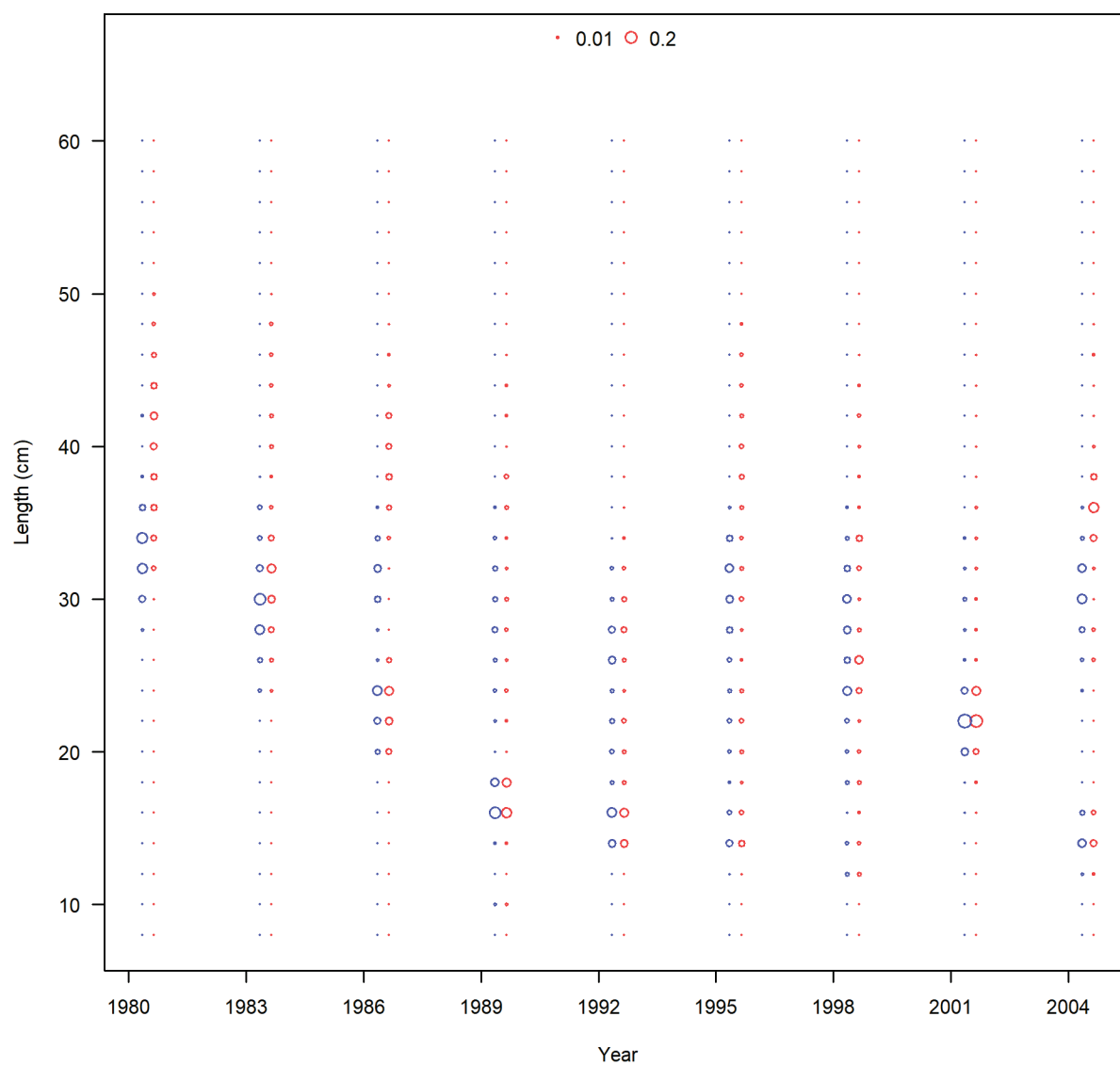


Figure 37: Triennial trawl survey length composition data (fork length in cm). Red circles are females, blue circles are males.

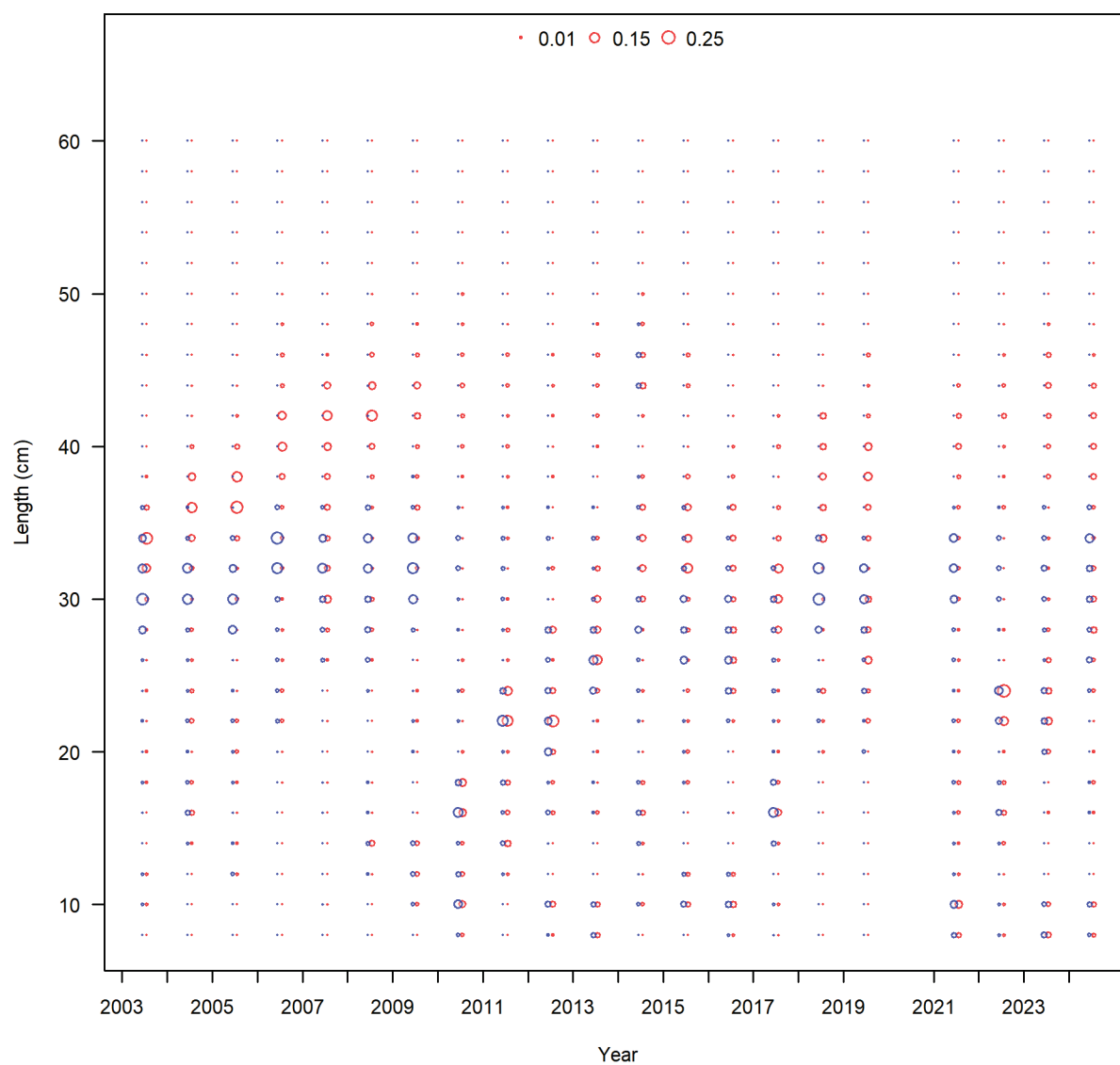


Figure 38: WCGBT survey length composition data (fork length in cm). Red circles are females, blue circles are males.

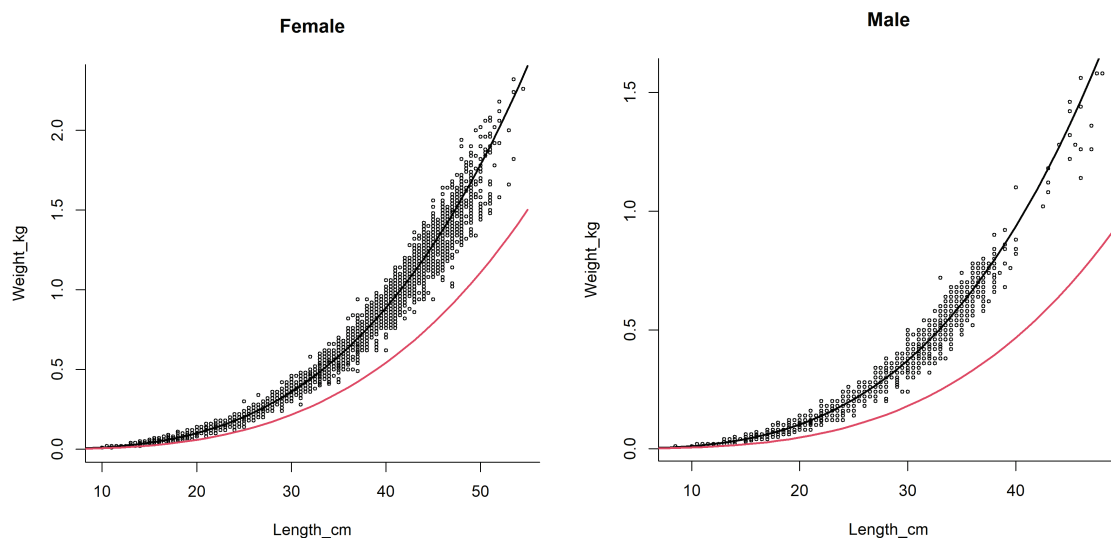


Figure 39: Revised fits (black line) to weight-at-length for female and male chilipepper rockfish. Data are from the WCG BTS. Estimates from the previous assessment are shown in red.

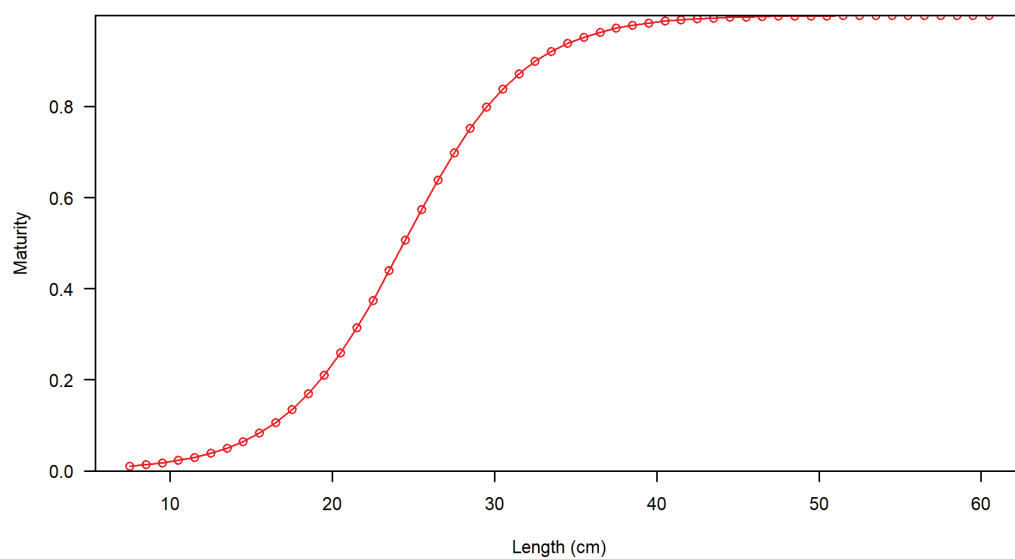


Figure 40: Proportion of mature females as a function of fork length (cm) in the 2025 chilipepper assessment.

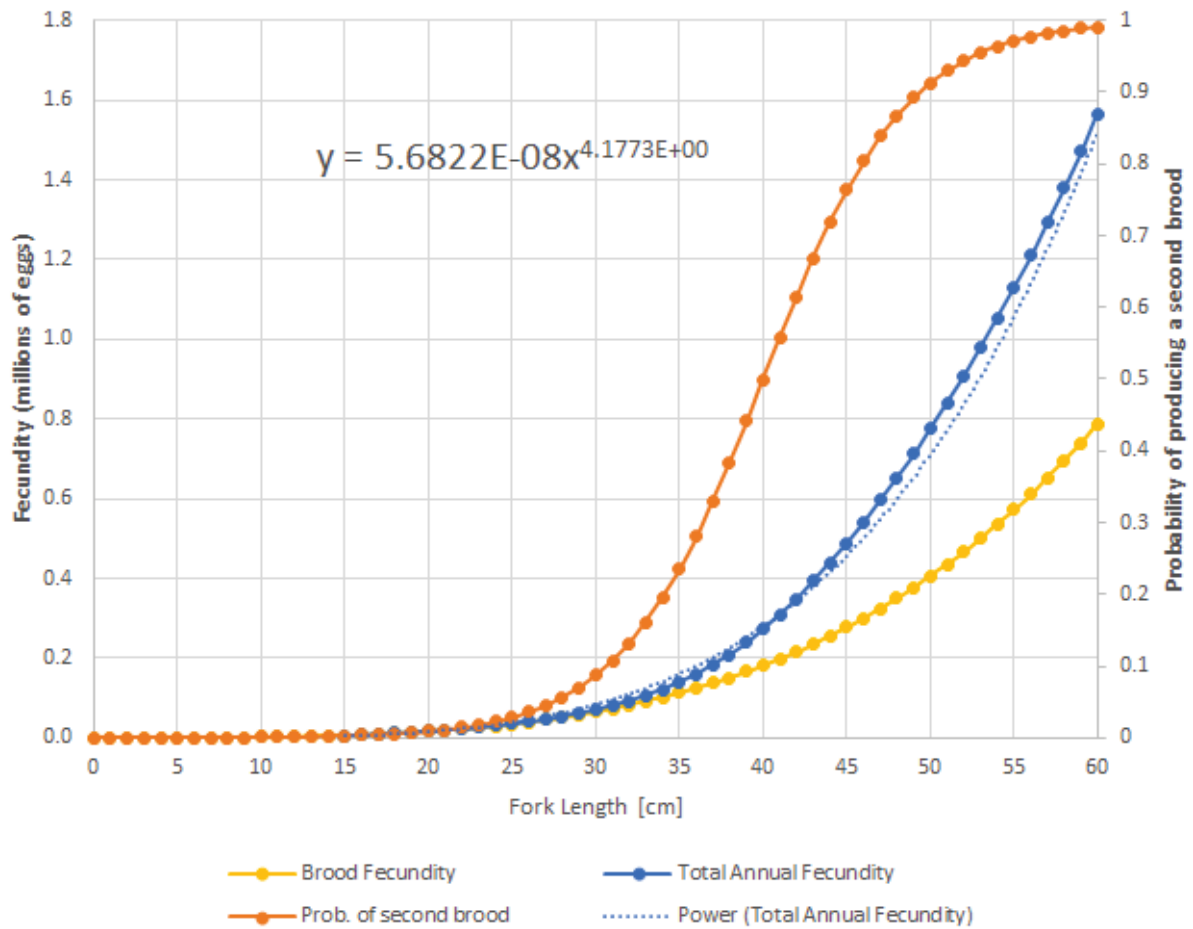


Figure 41: Illustration of method used to estimate total annual fecundity-at-length relationship (blue dotted line; “Power (Total Annual Fecundity)”) based on the brood-specific fecundity-length relationship from Dick et al. (2017; yellow line) and an updated length-based probability of multiple brooding (orange line) using data from central California, 2013-2019 (S. Beyer, AFSC, pers. comm.). See text for details.

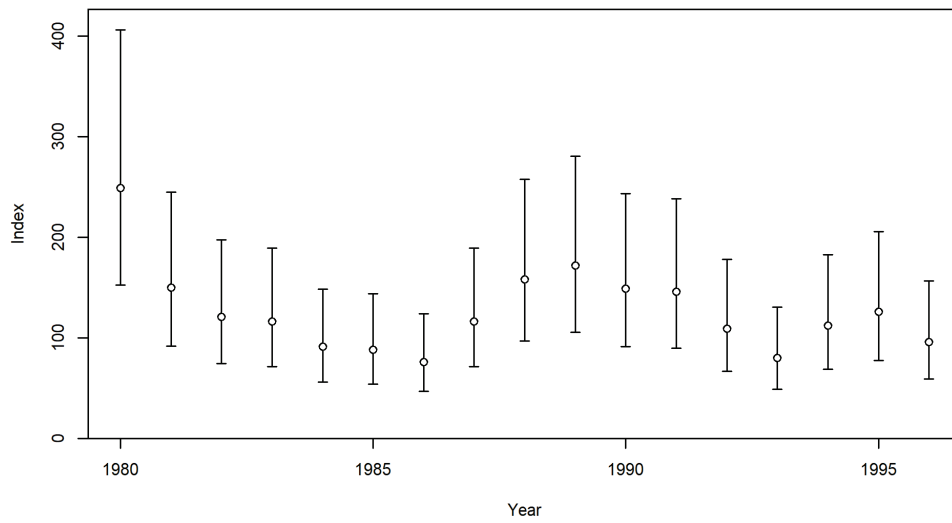


Figure 42: Index derived from commercial trawl logbook data for the 1998 chilipepper stock assessment (Ralston et al. 1998). This index is not used to fit the 2025 assessment, but is compared to model output for reference.

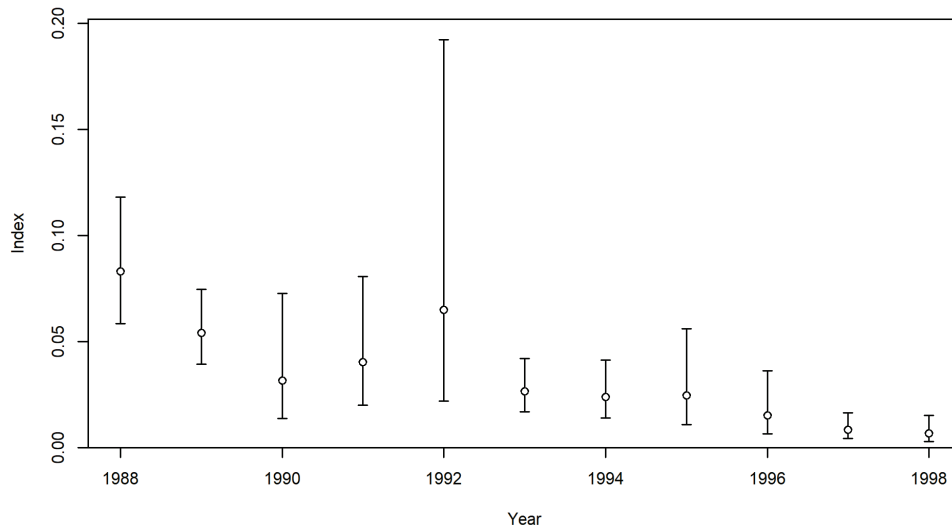


Figure 43: Index derived from recreational onboard observer CPUE data for the 1998 chilipepper stock assessment (Ralston et al. 1998). This index is not used to fit the 2025 assessment, but is compared to model output for reference.

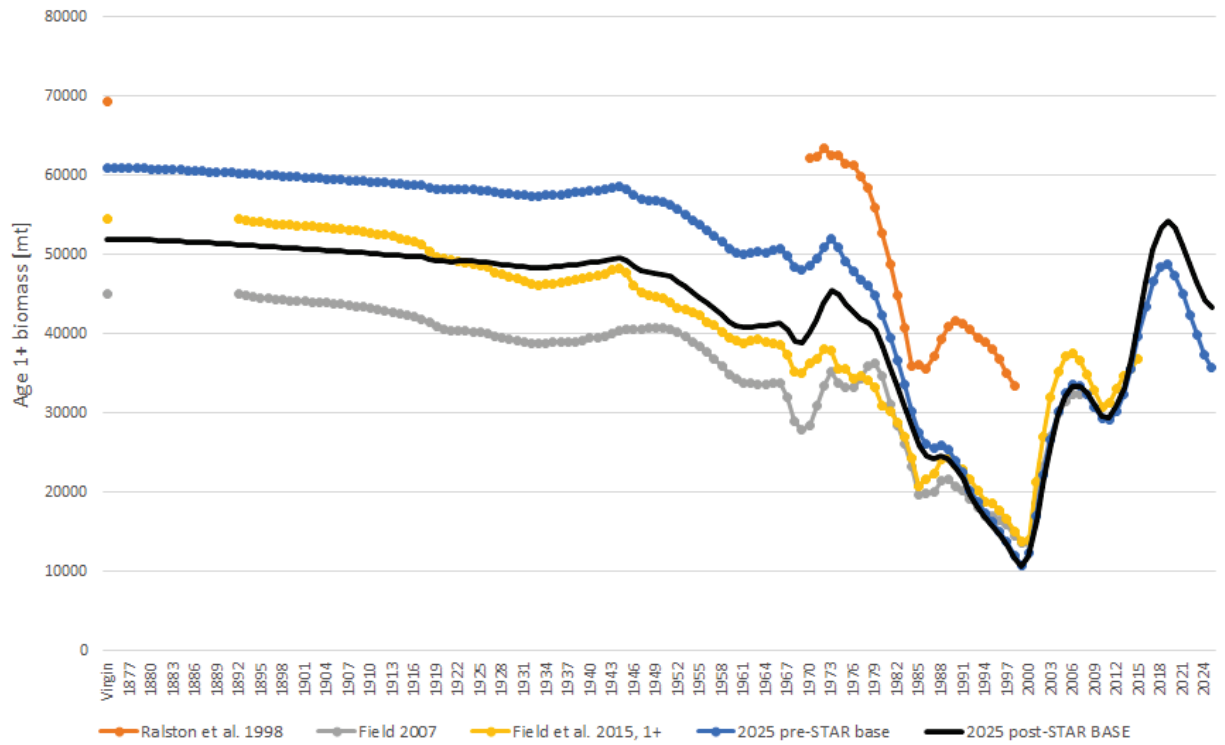


Figure 44: Comparison of trends in age 1+ biomass for previous stock assessments of chilipepper rockfish, including the pre- and post-STAR base models.

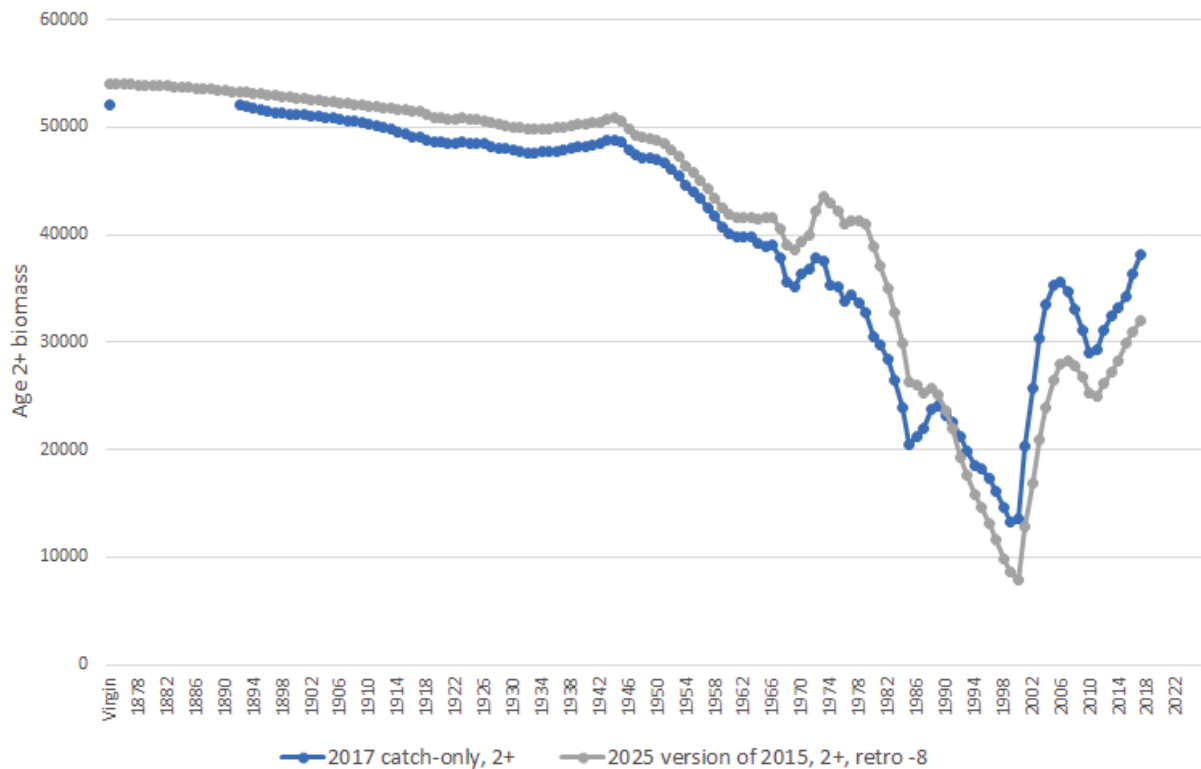


Figure 45: Comparison of age 2+ biomass time series for the 2017 catch-only update and a modified version of the pre-STAR base model. The pre-STAR base was changed to match the 2017 values for

natural mortality, steepness, recruitment deviation configuration, fecundity, and weight-at-length. The CalCOFI index was removed, and fishery-independent indices were included in the likelihood.

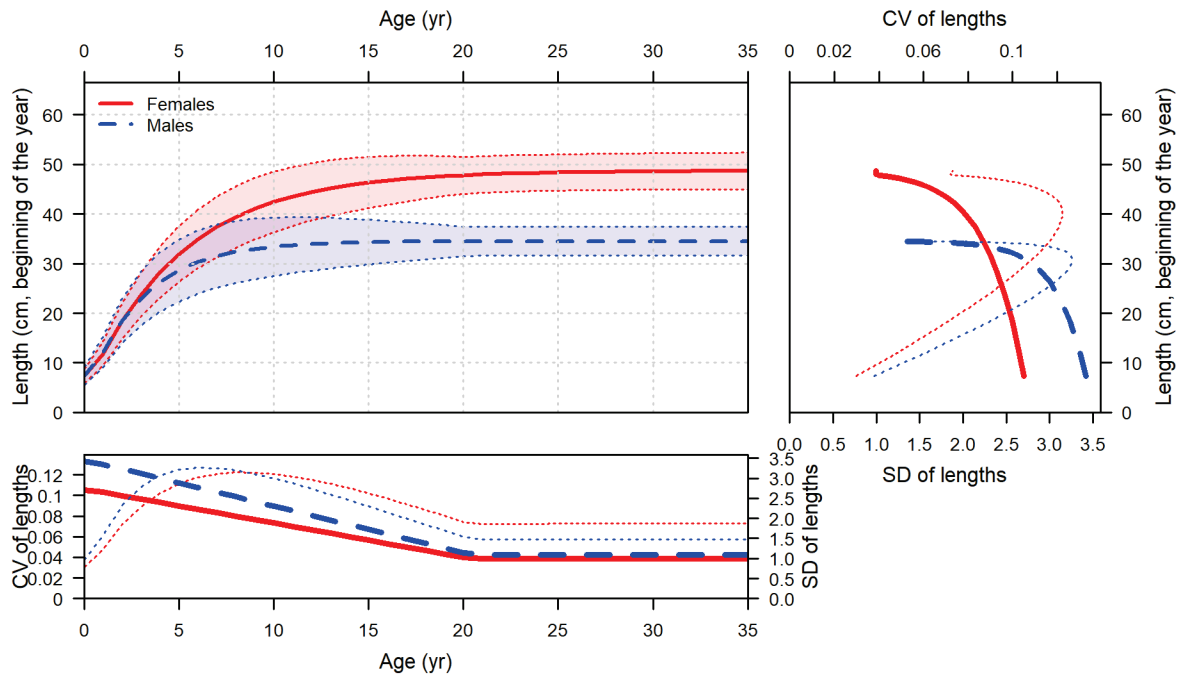


Figure 46: Base model estimates of growth (mean length-at-age by sex) with linear interpolation between estimates of the CV of length at age for ages 0 and 20.



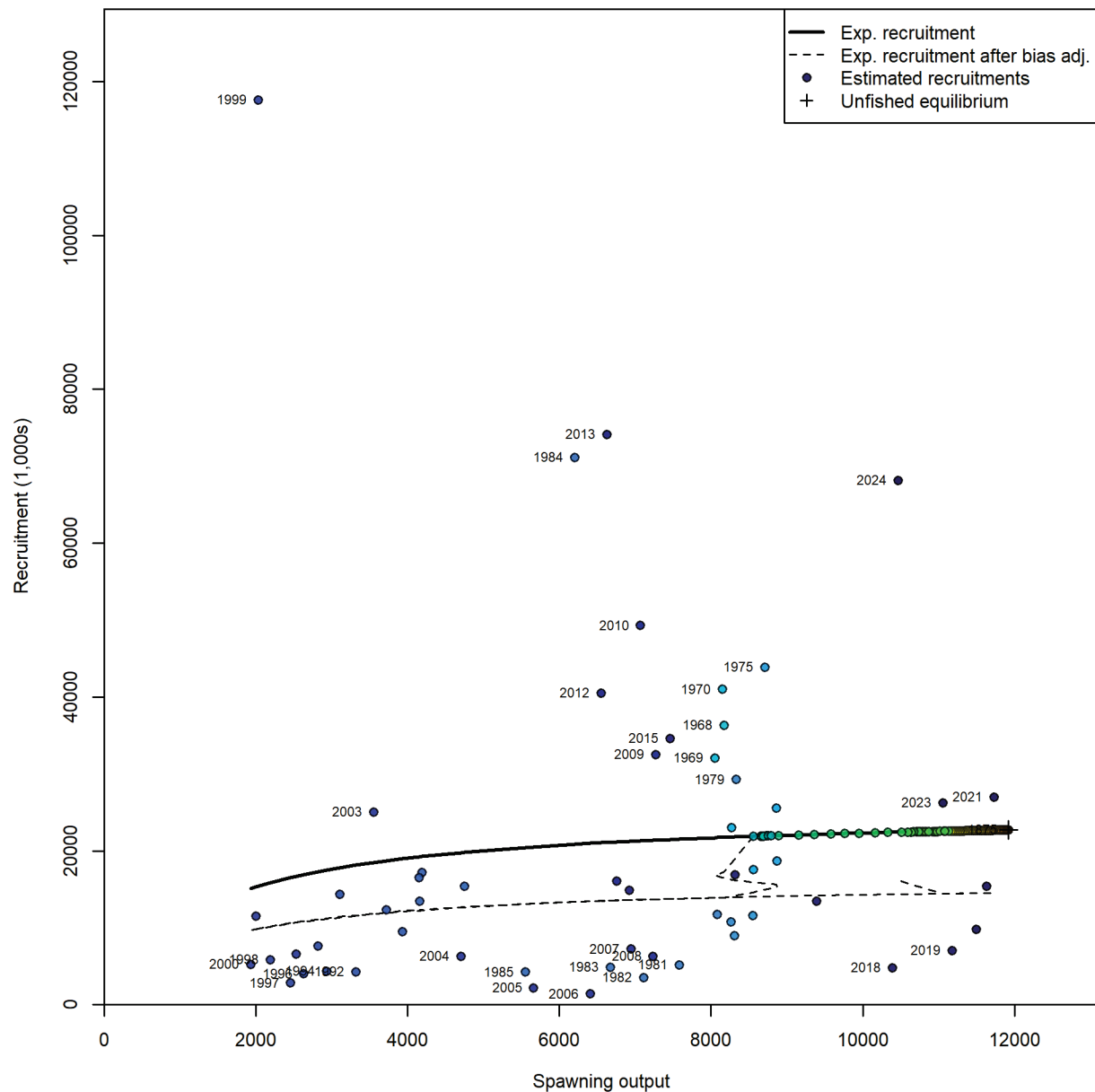


Figure 47: Base model stock-recruitment curve (Beverton-Holt) with steepness fixed at the prior mean (0.72) and estimated recruitment deviations (1968-2024). Recruitment is in 1000s of age-0 fish, and spawning output is in billions of eggs. Note that the precision of the estimated 2024 year class is low. See text for details.

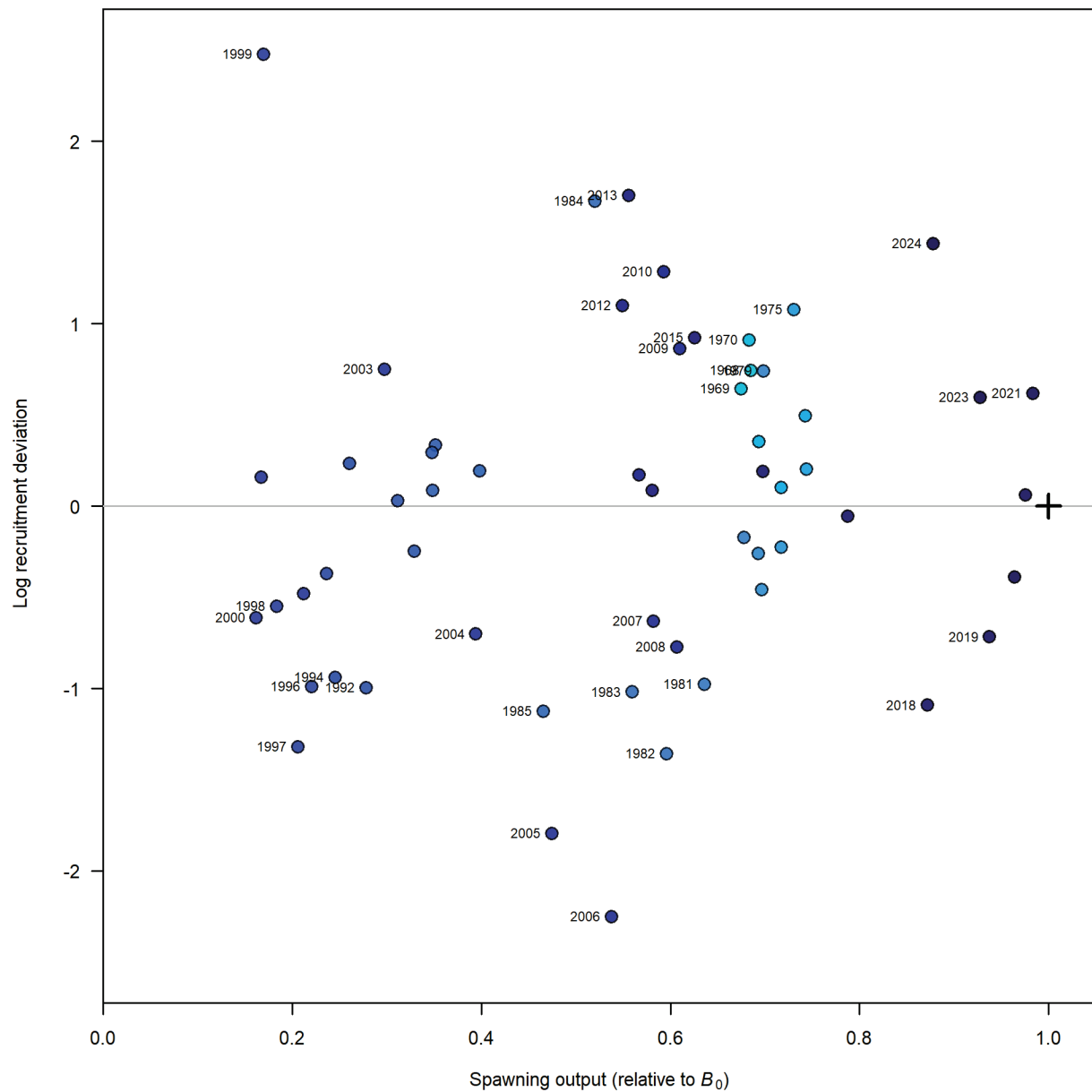


Figure 48: Log-scale residuals around the stock-recruitment curve (1968-2024). Years with deviations having an absolute value greater than 0.5 are labeled.

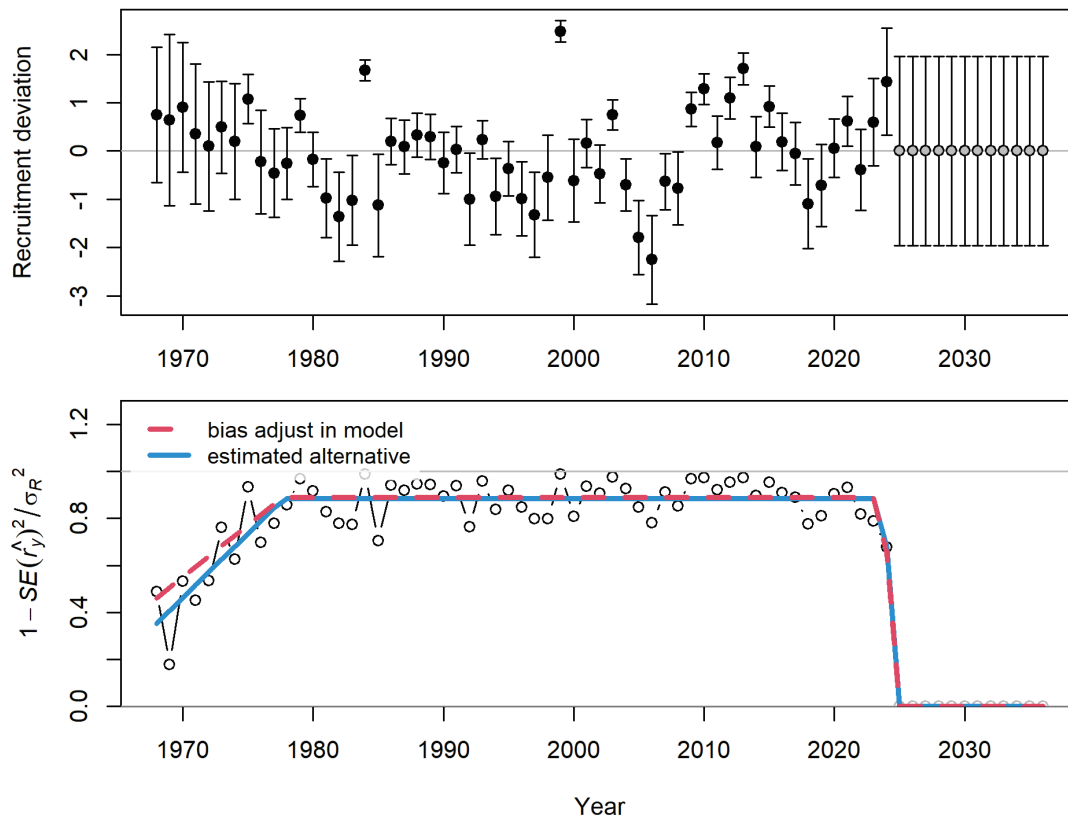


Figure 49: Time series of estimated recruitment deviations (top panel) and model-estimated annual bias adjustment fraction (bottom panel).

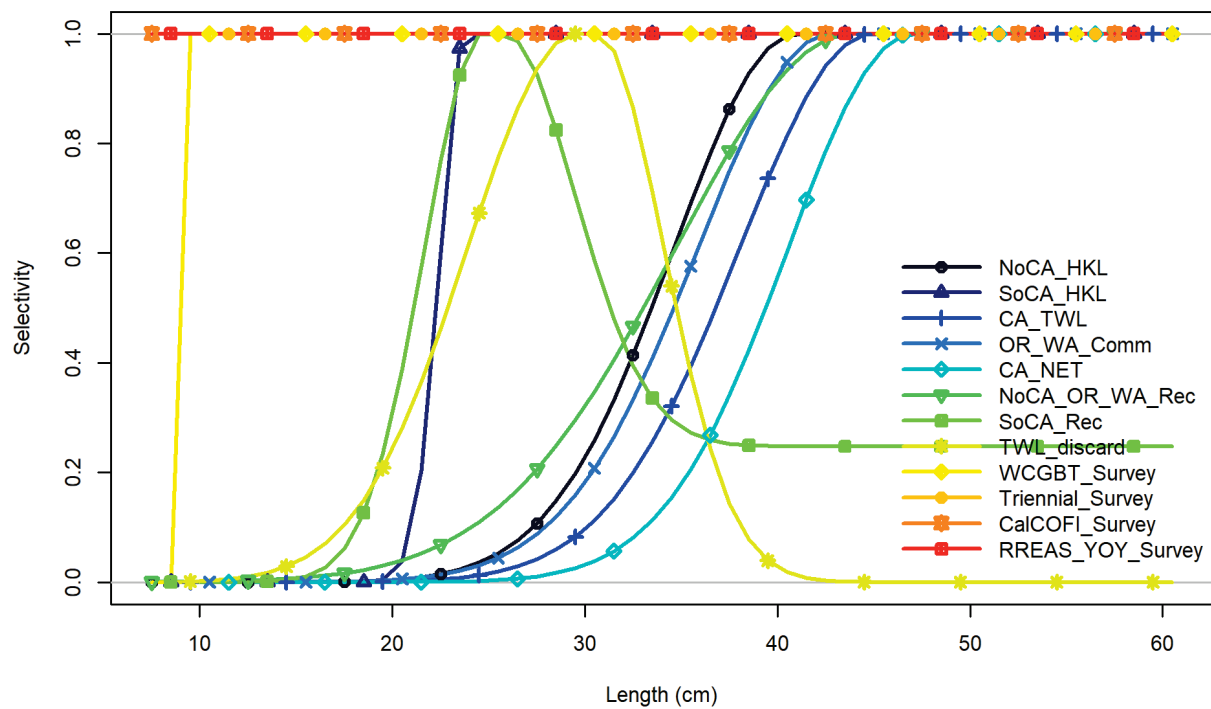


Figure 50: Ending year length-based selectivity curves by fleet in the base model. See figures below for fleets with time-varying selectivity.

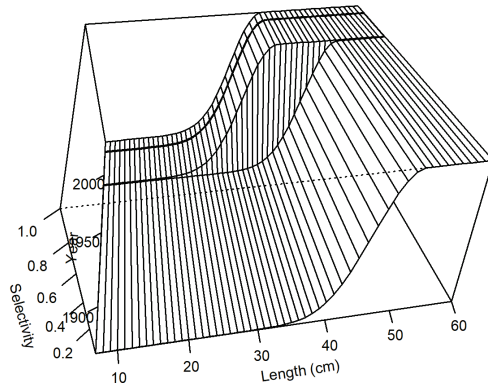


Figure 51: Time-varying selectivity for the Northern California commercial hook and line fleet.

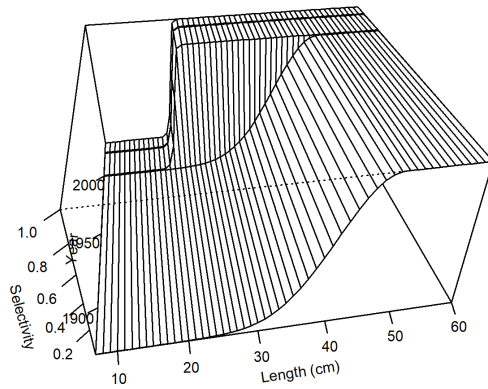


Figure 52: Time-varying selectivity for the Southern California commercial hook and line fleet.

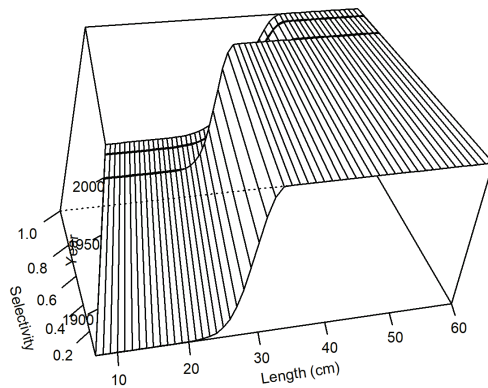


Figure 53: Time-varying selectivity for the California commercial trawl fleet.

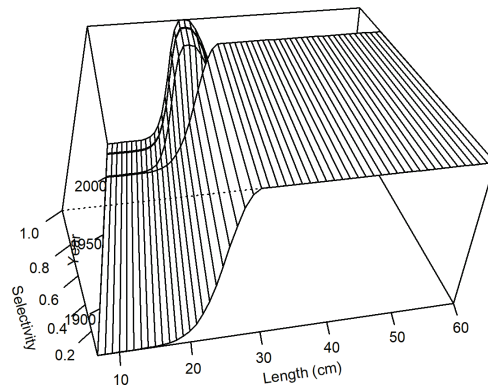


Figure 54: Time-varying selectivity for the Southern California recreational fleet.

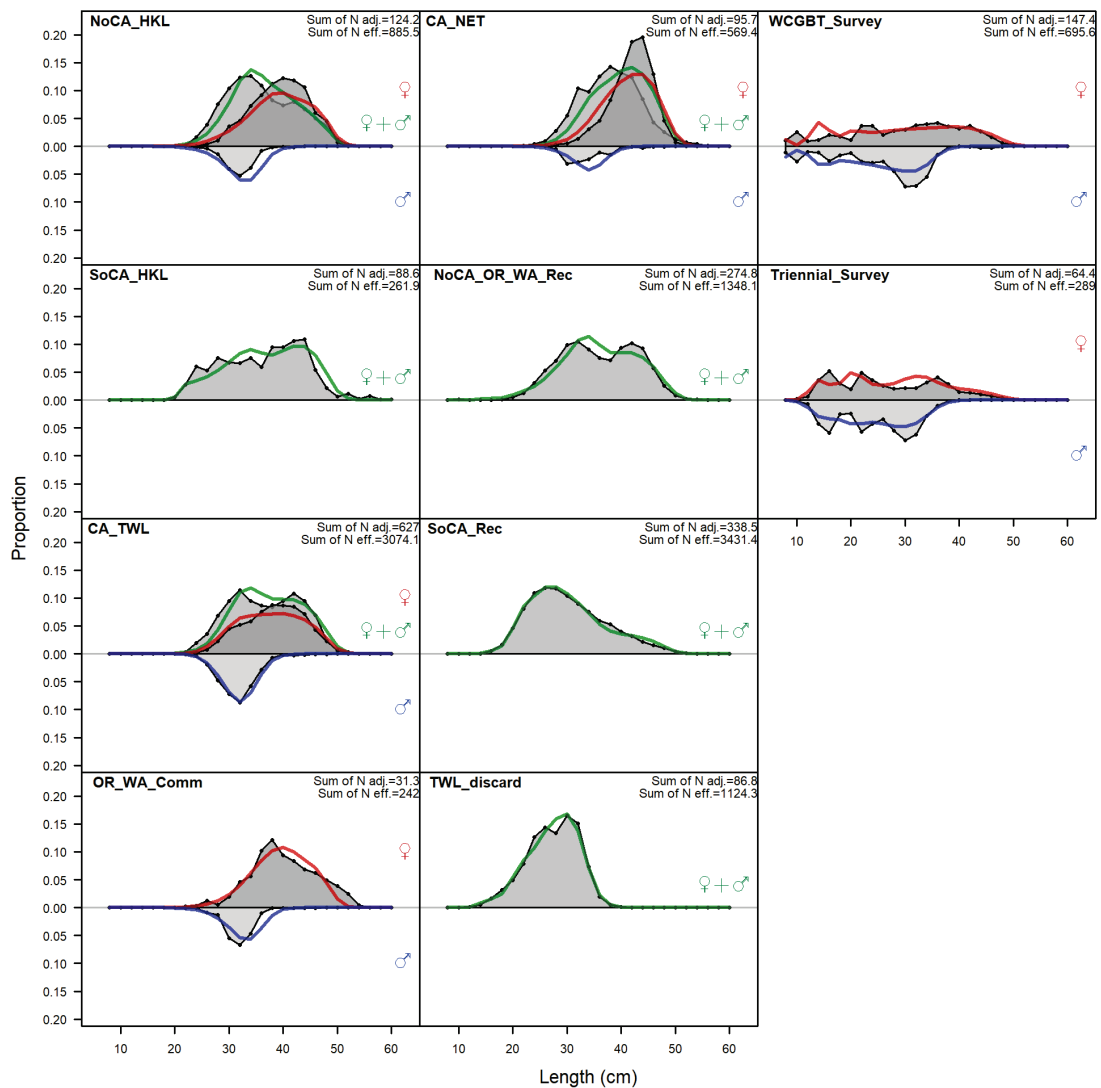


Figure 55: Base model fits to length composition data by modeled fleet, aggregated across time. Colored lines represent model fit (red = female, blue = male, green = combined sexes).

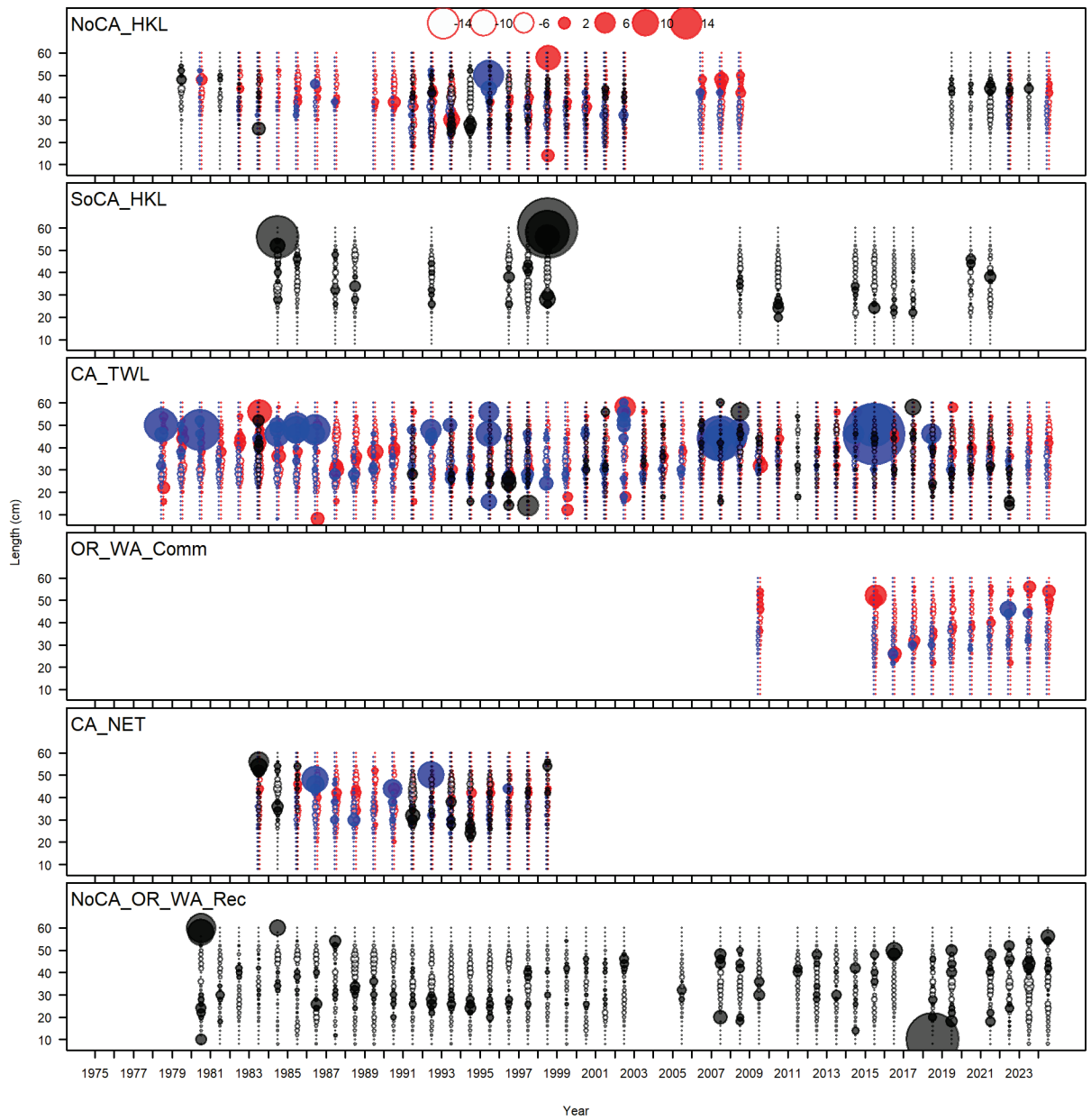


Figure 56: Pearson residuals for base model fits to length compositions by fleet and year (continued in next figure).

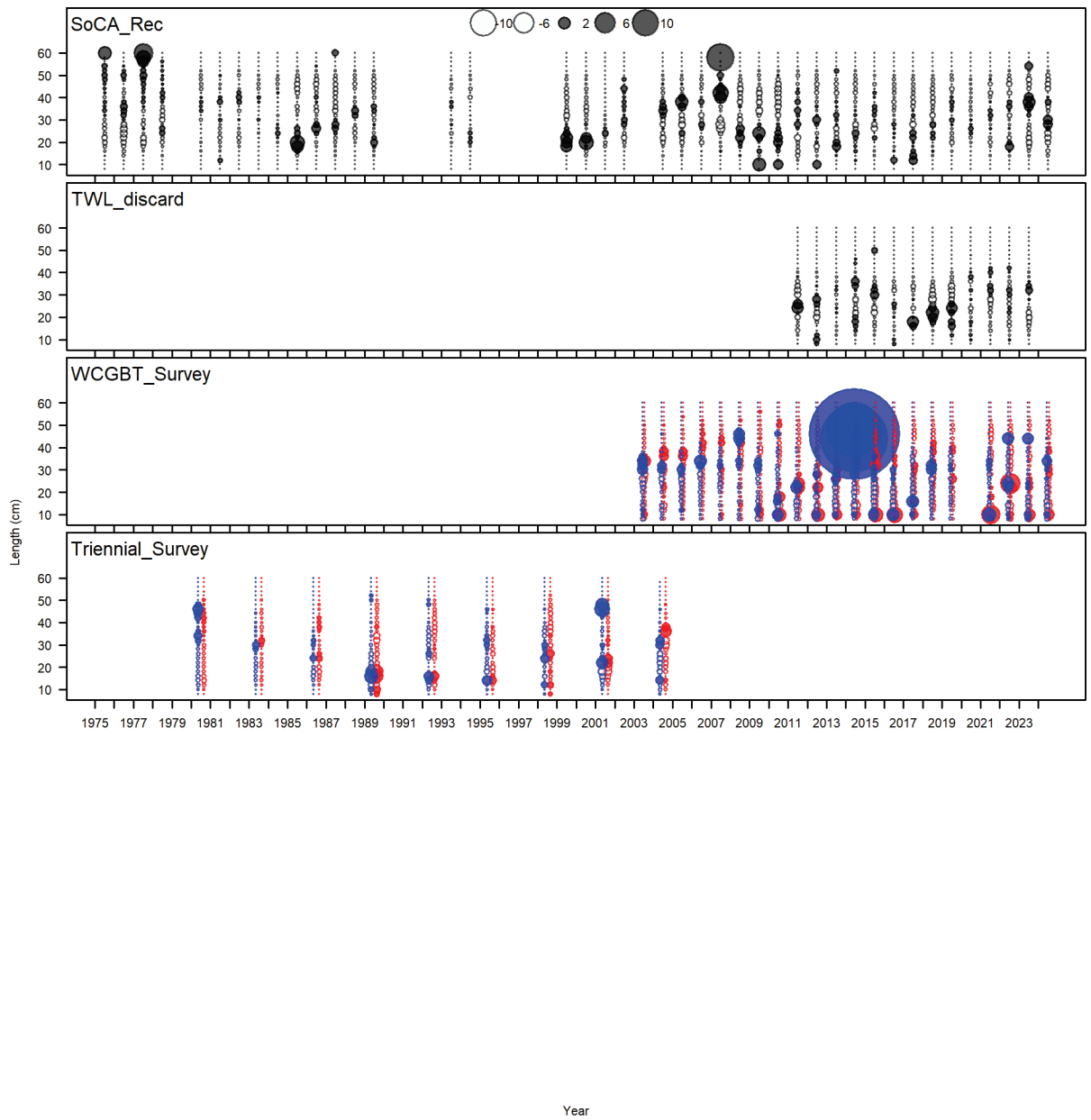


Figure 57: Pearson residuals for base model fits to length compositions by fleet and year (continued).

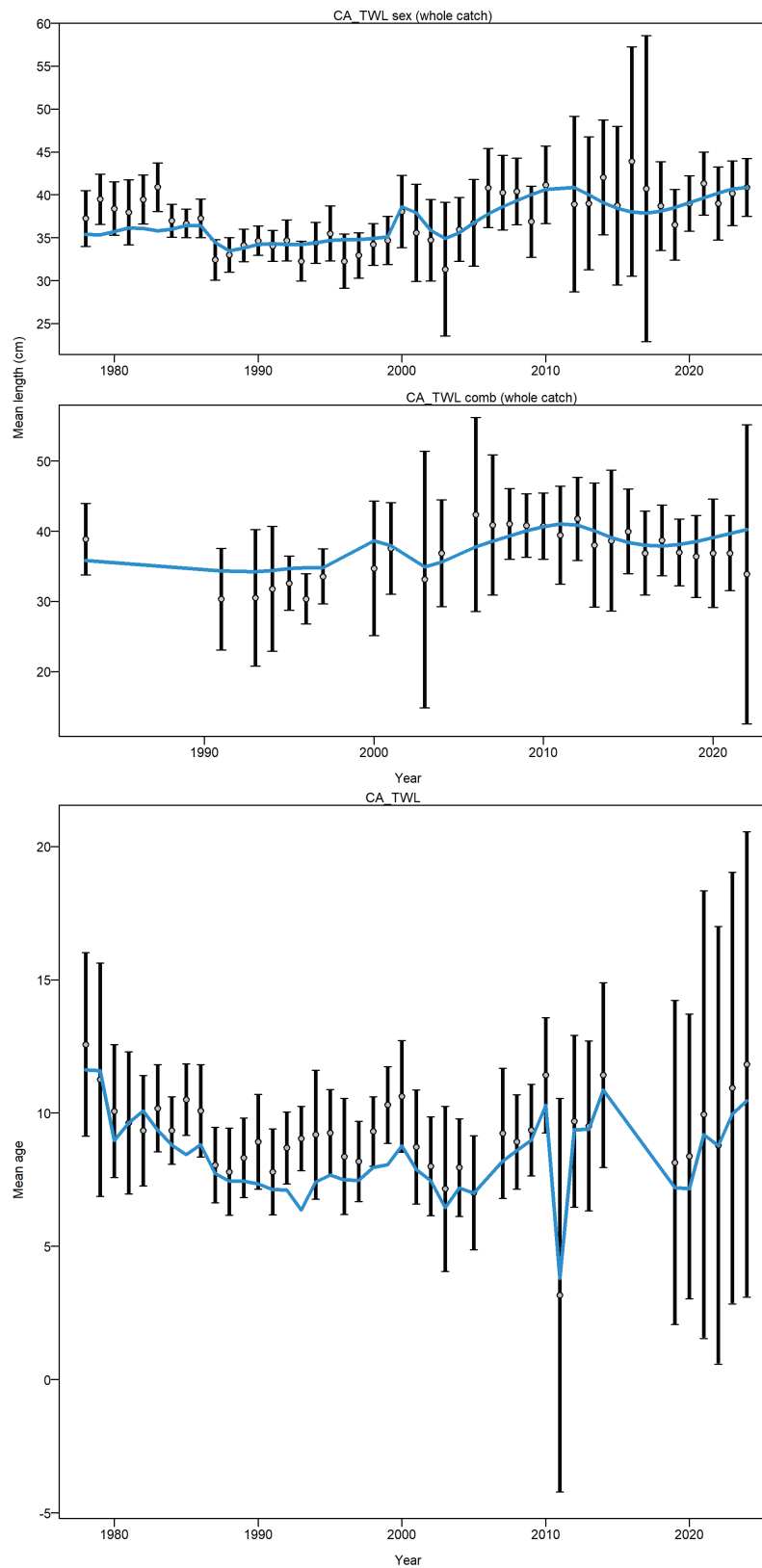


Figure 58: California trawl fleet: mean lengths (cm) for sexed fish (top panel) and unsexed fish (middle panel) for length compositions, and mean ages (years; bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.



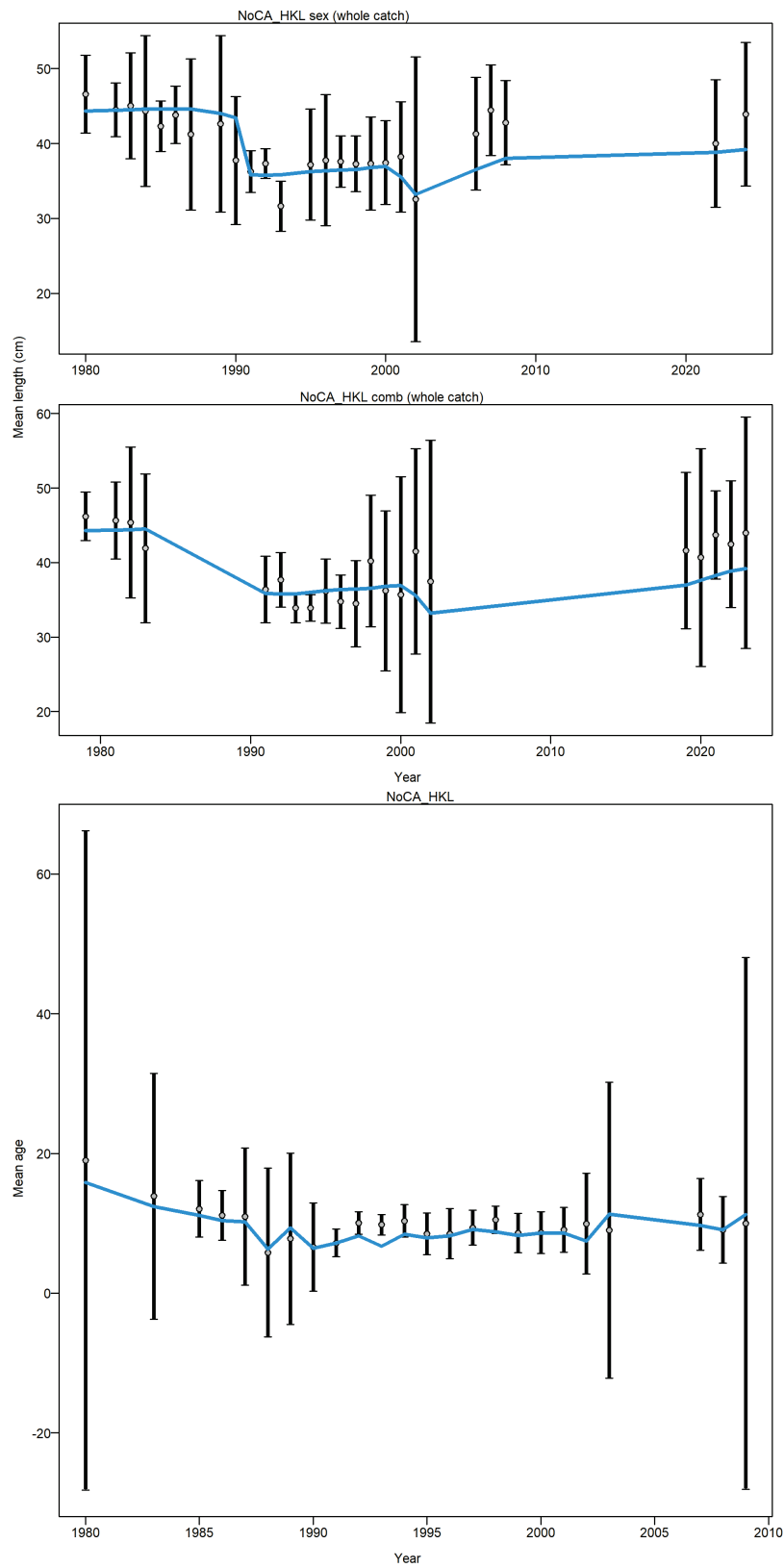


Figure 59: Northern California hook and line fleet: mean lengths (cm) for sexed fish (top panel) and unsexed fish (middle panel) for length compositions, and mean ages (years; bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

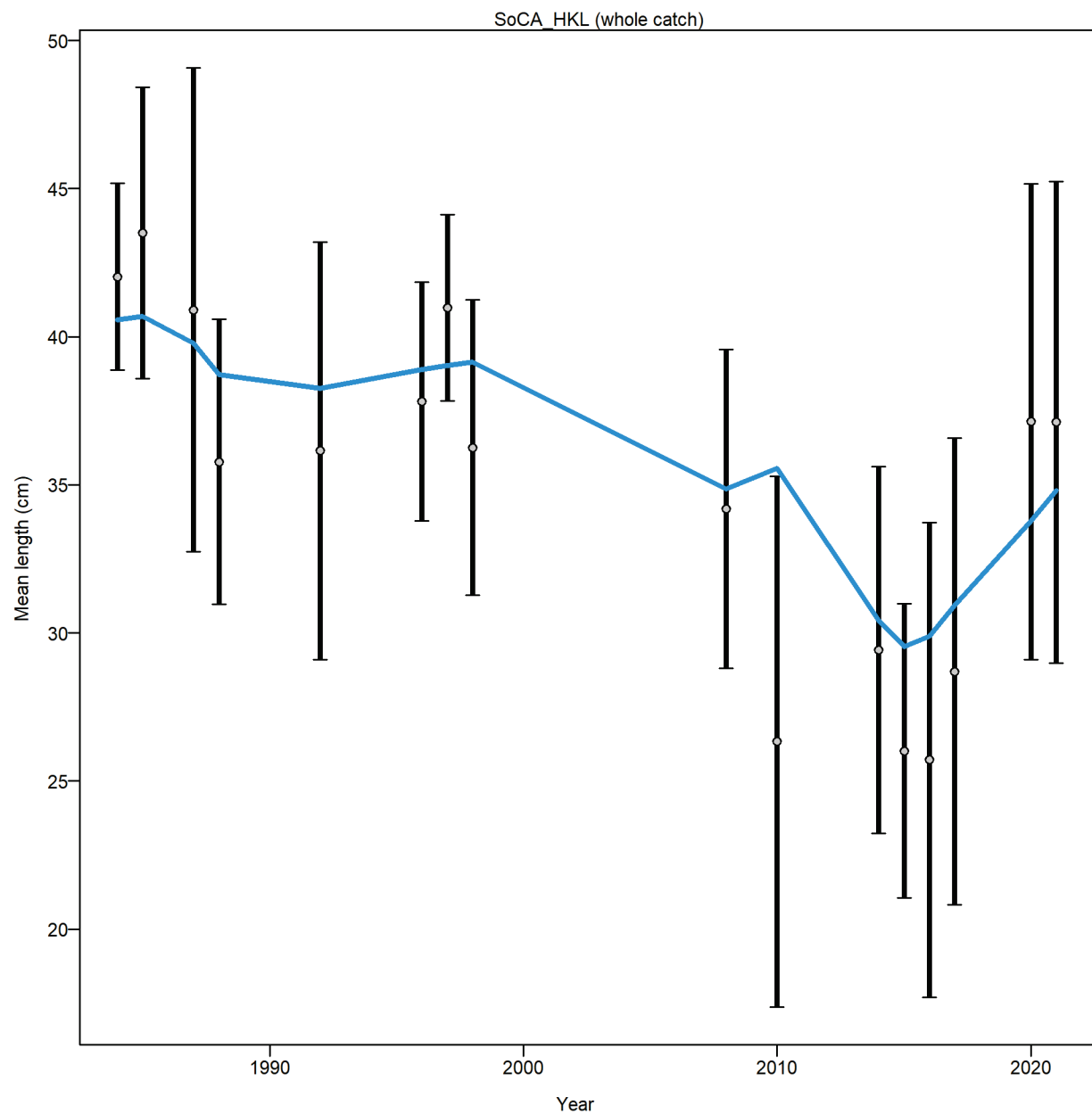


Figure 60: Southern California hook and line fleet: mean lengths (cm) for unsexed fish for length compositions with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

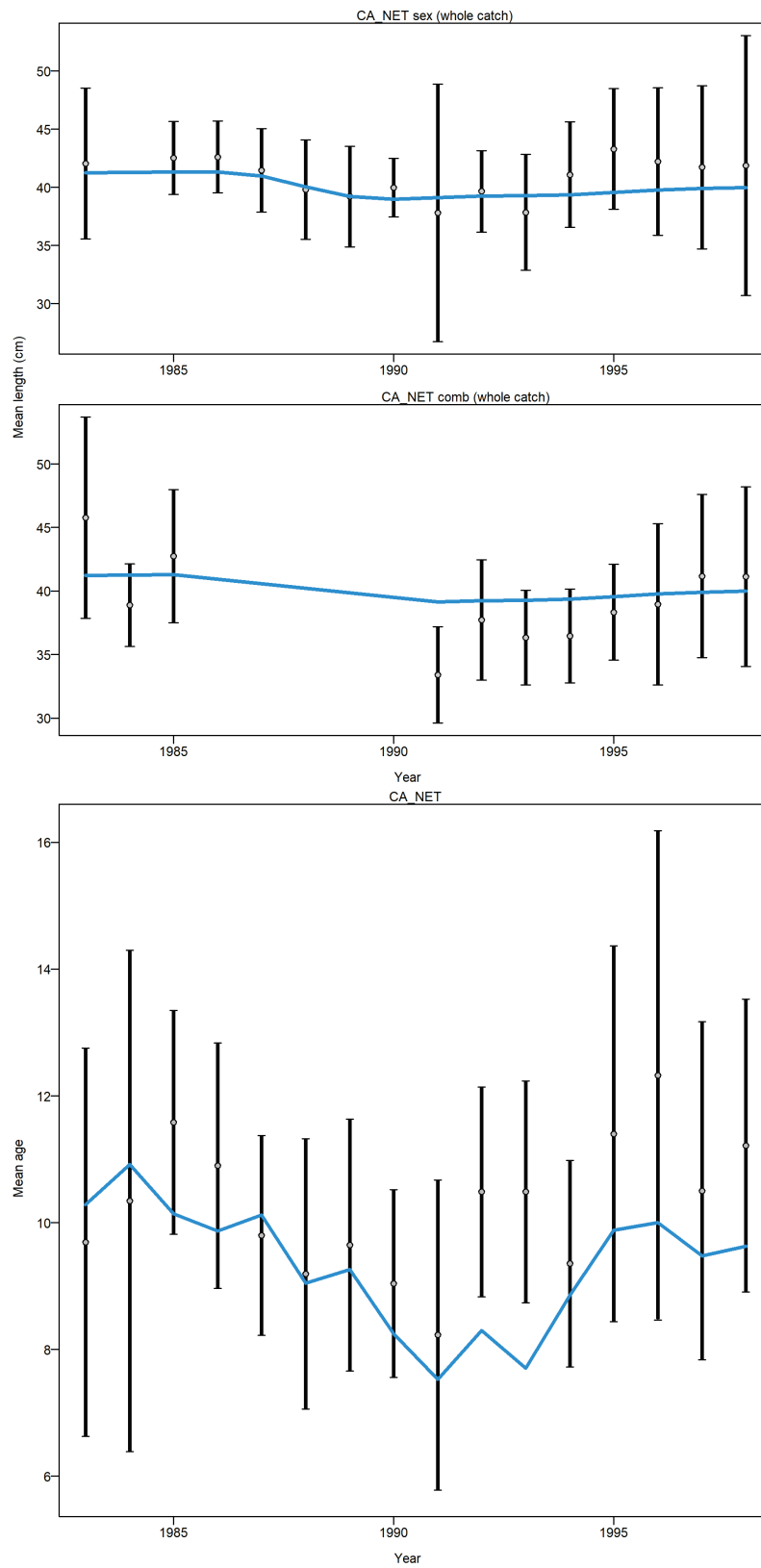


Figure 61: California net fleet: mean lengths (cm) for sexed fish (top panel) and unsexed fish (middle panel) for length compositions, and mean ages (years; bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

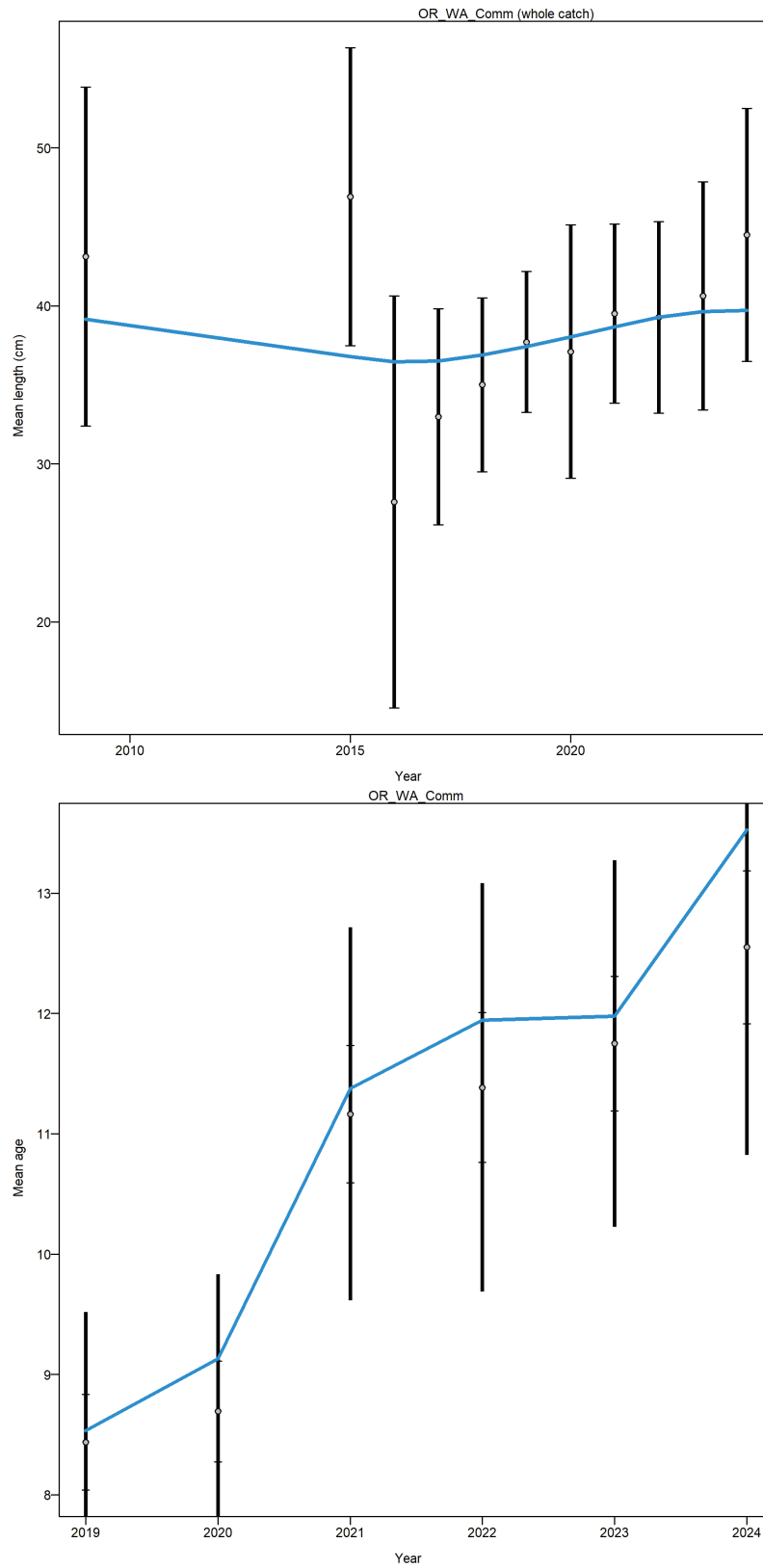


Figure 62: Oregon combined commercial fleets: mean lengths (cm) for unsexed fish (top panel) length compositions, and mean ages (years; bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

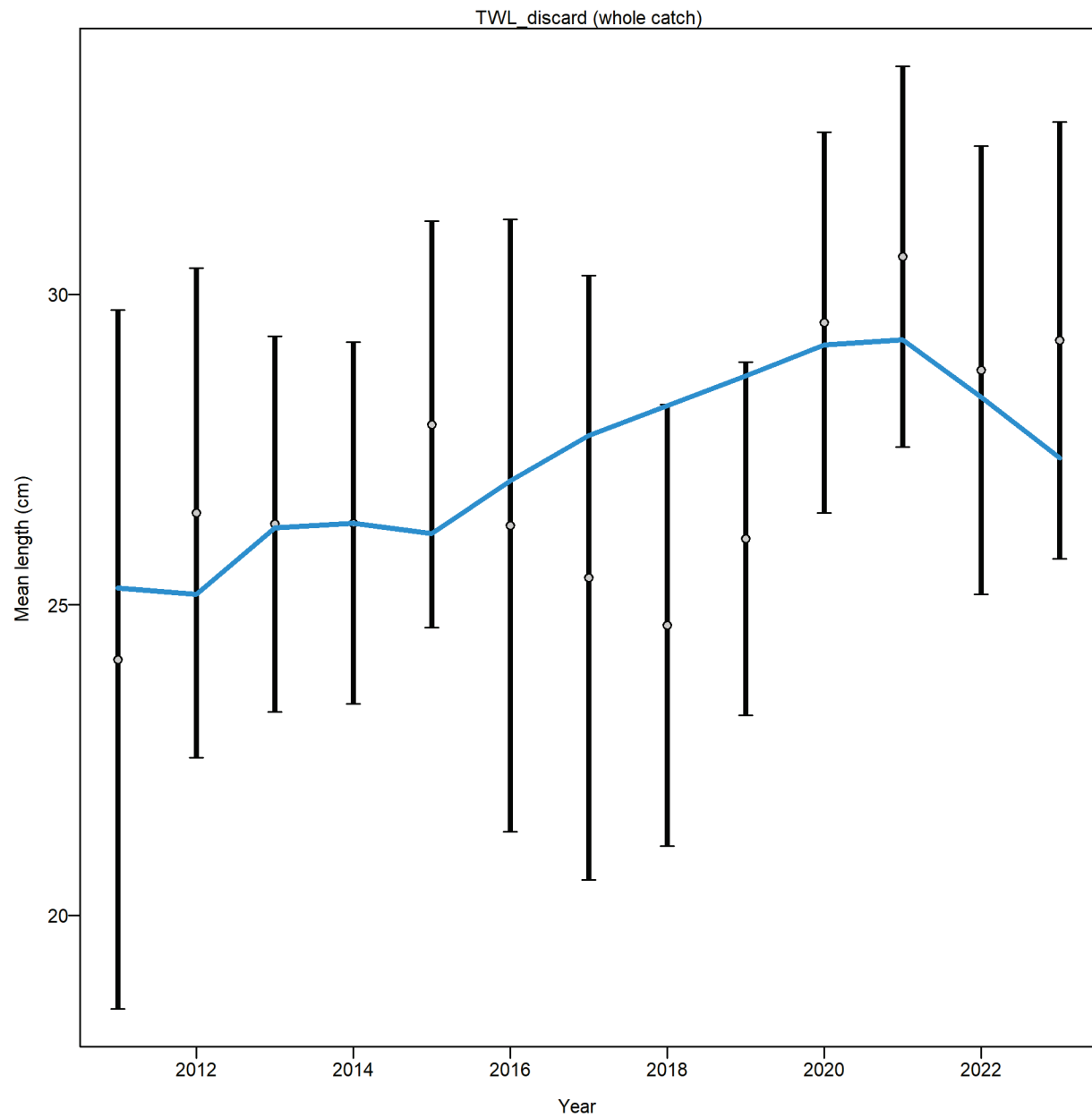


Figure 63: Trawl discard “fleet”: mean lengths (cm) for unsexed fish length compositions, with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

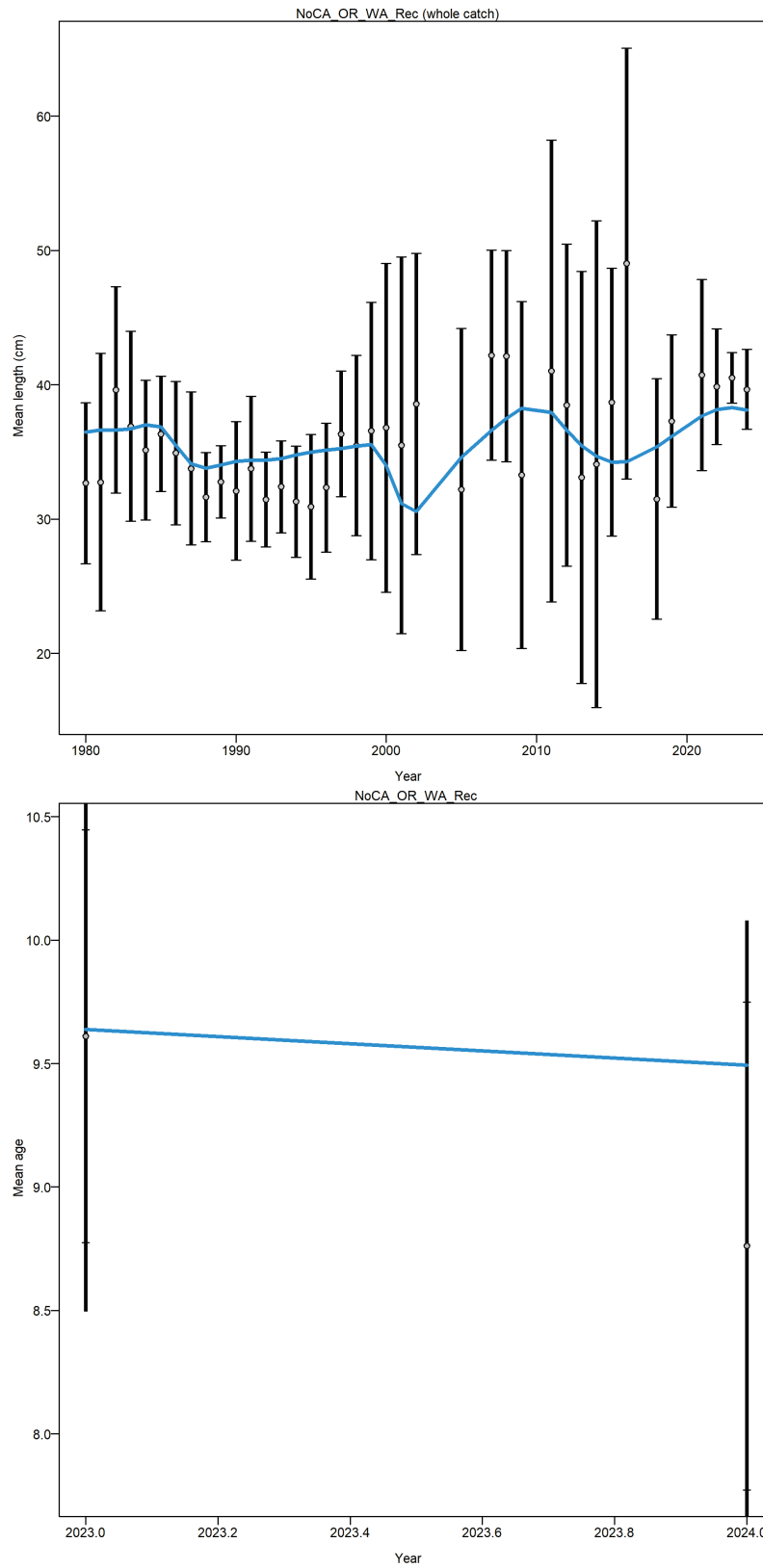


Figure 64: Recreational fleets north of Point Conception: mean lengths (cm) for unsexed fish length compositions (top panel), and mean ages (years; bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

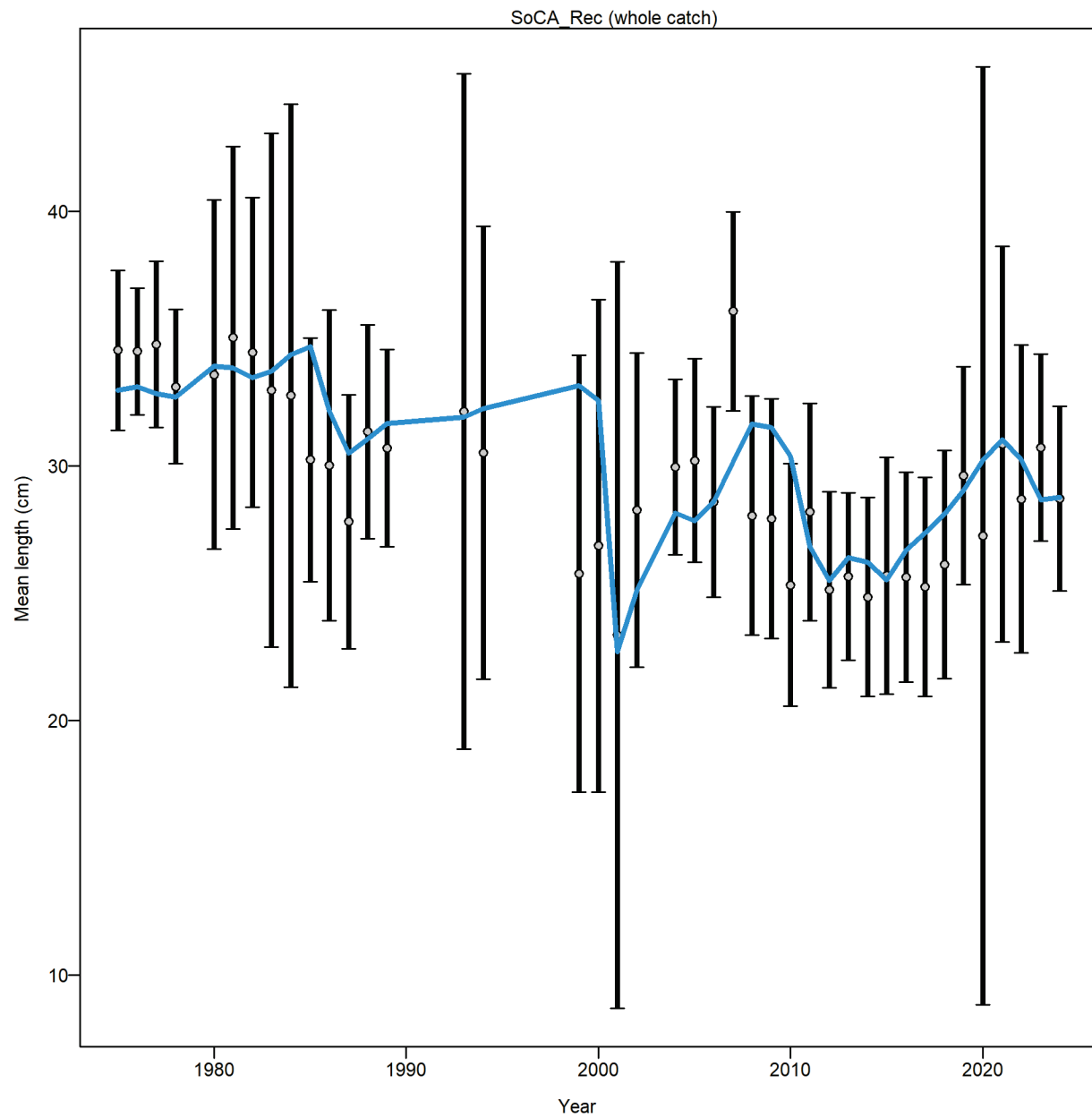


Figure 65: Recreational fleets south of Point Conception: mean lengths (cm) for unsexed fish length compositions with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

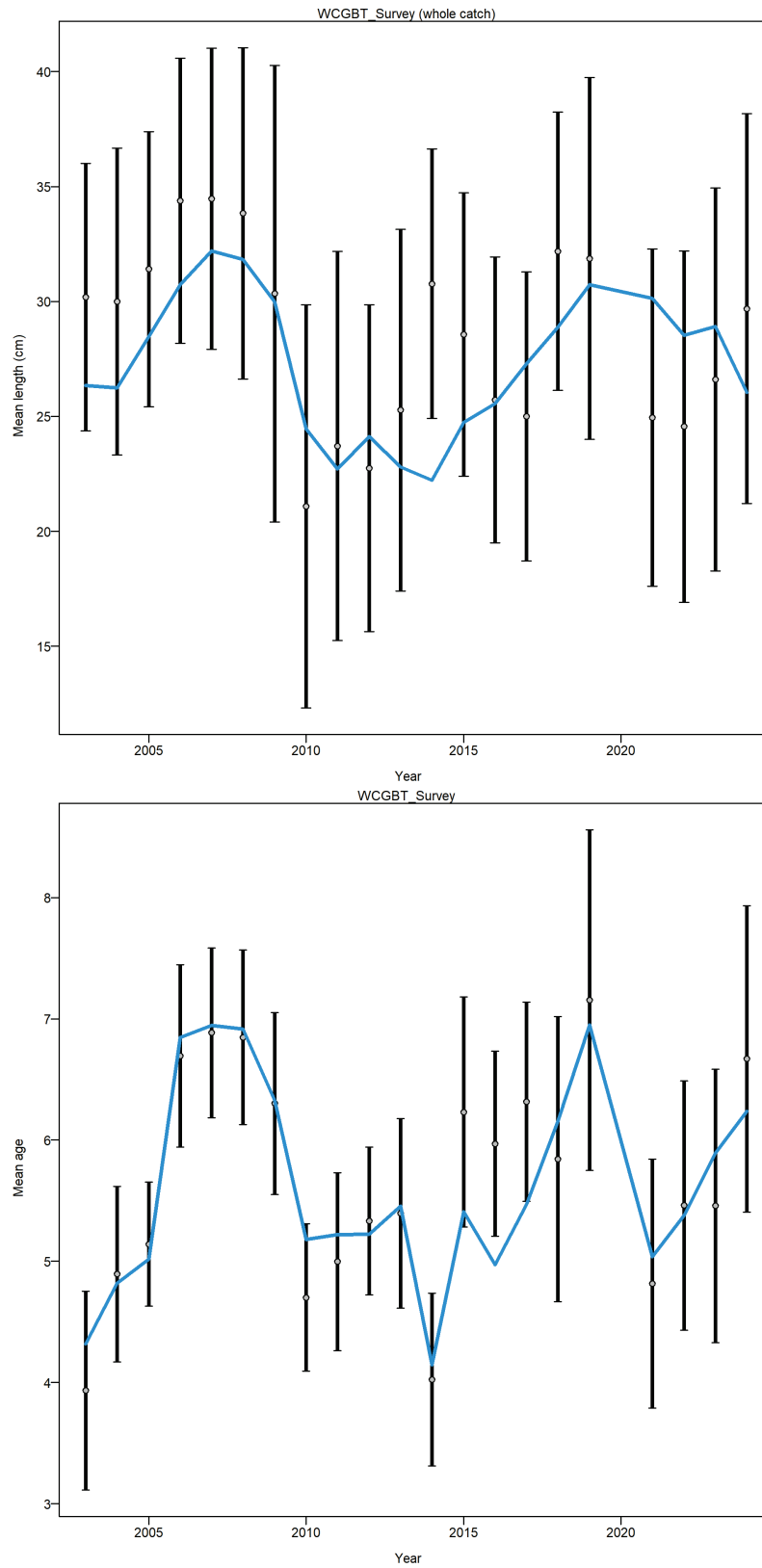


Figure 66: WCGBTs: mean lengths (cm) for sexed fish (top panel) for length compositions, and mean ages (years; bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.



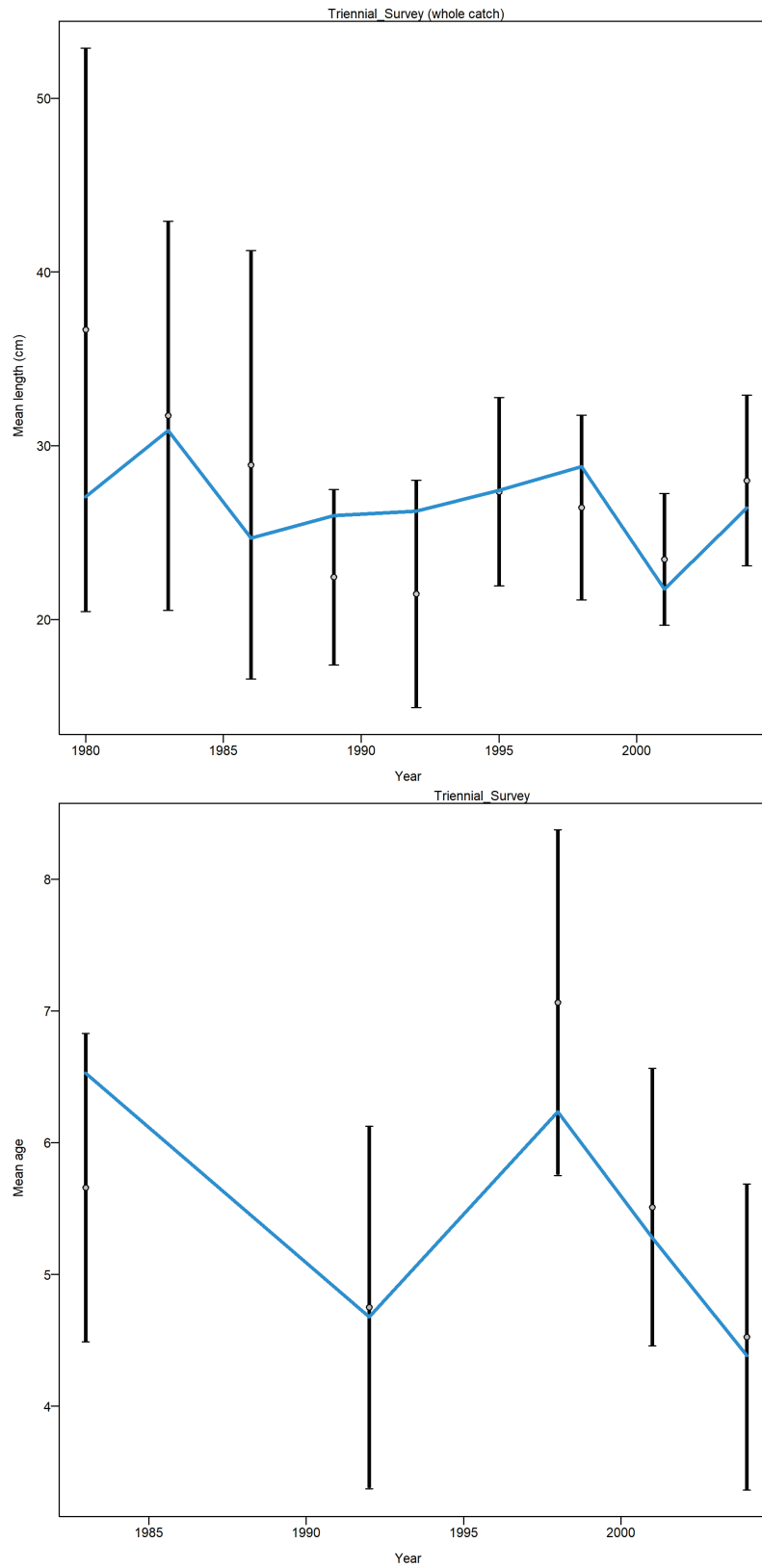


Figure 67: Triennial trawl survey: mean lengths (cm) for sexed fish (top panel) for length compositions, and mean ages (years; bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

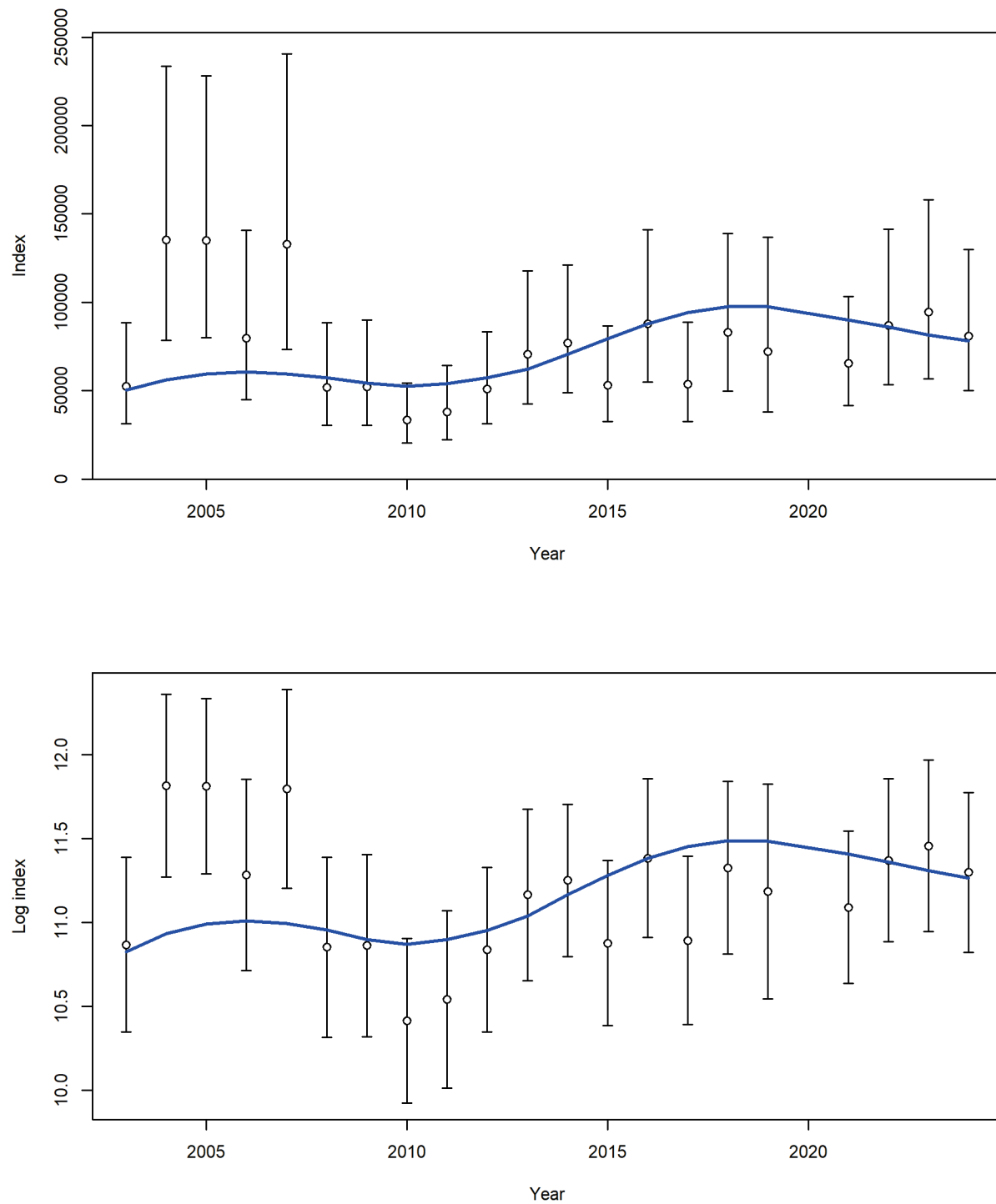


Figure 68: WCGBT survey index of relative abundance. Top panel: Arithmetic scale data with 95% C.I.s based on input SEs. Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

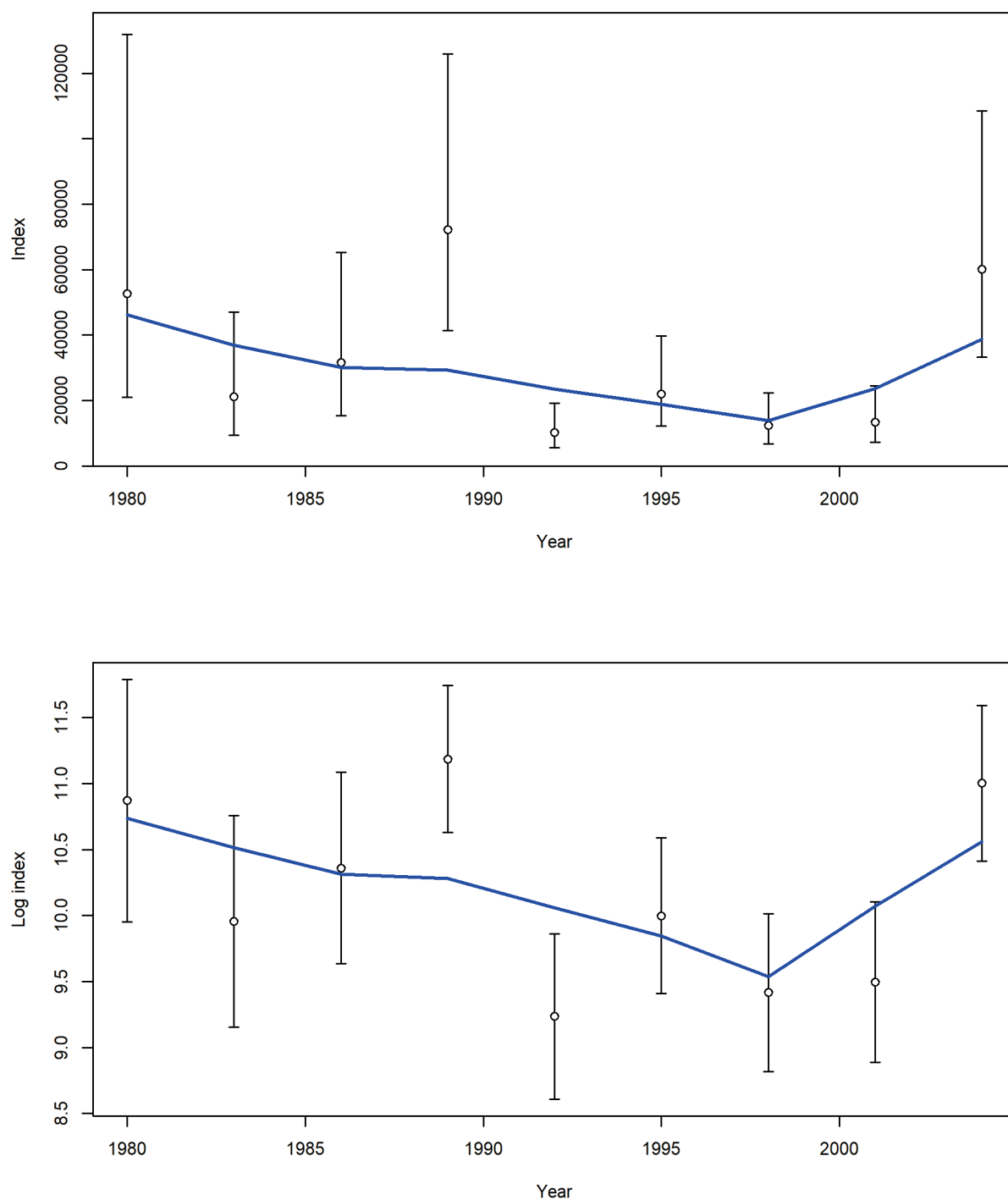


Figure 69: Triennial trawl survey index of relative abundance. Top panel: Arithmetic scale data with 95% C.I.s based on input SEs. Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

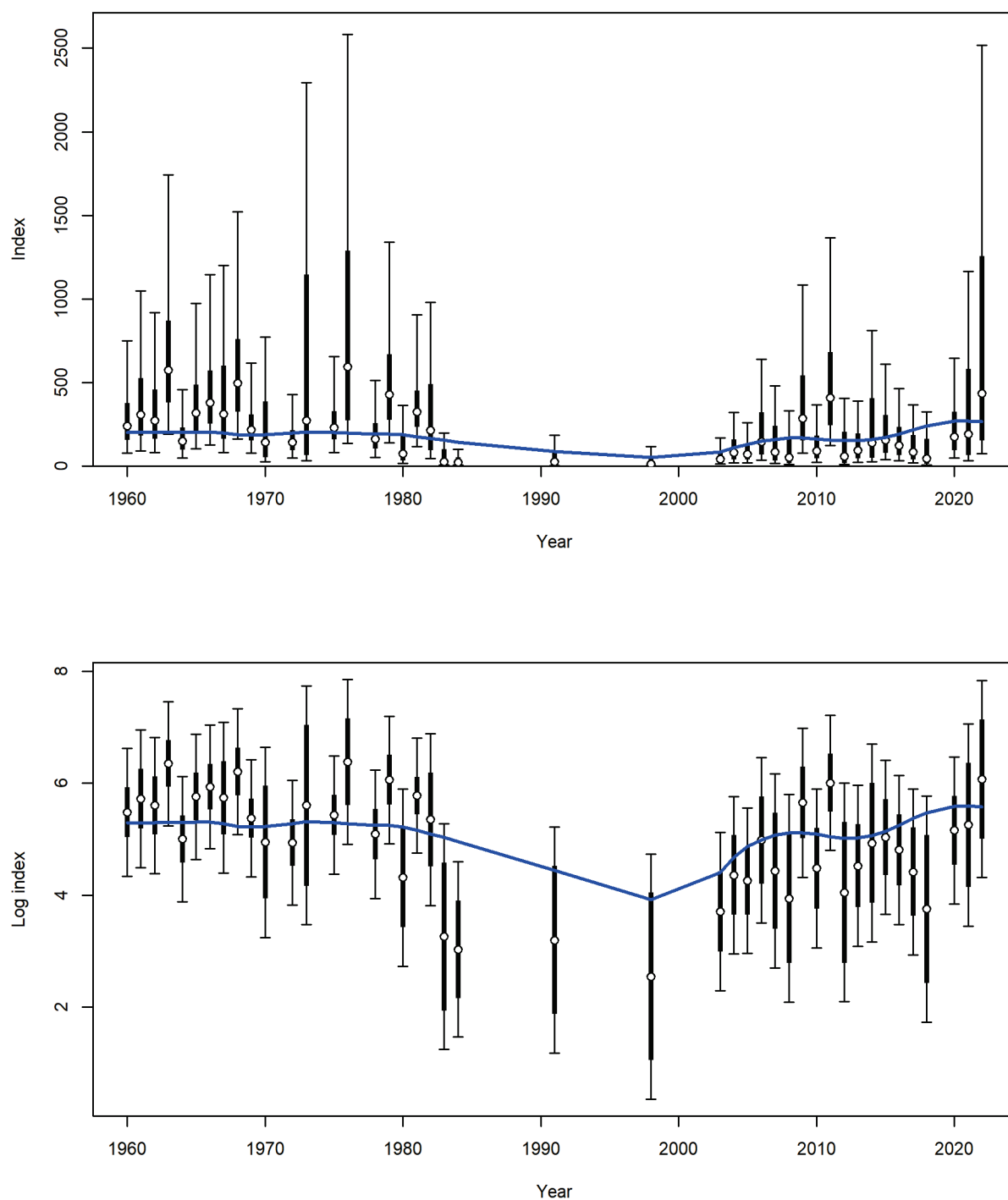


Figure 70: CalCOFI ichthyoplankton survey index of spawning output. Top panel: Arithmetic scale data with 95% C.I.s based on input SEs (thick vertical lines) and with estimated 'extra' variance (thin vertical lines with caps). Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

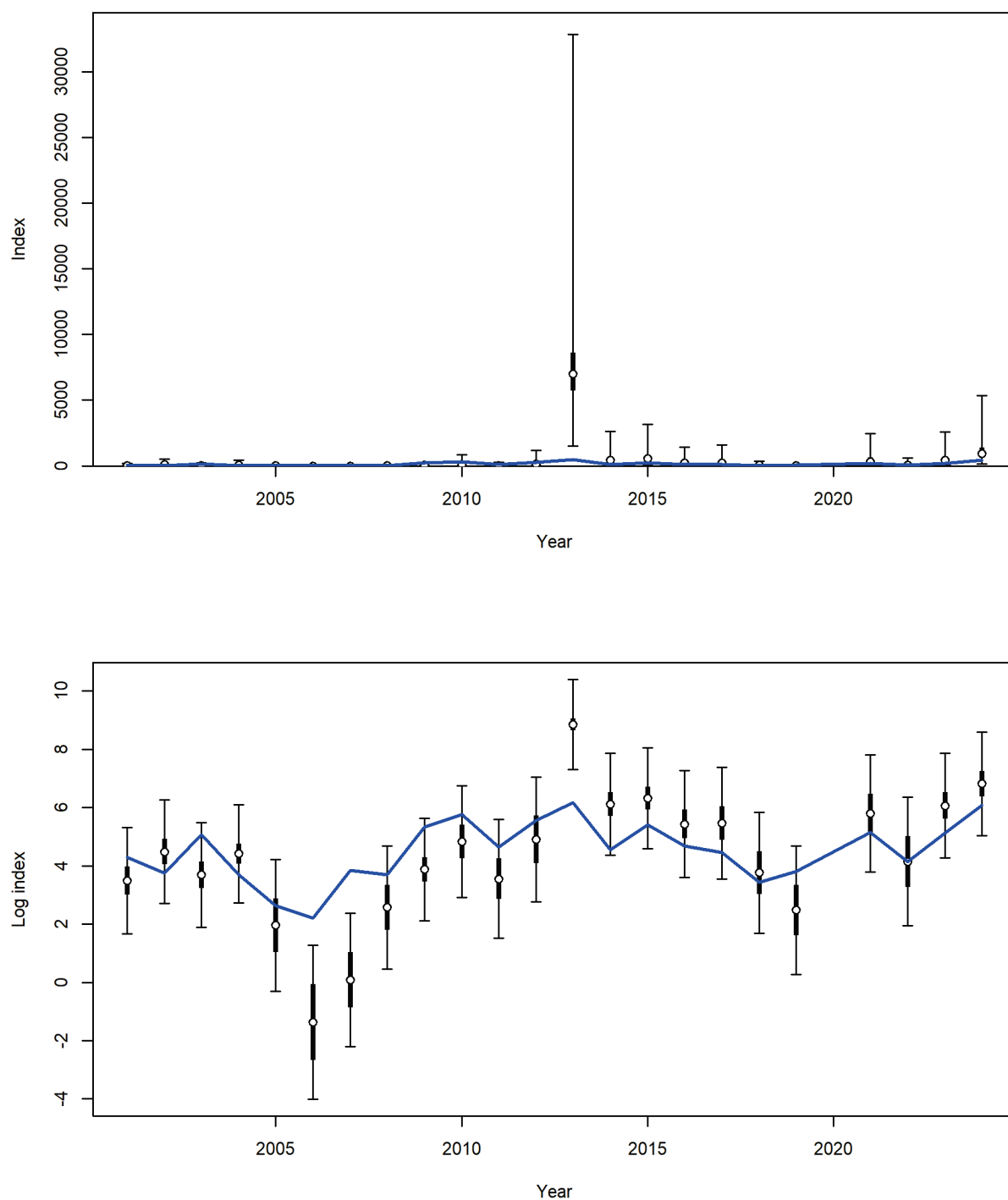


Figure 71: RREAS survey index of age-0 recruitment. Top panel: Arithmetic scale data with 95% C.I.s based on input SEs (thick vertical lines) and with 'extra' variance fixed at 0.683 (the difference between recruitment variability ( $\sigma_R$ ) and the average annual observation error; thin vertical lines with caps). See Appendix B, request 17). Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

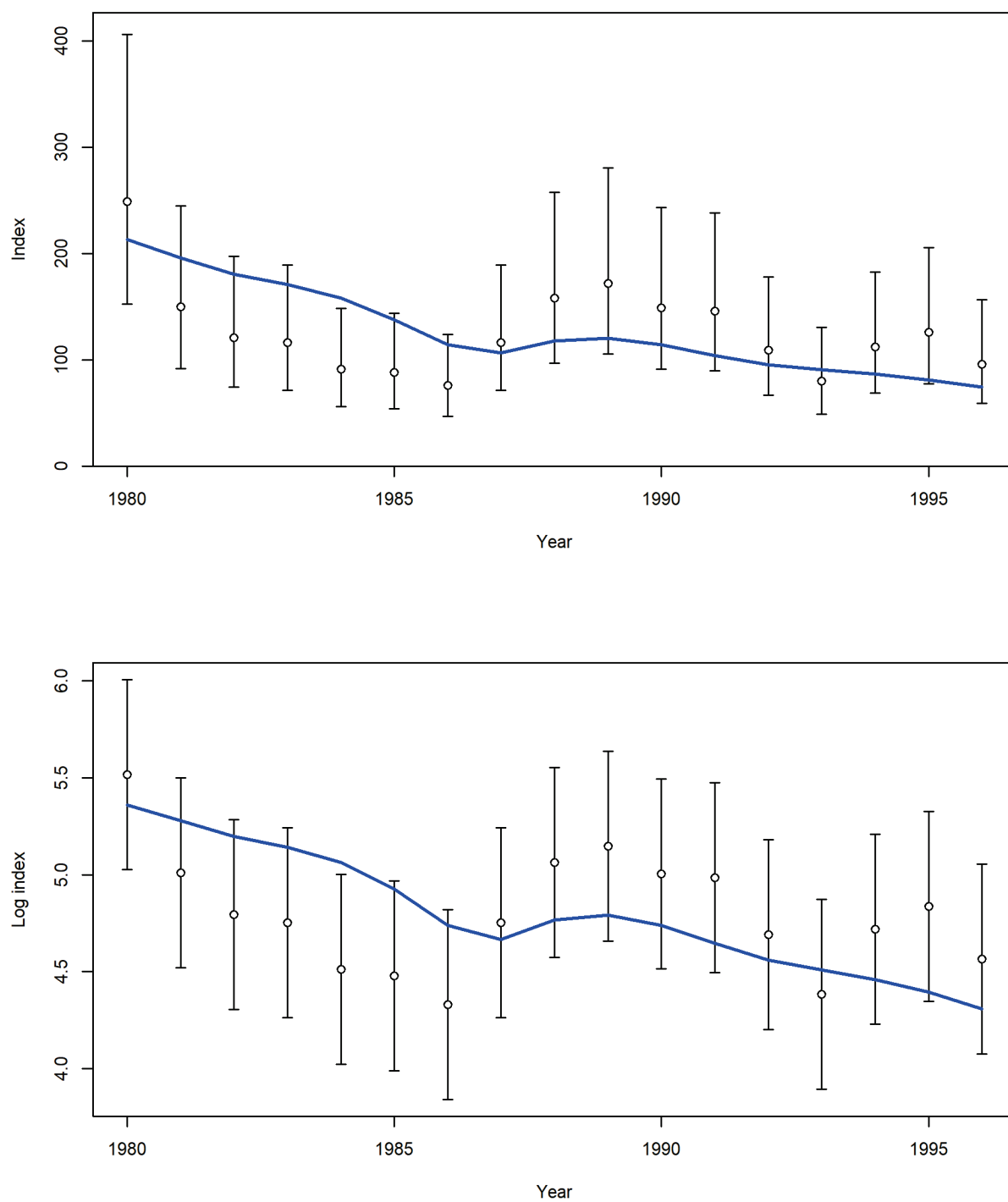


Figure 72: Trawl logbook index of relative abundance (for reference only; **not used to fit model**). Top panel: Arithmetic scale data with 95% C.I.s based on input SEs. Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

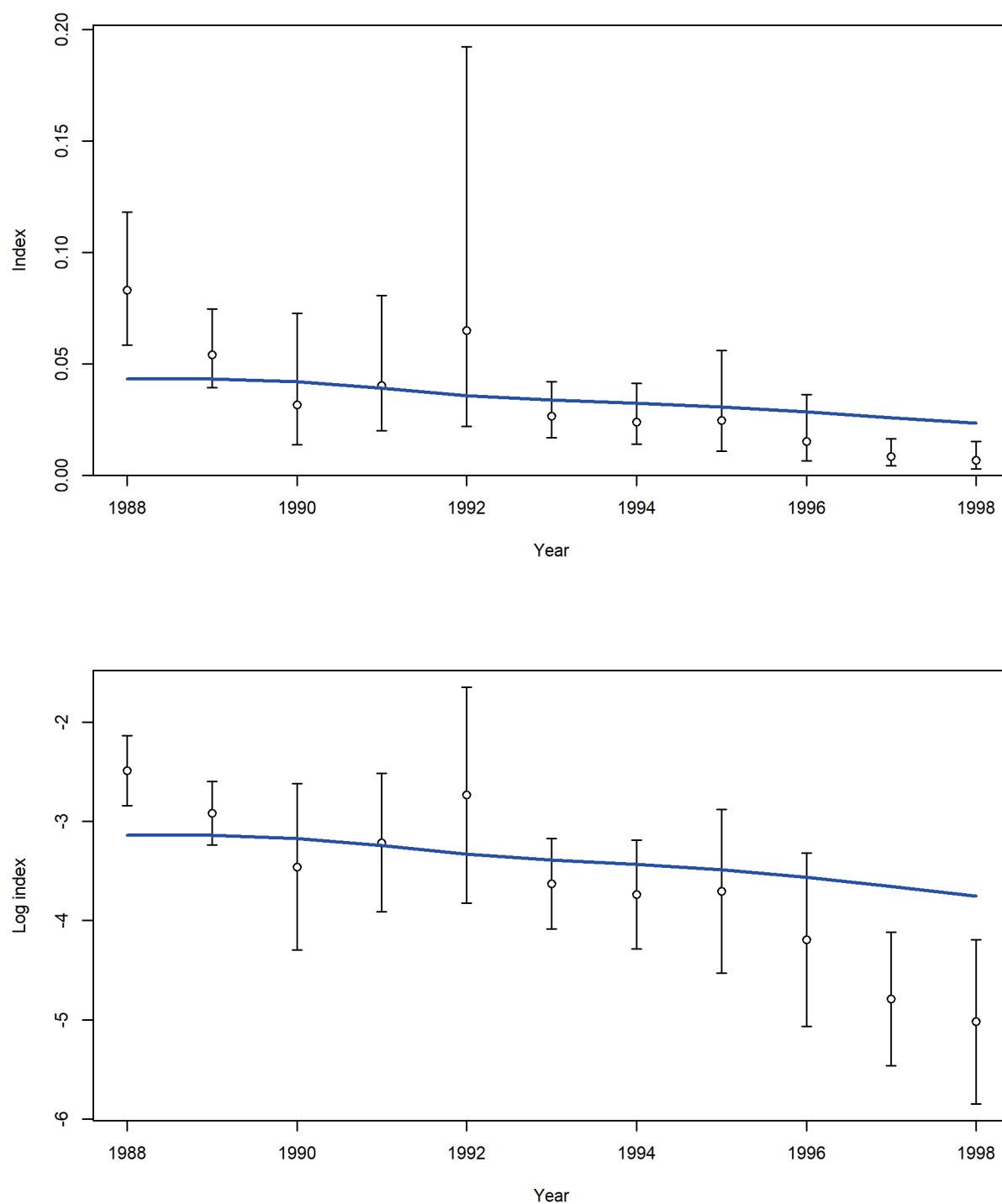


Figure 73: Recreational onboard observer index of relative abundance (for reference only; **not used to fit model**). Top panel: Arithmetic scale data with 95% C.I.s based on input SEs. Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

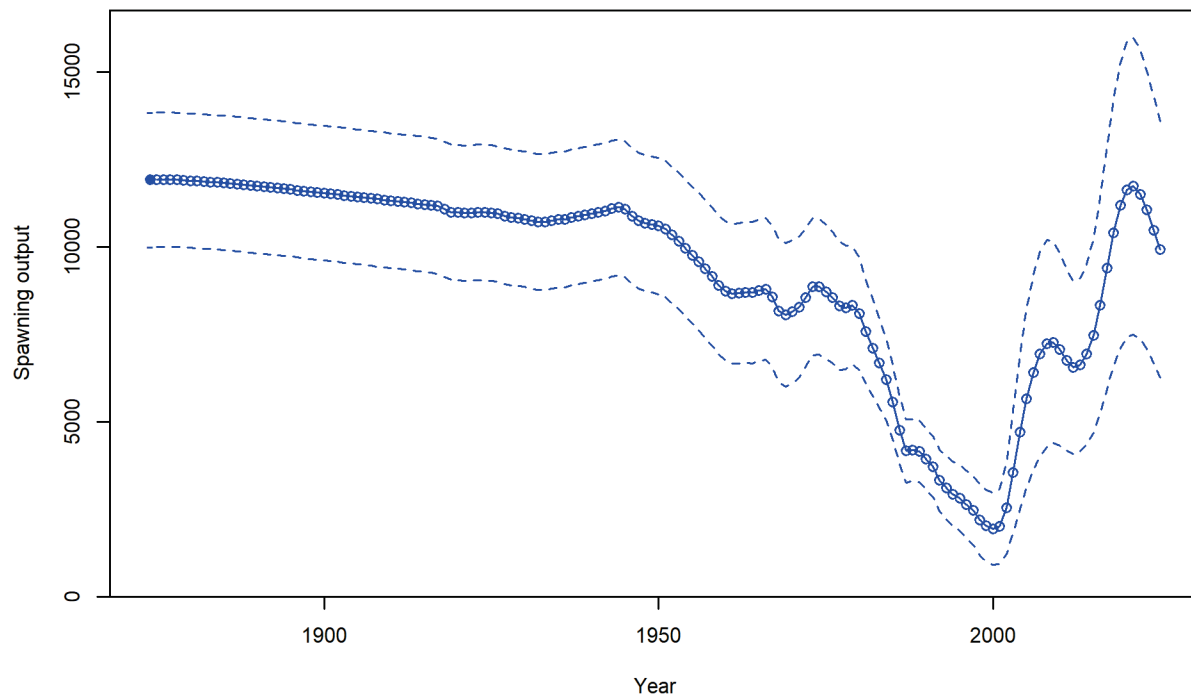


Figure 74: Estimated time series of spawning output in billions of eggs from the base model with 95% asymptotic confidence intervals.

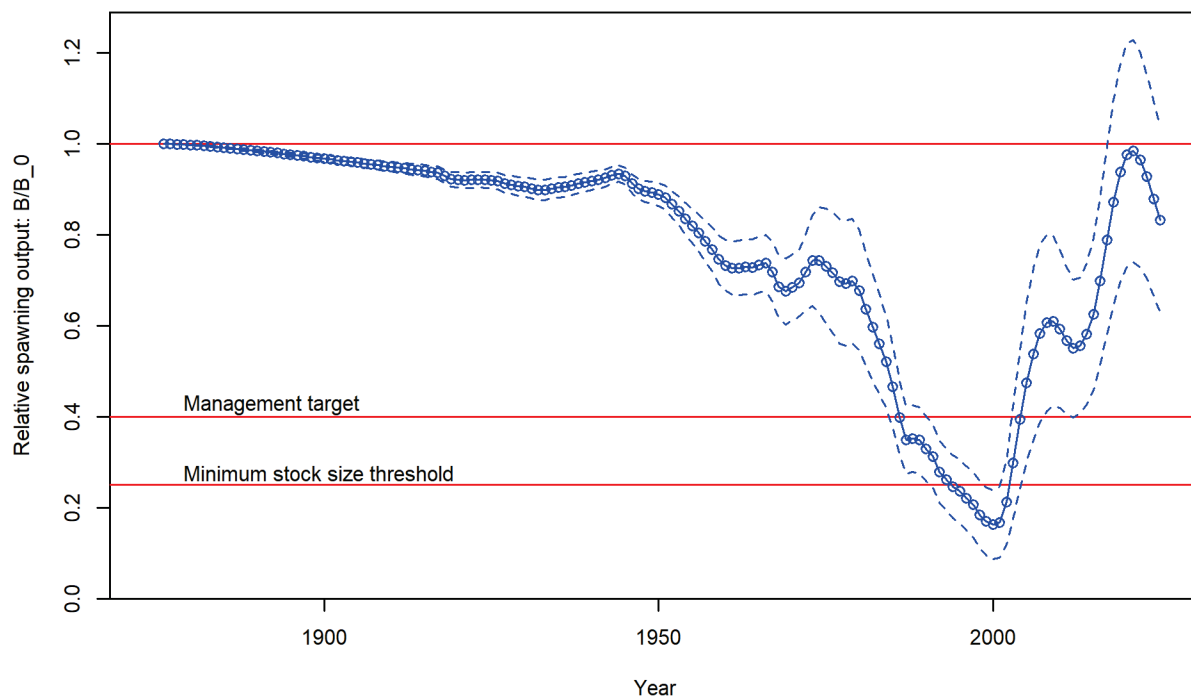


Figure 75: Estimated time series of relative spawning output from the base model with 95% asymptotic confidence intervals. Horizontal lines indicate PFMC target and minimum biomass levels for rockfish.



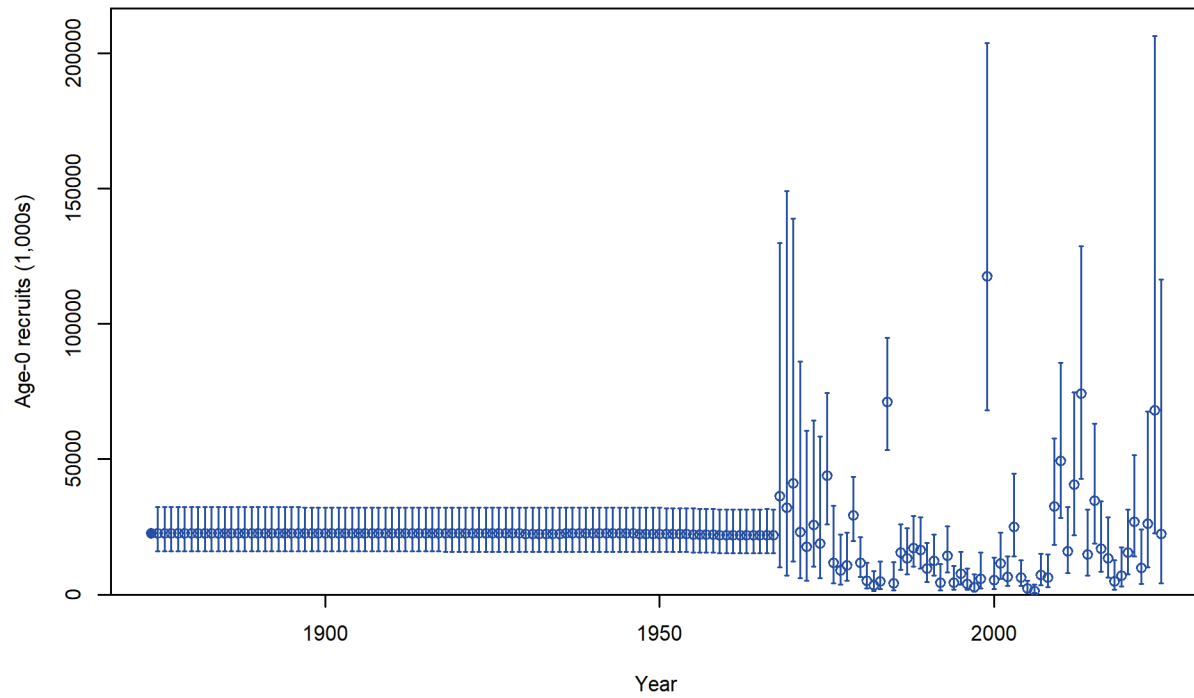


Figure 76: Estimated time series of age-0 recruits (1000s of fish) from the base model with 95% asymptotic confidence intervals.

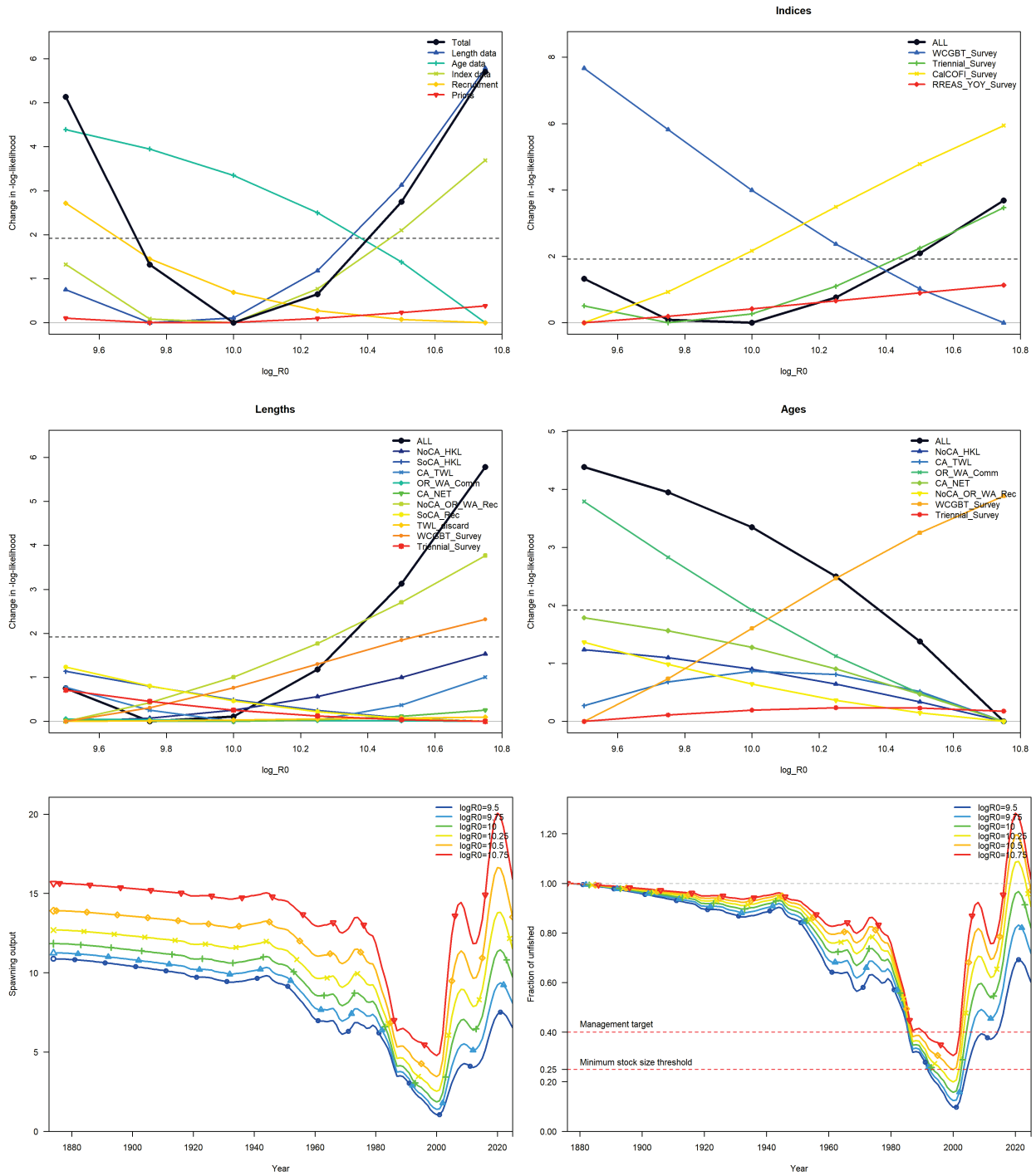


Figure 77: Likelihood profiles over  $R_0$  using the base model.

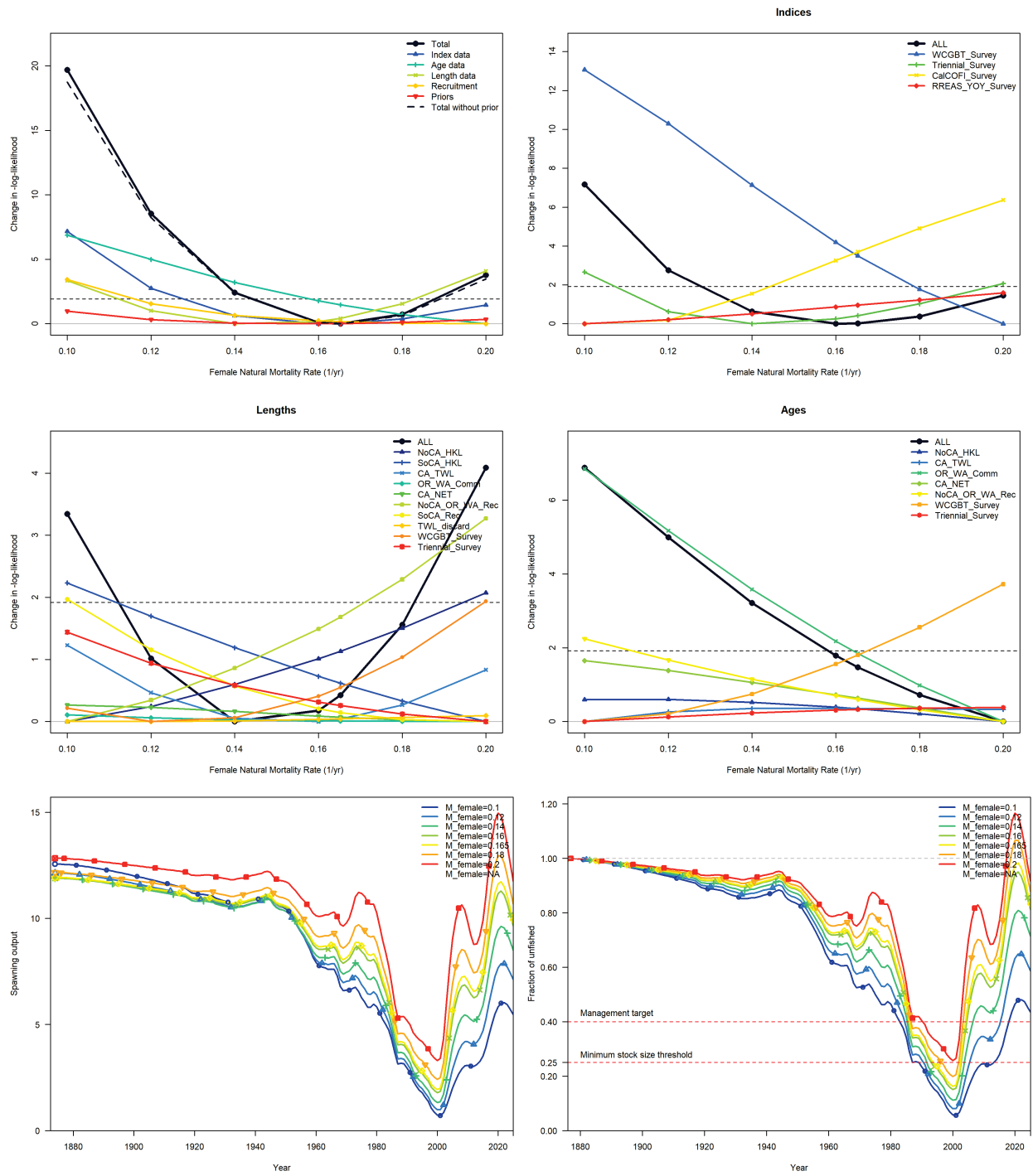


Figure 78: Likelihood profile using the base model over the female natural mortality rate,  $M$ , allowing male  $M$  to be estimated freely in each iteration.

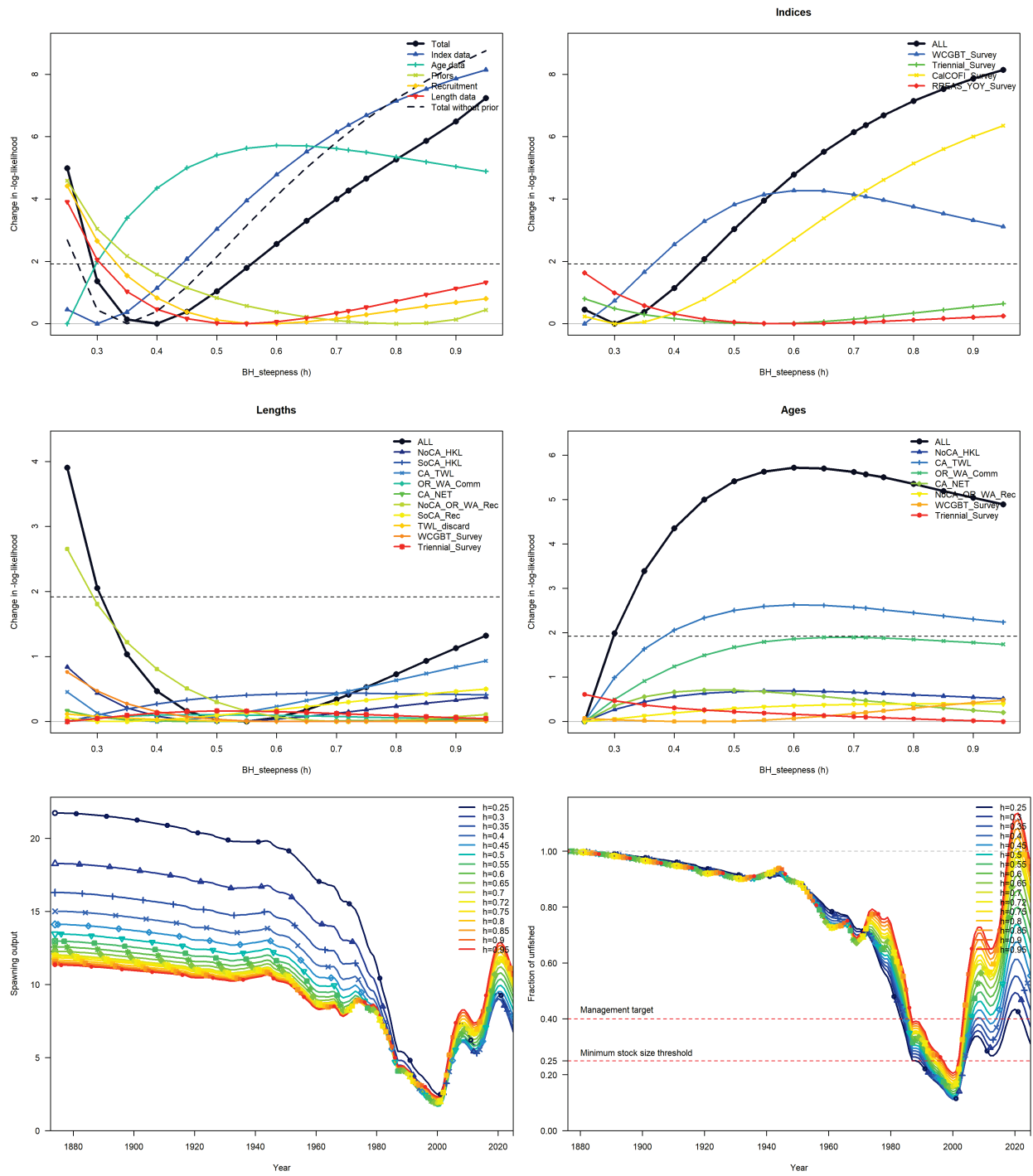


Figure 79: Likelihood profile over Beverton-Holt steepness ( $h$ ) using the base model.

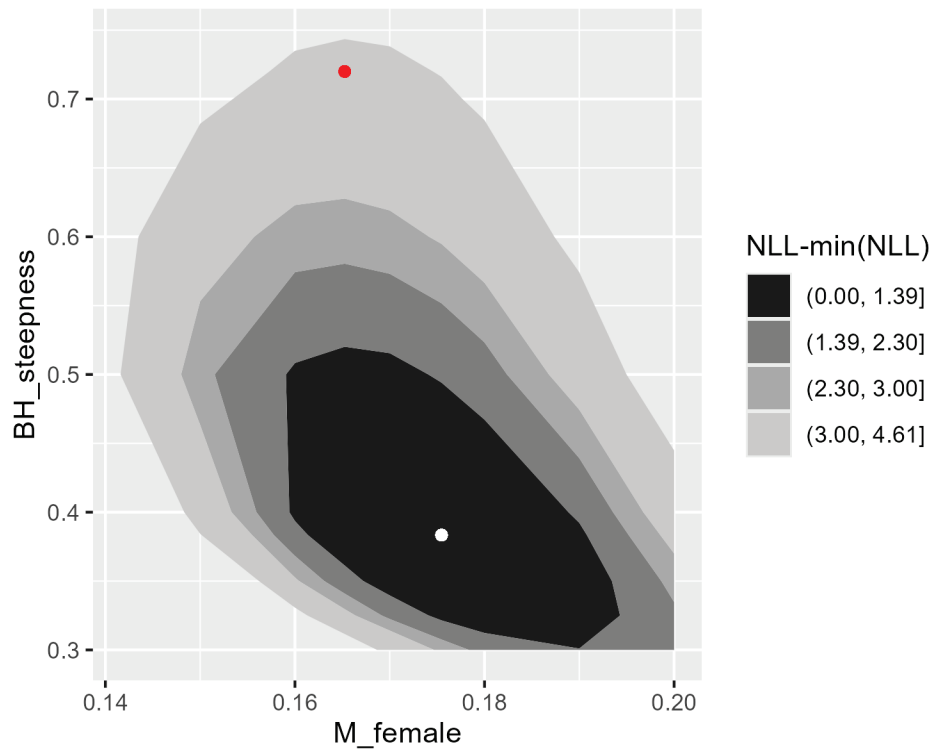


Figure 80: Bivariate likelihood profile over Beverton-Holt steepness and female natural mortality in the final base model that enforces a sum-to-zero constraint on the recruitment deviations. See Appendix B, request 17, for a comparison to the pre-STAR base model that did not have the sum-to-zero constraint. The white point is the minimum of the negative log-likelihood (NLL; with steepness, female M, and male M all estimated). The red point is the base model (estimating female and male M, but fixing steepness at the prior mean (0.72)). The contours represent bivariate confidence regions of 75% (black), 90%, 95%, and 99% (light grey). The base model (red point) is within the bivariate 99% confidence region, but outside the 95% region.

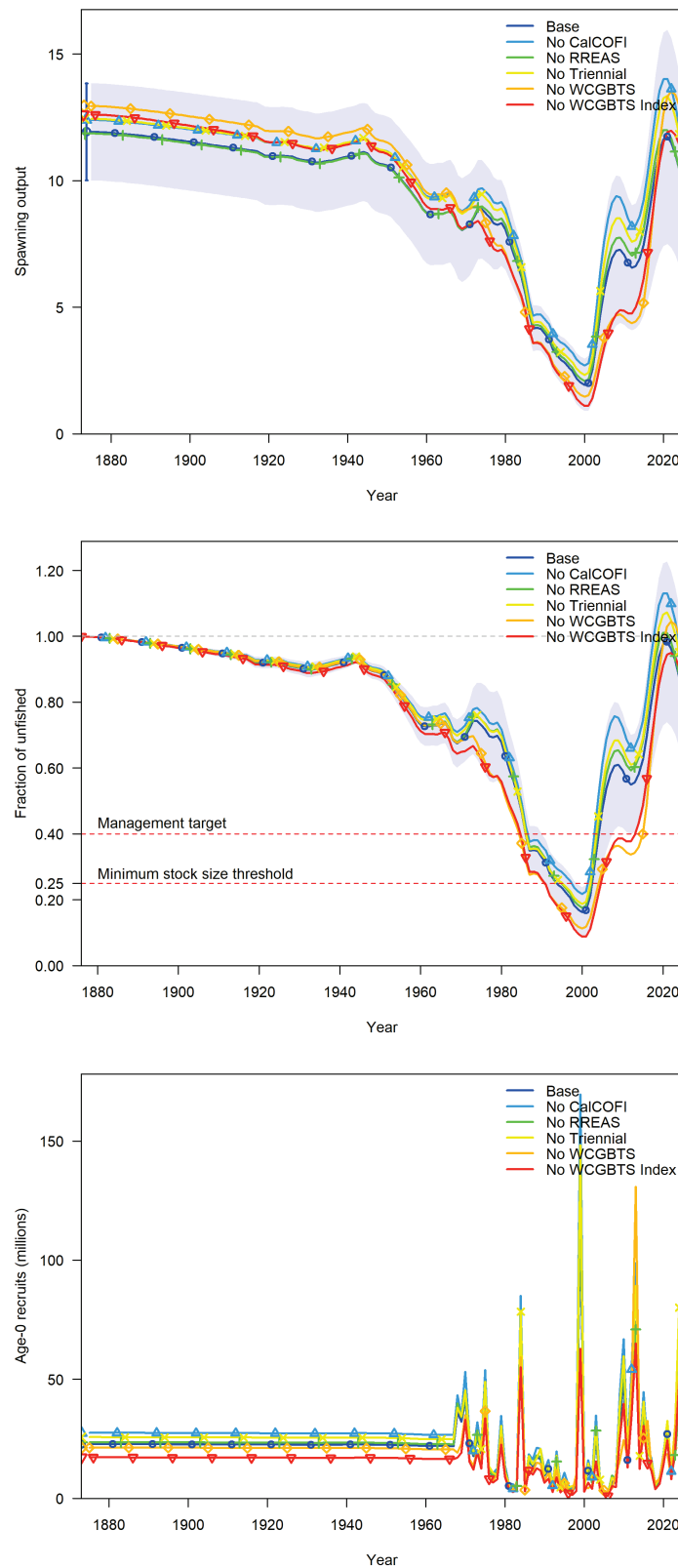


Figure 81: Sensitivity to removal of select data groups. These figures show time series of estimated spawning output (trillions of eggs), depletion and recruitment from a “drop-one” analysis for data sources used in base model (for WCGBTS, includes dropping all compositional and index data, as well as dropping the index only).

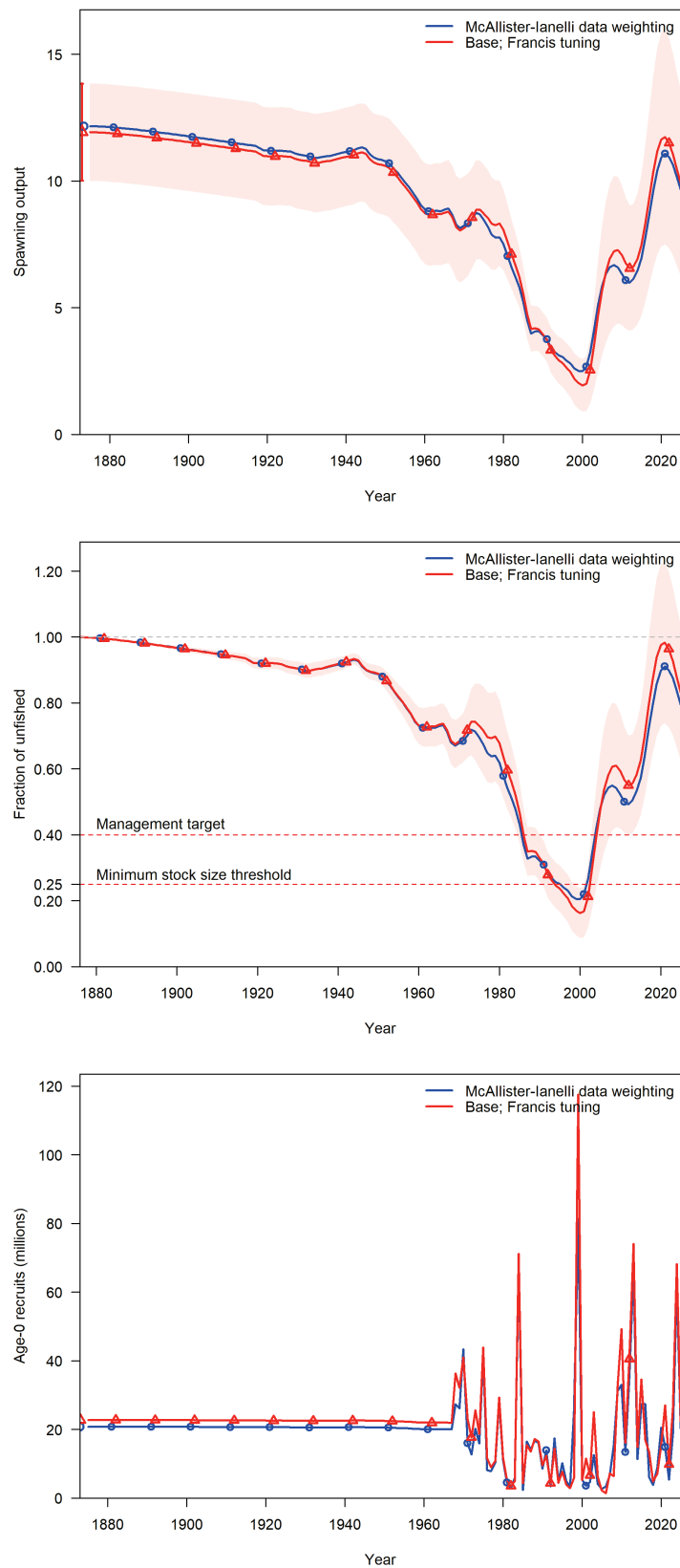


Figure 82: Base model sensitivity to alternative data-weighting methods (Francis vs. McAllister-Ianelli). Time series of spawning output (trillions of eggs, top panel), fraction unfished (middle panel), and recruitment (bottom panel).

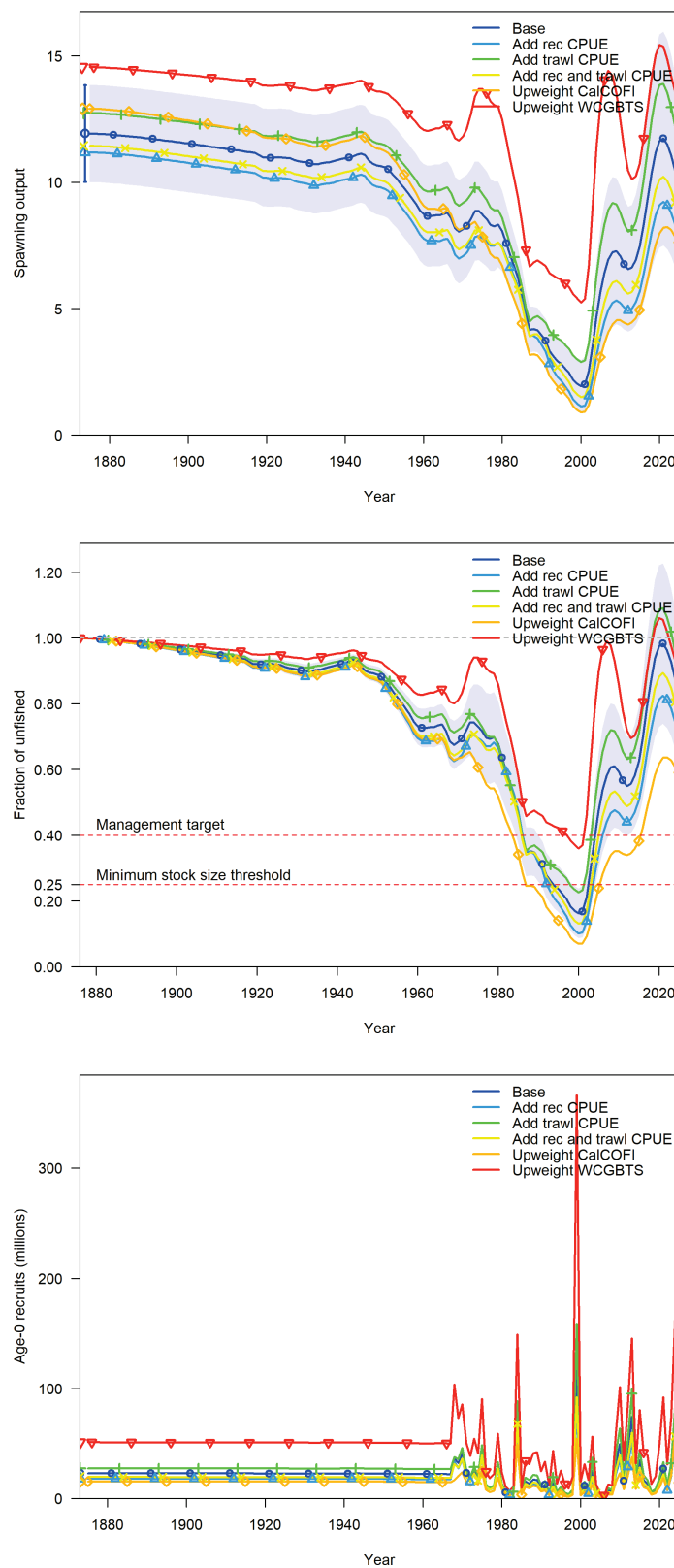


Figure 83: Sensitivity to data set choices and emphasis (“lambda”) settings. These figures show spawning output (trillions of eggs), fraction of unfished spawning output, and recruitment estimates when including indices that are currently not included in the base model, as well as when two of the key indices in the base model are substantially upweighted (lambdas set from 1 to 10).



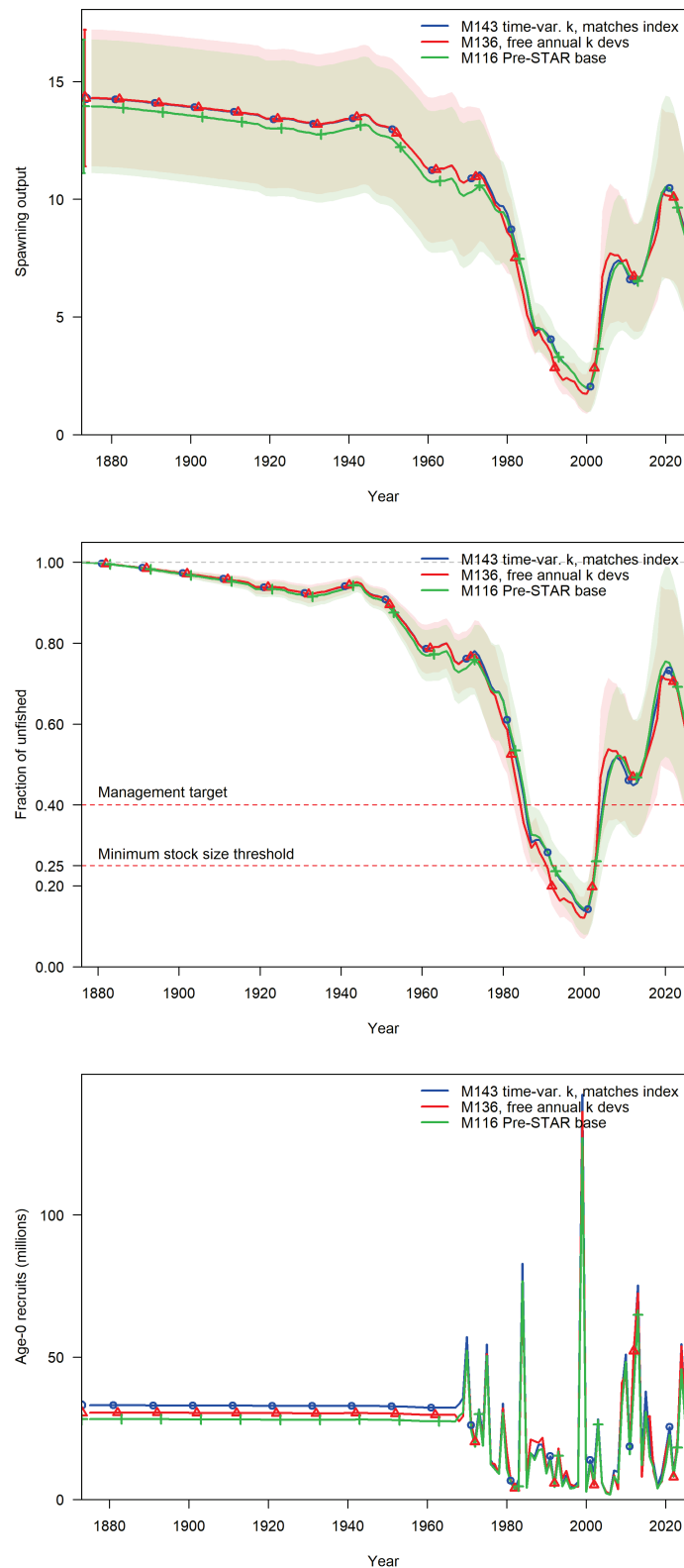


Figure 84: Time series of spawning output (top; trillions of eggs), fraction unfished (middle), and recruitment (bottom) from the pre-STAR base model with alternative parameterizations for the von Bertalanffy growth coefficient (female ' $k$ '). The female  $k$  parameter was estimated in all runs, with fixed multiplicative offsets (1978-2024) from Appendix A (blue line), freely estimated deviations over the same period (red), or held constant (green). Male  $k$  was estimated as an offset in all runs.

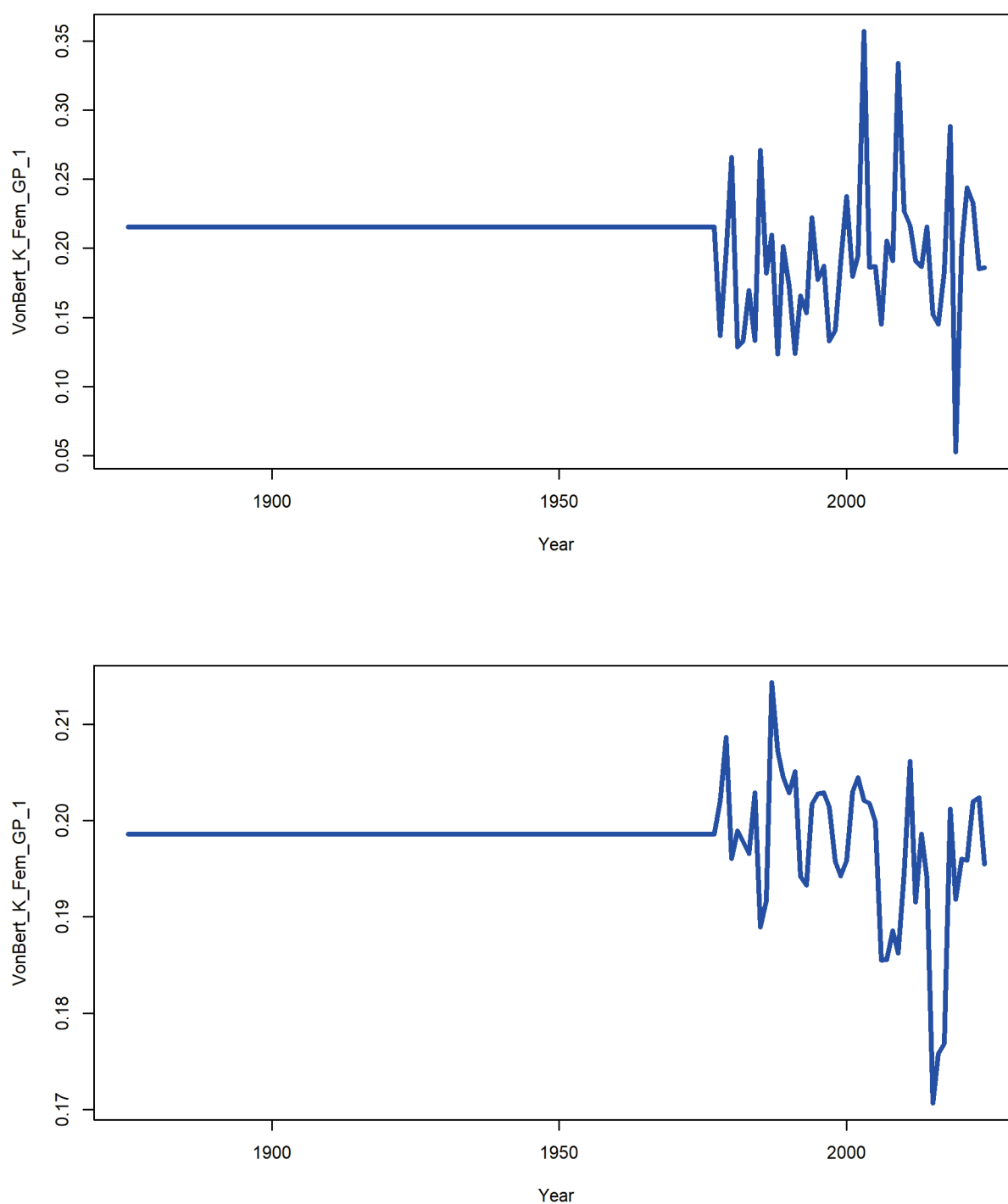


Figure 85: Estimates of annual variation in female ' $k$ ' parameter from the von Bertalanffy growth model. Upper panel: annual deviations from a base parameter value were estimated in the pre-STAR base model, given a S.E. of 0.5 (allowing considerable inter-annual variation; note scale of vertical axis), with had autocorrelation ( $\rho$ ) set to zero. Lower panel: estimated base parameter in the pre-STAR base, forced by externally estimated multiplicative deviations (see Appendix A). Note the reduced magnitude and lower frequency of deviations in the lower panel, relative to the freely estimated deviations in the upper panel.

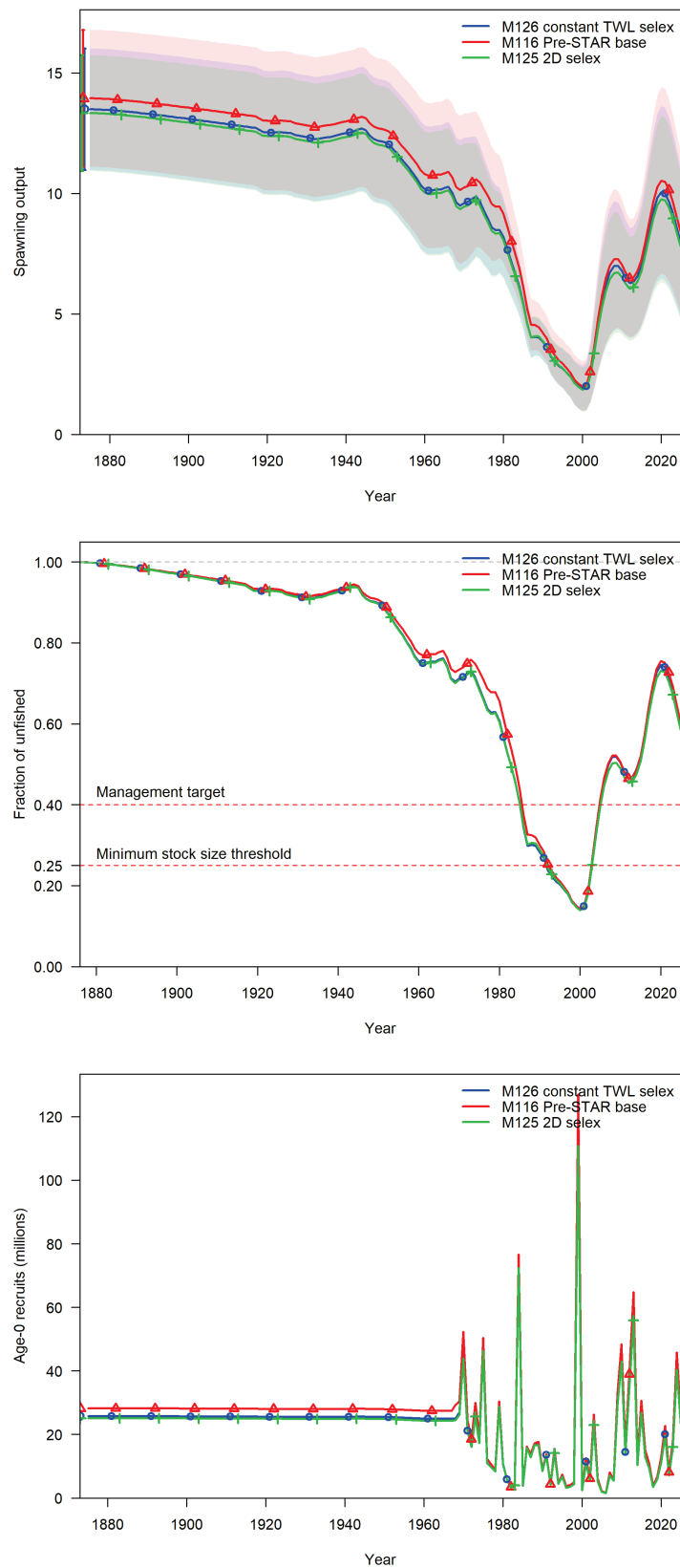


Figure 86: Time series of spawning output (top; trillions of eggs), fraction unfished (middle), and recruitment (bottom) from a sensitivity analysis of alternative selectivity parameterizations for the California trawl fleet in the pre-STAR base model.

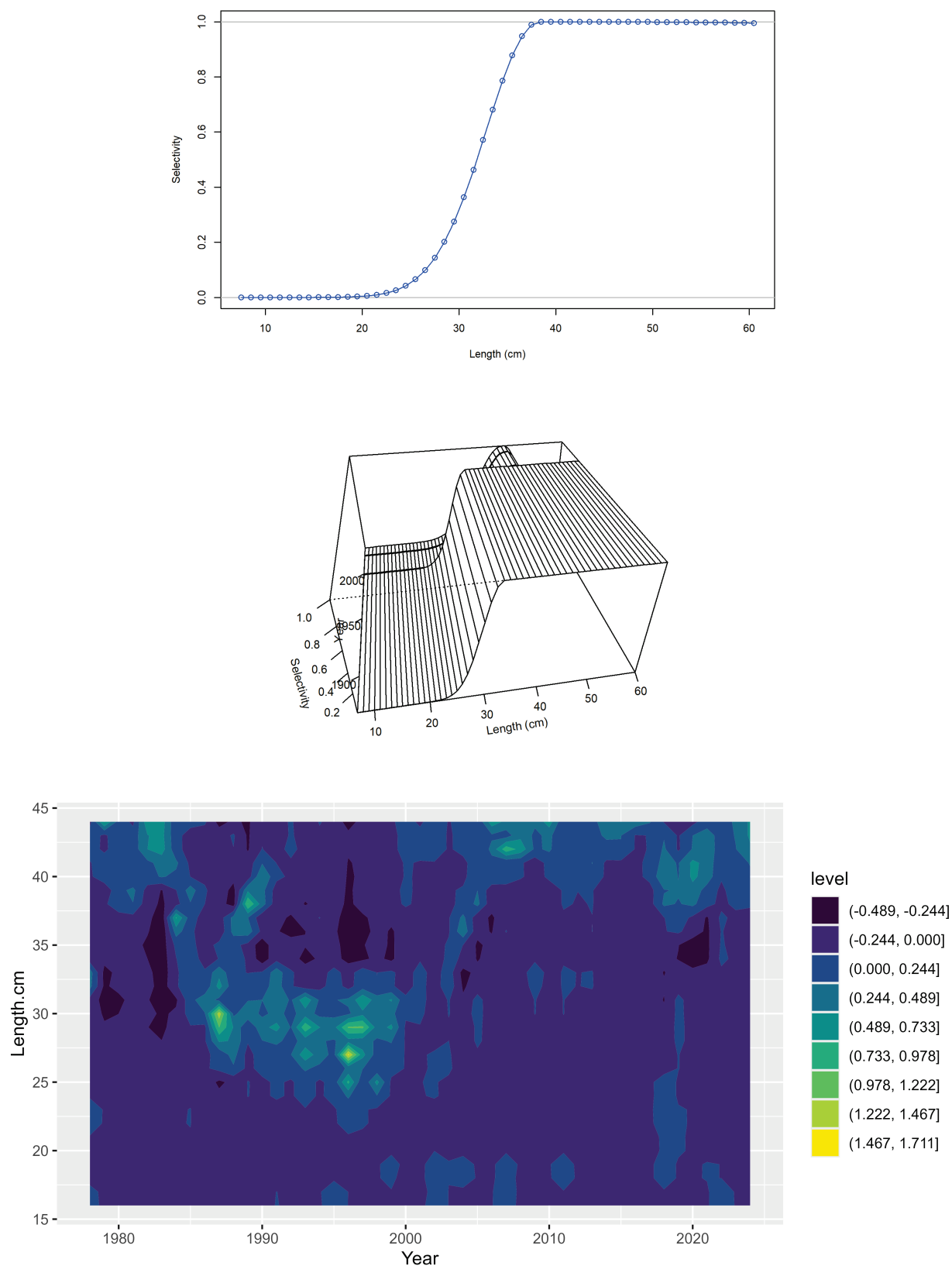


Figure 87: Illustrations of selectivity parameterizations with increasing complexity (top to bottom) for the California trawl fleet: constant (top), time-blocked in year 2000 (middle), deviations by length bin and year from a constant baseline logistic selectivity (bottom).

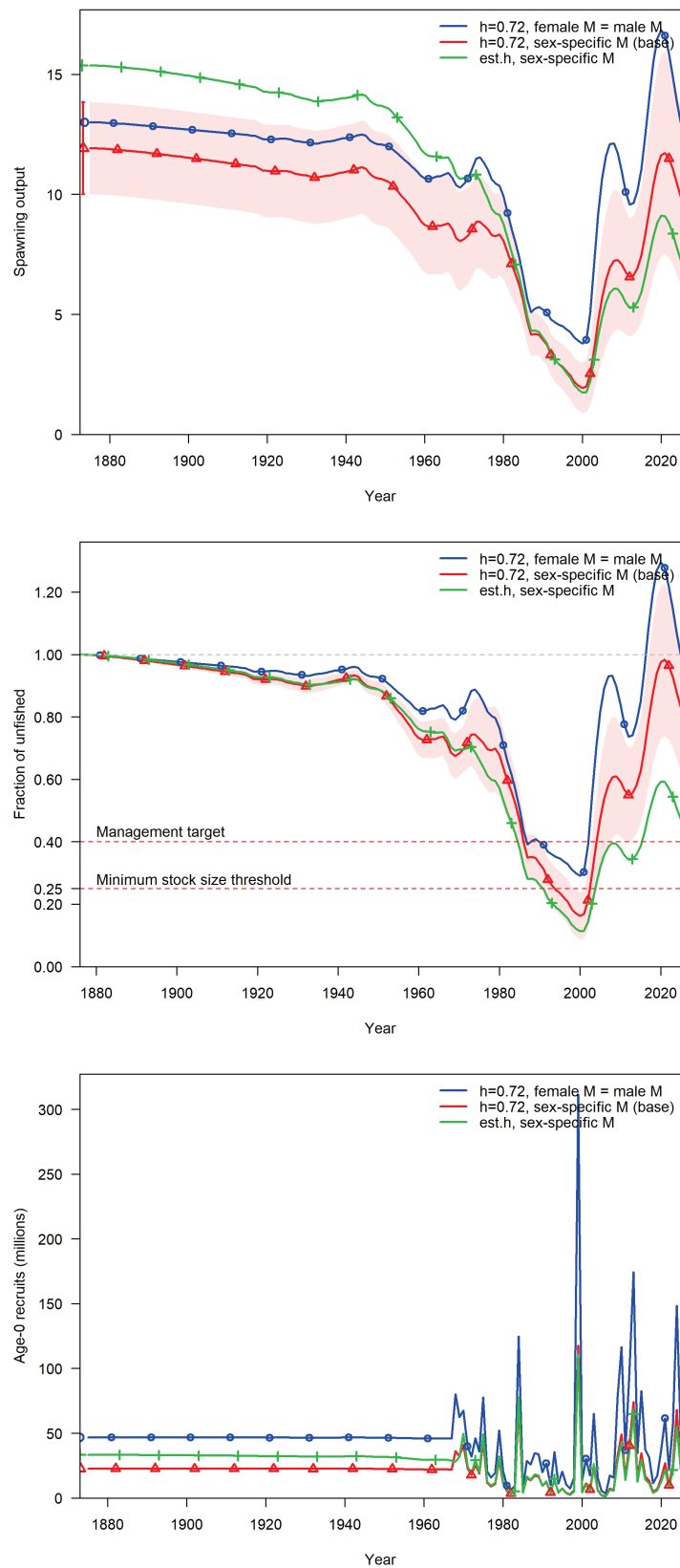


Figure 88: Time series of spawning output (top; trillions of eggs), fraction unfished (middle), and recruitment (bottom) from a sensitivity analysis of alternative steepness assumptions (fixed and estimated) and natural mortality values (estimated as sex-specific and sex-independent).

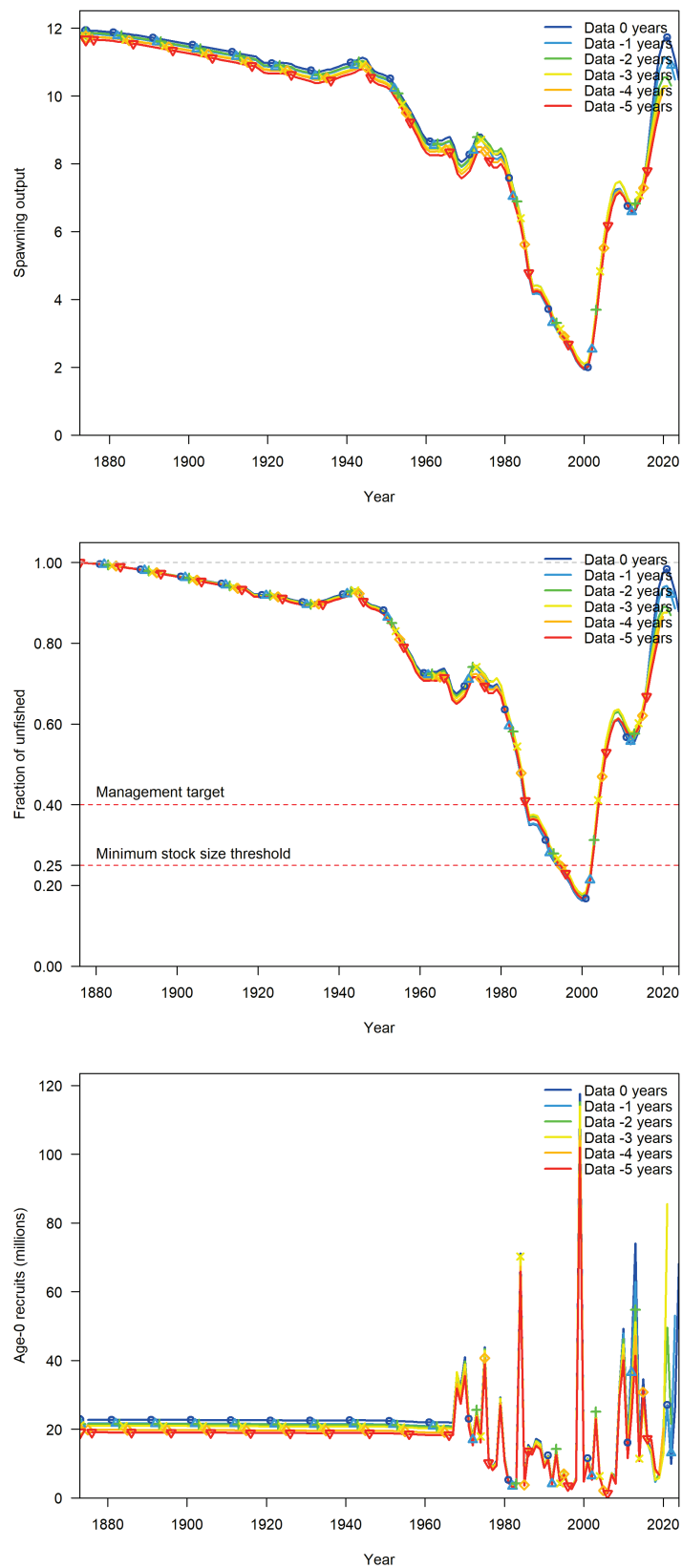


Figure 89: Time series of spawning output (top), fraction unfished (middle), and recruitment (bottom) from a retrospective analysis (sequential removal of 1-5 years of recent data).

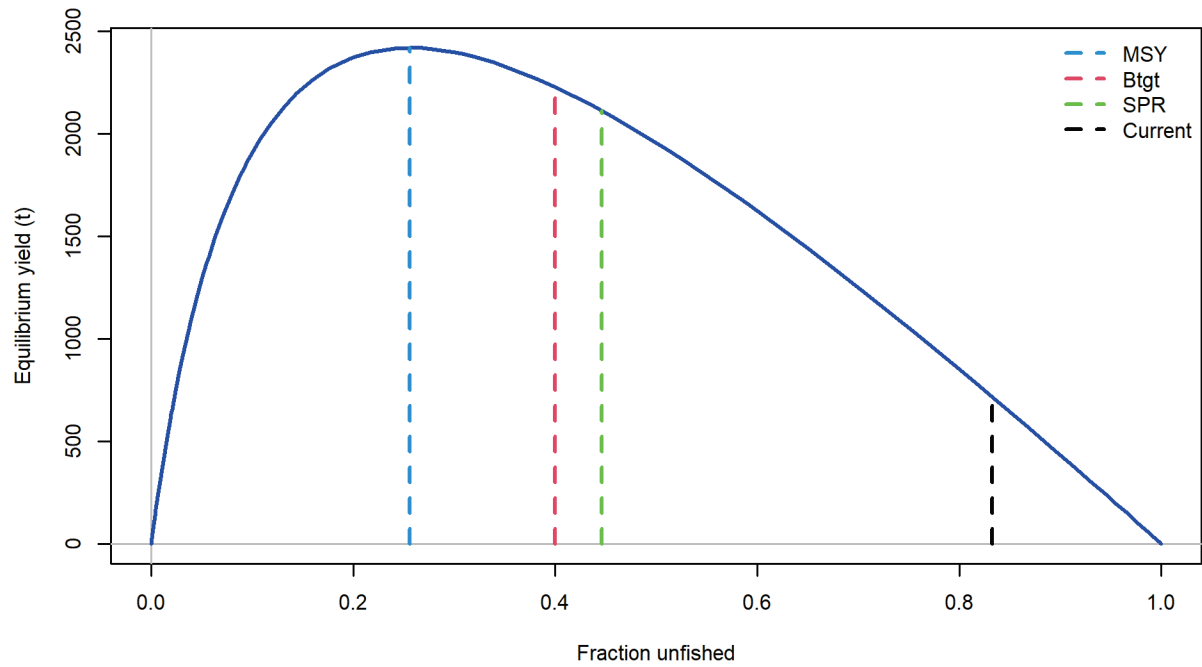


Figure 90: Equilibrium yield curve (mt) as a function of the fraction of unfished spawning output. Blue red, green, and black vertical lines represent equilibrium yield and relative biomass estimates associated with the model-based MSY, target spawning output (Btgt), SPR-based proxy harvest rate (SPR), and the model end-year harvest rate (“Current”), respectively.

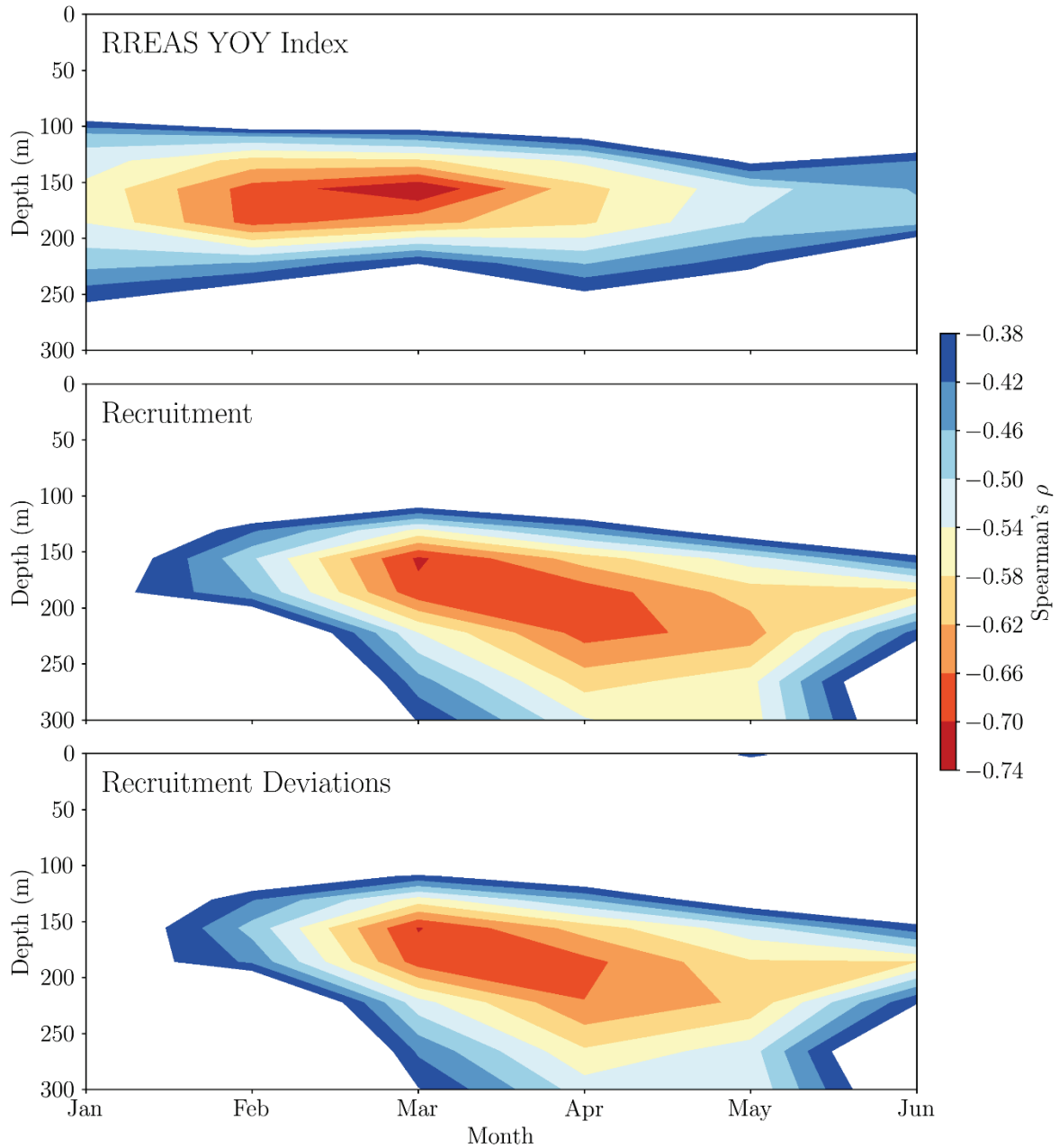


Figure 91: Depth and month when chilipepper has the highest significant correlation with subsurface ocean conditions (1993-2024). Three indicators of chilipepper recruitment variability were used; (top) RREAS YOY index based on midwater trawl survey data; (middle) recruitment estimates from this assessment; and (bottom) recruitment deviations estimates from this assessment. These indices were correlated against subsurface ocean conditions at depths (surface to 500 m) and for individual months (January to June). The subsurface ocean conditions were characterized by a "spiciness" index derived from a consistent monthly, spatial and depth resolved dataset of ocean temperature and salinity, the Global Ocean Physics Reanalysis (GLORYS12V1). Monthly values were spatially averaged over 35-37 N over an area 250 to 500 km offshore. Only significant correlations ( $p < 0.05$ ) are shown in the contour.



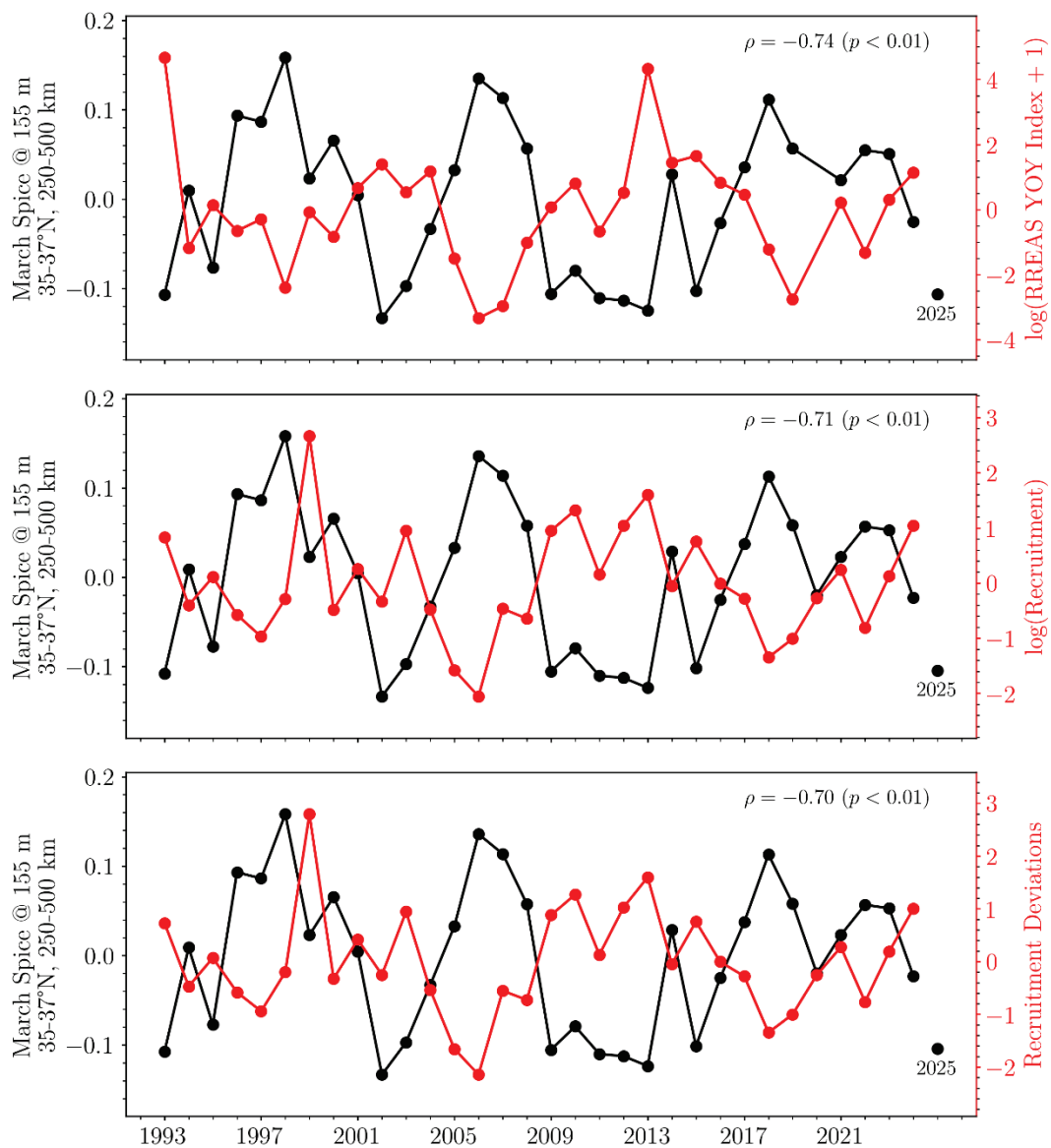


Figure 92: Time series of the recruitment indicators (YOY index, log of recruitment and recruitment deviation estimates from the base assessment model) and the spiciness estimates (spatially resolved spice at 155 m) from the maximum correlation shown in (Figure 91). Includes spiciness estimate for 2025. Correlations are Spearman's rank correlation ( $\rho$ ) values calculated from time series with long-term trends removed.

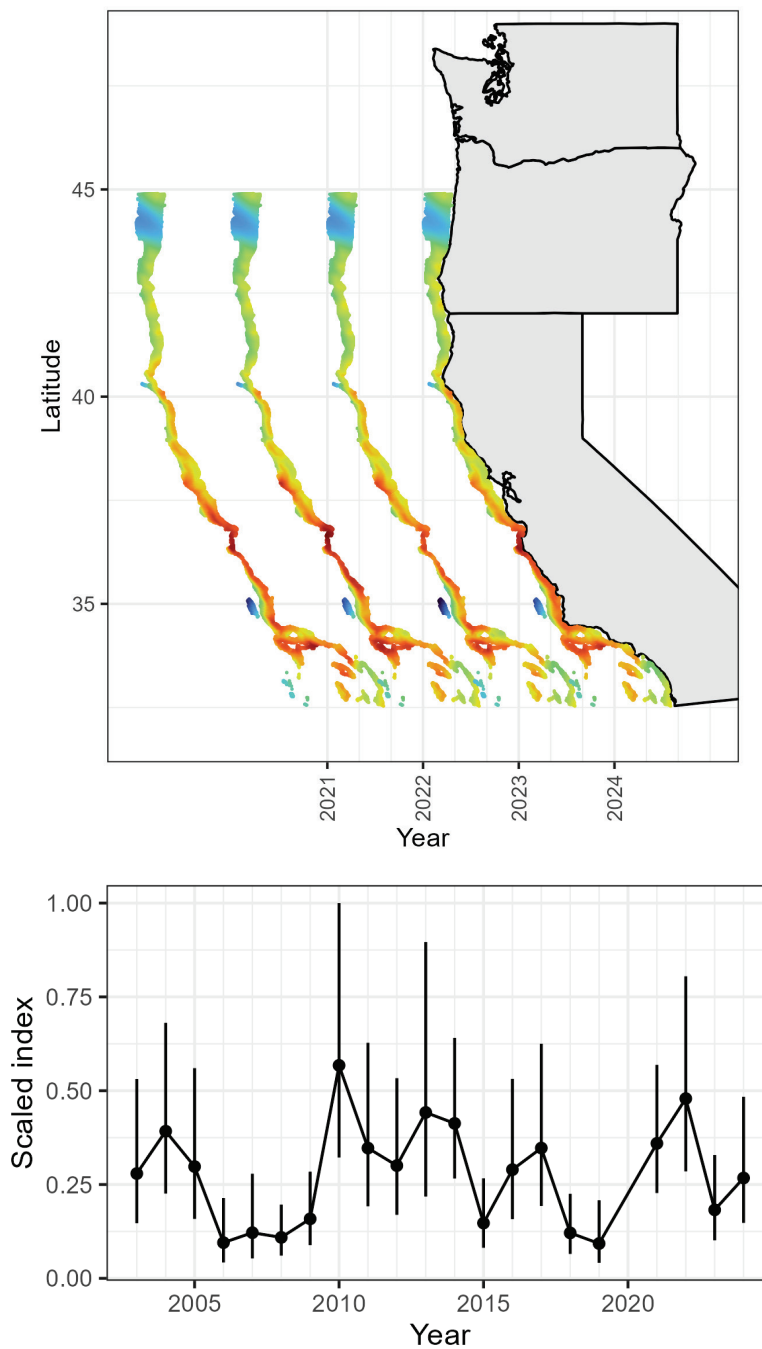


Figure 93: Top panel: Distribution and probability of encounter for settled chilipepper 16 cm and smaller (which should be all age 0 fish, and most age 1 fish) for the most recent four years of West Coast Groundfish Bottom Trawl Survey (WCGBTS) data; bottom panel, relative abundance of age 0 and 1 chilipepper based on the WCGBTS, estimated based on the methods described in Tolimieri et al. (2020).

## **Appendix A. A Model of Time-Varying Growth in Chilipepper Rockfish**

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# A Model of Time-Varying Growth in Chilipepper Rockfish

Nicholas R Grunloh

## Data

This analysis is based primarily on age/length observations of chilipepper rockfish, grouping data sources into either commercial or survey data types to be analyzed independently and then combined into a single index. Commercial age/length data are included from the Calcom and PacFIN databases, and survey age/length data are included from the NWFSC Combo Survey as well as the NWFSC Southern California HKL Survey.

Commercial Calcom age/length data was filtered to trawl-only observations in northern and central California to make a total of 46,722 observations in years from 1978 to 2024. Additionally, 240 commercial Oregon age/length observations, from PacFIN, were added to the commercial dataset for the years 2019-2024. Combining these data sources, the full commercial dataset then contains 46,962 observations.

The survey data primarily consist of NWFSC Combo Survey data from the `nwfscSurvey` R package [5]. The NWFSC Combo Survey contains 13,317 age/length observations of chilipepper in north, central, and southern California from 2003 to 2024. In recent years, 2019-2024, the combo survey data were combined with age/length observations from the NWFSC Shelf Rockfish Hook and Line Survey in Southern California, as provided by John Harms at the NWFSC, to complete the survey dataset. By combining these survey data sources to full survey dataset contains 13,517 age/length observations representing years 2003-2024 from northern California through Southern California.

Each observation was categorized spatially as being part of a northern, central, or southern region. The north region consists of data with latitudes greater than 40°10', the central region is defined as latitudes between 34°27' and 40°10', and the southern region is defined as latitudes less than 34°27'. Yearly sample size totals from each data-source are reported in Table (1).

| Year | Survey |     | Commercial |        |
|------|--------|-----|------------|--------|
|      | Combo  | HKL | Calcom     | PacFIN |
| 1978 | -      | -   | 559        | -      |
| 1979 | -      | -   | 330        | -      |
| 1980 | -      | -   | 1094       | -      |
| 1981 | -      | -   | 701        | -      |
| 1982 | -      | -   | 1217       | -      |
| 1983 | -      | -   | 2308       | -      |
| 1984 | -      | -   | 3576       | -      |
| 1985 | -      | -   | 3273       | -      |
| 1986 | -      | -   | 2011       | -      |
| 1987 | -      | -   | 2493       | -      |
| 1988 | -      | -   | 2428       | -      |
| 1989 | -      | -   | 2581       | -      |
| 1990 | -      | -   | 1694       | -      |
| 1991 | -      | -   | 1600       | -      |
| 1992 | -      | -   | 2081       | -      |
| 1993 | -      | -   | 2028       | -      |
| 1994 | -      | -   | 742        | -      |
| 1995 | -      | -   | 1403       | -      |
| 1996 | -      | -   | 803        | -      |
| 1997 | -      | -   | 1718       | -      |
| 1998 | -      | -   | 2135       | -      |
| 1999 | -      | -   | 2091       | -      |
| 2000 | -      | -   | 998        | -      |

| Year | Survey |     | Commercial |        |
|------|--------|-----|------------|--------|
|      | Combo  | HKL | Calcom     | PacFIN |
| 2001 | -      | -   | 768        | -      |
| 2002 | -      | -   | 1029       | -      |
| 2003 | 663    | -   | 309        | -      |
| 2004 | 743    | -   | 949        | -      |
| 2005 | 833    | -   | 349        | -      |
| 2006 | 596    | -   | -          | -      |
| 2007 | 590    | -   | 459        | -      |
| 2008 | 698    | -   | 437        | -      |
| 2009 | 616    | -   | 787        | -      |
| 2010 | 806    | -   | 305        | -      |
| 2011 | 647    | -   | 9          | -      |
| 2012 | 833    | -   | 348        | -      |
| 2013 | 683    | -   | 408        | -      |
| 2014 | 873    | -   | 301        | -      |
| 2015 | 608    | -   | -          | -      |
| 2016 | 720    | -   | -          | -      |
| 2017 | 540    | -   | -          | -      |
| 2018 | 500    | -   | -          | -      |
| 2019 | 349    | 40  | 76         | 40     |
| 2020 | -      | -   | 103        | 40     |
| 2021 | 500    | 40  | 60         | 40     |
| 2022 | 506    | 40  | 59         | 40     |
| 2023 | 506    | 40  | 55         | 40     |
| 2024 | 507    | 40  | 47         | 40     |

Table 1: Sample size summaries by data-source and year.

# Model

Recall the Schnute parameterization [4] of the Von Bertalanffy (VB) growth function,

$$VB(A; \kappa, L_{a_1}, L_{a_2}) = L_{a_1} + (L_{a_2} - L_{a_1}) \frac{1 - e^{-\kappa(A-a_1)}}{1 - e^{-\kappa(a_2-a_1)}}. \quad (1)$$

This parameterization is convenient for its stability in statistical inference and aligns well with the SS3 parameterization [3].  $\kappa$  is the instantaneous rate of growth (in length) with age.  $L_{a_1}$  is the length at the fixed lower age  $a_1$  and  $L_{a_2}$  is the length at the fixed upper age  $a_2$ .  $a_1$  and  $a_2$  are chosen to be 0 and 20 respectively so that  $L_0$  and  $L_{20}$  are well informed by the available data.  $L_{20}$  is modeled along with  $\kappa$  in the following sections so as to be informed by the above mentioned commercial and survey data.  $L_0$  is fixed to the constant 7.3 throughout this study based on the average of  $n = 20$  July length measurements of age 0 chilipepper rockfish collected in central California (between Morro Bay and Santa Cruz) in a diving study that ran from 1990-1999 by David Ventresca with California Department of Fish and Wildlife. The age 0 data were provided presently by Tom Laidig at SWFSC.

Given the above VB parameterization of growth, let  $\ell_{sti}$  be the  $i^{th}$  observation of chilipepper rockfish fork length with sex  $s$  in year  $t$ . Similarly let  $a_{sti}$  be a matched age observation on the same individual. Assuming normal residual variation of  $\ell_{sti}$  with VB growth at age  $a_{sti}$  the following observation model arises naturally,

$$\begin{aligned} \ell_{sti} &= VB(a_{sti}; \kappa_{st}, L_0, L_{20_{st}}) + \epsilon_{sti} \\ \epsilon_{sti} &\sim N(0, \sigma_s) \quad \sigma_s \sim \text{Student}_3(0, 10) \quad 1_{\sigma > 0}. \end{aligned} \quad (2)$$

Above  $L_0$  is fixed at 7.3 as previously mentioned, but  $\kappa_{st}$  and  $L_{20_{st}}$  are modeled as functions of only sex and year. Models accounting for spatial variability in VB growth are considered in Section (4). Ultimately spatial patterns reiterated the results presented here.

To capture time-varying growth the parameters  $\kappa_{st}$  and  $L_{20_{st}}$  are further modeled hierarchically as follows,

$$\begin{aligned} \log(\kappa_{st}) &= \mathbb{1}_{0.05 < \kappa < 0.5} (\kappa \alpha_s + \kappa \beta_t) \quad \kappa \beta_t \sim N(0, \kappa \phi) \quad \kappa \phi \sim N(0, 1) \quad 1_{\kappa \phi > 0} \\ L_{20_{st}} &= L_{20} \alpha_s + L_{20} \beta_t \quad L_{20} \beta_t \sim N(0, L_{20} \phi) \quad L_{20} \phi \sim N(0, 1) \quad 1_{L_{20} \phi > 0}. \end{aligned} \quad (3)$$

First since  $\kappa$  is a strictly positive quantity, the log is considered for numerical stability. Additionally the domain of  $\log(\kappa)$  is limited using a uniform prior such that  $\mathbb{1}_{0.05 < \kappa < 0.5}$ . This expedites sampling by more quickly focusing sampling to the relevant order of magnitude of  $\kappa_{st}$ . The parameters  $\kappa \alpha_s$  model separate intercepts for each sex. This then allows  $\kappa \beta_t$  to model the effect of each years offset (on the log scale) from the sex intercepts. To empirically encourage partial pooling of information between years the hierarchical prior  $\kappa \beta_t \sim N(0, \kappa \phi)$  is placed on  $\kappa \beta_t$  to shrink these parameters as much as the  $\phi$  parameter calls for through the data. Simpler models were explored, but the level complexity in this model is called for by the data. Most of the focus in this study was on  $\kappa$ , but the structure

of the VB curve clearly correlates estimates of  $\kappa$  with  $L_{20}$ . Consequently,  $L_{20}$  was given a similar level of model flexibility as  $\kappa$  to allow the parameters to covary. Mirroring the same basic modeling structure for  $L_{20_{st}}$  as  $\log(\kappa_{st})$  was found to be an effective model for  $L_{20_{st}}$ . Bayesian inference is given for this model by sampling the posterior distribution of the parameters using the **brms** R package [1] and the NUTS sampler.

## Results

Commercial and survey data were fit with independent instances of the above model. Figure(1) shows the model fits to each data set by year and sex. Overall, fit is very reasonable. Models convergence was ultimately good but required 1000 warm-up samples, with thinning every 3 draws. Occasionally it was necessary to restart some chains due to lack of convergence.

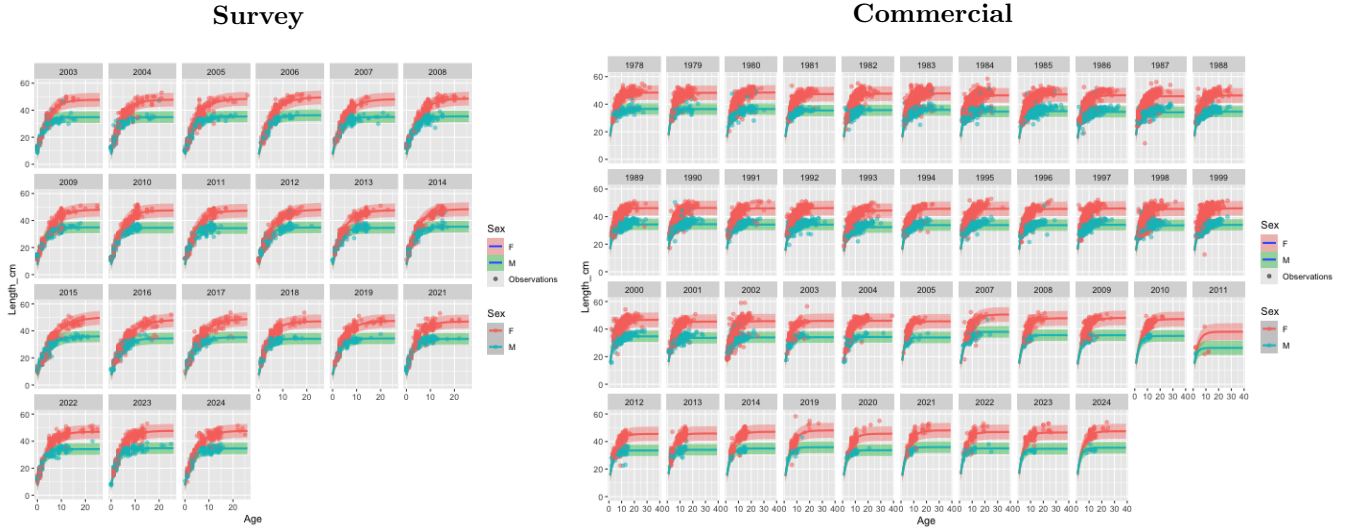


Figure 1: (*left*) Model fit to survey data, by year and sex. (*right*) Model fit to commercial data, by year and sex.

### 3.1 Combining Commercial/Survey Models

These models were fit independently due to practical limitations in computation time and model flexibility. Ideally these models would be fit jointly to allow the model to balance the influence of each data-source in the final index. An attempt was made at joint analysis of these data by including main effect additive offset parameters for commercial/survey data-type in each of the expressions of (2) and (3) and fitting a single model to all of these data. The resulting model was unstable and run times exceeded a week when run on a fully parallelized 46 core workstation. As a result, we concluded an additive offset modeling data-source was too simple a model to combine the data sources; instead more complex models that consider interactions between data sources and the existing parameters should be considered. This would allow more flexibility in how survey/commercial data could be combined to better align with the signal in the data with the structure of the model to therefore improve model stability. Such a model would be

similar to the separate model fits presented here, although would allow the parameters to be estimated jointly, but may lead to extensive run times and/or require lots of RAM to compute.

Since the commercial and survey data were fit independently, some care needs to be taken when combining the resulting indices. The raw posteriors of the  $\kappa_{st}$  from the commercial and survey fits appear approximately proportional in time, however the survey index is shifted (greater) as compared to the commercial index. If these posteriors were naively marginalized together it would introduce an inappropriate amount of uncertainty into the time varying growth index. One way to notice the problem is to look at the estimated posteriors of  $\kappa\alpha_s$  as seen in Figure (3, *left*). It is clear that the intercepts  $\kappa\alpha_s$  from the two models are offset by a constant factor which will be

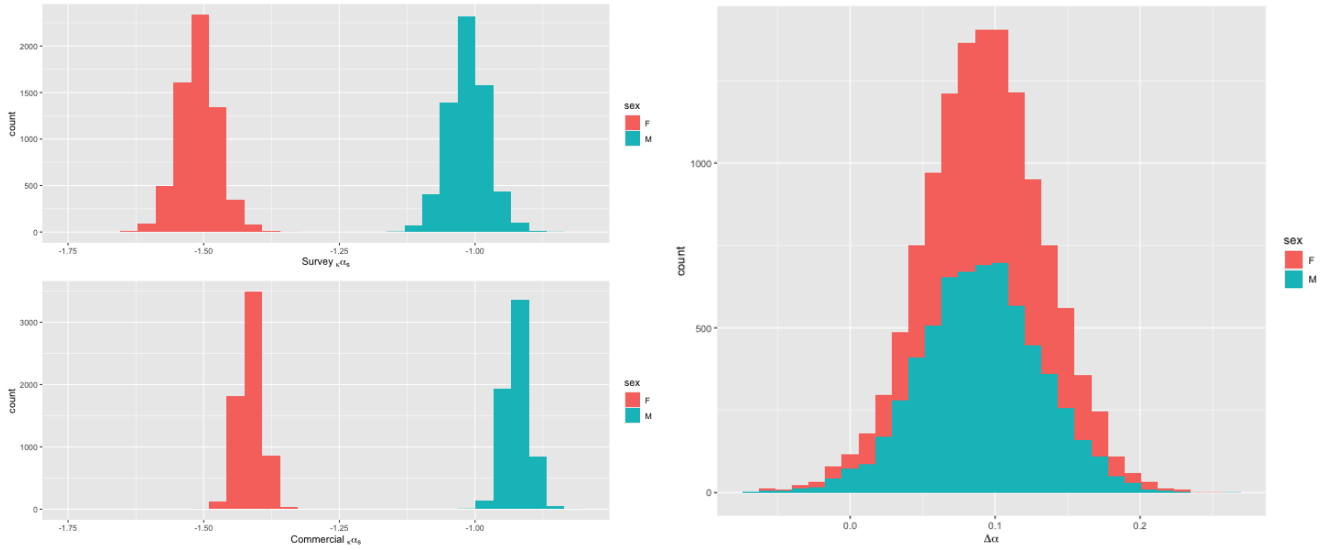


Figure 2: (*left*)  $\kappa\alpha_s$  posterior distributions. (*top*) Survey fit. (*bottom*) Commercial fit. (*right*) Stacked histogram showing the posterior of the difference between marginalized  $\kappa\alpha_s$  parameters.

referred to hence forth as  $\Delta\alpha$ . By estimating  $\Delta\alpha$  the indices from these separate model fits can be better aligned to combine the separate indices into one collective index of time varying growth that pulls from both data sources.  $\Delta\alpha$  is estimated by transforming the posteriors of  $\kappa\alpha_s$  from each fit so as to first marginalize over sex within a model fit and then subtract the marginalized intercept from the survey fit from that of the commercial fit. A summary of  $\Delta\alpha$  is seen Figure (3, *right*) as the stacked histogram. Notice that the offset is consistent between male and female intercepts and roughly estimated around 0.09. Rather than apply the point estimate,  $\Delta\alpha$  is maintained as a random variable and subtracted from the survey index to carry forward the full uncertainty of the posteriors into the final index while correcting the offset in the  $\kappa\beta_t$  as best as possible.

The latent quantity  $\kappa\beta_t$  from the above model can then be interpreted as a model-based empirical measure of time varying growth. Since the Von Bertalanffy growth parameter is modeled here as  $\log(\kappa)$ , a multiplicative index of time varying growth is based on the quantity  $e^{\kappa\beta_t}$ . Figure (3) shows the posteriors of  $e^{\kappa\beta_t}$  that result from fitting the above model to the commercial and survey data separately and then subsequently correcting the survey index by applying  $\Delta\alpha$  as  $e^{\kappa\beta_t - \Delta\alpha}$ .

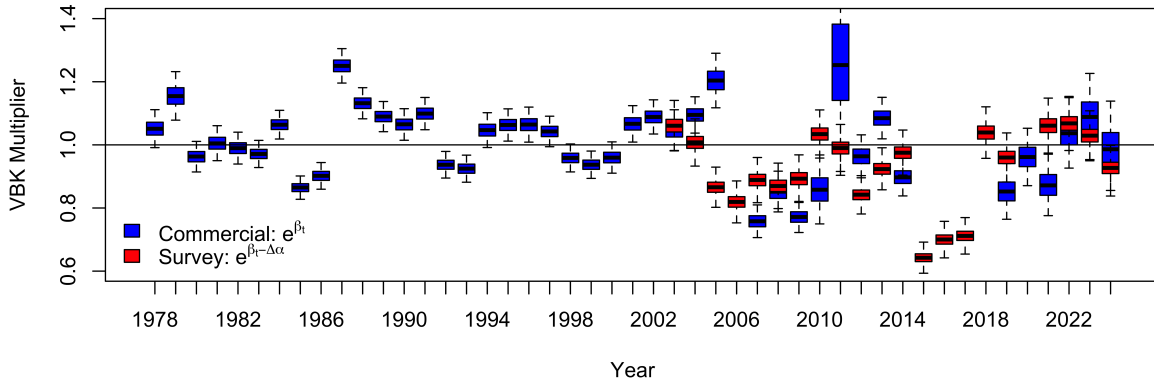


Figure 3: Separate indices of time varying growth as derived from independent fits to the commercial and survey data.

After correcting the survey index, combining the indices simply amounts to marginalizing the posterior draws of each index over data-source. To equally weight the indices this simply amounts to concatenating the samples from each year. When only one data source is available in a given year only the samples from the available index are used. Figure (4) displays the resulting index.

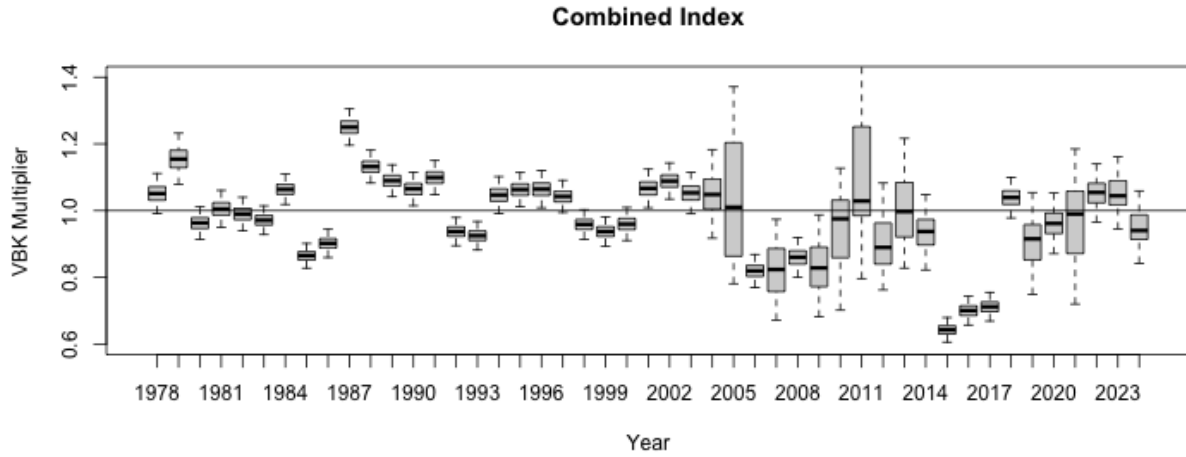


Figure 4: Combined index of time varying growth.



### 3.2 Autocorrelation

By considering the autocorrelation function [2, ACF] over posterior draws of the combined index of time varying growth we can not only inform a good model of time varying growth, but also inform hypothesis which drive it. Figure (5) shows the ACF as applied to the combined index seen in Figure (4). First, note that the peak of the ACF

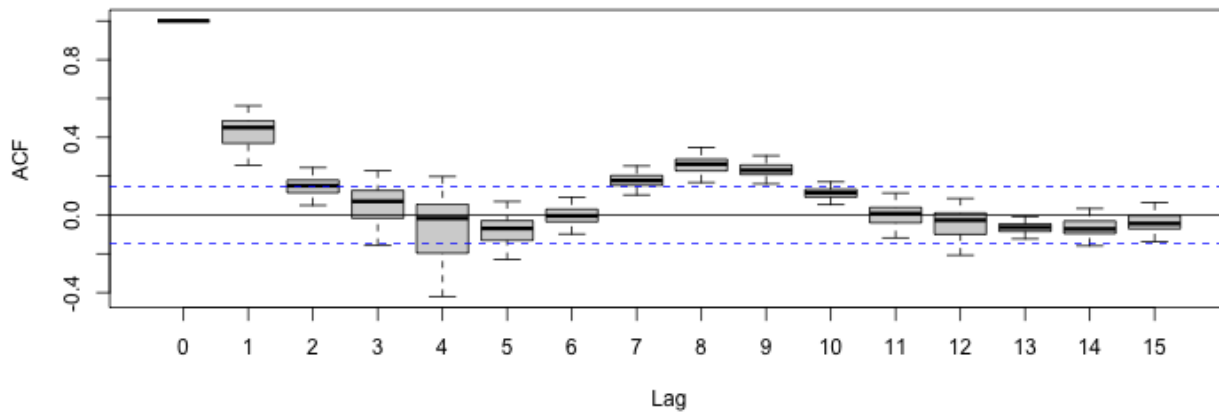


Figure 5: The grey boxplots represent the autocorrelation function as applied to the posterior draws of the combined index (whiskers represent an approximate  $2\sigma$  interval). The blue dashed lines represent the asymptotic  $2\sigma$  interval around the classical null hypothesis of 0 autocorrelation.

for a lag of one year (well beyond the limits of significance). This suggests that an AR1 model could be well suited for modeling this index. Second, observe the next most significant peak of the ACF arising around lags of eight or nine years. This is a consequence of the notable eight to nine year periodicity that is apparent in the indices. It is not clear why this cycle appears, but the presence of these features in this model are empirical evidence of a cyclic pattern in growth that may be driven by physical oceanographic phenomena over the modeled period. Furthermore, considering that the years of 2015, 2016, and 2017 in Figure (4) were the last years with notably low index values, this cyclic pattern suggests that a period of low growth may arrive in the near future if the observed cycle were to persist into the future.

## A Regional Spatio-Temporal Model

The previously presented model can be extended to account for regional,  $r \in \{N, C, S\}$ , spatial effects as,

$$\begin{aligned}
 \ell_{rsti} &= VB(a_{rsti}; \kappa_{rst}, L_0, L_{20_{rst}}) + \epsilon_{rsti} \\
 \epsilon_{rsti} &\sim N(0, \sigma_s) \quad \sigma_s \sim \text{Student}_3(0, 10) \quad 1_{\sigma > 0} \\
 \log(\kappa_{rst}) &= \mathbb{1}_{0.05 < \kappa < 0.5} (\kappa \alpha_{rs} + \kappa \beta_{rst}) \quad \kappa \beta_{rst} \sim N(0, \kappa \phi) \quad \kappa \phi \sim N(0, 1) \quad 1_{\kappa \phi > 0} \\
 L_0 &= 7.3 \quad L_{20_{rst}} = L_{20} \alpha_{rs} + L_{20} \beta_{rst} \quad L_{20} \beta_{rst} \sim N(0, L_{20} \phi) \quad L_{20} \phi \sim N(0, 1) \quad 1_{L_{20} \phi > 0}.
 \end{aligned} \tag{4}$$

Such a model not only exposes a latent yearly index of growth (i.e. the previous model's  $\kappa \beta_t$  parameters), but rather this model exposes latent spatio-temporal-varying indices of growth. By fitting this model to the two previously described sources of data the following indices can be derived from the  $\kappa \beta_{rst}$  parameters.

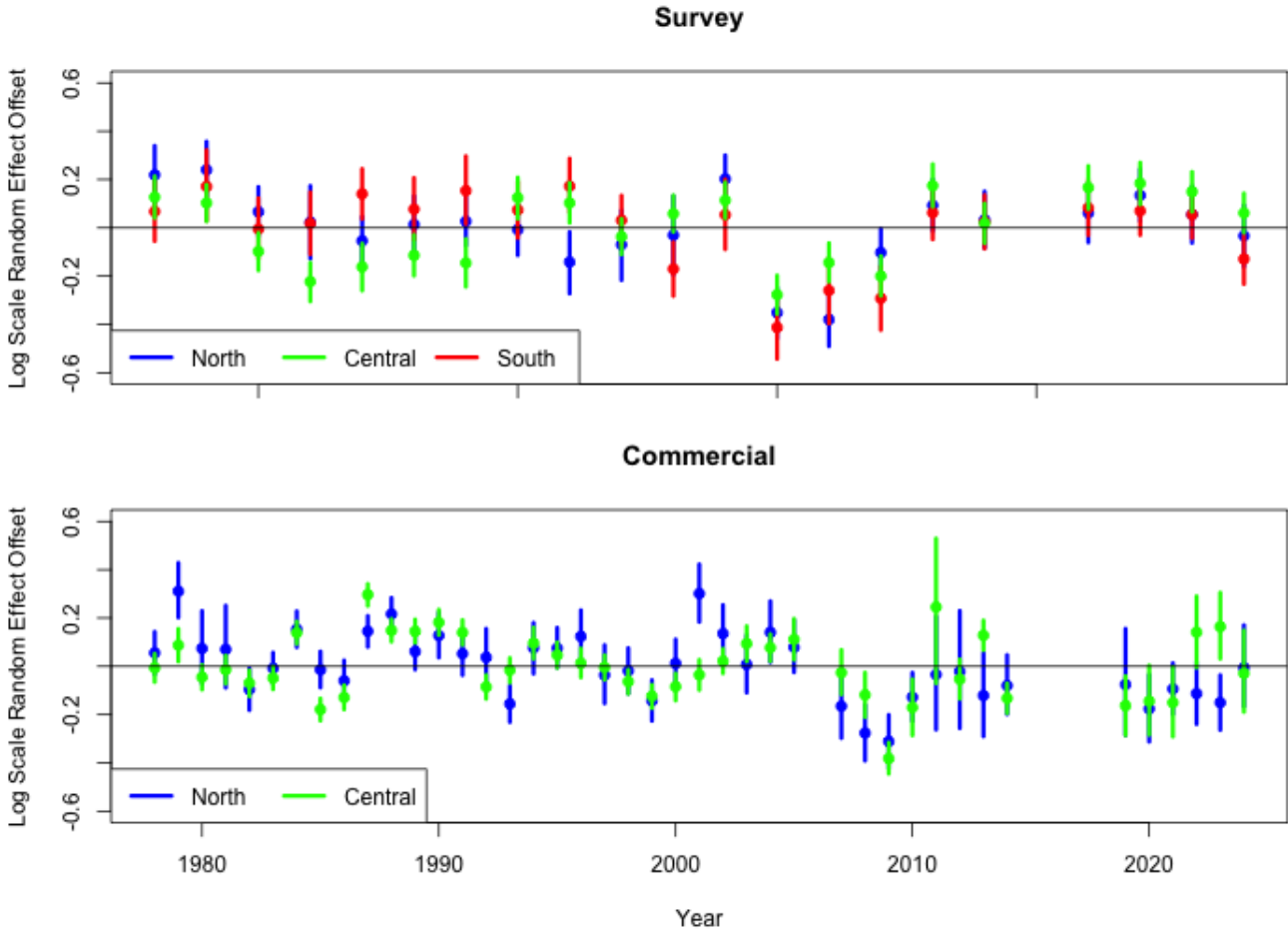


Figure 6: Separate spatio-temporal indices as derived from the survey (*top*) and commercial (*bottom*) data.

Note that while there is nothing in this model to demand similar autocorrelated indexes between regions, the regional indices appear very similar and have very similar autocorrelated structure as the previous time-only indices. The additional accounting of region reveals some subtle patterns in time and space, although this comes at the cost

of increasing index variance relative to the time-only model. While the addition of space in the model appears to improve model selection criterion (improved prediction despite the added variance), the longer run times of these models (exceeding a week) and increased index variance made this model a less practical model for the specific purposed of producing an index of time varying growth.

The subtly of spatial difference is further illustrated by the following simplified model,  $E[\ell_{rsi}] = VB(a_{rsi}; \kappa_{rs}, L_0, L_{20_{rs}})$  (i.e. no time). Figure (7) shows fits of this model with only modest differences in VB growth by region marginally. Within a sex, there may be apparent small differences in space, but any seeming spatial patterns within a sex are not persistent between sexes. This suggests that any observed spatial differences that may be observed are not so different to be predictively indistinguishable from noise.

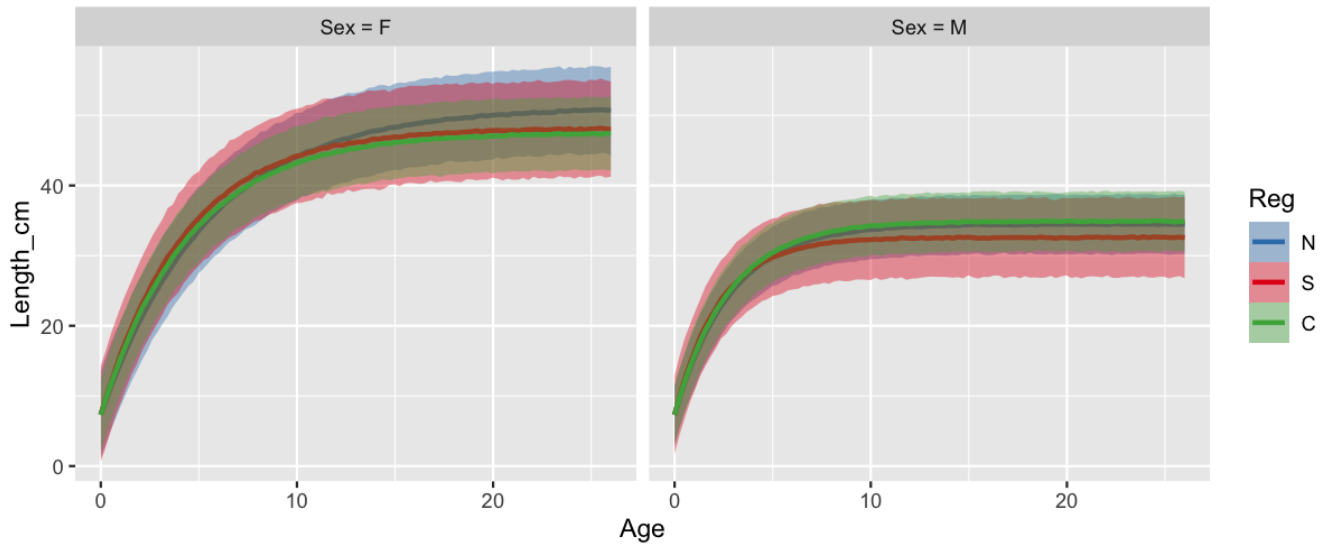


Figure 7: Posterior predictive 95% intervals of the VB function from the simplified spatial model.

## References

- [1] Paul-Christian Bürkner. brms: An R Package for Bayesian Multilevel Models Using Stan. *Journal of Statistical Software*, 80:1–28, August 2017.
- [2] A. John. *Probability and Random Processes for Electrical and Computer Engineers*. Cambridge university press, 2006.
- [3] Richard D. Methot, Chantel R Wetzel, Ian G. Taylor, Kathryn Doering, Kelli F. Johnson, and Elizabeth Perl. Stock Synthesis User Manual, 2025.
- [4] Jon Schnute. A Versatile Growth Model with Statistically Stable Parameters. *Canadian Journal of Fisheries and Aquatic Sciences*, 38(9):1128–1140, September 1981.
- [5] Chantel Wetzel, Kelli Johnson, and Allan Hicks. Northwest Fisheries Science Center Survey.

## **Appendix B. Stock Assessment Team (STAT) Responses to Stock Assessment Review (STAR) Panel Requests**

This section replicates content from the Chilipepper Rockfish STAR Panel Report (Panel requests and responses from the stock assessment team) for the reader's convenience. The full STAR Panel Report is available [online](#).

## **Stock Assessment Review (STAR) Panel for Chilipepper Rockfish**

Southwest Fisheries Science Center Auditorium, NOAA  
110 McAllister Way | Santa Cruz CA 95060

June 23-27, 2025

### **STAR Panel Members**

Cheryl Barnes, Oregon State University (Chair)  
Allan Hicks, International Pacific Halibut Commission  
Kotaro Ono, Center for Independent Experts  
Geoff Tingley, Center for Independent Experts

### **Stock Assessment Team (STAT) Members**

EJ Dick, Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA  
John Field, Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA  
Nicholas Grunloh, Fisheries Collaborative Program, University of California, Santa Cruz  
Tanya Rogers, Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA

### **STAR Panel Advisors**

Thompson Banez, California Department of Fish and Wildlife, Groundfish Management Team (GMT)  
Tim Klassen, Reel Steel Sportfishing, Groundfish Advisory Subpanel (GAP)  
Marlene A. Bellman, Pacific Fishery Management Council (PFMC)

### **1 - Request**

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

### **1 - Rationale**

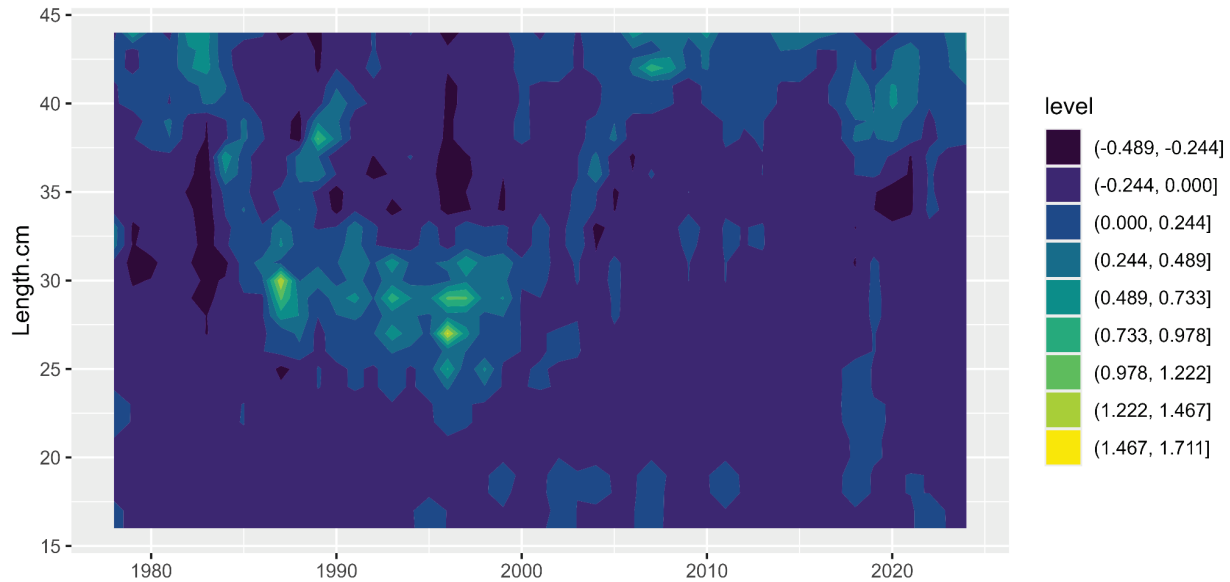
Given the poor fit to mean ages (~ 10 yr fish) and high selectivity of 25 to 30 cm fish from the mid-1980s to 2000s, changes in sex-specific selectivity may be having an effect. If this run improves the fits to mean age and mean length, an alternative selectivity parameterization or time block structure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

### **1 - STAT Response**

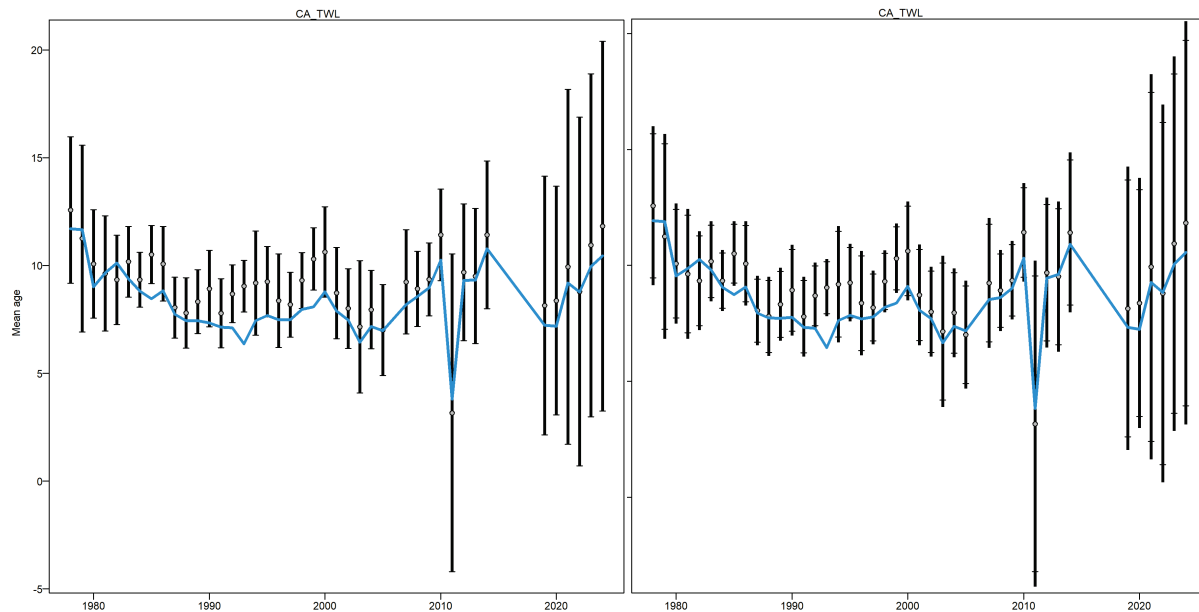
The pre-STAR base model was modified to use the “2D-AR” length-based selectivity function in Stock Synthesis for the California trawl fleet (1978-2024). The standard deviation of the selectivity deviations was fixed at 1. The model was not re-tuned to compare likelihood components. The estimated parameters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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

residual plots make visual comparison difficult. The STAR plotted the  $\log_{10}$  absolute value of the Pearson residuals from each model against each other, grouped by sex (Fig. 1G) and length bin (Fig. 1H). These suggest that improved model fit using the 2D selectivity is driven by better fits to large males.

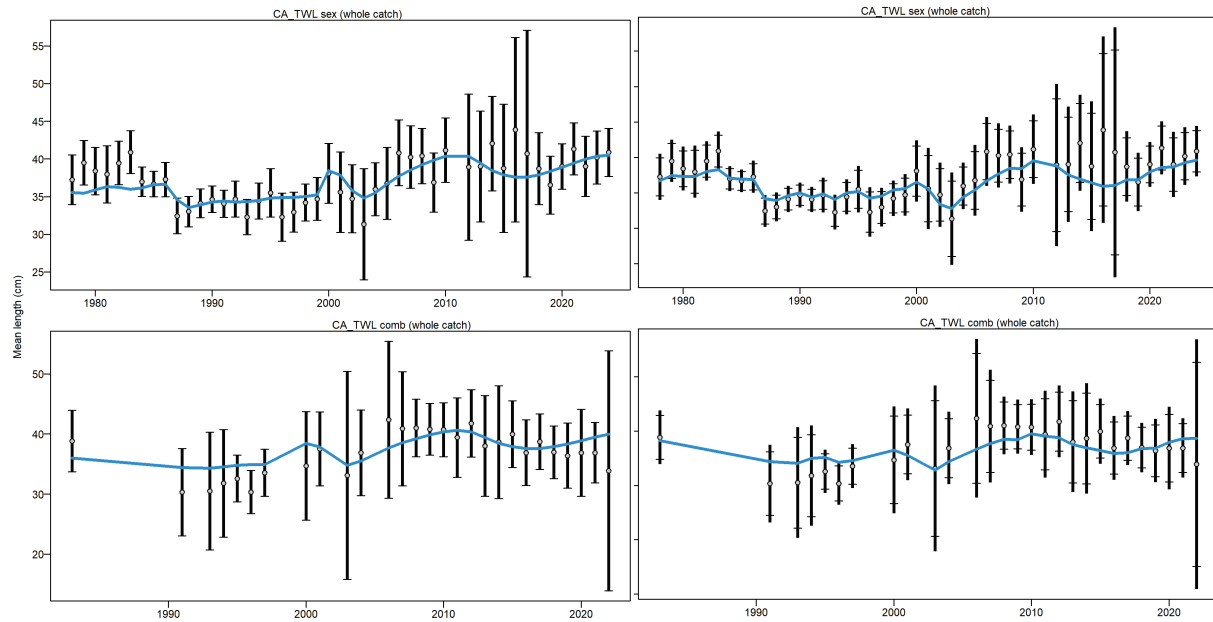


**Figure 1A.** Contour plot of deviations when estimating a logistic selectivity for the California trawl fleet.



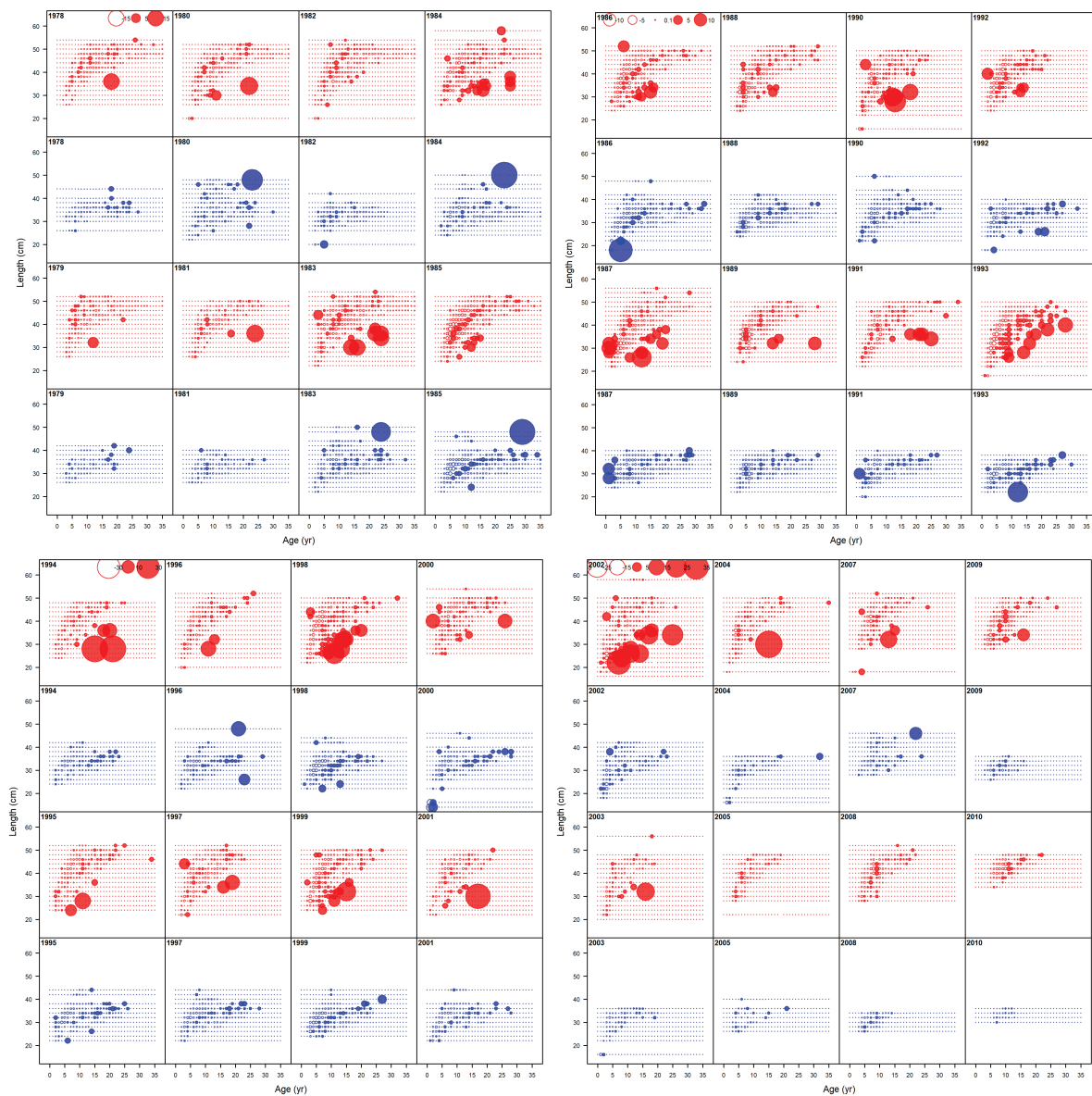
**Figure 1B.** Observed mean age (points) with 95% confidence intervals based on tuned sample sizes and model predictions of mean age (blue line) for the California trawl fleet. Results from the pre-STAR base model tuned using Francis weights (left) and the model using 2D-AR selectivity for the trawl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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

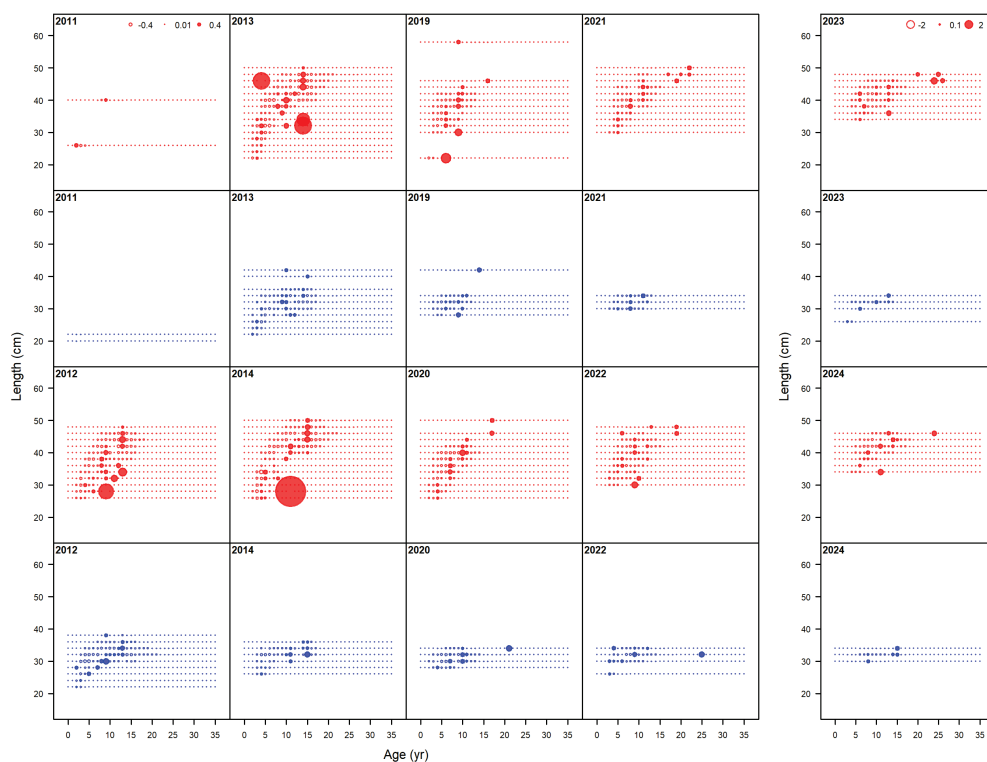
## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

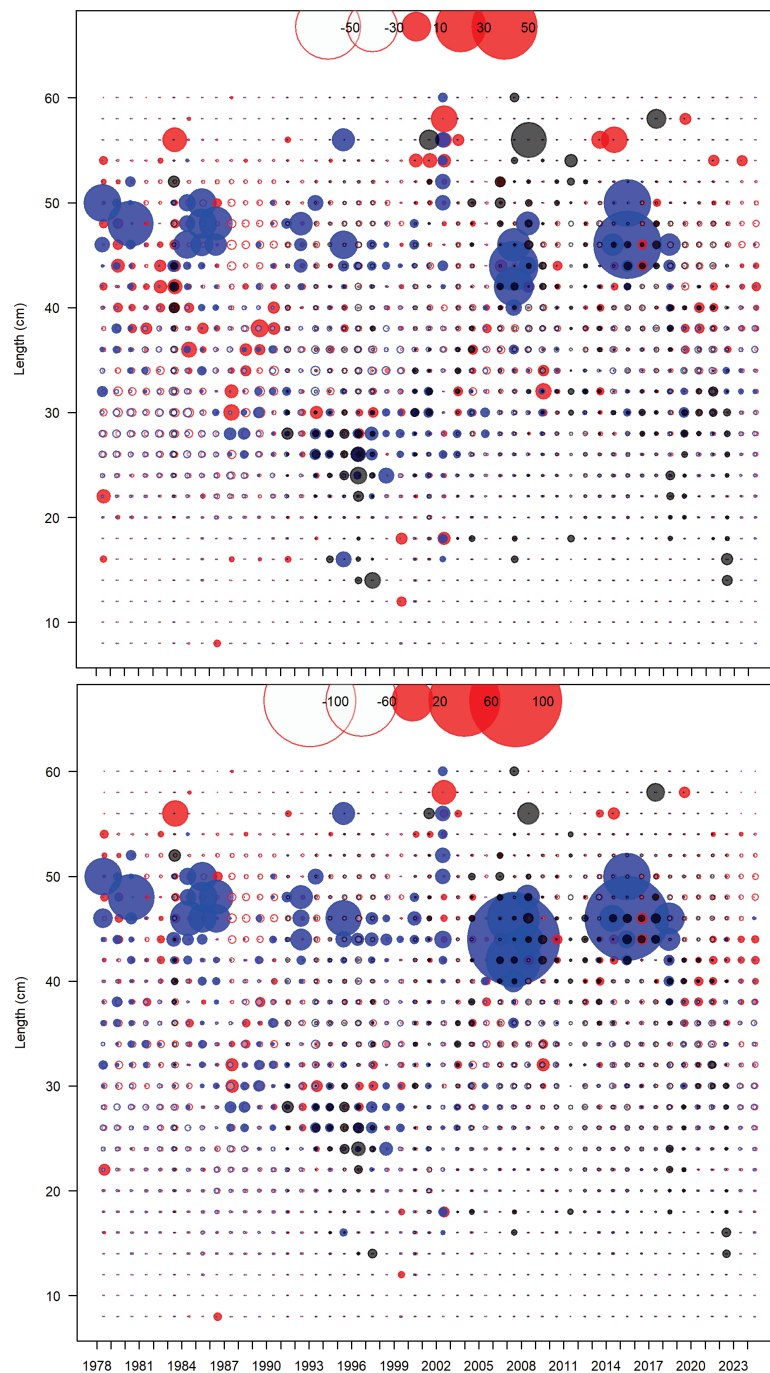


## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



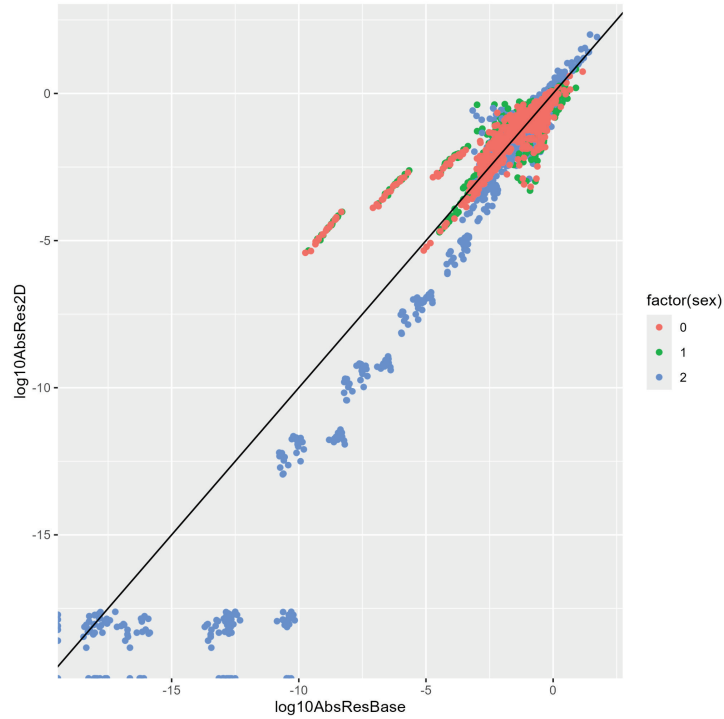
**Figure 1E.** Pearson residuals for conditional age-at-length data from the California trawl fleet (2011-2024). Length-based selectivity was modeled using the 2D-AR option in Stock Synthesis.

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

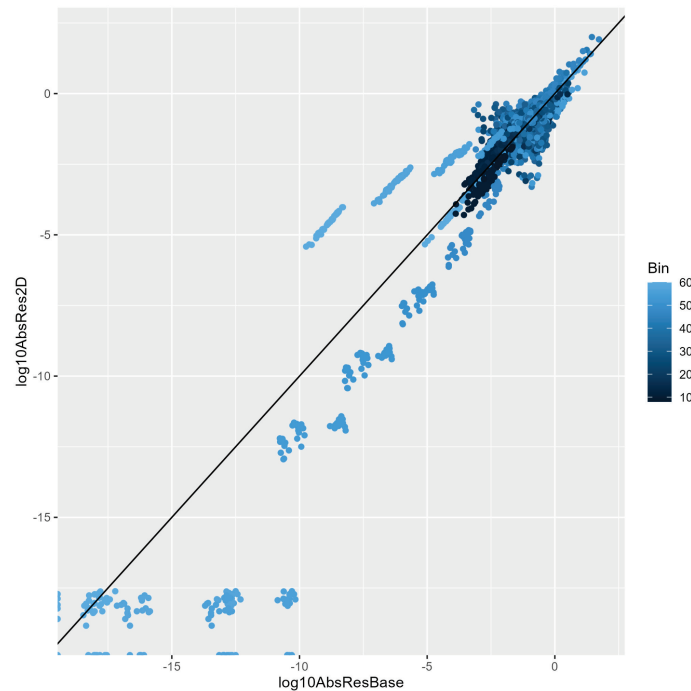


**Figure 1F.** Pearson residuals for length composition data from the California trawl fleet (1978-2024). Length-based selectivity was modeled using time-blocks from the pre-STAR base model (top) and the 2D-AR option in Stock Synthesis (bottom).

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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



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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

### 1 - Panel Conclusion

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

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

### 2 - Request

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

### 2 - Rationale

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

### 2 - STAT Response

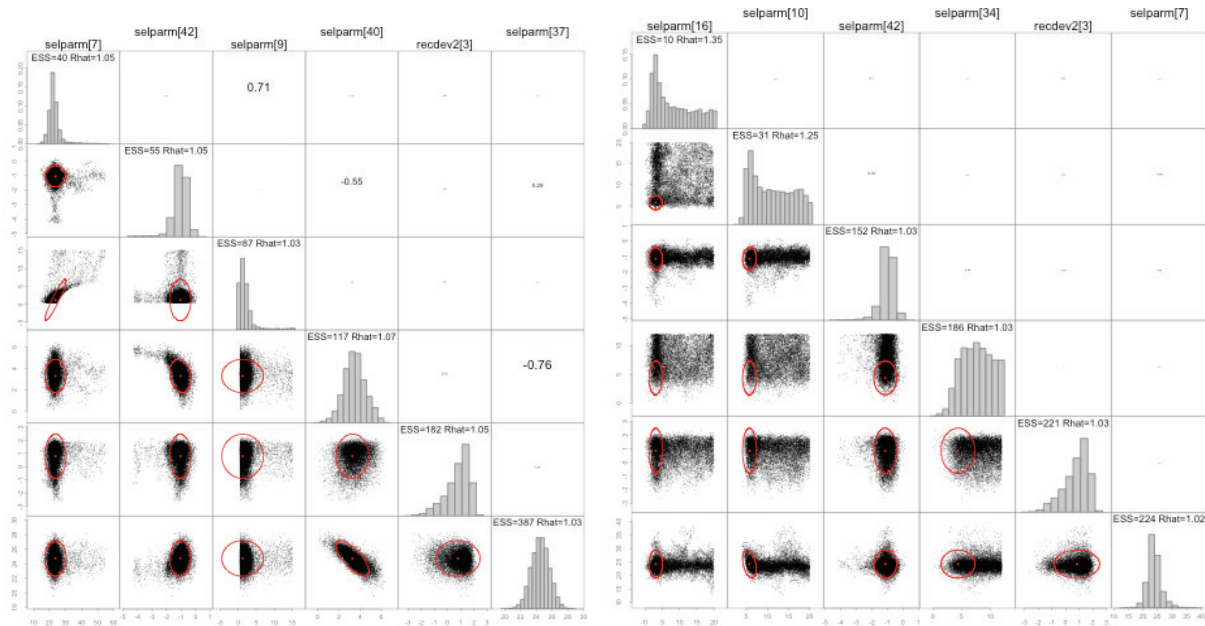
MCMC diagnostics of the pre-STAR base model showed that the descending scale parameter of the double-normal (DN) dome-shaped selectivities in the NoCA\_HKL, SoCA\_HK, CA\_TWL, CA\_NET, and NoCA\_OR\_WA\_Rec fleets appeared to have improper posteriors (Fig. 2A). Each of these fleets were given asymptotic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

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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

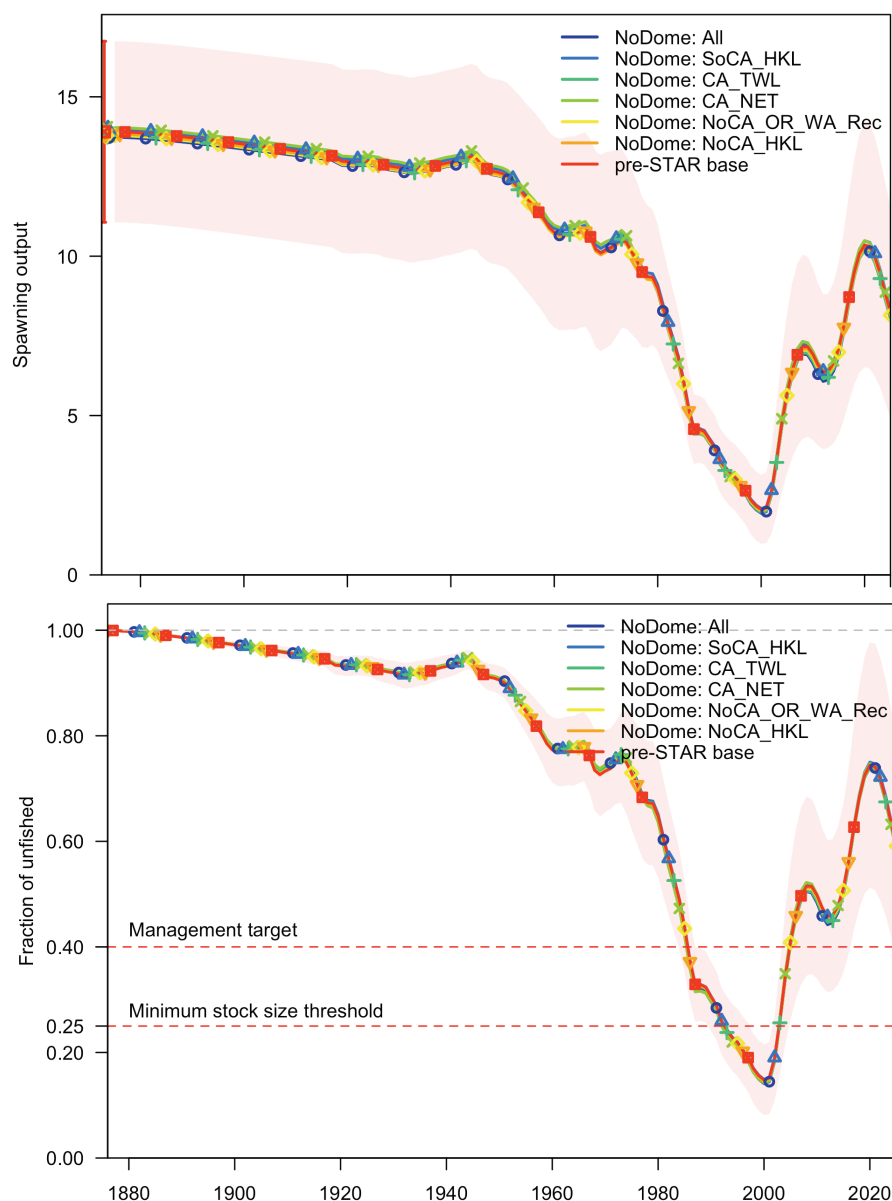
**Table 2.** Negative log-likelihood values for each of the fit models. Likelihood components are in the rows.

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



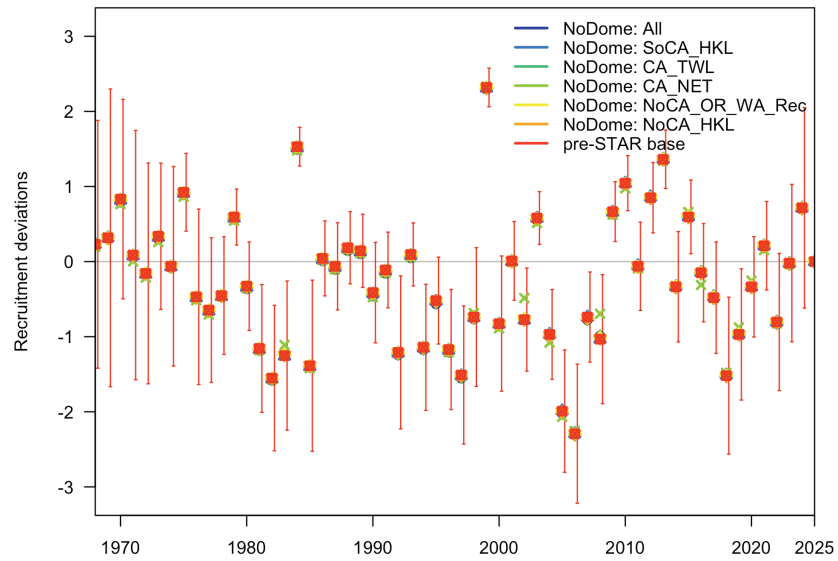
**Figure 2A.** Pairwise scatterplots and histograms of the slowest converging parameters from the MCMC diagnostics for the pre-STAR base model (left) and the all asymptotic selectivity model (right). Although convergence is not perfect, asymptotic selectivities largely remove the improper posteriors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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

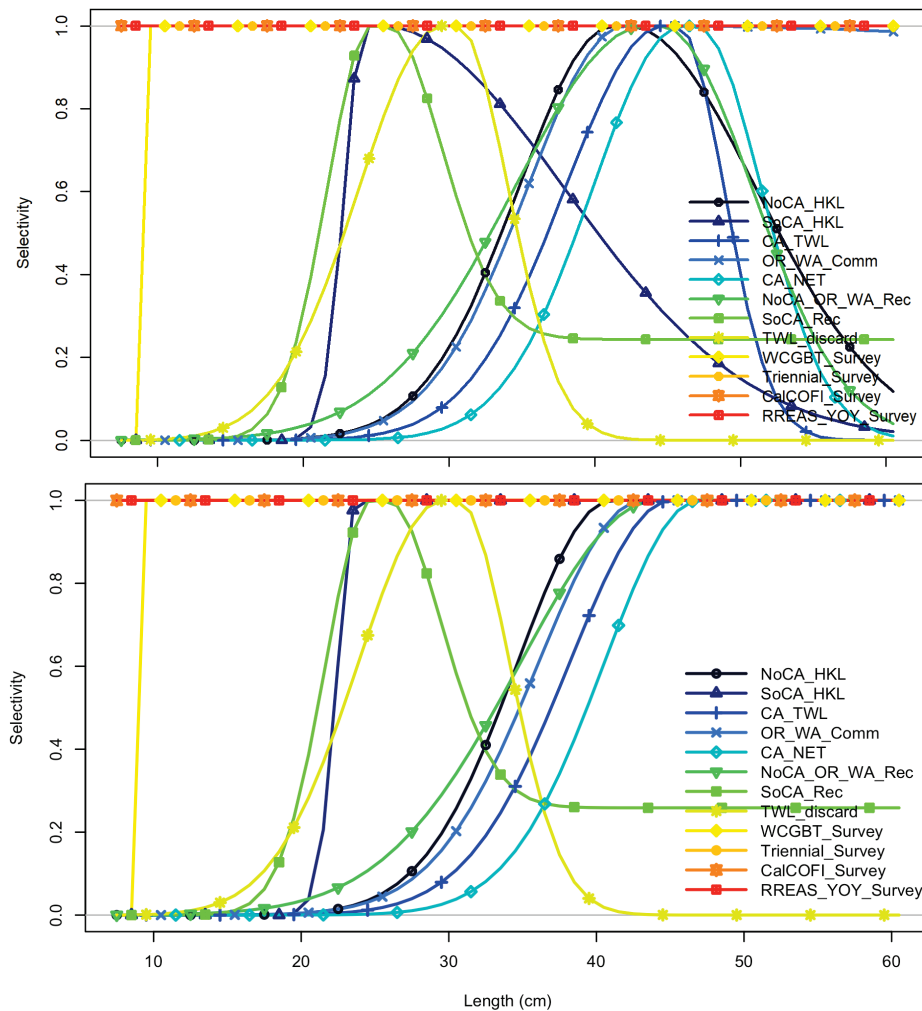


**Figure 2B.** Spawning output and fraction unfished when replacing dome-shaped selectivities with asymptotic selectivities. Estimates from the pre-STAR base model are also shown.

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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



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

## 2 - Panel Conclusion

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

### 3 - Request

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

### 3 - Rationale

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

### 3 - STAT Response

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

### 3 - Panel Conclusion

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

### 4 - Request

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

### 4 - Rationale

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

### 4 - STAT Response

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

Compared to the pre-STAR base model, models with a sum-to-zero constraint on recruitment deviations have a lower estimate of initial spawning output and similar end-year estimates of spawning output. Therefore, relative spawning output (i.e., fraction unfished) is higher (less depleted relative to unfished levels) in models with the sum-to-zero constraint (Fig. 4A).

Recruitment deviations without a sum-to-zero constraint have a negative offset relative to the

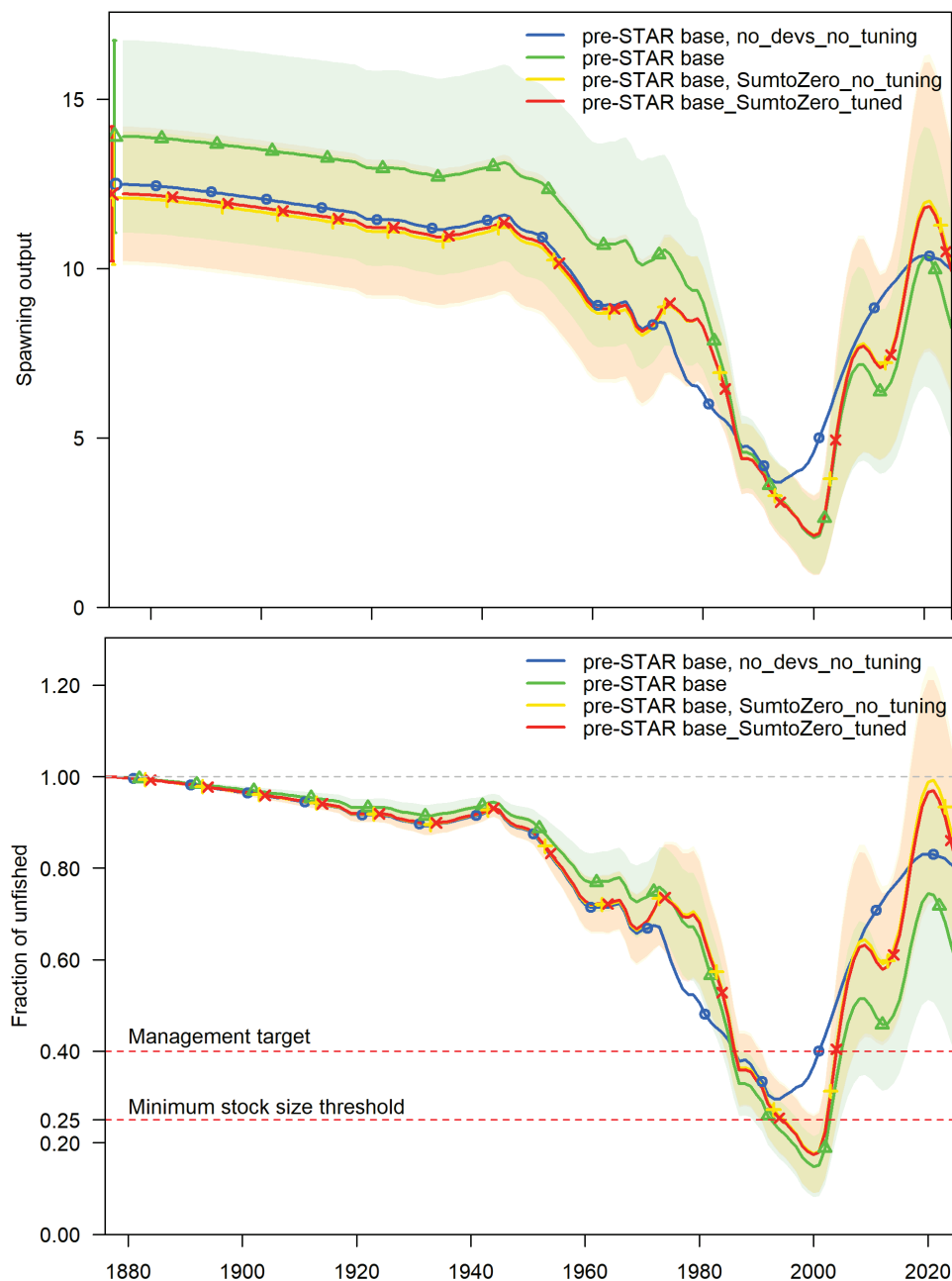


## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

constrained deviations, resulting in a higher estimate of unfished equilibrium recruitment ( $R_0$ ; Fig. 4B). Estimates of long-term sustainable yield from the pre-STAR base model are approximately 2500 mt, whereas estimates from models with the sum-to-zero constraint are approximately 2000 mt (similar to the previous assessment, which also used a sum-to-zero constraint). Likelihood components, estimated parameter values, and derived quantities from the four models are provided in Table 4. Estimates of natural mortality are lower for females, with a larger offset for males, in the models with a sum-to-zero constraint. All models assume a steepness ( $h$ ) of 0.72.

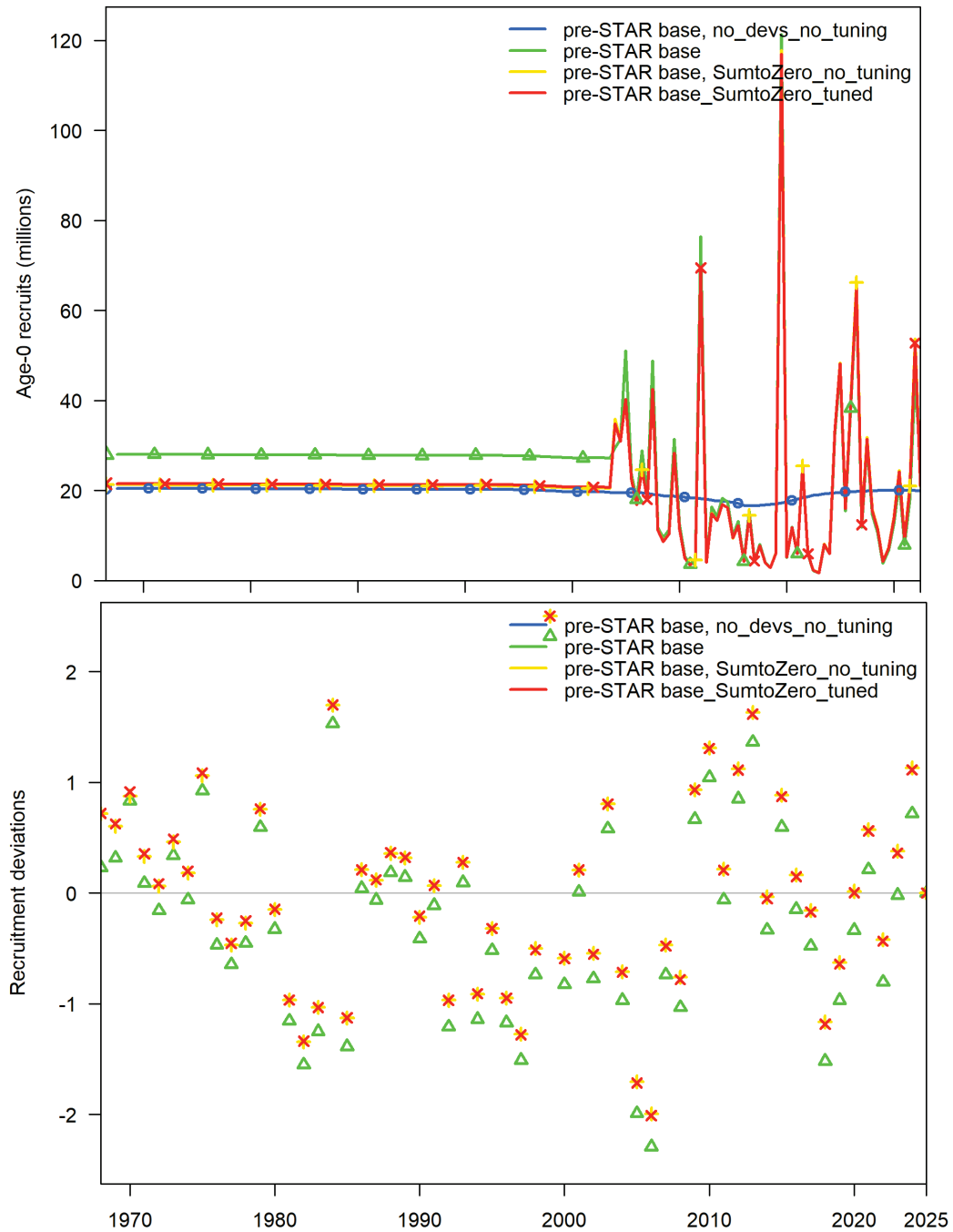
Models with sum-to-zero constraints and the pre-STAR base model include a bias adjustment following the methods of Methot and Taylor (2011). Methot and Taylor (2011) estimated deviations using a sum-to-zero constraint, so it is unclear to the STAR whether the bias adjustment is appropriate for the pre-STAR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

# Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

### Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



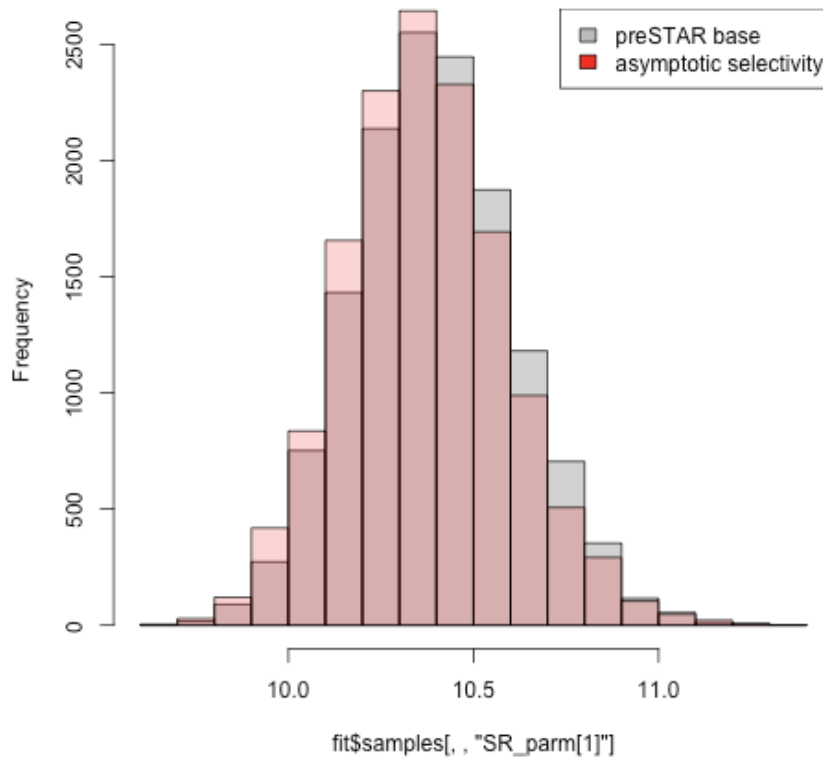
**Figure 4B.** Age-0 recruits (top) and recruitment deviations from the spawner-recruit curve (bottom) for models with and without a sum-to-zero constraint imposed on recruitment deviations.

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

### 4 - Panel Conclusion

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

### 5 - Request

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

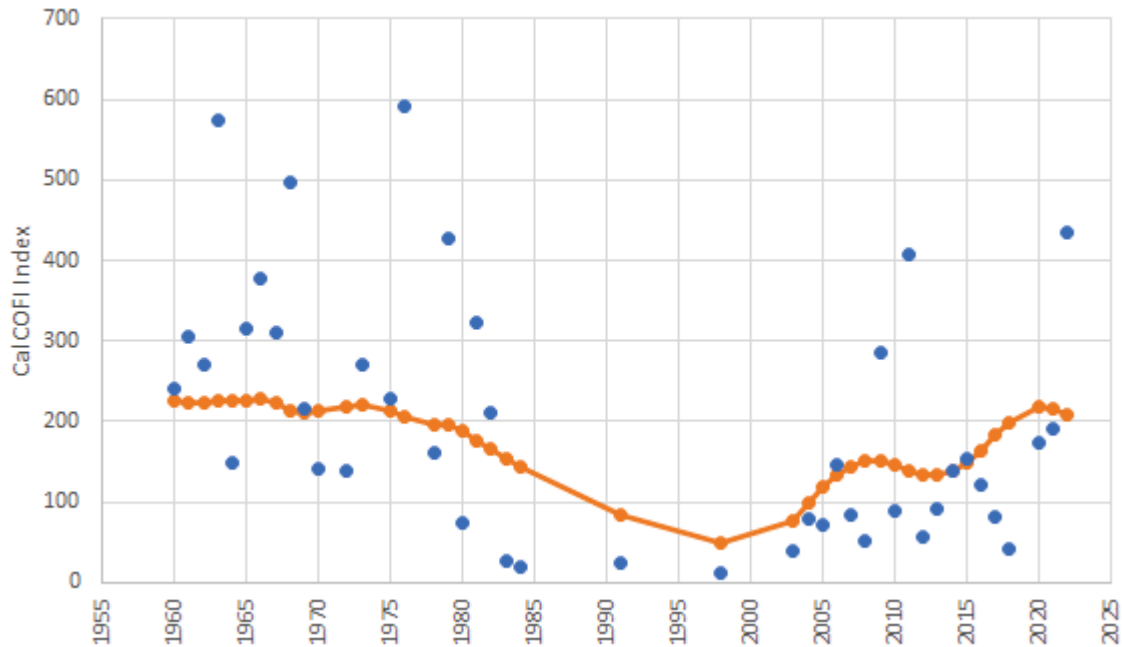
### 5 - Rationale

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

### 5 - STAT Response

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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

### 5 - Panel Conclusion

This plot clarifies the model fit to this index.

### 6 - Request

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

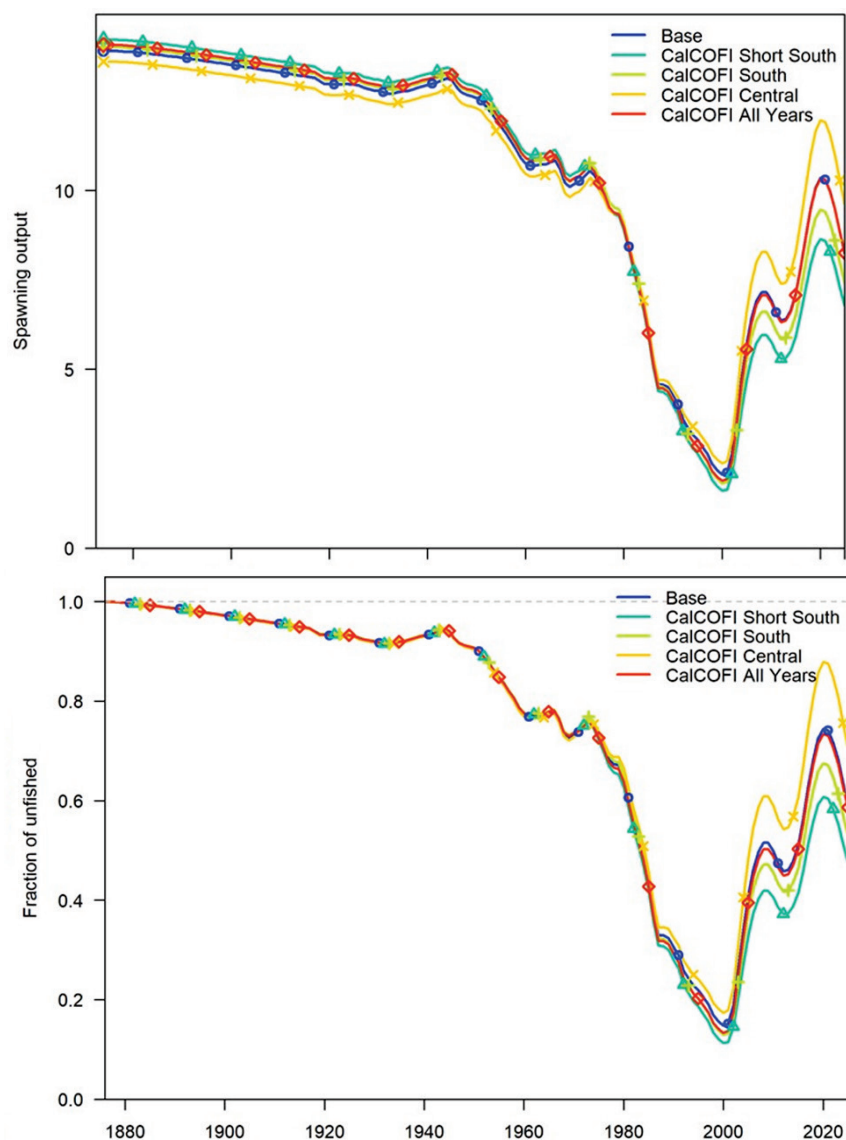
### 6 - Rationale

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

### 6 - STAT Response

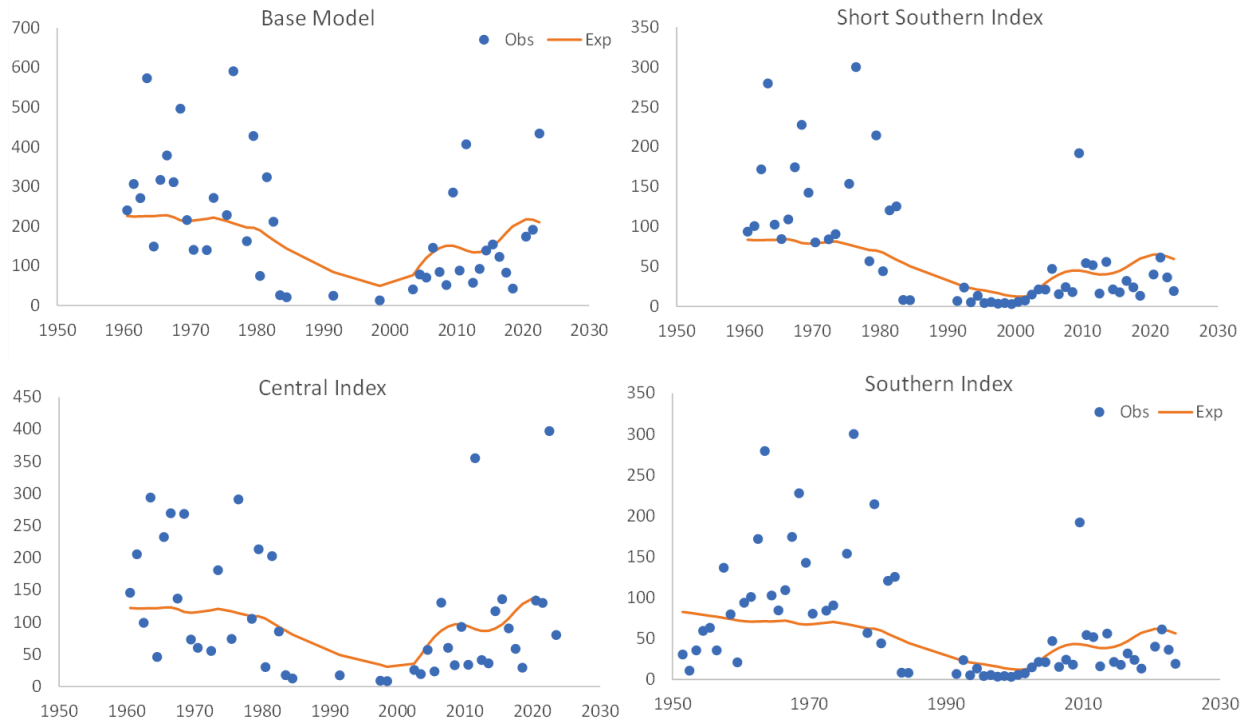
The STAT inadvertently used the shorter southern CalCOFI index instead of the central CalCOFI index for sensitivity runs. Corrected and additional runs are now a bit more intuitive (Fig. 6A). With the correct data, the central CalCOFI model is less depleted in the terminal year than the pre-STAR base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

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

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

### 6 - Panel Conclusion

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

### 7 - Request

Run an additional sensitivity that estimates additive variance for the WCG BTS index.

### 7 - Rationale

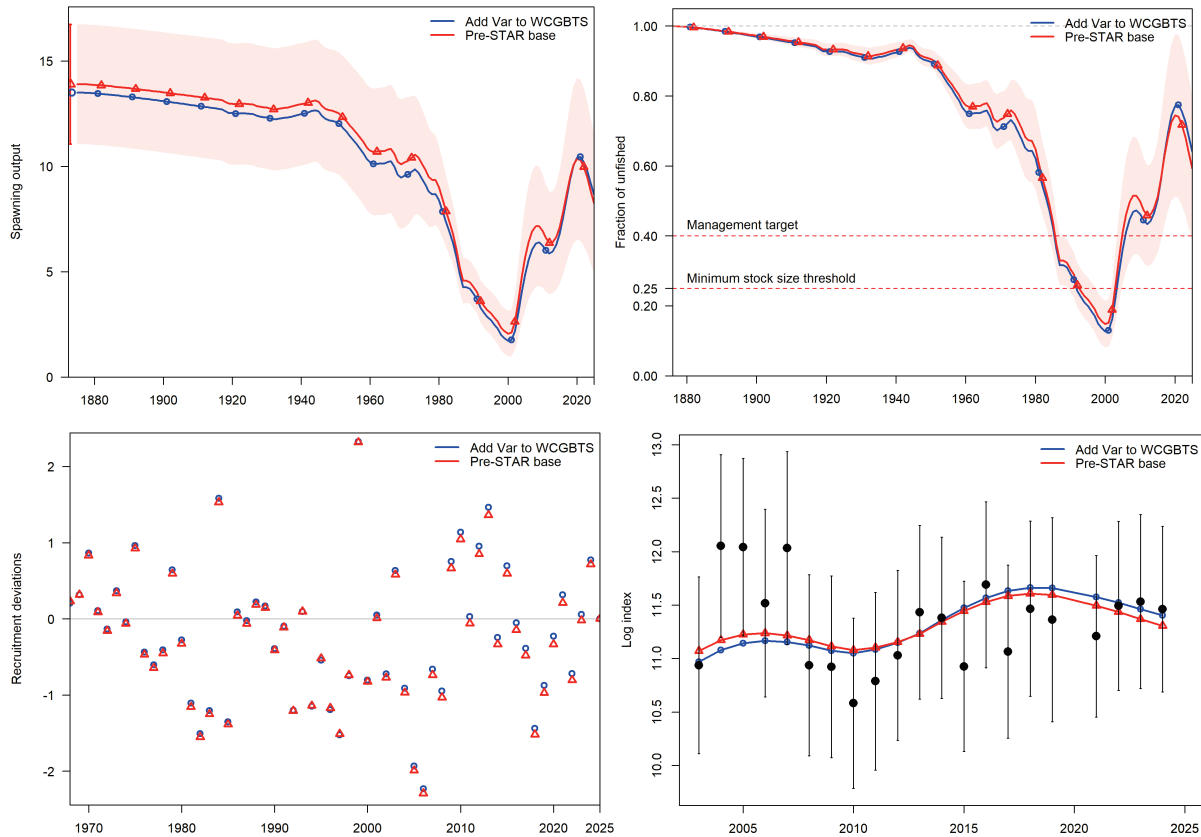
Although there is some justification for estimating additive variance for the CalCOFI index, justification for not estimating additive variance for the WCG BTS is missing. Additive variance may be warranted given poor fit during the early portion of the time series and high  $q$ .

### 7 - STAT Response

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



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

### 7 - Panel Conclusion

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

### 8 - Request

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

### 8 - Rationale

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

### 8 - STAT Response

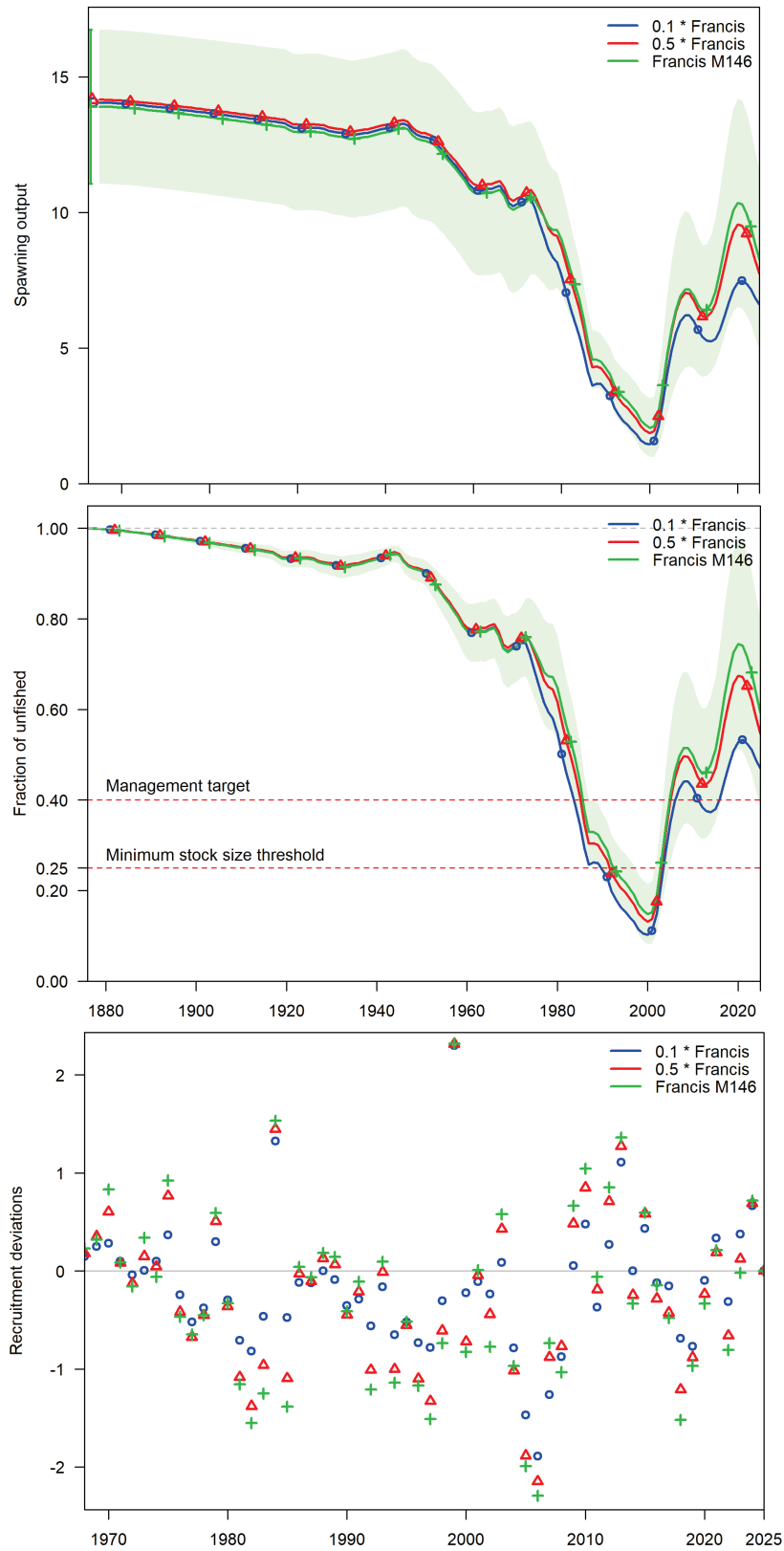
Two models were run with Francis weights from the pre-STAR base model divided by 2 and 10 (Table 8A). Downweighting the composition data resulted in a more depleted stock and less variable recruitment deviations (Fig. 8).

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

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

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

### 8 - Panel Conclusion

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

### 9 - Request

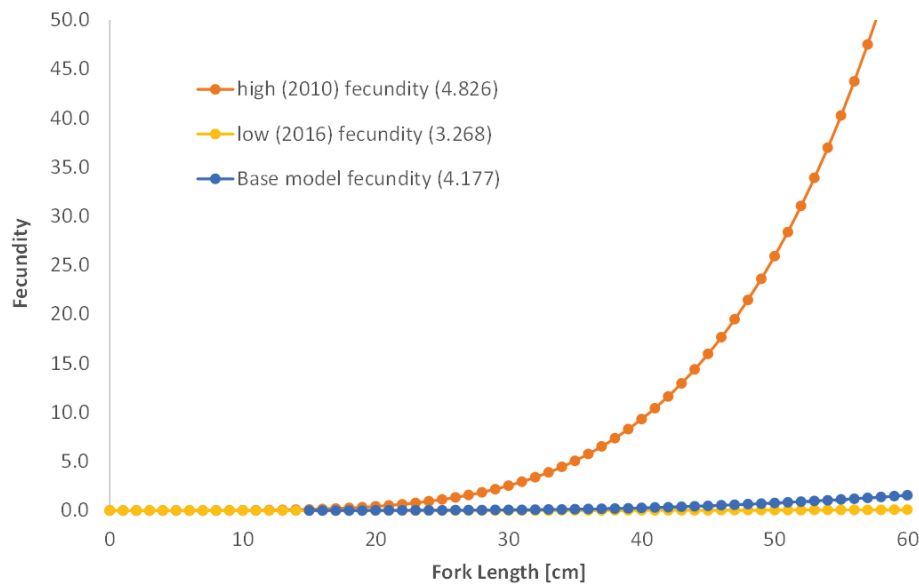
Present length-fecundity relationships that depict the variability given different environment regimes alongside the assumed length-fecundity relationship used in the pre-STAR base model. Conduct sensitivities using these alternative length-fecundity relationships with  $M$  fixed at the value from the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

### 9 - Rationale

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

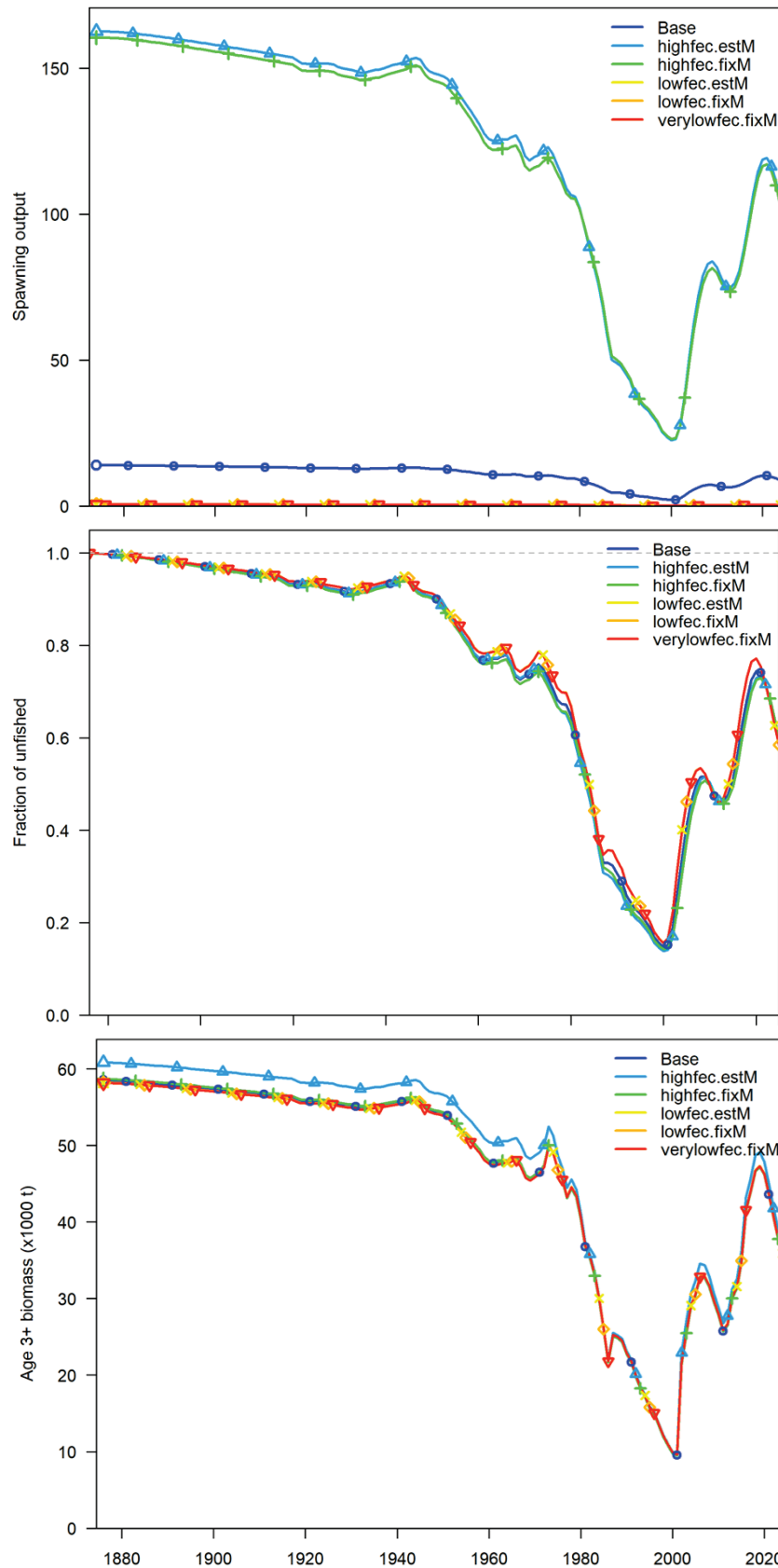
### 9 - STAT Response

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



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

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

### 9 - Panel Conclusion

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

### 10 - Request

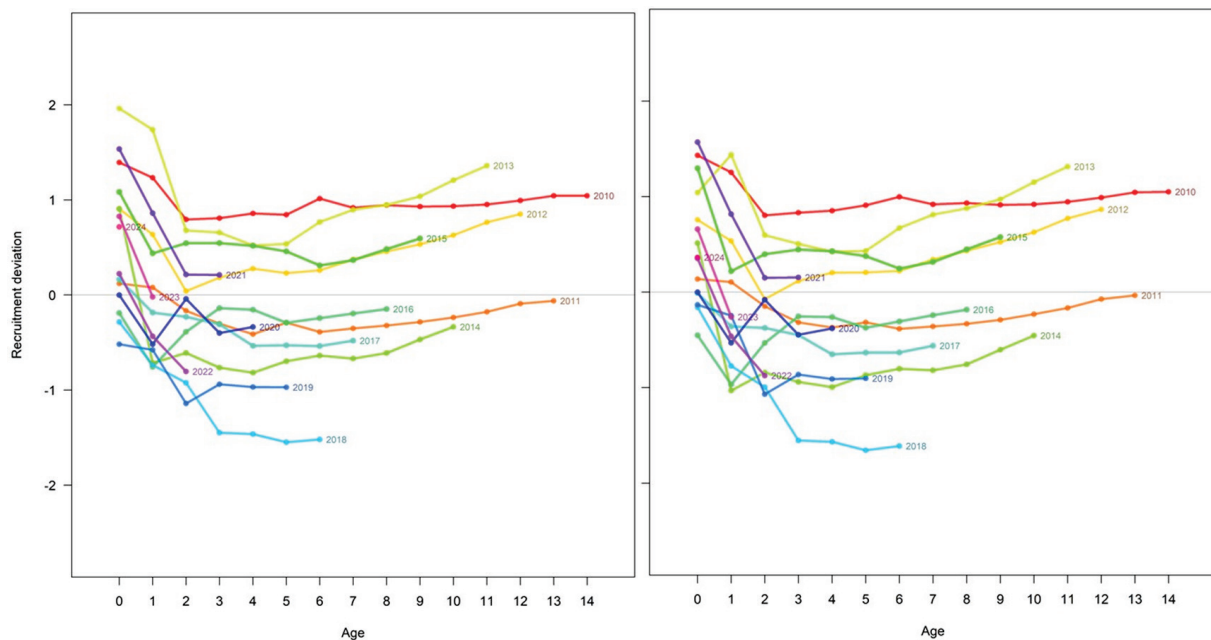
Create a squid plot using a 15-year retrospective analysis. This should include recruitment deviation on the y-axis and age on the x-axis, showing the age at which estimated recruitment begins to be informed by data.

### 10 - Rationale

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

### 10 - STAT Response

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



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

### 10 - Panel Conclusion

These plots show the importance of the WCGBTS index in predicting year class strength and that it provides information when the cohort was age 0 yr. Although the RREAS was appropriately weighted and included additive variance, the outcome was that this index had very little weight and virtually no influence on model results. The RREAS index became appropriately more influential when either removing the additive variance or when downweighting the

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

WCGBTS index. There was concern that the strength of a cohort at age 0 yr was estimated above average and tended to be reduced as the cohort aged in the pre-STAR base model. The Panel realizes that changes to the pre-STAR base model from other requests could modify these conclusions, so there may be a need to revise these figures as part of future requests.

### 11 - Request

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

### 11 - Rationale

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

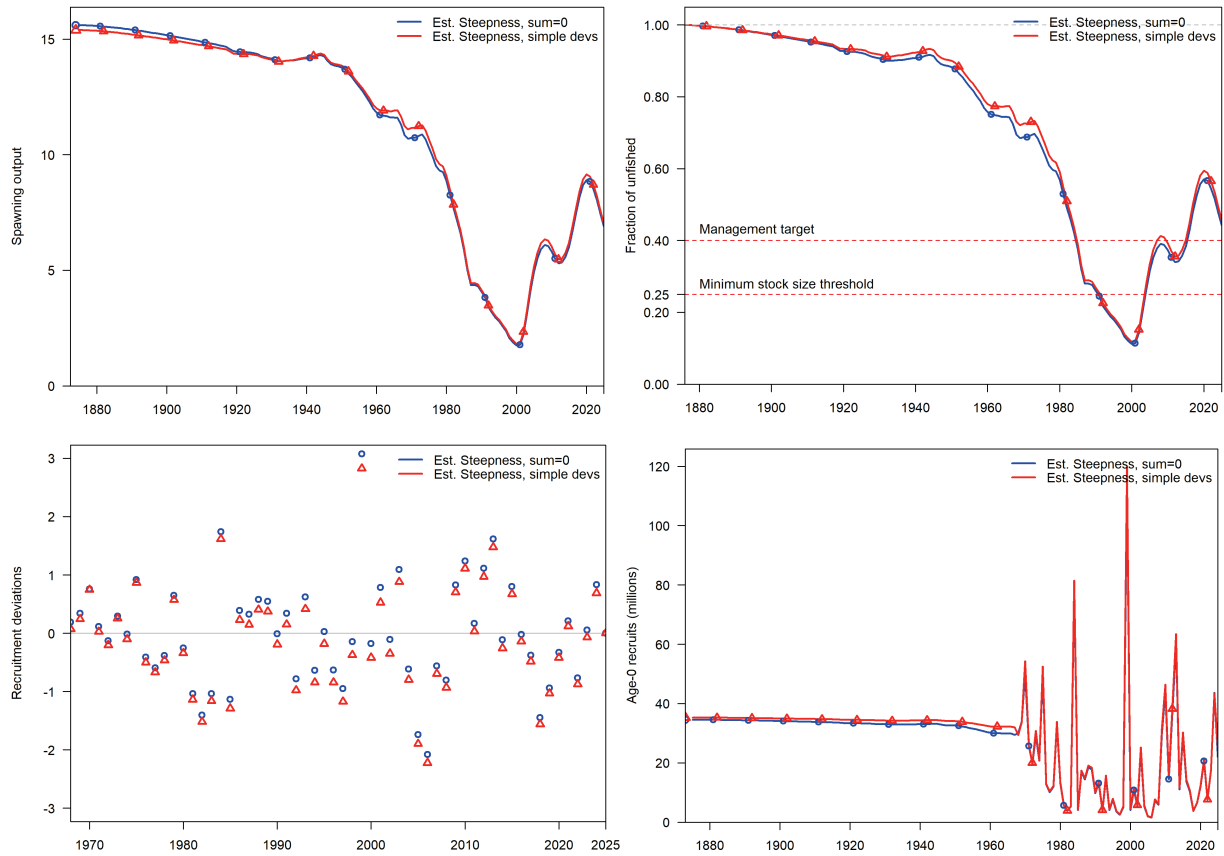
### 11 - STAT Response

The revised base model (i.e., pre-STAR base with asymptotic selectivity curves for fleets with poor MCMC diagnostics in the descending scale parameter; “M160”) was used to complete this request. Estimates of steepness were lower than the prior mean in both runs, resulting in a more depleted stock status. When steepness is estimated, the change in model scale and trend is less pronounced between models with and without the sum-to-zero constraint for recruitment deviations (Fig. 11A) compared to models with steepness fixed at the prior mean of 0.72 (Fig. 11B). When steepness is estimated, the mean recruitment deviation without a sum-to-zero constraint is -0.14. With the constraint, the mean is near zero ( $7 \times 10^{-8}$ ), as expected. By fixing steepness at a value that is slightly less consistent with the data (i.e.,  $h = 0.72$ ), the simple deviations are scaled down to best fit the data, decreasing productivity and increasing estimates of  $R_0$  and  $M$  (Table 11; Fig. 11B).

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

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

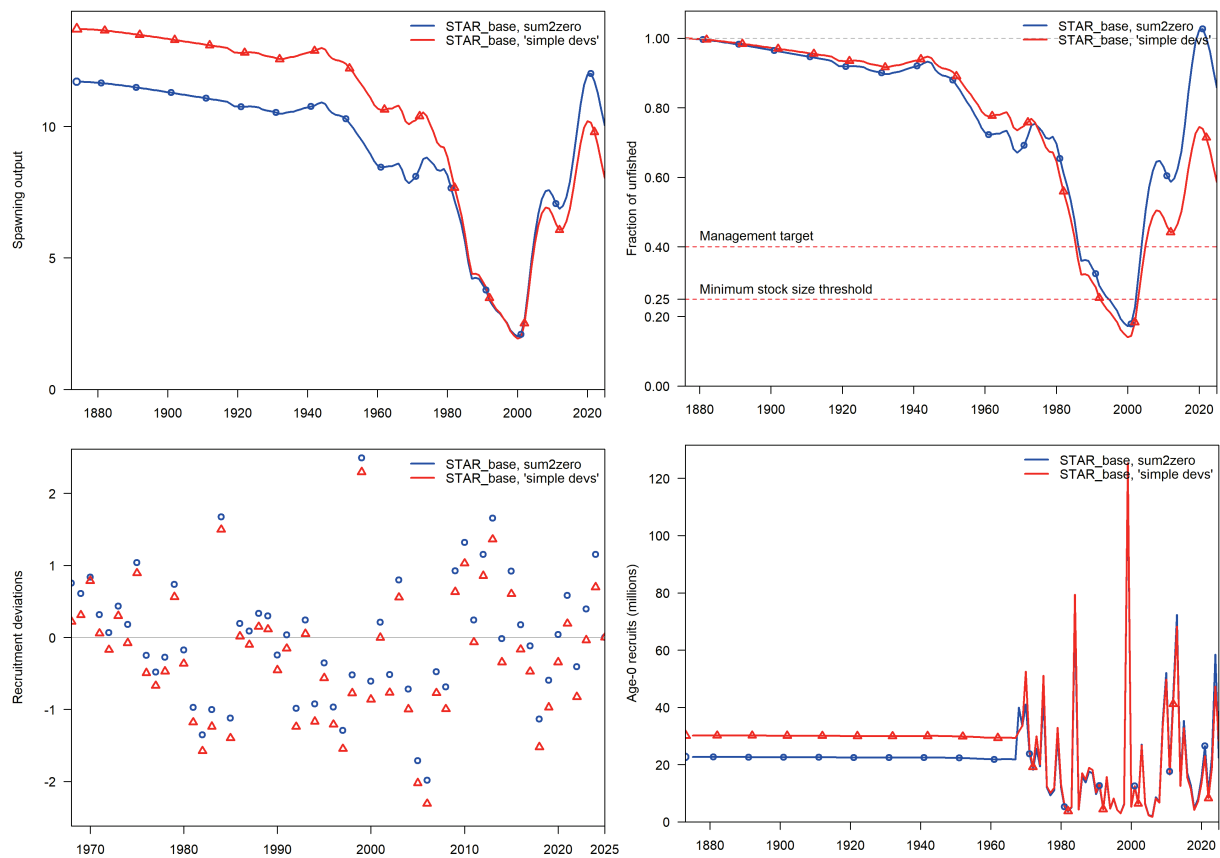
## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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



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

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

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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

### 11 - Panel Conclusion

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

### 12 - Request

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

### 12 - Rationale

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

### 12 - STAT Response

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

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

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

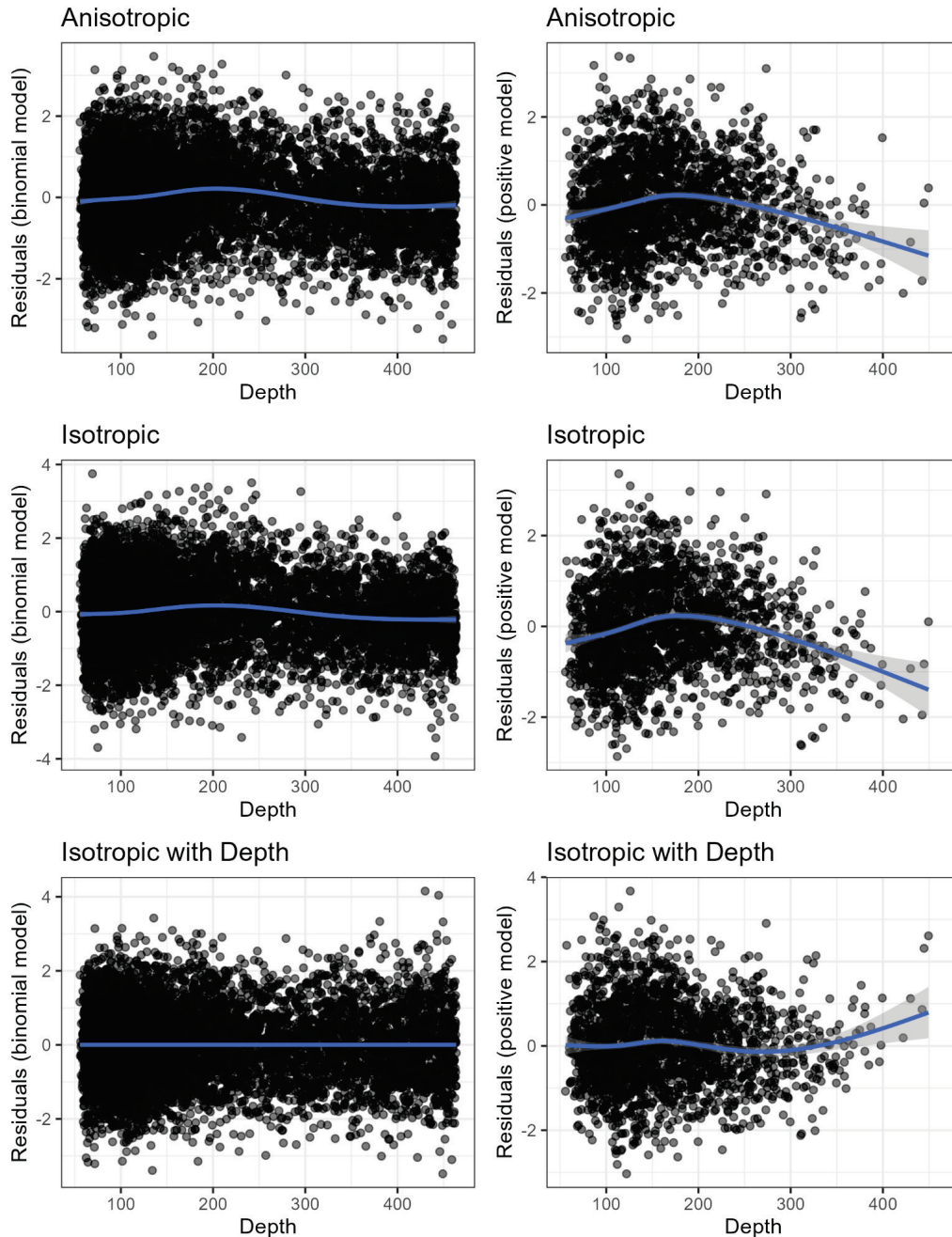
The relationship between model residuals and depth was explored for a) the original model without depth and assuming anisotropy, b) the original model without anisotropy, and c) the new model with depth and assuming isotropy (Fig. 12A). Models without depth showed a relationship between the residuals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

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

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

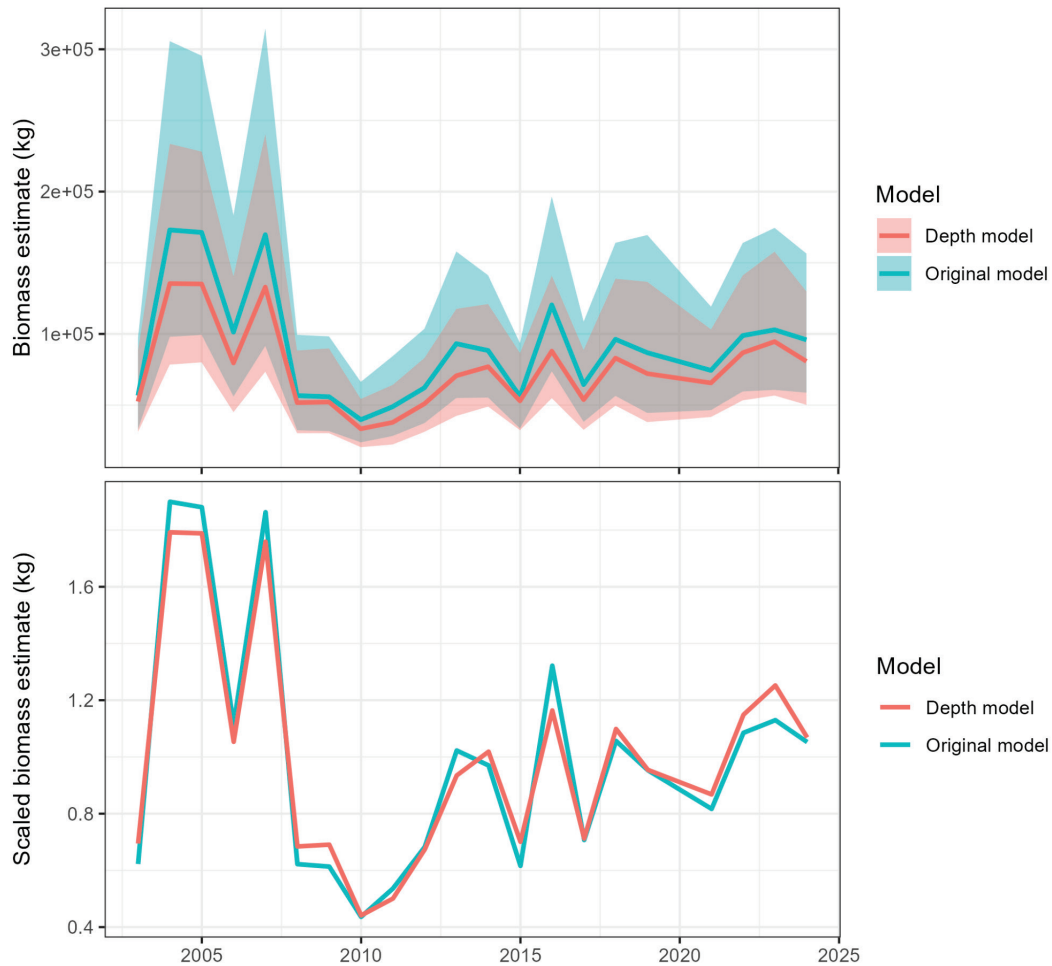
## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

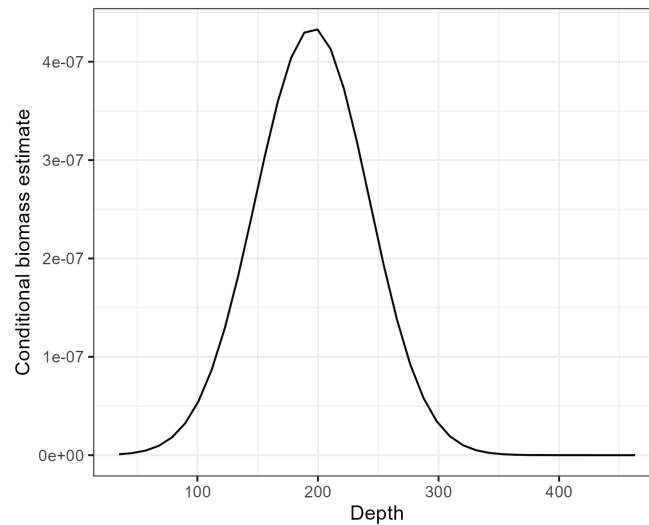


**Figure 12A.** Model residuals for the original WCG BTS index model that assumed anisotropy and did not include a depth effect (top), a revised WCG BTS index model that assumed isotropy (middle), and a revised WCG BTS index model that assumed isotropy and included a depth effect (bottom). Binomial (left)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

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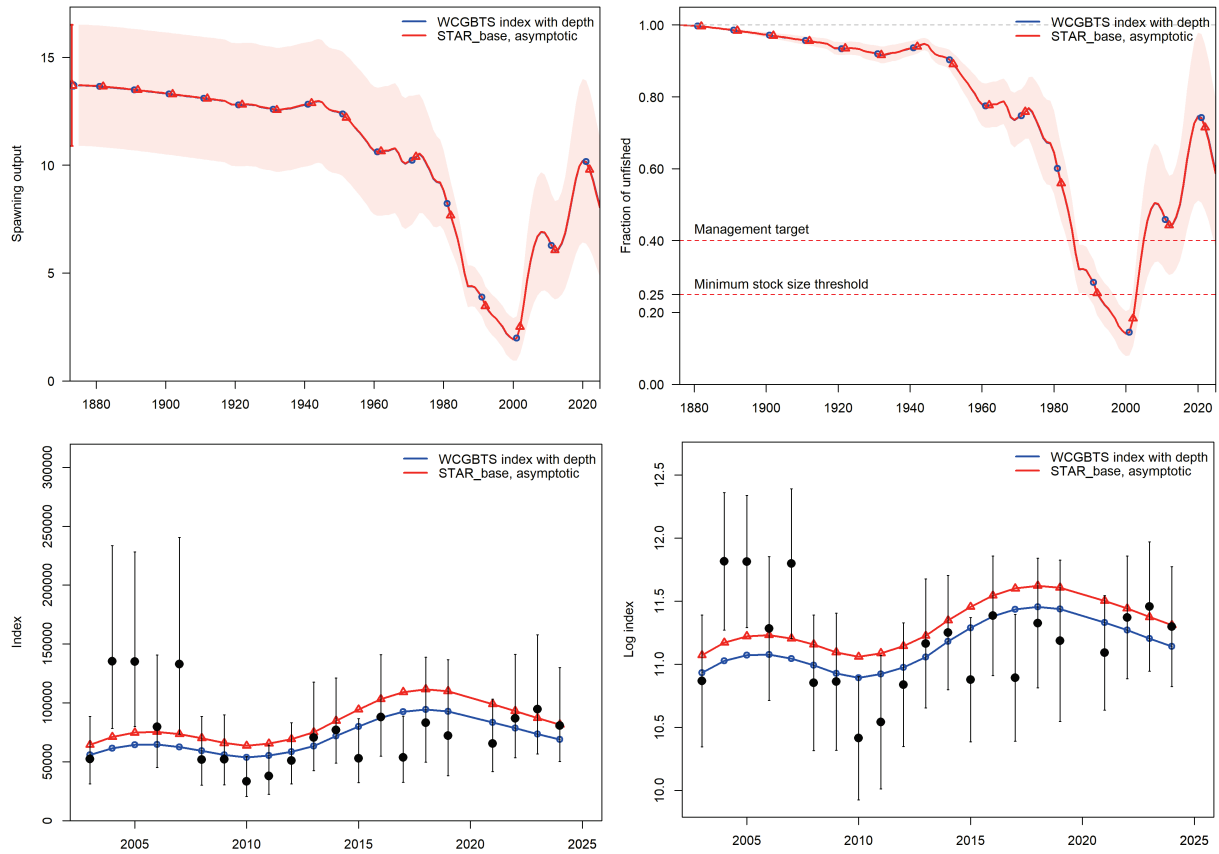


**Figure 12B.** The original WCG BTS index and a revised WCG BTS index that includes depth as a covariate and assumes isotropy (top). Biomass estimates were also scaled using their respective means (bottom).



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

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

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

| Label                                         | WCGBTS index<br>with depth | STAR_base,<br>asymptotic |
|-----------------------------------------------|----------------------------|--------------------------|
| N.Params                                      | 109                        | 109                      |
| TOTAL                                         | 2618.920                   | 2621.330                 |
| Survey                                        | 21.805                     | 24.307                   |
| Length_comp                                   | 572.090                    | 572.015                  |
| Age_comp                                      | 2000.530                   | 2000.480                 |
| Recruitment                                   | 24.400                     | 24.425                   |
| Parm_priors                                   | 0.093                      | 0.096                    |
| NatM_uniform_Fem_GP_1                         | 0.176                      | 0.177                    |
| L_at_Amax_Fem_GP_1                            | 47.861                     | 47.860                   |
| VonBert_K_Fem_GP_1                            | 0.197                      | 0.197                    |
| CV_young_Fem_GP_1                             | 0.105                      | 0.105                    |
| CV_old_Fem_GP_1                               | 0.039                      | 0.039                    |
| NatM_uniform_Mal_GP_1                         | 0.241                      | 0.241                    |
| L_at_Amax_Mal_GP_1                            | -0.329                     | -0.329                   |
| VonBert_K_Mal_GP_1                            | 0.528                      | 0.528                    |
| CV_young_Mal_GP_1                             | 0.235                      | 0.235                    |
| CV_old_Mal_GP_1                               | 0.100                      | 0.100                    |
| SR_LN(R0)                                     | 10.309                     | 10.314                   |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.310                      | 0.310                    |
| Q_extraSD_RREAS_YOY_Survey(12)                | 1.224                      | 1.230                    |
| Size_DbLN_peak_NoCA_HKL(1)                    | 41.088                     | 41.080                   |
| Size_DbLN_ascend_se_NoCA_HKL(1)               | 4.406                      | 4.405                    |
| Size_DbLN_peak_SoCA_HKL(2)                    | 23.803                     | 23.788                   |
| Size_DbLN_ascend_se_SoCA_HKL(2)               | 1.203                      | 1.195                    |
| Size_DbLN_peak_CA_TWL(3)                      | 45.106                     | 45.102                   |
| Size_DbLN_ascend_se_CA_TWL(3)                 | 4.564                      | 4.563                    |
| Size_DbLN_peak_OR_WA_Comm(4)                  | 43.154                     | 43.109                   |
| Size_DbLN_ascend_se_OR_WA_Comm(4)             | 4.602                      | 4.600                    |
| Size_DbLN_peak_CA_NET(5)                      | 46.981                     | 46.979                   |
| Size_DbLN_ascend_se_CA_NET(5)                 | 4.420                      | 4.420                    |
| Size_DbLN_peak_NoCA_OR_WA_Rec(6)              | 44.140                     | 44.110                   |
| Size_DbLN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.147                      | 5.145                    |
| Size_DbLN_peak_SoCA_Rec(7)                    | 24.734                     | 24.731                   |
| Size_DbLN_ascend_se_SoCA_Rec(7)               | 2.936                      | 2.936                    |
| Size_DbLN_descend_se_SoCA_Rec(7)              | 3.278                      | 3.278                    |
| Size_DbLN_end_logit_SoCA_Rec(7)               | -1.050                     | -1.049                   |
| Size_DbLN_peak_TWL_discard(8)                 | 29.586                     | 29.572                   |
| Size_DbLN_ascend_se_TWL_discard(8)            | 4.181                      | 4.181                    |
| Size_DbLN_descend_se_TWL_discard(8)           | 3.191                      | 3.194                    |
| Size_DbLN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.389                     | 51.396                   |
| Size_DbLN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.140                      | 4.141                    |
| Size_DbLN_peak_SoCA_HKL(2)_BLK2repl_1875      | 48.777                     | 48.776                   |
| Size_DbLN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.814                      | 4.814                    |
| Size_DbLN_peak_CA_TWL(3)_BLK3repl_1875        | 33.915                     | 33.920                   |
| Size_DbLN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.314                      | 3.315                    |
| Size_DbLN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.642                     | 30.648                   |
| Size_DbLN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.741                      | 3.742                    |
| Bratio_2025                                   | 0.591                      | 0.587                    |
| SSB_unfished                                  | 13694                      | 13702                    |
| Totbio_unfished                               | 61608                      | 61698                    |
| Recr_unfished                                 | 30000                      | 30156                    |
| Dead_Catch_SPR                                | 2626                       | 2633                     |
| OFLCatch_2025                                 | 3178                       | 3160                     |

### 12 - Panel Conclusion

Proceed with the new WCGBTS index that accounts for depth and assumes isotropy.



## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

### 13 - Request

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

### 13 - Rationale

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

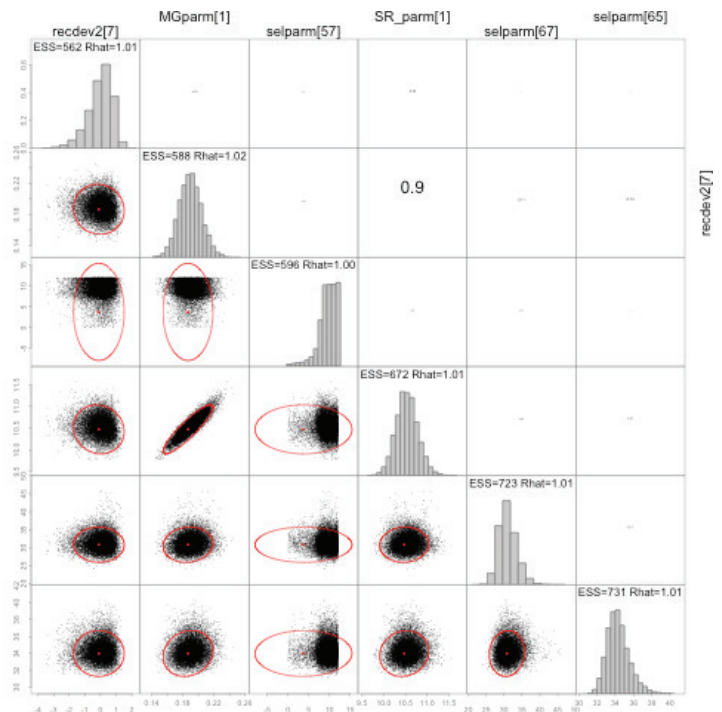
### 13 - STAT Response

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

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

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

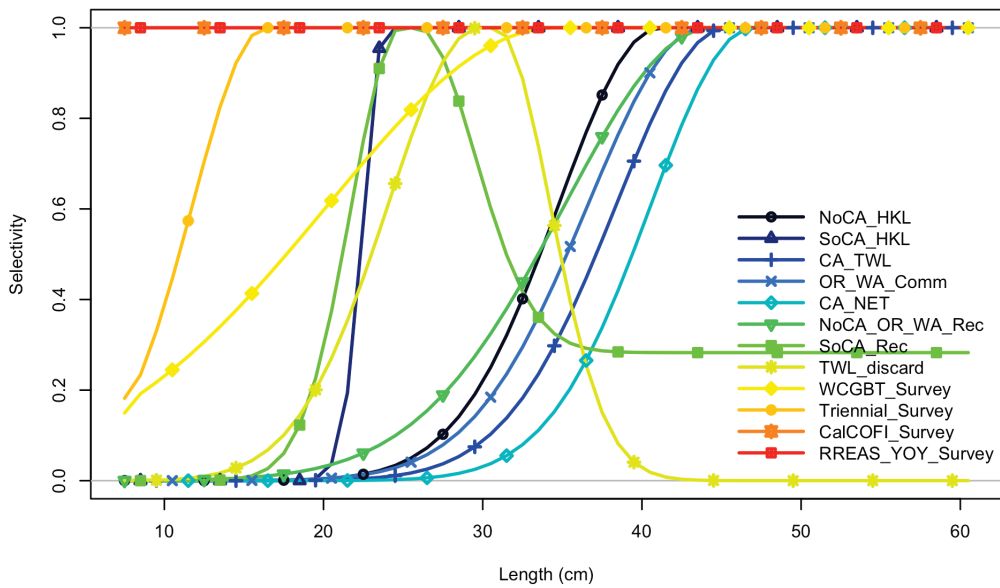
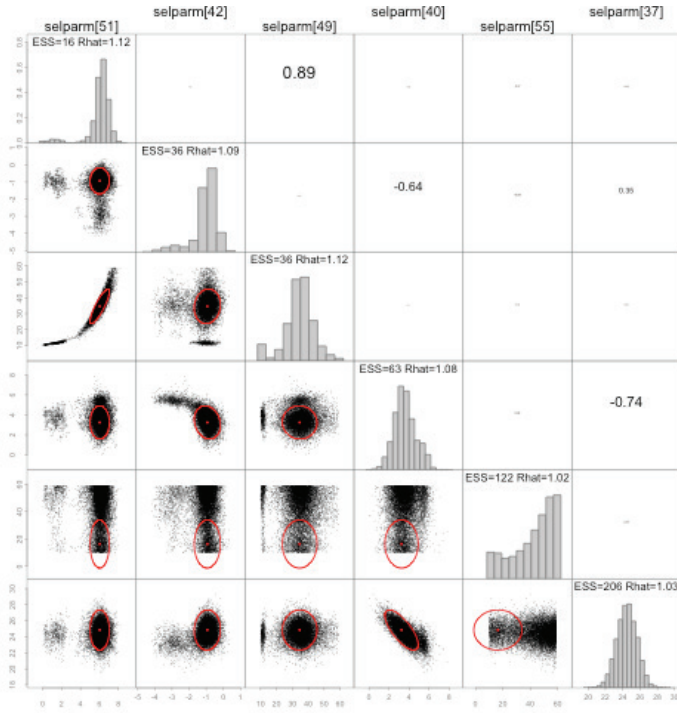
**Figure 13A.** Bivariate scatter plots and histograms of estimated selectivity parameters for the WCGBTS and Triennial survey, based on Request 13. Selparm[55] and selparm[57] are the Triennial peak and ascending scale parameters, respectively. Selparm[51] and





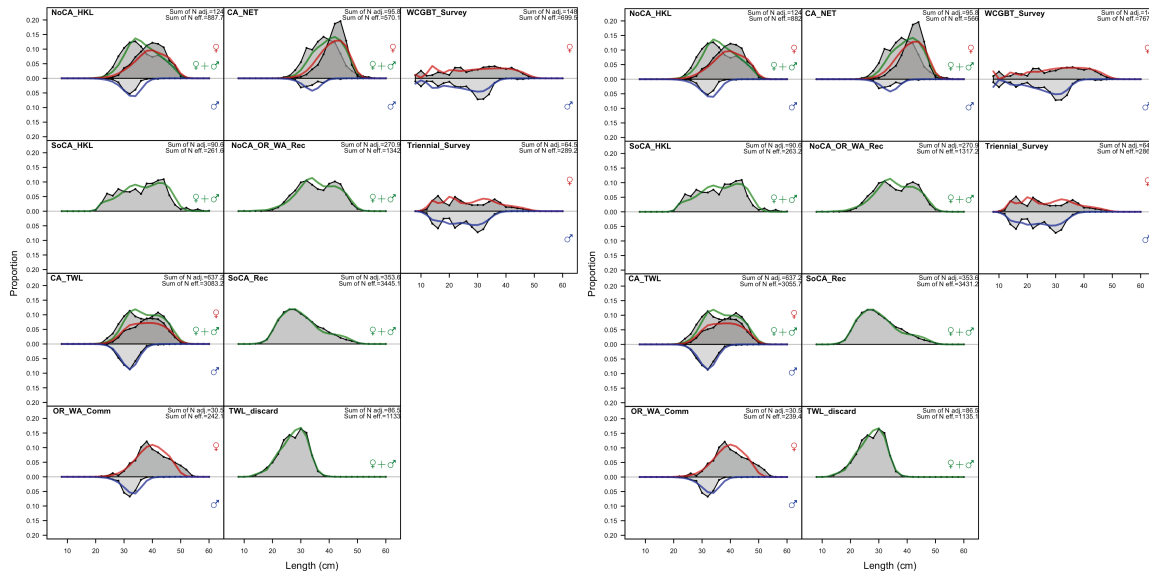
## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

selparm[49] are WCGBTS ascending scale and peak, respectively.



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

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

### 13 - Panel Conclusion

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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

### 14 - Request

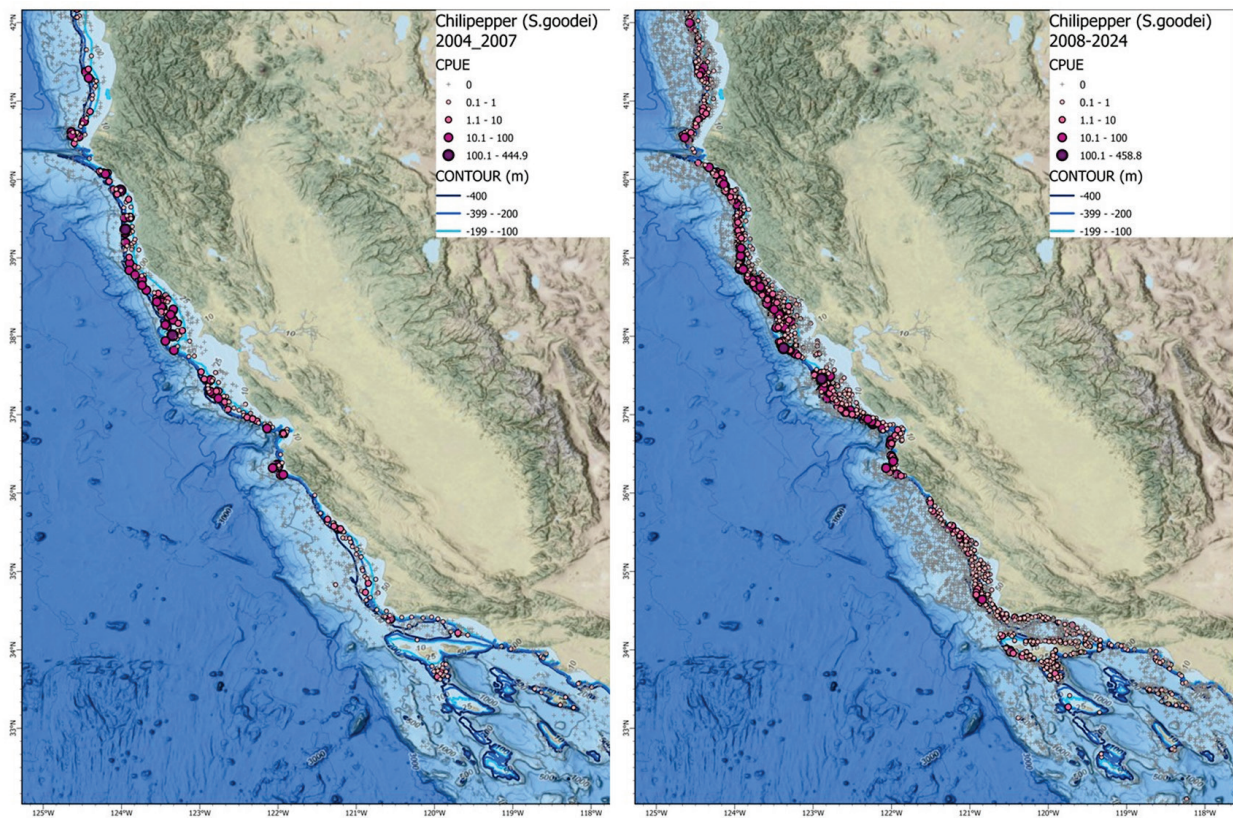
Examine catch rates in early years (2004 to 2007) of the WCGBTS and compare those to catch rates in later years (2008 to 2024). This may include creating bubble plots of raw catch rates, identifying the locations and magnitude of the 10 highest catch rates each year, and presenting depth-stratified proportions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

### 14 - Rationale

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

### 14 - STAT Response

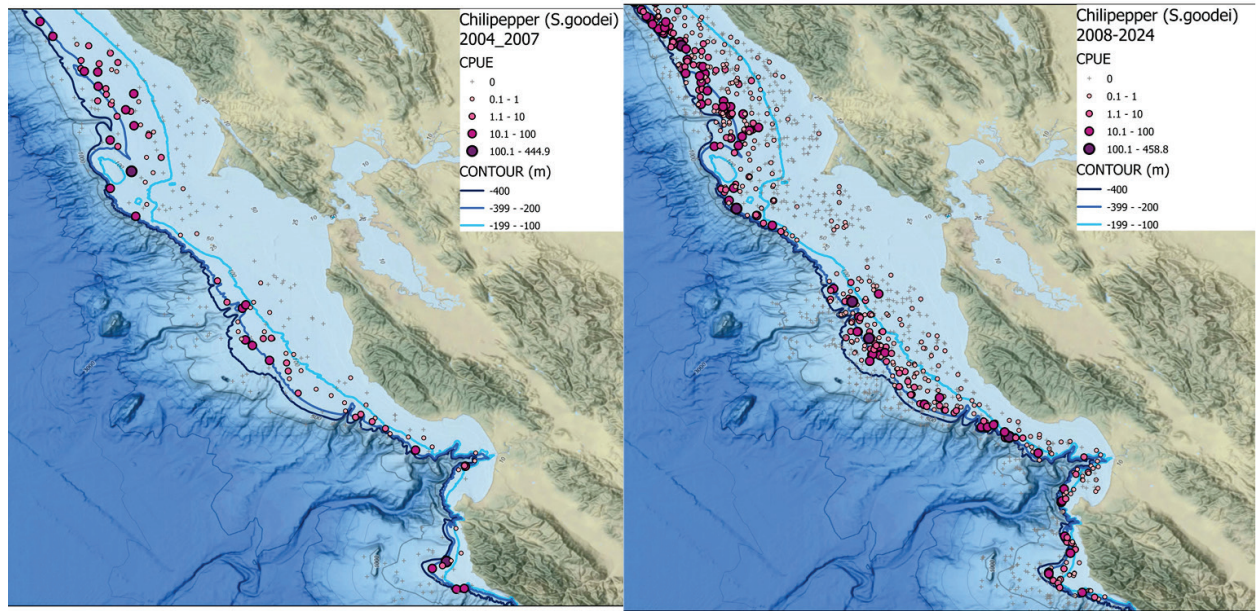
The STAT worked with GIS analyst, Rebecca Miller (UCSC), to update plots that were initially developed for the 2015 assessment update. These plots show WCGBTS catch rates for the entire California coast (i.e., the region of greatest abundance; Fig. 14A) and for central California (Fig. 14B) during two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



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



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

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

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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

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

### 14 - Panel Conclusion

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

### 15 - Request

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

### 15 - Rationale

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

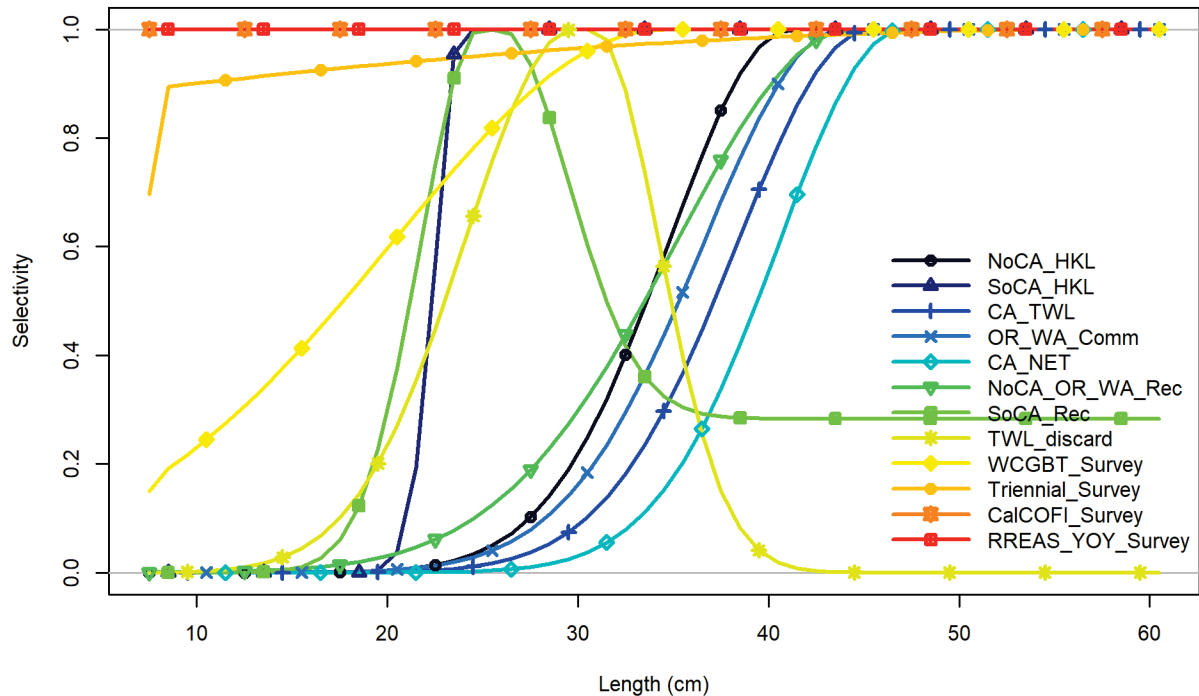
### 15 - STAT Response

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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

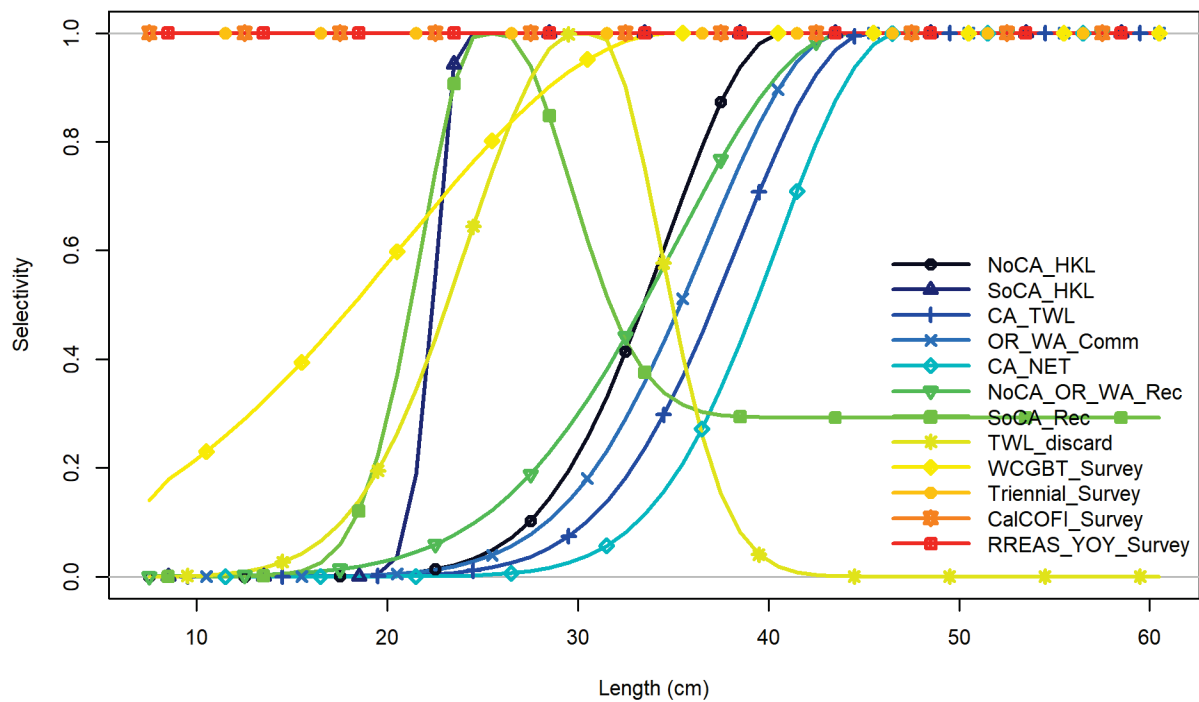
compositions). Fits to lengths from the WCGBTS were ultimately degraded by the estimated curve relative to the original pre-STAR base model, as determined by an increase of approximately 4 points in the negative log likelihood component (Table 15). There was minor improvement in fit to the WCGBTS index,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

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



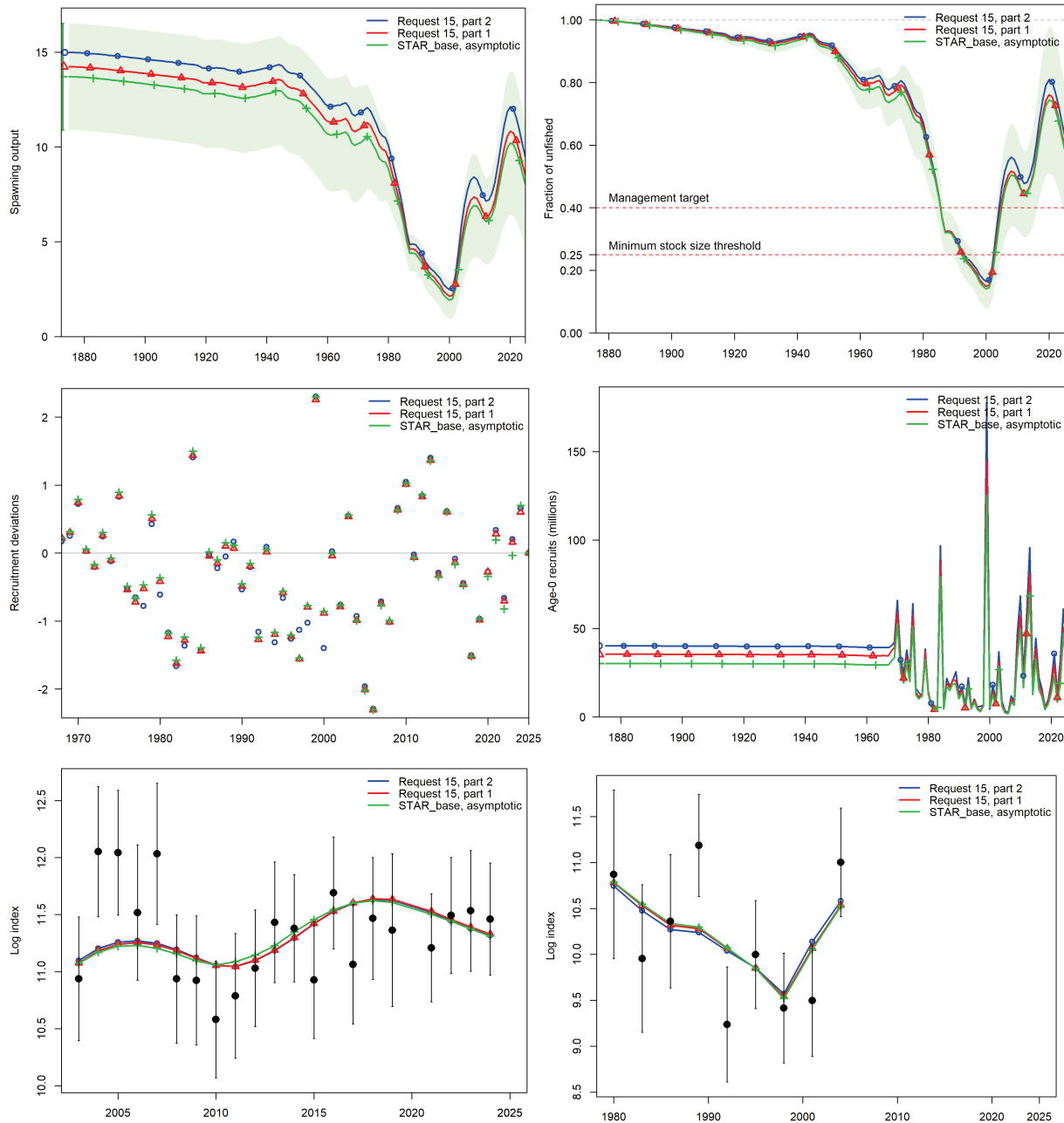
**Figure 15A.** End-year selectivity curves from the pre-STAR base model with estimated peak and ascending width parameters for the WCGBTS, and fixed selectivity parameters for the Triennial survey.

# Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

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



## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

| Label                                         | Request 15,<br>part 2 | Request 15,<br>part 1 | STAR_base,<br>asymptotic |
|-----------------------------------------------|-----------------------|-----------------------|--------------------------|
| N.Parms                                       | 111                   | 111                   | 109                      |
| TOTAL                                         | 2504.080              | 2623.980              | 2621.330                 |
| Survey                                        | 20.881                | 23.745                | 24.307                   |
| Length_comp                                   | 547.765               | 576.047               | 572.015                  |
| Age_comp                                      | 1910.190              | 1999.490              | 2000.480                 |
| Recruitment                                   | 24.978                | 24.495                | 24.425                   |
| Parm_priors                                   | 0.262                 | 0.191                 | 0.096                    |
| NatM_uniform_Fem_GP_1                         | 0.193                 | 0.187                 | 0.177                    |
| L_at_Amax_Fem_GP_1                            | 47.948                | 47.890                | 47.860                   |
| VonBert_K_Fem_GP_1                            | 0.195                 | 0.196                 | 0.197                    |
| CV_young_Fem_GP_1                             | 0.106                 | 0.105                 | 0.105                    |
| CV_old_Fem_GP_1                               | 0.038                 | 0.039                 | 0.039                    |
| NatM_uniform_Mal_GP_1                         | 0.211                 | 0.221                 | 0.241                    |
| L_at_Amax_Mal_GP_1                            | -0.332                | -0.329                | -0.329                   |
| VonBert_K_Mal_GP_1                            | 0.515                 | 0.522                 | 0.528                    |
| CV_young_Mal_GP_1                             | 0.283                 | 0.241                 | 0.235                    |
| CV_old_Mal_GP_1                               | 0.098                 | 0.099                 | 0.100                    |
| SR_LN(R0)                                     | 10.598                | 10.474                | 10.314                   |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.319                 | 0.311                 | 0.310                    |
| Q_extraSD_RREAS_YOY_Survey(12)                | 1.219                 | 1.221                 | 1.230                    |
| Size_DbIN_peak_NoCA_HKL(1)                    | 40.742                | 41.136                | 41.080                   |
| Size_DbIN_ascend_se_NoCA_HKL(1)               | 4.345                 | 4.401                 | 4.405                    |
| Size_DbIN_peak_SoCA_HKL(2)                    | 23.962                | 23.906                | 23.788                   |
| Size_DbIN_ascend_se_SoCA_HKL(2)               | 1.289                 | 1.259                 | 1.195                    |
| Size_DbIN_peak_CA_TWL(3)                      | 45.243                | 45.296                | 45.102                   |
| Size_DbIN_ascend_se_CA_TWL(3)                 | 4.557                 | 4.565                 | 4.563                    |
| Size_DbIN_peak_OR_WA_Comm(4)                  | 43.881                | 43.833                | 43.109                   |
| Size_DbIN_ascend_se_OR_WA_Comm(4)             | 4.651                 | 4.654                 | 4.600                    |
| Size_DbIN_peak_CA_NET(5)                      | 46.794                | 46.973                | 46.979                   |
| Size_DbIN_ascend_se_CA_NET(5)                 | 4.400                 | 4.414                 | 4.420                    |
| Size_DbIN_peak_NoCA_OR_WA_Rec(6)              | 44.128                | 44.372                | 44.110                   |
| Size_DbIN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.108                 | 5.140                 | 5.145                    |
| Size_DbIN_peak_SoCA_Rec(7)                    | 24.873                | 24.844                | 24.731                   |
| Size_DbIN_ascend_se_SoCA_Rec(7)               | 2.956                 | 2.954                 | 2.936                    |
| Size_DbIN_descend_se_SoCA_Rec(7)              | 3.282                 | 3.249                 | 3.278                    |
| Size_DbIN_end_logit_SoCA_Rec(7)               | -0.884                | -0.929                | -1.049                   |
| Size_DbIN_peak_TWL_discard(8)                 | 29.887                | 29.757                | 29.572                   |
| Size_DbIN_ascend_se_TWL_discard(8)            | 4.190                 | 4.185                 | 4.181                    |
| Size_DbIN_descend_se_TWL_discard(8)           | 3.126                 | 3.158                 | 3.194                    |
| Size_DbIN_peak_WCGBT_Survey(9)                | 35.007                | 34.585                | NA                       |
| Size_DbIN_top_logit_WCGBT_Survey(9)           | -6.000                | -6.000                | NA                       |
| Size_DbIN_ascend_se_WCGBT_Survey(9)           | 6.013                 | 6.022                 | NA                       |
| Size_DbIN_descend_se_WCGBT_Survey(9)          | 7.000                 | 7.000                 | NA                       |
| Size_DbIN_start_logit_WCGBT_Survey(9)         | -999.000              | -999.000              | NA                       |
| Size_DbIN_end_logit_WCGBT_Survey(9)           | 10.000                | 10.000                | NA                       |
| Size_DbIN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.194                | 51.365                | 51.396                   |
| Size_DbIN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.122                 | 4.135                 | 4.141                    |
| Size_DbIN_peak_SoCA_HKL(2)_BLK2repl_1875      | 48.393                | 48.771                | 48.776                   |
| Size_DbIN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.775                 | 4.806                 | 4.814                    |
| Size_DbIN_peak_CA_TWL(3)_BLK3repl_1875        | 33.940                | 33.997                | 33.920                   |
| Size_DbIN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.299                 | 3.322                 | 3.315                    |
| Size_DbIN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.960                | 30.791                | 30.648                   |
| Size_DbIN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.775                 | 3.757                 | 3.742                    |
| Size_DbIN_peak_Triennial_Survey(10)           | NA                    | 58.000                | NA                       |
| Size_DbIN_top_logit_Triennial_Survey(10)      | NA                    | -6.000                | NA                       |
| Size_DbIN_ascend_se_Triennial_Survey(10)      | NA                    | 10.000                | NA                       |
| Size_DbIN_descend_se_Triennial_Survey(10)     | NA                    | 7.000                 | NA                       |
| Size_DbIN_start_logit_Triennial_Survey(10)    | NA                    | -999.000              | NA                       |
| Size_DbIN_end_logit_Triennial_Survey(10)      | NA                    | 10.000                | NA                       |
| SizeSel=1_BinLo_WCGBT_Survey(9)               | NA                    | NA                    | 3.000                    |
| SizeSel=1_BinHi_WCGBT_Survey(9)               | NA                    | NA                    | 54.000                   |
| Bratio_2025                                   | 0.633                 | 0.597                 | 0.587                    |
| SSB_unfished                                  | 14983                 | 14233                 | 13702                    |
| Totbio_unfished                               | 70061                 | 65718                 | 61698                    |
| Recr_unfished                                 | 40069                 | 35386                 | 30156                    |
| Dead_Catch_SPR                                | 3198                  | 2927                  | 2633                     |
| OFLCatch_2025                                 | 4170                  | 3613                  | 3160                     |

## **Stock Assessment Review (STAR) Panel for Chilipepper Rockfish**

### **15 - Panel Conclusion**

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

### **16 - Request**

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

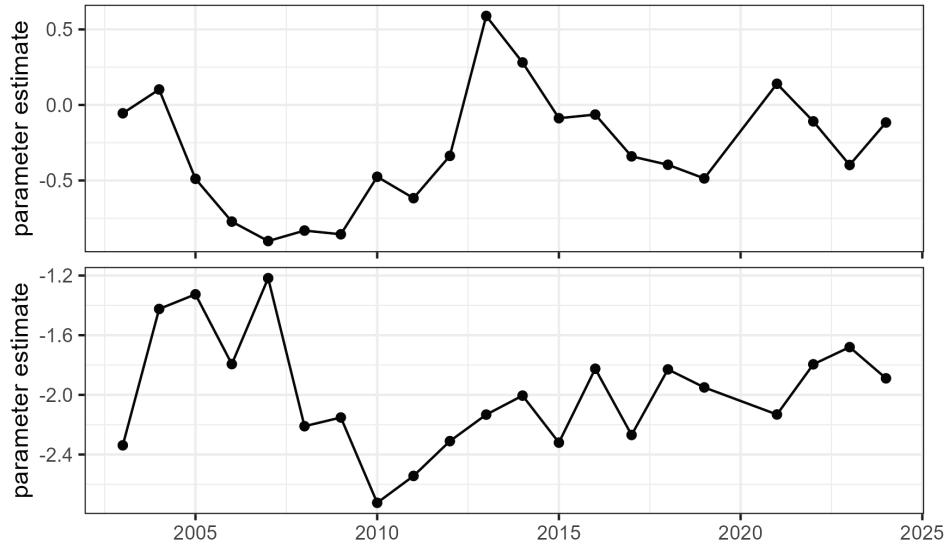
### **16 - Rationale**

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

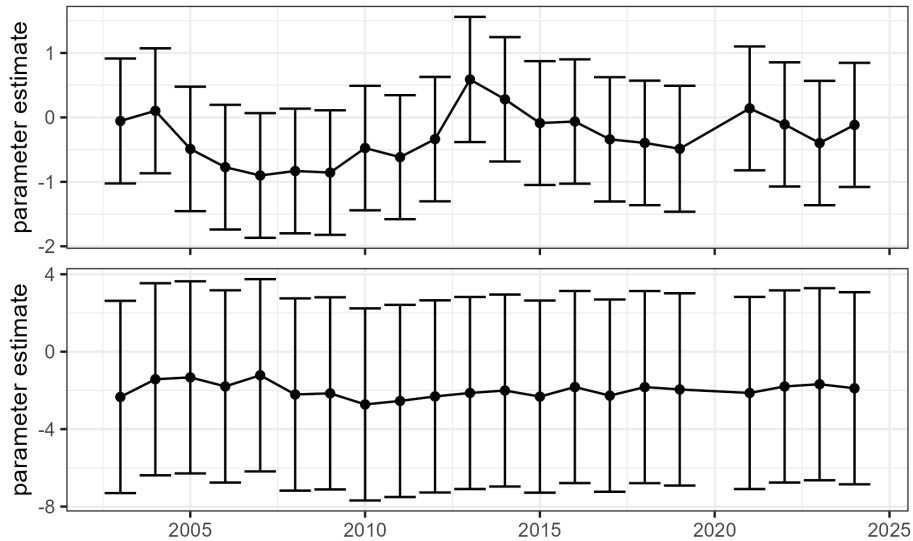
### **16 - STAT Response**

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

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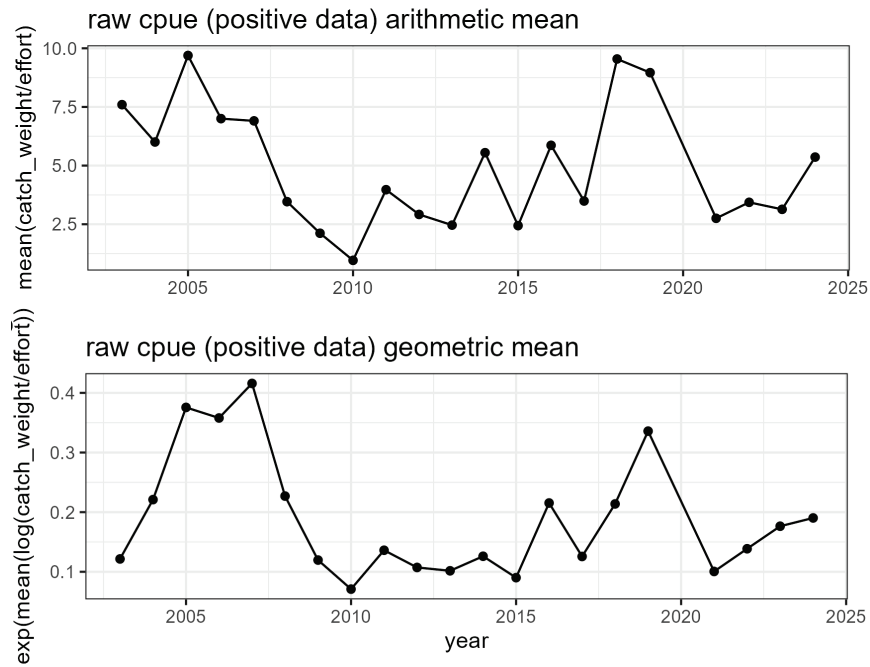


**Figure 16A.** Parameter estimates for the year effect from the binomial (top) and positive (bottom) components of the WCG BTS index model. Values are on the link scale.

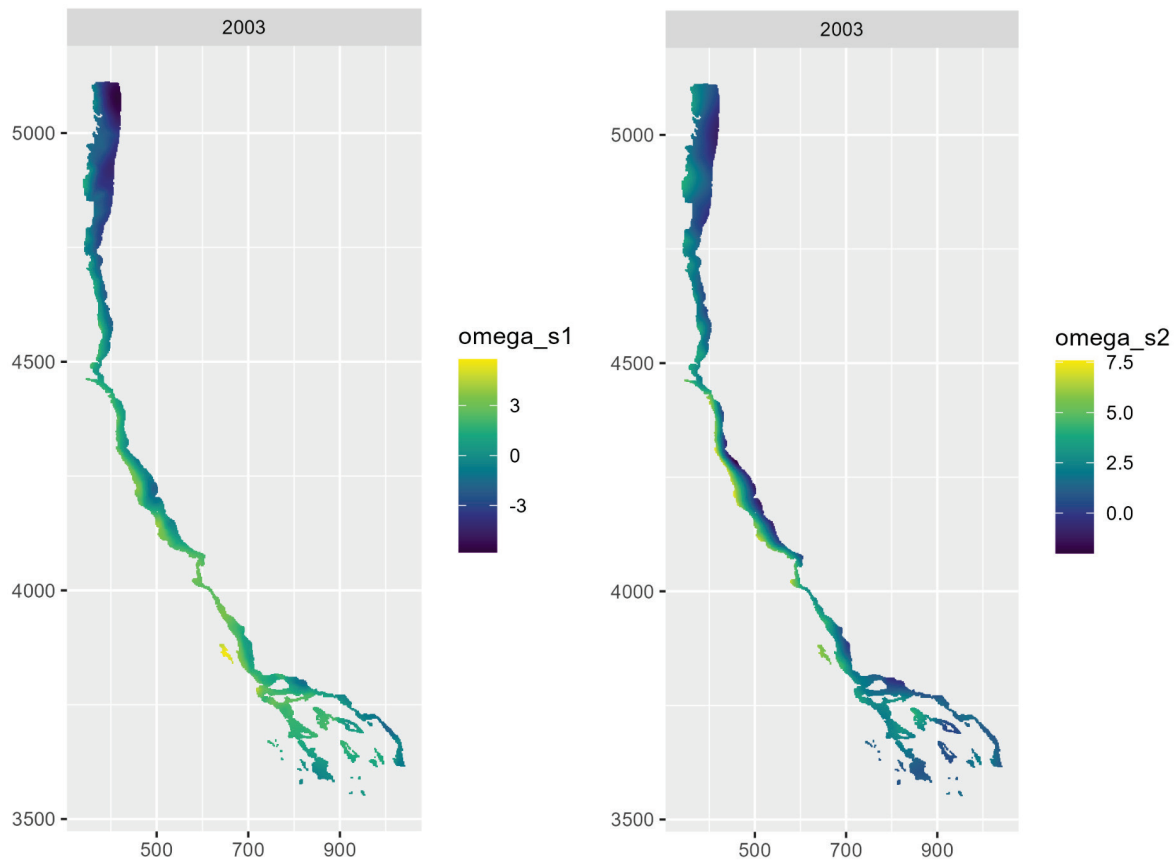


**Figure 16B.** Parameter estimates for the year effect from the binomial (top) and positive (bottom) components of the WCG BTS index model, with standard errors. The resemblance of the positive model coefficients is obscured when error bars are included.

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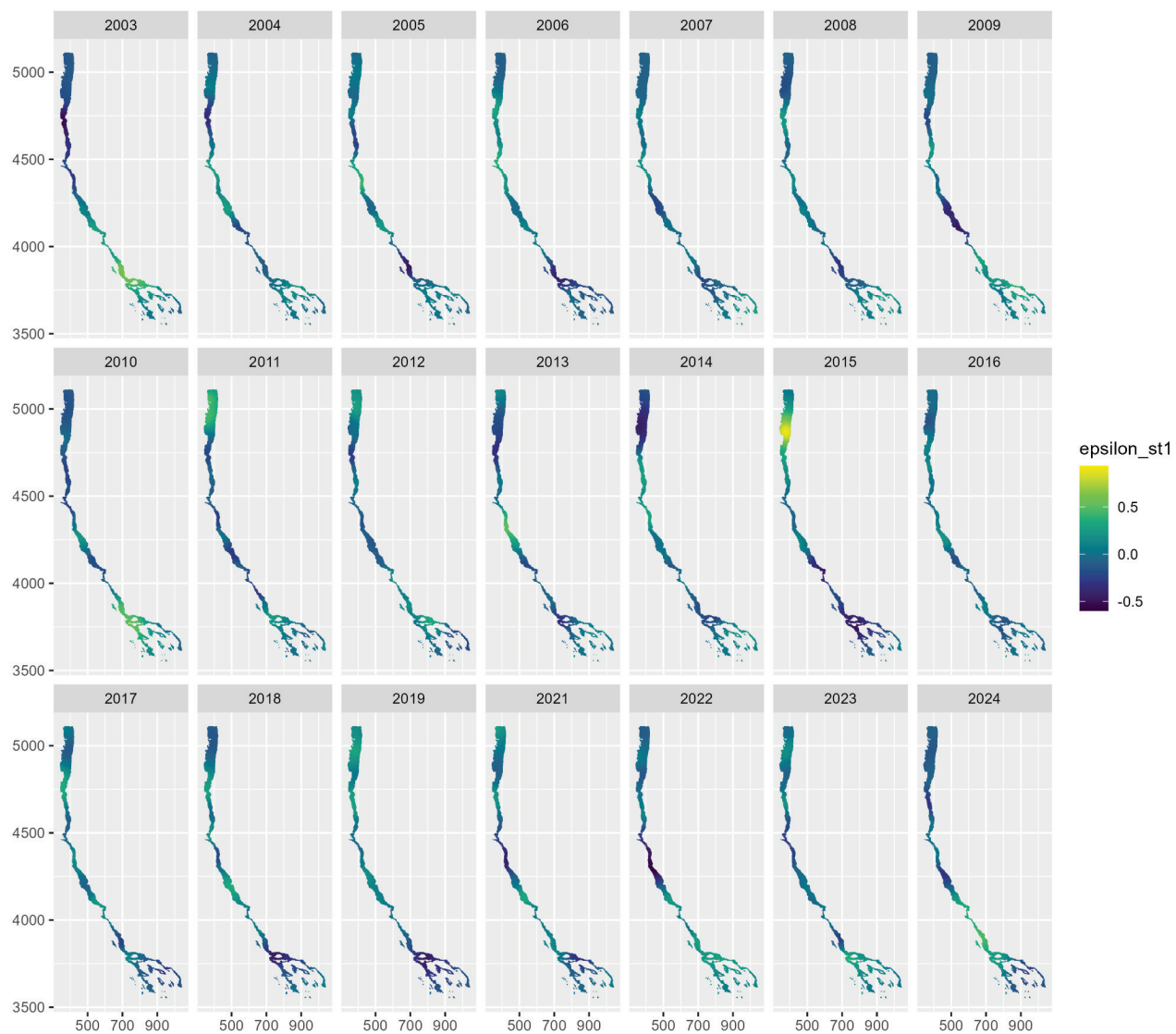


**Figure 16C.** Arithmetic (top) and geometric (bottom) mean catch-per-unit-effort (CPUE, kg per ha) from the WCGBTS index.



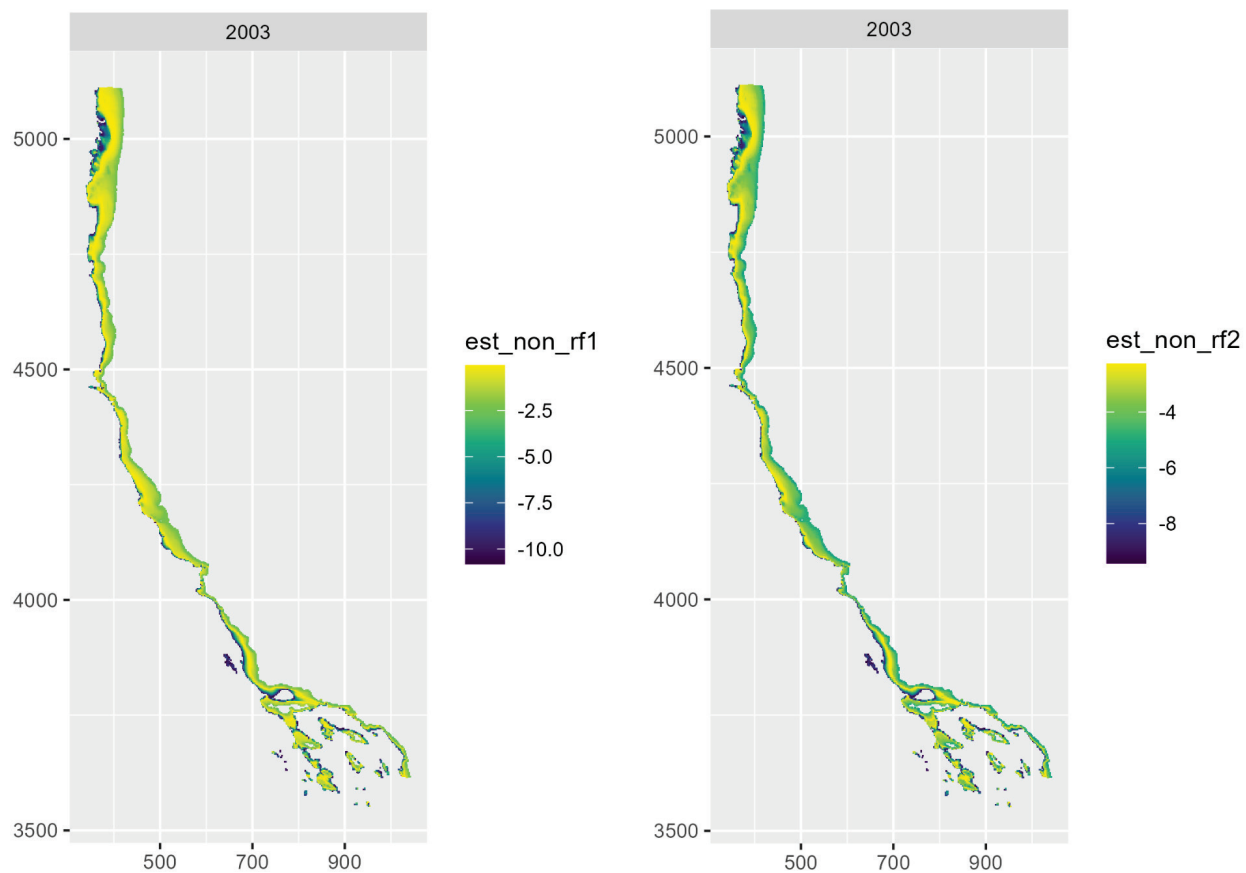
**Figure 16D.** Spatial random fields for the binomial (left) and positive (right) components of the WCGBTS index model. The spatial random field is shown for 2003, though the effect does not vary by year. Values are on the link scale.

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



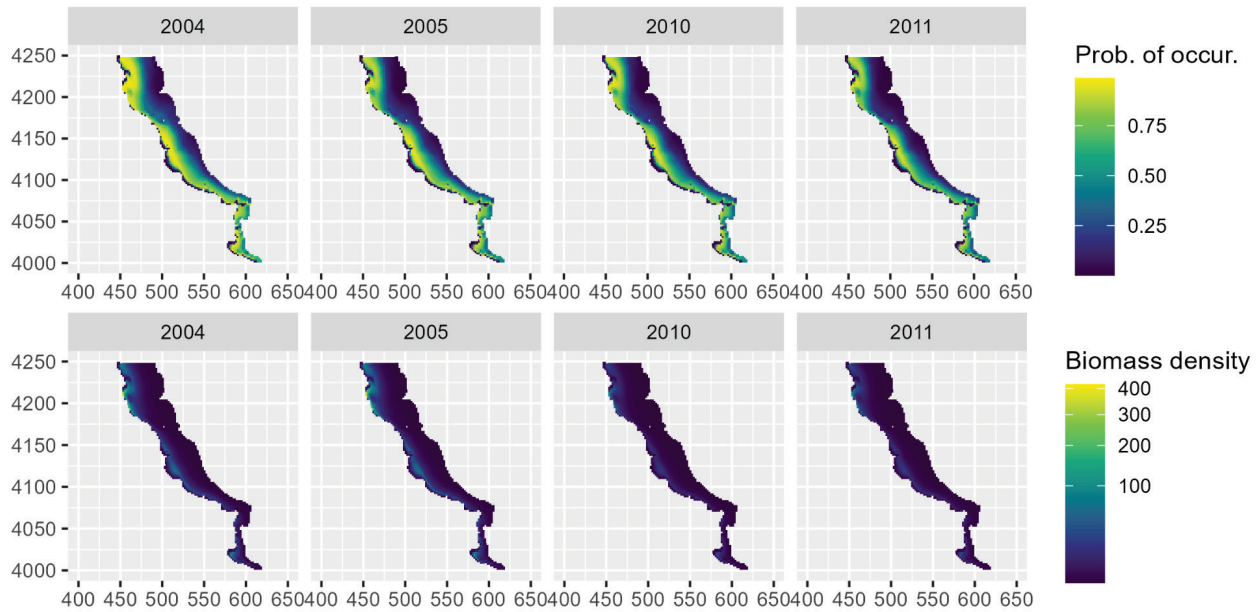
**Figure 16E.** Spatiotemporal random fields for the binomial component of the WCGBTS index model by year. Values are on the link scale.

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

### 16 - Panel Conclusion

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

### 17 - Request

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

### 17 - Rationale

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

### 17 - STAT Response

The STAT constructed a model with the previously mentioned asymptotic selectivity curves, a sum-to-zero constraint on recruitment deviations, steepness fixed at 0.72, a revised WCG BTS index, an additive variance parameter for the RREAS index that was fixed so total mean logSE = sigmaR (1.0), and trawl survey selectivities fixed at 1 for 9.5+ cm fish for the WCG BTS and fixed at 1 for age 1+ fish for the Triennial survey. The model was less stable than the pre-STAR base model, with multiple minima in the region of the best identified solution. Attempts to estimate the

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

Hessian for the best available solution after tuning the composition data failed. In an effort to stabilize the model, the STAT examined the parameter standard errors from a previous run and identified two parameters with standard errors greater than the MLE: the ascending limb of selectivity for the southern California hook-and-line fleet and the male offset for the CV of length at age 20 yr (Table 17A).

The STAT fixed the “CV\_old\_Mal\_GP\_1” parameter at 0.1, fixed the “Size\_DbIN\_ascend\_se\_SoCA\_HKL(2)” parameter at 1.2, and re-estimated and tuned the model. This change appeared to stabilize the model, as evidenced by rapid convergence of the Francis tuning algorithm, successful estimation of the Hessian, and use of the “-hess\_step” option to minimize the final gradient. The tuned model was used for a “jitter” analysis of 100 runs with “jitter fraction” of 0.2. The jitter analysis did not find a smaller NLL value than the proposed base model and 97 of the 100 runs found the same solution (NLL = 2633.05). This is evidence (but not proof) that the optimizer has found a global solution. It also suggests that fixing the two parameters resolved issues with convergence. Given that the new model enforces a sum-to-zero constraint, it is unclear to the STAT if the use of MCMC diagnostics to further diagnose the issue is appropriate.

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

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

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

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



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

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

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

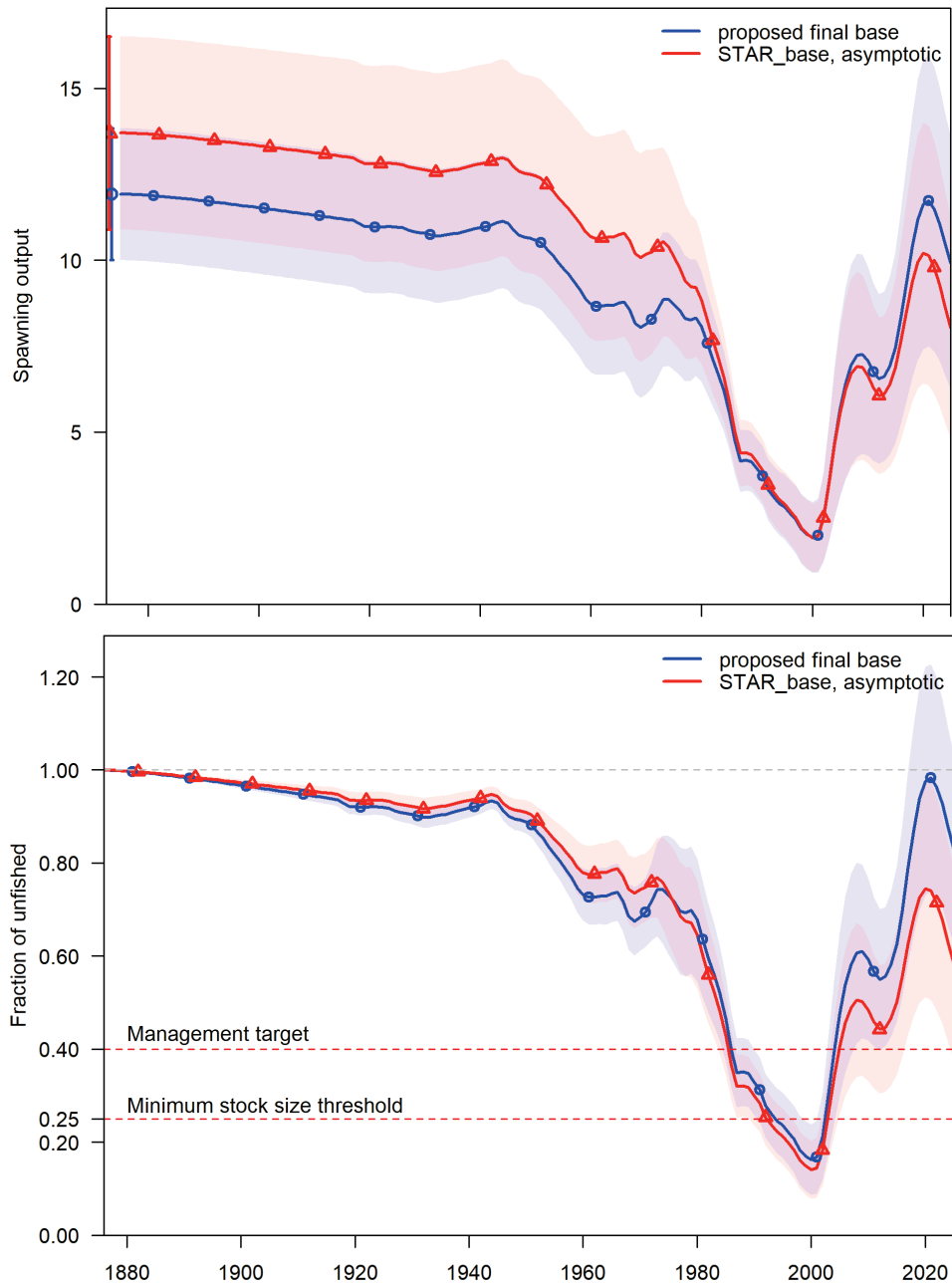
| Reference Point                                | Estimate | Lower Interval | Upper Interval |
|------------------------------------------------|----------|----------------|----------------|
| Unfished Spawning Output (billions of eggs)    | 11,922   | 10,006         | 13,839         |
| Unfished Age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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

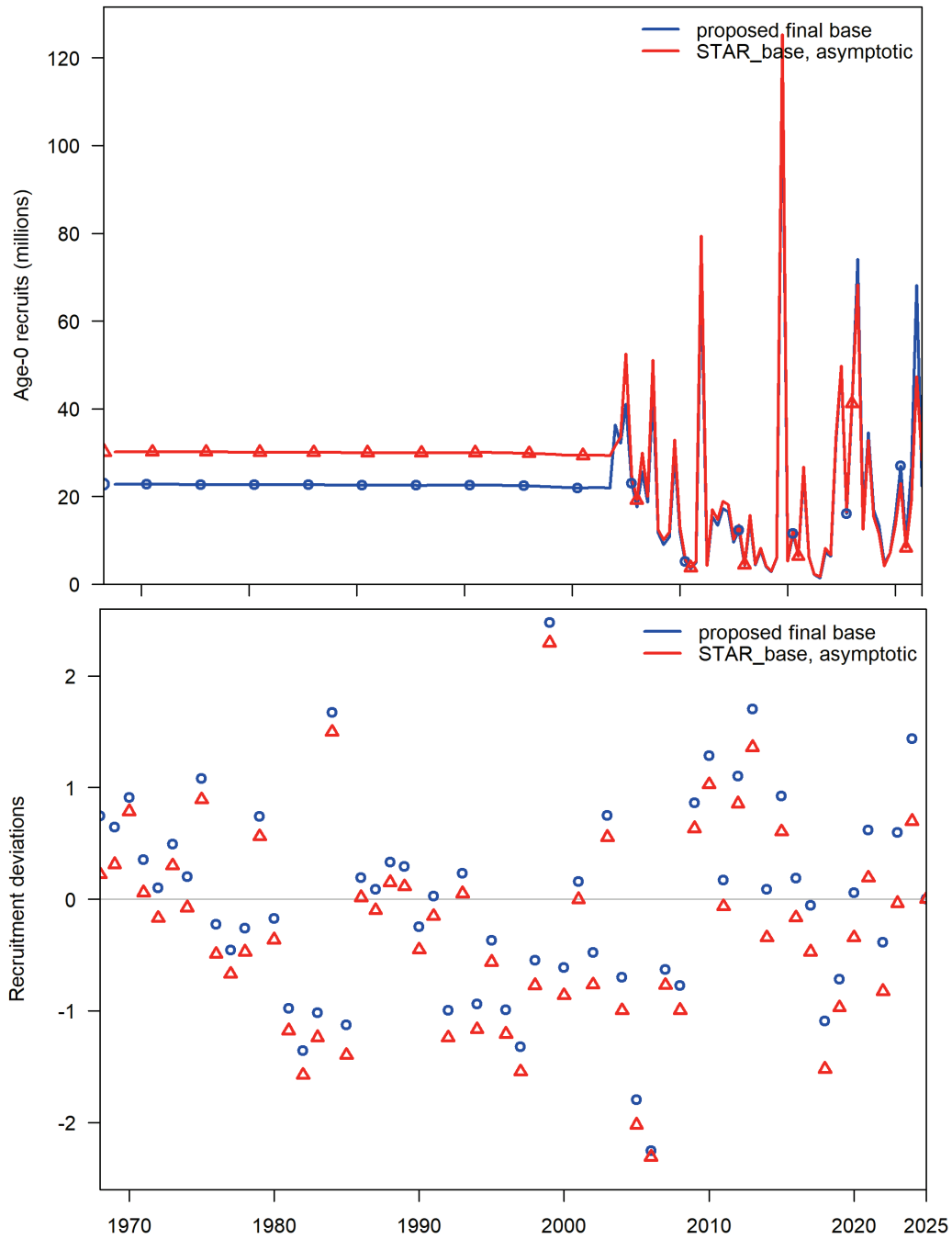
| Label                                         | proposed final base | STAR_base, asymptotic |
|-----------------------------------------------|---------------------|-----------------------|
| NParms                                        | 106                 | 109                   |
| TOTAL                                         | 2633.050            | 2621.330              |
| Survey                                        | 29.272              | 24.307                |
| Length_comp                                   | 569.289             | 572.015               |
| Age_comp                                      | 2011.060            | 2000.480              |
| Recruitment                                   | 23.397              | 24.425                |
| Parm_priors                                   | 0.025               | 0.096                 |
| NatM_uniform_Fem_GP_1                         | 0.165               | 0.177                 |
| L_at_Amax_Fem_GP_1                            | 47.901              | 47.860                |
| VonBert_K_Fem_GP_1                            | 0.197               | 0.197                 |
| CV_young_Fem_GP_1                             | 0.105               | 0.105                 |
| CV_old_Fem_GP_1                               | 0.039               | 0.039                 |
| NatM_uniform_Mal_GP_1                         | 0.266               | 0.241                 |
| L_at_Amax_Mal_GP_1                            | -0.328              | -0.329                |
| VonBert_K_Mal_GP_1                            | 0.526               | 0.528                 |
| CV_young_Mal_GP_1                             | 0.236               | 0.235                 |
| CV_old_Mal_GP_1                               | 0.1                 | 0.100                 |
| SR_LN(R0)                                     | 10.032              | 10.314                |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.355               | 0.310                 |
| Q_extraSD_RREAS_YOY_Survey(12)                | 0.683               | 1.230                 |
| Size_DbIN_peak_NoCA_HKL(1)                    | 40.974              | 41.080                |
| Size_DbIN_ascend_se_NoCA_HKL(1)               | 4.399               | 4.405                 |
| Size_DbIN_peak_SoCA_HKL(2)                    | 23.799              | 23.788                |
| Size_DbIN_ascend_se_SoCA_HKL(2)               | 1.2                 | 1.195                 |
| Size_DbIN_peak_CA_TWL(3)                      | 44.904              | 45.102                |
| Size_DbIN_ascend_se_CA_TWL(3)                 | 4.556               | 4.563                 |
| Size_DbIN_peak_OR_WA_Comm(4)                  | 42.753              | 43.109                |
| Size_DbIN_ascend_se_OR_WA_Comm(4)             | 4.559               | 4.600                 |
| Size_DbIN_peak_CA_NET(5)                      | 46.991              | 46.979                |
| Size_DbIN_ascend_se_CA_NET(5)                 | 4.426               | 4.420                 |
| Size_DbIN_peak_NoCA_OR_WA_Rec(6)              | 43.894              | 44.110                |
| Size_DbIN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.136               | 5.145                 |
| Size_DbIN_peak_SoCA_Rec(7)                    | 24.708              | 24.731                |
| Size_DbIN_ascend_se_SoCA_Rec(7)               | 2.924               | 2.936                 |
| Size_DbIN_descend_se_SoCA_Rec(7)              | 3.318               | 3.278                 |
| Size_DbIN_end_logit_SoCA_Rec(7)               | -1.112              | -1.049                |
| Size_DbIN_peak_TWL_discard(8)                 | 29.552              | 29.572                |
| Size_DbIN_ascend_se_TWL_discard(8)            | 4.167               | 4.181                 |
| Size_DbIN_descend_se_TWL_discard(8)           | 3.193               | 3.194                 |
| Size_DbIN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.604              | 51.396                |
| Size_DbIN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.157               | 4.141                 |
| Size_DbIN_peak_SoCA_HKL(2)_BLK2repl_1875      | 48.830              | 48.776                |
| Size_DbIN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.824               | 4.814                 |
| Size_DbIN_peak_CA_TWL(3)_BLK3repl_1875        | 33.792              | 33.920                |
| Size_DbIN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.290               | 3.315                 |
| Size_DbIN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.678              | 30.648                |
| Size_DbIN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.752               | 3.742                 |
| Bratio_2025                                   | 0.832               | 0.587                 |
| SSB_unfished                                  | 11922               | 13702                 |
| Totbio_unfished                               | 52043               | 61698                 |
| Recr_unfished                                 | 22734               | 30156                 |
| Dead_Catch_SPR                                | 2114                | 2633                  |
| OFLCatch_2025                                 | 3617                | 3160                  |

### Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



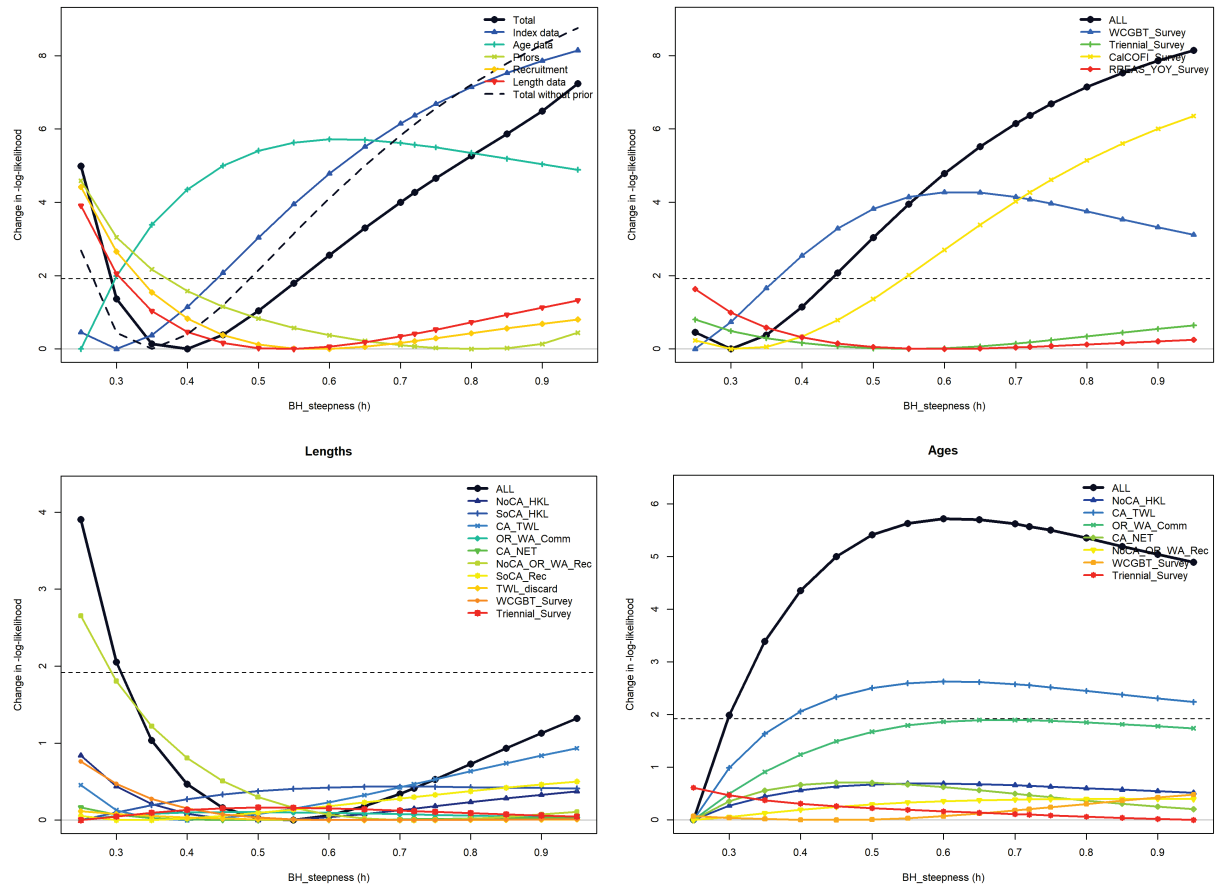
**Figure 17A.** Spawning output (top) and fraction unfished (bottom) from the model with unconstrained recruitment deviations (red) and the proposed final base model with sum-to-zero deviations and other changes as described in the request (blue). Shaded areas represent 95% asymptotic confidence intervals.

# Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



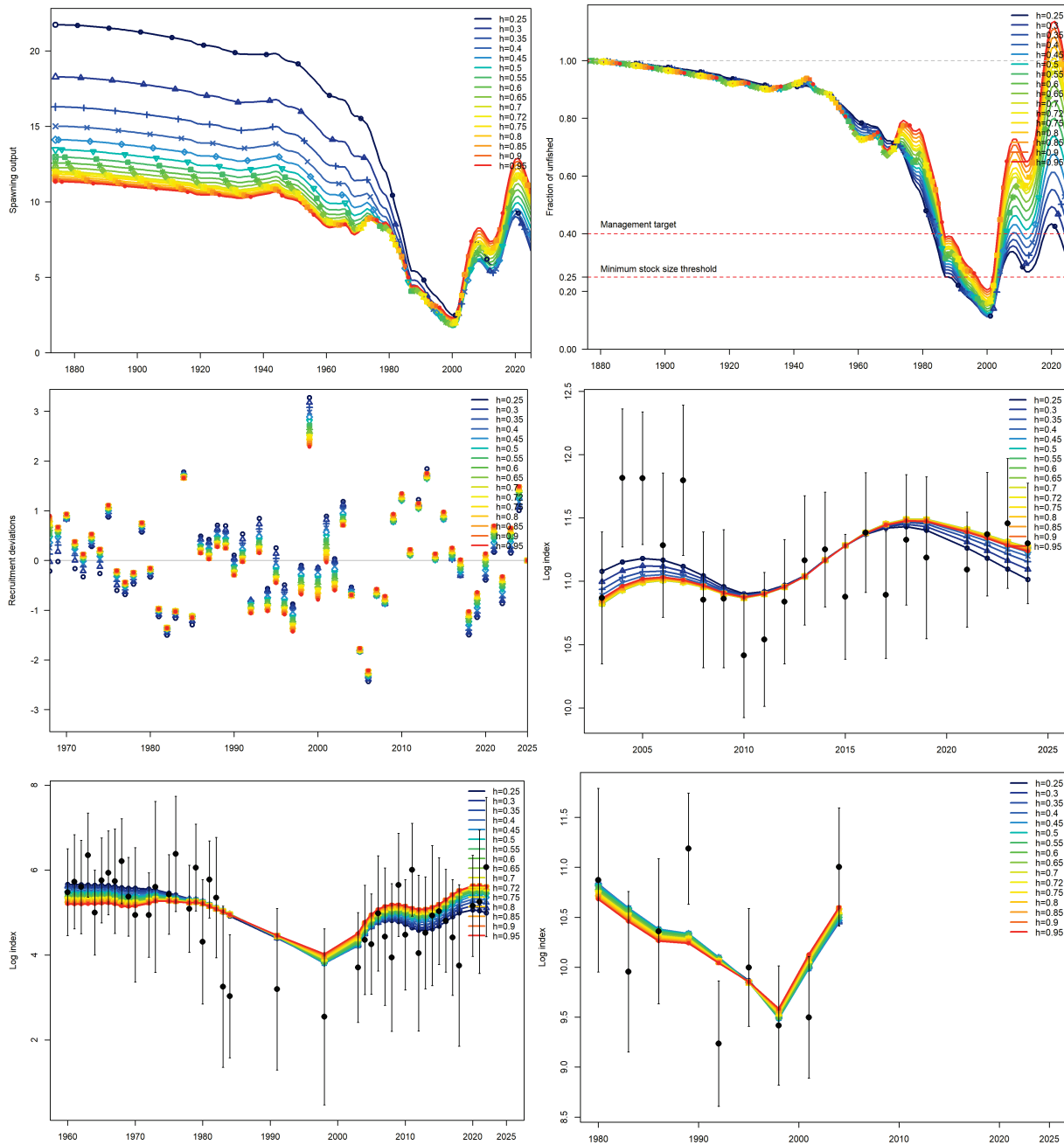
**Figure 17B.** Age-0 recruits (top) and recruitment deviations (bottom) from the model with unconstrained recruitment deviations (red) and the proposed final base model with a sum-to-zero constraint on recruitment deviations and other changes as described in the request (blue). Shaded areas represent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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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



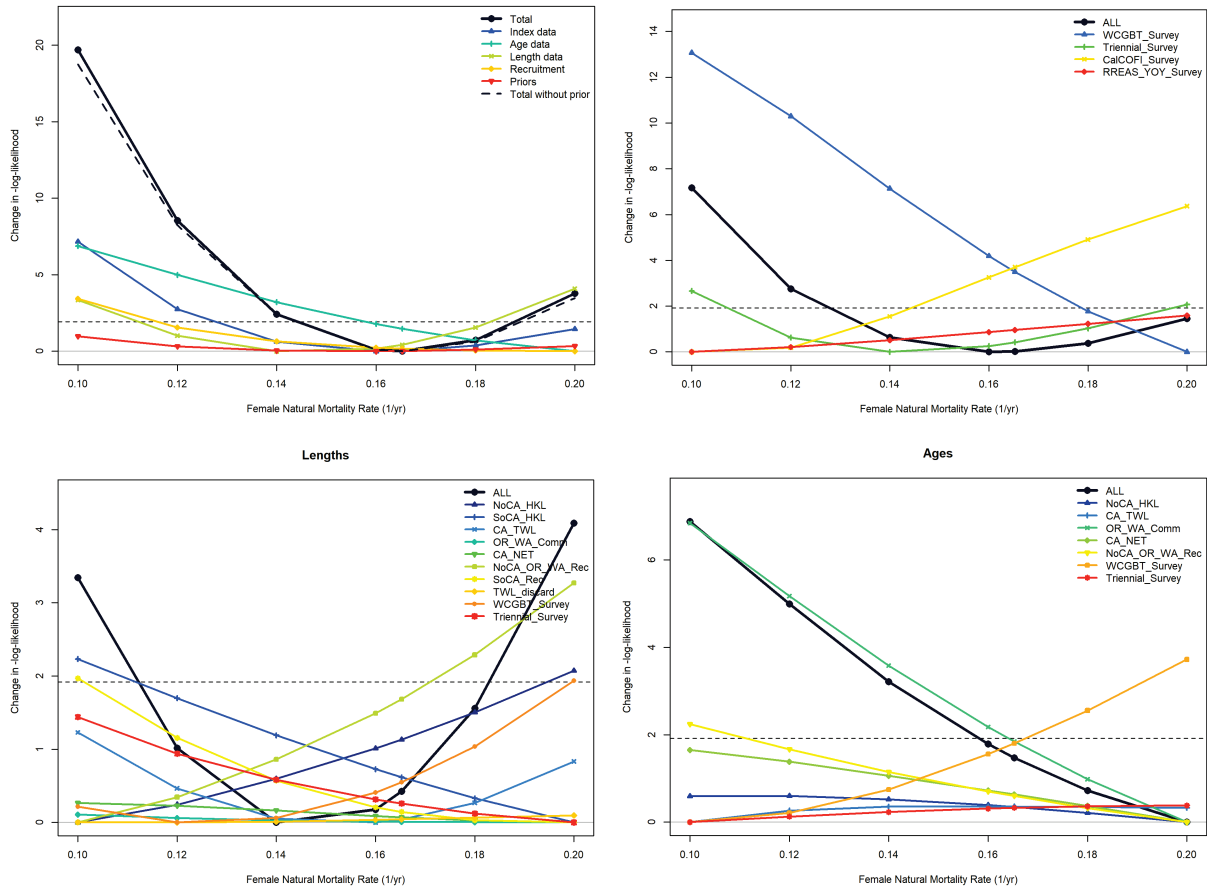
## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

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

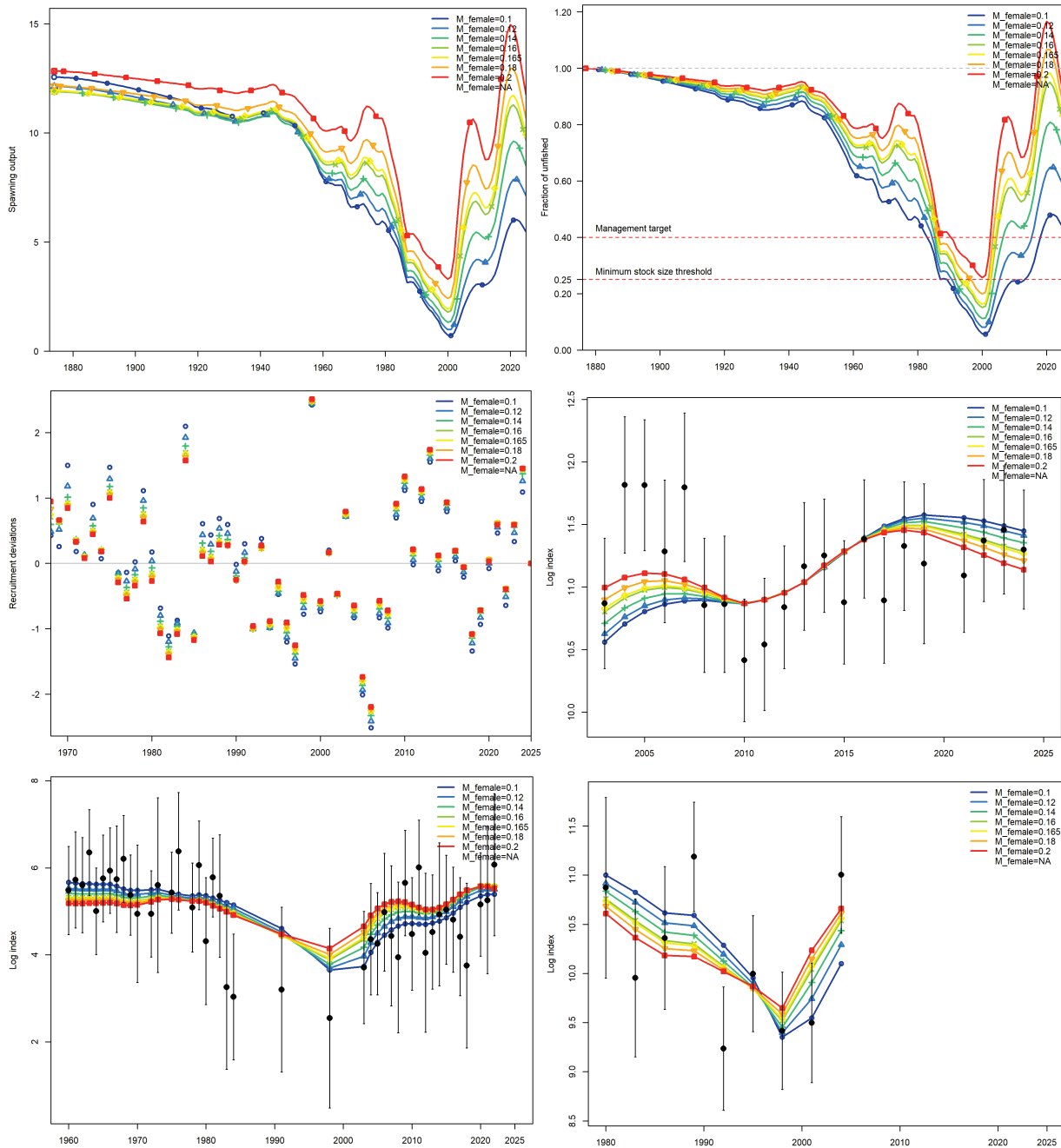


## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



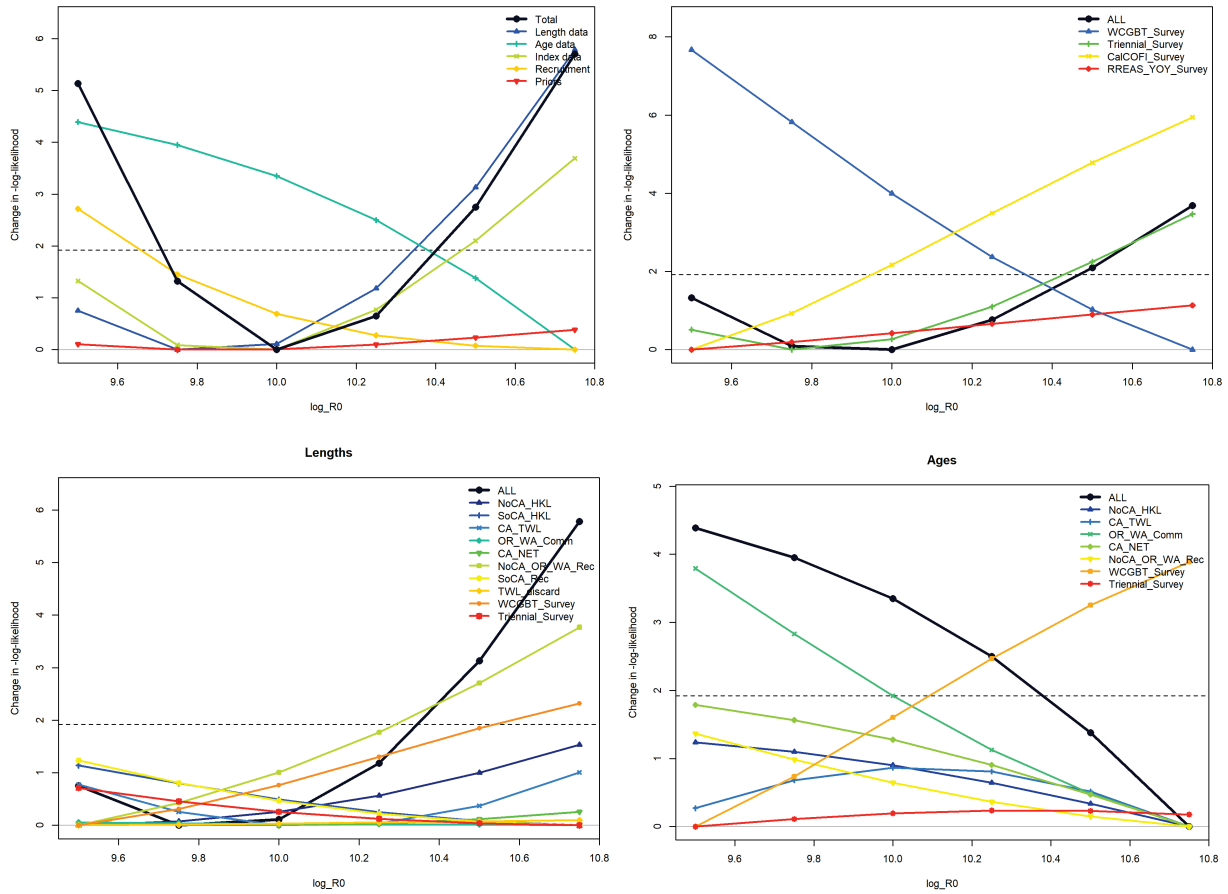
**Figure 17F.** Likelihood profiles for the female natural mortality ( $M$ ) parameter. Spawning output (top left), fraction unfished (top right), recruitment deviations (middle left), log-scale fit to WCGBTS index (middle right), log-scale fit to CalCOFI index (bottom left), and log-scale fit to Triennial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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

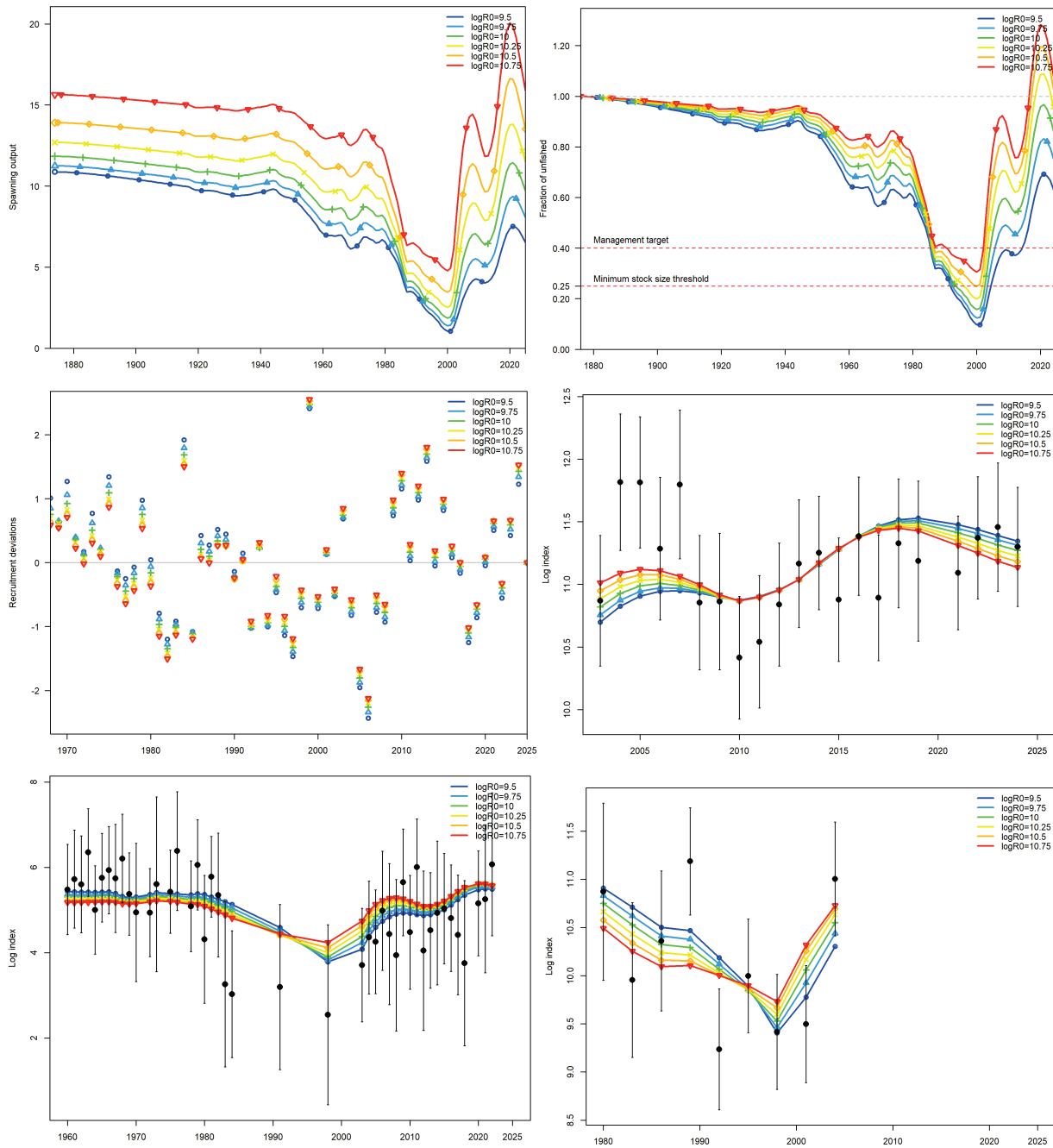
| Label                                         | M_female=0.1 | M_female=0.12 | M_female=0.14 | M_female=0.16 | M_female=0.165 | M_female=0.18 | M_female=0.2 |
|-----------------------------------------------|--------------|---------------|---------------|---------------|----------------|---------------|--------------|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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



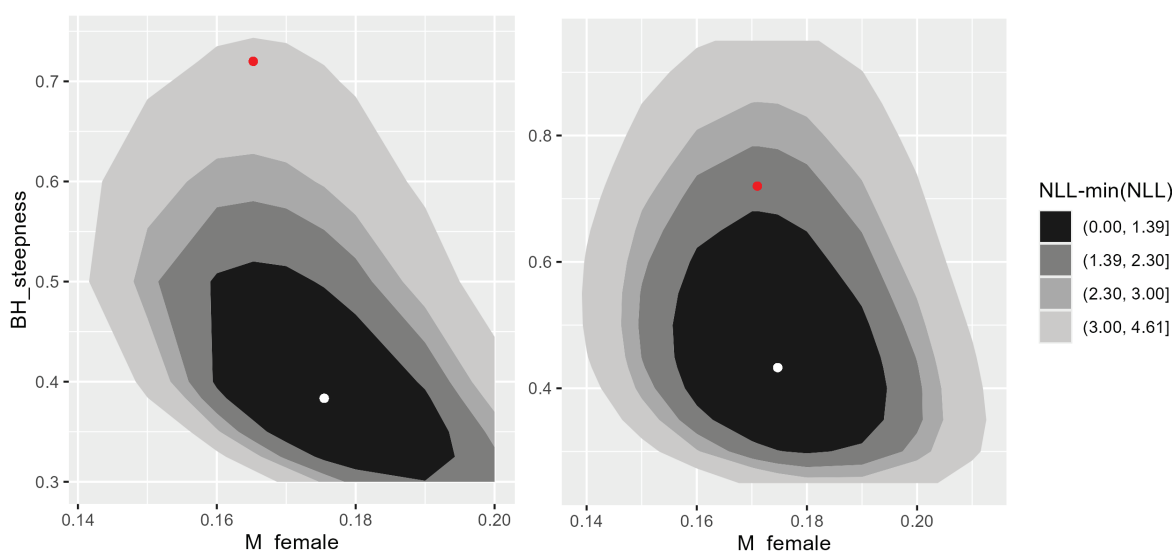
**Figure 17H.** Likelihood profiles for the log of unfished recruitment ( $\log R_0$ ) parameter. Spawning output (top left), fraction unfished (top right), recruitment deviations (middle left), log-scale fit to WCGBTS index (middle right), log-scale fit to CalCOFI index (bottom left), and log-scale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

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

| Label                                         | $\log R_0=9.5$ | $\log R_0=9.75$ | $\log R_0=10$ | $\log R_0=10.25$ | $\log R_0=10.5$ | $\log R_0=10.75$ |
|-----------------------------------------------|----------------|-----------------|---------------|------------------|-----------------|------------------|
| N.Parms                                       | 106            | 106             | 106           | 106              | 106             | 106              |
| TOTAL                                         | 2638.20        | 2634.39         | 2633.07       | 2633.72          | 2635.82         | 2638.77          |
| Survey                                        | 30.541         | 29.307          | 29.216        | 29.986           | 31.318          | 32.907           |
| Length_comp                                   | 569.843        | 569.091         | 569.205       | 570.272          | 572.219         | 574.874          |
| Age_comp                                      | 2012.20        | 2011.76         | 2011.16       | 2010.31          | 2009.19         | 2007.81          |
| Recruitment                                   | 25.490         | 24.226          | 23.466        | 23.050           | 22.851          | 22.773           |
| Parm_priors                                   | 0.116          | 0.008           | 0.017         | 0.105            | 0.240           | 0.393            |
| NatM_uniform_Fem_GP_1                         | 0.133          | 0.148           | 0.163         | 0.178            | 0.191           | 0.203            |
| L_at_Amax_Fem_GP_1                            | 47.912         | 47.907          | 47.901        | 47.898           | 47.898          | 47.901           |
| VonBert_K_Fem_GP_1                            | 0.198          | 0.197           | 0.197         | 0.197            | 0.196           | 0.196            |
| CV_young_Fem_GP_1                             | 0.106          | 0.105           | 0.105         | 0.105            | 0.105           | 0.105            |
| CV_old_Fem_GP_1                               | 0.038          | 0.038           | 0.039         | 0.039            | 0.039           | 0.039            |
| NatM_uniform_Mal_GP_1                         | 0.362          | 0.313           | 0.271         | 0.235            | 0.206           | 0.182            |
| L_at_Amax_Mal_GP_1                            | -0.326         | -0.327          | -0.328        | -0.329           | -0.329          | -0.329           |
| VonBert_K_Mal_GP_1                            | 0.526          | 0.526           | 0.526         | 0.526            | 0.525           | 0.524            |
| CV_young_Mal_GP_1                             | 0.236          | 0.236           | 0.236         | 0.236            | 0.236           | 0.236            |
| SR_LN(R0)                                     | 9.500          | 9.750           | 10.000        | 10.250           | 10.500          | 10.750           |
| Q_extraSD_CalCOFI_Survey(11)                  | 0.312          | 0.330           | 0.352         | 0.376            | 0.399           | 0.420            |
| Size_DbIN_peak_NoCA_HKL(1)                    | 40.926         | 40.991          | 40.982        | 40.862           | 40.626          | 40.290           |
| Size_DbIN_ascend_se_NoCA_HKL(1)               | 4.430          | 4.419           | 4.402         | 4.375            | 4.337           | 4.292            |
| Size_DbIN_peak_SoCA_HKL(2)                    | 23.695         | 23.744          | 23.793        | 23.839           | 23.879          | 23.912           |
| Size_DbIN_peak_CA_TWL(3)                      | 44.611         | 44.736          | 44.885        | 45.036           | 45.169          | 45.266           |
| Size_DbIN_ascend_se_CA_TWL(3)                 | 4.569          | 4.561           | 4.557         | 4.555            | 4.554           | 4.554            |
| Size_DbIN_peak_OR_WA_Comm(4)                  | 41.566         | 42.074          | 42.664        | 43.362           | 44.190          | 45.115           |
| Size_DbIN_ascend_se_OR_WA_Comm(4)             | 4.474          | 4.509           | 4.552         | 4.608            | 4.679           | 4.759            |
| Size_DbIN_peak_CA_NET(5)                      | 47.167         | 47.095          | 47.005        | 46.880           | 46.715          | 46.514           |
| Size_DbIN_ascend_se_CA_NET(5)                 | 4.456          | 4.442           | 4.428         | 4.412            | 4.397           | 4.381            |
| Size_DbIN_peak_NoCA_OR_WA_Rec(6)              | 43.343         | 43.624          | 43.867        | 44.046           | 44.131          | 44.102           |
| Size_DbIN_ascend_se_NoCA_OR_WA_Rec(6)         | 5.143          | 5.141           | 5.137         | 5.130            | 5.120           | 5.106            |
| Size_DbIN_peak_SoCA_Rec(7)                    | 24.543         | 24.621          | 24.698        | 24.772           | 24.836          | 24.889           |
| Size_DbIN_ascend_se_SoCA_Rec(7)               | 2.894          | 2.908           | 2.922         | 2.935            | 2.946           | 2.955            |
| Size_DbIN_descend_se_SoCA_Rec(7)              | 3.407          | 3.369           | 3.324         | 3.277            | 3.234           | 3.199            |
| Size_DbIN_end_logit_SoCA_Rec(7)               | -1.322         | -1.222          | -1.124        | -1.034           | -0.957          | -0.898           |
| Size_DbIN_peak_TWL_discard(8)                 | 29.300         | 29.421          | 29.537        | 29.651           | 29.747          | 29.822           |
| Size_DbIN_ascend_se_TWL_discard(8)            | 4.156          | 4.161           | 4.166         | 4.171            | 4.174           | 4.176            |
| Size_DbIN_descend_se_TWL_discard(8)           | 3.220          | 3.208           | 3.195         | 3.180            | 3.167           | 3.156            |
| Size_DbIN_peak_NoCA_HKL(1)_BLK1repl_1875      | 51.846         | 51.722          | 51.617        | 51.509           | 51.403          | 51.283           |
| Size_DbIN_ascend_se_NoCA_HKL(1)_BLK1repl_1875 | 4.183          | 4.170           | 4.158         | 4.147            | 4.137           | 4.128            |
| Size_DbIN_peak_SoCA_HKL(2)_BLK2repl_1875      | 49.115         | 48.999          | 48.853        | 48.637           | 48.389          | 48.128           |
| Size_DbIN_ascend_se_SoCA_HKL(2)_BLK2repl_1875 | 4.869          | 4.848           | 4.827         | 4.803            | 4.780           | 4.761            |
| Size_DbIN_peak_CA_TWL(3)_BLK3repl_1875        | 33.381         | 33.556          | 33.770        | 33.911           | 33.975          | 33.957           |
| Size_DbIN_ascend_se_CA_TWL(3)_BLK3repl_1875   | 3.213          | 3.244           | 3.286         | 3.309            | 3.314           | 3.302            |
| Size_DbIN_peak_SoCA_Rec(7)_BLK2repl_1875      | 30.446         | 30.547          | 30.663        | 30.776           | 30.877          | 30.952           |
| Size_DbIN_ascend_se_SoCA_Rec(7)_BLK2repl_1875 | 3.730          | 3.739           | 3.750         | 3.761            | 3.770           | 3.774            |
| Bratio_2025                                   | 0.601          | 0.717           | 0.821         | 0.906            | 0.972           | 1.017            |
| SSB_unfished                                  | 10867          | 11247           | 11831         | 12688            | 13909           | 15634            |
| Totbio_unfished                               | 43340          | 46831           | 51376         | 57344            | 65206           | 75658            |
| Recr_unfished                                 | 13360          | 17154           | 22027         | 28283            | 36316           | 46630            |
| Dead_Catch_SPR                                | 1494           | 1753            | 2069          | 2460             | 2952            | 3581             |
| OFLCatch_2025                                 | 1876           | 2600            | 3491          | 4573             | 5877            | 7448             |

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish



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

### 17 - Panel Conclusion

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

### 18 - Request

Provide a decision table using steepness ( $h$ ) as the primary axis of uncertainty (low  $h = 0.38$ , high  $h = 0.97$ ), with the decision table based on the catch time series reflecting full attainment (=ACL) as required by the TOR and alternative catch projections based on constant catch at the MSY proxy yield (2114 t) to bracket the range of catch alternatives in the decision table. If possible, plot spawning output, fraction unfished, age 3+ biomass (t), and relative fishing intensity  $(1-SPR)/(1-SPR_{50\%})$  with management reference points (where appropriate). Please provide this in the post-STAR assessment document and to the STAR Panel, if possible, for inclusion in the STAR Panel report.

These outputs are necessary to satisfy the Terms of Reference.

### 18 - Rationale

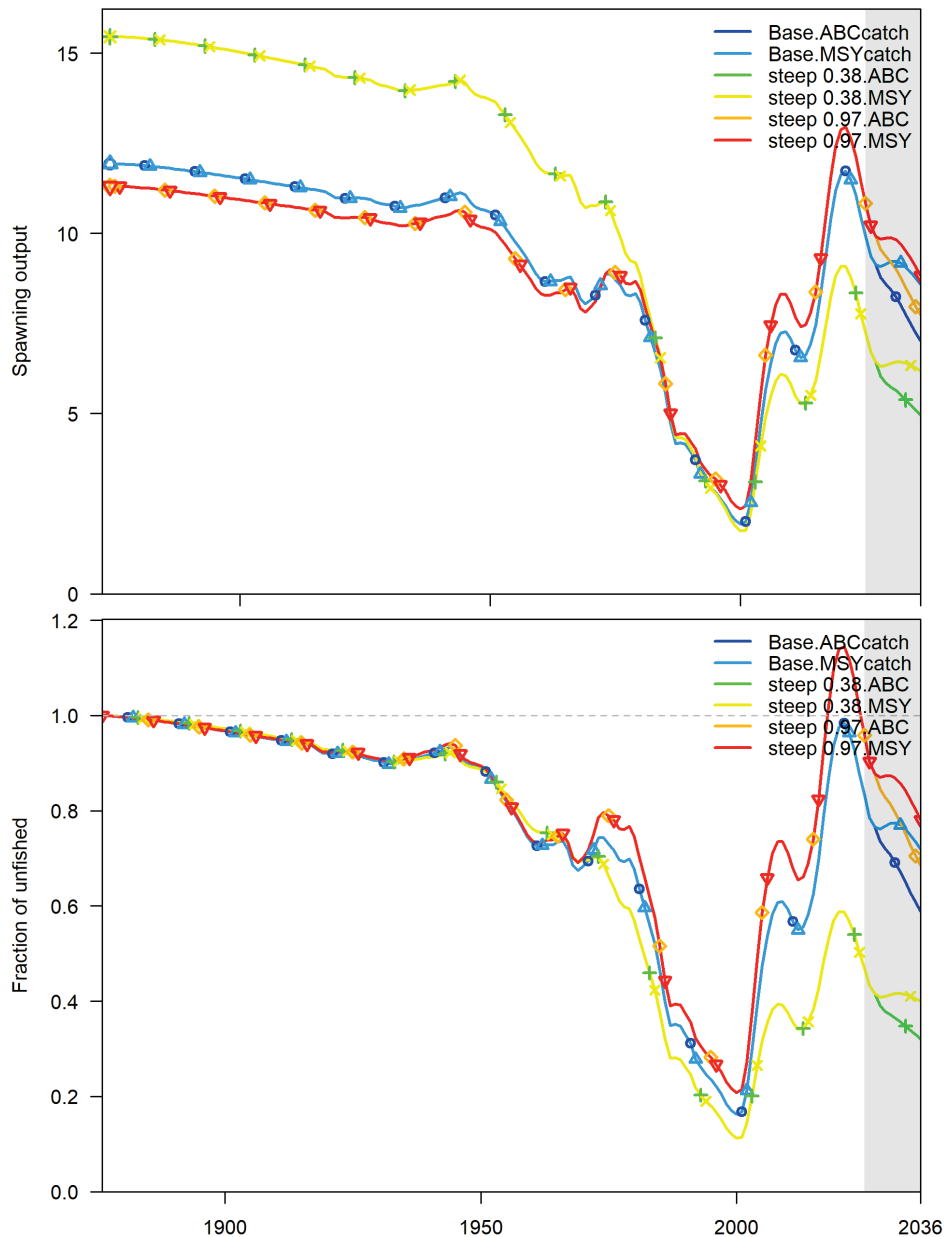
A few possible options for the axis of uncertainty were considered. However, it quickly became clear that the most appropriate axis of uncertainty was the Beverton-Holt steepness parameter ( $h$ ). The low value of  $h$  (0.38) was based on the model estimate of steepness and the high value of  $h$ 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

### 18 - STAT Response



## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

Runs with the three states of nature were conducted: the proposed final base model with a fixed steepness of 0.72, a high state of nature with steepness 0.97, and a low state of nature with steepness 0.38. The two catch streams used were the equilibrium MSY estimate from the base model (2114 t) and the ABC catch stream from the base model (in which 2027 ABC is 3211 t and the 2036 ABC is 2431 t). Catch apportionments were identical to those used for the 2025-2026 forecasts. Estimated stock trajectories are shown as Fig. 18A. For all projections, spawning output and depletion estimates decline over the course of the 12 year projection (2025-2036). Declines accelerated in the ABC catch streams relative to the equilibrium MSY catch streams for each state of nature. The models that assume high steepness start closer to the estimated unfished level (approximately 95% of the unfished level in 2025) and decline less rapidly than the base model and models with low steepness. The only scenario where spawning output declines below target levels is the low steepness model combined with ABC catches, which suggests that depletion could decline to approximately 32% by 2036.

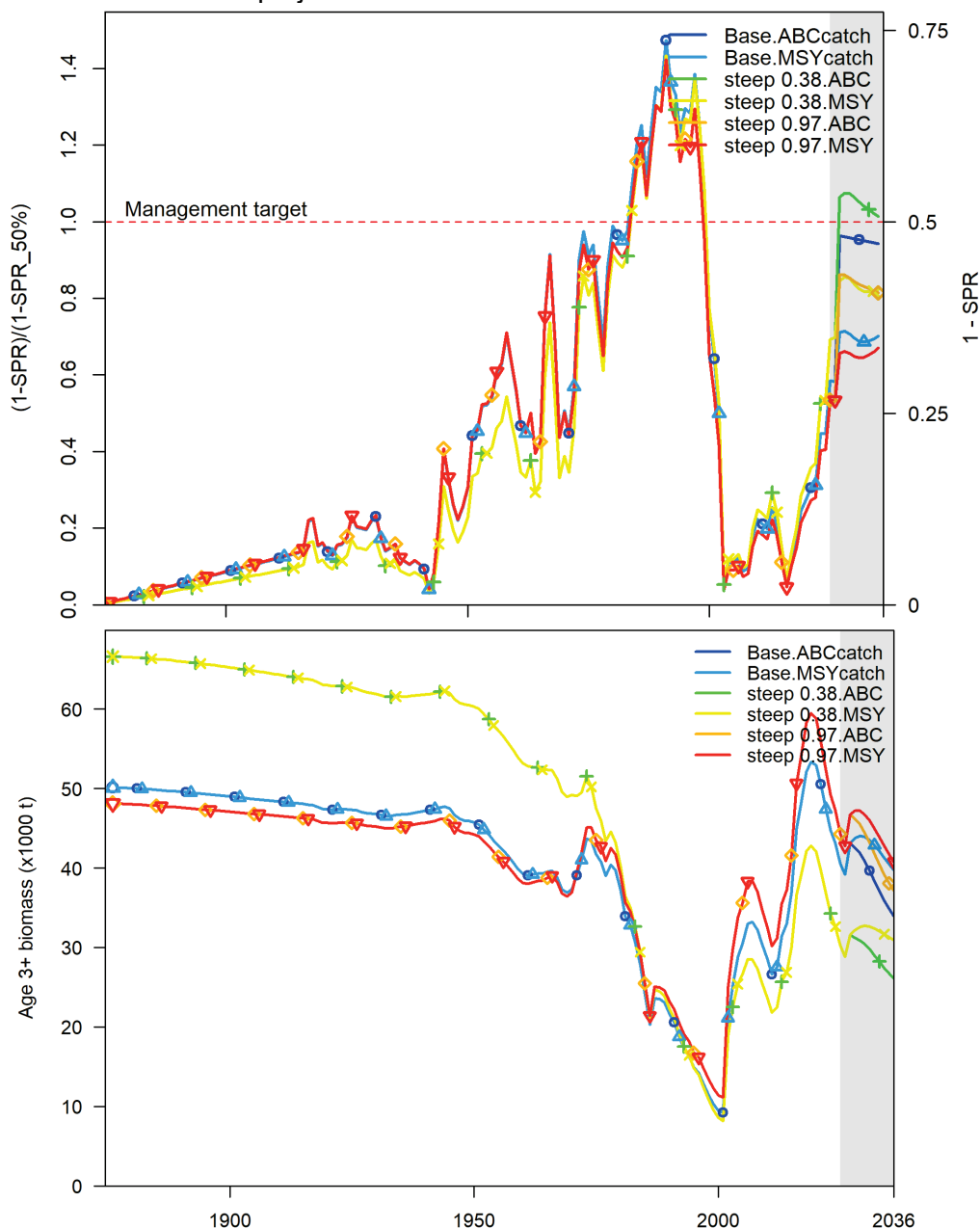


**Figures 18A.** Model estimates and 2025-2036 projections for: a) the base model ( $h = 0.72$ ), b) high state of nature ( $h = 0.97$ ), and c) low state of nature ( $h = 0.38$ ). Equilibrium MSY (2114 t)



## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

and the ABC catch stream ( $ABC_{2027} = 3211$  t and  $ABC_{2036} = 2431$  t) from the base model represent the basis for catch projections in each state of nature.



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

## Stock Assessment Review (STAR) Panel for Chilipepper Rockfish

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

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

### 18 - Panel Conclusion

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