

The Combined Status of Gopher (*Sebastodes carnatus*) and Black-and-Yellow Rockfishes (*Sebastodes 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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2019-08-16

- ¹⁹ This report may be cited as:
- ²⁰ Monk, M. H. and X. He. 2019. The Combined Status of Gopher *Sebastodes carnatus* and
- ²¹ Black-and-Yellow Rockfishes *Sebastodes chrysomelas* in U.S. Waters Off California in 2019. Pacific
- ²² Fishery Management Council, Portland, OR. Available from
- ²³ <http://www.pcouncil.org/groundfish/stock-assessments/>

24 The Combined Status of Gopher (*Sebastodes*
25 *carnatus*) and Black-and-Yellow Rockfishes
26 (*Sebastodes chrysomelas*) in U.S. Waters Off
27 California in 2019

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⁹⁶ **Executive Summary**

executive-summary

⁹⁷ **Stock**

stock

⁹⁸ This assessment reports the status of the gopher and black-and-yellow rockfish
⁹⁹ complex (GBYR, *Sebastodes carnatus*/*Sebastodes chrysomelas*) resource as in U.S. waters off the
¹⁰⁰ coast of California south of Cape Mendocino (40°10' N. latitude) using data through 2018.
¹⁰¹ Both gopher and black-and-yellow rockfishes are most abundant north of Point Conception
¹⁰² (34°27' N. latitude) and are rare north of Point Arena (38°57' N. latitude). The range of
¹⁰³ gopher rockfish extends into Baja California, but the black-and-yellow rockfish are rare south
¹⁰⁴ of Point Conception.

¹⁰⁵ **Catches**

catches

¹⁰⁶ Information on historical landings of GBYR are available back to 1916 (Table [a](#)). The
¹⁰⁷ recreational fleet began ramping up in the 1950s and has fluctuated over the the last 50 years
¹⁰⁸ (Figure [a](#)). The majority of gopher and black-and-yellow rockfish recreational landings are
¹⁰⁹ from north of Point Conception.

¹¹⁰ Commercial landings were small during the years of World War II, ranging between 4 to 28
¹¹¹ metric
¹¹² tons (mt) per year (Figure [b](#)). Commercial landings increased after World War II and show
¹¹³ periods of cyclical catch for gopher and black-and-yellow rockfishes. The commercial live fish
¹¹⁴ fishery began in the early 1990s, with the first reported live landings in 1993. Since then the
¹¹⁵ commercial catch has been dominated by the live fish fishery, with minimal landings of dead
¹¹⁶ gopher or black-and-yellow rockfishes. Estimates of total mortality of commercial discards
¹¹⁷ were available starting in 2004, and were estimated prior to then. The catches aggregated
¹¹⁸ by fleets modeled in this assessment can be found in Figure [c](#).

¹¹⁹ Since 2000, annual total landings of catch and discards of GBYR have ranged between 70-169
¹²⁰ mt, with landings (catch + discards) in 2018 totaling 92 mt.



Figure a: Catch history of GBYR for the recreational fleet. | fig:Exec_catch1

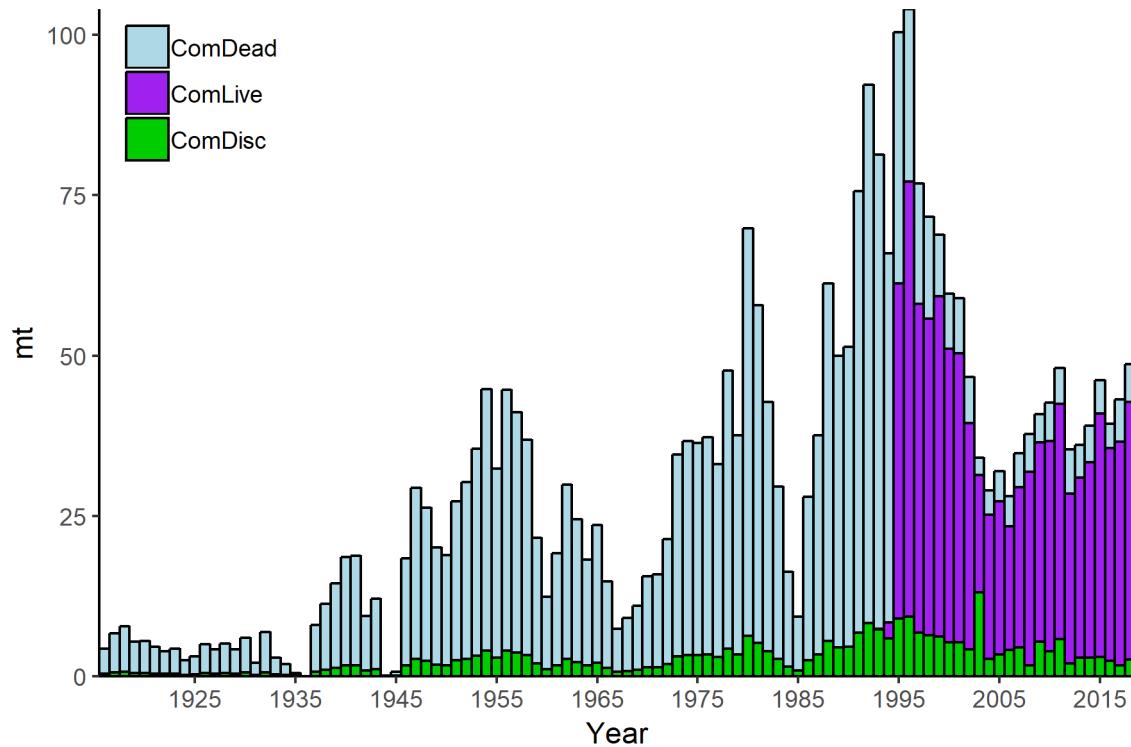


Figure b: Catch history of GBYR for the commercial fleet by dead and live landings, and discards. Catches in 1936 and 1946 were minimal. ^{fig:Exec_catch2}

Table a: Recent GBYR landings (mt) by fleet.

Year	Commercial Retained	Commercial Discard	Recreational North	Recreational South	tab:Exec_catch
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

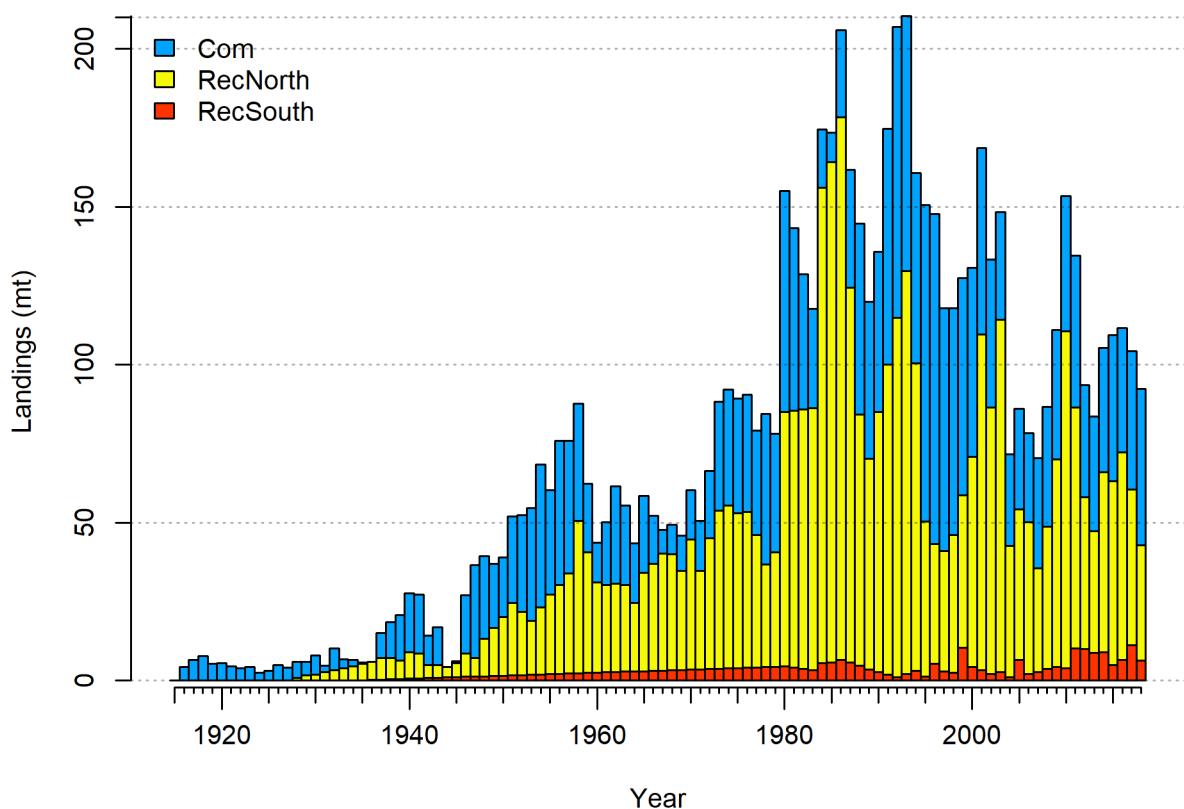


Figure c: Catch history of GBYR in the model. [fig:r4ss_catches](#)

¹²¹ **Data and Assessment**

data-and-assessment

¹²² Gopher rockfish north of Point Conception ($34^{\circ}27'$ N. latitude) was first assessed as a full
¹²³ stock assessment in 2005 (Key et al. 2005) using SS2 (version 1.19). The assessment was
¹²⁴ sensitive to the CPFV onboard observer index of abundance (referred to as Deb Wilson-
¹²⁵ Vandenberg's onboard observer index in this assessment). The final decision table was based
¹²⁶ around the emphasis given to a fishery-dependent index of abundance for the recreational
¹²⁷ fleet. The stock was found to be at 97% depletion.

¹²⁸ Gopher rockfish south of Point Conception was assessed as a data poor species in 2010 (Dick
¹²⁹ and MacCall 2010). A Depletion-Corrected Average Catch (DCAC) model was used due to
¹³⁰ time constraints. The mean yield from the DCAC distribution was 25.5 mt.

¹³¹ This is the first full assessment to include data for black-and-yellow rockfish. Black-and-
¹³² yellow rockfish was assessed coastwide as a data poor species using Depletion-Based Stock
¹³³ Reduction Analysis (DB-SRA) (Dick and MacCall 2010). The DB-SRA model assigned a
¹³⁴ 40% probability that the then recent (2008-2009) catch exceeded the 2010 OFL.

¹³⁵ This assessment covers the area from Cape Mendocino to the U.S./Mexico border (Figure
¹³⁶ d). The length composition data suggested that while the lengths of gopher and black-and-
¹³⁷ yellow rockfish were similar, fish encountered south of Point Conception were smaller. The
¹³⁸ similarity of the length distributions between species and among modes within a region were
¹³⁹ similar and justified one combined recreational fleet within each of the two regions (north
¹⁴⁰ and south of Point Conception).

¹⁴¹ This stock assessment retains a single fleet for the commercial fishery, including discards.
¹⁴² Data on commercial discards were not available for and not included in the 2005 assessment.
¹⁴³ The decision to retain one commercial fleet was made by examining the length distributions
¹⁴⁴ across species, fishing gears, and space, i.e., north and south of Point Conception. There is
¹⁴⁵ very little difference between the length composition of gopher and black-and-yellow rockfish
¹⁴⁶ landed in the commercial fleet north of Point Conception.

¹⁴⁷ A number of sources of uncertainty are addressed in this assessment. This assessment in-
¹⁴⁸ cludes length data, estimated growth, an updated length-weight curve, an updated maturity
¹⁴⁹ curve, a number of new indices, and new conditional age-at-length data.

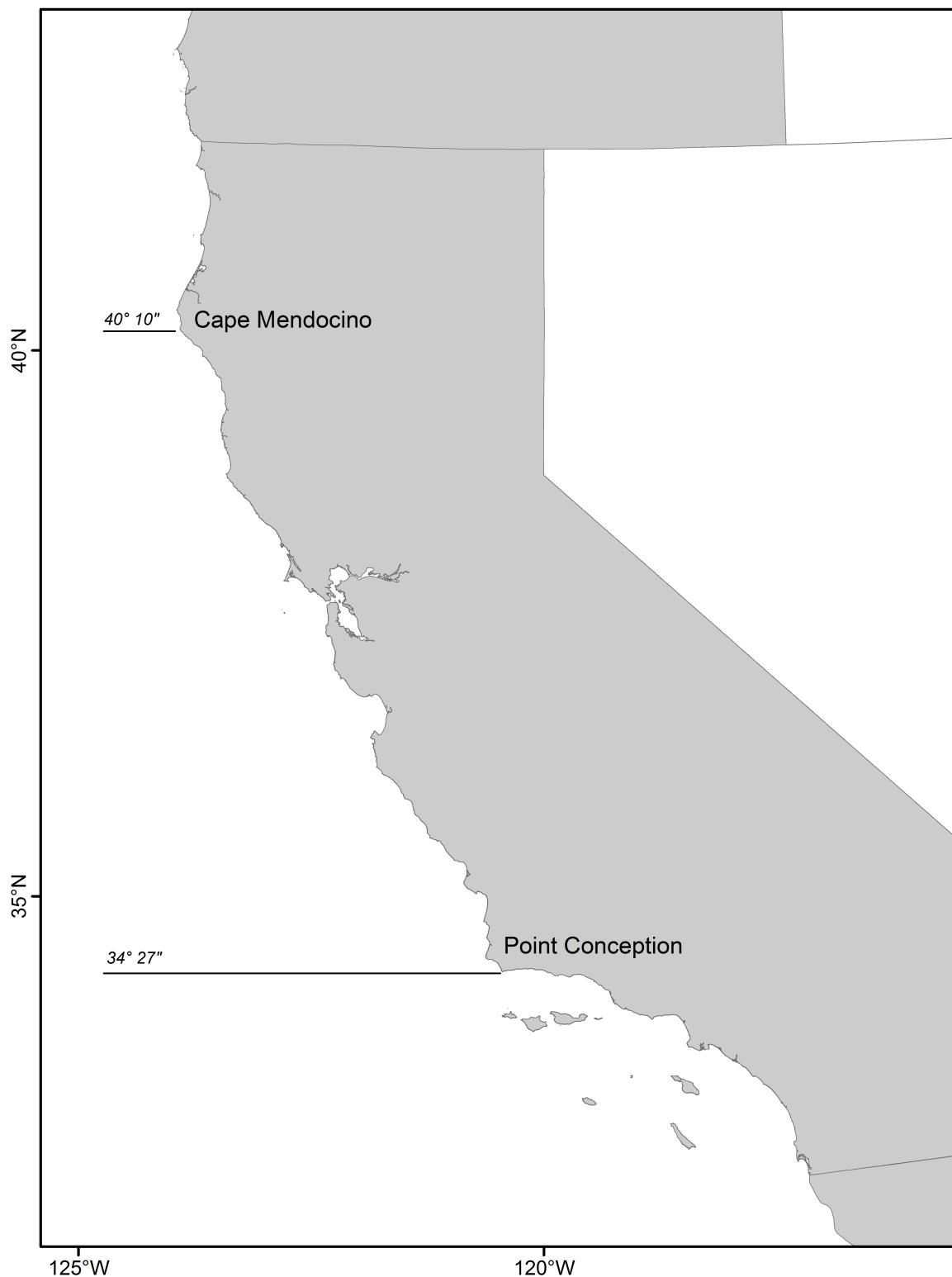


Figure d: Map depicting the core distribution of gopher and black-and-yellow rockfishes. The stock assessment is bounded at Cape Mendocino in the north to the U.S./Mexico border in the south. [fig:assess_region_map](#)

150 **Stock Biomass**

stock-biomass

151 The predicted spawning output from the base model generally showed a slight decline prior
152 to 1978, when the recruitment deviations were first estimated (Figure e and Table b). The
153 stock declined from 1978 to 1994, followed by a period increase from 1995 to 2003. From
154 2004-2018 the stock has been in decline, though increased in total biomass since 2016 and
155 stable spawning output since from 2018 to 2019. The 2019 estimated spawning output
156 relative to unfished equilibrium spawning output is above the target of 40% of unfished
157 spawning output at 43.82 (95% asymptotic interval: 33.57-54.06) (Figure f). Approximate
158 confidence intervals based on the asymptotic variance estimates show that the uncertainty
159 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.

Year	Spawning Output (million eggs)	~ 95% confidence interval	Estimated depletion	<small>tab:SpawningDeplete_mod1</small> ~ 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

Spawning output with ~95% asymptotic intervals

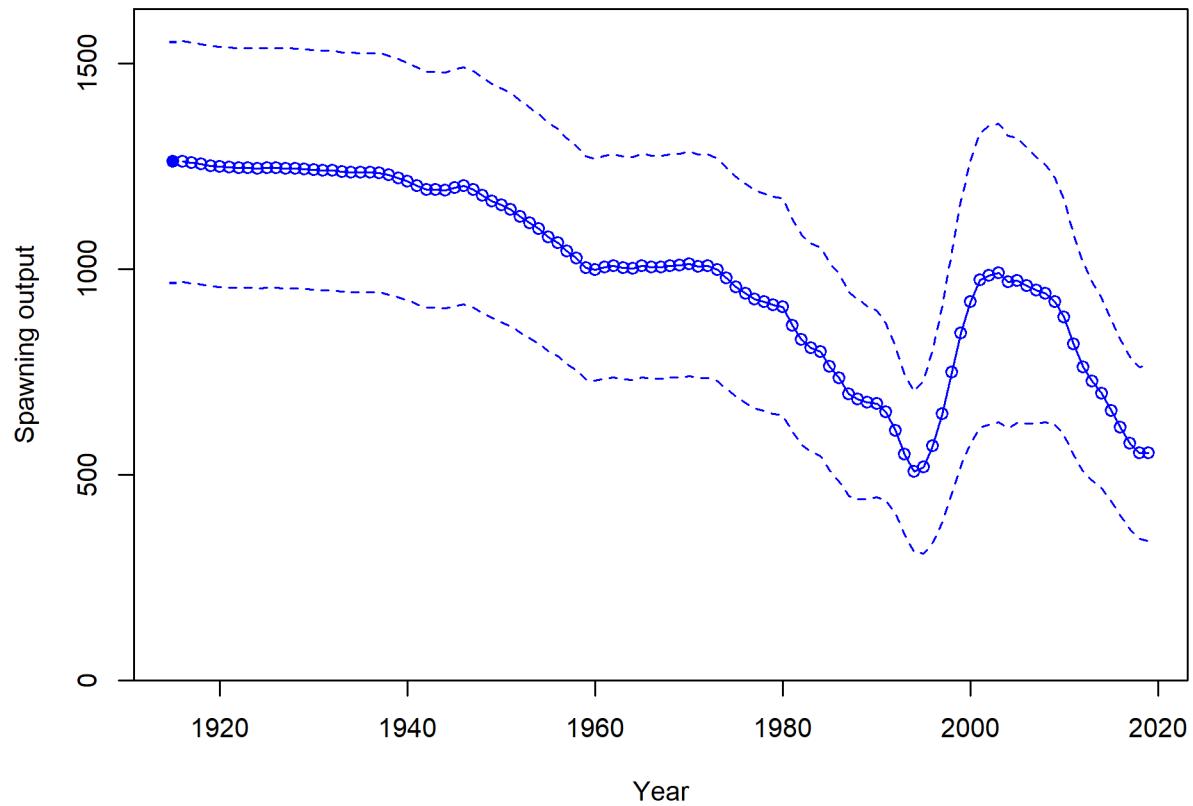


Figure e: Time series of spawning biomass trajectory (circles and line; median; light broken lines: 95% credibility intervals) for the base case assessment model. | [fig:Spawnbio_all](#)

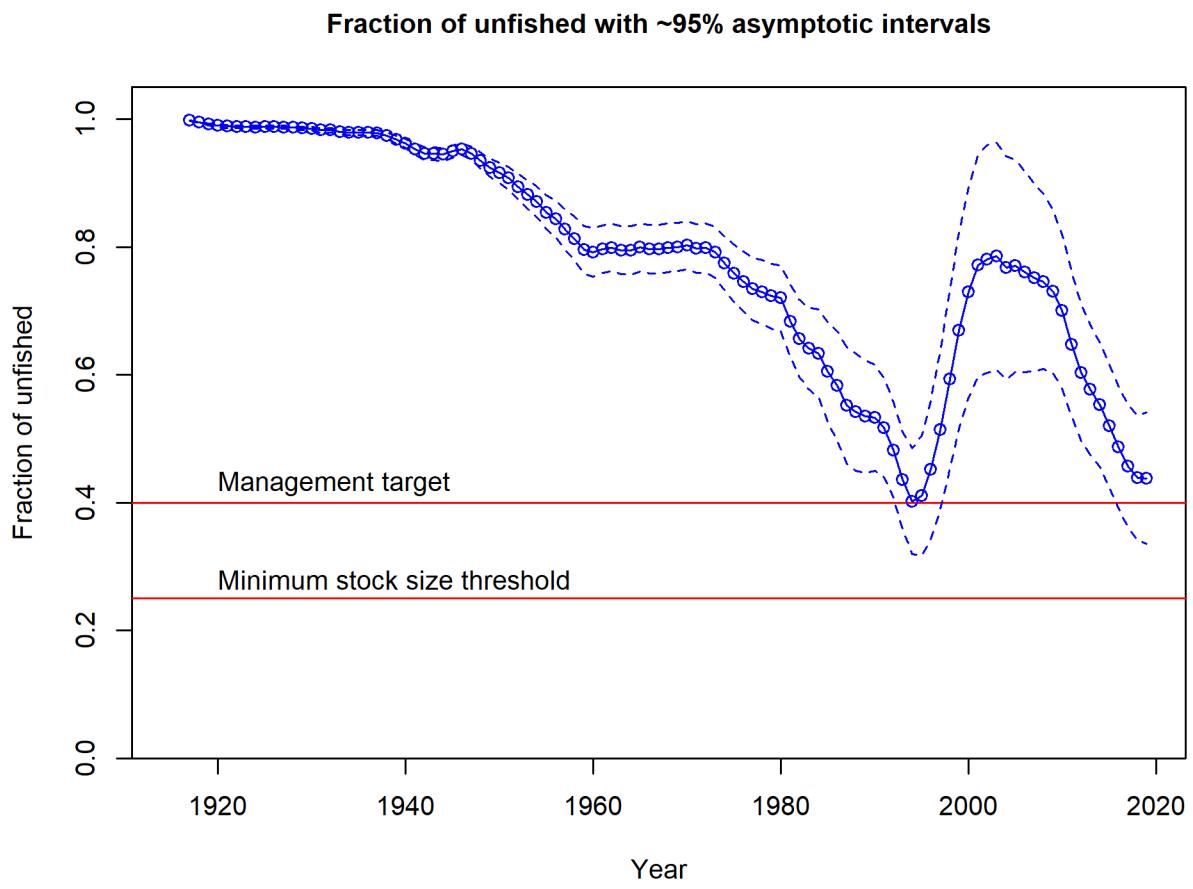


Figure f: Estimated percent depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. fig:Re1Deplete_all

160 **Recruitment**

recruitment

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

Table c: Recent recruitment for the GBYR assessment.

Year	Estimated Recruitment (1,000s)	<small>~ 95% confidence interval</small>
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

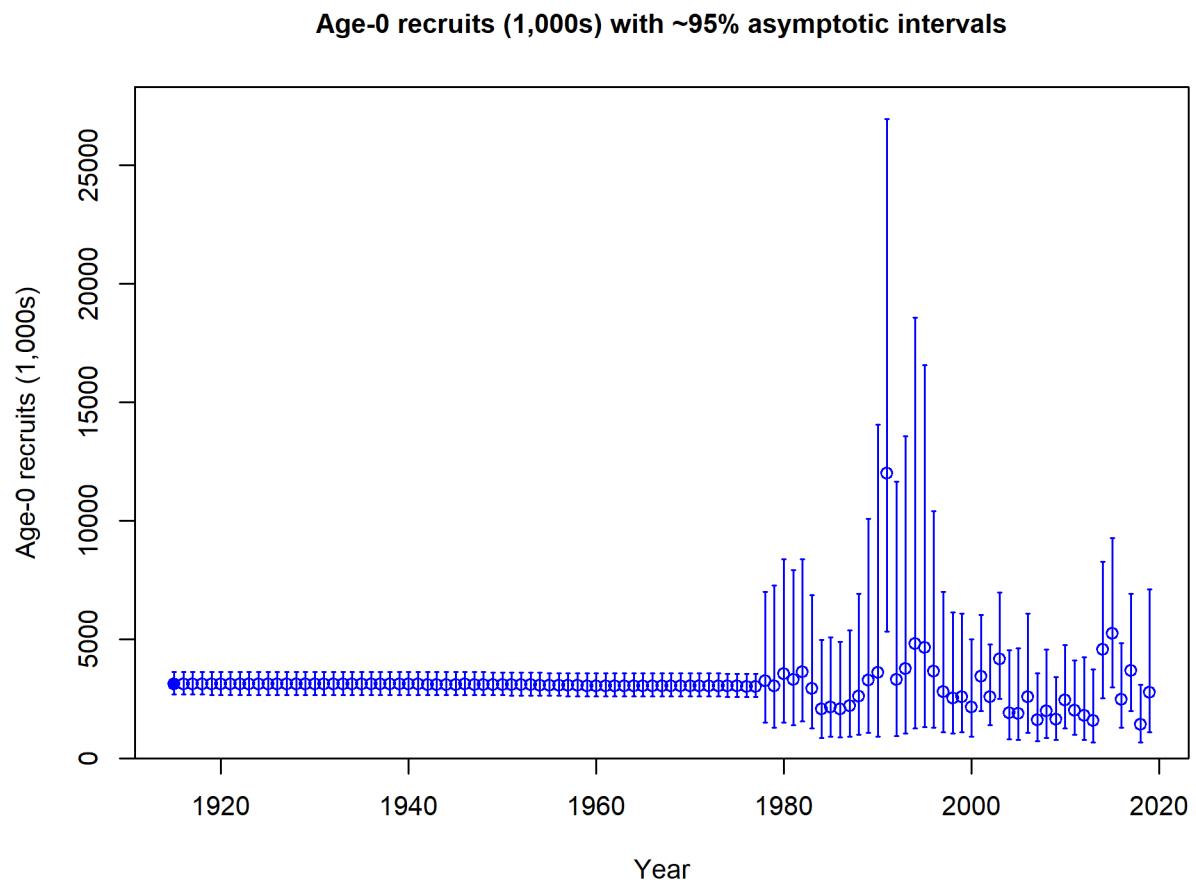


Figure g: Time series of estimated GBYR recruitments for the base-case model with 95% confidence or credibility intervals. [fig:Recruits_all](#)

¹⁶⁴ **Exploitation status**

exploitation-status

¹⁶⁵ Harvest rates estimated by the base model indicate catch levels have been below the limits
¹⁶⁶ that would be associated with the Spawning Potential Ratio (SPR) = 50% limit (corre-
¹⁶⁷ sponding to a relative fishing intensity of 100%) (Table [d](#) and Figure [h](#)). SPR is calculated
¹⁶⁸ as the lifetime spawning potential per recruit at a given fishing level relative to the life-
¹⁶⁹ time spawning potential per recruit with no fishing. The relative inverse SPR over the last
¹⁷⁰ decade increased ranged from 0.64 to 0.77 from 2009-2015, and ranged from 0.80 to 0.82
¹⁷¹ 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.

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

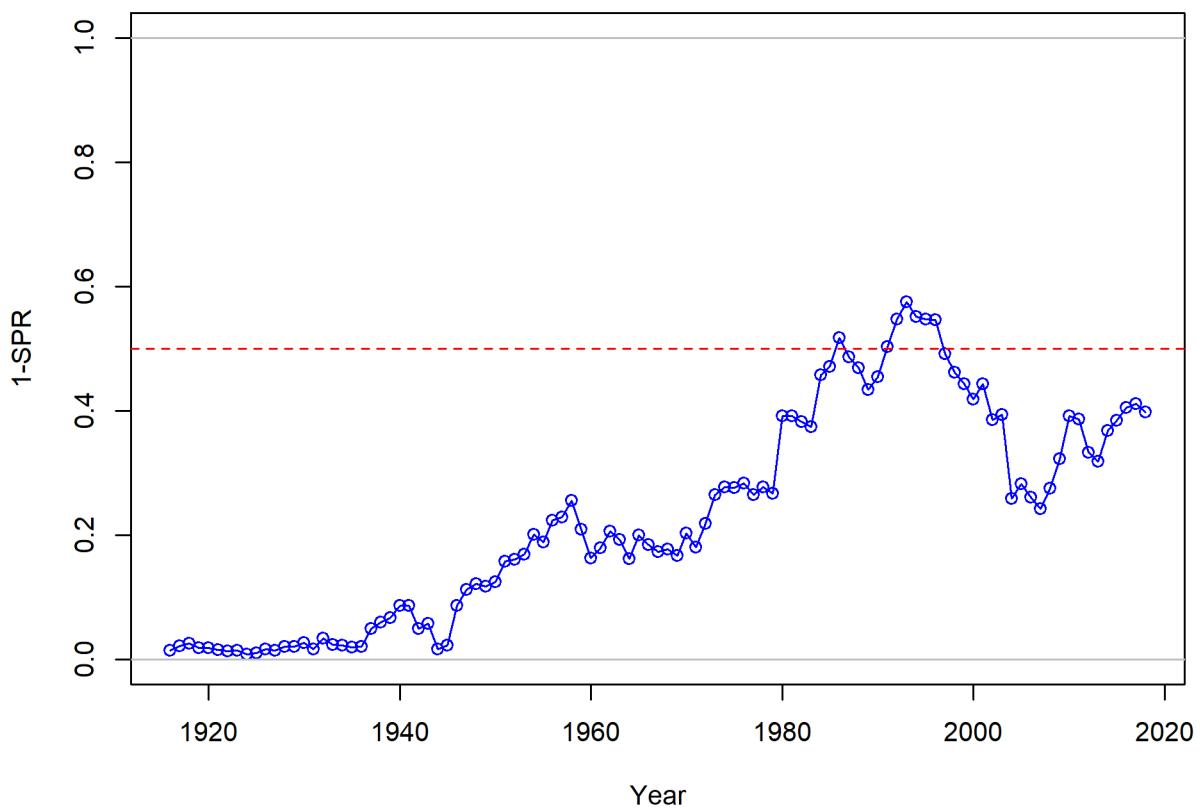


Figure h: Estimated inverse spawning potential ratio (SPR) for the post-STAR base model, plotted as one minus SPR so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the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

¹⁷² **Ecosystem Considerations**

ecosystem-considerations

- ¹⁷³ In this assessment, ecosystem considerations were not explicitly included in the analysis.
¹⁷⁴ This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere)
¹⁷⁵ that could contribute ecosystem-related quantitative information for the assessment.

¹⁷⁶ **Reference Points**

reference-points

- ¹⁷⁷ This stock assessment estimates that GBYR in the model is above the biomass target
¹⁷⁸ ($SB_{40\%}$), and well above the minimum stock size threshold ($SB_{25\%}$). The estimated relative
¹⁷⁹ depletion level for the base model in 2018 is 0.439 (95% asymptotic interval: 0.341-0.536,
¹⁸⁰ corresponding to an unfished spawning biomass of 552 million eggs (95% asymptotic interval:
¹⁸¹ 337 - 767 million eggs) of spawning biomass in the base model (Table e). Unfished age 1+
¹⁸² biomass was estimated to be 2,042 mt in the base case model. The target spawning biomass
¹⁸³ ($SB_{40\%}$) is 504 million eggs, which corresponds with an equilibrium yield of 143 mt. Equi-
¹⁸⁴ librium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 134 mt (Figure
¹⁸⁵ i).

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

Quantity	Estimate	tab:Ref_pts_mod1	
		Low	High
		2.5% limit	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 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

186 Management Performance

management-performance

187 Gopher and black-and-yellow rockfishes are managed as part of the minor nearshore complex
 188 in the Pacific Coast Groundfish Fishery Management Plan. The total mortality of the
 189 minor nearshore rockfish has been below the ACL in all years (2011-2016). Total mortality
 190 estimates from the NWFSC are not yet available are not yet available for 2017-2018. GBYR
 191 total mortality was on average 20% of the total minor nearshore rockfish total mortality
 192 from 2011-2016. A summary of these values as well as other base case summary results can
 193 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 $40^{\circ}10' N.$ latitude. Total mortality estimates are based on annual reports from the NMFS NWFSC.

GBYR		Shallow Nearshore Rockfish South	<small>tab:mnmgt_perform</small>	
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

194 Unresolved Problems and Major Uncertainties

unresolved-problems-and-major-uncertainties

195 The major source of uncertainty identified during the STAR panel is the structure of complex and contribution of each of the two species to the complex and biological parameters 196 differences. Additionally, there is currently no information for either species on regional 197 differences in biological parameters and contributions to the complex. 198

199 Decision Table

decision-table

200 The forecasts of stock abundance and yield were developed using the post-STAR base model, 201 with the forecasted projections of the OFL presented in Table [g](#). The total catches in 2019 202 and 2020 are set to the PFMC adopted ACL of 114 mt.

203 Uncertainty in the forecasts is based upon the three states of nature agreed upon at the 204 STAR panel and are based three states of nature of growth. The external estimates of 205 growth were different than the internal estimates. Given that natural mortality is fixed in 206 the post-STAR base model, and the growth parameter k is negatively correlated with natural 207 mortality, k was chosen as the axis of uncertainty. The high state of nature fixes k at the 208 external estimate, and the low state of nature is the same distance in log space from the 209 base as the high state of nature. The low state of nature fixed k at 0.46 and the L1 and L1 210 parameters are estimated at 14.1 and 30.6, respectively. The high state of nature fixes all 211 growth parameters, $k = 0.248$, L1 = 13.8, and L2 = 28.5 to the external estimate of growth. 212 The growth parameters in the base model were estimated as $k = 0.107$, L1 = 13.4, and L2 213 = 28.8.

214 The forecasted buffer ramp was calculated assuming a category 2 stock, with sigma = 1.0 215 and a $p^* = 0.45$. The buffer ranges from 0.874 in 2021 ramping to 0.803 in 2030. 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.

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

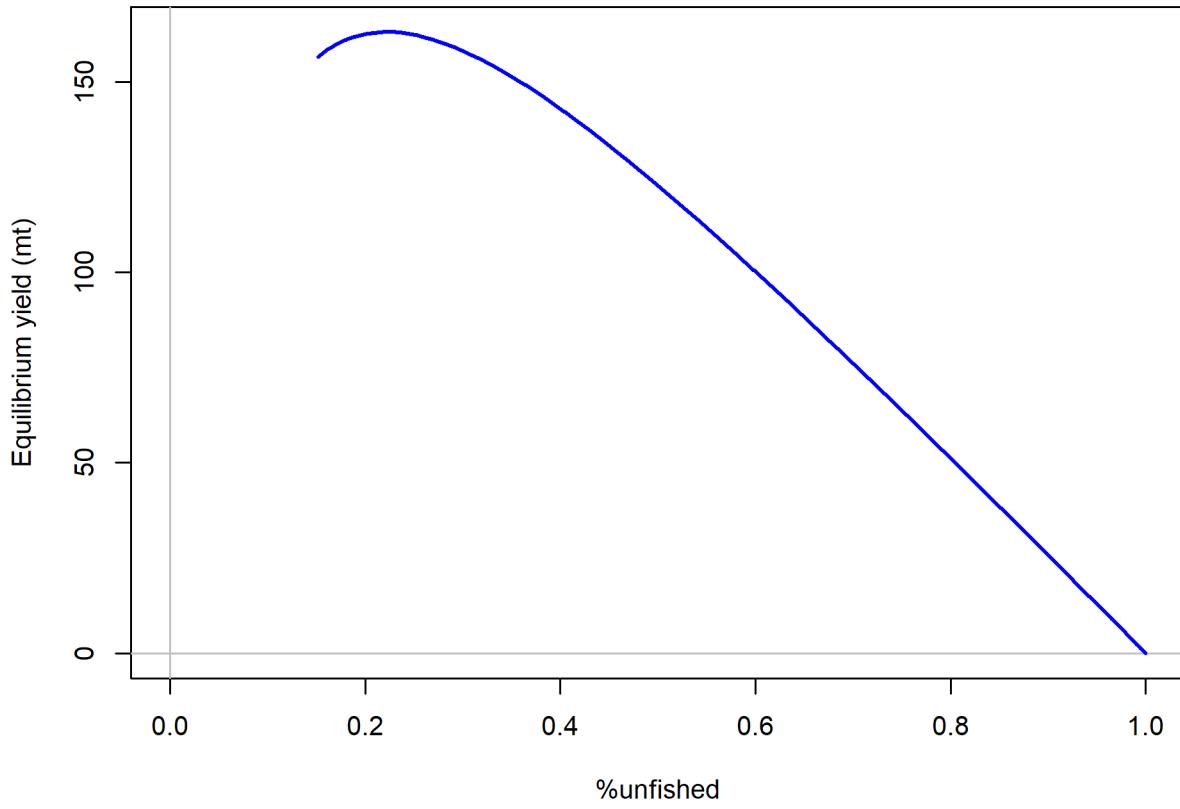


Figure i: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.72. [fig:Yield_all](#)

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 ($k = 0.248$, $L1 = 13.8$, $L2 = 28.5$)

		States of nature						
		Low State		Base State		High State		
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	
Default harvest for Low State	2021	75	449.6	37.7	571.9	44.7	1231.2	65.2
	2022	80	481.2	40.4	617.3	48.3	1296.5	68.6
	2023	85	510.4	42.8	655.3	51.3	1322.9	70.0
	2024	91	534.5	44.9	682.4	53.4	1329.1	70.4
	2025	96	552.0	46.3	698.5	54.6	1328.9	70.4
	2026	101	562.5	47.2	705.9	55.2	1326.8	70.2
	2027	104	567.1	47.6	707.6	55.3	1324.2	70.1
	2028	105	567.5	47.6	706.4	55.3	1321.7	70.0
	2029	105	565.8	47.5	704.7	55.1	1320.3	69.9
	2030	104	563.8	47.3	704.0	55.1	1320.2	69.9
Default harvest for Base State	2021	116	449.6	37.7	571.9	44.7	1231.2	65.2
	2022	116	462.5	38.8	596.6	46.7	1269.8	67.2
	2023	119	477.8	40.1	618.8	48.4	1274.9	67.5
	2024	124	490.4	41.2	632.4	49.5	1263.0	66.9
	2025	128	497.5	41.8	636.7	49.8	1247.9	66.1
	2026	129	499.1	41.9	634.3	49.6	1234.4	65.4
	2027	129	496.3	41.7	628.6	49.2	1224.3	64.8
	2028	127	491.4	41.3	622.7	48.7	1217.9	64.5
	2029	124	486.4	40.8	618.6	48.4	1215.1	64.3
	2030	122	482.7	40.5	617.1	48.3	1215.1	64.3
Default harvest for High State	2021	235	449.6	37.7	571.9	44.7	1231.2	65.2
	2022	225	410.9	34.5	537.5	42.0	1191.3	63.1
	2023	215	390.6	32.8	515.6	40.3	1132.0	59.9
	2024	204	377.9	31.7	496.8	38.9	1071.8	56.7
	2025	192	366.0	30.7	478.0	37.4	1025.9	54.3
	2026	183	353.2	29.7	460.5	36.0	996.7	52.8
	2027	177	340.4	28.6	446.0	34.9	980.5	51.9
	2028	173	328.9	27.6	435.3	34.1	972.2	51.5
	2029	170	320.2	26.9	428.6	33.5	968.2	51.3
	2030	168	314.3	26.4	424.8	33.2	966.0	51.1

Table i: Base case results 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

223 **Research and Data Needs**

research-and-data-needs

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

- 225 1. Investigate the structure of complex and contribution of each species to the GBYR
226 complex. Investigate possible spatial differences in biological parameters within a single
227 species and also between the two species. Little biological data for south of Point
228 Conception or north of Point Arena was available for this assessment and is needed to
229 better understand biological parameters.

230 (a) Conduct life history studies
231 (b) conduct research to identify the proportion of each species in population and in
232 catches
- 233 2. Take a closer look at the Ralston [-@Ralston2010] historical catch reconstruction for go-
234 per and black-and-yellow rockfishes. The recreational catch reconstruction for gopher
235 rockfish south of Point Conception was an order of magnitude higher than expected
236 when extracted for this assessment.
- 237 3. Refine the PISCO survey data and analysis to better identify age-0 fish in each month
238 of survey. Occasional sampling during all months of the year would better help identify
239 the length distribution of fish classified as age-0. This is the only recruitment index
240 available for gopher and black-and-yellow rockfish.
- 241 4. Refine CCFRP survey index to look at different possible model structures, including
242 a hierarchical structure and random effects. Limited time did not allow for these
243 explorations during this assessment cycle. It is also strongly recommended to continue
244 the coastwide sampling of the CCFRP program that began in 2017, as well as the
245 collection of biological samples for nearshore rockfish species. The CCFRP survey
246 is the only fishery-independent survey available for nearshore rockfish sampling the
247 nearshore rocky reef habitats. As of this assessment, only two years of coastwide data
248 are available, and the index was limited to the site in central California that have been
249 monitored since 2007.
- 250 5. Collection of length and age data are recommended for both the commercial and recre-
251 ational fisheries. Very little age data are available from either fishery for gopher rockfish
252 and none for black-and-yellow rockfish.
- 253 6. Data collection across Research Recommendations 1-5 is needed to improve the efficacy
254 of data collection and ensure that samples are representative of the data sources and the
255 fisheries. For example, the conditional age-at-length data in the dummy fleet represent
256 a number of sampling techniques, areas sampled, and selectivities. Better coordination
257 of research efforts will allow the age data to be better utilized by the assessment.
258 Sampling of the commercial and recreational fleets by area in proportion to the length
259 distribution of fish observed will also allow the model to better fit selectivity patterns
260 and avoid possible patterns in the length and age composition residuals.

- 261 7. Investigate possible environmental drivers/co-variates for biological parameters, par-
262 ticularly for recruitment.
- 263 8. Examine the CFRS angler interview data for the recreational private/rental mode to
264 create a "trip" based identifier or catch and effort. This will enable the creation of an
265 index of abundance for the private/rental mode as well as investigate if selectivity for
266 this mode differs from the party/charter mode.
- 267 9. Resolve differences between CalCOM and PacFIN expanded length composition data
268 sets.

269 **1 Introduction**

introduction

270 **1.1 Basic Information and Life History**

basic-information-and-life-history

271 *Population Structure and Complex Assessment Considerations*

272 There have been a number of analyses conducted on the genetic differentiation between go-
273 pher rockfish and black-and-yellow rockfish. The studies have yielded a range of results,
274 but have generally concluded that there is unusually low genetic differentiation between the
275 two species. The most frequently used measure of genetic analyses to evaluate evidence for
276 population differentiation is the fixation index (F_{ST}), defined as the proportion of the total
277 genetic variation in one sub-population (subscript S) relative to the total genetic variation
278 (subscript T) (Hauser and Carvalho 2008, Waples et al. 2008). Values of F_{ST} range from
279 0 to 1 where a zero value implies the populations are panmictic and a value closer to one
280 implies the two populations are genetically independent. Values of F_{ST} thought to be consis-
281 tent with biologically meaningful genetic differentiation and demographic isolation between
282 populations range from 0.01 to 0.05 (Waples and Gaggiotti 2006). It is also important to
283 note that F_{ST} values are dependent on the study's sample size and it may not necessarily be
284 appropriate to compare them across studies.

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

304 Most recently, an analysis of rockfish species assignment using microhaplotypes by Baetscher
305 (2019) observed mistaken genetic assignment of a small number of individuals between go-
306 pher and black-and-yellow rockfishes, while no other species among the 54 rockfishes analyzed

307 resulted in mis-assignments. In addition, comparisons of F_{ST} values within the study indicated
308 that the level of genetic differentiation observed between gopher and black-and-yellow
309 rockfishes is lower ($F_{ST} = 0.015$) than that observed among all other pairwise comparisons
310 of the 54 species in the *Sebastodes* genus that were included in their analysis. Baetscher (2019)
311 characterized the results as suggestive of the two species representing “sister species with
312 evidence of ongoing gene flow,” noting that a more rigorous evaluation of the level of genetic
313 distinction between these two species would benefit from whole-genome sequencing of
314 representatives from each species group.

315 In addition to the differences in coloration, the depth distribution and range differ between
316 the two species. The range of both species extends from Cape Blanco Oregon to Baja
317 California. Both species are uncommon north of Fort Bragg, California and black-and-yellow
318 rockfish is uncommon south of Point Conception, California. However, gopher rockfish can
319 be found as far south as Punta San Roque on the Baja peninsula. Gopher rockfish are found
320 in rocky reef habitat from the intertidal to depths of 264 ft (80 m) with a predominant depth
321 distribution of 30 to 120 ft (9-37 m), while the black-and-yellow rockfish occupies depths
322 from the intertidal to 120 ft (40 m) and is predominantly observed in depths shallower than
323 60 ft (18 m) (Eschmeyer et al. 1983, Love et al. 2002).

324 Both species are solitary, sedentary, and territorial with home ranges of 10-12 square meters
325 (Love et al. 2002). A large percentage (67-71%) of black-and-yellow rockfish returned to
326 the site of capture within two weeks after translocated within 50 m (Hallacher 1984). Lea
327 et al. (1999) found that gopher rockfish exhibit minor patterns of movement (<12.8 km)
328 with all fish being recaptured on the same reef system where they were tagged. Matthews
329 (1985) found that 11.8% of tagged and recaptured gopher rockfish, and 25% of black-and-
330 yellow rockfish, moved from four low-relief natural reefs to a new high-relief artificial reef
331 in Monterey Bay. The maximum distance between the natural and artificial reefs traveled
332 by gopher or black-and-yellow rockfish was 1.6 km. After only a year, the fish assemblage
333 on the artificial reef closely resembled that of the nearby natural reefs. The paper did not
334 address the spatial segregation of gopher and black-and-yellow rockfish on the new artificial
335 reef.

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

342 Both species feed at night, with similar diets composed primarily of crabs and shrimp,
343 supplemented by fish and cephalopods (Larson 1972, 1985, Love et al. 2002). Loury et al.
344 (2015) found no significant differences in the diet of gopher rockfish inside and outside the
345 year old Point Lobos Marine Protected Area (MPA). She did find the diet of gopher rockfish
346 at Año Nuevo (shallower and north of Point Lobos) was dominated by crabs and dominated
347 by brittle stars at southern, deeper study locations. Zuercher (2019) examined the diets of

348 a suite of nearshore rockfish species including black-and-yellow and found that they relied
349 on hard-bodied benthic invertebrates such as Brachyuran crabs, shrimps, other arthropods,
350 and octopus. The diet of black-and-yellow rockfish remained the same across sampling years,
351 but they occupied a lower trophic level during the upwelling season.

352 1.2 Early Life History

early-life-history

353 Gopher and black-and-yellow rockfish have similar juvenile development. Both rockfish
354 species are viviparous and release one brood per season between January and July (Echev-
355 erria 1987). Larvae are approximately 4 mm in length at birth and have a 1-2 month pelagic
356 stage before recruiting to the kelp forest canopy, i.e., surface fronds of *Macrosystis pyrifera*
357 and *Cystoseira osmundacea* at around 15-21 mm (Anderson 1983, Wilson et al. 2008).
358 The larvae are transparent until they reach juvenile stage at 22-23 mm. Differences in col-
359 oration between the two species begin to occur at 25-30 mm and can be used to identify one
360 species from the other. Gopher rockfish become more orange and brown, while black-and-
361 yellow rockfish become more black and yellow. Benthic juveniles associate with *Macrosystis*
362 holdfasts and sporophylls (Anderson 1983).

363 The juveniles undergo ontogenetic migration down the stalks to deeper depths, finally settling
364 on rocky reef habitat in their respective adult depth distribution. Juvenile bocaccio and other
365 fish predate on young of year and other reef dwelling species including cabezon predate on
366 post-settlement juveniles. Individuals avoid rough surge conditions and predators by hiding
367 in the rocky bottom during the daylight hours, then returning to more open water at dusk
368 (Love et al. 2002).

369 1.3 Map

map

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

373 1.4 Ecosystem Considerations

ecosystem-considerations-1

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

³⁷⁷ **1.5 Fishery Information**

fishery-information

³⁷⁸ The hook-and-line fishery off California developed in the late 19th century (Love et al. 2002).
³⁷⁹ The rockfish trawl fishery was established in the early 1940s, when the United States became
³⁸⁰ involved in World War II and wartime shortage of red meat created an increased demand
³⁸¹ for other sources of protein (Harry and Morgan 1961, Alverson et al. 1964).

³⁸² Gopher and black-and-yellow (referred to from hereon as GBYR when discussing the com-
³⁸³ plex) rockfish have been a minor component of the commercial and recreational rockfish
³⁸⁴ fishery since at least the late 1960s (CFIS and RecFIN). The commercial catch histories
³⁸⁵ of the two species cannot easily be separated (Figure 2). From 1916-1936 only black-and-
³⁸⁶ yellow rockfish were reported in the landings, and an average of 0.04 mt of black-and-yellow
³⁸⁷ rockfish are reported from 1937-1983. Black-and-yellow rockfish reappear in the landings in
³⁸⁸ 1984 with 7.2 mt landed commercially. From 1985-1988 the trend switches and only black-
³⁸⁹ and-yellow rockfish appear in the commercial landings, with gopher rockfish averaging 0.1
³⁹⁰ mt landed, and 0 mt reported in 1987. From 1988 and on, the landings are dominated by
³⁹¹ gopher rockfish, and both species are represented in the commercial landings.

³⁹² The landings from south of Point Conception are minor throughout the time period, with
³⁹³ peaks in the 1950s and 60s for gopher rockfish. Black-and-yellow rockfish are rare south of
³⁹⁴ Point Conception and expected that these catches are minimal.

³⁹⁵ The live fish fishery began in the early 1990s, with the first reported commercial landings of
³⁹⁶ live gopher rockfish in 1993, and black-and-yellow rockfish a year later. By 1995 over half
³⁹⁷ (57%; 39 mt) of the commercial landings were from the live fish fishery. This increased quickly
³⁹⁸ over the next few years and has been on average 84% of the landed gopher and black-and-
³⁹⁹ yellow rockfish (also referred to GBYR to reference the complex in this assessment) since
⁴⁰⁰ 2000. The majority of the landings are from gopher rockfish north of Point Conception.
⁴⁰¹ Landings of live GBYR south of Point Conception were higher in the late 1990s, (max. 3.2
⁴⁰² mt in 1999), and have been averaging 0.4 mt since 2003.

⁴⁰³ The ex-vessel value of GBYR increased from less than \$40,000 in 1984 and peaked at \$680,452
⁴⁰⁴ in 1996 (Figure 3). The ex-vessel revenue has been fairly stable at around \$500,000 a year
⁴⁰⁵ since 2007. Prior to the live fish fishery in 1994, the average price per pound for either
⁴⁰⁶ species was around \$2 a pound. The live fish fishery increased the value of both species to
⁴⁰⁷ an average of \$6-\$8 a pound. The maximum reported value of either a gopher or black-and-
⁴⁰⁸ yellow rockfish was \$20 a pound in 2003.

⁴⁰⁹ The recreational GBYR fishery for California is most prominent north of Point Conception
⁴¹⁰ throughout the entire catch history (Figure a). The recreational landings increased from
⁴¹¹ 1928 to 1980. The sharp increase in the 1980s could be an artifact of the MRFSS sampling
⁴¹² program that began in 1980; however, the more recent recreational landings also exhibit a
⁴¹³ cyclical trend of years with high catches followed by period of decreased recreational landings.
⁴¹⁴ The CRFS era recreational total mortality represents the most accurate description of the
⁴¹⁵ recreational fleet's catches in terms of area, mode and species (Figure 4).

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

423 1.6 Summary of Management History

summary-of-management-history

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

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

443 In 2000, changes in the PFMC’s rockfish management structure resulted in the discontinued
444 use of the *Sebastodes* complex, and was replaced with three species groups: nearshore, shelf,
445 and slope rockfishes (January 4, 2000; 65 FR 221), of which GBYR are included in the
446 nearshore group. Within the nearshore group, they are included in the “shallow nearshore
447 rockfish” component.

448 During the late 1990s and early 2000s, major changes also occurred in the way that California
449 managed its nearshore fishery. The Marine Life Management Act (MLMA), which was passed
450 in 1998 by the California Legislature and enacted in 1999, required that the FGC adopt an
451 FMP for nearshore finfish ([Wilson-Vandenberg et al. 2014](#)). It also gave authority to the
452 FGC to regulate commercial and recreational nearshore fisheries through FMPs and provided
453 broad authority to adopt regulations for the nearshore fishery during the time prior to

454 adoption of the nearshore finfish FMP. Within this legislation, the Legislature also included
455 commercial size limits for ten nearshore species including GBYR (10-inch minimum size)
456 and a requirement that commercial fishermen landing these ten nearshore species possess a
457 nearshore permit.

458 Following adoption of the Nearshore FMP and accompanying regulations by the FGC in fall
459 of 2002, the FGC adopted regulations in November 2002 which established a set of marine
460 reserves around the Channel Islands in southern California (which became effective April
461 2003). The FGC also adopted a nearshore restricted access program in December 2002
462 (which included the establishment of a Deeper Nearshore Permit) to be effective starting in
463 the 2003 fishing year.

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

472 The state of California has adopted regulatory measures to manage the fishery based on
473 the harvest guidelines set forth by the PFMC. The commercial open access and limited
474 entry fixed gear sectors have undergone three different spatial management changes since
475 2000. Since 2005, both have managed the area south of 40°10' N. latitude as one area. The
476 open access commercial fishery is managed based on bimonthly allowable catches, that have
477 ranged from 200 pounds to 1800 pounds per two months since 2000. From 2005 to 2018, the
478 catch limits have doubled and are now set at 1200 pounds per two months (for all months)
479 with March and April remaining closed. The limited entry fixed gear sector has followed the
480 same pattern as the open access sector with bi-monthly limits and a doubling of the catch
481 since 2005. The limited entry trawl fleet is managed on monthly limits on an annual basis.
482 Since 2011, the limit has been 300 pounds per month for non-IFQ species. A history of
483 California's commercial regulations from 2000-2018 can be found in [Appendix A](#). A 10-inch
484 total length minimum size limit was implemented in 1999 for both species in the commercial
485 fleet.

486 Significant regulatory changes in California's recreational sector began with a change from
487 unlimited number of hooks and lines allowed prior to 2000 to no more than three hooks and
488 one line per angler in 2000. Since 2001, the limit has been no more than two hooks and one
489 line per angler. There is no size limit in the recreational fishery for gopher or black-and-
490 yellow rockfish. A nearshore complex sub-bag limit that included GBYR was in place from
491 1999 to 2005, but was eliminated thereafter.

492 California also began spatial management, including area closures, and depth restrictions for
493 the recreational fleet in 2000. In general, the recreational season north of Point Conception

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

502 1.7 Management Performance

[management-performance-1](#)

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

514 1.8 Fisheries Off Mexico or Canada

[fisheries-off-mexico-or-canada](#)

515 The range of GBYR does not extend north to the Canadian border, and they are rarely
516 encountered in Oregon and Washington. The southern end of the gopher rockfish's range
517 extends to Punta San Roque (southern Baja California) while the southern end of the black-
518 and-yellow rockfish's range extends to Isla Natividad (central Baja California) (Love et al.
519 [2002](#)). However, black-and-yellow rockfish are rare south of Point Conception, California.
520 This was no available information on the fishery for GBYR at the time of this assessment,
521 nor additional details on the abundance or distribution patterns in Mexican waters.

522 2 Assessment

[assessment](#)

523 2.1 Data

[data](#)

524 Data used in the GBYR assessment are summarized in Figure [5](#). Descriptions of the data
525 sources are in the following sections.

526 **2.1.1 Commercial Fishery Landings**

commercial-fishery-landings

527 *Overview of gopher and black-and-yellow catch history*

528 Commercial fishery landings for gopher and black-and-yellow rockfishes have not been re-
529 ported consistently by species throughout the available catch history (Figure 2). The period
530 from 1916-1935 indicates that only black-and-yellow rockfish were landed in the commercial
531 fishery, which then switched to predominately gopher rockfish from 1937-1984. From 1985-
532 1988 the landings data suggest that only black-and-yellow rockfish were landed and not until
533 1995 are both species well-represented in the catches. Pearson et al. (2008) noted:

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

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

551 The stock assessment of gopher rockfish in 2005 did not explicitly include black-and-yellow
552 rockfish landings. A comparison of the recreational and commercial landings from the 2005
553 assessment to those used in this assessment suggest the 2005 assessment may have included
554 some black-and-yellow rockfish landings (Figure 6). The 2005 assessment estimated recre-
555 ational landings from 1969-1980 based on a ratio of commercial to recreational landings,
556 whereas this assessment makes use of the California Catch Reconstruction landings esti-
557 mates (Ralston et al. 2010).

558 *Commercial Landings Data Sources*

559 The California Catch Reconstruction (Ralston et al. 2010) contains landings estimates of
560 commercial landings from 1916-1968 and was queried on 4 April 2019 for GBYR. There were
561 no estimated gopher rockfish landings prior to 1937. Landings in this database are divided

562 into trawl and ‘non-trawl.’ Since the majority of GBYR are caught in the commercial fixed
563 gear fisheries, only estimated catch in the ‘non-trawl’ was used. A total of 0.154 mt (3.18%)
564 were removed from Eureka commercial landings (based on current proportions of commercial
565 catch from north of Cape Mendocino in Eureka) since the assessment represents the GBYR
566 stock south of Cape Mendocino. The majority of GBYR commercial landings (avg. 83%)
567 are landed in the Monterey and Morro Bay port complexes.

568 Contemporary landings were extracted from two data sources, the California Cooperative
569 Groundfish Survey, [CALCOM](#)) and the Pacific Fisheries Information Network ([PacFIN](#))
570 landings database. Both databases are based on the same data sources (CALCOM landing
571 receipts), but apply a catch expansion based on different algorithms. CALCOM collects
572 information including species composition data (i.e. the proportion of species landed in a
573 sampling stratum), and landing receipts (sometimes called “fish tickets”) that are a record
574 of pounds landed in a given stratum. Strata in California are defined by market category,
575 year, quarter, gear group, port complex, and disposition (live or dead). Although many
576 market categories are named after actual species, catch in a given market category can
577 consist of several species. These data form the basis for the “expanded” landings, i.e.,
578 species composition data collected by port samplers were used to allocate pounds recorded
579 on landing receipts to species starting in 1978. Use of the “Gopher Rockfish” or the “Black-
580 and-Yellow Rockfish” categories alone to represent actual landings of GBY would not be
581 accurate.

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

588 Commercial landings from 1981-2018 were queried for a final time from the CALCOM
589 database on 4 April 2019 and from PacFIN on 3 June 2019. There are very small dif-
590 ferences in commercial landings between CALCOM and PacFIN from 1981-2018 (Figure 7).
591 Landings estimates from PacFIN were used in the assessment (Table 1). Landings were
592 stratified by year, quarter, live/dead, market category, gear group, port complex, and source
593 of species composition data (actual port samples, borrowed samples, or assumed nominal
594 market category). Data from individual quarters were aggregated at the year level. Fish
595 landed live or dead were combined, due to changes over time in the reliability of condi-
596 tion information (Don Pearson, retired NMFS SWFSC, personal communication). From
597 1916-1968, on average, 74% of GBYR were landed north of Point Conception, which rose to
598 97% from 1978-2018. Given the smaller landings south of Point Conception and the similar
599 length composition of GBYR north and south of Point Conception, no spatial separation
600 was considered for the commercial fleet.

601 **2.1.2 Commercial Discards**

commercial-discards

602 The West Coast Groundfish Observer Program (WCGOP) provides observer data on dis-
603 carding across fishery sectors back to 2003. Gopher and black-and-yellow rockfishes have
604 species-specific depth-stratified commercial fishery discard mortality rates (Pacific Fishery
605 Management Council 2018). In consultation with WCGOP staff, the STAT used estimates of
606 total discard mortality from WCGOP's Groundfish Expanded Mortality Multiyear (GEMM)
607 report. WCGOP observes between 1-5% of nearshore fixed gear landings annually south of
608 40°10' N. latitude (coverage rates available [here](#)). The expanded estimates of total discard
609 weight by species is calculated as the ratio of the observed discard weight of the individual
610 species divided by the observed landed weight from PacFIN landing receipts. WCGOP dis-
611 card estimates for the nearshore fixed gear fishery take into account the depth distribution
612 of landings in order to appropriately apply the depth-stratified discard mortality rates by
613 species (Somers et al. 2018). The discard mortality for 2018 was estimated as an average
614 of the discard mortality from 2013-2017. Discard mortality was estimated from the period
615 prior to WCGOP discard estimates (1916-2002) based on the average discard mortality rate
616 from 2003-2016 (2017 was excluded because 2017 discard mortality was disproportionately
617 higher than all other years) (Table 1).

618 **2.1.3 Commercial Fishery Length and Age Data**

commercial-fishery-length-and-age-data

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

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

631 A total of 46 ages were available for gopher rockfish from the commercial fisheries 2009-2011,
632 2016, and 2018. Though sparse, the data were included as conditional age-at-length for the
633 commercial fleet.

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

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

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

Commercial length composition data are made available from PacFIN 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.

656 2.1.4 Recreational Fishery Landings and Discards

657 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.

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

680 The total difference in the catch streams from Figure 9 and Figure 10 is plotted in Figure
681 11. The differences in the catches are due to the addition of commercial discards prior to
682 2004 and the reduction of the recreational catches south of Point Conception.

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

684 From 1980-2003, the Marine Recreational Fisheries Statistics Survey (MRFSS) executed a
685 dockside (angler intercept) sampling program in Washington, Oregon, and California (see
686 Holliday et al. (1984) for a description of methods). Data from this survey are available from
687 the Recreational Fisheries Information Network [RecFIN](#). RecFIN serves as a repository for
688 recreational fishery data for California, Oregon, and Washington. Catch estimates for years
689 1980-2003 were downloaded on 23 March 2019, and are consistent from 1992-2004 with the
690 previous assessment (Key et al. 2005) (Figure 6).

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

706 Catches from north of Cape Mendocino were removed based on a CRFS-era average of frac-
707 tion of recreational landings north of Cape Mendocino by mode (3.3% of shore-based, 0.1% of
708 CPFV, and 0.2% of private/rental were removed). From 1980-1989, San Luis Obispo County
709 was sampled as part of Southern California (personal observation from MRFSS Type 3 sam-
710 pler examined catch where county is available for 1980-2004). This assessment separates the
711 recreational fleet at Point Conception. Recreational landings were re-allocated from southern
712 California from 1980-1992 by fleet based on the average proportion of recreational landings
713 in northern California from 1996-2004 (after sampling of the CPFV fleet in northern Cali-
714 fornia resumed). The average proportion re-allocated from southern to northern California

715 for the CPFV mode was 85%, 97% for the private/rental mode, and 81% for the shore-based
716 modes. Data were pooled over all years and modes to estimate the landings re-allocation
717 for the shore-based modes. Total recreational landings for 1981 and 1982 were 18.8 mt and
718 18.6 mt, respectively. These landings were >60 mt lower than any of the neighboring years.
719 Landings from 1981-1982 were interpolated from the 1980 and 1983 landings.

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

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

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

733 *Recreational Discards*

734 Recreational discards were only added to the California Catch Reconstruction landings, as
735 Ralston et al. (2010) did not address discards for the recreational reconstruction. Recre-
736ational removals from the California Department of Fish and Wildlife MRFSS era (1980-
737 2003) includes catch type A + B1. Catch type A refers to estimates of catch based on
738 sampler-examined catch. Catch type B1 includes mainly angler-reported discard, but also
739 angler-reported retained fish that were unavailable to the sampler during the interview (e.g.,
740 fillets). The CRFS era removals account for depth-stratified discard mortality rate and the
741 catch time series includes both retained and discarded catch (total mortality). We calculated
742 the ratio of dead discards to total mortality from the CRFS era by region and mode. The
743 region average across modes was applied to the California Catch Reconstruction as a con-
744 stant. The result added 4.68% annually to recreational removals north of Point Conception
745 and 4.05% annually to the removals South of Point Conception). The final time series of
746 landings and discard mortality are in Table 3.

747 **2.1.5 Recreational Fishery Length and Age Data**

recreational-fishery-length-and-age-data

748 Recreational length composition samples for California were obtained from several sources,
749 depending on the time period and boat mode (Table 2). This assessment makes use of a
750 much longer time series of length composition data, relative to the previous assessment, as

751 described below. Input sample sizes for recreational length composition data were based on
752 the number of observed trips, when available. Other proxies that were used to estimate the
753 number of trips are described below.

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

756 *CPFV length composition data, 1959-1978*

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

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

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

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

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

787 During the recent restructuring of the CRFS data on RecFIN, a “trip” identifier was not
788 carried over for all modes, and trip-level sample sizes could not be extracted from the bio-

logical 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 5. 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.

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 occurring in bays 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.

827 The species composition of catch in California varies greatly with latitude.
828 Therefore, Stephens-MacCall filtering was applied independently for north and south of Point
829 Conception. Separate indices were also developed to represent two recreational fleets in the
830 model. Since recreational fishing trips target a wide variety of species, standardization of
831 the catch rates requires selecting trips that are likely to have fished in habitats containing
832 GBYR. The Stephens-MacCall (2004) filtering approach was used to identify trips with a
833 high probability of catching GBYR, based on the species composition of the catch in a given
834 trip. Prior to applying the Stephens-MacCall filter, we identified potentially informative
835 predictor species, i.e., species with sufficient sample sizes and temporal coverage (at least 30
836 positive trips total) to inform the binomial model. Coefficients from the Stephens-MacCall
837 analysis (a binomial GLM) are positive for species which co-occur with GBYR, and negative
838 for species that are not caught with GBYR. Each of these filtering steps and the resulting
839 number of trips remaining in the sampling frame are provided in Table 18.

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

853 Two levels of possible filtering were applied using the Stephens-MacCall filter (Table 18).
854 The Stephens-MacCall filtering method identified the probability of occurrence (in this case
855 0.4) at which the rate of “false positives” equals “false negatives.” The trips selected using
856 this criteria were compared to an alternative method including all the “false positive” trips,
857 regardless of the probability of encountering GBYR (Table 21). This assumes that if GBYR
858 were caught, the anglers must have fished in appropriate habitat during the trip. The catch
859 included in this index is “sampler-examined” and the samplers are well trained in species
860 identification. The last filter applied was to exclude years after 1999 due to a number of
861 regulation changes, and years in which there were less than 20 observed trips. The final
862 index is represented by 544 trips, 220 of which encountered GBYR.

863 Due to the large number of zeros in the data, we modeled catch per angler hour (CPUE;
864 number of fish per angler hour) using maximum likelihood and Bayesian negative binomial
865 regression. Models incorporating temporal (year, 2-month waves) and geographic (region
866 and area_x) factors were evaluated. Counties were grouped into three regions, north of
867 Sonoma county, Sonoma county through Santa Cruz county, and San Luis Obispo county.
868 Based on AIC values from maximum likelihood fits (Table 19), a main effects model including

869 all factors (year, region, area_x, and 2-month waves) was fit in the “rstanarm” R package
870 (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo
871 standard error values) were all reasonable. Predicted means by stratum (Year) were strongly
872 correlated with observed means, suggesting a reasonable fit to the data (Figure 17). The
873 NB model generated data sets with roughly 50-70% zeros, compared to the observed 60%
874 (Figure 18).

875 The index represents the years 1984-1989, 1995, 1996 and 1999. There is not a lot of contrast
876 in the index, except for a small increase in 1986. The final index values and associated log
877 standard error included in the assessment can be found in Table 6.

878 *MRFSS Filtering and Index Standardization for South of Point Conception.* Note, the
879 MRFSS index for south of Point Conception was not used in the post-STAR base model.
880 Prior to the Stephens-MacCall filter, a total of 7,334 trips were available for the analy-
881 sis. As expected, positive indicators of GBYR trips included several nearshore species, e.g.,
882 kelp rockfish, treefish, and black croaker, while the strongest counter-indicator was opaleye
883 (Figure 19). While the filter is useful in identifying co-occurring or non-occurring species
884 assuming all effort was exerted in pursuit of a single target, the targeting of more than one
885 target species can result in co-occurrence of species in the catch that do not truly co-occur
886 in terms of habitat associations informative for an index of abundance. For consistency with
887 the methods used north of Point Conception (Table 18) the index includes the trips identified
888 as “false positives” from the Stephens-MacCall filtering that had a lower threshold level of
889 0.22 (Table 22). The last filter applied was to exclude years after 1999 due to a number
890 of regulation changes, and years in which there were less than 20 observed trips. The final
891 index is represented by 475 trips, 342 of which encountered GBYR.

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

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

904 The resulting index for south of Point Conception represents different years than the index for
905 north of Point Conception (Table 6). The index starts in 1980 with continuous data through
906 1986, and three additional years in 1996, 1998 and 1999. The index increases through 1983
907 and a marked decrease to 1986. The index for the three years in the 1990s does not exhibit
908 any significant trend.

909 **CPFV Onboard Observer Surveys**

910 Onboard observer survey data were available from three sources for this assessment, 1)
911 a CDFW survey in central California from 1987-1998 (referred to as the Deb Wilson-
912 Vandenberg onboard observer survey, (Reilly et al. 1998)), 2) the CDFW CPFV onboard
913 observer survey from 1999-2018, and 3) a Cal Poly survey from 2003-2018. During an on-
914 board observer trip the sampler rides along on the CPFV and records location-specific catch
915 and discard information to the species level for a subset of anglers onboard the vessel. The
916 subset of observed anglers is usually a maximum of 15 people the observed anglers change
917 during each fishing stop. The catch cannot be linked to an individual, but rather to a specific
918 fishing location. The sampler also records the starting and ending time, number of anglers
919 observed, starting and ending depth, and measures discarded fish.
920 The fine-scale catch and effort data allow us to better filter the data for indices to fishing
921 stops within suitable habitat for the target species.

922 The state of California implemented a statewide sampling program in 1999 (Monk et al.
923 2014). California Polytechnic State University (Cal Poly) has conducted an independent
924 onboard sampling program as of 2003 for boats in Port San Luis and Morro Bay, and follows
925 the protocols established in Reilly et al. (1998). Cal Poly has modified protocols reflect
926 sampling changes that CDFW has also adopted, e.g., observing fish as they are encountered
927 instead of at the level of a fisher's bag. Therefore, the Cal Poly data area incorporated in
928 the same index as the CDFW data from 1999-2018. The only difference is that Cal Poly
929 measures the length of both retained and discarded fish.

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

933 *Deb Wilson-Vandenberg Onboard Observer Index Filtering and Standardization.* A large
934 effort was made by the SWFSC to recover data from the original data sheets for this
935 survey and developed into a relational database (Monk et al. 2016). The specific fishing
936 locations at each fishing stop were recorded at a finer scale than the catch data for this survey.
937 We aggregated the relevant location information (time and number of observed anglers) to
938 match the available catch information. Between April 1987 and July 1992 the number of
939 observed anglers was not recorded for each fishing stop, but the number of anglers aboard the
940 vessel is available. We imputed the number of observed anglers using the number of anglers
941 aboard the vessel and the number of observed anglers at each fishing stop from the August
942 1992-December 1998 data (see Supplemental materials for details). In 1987, trips were only
943 observed in Monterey, CA and were therefore excluded from the analysis. The years 1990
944 and 1991 were also removed for low sample sizes. Final data filters included removing reefs
945 that never encountered GBYR, drifts that had fishing times outside 95% of the data, and
946 fishing stops with depths <9 m and >69m. The final data set contained 2,411 fishing stops,
947 with 1,096 of those encountering GBYR (Figure 20).

948 The index was fit using a delta-GLM model, with a lognormal model (AIC: 1,088) selected
949 over a gamma model (AIC: 1,143) for the positive encounters. Covariates considered in

950 the full model included year, depth, and month (Table 8). The model selected by AIC for
951 both the lognormal and binomial components of the delta-GLM included year, depth and
952 reef. Depth was included in 10 m depth bins and eight reefs were select in the final model
953 (Figure coming). The final index did not indicate an increasing trend that was seen in the
954 2005 gopher rockfish assessment using the same data set (Figure 21). A number of reasons
955 include that finer-scale location data was keypunched in 2012 for this survey, the index in
956 this assessment includes black-and-yellow rockfish, and different filters were applied to the
957 data. However, the the same peaks and decreases in the two indices are present.

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

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

970 Each drift was assigned to a reef (hard bottom). Hard bottom was extracted from the
971 [California Seafloor Mapping Project](#), with bathymetric data from state waters available at
972 a 2 m resolution. Reefs were developed based on a number of factors described in the
973 supplemental material (“Reef Delineation”).

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

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

982 *Filtering and Index Standardization for north of Point Conception* The number of drifts
983 remaining before region specific filtering was 13,792, with 6,036 drifts encountering GBYR
984 (Table 9).

985 Because GBYR are strongly associated with hard bottom habitat, the distance from a reef at
986 the start of a drift was re-examined for drifts encountering GBYR. The maximum distance
987 was 872 m, but the 97% quantile dropped to 42 m and was chosen as a reasonable cutoff
988 value, and only resulted in a reduction of 182 drifts that encountered gopher rockfish. The

989 final data were filtered to ensure all selected reefs were sampled in at least 2/3 of all years,
990 leaving 12,965 drifts for the final index, 5,796 of which encountered GBYR (Figure 22).

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

997 *Filtering and Index Standardization for south of Point Conception* Note, the CPFV onboard
998 index for south of Point Conception was not used in the final post-STAR base model. The
999 bathymetric data is not available at as fine-scale resolution for the Southern California Bight
1000 and more of the trips and drifts target mid-water species, including mid-water rockfish (Table
1001 9). Therefore, instead of using distance to reef as a filter, we filtered the data to drifts that
1002 encountered 20% or more groundfish. This resulted in the total number of drifts decreasing
1003 from 11,635 to 5,495, but only decreased the number of drifts encountering GBYR from
1004 1,277 to 1,171. A final check was made to ensure all reefs were sampled in at least 2/3 of all
1005 years, leaving 5,440 drift for the final index, of which 1,132 encountered GBYR (Figure 23).

1006 The index of abundance was modeled with a delta-GLM modeling approach, with year,
1007 month, 10 m depth bins from 10-59 m, and four reefs as possible covariates. A lognormal
1008 model (AIC: 162) was selected over a gamma (AIC: 277) for the positive observations using
1009 AIC. A model with year, depth and reef was selected by AIC for both the lognormal and
1010 binomial components of the delta-GLM. The index indicates a relatively stable trend from
1011 2001-2004 and a steady increase from 2005-2017.

1012 2.1.7 Fishery-Dependent Indices: Available Length and Age Data [fishery-dependent-indices-available-length-and-age-data](#)

1013 Length data associated with the MRFSS dockside CPFV survey and the current onboard ob-
1014 server surveys conducted by CDFW are incorporated into the biological data pulled from the
1015 respective data sources, MRFSS and CRFS. The additional length data are not incorporated
1016 as separate length composition data as they represent the same portion of the population
1017 sampled by the CDFW onboard observer program.

1018 Cal Poly collected otoliths from the onboard observer program starting in 2017 as part of a
1019 special study to correlate fish length before and after the fish was filleted by the deckhands
1020 onboard the CPFV vessels. All fish collected in 2017 only had associated post-fillet lengths
1021 and were not used in the assessment since the study has not been finalized nor has the
1022 method been endorsed by the SSC. A subset of fish from the 2018 collection included both
1023 pre- and post-fillet length and were used in the assessment as conditional age-at-length data
1024 associated with the recreational fleet north of Point Conception.

1025 Length composition from Deb Wilson-Vandenberg's onboard observer survey are included
1026 in the assessment. This program measured both retained and discarded fish, and represent
1027 the portion of the population sampled with the spatial extent of the index. This onboard
1028 observer program continued during the period from 1990-1992 when MRFSS was on hiatus.

1029 **2.1.8 Fishery-Independent Data Sources**

fishery-independent-data-sources

1030 Neither of the two fishery-independent surveys described below have previously been used
1031 in stock assessments as indices of abundance.

1032 **California Collaborative Fisheries Research Project**

1033 The California Collaborative Fisheries Research Project, [CCFRP](#), is a fishery-independent
1034 hook-and-line survey designed to monitor nearshore fish populations at a series of sampling
1035 locations both inside and adjacent to MPAs along the central California coast (Wendt and
1036 Starr [2009](#), Starr et al. [2015](#)). The CCFRP survey began in 2007 and was originally designed
1037 as a statewide program in collaboration with NMFS scientists and fishermen. From 2007-
1038 2016 the CCFRP project was focused on the central California coast, and has monitored four
1039 MPAs consistently since then ([Figure 24](#)). In 2017, the program was expanded coastwide
1040 within California. The index of abundance was developed from the four MPAs sampled
1041 consistently (Año Nuevo and Point Lobos by Moss Landing Marine Labs; Point Buchon and
1042 Piedras Blancas by Cal Poly).

1043 The survey design for CCFRP consists a number 500 x 500 m cells both within and outside
1044 each MPA. On any given survey day site cells are randomly selected within a stratum (MPA
1045 and/or reference cells). CPFVs are chartered for the survey and the fishing captain is allowed
1046 to search within the cell for a fishing location. During a sampling event, each cell is fished for
1047 a total of 30-45 minutes by volunteer anglers. Each fish encountered is recorded, measured,
1048 and can be linked back to a particular angler, and released (or descended to depth). Starting
1049 in 2017, a subset of fish have been retained to collect otoliths and fin clips that provide needed
1050 biological information for nearshore species. For the index of abundance, CPUE was modeled
1051 at the level of the drift, similar to the fishery-dependent onboard observer survey described
1052 above.

1053 The CCFRP data are quality controlled at the time they are key punched and little filtering
1054 was needed for the index. Cells not consistently sampled over time were excluded as well as
1055 cells that never encountered GBYR. CCFRP samples shallower depths to avoid barotrauma-
1056 induced mortality. The index was constrained to 5-39m in 5 m depth bins. The final index
1057 included 4,920 drifts, 3,848 of which encountered GBYR.

1058 We modeled catch per angler hour (CPUE; number of fish per angler hour) using maximum
1059 likelihood and Bayesian negative binomial regression. The proportion of zeroes in this data
1060 was relatively small (22%), and if overdispersion were not present, the regression would

1061 innately become Poisson. Models incorporating temporal (year, month) and geographic
1062 (MPA site and MPA vs Reference cells) factors were evaluated. Based on AIC values from
1063 maximum likelihood fits (Table 17), a main effects model including all factors (year, month,
1064 site and MPA/REF) was fit in the “rstanarm” R package (version 2.18.2). Diagnostic checks
1065 of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all
1066 reasonable. Predicted means by stratum (Year) were strongly correlated with observed
1067 means, suggesting a reasonable fit to the data (Figure 25). The NB model generated data
1068 sets with roughly 18-22% zeros, compared to the observed 22% (Figure 18).

1069 The CCFRP index of abundance closely matches the trend observed in the onboard observer
1070 index from 2009-2018 (Figure 12). The index decreases from 2009 to 2013, and then exhibits
1071 the same increase through 2018. When both indices are standardized to their means, the
1072 values for 2013 and 2018 are the same.

1073 *CCFRP Length Measurements and Available Ages*

1074 The CCFRP program measures every fish encountered to the nearest half centimeter. A
1075 total of 22,470 GBYR were measured by CCFRP from 2007-2018, of which only 212 were
1076 black-and-yellow rockfish. The length distributions for each of the four MPAs used in the
1077 index for this assessment show slight difference in their peaks (Figure 27). Año Nuevo is the
1078 most northern site and Point Buchon the most southern.

1079 Conditional age-at-length data were also incorporated into the assessment from the CCFRP
1080 program, including two master’s theses that are products of the CCFRP. Erin Loury (Loury
1081 2011) collected gopher rockfish otoliths as part of her thesis work from 2007-2009 that in-
1082 cluded specimens from both inside and outside the MPAs. Natasha Meyers-Cherry (Meyers-
1083 Cherry 2014) conducted another thesis focused on the life history of gopher rockfish and
1084 collected otoliths from 2011-2012, also both inside and outside the MPAs. Both MLML and
1085 Cal Poly began routinely collecting otoliths from a select number of fish in 2017 as part of
1086 the CCFRP program. Also included in the conditional age-at-length data for this fleet are
1087 otoliths collected in 2018 by the University of California Davis Bodega Marine Lab CCFRP
1088 program.

1089 **Partnership for Interdisciplinary Studies of Coastal Oceans**

1090 The Partnership for Interdisciplinary Studies of Coastal Oceans, [PISCO-UCSC](#), conducts
1091 a number of surveys to monitor the kelp forests, one of which is a kelp forest fish survey.
1092 PISCO has monitored fish population in the 0-20 m depth range as part of the Marine Life
1093 Protection Act (MLPA) since 1998. Paired sites inside and outside MPAs are surveyed to
1094 monitor the long-term dynamics of the kelp forest ecosystem and provide insight into the
1095 effect of MPAs on kelp forest species. PISCO conducts the fish surveys from late July through
1096 September. At each site, benthic, midwater, and canopy scuba transects are conducted at
1097 5, 10, 15, and 20 m depth. All divers are trained in species identification. Along each 30
1098 m transect, divers enumerate all identifiable non-cryptic fish, and measure total length to
1099 the nearest centimeter. PISCO surveys are conducted by the University of California Santa

1100 Cruz (UCSC) in central California and through the University of California Santa Barbara
1101 in southern California. All PISCO data were provided by Dan Malone (UCSC).

1102 The majority of filtering for the PISCO data set was to determine which sites to retain for
1103 the final index. After initial filtering the data for GBYR in southern California were too
1104 sparse to be considered for the index of abundance. Gopher and black-and-yellow rockfish
1105 were also rarely observed in the midwater and canopy transects, and therefore the index is
1106 based only on the benthic transects. Only sites sampled consistently throughout the time
1107 period 2001-2018 were kept for the index. Multiple transects can be conducted along the
1108 same line within a sampling event. All transects within a site were combined and effort was
1109 modeled as the number of transects represented in the number of fish observed. The final
1110 index included 3,231 transects, of which 1,729 observed GBYR (Figure 28).

1111 Three indices are described below. The pre-STAR base model includes a single index of
1112 abundance for the PISCO survey. During the STAR panel the decision was made to include
1113 two separate indices of abundance and selectivities for the PISCO data. The PISCO data
1114 include information on age-0 recruitment and also older fish. The PISCO age-0 recruitment
1115 index includes fish that are 6 cm or smaller, and the PISCO index for larger fish includes
1116 fish 15 cm and larger. There is uncertainty in the age of fish in the 7-14 cm range due to the
1117 timing of sampling, growth, and the timing of ages, i.e., all fish turn one on Jan 1 in the SS
1118 assessment model. Additionally, fish in the 7-14 cm are also not well sampled by the survey.

1119 For all three iterations of the index we modeled number of fish observed per transect(s) using
1120 maximum likelihood and Bayesian regression. The index containing all data and the index
1121 for larger fish (15+ cm) only were modeled as negative binomial, whereas the data for the
1122 age-0 (for which the 4-6 cm fish serve as a proxy) index were sparse and modeled as binomial.
1123 Models incorporating temporal (year, month) and geographic (site and zone) factors were
1124 evaluated. The zone is a factor indicating the depth stratification at a site, i.e., 5 m, 10 m,
1125 15 m, or 20 m targeted bottom depth.

1126 *Index based on all of the PISCO data (used in the pre-STAR base model).*

1127 Based on AIC values from maximum likelihood fits (Table 13), a main effects model including
1128 all factors (year, month, site and zone) was fit in the “rstanarm” R package (version 2.18.2).
1129 Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error
1130 values) were all reasonable. Predicted means by stratum (Year) were strongly correlated
1131 with observed means, suggesting a reasonable fit to the data (Figure 29). The NB model
1132 generated data sets with roughly 16-25% zeros, compared to the observed 23% (Figure 30).

1133 The final index decreases from 2001 to the late 2000s, with lower estimates of relative abun-
1134 dance from 2005-2010. From 2010 to 2015, the index increases and peaks in 2015, before
1135 the decreasing trends from 2016-2018. The trend observed in this index is counter to that
1136 observed in the onboard observer and CCFRP indices for north of Point Conception (Fig-
1137 ure 12). The PISCO survey is sampling different habitat types than the other two surveys,
1138 and covers much shallower depths. It’s possible that the PISCO index captures recruitment
1139 pulses, but because this index includes both young-of-the-year and adult fish, the trend may
1140 be captured in the model.

1141 *PISCO index based on fish 15 cm and larger (used in the post-STAR base model).*
1142 The same filtered dataset was used for the index for fish 15 cm and larger as for the PISCO
1143 index that included all fish. Based on AIC values from maximum likelihood fits (Table
1144 14), a main effects model including all factors (year, month, site and zone) was fit in the
1145 “rstanarm” R package (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff,
1146 Rhat, and Monte Carlo standard error values) were all reasonable. Predicted means by
1147 stratum (Year) were strongly correlated with observed means, suggesting a reasonable fit
1148 to the data (Figure 31). The NB model generated data sets with roughly 20-30% zeros,
1149 compared to the observed 25% (Figure 32).

1150 *PISCO recruitment index based on fish 6 cm and smaller (used in the post-STAR base model).*
1151 The same filtered dataset was used for the index for fish 15 cm and larger as for the PISCO
1152 index that included all fish. There was no consistent pattern in the presence of age-0 fish to
1153 exclude any sites or zones. All years were included in the final index, even if sample sizes
1154 were small. Age-0 fish were present in 14% of all transects. A negative binomial model
1155 was not well fit to the data so a binomial (presence/absence) model was selected for the
1156 recruitment index. Based on AIC values for maximum likelihood fits (Table 15), a main
1157 effects model including year, month, and zone was fit in the “rstanarm” R package (version
1158 2.18.2). The resulting index has large standard errors for years with sparse data, including
1159 2004-2008 and 2012-2013. A recruitment signal is present in the index in a number of years,
1160 including 2001-2003, 2010, and 2014-2017.

1161 *PISCO Length Measurements*

1162 All but one GBYR observed by PISCO divers was measured
1163 ($N = 11,965$). Divers measure fish to the nearest centimeter, and are trained to measure
1164 fish underwater and be aware of possible biases, e.g., ambient light, body color, visibility,
1165 and body shape. Both juvenile and adult GBYR were observed in the PISCO kelp forest
1166 fish survey data (Figure 33). Of note is the similarity in length distributions both between
1167 the species and for the two species combined across sites. Fish in the 10-17 cm size range
1168 (approximately) are rarely observed in this survey. There is significant post-settlement mor-
1169 tality for both species, which is thought to be due to density-dependent predation (Johnson
1170 2006, 2007). Secondly, both species can be cryptic and observed at higher frequency by
1171 divers at night than during the day (Mark Carr, PISCO-UCSC, personal communication).

1172 **2.1.9 Biological Parameters and Data**

biological-parameters-and-data

1173 Neither gopher nor black-and-yellow rockfish have forked tails, therefore total length and
1174 fork length are equal. All of the data provided for this assessment were either in fork length
1175 or total length.

1176 (Table 4)

1177 **Length and Age Compositions**

1178 Length compositions were provided from the following sources:

- 1179 • CALCOM (*commercial retained dead fish*, 1987, 1992-2018)
- 1180 • WCGOP (*commercial discarded fish*, 2004-2018)
- 1181 • Deb Wilson-Vandenberg's onboard observer survey (*recreational charter retained and*
1182 *discarded catch*, 1987-1998)
- 1183 • California recreational sources combined (*recreational charter retained catch*)
 - 1184 – Miller and Gotshall dockside survey (1959-1966)
 - 1185 – Ally et al. onboard observer survey (1985-1987)
 - 1186 – Collins and Crooke onboard observer survey (1975-1978)
 - 1187 – MRFSS dockside survey (1980-2003)
 - 1188 – CRFS onboard and dockside survey (2004-2018)
- 1189 • PISCO dive survey (*research*, 2001-2018)
- 1190 • CCFRP hook-and-line survey (*research*, 2007-2018)

1191 The length composition of all fisheries aggregated across time by fleet is in Figure 34 and
1192 Table 4. Descriptions and details of the length composition data are in the above section for
1193 each fleet or survey.

1194 Age Structures

1195 A total of 2,421 otoliths were incorporated in this assessment and a summary by source can
1196 be found in Table 23. The final base model excludes the commercial age data that were
1197 sparse and not representative of the fishery. Gopher rockfish comprised 79% of the samples
1198 (922 females, 879 males, 121 unknown sex), and all but a few black-and-yellow rockfish (247
1199 females, 232 males, 20 unknown sex) came from a directed study by Jody Zaitlin (1986),
1200 collected from 1983-1986 (Figure 35).

1201 Of the available ages, 94% were collected during fishery-independent surveys.
1202 The remaining 6% were recreational dockside surveys and collected by Cal Poly during their
1203 CPFV onboard observer survey (36 otoliths) in 2018.

1204 All otoliths were read by Don Pearson (NMFS SWFSC, now retired) and estimated ages
1205 ranged from 1-28. The aged black-and-yellow rockfish ranged in length from 7-32 cm with a
1206 mean of 24 cm and gopher rockfish ranged in length from 11-36 cm, with a mean of 26. In
1207 terms of ages, the black-and-yellow rockfish ranged from 2-19 and gophers from 2-28. Fits
1208 to the von Bertalanffy growth curve (Bertalanffy 1938), $L_i = L_\infty e^{(-k[t-t_0])}$, where L_i is the
1209 length (cm) at age i , t is age in years, k is rate of increase in growth, t_0 is the intercept, and
1210 L_∞ is the asymptotic length, were explore by species and sex.

1211 No significant differences were found in growth between gopher and black-and-yellow rock-
1212 fishes (Figure 36) or between males and females (Figure 37), species combined.

1213 Aging Precision and Bias

1214 Uncertainty in ageing error was estimated using a collection of 376 gopher and black-and-
1215 yellow rockfish otoliths with two age reads (Figure 39). Age-composition data used in the
1216 model were from a number of sources described above. All otoliths were read by Don Pearson
1217 (NMFS SWFSC, no retired) who also conducted all blind double reads.

1218 Ageing error was estimated using publicly available software (Thorson et al. 2012). The
1219 software setting for bias was set to unbiased since the same reader conducted the first and
1220 second readings. The best fit model chose by AIC for the standard deviation was a constant
1221 coefficient of variation for reader one ad mirrored for reader two (Figure 40).

1222 The resulting estimate indicated a standard deviation in age readings increasing from 0.74
1223 years at age 0 to a standard deviation of 2.07 years at age 28, the first year of the plus group
1224 in the assessment model.

1225 Weight-Length

1226 The weight-length relationship is based on the standard power function: $W = \alpha(L^\beta)$ where
1227 W is individual weight (kg), L is length (cm), and α and β are coefficients used as constants.

1228 The weight-length relationships was estimated from the three studies, Loury (2011), Meyers-
1229 Cherry (2014) (both gopher rockfish only from CCFRP) and Zaitlin (Zaitlin 1986) (black-
1230 and-yellow rockfish only). Only one weight-length relationship was estimated for the GBYR
1231 complex. The estimated parameters are $\alpha = 8.84e^{-006}$ and $\beta = 3.25584$. The estimated
1232 relationship is similar to that estimated by Lea et al. (1999) for gopher rockfish (Figure
1233 41). The weight-length relationship estimated here was used in the assessment model to
1234 best represent the GBYR complex.

1235 Sex Ratio, Maturity, and Fecundity

1236 The sex ratio for GBYR is assumed to be 50:50 as there is no evidence to suggest otherwise.

1237 Zaitlin (1986) found that females reached 50% maturity at 17.5 cm or 4 years of age in Central
1238 California and were 100% mature by age 6, with the same age of maturity found in southern
1239 California though individuals were smaller at age. Echeverria (1987) estimated maturity for
1240 17 rockfish species in central California. She found the size at first maturity and the size
1241 at 50% maturity for male and female gopher rockfish to be 17 cm total length, and 100%
1242 mature by 21 cm. Black-and-yellow rockfish males and females were first mature at 14 cm,
1243 50% of females were mature at 15 cm, 50% of males mature at 16 cm. Male black-and-yellow
1244 rockfish were 100% mature at 20 cm and females at 19 cm. In southern California waters,
1245 both males and females were found to reach first maturity at 13 cm total length (Larson
1246 1980). We did not have any samples from southern California to re-analyze the maturity
1247 ogive for that portion of the population. Both Zaitlin and Echeverria estimated the maturity
1248 ogives using ages from whole otoliths. A sample of 151 black-and-yellow rockfish otoliths

1249 surface read by Zaitlin were also read by Don Pearson, and Zaitlin's ages were consistently
1250 younger than Pearson's, by up to nine years. All of the available otoliths for this assessment
1251 were re-aged using a combination of surface reading and break-and-burn methodology.

1252 The maturity data from Zaitlin (1986) (422 black-and-yellow rockfish) were re-analyzed along
1253 with samples from Meyers-Cherry (2014) (115 gopher rockfish). Combining the two data sets
1254 provided an updated maturity ogive for the GBYR complex females (Figure 38). The first
1255 observed mature fish was 19 cm and the length at 50% was 21.66 cm, larger than suggested
1256 from the estimate used by Key et al. (2005) in the 2005 assessment. After re-analyzing the
1257 available data, the length at which 50% of female gopher rockfish were mature was estimated
1258 at 23.33 cm, and was 21.26 cm for female black-and-yellow rockfish. An important note is
1259 that the smaller fish from these studies were black-and-yellow rockfish and the larger fish
1260 were gopher rockfish. Although not used in this assessment, the estimate of 50% maturity
1261 for 23 GBYR from these studies was 21.88 cm. The age at 50% mature increased in this
1262 assessment to 21.66 cm, which is 3.96 cm larger than the value used in the 2005 assessment.

1263 Mature females in central California release larvae between January and July, peaking in
1264 February, March, and May (Larson 1980, Lea et al. 1999, Love et al. 2002). Both species of
1265 GBYR release one brood per season (Love et al. 2002). Black-and-yellow rockfish females
1266 can produce 25,000 - 450,000 eggs spawning from January to May. Gopher rockfish females
1267 ranging between 176 and 307 grams carry approximately 249 eggs per gram of body weight
1268 (MacGregor 1970). The fecundity estimates used in this assessment were provided by E.J.
1269 Dick (NMFS SWFSC) from a meta-analysis of fecundity in the genus *Sebastes* (Dick et al.
1270 2017).

1271 Natural Mortality

1272 Hamel (2015) developed a method for combining meta-analytic approaches to relating the
1273 natural mortality rate M to other life-history parameters such as longevity, size, growth
1274 rate and reproductive effort, to provide a prior on M . In that same issue of ICESJMS,
1275 Then et al. (2015), provided an updated data set of estimates of M and related life history
1276 parameters across a large number of fish species, from which to develop an M estimator
1277 for fish species in general. They concluded by recommending M estimates be based on
1278 maximum age alone, based on an updated Hoenig non-linear least squares (nls) estimator
1279 $M = 4.899 * A_{max}^{-0.916}$. The approach of basing M priors on maximum age alone was one that
1280 was already being used for west coast rockfish assessments. However, in fitting the alternative
1281 model forms relating $-0.916M$ to A_{max} , Then et al. (2015) did not consistently apply their
1282 transformation. In particular, in real space, one would expect substantial heteroscedasticity
1283 in both the observation and process error associated with the observed relationship of M to
1284 A_{max} . Therefore, it would be reasonable to fit all models under a log transformation. This
1285 was not done. Reevaluating the data used in Then et al. (2015) by fitting the one-parameter
1286 A_{max} model under a log-log transformation (such that the slope is forced to be -1 in the
1287 transformed space (as in Hamel (2015)), the point estimate for M is:

$$M = \frac{5.4}{A_{max}} \quad (1)$$

1288 The above is also the median of the prior. The prior is defined as a lognormal with mean
 1289 $\ln \frac{5.4}{A_{max}}$ and SE = 0.4384343 (Owen Hamel, personal communication, NMFS). Using a max-
 1290 imum age of 28 the point estimate and median of the prior is 0.193, which is used as a prior
 1291 for in the assessment model and as a fixed quantity in the post-STAR base model.

1292 2.1.10 Environmental or Ecosystem Data Included in the Assessment environmental-or-ecosystem-data-included-in-the-assessment

1293 In this assessment, neither environmental nor ecosystem considerations were explicitly in-
 1294 cluded in the analysis. This is primarily due to a lack of relevant data and results of analyses
 1295 (conducted elsewhere) that could contribute ecosystem-related quantitative information for
 1296 the assessment.

1297 2.2 Previous Assessments

previous-assessments

1298 2.2.1 History of Modeling Approaches Used for this Stock history-of-modeling-approaches-used-for-this-stock

1299 This is the first full assessment to include data for black-and-yellow rockfish. Black-and-
 1300 yellow rockfish was assessed coastwide as a data poor species using Depletion-Based Stock
 1301 Reduction Analysis (DB-SRA) (Dick and MacCall 2010). The DB-SRA model assigned a
 1302 40% probability that the then recent (2008-2009) catch exceeded the 2010 OFL.

1303 Gopher rockfish south of Point Conception was assessed as a data poor species in 2010 (Dick
 1304 and MacCall 2010). A Depletion-Corrected Average Catch (DCAC) model was used due to
 1305 time constraints. The mean yield from the DCAC distribution was 25.5 mt.

1306 Gopher rockfish north of Point Conception ($34^{\circ}27'$ N. latitude) was first assessed as a full
 1307 stock assessment in 2005 (Key et al. 2005) using SS2 (version 1.19). The assessment was
 1308 sensitive to the CPFV onboard observer index of abundance (referred to as Deb Wilson-
 1309 Vandenberg's onboard observer index in this assessment). The final decision table was based
 1310 around the emphasis given to the index. The stock was found to be at 97% depletion.

1311 2.2.2 2005 Assessment Recommendations

assessment-recommendations

1312 The 2005 STAR panel only had one recommendation specific to gopher rockfish. However,
 1313 they had a number of generic rockfish recommendations that can be found in the STAR
 1314 panel report available [here](#).

1315 **Recommendation 1: Additional length and age composition data should be**
1316 **collected for gopher rockfish. This would help to characterize spatial and**
1317 **possibly temporal variation in growth**

1318

1319 2019 STAT response: Additional age and length data have been collected from a num-
1320 ber of sources, the majority of which have been fishery-independent studies, including
1321 two master's theses focused on gopher rockfish. Only a handful of otoliths have been
1322 collected for gopher rockfish south of Point Conception. Additional length composition
1323 data are available since the last assessment.

1324 **2.3 Model Description**

model-description

1325 The model descriptions in the following sections reflect decisions and modelling choices the
1326 STAT team made prior to the STAR panel. Changes from the pre-STAR base model to the
1327 final post-STAR base model are documented in the “Responses to the Current STAR Panel
1328 Requests” section. During the STAR panel, the following structure change were made; 1) the
1329 commercial retained and commercial discard fleets were combined into one commercial fleet,
1330 2) the MRFSS recreational dockside and the CRFS recreational onboard indices south Point
1331 Conception were removed, 3) the PISCO index was split into two indices, one representing
1332 fish 15 cm and larger and an age-0 index representing fish 6 cm or less. All of the figures
1333 and tables reflect the post-STAR final base model. The section on the PISCO index of
1334 abundance has been updated to reflect the change in the indices.

1335 While investigating convergence issues in the cowcod assessment, Richard Methot (NMFS)
1336 identified an issue with the performance of the ‘sfabs’ function in ADMB. This led to poor
1337 convergence during the iterative search for F_{SPR} under certain conditions. Dr. Methot
1338 resolved the issue, and provided a new ‘safe’ version of SS (V3.30.13.09) to the cowcod and
1339 GBYR STATS on June 28, followed by an optimized executable on June 30. Apart from the
1340 iterative F_{SPR} search mentioned above, other model outputs and analyses were unaffected
1341 by the change. All of the base model results were run in this newest version of SS.

1342 **2.3.1 Transition to the Current Stock Assessment**

transition-to-the-current-stock-assessment

1343 The first formal stock assessment for gopher rockfish was conducted in 2005 (Key et al.
1344 2005). There are two major differences between the 2005 assessment this assessment, 1) this
1345 assessment models gopher and black-and-yellow rockfish as a complex, and 2) this assessment
1346 includes the area south of Point Conception.

1347 The 2005 model conducted in SS2 version 1.19 was first transitioned to SS3.24z as a bridge
1348 model, before moving forward to SS3.30. Below, we describe the most important changes
1349 made since the last full assessment in 2005 and explain rationale for each change. Some of

1350 these items are changes due to structure changes with Stock Synthesis, and some denote
1351 parameters chosen for options that were not available in SS2 (version 1.19).

1352 Changes in the bridge model from SS2 version 1.9 to SS3.24z and SS3.30.13.09 include:

1353 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 (A_{min}) as linearly increasing from the initial length bin to the length given by the $L_{at}A_{min}$ 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 51). 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).

1363 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 52). 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 we're modelling two species as a complex with differing depth-dependent discard mortality rates, the time series of commercial discards was incorporated as a fleet.

1378 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 53). 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.

1387 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).

1389 Differences in both the recreational and commercial catches used in this assessment are
1390 described in detail in Section 1.5.

1391 The bias adjustment for recruitment deviations did not exist in SS2 (version 1.19). We set
1392 1973-2015 as the range of years with full bias adjustment to span the time series that was
1393 modeled.

1394 The previous assessment modeled selectivity of the commercial fleet as logistic curve, and
1395 both parameters for the logistic selectivity were estimated. Selectivity for both the recre-
1396 ational fleet and onboard CPFV survey were modeled using the double logistic. The current
1397 assessment uses the six parameter double normal for all fleets for which selectivity is es-
1398 timated and not mirrored. The MRFSS dockside CPFV surveys and the CPFV onboard
1399 observer surveys are mirrored to the recreational fishing fleets, north and south of Point
1400 Conception, respectively.

1401 The 2005 assessment did not include any time blocks. This assessment includes two time
1402 blocks for the commercial fleet (1916-1998 and 1999-2018). A 10-inch minimum size limit
1403 was placed on the commercial fleet in 1999, which was reflected in the CALCOM length
1404 composition data. No additional time blocks were added for the recreational fleet. GBYR
1405 are a minor component of the nearshore rockfish complex and no significant changes were
1406 detected in the landings or length composition during the time when regulations changed
1407 (1999-2002).

1408 The 2005 assessment considered two candidate fishery-dependent indices of abundance, the
1409 Deb Wilson-Vandenberg onboard observer CPFV survey and a dockside intercept survey
1410 from MRFSS and RecFIN from 1983-2003. However, the dockside index was removed at the
1411 request of the STAR panel, citing “did not provide a reliable measure of relative abundance
1412 due to changes in regulations and fishery targeting during the 1990s-2000s.” The current
1413 assessment uses a version of the MRFSS database that has been more robustly aggregated
1414 to the trip level. Starting in 1999, the CDFW began angler interviews. Interviews are
1415 conducted for all the anglers on the boat, whereas the onboard data is only collected for a
1416 subset of anglers that changes with each fishing stop. Once the onboard observer program
1417 ramped up by the mid-2000s, almost all of the CPFV groundfish trips sampled as onboard
1418 observer trips were also sampled as angler interviews. Using both the onboard observer data
1419 and the dockside interviews for this time period would result in developing indices from the
1420 same fish. The fine-scale onboard observer data provides greater detail in terms of catch and
1421 location than the angler interviews. The onboard observer indices do not include the years
1422 1999 and 2000 due to the number of regulation changes occurring in those two years.

1423 The fishery-independent indices are all new for this assessment; the PISCO kelp forest fish
1424 survey and the CCFRP hook-and-line survey.

1425 Maturity was changed for this assessment based upon newly available data described in the
1426 biological specifications of this assessment.

1427 The 2005 assessment pre-STAR base model fixed steepness for gopher rockfish at 1.0, which
1428 was then changed to 0.65 (the Dorn prior at the time) during the STAR panel. In this
1429 assessment, steepness was set at 0.72, the mean of the prior developed from a meta-analysis of
1430 West Coast groundfish, with a standard deviation of 0.16 (see Accepted Practices Guidelines
1431 for Groundfish Stock Assessments in the supplemental material).

1432 The prior for female natural mortality was updated to the median of the prior from a meta-
1433 analysis conducted by Owen Hamel (see Accepted Practices Guidelines for Groundfish Stock
1434 Assessments in the supplemental material). Assuming a maximum age of 28 years, the
1435 median of the prior is 0.193, close to the fixed value used in the 2005 assessment of 0.2.

1436 Due to the fact that the 2005 model only included gopher rockfish and excluded the area
1437 south of Point Conception, a complete bridge model was not developed. Comparison of
1438 the 2005 input data, catch streams, and indices are provided throughout the document in
1439 appropriate sections.

1440 2.3.2 Summary of Data for Fleets and Areas

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

1441 There are 10 fleets in the post-STAR base model. They include:

1442 *Commercial*: There is one commercial fleet the includes GBYR landed (all gears combined)
1443 and dead discards.

1444 *Recreational*: The recreational fishery include two fleets, one for north of Point Conception
1445 and one for south of Point Conception (all modes combined).

1446 *Fishery-Dependent Surveys*: There are five fishery-dependent survey fleets, all north of Point
1447 Conception. There is one for MRFRSS CPFV dockside survey, one for the CDFW/Cal Poly
1448 onboard observer survey, and one from the Deb Wilson-Vandenberg CPFV onboard observer
1449 survey.

1450 *Research*: There are two main sources of fishery-independent data available the CCFRP
1451 survey and the PISCO kelp forest fish survey. The PISCO survey was split into two indices
1452 in the post-STAR base, one representing age-0 recruitment and one for fish 15+ cm. A third
1453 survey fleet is included as a “dummy” fleet to allow incorporation of additional conditional
1454 age-at-length composition data from the Zaitlin and Abrams theses, the Pearson groundfish
1455 cruise, and the special study conducted during the SWFSC’s juvenile rockfish and ecosystem
1456 cruise. This dummy fleet includes 1,067 ages of gopher and black-and-yellow rockfish. This
1457 dummy fleet does not have any length composition data or catches associated with it.

1458 **2.3.3 Other Specifications**

other-specifications

1459 Stock synthesis has a broad suite of structural options available. Where possible, the ‘default’
1460 or most commonly used approaches are applied to this stock assessment. The assessment
1461 is a one-sex model, as no significant differences in growth between males and females was
1462 detected in external analyses.

1463 The length composition data for some years and fleets was small, and may not be represen-
1464 tative of the total catch. Length composition data were removed from the model if fewer
1465 than 20 fish were measured in a given year and fleet. From 1985-1989, two surveys measured
1466 fish from the recreational party/charter fleet, the Ally et al. (Ally et al. 1991) onboard
1467 observer survey and the dockside intercept survey. The number of trips and fish sampled by
1468 the onboard observer survey was far greater than the MRFSS survey and were used in the
1469 model. Initial input sample sizes were also capped at 400 for each set of length composition
1470 data.

1471 The time-series of landings begins in 1916 for the commercial fleet and in 1928 for the
1472 recreational fleet. This captures the inception of the fishery, so the stock is assumed to be
1473 in equilibrium at the beginning of the modeled period.

1474 The internal population dynamics model tracks ages 0-28, where age 28 is the ‘plus-group.’
1475 There are relatively few observations in the age compositions that are greater than age 28.
1476 The population length bins and the length composition length bins are set at 1-cm bins from
1477 fish 4-40 cm.

1478 The extra standard deviation parameter was added to all indices except the MRFSS dockside
1479 index for north of Point Conception and the PISCO age-0 index since both had relatively
1480 large estimated variances associated with them. The extra parameter was explored, but
1481 estimated to be on the lower bound, and was removed for the post-STAR base model.
1482 All other indices, including the recreational onboard observer index, CCFRP, and PISCO
1483 (15+ cm fish), were estimated with relatively small variances (10-20%) from their respective
1484 indices. Extra variance was estimated for these indices in the post-STAR base model.

1485 The following likelihood components are included in this model: catch, indices, discards,
1486 length compositions, age compositions, recruitment, parameter priors, and parameter soft
1487 bounds. See the SS technical documentation for details (Methot et al. 2019).

1488 Electronic SS model files including the data, control, starter, and forecast files can be found
1489 on the [PFMC ftp site](#).

1490 **2.3.4 Modeling Software**

modeling-software

1491 The STAT team used Stock Synthesis 3 version 3.30.13.09 (published on 6/28/2019) by
1492 Dr. Richard Methot at the NWFSC. This most recent version was used, since it included

1493 improvements and corrections to older versions. The r4SS package (GitHub release number
1494 v1.35.1) was used to post-process output data from Stock Synthesis.

1495 2.3.5 Data Weighting

data-weighting

1496 Length composition and conditional-age-at-length (CAAL) compositions sample sizes for the
1497 base model were tuned by the “Francis method,” based on equation TA1.8 in Francis (2011),
1498 and implemented in the r4ss package. This approach involves comparing the residuals in the
1499 model’s expected mean length with respect to the observed mean length and associated
1500 uncertainty derived from the composition vectors and their associated input sample sizes.
1501 The sample sizes are then tuned so that the observed and expected variability are consistent.
1502 After adjustment to the sample sizes, models were not re-tuned if the bootstrap uncertainty
1503 value around the tuning factor overlapped 1.0.

1504 As outlined in the Best Practices, a sensitivity run was conducted with length and
1505 conditional-age-at-length (CAAL) compositions were re-weighted using the Ianelli-
1506 McAllister harmonic mean method (McAllister and Ianelli 1997). Additionally, weighting
1507 using the Dirichlet-Multinomial likelihood, that includes and estimable parameter (theta)
1508 that scales the input sample size, was explored. However, the model did not converge when
1509 the Dirichlet-Multinomial likelihood was applied to a number of the fleets with composition
1510 data. Given this, and the current challenges with this method described in the Stock
1511 Synthesis manual (Methot et al. 2019), the Francis weightings were applied in the pre-STAR
1512 and post-STAR base models. The final post-STAR base model was re-weighted twice at
1513 which point the Francis weights stabilized.

1514 A series of sensitivities were conducted to determine the need to estimate extra variability
1515 parameters were estimated and added to the survey CPUE indices, and described below in
1516 the Estimated Parameters section.

1517 2.3.6 Priors

priors

1518 The log-normal prior for female natural mortality were based on a meta-analysis completed
1519 by Hamel (2015), as described under “Natural Mortality.” Natural mortality was estimated
1520 using with a prior of, 0.193 (with log-space sigma of 0.438) for an assumed maximum age of
1521 28. Natural mortality was fixed at the value of the prior in the post-STAR base model.

1522 The prior for steepness (h) assumes a beta distribution with parameters based on an update
1523 for the Thorson-Dorn rockfish prior (Dorn, M. and Thorson, J., pers. comm.), which was
1524 endorsed by the Science and Statistical Committee in 2019. The prior is a beta distribution
1525 with $mu=0.72$ and $sigma=0.16$. Steepness is fixed in the post-STAR base model at the
1526 mean of the prior.

1527 **2.3.7 Estimated and Fixed Parameters**

estimated-and-fixed-parameters

1528 A full list of all estimated and fixed parameters is provided in Table 26. Time-invariant,
1529 growth is estimated in this assessment, with all SS growth parameters being estimated. The
1530 log of the unexploited recruitment level for the Beverton-Holt stock-recruit function is treated
1531 as an estimated parameter. The early annual recruitment deviations begin in 1960, with the
1532 main recruitment deviations estimated from 1972-2018. The survey catchability parameters
1533 are calculated analytically (set as scaling factors) such that the estimate is median unbiased,
1534 which is comparable to the way q is treated in most groundfish assessments.

1535 The post-STAR base model has a total of 61 estimated parameters in the following categories:

- 1536 • Equilibrium recruitment (R_0) and 41 recruitment deviations
- 1537 • Five growth parameters
- 1538 • Four index extra standard deviation parameter, and
- 1539 • Ten selectivity parameters

1540 The estimated parameters are described in greater detail below and a full list of all estimated
1541 and parameters is provided in Table 26.

1542 *Growth.* Five growth parameters were estimated for the one-sex model: three von Bertalanffy
1543 parameters and two parameters for CV as a function of length-at-age related to variability
1544 in length-at-age for small and large fish.

1545 *Selectivity.* Double-normal, asymptotic selectivity was estimated for all fleets with estimated
1546 selectivity parameters.

1547 Three parameters were estimated for the recreational and commercial fleets, the peak, the
1548 ascending width, and the selectivity at the first bin. Only the ascending width parameter
1549 was estimated for the PISCO fleet for fish 15+ cm.

1550 The Deb Wilson-Vandenberg onboard observer fleet and the CCFRP fleet were mirrored to
1551 the recreational fleet north of Point Conception.

1552 *Other Estimated Parameters.* Main recruitment deviations estimated from 1978 to 2018.
1553 The post-STAR base model also included estimated recruitment deviations for the forecast
1554 years, although these have no impact on the model estimates for the current year.

1555 Many variations of the base case model were explored during this analysis. Sensitivities to
1556 asymptotic vs. domed selectivity were explored for the appropriate fisheries, e.g. commercial
1557 fisheries and surveys, as well as estimating selectivity and mirroring fleet selectivities. Time

1558 blocked selectivity without the time block from 1999-2019 for the recreational fisheries was
1559 investigated.

1560 Much time was also spent tuning the advanced recruitment bias adjustment options.
1561 Sensitivities were performed to each of the thirteen advanced options for recruitment, e.g.,
1562 early recruitment deviation start year, early recruitment deviation phase, years with bias
1563 adjustments, and maximum bias adjustment. The final base model sets the first year of
1564 recruitment deviations just prior to when the majority of fishery/survey length composition
1565 are available.

1566 Several models were also investigated where steepness and natural mortality were either
1567 estimated, fixed at their respective priors.

1568 *Other Fixed Parameters.* The stock-recruitment steepness is fixed at the SSC approved
1569 steepness prior for rockfish of 0.72 and natural mortality is fixed at 0.193, the mean of the
1570 prior.

1571 **2.4 Model Selection and Evaluation**

model-selection-and-evaluation

1572 **2.4.1 Key Assumptions and Structural Choices**

key-assumptions-and-structural-choices

1573 Key assumptions in the model are that it is appropriate to model gopher and black-and-
1574 yellow rockfish as a complex. The catch histories are inseparable at this time, especially for
1575 the early commercial landings. The biological information available also precluded complete
1576 analyses of difference in growth, i.e., the majority of black-and-yellow rockfish aged were
1577 small fish and small fish were lacking for gopher rockfish. Data from both species were used
1578 to provide a complete picture of the growth curve.

1579 The assessment is a one area model with fleets as areas for the recreational fishery. There
1580 were only a handful of aged gopher rockfish from south of Point Conception, and not enough
1581 other biological information available that would have justified a multi-area model.

1582 **2.4.2 Alternate pre-STAR Models Considered**

alternate-pre-star-models-considered

1583 A number of models were run with different catch histories for the recreational fleet south of
1584 Point Conception, given that the catch histories were modified from the original data. None
1585 of the alternatives explored altered the model at any significant level due to the fact that
1586 the recreational catches south of Point Conception are relatively small. Results from select
1587 sensitivity runs compared to the base model are in Table 27.

1588 Two sensitivities were also performed altering the commercial discard catch history. The
1589 discard catch was set to zero for all years prior to 2004, the year when WCGOP estimates

1590 were first available, and to a constant rate of 17% of the commercial landings, the maximum
1591 discard rate observed in the WCGOP data. Neither of these sensitivities resulted in any
1592 significant change to the model outputs.

1593 Sensitivity of the model to the spawning and settlement months were also explored. The
1594 base model originally set settlement month to January. Both gopher and black-and-yellow
1595 rockfish settle at a small size (~2 cm) and over a course of several months. After exploring the
1596 young-of-the-year length data made available by Diana Baetscher, the timing of settlement
1597 was moved to July for the base model, when the majority of GBYR are 4 cm, the size of the
1598 smallest length bin. The change of the timing of settlement had little effect on the model
1599 results.

1600 Runs of the base case model estimating steepness were also considered.

1601 A sensitivity of the model to using the commercial length composition data from PacFIN
1602 was also considered. The fits changed only slightly, (increasing depletion from 0.46 to 0.48)
1603 but given the concerns outlined in the discussion on commercial length composition the base
1604 model includes the commercial length compositions from CALCOM.

1605 Sensitivities were developed to look at alternate selectivity patterns for the the commercial
1606 discard fleet and the CCFRP survey. Neither of the length compositions for these fleets
1607 observed larger fish. A time block for the commercial discard fishery was not considered
1608 since no length composition of discarded fish were available prior to 2004.

1609 **2.4.3 Uncertainty and Sensitivity Analyses to the pre-STAR base** **uncertainty-and-sensitivity-analyses-to-the-pre-star-base**

1610 A number of sensitivity analyses were conducted prior to the STAR panel, including:

- 1611 1. Fixing natural mortality at the prior of 0.193
- 1612 2. Fixing the von Bertalanffy k at the external estimate of 0.247
- 1613 3. Using the PacFIN expanded length composition data
- 1614 4. Data weighting scenarios including unweighted, harmonic means (McAllister-Ianelli
1615 method), and Francis weights

1616 The following sensitivities are based on the pre-STAR base model and indicate areas that the
1617 STAT identified as either areas of uncertainty or model sensitivities outlined in the Accepted
1618 Practices and Guidelines document. A summary of parameters for all sensitivity runs is in
1619 Table 27.

1620 Fixing either natural mortality or the von Bertalanffy k parameter results in a stock with
1621 higher spawning output in 2018 as compared to the base model (Figure 42).

1622 Fixing either M or k demonstrates the negative correlation between the two parameters. The
1623 von Bertalanffy k parameter is estimated at 0.12 when natural mortality (estimated at 0.21)
1624 and growth are both estimated. When natural mortality is fixed at the prior of 0.193, k is
1625 estimated at 0.14, but the two other growth parameters, L_1 and L_2 do not change much at
1626 all. When k is fixed to the external estimate of 0.247, natural mortality is estimated at 0.16,
1627 and the other growth parameters both decrease. A number of additional sensitivities to the
1628 growth parameters will be presented at the STAR panel.

1629 Replacing the CALCOM commercial length composition data with the PacFIN length com-
1630 position results in the stock at an overall lower level of biomass than the base model. Deple-
1631 tion in the final year with the PacFIN length composition is 0.50, compared to 0.46 in the
1632 base model. A detailed discussion on the decision to use the CALCOM length composition
1633 in the base model can be found in the discussion commercial length and age data, Section
1634 (2.1.3).

1635 Data weighting is an area of uncertainty for stock assessment, and research is ongoing to
1636 determine the effects of data weighting and the most appropriate initial sample sizes for
1637 length and age composition data. The base model used the Stewart sample sizes for initial
1638 sample sizes for the fishery data and either the Stewart sample sizes or number of “trips” for
1639 the survey sample sizes. Weighting the data by the harmonic mean resulted in a model with
1640 a total likelihood between the base model, which uses the Francis method for weighting, and
1641 the model with default weights (Figure 43). The end year spawning output is almost identical
1642 for the models using harmonic means and Francis weights, both of which down-weighted the
1643 composition data.

1644 The Francis weights in the base model were stable, and did not tend to serially decrease
1645 (down-weight) any of the data sets, which has been seen in other assessments. The final
1646 base model re-weights the composition data only once. As discussed above in the data
1647 weighting section, the Dirichlet-Multinomial weighting was explored, but a model with a
1648 positive definite Hessian was not identified with the pre-STAR base model.

1649 2.5 Response to the Current STAR Panel Requests

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

1650 **Request No. 1:** Develop catch curves from age data as appropriate during
1651 different periods of fishing intensity according to the model.

1652

1653 **Rationale:** To obtain an independent estimate of total mortality to better gauge
1654 natural mortality given the model uncertainty.

1655 **STAT Response:** The STAT created two catch curves using the available age data for
1656 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 44). 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 45). 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 46). 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.

1698 **Request No. 4:** Split PISCO survey such that the 0-age fish (4 and 5 cm) are
1699 in one survey and the 15 cm+ fish are in the other. Fix age selectivity to
1700 age-0 only for the first fleet and use a logistic selectivity for the second fleet.
1701

1702 **Rationale:** To separate out the recruitment index in the survey and to simplify the
1703 selectivity assumptions for this fleet.

1704 **STAT Response:** Response under Request #4a.

1705 **Request No. 4a: Include all years of the recruitment index developed above.**
1706

1707 **Rationale:** Years with low numbers of 4 and 5 cm fish indicate low recruitment and
1708 provide contrast to years with large numbers of those fish.

1709 **STAT Response:** The STAT developed an index of abundance using only fish that
1710 were 5 cm or less and re-developed the length composition data for the PISCO survey
1711 representing fish 15 cm and larger. The effect of splitting the PISCO index into two
1712 indices, one for young of the year and one representing older fish resulted in dampening
1713 of the age-0 recruits seen in the previous models (Figure 47). This was seen as a weak-
1714 ness in the model due to high uncertainty in the estimates due to limited compositional
1715 evidence of such an extended period of improved recruitment. The appropriateness of
1716 the size cutoff was investigated further in Request 8.

1717 **Request No. 5: Remove the autocorrelation recruitment.**
1718

1719 **Rationale:** Given the sensitivity run presented, auto correlation didn't make much
1720 of a difference in model results, and there was not adequate evidence in the data for
1721 autocorrelation.

1722 **STAT Response:** Removing the autocorrelation in recruitment resulted in no sig-
1723 nificant change to the model output. There was little evidence for autocorrelation in
1724 recruitment in the stock or that it provided much in the way of stability to the model,
1725 it was therefore decided that the assessment should not implement this option.

1726 **Request No. 6: 1) Start recruit deviation in 1978 as main recruit devs. and 2)**
1727 **Start these in 2001. Turn off all early recruit devs in both cases.**
1728

1729 **Rationale:** The composition data does not seem to be informing the estimates of the
1730 recruitment deviations but maybe driven by the artifacts in the catch data. The early
1731 recruit deviations are uninformed and all in one direction. Recruitment indices start
1732 in 2001.

1733 **STAT Response:** Starting the recruitment deviations in 2001 did not produce a
1734 reasonable recruitment signal. Starting the recruitment deviations in 1978 provided
1735 reasonable recruitment deviations and is a more appropriate starting year given the
1736 lack of sufficient length data prior to this period.

1737 **Request No. 7:** Start from model shown at request 6(1). Fix M at 0.193 and let
1738 the model estimate k. Change the ramp to estimated level with up ramp
1739 from 1978 to 1979. Provide all appropriate diagnostics.

1740

1741 **Rationale:** : STAT and STAR agree 6(1) was an improvement over the original base
1742 model and the request refers to adjusting the ramp value and M treatment consistent
1743 with the way these were dealt with in the original the pre-STAR-base model given the
1744 new settings.

1745 **STAT Response:** Requests 7 and 8 were conducted for comparison and the plots
1746 comparing the two requests are below Request 8. Fixing natural mortality at the
1747 mean of the prior results in an increase in the growth parameter k from 0.145 to 0.147
1748 from Request 6 due to the decrease in the modeled natural mortality rate and the
1749 observed correlation between estimated M and k values.

1750 **Request No. 8:** Determine if 6 cm or larger fish should be included in PISCO
1751 recruitment index. If so, update the PISCO index and include the updated
1752 index in the model from Request 7 (above).

1753

1754 **Rationale:** Better to use all appropriate data for the recruitment index. The panel
1755 felt the splitting of the PISCO index had advantages based on the results from Request
1756 4, but given the temporal variability in the survey over time wanted to ensure that
1757 the size cutoff included the majority of 0-group fish while minimizing the potential to
1758 include 1-group individuals.

1759 **STAT Response:** After an email discussion with Mark Carr, Dan Malone (UCSC
1760 PISCO) and Darren Johnson (CSU Long Beach) it was decided that fish of length 6
1761 cm at the end of the year of birth would still all be young of the year fish during the
1762 months in which the PISCO survey is conducted. Additional research could serve to
1763 verify the appropriate lengths to include, perhaps by month. The PISCO age-0 index
1764 developed for this request (including all fish size 4, 5, and 6 cm) resulted in a decrease
1765 in the recruitment index in the early 2000s, and an increase in the recruitment index in
1766 2010 and from 2014-2018 relative to include only 4 and 5 cm individuals (Figure 48).
1767 The effects on spawning output of the revised PISCO age-0 index of abundance (8b),
1768 and a fix to an issue in the selectivity mirroring, and an additional correction that
1769 fixes the last year of bias adjustment to 2019 and not 2020 (8c) are shown in Figure 6.
1770 With natural mortality fixed at 0.193, the growth parameter k is estimated at 0.114.
1771 The estimate of length at age-2 (L1) is 13.37, similar to the external estimates.

1772 **Request No. 9:** Mirror the DebWV_CPFV selectivity to the RecN selec-
1773 tivity. Fix the start logit parameter for the adult PISCO selectivity to
1774 zero. Investigate appropriate methods for modeling selectivity for CCFRP.

1775

1776 **Rationale:** These will result in more appropriate and parsimonious treatment of se-
1777 lectivity.

1778 **STAT Response:** The selectivity for the CCFRP index was also mirrored to the
1779 Recreational North fleet since the length compositions were not drastically different
1780 than the other fleets mirrored to the Recreational North fleet. The STAT could not
1781 find a domed selectivity pattern that had reasonable parameter estimates. The STAT
1782 also explored fitting asymptotic selectivity to the CCFRP index, but even when fixing
1783 the peak parameter to the upper bound, other parameters were not well estimated.
1784 Mirroring fleet selectivities was an advantage to the stability of the model.

1785 **Request No. 10: Perform a drop one out analysis for the index fleets.**

1786
1787 **Rationale:** To investigate the influence each of these data sets on the model.

1788 **STAT Response:** No single index had a substantial effect on the model output
1789 (Figure 50). Each index contributed to the status of the stock, with some indicating
1790 a an increase over the base model developed for Request 9, and some estimating a
1791 decreased stock status. Depending on which index was dropped, the year(s) of high
1792 recruitment predicted in the early 1990s did shift, and was either attributed to a single
1793 year, or spread over a few years. The PISCO age-0 index does inform recruitment and
1794 age-0 recruitment is dampened n recent years when this index is excluded.

1795 **2.6 Post-STAR Base Case Model Results**

[post-star-base-case-model-results](#)

1796 The following description of the model results reflects a base model that incorporates all
1797 of the changes made during the STAR panel. A comparison of the pre-STAR base model
1798 and the post-STAR base model can be found in Figures 54, 55, and 56 and Table 24. A
1799 number of changes to the fleet structures, removal of surveys south of Point Conception, and
1800 the splitting of the PISCO index into two indices to better reflect life stages contributed to
1801 the changes. The final model also fixes natural mortality, whereas it was estimated in the
1802 pre-STAR base model. The pre-STAR base model includes and ageing error matrix that was
1803 developed using only half of the available double reads. The post-STAR base includes the
1804 updated ageing error matrix (Figure 57), and the update did not significantly change the
1805 model outputs. The remainder of the document referencing the base model (or base case)
1806 refers to the post-STAR base model.

1807 The base model parameter estimates and their approximate asymptotic standard errors are
1808 shown in Table 26 and the likelihood components are in Table 28. Estimates of derived
1809 reference points and approximate 95% asymptotic confidence intervals are shown in Table e.
1810 Time-series of estimated stock size over time are shown in Table 29.

1811 Steepness of the assumed Beverton-Holt stock-recruitment relationship was fixed at 0.72,
1812 and natural mortality was fixed at 0.193.

1813 **2.6.1 Convergence**

convergence

1814 Model convergence was determined by starting the minimization process from dispersed val-
1815 ues of the maximum likelihood estimates to determine if the model found a better minimum.
1816 Jitter is a SS option that generates random starting values from a normal distribution lo-
1817 gistically transformed into each parameter's range (Methot et al. 2019). This was repeated
1818 300 times and the minimum was reached in 67% of the runs (Table 25). The model did not
1819 experience convergence issues, e.g., final gradient was below 0.0001, when reasonable starting
1820 values were used and there were no difficulties in inverting the Hessian to obtain estimates of
1821 variability. We did sensitivity runs for convergence by changing the phases for key estimated
1822 parameters; neither the total log-likelihood nor the parameter estimates changed.

1823 **2.6.2 Parameter Estimates**

parameter-estimates

1824 The base model produces estimates of growth parameters different from the external esti-
1825 mates (Figure 58). The external estimate of the von Bertalanffy growth coefficient k was
1826 0.247, whereas the internal estimate was much lower at 0.107. Using the Schnute param-
1827 eterization with the age for L1 set at 2 and L2 at 23, the external estimates of lengths at
1828 Amin and Amax were similar at 13.80 and 28.22, respectively. The internal estimates of the
1829 lengths for Amin and Amax were 13.4 and 28.80, respectively. Given that natural mortality
1830 was fixed in the base model and natural mortality and the growth parameter k are negatively
1831 correlated, the model estimated a slower rate of growth. A number of other factors including
1832 the lenght composition and selectivity affect the internal estimate of growth. Hence, growth
1833 was chosen as the axis of uncertainty for the decision table.

1834 The estimated selectivities for all fleets within the model are shown in Figure 59. The selec-
1835 tivity curves for the commercial fleet, recreational fleets north and south of Point Conception,
1836 and the larger PISCO (15+ cm) were estimated. All of the selectivities are asymptotic except
1837 for the PISCO age-0 index, which has an age selectivity set to 1.0. All of the recreational
1838 indices and the CCFRP index selectivities were mirrored to the recreational fleet north of
1839 Point Conception. Attempts to fit asymptotic and dome-shaped selectivity to the CCFRP
1840 data resulted in poor estimation, large standard deviations, or a lack of fit to the data. The
1841 aggregated CCFRP length composition over time was similar to the length composition data
1842 of the recreational fleets north of Point Conception and mirroring the CCFRP selectivity
1843 provided a more parsimonious model. The recreational fleet south of Point Conception en-
1844 counters smaller GBYR, which is reflected in the asymptotic selectivity shifted to the left
1845 of all other fleets. Selectivities for the recreational fleet north of Point Conception and the
1846 commercial fleet are very similar. Both fleets include both length composition of retained
1847 and discarded fish, although no information on the size of discards is available from the
1848 commercial fleet prior to 2004. The selectivity for the commercial fleet was kept separate
1849 because the fleet has different fishing behavior than the recreational fleet and going forward
1850 in time, may diverge further from the fleets depending on management decisions or changes
1851 in fishing behavior. Selectivity for the PISCO (15+ cm fish) index was estimated as the

1852 survey observes a wider range of length classes than the other fleets. The estimated peak
1853 of the PISCO selectivity hit the upper bound of 38 and was fixed at 38 in the base model.
1854 The age selectivity for the PISCO age-0 index was fixed at 1.0 and assumes that all age-0
1855 fish are selected.

1856 The additional survey variability (process error added directly to each year's input vari-
1857 ability) for all surveys except the recreational dockside index north of Point Conception
1858 (RecDocksideNorth) and the PISCO age-0 index, was estimated within the model. The
1859 added variance for Deb's onboard observer survey was estimated at 0.06. The added vari-
1860 aces were highest for the recreational onboard observer survey north of Point Conception
1861 (0.237) PISCO (0.152), and CCFRP (0.212).

1862 Recruitment deviations were estimated from 1978-2018 (Figure 60). Estimates of recruitment
1863 suggest that GBYR are characterized by cyclical years of high and low recruitment (Figure
1864 61). The final base model does not include early recruitment deviation and a steep bias
1865 adjustment ramp from 1978 to 1979 of 0.32 that extends to 2019 Figure 62. The years of
1866 highest estimated recruitment is 1991, with recruitment estimated more than double that of
1867 any other year.

1868 Fish from this cohort can be observed in the lenght composition data from Deb Wilson
1869 Vandenberg's onboard observer survey and recreational fleet north of Point Conception in
1870 the later half of the 1990s. Additional periodic recruitment events are estimated from 1994
1871 and onward, with the peaks from 2001 and on driven by the PISCO age-0 index. followed by
1872 a period of below average recruitment, and another high recruitment pulse in the late 2010s.

1873 The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 63.
1874 The stock has not been depleted to a low enough level that would inform the estimation of
1875 steepness. Steepness was not estimated in this model, and profiles over steepness values are
1876 discussed below.

1877 2.6.3 Fits to the Data

fits-to-the-data

1878 Model fits to the indices of abundance, fishery length composition, survey length composition,
1879 and conditional age-at-length observations are all discussed below. The full r4ss plotting
1880 output is available in the supplementary material.

1881 The fits to the three fishery-dependent and three fishery-independent survey indices are
1882 shown in Figures 64, 65, 66, 67, 68, and 69. All indices represent the area north of Point
1883 Conception only, and not all of these were fit well by the assessment model. The MRFSS
1884 CPFV recreational dockside survey index north of Point Conception spanning the 1980s-
1885 1990s was fit well by the model without added variance, but relatively flat, and is not a very
1886 informative index. The index for Deb Wilson-Vandenberg's CPFV onboard observer survey
1887 spanning 1988-1998 was well fit and indicates an increase in relative abundance in the last
1888 year of the survey. The current recreational CRFS/Cal Poly onboard observer survey north

1889 of Point Conception from 2001-2018 was relatively well fit, except for the decline suggested
1890 2013 and 2014. The increase in relative abundance observed in 2018 was not fit by the
1891 model, even with the added variance. The variance added to this survey was the highest for
1892 all indices.

1893 The model did not capture the contrast in the PISCO index for 15+ cm fish, fitting a decline
1894 to the time series from 2010 to 2018, when the index suggests an increase from 2010 to 2013
1895 and another increase after a decline in 2016. The model does capture the PISCO age-0 index
1896 without added variance. A number of years, e.g., 2004-2008, were marked by low relative
1897 abundance of age-0 GBYR and have larger standard errors. The years with lower relative
1898 abundance were not captured by the model, but fit to the upper bound of the input standard
1899 error. The increases in age-0 GBYR in 2001, 2001, 2014-2015 and 2017 were captured in the
1900 model fit.

1901 The model was not able to capture the trends observed in the fishery-independent CCFRP
1902 hook-and-line survey. The index suggested the same depressed relative abundance in 2013 as
1903 the fishery-dependent CRFS/Cal Poly onboard observer survey, that was also not captured
1904 here by the fit. The increasing trends in abundance from 2016-2018 was also not captured
1905 by the model fit, and the fit suggests a declining trend over the entire time series from
1906 2007-2018.

1907 The base model was re-weighted twice using Francis weights for the length and age compo-
1908 sition data. Fits to the length data are shown based on the proportions of lengths observed
1909 by year and the Pearson residuals-at-length for all fleets. Detailed fits to the length data
1910 by year and fleet are provided in Appendix 8. Aggregate fits by fleet are shown in Figure
1911 70. Overall, the length composition all fit well. The PISCO fleet has the noisiest of all the
1912 length composition data, but on an annual basis, the length data were relatively well fit.
1913 The fit to the aggregated CCFRP data suggests the model expects to see additional larger
1914 fish, which is likely due to the mirroring of the selectivity. However, on an annual basis,
1915 there is a trade-off with the CCFRP with under-fitting of the larger fish in the earlier years
1916 and an under-fitting of the smaller fish expected in the later years (2013-2018).

1917 The mean age of the recreational fleet varied from 1980-1986 ranging from approximately
1918 8-11, and increased in 2017 to approximately 13 (Figure 71). The conditional age data from
1919 the CCFRP data was not well fit for the earliest years in the data, but was reasonably well
1920 fit for the last four years of data (Figure 72). The conditional length composition data from
1921 the ‘dummy’ fleet was well fit, although heavily down-weighted. Age data in this fleet are
1922 from a number of sources and sampling programs (Figure 73).

1923 2.6.4 Retrospective Analysis

retrospective-analysis

1924 A 4-year retrospective analysis was conducted by running the model using data only through
1925 2017 (retro 1), 2016 (retro 2), 2015 (retro 3), and 2014 (retro 4) (Table 30). The initial popu-
1926 lation size and estimation of trends in spawning biomass in the retrospective runs were lower

1927 than the base model, except for retro 1 (Figure 74). All retrospective runs followed the same
1928 general trend, with the differences in the trends stemming from the change in recruitment
1929 deviations (Figure 75). The PISCO age-0 index has a signal of increased recruitment in
1930 the most recent years. For Retro2, Retro3, and Retro4, the trends in recruitment are not
1931 observed by the model. There is no conditional age-at-length composition data for 2015-
1932 2016, leading to the minor change in the age composition likelihood from Retro2 to Retro3
1933 and Retro4 (Table 30). The age composition data in 2017 accounts for 2.5% of all available
1934 ages, and 4.5% of all fish aged were from 2018. The available length data in each year from
1935 2015-2018 range from 4-6% of the total available length data. The length compositions of all
1936 the other fleets have similar length distributions for 2015-2018 (8). Additional investigations
1937 into the retrospective patters will be made by the STAT.

1938 2.6.5 Likelihood Profiles

likelihood-profiles

1939 Likelihood profiles were conducted for R_0 , steepness, and over natural mortality values sep-
1940 arately with the post-STAR base. These likelihood profiles were conducted by fixing the
1941 parameter at specific values and estimated the remaining parameters based on the fixed
1942 parameter value (Tables 31-32).

1943 In regards to values of R_0 , the negative log-likelihood was minimized at approximately
1944 $\log(R_0)$ of 8.0 (Table 31 and Figure 78). In terms of likelihood components, only the index
1945 data minimize at the upper bound, while the other components minimize between 8.0 and
1946 8.1. The individual surveys tend to minimize at the upper bound or just below, while the
1947 length composition data has conflicting trends, e.g., CCFRP and commercial fleets minimize
1948 at the upper bound while the recreational north fleet minimizes at the lower bound (Figures
1949 76-77). The majority of data all consistently minimize around 8. Over the range of values
1950 of R_0 , depletion ranged from 0.38-0.59 (Figure 79).

1951 For steepness, the negative log-likelihood reaches a minimum around a steepness near the
1952 upper bound of 1.0 (Figure 82 and Table 31 and Figure 87). The length composition like-
1953 lihood components declined towards the upper bound for Deb's onboard CPFV survey and
1954 the recreational north fleet, while the other fleets either reached a minimum around 0.55 or
1955 at the lower bound (Figure 80). Overall changes in the survey likelihood across the range
1956 of steepens was less than 2.0, with surveys either minimized at the lower or upper bound
1957 (Figure 81). The relative depletion for GBYR ranges from 0.375 to 0.493 across different
1958 assumed values of steepness (Table 31).

1959 The negative log-likelihood was minimized at a natural mortality value around 0.21, slightly
1960 higher than the prior of 0.193 (Table 31 and Figure 86). The age, length, index, and prior
1961 likelihood contributions were minimized at natural mortality values around 0.22, and the
1962 recruitment contribution was minimized at the upper bound. (Table 31). The length com-
1963 position minimizes around a natural mortality value of 0.14, with the commercial, recre-
1964 ational fleet north of Point Conception, and CCFRP data minimizing towards the lower

1965 bound (Figure 84). The length data from Deb's CPFV survey minimizes around 0.22, while
1966 the PISCO and recreational length compositions south of Point Conception minimize at the
1967 upper bound. The PISCO and CCFRP surveys minimized around a natural mortality value
1968 of 0.22, while the PISCO age-0 and overall survey likelihood minimized at the upper bound
1969 of 0.3 (Figure 85). The relative depletion for GBYR ranged from 0.32-0.59 across alternative
1970 values of natural mortality (Figure 87).

1971 2.6.6 Reference Points

reference-points-1

1972 Reference points were calculated using the estimated selectivities and catch distribution
1973 among fleets in the most recent year of the model, (2017). Sustainable total yield (landings
1974 plus discards) were 134 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95%
1975 confidence interval of 116 mt based on estimates of uncertainty. The spawning biomass
1976 equivalent to 40% of the unfished level ($SB_{40\%}$) was 504 mt.

1977 The predicted spawning output from the base model shows an initial decline starting the
1978 1950s, is then stable, and declines steeply until 1995 (Figure 88). The spawning output then
1979 rapidly increases through the early 2000s, and has been in a decline since 2006.

1980 The 2018 spawning biomass relative to unfished equilibrium spawning biomass is above the
1981 target of 40% of unfished levels (Figure 89). The relative fishing intensity, $(1 - SPR)/(1 -$
1982 $SPR_{50\%})$, was below the management target from 1981-1998, and below the minimum stock
1983 size threshold in 1995. The stock has been above the management target since 1999.

1984 Table e shows the full suite of estimated reference points for the base model and Figure 90
1985 shows the equilibrium curve based on a steepness value fixed at 0.72.

1986 3 Harvest Projections and Decision Tables

harvest-projections-and-decision-tables

1987 This section will be copied from the Executive Summary once decision tables are finalized
1988 after the groundfish SSC meeting in August 2019.

1989 4 Regional Management Considerations

regional-management-considerations

1990 While the proportion of the stock residing within U.S. waters is unknown, the assessment
1991 provides an adequate geographic representation of the portion assessed for management
1992 purposes. There is little evidence that black-and-yellow rockfish extend into Mexico, and
1993 the proportion of gopher rockfish residing south of Pt. Conception is small. While there has

1994 been work on the genetic structure between the two species, there has not been work done
1995 within each species to inform spatial structure of the populations. Given the relatively small
1996 area in the waters of California where these species occur, there is relatively little concern
1997 regarding exploitation in proportion to the regional distribution of abundance in the area
1998 assessed in this study.

1999 The state of California implements regional management for the recreational fleet in the form
2000 of five regions, referred to as management areas with differing depth and season restrictions.
2001 Neither gopher nor black-and-yellow rockfish are a large component of the total recreational
2002 landings and are managed as part of the
2003 nearshore rockfish complex. Current regional management appears appropriate for these
2004 species.

2005 **5 Research Needs**

research-needs

2006 This section will be copied from the Executive Summary after further discussions.

2007 **6 Acknowledgments**

acknowledgments

2008 We gratefully acknowledge input and review from the STAR panel including the Owen
2009 Hamel (STAR panel chair; Northwest Fisheries Science Center, NMFS, NOAA), Chantel
2010 Wetzel(Northwest Fisheries Science Center, NMFS, NOAA), Sven Kupschus (Center for
2011 Independent Experts), and Robin Cook (Center for Independent Experts). Thanks to Don
2012 Pearson for reading all of the gopher and black-and-yellow rockfish before retiring in 2018.
2013 We thank John Field, John Budrick, Rebecca Miller, and Emma Saas for contributions to the
2014 assessment document. A special thanks to the PISCO and CCFRP programs for conducting
2015 and providing the available fishery-independent data used in the assessment. Thank you
2016 to everyone who answered my countless emails regarding your survey methodologies and
2017 datasets.

7 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

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	Source
			Commercial Removals	
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	Source
			Commercial Removals	
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.

Year	CALCOM		WCGOP		Rec North		Rec South		Deb VW		tab:length_samples_fishery
	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

tab:Rec_removal

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
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

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tab:Rec_removal

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
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: Length composition sample sizes for survey data.

Year	CCFRP		PISCO	
	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 5: 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.

Fleet	Years	Name	Fishery ind.	Filtering	Method	tab:Index_summary
				Central	Delta	Endorsed
4	1988-1998	Deb Wilson-Vandenberg's Onboard Observer Survey	Fishery-dependent	California	Delta lognormal	SSC
5	2001-2018	CRFS CPFV Onboard Observer Survey	Fishery-dependent	North of Pt. Conception	Delta lognormal	SSC
				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
57				North of Pt. Conception	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 6: Index inputs.

tab:Indices

Year	Deb WV		MRFSS N		MRFSS S		Onboard N		Onboard S		CCFRP		PISCO 15+cm		PISCO age-0	
	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 7: Data filtering steps for Deb Wilson-Vandenberg's CPFV onboard observer index of abundance

Filter	tab:Fleet5_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 8: Model selection for Deb Wilson-Vandenberg's CPFV onboard observer index of abundance. Bold values indicate the model selected.

Model	Lognormal	Binomial	tab:Fleet5_AIC
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 9: Data filtering steps for the CRFS CPFV onboard observer index of abundance for north and south of Pt. Conception.

Filter	tab:Fleet6_7_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 10: Model selection for the CRFS CPFV onboard observer index of abundance for north of Pt. Conception. Bold values indicate the model selected.

Model	Lognormal	Binomial	tab:Fleet6_AIC
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 11: Model selection for the CRFS CPFV onboard observer index of abundance for south of Pt. Conception. Bold values indicate the model selected.

Model	Lognormal	Binomial	tab:Fleet7_AIC
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 12: Data filtering steps for the PISCO dive survey.

Filter		tab:Fleet8_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 13: Model selection for the PISCO dive survey data.

Model	AIC	tab:Fleet8_AIC
Year	5,687	
Year + Month	5,672	
Year + Month + Site	5,623	
Year + Month + Site + Zone	5,512	

Table 14: 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 15: 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 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 MRFSS dockside intercept survey index of abundance for north and south of Pt. Conception.

Filter	Trips	Positive Trips	tab:Fleet10_11_Filter
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 19: 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 20: Model selection for the MRFSS dockside intercept survey south of Pt. Conception. Bold values indicate the model selected.

Model	Lognormal	Binomial	tab:Fleet11_AIC
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 21: Contingency table for the Stephens-MacCall filtering for the MRFSS dockside CPFV index for GBYR north of Pt. Conception.

	GBYR absent	GBYR present	tab:Fleet10_contingency
Above 0.4	186	437	
Below 0.4	1982	183	

Table 22: Contingency table for the Stephens-MacCall filtering for the MRFSS dockside CPFV index for GBYR south of Pt. Conception.

	GBYR absent	GBYR present	tab:Fleet11_contingency
Above 0.22	246	184	
Below 0.22	6647	257	

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

Project	Source	Years	Region	Gear	Black-and-yellow	Gopher	tab:Age_data
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 CPFFV 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: Comparison of ket parameters and likelihood components from the pre-STAR base model and the post-STAR base model.

Parameter	Value	tab:preSTAR_postSTAR_compare 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 25: Results from 100 jitters from the base case model.

Description	Value	<code>tab:jitter</code>
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 26: 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

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Table 26: 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)	OK	0.078	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)	OK	0.078	None
94	LnQ_base_PISCOage(10)	-10.187	-1	(-15, 15)	OK	0.078	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)	OK	0.108	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)	OK	0.108	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)	OK	0.971	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)	OK	0.055	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)	OK	0.055	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)	OK	0.951	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)	OK	0.238	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)	OK	1.592	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)	OK	1.592	None
113	SizeSel_P1_DebCPFV(4)	-1.000	-5	(-1, 10)	OK	1.592	None
114	SizeSel_P2_DebCPFV(4)	-1.000	-5	(-1, 10)	OK	1.592	None
115	SizeSel_P1_RecOnboardNorth(5)	-1.000	-5	(-1, 10)	OK	1.592	None
116	SizeSel_P2_RecOnboardNorth(5)	-1.000	-5	(-1, 10)	OK	1.592	None
117	Size_DbLN_peak_PISCO(6)	38.000	-5	(19, 38)	OK	1.592	None

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Table 26: 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)	OK	0.085	None
119	Size_DbLN_ascend_se_PISCO(6)	4.699	5	(-9, 10)			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

Table 27: Sensitivity of the base model to alternative assumptions about natural mortality, growth, and using PacFIN-derived length composition data.

Label	Base model (Francis weights)	Fix M at prior	Fix k at external est.	PacFIN length comps	Default weighting	tab:Sensitivity_model1 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	112.00	112.00	112.00	112.00

Table 28: Likelihood components from the base model.

Likelihood component	Value	tab:like_components
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	
Parameter soft bounds	9.750E-04	

Table 29: 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

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Table 29: 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
1953	1885	1112	0.882	3085	55	0.03	0.83
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

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Table 29: 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
1990	1274	672	0.533	3596	136	0.11	0.55
1991	1269	652	0.517	11997	175	0.14	0.50
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 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.

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
Equilibrium 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 ($\ln R_0$) and steepness. Depletion and SPR ratio are for the year 2019.

Label	R07500	R07750	R08000	R08250	R08500	h0390	h0550	h0710	h0850	tab:like_profiles 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
$\ln R_0$	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. Depletion and SPR ratio are for the year 2019.

Label	M0140	M0180	M0220	M0260	M0300
Female M	0.14	0.18	0.22	0.26	0.30
Steepness	0.72	0.72	0.72	0.72	0.72
InR0	7.61	8.16	8.70	9.25	9.80
Total unfished biomass (mt)	2325.92	2290.85	2396.04	2613.52	2993.24
Depletion	0.32	0.40	0.47	0.54	0.59
SPR ratio	0.97	1.00	1.00	1.00	1.00
Female Lmin	9.43	9.57	9.69	9.76	9.76
Female Lmax	27.91	28.09	28.51	28.92	29.46
Female K	0.18	0.15	0.12	0.09	0.07
Negative log-likelihood					
TOTAL	520.87	517.09	516.39	517.29	518.96
Catch	0.00	0.00	0.00	0.00	0.00
Survey	-31.78	-32.25	-32.13	-31.84	-31.48
Length_comp	373.35	372.68	372.45	372.59	372.88
Age_comp	191.76	189.93	189.56	189.86	190.58
Recruitment	-12.73	-13.28	-13.54	-13.57	-13.53
Parm_priors	0.27	0.01	0.04	0.23	0.51
Parm_softbounds	0.00	0.00	0.00	0.01	0.01

2019 **8 Figures**

figures

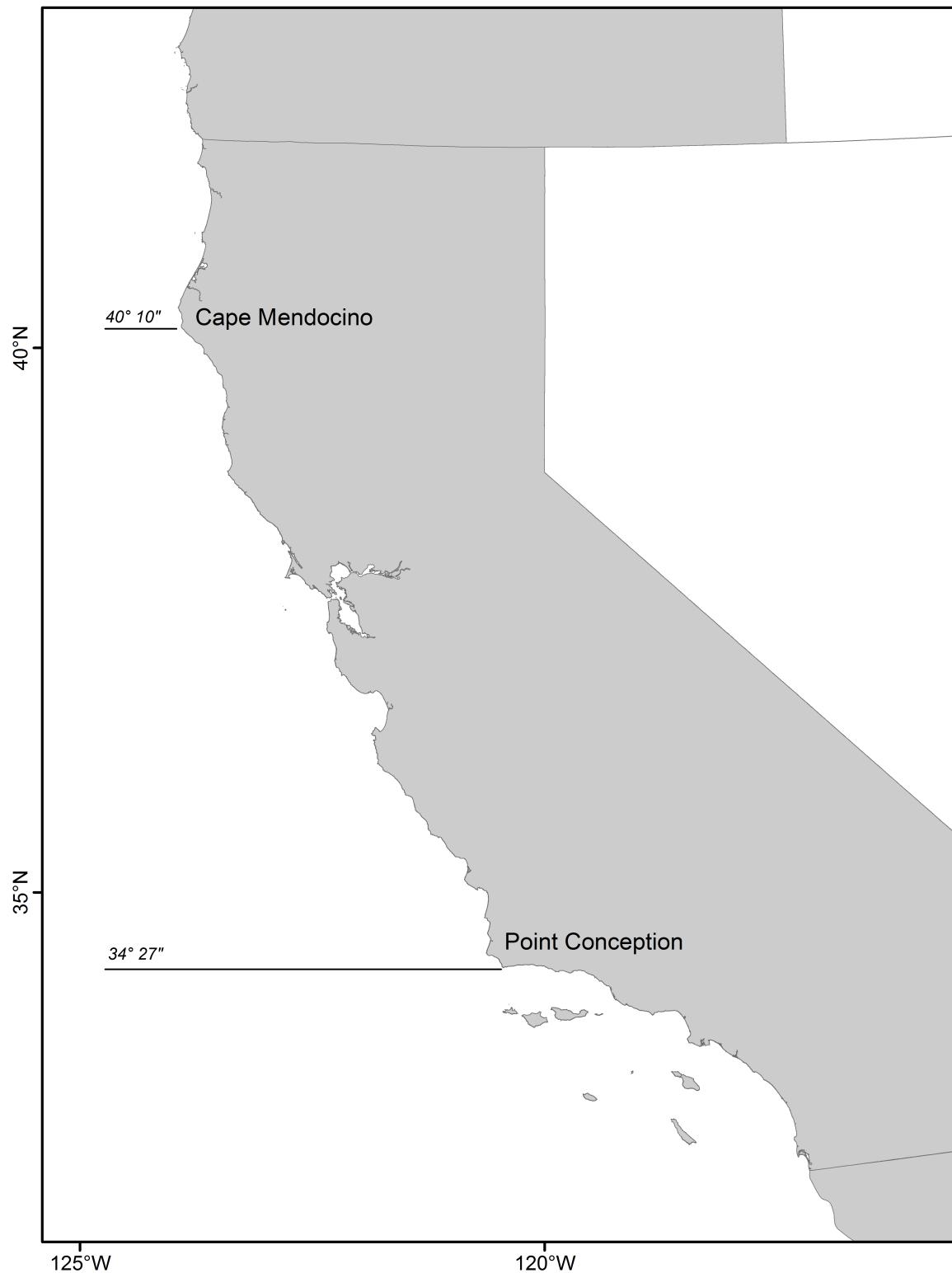


Figure 1: Map showing the management area for gopher and black-and-yellow rockfish from Cape Mendocino to the U.S.-Mexico border. fig:assess_region_map1

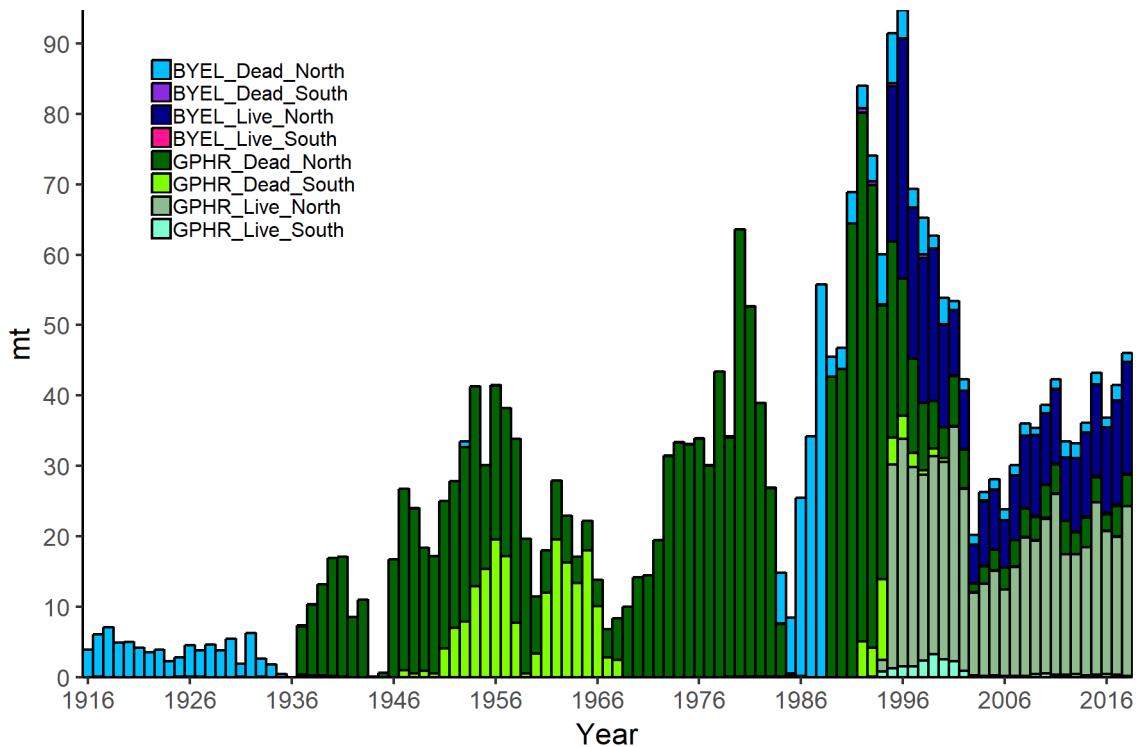


Figure 2: Commercial landings for gopher (GPHR) and black-and-yellow (BYEL) rockfishes landed live and dead north and south of Point Conception. All catch time series were combined for the assessment into one commercial fleet. fig:Catches_livedeadNS_gby

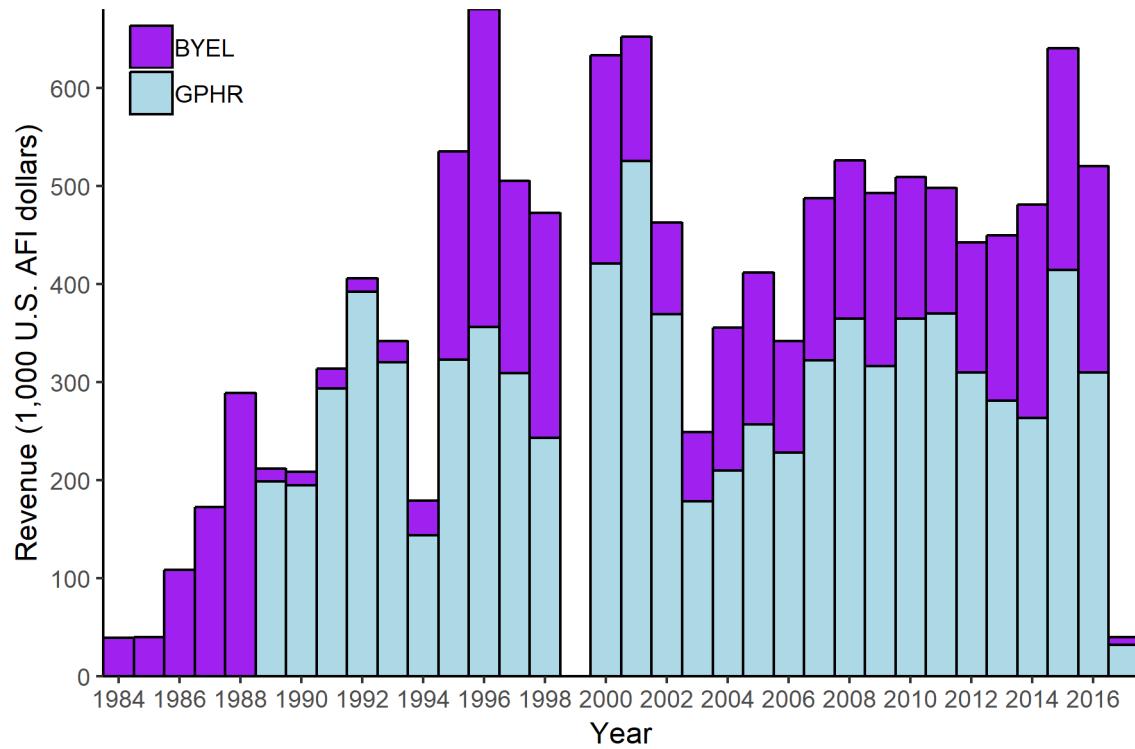


Figure 3: Annual ex-vessel revenue, adjusted for inflation (AFI) in thousands of dollars for gopher and black-and-yellow rockfish. [fig:GBY_revenue](#)

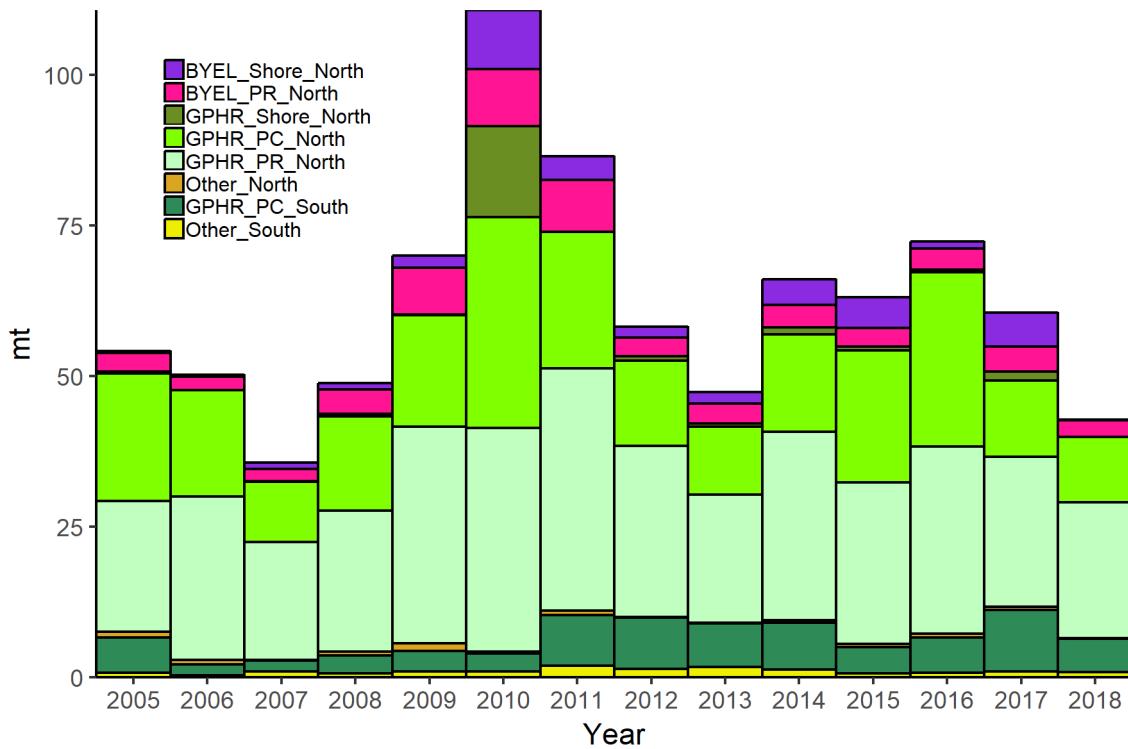


Figure 4: Recreational total mortality for gopher rockfish (GPHR) and black-and-yellow (BYEL) rockfish from the CDFW CRFS sampling era by mode and split north and south of Point Conception. fig:CFRS_catches

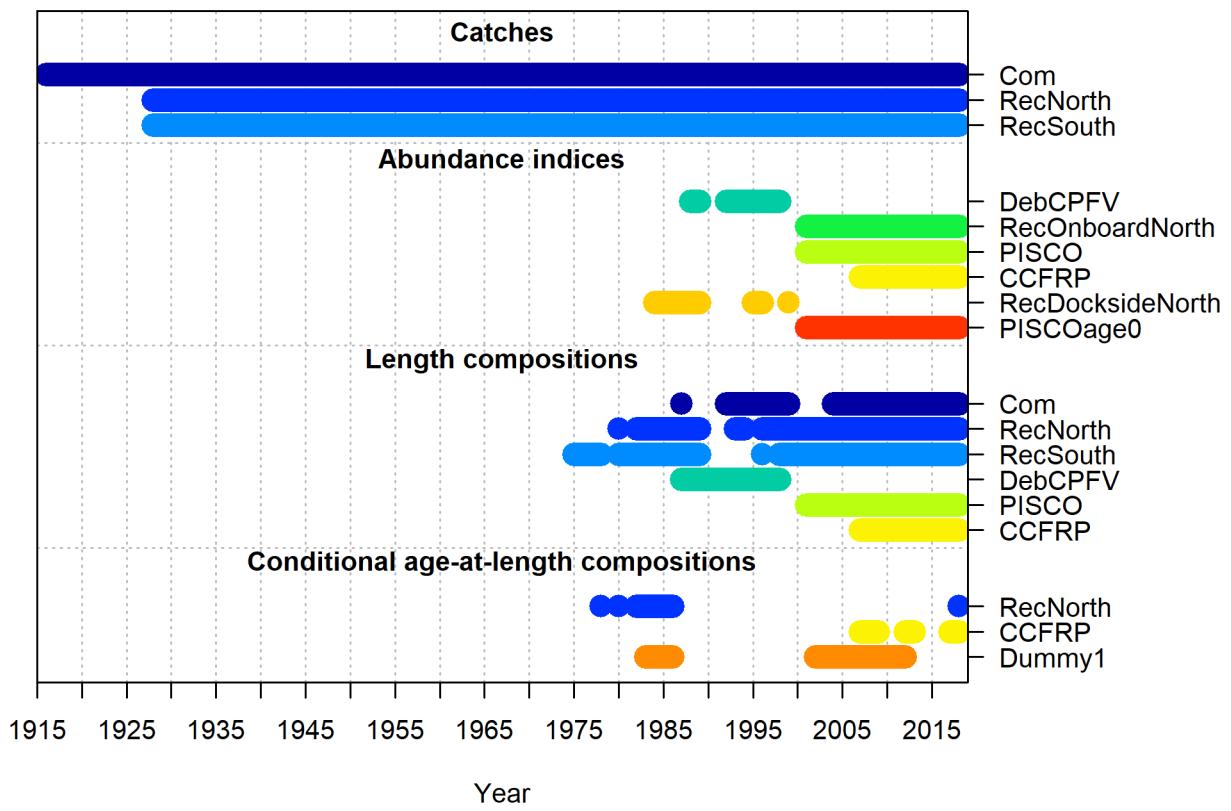


Figure 5: Summary of data sources used in the model. `fig: data_plot`

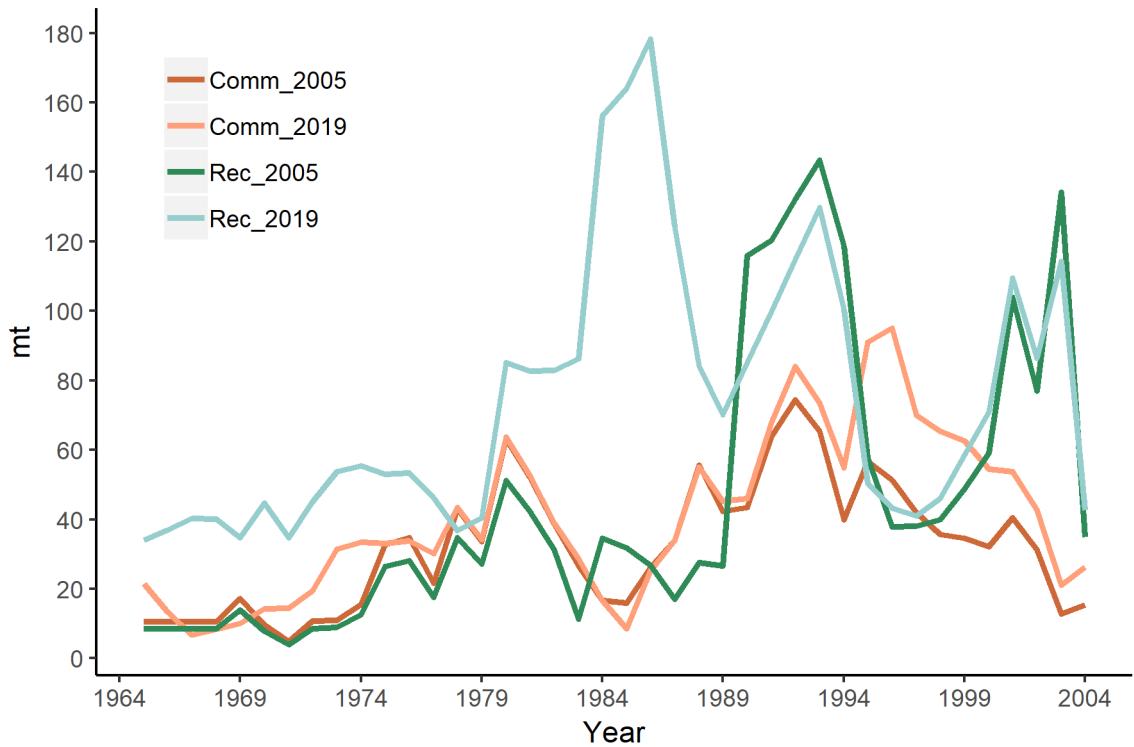


Figure 6: Comparison of the recreational and commercial fishery landings from the 2005 assessment to this 2019 assessment. Note that the 2019 assessment includes both gopher and black-and-yellow rockfish where the 2005 assessment represents gopher rockfish only. The 2005 assessment also did not include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

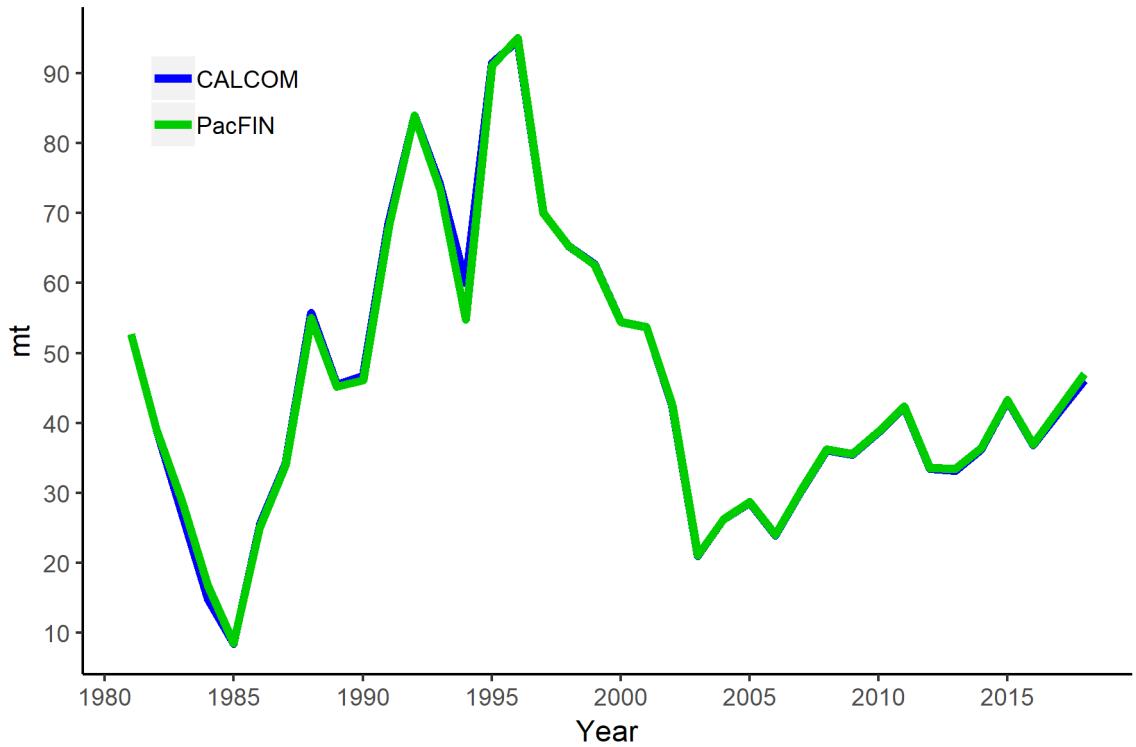


Figure 7: Commercial landings estimates from CALCOM and PacFIN. fig:Calcom_vs_Pacfin

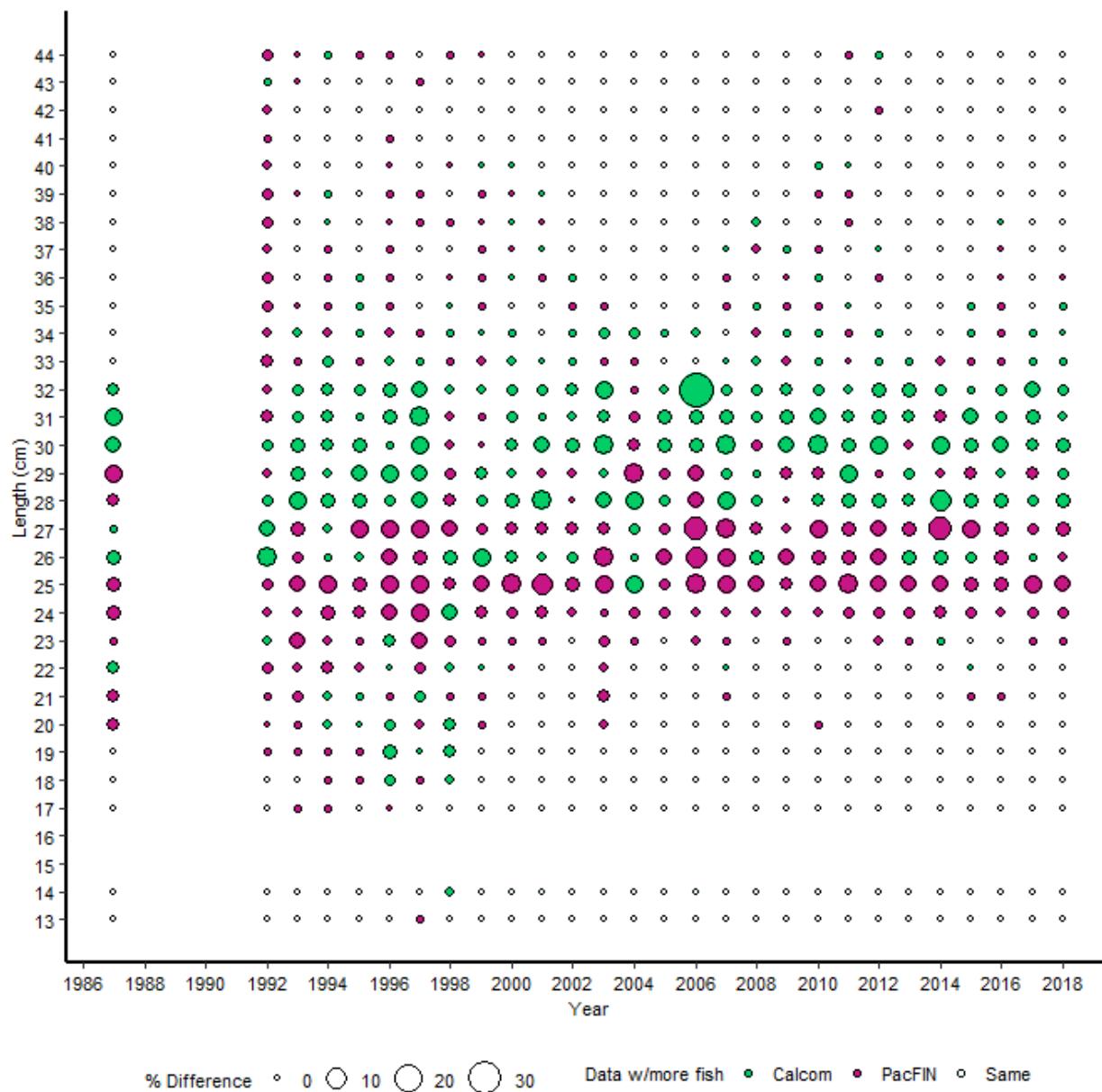


Figure 8: Percent differences in the expanded length compositions by year from CALCOM and PacFIN. The same market categories were used for each dataset, but each database was subject to further independent filtering criteria and expansion algorithms. fig:Calcom_vs_pacfin_length

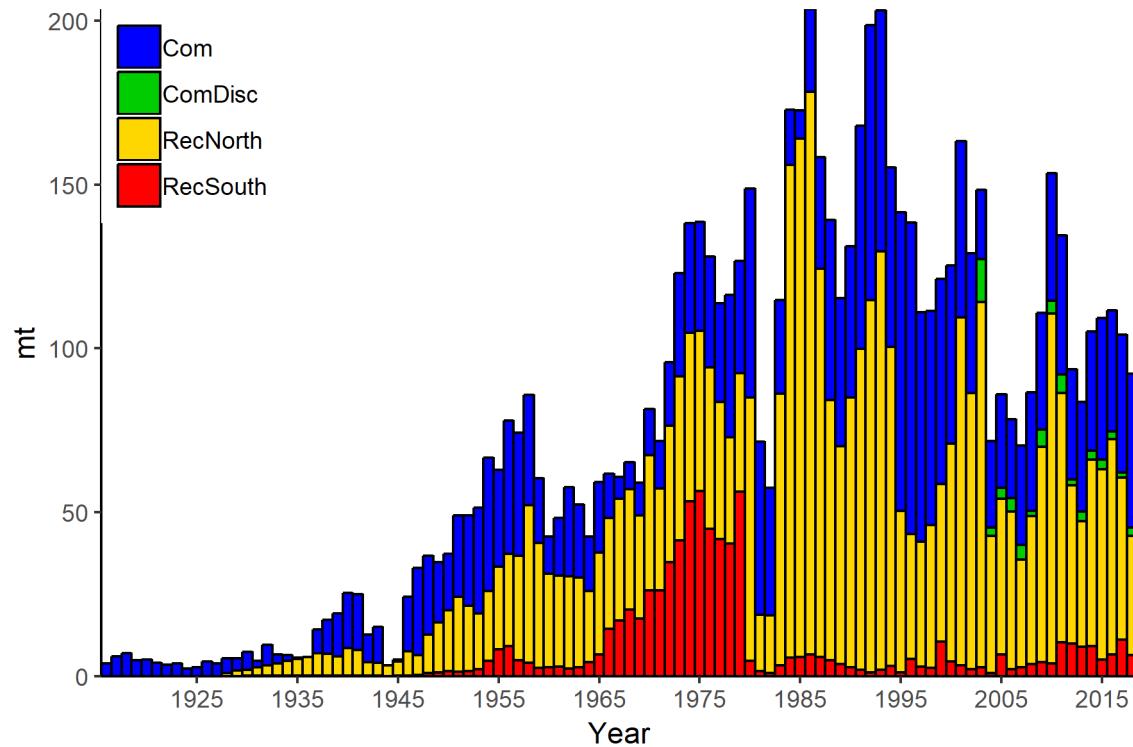


Figure 9: Commercial and recreational landings estimates prior to any data modification or interpolation to the recreational catches or hindcasting of commercial discards. [fig:Catches_original](#)

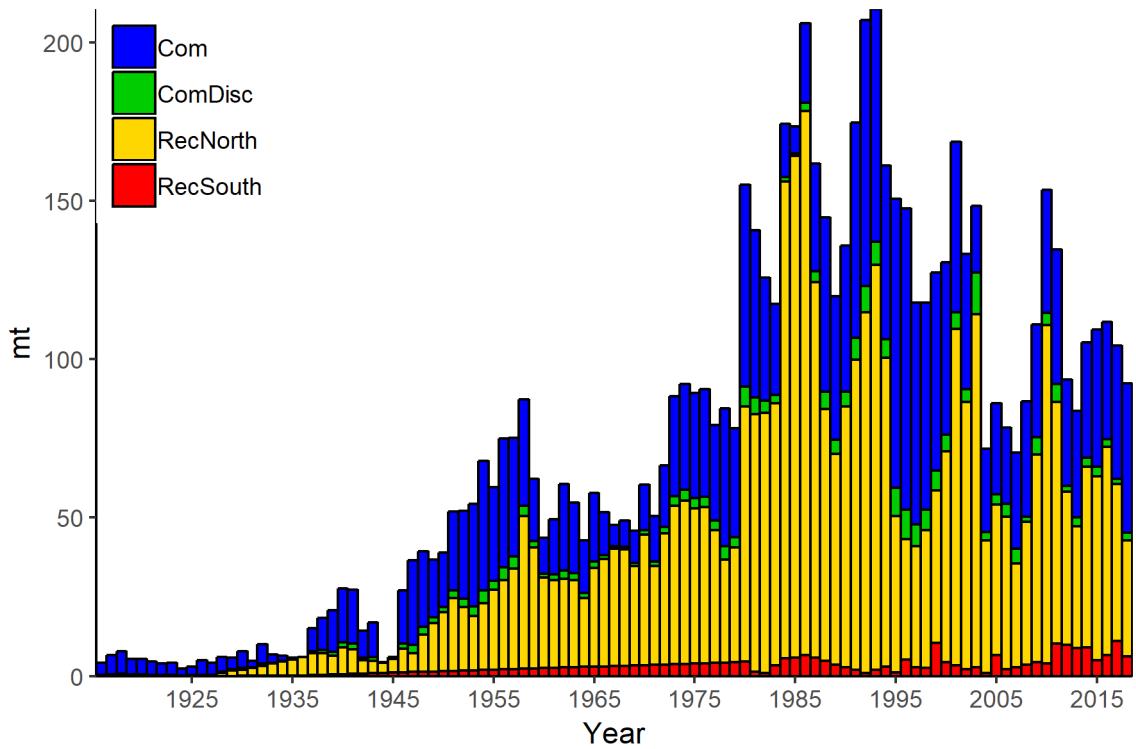


Figure 10: Commercial and recreational landings estimates after data modification and interpolations were made to the recreational catches and commercial discards. [fig:Catches_alternate](#)

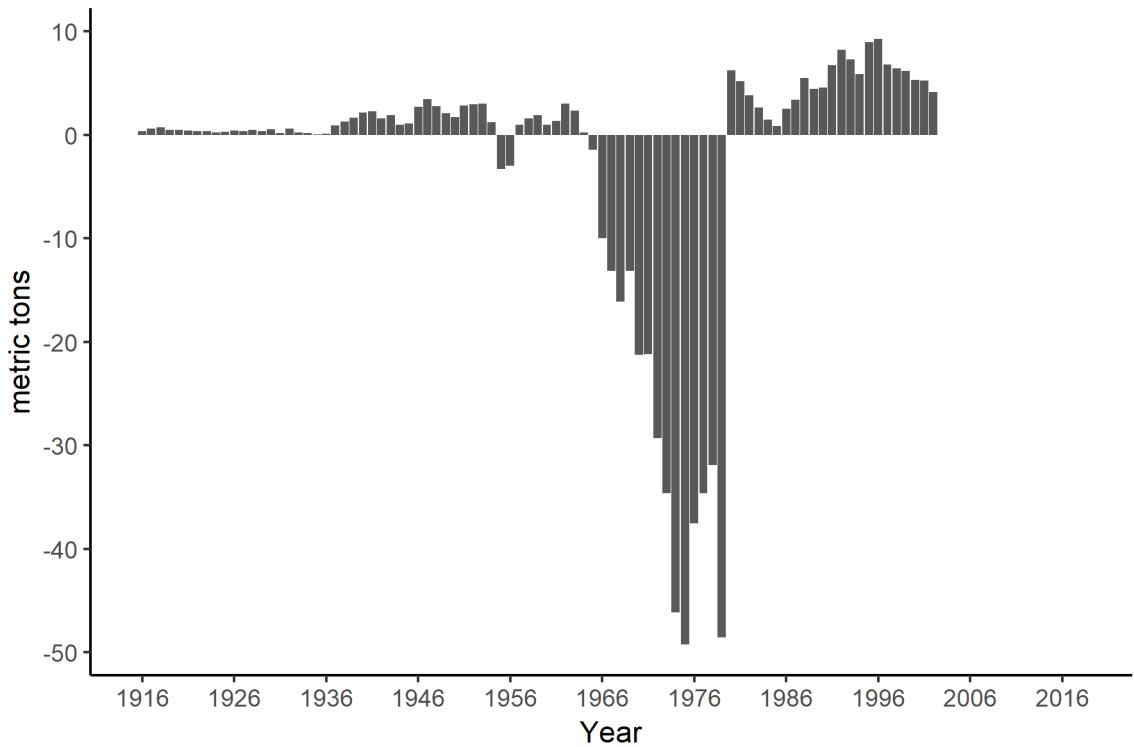


Figure 11: Difference in landings between the original and modified landings presented in the previous two figures. The only two fleets with modifications are recreational south and commercial discards. Negative values indicate catches removed from the original estimates and positive values represent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

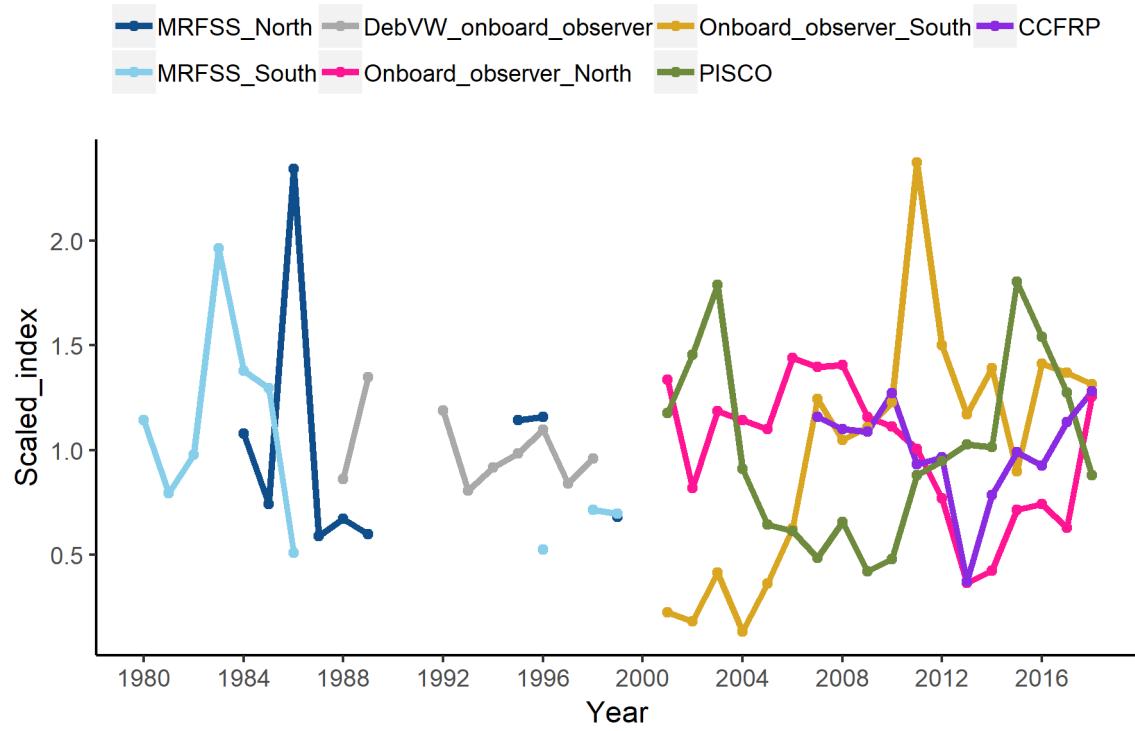


Figure 12: Comparison of all indices of abundance in the pre-STAR base model (with each index scaled to its mean). [fig:All_index_compare](#)

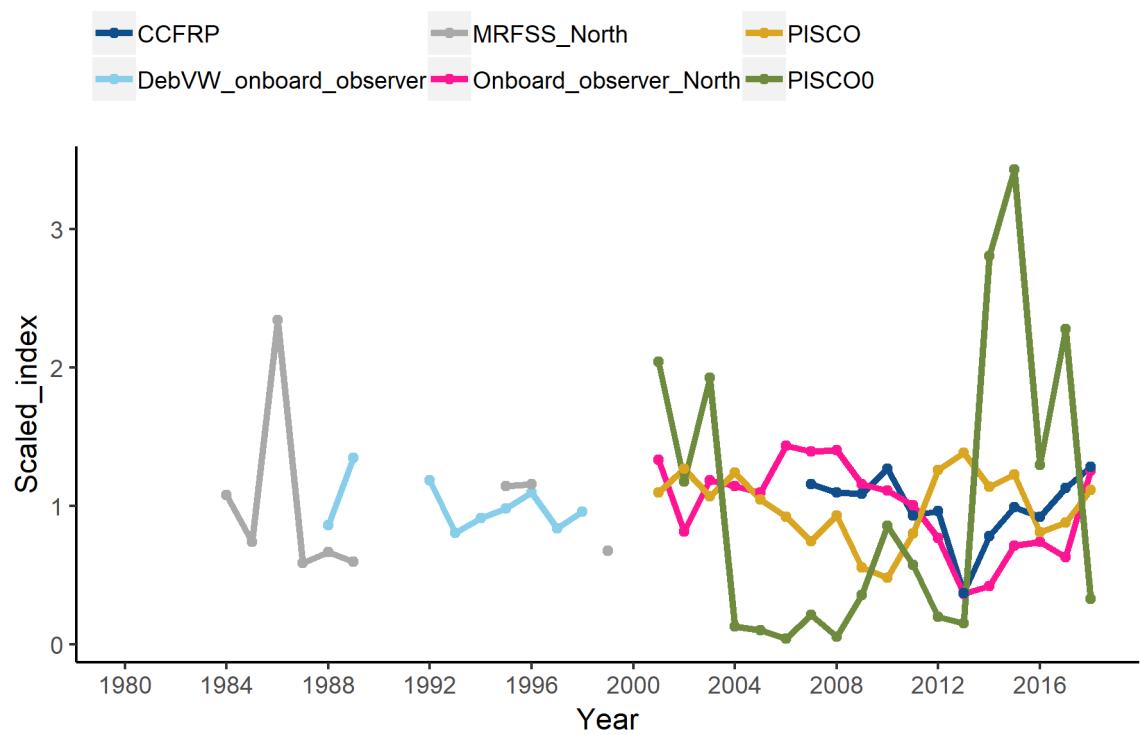


Figure 13: Comparison of all indices of abundance in the post-STAR base model (with each index scaled to its mean). [fig:All_index_compare_postSTAR](#)

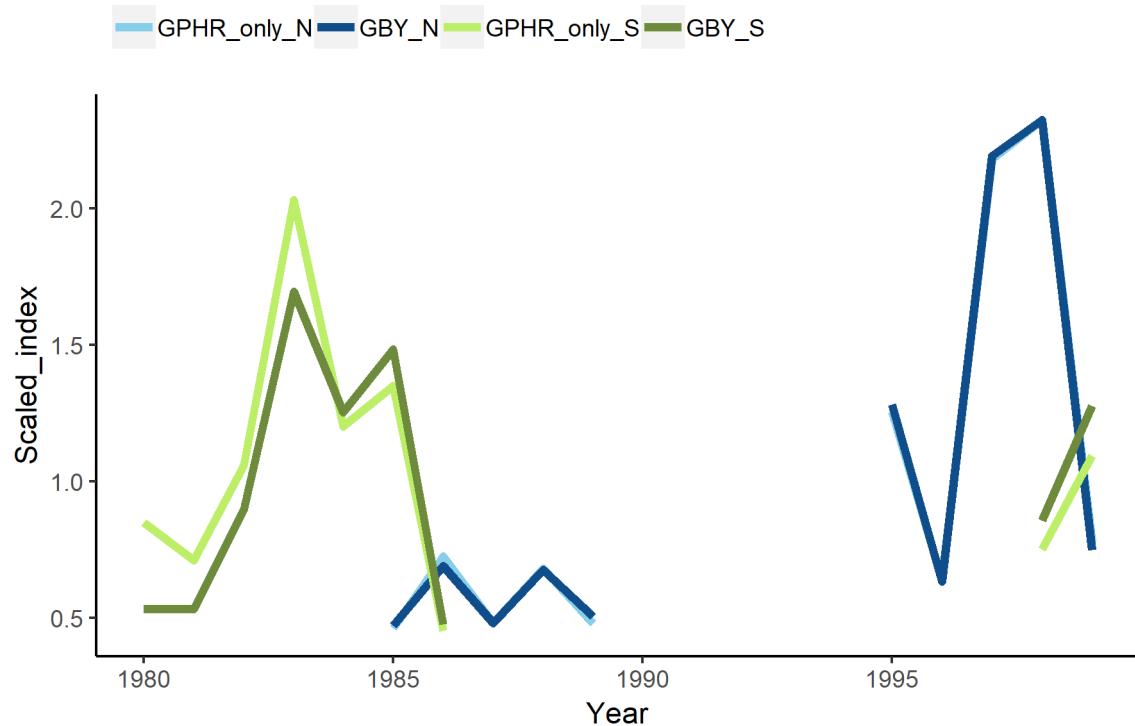


Figure 14: Comparison of indices of abundance (scaled to their means) for the MRFSS dockside CPFV survey between a gopher-only and GBYR complex index for north and south of Point Conception. [fig:MRFSS_index_compare](#)

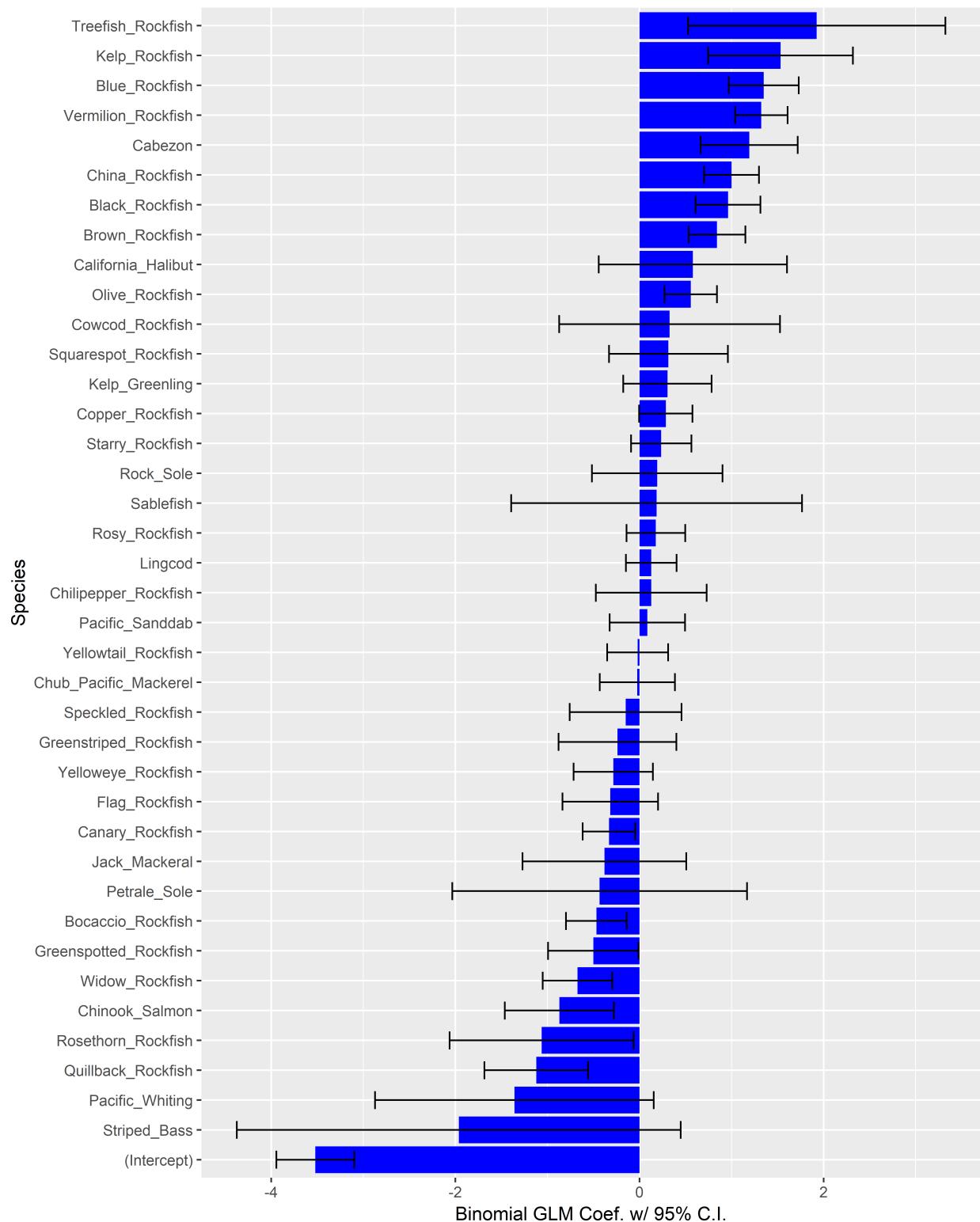


Figure 15: Species coefficients from the binomial GLM for presence/absence of GBYR in the Marine Recreational Fisheries Statistics Survey (MRFSS) CPFV mode dockside survey data set north of Point Conception. Horizontal bars are 95% confidence intervals. fig:Fleet10_SM_filter

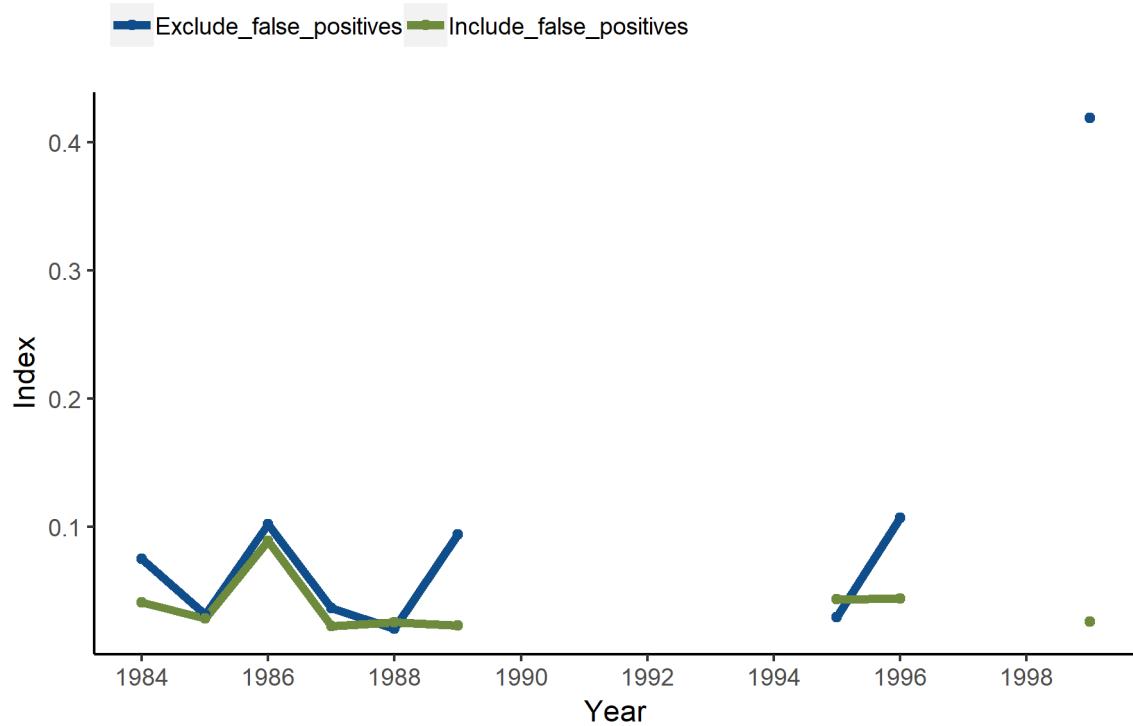


Figure 16: Comparisons of the indices of abundance for GBYR north of Point Conception from the MRFSS dockside CPFV survey that either include or exclude the trips identified as false positives from the Stephens-MacCall filter. [fig:MRFSS_index_N_SM_falsepos](#)

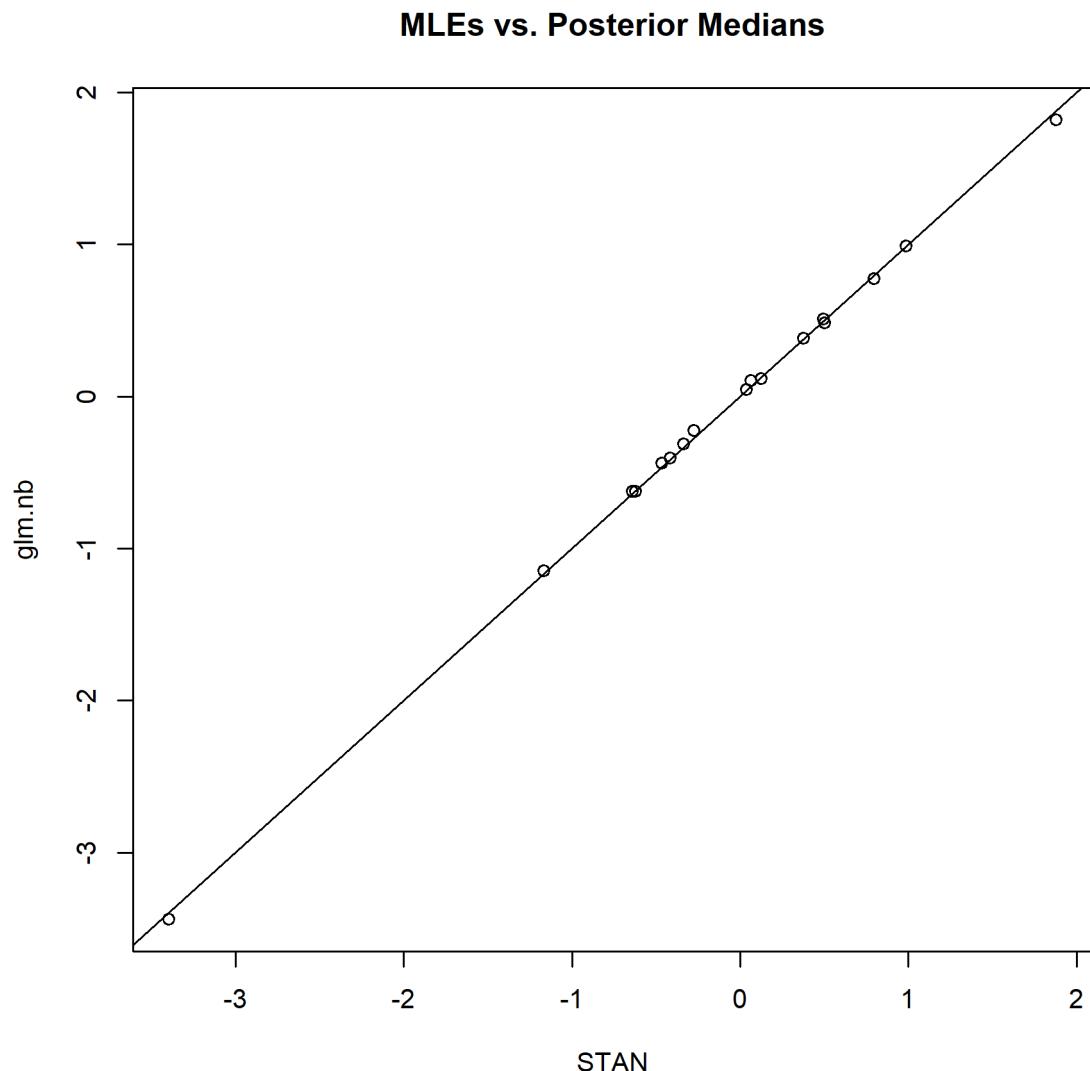


Figure 17: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year). MRFSS CPFV dockside index north of Point Conception. The 1:1 plot is for reference. [fig:Fleet10_MLE_stan](#)

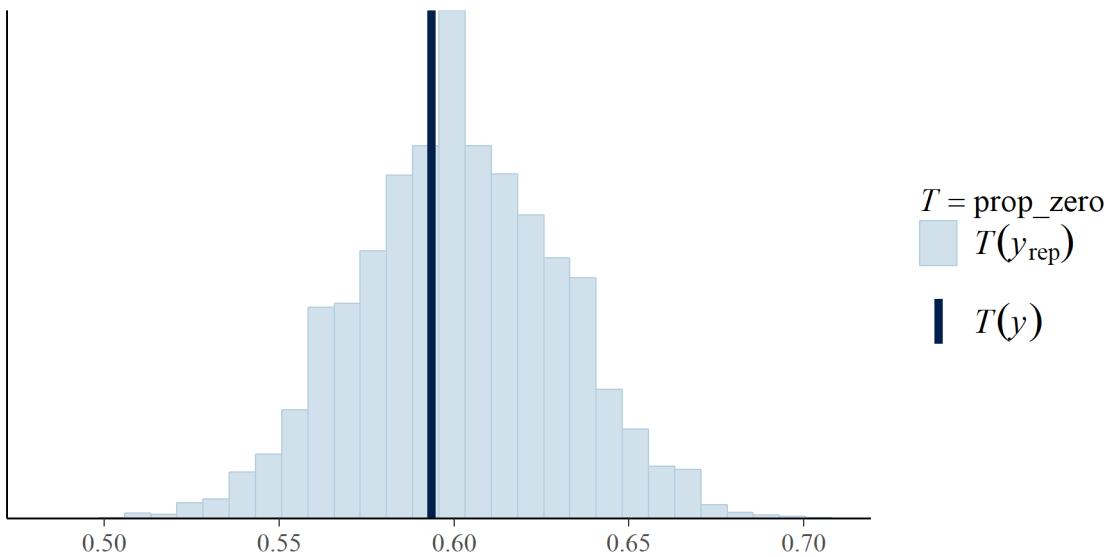


Figure 18: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for MRFSS dockside CPFV index north of Point Conception. [fig:Fleet10_prop_zero_STAN](#)

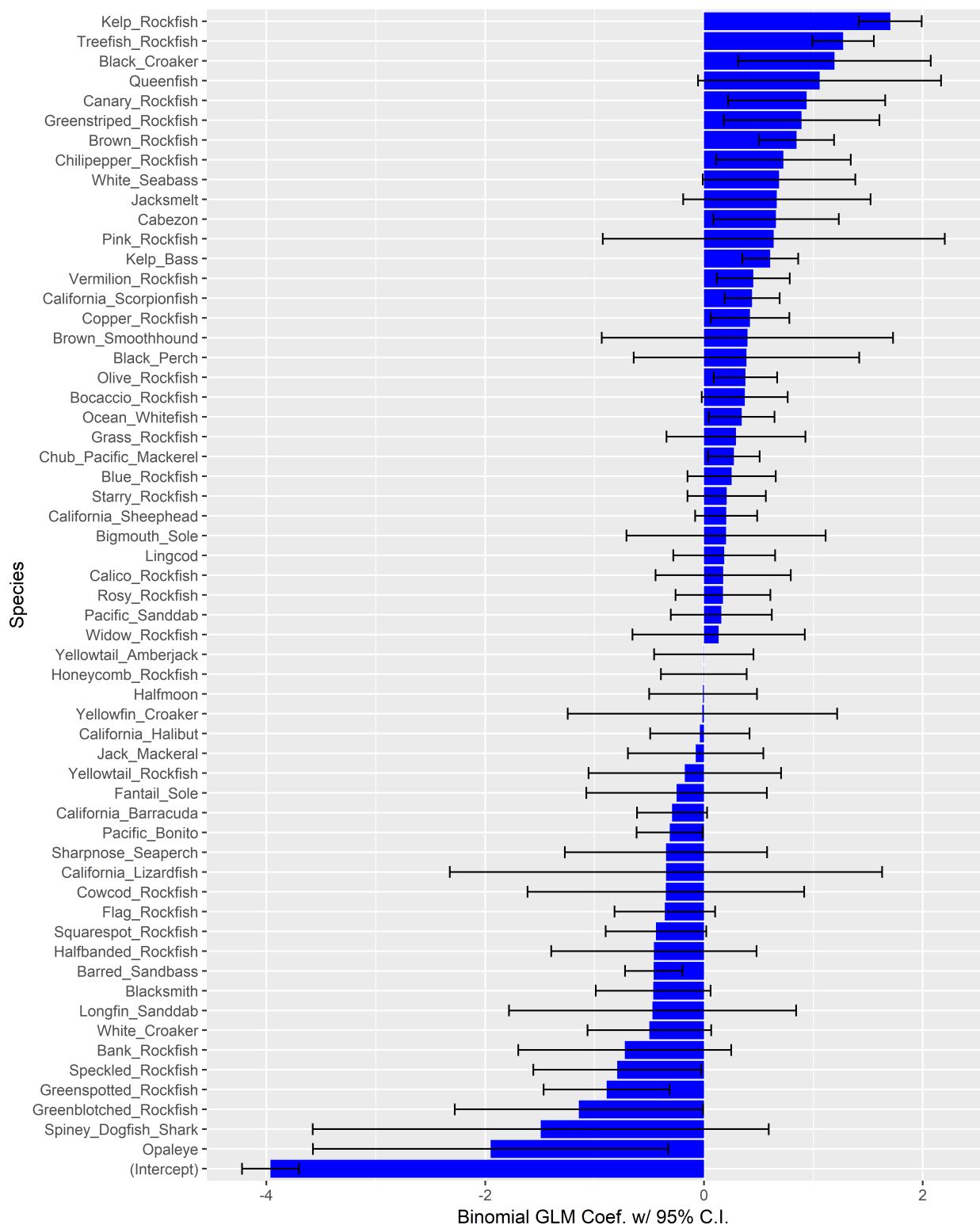


Figure 19: Species coefficients from the binomial GLM for presence/absence of GBYR in the Marine Recreational Fisheries Statistics Survey (MRFSS) CPFV mode dockside survey data set north of Point Conception. Horizontal bars are 95% confidence intervals. fig:Fleet11_SM_filter

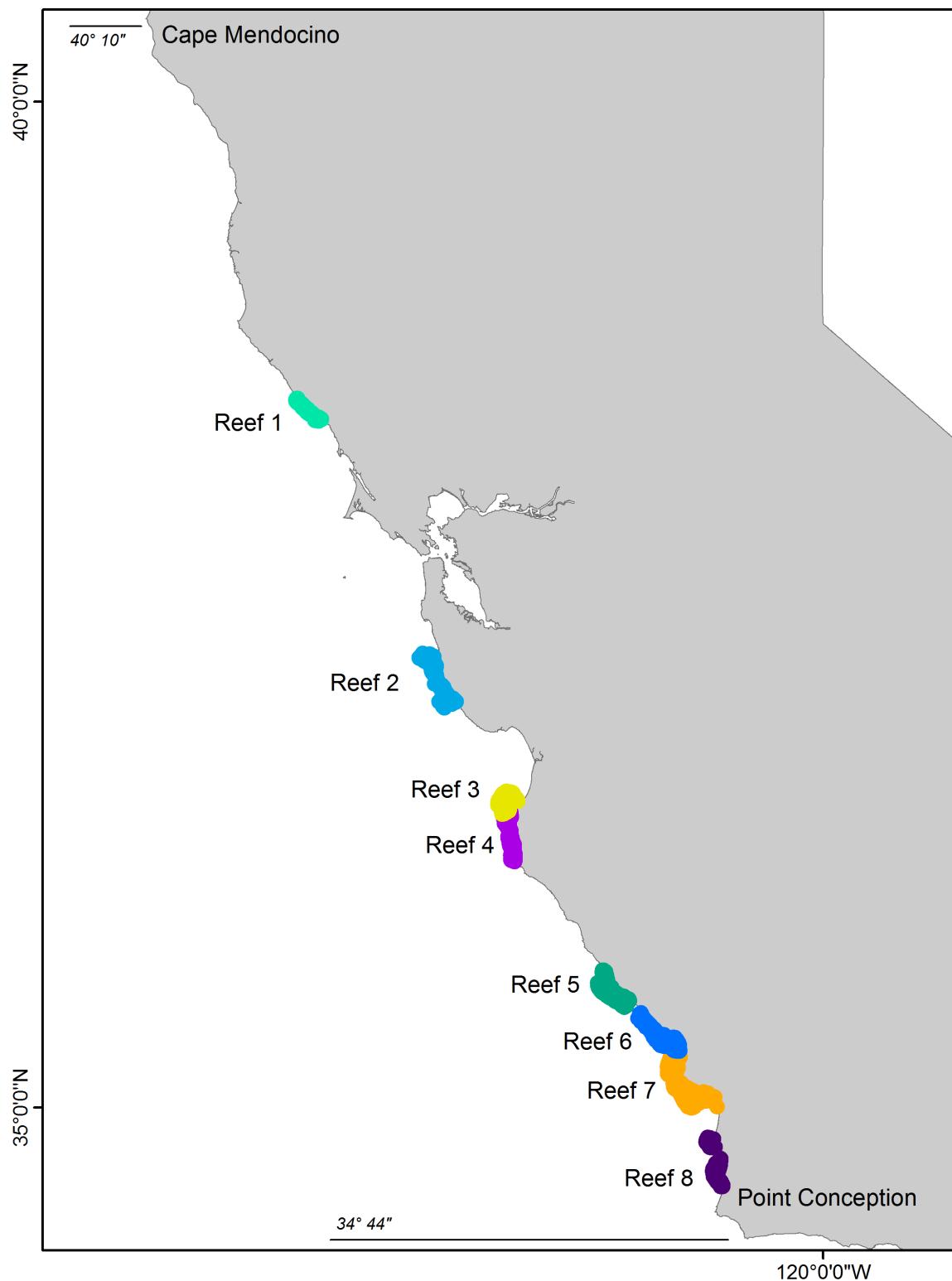


Figure 20: Map of the reefs used in the Deb Wilson-Vandenberg CPFV onboard observer survey index of abundance. [fig:DebWV_sites](#)

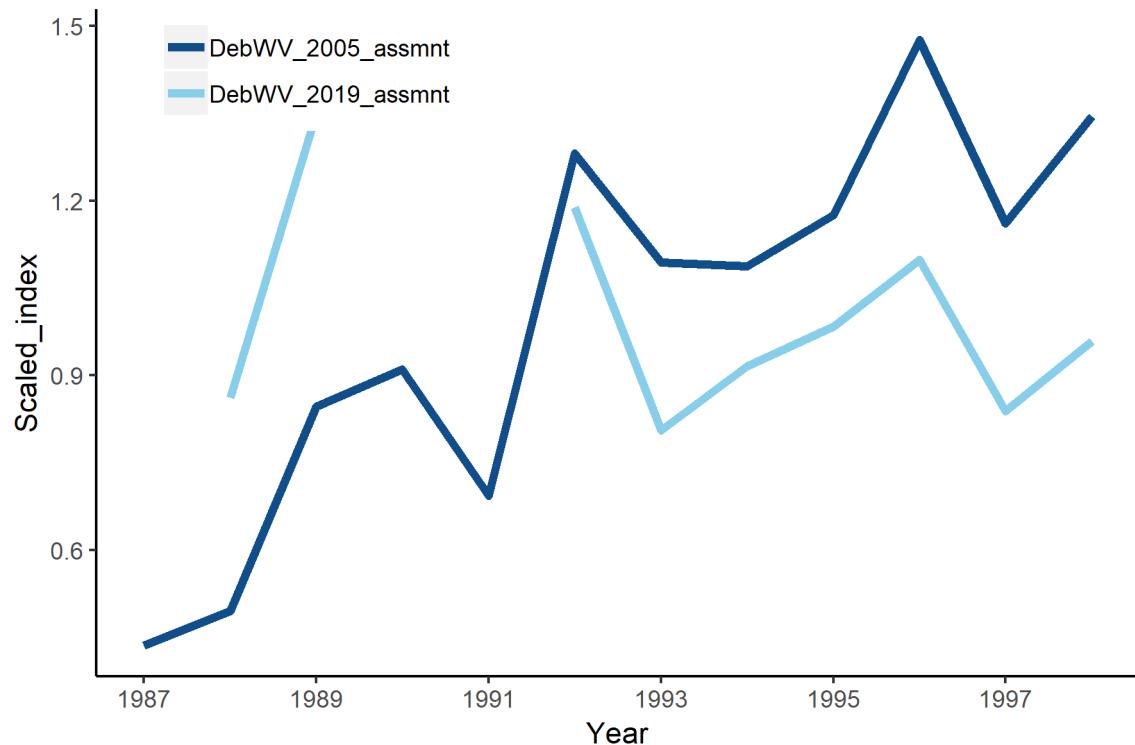


Figure 21: Comparison of the index developed for the Deb Wilson-Vandenberg CPFV onboard observer survey from the 2005 assessment and for the 2019 assessment. [Fig:DebWV_index_compare](#)

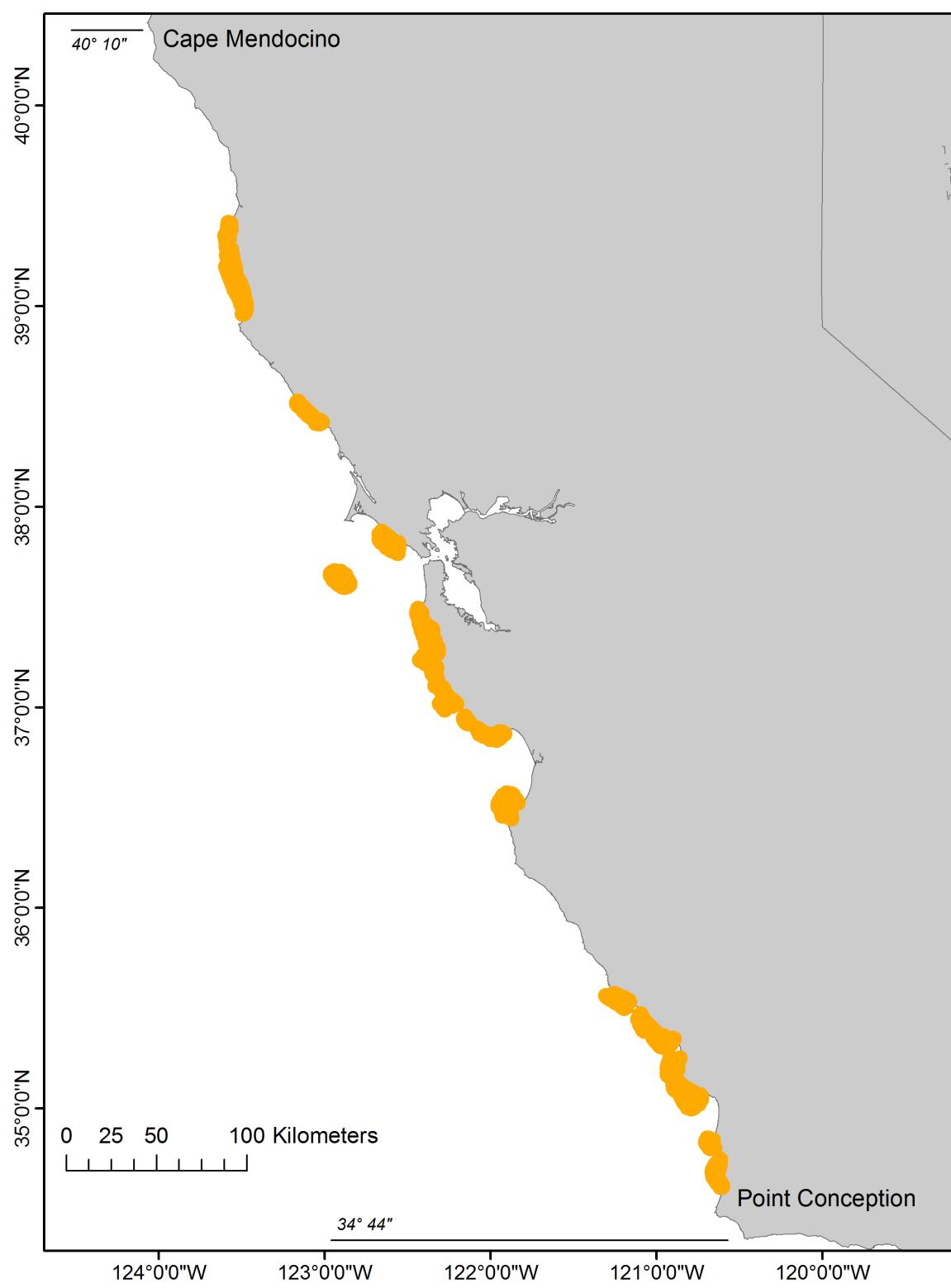


Figure 22: Map of the reefs selected for the final index for the onboard observer surveys (CDFW and Cal Poly) north of Point Conception

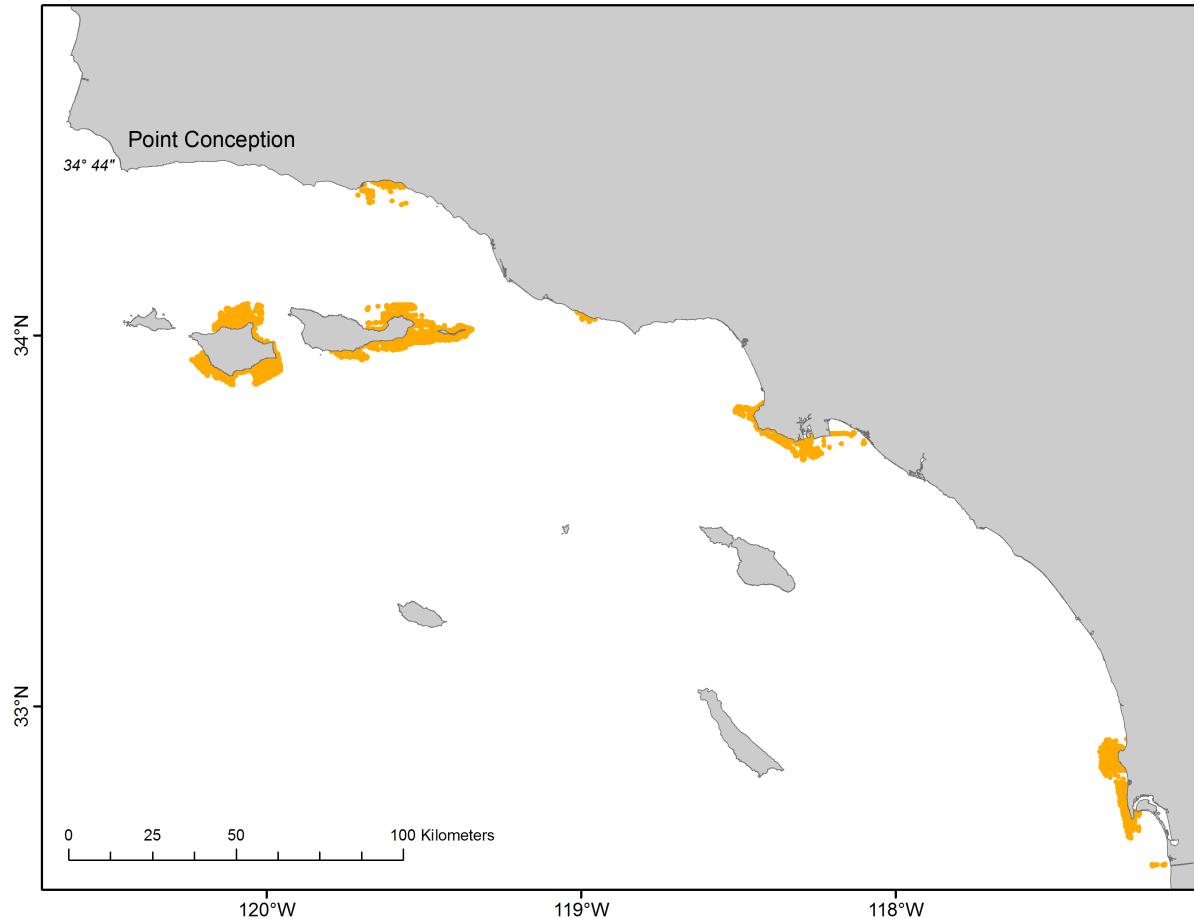


Figure 23: Map of the reefs selected for the final index for the CDFW onboard observer survey south of Point Conception | [fig:Unboard_observer_south_sites](#)

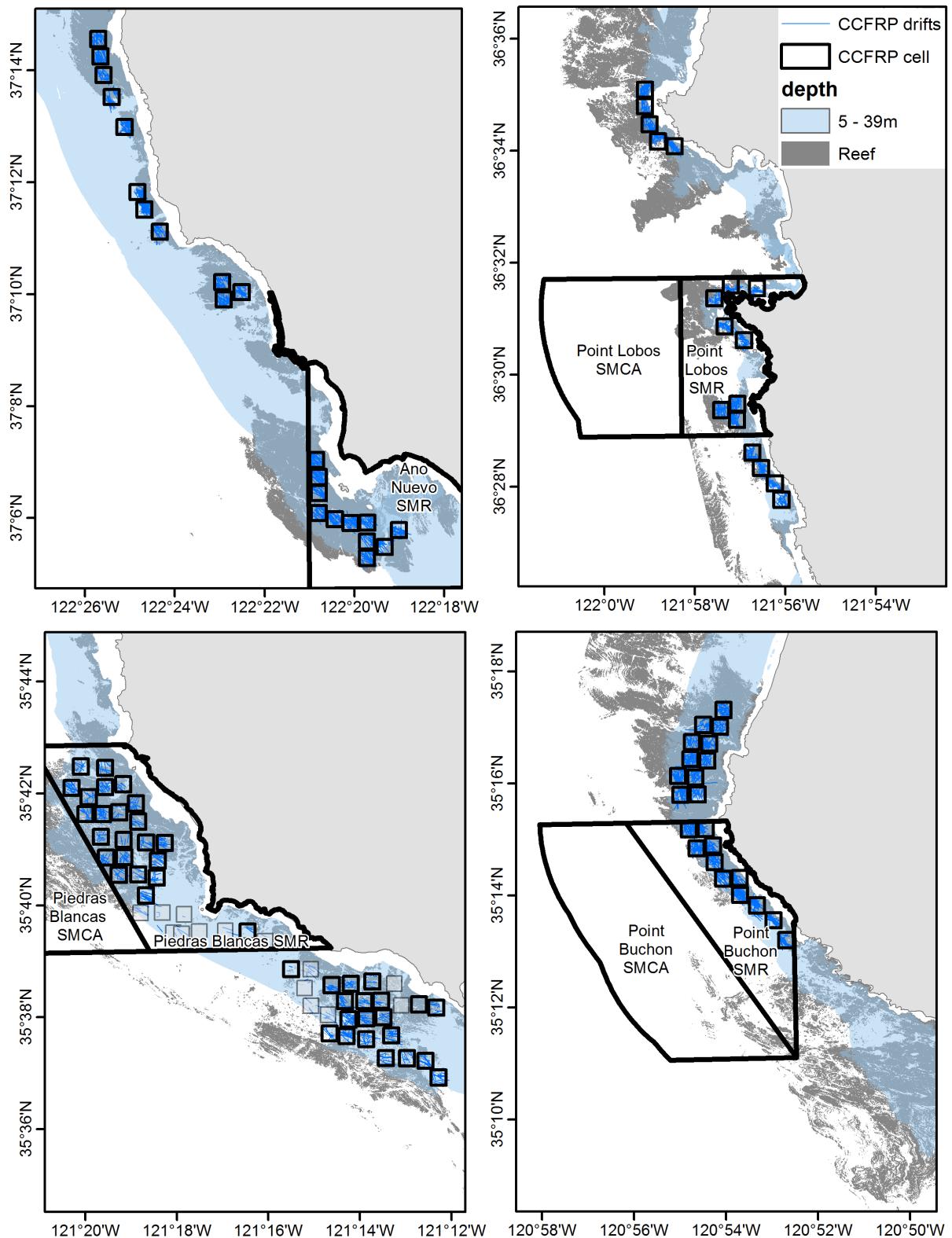


Figure 24: Map of the four MPAs sampled consistently through time for the CCFRP fishery-independent survey. [fig:CCFRP_sites](#)

MLEs vs. Posterior Medians

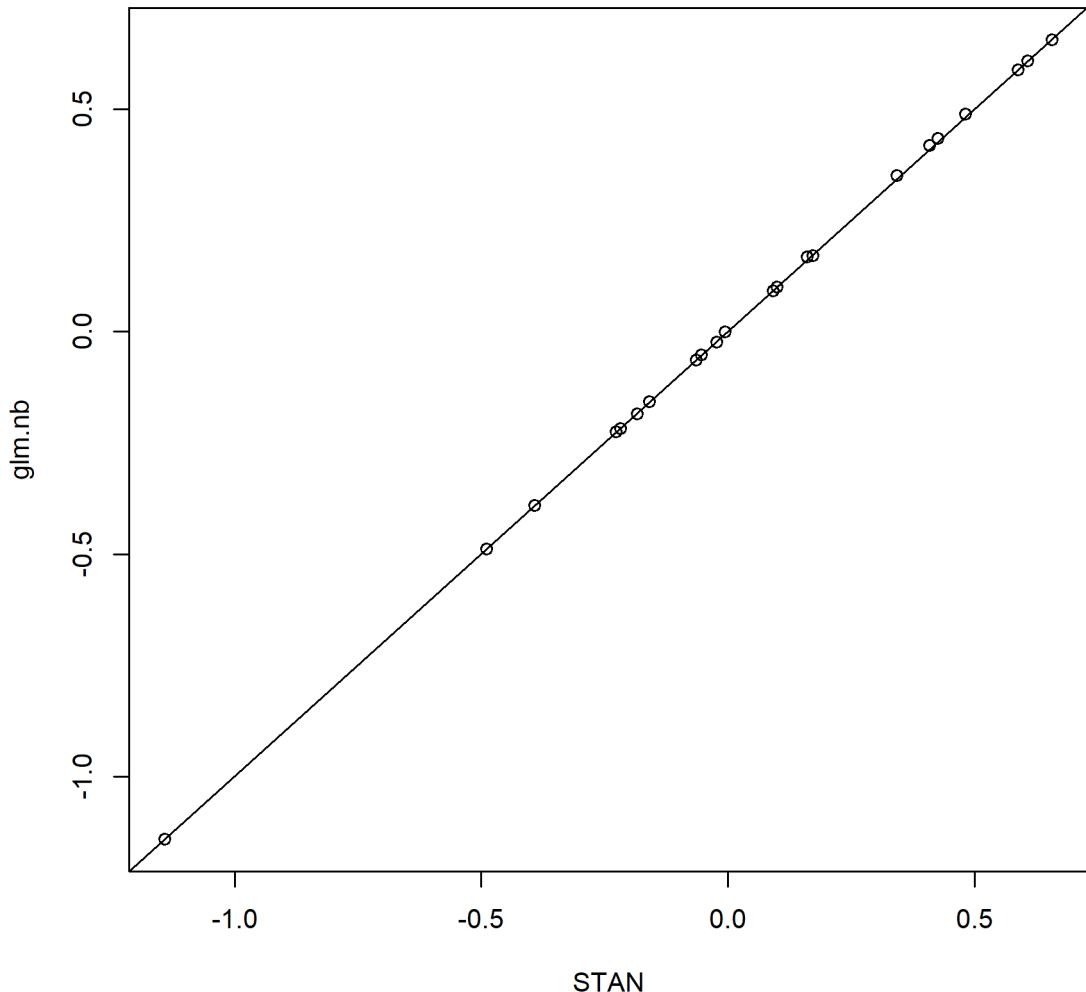


Figure 25: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year) for the CCFRP index. The 1:1 plot is for reference.

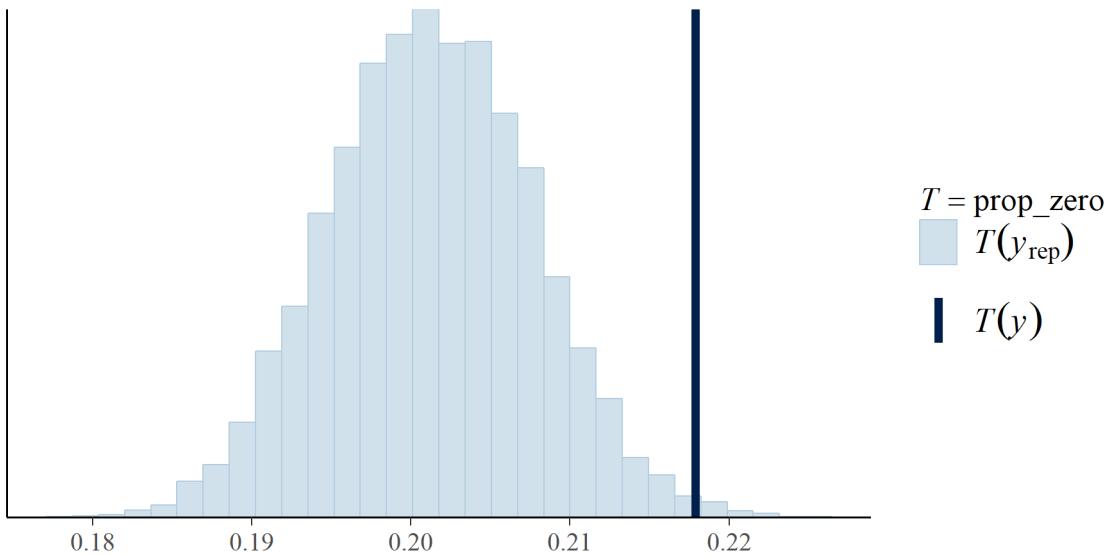


Figure 26: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the CCFRP index. [fig:Fleet9_prop_zero_STAN](#)

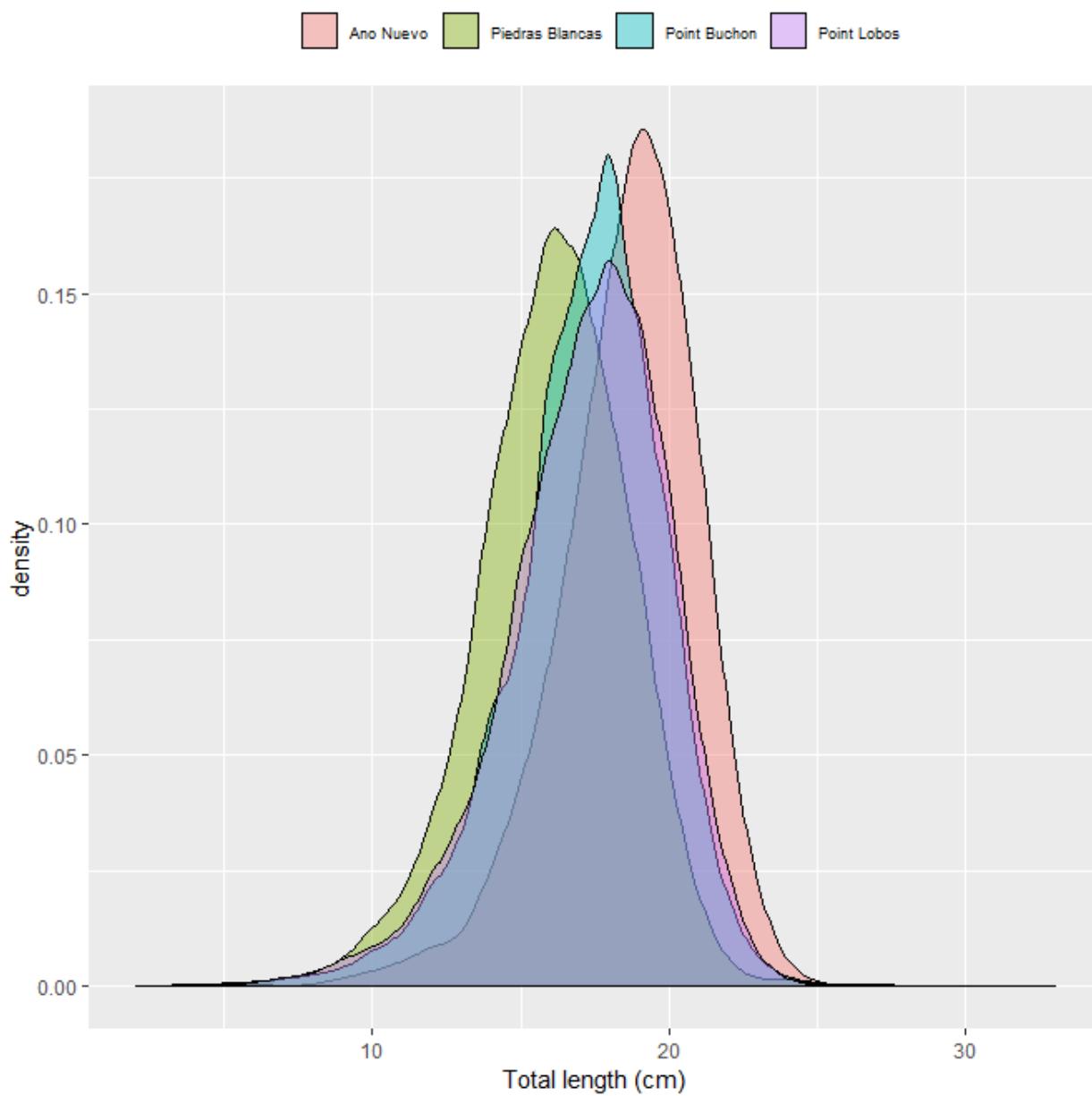


Figure 27: Length distributions of GBYR for the four MPAs sampled by the CCFRP survey used in this assessment. | [CCFRP_lengths_by_site](#)

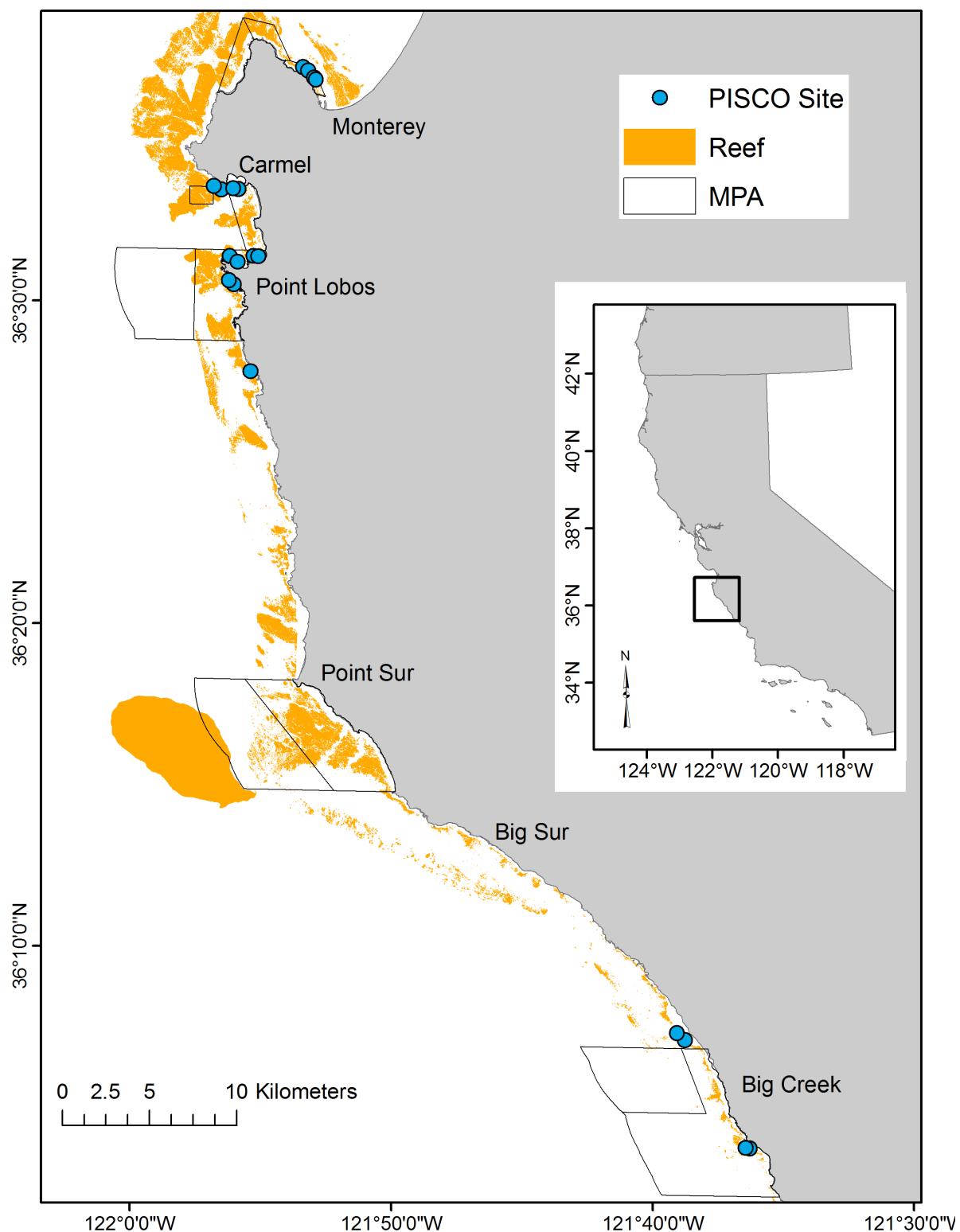


Figure 28: Map of the sites sampled consistently through time for the PISCO kelp forest fish survey. | [fig:PISCO_sites](#)

MLEs vs. Posterior Medians

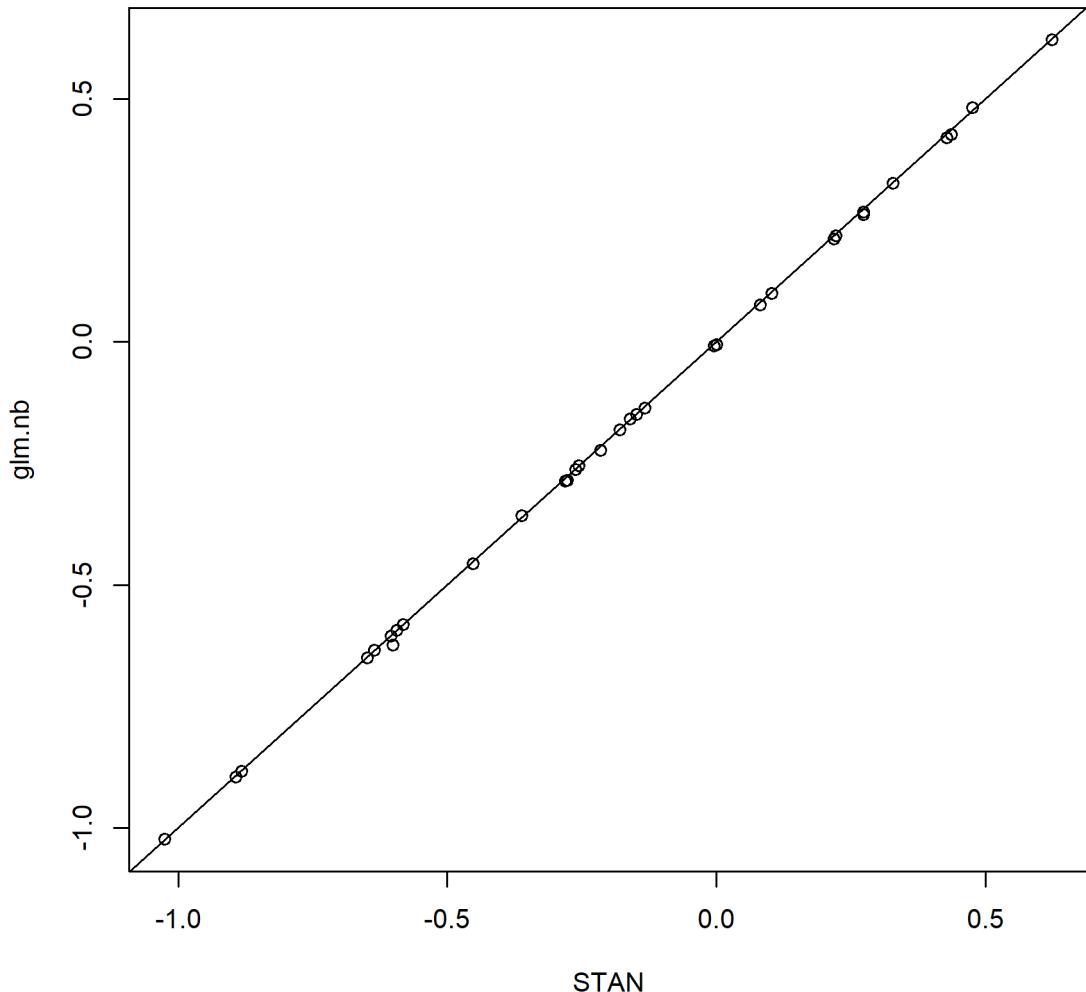


Figure 29: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year) for the PISCO kelp forest fish survey index. The 1:1 plot is for reference. [fig:Fleet8_MLE](#)

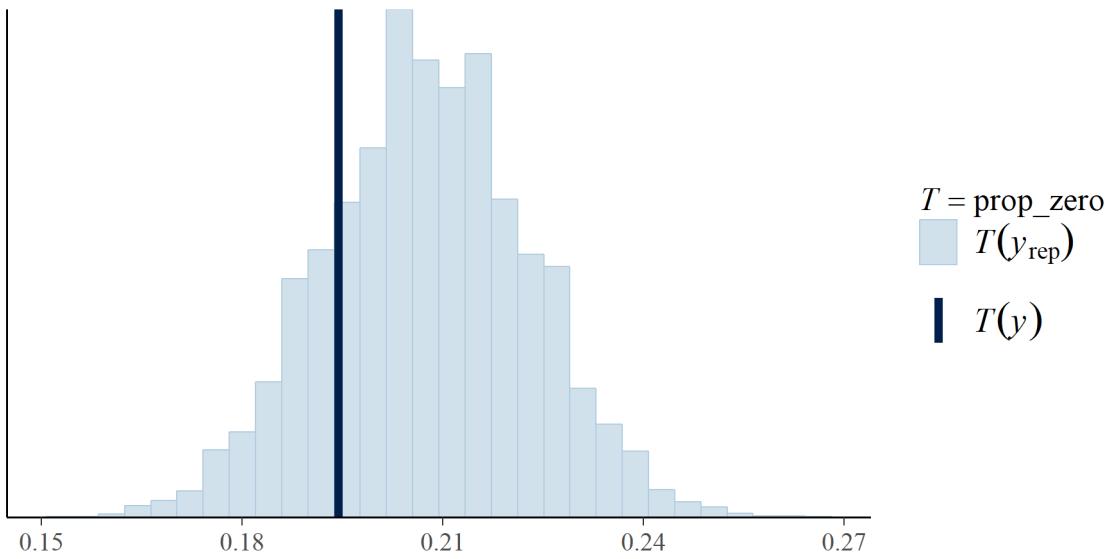


Figure 30: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the PISCO kelp forest fish survey. [fig:Fleet8_pr](#)

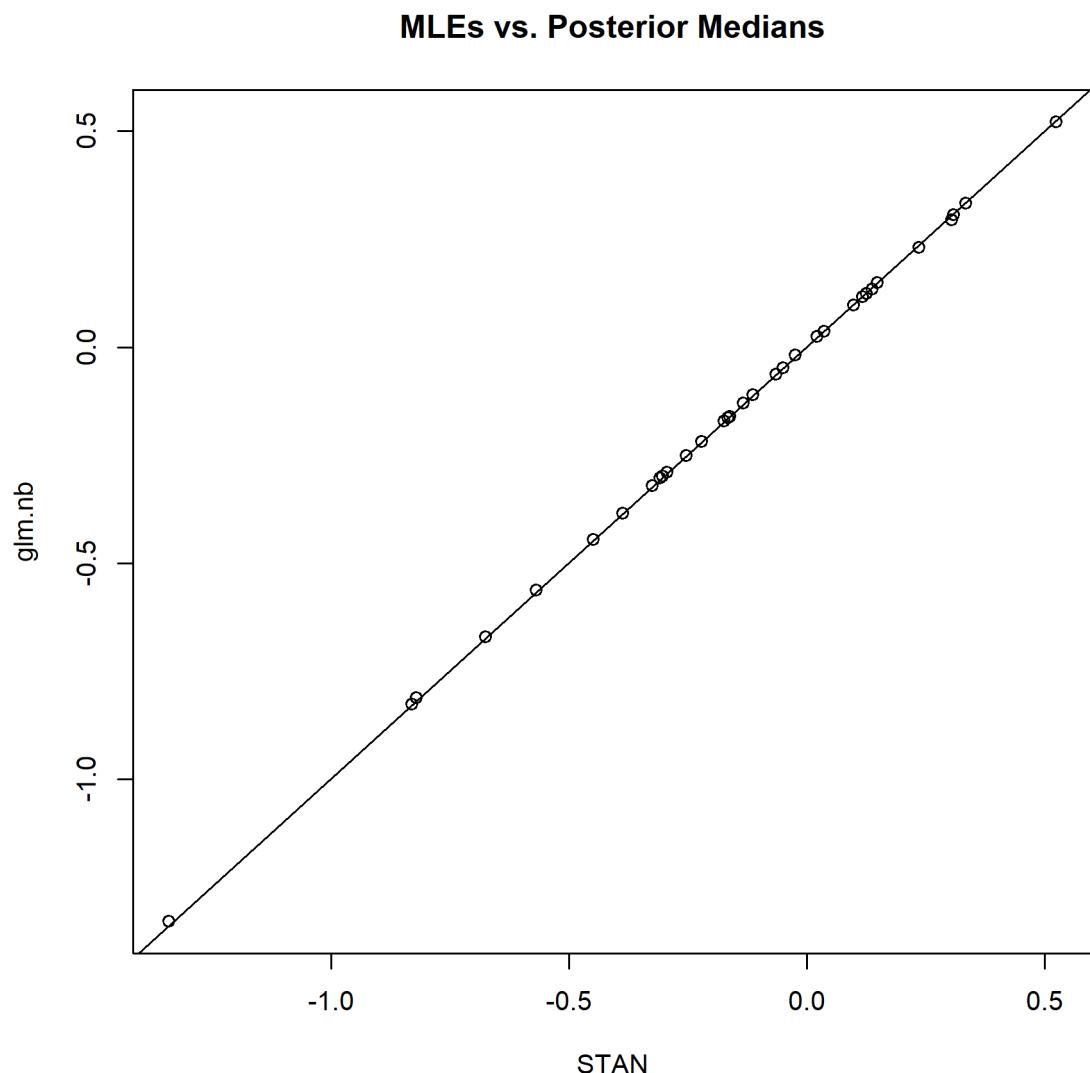


Figure 31: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year) for the PISCO kelp forest fish survey index for fish 15 cm and larger. The 1:1 plot is for reference. fig:Fleet8large_MLE_stan

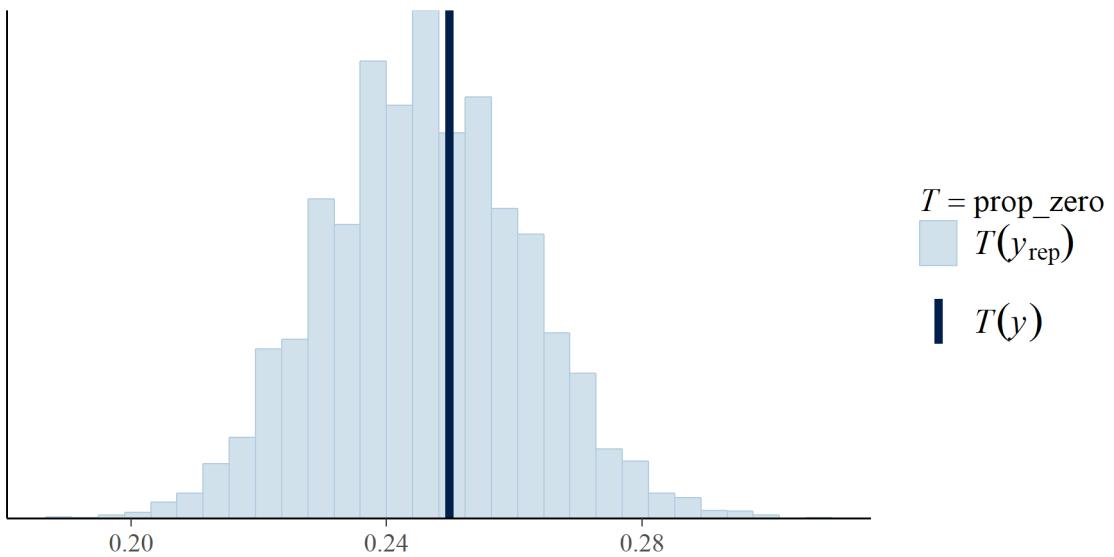


Figure 32: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the PISCO kelp forest fish survey for fish 15 cm and larger. [fig:Fleet8large_prop_zero_STAN](#)

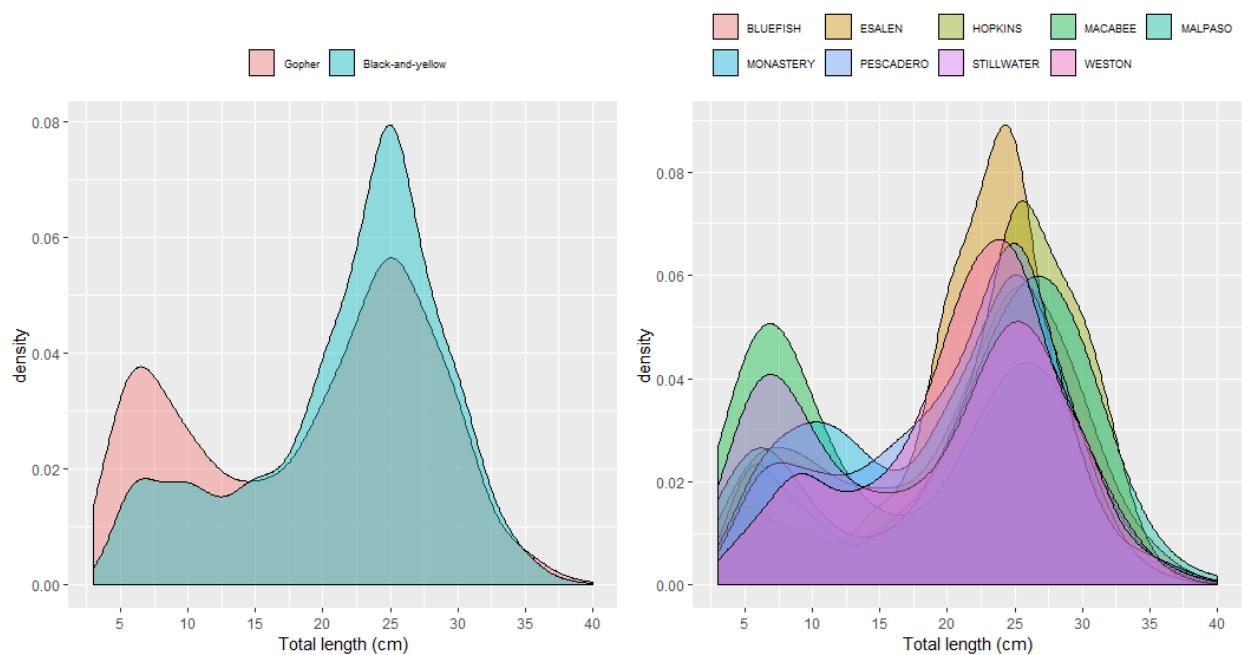


Figure 33: Plots of the length distributions from the PISCO kelp forest fish survey by species (left) and for combined species by site (right) for sites included in the final index of abundance. | [fig:PISCO_lengths](#)

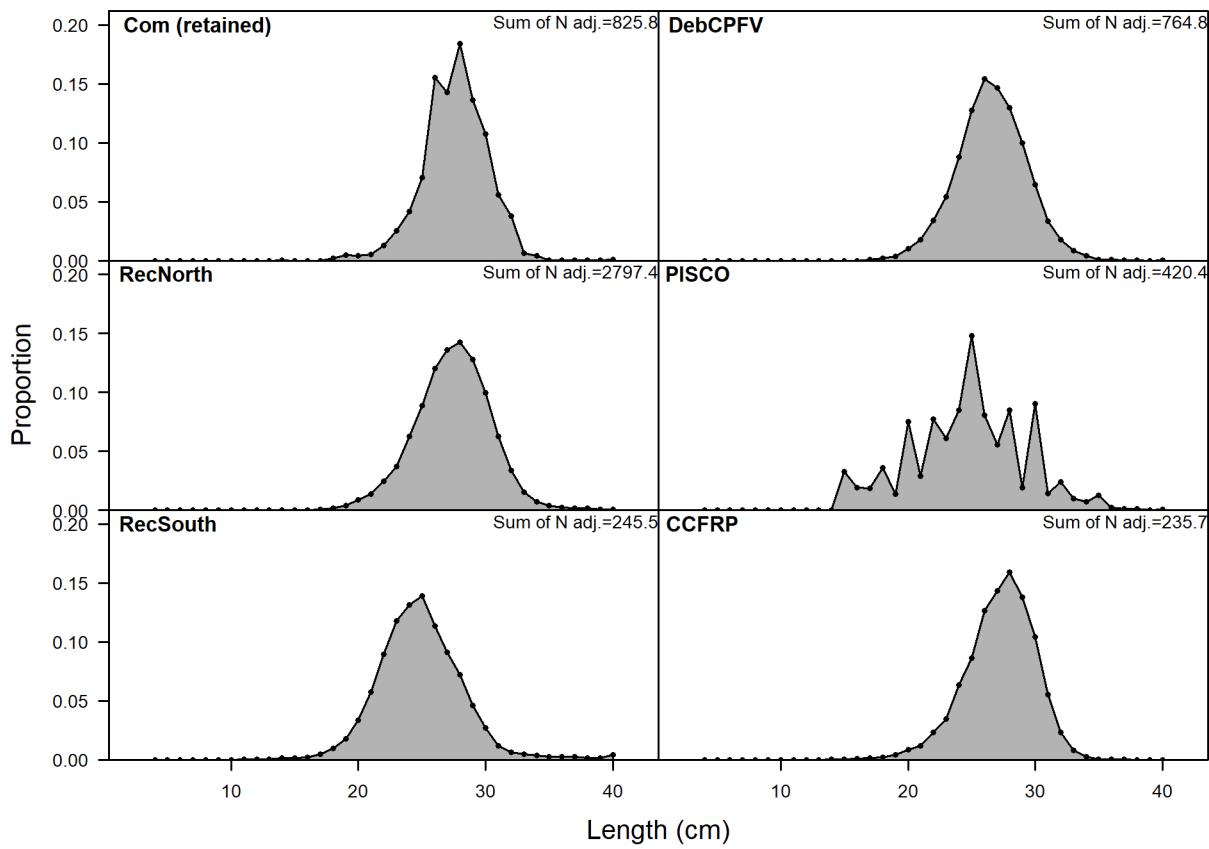


Figure 34: Length comp data, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. | [fig:comp_lendat_aggregated_across_time](#)

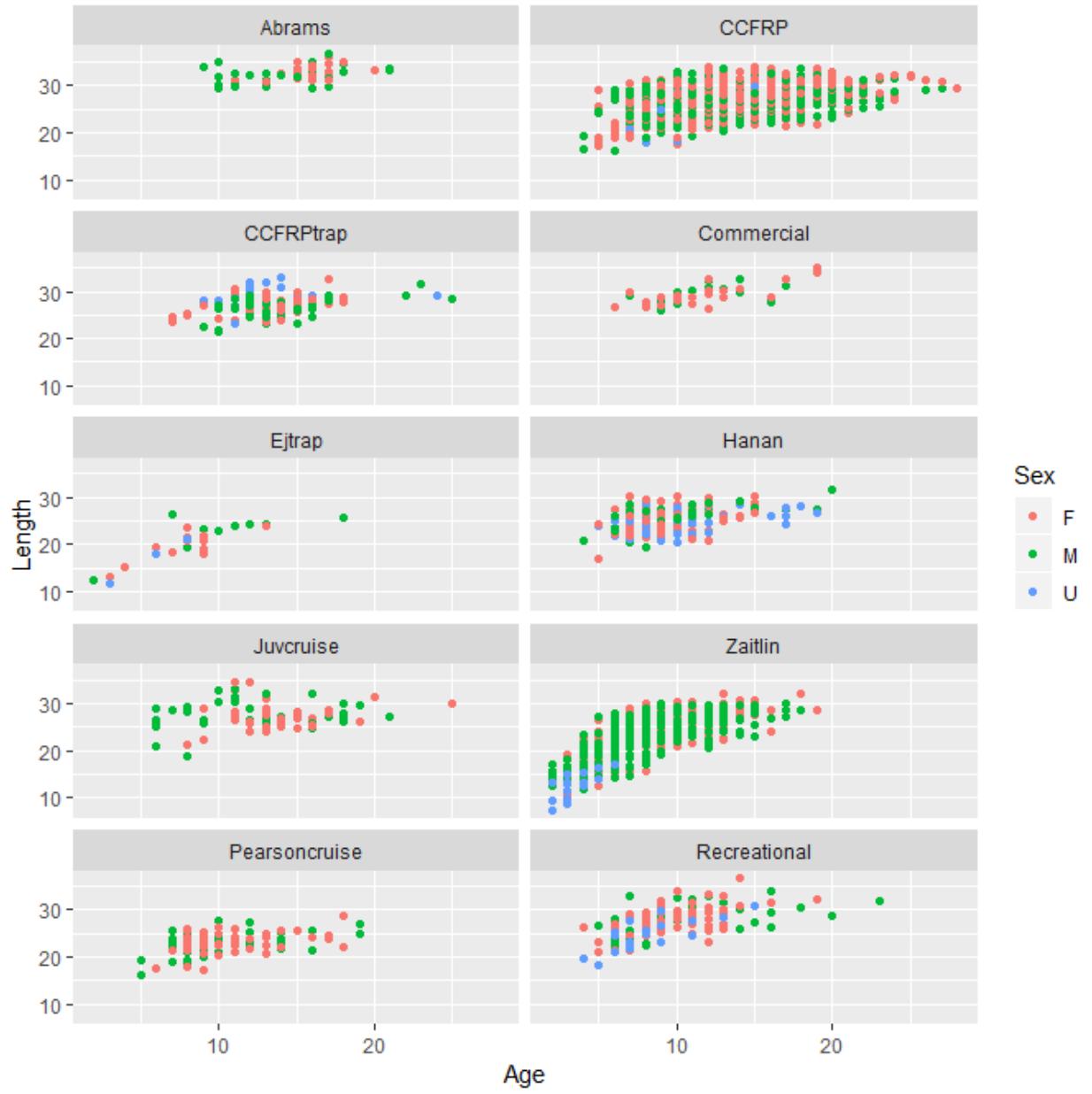


Figure 35: Available length-at-age data for gopher and black-and-yellow rockfish by sex and data source. The Zaitlin study is all black-and-yellow rockfish. The remaining plots represent gopher rockfish

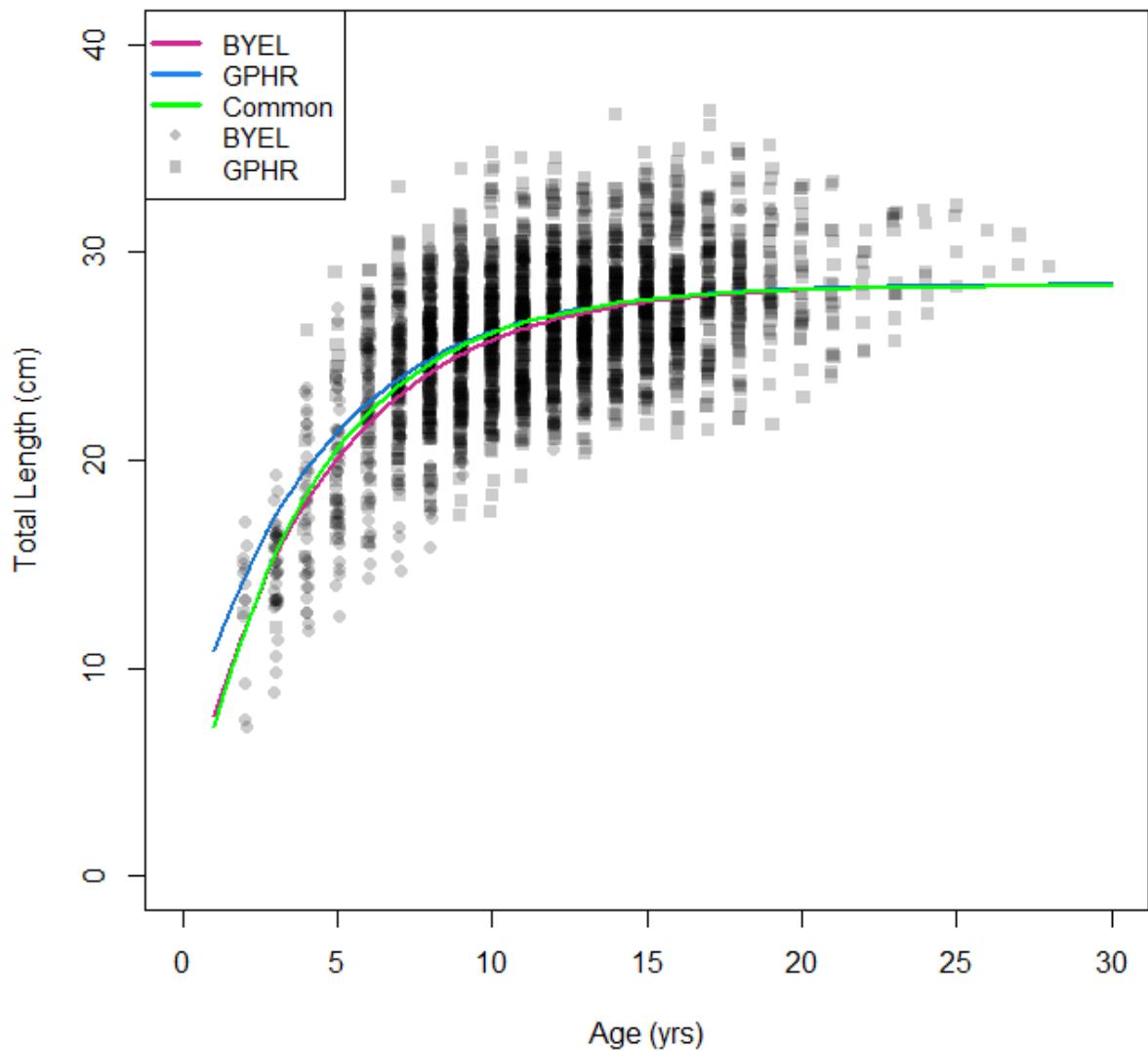


Figure 36: External estimates of growth for gopher and black-and-yellow rockfish from fits to von Bertalanffy growth models. | [Growth_by_species](#)

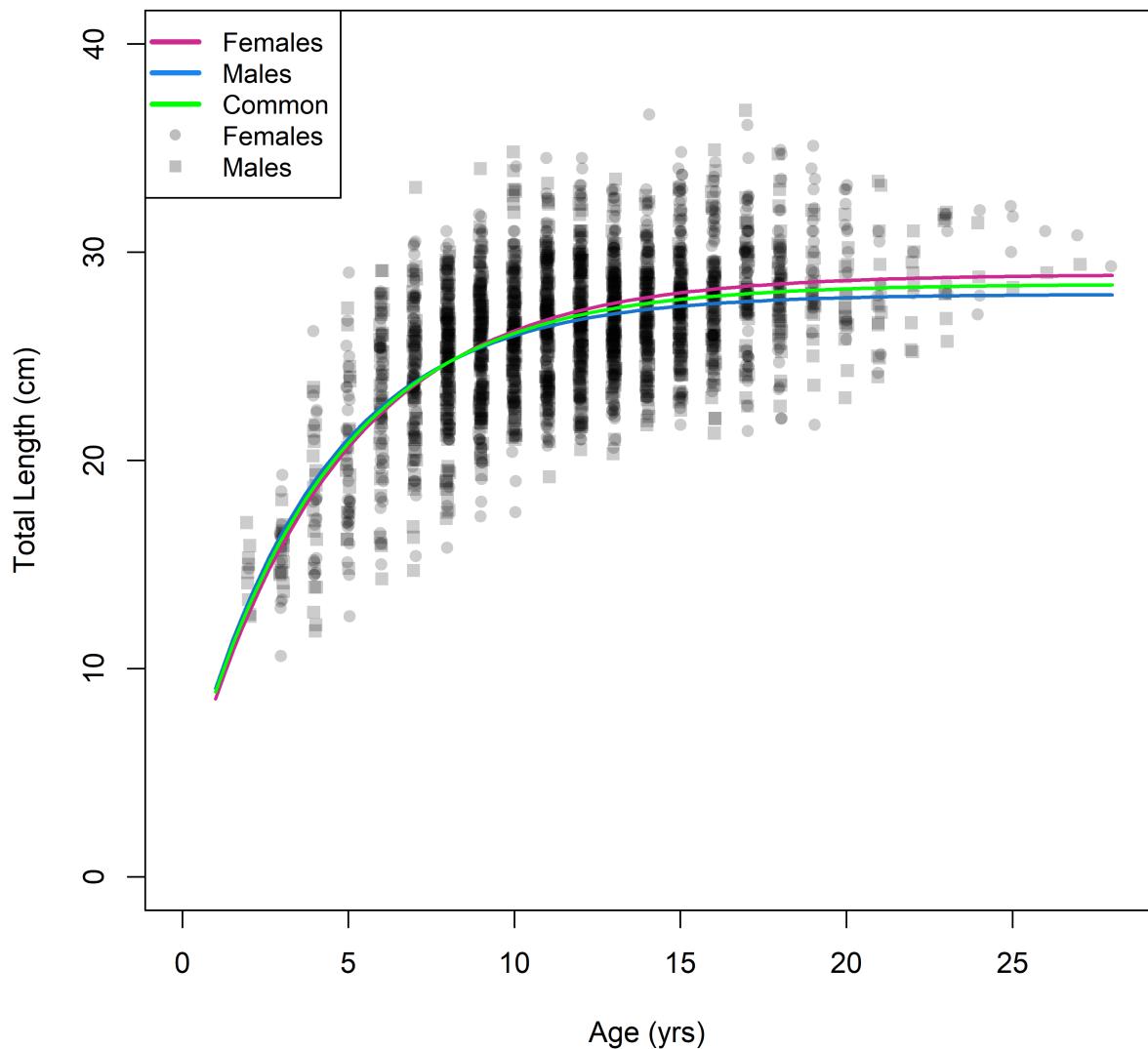


Figure 37: External estimates of growth for GBYR combined by sex from fits to von Berta-lanffy growth models. | [Growth_by_sex](#)

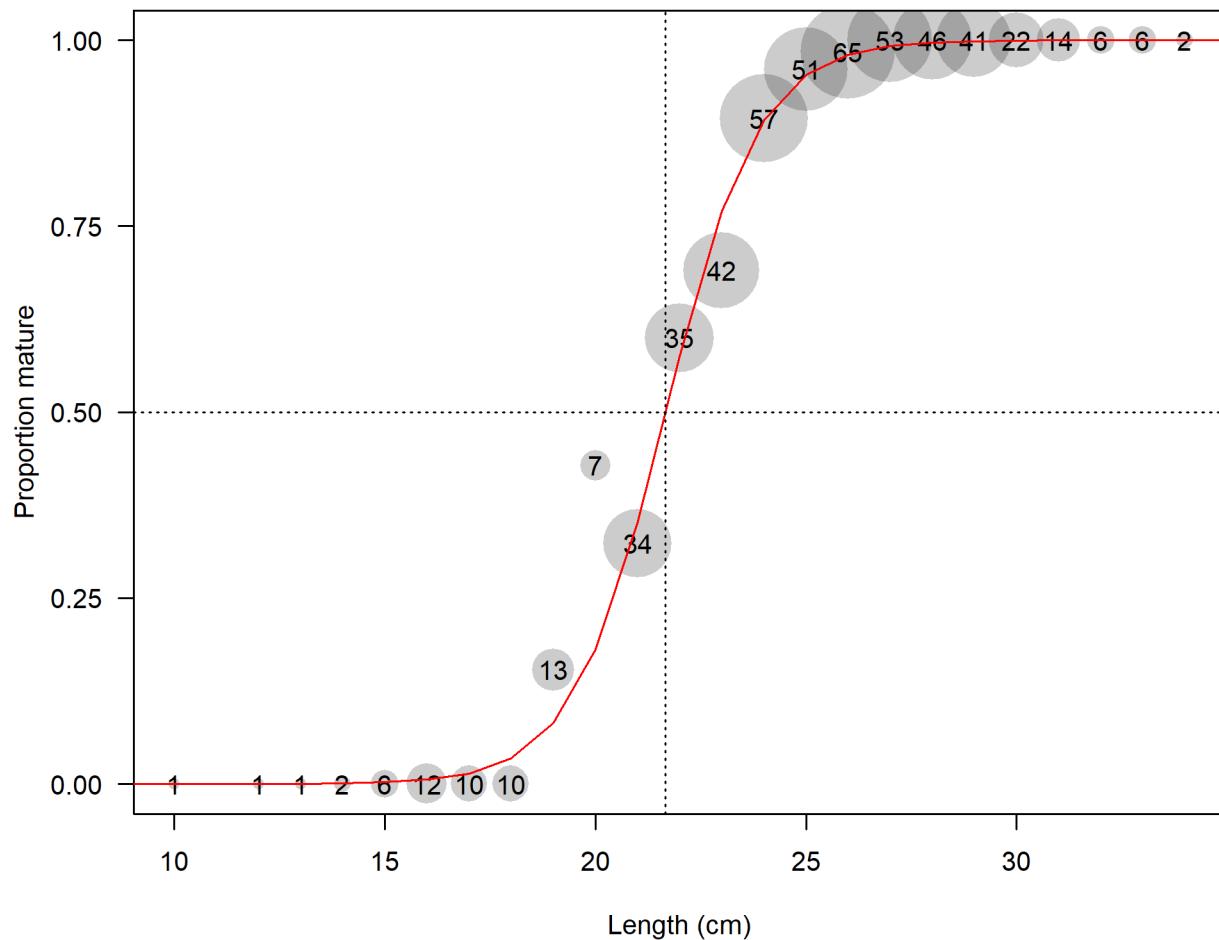


Figure 38: Maturity ogive for females estimated from black-and-yellow rockfish from Zaitlin (1986) and gopher rockfish from Meyers-Cherry (2014). Sample sizes at a given length are shown in the circles. [fig:GBY_maturity_ogive](#)

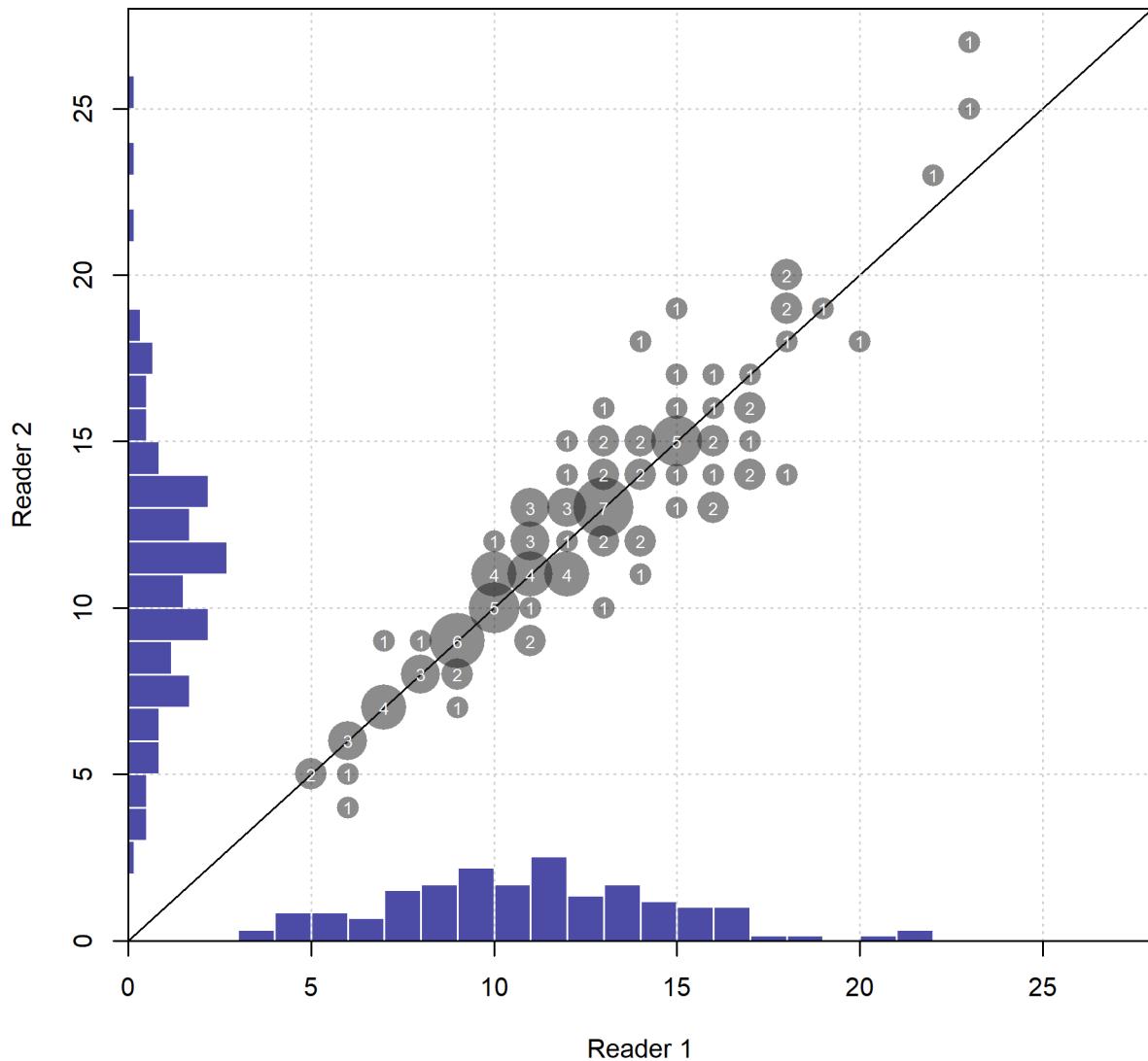


Figure 39: Aging precision between initial and blind double reads for GBYR. Numbers in the bubbles are the sample sizes of otoliths cross-read. [fig:GBY_age_error](#)

Reads(dot), Sd(blue), expected_read(red solid line),
and 95% CI for expected_read(red dotted line)

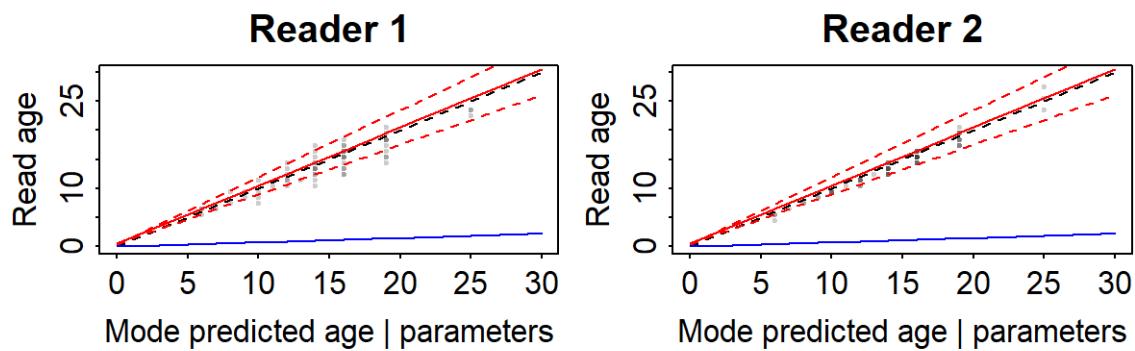


Figure 40: True versus predicted age for two current age readers at the NWFSC from the ageing error software with unbiased reads and curvilinear standard deviation for both readers.
fig:GBY_age_error2

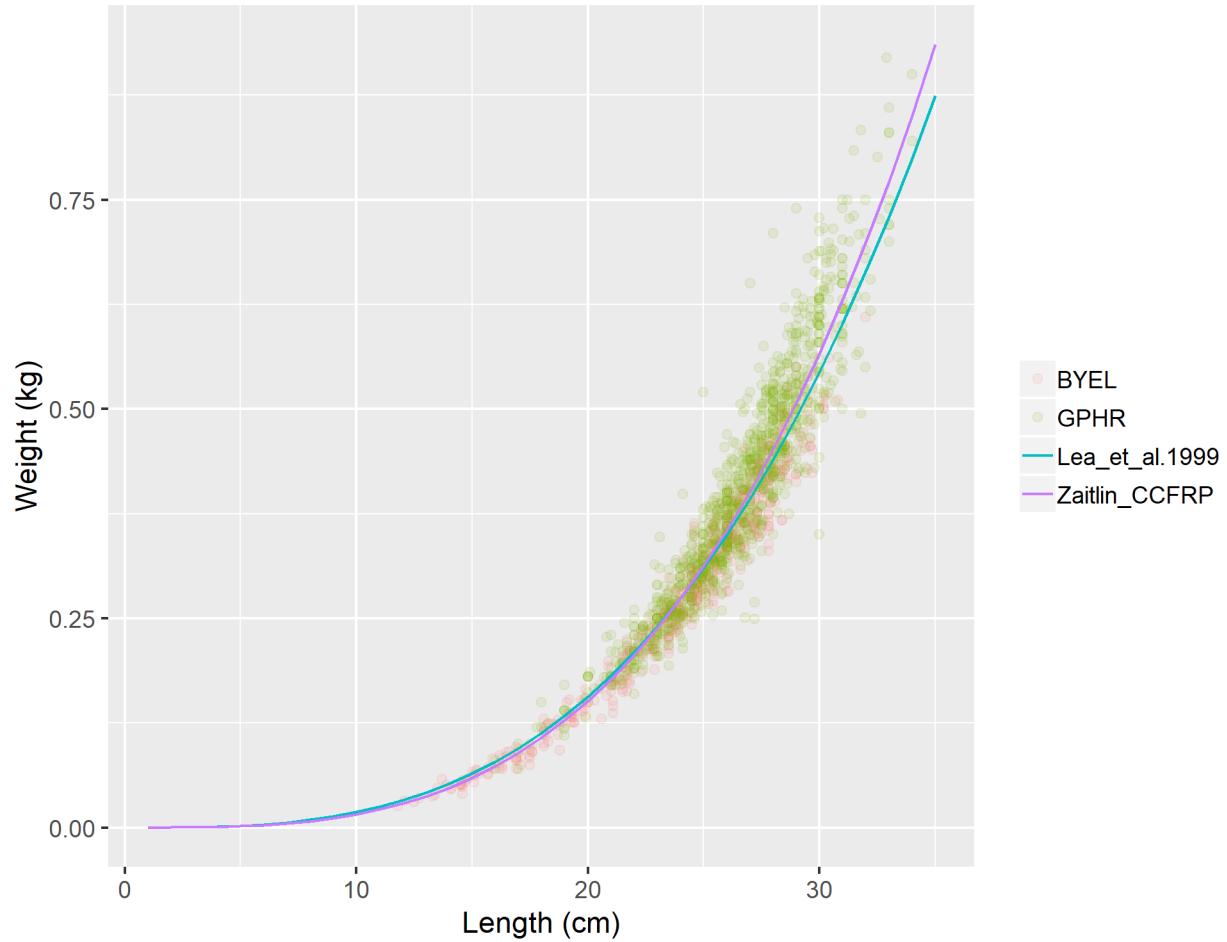


Figure 41: Comparison of the gopher rockfish weight-length curves from Lee et al. (1999) and the estimated from black-and-yellow rockfishes from Zaitlin (1986), and gopher rockfishes from Loury (2011) and Meyers-Cherry(2014). The estimated curve from the current data is used in this assessment. [fig:GBY_weight_length](#)

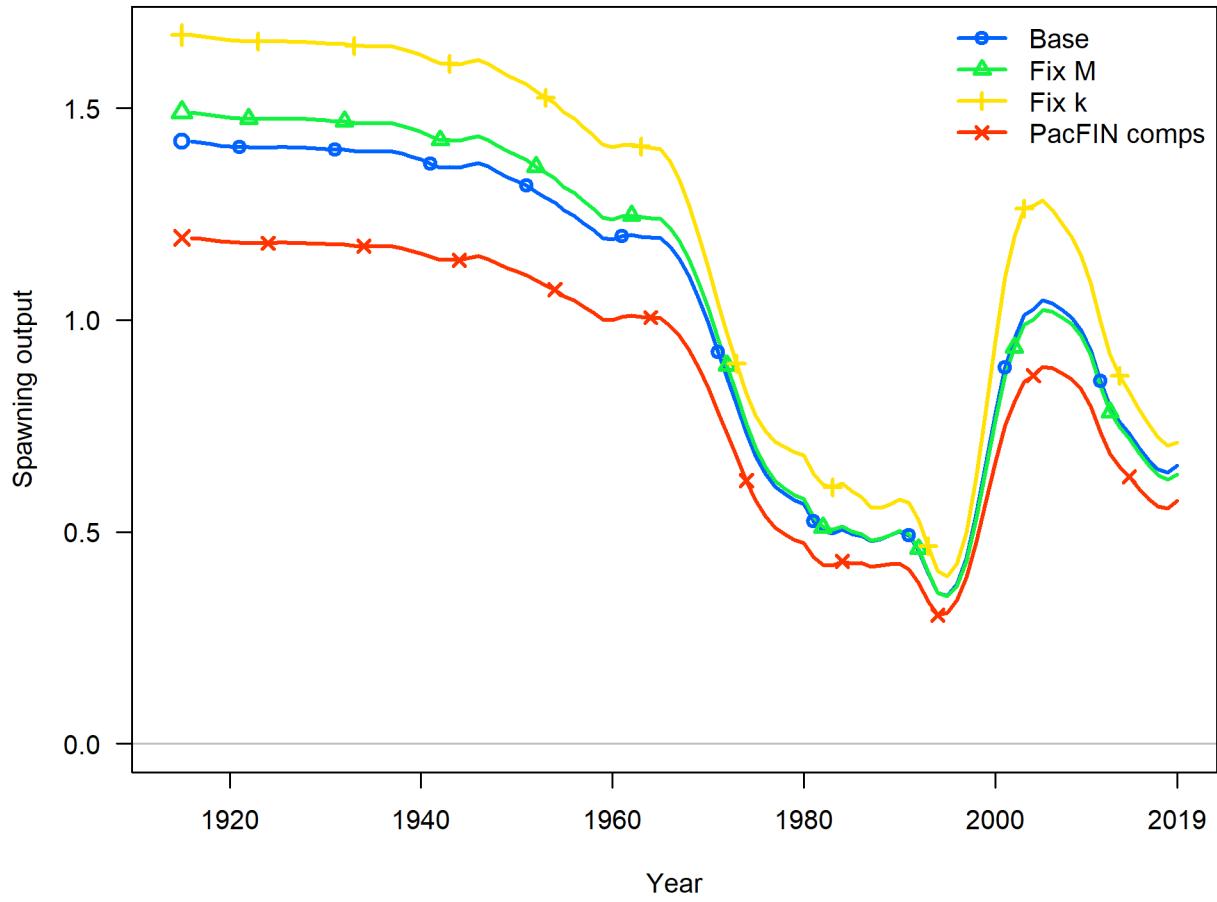


Figure 42: Sensitivity of the spawning biomass to fixing natural mortality to the prior, fixing the von Bertalanffy k parameter to the external estimate, or using commercial PacFIN length composition data instead of CALCOM, as compared to the pre-STAR base model. [fig:sensitivity1_spaw](#)

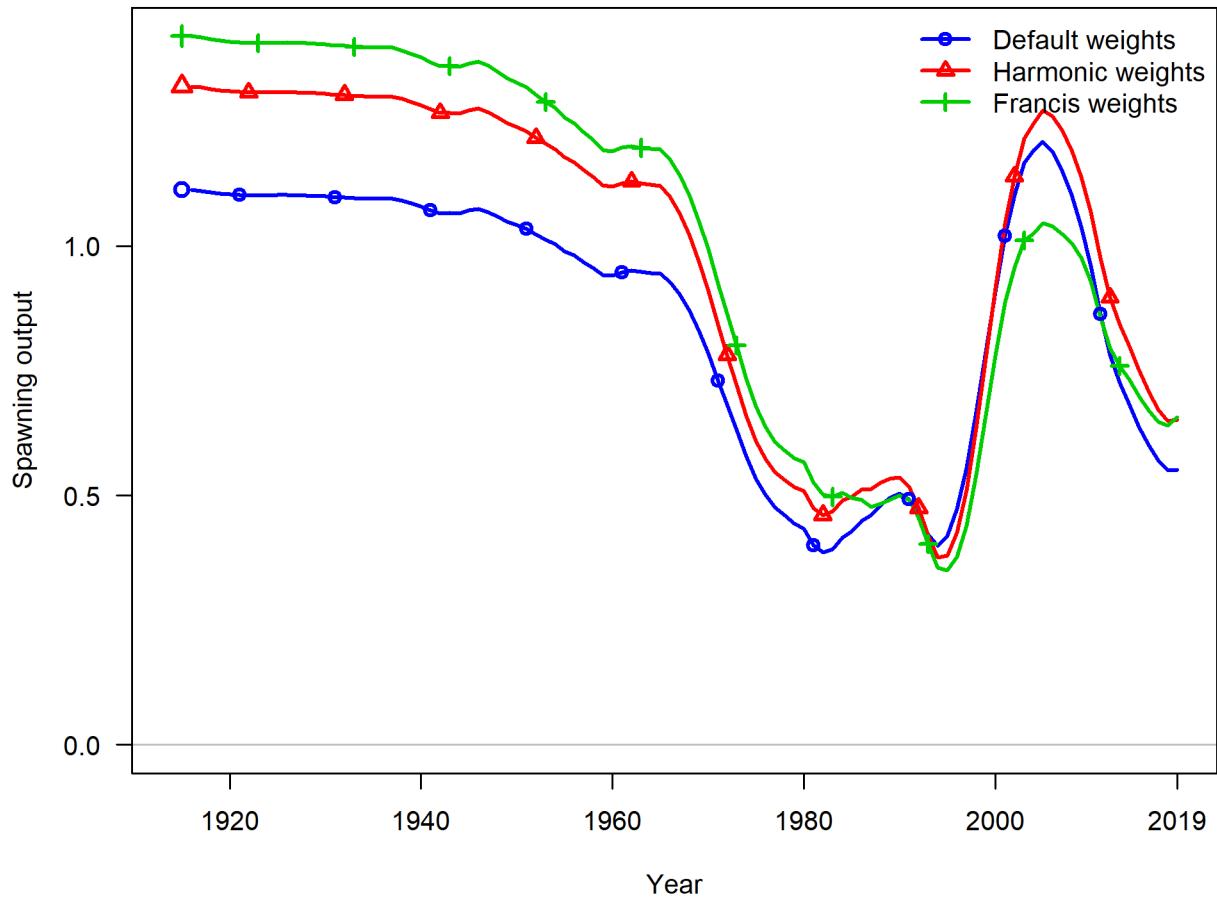


Figure 43: Sensitivity of the spawning biomass to either the default weight of composition data, the harmonic mean, or Francis weights. [fig:sensitivity2_spawnbio](#)

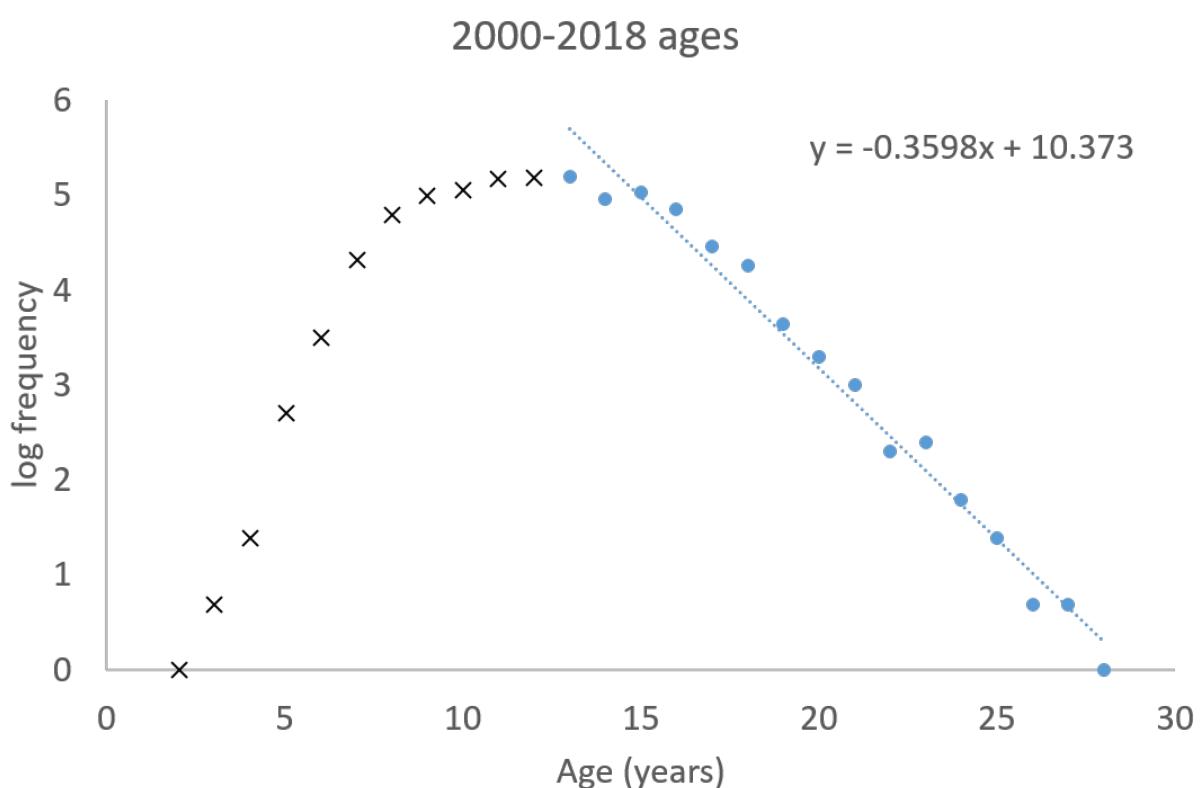
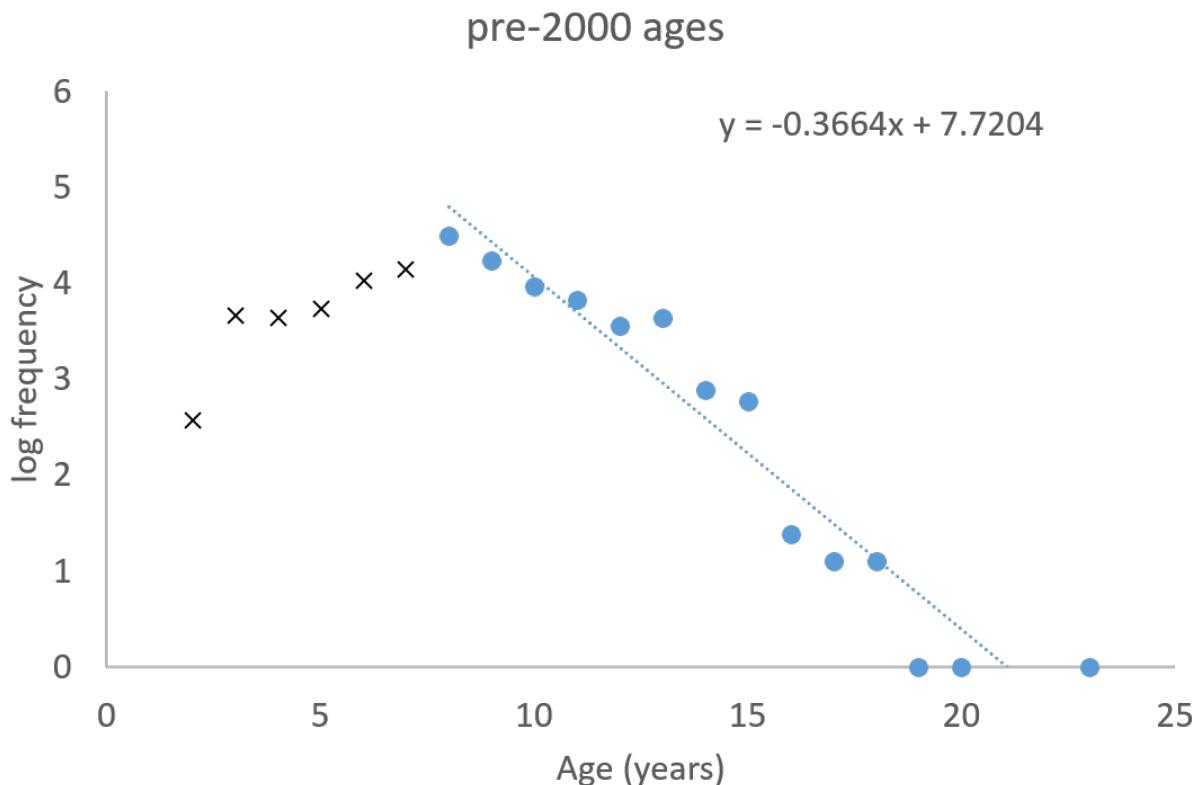


Figure 44: Catch curve analysis for age data prior to 2000 and for 2000-2018.

fig:STAR_request1

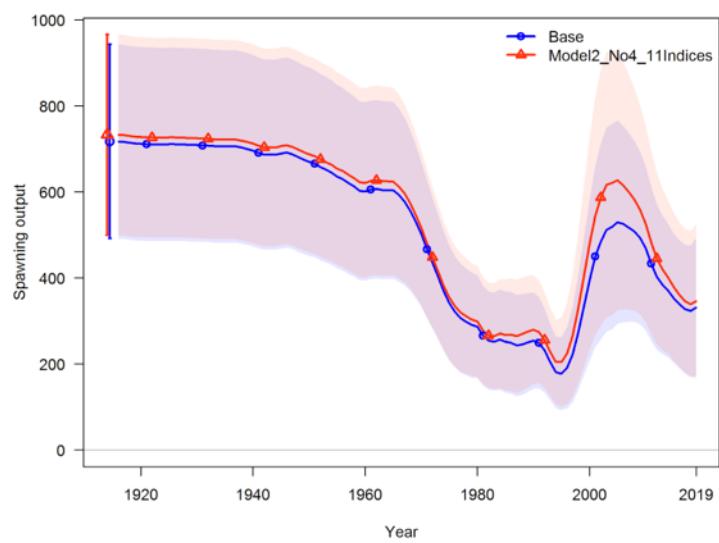
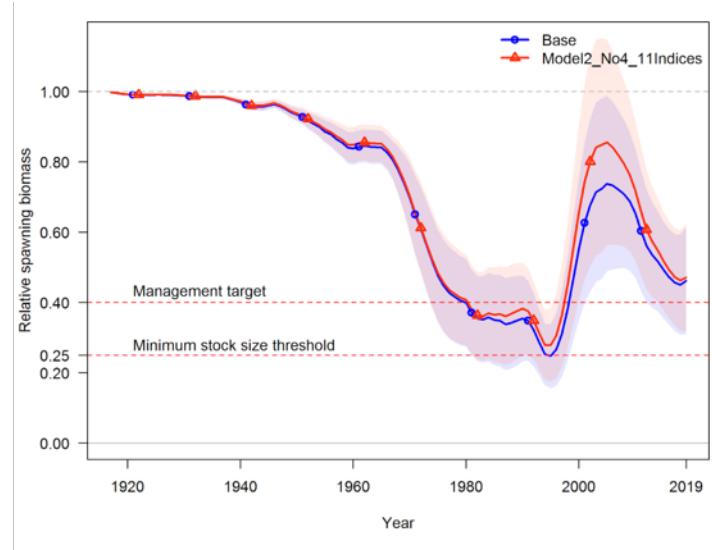


Figure 45: Comparison of time series of relative and absolute spawning output from pre-STAR base model and the model from request 2 removing southern indices. [fig:STAR_request2](#)

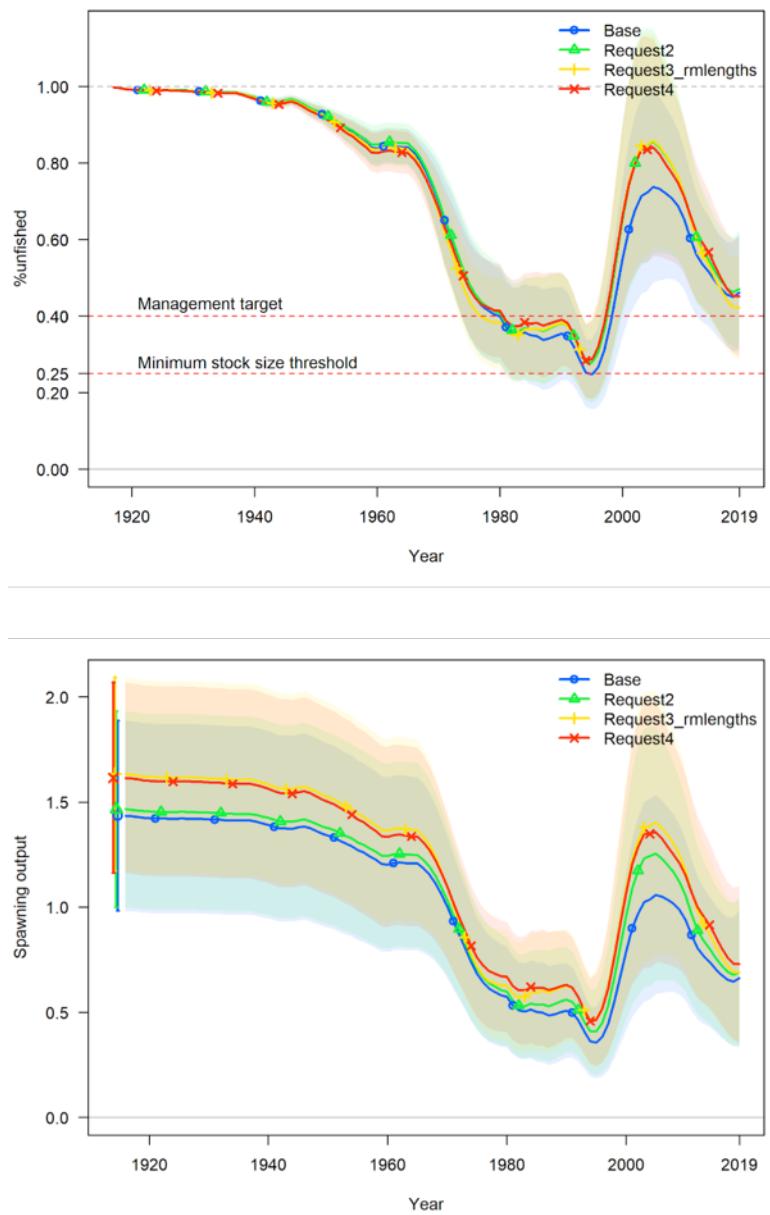


Figure 46: Comparison of time series of relative and absolute spawning output from pre-STAR base model and models from requests 2, 3a and 4. fig:STAR_request3

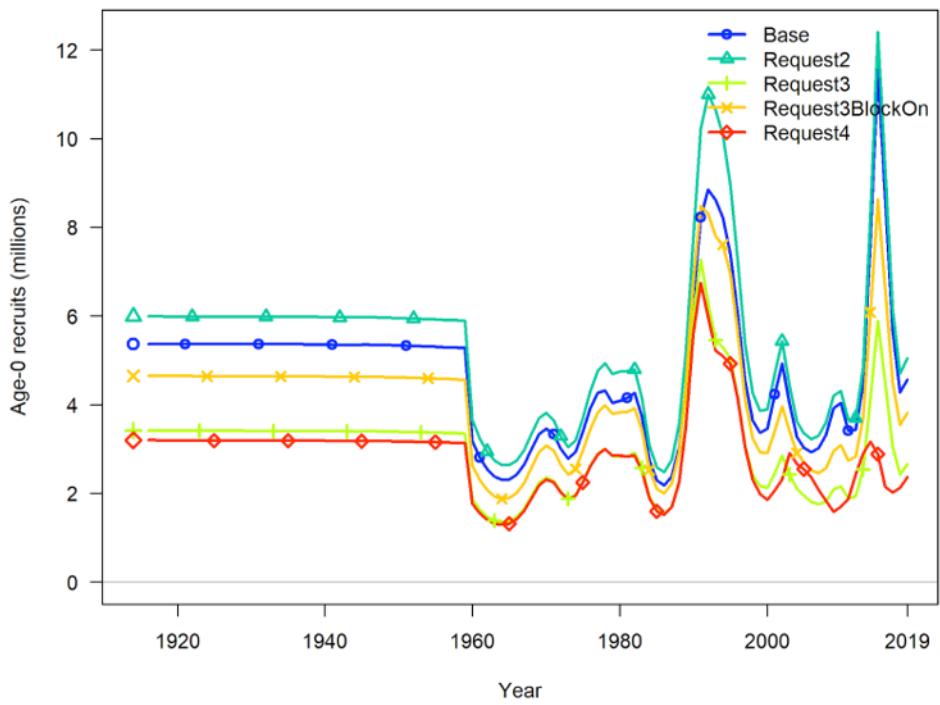


Figure 47: Comparison of time series of recruits from pre-STAR base model and models from requests 2, 3a and 4a. [fig:STAR_request4](#)

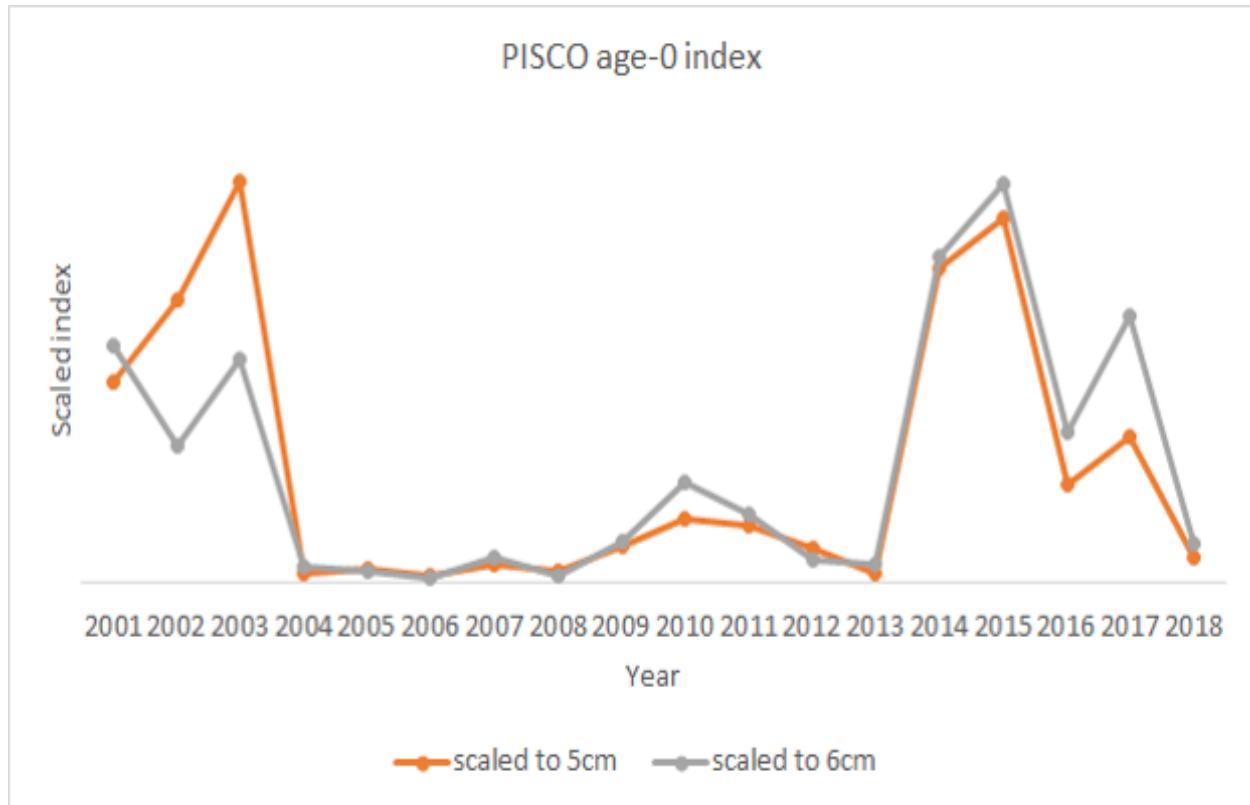


Figure 48: The PISCO recruitment index based upon observed individuals of 4 and 5 cm (“scaled to 5cm”) or 4, 5a and 6 cm (“scaled to 6 cm”).

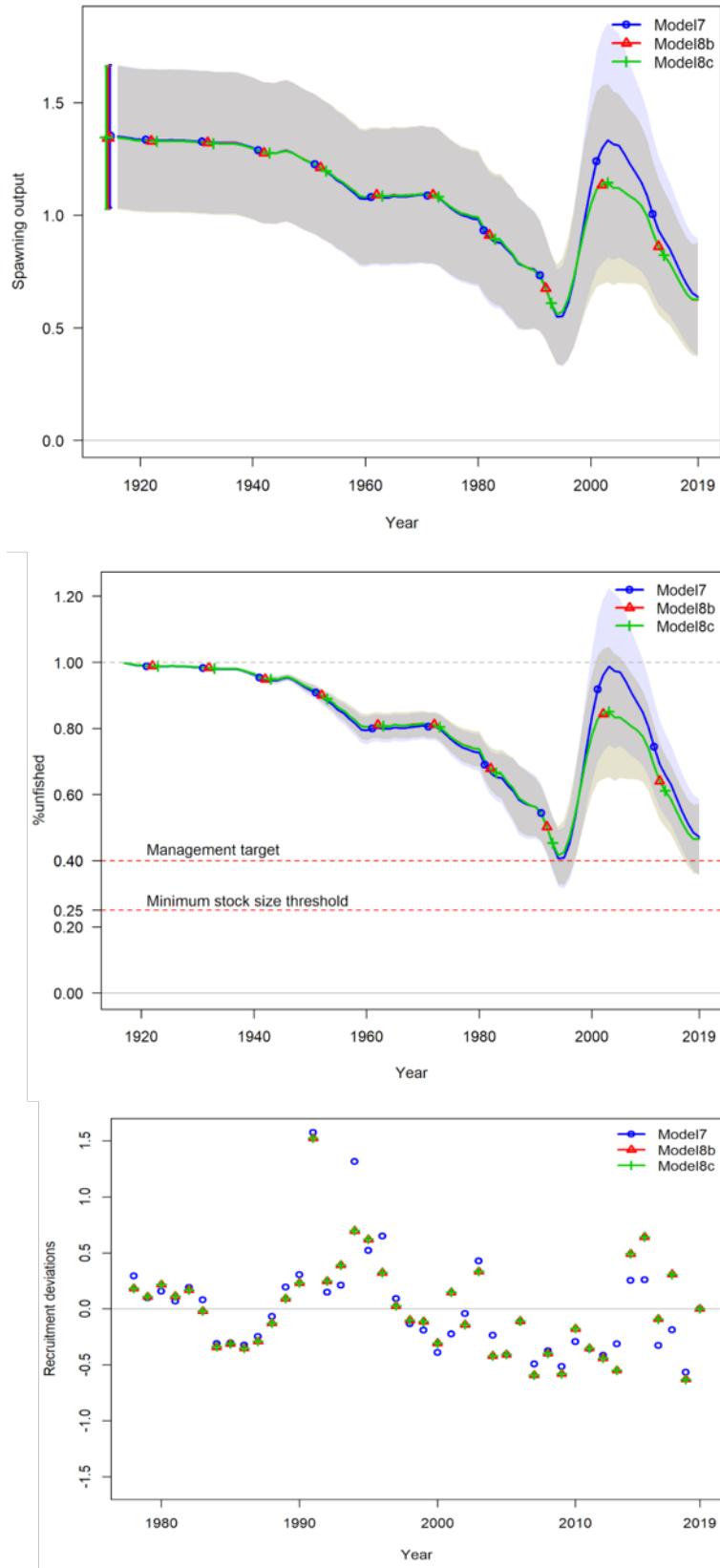


Figure 49: Results of request 7 and 8. Time series of absolute (top) and relative (middle) spawning output and recruitment deviations (now staring in 1978; bottom). [fig:STAR_request8_2](#)

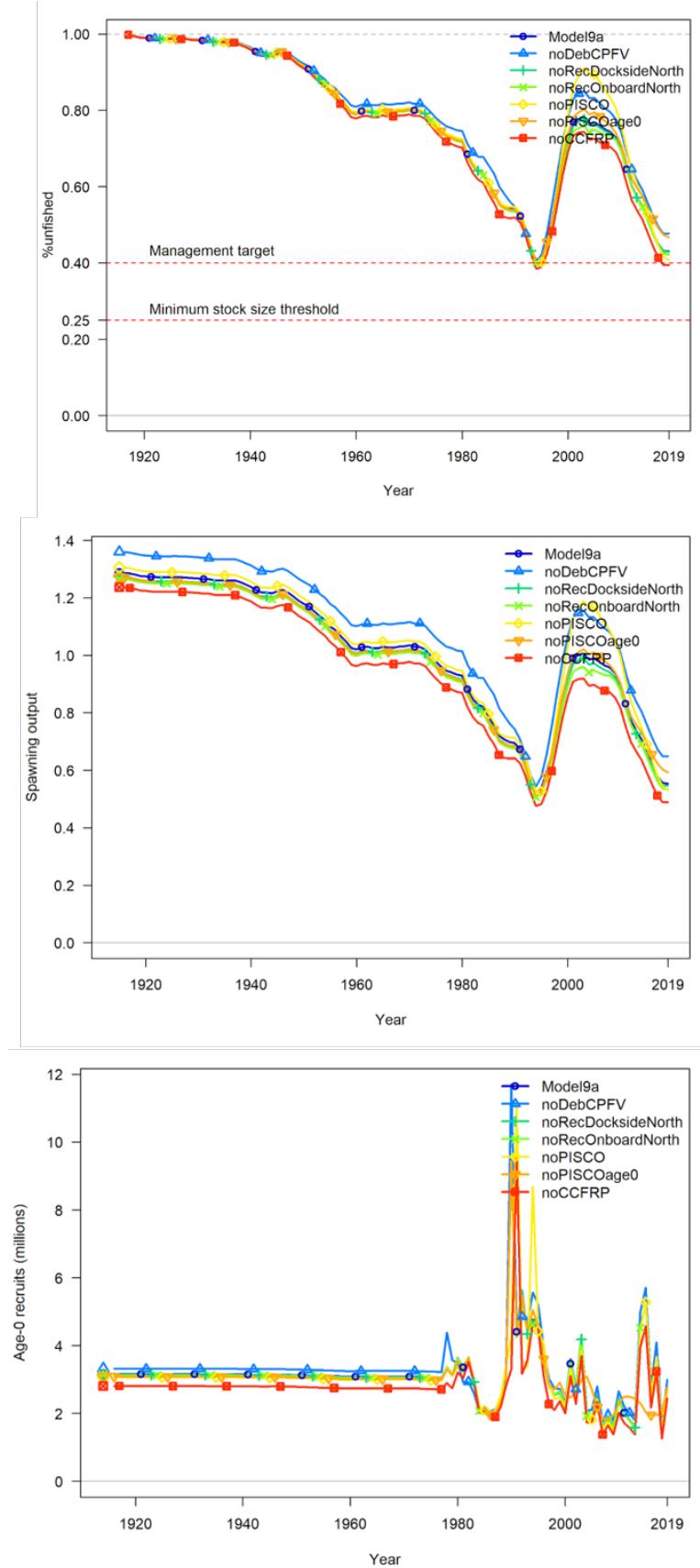


Figure 50: . Results of request 10, drop-1-out analysis. Time series of relative (top) and absolute (middle) spawning output and recruitment estimates (now staring in 1978; bottom).
 fig:STAR_request10

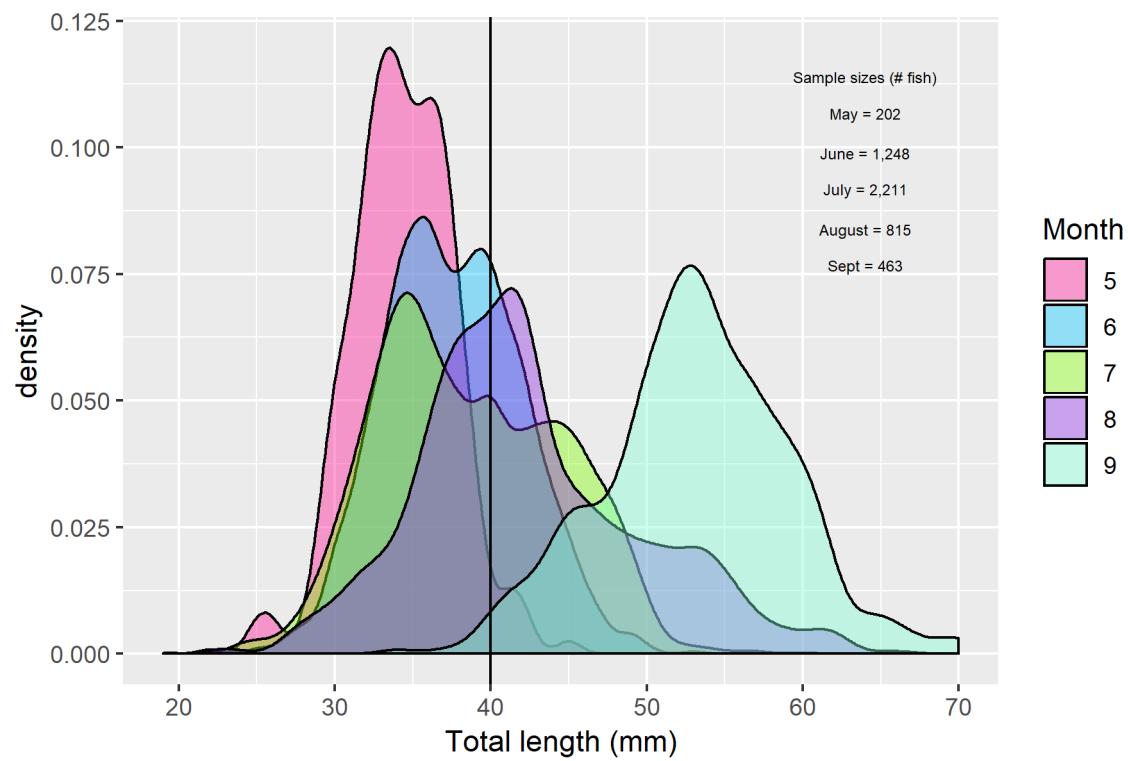


Figure 51: Length distribution by month for GBYR captured using a sampling tool called a Standard Monitoring Unit for the Recruitment of Fishes (SMURFs) from the UCSC-PISCO kelp forest fish survey, specifically as part of Diana Baetscher's dissertation work (Baetscher 2019). [fig:SMURF_lengths](#)

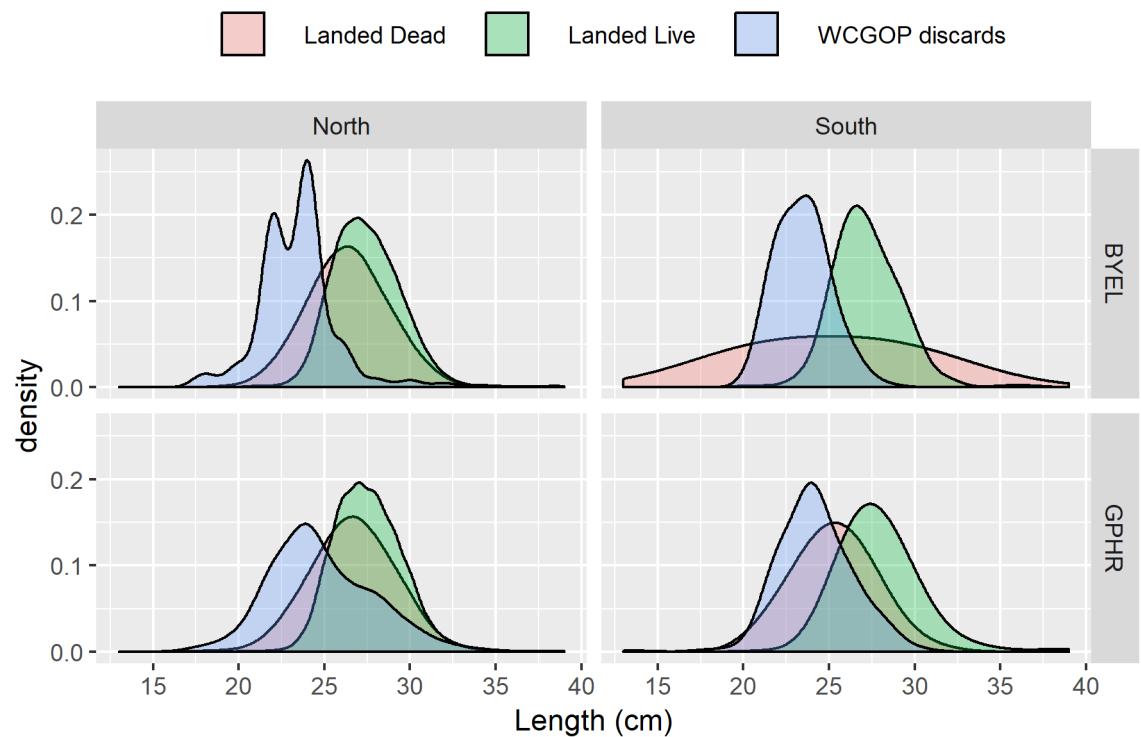


Figure 52: Length distributions of gopher and black-and-yellow rockfish for the commercial fleet and WCGOP discards north and south of Point Conception. The commercial landings were also separated between fish landed live and fish landed dead for this figure. [fig:Comm_lengths_justified](#)

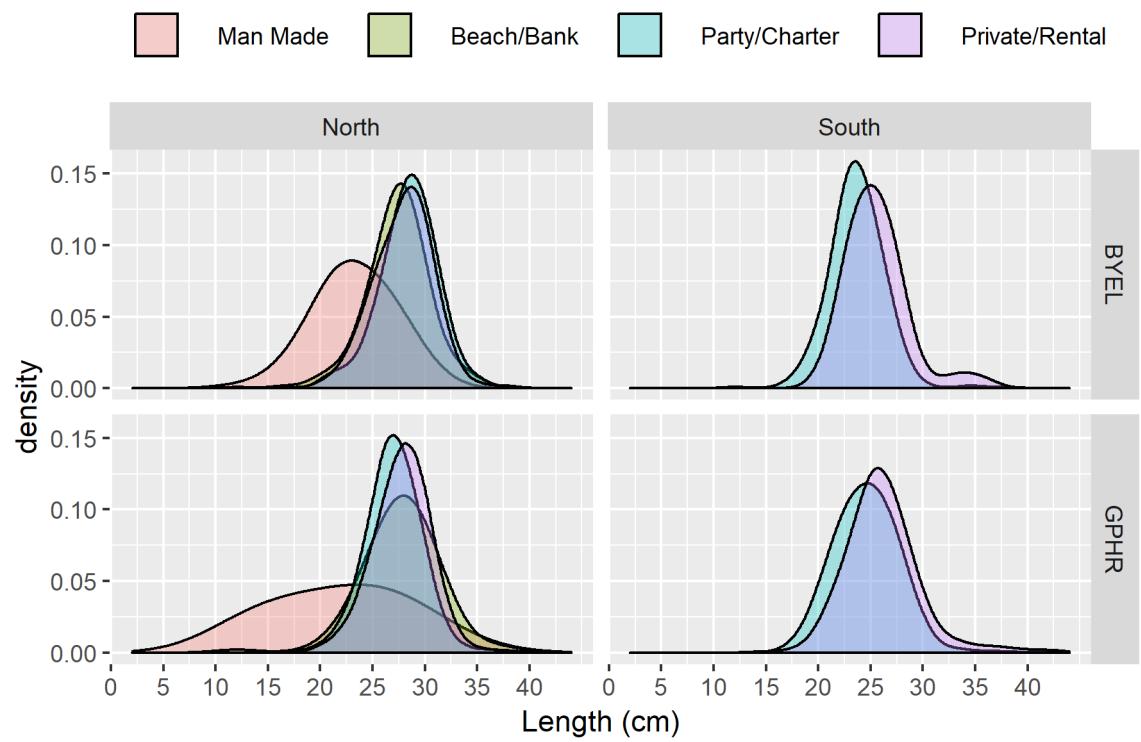


Figure 53: Length distributions of gopher and black-and-yellow rockfish for the recreational fleet north and south of Point Conception and by mode. fig:Rec_lengths_justification

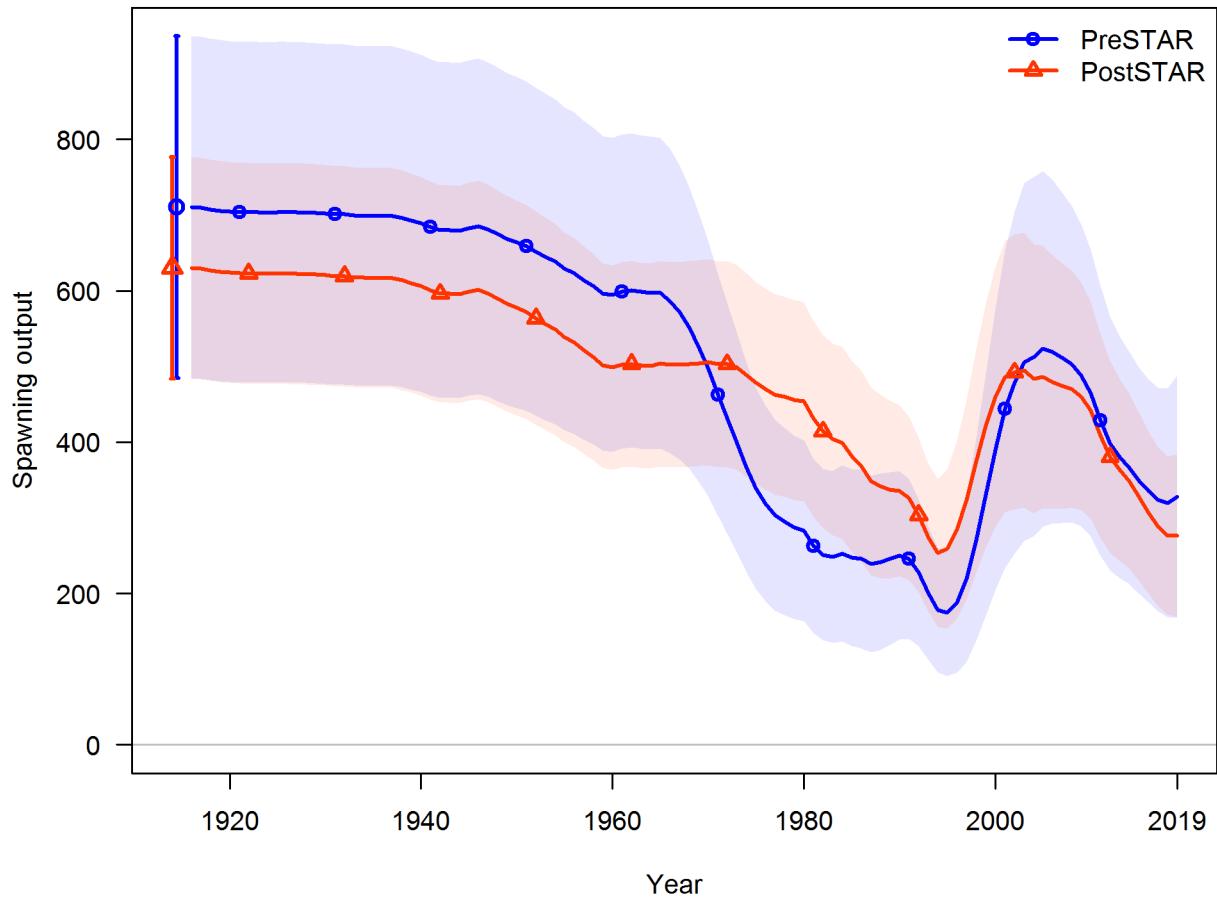


Figure 54: Comparison of the spawning output between the pre-STAR panel base model and the post-STAR model base. [fig:preSTAR_postSTAR_compare_spawnbio](#)

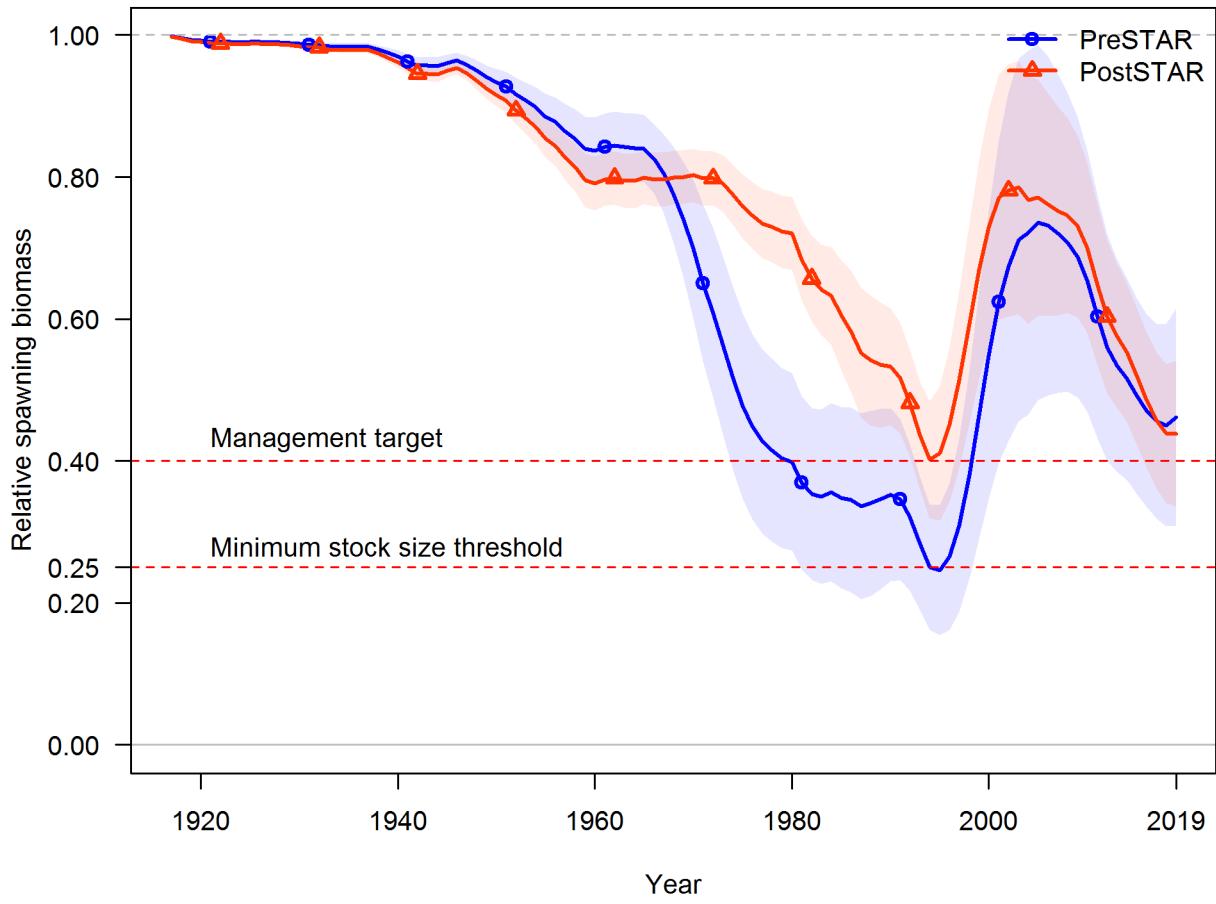


Figure 55: Comparison of the relative spawning output (depletion) between the pre-STAR panel base model and the post-STAR model base. [fig:preSTAR_postSTAR_compare_Bratio](#)

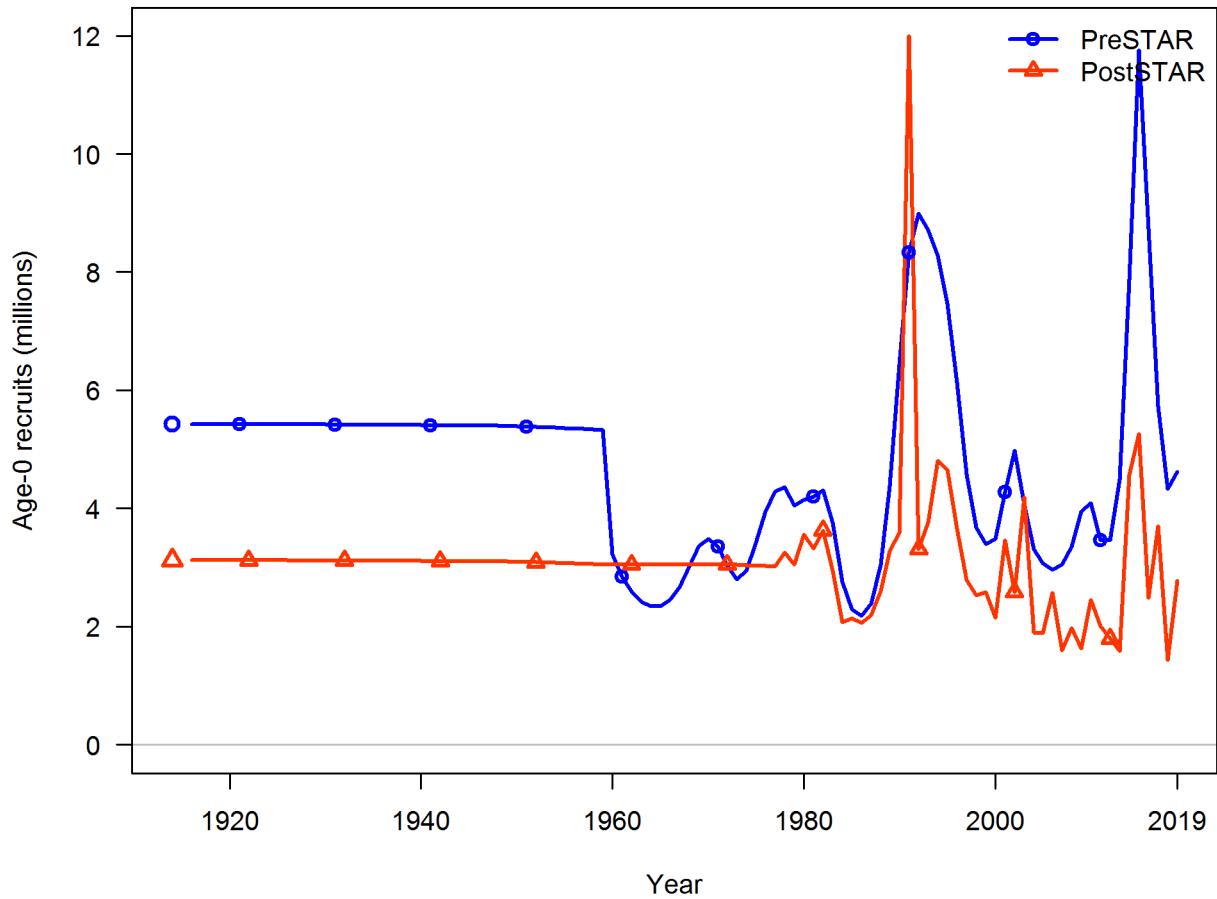


Figure 56: Comparison of the age-0 recruits between the pre-STAR panel base model and the post-STAR model base. [fig:preSTAR_postSTAR_compare_recruit](#)

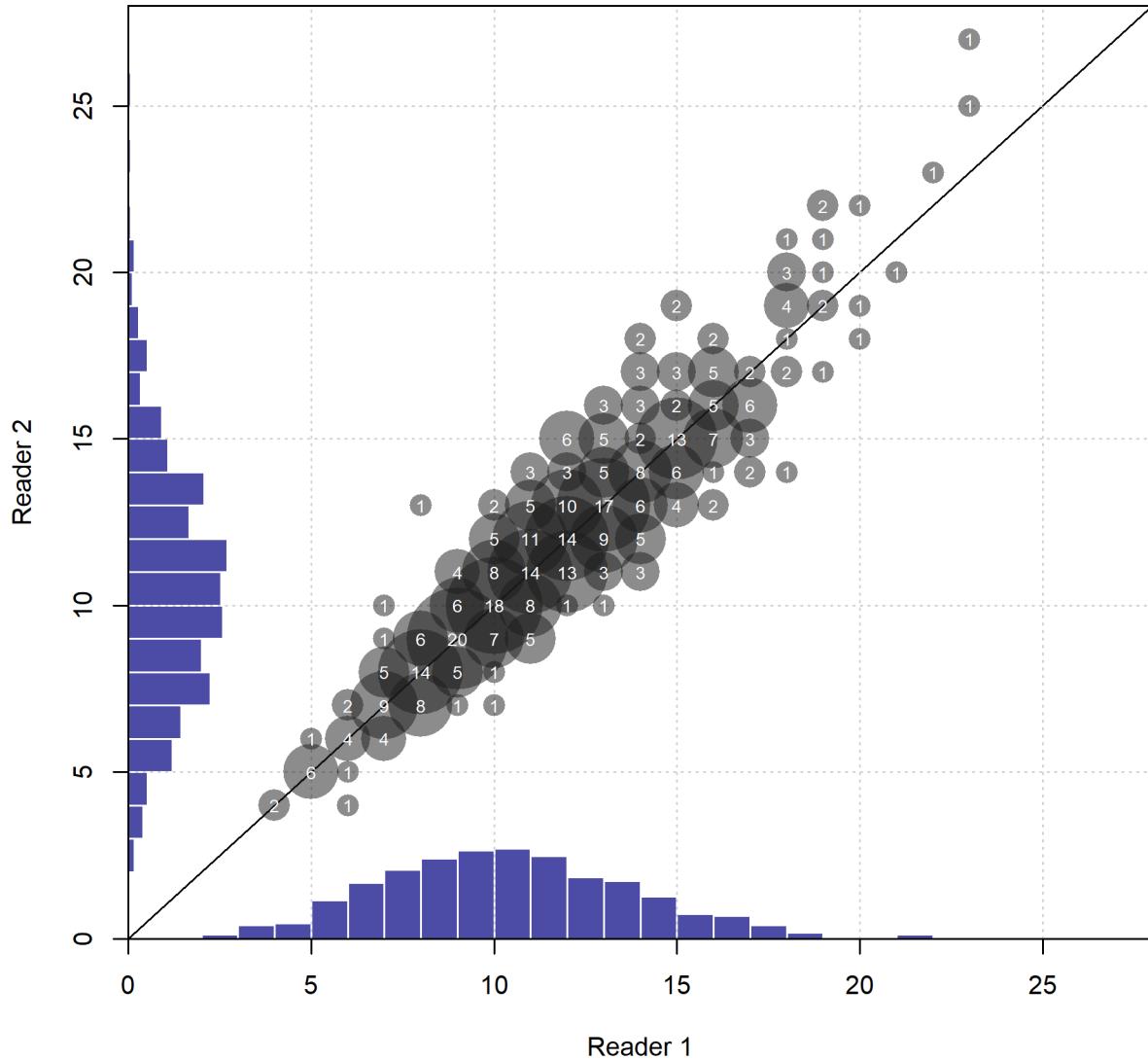


Figure 57: Updated aging precision used in the post-STAR base model between initial and blind double reads for GBYR. Numbers in the bubbles are the sample sizes of otoliths cross-read. [fig:GBY_age_error_updated](#)

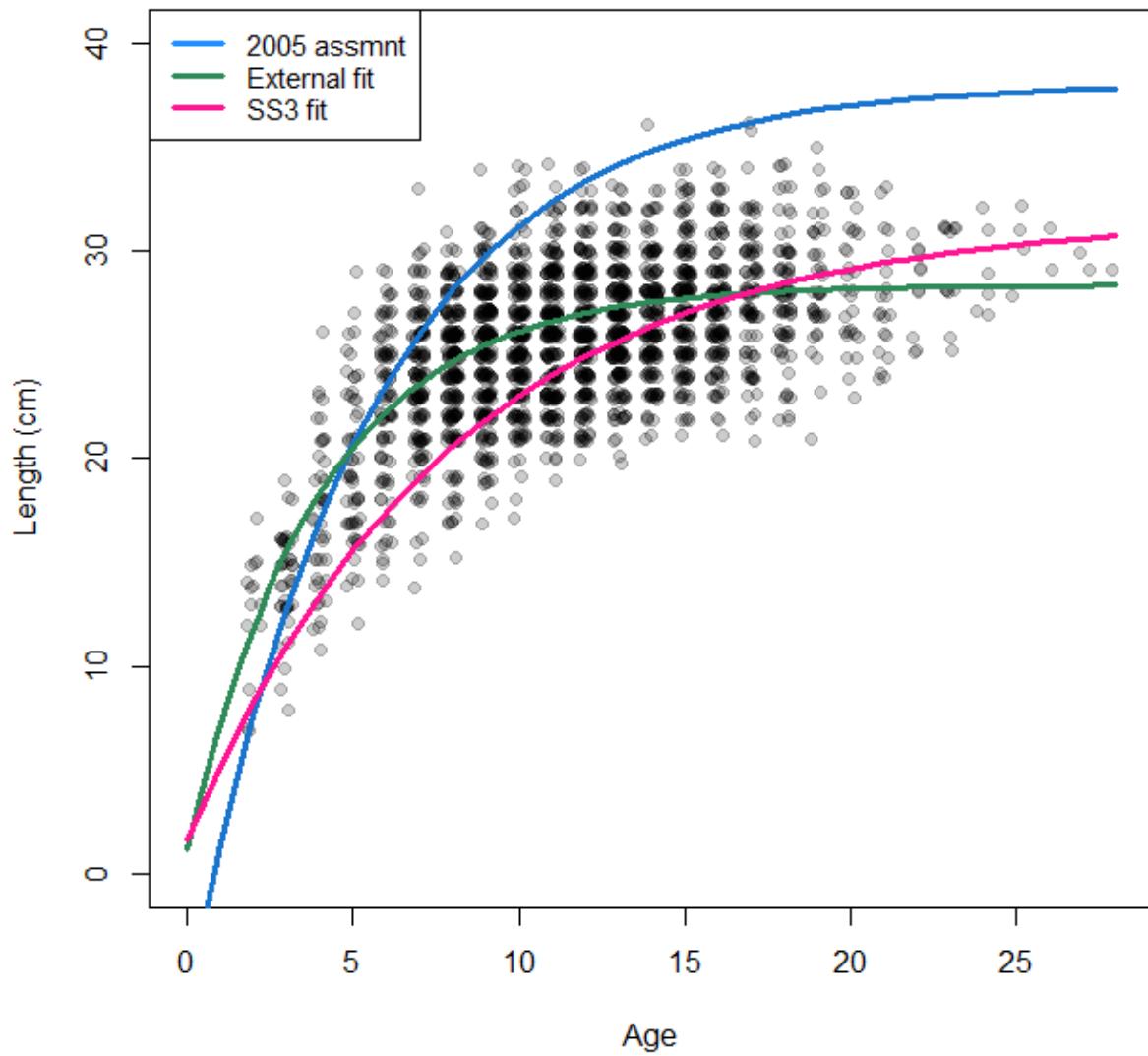


Figure 58: Estimates of growth for GBYR from the 2005 assessment, external fit to the CAAL data used in this assessment and the internal SS estimate of growth for this assessment. All growth curves were estimated using the Schnute parameterization of the von Bertalanffy growth curve. [fig:growth_compare](#)

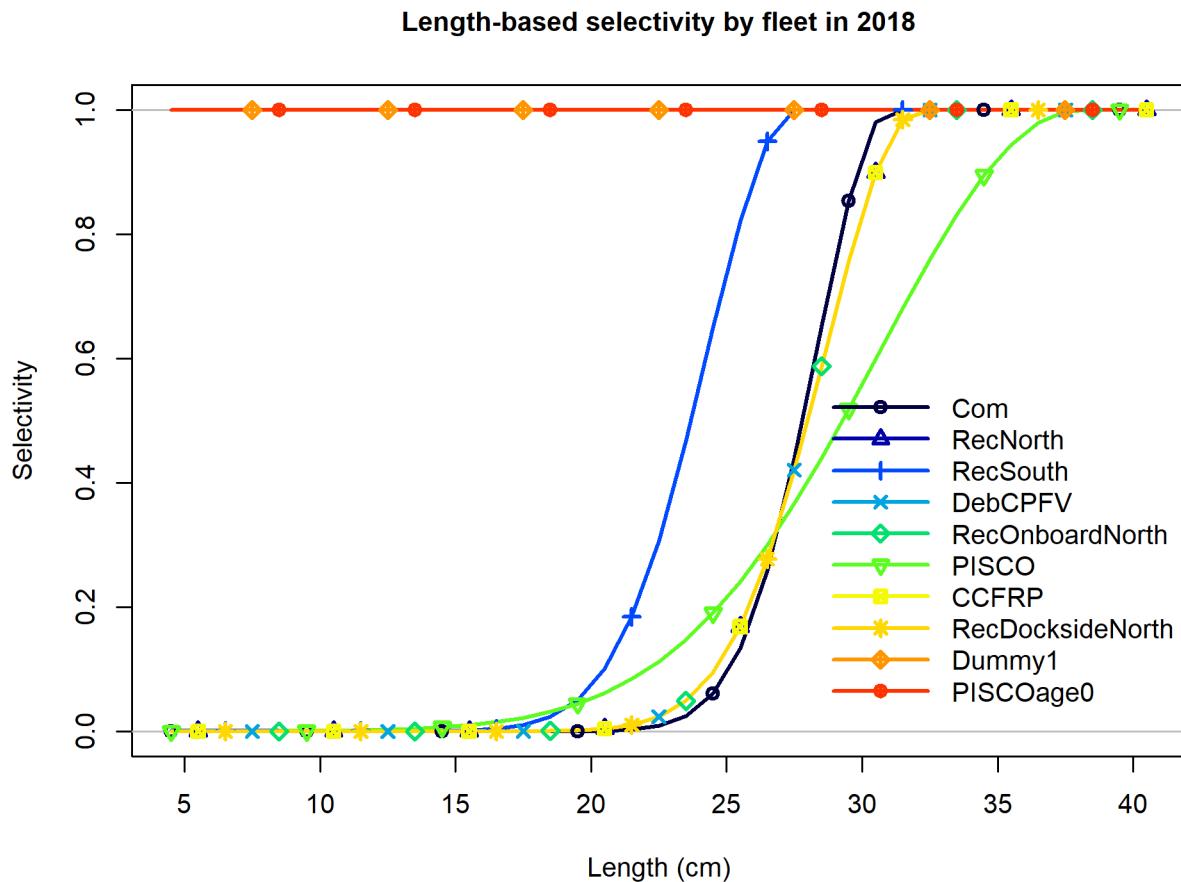


Figure 59: Selectivity at length for all of the fleets in the base model. fig:sel01_multiple_fle

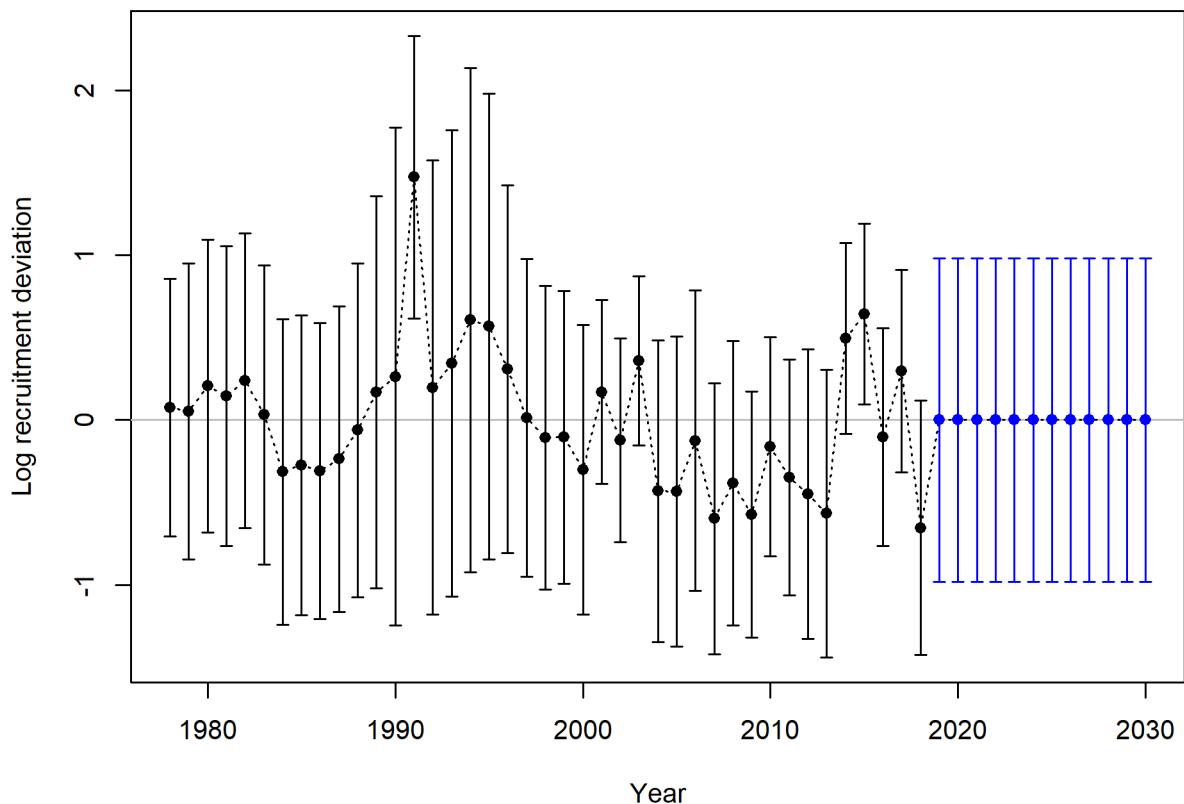


Figure 60: Estimated time-series of recruitment deviations for GBYR with 95% intervals. `fig:recdevs2`

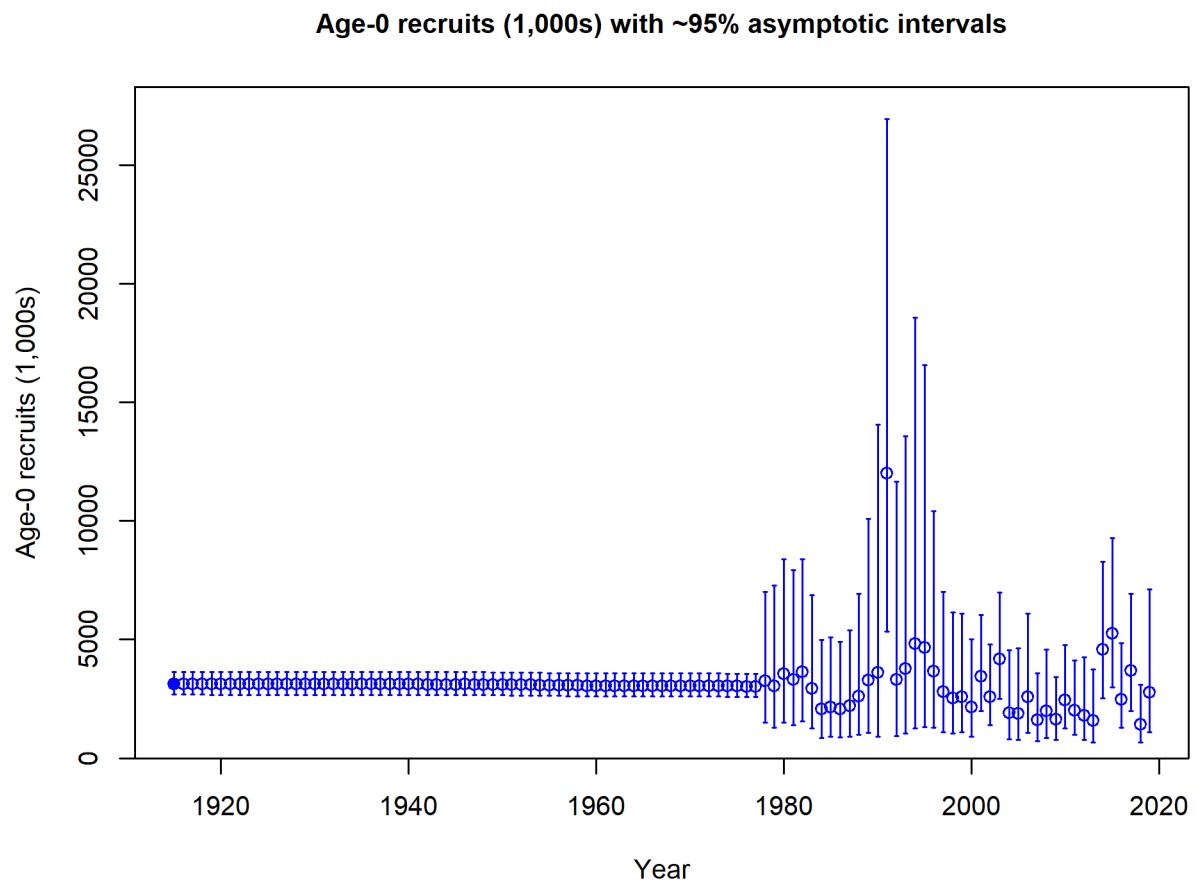


Figure 61: Time series of estimated GBYR recruitments for the base-case model with 95% confidence or credibility intervals. [fig:Recruit_mod1](#)

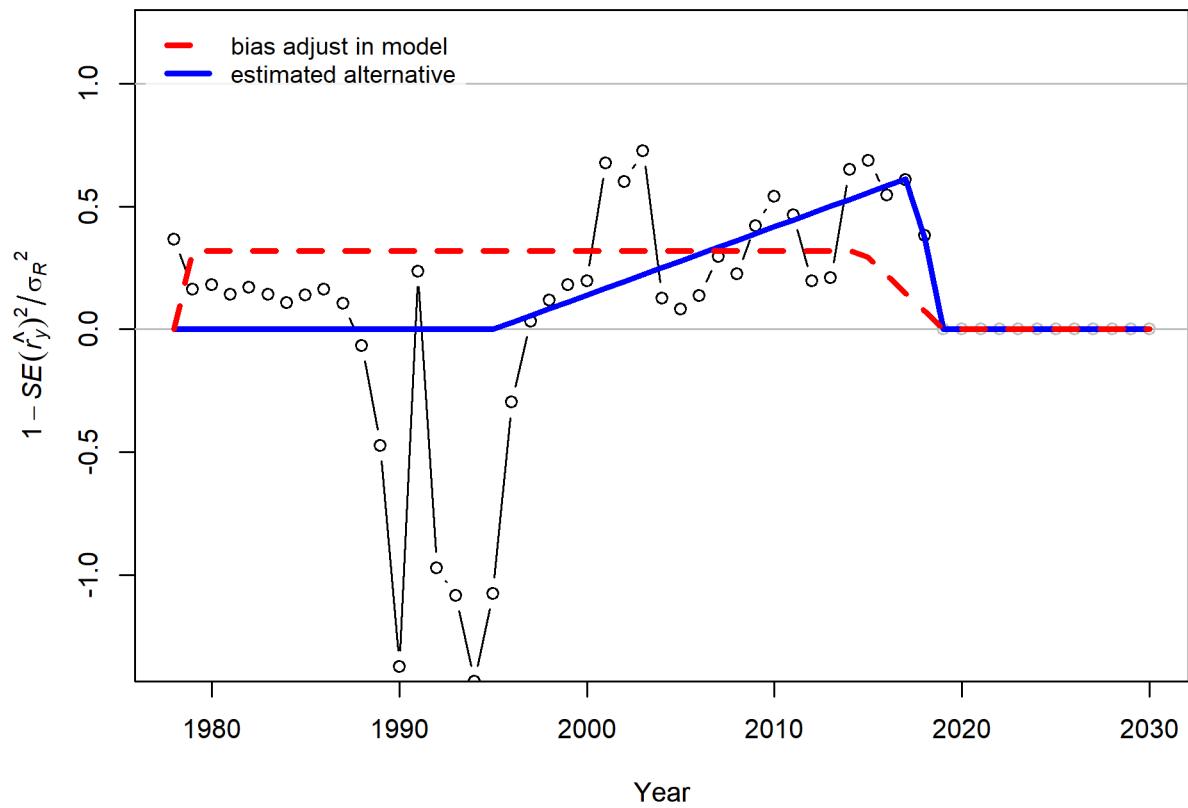


Figure 62: Bias adjustment for recruitment deviations. Points are transformed variances. Red line shows current settings for bias adjustment specified in the control file. Blue line shows the least squares estimate of alternative bias adjustment relationship for recruitment deviations.

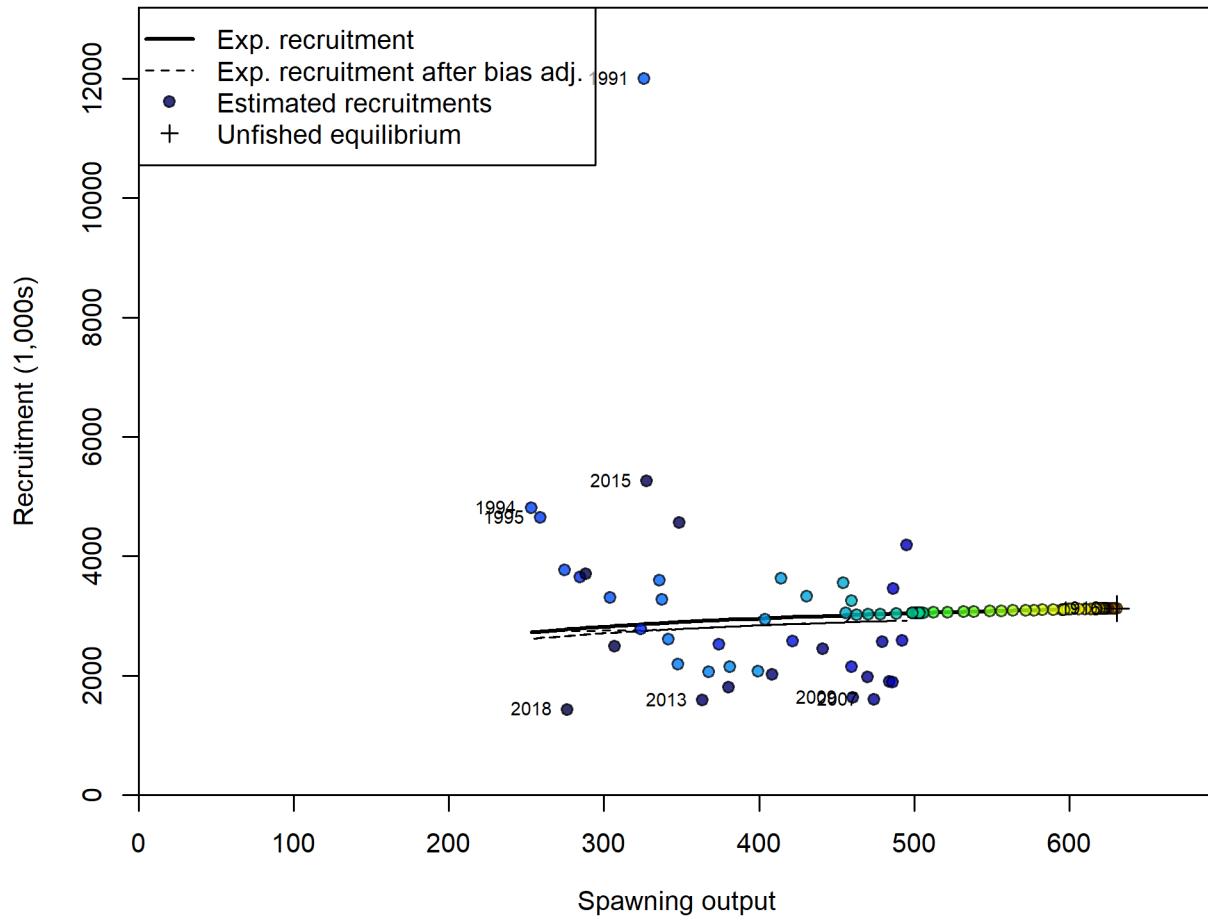


Figure 63: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line) for GBYR. The green line shows the effect of the bias correction for the lognormal distribution. ^{fig:SR_curve2}

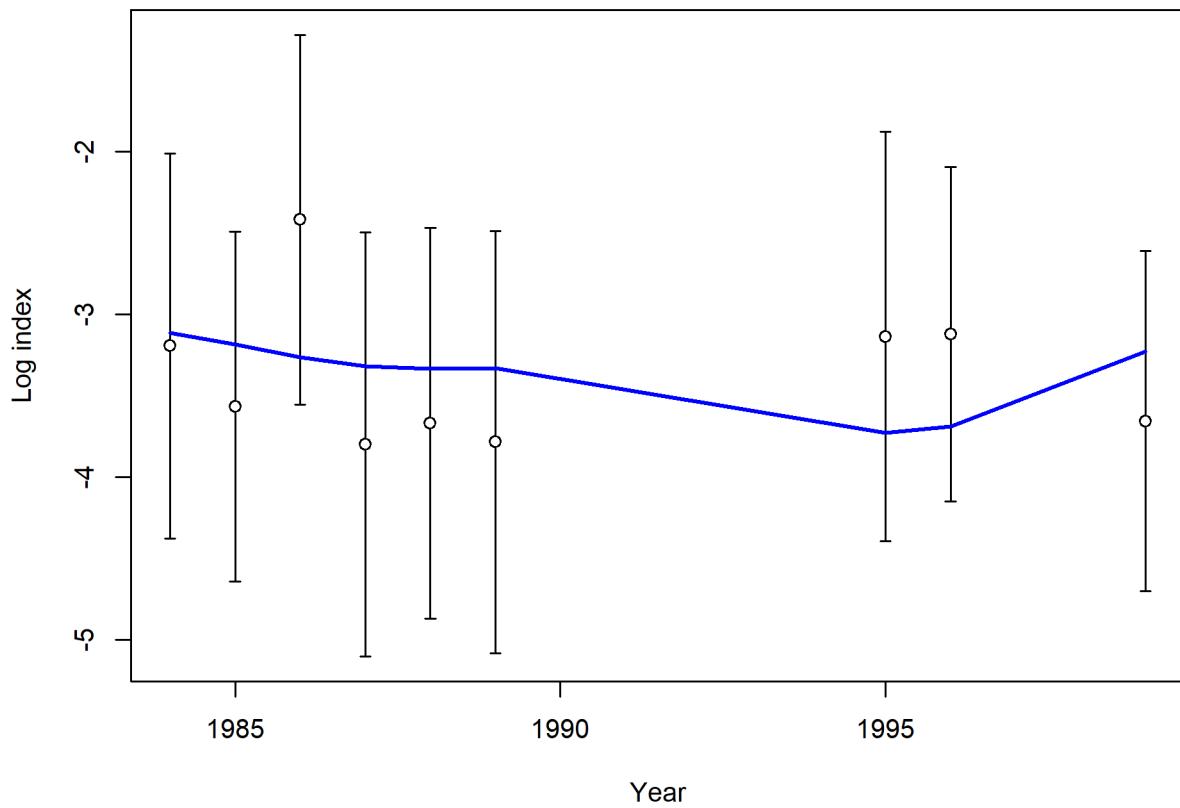


Figure 64: Fit to log index data on log scale for the recreational MRFSS dockside CPFV fishery north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. [fig:index5_logcpuefit_RecDocksideNorth](#)

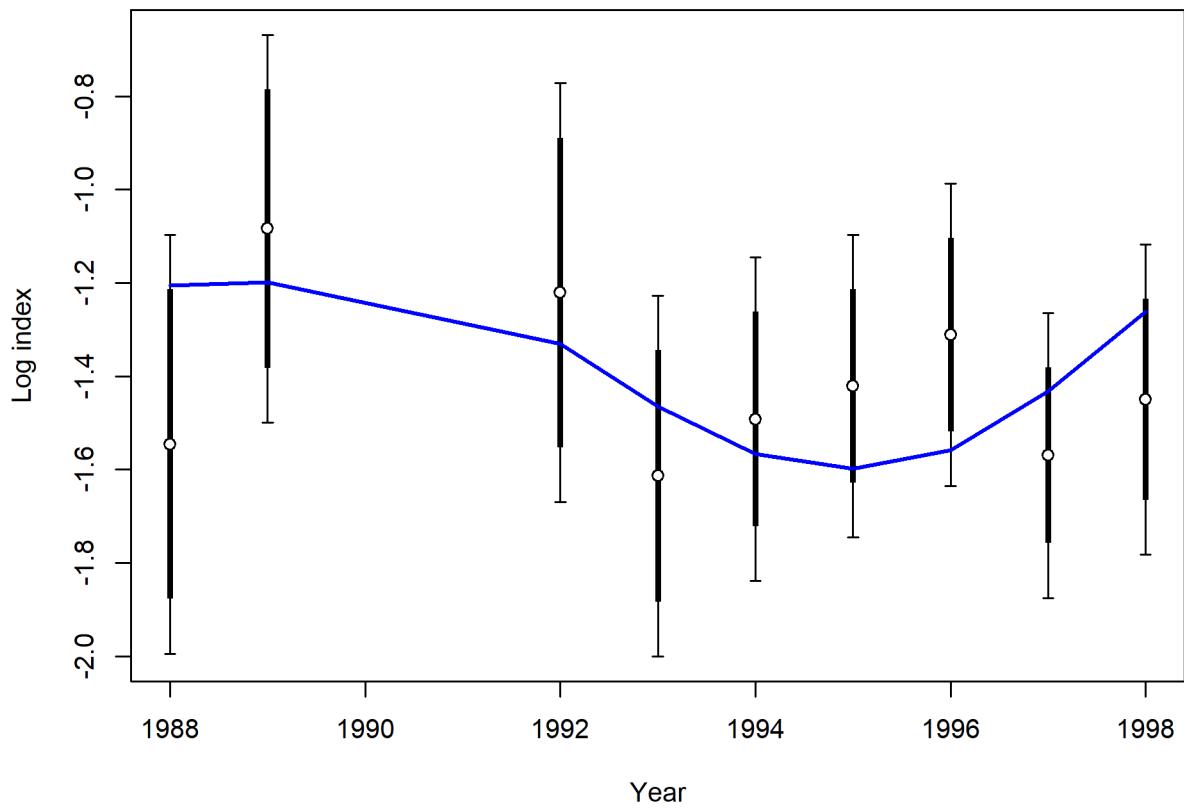


Figure 65: Fit to log index data on log scale for the recreational Deb's CPFV onboard observer program, representing north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.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

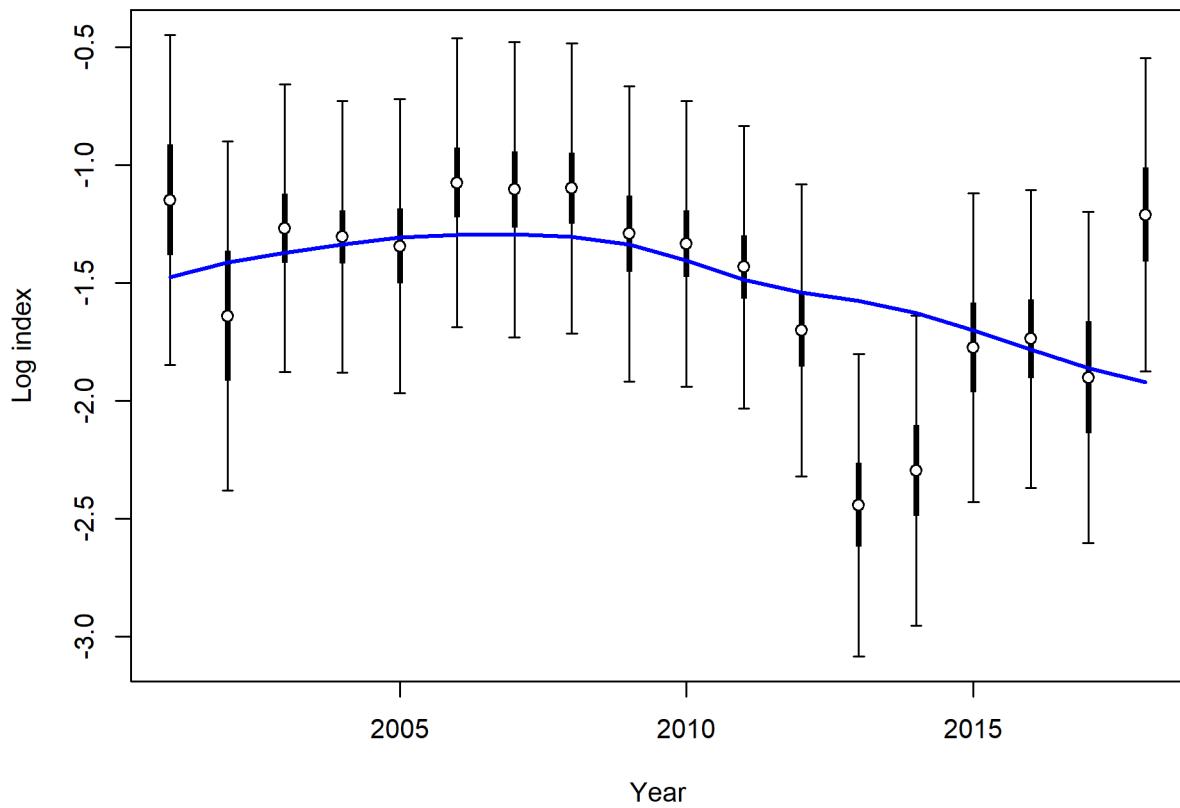


Figure 66: Fit to log index data on log scale for the CRFS/Cal Poly CPFV onboard observer survey north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. [fig:index5_logcpuefit_RecOnboardNorth](#)

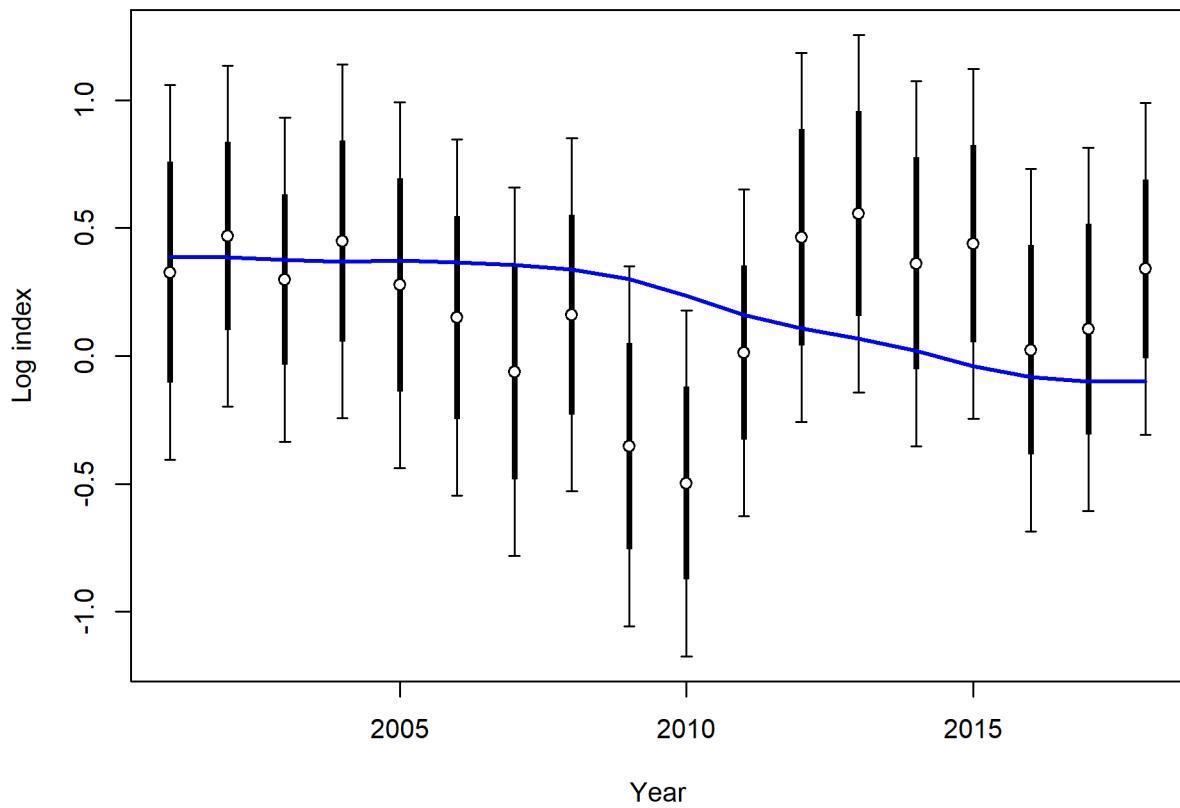


Figure 67: Fit to log index data on log scale for the fishery-independent PISCO kelp forest fish survey for fish 15 cm and larger. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. [fig:index5_logcpuefit_PISCO](#)

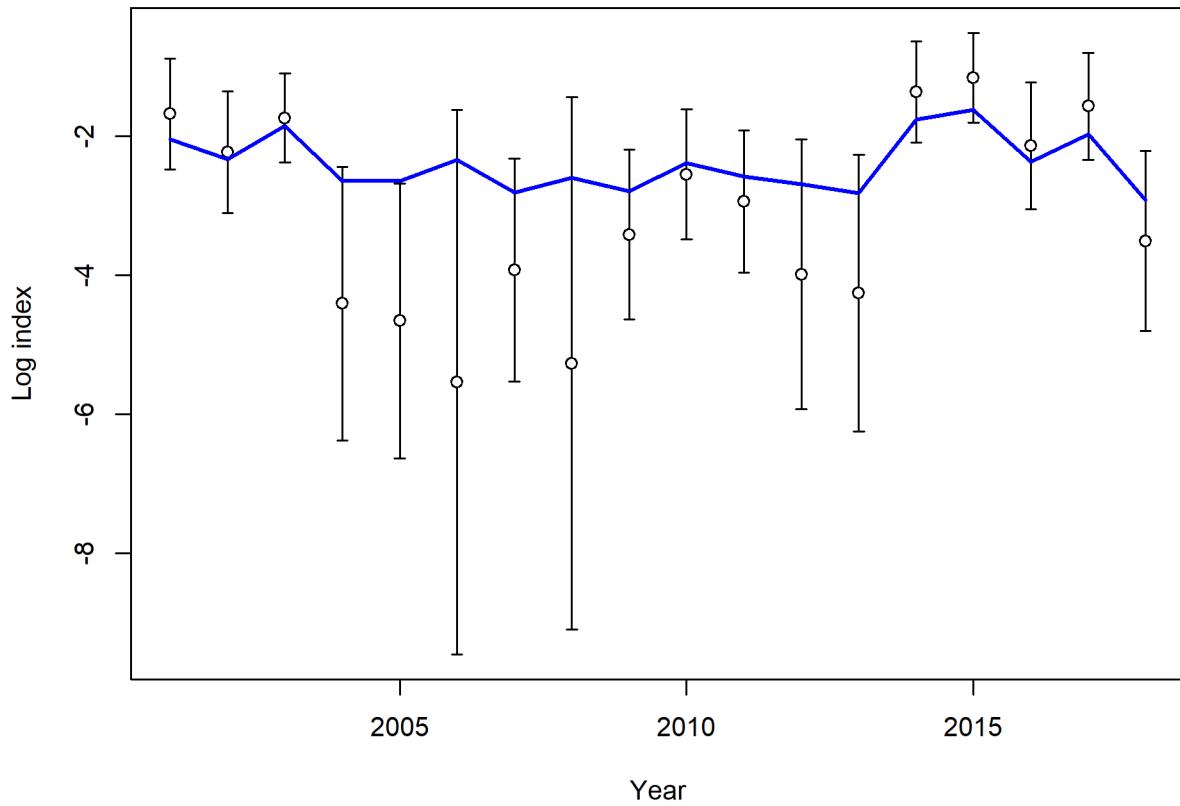


Figure 68: Fit to log index data on log scale for the fishery-independent PISCO age-0 (6 cm or less) kelp forest fish survey for fish 15 cm and larger. Lines indicate 95% uncertainty interval around index values. [fig:index5_logcpuefit_PISCOage0](#)

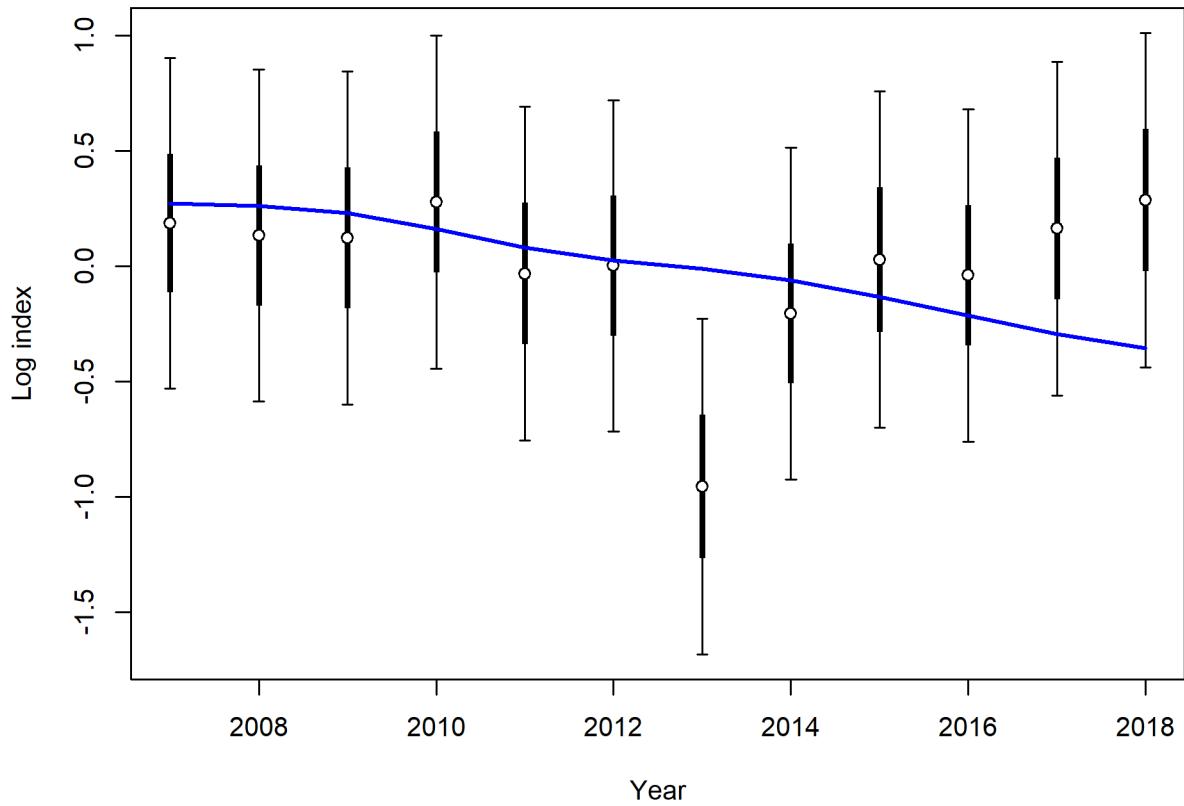


Figure 69: Fit to log index data on log scale for the fishery-independent CCFRP hook-and-line survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_log

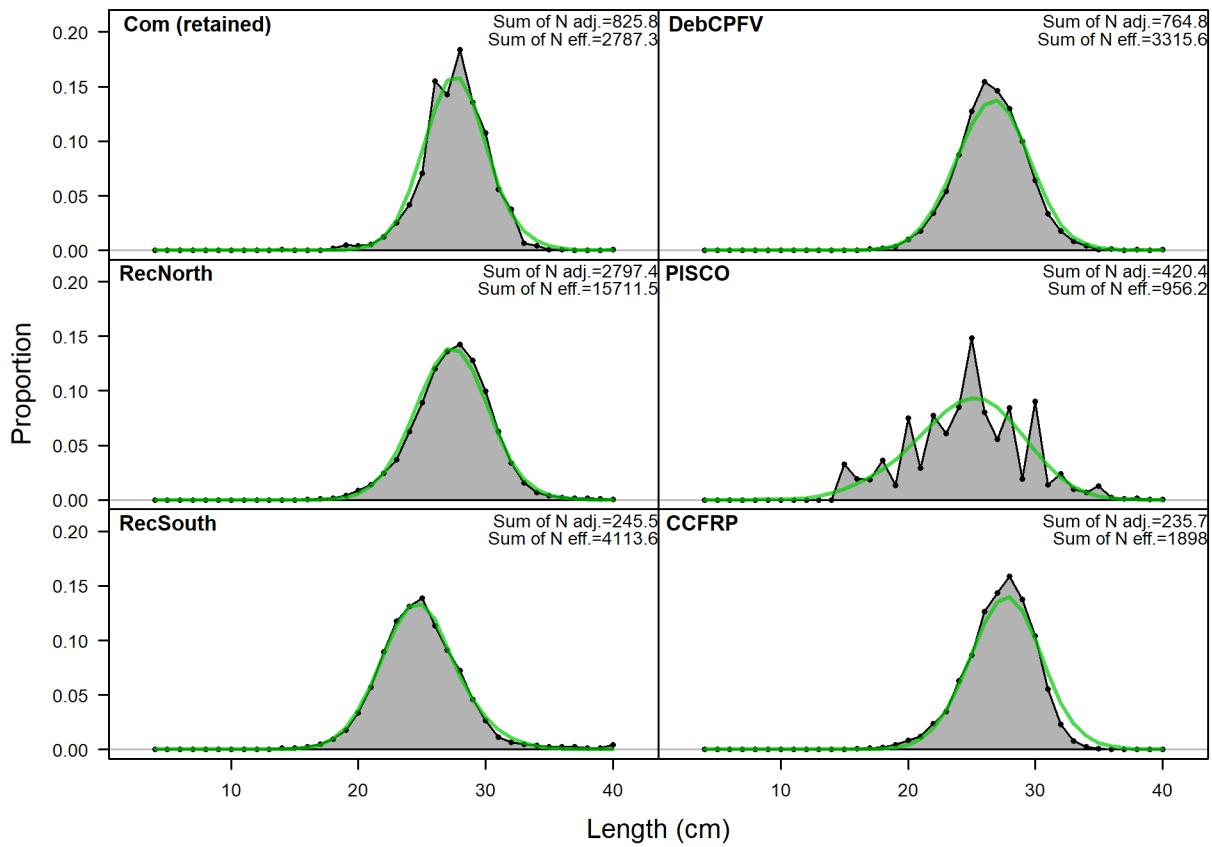


Figure 70: Length compositions aggregated across time by fleet. [fig:comp_lenfit__aggregat](#)

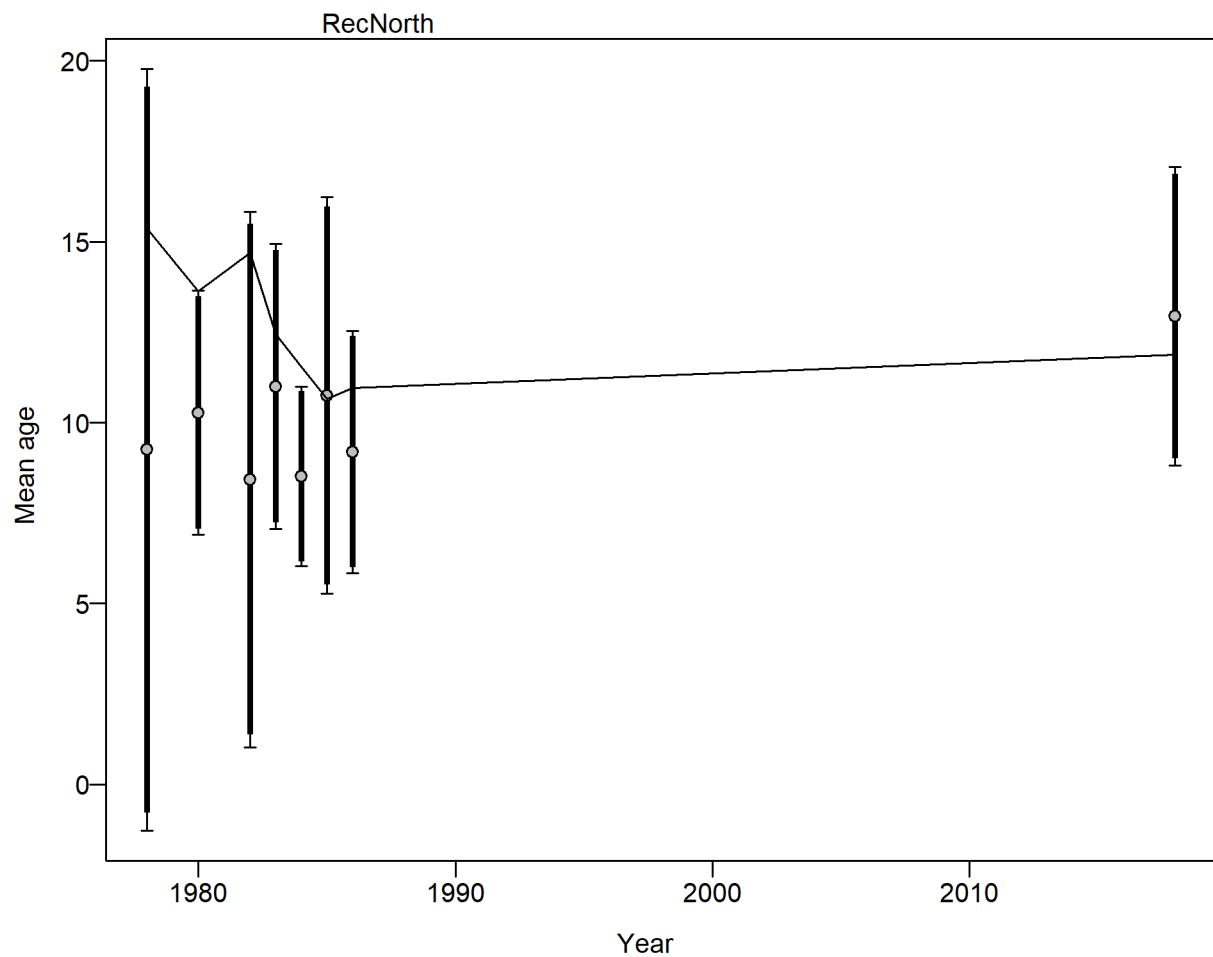


Figure 71: Mean age for the recreational fishery (ages from north of Point Conception only) with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (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](#)

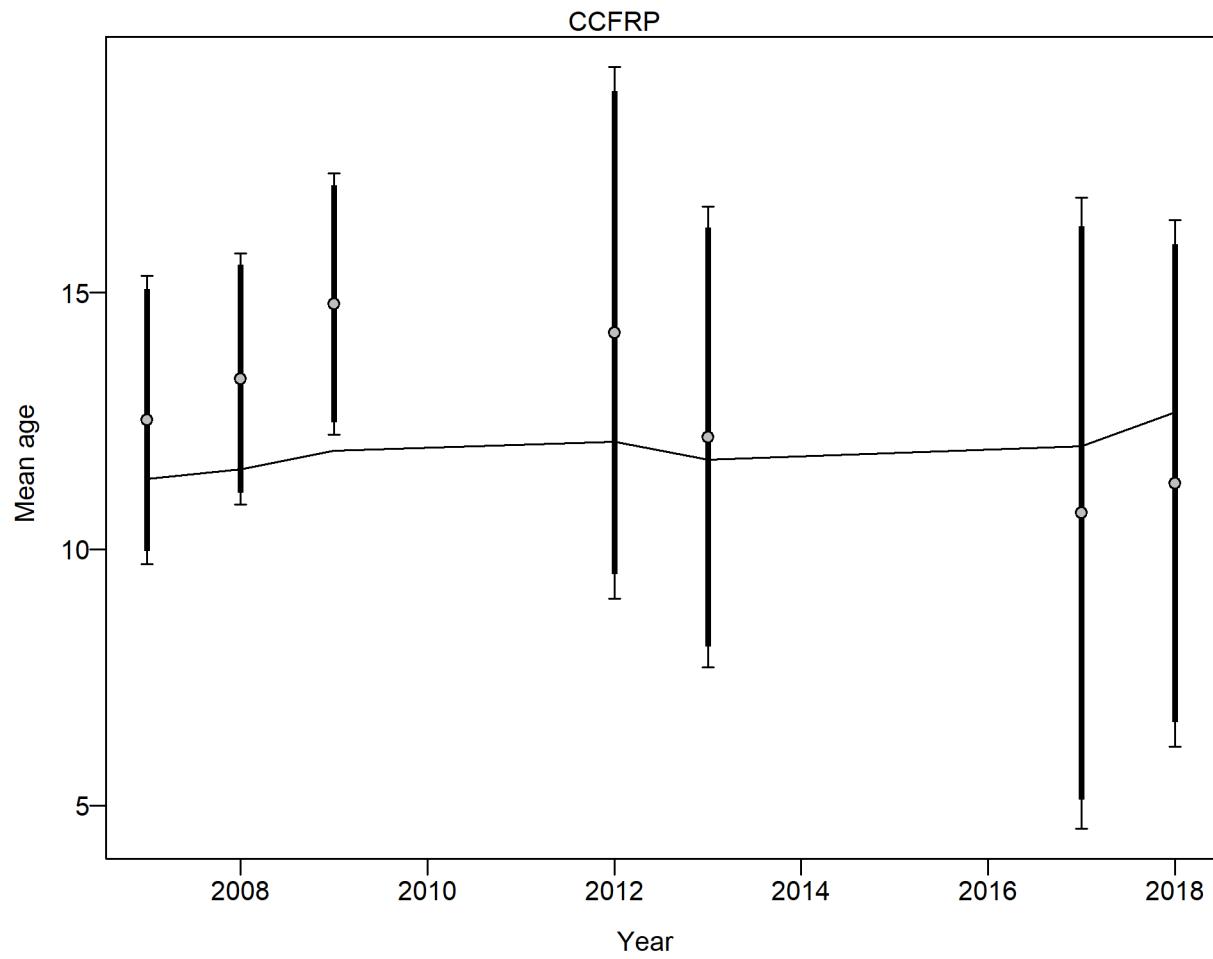


Figure 72: Mean age for the CCFRP survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.023 (0.511-3.745). For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

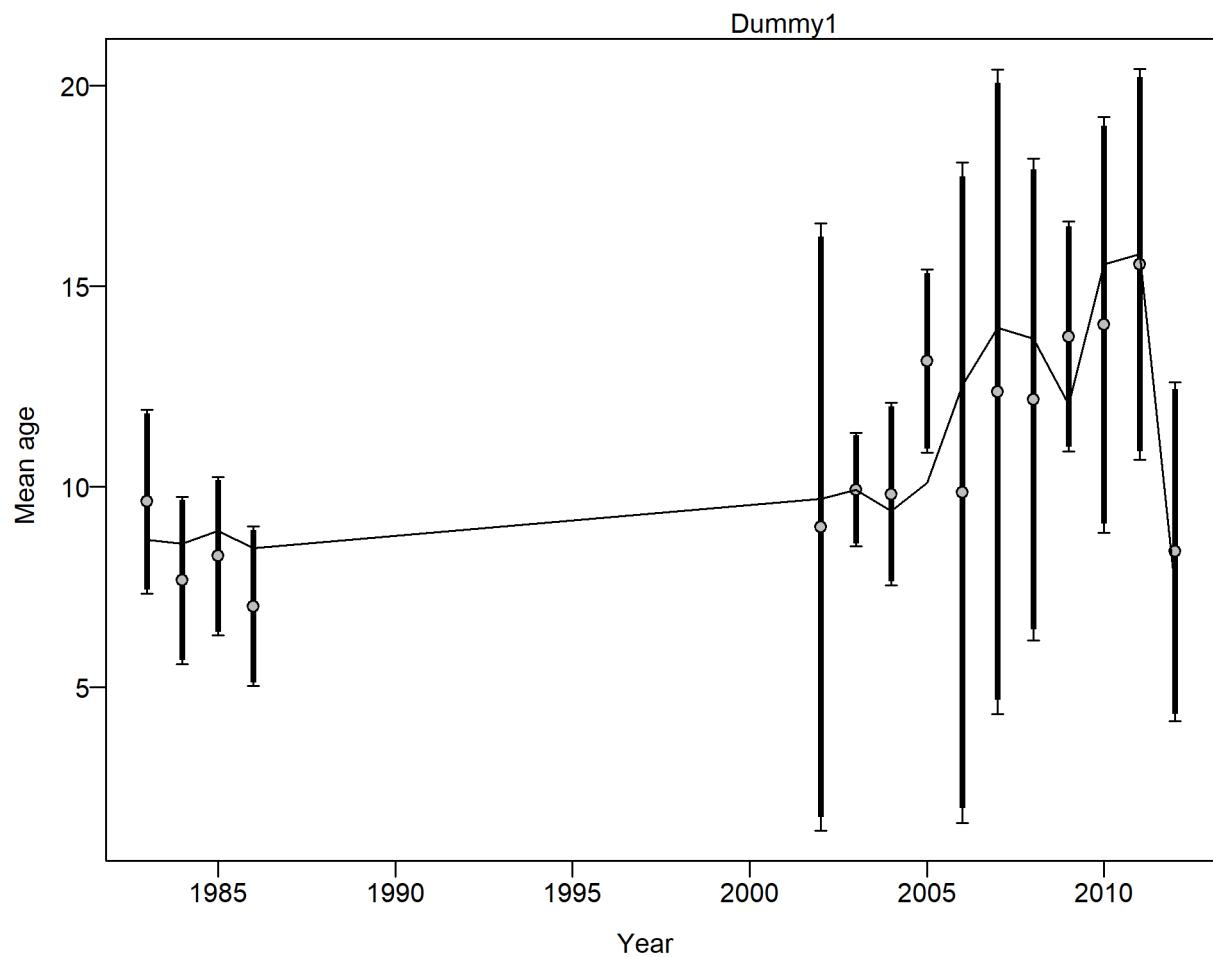


Figure 73: Mean age for the ‘dummy’ fleet with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.065 (0.507-3.692). For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

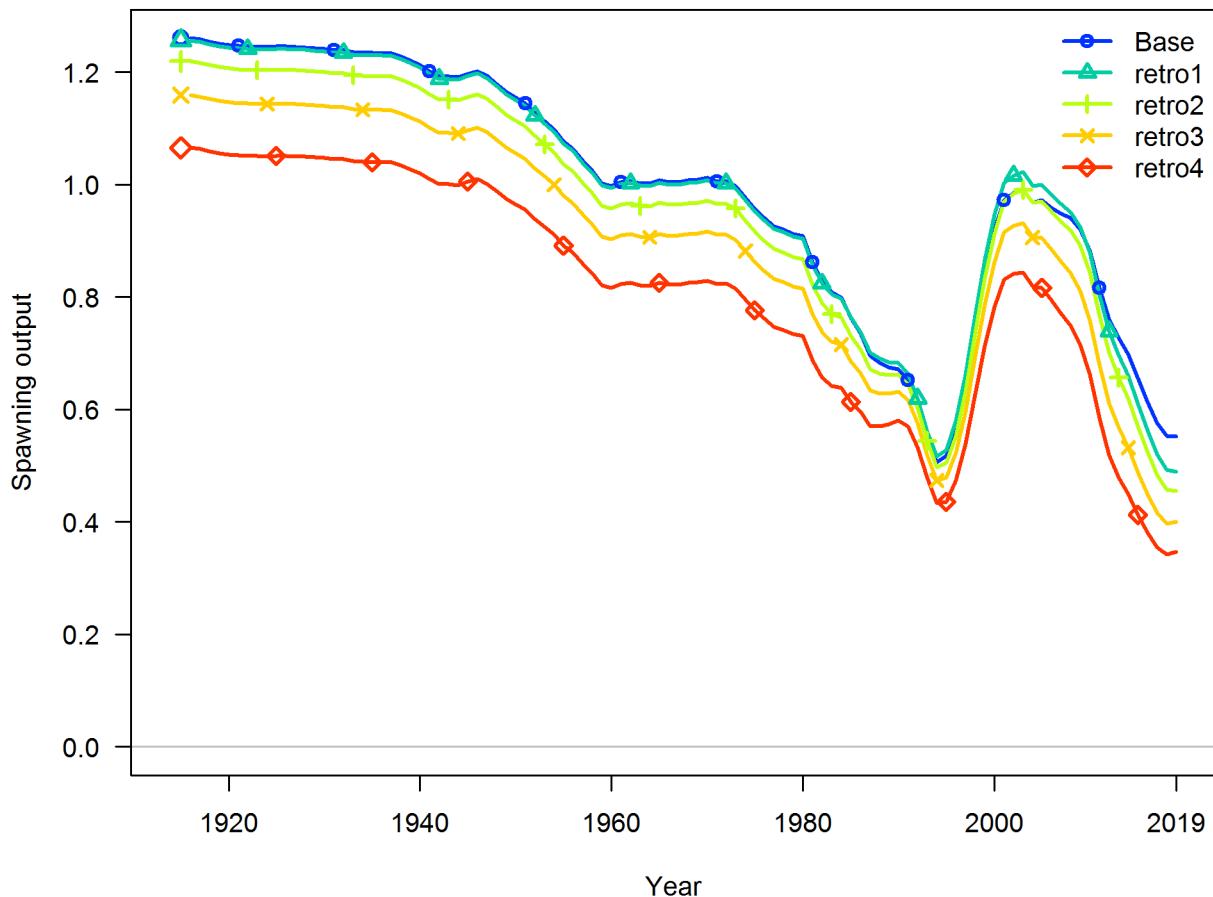


Figure 74: Retrospective pattern for spawning output. `fig:retro_spawnb`

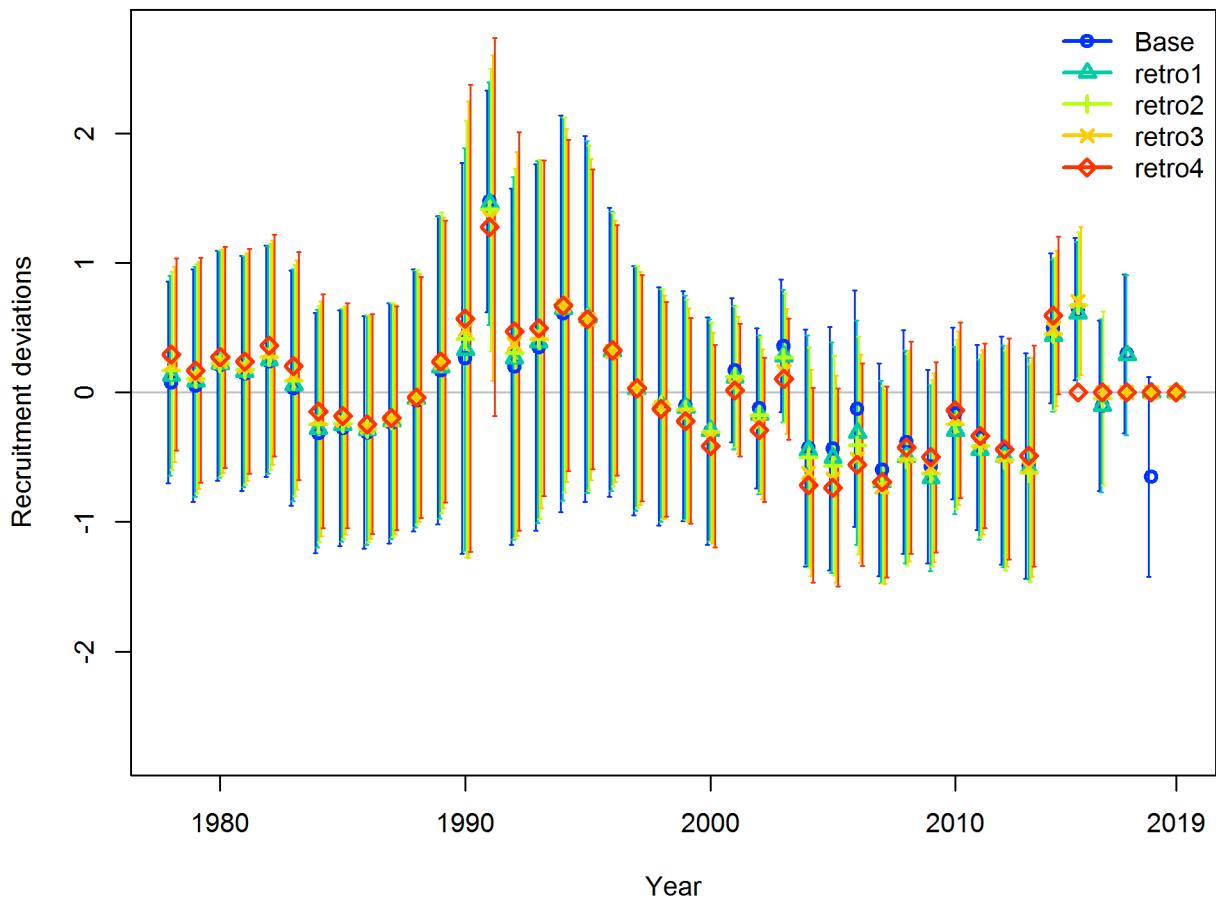


Figure 75: Retrospective pattern for estimated recruitment deviations. fig:retro_recdev

Changes in length-composition likelihoods by fleet

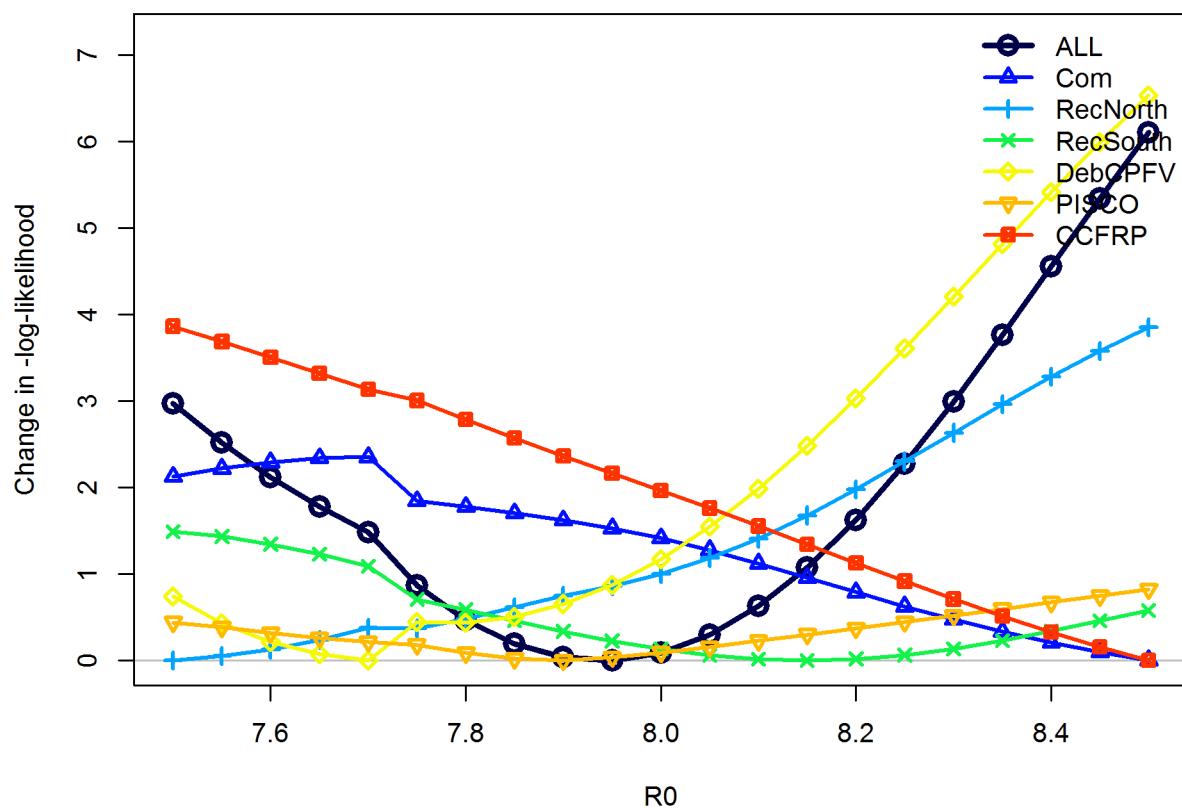


Figure 76: Likelihood profile across R_0 values of length composition by fleet. fig:profile_R0_pine

Changes in survey likelihoods

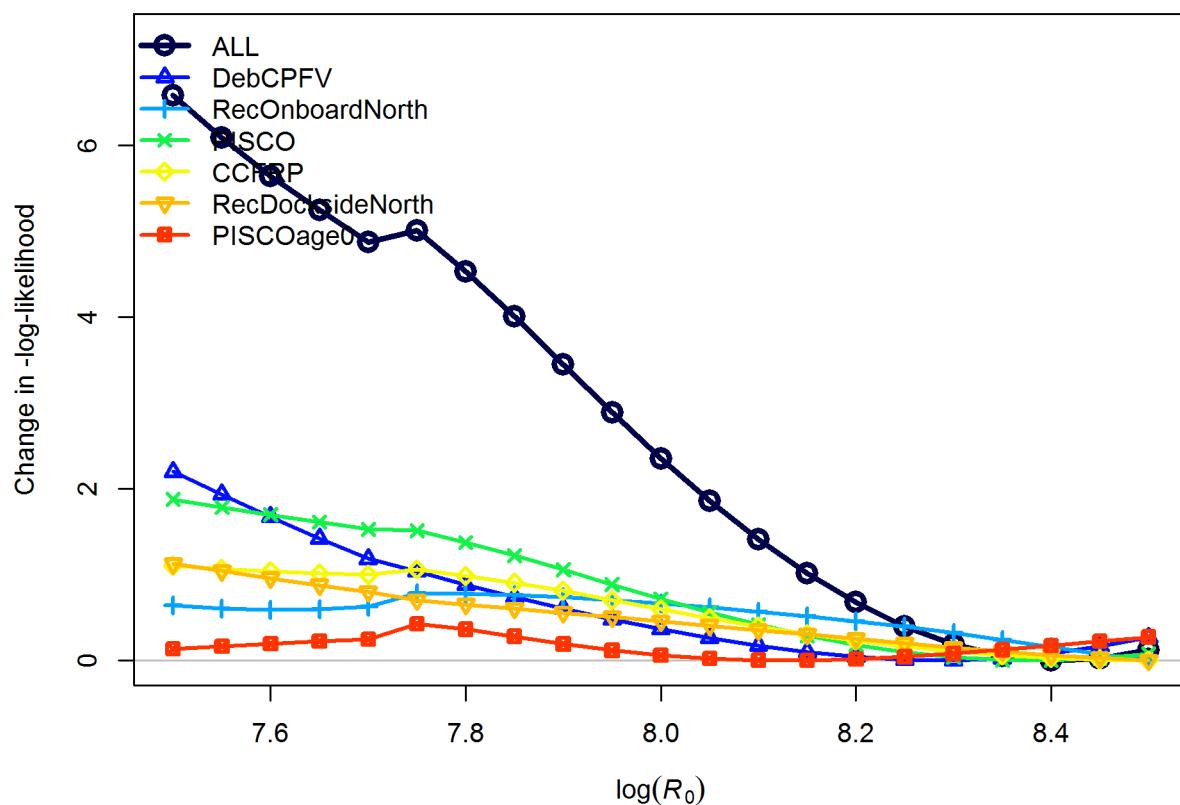


Figure 77: Likelihood profile for R_0 values across surveys. [fig:profile_R0_piner2](#)

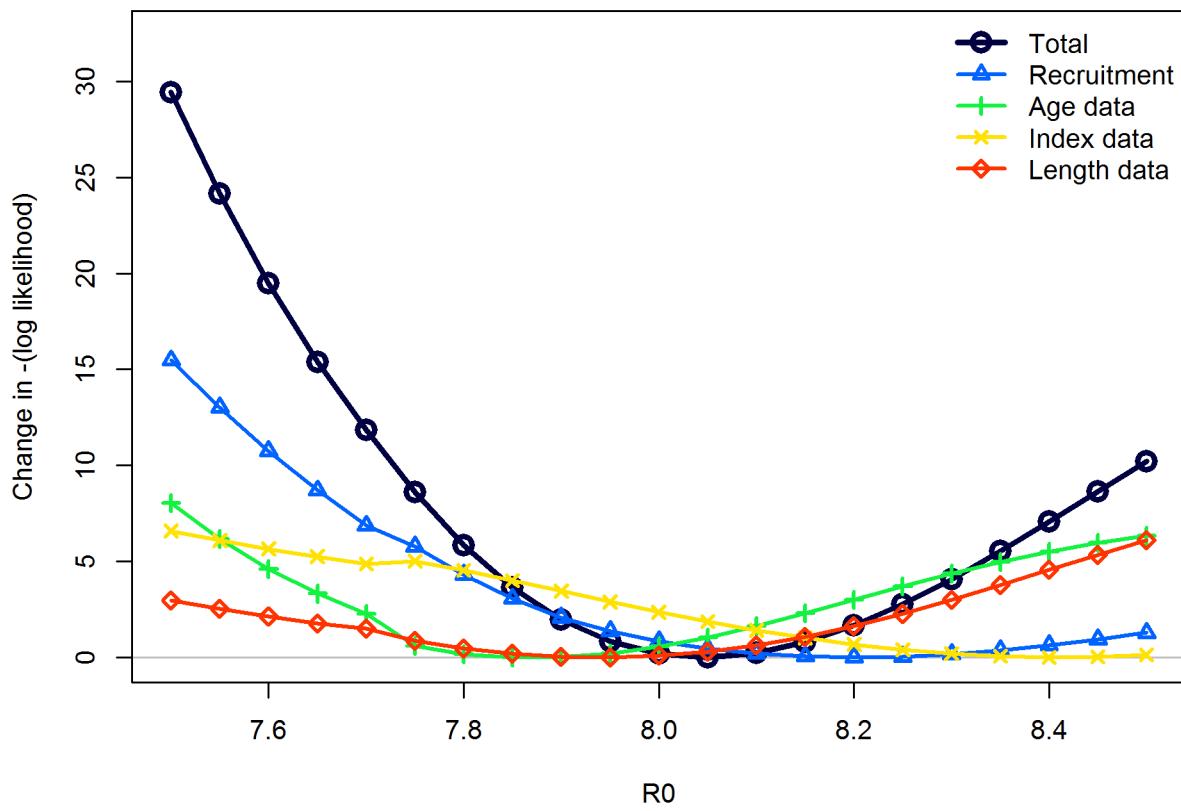


Figure 78: Likelihood profile across R_0 values for each data type. `fig:profile_R0_like`

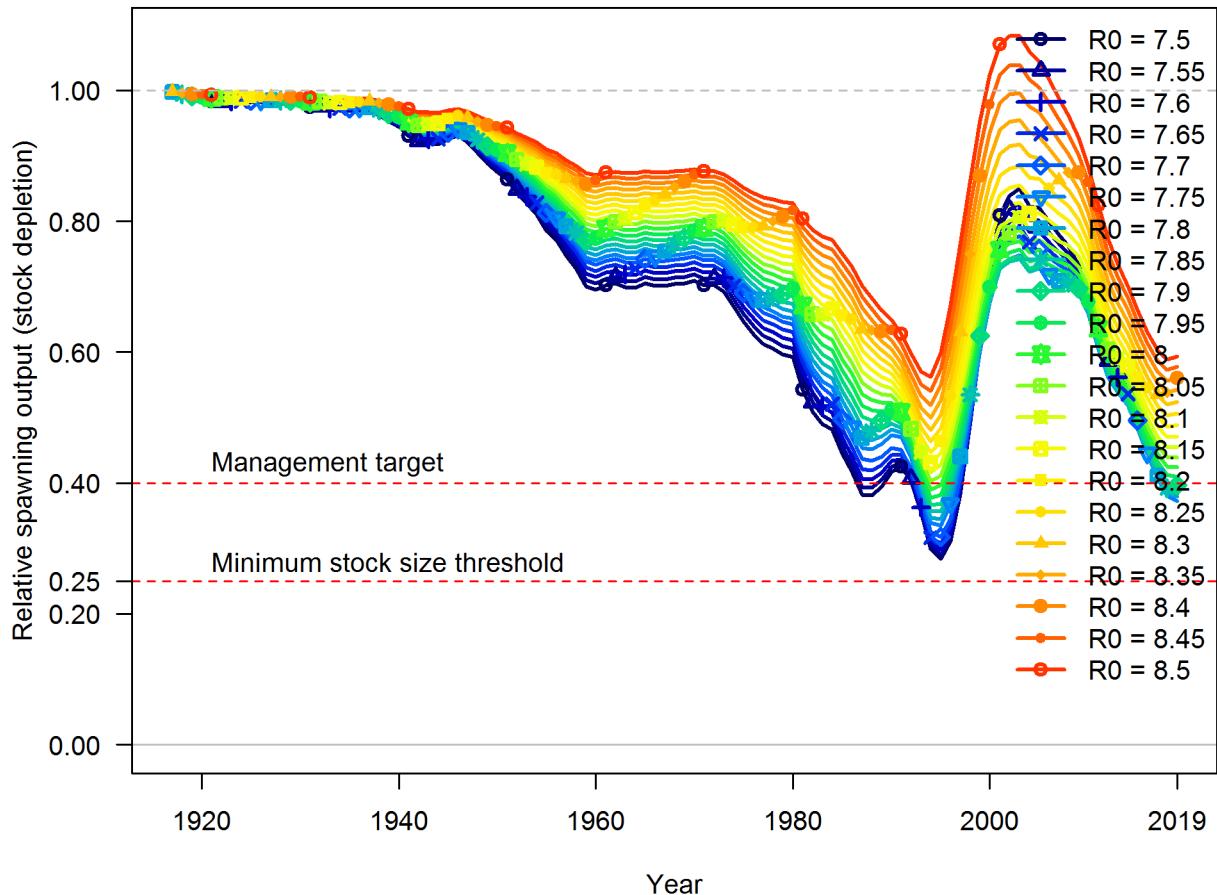


Figure 79: Trajectories of depletion across values of R_0 . [fig:profile_R0_depl](#)

Changes in length-composition likelihoods by fleet

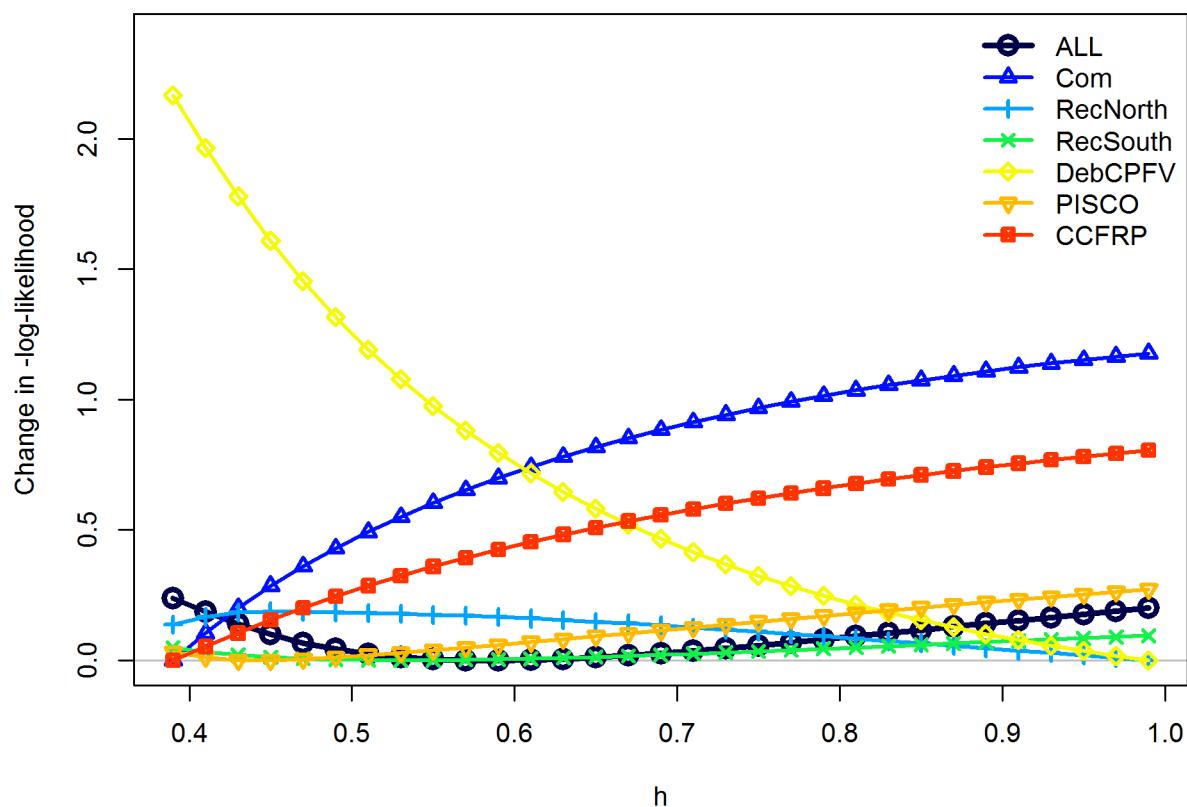


Figure 80: Likelihood profile across steepness values by fleet length composition. `fig:profile_h_pin`

Changes in survey likelihoods

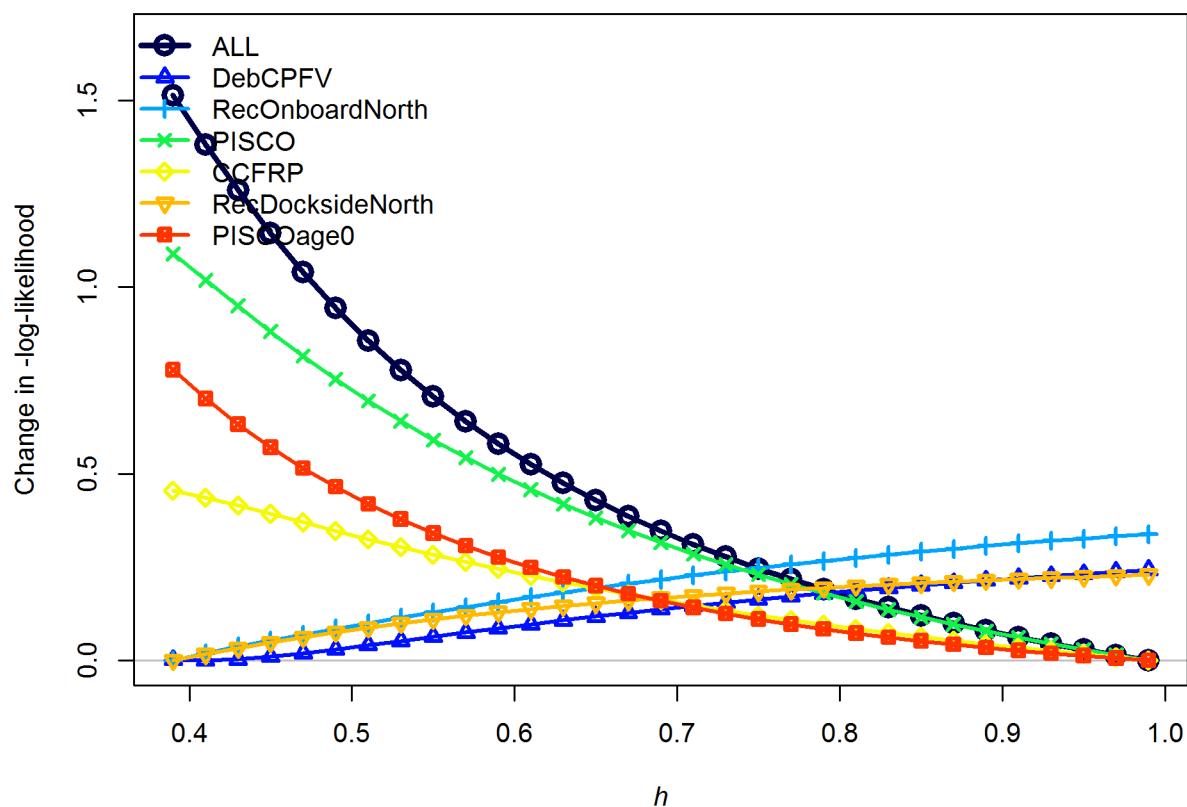


Figure 81: Likelihood profile across steepness values by surveys. [fig:profile_h_piner2](#)

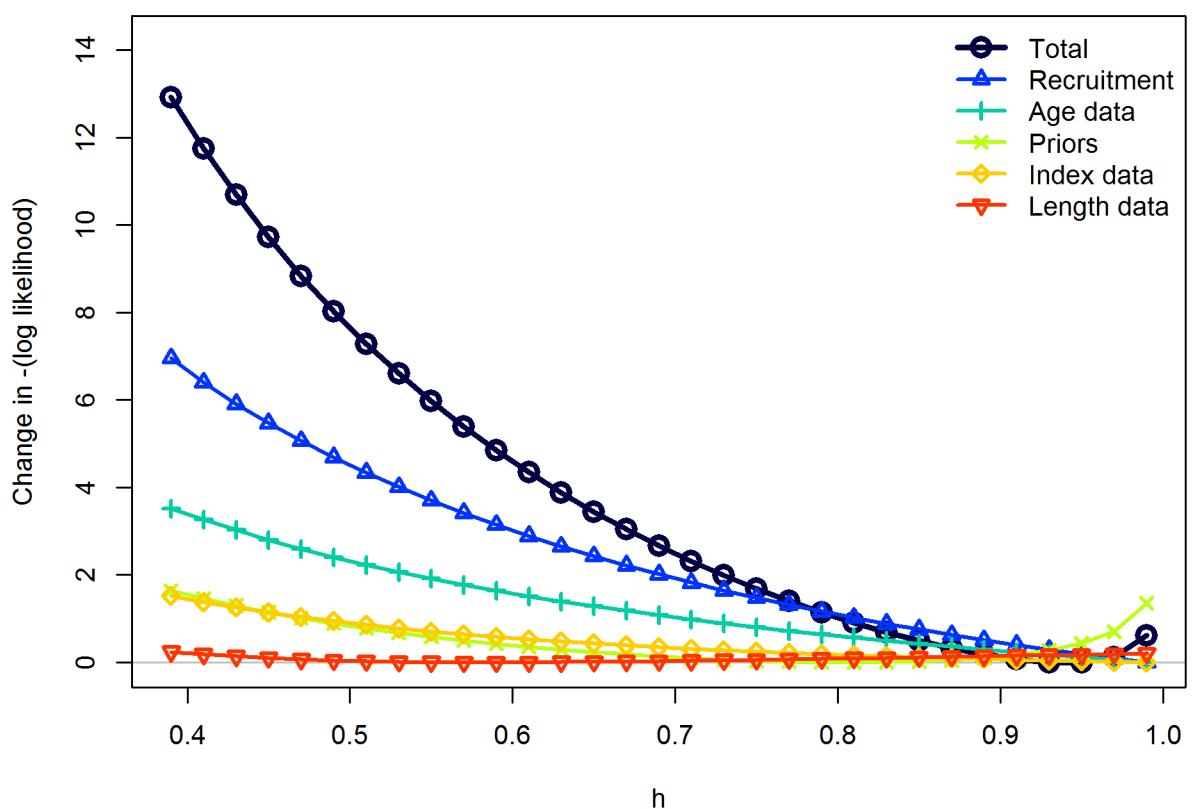


Figure 82: Likelihood profile across steepness values for each data type. [fig:profile_h_like](#)

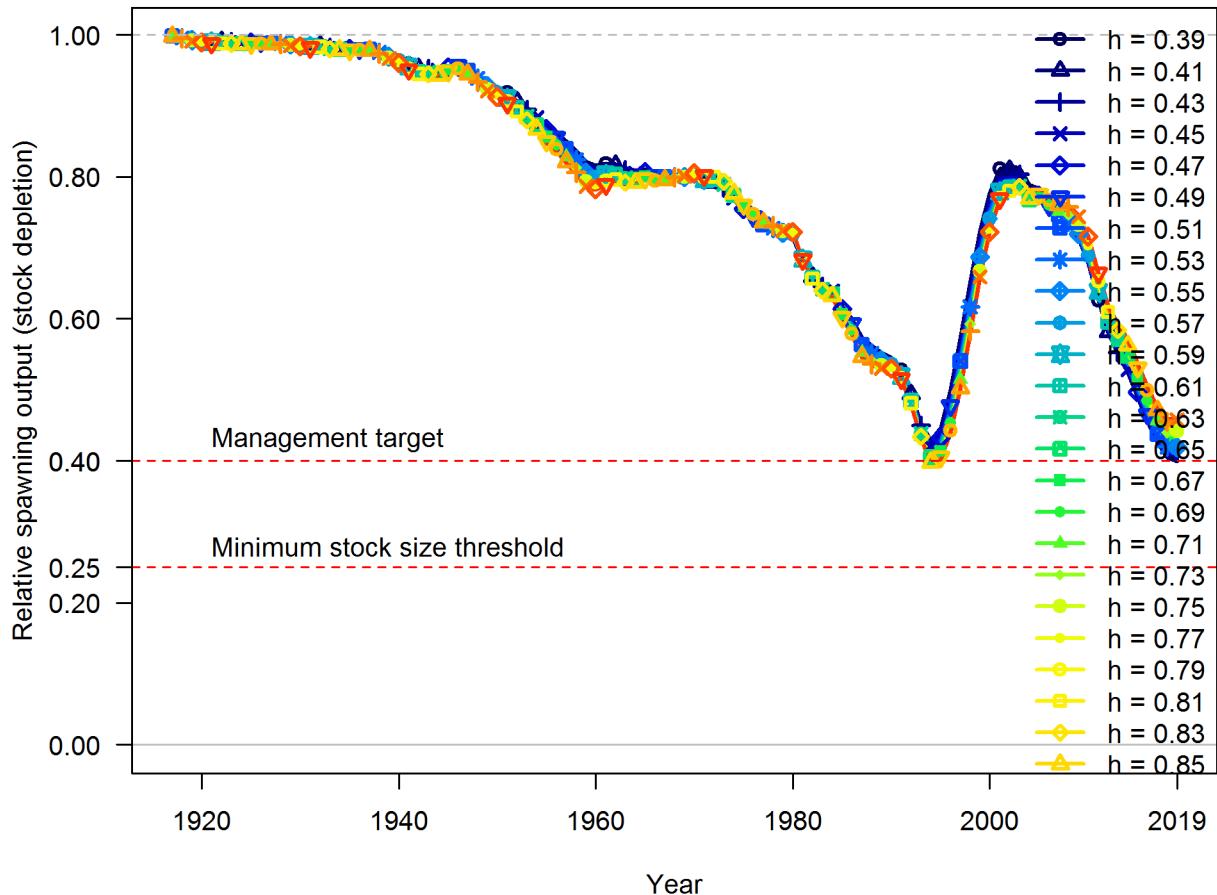


Figure 83: Trajectories of depletion across values of steepness. [fig:profile_h_depl](#)

Changes in length-composition likelihoods by fleet

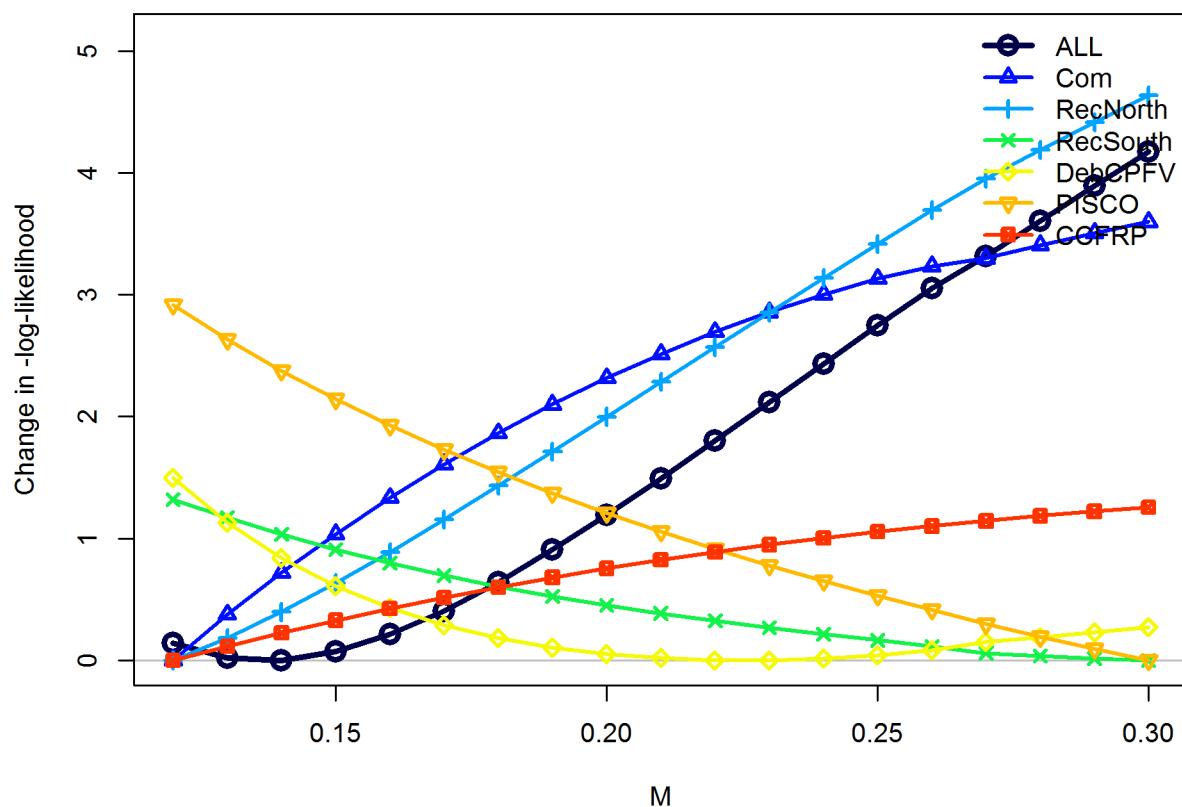


Figure 84: Likelihood profile across female natural mortality values by length composition. fig:profile_m

Changes in survey likelihoods

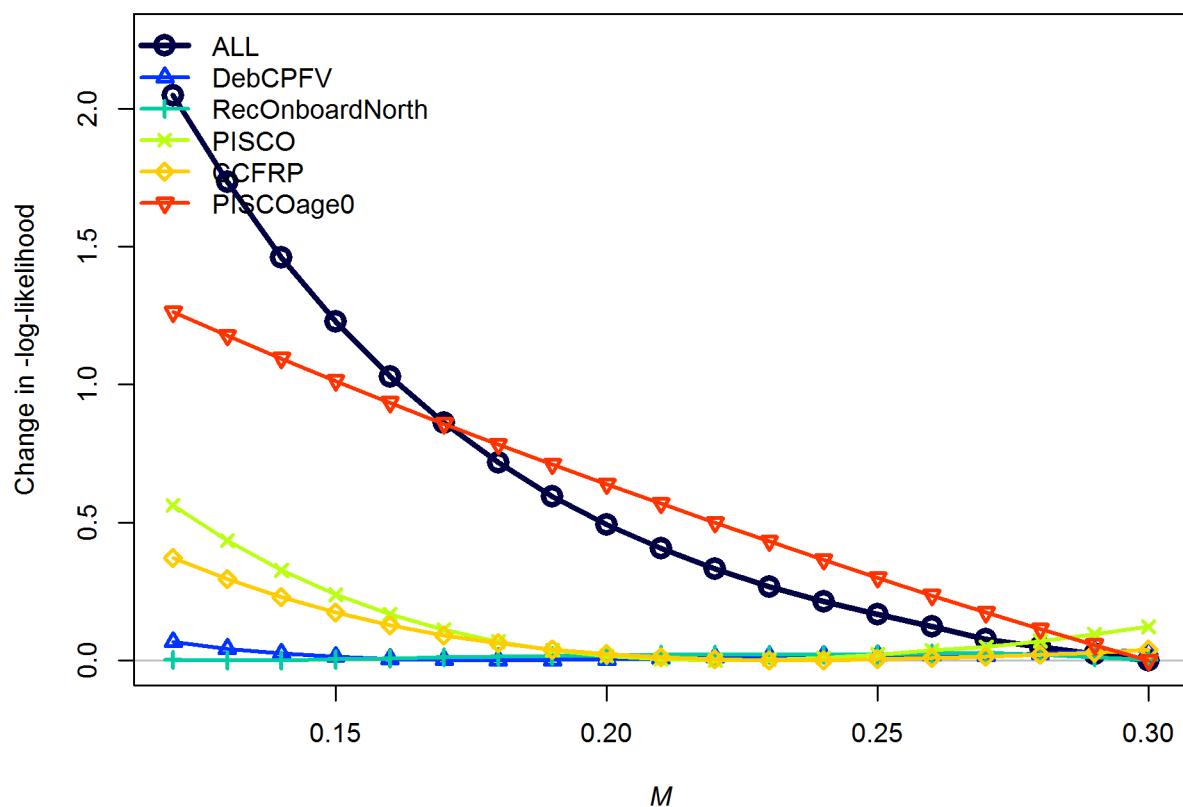


Figure 85: Likelihood profile across female natural mortality values by surveys. [fig:profile_m_pine](#)

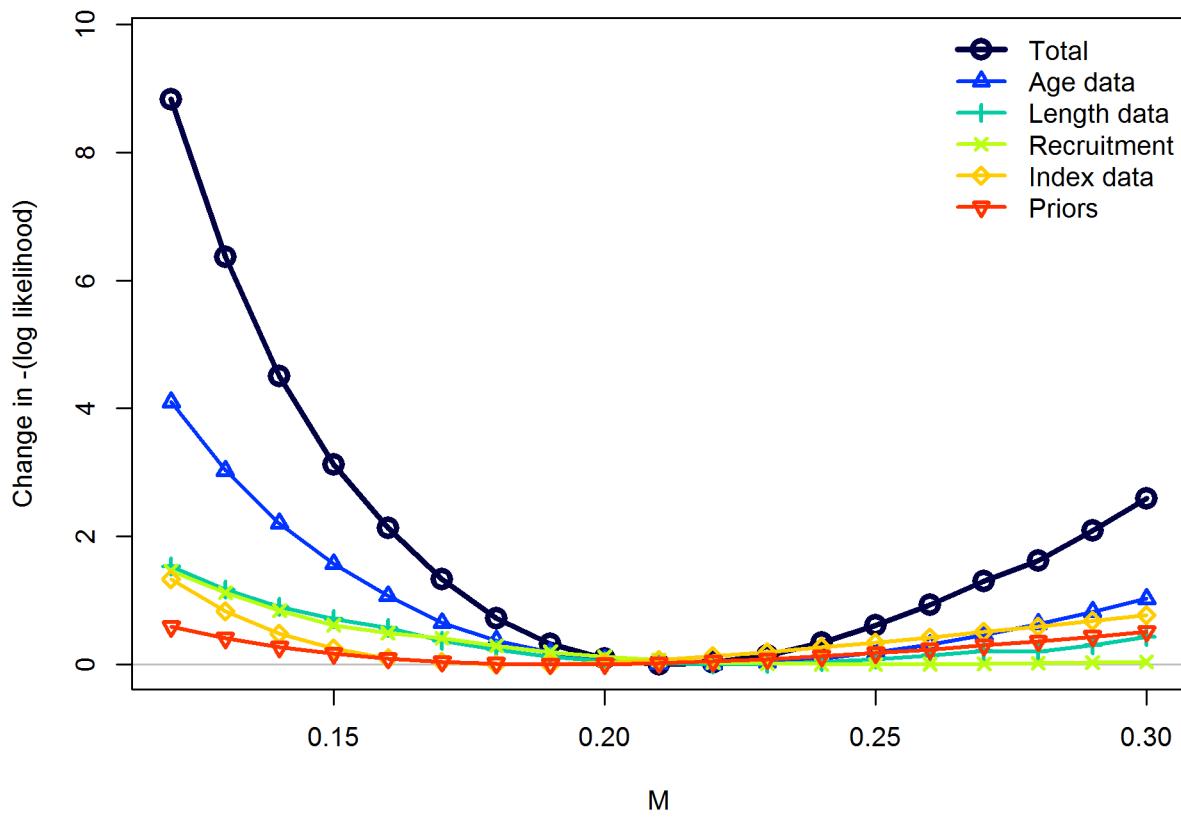


Figure 86: Likelihood profile across female natural mortality values for each data type. `fig:profile_m`

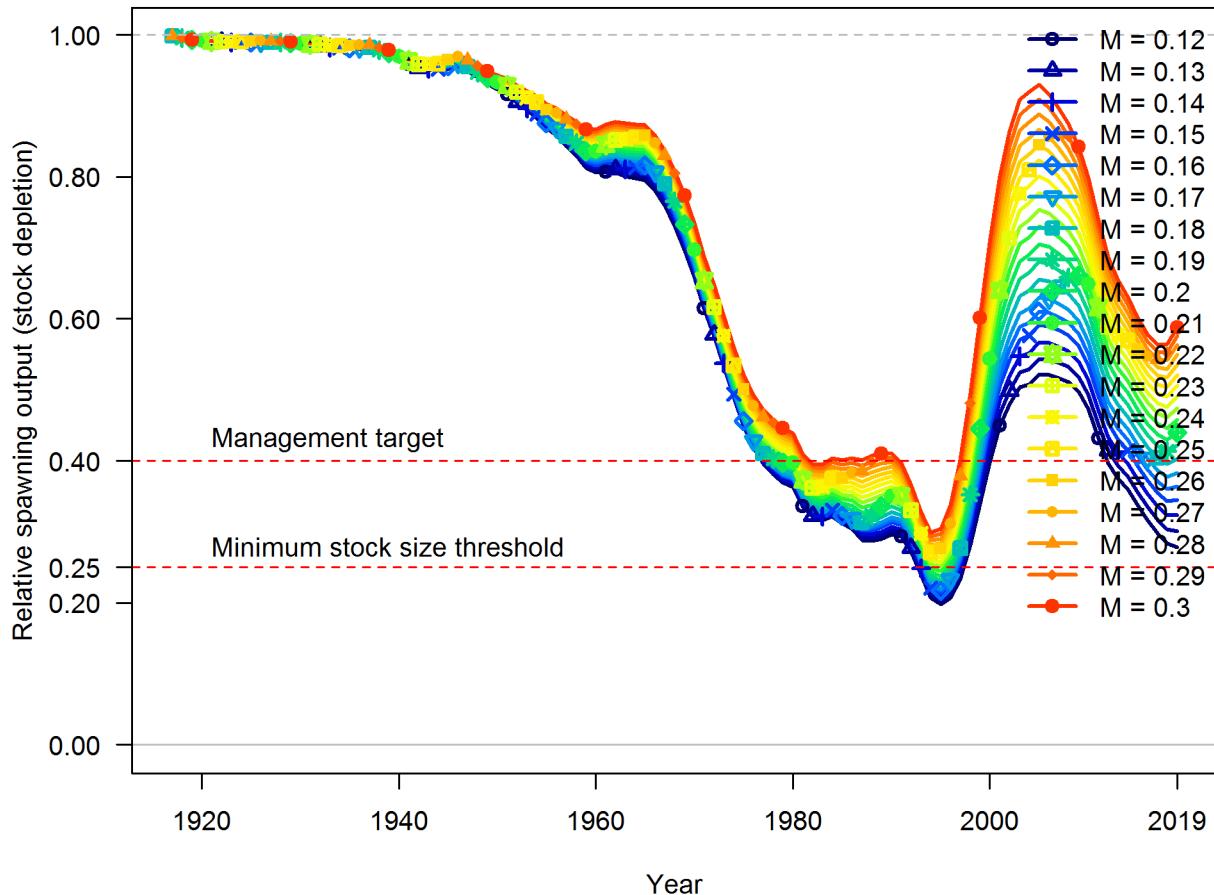


Figure 87: Trajectories of depletion across values of female natural mortality. `fig:profile_m_depl`

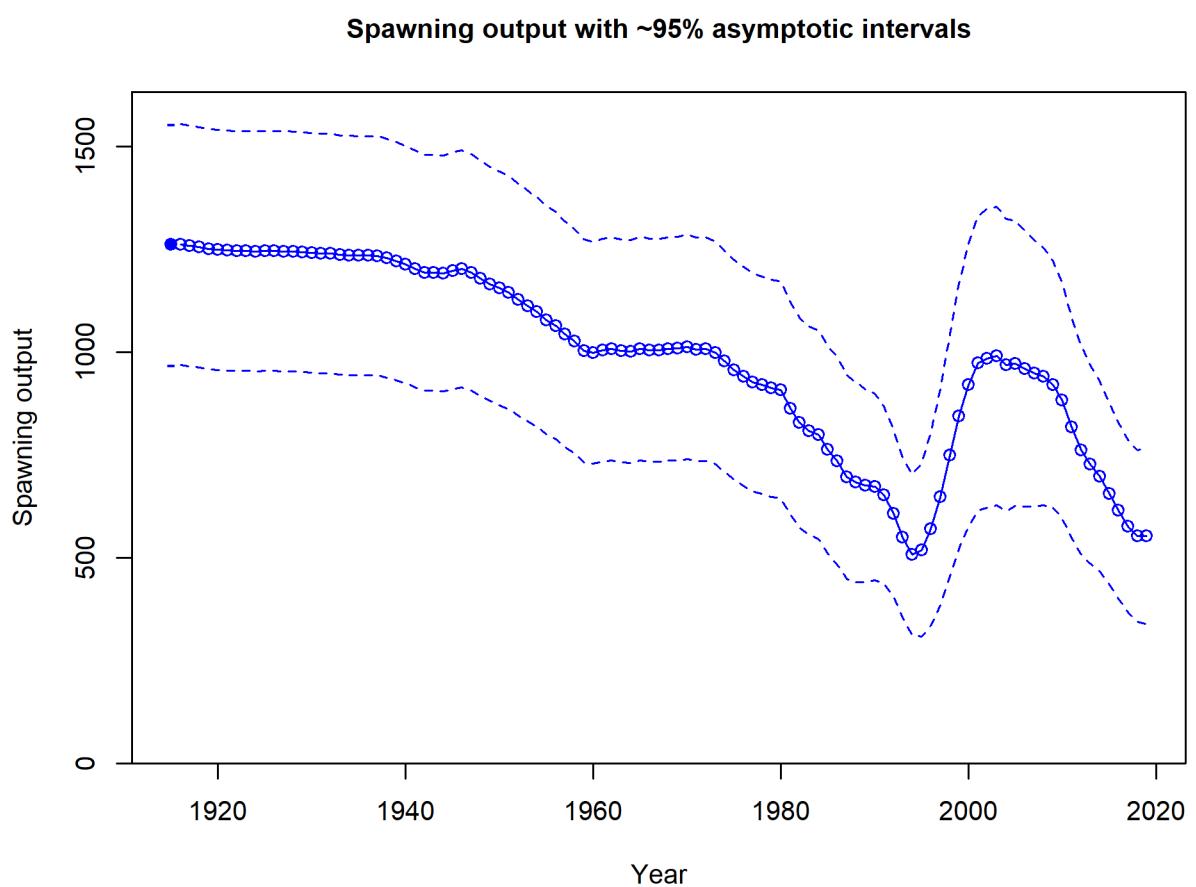


Figure 88: Estimated spawning output with approximate 95% asymptotic intervals. fig:ts7_Spawning

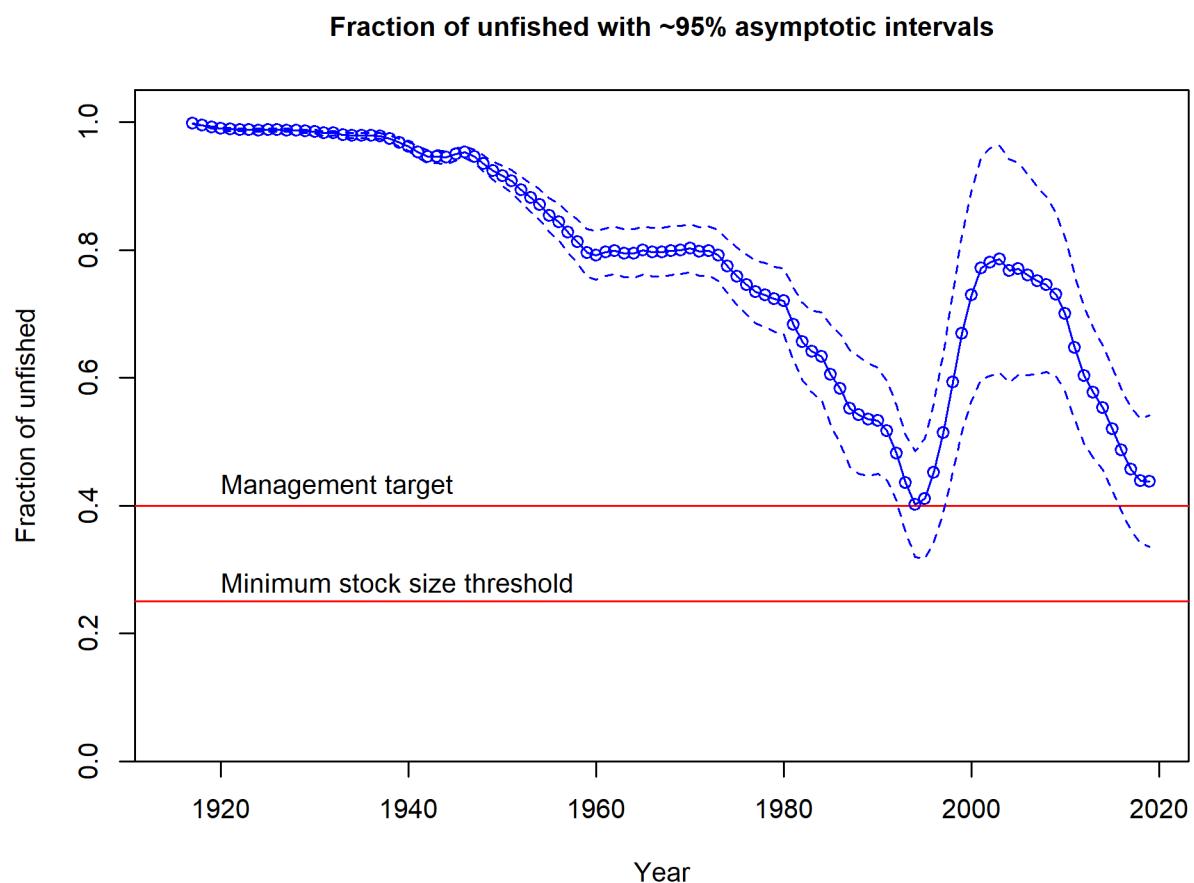


Figure 89: Estimated spawning depletion with approximate 95% asymptotic intervals. fig:ts9_unfisher

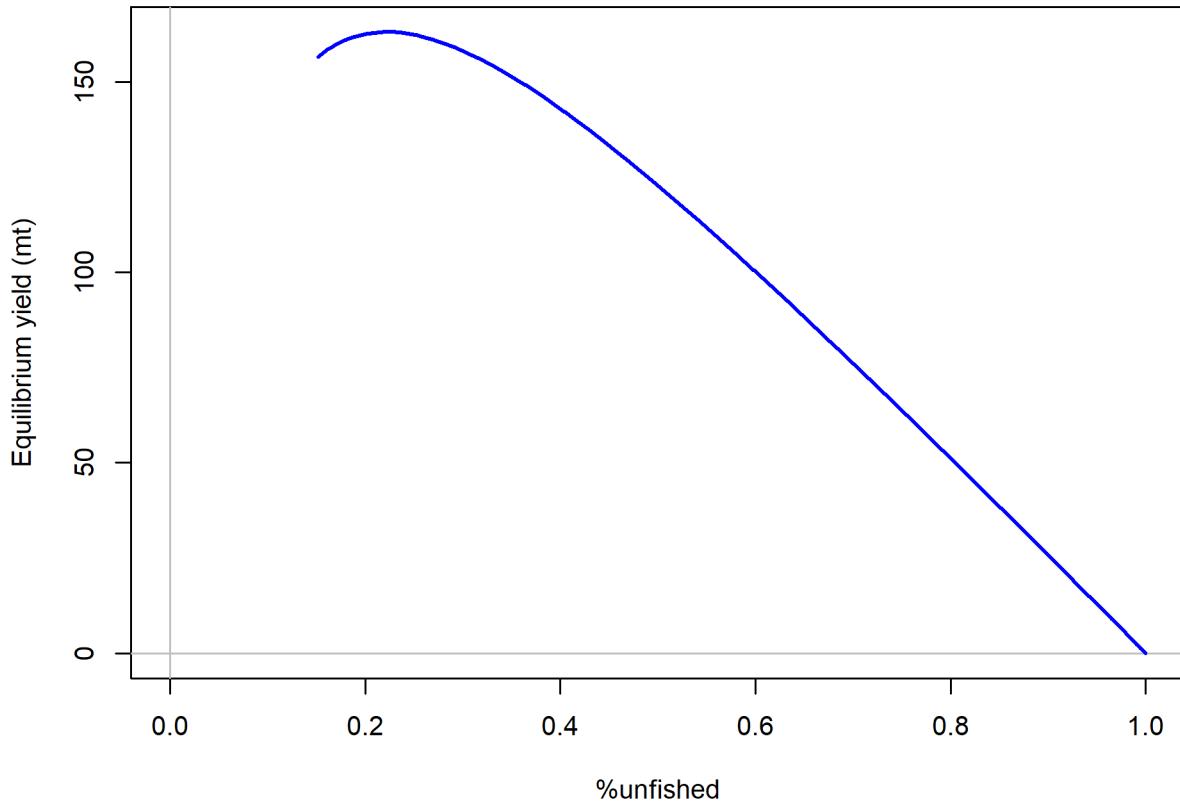


Figure 90: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.718. | [fig:yield1_yield_curve](#)

2020 **Appendix A. California's Commercial Fishery Regulations**

2021 [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		
		800 lbs/2 mths shoreward of 20 fm; otherwise closed	
2001 Jan	1800 lbs/2 mths		
2001 Mar	Closed	1800 lbs/2 mths	
		800 lbs/2 mths shoreward of 20 fm; otherwise closed	
2001 May			
2001 Jul	1800 lbs/2 mths	1800 lbs/2 mths	
2002 Jan	1200 lbs/2 mths	Closed	
2002 Mar	Closed	1200 lbs/2 mths	
		1200 lbs/2 mths shoreward of 20 fm; otherwise closed	
2002 May			
2002 Jul	1200 lbs/2 mths		
		1200 lbs/2 mths shoreward of 20 fm; otherwise closed	
2002 Sep			
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}

2022 **Appendix B. California's Recreational Fishery Regula-**

2023 **tions**

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

California's Recreational Fishing Regulations										
Year	Month	Northern	Mendocino	North-Central	San Francisco	South-Central	Central	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		Open	
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		Closed	
2004	Feb	Open					30		Closed	
2004	Mar	Open					Closed		60	
2004	Apr	Open					Closed		60	
2004	May	30					20		60	
2004	Jun	30					20		60	
2004	Jul	30					Closed		60	
2004	Aug	30					20		60	
2004	Sep	30					20		30	
2004	Oct	30					20		30	
2004	Nov	30					20		60	
2004	Dec	30					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.
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.
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°	37°11'-34°27'	36°-34°27'	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}

2024 **Appendix C. Detailed fits to length composition data**

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

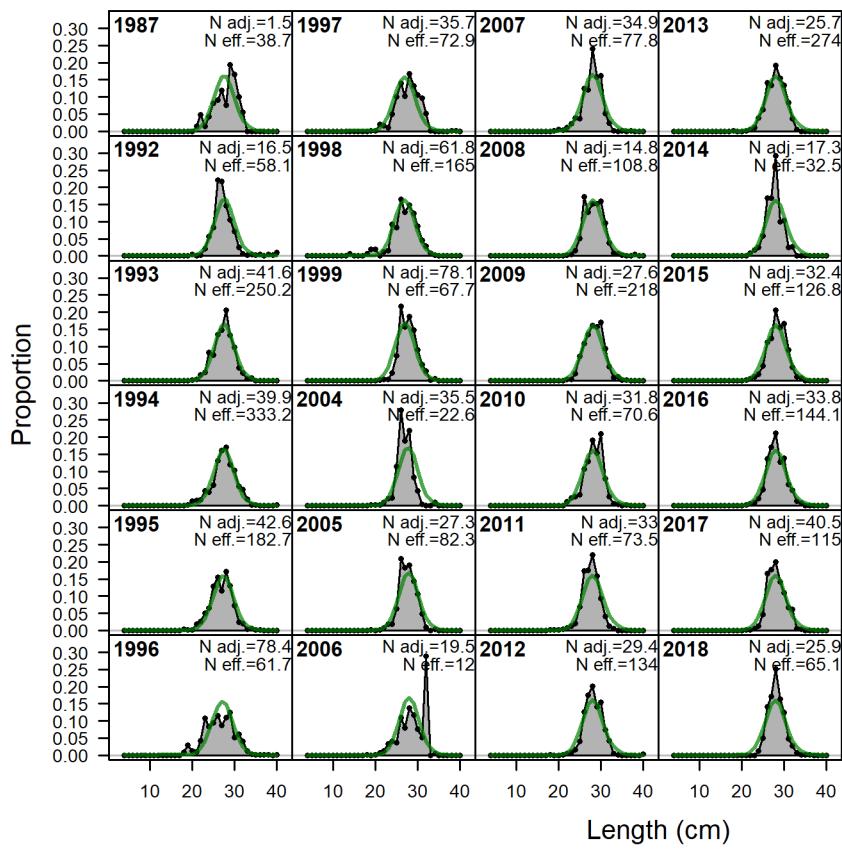


Figure C2: Length comps, retained, Com. ‘N adj.’ is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAlister_Iannelli tuning method. [fig:mod1_1_comp_1enfit_fltimkt2](#)

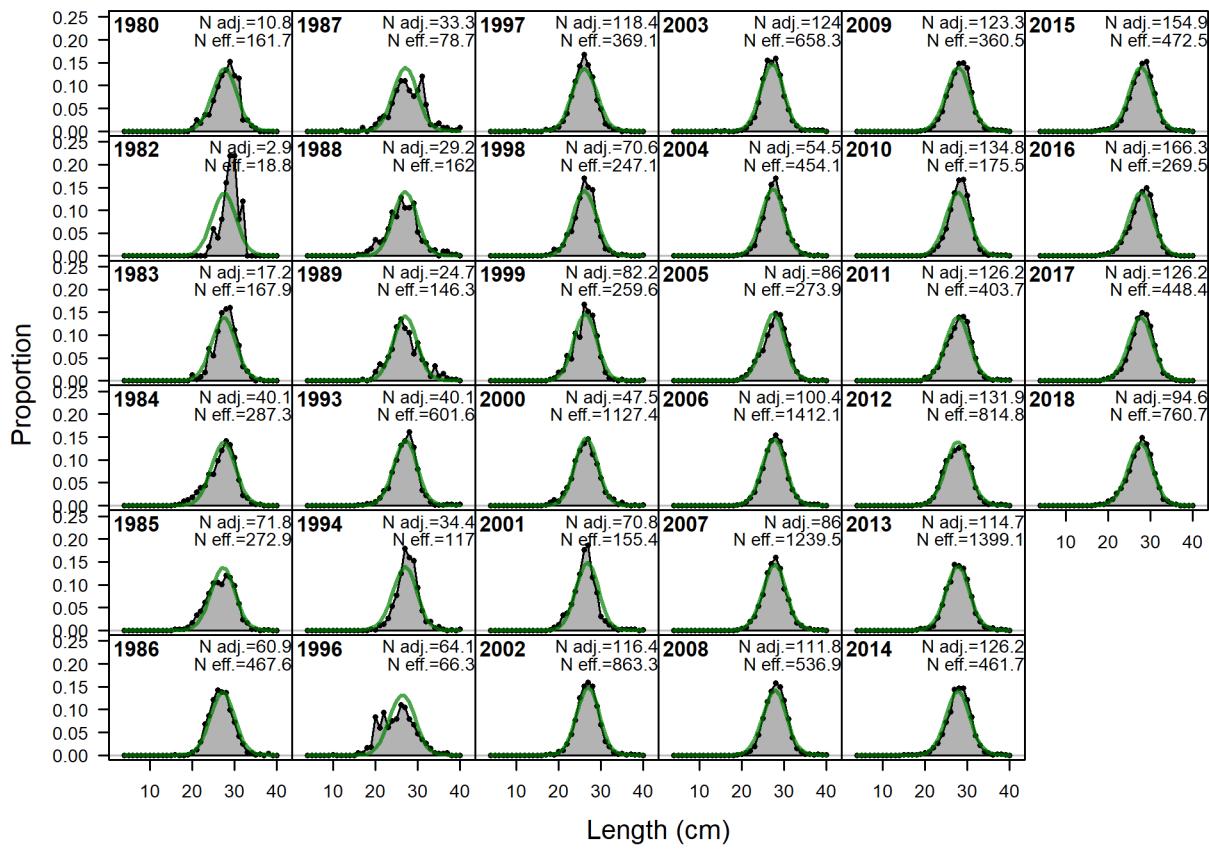


Figure C3: Length comps, whole catch, RecNorth. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. | [fig:mod1_2_comp_lenfit_flt2mkto](#)

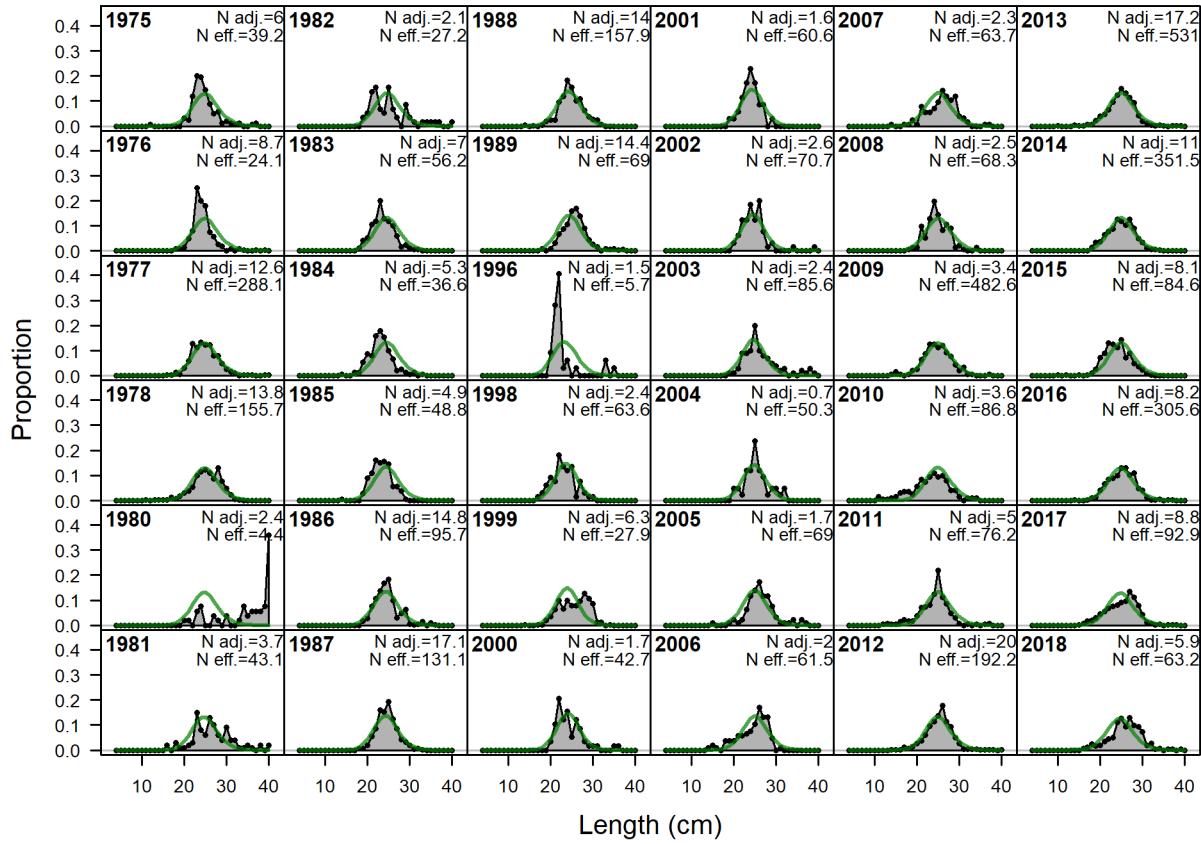


Figure C4: Length comps, whole catch, RecSouth. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. | [fig:mod1_3_comp_lenfit_flt3mkto](#)

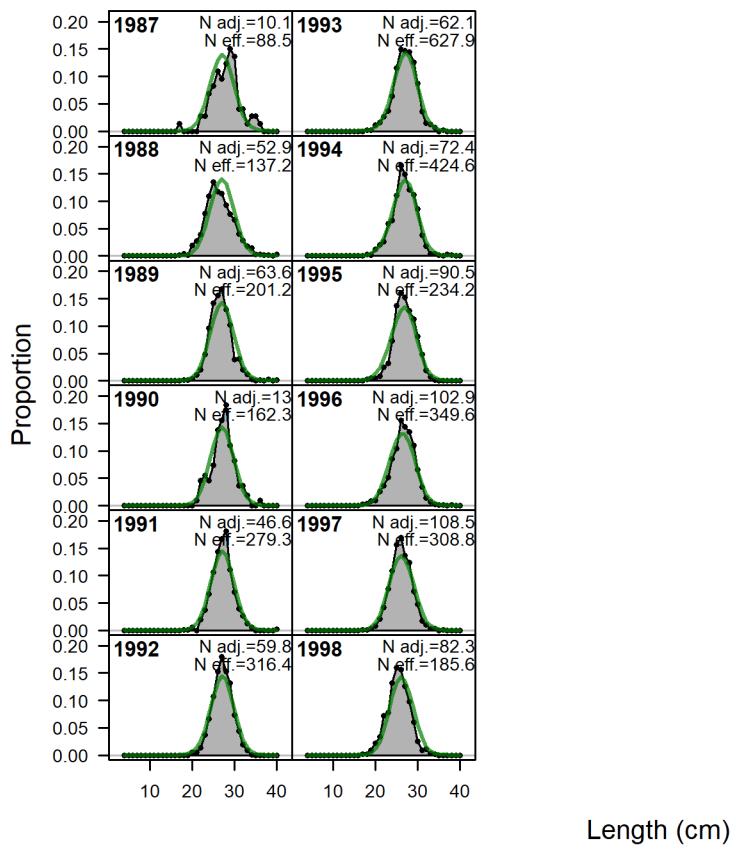


Figure C5: Length comps, whole catch, DebCPFV. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. | [fig:mod1_4_comp_lenfit_flt4mkt0](#)

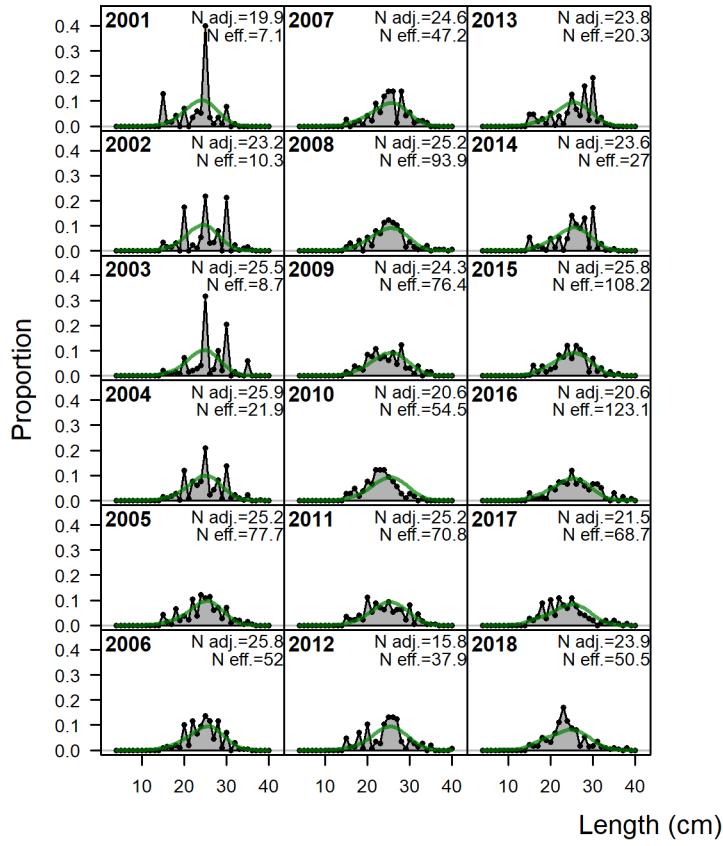


Figure C6: Length comps, whole catch, PISCO. ‘N adj.’ is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAlister_Iannelli tuning method. [fig:mod1_5_comp_1enfit_flt6mkto](#)

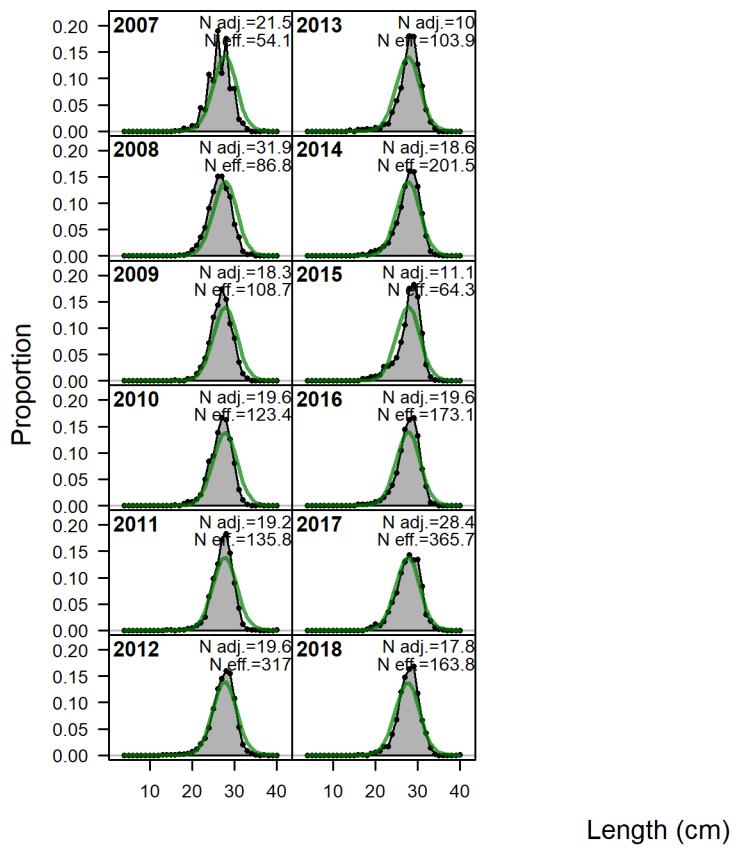


Figure C7: Length comps, whole catch, CCFRP. ‘N adj.’ is the input sample size after data_weighting adjustment. N_eff. is the calculated effective sample size used in the McAlister_Iannelli tuning method. [fig:mod1_6_comp_1enfit_flt7mkt0](#)

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