

1 The Combined Status of Gopher (*Sebastodes*
2 *carnatus*) and Black-and-Yellow Rockfishes
3 (*Sebastodes chrysomelas*) in U.S. Waters Off
4 California in 2019



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

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- ²¹ Black-and-Yellow Rockfishes *Sebastodes chrysomelas* in U.S. Waters Off California in 2019. Pacific
- ²² Fishery Management Council, Portland, OR. Available from
- ²³ <http://www.pcouncil.org/groundfish/stock-assessments/>

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

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⁹⁶ **Executive Summary**

`executive-summary`

⁹⁷ **Stock**

`stock`

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

¹⁰⁵ **Catches**

`catches`

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

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

¹¹⁸ Since 2000, annual total landings of catch and discards of GBYR have ranged between 70-169
¹¹⁹ mt, with landings (catch + discards) in 2018 totaling 92 mt.



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

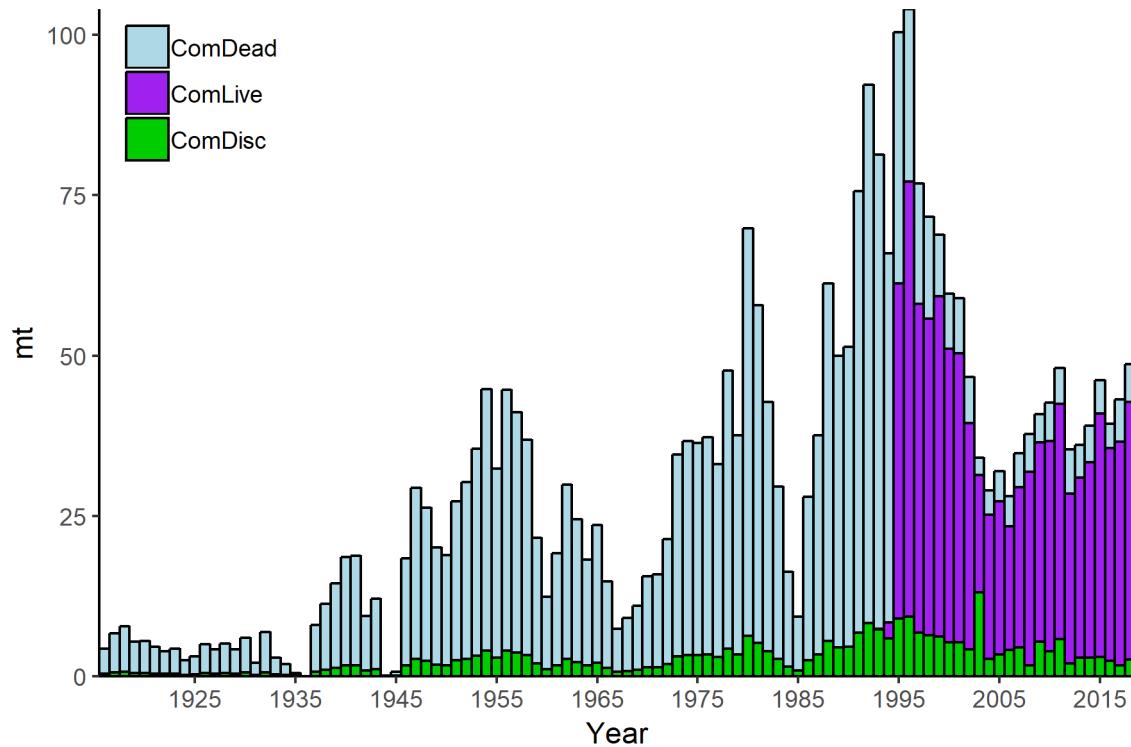


Figure b: Catch history of GBYR for the commercial fleet by dead and live landings, and discards. Catches in 1936 and 1946 were minimal. ^{fig:Exec_catch2}

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

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

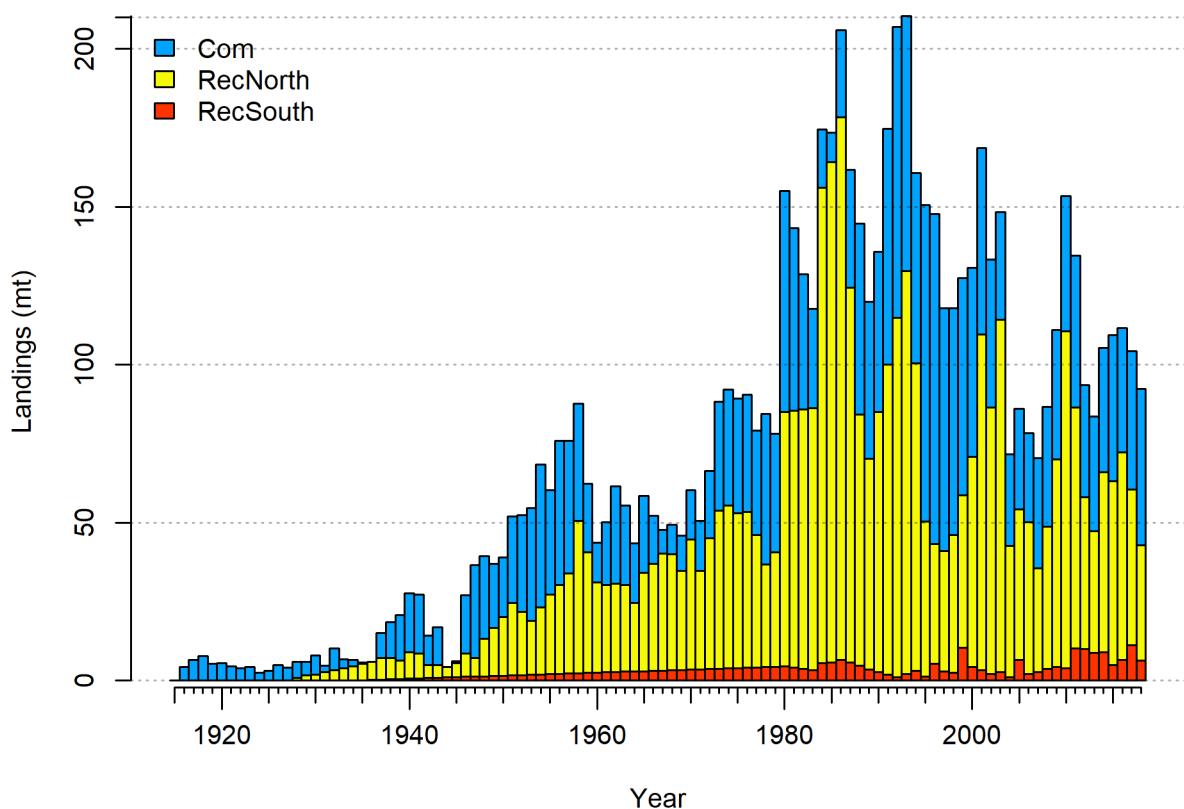


Figure c: Catch history of GBYR in the model. [fig:r4ss_catches](#)

¹²⁰ **Data and Assessment**

data-and-assessment

¹²¹ Gopher rockfish north of Point Conception ($34^{\circ}27'$ N. latitude) was first assessed as a full
¹²² stock assessment in 2005 (Key et al. 2005) using SS2 (version 1.19). The assessment was
¹²³ sensitive to the CPFV onboard observer index of abundance (referred to as Deb Wilson-
¹²⁴ Vandenberg's onboard observer index in this assessment). The final decision table was based
¹²⁵ around the emphasis given to a fishery-dependent index of abundance for the recreational
¹²⁶ fleet. The stock was found to be at 97% depletion.

¹²⁷ Gopher rockfish south of Point Conception was assessed as a data poor species in 2010 (Dick
¹²⁸ and MacCall 2010). A Depletion-Corrected Average Catch (DCAC) model was used due to
¹²⁹ time constraints. The mean yield from the DCAC distribution was 25.5 mt.

¹³⁰ This is the first full assessment to include data for black-and-yellow rockfish. Black-and-
¹³¹ yellow rockfish was assessed coastwide as a data poor species using Depletion-Based Stock
¹³² Reduction Analysis (DB-SRA) (Dick and MacCall 2010). The DB-SRA model assigned a
¹³³ 40% probability that the then recent (2008-2009) catch exceeded the 2010 OFL.

¹³⁴ This assessment covers the area from Cape Mendocino to the U.S./Mexico border (Figure
¹³⁵ d). The length composition data suggested that while the lengths of gopher and black-and-
¹³⁶ yellow rockfish were similar, fish encountered south of Point Conception were smaller. The
¹³⁷ similarity of the length distributions between species and among modes within a region were
¹³⁸ similar and justified one combined recreational fleet within each of the two regions (north
¹³⁹ and south of Point Conception).

¹⁴⁰ This stock assessment retains a single fleet for the commercial fishery, including discards.
¹⁴¹ Data on commercial discards were not available for and not included in the 2005 assessment.
¹⁴² The decision to retain one commercial fleet was made by examining the length distributions
¹⁴³ across species, fishing gears, and space, i.e., north and south of Point Conception. There is
¹⁴⁴ very little difference between the length composition of gopher and black-and-yellow rockfish
¹⁴⁵ landed in the commercial fleet north of Point Conception.

¹⁴⁶ A number of sources of uncertainty are addressed in this assessment. This assessment in-
¹⁴⁷ cludes length data, estimated growth, an updated length-weight curve, an updated maturity
¹⁴⁸ curve, a number of new indices, and new conditional length at age data.

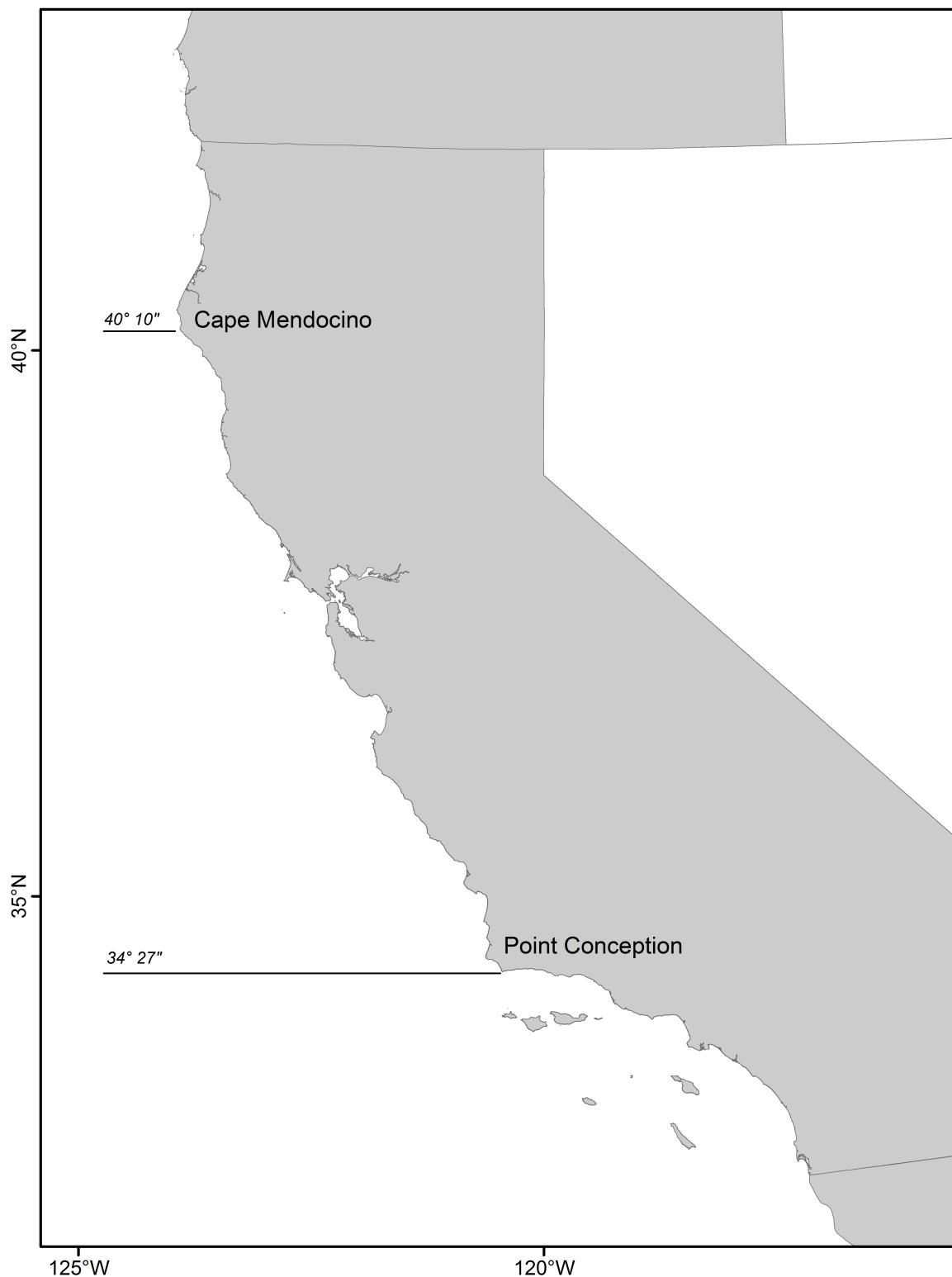


Figure d: Map depicting the core distribution of gopher and black-and-yellow rockfishes. The stock assessment is bounded at Cape Mendocino in the north to the U.S./Mexico border in the south. [fig:assess_region_map](#)

¹⁴⁹ **Stock Biomass**

stock-biomass

¹⁵⁰ The predicted spawning output from the base model generally showed a slight decline prior
¹⁵¹ to 1978, when the recruitment deviations were first estimated (Figure e and Table b). The
¹⁵² stock declined from 1978 to 1994, followed by a period increase from 1995 to 2003. From
¹⁵³ 2004-2018 the stock has been in decline, with an increase in total biomass since 2016 and
¹⁵⁴ stable spawning output since 2018. The 2018 estimated spawning output relative to unfished
¹⁵⁵ equilibrium spawning output is above the target of 40% of unfished spawning output at 43.82
¹⁵⁶ (95% asymptotic interval: 33.57-54.06) (Figure f). Approximate confidence intervals based
¹⁵⁷ on the asymptotic variance estimates show that the uncertainty in the estimated spawning
¹⁵⁸ output is high, (95% asymptotic interval: 337-767 million eggs).

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

Year	Spawning Output (million eggs)	~ 95% confidence interval	Estimated depletion	tab:SpawningDeplete_mod1 ~ 95% confidence interval
2010	882	597 - 1168	69.99	58.05 - 81.92
2011	817	548 - 1086	64.77	53.48 - 76.06
2012	761	507 - 1014	60.33	49.63 - 71.03
2013	727	486 - 968	57.66	47.5 - 67.81
2014	697	466 - 928	55.31	45.56 - 65.05
2015	655	434 - 877	51.98	42.4 - 61.55
2016	614	399 - 828	48.69	39.16 - 58.22
2017	576	367 - 786	45.70	36.12 - 55.28
2018	553	344 - 762	43.85	34.08 - 53.63
2019	552	337 - 767	43.82	33.57 - 54.06

Spawning output with ~95% asymptotic intervals

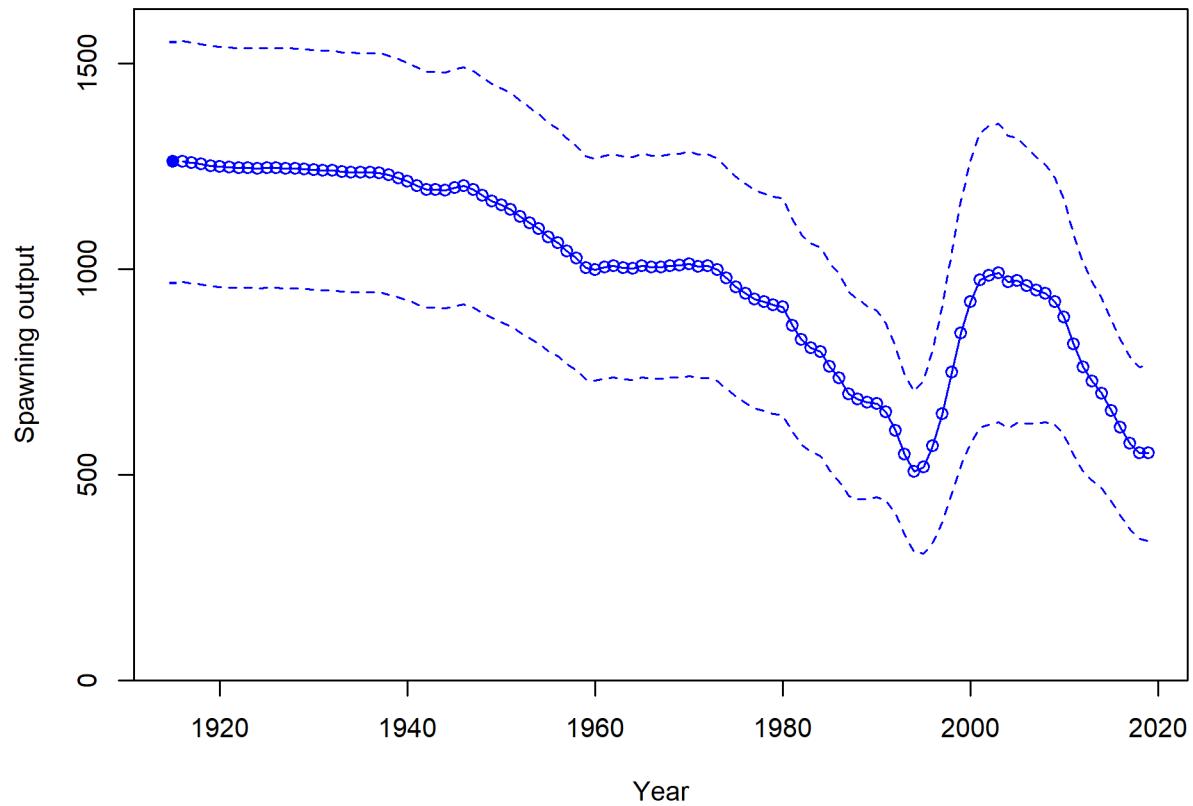


Figure e: Time series of spawning biomass trajectory (circles and line; median; light broken lines: 95% credibility intervals) for the base case assessment model. | [fig:Spawnbio_all](#)

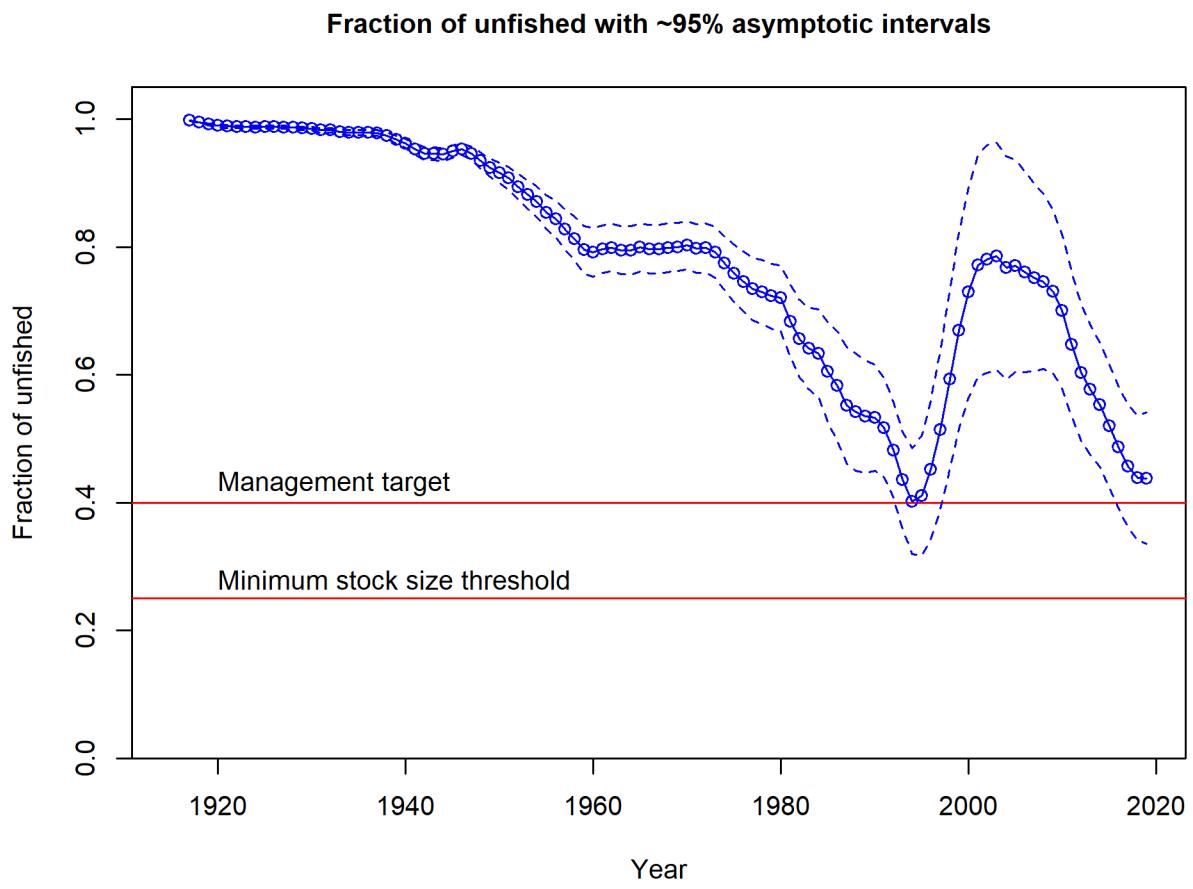


Figure f: Estimated percent depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model. fig:Re1Deplete_all

¹⁵⁹ **Recruitment**

recruitment

¹⁶⁰ Recruitment deviations were estimated from 1979-2018 (Figure [g](#) and Table [c](#)). There are
¹⁶¹ estimates of very strong recruitment in 1991. Estimated recruitment pulses were estimated
¹⁶² for a number of other years including 1994-1995 and 2014-2015.

Table c: Recent recruitment for the GBYR assessment.

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

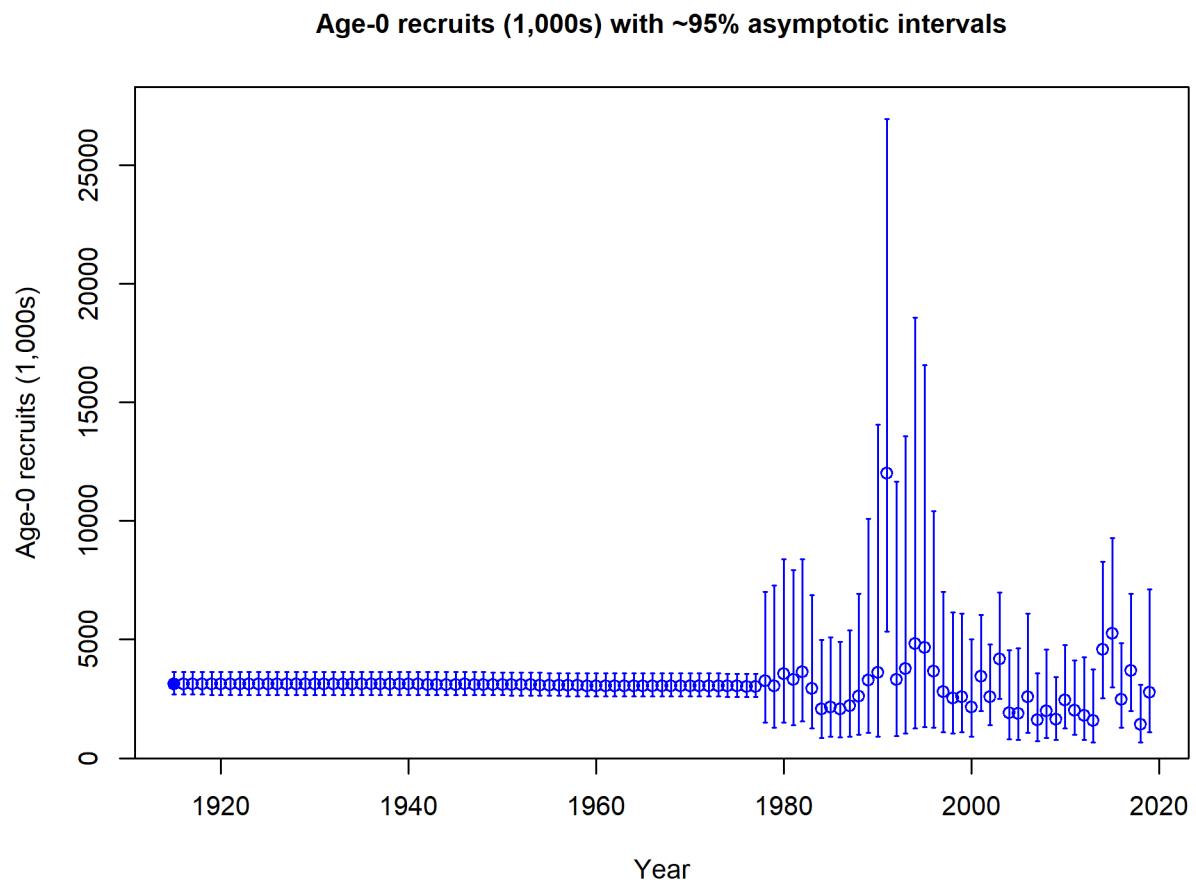


Figure g: Time series of estimated GBYR recruitments for the base-case model with 95% confidence or credibility intervals. [fig:Recruits_all](#)

¹⁶³ **Exploitation status**

exploitation-status

¹⁶⁴ Harvest rates estimated by the base model indicate catch levels have been below the limits
¹⁶⁵ that would be associated with the Spawning Potential Ratio (SPR) = 50% limit (corre-
¹⁶⁶ sponding to a relative fishing intensity of 100%) (Table d and Figure h). SPR is calculated
¹⁶⁷ as the lifetime spawning potential per recruit at a given fishing level relative to the lifetime
¹⁶⁸ spawning potential per recruit with no fishing. The SPR over the last decade increased
¹⁶⁹ 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.

Year	Estimated (1-SPR)/(1- SPR50%)	~ 95% confidence interval	Exploitation rate	^{tab:SPR_Exploit_mod1} 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

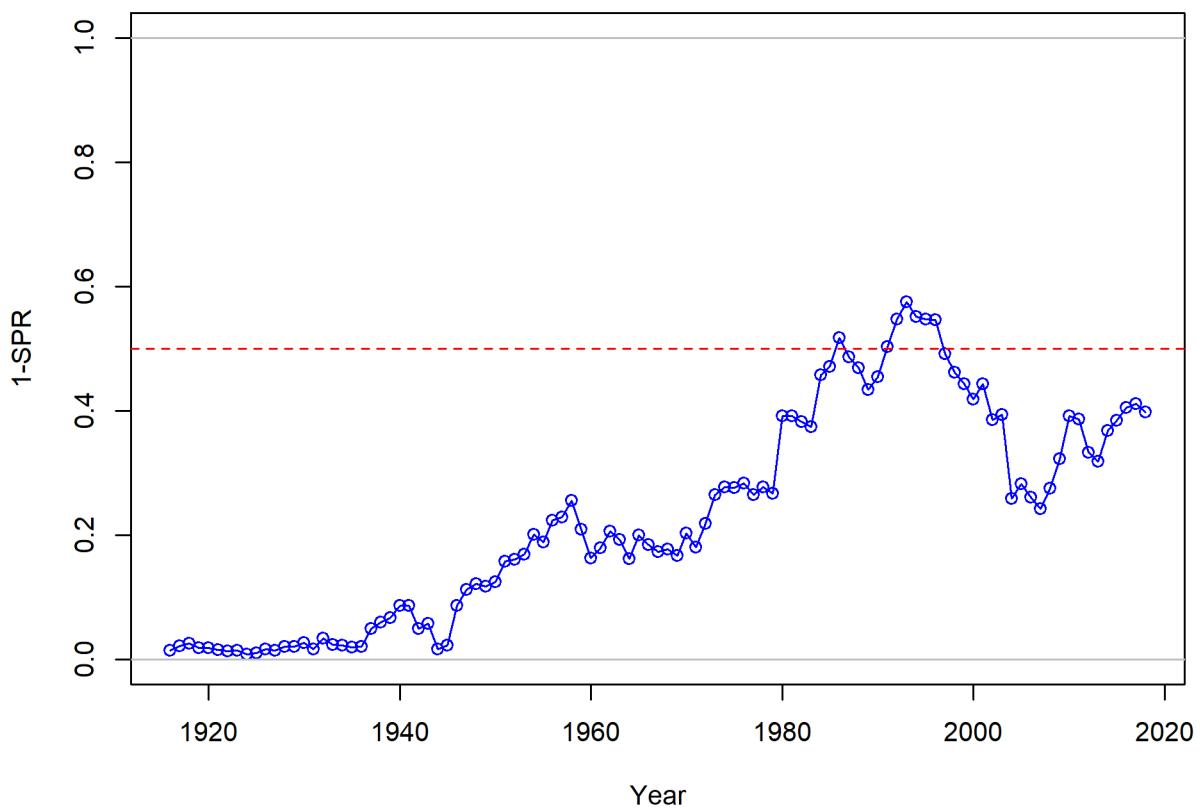


Figure h: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

¹⁷⁰ **Ecosystem Considerations**

ecosystem-considerations

- ¹⁷¹ In this assessment, ecosystem considerations were not explicitly included in the analysis.
¹⁷² This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere)
¹⁷³ that could contribute ecosystem-related quantitative information for the assessment.

¹⁷⁴ **Reference Points**

reference-points

- ¹⁷⁵ This stock assessment estimates that GBYR in the model is above the biomass target
¹⁷⁶ ($SB_{40\%}$), and well above the minimum stock size threshold ($SB_{25\%}$). The estimated relative
¹⁷⁷ depletion level for the base model in 2018 is 0.439 (95% asymptotic interval: 0.341-0.536,
¹⁷⁸ corresponding to an unfished spawning biomass of 552 million eggs (95% asymptotic interval:
¹⁷⁹ 337 - 767 million eggs) of spawning biomass in the base model (Table e). Unfished age 1+
¹⁸⁰ biomass was estimated to be 2,042 mt in the base case model. The target spawning biomass
¹⁸¹ ($SB_{40\%}$) is 504 million eggs, which corresponds with an equilibrium yield of 143 mt. Equi-
¹⁸² librium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 134 mt (Figure
¹⁸³ i).

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

Quantity	Estimate	tab:Ref_pts_mod1	
		Low	High
		2.5% limit	2.5% limit
Unfished spawning output (million eggs)	1,261	968	1,554
Unfished age 1+ biomass (mt)	2,042	1,637	2,448
Unfished recruitment (R_0)	3,125	2,643	3,606
Spawning output(2018 million eggs)	553	344	762
Depletion (2018)	0.439	0.341	0.536
Reference points based on SB_{40%}			
Proxy spawning output ($B_{40\%}$)	504	427	582
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.458	0.458	0.458
Exploitation rate resulting in $B_{40\%}$	0.126	0.109	0.144
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	143	124	162
Reference points based on SPR proxy for MSY			
Spawning output	563	476	649
SPR_{proxy}	0.5		
Exploitation rate corresponding to SPR_{proxy}	0.111	0.096	0.126
Yield with SPR_{proxy} at SB_{SPR} (mt)	134	116	152
Reference points based on estimated MSY values			
Spawning output at MSY (SB_{MSY})	281	235	328
SPR_{MSY}	0.299	0.29	0.308
Exploitation rate at MSY	0.209	0.174	0.244
Dead Catch MSY (mt)	163	141	185
Retained Catch MSY (mt)	163	141	185

184 Management Performance

management-performance

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

192 Unresolved Problems and Major Uncertainties

unresolved-problems-and-major-uncertainties

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

¹⁹³ **Decision Table**

decision-table

¹⁹⁴ This section will be completed after the STAR panel.

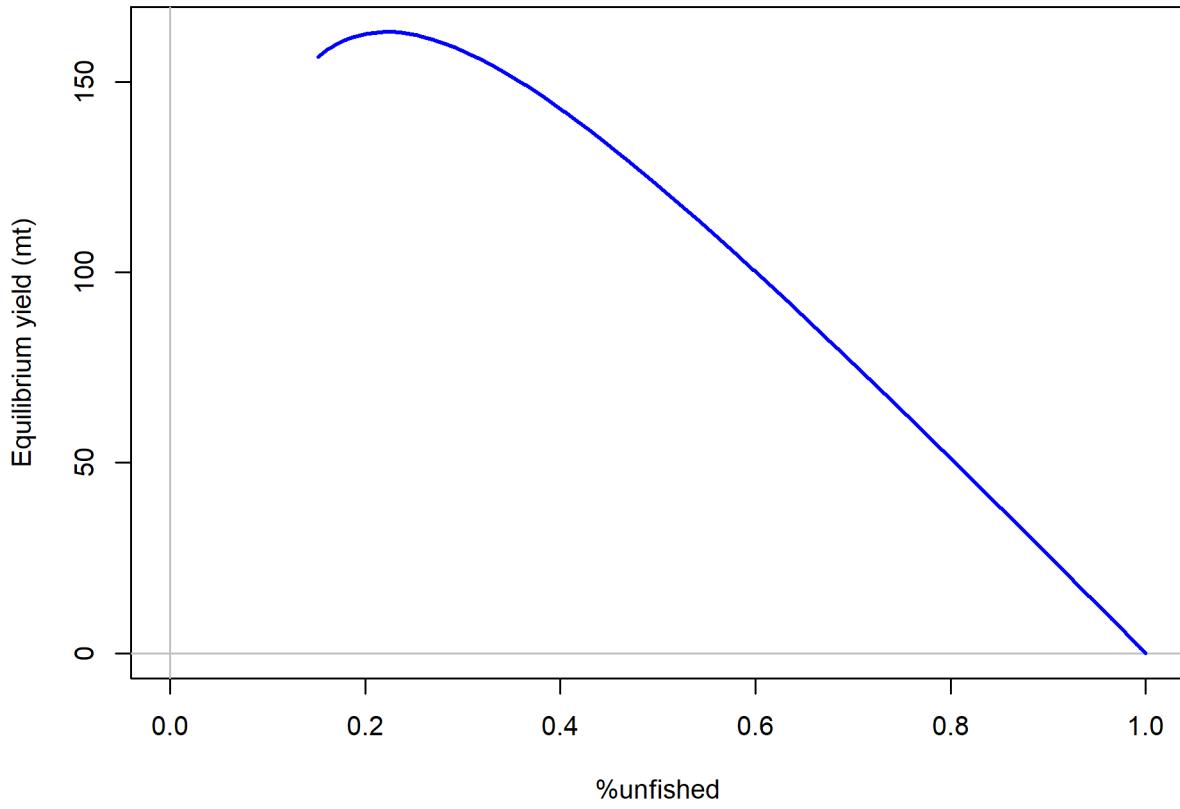


Figure i: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.72. [fig:Yield_all](#)

Table g: Base case results summary.

Quantity	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Landings (mt)										
Total Est. Catch (mt)										
OFL (mt)										
ACL (mt)										
(1- SPP)(1- $SPPR_{50\%}$)	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	1568	15264	2487	3701	1432	2778
95% CI	1257 - 4779	983 - 4127	761 - 4258	676 - 3734	2519 - 8284	2085 - 9282	1274 - 4857	1976 - 6935	664 - 3089	1086 - 7111

¹⁹⁵ **Research and Data Needs**

research-and-data-needs

¹⁹⁶ This section will be completed after the STAR panel.

197 **1 Introduction**

introduction

198 **1.1 Basic Information and Life History**

basic-information-and-life-history

199 *Population Structure and Complex Assessment Considerations*

200 There have been a number of analyses conducted on the genetic differentiation between go-
201 gopher rockfish and black-and-yellow rockfish. The studies have yielded a range of results,
202 but have generally concluded that there is unusually low genetic differentiation between the
203 two species. The most frequently used measure of genetic analyses to evaluate evidence for
204 population differentiation is the fixation index (F_{ST}), defined as the proportion of the total
205 genetic variation in one sub-population (subscript S) relative to the total genetic variation
206 (subscript T) (Hauser and Carvalho 2008, Waples et al. 2008). Values of F_{ST} range from
207 0 to 1 where a zero value implies the populations are panmictic and a value closer to one
208 implies the two populations are genetically independent. Values of F_{ST} thought to be consis-
209 tent with biologically meaningful genetic differentiation and demographic isolation between
210 populations range from 0.05 to 0.1 (Waples and Gaggiotti 2006). It is also important to
211 note that F_{ST} values are dependent on the study's sample size and it may not necessarily be
212 appropriate to compare them across studies.

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

232 Most recently, an analysis of rockfish species assignment using microhaplotypes by Baetscher
233 (2019) observed mistaken genetic assignment of a small number of individuals between go-
234 gopher and black-and-yellow rockfishes, while no other species among the 54 rockfishes analyzed

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

243 In addition to the differences in coloration, the depth distribution and range differ between
244 the two species. The range of both species extends from Cape Blanco Oregon to Baja
245 California. Both species are uncommon north of Fort Bragg, California and black-and-yellow
246 rockfish is uncommon south of Point Conception, California. However, gopher rockfish can
247 be found as far south as Punta San Roque on the Baja peninsula. Gopher rockfish are found
248 in rocky reef habitat from the intertidal to depths of 264 ft (80 m) with a predominant depth
249 distribution of 30 to 120 ft (9-37 m), while the black-and-yellow rockfish occupies depths
250 from the intertidal to 120 ft (40 m) and is predominantly observed in depths shallower than
251 60 ft (18 m) (Eschmeyer et al. 1983, Love et al. 2002).

252 Both species are solitary, sedentary, and territorial with home ranges of 10-12 square meters
253 (Love et al. 2002). A large percentage (67-71%) of black-and-yellow rockfish returned to
254 the site of capture within two weeks after translocated within 50 m (Hallacher 1984). Lea
255 et al. (1999) found that gopher rockfish exhibit minor patterns of movement (<12.8 km)
256 with all fish being recaptured on the same reef system where they were tagged. Matthews
257 (1985) found that 11.8% of tagged and recaptured gopher rockfish, and 25% of black-and-
258 yellow rockfish, moved from four low-relief natural reefs to a new high-relief artificial reef
259 in Monterey Bay. The maximum distance between the natural and artificial reefs traveled
260 by gopher or black-and-yellow rockfish was 1.6 km. After only a year, the fish assemblage
261 on the artificial reef closely resembled that of the nearby natural reefs. The paper did not
262 address the spatial segregation of gopher and black-and-yellow rockfish on the new artificial
263 reef.

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

270 Both species feed at night, with similar diets composed primarily of crabs and shrimp,
271 supplemented by fish and cephalopods (Larson 1972, 1985, Love et al. 2002). Loury et al.
272 (2015) found no significant differences in the diet of gopher rockfish inside and outside the
273 year old Point Lobos Marine Protected Area (MPA). She did find the diet of gopher rockfish
274 at Año Nuevo (shallower and north of Point Lobos) was dominated by crabs and dominated
275 by brittle stars at southern, deeper study locations. Zuercher (2019) examined the diets of

²⁷⁶ a suite of nearshore rockfish species including black-and-yellow and found that they relied
²⁷⁷ on hard-bodied benthic invertebrates such as Brachyuran crabs, shrimps, other arthropods,
²⁷⁸ and octopus. The diet of black-and-yellow rockfish remained the same across sampling years,
²⁷⁹ but they occupied a lower trophic level during the upwelling season.

²⁸⁰ 1.2 Early Life History

`early-life-history`

²⁸¹ Gopher and black-and-yellow rockfish have similar juvenile development. Both rockfish
²⁸² species are viviparous and release one brood per season between January and July (Echev-
²⁸³ erria 1987). Larvae are approximately 4 mm in length at birth and have a 1-2 month pelagic
²⁸⁴ stage before recruiting to the kelp forest canopy, i.e., surface fronds of *Macrosystis pyrifera*
²⁸⁵ and *Cystoseira osmundacea* at around 15-21 mm (Anderson 1983, Wilson et al. 2008).
²⁸⁶ The larvae are transparent until they reach juvenile stage at 22-23 mm. Differences in col-
²⁸⁷ oration between the two species begin to occur at 25-30 mm and can be used to identify one
²⁸⁸ species from the other. Gopher rockfish become more orange and brown, while black-and-
²⁸⁹ yellow rockfish become more black and yellow. Benthic juveniles associate with *Macrosystis*
²⁹⁰ holdfasts and sporophylls (Anderson 1983).

²⁹¹ The juveniles undergo ontogenetic migration down the stalks to deeper depths, finally settling
²⁹² on rocky reef habitat in their respective adult depth distribution. Juvenile bocaccio and other
²⁹³ fish predate on young of year and other reef dwelling species including cabezon predate on
²⁹⁴ post-settlement juveniles. Individuals avoid rough surge conditions and predators by hiding
²⁹⁵ in the rocky bottom during the daylight hours, then returning to more open water at dusk
²⁹⁶ (Love et al. 2002).

²⁹⁷ 1.3 Map

`map`

²⁹⁸ A map showing the scope of the assessment and depicting boundaries at Cape Mendocino
²⁹⁹ to the north and the U.S./ Mexico border at the south (Figure 1). The recreational fishing
³⁰⁰ fleet was split into two fleets at Point Conception.

³⁰¹ 1.4 Ecosystem Considerations

`ecosystem-considerations-1`

³⁰² In this assessment, ecosystem considerations were not explicitly included in the analysis.
³⁰³ This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere)
³⁰⁴ that could contribute ecosystem-related quantitative information for the assessment.

305 **1.5 Fishery Information**

fishery-information

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

310 Gopher and black-and-yellow (referred to from hereon as GBYR when discussing the com-
311 plex) rockfish have been a minor component of the commercial and recreational rockfish
312 fishery since at least the late 1960s (CFIS and RecFIN). The commercial catch histories
313 of the two species cannot easily be separated (Figure 2). From 1916-1936 only black-and-
314 yellow rockfish were reported in the landings, and an average of 0.04 mt of black-and-yellow
315 rockfish are reported from 1937-1983. Black-and-yellow rockfish reappear in the landings in
316 1984 with 7.2 mt landed commercially. From 1985-1988 the trend switches and only black-
317 and-yellow rockfish appear in the commercial landings, with gopher rockfish averaging 0.1
318 mt landed, and 0 mt reported in 1987. From 1988 and on, the landings are dominated by
319 gopher rockfish, and both species are represented in the commercial landings.

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

323 The live fish fishery began in the early 1990s, with the first reported commercial landings of
324 live gopher rockfish in 1993, and black-and-yellow rockfish a year later. By 1995 over half
325 (57%; 39 mt) of the commercial landings were from the live fish fishery. This increased quickly
326 over the next few years and has been on average 84% of the landed gopher and black-and-
327 yellow rockfish (also referred to GBYR to reference the complex in this assessment) since
328 2000. The majority of the landings are from gopher rockfish north of Point Conception.
329 Landings of live GBYR south of Point Conception were higher in the late 1990s, (max. 3.2
330 mt in 1999), and have been averaging 0.4 mt since 2003.

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

337 The recreational GBYR fishery for California is most prominent north of Point Conception
338 throughout the entire catch history (Figure a). The recreational landings increased from
339 1928 to 1980. The sharp increase in the 1980s could be an artifact of the MRFSS sampling
340 program that began in 1980; however, the more recent recreational landings also exhibit a
341 cyclical trend of years with high catches followed by period of decreased recreational landings.
342 The CRFS era recreational total mortality represents the most accurate description of the
343 recreational fleet's catches in terms of area, mode and species (Figure 4).

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

351 1.6 Summary of Management History

summary-of-management-history

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

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

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

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

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

386 Following adoption of the Nearshore FMP and accompanying regulations by the FGC in fall
387 of 2002, the FGC adopted regulations in November 2002 which established a set of marine
388 reserves around the Channel Islands in southern California (which became effective April
389 2003). The FGC also adopted a nearshore restricted access program in December 2002
390 (which included the establishment of a Deeper Nearshore Permit) to be effective starting in
391 the 2003 fishing year.

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

400 The state of California has adopted regulatory measures to manage the fishery based on
401 the harvest guidelines set forth by the PFMC. The commercial open access and limited
402 entry fixed gear sectors have undergone three different spatial management changes since
403 2000. Since 2005, both have managed the area south of 40°10' N. latitude as one area. The
404 open access commercial fishery is managed based on bimonthly allowable catches, that have
405 ranged from 200 pounds to 1800 pounds per two months since 2000. From 2005 to 2018, the
406 catch limits have doubled and are now set at 1200 pounds per two months (for all months)
407 with March and April remaining closed. The limited entry fixed gear sector has followed the
408 same pattern as the open access sector with bi-monthly limits and a doubling of the catch
409 since 2005. The limited entry trawl fleet is managed on monthly limits on an annual basis.
410 Since 2011, the limit has been 300 pounds per month for non-IFQ species. A history of
411 California's commercial regulations from 2000-2018 can be found in [Appendix A](#). A 10-inch
412 total length minimum size limit was implemented in 1999 for both species in the commercial
413 fleet.

414 Significant regulatory changes in California's recreational sector began with a change from
415 unlimited number of hooks and lines allowed prior to 2000 to no more than three hooks and
416 one line per angler in 2000. Since 2001, the limit has been no more than two hooks and one
417 line per angler. There is no size limit in the recreational fishery for gopher or black-and-
418 yellow rockfish. GBYR are part of the nearshore complex which has had a sub-bag limit
419 within the rockfish bag limit since 1999. The nearshore sub-bag limit has been 10 fish since
420 2005.

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

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

431 1.7 Management Performance

management-performance-1

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

440 1.8 Fisheries Off Mexico or Canada

fisheries-off-mexico-or-canada

441 The range of GBYR does not extend north to the Canadian border, and they are rarely
442 encountered in Oregon and Washington. The southern end of the gopher rockfish's range
443 extends to Punta San Roque (southern Baja California) while the southern end of the black-
444 and-yellow rockfish's range extends to Isla Natividad (central Baja California) (Love et al.
445 [2002](#)). However, black-and-yellow rockfish are rare south of Point Conception, California.
446 This was no available information on the fishery for GBYR at the time of this assessment,
447 nor additional details on the abundance or distribution patterns in Mexican waters.

448 2 Assessment

assessment

449 2.1 Data

data

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

452 2.1.1 Commercial Fishery Landings

commercial-fishery-landings

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

454 Commercial fishery landings for gopher and black-and-yellow rockfishes have not been re-
455 ported consistently by species throughout the available catch history (Figure 2). The period
456 from 1916-1935 indicates that only black-and-yellow rockfish were landed in the commercial
457 fishery, which then switched to predominately gopher rockfish from 1937-1984. From 1985-
458 1988 the landings data suggest that only black-and-yellow rockfish were landed and not until
459 1995 are both species well-represented in the catches. Pearson et al. (2008) noted:

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

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

477 The stock assessment of gopher rockfish in 2005 did not include black-and-yellow rockfish
478 landings. A comparison of the recreational and commercial landings from the 2005 assess-
479 ment to those used in this assessment suggest the 2005 assessment may have included some
480 black-and-yellow rockfish landings (Figure 6). The 2005 assessment estimated recreational
481 landings from 1969-1980 based on a ratio of commercial to recreational landings, whereas
482 this assessment makes use of the California Catch Reconstruction landings estimates (Ral-
483 ston et al. 2010).

484 *Commercial Landings Data Sources*

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

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

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

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

514 Commercial landings from 1981-2018 were queried for a final time from the CALCOM
515 database on 4 April 2019 and from PacFIN on 3 June 2019. There are very small dif-
516 ferences in commercial landings between CALCOM and PacFIN from 1981-2018 (Figure 7).
517 Landings estimates from PacFIN were used in the assessment (Table 1). Landings were
518 stratified by year, quarter, live/dead, market category, gear group, port complex, and source
519 of species composition data (actual port samples, borrowed samples, or assumed nominal
520 market category). Data from individual quarters were aggregated at the year level. Fish
521 landed live or dead were combined, due to changes over time in the reliability of condi-
522 tion information (Don Pearson, retired NMFS SWFSC, personal communication). From
523 1916-1968, on average, 74% of GBYR were landed north of Point Conception, which rose to
524 97% from 1978-2018. Given the smaller landings south of Point Conception and the similar
525 length composition of GBYR north and south of Point Conception, no spatial separation
526 was considered for the commercial fleet.

527 **2.1.2 Commercial Discards**

commercial-discards

528 The West Coast Groundfish Observer Program (WCGOP) provides observer data on dis-
529 carding across fishery sectors back to 2003. Gopher and black-and-yellow rockfishes have
530 species-specific depth-stratified commercial fishery discard mortality rates (Pacific Fishery
531 Management Council 2018). In consultation with WCGOP staff, the STAT used estimates of
532 total discard mortality from WCGOP’s Groundfish Expanded Mortality Multiyear (GEMM)
533 report. WCGOP observes between 1-5% of nearshore fixed gear landings annually south of
534 40°10' N. latitude (coverage rates available [here](#)). The expanded estimates of total discard
535 weight by species is calculated as the ratio of the observed discard weight of the individual
536 species divided by the observed landed weight from PacFIN landing receipts. WCGOP dis-
537 card estimates for the nearshore fixed gear fishery take into account the depth distribution
538 of landings in order to appropriately apply the depth-stratified discard mortality rates by
539 species (Somers et al. 2018). The discard mortality for 2018 was estimated as an average
540 of the discard mortality from 2013-2017. Discard mortality was estimated from the period
541 prior to WCGOP discard estimates (1916-2002) based on the average discard mortality rate
542 from 2003-2016 (2017 was excluded because 2017 discard mortality was disproportionately
543 higher than all other years) (Table 1).

544 **2.1.3 Commercial Fishery Length and Age Data**

commercial-fishery-length-and-age-data

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

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

557 A total of 46 ages were available for gopher rockfish from the commercial fisheries 2009-2011,
558 2016, and 2018. Though sparse, the data were included as conditional age-at-length for the
559 commercial fleet.

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

562
$$\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}} / N_{\text{trips}} < 44$$

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

564 Commercial length composition data are made available from PacFIN and the expanded
565 catch-weight length compositions were provided by Andi Stephens (NWFSC) processed
566 through the [PacFIN Utilities](#) package. We compared differences between the catch-weighted
567 length composition expansions from CALCOM and PacFIN. We were unable to reconcile the
568 difference between the two data sets. Sample sizes became more similar if the PacFIN data
569 were restricted to the same market categories used by CALCOM in the expansion. However,
570 both data sets apply other filters that we did not have time to explore. For instance, in the
571 year 2000, 290 more fish were used in the CALCOM expansion than in PacFIN, but in 2002,
572 150 more fish were used in the PacFIN expansions that were not used in CALCOM. Given
573 these caveats, Figure 8 shows the percent difference in the expanded length comps within a
574 year. The biggest difference is in length bin 32 in 2006. However, the same number of fish
575 and samples were used to expand the 2006 lengths in both databases, indicating there are
576 also fundamental differences in how the data are treated. Full documentation is not available
577 for the PacFIN length composition expansion program. Consequently the STAT chose to use
578 a query that they could completely understand and selectively develop from the CALCOM
579 database for the base model, although a sensitivity was conducted using the PacFIN-derived
580 length composition data.

581 **2.1.4 Recreational Fishery Landings and Discards**

[recreational-fishery-landings-and-discards](#)

582 *Historical recreational landings and discards, 1928-1980*

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

599 The California Catch Reconstruction applied a linear ramp from 1928-1936 that was not
600 altered in this assessment. From 1937-1979 a linear ramp was developed from the 1936

601 estimate to the average recreational landing from 1980 and 1983 (1981-1982 catches inter-
602 polated as described in the next section) of 4.3 mt. The recreational catches north of Point
603 Conception were not altered from the original catch reconstruction. The resulting alternate
604 recreational catch streams are in (Table 3 and Figure 10).

605 The total difference in the catch streams from Figure 9 and Figure 10 is plotted in Figure
606 11. The differences in the catches are due to the addition of commercial discards prior to
607 2004 and the reduction of the recreational catches south of Point Conception.

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

609 From 1980-2003, the Marine Recreational Fisheries Statistics Survey (MRFSS) executed a
610 dockside (angler intercept) sampling program in Washington, Oregon, and California (see
611 Holliday et al. (1984) for a description of methods). Data from this survey are available from
612 the Recreational Fisheries Information Network [RecFIN](#). RecFIN serves as a repository for
613 recreational fishery data for California, Oregon, and Washington. Catch estimates for years
614 1980-2003 were downloaded on 23 March 2019, and are consistent from 1992-2004 with the
615 previous assessment (Key et al. 2005) (Figure 6).

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

631 Catches from north of Cape Mendocino were removed based on a CRFS-era average of frac-
632 tion of recreational landings north of Cape Mendocino by mode (3.3% of shore-based, 0.1% of
633 CPFV, and 0.2% of private/rental were removed). From 1980-1989, San Luis Obispo County
634 was sampled as part of Southern California (personal observation from MRFSS Type 3 sam-
635 pler examined catch where county is available for 1980-2004). This assessment separates the
636 recreational fleet at Point Conception. Recreational landings were re-allocated from southern
637 California from 1980-1992 by fleet based on the average proportion of recreational landings
638 in northern California from 1996-2004 (after sampling of the CPFV fleet in northern Cali-
639 fornia resumed). The average proportion re-allocated from southern to northern California
640 for the CPFV mode was 85%, 97% for the private/rental mode, and 81% for the shore-based

641 modes. Data were pooled over all years and modes to estimate the landings re-allocation
642 for the shore-based modes. Total recreational landings for 1981 and 1982 were 18.8 mt and
643 18.6 mt, respectively. These landings were >60 mt lower than any of the neighboring years.
644 Landings from 1981-1982 were interpolated from the 1980 and 1983 landings.

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

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

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

658 *Recreational Discards*

659 Recreational discards were only added to the California Catch Reconstruction landings, as
660 Ralston et al. (2010) did not address discards for the recreational reconstruction. Recre-
661 ational removals from the California Department of Fish and Wildlife MRFSS era (1980-
662 2003) includes catch type A + B1. Catch type A refers to estimates of catch based on
663 sampler-examined catch. Catch type B1 includes mainly angler-reported discard, but also
664 angler-reported retained fish that were unavailable to the sampler during the interview (e.g.,
665 fillets). The CRFS era removals account for depth-stratified discard mortality rate and the
666 catch time series includes both retained and discarded catch (total mortality). We calculated
667 the ratio of dead discards to total mortality from the CRFS era by region and mode. The
668 region average across modes was applied to the California Catch Reconstruction as a con-
669 stant. The result added 4.68% annually to recreational removals north of Point Conception
670 and 4.05% annually to the removals South of Point Conception). The final time series of
671 landings and discard mortality are in Table 3.

672 **2.1.5 Recreational Fishery Length and Age Data**

recreational-fishery-length-and-age-data

673 Recreational length composition samples for California were obtained from several sources,
674 depending on the time period and boat mode (Table 2). This assessment makes use of a
675 much longer time series of length composition data, relative to the previous assessment, as
676 described below. Input sample sizes for recreational length composition data were based on

677 the number of observed trips, when available. Other proxies that were used to estimate the
678 number of trips are described below.

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

681 *CPFV length composition data, 1959-1978*

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

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

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

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

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

712 During the recent restructuring of the CRFS data on RecFIN, a “trip” identifier was not
713 carried over for all modes, and trip-level sample sizes could not be extracted from the bio-
714 logical detail table on RecFIN. A proxy for initial sample sizes for 2004-2018 were developed

715 using the 2015 data for which I had access to raw data files by mode from CDFW. In more
716 recent years, sampling of the shore-based modes has declined and were not sampled at all
717 in 2018. Samples sizes were calculated by mode as the number of port-days (or site-days for
718 shore-based modes) during bi-weekly intervals (e.g., Jan 1-15, Jan 16-31, etc). The number
719 of port-days sampled in the bi-weekly intervals was used as the initial sample size for number
720 of trips to calculate initial input sample sizes using Ian Stewart's method (described above).
721 All length data were re-weighted in the assessment model.

722 **2.1.6 Fishery-Dependent Indices of Abundance**

fishery-dependent-indices-of-abundance

723 A summary of all indices in the assessment can be found in Table 5. Figure 12 shows each
724 index scaled to the mean value of that index to show them all on the same scale, i.e., the
725 mean of each index in the plot is 1.

726 **MRFSS Dockside CPFV Index**

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

739 Initial trip filters included eliminating trips targeting species caught near the surface waters
740 for all or part of the trip, including trips with catch of bluefin tuna, yellowfin tuna, skipjack,
741 and albacore. Trips occurring in bays were also excluded.

742 The following filtering steps were applied to gopher rockfish, as well as the sum of the
743 two species to represent GBYR. No filtering or indices were developed for black-and-yellow
744 rockfish alone due to the sparseness in the data. In the raw data, unfiltered data, black-and-
745 yellow rockfish only occurred in 48 trips that did not also observe gopher rockfish. There
746 were an additional 65 trips that encountered both species. There was little difference between
747 indices developed for gopher-only and the GBYR complex for both north and south of Point
748 Conception (Figure 13). The descriptions of the filtering and data below represent those for
749 the GBYR complex.

750 The species composition of catch in California varies greatly with latitude.

751 Therefore, Stephens-MacCall filtering was applied independently for north and south of Point

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

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

776 Two levels of possible filtering were applied using the Stephens-MacCall filter (Table 16).
777 The Stephens-MacCall filtering method identified the probability of occurrence (in this case
778 0.4) at which the rate of “false positives” equals “false negatives.” The trips selected using
779 this criteria were compared to an alternative method including all the “false positive” trips,
780 regardless of the probability of encountering GBYR (Table 19). This assumes that if GBYR
781 were caught, the anglers must have fished in appropriate habitat during the trip. The catch
782 included in this index is “sampler-examined” and the samplers are well trained in species
783 identification. The last filter applied was to exclude years after 1999 due to a number of
784 regulation changes, and years in which there were less than 20 observed trips. The final
785 index is represented by 544 trips, 220 of which encountered GBYR.

786 Due to the large number of zeros in the data, we modeled catch per angler hour (CPUE;
787 number of fish per angler hour) using maximum likelihood and Bayesian negative binomial
788 regression. Models incorporating temporal (year, 2-month waves) and geographic (region
789 and area_x) factors were evaluated. Counties were grouped into three regions, north of
790 Sonoma county, Sonoma county through Santa Cruz county, and San Luis Obispo county.
791 Based on AIC values from maximum likelihood fits (Table 17), a main effects model including
792 all factors (year, region, area_x, and 2-month waves) was fit in the “rstanarm” R package
793 (version 2.18.2). Diagnostic checks of the Bayesian model fit (Neff, Rhat, and Monte Carlo

794 standard error values) were all reasonable. Predicted means by stratum (Year) were strongly
795 correlated with observed means, suggesting a reasonable fit to the data (Figure 16). The
796 NB model generated data sets with roughly 50-70% zeros, compared to the observed 60%
797 (Figure 17).

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

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

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

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

826 The resulting index for south of Point Conception represents different years than the index for
827 north of Point Conception (Table 6). The index starts in 1980 with continuous data through
828 1986, and three additional years in 1996, 1998 and 1999. The index increases through 1983
829 and a marked decrease to 1986. The index for the three years in the 1990s does not exhibit
830 any significant trend.

831 **CPFV Onboard Observer Surveys**

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

844 The state of California implemented a statewide sampling program in 1999 (Monk et al.
845 2014). California Polytechnic State University (Cal Poly) has conducted an independent
846 onboard sampling program as of 2003 for boats in Port San Luis and Morro Bay, and follows
847 the protocols established in Reilly et al. (1998). Cal Poly has modified protocols reflect
848 sampling changes that CDFW has also adopted, e.g., observing fish as they are encountered
849 instead of at the level of a fisher's bag. Therefore, the Cal Poly data area incorporated in
850 the same index as the CDFW data from 1999-2018. The only difference is that Cal Poly
851 measures the length of both retained and discarded fish.

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

855 *Deb Wilson-Vandenberg Onboard Observer Index Filtering and Standardization.* A large
856 effort was made by the SWFSC to recover data from the the original data sheets for this
857 survey and developed into a relational database (Monk et al. 2016). The specific fishing
858 locations at each fishing stop were recorded at a finer scale than the catch data for this survey.
859 We aggregated the relevant location information (time and number of observed anglers) to
860 match the available catch information. Between April 1987 and July 1992 the number of
861 observed anglers was not recorded for each fishing stop, but the number of anglers aboard the
862 vessel is available. We imputed the number of observed anglers using the number of anglers
863 aboard the vessel and the number of observed anglers at each fishing stop from the August
864 1992-December 1998 data (see Supplemental materials for details). In 1987, trips were only
865 observed in Monterey, CA and were therefore excluded from the analysis. The years 1990
866 and 1991 were also removed for low sample sizes. Final data filters included removing reefs
867 that never encountered GBYR, drifts that had fishing times outside 95% of the data, and
868 fishing stops with depths <9 m and >69m. The final data set contained 2,411 fishing stops,
869 with 1,096 of those encountering GBYR (Figure 19).

870 The index was fit using a delta-GLM model, with a lognormal model (AIC: 1,088) selected
871 over a gamma model (AIC: 1,143) for the positive encounters. Covariates considered in
872 the full model included year, depth, and month (Table 8). The model selected by AIC for

873 both the lognormal and binomial components of the delta-GLM included year, depth and
874 reef. Depth was included in 10 m depth bins and eight reefs were select in the final model
875 (Figure coming). The final index did not indicate an increasing trend that was seen in the
876 2005 gopher rockfish assessment using the same data set (Figure 20). A number of reasons
877 include that finer-scale location data was keypunched in 2012 for this survey, the index in
878 this assessment includes black-and-yellow rockfish, and different filters were applied to the
879 data. However, the the same peaks and decreases in the two indices are present.

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

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

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

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

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

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

907 Because GBYR are strongly associated with hard bottom habitat, the distance from a reef at
908 the start of a drift was re-examined for drifts encountering GBYR. The maximum distance
909 was 872 m, but the 97% quantile dropped to 42 m and was chosen as a reasonable cutoff
910 value, and only resulted in a reduction of 182 drifts that encountered gopher rockfish. The
911 final data were filtered to ensure all selected reefs were sampled in at least 2/3 of all years,
912 leaving 12,965 drifts for the final index, 5,796 of which encountered GBYR (Figure 21).

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

919 *Filtering and Index Standardization for south of Point Conception* The bathymetric data is
920 not available at as fine-scale resolution for the Southern California Bight and more of the
921 trips and drifts target mid-water species, including mid-water rockfish (Table 9). Therefore,
922 instead of using distance to reef as a filter, we filtered the data to drifts that encountered
923 20% or more groundfish. This resulted in the total number of drifts decreasing from 11,635
924 to 5,495, but only decreased the number of drifts encountering GBYR from 1,277 to 1,171.
925 A final check was made to ensure all reefs were sampled in at least 2/3 of all years, leaving
926 5,440 drift for the final index, of which 1,132 encountered GBYR (Figure 22).

927 The index of abundance was modeled with a delta-GLM modeling approach, with year,
928 month, 10 m depth bins from 10-59 m, and four reefs as possible covariates. A lognormal
929 model (AIC: 162) was selected over a gamma (AIC: 277) for the positive observations using
930 AIC. A model with year, depth and reef was selected by AIC for both the lognormal and
931 binomial components of the delta-GLM. The index indicates a relatively stable trend from
932 2001-2004 and a steady increase from 2005-2017.

933 2.1.7 Fishery-Dependent Indices: Available Length and Age Data [fishery-dependent-indices-available-length-and-age-data](#)

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

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

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

950 **2.1.8 Fishery-Independent Data Sources**

fishery-independent-data-sources

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

953 **California Collaborative Fisheries Research Project**

954 The California Collaborative Fisheries Research Project, [CCFRP](#), is a fishery-independent
955 hook-and-line survey designed to monitor nearshore fish populations at a series of sampling
956 locations both inside and adjacent to MPAs along the central California coast (Wendt and
957 Starr [2009](#), Starr et al. [2015](#)). The CCFRP survey began in 2007 and was originally designed
958 as a statewide program in collaboration with NMFS scientists and fishermen. From 2007-
959 2016 the CCFRP project was focused on the central California coast, and has monitored four
960 MPAs consistently since then (Figure [23](#)). In 2017, the program was expanded coastwide
961 within California. The index of abundance was developed from the four MPAs sampled
962 consistently (Año Nuevo and Point Lobos by Moss Landing Marine Labs; Point Buchon and
963 Piedras Blancas by Cal Poly).

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

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

979 We modeled catch per angler hour (CPUE; number of fish per angler hour) using maximum
980 likelihood and Bayesian negative binomial regression. The proportion of zeroes in this data
981 was relatively small (22%), and if overdispersion were not present, the regression would
982 innately become Poisson. Models incorporating temporal (year, month) and geographic
983 (MPA site and MPA vs Reference cells) factors were evaluated. Based on AIC values from
984 maximum likelihood fits (Table [15](#)), a main effects model including all factors (year, month,
985 site and MPA/REF) was fit in the “rstanarm” R package (version 2.18.2). Diagnostic checks
986 of the Bayesian model fit (Neff, Rhat, and Monte Carlo standard error values) were all
987 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

1064 or total length.

1065 (Table 4)

1066 Length and Age Compositions

1067 Length compositions were provided from the following sources:

- 1068 • CALCOM (*commercial retained dead fish*, 1987, 1992-2018)
- 1069 • WCGOP (*commercial discarded fish*, 2004-2018)
- 1070 • Deb Wilson-Vandenberg's onboard observer survey (*recreational charter retained and*
1071 *discarded catch*, 1987-1998)
- 1072 • California recreational sources combined (*recreational charter retained catch*)
 - 1073 – Miller and Gotshall dockside survey (1959-1966)
 - 1074 – Ally et al. onboard observer survey (1985-1987)
 - 1075 – Collins and Crooke onboard observer survey (1975-1978)
 - 1076 – MRFSS dockside survey (1980-2003)
 - 1077 – CRFS onboard and dockside survey (2004-2018)
- 1078 • PISCO dive survey (*research*, 2001-2018)
- 1079 • CCFRP hook-and-line survey (*research*, 2007-2018)

1080 The length composition of all fisheries aggregated across time by fleet is in Figure 31 and
1081 Table 4. Descriptions and details of the length composition data are in the above section for
1082 each fleet or survey.

1083 Age Structures

1084 A total of 2,421 otoliths were incorporated in this assessment and a summary by source can
1085 be found in Table 21. The final base model excludes the commercial age data that were
1086 sparse and not representative of the fishery. Gopher rockfish comprised 79% of the samples
1087 (922 females, 879 males, 121 unknown sex), and all but a few black-and-yellow rockfish (247
1088 females, 232 males, 20 unknown sex) came from a directed study by Jody Zaitlin (1986),
1089 collected from 1983-1986 (Figure 32).

1090 Of the available ages, 94% were collected during fishery-independent surveys.

1091 The remaining 6% were recreational dockside surveys and collected by Cal Poly during their
1092 CPFV onboard observer survey (36 otoliths) in 2018.

1093 All otoliths were read by Don Pearson (NMFS SWFSC, now retired) and estimated ages
1094 ranged from 1-28. The aged black-and-yellow rockfish ranged in length from 7-32 cm with a
1095 mean of 24 cm and gopher rockfish ranged in length from 11-36 cm, with a mean of 26. In
1096 terms of ages, the black-and-yellow rockfish ranged from 2-19 and gophers from 2-28. Fits
1097 to the von Bertalanffy growth curve (Bertalanffy 1938), $L_i = L_\infty e^{(-k|t-t_0|)}$, where L_i is the
1098 length (cm) at age i , t is age in years, k is rate of increase in growth, t_0 is the intercept, and
1099 L_∞ is the asymptotic length, were explore by species and sex.

₁₁₀₀ No significant differences were found in growth between gopher and black-and-yellow rock-
₁₁₀₁ fishes (Figure 33) or between males and females (Figure 34), species combined.

₁₁₀₂ Aging Precision and Bias

₁₁₀₃ Uncertainty in ageing error was estimated using a collection of 376 gopher and black-and-
₁₁₀₄ yellow rockfish otoliths with two age reads (Figure 36). Age-composition data used in the
₁₁₀₅ model were from a number of sources described above. All otoliths were read by Don Pearson
₁₁₀₆ (NMFS SWFSC, no retired) who also conducted all blind double reads.

₁₁₀₇ Ageing error was estimated using publicly available software (Thorson et al. 2012). The
₁₁₀₈ software setting for bias was set to unbiased since the same reader conducted the first and
₁₁₀₉ second readings. The best fit model chose by AIC for the standard deviation was a constant
₁₁₁₀ coefficient of variation for reader one ad mirrored for reader two (Figure 37).

₁₁₁₁ The resulting estimate indicated a standard deviation in age readings increasing from 0.74
₁₁₁₂ years at age 0 to a standard deviation of 2.07 years at age 28, the first year of the plus group
₁₁₁₃ in the assessment model.

₁₁₁₄ Weight-Length

₁₁₁₅ The weight-length relationship is based on the standard power function: $W = \alpha(L^\beta)$ where
₁₁₁₆ W is individual weight (kg), L is length (cm), and α and β are coefficients used as constants.

₁₁₁₇ The weight-length relationships was estimated from the three studies, Loury (2011), Meyers-
₁₁₁₈ Cherry (2014) (both gopher rockfish only from CCFRP) and Zaitlin (Zaitlin 1986) (black-
₁₁₁₉ and-yellow rockfish only). Only one weight-length relationship was estimated for the GBYR
₁₁₂₀ complex. The estimated parameters are $\alpha = 8.84e^{-006}$ and $\beta = 3.25584$. The estimated
₁₁₂₁ relationship is similar to that estimated by Lea et al. (1999) for gopher rockfish (Figure
₁₁₂₂ 38). The weight-length relationship estimated here was used in the assessment model to
₁₁₂₃ best represent the GBYR complex.

₁₁₂₄ Sex Ratio, Maturity, and Fecundity

₁₁₂₅ The sex ratio for GBYR is assumed to be 50:50 as there is no evidence to suggest otherwise.

₁₁₂₆ Zaitlin (1986) found that females reached 50% maturity at 17.5 cm or 4 years of age in Central
₁₁₂₇ California and were 100% mature by age 6, with the same age of maturity found in southern
₁₁₂₈ California though individuals were smaller at age. Echeverria (1987) estimated maturity for
₁₁₂₉ 17 rockfish species in central California. She found the size at first maturity and the size
₁₁₃₀ at 50% maturity for male and female gopher rockfish to be 17 cm total length, and 100%
₁₁₃₁ mature by 21 cm. Black-and-yellow rockfish males and females were first mature at 14 cm,

1132 50% of females were mature at 15 cm, 50% of males mature at 16 cm. Male black-and-yellow
1133 rockfish were 100% mature at 20 cm and females at 19 cm. In southern California waters,
1134 both males and females were found to reach first maturity at 13 cm total length (Larson
1135 1980). We did not have any samples from southern California to re-analyze the maturity
1136 ogive for that portion of the population. Both Zaitlin and Echeverria estimated the maturity
1137 ogives using ages from whole otoliths. A sample of 151 black-and-yellow rockfish otoliths
1138 surface read by Zaitlin were also read by Don Pearson, and Zaitlin's ages were consistently
1139 younger than Pearson's, by up to nine years. All of the available otoliths for this assessment
1140 were re-aged using a combination of surface reading and break-and-burn methodology.

1141 The maturity data from Zaitlin (1986) (422 black-and-yellow rockfish) were re-analyzed along
1142 with samples from Meyers-Cherry (2014) (115 gopher rockfish). Combining the two data sets
1143 provided an updated maturity ogive for the GBYR complex females (Figure 35). The first
1144 observed mature fish was 19 cm and the length at 50% was 21.66 cm, larger than suggested
1145 from the estimate used by Key et al. (2005) in the 2005 assessment. After re-analyzing the
1146 available data, the length at which 50% of female gopher rockfish were mature was estimated
1147 at 23.33 cm, and was 21.26 cm for female black-and-yellow rockfish. An important note is
1148 that the smaller fish from these studies were black-and-yellow rockfish and the larger fish
1149 were gopher rockfish. Although not used in this assessment, the estimate of 50% maturity
1150 for 23 GBYR from these studies was 21.88 cm. The age at 50% mature increased in this
1151 assessment to 21.66 cm, which is 3.96 cm larger than the value used in the 2005 assessment.

1152 Mature females in central California release larvae between January and July, peaking in
1153 February, March, and May (Larson 1980, Lea et al. 1999, Love et al. 2002). Both species of
1154 GBYR release one brood per season (Love et al. 2002). Black-and-yellow rockfish females
1155 can produce 25,000 - 450,000 eggs spawning from January to May. Gopher rockfish females
1156 ranging between 176 and 307 grams carry approximately 249 eggs per gram of body weight
1157 (MacGregor 1970). The fecundity estimates used in this assessment were provided by E.J.
1158 Dick (NMFS SWFSC) from a meta-analysis of fecundity in the genus *Sebastes* (Dick et al.
1159 2017).

1160 Natural Mortality

1161 Hamel (2015) developed a method for combining meta-analytic approaches to relating the
1162 natural mortality rate M to other life-history parameters such as longevity, size, growth
1163 rate and reproductive effort, to provide a prior on M . In that same issue of ICESJMS,
1164 Then et al. (2015), provided an updated data set of estimates of M and related life history
1165 parameters across a large number of fish species, from which to develop an M estimator
1166 for fish species in general. They concluded by recommending M estimates be based on
1167 maximum age alone, based on an updated Hoenig non-linear least squares (nls) estimator
1168 $M = 4.899 * A_{max}^{-0.916}$. The approach of basing M priors on maximum age alone was one that
1169 was already being used for west coast rockfish assessments. However, in fitting the alternative
1170 model forms relating $-0.916M$ to A_{max} , Then et al. (2015) did not consistently apply their
1171 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. Reevaluating 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:

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

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 ($34^{\circ}27'$ 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 (lambda) given to the index. Lambda of 1, 5, and 10 were used to

1200 weight the index, with the lambda of 5 used in the baseline model. The stock was found to
1201 be at 97% depletion.

1202 2.2.2 2005 Assessment Recommendations

assessment-recommendations

1203 The 2005 STAR panel only had one recommendation specific to gopher rockfish. However,
1204 they had a number of generic rockfish recommendations that can be found in the STAR
1205 panel report available [here](#).

1206 **Recommendation 1: Additional length and age composition data should be
1207 collected for gopher rockfish. This would help to characterize spatial and
1208 possibly temporal variation in growth**

1209

1210 2019 STAT response: Additional age and length data have been collected from a num-
1211 ber of sources, the majority of which have been fishery-independent studies, including
1212 two master's theses focused on gopher rockfish. Only a handful of otoliths have been
1213 collected for gopher rockfish south of Point Conception. Additional length composition
1214 data are available since the last assessment.

1215 2.3 Model Description

model-description

1216 The model descriptions in the following sections reflect decisions and modelling choices the
1217 STAT team made prior to the STAR panel. Changes from the pre-STAR base model to the
1218 final post-STAR base model are documented in the "Responses to the Current STAR Panel
1219 Requests" section. During the STAR panel, the following structrue change were made; 1) the
1220 commercial retained and commercial discard fleets were combined into one commercial fleet,
1221 2) the MRFSS recreational dockside and the CRFS recreational onboard indices south Point
1222 Conception were removed, 3) the PISCO index was split into two indices, one representing
1223 fish 15 cm and larger and an age-0 index representing fish 6 cm or less. All of the figures
1224 and tables reflect the post-STAR final base model. The section on the PISCO index of
1225 abundance has been updated to reflect the change in the indices.

1226 While investigating convergence issues in the cowcod assessment, Richard Methot (NMFS)
1227 identified an issue with the performance of the 'sfabs' function in ADMB. This led to poor
1228 convergence during the iterative search for F_{SPR} under certain conditions. Dr. Methot
1229 resolved the issue, and provided a new 'safe' version of SS (V3.30.13.09) to the cowcod and
1230 GBYR STATs on June 28, followed by an optimized executable on June 30. Apart from the
1231 iterative F_{SPR} search mentioned above, other model outputs and analyses were unaffected
1232 by the change. All of the base model results were run in this newest version of SS.

1233 **2.3.1 Transition to the Current Stock Assessment**
1234 [transition-to-the-current-stock-assessment](#)

1234 The first formal stock assessment for gopher rockfish was conducted in 2005 (Key et al.
1235 2005). There are two major differences between the 2005 assessment this assessment, 1) this
1236 assessment models gopher and black-and-yellow rockfish as a complex, and 2) this assessment
1237 includes the area south of Point Conception.

1238 The 2005 model conducted in SS2 version 1.19 was first transitioned to SS3.24z as a bridge
1239 model, before moving forward to SS3.30. Below, we describe the most important changes
1240 made since the last full assessment in 2005 and explain rationale for each change. Some of
1241 these items are changes due to structure changes with Stock Synthesis, and some denote
1242 parameters chosen for options that were not available in SS2 (version 1.19).

1243 Changes in the bridge model from SS2 version 1.9 to SS3.24z and SS3.30.13.09 include:

1244 The way growth is modeled for age-0 fish has changed. More recent versions of Stock Syn-
1245 thesis model length-at-age for fish below the first reference age (A_{min}) as linearly increasing
1246 from the initial length bin to the length given by the $L_{at}A_{min}$ parameter. The mini-
1247 mum population length bin was reduced from 10 cm in the 2005 assessment to 4 cm in this
1248 assessment. The timing of settlement was set at July to reflect the month at which
1249 the young-of-the-year are expected to be at 4 cm (Figure 39). The length data leading to
1250 this decision were provided by Diana Baetscher (UCSC) and were collected via Standard
1251 Monitoring Unit for the Recruitment of Fishes (SMURFs) (Ammann 2004) from the UCSC-
1252 PISCO kelp forest fish survey as part of her dissertation work on rockfish genetics (Baetscher
1253 2019).

1254 This stock assessment retains a single fleet for the commercial fishery, and also includes
1255 a commercial discard fleet. Data on commercial discards were not available for and not
1256 included in the 2005 assessment. The decision to retain one commercial fleet was made by
1257 examining the length distributions across species, fishing gears, and space, i.e., north and
1258 south of Point Conception (Figure 40). There is very little difference between the length
1259 composition of gopher and black-and-yellow rockfish landed in the commercial fleet north of
1260 Point Conception, which contributed 97% of the commercial landings from 1978-2018. The
1261 length distributions suggest that gopher rockfish south of Point Conception landed dead
1262 south of Point Conception are slightly smaller on average than north of Point Conception.
1263 However, there is not enough data available to justify splitting the commercial fishery north
1264 and south of Point Conception. The length compositions of discarded fish are small in all
1265 of the subplots, suggesting size-based discarding. Because Stock Synthesis is not set up to
1266 handle depth-dependent discard mortality rates and we're modelling two species as a complex
1267 with differing depth-dependent discard mortality rates, the time series of commercial discards
1268 was incorporated as a fleet.

1269 This assessment incorporates the area south of Point Conception, which was previously
1270 excluded from the 2005 assessment. The length composition data suggested that while the
1271 lengths of gopher and black-and-yellow rockfish were similar, fish encountered south of Point

1272 Conception were smaller (Figure 41). The recreational catches from the man-made/jetty
1273 mode are negligible and did not influence the decision to split the fleet at Point Conception.
1274 From 2005-2018, the man-made/jetty mode averaged 0.5% of the total recreational catch and
1275 discards north of Point Conception and 0.03% south of Point Conception. The similarity of
1276 the length distributions between species and among modes within a region were similar and
1277 justified one recreational fleet.

1278 The 2005 model was a length-based model. This assessment uses conditional age-at-length
1279 from fish aged from a number of sources (Table 21).

1280 Differences in both the recreational and commercial catches used in this assessment are
1281 described in detail in Section 1.5.

1282 The bias adjustment for recruitment deviations did not exist in SS2 (version 1.19). We set
1283 1973-2015 as the range of years with full bias adjustment to span the time series that was
1284 modeled.

1285 The previous assessment modeled selectivity of the commercial fleet as logistic curve, and
1286 both parameters for the logistic selectivity were estimated. Selectivity for both the recre-
1287 ational fleet and onboard CPFV survey were modeled using the double logistic. The current
1288 assessment uses the six parameter double normal for all fleets for which selectivity is es-
1289 timated and not mirrored. The MRFSS dockside CPFV surveys and the CPFV onboard
1290 observer surveys are mirrored to the recreational fishing fleets, north and south of Point
1291 Conception, respectively.

1292 The 2005 assessment did not include any time blocks. This assessment includes two time
1293 blocks for the commercial fleet (1916-1998 and 1999-2018). A 10-inch minimum size limit
1294 was placed on the commercial fleet in 1999, which was reflected in the CALCOM length
1295 composition data. No additional time blocks were added for the recreational fleet. GBYR
1296 are a minor component of the nearshore rockfish complex and no significant changes were
1297 detected in the landings or length composition during the time when regulations changed
1298 (1999-2002).

1299 The 2005 assessment considered two candidate fishery-dependent indices of abundance, the
1300 Deb Wilson-Vandenberg onboard observer CPFV survey and a dockside intercept survey
1301 from MRFSS and RecFIN from 1983-2003. However, the dockside index was removed at the
1302 request of the STAR panel, citing “did not provide a reliable measure of relative abundance
1303 due to changes in regulations and fishery targeting during the 1990s-2000s.” The current
1304 assessment uses a version of the MRFSS database that has been more robustly aggregated
1305 to the trip level. Starting in 1999, the CDFW began angler interviews. Interviews are
1306 conducted for all the anglers on the boat, whereas the onboard data is only collected for a
1307 subset of anglers that changes with each fishing stop. Once the onboard observer program
1308 ramped up by the mid-2000s, almost all of the CPFV groundfish trips sampled as onboard
1309 observer trips were also sampled as angler interviews. Using both the onboard observer data
1310 and the dockside interviews for this time period would result in developing indices from the

1311 same fish. The fine-scale onboard observer data provides greater detail in terms of catch and
1312 location than the angler interviews. The onboard observer indices do not include the years
1313 1999 and 2000 due to the number of regulation changes occurring in those two years.

1314 The fishery-independent indices are all new for this assessment; the PISCO kelp forest fish
1315 survey and the CCFRP hook-and-line survey.

1316 Maturity was changed for this assessment based upon newly available data described in the
1317 biological specifications of this assessment.

1318 The 2005 assessment pre-STAR base model fixed steepness for gopher rockfish at 1.0, which
1319 was then changed to 0.65 (the Dorn prior at the time) during the STAR panel. In this
1320 assessment, steepness was set at 0.72, the mean of the prior developed from a meta-analysis of
1321 West Coast groundfish, with a standard deviation of 0.16 (see Accepted Practices Guidelines
1322 for Groundfish Stock Assessments in the supplemental material).

1323 The prior for female natural mortality was updated to the median of the prior from a meta-
1324 analysis conducted by Owen Hamel (see Accepted Practices Guidelines for Groundfish Stock
1325 Assessments in the supplemental material). Assuming a maximum age of 28 years, the
1326 median of the prior is 0.193, close to the fixed value used in the 2005 assessment of 0.2.

1327 Due to the fact that the 2005 model only included gopher rockfish and excluded the area
1328 south of Point Conception, a complete bridge model was not developed. Comparison of
1329 the 2005 input data, catch streams, and indices are provided throughout the document in
1330 appropriate sections.

1331 **2.3.2 Summary of Data for Fleets and Areas**

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

1332 There are 12 fleets in the base model. They include:

1333 *Commercial*: The commercial fleets include two separate fleets, one for GBYR landed (all
1334 gears combined), and one for commercial dead discards.

1335 *Recreational*: The recreational fleets include two fleets, one for north of Point Conception
1336 and one for south of Point Conception (all modes combined).

1337 *Fishery-Dependent Surveys*: There are five fishery-dependent survey fleets, one each for
1338 north and south of Point Conception from the MFRSS CPFV dockside survey, one each
1339 for north and south of Point Conception from the CDFW/Cal Poly onboard observer survey,
1340 and one from the Deb Wilson-Vandenberg CPFV onboard observer survey that represents
1341 north of Point Conception only.

1342 *Research*: There are two main sources of fishery-independent data available the CCFRP
1343 survey the PISCO kelp forest fish survey. A third survey fleet is included as a “dummy”

1344 fleet to allow incorporation of additional conditional age-at-length composition data from the
1345 Zaitlin and Abrams theses, the Pearson groundfish cruise, and the special study conducted
1346 during the SWFSC's juvenile rockfish and ecosystem cruise. This dummy fleet includes 1,067
1347 ages of gopher and black-and-yellow rockfish. This dummy fleet does not have any length or
1348 catches associated with it.

1349 2.3.3 Other Specifications

other-specifications

1350 Stock synthesis has a broad suite of structural options available. Where possible, the 'default'
1351 or most commonly used approaches are applied to this stock assessment. The assessment
1352 is a one-sex model, as no significant differences in growth between males and females was
1353 detected in external analyses.

1354 The length composition data for some years and fleets was small, and may not be represen-
1355 tative of the total catch. Length composition data were removed from the model if fewer
1356 than 20 fish were measured in a given year and fleet. From 1985-1989, two surveys measured
1357 fish from the recreational party/charter fleet, the Ally et al. (Ally et al. 1991) onboard
1358 observer survey and the dockside intercept survey. The number of trips and fish sampled by
1359 the onboard observer survey was far greater than the MRFSS survey and were used in the
1360 model. Initial input sample sizes were also capped at 400 for each set of length composition
1361 data.

1362 The time-series of landings begins in 1916 for the commercial fleet and in 1928 for the
1363 recreational fleet. This captures the inception of the fishery, so the stock is assumed to be
1364 in equilibrium at the beginning of the modeled period.

1365 The internal population dynamics model tracks ages 0-28, where age 28 is the 'plus-group.'
1366 There are relatively few observations in the age compositions that are greater than age 28.
1367 The population length bins and the length composition length bins are set at 1-cm bins from
1368 fish 4-40 cm.

1369 The extra standard deviation parameter was added to all indices except the Deb Wilson-
1370 Vandenberg CPVF onboard observer index and the MRFSS dockside index for north of Point
1371 Conception that both had relatively large estimated variances associated with them. The
1372 extra parameter was explored, but estimated to be on the lower bound, and was removed for
1373 the final base model. All other indices, both recent recreational onboard observer indices,
1374 CCFRP, PISCO, and the MRFSS dockside index south of Point Conception, were estimated
1375 with relatively small variances (10-20%) from their respective indices. Extra variance was
1376 estimated for these indices in the base model.

1377 The following likelihood components are included in this model: catch, indices, discards,
1378 length compositions, age compositions, recruitment, parameter priors, and parameter soft
1379 bounds. See the SS technical documentation for details (Methot et al. 2019).

1380 Electronic SS model files including the data, control, starter, and forecast files can be found
1381 on the [PFMC ftp site](#).

1382 **2.3.4 Modeling Software**

`modeling-software`

1383 The STAT team used Stock Synthesis 3 version 3.30.13.09 (published on 6/28/2019) by
1384 Dr. Richard Methot at the NWFSC. This most recent version was used, since it included
1385 improvements and corrections to older versions. The r4SS package (GitHub release number
1386 v1.35.1) was used to post-process output data from Stock Synthesis.

1387 **2.3.5 Data Weighting**

`data-weighting`

1388 Length composition and conditional-age-at-length (CAAL) compositions sample sizes for the
1389 base model were tuned by the “Francis method,” based on equation TA1.8 in Francis ([2011](#)),
1390 and implemented in the r4ss package. This approach involves comparing the residuals in the
1391 model’s expected mean length with respect to the observed mean length and associated
1392 uncertainty derived from the composition vectors and their associated input sample sizes.
1393 The sample sizes are then tuned so that the observed and expected variability are consistent.
1394 After adjustment to the sample sizes, models were not re-tuned if the bootstrap uncertainty
1395 value around the tuning factor overlapped 1.0.

1396 As outlined in the Best Practices, a sensitivity run was conducted with length and
1397 conditional-age-at-length (CAAL) compositions were re-weighted using the Ianelli-
1398 McAllister harmonic mean method (McAllister and Ianelli [1997](#)). Additionally, weighting
1399 using the Dirichlet-Multinomial likelihood, that includes and estimable parameter (theta)
1400 that scales the input sample size, was explored. However, the model did not converge when
1401 the Dirichlet-Multinomial likelihood was applied to a number of the fleets with composition
1402 data. Given this, and the current challenges with this method described in the Stock
1403 Synthesis manual (Methot et al. [2019](#)), the Francis weightings were applied in the base
1404 model.

1405 A series of sensitivities were conducted to determine the need to estimate extra variability
1406 parameters were estimated and added to the survey CPUE indices, and described below in
1407 the Estimated Parameters section.

1408 **2.3.6 Priors**

`priors`

1409 The log-normal prior for female natural mortality were based on a meta-analysis completed
1410 by Hamel ([2015](#)), as described under “Natural Mortality.” Natural mortality was estimated

1411 using with a prior of, 0.193 (with log-space sigma of 0.438) for an assumed maximum age of
1412 28.

1413 The prior for steepness (h) assumes a beta distribution with parameters based on an update
1414 for the Thorson-Dorn rockfish prior (Dorn, M. and Thorson, J., pers. comm.), which was
1415 endorsed by the Science and Statistical Committee in 2019. The prior is a beta distribution
1416 with $mu=0.72$ and $sigma=0.16$. Steepness is fixed in the base model at the mean of the
1417 prior.

1418 2.3.7 Estimated and Fixed Parameters

estimated-and-fixed-parameters

1419 A full list of all estimated and fixed parameters is provided in Tables 23. Time-invariant,
1420 growth is estimated in this assessment, with all SS growth parameters being estimated. The
1421 log of the unexploited recruitment level for the Beverton-Holt stock-recruit function is treated
1422 as an estimated parameter. The early annual recruitment deviations begin in 1960, with the
1423 main recruitment deviations estimated from 1972-2018. The survey catchability parameters
1424 are calculated analytically (set as scaling factors) such that the estimate is median unbiased,
1425 which is comparable to the way q is treated in most groundfish assessments.

1426 The base model has a total of 111 estimated parameters in the following categories:

- 1427 • Natural mortality
- 1428 • Equilibrium recruitment (R_0) and 71 recruitment deviations
- 1429 • Stock recruitment autocorrelation parameter
- 1430 • Five growth parameters
- 1431 • Five index extra standard deviation parameter, and
- 1432 • 27 selectivity parameters

1433 The estimated parameters are described in greater detail below and a full list of all estimated
1434 and parameters is provided in Table 23.

1435 *Growth.* Five growth parameters were estimated for the one-sex model: three von Bertalanffy
1436 parameters and two parameters for CV as a function of length-at-age related to variability
1437 in length-at-age for small and large fish.

1438 *Natural Mortality.* The estimated natural mortality of 0.212 is close to the median of the
1439 prior, 0.193.

1440 *Selectivity.* Selectivity for all fleets was estimated as double-normal.

1441 Selectivity was estimated as asymptotic for the commercial fleet, with one time block.
1442 Asymptotic selectivity was also estimated for both recreational fleets, Deb Wilson-
1443 Vandenberg's onboard observer survey, and the PISCO. Three parameters were estimated
1444 for each of these fleets, the peak, the ascending width, and the selectivity at the first bin.

1445 Dome-shaped selectivity was estimated for the commercial discard fleet and the CCFRP
1446 survey. Five of the size parameters were estimated for the commercial discard selectivity
1447 (selectivity at the last bin was fixed). Four parameters were estimated for the CCFRP
1448 length compositions (selectivity at the first and last bins was fixed).

1449 *Other Estimated Parameters.* Early recruitment deviations for the base model are estimated
1450 from 1960-1972, with the main recruitment deviations estimated from 1978 to 2018. The
1451 base model also included estimated recruitment deviations for the forecast years, although
1452 these have no impact on the model estimates for the current year.

1453 Many variations of the base case model were explored during this analysis. Sensitivities to
1454 asymptotic vs. domed selectivity were explored for the appropriate fisheries, e.g. commercial
1455 fisheries and surveys, as well as estimating selectivity and mirroring fleet selectivities. Time
1456 blocked selectivity without the time block from 1999-2019 for the recreational fisheries was
1457 investigated.

1458 Much time was also spent tuning the advanced recruitment bias adjustment options.
1459 Sensitivities were performed to each of the thirteen advanced options for recruitment, e.g.,
1460 early recruitment deviation start year, early recruitment deviation phase, years with bias
1461 adjustments, and maximum bias adjustment. The final base model sets the first year of
1462 recruitment deviations just prior to when the majority of fishery/survey length composition
1463 are available.

1464 Initial runs showed that the estimated recruitments were highly auto-correlated.
1465 Therefore, an auto-correlation parameter was later estimated and its value was estimated to
1466 be positive and significantly different from zero.

1467 Several models were also investigated where steepness and natural mortality were either
1468 estimated, fixed at their respective priors.

1469 *Other Fixed Parameters.* The stock-recruitment steepness is fixed at the SSC approved
1470 steepness prior for rockfish of 0.72.

1471 2.4 Model Selection and Evaluation

model-selection-and-evaluation

1472 2.4.1 Key Assumptions and Structural Choices

key-assumptions-and-structural-choices

1473 Key assumptions in the model are that it is appropriate to model gopher and black-and-
1474 yellow rockfish as a complex. The catch histories are inseparable at this time, especially for

1475 the early commercial landings. The biological information available also precluded complete
1476 analyses of difference in growth, i.e., the majority of black-and-yellow rockfish aged were
1477 small fish and small fish were lacking for gopher rockfish. Data from both species were used
1478 to provide a complete picture of the growth curve.

1479 The assessment is a one area model with fleets as areas for the recreational fishery. There
1480 were only a handful of aged gopher rockfish from south of Point Conception, and not enough
1481 other biological information available that would have justified a multi-area model.

1482 2.4.2 Alternate Models Considered

alternate-models-considered

1483 A number of models were run with different catch histories for the recreational fleet south of
1484 Point Conception, given that the catch histories were modified from the original data. None
1485 of the alternatives explored altered the model at any significant level due to the fact that
1486 the recreational catches south of Point Conception are relatively small. Results from select
1487 sensitivity runs compared to the base model are in Table 26.

1488 Two sensitivities were also performed altering the commercial discard catch history. The
1489 discard catch was set to zero for all years prior to 2004, the year when WCGOP estimates
1490 were first available, and to a constant rate of 17% of the commercial landings, the maximum
1491 discard rate observed in the WCGOP data. Neither of these sensitivities resulted in any
1492 significant change to the model outputs.

1493 Sensitivity of the model to the spawning and settlement months were also explored. The
1494 base model originally set settlement month to January. Both gopher and black-and-yellow
1495 rockfish settle at a small size (~2 cm) and over a course of several months. After exploring the
1496 young-of-the-year length data made available by Diana Baetscher, the timing of settlement
1497 was moved to July for the base model, when the majority of GBYR are 4 cm, the size of the
1498 smallest length bin. The change of the timing of settlement had little effect on the model
1499 results.

1500 Runs of the base case model estimating steepness were also considered.

1501 A sensitivity of the model to using the commercial length composition data from PacFIN
1502 was also considered. The fits changed only slightly, (increasing depletion from 0.46 to 0.48)
1503 but given the concerns outlined in the discussion on commercial length composition the base
1504 model includes the commercial length compositions from CALCOM.

1505 Sensitivities were developed to look at alternate selectivity patterns for the the commercial
1506 discard fleet and the CCFRP survey. Neither of the length compositions for these fleets
1507 observed larger fish. A time block for the commercial discard fishery was not considered
1508 since no length composition of discarded fish were available prior to 2004.

1509 **2.4.3 Convergence**

convergence

1510 Model convergence was determined by starting the minimization process from dispersed val-
1511 ues of the maximum likelihood estimates to determine if the model found a better minimum.
1512 Jitter is a SS option that generates random starting values from a normal distribution lo-
1513 gistically transformed into each parameter's range (Methot et al. 2019). This was repeated
1514 300 times and the minimum was reached in 67% of the runs (Table 22). The model did not
1515 experience convergence issues, e.g., final gradient was below 0.0001, when reasonable starting
1516 values were used and there were no difficulties in inverting the Hessian to obtain estimates of
1517 variability. We did sensitivity runs for convergence by changing the phases for key estimated
1518 parameters; neither the total log-likelihood nor the parameter estimates changed.

1519 **2.5 Response to the Current STAR Panel Requests**

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

1520 To be populated after the STAR panel.

1521 **2.6 Base Case Model Results**

base-case-model-results

1522 The following description of the model results reflects a base model that incorporates all of
1523 the changes made during the STAR panel. A comparison of the pre-STAR base model and
1524 the post-STAR base model can be found in Figures 42, 43, and 44 and Table . A number
1525 of changes to the fleet structures, removal of surveys south of Point Conception, and the
1526 splitting of the PISCO index into two indices to better reflect life stages contributed to the
1527 changes. The final model also fixes natural mortality, whereas it was estimated in the pre-
1528 STAR base model. The pre-STAR base model includes and ageing error matrix that was
1529 developed using only half of the available double reads. The post-STAR base includes the
1530 updated ageing error matrix (Figure 45), and the update did not significantly change the
1531 model outputs.

1532 The base model parameter estimates and their approximate asymptotic standard errors are
1533 shown in Table 23 and the likelihood components are in Table 24. Estimates of derived
1534 reference points and approximate 95% asymptotic confidence intervals are shown in Table e.
1535 Time-series of estimated stock size over time are shown in Table 25.

1536 Steepness of the assumed Beverton-Holt stock-recruitment relationship was fixed at 0.72,
1537 and natural mortality was fixed at 0.193.

1538 **2.6.1 Parameter Estimates****parameter-estimates**

1539 The base model produces estimates of growth parameters different from the external esti-
1540 mates (Figure 46). The external estimate of the von Bertalanffy growth coefficient k was
1541 0.247, whereas the internal estimate was much lower at 0.107. Using the Schnute param-
1542 eterization with the age for L1 set at 2 and L2 at 23, the external estimates of lengths at
1543 Amin and Amax were similar at 13.80 and 28.22, respectively. The internal estimates of the
1544 lengths for Amin and Amax were 13.4 and 28.80, respectively. Given that natural mortality
1545 was fixed in the base model and natural mortality and the growth parameter k are negatively
1546 correlated, the model estimated a slower rate of growth. A number of other factors including
1547 the lenght composition and selectivity affect the internal estimate of growth. Hence, growth
1548 was chosen as the axis of uncertainty for the decision table.

1549 The estimated selectivities for all fleets within the model are shown in Figure 47. The selec-
1550 tivity curves for the commercial fleet, recreational fleets north and south of Point Conception,
1551 and the larger PISCO (15+ cm) were estimated. All of the selectivities are asymptotic ex-
1552 cept for the PISCO age-0 index, which has an age selectivity set to 1.0. All of the recreational
1553 indices and the CCFRP index selectivities were mirrored to the recreational fleet north of
1554 Point Conception. Attempts to fit asymptotic and dome-shaped selectivity to the CCFRP
1555 data resulted in poor estimation, large standard deviations, or a lack of fit to the data. The
1556 aggregated CCFRP length composition over time was similiar to the length composition
1557 data of the recreational fleets north of Point Conception and mirroring the CCFRP selectiv-
1558 ity provided a more parsimonious model. The recreational fleet south of Point Conception
1559 encounters smaller GBYR, which is reflected in the asymptotic selectivity shifted to the left
1560 of all other fleets. Selectivities for the recreational fleet north of Point Conception and the
1561 commercial fleet are very similar. Both fleets include both length composition of retained
1562 and discarded fish, although no information on the size of discards is available from the
1563 commercial fleet prior to 2004. The selectivity for the commercial fleet was kept separate
1564 because the fleet has different fishing behavior than the recreational fleet and going forward
1565 in time, may diverge further from the fleets depending on management decisions or changes
1566 in fishing behavior. Selectivity for the PISCO (15+ cm fish) index was estimated as the
1567 survey observes a wider range of length classes than the other fleets. The estimated peak
1568 of the PISCO selectivity hit the upper bound of 38 and was fixed at 38 in the base model.
1569 The age selectivity for the PISCO age-0 index was fixed at 1.0 and assumes that all age-0
1570 fish are selected.

1571 The additional survey variability (process error added directly to each year's input variabil-
1572 ity) for all surveys except the recreational dockside index north of Point Conception (Rec-
1573 DocksideNorth) and the PISCO age-0 index, was estimated within the model. The added
1574 variance for Deb's onboard observer survey was estimated at . The added variances were
1575 highest for the recreational onboard observer survey north of Point Conception () PISCO (),
1576 and CCFRP ().

1577 Recruitment deviations were estimated from 1978-2018 (Figure 48). Estimates of recruitment
1578 suggest that GBYR are characterized by cyclical years of high and low recruitment (Figure

1579 49). The final base model does not include early recruitment deviation and a steep bias
1580 adjustment ramp from 1978 to 1979 of 0.32 that extends to 2019 Figure 50. The years of
1581 highest estimated recruitment is 1991, with recruitment estimated more than double that of
1582 any other year.

1583 Fish from this cohort can be observed in the lenght composition data from Deb Wilson
1584 Vandenberg's onboard observer survey and recreational fleet north of Point Conception in
1585 the later half of the 1990s. Additional periodic recruitment events are estimated from 1994
1586 and onward, with the peaks from 2001 and on driven by the PISCO age-0 index. followed by
1587 a period of below average recruitment, and another high recruitment pulse in the late 2010s.

1588 The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 51.
1589 The stock has not been depleted to a low enough level that would inform the estimation of
1590 steepness. Steepness was not estimated in this model, and profiles over steepness values are
1591 discussed below.

1592 2.6.2 Fits to the Data

fits-to-the-data

1593 Model fits to the indices of abundance, fishery length composition, survey length composition,
1594 and conditional age-at-length observations are all discussed below. The full r4ss plotting
1595 output is available in the supplementary material.

1596 The fits to the three fishery-dependent and three fishery-independent survey indices are
1597 shown in Figures 52, 53, 54, 55, 56, and 57. All indices represent the area north of Point
1598 Conception only, and not all of these were fit well by the assessment model. The MRFSS
1599 CPFV recreational dockside survey index north of Point Conception spanning the 1980s-
1600 1990s was fit well by the model without added variance, but relatively flat, and is not a very
1601 informative index. The index for Deb Wilson-Vandenberg's CPFV onboard observer survey
1602 spanning 1988-1998 was well fit and indicates an increase in relative abundance in the last
1603 year of the survey. The current recreational CRFS/Cal Poly onboard observer survey north
1604 of Point Conception from 2001-2018 was relatively well fit, except for the decline suggested
1605 2013 and 2014. The increase in relative abundance observed in 2018 was not fit by the
1606 model, even with the added variance. The variance added to this survey was the highest for
1607 all indices.

1608 The model did not capture the contrast in the PISCO index for 15+ cm fish, fitting a decline
1609 to the time series from 2010 to 2018, when the index suggests an increase from 2010 to 2013
1610 and another increase after a declin in 2016. The model does capture the PISCO age-0 index
1611 without added variance. A number of years, e.g., 2004-2008, were marked by low relative
1612 abundance of age-0 GBYR and have larger standard errors. The years with lower relative
1613 abundance were not captured by the model, but fit to the uppder bound of the input standard
1614 error. The increases in age-0 GBYR in 2001, 2001, 2014-2015 and 2017 were captured in the
1615 model fit.

1616 The model was not able to capture the trends observed in the fishery-independent CCFRP
1617 hook-and-line survey. The index suggested the same depressed relative abundance in 2013 as
1618 the fishery-dependent CRFS/Cal Poly onboard observer survey, that was also not captured
1619 here by the fit. The increasing trends in abundance from 2016-2018 was also not captured
1620 by the model fit, and the fit suggests a declining trend over the entire time series from
1621 2007-2018.

1622 The base model was re-weighted twice using Francis weights for the length and age compo-
1623 sition data. Fits to the length data are shown based on the proportions of lengths observed
1624 by year and the Pearson residuals-at-length for all fleets. Detailed fits to the length data
1625 by year and fleet are provided in Appendix 8. Aggregate fits by fleet are shown in Figure
1626 58. Overall, the length composition all fit well. The PISCO fleet has the noisiest of all the
1627 length composition data, but on an annual basis, the length data were relatively well fit.
1628 The fit to the aggregated CCFRP data suggests the model expects to see additional larger
1629 fish, which is likely due to the mirroring of the selectivity. However, on an annual basis,
1630 there is a tradeoff with the CCFRP with under-fitting of the larger fish in the earlier years
1631 and an under-fitting of the smaller fish expected in the later years (2013-2018).

1632 The mean age of the recreational fleet varied from 1980-1986 ranging from approximately
1633 8-11, and increased in 2017 to approximately 13 (Figure 59). The conditional age data from
1634 the CCFRP data was not well fit for the earliest years in the data, but was reasonably well
1635 fit for the last four years of data (Figure 60). The conditional length composition data from
1636 the ‘dummy’ fleet was well fit, although heavily down-weighted. Age data in this fleet are
1637 from a number of sources and sampling programs (Figure 61).

1638 2.6.3 Uncertainty and Sensitivity Analyses

uncertainty-and-sensitivity-analyses

1639 A number of sensitivity analyses were conducted, including:

- 1640 1. Fixing natural mortality at the prior of 0.193
- 1641 2. Fixing the von Bertalanffy k at the external estimate of 0.247
- 1642 3. Using the PacFIN expanded length composition data
- 1643 4. Data weighting scenarios including unweighted, harmonic means (McAllister-Ianelli
1644 method), and Francis weights

1645 The following sensitivities are based on the pre-STAR base model and indicate areas that the
1646 STAT identified as either areas of uncertainty or model sensitivities outlined in the Accepted
1647 Practices and Guidelines document. A summary of parameters for all sensitivity runs is in
1648 Table 26.

1649 Fixing either natural mortality or the von Bertalanffy k parameter results in a stock with
1650 higher spawning output in 2018 as compared to the base model (Figure 62).

1651 Fixing either M or k demonstrates the negative correlation between the two parameters. The
1652 von Bertalanffy k parameter is estimated at 0.12 when natural mortality (estimated at 0.21)
1653 and growth are both estimated. When natural mortality is fixed at the prior of 0.19, k is
1654 estimated at 0.14, but the two other growth parameters, L1 and L2 do not change much at
1655 all. When k is fixed to the external estimate of 0.247, natural mortality is estimated at 0.16,
1656 and the other growth parameters both decrease. A number of additional sensitivities to the
1657 growth parameters will be presented at the STAR panel.

1658 Replacing the CALCOM commercial length composition data with the PacFIN length com-
1659 position results in the stock at an overall lower level of biomass than the base model. Deple-
1660 tion in the final year with the PacFIN length composition is 0.50, compared to 0.46 in the
1661 base model. A detailed discussion on the decision to use the CALCOM length composition
1662 in the base model can be found in the discussion commercial length and age data, Section
1663 (2.1.3).

1664 Data weighting is an area of uncertainty for stock assessment, and research is ongoing to
1665 determine the effects of data weighting and the most appropriate initial sample sizes for
1666 length and age composition data. The base model used the Stewart sample sizes for initial
1667 sample sizes for the fishery data and either the Stewart sample sizes or number of “trips” for
1668 the survey sample sizes. Weighting the data by the harmonic mean resulted in a model with
1669 a total likelihood between the base model, which uses the Francis method for weighting, and
1670 the model with default weights (Figure 63). The end year spawning output is almost identical
1671 for the models using harmonic means and Francis weights, both of which down-weighted the
1672 composition data.

1673 The Francis weights in the base model were stable, and did not tend to serially decrease
1674 (down-weight) any of the data sets, which has been seen in other assessments. The final
1675 base model re-weights the composition data only once. As discussed above in the data
1676 weighting section, the Dirichlet-Multinomial weighting was explored, but a model with a
1677 positive definite Hessian was not identified with the pre-STAR base model.

1678 2.6.4 Retrospective Analysis

retrospective-analysis

1679 A 4-year retrospective analysis was conducted by running the model using data only through
1680 2017 (retro 1), 2016 (retro 2), 2015 (retro 3), and 2014 (retro 4) (Table 27). The initial popu-
1681 lation size and estimation of trends in spawning biomass in the retrospective runs were lower
1682 than the base model, except for retro 1 (Figure 64). All retrospective runs followed the same
1683 general trend, with the differences in the trends stemming from the change in recruitment
1684 deviations (Figure 65). The PISCO age-0 index has a signal of increased recruitment in
1685 the most recent years. For Retro2, Retro3, and Retro4, the trends in recruitment are not

1686 observed by the model. There is no conditional age-at-length composition data for 2015-
1687 2016, leading to the minor change in the age composition likelihood from Retro2 to Retro3
1688 and Retro4 (Table 27). The age composition data in 2017 accounts for 2.5% of all available
1689 ages, and 4.5% of all fish aged were from 2018. The available length data in each year from
1690 2015-2018 range from 4-6% of the total available length data. The length compositions of all
1691 the other fleets have similar length distributions for 2015-2018 (8). Additional investigations
1692 into the retrospective patterns will be made by the STAT.

1693 2.6.5 Likelihood Profiles

likelihood-profiles

1694 Likelihood profiles were conducted for R_0 , steepness, and over natural mortality values sep-
1695 arately. These likelihood profiles were conducted by fixing the parameter at specific values
1696 and estimated the remaining parameters based on the fixed parameter value (Tables 28-29).

1697 In regards to values of R_0 , the negative log-likelihood was minimized at approximately
1698 $\log(R_0)$ of 8.0 (Table 28). The individual surveys tend to minimize at the upper bound
1699 or just below, while the length composition data has conflicting trends, e.g., CCFRP and
1700 commercial fleets, or the upper bound, e.g., PISCO and the recreational north fleets (Figures
1701 66-67). The data all consistently minimize around 8.5 and the recreational fleet south of Point
1702 Conception minimize R_0 at the lower bound. (Figure 68). Over the range of values of R_0 ,
1703 depletion ranged from 0.38-0.59 (Figure 69).

1704 For steepness, the negative log-likelihood reaches a minimum around a steepness near the
1705 upper bound (Figure 72 and Table 28 and Figure 77). The length composition likelihood
1706 components declined towards the upper bound for Deb's CPFV and the recreational south
1707 fleets, while the other fleets either reached a minimum around 0.55 or at the lower bound.
1708 (Figure 70). Overall changes in the survey likelihood across the range of steepnes was less
1709 than 2.0, with surveys either minimized at the lower or upper bound (Figure 71). The
1710 relative depletion for GBYR ranges from 0.375 to 0.493 across different assumed values of
1711 steepness (Table 28).

1712 The negative log-likelihood was minimized at a natural mortality value near 0.2, slightly
1713 higher than the prior of 0.193 (Table 28 and Figure 76). The age, length, index, and prior
1714 likelihood contributions were minimized at natural mortality values around 0.22, and the re-
1715 cruitment contribution was minimized at the second to largest value of M run, 026. (Table
1716 28). The length composition minimizes around a natural mortality value of 0.14, with the
1717 commercial, recreational fleet north of Point Conception, and CCFRP data minimizing wars
1718 the lower bound (Figure 74). The length data from Deb's CPFV survey minimizes around
1719 0.22, while the PISCO and recreational length compositions south of Point Conception min-
1720 imizes at the upper bound. The PISCO and CCFRP minimized around a natural mortality
1721 value of 0.22, while the PISCO age-0 and overall survey likelihood minimized at the upper
1722 bound of 0.3 (Figure 75). The relative depletion for GBYR ranged from 0.32-0.59 across
1723 alternative values of natural mortality (Figure 77).

1724 **2.6.6 Reference Points**

reference-points-1

1725 Reference points were calculated using the estimated selectivities and catch distribution
1726 among fleets in the most recent year of the model, (2017). Sustainable total yield (landings
1727 plus discards) were 134 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95%
1728 confidence interval of 116 mt based on estimates of uncertainty. The spawning biomass
1729 equivalent to 40% of the unfished level ($SB_{40\%}$) was 504 mt.

1730 The predicted spawning output from the base model shows an initial decline starting the
1731 1950s, is then stable, and declines steeply until 1995 (Figure 78). The spawning output then
1732 rapidly increases through the early 2000s, and has been in a decline since 2006.

1733 The 2018 spawning biomass relative to unfished equilibrium spawning biomass is above the
1734 target of 40% of unfished levels (Figure 79). The relative fishing intensity, $(1 - SPR)/(1 -$
1735 $SPR_{50\%})$, was below the management target from 1981-1998, and below the minimum stock
1736 size threshold in 1995. The stock has been above the management target since 1999.

1737 Table e shows the full suite of estimated reference points for the base model and Figure 80
1738 shows the equilibrium curve based on a steepness value fixed at 0.72.

1739 **3 Harvest Projections and Decision Tables**

harvest-projections-and-decision-tables

1740 This section will be completed at or after the STAR panel.

1741 **4 Regional Management Considerations**

regional-management-considerations

1742 While the proportion of the stock residing within U.S. waters is unknown, the assessment
1743 provides an adequate geographic representation of the portion assessed for management
1744 purposes. There is little evidence that black-and-yellow rockfish extend into Mexico, and
1745 the proportion of gopher rockfish residing south of Pt. Conception is small. While there has
1746 been work on the genetic structure between the two species, there has not been work done
1747 within each species to inform spatial structure of the populations. Given the relatively small
1748 area in the waters of California where these species occur, there is relatively little concern
1749 regarding exploitation in proportion to the regional distribution of abundance in the area
1750 assessed in this study.

1751 The state of California implements regional management for the recreational fleet in the form
1752 of five regions, referred to as management areas with differing depth and season restrictions.
1753 Neither gopher nor black-and-yellow rockfish are a large component of the total recreational

₁₇₅₄ landings and are managed as part of the
₁₇₅₅ nearshore rockfish complex. Current regional management appears appropriate for these
₁₇₅₆ species.

₁₇₅₇ **5 Research Needs**

research-needs

₁₇₅₈ This section will be completed at or after the STAR panel.

₁₇₅₉ **6 Acknowledgments**

acknowledgments

₁₇₆₀ This section will be completed at or after the STAR panel.

7 Tables

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

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

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

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

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

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

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

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

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

Continues next page

tab:Rec_removal

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

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

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tab:Rec_removal

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

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

Table 4: Length composition sample sizes for survey data.

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

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

Fleet Years	Name	Fishery ind.	Filtering	Method	Endorsed	tab:Index_summary
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 inputs.

Year	Deb WV		MRFSS N		MRFSS S		Onboard N		Onboard S		CCFRP		PISCO	
	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

Filter	tab:Fleet5_Filter	Drifts	Positive Drifts
Remove errors, missing data		6691	1470
Remove 1987 (sampled only MNT), 1990-1991 low sample sizes		4283	1372
Remove reefs that never encountered GBY		4022	1372
Remove lower and upper 2.5% of time fished		3762	1300
Remove depth less than 9 m and greater than 69 m		3515	1279
Remove reefs with low sample rates		2411	1096

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

Model	Lognormal	Binomial	tab:Fleet5_AIC
Year	2834	3330	
Year + Depth	2781	2906	
Year + Reef	2716	2880	
Year + Month	2839	3286	
Year + Depth + Reef	2625	2488	
Year + Month+ Reef	2725	2844	
Year + Depth + Month	2780	2902	
Year+ Depth+Month+Reef	2632	2479	

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

Filter	Drifts	Positive Drifts	tab:Fleet6_7_Filter
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 $\geq 20\%$ groundfish and recheck reefs	5495	1171	
Make sure reefs still sampled at least 2/3 of years	5440	1132	

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

Model	Lognormal	Binomial	tab:Fleet6_AIC
Year	14135	17531	
Year + Month	14120	17529	
Year + Depth	13953	17025	
Year + Reef	14126	17293	
Year + Month + Depth	13951	17027	
Year + Month + Depth + Reef	13921	16674	

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

Model	Lognormal	Binomial	tab:Fleet7_AIC
Year	2798	5490	
Year + Month	2799	5487	
Year + Depth	2744	5159	
Year + Reef	2653	5390	
Year + Depth + Reef	2652	5071	
Year + Depth + Reef + Month	2663	5072	

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

Filter	Transects	Positive Transects	tab:Fleet8_Filter
Remove missing data and retain only bottom transects	22,055	6,330	
Remove month of June - few samples	21,941	6,318	
Remove dives earlier than 2004 for UCSB and 2001 for UCSC	20,659	6,165	
Keep sites sampled in at least half of all years (UCSC and UCSB separate)	14,721	4,097	
Keep sites observing GBYR in at least half of all years	12,139	4,002	
Remove transects denoted as old, no longer sampled	10,712	3,268	
Subset to just UCSC sites	5,686	2,939	
Use only consistently sampled sites	3,231	1,729	
Collapse repeated transects	1,928	1,487	

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

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

Table 14: Data filtering steps for the fishery-independent CCFRP hook-and-line survey.

Filter	Drifts	Positive Drifts	tab:Fleet9_Filter
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.

Model	AIC	tab:Fleet9_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.

Filter	<code>tab:Fleet10_11_Filter</code>	
	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.

Model	AIC	<code>tab:Fleet10_AIC</code>
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.

Model	Lognormal	Binomial	tab:Fleet11_AIC
Year	911	552	
Year + Wave	908	538	
Year + Wave + Area_X	905	540	
Year + Wave + Area_X + SubRegion	903	537	
Year + Wave + SubRegion	908	536	

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

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

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

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

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

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

Table 22: Results from 100 jitters from the base case model.

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

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

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Table 23: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD)).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
91	LnQ_base_CCFRP(7)	-6.199	-1	(-15, 15)	OK	0.078	None
92	Q_extraSD_CCFRP(7)	0.212	4	(0.0001, 2)	OK	0.078	None
93	LnQ_base_RecDocksideNorth(8)	-9.288	-1	(-15, 15)	OK	0.078	None
94	LnQ_base_PISCOage(10)	-10.187	-1	(-15, 15)	OK	0.078	None
95	Size_DbLN_peak_Com(1)	31.058	1	(19, 38)	OK	0.383	None
96	Size_DbLN_top_logit_Com(1)	8.000	-5	(-5, 10)	OK	0.108	None
97	Size_DbLN_ascend_se_Com(1)	2.733	5	(-9, 10)	OK	0.108	None
98	Size_DbLN_descend_se_Com(1)	5.000	-5	(-9, 9)	OK	0.108	None
99	Size_DbLN_start_logit_Com(1)	-9.363	5	(-15, -5)	OK	0.971	None
100	Size_DbLN_end_logit_Com(1)	10.000	-5	(-5, 15)	OK	0.971	None
101	Size_DbLN_peak_RecNorth(2)	32.116	3	(19, 39)	OK	0.331	None
102	Size_DbLN_top_logit_RecNorth(2)	8.000	-5	(-5, 10)	OK	0.055	None
103	Size_DbLN_ascend_se_RecNorth(2)	3.202	5	(-9, 10)	OK	0.055	None
104	Size_DbLN_descend_se_RecNorth(2)	5.000	-5	(-9, 9)	OK	1.137	None
105	Size_DbLN_start_logit_RecNorth(2)	-11.110	5	(-15, -5)	OK	0.951	None
106	Size_DbLN_end_logit_RecNorth(2)	10.000	-5	(-5, 15)	OK	0.238	None
107	Size_DbLN_peak_RecSouth(3)	27.565	4	(19, 38)	OK	0.951	None
108	Size_DbLN_top_logit_RecSouth(3)	8.000	-5	(-5, 10)	OK	0.951	None
109	Size_DbLN_ascend_se_RecSouth(3)	3.078	5	(-9, 10)	OK	0.238	None
110	Size_DbLN_descend_se_RecSouth(3)	5.000	-5	(-9, 9)	OK	1.592	None
111	Size_DbLN_start_logit_RecSouth(3)	-7.504	5	(-15, -5)	OK	1.592	None
112	Size_DbLN_end_logit_RecSouth(3)	10.000	-5	(-5, 15)	OK	1.592	None
113	SizeSel_P1_DebCPFV(4)	-1.000	-5	(-1, 10)	OK	1.592	None
114	SizeSel_P2_DebCPFV(4)	-1.000	-5	(-1, 10)	OK	1.592	None
115	SizeSel_P1_RecOnboardNorth(5)	-1.000	-5	(-1, 10)	OK	1.592	None
116	SizeSel_P2_RecOnboardNorth(5)	-1.000	-5	(-1, 10)	OK	1.592	None
117	Size_DbLN_peak_PISCO(6)	38.000	-5	(19, 38)	OK	1.592	None

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Table 23: List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values indicate not estimated), status (indicates if parameters are near bounds, and prior type information (mean, SD)).

No.	Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp. Val, SD)
118	Size_DbLN_top_logit_PISCO(6)	8.000	-5	(-15, 10)	OK	0.085	None
119	Size_DbLN_ascend_se_PISCO(6)	4.699	5	(-9, 10)			None
120	Size_DbLN_descend_se_PISCO(6)	5.000	-5	(-9, 9)			None
121	Size_DbLN_start_logit_PISCO(6)	-17.029	-5	(-25, 15)			None
122	Size_DbLN_end_logit_PISCO(6)	10.000	-5	(-5, 15)			None
123	SizeSel_P1_CCFRP(7)	-1.000	-5	(-1, 10)			None
124	SizeSel_P2_CCFRP(7)	-1.000	-5	(-1, 10)			None
125	SizeSel_P1_RecDocksideNorth(8)	-1.000	-5	(-1, 10)			None
126	SizeSel_P2_RecDocksideNorth(8)	-1.000	-5	(-1, 10)			None
127	minage@sel=1_PISCOAge0(10)	0.000	-5	(0, 1)			None
128	maxage@sel=1_PISCOAge0(10)	0.000	-5	(0, 1)			None

Table 24: Likelihood components from the base model.

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

Table 25: 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 25: Time-series of population estimates from the base-case model. Relative exploitation rate is $(1 - SPR)/(1 - SPR_{50\%})$.

Year	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1953	1885	1112	0.882	3085	55	0.03	0.83
1954	1869	1098	0.871	3080	68	0.04	0.80
1955	1846	1077	0.854	3074	60	0.03	0.81
1956	1831	1064	0.844	3069	76	0.04	0.78
1957	1808	1043	0.827	3063	76	0.04	0.77
1958	1788	1025	0.813	3056	88	0.05	0.74
1959	1763	1003	0.795	3048	62	0.04	0.79
1960	1757	998	0.791	3047	44	0.02	0.84
1961	1764	1005	0.797	3049	50	0.03	0.82
1962	1766	1007	0.799	3050	61	0.03	0.79
1963	1759	1002	0.795	3048	56	0.03	0.81
1964	1758	1002	0.794	3048	43	0.02	0.84
1965	1764	1008	0.799	3050	58	0.03	0.80
1966	1760	1004	0.796	3049	52	0.03	0.82
1967	1760	1004	0.797	3049	48	0.03	0.83
1968	1763	1007	0.799	3050	49	0.03	0.82
1969	1764	1009	0.800	3051	46	0.03	0.83
1970	1767	1012	0.802	3052	60	0.03	0.80
1971	1761	1006	0.798	3050	51	0.03	0.82
1972	1762	1007	0.798	3050	66	0.04	0.78
1973	1752	998	0.791	3047	88	0.05	0.74
1974	1729	977	0.775	3039	92	0.05	0.72
1975	1707	957	0.759	3031	89	0.05	0.72
1976	1689	940	0.746	3024	91	0.05	0.72
1977	1673	926	0.734	3018	79	0.05	0.73
1978	1666	920	0.729	3257	84	0.05	0.72
1979	1657	912	0.723	3049	78	0.05	0.73
1980	1657	908	0.720	3557	155	0.09	0.61
1981	1610	862	0.683	3325	143	0.09	0.61
1982	1583	828	0.657	3627	129	0.08	0.62
1983	1575	808	0.641	2938	118	0.07	0.63
1984	1577	799	0.633	2076	174	0.11	0.54
1985	1539	763	0.605	2143	173	0.11	0.53
1986	1485	735	0.583	2061	206	0.14	0.48
1987	1400	696	0.552	2195	162	0.12	0.51
1988	1343	683	0.542	2609	145	0.11	0.53
1989	1297	675	0.535	3277	120	0.09	0.57

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Table 25: 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 26: Sensitivity of the base model to alternative assumptions about natural mortality, growth, and using PacFIN-derived length composition data.

Label	Base model (Francis weights)	Fix M at prior	Fix k at external est.	PacFIN length comps	Default weighting	tab:Sensitivity_model1 Harmonic mean weighting
TOTAL_like	516.36	516.61	524.71	508.20	4041.05	1734.79
Catch_like	0.00	0.00	0.00	0.00	0.00	0.00
Equil_catch_like	0.00	0.00	0.00	0.00	0.00	0.00
Survey_like	-32.17	-32.25	-31.21	-31.91	-25.08	-27.59
Length_comp_like	372.46	372.55	373.98	365.19	2192.10	1015.78
Age_comp_like	189.56	189.70	194.77	188.81	1872.77	753.42
Recruitment_like	-13.51	-13.40	-12.94	-13.99	1.13	-6.87
Param_prior_like	0.02	0.00	0.11	0.09	0.13	0.05
Param_softbounds_like	0.00	0.00	0.01	0.01	0.01	0.01
Female_M	0.21	0.19	0.16	0.23	0.24	0.22
Steepness	0.72	0.72	0.72	0.72	0.72	0.72
lnR0	8.60	8.33	7.86	8.87	9.03	8.80
Total Biomass	2369.39	2313.35	2322.80	2307.70	2321.26	2439.02
Depletion	0.46	0.43	0.42	0.00	0.50	0.49
SPR ratio	1.00	1.00	1.00	0.00	1.00	1.00
L_at_Amin_Fem_GP_1	9.67	9.61	8.53	9.91	9.62	9.88
L_at_Amax_Fem_GP_1	28.44	28.23	26.39	27.79	27.24	27.64
VonBert_K_Fem_GP_1	0.12	0.14	0.25	0.11	0.10	0.12
No. para	112.00	111.00	112.00	112.00	112.00	112.00

Table 27: Summaries of key assessment outputs and likelihood values from the retrospective analysis. The base model includes all of the data. Retro1 removes the last year of data (2018), Retro2 removes the last two years of data, Retro3 removes three years and Retro4 removes four years.

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

Table 28: Summaries of key assessment outputs and likelihood values from selected likelihood profile runs on virgin recruitment ($\ln R_0$) and steepness. Depletion and SPR ratio are for the year 2019.

Label	R07500	R07750	R08000	R08250	R08500	h0390	h0550	h0710	h0850	tab:like_profiles h0990
Female M	0.19	0.19	0.19	0.19	0.19	0.27	0.23	0.21	0.20	0.20
Steepness	0.72	0.72	0.72	0.72	0.72	0.39	0.55	0.71	0.85	0.99
$\ln R_0$	7.50	7.75	8.00	8.25	8.50	9.71	9.02	8.62	8.39	8.23
Total unfished biomass (mt)	1136.52	1494.09	1948.53	2528.35	3313.95	4035.93	2872.00	2389.96	2158.79	2009.99
Depletion	0.38	0.37	0.42	0.51	0.59	0.38	0.43	0.46	0.48	0.49
SPR ratio	0.99	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00
Female Lmin	12.29	12.79	13.35	13.68	13.93	10.08	9.82	9.67	9.60	9.54
Female Lmax	27.47	28.25	28.78	28.67	28.23	28.74	28.55	28.45	28.38	28.34
Female K	0.14	0.12	0.11	0.11	0.12	0.10	0.12	0.12	0.13	0.13
Negative log-likelihood										
TOTAL	559.53	538.72	530.29	532.87	540.31	525.26	519.36	516.49	515.18	515.70
Catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Survey	-29.36	-30.94	-33.60	-35.55	-35.83	-30.36	-31.68	-32.16	-32.35	-32.46
Length_comp	414.22	412.12	411.34	413.52	417.35	373.67	372.78	372.47	372.35	372.29
Age_comp	154.09	146.67	146.61	149.75	152.41	191.65	190.34	189.60	189.18	188.88
Recruitment	20.58	10.87	5.94	5.14	6.38	-11.56	-12.69	-13.47	-13.94	-14.28
Parm_priors	0.00	0.00	0.00	0.00	0.00	1.85	0.60	0.04	-0.05	1.27
Parm_softbounds	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00

Table 29: Summaries of key assessment outputs and likelihood values from selected likelihood profile runs on female natural mortality. Depletion and SPR ratio are for the year 2019.

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

₁₇₆₂ 8 Figures

figures

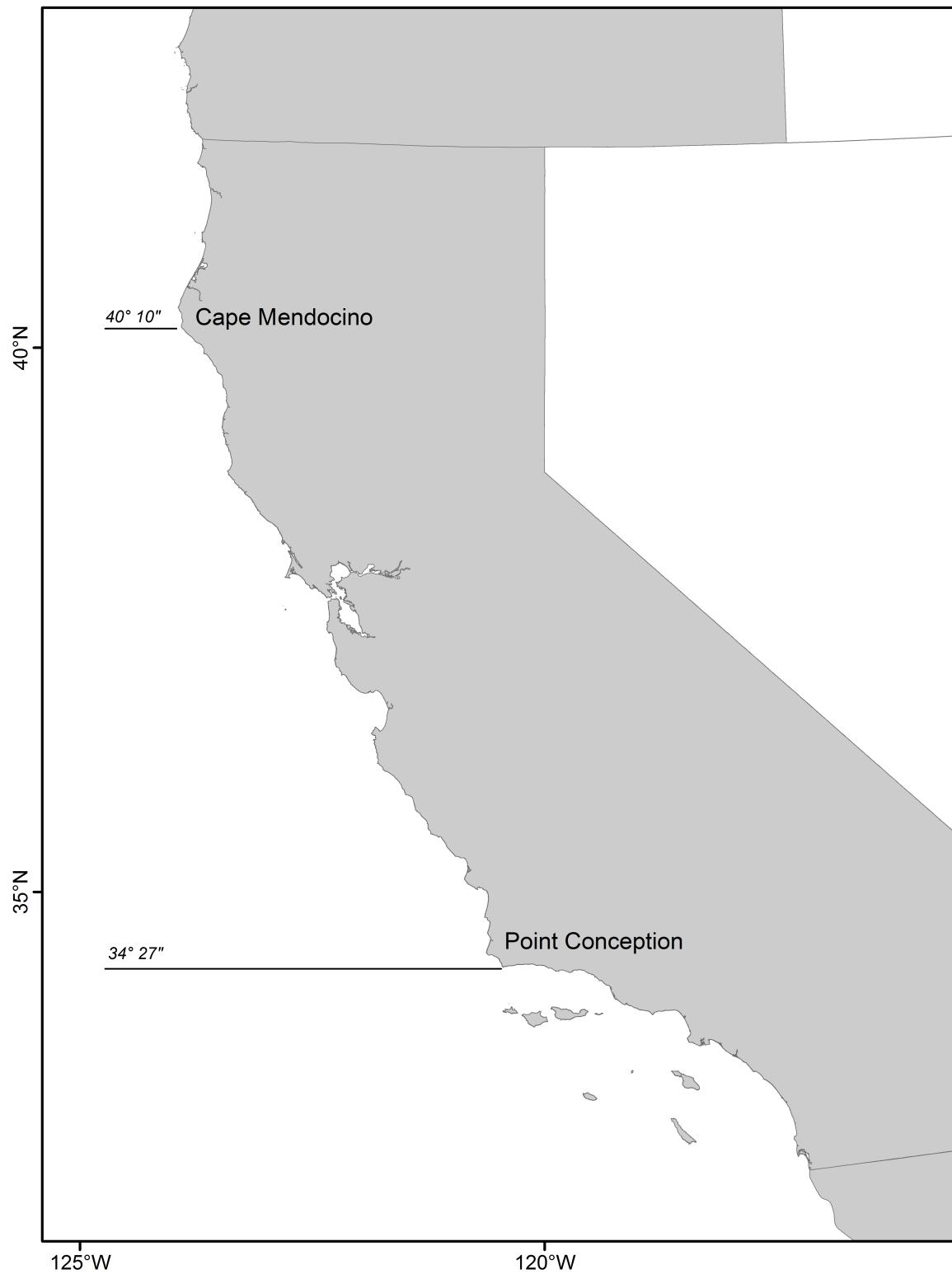


Figure 1: Map showing the management area for gopher and black-and-yellow rockfish from Cape Mendocino to the U.S.-Mexico border. fig:assess_region_map1

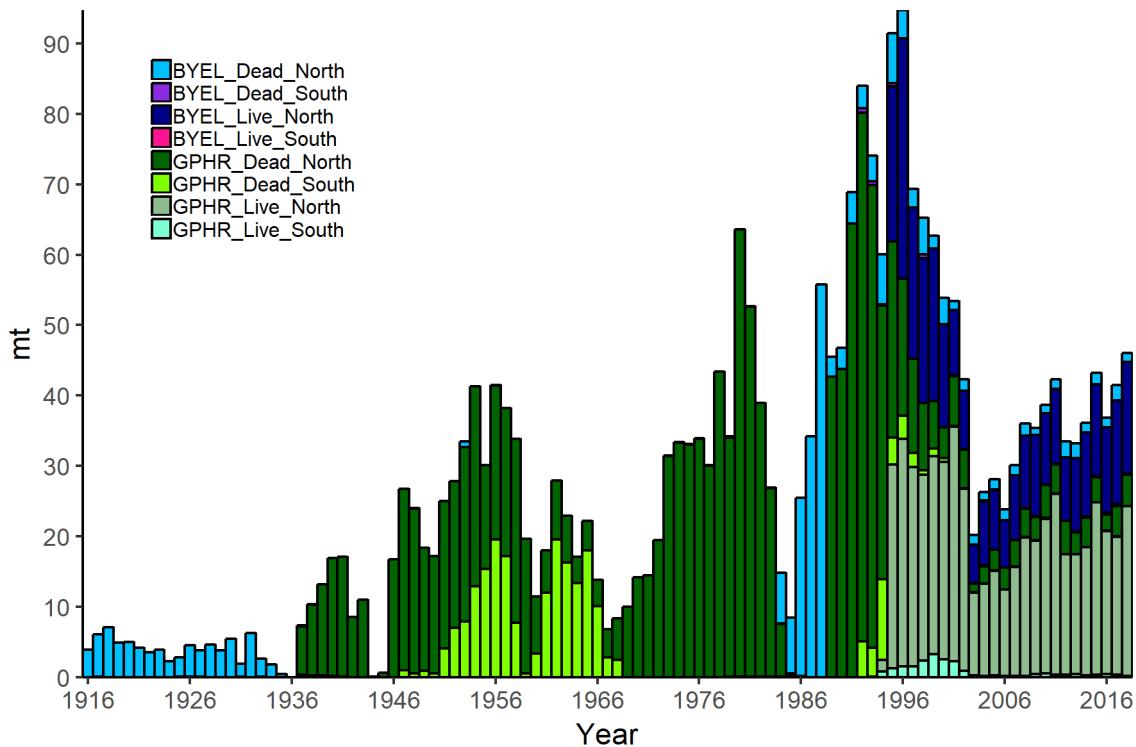


Figure 2: Commercial landings for gopher (GPHR) and black-and-yellow (BYEL) rockfishes landed live and dead north and south of Point Conception. All catch time series were combined for the assessment into one commercial fleet.

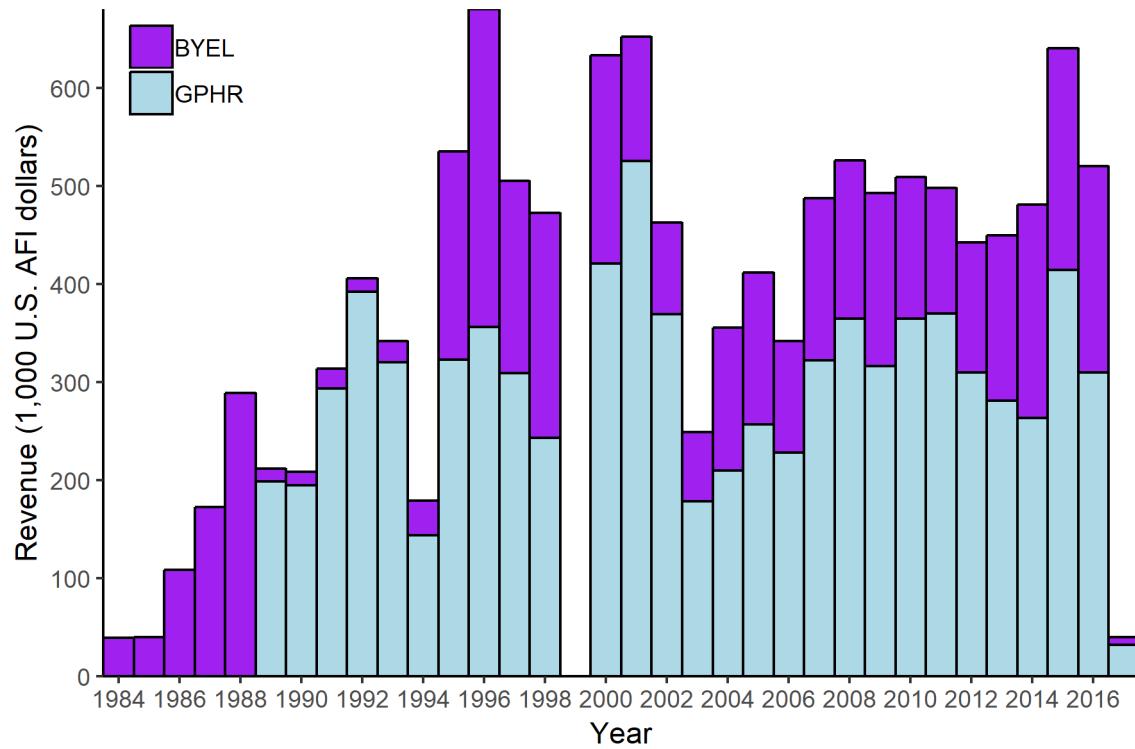


Figure 3: Annual ex-vessel revenue, adjusted for inflation (AFI) in thousands of dollars for gopher and black-and-yellow rockfish. [fig:GBY_revenue](#)

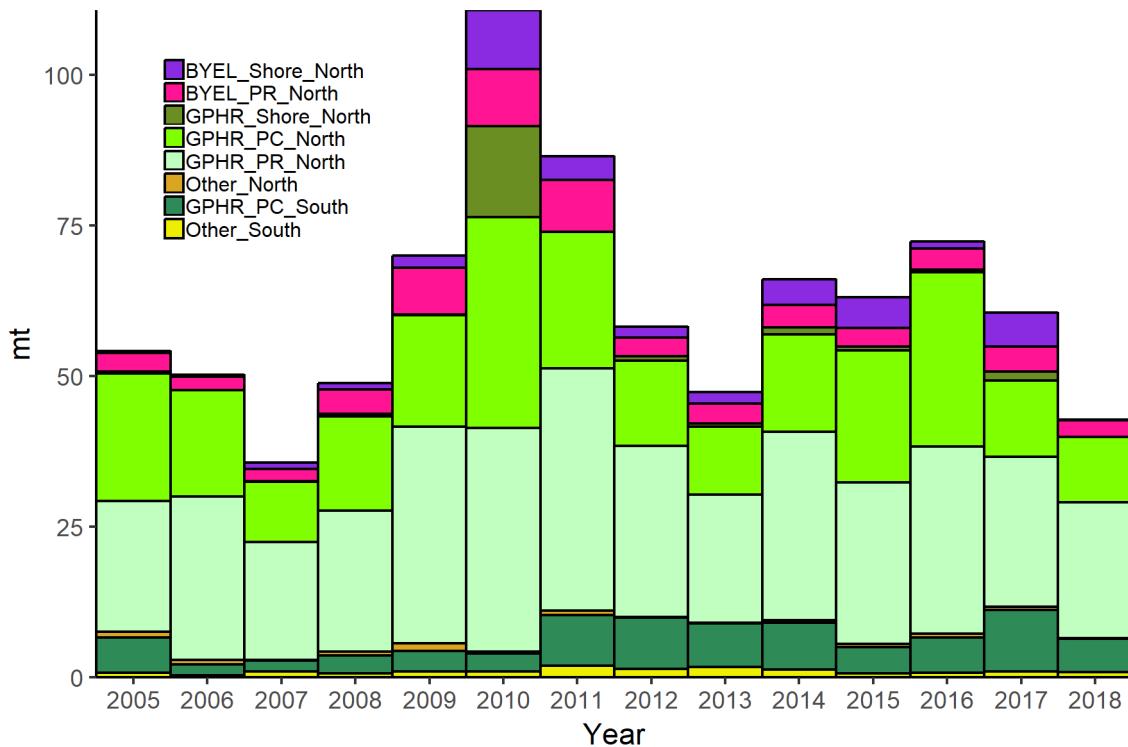


Figure 4: Recreational total mortality for gopher rockfish (GPHR) and black-and-yellow (BYEL) rockfish from the CDFW CRFS sampling era by mode and split north and south of Point Conception. fig:CFRS_catches

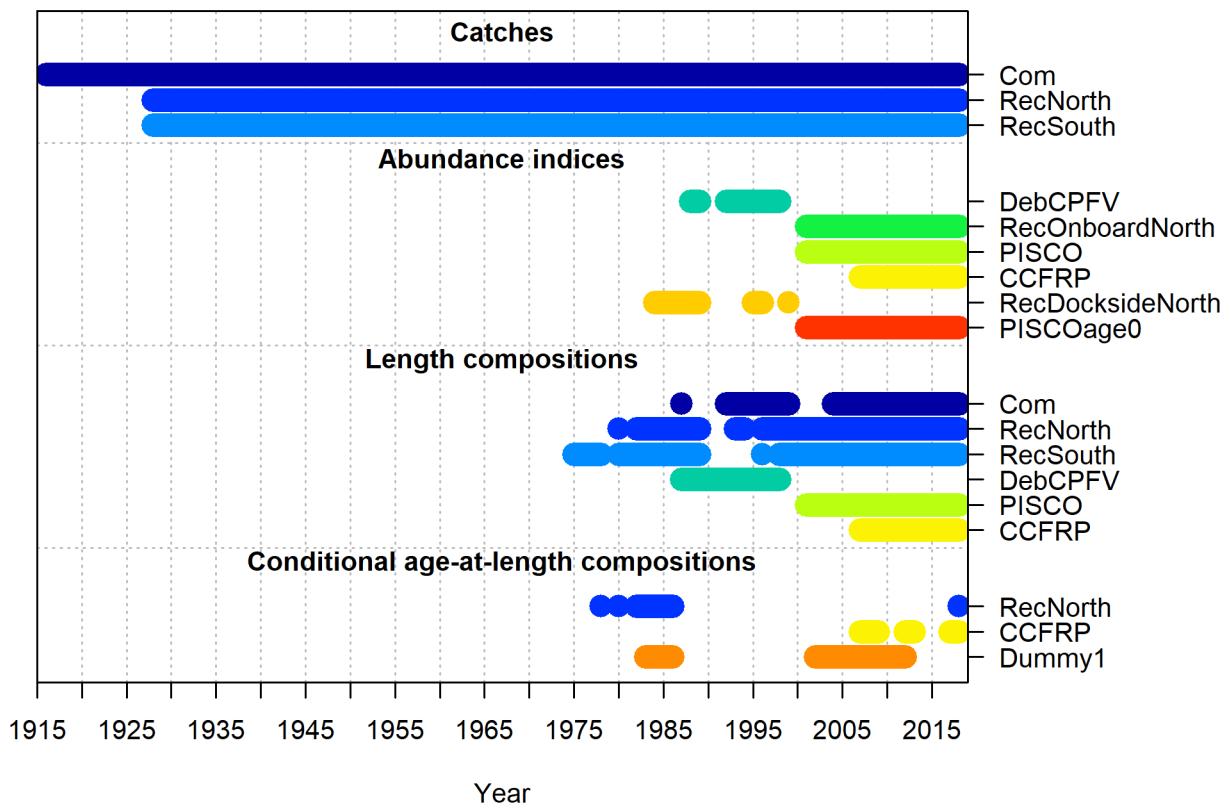


Figure 5: Summary of data sources used in the model. `fig: data_plot`

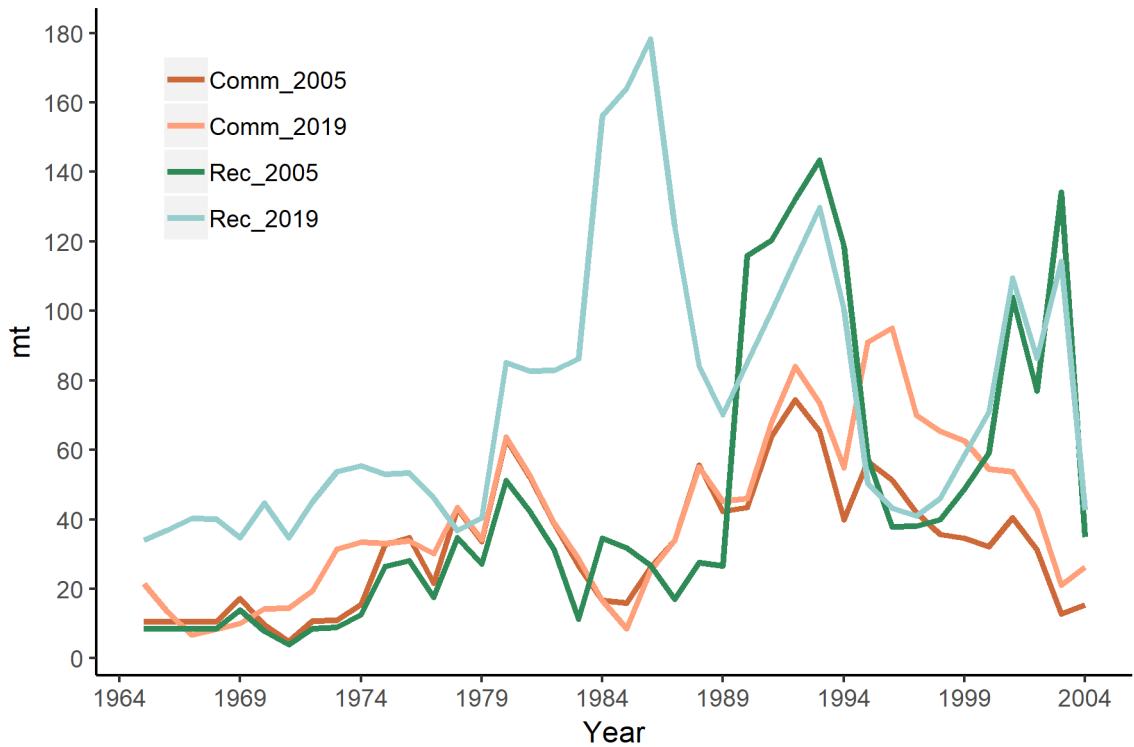


Figure 6: Comparison of the recreational and commercial fishery landings from the 2005 assessment to this 2019 assessment. Note that the 2019 assessment includes both gopher and black-and-yellow rockfish where the 2005 assessment represents gopher rockfish only. The 2005 assessment also did not include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

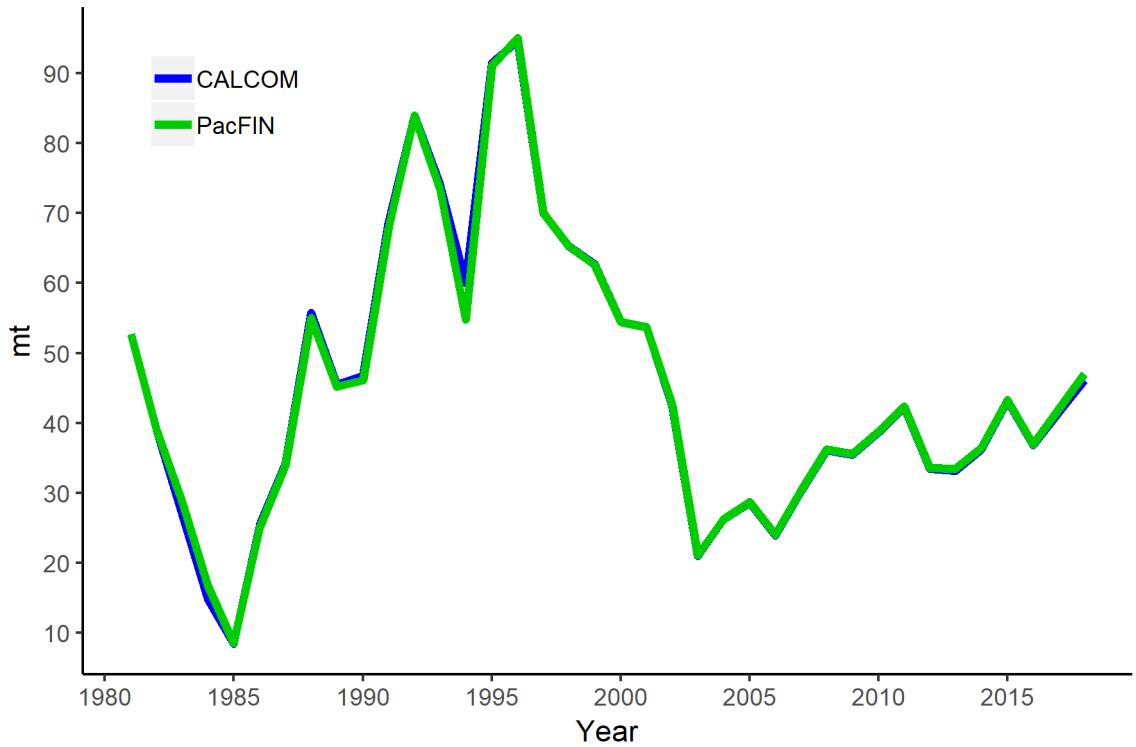


Figure 7: Commercial landings estimates from CALCOM and PacFIN. fig:Calcom_vs_Pacfinc

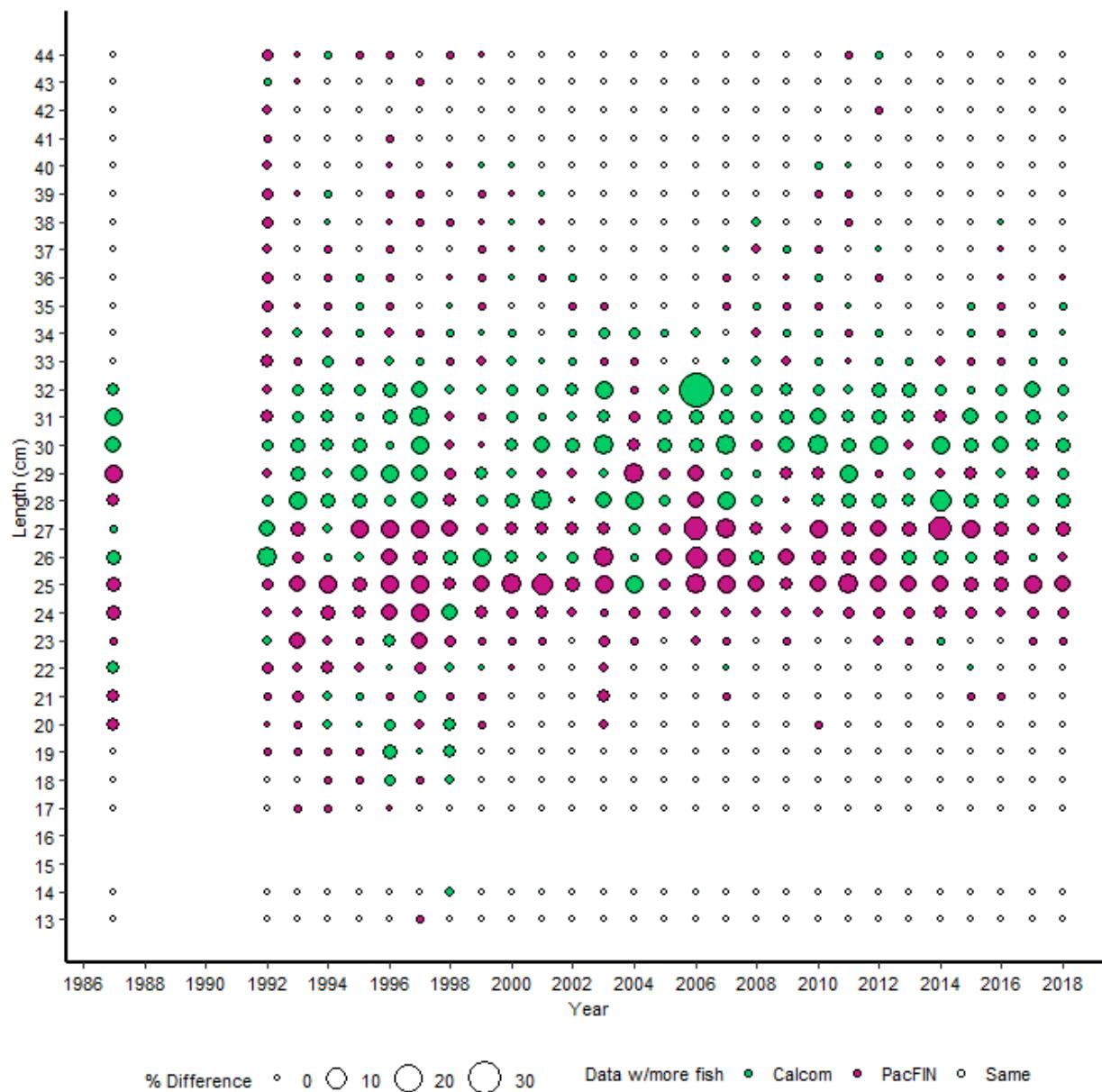


Figure 8: Percent differences in the expanded length compositions by year from CALCOM and PacFIN. The same market categories were used for each dataset, but each database was subject to further independent filtering criteria and expansion algorithms. fig:Calcom_vs_pacfin_length

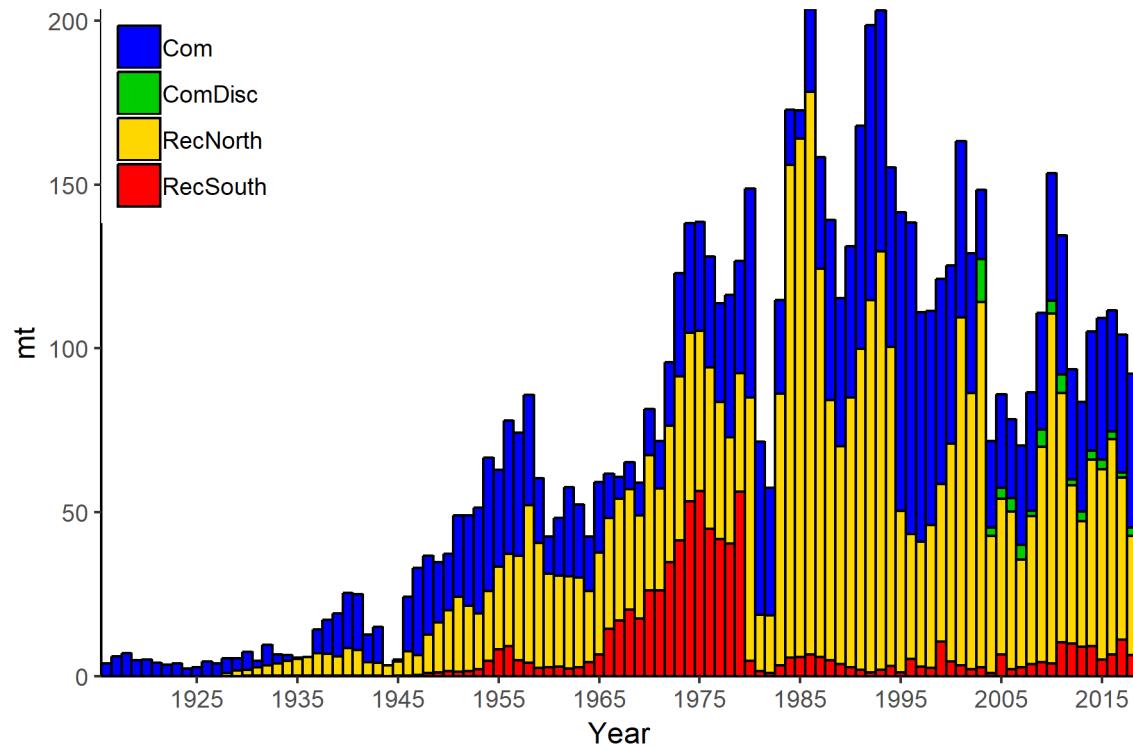


Figure 9: Commercial and recreational landings estimates prior to any data modification or interpolation to the recreational catches or hindcasting of commercial discards. [fig:Catches_original](#)

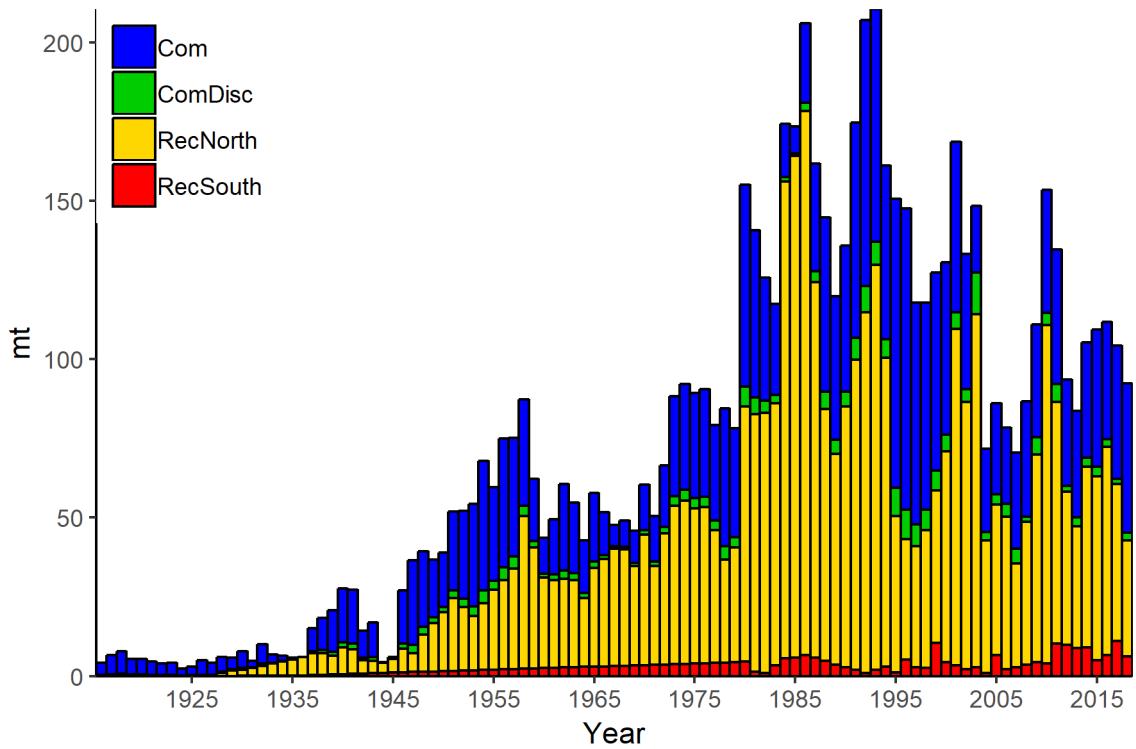


Figure 10: Commercial and recreational landings estimates after data modification and interpolations were made to the recreational catches and commercial discards. [fig:Catches_alternate](#)

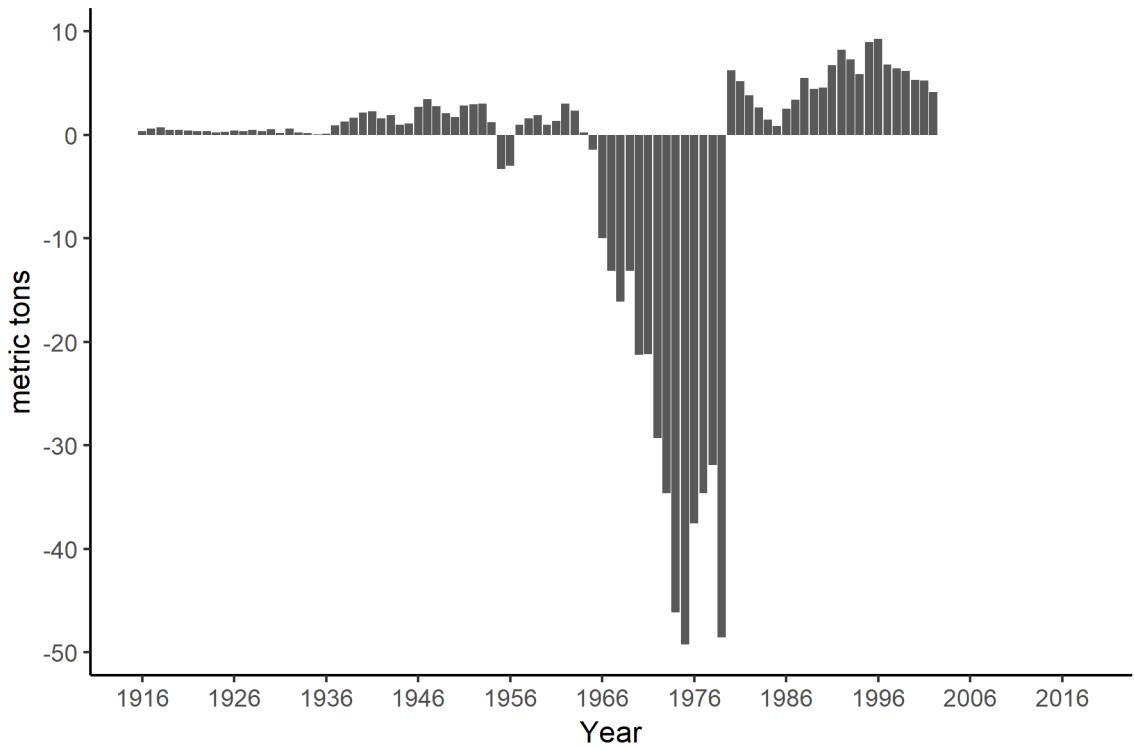


Figure 11: Difference in landings between the original and modified landings presented in the previous two figures. The only two fleets with modifications are recreational south and commercial discards. Negative values indicate catches removed from the original estimates and positive values represent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

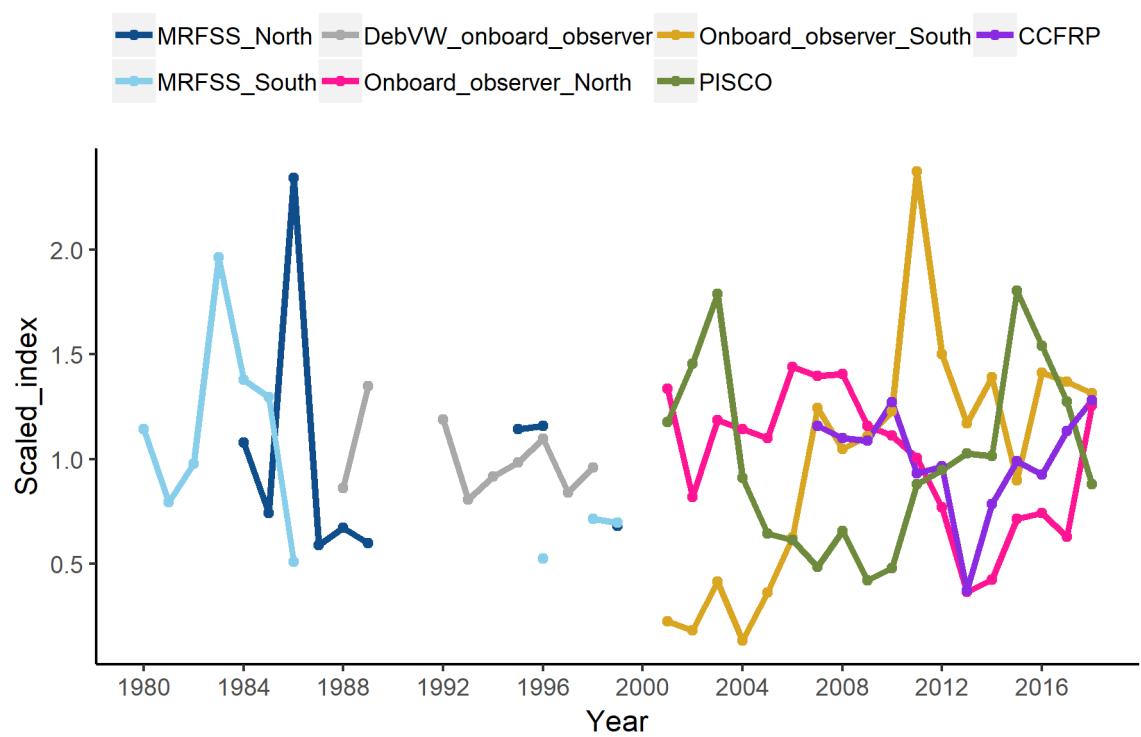


Figure 12: Comparison of all indices of abundance (with each index scaled to its mean). fig:All_index

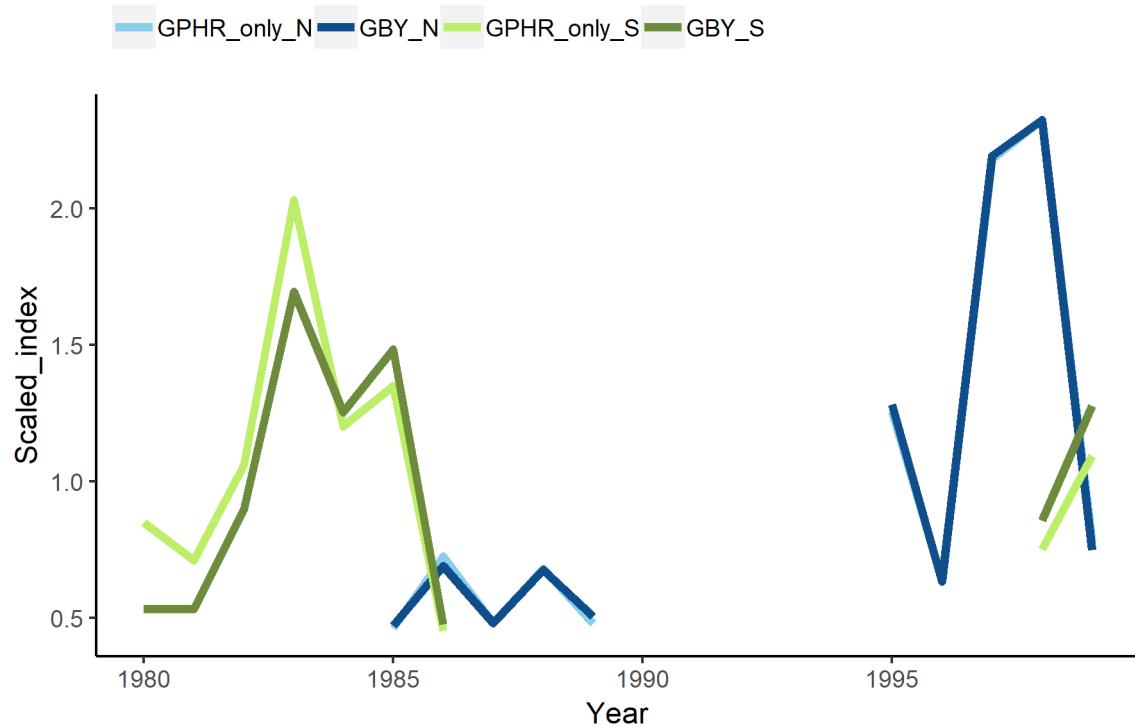


Figure 13: Comparison of indices of abundance (scaled to their means) for the MRFSS dockside CPFV survey between a gopher-only and GBYR complex index for north and south of Point Conception. [fig:MRFSS_index_compare](#)

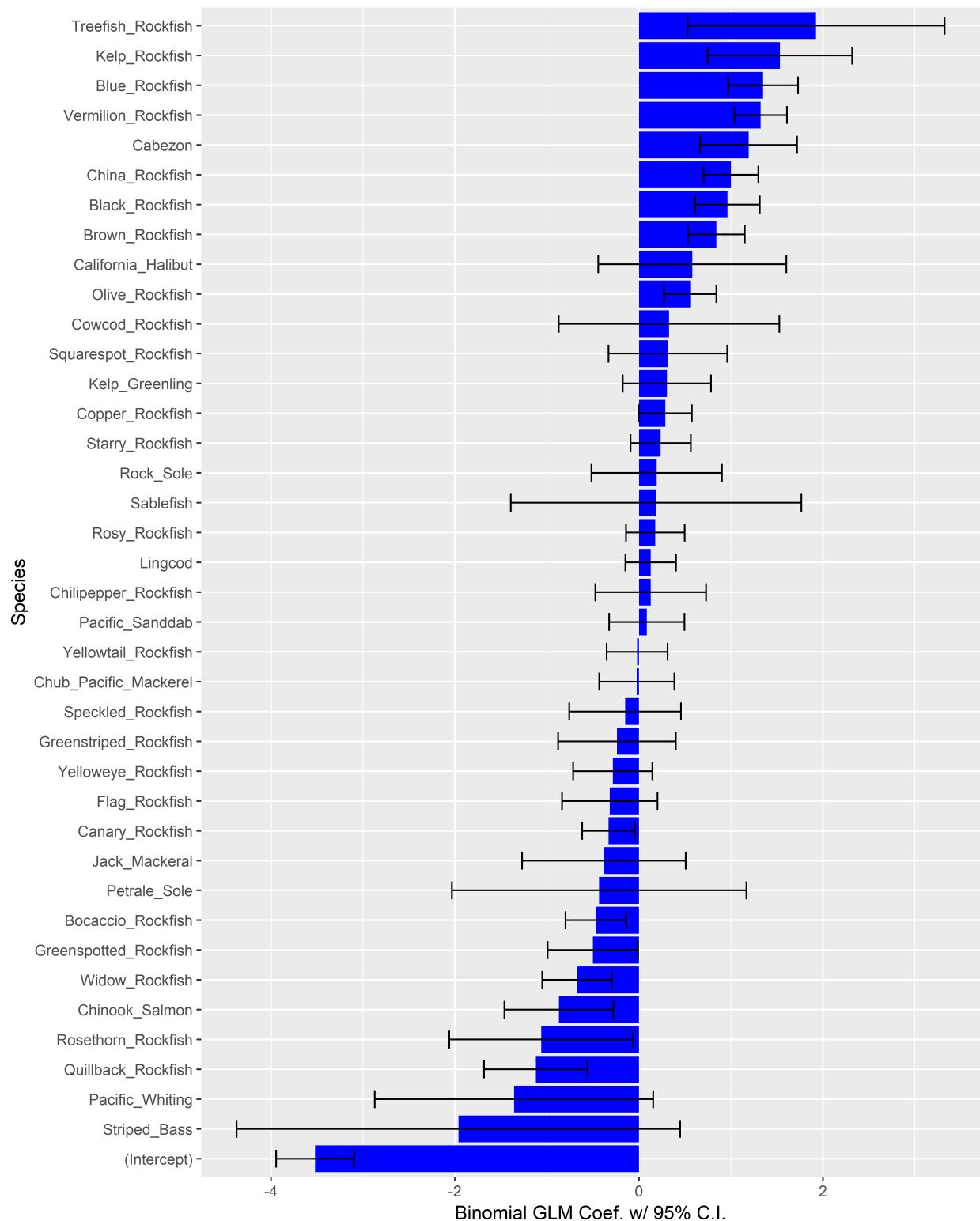


Figure 14: Species coefficients from the binomial GLM for presence/absence of GBYR in the Marine Recreational Fisheries Statistics Survey (MRFSS) CPFV mode dockside survey data set north of Point Conception. Horizontal bars are 95% confidence intervals. fig:Fleet10_SM_filter

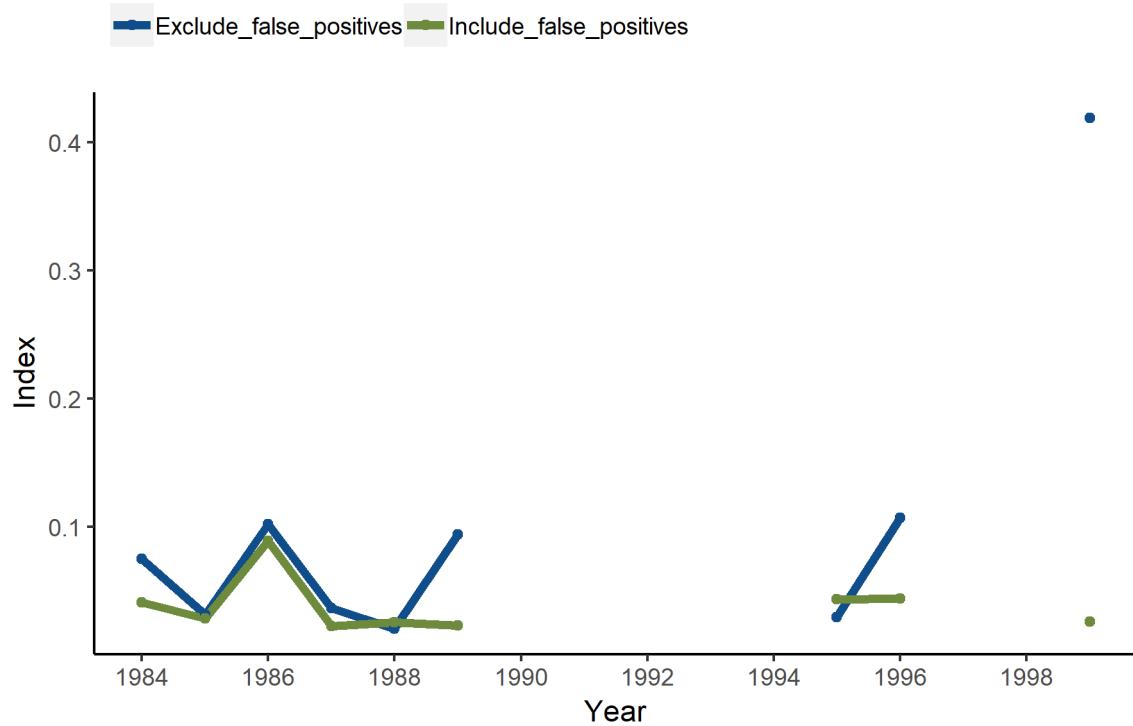


Figure 15: Comparisons of the indices of abundance for GBYR north of Point Conception from the MRFSS dockside CPFV survey that either include or exclude the trips identified as false positives from the Stephens-MacCall filter. [fig:MRFSS_index_N_SM_falsepos](#)

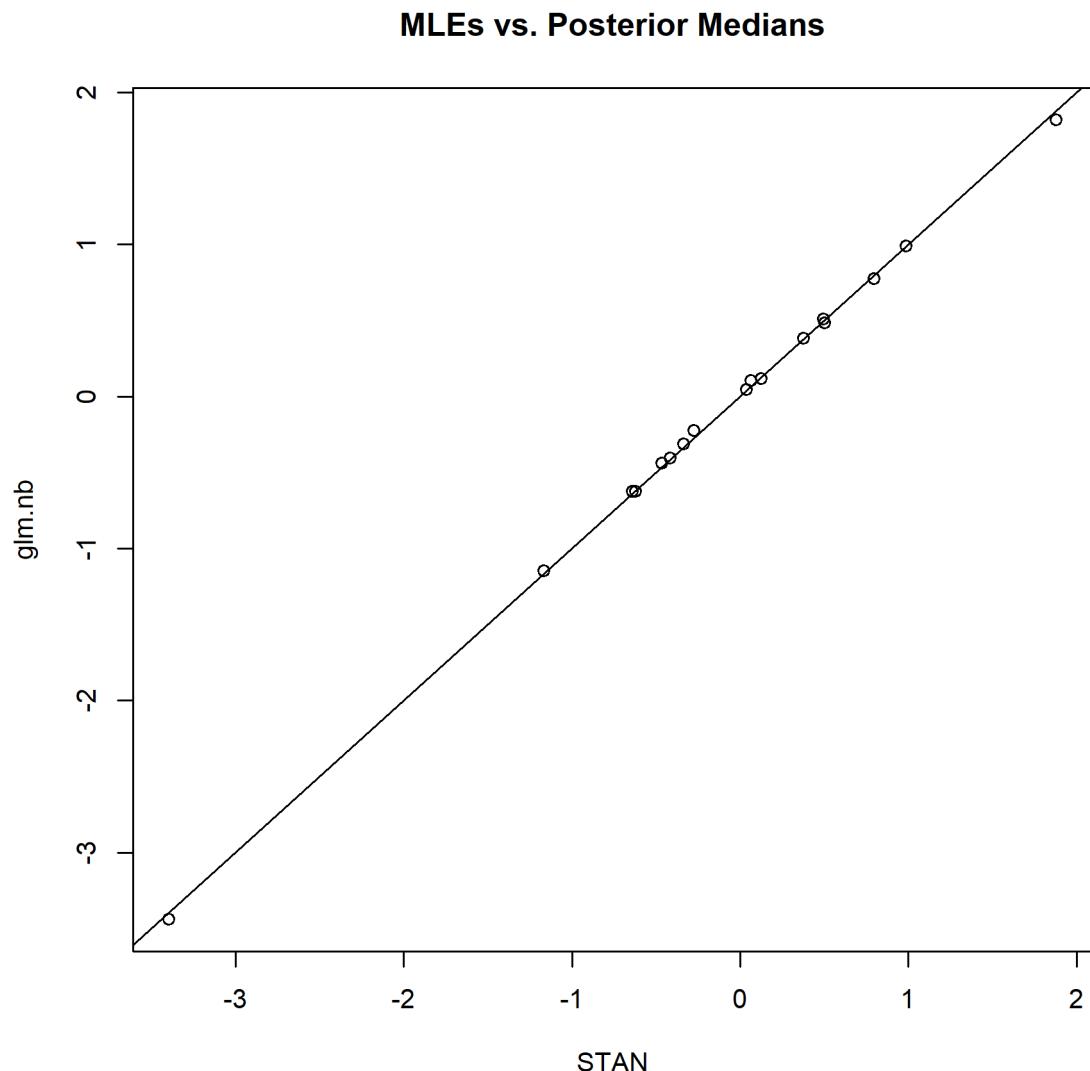


Figure 16: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year). MRFSS CPFV dockside index north of Point Conception. The 1:1 plot is for reference. [fig:Fleet10_MLE_stan](#)

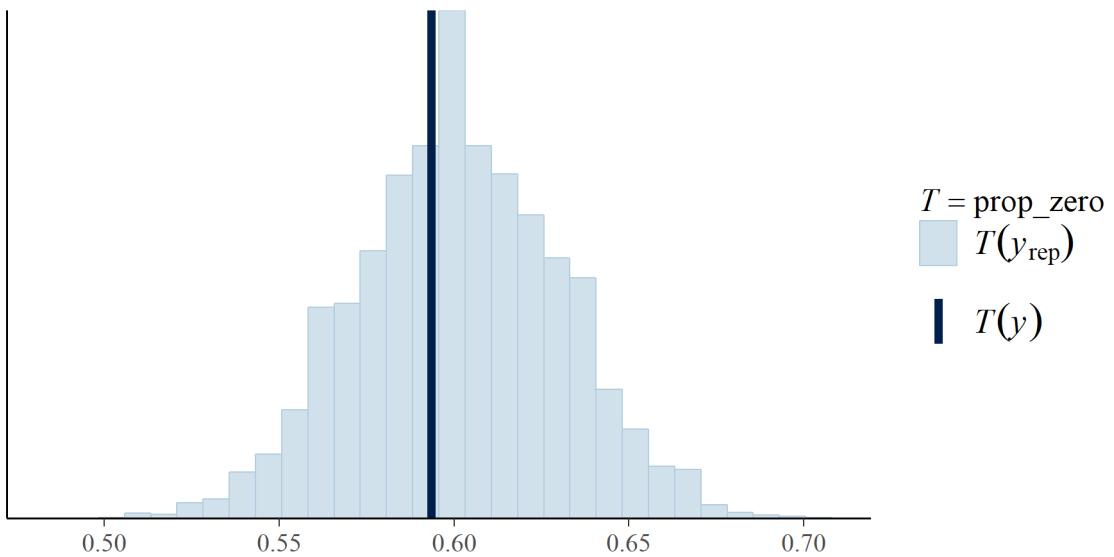


Figure 17: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for MRFSS dockside CPFV index north of Point Conception. [fig:Fleet10_prop_zero_STAN](#)

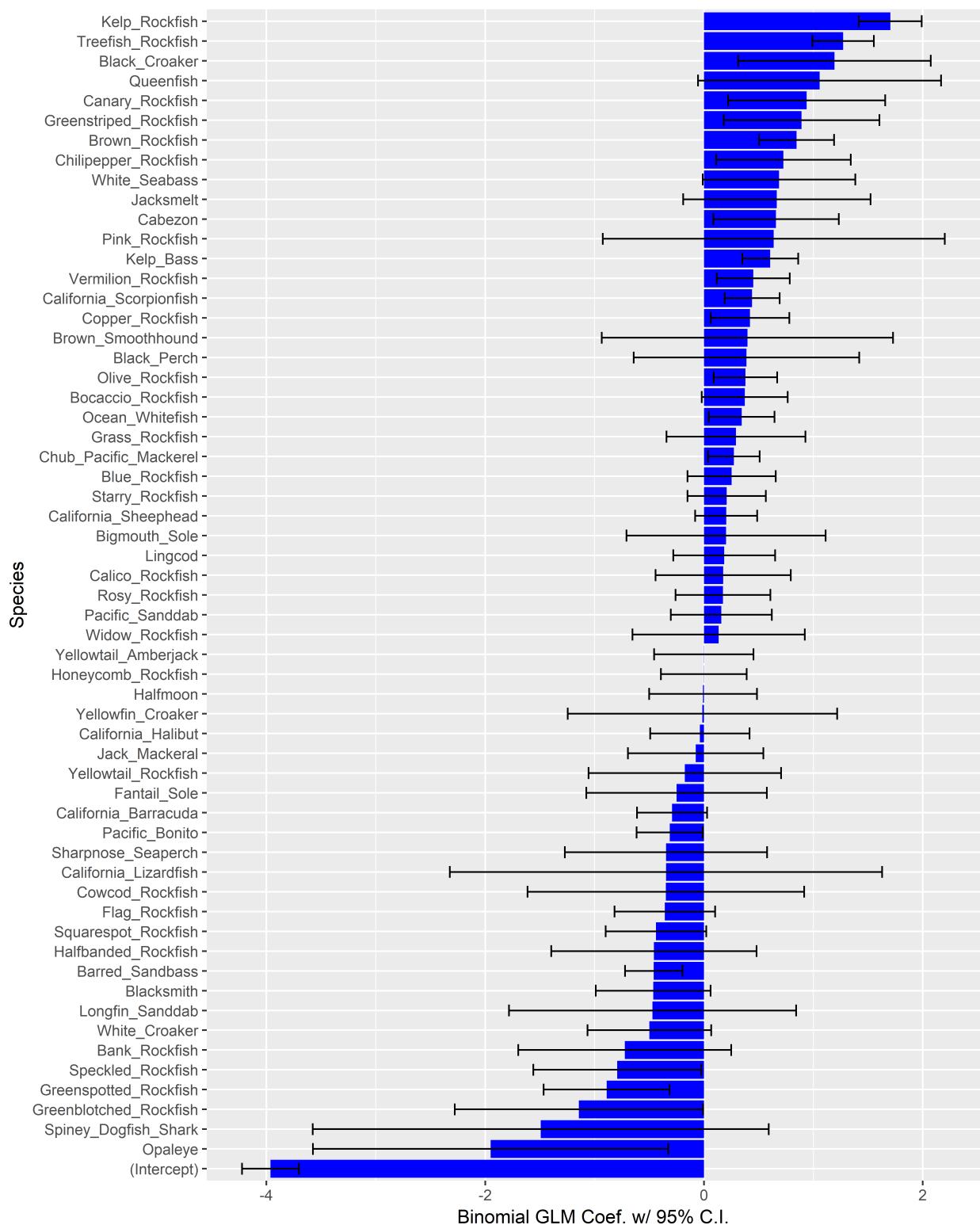


Figure 18: Species coefficients from the binomial GLM for presence/absence of GBYR in the Marine Recreational Fisheries Statistics Survey (MRFSS) CPFV mode dockside survey data set north of Point Conception. Horizontal bars are 95% confidence intervals. fig:Fleet11_SM_filter

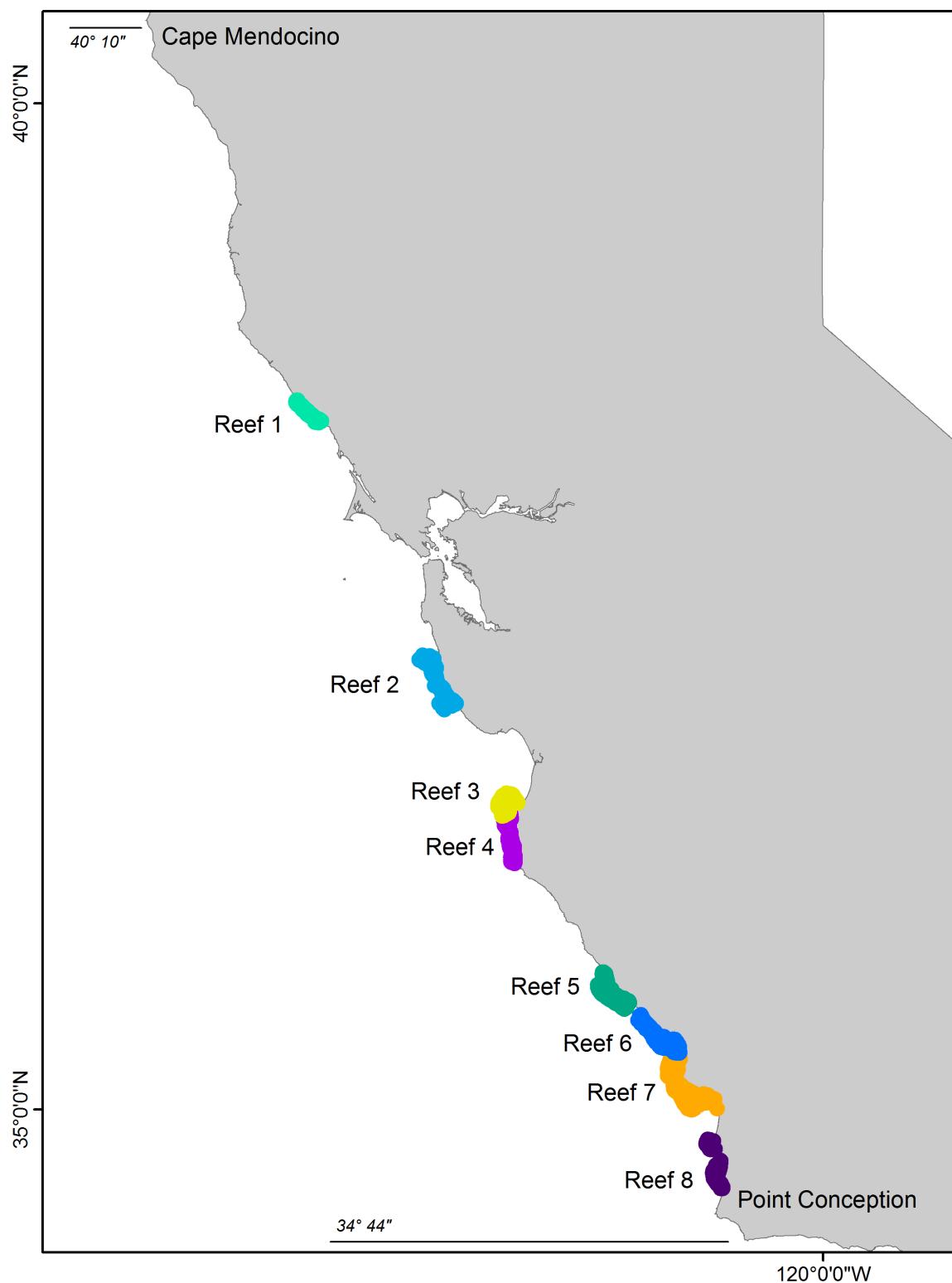


Figure 19: Map of the reefs used in the Deb Wilson-Vandenberg CPFV onboard observer survey index of abundance. [fig:DebWV_sites](#)

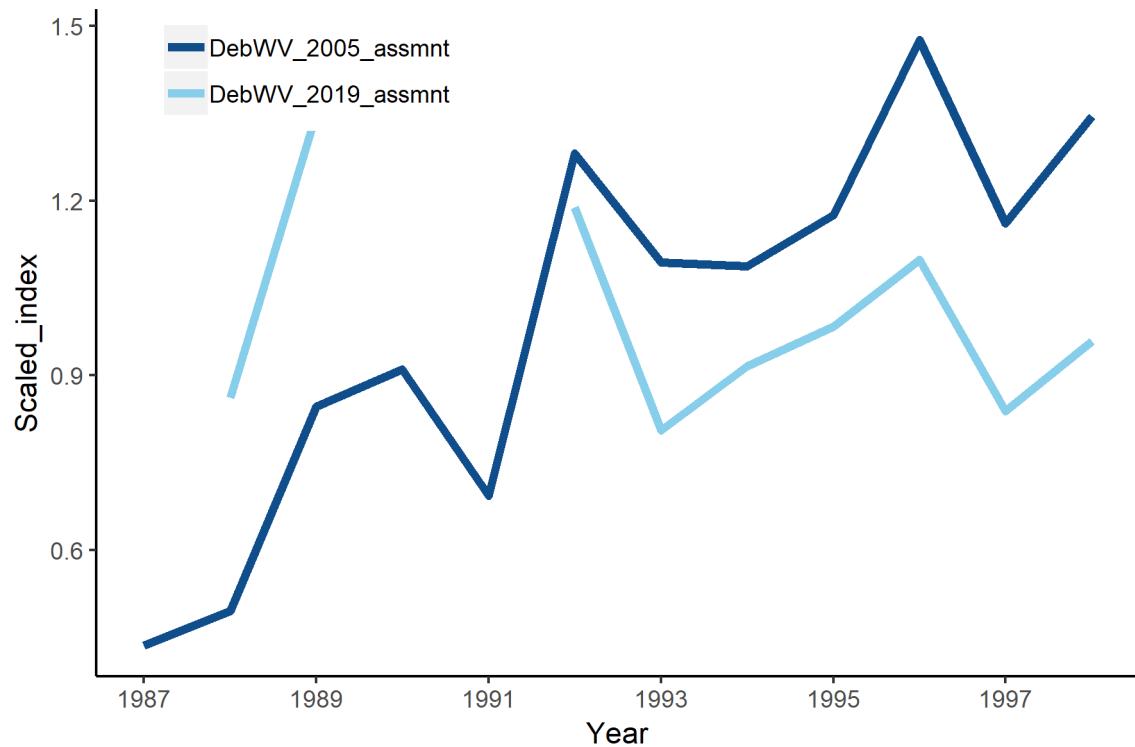


Figure 20: Comparison of the index developed for the Deb Wilson-Vandenberg CPFV onboard observer survey from the 2005 assessment and for the 2019 assessment. [Fig:DebWV_index_compare](#)

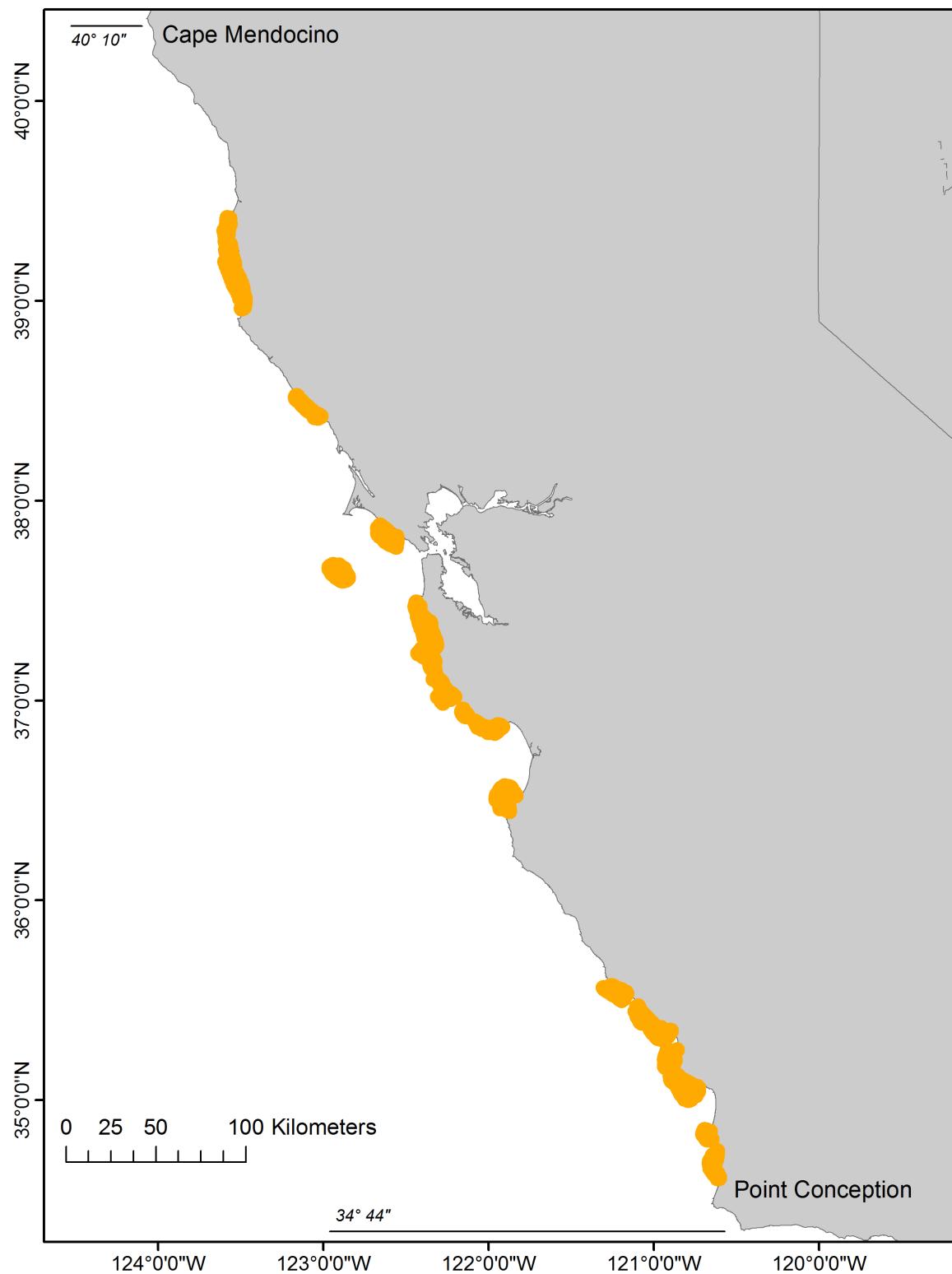


Figure 21: Map of the reefs selected for the final index for the onboard observer surveys (CDFW and Cal Poly) north of Point Conception

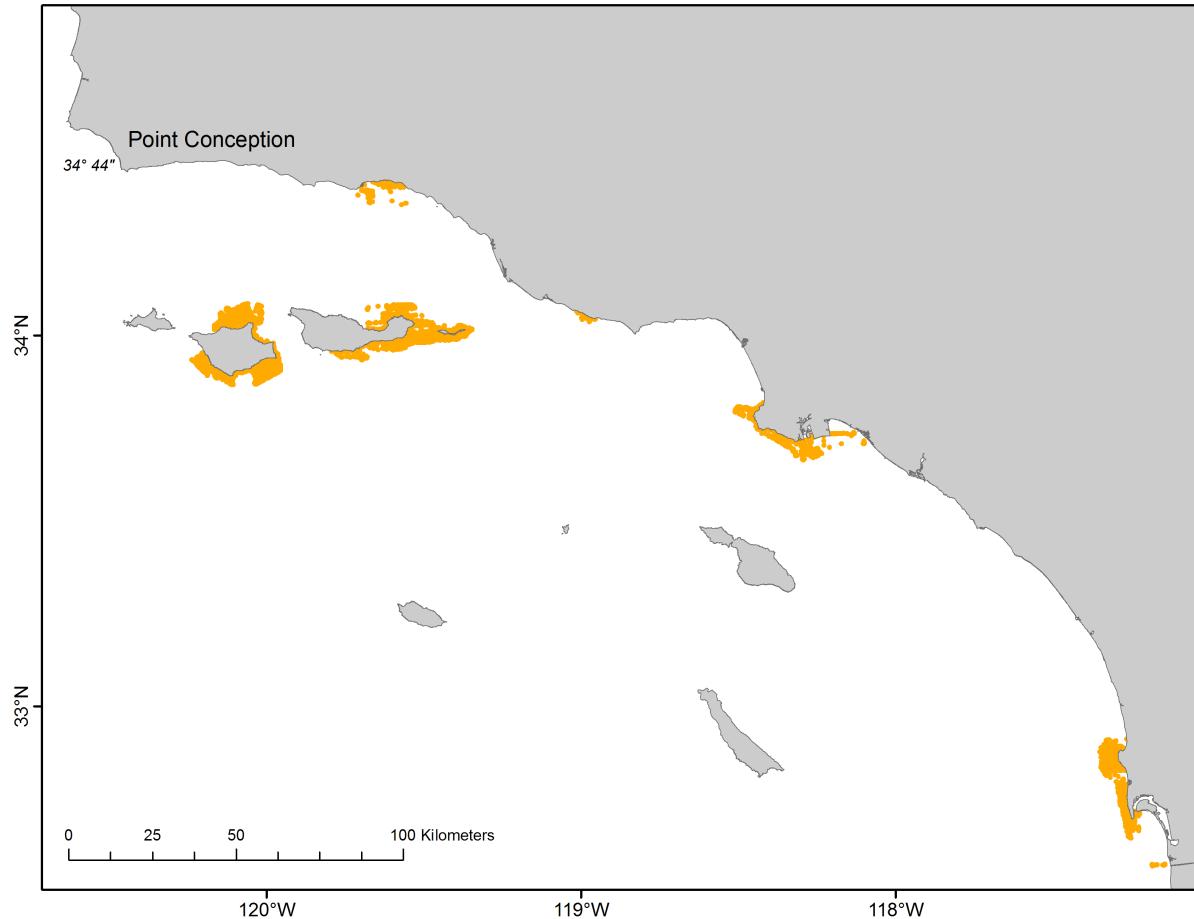


Figure 22: Map of the reefs selected for the final index for the CDFW onboard observer survey south of Point Conception | [fig:Unboard_observer_south_sites](#)

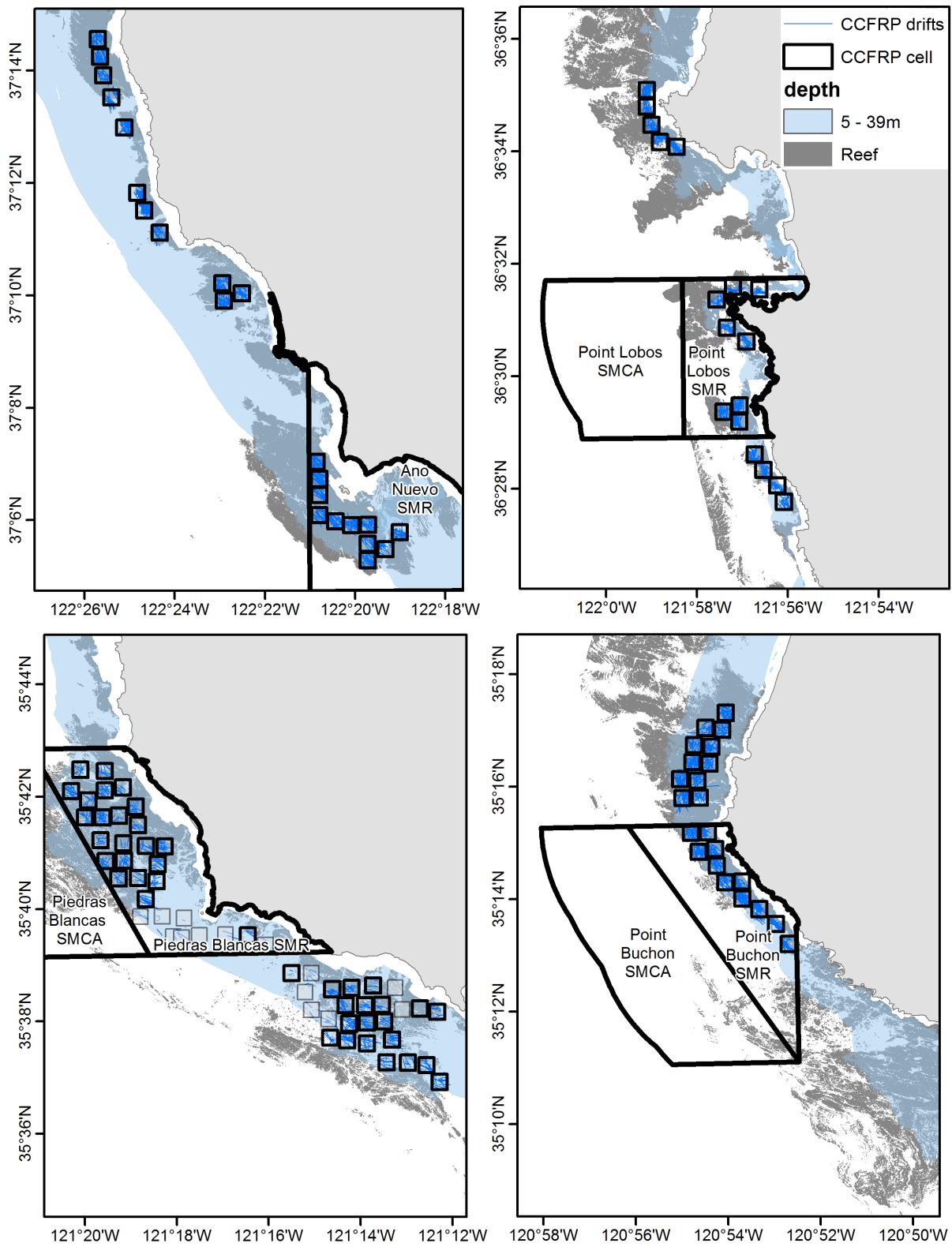


Figure 23: Map of the four MPAs sampled consistently through time for the CCFRP fishery-independent survey. [fig:CCFRP_sites](#)

MLEs vs. Posterior Medians

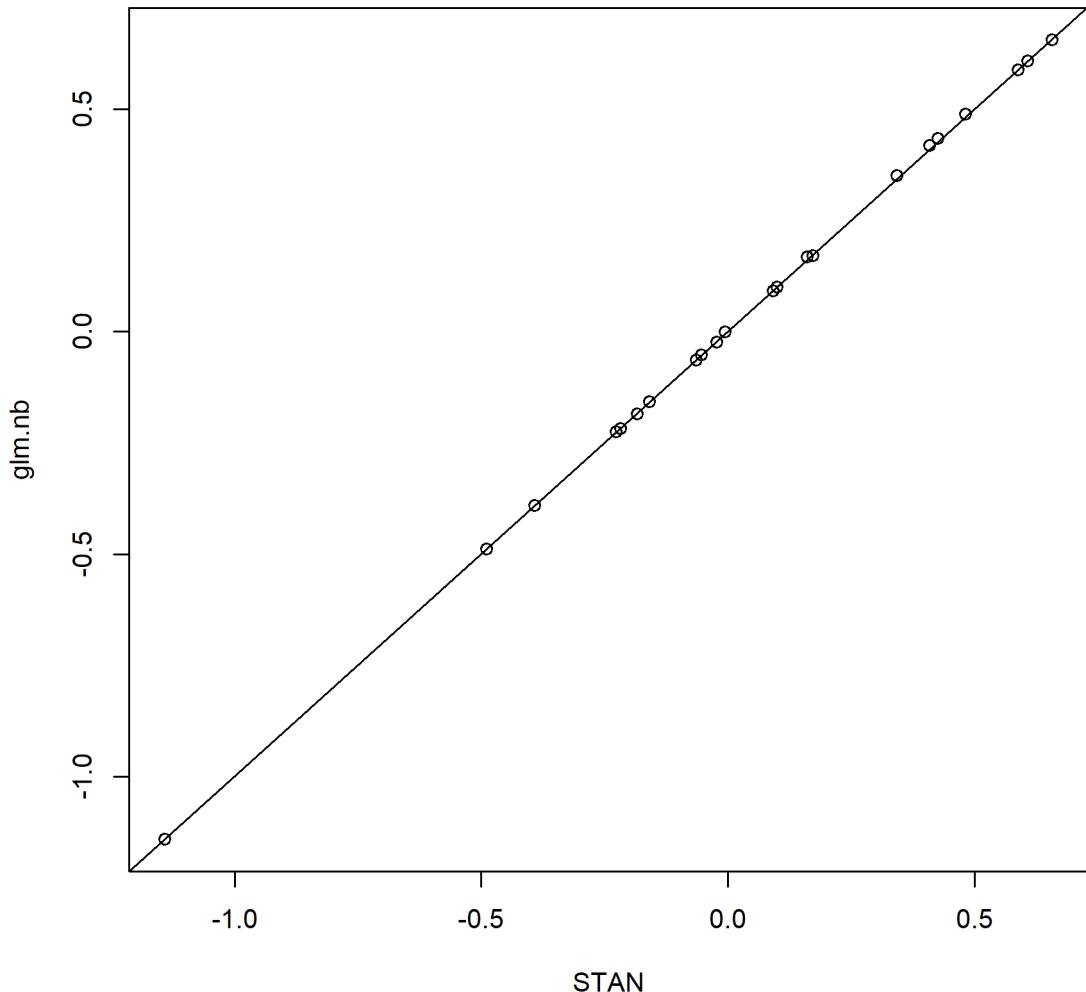


Figure 24: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year) for the CCFRP index. The 1:1 plot is for reference.

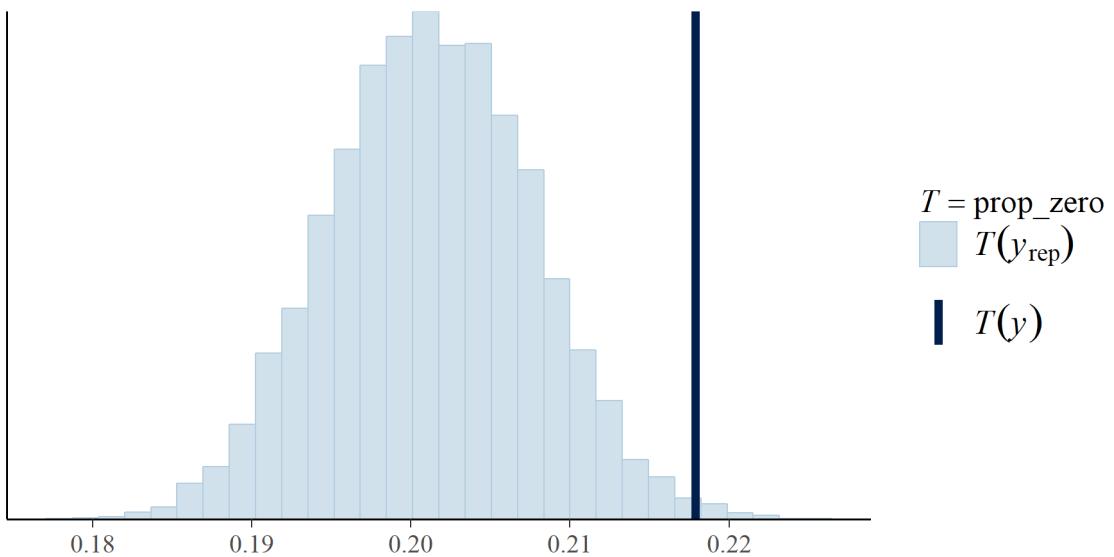


Figure 25: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the CCFRP index. [fig:Fleet9_prop_zero_STAN](#)

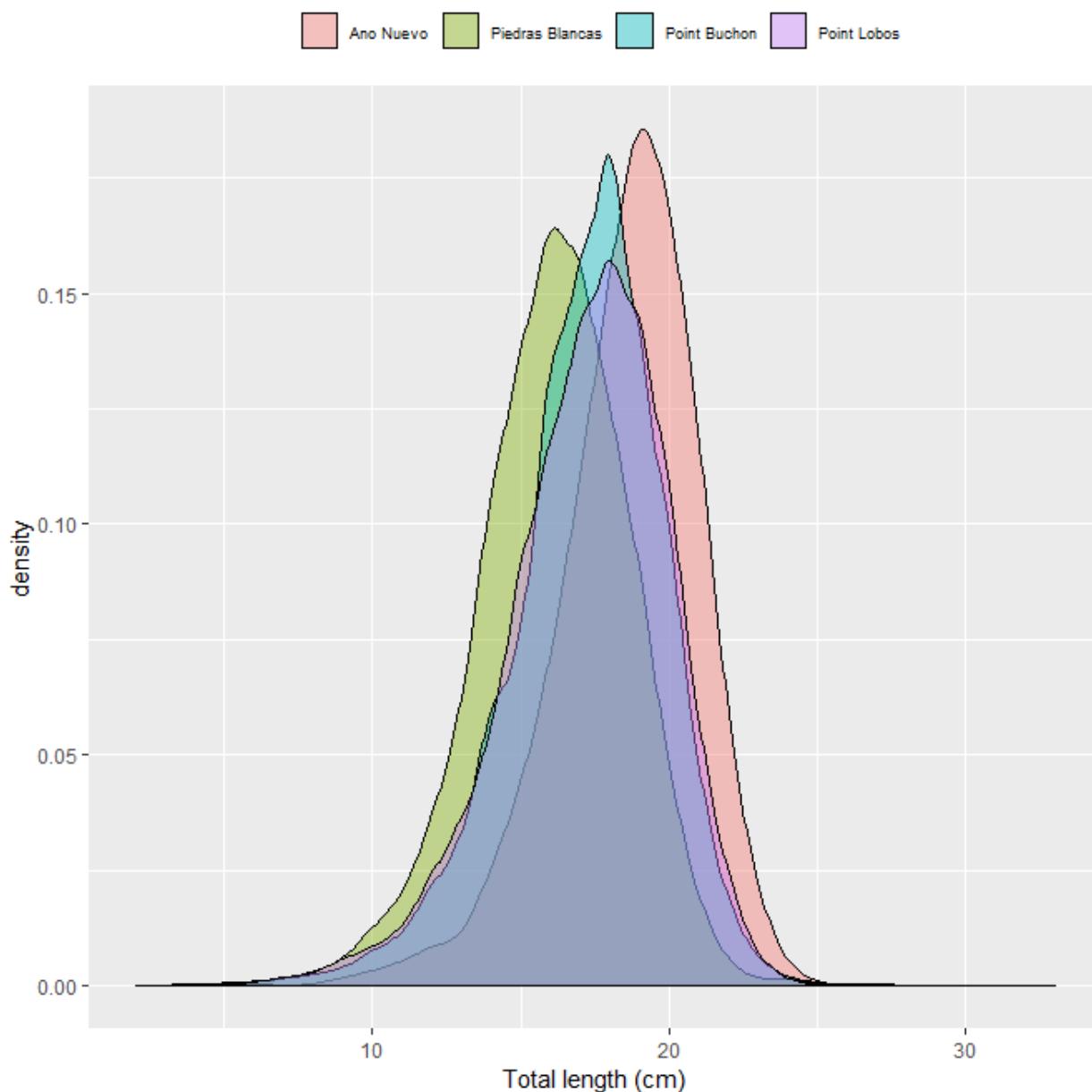


Figure 26: Length distributions of GBYR for the four MPAs sampled by the CCFRP survey used in this assessment. | [CCFRP_lengths_by_site](#)

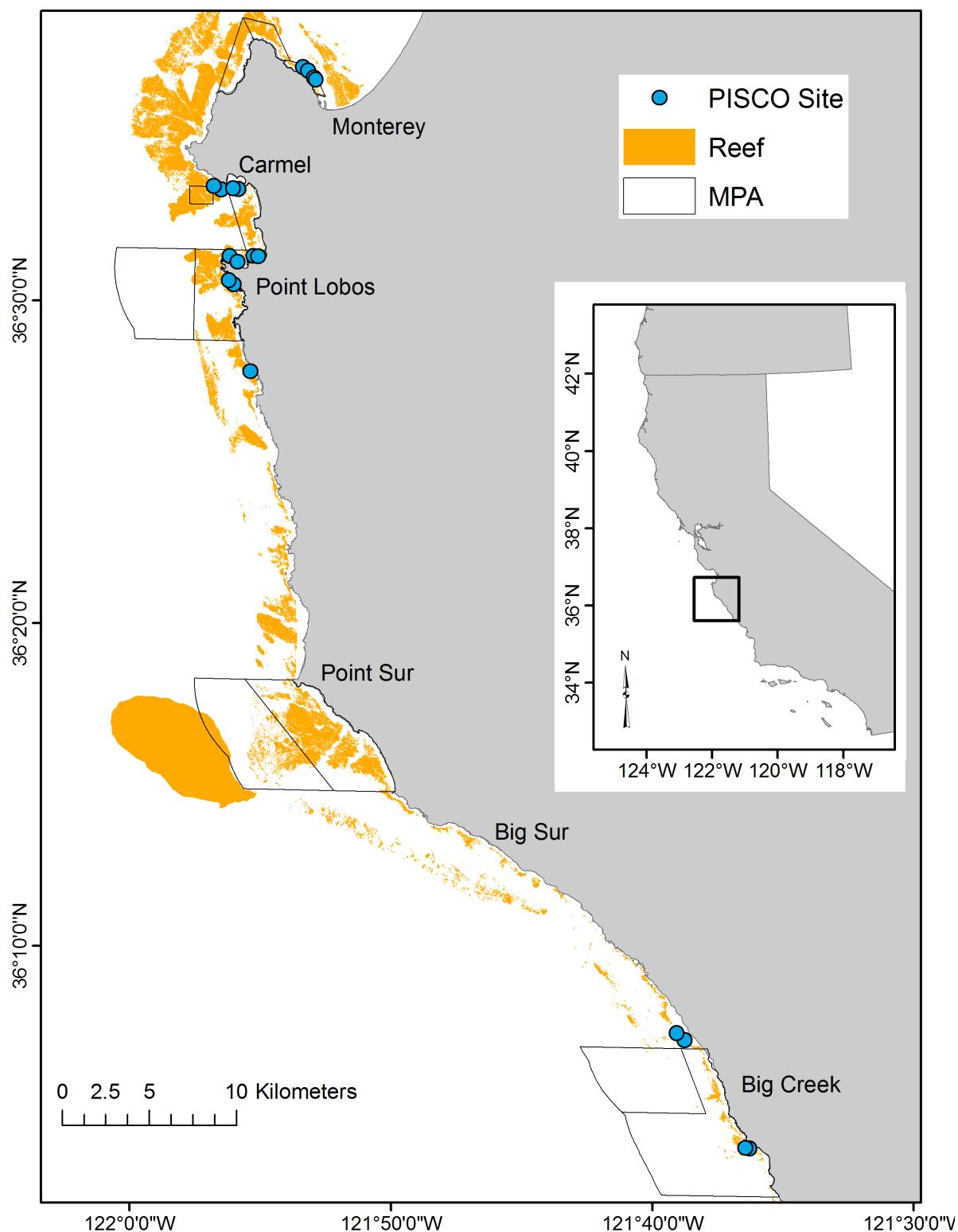


Figure 27: Map of the sites sampled consistently through time for the PISCO kelp forest fish survey.

MLEs vs. Posterior Medians

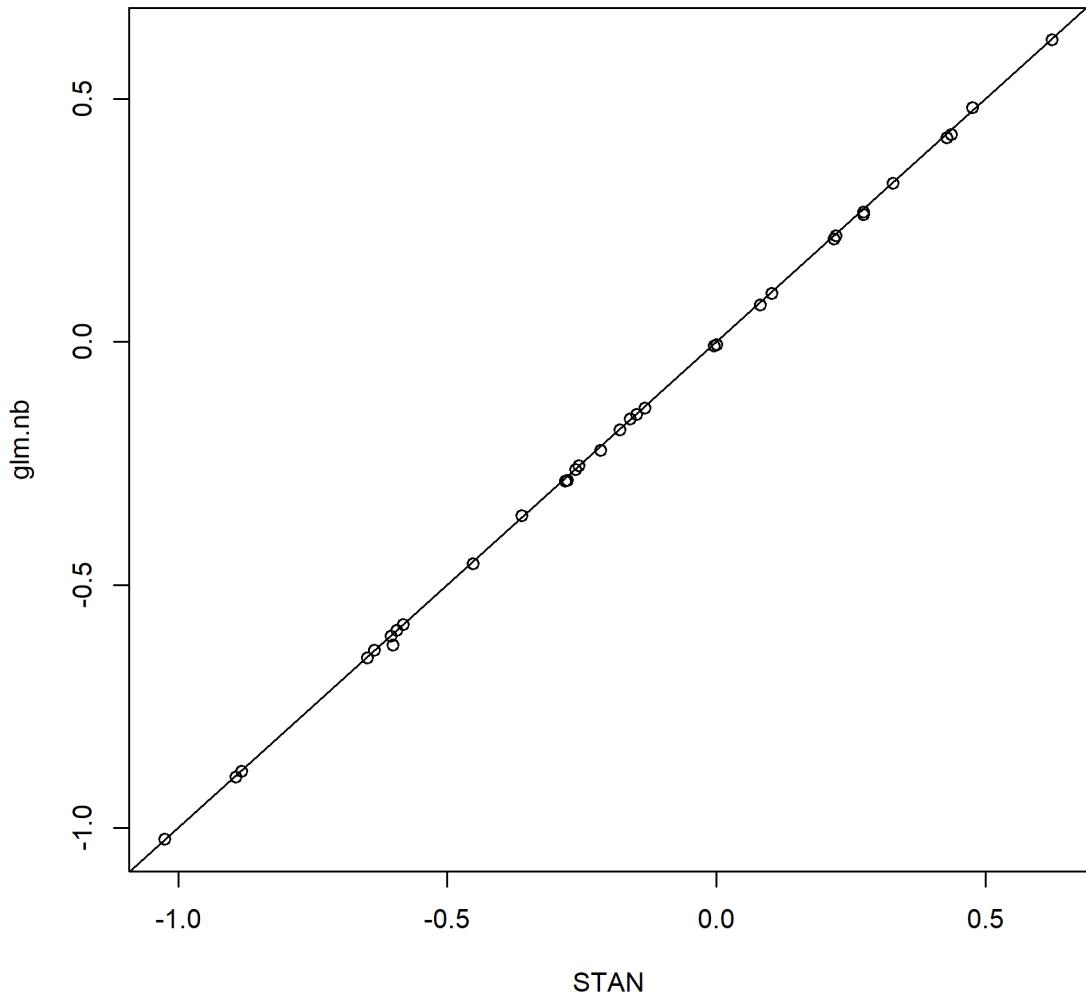


Figure 28: Comparison of negative binomial predictions (CPUE) to observed means in each stratum (year) for the PISCO kelp forest fish survey index. The 1:1 plot is for reference. [fig:Fleet8_MLE](#)

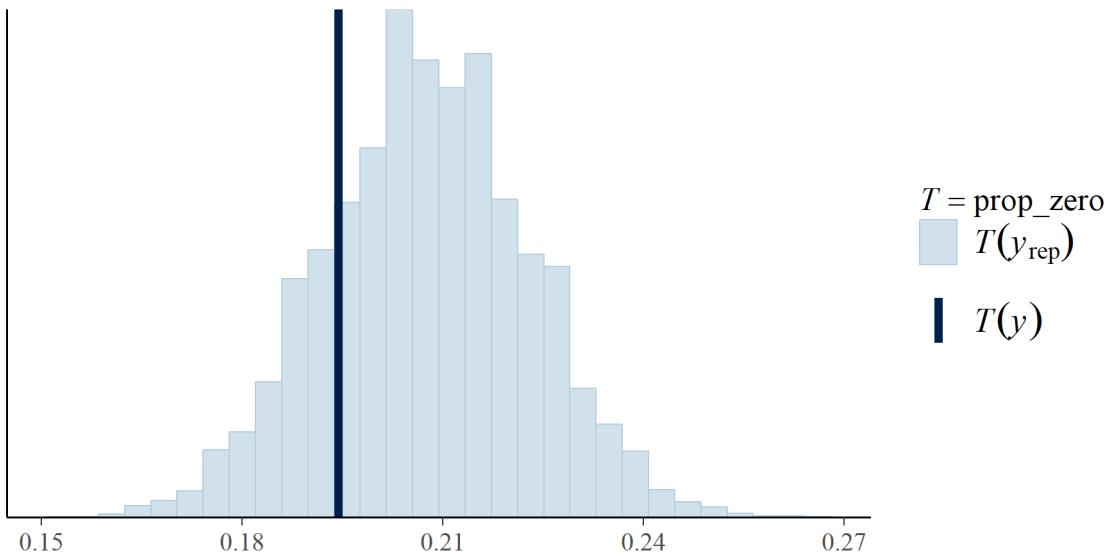


Figure 29: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the PISCO kelp forest fish survey. [fig:Fleet8_pr](#)

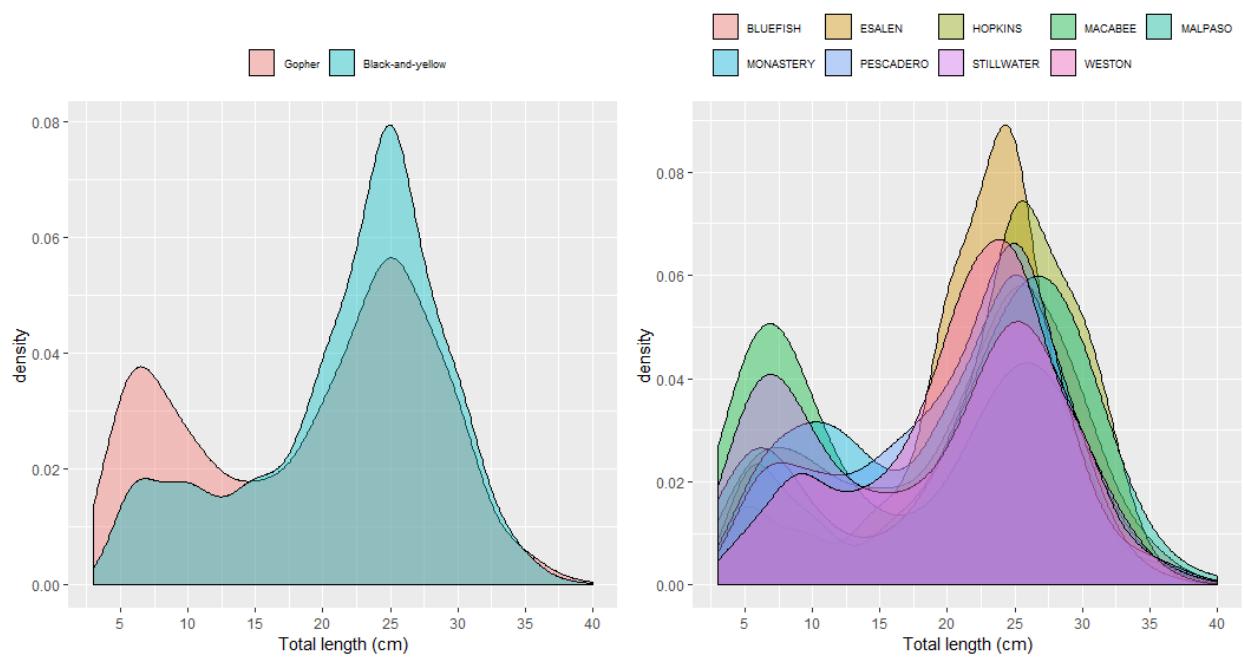


Figure 30: Plots of the length distributions from the PISCO kelp forest fish survey by species (left) and for combined species by site (right) for sites included in the final index of abundance. [fig:PISCO_lengths](#)

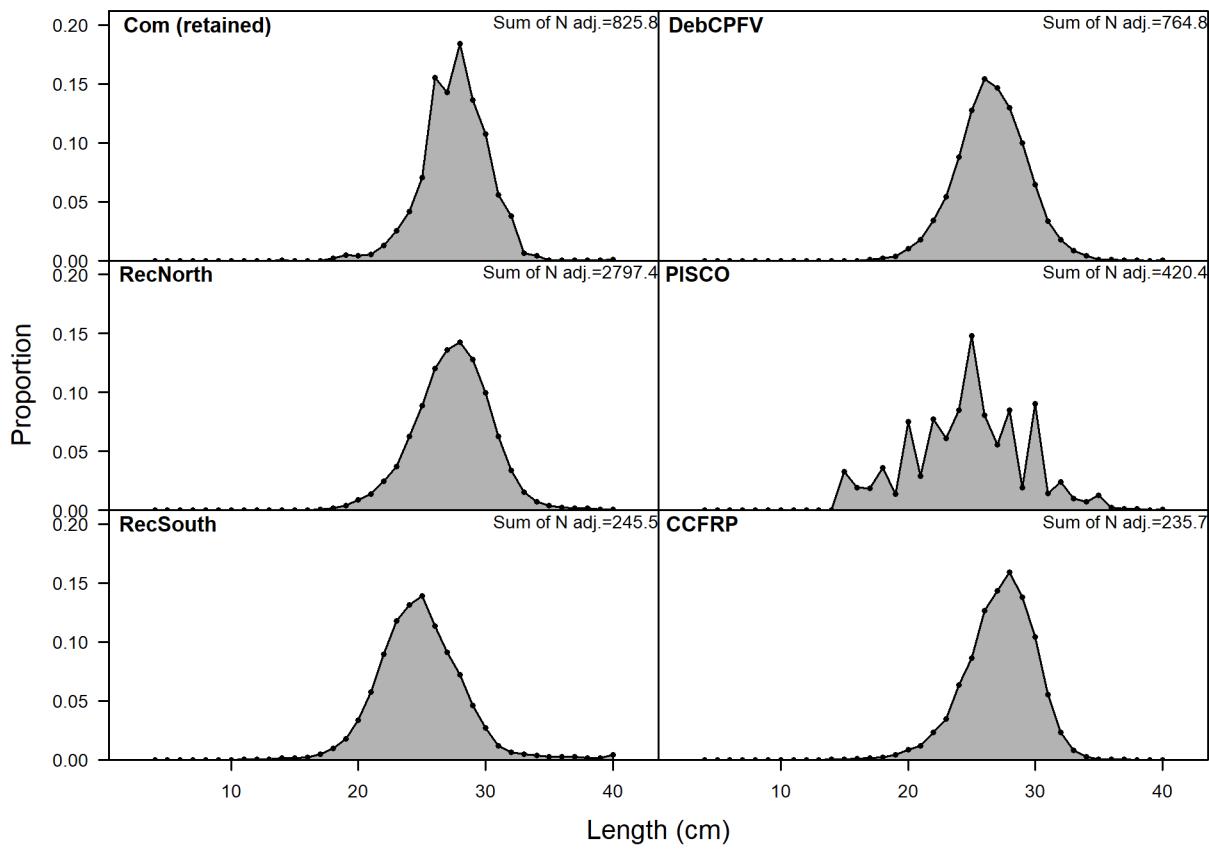


Figure 31: Length comp data, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch. | [fig:comp_lendat_aggregated_across_time](#)

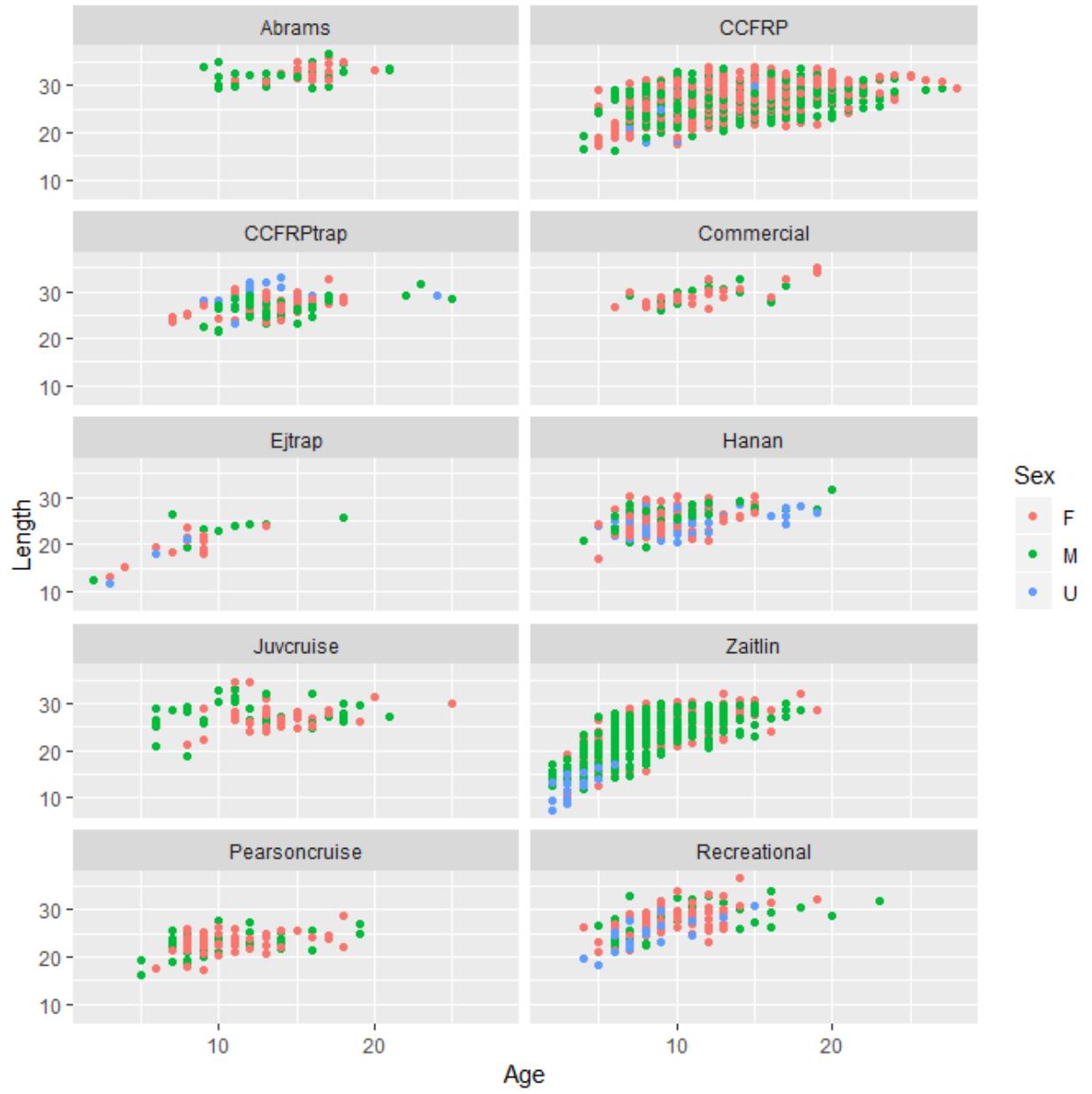


Figure 32: Available length-at-age data for gopher and black-and-yellow rockfish by sex and data source. The Zaitlin study is all black-and-yellow rockfish. The remaining plots represent gopher rockfish

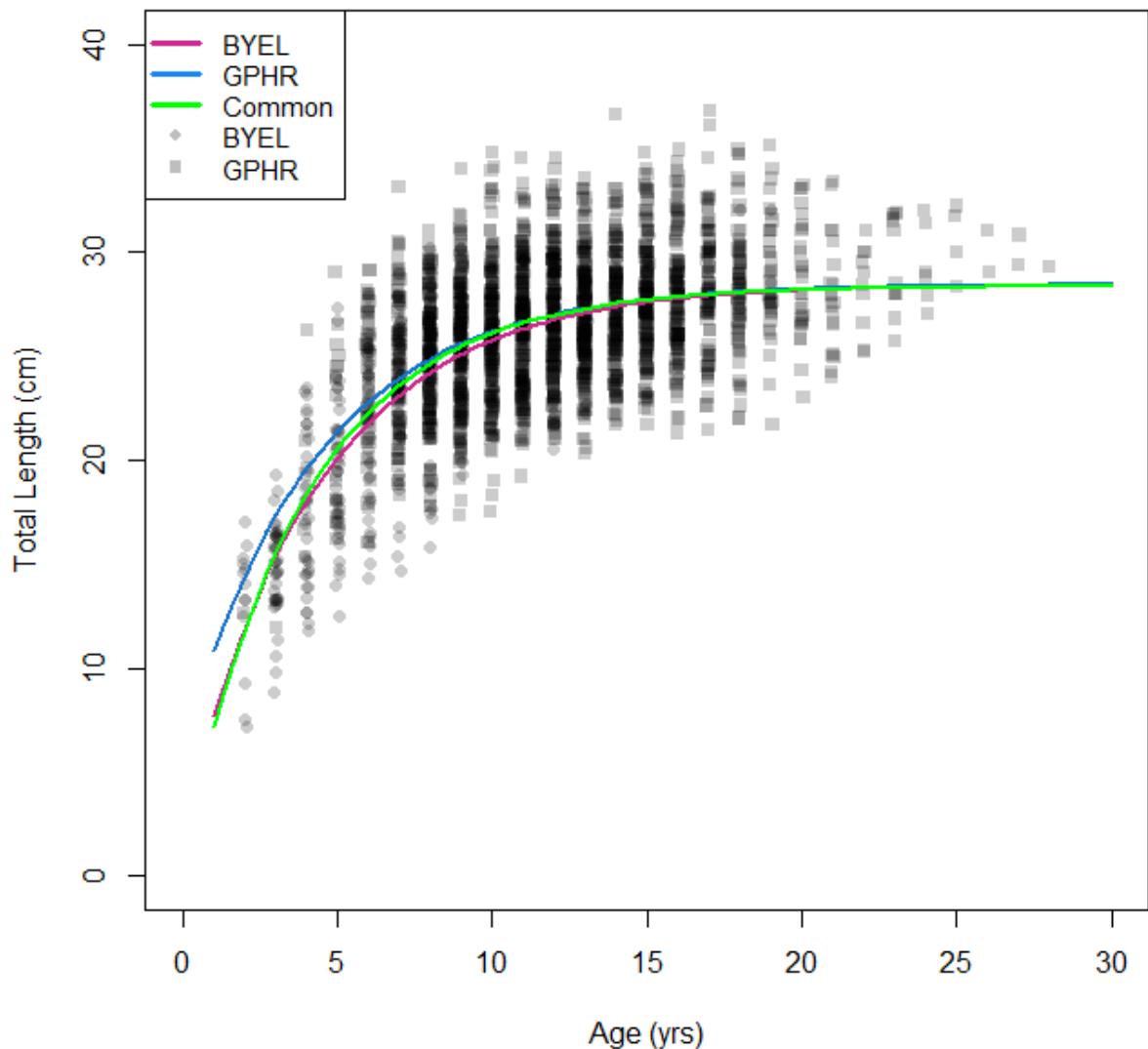


Figure 33: External estimates of growth for gopher and black-and-yellow rockfish from fits to von Bertalanffy growth models. | [Growth_by_species](#)

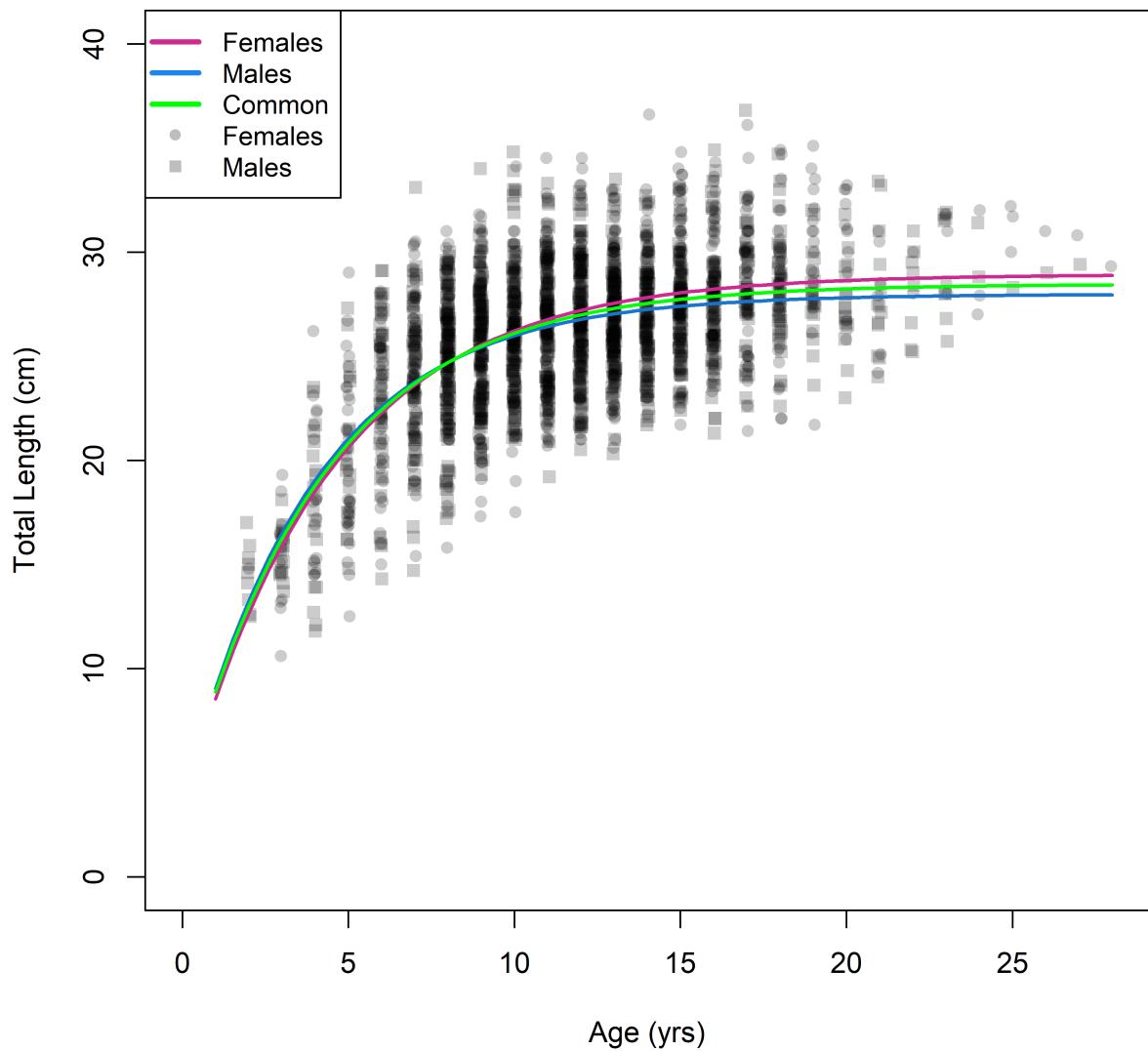


Figure 34: External estimates of growth for GBYR combined by sex from fits to von Bertalanffy growth models. | [Growth_by_sex](#)

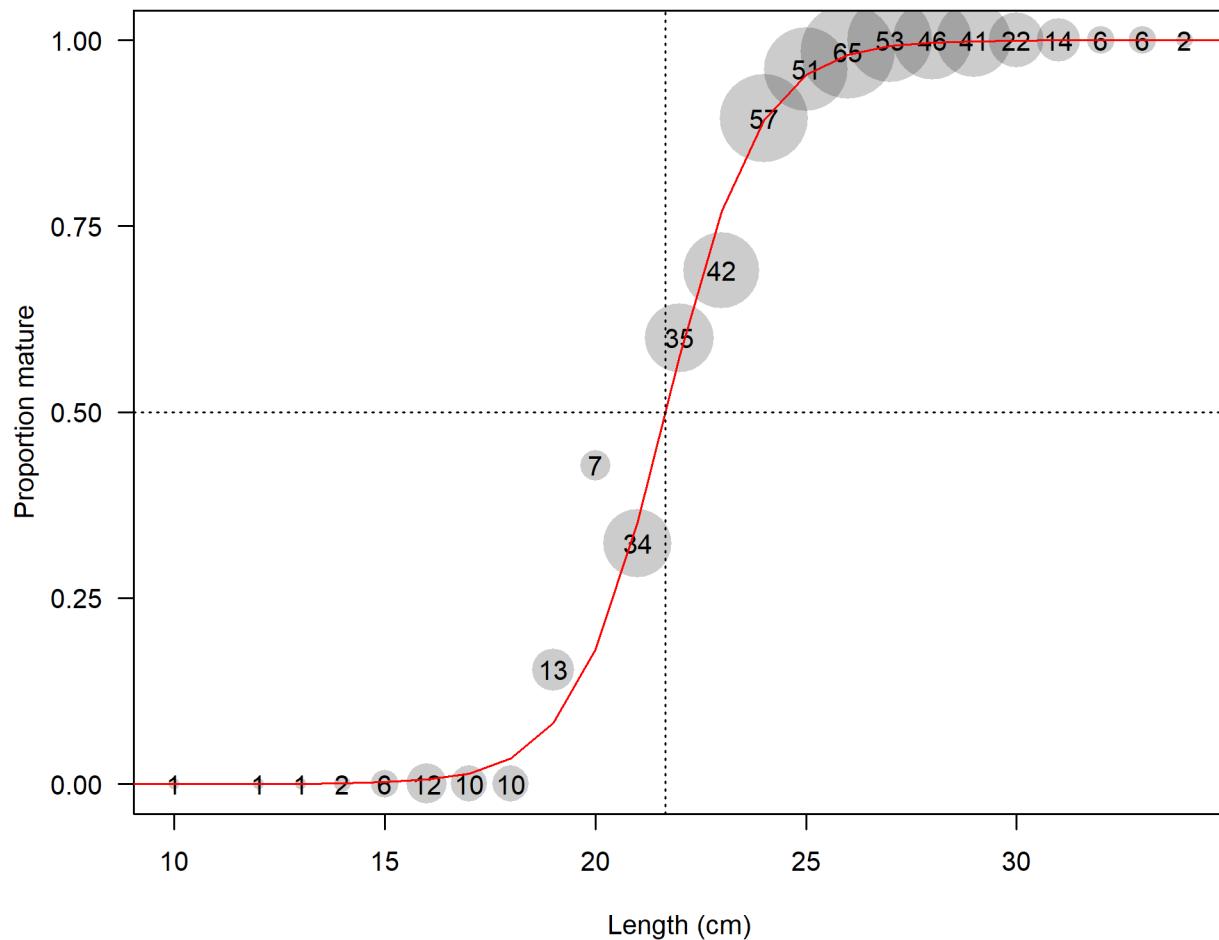


Figure 35: Maturity ogive for females estimated from black-and-yellow rockfish from Zaitlin (1986) and gopher rockfish from Meyers-Cherry (2014). Sample sizes at a given length are shown in the circles. [fig:GBY_maturity_ogive](#)

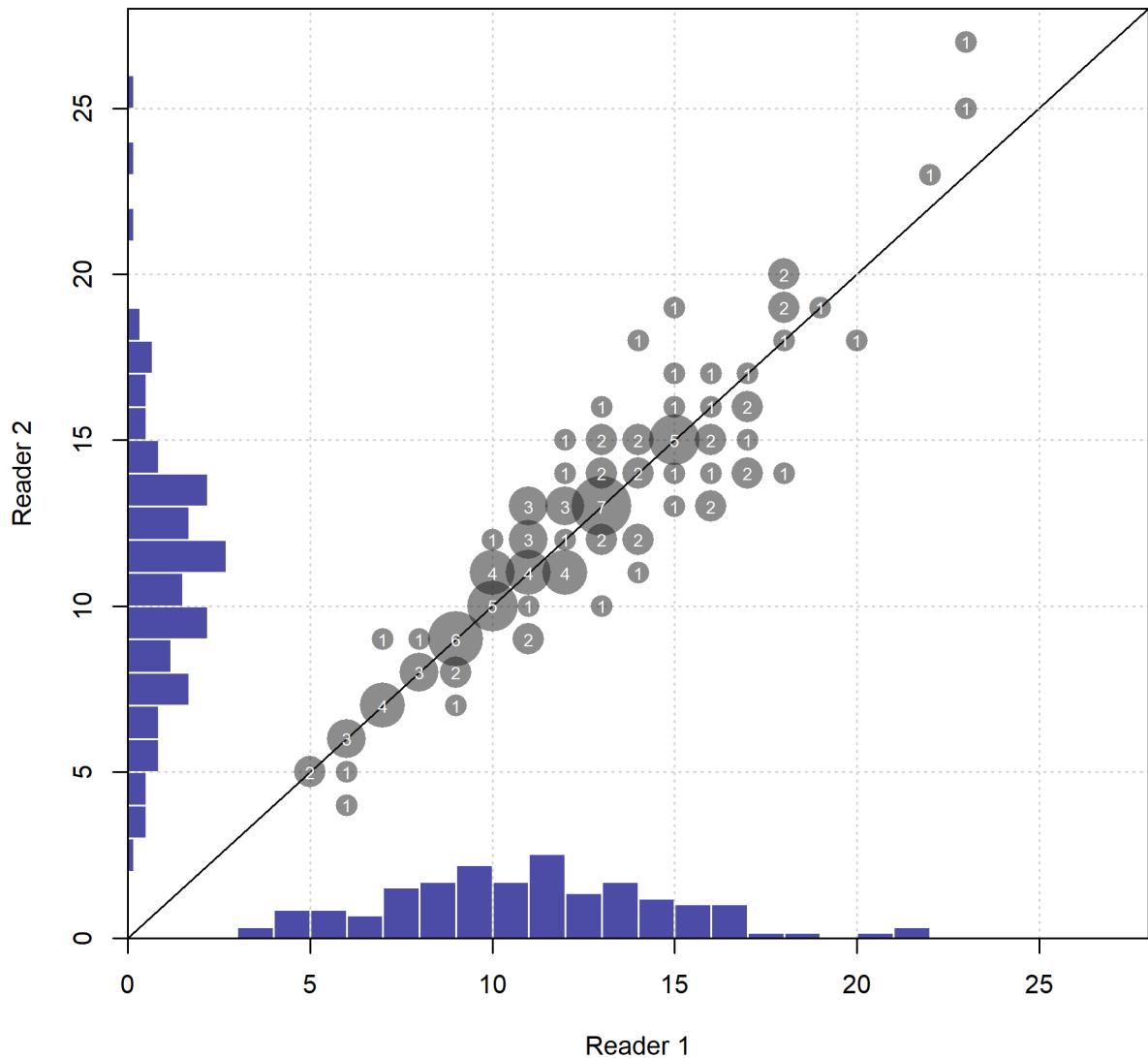


Figure 36: Aging precision between initial and blind double reads for GBYR. Numbers in the bubbles are the sample sizes of otoliths cross-read. [fig:GBY_age_error](#)

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

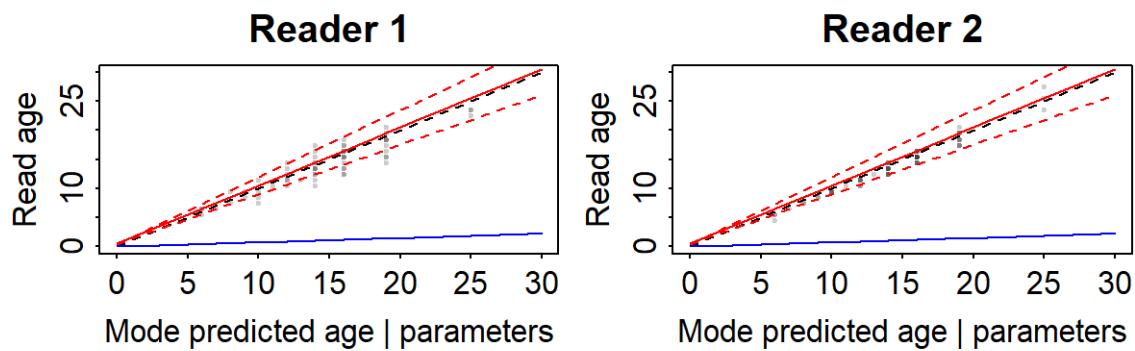


Figure 37: True versus predicted age for two current age readers at the NWFSC from the ageing error software with unbiased reads and curvilinear standard deviation for both readers.
fig:GBY_age_error2

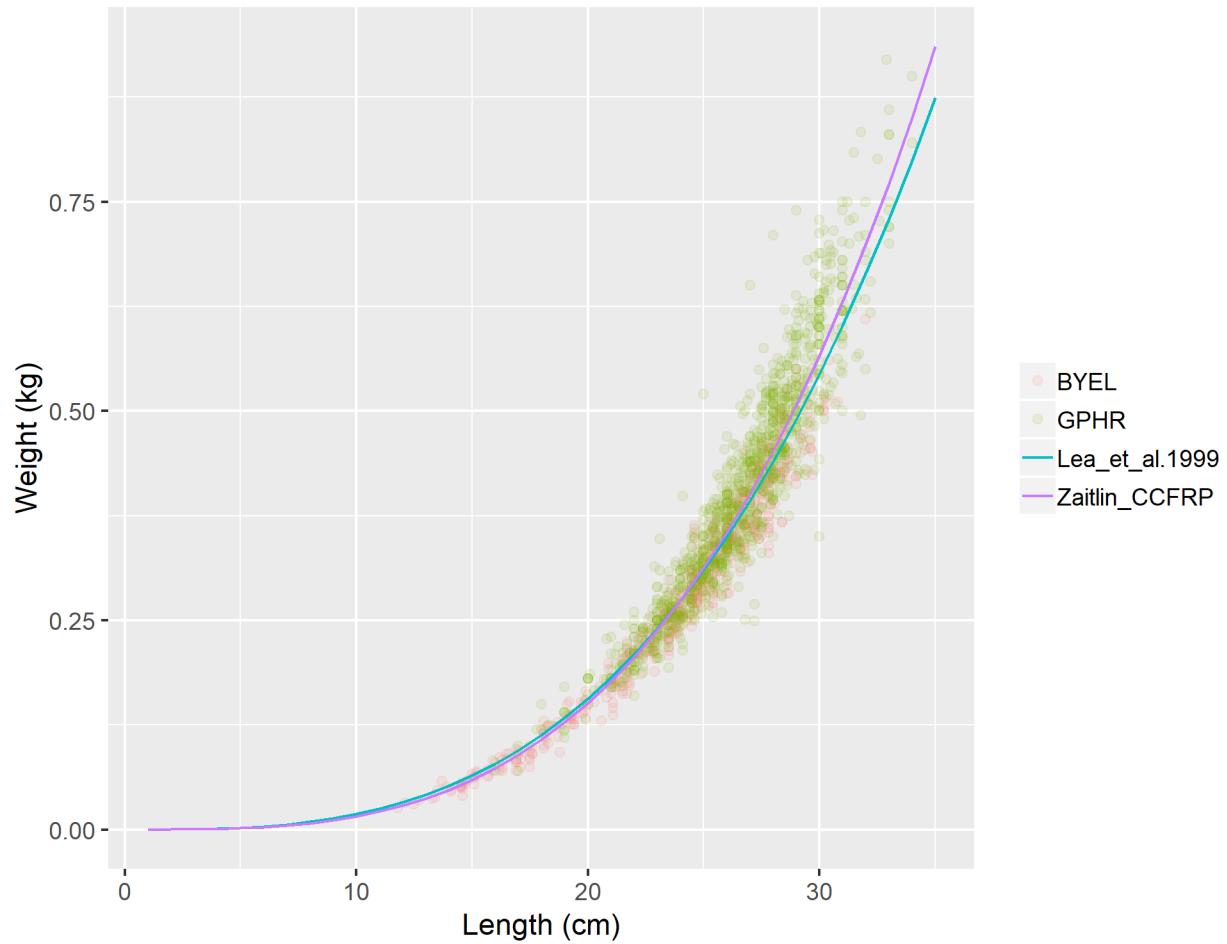


Figure 38: Comparison of the gopher rockfish weight-length curves from Lee et al. (1999) and the estimated from black-and-yellow rockfishes from Zaitlin (1986), and gopher rockfishes from Loury (2011) and Meyers-Cherry(2014). The estimated curve from the current data is used in this assessment. [fig:GBY_weight_length](#)

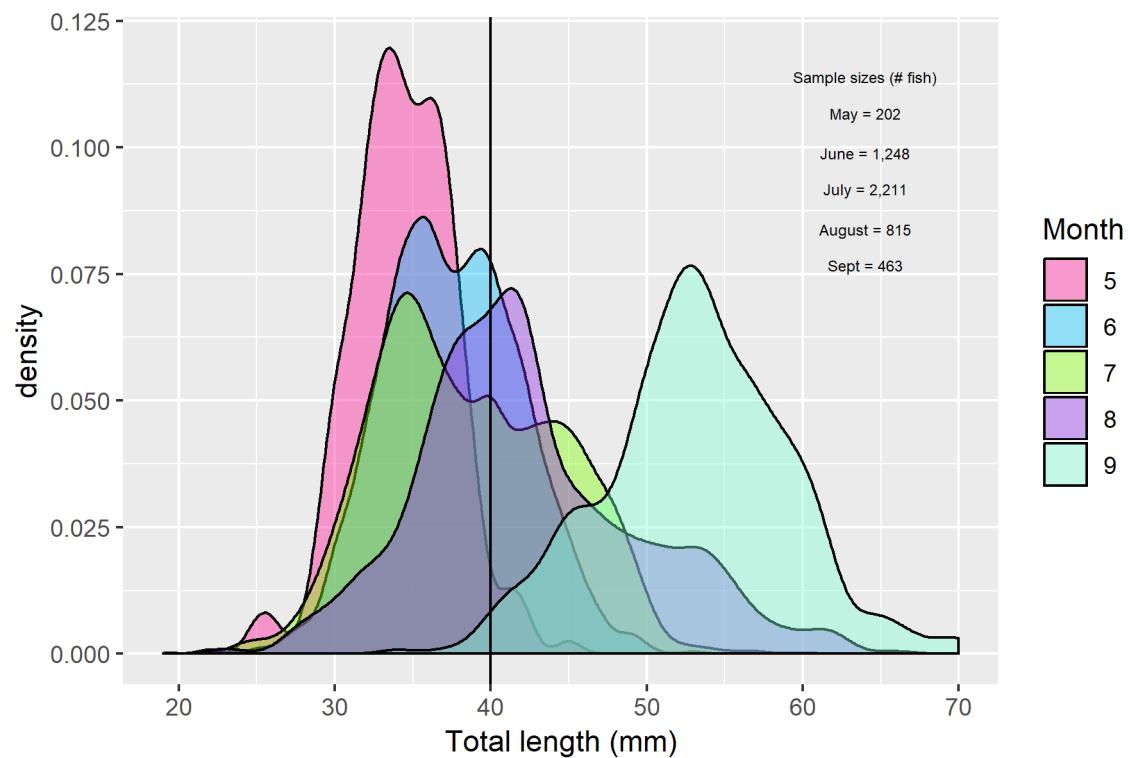


Figure 39: Length distribution by month for GBYR captured using a sampling tool called a Standard Monitoring Unit for the Recruitment of Fishes (SMURFs) from the UCSC-PISCO kelp forest fish survey, specifically as part of Diana Baetscher's dissertation work (Baetscher 2019). [fig:SMURF_lengths](#)

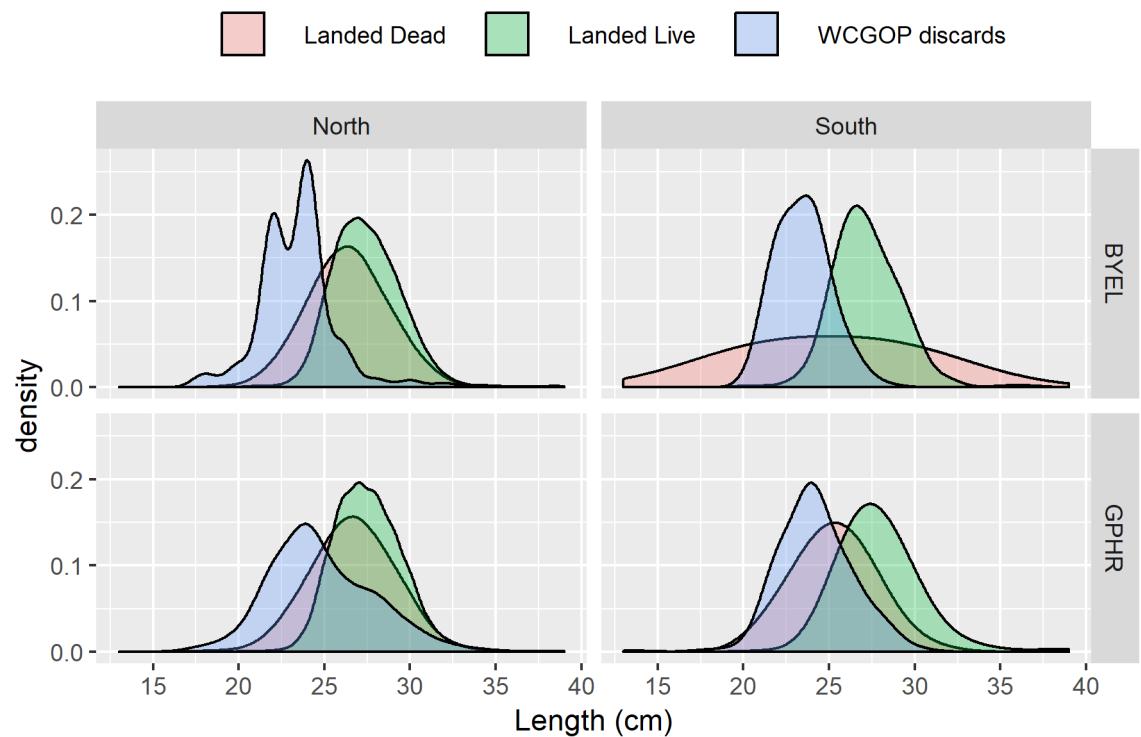


Figure 40: Length distributions of gopher and black-and-yellow rockfish for the commercial fleet and WCGOP discards north and south of Point Conception. The commercial landings were also separated between fish landed live and fish landed dead for this figure. [fig:Comm_lengths_justified](#)

1763 [Double reads]

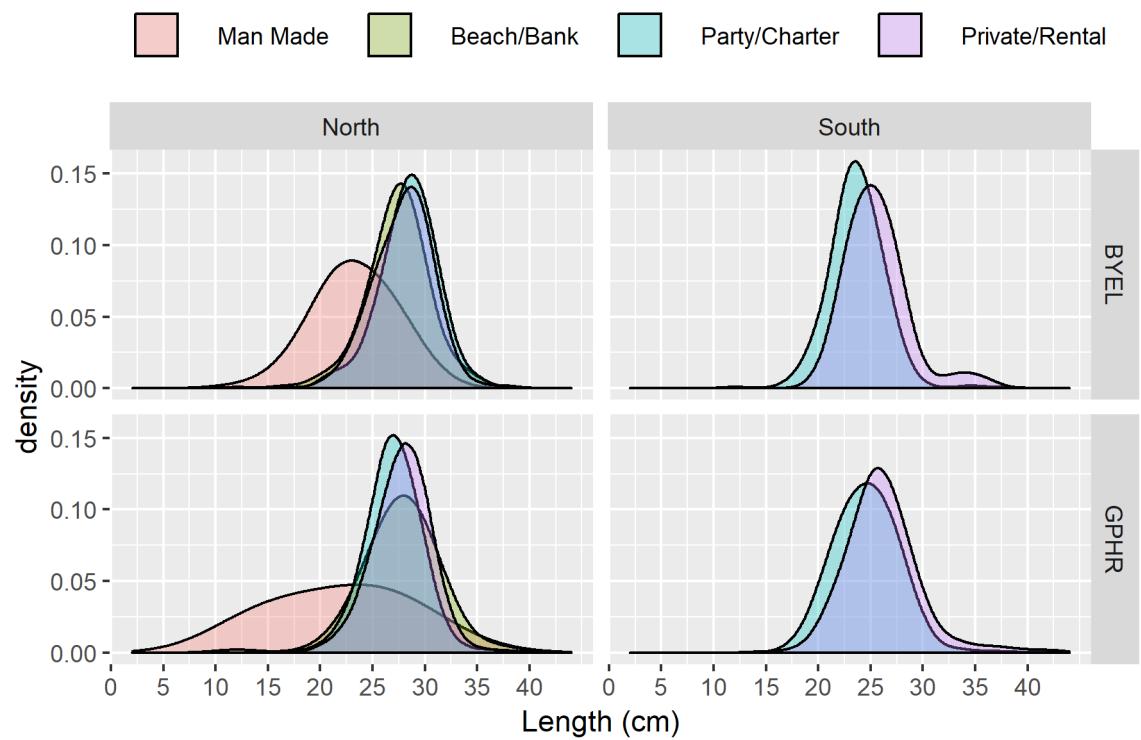


Figure 41: Length distributions of gopher and black-and-yellow rockfish for the recreational fleet north and south of Point Conception and by mode. [fig:Rec_lengths_justification](#)

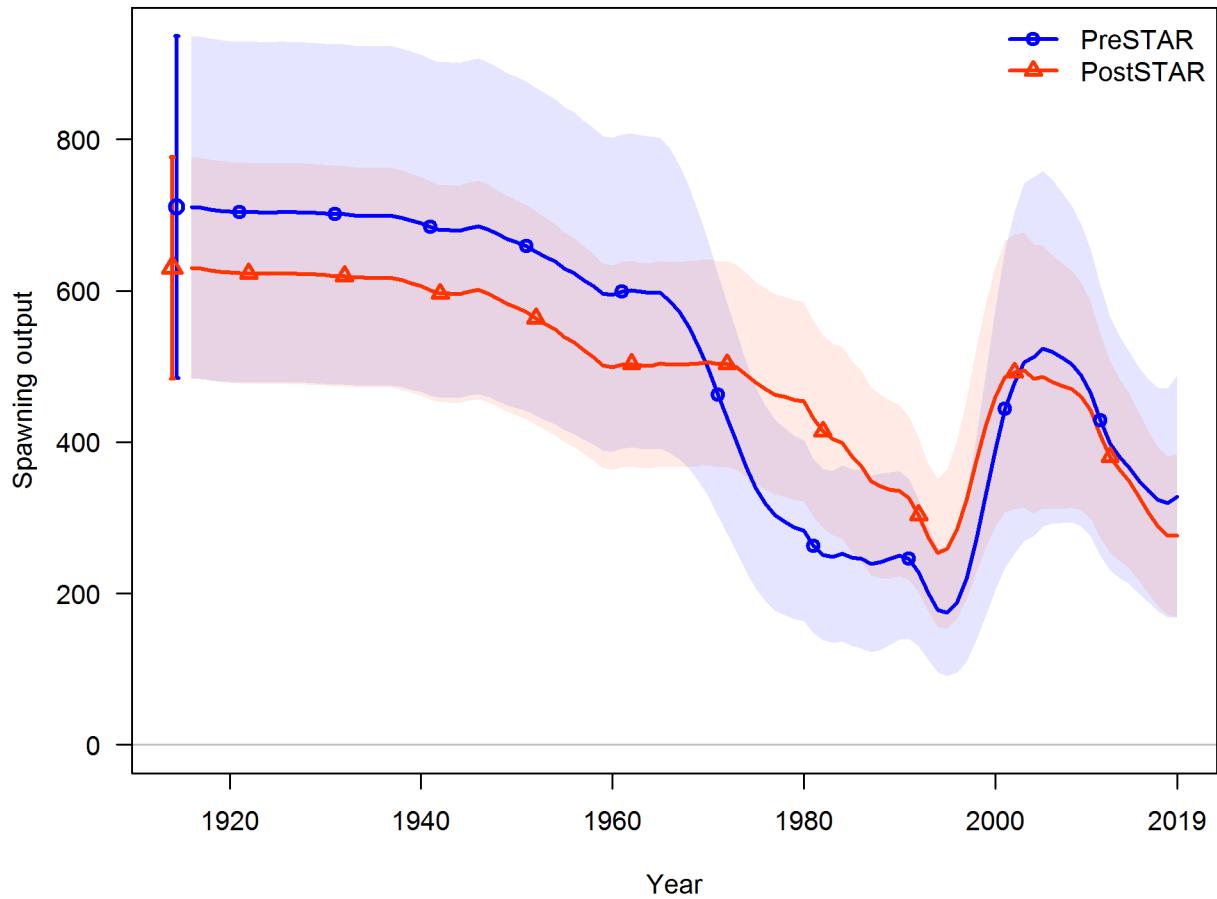


Figure 42: Comparison of the spawning output between the pre-STAR panel base model and the post-STAR model base. [fig:preSTAR_postSTAR_compare_spawnbio](#)

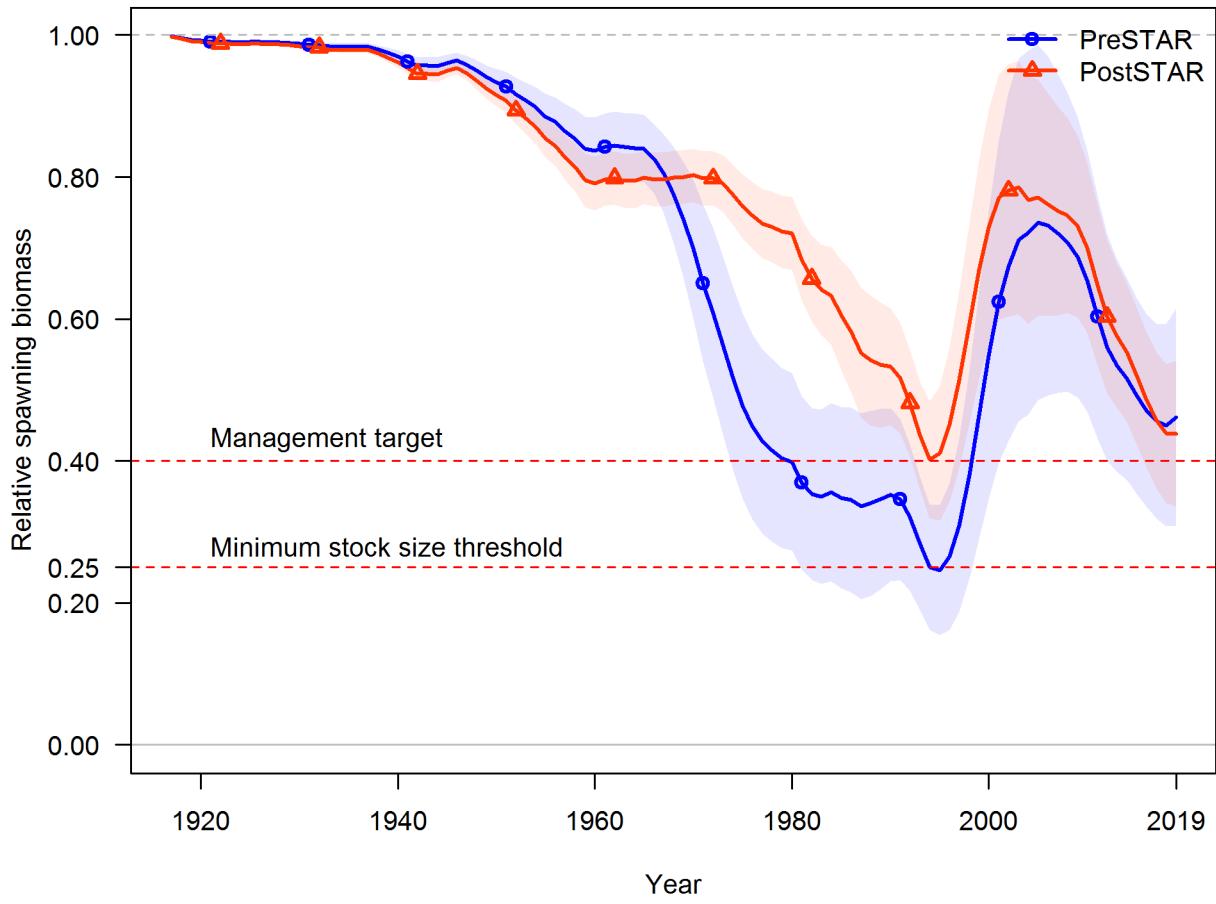


Figure 43: Comparison of the relative spawning output (depletion) between the pre-STAR panel base model and the post-STAR model base. [fig:preSTAR_postSTAR_compare_Bratio](#)

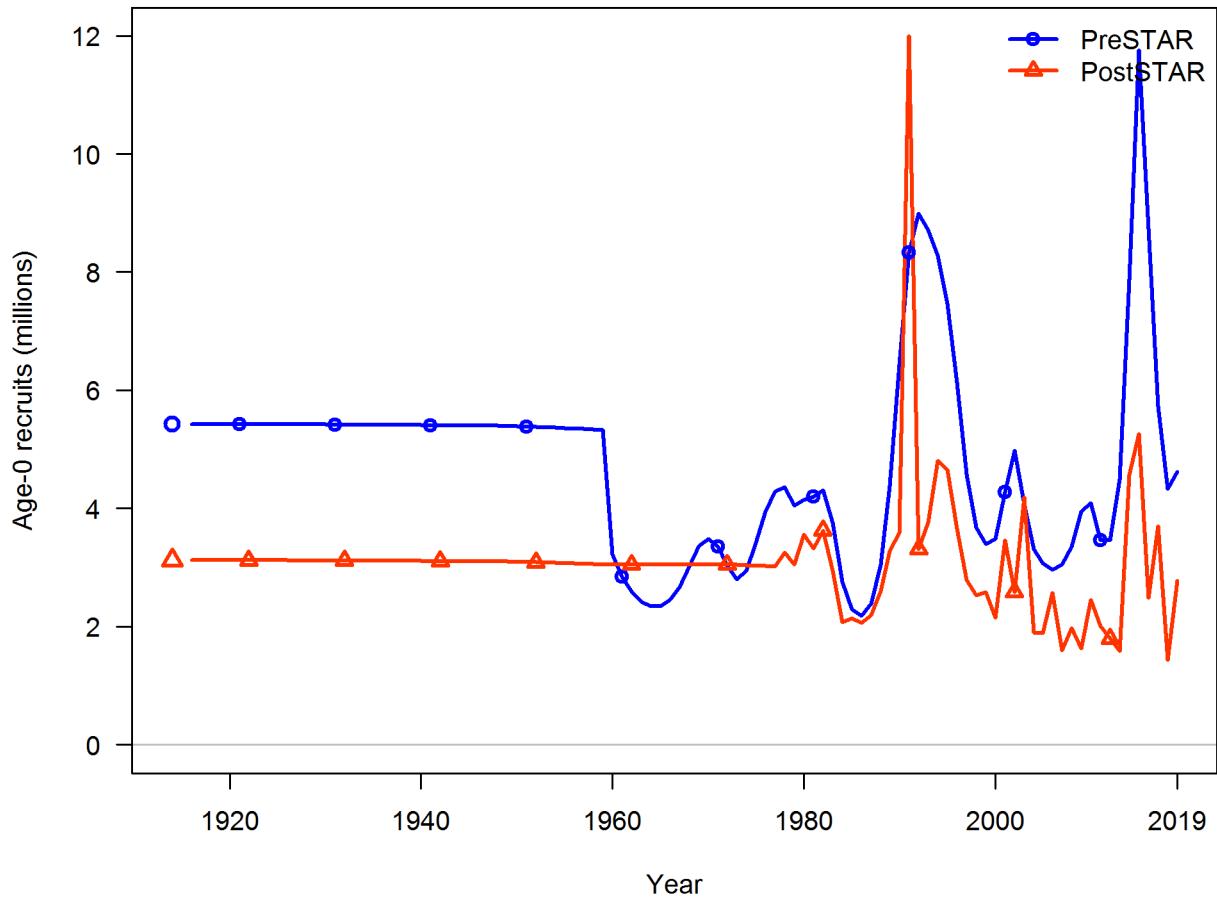


Figure 44: Comparison of the age-0 recruits between the pre-STAR panel base model and the post-STAR model base. [fig:preSTAR_postSTAR_compare_recruit](#)

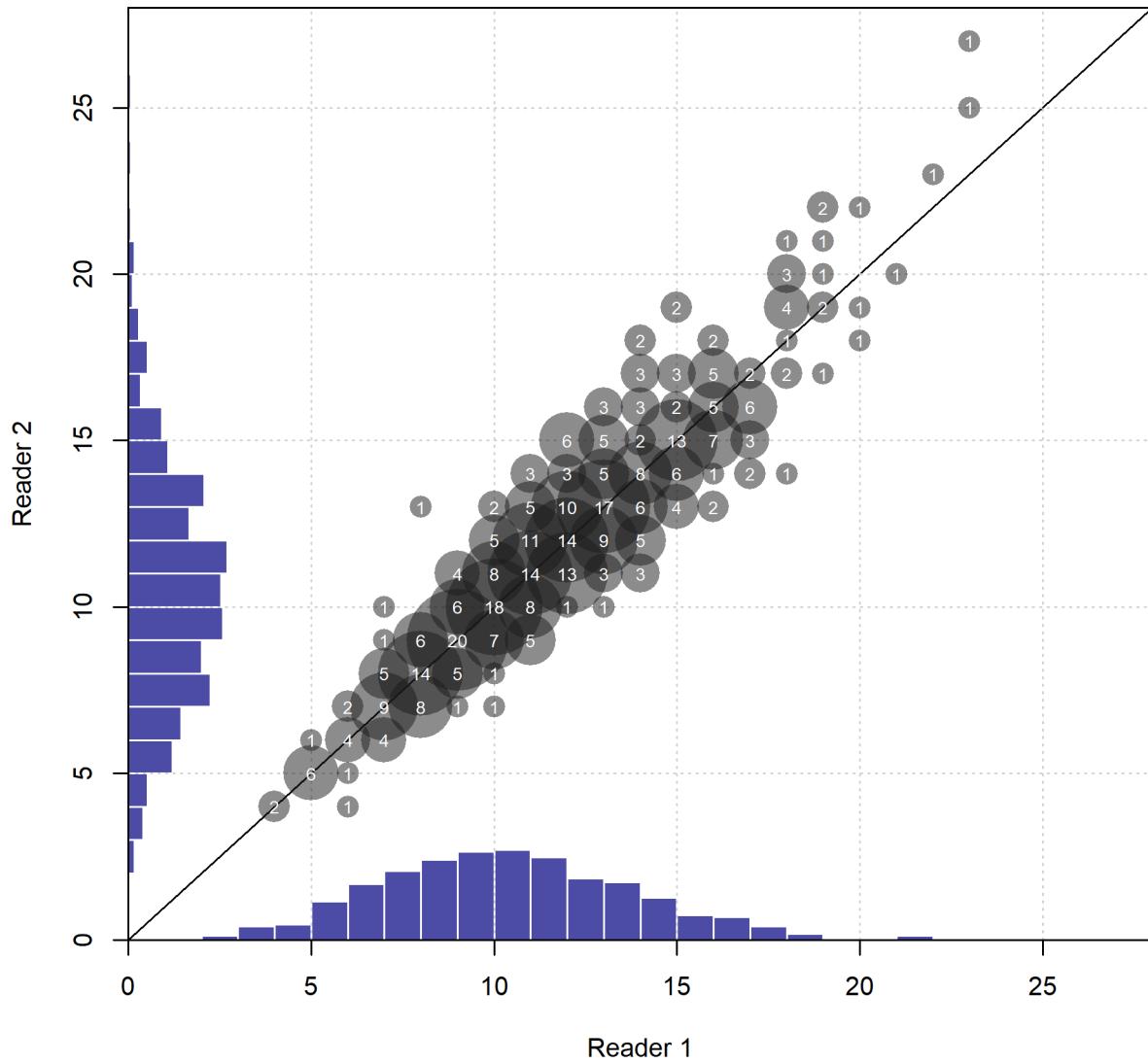


Figure 45: Updated aging precision used in the post-STAR base model between initial and blind double reads for GBYR. Numbers in the bubbles are the sample sizes of otoliths cross-read. [fig:GBY_age_error_updated](#)

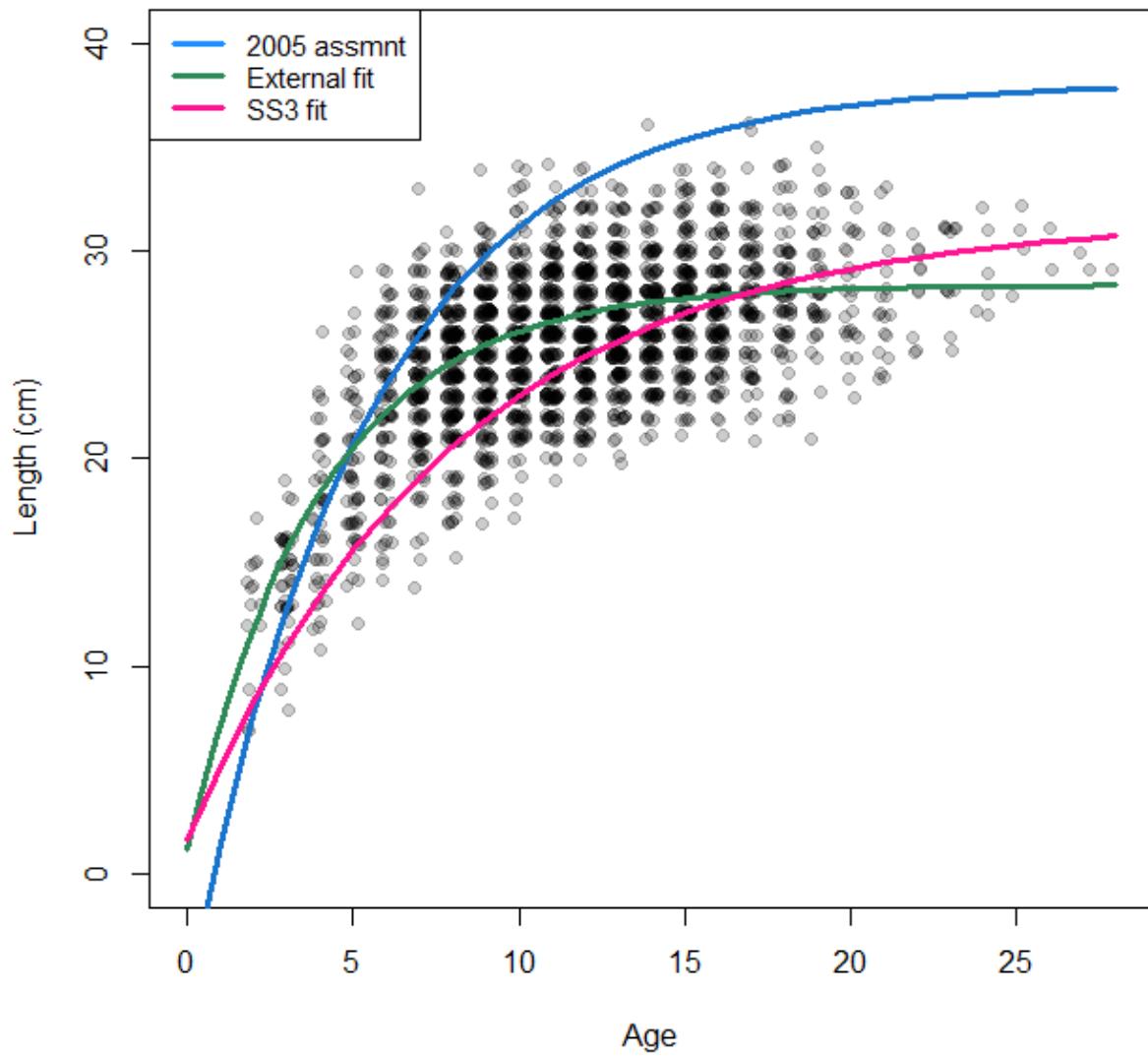


Figure 46: Estimates of growth for GBYR from the 2005 assessment, external fit to the CAAL data used in this assessment and the internal SS estimate of growth for this assessment. All growth curves were estimated using the Schnute parameterization of the von Bertalanffy growth curve. [fig:growth_compare](#)

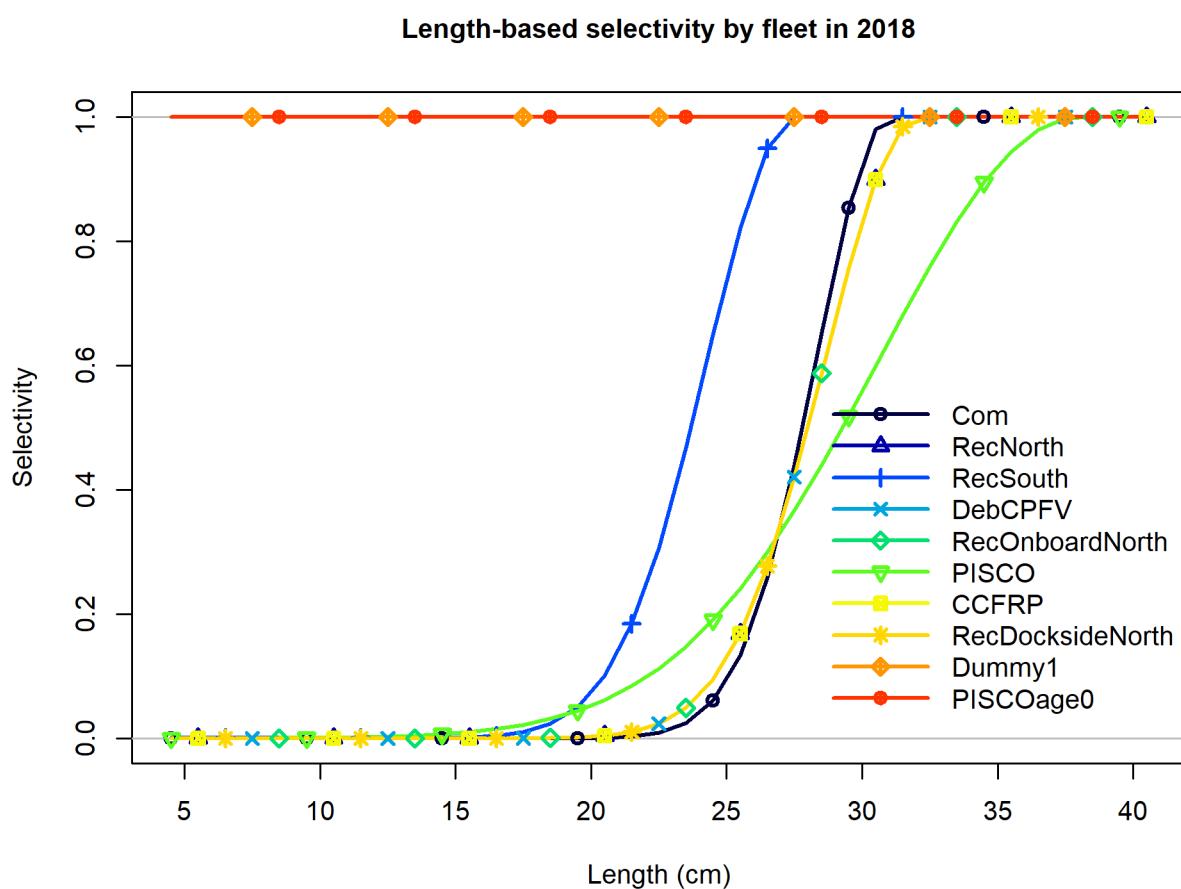


Figure 47: Selectivity at length for all of the fleets in the base model. fig:sel01_multiple_fle

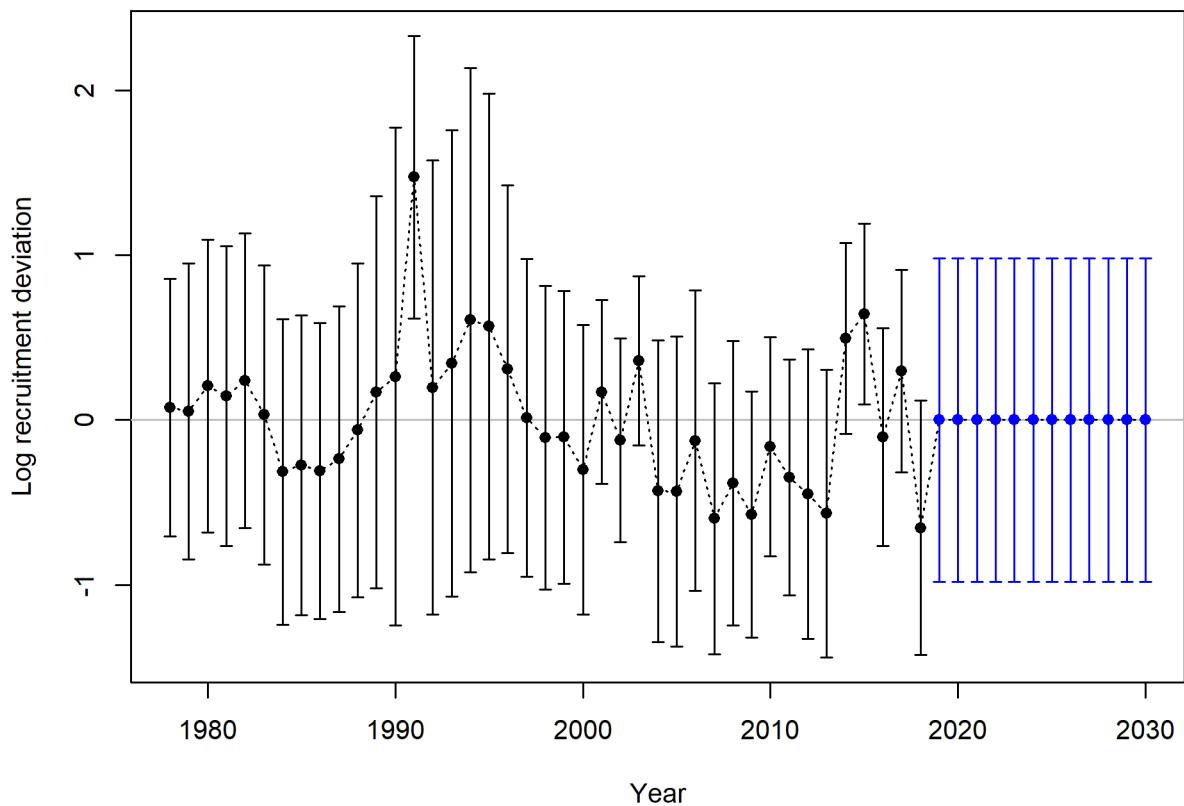


Figure 48: Estimated time-series of recruitment deviations for GBYR with 95% intervals. fig:recdevs2

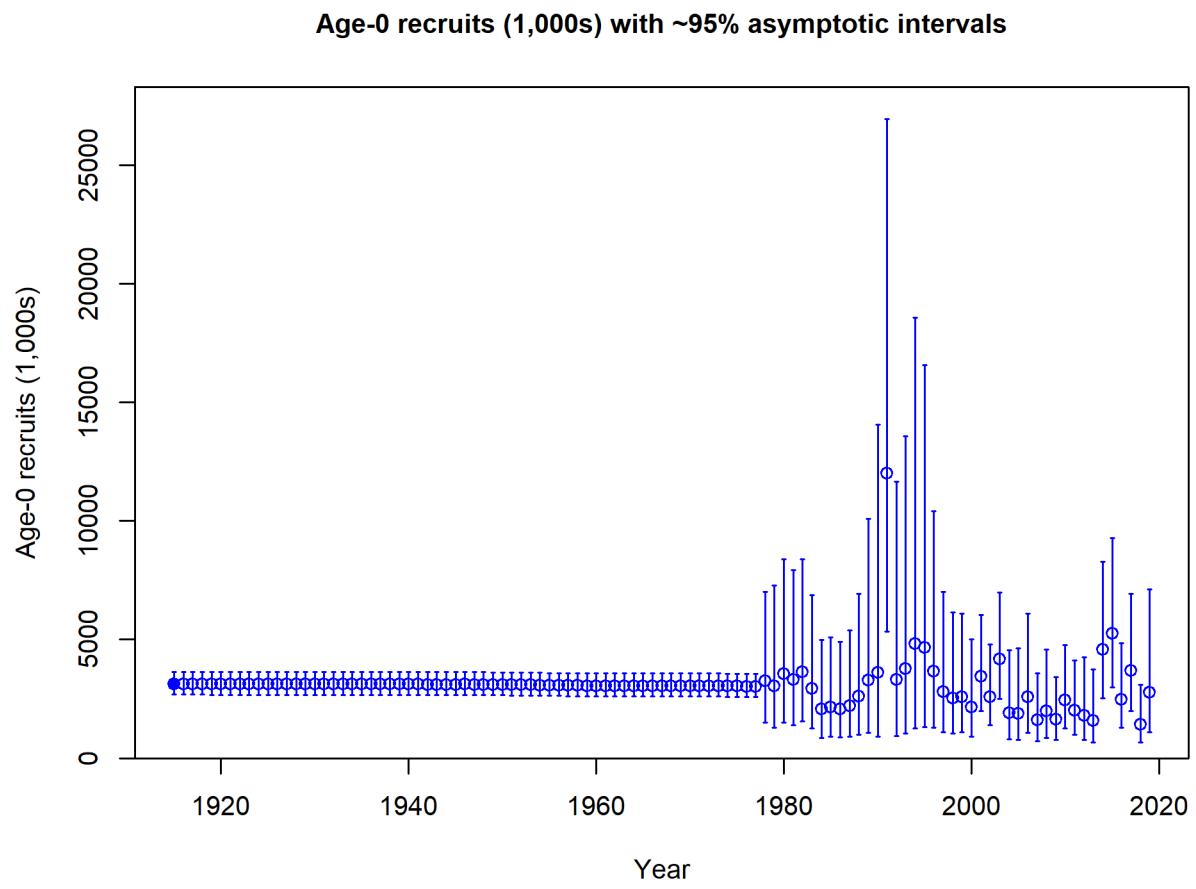


Figure 49: Time series of estimated GBYR recruitments for the base-case model with 95% confidence or credibility intervals. [fig:Recruit_mod1](#)

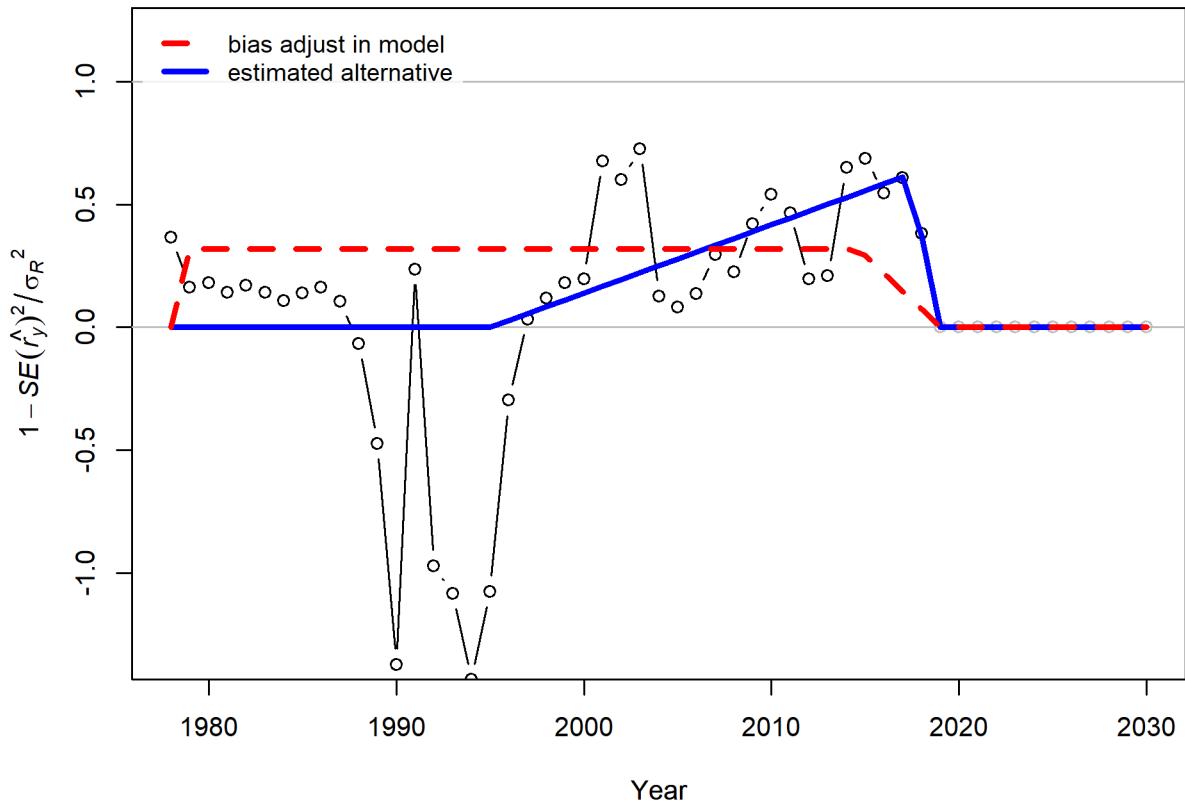


Figure 50: Bias adjustment for recruitment deviations. Points are transformed variances. Red line shows current settings for bias adjustment specified in the control file. Blue line shows the least squares estimate of alternative bias adjustment relationship for recruitment deviations.

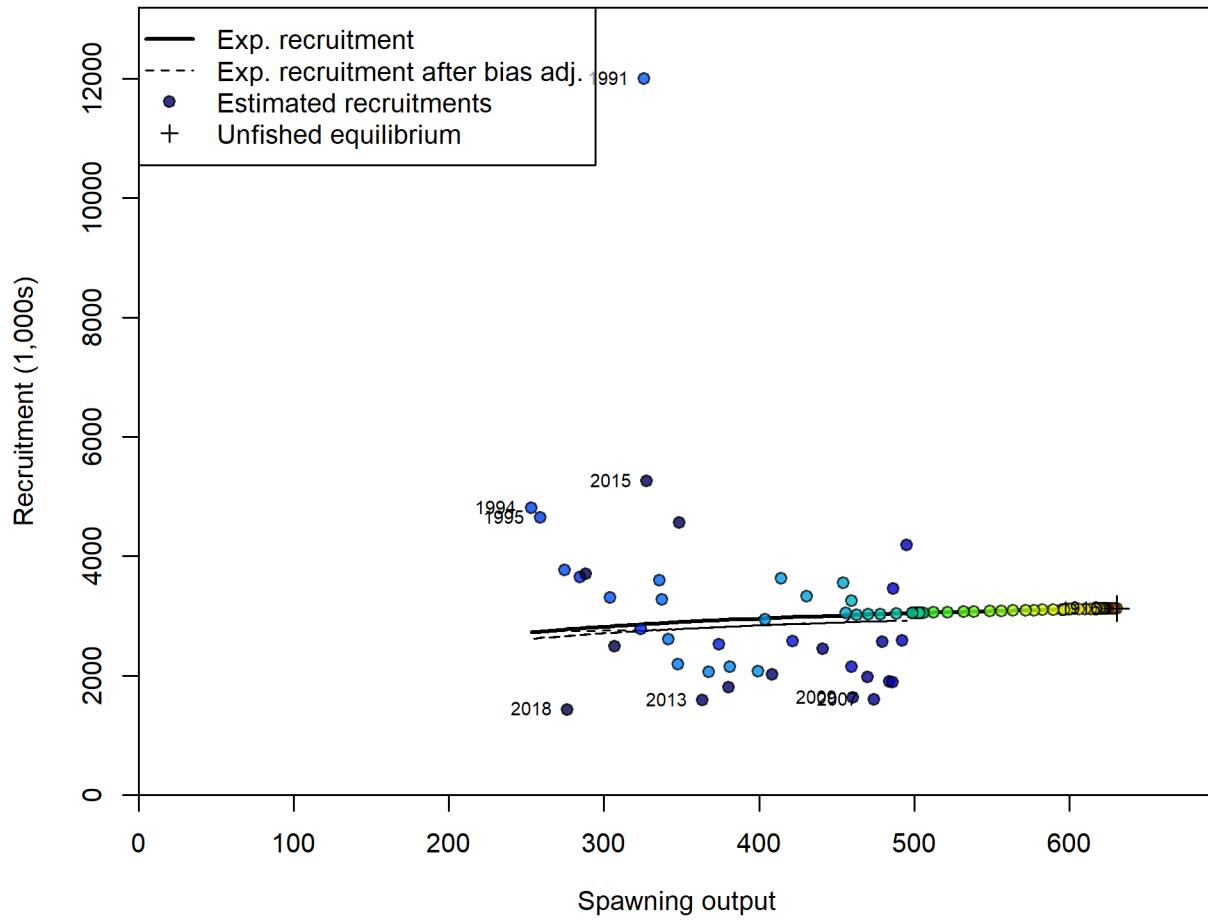


Figure 51: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line) for GBYR. The green line shows the effect of the bias correction for the lognormal distribution. ^{fig:SR_curve2}

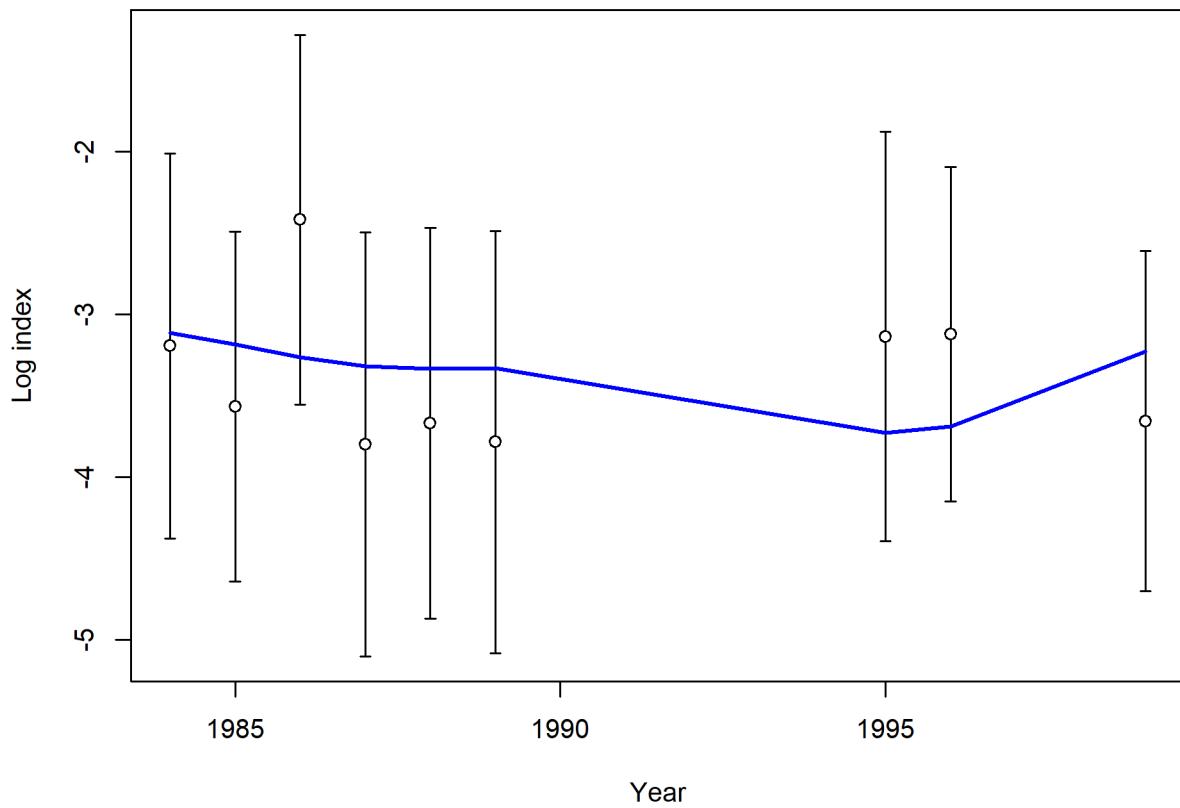


Figure 52: Fit to log index data on log scale for the recreational MRFSS dockside CPFV fishery north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. [fig:index5_logcpuefit_RecDocksideNorth](#)

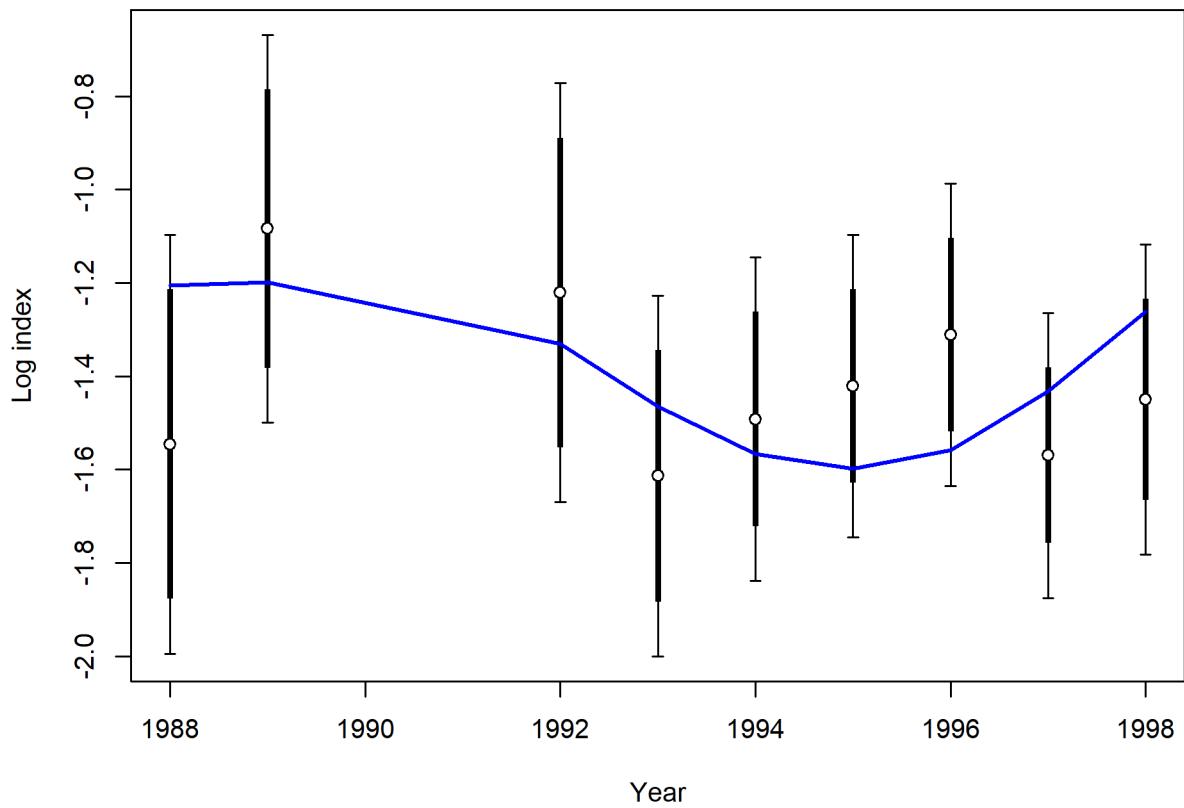


Figure 53: Fit to log index data on log scale for the recreational Deb's CPFV onboard observer program, representing north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.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

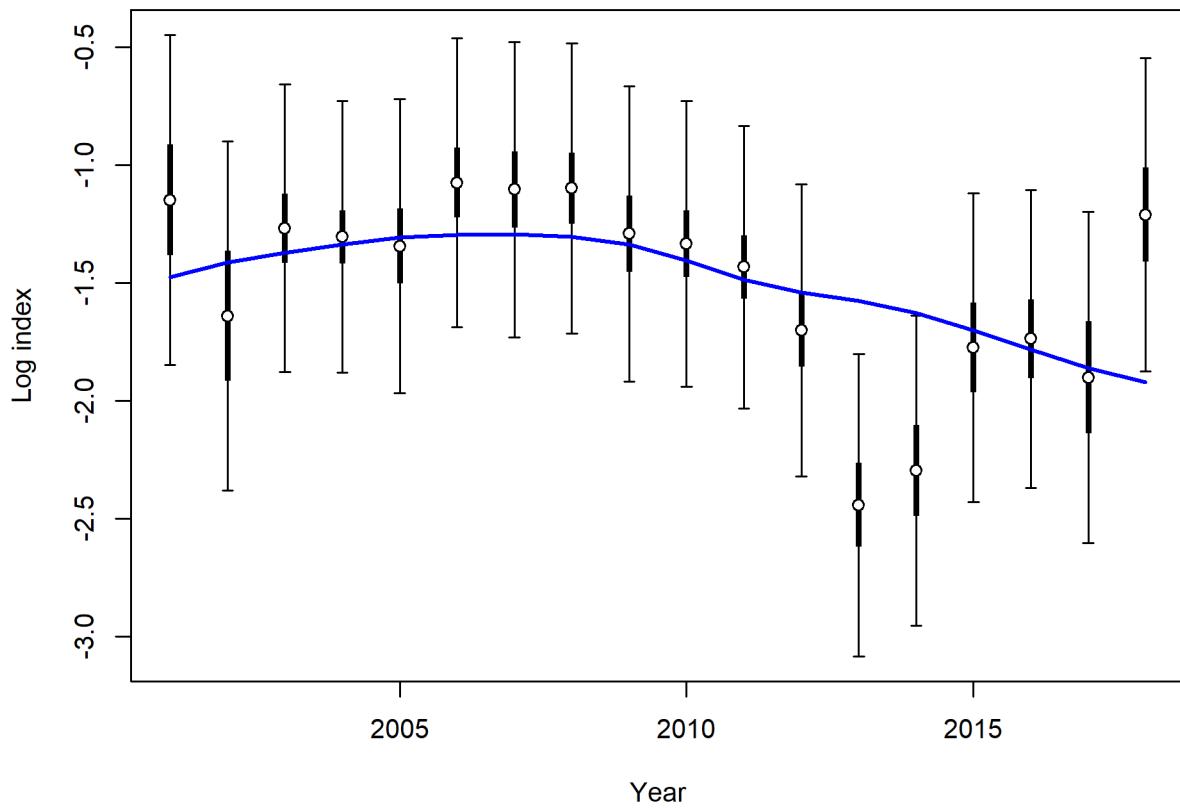


Figure 54: Fit to log index data on log scale for the CRFS/Cal Poly CPFV onboard observer survey north of Point Conception. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. [fig:index5_logcpuefit_RecOnboardNorth](#)

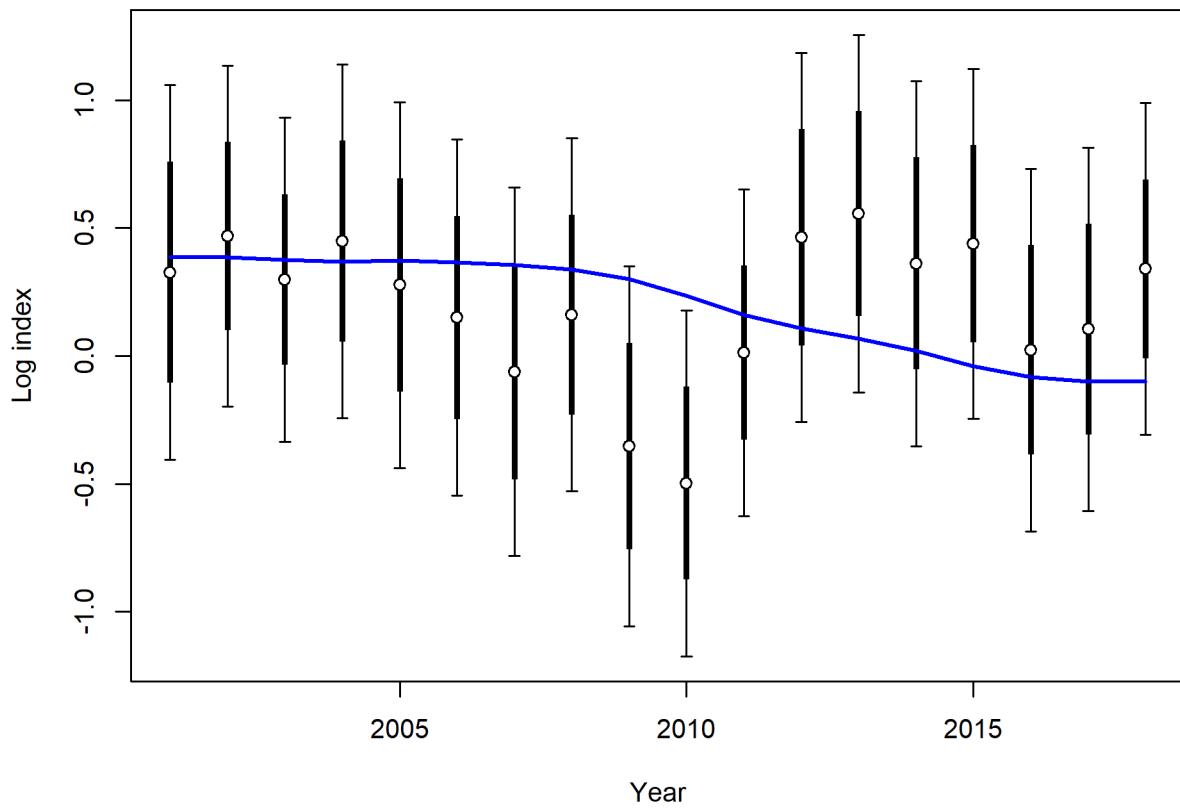


Figure 55: Fit to log index data on log scale for the fishery-independent PISCO kelp forest fish survey for fish 15 cm and larger. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. [fig:index5_logcpuefit_PISCO](#)

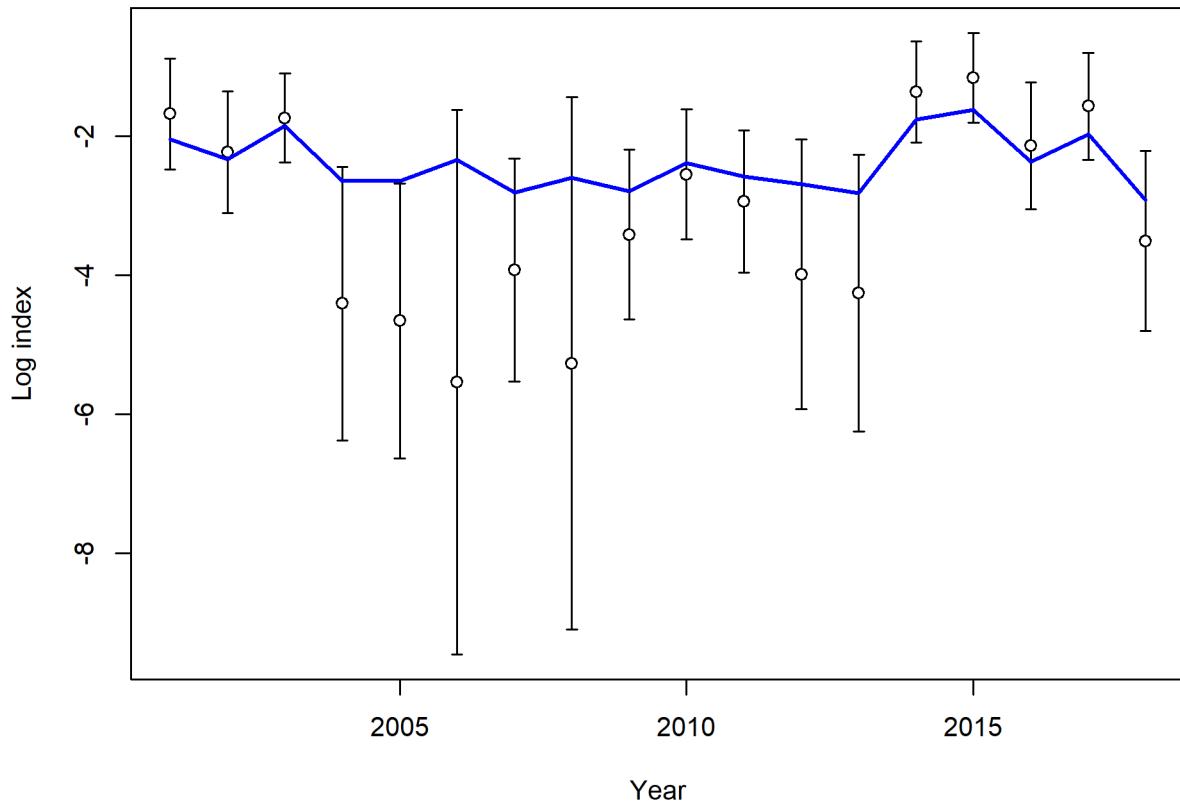


Figure 56: Fit to log index data on log scale for the fishery-independent PISCO age-0 (6 cm or less) kelp forest fish survey for fish 15 cm and larger. Lines indicate 95% uncertainty interval around index values. [fig:index5_logcpuefit_PISCOage0](#)

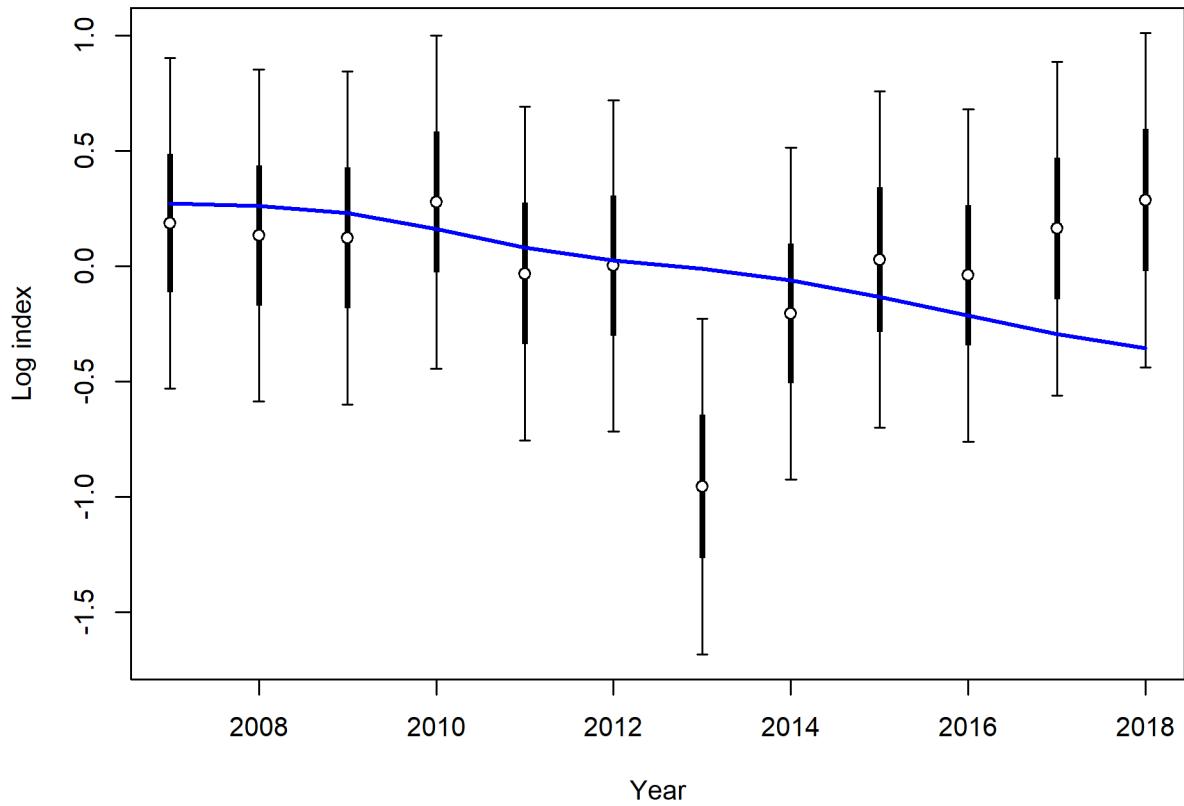


Figure 57: Fit to log index data on log scale for the fishery-independent CCFRP hook-and-line survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter. fig:index5_log

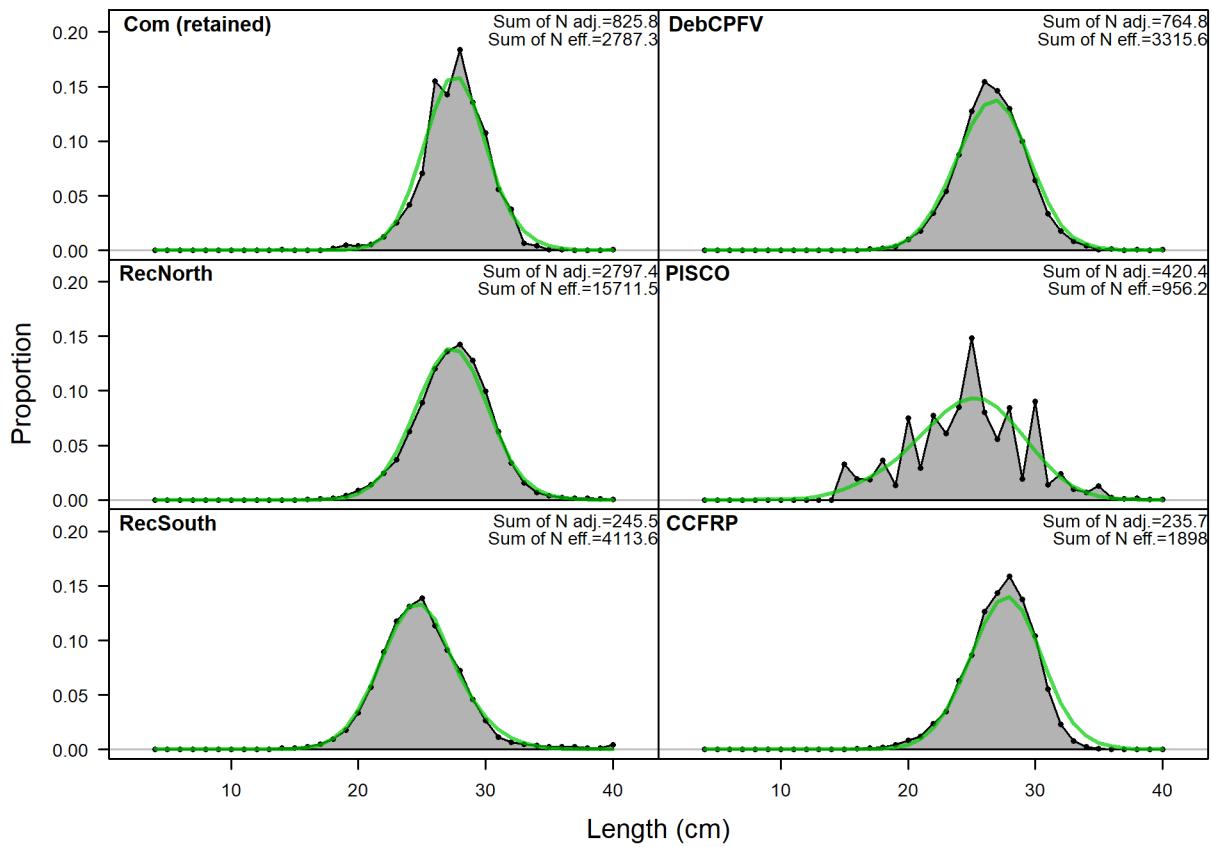


Figure 58: Length compositions aggregated across time by fleet. [fig:comp_lenfit__aggregat](#)

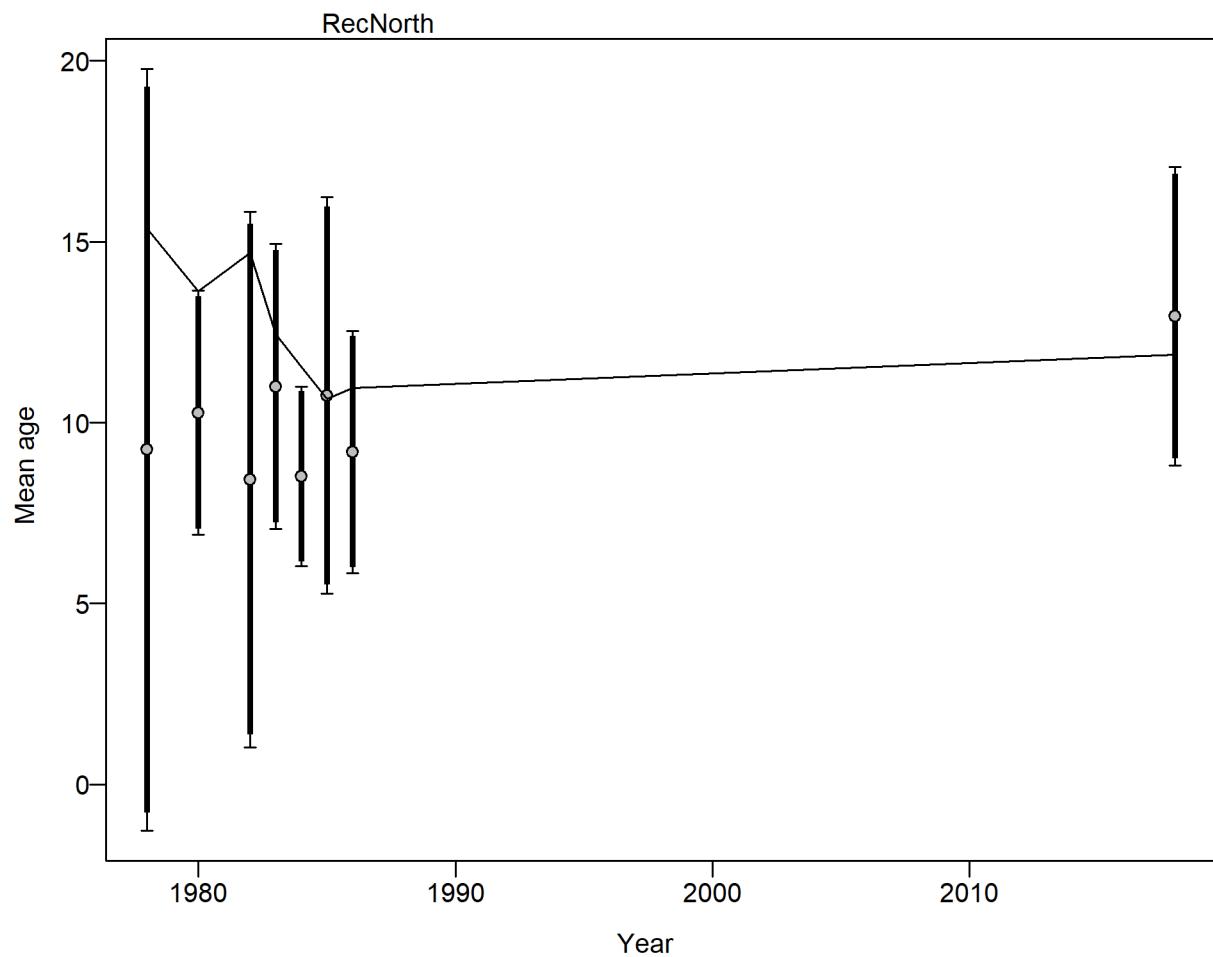


Figure 59: Mean age for the recreational fishery (ages from north of Point Conception only) with 95% confidence intervals based on current sample sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.065069 (0.507011-3.69171). For more info, see Francis et al. (2011).
 fig:comp_condAALfit_data_weighting_TA1.8_condAgeRecNorth

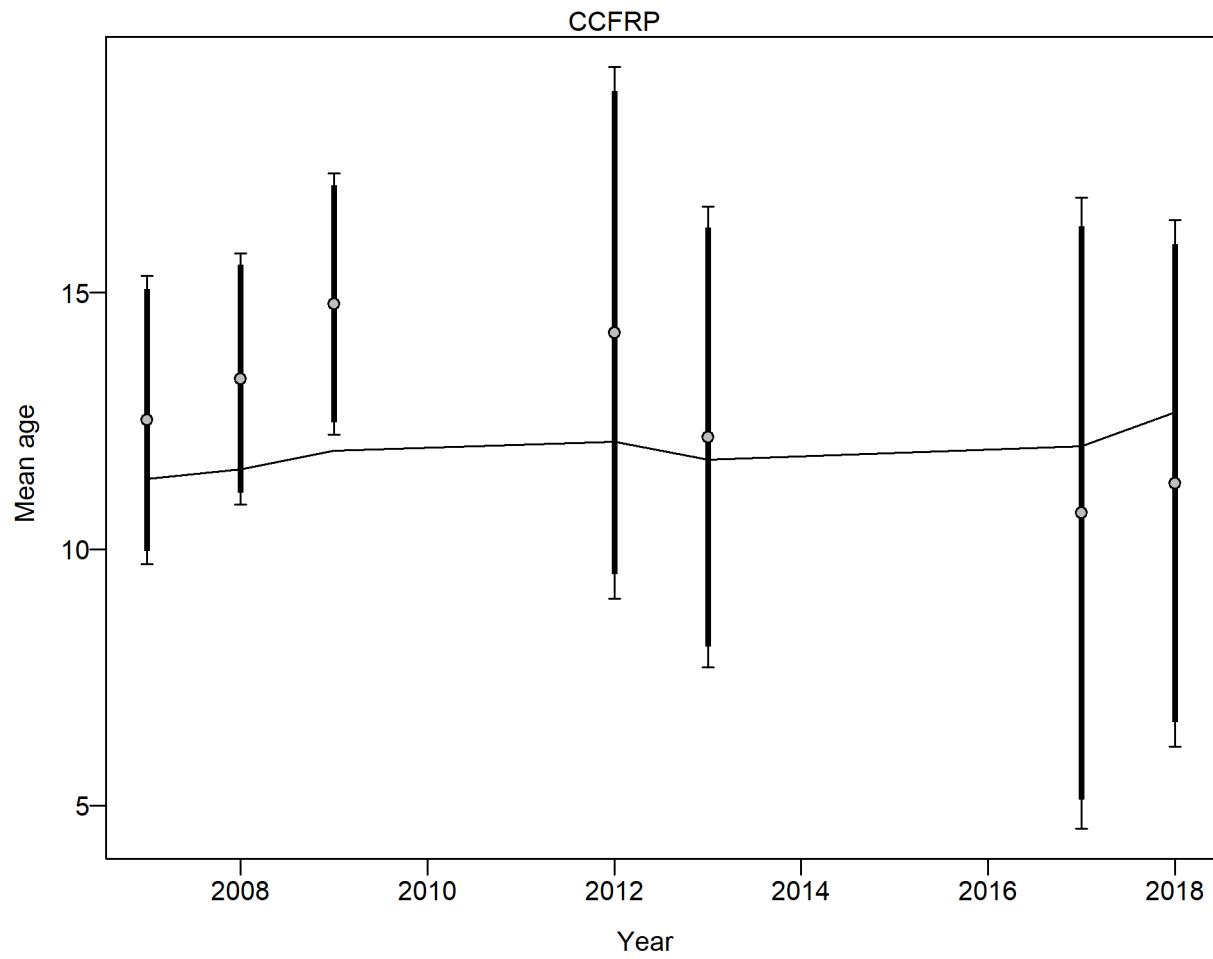


Figure 60: Mean age for the CCFRP survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is NA (NA-NA). For more info,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

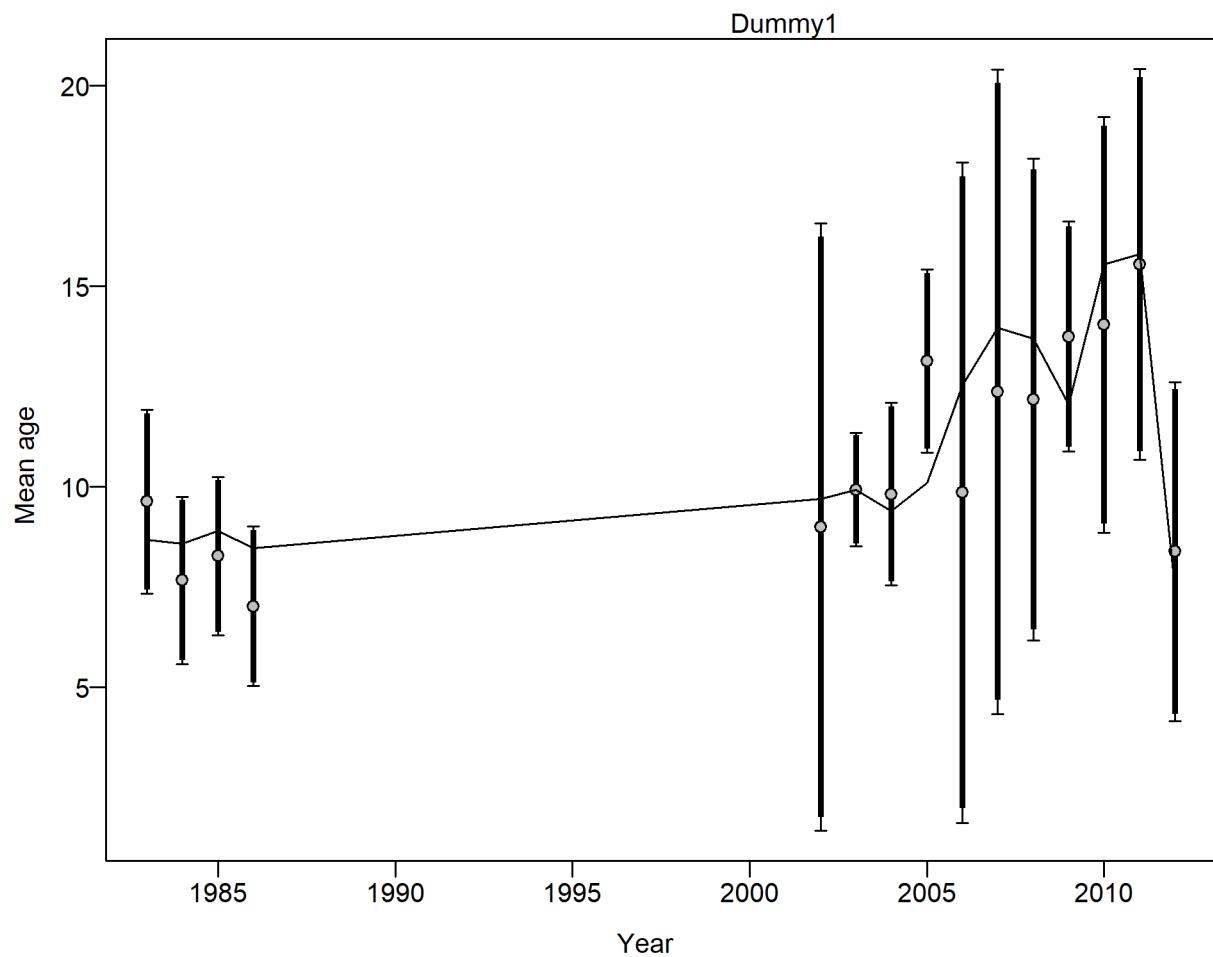


Figure 61: Mean age for the 'dummy' fleet with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is NA (NA-NA). For more info,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

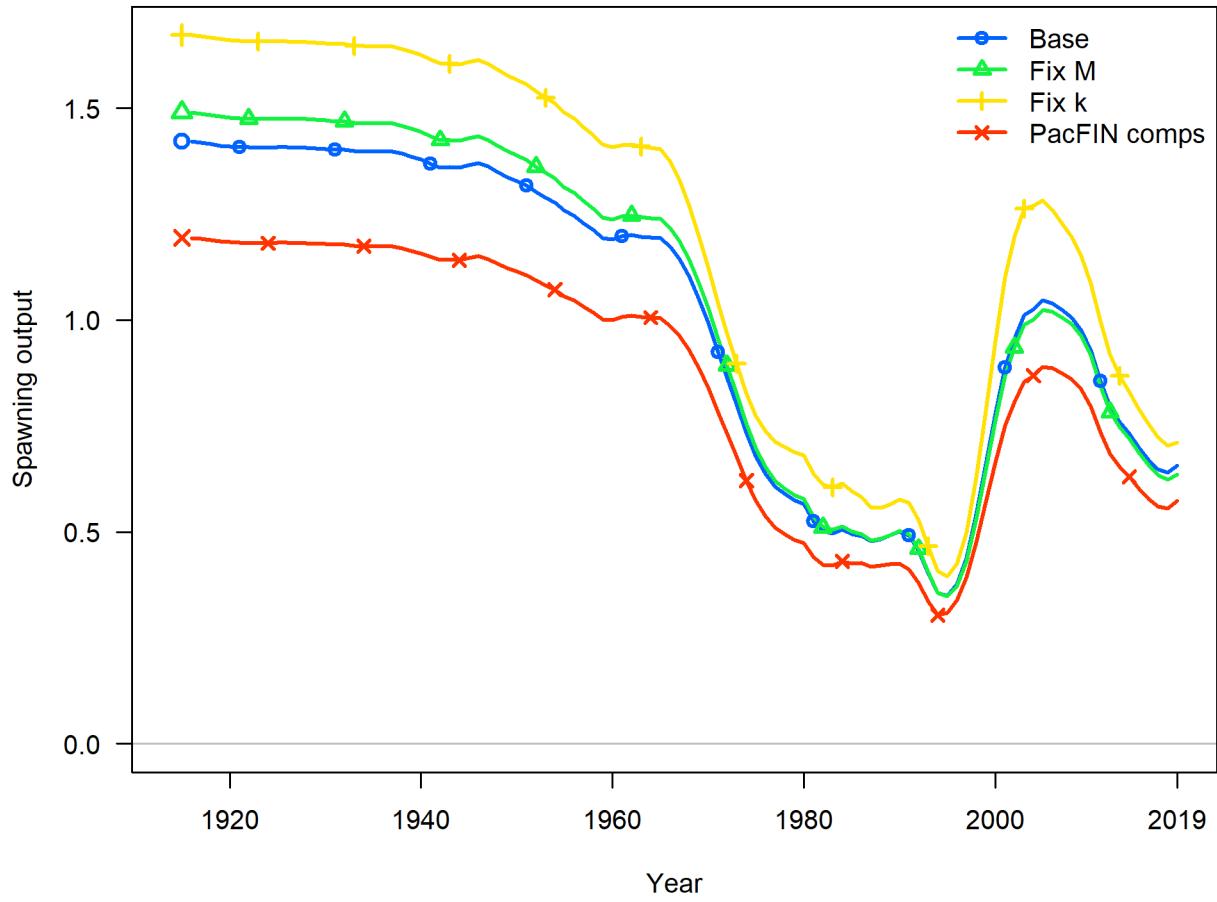


Figure 62: Sensitivity of the spawning biomass to fixing natural mortality to the prior, fixing the von Bertalanffy k parameter to the external estimate, or using commercial PacFIN length composition data instead of CALCOM, as compared to the pre-STAR base model. [fig:sensitivity1_spaw](#)

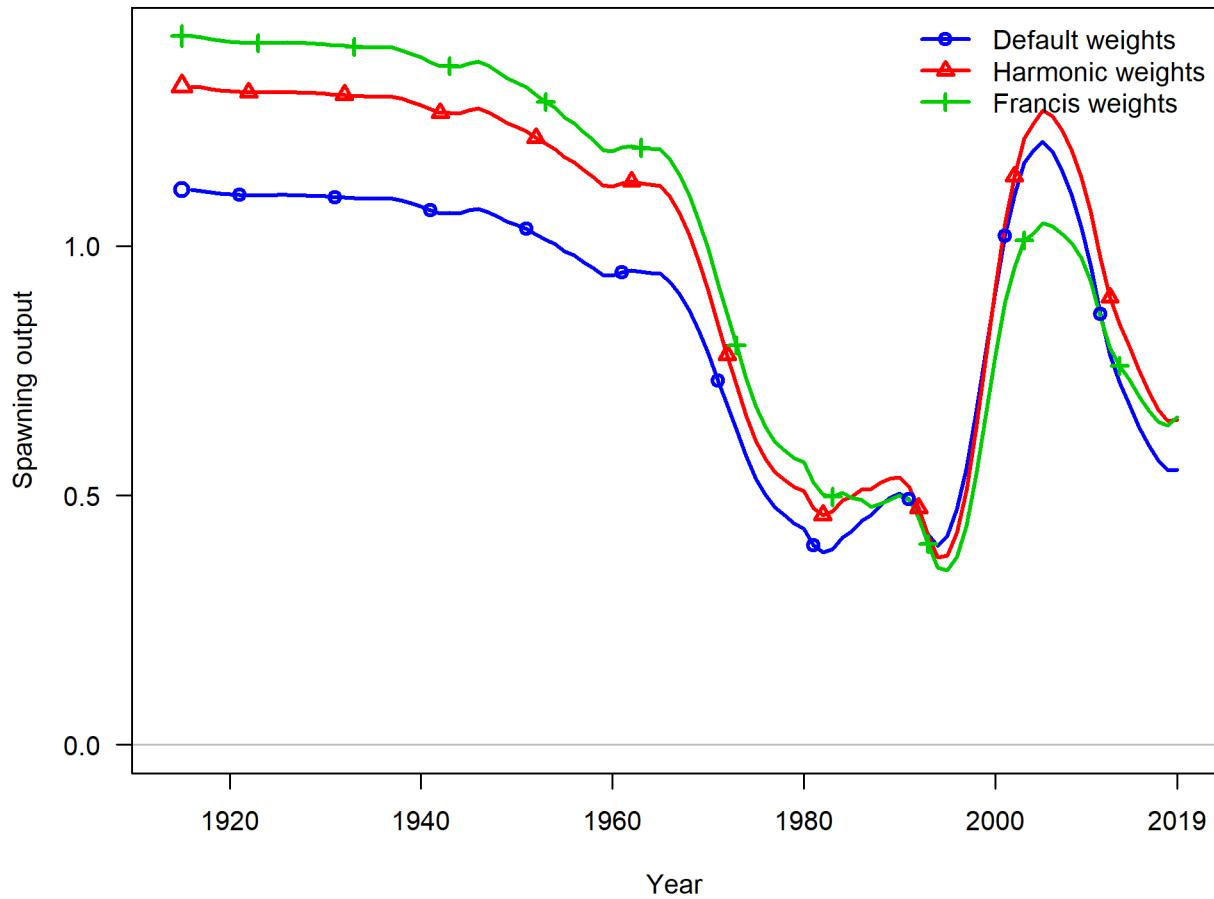


Figure 63: Sensitivity of the spawning biomass to either the default weight of composition data, the harmonic mean, or Francis weights. [fig:sensitivity2_spawnbio](#)

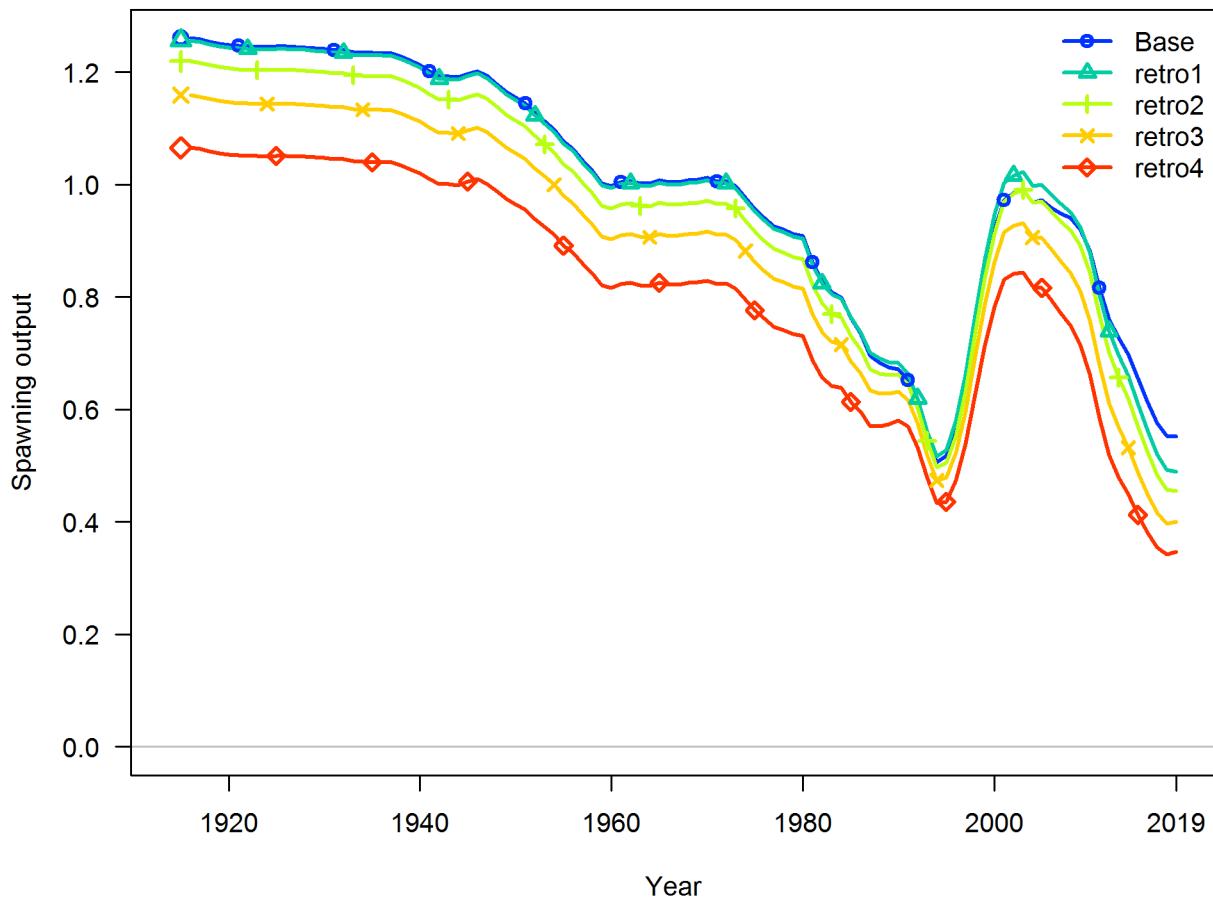


Figure 64: Retrospective pattern for spawning output. [fig:retro_spawnb](#)

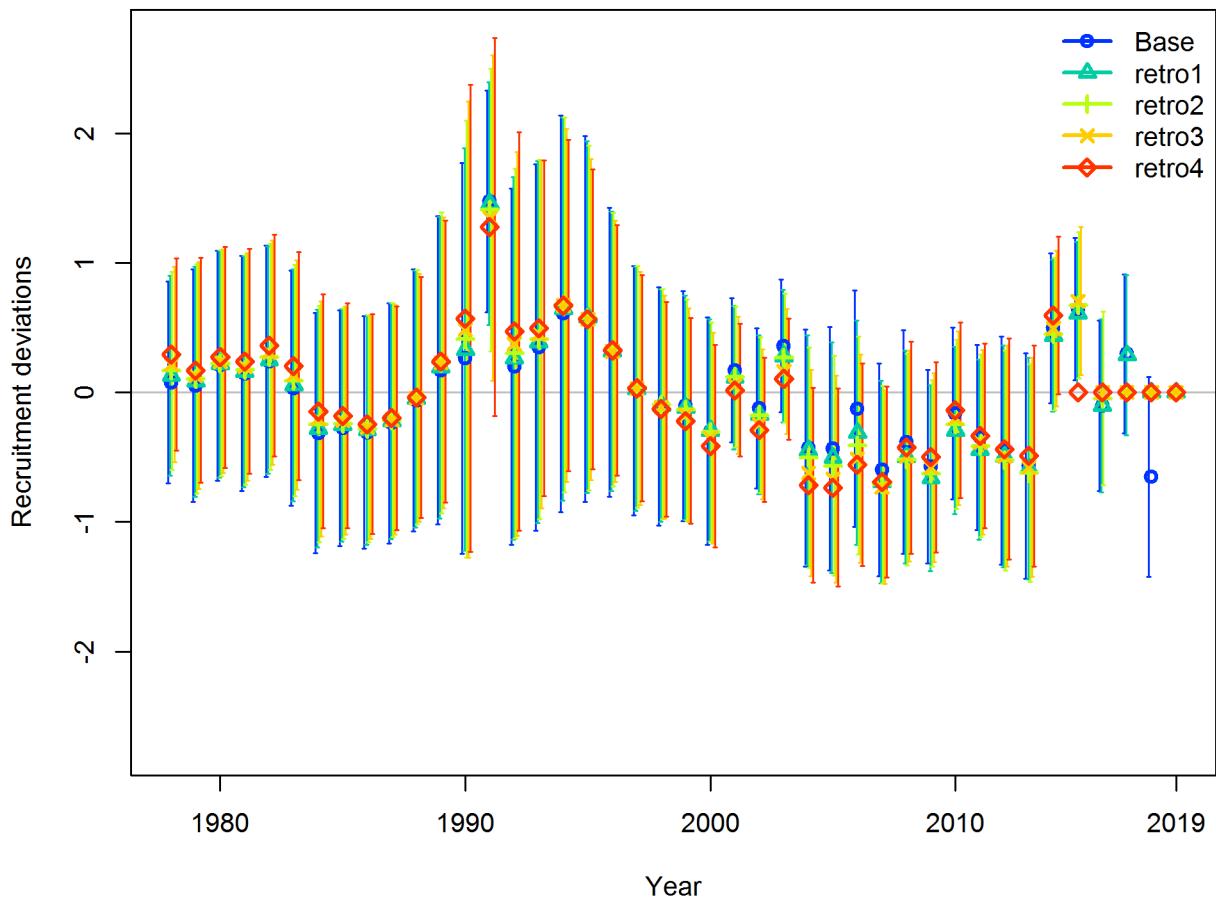


Figure 65: Retrospective pattern for estimated recruitment deviations. fig:retro_recdev

Changes in length-composition likelihoods by fleet

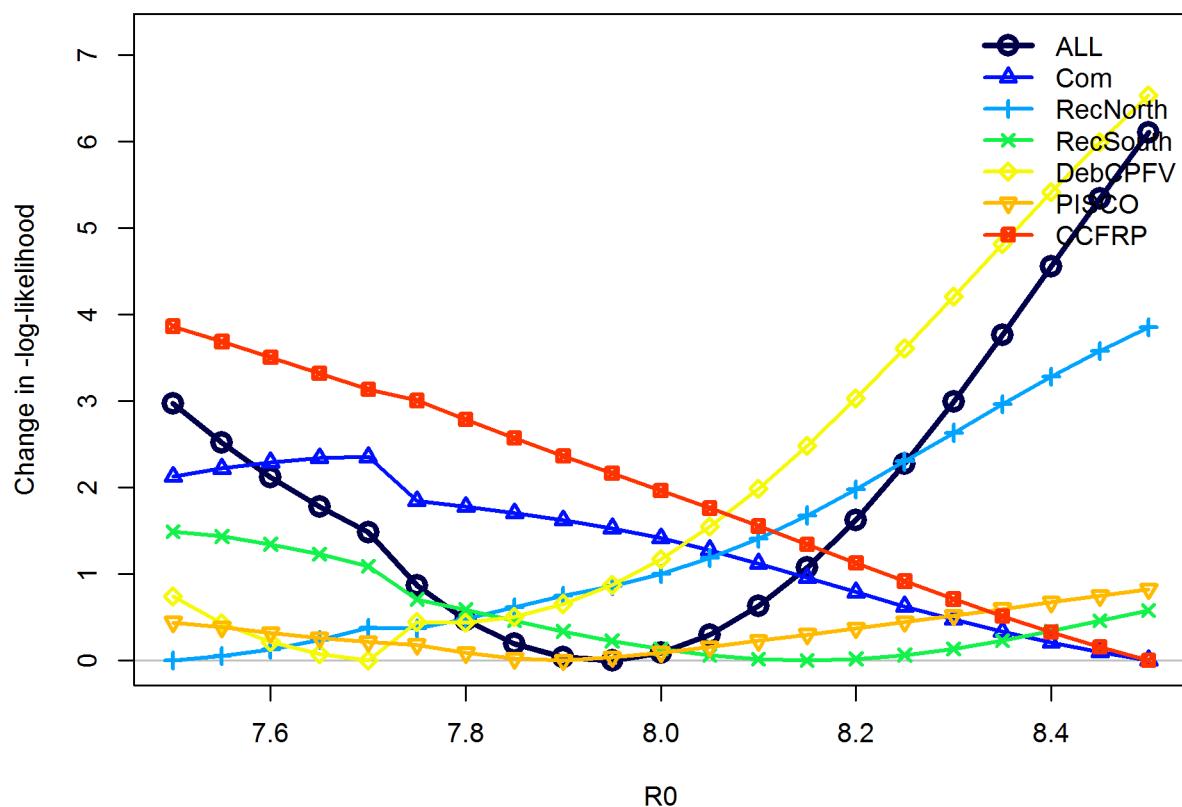


Figure 66: Likelihood profile across R_0 values of length composition by fleet. fig:profile_R0_pine

Changes in survey likelihoods

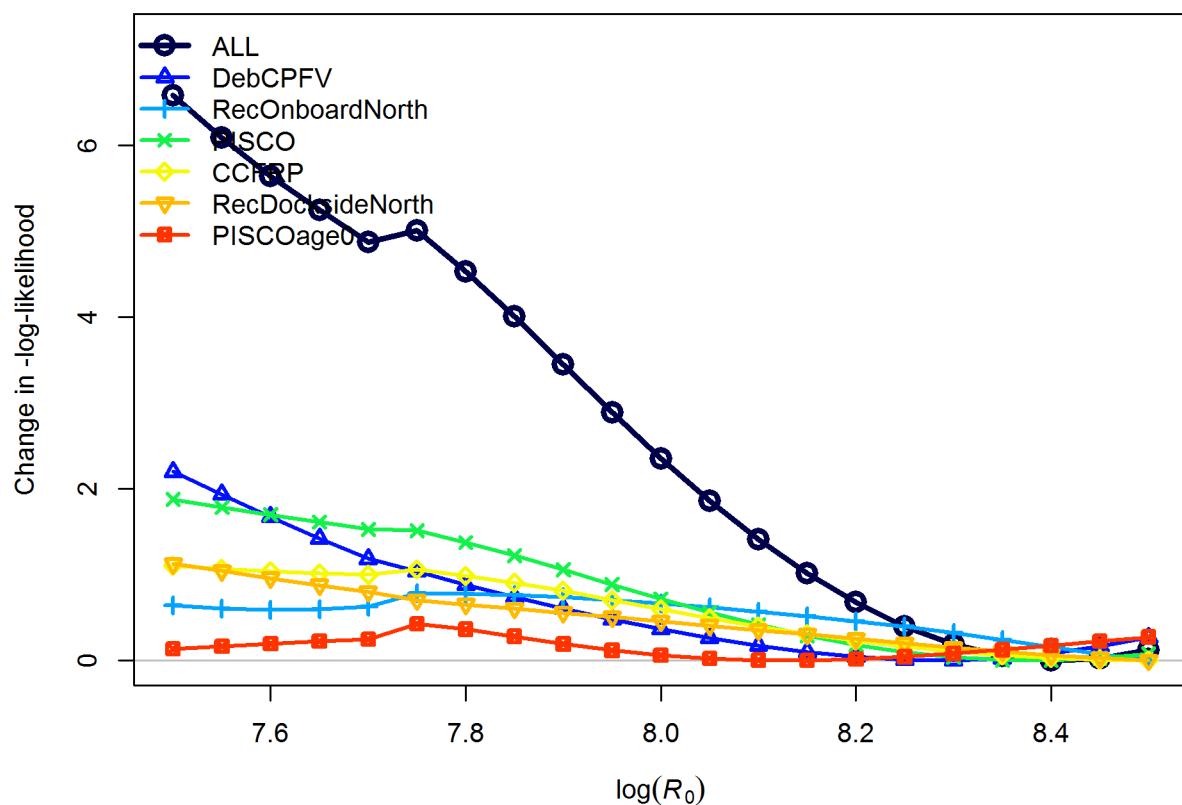


Figure 67: Likelihood profile for R_0 values across surveys. [fig:profile_R0_piner2](#)

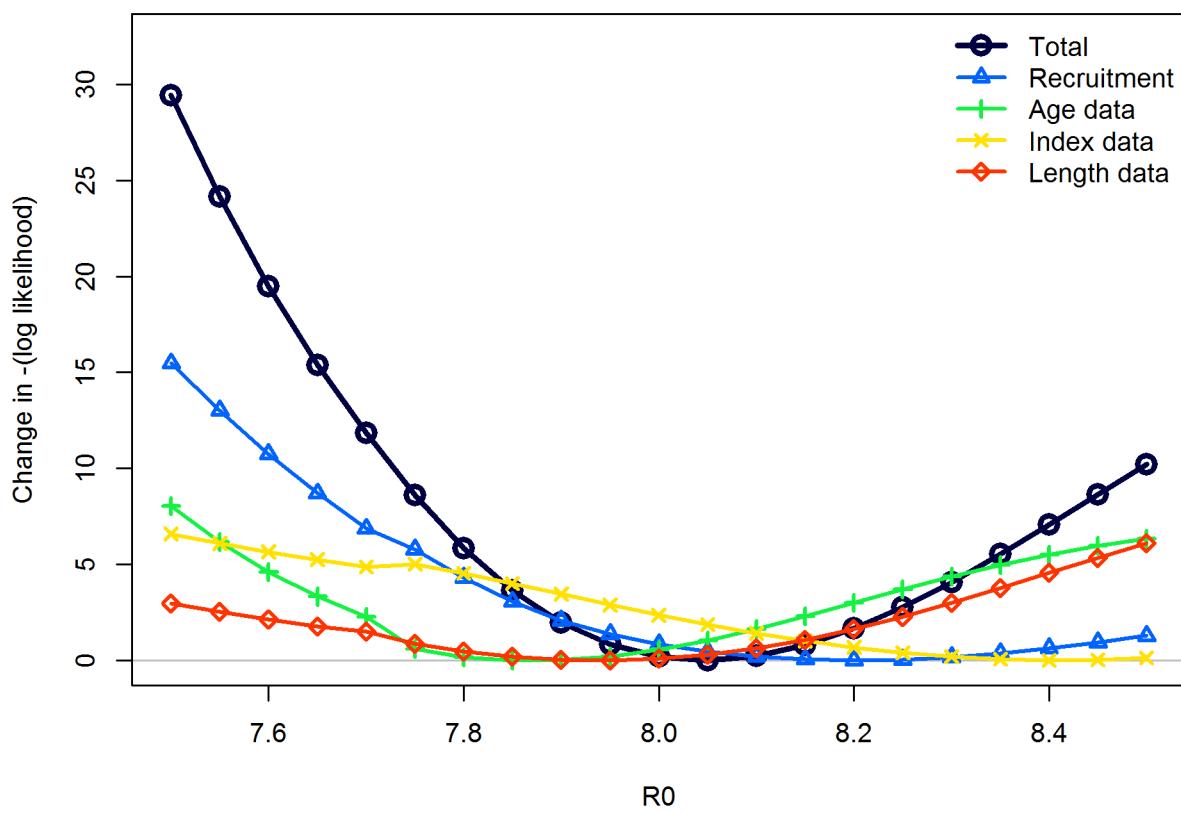


Figure 68: Likelihood profile across R_0 values for each data type. `fig:profile_R0_like`

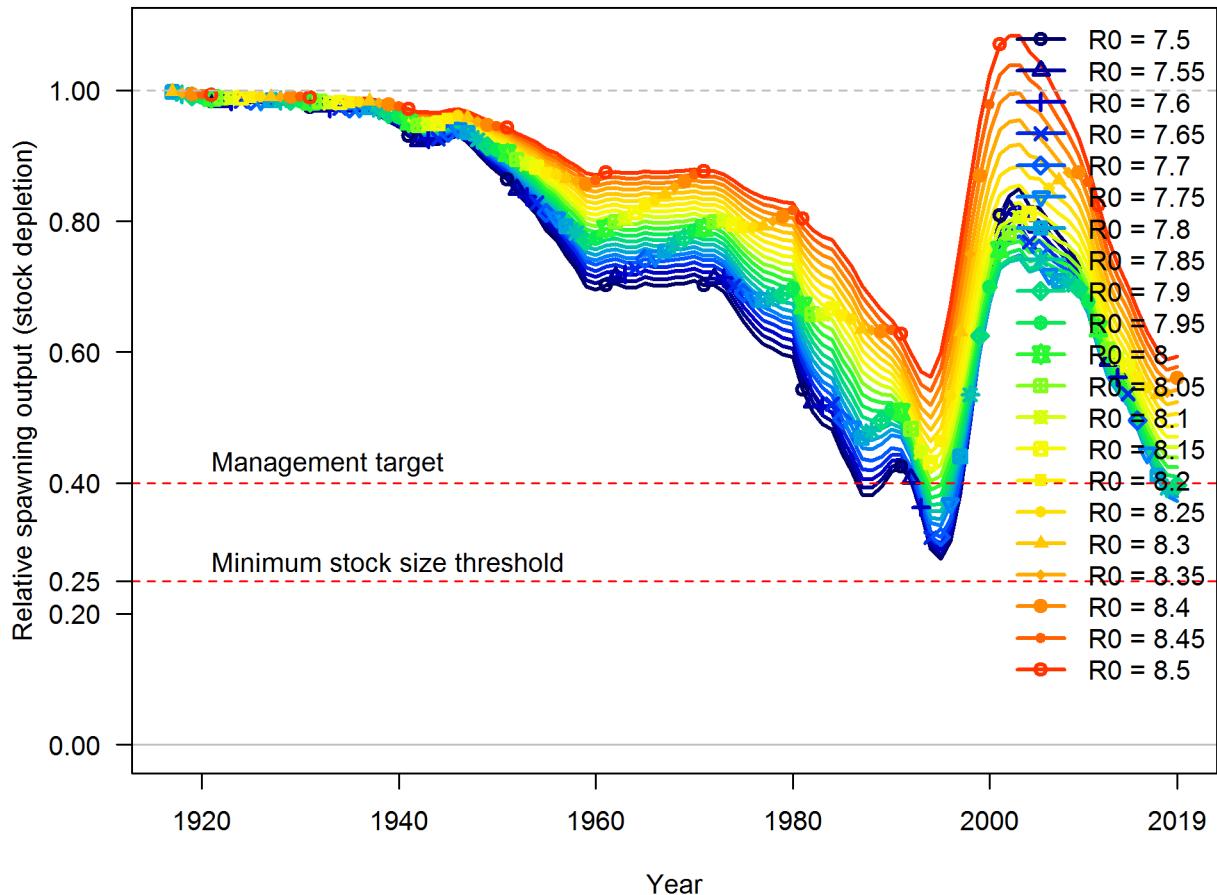


Figure 69: Trajectories of depletion across values of R_0 . [fig:profile_R0_depl](#)

Changes in length-composition likelihoods by fleet

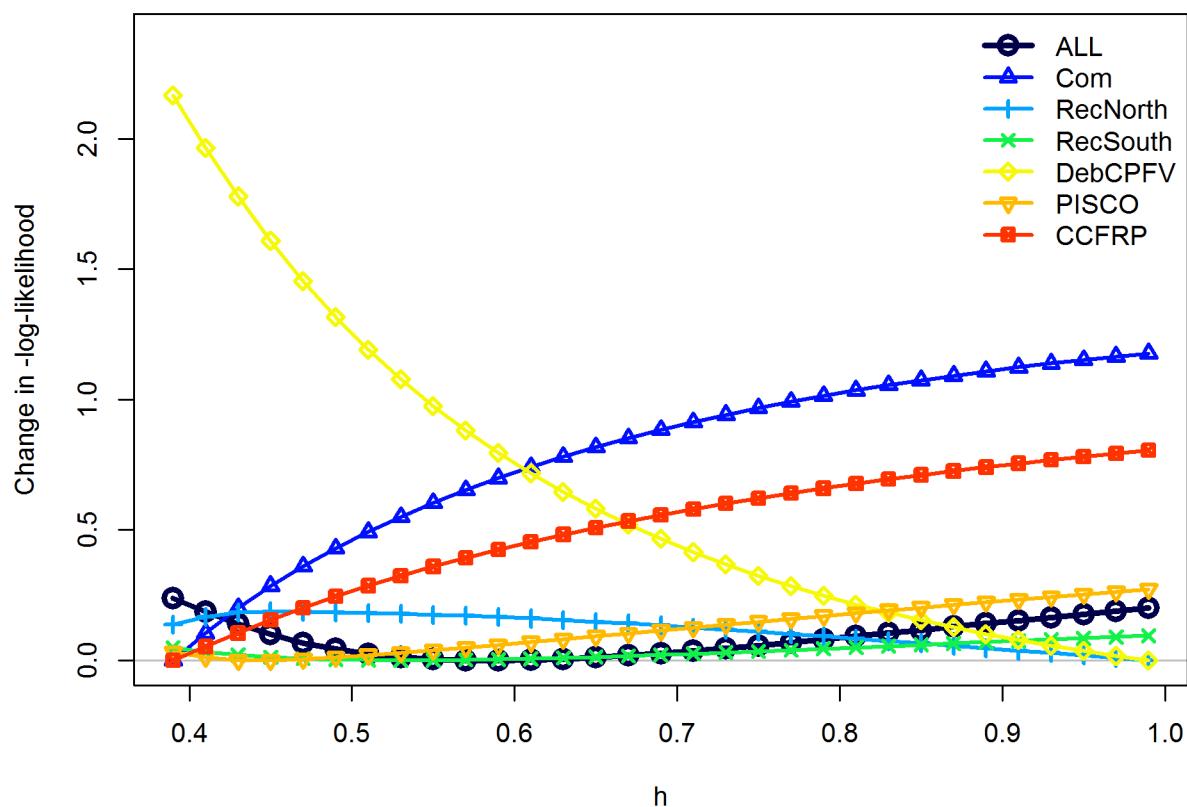


Figure 70: Likelihood profile across steepness values by fleet length composition. `fig:profile_h_pin`

Changes in survey likelihoods

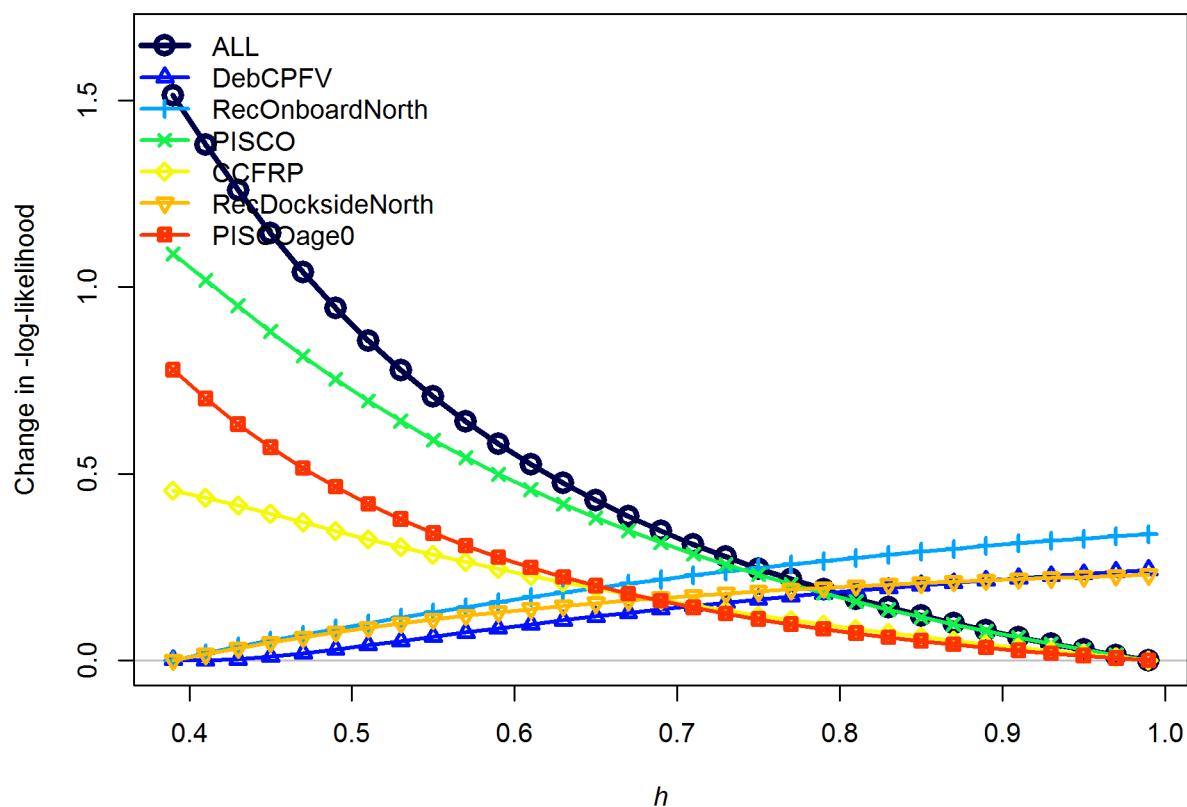


Figure 71: Likelihood profile across steepness values by surveys. [fig:profile_h_piner2](#)

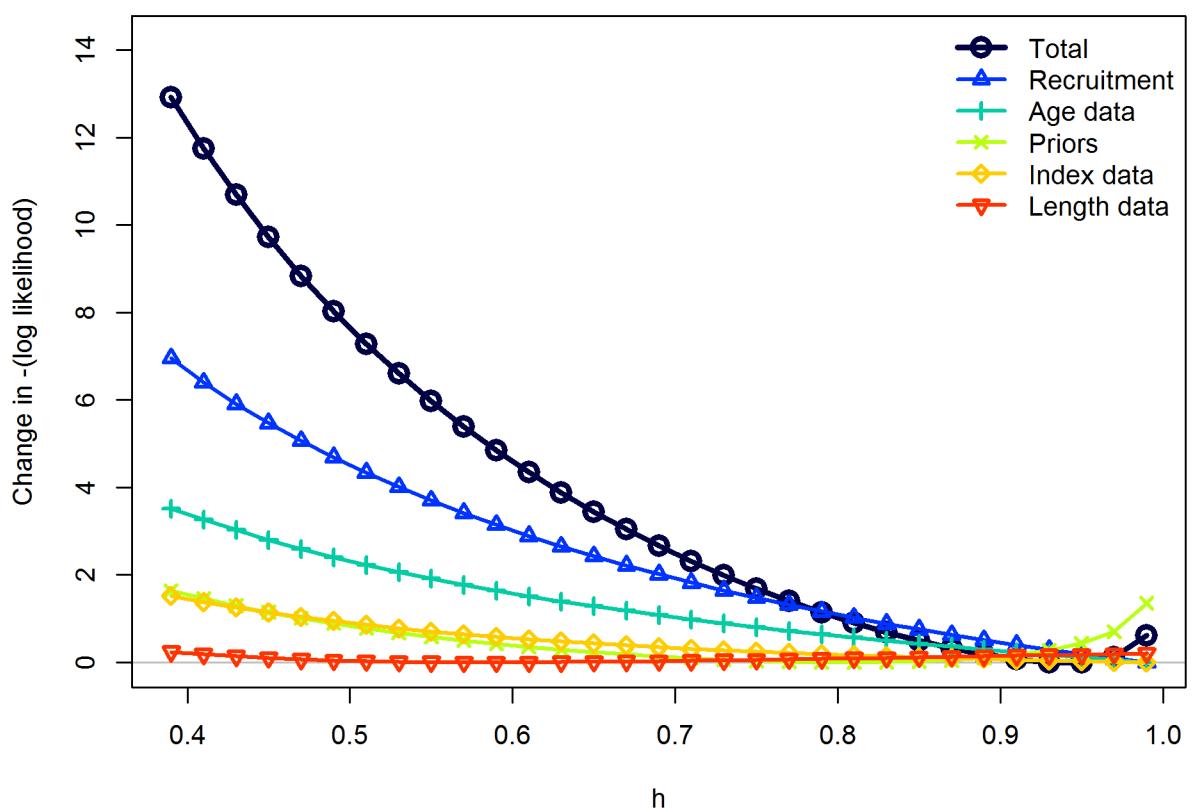


Figure 72: Likelihood profile across steepness values for each data type. [fig:profile_h_like](#)

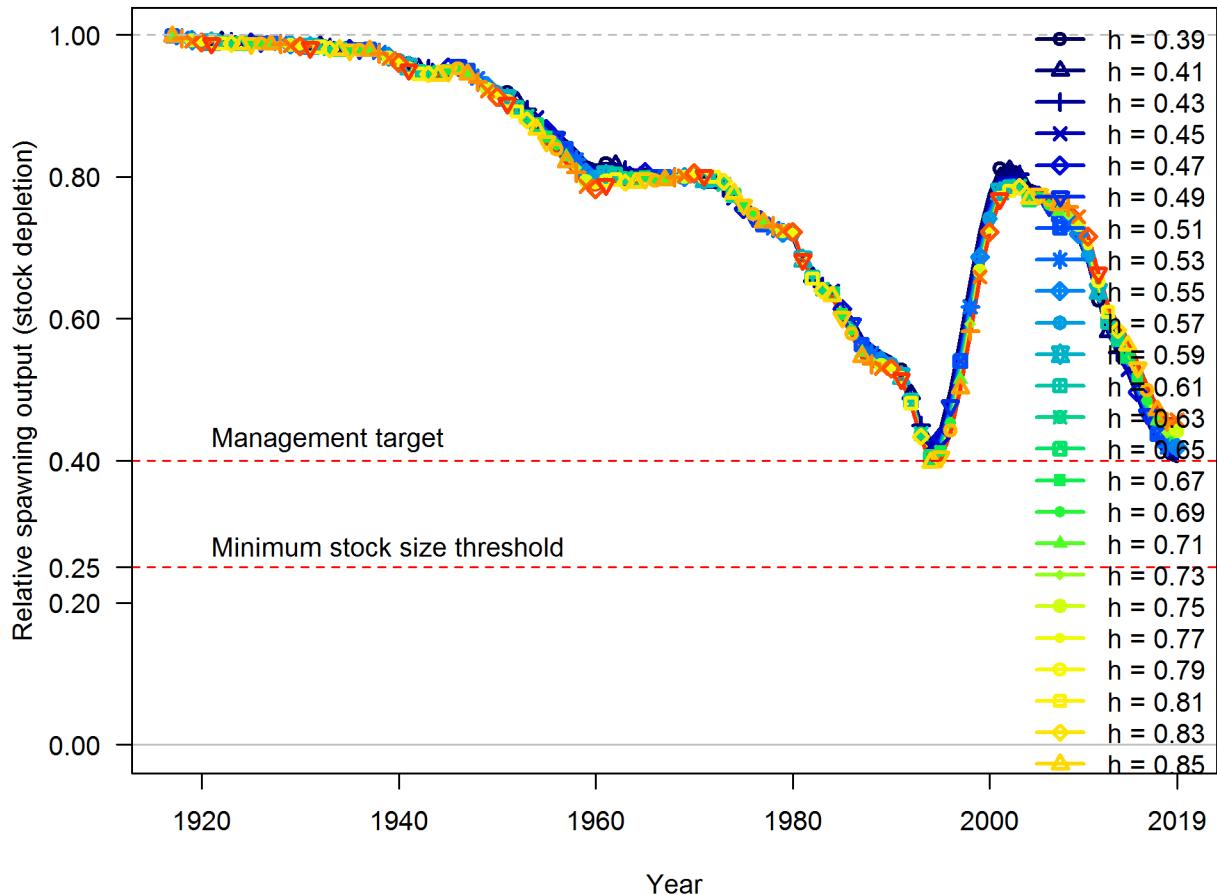


Figure 73: Trajectories of depletion across values of steepness. [fig:profile_h_depl](#)

Changes in length-composition likelihoods by fleet

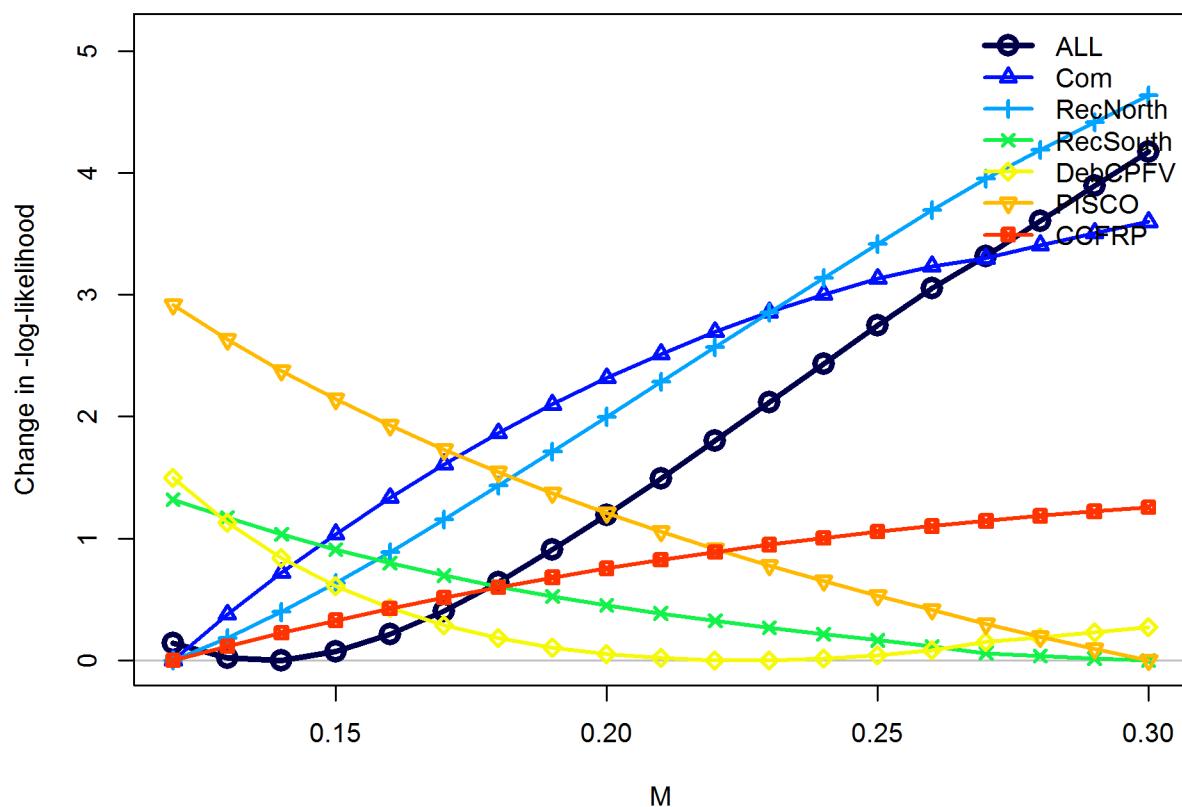


Figure 74: Likelihood profile across female natural mortality values by length composition. fig:profile_m

Changes in survey likelihoods

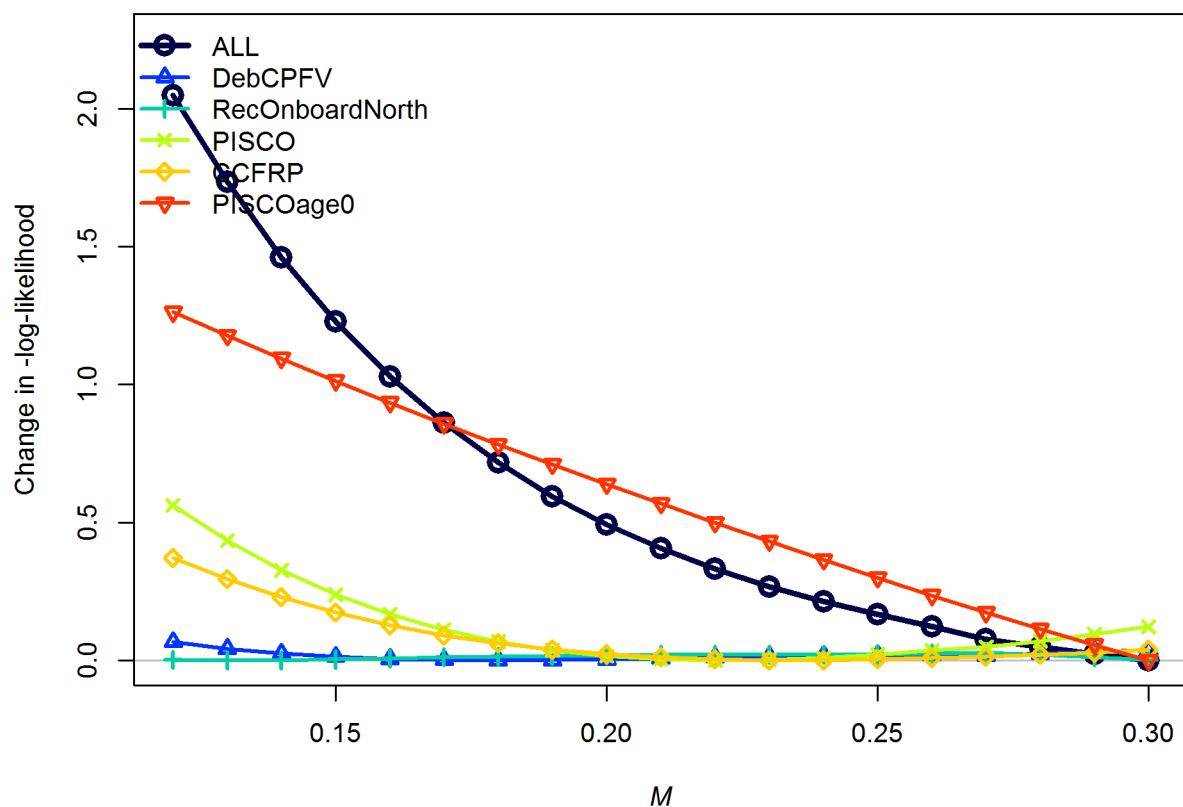


Figure 75: Likelihood profile across female natural mortality values by surveys. [fig:profile_m_pine](#)

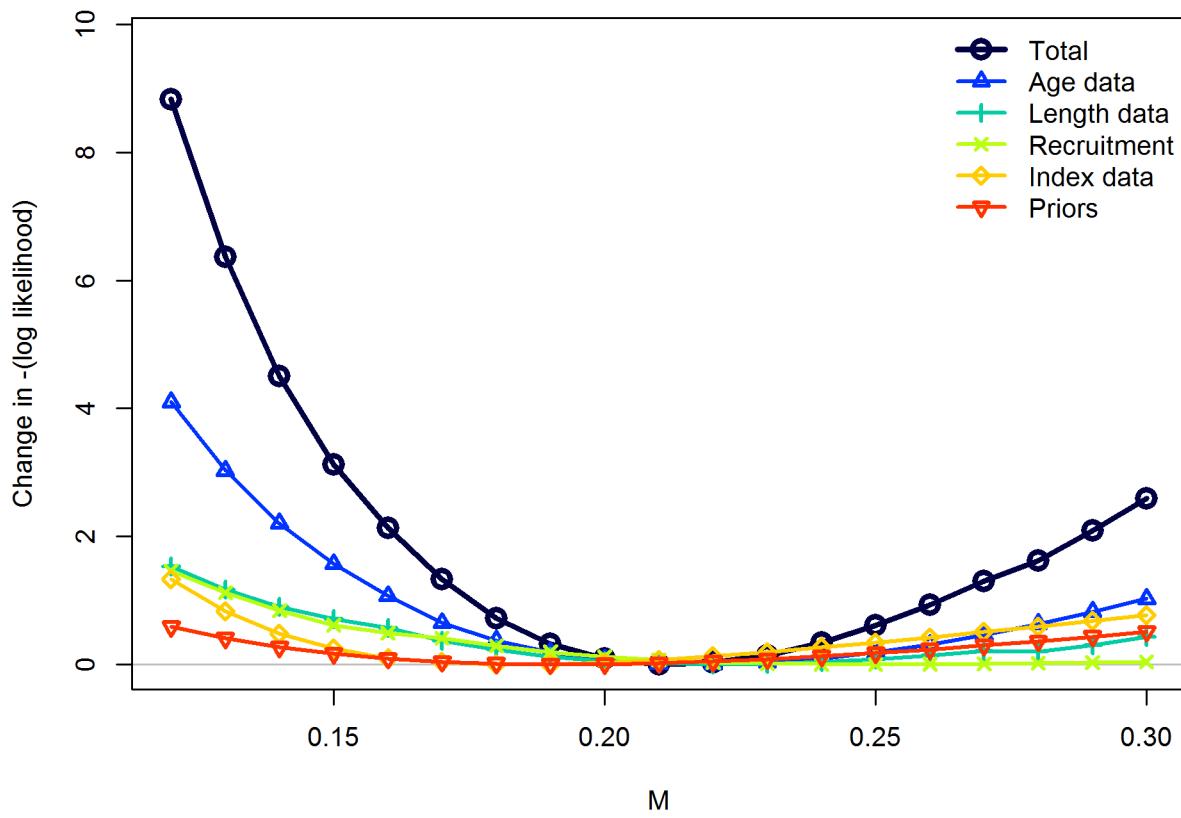


Figure 76: Likelihood profile across female natural mortality values for each data type. `fig:profile_m`

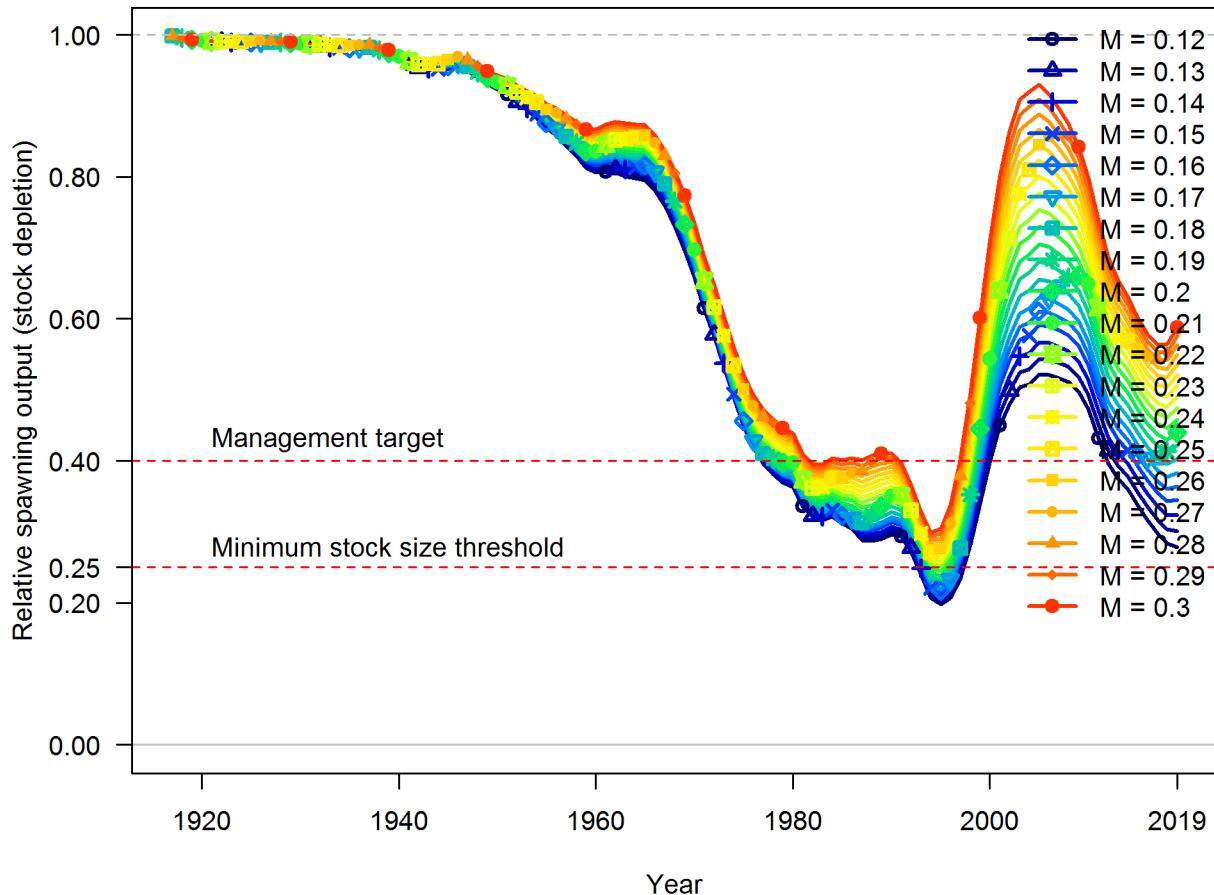


Figure 77: Trajectories of depletion across values of female natural mortality. `fig:profile_m_depl`

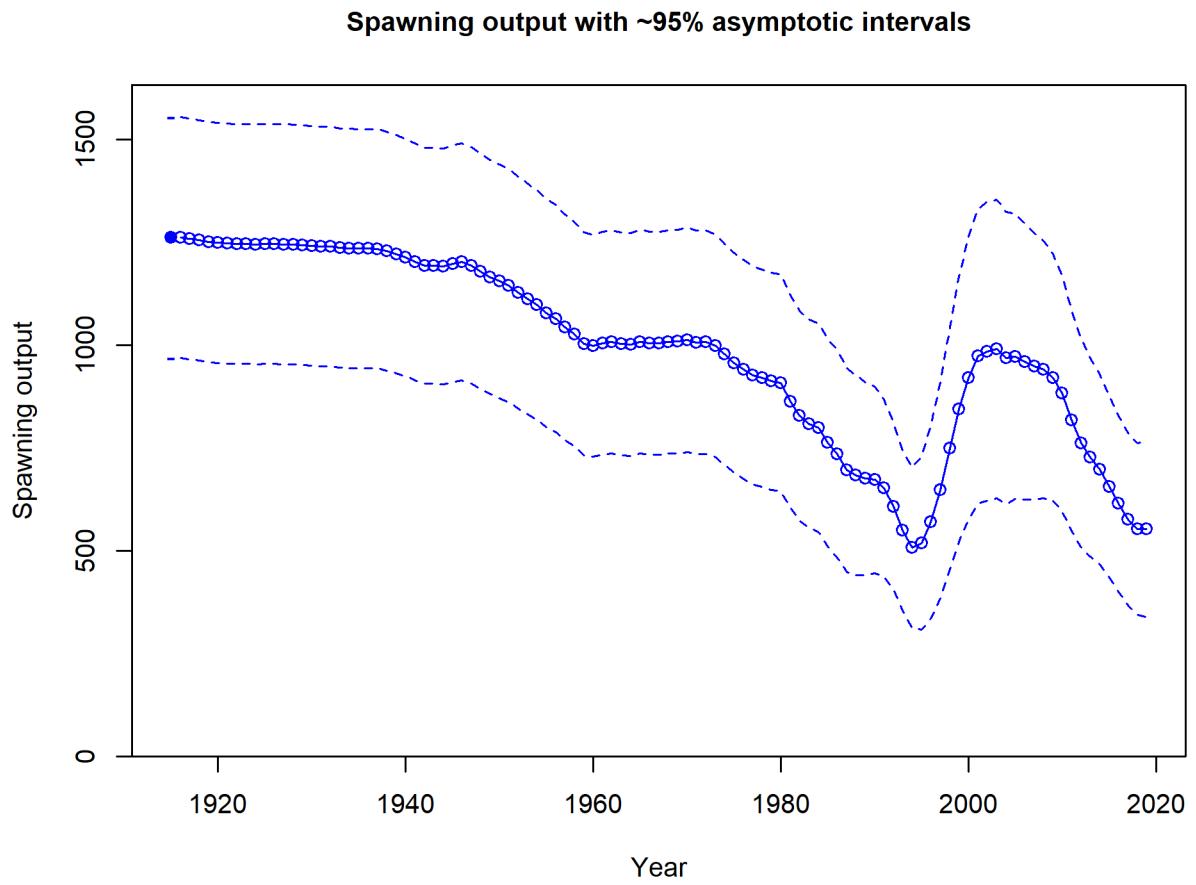


Figure 78: Estimated spawning output with approximate 95% asymptotic intervals. fig:ts7_Spawning

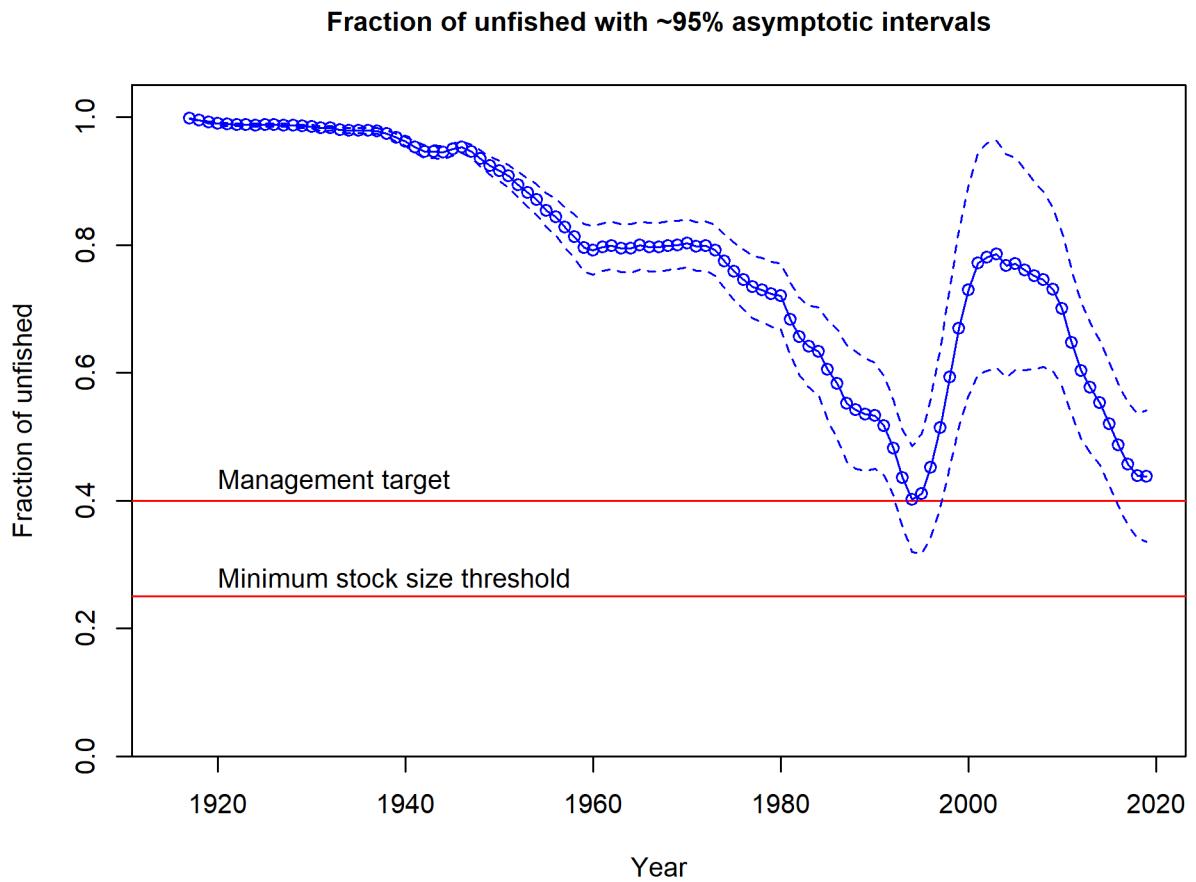


Figure 79: Estimated spawning depletion with approximate 95% asymptotic intervals. fig:ts9_unfisher

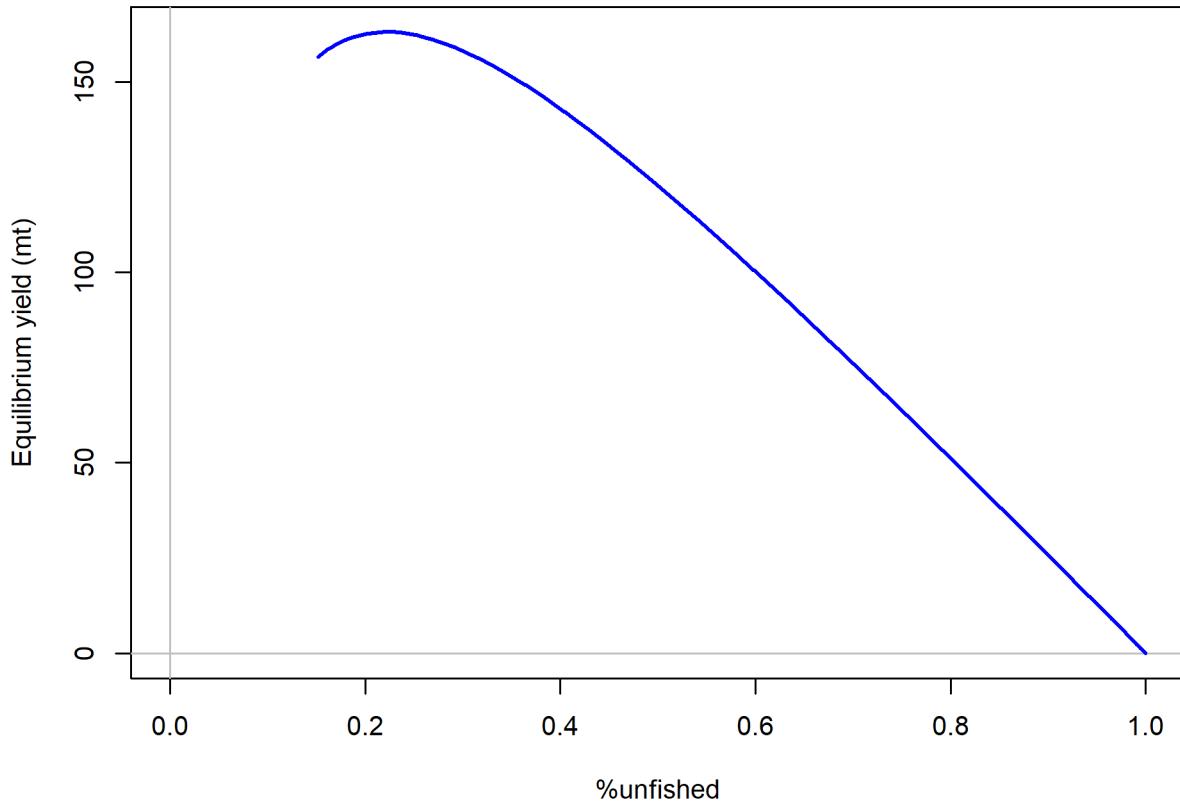


Figure 80: Equilibrium yield curve for the base case model. Values are based on the 2018 fishery selectivity and with steepness fixed at 0.718. | [fig:yield1_yield_curve](#)

¹⁷⁶⁴ **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		
		800 lbs/2 mths shoreward of 20 fm; otherwise closed	
2001 Jan	1800 lbs/2 mths		
2001 Mar	Closed	1800 lbs/2 mths	
		800 lbs/2 mths shoreward of 20 fm; otherwise closed	
2001 May			
2001 Jul	1800 lbs/2 mths	1800 lbs/2 mths	
2002 Jan	1200 lbs/2 mths	Closed	
2002 Mar	Closed	1200 lbs/2 mths	
		1200 lbs/2 mths shoreward of 20 fm; otherwise closed	
2002 May			
2002 Jul	1200 lbs/2 mths		
		1200 lbs/2 mths shoreward of 20 fm; otherwise closed	
2002 Sep			
2002 Nov	Closed	Closed	
2003 Jan			200 lbs/2 mths
2003 Mar			Closed
2003 May			400 lbs/2 mths
2003 Jul			400 lbs/2 mths
2003 Sep			300 lbs/2 mths
2003 Nov			200 lbs/2 mths
2004 Jan	300 lbs/2 mths	Closed	
2004 Mar	Closed	300 lbs/2 mths	
2004 May	500 lbs/2 mths	500 lbs/2 mths	
2004 Jul	600 lbs/2 mths	600 lbs/2 mths	
2004 Sep	500 lbs/2 mths	500 lbs/2 mths	
2004 Nov	300 lbs/2 mths	300 lbs/2 mths	
2005-2006 Jan			300 lbs/2 mths
2005-2006 Mar			Closed
2005-2006 May			500 lbs/2 mths
2005-2006 Jul			600 lbs/2 mths
2005-2006 Sep			500 lbs/2 mths
2005-2006 Nov			300 lbs/2 mths
2007-2008 Jan			600 lbs/2 mths
2007-2008 Mar			Closed
2007-2008 May			800 lbs/2 mths
2007-2008 Jul			900 lbs/2 mths
2007-2008 Sep			800 lbs/2 mths
2007-2008 Nov			600 lbs/2 mths
2009-2016 Jan			600 lbs/2 mths
2009-2016 Mar			Closed
2009-2016 May			800 lbs/2 mths
2009-2016 Jul			900 lbs/2 mths
2009-2016 Sep			800 lbs/2 mths
2009-2016 Nov			1000 lbs/2 mths
2017-2018 Jan			1200 lbs/2 mths
2017-2018 Mar			Closed
2017-2018 May			1200 lbs/2 mths
2017-2018 Jul			1200 lbs/2 mths
2017-2018 Sep			1200 lbs/2 mths
2017-2018 Nov			1200 lbs/2 mths

Figure A2^{fig:Comm_regs1}

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

Figure A3^{fig:Comm_regs2}

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

Figure A4^{fig:Comm_regs3}

¹⁷⁶⁶ **Appendix B. California's Recreational Fishery Regulations**

[appendix-b.-californias-recreational-fishery-regulations](#)

California's Recreational Fishing Regulations										
Year	Month	Northern	Mendocino	North-Central	San Francisco	South-Central	Central	South-Central	Southern	
2000	Jan	Open					Open		Closed	
2000	Feb	Open					Open		Closed	
2000	Mar	Open					Closed		Open	
2000	Apr	Open					Closed		Open	
2000	May	Open					Open		Open	
2000	Jun	Open					Open		Open	
2000	Jul	Open					Open		Open	
2000	Aug	Open					Open		Open	
2000	Sep	Open					Open		Open	
2000	Oct	Open					Open		Open	
2000	Nov	Open					Open		Open	
2000	Dec	Open					Open		Open	
2001	Jan	Open					Open		Closed	
2001	Feb	Open					Open		Closed	
2001	Mar	Open					Closed		Open	
2001	Apr	Open					Closed		Open	
2001	May	Open					20		Open	
2001	Jun	Open					20		Open	
2001	Jul	Open					Open		Open	
2001	Aug	Open					Open		Open	
2001	Sep	Open					Open		Open	
2001	Oct	Open					Open		Open	
2001	Nov	Open					20		Open	
2001	Dec	Open					20		20	
2002	Jan	Open					Open		Closed	
2002	Feb	Open					Open		Closed	
2002	Mar	Open					Closed		Open	
2002	Apr	Open					Closed		Open	
2002	May	Open					20		Open	
2002	Jun	Open					20		Open	
2002	Jul	Open					20		20	
2002	Aug	Open					20		20	
2002	Sep	Open					20		20	
2002	Oct	Open					20		20	
2002	Nov	Open					Closed		Closed	
2002	Dec	Open					Closed		Closed	
2003	Jan	Open					Closed		Closed	
2003	Feb	Open					Closed		Closed	
2003	Mar	Open					Closed		Closed	
2003	Apr	Open					Closed		Closed	
2003	May	Open					Closed		Closed	
2003	Jun	Open					Closed		Closed	
2003	Jul	Open					20		20	
2003	Aug	Open					20		20	
2003	Sep	Open					20		30	
2003	Oct	Open					20		30	
2003	Nov	Open					20		30	
2003	Dec	Open->Closed					20->Closed		30->Closed	
2004	Jan	Open					30		Closed	
2004	Feb	Open					30		Closed	
2004	Mar	Open					Closed		60	
2004	Apr	Open					Closed		60	
2004	May	30					20		60	
2004	Jun	30					20		60	
2004	Jul	30					Closed		60	
2004	Aug	30					20		60	
2004	Sep	30					20		30	
2004	Oct	30					20		30	
2004	Nov	30					20		60	
2004	Dec	30					20		60	

Figure B2^{fig:Rec_regs1}

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

Figure B3
fig:Rec_regs2

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

Figure B4^{fig:Rec_regs3}

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

Figure B5^{fig:Rec_reg4}

1768 **Appendix C. Detailed fits to length composition data**

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

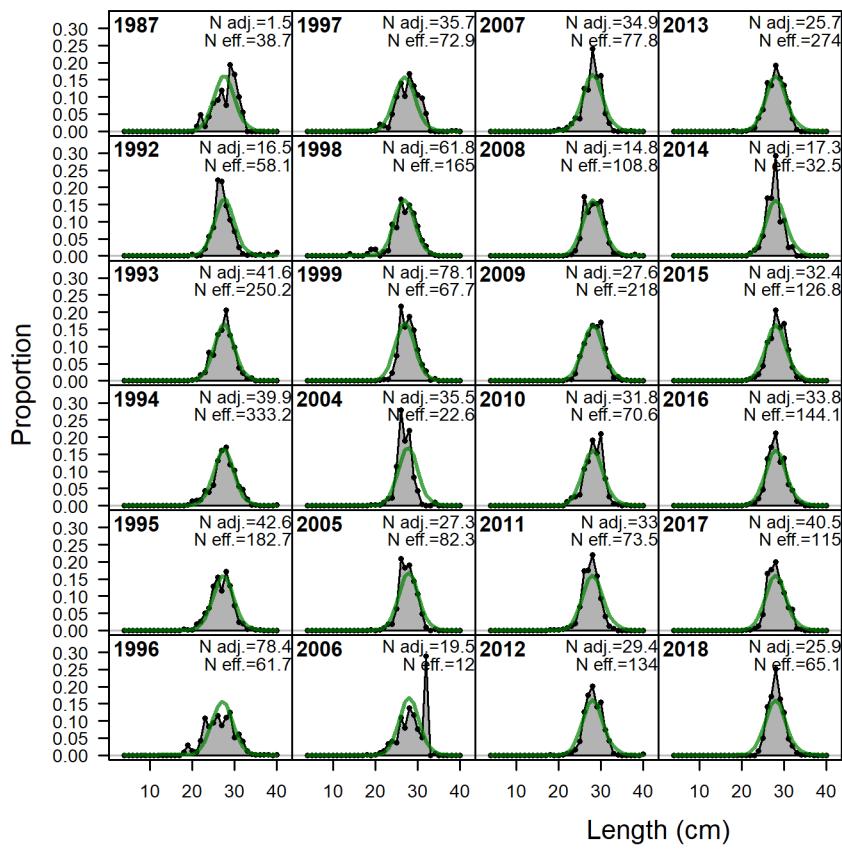


Figure C2: Length comps, retained, Com. ‘N adj.’ is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAlister_Iannelli tuning method. [fig:mod1_1_comp_1enfit_fltimkt2](#)

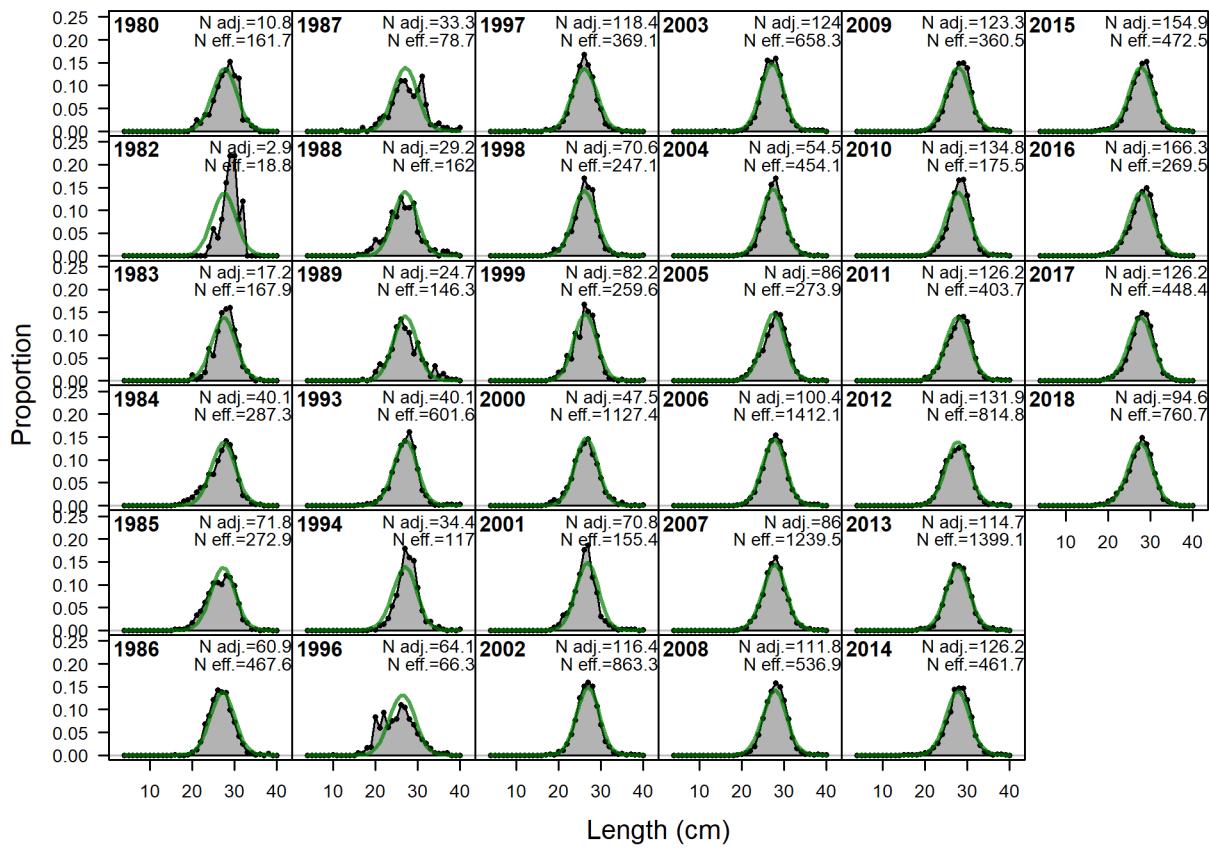


Figure C3: Length comps, whole catch, RecNorth. ‘N adj.’ is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. | [fig:mod1_2_comp_lenfit_flt2mkto](#)

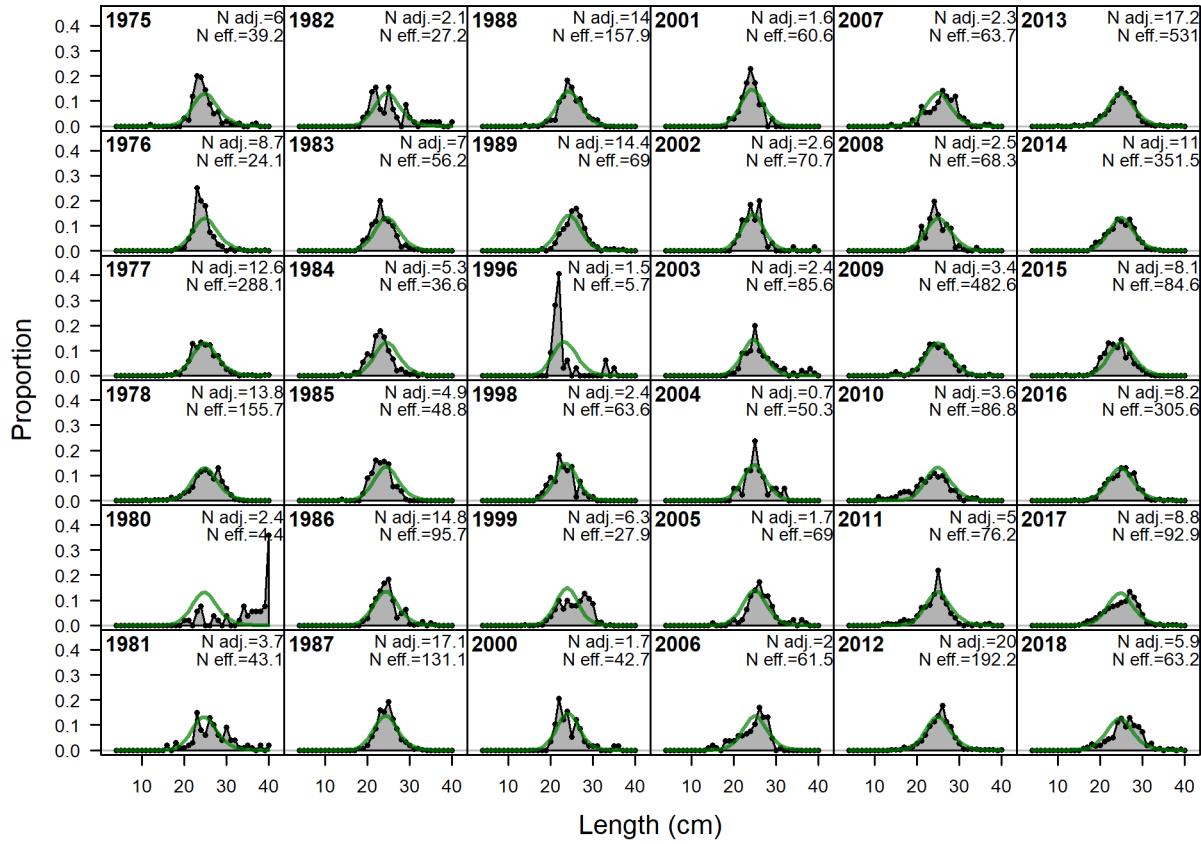


Figure C4: Length comps, whole catch, RecSouth. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. | [fig:mod1_3_comp_lenfit_flt3mkto](#)

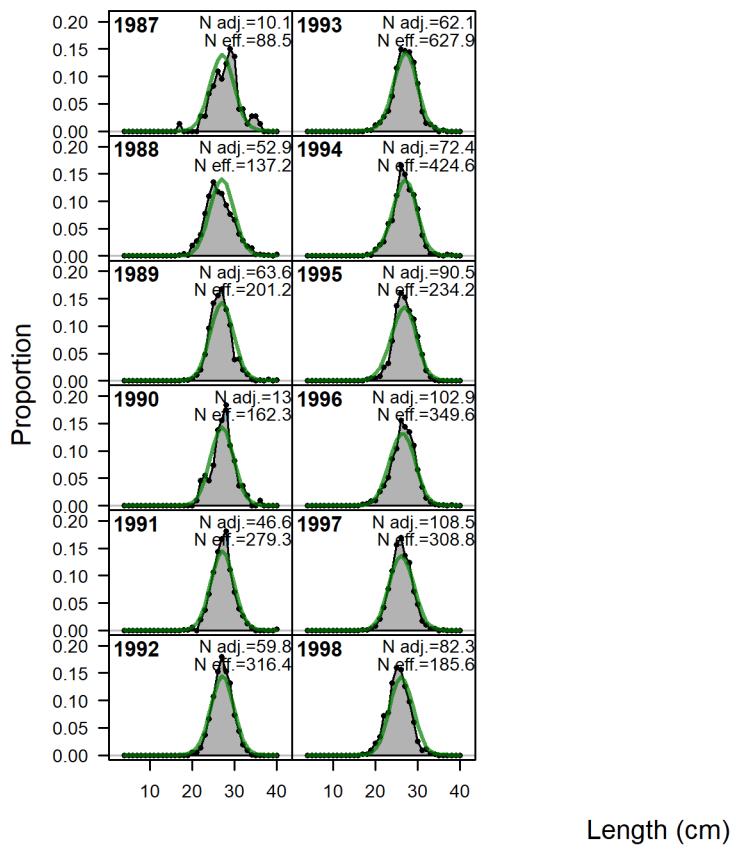


Figure C5: Length comps, whole catch, DebCPFV. 'N adj.' is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAllister_Iannelli tuning method. | [fig:mod1_4_comp_lenfit_flt4mkt0](#)

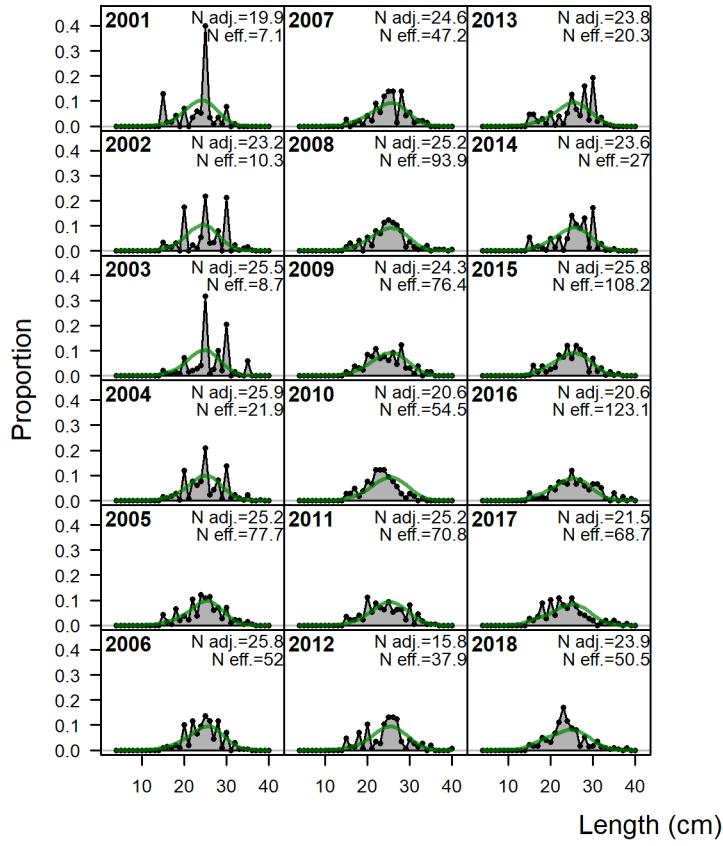


Figure C6: Length comps, whole catch, PISCO. ‘N adj.’ is the input sample size after data_weighting adjustment. N eff. is the calculated effective sample size used in the McAlister_Iannelli tuning method. [fig:mod1_5_comp_1enfit_flt6mkto](#)

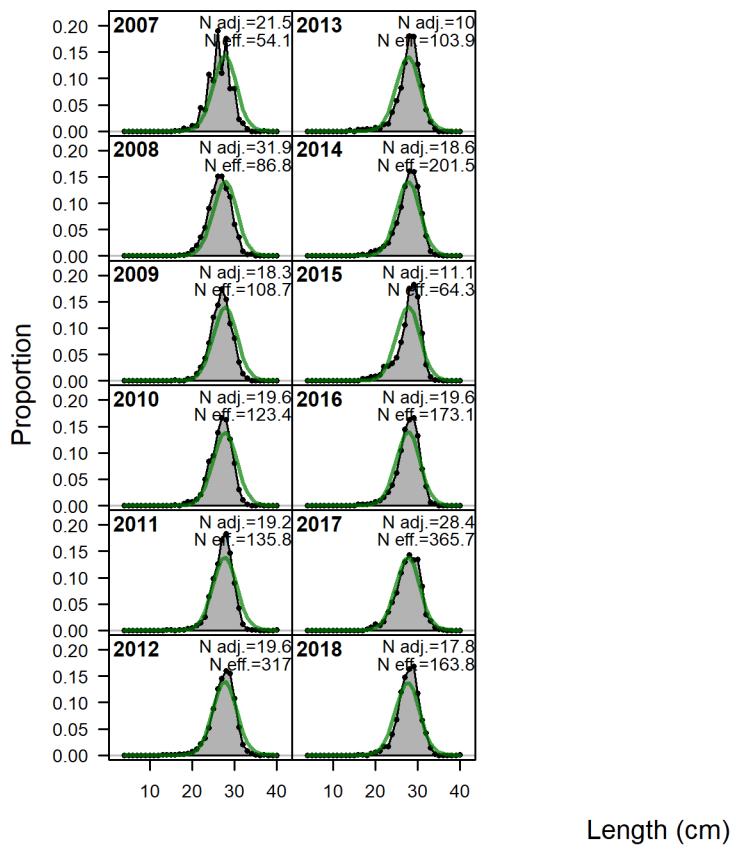


Figure C7: Length comps, whole catch, CCFRP. ‘N adj.’ is the input sample size after data_weighting adjustment. N_eff. is the calculated effective sample size used in the McAlister_Iannelli tuning method. [fig:mod1_6_comp_1enfit_flt7mkt0](#)

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