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

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

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

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Executive Summary

executive-summary

Stock

stock

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

Catches

catches

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

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

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

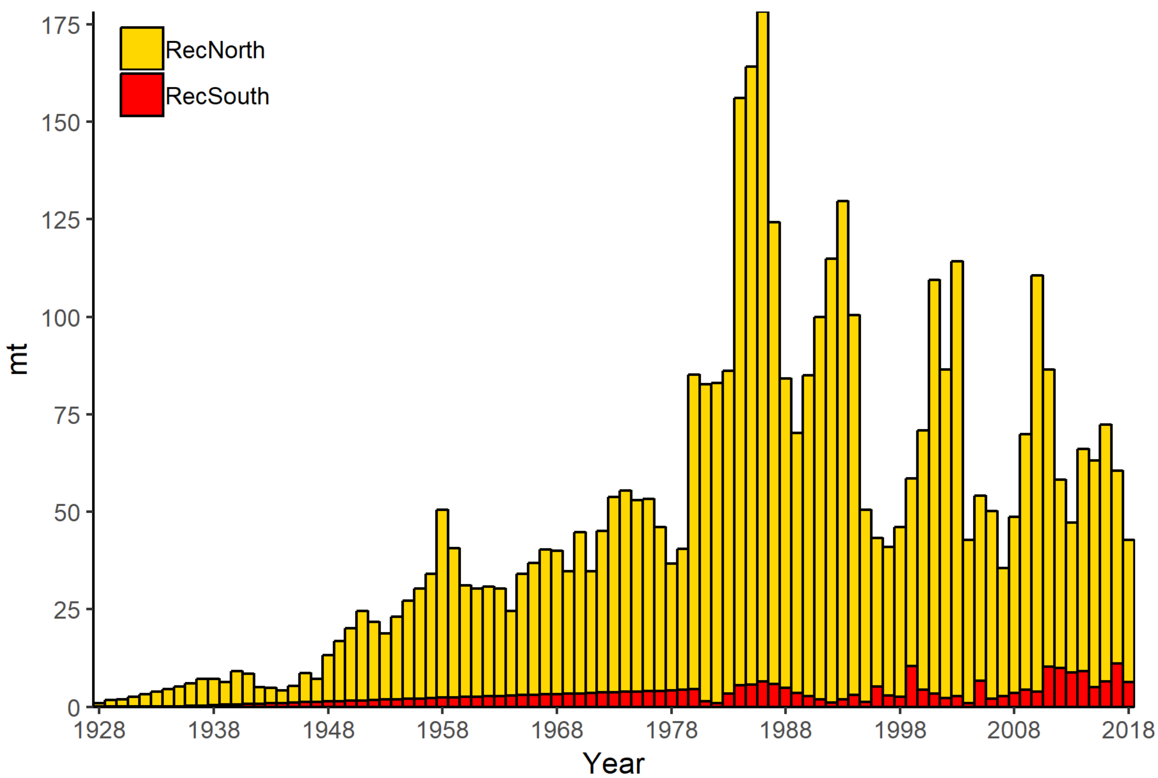

Figure a: Catch history of GBYR for the recreational fleet. fig:Exec_catch1

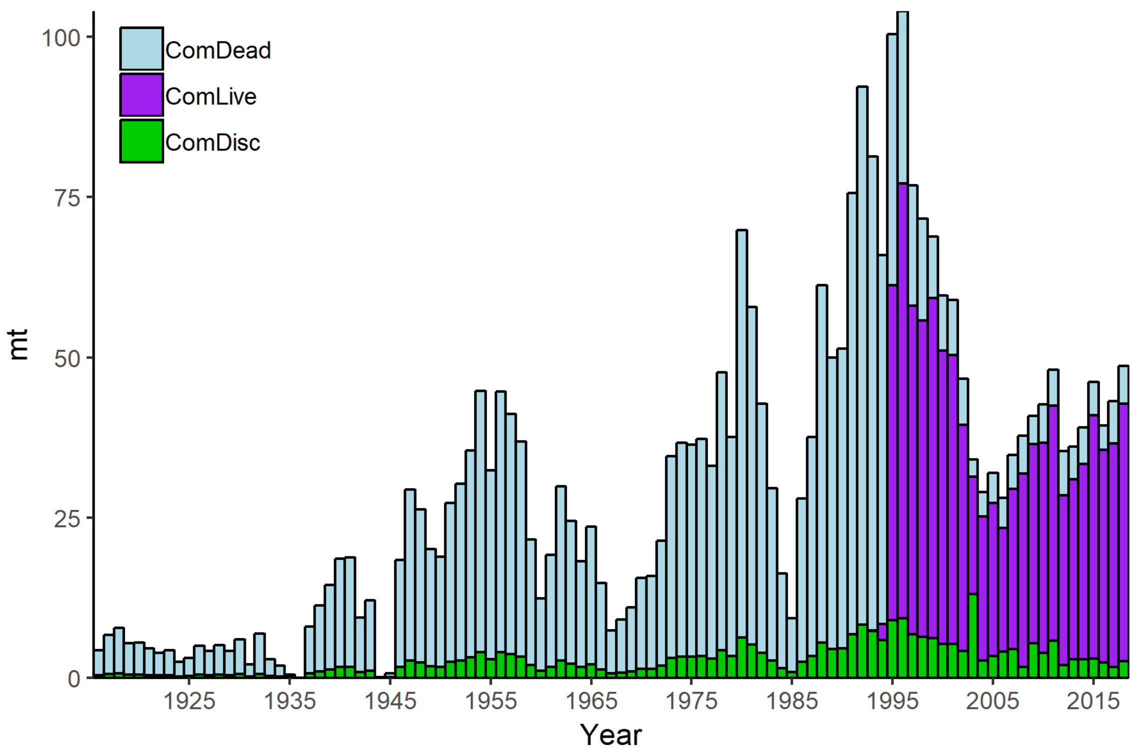

Figure b: Catch history of GBYR for the commercial fleet by dead and live landings, and discards. Catches in 1936 and 1946 were minimal. fig:Exec_catch2

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

tab:Exec_catch

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

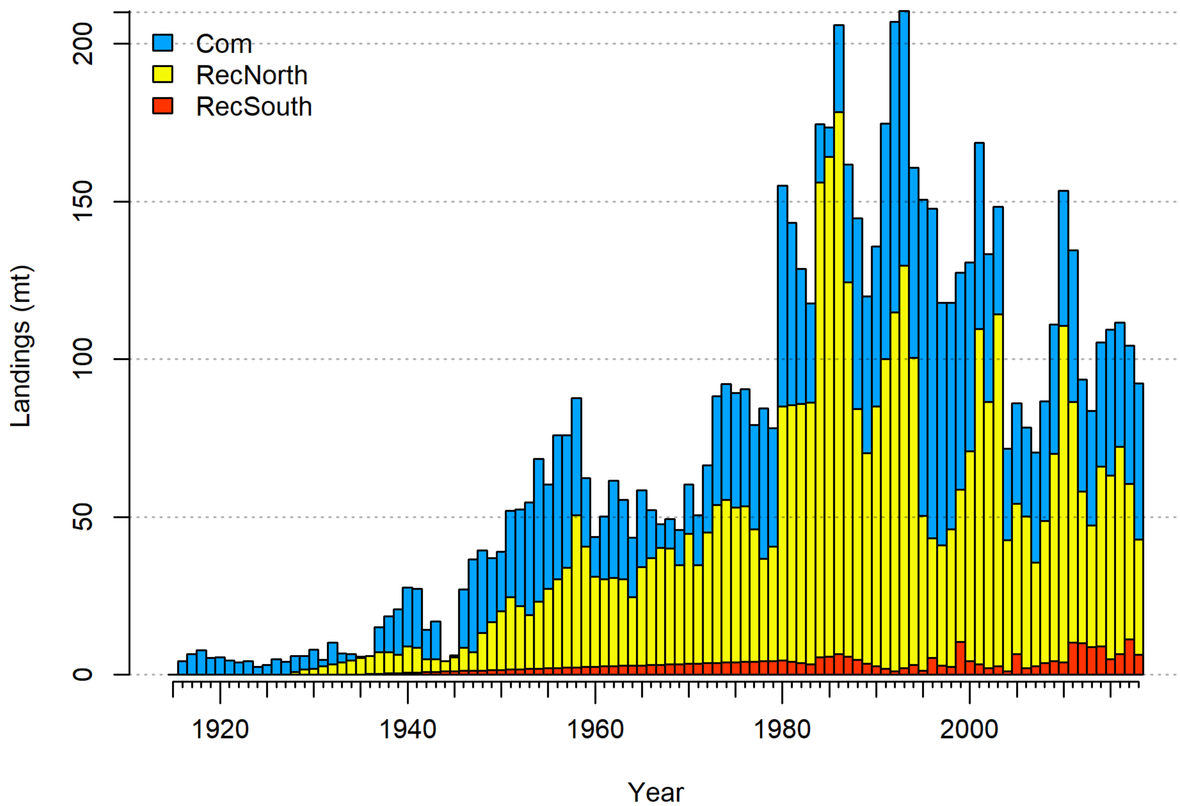

Figure c: Catch history of GBYR in the model. fig:r4ss_catches

Data and Assessment

data-and-assessment

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

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

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

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

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

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

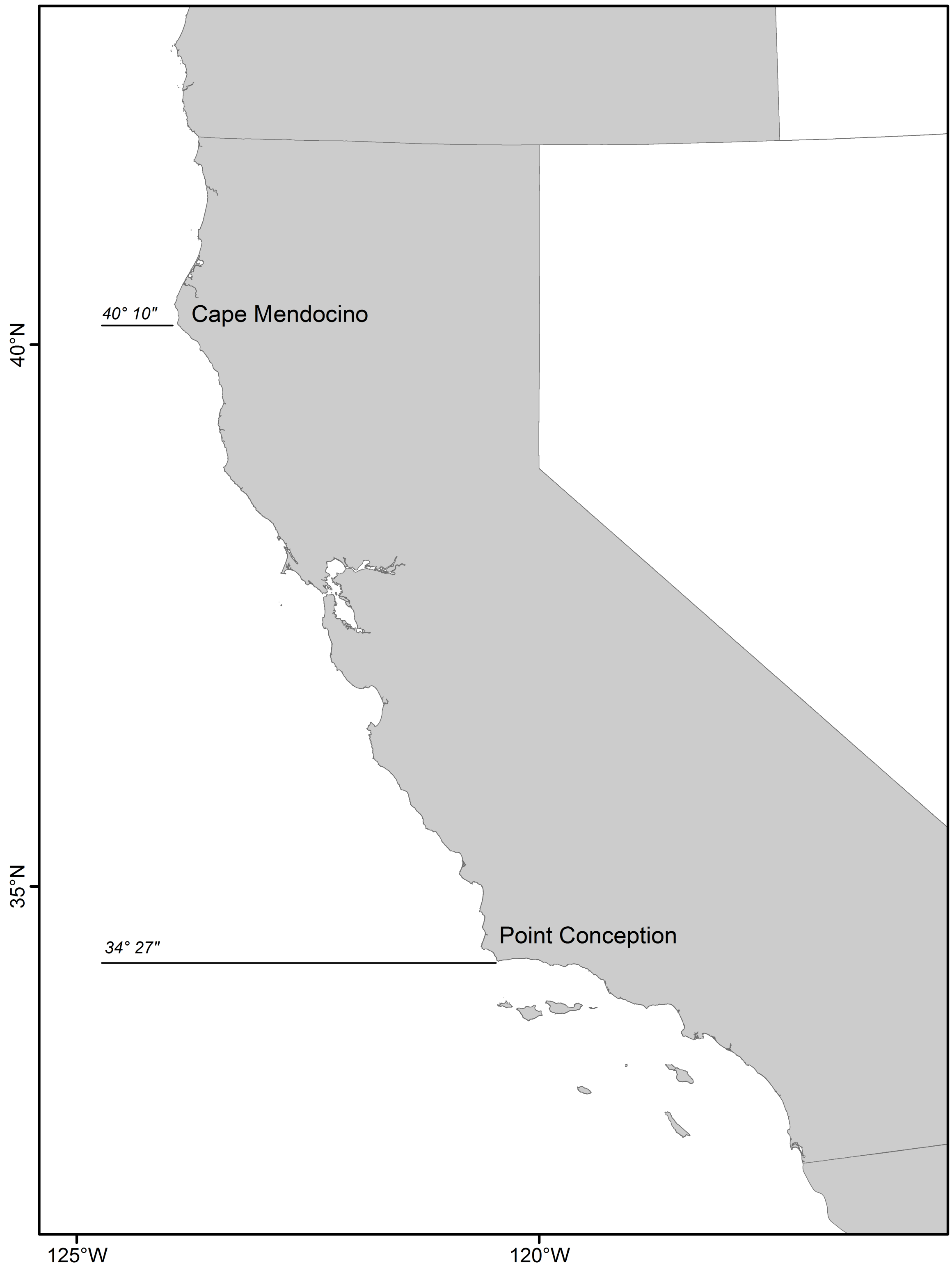

Figure d: Map depicting the core distribution of gopher and black-and-yellow rockfishes. The stock assessment is bounded at Cape Mendocino in the north to the U.S./Mexico border in the south. fig:assess_region_map

Stock Biomass

stock-biomass

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

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

tab:SpawningDeplete_mod1

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

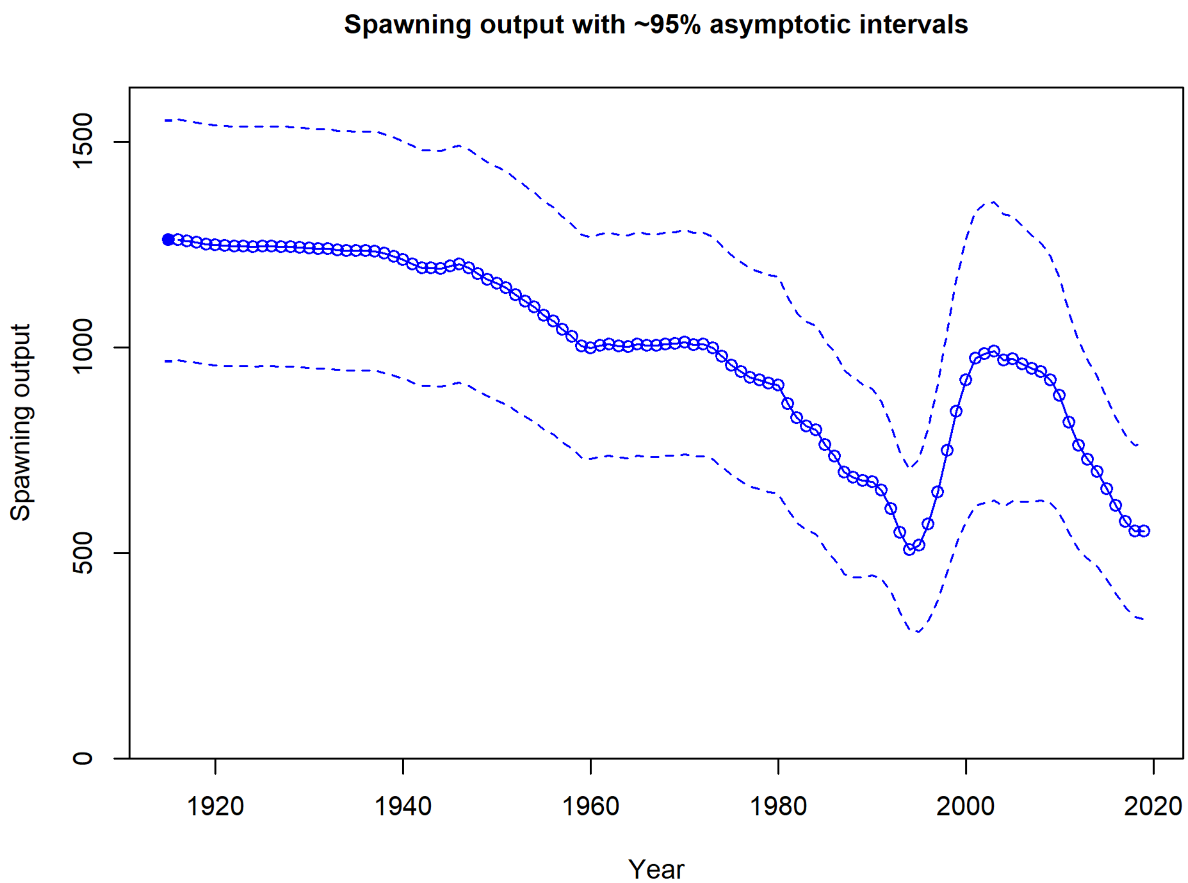

Figure e: Time series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model. fig:Spawnbio_all

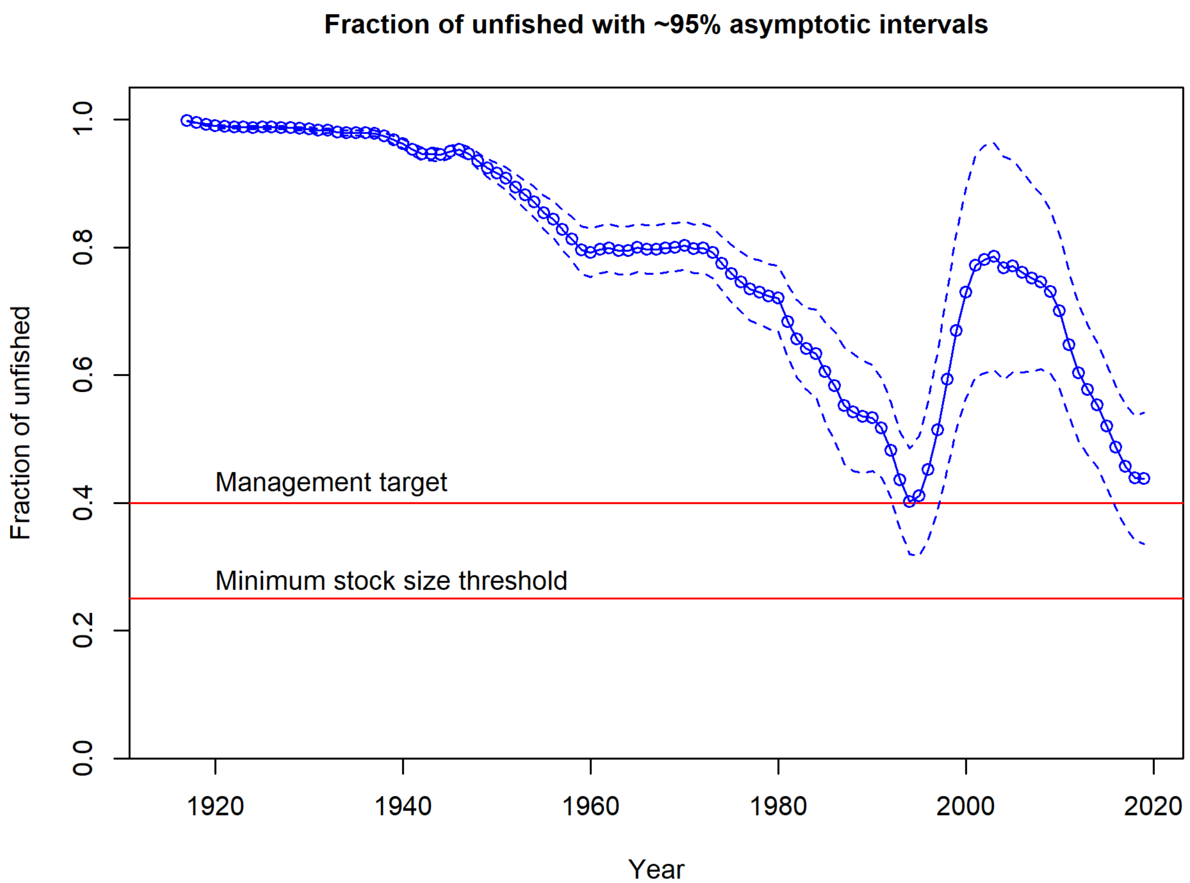

Figure f: Estimated percent depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. fig:RelDeplete_all

Recruitment

recruitment

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

Table c: Recent recruitment for the GBYR assessment.

tab:Recruit_mod1

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

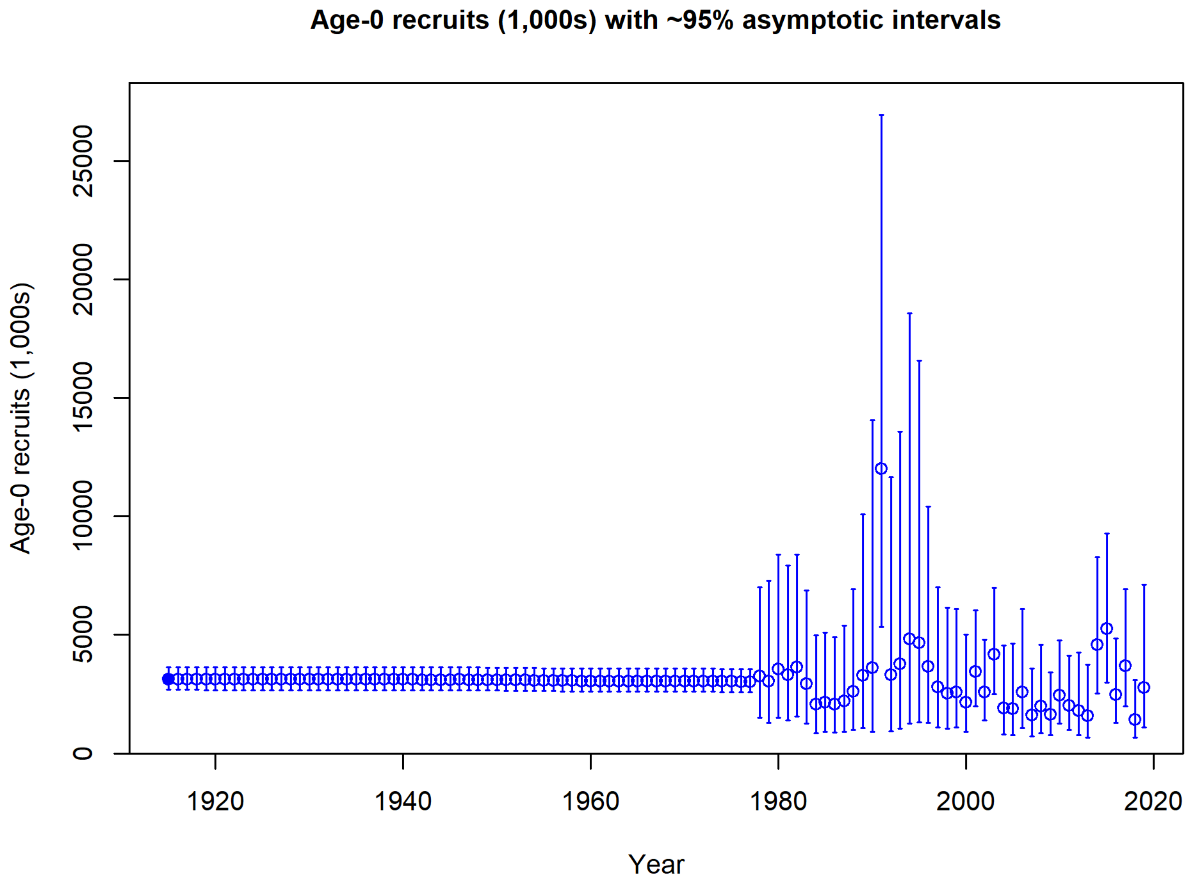

Figure g: Time series of estimated GBYR recruitments for the base-case model with 95% confidence or credibility intervals. fig:Recruits_all

Exploitation status

exploitation-status

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

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

tab:SPR_Exploit_mod1

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

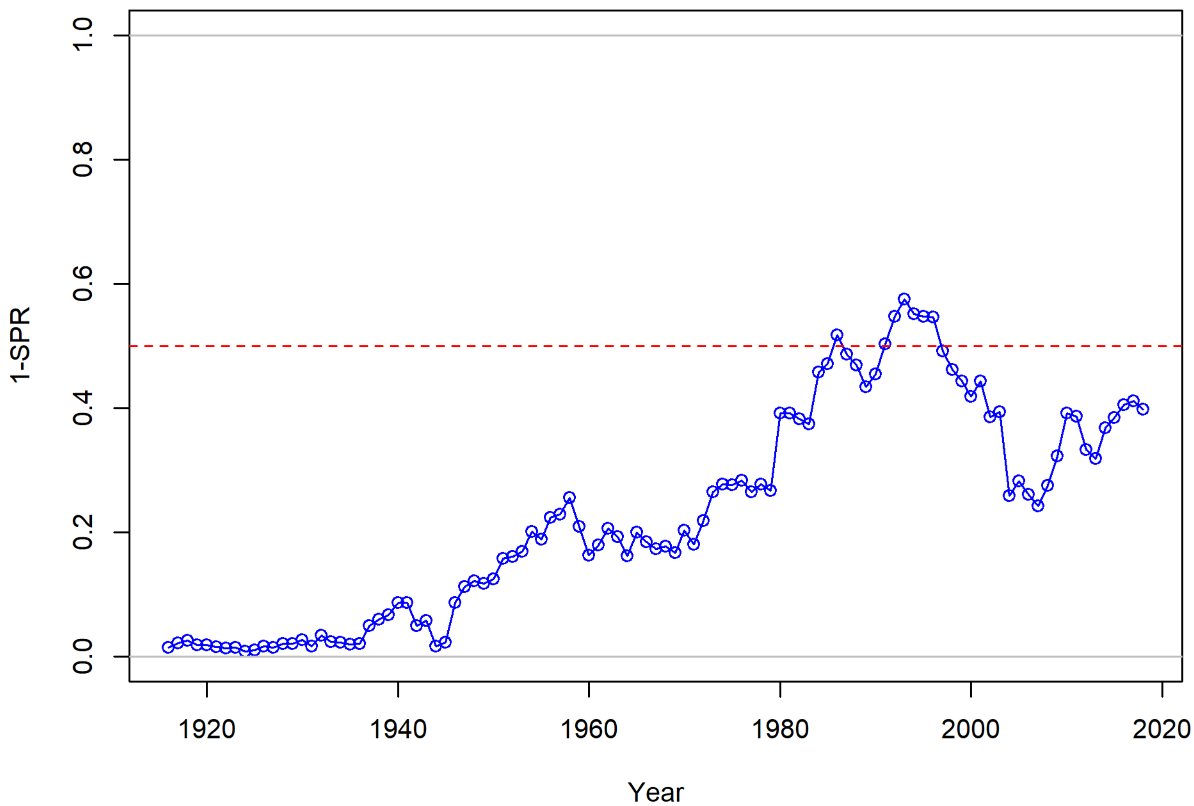

Figure h: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

Ecosystem Considerations

ecosystem-considerations

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

Reference Points

reference-points

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

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

tab:Ref_pts_mod1

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

Management Performance

management-performance

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

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

tab:mnmgt_perform

	GBYR	Minor Nearshore Rockfish		
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	-	-	1,329	1,163
2018	-	-	1,344	1,179

Unresolved Problems and Major Uncertainties

unresolved-problems-and-major-uncertainties

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 differences. Additionally, there is currently no information for either species on regional differences in biological parameters and contributions to the complex.

Decision Table

decision-table

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

Uncertainty in the forecasts is based upon the three states of nature agreed upon at the STAR panel and are based three states of nature of growth. The external estimates of growth were different than the internal estimates. Given that natural mortality is fixed in the post-STAR base model, and the growth parameter k is negatively correlated with natural mortality, k was chosen as the axis of uncertainty. The low state of nature fixed k at 0.46 and the L1 and L1 parameters are estimated. The high state of nature fixes all growth parameters, k = 0.248, L1 = 13.8, and L2 = 28.5. The L1 and L2 parameters were fixed in the high state of nature as they weren't well estimated by the model in the high state of nature. The growth parameters in the base model were estimated as $k = 0.107$, L1 = 13.4, and L2 = 28.8.

The forecasted buffer ramp was calculated assuming a category 2 stock, with sigma = 1.0 and a $p^* = 0.45$. The buffer is assumed to be 1.0 for 2019 and 2020 since the catches are assumed, and 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 state of nature catches results in a stock at 26.4% of unfished in 2030 and the base state model with the high state of nature catches results in a stock at 33.2% of unfished in 2030. The base case model with the base case 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: Projection OFL, default harvest control rule catch (ABC = ACL) above 40% SSB), biomass, and depletion using the base case model with 2019-2020 catches set equal to the ACL catch (114 mt).

tab:OFL_projection

Year	OFL (mt)	ABC Catch (mt)	Age 0+ Biomass (mt)	Spawning Output (million eggs)	Fraction unfished
2019	148	114	1281	552.5	43.8
2020	139	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

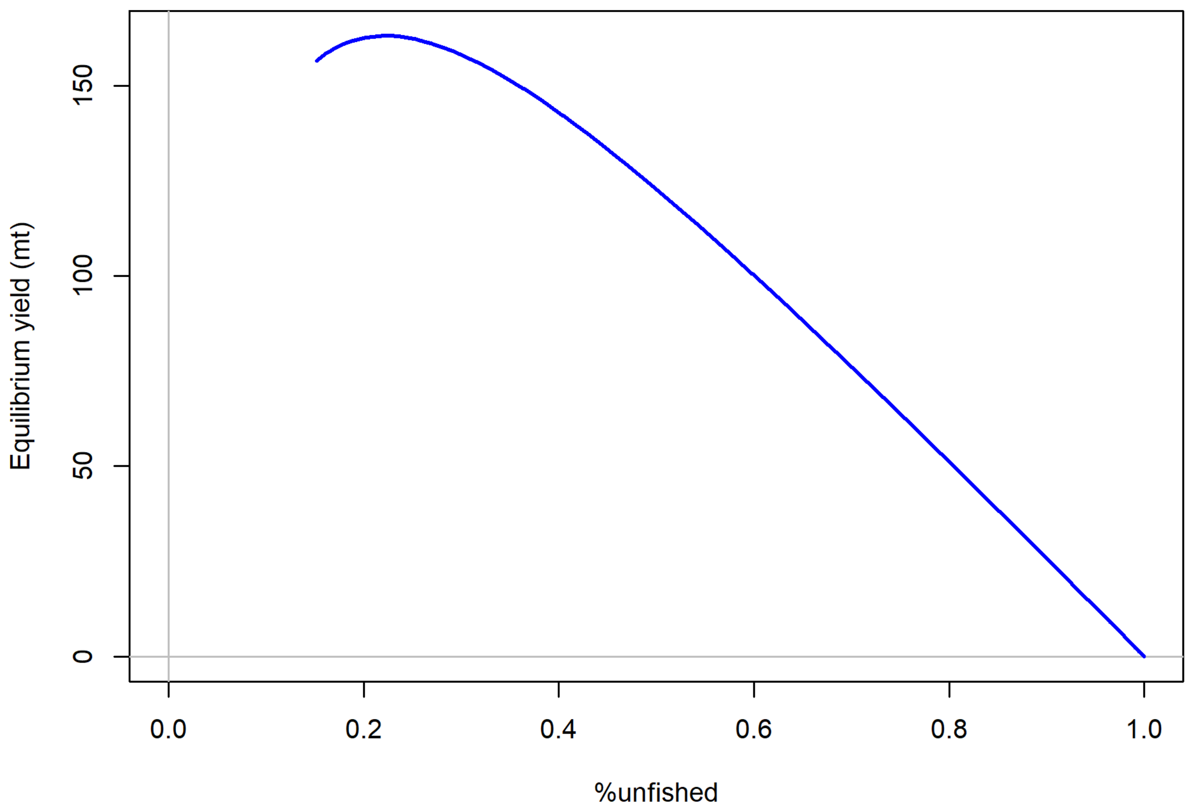

Figure i: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.72. fig:Yield_all

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)

tab:Decision_table_mod1

			States of nature					
			Low State		Base State		High State	
	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
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.

tab:base_summary

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

Research and Data Needs

research-and-data-needs

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

1. Investigate structure of complex and contribution of each species to the complex and biological parameters differences. Also, investigate regional differences within species.
2. Structure of complex and contribution of each species to the complex and biological parameters differences. Also regional differences within species.
    (a) Life history studies
    (b) Research to identify proportion of each species in population and in catch
3. Historical catch reconstruction data, more so for the recreational fishery
4. Refine PISCO survey and analysis to better identify age-0 in each month of survey, which would benefit from occasional sampling later in the year to identify size at age-0.
5. Refine CCFRP survey index and continue coastwide sampling.
6. Recommend commercial and recreational data length and age collection.
7. Integrating data collection across the different research needs to improve efficacy of data collection.
8. Environmental drivers/co-variates for biological parameters, particularly recruitment.
9. Make recreational survey dockside (PR) data available at trip level because of differences in the selectivity.
10. Resolve differences between CalCOM and PacFIN expanded length compositions.

1 Introduction

introduction

1.1 Basic Information and Life History

basic-information-and-life-history

Population Structure and Complex Assessment Considerations

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

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

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

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

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

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

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

1.2 Early Life History

early-life-history

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

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

1.3 Map

map

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

1.4 Ecosystem Considerations

ecosystem-considerations-1

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

1.5 Fishery Information

fishery-information

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

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

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

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

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

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

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

1.6 Summary of Management History

`summary-of-management-history`

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

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

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

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

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

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

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

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

California also began spatial management, including area closures, and depth restrictions for the recreational fleet in 2000. In general, the recreational season north of Point Conception extends from April to December, and south of Point Conception from March to December. In the area that GBYR are most commonly landed, from Monterey to Morro Bay, the depth restrictions have been between 30 and 40 fathoms until 2017. In 2017 the depth restrictions were eased by 10 fathoms, opening up fishing depths along the central California coast that had not been open consistently since 2002. In both 2017 and 2018, the deepest 10 fathoms was closed prior to the season in December due to high by-catch rates of yelloweye rockfish, one of two rockfish species that are still overfished. A full history of the recreational regulations relating to the spatial management of the fleet can be found in Appendix B.

1.7 Management Performance

management-performance-1

The contribution of GBYR to the minor nearshore rockfish OFLs is currently derived from two sources: 1) forecasts from Key et al. (2005), from Cape Mendocino to Point Conception, and 2) a Depletion Corrected Average Catch (DCAC (MacCall 2009)) for the area south of Point Conception. The total mortality of the minor nearshore rockfish has been below the ACL in all years (2011-2016). Total mortality estimates from the NWFSC are not yet available for 2017-2018. GBYR total mortality was on average 20% of the total minor nearshore rockfish total mortality from 2011-2016. A summary of these values as well as other base case summary results can be found in Table f.

1.8 Fisheries Off Mexico or Canada

fisheries-off-mexico-or-canada

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

2 Assessment

assessment

2.1 Data

data

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

2.1.1 Commercial Fishery Landings

commercial-fishery-landings

Overview of gopher and black-and-yellow catch history

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

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

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

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

Commercial Landings Data Sources

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

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

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

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

2.1.2 Commercial Discards

commercial-discards

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

2.1.3 Commercial Fishery Length and Age Data

commercial-fishery-length-and-age-data

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

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

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

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

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

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

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.

2.1.4 Recreational Fishery Landings and Discards

`recreational-fishery-landings-and-discards`

Historical recreational landings and discards, 1928-1980

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

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

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

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

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

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

Catches from north of Cape Mendocino were removed based on a CRFS-era average of fraction of recreational landings north of Cape Mendocino by mode (3.3% of shore-based, 0.1% of CPFV, and 0.2% of private/rental were removed). From 1980-1989, San Luis Obispo County was sampled as part of Southern California (personal observation from MRFSS Type 3 sampler examined catch where county is available for 1980-2004). This assessment separates the recreational fleet at Point Conception. Recreational landings were re-allocated from southern California from 1980-1992 by fleet based on the average proportion of recreational landings in northern California from 1996-2004 (after sampling of the CPFV fleet in northern California resumed). The average proportion re-allocated from southern to northern California for the CPFV mode was 85%, 97% for the private/rental mode, and 81% for the shore-based modes. Data were pooled over all years and modes to estimate the landings re-allocation for the shore-based modes. Total recreational landings for 1981 and 1982 were 18.8 mt and 18.6 mt, respectively. These landings were >60 mt lower than any of the neighboring years. Landings from 1981-1982 were interpolated from the 1980 and 1983 landings.

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

California Recreational Fisheries Survey (CRFS), 2004-2016

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

Recreational Discards

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

2.1.5 Recreational Fishery Length and Age Data

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

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

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

CPFV length composition data, 1959-1978

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

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

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

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

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

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

2.1.6 Fishery-Dependent Indices of Abundance

`fishery-dependent-indices-of-abundance`

A summary of all indices in the assessment can be found in Table 5. Figure 12 shows each index 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.

MRFSS Dockside CPFV Index

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

Initial trip filters included eliminating trips targeting species caught near the surface waters for all or part of the trip, including trips with catch of bluefin tuna, yellowfin tuna, skipjack, and albacore. Trips occuring in bays 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 13). The descriptions of the filtering and data below represent those for the GBYR complex.

The species composition of catch in California varies greatly with latitude.
Therefore, Stephens-MacCall filtering was applied independently for north and south of Point

Conception. Separate indices were also developed to represent two recreational fleets in the model. Since recreational fishing trips target a wide variety of species, standardization of the catch rates requires selecting trips that are likely to have fished in habitats containing GBYR. The Stephens-MacCall (2004) filtering approach was used to identify trips with a high probability of catching GBYR, based on the species composition of the catch in a given trip. Prior to applying the Stephens-MacCall filter, we identified potentially informative predictor species, i.e., species with sufficient sample sizes and temporal coverage (at least 30 positive trips total) to inform the binomial model. Coefficients from the Stephens-MacCall analysis (a binomial GLM) are positive for species which co-occur with GBYR, and negative for species that are not caught with GBYR. Each of these filtering steps and the resulting number of trips remaining in the sampling frame are provided in Table 16.

MRFSS Filtering and Index Standardization for North of Point Conception. Prior to the Stephens-MacCall filter, a total of 2,788 trips were retained for the analysis. As expected, positive indicators of GBYR trips include several species of nearshore rockfish, treefish, kelp rockfish, and blue rockfish, and the strongest counter-indicator was striped bass (Figure 14). While the filter is useful in identifying co-occurring or non-occurring species assuming all effort was exerted in pursuit of a single target, the targeting of more than one target species can result in co-occurrence of species in the catch that do not truly co-occur in terms of habitat associations informative for an index of abundance. Stephens and MacCall (Stephens and MacCall 2004) recommended including all trips above a threshold where the false negatives and false positives are equally balanced. However, this does not have any biological relevance and for this data set, we assume that if a GBYR was landed, the anglers had to have fished in appropriate habitat, especially given how territorial GBYR and both species are strongly associated with rocky habitat.

Two levels of possible filtering were applied using the Stephens-MacCall filter (Table 16). The Stephens-MacCall filtering method identified the probability of occurrence (in this case 0.4) at which the rate of "false positives" equals "false negatives." The trips selected using this criteria were compared to an alternative method including all the "false positive" trips, regardless of the probability of encountering GBYR (Table 19). This assumes that if GBYR were caught, the anglers must have fished in appropriate habitat during the trip. The catch included in this index is "sampler-examined" and the samplers are well trained in species identification. The last filter applied was to exclude years after 1999 due to a number of regulation changes, and years in which there were less than 20 observed trips. The final index is represented by 544 trips, 220 of which encountered GBYR.

Due to the large number of zeros in the data, we modeled catch per angler hour (CPUE; number of fish per angler hour) using maximum likelihood and Bayesian negative binomial regression. Models incorporating temporal (year, 2-month waves) and geographic (region and area_x) factors were evaluated. Counties were grouped into three regions, north of Sonoma county, Sonoma county through Santa Cruz county, and San Luis Obispo county. Based on AIC values from maximum likelihood fits (Table 17), a main effects model including all factors (year, region, area_x, and 2-month waves) was fit in the "rstanarm" R package (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all reasonable. Predicted means by stratum (Year) were strongly correlated with observed means, suggesting a reasonable fit to the data (Figure 16). The NB model generated data sets with roughly 50-70% zeros, compared to the observed 60% (Figure 17).

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

MRFSS Filtering and Index Standardization for South of Point Conception. Prior to the Stephens-MacCall filter, a total of 7,334 trips were available for the analysis. As expected, positive indicators of GBYR trips included several nearshore species, e.g., kelp rockfish, treefish, and black croaker, while the strongest counter-indicator was opaleye (Figure 18). While the filter is useful in identifying co-occurring or non-occurring species assuming all effort was exerted in pursuit of a single target, the targeting of more than one target species can result in co-occurrence of species in the catch that do not truly co-occur in terms of habitat associations informative for an index of abundance. For consistency with the methods used north of Point Conception (Table 16) the index includes the trips identified as "false positives" from the Stephens-MacCall filtering that had a lower threshold level of 0.22 (Table 20). The last filter applied was to exclude years after 1999 due to a number of regulation changes, and years in which there were less than 20 observed trips. The final index is represented by 475 trips, 342 of which encountered GBYR.

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

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

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

CPFV Onboard Observer Surveys

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

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

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

Deb Wilson-Vandenberg Onboard Observer Index Filtering and Standardization. A large effort was made by the SWFSC to recover data from the the original data sheets for this survey and developed into a relational database (Monk et al. 2016). The specific fishing locations at each fishing stop were recorded at a finer scale than the catch data for this survey. We aggregated the relevant location information (time and number of observed anglers) to match the available catch information. Between April 1987 and July 1992 the number of observed anglers was not recorded for each fishing stop, but the number of anglers aboard the vessel is available. We imputed the number of observed anglers using the number of anglers aboard the vessel and the number of observed anglers at each fishing stop from the August 1992-December 1998 data (see Supplemental materials for details). In 1987, trips were only observed in Monterey, CA and were therefore excluded from the analysis. The years 1990 and 1991 were also removed for low sample sizes. Final data filters included removing reefs that never encountered GBYR, drifts that had fishing times outside 95% of the data, and fishing stops with depths <9 m and >69m. The final data set contained 2,411 fishing stops, with 1,096 of those encountering GBYR (Figure 19).

The index was fit using a delta-GLM model, with a lognormal model (AIC: 1,088) selected over a gamma model (AIC: 1,143) for the positive encounters. Covariates considered in the full model included year, depth, and month (Table 8). The model selected by AIC for both the lognormal and binomial components of the delta-GLM included year, depth and reef. Depth was included in 10 m depth bins and eight reefs were select in the final model (Figure coming). The final index did not indicate an increasing trend that was seen in the 2005 gopher rockfish assessment using the same data set (Figure 20). A number of reasons include that finer-scale location data was keypunched in 2012 for this survey, the index in this assessment includes black-and-yellow rockfish, and different filters were applied to the data. However, the the same peaks and decreases in the two indices are present.

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

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

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

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

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

Filtering and Index Standardization for north of Point Conception The number of drifts remaining before region specific filtering was 13,792, with 6,036 drifts encountering GBYR (Table 9).
Because GBYR are strongly associated with hard bottom habitat, the distance from a reef at the start of a drift was re-examined for drifts encountering GBYR. The maximum distance was 872 m, but the 97% quantile dropped to 42 m and was chosen as a reasonable cutoff value, and only resulted in a reduction of 182 drifts that encountered gopher rockfish. The final data were filtered to ensure all selected reefs were sampled in at least 2/3 of all years, leaving 12,965 drifts for the final index, 5,796 of which encountered GBYR (Figure 21).

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

Filtering and Index Standardization for south of Point Conception The bathymetric data is not available at as fine-scale resolution for the Southern California Bight and more of the trips and drifts target mid-water species, including mid-water rockfish (Table 9). Therefore, instead of using distance to reef as a filter, we filtered the data to drifts that encountered 20% or more groundfish. This resulted in the total number of drifts decreasing from 11,635 to 5,495, but only decreased the number of drifts encountering GBYR from 1,277 to 1,171. A final check was made to ensure all reefs were sampled in at least 2/3 of all years, leaving 5,440 drift for the final index, of which 1,132 encountered GBYR (Figure 22).

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

2.1.7 Fishery-Dependent Indices: Available Length and Age Data

fishery-dependent-indices-available-length-and-age-data

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

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

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

2.1.8 Fishery-Independent Data Sources

fishery-independent-data-sources

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

California Collaborative Fisheries Research Project

The California Collaborative Fisheries Research Project, CCFRP, is a fishery-independent hook-and-line survey designed to monitor nearshore fish populations at a series of sampling locations both inside and adjacent to MPAs along the central California coast (Wendt and Starr 2009, Starr et al. 2015). The CCFRP survey began in 2007 and was originally designed as a statewide program in collaboration with NMFS scientists and fishermen. From 2007-2016 the CCFRP project was focused on the central California coast, and has monitored four MPAs consistently since then (Figure 23). In 2017, the program was expanded coastwide within California. The index of abundance was developed from the four MPAs sampled consistently (Año Nuevo and Point Lobos by Moss Landing Marine Labs; Point Buchon and Piedras Blancas by Cal Poly).

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

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

We modeled catch per angler hour (CPUE; number of fish per angler hour) using maximum likelihood and Bayesian negative binomial regression. The proportion of zeroes in this data was relatively small (22%), and if overdispersion were not present, the regression would innately become Poisson. Models incorporating temporal (year, month) and geographic (MPA site and MPA vs Reference cells) factors were evaluated. Based on AIC values from maximum likelihood fits (Table 15), a main effects model including all factors (year, month, site and MPA/REF) was fit in the "rstanarm" R package (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all reasonable. Predicted means by stratum (Year) were strongly correlated with observed means, suggesting a reasonable fit to the data (Figure 24). The NB model generated data sets with roughly 18-22% zeros, compared to the observed 22% (Figure 17).

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

CCFRP Length Measurements and Available Ages

The CCFRP program measures every fish encountered to the nearest half centimeter. A total of 22,470 GBYR were measured by CCFRP from 2007-2018, of which only 212 were black-and-yellow rockfish. The length distributions for each of the four MPAs used in the index for this assessment show slight difference in their peaks (Figure 26). Año Nuevo is the most northern site and Point Buchon the most southern.

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

Partnership for Interdisciplinary Studies of Coastal Oceans

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

The majority of filtering for the PISCO data set was to determine which sites to keep for the final index. After initial filtering the data for GBYR in southern California were too sparse to be considered for the index of abundance. Gopher and black-and-yellow rockfish were also rarely observed in the midwater and canopy transects, and therefore the index is based only on the benthic transects. Only sites sampled consistently throughout the time period 2001-2018 were kept for the index. Multiple transects can be conducted along the same line within a sampling event. All transects within a site were combined and effort was modeled as the number of transects represented in the number of fish observed. The final index included 3,231 transects, of which 1,729 observed GBYR (Figure 27).

We modeled number of fish observed per transect(s) using maximum likelihood and Bayesian negative binomial regression. Models incorporating temporal (year, month) and geographic (site and zone) factors were evaluated. The zone is a factor indicating the depth stratification at a site, i.e., 5 m, 10 m, 15 m, or 20 m targeted bottom depth. Based on AIC values from maximum likelihood fits (Table 13), a main effects model including all factors (year, month, site and zone) was fit in the "rstanarm" R package (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all reasonable. Predicted means by stratum (Year) were strongly correlated with observed means, suggesting a reasonable fit to the data (Figure 28). The NB model generated data sets with roughly 16-25% zeros, compared to the observed 23% (Figure 29).

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

PISCO Length Measurements

Every GBYR observed by PISCO divers except one, had an associated length measurement (N = 11,965). Divers measure fish to the nearest centimeter, and are trained to measure fish underwater and be aware of possible biases, e.g., ambient light, body color, visibility, and body shape. Both juvenile and adult GBYR were observed in the PISCO kelp forest fish survey data (Figure 30). Of note is the similarity in length distributions both between the species and for the two species combined across sites. Fish in the 10-17 cm size range (approximately) are not observed in this survey. There is significant post-settlement mortality for both species, which is thought to be due to density-dependent predation (Johnson 2006, 2007). Secondly, both species are cryptic and observed more often at night than during the day (Mark Carr, PISCO-UCSC, personal communication).

2.1.9 Biological Parameters and Data

`biological-parameters-and-data`

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

(Table 4)

Length and Age Compositions

Length compositions were provided from the following sources:

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

The length composition of all fisheries aggregated across time by fleet is in Figure 31 and Table 4. Descriptions and details of the length composition data are in the above section for each fleet or survey.

Age Structures

A total of 2,421 otoliths were incorporated in this assessment and a summary by source can be found in Table 21. The final base model excludes the commercial age data that were sparse and not representative of the fishery. Gopher rockfish comprised 79% of the samples (922 females, 879 males, 121 unknown sex), and all but a few black-and-yellow rockfish (247 females, 232 males, 20 unknown sex) came from a directed study by Jody Zaitlin (1986), collected from 1983-1986 (Figure 32).

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

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

No significant differences were found in growth between gopher and black-and-yellow rockfishes (Figure 33) or between males and females (Figure 34), species combined.

Aging Precision and Bias

Uncertainty in ageing error was estimated using a collection of 376 gopher and black-and-yellow rockfish otoliths with two age reads (Figure 36). Age-composition data used in the model were from a number of sources described above. All otoliths were read by Don Pearson (NMFS SWFSC, no retired) who also conducted all blind double reads.

Ageing error was estimated using publicly available software (Thorson et al. 2012). The software setting for bias was set to unbiased since the same reader conducted the first and second readings. The best fit model chose by AIC for the standard deviation was a constant coefficient of variation for reader one ad mirrored for reader two (Figure 37).

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

Weight-Length

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

The weight-length relationships was estimated from the three studies, Loury (2011), Meyers-Cherry (2014) (both gopher rockfish only from CCFRP) and Zaitlin (Zaitlin 1986) (black-and-yellow rockfish only). Only one weight-length relationship was estimated for the GBYR complex. The estimated parameters are $\alpha = 8.84e^{-006}$ and $\beta = 3.25584$. The estimated relationship is similar to that estimated by Lea et al. (1999) for gopher rockfish (Figure 38). The weight-length relationship estimated here was used in the assessment model to best represent the GBYR complex.

Sex Ratio, Maturity, and Fecundity

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

Zaitlin (1986) found that females reached 50% maturity at 17.5 cm or 4 years of age in Central California and were 100% mature by age 6, with the same age of maturity found in southern California though individuals were smaller at age. Echeverria (1987) estimated maturity for 17 rockfish species in central California. She found the size at first maturity and the size at 50% maturity for male and female gopher rockfish to be 17 cm total length, and 100% mature by 21 cm. Black-and-yellow rockfish males and females were first mature at 14 cm, 50% of females were mature at 15 cm, 50% of males mature at 16 cm. Male black-and-yellow rockfish were 100% mature at 20 cm and females at 19 cm. In southern California waters, both males and females were found to reach first maturity at 13 cm total length (Larson 1980). We did not have any samples from southern California to re-analyze the maturity ogive for that portion of the population. Both Zaitlin and Echeverria estimated the maturity ogives using ages from whole otoliths. A sample of 151 black-and-yellow rockfish otoliths surface read by Zaitlin were also read by Don Pearson, and Zaitlin's ages were consistently younger than Pearson's, by up to nine years. All of the available otoliths for this assessment were re-aged using a combination of surface reading and break-and-burn methodology.

The maturity data from Zaitlin (1986) (422 black-and-yellow rockfish) were re-analyzed along with samples from Meyers-Cherry (2014) (115 gopher rockfish). Combining the two data sets provided an updated maturity ogive for the GBYR complex females (Figure 35). The first observed mature fish was 19 cm and the length at 50% was 21.66 cm, larger than suggested from the estimate used by Key et al. (2005) in the 2005 assessment. After re-analyzing the available data, the length at which 50% of female gopher rockfish were mature was estimated at 23.33 cm, and was 21.26 cm for female black-and-yellow rockfish. An important note is that the smaller fish from these studies were black-and-yellow rockfish and the larger fish were gopher rockfish. Although not used in this assessment, the estimate of 50% maturity for 23 GBYR from these studies was 21.88 cm. The age at 50% mature increased in this assessment to 21.66 cm, which is 3.96 cm larger than the value used in the 2005 assessment.

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

Natural Mortality

Hamel (2015) developed a method for combining meta-analytic approaches to relating the natural mortality rate M to other life-history parameters such as longevity, size, growth rate and reproductive effort, to provide a prior on M. In that same issue of ICESJMS, Then et al. (2015), provided an updated data set of estimates of M and related life history parameters across a large number of fish species, from which to develop an M estimator for fish species in general. They concluded by recommending M estimates be based on maximum age alone, based on an updated Hoenig non-linear least squares (nls) estimator $M = 4.899 * {A_{max}}^{-.916}$. The approach of basing M priors on maximum age alone was one that was already being used for west coast rockfish assessments. However, in fitting the alternative model forms relating $-.916M$ to A_{max}, Then et al. (2015) did not consistently apply their transformation. In particular, in real space, one would expect substantial heteroscedasticity in both the observation and process error associated with the observed relationship of M to A_{max}. Therefore, it would be reasonable to fit all models under a log transformation. This was not done. Revaluating the data used in Then et al. (2015) by fitting the one-parameter A_{max} model under a log-log transformation (such that the slope is forced to be -1 in the transformed space (as in Hamel (2015)), the point estimate for M is:

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

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

2.1.10 Environmental or Ecosystem Data Included in the Assessment

environmental-or-ecosystem-data-included-in-the-assessment

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

2.2 Previous Assessments

previous-assessments

2.2.1 History of Modeling Approaches Used for this Stock

history-of-modeling-approaches-used-for-this-stock

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

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

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

2.2.2 2005 Assessment Recommendations

assessment-recommendations

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

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

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

2.3 Model Description

model-description

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

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

2.3.1 Transition to the Current Stock Assessment

transition-to-the-current-stock-assessment

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

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

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

The way growth is modeled for age-0 fish has changed. More recent versions of Stock Synthesis model length-at-age for fish below the first reference age (Amin) as linearly increasing from the initial length bin to the length given by the L_at_Amin parameter. The minimum population length bin was reduced from 10 cm in the 2005 assessment to 4 cm in this assessment. The timing of settlement was set at July to reflect the the month at which the young-of-the-year are expected to be at 4 cm (Figure 39). The length data leading to this decision were provided by Diana Baetscher (UCSC) and were collected via Standard Monitoring Unit for the Recruitment of Fishes (SMURFs) (Ammann 2004) from the UCSC-PISCO kelp forest fish survey as part of her dissertation work on rockfish genetics (Baetscher 2019).

This stock assessment retains a single fleet for the commercial fishery, and also includes a commercial discard fleet. Data on commercial discards were not available for and not included in the 2005 assessment. The decision to retain one commercial fleet was made by examining the length distributions across species, fishing gears, and space, i.e., north and south of Point Conception (Figure 40). 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.

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 41). The recreational catches from the man-made/jetty mode are negligible and did not influence the decision to split the fleet at Point Conception. From 2005-2018, the man-made/jetty mode averaged 0.5% of the total recreational catch and discards north of Point Conception and 0.03% south of Point Conception. The similarity of the length distributions between species and among modes within a region were similar and justified one recreational fleet.

The 2005 model was a length-based model. This assessment uses conditional age-at-length from fish aged from a number of sources (Table 21).

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

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

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

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

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

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

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

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

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

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

2.3.2 Summary of Data for Fleets and Areas

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

There are 12 fleets in the base model. They include:

Commercial: The commercial fleets include two separate fleets, one for GBYR landed (all gears combined), and one for commercial dead discards.

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

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

Research: There are two main sources of fishery-independent data available the CCFRP survey the PISCO kelp forest fish survey. A third survey fleet is included as a "dummy" fleet to allow incorporation of additional conditional age-at-length composition data from the Zaitlin and Abrams theses, the Pearson groundfish cruise, and the special study conducted during the SWFSC's juvenile rockfish and ecosystem cruise. This dummy fleet includes 1,067 ages of gopher and black-and-yellow rockfish. This dummy fleet does not have any length or catches associated with it.

2.3.3 Other Specifications

other-specifications

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

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

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

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

The extra standard deviation parameter was added to all indices except the Deb Wilson-Vandenberg CPFV onboard observer index and the MRFSS dockside index for north of Point Conception that both had relatively large estimated variances associated with them. The extra parameter was explored, but estimated to be on the lower bound, and was removed for the final base model. All other indices, both recent recreational onboard observer indices, CCFRP, PISCO, and the MRFSS dockside index south of Point Conception, were estimated with relatively small variances (10-20%) from their respective indices. Extra variance was estimated for these indices in the base model.

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

Electronic SS model files including the data, control, starter, and forecast files can be found on the PFMC ftp site.

2.3.4 Modeling Software

modeling-software

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

2.3.5 Data Weighting

data-weighting

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

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

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

2.3.6 Priors

priors

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

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

2.3.7 Estimated and Fixed Parameters

`estimated-and-fixed-parameters`

A full list of all estimated and fixed parameters is provided in Tables 24. Time-invariant, growth is estimated in this assessment, with all SS growth parameters being estimated. The log of the unexploited recruitment level for the Beverton-Holt stock-recruit function is treated as an estimated parameter. The early annual recruitment deviations begin in 1960, with the main recruitment deviations estimated from 1972-2018. The survey catchability parameters are calculated analytically (set as scaling factors) such that the estimate is median unbiased, which is comparable to the way q is treated in most groundfish assessments.

The base model has a total of 111 estimated parameters in the following categories:

- Natural mortality
- Equilibrium recruitment (R_0) and 71 recruitment deviations
- Stock recruitment auto-correlation parameter
- Five growth parameters
- Five index extra standard deviation parameter, and
- 27 selectivity parameters

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

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

Natural Mortality. The estimated natural mortality of 0.212 is close to the median of the prior, 0.193.

Selectivity. Selectivity for all fleets was estimated as double-normal.

Selectivity was estimated as asymptotic for the commercial fleet, with one time block. Asymptotic selectivity was also estimated for both recreational fleets, Deb Wilson-Vandenberg's onboard observer survey, and the PISCO. Three parameters were estimated for each of these fleets, the peak, the ascending width, and the selectivity at the first bin.

Dome-shaped selectivity was estimated for the commercial discard fleet and the CCFRP survey. Five of the size parameters were estimated for the commercial discard selectivity (selectivity at the last bin was fixed). Four parameters were estimated for the CCFRP length compositions (selectivity at the first and last bins was fixed).

Other Estimated Parameters. Early recruitment deviations for the base model are estimated from 1960-1972, with the main recruitment deviations estimated from 1978 to 2018. The base model also included estimated recruitment deviations for the forecast years, although these have no impact on the model estimates for the current year.

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

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

Initial runs showed that the estimated recruitments were highly auto-correlated. Therefore, an auto-correlation parameter was later estimated and its value was estimated to be positive and significantly different from zero.

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

Other Fixed Parameters. The stock-recruitment steepness is fixed at the SSC approved steepness prior for rockfish of 0.72.

2.4 Model Selection and Evaluation

`model-selection-and-evaluation`

2.4.1 Key Assumptions and Structural Choices

`key-assumptions-and-structural-choices`

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

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

2.4.2 Alternate Models Considered

alternate-models-considered

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

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

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

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

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

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

2.5 Response to the Current STAR Panel Requests

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

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

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

STAT Response: The STAT created two catch curves using the available age data for gopher and black-and-yellow rockfish, one for the time period pre-2000 (629 available ages) and the second from 2000-2018 (1,791 available ages). 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.

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 North and South indices

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. 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. 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.

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

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

STAT Response: Response under Request #4a.

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

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

STAT Response: The STAT developed an index of abundance using only fish that were 5 cm or less and re-developed the length composition data for the PISCO survey representing fish 15 cm and larger. The effect of splitting the PISCO index into two indices, one for young of the year and one representing older fish resulted in dampening of the age-0 recruits seen in the previous models.

Request No. 5: Remove the auto-correlation recruitment.

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

STAT Response: Removing the auto-correlation in recruitment resulted in no significant change to the model output.

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

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

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

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

from 1978 to 1979. Provide all appropriate diagnostics.

Rationale: : STAT and STAR agree this was an improvement over the original base model.

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

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

Rationale: Better to use all appropriate data for the recruitment index.

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

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

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

STAT Response: The selectivity for the CCFRP index was also mirrored to the Recreational North fleet since the length compositions were not drastically different than the other fleets mirrored to the Recreational North fleet. The STAT could not find a domed selectivity pattern that had reasonable parameter estimates.

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

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

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

2.6 Base Case Model Results

base-case-model-results

The following description of the model results reflects a base model that incorporates all of the changes made during the STAR panel. A comparison of the pre-STAR base model and the post-STAR base model can be found in Figures 42, 43, and 44 and Table 22. A number of changes to the fleet structures, removal of surveys south of Point Conception, and the splitting of the PISCO index into two indices to better reflect life stages contributed to the changes. The final model also fixes natural mortality, whereas it was estimated in the pre-STAR base model. The pre-STAR base model includes and ageing error matrix that was developed using only half of the available double reads. The post-STAR base includes the updated ageing error matrix (Figure 45), and the update did not significantly change the model outputs.

The base model parameter estimates and their approximate asymptotic standard errors are shown in Table 24 and the likelihood components are in Table 25. Estimates of derived reference points and approximate 95% asymptotic confidence intervals are shown in Table e. Time-series of estimated stock size over time are shown in Table 26.

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

2.6.1 Convergence

convergence

Model convergence was determined by starting the minimization process from dispersed values of the maximum likelihood estimates to determine if the model found a better minimum. Jitter is a SS option that generates random starting values from a normal distribution logistically transformed into each parameter's range (Methot et al. 2019). This was repeated 300 times and the minimum was reached in 67% of the runs (Table 23). The model did not experience convergence issues, e.g., final gradient was below 0.0001, when reasonable starting values were used and there were no difficulties in inverting the Hessian to obtain estimates of variability. We did sensitivity runs for convergence by changing the phases for key estimated parameters; neither the total log-likelihood nor the parameter estimates changed.

2.6.2 Parameter Estimates

parameter-estimates

The base model produces estimates of growth parameters different from the external estimates (Figure 46). The external estimate of the von Bertalanffy growth coefficient k was 0.247, whereas the internal estimate was much lower at 0.107. Using the Schnute parameterization with the age for L1 set at 2 and L2 at 23, the external estimates of lengths at Amin and Amax were similar at 13.80 and 28.22, respectively. The internal estimates of the lengths for Amin and Amax were 13.4 and 28.80, respectively. Given that natural mortality was fixed in the base model and natural mortality and the growth parameter k are negatively correlated, the model estimated a slower rate of growth. A number of other factors including the lenght composition and selectivity affect the internal estimate of growth. Hence, growth was chosen as the axis of uncertainty for the decision table.

The estimated selectivities for all fleets within the model are shown in Figure 47. The selectivity curves for the commercial fleet, recreational fleets north and south of Point Conception, and the larger PISCO (15+ cm) were estimated. All of the selectivities are asymptotic except for the PISCO age-0 index, which has an age selectivity set to 1.0. All of the recreational indices and the CCFRP index selectivities were mirrored to the recreational fleet north of Point Conception. Attempts to fit asymptotic and dome-shaped selectivity to the CCFRP data resulted in poor estimation, large standard deviations, or a lack of fit to the data. The aggregated CCFRP length composition over time was similar to the length composition data of the recreational fleets north of Point Conception and mirroring the CCFRP selectivity provided a more parsimonious model. The recreational fleet south of Point Conception encounters smaller GBYR, which is reflected in the asymptotic selectivity shifted to the left of all other fleets. Selectivities for the recreational fleet north of Point Conception and the commercial fleet are very similar. Both fleets include both length composition of retained and discarded fish, although no information on the size of discards is available from the commercial fleet prior to 2004. The selectivity for the commercial fleet was kept separate because the fleet has different fishing behavior than the recreational fleet and going forward in time, may diverge further from the fleets depending on management decisions or changes in fishing behavior. Selectivity for the PISCO (15+ cm fish) index was estimated as the survey observes a wider range of length classes than the other fleets. The estimated peak of the PISCO selectivity hit the upper bound of 38 and was fixed at 38 in the base model. The age selectivity for the PISCO age-0 index was fixed at 1.0 and assumes that all age-0 fish are selected.

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

Recruitment deviations were estimated from 1978-2018 (Figure 48). Estimates of recruitment suggest that GBYR are characterized by cyclical years of high and low recruitment (Figure

49). The final base model does not include early recruitment deviation and a steep bias adjustment ramp from 1978 to 1979 of 0.32 that extends to 2019 Figure 50. The years of highest estimated recruitment is 1991, with recruitment estimated more than double that of any other year.
Fish from this cohort can be observed in the lenght composition data from Deb Wilson Vandenberg's onboard observer survey and recreational fleet north of Point Conception in the later half of the 1990s. Additional periodic recruitment events are estimated from 1994 and onward, with the peaks from 2001 and on driven by the PISCO age-0 index. followed by a period of below average recruitment, and another high recruitment pulse in the late 2010s.

The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 51. The stock has not been depleted to a low enough level that would inform the estimation of steepness. Steepness was not estimated in this model, and profiles over steepness values are discussed below.

2.6.3 Fits to the Data

`fits-to-the-data`

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

The fits to the three fishery-dependent and three fishery-independent survey indices are shown in Figures 52, 53, 54, 55, 56, and 57. All indices represent the area north of Point Conception only, and not all of these were fit well by the assessment model. The MRFSS CPFV recreational dockside survey index north of Point Conception spanning the 1980s-1990s was fit well by the model without added variance, but relatively flat, and is not a very informative index. The index for Deb Wilson-Vandenberg's CPFV onboard observer survey spanning 1988-1998 was well fit and indicates an increase in relative abundance in the last year of the survey. The current recreational CRFS/Cal Poly onboard observer survey north of Point Conception from 2001-2018 was relatively well fit, except for the decline suggested 2013 and 2014. The increase in relative abundance observed in 2018 was not fit by the model, even with the added variance. The variance added to this survey was the highest for all indices.

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

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

The base model was re-weighted twice using Francis weights for the length and age composition data. Fits to the length data are shown based on the proportions of lengths observed by year and the Pearson residuals-at-length for all fleets. Detailed fits to the length data by year and fleet are provided in Appendix 8. Aggregate fits by fleet are shown in Figure 58. Overall, the length composition all fit well. The PISCO fleet has the noisiest of all the length composition data, but on an annual basis, the length data were relatively well fit. The fit to the aggregated CCFRP data suggests the model expects to see additional larger fish, which is likely due to the mirroring of the selectivity. However, on an annual basis, there is a trade-off with the CCFRP with under-fitting of the larger fish in the earlier years and an under-fitting of the smaller fish expected in the later years (2013-2018).

The mean age of the recreational fleet varied from 1980-1986 ranging from approximately 8-11, and increased in 2017 to approximately 13 (Figure 59). The conditional age data from the CCFRP data was not well fit for the earliest years in the data, but was reasonably well fit for the last four years of data (Figure 60). The conditional length composition data from the 'dummy' fleet was well fit, although heavily down-weighted. Age data in this fleet are from a number of sources and sampling programs (Figure 61).

2.6.4 Uncertainty and Sensitivity Analyses

`uncertainty-and-sensitivity-analyses`

A number of sensitivity analyses were conducted, including:

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

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

Fixing either natural mortality or the von Bertalanffy k parameter results in a stock with higher spawning output in 2018 as compared to the base model (Figure 62).

Fixing either M or k demonstrates the negative correlation between the two parameters. The von Bertalanffy k parameter is estimated at 0.12 when natural mortality (estimated at 0.21) and growth are both estimated. When natural mortality is fixed at the prior of 0.19, k is estimated at 0.14, but the two other growth parameters, L1 and L2 do not change much at all. When k is fixed to the external estimate of 0.247, natural mortality is estimated at 0.16, and the other growth parameters both decrease. A number of additional sensitivities to the growth parameters will be presented at the STAR panel.

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

Data weighting is an area of uncertainty for stock assessment, and research is ongoing to determine the effects of data weighting and the most appropriate initial sample sizes for length and age composition data. The base model used the Stewart sample sizes for initial sample sizes for the fishery data and either the Stewart sample sizes or number of "trips" for the survey sample sizes. Weighting the data by the harmonic mean resulted in a model with a total likelihood between the base model, which uses the Francis method for weighting, and the model with default weights (Figure 63). The end year spawning output is almost identical for the models using harmonic means and Francis weights, both of which down-weighted the composition data.

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

2.6.5 Retrospective Analysis

`retrospective-analysis`

A 4-year retrospective analysis was conducted by running the model using data only through 2017 (retro 1), 2016 (retro 2), 2015 (retro 3), and 2014 (retro 4) (Table 28). The initial population size and estimation of trends in spawning biomass in the retrospective runs were lower than the base model, except for retro 1 (Figure 64). All retrospective runs followed the same general trend, with the differences in the trends stemming from the change in recruitment deviations (Figure 65). The PISCO age-0 index has a signal of increased recruitment in the most recent years. For Retro2, Retro3, and Retro4, the trends in recruitment are not observed by the model. There is no conditional age-at-length composition data for 2015-2016, leading to the minor change in the age composition likelihood from Retro2 to Retro3 and Retro4 (Table 28). The age composition data in 2017 accounts for 2.5% of all available ages, and 4.5% of all fish aged were from 2018. The available length data in each year from 2015-2018 range from 4-6% of the total available length data. The length compositions of all the other fleets have similar length distributions for 2015-2018 (8). Additional investigations into the retrospective patters will be made by the STAT.

2.6.6 Likelihood Profiles

likelihood-profiles

Likelihood profiles were conducted for R_0, steepness, and over natural mortality values separately. These likelihood profiles were conducted by fixing the parameter at specific values and estimated the remaining parameters based on the fixed parameter value (Tables 29-30).

In regards to values of R_0, the negative log-likelihood was minimized at approximately $\log(R_0)$ of 8.0 (Table 29). The individual surveys tend to minimize at the upper bound or jut below, while the length composition data has conflicting trends, e.g., CCFRP and commercial fleets, or the upper bound, e.g., PISCO and the recreational north fleets (Figures 66-67). The data all consistently minimize around 8.5 and the recreational fleet south of Point Conception minimize R_0 at the lower bound. (Figure 68). Over the range of values of R_0, depletion ranged from 0.38-0.59 (Figure 69).

For steepness, the negative log-likelihood reaches a minimum around a steepness near the upper bound (Figure 72 and Table 29 and Figure 77). The length composition likelihood components declined towards the upper bound for Deb's CPFV and the recreational south fleets, while the other fleets either reached a minimum around 0.55 or at the lower bound. (Figure 70). Overall changes in the survey likelihood across the range of steepens was less than 2.0, with surveys either minimized at the lower or upper bound (Figure 71). The relative depletion for GBYR ranges from 0.375 to 0.493 across different assumed values of steepness (Table 29).

The negative log-likelihood was minimized at a natural mortality value near 0.2, slightly higher than the prior of 0.193 (Table 29 and Figure 76). The age, length, index, and prior likelihood contributions were minimized at natural mortality values around 0.22, and the recruitment contribution was minimized at the second to largest value of M run, 026. (Table 29). The length composition minimizes around a natural mortality value of 0.14, with the commercial, recreational fleet north of Point Conception, and CCFRP data minimizing wars the lower bound (Figure 74). The length data from Deb's CPFV survey minimizes around 0.22, while the PISCO and recreational length compositions south of Point Conception minimizes at the upper bound. The PISCO and CCFRP minimized around a natural mortality value of 0.22, while the PISCO age-0 and overall survey likelihood minimized at the upper bound of 0.3 (Figure 75). The relative depletion for GBYR ranged from 0.32-0.59 across alternative values of natural mortality (Figure 77).

2.6.7 Reference Points

reference-points-1

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

The predicted spawning output from the base model shows an initial decline starting the 1950s, is then stable, and declines steeply until 1995 (Figure 78). The spawning output then rapidly increases through the early 2000s, and has been in a decline since 2006.

The 2018 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished levels (Figure 79). The relative fishing intensity, $(1 - SPR)/(1 - SPR_{50\%})$, was below the management target from 1981-1998, and below the minimum stock size threshold in 1995. The stock has been above the management target since 1999.

Table e shows the full suite of estimated reference points for the base model and Figure 80 shows the equilibrium curve based on a steepness value fixed at 0.72.

3 Harvest Projections and Decision Tables

harvest-projections-and-decision-tables

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

4 Regional Management Considerations

regional-management-considerations

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

The state of California implements regional management for the recreational fleet in the form of five regions, referred to as management areas with differing depth and season restrictions.

Neither gopher nor black-and-yellow rockfish are a large componenet of the total recreational landings and are managed as part of the
nearshore rockfish complex. Current regional management appears appropriate for these species.

5 Research Needs

research-needs

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

6 Acknowledgments

acknowledgments

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7 Tables

tables

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

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

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tab:CommCatches

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

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

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tab:CommCatches

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

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

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

tab:length_samples_fishery

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

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

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

Continues next page

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

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

Table 4: Length composition sample sizes for survey data.
tab:length_samples_survey

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

Table 5: Summary of the biomass/abundance time series used in the stock assessment.

tab:Index_summary

Fleet	Years	Name	Fishery ind.	Filtering	Method	Endorsed
5	1988-1998	Deb Wilson-Vandenberg's Onboard Observer Survey	Fishery-dependent	Central California	Delta lognormal	SSC
6	2001-2018	CRFS CPFV Onboard Observer Survey	Fishery-dependent	North of Pt. Conception	Delta lognormal	SSC
7	2001-2018	CRFS CPFV Onboard Observer Survey	Fishery-dependent	South of Pt. Conception	Delta lognormal	SSC
8	2001-2018	PISCO Dive Survey	Fishery-independent	North of Pt. Conception	Negative Binomial	First use in stock assmnt
9	2007-2018	CCFRP Hook-and-Line Survey	Fishery-independent	Central California	Negative Binomial	First use in stock assmnt
10	1984-1999	MRFSS Dockside Survey	Fishery-dependent	North of Pt. Conception	Negative Binomial	SSC
11	1980-1999	MRFSS Dockside Survey	Fishery-dependent	South of Pt. Conception	Negative Binomial	SSC

Table 6: Index inpus.

tab:Indices

	Deb WV		MRFSS N		MRFSS S		Onboard N		Onboard S		CCFRP		PISCO	
Year	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			1.66	0.23
2002							0.19	0.14	0.01	0.37			2.05	0.21
2003							0.28	0.07	0.03	0.33			2.53	0.19
2004							0.27	0.06	0.01	0.37			1.29	0.22
2005							0.26	0.08	0.02	0.24			0.91	0.24
2006							0.34	0.08	0.04	0.21			0.87	0.23
2007							0.33	0.08	0.08	0.16	1.20	0.15	0.69	0.24
2008							0.33	0.08	0.06	0.16	1.14	0.16	0.92	0.22
2009							0.27	0.08	0.07	0.16	1.13	0.16	0.59	0.22
2010							0.26	0.07	0.08	0.15	1.32	0.16	0.67	0.21
2011							0.24	0.07	0.15	0.11	0.97	0.16	1.24	0.19
2012							0.18	0.08	0.09	0.11	1.00	0.15	1.34	0.23
2013							0.09	0.09	0.07	0.12	0.38	0.16	1.45	0.22
2014							0.10	0.10	0.09	0.13	0.81	0.15	1.43	0.23
2015							0.17	0.10	0.06	0.17	1.03	0.16	2.55	0.22
2016							0.18	0.08	0.09	0.14	0.96	0.16	2.17	0.22
2017							0.15	0.12	0.08	0.17	1.18	0.16	1.80	0.23
2018							0.30	0.10	0.08	0.18	1.33	0.16	1.24	0.19

Table 7: Data filtering steps for Deb Wilson-Vandenberg's CPFV onboard observer index of abundance

tab:Fleet5_Filter

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

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

tab:Fleet5_AIC

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

Table 9: Data filtering steps for the CRFS CPFV onboard observer index of abundance for north and south of Pt. Conception.

tab:Fleet6_7_Filter

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

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

tab:Fleet6_AIC

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

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

tab:Fleet7_AIC

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

Table 12: Data filtering steps for the PISCO dive survey.

tab:Fleet8_Filter

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

Table 13: Model selection for the PISCO dive survey data.

tab:Fleet8_AIC

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

Table 14: 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 15: 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 16: Data filtering steps for the MRFSS dockside intercept survey index of abundance for north and south of Pt. Conception.

tab:Fleet10_11_Filter

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

Table 17: 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 18: Model selection for the MRFSS dockside intercept survey south of Pt. Conception. Bold values indicate the model selected.

tab:Fleet11_AIC

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

Table 19: Contingency table for the Stephens-MacCall filtering for the MRFSS dockside CPFV index for GBYR north of Pt. Conception.

tab:Fleet10_contingency

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

Table 20: Contingency table for the Stephens-MacCall filtering for the MRFSS dockside CPFV index for GBYR south of Pt. Conception.

tab:Fleet11_contingency

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

Table 21: Summary of available age data. All ages except the commercial ages were used in the assessment.

tab:Age_data

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

Table 22: Comparison of ket parameters and likelihood components from the pre-STAR base model and the post-STAR base model.

tab:preSTAR_postSTAR_compare

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

Table 23: Results from 100 jitters from the base case model.

tab:jitter

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

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

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

Continued on next page

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

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

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

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

tab:model_params

Table 25: Likelihood components from the base model.

tab:like_components

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

Table 26: 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 26: Time-series of population estimates from the base-case model. Relative exploitation rate is $(1 - SPR)/(1 - SPR_{50\%})$. tab:Timeseries_mo

Year	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
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

Continues next page

tab:Timeseries_mo

Table 26: 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 27: Sensitivity of the base model to alternative assumptions about natural mortality, growth, and using PacFIN-derived length composition data.

tab:Sensitivity_model1

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

Table 28: Summaries of key assessment outputs and likelihood values from the retrospective analysis. The base model includes all of the data. Retro1 removes the last year of data (2018), Retro2 removes the last two years of data, Retro3 removes three years and Retro4 removes four years.

tab:retro

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

Table 29: Summaries of key assessment outputs and likelihood values from selected likelihood profile runs on virgin recruitment (lnR0) and steepness. Depletion and SPR ratio are for the year 2019.

tab:like_profiles

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

Table 30: 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.

tab:like_profiles2

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
lnR0	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

8 Figures

figures

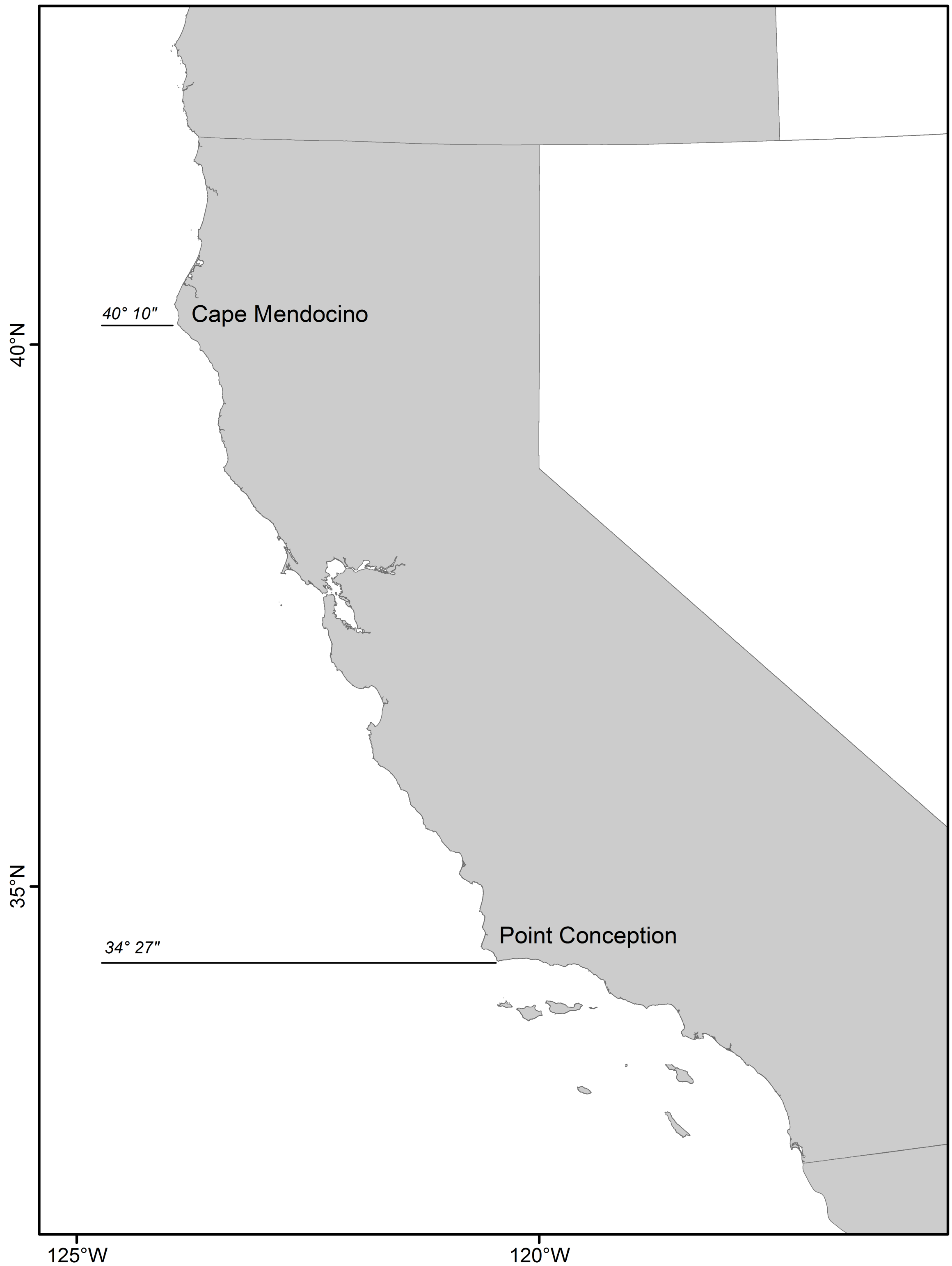

Figure 1: Map showing the management area for gopher and black-and-yellow rockfish from Cape Mendocino to the U.S.-Mexico border. fig:assess_region_map1

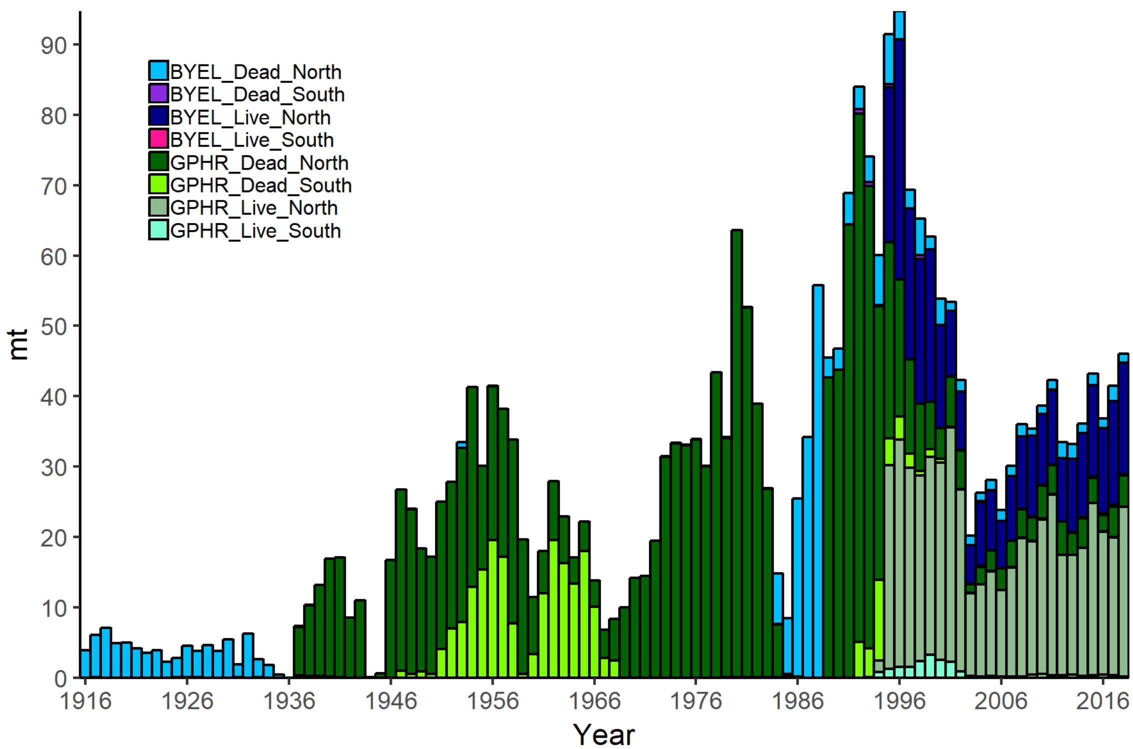

Figure 2: Commercial landings for gopher (GPHR) and black-and-yellow (BYEL) rockfishes landed live and dead north and south of Point Conception. All catch time series were combined for the assessment into one commercial fleet. fig:Catches_livedeadNS_gby

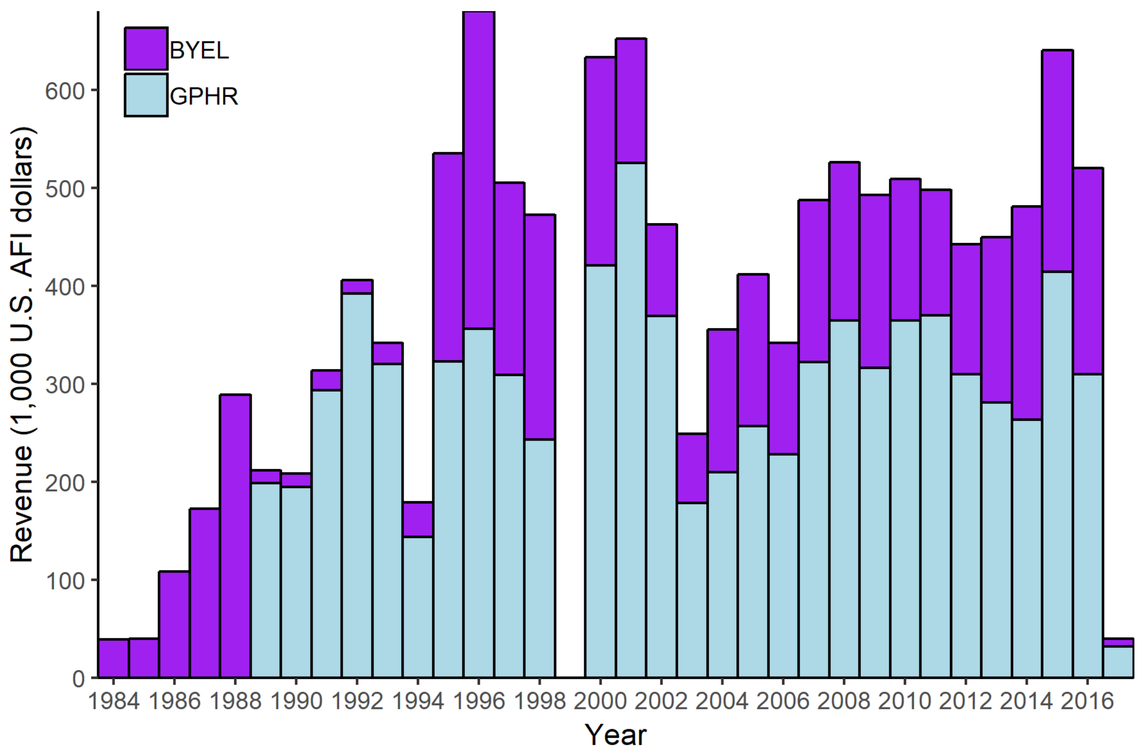

Figure 3: Annual ex-vessel revenue, adjusted for inflation (AFI) in thousands of dollars for gopher and black-and-yellow rockfish. fig:GBY_revenue

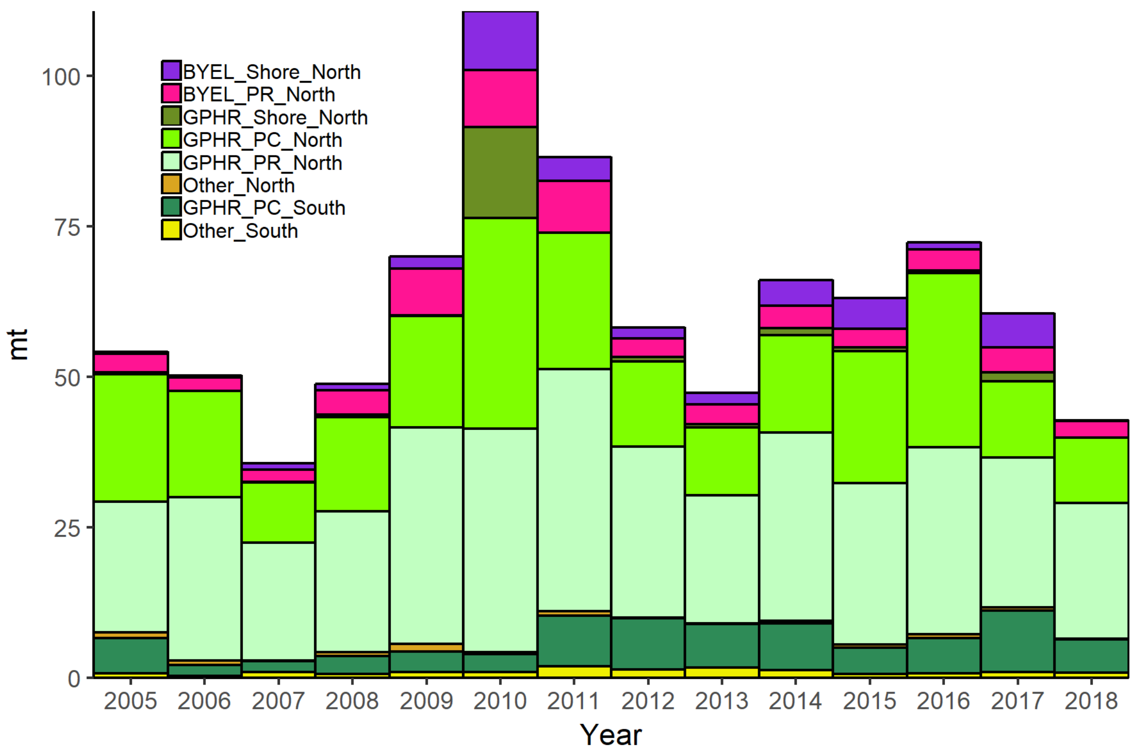

Figure 4: Recreational total mortality for gopher rockfish (GPHR) and black-and-yellow (BYEL) rockfish from the CDFW CRFS sampling era by mode and split north and south of Point Conception. fig:CFRS_catches

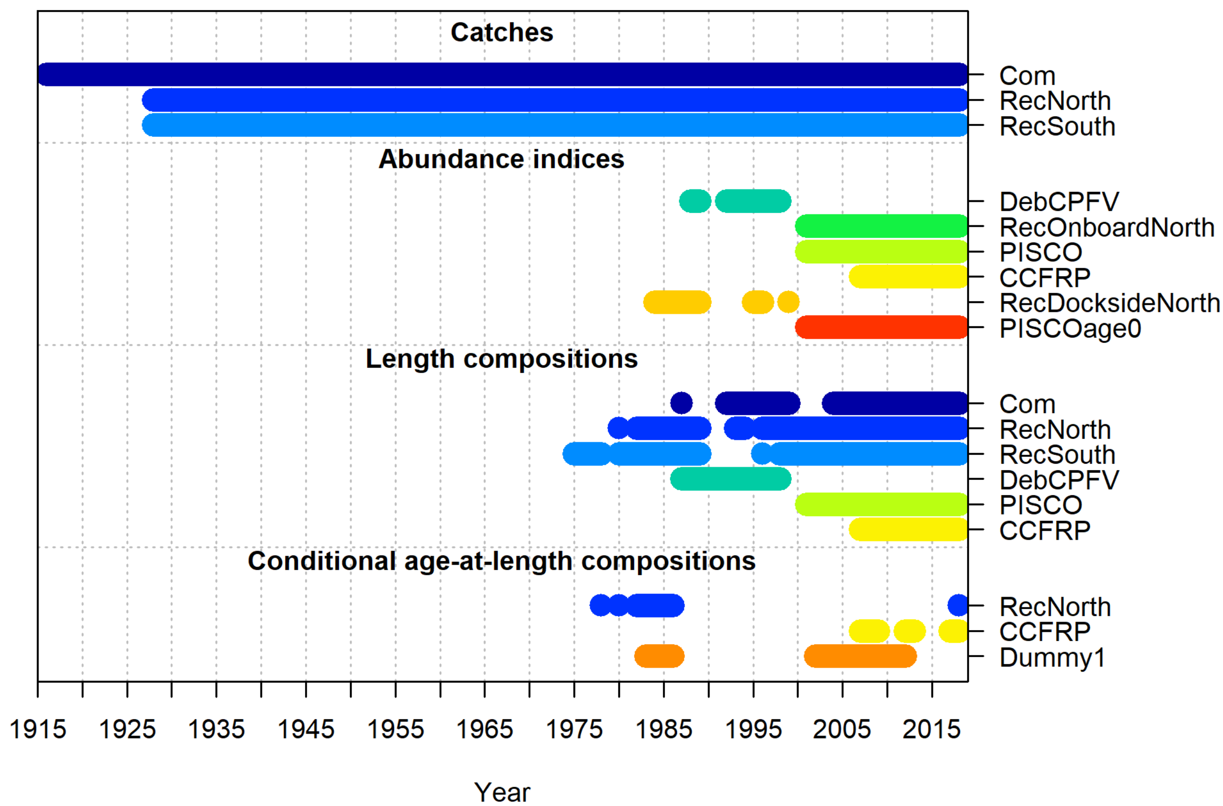

Figure 5: Summary of data sources used in the model. fig:data_plot

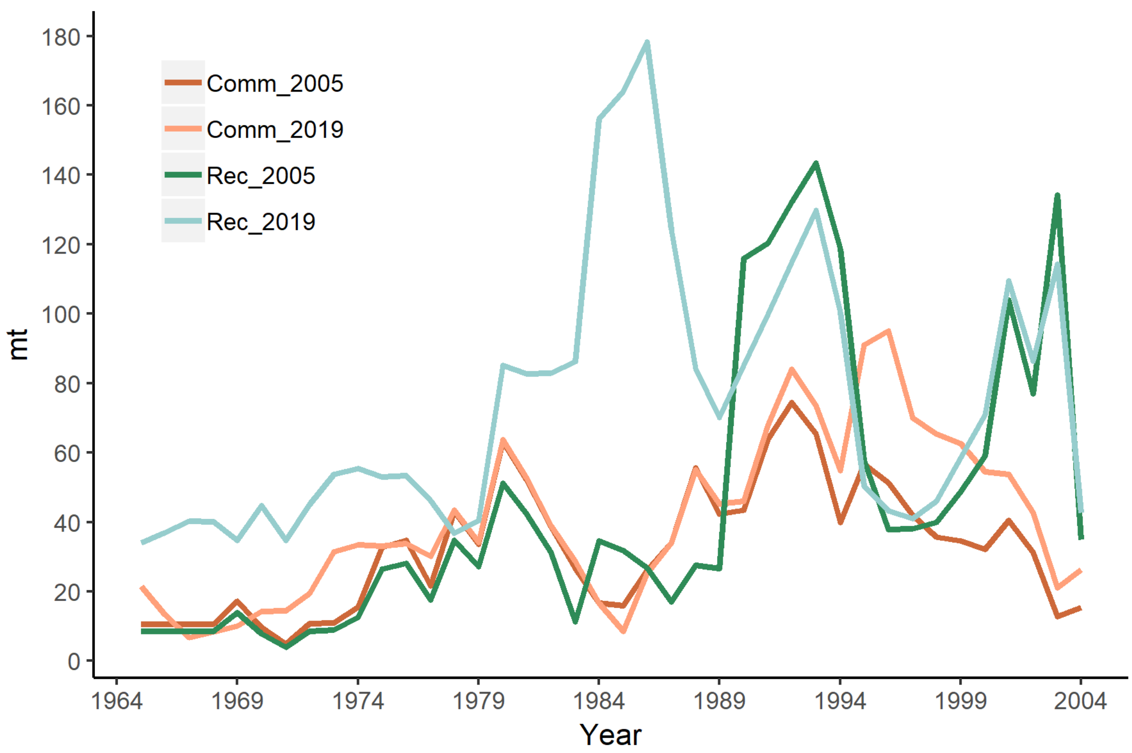

Figure 6: Comparison of the recreational and commercial fishery landings from the 2005 assessment to this 2019 assessment. Note that the 2019 assessment includes both gopher and black-and-yellow rockfish where the 2005 assessment represents gopher rockfish only. The 2005 assessment also did not include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

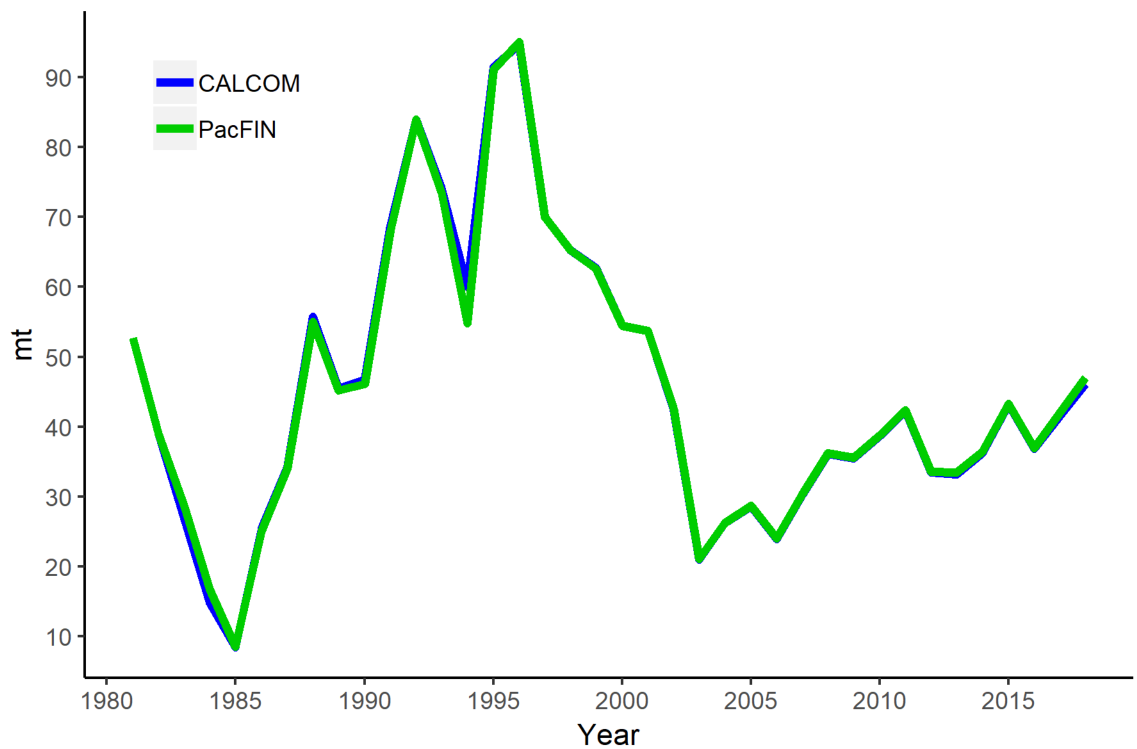

Figure 7: Commercial landings estimates from CALCOM and PacFIN. fig:Calcom_vs_Pacfin

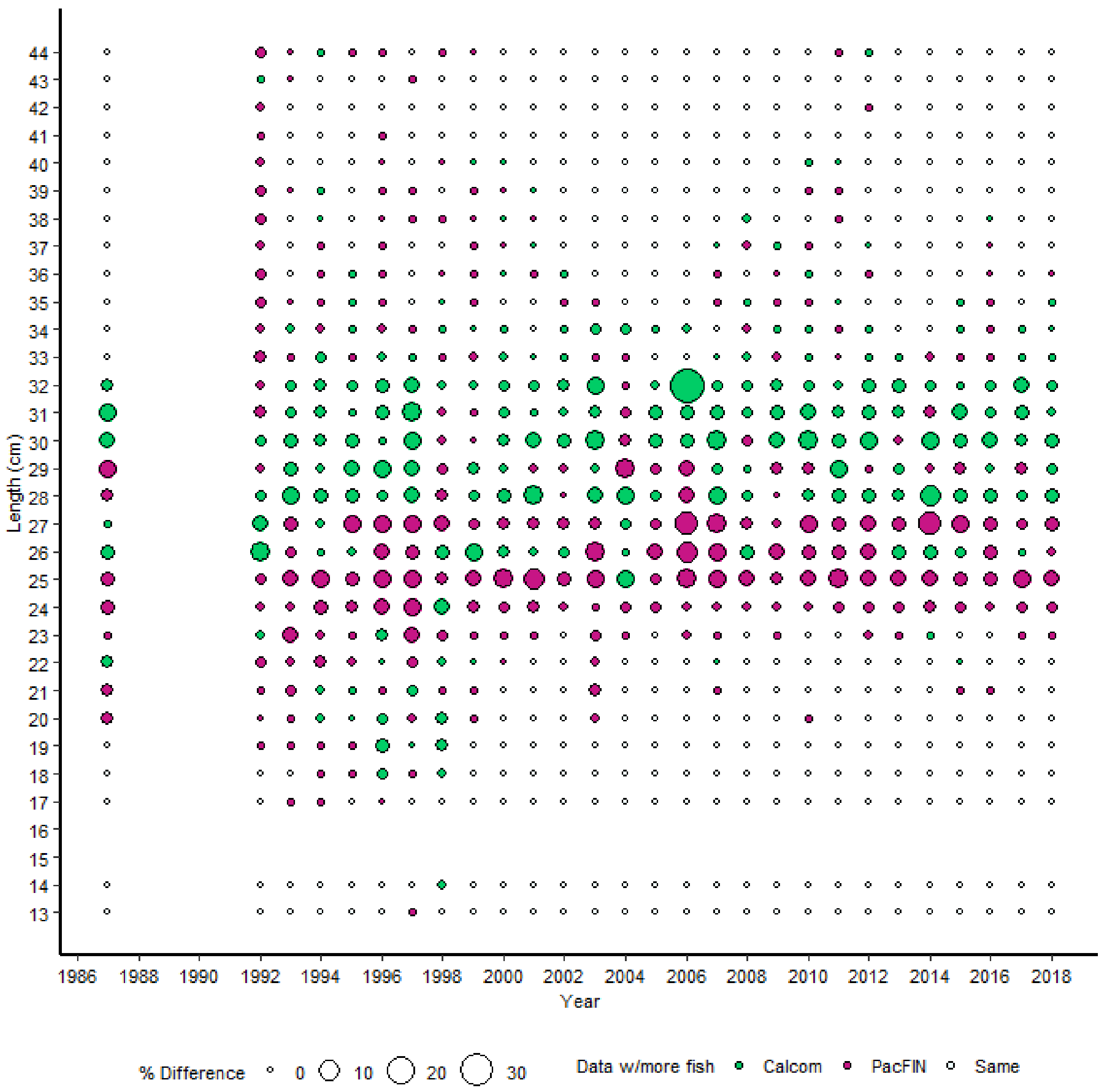

Figure 8: Percent differences in the expanded length compositions by year from CALCOM and PacFIN. The same market categories were used for each dataset, but each database was subject to further independent filtering criteria and expansion algorithms. fig:Calcom_vs_pacfin_length

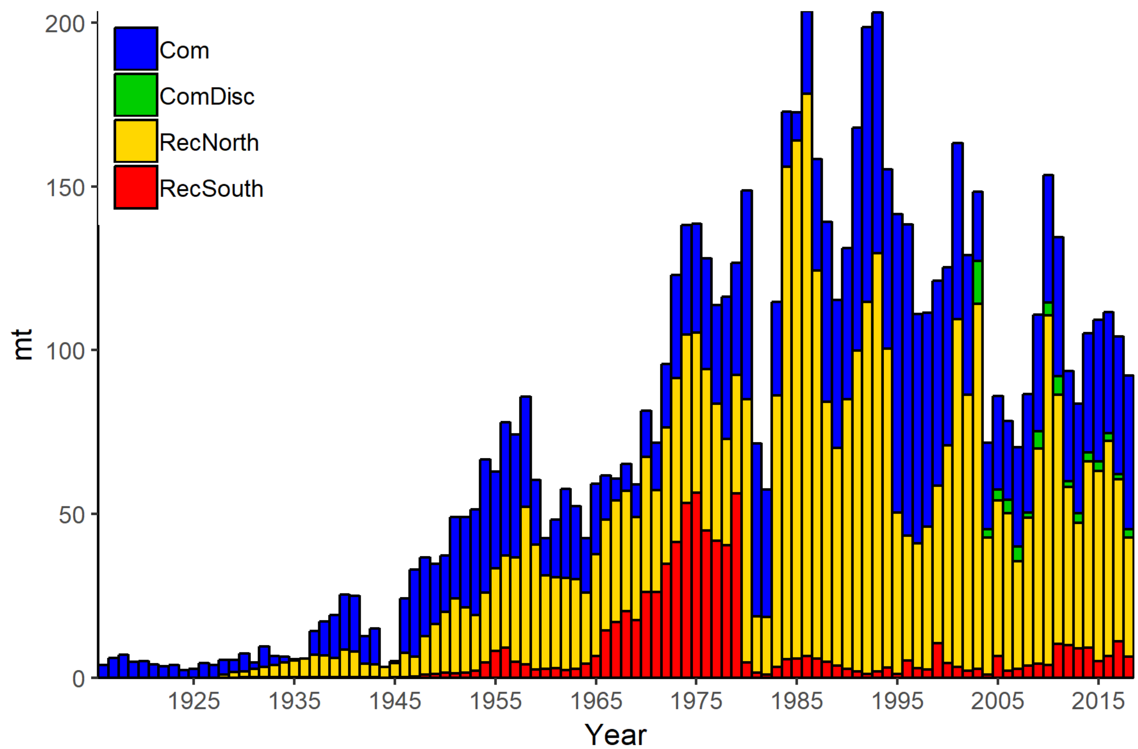

Figure 9: Commercial and recreational landings estimates prior to any data modification or interpolation to the recreational catches or hindcasting of commercial discards. fig:Catches_original

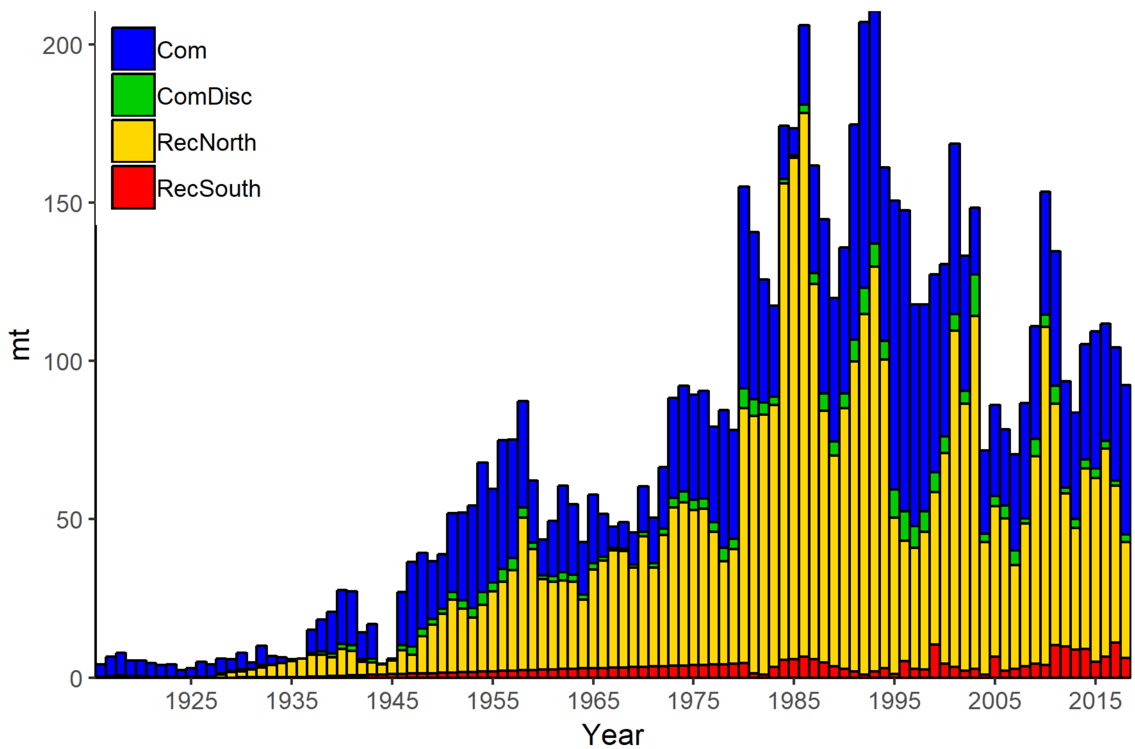

Figure 10: Commercial and recreational landings estimates after data modification and interpolations were made to the recreational catches and commercial discards. fig:Catches_alternate

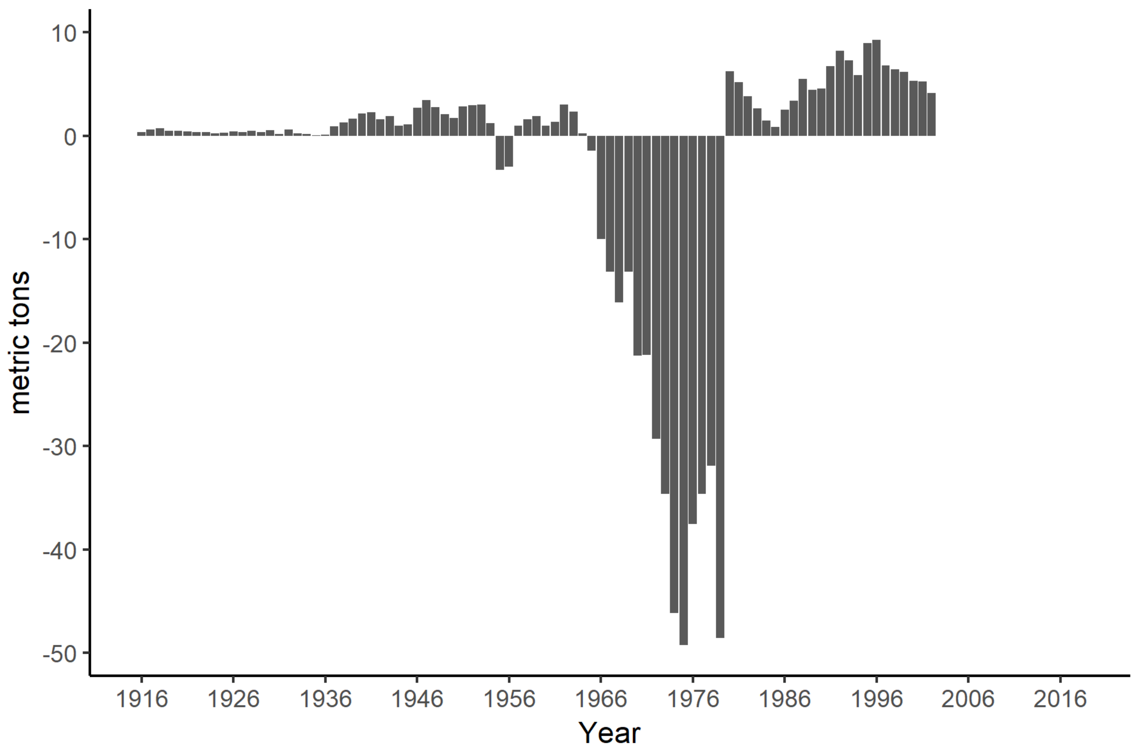

Figure 11: Difference in landings between the original and modified landings presented in the previous two figures. The only two fleets with modifications are recreational south and commercial discards. Negative values indicate catches removed from the original estimates and positive values represent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

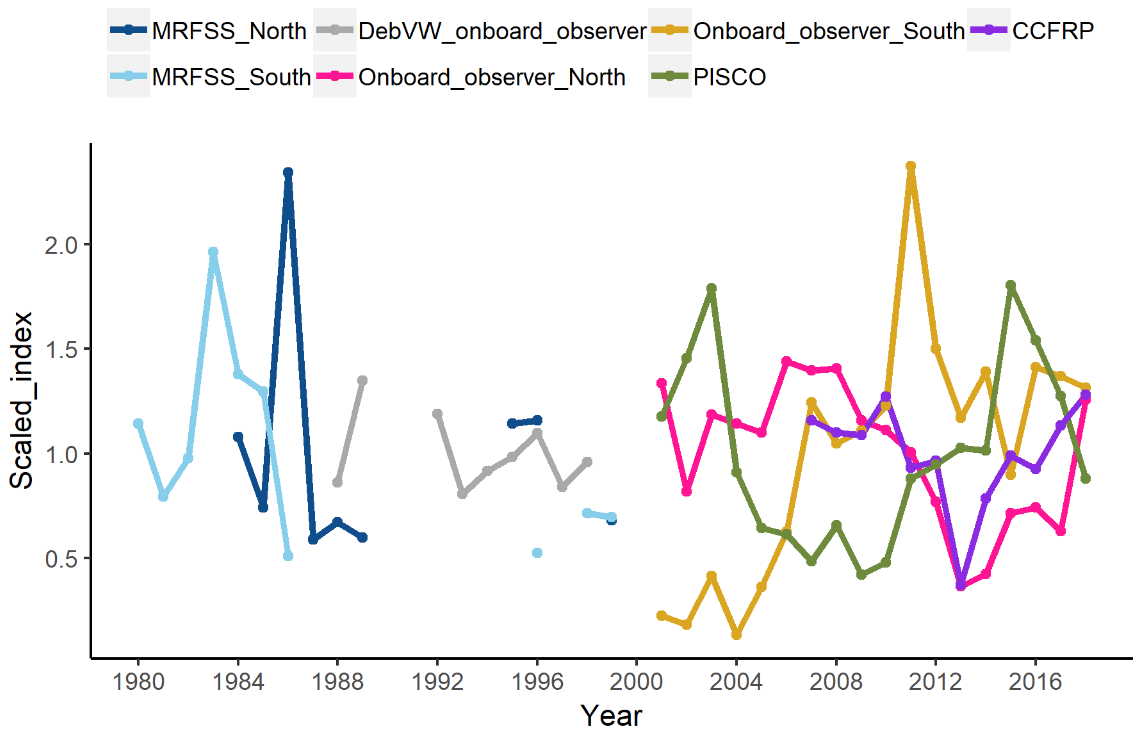

Figure 12: Comparison of all indices of abundance (with each index scaled to its mean). fig:All_index_

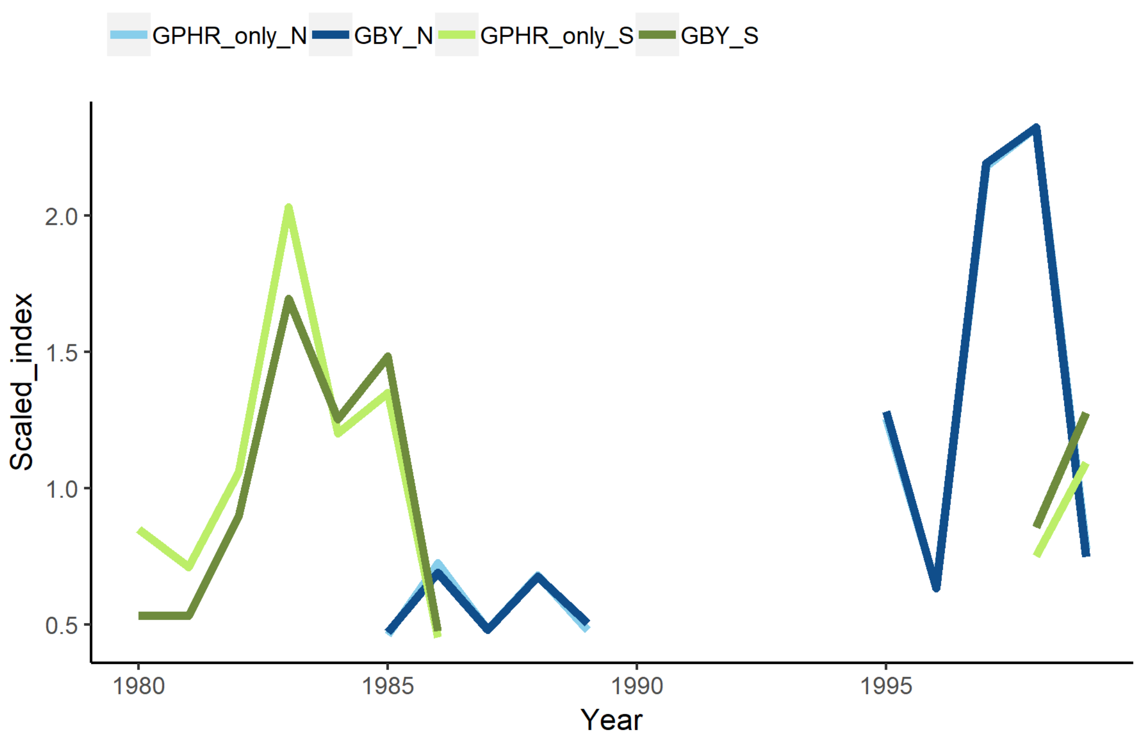

Figure 13: Comparison of indices of abundance (scaled to their means) for the MRFSS dockside CPFV survey between a gopher-only and GBYR complex index for north and south of Point Conception. fig:MRFSS_index_compare

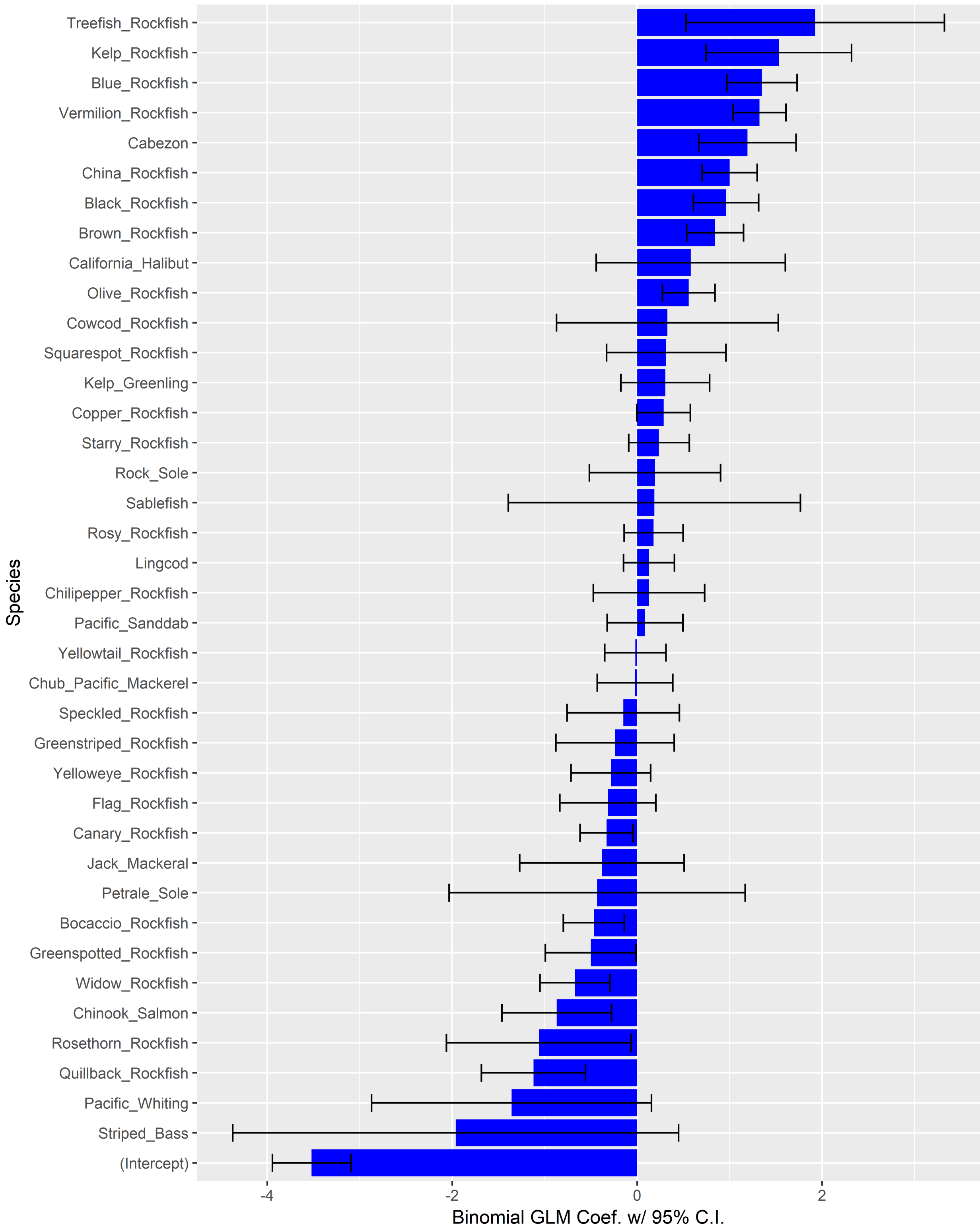

Figure 14: Species coefficients from the binomial GLM for presence/absence of GBYR in the Marine Recreational Fisheries Statistics Survey (MRFSS) CPFV mode dockside survey data set north of Point Conception. Horizontal bars are 95% confidence intervals. fig:Fleet10_SM_filter

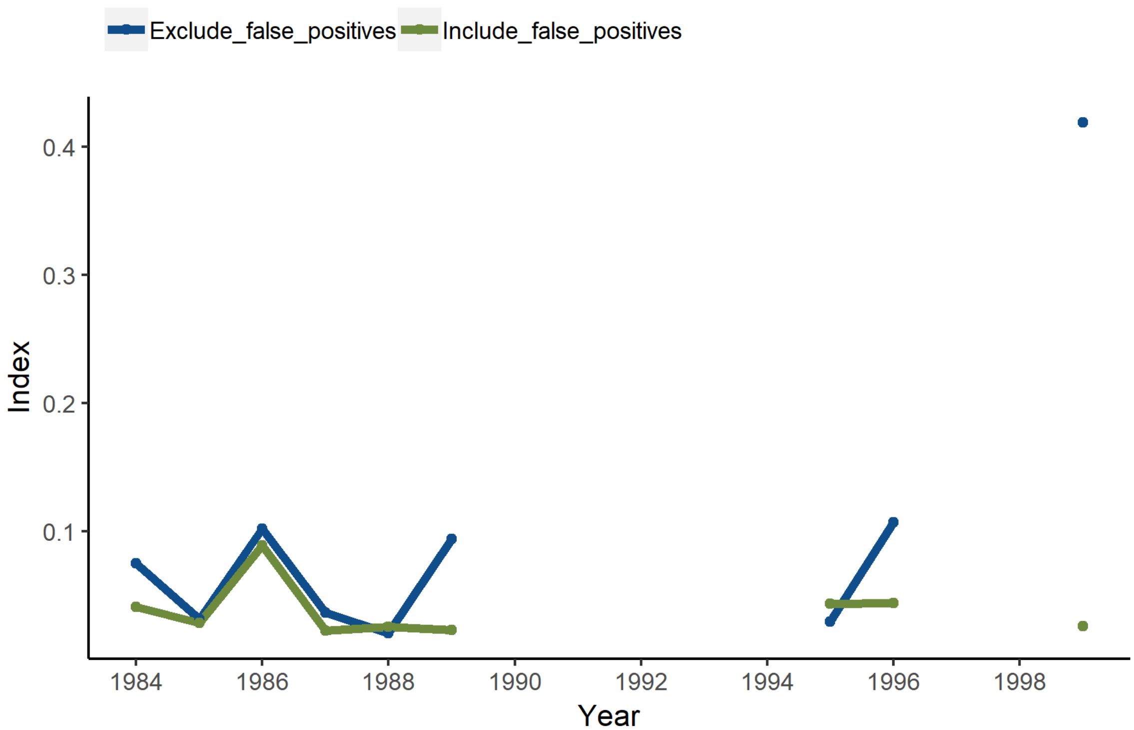

Figure 15: Comparisons of the indices of abundance for GBYR north of Point Conception from the MRFSS dockside CPFV survey that either include of exclude the trips identified as false positives from the Stephens-MacCall filter. fig:MRFSS_index_N_SM_falsepos

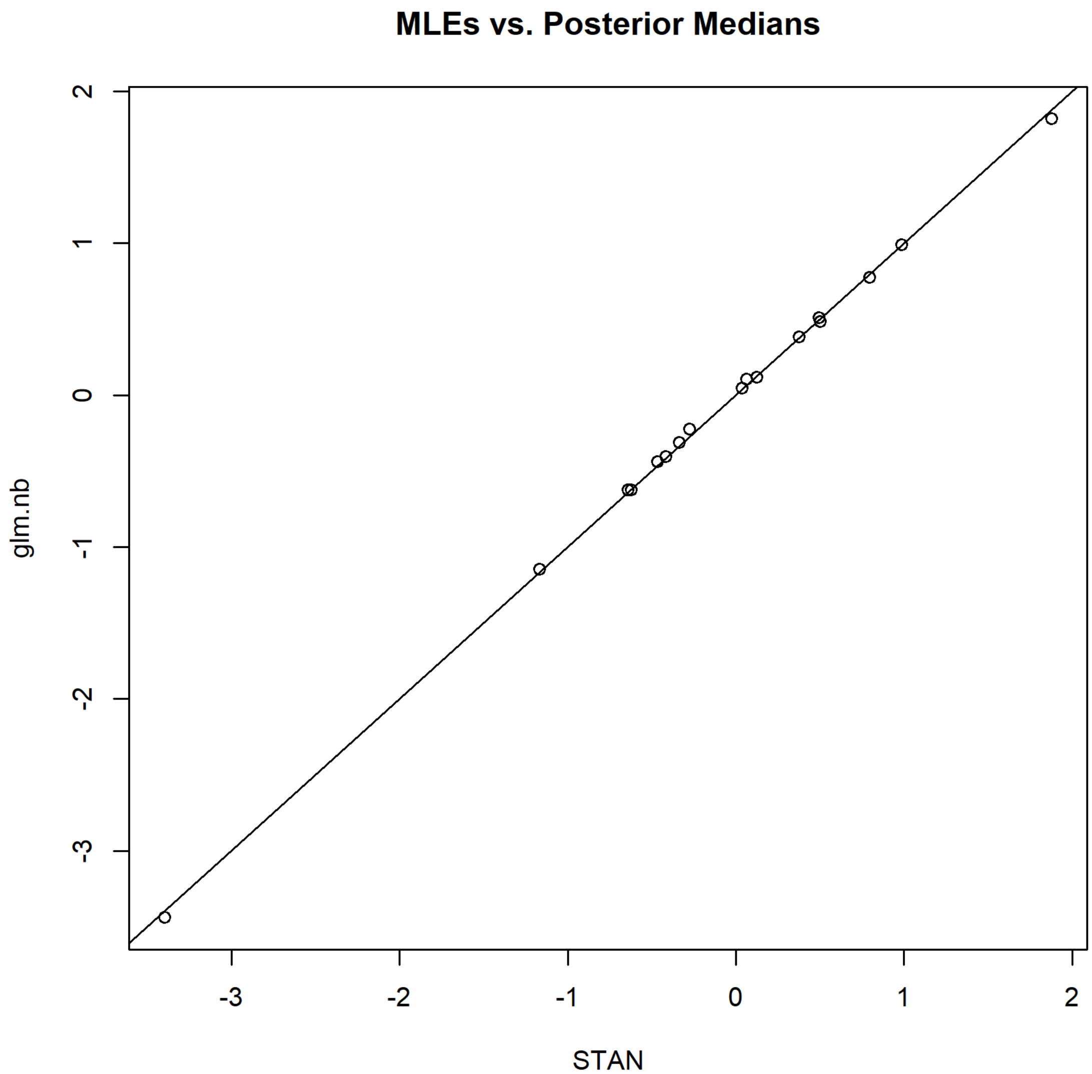

Figure 16: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year) MRFSS CPFV dockside index north of Point Conception. The 1:1 plot is for reference. fig:Fleet10_MLE_stan

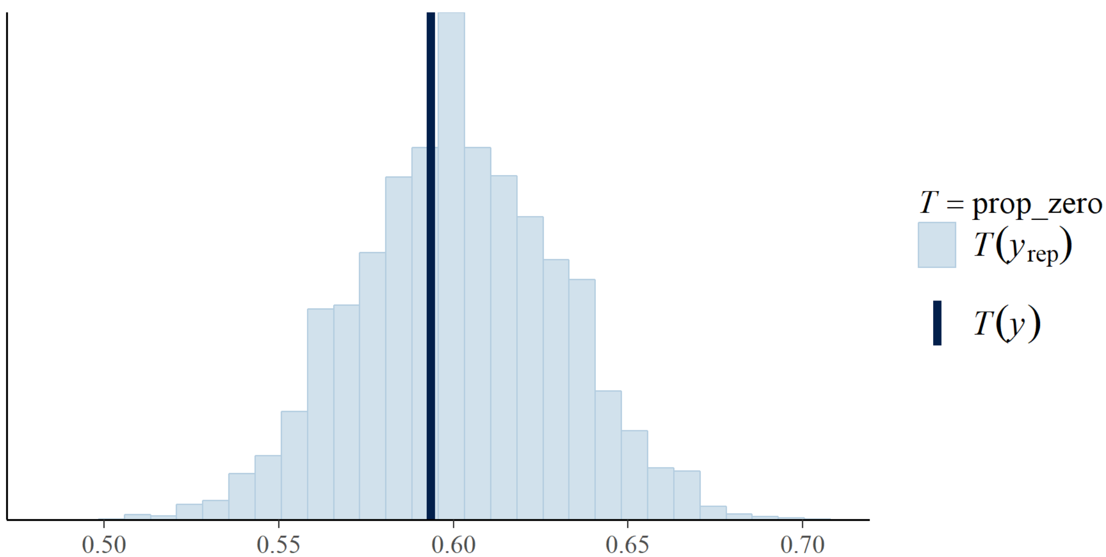

Figure 17: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for MRFSS dockside CPFV index north of Point Conception. fig:Fleet10_prop_zero_STAN

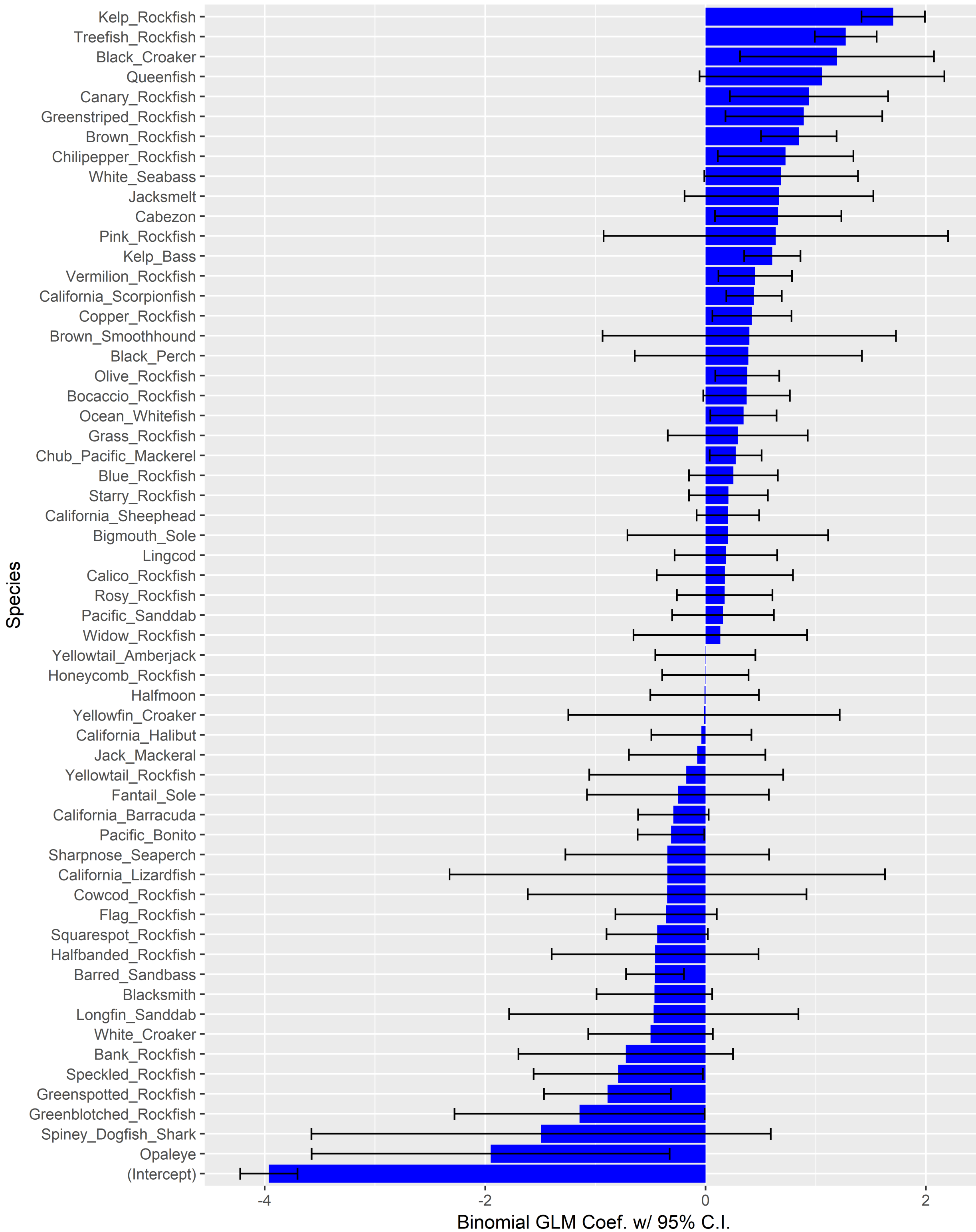

Figure 18: Species coefficients from the binomial GLM for presence/absence of GBYR in the Marine Recreational Fisheries Statistics Survey (MRFSS) CPFV mode dockside survey data set north of Point Conception. Horizontal bars are 95% confidence intervals. fig:Fleet11_SM_filter

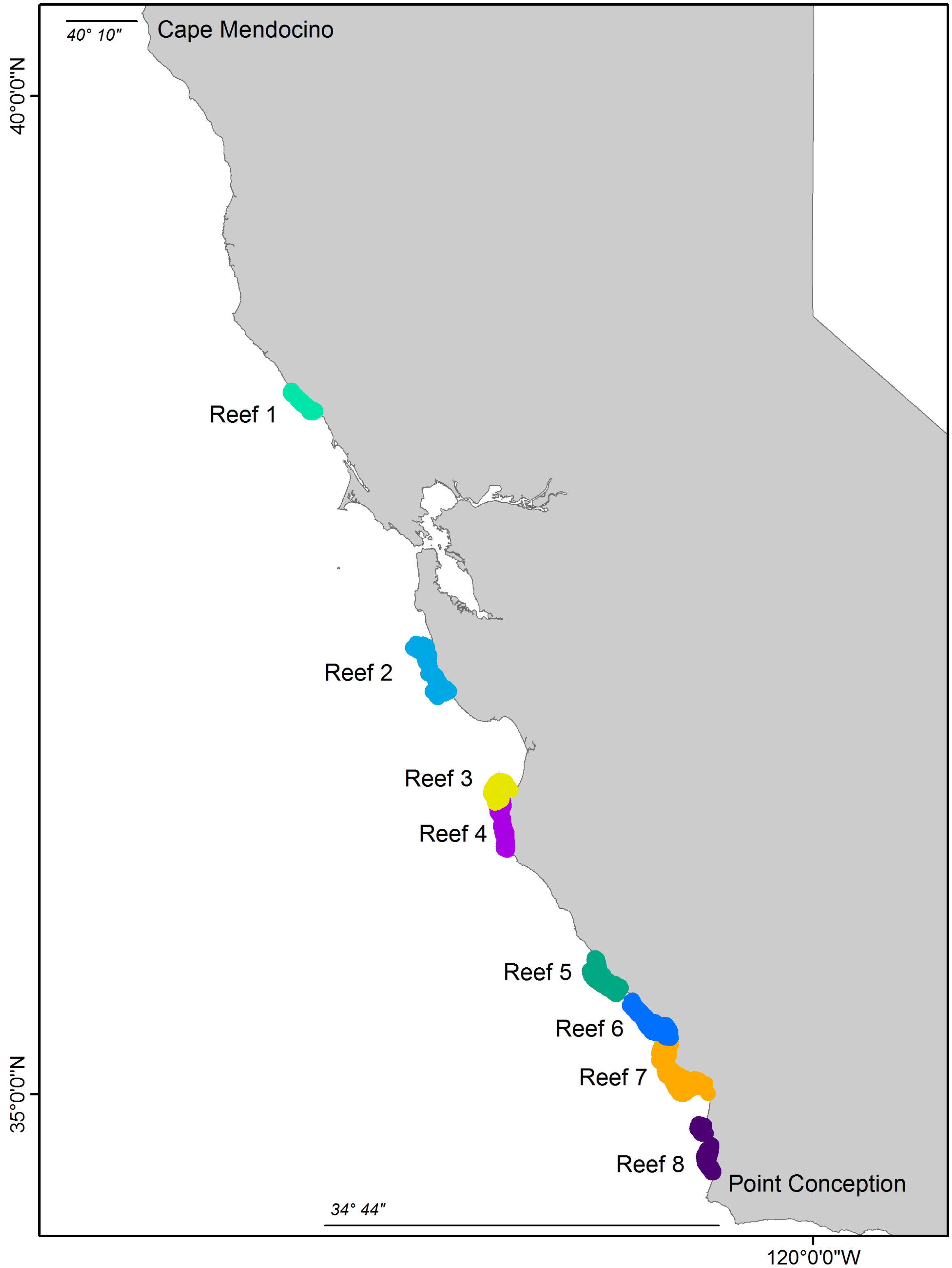

Figure 19: Map of the reefs used in the Deb Wilson-Vandenberg CPFV onboard observer survey index of abundance. fig:DebWV_sites

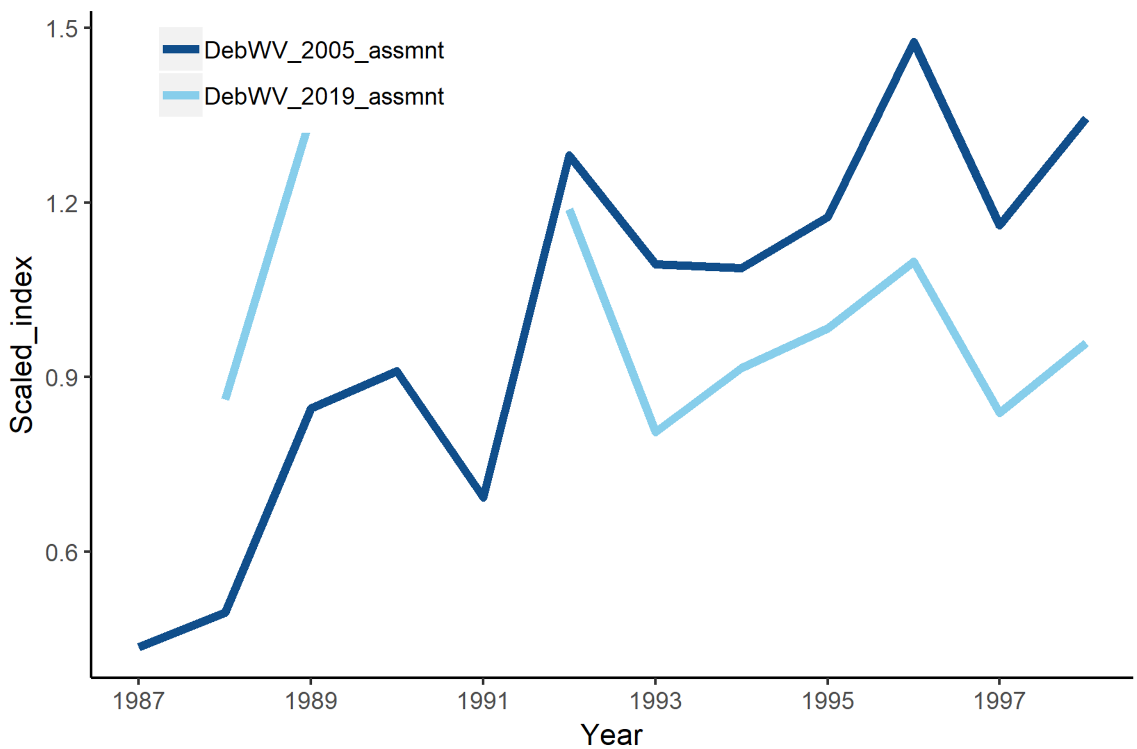

Figure 20: Comparison of the index developed for the Deb Wilson-Vandenberg CPFV onboard observer survey from the 2005 assessment and for the 2019 assessment. fig:DebWV_index_compare

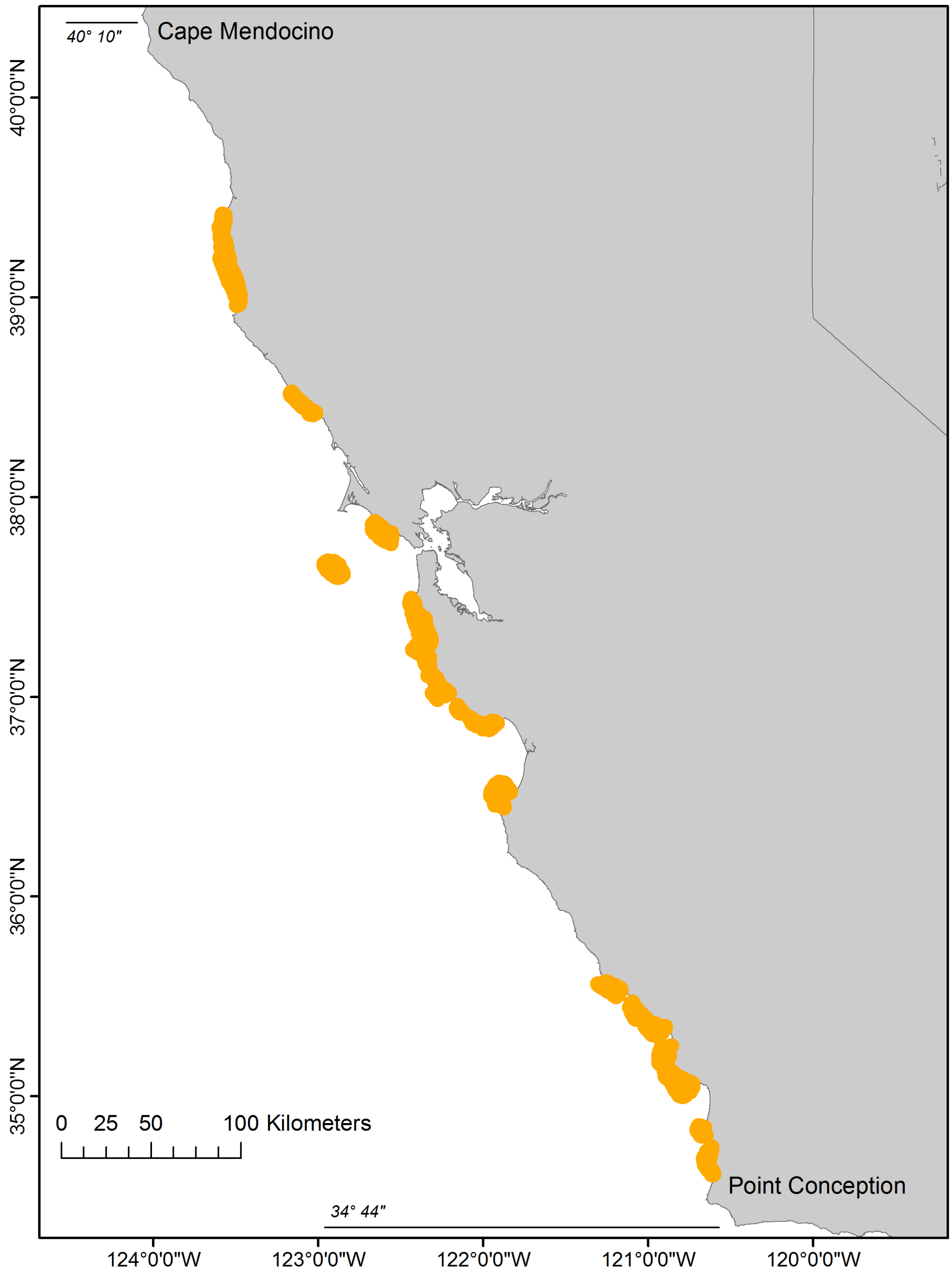

Figure 21: Map of the reefs selected for the final index for the onboard observer surveys (CDFW and Cal Poly) north of Point Conception fig:Onboard_observer_north_sites

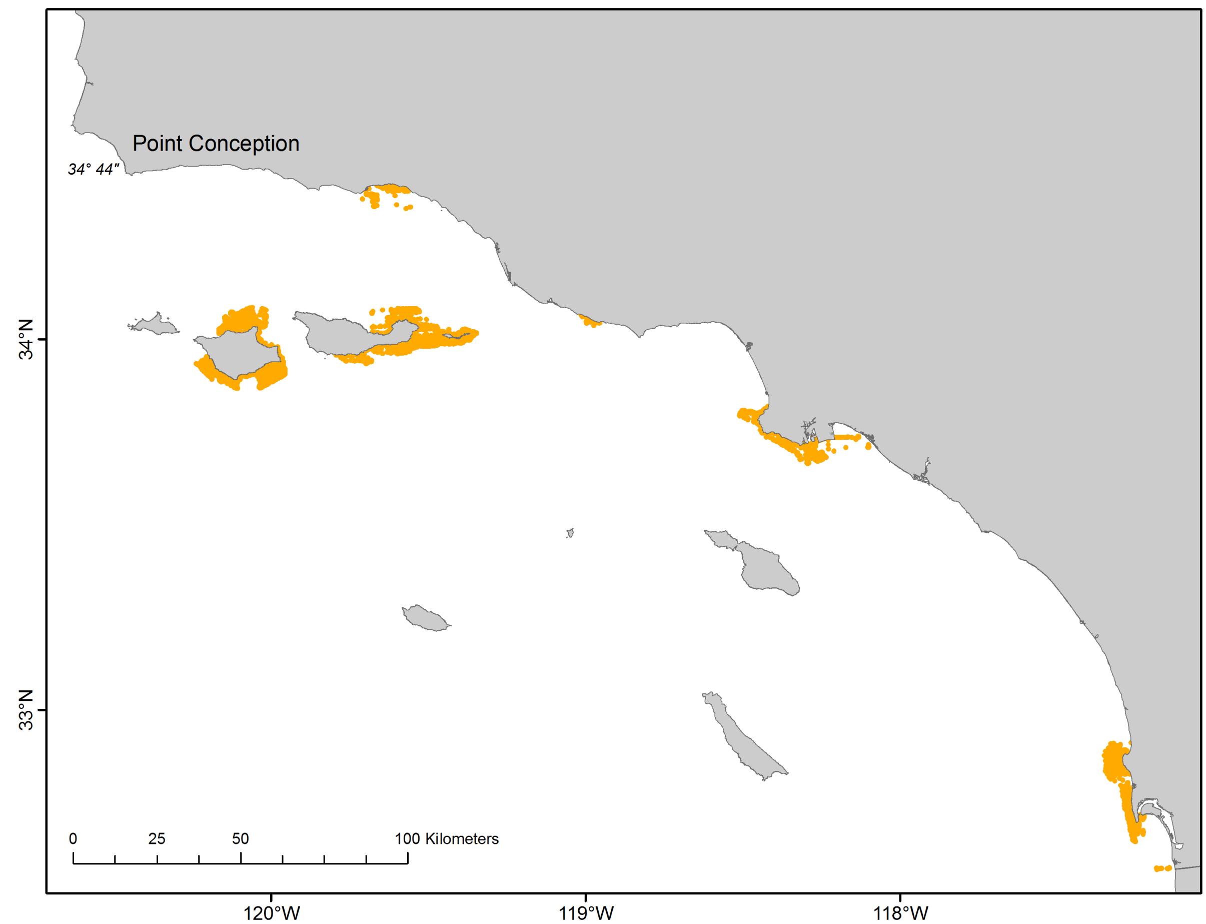

Figure 22: Map of the reefs selected for the final index for the CDFW onboard observer survey south of Point Conception fig:Onboard_observer_south_sites

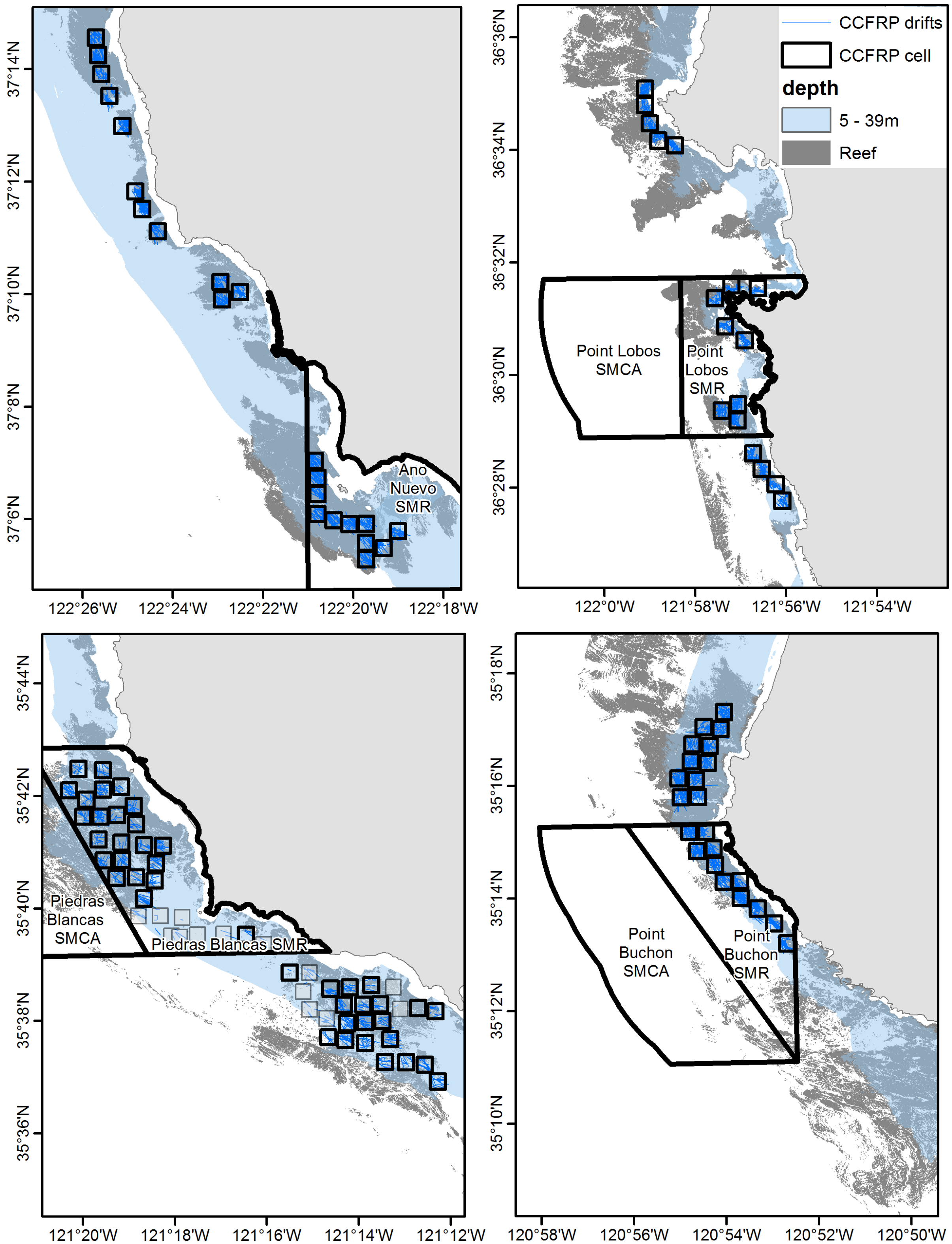

Figure 23: Map of the four MPAs sampled consistently through time for the CCFRP fishery-independent survey. fig:CCFRP_sites

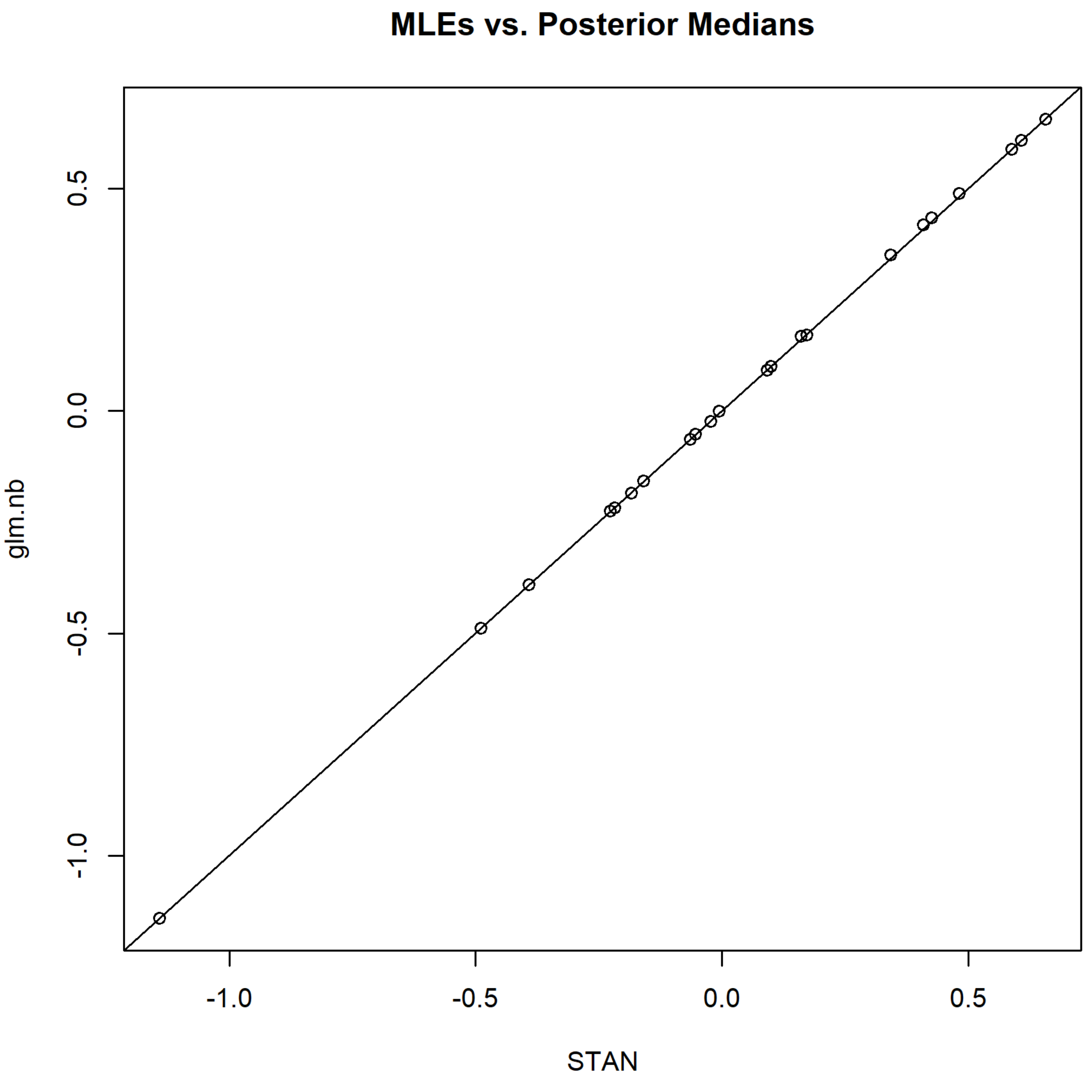

Figure 24: Comparison of negative bionimial predictions (CPUE) to observed means in each stratum (year) for the CCFRP index. The 1:1 plot is for reference. fig:Fleet9_MLE_stan

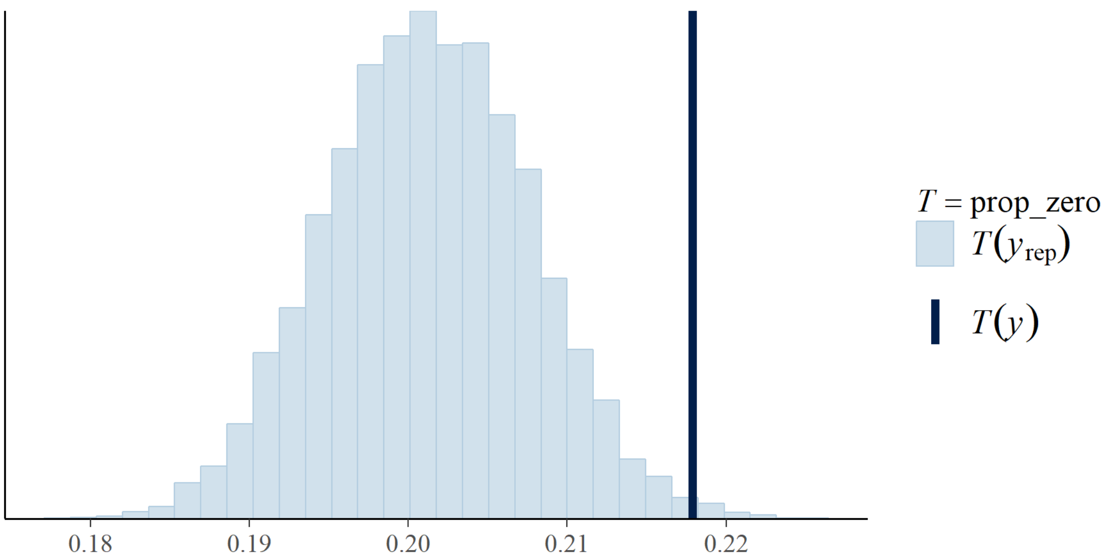

Figure 25: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the CCFRP index. fig:Fleet9_prop_zero_STAN

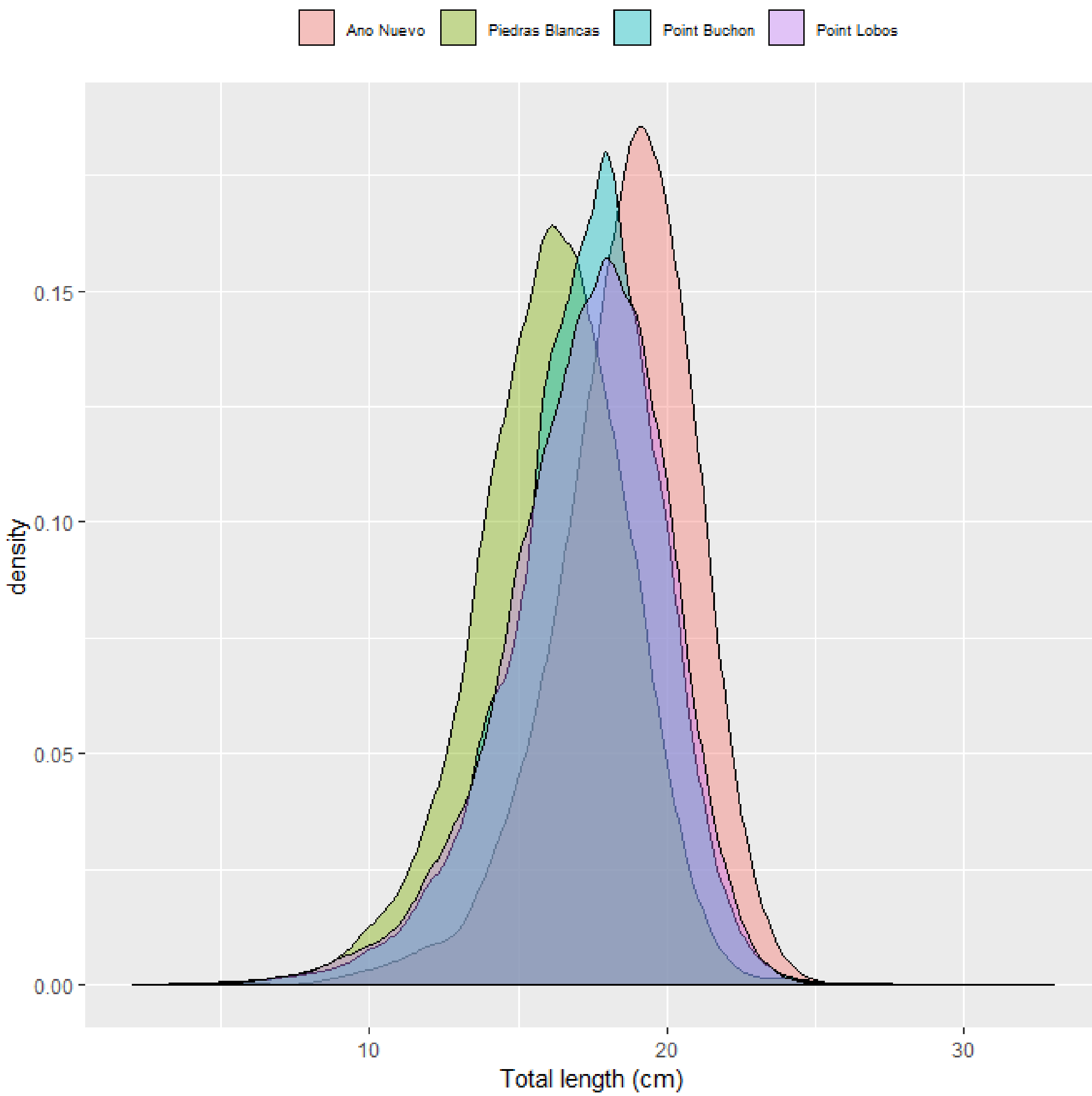

Figure 26: Length distributions of GBYR for the four MPAs sampled by the CCFRP survey used in this assessment. | CCFRP_lengths_by_site

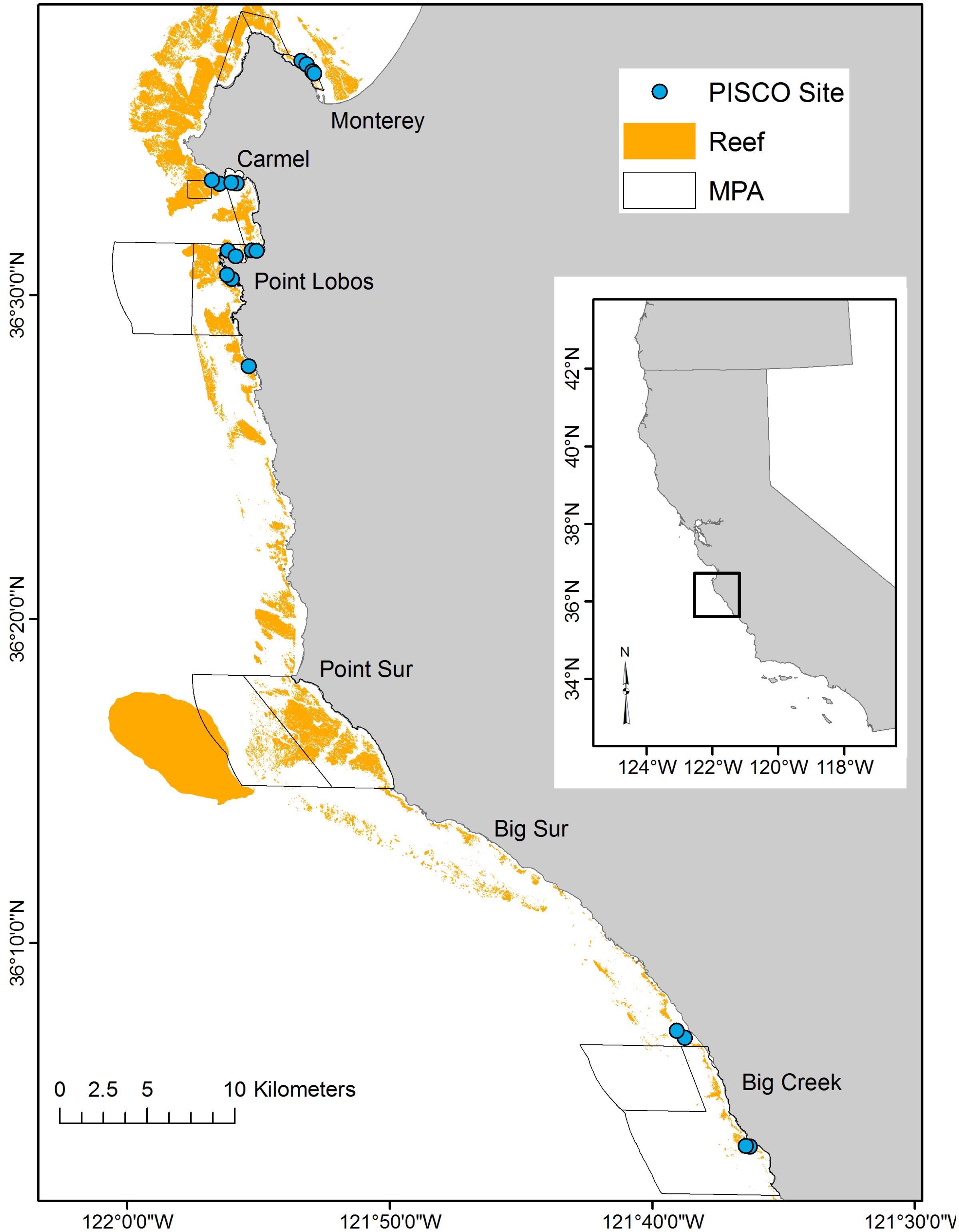

Figure 27: Map of the sites sampled consistently through time for the PISCO kelp forest fish survey. fig:PISCO_sites

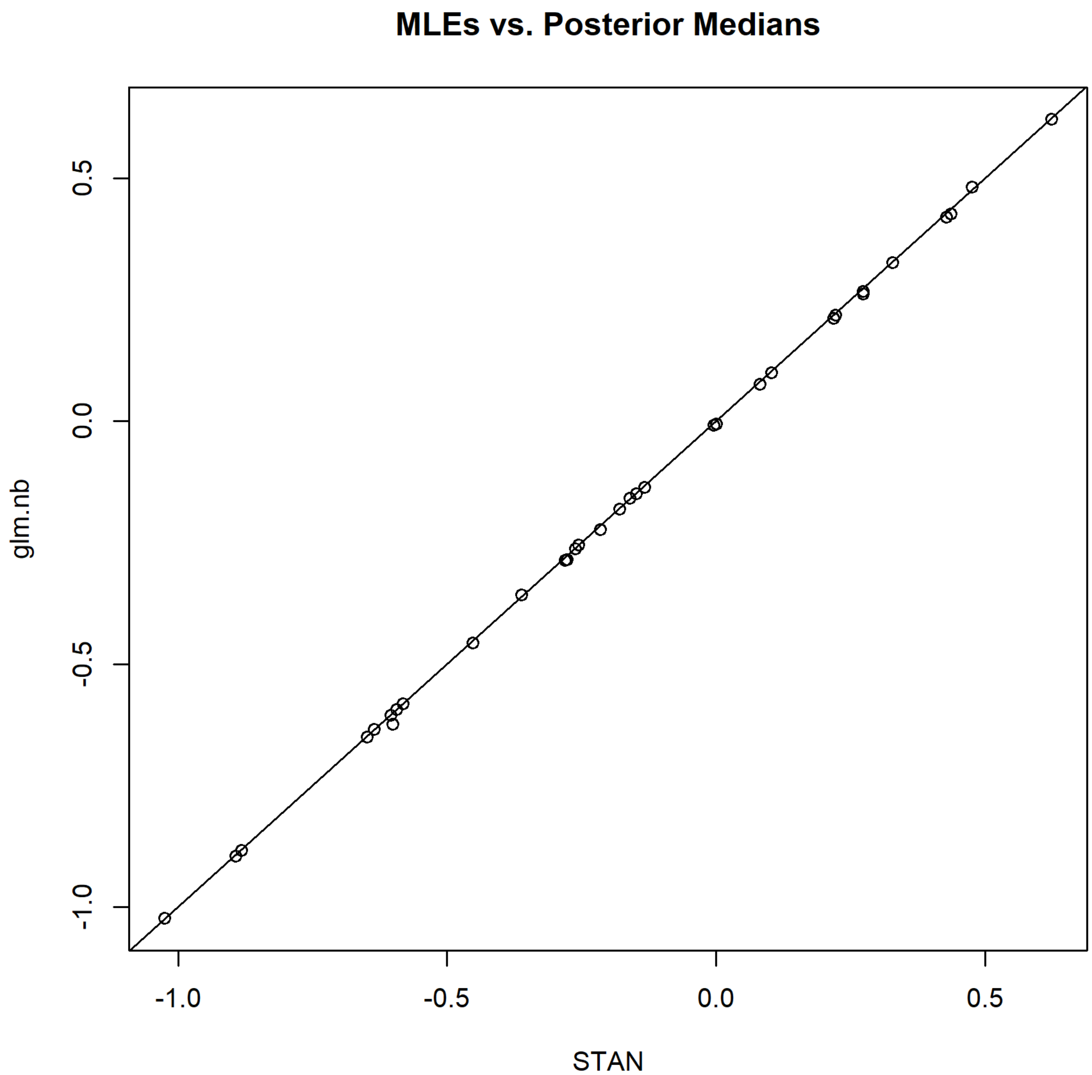

Figure 28: Comparison of negative bionimial predictions (CPUE) to observed means in each stratum (year) for the PISCO kelp forest fish survey index. The 1:1 plot is for reference. fig:Fleet8_MLE_

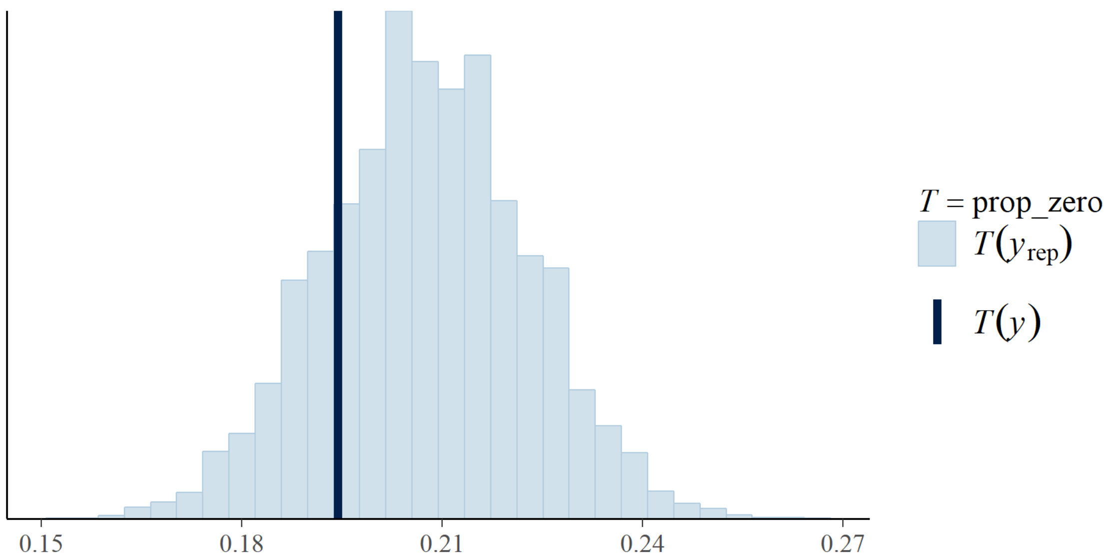

Figure 29: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the PISCO kelp forest fish survey. fig:Fleet8_pr

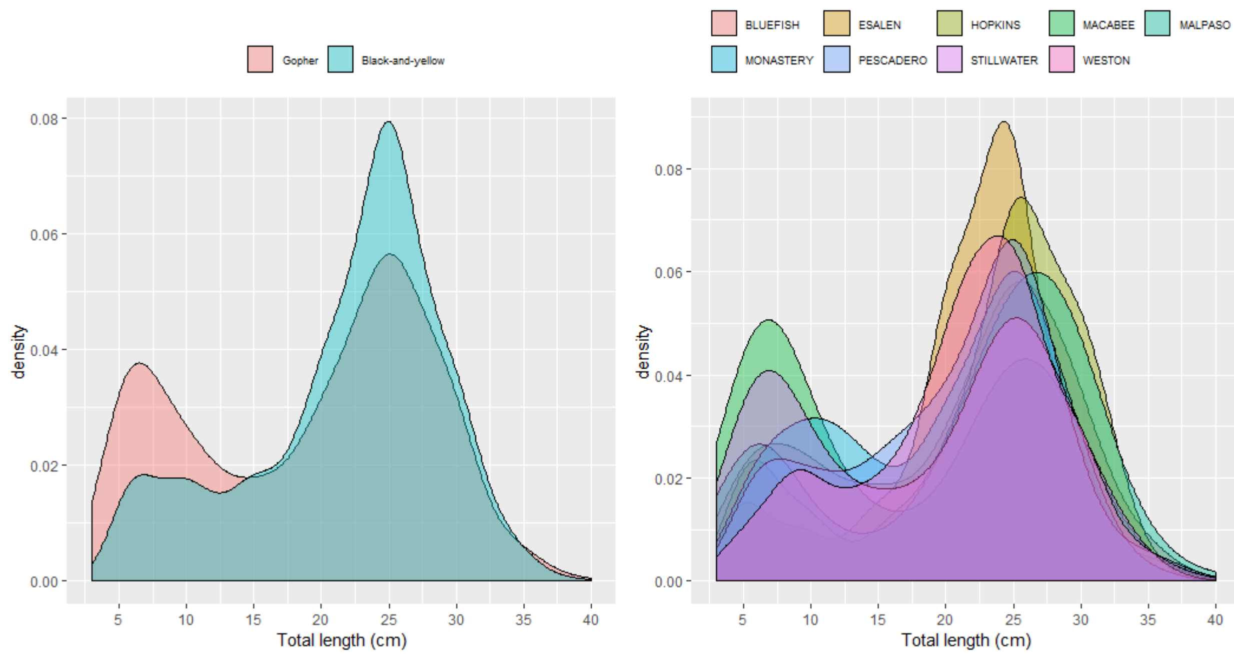

Figure 30: Plots of the length distributions from the PISCO kelp forest fish survey by species (left) and for combined species by site (right) for sites included in the final index of abundance. fig:PISCO_lengths

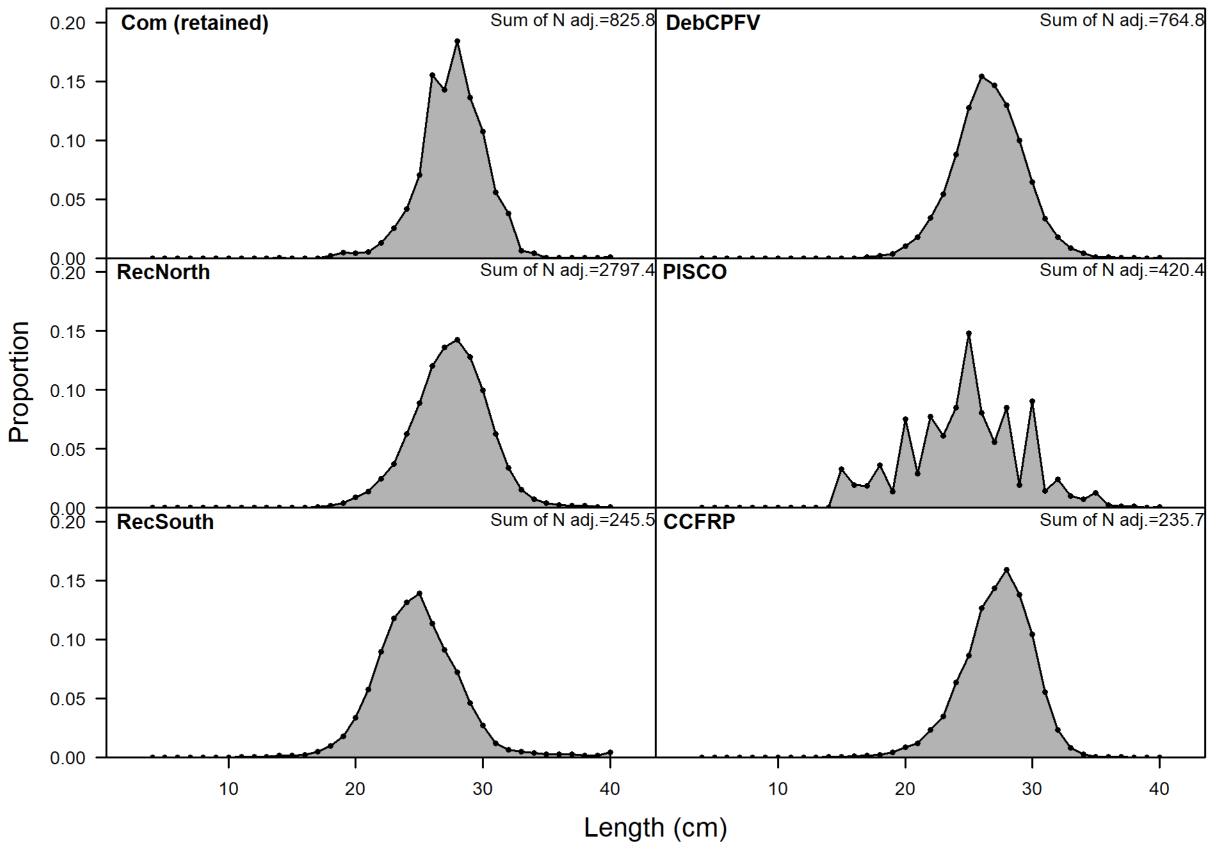

Figure 31: Length comp data, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. fig:comp_lendat_aggregated_across_time

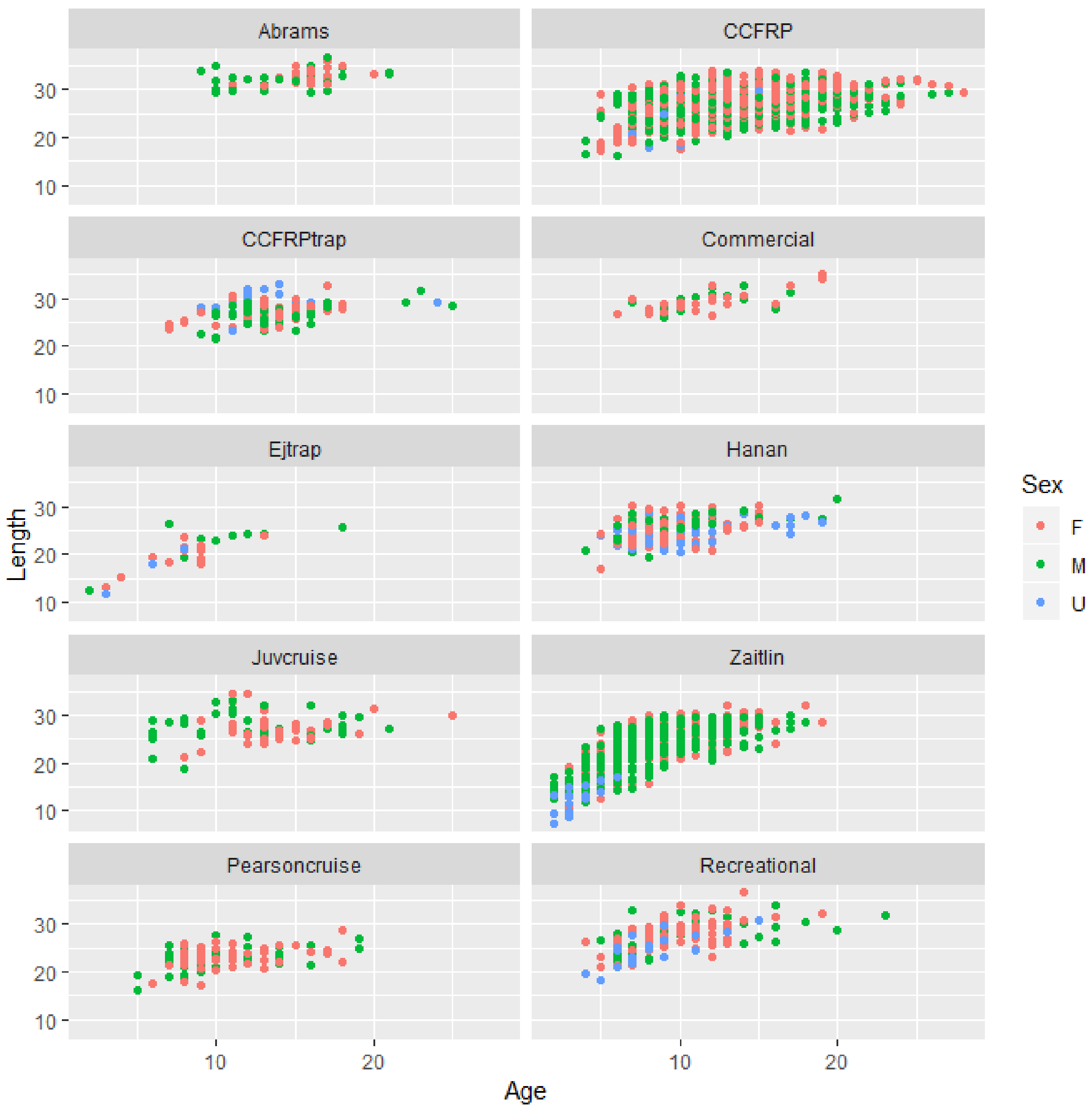

Figure 32: Available length-at-age data for gopher and black-and-yellow rockfish by sex and data source. The Zaitlin study is all black-and-yellow rockfish. The remaining plots represent gopher rockfish fig:Age_length_by_study

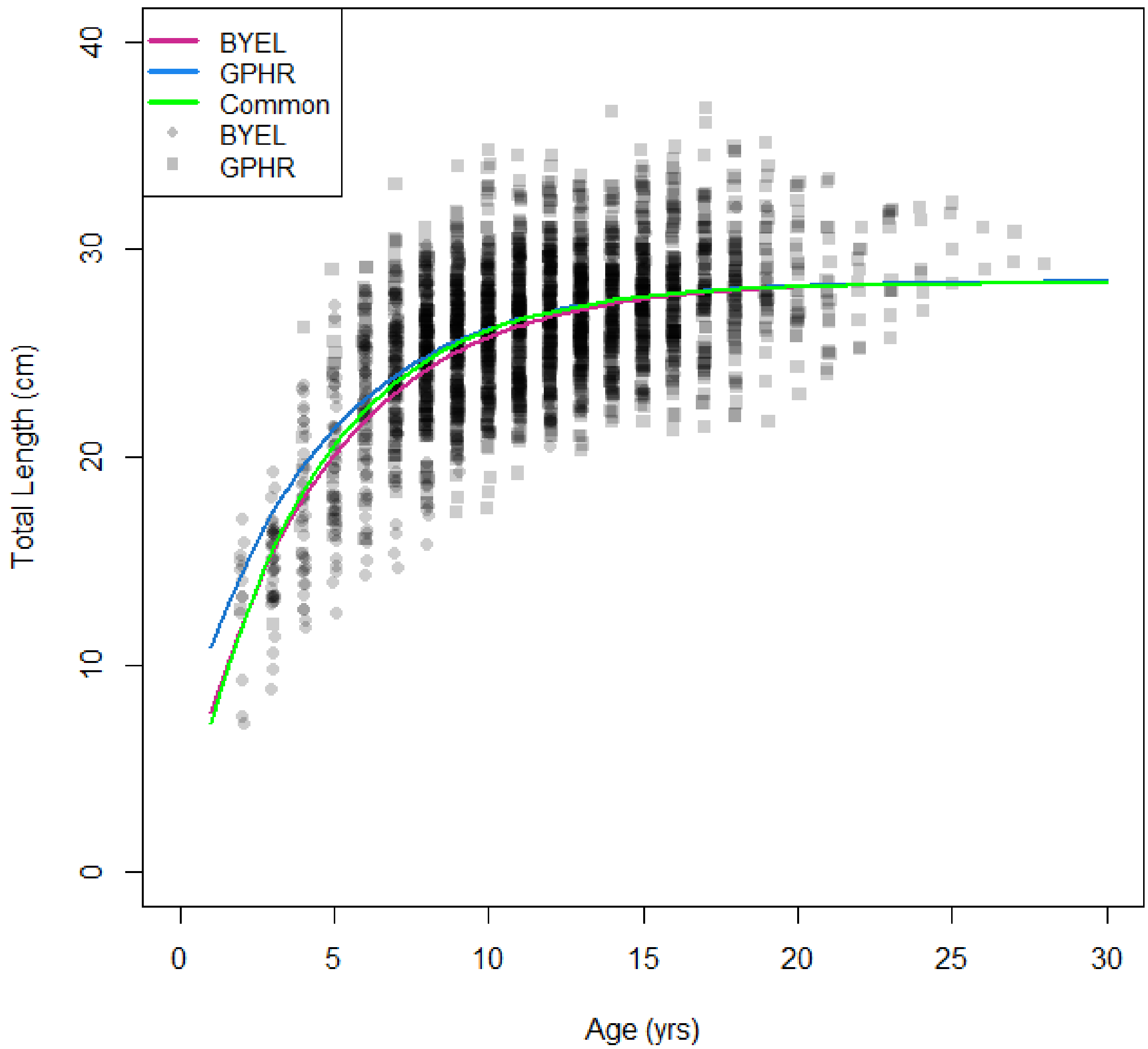

Figure 33: External estimates of growth for gopher and black-and-yellow rockfish from fits to von Bertalanffy growth models. Growth_by_species

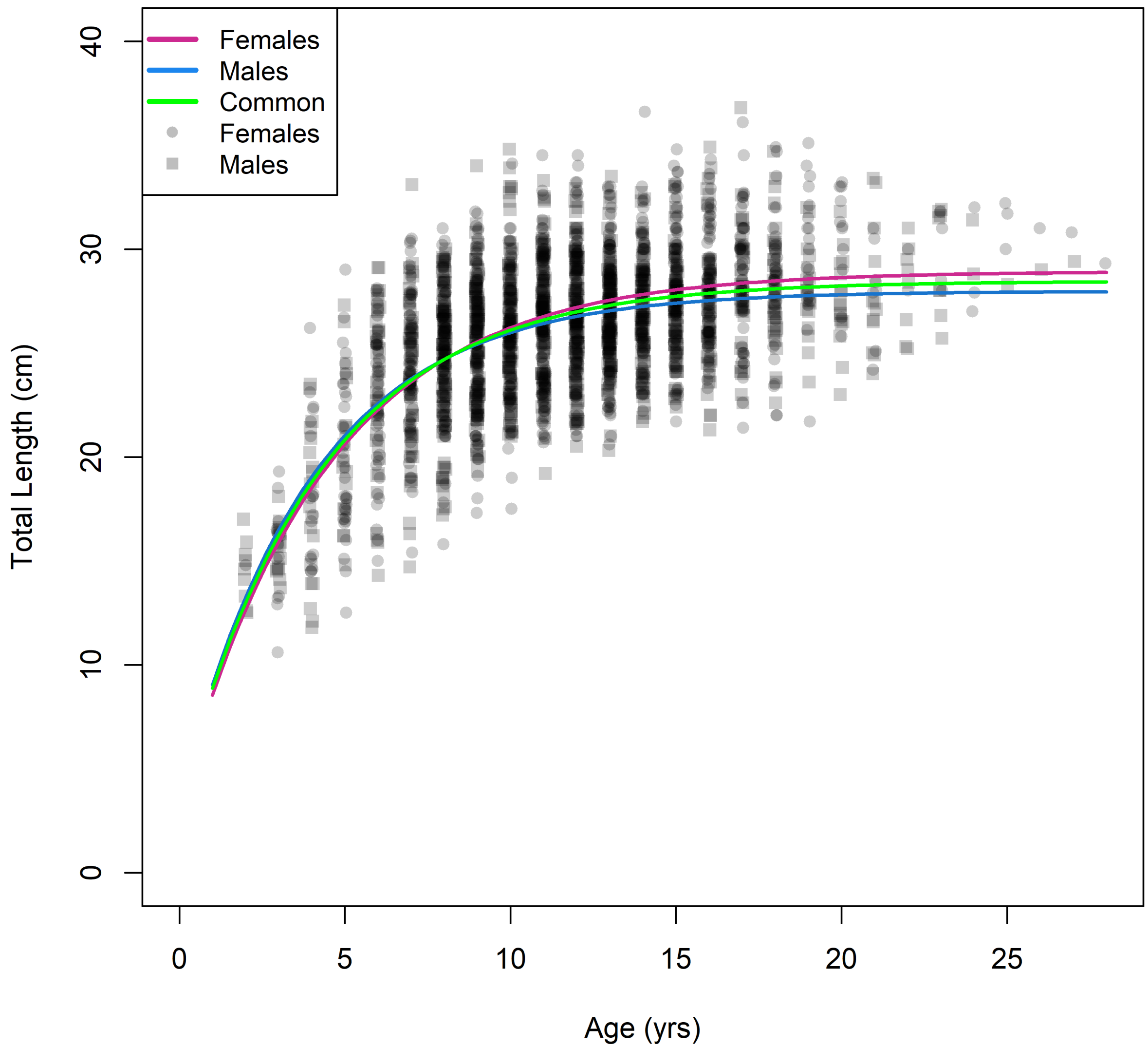

Figure 34: External estimates of growth for GBYR combined by sex from fits to von Bertalanffy growth models. | Growth_by_sex

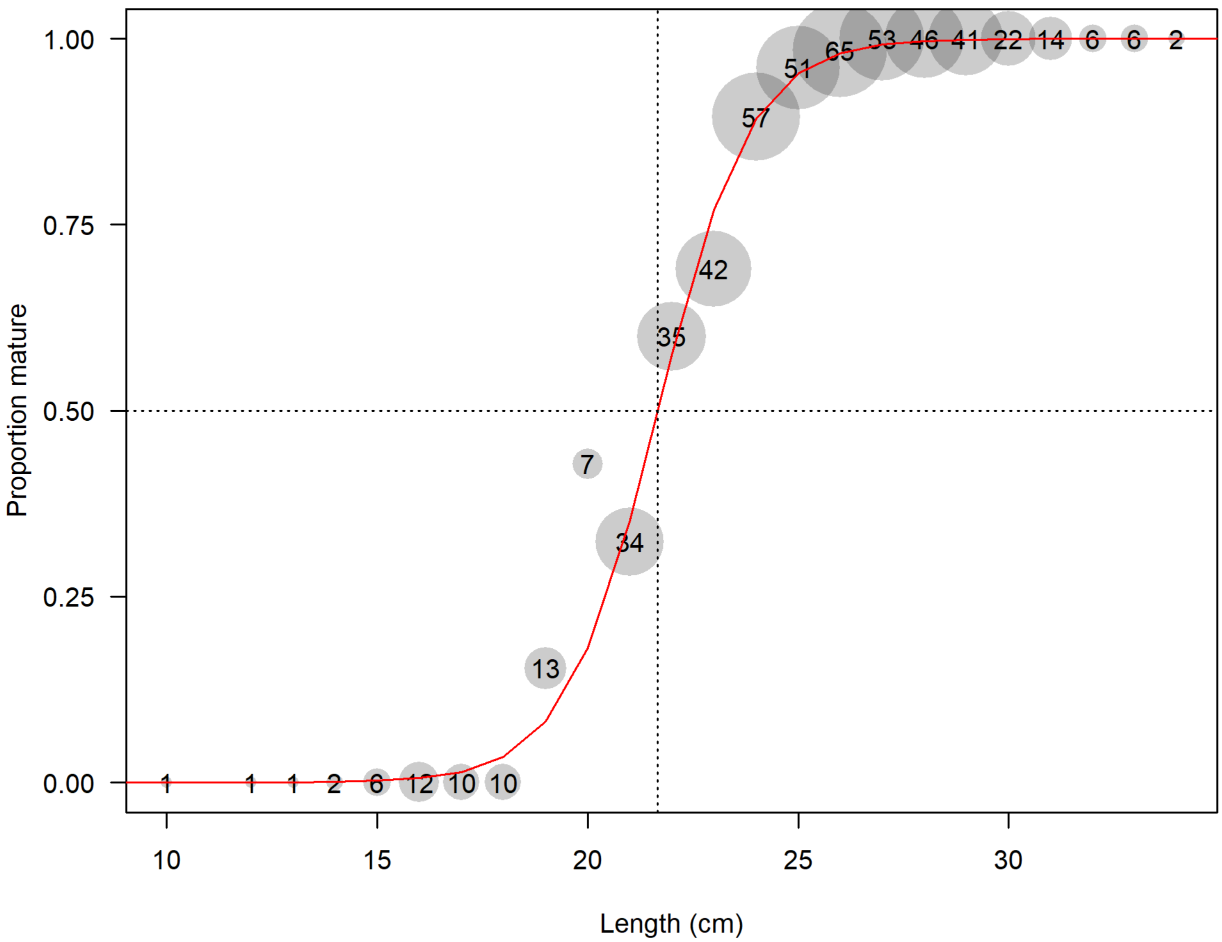

Figure 35: Maturity ogive for females estimated from black-and-yellow rockfish from Zaitlin (1986) and gopher rockfish from Meyers-Cherry (2014). Sample sizes at a given length are shown in the circles. fig:GBY_maturity_ogive

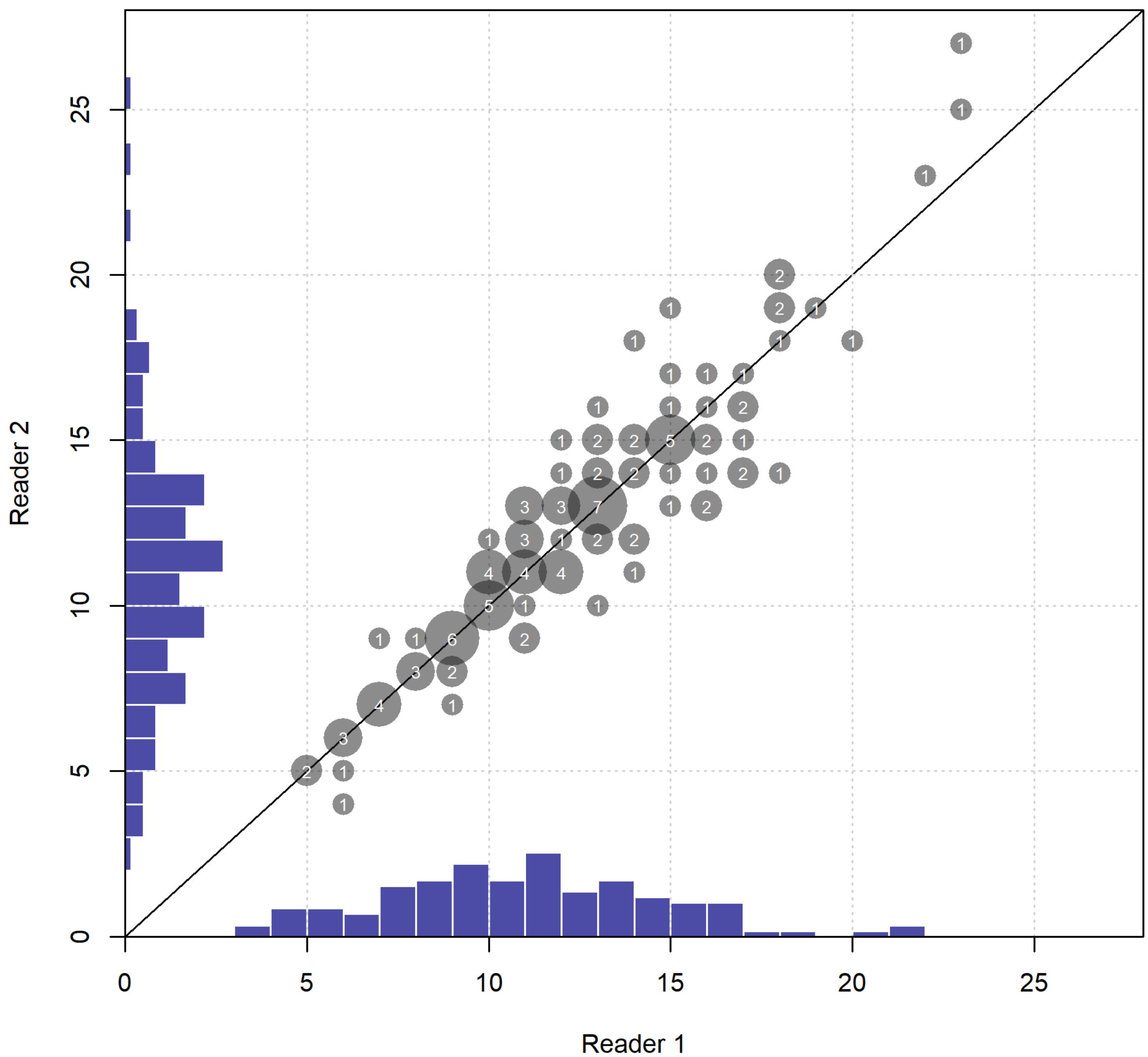

Figure 36: Aging precision between initial and blind double reads for GBYR. Numbers in the bubbles are the sample sizes of otoliths cross-read. fig:GBY_age_error

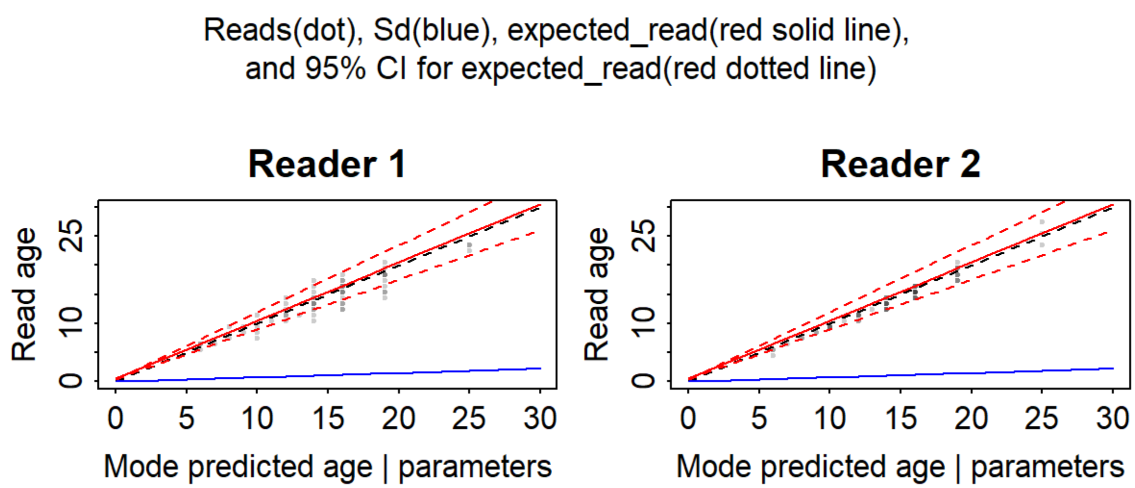

Figure 37: True versus predicted age for two current age readers at the NWFSC from the ageing error software with unbiased reads and curvilinear standard deviation for both readers. fig:GBY_age_error2

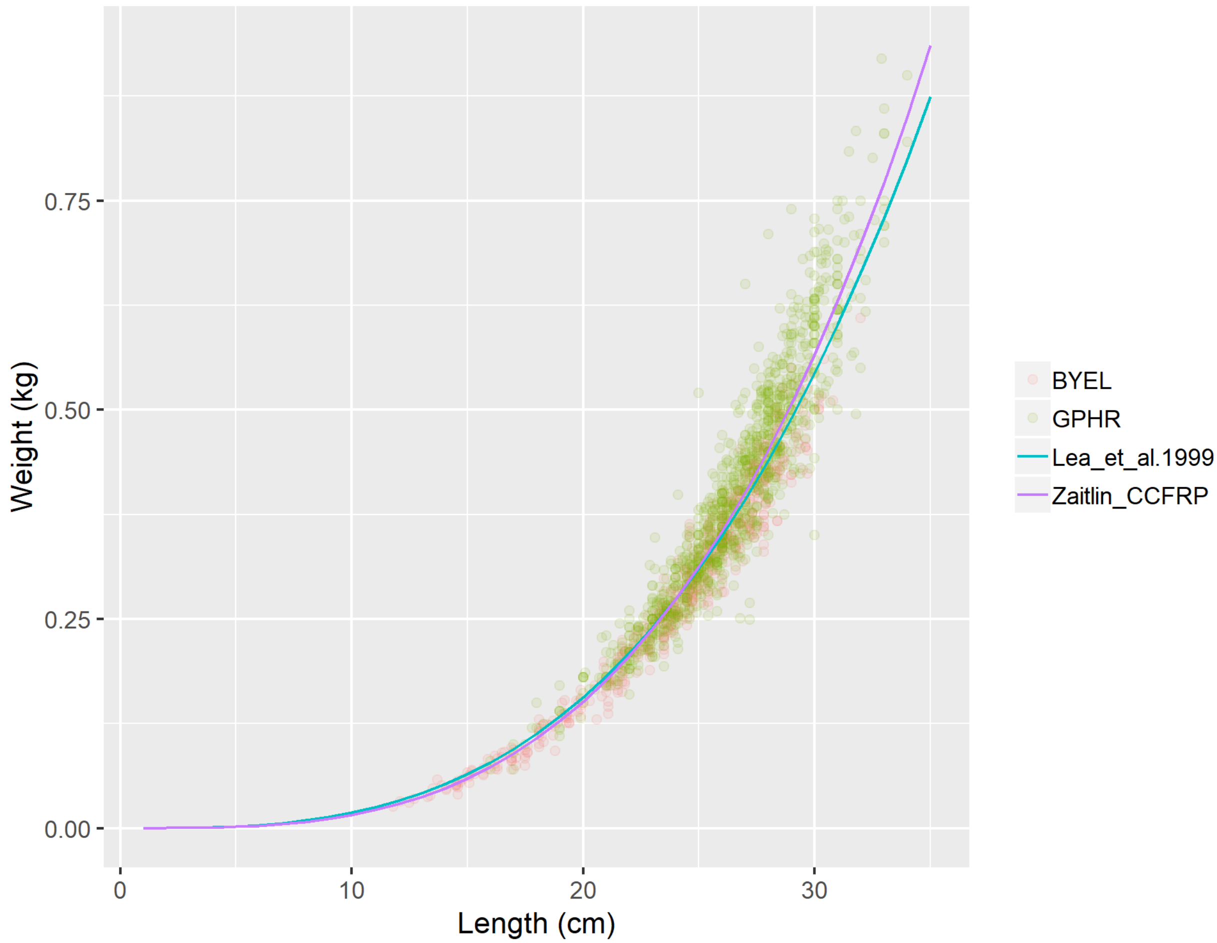

Figure 38: Comparison of the gopher rockfish weight-length curves from Lee et al. (1999) and tha estimated from black-and-yellow rockfishes from Zaitlin (1986), and gopher rockfishes from Loury (2011) and Meyers-Cherry(2014). The estimated curve from the current data is used in this assessment. fig:GBY_weight_length

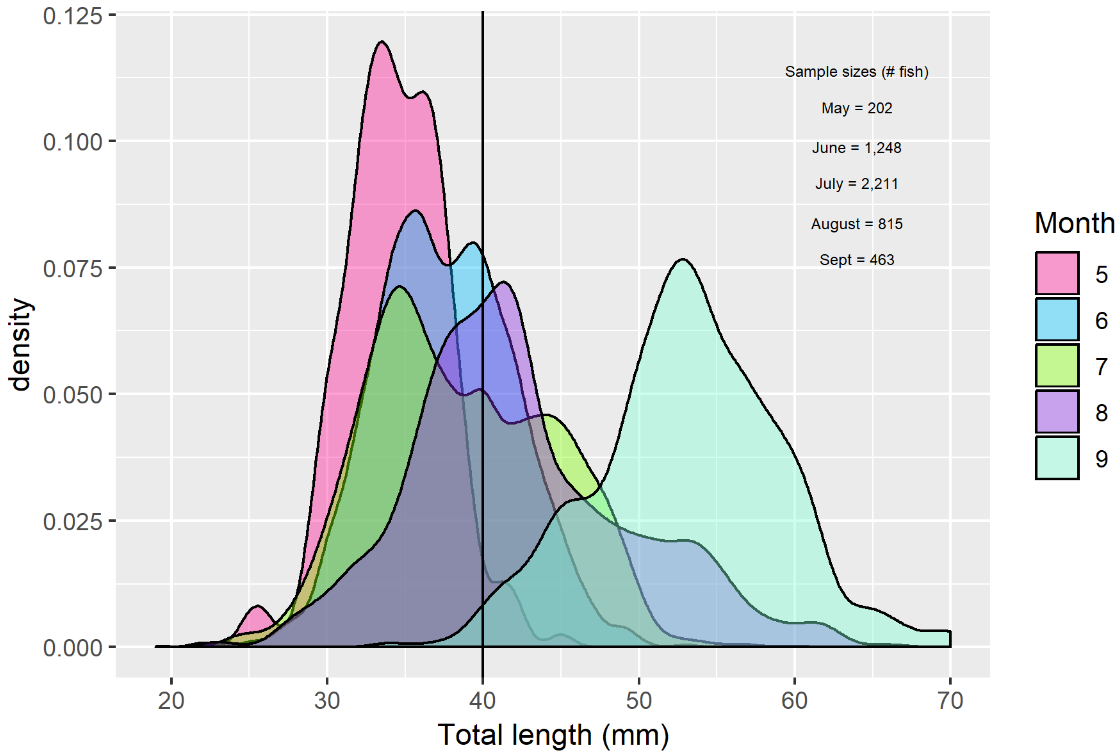

Figure 39: Length distribution by month for GBYR captured using a sampling tool called a Standard Monitoring Unit for the Recruitment of Fishes (SMURFs) from the UCSC-PISCO kelp forest fish survey, specifically as part of Diana Baetscher's dissertation work (Baetscher 2019). fig:SMURF_lengths

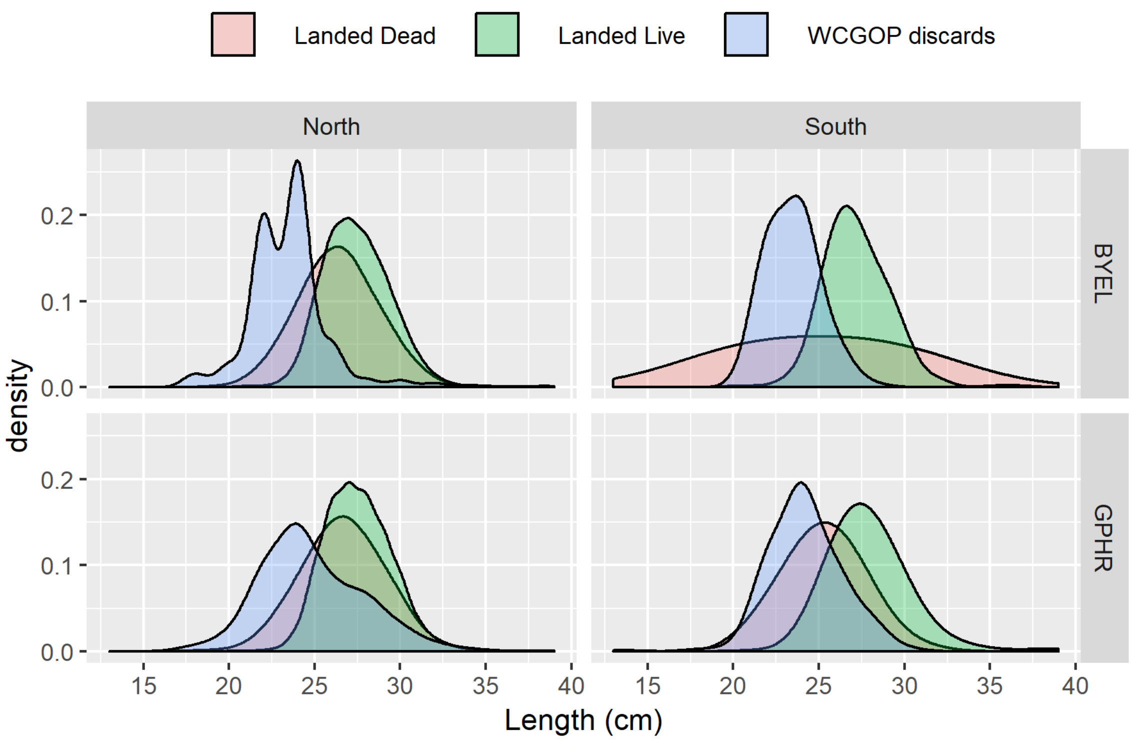

Figure 40: Length distributions of gopher and black-and-yellow rockfish for the commercial fleet and WCGOP discards north and south of Point Conception. The commercial landings were also separated between fish landed live and fish landed dead for this figure. fig:Comm_lengths_justi

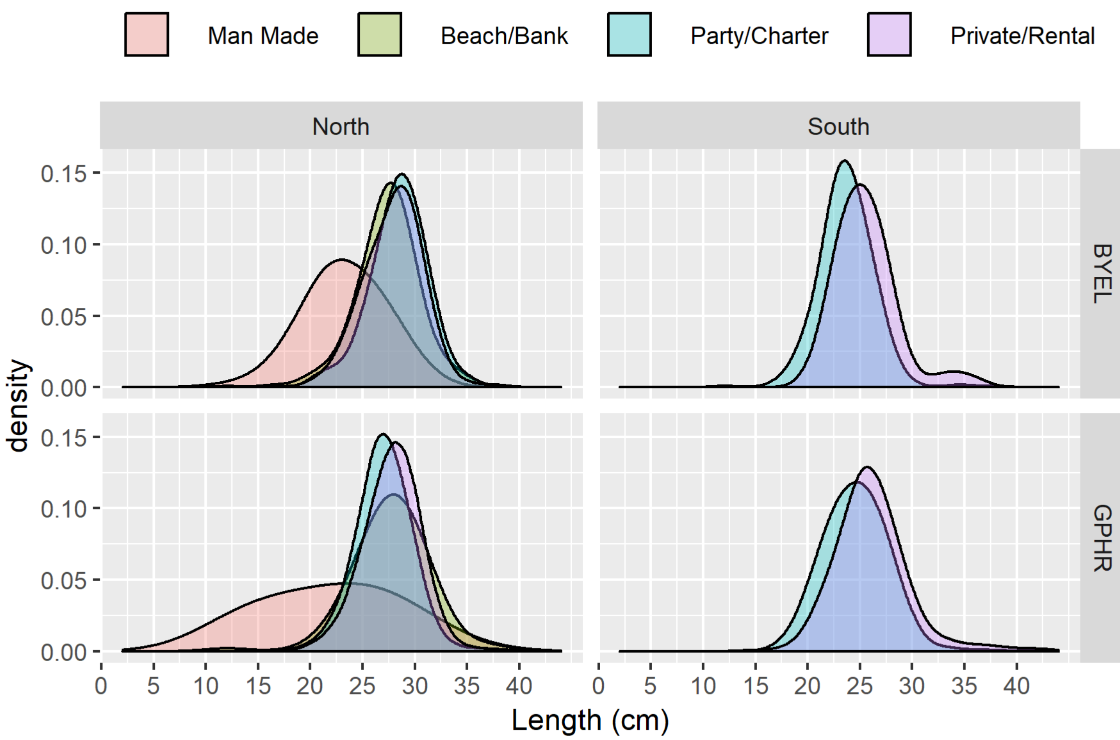

Figure 41: Length distributions of gopher and black-and-yellow rockfish for the recreational fleet north and south of Point Conception and by mode. fig:Rec_lengths_justification

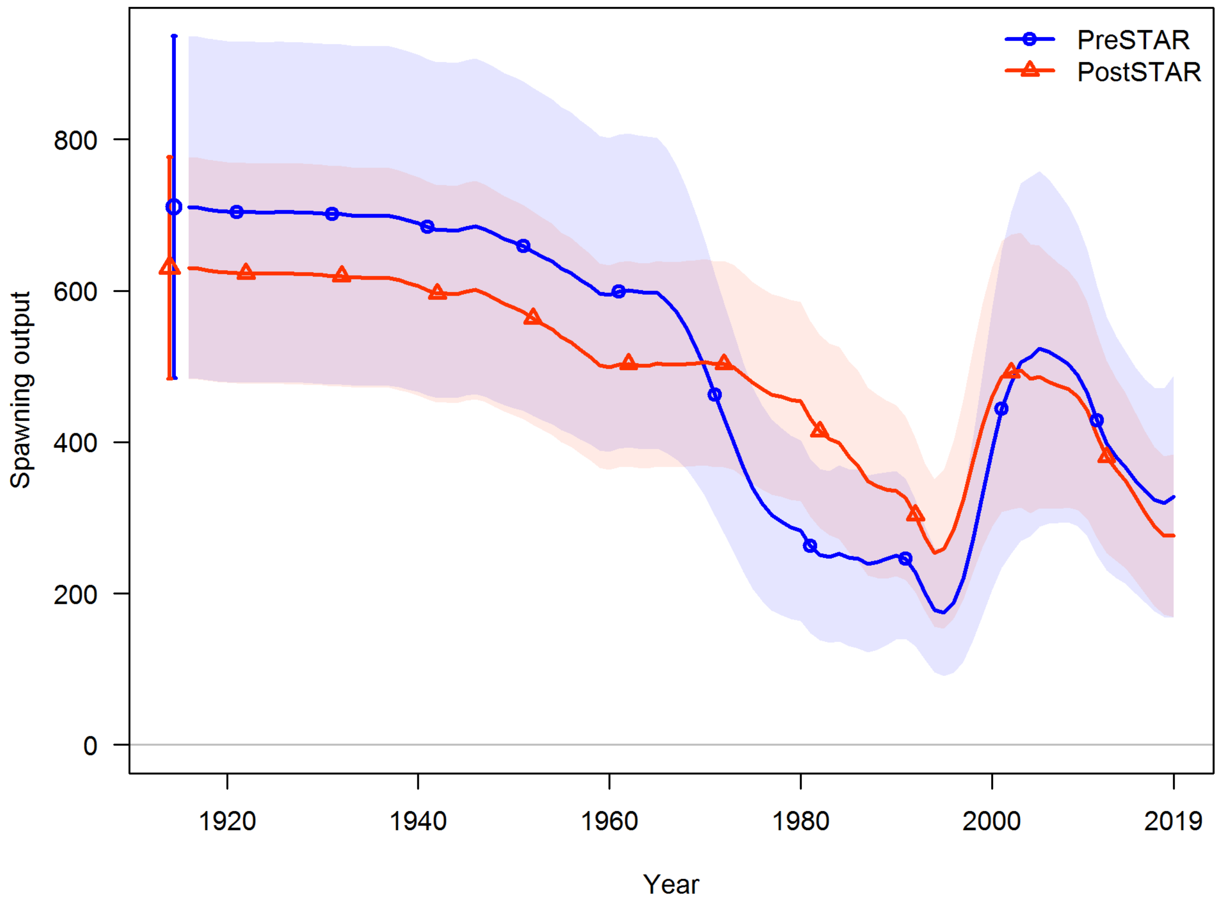

Figure 42: Comparison of the spawning output between the pre-STAR panel base model and the post-STAR model base. fig:preSTAR_postSTAR_compare_spawnbio

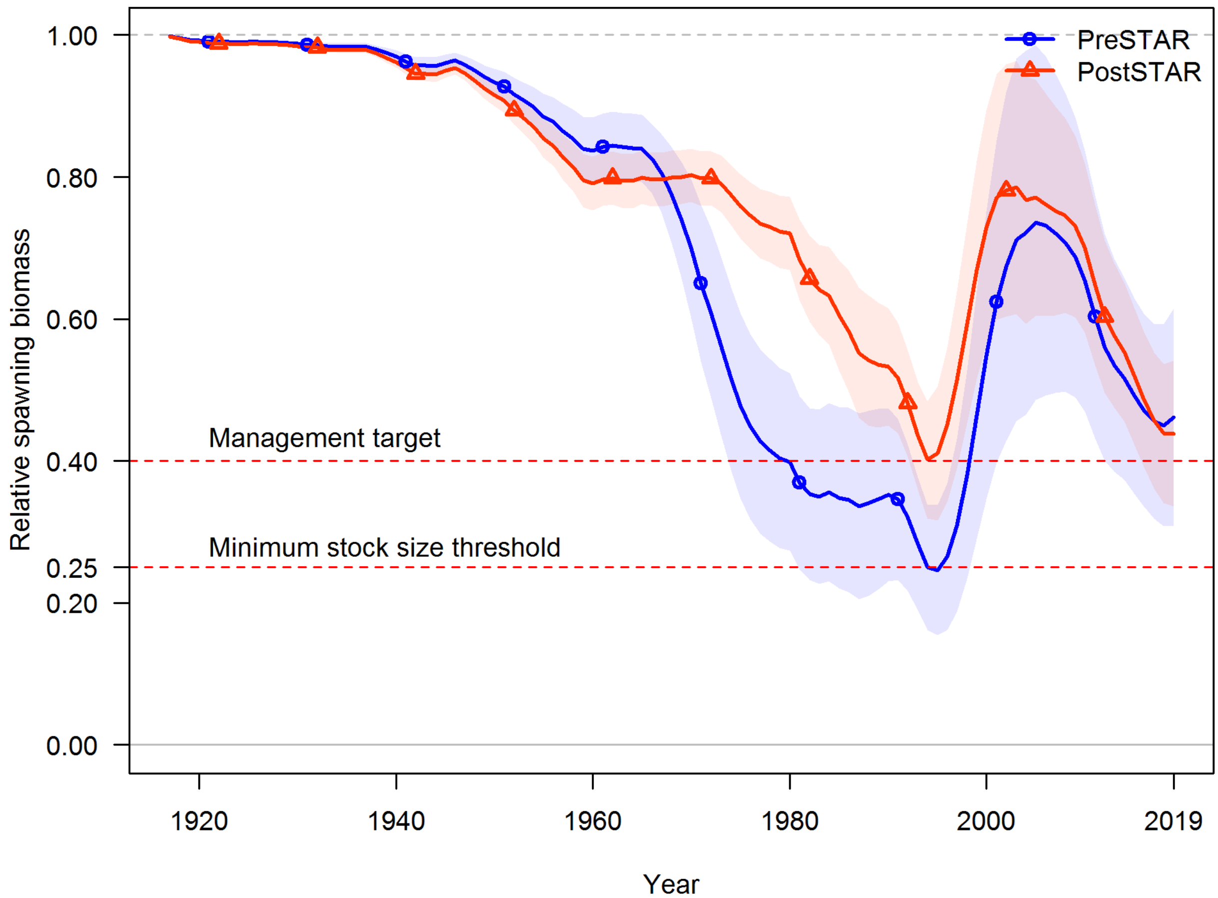

Figure 43: Comparison of the relative spawning output (depletion) between the pre-STAR panel base model and the post-STAR model base. fig:preSTAR_postSTAR_compare_Bratio

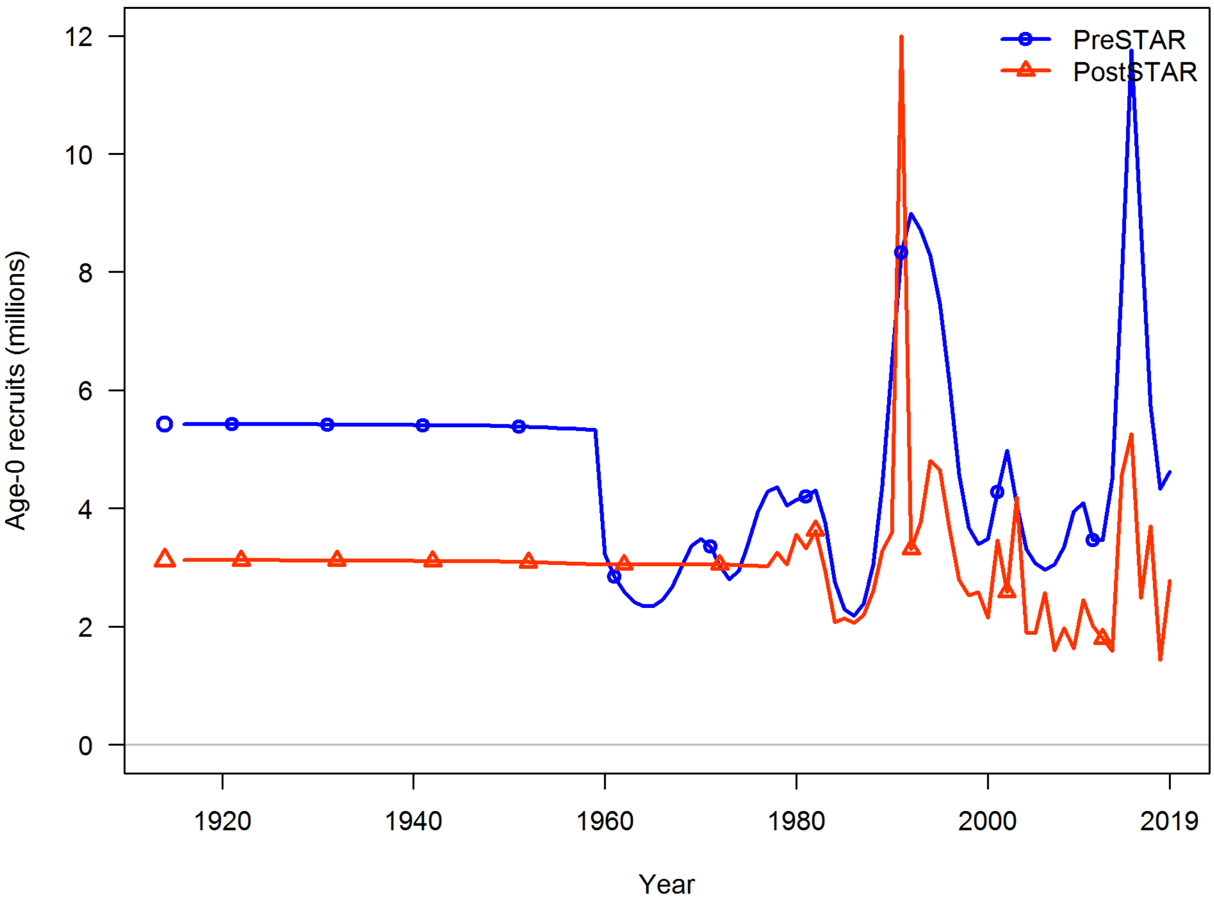

Figure 44: Comparison of the age-0 recruits between the pre-STAR panel base model and the post-STAR model base. fig:preSTAR_postSTAR_compare_recruit

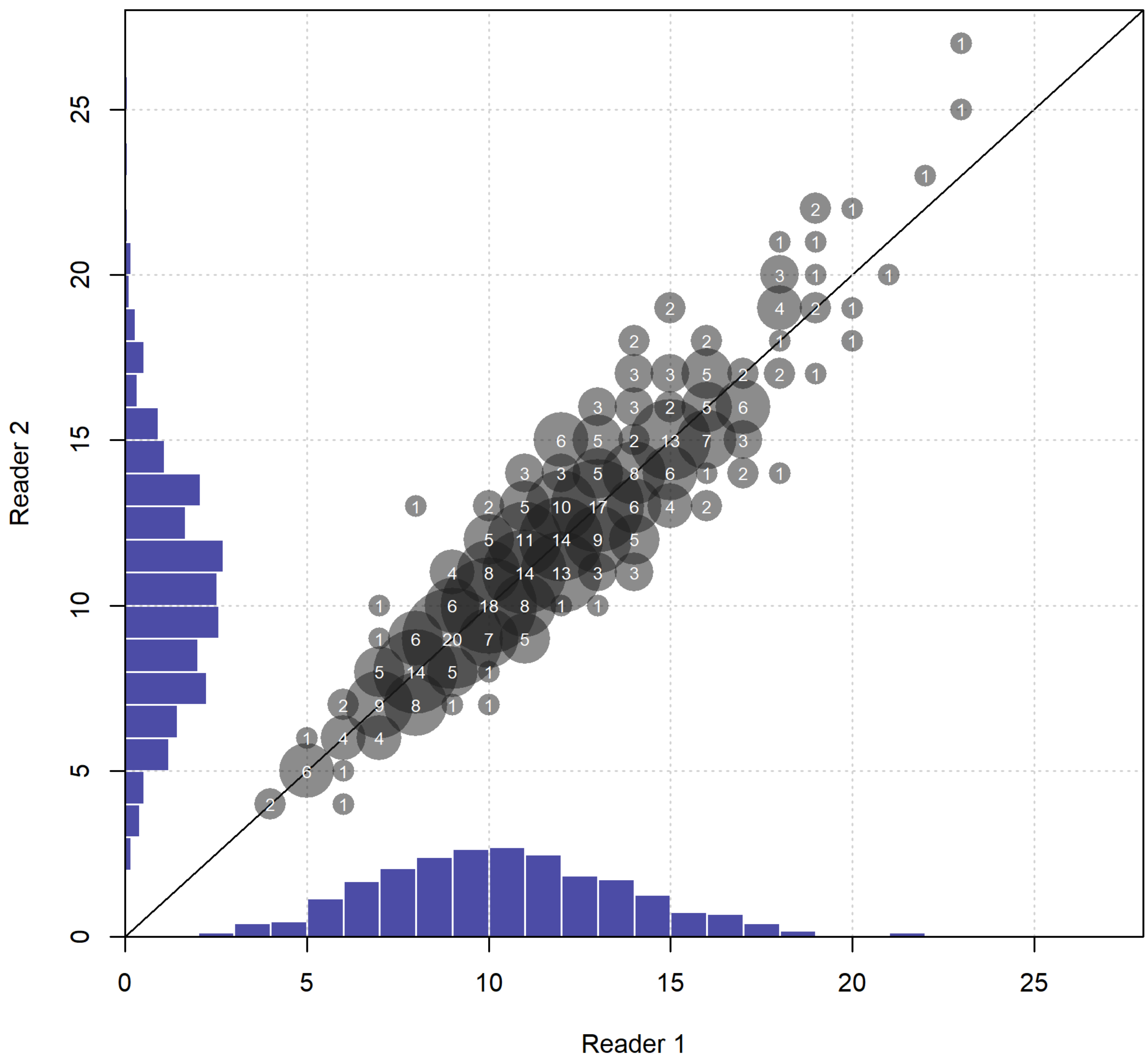

Figure 45: Updated aging precision used in the post-STAR base model between initial and blind double reads for GBYR. Numbers in the bubbles are the sample sizes of otoliths cross-read. fig:GBY_age_error_updated

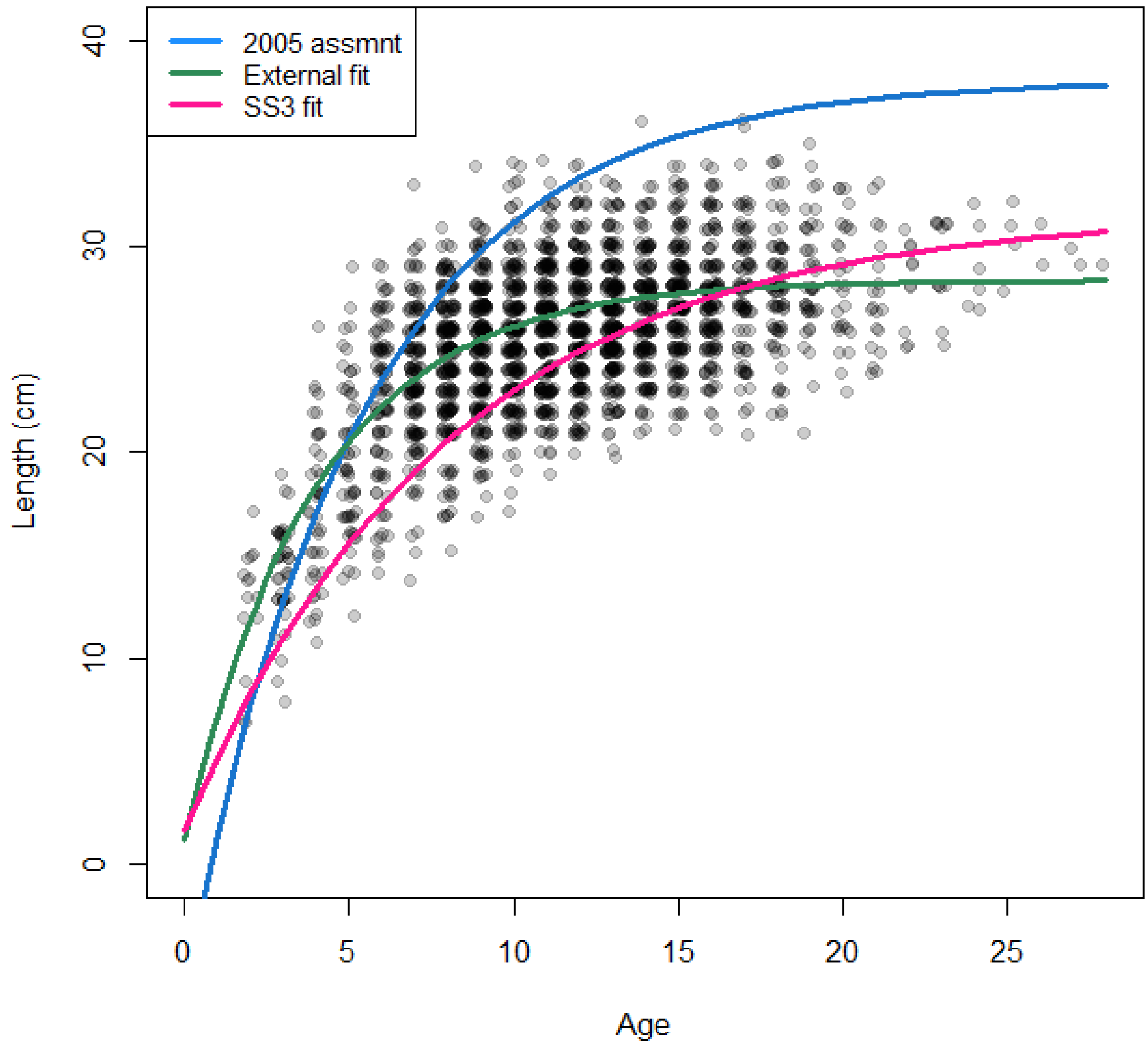

Figure 46: Estiamtes of growth for GBYR from the 2005 assessment, external fit to the CAAL data used in this assessment and the internal SS estimate of growth for this assessment. All growth curves were estimated using the Schnute parameterization of the von Bertalanffy growth curve. fig:growth_compare

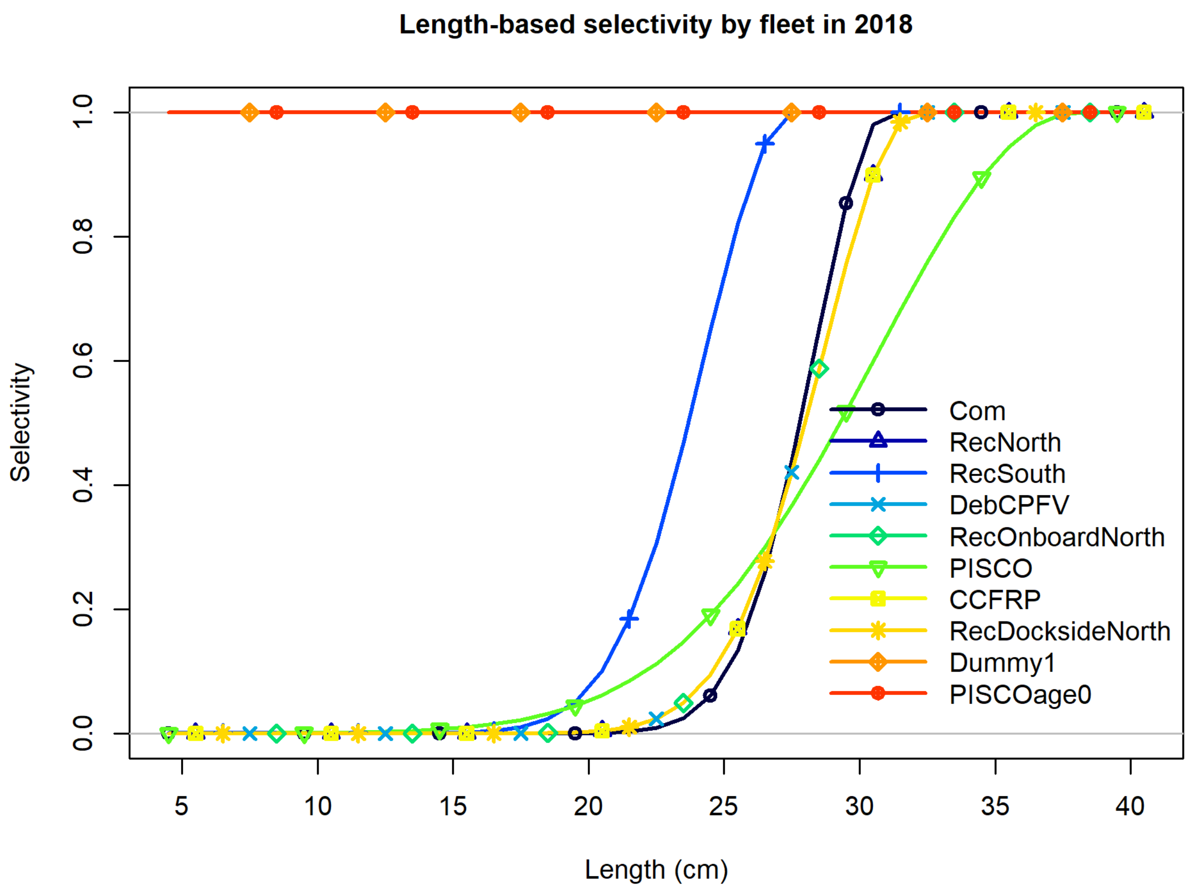

Figure 47: Selectivity at length for all of the fleets in the base model. fig:sel01_multiple_fle

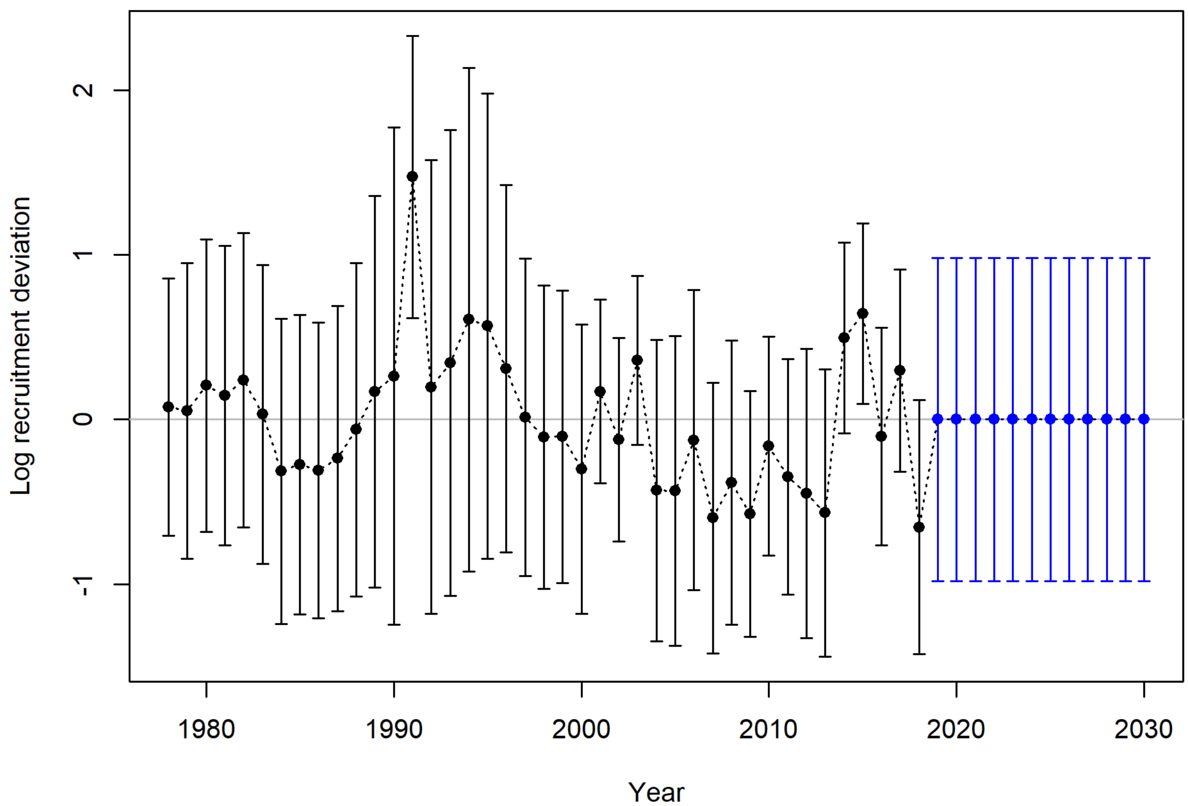

Figure 48: Estimated time-series of recruitment deviations for GBYR with 95% intervals. fig:recdevs2_

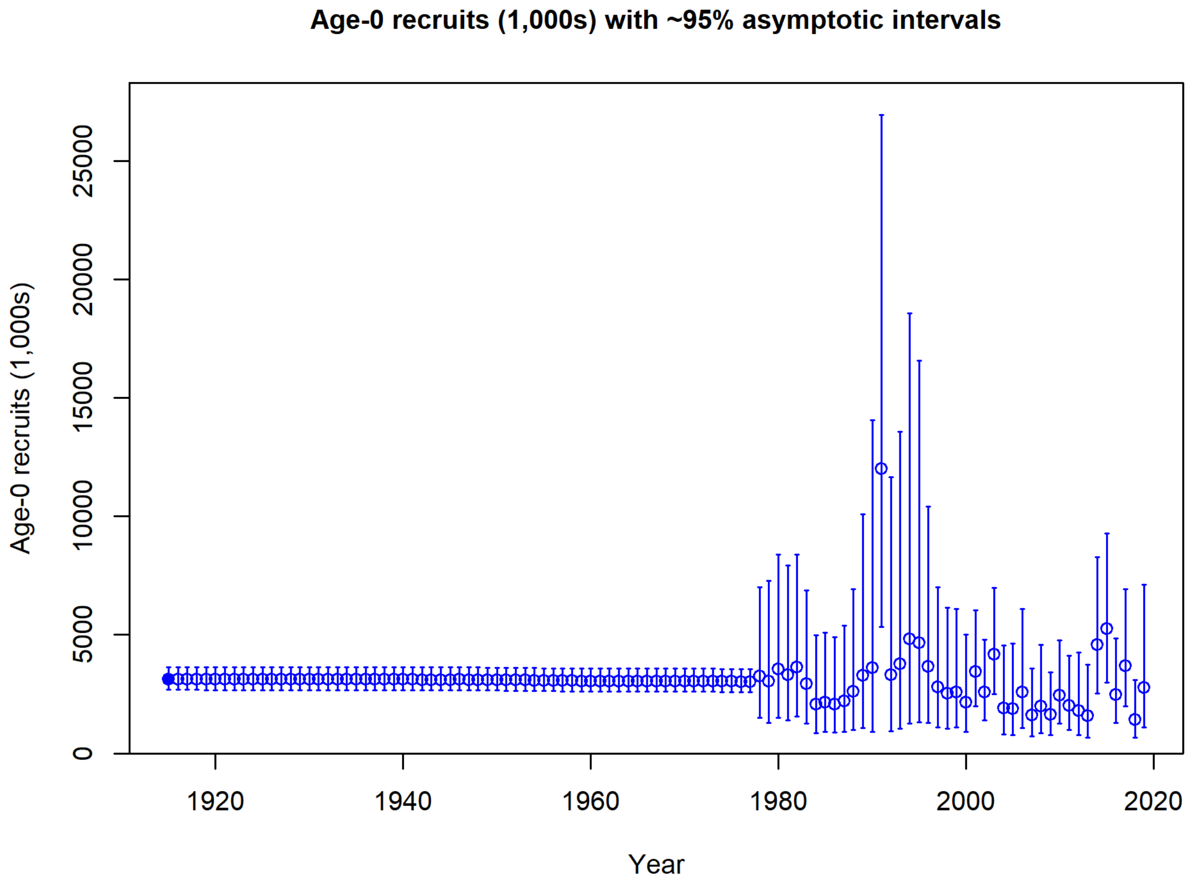

Figure 49: Time series of estimated GBYR recruitments for the base-case model with 95% confidence or credibility intervals. fig:Recruit_mod1

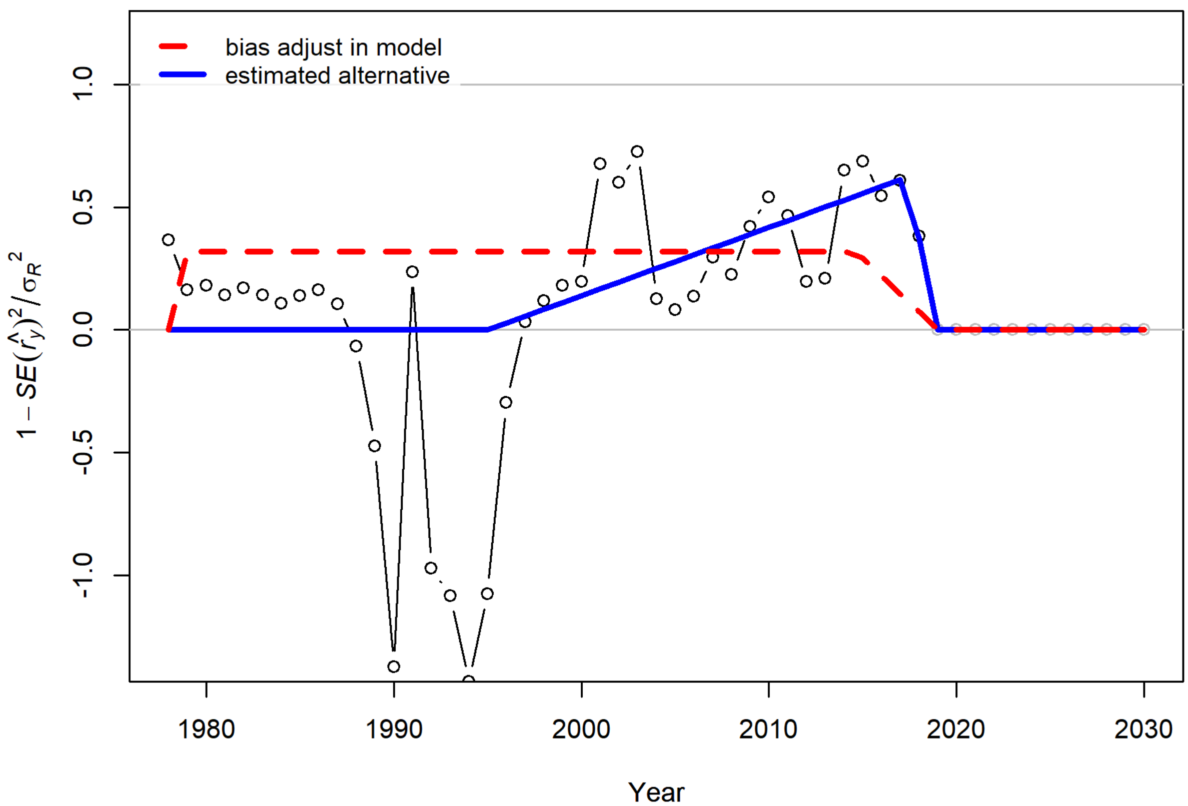

Figure 50: Bias adjustment for recruitment deviations. Points are transformed variances. Red line shows current settings for bias adjustment specified in the control file. Blue line shows the least squares estimate of alternative bias adjustment relationship for recruitment deviations. fig:recruit_fit_bias_adjust

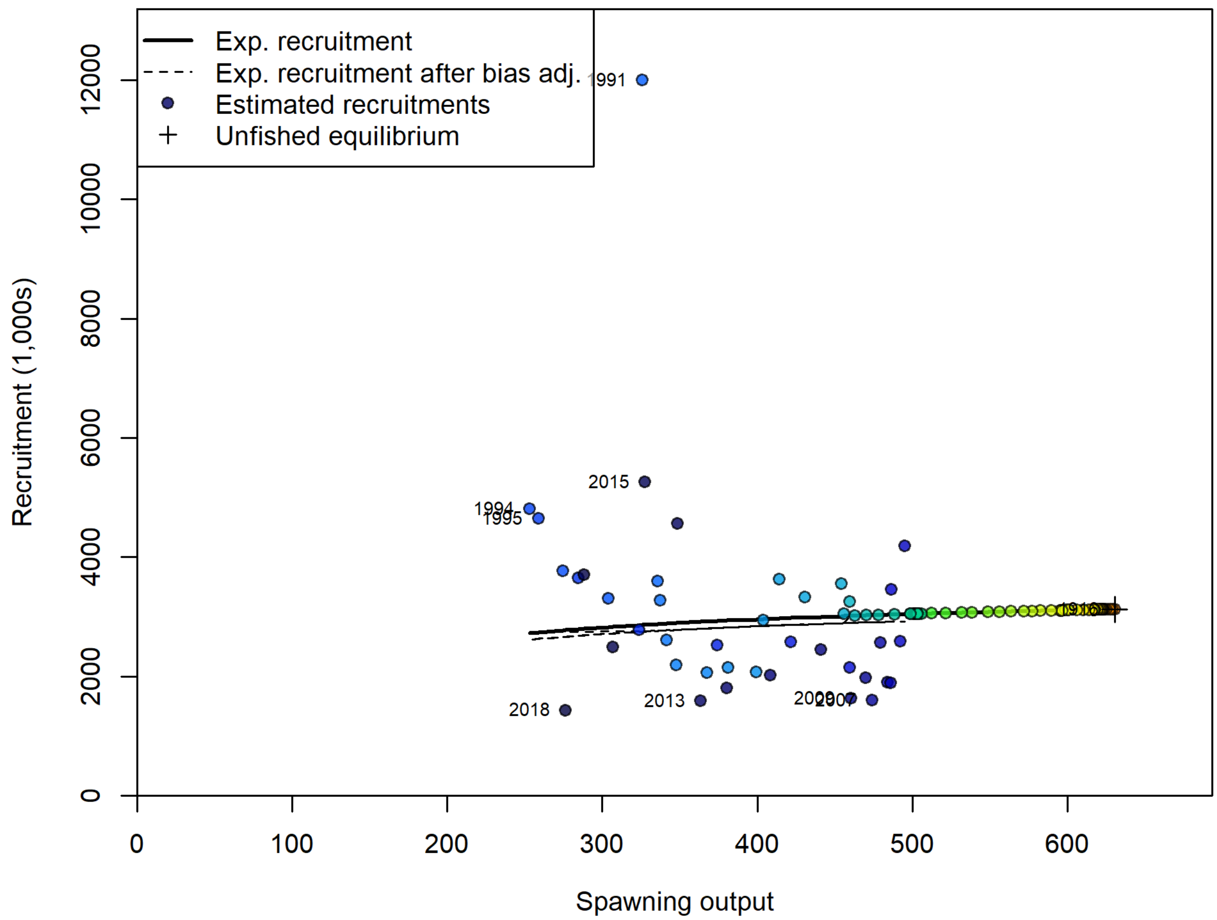

Figure 51: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line) for GBYR. The green line shows the effect of the bias correction for the lognormal distribution. fig:SR_curve2

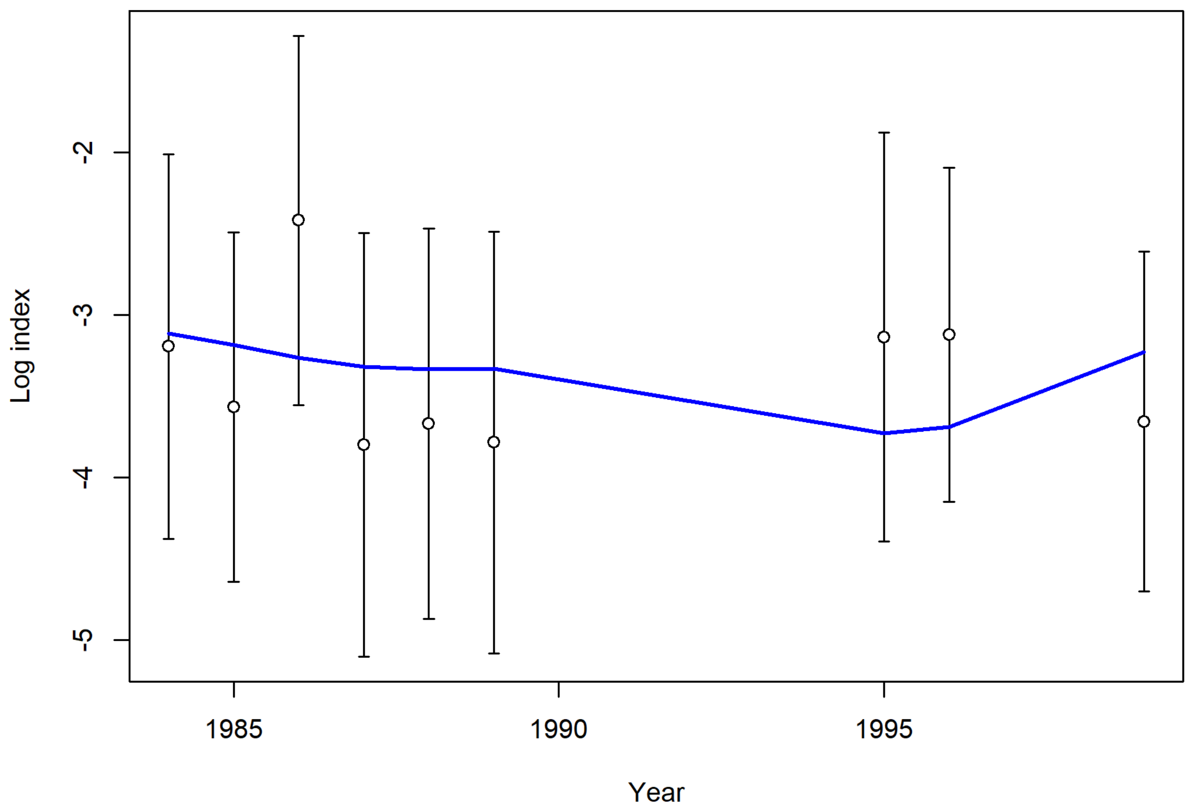

Figure 52: Fit to log index data on log scale for the receratational MRFSS dockside CPFV fishery north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit_RecDocksideNorth

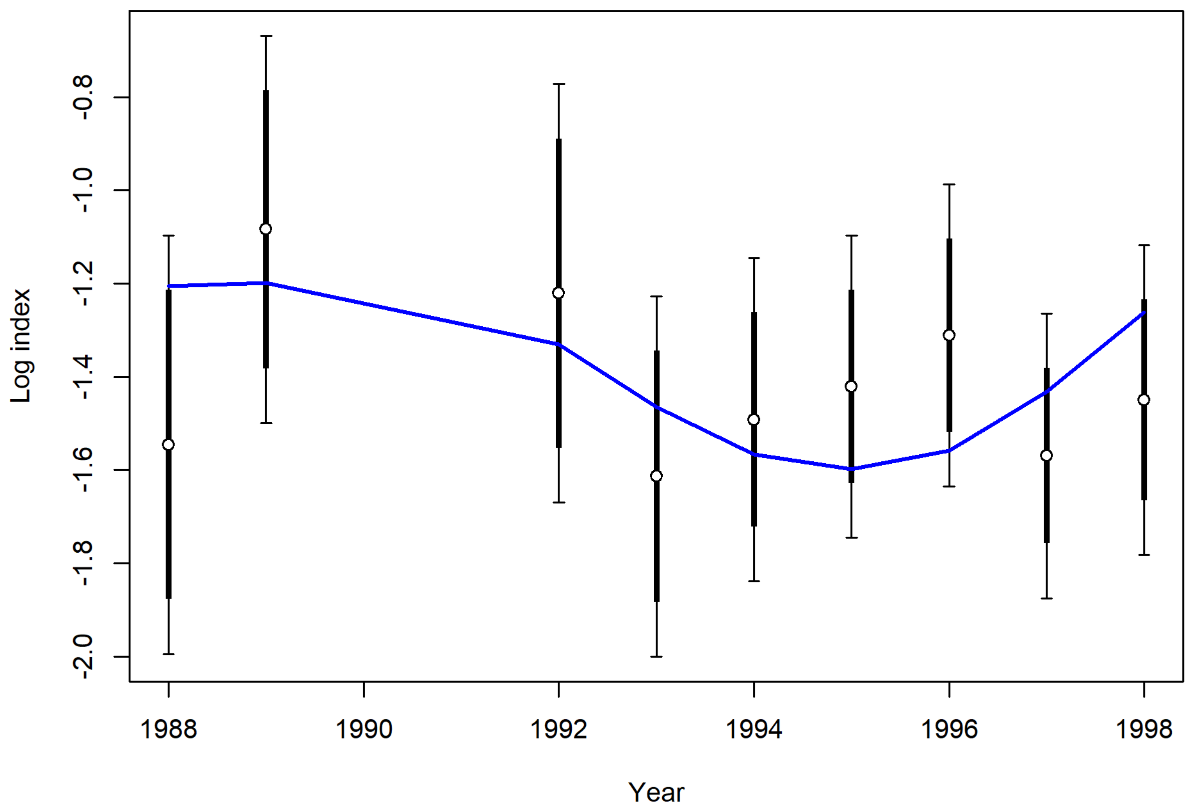

Figure 53: Fit to log index data on log scale for the recreational Deb's CPFV onboard observer program, representing north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit_DebCPFV

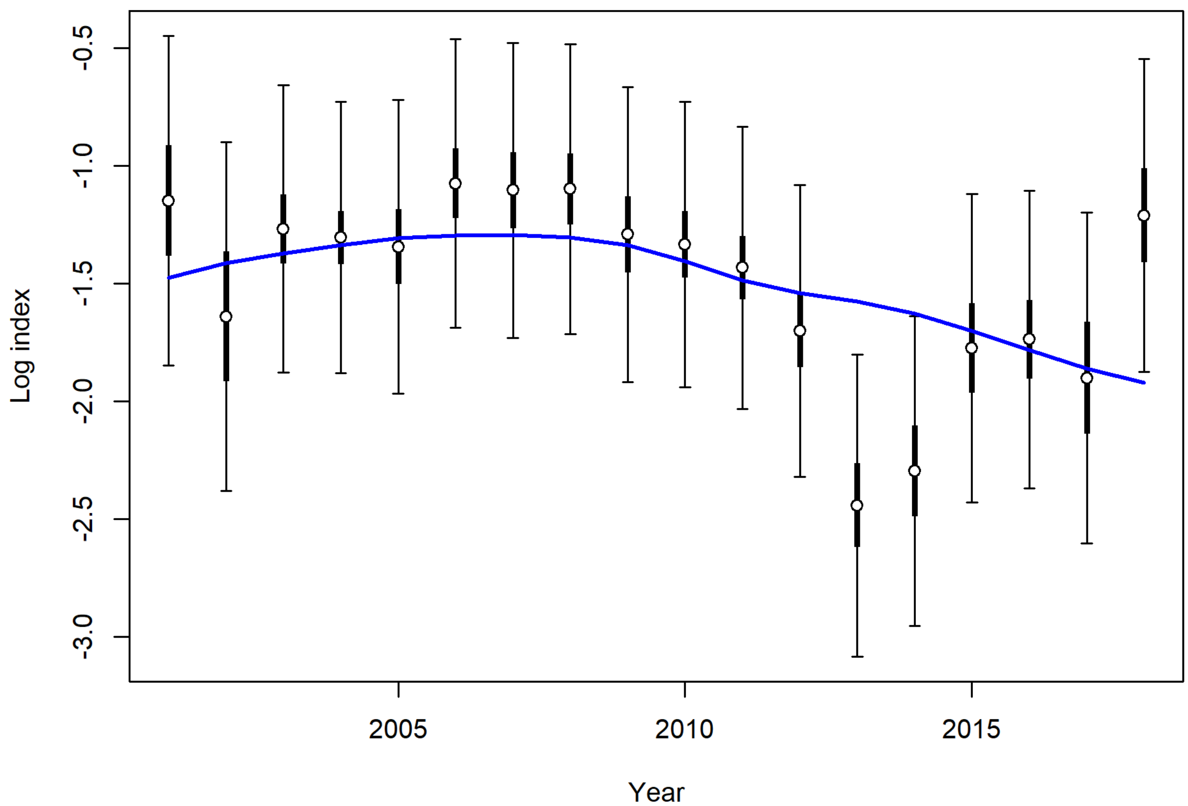

Figure 54: Fit to log index data on log scale for the CRFS/Cal Poly CPFV onboard observer survey north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit_RecOnboardNorth

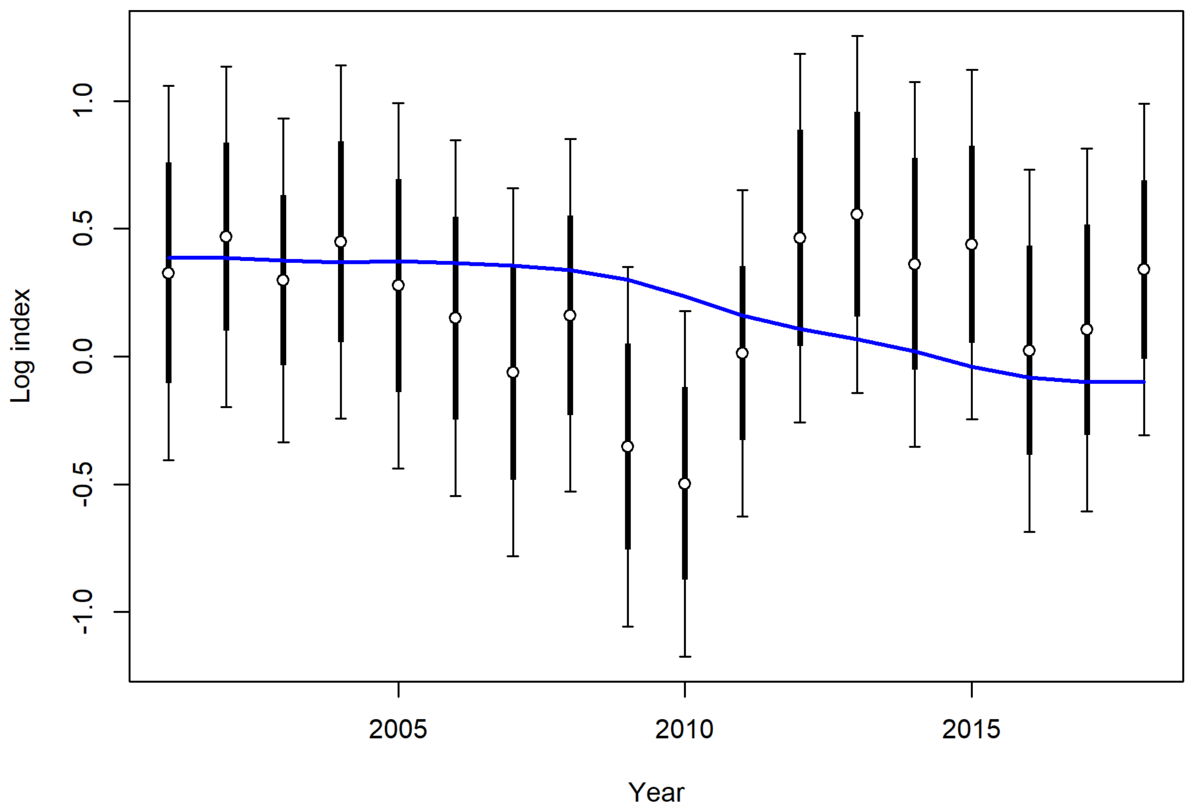

Figure 55: Fit to log index data on log scale for the fishery-independent PISCO kelp forest fish survey for fish 15 cm and larger. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_logcpuefit_PISCO

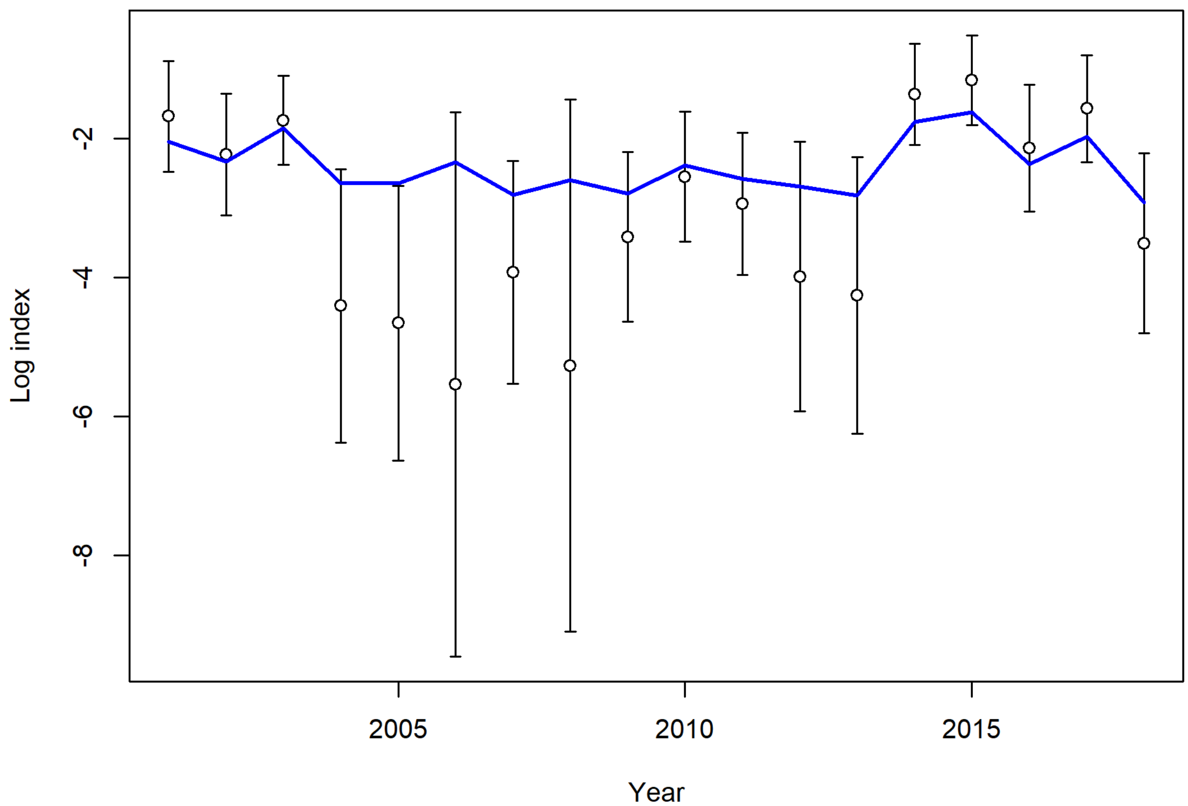

Figure 56: Fit to log index data on log scale for the fishery-independent PISCO age-0 (6 cm or less) kelp forest fish survey for fish 15 cm and larger. Lines indicate 95% uncertainty interval around index values. fig:index5_logcpuefit_PISCOage0

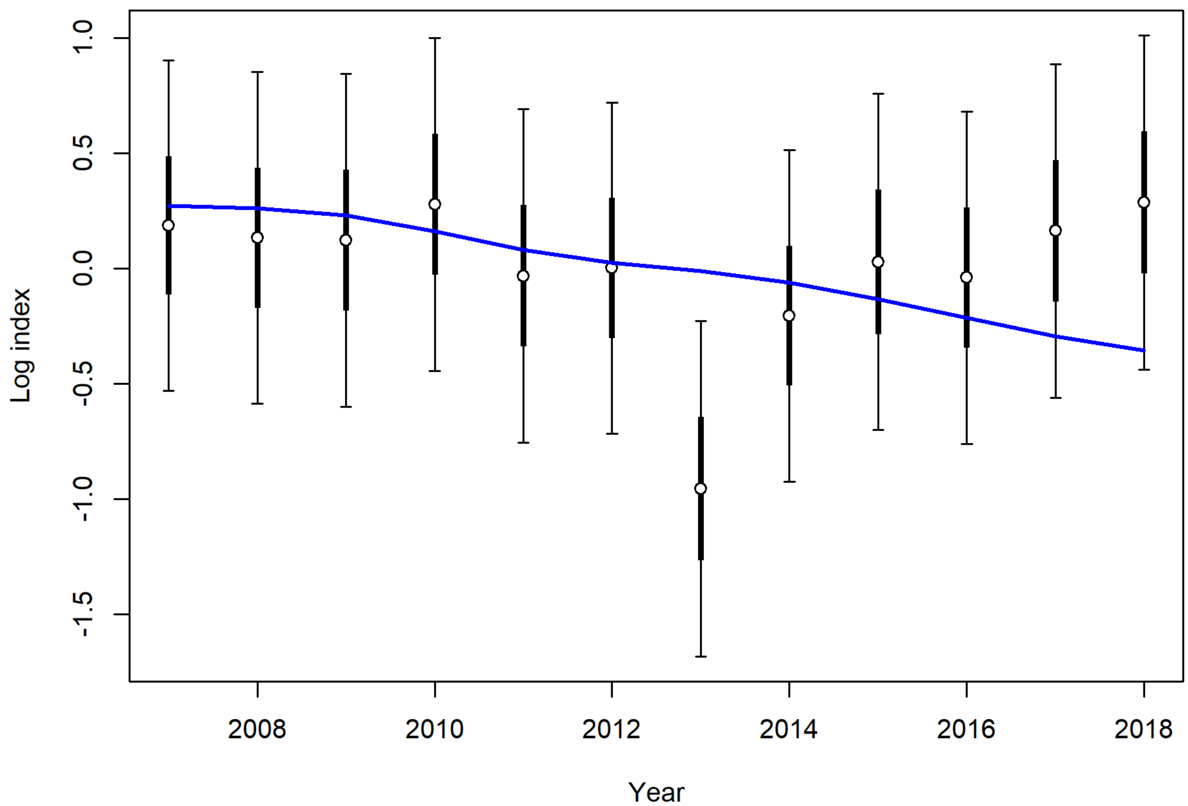

Figure 57: Fit to log index data on log scale for the fishery-independent CCFRP hook-and-line survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_log

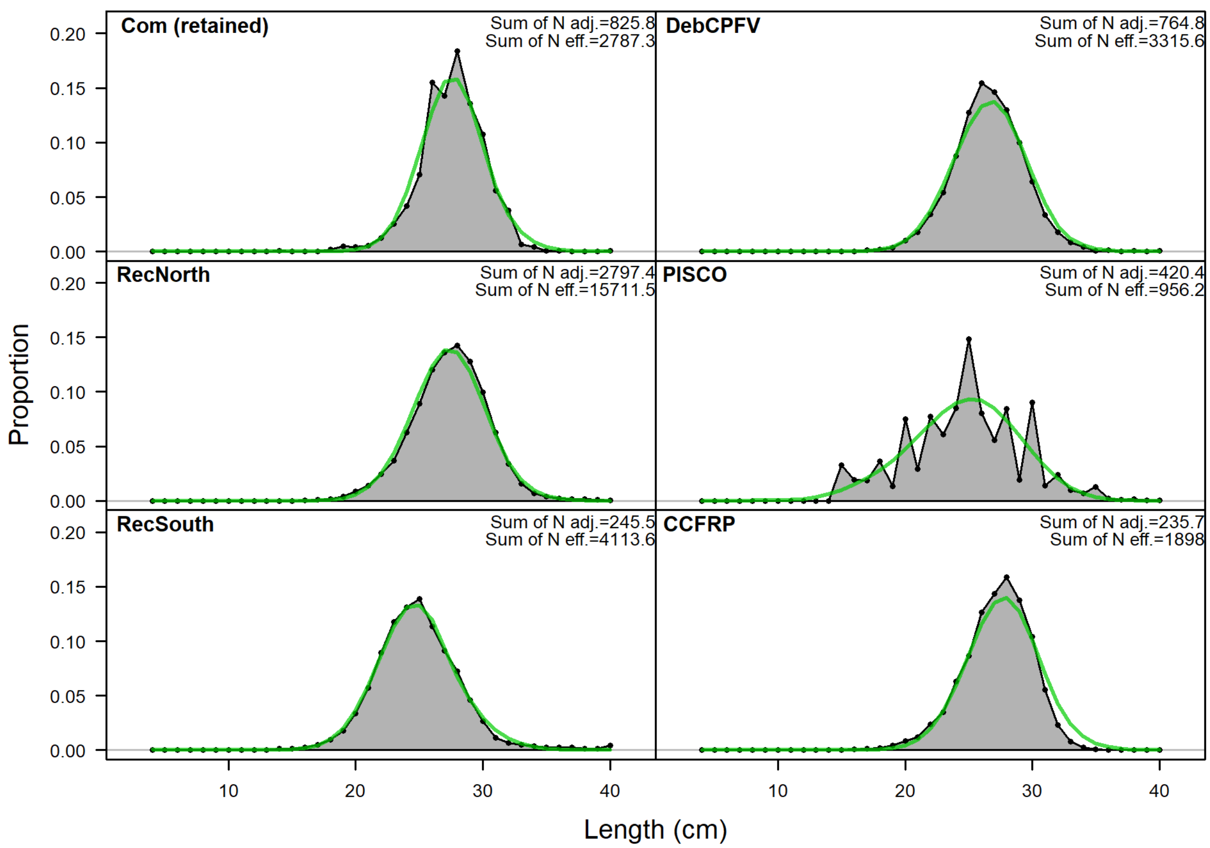

Figure 58: Length compositions aggregated across time by fleet. fig:comp_lenfit__aggregat

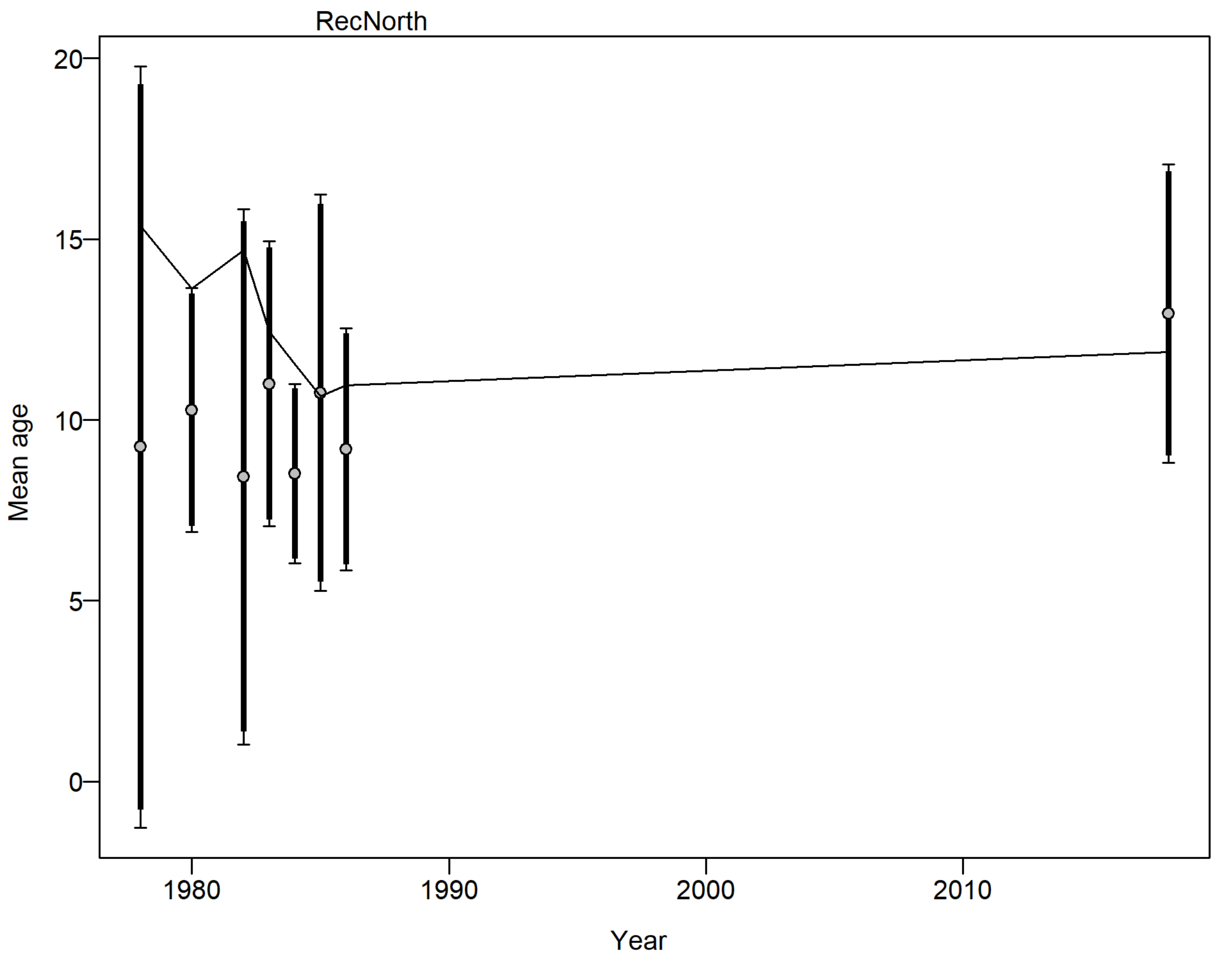

Figure 59: Mean age for the recreational fishery (ages from north of Point Conception only) with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.182 (0.588-3.588). For more info, see Francis et al. (2011). fig:comp_condAALfit_data_weighting_TA1.8_condAgeRecNorth

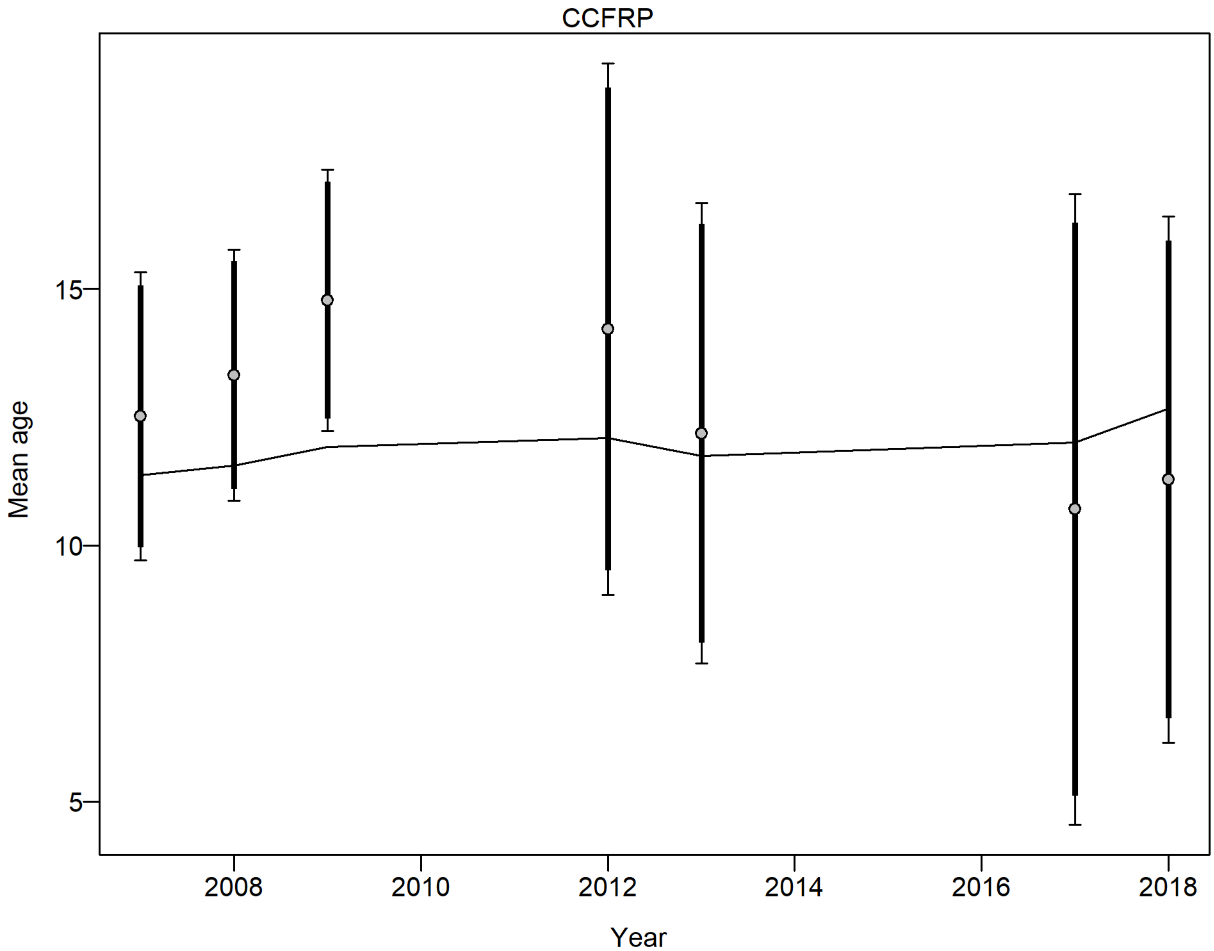

Figure 60: Mean age for the CCFRP survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.023 (0.511-3.745). For more info, see Francis et al. (2011). fig:comp_condAALfit_data_weigh

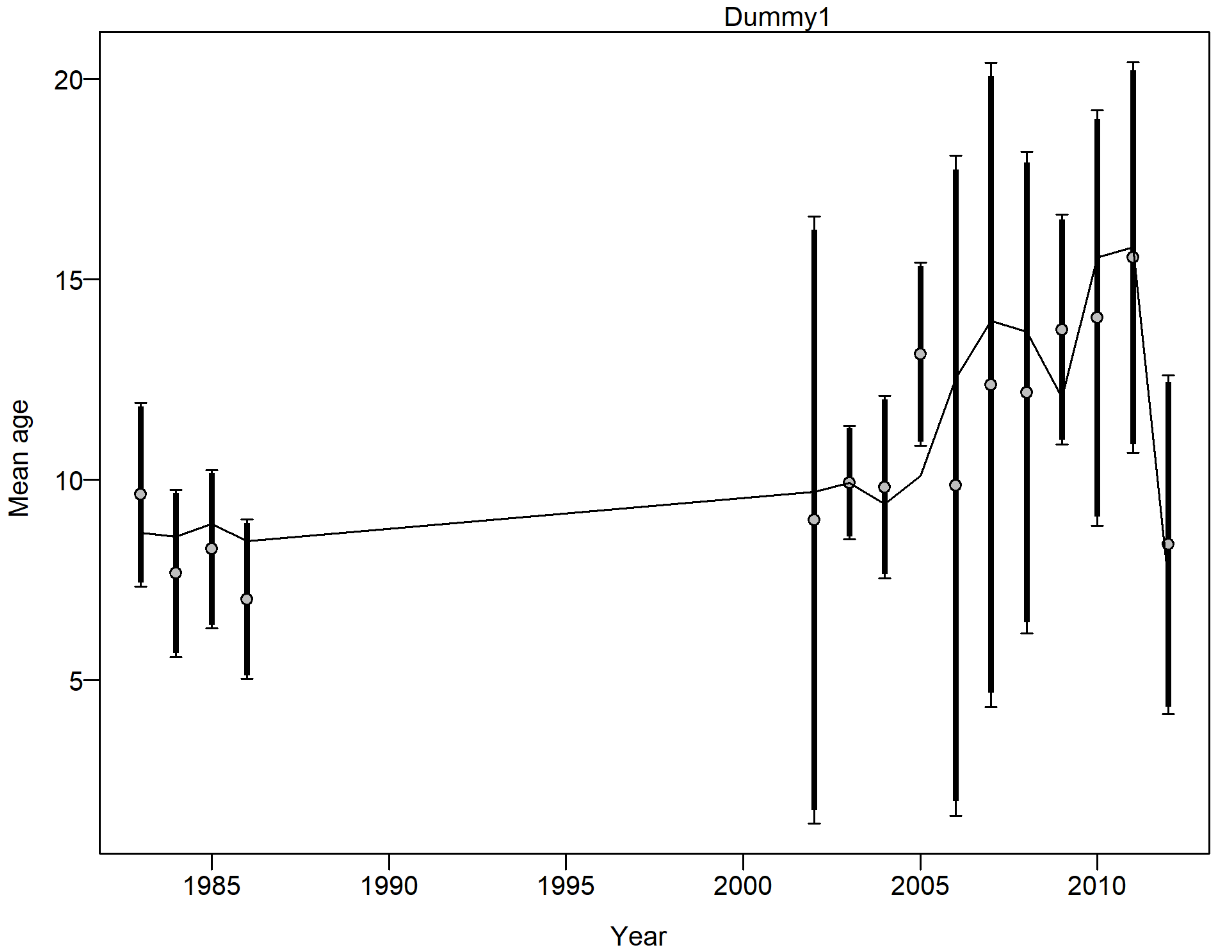

Figure 61: Mean age for the 'dummy' fleet with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.065 (0.507-3.692). For more info, see Francis et al. (2011). fig:comp_condAALfit_data_weigl

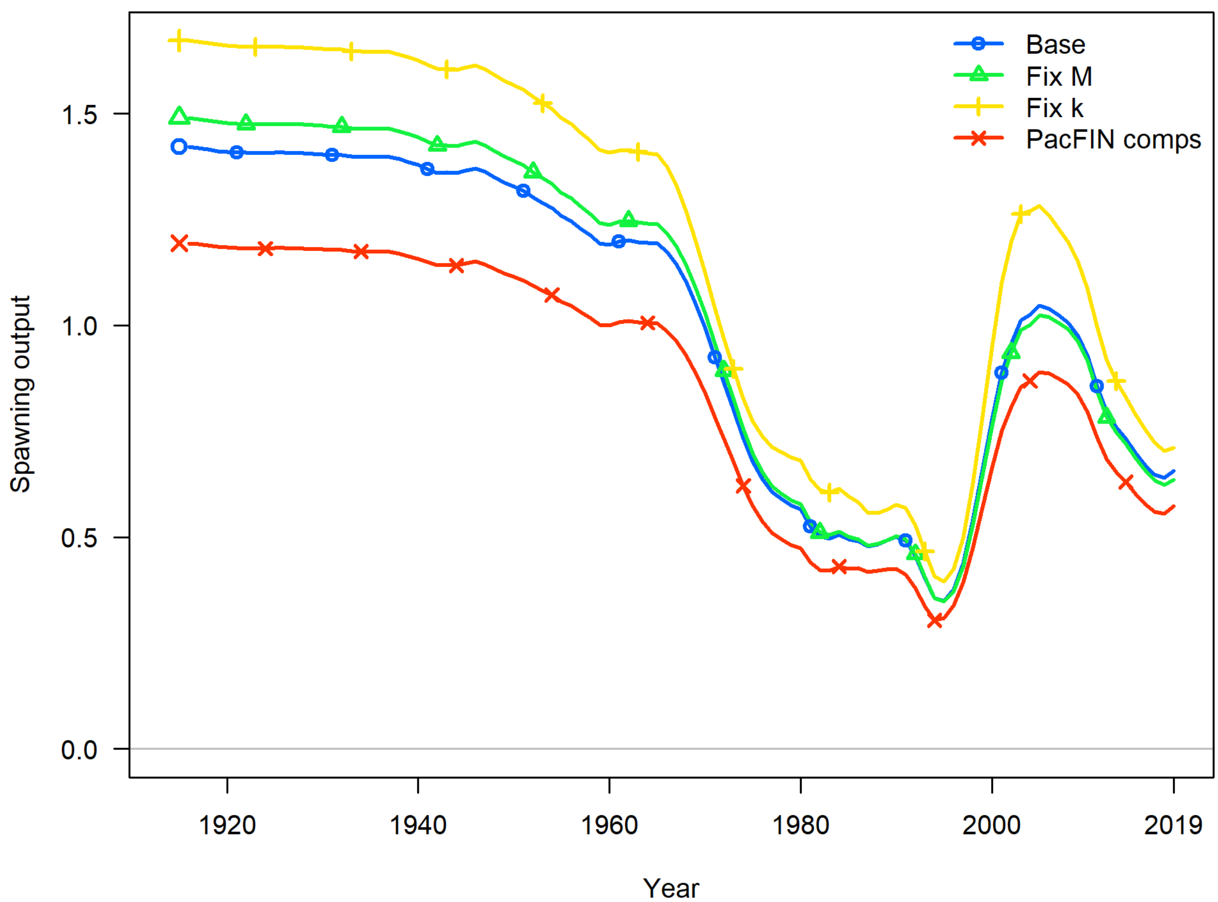

Figure 62: Sensitivity of the spawning biomass to fixing natural mortality to the prior, fixing the von Bertalanffy k parameter to the external estimate, or using commercial PacFIN length composition data instead of CALCOM, as compared to the pre-STAR base model. fig:sensitivity1_spa

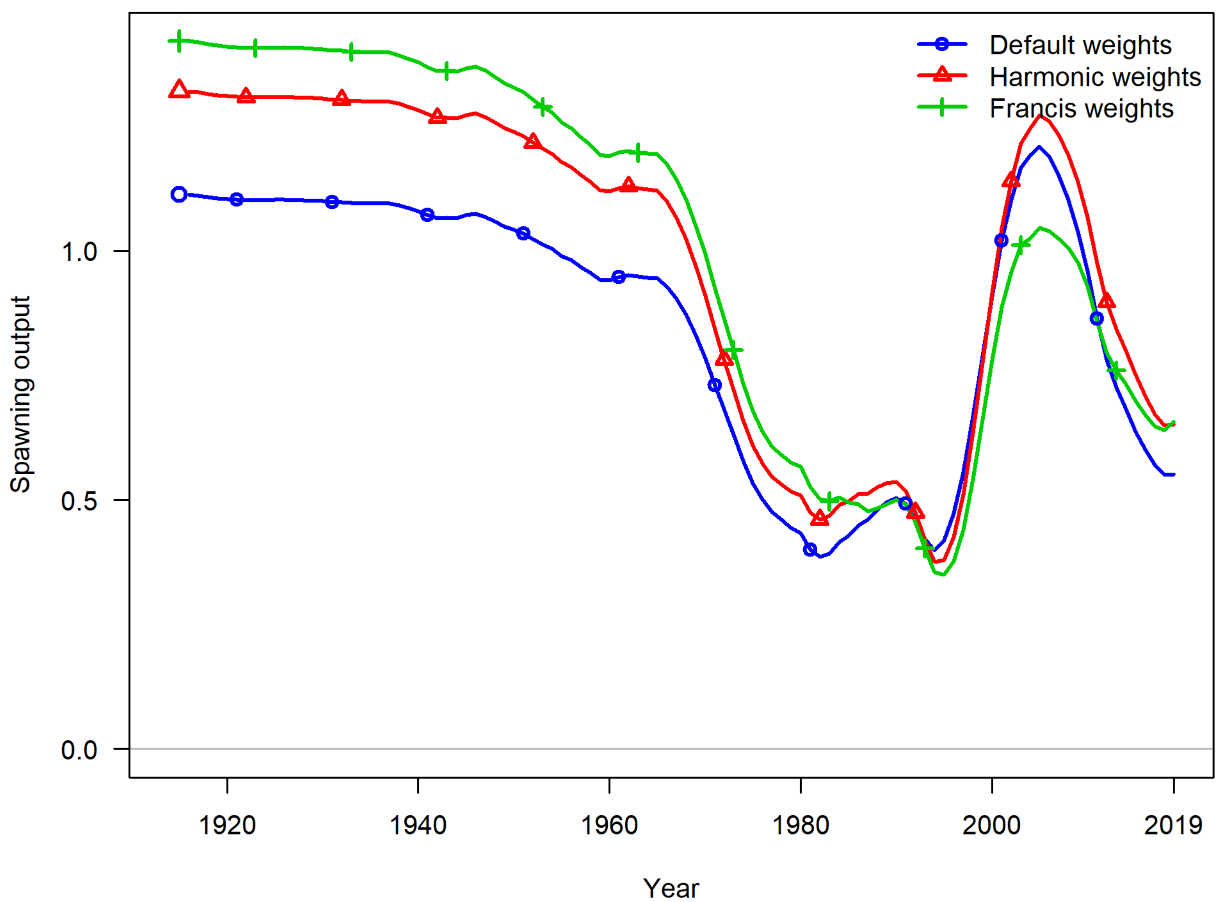

Figure 63: Sensitivity of the spawning biomass to either the default weight of composition data, the harmonic mean, or Francis weights. fig:sensitivity2_spawnbio

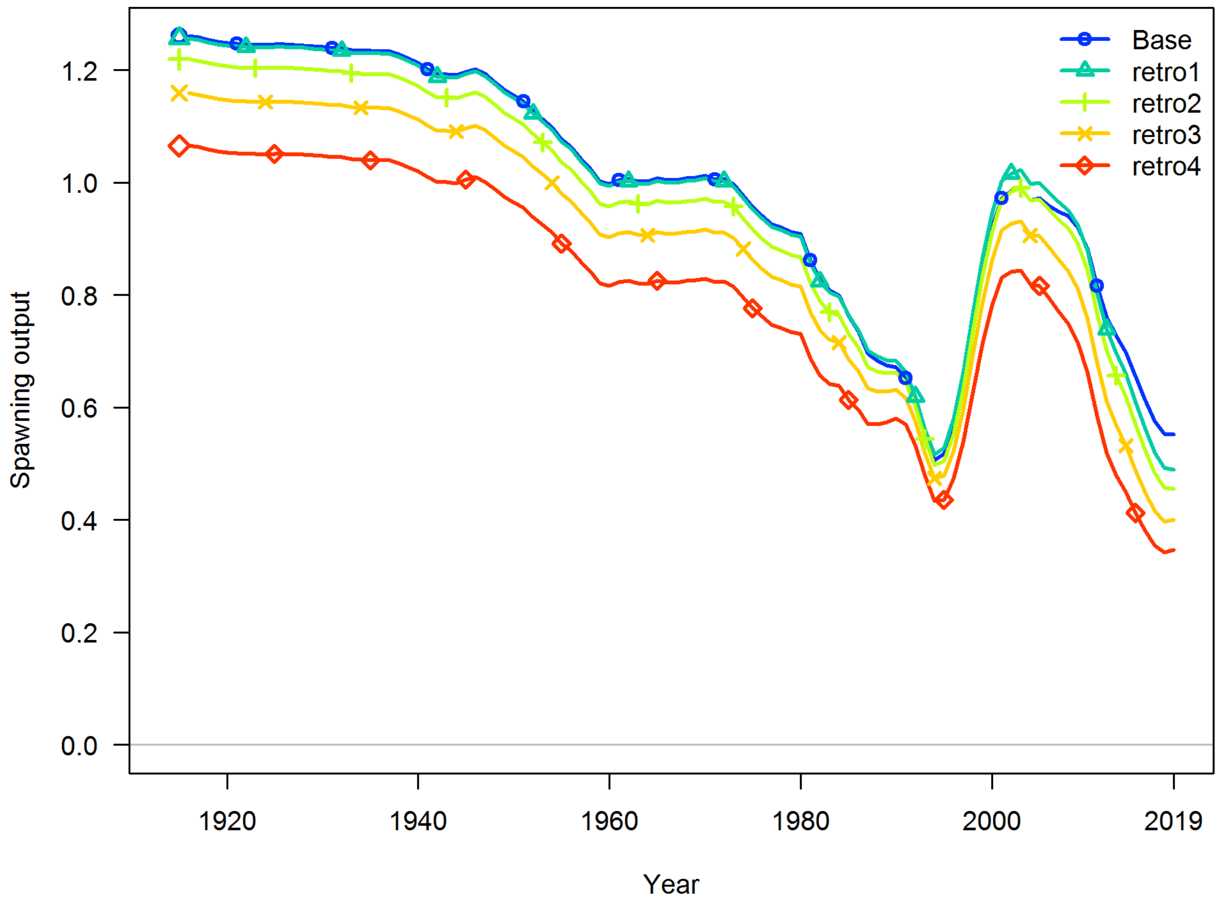

Figure 64: Retrospective pattern for spawning output. fig:retro_spawnb

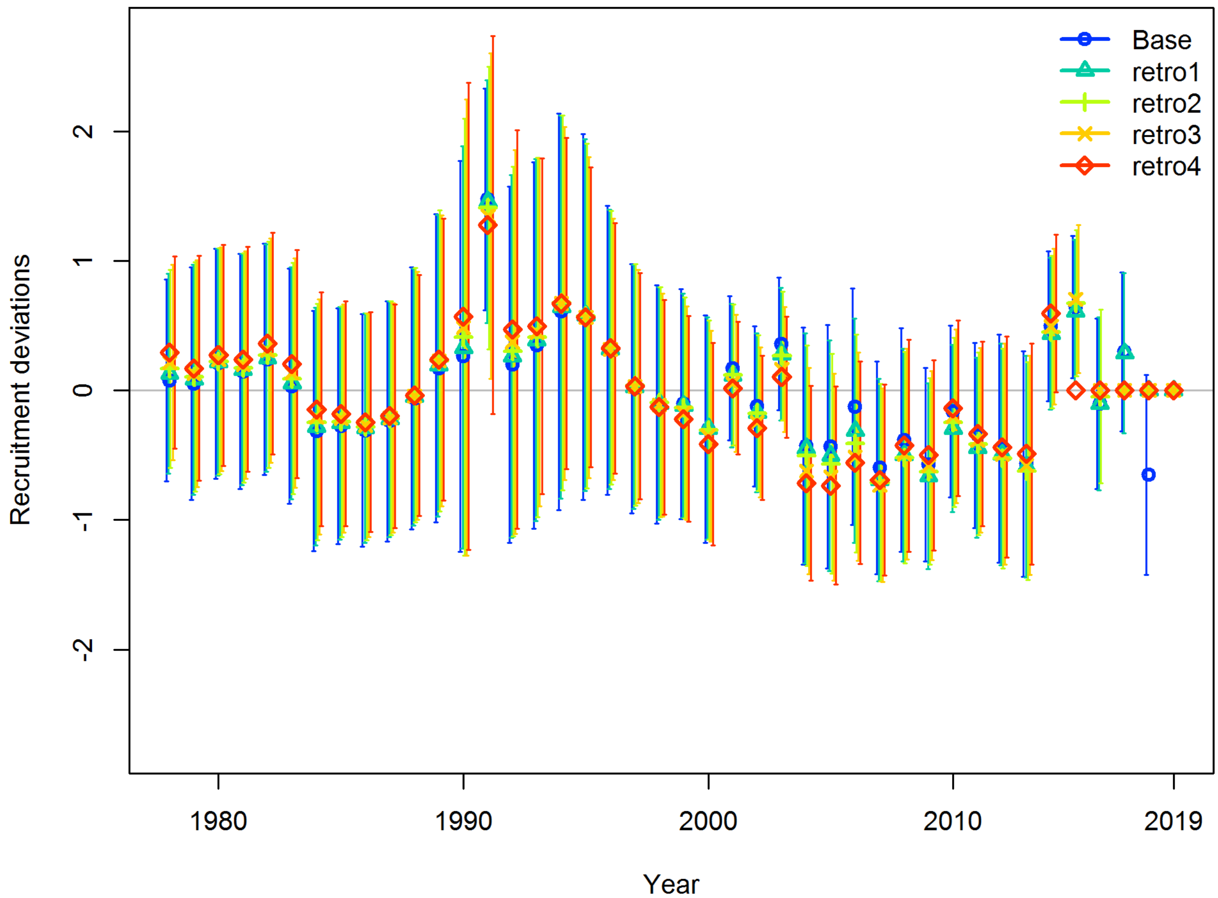

Figure 65: Retrospective pattern for estimated recruitment deviations. fig:retro_recdev

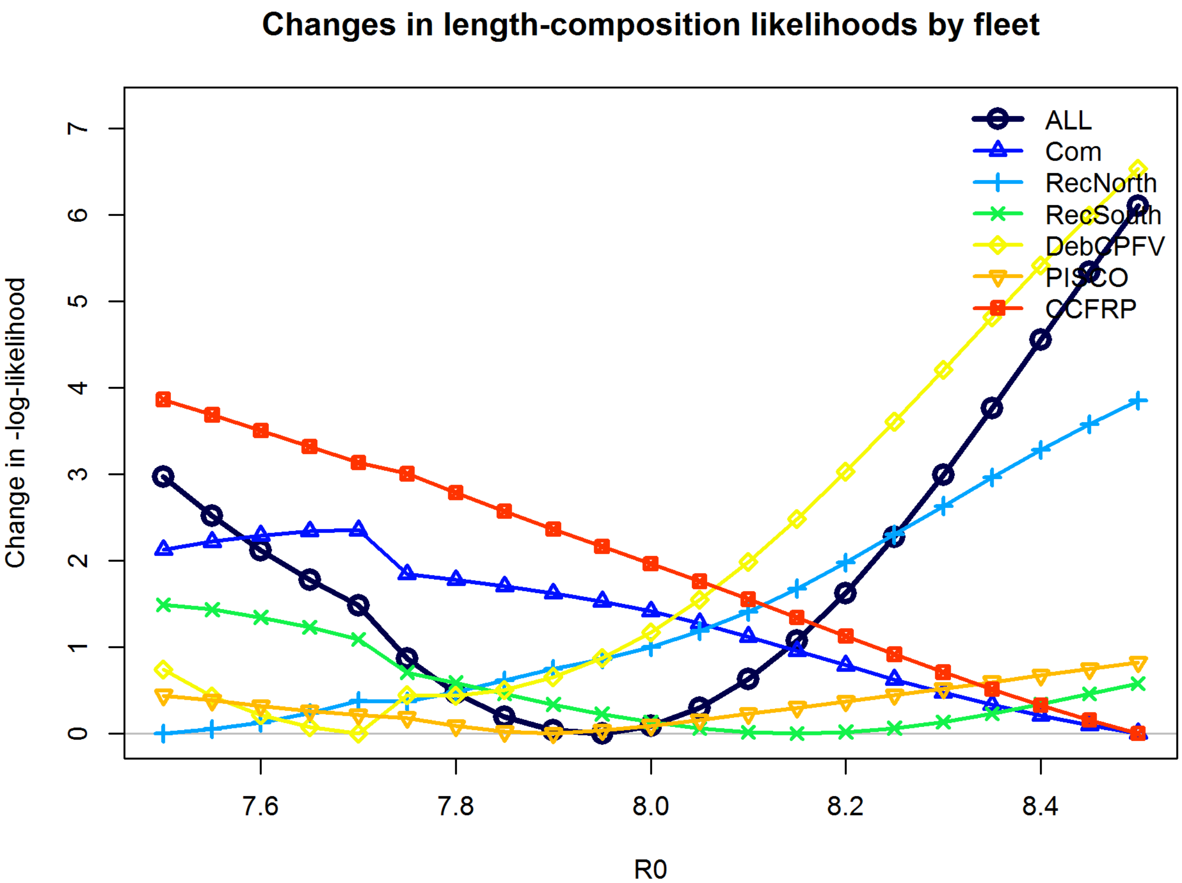

Figure 66: Likelihood profile across R_0 values of length composition by fleet. fig:profile_R0_pine

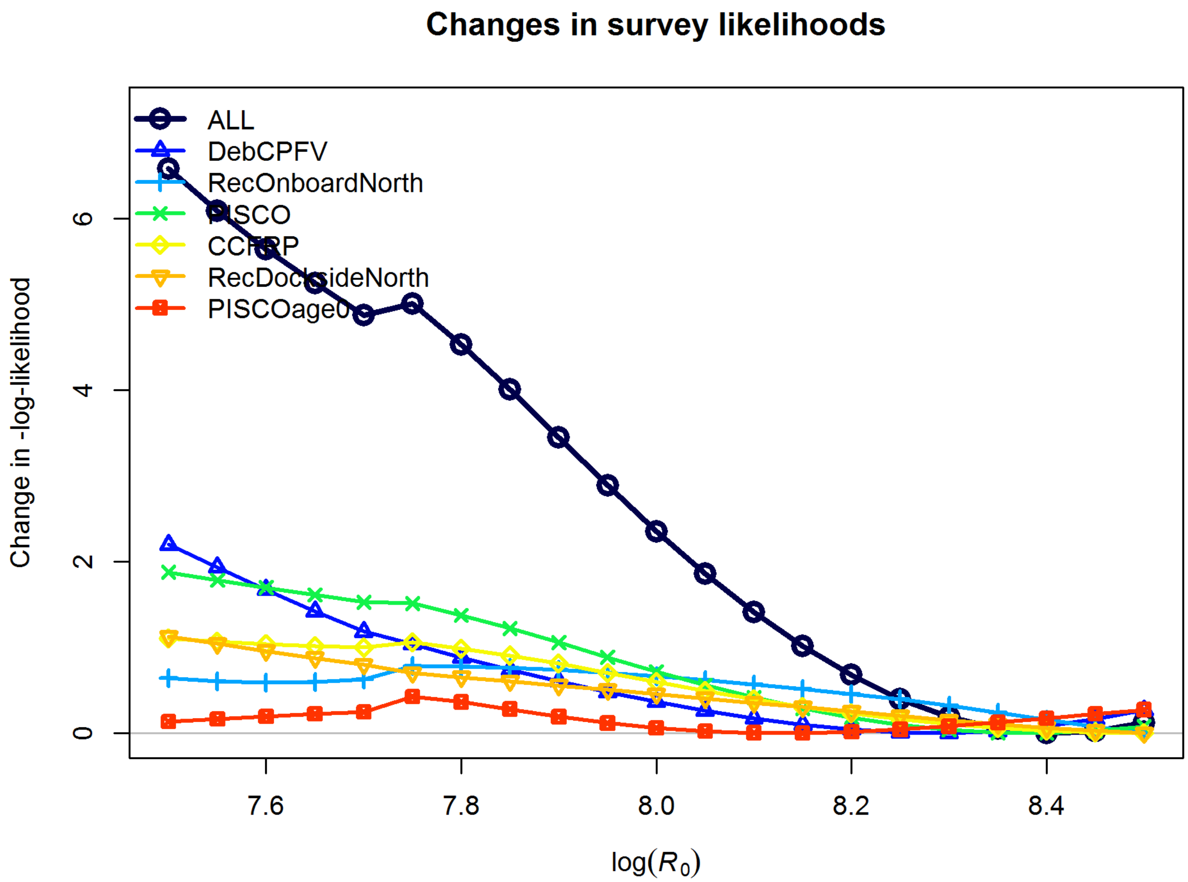

Figure 67: Likelihood profile for R_0 values across surveys. fig:profile_R0_piner2

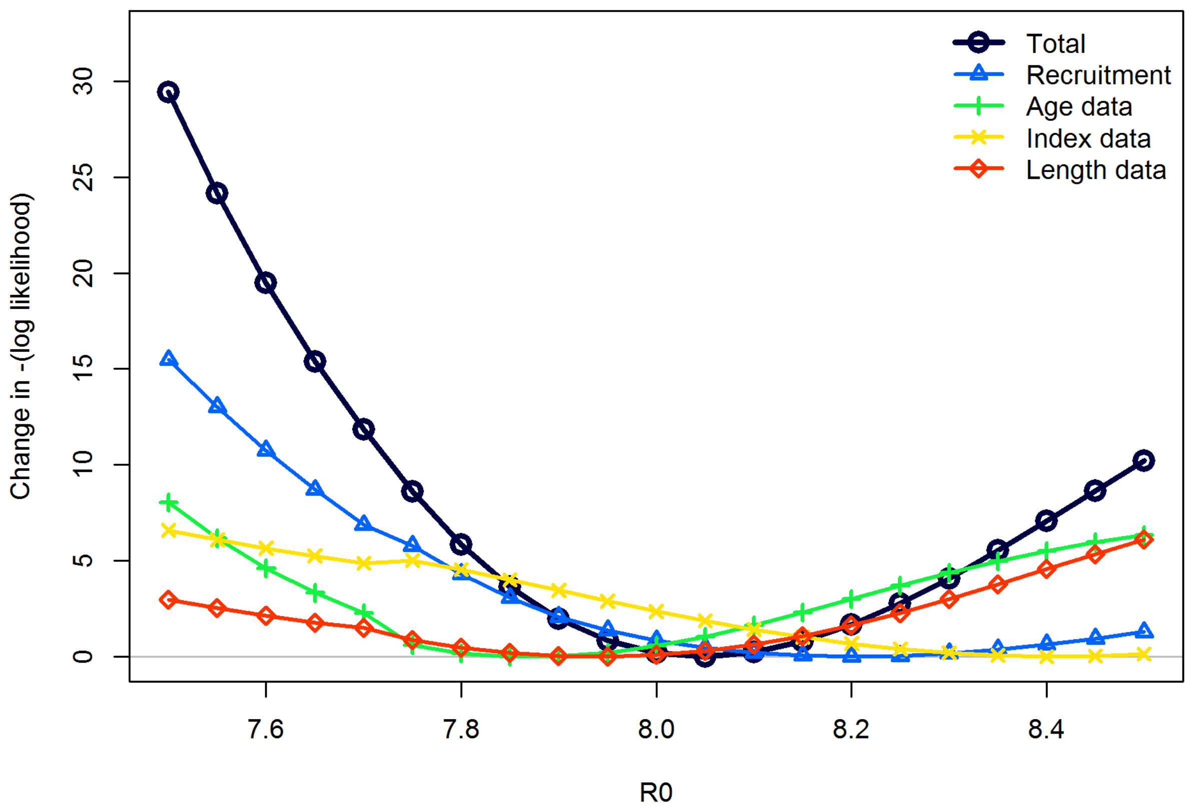

Figure 68: Likelihood profile across R_0 values for each data type. fig:profile_R0_like

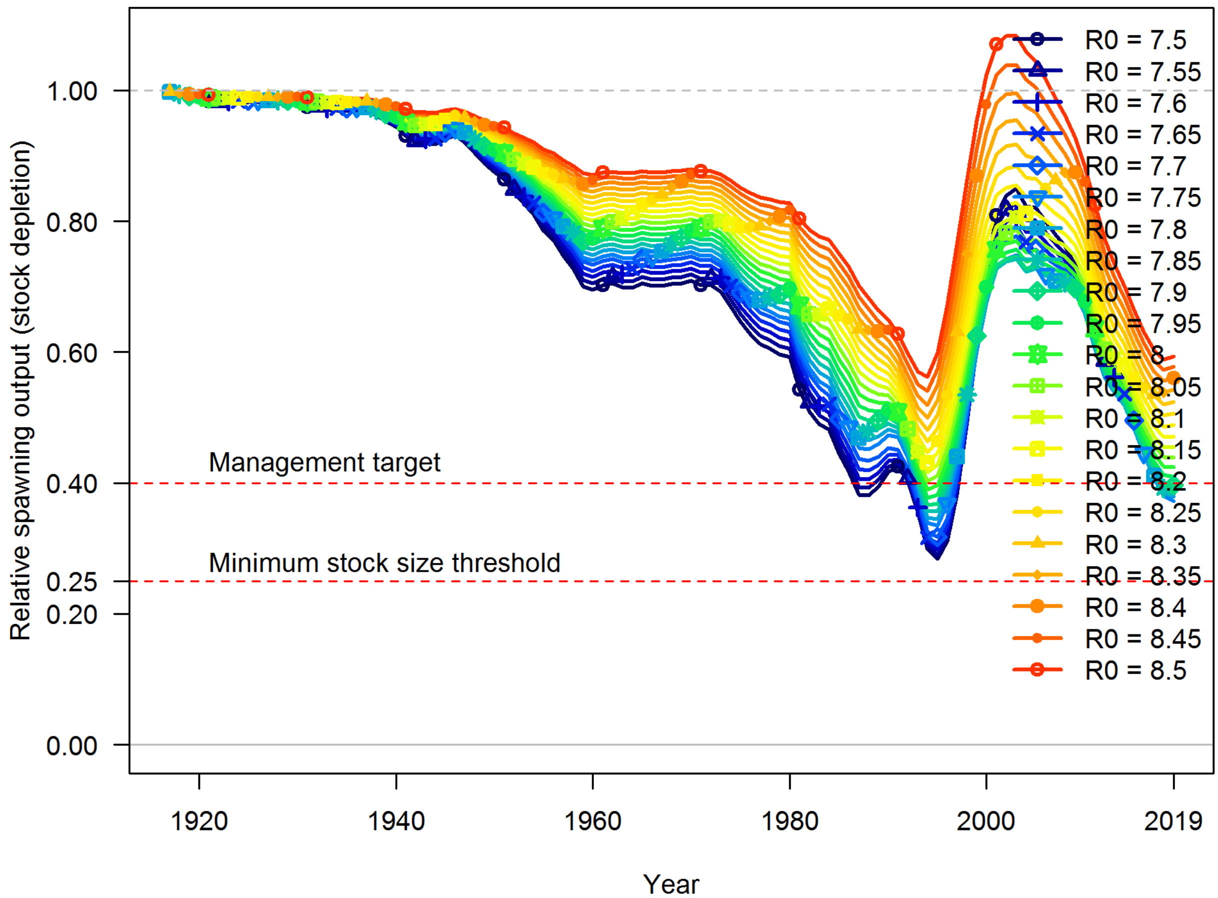

Figure 69: Trajectories of depletion across values of R_0. fig:profile_R0_depl

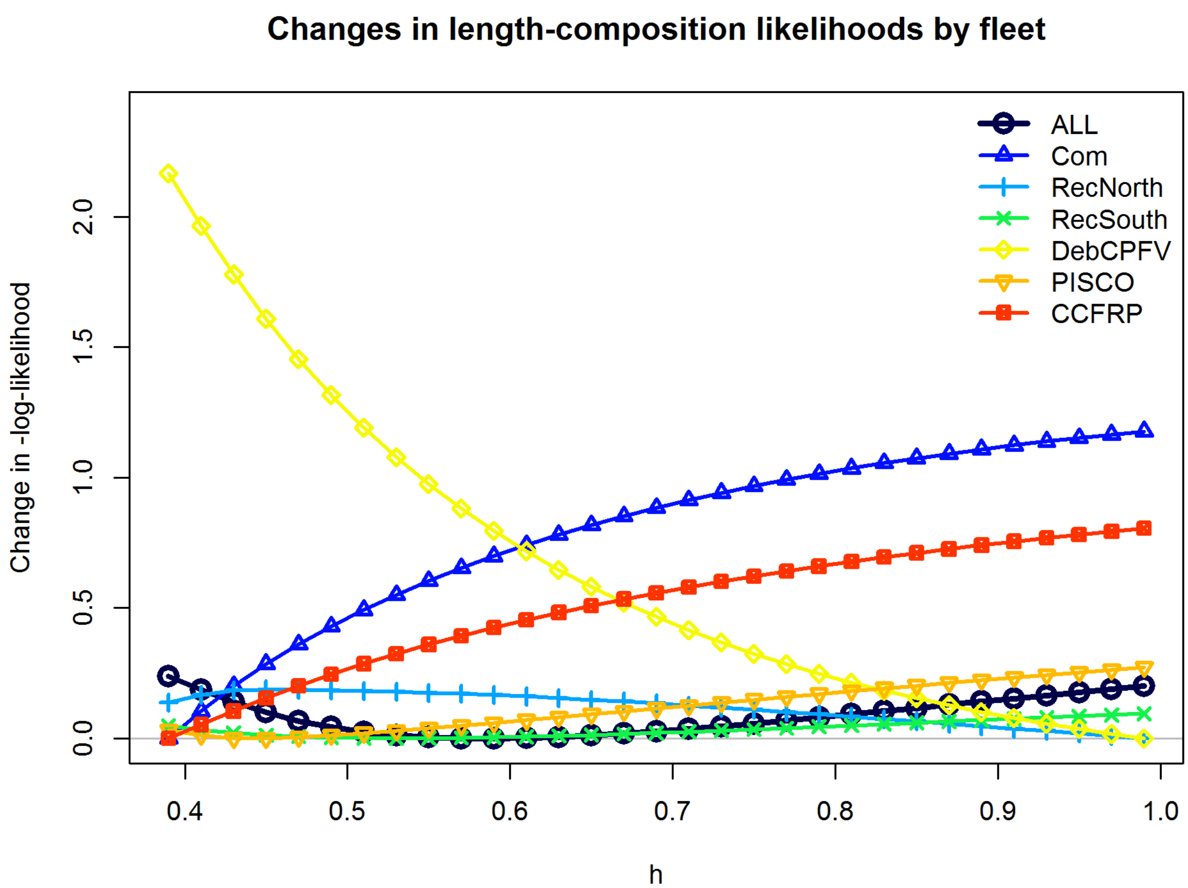

Figure 70: Likelihood profile across steepness values by fleet length composition. fig:profile_h_pin

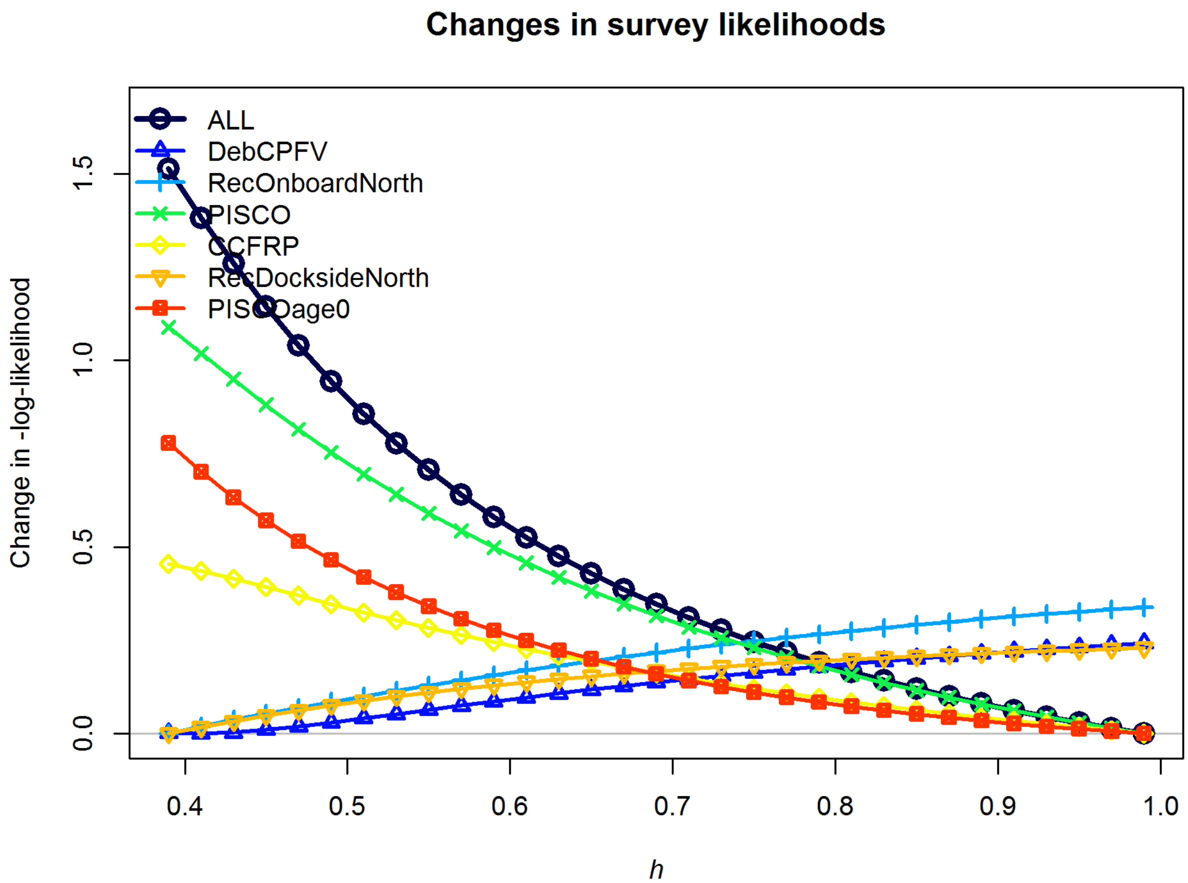

Figure 71: Likelihood profile across steepness values by surveys. fig:profile_h_piner2

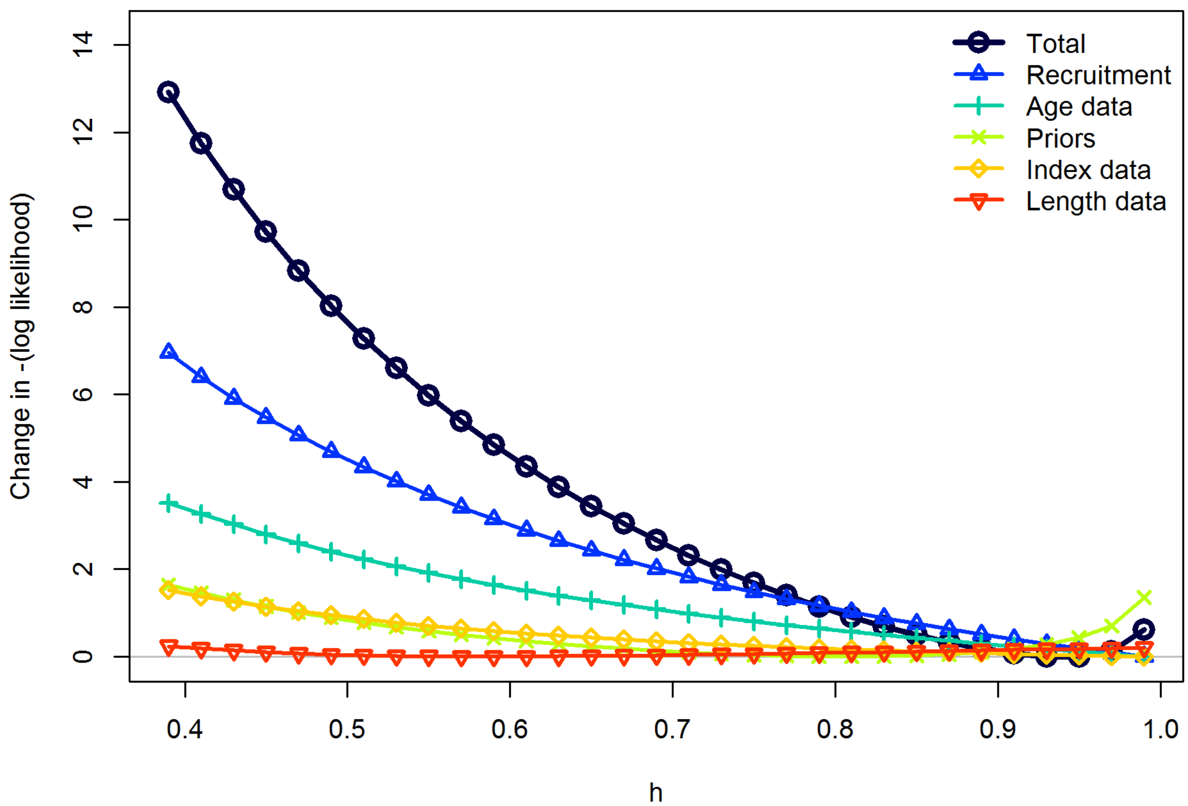

Figure 72: Likelihood profile across steepness values for each data type. fig:profile_h_like

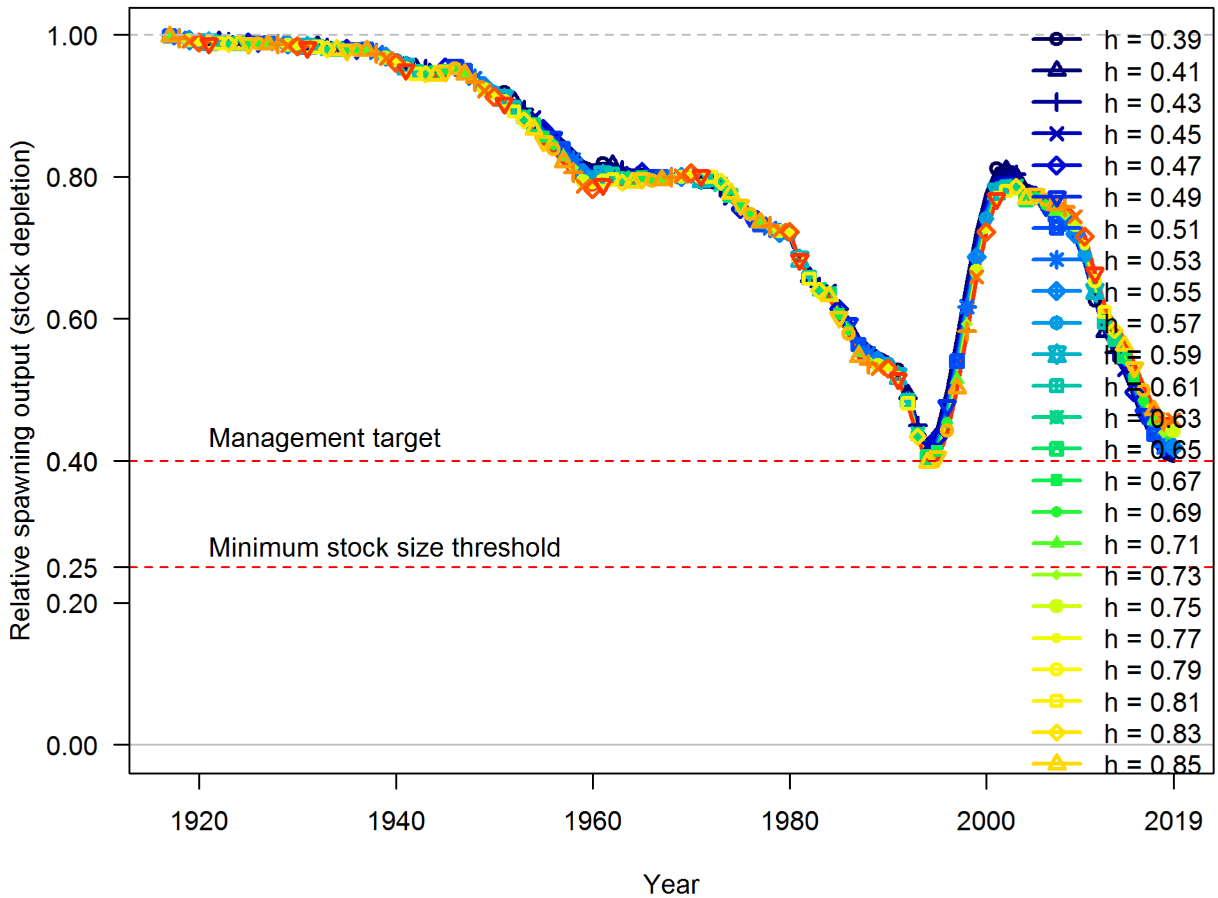

Figure 73: Trajectories of depletion across values of steepness. fig:profile_h_depl

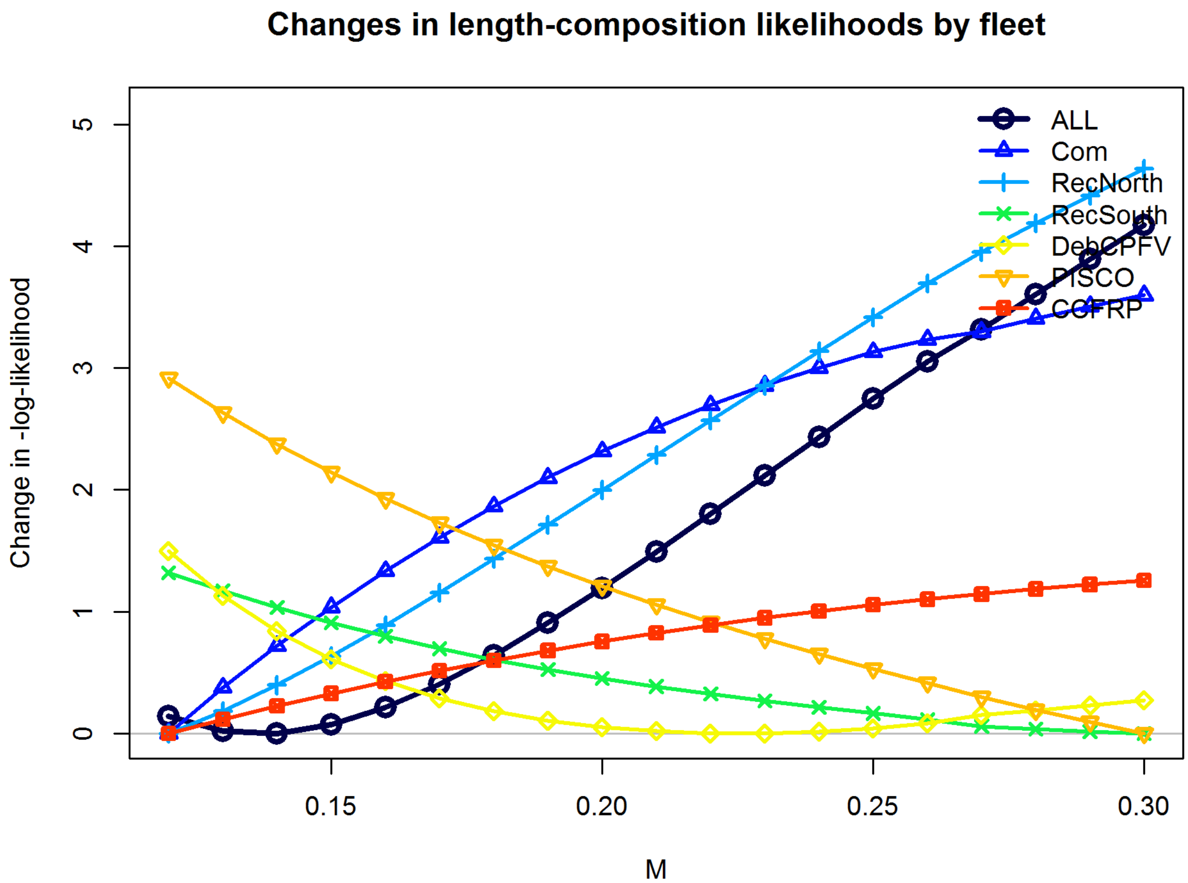

Figure 74: Likelihood profile across female natural mortality values by length composition. fig:profile_m

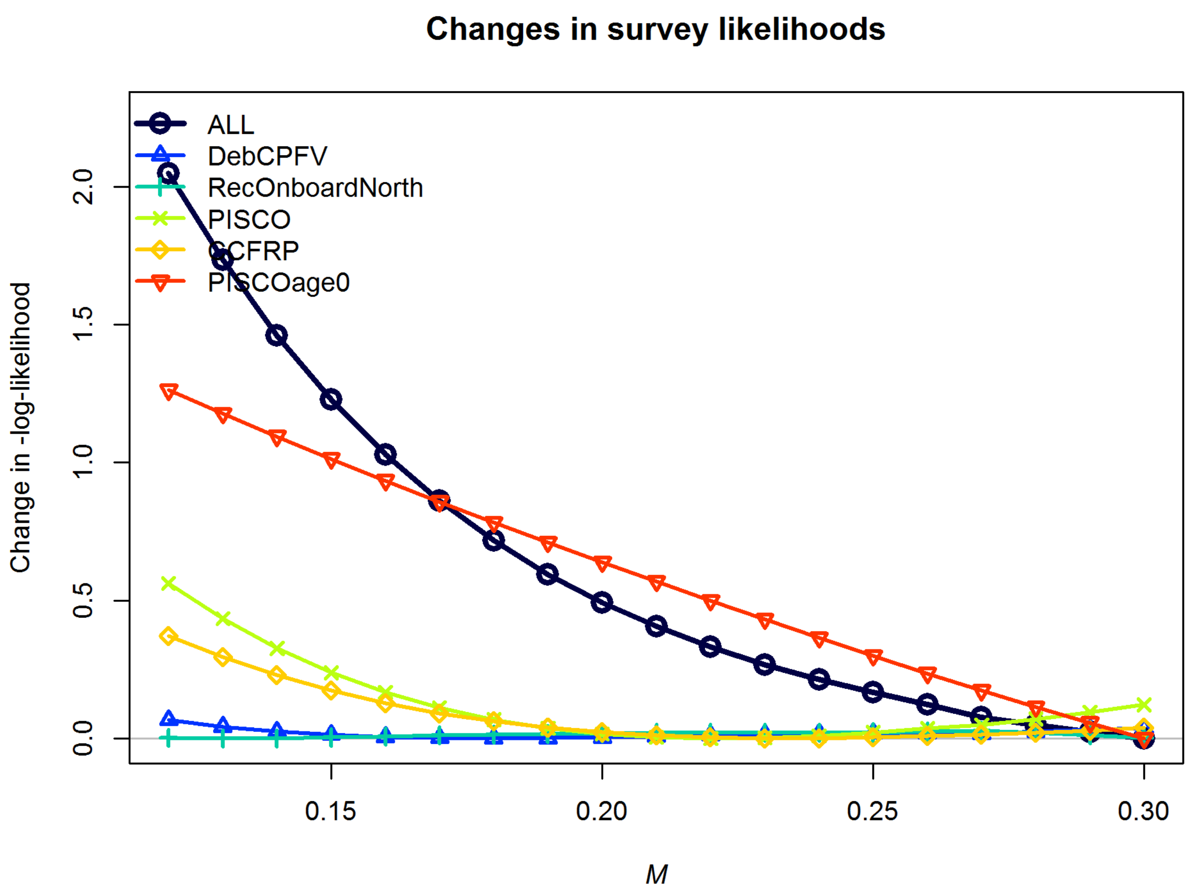

Figure 75: Likelihood profile across female natural mortality values by surveys. fig:profile_m_pine

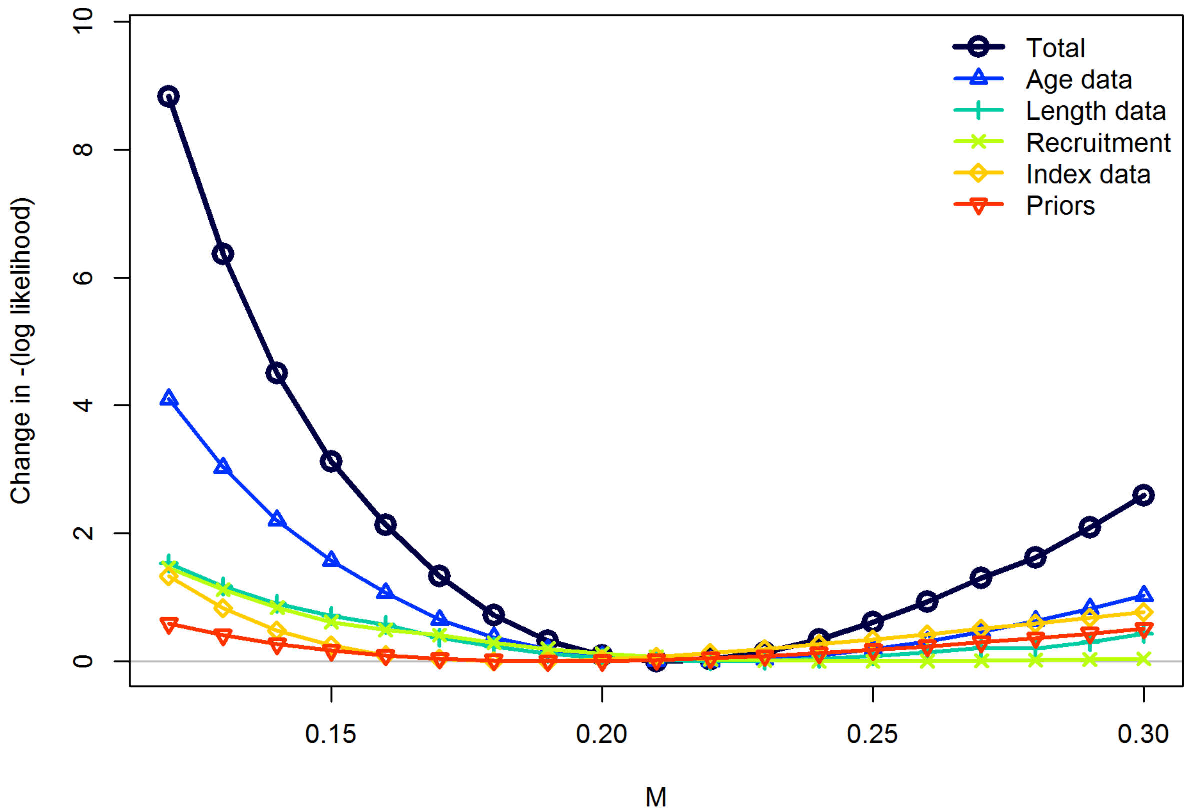

Figure 76: Likelihood profile across female natural mortality values for each data type. fig:profile_m_

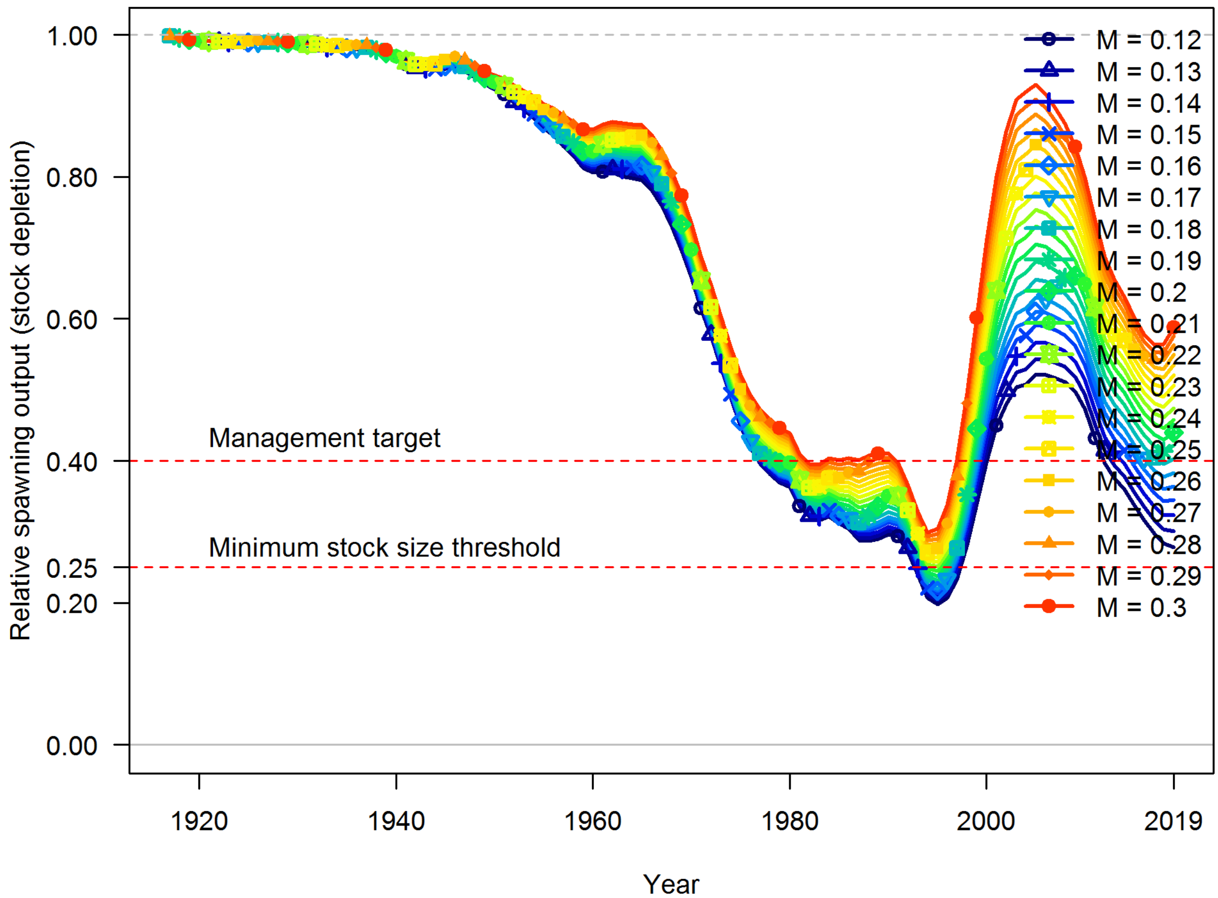

Figure 77: Trajectories of depletion across values of female natural mortality. fig:profile_m_depl

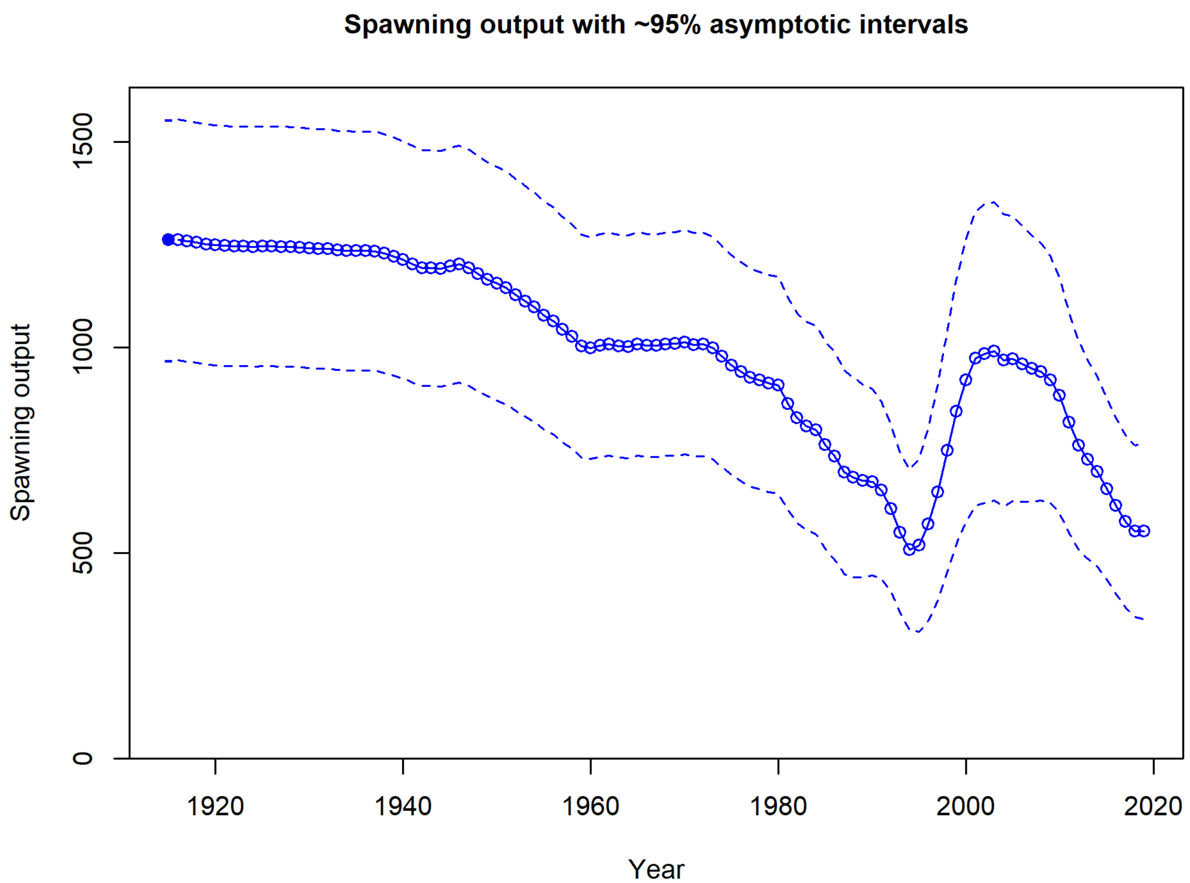

Figure 78: Estimated spawning output with approximate 95% asymptotic intervals. fig:ts7_Spawning

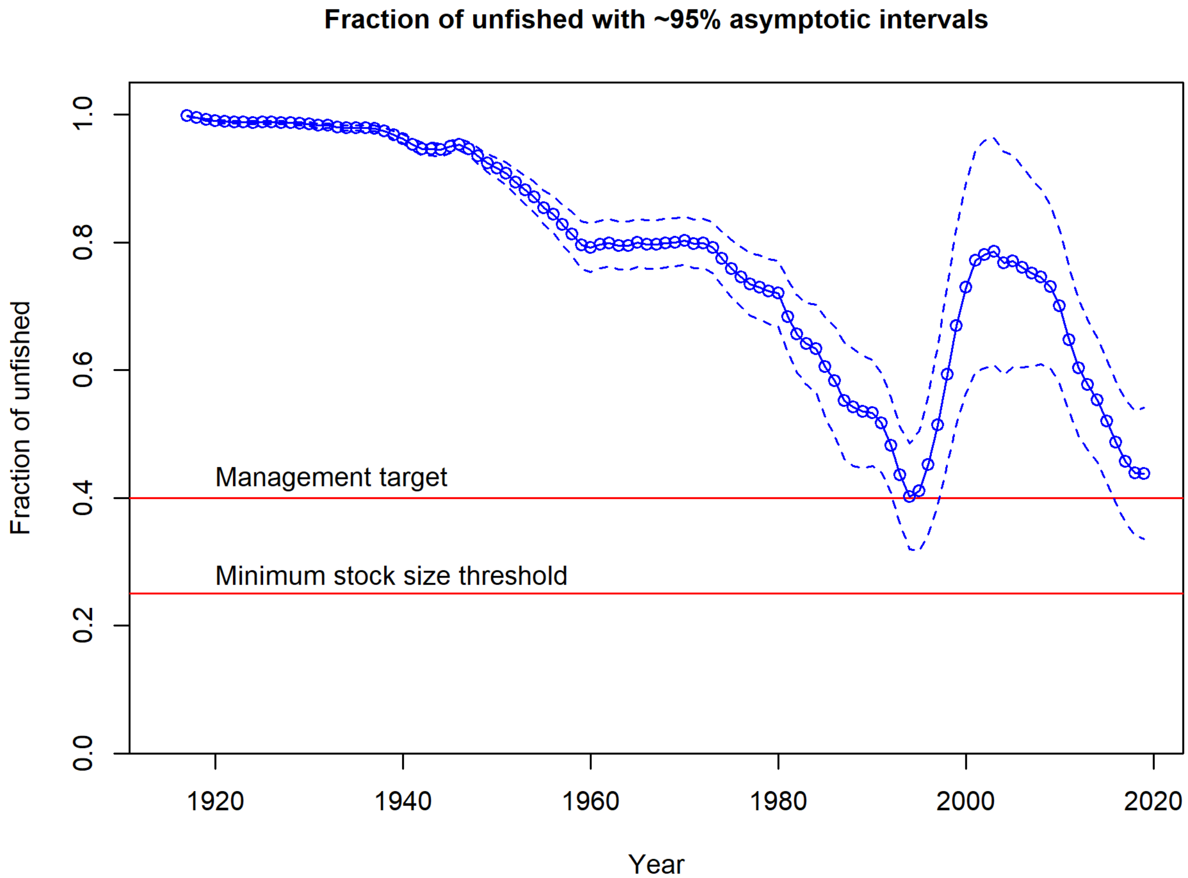

Figure 79: Estimated spawning depletion with approximate 95% asymptotic intervals. fig:ts9_unfishe

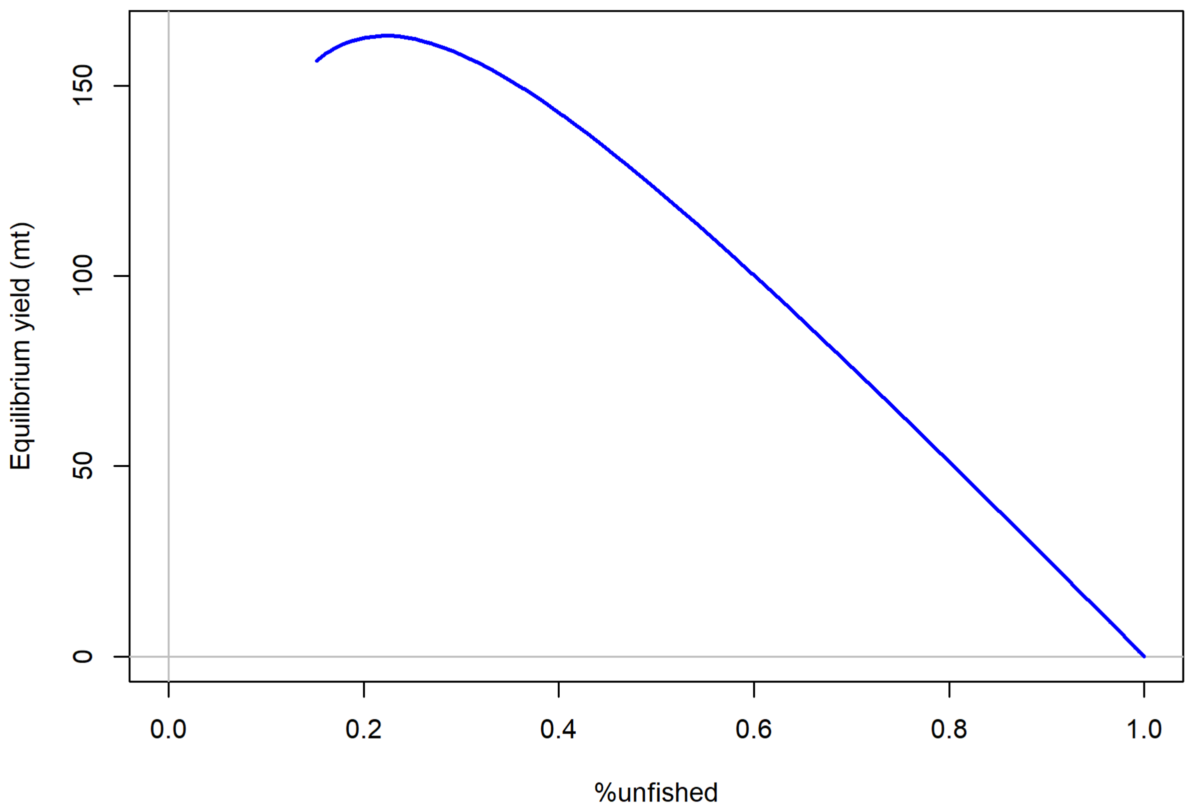

Figure 80: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.718. fig:yield1_yield_curve

Appendix A. California's Commercial Fishery Regulations

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

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

Figure A2 fig:Comm_regs1

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

Figure A3 fig:Comm_regs2

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

Figure A4 fig:Comm_regs3

Appendix B. California's Recreational Fishery Regulations

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

California's Recreational Fishing Regulations

Latitude Range		42°-40°10'	40°10'-38°57'	40°10'-37°11'	38°57'-37°11'	37°11'-36°	37°11'-34°27'	36°-34°27'	34°27'-Mex.
						Monterey		Morro Bay	
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		20
2001	Dec	Open					20		20
2002	Jan	Open					Open		Closed
2002	Feb	Open					Open		Closed
2002	Mar	Open					Closed		Open
2002	Apr	Open					Closed		Open
2002	May	Open					20		Open
2002	Jun	Open					20		Open
2002	Jul	Open					20		20
2002	Aug	Open					20		20
2002	Sep	Open					20		20
2002	Oct	Open					20		20
2002	Nov	Open					Closed		Closed
2002	Dec	Open					Closed		Closed
2003	Jan	Open					Closed		Closed
2003	Feb	Open					Closed		Closed
2003	Mar	Open					Closed		Closed
2003	Apr	Open					Closed		Closed
2003	May	Open					Closed		Closed
2003	Jun	Open					Closed		Closed
2003	Jul	Open					20		20
2003	Aug	Open					20		20
2003	Sep	Open					20		30
2003	Oct	Open					20		30
2003	Nov	Open					20		30
2003	Dec	Open->Closed					20->Closed		30->Closed
2004	Jan	Open		30				30	Closed
2004	Feb	Open		30				30	Closed
2004	Mar	Open		Closed				Closed	60
2004	Apr	Open		Closed				Closed	60
2004	May	30		Closed				20	60
2004	Jun	30		Closed				20	60
2004	Jul	30		Closed				Closed	60
2004	Aug	30		20				20	60
2004	Sep	30		20				20	30
2004	Oct	30		20				20	30
2004	Nov	30		Closed				20	60
2004	Dec	30		Closed				20	60

Figure B2 fig:Rec_regs1

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

Figure B4 fig:Rec_regs3

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

Figure B5 fig:Rec_reg4

Appendix C. Detailed fits to length composition data

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

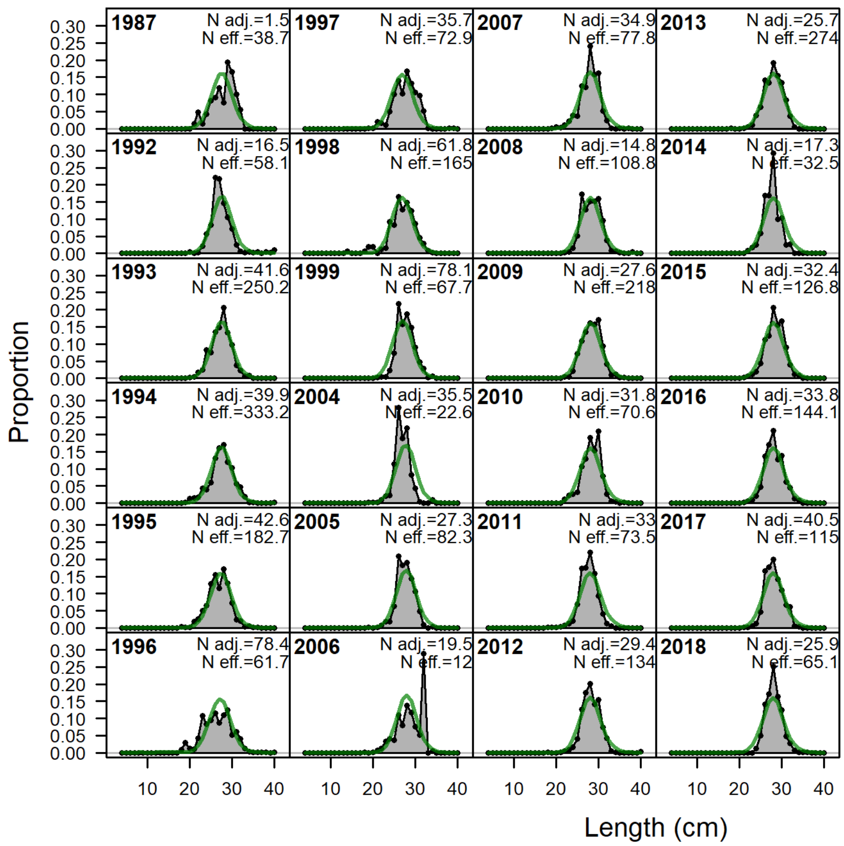

Figure C2: Length comps, retained, Com. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_1_comp_lenfit_flt1mkt2

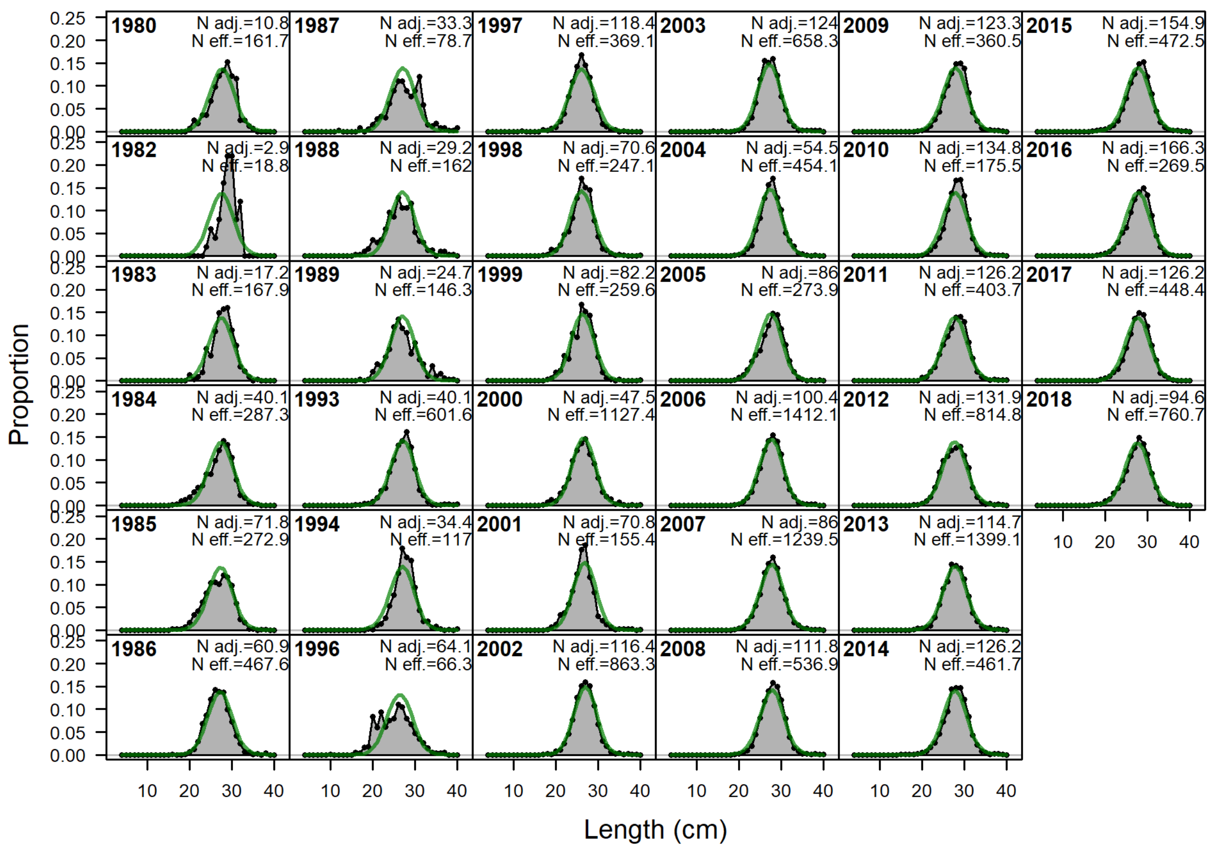

Figure C3: Length comps, whole catch, RecNorth. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_2_comp_lenfit_flt2mkt0

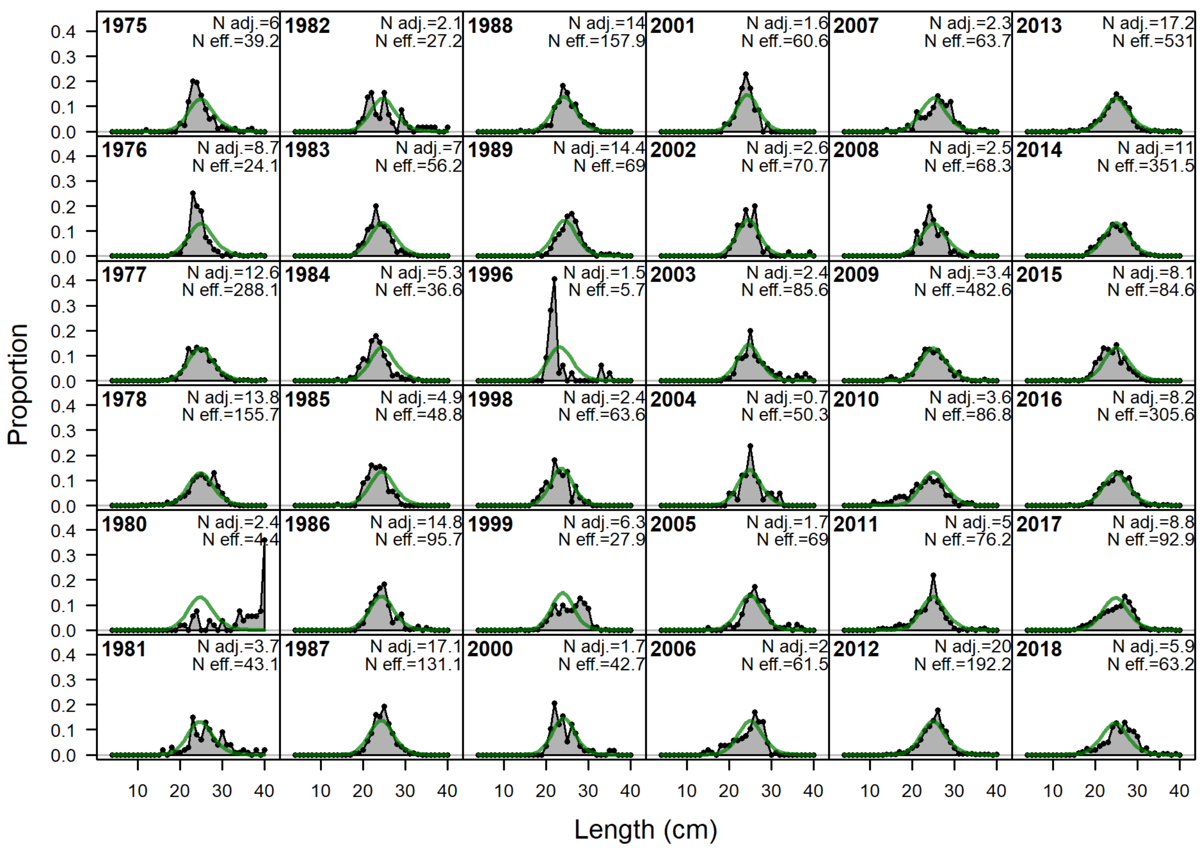

Figure C4: Length comps, whole catch, RecSouth. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_3_comp_lenfit_flt3mkt0

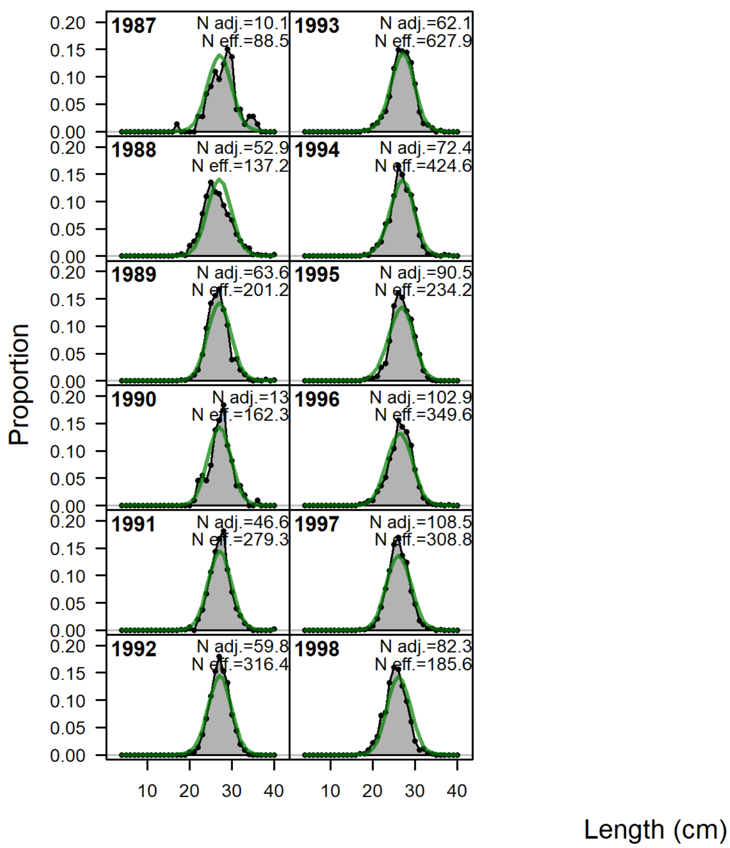

Figure C5: Length comps, whole catch, DebCPFV. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_4_comp_lenfit_flt4mkt0

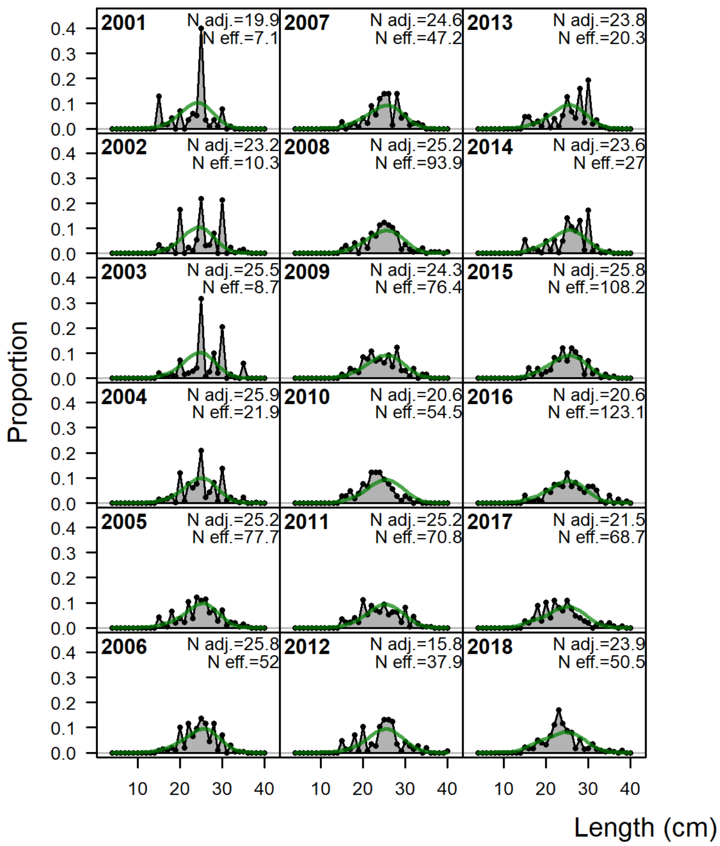

Figure C6: Length comps, whole catch, PISCO. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_5_comp_lenfit_flt6mkt0

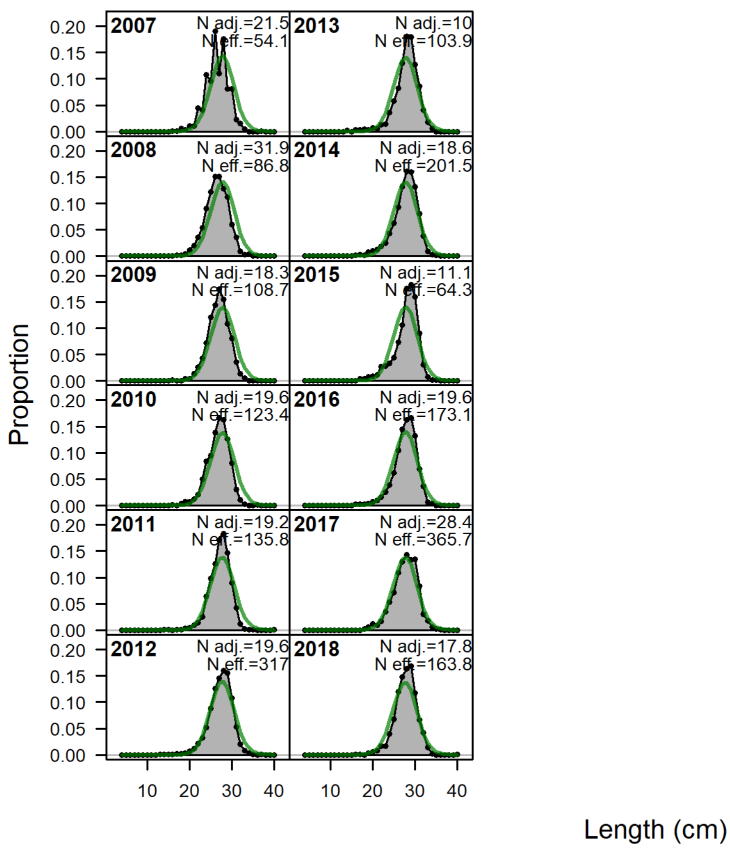

Figure C7: Length comps, whole catch, CCFRP. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. fig:mod1_6_comp_lenfit_flt7mkt0

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