# The Combined Status of Gopher (*Sebastes carnatus*) and Black-and-Yellow Rockfishes (*Sebastes chrysomelas*) in U.S. Waters Off California in 2019

Gopher rockfish (left) and black-and-yellow rockfish (right). Photos by Steve Lonhart.

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# The Combined Status of Gopher (*Sebastes carnatus*) and Black-and-Yellow Rockfishes (*Sebastes chrysomelas*) in U.S. Waters Off California in 2019

## Contents

# Executive Summary

executive-summary

## Stock

stock

This assessment reports the status of the gopher and black-and-yellow rockfish complex (GBYR, *Sebastes carnatus/Sebastes chrysomelas*) resource in U.S. waters off the coast of California south of Cape Mendocino (40°10′ N. latitude) using data through 2018. Both gopher and black-and-yellow rockfishes are most abundant north of Point Conception (34°27′ N. latitude) and are uncommon north of Point Arena (38°57′ N. latitude). The range of gopher rockfish extends into Baja California, but the black-and-yellow rockfish are rare south of Point Conception.

## Catches

catches

Information on historical landings of GBYR are available back to 1916 (Table a). The recreational fleet began ramping up in the 1950s and has fluctuated over the the last 50 years (Figure a). The majority of GBYR recreational landings have been from north of Point Conception throughtout the time period modelled.

Commercial landings were small during the years of World War II, ranging between 4 to 28 metric tons (mt) per year (Figure b). Commercial landings increased after World War II and show periods of cyclical catch for gopher and black-and-yellow rockfishes. The commercial live fish fishery began in the early 1990s, with the first reported live landings in 1993. Since then the commercial catch has been dominated by the live fish fishery, with minimal landings of dead gopher or black-and-yellow rockfishes. Estimates of total mortality of commercial discards were available starting in 2004, and were estimated prior to then. The catches aggregated by fleets modeled in this assessment can be found in Figure c.

Since 2000, annual total landings of catch and discards of GBYR have ranged between 70-169 mt, with landings (catch + discards) in 2018 totaling 92 mt.

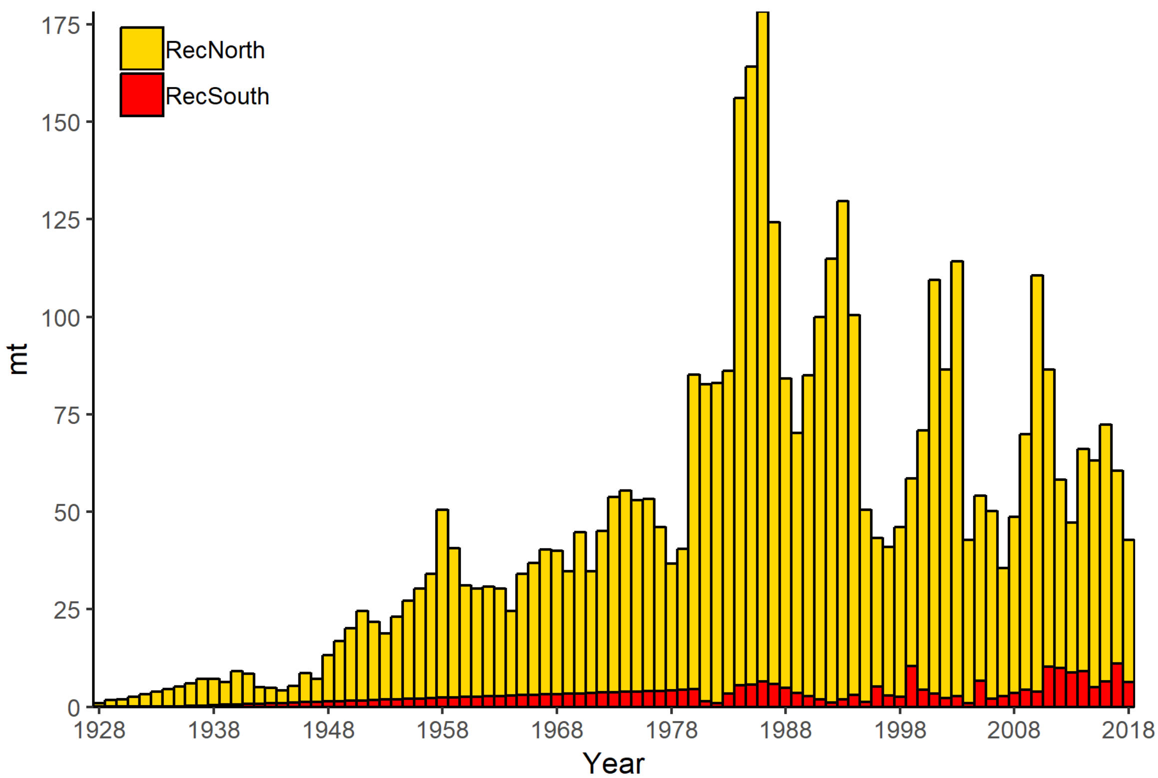


Figure a: Catch history of GBYR landings for the recreational fleet north (RecNorth) and south (RecSouth) of Point Conception.. fig:Exec_catch1

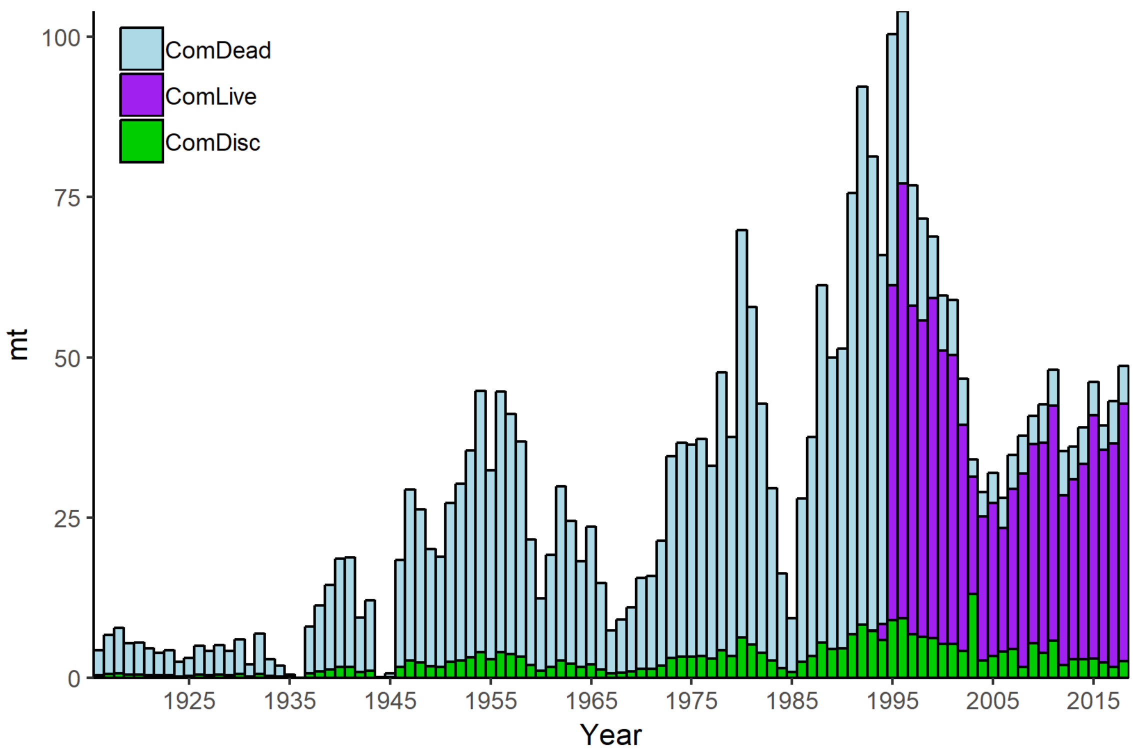


Figure b: Catch history of GBYR for the commercial fleet by dead (ComDead) and live (ComLive) landings, and discards (ComdDisc). Catches in 1936 and 1946 were minimal. fig:Exec_catch2

Table a: Recent GBYR landings (mt) by fleet, where the recreational fleet is split at Point Conception.

tab:Exec_catch

| Year | Commercial Retained | Commercial Discard | Recreational North | Recreational South | Total |
|---|---|---|---|---|---|
| 2009 | 35.62 | 5.38 | 65.64 | 4.30 | 110.93 |
| 2010 | 38.83 | 3.92 | 106.76 | 3.90 | 153.41 |
| 2011 | 42.39 | 5.72 | 76.16 | 10.24 | 134.52 |
| 2012 | 33.55 | 1.93 | 48.25 | 9.89 | 93.62 |
| 2013 | 33.45 | 2.85 | 38.43 | 8.86 | 83.59 |
| 2014 | 36.40 | 2.85 | 56.96 | 9.06 | 105.27 |
| 2015 | 43.25 | 2.93 | 58.09 | 5.00 | 109.27 |
| 2016 | 36.96 | 2.42 | 65.72 | 6.57 | 111.67 |
| 2017 | 42.04 | 1.65 | 49.36 | 11.15 | 104.19 |
| 2018 | 47.00 | 2.54 | 36.48 | 6.30 | 92.32 |

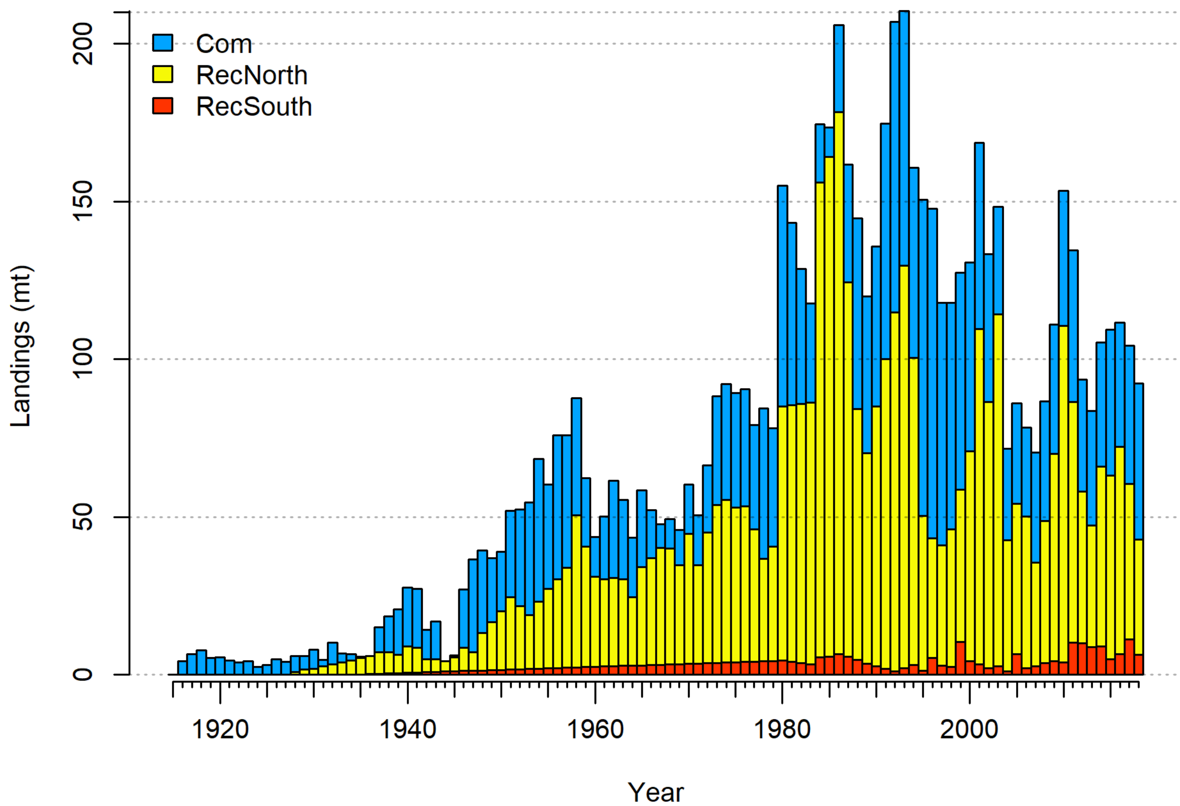


Figure c: Catch history of GBYR in the model. fig:r4ss_catches

# Data and Assessment

data-and-assessment

Gopher rockfish north of Point Conception (34°27′ N. latitude) was first assessed as a full stock assessment in 2005 (Key et al. 2005) using SS2 (version 1.19). The assessment was sensitive to the recreational party boat onboard observer index of relative abundance (referred to as Deb Wilson-Vandenberg's onboard observer index in this assessment). The final decision table was based around the emphasis given to this index of relative abundance. The stock was found to be at 97% depletion in 2005.

Gopher rockfish south of Point Conception was assessed as a data poor species in 2010 (Dick and MacCall 2010). A Depletion-Corrected Average Catch (DCAC) model was used due to time constraints. The mean yield from the DCAC distribution was 25.5 mt.

This is the first full assessment to include data for black-and-yellow rockfish. Black-and-yellow rockfish was assessed coastwide as a data poor species using Depletion-Based Stock Reduction Analysis (DB-SRA) (Dick and MacCall 2010). The DB-SRA model assigned a 40% probability that the then recent (2008-2009) catch exceeded the 2010 OFL.

This assessment of the GBYR complex covers the area from Cape Mendocino to the U.S./Mexico border (Figure d). The length composition data suggested that while the lengths of gopher and black-and-yellow rockfish were similar, fish encountered south of Point Conception were smaller. The similarity of the length distributions between species and among modes within a region were similar and justified one combined recreational fleet within each of the two regions (north and south of Point Conception).

This stock assessment retains a single fleet for the commercial fishery, including discards. Data on commercial discards were not available for and not included in the 2005 assessment. The decision to retain one commercial fleet was made by examining the length distributions across species, fishing gears, and space, i.e., north and south of Point Conception. There is very little difference between the length composition of gopher and black-and-yellow rockfish landed in the commercial fleet north and south of Point Conception.

A number of sources of uncertainty are addressed in this assessment. This assessment includes length data, estimated growth, an updated length-weight curve, an updated maturity curve, a number of new indices, and new conditional age-at-length data.

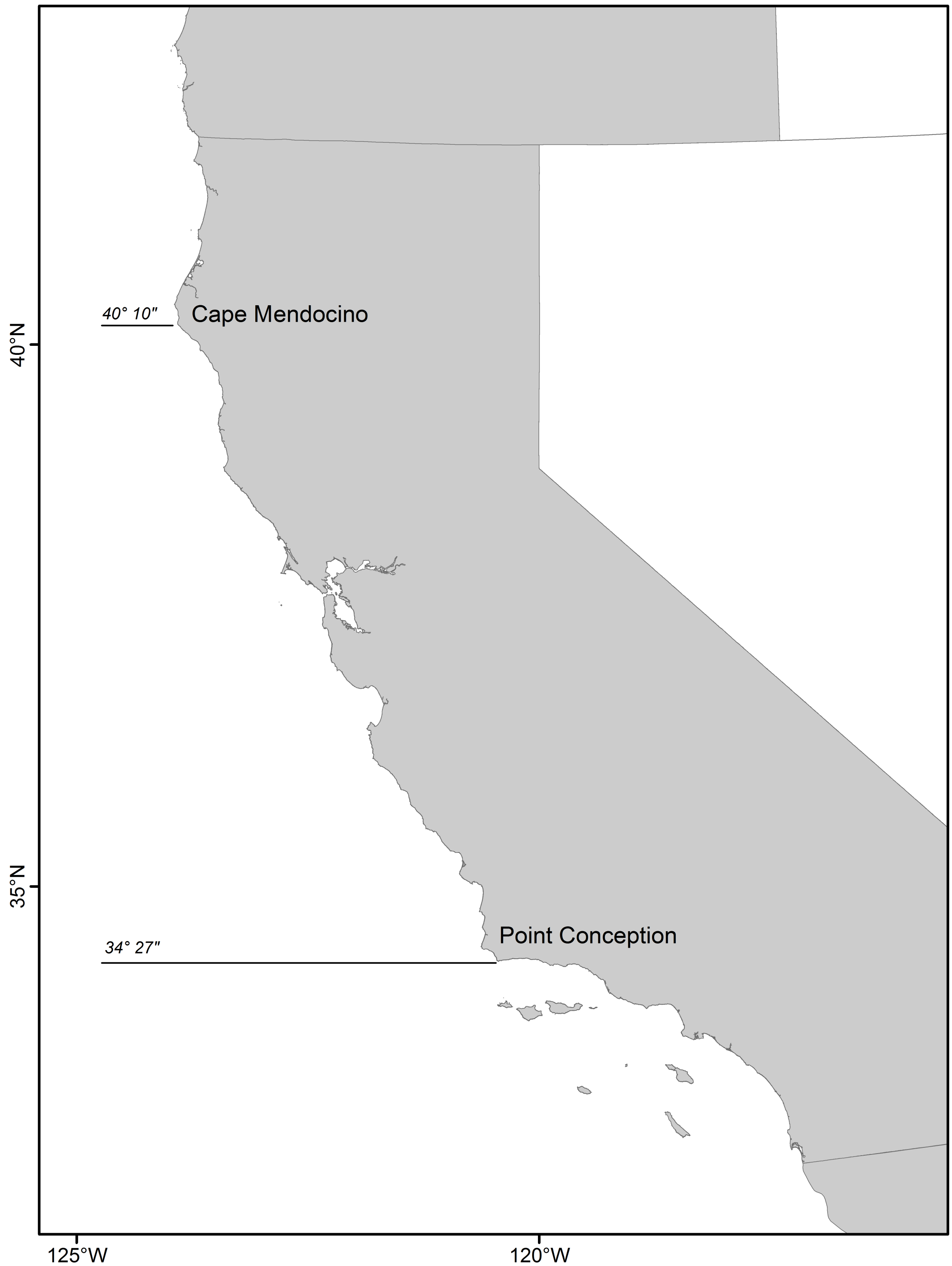


Figure d: Map depicting the core distribution of gopher and black-and-yellow rockfishes. The stock assessment is bounded at Cape Mendocino in the north to the U.S./Mexico border in the south. fig:assess_region_map

## Stock Biomass

stock-biomass

The predicted spawning output from the base model generally showed a slight decline prior to 1978, when the recruitment deviations were first estimated (Figure e and Table b). The stock declined from 1978 to 1994, followed by a period of increase from 1995 to 2003. From 2004-2018 the stock has been in decline, though increased in total biomass since 2016 and exhibits stable spawning output since from 2018 to 2019. The 2019 estimated spawning output relative to unfished equilibrium spawning output is above the target of 40% of unfished spawning output at 43.82 (95% asymptotic interval: 33.57-54.06) (Figure f). Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning output is high, (95% asymptotic interval: 337-767 million eggs).

Table b: Recent trend in beginning of the year spawning output and depletion for the model for GBYR.

tab:SpawningDeplete_mod1

| Year | Spawning Output (million eggs) | ~ 95% confidence interval | Estimated depletion | ~ 95% confidence interval |
|---|---|---|---|---|
| 2010 | 882 | 597 - 1168 | 69.99 | 58.05 - 81.92 |
| 2011 | 817 | 548 - 1086 | 64.77 | 53.48 - 76.06 |
| 2012 | 761 | 507 - 1014 | 60.33 | 49.63 - 71.03 |
| 2013 | 727 | 486 - 968 | 57.66 | 47.5 - 67.81 |
| 2014 | 697 | 466 - 928 | 55.31 | 45.56 - 65.05 |
| 2015 | 655 | 434 - 877 | 51.98 | 42.4 - 61.55 |
| 2016 | 614 | 399 - 828 | 48.69 | 39.16 - 58.22 |
| 2017 | 576 | 367 - 786 | 45.70 | 36.12 - 55.28 |
| 2018 | 553 | 344 - 762 | 43.85 | 34.08 - 53.63 |
| 2019 | 552 | 337 - 767 | 43.82 | 33.57 - 54.06 |

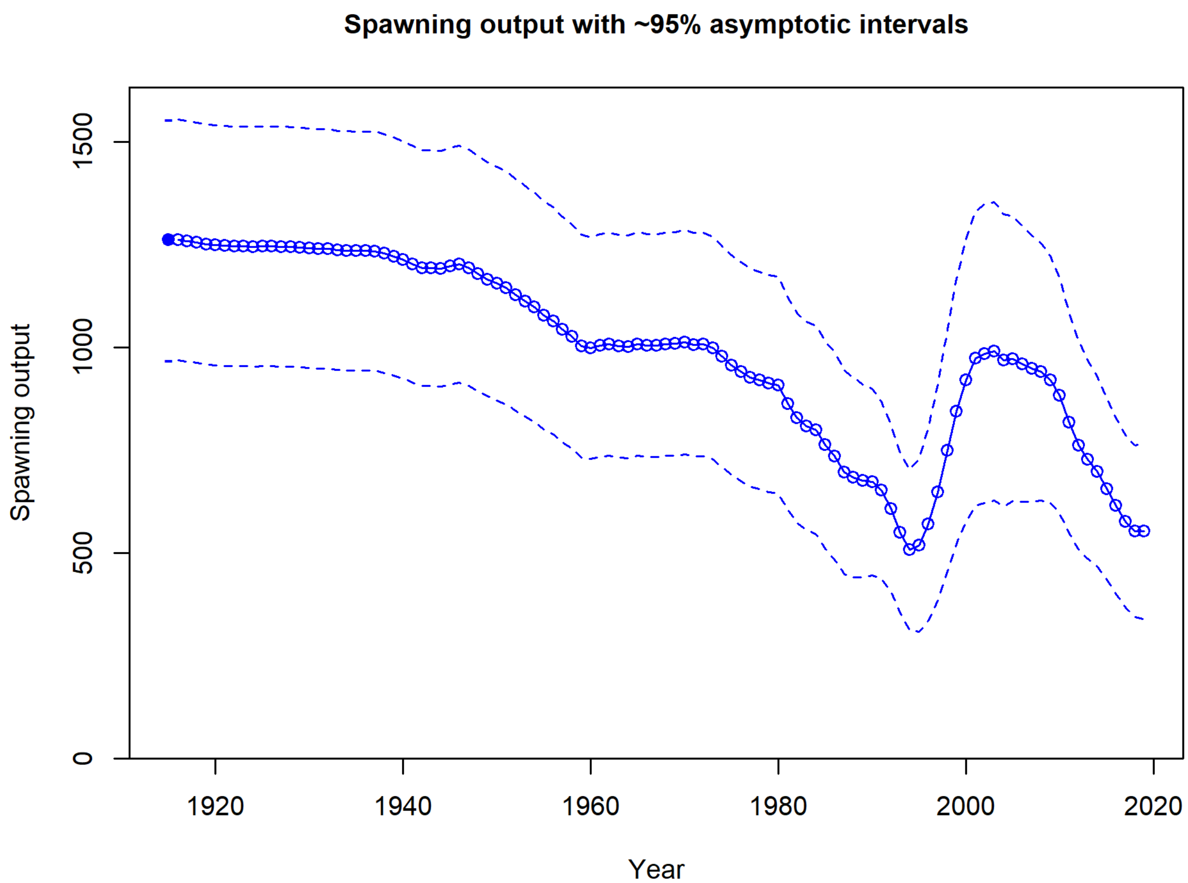


Figure e: Time series of spawning output trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. fig:Spawnbio_all

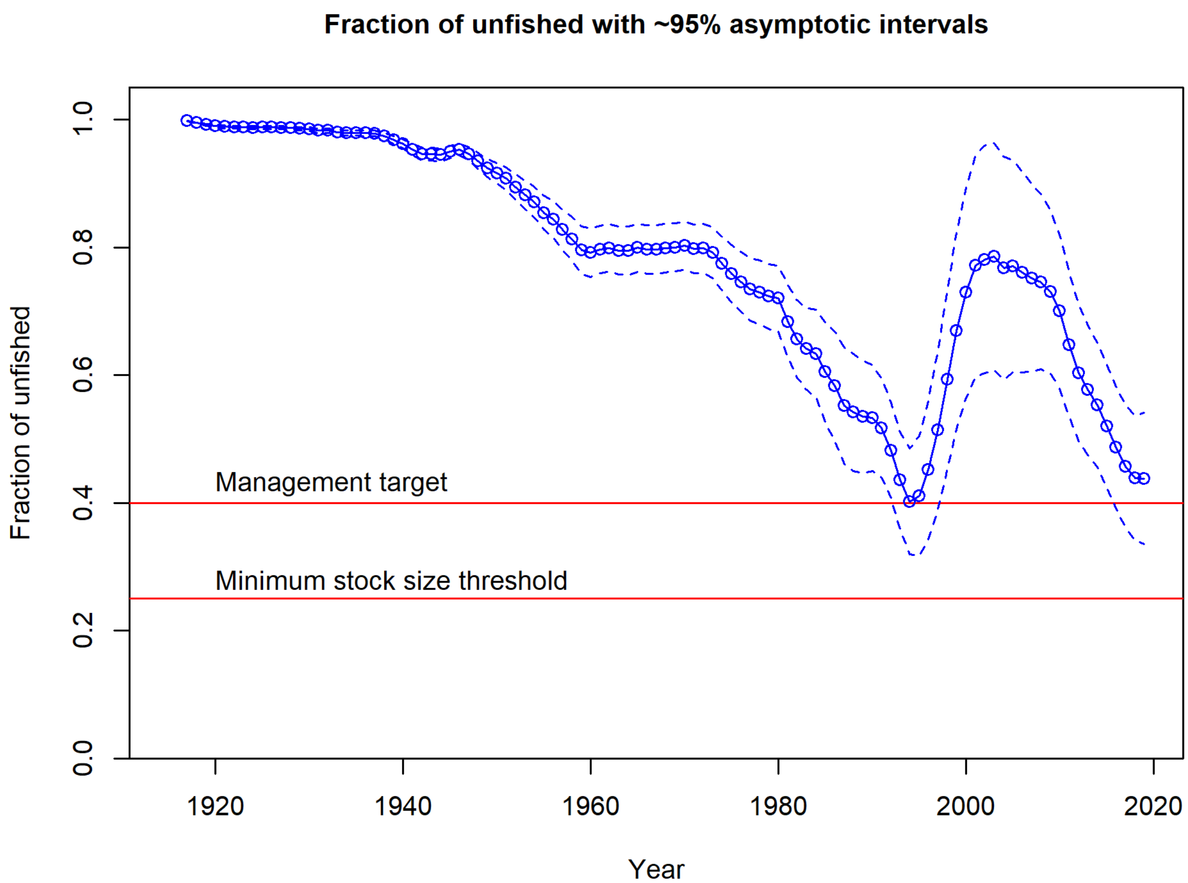


Figure f: Estimated fraction of unfished (percent depletion) with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. fig:RelDeplete_all

# Recruitment

recruitment

Recruitment deviations were estimated from 1979-2018 (Figure g and Table c). There are estimates of very strong recruitment in 1991, with high recruitment pulses for a number of other years including 1994-1995 and 2014-2015.

Table c: Recent recruitment for the GBYR assessment.

tab:Recruit_mod1

| Year | Estimated Recruitment (1,000s) | ~ 95% confidence interval |
|---|---|---|
| 2010 | 2451 | 1257 - 4779 |
| 2011 | 2014 | 983 - 4127 |
| 2012 | 1800 | 761 - 4258 |
| 2013 | 1589 | 676 - 3734 |
| 2014 | 4568 | 2519 - 8284 |
| 2015 | 5264 | 2985 - 9282 |
| 2016 | 2487 | 1274 - 4857 |
| 2017 | 3701 | 1976 - 6935 |
| 2018 | 1432 | 664 - 3089 |
| 2019 | 2778 | 1086 - 7111 |

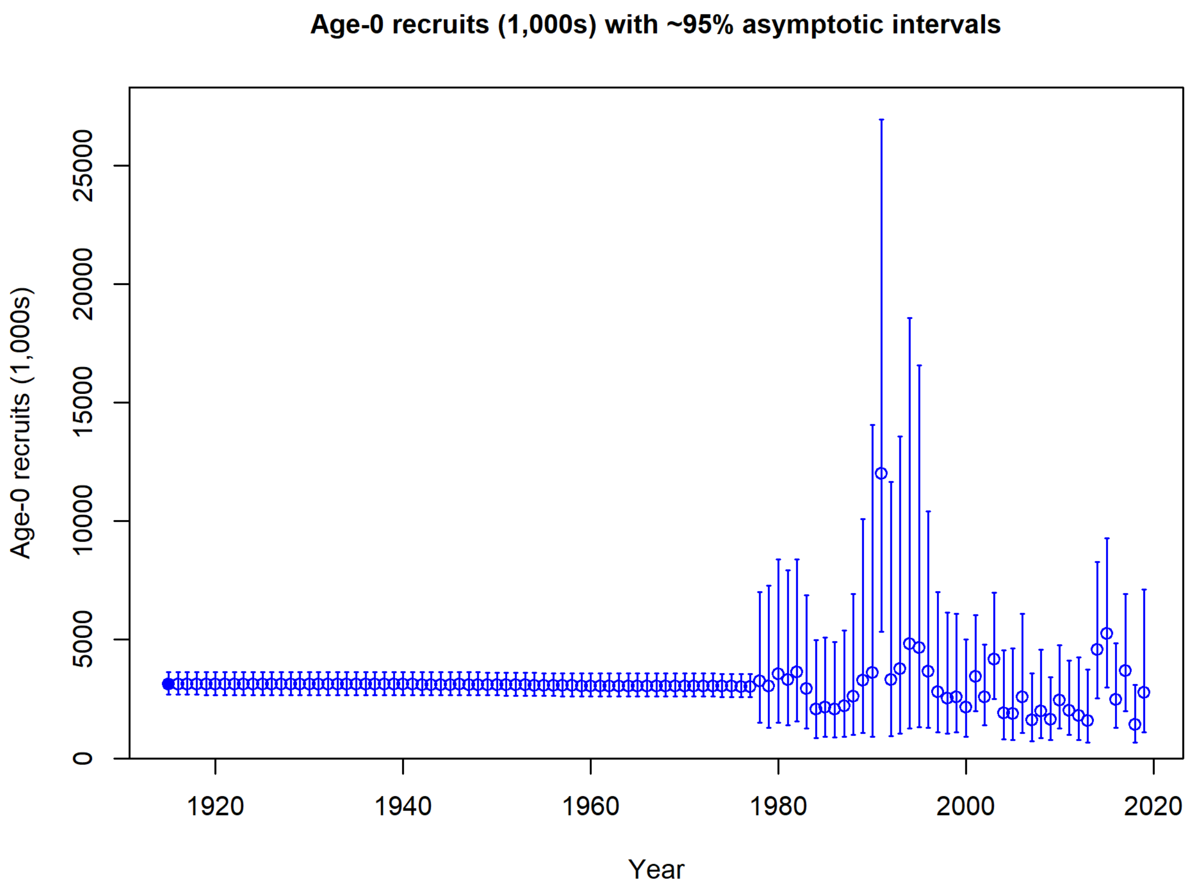


Figure g: Time series of estimated GBYR recruitments for the post-STAR base model with 95% confidence or credibility intervals. fig:Recruits_all

# Exploitation status

exploitation-status

Harvest rates estimated by the base model indicate catch levels have been below the limits that would be associated with the Spawning Potential Ratio (SPR) = 50% limit (corresponding to a relative fishing intensity of 100%) (Table d and Figure h). SPR is calculated as the lifetime spawning potential per recruit at a given fishing level relative to the lifetime spawning potential per recruit with no fishing. The relative inverse SPR over the last decade increased ranged from 0.64 to 0.77 from 2009-2015, and ranged from 0.80 to 0.82 from 2016-2018 (Table d).

Table d: Recent trend in spawning potential ratio (entered as $(1 - SPR)/(1 - SPR_{50\%})$) and exploitation for GBYR in the model.

tab:SPR_Exploit_mod1

| Year | Estimated (1-SPR)/(1-SPR50%) | ˜ 95% confidence interval | Exploitation rate | 95% confidence interval |
|---|---|---|---|---|
| 2009 | 0.64 | 0.5 - 0.78 | 0.07 | 0.05 - 0.09 |
| 2010 | 0.78 | 0.64 - 0.93 | 0.10 | 0.08 - 0.13 |
| 2011 | 0.77 | 0.62 - 0.92 | 0.10 | 0.07 - 0.12 |
| 2012 | 0.67 | 0.52 - 0.81 | 0.07 | 0.05 - 0.09 |
| 2013 | 0.64 | 0.49 - 0.78 | 0.07 | 0.05 - 0.09 |
| 2014 | 0.74 | 0.59 - 0.88 | 0.09 | 0.06 - 0.11 |
| 2015 | 0.77 | 0.62 - 0.92 | 0.10 | 0.07 - 0.12 |
| 2016 | 0.81 | 0.66 - 0.96 | 0.10 | 0.07 - 0.13 |
| 2017 | 0.82 | 0.66 - 0.98 | 0.09 | 0.06 - 0.11 |
| 2018 | 0.80 | 0.63 - 0.96 | 0.07 | 0.05 - 0.1 |

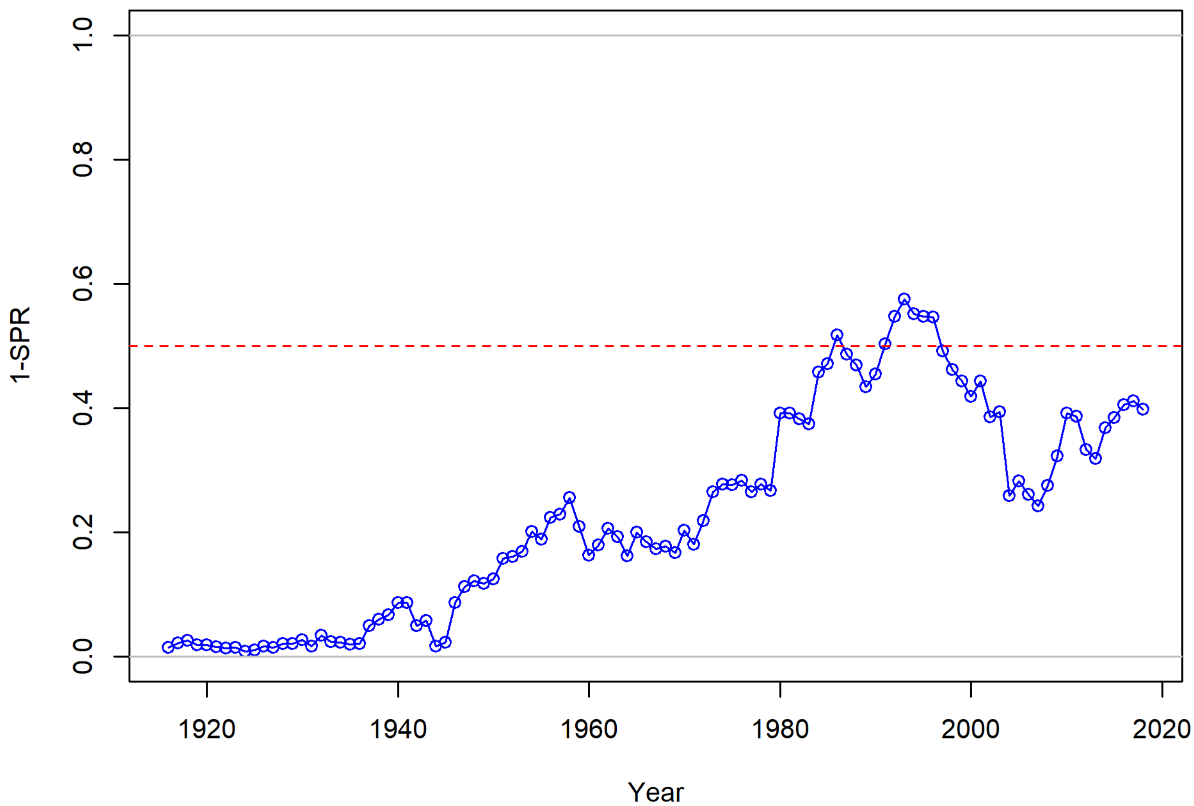


Figure h: Estimated inverse spawning potential ratio (SPR) for the post-STAR base model, plotted as one minus SPR so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$ harvest rate. The last year in the time series is 2018. fig:SPR_all

# Ecosystem Considerations

ecosystem-considerations

In this assessment, ecosystem considerations were not explicitly included in the analysis. This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere) that could contribute ecosystem-related quantitative information for the assessment.

# Reference Points

reference-points

This stock assessment estimates that GBYR in the model is above the biomass target ($SB_{40\%}$), and well above the minimum stock size threshold ($SB_{25\%}$). The estimated relative depletion level for the base model in 2018 is 0.439 (95% asymptotic interval: 0.341-0.536, corresponding to an unfished spawning of 552 million eggs (95% asymptotic interval: 337 - 767 million eggs) of spawning output in the base model (Table e). Unfished age 1+ biomass was estimated to be 2,042 mt in the base case model. The target spawning output ($SB_{40\%}$) is 504 million eggs, which corresponds with an equilibrium yield of 143 mt. Equilibrium yield at the proxy $F_{MSY}$ harvest rate corresponding to $SPR_{50\%}$ is 134 mt (Figure i).

Table e: Summary of reference points and management quantities for the base case model.

tab:Ref_pts_mod1

| Quantity | Estimate | Low 2.5% limit | High 2.5% limit |
|---|---|---|---|
| Unfished spawning output (million eggs) | 1,261 | 968 | 1,554 |
| Unfished age 1+ biomass (mt) | 2,042 | 1,637 | 2,448 |
| Unfished recruitment ($R_0$) | 3,125 | 2,643 | 3,606 |
| Spawning output (2018 million eggs) | 553 | 344 | 762 |
| Depletion (2018) | 0.439 | 0.341 | 0.536 |
| **Reference points based on $\mathbf{SB_{40\%}}$** | | | |
| Proxy spawning output ($B_{40\%}$) | 504 | 427 | 582 |
| SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$) | 0.458 | 0.458 | 0.458 |
| Exploitation rate resulting in $B_{40\%}$ | 0.126 | 0.109 | 0.144 |
| Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt) | 143 | 124 | 162 |
| ***Reference points based on SPR proxy for MSY*** | | | |
| Spawning output | 563 | 476 | 649 |
| $SPR_{proxy}$ | 0.5 | | |
| Exploitation rate corresponding to $SPR_{proxy}$ | 0.111 | 0.096 | 0.126 |
| Yield with $SPR_{proxy}$ at $SB_{SPR}$ (mt) | 134 | 116 | 152 |
| ***Reference points based on estimated MSY values*** | | | |
| Spawning output at $MSY$ ($SB_{MSY}$) | 281 | 235 | 328 |
| $SPR_{MSY}$ | 0.299 | 0.29 | 0.308 |
| Exploitation rate at $MSY$ | 0.209 | 0.174 | 0.244 |
| Dead Catch $MSY$ (mt) | 163 | 141 | 185 |
| Retained Catch $MSY$ (mt) | 163 | 141 | 185 |

# Management Performance

management-performance

Gopher and black-and-yellow rockfishes are managed as part of the minor nearshore complex in the Pacific Coast Groundfish Fishery Management Plan. The total mortality of the minor nearshore rockfish has been below the ACL in all years (2011-2016). Total mortality estimates from the NWFSC are not yet available for 2017-2018. GBYR total mortality was on average 20% of the total minor nearshore rockfish total mortality from 2011-2016. A summary of these values as well as other base case summary results can be found in Table f.

Table f: Recent trend in total mortality for gopher and black-and-yellow rockfishes (GBYR), combined, relative to the management guidelines for Nearshore Rockfish South of 40°10′ N. latitude. Total mortality estimates are based on annual reports from the NMFS NWFSC.

tab:mnmgt_perform

| | GBYR | Shallow Nearshore Rockfish South | Nearshore Rockfish South | |
|---|---|---|---|---|
| Year | Total mortality | Total mortality | ACL | OFL |
| **2011** | 122.87 | 436 | 1,001 | 1,156 |
| **2012** | 91.96 | 445 | 1,001 | 1,145 |
| **2013** | 104.53 | 495 | 990 | 1,164 |
| **2014** | 103.63 | 596 | 990 | 1,160 |
| **2015** | 107.95 | 676 | 1,114 | 1,313 |
| **2016** | 111.55 | 641 | 1,006 | 1,288 |
| **2017** | - | - | 1,163 | 1,329 |
| **2018** | - | - | 1,179 | 1,344 |

# Unresolved Problems and Major Uncertainties

unresolved-problems-and-major-uncertainties

The major source of uncertainty identified during the STAR panel are the structure of two species complex, the contribution of each of the two species to the complex, and differences in biological parameters between the species. There is currently no information for either species on regional differences in biological parameters and contributions to the complex.

# Decision Table

decision-table

The forecasts of stock abundance and yield were developed using the post-STAR base model, with the forecasted projections of the OFL presented in Table g. The total catches in 2019 and 2020 are set to the projected catch from the California Department of Fish and Wildlife (CDFW) of 114 mt.

Uncertainty in the forecasts is based upon the three states of nature agreed upon at the STAR panel and are based three states of nature of growth. The external estimate of growth was different than the internal Stock Synthesis estimate. Given that natural mortality is fixed in the post-STAR base model, and the growth parameter $k$ is negatively correlated with natural mortality, $k$ was chosen as the axis of uncertainty. The high state of nature fixes $k$ at the external estimate, and the low state of nature is the same distance in log space from the base as the high state of nature. The low state of nature fixed $k$ at 0.046 and the L1 and L1 parameters were estimated at 14.1 and 30.6, respectively. The high state of nature fixed all growth parameters, $k = 0.248$, L1 = 13.8, and L2 = 28.5 to the external estimate of growth (due to improbable estimates of L1 and L2 if only $k$ was fixed to the external estimate). The growth parameters in the base model were estimated as $k = 0.107$, L1 = 13.4, and L2 = 28.8.

The forecasted buffer ramp was calculated assuming a category 2 stock, with sigma = 1.0 and a $p^* = 0.45$. The buffer ranges from 0.874 in 2021 ramping to 0.803 in 2030. For reference, the model predicted sigma is 0.189 and the decision table-based sigma is 0.197. Current medium-term forecasts based on the alternative states of nature project that the stock will remain above the target threshold of 40% for all but two scenarios (Table h). The low state of nature with the high catches results in a stock at 26.4% of unfished in 2030 and the base state model with the high catches results in a stock at 33.2% of unfished in 2030. The base case model with the base catches results in an increasing stock over the period from 2021-2030. If the growth of GBYR is slower than the base model suggests, but the base case catches are removed, the stock will be at the target threshold in 2030.

Table g: Projected OFL, default harvest control rule catch (ABC = ACL) above 40% SSB, biomass, and depletion using the post-STAR base case model with 2019-2020 catches set equal to the projected catch (114 mt) rather than the ABC.

tab:OFL_projection

| Year | OFL (mt) | ABC Catch (mt) | Age 0+ Biomass (mt) | Spawning Output (million eggs) | Fraction unfished |
|---|---|---|---|---|---|
| 2019 | 154 | *114* | 1281 | 552.5 | 43.8 |
| 2020 | 154 | *114* | 1292 | 558.3 | 44.3 |
| 2021 | 136 | 119 | 1291 | 578.2 | 45.9 |
| 2022 | 137 | 119 | 1296 | 601.1 | 47.7 |
| 2023 | 143 | 122 | 1300 | 621.5 | 49.3 |
| 2024 | 150 | 127 | 1302 | 633.3 | 50.2 |
| 2025 | 155 | 130 | 1300 | 636.2 | 50.5 |
| 2026 | 158 | 131 | 1295 | 632.6 | 50.2 |
| 2027 | 158 | 130 | 1290 | 626.0 | 49.7 |
| 2028 | 156 | 128 | 1286 | 619.4 | 49.1 |
| 2029 | 155 | 125 | 1284 | 614.8 | 48.8 |
| 2030 | 153 | 123 | 1283 | 612.7 | 48.6 |

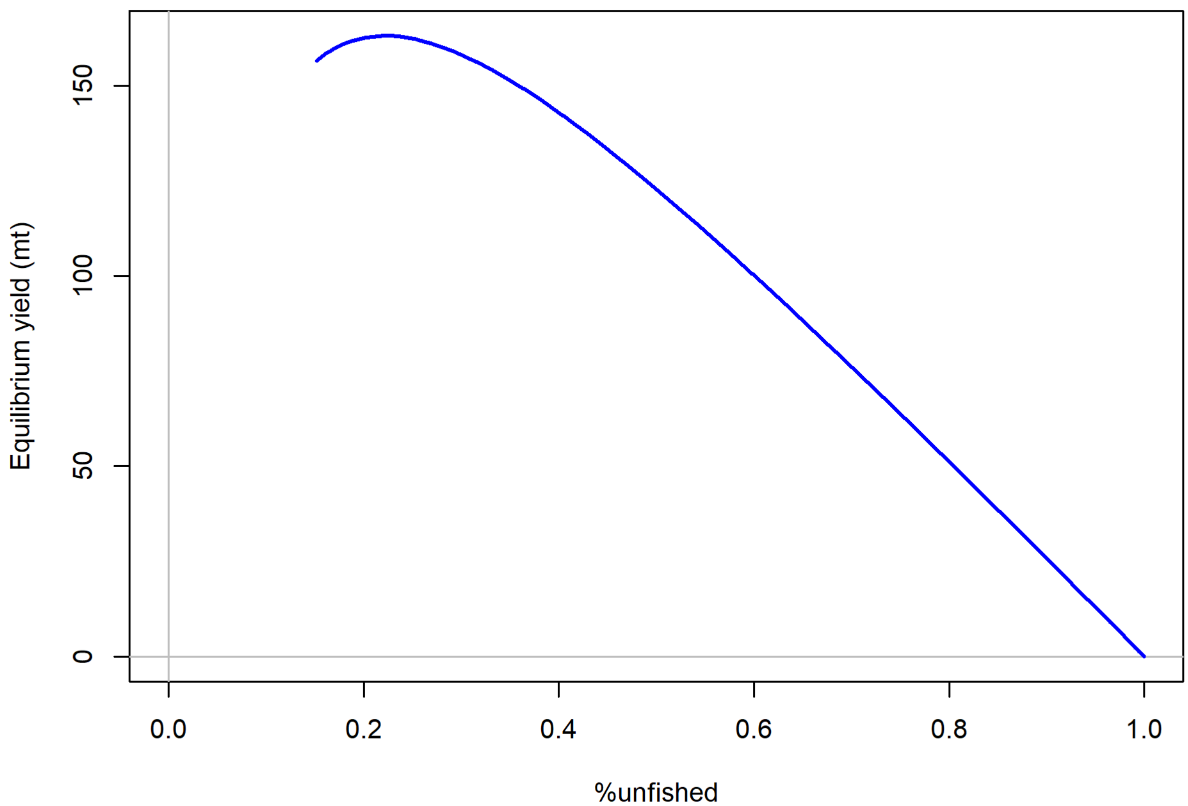


Figure i: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.72. fig:Yield_all

Table h: Summary of 10-year projections beginning in 2020 for alternate states of nature based on an axis of uncertainty for the model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. The low state of nature fixed the growth parameter $k$ at 0.046 and the high state fixes all growth parameters to the external estimate ($k$ = 0.248, L1 = 13.8, L2 = 28.5). For reference the base case estimated $k$ = 0.106, L1 = 13.4 and L2 = 28.9. The 2019 and 2020 catches were set to the projected catch of 114 mt, provided by CDFW.

tab:Decision_table_mod1

| | | | States of nature | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Low State | | Base State | | High State | |
| | Year | Catch | Spawning Output | Depletion | Spawning Output | Depletion | Spawning Output | Depletion |
| | 2019 | 114 | 444.4 | 37.3 | 552.5 | 43.8 | 1105.4 | 58.5 |
| | 2020 | 114 | 443.3 | 37.2 | 558.3 | 44.3 | 1168.8 | 61.9 |
| | 2021 | 75 | 449.6 | 37.7 | 578.2 | 45.9 | 1231.2 | 65.2 |
| | 2022 | 80 | 481.2 | 40.4 | 623.4 | 49.4 | 1296.5 | 68.6 |
| Default harvest for Low State | 2023 | 85 | 510.4 | 42.8 | 660.8 | 52.4 | 1322.9 | 70.0 |
| | 2024 | 91 | 534.5 | 44.9 | 687.1 | 54.5 | 1329.1 | 70.4 |
| | 2025 | 96 | 552.0 | 46.3 | 702.5 | 55.7 | 1328.9 | 70.4 |
| | 2026 | 101 | 562.5 | 47.2 | 709.3 | 56.3 | 1326.8 | 70.2 |
| | 2027 | 104 | 567.1 | 47.6 | 710.4 | 56.3 | 1324.2 | 70.1 |
| | 2028 | 105 | 567.5 | 47.6 | 708.5 | 56.2 | 1321.7 | 70.0 |
| | 2029 | 105 | 565.8 | 47.5 | 706.1 | 56.0 | 1320.3 | 69.9 |
| | 2030 | 104 | 563.8 | 47.3 | 704.8 | 55.9 | 1320.2 | 69.9 |
| | 2019 | 114 | 444.4 | 37.3 | 552.5 | 43.8 | 1105.4 | 58.5 |
| | 2020 | 114 | 443.3 | 37.2 | 558.3 | 44.3 | 1168.8 | 61.9 |
| | 2021 | 119 | 449.6 | 37.7 | 578.2 | 45.9 | 1231.2 | 65.2 |
| | 2022 | 119 | 460.9 | 38.7 | 601.1 | 47.7 | 1267.4 | 67.1 |
| Default harvest for Base State | 2023 | 122 | 475.0 | 39.9 | 621.5 | 49.3 | 1270.6 | 67.3 |
| | 2024 | 127 | 486.5 | 40.8 | 633.3 | 50.2 | 1257.1 | 66.6 |
| | 2025 | 130 | 492.9 | 41.4 | 636.2 | 50.5 | 1240.8 | 65.7 |
| | 2026 | 131 | 493.9 | 41.5 | 632.6 | 50.2 | 1226.6 | 64.9 |
| | 2027 | 130 | 490.8 | 41.2 | 626.0 | 49.7 | 1216.1 | 64.4 |
| | 2028 | 128 | 485.6 | 40.8 | 619.4 | 49.1 | 1209.7 | 64.0 |
| | 2029 | 125 | 480.5 | 40.3 | 614.8 | 48.8 | 1207.0 | 63.9 |
| | 2030 | 123 | 476.8 | 40.0 | 612.7 | 48.6 | 1207.2 | 63.9 |
| | 2019 | 114 | 444.4 | 37.3 | 552.5 | 43.8 | 1105.4 | 58.5 |
| | 202 | 114 | 443.3 | 37.2 | 558.3 | 44.3 | 1168.8 | 61.9 |
| | 2021 | 235 | 449.6 | 37.7 | 578.2 | 45.9 | 1231.2 | 65.2 |
| | 2022 | 225 | 410.9 | 34.5 | 544.4 | 43.2 | 1191.3 | 63.1 |
| Default harvest for High State | 2023 | 215 | 390.6 | 32.8 | 522.5 | 41.4 | 1132.0 | 59.9 |
| | 2024 | 204 | 377.9 | 31.7 | 503.3 | 39.9 | 1071.8 | 56.7 |
| | 2025 | 192 | 366.0 | 30.7 | 484.2 | 38.4 | 1025.9 | 54.3 |
| | 2026 | 183 | 353.2 | 29.7 | 466.5 | 37.0 | 996.7 | 52.8 |
| | 2027 | 177 | 340.4 | 28.6 | 451.7 | 35.8 | 980.5 | 51.9 |
| | 2028 | 173 | 328.9 | 27.6 | 440.7 | 34.9 | 972.2 | 51.5 |
| | 2029 | 170 | 320.2 | 26.9 | 433.5 | 34.4 | 968.2 | 51.3 |
| | 2030 | 168 | 314.3 | 26.4 | 429.2 | 34.0 | 966.0 | 51.1 |

Table i: Base case results summary.

tab:base_summary

| Quantity | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total mortality (mt) | 153 | 135 | 94 | 84 | 105 | 109 | 112 | 104 | 92 | |
| Complex OFL (mt) | | 1,156 | 1,145 | 1,164 | 1,160 | 1,313 | 1,288 | 1,329 | 1,344 | |
| Complex ACL (mt) | | 1,001 | 1,001 | 990 | 990 | 1,114 | 1,006 | 1,163 | 1,179 | |
| (1-$SPR$)(1-$SPR_{50\%}$) | 0.78 | 0.77 | 0.67 | 0.64 | 0.74 | 0.77 | 0.81 | 0.82 | 0.80 | |
| Exploitation rate | 0.10 | 0.10 | 0.07 | 0.07 | 0.09 | 0.10 | 0.10 | 0.09 | 0.07 | |
| Age 1+ biomass (mt) | 1550.00 | 1469.27 | 1364.64 | 1283.44 | 1238.94 | 1196.76 | 1148.01 | 1143.82 | 1190.26 | 1237.83 |
| Spawning Output | 882 | 817 | 761 | 727 | 697 | 655 | 614 | 576 | 553 | 552 |
| 95% CI | 597 - 1168 | 548 - 1086 | 507 - 1014 | 486 - 968 | 466 - 928 | 434 - 877 | 399 - 828 | 367 - 786 | 344 - 762 | 337 - 767 |
| Depletion | 70.0 | 64.8 | 60.3 | 57.7 | 55.3 | 52.0 | 48.7 | 45.7 | 43.9 | 43.8 |
| 95% CI | 58.05 - 81.92 | 53.48 - 76.06 | 49.63 - 71.03 | 47.5 - 67.81 | 45.56 - 65.05 | 42.4 - 61.55 | 39.16 - 58.22 | 36.12 - 55.28 | 34.08 - 53.63 | 33.57 - 54.06 |
| Recruits | 2451 | 2014 | 1800 | 1589 | 4568 | 5264 | 2487 | 3701 | 1432 | 2778 |
| 95% CI | 1257 - 4779 | 983 - 4127 | 761 - 4258 | 676 - 3734 | 2519 - 8284 | 2985 - 9282 | 1274 - 4857 | 1976 - 6935 | 664 - 3089 | 1086 - 7111 |

# Research and Data Needs

research-and-data-needs

We recommend the following research be conducted before the next assessment:

1. Investigate the structure of complex and contribution of each species to the GBYR complex. Investigate possible spatial differences in biological parameters within a single species and also between the two species. Little biological data for south of Point Conception or north of Point Arena were available for this assessment and is needed to better under biological parameters.
   (a) Conduct life history studies
   (b) conduct research to identify the proportion of each species in population and in catches
2. Take a closer look at the Ralston (Ralston et al. 2010) historical catch reconstruction for gopher and black-and-yellow rockfishes. The recreational catch reconstruction for gopher rockfish south of Point Conception was an order of magnitude higher than expected when extracted for this assessment.
3. Refine the PISCO survey data and analysis to better identify age-0 fish in each month of survey. Occasional sampling during all months of the year would better help identify the length distribution of fish classified as age-0. This is the only recruitment index available for gopher and black-and-yellow rockfish. If possible, age data should be collected from the PISCO survey to aid in determining the growth of young gopher and black-and-yellow rockfish, and larger black-and-yellow rockfish.
4. Refine CCFRP survey index to look at alternative possible model structures, including a hierarchical structure and random effects. Limited time did not allow for these explorations during this assessment cycle. It is also strongly recommended to continue the coastwide sampling of the CCFRP program that began in 2017, as well as the collection of biological samples for nearshore rockfish species. The CCFRP survey is the only fishery-independent survey available for nearshore rockfish sampling the nearshore rocky reef habitats. As of this assessment, only two years of coastwide data are available, and the index was limited to the site in central California that have been monitored since 2007.
5. Collection of length and age data are recommended for both the commercial and recreational fisheries. Very little age data are available from either fishery for gopher rockfish and none for black-and-yellow rockfish.
6. Data collection and coordination across Research Recommendations 1-5 is needed to improve the efficacy of data collection and ensure that samples are representative of the data sources and the fisheries. For example, the conditional age-at-length data in the dummy fleet represent a number of sampling techniques, areas sampled, and selectivities. Better coordination of research efforts will allow the age data to be better

utilized by the assessment. Sampling of the commercial and recreational fleets by area in proportion to the length distribution of fish observed will also allow the model to better fit selectivity patterns and avoid possible patterns in the length and age composition residuals.

7. Investigate possible environmental drivers/co-variates for biological parameters, particularly for recruitment.

8. Examine the CFRS angler interview data for the recreational private/rental mode to create a "trip" based identifier or catch and effort. This will enable the creation of an index of abundance for the private/rental mode as well as investigate if selectivity for this mode differs from the party/charter mode.

9. Resolve differences between CalCOM and PacFIN expanded length composition data sets.

# 1 Introduction

introduction

## 1.1 Basic Information and Life History

basic-information-and-life-history

*Population Structure and Complex Assessment Considerations*

There have been a number of analyses conducted on the genetic differentiation between gopher rockfish and black-and-yellow rockfish. The studies have yielded a range of results, but have generally concluded that there is unusually low genetic differentiation between the two species. The most frequently used measure of genetic analyses to evaluate evidence for population differentiation is the fixation index ($F_{ST}$), defined as the proportion of the total genetic variation in one sub-population (subscript S) relative to the total genetic variation (subscript T) (Hauser and Carvalho 2008, Waples et al. 2008). Values of $F_{ST}$ range from 0 to 1 where a zero value implies the populations are panmictic and a value closer to one implies the two populations are genetically independent. Values of $F_{ST}$ thought to be consistent with biologically meaningful genetic differentiation and demographic isolation between populations range from 0.01 to 0.05 (Waples and Gaggiotti 2006). It is also important to note that $F_{ST}$ values are dependent on the study's sample size and it may not necessarily be appropriate to compare them across studies.

Morphologically, gopher and black-and-yellow rockfishes are almost indistinct, except for their color variation (Hubbs and Schultz 1933). Early efforts to evaluate whether the two species were genetically distinct began with an allozyme analysis by Seeb et al. (1986), which did not detect genetic differentiation between gopher and black-and-yellow rockfish. However, as allozymes are proteins that are often conserved, this early work was not necessarily representative of genome-wide relationships between the two groups. In a subsequent study of restriction site polymorphisms, Hunter et al. (1994) found slight but significant differences between species based on restriction fragment length polymorphisms (RFLP's). Following that study, an analysis of the mitochondrial control region by Alesandrini and Bernardi (1999) did not detect differences between the two species, although mtDNA also has limitations regarding how results can be extrapolated across the nuclear genome. Analysis of seven microsatellite loci by Narum et al. (2004) found an $F_{ST}$ of 0.049 across the overlapping range of the two species, which provided some evidence of divergence, although such divergence is relatively low compared to other species within *Sebastes*. Those authors characterized their results as suggesting that the two are "reproductively isolated incipient species." Buonaccorsi et al. (2011) found an even lower $F_{ST}$ of 0.01 using 25 microsatellite loci, and concluded that gopher and black-and-yellow rockfish "have not completed the speciation process." All of these studies are indicative of low levels of genetic divergence and a high probability of ongoing gene flow between the two nominal species or incomplete lineage sorting.

Most recently, an analysis of rockfish species assignment using microhaplotypes by Baetscher (2019) observed mistaken genetic assignment of a small number of individuals between gopher and black-and-yellow rockfishes, while no other species among the 54 rockfishes analyzed resulted in mis-assignments. In addition, comparisons of $F_{ST}$ values within the study indicated that the level of genetic differentiation observed between gopher and black-and-yellow rockfishes is lower ($F_{ST} = 0.015$) than that observed among all other pairwise comparisons of the 54 species in the *Sebastes* genus that were included in their analysis. Baetscher (2019) characterized the results as suggestive of the two species representing "sister species with evidence of ongoing gene flow," noting that a more rigorous evaluation of the level of genetic distinction between these two species would benefit from whole-genome sequencing of representatives from each species group.

In addition to the differences in coloration, the depth distribution and range differ between the two species. The range of both species extends from Cape Blanco Oregon to Baja California. Both species are uncommon north of Fort Bragg, California and black-and-yellow rockfish is uncommon south of Point Conception, California. However, gopher rockfish can be found as far south as Punta San Roque on the Baja peninsula. Gopher rockfish are found in rocky reef habitat from the intertidal to depths of 264 ft (80 m) with a predominant depth distribution of 30 to 120 ft (9-37 m), while the black-and-yellow rockfish occupies depths from the intertidal to 120 ft (40 m) and is predominantly observed in depths shallower than 60 ft (18 m) (Eschmeyer et al. 1983, Love et al. 2002).

Both species are solitary, sedentary, and territorial with home ranges of 10-12 square meters (Love et al. 2002). A large percentage (67-71%) of black-and-yellow rockfish returned to the site of capture within two weeks after translocated within 50 m (Hallacher 1984). Lea et al. (1999) found that gopher rockfish exhibit minor patterns of movement (<12.8 km) with all fish being recaptured on the same reef system where they were tagged. Matthews (1985) found that 11.8% of tagged and recaptured gopher rockfish, and 25% of black-and-yellow rockfish, moved from four low-relief natural reefs to a new high-relief artificial reef in Monterey Bay. The maximum distance between the natural and artificial reefs traveled by gopher or black-and-yellow rockfish was 1.6 km. After only a year, the fish assemblage on the artificial reef closely resembled that of the nearby natural reefs. The paper did not address the spatial segregation of gopher and black-and-yellow rockfish on the new artificial reef.

Larson (1980) conducted a study on the territoriality and segregation between gopher and black-and-yellow rockfishes. When one species was removed, the other extended its depth range to areas where the other previously occupied, indicating inter-specific competition plays a role in controlling their depth distributions where both species are present. Of the two species, black-and-yellow rockfish are socially dominant and aggressive towards excluding gopher rockfish from shallower waters.

Both species feed at night, with similar diets composed primarily of crabs and shrimp, supplemented by fish and cephalopods (Larson 1972, 1985, Love et al. 2002). Loury et al. (2015) found no significant differences in the diet of gopher rockfish inside and outside the 35 year old Point Lobos Marine Protected Area (MPA). She did find the diet of gopher rockfish at Año Nuevo (shallower and north of Point Lobos) was dominated by crabs and dominated by brittle stars at southern, deeper study locations. Zuercher (2019) examined the diets of a suite of nearshore rockfish species including black-and-yellow and found that they relied on hard-bodied benthic invertebrates such as Brachyuran crabs, shrimps, other arthropods, and octopus. The diet of black-and-yellow rockfish remained the same across sampling years, but they occupied a lower trophic level during the upwelling season.

## 1.2 Early Life History

early-life-history

Gopher and black-and-yellow rockfish have similar juvenile development. Both rockfish species are viviparous and release one brood per season between January and July (Echeverria 1987). Larvae are approximately 4 mm in length at birth and have a 1-2 month pelagic stage before recruiting to the kelp forest canopy, i.e., surface fronds of *Macrosystis pyrifera* and *Cysteoseira osmundacea* at around 15-21 mm (Anderson 1983, Wilson et al. 2008). The larvae are transparent until they reach juvenile stage at 22-23 mm. Differences in coloration between the two species begin to occur at 25-30 mm and can be used to identify one species from the other. Gopher rockfish become more orange and brown, while black-and-yellow rockfish become more black and yellow.

The juveniles undergo ontogenetic migration down the stalks to deeper depths, finally settling on rocky reef habitat in their respective adult depth distribution. Benthic juveniles associate with *Macrosystis* holdfasts and sporophylls (Anderson 1983). Juvenile bocaccio and other fish predate on young of year and other reef dwelling species; individuals avoid rough surge conditions and predators by hiding in the rocky bottom during the daylight hours, then returning to more open water at dusk (Love et al. 2002).

## 1.3 Map

map

A map showing the scope of the assessment and depicting boundaries at Cape Mendocino to the north and the U.S./ Mexico border at the south (Figure 1). The recreational fishing fleet was split into two fleets at Point Conception.

## 1.4 Ecosystem Considerations

ecosystem-considerations-1

In this assessment, ecosystem considerations were not explicitly included in the analysis. This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere) that could contribute ecosystem-related quantitative information for the assessment.

## 1.5 Fishery Information

fishery-information

The hook-and-line fishery off California developed in the late 19th century (Love et al. 2002). The rockfish trawl fishery was established in the early 1940s, when the United States became involved in World War II and wartime shortage of red meat created an increased demand for other sources of protein (Harry and Morgan 1961, Alverson et al. 1964).

Gopher and black-and-yellow (referred to from hereon as GBYR when discussing the complex) rockfish have been a minor component of the commercial and recreational rockfish fishery since at least the late 1960s (CFIS and RecFIN). The commercial catch histories of the two species cannot easily be separated (Figure 2); from 1916-1936 only black-and-yellow rockfish were reported in the landings, and an average of 0.04 mt of black-and-yellow rockfish are reported from 1937-1983. Black-and-yellow rockfish reappear in the landings in 1984 with 7.2 mt landed commercially. From 1985-1988 the trend switches and only black-and-yellow rockfish appear in the commercial landings, with gopher rockfish averaging 0.1 mt landed, and 0 mt reported in 1987. From 1988 and on, the landings are dominated by gopher rockfish, and both species are represented in the commercial landings.

The landings from south of Point Conception are minor throughout the time period, with peaks in the 1950s and 1960s for gopher rockfish. Black-and-yellow rockfish are rare south of Point Conception and it is therfore expected that these catches are minimal.

The live fish fishery began in the early 1990s, with the first reported commercial landings of live gopher rockfish in 1993, and black-and-yellow rockfish a year later. By 1995 over half (57%; 39 mt) of the commercial landings were from the live fish fishery. This increased quickly over the next few years and has been on average 84% of the landed gopher and black-and-yellow rockfish since 2000. The majority of the landings are from gopher rockfish north of Point Conception. Landings of live GBYR south of Point Conception were higher in the late 1990s, (max. 3.2 mt in 1999), and have been averaging 0.4 mt since 2003.

The ex-vessel value of GBYR increased from less than $40,000 in 1984 and peaked at $680,452 in 1996 (source: PacFIN, Figure 3). The ex-vessel revenue has been fairly stable at around $500,000 a year since 2007. Prior to the live fish fishery in 1994, the average price per pound for either species was around $2 a pound. The live fish fishery increased the value of both species to an average of $6-$8 a pound, with maximum reported value of either a gopher or black-and-yellow rockfish was $20 a pound in 2003.

The recreational GBYR fishery for California is most prominent north of Point Conception throughout the entire catch history from 1928 to 1980 (Figure a).
The sharp increase in the 1980s could be an artifact of the MRFSS sampling program that began in 1980; however, the more recent recreational landings also exhibit a cyclical trend of years with high catches followed by period of decreased recreational landings. The California Recreational Fisheries Survey (CRFS) era recreational total mortality represents the most accurate description of the recreational fleet's catches in terms of area, mode and species (Figure 4).

Recreational GBYR catches are dominated by gopher rockfish north of Point Conception in the private/rental (PR) and party/charter (PC or CPFV) modes. South of Point Conception gopher rockfish are predominately caught by the CPFV fleet, with all other modes being insignificant. The total recreational mortality of black-and-yellow rockfish south of Point Conception since 2005 is 3 mt, compared to 106 mt north of Point Conception. The total mortality since 2005 for gopher rockfish is 86 mt south of Point Conception and 669 mt north of Point Conception.

## 1.6 Summary of Management History

summary-of-management-history

Prior to the adoption of the Pacific Coast Groundfish Fishery Management Plan (FMP) in 1982, GBYR were managed through a regulatory process that included the California Department of Fish and Wildlife (CDFW) along with either the California State Legislature or the Fish and Game Commission (FGC) depending on the sector (recreation or commercial) and fishery. With implementation of the Pacific Coast Groundfish FMP, GBYR came under the management authority of the Pacific Fishery Management Council (PFMC), and were managed as part of the *Sebastes* complex. Because neither species had undergone rigorous stock assessment and did not compose a large fraction of the landings they were classified and managed as part of "Remaining Rockfish" under the larger heading of "Other Rockfish" (PFMC (2002, 2004)).

Since the early 1980s a number of federal regulatory measures have been used to manage the commercial rockfish fishery including cumulative trip limits (generally for two- month periods) and seasons. Starting in 1994 the commercial groundfish fishery sector was divided into two components: limited entry and open access with specific regulations designed for each component. Other regulatory actions for the general rockfish categories have included area closures, gear restrictions, and cumulative bimonthly trip limits set for the four different commercial sectors - limited entry fixed gear, limited entry trawl, open access trawl, and open access non-trawl. Harvest guidelines are also used to regulate the annual harvest for both the recreational and commercial sectors.

In 2000, changes in the PFMC's rockfish management structure resulted in the discontinued use of the *Sebastes* complex, and was replaced with three species groups: nearshore, shelf, and slope rockfishes (January 4, 2000; 65 FR 221), of which GBYR are included in the nearshore group. Within the nearshore group, they are included in the "shallow nearshore rockfish" component.

During the late 1990s and early 2000s, major changes also occurred in the way that California managed its nearshore fishery. The Marine Life Management Act (MLMA), which was passed in 1998 by the California Legislature and enacted in 1999, required that the FGC adopt an FMP for nearshore finfish (Wilson-Vandenberg et al. 2014). It also gave authority to the FGC to regulate commercial and recreational nearshore fisheries through FMPs and provided broad authority to adopt regulations for the nearshore fishery during the time prior to adoption of the nearshore finfish FMP. Within this legislation, the Legislature also included commercial size limits for ten nearshore species including GBYR (10-inch minimum size) and a requirement that commercial fishermen landing these ten nearshore species possess a nearshore permit.

Following adoption of the Nearshore FMP and accompanying regulations by the FGC in fall of 2002, the FGC adopted regulations in November 2002 which established a set of marine reserves around the Channel Islands in southern California (which became effective April 2003). The FGC also adopted a nearshore restricted access program in December 2002 (which included the establishment of a Deeper Nearshore Permit) to be effective starting in the 2003 fishing year.

Also, since the enactment of the MLMA, the Council and State in a coordinated effort developed and adopted various management specifications to keep harvest within the harvest targets, including seasonal and area closures (e.g. the CCAs; a closure of Cordell Banks to specific fishing), depth restrictions, minimum size limits, and bag limits to regulate the recreational fishery and license and permit regulations, finfish trap permits, gear restrictions, seasonal and area closures (e.g. the RCAs and CCAs; a closure of Cordell Banks to specific fishing), depth restrictions, trip limits, and minimum size limits to regulate the commercial fishery.

The state of California has adopted regulatory measures to manage the fishery based on the harvest guidelines set forth by the PFMC. The commercial open access and limited entry fixed gear sectors have undergone three different spatial management changes since 2000. Since 2005, both have managed the area south of $40^{\circ}10'$ N. latitude as one area. The open access commercial fishery is managed based on bimonthly allowable catches, that have ranged from 200 pounds to 1800 pounds per two months since 2000. From 2005 to 2018, the catch limits have doubled and are now set at 1200 pounds per two months (for all months) with March and April remaining closed. The limited entry fixed gear sector has followed the same pattern as the open access sector with bi-monthly limits and a doubling of the catch since 2005. The limited entry trawl fleet is managed on monthly limits on an annual basis. Since 2011, the limit has been 300 pounds per month for non-IFQ species. A history of California's commercial regulations from 2000-2018 can be found in Appendix A. A 10-inch total length minimum size limit was implemented in 1999 for both species in the commercial fleet.

Significant regulatory changes in California's recreational sector began with a change from unlimited number of hooks and lines allowed prior to 2000 to no more than three hooks and one line per angler in 2000. Since 2001, the limit has been no more than two hooks and one line per angler. There is no size limit in the recreational fishery for gopher or black-and-yellow rockfish. A nearshore complex sub-bag limit that included GBYR was in place from 1999 to 2005, but was eliminated thereafter.

California also began spatial management, including area closures, and depth restrictions for the recreational fleet in 2000. In general, the recreational season north of Point Conception extends from April to December, and south of Point Conception from March to December.

In the area that GBYR are most commonly landed, from Monterey to Morro Bay, the depth restrictions have been between 30 and 40 fathoms until 2017. In 2017 the depth restrictions were eased by 10 fathoms, opening up fishing depths along the central California coast that had not been open consistently since 2002. In both 2017 and 2018, the deepest 10 fathoms was closed prior to the prescribed season in December due to high by-catch rates of yelloweye rockfish, one of two rockfish species that are still overfished. A full history of the recreational regulations relating to the spatial management of the fleet can be found in Appendix B.

## 1.7 Management Performance

`management-performance-1`

The contribution of GBYR to the nearshore rockfish OFLs is currently derived from two sources: 1) forecasts from Key et al. (2005), from Cape Mendocino to Point Conception, and 2) a Depletion Corrected Average Catch (DCAC (MacCall 2009)) for the area south of Point Conception. The total mortality of the nearshore rockfish south complex has been below the ACL in all years (2011-2016). Total mortality estimates from the NMFS NWFSC are not yet available for 2017-2018. GBYR total mortality was on average 20% of the total nearshore rockfish south total mortality from 2011-2016. The recent GBYR total mortality contributed approximately 9% to the nearshore rockfish south OFL, and GBYR catches have not exceded the GBYR OFLs in recent years. GBYR is a small component of the nearshore rockfish south complex that includes twelve other species. A summary of these values as well as other post-STAR base model summary results can be found in Table f.

## 1.8 Fisheries Off Mexico or Canada

`fisheries-off-mexico-or-canada`

The range of GBYR does not extend north to the Canadian border, and they are rarely encountered in Oregon and Washington. The southern end of the gopher rockfish's range extends to Punta San Roque (southern Baja California) while the southern end of the black-and-yellow rockfish's range extends to Isla Natividad (central Baja California) (Love et al. 2002). However, black-and-yellow rockfish are rare south of Point Conception, California. This was no available information on the fishery for GBYR at the time of this assessment, nor additional details on the abundance or distribution patterns in Mexican waters.

# 2 Assessment

`assessment`

## 2.1 Data

`data`

Data used in the GBYR assessment are summarized in Figure 5. Descriptions of the data sources are in the following sections.

### 2.1.1 Commercial Fishery Landings

`commercial-fishery-landings`

*Overview of gopher and black-and-yellow catch histories*

Commercial fishery landings for gopher and black-and-yellow rockfishes have not been reported consistently by species throughout the available catch history (Figure 2). The period from 1916-1935 suggests that only black-and-yellow rockfish were landed in the commercial fishery, which then switched to predominately gopher rockfish from 1937-1984. From 1985-1988 the landings data suggest that only black-and-yellow rockfish were landed and not until 1995 are both species well-represented in the catches. Pearson et al. (2008) noted:

> The fact that the majority of estimated landings are not based on actual sampling, combined with the likelihood for misidentification [between gopher and black-and-yellow rockfishes], suggests that our landing estimates are generally unreliable [see Figure 37 in Pearson et al. (2008)]. This is particularly true for the time interval between 1983 and 1988. Between 1983 and 1988, market category 962 (group gopher) landings increased sharply while market category 263 (gopher rockfish) landings declined (not visible in Figure 37 since the stratum was unsampled and the landings were converted to unspecified rockfish). Port samples indicated a shift from gopher rockfish to black-and-yellow rockfish during the same time interval, suggesting problems with identification. We suggest that if black-and-yellow landings are combined with gopher landings, the estimates would be generally reliable for the group.

There is no way to tease apart the historical catches by species and even across north and south of Point Conception prior to about 1995. This precludes the ability to model the catch histories for either species accurately. Given these constraints, all commercial data were combined to represent one commercial fleet in the assessment. Additional details regarding this decision are described below.

The stock assessment of gopher rockfish in 2005 did not excplicitly include black-and-yellow rockfish landings. A comparison of the recreational and commercial landings from the 2005 assessment to those used in this assessment suggest the 2005 assessment may have included some black-and-yellow rockfish landings (Figure 6). The 2005 assessment estimated recreational landings from 1969-1980 based on a ratio of commercial to recreational landings, where as this assessment makes use of the California Catch Reconstruction landings estimates (Ralston et al. 2010).

*Commercial Landings Data Sources*

The California Catch Reconstruction (Ralston et al. 2010) contains landings estimates of commercial landings from 1916-1968 and was queried on 4 April 2019 for GBYR. There were no estimated gopher rockfish landings prior to 1937. Landings in this database are divided into trawl and 'non-trawl.' Since the majority of GBYR are caught in the commercial fixed gear fisheries, only estimated catch in the 'non-trawl' was used. A total of 0.154 mt (3.18%) were removed from Eureka commercial landings (based on current proportions of commercial catch from north of Cape Mendocino in Eureka) since the assessment represents the GBYR stock south of Cape Mendocino. The majority of GBYR commercial landings (avg. 83%) are landed in the Monterey and Morro Bay port complexes.

Contemporary landings were extracted from two data sources, the California Cooperative Groundfish Survey, CALCOM) and the Pacific Fisheries Information Network (PacFIN) landings databases. Both databases are based on the same data sources (CALCOM landing receipts), but apply a catch expansion based on different algorithms. CALCOM collects information including species composition data (i.e. the proportion of species landed in a sampling stratum), and landing receipts (sometimes called "fish tickets") that are a record of pounds landed in a given stratum. 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 a given market category can consist of several species. These data form the basis for the "expanded" landings, i.e., species composition data collected by port samplers were used to allocate pounds recorded on landing receipts to species starting in 1978. Use of the "Gopher Rockfish" or the "Black-and-Yellow Rockfish" categories alone to represent actual landings of GBY would not be accurate.

See Pearson et al. Appendix C (2008) for a simple example of the expansion calculations for the CALCOM database and a description of the landings in PacFIN can be found in Sampson and Crone (1997). Both databases, including species compositions, and expanded landings estimates are stored at the Pacific States Marine Fisheries Commission, a central repository of commercial landings data for the U.S. West Coast. As a note, CALCOM is the only source for landings from 1969-1980.

Commercial landings from 1981-2018 were queried for a final time from the CALCOM database on 4 April 2019 and from PacFIN on 3 June 2019. There are very small differences in commercial landings between CALCOM and PacFIN from 1981-2018 (Figure 7). Landings estimates from PacFIN were used in the assessment (Table 1). Landings were stratified by year, quarter, live/dead, market category, gear group, port complex, and source of species composition data (actual port samples, borrowed samples, or assumed nominal market category). Data from individual quarters were aggregated at the year level. Fish landed live or dead were combined, due to changes over time in the reliability of condition information (Don Pearson, retired NMFS SWFSC, personal communication). From 1916-1968, on average, 74% of GBYR were landed north of Point Conception, which rose to 97% from 1978-2018. Given the smaller landings south of Point Conception and the similar length composition of GBYR north and south of Point Conception, no spatial separation was considered for the commercial fleet.

### 2.1.2 Commercial Discards

commercial-discards

The West Coast Groundfish Observer Program (WCGOP) provides observer data on discarding across fishery sectors back to 2003. Gopher and black-and-yellow rockfishes have species-specific depth-stratified commercial fishery discard mortality rates (Pacific Fishery Managment Council 2018). In consultation with WCGOP staff, the STAT used estimates of total discard mortality from WCGOP's Groundfish Expanded Mortality Multiyear (GEMM) report as the best available estimate of discards for GBYR. WCGOP observes between 1-5% of nearshore fixed gear landings annually south of 40°10′ N. latitude (coverage rates available here). The expanded estimates of total discard weight by species is calculated as the ratio of the observed discard weight of the individual species divided by the observed landed weight from PacFIN landing receipts. WCGOP discard estimates for the nearshore fixed gear fishery take into account the depth distribution of landings in order to appropriately apply the depth-stratified discard mortality rates by species (Somers et al. 2018). The discard mortality for 2018 was estimated as an average of the discard mortality from 2013-2017. Discard mortality was estimated from the period prior to WCGOP discard estimates (1916-2002) based on the average discard mortality rate from 2004-2017 (2003 was excluded because 2003 discard mortality was disproportionately higher than all other years) (Table 1).

### 2.1.3 Commercial Fishery Length and Age Data

commercial-fishery-length-and-age-data

Biological data from the commercial fisheries that caught GBYR were extracted from CALCOM on 9 May 2019. The CALCOM length composition data were catch-weighted to "expanded" length the raw length composition data (Table 2). The 2005 assessment used commercial length composition information from CALCOM, but did not include black-and-yellow rockfish and is not directly comparable. The 2005 assessment used 2 cm length bins from 16-40 cm, where this assessment uses 1 cm length bins from 4-40 cm. Sex was not available for the majority (99.5%) of the commercial length, and the assessment did not find sexual dimorphism in growth for either species. We aggregated the commercial length composition among all gears and regions south of Cape Mendocino.

Discard length compositions from WCGOP (2003-2017) were expanded based on the discard estimates and were aggregated for all regions south of Cape Mendocino and across all fixed gear fisheries.

A total of 46 ages were available for gopher rockfish from the commercial fisheries 2009-2011, 2016, and 2018. Though sparse, the data were considerd as conditional age-at-length for the commercial fleet, but not used in the final post-STAR base model.

The input sample sizes for commercial length composition data were calculated via the Stewart Method for fisheries (Ian Stewart, personal communication, IPHC, and develped at NWFSC):

$$\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} < 44$$

$$\text{Input effN} = 7.06 * N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} \geq 44$$

The PacFIN commercial length composition and the expanded catch-weight length compositions were provided by Andi Stephens (NWFSC) processed through the PacFIN Utilities package. We compared differences between the catch-weighted length composition expansions from CALCOM and PacFIN. We were unable to reconcile the difference between the two data sets. Sample sizes became more similar if the PacFIN data were restricted to the same market categories used by CALCOM in the expansion. However, both data sets apply other filters that we did not have time to explore. For instance, in the year 2000, 290 more fish were used in the CALCOM expansion than in PacFIN, but in 2002, 150 more fish were used in the PacFIN expansions that were not used in CALCOM. Given these caveats, Figure 8 shows the percent difference in the expanded length comps within a year. The biggest difference is in length bin 32 in 2006. However, the same number of fish and samples were used to expand the 2006 lengths in both databases, indicating there are also fundamental differences in how the data are treated. Full documentation is not available for the PacFIN length composition expansion program. Consequently the STAT chose to use a query that they could completely understand and selectively develop from the CALCOM database for the base model, although a sensitivity was conducted using the PacFIN-derived length composition data.

### 2.1.4 Recreational Fishery Landings and Discards

recreational-fishery-landings-and-discards

*Historical recreational landings and discards, 1928-1980*

Ralston et al. (2010) reconstructed estimates of recreational rockfish landings and discards in California, 1928-1980. Reported landings of total rockfish were allocated to species based on several sources of species composition data. Estimates of GBYR landings and discards (combined) from 1928-1979 are available from the SWFSC. For this assessment, historical recreational catch was stratified by year and area (north and south of Point Conception). The catches of GBYR reported in Ralston et al. (2010) are higher by an order of magnitude than expected given the more recent catches of GBYR in the MRFSS and CRFS eras south of Point Conception (Figure 9). The recreational catches estimated by Ralston et al. (2010) were discussed with the paper's co-authors and also Commercial Passenger Fishing Vessel (CPFV), i.e., party/charter mode, captains in California. A consensus was reached that the estimated landings did not accurately represent the historical GBYR landings and an alternative catch stream should be developed. One possibility for the inflated catches of GBYR in southern California is that all nearshore shallow species were combined and a constant relative fraction between the two was used to assign catches to each combination of CDFW fishing block and year. The fraction of GBYR within the nearshore shallow species group was likely overestimated.

The California Catch Reconstruction applied a linear ramp from 1928-1936 that was not altered in this assessment. From 1937-1979 a linear ramp was developed from the 1936 estimate to the average recreational landing from 1980 and 1983 (1981-1982 catches interpolated as described in the next section) of 4.3 mt. The recreational catches north of Point Conception were not altered from the original catch reconstruction. The resulting alternate recreational catch streams are in Table 3 and Figure 10.

The total difference in the catch streams from Figure 9 and Figure 10 is plotted in Figure 11. The differences in the catches are due to the addition of commercial discards prior to 2004 and the reduction of the recreational catches south of Point Conception.

*Marine Recreational Fisheries Statistics Survey (MRFSS), 1980-2003*

From 1980-2003, the Marine Recreational Fisheries Statistics Survey (MRFSS) executed a dockside (angler intercept) sampling program in Washington, Oregon, and California (see Holliday et al. (1984) for a description of methods). 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. Catch estimates for years 1980-2003 were downloaded on 23 March 2019, and are consistent from 1992-2004 with the previous assessment (Key et al. 2005) (Figure 6).

MRFSS-era recreational removals for California were estimated for two regions: north and south of Point Conception. No finer-scale estimates of landings are available for this period. Catches were downloaded in numbers and weight. Catch in weight is sometimes missing from the database due to missing average weight estimates. We estimated average weights based on adjacent strata as needed, although the effect was relatively minor (7.4 mt over all years for gopher rockfish and 0.6 mt for black-and-yellow rockfish). Data were not available for the CPFVs in Northern California from 1980-1982, and we used the average value from this mode and region from 1983-1987 for these three years. MRFSS sampling was temporarily suspended from 1990-1992, and we used linear interpolation to fill the missing years. Sampling of CPFVs in Northern California was further delayed, and the linear interpolation spans the period 1990-1995 for this boat mode and region. Landings data for the shore-based modes (beach/bank, man-made/jetty and shore) were sparse throughout the MRFSS sampling. All three shore-based modes were combined by region and linear interpolations were applied missing data in 1981 for the Northern California and 1995, 1996-2001, and 2004 in Southern California.

Catches from north of Cape Mendocino were removed based on a CRFS-era average of fraction of recreational landings north of Cape Mendocino by mode (3.3% of shore-based, 0.1% of CPFV, and 0.2% of private/rental were removed). From 1980-1989, San Luis Obispo County was sampled as part of Southern California (personal observation from MRFSS Type 3 sampler examined catch where county is available for 1980-2004). This assessment separates the recreational fleet at Point Conception. Recreational landings were re-allocated from southern California from 1980-1992 by fleet based on the average proportion of recreational landings in northern California from 1996-2004 (after sampling of the CPFV fleet in northern

California resumed). The average proportion re-allocated from southern to northern California for the CPFV mode was 85%, 97% for the private/rental mode, and 81% for the shore-based modes. Data were pooled over all years and modes to estimate the landings re-allocation for the shore-based modes. Total recreational landings for 1981 and 1982 were 18.8 mt and 18.6 mt, respectively. These landings were >60 mt lower than any of the neighboring years. Landings from 1981-1982 were interpolated from the 1980 and 1983 landings.

Onboard sampling of the CPFV fleet began in 1999. A sampler rides along during a CPFV trip and records the catch from a subset of anglers onboard the vessel at each fishing location. Effort data are also recorded, allowing for CPUE calculations at a fine spatial resolution.

*California Recreational Fisheries Survey (CRFS), 2004-2016*

MRFSS was replaced with the California Recreational Fisheries Survey (CRFS) beginning January 1, 2004. Among other improvements to MRFSS, CRFS provides higher sampling intensity, finer spatial resolution (6 districts vs. 2 regions), and continued onboard CPFV sampling. Estimates of catch from 2004-2018 were downloaded from the RecFIN database a final time on 4 June 2019. We queried and aggregated CRFS data to match the structure of the MRFSS data, by year, and region (Table 3). Catches in the shore-based modes are small compared to the CPFV and private rental modes. All modes are combined, but separated at Point Conception for two recreational fleets in this assessment, just as was done for the California Catch Reconstruction and MRFSS time series.

*Recreational Discards*

Recreational discards were only added to the California Catch Reconstruction landings, as Ralston et al. (2010) did not address discards for the recreational reconstruction. Recreational removals from the California Department of Fish and Wildlife MRFSS era (1980-2003) includes catch type A + B1. Catch type A refers to estimates of catch based on sampler-examined catch. Catch type B1 includes mainly angler-reported discard, but also angler-reported retained fish that were unavailable to the sampler during the interview (e.g., fillets). The CRFS era removals account for depth-stratified discard mortality rate and the catch time series includes both retained and discarded catch (total mortality). We calculated the ratio of dead discards to total mortality from the CRFS era by region and mode. The region average across modes was applied to the California Catch Reconstruction as a constant. The result added 4.68% annually to recreational removals north of Point Conception and 4.05% annually to the removals South of Point Conception). The final time series of landings and discard mortality are in Table 3.

### 2.1.5 Recreational Fishery Length and Age Data

`recreational-fishery-length-and-age-data`

Recreational length composition samples for California were obtained from several sources, depending on the time period and boat mode (Table 2). This assessment makes use of a much longer time series of length composition data, relative to the previous assessment, as described below. Input sample sizes for recreational length composition data were based on the number of observed trips, when available. Other proxies that were used to estimate the number of trips are described below.

There were no standardized coastwide surveys measuring retained or discarded fish from the recreational fleet prior to 1980.

*CPFV length composition data, 1959-1978*

The earliest available length data for this assessment were described by Karpov et al. (1995), who assembled a time series (1959-1972) of available California CPFV length data (made available courtesy of W. Van Buskirk). For GBYR, data from 1959-1961 and 1966 were available north of Point Conception and from 1959-1961 from south of Pt Conception. A total of 716 (680 north of Point Conception) unsexed measurements of retained fish (no discards) were included in the assessment (Table 2). Sampling of these length data did not follow a consistent protocol over time and areas (data are unweighted), and therefore may not be representative of total catch. Since the number of trips sampled was not reported by Karpov et al. (1995), we assume the number of sampled trips is proportional to the number of measured fish in each year, and estimated the number of trips using the ratio of fish measured per trip in the MRFSS data (roughly 10 fish per trip).

Collins and Crooke (n.d.) conducted an onboard observer survey of the CPFV fleet in southern California from 1975-1978. A total of 1,308 GBYR lengths were available from the study and were assumed to all be from retained fish. Ally et al. (1991) conducted an onboard observer program of the CPFV fleet from 1985-1987 in southern California. Because MRFSS data were available for this time period as well and represents multiple recreational modes, the Ally et al. (1991) length data were not used in the assessment.

*MRFSS Recreational Length Data, 1980-1989 and 1993-2003*

Unsexed length data of retained fish were collected by MRFSS dockside samplers and downloaded from the RecFIN website. We identified a subset of lengths that were converted from weight measurements, and these were excluded from the final data set (Table 2). The length measurements from Collins and Crooke (n.d.) from 1975-1978 are assumed to all be from retained fish. As of 2003, the CDFW Onboard Observer program has taken length measurements for discarded fish. The retained catch is measured during the dockside (angler intercept) surveys.

The number of CPFV trips used as initial sample sizes for the MRFSS was based on the number of CPFV trips was determined from the trip-level MRFS CPFV database and the number of private boat trips was determined based on unique combinations of the variables ASSNID ,ID_CODE, MODE_FX, AREA_X, DIST, INTSITE, HRSF, CNTRBTRS, SUB_REG, WAVE, YEAR, and CNTY in the Type 3 (sampler-examined catch) data.

During the recent restructuring of the CRFS data on RecFIN, a "trip" identifier was not carried over for all modes, and trip-level sample sizes could not be extracted from the biological detail table on RecFIN. A proxy for initial sample sizes for 2004-2018 were developed using the 2015 data for which I had access to raw data files by mode from CDFW. In more recent years, sampling of the shore-based modes has declined and were not sampled at all in 2018. Samples sizes were calculated by mode as the number of port-days (or site-days for shore-based modes) during bi-weekly intervals (e.g., Jan 1-15, Jan 16-31, etc). The number of port-days sampled in the bi-weekly intervals was used as the initial sample size for number of trips to calculate initial input sample sizes using Ian Stewart's method (described above). All length data were re-weighted in the assessment model.

### 2.1.6 Fishery-Dependent Indices of Abundance

fishery-dependent-indices-of-abundance

A summary of all indices in the post-STAR base model can be found in Table 4. Figure 12 shows each index from the pre-STAR base model (before any were modified or removed from the model) scaled to the mean value of that index to show them all on the same scale, i.e., the mean of each index in the plot is 1. Figure 13 shows the final set of indices in the post-STAR base model, each scaled to their mean. The final index values and associated log standard error included in the assessment can be found in Table 5.

#### MRFSS Dockside CPFV Index

From 1980 to 2003 the MRFSS program conducted dockside intercept surveys of recreational fishing fleet. The program was temporarily suspended from 1990-1992 due to lack of funding. For purposes of this assessment, the MRFSS time series was truncated at 1998 due to sampling overlap with the onboard observer program (i.e., the same observer samples the catch while onboard the vessel and also conducts the dockside intercept survey for the same vessel). Each entry in the RecFIN Type 3 database corresponds to a single fish examined by a sampler at a particular survey site. Since only a subset of the catch may be sampled, each record also identifies the total number of that species possessed by the group of anglers being interviewed. The number of anglers and the hours fished are also recorded. The data, as they exist in RecFIN, do not indicate which records belong to the same boat trip. A description of the algorithms and process used to aggregate the RecFIN records to the trip level is outlined Supplemental Materials ("Identifying Trips in RecFIN").

Initial trip filters included eliminating trips targeting species caught near the surface waters for all or part of the trip, including trips with catch of bluefin tuna, yellowfin tuna, skipjack, and albacore. Trips occuring in bays, e.g., San Francisco Bay, were also excluded.

The following filtering steps were applied to gopher rockfish, as well as the sum of the two species to represent GBYR. No filtering or indices were developed for black-and-yellow rockfish alone due to the sparseness in the data. In the raw data, unfiltered data, black-and-yellow rockfish only occurred in 48 trips that did not also observe gopher rockfish. There were an additional 65 trips that encountered both species. There was little difference between indices developed for gopher-only and the GBYR complex for both north and south of Point Conception (Figure 14). The descriptions of the filtering and data below represent those for the GBYR complex.

The species composition of catch in California varies greatly with latitude. Therefore, Stephens-MacCall filtering was applied independently for north and south of Point Conception. Separate indices were also developed to represent two recreational fleets in the model. Since recreational fishing trips target a wide variety of species, standardization of the catch rates requires selecting trips that are likely to have fished in habitats containing GBYR. The Stephens-MacCall (2004) filtering approach was used to identify trips with a high probability of catching GBYR, based on the species composition of the catch in a given trip. Prior to applying the Stephens-MacCall filter, we identified potentially informative predictor species, i.e., species with sufficient sample sizes and temporal coverage (at least 30 positive trips total) to inform the binomial model. Coefficients from the Stephens-MacCall analysis (a binomial GLM) are positive for species which co-occur with GBYR, and negative for species that are not caught with GBYR. Each of these filtering steps and the resulting number of trips remaining in the sampling frame are provided in Table 6.

*MRFSS Filtering and Index Standardization for North of Point Conception.* Prior to the Stephens-MacCall filter, a total of 2,788 trips were retained for the analysis. As expected, positive indicators of GBYR trips include several species of nearshore rockfish, treefish, kelp rockfish, and blue rockfish, and the strongest counter-indicator was striped bass (Figure 15). While the filter is useful in identifying co-occurring or non-occurring species assuming all effort was exerted in pursuit of a single target, the targeting of more than one target species can result in co-occurrence of species in the catch that do not truly co-occur in terms of habitat associations informative for an index of abundance. Stephens and MacCall (Stephens and MacCall 2004) recommended including all trips above a threshold where the false negatives and false positives are equally balanced. However, this does not have any biological relevance and for this data set, we assume that if a GBYR was landed, the anglers had to have fished in appropriate habitat, especially given how territorial GBYR and both species are strongly associated with rocky habitat.

Two levels of possible filtering were applied using the Stephens-MacCall filter (Table 6). The Stephens-MacCall filtering method identified the probability of occurrence (in this case 0.4) at which the rate of "false positives" equals "false negatives." The trips selected using this criteria were compared to an alternative method including all the "false positive" trips, regardless of the probability of encountering GBYR (Table 7 and Figure 16). This assumes that if GBYR were caught, the anglers must have fished in appropriate habitat during the trip. The catch included in this index is "sampler-examined" and the samplers are well trained in species identification. The last filter applied was to exclude years after 1999 due to a number of regulation changes, and years in which there were less than 20 observed trips. The final index is represented by 544 trips, 220 of which encountered GBYR.

Due to the large number of zeros in the data, we modeled catch per angler hour (CPUE;

number of fish per angler hour) using maximum likelihood and Bayesian negative binomial regression. Models incorporating temporal (year, 2-month waves) and geographic (region and area_x) factors were evaluated. Counties were grouped into three regions, north of Sonoma county, Sonoma county through Santa Cruz county, and San Luis Obispo county. Based on AIC values from maximum likelihood fits (Table 8), a main effects model including all factors (year, region, area_x, and 2-month waves) was fit in the "rstanarm" R package (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all reasonable. Predicted means by stratum (Year) were strongly correlated with observed means, suggesting a reasonable fit to the data (Figure 17). The NB model generated data sets with roughly 50-70% zeros, compared to the observed 60% (Figure 18).

The index represents the years 1984-1989, 1995, 1996 and 1999. There is not a lot of contrast in the index, except for a small increase in 1986. The final index values and associated log standard error included in the assessment can be found in Table 5.

*MRFSS Filtering and Index Standardization for South of Point Conception.*
Note, the MRFSS index for south of Point Conception was not used in the post-STAR base model.

Prior to the Stephens-MacCall filter, a total of 7,334 trips were available for the analysis. As expected, positive indicators of GBYR trips included several nearshore species, e.g., kelp rockfish, treefish, and black croaker, while the strongest counter-indicator was opaleye (Figure 19). While the filter is useful in identifying co-occurring or non-occurring species assuming all effort was exerted in pursuit of a single target, the targeting of more than one target species can result in co-occurrence of species in the catch that do not truly co-occur in terms of habitat associations informative for an index of abundance. For consistency with the methods used north of Point Conception (Table 6) the index includes the trips identified as "false positives" from the Stephens-MacCall filtering that had a lower threshold level of 0.22 (Table 9). The last filter applied was to exclude years after 1999 due to a number of regulation changes, and years in which there were less than 20 observed trips. The final index is represented by 475 trips, 342 of which encountered GBYR.

Catch per angler hour (CPUE; number of fish per angler hour) was modeled using the delta-GLM approach (Lo et al. 1992, Stefánsson 1996). A negative binomial model was explored, but the proportion of zeroes was not well estimated in the negative binomial models. This is likely due to the facts that MRFSS sampling effort was higher south of Point Conception, and GBYR are also rare south of Point Conception, both leading to a higher proportion of zeroes in the trip data than for north of Point Conception.

Model selection using Akaike Information Criterion (AIC) supported inclusion of year, region, area_x, and 2-month waves (Table 10). Counties were grouped into three regions, Santa Barbara to Ventura counties, Los Angeles and Orange counties, and San Diego county for both the positive observation model and the binomial model. Area_x is a measure of distance from shore, a categorical variable indicating whether most of the fishing occurred inside or outside three nautical miles from shore.

The resulting index for south of Point Conception represents different years than the index for north of Point Conception (Table 5). The index starts in 1980 with continuous data through 1986, and three additional years in 1996, 1998 and 1999. The index increases through 1983 and a marked decrease to 1986. The index for the three years in the 1990s does not exhibit any significant trend.

## CPFV Onboard Observer Surveys

Onboard observer survey data were available from three sources for this assessment, 1) a CDFW survey in central California from 1987-1998 (referred to as the Deb Wilson-Vandenberg onboard observer survey, (Reilly et al. 1998)) the CDFW CPFV onboard observer survey from 1999-2018, and 3) a Cal Poly survey from 2003-2018. During an onboard observer trip the sampler rides along on the CPFV and records location-specific catch and discard information to the species level for a subset of anglers onboard the vessel. The subset of observed anglers is usually a maximum of 15 people the observed anglers change during each fishing stop. The catch cannot be linked to an individual, but rather to a specific fishing location. The sampler also records the starting and ending time, number of anglers observed, starting and ending depth, and measures discarded fish. The fine-scale catch and effort data allow us to better filter the data for indices to fishing stops within suitable habitat for the target species.

The state of California implemented a statewide onboard observer sampling program in 1999 (Monk et al. 2014). California Polytechnic State University (Cal Poly) has conducted an independent onboard sampling program as of 2003 for boats in Port San Luis and Morro Bay, and follows the protocols established in Reilly et al. (1998). Cal Poly has modified protocols reflect sampling changes that CDFW has also adopted, e.g., observing fish as they are encountered instead of at the level of a fisher's bag. Therefore, the Cal Poly data area incorporated in the same index as the CDFW data from 1999-2018. The only difference is that Cal Poly measures the length of both retained and discarded fish.

We generated separate relative indices of abundance in for the 1987-1999 and 2000-2018 data sets due to the number of regulation changes occurring throughout the time period (see Appendix B). Separate indices were also developed for north and south of Point Conception.

*Deb Wilson-Vandenberg Onboard Observer Index Filtering and Standardization.* A large effort was made by the SWFSC to recover data from the original data sheets for this survey and developed into a relational database (Monk et al. 2016). The specific fishing locations at each fishing stop were recorded at a finer scale than the catch data for this survey. We aggregated the relevant location information (time and number of observed anglers) to match the available catch information. Between April 1987 and July 1992 the number of observed anglers was not recorded for each fishing stop, but the number of anglers aboard the vessel is available. We imputed the number of observed anglers using the number of anglers aboard the vessel and the number of observed anglers at each fishing stop from the August 1992-December 1998 data (see Supplemental materials for details). In 1987, trips were only observed in Monterey, CA and were therefore excluded from the analysis. The years 1990 and 1991 were also removed for low sample sizes. Final data filters included removing reefs that never encountered GBYR, drifts that had fishing times outside 95% of the data, and fishing stops with depths <9 m and >69m (Table 11). The final data set contained 2,411 fishing stops, with 1,096 of those encountering GBYR (Figure 20).

The index was fit using a delta-GLM model, with a lognormal model (AIC: 1,088) selected over a gamma model (AIC: 1,143) for the positive encounters. Covariates considered in the full model included year, depth, and month (Table 12). The model selected by AIC for both the lognormal and binomial components of the delta-GLM included year, depth and reef. Depth was included in 10 m depth bins and eight reefs were select in the final model. The final index did not indicate an increasing trend that was seen in the 2005 gopher rockfish assessment using the same data set (Figure 21). A number of reasons include that finer-scale location data was keypunched in 2012 for this survey, the index in this assessment includes black-and-yellow rockfish, and different filters were applied to the data. However, the the same peaks and decreases in the two indices are present.

*CDFW and Cal Poly Onboard Observer Index Filtering and Standardization* As described above the CDFW and Cal Poly onboard observer programs are identical in that the same protocols are followed. The only difference is that Cal Poly measures both retained and discarded fish from the observed anglers and CDFW measures only discarded fish from the observed anglers. CDFW measures retained fish as part of the angler interview at the bag and trip level. Cal Poly has also begun collecting otoliths during the onboard observer trips, which are used as conditional age-at-length data the recreational fishery north of Point Conception in this assessment.

A number of filters are applied to these data. All of the Cal Poly data have been through a QA/QC process once key-punched, whereas a number of errors remain in the data from CDFW. Data sheets from CDFW are no longer available prior to 2012 and staff constraints have also prevented a quality control review of the data.

Each drift was assigned to a reef (hard bottom). Hard bottom was extracted from the California Seafloor Mapping Project, with bathymetric data from state waters available at a 2 m resolution. Reefs were developed based on a number of factors described in the supplemental material ("Reef Delineation"). Reefs outside the state boundary not included in the high resolution mappin project were mapped using other data sources.

Initial filters were applied to the entire data set, north and south of Point Conception combined. After an initial clean-up of the data, 67,850 drifts remained, with GBYR present in 9,317 (Table 13). This was reduced to 25,427 drifts with GBYR present in 7,250 drifts after filtering the data to remove potential outliers in the time fished and observed anglers, limiting the data to reefs that observed GBYR and were sampled in at least 2/3 of all years, and to drifts with starting locations within 1,000 m of a reef.

Recreational fishing trips north and south of Point Conception can be fundamentally different due to differences in habitat structure, target species, and weather.

*Filtering and Index Standardization for north of Point Conception* The number of drifts remaining before region specific filtering was 13,792, with 6,036 drifts encountering GBYR (Table 13).
Because GBYR are strongly associated with hard bottom habitat, the distance from a reef at the start of a drift was re-examined for drifts encountering GBYR. The maximum distance was 872 m, but the 97% quantile dropped to 42 m and was chosen as a reasonable cutoff value, and only resulted in a reduction of 182 drifts that encountered gopher rockfish. The final data were filtered to ensure all selected reefs were sampled in at least 2/3 of all years, leaving 12,965 drifts for the final index, 5,796 of which encountered GBYR (Figure 22).

The index of abundance was modeled with a delta-GLM modeling approach, with year, month, 10 m depth bins from 10-59 m, and 12 reefs as possible covariates. A lognormal model (AIC: 12,185) was selected over a gamma (AIC: 12,520) for the positive observations using AIC (Table 14). The full model was selected by AIC for the lognormal and binomial components of the delta-GLM. The index indicates a relatively stable trend from 2001-2009 and a steady decrease from 2010-2013. The relative index of abundance has increased since 2014.

*Filtering and Index Standardization for south of Point Conception*

Note, the CPFV onboard index for south of Point Conception was not used in the final post-STAR base model.

The bathymetric data is not available at as fine-scale resolution for the Southern California Bight and more of the trips and drifts target mid-water species, including mid-water rockfish (Table 13). Therefore, instead of using distance to reef as a filter, we filtered the data to drifts that encountered 20% or more groundfish. This resulted in the total number of drifts decreasing from 11,635 to 5,495, but only decreased the number of drifts encountering GBYR from 1,277 to 1,171. A final check was made to ensure all reefs were sampled in at least 2/3 of all years, leaving 5,440 drift for the final index, of which 1,132 encountered GBYR (Figure 23).

The index of abundance was modeled with a delta-GLM modeling approach, with year, month, 10 m depth bins from 10-59 m, and four reefs as possible covariates. A lognormal model (AIC: 162) was selected over a gamma (AIC: 277) for the positive observations using AIC (Table 15). A model with year, depth and reef was selected by AIC for both the lognormal and binomial components of the delta-GLM. The index indicates a relatively stable trend from 2001-2004 and a steady increase from 2005-2017.

#### 2.1.7 Fishery-Dependent Indices: Available Length and Age Data
`fishery-dependent-indices-available-length-and-age-data`

Length data associated with the MRFSS dockside CPFV survey and the current onboard observer surveys conducted by CDFW are incorporated into the biological data pulled from the respective data sources, MRFSS and CRFS. The additional length data are not incorporated as separate length composition data as they represent the same portion of the population sampled by the CDFW onboard observer program.

Cal Poly collected otoliths from the onboard observer program starting in 2017 as part of a special study to correlate fish length before and after the fish was filleted by the deckhands onboard the CPFV vessels. All fish collected in 2017 only had associated post-fillet lengths and were not used in the assessment since the study has not been finalized nor has the method been endorsed by the SSC. A subset of fish form the 2018 collection included both pre- and post-fillet length and were used in the assessment as conditional age-at-length data associated with the recreational fleet north of Point Conception.

Length composition from Deb Wilson-Vandenberg's onboard observer survey are included in the assessment. This program measured both retained and discarded fish, and represent the portion of the population sampled with the spatial extent of the index. This onboard observer program continued during the period from 1990-1992 when MRFSS was on hiatus.

#### 2.1.8 Fishery-Independent Data Sources

`fishery-independent-data-sources`

The PISCO survey data have previously been used in one stock assessment (cabezon) and the CCFRP data have not previously been used in stock assessments as an index of abundance.

**California Collaborative Fisheries Research Project**

The California Collaborative Fisheries Research Project, CCFRP, is a fishery-independent hook-and-line survey designed to monitor nearshore fish populations at a series of sampling locations both inside and adjacent to MPAs along the central California coast (Wendt and Starr 2009, Starr et al. 2015). The CCFRP survey began in 2007 and was originally designed as a statewide program in collaboration with NMFS scientists and fishermen. From 2007-2016 the CCFRP project was focused on the central California coast, and has monitored four MPAs consistently since then (Figure 24). In 2017, the program was expanded coastwide within California. The index of abundance was developed from the four MPAs sampled consistently (Año Nuevo and Point Lobos by Moss Landing Marine Labs; Point Buchon and Piedras Blancas by Cal Poly).

The survey design for CCFRP consists a number 500 x 500 m cells both within and outside each MPA. On any given survey day site cells are randomly selected within a stratum (MPA and/or reference cells). CPFVs are chartered for the survey and the fishing captain is allowed to search within the cell for a fishing location. During a sampling event, each cell is fished for a total of 30-45 minutes by volunteer anglers. Each fish encountered is recorded, measured, and can be linked back to a particular angler, and released (or descended to depth). Starting in 2017, a subset of fish have been retained to collect otoliths and fin clips that provide needed biological information for nearshore species. For the index of abundance, CPUE was modeled at the level of the drift, similar to the fishery-dependent onboard observer survey described above.

The CCFRP data are quality controlled at the time they are key punched and little filtering was needed for the index (Table 16). Cells not consistently sampled over time were excluded as well as cells that never encountered GBYR. CCFRP samples shallower depths to avoid barotrauma-induced mortality. The index was constrained to 5-39m in 5 m depth bins. The final index included 4,920 drifts, 3,848 of which encountered GBYR.

We modeled catch per angler hour (CPUE; number of fish per angler hour) using maximum likelihood and Bayesian negative binomial regression. The proportion of zeroes in this data was relatively small (22%), and if overdispersion were not present, the regression would innately become Poisson. Models incorporating temporal (year, month) and geographic (MPA site and MPA vs Reference cells) factors were evaluated. Based on AIC values from maximum likelihood fits (Table 17), a main effects model including all factors (year, month, site and MPA/REF) was fit in the "rstanarm" R package (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all reasonable. Predicted means by stratum (Year) were strongly correlated with observed means, suggesting a reasonable fit to the data (Figure 25). The NB model generated data sets with roughly 18-22% zeros, compared to the observed 22% (Figure 26).

The CCFRP index of abundance closely matches the trend observed in the CDFW/Cal Poly onboard observer index from 2009-2018 (Figure 12). The index decreases from 2009 to 2013, and then exhibits the same increase through 2018. When both indices are standardized to their means, the values for 2013 and 2018 are the same.

*CCFRP Length Measurements and Available Ages*

The CCFRP program measures every fish encountered to the nearest half centimeter. A total of 22,470 GBYR were measured by CCFRP from 2007-2018, of which only 212 were black-and-yellow rockfish. The length distributions for each of the four MPAs used in the index for this assessment show slight differences in the peak length (Figure 27). Año Nuevo is the most northern site and Point Buchon the most southern.

Conditional age-at-length data were also incorporated into the assessment from the CCFRP program, including two master's theses that are products of the CCFRP. Erin Loury (Loury 2011) collected gopher rockfish otoliths as part of her thesis work from 2007-2009 that included specimens from both inside and outside the MPAs. Natasha Meyers-Cherry (Meyers-Cherry 2014) conducted another thesis focused on the life history of gopher rockfish and collected otoliths from 2011-2012, also both inside and outside the MPAs. Both MLML and Cal Poly began routinely collecting otoliths from a select number of fish in 2017 as part of the CCFRP program. Also included in the conditional age-at-length data for this fleet are otoliths collected in 2018 by the University of California Davis Bodega Marine Lab CCFRP program.

**Partnership for Interdisciplinary Studies of Coastal Oceans**

The Partnership for Interdisciplinary Studies of Coastal Oceans, PISCO-UCSC, conducts a number of surveys to monitor the kelp forests, one of which is a kelp forest fish survey. PISCO has monitored fish population in the 0-20 m depth range as part of the Marine Life Protection Act (MLPA) since 1998. Paired sites inside and outside MPAs are surveyed to monitor the long-term dynamics of the kelp forest ecosystem and provide insight into the effect of MPAs on kelp forest species. PISCO conducts the fish surveys from late July through September. At each site, benthic, midwater, and canopy scuba transects are conducted at 5, 10, 15, and 20 m depth. All divers are trained in species identification. Along each 30 m transect, divers enumerate all identifiable non-cryptic fish, and measure total length to the nearest centimeter. PISCO surveys are conducted by the University of California Santa Cruz (UCSC) in central California and through the University of California Santa Barbara in southern California. All PISCO data were provided by Dan Malone (UCSC).

The majority of filtering for the PISCO data set was to determine which sites to retain for the final index (Table 18). After initial filtering the data for GBYR in southern California were too sparse to be considered for the index of abundance. Gopher and black-and-yellow rockfish were also rarely observed in the midwater and canopy transects, and therefore the index is based only on the benthic transects. Only sites sampled consistently throughout the time period 2001-2018 were kept for the index. Multiple transects can be conducted along the same line within a sampling event. All transects within a site were combined and effort was modeled as the number of transects represented in the number of fish observed. The final index included 3,231 transects, of which 1,729 observed GBYR (Figure 28).

Three indices are described below. The pre-STAR base model includes a single index of abundance for the PISCO survey. During the STAR panel the decision was made to include two separate indices of abundance and selectivities for the PISCO data. The PISCO data include information on age-0 recruitment and also older fish. The PISCO age-0 recruitment index includes fish that are 6 cm or smaller, and the PISCO index for larger fish includes fish 15 cm and larger. There is uncertainty in the age of fish in the 7-14 cm range due to the timing of sampling, growth, and the timing of ages, i.e., all fish turn one on Jan 1 in the SS assessment model. Additionally, fish in the 7-14 cm are also not well sampled by the survey.

For all three iterations of the index we modeled number of fish observed per transect(s) using maximum likelihood and Bayesian regression. The index containing all data and the index for larger fish (15+ cm) only were modeled as negative binomial, whereas the data for the age-0 (for which the 4-6 cm fish serve as a proxy) index were sparse and modeled as binomial. Models incorporating temporal (year, month) and geographic (site and zone) factors were evaluated. The zone is a factor indicating the depth stratification at a site, i.e., 5 m, 10 m, 15 m, or 20 m targeted bottom depth.

*Index based on all of the PISCO data (used in the pre-STAR base model).*
Based on AIC values from maximum likelihood fits (Table 19), a main effects model including all factors (year, month, site and zone) was fit in the "rstanarm" R package (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all reasonable. Predicted means by stratum (Year) were strongly correlated

with observed means, suggesting a reasonable fit to the data (Figure 29). The NB model generated data sets with roughly 16-25% zeros, compared to the observed 23% (Figure 30).

The final index decreases from 2001 to the late 2000s, with lower estimates of relative abundance from 2005-2010. From 2010 to 2015, the index increases and peaks in 2015, before the decreasing trends from 2016-2018. The trend observed in this index is counter to that observed in the onboard observer and CCFRP indices for north of Point Conception (Figure 12). The PISCO survey is sampling different habitat types than the other two surveys, and covers much shallower depths. It's possible that the PISCO index captures recruitment pulses, but because this index includes both young-of-the-year and adult fish, the trend may be captured in the model.

*PISCO index based on fish 15 cm and larger (used in the post-STAR base model).*
The same filtered dataset was used for the index for fish 15 cm and larger as for the PISCO index that included all fish. Based on AIC values from maximum likelihood fits (Table 20), a main effects model including all factors (year, month, site and zone) was fit in the "rstanarm" R package (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all reasonable. Predicted means by stratum (Year) were strongly correlated with observed means, suggesting a reasonable fit to the data (Figure 31). The NB model generated data sets with roughly 20-30% zeros, compared to the observed 25% (Figure 32).

*PISCO recruitment index based on fish 6 cm and smaller (used in the post-STAR base model).*
The same filtered dataset was used for the index for fish 15 cm and larger as for the PISCO index that included all fish. There was no consistent pattern in the presence of age-0 fish to exclude any sites or zones. All years were included in the final index, even if sample sizes were small. Age-0 fish were present in 14% of all transects. A negative binomial model was not well fit to the data so a binomial (presence/absence) model was selected for the recruitment index. Based on AIC values for maximum likelihood fits (Table 21), a main effects model including year, month, and zone was fit in the "rstanarm" R package (version 2.18.2). The resulting index has large standard errors for years with sparse data, including 2004-2008 and 2012-2013. A recruitment signal is present in the index in a number of years, including 2001-2003, 2010, and 2014-2017.

*PISCO Length Measurements*

All but one GBYR observed by PISCO divers was measured (N = 11,965). Divers measure fish to the nearest centimeter, and are trained to measure fish underwater and be aware of possible biases, e.g., ambient light, body color, visibility, and body shape. Both juvenile and adult GBYR were observed in the PISCO kelp forest fish survey data (Figure 33). Of note is the similarity in length distributions both between the species and for the two species combined across sites. Fish in the 10-17 cm size range (approximately) are rarely observed in this survey. There is significant post-settlement mortality for both species, which is thought to be due to density-dependent predation (Johnson 2006, 2007). Secondly, both species can be cryptic and observed at higher frequency by divers at night than during the day (Mark Carr, PISCO-UCSC, personal communication).

### 2.1.9 Biological Parameters and Data

biological-parameters-and-data

Neither gopher nor black-and-yellow rockfish have forked tails, therefore total length and fork length are equal. All of the data provided for this assessment were either in fork length or total length.

#### Length and Age Compositions

Length compositions were provided from the following sources:

- CALCOM (*commercial retained dead fish*, 1987, 1992-2018)
- WCGOP (*commercial discarded fish*, 2004-2018)
- Deb Wilson-Vandenberg's onboard observer survey (*recreational charter retained and discarded catch*, 1987-1998)
- California recreational sources combined (*recreational charter retained catch*)
  - Miller and Gotshall dockside survey (1959-1966)
  - Ally et al. onboard observer survey (1985-1987)
  - Collins and Crooke onboard observer survey (1975-1978)
  - MRFSS dockside survey (1980-2003)
  - CRFS onboard and dockside survey (2004-2018)
- PISCO dive survey (*research*, 2001-2018)
- CCFRP hook-and-line survey (*research*, 2007-2018)

The length composition of all fisheries aggregated across time by fleet is in Figure 34 and Table 22. Descriptions and details of the length composition data are in the above section for each fleet or survey.

#### Age Structures

A total of 2,421 otoliths were incorporated in this assessment and a summary by source can be found in Table 23. The final base model excludes the commercial age data that were sparse and not representative of the fishery. Gopher rockfish comprised 79% of the samples (922 females, 879 males, 121 unknown sex), and all but a few black-and-yellow rockfish (247 females, 232 males, 20 unknown sex) came from a directed study by Jody Zaitlin (1986), collected from 1983-1986 (Figure 35).

Of the available ages, 94% were collected during fishery-independent surveys. The remaining 6% were recreational dockside surveys and collected by Cal Poly during their CPFV onboard observer survey (36 otoliths) in 2018.

All otoliths were read by Don Pearson (NMFS SWFSC, now retired) and estimated ages ranged from 1-28. The aged black-and-yellow rockfish ranged in length from 7-32 cm with a mean of 24 cm and gopher rockfish ranged in length from 11-36 cm, with a mean of 26. In terms of ages, the black-and-yellow rockfish ranged from 2-19 and gophers from 2-28. Fits to the von Bertalanffy growth curve (Bertalanffy 1938), $L_i = L_\infty e^{(-k[t-t_0])}$, where $L_i$ is the length (cm) at age $i$, $t$ is age in years, $k$ is rate of increase in growth, $t_0$ is the intercept, and $L_\infty$ is the asymptotic length, were explore by species and sex.

No significant differences were found in growth between gopher and black-and-yellow rockfishes (Figure 36) or between males and females (Figure 37), species combined.

## Aging Precision and Bias

Uncertainty in ageing error was estimated using a collection of 376 gopher and black-and-yellow rockfish otoliths with two age reads (Figure 38). Age-composition data used in the model were from a number of sources described above. All otoliths were read by Don Pearson (NMFS SWFSC, now retired) who also conducted all blind double reads.

Ageing error was estimated using publicly available software (Thorson et al. 2012). The software setting for bias was set to unbiased since the same reader conducted the first and second readings. The best fit model chose by AIC for the standard deviation was a constant coefficient of variation for reader one and mirrored for reader two (Figure 39).

The resulting estimate indicated a standard deviation in age readings increasing from 0.74 years at age 0 to a standard deviation of 2.07 years at age 28, the first year of the plus group in the assessment model.

## Weight-Length

The weight-length relationship is based on the standard power function: $W = \alpha(L^\beta)$ where $W$ is individual weight (kg), $L$ is length (cm), and $\alpha$ and $\beta$ are coefficients used as constants.

The weight-length relationships was estimated from the three studies, Loury (2011), Meyers-Cherry (2014) (both gopher rockfish only from CCFRP) and Zaitlin (Zaitlin 1986) (black-and-yellow rockfish only). Only one weight-length relationship was estimated for the GBYR complex. The estimated parameters are $\alpha = 8.84e^{-006}$ and $\beta = 3.25584$. The estimated relationship is similar to that estimated by Lea et al. (1999) for gopher rockfish (Figure 40). The weight-length relationship estimated here was used in the assessment model to best represent the GBYR complex.

## Sex Ratio, Maturity, and Fecundity

The sex ratio for GBYR is assumed to be 50:50 as there is no evidence to suggest otherwise.

Zaitlin (1986) found that females reached 50% maturity at 17.5 cm or 4 years of age in Central California and were 100% mature by age 6, with the same age of maturity found in southern

California though individuals were smaller at age. Echeverria (1987) estimated maturity for 17 rockfish species in central California. She found the size at first maturity and the size at 50% maturity for male and female gopher rockfish to be 17 cm total length, and 100% mature by 21 cm. Black-and-yellow rockfish males and females were first mature at 14 cm, 50% of females were mature at 15 cm, 50% of males mature at 16 cm. Male black-and-yellow rockfish were 100% mature at 20 cm and females at 19 cm. In southern California waters, both males and females were found to reach first maturity at 13 cm total length (Larson 1980). We did not have any samples from southern California to re-analyze the maturity ogive for that portion of the population. Both Zaitlin and Echeverria estimated the maturity ogives using ages from whole otoliths. A sample of 151 black-and-yellow rockfish otoliths surface read by Zaitlin were also read by Don Pearson, and Zaitlin's ages were consistently younger than Pearson's, by up to nine years. All of the available otoliths for this assessment were re-aged using a combination of surface reading and break-and-burn methodology.

The maturity data from Zaitlin (1986) (422 black-and-yellow rockfish) were re-analyzed along with samples from Meyers-Cherry (2014) (115 gopher rockfish). Combining the two data sets provided an updated maturity ogive for the GBYR complex females (Figure 41). The first observed mature fish was 19 cm and the length at 50% was 21.66 cm, larger than suggested from the estimate used by Key et al. (2005) in the 2005 assessment. After re-analyzing the available data, the length at which 50% of female gopher rockfish were mature was estimated at 23.33 cm, and was 21.26 cm for female black-and-yellow rockfish. An important note is that the smaller fish from these studies were black-and-yellow rockfish and the larger fish were gopher rockfish. Although not used in this assessment, the estimate of 50% maturity for 23 GBYR from these studies was 21.88 cm. The age at 50% mature increased in this assessment to 21.66 cm, which is 3.96 cm larger than the value used in the 2005 assessment.

Mature females in central California release larvae between January and July, peaking in February, March, and May (Larson 1980, Lea et al. 1999, Love et al. 2002). Both species of GBYR release one brood per season (Love et al. 2002). Black-and-yellow rockfish females can produce 25,000 - 450,000 eggs spawning from January to May. Gopher rockfish females ranging between 176 and 307 grams carry approximately 249 eggs per gram of body weight (MacGregor 1970). The fecundity estimates used in this assessment were provided by E.J. Dick (NMFS SWFSC) from a meta-analysis of fecundity in the genus *Sebastes* (Dick et al. 2017).

## 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 a large number of 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 alone, based on an updated Hoenig non-linear least squares (nls) estimator

$M = 4.899 * {A_{max}}^{-0.916}$. 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 $-0.916M$ to $A_{max}$, Then et al. (2015) did not consistently apply their transformation. In particular, 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:

$$M = \frac{5.4}{A_{max}} \tag{1}$$

The above is also the median of the prior. The prior is defined as a lognormal with mean $ln\frac{5.4}{A_{max}}$ and SE = 0.4384343 (Owen Hamel, personal communication, NMFS). Using a maximum age of 28 the point estimate and median of the prior is 0.193, which is used as a prior for in the assessment model and as a fixed quantity in the post-STAR base model.

#### 2.1.10 Environmental or Ecosystem Data Included in the Assessment
environmental-or-ecosystem-data-included-in-the-assessment

In this assessment, neither environmental nor ecosystem considerations were explicitly included in the analysis. This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere) that could contribute ecosystem-related quantitative information for the assessment.

## 2.2 Previous Assessments
previous-assessments

### 2.2.1 History of Modeling Approaches Used for this Stock
history-of-modeling-approaches-used-for-this-stock

This is the first full assessment to include data for black-and-yellow rockfish. Black-and-yellow rockfish was assessed coastwide as a data poor species using Depletion-Based Stock Reduction Analysis (DB-SRA) (Dick and MacCall 2010). The DB-SRA model assigned a 40% probability that the then recent (2008-2009) catch exceeded the 2010 OFL.

Gopher rockfish south of Point Conception was assessed as a data poor species in 2010 (Dick and MacCall 2010). A Depletion-Corrected Average Catch (DCAC) model was used due to time constraints. The mean yield from the DCAC distribution was 25.5 mt.

Gopher rockfish north of Point Conception (34°27′ N. latitude) was first assessed as a full stock assessment in 2005 (Key et al. 2005) using SS2 (version 1.19). The assessment was sensitive to the CPFV onboard observer index of abundance (referred to as Deb Wilson-Vandenberg's onboard observer index in this assessment). The final decision table was based around the emphasis given to this index. The stock was found to be at 97% depletion in 2005.

### 2.2.2 2005 Assessment Recommendations

assessment-recommendations

The 2005 gopher rockfish STAR panel only had one recommendation specific to gopher rockfish. However, they had a number of generic rockfish recommendations that can be found in the STAR panel report available here.

**Recommendation 1: Additional length and age composition data should be collected for gopher rockfish. This would help to characterize spatial and possibly temporal variation in growth**

2019 STAT response: Additional age and length data have been collected from a number of sources, the majority of which have been fishery-independent studies, including two master's theses focused on gopher rockfish. Only a handful of otoliths have been collected for gopher rockfish south of Point Conception. Additional length composition data are available since the last assessment.

## 2.3 Model Description

model-description

The model descriptions in the following sections reflect decisions and modelling choices the STAT team made prior to the STAR panel. Changes from the pre-STAR base model to the final post-STAR base model are documented in the "Responses to the Current STAR Panel Requests" section. During the STAR panel, the following structure change were made; 1) the commercial retained and commercial discard fleets were combined into one commercial fleet, 2) the MRFSS recreational dockside and the CRFS recreational onboard indices south Point Conception were removed, 3) the PISCO index was split into two indices, one representing fish 15 cm and larger and an age-0 index representing fish 6 cm or less. All of the figures and tables reflect the post-STAR final base model. The section on the PISCO index of abundance has been updated to reflect the change in the indices.

While investigating convergence issues in the cowcod assessment, Richard Methot (NMFS) identified an issue with the performance of the 'sfabs' function in ADMB. This led to poor convergence during the iterative search for $F_{SPR}$ under certain conditions. Dr. Methot resolved the issue, and provided a new 'safe' version of SS (V3.30.13.09) to the cowcod and GBYR STATs on June 28, followed by an optimized executable on June 30. Apart from the iterative $F_{SPR}$ search mentioned above, other model outputs and analyses were unaffected by the change. All of the base model results were run in this newest version of SS.

### 2.3.1 Transition to the Current Stock Assessement

transition-to-the-current-stock-assessment

The first formal stock assessment for gopher rockfish was conducted in 2005 (Key et al. 2005). There are two major differences between the 2005 assessment this assessment, 1) this assessment models gopher and black-and-yellow rockfish as a complex, and 2) this assessment includes the area south of Point Conception.

The 2005 model conducted in SS2 version 1.19 was first transitioned to SS3.24z as a bridge model, before moving forward to SS3.30. Below, we describe the most important changes made since the last full assessment in 2005 and explain rationale for each change. Some of these items are changes due to structure changes with Stock Synthesis, and some denote parameters chosen for options that were not available in SS2 (version 1.19).

Changes in the bridge model from SS2 version 1.9 to SS3.24z and SS3.30.13.09 include:

The way growth is modeled for age-0 fish has changed. More recent versions of Stock Synthesis model length-at-age for fish below the first reference age (Amin) as linearly increasing from the initial length bin to the length given by the L_at_Amin parameter. The minimum population length bin was reduced from 10 cm in the 2005 assessment to 4 cm in this assessment. The timing of settlement was set at July to reflect the month at which the young-of-the-year are expected to be at 4 cm (Figure 42). The length data leading to this decision were provided by Diana Baetscher (UCSC) and were collected via Standard Monitoring Unit for the Recruitment of Fishes (SMURFs) (Ammann 2004) from the UCSC-PISCO kelp forest fish survey as part of her dissertation work on rockfish genetics (Baetscher 2019).

This stock assessment retains a single fleet for the commercial fishery, and also includes a commercial discard fleet. Data on commercial discards were not available for and not included in the 2005 assessment. The decision to retain one commercial fleet was made by examining the length distributions across species, fishing gears, and space, i.e., north and south of Point Conception (Figure 43). There is very little difference between the length composition of gopher and black-and-yellow rockfish landed in the commercial fleet north of Point Conception, which contributed 97% of the commercial landings from 1978-2018. The length distributions suggest that gopher rockfish south of Point Conception landed dead south of Point Conception are slightly smaller on average than north of Point Conception. However, there is not enough data available to justify splitting the commercial fishery north and south of Point Conception. The length compositions of discarded fish are small in all of the subplots, suggesting size-based discarding. Because Stock Synthesis is not set up to handle depth-dependent discard mortality rates and this assessment represents a species complex with differing depth-dependent discard mortality rates for each species, the time series of commercial discards was incorporated as a fleet.

This assessment incorporates the area south of Point Conception, which was previously excluded from the 2005 assessment. The length composition data suggested that while the lengths of gopher and black-and-yellow rockfish were similar, fish encountered south of Point Conception were smaller (Figure 44). The recreational catches from the man-made/jetty mode are negligible and did not influence the decision to split the fleet at Point Conception. From 2005-2018, the man-made/jetty mode averaged 0.5% of the total recreational catch and discards north of Point Conception and 0.03% south of Point Conception. The similarity of the length distributions between species and among modes within a region were similar and justified one recreational fleet.

The 2005 model was a length-based model. This assessment uses conditional age-at-length from fish aged from a number of sources (Table 23).

Differences in both the recreational and commercial catches used in this assessment are described in detail in Section 1.5.

The bias adjustment for recruitment deviations did not exist in SS2 (version 1.19). We set 1973-2015 as the range of years with full bias adjustment to span the time series that was modeled.

The previous assessment modeled selectivity of the commercial fleet as logistic curve, and both parameters for the logistic selectivity were estimated. Selectivity for both the recreational fleet and onboard CPFV survey were modeled using the double logistic. The current assessment uses the six parameter double normal for all fleets for which selectivity is estimated and not mirrored. The MRFSS dockside CPFV surveys and the two CPFV onboard observer surveys are mirrored to the recreational fishing fleets, north and south of Point Conception, respectively.

The 2005 assessment did not include any time blocks. This assessment includes two time blocks for the commercial fleet (1916-1998 and 1999-2018). A 10-inch minimum size limit was placed on the commercial fleet in 1999, which was reflected in the CALCOM length composition data. No additional time blocks were added for the recreational fleet. GBYR are a minor component of the nearshore rockfish complex and no significant changes were detected in the landings or length composition during the time when regulations changed (1999-2002).

The 2005 assessment considered two candidate fishery-dependent indices of abundance, the Deb Wilson-Vandenberg onboard observer CPFV survey and a dockside intercept survey from MRFSS from 1983-2003. However, the dockside index was removed at the request of the STAR panel, citing "did not provide a reliable measure of relative abundance due to changes in regulations and fishery targeting during the 1990s-2000s." The current assessment uses a version of the MRFSS database that has been more robustly aggregated to the trip level. Starting in 1999, MRFSS began angler interviews. Interviews are conducted for all the anglers on the boat, whereas the onboard data is only collected for a subset of anglers that changes with each fishing stop. Using both the onboard observer data and the angler interviews for this time period would result in developing indices from the same fish. The fine-scale onboard observer data provides greater detail in terms of catch and location than the angler interviews. The onboard observer indices do not include the years 1999 and 2000 due to the number of regulation changes occurring in those two years.

The fishery-independent indices are all new for this assessment; the PISCO kelp forest fish survey and the CCFRP hook-and-line survey.

Maturity was changed for this assessment based upon newly available data described in the biological specifications of this assessment.

The 2005 assessment pre-STAR base model fixed steepness for gopher rockfish at 1.0, which was then changed to 0.65 (the Dorn prior at the time) during the STAR panel. In this assessment, steepness was set at 0.72, the mean of the prior developed from a meta-analysis of West Coast groundfish, with a standard deviation of 0.16 (see Accepted Practices Guidelines for Groundfish Stock Assessments in the supplemental material).

The prior for female natural mortality was updated to the median of the prior from a meta-analysis conducted by Owen Hamel (see Accepted Practices Guidelines for Groundfish Stock Assessments in the supplemental material). Assuming a maximum age of 28 years, the median of the prior is 0.193, close to the fixed value used in the 2005 assessment of 0.2.

Due to the fact that the 2005 model only included gopher rockfish and excluded the area south of Point Conception, a complete bridge model was not developed. Comparison of the 2005 input data, catch streams, and indices are provided throughout the document in appropriate sections.

### 2.3.2 Summary of Data for Fleets and Areas

summary-of-data-for-fleets-and-areas

There are 10 fleets in the post-STAR base model. They include:

*Commercial*: There is one commercial fleet that includes GBYR landed (all gears combined) and dead discards.

*Recreational*: The recreational fishery include two fleets, one for north of Point Conception and one for south of Point Conception (all modes combined) and includes dead discards.

*Fishery-Dependent Surveys*: There are five fishery-dependent survey fleets, all north of Point Conception. There is one for MRFRSS CPFV dockside survey, one for the CDFW/Cal Poly onboard observer survey, and one from the Deb Wilson-Vandenberg CPFV onboard observer survey.

*Research*: There are two main sources of fishery-independent data available the CCFRP survey and the PISCO kelp forest fish survey. The PISCO survey was split into two indices in the post-STAR base, one representing age-0 recruitment and one for fish 15+ cm. A third survey fleet is included as a “dummy” fleet to allow incorporation of additional conditional age-at-length composition data from the Zaitlin and Abrams theses, the Pearson groundfish cruise, and the special study conducted during the SWFSC’s juvenile rockfish and ecosystem cruise. This dummy fleet includes 1,067 ages of gopher and black-and-yellow rockfish. This dummy fleet does not have any length composition data or catches associated with it.

### 2.3.3 Other Specifications

other-specifications

Stock Synthesis has a broad suite of structural options available. Where possible, the 'default' or most commonly used approaches are applied to this stock assessment. The assessment is a one-sex model, as no significant differences in growth between males and females was detected in external analyses.

The length composition data for some years and fleets was small, and may not be representative of the total catch. Length composition data were removed from the model if fewer than 20 fish were measured in a given year and fleet. From 1985-1989, two surveys measured fish from the recreational party/charter fleet, the Ally et al. (Ally et al. 1991) onboard observer survey and the dockside intercept survey. The number of trips and fish sampled by the onboard observer survey was far greater than the MRFSS survey and were used in the model. Initial input sample sizes were also capped at 400 for each set of length composition data.

The time-series of landings begins in 1916 for the commercial fleet and in 1928 for the recreational fleet. This captures the inception of the fishery, so the stock is assumed to be in equilibrium at the beginning of the modeled period.

The internal population dynamics model tracks ages 0-28, where age 28 is the 'plus-group.' There are relatively few observations in the age compositions that are greater than age 28. The population length bins and the length composition length bins are set at 1-cm bins from fish 4-40 cm.

The extra standard deviation parameter was added to all indices except the MRFSS dockside index for north of Point Conception and the PISCO age-0 index since both had relatively large estimated variances associated with them. The extra parameter was explored, but estimated to be on the lower bound, and was removed for the post-STAR base model. All other indices, including the recreational onboard observer index, CCFRP, and PISCO (15+ cm fish), were estimated with relatively small variances (10-20%) from their respective indices. Extra variance was estimated for these indices in the post-STAR base model.

The following likelihood components are included in this model: catch, indices, discards, length compositions, age compositions, recruitment, parameter priors, and parameter soft bounds. See the SS technical documentation for details (Methot et al. 2019).

Electronic SS model files including the data, control, starter, and forecast files can be found on the PFMC's website.

### 2.3.4 Modeling Software

modeling-software

The STAT team used Stock Synthesis 3 version 3.30.13.09 (published on 6/28/2019) by Dr. Richard Methot at the NWFSC. This most recent version was used, since it included improvements and corrections to older versions. The r4SS package (GitHub release number v1.35.1) was used to post-process output data from Stock Synthesis.

### 2.3.5 Data Weighting

data-weighting

Length composition and conditional-age-at-length (CAAL) compositions sample sizes for the base model were tuned by the "Francis method," based on equation TA1.8 in Francis (2011), and implemented in the r4ss package. This approach involves comparing the residuals in the model's expected mean length with respect to the observed mean length and associated uncertainty derived from the composition vectors and their associated input sample sizes. The sample sizes are then tuned so that the observed and expected variability are consistent. After adjustment to the sample sizes, models were not re-tuned if the bootstrap uncertainty value around the tuning factor overlapped 1.0.

As outlined in the Best Practices, a sensitivity run was conducted with length and conditional-age-at-length (CAAL) compositions were re-weighted using the Ianelli-McAllister harmonic mean method (McAllister and Ianelli 1997). Additionally, weighting using the Dirichlet-Multinomial likelihood, that includes and estimable parameter (theta) that scales the input sample size, was explored. However, the model did not converge when the Dirichlet-Multinomial likelihood was applied to a number of the fleets with composition data. Given this, and the current challenges with this method described in the Stock Synthesis manual (Methot et al. 2019), the Francis weightings were applied in the pre-STAR and post-STAR base models. The final post-STAR base model was re-weighted twice at which point the Francis weights stabilized.

A series of sensitivities were conducted to determine the need to estimate extra variability parameters were estimated and added to the survey CPUE indices, and described below in the Estimated Parameters section.

### 2.3.6 Priors

priors

The log-normal prior for female natural mortality were based on a meta-analysis completed by Hamel (2015), as described under "Natural Mortality." Natural mortality was estimated using with a prior of 0.193 (with log-space sigma of 0.438) for an assumed maximum age of 28. Natural mortality was fixed at the value of the prior in the post-STAR base model.

The prior for steepness ($h$) assumes a beta distribution with parameters based on an update for the Thorson-Dorn rockfish prior (Dorn, M. and Thorson, J., pers. comm.), which was endorsed by the Science and Statistical Committee in 2019. The prior is a beta distribution with $mu$=0.72 and $sigma$=0.16. Steepness is fixed in the post-STAR base model at the mean of the prior.

### 2.3.7 Estimated and Fixed Parameters

estimated-and-fixed-parameters

A full list of all estimated and fixed parameters is provided in Table 24. Time-invariant, growth is estimated in this assessment, with all SS growth parameters being estimated. The log of the unexploited recruitment level for the Beverton-Holt stock-recruit function is treated as an estimated parameter. The main recruitment deviations estimated from 1978-2018, with no early recruitment deviations. The survey catchability parameters are calculated analytically (set as scaling factors) such that the estimate is median unbiased, which is comparable to the way q is treated in most groundfish assessments.

The post-STAR base model has a total of 61 estimated parameters in the following categories:

- Equilibrium recruitment ($R_0$) and 41 recruitment deviations
- Five growth parameters
- Four index extra standard deviation parameter, and
- Ten selectivity parameters

The estimated parameters are described in greater detail below and a full list of all estimated and parameters is provided in Table 24.

*Growth.* Five growth parameters were estimated for the one-sex model: three von Bertalanffy parameters and two parameters for CV as a function of length-at-age related to variability in length-at-age for small and large fish.

*Selectivity.* Double-normal, asymptotic selectivity was estimated for all fleets with estimated selectivity parameters.

Three parameters were estimated for the recreational and commercial fleets, the peak, the ascending width, and the selectivity at the first bin. Only the ascending width parameter was estimated for the PISCO fleet for fish 15+ cm.

The Deb Wilson-Vandenberg onboard observer fleet and the CCFRP fleet were mirrored to the recreational fleet north of Point Conception.

*Other Estimated Parameters.* Main recruitment deviations estimated from 1978 to 2018. The post-STAR base model also included estimated recruitment deviations for the forecast years, although these have no impact on the model estimates for the current year.

Many variations of the base case model were explored during this analysis. Sensitivities to asymptotic vs. domed selectivity were explored for the appropriate fisheries, e.g. commercial fisheries and surveys, as well as estimating selectivity and mirroring fleet selectivities. Time blocked selectivity without the time block from 1999-2019 for the recreational fisheries was investigated.

Much time was also spent tuning the advanced recruitment bias adjustment options. Sensitivities were performed to each of the thirteen advanced options for recruitment, e.g., early recruitment deviation start year, early recruitment deviation phase, years with bias adjustments, and maximum bias adjustment. The final post-STAR base model sets the first year of recruitment deviations just prior to when the majority of fishery/survey length composition are available.

Several models were also investigated where steepness and natural mortality were either estimated or fixed at their respective priors.

*Other Fixed Parameters.* The stock-recruitment steepness was fixed at the SSC approved steepness prior for rockfish of 0.72 and natural mortality was fixed at 0.193, the mean of the prior given a maximum age of 28 years.

## 2.4 Model Selection and Evaluation

`model-selection-and-evaluation`

### 2.4.1 Key Assumptions and Structural Choices

`key-assumptions-and-structural-choices`

Key assumptions in the model are that it is appropriate to model gopher and black-and-yellow rockfish as a complex. The catch histories are inseparable at this time, especially for the early commercial landings. The biological information available also precluded complete analyses of difference in growth, i.e., the majority of black-and-yellow rockfish aged were small fish and small fish were lacking for gopher rockfish. Data from both species were used to provide a complete picture of the growth curve.

The assessment is a one area model with fleets as areas for the recreational fishery. There were only a handful of aged gopher rockfish from south of Point Conception, and not enough other biological information available that would have justified a multi-area model.

### 2.4.2 Alternate pre-STAR Models Considered

`alternate-pre-star-models-considered`

A number of models were run with differing catch histories for the recreational fleet south of Point Conception, given that the catch histories were modified from the original data. None of the alternatives explored altered the model at any significant level due to the fact that the recreational catches south of Point Conception are relatively small compare to catches north of Point Conception. Results from select sensitivity runs compared to the base model are in Table 25.

Two sensitivities were also performed altering the commercial discard catch history. The discard catch was set to zero for all years prior to 2004, the year when WCGOP estimates were first available, and to a constant rate of 17% of the commercial landings, the maximum discard rate observed in the WCGOP data. Neither of these sensitivities resulted in any significant change to the model outputs.

Sensitivity of the model to the spawning and settlement months were also explored. The base model originally set settlement month to January. Both gopher and black-and-yellow rockfish settle at a small size (~2 cm) and over a course of several months. After exploring the young-of-the-year length data made available by Diana Baetscher (UCSC), the timing of settlement was moved to July for the base model, when the majority of GBYR are 4 cm, the size of the smallest length bin. The change of the timing of settlement had little effect on the model results.

Runs of the base case model estimating steepness were also considered.

A sensitivity of the model to using the commercial length composition data from PacFIN was also considered. The fits changed only slightly, (increasing depletion from 0.46 to 0.48) but given the concerns outlined in the discussion on commercial length composition the pre- and post-STAR base models include the commercial length compositions from CALCOM.

Sensitivities were developed to look at alternate selectivity patterns for the commercial discard fleet and the CCFRP survey. A time block for the commercial discard fishery was not considered since no length composition of discarded fish were available prior to 2004.

### 2.4.3 Uncertainty and Sensitivity Analyses to the pre-STAR base
`uncertainty-and-sensitivity-analyses-to-the-pre-star-base`

A number of sensitivity analyses were conducted prior to the STAR panel, including:

1. Fixing natural mortality at the prior of 0.193
2. Fixing the von Bertalanffy $k$ at the external estimate of 0.247
3. Using the PacFIN expanded length composition data
4. Data weighting scenarios including unweighted, harmonic means (McAllister-Ianelli method), and Francis weights

The following sensitivities are based on the pre-STAR base model and indicate areas that the STAT identified as either areas of uncertainty or model sensitivities outlined in the Accepted Practices and Guidelines document. A summary of parameters for all sensitivity runs is in Table 25.

Fixing either natural mortality or the von Bertalanffy $k$ parameter results in a stock with higher spawning output in 2018 as compared to the base model (Figure 45).

Fixing either $M$ or $k$ demonstrates the negative correlation between the two parameters. The von Bertalanffy $k$ parameter is estimated at 0.12 when natural mortality (estimated at 0.21) and growth are both estimated. When natural mortality is fixed at the prior of 0.193, $k$ is estimated at 0.14, but the two other growth parameters, L1 and L2 do not change much at all. When $k$ is fixed to the external estimate of 0.247, natural mortality is estimated at 0.16, and the other growth parameters both decrease. A number of additional sensitivities to the growth parameters will be presented at the STAR panel.

Replacing the CALCOM commercial length composition data with the PacFIN length composition results in the stock at an overall lower level of biomass than the base model. Depletion in the final year with the PacFIN length composition is 0.50, compared to 0.46 in the base model. A detailed discussion on the decision to use the CALCOM length composition in the base model can be found in the discussion commercial length and age data, Section (2.1.3).

Data weighting is an area of uncertainty for stock assessment, and research is ongoing to determine the effects of data weighting and the most appropriate initial sample sizes for length and age composition data. The base model used the Stewart sample sizes for initial sample sizes for the fishery data and either the Stewart sample sizes or number of "trips" for the survey sample sizes. Weighting the data by the harmonic mean resulted in a model with a total likelihood between the base model, which uses the Francis method for weighting, and the model with default weights (Figure 46). The end year spawning output is almost identical for the models using harmonic means and Francis weights, both of which down-weighted the composition data.

The Francis weights in the base model were stable, and did not tend to serially decrease (down-weight) any of the data sets, which has been seen in other assessments. The final base model re-weights the composition data only once. As discussed above in the data weighting section, the Dirichlet-Multinomial weighting was explored, but a model with a positive definite Hessian was not identified with the pre-STAR base model.

## 2.5 Response to the Current STAR Panel Requests

response-to-the-current-star-panel-requests

**Request No. 1: Develop catch curves from age data as appropriate during different periods of fishing intensity according to the model.**

**Rationale:** To obtain an independent estimate of total mortality to better gauge natural mortality given the model uncertainty.

**STAT Response:** The STAT created two catch curves using the available age data for gopher and black-and-yellow rockfish, one for the time period pre-2000 (629 available ages) and the second from 2000-2018 (1,791 available ages) (Figure 47). The pre-2000 plot used fish aged eight and older, while the 2000-2018 plot used fish aged 13 and older. The estimate of total mortality (Z) was not very different between the two time periods, 0.37 for the earlier period and 0.36 for the later years. If restricted to the same ages (13 and older), the earlier period would have a steeper decline supporting higher mortality rates in the earlier period and suggesting estimates of $M$ are reasonable.

**Request No. 2: Remove the indices from the Southern fleets 7 and 11 from the model**

**Rationale:** These cover a small portion of the population and would not be expected to have the same trends as the majority of the population are in conflict with the northern trends, and there is no straightforward way to combine indices from the two separate regions.

**STAT Response:** The STAT removed the two fishery-dependent indices representing the portion of the stock south of Pt. Conception, the CDFW MRFSS-era dockside survey and the CDFW CRFS-era onboard observer survey index (Figure 48). There were minor changes to the model, with the total likelihood going from 515 to 511 and the estimate of natural mortality going from 0.212 to 0.219.

**Request No. 3: Add discard to commercial catch data in terms of both catch and compositions (by weighting comps by the number of fish discarded or retained), and remove selectivity time block. Apply discard rate back in time.**

**Rationale:** Simpler to have a single fleet for all commercial catch and the model is likely to better reflect the actual dynamics.

**STAT Response:** Response under Request #3a.

**Request No. 3a: Remove commercial length comp data from 2000-2003 in addition to request.**

**Rationale:** Length limit imposed in 2000 but length discards not available until 2004. Therefore, comp data from these years are not representative of total removals.

**STAT Response:** The STAT combined the catches from the commercial retained and commercial discard fleets, to create one commercial fleet representing both catch streams (Figure 49). The length composition data from the two fleets from 2004-2017 were combined by weighting the length compositions by the catches from each fleet. Compared to the pre-STAR base, the model run for request 3a, reduced the number of estimated parameters by 10, and resulted in a decrease in natural mortality to 0.195. The overall model output did not change from the base model or the changes made from Request #2. Nevertheless, the more appropriate treatment of the data in terms of the processes reflected in the model was deemed to be an improvement and was used in subsequent requests as the base model.

**Request No. 4: Split PISCO survey such that the 0-age fish (4 and 5 cm) are in one survey and the 15 cm+ fish are in the other. Fix age selectivity to age-0 only for the first fleet and use a logistic selectivity for the second fleet.**

**Rationale:** To separate out the recruitment index in the survey and to simplify the selectivity assumptions for this fleet.

**STAT Response:** Response under Request #4a.

**Request No. 4a: Include all years of the recruitment index developed above.**

**Rationale:** Years with low numbers of 4 and 5 cm fish indicate low recruitment and provide contrast to years with large numbers of those fish.

**STAT Response:** The STAT developed an index of abundance using only fish that were 5 cm or less and re-developed the length composition data for the PISCO survey representing fish 15 cm and larger. The effect of splitting the PISCO index into two indices, one for young of the year and one representing older fish resulted in dampening of the age-0 recruits seen in the previous models (Figure 50). This was seen as a weakness in the model due to high uncertainty in the estimates due to limited compositional evidence of such an extended period of improved recruitment. The appropriateness of the size cutoff was investigated further in Request 8.

**Request No. 5: Remove the autocorrelation recruitment.**

**Rationale:** Given the sensitivity run presented, auto correlation didn't make much of a difference in model results, and there was not adequate evidence in the data for autocorrelation.

**STAT Response:** Removing the autocorrelation in recruitment resulted in no significant change to the model output. There was little evidence for autocorrelation in recruitment in the stock or that it provided much in the way of stability to the model, it was therefore decided that the assessment should not implement this option.

**Request No. 6: 1) Start recruit deviation in 1978 as main recruit deviations and 2) Start these in 2001. Turn off all early recruit devs in both cases.**

**Rationale:** The composition data does not seem to be informing the estimates of the recruitment deviations but maybe driven by the artifacts in the catch data. The early recruit deviations are uninformed and all in one direction. Recruitment indices start in 2001.

**STAT Response:** Starting the recruitment deviations in 2001 did not produce a reasonable recruitment signal. Starting the recruitment deviations in 1978 provided reasonable recruitment deviations and is a more appropriate starting year given the lack of sufficient length data prior to this period.

**Request No. 7: Start from model shown at request 6(1). Fix M at 0.193 and let the model estimate k. Change the ramp to estimated level with up ramp from 1978 to 1979. Provide all appropriate diagnostics.**

**Rationale:** STAT and STAR agree 6(1) was an improvement over the original base model and the request refers to adjusting the ramp value and M treatment consistent with the way these were dealt with in the original the pre-STAR-base model given the new settings.

**STAT Response:** Requests 7 and 8 were conducted for comparison and the plots comparing the two requests are below Request 8. Fixing natural mortality at the mean of the prior results in an increase in the growth parameter $k$ from 0.145 to 0.147 from Request 6 due to the decrease in the modeled natural mortality rate and the observed correlation between estimated $M$ and $k$ values.

**Request No. 8: Determine if 6 cm or larger fish should be included in PISCO recruitment index. If so, update the PISCO index and include the updated index in the model from Request 7 (above).**

**Rationale:** Better to use all appropriate data for the recruitment index. The panel felt the splitting of the PISCO index had advantages based on the results from Request 4, but given the temporal variability in the survey over time wanted to ensure that the size cutoff included the majority of 0-group fish while minimizing the potential to include 1-group individuals.

**STAT Response:** After an email discussion with Mark Carr, Dan Malone (UCSC PISCO) and Darren Johnson (CSU Long Beach) it was decided that fish of length 6 cm at the end of the year of birth would still all be young of the year fish during the months in which the PISCO survey is conducted. Additional research could serve to verify the appropriate lengths to include, perhaps by month. The PISCO age-0 index developed for this request (including all fish size 4, 5, and 6 cm) resulted in a decrease in the recruitment index in the early 2000s, and an increase in the recruitment index in 2010 and from 2014-2018 relative to include only 4 and 5 cm individuals (Figure 51). The effects on spawning output of the revised PISCO age-0 index of abundance (8b), and a fix to an issue in the selectivity mirroring, and an additional correction that fixes the last year of bias adjustment to 2019 and not 2020 (8c) are shown in Figure 52. With natural mortality fixed at 0.193, the growth parameter $k$ is estimated at 0.114. The estimate of length at age-2 (L1) is 13.37, similar to the external estimates.

**Request No. 9: Mirror the DebWV_CPFV selectivity to the RecN selectivity. Fix the start logit parameter for the adult PISCO selectivity to zero. Investigate appropriate methods for modeling selectivity for CCFRP.**

**Rationale:** These will result in more appropriate and parsimonious treatment of selectivity.

**STAT Response:** The selectivity for the CCFRP index was also mirrored to the Recreational North fleet since the length compositions were not drastically different than the other fleets mirrored to the Recreational North fleet. The STAT could not find a domed selectivity pattern that had reasonable parameter estimates. The STAT also explored fitting asymptotic selectivity to the CCFRP index, but even when fixing the peak parameter to the upper bound, other parameters were not well estimated. Mirroring fleet selectivities was an advantage to the stability of the model.

**Request No. 10: Perform a drop one out analysis for the index fleets.**

**Rationale:** To investigate the influence each of these data sets on the model.

**STAT Response:** No single index had a substantial effect on the model output (Figure 53). Each index contributed to the status of the stock, with some indicating an increase over the base model developed for Request 9, and some estimating a decreased stock status. Depending on which index was dropped, the year(s) of high recruitment predicted in the early 1990s did shift, and was either attributed to a single year, or spread over a few years. The PISCO age-0 index does inform recruitment and age-0 recruitment is dampened in recent years when this index is excluded.

## 2.6 Post-STAR Base Case Model Results

post-star-base-case-model-results

The following description of the model results reflects a base model that incorporates all of the changes made during the STAR panel. A comparison of the pre-STAR base model and the post-STAR base model can be found in Figures 54, 55, and 56 and Table 26. A number of changes to the fleet structures, removal of surveys south of Point Conception, and the splitting of the PISCO index into two indices to better reflect life stages contributed to the changes. The final model also fixes natural mortality, whereas it was estimated in the pre-STAR base model. The pre-STAR base model includes and ageing error matrix that was developed using only half of the available double reads. The post-STAR base includes the updated ageing error matrix (Figure 57), and the update did not significantly change the model outputs. The remainder of the document referencing the base model (or base case) refers to the post-STAR base model.

The base model parameter estimates and their approximate asymptotic standard errors are shown in Table 24 and the likelihood components are in Table 27. Estimates of derived reference points and approximate 95% asymptotic confidence intervals are shown in Table e. Time-series of estimated stock size over time are shown in Table 28.

Steepness of the assumed Beverton-Holt stock-recruitment relationship was fixed at 0.72, and natural mortality was fixed at 0.193.

### 2.6.1 Convergence

convergence

Model convergence was determined by starting the minimization process from dispersed values of the maximum likelihood estimates to determine if the model found a better minimum. Jitter is a SS option that generates random starting values from a normal distribution logistically transformed into each parameter's range (Methot et al. 2019). This was repeated 300 times and the minimum was reached in 67% of the runs (Table 29). The model did not experience convergence issues, e.g., final gradient was below 0.0001, when reasonable starting values were used and there were no difficulties in inverting the Hessian to obtain estimates of variability. We did sensitivity runs for convergence by changing the phases for key estimated parameters; neither the total log-likelihood nor the parameter estimates changed.

### 2.6.2 Parameter Estimates

parameter-estimates

The base model produces estimates of growth parameters different from the external estimates (Figure 58). The external estimate of the von Bertalanffy growth coefficient $k$ was 0.247, whereas the internal estimate was much lower at 0.107. Using the Schnute parameterization with the age for L1 set at 2 and L2 at 23, the external estimates of lengths at Amin and Amax were similar at 13.80 and 28.22, respectively. The internal estimates of the lengths for Amin and Amax were 13.4 and 28.80, respectively. Given that natural mortality was fixed in the base model and natural mortality and the growth parameter $k$ are negatively correlated, the model estimated a slower rate of growth. A number of other factors including the length composition and selectivity affect the internal estimate of growth. Hence, growth was chosen as the axis of uncertainty for the decision table.

The estimated selectivities for all fleets within the model are shown in Figure 59. The selectivity curves for the commercial fleet, recreational fleets north and south of Point Conception, and the larger PISCO (15+ cm) were estimated. All of the selectivities are asymptotic except for the PISCO age-0 index, which has an age selectivity set to 1.0. All of the recreational indices and the CCFRP index selectivities were mirrored to the recreational fleet north of Point Conception. Attempts to fit asymptotic and dome-shaped selectivity to the CCFRP data resulted in poor estimation, large standard deviations, or a lack of fit to the data. The aggregated CCFRP length composition over time was similar to the length composition data of the recreational fleets north of Point Conception and mirroring the CCFRP selectivity provided a more parsimonious model.

The recreational fleet south of Point Conception encounters smaller GBYR, which is reflected in the asymptotic selectivity shifted to the left of all other fleets. Selectivities for the recreational fleet north of Point Conception and the commercial fleet are very similar. Both fleets include length composition of retained and discarded fish, although no information on the size of discards is available from the commercial fleet prior to 2004.

The selectivity for the commercial fleet was kept separate because the fleet has different fishing behavior than the recreational fleet and going forward in time, may diverge further from the fleets depending on management decisions or changes in fishing behavior.

Selectivity for the PISCO (15+ cm fish) index was estimated as the survey observes a wider range of length classes than the other fleets. The estimated peak of the PISCO selectivity hit the upper bound of 38 and was fixed at 38 in the base model. The age selectivity for the PISCO age-0 index was fixed at 1.0 and assumes that all age-0 fish are selected.

The additional survey variability (process error added directly to each year's input variability) for all surveys except the recreational dockside index north of Point Conception (RecDockside-North) and the PISCO age-0 index, was estimated within the model. The added variance for Deb's onboard observer survey was estimated at 0.06. The added variances were highest for the recreational onboard observer survey north of Point Conception (0.237), PISCO (0.152), and CCFRP (0.212).

Recruitment deviations were estimated from 1978-2018 (Figure 60). Estimates of recruitment suggest that GBYR are characterized by cyclical years of high and low recruitment (Figure 61). The final base model does not include early recruitment deviation and a steep bias adjustment ramp from 1978 to 1979 of 0.32 that extends to 2019 (Figure 62). The years of highest estimated recruitment is 1991, with recruitment estimated more than double that of any other year. Fish from this cohort can be observed in the length composition data from Deb Wilson Vandenberg's onboard observer survey and recreational fleet north of Point Conception in the later half of the 1990s. Additional periodic recruitment events are estimated from 1994 and onward, with the peaks from 2001 and on driven by the PISCO age-0 index. A period of below average recruitment was estimated from 2004-2013, with another high recruitment pulse from 2014-2015.

The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 63. The stock has not been depleted to a low enough level that would inform the estimation of steepness. Steepness was not estimated in this model, and profiles over steepness values are discussed below.

### 2.6.3 Fits to the Data

fits-to-the-data

Model fits to the indices of abundance, fishery length composition, survey length composition, and conditional age-at-length observations are all discussed below. The full r4ss plotting output is available in the supplementary material.

The fits to the three fishery-dependent and three fishery-independent survey indices are shown in Figures 64, 65, 66, 67, 68, and 69. All indices represent the area north of Point Conception only, and not all of these were fit well by the assessment model. The MRFSS CPFV recreational dockside survey index north of Point Conception spanning the 1980s-1990s was fit well by the model without added variance, but relatively flat, and is not a very informative index. The index for Deb Wilson-Vandenberg's CPFV onboard observer survey spanning 1988-1998 was well fit and indicates an increase in relative abundance in the last year of the survey. The current recreational CDFW/Cal Poly onboard observer survey north of Point Conception from 2001-2018 was relatively well fit, except for the decline suggested 2013 and 2014. The increase in relative abundance observed in 2018 was not fit by the model, even with the added variance. The variance added to this survey was the highest for all indices.

The model did not capture the contrast in the PISCO index for 15+ cm fish, fitting a decline to the time series from 2010 to 2018, when the index suggests an increase from 2010 to 2013 and another increase after a decline in 2016. The model does capture the PISCO age-0 index without added variance. A number of years, e.g., 2004-2008, were marked by low relative abundance of age-0 GBYR and have larger standard errors. The years with lower relative abundance were not captured by the model, but fit to the upper bound of the input standard error. The increases in age-0 GBYR in 2001, 2001, 2014-2015 and 2017 were captured in the model fit.

The model was not able to capture the trends observed in the fishery-independent CCFRP hook-and-line survey. The index suggested the same depressed relative abundance in 2013 as the fishery-dependent CRFS/Cal Poly onboard observer survey, that was also not captured here by the fit. The increasing trends in abundance from 2016-2018 was also not captured by the model fit, and the fit suggests a declining trend over the entire time series from 2007-2018.

The base model was re-weighted twice using Francis weights for the length and age composition data. Fits to the length data are shown based on the proportions of lengths observed by year and the Pearson residuals-at-length for all fleets. Detailed fits to the length data by year and fleet are provided in Appendix C. Aggregate fits by fleet are shown in Figure 70. Overall, the length composition all fit well. The PISCO fleet has the noisiest of all the length composition data, but on an annual basis, the length data were relatively well fit. The fit to the aggregated CCFRP data suggests the model expects to see additional larger fish, which is likely due to the mirroring of the selectivity. However, on an annual basis, there is a trade-off with the CCFRP with under-fitting of the larger fish in the earlier years and an under-fitting of the smaller fish expected in the later years (2013-2018).

The mean age of the recreational fleet varied from 1980-1986 ranged from approximately 8-11 years old, and increased in 2017 to approximately 13 years old (Figure 71). The conditional age data from the CCFRP data was not well fit for the earliest years in the data, but was reasonably well fit for the last four years of data (Figure 72). The conditional age composition data from the 'dummy' fleet was well fit, although heavily down-weighted. Age data in this fleet are from a number of sources and sampling programs (Figure 73).

### 2.6.4 Retrospective Analysis

retrospective-analysis

A 4-year retrospective analysis was conducted by running the model using data only through 2017 (Retro1), 2016 (Retro2), 2015 (Retro3), and 2014 (Retro4) (Table 30). The initial population size and estimation of trends in spawning biomass in the retrospective runs were lower than the base model, except for Retro1 (Figure 74). All retrospective runs followed the same general trend, with the differences in the trends stemming from the change in recruitment deviations (Figure 75). The PISCO age-0 index has a signal of increased recruitment in the most recent years. For Retro2, Retro3, and Retro4, the trends in recruitment are not observed by the model. There is no conditional age-at-length composition data for 2015-2016, leading to the minor change in the age composition likelihood from Retro2 to Retro3 and Retro4 (Table 30). The age composition data in 2017 accounts for 2.5% of all available ages, and 4.5% of all fish aged were from 2018. The available length data in each year from 2015-2018 range from 4-6% of the total available length data. The length compositions of all the other fleets have similar length distributions for 2015-2018 (Appendix C). Additional investigations into the retrospective patterns will be made by the STAT.

### 2.6.5 Likelihood Profiles

likelihood-profiles

Likelihood profiles were conducted for $R_0$, steepness, and over natural mortality values separately with the post-STAR base. These likelihood profiles were conducted by fixing the parameter at specific values and estimated the remaining parameters based on the fixed parameter value (Tables 31-32).

In regards to values of $R_0$, the negative log-likelihood was minimized at approximately $\log(R_0)$ of 8.0 (Table 31 and Figure 77). In terms of likelihood components, only the index data minimize at the upper bound, while the other components minimize between 8.0 and 8.1. The individual surveys tend to minimize at the upper bound or just below, while the length composition data has conflicting trends, e.g., CCFRP and commercial fleets minimize at the upper bound while the recreational north fleet minimizes at the lower bound (Figures 78-76). The majority of data all consistently minimize around 8. Over the range of values of $R_0$, depletion ranged from 0.38-0.59 (Figure 79).

For steepness, the negative log-likelihood reaches a minimum around a steepness near the upper bound of 1.0 (Figures 80-81 and Table 31). The length composition likelihood components declined towards the upper bound for Deb's onboard CPFV survey and the recreational north fleet, while the other fleets either reached a minimum around 0.55 or at the lower bound (Figure 82). Overall changes in the survey likelihood across the range of steepness was less than 2.0, with surveys either minimized at the lower or upper bound (Figure 83). The relative depletion for GBYR ranges from 0.375 to 0.493 across different assumed values of steepness (Table 31).

The negative log-likelihood was minimized at a natural mortality value around 0.21, slightly higher than the prior of 0.193 (Table 32 and Figure 84). The age, length, index, and prior likelihood contributions were minimized at natural mortality values around 0.22, and the recruitment contribution was minimized at the upper bound (Table 32). The length composition minimizes around a natural mortality value of 0.14, with the commercial, recreational fleet north of Point Conception, and CCFRP data minimizing towards the lower bound (Figure 85). The length data from Deb's CPFV survey minimizes around 0.22, while the PISCO and recreational length compositions south of Point Conception minimize at the upper bound. The PISCO and CCFRP surveys minimized around a natural mortality value of 0.22, while the PISCO age-0 and overall survey likelihood minimized at the upper bound of 0.3 (Figure 86). The relative depletion for GBYR ranged from 0.32-0.59 across alternative values of natural mortality (Figure 87).

A profile over the growth parameter $k$ from 0.07 to 0.25 (with natural mortality fixed at 0.193) log-likelihood minimized at 0.11 (Table 32 and Figure 88). The total change in the negative log-likelihood is small until $k$ increases higher than 0.15. The combined age data minimize at a higher value of 0.18, while the remaining components minimize at the lower bound. The age composition by fleet also has conflicting trends with the dummy fleet minimizing just lower than the over all around 0.17, the CCFRP ages minimizing at the lower bound and the RecNorth ages minimizing at the upper bound (Figure 89). The RecOnboardNorth survey likelihood component was the only survey component minimized at the upper bround, with the remaining survey component minimized at the lower bound of the $k$ values explored (Figure 90). The resulting 2019 depletion over the range of $k$ values spans 0.4 to 0.49 (Figure 91).

### 2.6.6 Reference Points

`reference-points-1`

Reference points were calculated using the estimated selectivities and catch distribution among fleets in the most recent year of the model, 2018. Sustainable total yield (landings plus discards) were 134 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95% confidence interval of 116 mt based on estimates of uncertainty. The spawning biomass equivalent to 40% of the unfished level ($SB_{40\%}$) was 504 mt.

The predicted spawning output from the base model shows an initial decline starting the 1950s, is then stable, and declines steeply until 1995 (Figure 92).
The spawning output then rapidly increases through the early 2000s, and has been in a decline since 2006.

The 2018 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished levels (Figure 93). The relative fishing intensity, $(1 - SPR)/(1 - SPR_{50\%})$, was above the management target in 1987 and from 1992-1996. The stock has been below the management target since 1997.

Table e shows the full suite of estimated reference points for the base model and Figure 94 shows the equilibrium curve based on a steepness value fixed at 0.72.

# 3 Harvest Projections and Decision Tables

`harvest-projections-and-decision-tables`

The forecasts of stock abundance and yield were developed using the post-STAR base model, with the forecasted projections of the OFL presented in Table g. The total catches in 2019 and 2020 are set to the projected catch from the California Department of Fish and Wildlife (CDFW) of 114 mt.

Uncertainty in the forecasts is based upon the three states of nature agreed upon at the STAR panel and are based three states of nature of growth. The external estimate of growth was different than the internal Stock Synthesis estimate. Given that natural mortality is fixed in the post-STAR base model, and the growth parameter $k$ is negatively correlated with natural mortality, $k$ was chosen as the axis of uncertainty. The high state of nature fixes $k$ at the external estimate, and the low state of nature is the same distance in log space from the base as the high state of nature. The low state of nature fixed $k$ at 0.046 and the L1 and L1 parameters were estimated at 14.1 and 30.6, respectively. The high state of nature fixed all growth parameters, $k = 0.248$, L1 = 13.8, and L2 = 28.5 to the external estimate of growth (due to improbable estimates of L1 and L2 if only $k$ was fixed to the external estimate). The growth parameters in the base model were estimated as $k = 0.107$, L1 = 13.4, and L2 = 28.8.

The forecasted buffer ramp was calculated assuming a category 2 stock, with sigma = 1.0 and a $p^* = 0.45$. The buffer ranges from 0.874 in 2021 ramping to 0.803 in 2030. For reference, the model predicted sigma is 0.189 and the decision table-based sigma is 0.197. Current medium-term forecasts based on the alternative states of nature project that the stock will remain above the target threshold of 40% for all but two scenarios (Table h). The low state of nature with the high catches results in a stock at 26.4% of unfished in 2030 and the base state model with the high catches results in a stock at 33.2% of unfished in 2030. The base case model with the base catches results in an increasing stock over the period from 2021-2030. If the growth of GBYR is slower than the base model suggests, but the base case catches are removed, the stock will be at the target threshold in 2030.

# 4 Regional Management Considerations

`regional-management-considerations`

While the proportion of the stock residing within U.S. waters is unknown, the assessment provides an adequate geographic representation of the portion assessed for management purposes. There is little evidence that black-and-yellow rockfish extend into Mexico, and the proportion of gopher rockfish residing south of Pt. Conception is small. While there has been work on the genetic structure between the two species, there has not been work done within each species to inform spatial structure of the populations. Given the relatively small area in the waters of California where these species occur, there is relatively little concern regarding exploitation in proportion to the regional distribution of abundance in the area assessed in this study.

The state of California implements regional management for the recreational fleet in the form of five regions, referred to as management areas with differing depth and season restrictions. Neither gopher nor black-and-yellow rockfish are a large component of the total recreational landings and are managed as part of the nearshore rockfish complex. Current regional management appears appropriate for these species.

# 5 Research Needs

`research-needs`

We recommend the following research be conducted before the next assessment:

1. Investigate the structure of complex and contribution of each species to the GBYR complex. Investigate possible spatial differences in biological parameters within a single species and also between the two species. Little biological data for south of Point Conception or north of Point Arena were available for this assessment and is needed to better under biological parameters.
   (a) Conduct life history studies
   (b) Conduct research to identify the proportion of each species in population and in catches
2. Take a closer look at the Ralston (Ralston et al. 2010) historical catch reconstruction for gopher and black-and-yellow rockfishes. The recreational catch reconstruction for gopher rockfish south of Point Conception was an order of magnitude higher than expected when extracted for this assessment.
3. Refine the PISCO survey data and analysis to better identify age-0 fish in each month of survey. Occasional sampling during all months of the year would better help identify the length distribution of fish classified as age-0. This is the only recruitment index available for gopher and black-and-yellow rockfish. If possible, age data should be collected from the PISCO survey to aid in determining the growth of young gopher and black-and-yellow rockfish, and larger black-and-yellow rockfish.
4. Refine CCFRP survey index to look at alternative possible model structures, including a hierarchical structure and random effects. Limited time did not allow for these explorations during this assessment cycle. It is also strongly recommended to continue the coastwide sampling of the CCFRP program that began in 2017, as well as the collection of biological samples for nearshore rockfish species. The CCFRP survey is the only fishery-independent survey available for nearshore rockfish sampling the nearshore rocky reef habitats. As of this assessment, only two years of coastwide data are available, and the index was limited to the site in central California that have been monitored since 2007.

5. Collection of length and age data are recommended for both the commercial and recreational fisheries. Very little age data are available from either fishery for gopher rockfish and none for black-and-yellow rockfish.

6. Data collection and coordination across Research Recommendations 1-5 is needed to improve the efficacy of data collection and ensure that samples are representative of the data sources and the fisheries. For example, the conditional age-at-length data in the dummy fleet represent a number of sampling techniques, areas sampled, and selectivities. Better coordination of research efforts will allow the age data to be better utilized by the assessment. Sampling of the commercial and recreational fleets by area in proportion to the length distribution of fish observed will also allow the model to better fit selectivity patterns and avoid possible patterns in the length and age composition residuals.

7. Investigate possible environmental drivers/co-variates for biological parameters, particularly for recruitment.

8. Examine the CFRS angler interview data for the recreational private/rental mode to create a "trip" based identifier or catch and effort. This will enable the creation of an index of abundance for the private/rental mode as well as investigate if selectivity for this mode differs from the party/charter mode.

9. Resolve differences between CalCOM and PacFIN expanded length composition data sets.

# 6 Acknowledgments

`acknowledgments`

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# 7 Tables

tables

Table 1: Commercial landings and discards (mt) from the commercial fisheries. Data sources are the California Catch Reconstruction, CALCOM, PacFIN, and WCGOP GEMM report.

| Year | Landings | Discards | Total Commercial Removals | Source |
|---|---|---|---|---|
| 1916 | 3.88 | 0.38 | 4.27 | Catch Reconstruction |
| 1917 | 6.03 | 0.59 | 6.63 | Catch Reconstruction |
| 1918 | 7.06 | 0.69 | 7.75 | Catch Reconstruction |
| 1919 | 4.91 | 0.48 | 5.39 | Catch Reconstruction |
| 1920 | 5.01 | 0.49 | 5.50 | Catch Reconstruction |
| 1921 | 4.13 | 0.41 | 4.54 | Catch Reconstruction |
| 1922 | 3.56 | 0.35 | 3.90 | Catch Reconstruction |
| 1923 | 3.84 | 0.38 | 4.22 | Catch Reconstruction |
| 1924 | 2.22 | 0.22 | 2.44 | Catch Reconstruction |
| 1925 | 2.78 | 0.27 | 3.05 | Catch Reconstruction |
| 1926 | 4.48 | 0.44 | 4.92 | Catch Reconstruction |
| 1927 | 3.81 | 0.37 | 4.18 | Catch Reconstruction |
| 1928 | 4.60 | 0.45 | 5.06 | Catch Reconstruction |
| 1929 | 3.81 | 0.37 | 4.18 | Catch Reconstruction |
| 1930 | 5.40 | 0.53 | 5.93 | Catch Reconstruction |
| 1931 | 1.93 | 0.19 | 2.11 | Catch Reconstruction |
| 1932 | 6.24 | 0.61 | 6.85 | Catch Reconstruction |
| 1933 | 2.58 | 0.25 | 2.84 | Catch Reconstruction |
| 1934 | 1.75 | 0.17 | 1.92 | Catch Reconstruction |
| 1935 | 0.43 | 0.04 | 0.47 | Catch Reconstruction |
| 1936 | 0.01 | 0.00 | 0.01 | Catch Reconstruction |
| 1937 | 7.27 | 0.71 | 7.98 | Catch Reconstruction |
| 1938 | 10.29 | 1.01 | 11.30 | Catch Reconstruction |
| 1939 | 13.13 | 1.29 | 14.42 | Catch Reconstruction |
| 1940 | 16.90 | 1.66 | 18.56 | Catch Reconstruction |
| 1941 | 17.06 | 1.67 | 18.73 | Catch Reconstruction |
| 1942 | 8.55 | 0.84 | 9.38 | Catch Reconstruction |
| 1943 | 11.00 | 1.08 | 12.08 | Catch Reconstruction |
| 1944 | 0.05 | 0.00 | 0.05 | Catch Reconstruction |
| 1945 | 0.59 | 0.06 | 0.65 | Catch Reconstruction |
| 1946 | 16.71 | 1.64 | 18.35 | Catch Reconstruction |
| 1947 | 26.71 | 2.62 | 29.33 | Catch Reconstruction |
| 1948 | 23.95 | 2.35 | 26.30 | Catch Reconstruction |
| 1949 | 18.29 | 1.79 | 20.09 | Catch Reconstruction |
| 1950 | 17.15 | 1.68 | 18.83 | Catch Reconstruction |
| 1951 | 24.83 | 2.44 | 27.26 | Catch Reconstruction |

*Continues next page*

tab:CommCatches

Table 1: Commercial landings and discards (mt) from the commercial fisheries. Data sources are the California Catch Reconstruction, CALCOM, PacFIN, and WCGOP GEMM report.

| Year | Landings | Discards | Total Commercial Removals | Source |
|---|---|---|---|---|
| 1952 | 27.59 | 2.71 | 30.29 | Catch Reconstruction |
| 1953 | 32.30 | 3.17 | 35.47 | Catch Reconstruction |
| 1954 | 40.75 | 4.00 | 44.74 | Catch Reconstruction |
| 1955 | 29.49 | 2.89 | 32.38 | Catch Reconstruction |
| 1956 | 40.66 | 3.99 | 44.65 | Catch Reconstruction |
| 1957 | 37.52 | 3.68 | 41.20 | Catch Reconstruction |
| 1958 | 33.56 | 3.29 | 36.86 | Catch Reconstruction |
| 1959 | 19.62 | 1.92 | 21.54 | Catch Reconstruction |
| 1960 | 11.30 | 1.11 | 12.41 | Catch Reconstruction |
| 1961 | 17.49 | 1.72 | 19.20 | Catch Reconstruction |
| 1962 | 27.18 | 2.67 | 29.85 | Catch Reconstruction |
| 1963 | 22.29 | 2.19 | 24.48 | Catch Reconstruction |
| 1964 | 16.55 | 1.62 | 18.17 | Catch Reconstruction |
| 1965 | 21.50 | 2.11 | 23.61 | Catch Reconstruction |
| 1966 | 13.44 | 1.32 | 14.76 | Catch Reconstruction |
| 1967 | 6.70 | 0.66 | 7.36 | Catch Reconstruction |
| 1968 | 8.29 | 0.81 | 9.10 | Catch Reconstruction |
| 1969 | 9.99 | 0.98 | 10.97 | CALCOM |
| 1970 | 14.21 | 1.39 | 15.60 | CALCOM |
| 1971 | 14.41 | 1.41 | 15.83 | CALCOM |
| 1972 | 19.42 | 1.91 | 21.33 | CALCOM |
| 1973 | 31.43 | 3.08 | 34.51 | CALCOM |
| 1974 | 33.41 | 3.28 | 36.69 | CALCOM |
| 1975 | 33.08 | 3.25 | 36.33 | CALCOM |
| 1976 | 33.90 | 3.33 | 37.23 | CALCOM |
| 1977 | 30.13 | 2.96 | 33.09 | CALCOM |
| 1978 | 43.41 | 4.26 | 47.67 | CALCOM |
| 1979 | 34.24 | 3.36 | 37.60 | CALCOM |
| 1980 | 63.65 | 6.24 | 69.89 | CALCOM |
| 1981 | 52.71 | 5.17 | 57.87 | PacFIN |
| 1982 | 38.97 | 3.82 | 42.79 | PacFIN |
| 1983 | 28.67 | 2.64 | 31.30 | PacFIN |
| 1984 | 16.74 | 1.45 | 18.20 | PacFIN |
| 1985 | 8.54 | 0.83 | 9.37 | PacFIN |
| 1986 | 25.16 | 2.50 | 27.66 | PacFIN |
| 1987 | 34.05 | 3.36 | 37.40 | PacFIN |
| 1988 | 54.98 | 5.47 | 60.44 | PacFIN |
| 1989 | 45.22 | 4.46 | 49.68 | PacFIN |

*Continues next page*

tab:CommCatches

Table 1: Commercial landings and discards (mt) from the commercial fisheries. Data sources are the California Catch Reconstruction, CALCOM, PacFIN, and WCGOP GEMM report.

| Year | Landings | Discards | Total Commercial Removals | Source |
|---|---|---|---|---|
| 1990 | 46.08 | 4.59 | 50.67 | PacFIN |
| 1991 | 67.98 | 6.75 | 74.73 | PacFIN |
| 1992 | 83.91 | 8.24 | 92.15 | PacFIN |
| 1993 | 73.43 | 7.27 | 80.70 | PacFIN |
| 1994 | 54.84 | 5.89 | 60.74 | PacFIN |
| 1995 | 91.10 | 8.97 | 100.07 | PacFIN |
| 1996 | 95.08 | 9.29 | 104.37 | PacFIN |
| 1997 | 69.99 | 6.81 | 76.80 | PacFIN |
| 1998 | 65.29 | 6.40 | 71.70 | PacFIN |
| 1999 | 62.65 | 6.15 | 68.80 | PacFIN |
| 2000 | 54.44 | 5.29 | 59.72 | PacFIN |
| 2001 | 53.76 | 5.24 | 59.00 | PacFIN |
| 2002 | 42.64 | 4.15 | 46.79 | PacFIN |
| 2003 | 21.08 | 13.04 | 34.12 | PacFIN & WCGOP |
| 2004 | 26.25 | 2.66 | 28.91 | PacFIN & WCGOP |
| 2005 | 28.67 | 3.33 | 31.99 | PacFIN & WCGOP |
| 2006 | 24.05 | 4.10 | 28.15 | PacFIN & WCGOP |
| 2007 | 30.36 | 4.50 | 34.87 | PacFIN & WCGOP |
| 2008 | 36.22 | 1.63 | 37.85 | PacFIN & WCGOP |
| 2009 | 35.62 | 5.38 | 40.99 | PacFIN & WCGOP |
| 2010 | 38.83 | 3.92 | 42.75 | PacFIN & WCGOP |
| 2011 | 42.39 | 5.72 | 48.12 | PacFIN & WCGOP |
| 2012 | 33.55 | 1.93 | 35.48 | PacFIN & WCGOP |
| 2013 | 33.45 | 2.85 | 36.31 | PacFIN & WCGOP |
| 2014 | 36.40 | 2.85 | 39.24 | PacFIN & WCGOP |
| 2015 | 43.25 | 2.93 | 46.18 | PacFIN & WCGOP |
| 2016 | 36.96 | 2.42 | 39.38 | PacFIN & WCGOP |
| 2017 | 42.04 | 1.65 | 43.68 | PacFIN & WCGOP |
| 2018 | 47.00 | 2.54 | 49.54 | PacFIN & WCGOP |

Table 2: Length composition sample sizes for fishery dependent data. Continuous years begin in 1975. Recreational north samples include Karpov et al., MRFSS, and CRFS data. Recreational south samples include Karpov et al., Collins and Crooke unpub., Ally et al. 1991, MRFSS, and CRFS data.

tab:length_samples_fishery

| | CALCOM | | WCGOP | | Rec North | | Rec South | | Deb WV | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Trips | Lengths | Trips | Lengths | Trips | Lengths | Trips | Lengths | Trips | Lengths |
| 1959 | | | | | 27 | 271 | 2.10 | 21 | | |
| 1960 | | | | | 39 | 394 | 1.40 | 14 | | |
| 1961 | | | | | 1 | 8 | 0.10 | 1 | | |
| 1966 | | | | | 1 | 7 | | | | |
| 1975 | | | | | | | 50.00 | 159 | | |
| 1976 | | | | | | | 73.00 | 224 | | |
| 1977 | | | | | | | 96.00 | 392 | | |
| 1978 | | | | | | | 91.00 | 533 | | |
| 1979 | | | | | | | | | | |
| 1980 | | | | | 4 | 164 | 21.00 | 53 | | |
| 1981 | | | | | 1 | 19 | 30.00 | 100 | | |
| 1982 | | | | | 1 | 50 | 17.00 | 58 | | |
| 1983 | | | | | 6 | 323 | 60.00 | 170 | | |
| 1984 | | | | | 14 | 849 | 42.00 | 150 | | |
| 1985 | | | | | 35 | 1027 | 34.00 | 180 | | |
| 1986 | | | | | 36 | 826 | 126.00 | 362 | | |
| 1987 | 2 | 82 | | | 28 | 392 | 131.00 | 529 | 14 | 73 |
| 1988 | | | | | 30 | 303 | 110.00 | 410 | 54 | 664 |
| 1989 | | | | | 19 | 303 | 111.00 | 436 | 70 | 727 |
| 1990 | | | | | | | | | 17 | 109 |
| 1991 | | | | | | | | | 38 | 722 |
| 1992 | 56 | 671 | | | | | | | 55 | 838 |
| 1993 | 148 | 1648 | | | 14 | 1094 | 8.00 | 24 | 75 | 614 |
| 1994 | 170 | 1379 | | | 12 | 608 | 1.00 | 15 | 86 | 735 |
| 1995 | 174 | 1523 | | | | | | | 90 | 1171 |
| 1996 | 256 | 3270 | | | 74 | 607 | 14.00 | 32 | 100 | 1364 |
| 1997 | 140 | 1319 | | | 95 | 1424 | 7.00 | 23 | 107 | 1415 |
| 1998 | 206 | 2549 | | | 89 | 614 | 19.00 | 66 | 83 | 1048 |
| 1999 | 251 | 3283 | | | 49 | 1112 | 33.00 | 301 | | |
| 2000 | 384 | 4918 | | | 21 | 695 | 12.00 | 58 | | |
| 2001 | 142 | 2179 | | | 46 | 929 | 14.00 | 35 | | |
| 2002 | 59 | 870 | | | 58 | 1656 | 22.00 | 65 | | |
| 2003 | 55 | 625 | | | 72 | 1690 | 15.00 | 100 | | |
| 2004 | 63 | 770 | 72 | 572 | 19 | 2023 | 3.00 | 42 | | |
| 2005 | 72 | 700 | 42 | 260 | 30 | 3217 | 8.00 | 93 | | |
| 2006 | 31 | 478 | 42 | 266 | 35 | 3737 | 9.00 | 106 | | |
| 2007 | 80 | 1165 | 37 | 268 | 30 | 3200 | 10.00 | 126 | | |
| 2008 | 46 | 503 | 12 | 46 | 39 | 4165 | 11.00 | 132 | | |
| 2009 | 73 | 854 | 22 | 263 | 43 | 4612 | 15.00 | 184 | | |
| 2010 | 75 | 925 | 37 | 344 | 47 | 4992 | 16.00 | 192 | | |
| 2011 | 61 | 858 | 68 | 366 | 44 | 4692 | 22.00 | 270 | | |
| 2012 | 57 | 709 | 69 | 302 | 46 | 4904 | 89.00 | 1081 | | |
| 2013 | 48 | 581 | 56 | 348 | 40 | 4339 | 77.00 | 930 | | |
| 2014 | 15 | 184 | 62 | 388 | 44 | 4746 | 49.00 | 595 | | |
| 2015 | 48 | 578 | 93 | 521 | 54 | 5789 | 36.00 | 436 | | |
| 2016 | 77 | 928 | 56 | 317 | 58 | 6265 | 37.00 | 444 | | |
| 2017 | 67 | 1581 | 49 | 226 | 44 | 4691 | 39.00 | 478 | | |
| 2018 | 67 | 1210 | | | 33 | 3563 | 26.00 | 317 | | |

Table 3: Recreational removals (mt) of GBYR. Data sources are the California Catch Reconstruction (modified for south of Pt. Conception), MRFSS (modified for 1981-1982), and CRFS.

| Year | North of Pt. Conception | South of Pt. Conception | Total Recreational Removals | Source |
|---|---|---|---|---|
| 1928 | 0.84 | 0.02 | 0.85 | Catch Reconstruction |
| 1929 | 1.67 | 0.03 | 1.70 | Catch Reconstruction |
| 1930 | 1.92 | 0.05 | 1.97 | Catch Reconstruction |
| 1931 | 2.56 | 0.06 | 2.62 | Catch Reconstruction |
| 1932 | 3.20 | 0.08 | 3.28 | Catch Reconstruction |
| 1933 | 3.84 | 0.09 | 3.93 | Catch Reconstruction |
| 1934 | 4.48 | 0.11 | 4.59 | Catch Reconstruction |
| 1935 | 5.12 | 0.12 | 5.24 | Catch Reconstruction |
| 1936 | 5.76 | 0.22 | 5.98 | Catch Reconstruction |
| 1937 | 6.82 | 0.31 | 7.14 | Catch Reconstruction |
| 1938 | 6.71 | 0.41 | 7.12 | Catch Reconstruction |
| 1939 | 5.87 | 0.50 | 6.37 | Catch Reconstruction |
| 1940 | 8.45 | 0.60 | 9.05 | Catch Reconstruction |
| 1941 | 7.81 | 0.69 | 8.51 | Catch Reconstruction |
| 1942 | 4.15 | 0.79 | 4.94 | Catch Reconstruction |
| 1943 | 3.97 | 0.88 | 4.85 | Catch Reconstruction |
| 1944 | 3.26 | 0.98 | 4.24 | Catch Reconstruction |
| 1945 | 4.35 | 1.07 | 5.42 | Catch Reconstruction |
| 1946 | 7.48 | 1.17 | 8.65 | Catch Reconstruction |
| 1947 | 5.92 | 1.26 | 7.18 | Catch Reconstruction |
| 1948 | 11.81 | 1.36 | 13.17 | Catch Reconstruction |
| 1949 | 15.30 | 1.45 | 16.76 | Catch Reconstruction |
| 1950 | 18.65 | 1.55 | 20.20 | Catch Reconstruction |
| 1951 | 22.97 | 1.64 | 24.61 | Catch Reconstruction |
| 1952 | 19.99 | 1.74 | 21.73 | Catch Reconstruction |
| 1953 | 17.02 | 1.83 | 18.85 | Catch Reconstruction |
| 1954 | 21.16 | 1.93 | 23.09 | Catch Reconstruction |
| 1955 | 25.23 | 2.02 | 27.25 | Catch Reconstruction |
| 1956 | 28.17 | 2.12 | 30.28 | Catch Reconstruction |
| 1957 | 31.80 | 2.21 | 34.01 | Catch Reconstruction |
| 1958 | 48.15 | 2.31 | 50.46 | Catch Reconstruction |
| 1959 | 38.25 | 2.40 | 40.65 | Catch Reconstruction |
| 1960 | 28.66 | 2.50 | 31.15 | Catch Reconstruction |
| 1961 | 27.74 | 2.59 | 30.33 | Catch Reconstruction |
| 1962 | 28.04 | 2.69 | 30.73 | Catch Reconstruction |
| 1963 | 27.53 | 2.78 | 30.32 | Catch Reconstruction |
| 1964 | 21.73 | 2.88 | 24.61 | Catch Reconstruction |

*Continues next page*

Table 3: Recreational removals (mt) of GBYR. Data sources are the California Catch Reconstruction (modified for south of Pt. Conception), MRFSS (modified for 1981-1982), and CRFS. tab:Rec_removal

| Year | North of Pt. Conception | South of Pt. Conception | Total Recreational Removals | Source |
|---|---|---|---|---|
| 1965 | 31.10 | 2.97 | 34.07 | Catch Reconstruction |
| 1966 | 33.85 | 3.07 | 36.91 | Catch Reconstruction |
| 1967 | 37.08 | 3.16 | 40.25 | Catch Reconstruction |
| 1968 | 36.78 | 3.26 | 40.03 | Catch Reconstruction |
| 1969 | 31.46 | 3.35 | 34.81 | Catch Reconstruction |
| 1970 | 41.25 | 3.45 | 44.70 | Catch Reconstruction |
| 1971 | 31.18 | 3.54 | 34.72 | Catch Reconstruction |
| 1972 | 41.50 | 3.64 | 45.13 | Catch Reconstruction |
| 1973 | 50.02 | 3.73 | 53.75 | Catch Reconstruction |
| 1974 | 51.60 | 3.83 | 55.43 | Catch Reconstruction |
| 1975 | 49.01 | 3.92 | 52.93 | Catch Reconstruction |
| 1976 | 49.30 | 4.02 | 53.32 | Catch Reconstruction |
| 1977 | 41.99 | 4.11 | 46.10 | Catch Reconstruction |
| 1978 | 32.57 | 4.21 | 36.77 | Catch Reconstruction |
| 1979 | 36.23 | 4.30 | 40.53 | Catch Reconstruction |
| 1980 | 80.56 | 4.54 | 85.10 | MRFSS |
| 1981 | 81.32 | 1.42 | 82.74 | Estimated |
| 1982 | 82.08 | 0.90 | 82.99 | Estimated |
| 1983 | 82.85 | 3.29 | 86.14 | MRFSS |
| 1984 | 150.47 | 5.58 | 156.05 | MRFSS |
| 1985 | 158.34 | 5.74 | 164.08 | MRFSS |
| 1986 | 171.81 | 6.52 | 178.33 | MRFSS |
| 1987 | 118.51 | 5.78 | 124.29 | MRFSS |
| 1988 | 79.43 | 4.80 | 84.23 | MRFSS |
| 1989 | 66.61 | 3.57 | 70.19 | MRFSS |
| 1990 | 82.33 | 2.73 | 85.06 | MRFSS |
| 1991 | 98.04 | 1.89 | 99.93 | MRFSS |
| 1992 | 113.76 | 1.04 | 114.80 | MRFSS |
| 1993 | 127.71 | 1.97 | 129.68 | MRFSS |
| 1994 | 97.39 | 3.03 | 100.42 | MRFSS |
| 1995 | 49.25 | 1.19 | 50.44 | MRFSS |
| 1996 | 38.06 | 5.23 | 43.28 | MRFSS |
| 1997 | 38.15 | 2.84 | 40.99 | MRFSS |
| 1998 | 43.55 | 2.52 | 46.07 | MRFSS |
| 1999 | 48.17 | 10.45 | 58.61 | MRFSS |
| 2000 | 66.53 | 4.39 | 70.92 | MRFSS |
| 2001 | 106.23 | 3.29 | 109.53 | MRFSS |

*Continues next page*

Table 3: Recreational removals (mt) of GBYR. Data sources are the California Catch Reconstruction (modified for south of Pt. Conception), MRFSS (modified for 1981-1982), and CRFS. tab:Rec_removal

| Year | North of Pt. Conception | South of Pt. Conception | Total Recreational Removals | Source |
|---|---|---|---|---|
| 2002 | 84.28 | 2.15 | 86.43 | MRFSS |
| 2003 | 111.50 | 2.70 | 114.20 | MRFSS |
| 2004 | 41.75 | 0.98 | 42.73 | CRFS |
| 2005 | 47.51 | 6.59 | 54.10 | CRFS |
| 2006 | 48.10 | 2.13 | 50.22 | CRFS |
| 2007 | 32.88 | 2.70 | 35.58 | CRFS |
| 2008 | 45.14 | 3.61 | 48.74 | CRFS |
| 2009 | 65.64 | 4.30 | 69.94 | CRFS |
| 2010 | 106.76 | 3.90 | 110.67 | CRFS |
| 2011 | 76.16 | 10.24 | 86.40 | CRFS |
| 2012 | 48.25 | 9.89 | 58.14 | CRFS |
| 2013 | 38.43 | 8.86 | 47.28 | CRFS |
| 2014 | 56.96 | 9.06 | 66.02 | CRFS |
| 2015 | 58.09 | 5.00 | 63.09 | CRFS |
| 2016 | 65.72 | 6.57 | 72.29 | CRFS |
| 2017 | 49.36 | 11.15 | 60.51 | CRFS |
| 2018 | 36.48 | 6.30 | 42.78 | CRFS |

Table 4: Summary of the biomass/abundance time series used in the stock assessment. Blank fleet number indicates the index was not used in the post-STAR base model.

tab:Index_summary

| Fleet | Years | Name | Fishery ind. | Filtering | Method | Endorsed |
|---|---|---|---|---|---|---|
| 4 | 1988-1998 | Deb Wilson-Vandenberg's Onboard Observer Survey | Fishery-dependent | Central California | Delta lognormal | SSC |
| 5 | 2001-2018 | CRFS CPFV Onboard Observer Survey | Fishery-dependent | North of Pt. Conception | Delta lognormal | SSC |
| | 2001-2018 | CRFS CPFV Onboard Observer Survey | Fishery-dependent | South of Pt. Conception | Delta lognormal | SSC |
| 6 | 2001-2018 | PISCO Dive Survey 15+ cm fish | Fishery-independent | North of Pt. Conception | Negative Binomial | First use in stock assmnt |
| 10 | 2001-2018 | PISCO Dive Survey age=0 fish | Fishery-independent | North of Pt. Conception | Binomial | First use in stock assmnt |
| 7 | 2007-2018 | CCFRP Hook-and-Line Survey | Fishery-independent | Central California | Negative Binomial | First use in stock assmnt |
| 8 | 1984-1999 | MRFSS Dockside Survey | Fishery-dependent | North of Pt. Conception | Negative Binomial | SSC |
| | 1980-1999 | MRFSS Dockside Survey | Fishery-dependent | South of Pt. Conception | Delta lognormal | SSC |

Table 5: Index inputs.

tab:Indices

| | Deb WV | | MRFSS N | | MRFSS S | | Onboard N | | Onboard S | | CCFRP | | PISCO 15+cm | | PISCO age-0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Obs | se_log | Obs | se_log | Obs | se_log | Obs | se_log | Obs | se_log | Obs | se_log | Obs | se_log | Obs | se_log |
| 1980 | | | | | 0.08 | 0.21 | | | | | | | | | | |
| 1981 | | | | | 0.05 | 0.24 | | | | | | | | | | |
| 1982 | | | | | 0.07 | 0.25 | | | | | | | | | | |
| 1983 | | | | | 0.13 | 0.13 | | | | | | | | | | |
| 1984 | | | 0.04 | 0.60 | 0.09 | 0.17 | | | | | | | | | | |
| 1985 | | | 0.03 | 0.55 | 0.09 | 0.21 | | | | | | | | | | |
| 1986 | | | 0.09 | 0.58 | 0.03 | 0.19 | | | | | | | | | | |
| 1987 | | | 0.02 | 0.66 | | | | | | | | | | | | |
| 1988 | 0.22 | 0.17 | 0.03 | 0.61 | | | | | | | | | | | | |
| 1989 | 0.34 | 0.15 | 0.02 | 0.66 | | | | | | | | | | | | |
| 1990 | | | | | | | | | | | | | | | | |
| 1991 | | | | | | | | | | | | | | | | |
| 1992 | 0.30 | 0.17 | | | | | | | | | | | | | | |
| 1993 | 0.20 | 0.14 | | | | | | | | | | | | | | |
| 1994 | 0.23 | 0.12 | | | | | | | | | | | | | | |
| 1995 | 0.25 | 0.10 | 0.04 | 0.64 | | | | | | | | | | | | |
| 1996 | 0.28 | 0.10 | 0.04 | 0.52 | 0.04 | 0.28 | | | | | | | | | | |
| 1997 | 0.21 | 0.09 | | | | | | | | | | | | | | |
| 1998 | 0.24 | 0.11 | | | 0.05 | 0.26 | | | | | | | | | | |
| 1999 | | | 0.03 | 0.53 | 0.05 | 0.22 | | | | | | | | | | |
| 2000 | | | | | | | | | | | | | | | | |
| 2001 | | | | | | | 0.32 | 0.12 | 0.01 | 0.52 | | | 1.39 | 0.22 | 0.19 | 0.41 |
| 2002 | | | | | | | 0.19 | 0.14 | 0.01 | 0.37 | | | 1.60 | 0.19 | 0.11 | 0.45 |
| 2003 | | | | | | | 0.28 | 0.07 | 0.03 | 0.33 | | | 1.35 | 0.17 | 0.18 | 0.33 |
| 2004 | | | | | | | 0.27 | 0.06 | 0.01 | 0.37 | | | 1.56 | 0.20 | 0.01 | 1.00 |
| 2005 | | | | | | | 0.26 | 0.08 | 0.02 | 0.24 | | | 1.32 | 0.21 | 0.01 | 1.01 |
| 2006 | | | | | | | 0.34 | 0.08 | 0.04 | 0.21 | | | 1.16 | 0.20 | 0.00 | 2.00 |
| 2007 | | | | | | | 0.33 | 0.08 | 0.08 | 0.16 | 1.20 | 0.15 | 0.94 | 0.22 | 0.02 | 0.82 |
| 2008 | | | | | | | 0.33 | 0.08 | 0.06 | 0.16 | 1.14 | 0.16 | 1.17 | 0.20 | 0.01 | 1.96 |
| 2009 | | | | | | | 0.27 | 0.08 | 0.07 | 0.16 | 1.13 | 0.16 | 0.70 | 0.21 | 0.03 | 0.62 |
| 2010 | | | | | | | 0.26 | 0.07 | 0.08 | 0.15 | 1.32 | 0.16 | 0.61 | 0.19 | 0.08 | 0.48 |
| 2011 | | | | | | | 0.24 | 0.07 | 0.15 | 0.11 | 0.97 | 0.16 | 1.01 | 0.17 | 0.05 | 0.52 |
| 2012 | | | | | | | 0.18 | 0.08 | 0.09 | 0.11 | 1.00 | 0.15 | 1.59 | 0.22 | 0.02 | 0.99 |
| 2013 | | | | | | | 0.09 | 0.09 | 0.07 | 0.12 | 0.38 | 0.16 | 1.74 | 0.20 | 0.01 | 1.02 |
| 2014 | | | | | | | 0.10 | 0.10 | 0.09 | 0.13 | 0.81 | 0.15 | 1.44 | 0.21 | 0.26 | 0.37 |
| 2015 | | | | | | | 0.17 | 0.10 | 0.06 | 0.17 | 1.03 | 0.16 | 1.55 | 0.20 | 0.31 | 0.33 |
| 2016 | | | | | | | 0.18 | 0.08 | 0.09 | 0.14 | 0.96 | 0.16 | 1.02 | 0.21 | 0.12 | 0.47 |
| 2017 | | | | | | | 0.15 | 0.12 | 0.08 | 0.17 | 1.18 | 0.16 | 1.11 | 0.21 | 0.21 | 0.39 |
| 2018 | | | | | | | 0.30 | 0.10 | 0.08 | 0.18 | 1.33 | 0.16 | 1.41 | 0.18 | 0.03 | 0.66 |

Table 6: Data filtering steps for the MRFSS dockside intercept survey index of abundance for north and south of Pt. Conception.

tab:Fleet10_11_Filter

| Filter | Trips | Positive Trips |
|---|---|---|
| All data | 10,392 | 1,061 |
| Remove north of Cape Mendocino | 10,327 | 1,061 |
| Remove trips targeting offshore species | 10,122 | 1,061 |
| | | |
| Start northern filtering | 2,788 | 620 |
| Remove species that never co-occur and not present in at least 1% of all | 2,788 | 620 |
| Stephens-MacCall filter (keep all positives - selected filter) | 806 | 620 |
| Alternate Stephens-MacCall filter (keep only above threshold) | 623 | 437 |
| Remove years after 1999 due to regulation changes and with fewer than 20 trips | 544 | 220 |
| | | |
| Start southern filtering | 7,334 | 441 |
| Remove species that never co-occur and not present in at least 1% of all | 7,334 | 441 |
| Stephens-MacCall filter (keep all positives - selected filter) | 687 | 441 |
| Alternate Stephens-MacCall filter (keep only above threshold) | 430 | 184 |
| Remove years after 1999 due to regulation changes and with fewer than 20 trips | 475 | 342 |

Table 7: Contingency table for the Stephens-MacCall filtering for the MRFSS dockside CPFV index for GBYR north of Pt. Conception.

tab:Fleet10_contingency

| | GBYR absent | GBYR present |
|---|---|---|
| Above 0.4 | 186 | 437 |
| Below 0.4 | 1982 | 183 |

Table 8: Model selection for the MRFSS dockside intercept survey north of Pt. Conception. Bold values indicate the model selected.

tab:Fleet10_AIC

| Model | AIC |
|---|---|
| Year | 1,481 |
| Year + Region | 1,429 |
| Year + Region + Area_X | 1,403 |
| Year + Region + Area_X + Wave | **1,397** |

Table 9: Contingency table for the Stephens-MacCall filtering for the MRFSS dockside CPFV index for GBYR south of Pt. Conception.

tab:Fleet11_contingency

| | GBYR absent | GBYR present |
|---|---|---|
| Above 0.22 | 246 | 184 |
| Below 0.22 | 6647 | 257 |

Table 10: Model selection for the MRFSS dockside intercept survey south of Pt. Conception. Bold values indicate the model selected.

tab:Fleet11_AIC

| Model | Lognormal | Binomial |
|---|---|---|
| Year | 911 | 552 |
| Year+ Wave | 908 | 538 |
| Year + Wave + Area_X | 905 | 540 |
| Year + Wave + Area_X + SubRegion | **903** | **537** |
| Year + Wave + SubRegion | 908 | 536 |

Table 11: Data filtering steps for Deb Wilson-Vandenberg's CPFV onboard observer index of abundance.

tab:Fleet5_Filter

| Filter | Drifts | Positive Drifts |
|---|---|---|
| Remove errors, missing data | 6691 | 1470 |
| Remove 1987 (sampled only MNT), 1990-1991 low sample sizes | 4283 | 1372 |
| Remove reefs that never encountered GBY | 4022 | 1372 |
| Remove lower and upper 2.5% of time fished | 3762 | 1300 |
| Remove depth less than 9 m and greater than 69 m | 3515 | 1279 |
| Remove reefs with low sample rates | 2411 | 1096 |

Table 12: Model selection for Deb Wilson-Vandenberg's CPFV onboard observer index of abundance. Bold values indicate the model selected.

tab:Fleet5_AIC

| Model | Lognormal | Binomial |
|---|---|---|
| Year | 2834 | 3330 |
| Year + Depth | 2781 | 2906 |
| Year + Reef | 2716 | 2880 |
| Year + Month | 2839 | 3286 |
| Year + Depth + Reef | **2625** | **2488** |
| Year + Month+ Reef | 2725 | 2844 |
| Year + Depth + Month | 2780 | 2902 |
| Year+ Depth+Month+Reef | 2632 | 2479 |

Table 13: Data filtering steps for the CRFS CPFV onboard observer index of abundance for north and south of Pt. Conception.

tab:Fleet6_7_Filter

| Filter | Drifts | Positive Drifts |
|---|---|---|
| Data from SQL filtered for missing data | 67850 | 9317 |
| Remove years prior to 2001 and north of Cape Mendocino | 64448 | 9129 |
| Depth, remove 1% data on each tail of positive catches | 50846 | 8955 |
| Time fished, remove 1% data on each tail | 50100 | 8903 |
| Observed anglers, remove 1% data on each tail | 48089 | 8774 |
| Limit to reefs observering gopher/byel in at least 20 drifts | 29639 | 8025 |
| Limit to reefs sampled in at least 2/3 of all years | 32672 | 7517 |
| Limit to drifts within 1000 m of a reef | 27355 | 7358 |
| Put depth in 10m depth bins, remove 0-9 and 60-69 m bins | 25427 | 7250 |
| | | |
| Start of north filtering | 13792 | 6036 |
| Filter to drifts within 43 m of a reef, 97% quantile | 13145 | 5854 |
| Make sure reefs still sampled at least 2/3 of years | 12965 | 5796 |
| | | |
| Start of south filtering | 11635 | 1277 |
| Filter to drifts with >=20% groundfish and recheck reefs | 5495 | 1171 |
| Make sure reefs still sampled at least 2/3 of years | 5440 | 1132 |

Table 14: Model selection for the CRFS CPFV onboard observer index of abundance for north of Pt. Conception. Bold values indicate the model selected.

tab:Fleet6_AIC

| Model | Lognormal | Binomial |
|---|---|---|
| Year | 14135 | 17531 |
| Year + Month | 14120 | 17529 |
| Year + Depth | 13953 | 17025 |
| Year + Reef | 14126 | 17293 |
| Year + Month + Depth | 13951 | 17027 |
| Year + Month + Depth + Reef | **13921** | **16674** |

Table 15: Model selection for the CRFS CPFV onboard observer index of abundance for south of Pt. Conception. Bold values indicate the model selected.

tab:Fleet7_AIC

| Model | Lognormal | Binomial |
|---|---|---|
| Year | 2798 | 5490 |
| Year + Month | 2799 | 5487 |
| Year + Depth | 2744 | 5159 |
| Year + Reef | 2653 | 5390 |
| Year + Depth + Reef | **2652** | **5071** |
| Year + Depth + Reef + Month | 2663 | 5072 |

Table 16: Data filtering steps for the fishery-independent CCFRP hook-and-line survey.
tab:Fleet9_Filter

| Filter | Drifts | Positive Drifts |
|---|---|---|
| All data | 5,886 | Drift and catch data not merged |
| Remove missing data and cells not sampled consistently at Piedras Blancas | 4,942 | 3,857 |
| Remove cells that never encountered GBYR | 4,934 | 3,857 |
| Remove depth bins with little or no sampling (keep 5-39 m) | 4,920 | 3,848 |

Table 17: Model selection for the fishery-independent CCFRP hook-and-line survey.
tab:Fleet9_AIC

| Model | AIC |
|---|---|
| Year | 23,212 |
| Year + Month | 23,214 |
| Year + Depth | 22,901 |
| Year + Depth + Site | 22,642 |
| Year + Depth + Site + MPA/REF | **22,341** |

Table 18: Data filtering steps for the PISCO dive survey.

tab:Fleet8_Filter

| Filter | Transects | Positive Transects |
|---|---|---|
| Remove missing data and retain only bottom transects | 22,055 | 6,330 |
| Remove month of June - few samples | 21,941 | 6,318 |
| Remove dives earlier than 2004 for UCSB and 2001 for UCSC | 20,659 | 6,165 |
| Keep sites sampled in at least half of all years (UCSC and UCSB separate) | 14,721 | 4,097 |
| Keep sites observing GBYR in at least half of all years | 12,139 | 4,002 |
| Remove transects denoted as old, no longer sampled | 10,712 | 3,268 |
| Subset to just UCSC sites | 5,686 | 2,939 |
| Use only consistently sampled sites | 3,231 | 1,729 |
| Collapse repeated transects | 1,928 | 1,487 |

Table 19: Model selection for the PISCO dive survey data.

tab:Fleet8_AIC

| Model | AIC |
|---|---|
| Year | 5,687 |
| Year + Month | 5,672 |
| Year + Month + Site | 5,623 |
| Year + Month + Site + Zone | **5,512** |

Table 20: Model selection for the PISCO dive survey data for fish 15 cm and larger.
tab:Fleet8large_AIC

| Model | AIC |
|---|---|
| Year | 4,940 |
| Year + Month | 4,937 |
| Year + Month + Site | 4,770 |
| Year + Month + Zone | **4,651** |

Table 21: Model selection for the PISCO dive survey data recruitment index.
tab:Fleet8age0_AIC

| Model | AIC |
|---|---|
| Year | 708 |
| Year + Month | 703 |
| Year + Month + Site | 713 |
| Year + Month + Site + Zone | **699** |

Table 22: Length composition sample sizes for survey data.
tab:length_samples_survey

| | CCFRP | | PISCO | |
|---|---|---|---|---|
| Year | Trips | Lengths | Trips | Lengths |
| 2001 | | | 55 | 222 |
| 2002 | | | 56 | 438 |
| 2003 | | | 64 | 473 |
| 2004 | | | 64 | 312 |
| 2005 | | | 65 | 241 |
| 2006 | | | 68 | 220 |
| 2007 | 35 | 2147 | 68 | 156 |
| 2008 | 52 | 3143 | 67 | 198 |
| 2009 | 35 | 1579 | 68 | 154 |
| 2010 | 32 | 2201 | 58 | 144 |
| 2011 | 32 | 1727 | 68 | 260 |
| 2012 | 32 | 1820 | 40 | 183 |
| 2013 | 32 | 685 | 61 | 258 |
| 2014 | 32 | 1655 | 61 | 313 |
| 2015 | 18 | 1121 | 64 | 622 |
| 2016 | 32 | 2015 | 56 | 346 |
| 2017 | 58 | 2402 | 58 | 317 |
| 2018 | 29 | 1975 | 60 | 264 |

Table 23: Summary of available age data. All ages except the commercial ages were used in the assessment.

tab:Age_data

| Project | Source | Years | Region | Gear | Black-and-yellow | Gopher |
|---|---|---|---|---|---|---|
| Port sampling | Commercial | 2009-2010; 2018 | Bodega; Morro Bay | hook-and-line | 0 | 46 |
| CDFW sampling | Recreational | 1978; 1980; 1982-1986 | Morro Bay; San Francisco | hook-and-line | 0 | 138 |
| Cal Poly onboard observer | Recreational | 2018 | Morro Bay | hook-and-line | 0 | 36 |
| E.J.'s trap survey | Research | 2012 | Monterey | trap | 1 | 25 |
| Zaitlin thesis | Research | 1983-1986 | Monterey | spear | 491 | 0 |
| Pearson groundfish cruise | Research | 2002-2005 | Monterey | hook-and-line | 0 | 118 |
| Hanan CPFV survey | Research | 2003-2004 | Morro Bay; Santa Barbara | hook-and-line | 0 | 189 |
| Juv. rockfish cruise special study | Research | 2004-2005 | Monterey | hook-and-line | 0 | 79 |
| CCFRP | Research | 2007-2013 | Central CA | hook-and-line | 7 | 1,191 |
| CCFRP trap | Research | 2008-2009 | Central CA | trap | 0 | 87 |
| Abrams thesis | Research | 2010-2011 | Fort Bragg | hook-and-line | 0 | 59 |
| **Total** | | | | | **499** | **1,968** |

Table 24: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

| No. | Parameter | Value | Phase | Bounds | Status | SD | Prior (Exp.Val, SD) |
|---|---|---|---|---|---|---|---|
| 1 | NatM_p_1_Fem_GP_1 | 0.193 | -2 | (0.05, 0.4) | | | Log_Norm (-1.6458, 0.4384) |
| 2 | L_at_Amin_Fem_GP_1 | 13.422 | 3 | (4, 50) | OK | 0.853 | None |
| 3 | L_at_Amax_Fem_GP_1 | 28.799 | 3 | (20, 60) | OK | 0.827 | None |
| 4 | VonBert_K_Fem_GP_1 | 0.107 | 3 | (0.01, 0.3) | OK | 0.020 | None |
| 5 | CV_young_Fem_GP_1 | 0.171 | 3 | (0.05, 0.5) | OK | 0.026 | None |
| 6 | CV_old_Fem_GP_1 | 0.121 | 3 | (0.03, 0.3) | OK | 0.012 | None |
| 7 | Wtlen_1_Fem_GP_1 | 0.000 | -3 | (-3, 3) | | | None |
| 8 | Wtlen_2_Fem_GP_1 | 3.256 | -3 | (2, 4) | | | None |
| 9 | Mat50%_Fem_GP_1 | 21.666 | -3 | (-3, 3) | | | None |
| 10 | Mat_slope_Fem_GP_1 | -0.906 | -3 | (-6, 3) | | | None |
| 11 | Eggs/kg_inter_Fem_GP_1 | 1.000 | -3 | (-3, 3) | | | None |
| 12 | Eggs/kg_slope_wt_Fem_GP_1 | 0.000 | -3 | (-3, 3) | | | None |
| 13 | CohortGrowDev | 1.000 | -1 | (0.1, 10) | | | None |
| 14 | FracFemale_GP_1 | 0.500 | -4 | (0.000001, 0.999999) | | | None |
| 15 | SR_LN(R0) | 8.047 | 1 | (2, 15) | OK | 0.079 | None |
| 16 | SR_BH_steep | 0.720 | -1 | (0.2, 1) | | | Full_Beta (0.72, 0.16) |
| 17 | SR_sigmaR | 0.500 | -2 | (0, 2) | | | None |
| 18 | SR_regime | 0.000 | -4 | (-5, 5) | | | None |
| 19 | SR_autocorr | 0.000 | -4 | (-1, 1) | | | None |
| 85 | LnQ_base_DebCPFV(4) | -7.157 | -1 | (-15, 15) | | | None |
| 86 | Q_extraSD_DebCPFV(4) | 0.060 | 4 | (0, 2) | OK | 0.045 | None |
| 87 | LnQ_base_RecOnboardNorth(5) | -7.766 | -1 | (-15, 15) | | | None |
| 88 | Q_extraSD_RecOnboardNorth(5) | 0.237 | 4 | (0.0001, 2) | OK | 0.056 | None |
| 89 | LnQ_base_PISCO(6) | -6.425 | -1 | (-15, 15) | | | None |
| 90 | Q_extraSD_PISCO(6) | 0.152 | 4 | (0.0001, 2) | OK | 0.061 | None |

Continued on next page

Table 24: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

| No. | Parameter | Value | Phase | Bounds | Status | SD | Prior (Exp.Val, SD) |
|---|---|---|---|---|---|---|---|
| 91 | LnQ_base_CCFRP(7) | -6.199 | -1 | (-15, 15) | | | None |
| 92 | Q_extraSD_CCFRP(7) | 0.212 | 4 | (0.0001, 2) | OK | 0.078 | None |
| 93 | LnQ_base_RecDocksideNorth(8) | -9.288 | -1 | (-15, 15) | | | None |
| 94 | LnQ_base_PISCOage0(10) | -10.187 | -1 | (-15, 15) | | | None |
| 95 | Size_DblN_peak_Com(1) | 31.058 | 1 | (19, 38) | OK | 0.383 | None |
| 96 | Size_DblN_top_logit_Com(1) | 8.000 | -5 | (-5, 10) | | | None |
| 97 | Size_DblN_ascend_se_Com(1) | 2.733 | 5 | (-9, 10) | OK | 0.108 | None |
| 98 | Size_DblN_descend_se_Com(1) | 5.000 | -5 | (-9, 9) | | | None |
| 99 | Size_DblN_start_logit_Com(1) | -9.363 | 5 | (-15, -5) | OK | 0.971 | None |
| 100 | Size_DblN_end_logit_Com(1) | 10.000 | -5 | (-5, 15) | | | None |
| 101 | Size_DblN_peak_RecNorth(2) | 32.116 | 3 | (19, 39) | OK | 0.331 | None |
| 102 | Size_DblN_top_logit_RecNorth(2) | 8.000 | -5 | (-5, 10) | | | None |
| 103 | Size_DblN_ascend_se_RecNorth(2) | 3.202 | 5 | (-9, 10) | OK | 0.055 | None |
| 104 | Size_DblN_descend_se_RecNorth(2) | 5.000 | -5 | (-9, 9) | | | None |
| 105 | Size_DblN_start_logit_RecNorth(2) | -11.110 | 5 | (-15, -5) | OK | 1.137 | None |
| 106 | Size_DblN_end_logit_RecNorth(2) | 10.000 | -5 | (-5, 15) | | | None |
| 107 | Size_DblN_peak_RecSouth(3) | 27.565 | 4 | (19, 38) | OK | 0.951 | None |
| 108 | Size_DblN_top_logit_RecSouth(3) | 8.000 | -5 | (-5, 10) | | | None |
| 109 | Size_DblN_ascend_se_RecSouth(3) | 3.078 | 5 | (-9, 10) | OK | 0.238 | None |
| 110 | Size_DblN_descend_se_RecSouth(3) | 5.000 | -5 | (-9, 9) | | | None |
| 111 | Size_DblN_start_logit_RecSouth(3) | -7.504 | 5 | (-15, -5) | OK | 1.592 | None |
| 112 | Size_DblN_end_logit_RecSouth(3) | 10.000 | -5 | (-5, 15) | | | None |
| 113 | SizeSel_P1_DebCPFV(4) | -1.000 | -5 | (-1, 10) | | | None |
| 114 | SizeSel_P2_DebCPFV(4) | -1.000 | -5 | (-1, 10) | | | None |
| 115 | SizeSel_P1_RecOnboardNorth(5) | -1.000 | -5 | (-1, 10) | | | None |
| 116 | SizeSel_P2_RecOnboardNorth(5) | -1.000 | -5 | (-1, 10) | | | None |
| 117 | Size_DblN_peak_PISCO(6) | 38.000 | -5 | (19, 38) | | | None |

Continued on next page

Table 24: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD).

| No. | Parameter | Value | Phase | Bounds | Status | SD | Prior (Exp.Val, SD) |
|---|---|---|---|---|---|---|---|
| 118 | Size_DblN_top_logit_PISCO(6) | 8.000 | -5 | (-15, 10) | | | None |
| 119 | Size_DblN_ascend_se_PISCO(6) | 4.699 | 5 | (-9, 10) | OK | 0.085 | None |
| 120 | Size_DblN_descend_se_PISCO(6) | 5.000 | -5 | (-9, 9) | | | None |
| 121 | Size_DblN_start_logit_PISCO(6) | -17.029 | -5 | (-25, 15) | | | None |
| 122 | Size_DblN_end_logit_PISCO(6) | 10.000 | -5 | (-5, 15) | | | None |
| 123 | SizeSel_P1_CCFRP(7) | -1.000 | -5 | (-1, 10) | | | None |
| 124 | SizeSel_P2_CCFRP(7) | -1.000 | -5 | (-1, 10) | | | None |
| 125 | SizeSel_P1_RecDocksideNorth(8) | -1.000 | -5 | (-1, 10) | | | None |
| 126 | SizeSel_P2_RecDocksideNorth(8) | -1.000 | -5 | (-1, 10) | | | None |
| 127 | minage@sel=1_PISCOage0(10) | 0.000 | -5 | (0, 1) | | | None |
| 128 | maxage@sel=1_PISCOage0(10) | 0.000 | -5 | (0, 1) | | | None |

tab:model_params

Table 25: Sensitivity of the base model to alternative assumptions about natural mortality, growth, and using PacFIN-derived length composition data.

tab:Sensitivity_model1

| Label | Base model (Francis weights) | Fix M at prior | Fix k at external est. | PacFIN length comps | Default weighting | Harmonic mean weighting |
|---|---|---|---|---|---|---|
| TOTAL_like | 516.36 | 516.61 | 524.71 | 508.20 | 4041.05 | 1734.79 |
| Catch_like | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Equil_catch_like | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Survey_like | -32.17 | -32.25 | -31.21 | -31.91 | -25.08 | -27.59 |
| Length_comp_like | 372.46 | 372.55 | 373.98 | 365.19 | 2192.10 | 1015.78 |
| Age_comp_like | 189.56 | 189.70 | 194.77 | 188.81 | 1872.77 | 753.42 |
| Recruitment_like | -13.51 | -13.40 | -12.94 | -13.99 | 1.13 | -6.87 |
| Param_prior_like | 0.02 | 0.00 | 0.11 | 0.09 | 0.13 | 0.05 |
| Param_softbounds_like | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| Female_M | 0.21 | 0.19 | 0.16 | 0.23 | 0.24 | 0.22 |
| Steepness | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 |
| lnR0 | 8.60 | 8.33 | 7.86 | 8.87 | 9.03 | 8.80 |
| Total Biomass | 2369.39 | 2313.35 | 2322.80 | 2307.70 | 2321.26 | 2439.02 |
| Depletion | 0.46 | 0.43 | 0.42 | 0.00 | 0.50 | 0.49 |
| SPR ratio | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 |
| L_at_Amin_Fem_GP_1 | 9.67 | 9.61 | 8.53 | 9.91 | 9.62 | 9.88 |
| L_at_Amax_Fem_GP_1 | 28.44 | 28.23 | 26.39 | 27.79 | 27.24 | 27.64 |
| VonBert_K_Fem_GP_1 | 0.12 | 0.14 | 0.25 | 0.11 | 0.10 | 0.12 |
| No. para | 112.00 | 111.00 | 111.00 | 112.00 | 112.00 | 112.00 |

Table 26: Comparison of ket parameters and likelihood components from the pre-STAR base model and the post-STAR base model.

tab:preSTAR_postSTAR_compare

| Parameter | Value | NA |
|---|---|---|
| Female M | 0.21 | 0.19 |
| Steepness | 0.72 | 0.72 |
| lnR0 | 8.60 | 8.05 |
| Total biomass (mt) | 2369.39 | 2046.78 |
| Depletion | 0.46 | 0.44 |
| SPR ratio | 1.00 | 0.90 |
| Female Lmin | 9.67 | 13.42 |
| Female Lmax | 28.44 | 28.80 |
| Female K | 0.12 | 0.11 |
| Negative log-likelihood | | |
| TOTAL | 516.36 | 530.10 |
| Catch | 0.00 | 0.00 |
| Survey | -32.17 | -34.06 |
| Length_comp | 372.46 | 411.53 |
| Age_comp | 189.56 | 147.06 |
| Recruitment | -13.51 | 5.58 |
| Parm_priors | 0.02 | 0.00 |
| Parm_softbounds | 0.00 | 0.00 |

Table 27: Likelihood components from the base model.

tab:like_components

| Likelihood component | Value |
|---|---|
| TOTAL | 530.102 |
| Catch | 1.450E-07 |
| Survey | -34.063 |
| Length composition | 411.530 |
| Age composition | 147.059 |
| Recruitment | 5.575 |
| Forecast recruitment | 0.000E+00 |
| Parameter priors | 1.410E-06 |
| Parmeter soft bounds | 9.750E-04 |

Table 28: Time-series of population estimates from the base-case model. Relative exploitation rate is $(1 - SPR)/(1 - SPR_{50\%})$.

| Year | Total biomass (mt) | Spawning biomass (mt) | Depletion | Age-0 recruits | Total catch (mt) | Relative exploitation rate | SPR |
|---|---|---|---|---|---|---|---|
| 1916 | 2047 | 1261 | 0.000 | 3125 | 4 | 0.00 | 0.99 |
| 1917 | 2044 | 1258 | 0.998 | 3124 | 7 | 0.00 | 0.98 |
| 1918 | 2040 | 1254 | 0.995 | 3123 | 8 | 0.00 | 0.97 |
| 1919 | 2036 | 1250 | 0.992 | 3122 | 5 | 0.00 | 0.98 |
| 1920 | 2033 | 1248 | 0.990 | 3122 | 5 | 0.00 | 0.98 |
| 1921 | 2032 | 1247 | 0.989 | 3121 | 5 | 0.00 | 0.98 |
| 1922 | 2031 | 1246 | 0.988 | 3121 | 4 | 0.00 | 0.99 |
| 1923 | 2030 | 1245 | 0.988 | 3121 | 4 | 0.00 | 0.99 |
| 1924 | 2029 | 1245 | 0.987 | 3121 | 2 | 0.00 | 0.99 |
| 1925 | 2030 | 1245 | 0.988 | 3121 | 3 | 0.00 | 0.99 |
| 1926 | 2030 | 1246 | 0.988 | 3121 | 5 | 0.00 | 0.98 |
| 1927 | 2029 | 1245 | 0.987 | 3121 | 4 | 0.00 | 0.99 |
| 1928 | 2029 | 1244 | 0.987 | 3121 | 6 | 0.00 | 0.98 |
| 1929 | 2027 | 1243 | 0.986 | 3120 | 6 | 0.00 | 0.98 |
| 1930 | 2026 | 1241 | 0.985 | 3120 | 8 | 0.00 | 0.97 |
| 1931 | 2023 | 1239 | 0.983 | 3119 | 5 | 0.00 | 0.98 |
| 1932 | 2023 | 1239 | 0.983 | 3119 | 10 | 0.01 | 0.97 |
| 1933 | 2019 | 1236 | 0.980 | 3118 | 7 | 0.00 | 0.98 |
| 1934 | 2018 | 1235 | 0.979 | 3118 | 7 | 0.00 | 0.98 |
| 1935 | 2018 | 1234 | 0.979 | 3118 | 6 | 0.00 | 0.98 |
| 1936 | 2017 | 1234 | 0.979 | 3118 | 6 | 0.00 | 0.98 |
| 1937 | 2017 | 1234 | 0.978 | 3118 | 15 | 0.01 | 0.95 |
| 1938 | 2011 | 1228 | 0.974 | 3117 | 18 | 0.01 | 0.94 |
| 1939 | 2003 | 1221 | 0.968 | 3115 | 21 | 0.01 | 0.93 |
| 1940 | 1995 | 1213 | 0.962 | 3113 | 28 | 0.01 | 0.91 |
| 1941 | 1983 | 1202 | 0.953 | 3110 | 27 | 0.01 | 0.91 |
| 1942 | 1973 | 1193 | 0.946 | 3107 | 14 | 0.01 | 0.95 |
| 1943 | 1973 | 1192 | 0.946 | 3107 | 17 | 0.01 | 0.94 |
| 1944 | 1971 | 1191 | 0.944 | 3107 | 4 | 0.00 | 0.98 |
| 1945 | 1978 | 1197 | 0.950 | 3109 | 6 | 0.00 | 0.98 |
| 1946 | 1982 | 1202 | 0.953 | 3110 | 27 | 0.01 | 0.91 |
| 1947 | 1972 | 1193 | 0.946 | 3108 | 37 | 0.02 | 0.89 |
| 1948 | 1957 | 1179 | 0.935 | 3104 | 39 | 0.02 | 0.88 |
| 1949 | 1942 | 1165 | 0.924 | 3100 | 37 | 0.02 | 0.88 |
| 1950 | 1931 | 1155 | 0.916 | 3097 | 39 | 0.02 | 0.88 |
| 1951 | 1919 | 1144 | 0.907 | 3094 | 52 | 0.03 | 0.84 |
| 1952 | 1901 | 1127 | 0.894 | 3089 | 52 | 0.03 | 0.84 |
| 1953 | 1885 | 1112 | 0.882 | 3085 | 55 | 0.03 | 0.83 |

*Continues next page*

tab:Timeseries_mc

Table 28: Time-series of population estimates from the base-case model. Relative exploitation rate is $(1 - SPR)/(1 - SPR_{50\%})$.

| Year | Total biomass (mt) | Spawning biomass (mt) | Depletion | Age-0 recruits | Total catch (mt) | Relative exploitation rate | SPR |
|---|---|---|---|---|---|---|---|
| 1954 | 1869 | 1098 | 0.871 | 3080 | 68 | 0.04 | 0.80 |
| 1955 | 1846 | 1077 | 0.854 | 3074 | 60 | 0.03 | 0.81 |
| 1956 | 1831 | 1064 | 0.844 | 3069 | 76 | 0.04 | 0.78 |
| 1957 | 1808 | 1043 | 0.827 | 3063 | 76 | 0.04 | 0.77 |
| 1958 | 1788 | 1025 | 0.813 | 3056 | 88 | 0.05 | 0.74 |
| 1959 | 1763 | 1003 | 0.795 | 3048 | 62 | 0.04 | 0.79 |
| 1960 | 1757 | 998 | 0.791 | 3047 | 44 | 0.02 | 0.84 |
| 1961 | 1764 | 1005 | 0.797 | 3049 | 50 | 0.03 | 0.82 |
| 1962 | 1766 | 1007 | 0.799 | 3050 | 61 | 0.03 | 0.79 |
| 1963 | 1759 | 1002 | 0.795 | 3048 | 56 | 0.03 | 0.81 |
| 1964 | 1758 | 1002 | 0.794 | 3048 | 43 | 0.02 | 0.84 |
| 1965 | 1764 | 1008 | 0.799 | 3050 | 58 | 0.03 | 0.80 |
| 1966 | 1760 | 1004 | 0.796 | 3049 | 52 | 0.03 | 0.82 |
| 1967 | 1760 | 1004 | 0.797 | 3049 | 48 | 0.03 | 0.83 |
| 1968 | 1763 | 1007 | 0.799 | 3050 | 49 | 0.03 | 0.82 |
| 1969 | 1764 | 1009 | 0.800 | 3051 | 46 | 0.03 | 0.83 |
| 1970 | 1767 | 1012 | 0.802 | 3052 | 60 | 0.03 | 0.80 |
| 1971 | 1761 | 1006 | 0.798 | 3050 | 51 | 0.03 | 0.82 |
| 1972 | 1762 | 1007 | 0.798 | 3050 | 66 | 0.04 | 0.78 |
| 1973 | 1752 | 998 | 0.791 | 3047 | 88 | 0.05 | 0.74 |
| 1974 | 1729 | 977 | 0.775 | 3039 | 92 | 0.05 | 0.72 |
| 1975 | 1707 | 957 | 0.759 | 3031 | 89 | 0.05 | 0.72 |
| 1976 | 1689 | 940 | 0.746 | 3024 | 91 | 0.05 | 0.72 |
| 1977 | 1673 | 926 | 0.734 | 3018 | 79 | 0.05 | 0.73 |
| 1978 | 1666 | 920 | 0.729 | 3257 | 84 | 0.05 | 0.72 |
| 1979 | 1657 | 912 | 0.723 | 3049 | 78 | 0.05 | 0.73 |
| 1980 | 1657 | 908 | 0.720 | 3557 | 155 | 0.09 | 0.61 |
| 1981 | 1610 | 862 | 0.683 | 3325 | 143 | 0.09 | 0.61 |
| 1982 | 1583 | 828 | 0.657 | 3627 | 129 | 0.08 | 0.62 |
| 1983 | 1575 | 808 | 0.641 | 2938 | 118 | 0.07 | 0.63 |
| 1984 | 1577 | 799 | 0.633 | 2076 | 174 | 0.11 | 0.54 |
| 1985 | 1539 | 763 | 0.605 | 2143 | 173 | 0.11 | 0.53 |
| 1986 | 1485 | 735 | 0.583 | 2061 | 206 | 0.14 | 0.48 |
| 1987 | 1400 | 696 | 0.552 | 2195 | 162 | 0.12 | 0.51 |
| 1988 | 1343 | 683 | 0.542 | 2609 | 145 | 0.11 | 0.53 |
| 1989 | 1297 | 675 | 0.535 | 3277 | 120 | 0.09 | 0.57 |
| 1990 | 1274 | 672 | 0.533 | 3596 | 136 | 0.11 | 0.55 |
| 1991 | 1269 | 652 | 0.517 | 11997 | 175 | 0.14 | 0.50 |

*Continues next page*

Table 28: Time-series of population estimates from the base-case model. Relative exploitation rate is $(1 - SPR)/(1 - SPR_{50\%})$. tab:Timeseries_mo

| Year | Total biomass (mt) | Spawning biomass (mt) | Depletion | Age-0 recruits | Total catch (mt) | Relative exploitation rate | SPR |
|---|---|---|---|---|---|---|---|
| 1992 | 1267 | 608 | 0.482 | 3312 | 207 | 0.16 | 0.45 |
| 1993 | 1366 | 549 | 0.436 | 3764 | 210 | 0.15 | 0.43 |
| 1994 | 1490 | 507 | 0.402 | 4812 | 161 | 0.11 | 0.45 |
| 1995 | 1569 | 518 | 0.411 | 4650 | 150 | 0.10 | 0.45 |
| 1996 | 1663 | 569 | 0.451 | 3656 | 148 | 0.09 | 0.45 |
| 1997 | 1758 | 648 | 0.514 | 2786 | 118 | 0.07 | 0.51 |
| 1998 | 1843 | 748 | 0.594 | 2528 | 118 | 0.06 | 0.54 |
| 1999 | 1887 | 844 | 0.669 | 2579 | 127 | 0.07 | 0.56 |
| 2000 | 1888 | 919 | 0.729 | 2147 | 131 | 0.07 | 0.58 |
| 2001 | 1864 | 973 | 0.772 | 3459 | 169 | 0.09 | 0.56 |
| 2002 | 1797 | 985 | 0.781 | 2585 | 133 | 0.07 | 0.61 |
| 2003 | 1754 | 990 | 0.785 | 4185 | 148 | 0.08 | 0.61 |
| 2004 | 1702 | 968 | 0.767 | 1896 | 72 | 0.04 | 0.74 |
| 2005 | 1705 | 972 | 0.771 | 1891 | 86 | 0.05 | 0.72 |
| 2006 | 1687 | 959 | 0.761 | 2569 | 78 | 0.05 | 0.74 |
| 2007 | 1645 | 948 | 0.752 | 1600 | 70 | 0.04 | 0.76 |
| 2008 | 1608 | 940 | 0.746 | 1981 | 87 | 0.05 | 0.72 |
| 2009 | 1552 | 921 | 0.730 | 1634 | 111 | 0.07 | 0.68 |
| 2010 | 1473 | 882 | 0.700 | 2451 | 153 | 0.10 | 0.61 |
| 2011 | 1367 | 817 | 0.648 | 2014 | 135 | 0.10 | 0.61 |
| 2012 | 1286 | 761 | 0.603 | 1800 | 94 | 0.07 | 0.67 |
| 2013 | 1241 | 727 | 0.577 | 1589 | 84 | 0.07 | 0.68 |
| 2014 | 1203 | 697 | 0.553 | 4568 | 105 | 0.09 | 0.63 |
| 2015 | 1155 | 655 | 0.520 | 5264 | 109 | 0.10 | 0.62 |
| 2016 | 1147 | 614 | 0.487 | 2487 | 112 | 0.10 | 0.59 |
| 2017 | 1195 | 576 | 0.457 | 3701 | 104 | 0.09 | 0.59 |
| 2018 | 1240 | 553 | 0.439 | 1432 | 92 | 0.07 | 0.60 |
| 2019 | 1281 | 552 | 0.438 | 2778 | | | |

Table 29: Results from 100 jitters from the base case model.

tab:jitter

| Description | Value |
|---|---|
| MinLike | 530.10 |
| MaxLike | 538.08 |
| DiffLike | 7.98 |
| MinMGC | 0.00 |
| MaxMGC | 0.00 |
| DepletionAtMinLikePercent | 43.82 |
| DepletionAtMaxLikePercent | 41.40 |
| DiffDepletionPercent | -2.41 |
| NJitter | 300.00 |
| PropRunAtMinLike | 0.67 |
| PropRunAtMaxLike | 0.00 |

Table 30: Summaries of key assessment outputs and likelihood values from the retrospective analysis. The base model includes all of the data. Retro1 removes the last year of data (2018), Retro2 removes the last two years of data, Retro3 removes three years and Retro4 removes four years.

tab:retro

| Label | Base | Retro1 | Retro2 | Retro3 | Retro4 |
|---|---|---|---|---|---|
| Female natural mortality | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| Steepness | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 |
| lnR0 | 8.05 | 8.04 | 8.02 | 7.98 | 7.93 |
| Total Unfished Biomass (mt) | 2046.78 | 2021.95 | 1950.40 | 1864.26 | 1730.31 |
| Depletion | 0.44 | 0.39 | 0.37 | 0.35 | 0.32 |
| SPR ratio | 1.00 | 1.00 | 0.99 | 0.98 | 0.97 |
| Female Lmin | 13.42 | 13.19 | 12.78 | 12.70 | 12.52 |
| Female Lmax | 28.80 | 28.73 | 28.67 | 28.46 | 28.25 |
| Female K | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 |
| Negative log-likelihood | | | | | |
| TOTAL | 530.10 | 507.41 | 494.56 | 484.87 | 472.75 |
| Equililibrium catch | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Survey | -34.06 | -35.72 | -34.67 | -32.52 | -32.50 |
| Length composition | 411.53 | 400.45 | 389.17 | 377.93 | 367.72 |
| Age composition | 147.06 | 136.61 | 133.40 | 132.14 | 130.62 |
| Recruitment | 5.58 | 6.07 | 6.67 | 7.32 | 6.90 |
| Forecast Recruitment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Parameter priors | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 31: Summaries of key assessment outputs and likelihood values from selected likelihood profile runs on virgin recruitment (lnR0) and steepness. Depletion and SPR ratio are for the year 2019.

tab:like_profiles

| Label | R07500 | R07750 | R08000 | R08250 | R08500 | h0390 | h0550 | h0710 | h0850 | h0990 |
|---|---|---|---|---|---|---|---|---|---|---|
| Female M | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.27 | 0.23 | 0.21 | 0.20 | 0.20 |
| Steepness | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.39 | 0.55 | 0.71 | 0.85 | 0.99 |
| lnR0 | 7.50 | 7.75 | 8.00 | 8.25 | 8.50 | 9.71 | 9.02 | 8.62 | 8.39 | 8.23 |
| Total unfished biomass (mt) | 1136.52 | 1494.09 | 1948.53 | 2528.35 | 3313.95 | 4035.93 | 2872.00 | 2389.96 | 2158.79 | 2009.99 |
| Depletion | 0.38 | 0.37 | 0.42 | 0.51 | 0.59 | 0.38 | 0.43 | 0.46 | 0.48 | 0.49 |
| SPR ratio | 0.99 | 0.99 | 1.00 | 1.00 | 1.00 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| Female Lmin | 12.29 | 12.79 | 13.35 | 13.68 | 13.93 | 10.08 | 9.82 | 9.67 | 9.60 | 9.54 |
| Female Lmax | 27.47 | 28.25 | 28.78 | 28.67 | 28.23 | 28.74 | 28.55 | 28.45 | 28.38 | 28.34 |
| Female K | 0.14 | 0.12 | 0.11 | 0.11 | 0.12 | 0.10 | 0.12 | 0.12 | 0.13 | 0.13 |
| Negative log-likelihood | | | | | | | | | | |
| TOTAL | 559.53 | 538.72 | 530.29 | 532.87 | 540.31 | 525.26 | 519.36 | 516.49 | 515.18 | 515.70 |
| Catch | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Survey | -29.36 | -30.94 | -33.60 | -35.55 | -35.83 | -30.36 | -31.68 | -32.16 | -32.35 | -32.46 |
| Length_comp | 414.22 | 412.12 | 411.34 | 413.52 | 417.35 | 373.67 | 372.78 | 372.47 | 372.35 | 372.29 |
| Age_comp | 154.09 | 146.67 | 146.61 | 149.75 | 152.41 | 191.65 | 190.34 | 189.60 | 189.18 | 188.88 |
| Recruitment | 20.58 | 10.87 | 5.94 | 5.14 | 6.38 | -11.56 | -12.69 | -13.47 | -13.94 | -14.28 |
| Parm_priors | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.85 | 0.60 | 0.04 | -0.05 | 1.27 |
| Parm_softbounds | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |

Table 32: Summaries of key assessment outputs and likelihood values from selected likelihood profile runs on female natural mortality and the growth parameter k. Depletion and SPR ratio are for the year 2019.

tab:like_profiles2

| Label | M0140 | M0180 | M0220 | M0260 | M0300 | K0070 | K0110 | K0150 | K0200 | K0250 |
|---|---|---|---|---|---|---|---|---|---|---|
| Female M | 0.14 | 0.18 | 0.22 | 0.26 | 0.30 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| Steepness | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 |
| lnR0 | 7.61 | 8.16 | 8.70 | 9.25 | 9.80 | 8.06 | 8.05 | 8.03 | 7.99 | 7.96 |
| Total unfished biomass (mt) | 2325.92 | 2290.85 | 2396.04 | 2613.52 | 2993.24 | 2049.72 | 2045.80 | 1992.79 | 1901.63 | 1856.94 |
| Depletion | 0.32 | 0.40 | 0.47 | 0.54 | 0.59 | 0.40 | 0.44 | 0.46 | 0.47 | 0.49 |
| SPR ratio | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Female Lmin | 9.43 | 9.57 | 9.69 | 9.76 | 9.76 | 13.94 | 13.37 | 12.39 | 10.73 | 9.71 |
| Female Lmax | 27.91 | 28.09 | 28.51 | 28.92 | 29.46 | 29.87 | 28.73 | 27.92 | 27.29 | 26.62 |
| Female K | 0.18 | 0.15 | 0.12 | 0.09 | 0.07 | 0.07 | 0.11 | 0.15 | 0.20 | 0.25 |
| Negative log-likelihood | | | | | | | | | | |
| TOTAL | 520.87 | 517.09 | 516.39 | 517.29 | 518.96 | 531.89 | 530.11 | 532.03 | 536.74 | 542.96 |
| Catch | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Survey | -31.78 | -32.25 | -32.13 | -31.84 | -31.48 | -34.86 | -33.97 | -32.58 | -30.84 | -29.45 |
| Length_comp | 373.35 | 372.68 | 372.45 | 372.59 | 372.88 | 411.36 | 411.62 | 413.73 | 416.31 | 418.00 |
| Age_comp | 191.76 | 189.93 | 189.56 | 189.86 | 190.58 | 149.97 | 146.86 | 144.62 | 144.22 | 146.40 |
| Recruitment | -12.73 | -13.28 | -13.54 | -13.57 | -13.53 | 5.43 | 5.61 | 6.26 | 7.04 | 8.01 |
| Parm_priors | 0.27 | 0.01 | 0.04 | 0.23 | 0.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Parm_softbounds | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

# 8 Figures

figures

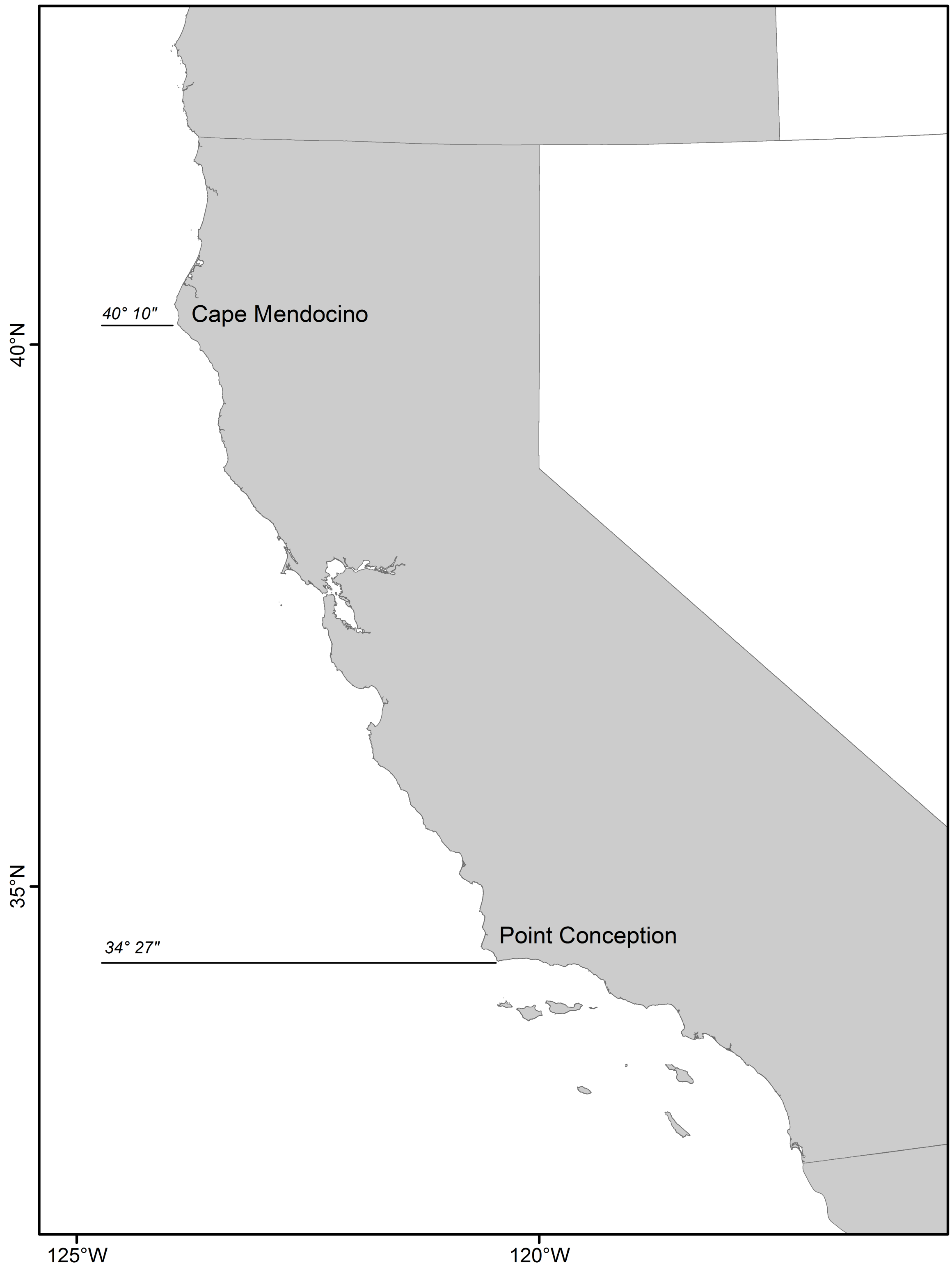



Figure 1: Map showing the management area for gopher and black-and-yellow rockfish from Cape Mendocino to the U.S.-Mexico border. fig:assess_region_map1

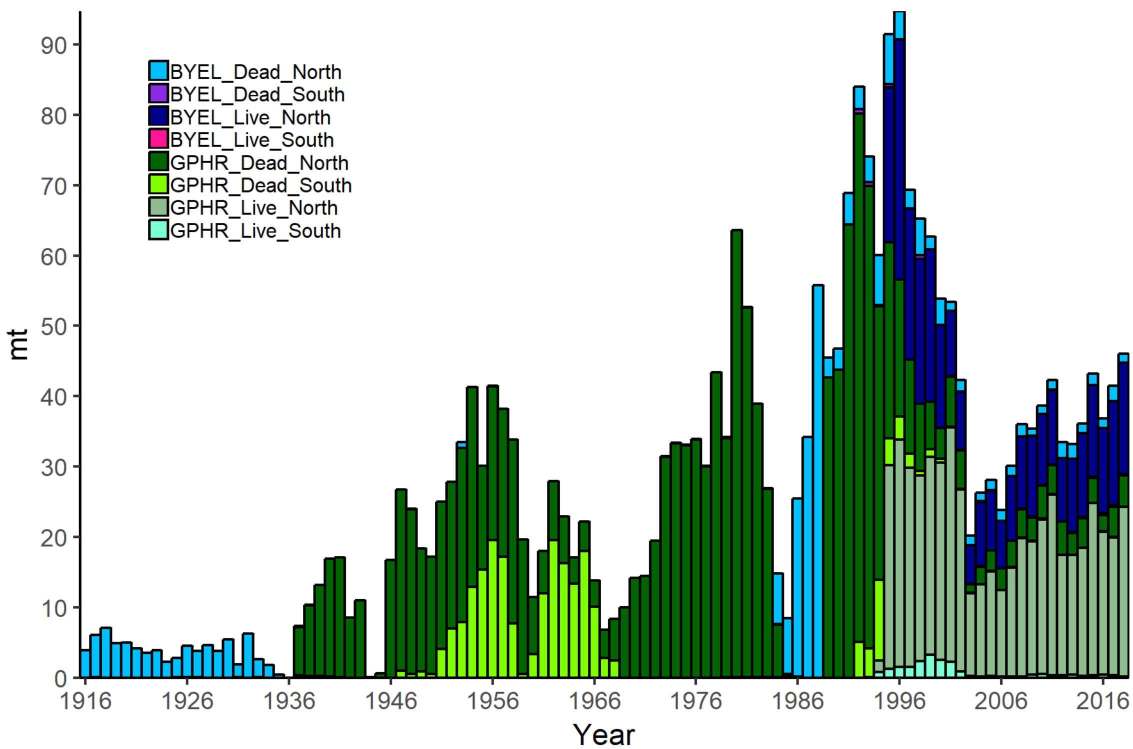



Figure 2: Commercial landings for gopher (GPHR) and black-and-yellow (BYEL) rockfishes landed live and dead north and south of Point Conception. All catch time series were combined for the assessment into one commercial fleet. fig:Catches_livedeadNS_gby

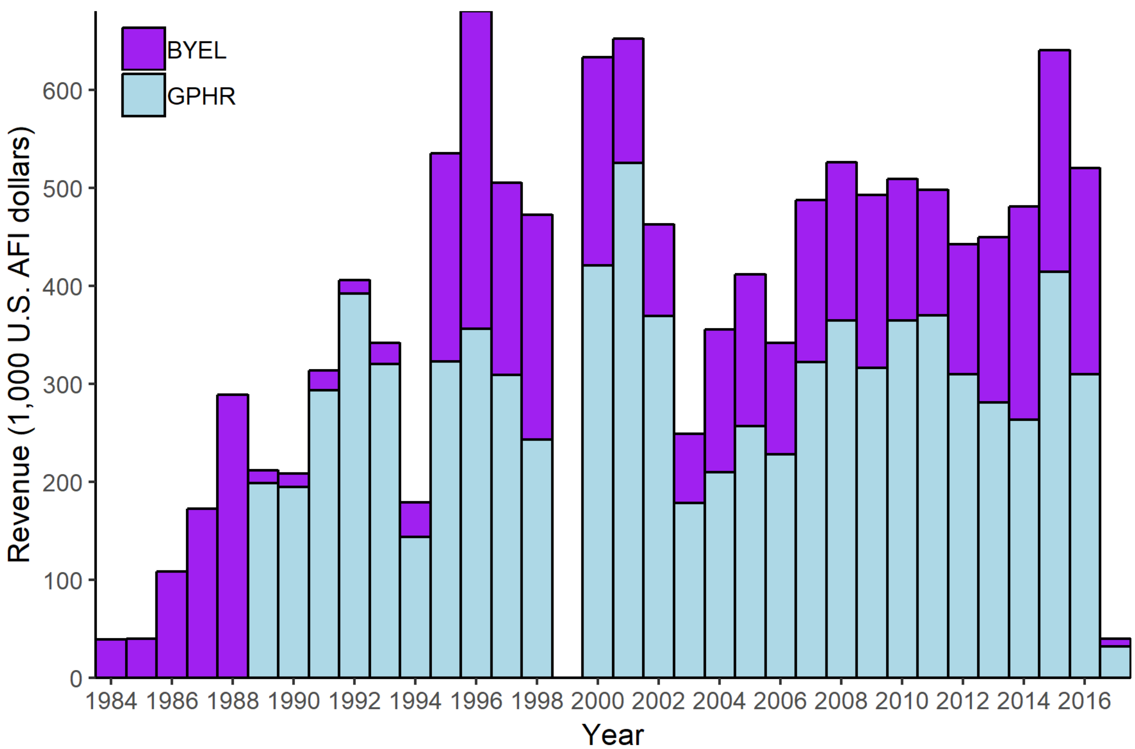



Figure 3: Annual ex-vessel revenue, adjusted for inflation (AFI) in thousands of dollars for gopher and black-and-yellow rockfish. fig:GBY_revenue

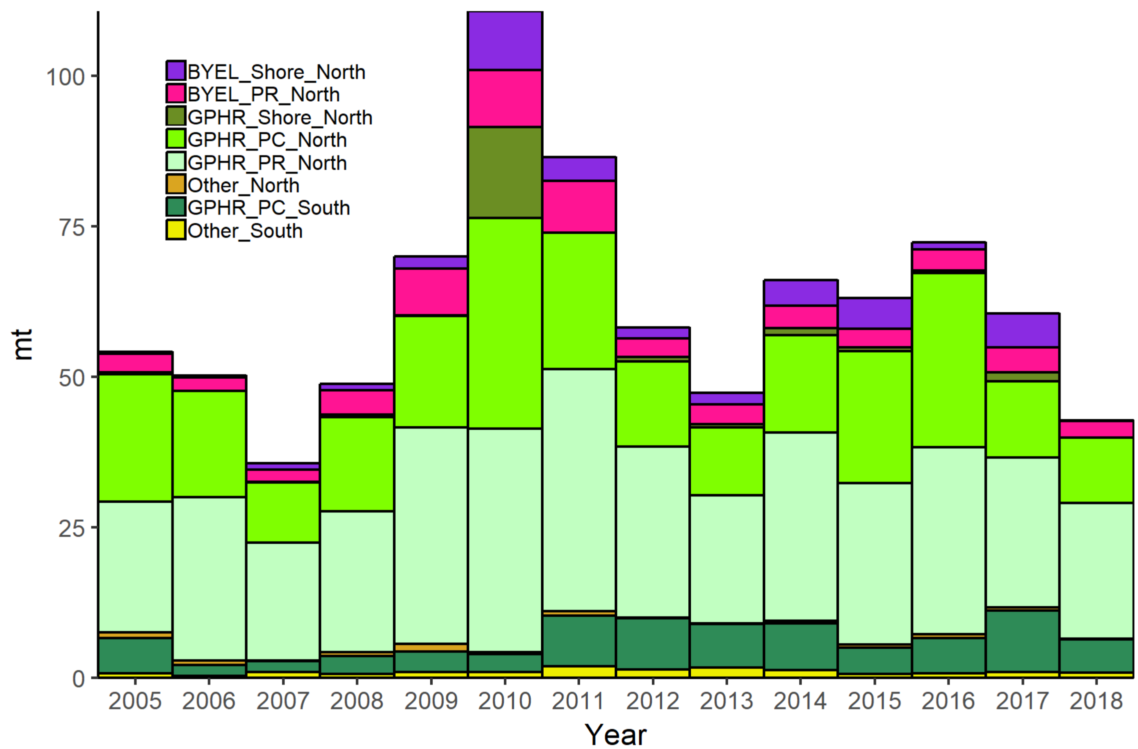



Figure 4: Recreational total mortality for gopher rockfish (GPHR) and black-and-yellow (BYEL) rockfish from the CRFS sampling era by mode and split north and south of Point Conception. fig:CFRS_catches

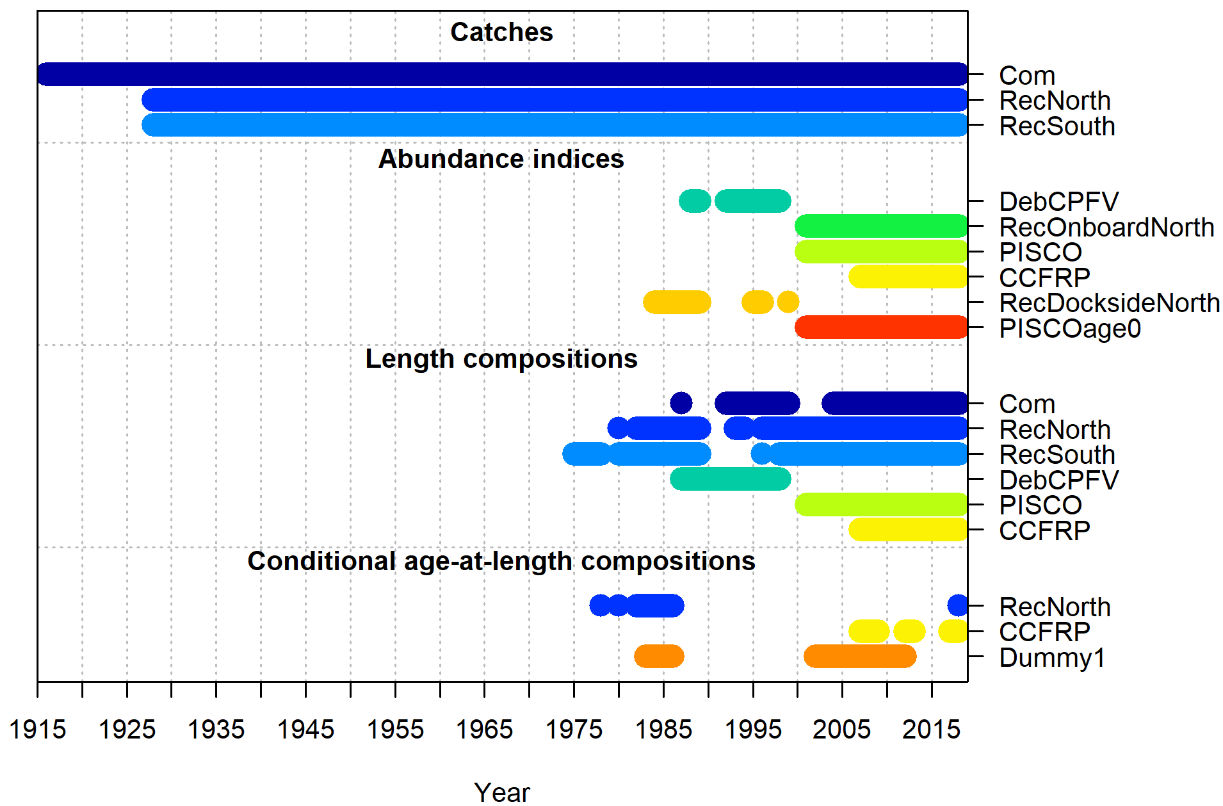



Figure 5: Summary of data sources used in the model. fig:data_plot

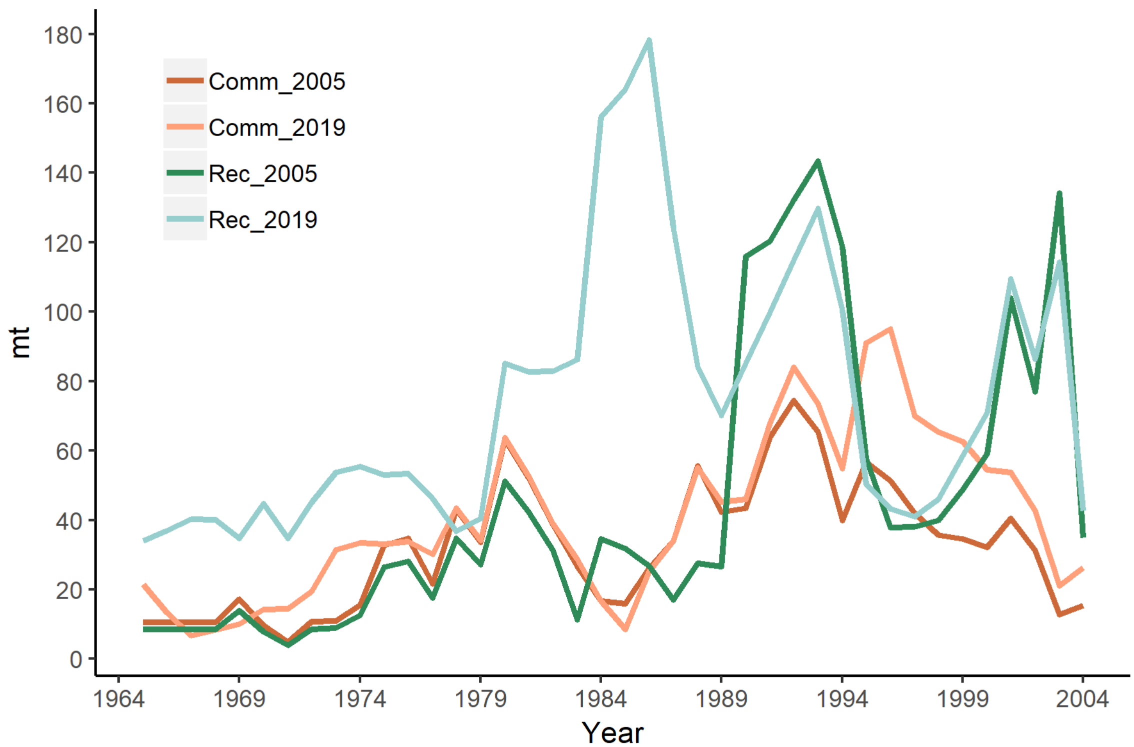



Figure 6: Comparison of the recreational and commercial fishery landings from the 2005 assessment to this 2019 assessment. Note that the 2019 assessment includes both gopher and black-and-yellow rockfish where the 2005 assessment represents gopher rockfish only. The 2005 assessment also did not include landings from south of Point Conception. fig:Assessment_compare

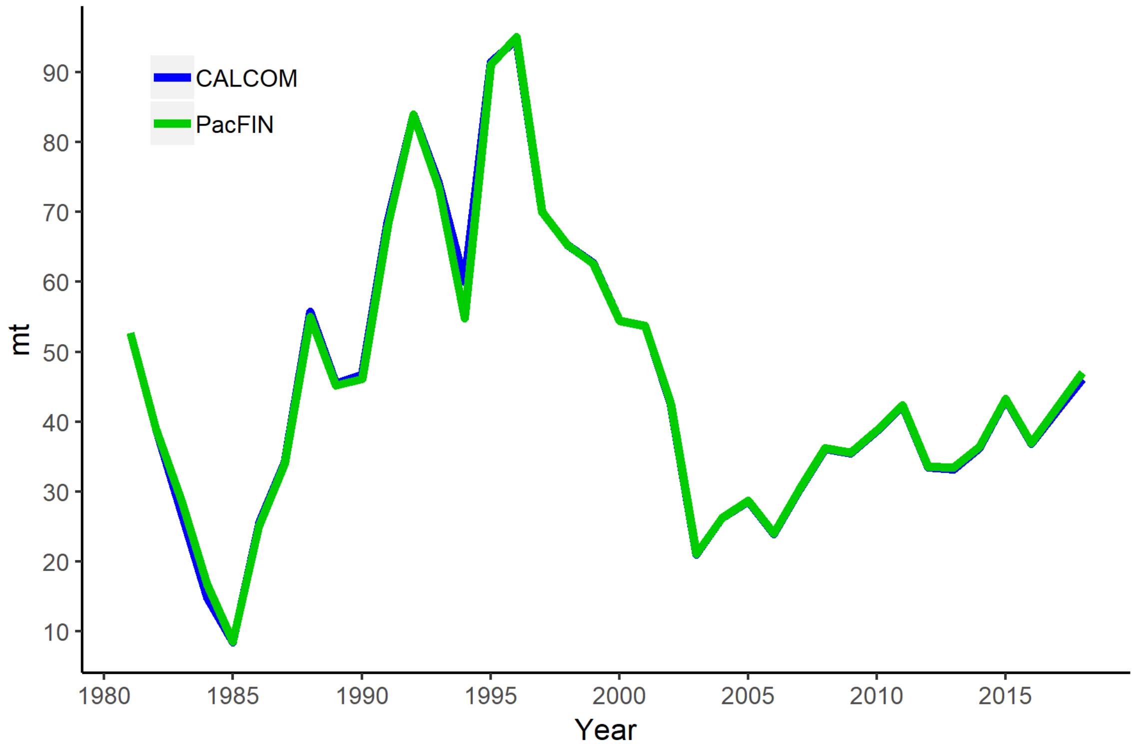



Figure 7: Commercial landings estimates from CALCOM and PacFIN. fig:Calcom_vs_Pacfin


Figure 8: Percent differences in the expanded length compositions by year from CALCOM and PacFIN. The same market categories were used for each dataset, but each database was subject to further independent filtering criteria and expansion algorithms. fig:Calcom_vs_pacfin_length

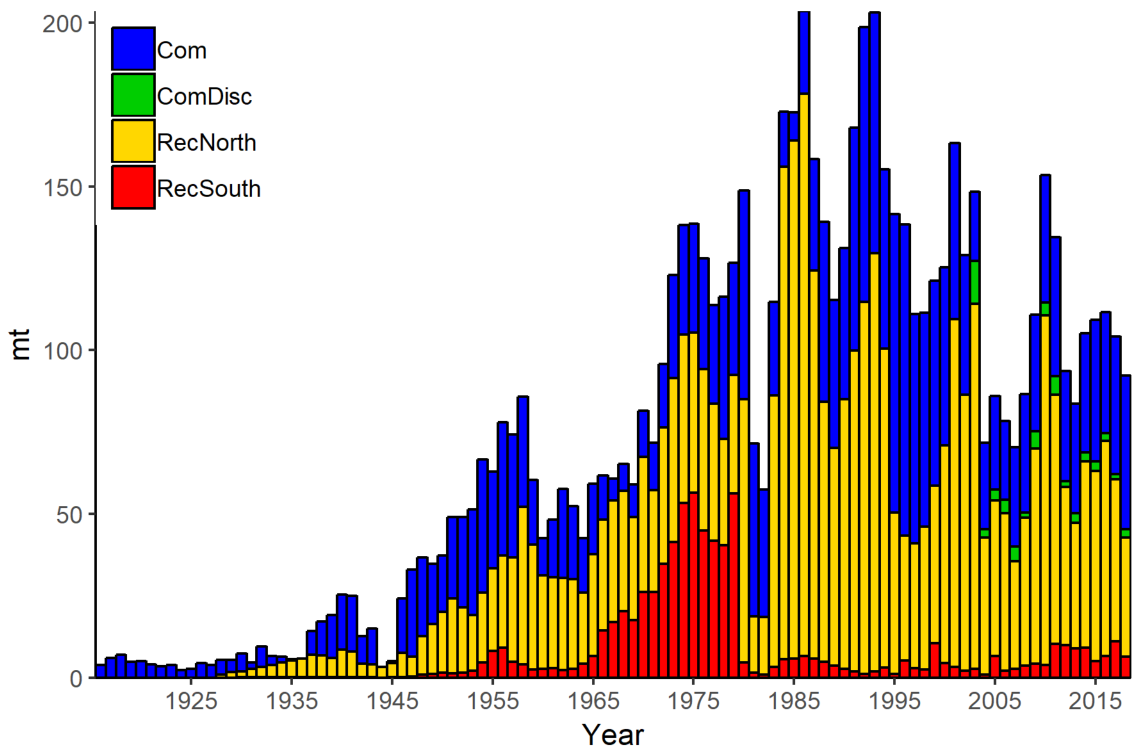



Figure 9: Commercial and recreational landings estimates prior to any data modification or interpolation to the recreational catches or hindcasting of commercial discards. fig:Catches_original

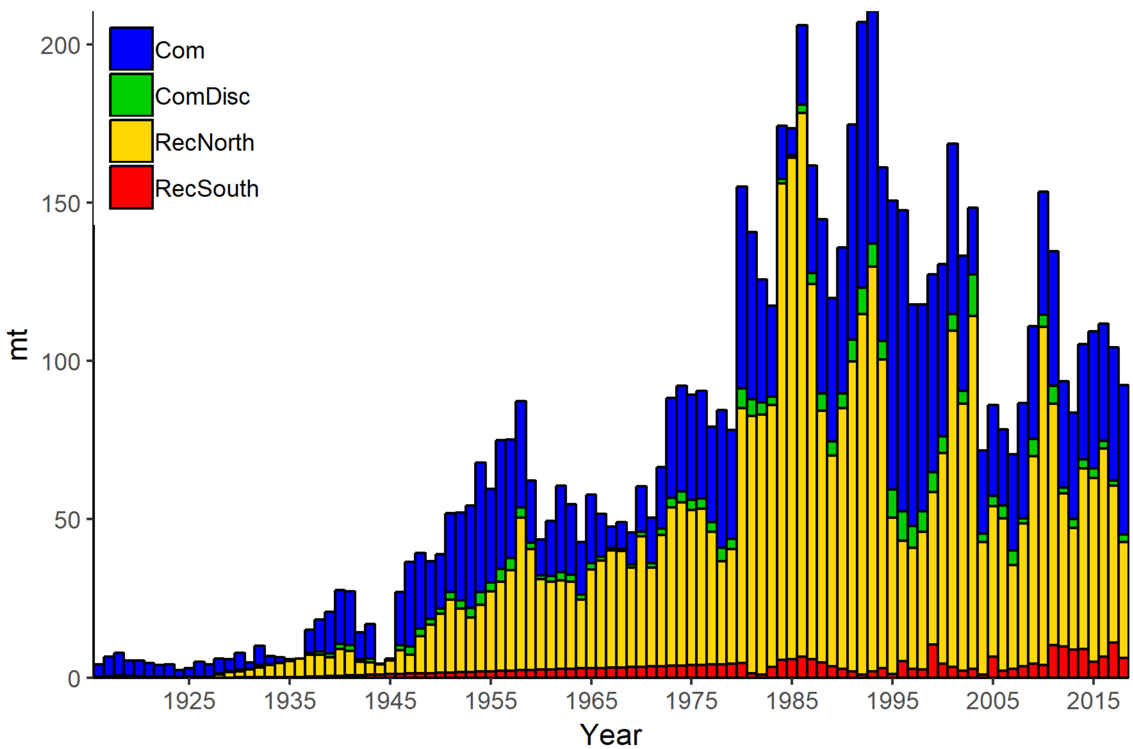



Figure 10: Commercial and recreational landings estimates after data modification and interpolations were made to the recreational catches and commercial discards. fig:Catches_alternate

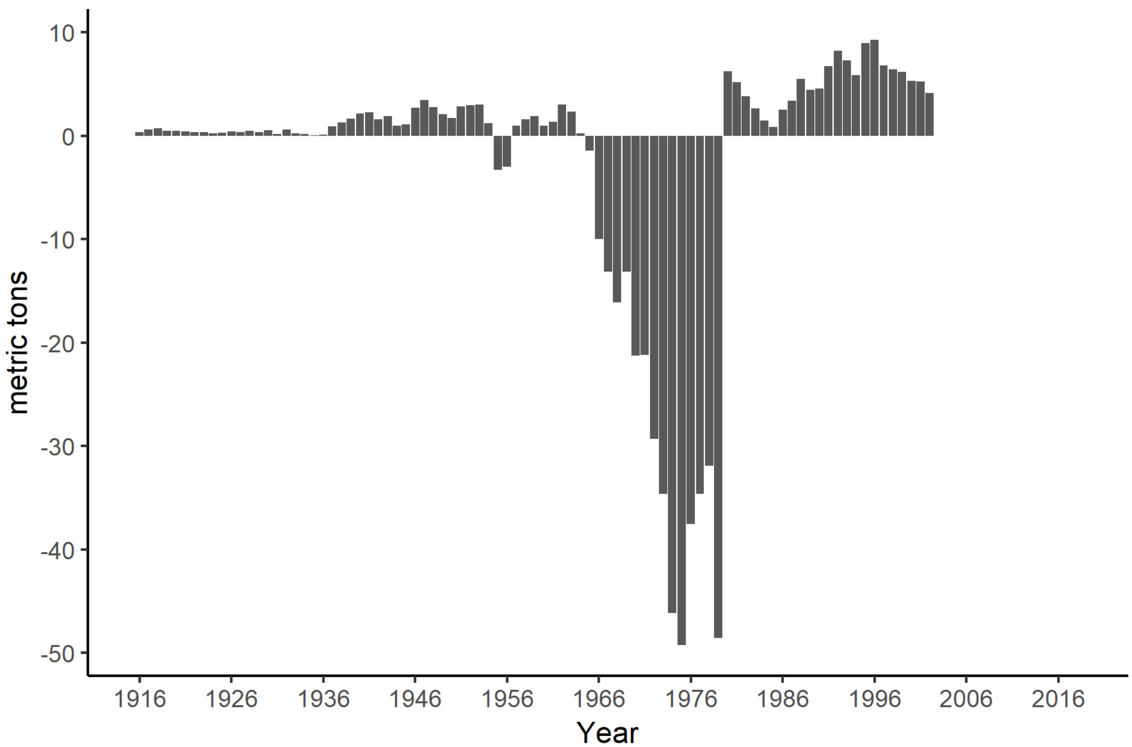



Figure 11: Difference in landings between the original and modified landings presented in the previous two figures. The only two fleets with modifications are recreational south and commercial discards. Negative values indicate catches removed from the original estimates and positive values represent the addition of landings from the commercial discards. fig:catches_differ

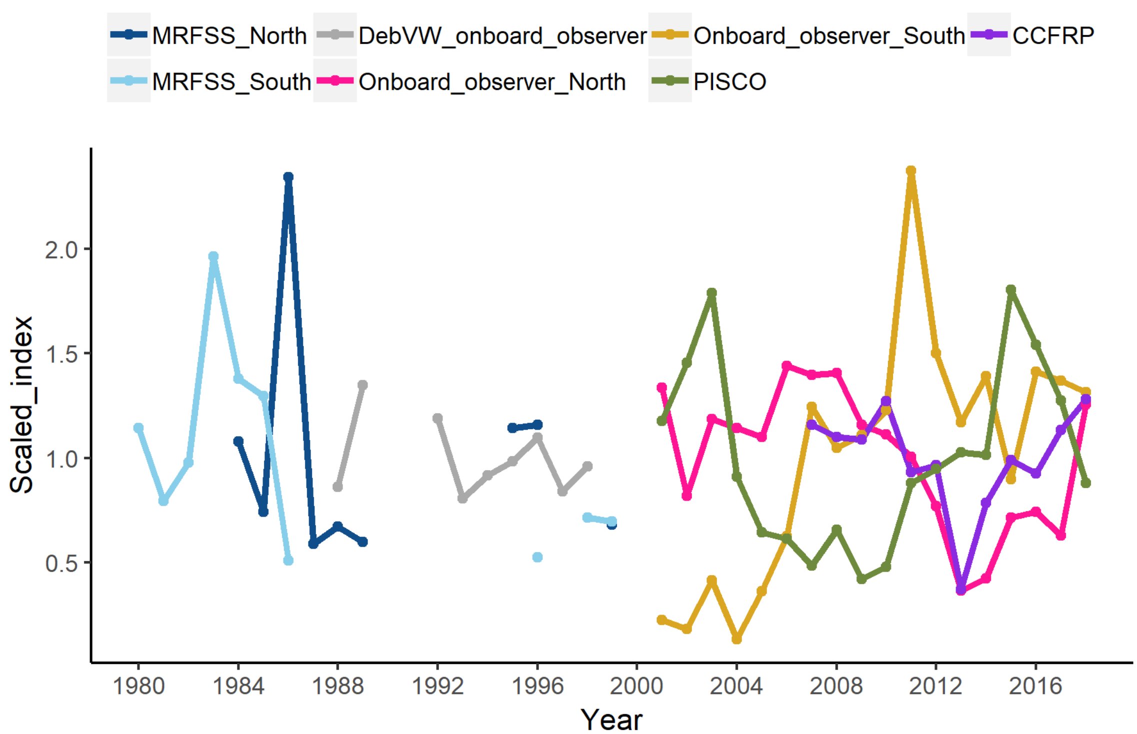



Figure 12: Comparison of all indices of abundance in the pre-STAR base model (with each index scaled to its mean). fig:All_index_compare

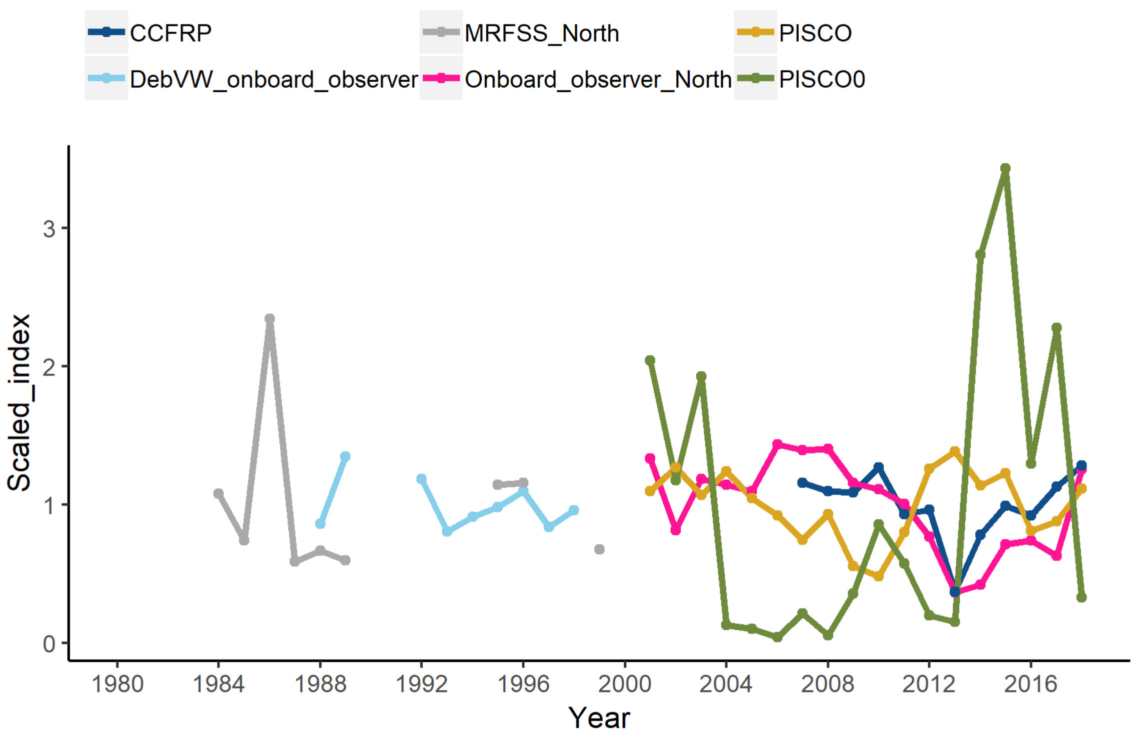



Figure 13: Comparison of all indices of abundance in the post-STAR base model (with each index scaled to its mean). fig:All_index_compare_postSTAR

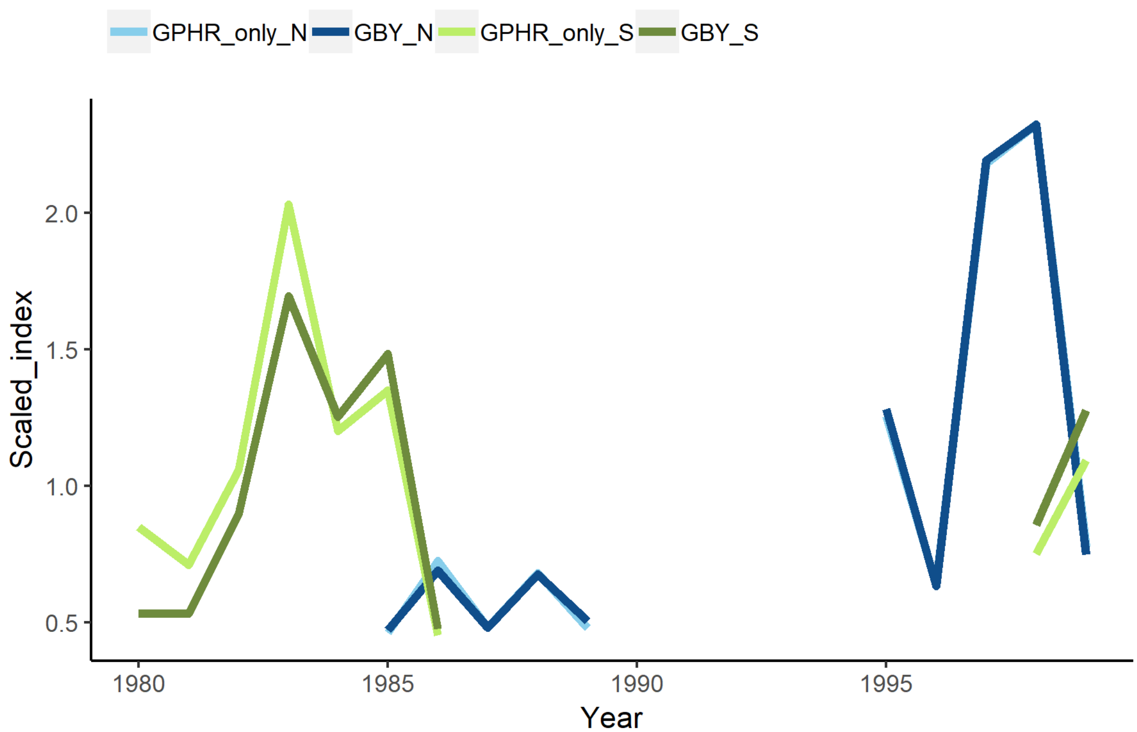



Figure 14: Comparison of indices of abundance (scaled to their means) for the MRFSS dockside CPFV survey between a gopher-only and GBYR complex index for north and south of Point Conception. fig:MRFSS_index_compare

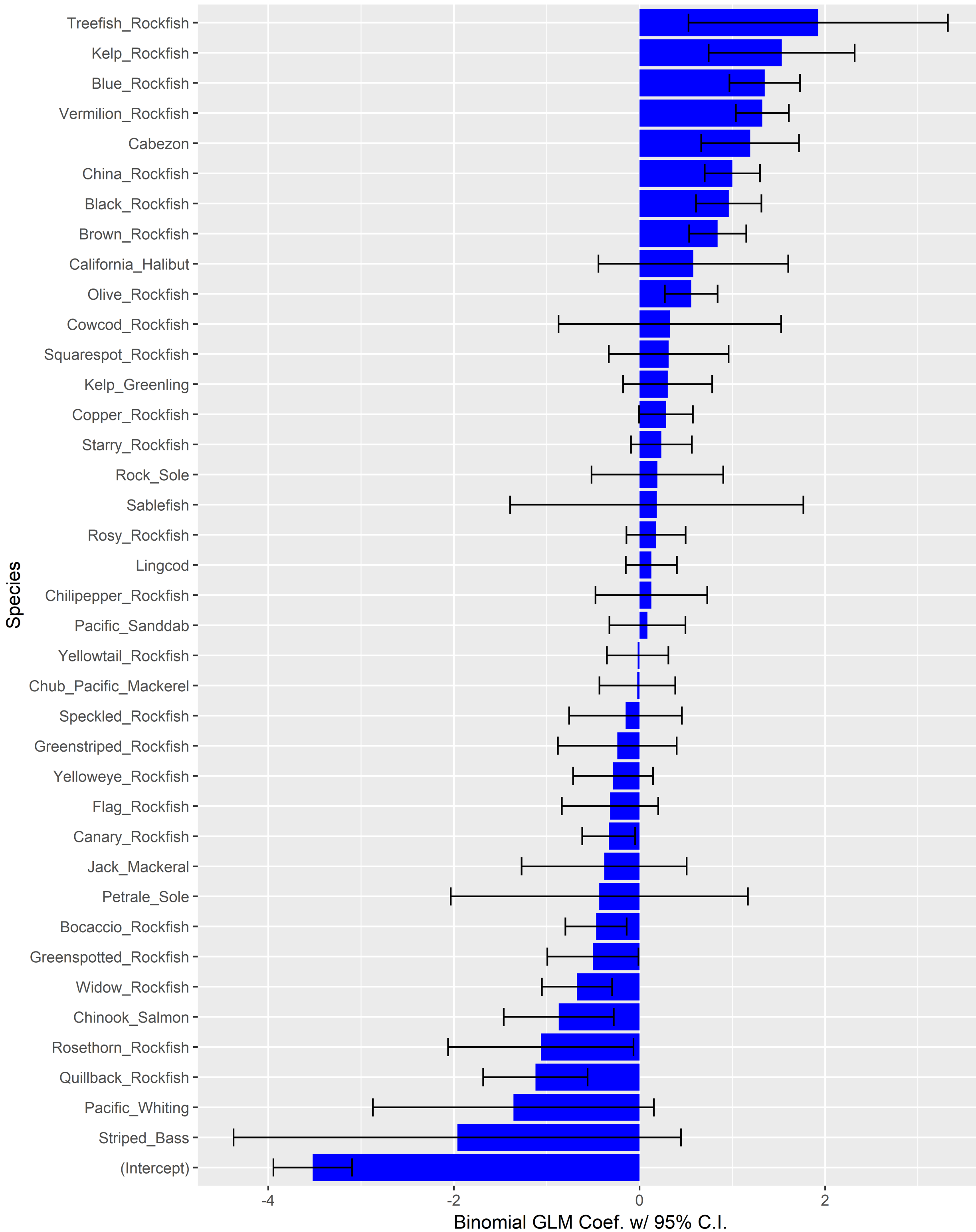



Figure 15: Species coefficients from the binomial GLM for presence/absence of GBYR in the Marine Recreational Fisheries Statistics Survey (MRFSS) CPFV mode dockside survey data set north of Point Conception. Horizontal bars are 95% confidence intervals. fig:Fleet10_SM_filter

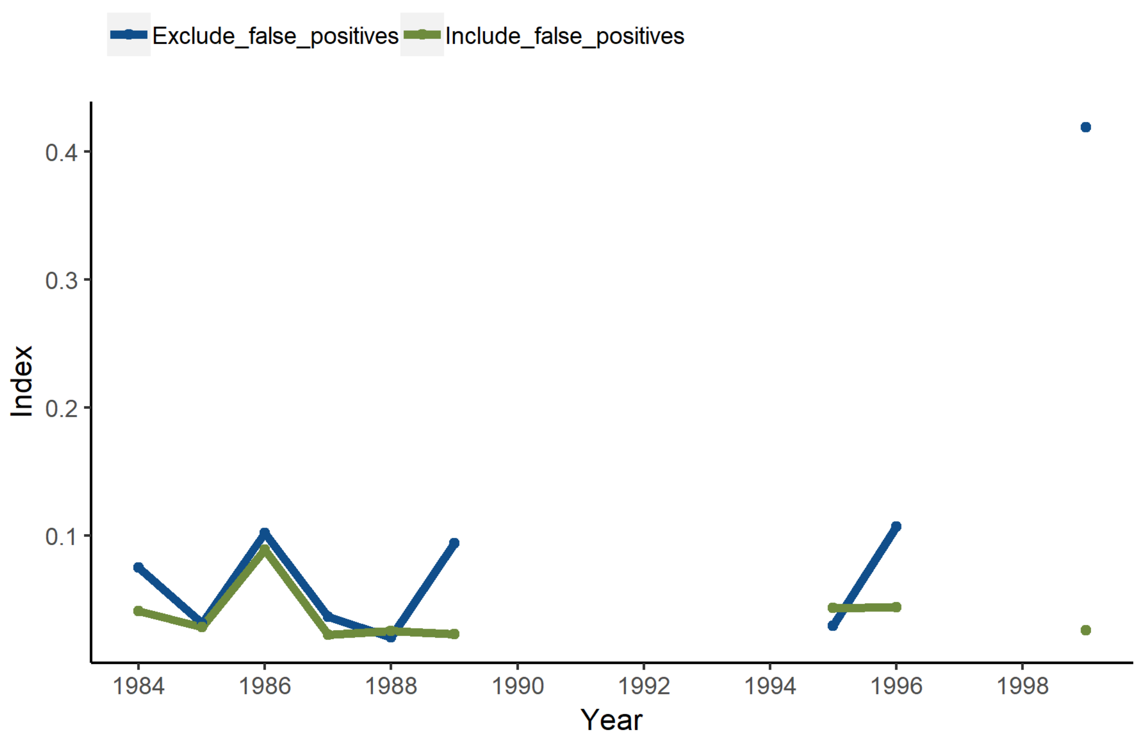



Figure 16: Comparisons of the indices of abundance for GBYR north of Point Conception from the MRFSS dockside CPFV survey that either include of exclude the trips identified as false positives from the Stephens-MacCall filter. fig:MRFSS_index_N_SM_falsepos

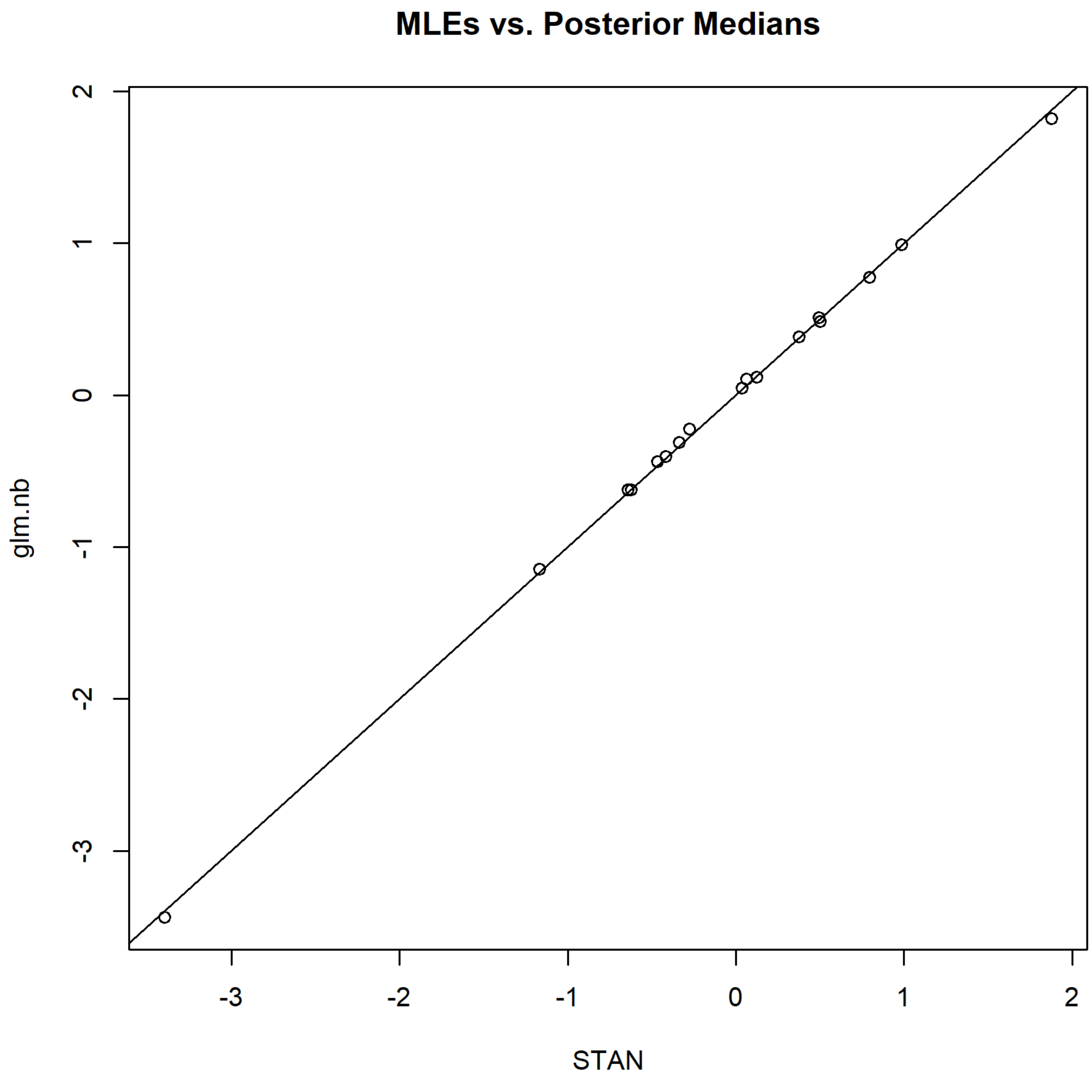



Figure 17: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year) MRFSS CPFV dockside index north of Point Conception. The 1:1 plot is for reference. fig:Fleet10_MLE_stan

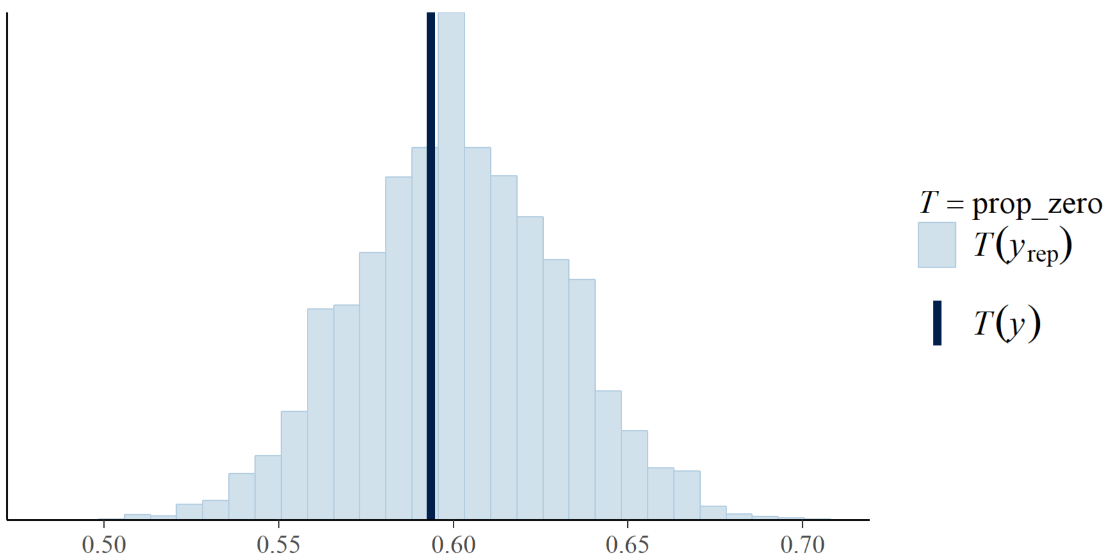



Figure 18: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for MRFSS dockside CPFV index north of Point Conception. fig:Fleet10_prop_zero_STAN

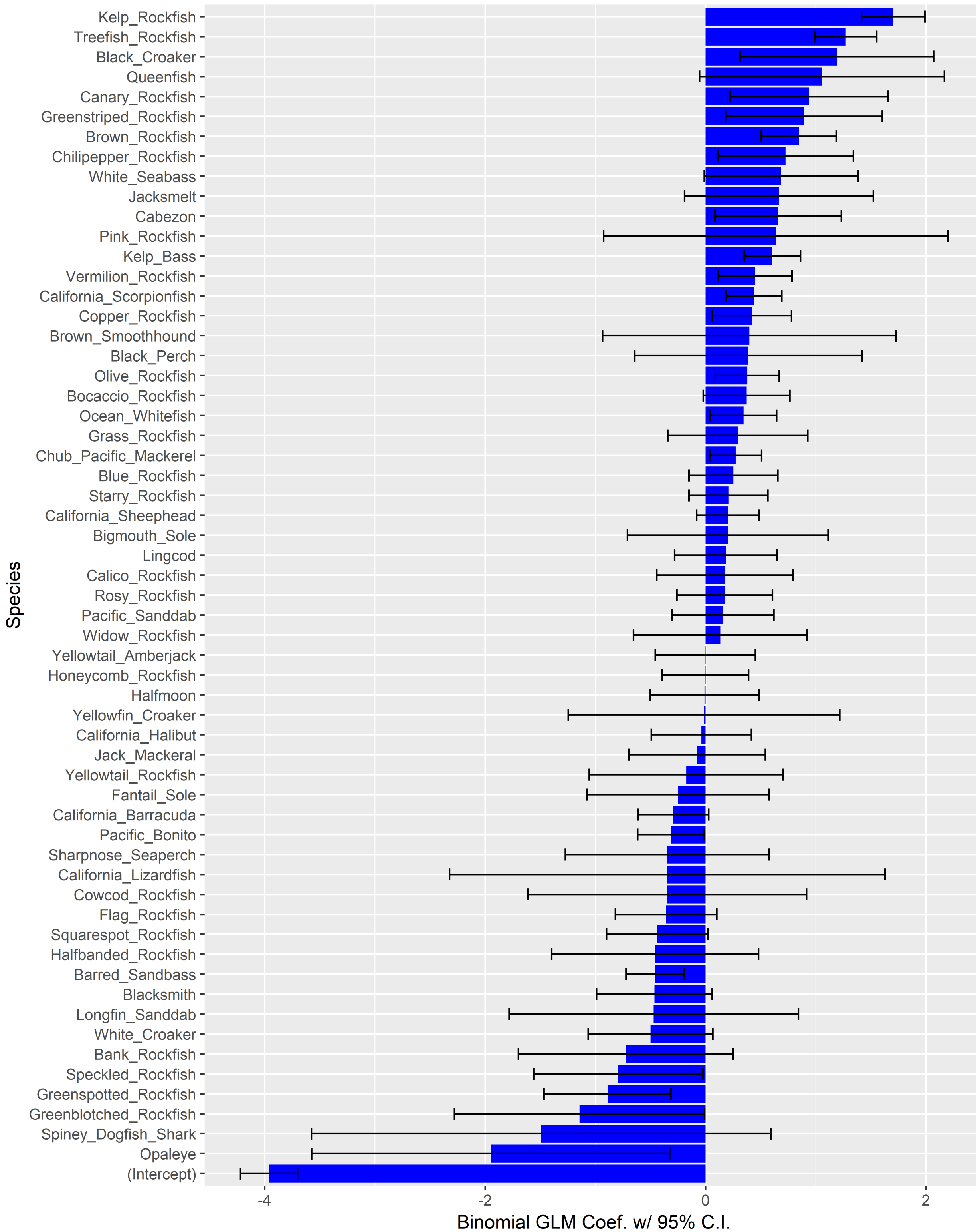



Figure 19: Species coefficients from the binomial GLM for presence/absence of GBYR in the Marine Recreational Fisheries Statistics Survey (MRFSS) CPFV mode dockside survey data set north of Point Conception. Horizontal bars are 95% confidence intervals. fig:Fleet11_SM_filter

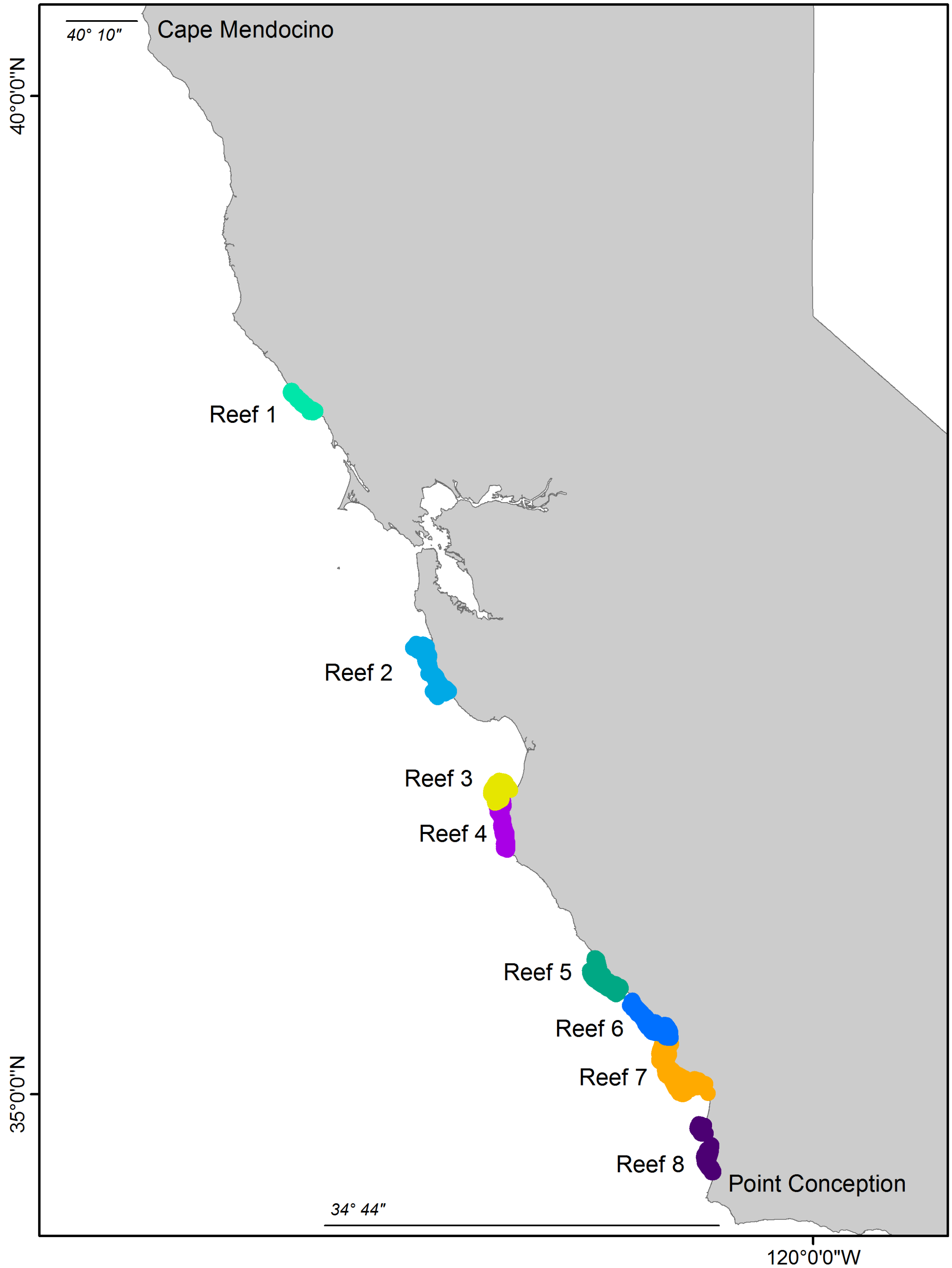



Figure 20: Map of the reefs used in the Deb Wilson-Vandenberg CPFV onboard observer survey index of abundance. fig:DebWV_sites

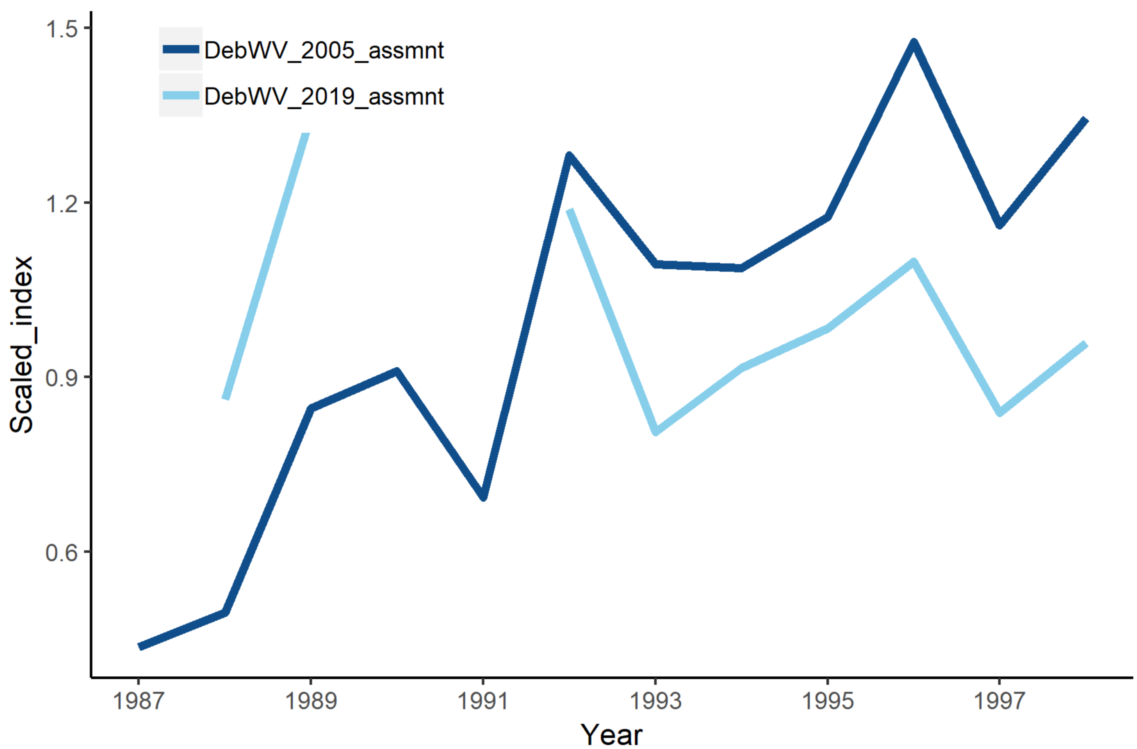



Figure 21: Comparison of the index developed for the Deb Wilson-Vandenberg CPFV onboard observer survey from the 2005 assessment and for the 2019 assessment. fig:DebWV_index_compare

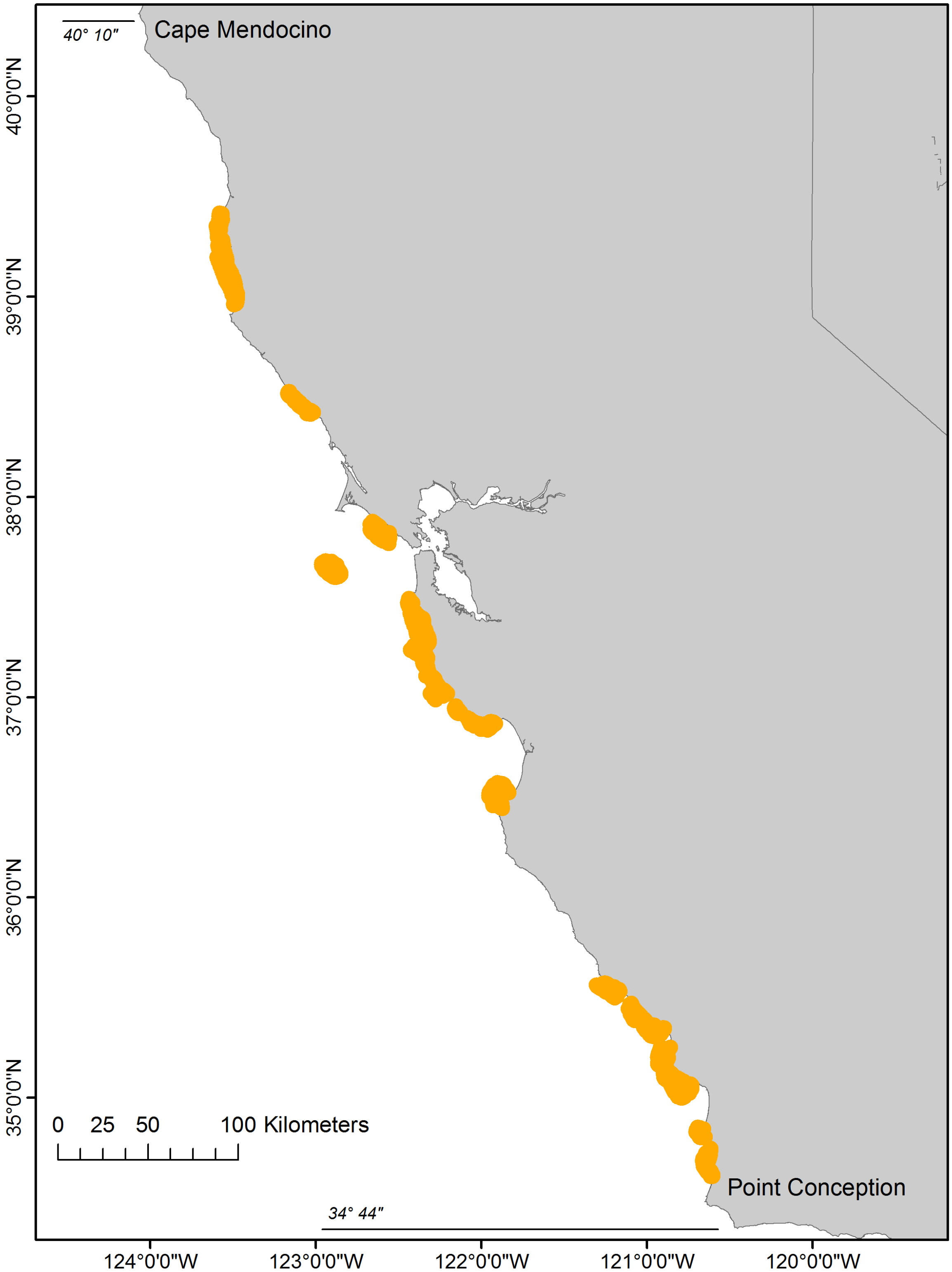



Figure 22: Map of the reefs selected for the final index for the onboard observer surveys (CDFW and Cal Poly) north of Point Conception fig:Onboard_observer_north_sites

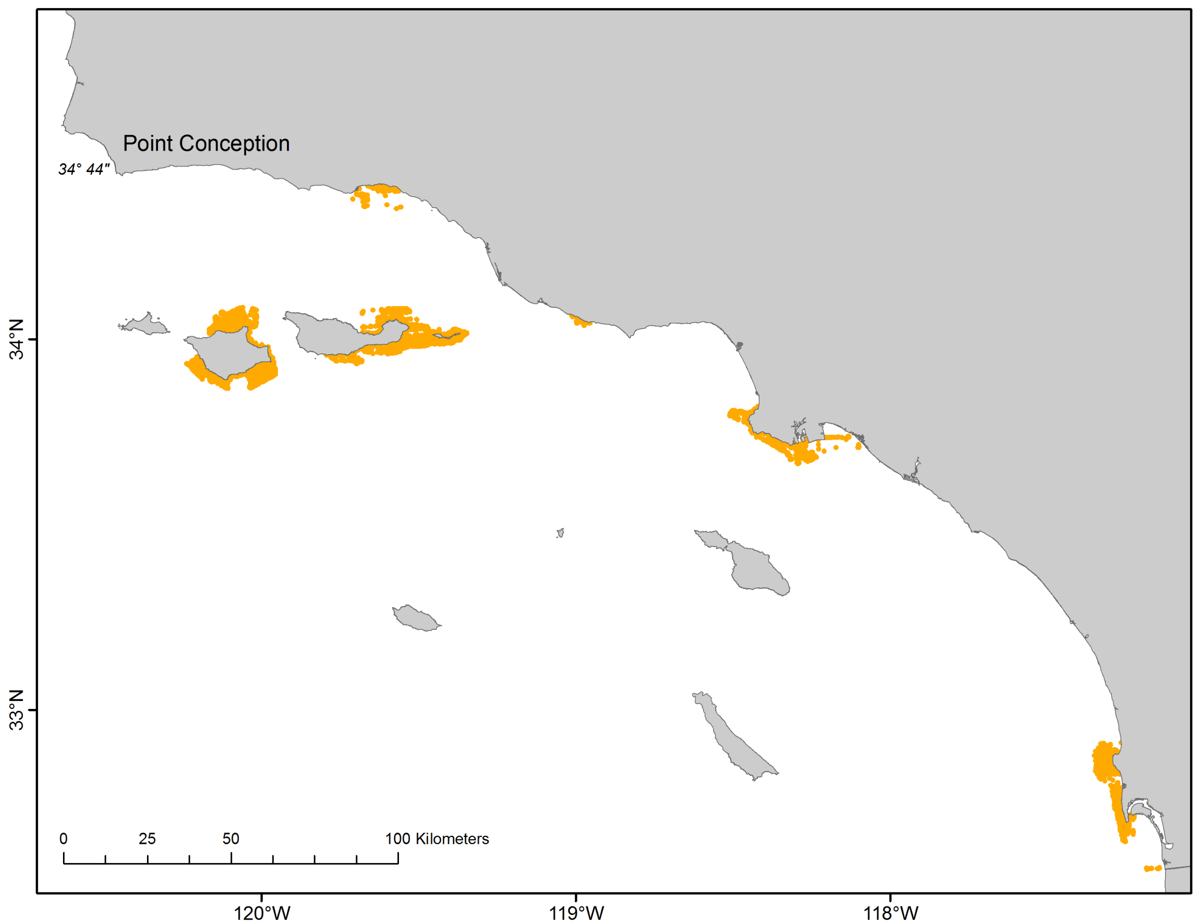



Figure 23: Map of the reefs selected for the final index for the CDFW onboard observer survey south of Point Conception fig:Onboard_observer_south_sites

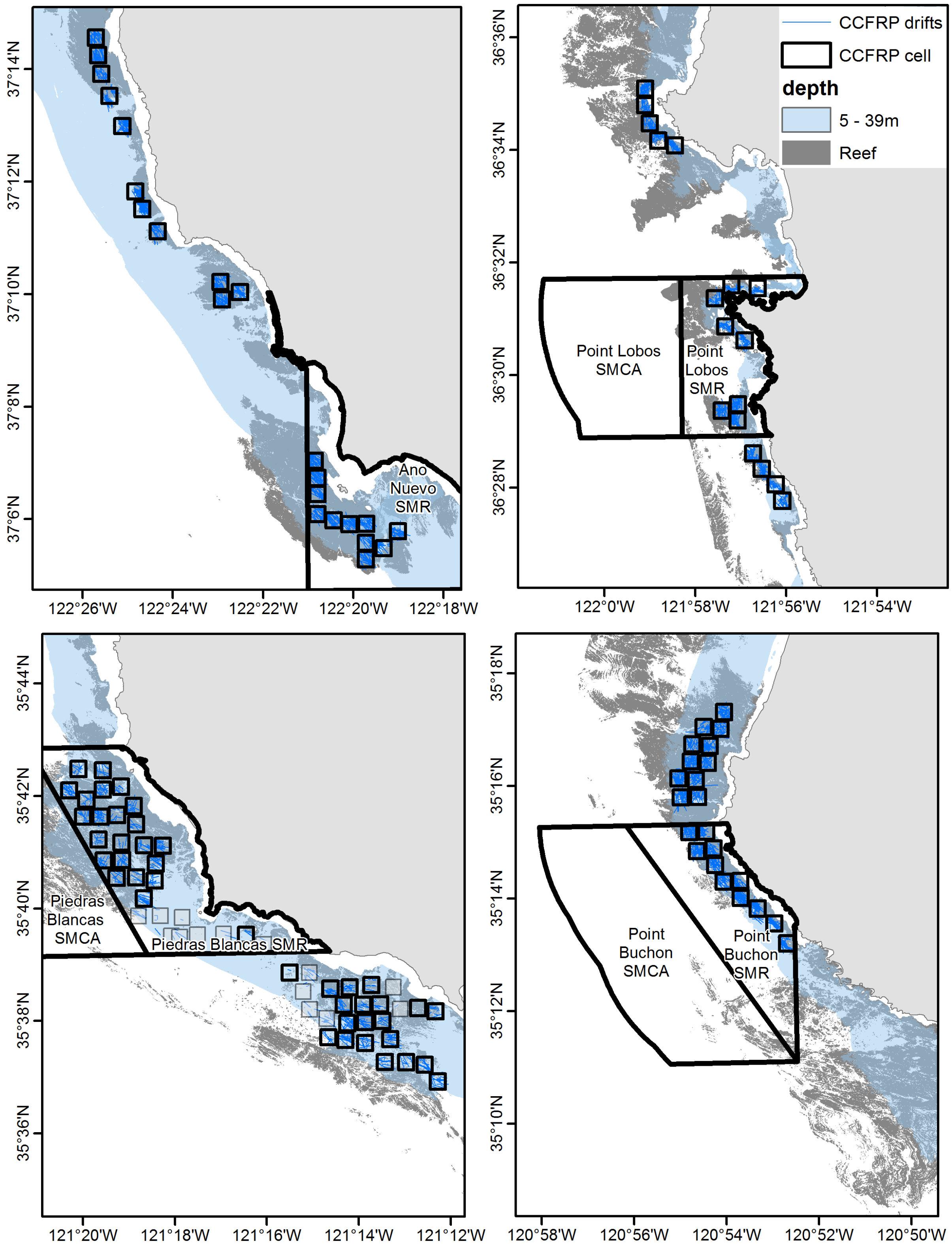



Figure 24: Map of the four MPAs sampled consistently through time for the CCFRP fishery-independent survey. fig:CCFRP_sites

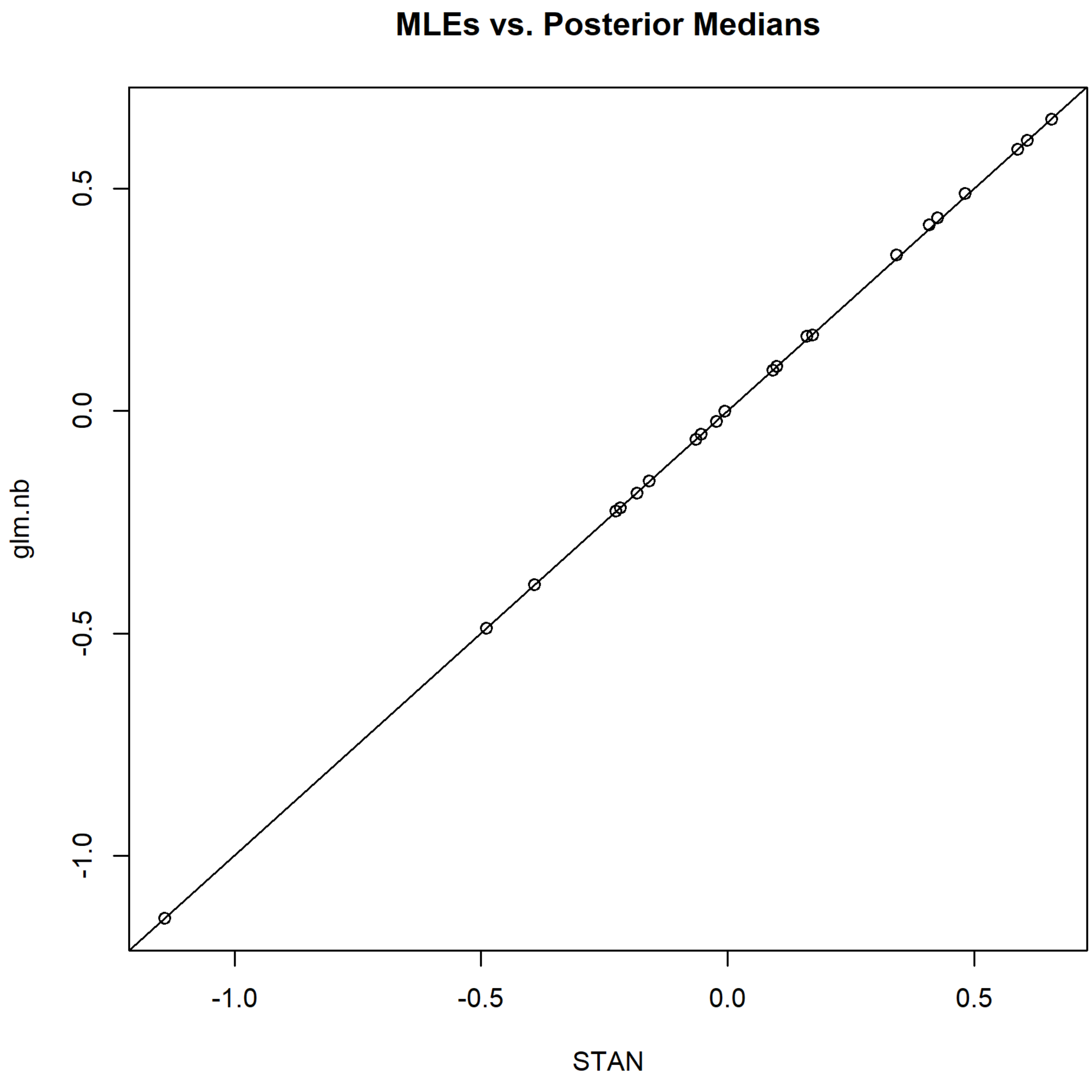



Figure 25: Comparison of negative bionimial predictions (CPUE) to observed means in each stratum (year) for the CCFRP index. The 1:1 plot is for reference. fig:Fleet9_MLE_stan

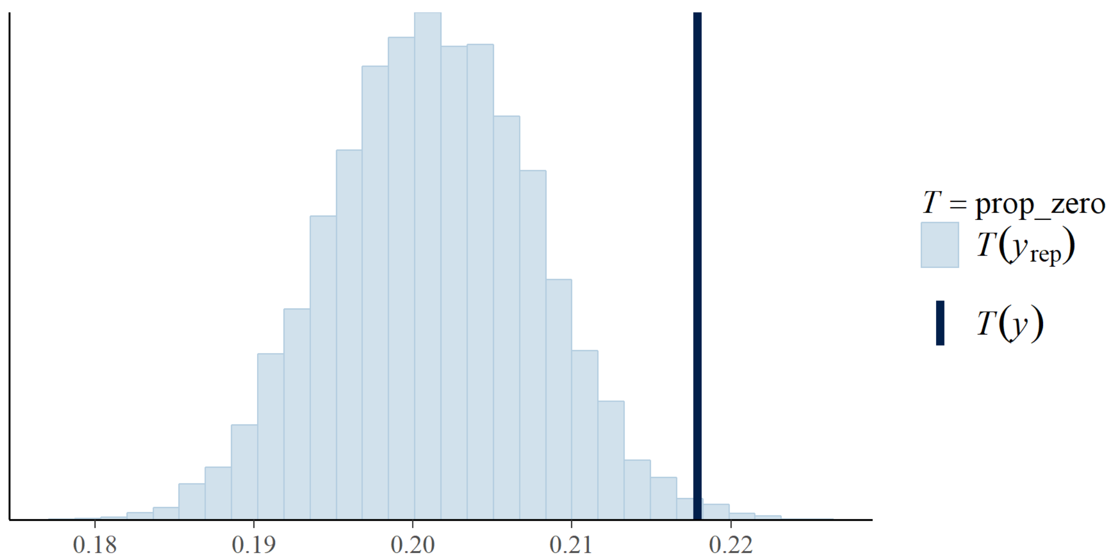



Figure 26: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the CCFRP index. fig:Fleet9_prop_zero_STAN

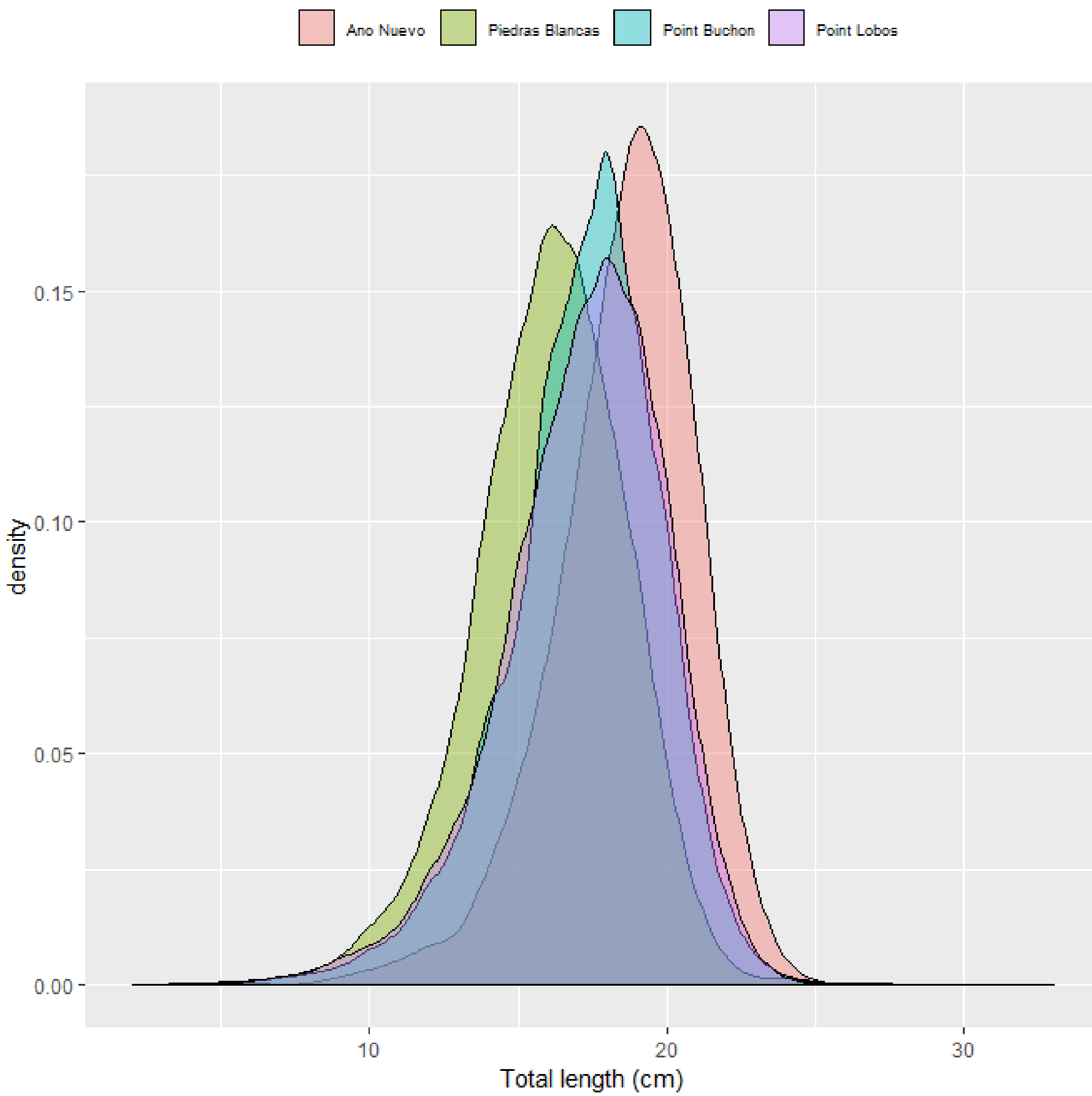



Figure 27: Length distributions of GBYR for the four MPAs sampled by the CCFRP survey used in this assessment. | CCFRP_lengths_by_site

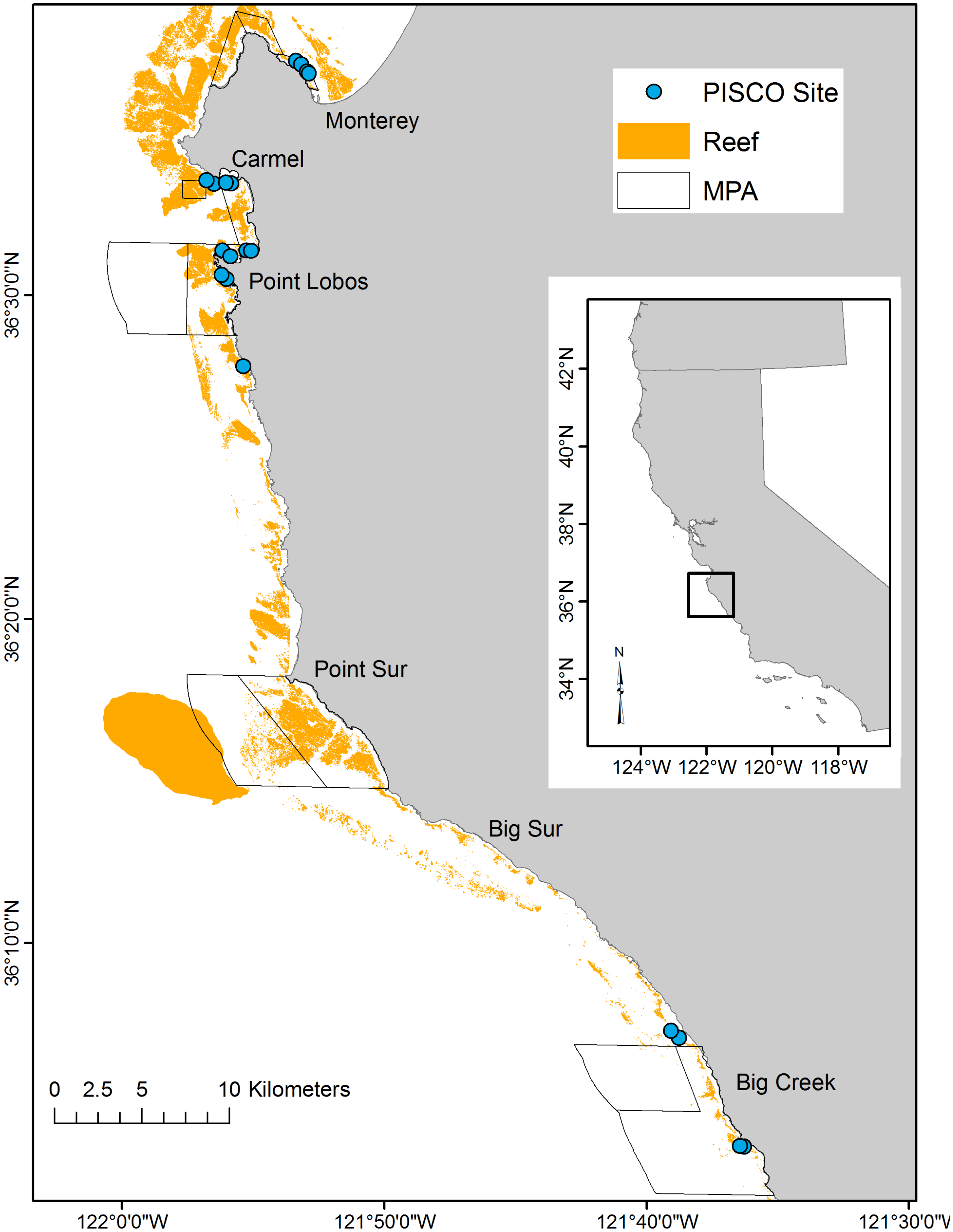



Figure 28: Map of the sites sampled consistently through time for the PISCO kelp forest fish survey. fig:PISCO_sites

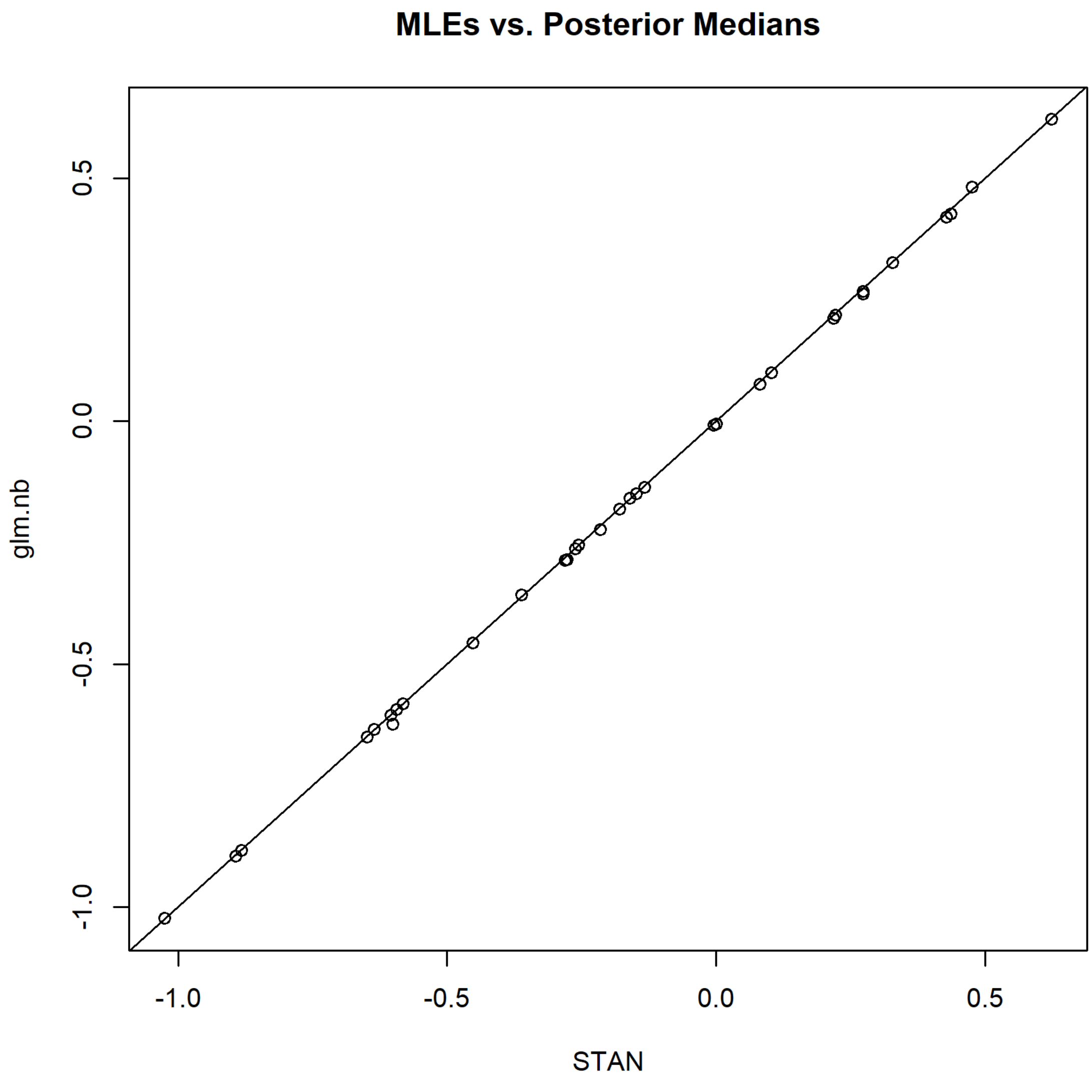



Figure 29: Comparison of negative bionimial predictions (CPUE) to observed means in each stratum (year) for the PISCO kelp forest fish survey index. The 1:1 plot is for reference. fig:Fleet8_MLE_

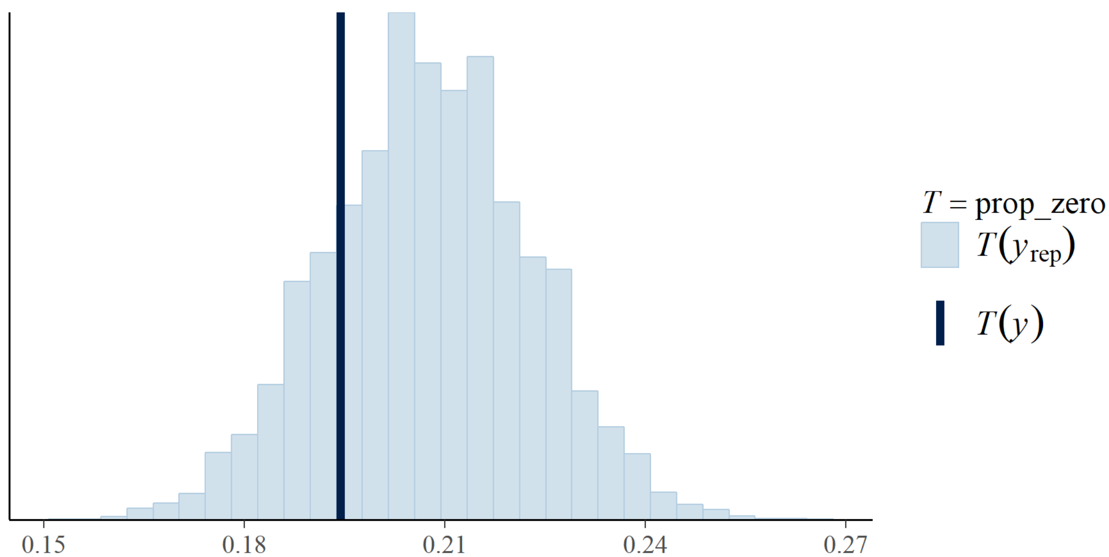



Figure 30: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the PISCO kelp forest fish survey. fig:Fleet8_pr

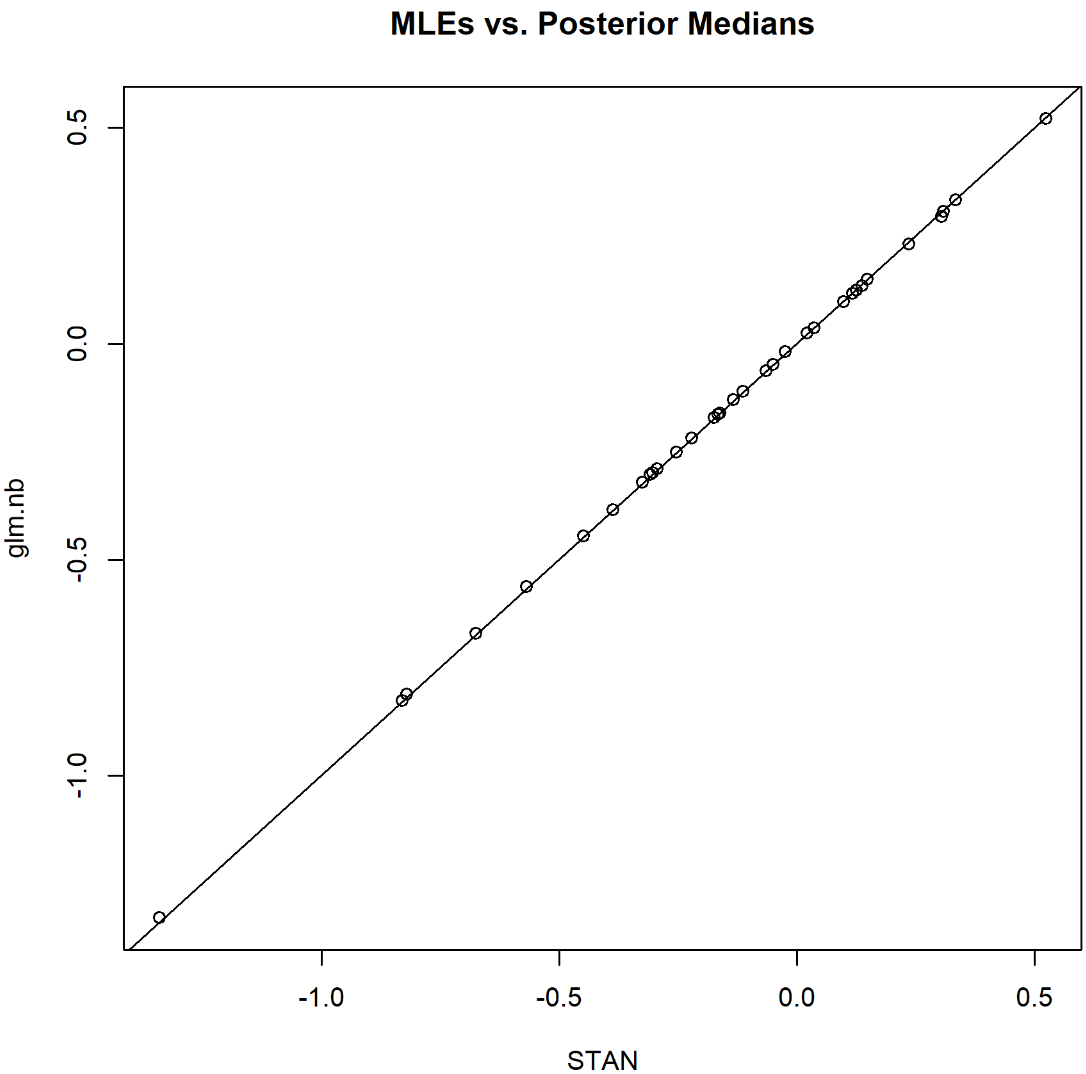



Figure 31: Comparison of negative bionimial predictions (CPUE) to observed means in each stratum (year) for the PISCO kelp forest fish survey index for fish 15 cm and larger. The 1:1 plot is for reference. fig:Fleet8large_MLE_stan

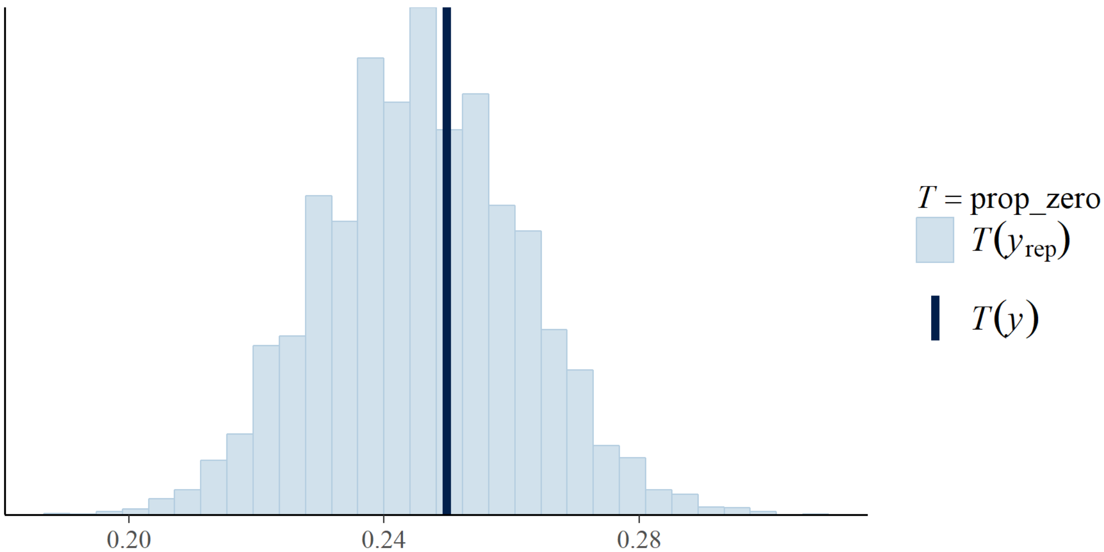



Figure 32: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the PISCO kelp forest fish survey for fish 15 cm and larger. fig:Fleet8large_prop_zero_STAN

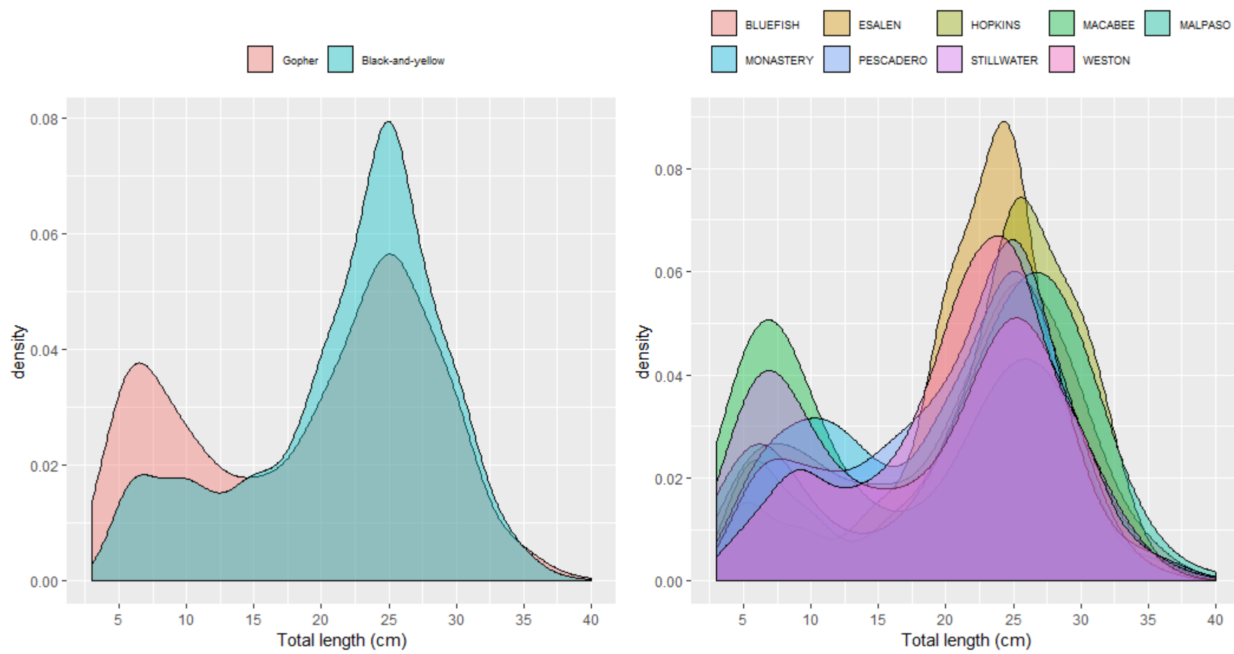



Figure 33: Plots of the length distributions from the PISCO kelp forest fish survey by species (left) and for combined species by site (right) for sites included in the final index of abundance. fig:PISCO_lengths

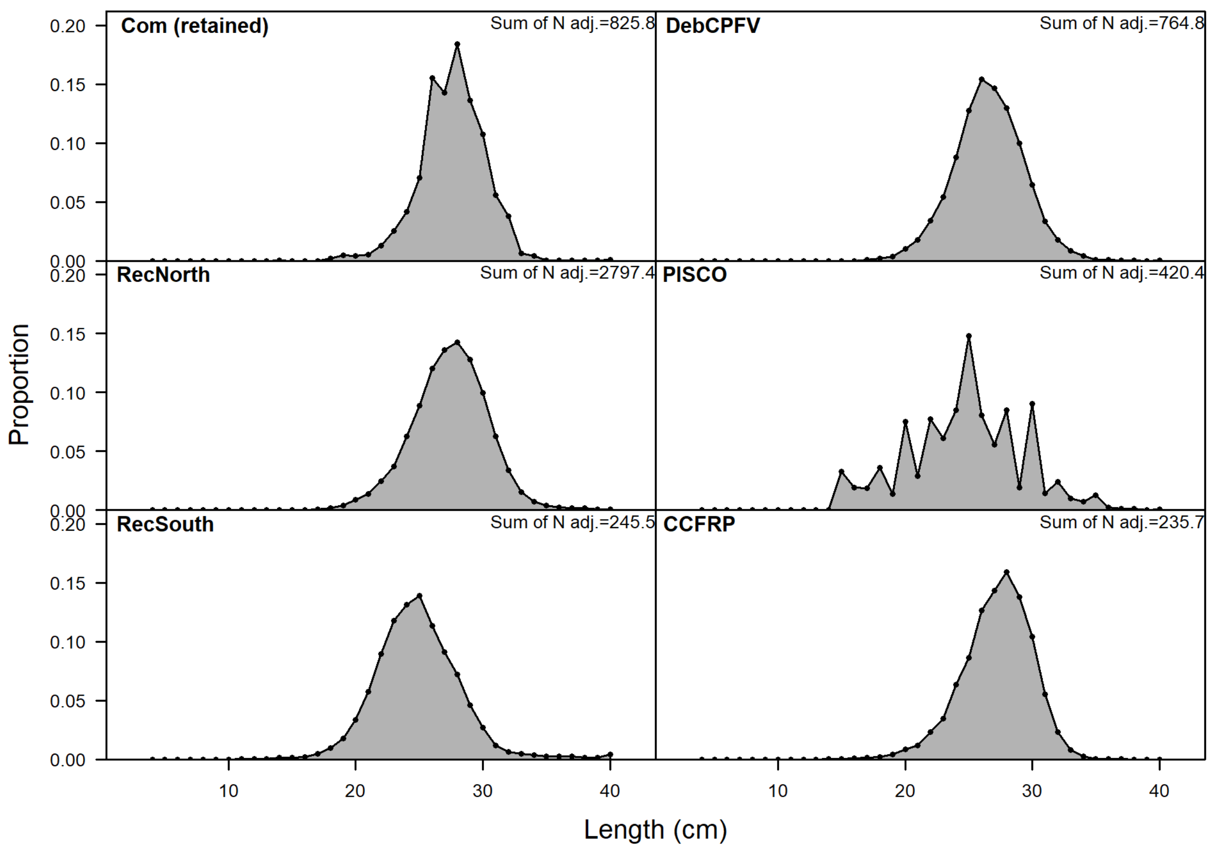



Figure 34: Length comp data, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. fig:comp_lendat_aggregated_across_time


Figure 35: Available length-at-age data for gopher and black-and-yellow rockfish by sex and data source. The Zaitlin study is all black-and-yellow rockfish. The remaining plots represent gopher rockfish fig:Age_length_by_study

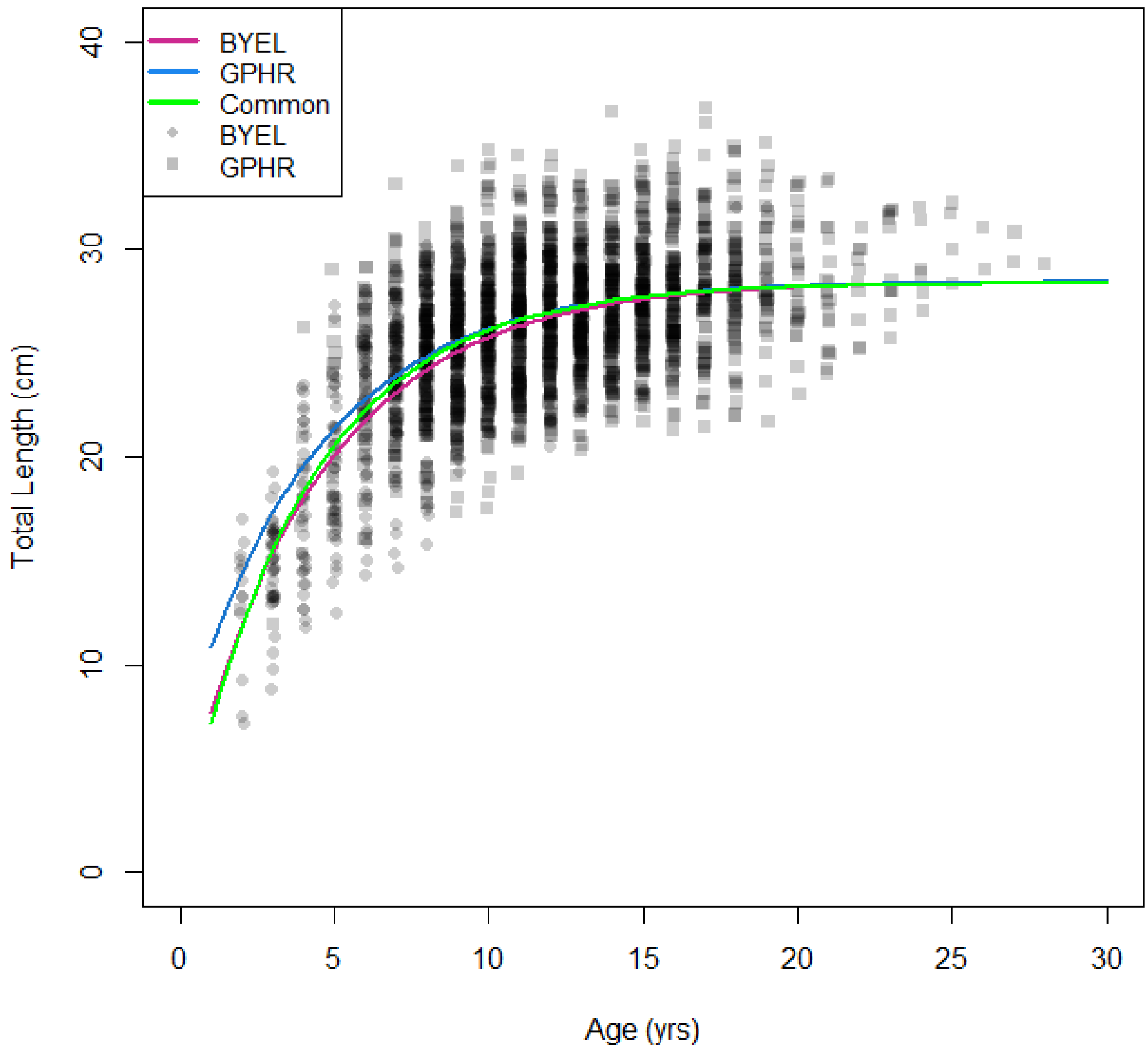



Figure 36: External estimates of growth for gopher and black-and-yellow rockfish from fits to von Bertalanffy growth models. Growth_by_species

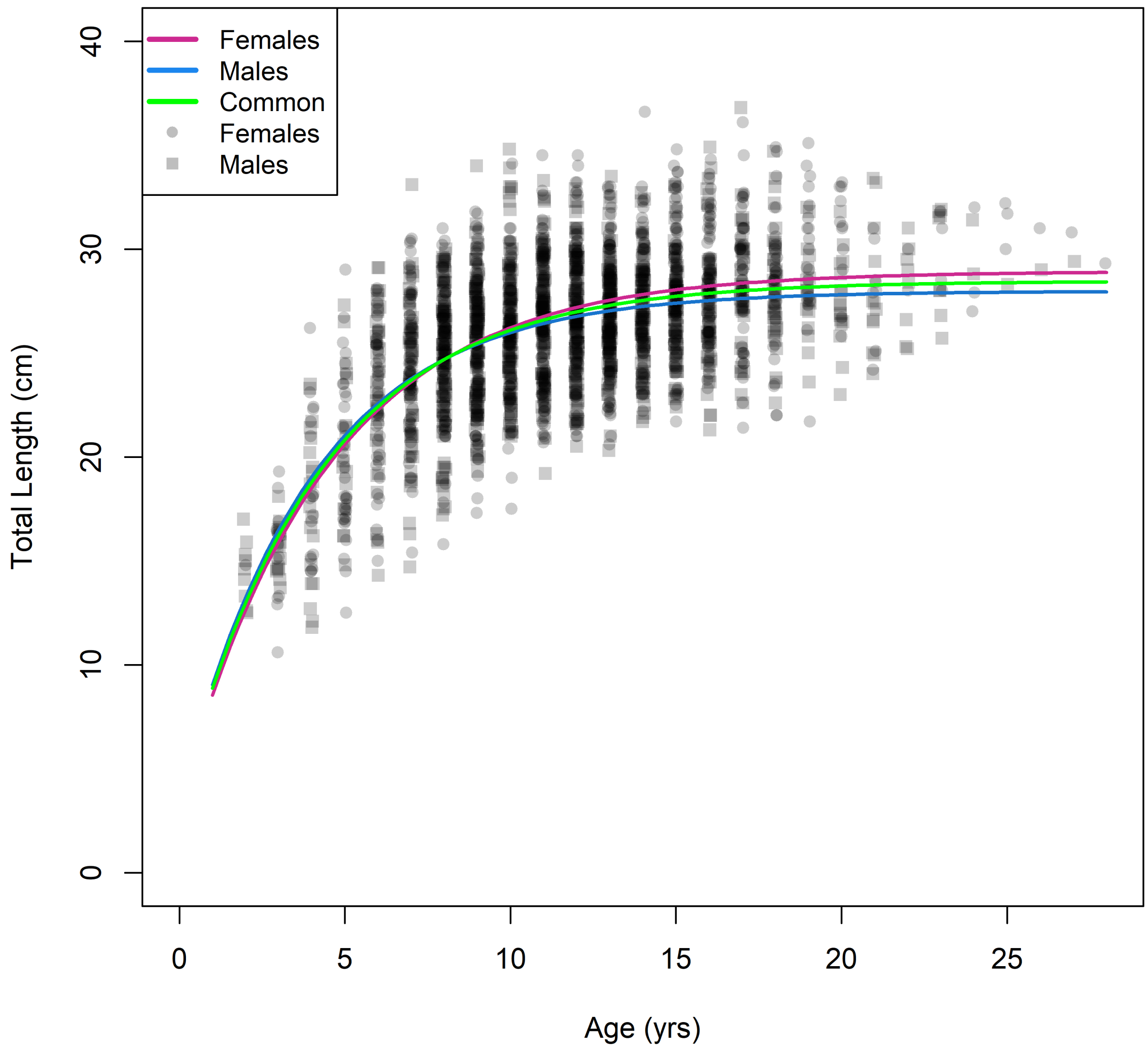



Figure 37: External estimates of growth for GBYR combined by sex from fits to von Bertalanffy growth models. Growth_by_sex

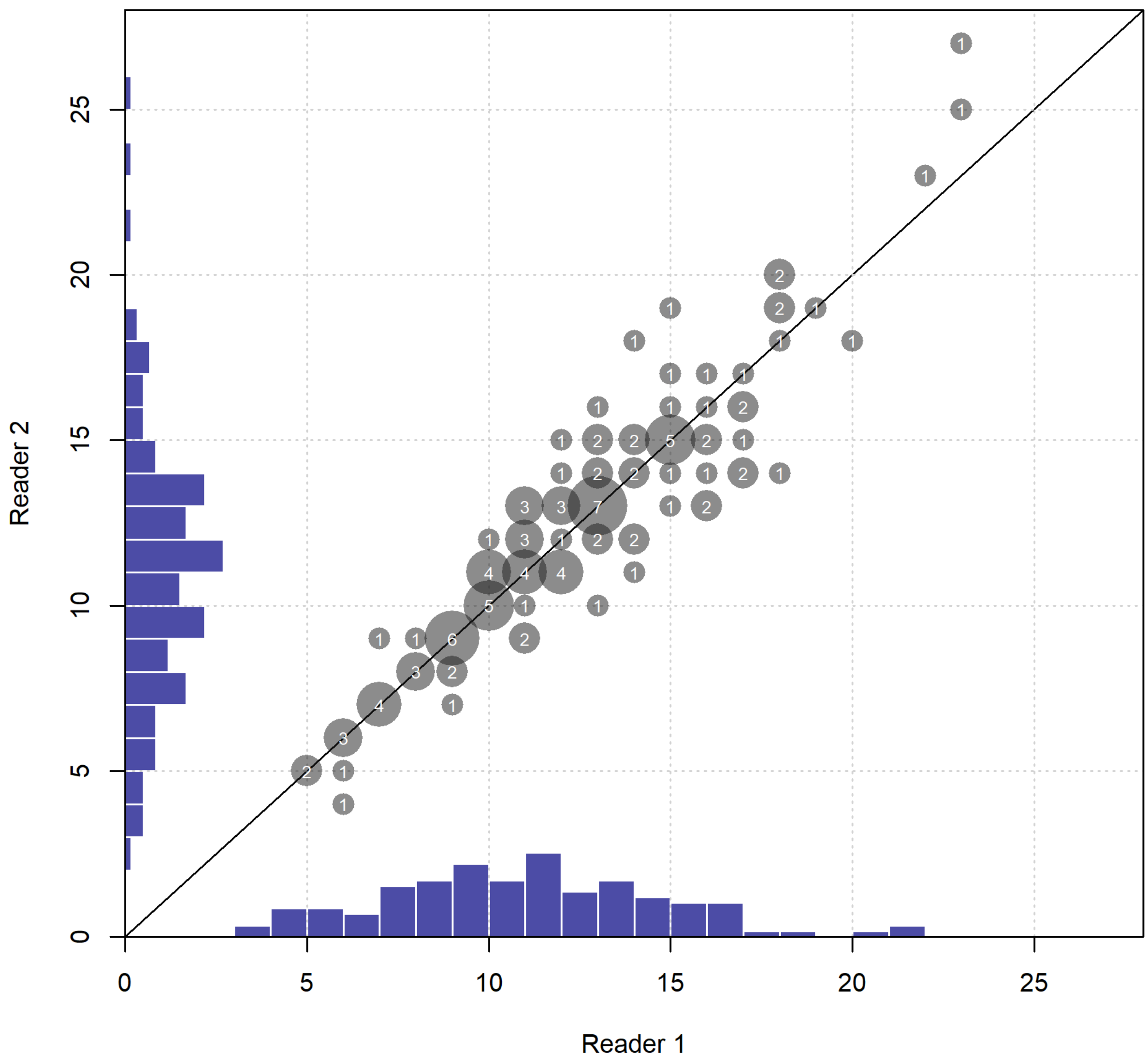



Figure 38: Aging precision between initial and blind double reads for GBYR. Numbers in the bubbles are the sample sizes of otoliths cross-read. fig:GBY_age_error

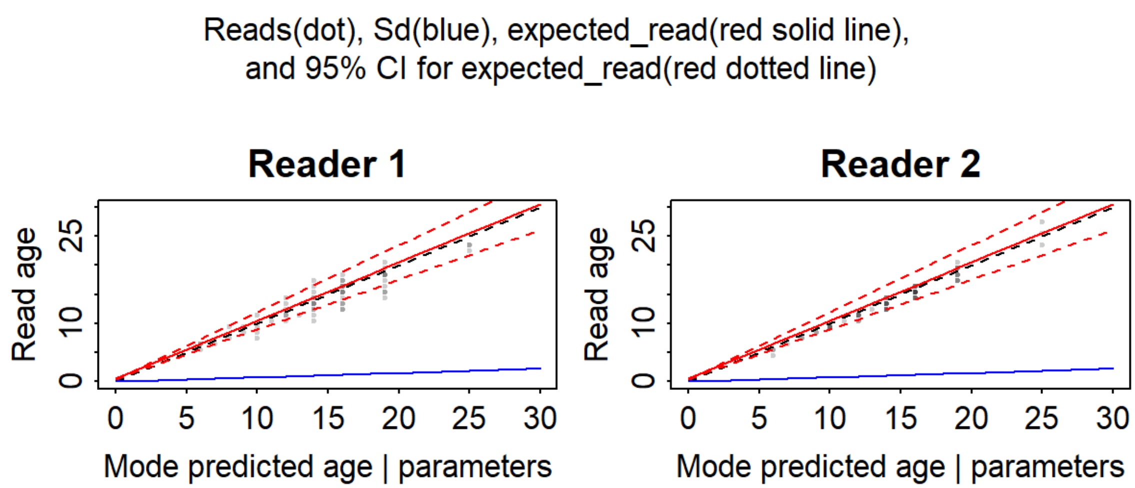



Figure 39: True versus predicted age for two current age readers at the NWFSC from the ageing error software with unbiased reads and curvilinear standard deviation for both readers.
fig:GBY_age_error2

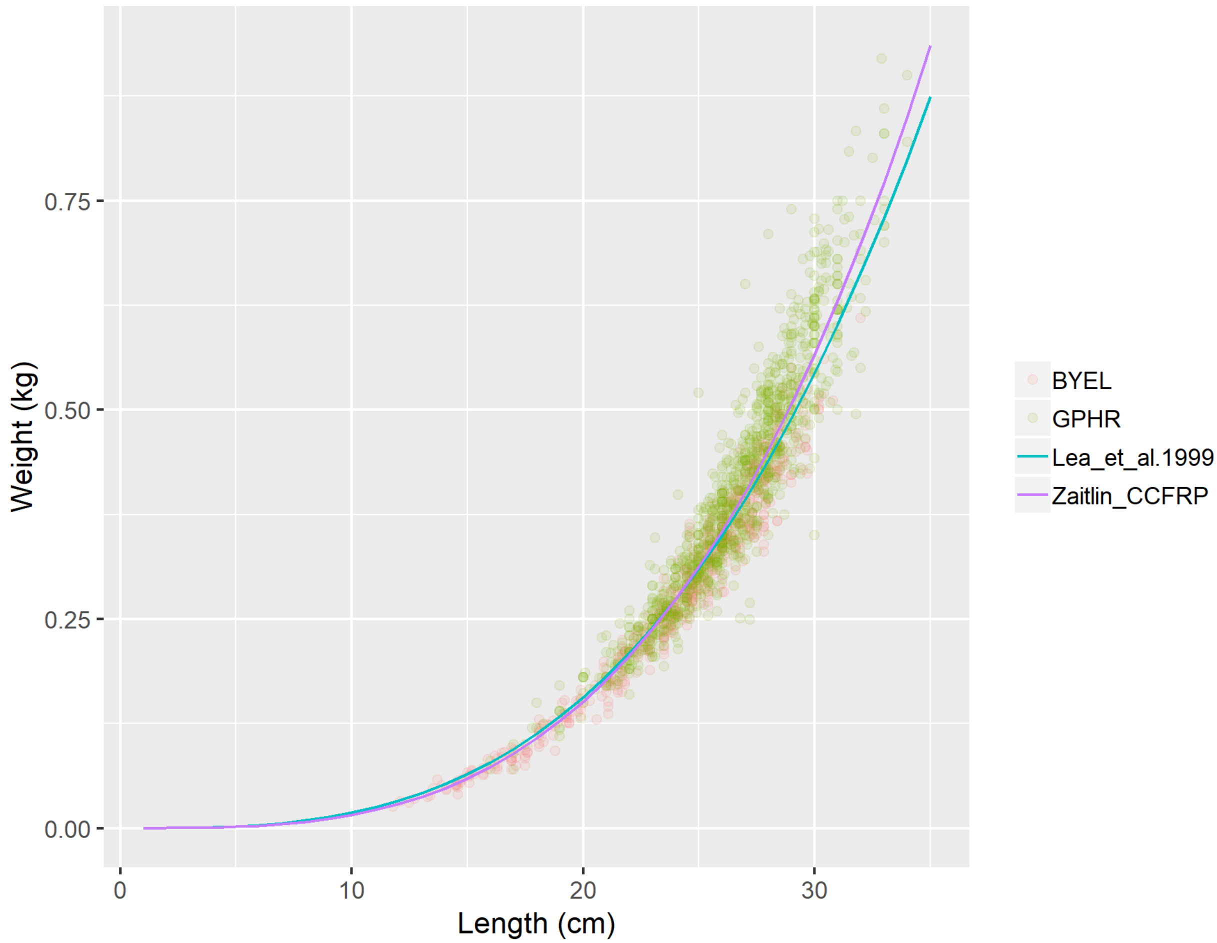



Figure 40: Comparison of the gopher rockfish weight-length curves from Lea et al. (1999) and tha estimated from black-and-yellow rockfishes from Zaitlin (1986), and gopher rockfishes from Loury (2011) and Meyers-Cherry (2014). The estimated curve from the current data is used in this assessment. fig:GBY_weight_length

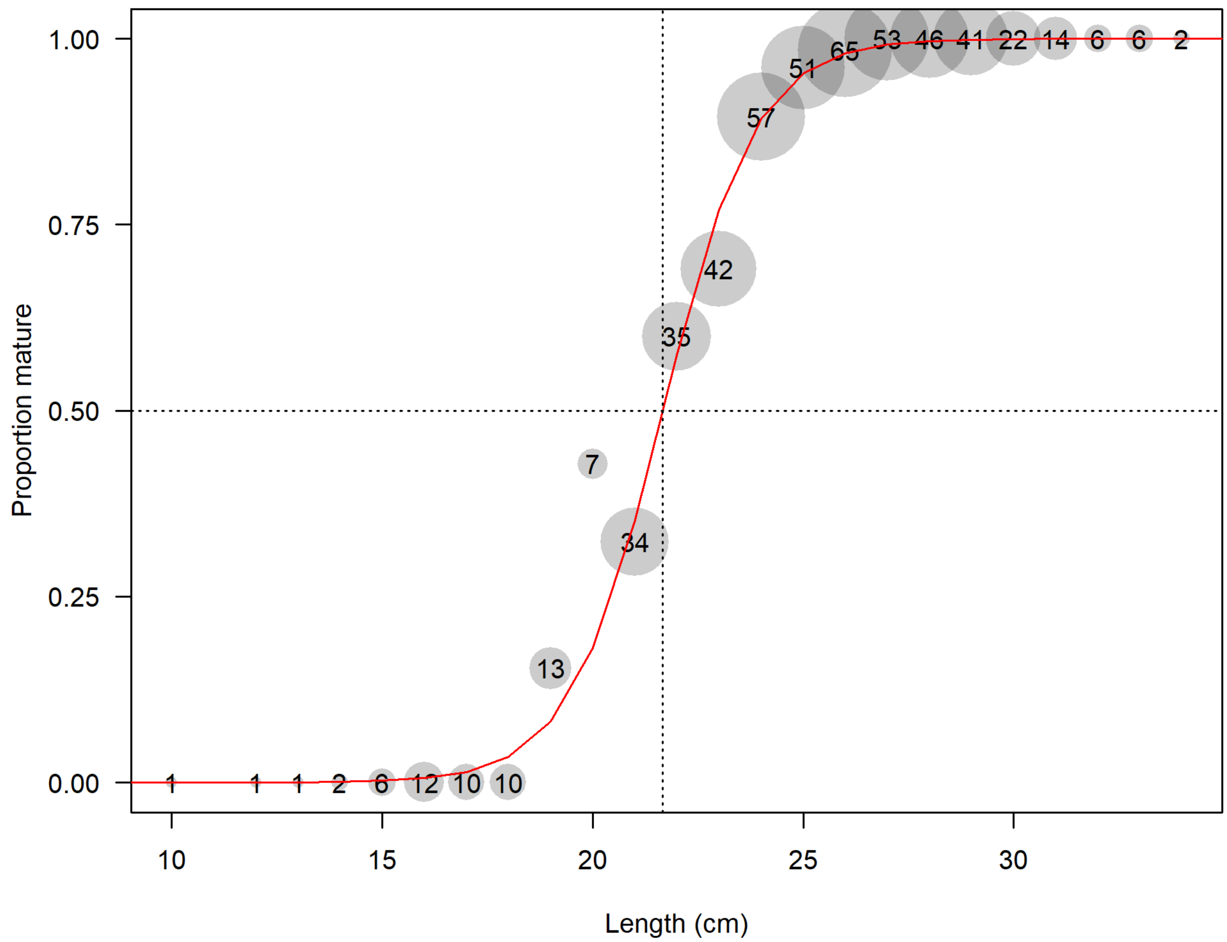



Figure 41: Maturity ogive for females estimated from black-and-yellow rockfish from Zaitlin (1986) and gopher rockfish from Meyers-Cherry (2014). Sample sizes at a given length are shown in the circles. fig:GBY_maturity_ogive

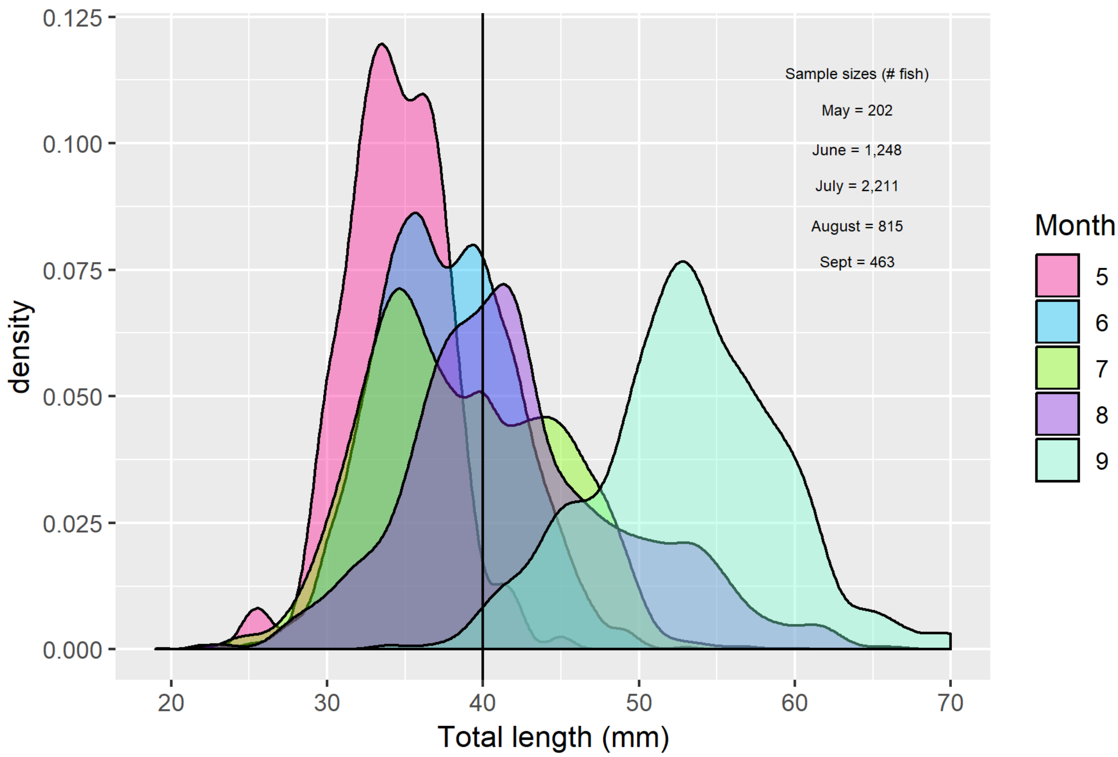



Figure 42: Length distribution by month for GBYR captured using a sampling tool called a Standard Monitoring Unit for the Recruitment of Fishes (SMURFs) from the UCSC-PISCO kelp forest fish survey, specifically as part of Diana Baetscher's dissertation work (Baetscher 2019). fig:SMURF_lengths

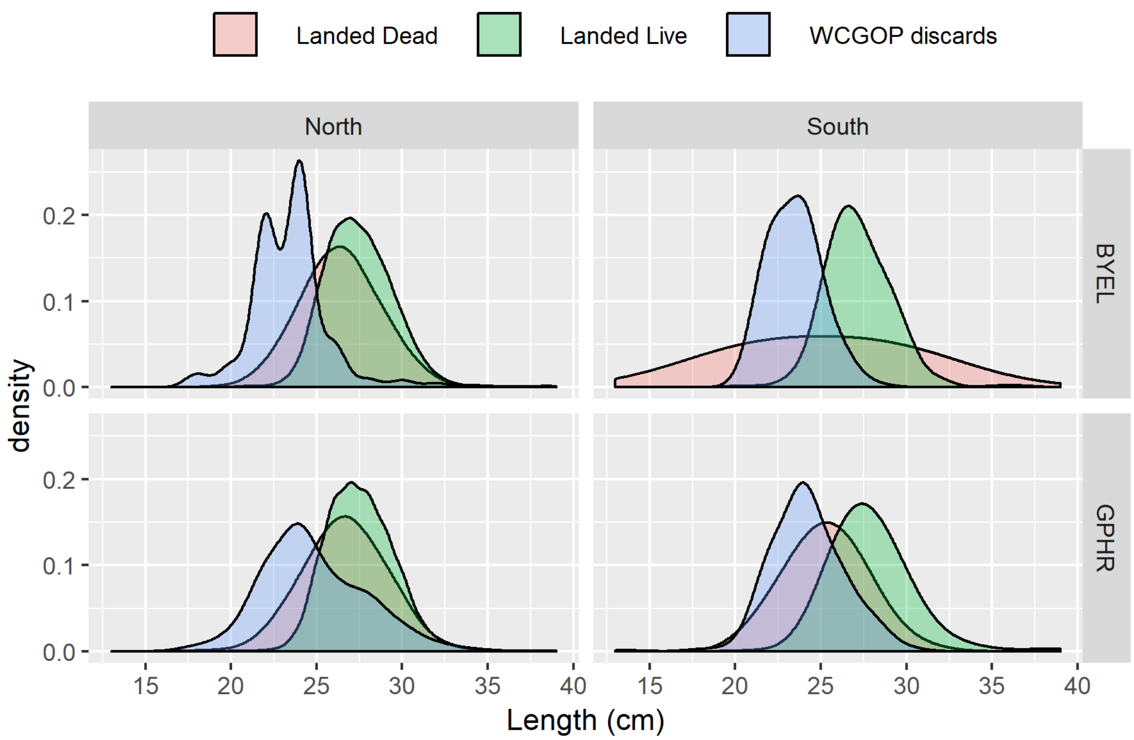



Figure 43: Length distributions of gopher and black-and-yellow rockfish for the commercial fleet and WCGOP discards north and south of Point Conception. The commercial landings were also separated between fish landed live and fish landed dead for this figure. fig:Comm_lengths_justi

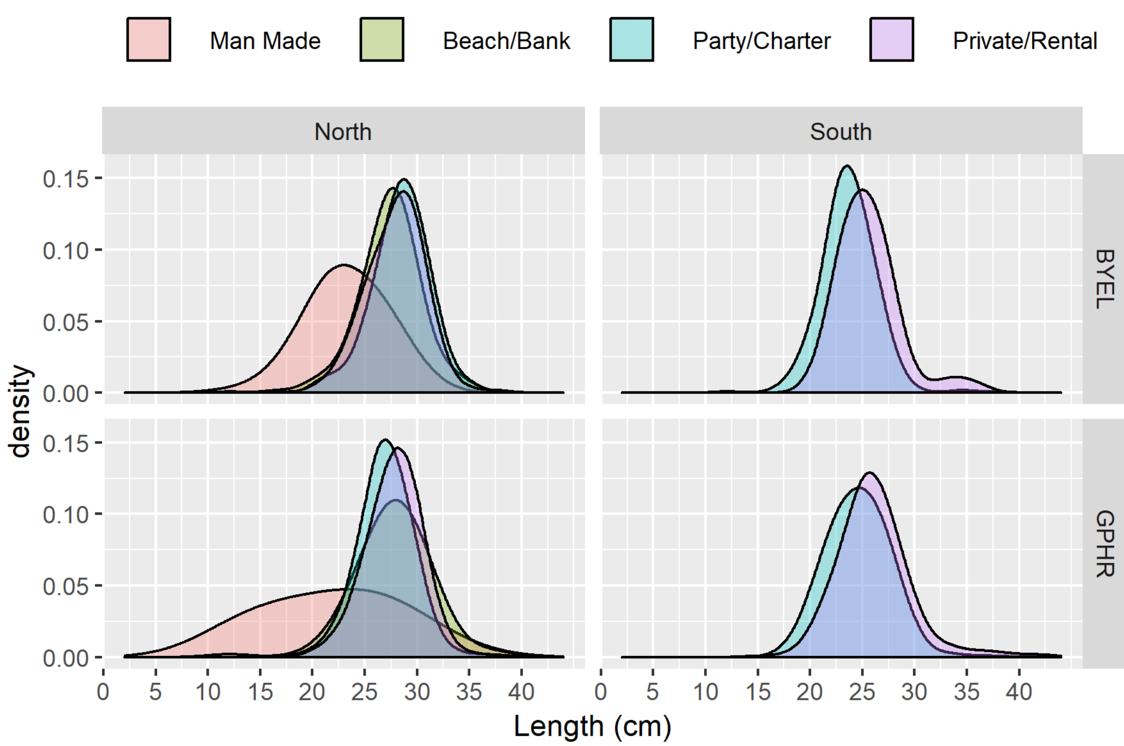



Figure 44: Length distributions of gopher and black-and-yellow rockfish for the recreational fleet north and south of Point Conception and by mode. fig:Rec_lengths_justification

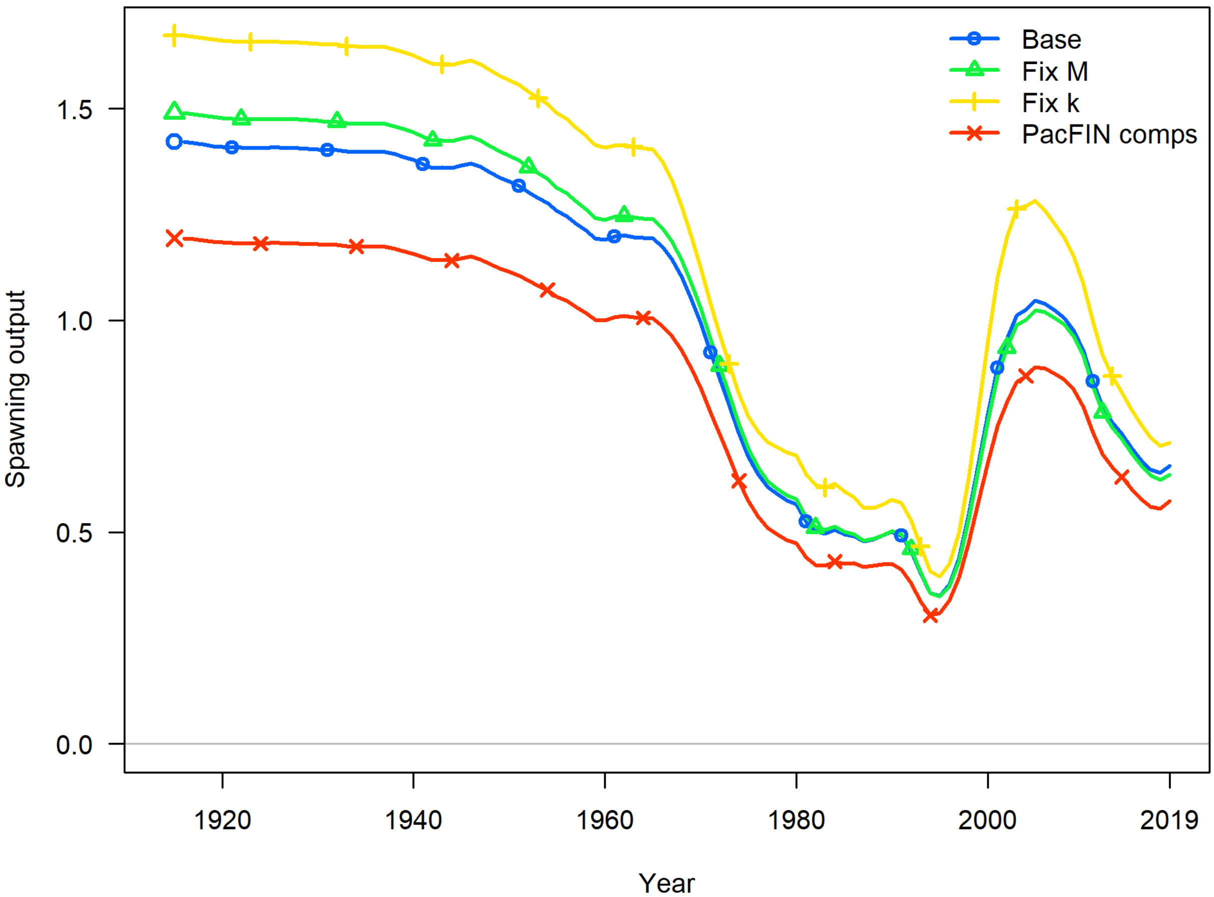



Figure 45: Sensitivity of the spawning biomass to fixing natural mortality to the prior, fixing the von Bertalanffy $k$ parameter to the external estimate, or using commercial PacFIN length composition data instead of CALCOM, as compared to the pre-STAR base model. fig:sensitivity1_spa

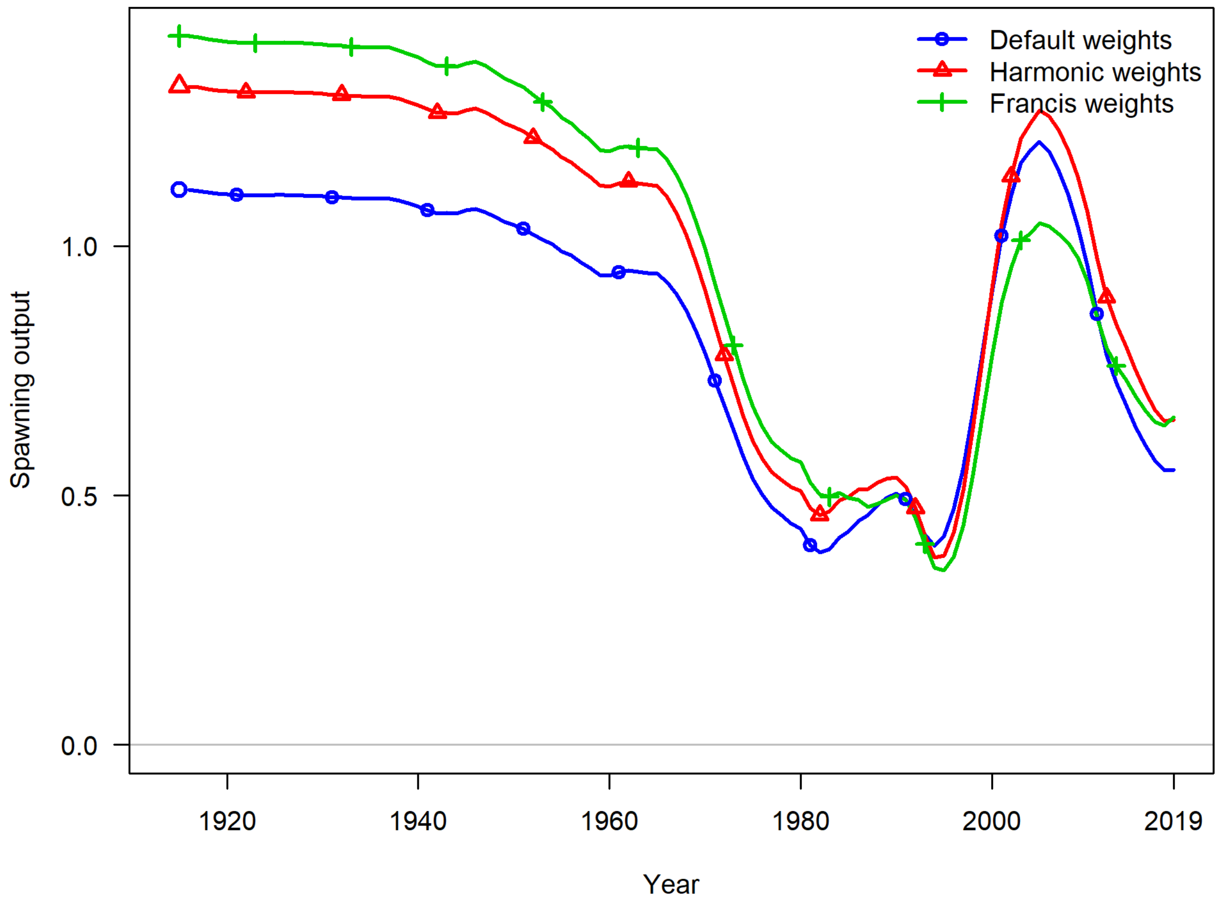



Figure 46: Sensitivity of the spawning biomass to either the default weight of composition data, the harmonic mean, or Francis weights. fig:sensitivity2_spawnbio

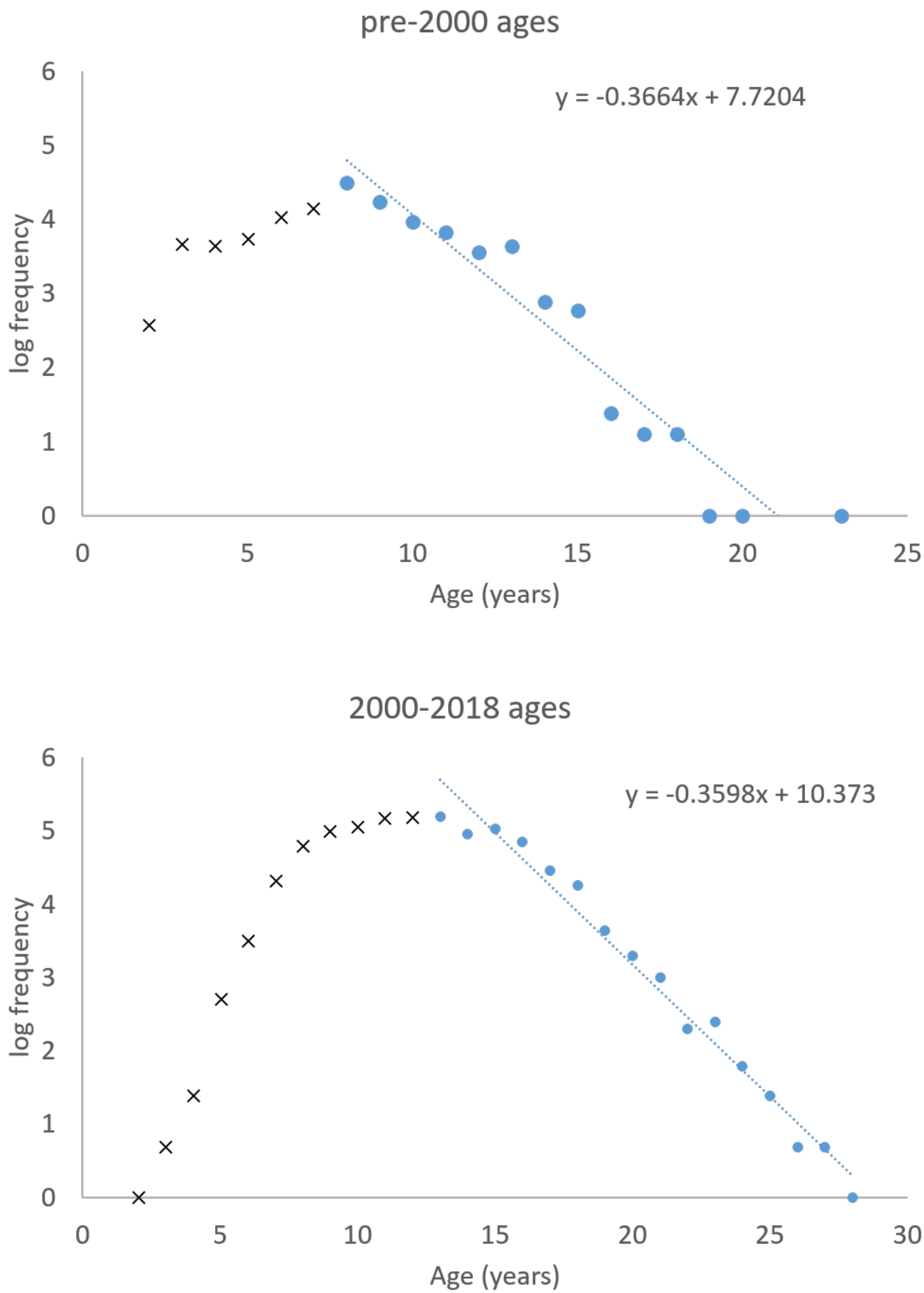
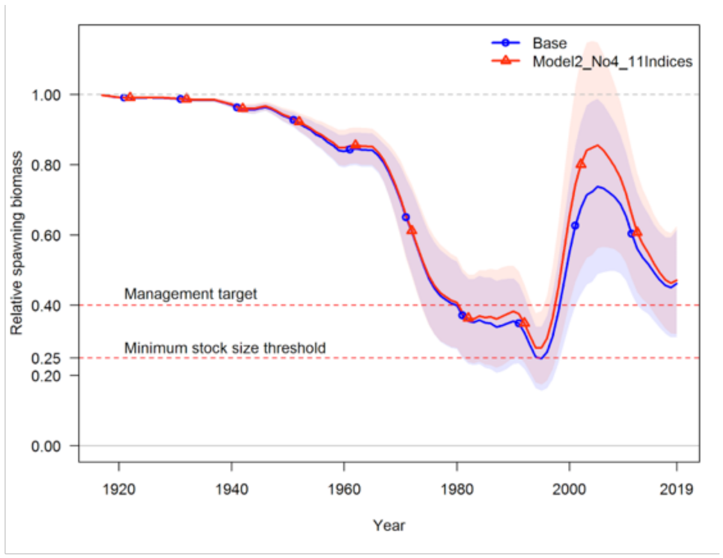



Figure 47: Catch curve analysis for age data prior to 2000 and for 2000-2018. fig:STAR_request1



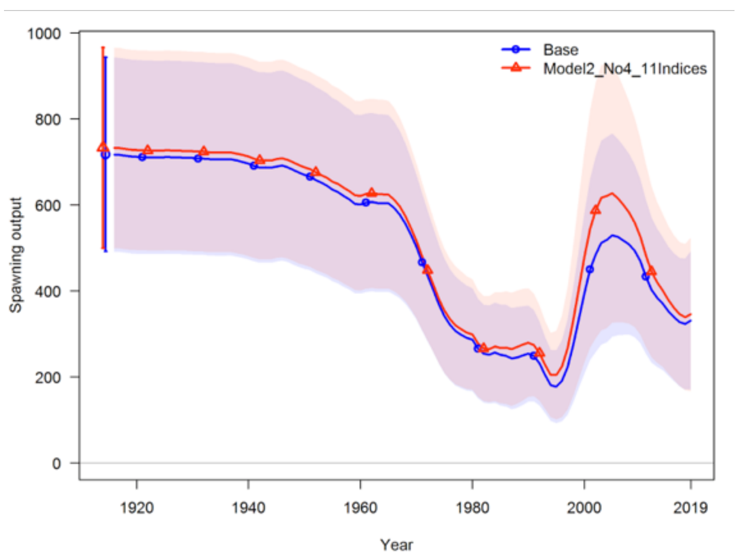




Figure 48: Comparison of time series of relative and absolute spawning output from pre-STAR base model and the model from request 2 removing southern indices. fig:STAR_request2

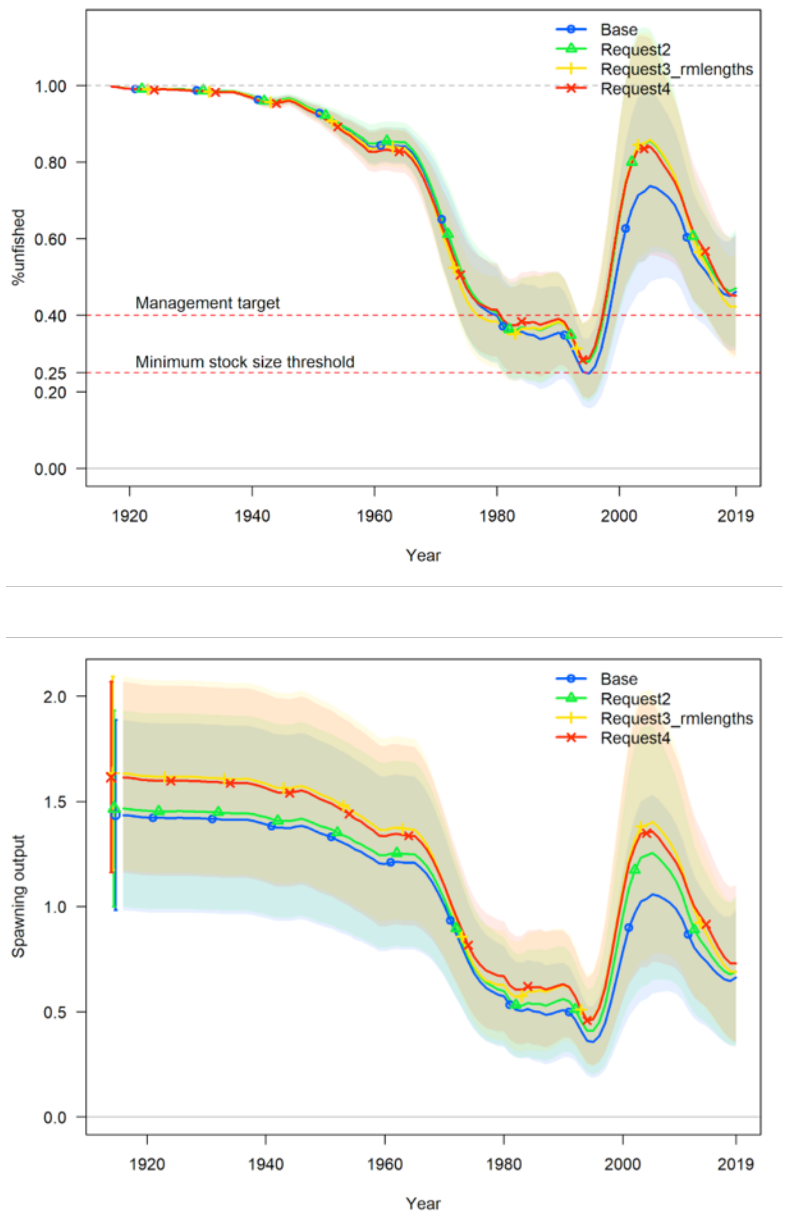



Figure 49: Comparison of time series of relative and absolute spawning output from pre-STAR base model and models from requests 2, 3a and 4. fig:STAR_request3

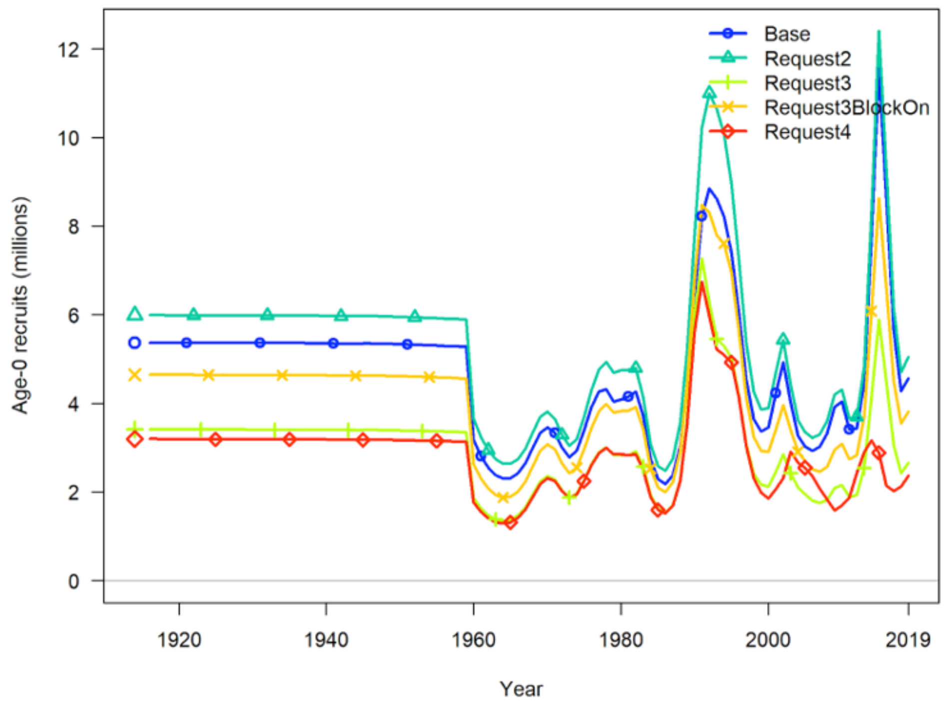



Figure 50: Comparison of time series of recruits from pre-STAR base model and models from requests 2, 3a and 4a. fig:STAR_request4

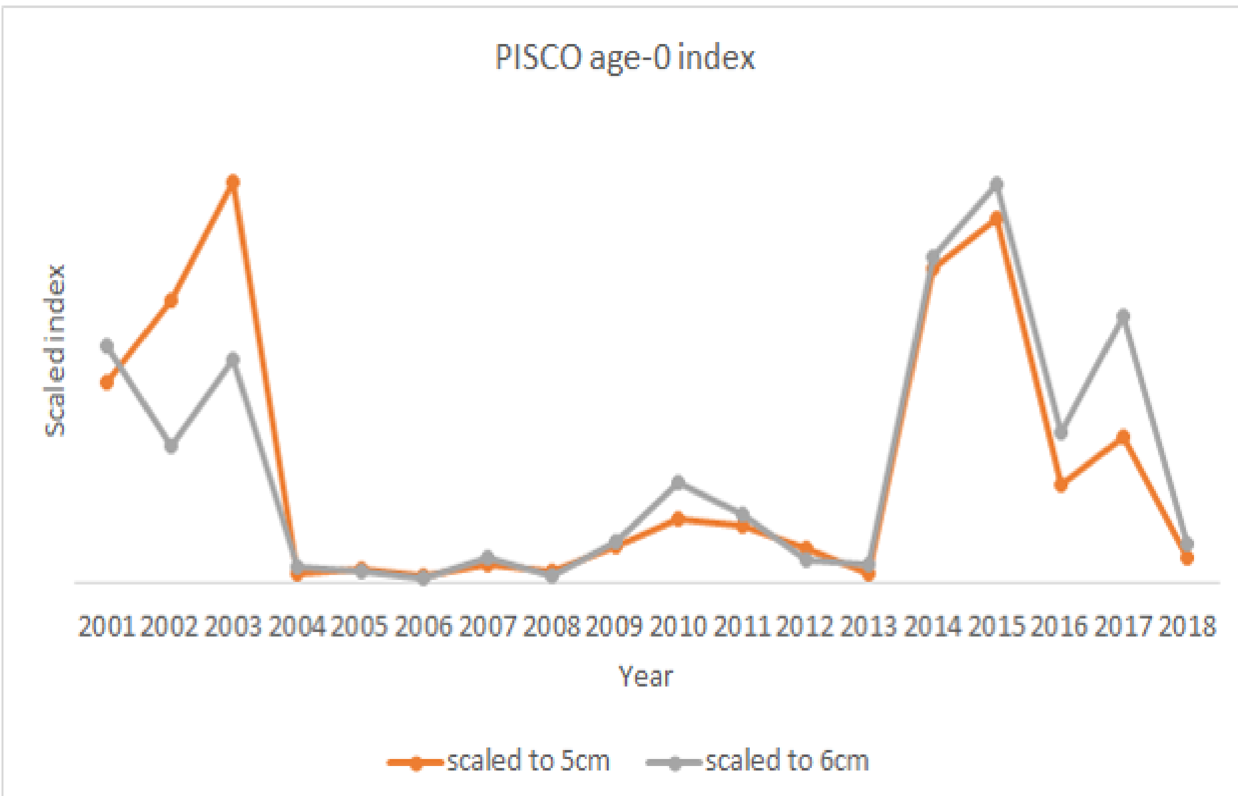
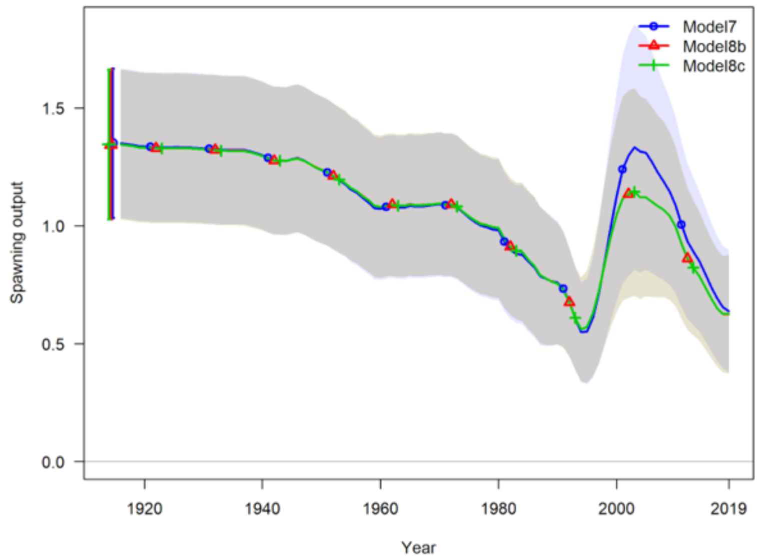
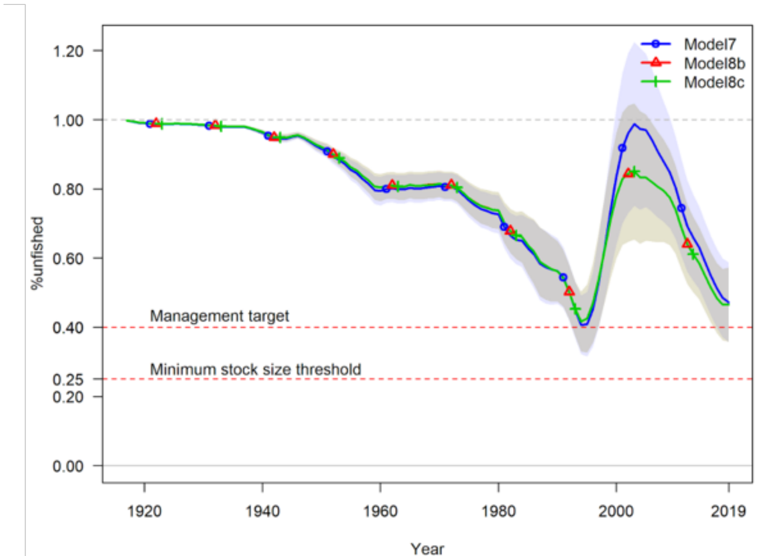



Figure 51: The PISCO recruitment index based upon observed individuals of 4 and 5 cm ("scaled to 5cm") or 4, 5a and 6 cm ("scaled to 6 cm"). fig:STAR_request8



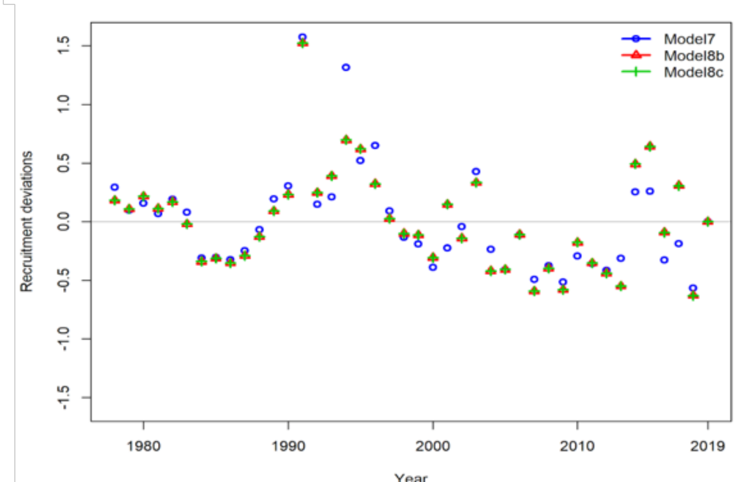




Figure 52: Results of request 7 and 8. Time series of absolute (top) and relative (middle) spawning output and recruitment deviations (now staring in 1978; bottom). fig:STAR_request8_2

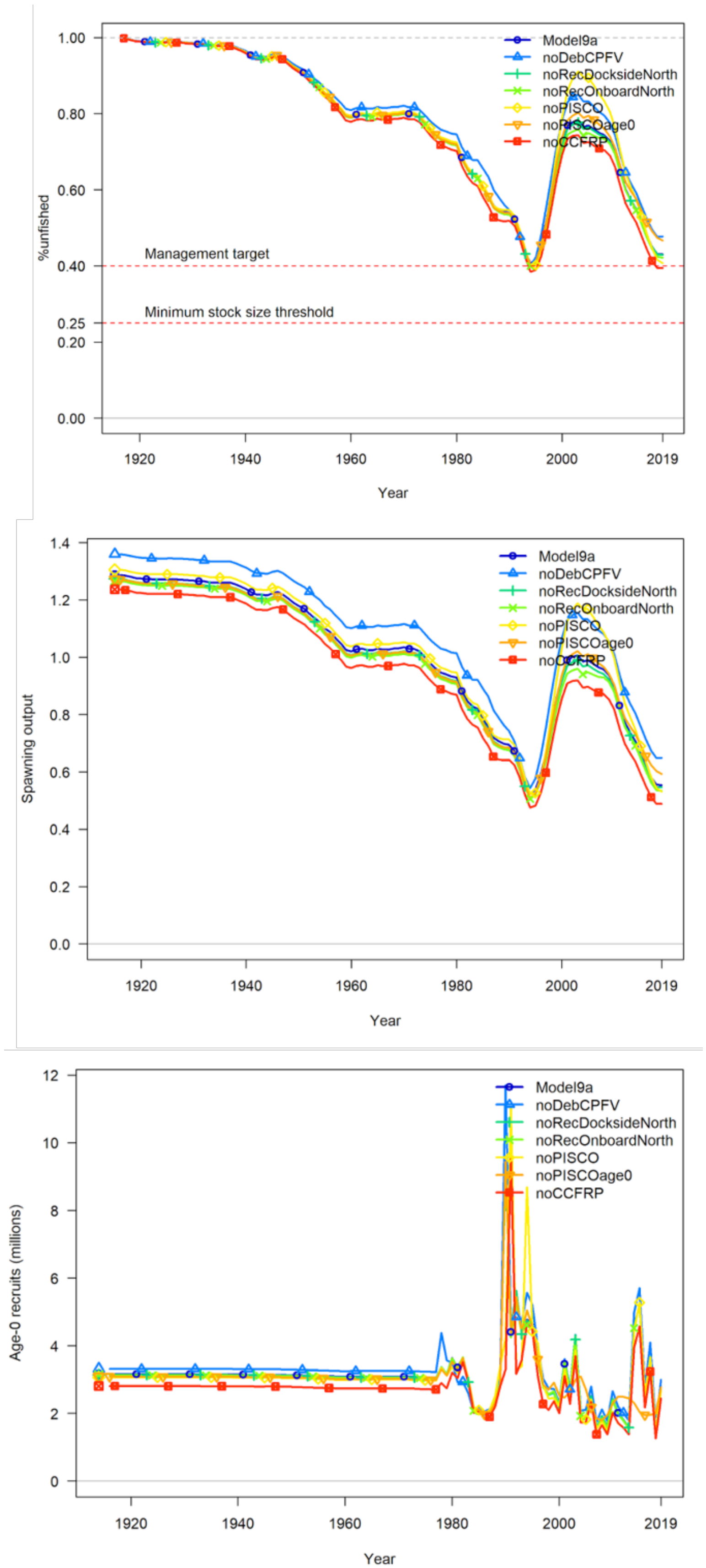



Figure 53: . Results of request 10, drop-1-out analysis. Time series of relative (top) and absolute (middle) spawning output and recruitment estimates (now staring in 1978; bottom). fig:STAR_request10

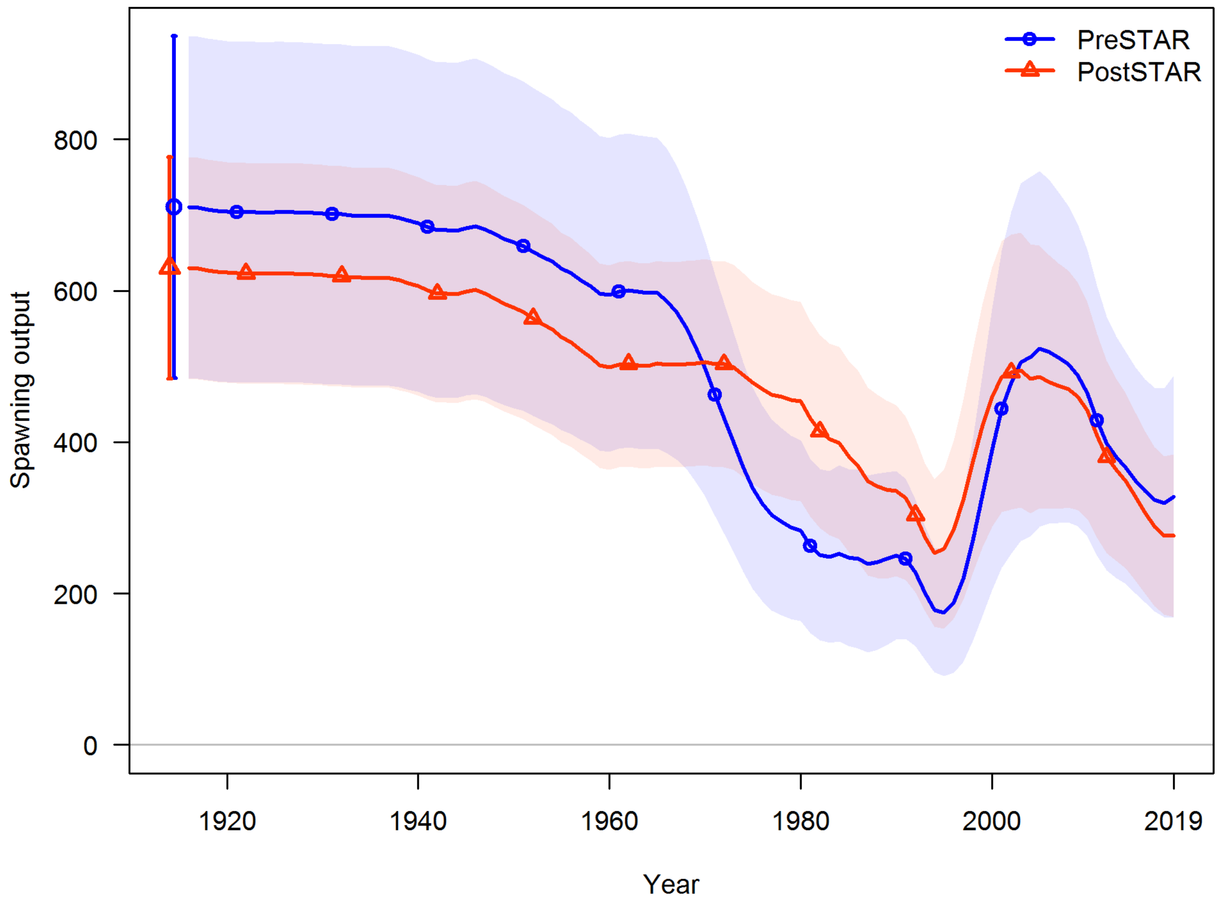



Figure 54: Comparison of the spawning output between the pre-STAR panel base model and the post-STAR model base. fig:preSTAR_postSTAR_compare_spawnbio

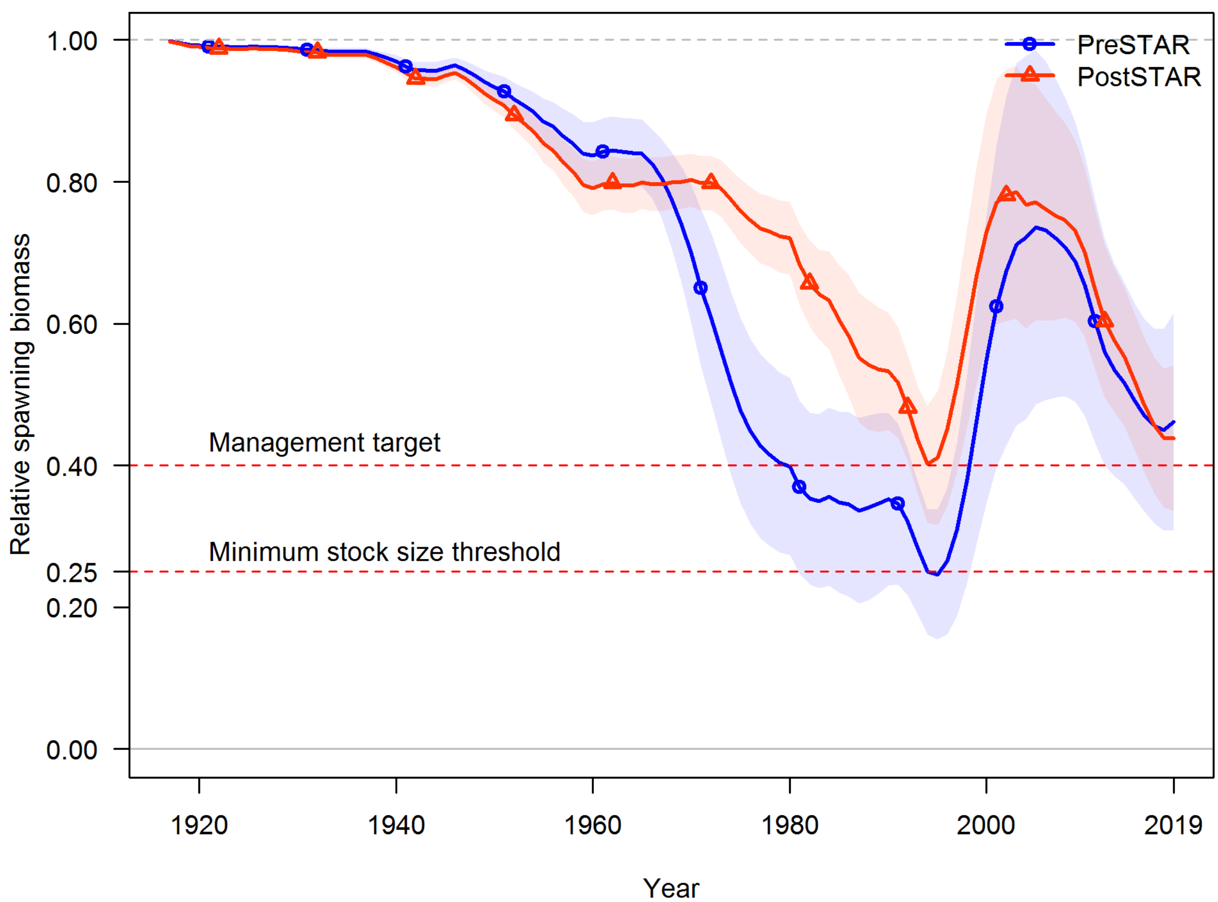



Figure 55: Comparison of the relative spawning output (depletion) between the pre-STAR panel base model and the post-STAR model base. fig:preSTAR_postSTAR_compare_Bratio

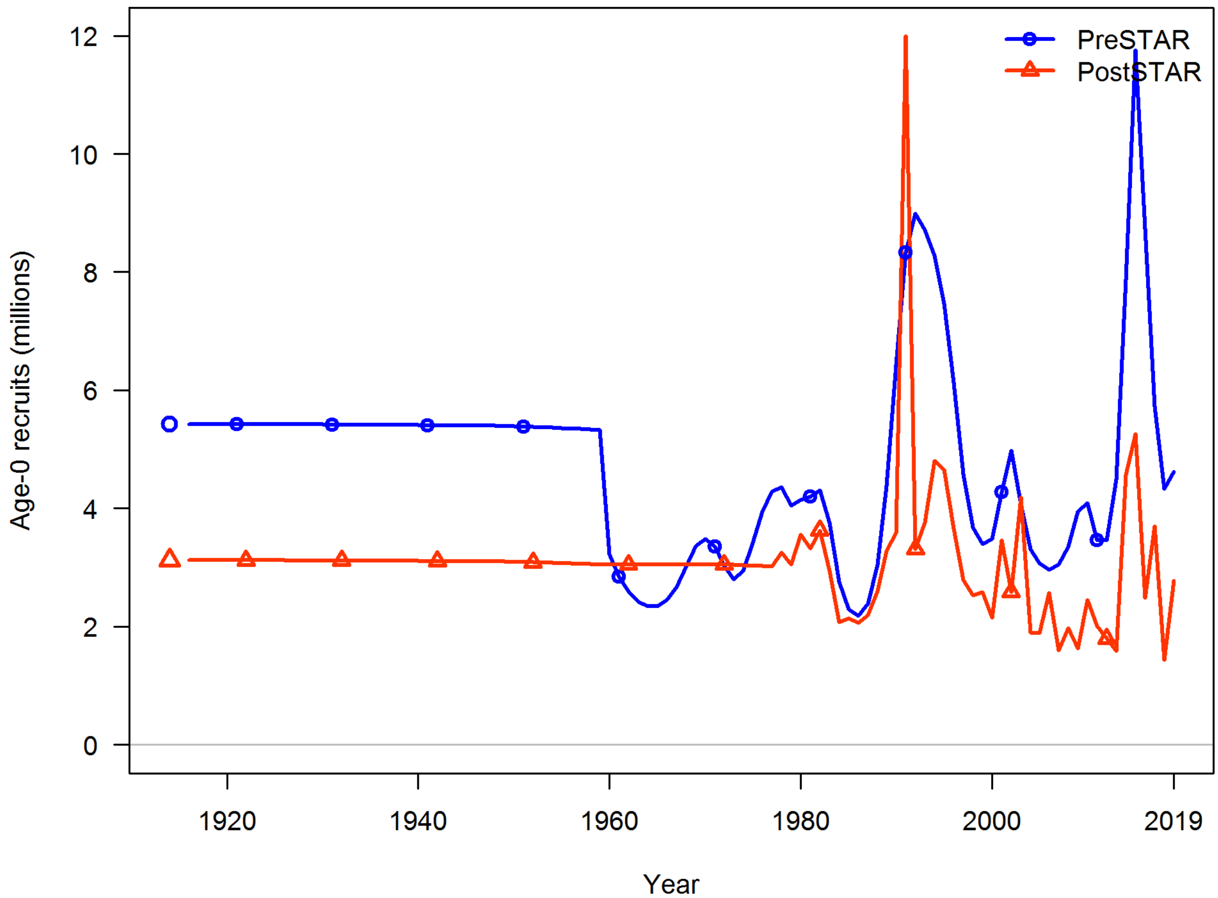



Figure 56: Comparison of the age-0 recruits between the pre-STAR panel base model and the post-STAR model base. fig:preSTAR_postSTAR_compare_recruit

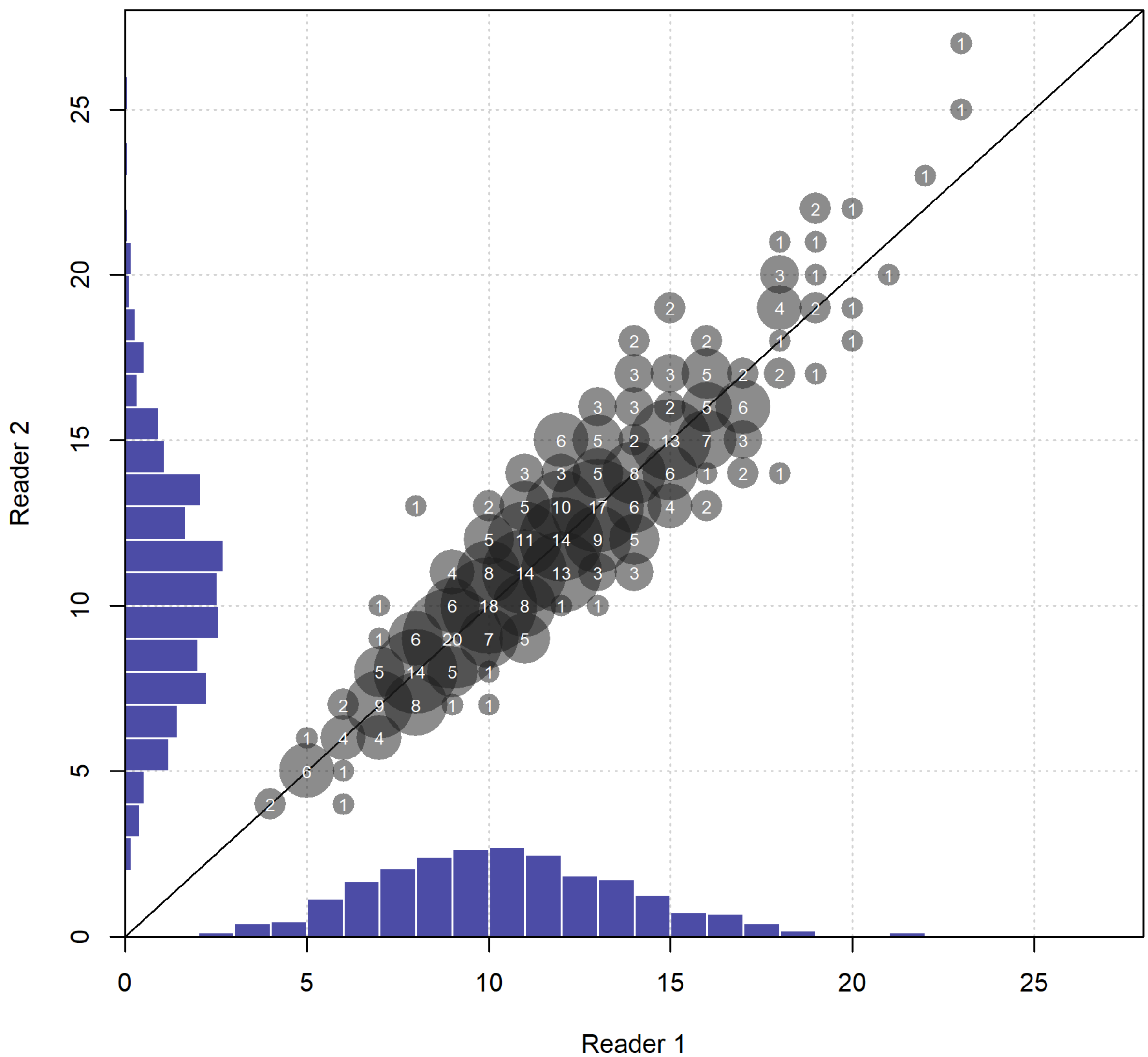



Figure 57: Updated aging precision used in the post-STAR base model between initial and blind double reads for GBYR. Numbers in the bubbles are the sample sizes of otoliths cross-read. fig:GBY_age_error_updated

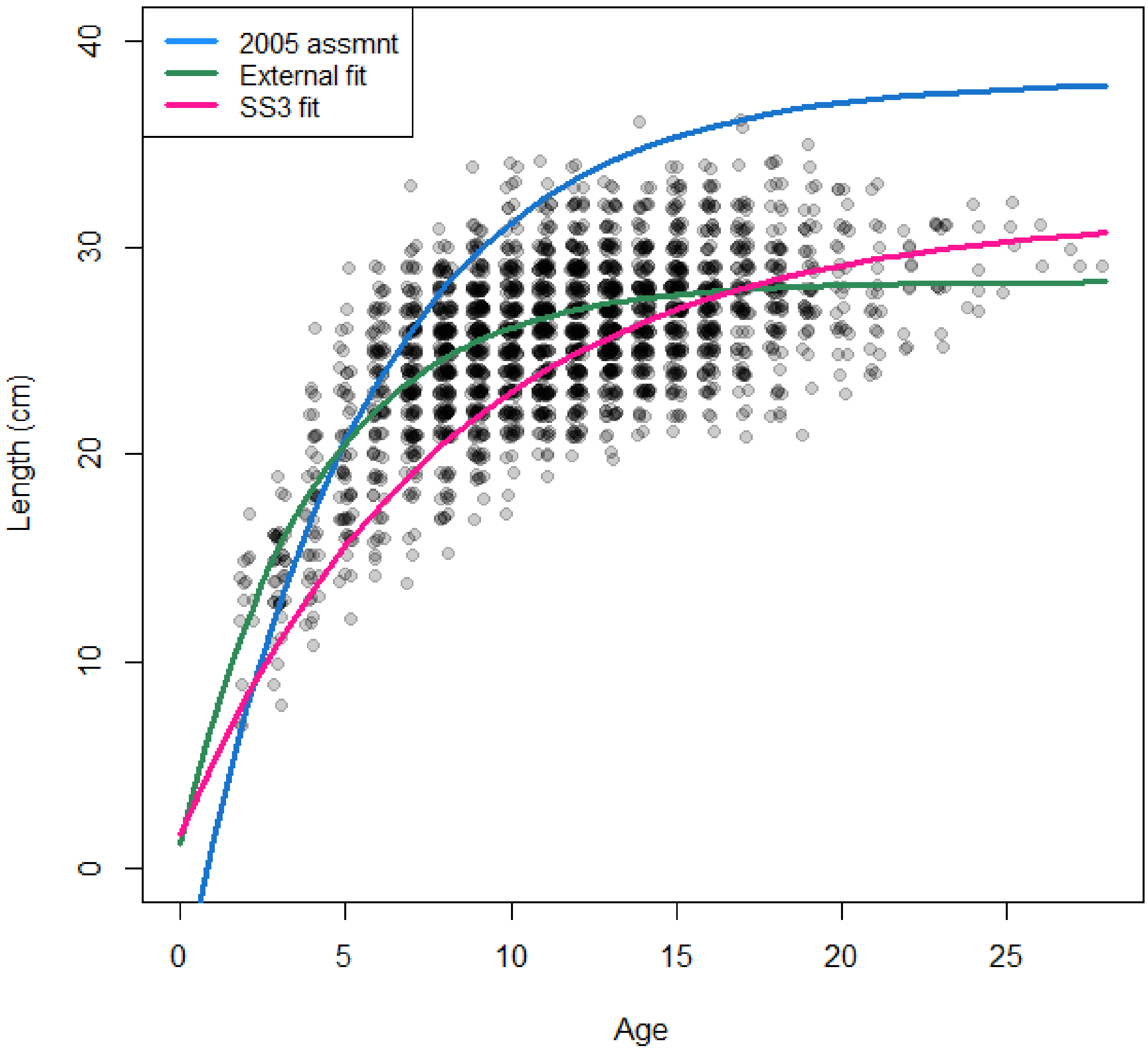



Figure 58: Estimates of growth for GBYR from the 2005 assessment, external fit to the CAAL data used in this assessment and the internal SS estimate of growth for this assessment. All growth curves were estimated using the Schnute parameterization of the von Bertalanffy growth curve. fig:growth_compare

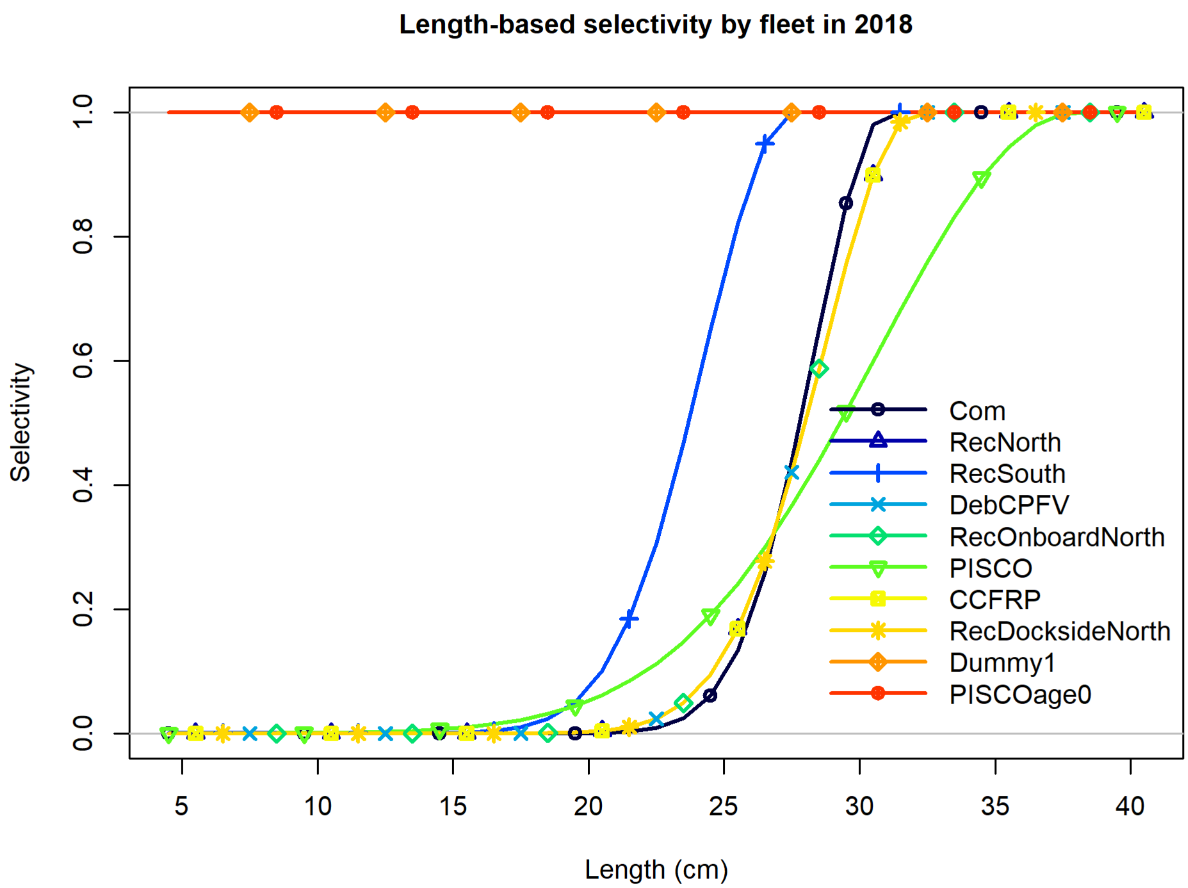



Figure 59: Selectivity at length for all of the fleets in the base model. fig:sel01_multiple_fle

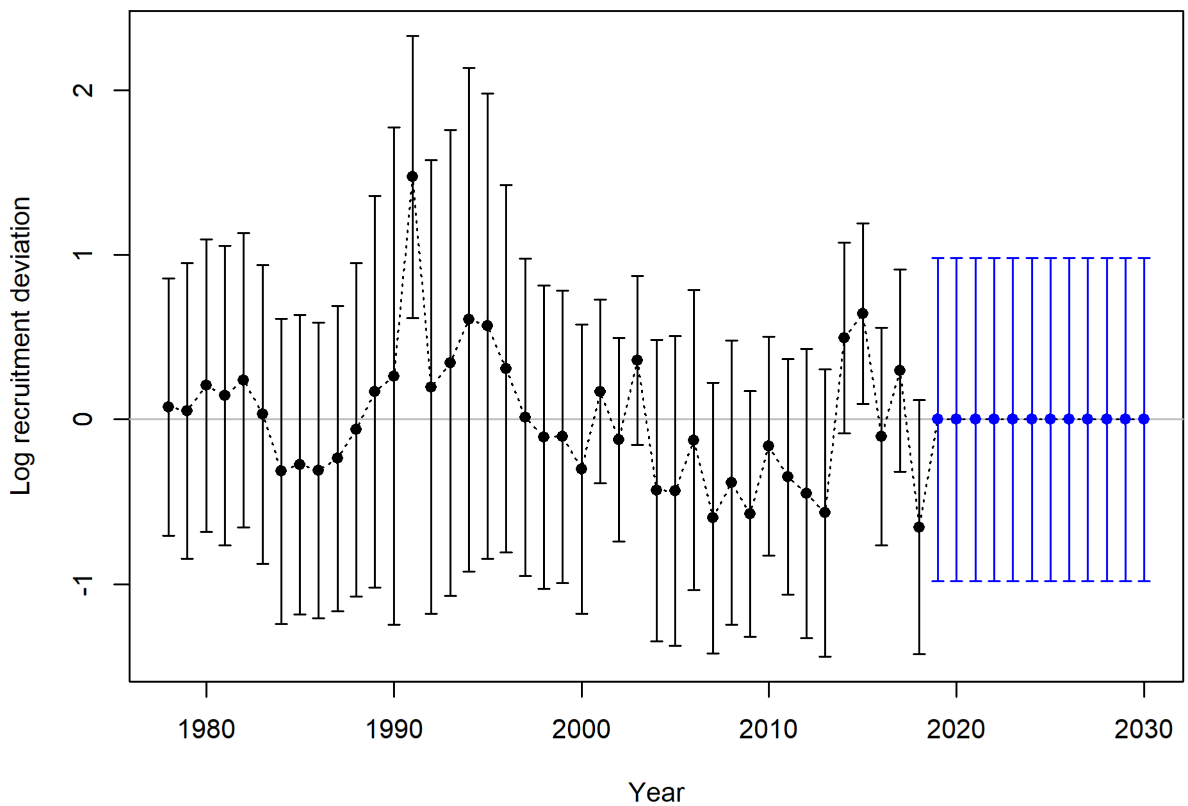



Figure 60: Estimated time-series of recruitment deviations for GBYR with 95% intervals. fig:recdevs2_

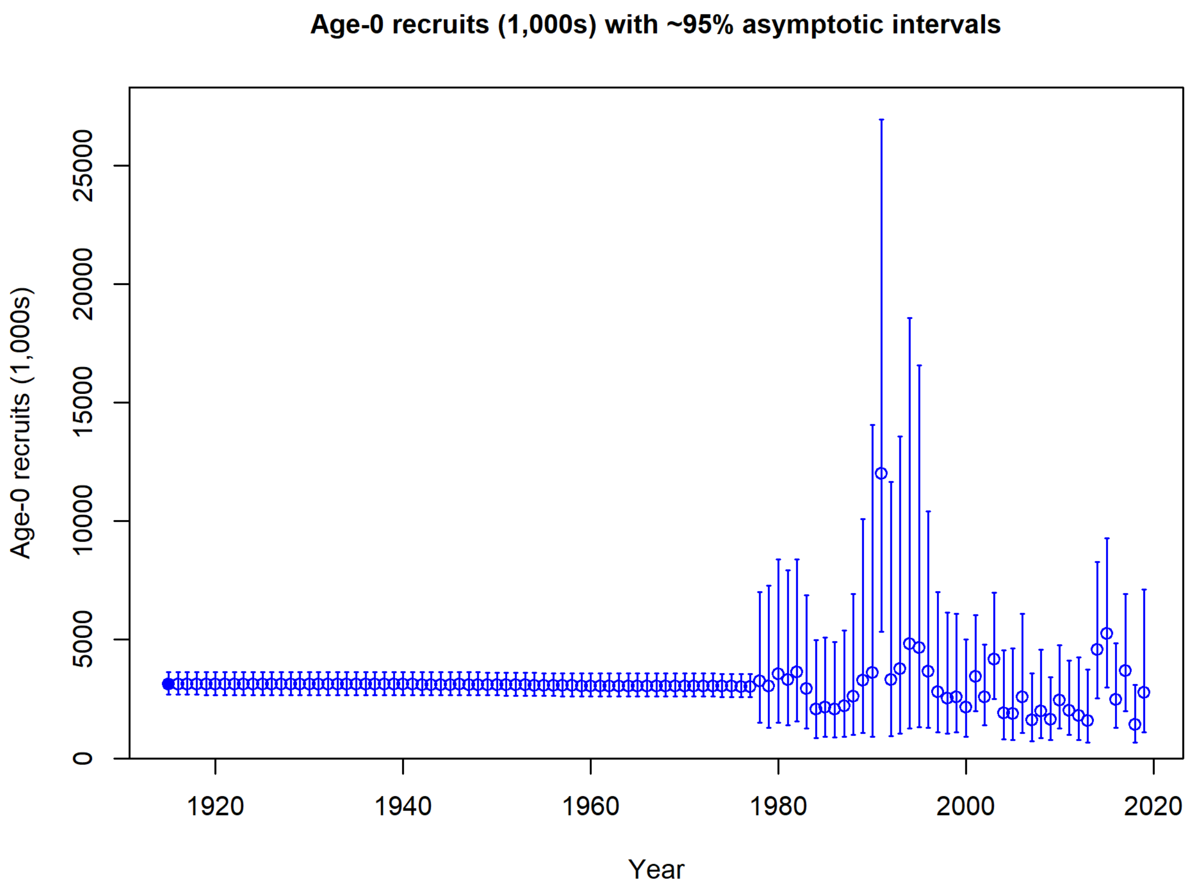



Figure 61: Time series of estimated GBYR recruitments for the base-case model with 95% confidence or credibility intervals. fig:Recruit_mod1

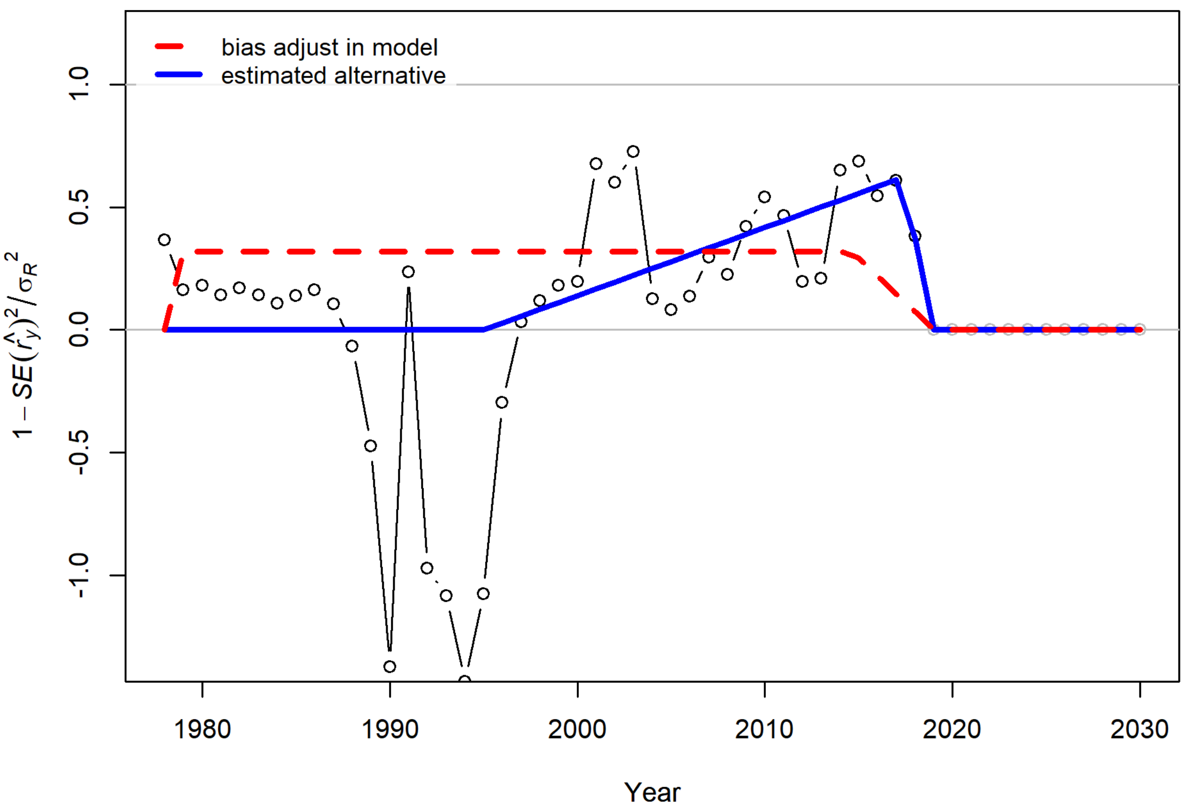



Figure 62: Bias adjustment for recruitment deviations. Points are transformed variances. Red line shows current settings for bias adjustment specified in the control file. Blue line shows the least squares estimate of alternative bias adjustment relationship for recruitment deviations. fig:recruit_fit_bias_adjust

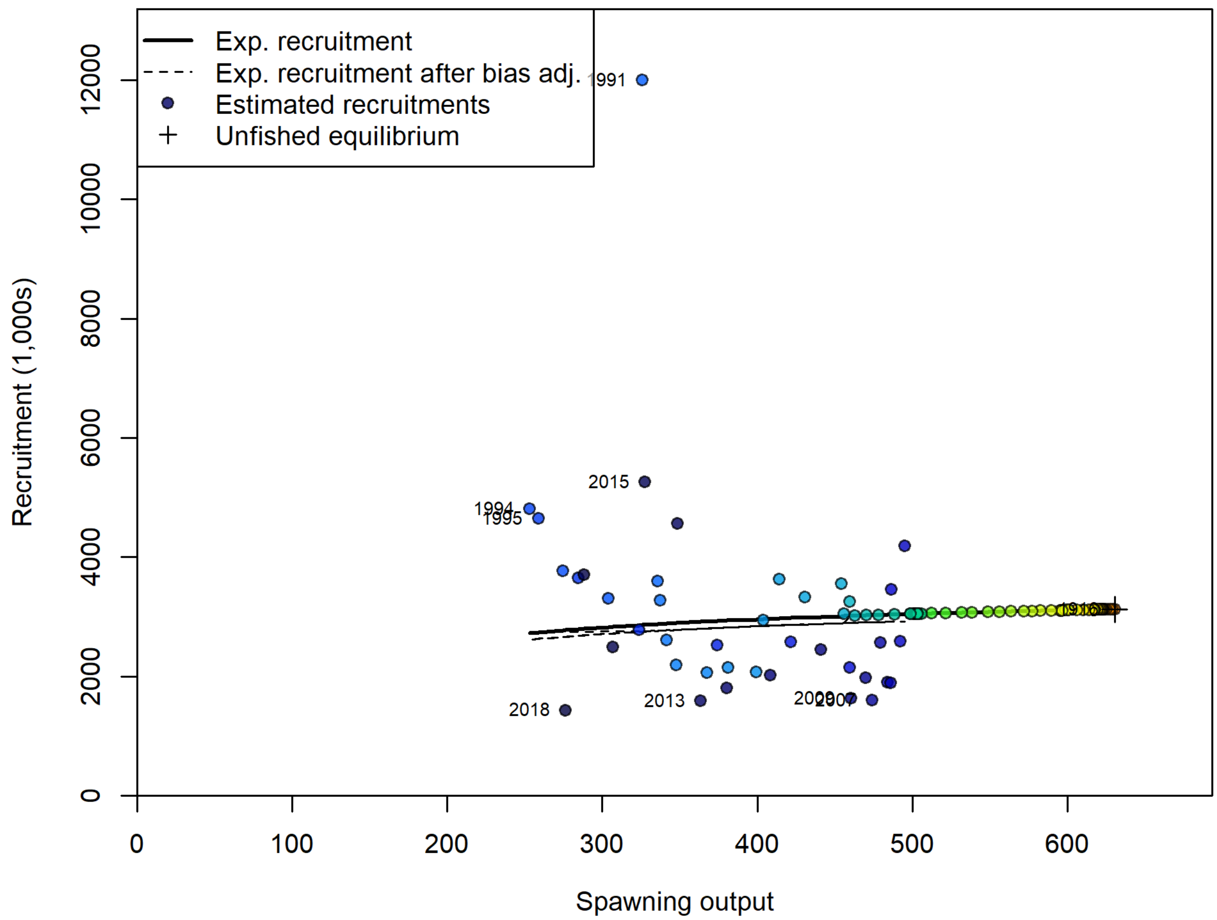



Figure 63: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line) for GBYR. The green line shows the effect of the bias correction for the lognormal distribution. fig:SR_curve2

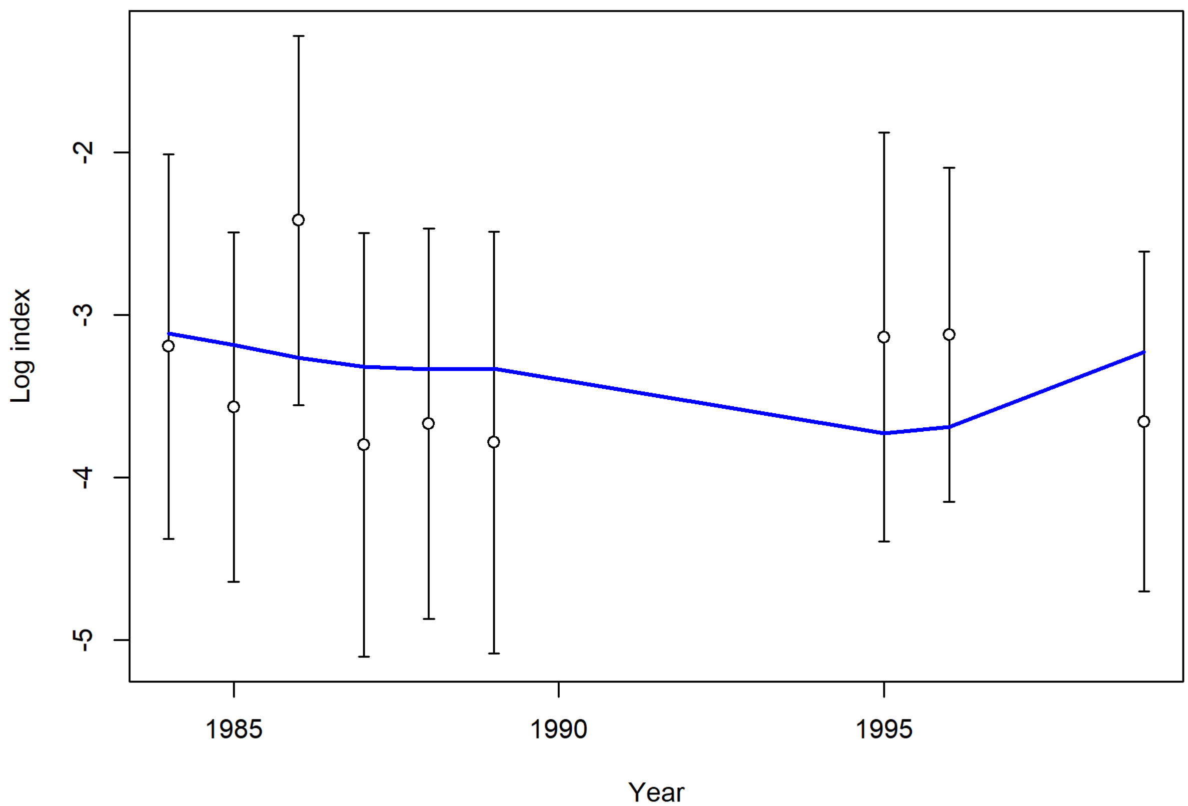



Figure 64: Fit to log index data on log scale for the recreational MRFSS dockside CPFV fishery north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit_RecDocksideNorth

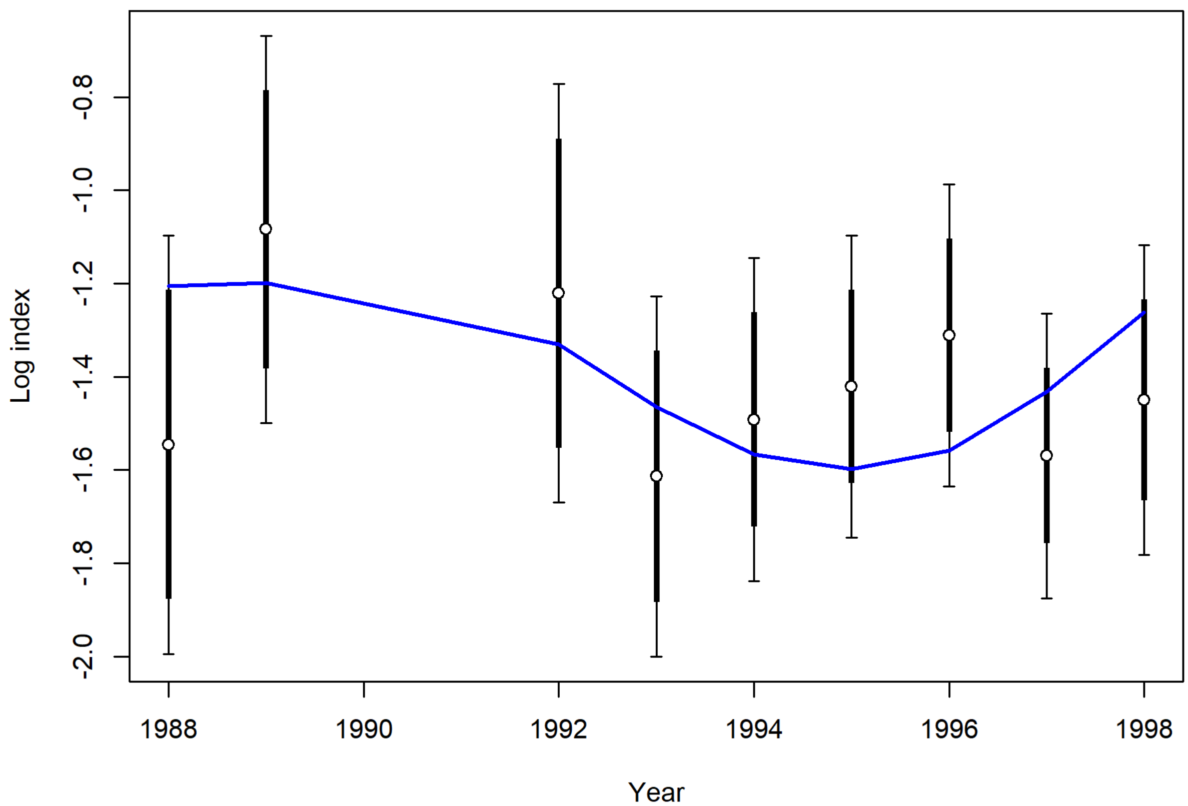



Figure 65: Fit to log index data on log scale for the recreational Deb's CPFV onboard observer program, representing north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit_DebCPFV

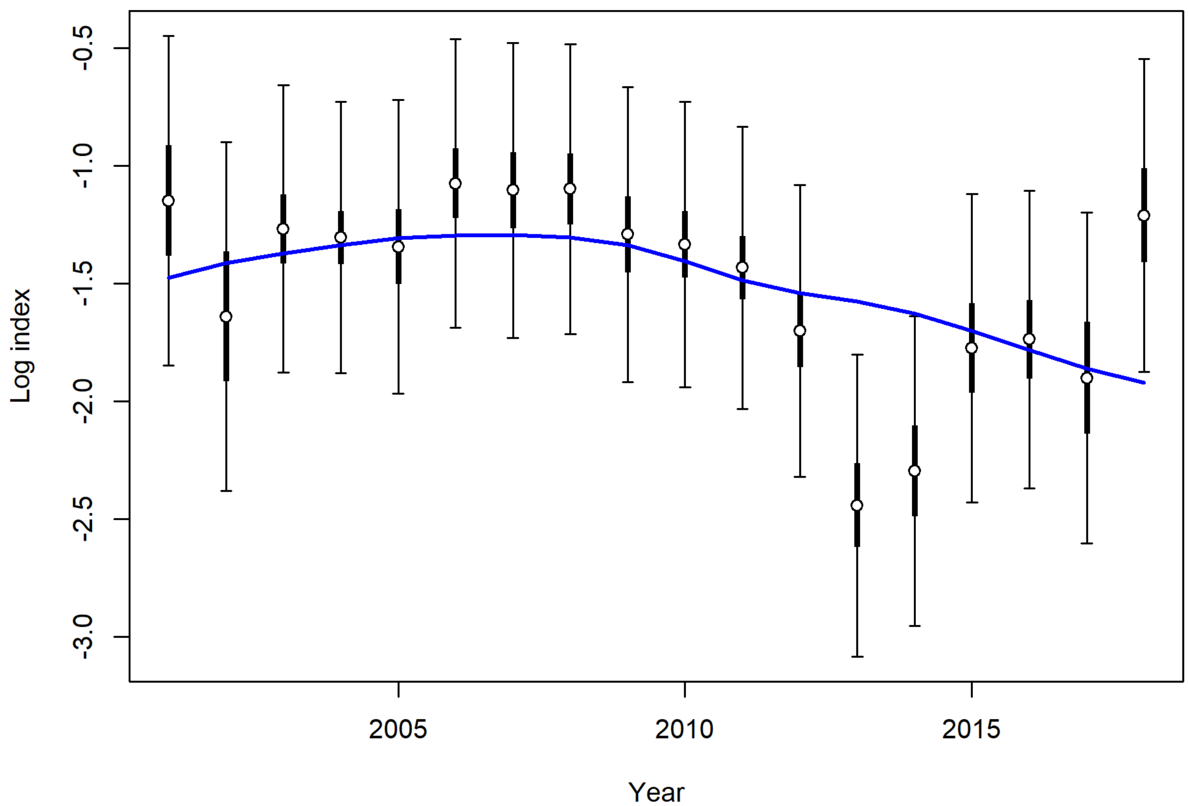



Figure 66: Fit to log index data on log scale for the CRFS/Cal Poly CPFV onboard observer survey north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit_RecOnboardNorth

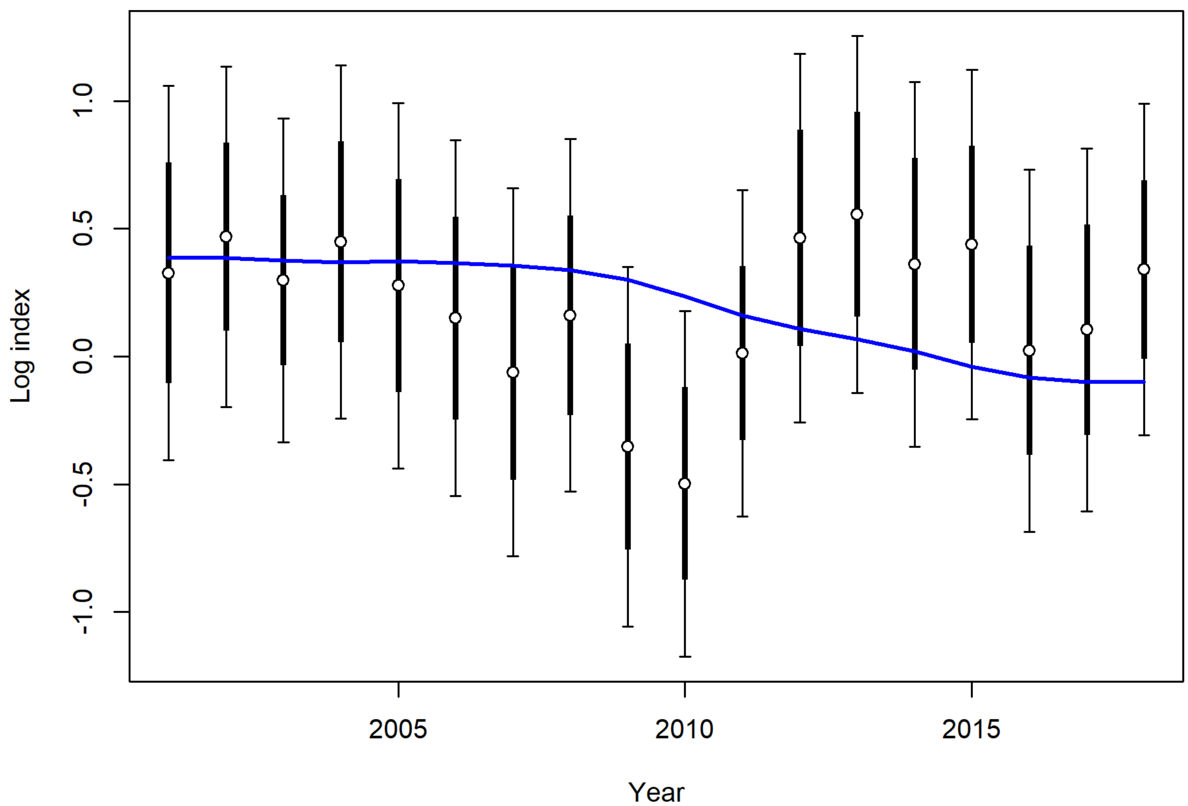



Figure 67: Fit to log index data on log scale for the fishery-independent PISCO kelp forest fish survey for fish 15 cm and larger. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit_PISCO

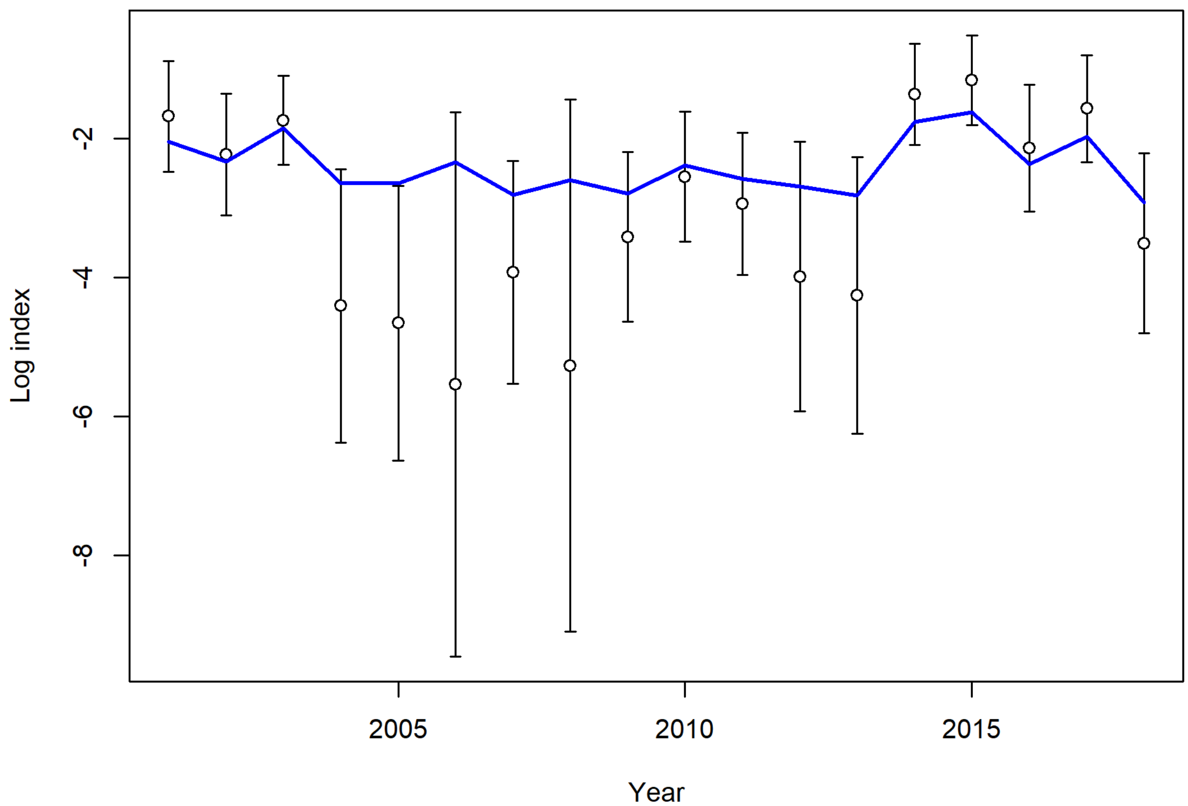



Figure 68: Fit to log index data on log scale for the fishery-independent PISCO age-0 (6 cm or less) kelp forest fish survey for fish 15 cm and larger. Lines indicate 95% uncertainty interval around index values. fig:index5_logcpuefit_PISCOage0

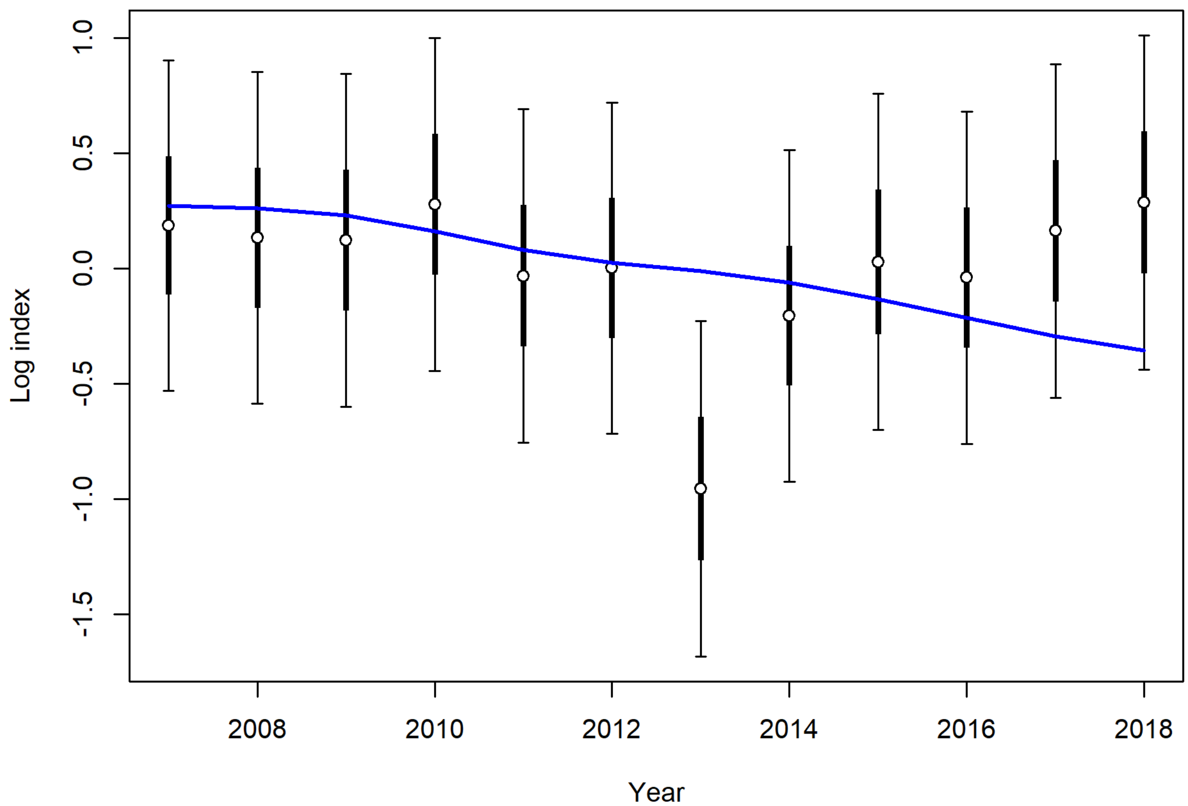



Figure 69: Fit to log index data on log scale for the fishery-independent CCFRP hook-and-line survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit

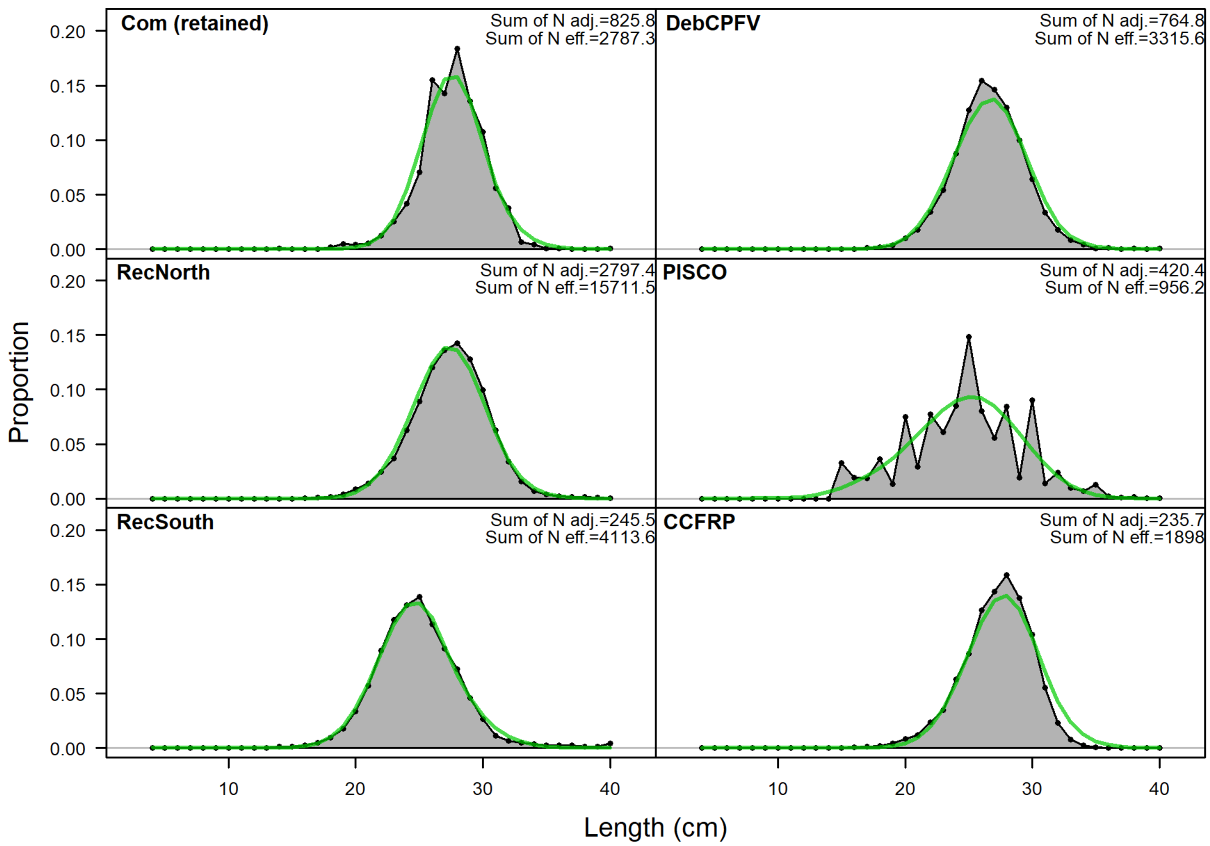



Figure 70: Length compositions aggregated across time by fleet. fig:comp_lenfit__aggregat

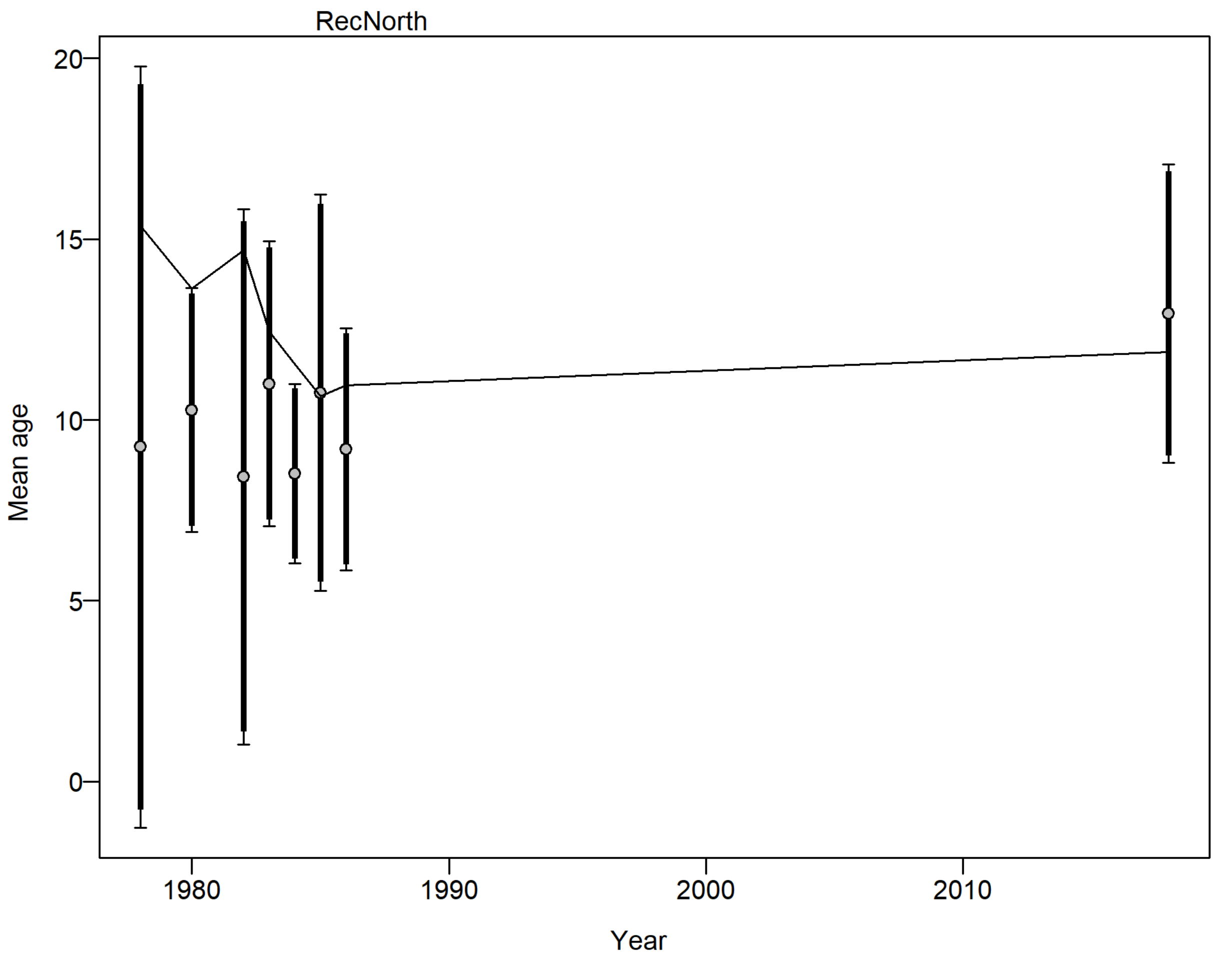



Figure 71: Mean age for the recreational fishery (ages from north of Point Conception only) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.182 (0.588-3.588). For more info, see Francis et al. (2011). fig:comp_condAALfit_data_weighting_TA1.8_condAgeRecNorth

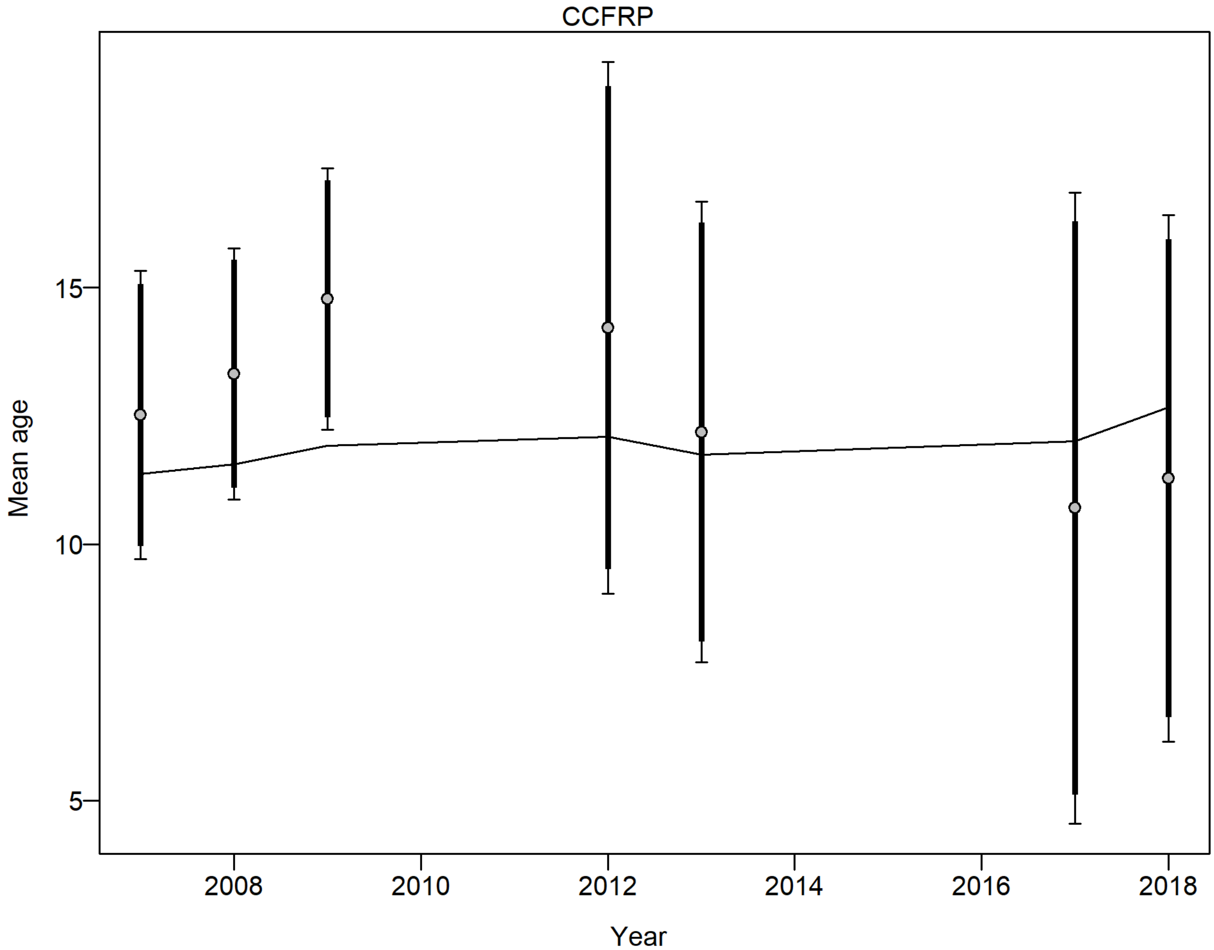



Figure 72: Mean age for the CCFRP survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.023 (0.511-3.745). For more info, see Francis et al. (2011). fig:comp_condAALfit_data_weighting_TA1

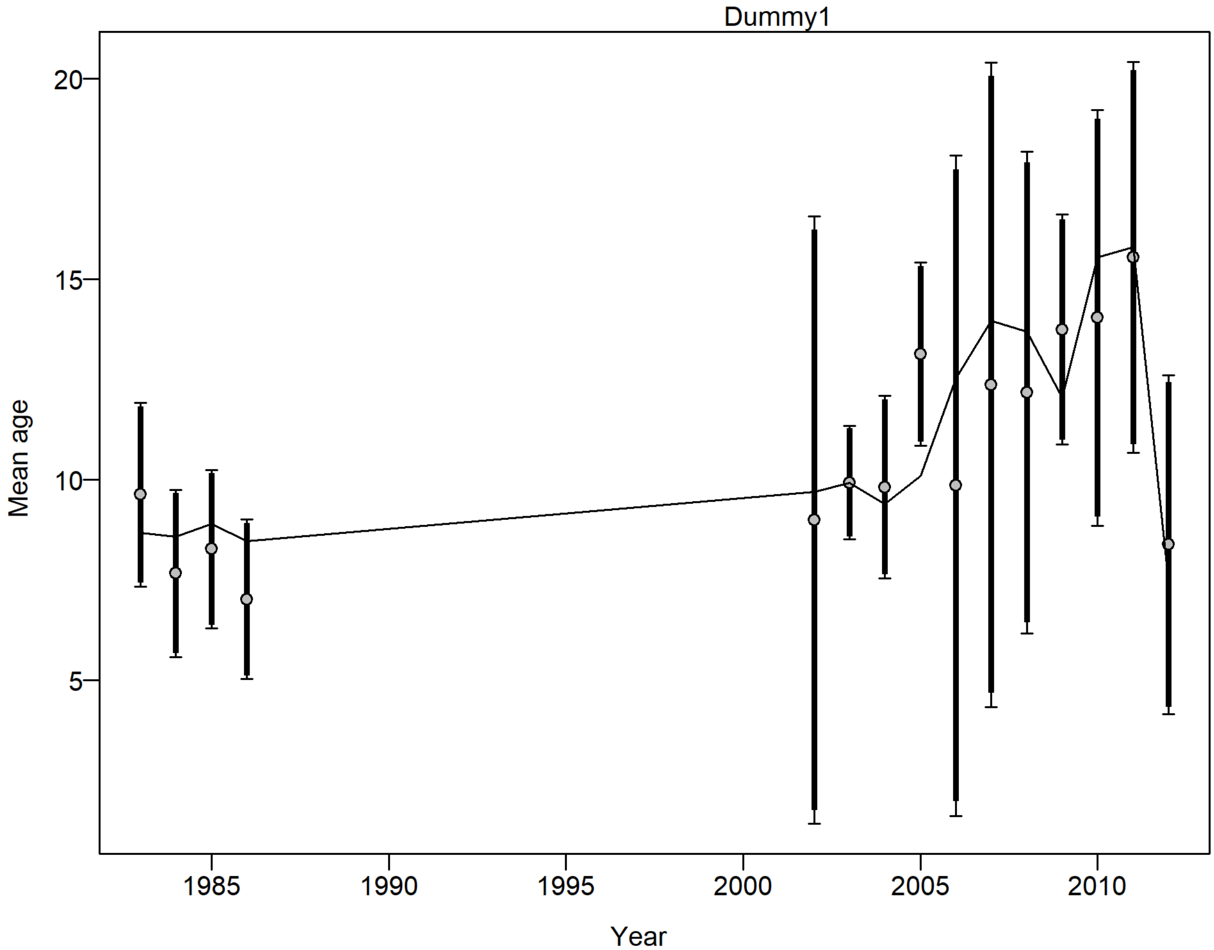



Figure 73: Mean age for the 'dummy' fleet with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.065 (0.507-3.692). For more info, see Francis et al. (2011). fig:comp_condAALfit_data_weighting_TA1

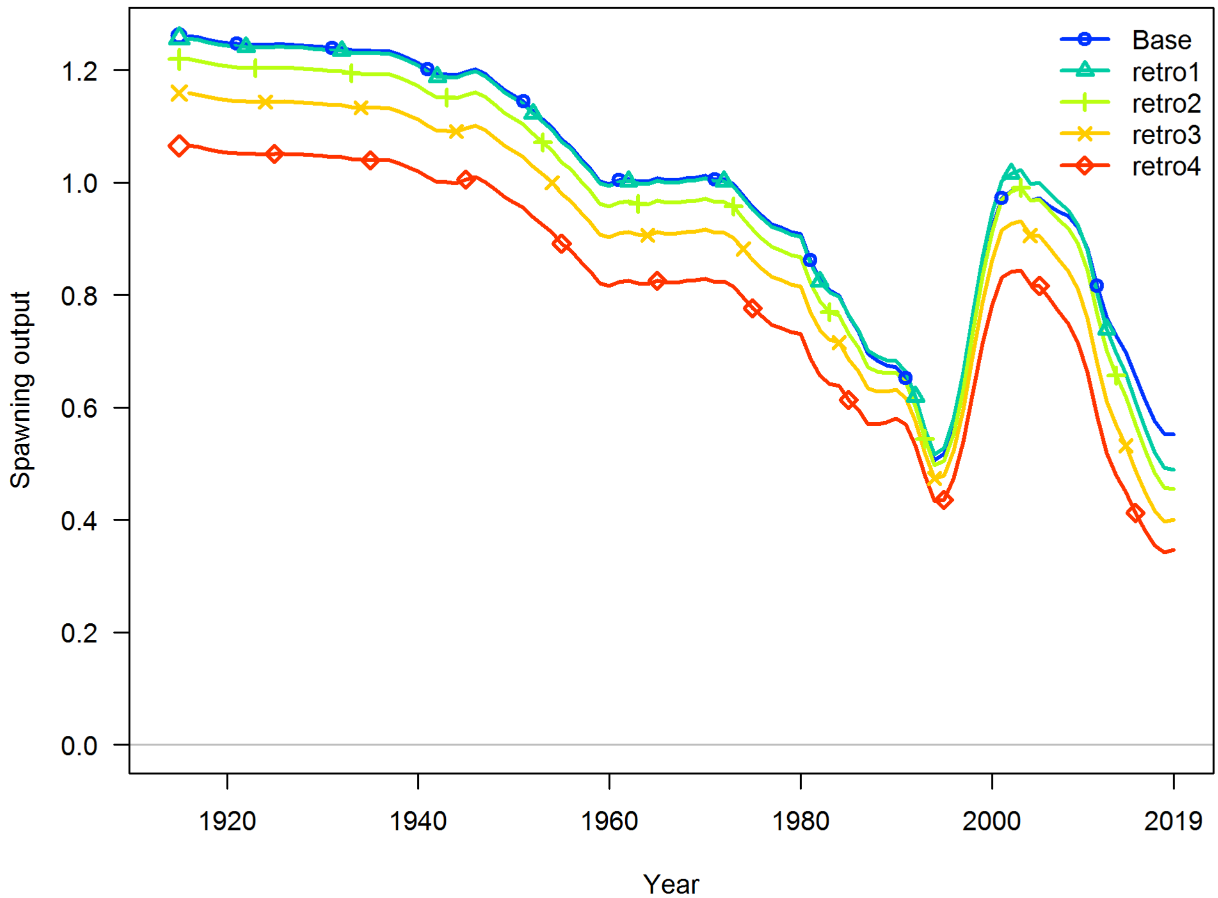



Figure 74: Retrospective pattern for spawning output. fig:retro_spawnb

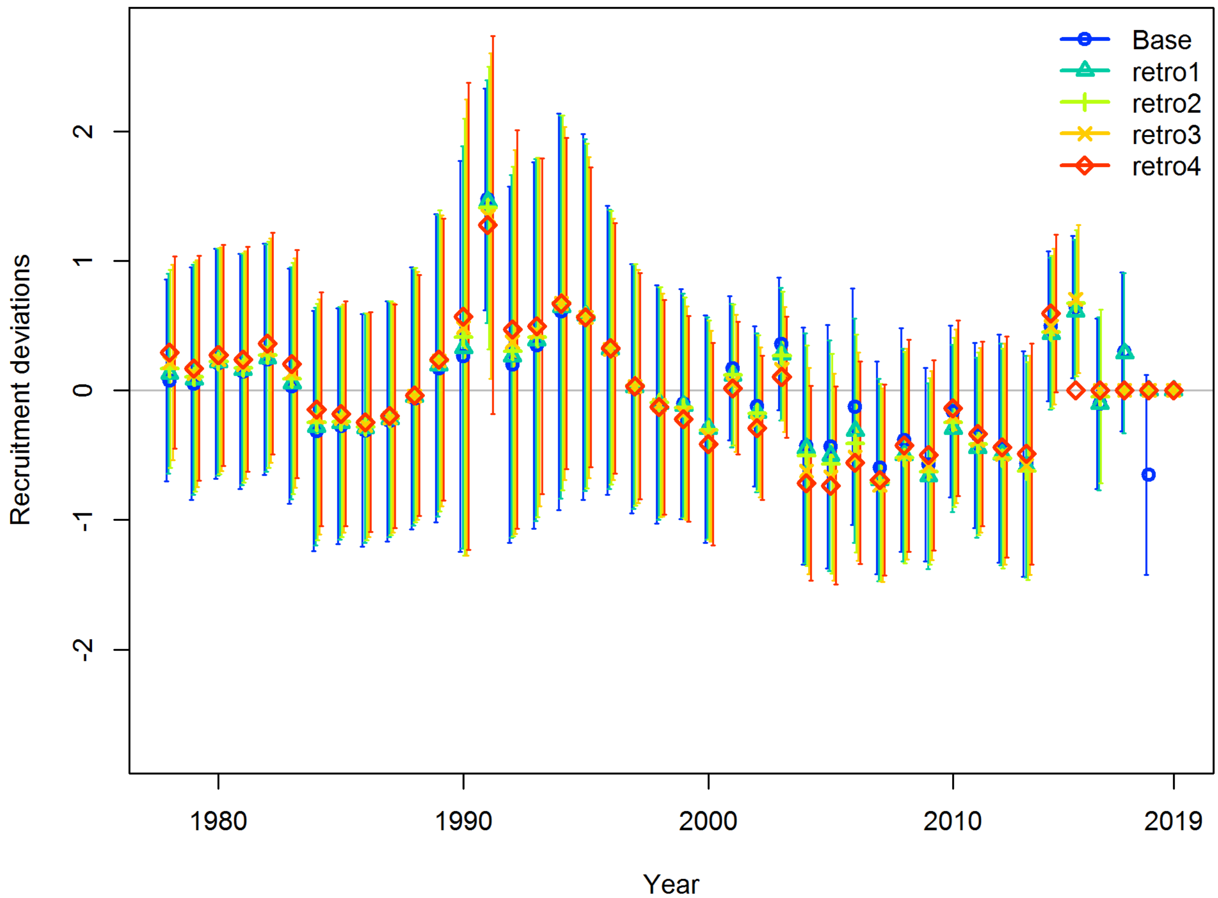



Figure 75: Retrospective pattern for estimated recruitment deviations. fig:retro_recdev

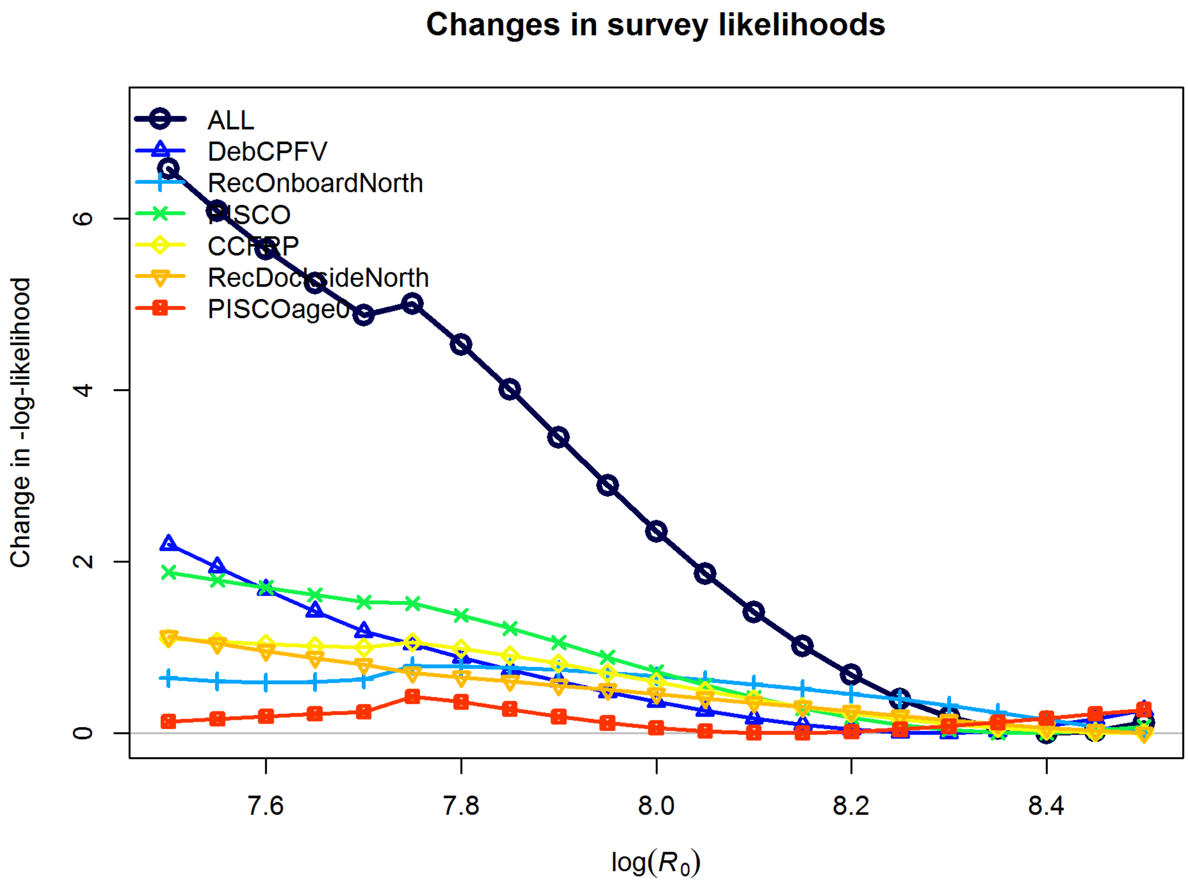



Figure 76: Likelihood profile for $R_0$ values across surveys. fig:profile_R0_piner2

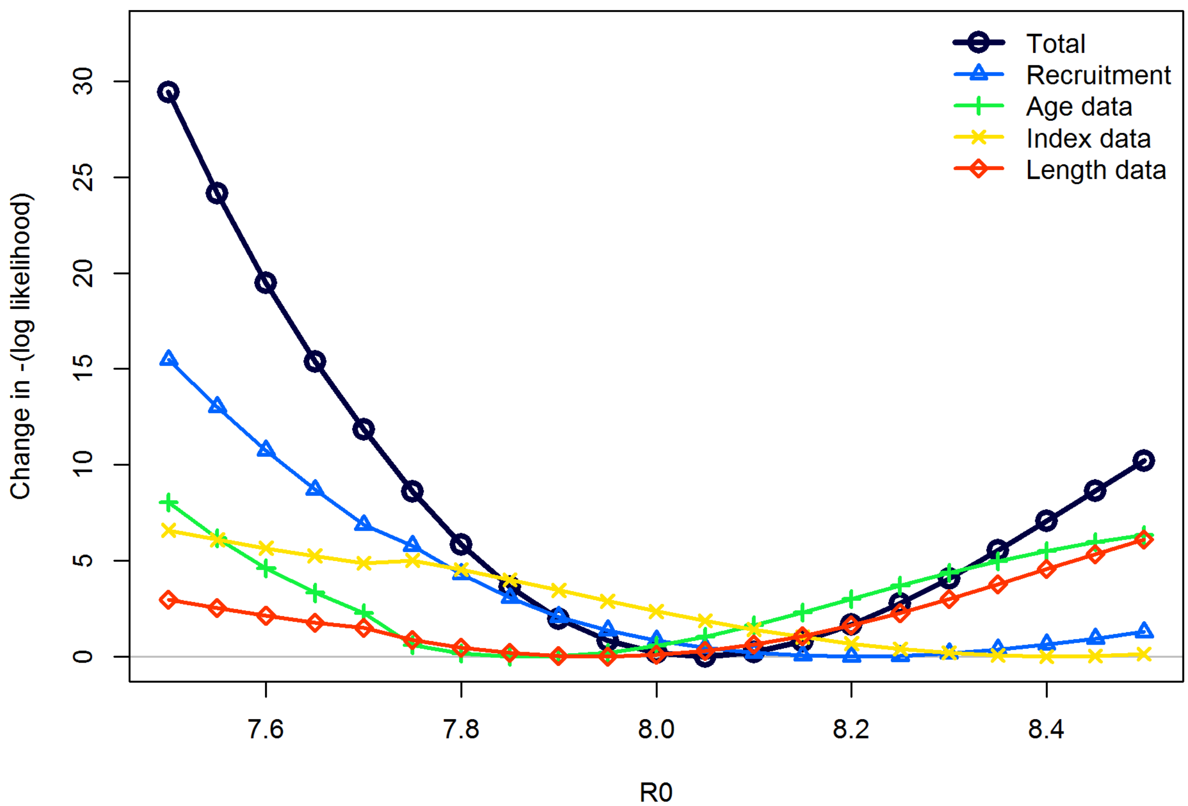



Figure 77: Likelihood profile across $R_0$ values for each data type. fig:profile_R0_like

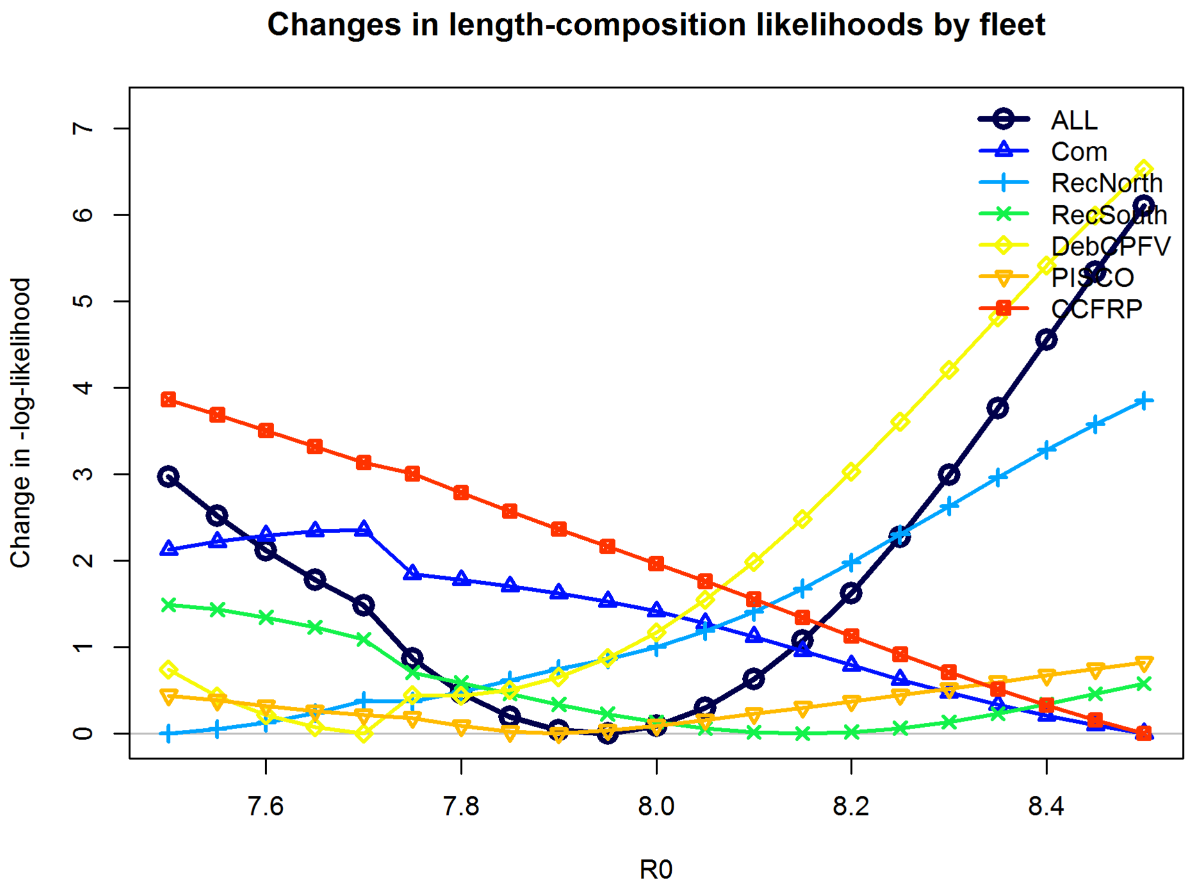



Figure 78: Likelihood profile across $R_0$ values of length composition by fleet. fig:profile_R0_pine

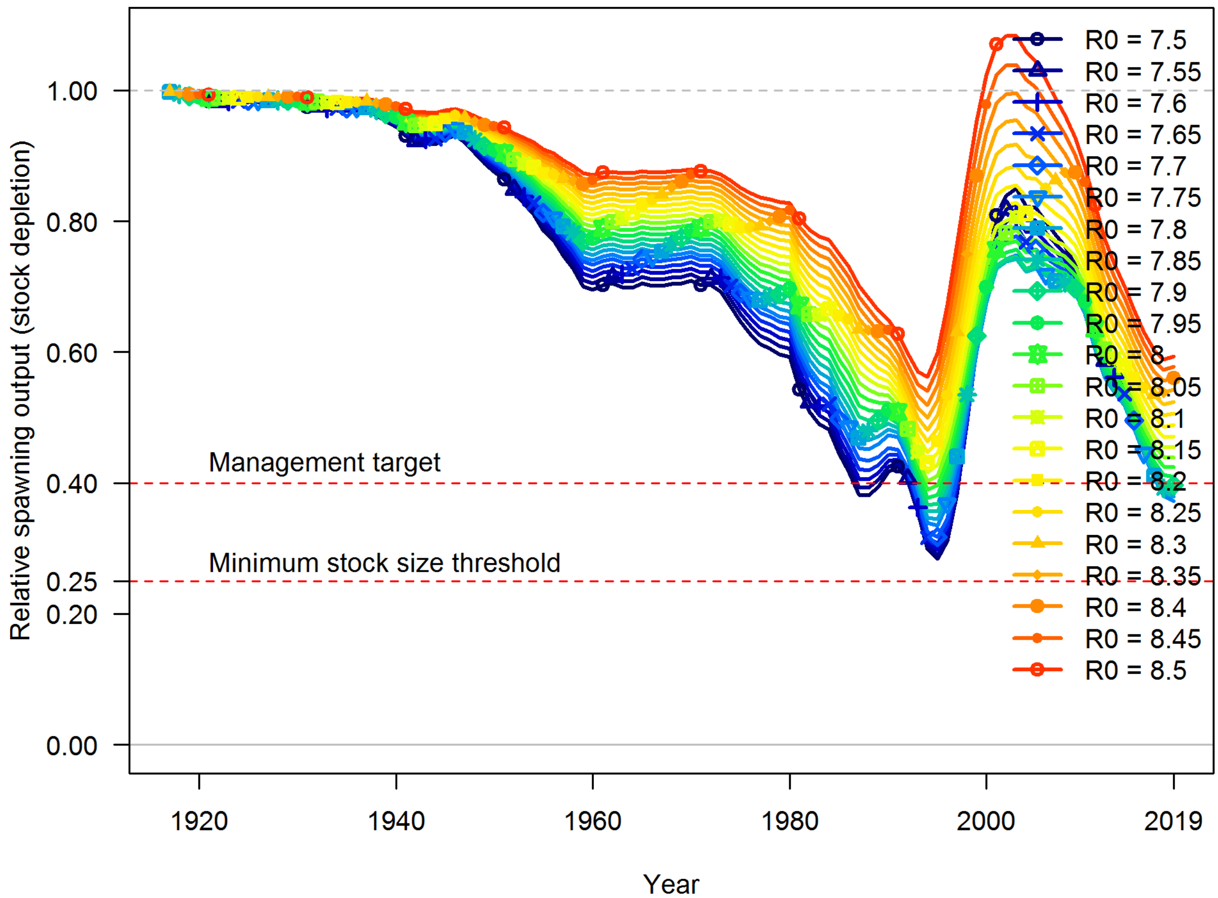



Figure 79: Trajectories of depletion across values of $R_0$. fig:profile_R0_depl

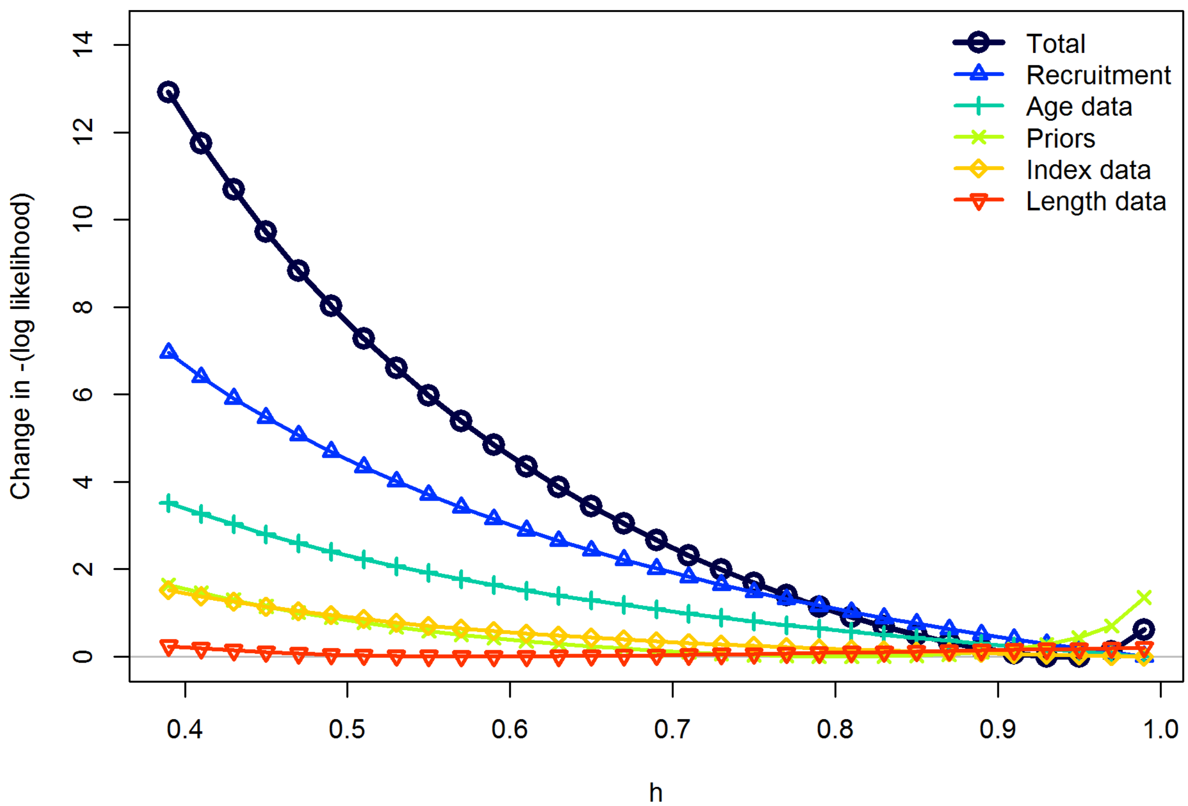



Figure 80: Likelihood profile across steepness values for each data type. fig:profile_h_like

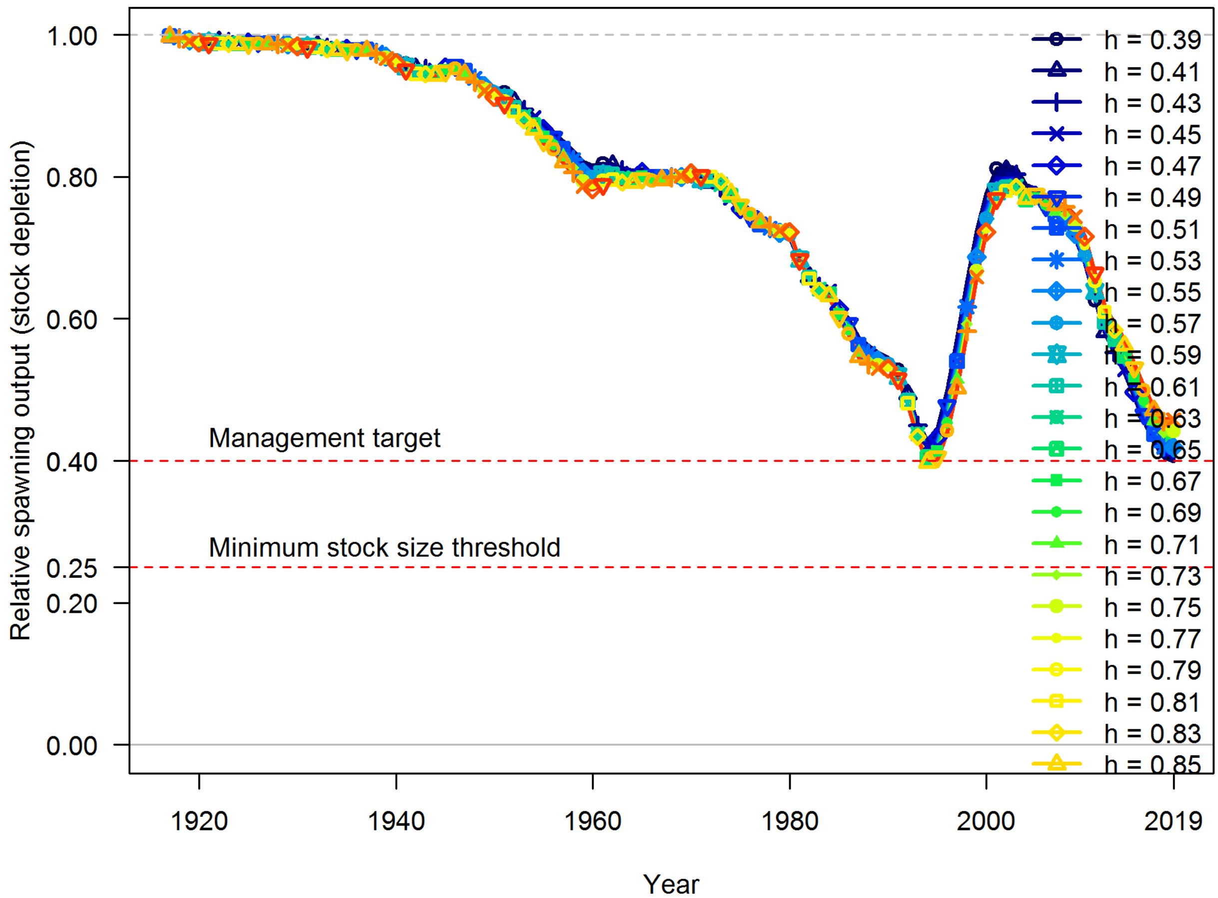



Figure 81: Trajectories of depletion across values of steepness. fig:profile_h_depl

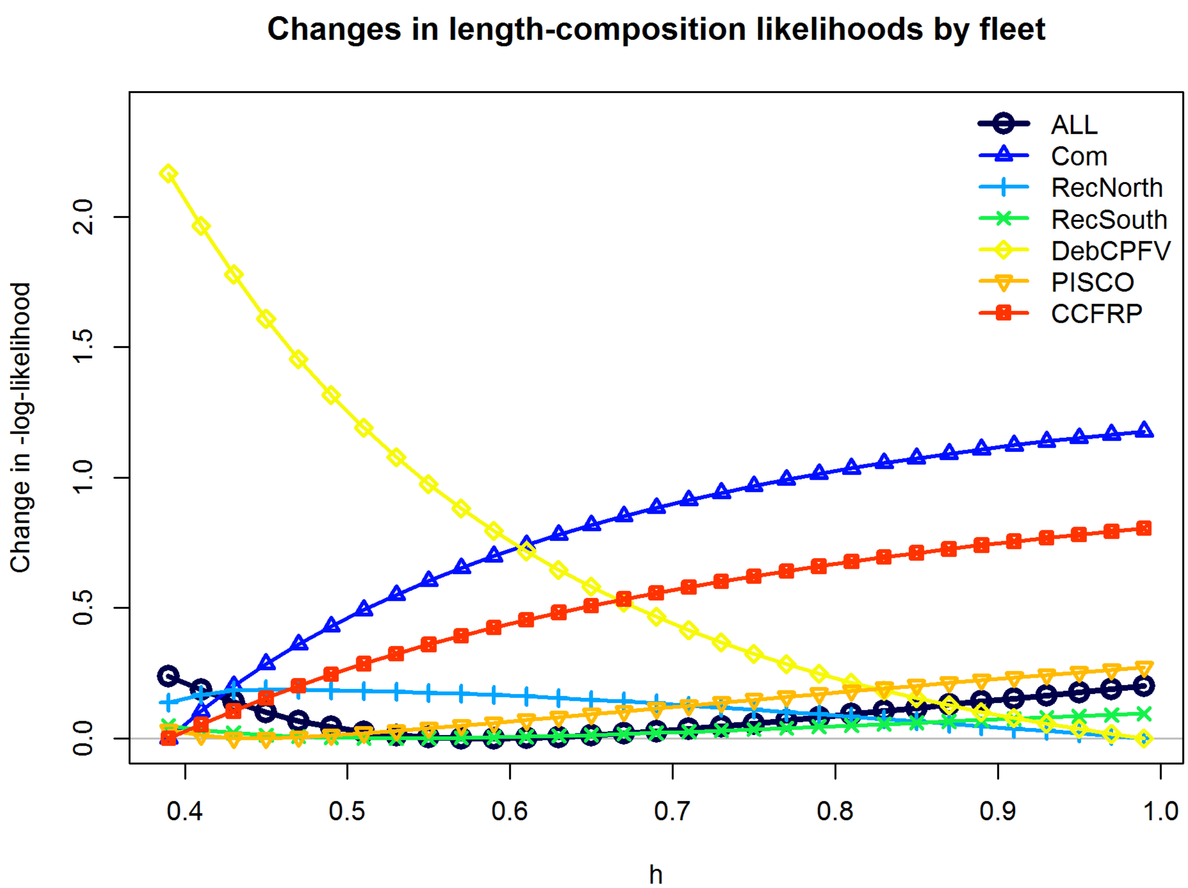



Figure 82: Likelihood profile across steepness values by fleet length composition. fig:profile_h_pin

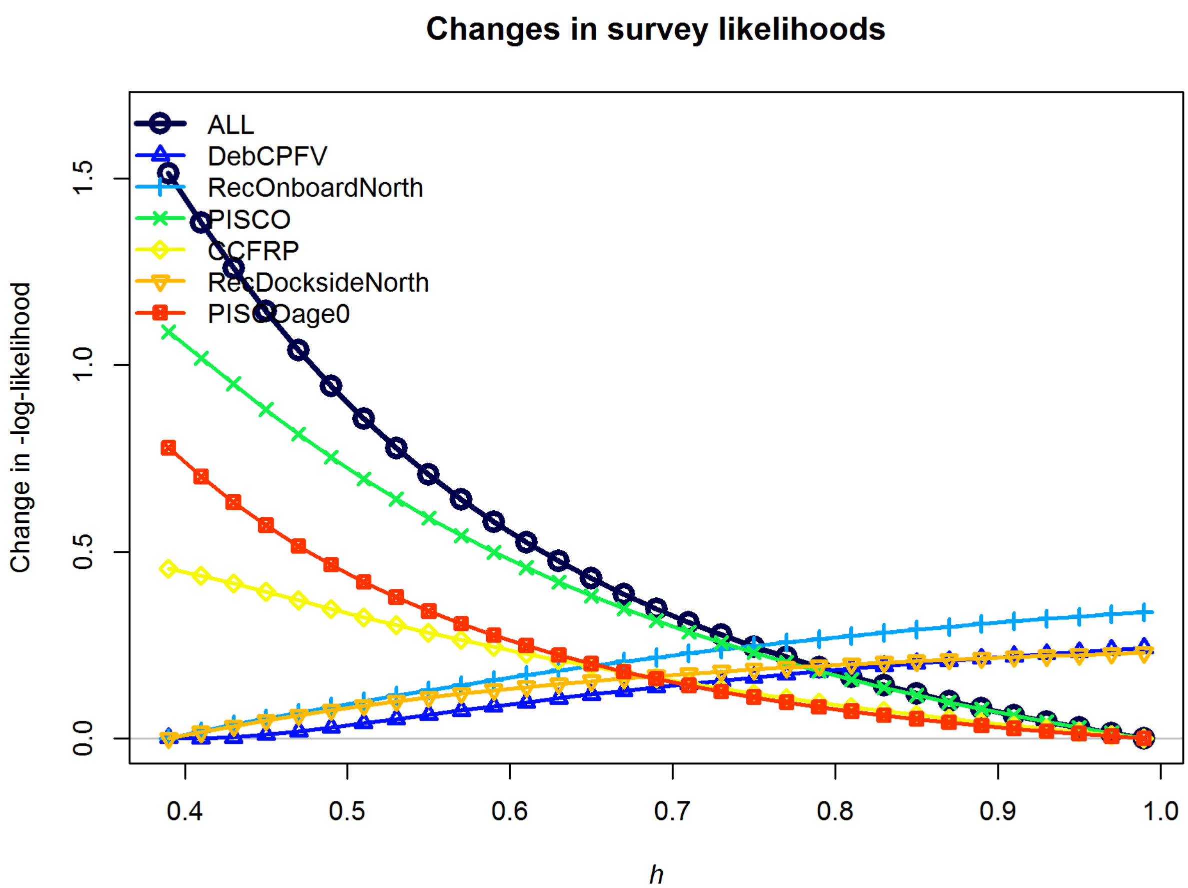



Figure 83: Likelihood profile across steepness values by surveys. fig:profile_h_piner2

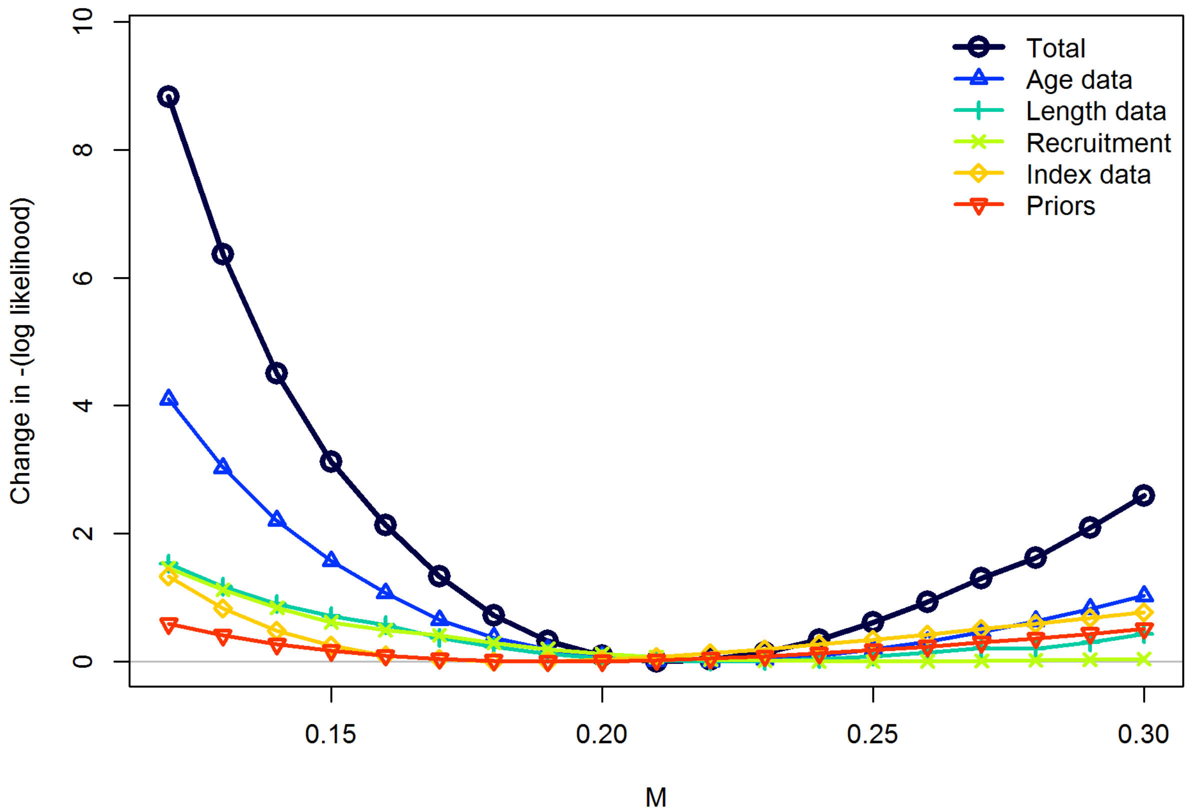



Figure 84: Likelihood profile across female natural mortality values for each data type. fig:profile_m_

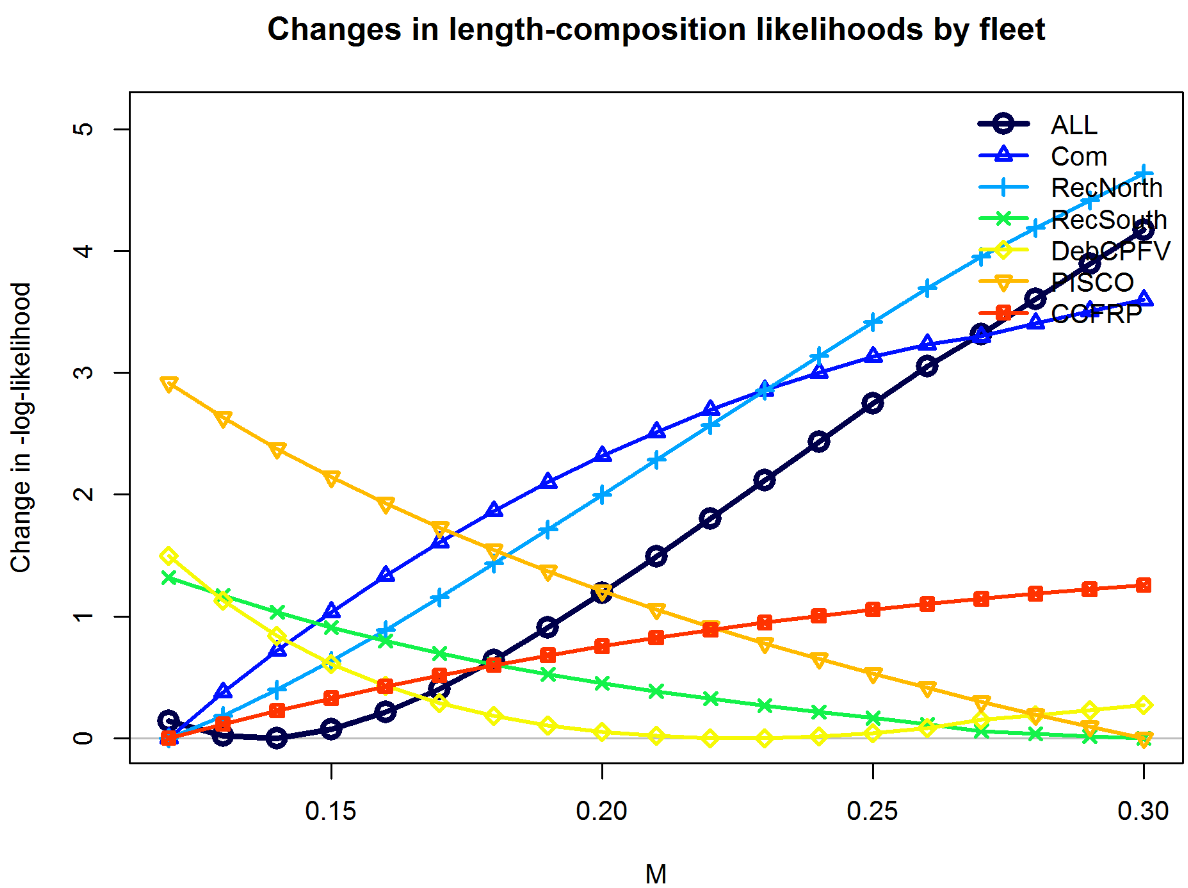



Figure 85: Likelihood profile across female natural mortality values by length composition. fig:profile_m

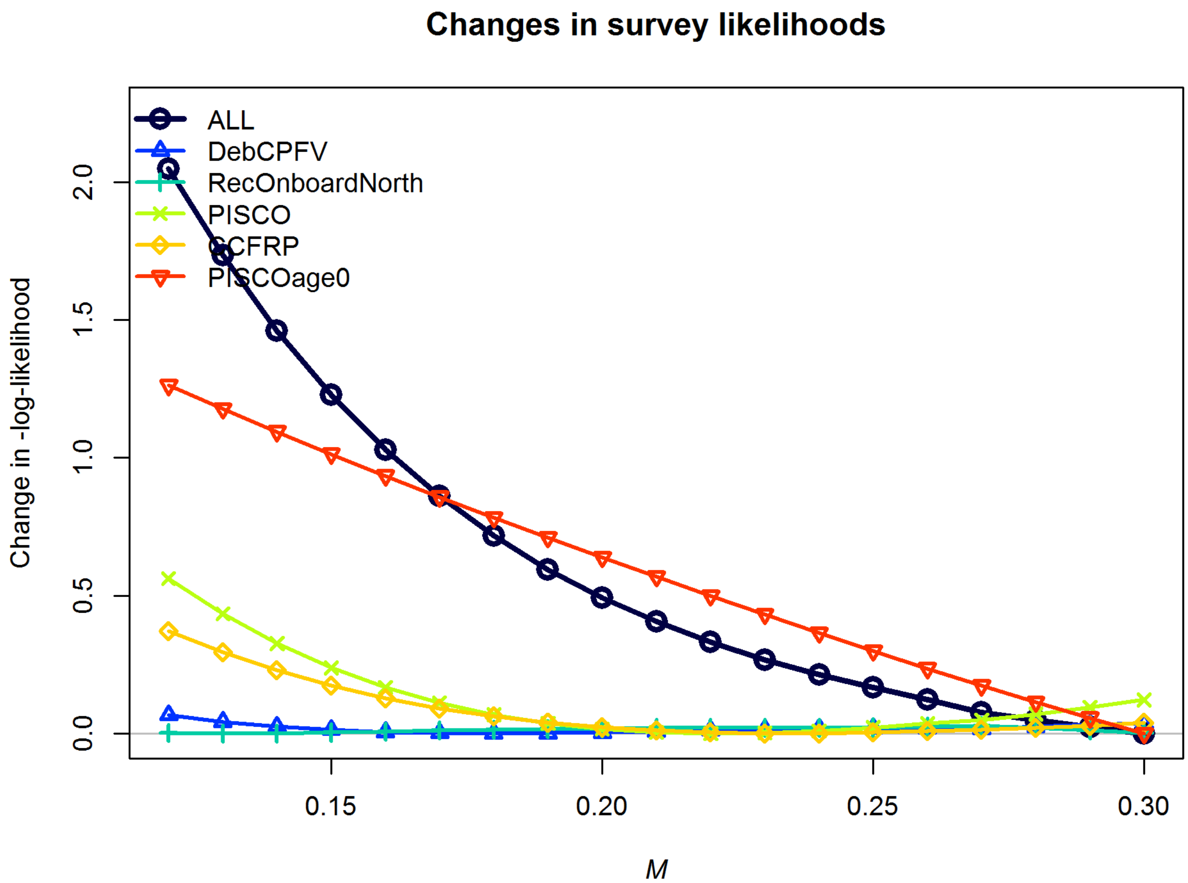



Figure 86: Likelihood profile across female natural mortality values by surveys. fig:profile_m_pine

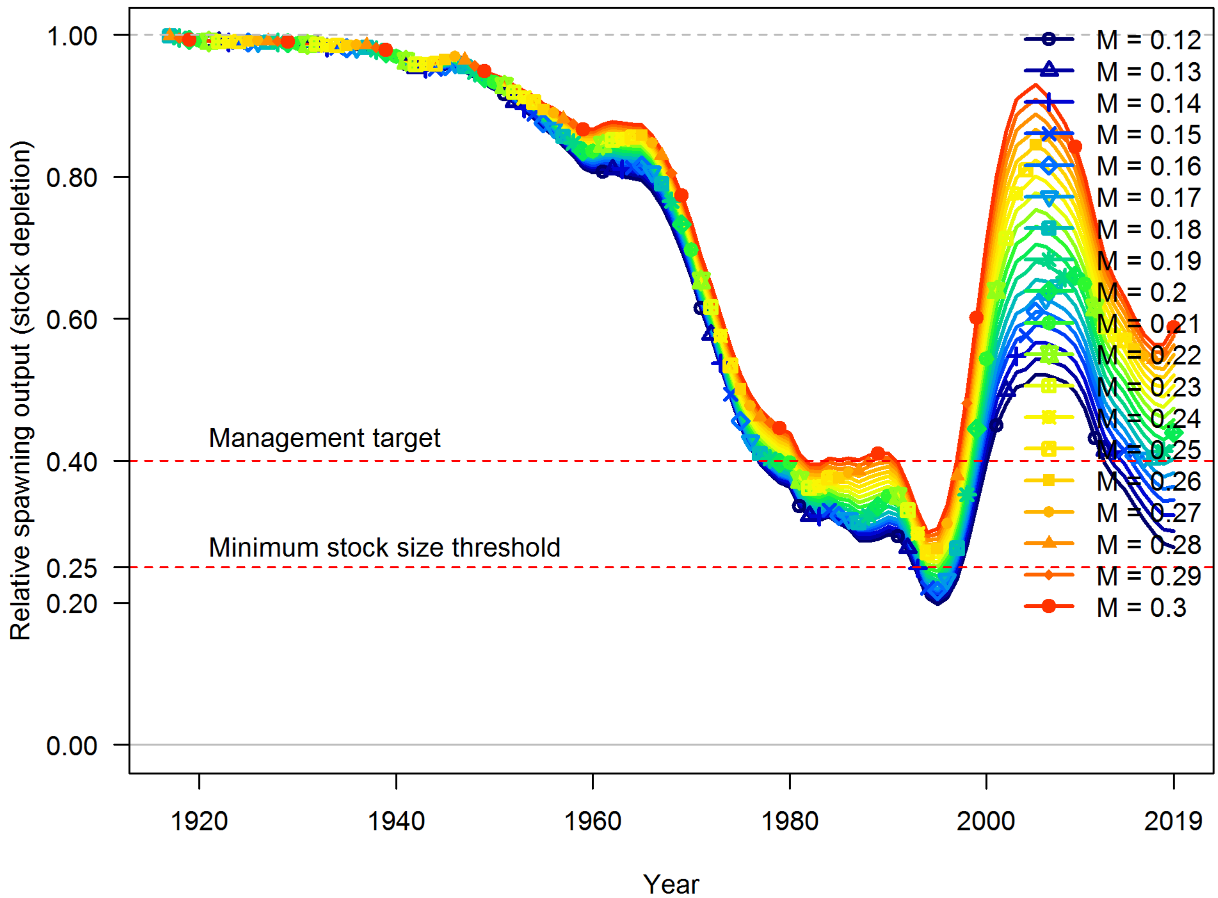



Figure 87: Trajectories of depletion across values of female natural mortality. fig:profile_m_depl

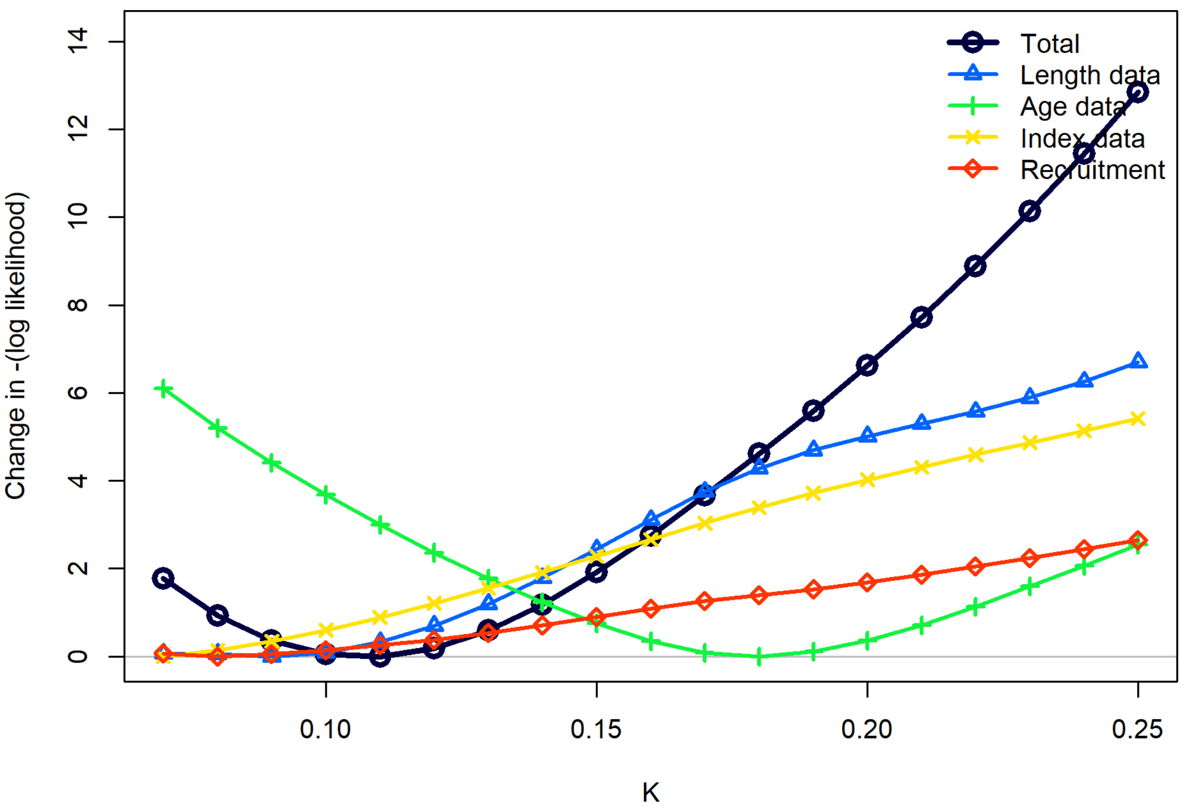



Figure 88: Likelihood profile across the growth parameter $k$ for each data type. fig:profile_k_like

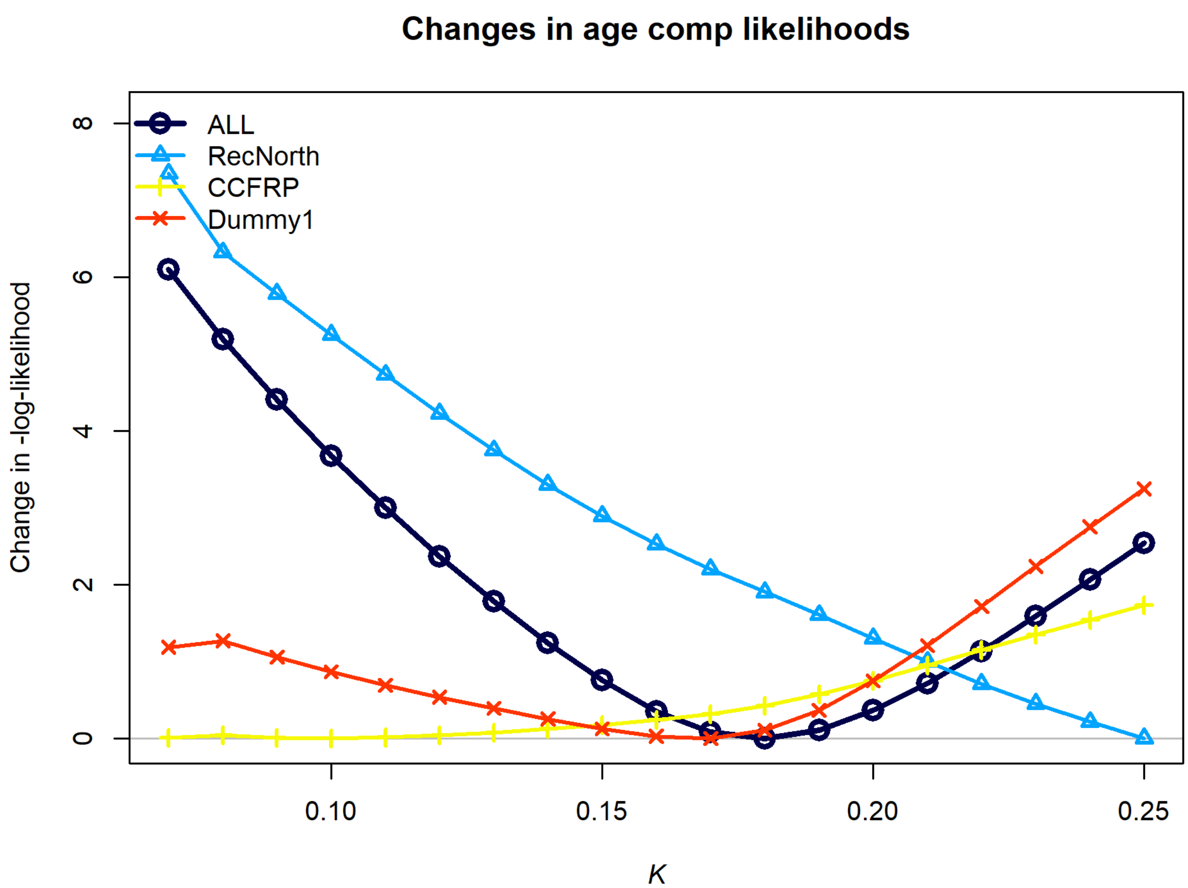



Figure 89: Likelihood profile across the growth parameter $k$ by age composition. fig:profile_k_pin

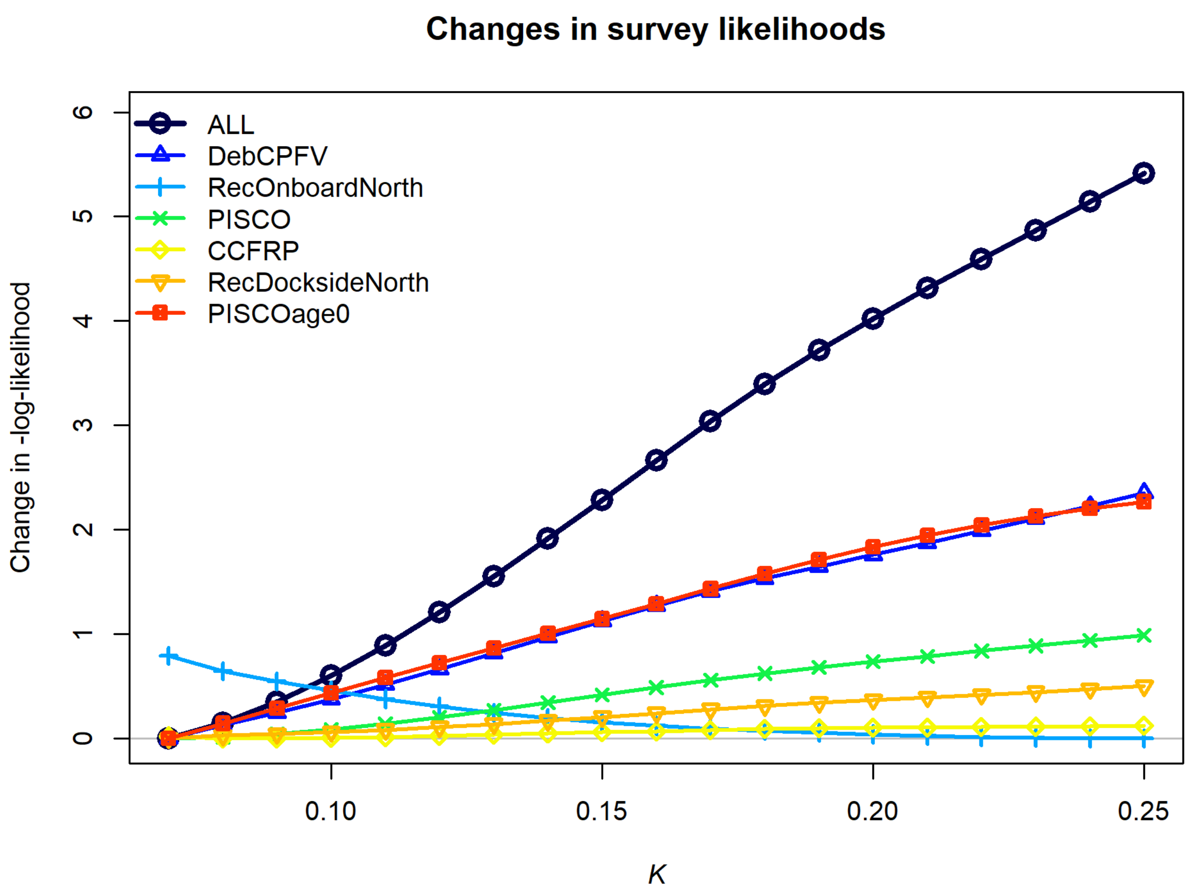



Figure 90: Likelihood profile across the growth parameter $k$ by surveys. fig:profile_k_piner2

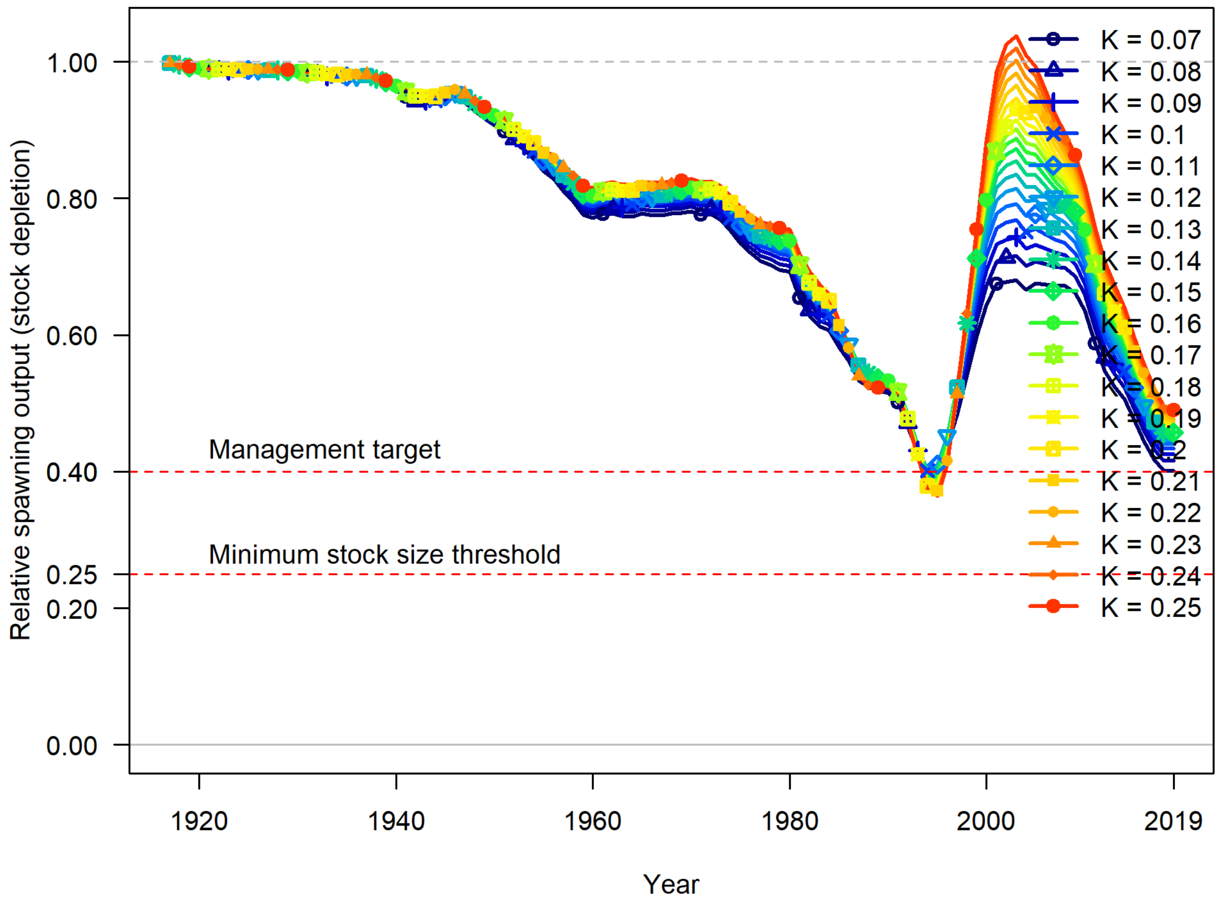



Figure 91: Trajectories of depletion across values of the growth parameter $k$. fig:profile_k_depl

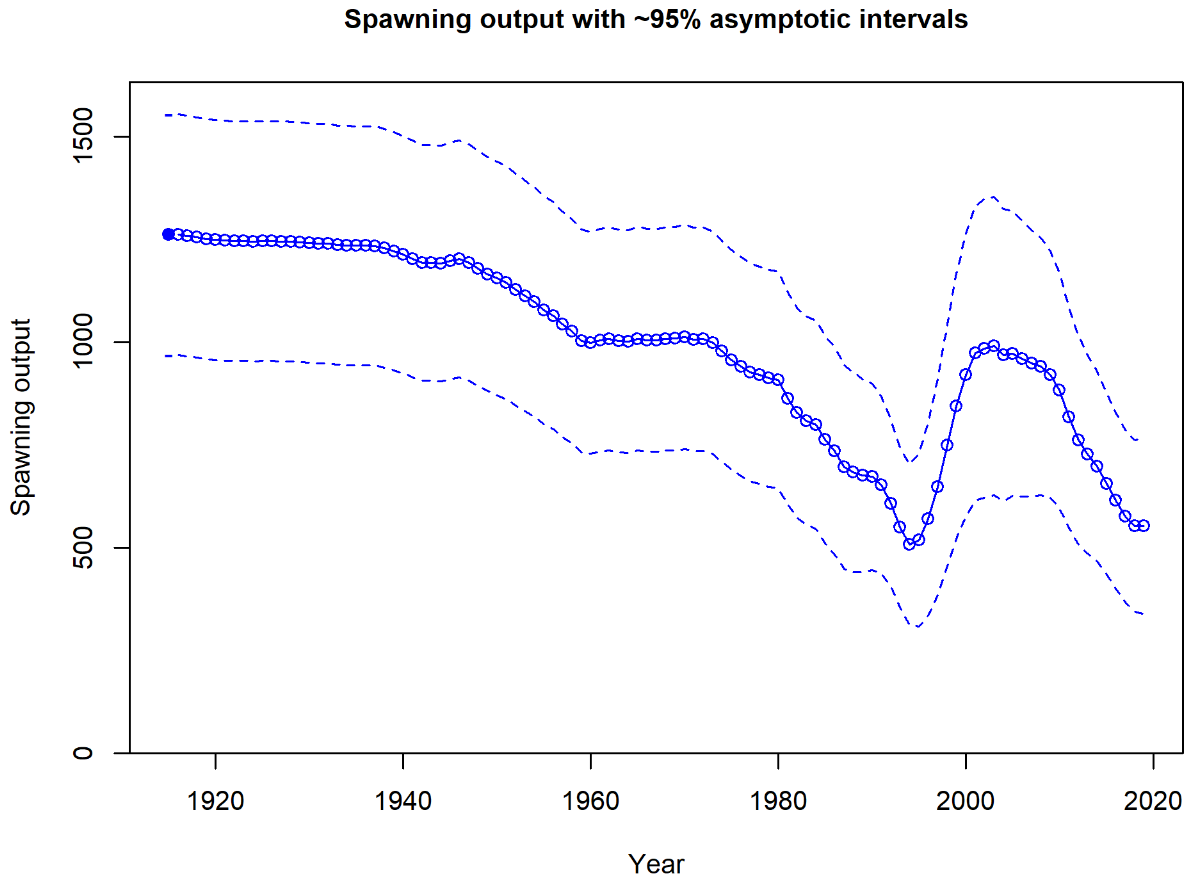



Figure 92: Estimated spawning output with approximate 95% asymptotic intervals. fig:ts7_Spawning

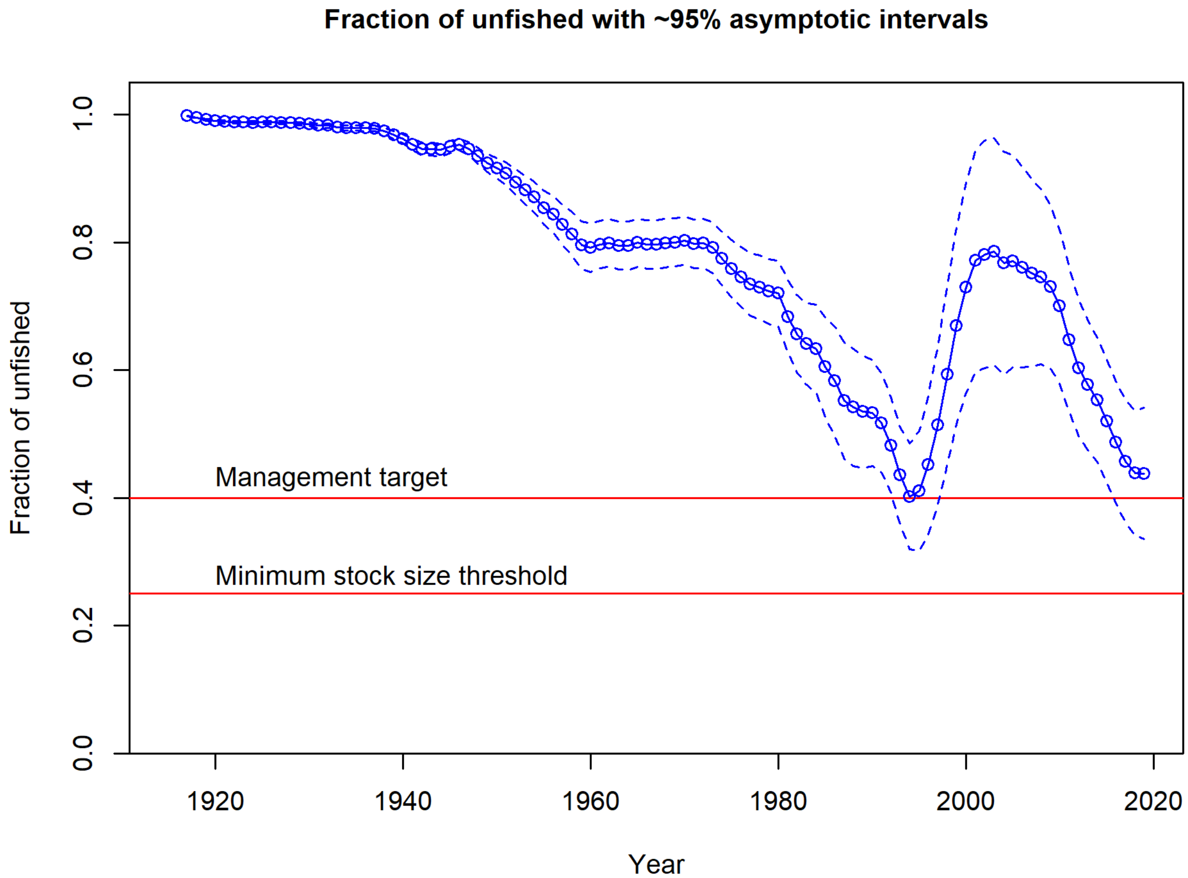



Figure 93: Estimated spawning depletion with approximate 95% asymptotic intervals. fig:ts9_unfishe

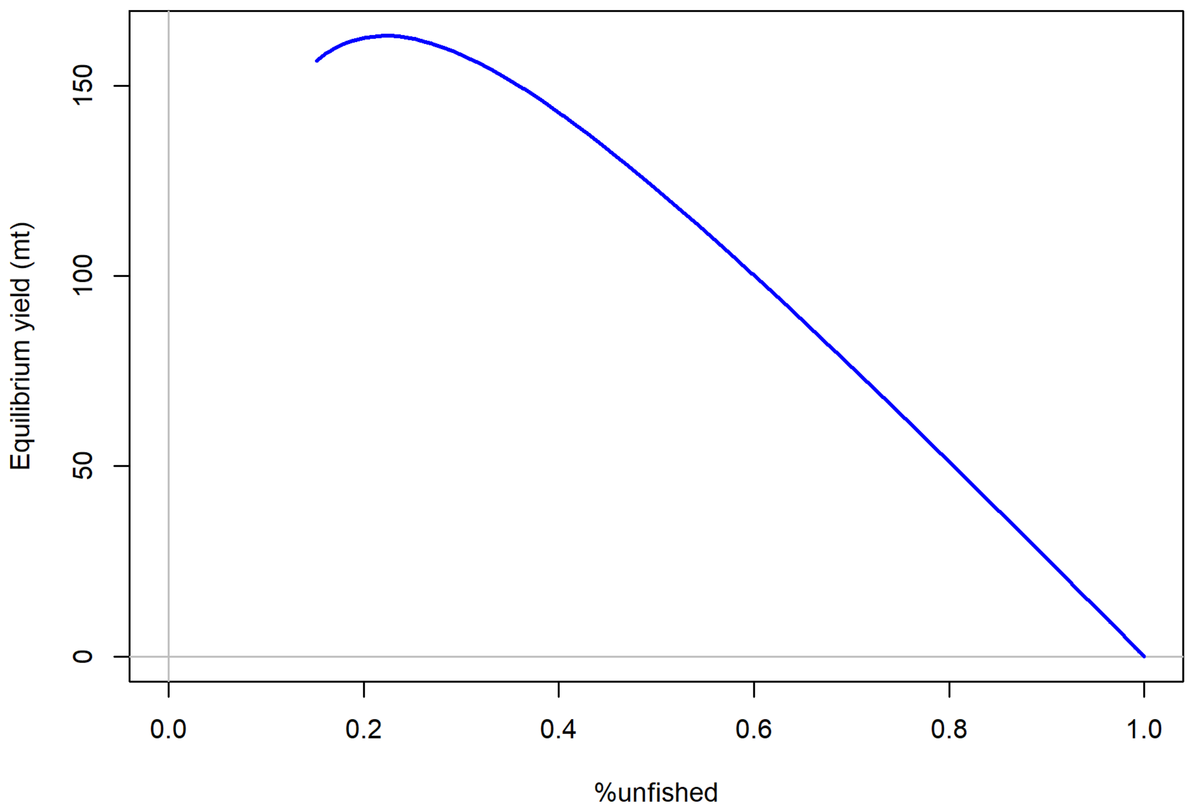



Figure 94: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.718. fig:yield1_yield_curve

# Appendix A. California's Commercial Fishery Regulations

appendix-a.-californias-commercial-fishery-regulations

**California Commercial Regulations for Open Access Fixed Gear**

| Year Month | 40°10'-34°27' | 34°27' - Mex. | 40°10' - Mex. |
|---|---|---|---|
| **2000** Jan | 550 lbs/2 mths* | Closed* | |
| **2000** Mar | Closed* | 550 lbs/2 mths* | |
| **2000** May | 550 lbs/2 mths | | |
| **2001** Jan | 1800 lbs/2 mths | 800 lbs/2 mths shoreward of 20 fm; otherwise closed | |
| **2001** Mar | Closed | 1800 lbs/2 mths | |
| **2001** May | 800 lbs/2 mths shoreward of 20 fm; otherwise closed | | |
| **2001** Jul | 1800 lbs/2 mths | 1800 lbs/2 mths | |
| **2002** Jan | 1200 lbs/2 mths | Closed | |
| **2002** Mar | Closed | 1200 lbs/2 mths | |
| **2002** May | 1200 lbs/2 mths shoreward of 20 fm; otherwise closed | | |
| **2002** Jul | 1200 lbs/2 mths | | |
| **2002** Sep | 1200 lbs/2 mths shoreward of 20 fm; otherwise closed | | |
| **2002** Nov | Closed | Closed | |
| **2003** Jan | | | 200 lbs/2 mths |
| **2003** Mar | | | Closed |
| **2003** May | | | 400 lbs/2 mths |
| **2003** Jul | | | 400 lbs/2 mths |
| **2003** Sep | | | 300 lbs/2 mths |
| **2003** Nov | | | 200 lbs/2 mths |
| **2004** Jan | 300 lbs/2 mths | Closed | |
| **2004** Mar | Closed | 300 lbs/2 mths | |
| **2004** May | 500 lbs/2 mths | 500 lbs/2 mths | |
| **2004** Jul | 600 lbs/2 mths | 600 lbs/2 mths | |
| **2004** Sep | 500 lbs/2 mths | 500 lbs/2 mths | |
| **2004** Nov | 300 lbs/2 mths | 300 lbs/2 mths | |
| **2005-2006** Jan | | | 300 lbs/2 mths |
| **2005-2006** Mar | | | Closed |
| **2005-2006** May | | | 500 lbs/2 mths |
| **2005-2006** Jul | | | 600 lbs/2 mths |
| **2005-2006** Sep | | | 500 lbs/2 mths |
| **2005-2006** Nov | | | 300 lbs/2 mths |
| **2007-2008** Jan | | | 600 lbs/2 mths |
| **2007-2008** Mar | | | Closed |
| **2007-2008** May | | | 800 lbs/2 mths |
| **2007-2008** Jul | | | 900 lbs/2 mths |
| **2007-2008** Sep | | | 800 lbs/2 mths |
| **2007-2008** Nov | | | 600 lbs/2 mths |
| **2009-2016** Jan | | | 600 lbs/2 mths |
| **2009-2016** Mar | | | Closed |
| **2009-2016** May | | | 800 lbs/2 mths |
| **2009-2016** Jul | | | 900 lbs/2 mths |
| **2009-2016** Sep | | | 800 lbs/2 mths |
| **2009-2016** Nov | | | 1000 lbs/2 mths |
| **2017-2018** Jan | | | 1200 lbs/2 mths |
| **2017-2018** Mar | | | Closed |
| **2017-2018** May | | | 1200 lbs/2 mths |
| **2017-2018** Jul | | | 1200 lbs/2 mths |
| **2017-2018** Sep | | | 1200 lbs/2 mths |
| **2017-2018** Nov | | | 1200 lbs/2 mths |

Figure A2 fig:Comm_regs1

| California Commercial Regulations for Limited Entry Fixed Gear | | | |
|---|---|---|---|
| **Year** Month | **40°10'-34°27'** | **34°27' - Mex.** | **40°10' - Mex.** |
| **2000** Jan | 1000 lbs/2 mths* | closed* | |
| **2000** Mar | closed* | 1000 lbs/2 mths* | |
| **2000** May | 1000 lbs/2 mths* | 1000 lbs/2 mths* | |
| **2001** Jan | 2000 lbs/2 mths | 2000 lbs/2 mths shoreward of 20 fm; otherwise closed | |
| **2001** Apr | closed | 2000 lbs/2 mths | |
| **2001** May | 2000 lbs/2 mths shoreward of 20 fm; otherwise closed | | |
| **2001** Jul | 2000 lbs/2 mths | 2000 lbs/2 mths | |
| **2002** Jan | 1600 lbs/2 mths | closed | |
| **2002** Mar | closed | | |
| **2002** May | 1600 lbs/2 mths shoreward of 20 fm; otherwise closed | 2000 lbs/2 mths | |
| **2002** Jul | 1600 lbs/2 mths | | |
| **2002** Sep | 1600 lbs/2 mths shoreward of 20 fm; otherwise closed | | |
| **2002** Nov | closed | closed | |
| **2003** Jan | | | 200 lbs/2 mths |
| **2003** Mar | | | closed |
| **2003** May | | | 400 lbs/2 mths |
| **2003** Jul | | | 400 lbs/2 mths |
| **2003** Sep | | | 300 lbs/2 mths |
| **2003** Nov | | | 200 lbs/2 mths |
| **2004** Jan | 300 lbs/2 mths | closed | |
| **2004** Mar | closed | 300 lbs/2 mths | |
| **2004** May | 500 lbs/2 mths | 500 lbs/2 mths | |
| **2004** Jul | 600 lbs/2 mths | 600 lbs/2 mths | |
| **2004** Sep | 500 lbs/2 mths | 500 lbs/2 mths | |
| **2004** Nov | 300 lbs/2 mths | 300 lbs/2 mths | |
| **2005-2006** Jan | | | 300 lbs/2 mths |
| **2005-2006** Mar | | | closed |
| **2005-2006** May | | | 500 lbs/2 mths |
| **2005-2006** Jul | | | 600 lbs/2 mths |
| **2005-2006** Sep | | | 500 lbs/2 mths |
| **2005-2006** Nov | | | 300 lbs/2 mths |
| **2007-2008** Jan | | | 600 lbs/2 mths |
| **2007-2008** Mar | | | closed |
| **2007-2008** May | | | 800 lbs/2 mths |
| **2007-2008** Jul | | | 900 lbs/2 mths |
| **2007-2008** Sep | | | 800 lbs/2 mths |
| **2007-2008** Nov | | | 600 lbs/2 mths |
| **2009** Jan | | | 600 lbs/2 mths |
| **2009** Mar | | | closed |
| **2009** May | | | 800 lbs/2 mths |
| **2009** Jul | | | 900 lbs/2 mths |
| **2009** Sep | | | 800 lbs/2 mths |
| **2009** Nov | | | 800 lbs/2 mths |
| **2010-2011** Jan | | | 600 lbs/2 mths |
| **2010-2011** Mar | | | closed |
| **2010-2011** May | | | 800 lbs/2 mths |
| **2010-2011** Jul | | | 900 lbs/2 mths |
| **2010-2011** Sep | | | 800 lbs/2 mths |
| **2010-2011** Nov | | | 600 lbs/2 mths |
| **2012-2016** Jan | | | 600 lbs/2 mths |
| **2012-2016** Mar | | | closed |
| **2012-2016** May | | | 800 lbs/2 mths |
| **2012-2016** Jul | | | 900 lbs/2 mths |
| **2012-2016** Sep | | | 800 lbs/2 mths |
| **2012-2016** Nov | | | 1000 lbs/2 mths |
| **2017-2018** Jan | | | 1200 lbs/2 mths |
| **2017-2018** Mar | | | closed |
| **2017-2018** May | | | 1200 lbs/2 mths |
| **2017-2018** Jul | | | 1200 lbs/2 mths |
| **2017-2018** Sep | | | 1200 lbs/2 mths |
| **2017-2018** Nov | | | 1200 lbs/2 mths |

Figure A3 fig:Comm_regs2

| California Commercial Regulations for Limited Entry Trawl for 40°10' - Mex. | | | | |
|---|---|---|---|---|
| **Year** | **Month** | **All trawls** | **Large footrope or midwater trawl** | **Small footrope** |
| **2000-2001** | Jan | 200 lbs/mth | | |
| **2002-2003** | Jan | 300 lbs/mth | | |
| **2004** | Jan | | closed | 300 lbs/mth |
| **2004** | Nov | | | closed |
| **2005-2010** | Jan | | closed | 300 lbs/mth |
| **2011-2018** | Jan | 300 lbs/mth, nonIFQ species | | |

Figure A4 fig:Comm_regs3

# Appendix B. California's Recreational Fishery Regulations

appendix-b.-californias-recreational-fishery-regulations

| California's Recreational Fishing Regulations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Latitude Range | | 42°-40°10' | 40°10'-38°57' | 40°10'-37°11' | 38°57'-37°11' | 37°11'-36° | 37°11'-34°27' | 36°-34°27' | 34°27'-Mex. |
| Year | Month | Northern | Mendocino | North-Central | San Francisco | Monterey South-Central | Central | Morro Bay South-Central | Southern |
| **2000** | Jan | Open | | | | | Open | | Closed |
| **2000** | Feb | Open | | | | | Open | | Closed |
| **2000** | Mar | Open | | | | | Closed | | Open |
| **2000** | Apr | Open | | | | | Closed | | Open |
| **2000** | May | Open | | | | | Open | | Open |
| **2000** | Jun | Open | | | | | Open | | Open |
| **2000** | Jul | Open | | | | | Open | | Open |
| **2000** | Aug | Open | | | | | Open | | Open |
| **2000** | Sep | Open | | | | | Open | | Open |
| **2000** | Oct | Open | | | | | Open | | Open |
| **2000** | Nov | Open | | | | | Open | | Open |
| **2000** | Dec | Open | | | | | Open | | Open |
| **2001** | Jan | Open | | | | | Open | | Closed |
| **2001** | Feb | Open | | | | | Open | | Closed |
| **2001** | Mar | Open | | | | | Closed | | Open |
| **2001** | Apr | Open | | | | | Closed | | Open |
| **2001** | May | Open | | | | | 20 | | Open |
| **2001** | Jun | Open | | | | | 20 | | Open |
| **2001** | Jul | Open | | | | | Open | | Open |
| **2001** | Aug | Open | | | | | Open | | Open |
| **2001** | Sep | Open | | | | | Open | | Open |
| **2001** | Oct | Open | | | | | Open | | Open |
| **2001** | Nov | Open | | | | | 20 | | 20 |
| **2001** | Dec | Open | | | | | 20 | | 20 |
| **2002** | Jan | Open | | | | | Open | | Closed |
| **2002** | Feb | Open | | | | | Open | | Closed |
| **2002** | Mar | Open | | | | | Closed | | Open |
| **2002** | Apr | Open | | | | | Closed | | Open |
| **2002** | May | Open | | | | | 20 | | Open |
| **2002** | Jun | Open | | | | | 20 | | Open |
| **2002** | Jul | Open | | | | | 20 | | 20 |
| **2002** | Aug | Open | | | | | 20 | | 20 |
| **2002** | Sep | Open | | | | | 20 | | 20 |
| **2002** | Oct | Open | | | | | 20 | | 20 |
| **2002** | Nov | Open | | | | | Closed | | Closed |
| **2002** | Dec | Open | | | | | Closed | | Closed |
| **2003** | Jan | Open | | | | | Closed | | Closed |
| **2003** | Feb | Open | | | | | Closed | | Closed |
| **2003** | Mar | Open | | | | | Closed | | Closed |
| **2003** | Apr | Open | | | | | Closed | | Closed |
| **2003** | May | Open | | | | | Closed | | Closed |
| **2003** | Jun | Open | | | | | Closed | | Closed |
| **2003** | Jul | Open | | | | | 20 | | 20 |
| **2003** | Aug | Open | | | | | 20 | | 20 |
| **2003** | Sep | Open | | | | | 20 | | 30 |
| **2003** | Oct | Open | | | | | 20 | | 30 |
| **2003** | Nov | Open | | | | | 20 | | 30 |
| **2003** | Dec | Open->Closed | | | | | 20->Closed | | 30->Closed |
| **2004** | Jan | Open | | 30 | | | | 30 | Closed |
| **2004** | Feb | Open | | 30 | | | | 30 | Closed |
| **2004** | Mar | Open | | Closed | | | | Closed | 60 |
| **2004** | Apr | Open | | Closed | | | | Closed | 60 |
| **2004** | May | 30 | | Closed | | | | 20 | 60 |
| **2004** | Jun | 30 | | Closed | | | | 20 | 60 |
| **2004** | Jul | 30 | | Closed | | | | Closed | 60 |
| **2004** | Aug | 30 | | 20 | | | | 20 | 60 |
| **2004** | Sep | 30 | | 20 | | | | 20 | 30 |
| **2004** | Oct | 30 | | 20 | | | | 20 | 30 |
| **2004** | Nov | 30 | | Closed | | | | 20 | 60 |
| **2004** | Dec | 30 | | Closed | | | | 20 | 60 |

Figure B2 fig:Rec_regs1

| Latitude Range | | 42°-40°10' | 40°10'-38°57' | 40°10'-37°11' | 38°57'-37°11' | 37°11'-36° | 37°11'-34°27' | 36°-34°27' | 34°27'-Mex. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **Monterey** | | **Morro Bay** | |
| **Year** | **Month** | **Northern** | **Mendocino** | **North-Central** | **San Francisco** | **South-Central** | **Central** | **South-Central** | **Southern** |
| **2005** | Jan | Closed | | Closed | | Closed | | Closed | Closed |
| **2005** | Feb | Closed | | Closed | | Closed | | Closed | Closed |
| **2005** | Mar | Closed | | Closed | | Closed | | Closed | 60 |
| **2005** | Apr | Closed | | Closed | | Closed | | Closed | 60 |
| **2005** | May | 30 | | Closed | | Closed | | 40 | 60 |
| **2005** | Jun | 30 | | Closed | | Closed | | 40 | 60 |
| **2005** | Jul | 30 | | 20 | | 20 | | 40 | 60 |
| **2005** | Aug | 30 | | 20 | | 20 | | 40 | 60 |
| **2005** | Sep | 30 | | 20 | | 20 | | 40 | 30 |
| **2005** | Oct | 30 | | 20 | | 20 | | Closed | 30 |
| **2005** | Nov | 30 | | 20 | | 20 | | Closed | 60 |
| **2005** | Dec | 30 | | 20 | | 20 | | Closed | 60 |
| **2006** | Jan | Closed | | Closed | | Closed | | Closed | Closed |
| **2006** | Feb | Closed | | Closed | | Closed | | Closed | Closed |
| **2006** | Mar | Closed | | Closed | | Closed | | Closed | 60 |
| **2006** | Apr | Closed | | Closed | | Closed | | Closed | 60 |
| **2006** | May | 30 | | Closed | | Closed | | 40 | 60 |
| **2006** | Jun | 30 | | Closed | | Closed | | 40 | 60 |
| **2006** | Jul | 30 | | 30 | | 30 | | 40 | 60 |
| **2006** | Aug | 30 | | 30 | | 30 | | 40 | 60 |
| **2006** | Sep | 30 | | 30 | | 30 | | 40 | 60 |
| **2006** | Oct | 30 | | 30 | | 30 | | 40 | 60 |
| **2006** | Nov | 30 | | 30 | | 30 | | Closed | 60 |
| **2006** | Dec | 30 | | 30 | | 30 | | Closed | 60 |
| **2007** | Jan | Closed | | Closed | | Closed | | Closed | Closed |
| **2007** | Feb | Closed | | Closed | | Closed | | Closed | Closed |
| **2007** | Mar | Closed | | Closed | | Closed | | Closed | 60 |
| **2007** | Apr | Closed | | Closed | | Closed | | Closed | 60 |
| **2007** | May | 30 | | Closed | | 40 | | 40 | 60 |
| **2007** | Jun | 30 | | 30 | | 40 | | 40 | 60 |
| **2007** | Jul | 30 | | 30 | | 40 | | 40 | 60 |
| **2007** | Aug | 30 | | 30 | | 40 | | 40 | 60 |
| **2007** | Sep | 30 | | 30 | | 40 | | 40 | 60 |
| **2007** | Oct | Closed | | Closed | | 40 | | 40 | 60 |
| **2007** | Nov | Closed | | Closed | | 40 | | 40 | 60 |
| **2007** | Dec | Closed | | Closed | | Closed | | Closed | 60 |
| **2008** | Jan | Closed | Closed | | Closed | Closed | | Closed | Closed |
| **2008** | Feb | Closed | Closed | | Closed | Closed | | Closed | Closed |
| **2008** | Mar | Closed | Closed | | Closed | Closed | | Closed | 60 |
| **2008** | Apr | Closed | Closed | | Closed | Closed | | Closed | 60 |
| **2008** | May | 20 | Closed | | Closed | 40 | | 40 | 60 |
| **2008** | Jun | 20 | 20 | | 20 | 40 | | 40 | 60 |
| **2008** | Jul | 20 | 20 | | 20 | 40 | | 40 | 60 |
| **2008** | Aug | 20 | 20 | | 20 | 40 | | 40 | 60 |
| **2008** | Sep | Closed | Closed | | 20 | 40 | | 40 | 60 |
| **2008** | Oct | Closed | Closed | | 20 | 40 | | 40 | 60 |
| **2008** | Nov | Closed | Closed | | 20 | 40 | | 40 | 60 |
| **2008** | Dec | Closed | Closed | | Closed | Closed | | Closed | 60 |
| **2009** | Jan | Closed | Closed | | Closed | Closed | | Closed | Closed |
| **2009** | Feb | Closed | Closed | | Closed | Closed | | Closed | Closed |
| **2009** | Mar | Closed | Closed | | Closed | Closed | | Closed | 60 |
| **2009** | Apr | Closed | Closed | | Closed | Closed | | Closed | 60 |
| **2009** | May | Closed->20 | Closed->20 | | Closed | 40 | | 40 | 60 |
| **2009** | Jun | 20 | 20 | | Closed->20 | 40 | | 40 | 60 |
| **2009** | Jul | 20 | 20 | | 20 | 40 | | 40 | 60 |
| **2009** | Aug | 20 | 20->Closed | | 20 | 40 | | 40 | 60 |
| **2009** | Sep | 20->Closed | Closed | | 20 | 40 | | 40 | 60 |
| **2009** | Oct | Closed | Closed | | 20 | 40 | | 40 | 60 |
| **2009** | Nov | Closed | Closed | | Closed | 40->Closed | | 40->Closed | 60 |
| **2009** | Dec | Closed | Closed | | Closed | Closed | | Closed | 60 |

Figure B3|fig:Rec_regs2

| Latitude Range | | 42°-40°10' | 40°10'-38°57' | 40°10'-37°11' | 38°57'-37°11' | 37°11'-36° | 37°11'-34°27' | 36°-34°27' | 34°27'-Mex. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **Monterey** | | **Morro Bay** | |
| **Year** | **Month** | **Northern** | **Mendocino** | **North-Central** | **San Francisco** | **South-Central** | **Central** | **South-Central** | **Southern** |
| **2010** | Jan | Closed | Closed | | Closed | Closed | | Closed | Closed |
| **2010** | Feb | Closed | Closed | | Closed | Closed | | Closed | Closed |
| **2010** | Mar | Closed | Closed | | Closed | Closed | | Closed | 60 |
| **2010** | Apr | Closed | Closed | | Closed | Closed | | Closed | 60 |
| **2010** | May | Closed->20 | Closed->20 | | Closed | Closed | | 40 | 60 |
| **2010** | Jun | 20 | 20 | | Closed->30 | Closed->20 | | 40 | 60 |
| **2010** | Jul | 20 | 20 | | 30 | 20 | | 40 | 60 |
| **2010** | Aug | 20 | 20->Closed | | 30 | 20 | | 40 | 60 |
| **2010** | Sep | 20->Closed | Closed | | 30 | 20 | | 40 | 60 |
| **2010** | Oct | Closed | Closed | | 30 | 20 | | 40 | 60 |
| **2010** | Nov | Closed | Closed | | Closed | Closed | | 40->Closed | 60 |
| **2010** | Dec | Closed | Closed | | Closed | Closed | | Closed | 60 |
| **2011** | Jan | Closed | Closed | | Closed | | Closed | | Closed |
| **2011** | Feb | Closed | Closed | | Closed | | Closed | | Closed |
| **2011** | Mar | Closed | Closed | | Closed | | Closed | | 60 |
| **2011** | Apr | Closed | Closed | | Closed | | Closed | | 60 |
| **2011** | May | Closed->20 | Closed->20 | | Closed | | 40 | | 60 |
| **2011** | Jun | 20 | 20 | | Closed->30 | | 40 | | 60 |
| **2011** | Jul | 20 | 20 | | 30 | | 40 | | 60 |
| **2011** | Aug | 20 | 20->Closed | | 30 | | 40 | | 60 |
| **2011** | Sep | 20 | Closed | | 30 | | 40 | | 60 |
| **2011** | Oct | 20 | Closed | | 30 | | 40 | | 60 |
| **2011** | Nov | Closed | Closed | | 30 | | 40 | | 60 |
| **2011** | Dec | Closed | Closed | | 30 | | 40 | | 60 |
| **2012** | Jan | Closed | Closed | | Closed | | Closed | | Closed |
| **2012** | Feb | Closed | Closed | | Closed | | Closed | | Closed |
| **2012** | Mar | Closed | Closed | | Closed | | Closed | | 60 |
| **2012** | Apr | Closed | Closed | | Closed | | Closed | | 60 |
| **2012** | May | Closed->20 | 20->Closed | | Closed | | 40 | | 60 |
| **2012** | Jun | 20 | 20 | | 30 | | 40 | | 60 |
| **2012** | Jul | 20 | 20 | | 30 | | 40 | | 60 |
| **2012** | Aug | 20 | 20->Closed | | 30 | | 40 | | 60 |
| **2012** | Sep | 20 | Closed | | 30 | | 40 | | 60 |
| **2012** | Oct | 20 | Closed | | 30 | | 40 | | 60 |
| **2012** | Nov | Closed | Closed | | 30 | | 40 | | 50 |
| **2012** | Dec | Closed | Closed | | 30 | | 40 | | 50 |
| **2013** | Jan | Closed | Closed | | Closed | | Closed | | Closed |
| **2013** | Feb | Closed | Closed | | Closed | | Closed | | Closed |
| **2013** | Mar | Closed | Closed | | Closed | | Closed | | 50 |
| **2013** | Apr | Closed | Closed | | Closed | | Closed | | 50 |
| **2013** | May | Closed->20 | Closed->20 | | Closed | | 40 | | 50 |
| **2013** | Jun | 20 | 20 | | 30 | | 40 | | 50 |
| **2013** | Jul | 20 | 20 | | 30 | | 40 | | 50 |
| **2013** | Aug | 20 | 20 | | 30 | | 40 | | 50 |
| **2013** | Sep | 20 | 20->Closed | | 30 | | 40 | | 50 |
| **2013** | Oct | 20 | Closed | | 30 | | 40 | | 50 |
| **2013** | Nov | Closed | Closed | | 30 | | 40 | | 50 |
| **2013** | Dec | Closed | Closed | | 30 | | 40 | | 50 |
| **2014** | Jan | Closed | Closed | | Closed | | Closed | | Closed |
| **2014** | Feb | Closed | Closed | | Closed | | Closed | | Closed |
| **2014** | Mar | Closed | Closed | | Closed | | Closed | | 50 |
| **2014** | Apr | Closed | Closed | | Closed | | Closed | | 50 |
| **2014** | May | Closed->20 | Closed->20 | | Closed | | 40 | | 50 |
| **2014** | Jun | 20 | 20 | | 30 | | 40 | | 50 |
| **2014** | Jul | 20 | 20 | | 30 | | 40 | | 50 |
| **2014** | Aug | 20 | 20 | | 30 | | 40 | | 50 |
| **2014** | Sep | 20 | 20->Closed | | 30 | | 40 | | 50 |
| **2014** | Oct | 20 | Closed | | 30 | | 40 | | 50 |
| **2014** | Nov | Closed | Closed | | 30 | | 40 | | 50 |
| **2014** | Dec | Closed | Closed | | 30 | | 40 | | 50 |

Figure B4 fig:Rec_regs3

| Latitude Range | | 42°-40°10' | 40°10'-38°57' | 40°10'-37°11' | 38°57'-37°11' | 37°11'-36° Monterey | 37°11'-34°27' | 36°-34°27' Morro Bay | 34°27'-Mex. |
|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Month** | **Northern** | **Mendocino** | **North-Central** | **San Francisco** | **South-Central** | **Central** | **South-Central** | **Southern** |
| **2015** | Jan | Closed | Closed | | Closed | | Closed | | Closed |
| **2015** | Feb | Closed | Closed | | Closed | | Closed | | Closed |
| **2015** | Mar | Closed | Closed | | Closed | | Closed | | Closed |
| **2015** | Apr | Closed | Closed | | Closed->30 | | 40 | | Closed |
| **2015** | May | Closed->20 | Closed->20 | | 30 | | 40 | | Closed |
| **2015** | Jun | 20 | 20 | | 30 | | 40 | | Closed |
| **2015** | Jul | 20 | 20 | | 30 | | 40 | | Closed |
| **2015** | Aug | 20 | 20 | | 30 | | 40 | | Closed |
| **2015** | Sep | 20 | 20 | | 30 | | 40 | | Closed |
| **2015** | Oct | 20 | 20 | | 30 | | 40 | | Closed |
| **2015** | Nov | Closed | Closed | | 30 | | 40 | | Closed |
| **2015** | Dec | Closed | Closed | | 30 | | 40 | | Closed |
| **2016** | Jan | Closed | Closed | | Closed | | Closed | | Closed |
| **2016** | Feb | Closed | Closed | | Closed | | Closed | | Closed |
| **2016** | Mar | Closed | Closed | | Closed | | Closed | | Closed |
| **2016** | Apr | Closed | Closed | | Closed->30 | | 40 | | Closed |
| **2016** | May | Closed->20 | Closed->20 | | 30 | | 40 | | Closed |
| **2016** | Jun | 20 | 20 | | 30 | | 40 | | Closed |
| **2016** | Jul | 20 | 20 | | 30 | | 40 | | Closed |
| **2016** | Aug | 20 | 20 | | 30 | | 40 | | Closed |
| **2016** | Sep | 20 | 20 | | 30 | | 40 | | Closed |
| **2016** | Oct | 20 | 20 | | 30 | | 40 | | Closed |
| **2016** | Nov | Closed | Closed | | 30 | | 40 | | Closed |
| **2016** | Dec | Closed | Closed | | 30 | | 40 | | Closed |
| **2017** | Jan | Closed | Closed | | Closed | | Closed | | Closed |
| **2017** | Feb | Closed | Closed | | Closed | | Closed | | Closed |
| **2017** | Mar | Closed | Closed | | Closed | | Closed | | 60 |
| **2017** | Apr | Closed | Closed | | Closed | | 50 | | 60 |
| **2017** | May | 30 | 20 | | 40 | | 50 | | 60 |
| **2017** | Jun | 30 | 20 | | 40 | | 50 | | 60 |
| **2017** | Jul | 30 | 20 | | 40 | | 50 | | 60 |
| **2017** | Aug | 30 | 20 | | 40 | | 50 | | 60 |
| **2017** | Sep | 30 | 20 | | 40 | | 50 | | 60 |
| **2017** | Oct | 30->20 | 20 | | 40->30 | | 50->40 | | 60 |
| **2017** | Nov | 20 | 20 | | 30 | | 40 | | 60 |
| **2017** | Dec | 20 | 20 | | 30 | | 40 | | 60 |
| **2018** | Jan | Closed | Closed | | Closed | | Closed | | 60 |
| **2018** | Feb | Closed | Closed | | Closed | | Closed | | 60 |
| **2018** | Mar | Closed | Closed | | Closed | | Closed | | 60 |
| **2018** | Apr | Closed | Closed | | Closed | | 50 | | 60 |
| **2018** | May | 30 | 20 | | 40 | | 50 | | 60 |
| **2018** | Jun | 30 | 20 | | 40 | | 50 | | 60 |
| **2018** | Jul | 30 | 20 | | 40 | | 50 | | 60 |
| **2018** | Aug | 30->20 | 20 | | 40->30 | | 50->40 | | 60 |
| **2018** | Sep | 20 | 20 | | 30 | | 40 | | 60 |
| **2018** | Oct | 20 | 20 | | 30 | | 40 | | 60 |
| **2018** | Nov | 20 | 20 | | 30 | | 40 | | 60 |
| **2018** | Dec | 20 | 20 | | 30 | | 40 | | 60 |

Figure B5 fig:Rec_reg4

# Appendix C. Detailed fits to length composition data

appendix-c.-detailed-fits-to-length-composition-data

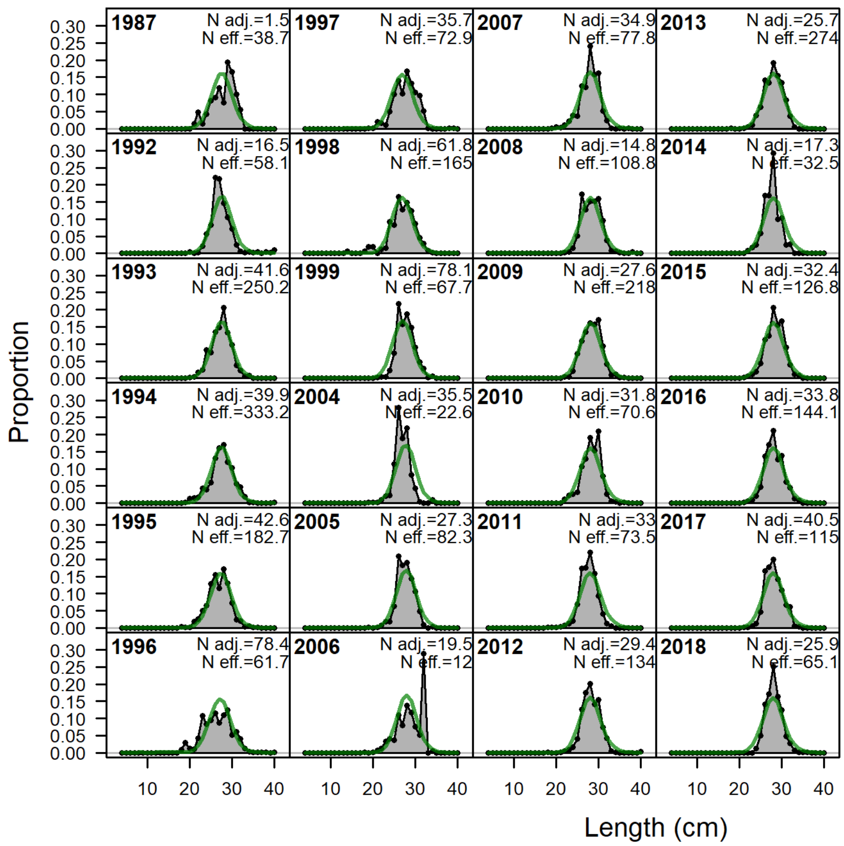



Figure C2: Length comps, retained, Com. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_1_comp_lenfit_flt1mkt2

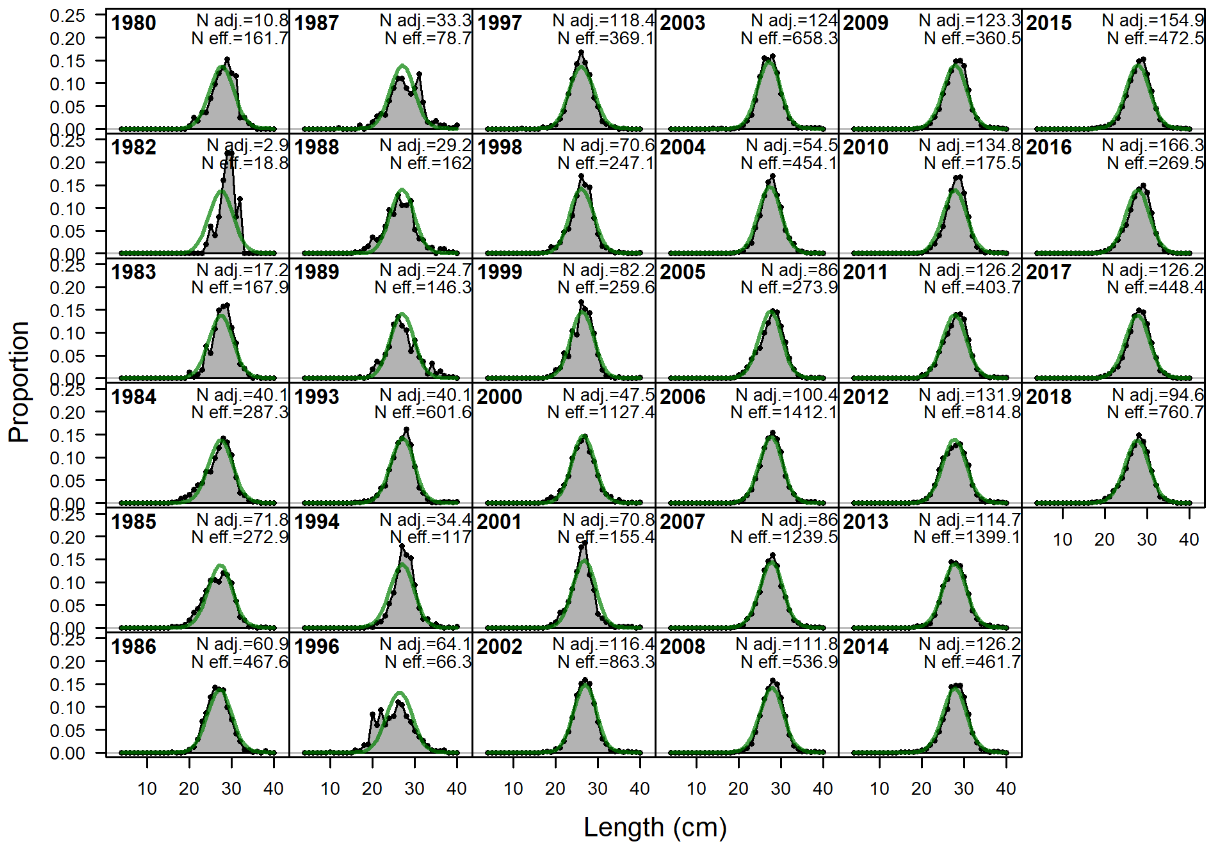



Figure C3: Length comps, whole catch, RecNorth. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_2_comp_lenfit_flt2mkt0

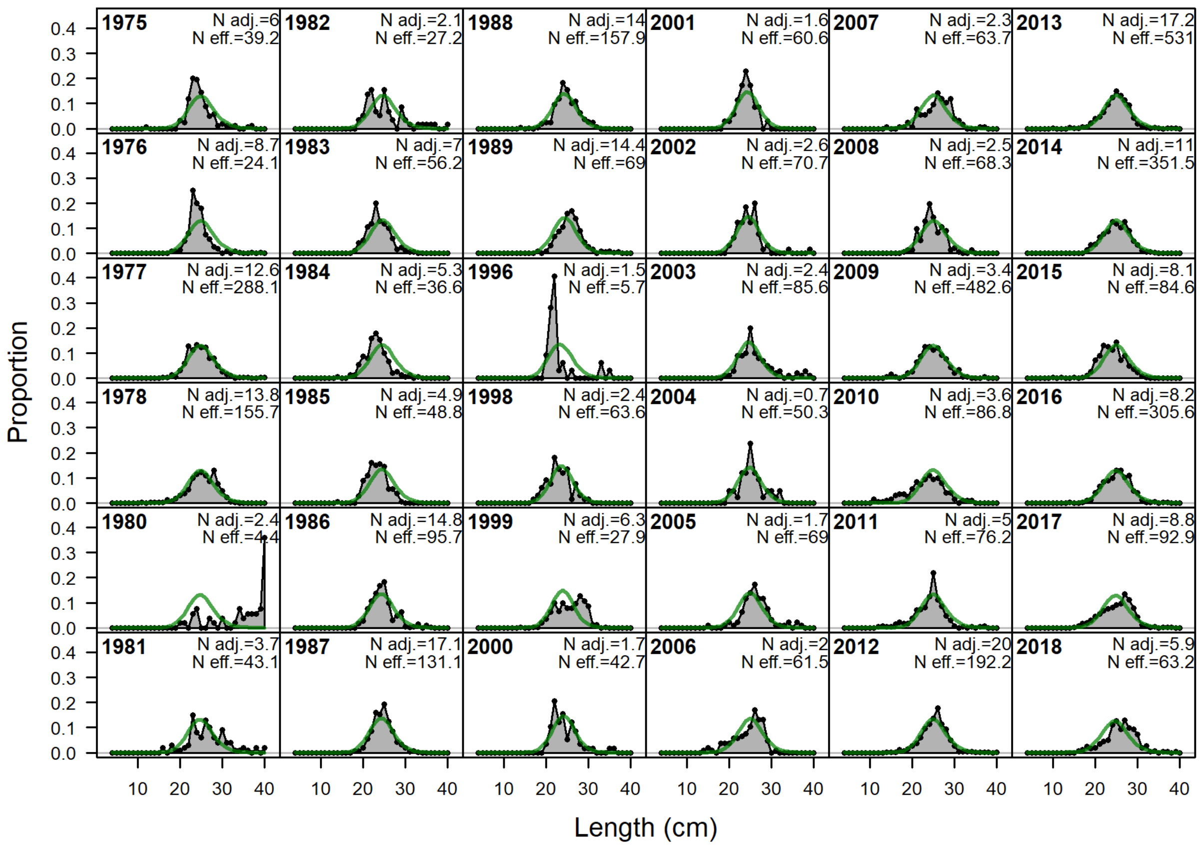


Figure C4: Length comps, whole catch, RecSouth. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_3_comp_lenfit_flt3mkt0

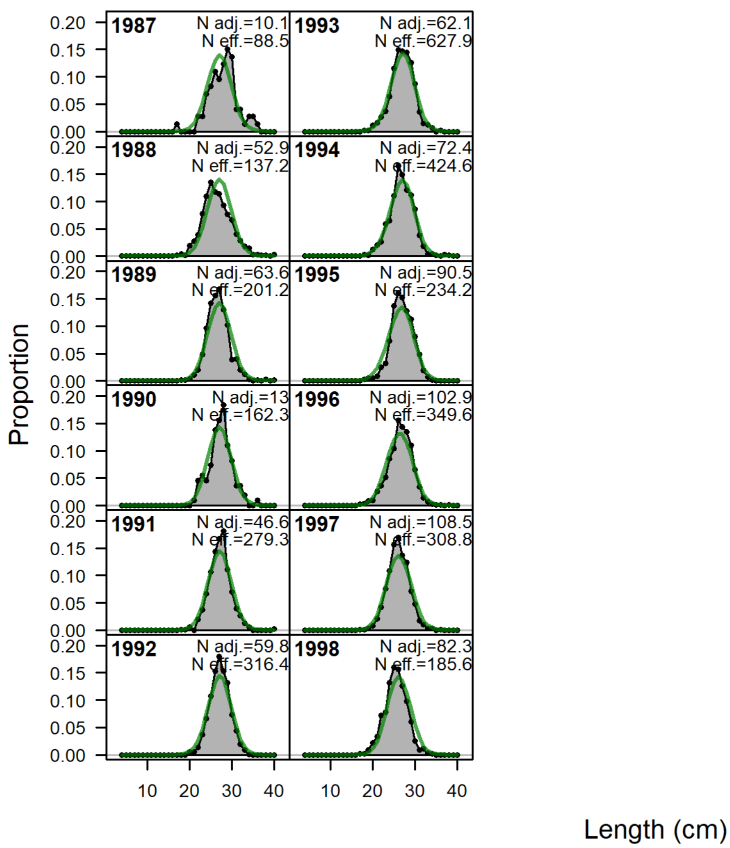



Figure C5: Length comps, whole catch, DebCPFV. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_4_comp_lenfit_flt4mkt0

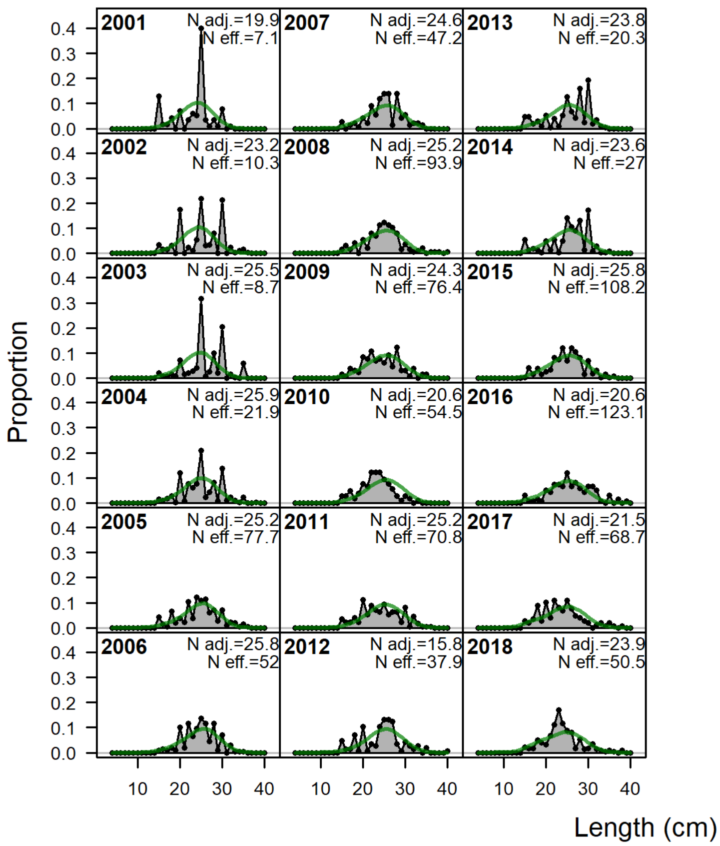



Figure C6: Length comps, whole catch, PISCO. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_5_comp_lenfit_flt6mkt0

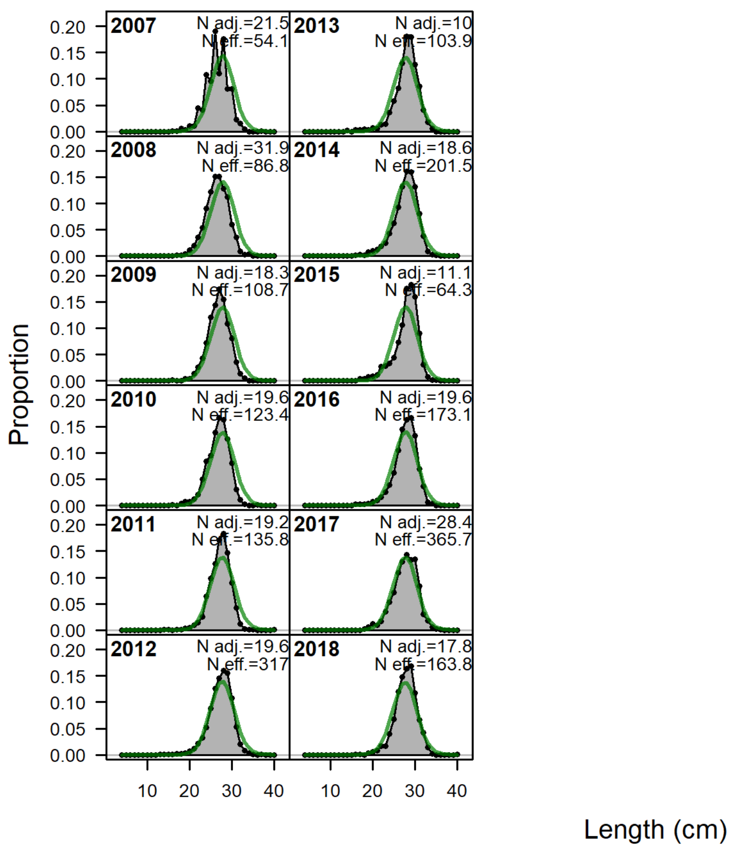



Figure C7: Length comps, whole catch, CCFRP. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_6_comp_lenfit_flt7mkt0

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