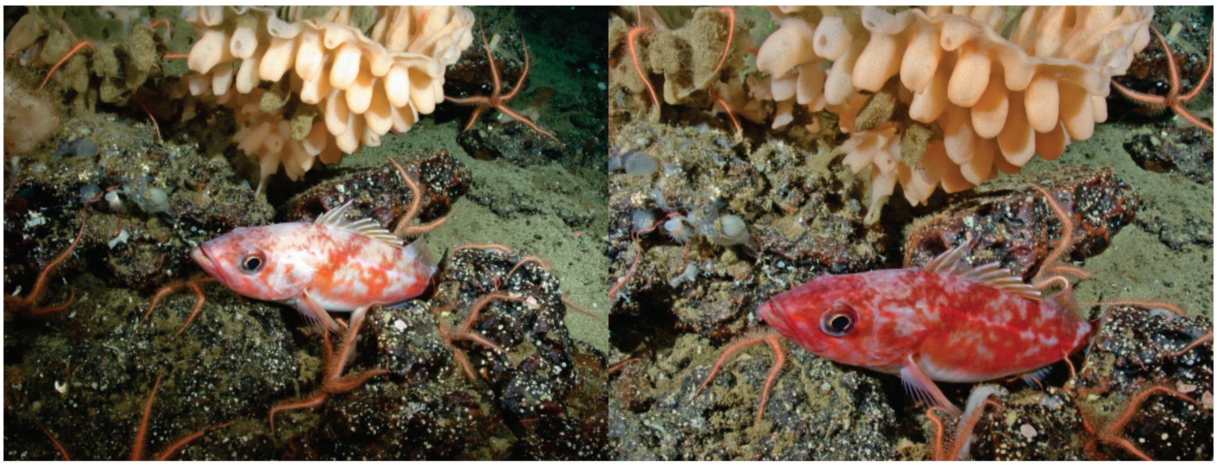
The Status of Chilipepper Rockfish (*Sebastes goodei*) in U.S. Waters off California, Oregon, and Washington in 2025

DRAFT REPORT, June 9, 2025



Report Prepared by E.J. Dick[1,*], John C. Field[1], Nicholas Grunloh[2,1], and Tanya Rogers[1].
[*] Corresponding author: edward.dick@noaa.gov

[1] 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
[2] University of California, Santa Cruz, Cooperative Institute for Marine, Earth, and Atmospheric Systems, 1156 High Street, Santa Cruz, CA 95064, USA

U.S. Department of Commerce
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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*."

DISCLAIMER

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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
CCFRP: California Collaborative Fisheries Research Program
CDFW (formerly CDFG): California Department of Fish and Wildlife (formerly Fish and Game)
CPAH: Catch-per-angler-hour
CPFV: Commercial Passenger Fishing Vessel (aka "party" or "charter" boats, or "PC mode")
CPUE: Catch-per-unit-effort
CRFS: California Recreational Fisheries Survey
GMT: Groundfish Management Team of the PFMC
MRFSS: Marine Recreational Fisheries Statistics Survey
MSST: Minimum Stock Size Threshold (25% of unfished biomass 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
PISCO: Partnership for the Interdisciplinary Study of Coastal Oceans
PR: Private/Rental recreational boat (aka private boat or "skiff")
PSMFC: Pacific States Marine Fisheries Commission
RecFIN: Recreational Fisheries Information Network
RREAS: The NMFS SWFSC's Rockfish Recruitment and Ecosystem Assessment Survey
SPR: Spawning Potential Ratio
SSC: Scientific and Statistical Committee of the PFMC
STAR: Stock Assessment Review (Panel)
STAT: Stock Assessment Team
SWFSC: Southwest Fisheries Science Center
WCGOP: West Coast Groundfish Observer Program
WDFW: Washington Department of Fish and Wildlife
YOY: Young-of-the-year

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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 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, 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.).

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 at roughly 20% of total mortality. 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 model area. HKL = hook and line, TWL = trawl, Comm. = all commercial gears, Rec. = recreational, and Pt. Conc. = Point Conception, CA.

Year	North CA HKL	South CA HKL	CA_TWL	OR + WA Comm.	CA Net	Rec. N. of Pt. Conc.	Rec. S. of Pt. Conc.	TWL discard	Total 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

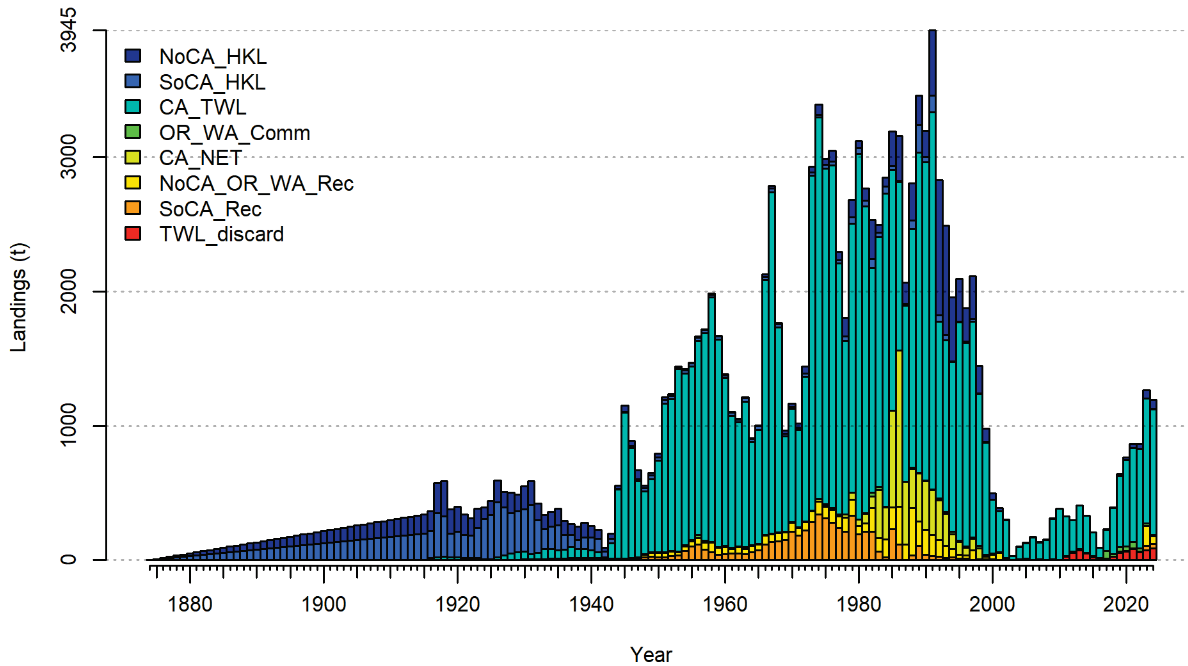

Figure a. Estimated coastwide landings (mt) of chilipepper rockfish, 1875-2024, by model fleet. Discarded dead catch from trawl gears is modeled as a separate fleet to account for differences in size composition between retained and discarded catch.

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. Another catch-only projection based on the 2017 update was completed in 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 separates some fishing fleets by gear alone, 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 twelve fleets (8 fishing fleets and 4 "survey" fleets), and is informed by four, 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).

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). Dead recreational discards were combined with retained catch and not modeled separately 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 is evidence of time-varying growth (see Appendix A by Nick Grunloh), sensitivity analyses did not find that changes in growth significantly affect estimated population dynamics over the modeled time period, and subsequently 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 many 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. The 2023 catch projection estimated spawning output to be at 74% of unfished levels in 2023. The current assessment similarly estimates that relative spawning output ("depletion") in 2023 was between 47% and 92% of the unfished equilibrium level, with a slightly lower point estimate of 69% (Table b). Spawning output in 2025 is centered around 8.4 trillion eggs (~95% asymptotic interval: 5.1-11.7 trillion). Relative to the updated unfished level, this places the stock above the target with high probability, at roughly 60% 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 39% - 81% in 2025 (Table b).

Chilipepper spawning output estimates declined from unfished levels until about 2000 (Figure b), 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. Subsequent increases in estimated chilipepper biomass resulted from a combination of reduced fishing pressure and 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	7236	4524	9948	0.519	0.357	0.681
2016	7976	4999	10953	0.572	0.394	0.750
2017	8873	5588	12158	0.636	0.440	0.833
2018	9670	6109	13230	0.693	0.480	0.907
2019	10256	6491	14020	0.735	0.508	0.962
2020	10528	6658	14399	0.755	0.520	0.990
2021	10479	6609	14349	0.751	0.515	0.988
2022	10144	6367	13921	0.727	0.495	0.960
2023	9644	6012	13275	0.692	0.466	0.917
2024	8999	5520	12478	0.645	0.427	0.863
2025	8402	5063	11741	0.603	0.392	0.813

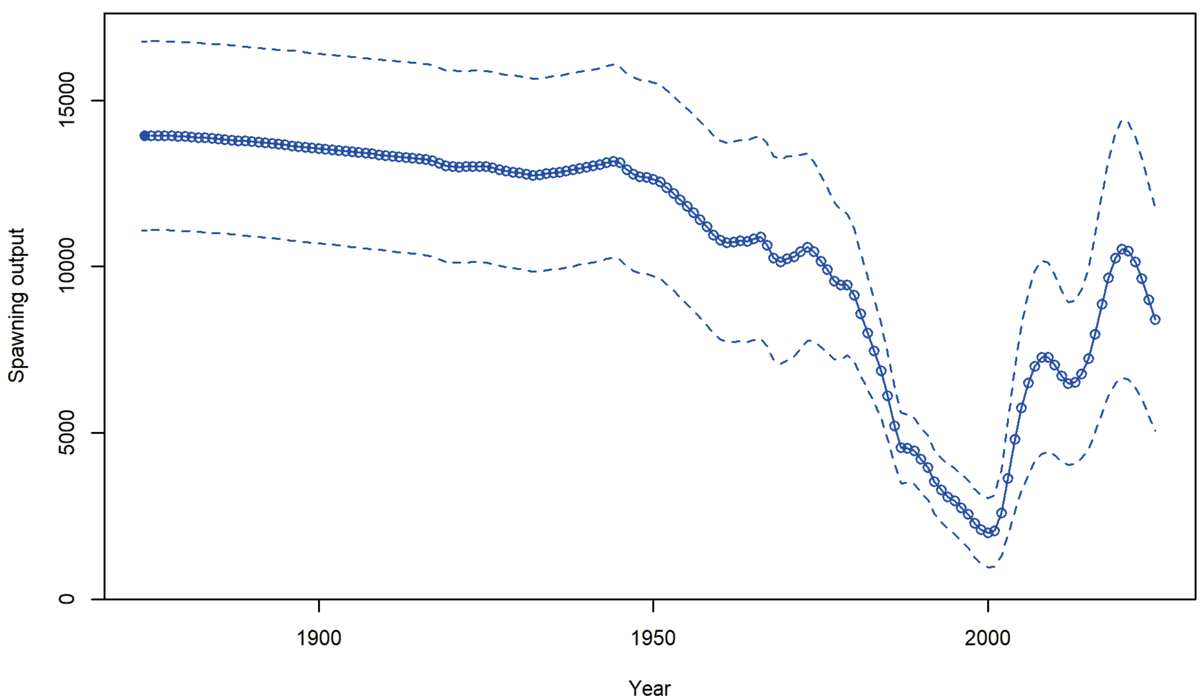

Figure b. Time series of estimated spawning output (trillions of eggs) for the 2025 chilipepper rockfish model. Shaded area represents the 95% asymptotic confidence interval.

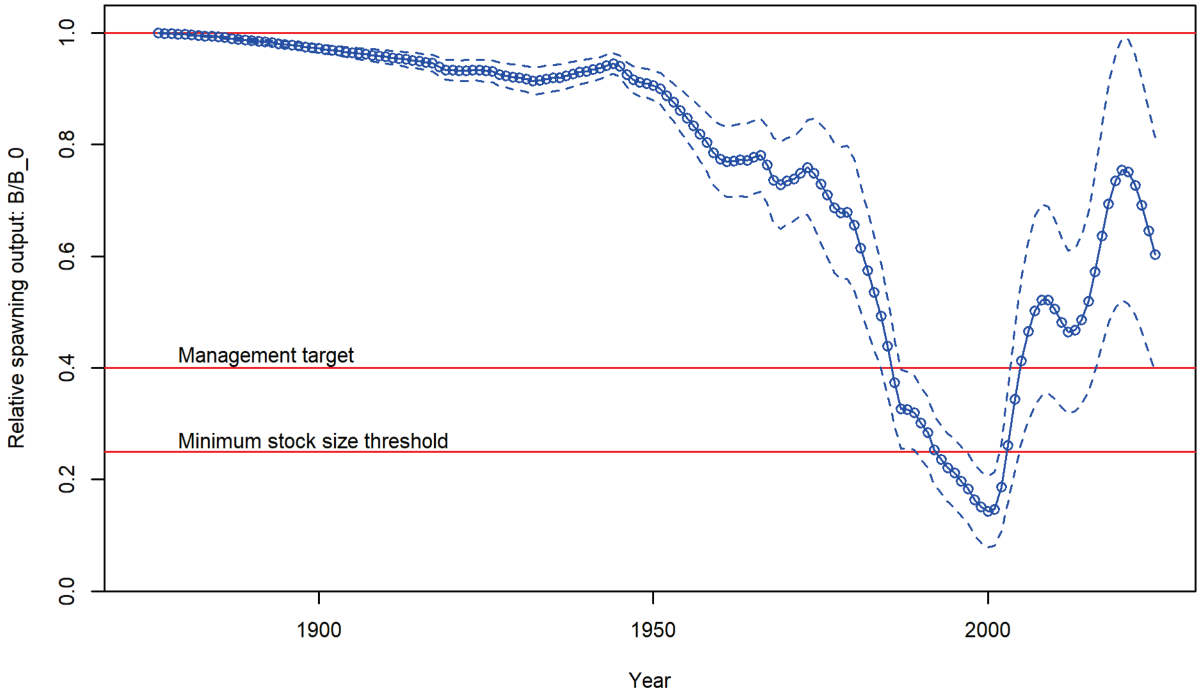

Figure c. Spawning output relative to unfished spawning output chilipepper rockfish, 1875-2024. The target level of spawning output (40% of unfished) and minimum stock size threshold (25% of unfished) are shown as horizontal lines for reference.

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).

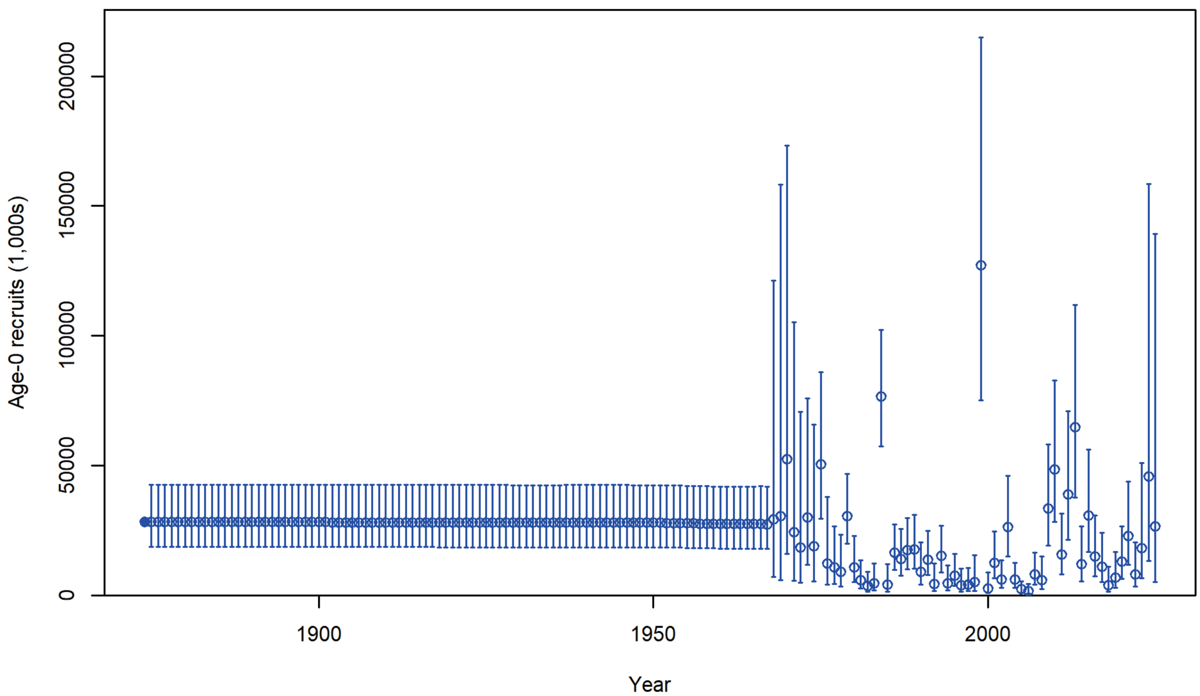

Figure d. Time series of estimated recruitment (1000's of age-0 fish) in the chilipepper base model.

Table c. Estimated recent trend in recruitment (1,000s) and recruitment deviations with 95 percent intervals for the model area.

Year	Recruitment (1,000s)	Lower Interval	Upper Interval	Recruitment Deviations	Lower Interval	Upper Interval
2015	30693	16782	56136	0.600	0.111	1.089
2016	15003	7307	30802	-0.132	-0.780	0.516
2017	10922	4968	24011	-0.465	-1.204	0.273
2018	3874	1381	10867	-1.514	-2.559	-0.469
2019	6756	2751	16590	-0.965	-1.843	-0.087
2020	12856	6229	26535	-0.325	-0.997	0.346
2021	22763	11824	43823	0.247	-0.340	0.834
2022	8107	3228	20365	-0.782	-1.692	0.129
2023	18248	6545	50872	-0.008	-1.052	1.036
2024	45831	13242	158623	0.730	-0.599	2.058
2025	26515	5050	139207	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-1980sthrough 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).

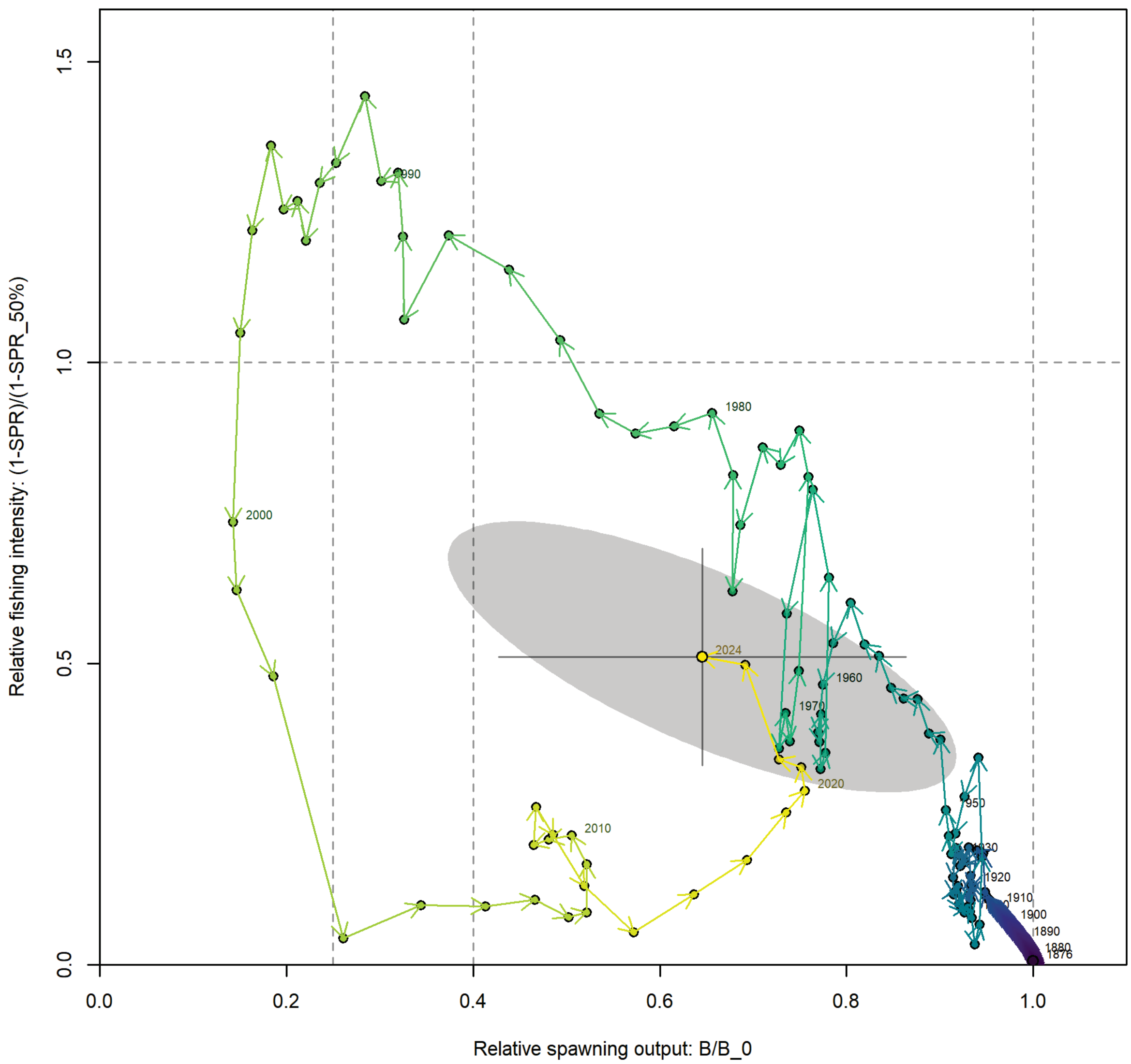

Figure e. “Phase” plot illustrating the rate of fishing intensity relative to the target level (vertical axis) versus the annual spawning output of the stock relative to target level, 1875-2024.

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 lower and upper intervals for each quantity are based on 95% asymptotic confidence intervals.

Year	(1-SPR)/ (1-SPR 50%)	Lower Interval	Upper Interval	Exploitation Rate	Lower Interval	Upper Interval
2015	0.131	0.076	0.185	0.006	0.004	0.008
2016	0.054	0.030	0.077	0.002	0.001	0.003
2017	0.117	0.067	0.166	0.005	0.003	0.007
2018	0.173	0.102	0.244	0.008	0.005	0.011
2019	0.253	0.153	0.352	0.013	0.008	0.018
2020	0.289	0.177	0.400	0.016	0.010	0.022
2021	0.328	0.204	0.453	0.019	0.012	0.027
2022	0.341	0.212	0.470	0.021	0.013	0.029
2023	0.498	0.323	0.672	0.033	0.020	0.045
2024	0.511	0.331	0.691	0.033	0.020	0.045

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 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 60% of unfished spawning output in 2025 (95% asymptotic confidence interval: 39% - 81%). Long-term equilibrium yield based on SPR proxy harvest rates is 2509 mt coastwide (95% asymptotic confidence interval: 1719 – 3298 mt), compared to 2650 mt based on the SB40% proxy and 2893 mt based on the assumed stock-recruitment relationship with steepness fixed at 0.72.

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

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output (billions of eggs)	13,945	11,106	16,784
Unfished Age 3+ Biomass (mt)	58,706	45,124	72,288
Unfished Recruitment (R0, 1000s)	28,215	16,402	40,029
Spawning Output (2025, billions of eggs)	8,402	5,063	11,741
Fraction Unfished (2025)	0.603	0.392	0.813
Reference Points Based SB40%			
Proxy Spawning Output SB40%	5,578	4,442	6,714
SPR Resulting in SB40%	0.458	0.458	0.458
Exploitation Rate Resulting in SB40%	0.090	0.081	0.099
Yield with SPR Based on SB40% (mt)	2,650	1,814	3,487
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Output (SPR50)	6,222	4,955	7,488
SPR50	0.5	--	--
Exploitation Rate Corresponding to SPR50	0.078	0.070	0.086
Yield with SPR50 at SB SPR (mt)	2,509	1,719	3,298
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY (SB MSY)	3,515	2,808	4,221
SPR MSY	0.325	0.319	0.330
Exploitation Rate Corresponding to SPR MSY	0.140	0.125	0.155
MSY (mt)	2,893	1,970	3,817

Management performance

Total coastwide mortality estimates for chilipepper rockfish are well below the Annual Catch Limit in recent years (Table f). The Groundfish Expanded Mortality Multiyear (GEMM) report contains estimates for coastwide mortality, so actual mortality south of 40 10 N. latitude is slightly lower.

Table f. 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

Unresolved problems and major uncertainties

- The available data are not informative about the steepness parameter (*h*) of the assumed Beverton-Holt stock recruitment relationship. 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 (~0.4), but likelihood profiles indicate that the model can't effectively discriminate between a wide range of steepness values.
- 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 fits to 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. Further investigation into data errors and/or model misspecification is warranted.
- 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.

Decision table and harvest projections

[Pending STAR Panel Review: Alternative states of nature identified during the STAR panel were used to forecast population dynamics for the coastwide stock assuming low, medium, and high catch projections (Table g).] Catch projections for 2025-2026 and fleet allocations for 2027-2036 were provided for each area and fleet by representatives on the GMT (Table h).

Table g. **[DUE AFTER STAR PANEL]** 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 corresponding to the forecast catches from each state of nature. Spawning output units are billions of eggs. Catches in 2027-2036 assume full attainment of the ACL as forecast by the 2025 assessment.

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 Pstar = 0.45).

Year	Predicted OFL (mt)	ABC (mt)	Age 3+ Biomass (mt)	Spawning output	Fraction Unfished
2025	2894.4	1598.7	33819	8402	0.603
2026	2679.2	1521.6	31810	7760	0.556
2027	2586.2	2418.1	33232	7348	0.527
2028	2504.5	2329.2	33139	6972	0.500
2029	2498.6	2313.7	33351	6816	0.489
2030	2540.4	2342.2	33633	6772	0.486
2031	2595.5	2380.1	33859	6774	0.486
2032	2640.6	2410.9	33998	6785	0.487
2033	2668.0	2425.2	34058	6790	0.487
2034	2680.6	2423.2	34070	6788	0.487
2035	2684.9	2416.4	34059	6781	0.486
2036	2685.0	2405.7	34042	6772	0.486

Research and data needs

- 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_∞).
- 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).
- 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.

- 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.
- 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.
- 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.

Scientific uncertainty

The base model’s estimate of the log-scale standard deviation of the overfishing limit (OFL) in 2025 is 0.232. This is less than the default SSC value of 0.5 for a category 1 assessment, so harvest projections assume an initial sigma of 0.5.

Risk Table

For chilipepper, there is a considerable body of literature, from 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, 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 early life 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 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 (see section 4.3.1). Thus, environmental information is consistent with estimates of above average 2024 recruitment in the base model, as well as with the expectation of above average recruitment for the 2025 year class (Table i).

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 a favorable ranking, Level 2 is neutral and Level 3 is unfavorable

Ecosystem and environmental conditions	Assessment data inputs	Assessment model fits and structural uncertainty
Larval production: Based on 2024- 2025 environmental conditions, neutral to unfavorable. Recruitment: 2024 pelagic YOY abundance high for chilipepper (index in model), with diverse pelagic YOY groundfish community (not in model). 2025 environmental conditions are favorable (good spiciness), as are preliminary RREAS catches. Overall, favorable conditions for recruitment. Prey: Most evidence suggests abundant forage, favorable conditions, positive. Predators: Ongoing long-term increases in abundance, but no evidence of recent sharp increases, neutral. Growth: Neutral (recent years) to potentially unfavorable in near term (based on autocorrelation in growth variability).	Historically and currently among most important commercial species in California, catch reconstruction and recent catch data are reliable Robust age data to inform assessment, good fits to age and length composition data. Modest aging error concerns need resolution Robust information on reproductive ecology, but some uncertainty in role of multiple brooding Long term time series (CalCOFI) is noisy but provides a “low frequency” signal, WCGBTS index is reasonably well fit in most years Index of pelagic juvenile abundance provides information on incoming recruitment	TO BE COMPLETED FOLLOWING THE STAR PANEL
Level 1	Level 1	

1 Introduction

1.1 Basic Information

Chilipepper rockfish (*Sebastes goodei*) are a mid-size, semipelagic 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 2009). 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.

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.

Their distribution is generally described as ranging from Queen Charlotte Sound in British Columbia to Bahia Magdalena in Baja California Sur (Westrheim 1965; Eschmeyer 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 ongoing stock definition recommendations of the PFMC (PFMC 2025; EJ I'll get details and exact cite for that document). 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 Choice of stock structure

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 one 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 2009; Butler et al. 2011). 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 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 1949).

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 19980s, 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 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 40º10’ 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.

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 Conservations 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.

Table 1 compares the OFL, ABC, and ACL for chilipepper south of Cape Mendocino to estimates of total mortality from the GEMM report.

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 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 data have not been evaluated to ascertain whether chilipepper remain a significant fraction of the rockfish community in this region.

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 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 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 in Oregon and Washington makes up a small fraction of total recreational landings. Recreational landings 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).

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.

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. 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. 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.

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 14) and port complex (Figure 15) 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. 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, samples 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 MRFS 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 8). 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/JRWToolBox) 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 the 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 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 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 approximate 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.

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 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 21, model diagnostics are provided as Figure 22 and a map of the spatial residuals to the model fit is provided as Figure 23.

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 2017) 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 California halibut (unpublished). 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.

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 analysis, we used only tow types C1 (CalCOFI One Meter Oblique Tow, 0.8 m^2 mouth area, 1-m diameter) and CB (CalCOFI Oblique Bongo Tow, 0.4 m^2 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 <= 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 <= 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 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 24 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 25), 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 26).

Predictions were made to a grid of 74 standard CalCOFI stations (lines 60 to 93.3 and station <= 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 27, Figure 28). The same model was also used to generate regional (southern, central) indices (), by summing together the predictions for just the central area stations (line<76.7) or southern area stations (line>=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. 2017), 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 30), 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, dharma quantile residuals from model simulations suggested that Tweedie distribution was the best (Figure 31), 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 32, Figure 33). 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 32, same as the other coastwide indices generated), and once using historical data back to 1984 (Figure 34, Figure 35; 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).

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 know issues with that year, but in other years samples sizes were in the 1000s of fish (Table 6, Figure 36). Length compositions from the WCGBTS were available for all years from 2003-2024, with the exception of 2020 (Table 7, Figure 37). 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 using FT-NIRS methods (see section). 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. As a result of some confusion over the nature of the re-aged structures, the four years of re-aged triennial survey age data were inadvertently left out of the current base model. However, prior to the review panel, the STAT will add these data to the current pre-STAR base model and provide an updated analysis of the extent to which they may or may not alter or influence the model results.

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%).

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 Amax and M. They recommend a prior defined as a lognormal distribution with median 5.4/Amax, 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).

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 (**Error! Reference source not found.**) 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.

The base model assumes constant growth, and models with variable growth are evaluated as sensitivities. Known issues with reference point calculations are being resolved for models with time-varying biology in Stock Synthesis, and future assessments may wish to revisit the inclusion of time-varying growth.

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 38), but this has little effect as it is roughly equivalent to changing the (arbitrary) units of spawning output in the model. Estimates of biomass, recruitment, yield, and depletion show little difference as a result of the change.

2.4.3 Maturity

Maturity was updated for the 2015 update assessment (Field et al. 2015) based on the results of Beyer et al. (2015). The 2025 model uses the same estimates for maturity-at-length (Figure 39).

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). We account for this by multiplying the "brood" fecundity-length relationship from Dick et al. (2017) by a factor of 1 + Pr{multiple brooding | length}, and approximating total annual fecundity (assuming at most 2 broods per year) using a fitted power function (Figure 40). S. Beyer (AFSC) provided updated estimates of Pr{multiple brooding | 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 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 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).

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 41), 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 42.

CDFW Onboard CPFV Observer Index, 1999-2024

A database of California onboard CPFV observer data spanning the years 1999-2024 is described by Monk et al. (2014). Due to large-scale spatial closures over multiple decades, this index was not included in the model, but should be revisited in future assessments if recreational fisheries retain 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.

3 Assessment Model

3.1 History of Modeling Approaches Used for this Stock

The first assessment for chilipepper was developed 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).

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 F35% 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 data base, 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 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 43) 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 WCGBTS (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 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
- Applied recruitment bias adjustment following Methot and Taylor (2011) to reduce bias in estimate of initial biomass
- No constraint forcing recruitment deviations to sum to zero
- Use of conditional age-at-length compositions
- Use of the CalCOFI ichthyoplankton survey data as an index of spawning output

- Constant adult growth over time (length-at-age; still estimated within the model)
- Removal of fishery-dependent indices of abundance
- "Fleets as areas" approach for commercial hook & line fleets, recreational fishery, separation of California trawl and Oregon commercial fleets
- Addition of trawl discard fleet to account for size differences in retained vs. discarded fish
- Increase in maximum age and length bins ("plus groups")
- Revised priors for natural mortality and steepness
- Updated ageing error matrices
- Added bycatch from the at-sea hake fishery
- Revised fecundity-at-length and weight-at-length relationships

3.3.2 Modeling Platform and Structure

The assessment is structured as a single, sex-disaggregated population, spanning U.S. waters between the US/Mexico border to the US/Canada border. The assessment 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. 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 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 catch was 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 (λ=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 λ=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 PFMC 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 114 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 WCGBTS 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.

Additive variance parameters were estimated for the CalCOFI index and RREAS index, but not the trawl surveys. 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.

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 WCGBTS have changed the magnitude of relative biomass estimates in early years of the index (Figure 44). 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 current 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 114 parameters were estimated in the model, 57 of which were recruitment parameters, 30 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. The point estimate of natural mortality for females (M_female = 0.171 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 (0.261), producing an estimate of male M = 0.222 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 R0 = 10.248), 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. The method of Methot and Taylor (2011) was used to estimate annual variation in bias correction factor (Figure 49).

Selectivity curves estimates for many fleets were domed in the terminal year (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. 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).

Fits to abundance indices (both arithmetic- and log-scale) are shown in Figure 68 through Figure 71. 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). 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 8.4 trillion eggs in 2025 (~95% asymptotic interval: 5.1-11.7; Table 11), which equates to a "depletion" level of 60% (~95% asymptotic interval: 39%-81%) 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 2509 mt (~95% asymptotic interval: 1719-3298). 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 parameters were hit the bounds (min or max), and the gradient of the base model was effectively zero after using the -hess_step option. The –hess_step run reported the following:

```
The 2 Hessian step(s) reduced maxgrad from 0.000998536 to 0 and NLL by 4.22642e-09.
All output files should be updated, but confirm as this is experimental still.
The fact this was successful gives strong evidence of convergence to a mode
with quadratic log-likelihood surface.
Iterations: 920
```

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 (2597.98). 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 8.5 to 11.5 showed a minimum for the total negative log-likelihood (NLL) around 10.25, with better fits to age data overall at larger sizes, but a univariate profile interval of roughly 9.9 to10.6 (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 between 0.15 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 between 0.4 and 0.5, but values between 0.3 and roughly 0.75 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 over all 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 well within 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.

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 WCGBTS 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)
- Estimation of all growth parameters

We evaluated the uncertainty associated with each of the primary data sources, as well as with alternative weighting schemes for compositional data. Figure 81 shows model results (spawning output, depletion and recruitment) when each of the primary survey indices were sequentially removed from the model. In the case of the triennial and WCGBTS, this included the associated compositional (age and length) data, however for the WCGBTS we also evaluated the sensitivity of only removing the index and leaving the compositional data in the model, given the importance of the age composition data for informing growth (most of the fisheries dependent age data does not include smaller, younger individuals). The greatest changes were observed with the removal of the CalCOFI and the WCGBTS data (Table 18). The removal of CalCOFI data which resulted in a considerably more optimistic estimate of relative abundance over the past two decades, without this index relative abundance is estimated to have briefly surpassed the unfished level around 2020. This reflects the considerable value of having both historical and recent estimates of larval production (albeit rather noisy ones) prior to the major impacts of fishing on total abundance in the 1980s and 1990s. The removal of the WCGBTS data (both with and without the compositional data) resulted in a more pessimistic estimate of relative stock status between approximately 2000 and 2015, but a slightly more optimistic estimate of stock status over the past 8-10 years. This was largely in response to changes in the relative strength of several very strong year classes; without the WCGBTS data the 1999 year-class was barely over half of what is estimated in the base model, while the 2013 year-class was nearly double what is estimated in the base model.

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.”; year) 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 1/20th 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 downweighted 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.

We also explored the sensitivity of the model to the inclusion of data sources used in the 2007 and 2015/2017 models, 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 the earlier models, 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. Given that the “leave one out” sensitivity analysis suggested that the more influential indices 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 how that would influence the model result. For the scenario in which the WCGBTS index was upweighted, the resulting abundance 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. This was a result of a relatively greater recruitment in 1999 and a substantial increase in the model estimated natural mortality rate (0.215 rather than 0.171 for female chilipepper). However, the terminal depletion estimate did not vary by more than a percentage point from that of the base model (0.60 in 2025). By contrast, when the CalCOFI index was upweighted, the model result was somewhat more pessimistic, with a downward scaling of abundance and recruitment and a considerably more pessimistic ending depletion value (0.45 rather than 0.60). The estimated natural mortality rate did not change.

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 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 (~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. Ultimately, attempts to implement the third approach (linking k to an externally estimated index) were not successful, as details of proper implementation in SS3 were unclear to the STAT at the time of writing. Comparing results from the models with annual deviations in k and constant k reveals similar trends in spawning output, depletion, and recruitment (Figure 84, Figure 85). Associated likelihood values (runs both used the 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.

We compared the 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 (Table 23). 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.

If the 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 20 points, mainly due to degraded fits to the age data (Table 24). Population scale with sex-invariant M is increased, and current stock status is slightly less depleted (Figure 88).

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 did not produce strong retrospective patterns, but all retrospective runs estimated slightly lower unfished spawning output and a slightly lower ending status, relative to the base model (Figure 87). Mohn's rho values were calculated using the r4ss function "SSmohnsrho" (Table 25).

3.6 Unresolved Problems and Major Uncertainties

- The available data are not informative about the steepness parameter (*h*) of the assumed Beverton-Holt stock recruitment relationship. 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 (~0.4), but likelihood profiles indicate that the model can't effectively discriminate between a wide range of steepness values.
- 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 fits to 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. Further investigation into data errors and/or model misspecification is warranted.

- 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.

4 Management

4.1 Reference Points

Chilipepper rockfish spawning output was estimated to be 8.4 trillion eggs in 2025 (~95% asymptotic interval: 5.1 - 11.7; Table 11), which equates to a "depletion" level of 60% (~95% asymptotic interval: 39%-81%) 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 89) is 2509 mt (~95% asymptotic interval: 1719-3298).

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.

A "decision table" that evaluates alternative management decision under alternative states of nature, given the model, will be completed during the STAR panel.

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) 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 (Table 27). For chilipepper, there is a considerable body of literature, from 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, 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 early life stages, are generally higher during these cooler environmental phases. Herein, we provide an overview of source-water variability as a potential driver of rockfish recruitment, and review environmental influences on each life stage 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 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 a potential mechanism 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. 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). 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. 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) is needed to evaluate connections between 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 chilipepper abundance and recruitment estimates from the 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 also influenced reproduction of adult rockfish at depth of their habitats, consistent with the results of Beyer et al. (2024).

Beyer et al. (2024) describe interannual variability in the reproductive output of four species of rockfish, including chilipepper, spanning between the mid-1980s and 2019. Results suggest 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). Further, 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). These results also provide strong evidence for environmental and bioenergetic drivers of interannual variability in reproductive output. 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 juvenile abundance may be more important than those associated with reproductive output. In the longer term, a better understanding of these dynamics may also help address the high interannual variance observed in the CalCOFI larval abundance index.
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 recent study based on larvae from the CalCOFI sampling program evaluated spatial and temporal variability in otolith core width at extrusion (parturition) found evidence of both maternal and environmental conditions for chilipepper, which were related to larval rockfish growth rate and survival (Fennie et al. 2024). Further, larval chilipepper rockfish growth rate during winter was related to source water variability within southern California the previous fall.

Juvenile growth, survival and recruitment dynamics

Similar to the recent published work on larval otolith growth and survival rates, 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 young-of-the-year 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 central California (35-37° N) have been among their “mintiest” (most subarctic) since 2015. 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 are also strong correlations (Spearman rho=-0.72 and -0.73, respectively; p<0.01), which would indicate that the 2025 year class should be expected to be well above average (Figure 90, Figure 91). However, 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. 2024) 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. (2024) used data through 1990-2023, the analysis was updated using 2024 survey data, and the results suggests 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 ongoing reports from the RREAS 2025 survey (105 mid-water trawls as of 6 June), 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 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.

Time-varying growth of adults

Time varying growth has been suggested or documented for several 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 von Bertalanffy 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), although it is not included 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), which might suggest that density dependent processes could be important. The observation of significant autocorrelation in the time-varying growth analysis could 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 WCGBTS (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.

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. Updated estimates of the relative abundance of chilipepper in each area could be derived from the WCGBT survey. The STAT will investigate this prior to the panel and report results at that time.

As noted earlier, 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.

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 since 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 (2019) 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

- 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_{∞}).
- 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).
- 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.
- 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.
- 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.
- 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.

5 Acknowledgements

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7 Auxiliary Files

Files archived with the 2025 chilipepper assessment

Chili_2025.ctl
Chili_2025.dat
forecast.ss
Report.sso
starter.ss
[r4ss html output and associated figures in ‘plots’ folder]

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 HKL	SoCA HKL	CA TWL	OR_WA Comm	CA NET	NoCA OR WA_Rec	SoCA Rec	TWL discard	Grand 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 HKL	SoCA HKL	CA TWL	OR_WA Comm	CA NET	NoCA OR WA_Rec	SoCA Rec	TWL discard	Grand Total
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 HKL	SoCA HKL	CA TWL	OR_WA Comm	CA NET	NoCA OR WA_Rec	SoCA Rec	TWL discard	Grand 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 Total	13953.7	11657.7	92960.6	624.1	5624.7	4685.1	5639.2	684.4	135829.5
% of 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.

	Commercial No. CA HKL		Commercial So. CA HKL		Commercial CA Trawl		Commercial Oregon		Commercial CA Net		WCGOP IFQ Trawl Discard		Recreational No. CA, OR, WA		Recreational So. CA	
Year	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
NoCA_HKL	1980	2	0	0	2
NoCA_HKL	1983	7	1	0	8
NoCA_HKL	1985	99	3	0	102
NoCA_HKL	1986	123	5	0	128
NoCA_HKL	1987	14	3	0	17
NoCA_HKL	1988	4	1	0	5
NoCA_HKL	1989	9	0	0	9
NoCA_HKL	1990	12	3	0	15
NoCA_HKL	1991	285	132	0	417
NoCA_HKL	1992	582	163	0	745
NoCA_HKL	1993	369	63	0	432
NoCA_HKL	1994	199	26	0	225
NoCA_HKL	1995	185	64	0	249
NoCA_HKL	1996	125	39	0	164
NoCA_HKL	1997	198	10	0	208
NoCA_HKL	1998	263	59	0	322
NoCA_HKL	1999	147	18	0	165
NoCA_HKL	2000	117	44	0	161
NoCA_HKL	2001	73	55	0	128
NoCA_HKL	2002	10	28	0	38
NoCA_HKL	2003	3	0	0	3
NoCA_HKL	2007	46	2	0	48
NoCA_HKL	2008	24	5	0	29
NoCA_HKL	2009	1	0	0	1
CA_TWL	1978	447	112	0	559
CA_TWL	1979	270	60	0	330
CA_TWL	1980	717	335	0	1052
CA_TWL	1981	475	224	0	699
CA_TWL	1982	825	392	0	1217
CA_TWL	1983	1721	581	0	2302
CA_TWL	1984	2539	1035	0	3574
CA_TWL	1985	2126	1145	0	3271
CA_TWL	1986	1285	712	0	1997
CA_TWL	1987	1638	880	0	2518
CA_TWL	1988	1472	938	0	2410
CA_TWL	1989	1631	924	0	2555
CA_TWL	1990	978	700	0	1678
CA_TWL	1991	962	636	0	1598
CA_TWL	1992	1363	714	0	2077
CA_TWL	1993	1325	680	0	2005
CA_TWL	1994	448	285	0	733
CA_TWL	1995	895	502	0	1397
CA_TWL	1996	455	343	0	798
CA_TWL	1997	1095	618	0	1713
CA_TWL	1998	1486	646	0	2132
CA_TWL	1999	1464	613	0	2077
CA_TWL	2000	707	288	0	995
CA_TWL	2001	448	318	0	766
CA_TWL	2002	729	294	0	1023
CA_TWL	2003	201	97	0	298
CA_TWL	2004	661	285	0	946
CA_TWL	2005	286	63	0	349
CA_TWL	2007	340	118	0	458
CA_TWL	2008	363	72	0	435
CA_TWL	2009	599	106	0	705
CA_TWL	2010	287	15	0	302
CA_TWL	2011	4	2	0	6
CA_TWL	2012	210	137	0	347
CA_TWL	2013	315	92	0	407
CA_TWL	2014	258	42	0	300
CA_TWL	2019	58	18	0	76
CA_TWL	2020	61	42	0	103
CA_TWL	2021	44	16	0	60
CA_TWL	2022	42	17	0	59
CA_TWL	2023	46	9	0	55
CA_TWL	2024	42	5	0	47
OR_WA_Comm	2019	33	7	0	40
OR_WA_Comm	2020	35	5	0	40
OR_WA_Comm	2021	36	4	0	40
OR_WA_Comm	2022	32	8	0	40
OR_WA_Comm	2023	34	6	0	40
OR_WA_Comm	2024	35	5	0	40
CA_NET	1983	64	4	0	68
CA_NET	1984	41	0	0	41
CA_NET	1985	218	46	0	264
CA_NET	1986	358	53	0	411
CA_NET	1987	328	38	0	366
CA_NET	1988	161	58	0	219
CA_NET	1989	273	41	0	314
CA_NET	1990	320	110	0	430
CA_NET	1991	74	22	0	96
CA_NET	1992	317	85	0	402
CA_NET	1993	158	29	0	187
CA_NET	1994	154	38	0	192
CA_NET	1995	59	1	0	60
CA_NET	1996	36	1	0	37
CA_NET	1997	58	5	0	63
CA_NET	1998	85	8	0	93
NoCA_OR_WA_Rec	2023	0	0	59	59
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>=60 & line<=93.3 & station<=80	20,390	3,148
Exclude years 1985-1990	19,052	3,147
Excluded lines <= 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 for fishery-independent surveys.

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	2004	340	291	0	631

Table 9: Summary of base model parameters.

	Number Estimated	Bounds (low, high)	Prior Distribution (Mean, SD) - Type	Point Estimate	Transformed Value	SE
Natural mortality (*M*) - *female*	1	(0.01, 0.5)	(-1.869, 0.31) - Lognormal	0.171		0.012
Nat. mortality (*M*) - *male (offset)*	1	(-0.5, 1)	-	0.261	0.222	0.043
Ln (R_0)	1	(8, 13)	-	10.248	28214.7	0.214
Steepness (*h*)	0	(0.201, 0.999)	(0.72, 0.16) - Full Beta	0.720		-
Length at age 0 - *female*	0	(5, 15)	-	7.300		-
Length at age 20 - *female*	1	(44, 52)	-	48.190		0.278
von Bertalnaffy k - f*emale*	1	(0.15, 0.25)	-	0.194		0.004
CV(L(age 0)) - *female*	0	(0.01, 0.2)	-	0.110		-
CV(L(age 20)) - *female*	1	(0.01, 0.15)	-	0.037		0.004
Length at age 0 - *male (offset)*	0	(-0.6, 0)	-	0.000	7.300	-
Length at age 20 - *male (offset)*	1	(-0.8, 0)	-	-0.337	34.388	0.011
von Bertalnaffy k - *male (offset)*	1	(0.2, 1)	-	0.549	0.335	0.041
CV(L(age 0)) - *male (offset)*	0	(-1, 1)	-	0.208	0.136	-
CV(L(age 20)) - *male (offset)*	1	(-1, 2)	-	0.148	0.043	0.194
Extra SD - CalCOFI	1	(0, 1)		0.313		0.075
Extra SD - RREAS	1	(0, 3)	-	1.233		0.238
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)	-	-2.290	2.372	1.005
Number of parameters in model	167					
Estimated parameters	114	(including 12 forecast devs)				
Number within 1% of bound	0					

Table 10: Log-scale catchability coefficients ('LnQ'), additive variance parameters ('extraSD') and selectivity parameters from the base model.

Parameter Label in SS3 (fleet # in parentheses)	Value	Estimated	Phase	Min	Max	Parm_StDev
LnQ_base_CA_TWL(3)	-5.05784	_	-1	-15	0	_
LnQ_base_NoCA_OR_WA_Rec(6)	-12.658	_	-1	-15	0	_
LnQ_base_WCGBT_Survey(9)	0.812175	_	-1	-15	3	_
LnQ_base_Triennial_Survey(10)	0.181108	_	-1	-15	3	_
LnQ_base_CalCOFI_Survey(11)	-3.87272	_	-1	-15	0	_
Q_extraSD_CalCOFI_Survey(11)	0.313158	Yes	1	0	1	0.075231
LnQ_base_RREAS_YOY_Survey(12)	-5.03945	_	-1	-15	0	_
Q_extraSD_RREAS_YOY_Survey(12)	1.23343	Yes	1	0	3	0.237946
Size_DblN_peak_NoCA_HKL(1)	41.2474	Yes	3	10	59	2.20246
Size_DblN_top_logit_NoCA_HKL(1)	-6	_	-3	-10	10	_
Size_DblN_ascend_se_NoCA_HKL(1)	4.42847	Yes	3	0.01	12	0.295313
Size_DblN_descend_se_NoCA_HKL(1)	5.02413	Yes	3	0.01	12	1.74252
Size_DblN_start_logit_NoCA_HKL(1)	-999	_	-3	-1000	-998	_
Size_DblN_end_logit_NoCA_HKL(1)	-999	_	-3	-1000	-998	_
Size_DblN_peak_SoCA_HKL(2)	24.2451	Yes	3	8.5	59.5	2.13178
Size_DblN_top_logit_SoCA_HKL(2)	-6	_	-3	-10	10	_
Size_DblN_ascend_se_SoCA_HKL(2)	1.41033	Yes	3	0.5	15	1.74941
Size_DblN_descend_se_SoCA_HKL(2)	5.78144	Yes	3	0.5	20	0.673298
Size_DblN_start_logit_SoCA_HKL(2)	-999	_	-3	-1000	-998	_
Size_DblN_end_logit_SoCA_HKL(2)	-999	_	-3	-1000	-998	_
Size_DblN_peak_CA_TWL(3)	44.6731	Yes	3	10	59	1.1664
Size_DblN_top_logit_CA_TWL(3)	-6	_	-3	-10	10	_
Size_DblN_ascend_se_CA_TWL(3)	4.50165	Yes	3	0.01	12	0.16361
Size_DblN_descend_se_CA_TWL(3)	2.98528	Yes	3	0.01	20	0.791551
Size_DblN_start_logit_CA_TWL(3)	-10	_	-3	-10	10	_
Size_DblN_end_logit_CA_TWL(3)	-999	_	-3	-1000	-998	_
Size_DblN_peak_OR_WA_Comm(4)	41.925	Yes	3	10	59	5.53774
Size_DblN_top_logit_OR_WA_Comm(4)	-6	_	-3	-10	10	_
Size_DblN_ascend_se_OR_WA_Comm(4)	4.47569	Yes	3	0.01	12	0.818901
Size_DblN_descend_se_OR_WA_Comm(4)	10	_	-3	0.01	20	_
Size_DblN_start_logit_OR_WA_Comm(4)	-999	_	-3	-1000	-998	_
Size_DblN_end_logit_OR_WA_Comm(4)	-999	_	-3	-1000	-998	_
Size_DblN_peak_CA_NET(5)	45.8676	Yes	3	10	59	1.38218
Size_DblN_top_logit_CA_NET(5)	-6	_	-3	-10	10	_
Size_DblN_ascend_se_CA_NET(5)	4.30744	Yes	3	0.01	12	0.198695

Parameter Label in SS3 (fleet # in parentheses)	Value	Estimated	Phase	Min	Max	Parm_StDev
Size_DblN_descend_se_CA_NET(5)	3.63213	Yes	3	0.01	12	1.33822
Size_DblN_start_logit_CA_NET(5)	-999	_	-3	-1000	-998	_
Size_DblN_end_logit_CA_NET(5)	-999	_	-3	-1000	-998	_
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.4907	Yes	3	10	59	1.81308
Size_DblN_top_logit_NoCA_OR_WA_Rec(6)	-6	_	-3	-10	10	_
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.08974	Yes	3	0.01	12	0.187804
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	4.32053	Yes	3	0.01	12	1.1641
Size_DblN_start_logit_NoCA_OR_WA_Rec(6)	-999	_	-3	-1000	-998	_
Size_DblN_end_logit_NoCA_OR_WA_Rec(6)	-999	_	-3	-1000	-998	_
Size_DblN_peak_SoCA_Rec(7)	24.6445	Yes	3	8.5	50	1.00653
Size_DblN_top_logit_SoCA_Rec(7)	-6	_	-3	-10	10	_
Size_DblN_ascend_se_SoCA_Rec(7)	2.91266	Yes	3	0.5	10	0.361253
Size_DblN_descend_se_SoCA_Rec(7)	3.36501	Yes	3	0.01	8	0.649491
Size_DblN_start_logit_SoCA_Rec(7)	-10	_	-3	-11	-10	_
Size_DblN_end_logit_SoCA_Rec(7)	-1.10801	Yes	3	-12	12	0.303268
Size_DblN_peak_TWL_discard(8)	29.5467	Yes	3	10	50	1.58135
Size_DblN_top_logit_TWL_discard(8)	-6	_	-3	-10	10	_
Size_DblN_ascend_se_TWL_discard(8)	4.18199	Yes	3	0.5	8	0.375224
Size_DblN_descend_se_TWL_discard(8)	3.20012	Yes	3	0.01	8	0.594307
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	50.2373	Yes	3	10	59.5	3.48964
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.05049	Yes	3	0.5	10	0.504181
Size_DblN_descend_se_NoCA_HKL(1)_BLK1repl_1875	10	_	-3	0.5	10	_
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.4103	Yes	3	8.5	59.5	3.40829
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.71708	Yes	3	0.5	15	0.380984
Size_DblN_descend_se_SoCA_HKL(2)_BLK2repl_1875	10	_	-3	0.5	15	_
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.5853	Yes	3	10	59	1.18839
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.23437	Yes	3	0.01	12	0.334935
Size_DblN_descend_se_CA_TWL(3)_BLK3repl_1875	19	_	-3	0.01	20	_
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.5808	Yes	3	8.5	50	1.99677
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.

Reference Point	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output (billions of eggs)	13,945	11,106	16,784
Unfished Age 3+ Biomass (mt)	58,706	45,124	72,288
Unfished Recruitment (R0, 1000s)	28,215	16,402	40,029
Spawning Output (2025, billions of eggs)	8,402	5,063	11,741
Fraction Unfished (2025)	0.603	0.392	0.813
Reference Points Based SB40%			
Proxy Spawning Output SB40%	5,578	4,442	6,714
SPR Resulting in SB40%	0.458	0.458	0.458
Exploitation Rate Resulting in SB40%	0.090	0.081	0.099
Yield with SPR Based On SB40% (mt)	2,650	1,814	3,487
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Output (SPR50)	6,222	4,955	7,488
SPR50	0.5	--	--
Exploitation Rate Corresponding to SPR50	0.078	0.070	0.086
Yield with SPR50 at SB SPR (mt)	2,509	1,719	3,298
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY (SB MSY)	3,515	2,808	4,221
SPR MSY	0.325	0.319	0.330
Exploitation Rate Corresponding to SPR MSY	0.140	0.125	0.155
MSY (mt)	2,893	1,970	3,817

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

Year	Total Biomass (mt)	Spawning output	Total Biomass Age 3+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/ (1-SPR50%)	Exploitation Rate
1875	61069	13945	58706	1	28215	8.3	0.003	0.000
1876	61061	13942	58699	1.000	28215	16.5	0.006	0.000
1877	61048	13938	58685	0.999	28214	24.8	0.008	0.000
1878	61028	13931	58665	0.999	28212	33.1	0.011	0.001
1879	61003	13922	58641	0.998	28211	41.4	0.014	0.001
1880	60974	13912	58612	0.998	28209	49.6	0.017	0.001
1881	60941	13900	58579	0.997	28207	57.9	0.019	0.001
1882	60905	13888	58543	0.996	28204	66.2	0.022	0.001
1883	60865	13874	58504	0.995	28201	74.4	0.025	0.001
1884	60823	13859	58462	0.994	28198	82.7	0.028	0.001
1885	60779	13844	58417	0.993	28195	91.0	0.030	0.002
1886	60732	13827	58371	0.992	28192	99.3	0.033	0.002
1887	60683	13810	58323	0.990	28189	107.5	0.036	0.002
1888	60633	13793	58273	0.989	28185	115.8	0.039	0.002
1889	60582	13775	58221	0.988	28181	124.1	0.041	0.002
1890	60529	13757	58169	0.986	28178	132.3	0.044	0.002
1891	60474	13738	58115	0.985	28174	140.6	0.047	0.002
1892	60419	13719	58060	0.984	28170	148.9	0.050	0.003
1893	60363	13699	58004	0.982	28166	157.2	0.052	0.003
1894	60306	13680	57948	0.981	28162	165.4	0.055	0.003
1895	60249	13660	57890	0.980	28158	173.7	0.058	0.003
1896	60191	13640	57833	0.978	28154	182.0	0.061	0.003
1897	60132	13620	57774	0.977	28150	190.3	0.064	0.003
1898	60072	13599	57715	0.975	28146	198.5	0.066	0.003
1899	60013	13579	57656	0.974	28142	206.8	0.069	0.004
1900	59953	13558	57596	0.972	28137	215.1	0.072	0.004
1901	59892	13537	57536	0.971	28133	223.3	0.075	0.004
1902	59831	13516	57475	0.969	28129	231.6	0.077	0.004
1903	59770	13495	57414	0.968	28124	239.9	0.080	0.004
1904	59709	13474	57353	0.966	28120	248.2	0.083	0.004
1905	59647	13453	57292	0.965	28115	256.4	0.086	0.004
1906	59585	13432	57231	0.963	28111	264.7	0.088	0.005
1907	59523	13411	57169	0.962	28106	273.0	0.091	0.005
1908	59461	13390	57107	0.960	28102	281.2	0.094	0.005
1909	59398	13368	57045	0.959	28097	289.5	0.097	0.005
1910	59336	13347	56983	0.957	28093	297.8	0.100	0.005
1911	59273	13326	56921	0.956	28088	306.1	0.102	0.005
1912	59210	13304	56858	0.954	28084	314.3	0.105	0.006
1913	59148	13283	56796	0.953	28079	322.6	0.108	0.006
1914	59085	13261	56733	0.951	28075	330.9	0.111	0.006
1915	59021	13240	56670	0.949	28070	339.1	0.113	0.006
1916	58958	13218	56608	0.948	28065	361.8	0.121	0.006
1917	58882	13193	56531	0.946	28060	574.4	0.185	0.010
1918	58625	13106	56275	0.940	28041	588.0	0.189	0.010
1919	58385	13024	56036	0.934	28023	379.5	0.128	0.007
1920	58358	13014	56011	0.933	28020	398.9	0.134	0.007
1921	58318	13000	55972	0.932	28017	338.8	0.115	0.006
1922	58336	13006	55990	0.933	28019	312.4	0.107	0.006
1923	58375	13021	56029	0.934	28022	380.5	0.129	0.007
1924	58348	13013	56002	0.933	28020	390.1	0.132	0.007
1925	58313	13005	55967	0.933	28018	439.1	0.148	0.008
1926	58238	12981	55892	0.931	28013	594.7	0.194	0.011
1927	58032	12913	55686	0.926	27998	508.5	0.170	0.009
1928	57924	12878	55578	0.924	27990	501.0	0.167	0.009
1929	57835	12849	55491	0.921	27983	487.1	0.164	0.009
1930	57768	12829	55424	0.920	27979	549.4	0.183	0.010
1931	57653	12792	55310	0.917	27970	585.5	0.194	0.011
1932	57519	12747	55177	0.914	27960	421.5	0.144	0.008
1933	57546	12756	55204	0.915	27962	335.7	0.116	0.006
1934	57646	12792	55304	0.917	27970	356.8	0.123	0.006
1935	57715	12819	55373	0.919	27976	382.6	0.131	0.007
1936	57754	12834	55411	0.920	27980	290.2	0.101	0.005
1937	57870	12875	55527	0.923	27989	267.9	0.093	0.005
1938	57991	12920	55648	0.926	27999	251.1	0.087	0.005
1939	58115	12963	55771	0.930	28009	278.2	0.096	0.005

Year	Total Biomass (mt)	Spawning output	Total Biomass Age 3+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/ (1-SPR50%)	Exploitation Rate
1940	58200	12993	55856	0.932	28016	254.6	0.088	0.005
1941	58297	13027	55952	0.934	28023	223.0	0.077	0.004
1942	58411	13065	56065	0.937	28032	93.3	0.033	0.002
1943	58630	13137	56283	0.942	28048	195.8	0.067	0.003
1944	58729	13176	56382	0.945	28056	556.0	0.179	0.010
1945	58480	13120	56131	0.941	28044	1148.5	0.344	0.020
1946	57698	12913	55349	0.926	27998	888.5	0.279	0.016
1947	57226	12782	54879	0.917	27968	668.3	0.217	0.012
1948	57010	12713	54666	0.912	27952	553.3	0.184	0.010
1949	56926	12685	54584	0.910	27945	648.7	0.213	0.012
1950	56767	12637	54426	0.906	27934	793.8	0.257	0.015
1951	56491	12558	54152	0.901	27916	1213.4	0.374	0.022
1952	55854	12380	53515	0.888	27873	1234.1	0.383	0.023
1953	55255	12211	52919	0.876	27831	1440.1	0.441	0.027
1954	54524	12003	52191	0.861	27778	1421.9	0.442	0.027
1955	53881	11816	51552	0.847	27730	1471.2	0.459	0.029
1956	53257	11634	50932	0.834	27681	1664.1	0.513	0.033
1957	52518	11420	50198	0.819	27622	1717.3	0.532	0.034
1958	51803	11212	49487	0.804	27562	1983.4	0.601	0.040
1959	50915	10956	48604	0.786	27486	1669.3	0.534	0.034
1960	50404	10800	48098	0.774	27438	1386.3	0.465	0.029
1961	50213	10730	47913	0.769	27417	1103.8	0.386	0.023
1962	50311	10743	48014	0.770	27421	1050.6	0.370	0.022
1963	50458	10775	48163	0.773	27431	1212.7	0.416	0.025
1964	50446	10769	48149	0.772	27429	905.1	0.324	0.019
1965	50718	10841	48421	0.777	27451	1000.7	0.352	0.021
1966	50878	10887	48580	0.781	27465	2128.9	0.643	0.044
1967	49973	10652	47675	0.764	27392	2785.4	0.789	0.058
1968	48540	10265	46232	0.736	29304	1767.1	0.582	0.038
1969	48205	10148	45860	0.728	30409	962.2	0.359	0.021
1970	48884	10242	46282	0.734	52372	1164.9	0.418	0.025
1971	49621	10304	46701	0.739	24335	1016.9	0.371	0.022
1972	51110	10444	47432	0.749	18500	1441.8	0.488	0.030
1973	52083	10585	50122	0.759	29954	2930.3	0.810	0.058
1974	51088	10450	49324	0.749	18839	3392.1	0.887	0.069
1975	49495	10169	47080	0.729	50432	2987.7	0.830	0.063
1976	48029	9905	45902	0.710	12331	3046.1	0.859	0.066
1977	46915	9570	43618	0.686	10664	2294.4	0.730	0.053
1978	46088	9449	45105	0.678	8994	1802.3	0.620	0.040
1979	45031	9459	44059	0.678	30482	2683.1	0.813	0.061
1980	42461	9147	41299	0.656	10815	3119.9	0.916	0.076
1981	39478	8574	37427	0.615	5899	2764.8	0.894	0.074
1982	36628	8004	35854	0.574	3485	2531.9	0.883	0.071
1983	33623	7460	33181	0.535	4596	2494.6	0.915	0.075
1984	30628	6875	29911	0.493	76705	2850.0	1.037	0.095
1985	27575	6114	25856	0.438	4031	3190.8	1.154	0.123
1986	26278	5212	21537	0.374	16299	3156.6	1.211	0.147
1987	25614	4547	24994	0.326	13854	2067.7	1.072	0.083
1988	26022	4531	24697	0.325	17282	2805.0	1.209	0.114
1989	25464	4455	24219	0.319	17752	3458.4	1.315	0.143
1990	24017	4203	22607	0.301	9031	3194.0	1.302	0.141
1991	22653	3961	21350	0.284	13803	3945.1	1.443	0.185
1992	20285	3527	19466	0.253	4356	2829.1	1.331	0.145
1993	18834	3286	17845	0.236	15284	2487.9	1.299	0.139
1994	17395	3081	16827	0.221	4622	1957.1	1.202	0.116
1995	16389	2950	15350	0.212	7452	2093.7	1.268	0.136
1996	15040	2746	14605	0.197	3764	1873.0	1.255	0.128
1997	13739	2559	13202	0.184	4118	2112.3	1.360	0.160
1998	12041	2276	11712	0.163	4980	1445.8	1.219	0.123
1999	11527	2097	10486	0.150	127062	979.5	1.049	0.093
2000	12302	1989	9635	0.143	2690	496.4	0.735	0.052
2001	16993	2048	9293	0.147	12556	389.2	0.622	0.042
2002	22263	2594	21836	0.186	6077	302.2	0.479	0.014
2003	26817	3637	25810	0.261	26319	29.5	0.044	0.001
2004	30219	4800	29335	0.344	6042	100.2	0.099	0.003
2005	32561	5759	30866	0.413	2235	130.3	0.097	0.004
2006	33651	6495	33239	0.466	1672	172.2	0.107	0.005
2007	33494	7006	33285	0.502	8090	134.9	0.078	0.004
2008	32403	7271	32121	0.521	5779	156.2	0.087	0.005
2009	30945	7275	30171	0.522	33339	309.5	0.167	0.010

Year	Total Biomass (mt)	Spawning output	Total Biomass Age 3+ (mt)	Fraction Unfished	Age-0 Recruits (1,000s)	Total Mortality (mt)	(1-SPR)/ (1-SPR50%)	Exploitation Rate
2010	29547	7048	28317	0.505	48379	384.9	0.214	0.014
2011	29172	6710	26199	0.481	15788	325.1	0.207	0.012
2012	30477	6479	27083	0.465	38958	298.9	0.199	0.011
2013	32691	6520	30669	0.468	64824	407.0	0.262	0.013
2014	35629	6772	32037	0.486	12021	331.9	0.216	0.010
2015	39769	7236	35509	0.519	30693	205.6	0.131	0.006
2016	43588	7976	42219	0.572	15003	90.4	0.054	0.002
2017	46758	8873	44588	0.636	10922	230.2	0.117	0.005
2018	48535	9670	47415	0.693	3874	390.8	0.173	0.008
2019	48760	10256	48000	0.735	6756	641.1	0.253	0.013
2020	47419	10528	46991	0.755	12856	765.1	0.289	0.016
2021	45112	10479	44345	0.751	22763	862.2	0.328	0.019
2022	42426	10144	41192	0.727	8107	866.2	0.341	0.021
2023	40034	9644	38425	0.692	18248	1262.9	0.498	0.033
2024	37601	8999	36526	0.645	45831	1193.2	0.511	0.033
2025	35904	8402	33819	0.603	26515	1598.7	0.678	0.047

[end of time series table]

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)	2597.98	0	yes
2	2597.98	0.00034	no
3	2597.98	0.00102	no
4	2597.98	0.00094	no
5	2597.98	0.00094	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=0.1	M=0.125	M=0.15	M=0.171	M=0.175	M=0.2	M=0.225	M=0.25
N.Parms	114	114	114	114	114	114	114	114
TOTAL	2618.0	2605.9	2599.6	2598.0	2598.0	2600.7	2607.1	2616.4
Survey	34.36	29.01	25.79	24.51	24.40	24.55	25.98	28.41
Length_comp	575.58	573.07	571.98	572.24	572.39	574.38	578.10	583.40
Age_comp	1982.0	1979.4	1977.4	1976.3	1976.1	1975.6	1975.6	1976.2
Recruitment	25.11	24.25	24.39	24.92	25.04	25.86	26.64	27.16
Parm_priors	0.98	0.23	0.00	0.06	0.08	0.35	0.74	1.21
NatM_uniform_Fem_GP_1	**0.100**	**0.125**	**0.150**	**0.171**	**0.175**	**0.200**	**0.225**	**0.250**
L_at_Amax_Fem_GP_1	48.32	48.27	48.23	48.19	48.18	48.14	48.11	48.07
VonBert_K_Fem_GP_1	0.193	0.193	0.194	0.194	0.194	0.193	0.193	0.193
CV_young_Fem_GP_1	0.114	0.112	0.111	0.110	0.110	0.109	0.108	0.107
CV_old_Fem_GP_1	0.035	0.036	0.037	0.037	0.037	0.038	0.038	0.039
NatM_uniform_Mal_GP_1	**0.53**	**0.41**	**0.32**	**0.26**	**0.25**	**0.19**	**0.14**	**0.10**
L_at_Amax_Mal_GP_1	-0.33	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34	-0.34
VonBert_K_Mal_GP_1	0.551	0.550	0.549	0.549	0.549	0.550	0.551	0.551
CV_young_Mal_GP_1	0.19	0.20	0.20	0.21	0.21	0.21	0.21	0.22
CV_old_Mal_GP_1	0.14	0.14	0.14	0.15	0.15	0.16	0.17	0.18
SR_LN(R0)	9.11	9.52	9.91	10.25	10.31	10.72	11.15	11.67
Q_extraSD_CalCOFI_Survey(11)	0.29	0.30	0.31	0.31	0.31	0.33	0.34	0.36
Q_extraSD_RREAS_YOY_Survey(12)	1.18	1.20	1.22	1.23	1.24	1.25	1.27	1.28
Size_DblN_peak_NoCA_HKL(1)	40.99	41.10	41.19	41.25	41.26	41.32	41.34	41.32
Size_DblN_ascend_se_NoCA_HKL(1)	4.47	4.46	4.44	4.43	4.43	4.41	4.39	4.37
Size_DblN_descend_se_NoCA_HKL(1)	4.85	4.90	4.96	5.02	5.04	5.11	5.17	5.25
Size_DblN_peak_SoCA_HKL(2)	23.99	24.08	24.17	24.25	24.26	24.35	24.45	24.51
Size_DblN_ascend_se_SoCA_HKL(2)	1.27	1.33	1.37	1.41	1.42	1.46	1.51	1.53
Size_DblN_descend_se_SoCA_HKL(2)	5.51	5.59	5.69	5.78	5.80	5.93	6.09	6.29
Size_DblN_peak_CA_TWL(3)	43.94	44.17	44.43	44.67	44.72	45.04	45.37	45.69
Size_DblN_ascend_se_CA_TWL(3)	4.52	4.51	4.50	4.50	4.50	4.50	4.50	4.51
Size_DblN_descend_se_CA_TWL(3)	3.02	3.01	3.00	2.99	2.98	2.95	2.89	2.85
Size_DblN_peak_OR_WA_Comm(4)	39.57	40.27	41.10	41.93	42.10	43.36	45.40	53.99
Size_DblN_ascend_se_OR_WA_Comm(4)	4.30	4.35	4.41	4.48	4.49	4.59	4.77	5.39
Size_DblN_peak_CA_NET(5)	45.81	45.82	45.84	45.87	45.87	45.91	45.92	45.92
Size_DblN_ascend_se_CA_NET(5)	4.33	4.32	4.31	4.31	4.31	4.30	4.29	4.28
Size_DblN_descend_se_CA_NET(5)	3.54	3.56	3.60	3.63	3.64	3.69	3.73	3.79
Size_DblN_peak_NoCA_OR_WA_Rec(6)	42.63	42.90	43.21	43.49	43.55	43.96	44.37	44.82
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.11	5.10	5.09	5.09	5.09	5.09	5.09	5.09
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	4.10	4.17	4.24	4.32	4.33	4.43	4.56	4.78
Size_DblN_peak_SoCA_Rec(7)	24.20	24.37	24.53	24.64	24.67	24.79	24.91	25.03
Size_DblN_ascend_se_SoCA_Rec(7)	2.81	2.85	2.89	2.91	2.92	2.94	2.96	2.98
Size_DblN_descend_se_SoCA_Rec(7)	3.66	3.56	3.45	3.37	3.35	3.24	3.13	3.02
Size_DblN_end_logit_SoCA_Rec(7)	-1.58	-1.41	-1.25	-1.11	-1.08	-0.91	-0.74	-0.58
Size_DblN_peak_TWL_discard(8)	29.08	29.23	29.40	29.55	29.58	29.77	29.97	30.16
Size_DblN_ascend_se_TWL_discard(8)	4.16	4.17	4.17	4.18	4.18	4.19	4.20	4.21
Size_DblN_descend_se_TWL_discard(8)	3.25	3.23	3.22	3.20	3.20	3.17	3.15	3.12
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	49.90	49.98	50.10	50.24	50.27	50.44	50.64	50.89
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.03	4.04	4.04	4.05	4.05	4.06	4.07	4.08
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.17	47.25	47.33	47.41	47.43	47.53	47.62	47.72
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.75	4.74	4.73	4.72	4.72	4.71	4.70	4.69
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.02	33.20	33.39	33.59	33.64	33.94	34.22	34.45
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.14	3.17	3.20	3.23	3.24	3.30	3.35	3.38
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.07	30.21	30.39	30.58	30.63	30.94	31.32	31.78
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.68	3.69	3.71	3.73	3.74	3.78	3.82	3.88
Bratio_2025	0.539	0.586	0.603	0.603	0.601	0.590	0.575	0.563
SSB_unfished	12682	12675	13154	13945	14136	15771	18568	24157
Totbio_unfished	45142	48603	54241	61069	62604	74955	94651	132128
Recr_unfished	9028	13599	20227	28215	30040	45036	69663	116945
Dead_Catch_SPR	1207	1557	2010	2509	2618	3473	4793	7236
OFLCatch_2025	1343	1797	2334	2894	3015	3951	5400	8170

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= 8.5	logR0= 9	logR0= 9.5	logR0= 10	logR0= 10.248	logR0= 10.5	logR0= 11	logR0= 11.5
N.Parms	114	114	114	114	114	114	114	114
TOTAL	2642.2	2619.3	2605.1	2598.7	2598.0	2598.6	2603.0	2609.1
Survey	44.33	35.40	29.06	25.41	24.51	24.16	25.09	28.10
Length_comp	580.40	575.70	572.63	571.82	572.24	573.25	577.25	583.73
Age_comp	1983.1	1980.3	1978.3	1976.9	1976.3	1975.6	1973.5	1969.7
Recruitment	31.59	27.05	24.91	24.57	24.92	25.49	26.76	26.88
Parm_priors	2.77	0.86	0.14	0.00	0.06	0.16	0.43	0.69
NatM_uniform_Fem_GP_1	0.074	0.103	0.131	0.158	0.171	0.184	0.206	0.222
L_at_Amax_Fem_GP_1	48.44	48.37	48.29	48.22	48.19	48.17	48.18	48.25
VonBert_K_Fem_GP_1	0.193	0.193	0.193	0.193	0.194	0.193	0.193	0.192
CV_young_Fem_GP_1	0.116	0.115	0.113	0.111	0.110	0.110	0.109	0.111
CV_old_Fem_GP_1	0.034	0.035	0.036	0.037	0.037	0.038	0.038	0.037
NatM_uniform_Mal_GP_1	0.681	0.500	0.378	0.294	0.261	0.232	0.187	0.161
L_at_Amax_Mal_GP_1	-0.334	-0.335	-0.336	-0.337	-0.337	-0.338	-0.338	-0.339
VonBert_K_Mal_GP_1	0.555	0.554	0.552	0.550	0.549	0.549	0.547	0.546
CV_young_Mal_GP_1	0.170	0.180	0.193	0.204	0.208	0.211	0.212	0.206
CV_old_Mal_GP_1	0.138	0.147	0.149	0.148	0.148	0.149	0.145	0.138
SR_LN(R0)	8.50	9.00	9.50	10.00	10.25	10.50	11.00	11.50
Q_extraSD_CalCOFI_Survey(11)	0.318	0.316	0.314	0.313	0.313	0.315	0.326	0.351
Q_extraSD_RREAS_YOY_Survey(12)	1.172	1.189	1.207	1.225	1.233	1.242	1.257	1.273
Size_DblN_peak_NoCA_HKL(1)	41.056	41.165	41.238	41.260	41.247	41.207	40.987	40.587
Size_DblN_ascend_se_NoCA_HKL(1)	4.51	4.49	4.47	4.44	4.43	4.41	4.38	4.33
Size_DblN_descend_se_NoCA_HKL(1)	4.727	4.790	4.899	4.996	5.024	5.031	4.963	4.793
Size_DblN_peak_SoCA_HKL(2)	23.882	23.991	24.099	24.199	24.245	24.291	24.373	24.432
Size_DblN_ascend_se_SoCA_HKL(2)	1.21	1.28	1.34	1.39	1.41	1.43	1.47	1.50
Size_DblN_descend_se_SoCA_HKL(2)	5.460	5.530	5.622	5.726	5.781	5.839	5.941	5.993
Size_DblN_peak_CA_TWL(3)	43.888	44.054	44.285	44.540	44.673	44.798	44.973	44.969
Size_DblN_ascend_se_CA_TWL(3)	4.54	4.52	4.51	4.50	4.50	4.50	4.50	4.49
Size_DblN_descend_se_CA_TWL(3)	3.001	2.988	2.994	2.994	2.985	2.972	2.933	2.884
Size_DblN_peak_OR_WA_Comm(4)	39.188	39.811	40.558	41.437	41.925	42.418	43.398	43.950
Size_DblN_ascend_se_OR_WA_Comm(4)	4.28	4.32	4.37	4.44	4.48	4.51	4.59	4.64
Size_DblN_peak_CA_NET(5)	45.877	45.902	45.935	45.911	45.868	45.795	45.536	45.083
Size_DblN_ascend_se_CA_NET(5)	4.35	4.34	4.33	4.32	4.31	4.30	4.27	4.23
Size_DblN_descend_se_CA_NET(5)	3.540	3.576	3.625	3.642	3.632	3.607	3.508	3.391
Size_DblN_peak_NoCA_OR_WA_Rec(6)	42.619	42.832	43.099	43.367	43.491	43.597	43.644	43.399
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.14	5.12	5.11	5.10	5.09	5.08	5.06	5.04
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	3.990	4.068	4.175	4.279	4.321	4.350	4.359	4.287
Size_DblN_peak_SoCA_Rec(7)	24.118	24.260	24.424	24.578	24.645	24.709	24.820	24.887
Size_DblN_ascend_se_SoCA_Rec(7)	2.80	2.83	2.87	2.90	2.91	2.92	2.94	2.95
Size_DblN_descend_se_SoCA_Rec(7)	3.663	3.597	3.505	3.410	3.365	3.321	3.247	3.215
Size_DblN_end_logit_SoCA_Rec(7)	-1.700	-1.541	-1.364	-1.190	-1.108	-1.029	-0.903	-0.846
Size_DblN_peak_TWL_discard(8)	28.924	29.073	29.259	29.451	29.547	29.644	29.803	29.881
Size_DblN_ascend_se_TWL_discard(8)	4.15	4.16	4.17	4.18	4.18	4.19	4.19	4.19
Size_DblN_descend_se_TWL_discard(8)	3.258	3.250	3.233	3.212	3.200	3.187	3.163	3.150
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	50.455	50.394	50.360	50.290	50.237	50.167	49.949	49.608
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.07	4.07	4.06	4.05	4.05	4.04	4.03	4.01
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.321	47.373	47.442	47.444	47.410	47.341	47.044	46.520
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.78	4.76	4.74	4.73	4.72	4.71	4.68	4.65
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	32.739	32.995	33.254	33.469	33.585	33.684	33.689	33.410
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.08	3.13	3.18	3.21	3.23	3.25	3.24	3.17
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.110	30.271	30.416	30.529	30.581	30.628	30.683	30.663
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.70	3.71	3.72	3.73	3.73	3.73	3.73	3.72
Bratio_2025	0.403	0.530	0.592	0.606	0.603	0.596	0.591	0.622
SSB_unfished	11427	10880	11356	12825	13945	15409	19664	27272
Totbio_unfished	37668	39115	44401	54188	61068	69849	94651	136732
Recr_unfished	4915	8103	13360	22027	28215	36316	59874	98716
Dead_Catch_SPR	790	1069	1479	2095	2509	3030	4483	6856
OFLCatch_2025	725	1169	1718	2440	2894	3455	5045	8001

Table 16: Likelihoods, estimated parameters, and select derived quantities from a likelihood profile over the Beverton-Holt steepness parameter (h), for values from 0.25-0.6. ** The default harvest rate proxy ($F_{SPR=50\%}$) for rockfish is inconsistent with steepness values of 0.3 and lower.

Label	h=0.25	h=0.3	h=0.35	h=0.4	h=0.45	h=0.5	h=0.55	h=0.6
N.Parms	114	114	114	114	114	114	114	114
TOTAL	2599.5	2597.5	2596.7	2596.3	2596.3	2596.4	2596.7	2597.0
Survey	21.95	22.08	22.31	22.58	22.88	23.18	23.49	23.80
Length_comp	574.51	573.77	573.25	572.89	572.62	572.44	572.31	572.24
Age_comp	1972.8	1973.8	1974.6	1975.1	1975.5	1975.8	1976.0	1976.2
Recruitment	25.92	24.92	24.40	24.17	24.11	24.16	24.28	24.44
Parm_priors	4.34	2.92	2.11	1.55	1.14	0.82	0.57	0.37
NatM_uniform_Fem_GP_1	0.185	0.181	0.178	0.176	0.174	0.173	0.172	0.171
L_at_Amax_Fem_GP_1	48.17	48.16	48.16	48.16	48.17	48.17	48.17	48.18
VonBert_K_Fem_GP_1	0.194	0.194	0.194	0.194	0.194	0.194	0.194	0.194
CV_young_Fem_GP_1	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110
CV_old_Fem_GP_1	0.038	0.038	0.038	0.038	0.038	0.037	0.037	0.037
NatM_uniform_Mal_GP_1	0.233	0.240	0.246	0.250	0.254	0.256	0.258	0.259
L_at_Amax_Mal_GP_1	-0.337	-0.337	-0.337	-0.337	-0.337	-0.337	-0.337	-0.337
VonBert_K_Mal_GP_1	0.548	0.548	0.548	0.548	0.548	0.549	0.549	0.549
CV_young_Mal_GP_1	0.208	0.210	0.211	0.211	0.211	0.211	0.210	0.210
CV_old_Mal_GP_1	0.145	0.144	0.145	0.145	0.146	0.146	0.147	0.147
SR_LN(R0)	10.76	10.62	10.52	10.45	10.39	10.35	10.32	10.29
SR_BH_steep	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.600
Q_extraSD_CalCOFI_Survey(11)	0.288	0.288	0.289	0.291	0.294	0.297	0.300	0.303
Q_extraSD_RREAS_YOY_Survey(12)	1.258	1.249	1.242	1.238	1.236	1.234	1.233	1.233
Size_DblN_peak_NoCA_HKL(1)	41.12	41.18	41.22	41.25	41.27	41.27	41.28	41.27
Size_DblN_ascend_se_NoCA_HKL(1)	4.413	4.421	4.426	4.429	4.431	4.431	4.432	4.431
Size_DblN_descend_se_NoCA_HKL(1)	5.032	5.052	5.062	5.065	5.064	5.059	5.053	5.046
Size_DblN_peak_SoCA_HKL(2)	24.28	24.27	24.27	24.26	24.26	24.25	24.25	24.25
Size_DblN_ascend_se_SoCA_HKL(2)	1.427	1.424	1.421	1.418	1.416	1.414	1.413	1.412
Size_DblN_descend_se_SoCA_HKL(2)	5.832	5.822	5.813	5.807	5.801	5.796	5.792	5.788
Size_DblN_peak_CA_TWL(3)	44.82	44.81	44.79	44.78	44.76	44.74	44.72	44.71
Size_DblN_ascend_se_CA_TWL(3)	4.507	4.508	4.507	4.507	4.506	4.505	4.504	4.504
Size_DblN_descend_se_CA_TWL(3)	2.978	2.983	2.986	2.987	2.988	2.989	2.988	2.988
Size_DblN_peak_OR_WA_Comm(4)	42.52	42.41	42.32	42.24	42.17	42.10	42.05	42.01
Size_DblN_ascend_se_OR_WA_Comm(4)	4.529	4.519	4.511	4.504	4.498	4.492	4.487	4.483
Size_DblN_peak_CA_NET(5)	45.75	45.82	45.85	45.88	45.89	45.90	45.90	45.89
Size_DblN_ascend_se_CA_NET(5)	4.298	4.303	4.306	4.308	4.309	4.310	4.310	4.309
Size_DblN_descend_se_CA_NET(5)	3.590	3.616	3.633	3.642	3.647	3.649	3.648	3.645
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.58	43.60	43.60	43.60	43.58	43.57	43.55	43.53
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.090	5.093	5.094	5.094	5.094	5.094	5.093	5.092
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	4.344	4.348	4.348	4.346	4.343	4.339	4.335	4.331
Size_DblN_peak_SoCA_Rec(7)	24.70	24.69	24.69	24.68	24.67	24.66	24.66	24.65
Size_DblN_ascend_se_SoCA_Rec(7)	2.924	2.922	2.921	2.919	2.918	2.917	2.916	2.915
Size_DblN_descend_se_SoCA_Rec(7)	3.317	3.325	3.332	3.339	3.344	3.349	3.354	3.358
Size_DblN_end_logit_SoCA_Rec(7)	-1.044	-1.055	-1.064	-1.073	-1.080	-1.087	-1.093	-1.098
Size_DblN_peak_TWL_discard(8)	29.63	29.62	29.61	29.59	29.58	29.58	29.57	29.56
Size_DblN_ascend_se_TWL_discard(8)	4.186	4.186	4.186	4.185	4.185	4.184	4.184	4.183
Size_DblN_descend_se_TWL_discard(8)	3.186	3.188	3.190	3.192	3.193	3.195	3.196	3.198
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	50.07	50.12	50.15	50.17	50.19	50.20	50.21	50.22
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.038	4.042	4.044	4.046	4.047	4.048	4.049	4.049
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.28	47.36	47.40	47.43	47.44	47.45	47.45	47.44
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.709	4.713	4.716	4.718	4.719	4.719	4.719	4.719
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.57	33.59	33.60	33.61	33.61	33.61	33.60	33.60
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.226	3.233	3.237	3.239	3.240	3.240	3.240	3.239
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.56	30.55	30.55	30.55	30.55	30.55	30.56	30.56
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.723	3.724	3.725	3.725	3.726	3.727	3.728	3.729
Bratio_2025	0.346	0.386	0.420	0.451	0.480	0.506	0.530	0.553
SSB_unfished	19629	17855	16785	16051	15507	15082	14740	14457
Totbio_unfished	89223	80316	74925	71231	68511	66417	64755	63409
Recr_unfished	47175	40881	37071	34495	32645	31270	30228	29432
Dead_Catch_SPR	**	**	475	1342	1793	2058	2226	2341
OFLCatch_2025	2584	2561	2573	2602	2640	2683	2729	2777

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	114	114	114	114	114	114	114	114
TOTAL	2597.4	2597.8	2598.0	2598.3	2598.7	2599.2	2599.8	2600.5
Survey	24.10	24.39	24.51	24.69	24.98	25.26	25.54	25.81
Length_comp	572.22	572.23	572.24	572.27	572.34	572.44	572.55	572.67
Age_comp	1976.2	1976.3	1976.3	1976.2	1976.2	1976.1	1976.0	1975.9
Recruitment	24.63	24.83	24.92	25.04	25.23	25.41	25.57	25.71
Parm_priors	0.21	0.09	0.06	0.01	-0.02	0.00	0.11	0.41
NatM_uniform_Fem_GP_1	0.171	0.171	0.171	0.171	0.171	0.172	0.172	0.172
L_at_Amax_Fem_GP_1	48.18	48.19	48.19	48.19	48.20	48.20	48.21	48.21
VonBert_K_Fem_GP_1	0.194	0.194	0.194	0.194	0.193	0.193	0.193	0.193
CV_young_Fem_GP_1	0.110	0.110	0.110	0.110	0.110	0.111	0.111	0.111
CV_old_Fem_GP_1	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
NatM_uniform_Mal_GP_1	0.260	0.261	0.261	0.261	0.260	0.260	0.259	0.258
L_at_Amax_Mal_GP_1	-0.337	-0.337	-0.337	-0.337	-0.338	-0.338	-0.338	-0.338
VonBert_K_Mal_GP_1	0.549	0.549	0.549	0.549	0.549	0.550	0.550	0.550
CV_young_Mal_GP_1	0.209	0.209	0.208	0.208	0.207	0.206	0.205	0.204
CV_old_Mal_GP_1	0.148	0.148	0.148	0.149	0.149	0.149	0.150	0.150
SR_LN(R0)	10.27	10.25	10.25	10.24	10.23	10.23	10.22	10.22
SR_BH_steep	0.650	0.700	0.720	0.750	0.800	0.850	0.900	0.950
Q_extraSD_CalCOFI_Survey(11)	0.307	0.311	0.313	0.316	0.320	0.325	0.329	0.333
Q_extraSD_RREAS_YOY_Survey(12)	1.233	1.233	1.233	1.234	1.235	1.236	1.237	1.238
Size_DblN_peak_NoCA_HKL(1)	41.26	41.25	41.25	41.24	41.22	41.20	41.18	41.16
Size_DblN_ascend_se_NoCA_HKL(1)	4.430	4.429	4.428	4.427	4.426	4.424	4.422	4.419
Size_DblN_descend_se_NoCA_HKL(1)	5.037	5.028	5.024	5.018	5.008	4.998	4.989	4.979
Size_DblN_peak_SoCA_HKL(2)	24.25	24.25	24.25	24.24	24.24	24.24	24.24	24.24
Size_DblN_ascend_se_SoCA_HKL(2)	1.411	1.410	1.410	1.410	1.410	1.410	1.410	1.411
Size_DblN_descend_se_SoCA_HKL(2)	5.785	5.782	5.781	5.780	5.779	5.777	5.776	5.776
Size_DblN_peak_CA_TWL(3)	44.69	44.68	44.67	44.66	44.65	44.64	44.63	44.62
Size_DblN_ascend_se_CA_TWL(3)	4.503	4.502	4.502	4.501	4.501	4.500	4.499	4.499
Size_DblN_descend_se_CA_TWL(3)	2.987	2.986	2.985	2.984	2.983	2.981	2.979	2.977
Size_DblN_peak_OR_WA_Comm(4)	41.97	41.94	41.93	41.91	41.89	41.87	41.86	41.85
Size_DblN_ascend_se_OR_WA_Comm(4)	4.480	4.477	4.476	4.474	4.472	4.471	4.469	4.469
Size_DblN_peak_CA_NET(5)	45.88	45.87	45.87	45.86	45.84	45.83	45.81	45.79
Size_DblN_ascend_se_CA_NET(5)	4.309	4.308	4.307	4.307	4.306	4.304	4.303	4.301
Size_DblN_descend_se_CA_NET(5)	3.640	3.635	3.632	3.628	3.621	3.613	3.605	3.597
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.52	43.50	43.49	43.48	43.46	43.45	43.43	43.42
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.091	5.090	5.090	5.089	5.088	5.086	5.085	5.084
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	4.326	4.322	4.321	4.318	4.314	4.309	4.305	4.301
Size_DblN_peak_SoCA_Rec(7)	24.65	24.65	24.64	24.64	24.64	24.64	24.64	24.64
Size_DblN_ascend_se_SoCA_Rec(7)	2.914	2.913	2.913	2.912	2.912	2.911	2.911	2.911
Size_DblN_descend_se_SoCA_Rec(7)	3.361	3.364	3.365	3.366	3.369	3.370	3.372	3.373
Size_DblN_end_logit_SoCA_Rec(7)	-1.103	-1.107	-1.108	-1.110	-1.113	-1.115	-1.117	-1.119
Size_DblN_peak_TWL_discard(8)	29.55	29.55	29.55	29.54	29.54	29.54	29.54	29.53
Size_DblN_ascend_se_TWL_discard(8)	4.183	4.182	4.182	4.182	4.181	4.181	4.180	4.180
Size_DblN_descend_se_TWL_discard(8)	3.199	3.200	3.200	3.201	3.201	3.202	3.202	3.203
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	50.23	50.24	50.24	50.24	50.24	50.25	50.25	50.25
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.050	4.050	4.050	4.051	4.051	4.051	4.051	4.051
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.43	47.42	47.41	47.40	47.38	47.36	47.34	47.32
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.718	4.717	4.717	4.717	4.716	4.714	4.713	4.712
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.59	33.59	33.59	33.58	33.57	33.56	33.55	33.54
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.237	3.235	3.234	3.233	3.231	3.228	3.225	3.223
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.57	30.58	30.58	30.59	30.60	30.60	30.61	30.62
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.730	3.731	3.732	3.733	3.734	3.735	3.736	3.738
Bratio_2025	0.575	0.595	0.603	0.614	0.632	0.648	0.664	0.679
SSB_unfished	14219	14017	13945	13844	13695	13567	13457	13362
Totbio_unfished	62304	61389	61069	60630	59999	59476	59044	58688
Recr_unfished	28824	28364	28215	28025	27783	27621	27523	27475
Dead_Catch_SPR	2424	2487	2509	2538	2580	2617	2650	2680
OFLCatch_2025	2825	2874	2894	2924	2975	3025	3074	3123

Table 18: Likelihoods, parameter estimates, and select derived quantiteis associated with "leave one out" sensitivity runs.

Quantity Description	base	no CalCOFI	no RREAS	no Triennial	no WCGBTS	no WCGBTS index
N.Parms	114	114	114	114	114	114
TOTAL	2597.98	2590.69	2575.76	2524.52	1656.39	2600.01
Survey	24.51	19.37	3.02	21.99	29.22	28.55
Length_comp	572.24	573.73	571.41	545.92	464.54	571.21
Age_comp	1976.25	1973.68	1976.89	1931.66	1144.73	1975.63
Recruitment	24.92	23.83	24.38	24.86	17.88	24.58
Parm_priors	0.06	0.09	0.06	0.07	0.02	0.02
NatM_uniform_Fem_GP_1	0.171	0.176	0.173	0.174	0.164	0.144
L_at_Amax_Fem_GP_1	48.190	48.245	48.197	48.272	47.922	48.116
VonBert_K_Fem_GP_1	0.194	0.193	0.193	0.192	0.194	0.194
CV_young_Fem_GP_1	0.110	0.112	0.111	0.112	0.092	0.109
CV_old_Fem_GP_1	0.037	0.037	0.037	0.037	0.046	0.038
NatM_uniform_Mal_GP_1	0.261	0.250	0.258	0.261	0.185	0.323
L_at_Amax_Mal_GP_1	-0.337	-0.338	-0.338	-0.336	-0.393	-0.336
VonBert_K_Mal_GP_1	0.549	0.551	0.552	0.538	0.746	0.545
CV_young_Mal_GP_1	0.208	0.196	0.203	0.224	-0.488	0.223
CV_old_Mal_GP_1	0.148	0.157	0.155	0.119	1.089	0.132
SR_LN(R0)	10.248	10.251	10.270	10.313	10.142	9.838
Q_extraSD_CalCOFI_Survey(11)	0.313	0.314	0.316	0.321	0.308	0.310
Q_extraSD_RREAS_YOY_Survey(12)	1.233	1.251	1.233	1.235	1.156	1.185
Size_DblN_peak_NoCA_HKL(1)	41.247	40.988	41.232	40.984	42.149	41.382
Size_DblN_ascend_se_NoCA_HKL(1)	4.428	4.398	4.425	4.405	4.389	4.463
Size_DblN_descend_se_NoCA_HKL(1)	5.024	4.932	4.997	4.979	9.159	5.164
Size_DblN_peak_SoCA_HKL(2)	24.245	24.234	24.211	24.270	24.810	24.249
Size_DblN_ascend_se_SoCA_HKL(2)	1.410	1.407	1.396	1.422	1.481	1.410
Size_DblN_descend_se_SoCA_HKL(2)	5.781	5.772	5.783	5.774	6.407	5.794
Size_DblN_peak_CA_TWL(3)	44.673	44.535	44.644	44.602	45.224	44.794
Size_DblN_ascend_se_CA_TWL(3)	4.502	4.491	4.500	4.502	4.475	4.518
Size_DblN_descend_se_CA_TWL(3)	2.985	2.972	2.989	2.958	3.131	3.014
Size_DblN_peak_OR_WA_Comm(4)	41.925	41.762	41.754	41.848	44.426	41.936
Size_DblN_ascend_se_OR_WA_Comm(4)	4.476	4.461	4.463	4.469	4.554	4.492
Size_DblN_peak_CA_NET(5)	45.868	45.687	45.836	45.707	47.115	46.111
Size_DblN_ascend_se_CA_NET(5)	4.307	4.293	4.304	4.296	4.351	4.339
Size_DblN_descend_se_CA_NET(5)	3.632	3.557	3.617	3.517	5.330	3.775
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.491	43.303	43.454	43.325	45.947	43.460
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.090	5.074	5.087	5.077	5.180	5.118
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	4.321	4.279	4.290	4.273	7.284	4.451
Size_DblN_peak_SoCA_Rec(7)	24.645	24.627	24.631	24.670	23.993	24.630
Size_DblN_ascend_se_SoCA_Rec(7)	2.913	2.907	2.916	2.914	2.796	2.910
Size_DblN_descend_se_SoCA_Rec(7)	3.365	3.378	3.366	3.404	3.211	3.396
Size_DblN_end_logit_SoCA_Rec(7)	-1.108	-1.130	-1.098	-1.119	-0.542	-1.121
Size_DblN_peak_TWL_discard(8)	29.547	29.511	29.523	29.598	30.992	29.528
Size_DblN_ascend_se_TWL_discard(8)	4.182	4.177	4.189	4.178	4.403	4.186
Size_DblN_descend_se_TWL_discard(8)	3.200	3.209	3.206	3.178	2.930	3.193
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	50.237	50.272	50.221	50.016	51.419	50.306
Size_DblN_ascend_se_NoCA_HKL(1) _BLK1repl_1875	4.050	4.050	4.049	4.032	4.138	4.059
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.410	47.191	47.373	47.187	48.939	47.705
Size_DblN_ascend_se_SoCA_HKL(2) _BLK2repl_1875	4.717	4.705	4.714	4.709	4.725	4.749
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.585	33.529	33.609	33.401	36.561	33.451
Size_DblN_ascend_se_CA_TWL(3) _BLK3repl_1875	3.234	3.215	3.239	3.186	3.732	3.220
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.581	30.753	30.598	30.563	35.165	30.363
Size_DblN_ascend_se_SoCA_Rec(7) _BLK2repl_1875	3.732	3.754	3.734	3.723	4.458	3.712
Bratio_2025	0.603	0.825	0.594	0.625	0.817	0.780
SSB_unfished	13945	13260	14010	14396	13371	13115
Totbio_unfished	61069	58718	61564	63220	59406	53619
Recr_unfished	28215	28320	28853	30132	25380	18727
Dead_Catch_SPR	2509	2457	2543	2627	2313	1934
OFLCatch_2025	2894	3791	2867	3107	3975	3006

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).

Fleet identifier	Data type	Tuned Francis Weight (base model)	Tuned M.I. Weight
NoCA_HKL	Lengths	0.5385	1.2749
SoCA_HKL	Lengths	2.4611	6.2149
CA_TWL	Lengths	0.2449	0.6113
OR_WA_Comm	Lengths	0.0906	0.3759
CA_NET	Lengths	0.4095	1.7378
NoCA_OR_WA_Rec	Lengths	0.3798	0.5838
SoCA_Rec	Lengths	0.1706	0.7070
TWL_discard	Lengths	0.0206	0.0777
WCGBT_Survey	Lengths	0.0360	0.1402
Triennial_Survey	Lengths	0.0581	0.1785
NoCA_HKL	CAAL	0.0304	0.1565
CA_TWL	CAAL	0.0162	0.0371
OR_WA_Comm	CAAL	1	0.4189
CA_NET	CAAL	0.0642	0.1658
NoCA_OR_WA_Rec	CAAL	1	0.5657
WCGBT_Survey	CAAL	0.0955	0.0050
Triennial_Survey	CAAL	0.1161	0.1171

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

Quantity	Francis Weights (base model)	McAllister-Ianneli Weights
N.Parms	114	114
TOTAL	2597.98	3504.89
Survey	24.51	28.74
Length_comp	572.24	1643.55
Age_comp	1976.25	1807.70
Recruitment	24.92	24.89
Parm_priors	0.06	0.01
NatM_uniform_Fem_GP_1	0.171	0.161
L_at_Amax_Fem_GP_1	48.190	47.444
VonBert_K_Fem_GP_1	0.194	0.197
CV_young_Fem_GP_1	0.110	0.105
CV_old_Fem_GP_1	0.037	0.042
NatM_uniform_Mal_GP_1	0.261	0.209
L_at_Amax_Mal_GP_1	-0.337	-0.343
VonBert_K_Mal_GP_1	0.549	0.529
CV_young_Mal_GP_1	0.208	0.044
CV_old_Mal_GP_1	0.148	0.640
SR_LN(R0)	10.248	10.109
Q_extraSD_CalCOFI_Survey(11)	0.313	0.328
Q_extraSD_RREAS_YOY_Survey(12)	1.233	1.392
Size_DblN_peak_NoCA_HKL(1)	41.247	41.302
Size_DblN_ascend_se_NoCA_HKL(1)	4.428	4.391
Size_DblN_descend_se_NoCA_HKL(1)	5.024	10.193
Size_DblN_peak_SoCA_HKL(2)	24.245	24.393
Size_DblN_ascend_se_SoCA_HKL(2)	1.410	1.442
Size_DblN_descend_se_SoCA_HKL(2)	5.781	5.828
Size_DblN_peak_CA_TWL(3)	44.673	44.691
Size_DblN_ascend_se_CA_TWL(3)	4.502	4.518
Size_DblN_descend_se_CA_TWL(3)	2.985	3.254
Size_DblN_peak_OR_WA_Comm(4)	41.925	41.931
Size_DblN_ascend_se_OR_WA_Comm(4)	4.476	4.418
Size_DblN_peak_CA_NET(5)	45.868	47.234
Size_DblN_ascend_se_CA_NET(5)	4.307	4.420
Size_DblN_descend_se_CA_NET(5)	3.632	10.464
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.491	45.058
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.090	5.192
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	4.321	7.400
Size_DblN_peak_SoCA_Rec(7)	24.645	24.268
Size_DblN_ascend_se_SoCA_Rec(7)	2.913	2.864
Size_DblN_descend_se_SoCA_Rec(7)	3.365	3.369
Size_DblN_end_logit_SoCA_Rec(7)	-1.108	-0.992
Size_DblN_peak_TWL_discard(8)	29.547	30.011
Size_DblN_ascend_se_TWL_discard(8)	4.182	4.357
Size_DblN_descend_se_TWL_discard(8)	3.200	3.150
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	50.237	52.963
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.050	4.271
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.410	49.732
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.717	4.859
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.585	34.986
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.234	3.510
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.581	31.538
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.732	3.896
Bratio_2025	0.603	0.579
SSB_unfished	13945	13047
Totbio_unfished	61069	57939
Recr_unfished	28215	24570
Dead_Catch_SPR	2509	2281
OFLCatch_2025	2894	2655

Table 21: Likelihoods, parameter estimates, and select derived quantiteis 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. CPUE	add Trawl CPUE	add Rec. & Trawl	Upweight CalCOFI	Upweight WCGBTS
N.Parms	114	114	114	114	114	114
TOTAL	2597.98	2601.92	2587.56	2596.66	2635.87	2516.32
Survey	24.51	25.71	13.68	21.49	43.96	-75.90
Length_comp	572.24	574.16	573.46	573.59	574.40	584.68
Age_comp	1976.25	1976.47	1976.09	1976.69	1990.84	1980.12
Recruitment	24.92	25.56	24.21	24.86	26.60	26.85
Parm_priors	0.06	0.01	0.11	0.02	0.06	0.57
NatM_uniform_Fem_GP_1	0.171	0.161	0.179	0.164	0.172	0.215
L_at_Amax_Fem_GP_1	48.190	48.087	48.214	48.101	48.086	48.092
VonBert_K_Fem_GP_1	0.194	0.195	0.193	0.195	0.194	0.194
CV_young_Fem_GP_1	0.110	0.108	0.111	0.109	0.107	0.108
CV_old_Fem_GP_1	0.037	0.038	0.037	0.038	0.038	0.038
NatM_uniform_Mal_GP_1	0.261	0.284	0.242	0.279	0.238	0.161
L_at_Amax_Mal_GP_1	-0.337	-0.336	-0.337	-0.335	-0.352	-0.339
VonBert_K_Mal_GP_1	0.549	0.545	0.547	0.543	0.606	0.548
CV_young_Mal_GP_1	0.208	0.226	0.204	0.222	-0.100	0.216
CV_old_Mal_GP_1	0.148	0.130	0.145	0.130	0.581	0.167
SR_LN(R0)	10.248	10.060	10.403	10.100	10.434	10.986
Q_extraSD_CalCOFI_Survey(11)	0.313	0.294	0.343	0.307	0.274	0.338
Q_extraSD_RREAS_YOY_Survey(12)	1.233	1.221	1.244	1.226	1.222	1.166
Size_DblN_peak_NoCA_HKL(1)	41.247	41.327	40.709	40.807	42.444	41.297
Size_DblN_ascend_se_NoCA_HKL(1)	4.428	4.440	4.378	4.399	4.484	4.394
Size_DblN_descend_se_NoCA_HKL(1)	5.024	5.155	5.155	5.349	5.181	5.218
Size_DblN_peak_SoCA_HKL(2)	24.245	24.223	24.263	24.226	24.307	24.484
Size_DblN_ascend_se_SoCA_HKL(2)	1.410	1.397	1.420	1.399	1.419	1.526
Size_DblN_descend_se_SoCA_HKL(2)	5.781	5.771	5.788	5.756	5.915	5.965
Size_DblN_peak_CA_TWL(3)	44.673	44.857	44.568	44.694	44.814	45.126
Size_DblN_ascend_se_CA_TWL(3)	4.502	4.508	4.499	4.507	4.452	4.488
Size_DblN_descend_se_CA_TWL(3)	2.985	3.024	2.970	3.025	3.079	2.923
Size_DblN_peak_OR_WA_Comm(4)	41.925	41.953	42.025	41.836	42.017	44.462
Size_DblN_ascend_se_OR_WA_Comm(4)	4.476	4.487	4.484	4.476	4.409	4.631
Size_DblN_peak_CA_NET(5)	45.868	46.012	45.857	46.179	46.208	45.939
Size_DblN_ascend_se_CA_NET(5)	4.307	4.333	4.308	4.353	4.285	4.295
Size_DblN_descend_se_CA_NET(5)	3.632	3.786	3.639	3.919	3.901	3.755
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.491	43.580	43.452	43.225	44.418	44.633
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.090	5.131	5.079	5.107	5.096	5.077
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	4.321	4.792	4.318	4.900	4.300	4.510
Size_DblN_peak_SoCA_Rec(7)	24.645	24.625	24.663	24.614	24.610	24.994
Size_DblN_ascend_se_SoCA_Rec(7)	2.913	2.912	2.914	2.908	2.932	2.982
Size_DblN_descend_se_SoCA_Rec(7)	3.365	3.361	3.365	3.383	3.132	3.167
Size_DblN_end_logit_SoCA_Rec(7)	-1.108	-1.121	-1.103	-1.145	-0.886	-0.792
Size_DblN_peak_TWL_discard(8)	29.547	29.516	29.561	29.502	29.741	30.279
Size_DblN_ascend_se_TWL_discard(8)	4.182	4.185	4.179	4.182	4.246	4.197
Size_DblN_descend_se_TWL_discard(8)	3.200	3.202	3.198	3.202	3.241	3.082
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	50.237	50.584	50.148	50.644	50.061	50.594
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.050	4.080	4.041	4.083	4.055	4.068
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.410	47.735	47.158	47.545	47.640	47.614
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.717	4.741	4.699	4.731	4.661	4.703
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.585	33.520	33.355	33.325	35.505	34.124
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.234	3.233	3.168	3.177	3.635	3.330
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.581	30.518	30.708	30.665	30.581	31.148
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.732	3.729	3.743	3.746	3.757	3.801
Bratio_2025	0.603	0.521	0.680	0.572	0.458	0.605
SSB_unfished	13945	12978	14818	13136	16409	17607
Totbio_unfished	61069	55516	66267	56499	72654	87354
Recr_unfished	28215	23379	32950	24347	34000	59036
Dead_Catch_SPR	2509	2189	2817	2251	2980	4297
OFLCatch_2025	2894	2243	3597	2497	2733	5232

Table 22: Likelihoods, parameter estimates, and select derived quantities based on assumptions of constant and time-varying growth (length-at-age). Likelihoods and derived quantities are shaded.

Quantity	Constant Growth (base model)	Annual variation in female 'k'
N.Parms	114	161
TOTAL	2597.98	2401.00
Survey	24.51	21.11
Length_comp	572.24	538.57
Age_comp	1976.25	1805.25
Recruitment	24.92	24.62
Parm_priors	0.06	0.12
Parm_devs	0.00	11.31
NatM_uniform_Fem_GP_1	0.171	0.180
L_at_Amax_Fem_GP_1	48.190	47.851
VonBert_K_Fem_GP_1	0.194	0.215
CV_young_Fem_GP_1	0.110	0.098
CV_old_Fem_GP_1	0.037	0.036
NatM_uniform_Mal_GP_1	0.261	0.207
L_at_Amax_Mal_GP_1	-0.337	-0.341
VonBert_K_Mal_GP_1	0.549	0.577
CV_young_Mal_GP_1	0.208	-0.100
CV_old_Mal_GP_1	0.148	0.558
VonBert_K_Fem_GP_1_dev_se	NA	0.500
VonBert_K_Fem_GP_1_dev_autocorr	NA	0.000
SR_LN(R0)	10.248	10.325
Q_extraSD_CalCOFI_Survey(11)	0.313	0.309
Q_extraSD_RREAS_YOY_Survey(12)	1.233	1.258
Size_DblN_peak_NoCA_HKL(1)	41.247	43.464
Size_DblN_ascend_se_NoCA_HKL(1)	4.428	4.492
Size_DblN_descend_se_NoCA_HKL(1)	5.024	6.470
Size_DblN_peak_SoCA_HKL(2)	24.245	24.462
Size_DblN_ascend_se_SoCA_HKL(2)	1.410	1.522
Size_DblN_descend_se_SoCA_HKL(2)	5.781	5.933
Size_DblN_peak_CA_TWL(3)	44.673	44.763
Size_DblN_ascend_se_CA_TWL(3)	4.502	4.462
Size_DblN_descend_se_CA_TWL(3)	2.985	3.053
Size_DblN_peak_OR_WA_Comm(4)	41.925	42.483
Size_DblN_ascend_se_OR_WA_Comm(4)	4.476	4.432
Size_DblN_peak_CA_NET(5)	45.868	47.336
Size_DblN_ascend_se_CA_NET(5)	4.307	4.336
Size_DblN_descend_se_CA_NET(5)	3.632	8.896
Size_DblN_peak_NoCA_OR_WA_Rec(6)	43.491	45.889
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.090	5.169
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	4.321	4.687
Size_DblN_peak_SoCA_Rec(7)	24.645	24.341
Size_DblN_ascend_se_SoCA_Rec(7)	2.913	2.854
Size_DblN_descend_se_SoCA_Rec(7)	3.365	3.247
Size_DblN_end_logit_SoCA_Rec(7)	-1.108	-1.022
Size_DblN_peak_TWL_discard(8)	29.547	29.968
Size_DblN_ascend_se_TWL_discard(8)	4.182	4.306
Size_DblN_descend_se_TWL_discard(8)	3.200	3.193
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	50.237	50.647
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.050	4.068
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	47.410	51.097
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.717	4.850
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	33.585	37.348
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.234	3.919
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	30.581	31.539
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	3.732	3.920
Bratio_2025	0.603	0.588
SSB_unfished	13945	13710
Totbio_unfished	61069	62341
Recr_unfished	28215	30485
Dead_Catch_SPR	2509	2636
OFLCatch_2025	2894	3287

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	**1474**
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 trawl selectivity in California. Likelihoods and derived quantities are shaded.

Label	h=0.72, female M=male M	h=0.72, sex-specific M	est. h, sex-specific M
N.Parms	113	114	115
TOTAL	2618.64	2597.98	2596.26
Survey	25.79	24.51	22.77
Length_comp	578.65	572.24	572.70
Age_comp	1987.97	1976.25	1975.40
Recruitment	25.50	24.92	24.12
Parm_priors	0.71	0.06	1.27
NatM_uniform_Fem_GP_1	0.224	0.171	0.175
L_at_Amax_Fem_GP_1	47.829	48.190	48.165
VonBert_K_Fem_GP_1	0.196	0.194	0.194
CV_young_Fem_GP_1	0.105	0.110	0.110
CV_old_Fem_GP_1	0.040	0.037	0.038
NatM_uniform_Mal_GP_1	0.000	0.261	0.253
L_at_Amax_Mal_GP_1	-0.360	-0.337	-0.337
VonBert_K_Mal_GP_1	0.626	0.549	0.548
CV_young_Mal_GP_1	0.177	0.208	0.211
CV_old_Mal_GP_1	0.428	0.148	0.145
SR_LN(R0)	10.991	10.248	10.411
SR_BH_steep	0.720	0.720	0.433
Q_extraSD_CalCOFI_Survey(11)	0.342	0.313	0.293
Q_extraSD_RREAS_YOY_Survey(12)	1.252	1.233	1.236
Size_DblN_peak_NoCA_HKL(1)	43.784	41.247	41.261
Size_DblN_ascend_se_NoCA_HKL(1)	4.587	4.428	4.430
Size_DblN_descend_se_NoCA_HKL(1)	5.572	5.024	5.064
Size_DblN_peak_SoCA_HKL(2)	24.308	24.245	24.259
Size_DblN_ascend_se_SoCA_HKL(2)	1.461	1.410	1.417
Size_DblN_descend_se_SoCA_HKL(2)	6.512	5.781	5.803
Size_DblN_peak_CA_TWL(3)	46.058	44.673	44.764
Size_DblN_ascend_se_CA_TWL(3)	4.500	4.502	4.506
Size_DblN_descend_se_CA_TWL(3)	2.888	2.985	2.988
Size_DblN_peak_OR_WA_Comm(4)	55.028	41.925	42.189
Size_DblN_ascend_se_OR_WA_Comm(4)	5.414	4.476	4.500
Size_DblN_peak_CA_NET(5)	47.494	45.868	45.887
Size_DblN_ascend_se_CA_NET(5)	4.362	4.307	4.309
Size_DblN_descend_se_CA_NET(5)	9.354	3.632	3.646
Size_DblN_peak_NoCA_OR_WA_Rec(6)	47.828	43.491	43.588
Size_DblN_ascend_se_NoCA_OR_WA_Rec(6)	5.272	5.090	5.095
Size_DblN_descend_se_NoCA_OR_WA_Rec(6)	9.935	4.321	4.344
Size_DblN_peak_SoCA_Rec(7)	24.683	24.645	24.672
Size_DblN_ascend_se_SoCA_Rec(7)	2.939	2.913	2.918
Size_DblN_descend_se_SoCA_Rec(7)	2.772	3.365	3.343
Size_DblN_end_logit_SoCA_Rec(7)	-0.485	-1.108	-1.078
Size_DblN_peak_TWL_discard(8)	29.948	29.547	29.588
Size_DblN_ascend_se_TWL_discard(8)	4.273	4.182	4.185
Size_DblN_descend_se_TWL_discard(8)	3.267	3.200	3.193
Size_DblN_peak_NoCA_HKL(1)_BLK1repl_1875	51.777	50.237	50.182
Size_DblN_ascend_se_NoCA_HKL(1)_BLK1repl_1875	4.117	4.050	4.046
Size_DblN_peak_SoCA_HKL(2)_BLK2repl_1875	50.630	47.410	47.439
Size_DblN_ascend_se_SoCA_HKL(2)_BLK2repl_1875	4.838	4.717	4.718
Size_DblN_peak_CA_TWL(3)_BLK3repl_1875	37.666	33.585	33.607
Size_DblN_ascend_se_CA_TWL(3)_BLK3repl_1875	3.997	3.234	3.240
Size_DblN_peak_SoCA_Rec(7)_BLK2repl_1875	33.276	30.581	30.549
Size_DblN_ascend_se_SoCA_Rec(7)_BLK2repl_1875	4.176	3.732	3.726
Bratio_2025	0.646	0.603	0.470
SSB_unfished	15855.9	13944.9	15678.3
Totbio_unfished	87868.4	61068.6	69364.8
Recr_unfished	59347.2	28215.2	33219.5
Dead_Catch_SPR	4340.3	2508.7	1665.6
OFLCatch_2025	5894.4	2894.4	2626.3

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

Quantity	value
SSB	-0.806
Rec	6.160
Bratio	-0.744
F	1.061
WoodHole_SSB.all	-0.792
WoodHole_Rec.all	3.025
WoodHole_Bratio.all	-0.730
WoodHole_F.all	1.047
AFSC_Hurtado_SSB	-0.161
AFSC_Hurtado_Rec	1.232
AFSC_Hurtado_F	0.212
AFSC_Hurtado_Bratio	-0.149

Table 26: Harvest projections assuming GMT-specified catches in 2025-2026, and ABC=ACL catches from 2027 onward. ABC values are based on default values for a “category 1” assessment (sigma=0.5 and Pstar = 0.45).

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 3+ Biomass (mt)	Spawning output	Fraction Unfished
2025	2894.4	1598.7	33819	8402	0.603
2026	2679.2	1521.6	31810	7760	0.556
2027	2586.2	2418.1	33232	7348	0.527
2028	2504.5	2329.2	33139	6972	0.500
2029	2498.6	2313.7	33351	6816	0.489
2030	2540.4	2342.2	33633	6772	0.486
2031	2595.5	2380.1	33859	6774	0.486
2032	2640.6	2410.9	33998	6785	0.487
2033	2668.0	2425.2	34058	6790	0.487
2034	2680.6	2423.2	34070	6788	0.487
2035	2684.9	2416.4	34059	6781	0.486
2036	2685.0	2405.7	34042	6772	0.486

Table 27: ‘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 a favorable ranking, Level 2 is neutral and Level 3 is unfavorable

Ecosystem and environmental conditions	Assessment data inputs	Assessment model fits and structural uncertainty
Larval production: Based on 2024- 2025 environmental conditions, neutral to unfavorable. Recruitment: 2024 pelagic YOY abundance high for chilipepper (index in model), with diverse pelagic YOY groundfish community (not in model). 2025 environmental conditions are favorable (good spiciness), as are preliminary RREAS catches. Overall, favorable conditions for recruitment. Prey: Most evidence suggests abundant forage, favorable conditions, positive. Predators: Ongoing long-term increases in abundance, but no evidence of recent sharp increases, neutral. Growth: Neutral (recent years) to potentially unfavorable in near term (based on autocorrelation in growth variability).	Historically and currently among most important commercial species in California, catch reconstruction and recent catch data are reliable Robust age data to inform assessment, good fits to age and length composition data. Modest aging error concerns need resolution Robust information on reproductive ecology, but some uncertainty in role of multiple brooding Long term time series (CalCOFI) is noisy but provides a “low frequency” signal, WCGBTS index is reasonably well fit in most years Index of pelagic juvenile abundance provides information on incoming recruitment	TO BE COMPLETED FOLLOWING THE STAR PANEL
Level 1	Level 1	

9 Figures

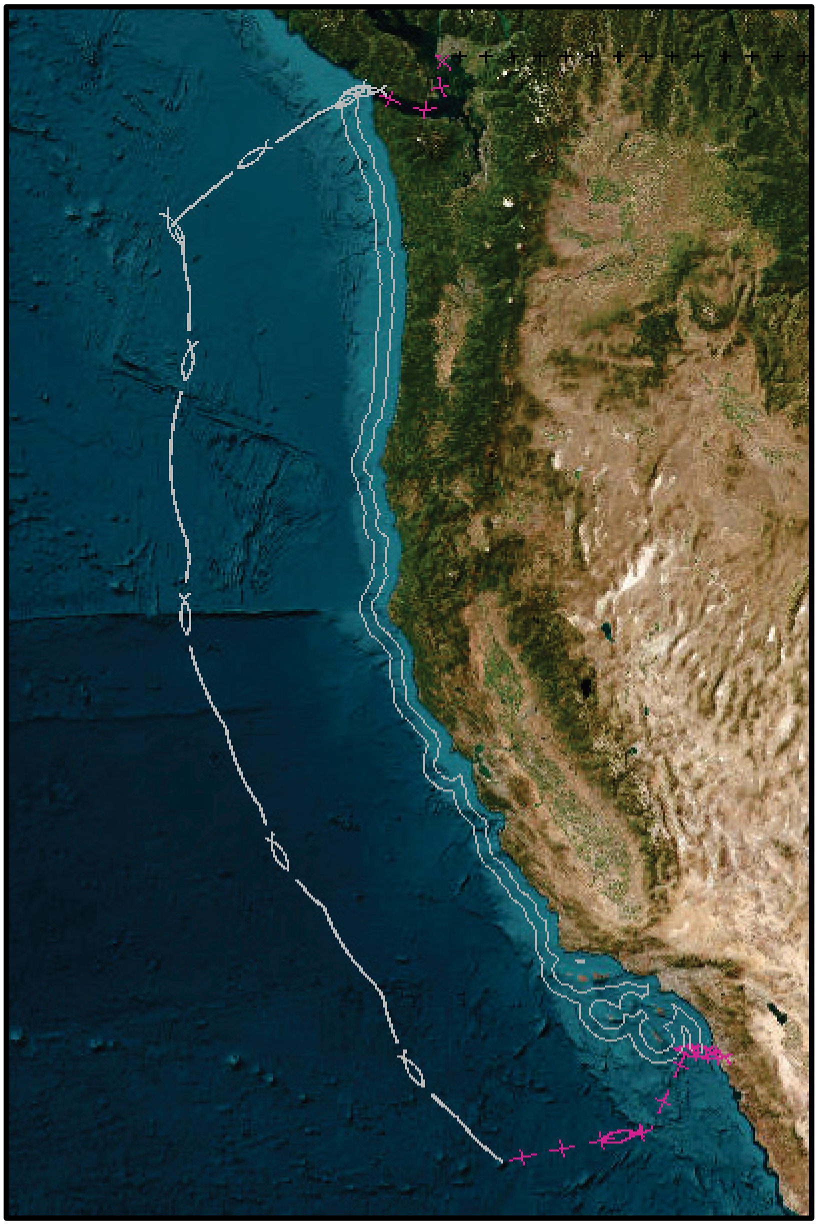

Figure 1: Map of the assessed area: Waters inside the U.S. Exclusive Economic Zone (EEZ) off the coasts of Washington, Oregon, and California. Source: NOAA U.S. Maritime Limits and Boundaries Webmap.

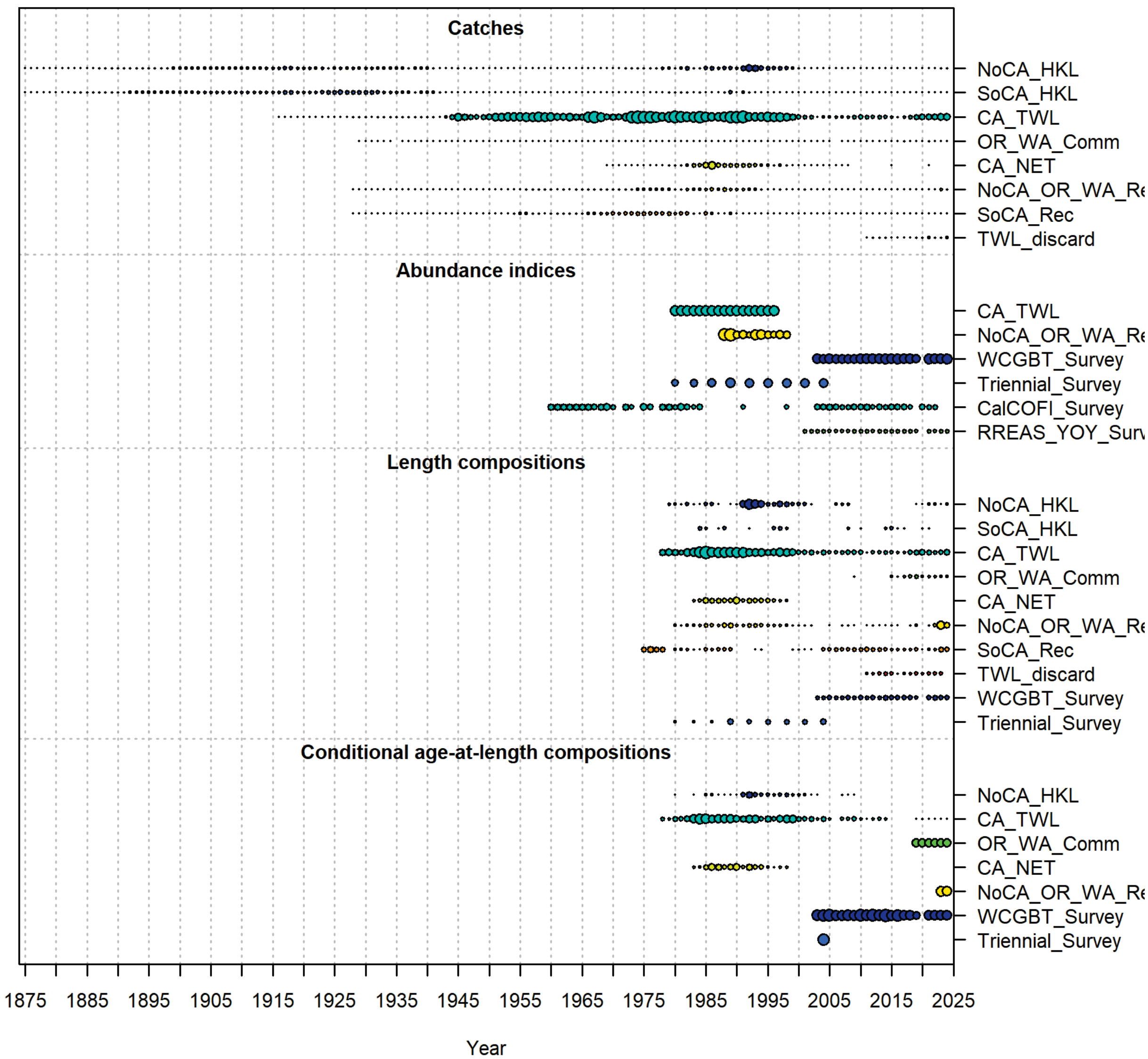

Figure 2: Summary of data sources by year, type, and fleet in the chilipepper base model. Two abundance indices ("CA_TWL" and "NoCA_OR_WA_Rec") were in previous assessments, but are not included in the likelihood (i.e. not used to fit the 2025 model). Circle area is relative within a data type. Circles are proportional to total catch for catches; to precision for indices; to total sample size for length compositions or conditional age-at-length observations.

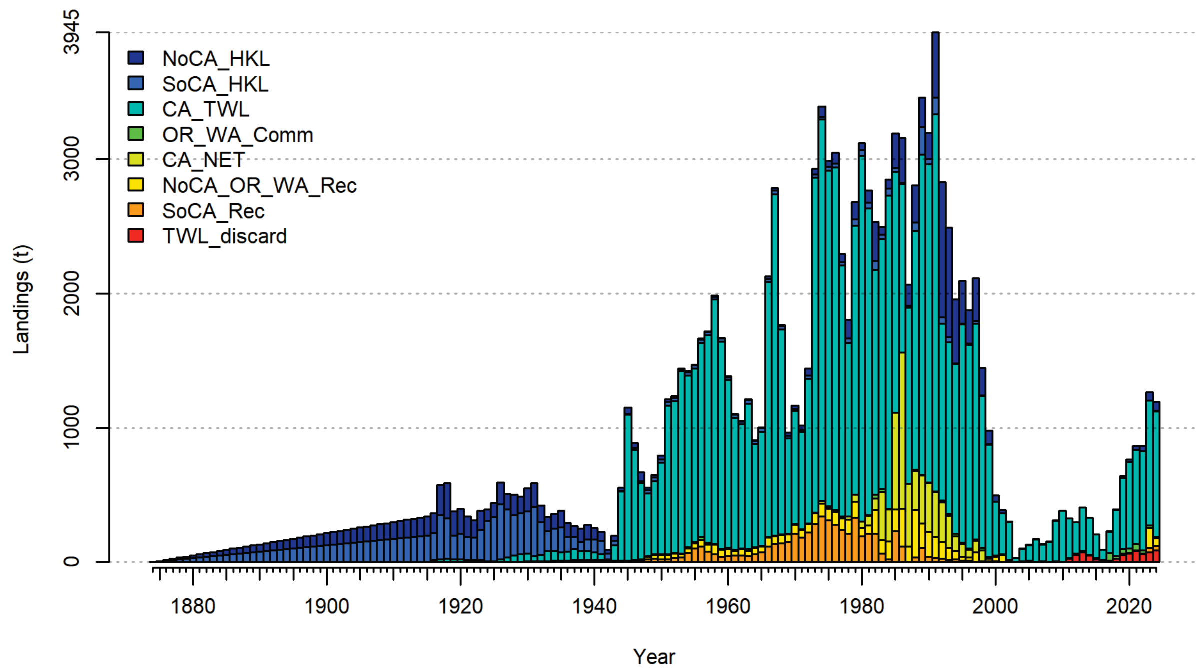

Figure 3: Total catch (mt) by fleet and year (including discards) used in the model. Values are stacked so bar height equals total removals in each year.

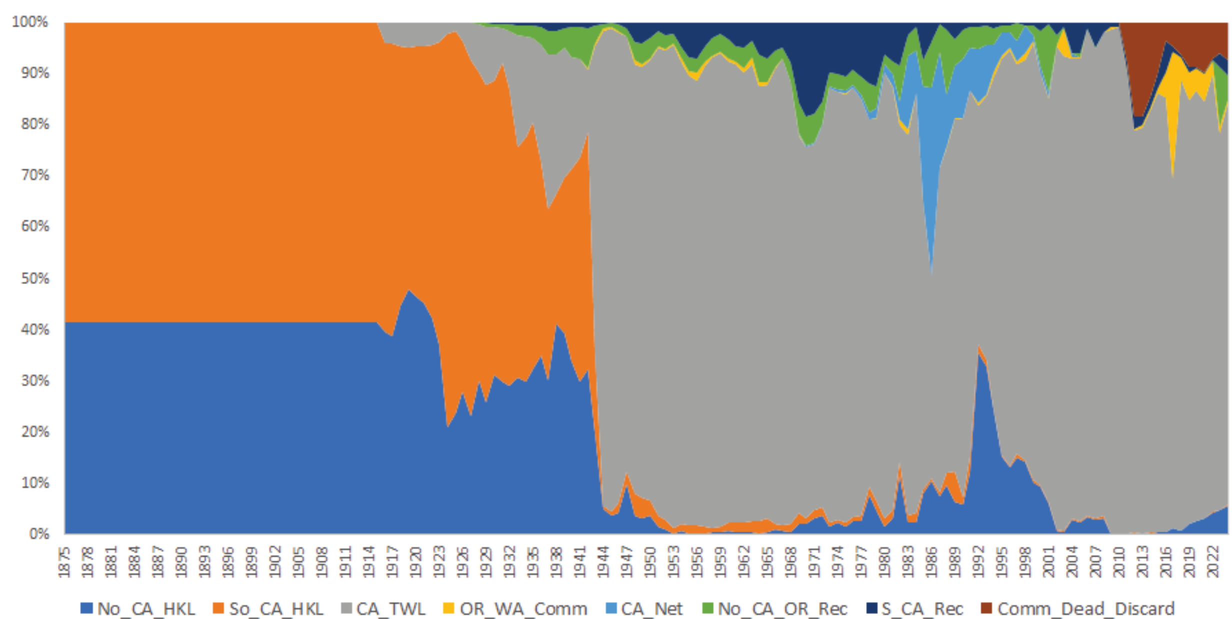

Figure 4: Percentage of total annual catch by fleet and year.

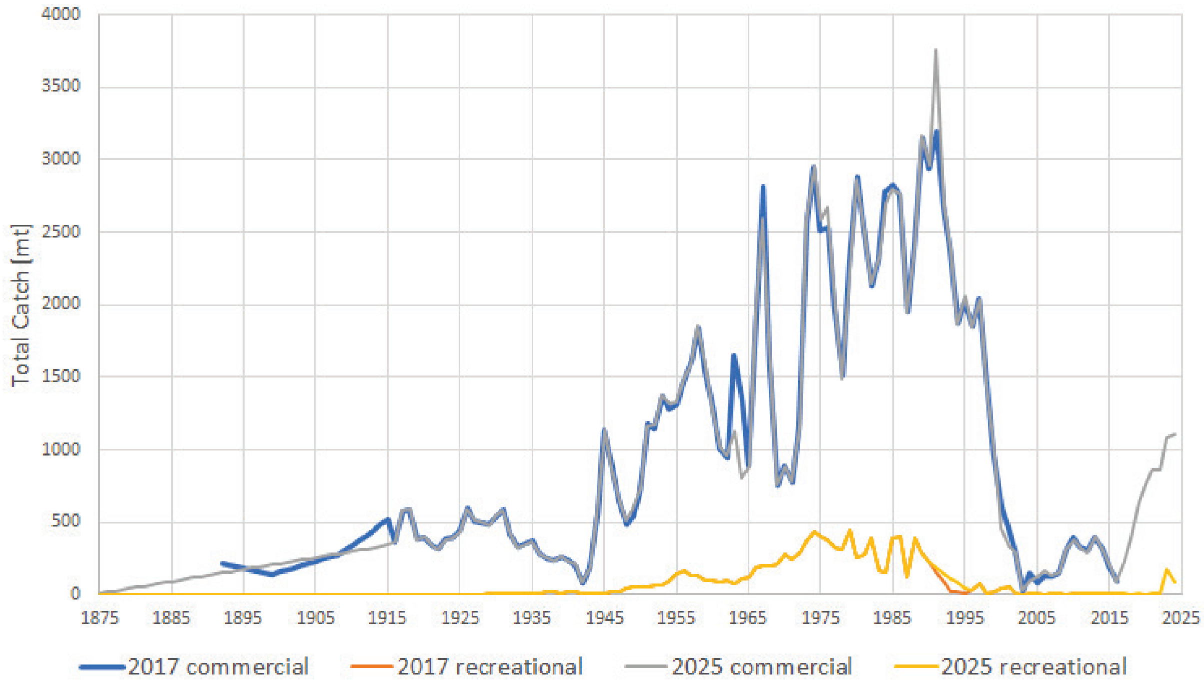

Figure 5: Comparison of catch estimates (mt) by year, sector (commercial or recreational), and assessment.

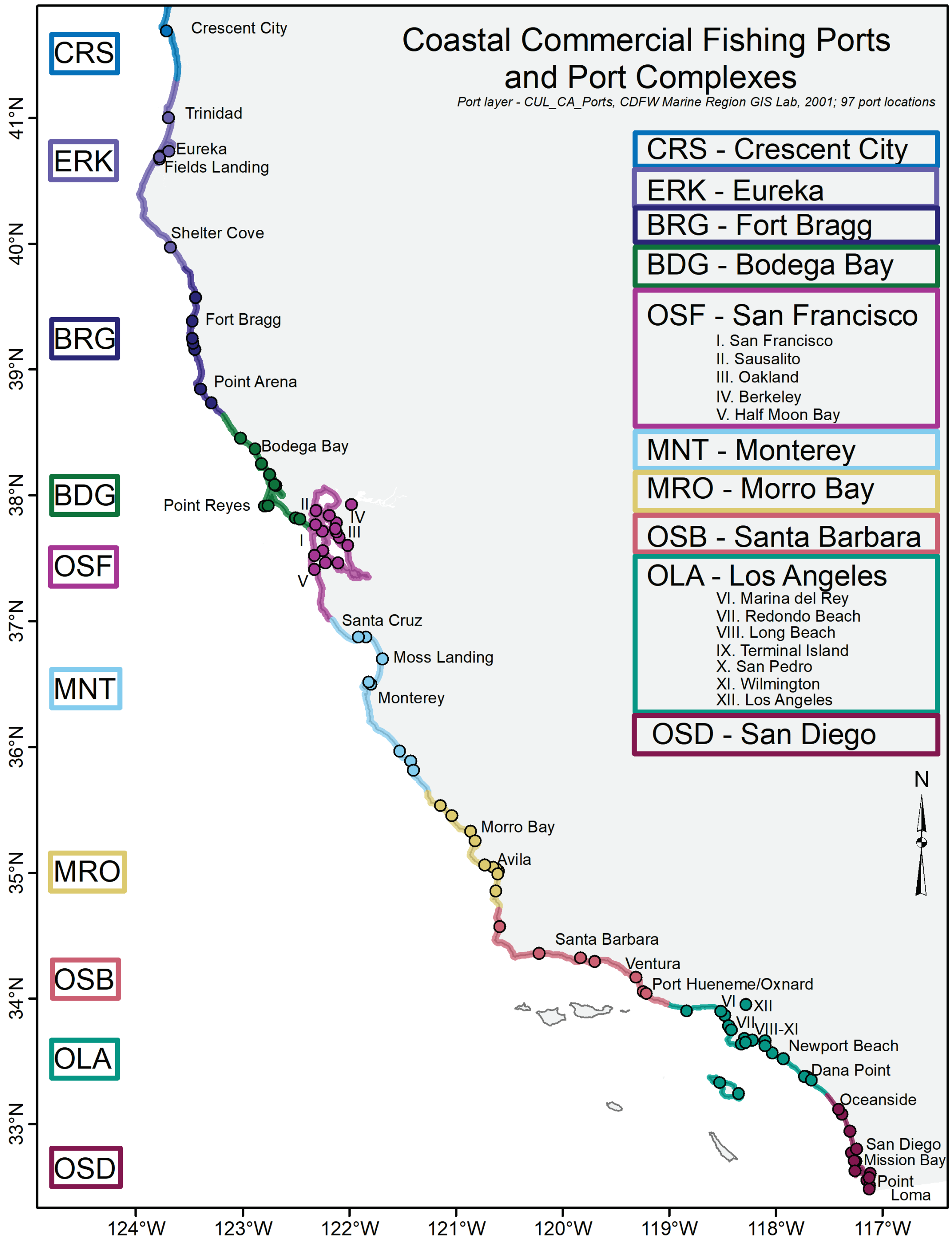

Figure 6: California commercial fishing ports and port complexes sampled by the CCGS.

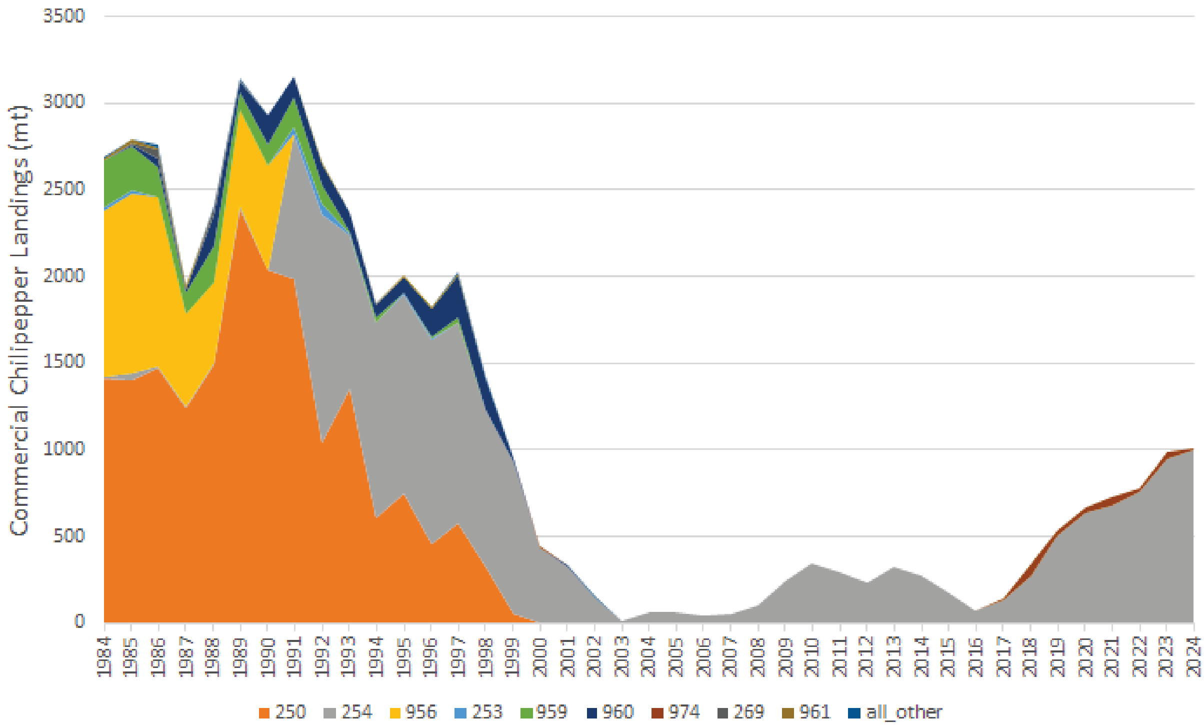

Figure 7: Chilipepper rockfish landings in California by market category and year. The "chilipepper"market category is 254. Other categories shown include 250 (Rockfish, unspecified), and 956 (Rockfish, group bocaccio/chili).

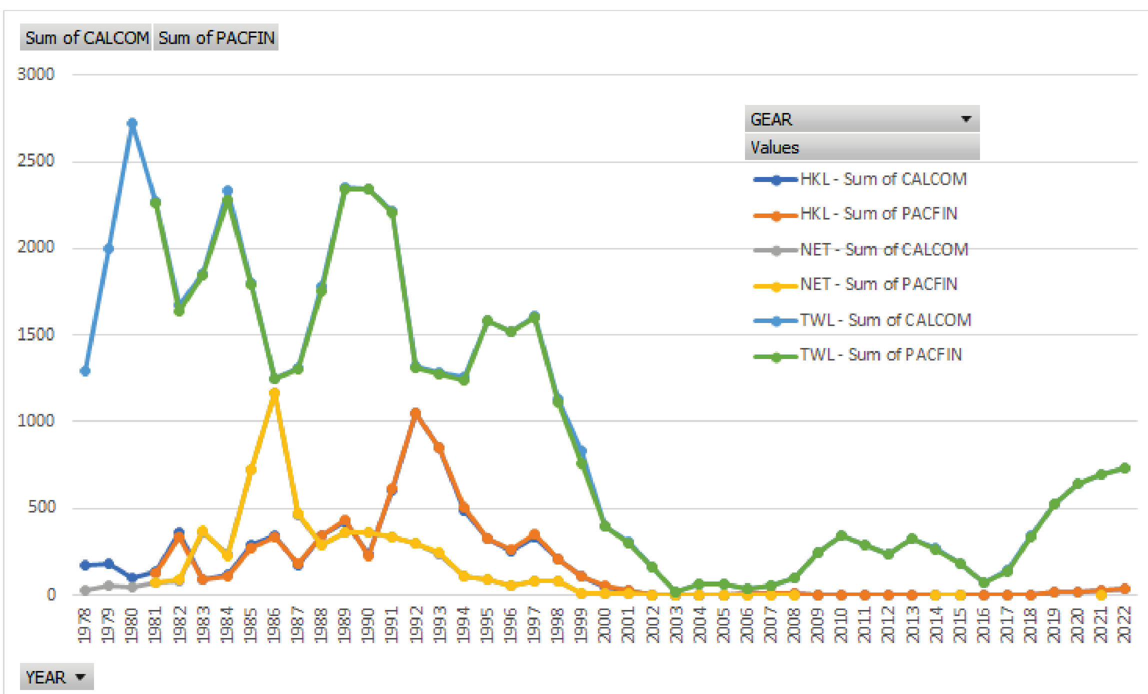

Figure 8: Comparison of catch estimates (mt) by year, commercial gear type, and database.

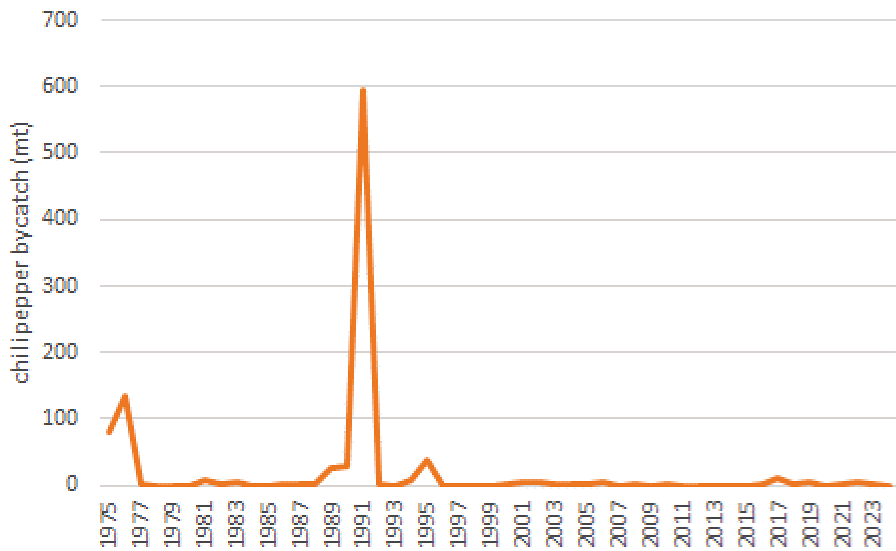

Figure 9: Chilipepper bycatch in the at-sea hake fishery.

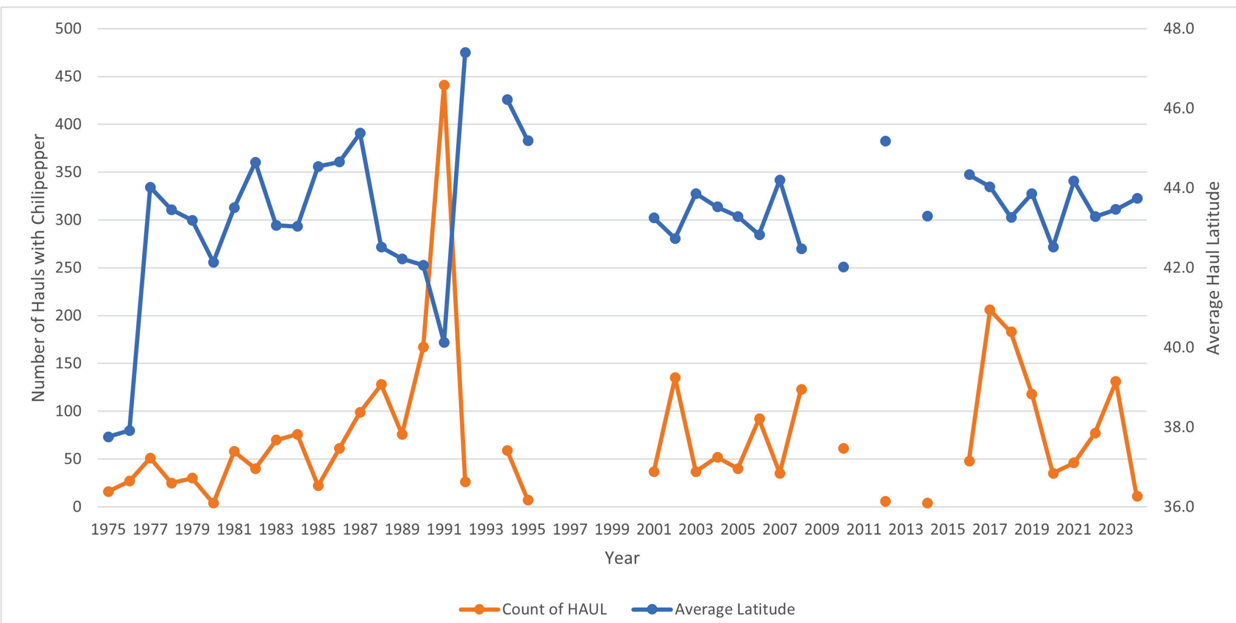

Figure 10: Annual number of hauls and average latitude fished in the at-sea hake fishery.

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

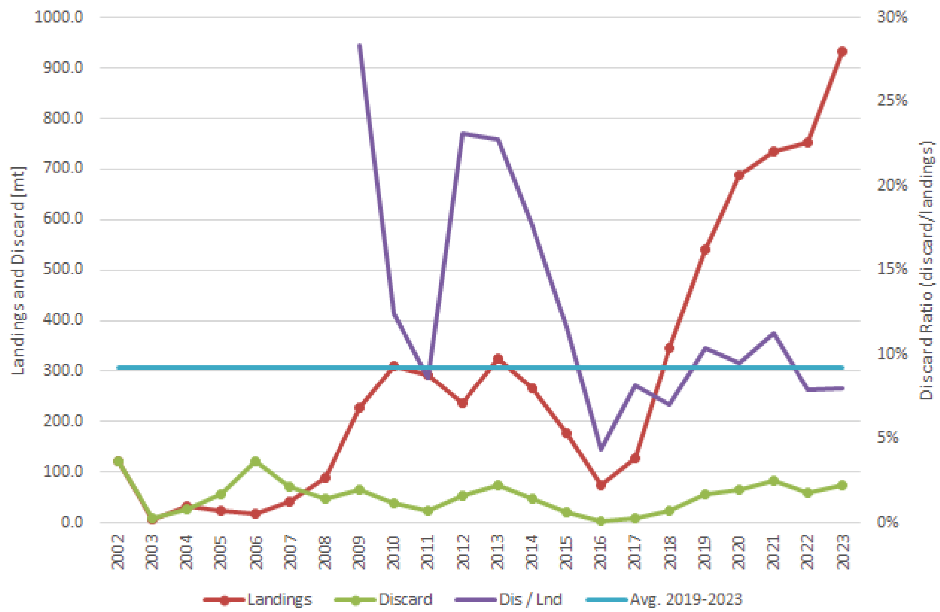

Figure 12: Landings and discards from trawl sectors (combined) in the GEMM report.

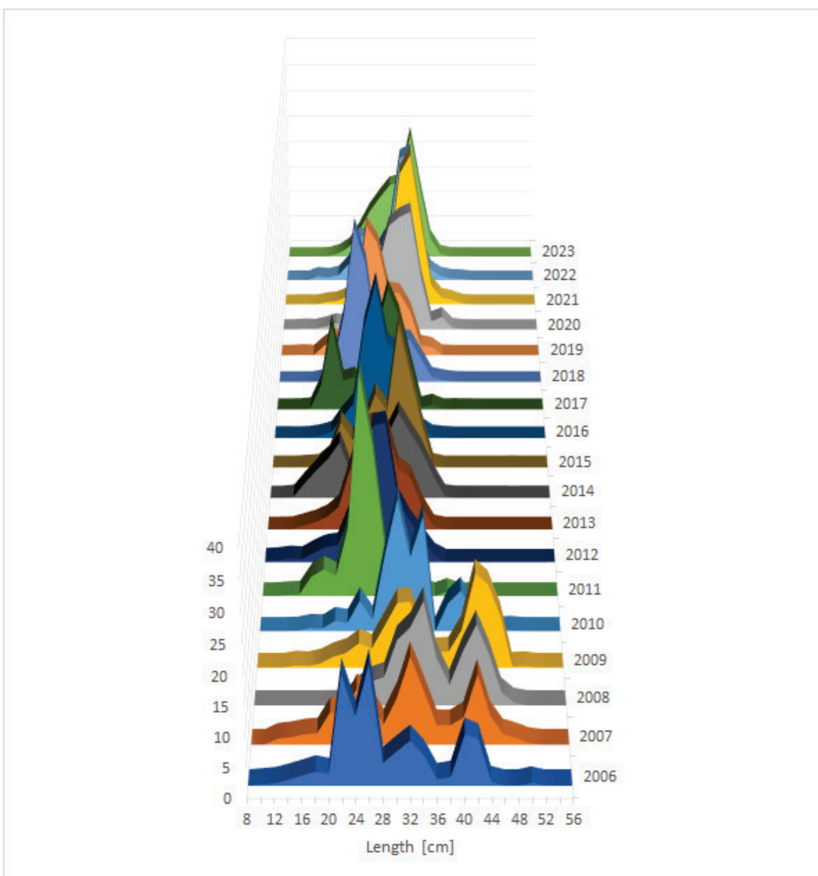

Figure 13: Length distributions of discarded chilipepper in the trawl fleet. Note the shift in 2011 at the beginning of the IFQ fishery. Source: WCGOP.

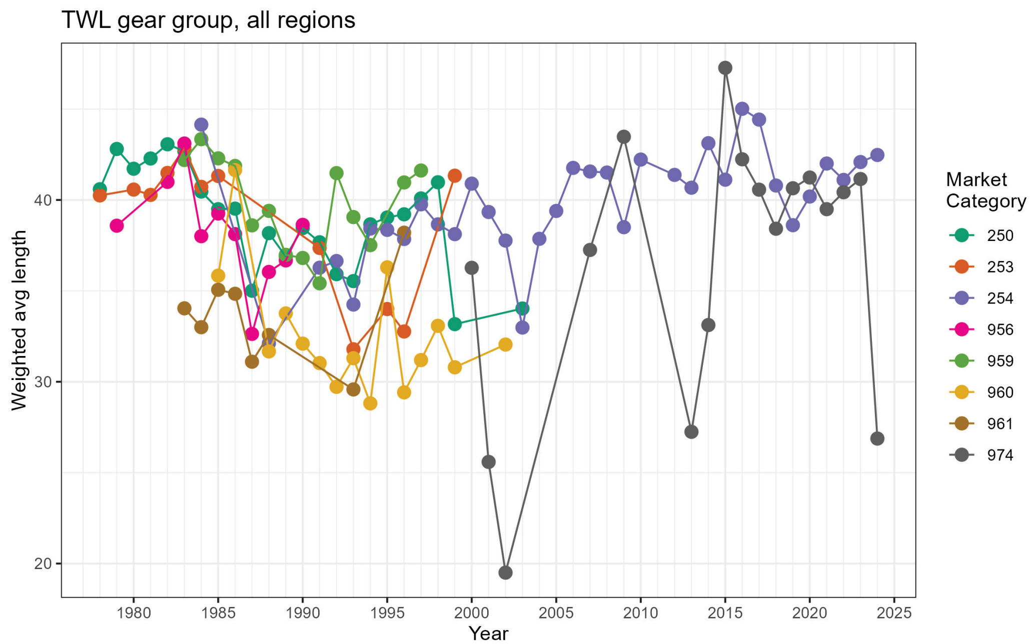

Figure 14: Catch-weighted differences in mean chilipepper length in California, all trawl gears combined, by year and market category.

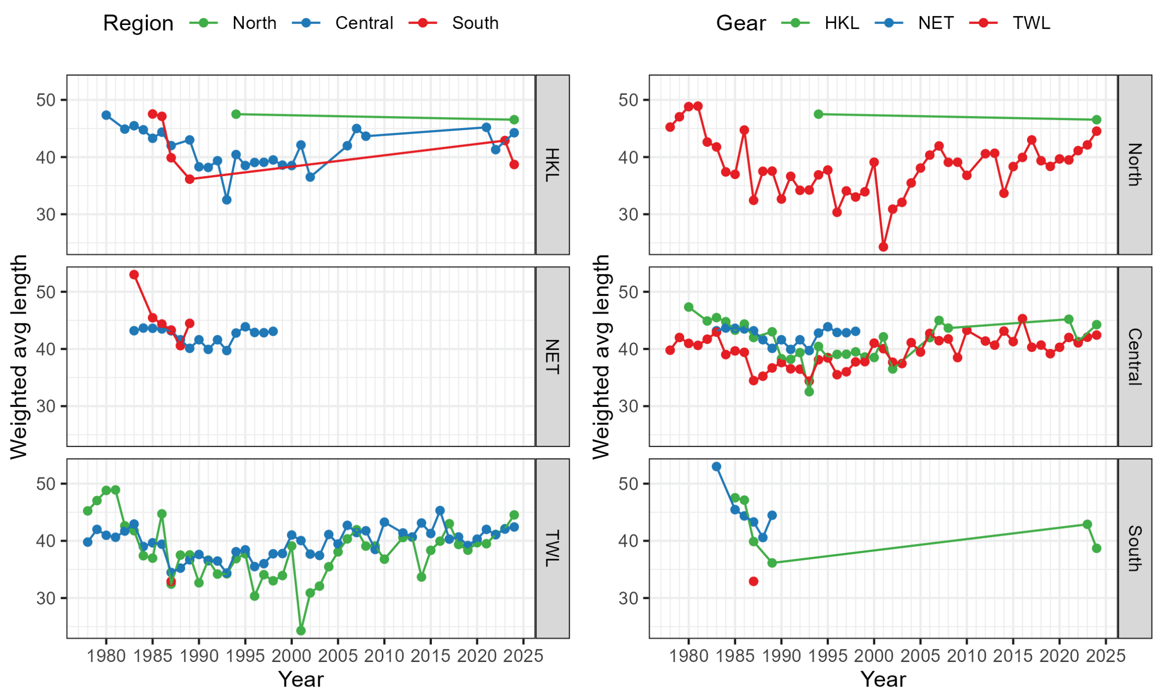

Figure 15: Differences in catch-weighted mean length in California, by year, gear, and region (North = Eureka and Crescent City port complexes, Central = Fort Bragg, Bodega Bay, San Francisco, Monterey, and Morro Bay port complexes, South = Santa Barbara, Los Angeles and San Diego port complexes).

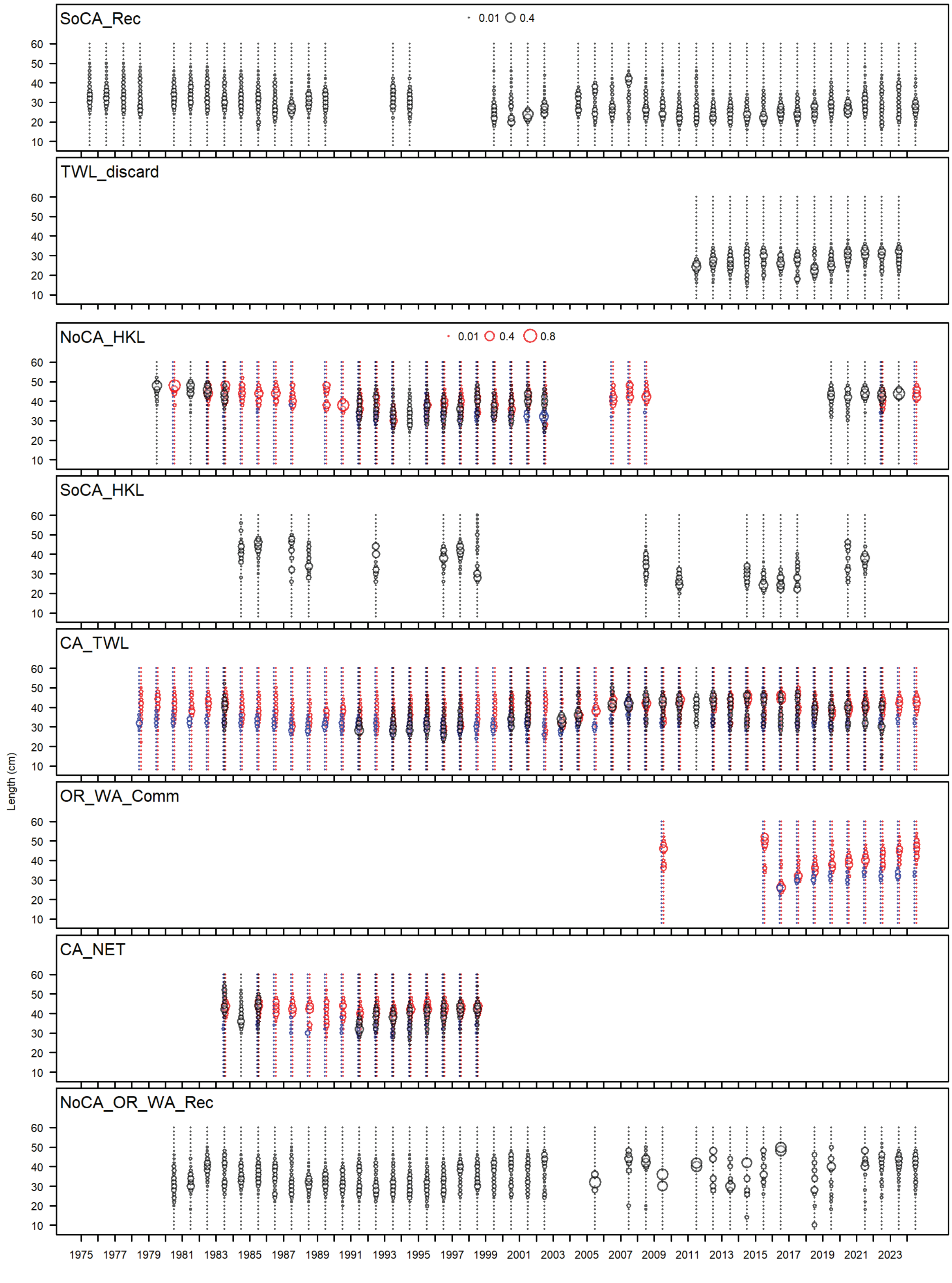

Figure 16: Length composition data from fishery fleets.

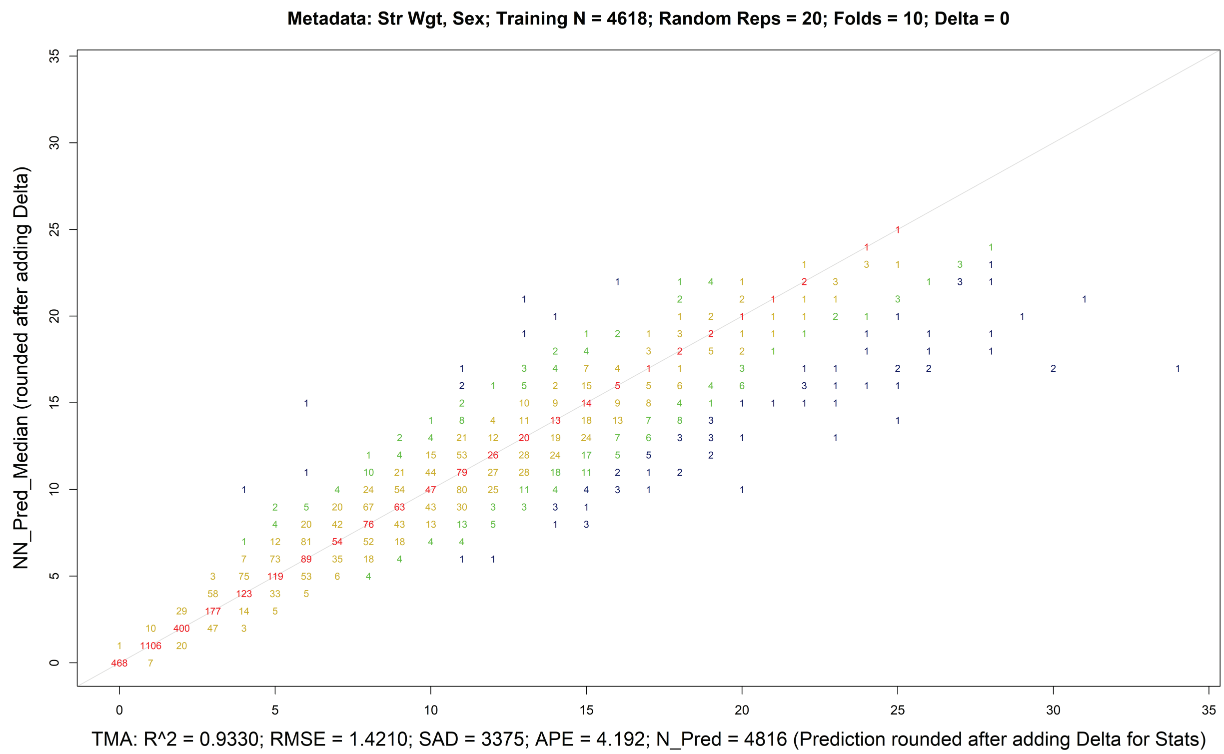

Figure 17: Traditional age estimates relative to the predictions for the training set of 4618 otoliths used to develop the Neural Network model. Results indicate a bias to younger estimates after approximately age 15.

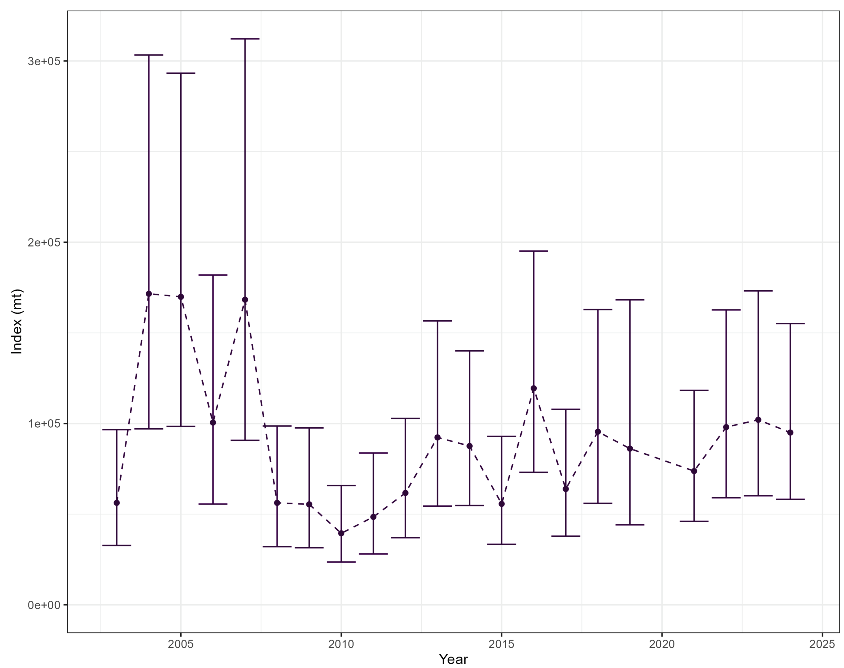

Figure 18: WCGBTS relative abundance index for chilipepper rockfish. Hauls from Washington were excluded due to a small number of positive observations.

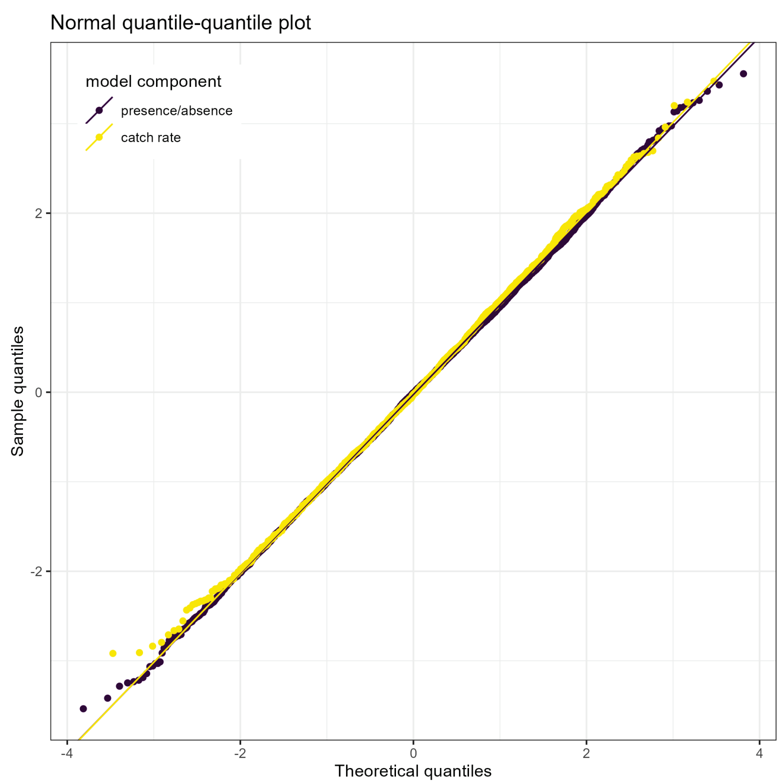

Figure 19: Quantile-quantile plot for component models (binomial and lognormal) of the WCGBTS relative abundance index for chilipepper rockfish.

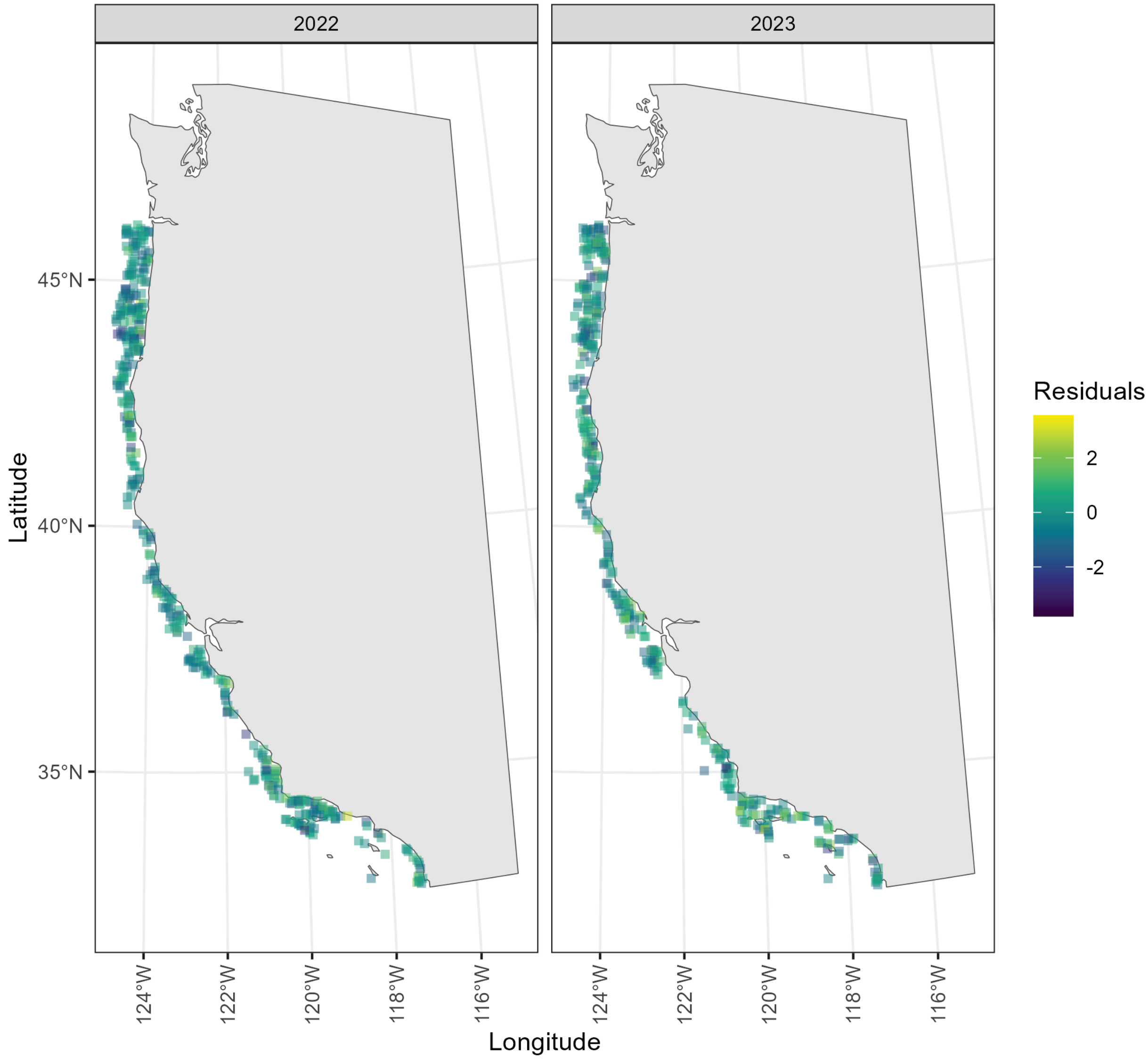

Figure 20: Map of residuals from the WCGBTS index used in the chilipepper rockfish assessment. Example shown is for 2022-2023.

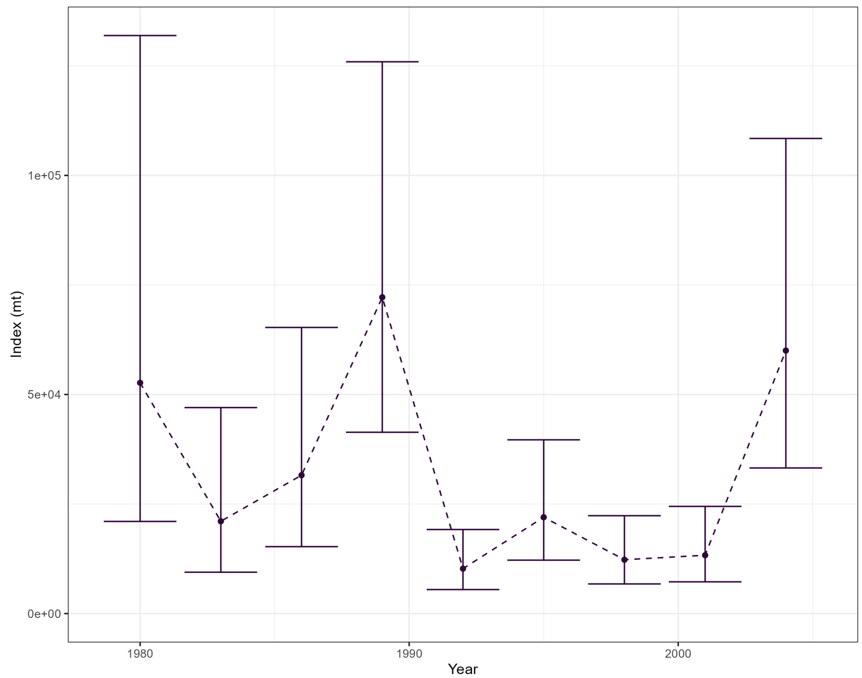

Figure 21: Triennial trawl survey relative abundance index for chilipepper rockfish.

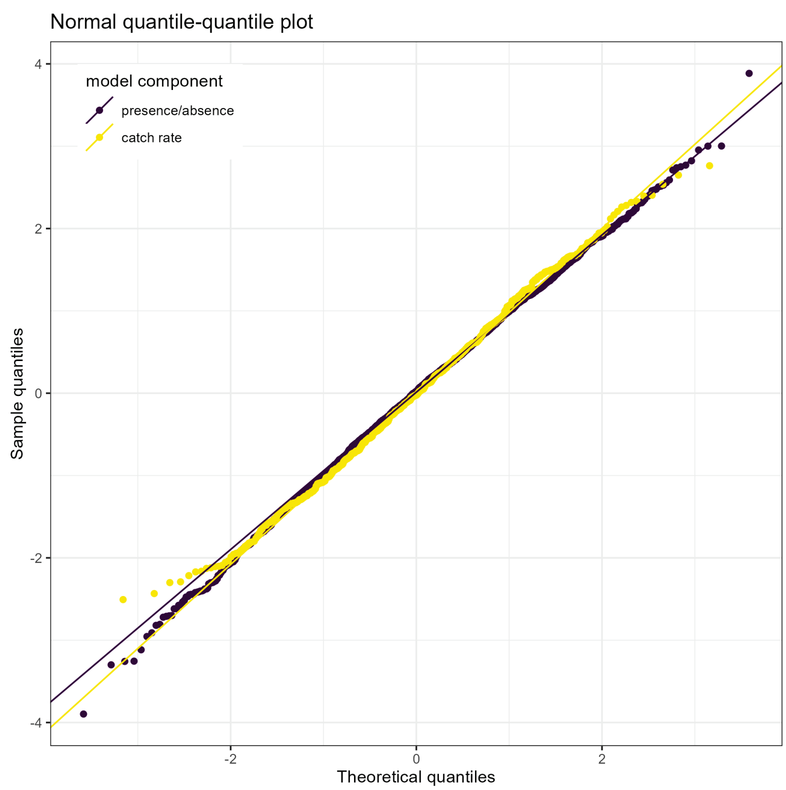

Figure 22: Quantile-quantile plot for component models (binomial and lognormal) of the Triennial trawl survey relative abundance index for chilipepper rockfish.

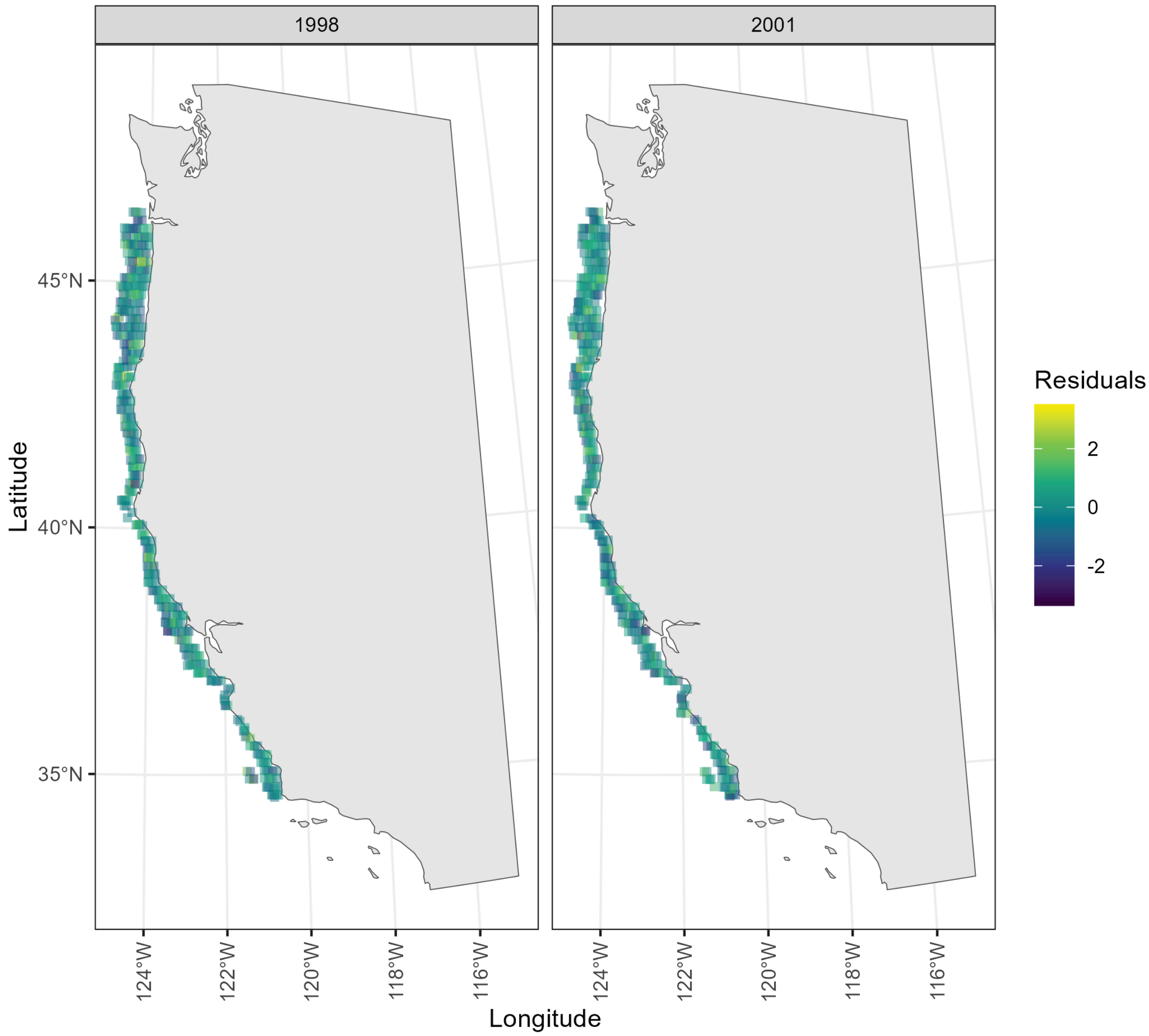

Figure 23: Map of residuals from the Triennial trawl survey index used in the chilipepper rockfish assessment. Example shown is for 1998 & 2001.

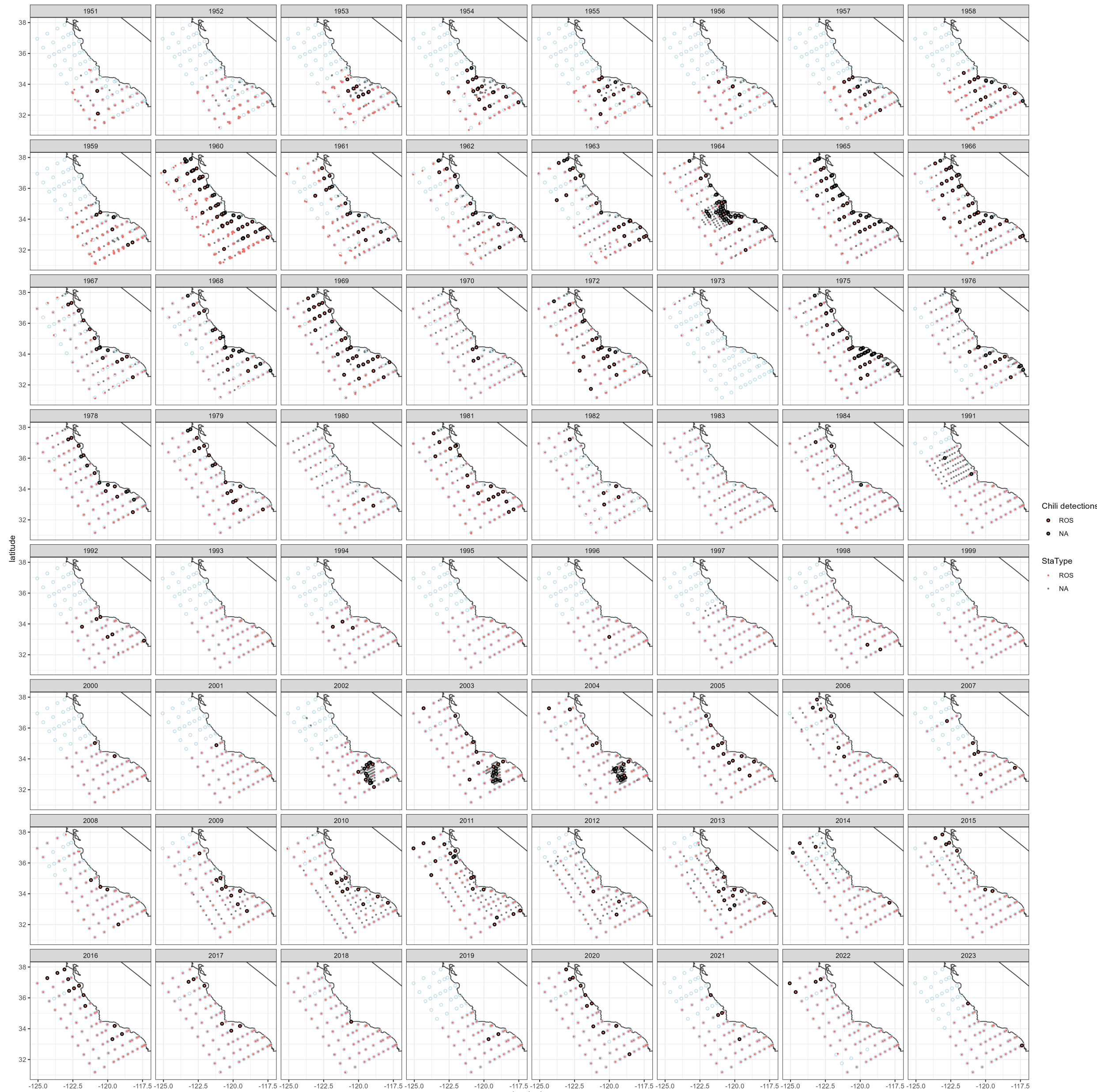

Figure 24: Spatial and temporal distribution of all CalCOFI tows retained for analysis. Light blue open circles are locations of the standard CalCOFI stations. Filled circles are tows, with color indicating whether they are at standard CalCOFI stations or other stations. The filled circles outlined in black are samples with a positive catch of chilipepper.

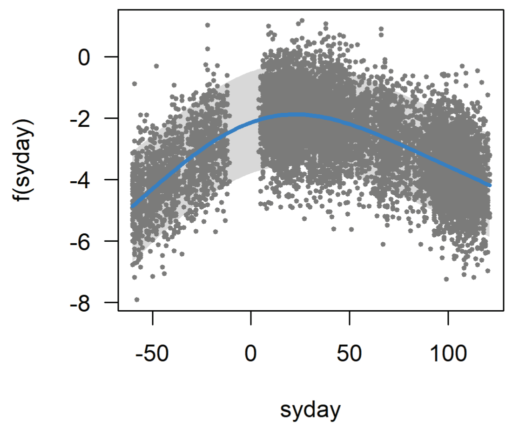

Figure 25: Conditional effect of Julian date on larval chilipepper rockfish density from the CalCOFI survey. Points are partial randomized quantile residuals

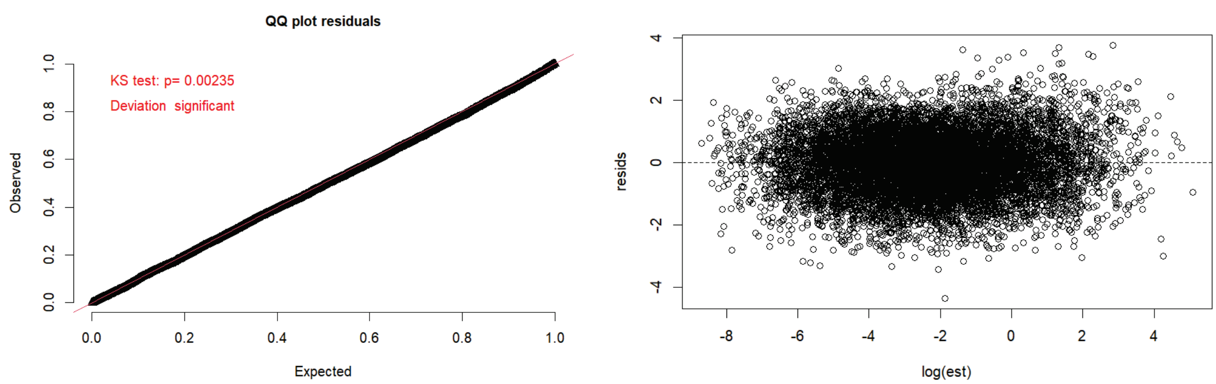

Figure 26: Diagnostic plots for the model of larval chilipepper rockfish from the CalCOFI survey. Q-Q plot for Dharma residuals based on 500 simulations, and plot of predicted values vs. residual. The KS normality test is often statistically significant when sample sizes are large, but there is not strong visual evidence of a meaningful deviation.

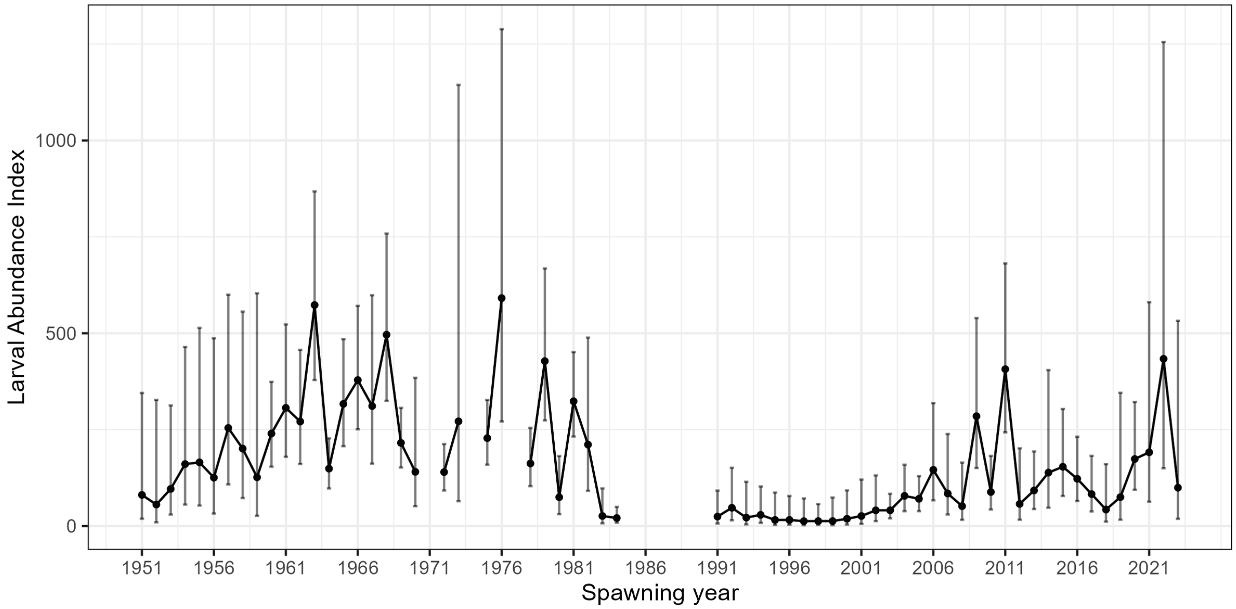

Figure 27: Abundance index for larval chilipepper rockfish from the CalCOFI survey. Error bars are 95% CI.

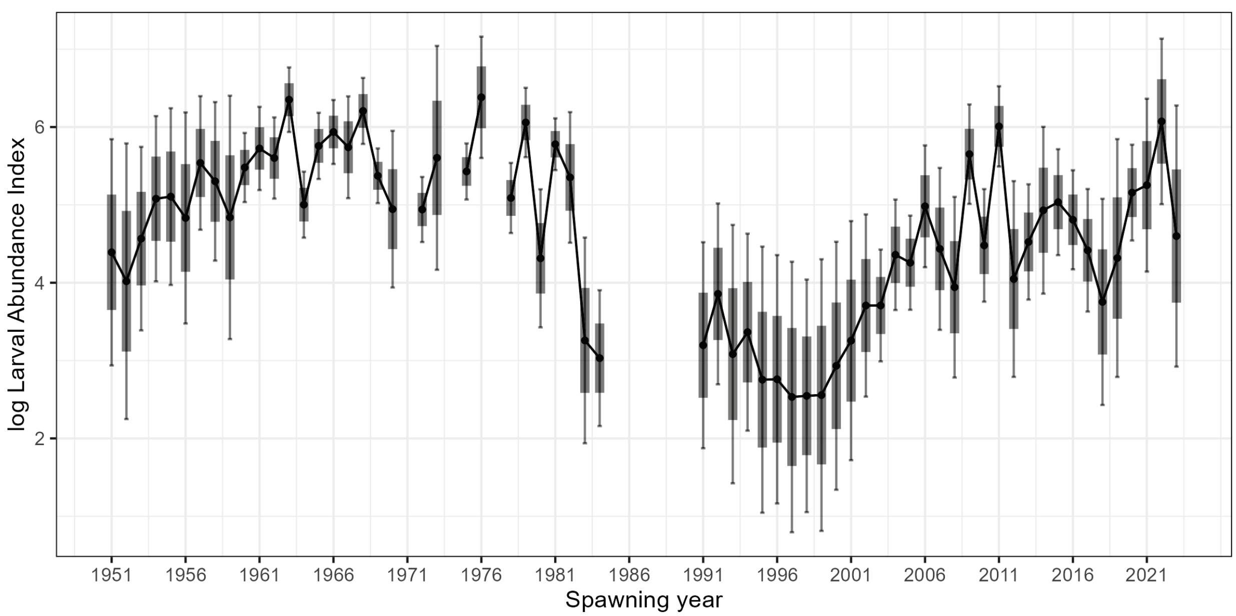

Figure 28: Log abundance index for larval chilipepper rockfish from the CalCOFI survey. Error bars are +/- 1 SE (thick bars) and 95% CI (thin bars).

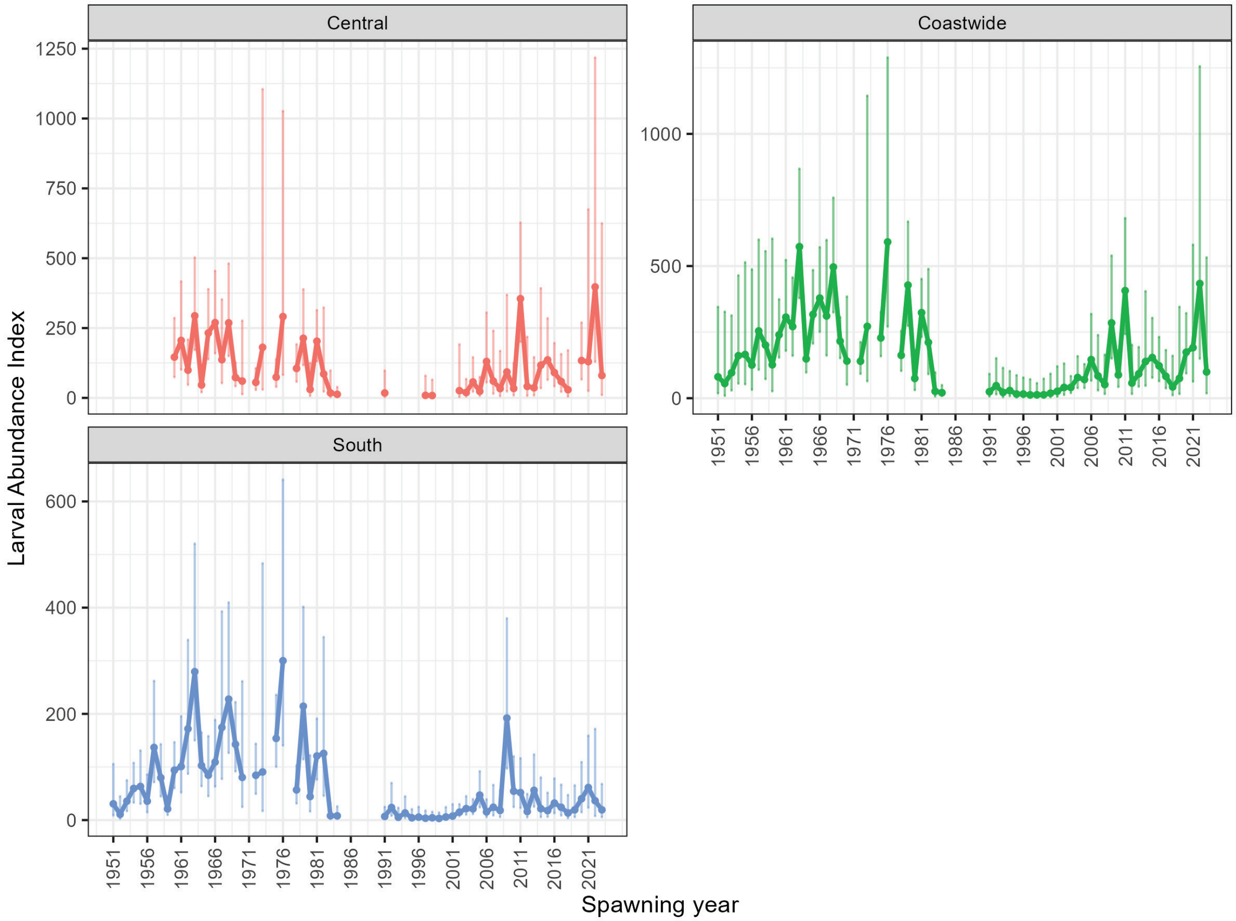

Figure 29: Abundance index for larval chilipepper rockfish from the CalCOFI survey, for coastwide (same as Figure 27), central, and south regions. The index for the central region excludes years with no sampling in this region.

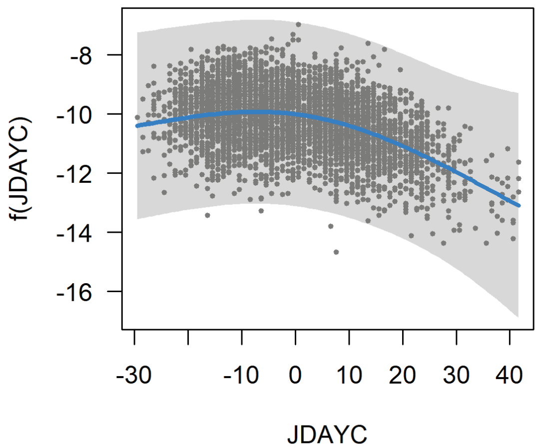

Figure 30: Julian date effect estimated in the RREAS index of age-0 recruits. Declines in density are expected over time due to settlement out of the pelagic juvenile stage.

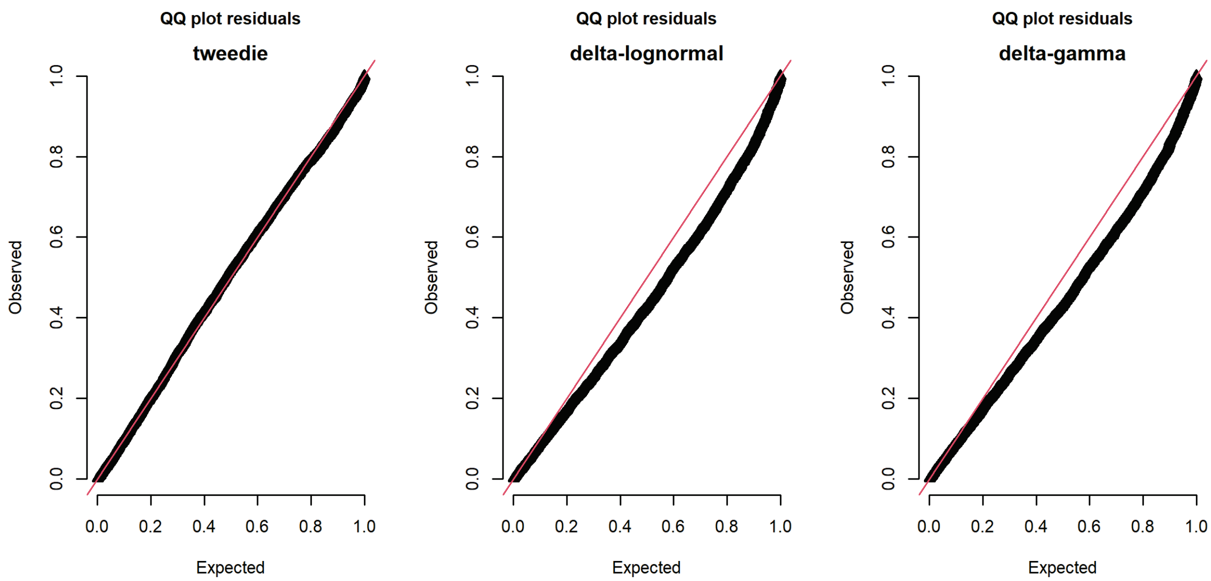

Figure 31: Evaluation of alternative distributional assumptions for the RREAS index of age-0 recruits.

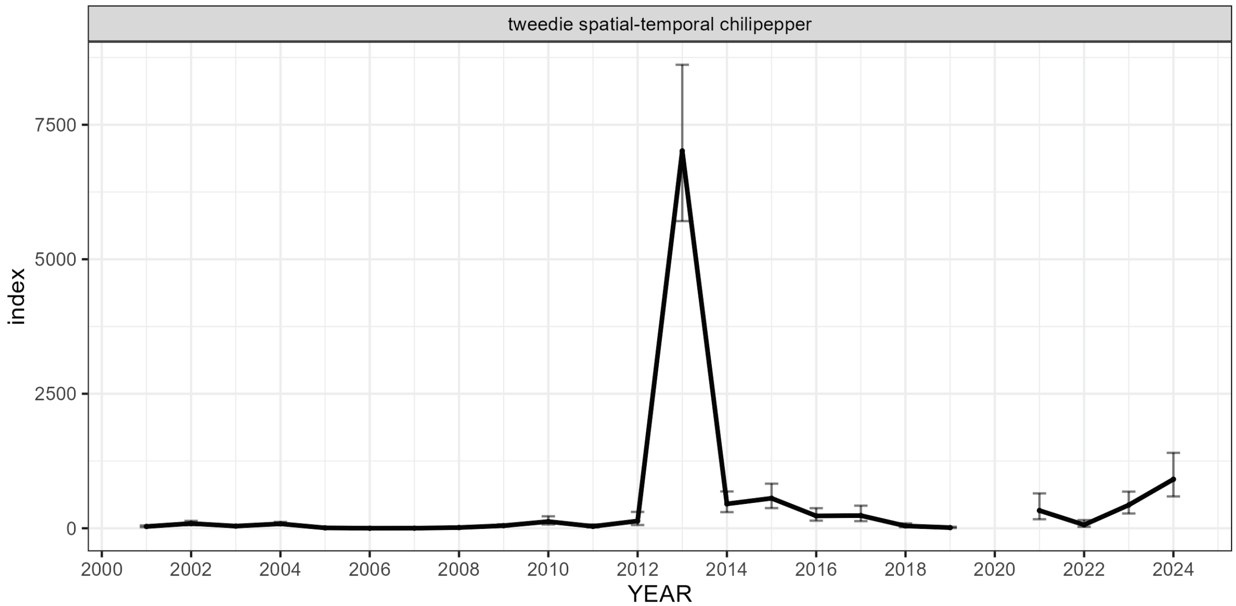

Figure 32: RREAS index of age-0 recruits for chilipepper rockfish, 2001-2024.

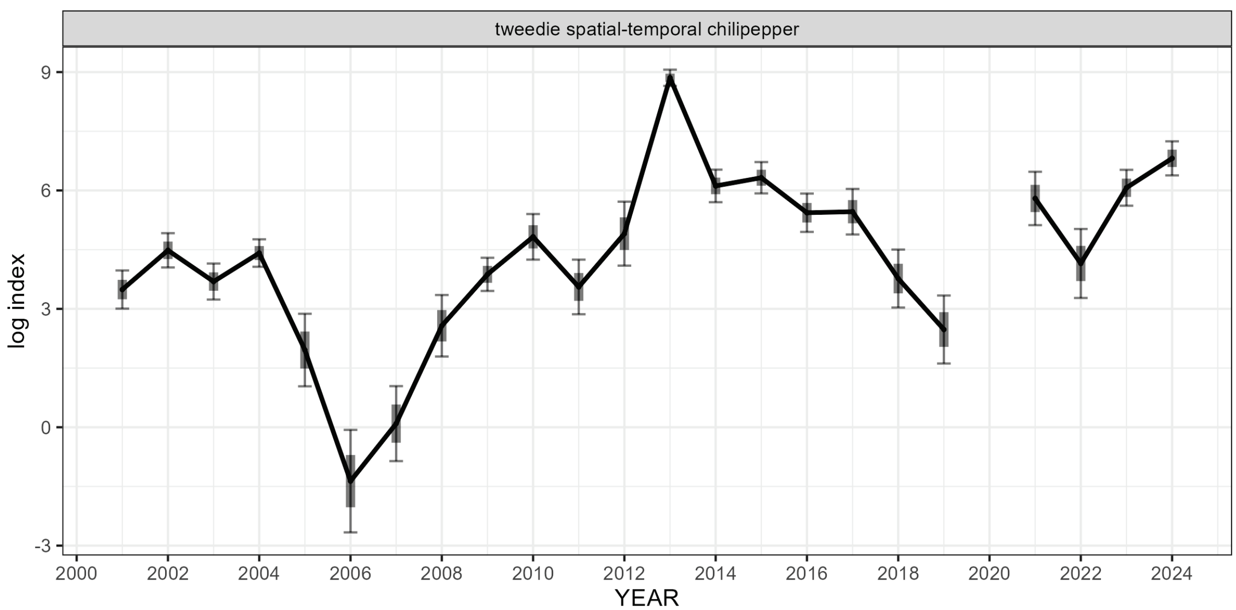

Figure 33: RREAS index (log scale) of age-0 recruits for chilipepper rockfish, 2001-2024.

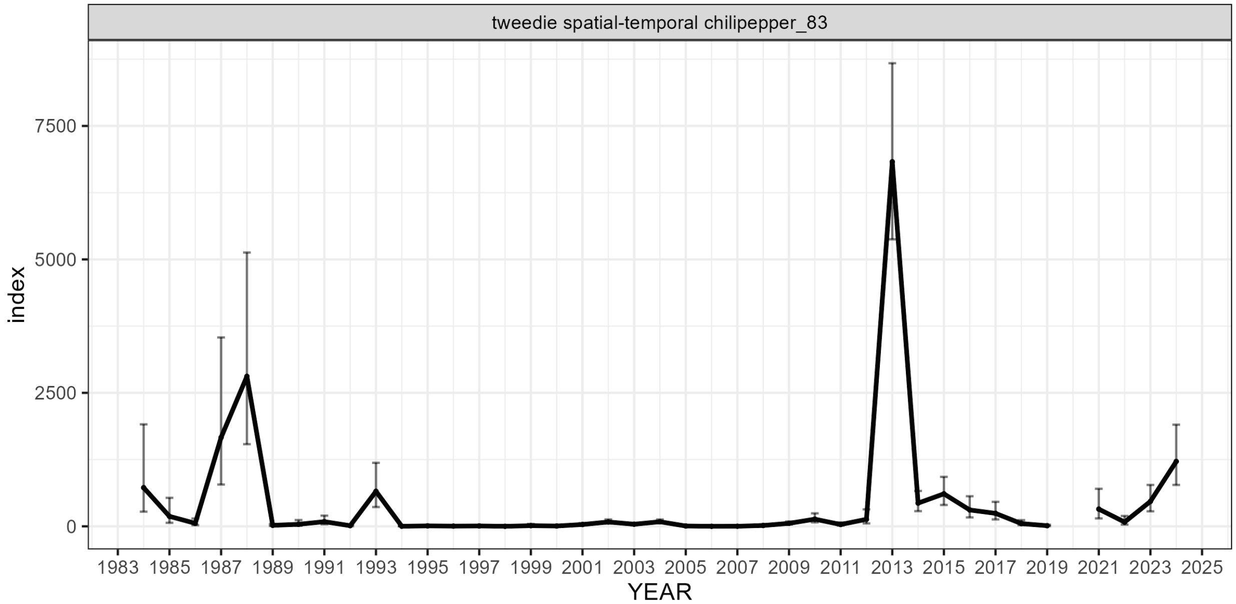

Figure 34: RREAS index of age-0 recruits for chilipepper rockfish, 1984-2024.

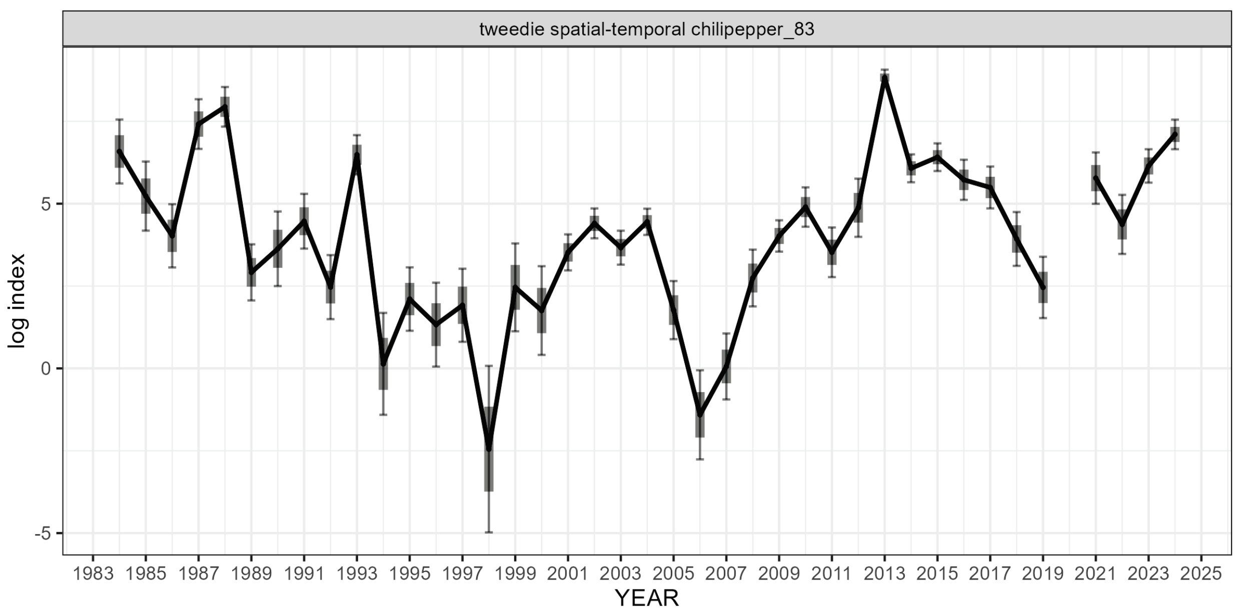

Figure 35: RREAS index (log scale) of age-0 recruits for chilipepper rockfish, 1984-2024.

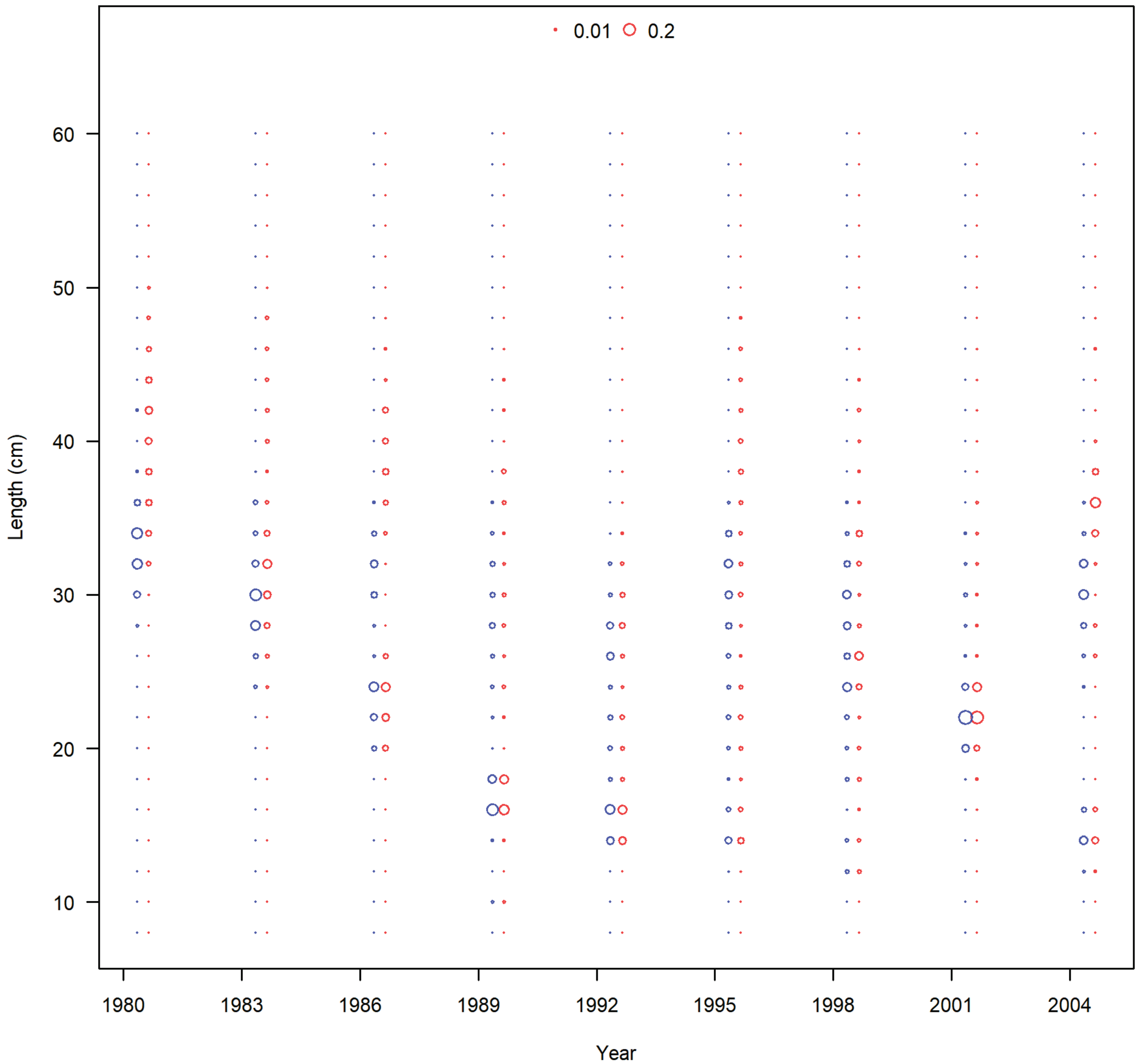

Figure 36: Triennial trawl survey length composition data.

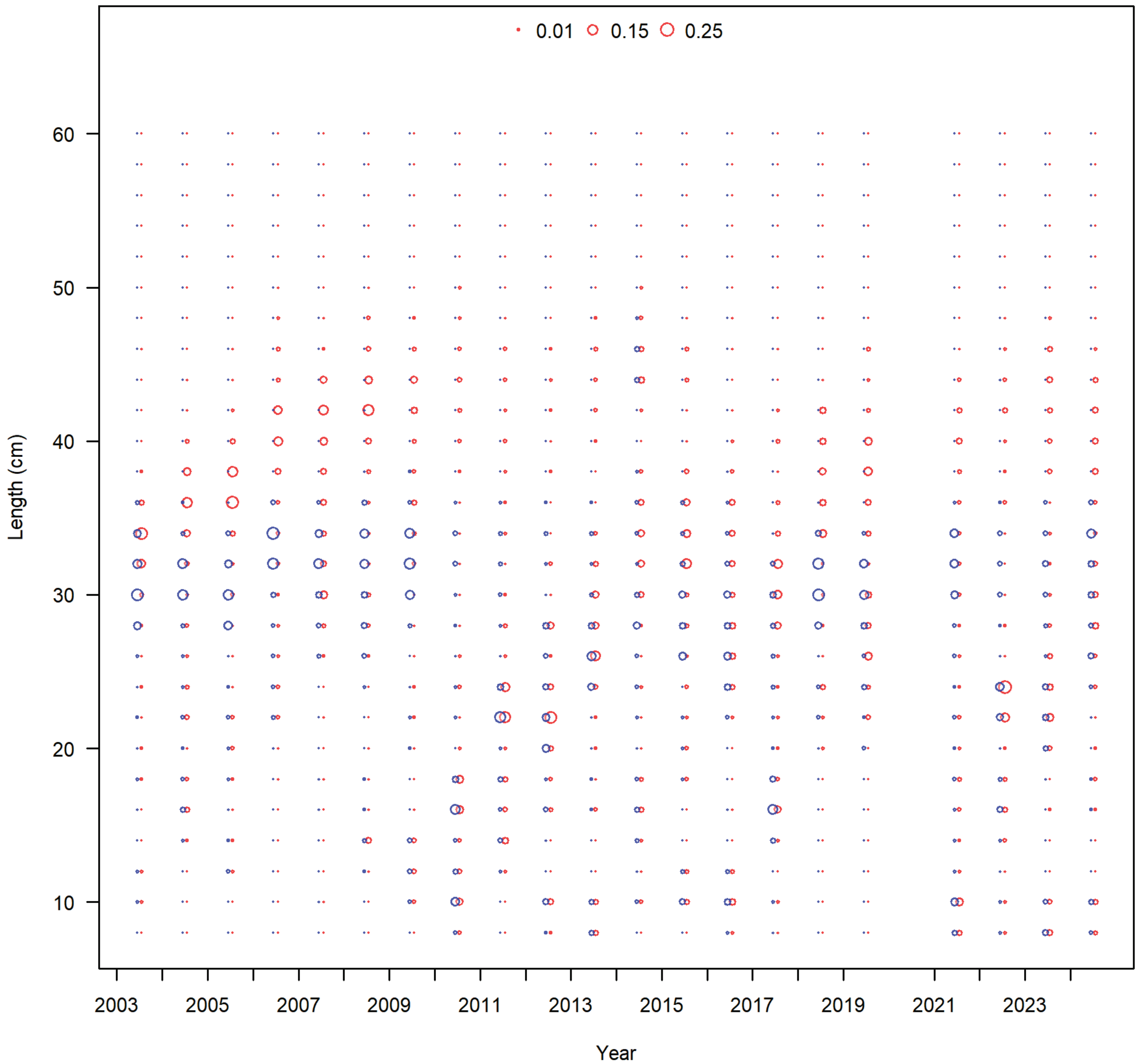

Figure 37: WCGBT survey length composition data.

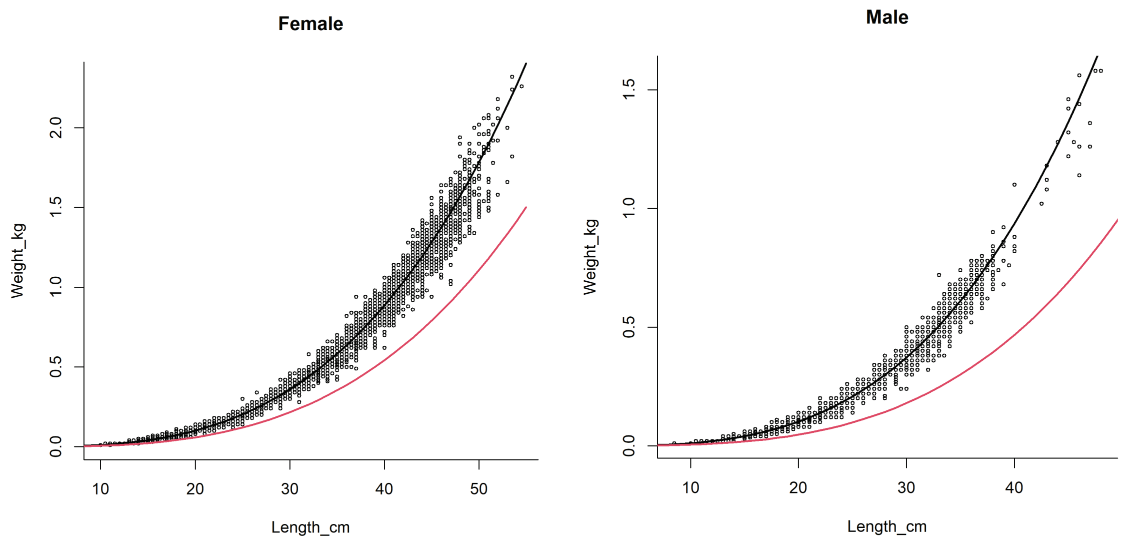

Figure 38: Revised fits (black line) to weight-at-length for female and male chilipepper rockfish. Data are from the WCGBTS. Estimates from the previous assessment are shown in red.

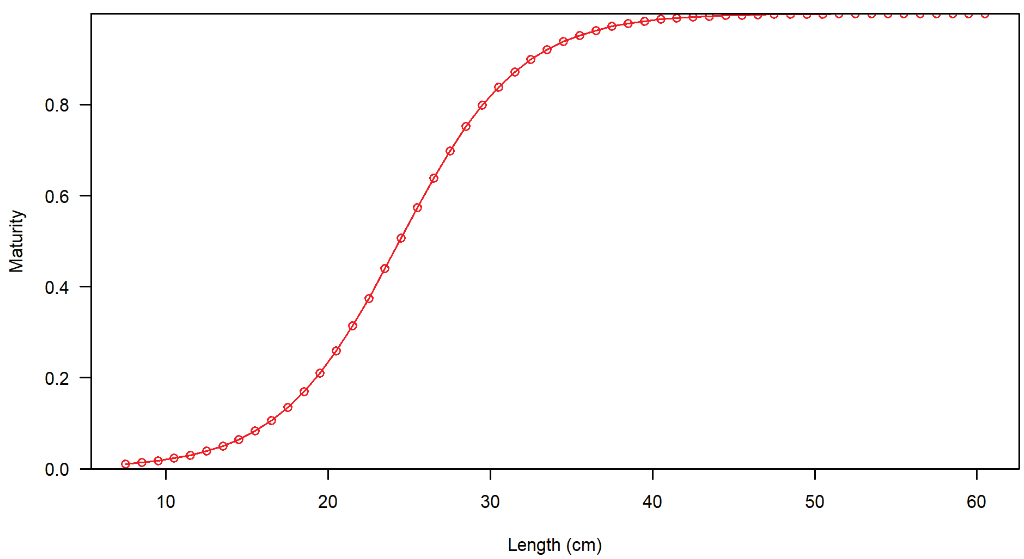

Figure 39: Proportion of mature females as a function of length (cm) in the 2025 chilipepper assessment.

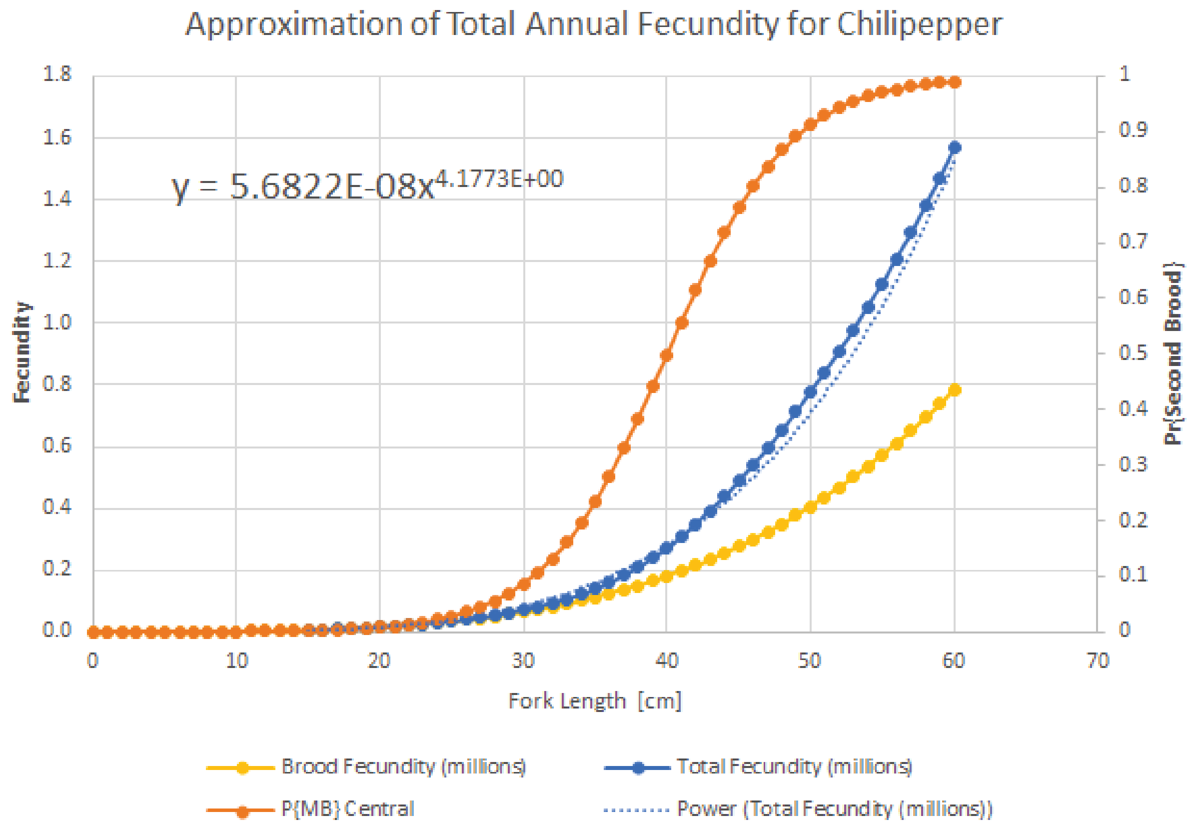

Figure 40: Derivation of a total annual fecundity-at-length relationship based on the brood-specific fecundity-length relationship from Dick et al. (2017) and an updated length-based probability of multiple.brooding (S. Beyer, AFSC, pers. comm.).

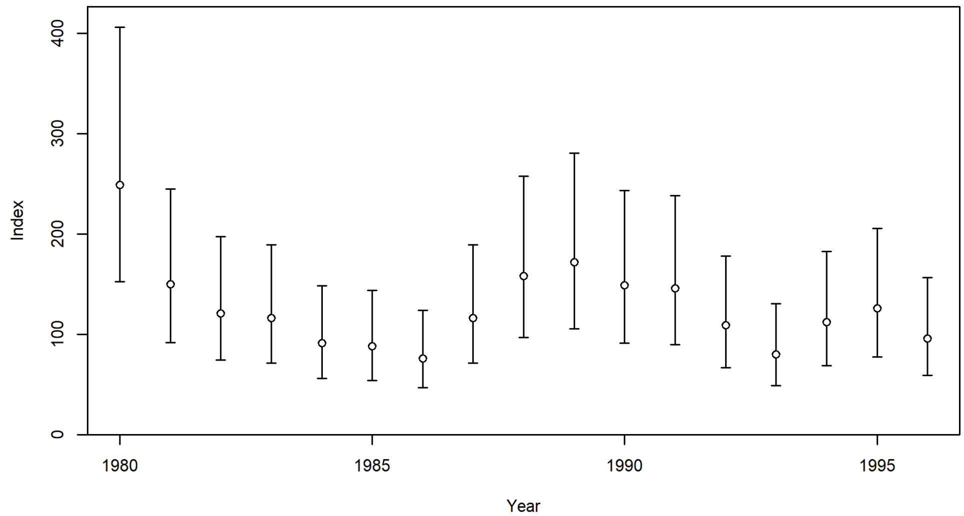

Figure 41: Index derived from commercial trawl logbook data for the 1998 chilipepper stock assessment (Ralston et al. 1998). This index is not used to fit the 2025 assessment, but is compared to model output for reference.

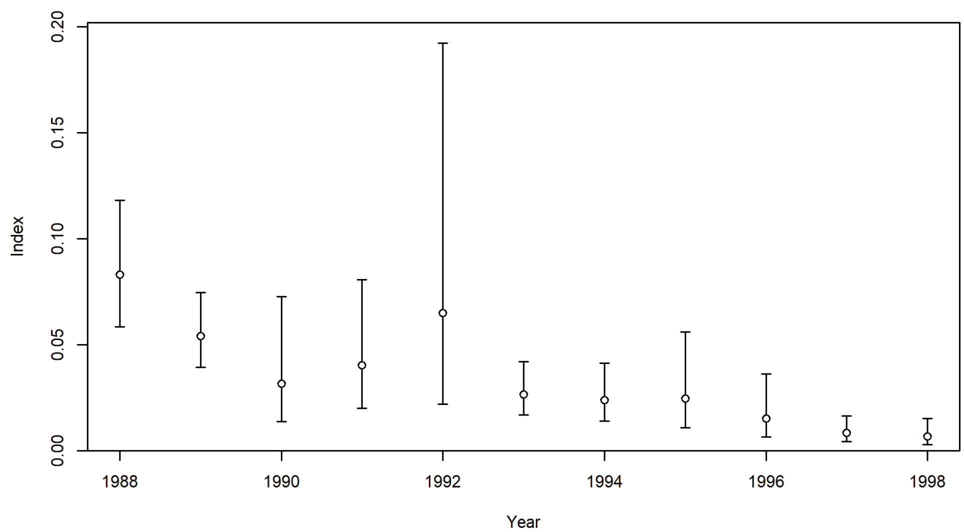

Figure 42: Index derived from recreational onboard observer CPUE data for the 1998 chilipepper stock assessment (Ralston et al. 1998). This index is not used to fit the 2025 assessment, but is compared to model output for reference.

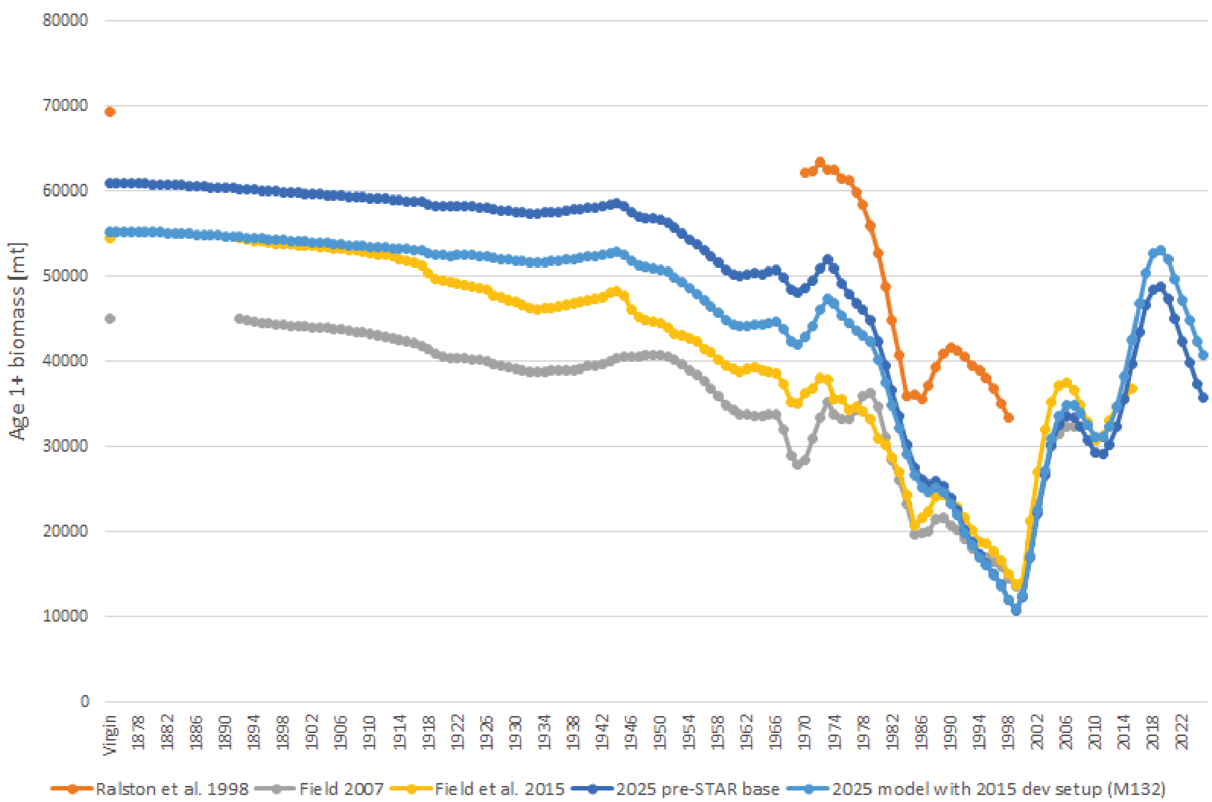

Figure 43: Comparison of trends in age 1+ biomass for four recent stock assessments of chilipepper rockfish. Scale of the 2015 assessment is closely approximated by turning off the recruitment bias adjustment and forcing recruitment deviation to sum to zero (standard practice at the time of the last benchmark assessment in 2007).

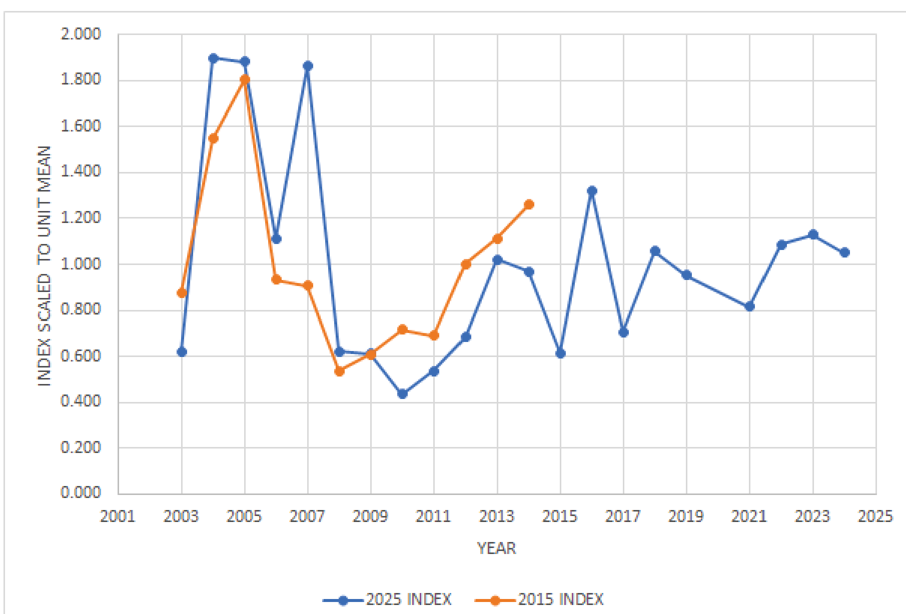

Figure 44: Comparison of WCGBTS indices from the 2015 and 2025 chilipepper stock assessments.

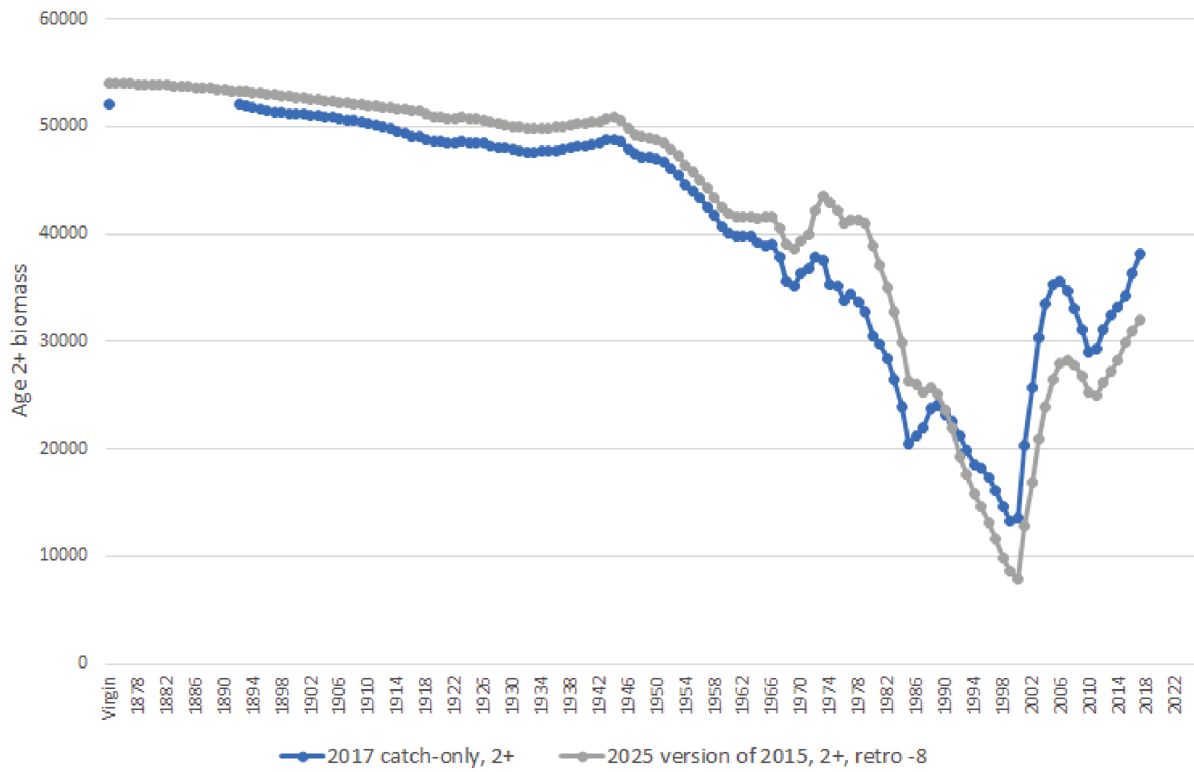

Figure 45: Comparison of age 2+ biomass time series for the 2017 catch-only update and a modified version of the pre-STAR base model. The pre-STAR base was changed to match the 2017 values for natural mortality, steepness, recruitment deviation configuration, fecundity, and weight-at-length. The CalCOFI index was removed, and fishery-independent indices were included in the likelihood.

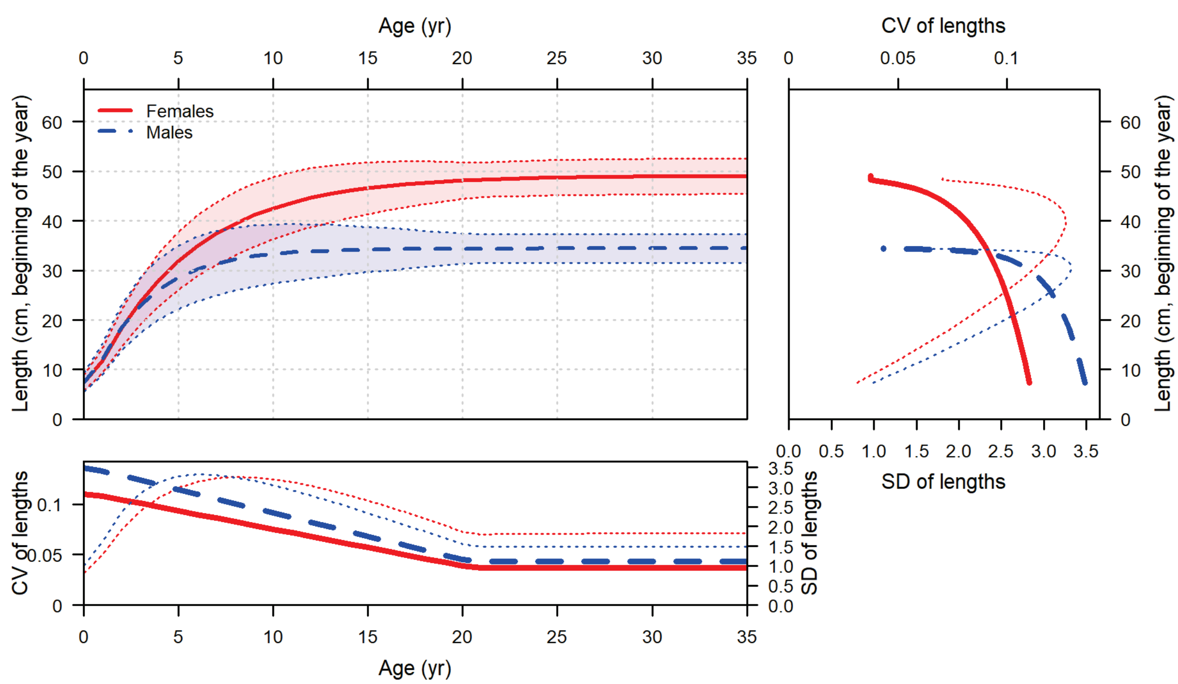

Figure 46: Base model estimates of growth (mean length-at-age by sex) with linear interpolation between estimates of the CV of length at age for ages 0 and 20.

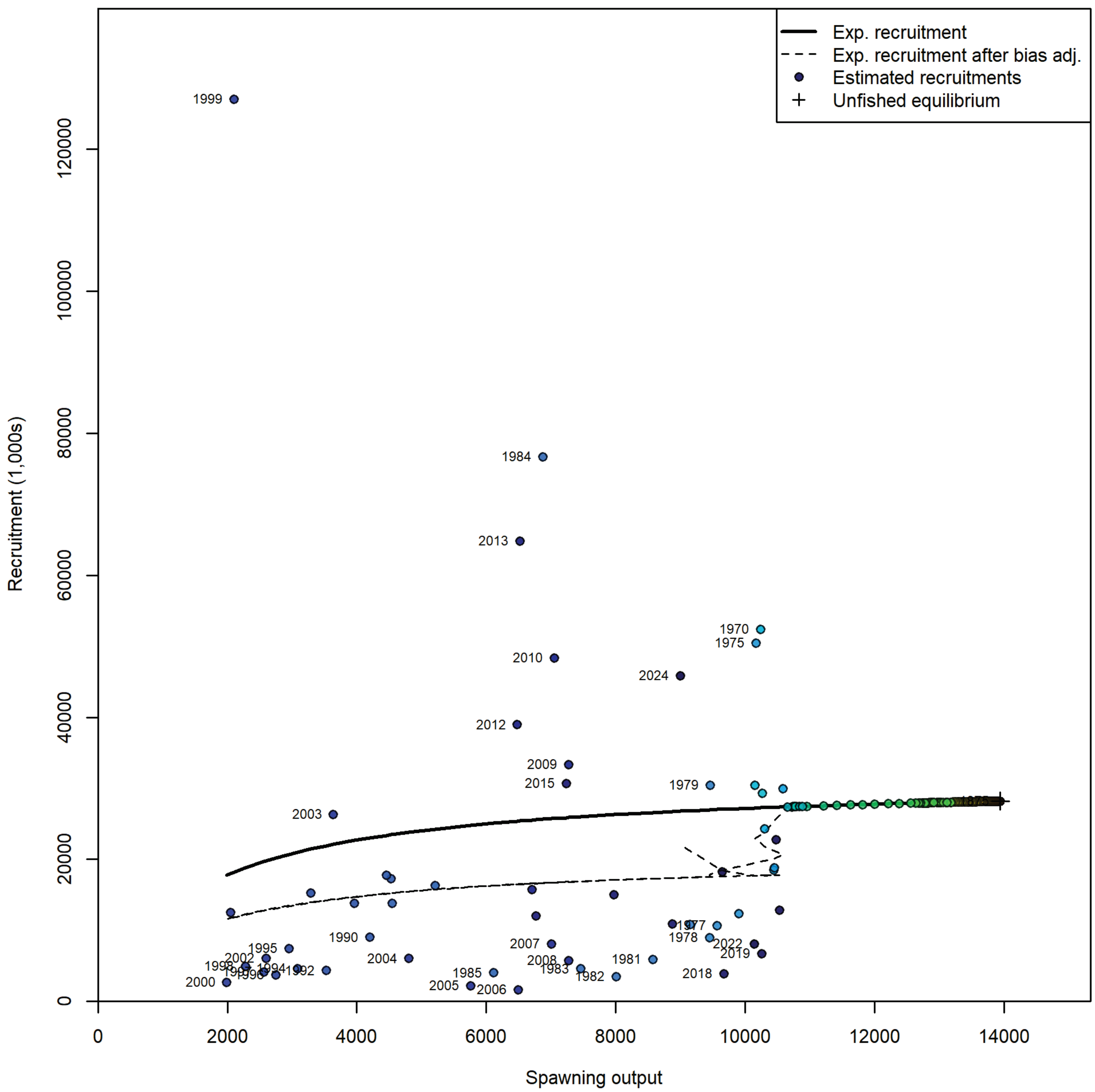

Figure 47: Base model stock-recruitment curve (Beverton-Holt) with steepness fixed at the prior mean (0.72) and estimated recruitment deviations (1968-2024).

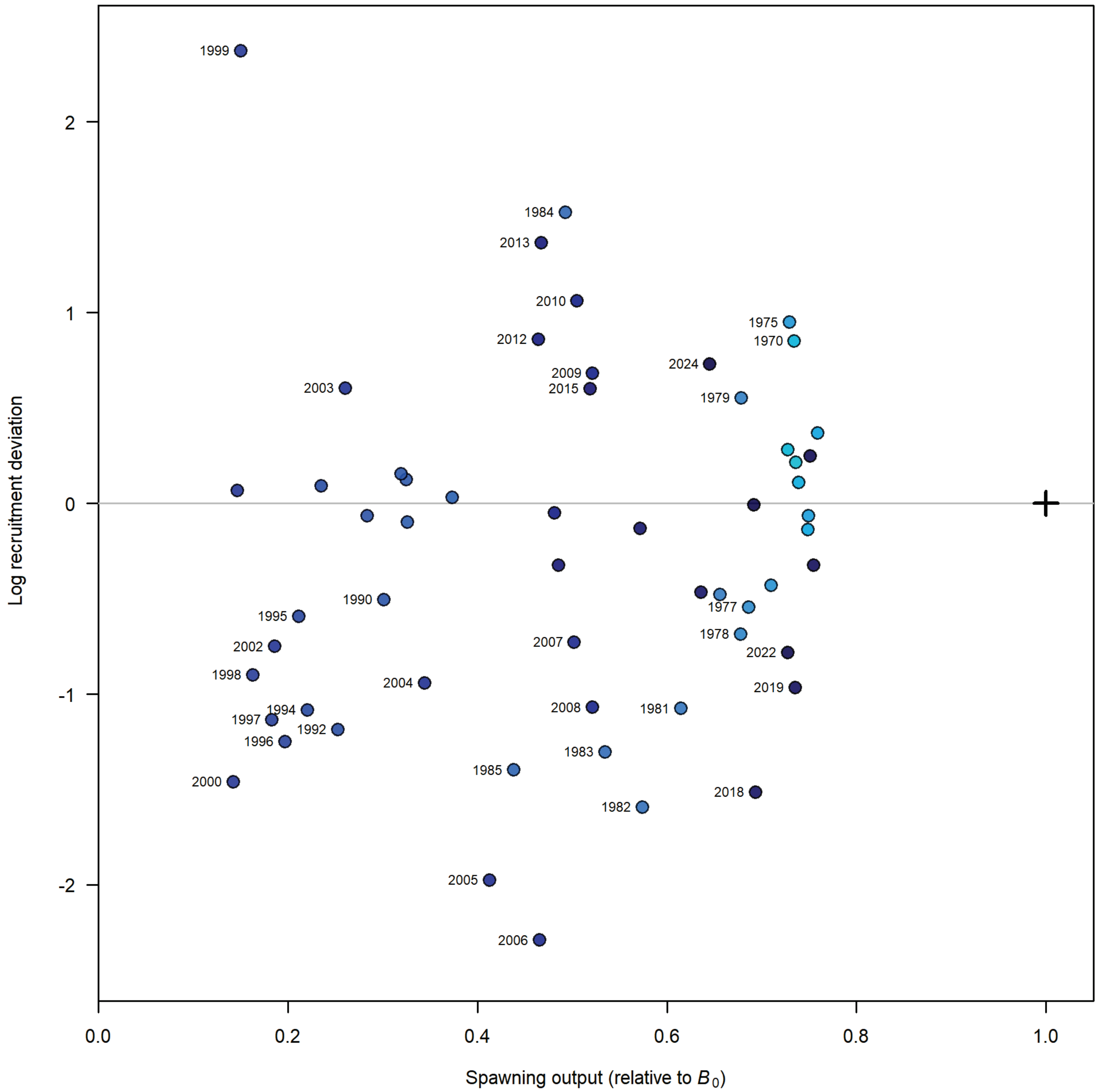

Figure 48: Log-scale residuals around the stock-recruitment curve (1968-2024). Years with deviations having an absolute value greater than 0.5 are labeled.

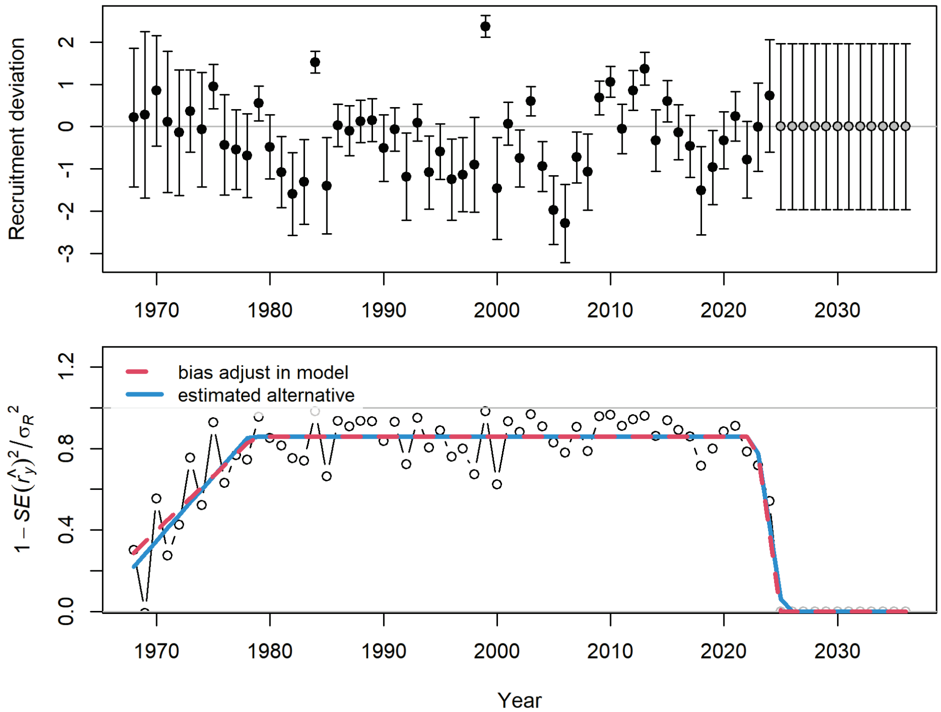

Figure 49: Time series of estimated recruitment deviations (top panel) and model-estimated annual bias adjustment fraction.

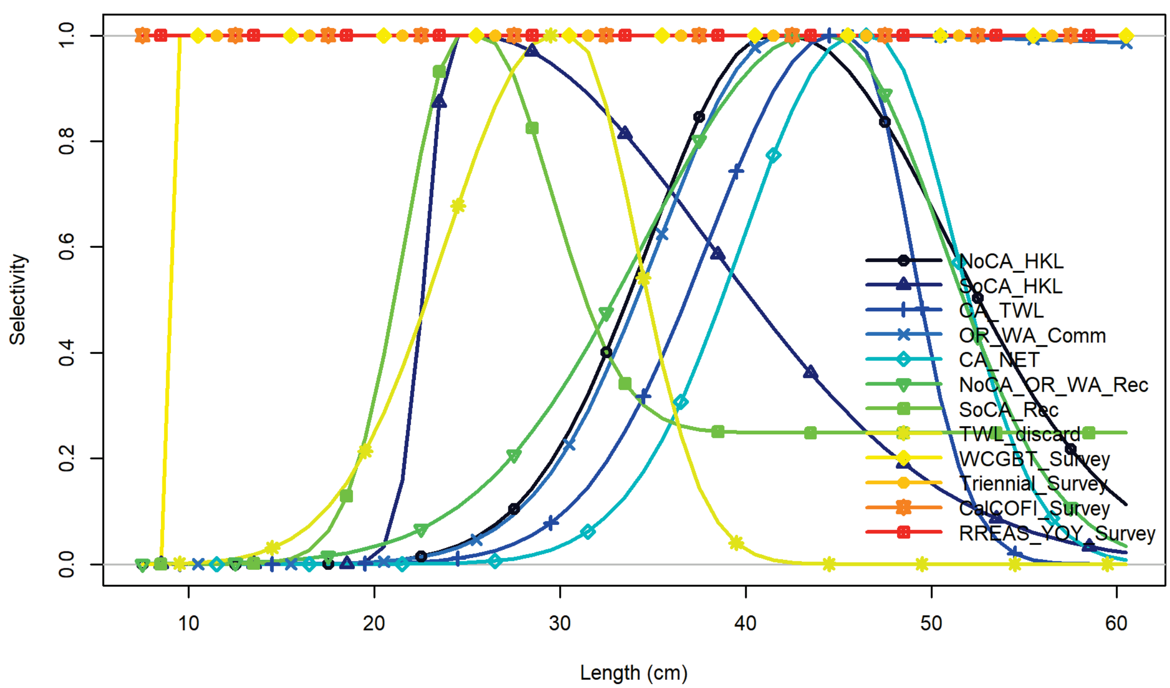

Figure 50: Ending year length-based selectivity curves by fleet in the base model. See figures below for fleets with time-varying selectivity.

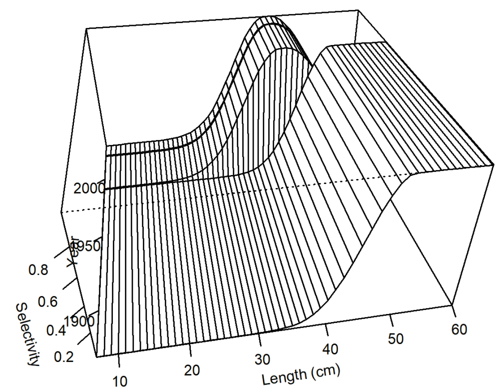

Figure 51: Time-varying selectivity for the Northern California hook and line fleet.

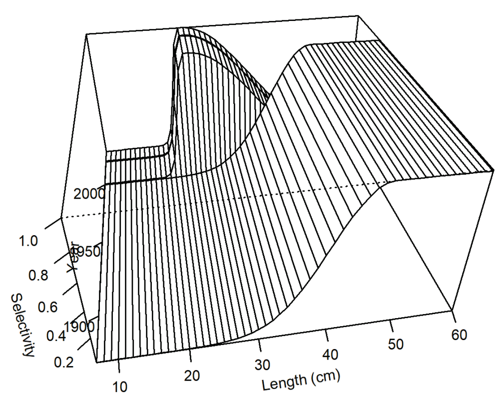

Figure 52: Time-varying selectivity for the Southern California hook and line fleet.

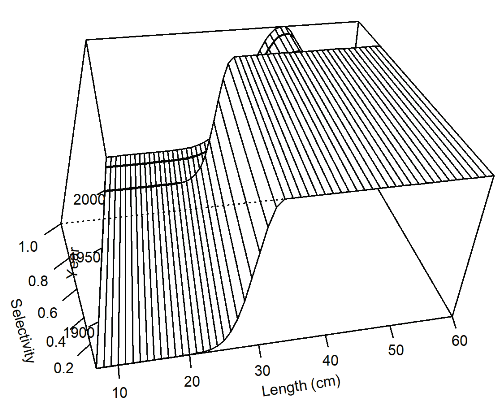

Figure 53: Time-varying selectivity for the California trawl fleet.

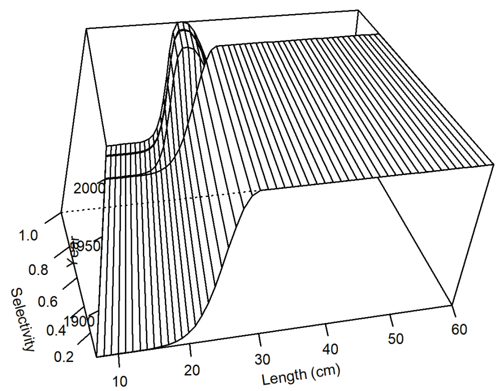

Figure 54: Time-varying selectivity for the Southern California recreational fleet.

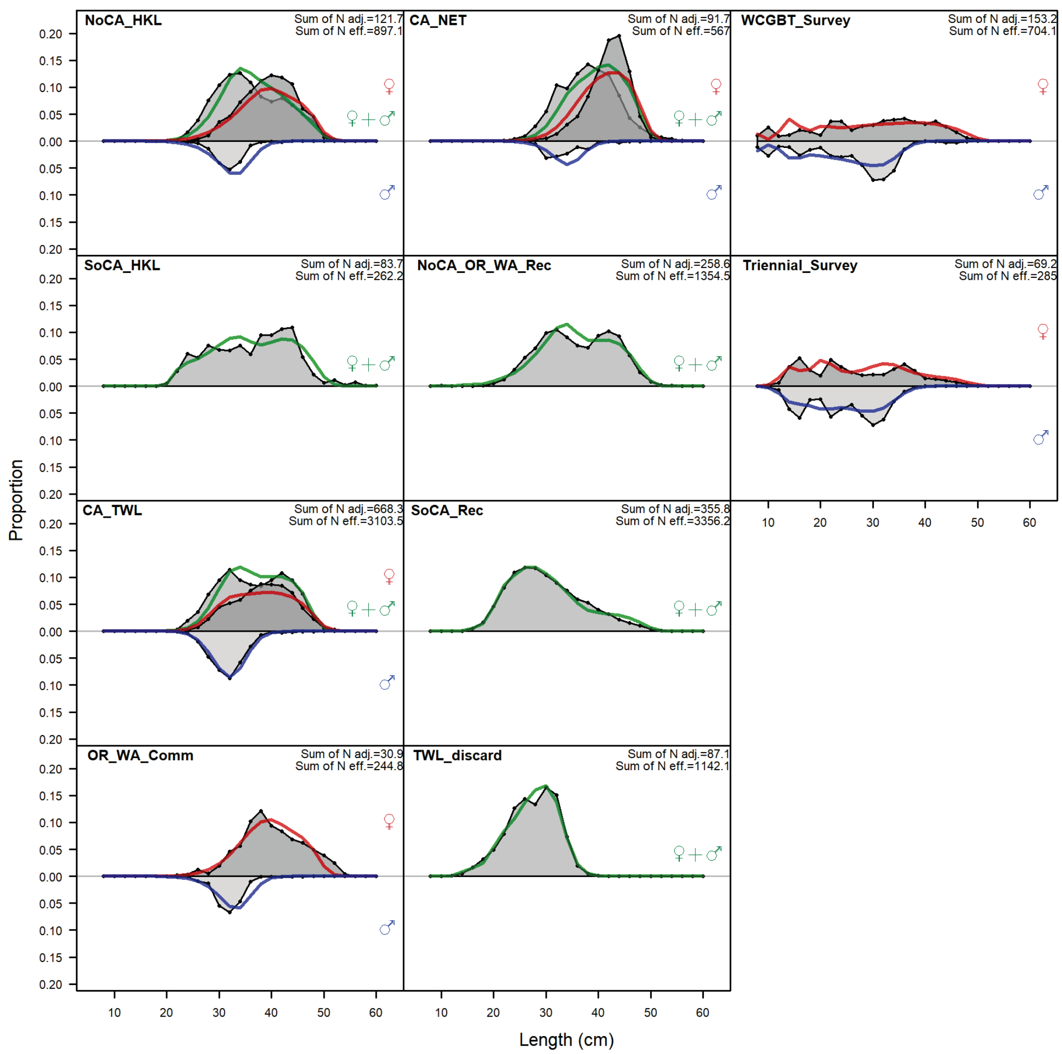

Figure 55: Base model fits to length compositions by fleet, aggregated across time.

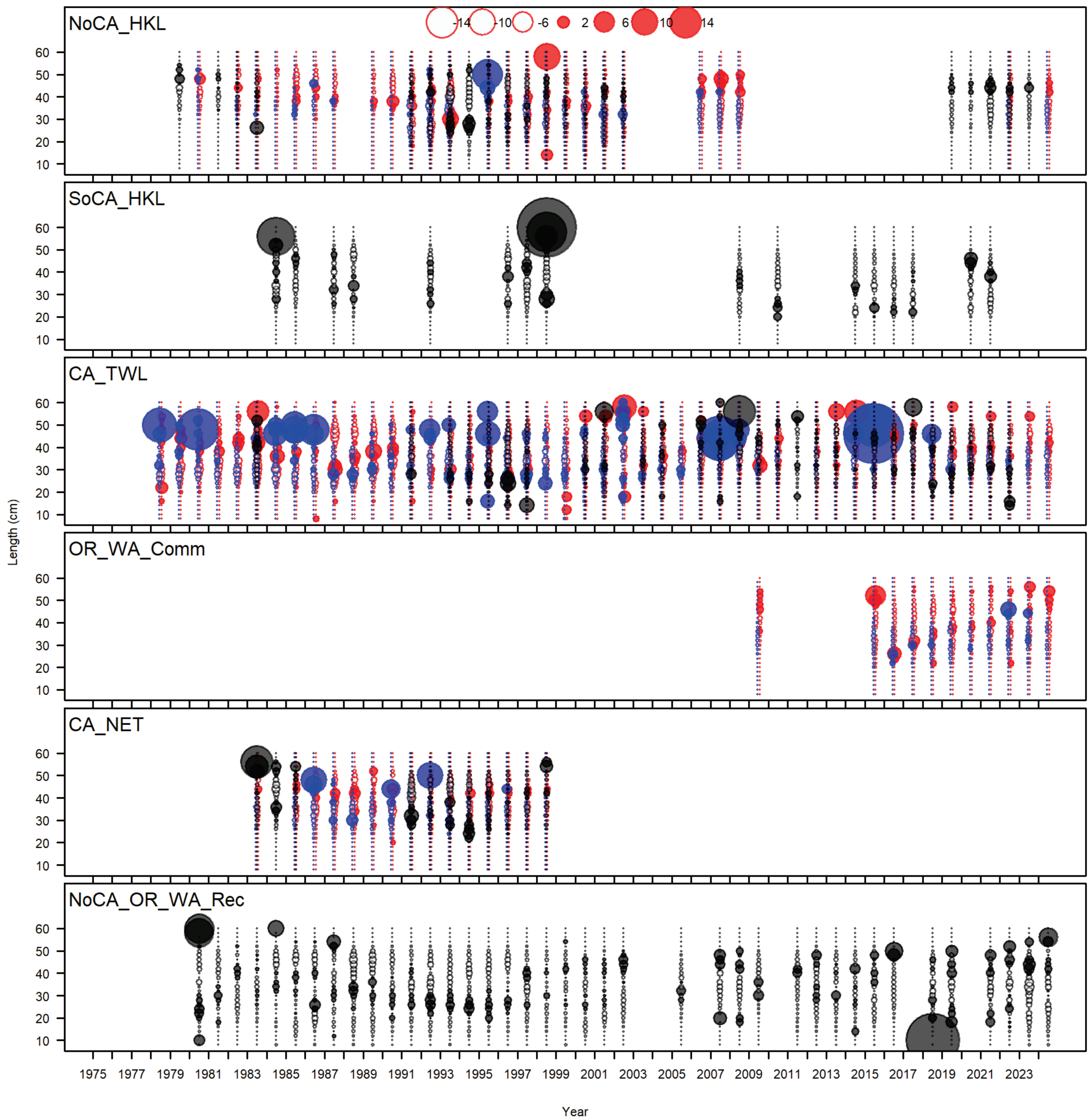

Figure 56: Pearson residuals for base model fits to length compositions by fleet and year.

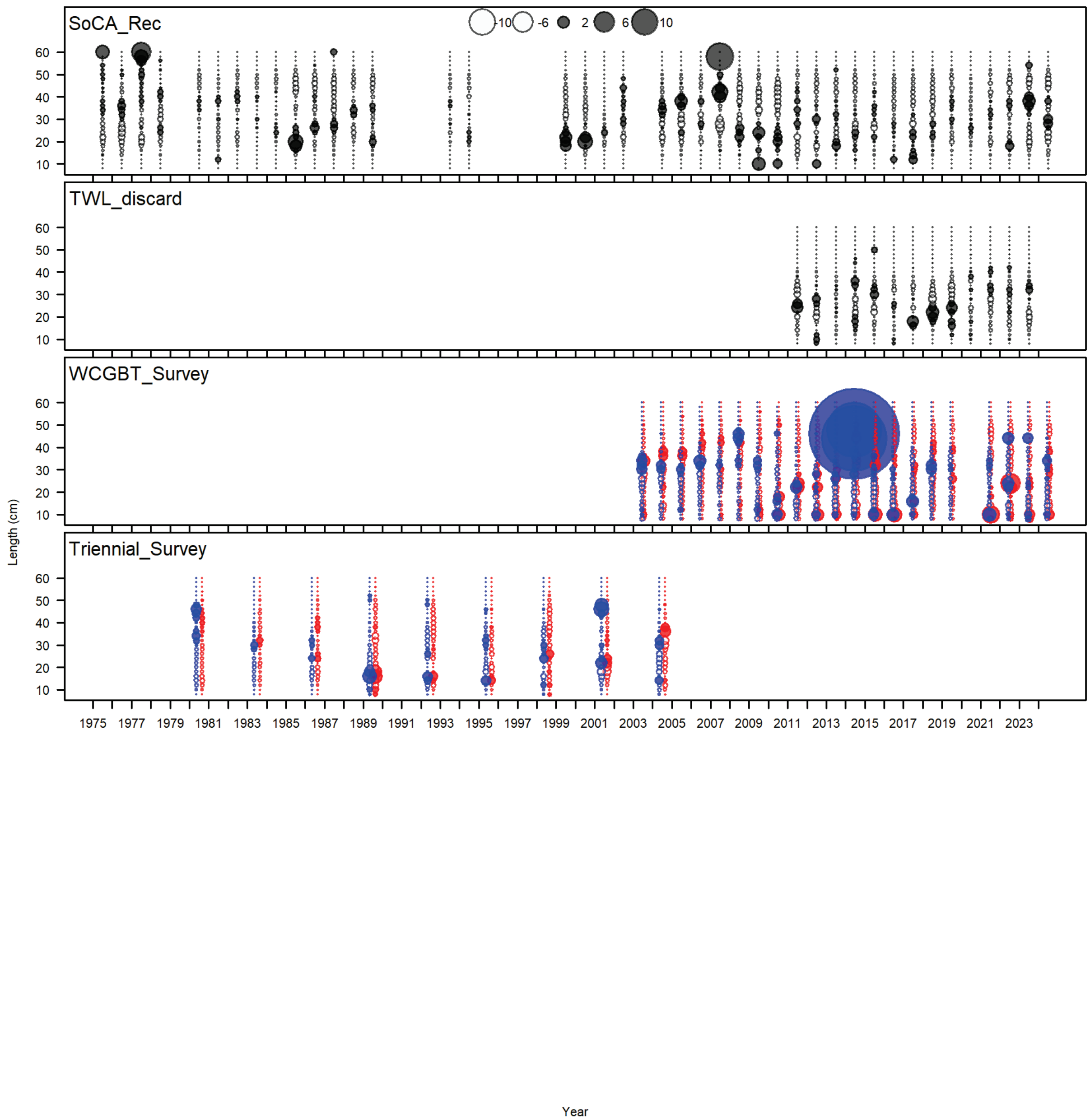

Figure 57: Pearson residuals for base model fits to length compositions by fleet and year (continued).

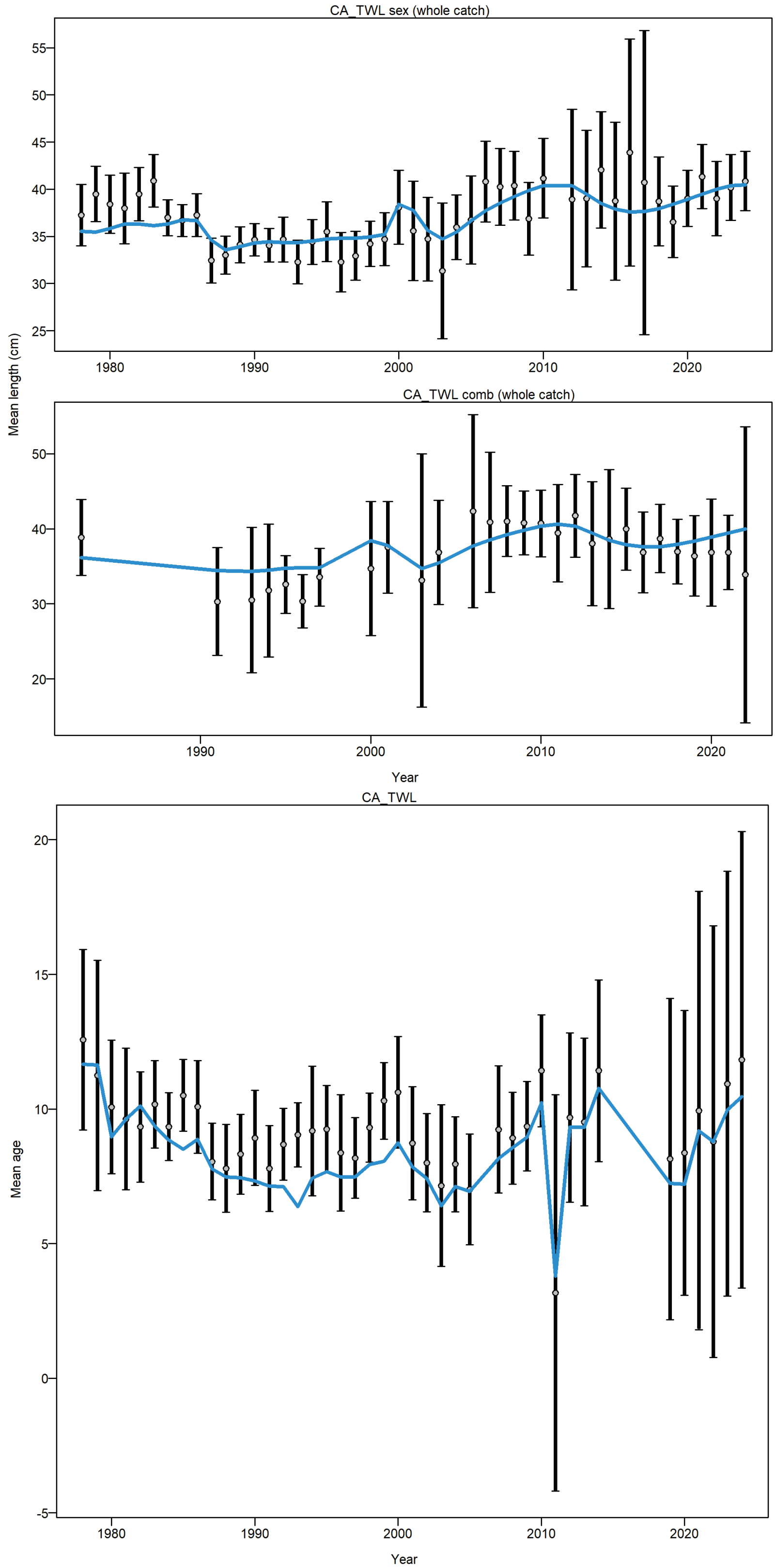

Figure 58: California trawl fleet: mean lengths (cm) for sexed fish (top panel) and unsexed fish (middle panel) for length compositions, and mean ages (bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

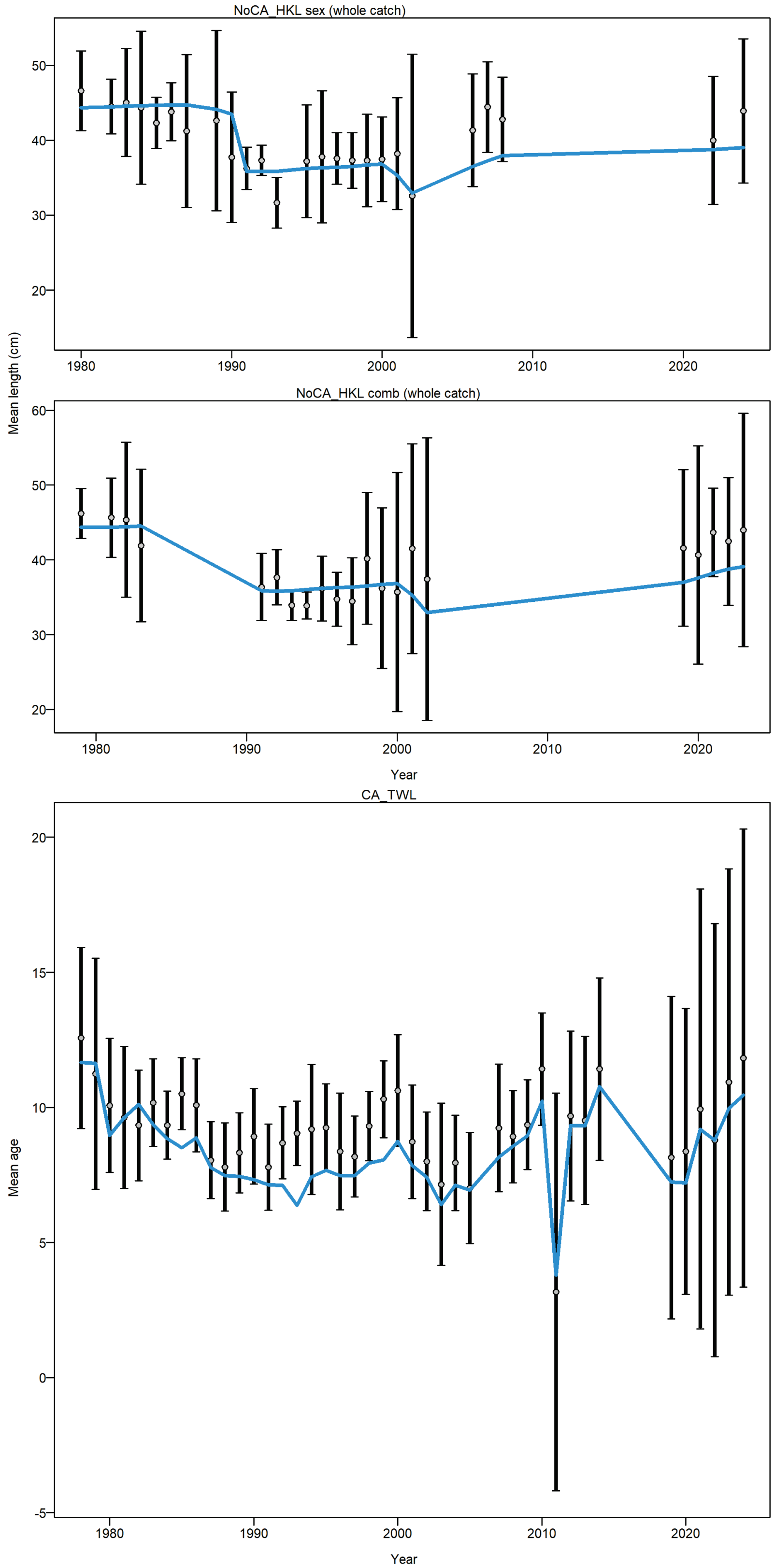

Figure 59: Northern California hook and line fleet: mean lengths (cm) for sexed fish (top panel) and unsexed fish (middle panel) for length compositions, and mean ages (bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

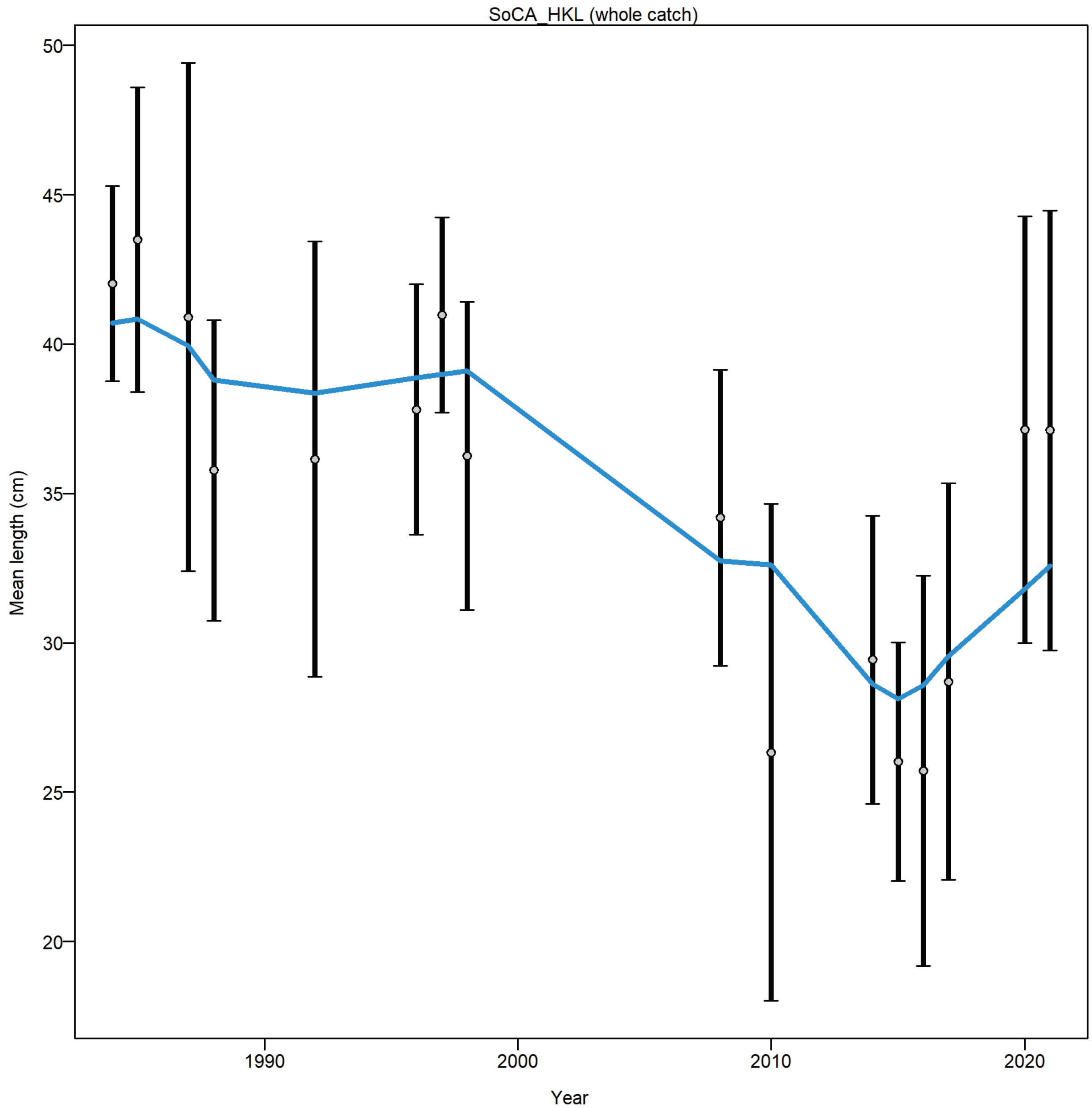

Figure 60: Southern California hook and line fleet: mean lengths (cm) for unsexed fish for length compositions with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

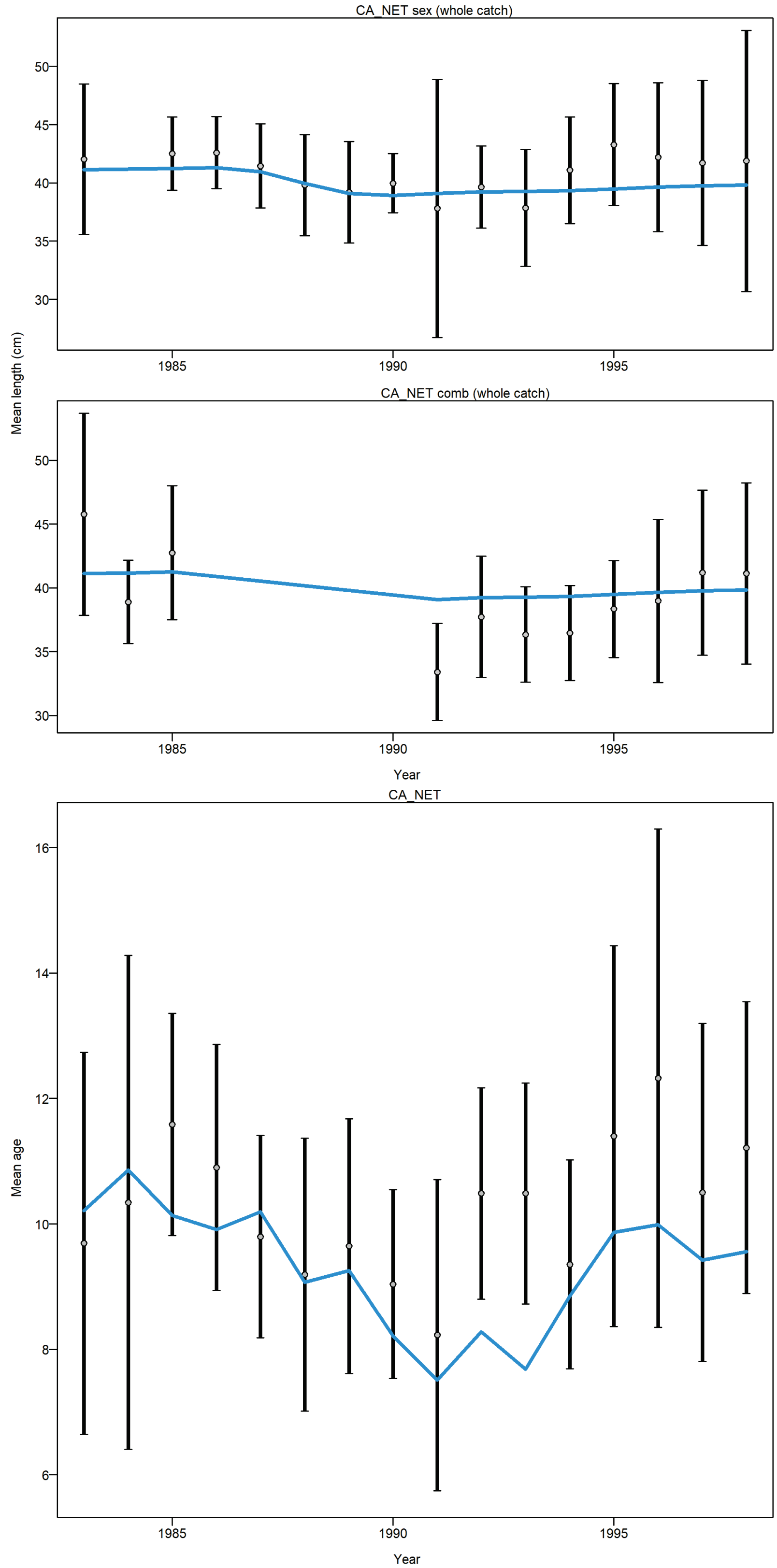

Figure 61: California net fleet: mean lengths (cm) for sexed fish (top panel) and unsexed fish (middle panel) for length compositions, and mean ages (bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

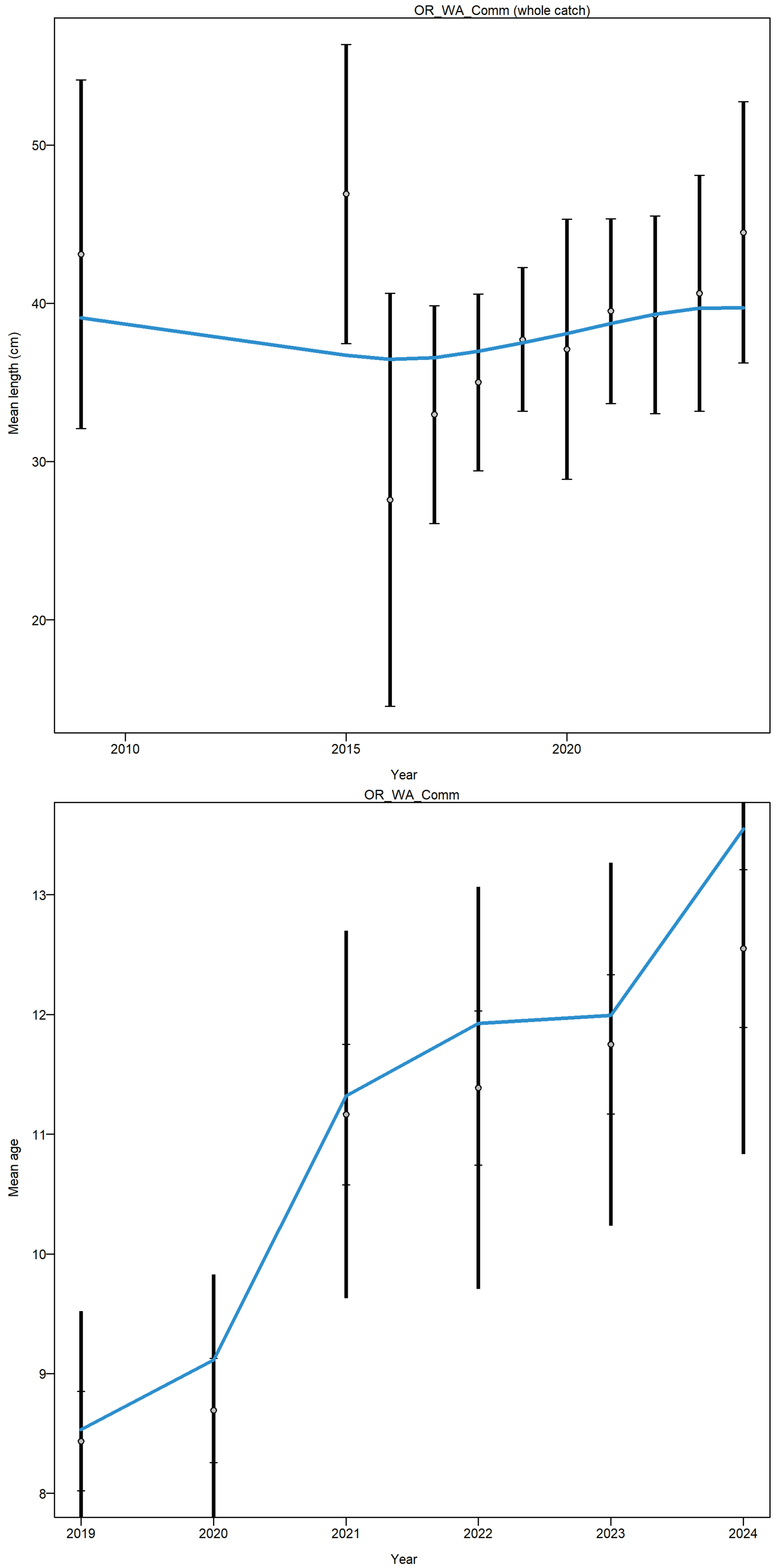

Figure 62: Oregon combined commercial fleets: mean lengths (cm) for unsexed fish (top panel) length compositions, and mean ages (bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

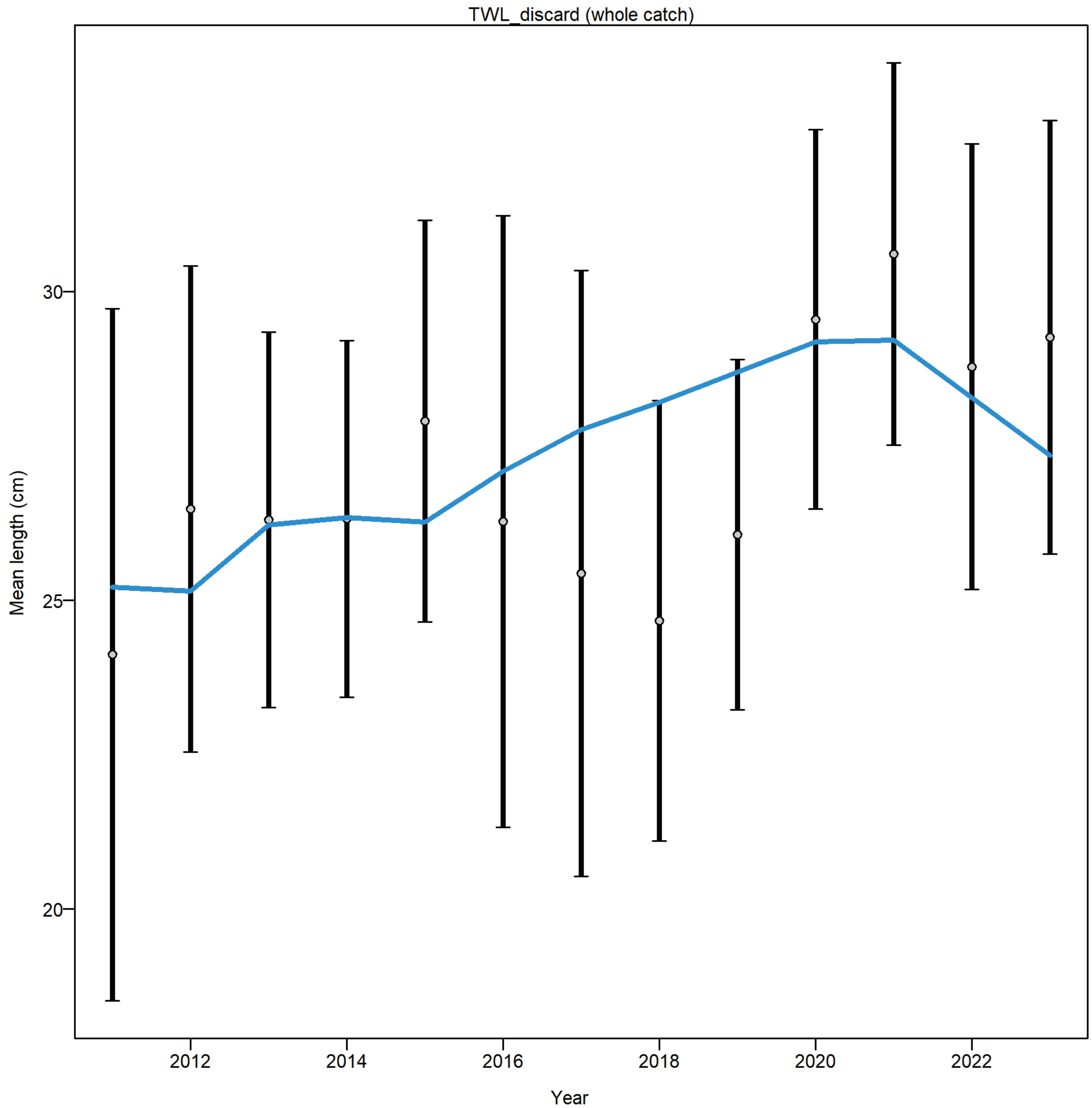

Figure 63: Trawl discard “fleet”: mean lengths (cm) for unsexed fish length compositions, with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

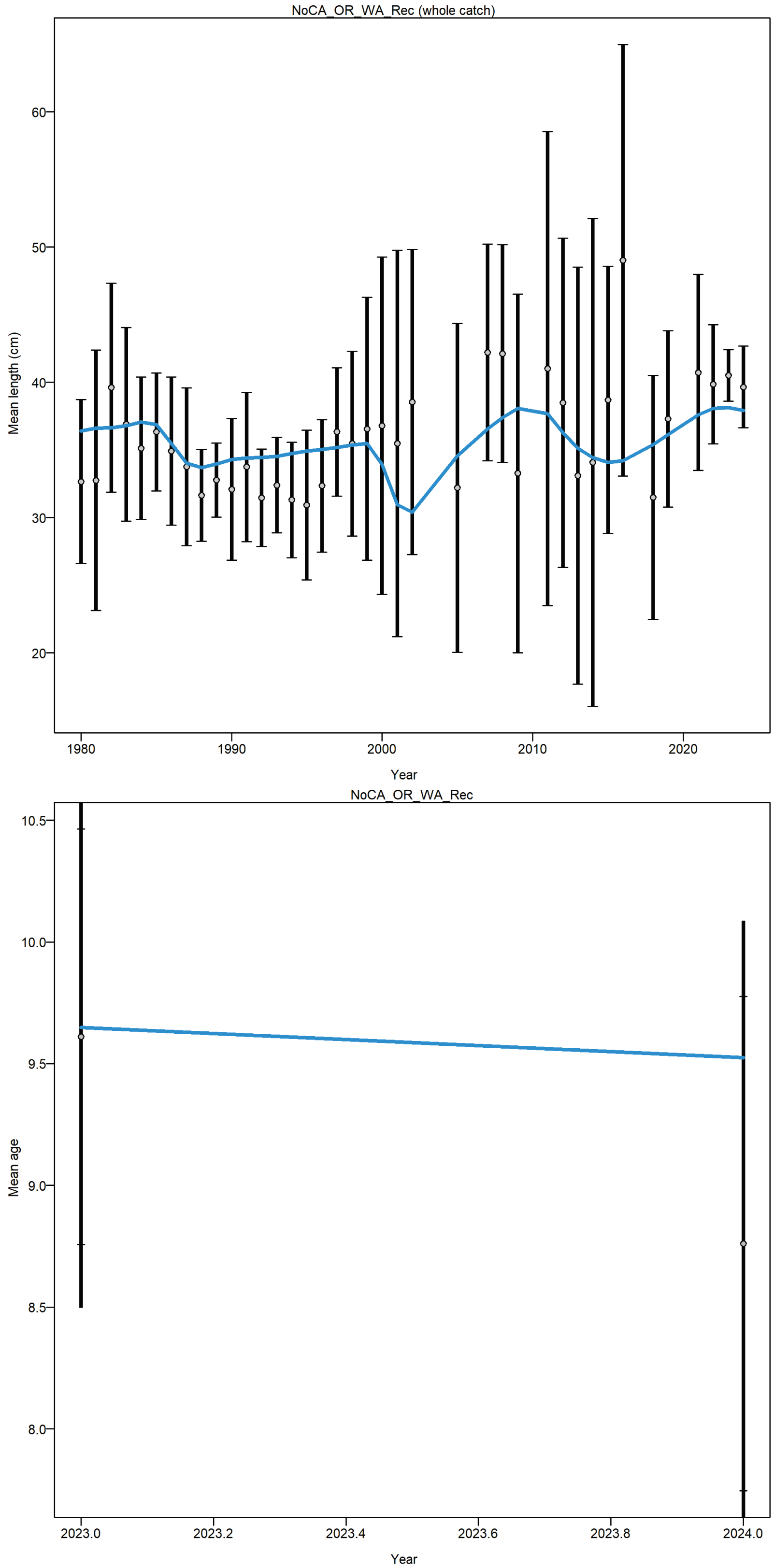

Figure 64: Recreational fleets north of Point Conception: mean lengths (cm) for unsexed fish length compositions (top panel), and mean ages (bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

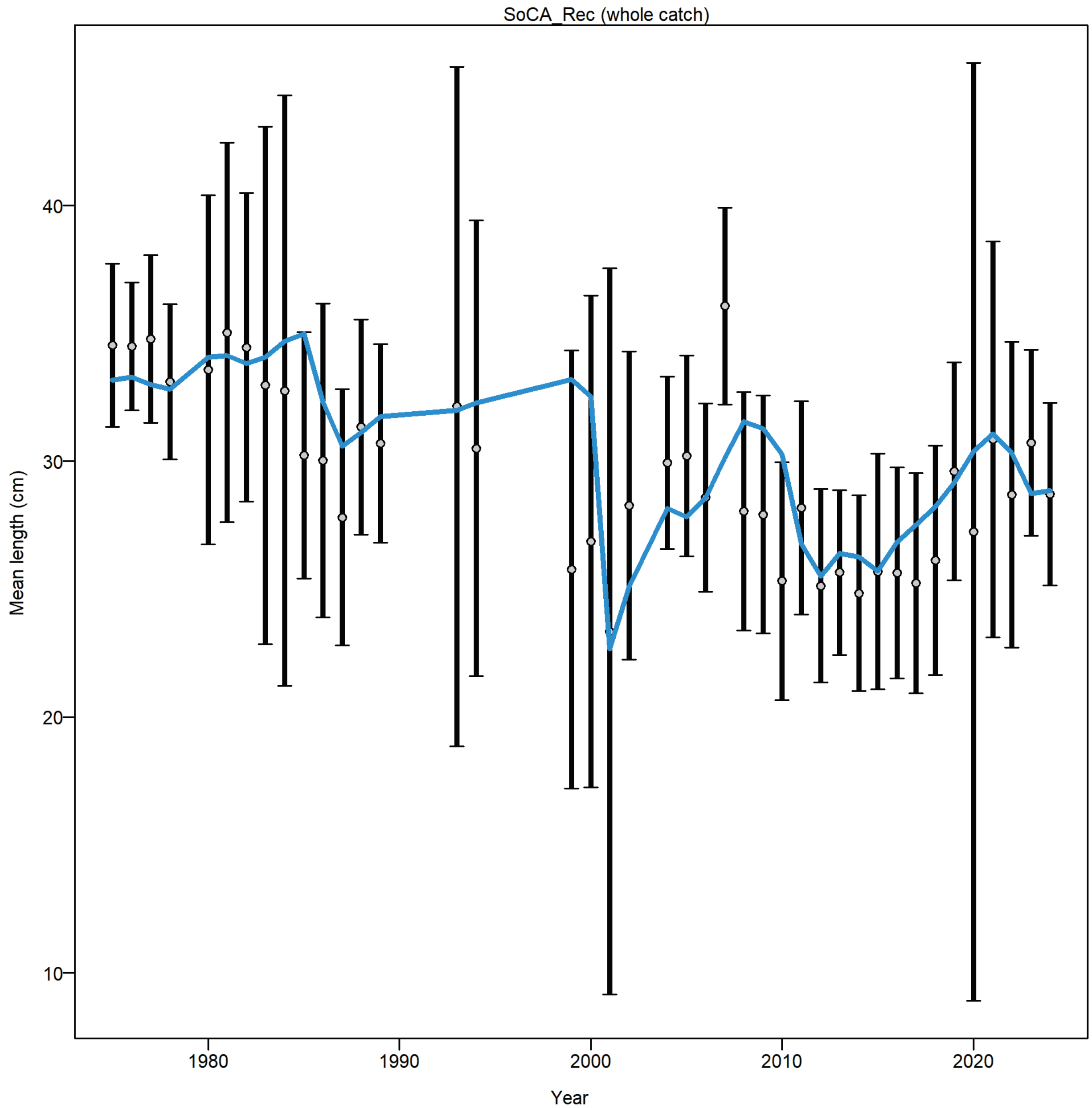

Figure 65: Recreational fleets south of Point Conception: mean lengths (cm) for unsexed fish length compositions with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

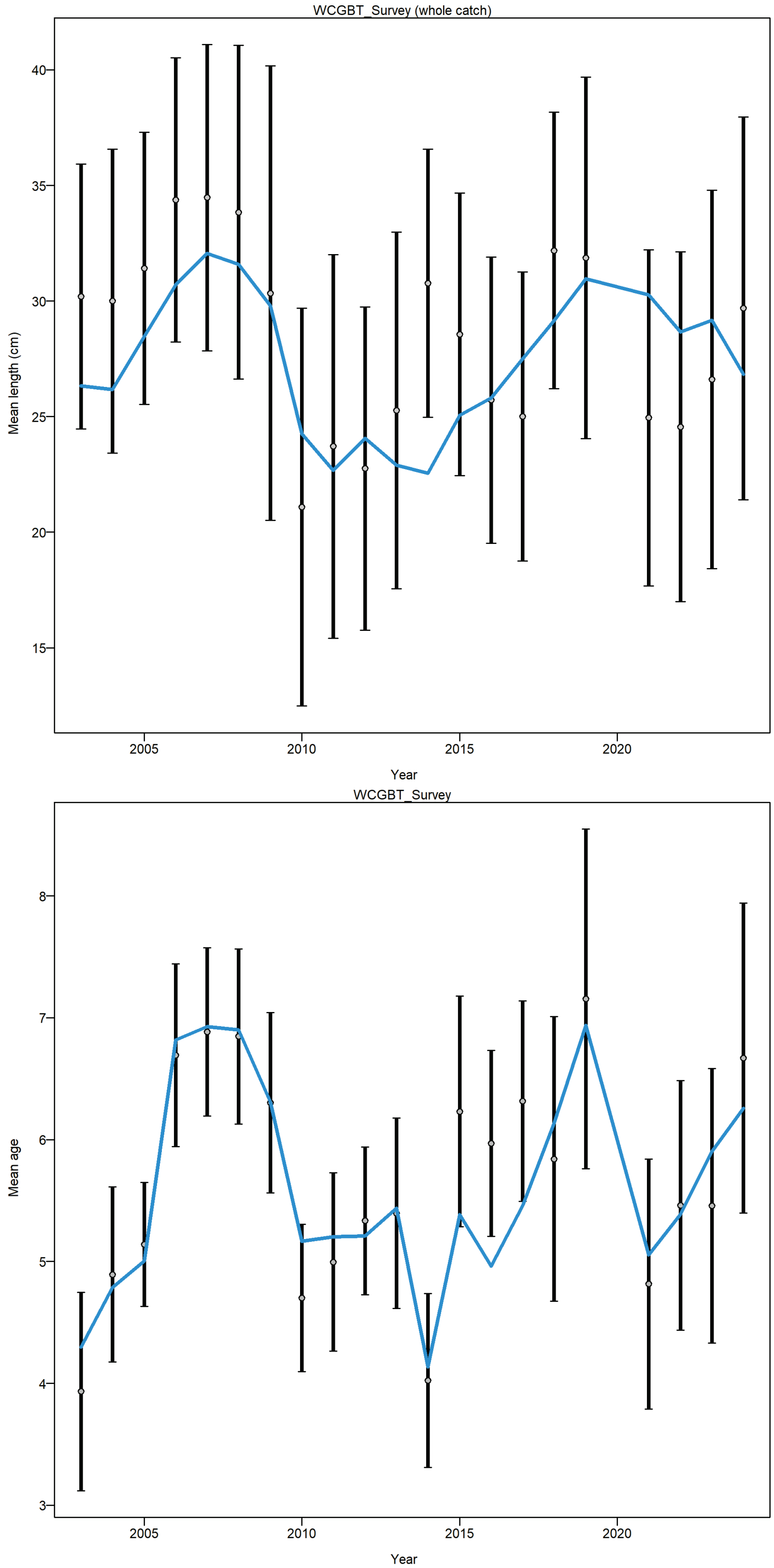

Figure 66: WCGBTS: mean lengths (cm) for sexed fish (top panel) for length compositions, and mean ages (bottom panel) from CAAL data with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model.

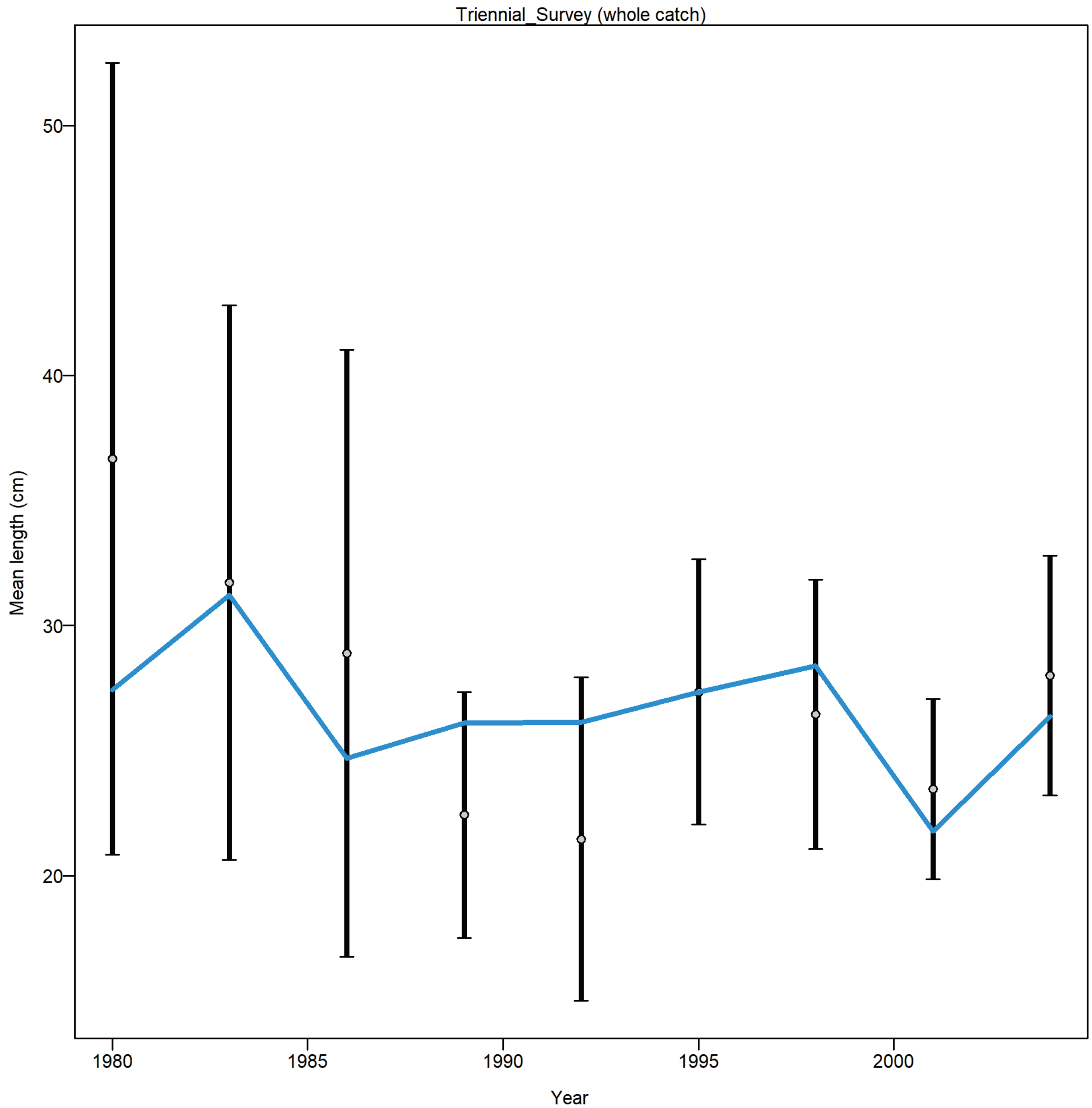

Figure 67: Triennial trawl survey: mean lengths (cm) for sexed length compositions with 95% C.I. based on adjusted input sample sizes. Blue lines are the predicted value from the base model. Plot for mean ages from CAAL data is not available because only one year of age data is included in the model.

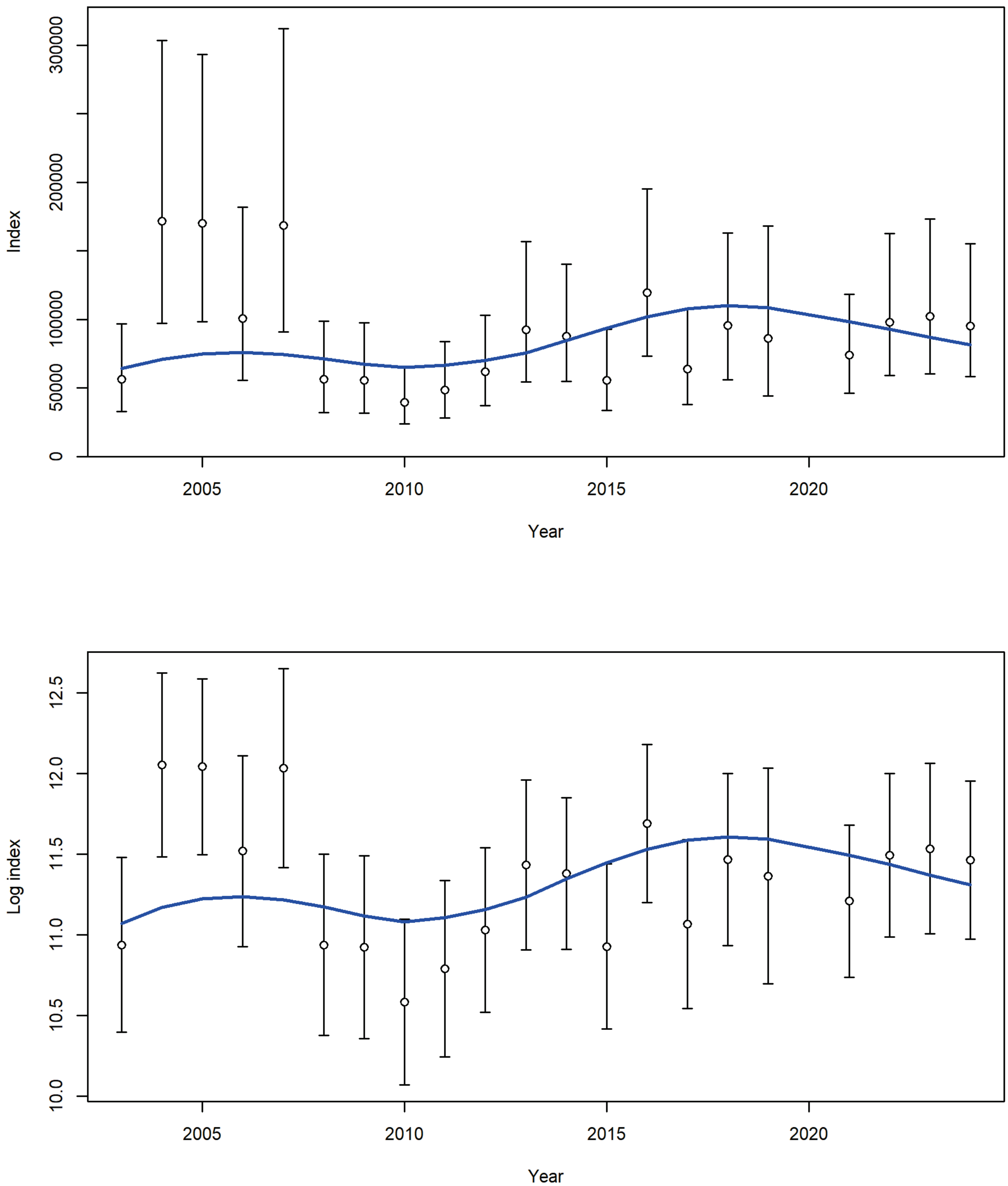

Figure 68: WCGBT survey index of relative abundance. Top panel: Arithmetic scale data with 95% C.I.s based on input SEs. Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

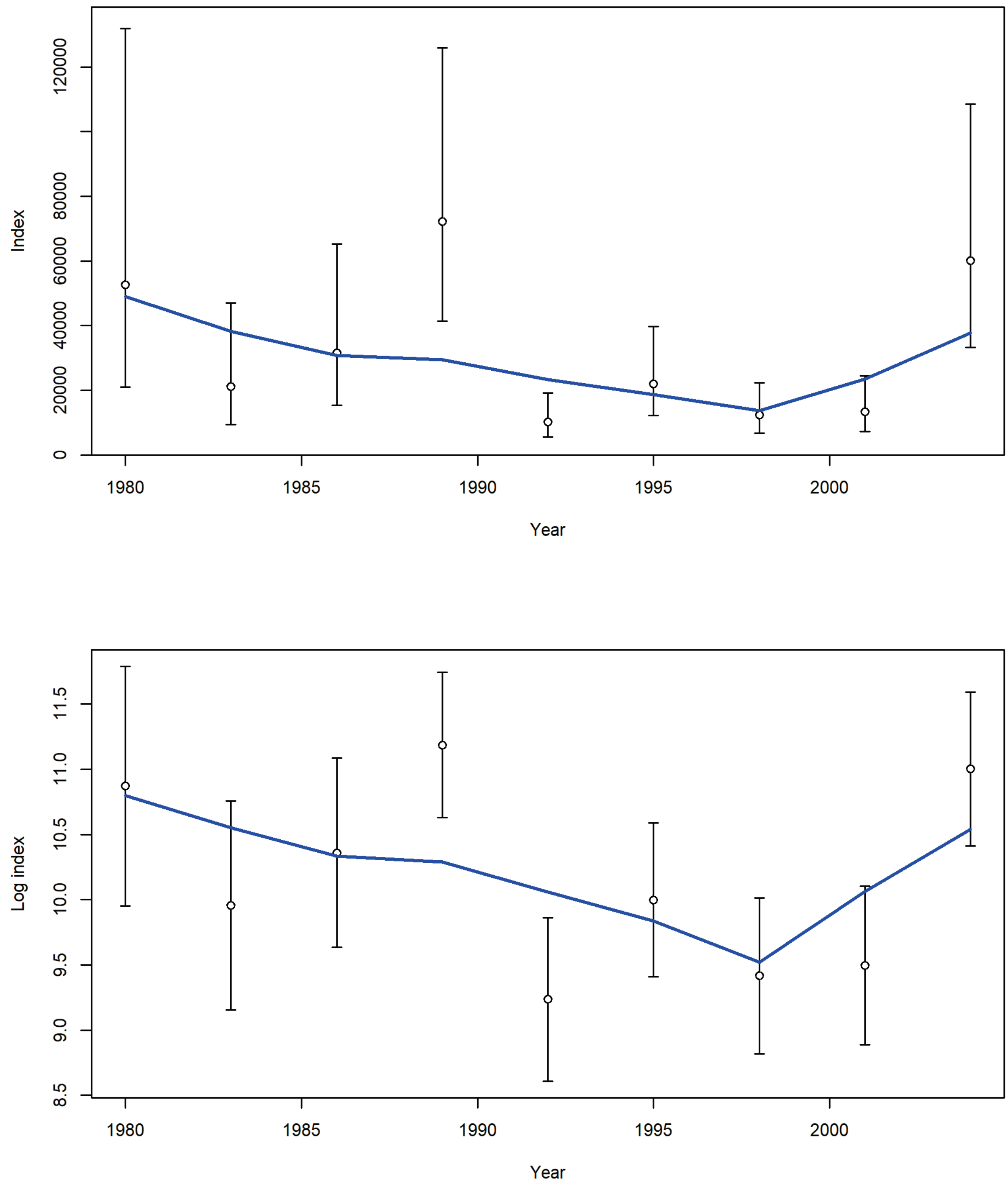

Figure 69: Triennial trawl survey index of relative abundance. Top panel: Arithmetic scale data with 95% C.I.s based on input SEs. Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

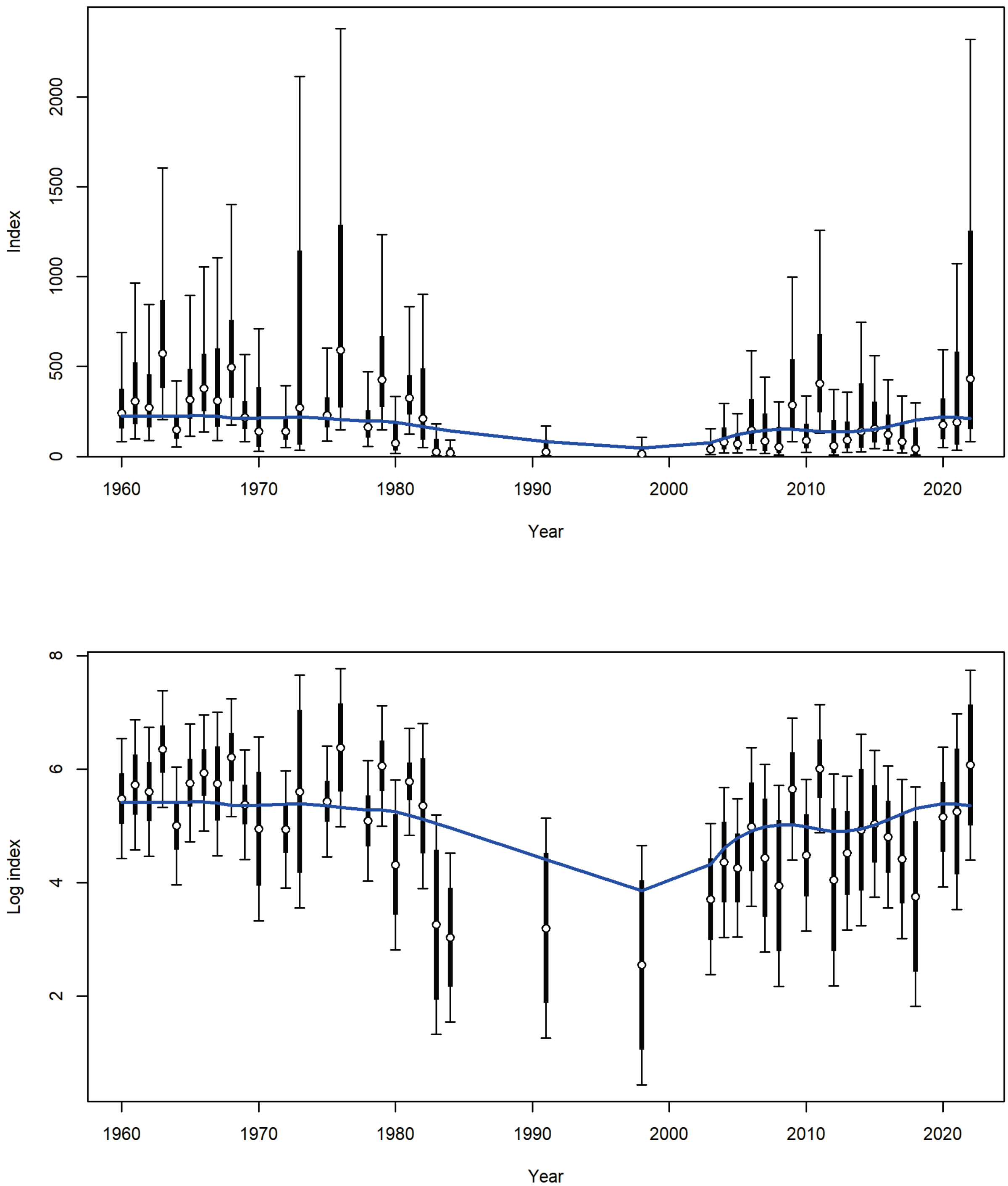

Figure 70: CalCOFI ichthyoplankton survey index of spawning output. Top panel: Arithmetic scale data with 95% C.I.s based on input SEs (thick vertical lines) and with estimated 'extra' variance (thin vertical lines with caps). Bottom panel: fit to log-scale index. Blue lines are the predicted values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

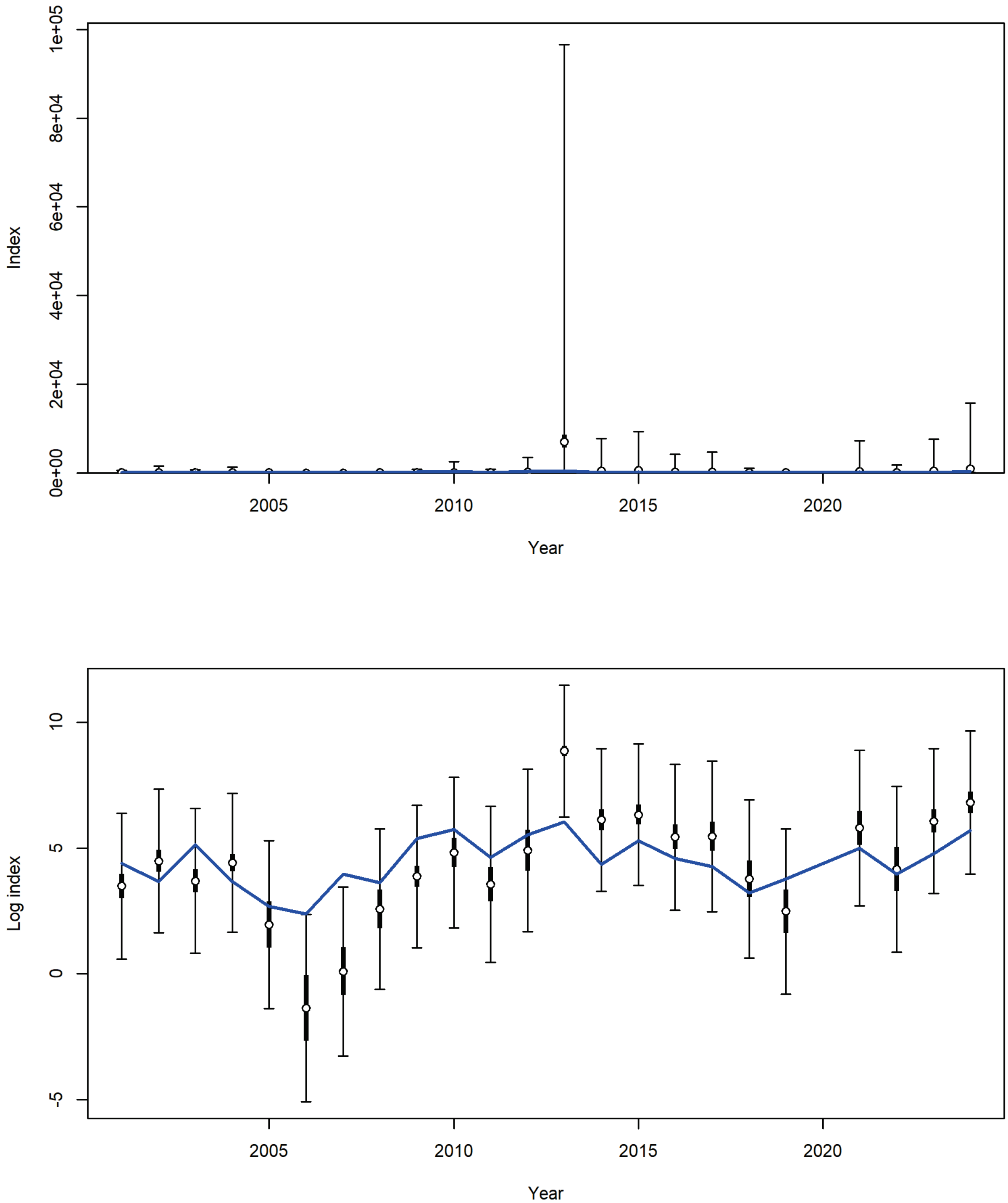

Figure 71: RREAS survey index of age-0 recruitment. Top panel: Arithmetic scale data with 95% C.I.s based on input SEs (thick vertical lines) and with estimated ‘extra’ variance (thin vertical lines with caps). Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

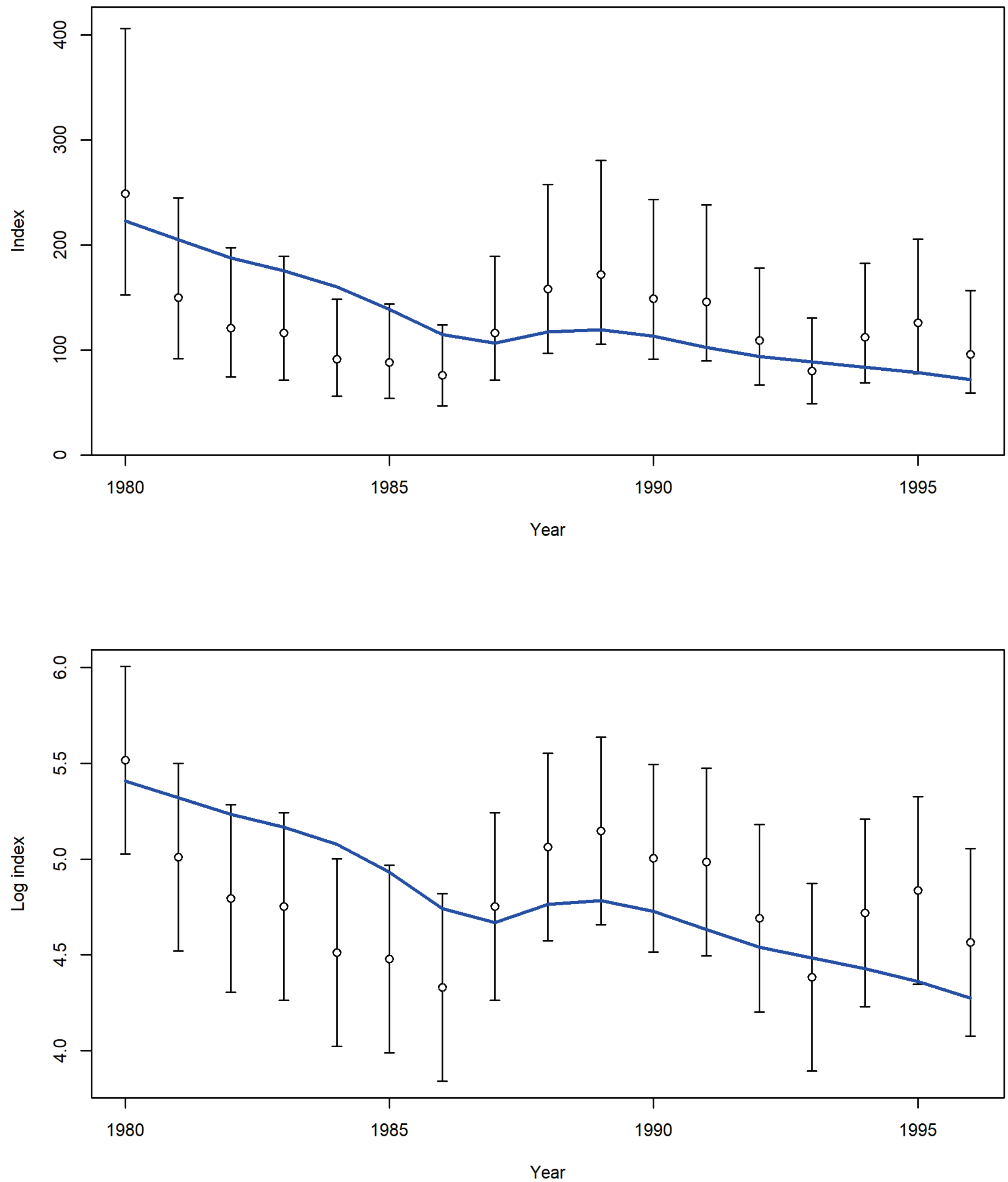

Figure 72: Trawl logbook index of relative abundance (for reference only; **not used to fit model**). Top panel: Arithmetic scale data with 95% C.I.s based on input SEs. Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

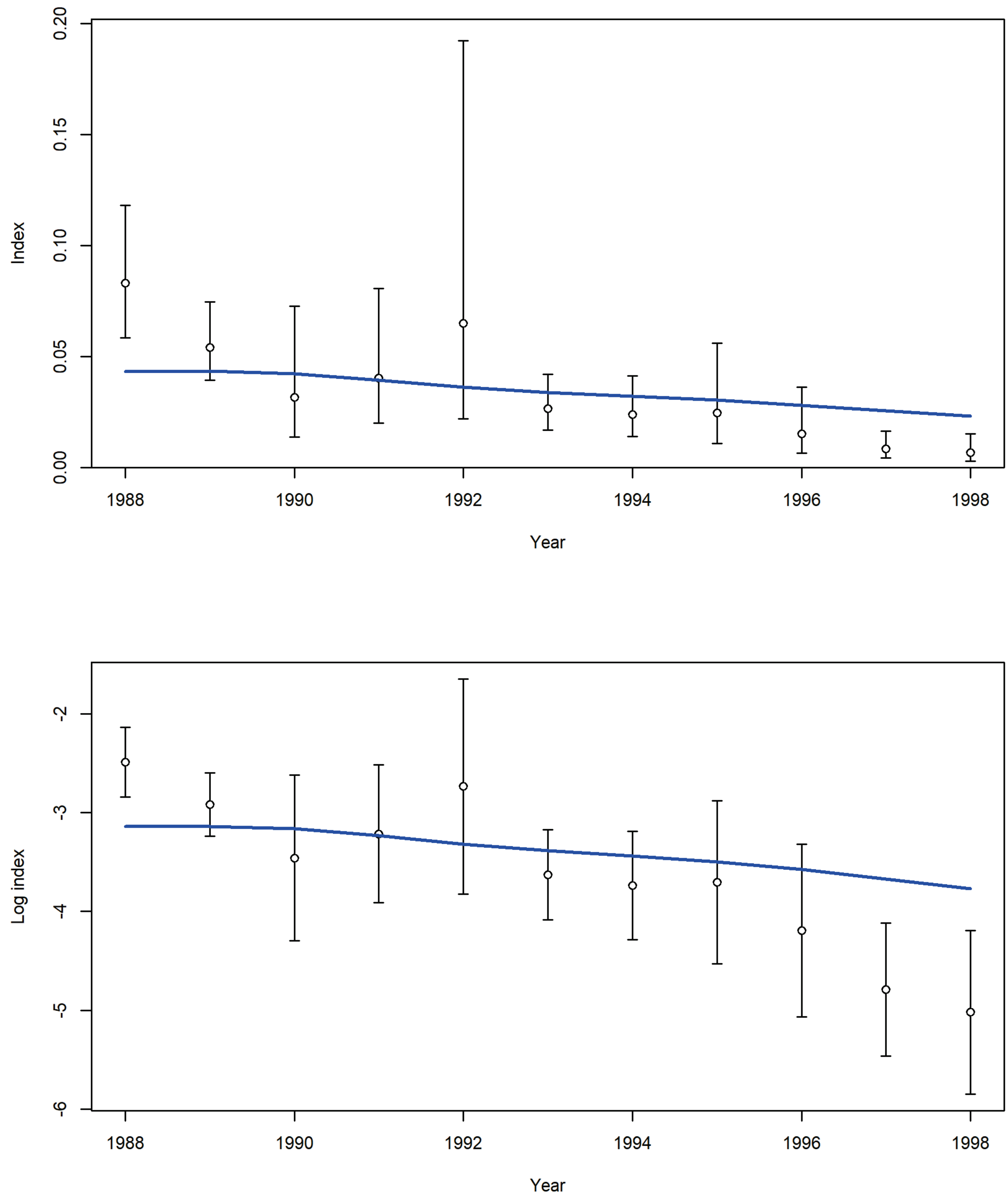

Figure 73: Recreational onboard observer index of relative abundance (for reference only; **not used to fit model**). Top panel: Arithmetic scale data with 95% C.I.s based on input SEs. Bottom panel: fit to log-scale index. Blue lines are the predicted values from the base model.

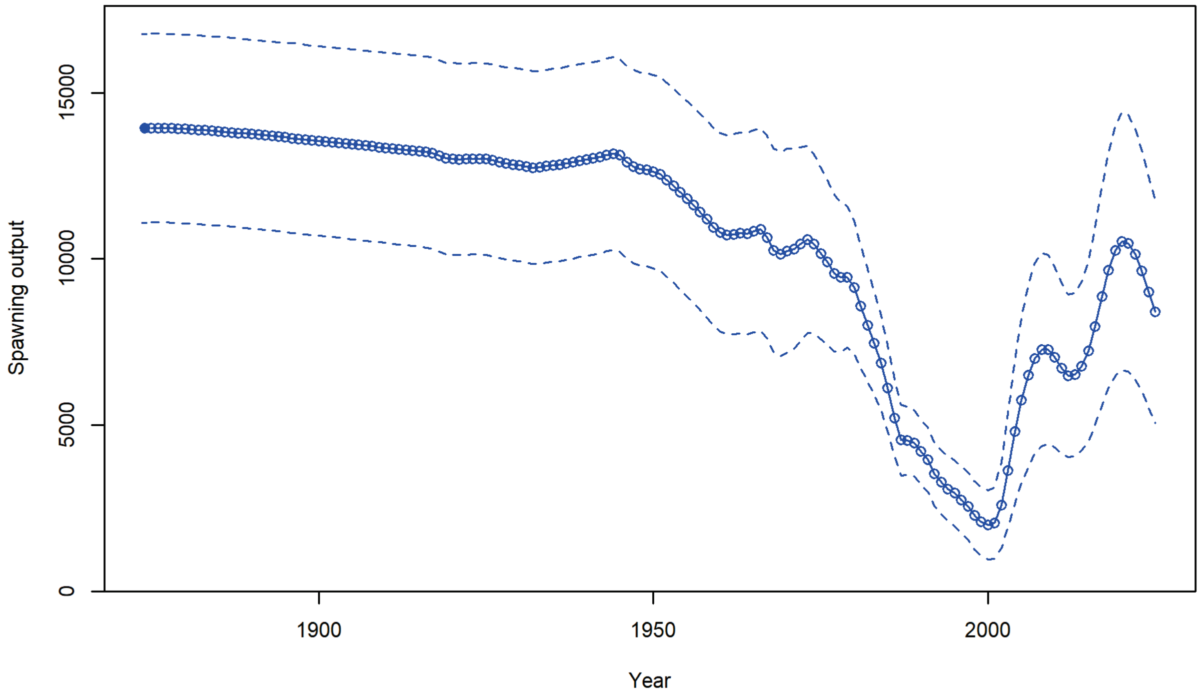

Figure 74: Estimated time series of spawning output from the base model with 95% asymptotic confidence intervals.

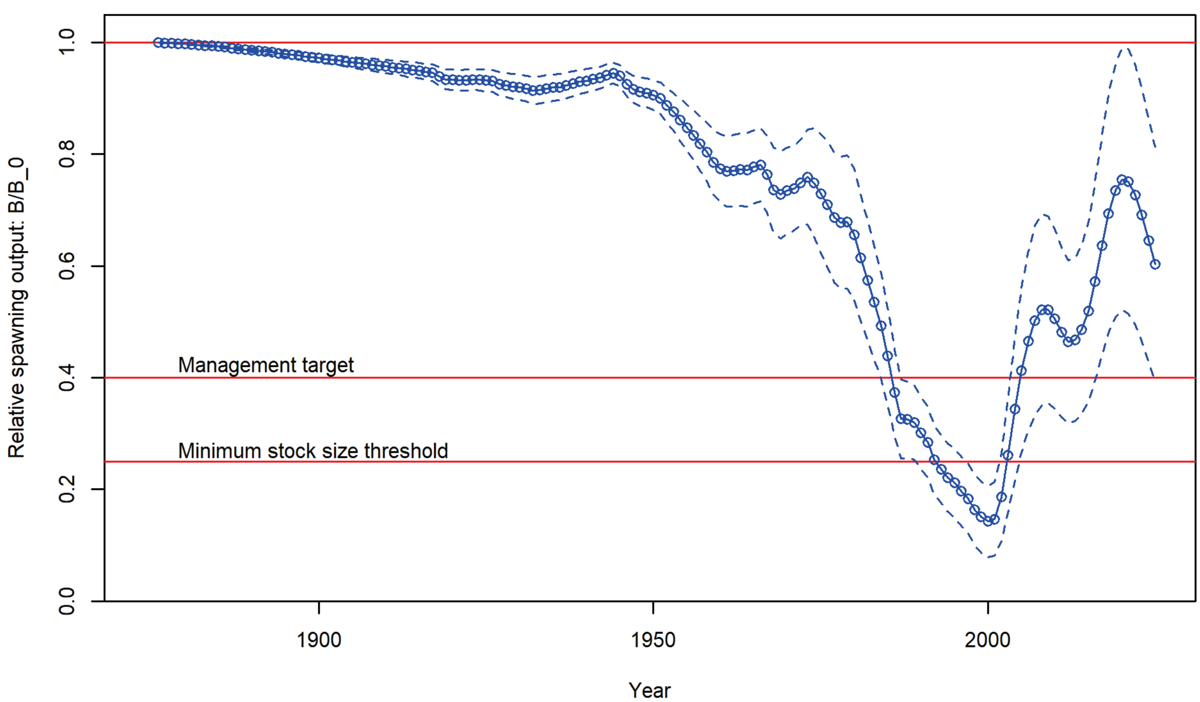

Figure 75: Estimated time series of relative spawning output from the base model with 95% asymptotic confidence intervals. Horizontal lines indicate PFMC target and minimum biomass levels for rockfish.

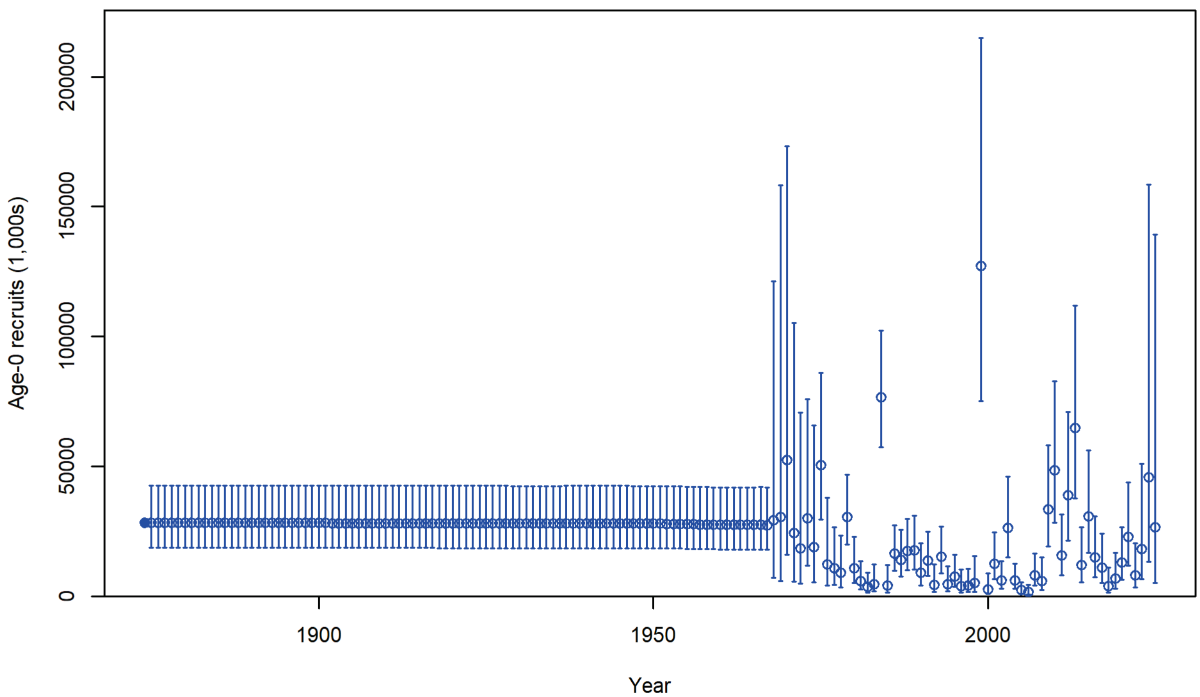

Figure 76: Estimated time series of age-0 recruits (1000s of fish) from the base model with 95% asymptotic confidence intervals.

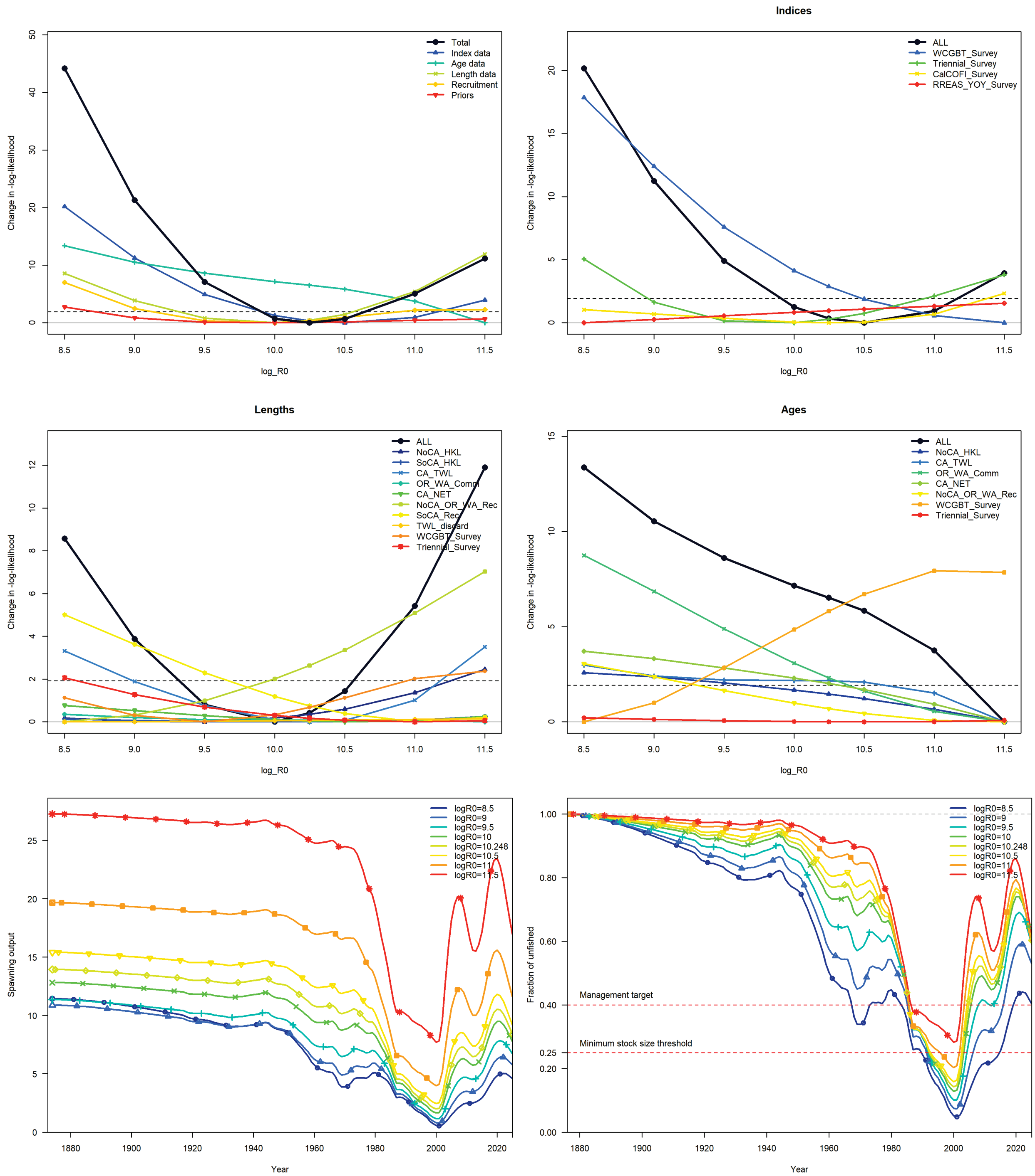

Figure 77: Likelihood profile over R0 using the base model.

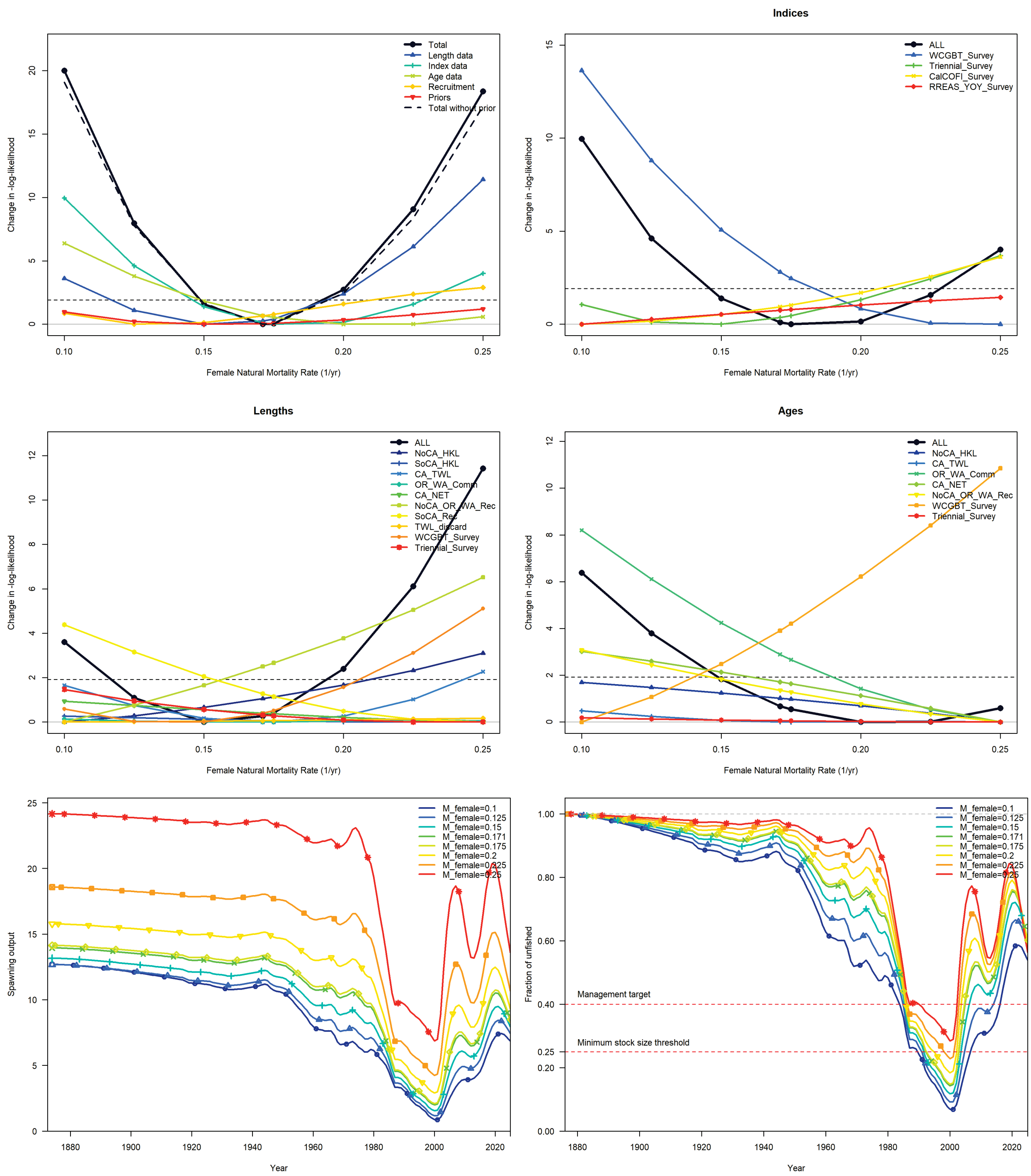

Figure 78: Likelihood profile over female M (allowing male M to be estimated) using the base model.

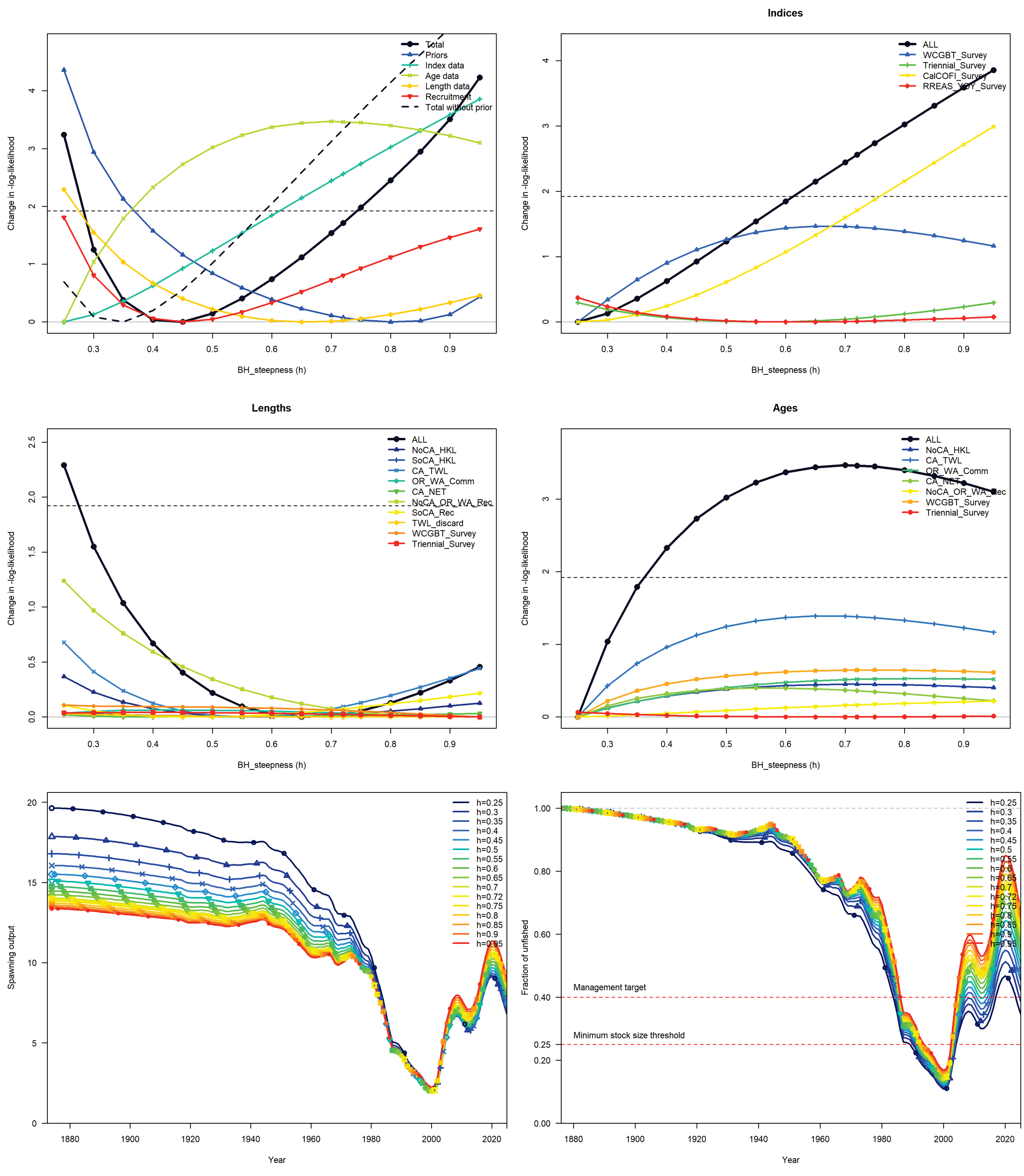

Figure 79: Likelihood profile over Beverton-Holt steepness using the base model.

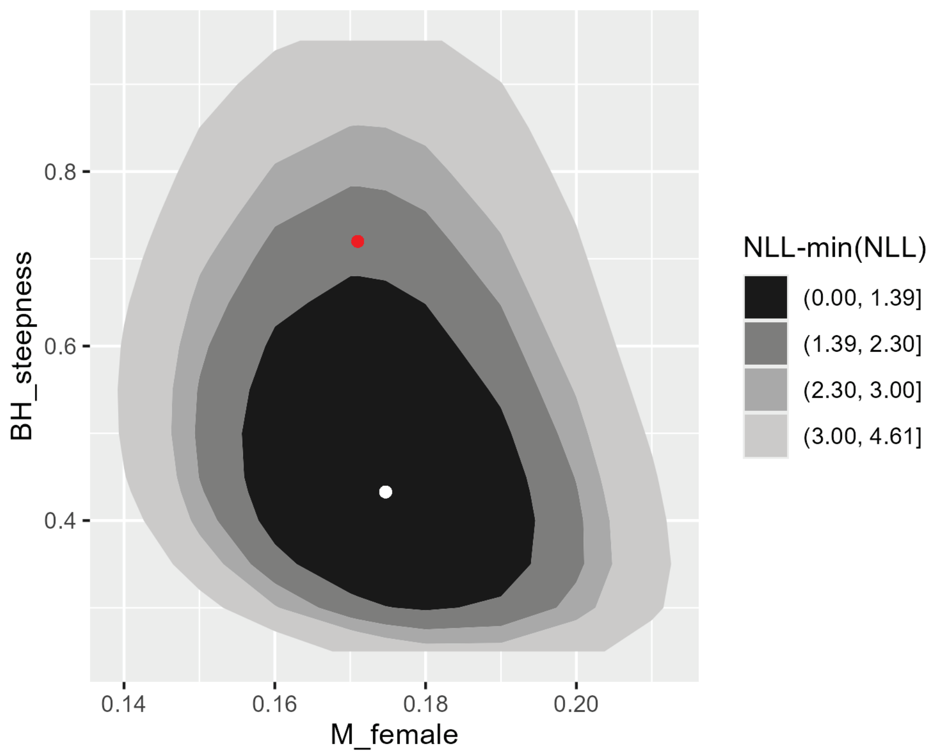

Figure 80: Bivariate likelihood profile over Beverton-Holt steepness and female natural mortality based on 204 model runs. The white point is the minimum of the NLL (steepness, female M, and male M all estimated). The red point is the base model (estimating female and male M, but fixing steepness at the prior mean (0.72). The contours represent bivariate 75% (black), 90%, 95%, and 99% (light grey) confidence regions.

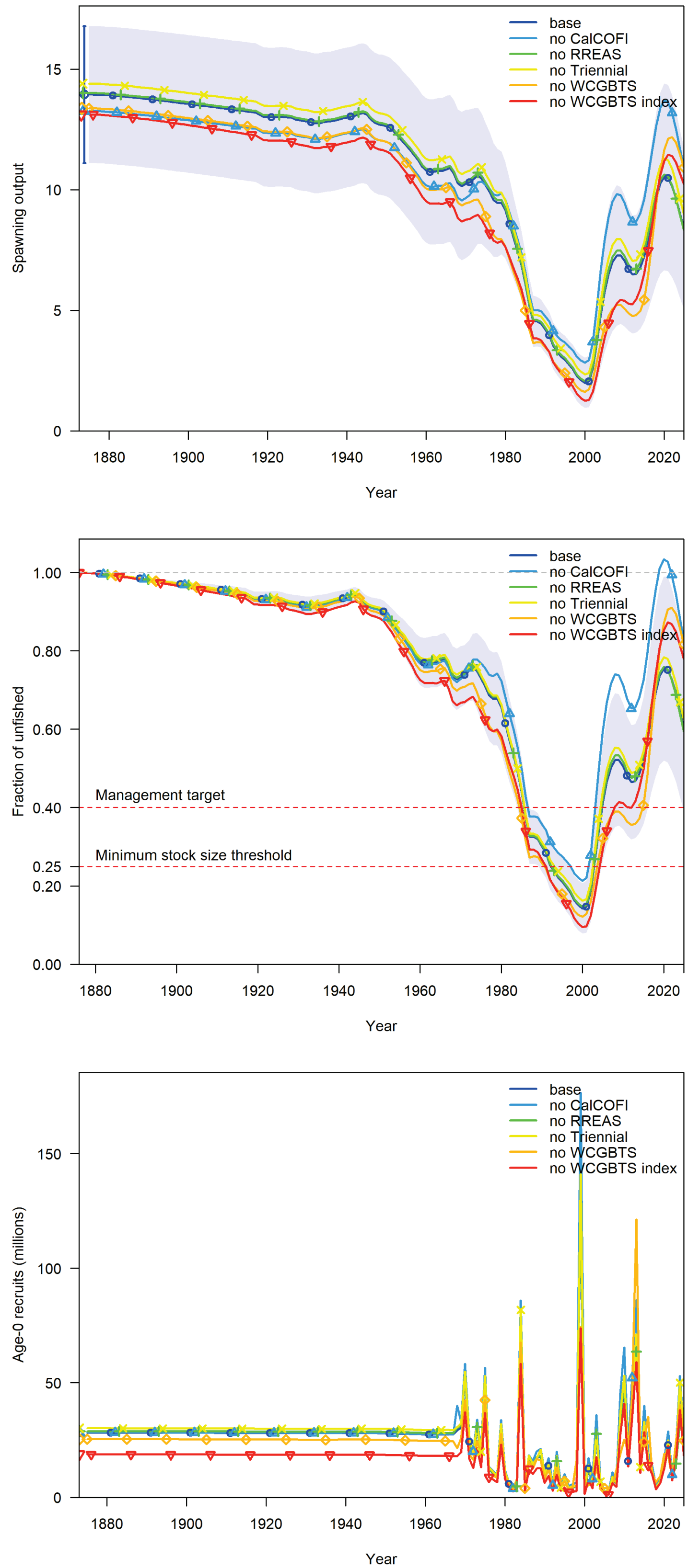

Figure 81: Sensitivity to removal of select data groups. These figures show spawning output, depletion and recruitment estimates from a “drop-one” analysis for data sources used in base model (for WCGBTS, includes dropping all compositional and index data, as well as dropping the index only).

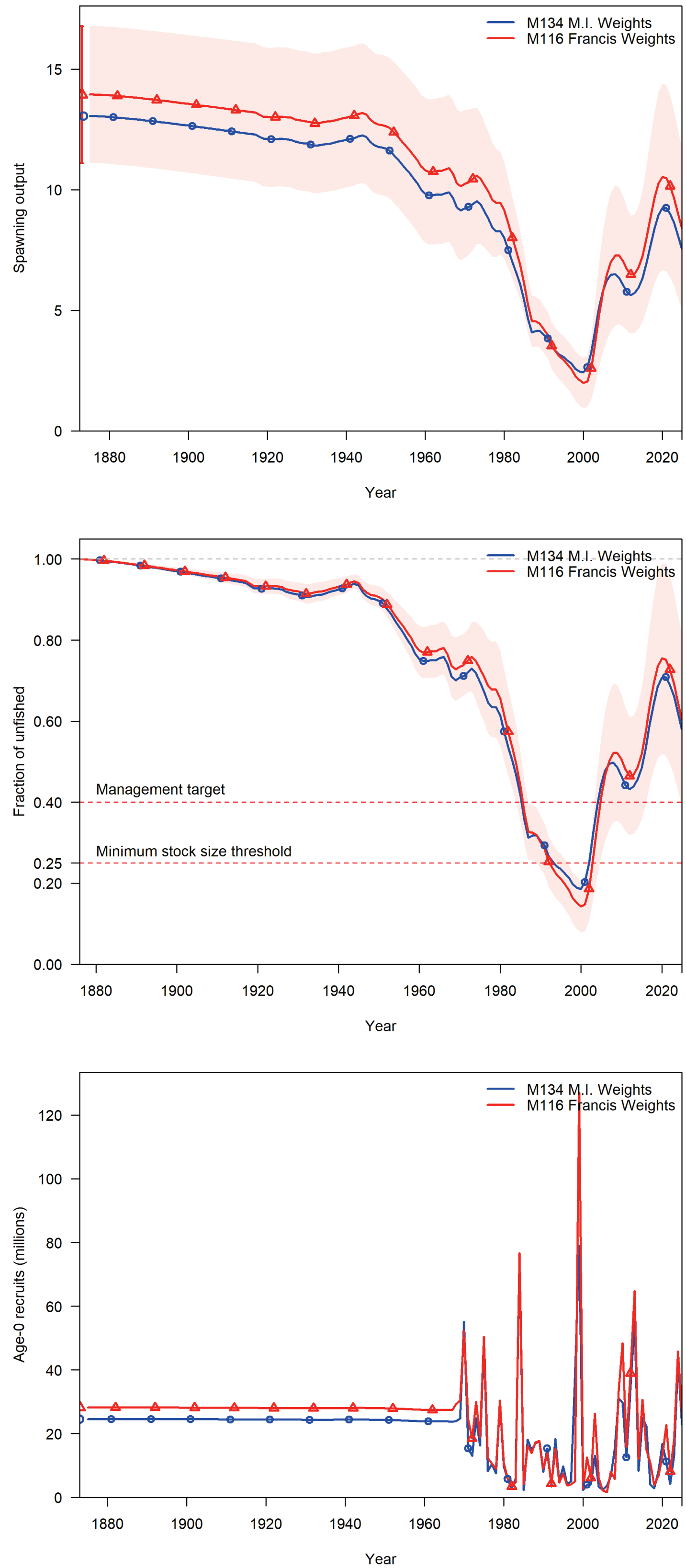

Figure 82: Model sensitivity to alternative data-weighting methods (Francis vs. McAllister-Ianelli). Time series of spawning output (billions of eggs, top panel), fraction unfished (middle panel), and recruitment (bottom panel).

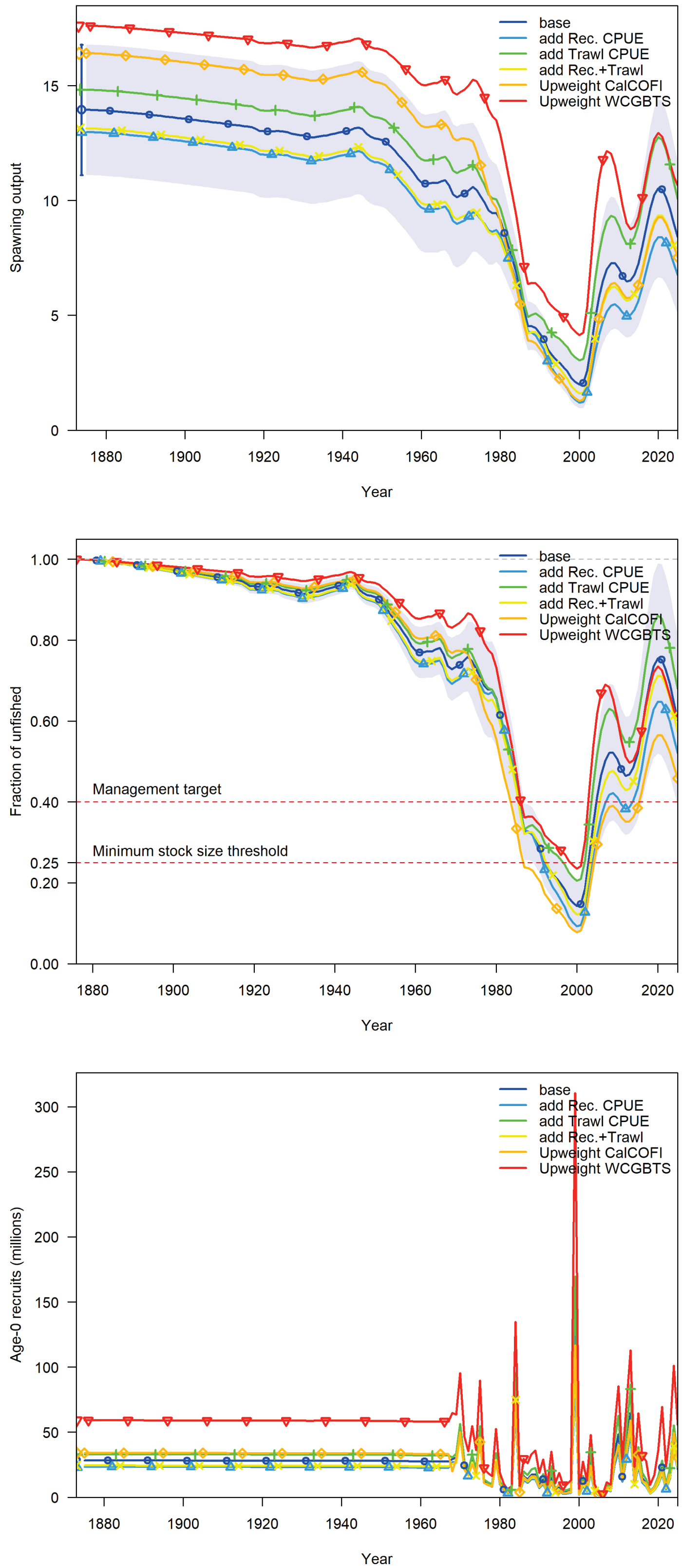

Figure 83: Sensitivity to data set choices and weighting schemes. These figures show spawning output, depletion and recruitment estimates when including indices that are currently not included in the base model, as well as when two of the key indices in the base model are substantially upweighted (lambdas set from 1 to 10).

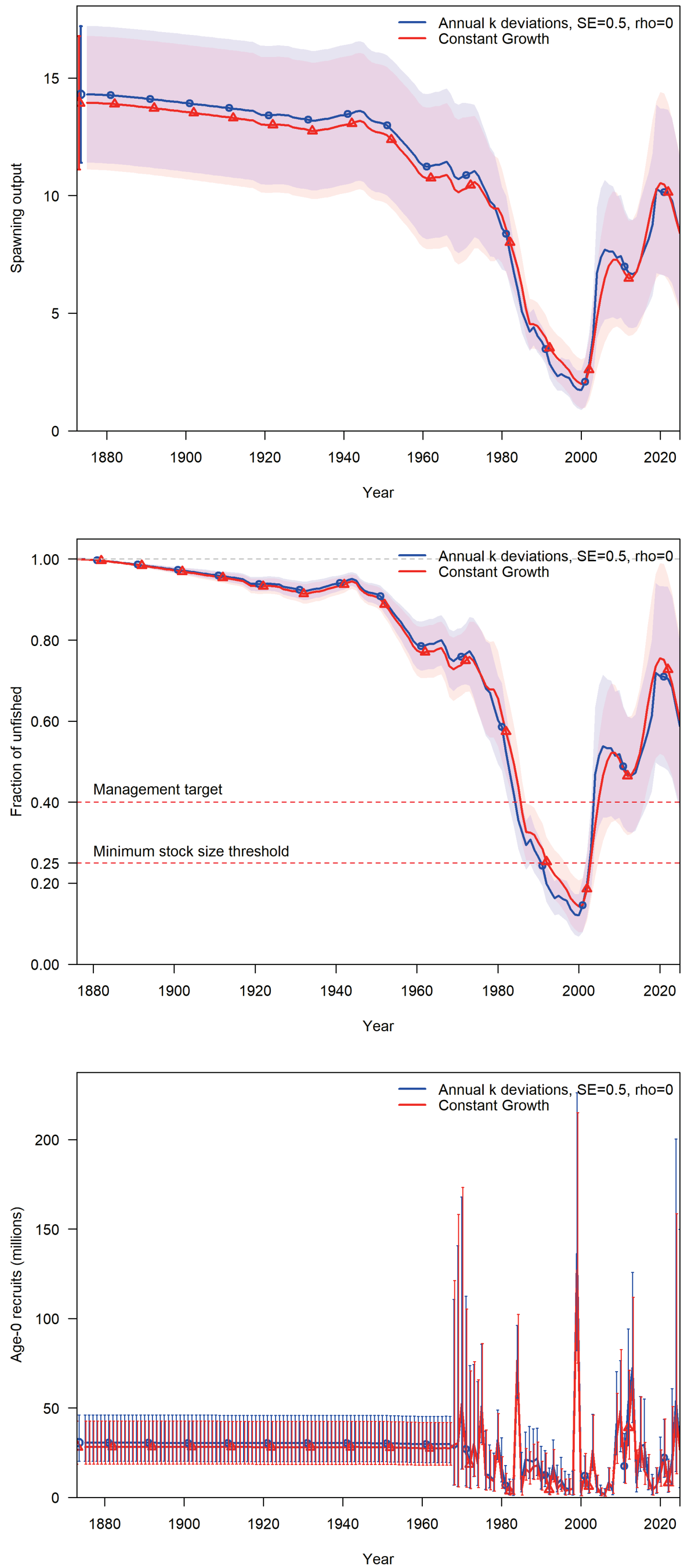

Figure 84: Time series of spawning output (top), fraction unfished (middle), and recruitment (bottom) from a sensitivity to annual deviations in growth (female ‘k’ from the von Bertalanffy growth model).

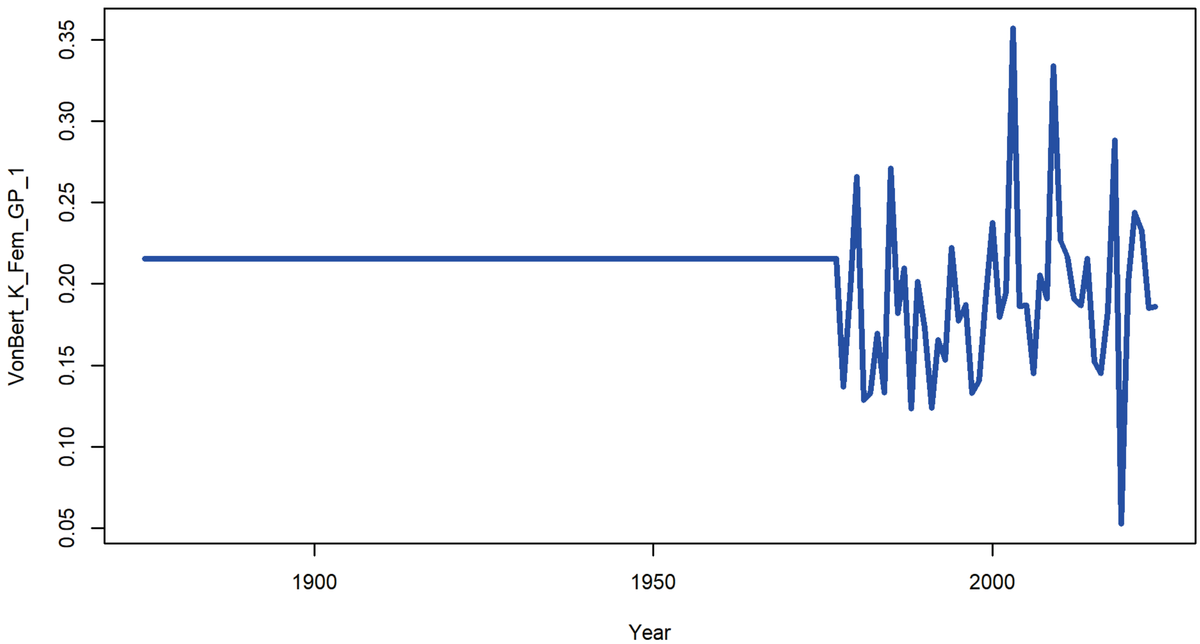

Figure 85: Estimated annual variation in female ‘k’ parameter from the von Bertalanffy growth model. Deviations were given an assumed S.E. of 0.5 (allowing considerable inter-annual variation), and had autocorrelation (rho) set to zero.

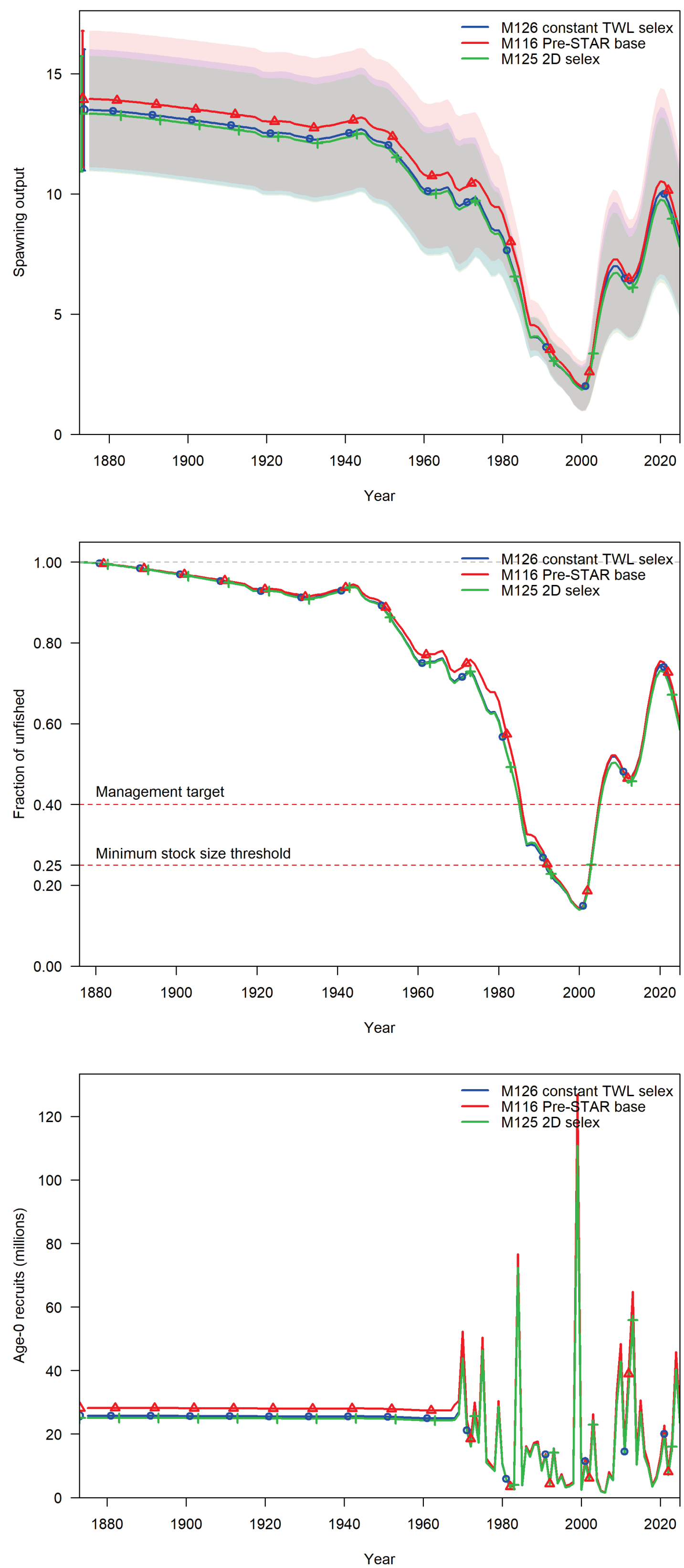

Figure 86: Time series of spawning output (top), fraction unfished (middle), and recruitment (bottom) from a sensitivity analysis of alternative selectivity parameterizations for the California trawl fleet.

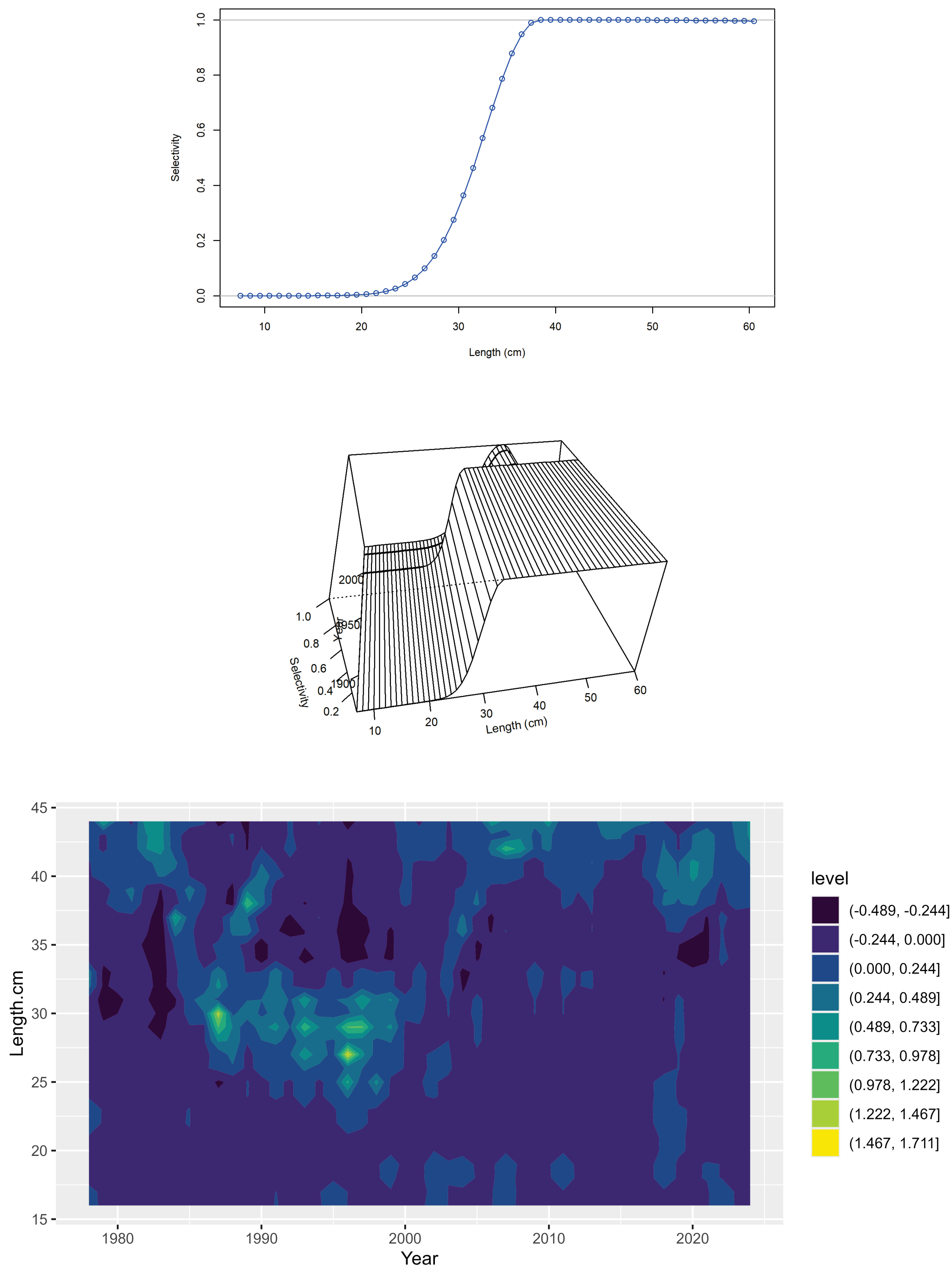

Figure 87: Illustrations of selectivity parameterizations with increasing complexity (top to bottom) for the California trawl fleet: constant (top), time-blocked in year 2000 (middle), deviations by length bin and year from a constant baseline logistic selectivity (bottom).

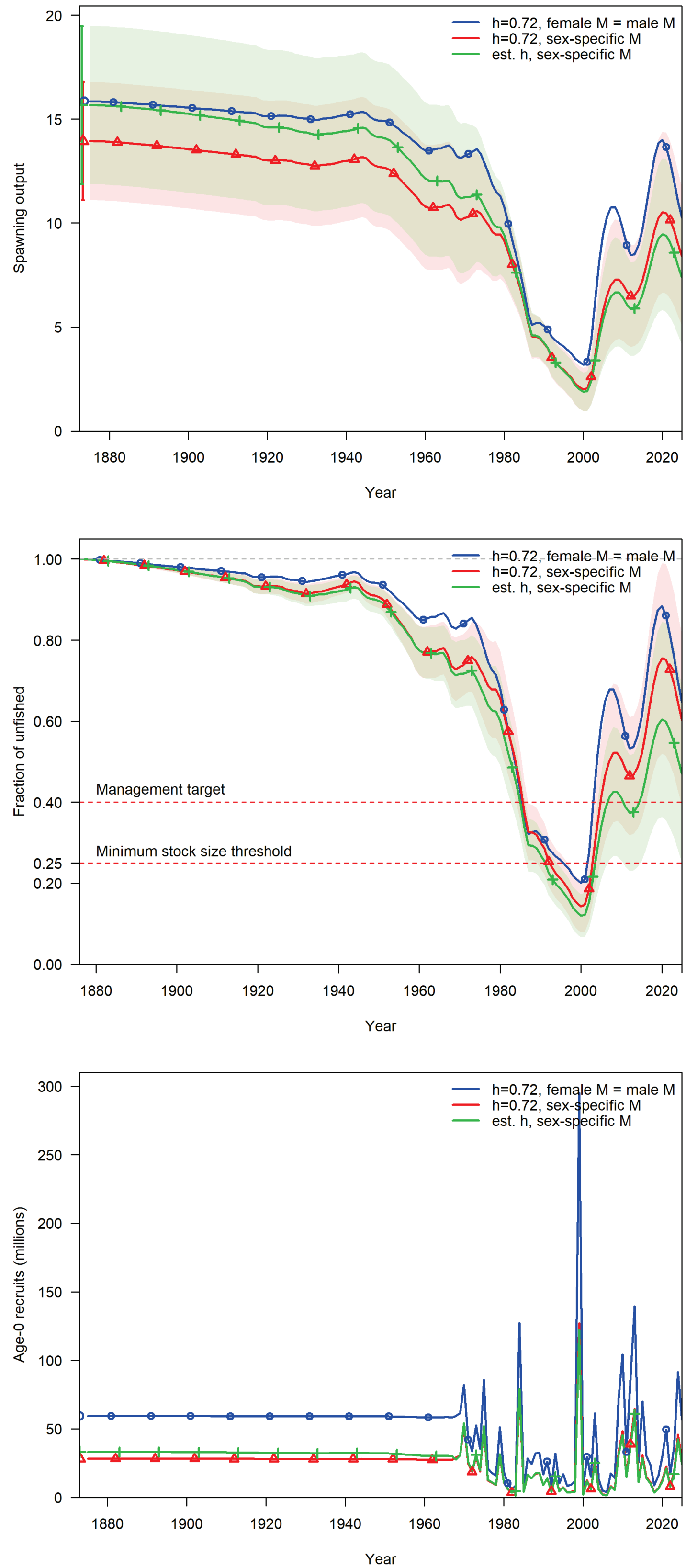

Figure 88: Time series of spawning output (top), fraction unfished (middle), and recruitment (bottom) from a sensitivity analysis of alternative steepness and natural mortality values (fixed and estimated).

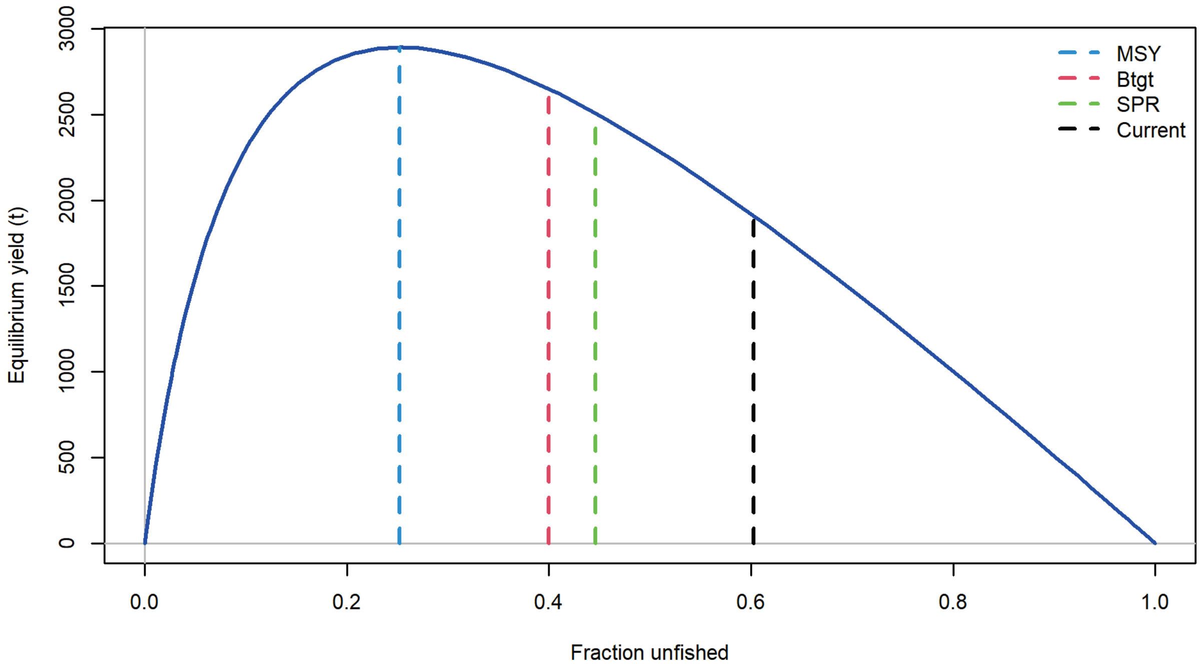

Figure 89: Equilibrium yield curve (mt) as a function of the fraction of unfished spawning output. Blue red, green, and black vertical lines represent equilibrium yield and relative biomass estimates associated with the model-based MSY, target spawning output (Btgt), SPR-based proxy harvest rate (SPR), and the model end-year harvest rate, respectively.

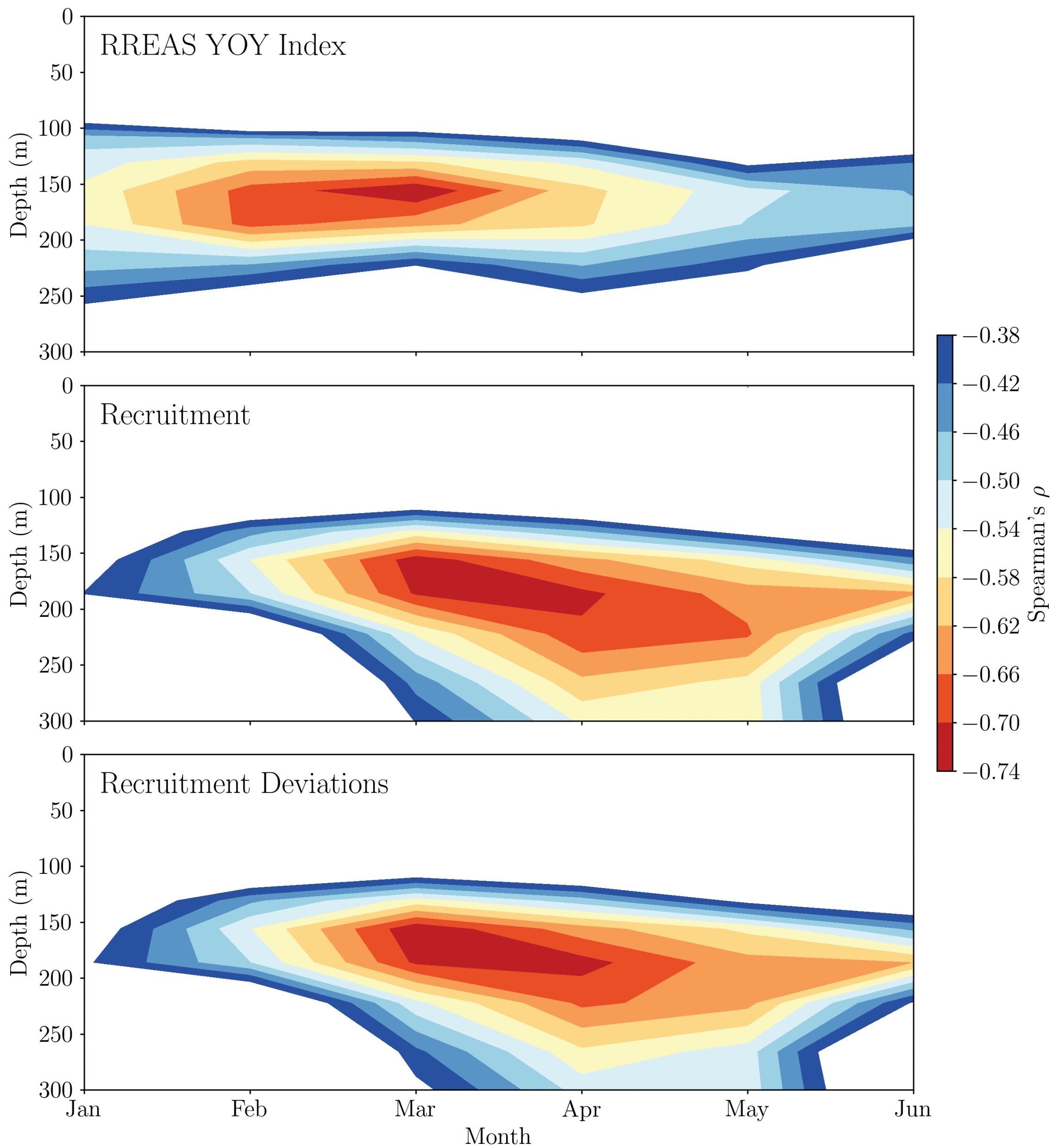

Figure 90: Depth and month when chilipepper has the highest significant correlation with subsurface ocean conditions (1993-2024). Three indicators of chilipepper recruitment variability were used; (top) RREAS YOY index based on midwater trawl survey data; (middle) recruitment estimates from this assessment; and (bottom) recruitment deviation 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 Glorys 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.

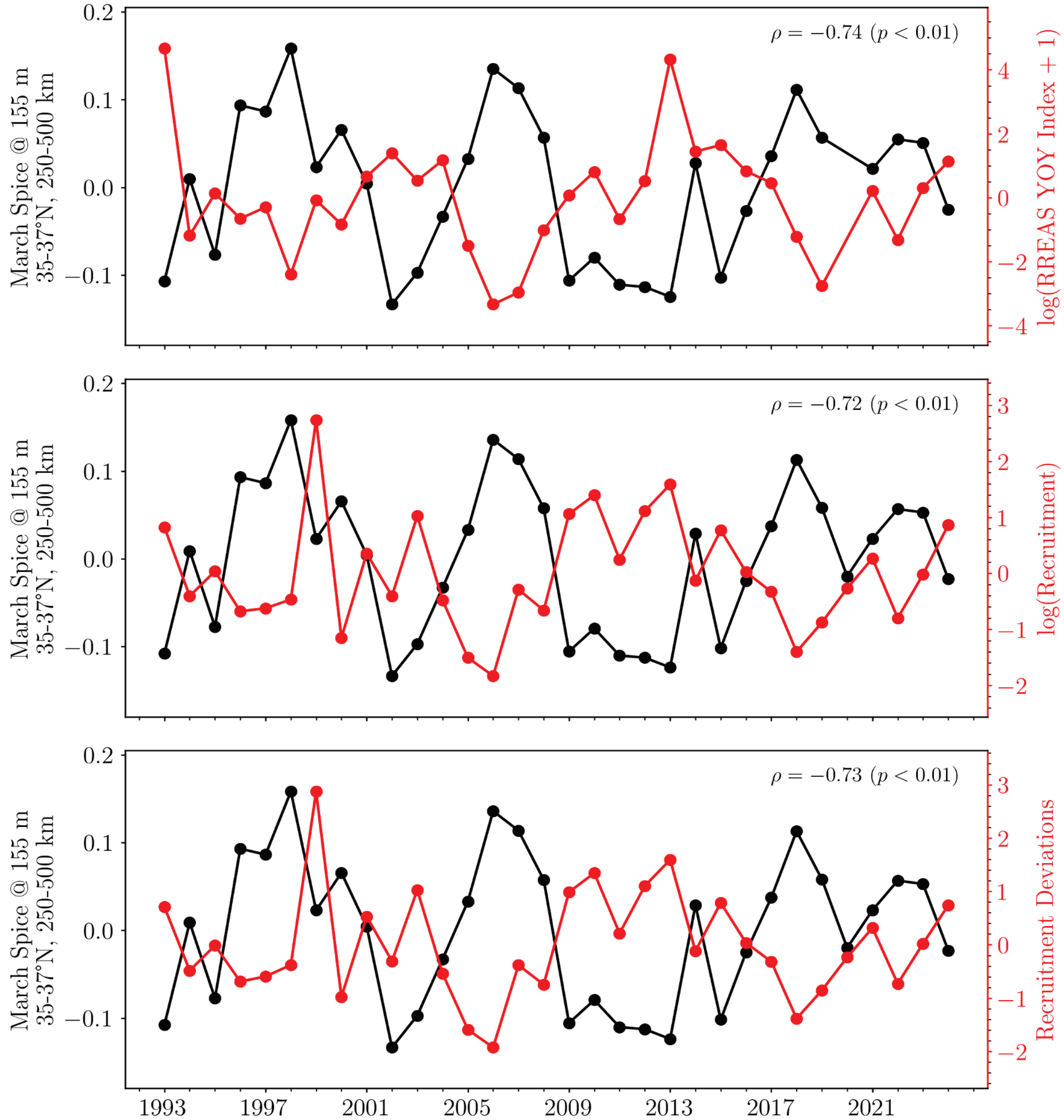

Figure 91: Time series of the recruitment indicators (YOY index, log of recruitment and recruitment deviation estimates from the base assessment model) and the spiciness estimates from the maximum correlation shown in (Figure 88). Correlations are Spearman's rank correlation (p) values calculated from time series with long-term trends removed.

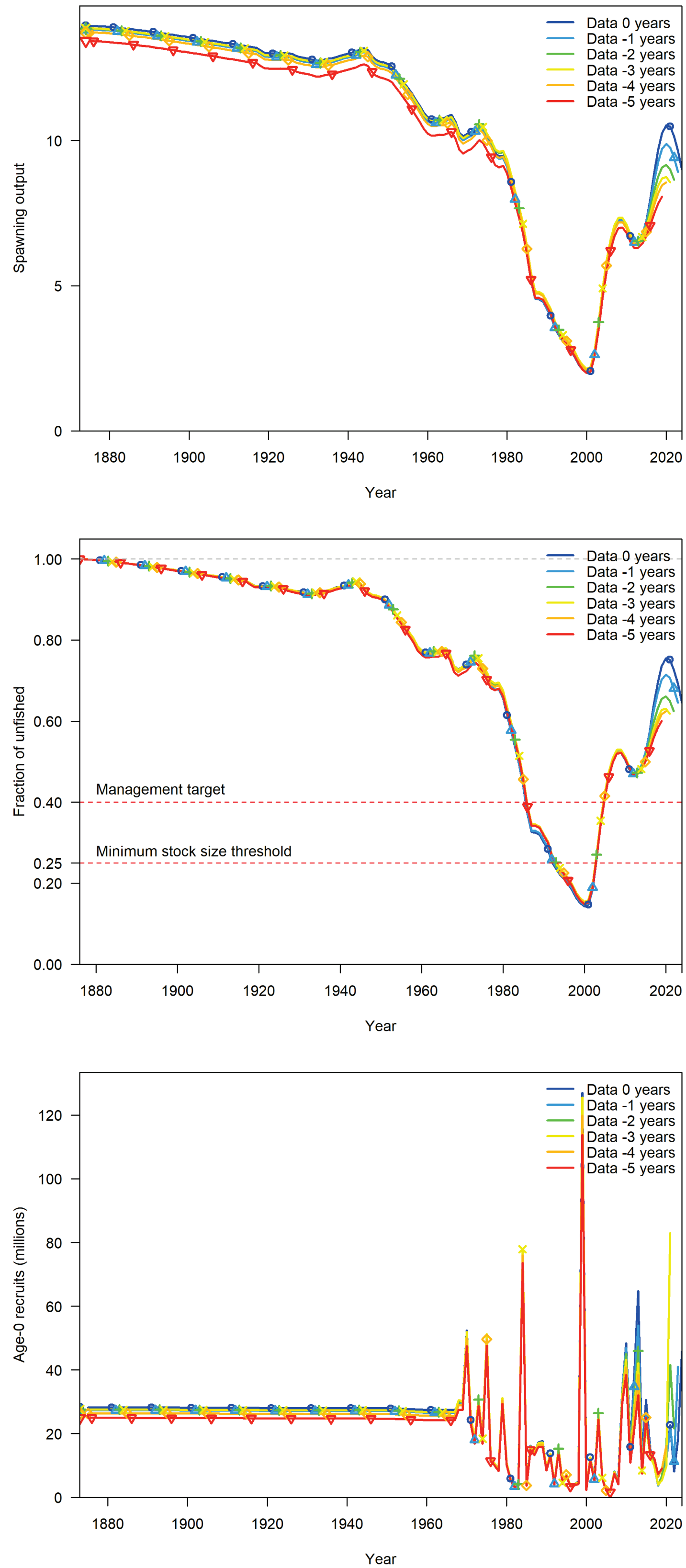

Figure 92: Time series of spawning output (top), fraction unfished (middle), and recruitment (bottom) from a retrospective analysis (sequential removal of 1-5 years of recent data).

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

1 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	-
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.

2 Model

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

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

This parameterization is convenient for its stability in statistical inference and aligns well with the SS3 parameterization [3]. κ 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 κ 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 ℓ_{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 ℓ_{sti} with VB growth at age a_{sti} the following observation model arises naturally,

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

Above L_0 is fixed at 7.3 as previously mentioned, but κ_{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 κ_{st} and $L_{20_{st}}$ are further modeled hierarchically as follows,

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

First since κ 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 κ_{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 ϕ 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 κ, but the structure of the VB curve clearly correlates estimates of κ with L_{20}. Consequently, L_{20} was given a similar level of model flexibility as κ 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.

3 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.

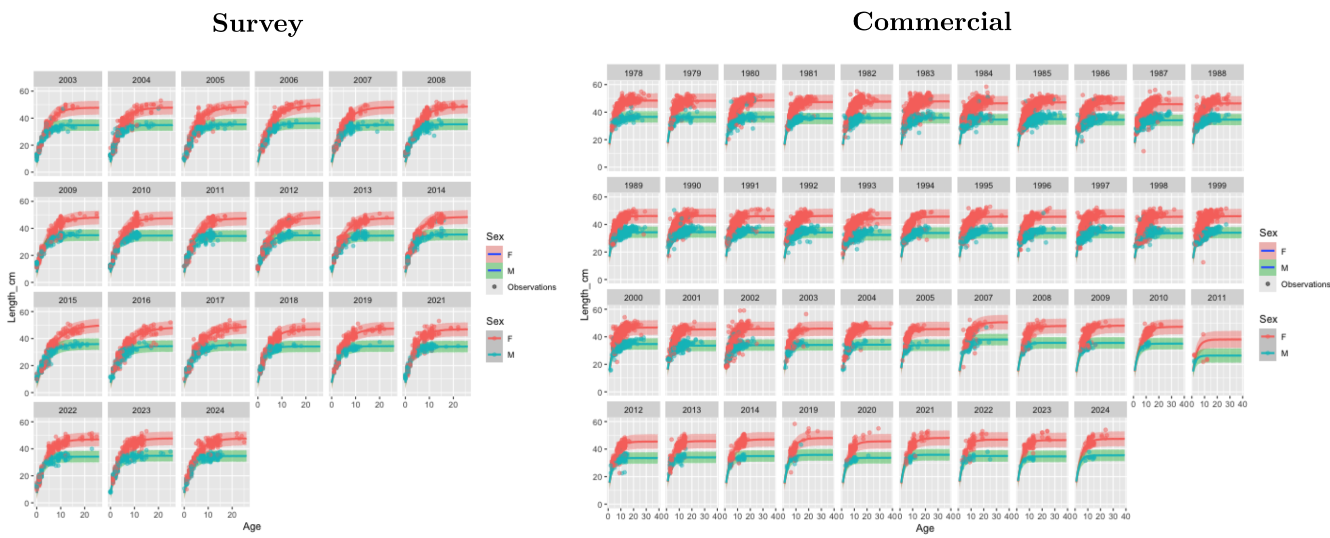

Figure 1: $(left)$ Model fit to survey data, by year and sex. $(right)$ Model fit to commercial data, by year and sex.

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 κ_{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

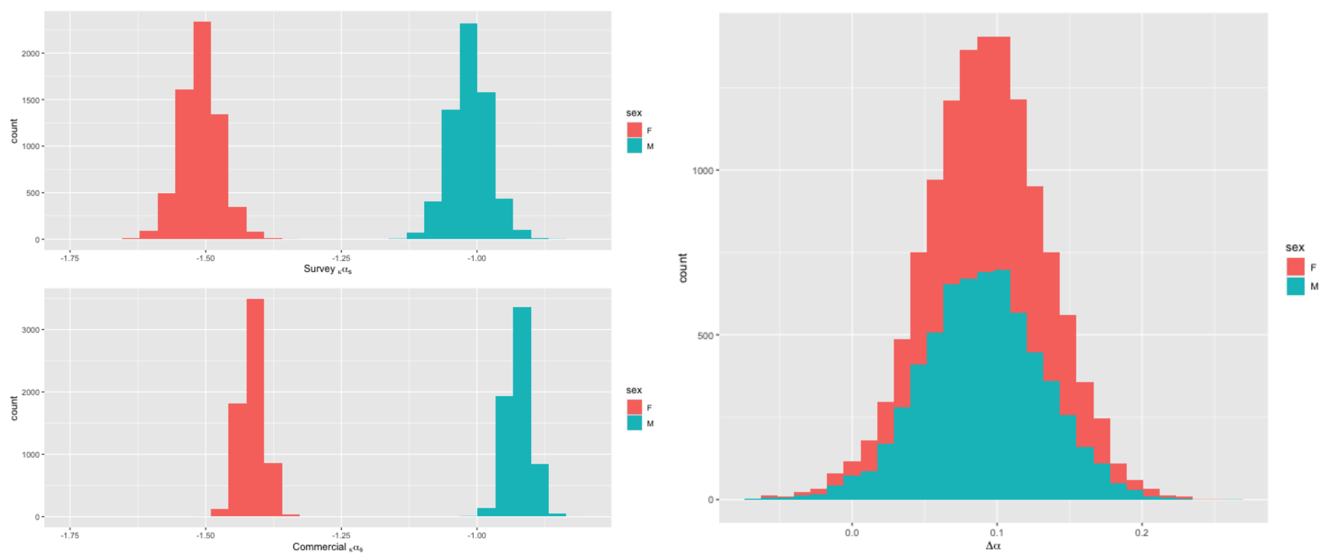

Figure 2: ($left$) ${}_{\kappa}\alpha_s$ posterior distributions. (top) Survey fit. ($bottom$) Commercial fit.
($right$) Stacked histogram showing the posterior of the difference between marginalized ${}_{\kappa}\alpha_s$ parameters.

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 $e^{{}_{\kappa}\beta_t-\Delta\alpha}$.

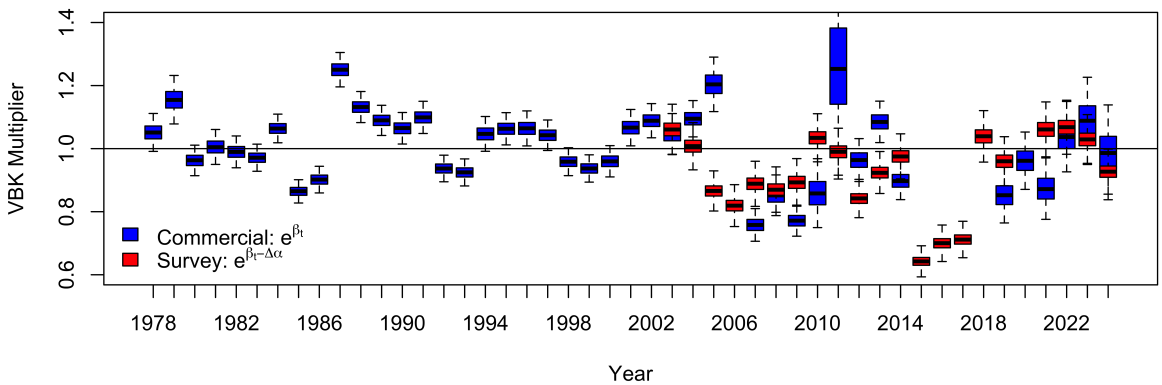

Figure 3: Separate indices of time varying growth as derived from independent fits to the commercial and survey data.

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.

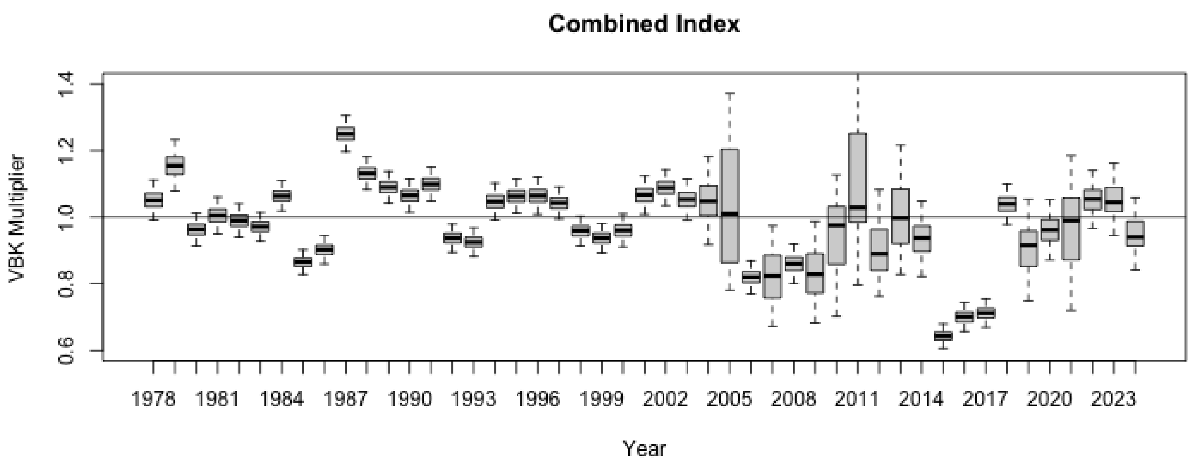

Figure 4: Combined index of time varying growth.

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

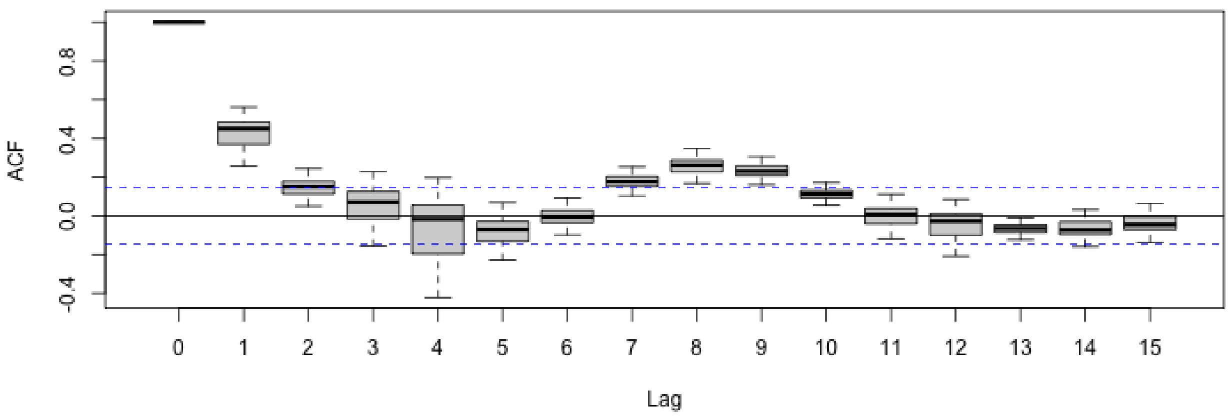

Figure 5: The grey boxplots represent the autocorrelation function as applied to the posterior draws of the combined index (whiskers represent an approximate 2σ interval). The blue dashed lines represent the asymptotic 2σ interval around the classical null hypothesis of 0 autocorrelation.

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.

4 A Regional Spatio-Temporal Model

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

$$\ell_{rsti} = VB(a_{rsti};\ \kappa_{rst}, L_0, L_{20_{rst}}) + \epsilon_{rsti} \tag{4}$$

$$\epsilon_{rsti} \sim N(0, \sigma_s) \quad \sigma_s \sim \text{Student}_3(0, 10)\ 1_{\sigma>0}$$

$$\log(\kappa_{rst}) = \mathbb{1}_{0.05<\kappa<0.5}({}_{\kappa}\alpha_{rs} + {}_{\kappa}\beta_{rst}) \quad {}_{\kappa}\beta_{rst} \sim N(0, {}_{\kappa}\phi) \quad {}_{\kappa}\phi \sim N(0,1)\ 1_{{}_{\kappa}\phi>0}$$

$$L_0 = 7.3 \quad L_{20_{rst}} = {}_{L_{20}}\alpha_{rs} + {}_{L_{20}}\beta_{rst} \quad {}_{L_{20}}\beta_{rst} \sim N(0, {}_{L_{20}}\phi) \quad {}_{L_{20}}\phi \sim N(0,1)\ 1_{{}_{L_{20}}\phi>0}.$$

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.

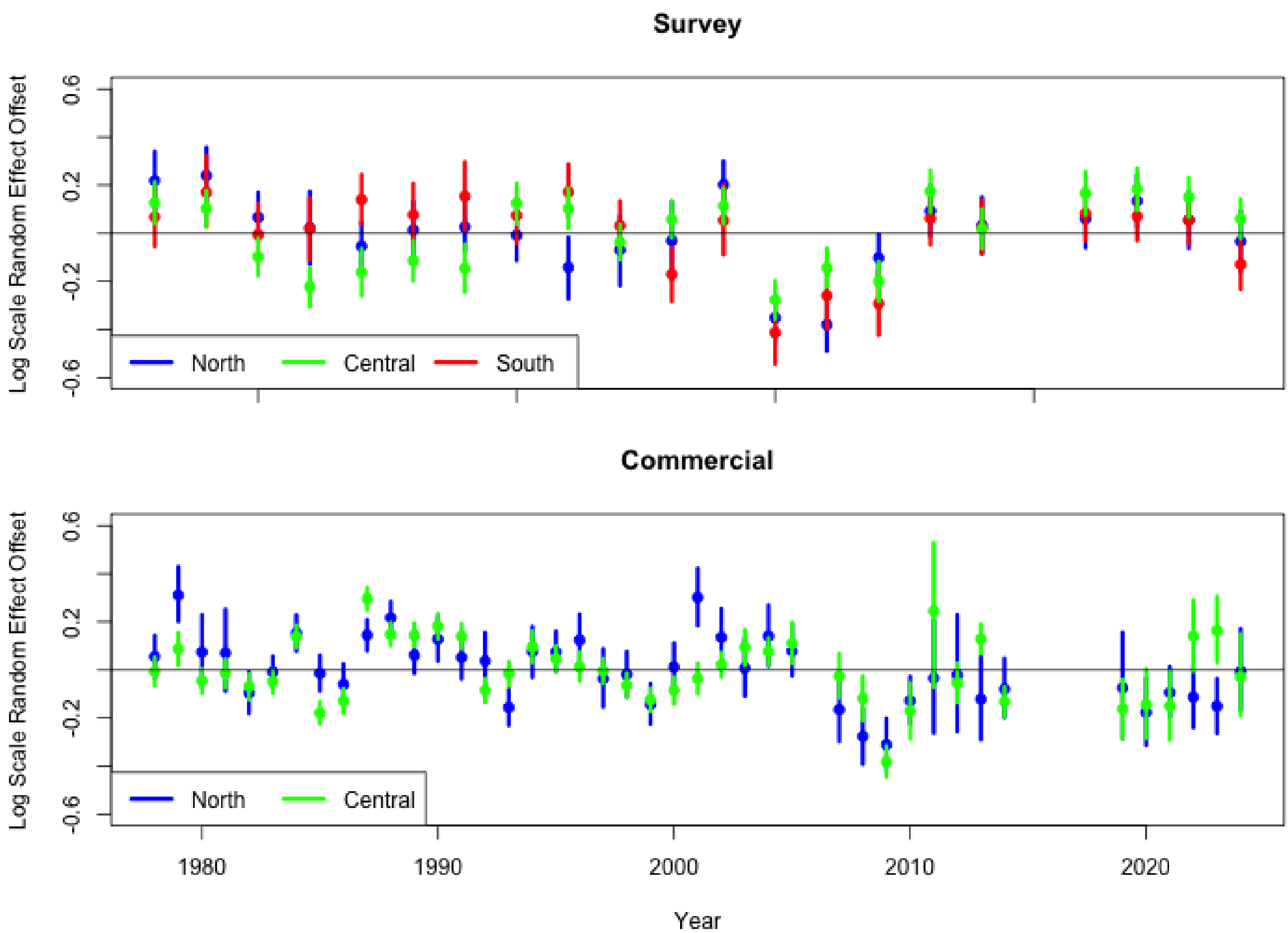

Figure 6: Separate spatio-temporal indices as derived from the survey (*top*) and commercial (*bottom*) data.

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, $\mathbb{E}[\ell_{rsi}] = VB(a_{rsi};\, \kappa_{rs}, L_0, L_{20_{rs}})$ (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.

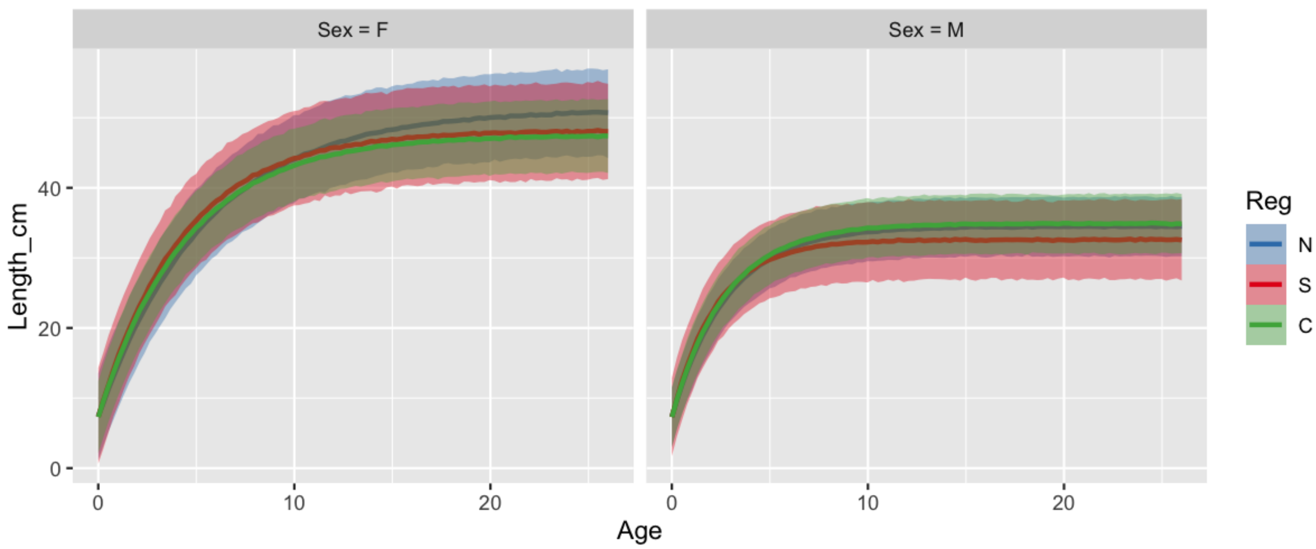

Figure 7: Posterior predictive 95% intervals of the VB function from the simplified spatial model.

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[4] Jon Schnute. A Versatile Growth Model with Statistically Stable Parameters. *Canadian Journal of Fisheries and Aquatic Sciences*, 38(9):1128–1140, September 1981.

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