

¹ Status of California Scorpionfish (*Scorpaena guttata*) Off Southern California in 2017



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DRAFT Pre-STAR

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- ¹⁸ *guttata*) Off Southern California in 2017.. Pacific Fishery Management Council, Portland, OR.
- ¹⁹ Available from <http://www.pfcouncil.org/groundfish/stock-assessments/>

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⁸⁶ **Executive Summary**

⁸⁷ **Stock**

⁸⁸ This assessment reports the status of the California scorpionfish (*Scorpaena guttata*) resource
⁸⁹ in U.S. waters off the coast of southern California (south of Pt. Conception) using data
⁹⁰ through 2016. California scorpionfish are most abundant in the southern California Bight
⁹¹ and their range extends to Punta Eugena, Mexico, about halfway down the Baja peninsula.
⁹² Catches from Mexico were not included in this assessment, and catches from Mexican waters
⁹³ that were landed in the U.S. were excluded from the catch histories.

⁹⁴ **Catches**

⁹⁵ Information on historical landings of California scorpionfish are available back to 1916, with
⁹⁶ the assumption that from 1916 to 1968 all of the commercial landings were caught by hook-
⁹⁷ and-line (Table [a](#)). Commercial landings were small during the years of World War II, ranging
⁹⁸ between 16 to 63 metric tons (mt) per year. The recreational fleets began ramping up in the
⁹⁹ 1960s and have dominated the catch since then (Figures [a-c](#)). The party/charter fleet has
¹⁰⁰ been the major component of the recreational sector since the early 2000s.

¹⁰¹ The catches from the commercial fleets has been small in the last decade, range from 1.19 to
¹⁰² 4.54 mt per year (Figure [d](#)). Since 2000, annual total landings of California scorpionfish have
¹⁰³ ranged between 57-199 mt, with landings in 2016 totaling 74 mt.

¹⁰⁴ California scorpionfish is not a major component of the commercial or recreational fisheries
¹⁰⁵ in southern California. There has been little discarding of the species in the commercial
¹⁰⁶ fisheries and the discard mortality rate for the recreational fisheries is estimated to be 7%.
¹⁰⁷ The peak in discards from 2001-2005 was due to the closure of California scorpionfish fishery
¹⁰⁸ between two and ten months of the year during that period.

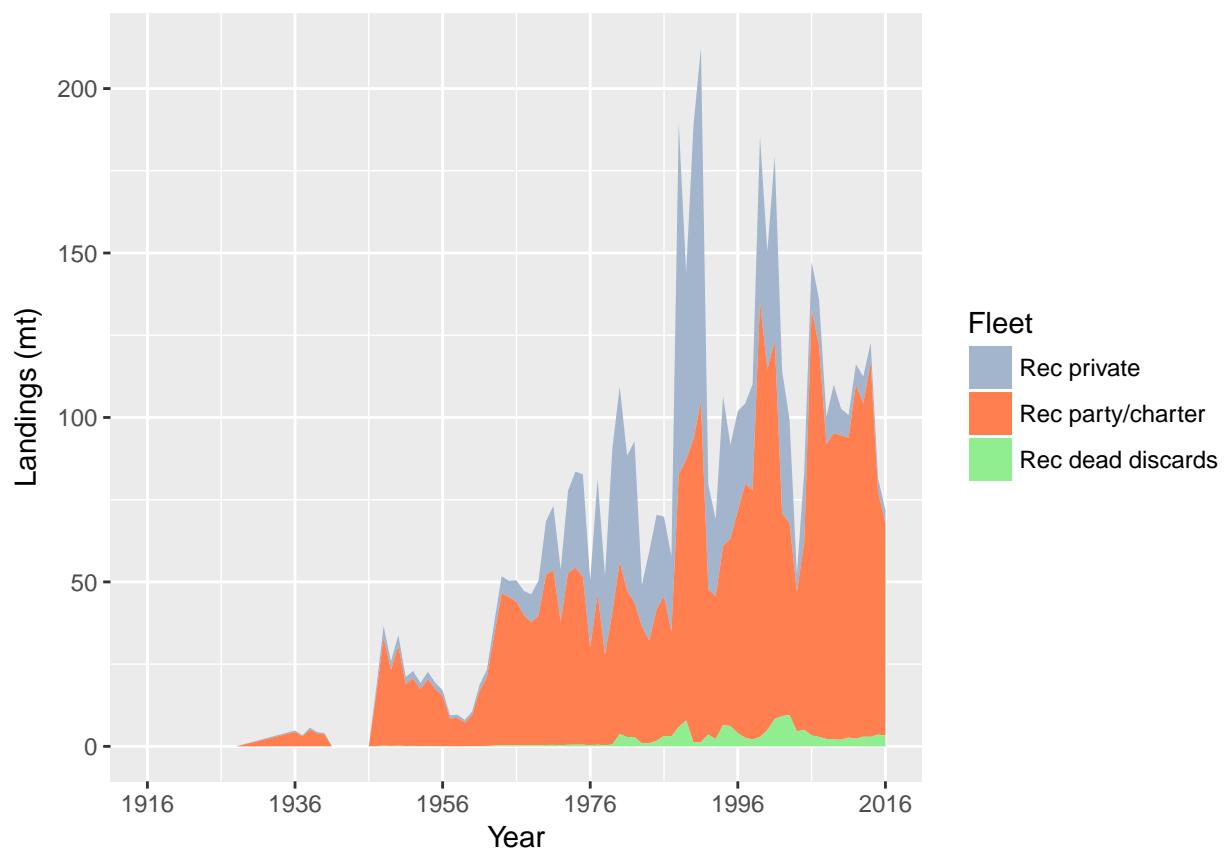


Figure a: California scorpionfish catch history for the recreational fleets.

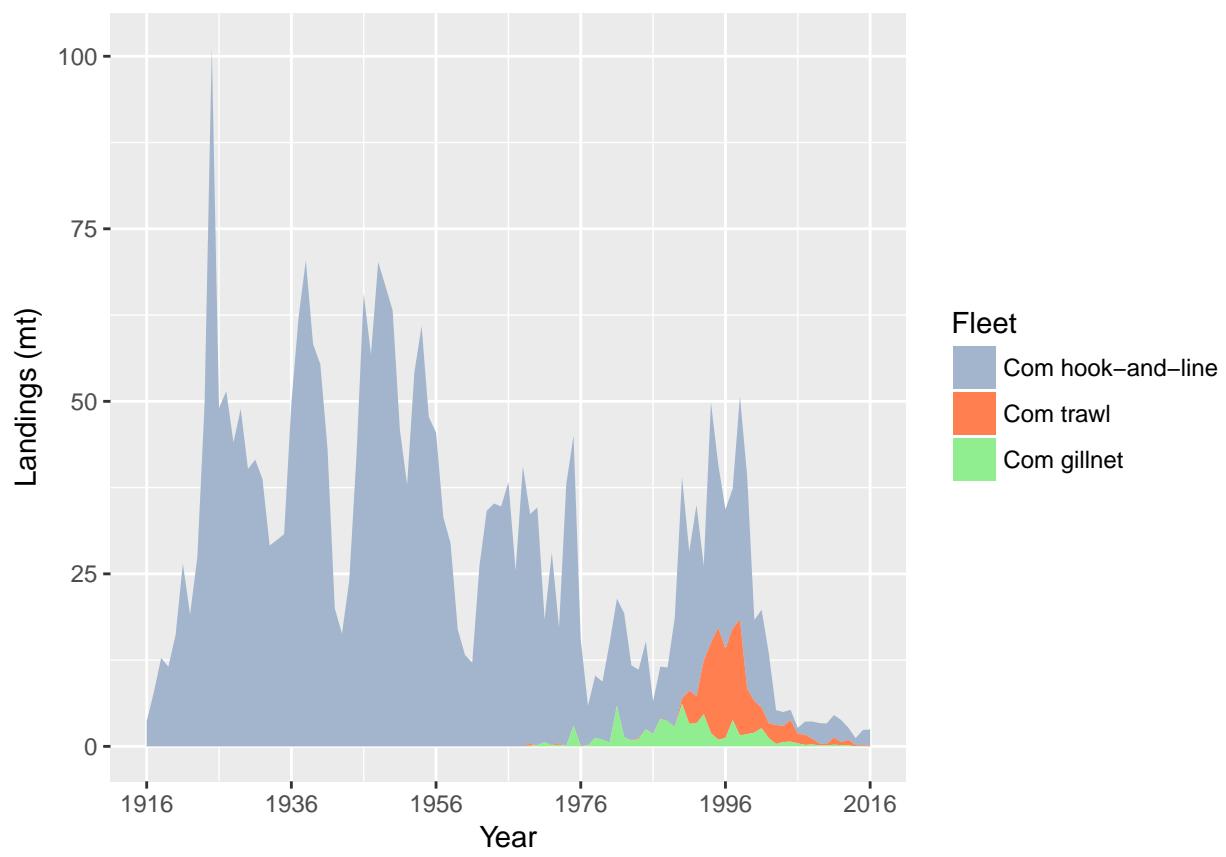


Figure b: Stacked line plot of California scorpionfish catch history for the commercial fleets.

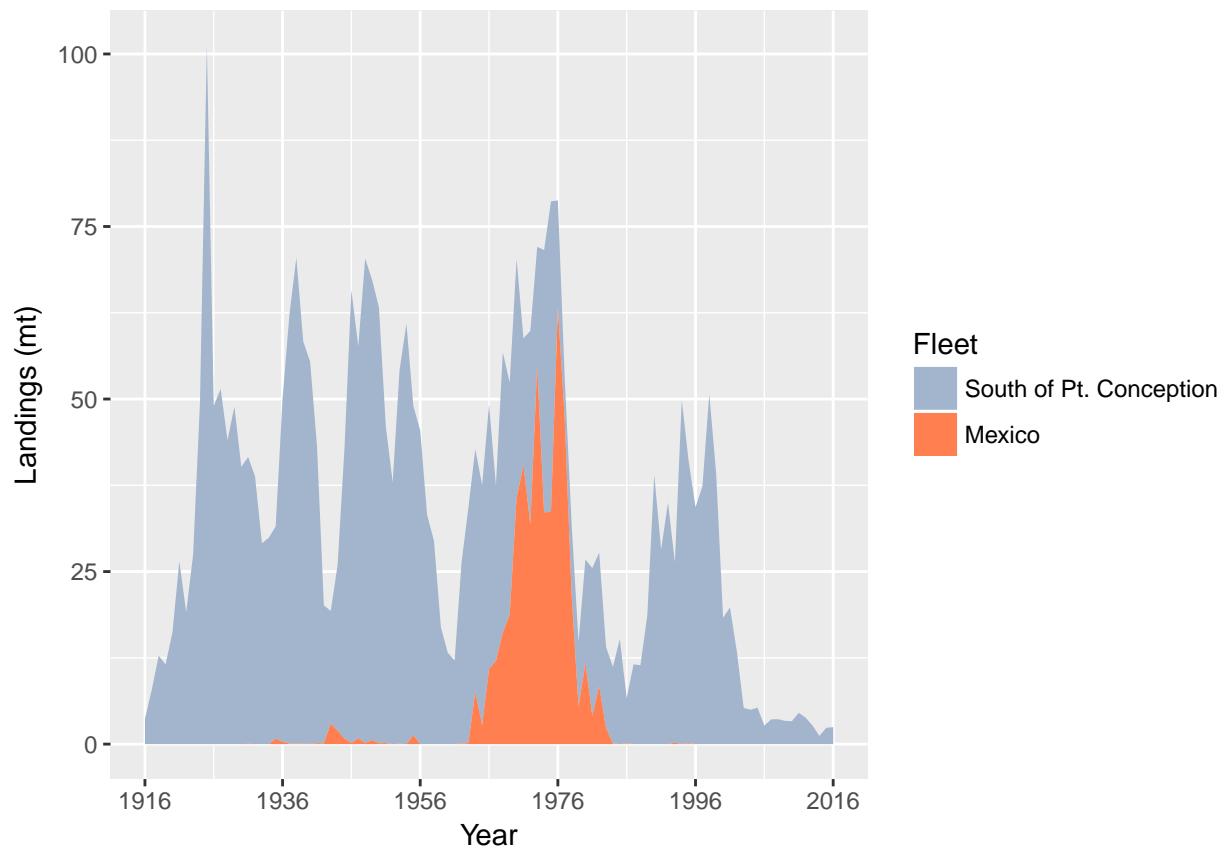


Figure c: Stacked line plot of California scorpionfish catch history from Pt. Conception to the U.S.-Mexico border and catches from Mexican waters.

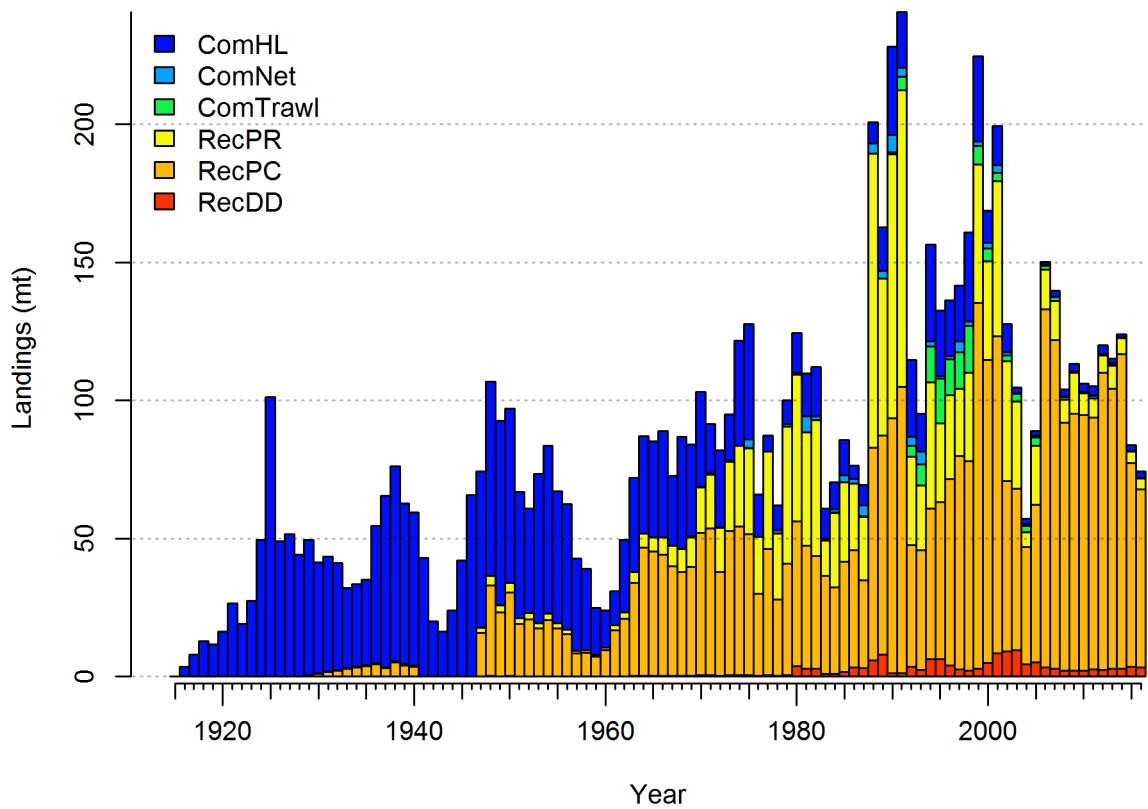


Figure d: Catch history of California scorpionfish in the base model.

Table a: Recent California scorpionfish landings (mt) by recreational (Rec.) and commercial (Com.) fleets.

Year	Rec. Private	Rec. Party/Charter	Rec. Dead Discards	Com. Hook-and-line	Com. Trawl	Com. Gillnet	Total
2007	14.24	118.87	2.89	1.90	1.48	0.21	139.58
2008	8.38	89.65	2.25	2.46	0.86	0.28	103.89
2009	14.68	93.16	2.09	2.97	0.27	0.13	113.31
2010	8.07	92.55	2.03	2.99	0.18	0.14	105.97
2011	6.84	91.18	2.66	3.24	1.05	0.24	105.21
2012	6.22	107.63	2.34	3.22	0.43	0.18	120.00
2013	8.18	101.31	2.94	1.73	0.83	0.14	115.14
2014	5.88	113.83	2.93	1.03	0.13	0.04	123.82
2015	4.15	73.78	3.59	2.21	0.13	0.03	83.89
2016	3.86	64.56	3.29	2.32	0.13	0.00	74.16

109 Data and Assessment

110 This a new full assessment for California scorpionfish, which was last assessed in 2005
 111 (Maunder et al. 2005) using Stock Synthesis II version 1.18. This assessment uses the newest
 112 version of Stock Synthesis (3.30.05). The model begins in 1916, and assumes the stock was
 113 at an unfished equilibrium that year. In this assessment, aspects of the model including
 114 landings, data, and modelling assumptions were re-evaluated. The assessment was conducted
 115 using the length- and age-structured modeling software Stock Synthesis (version 3.30.05.03).
 116 The population was modeled allowing separate growth and mortality parameters for each sex
 117 (a two-sex model) from 1916 to 2016, and forecast beyond 2016.

118 All of the data sources for California scorpionfish have been re-evaluated for 2016, including
 119 the historical fishery catch-per-unit effort time-series. The landings history has been updated
 120 and extended back to 1916. Harvest was negligible prior to that year. Survey data from five
 121 sources were used to develop indices of abundance: 1) sanitation district trawl surveys, 2)
 122 the NWFSC trawl survey, 3) a fishery-independent gill net survey, 4) the Southern California
 123 Bight regional monitoring program trawl survey, and 5) the onboard observer survey for
 124 retained catch. Length and conditional age-at-length compositions were also created for each
 125 fishery-dependent and -independent data source, including a generating station impingement
 126 survey that did not have an associated index of abundance.

127 The definition of fishing fleets have changed from those in the 2005 assessment.
 128 Six fishing fleets were specified within this model: 1) a combined hook-and-line, fish pot, and
 129 “other” fishery fleet where only a small fraction of California scorpionfish, 2) the commercial
 130 gill net fleet, 3) the commercial trawl fleet, 4) the recreational party/charter boat fleet
 131 (retained catch only), 5) the recreational private boat fleet (retained catch only), and 6) a
 132 discard fleet that combined the estimated discards from the recreational party/charter and
 133 private boat fleets

¹³⁴ The assessment uses landings data; catch-per-unit-effort and survey indices; length or age
¹³⁵ composition data for each year and fishery or survey (with conditional age-at-length compo-
¹³⁶ sition data for the NWFSC trawl survey); information on weight-at-length; and estimates
¹³⁷ of ageing error. Recruitment at “equilibrium spawning output”, length-based selectivity of
¹³⁸ the fisheries and surveys, retention of the fishery, catchability of the surveys, growth, the
¹³⁹ time-series of spawning biomass, age and size structure, and current and projected future
¹⁴⁰ stock status are outputs of the model. Natural mortality and steepness were fixed in the final
¹⁴¹ model. This was done due to relatively flat likelihood surfaces, such that fixing parameters
¹⁴² and then varying them in sensitivity analyses was deemed the best way to characterize
¹⁴³ uncertainty.

¹⁴⁴ Although there are many types of data available for California scorpionfish since the 1980s
¹⁴⁵ which were used in this assessment, there is little information about steepness and natural
¹⁴⁶ mortality. Estimates of steepness are uncertain partly because of highly variable recruitment.
¹⁴⁷ Uncertainty in natural mortality is common in many fish stock assessments even when length
¹⁴⁸ and age data are available.

¹⁴⁹ A number of sources of uncertainty are explicitly included in this assessment. This assessment
¹⁵⁰ includes gender differences in growth, an updated length-weight curve, and new conditional
¹⁵¹ length at age data. One of the largest sources of uncertainty that is not considered in the
¹⁵² current model is the proportion of the stock in Mexico and the connectivity between the
¹⁵³ portion of the fishery in Mexican and U.S. waters.

¹⁵⁴ A base model was selected which best captures the central tendency for those sources of
¹⁵⁵ uncertainty considered in the model for the California scorpionfish stock in southern California
¹⁵⁶ (Figure e).

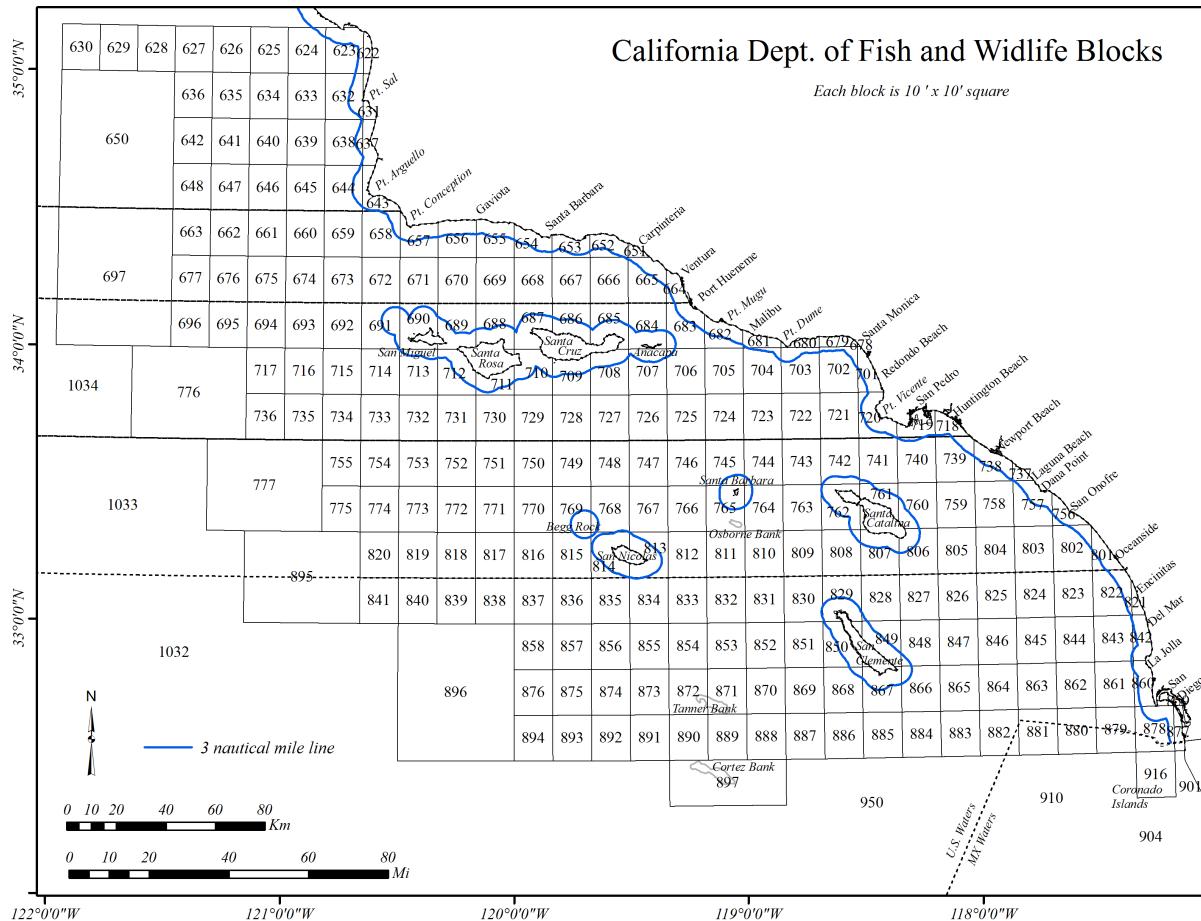


Figure e: Map depicting the boundaries for the base-case model.

157 **Stock Biomass**

158 The predicted spawning biomass from the base model generally showed a slight decline prior
159 to 1965, when information on recruitment variability was available (Figure f and Table b).
160 A short, but sharp decline occurred between 1965 and 1985, followed by a period cyclical
161 spawning biomass and a decline from 2000 to 2015. The stock showed increases in stock size
162 in 2015 due to a combination of strong recruitment and smaller catches in 2015 and 2016.
163 The 2016 estimated spawning biomass relative to unfished equilibrium spawning biomass is
164 above the target of 40% of unfished spawning biomass at 57.4% (~95% asymptotic interval: ±
165 45.5%-69.4%) (Figure g). Approximate confidence intervals based on the asymptotic variance
166 estimates show that the uncertainty in the estimated spawning biomass is high.

Table b: Recent trend in beginning of the year spawning biomass and depletion for the base model for California scorpionfish.

Year	Spawning biomass (mt)	~ 95% confidence interval	Estimated depletion	~ 95% confidence interval
2008	963.566	(555.81-1371.32)	0.704	(0.572-0.837)
2009	927.070	(539.76-1314.38)	0.678	(0.554-0.802)
2010	878.164	(513.26-1243.07)	0.642	(0.526-0.758)
2011	841.147	(494.98-1187.31)	0.615	(0.508-0.722)
2012	814.873	(483.41-1146.34)	0.596	(0.495-0.696)
2013	765.845	(451.39-1080.3)	0.560	(0.465-0.655)
2014	693.818	(401.18-986.46)	0.507	(0.417-0.598)
2015	644.488	(362.67-926.31)	0.471	(0.382-0.561)
2016	681.671	(382.78-980.56)	0.498	(0.399-0.597)
2017	785.329	(439.85-1130.8)	0.574	(0.455-0.694)

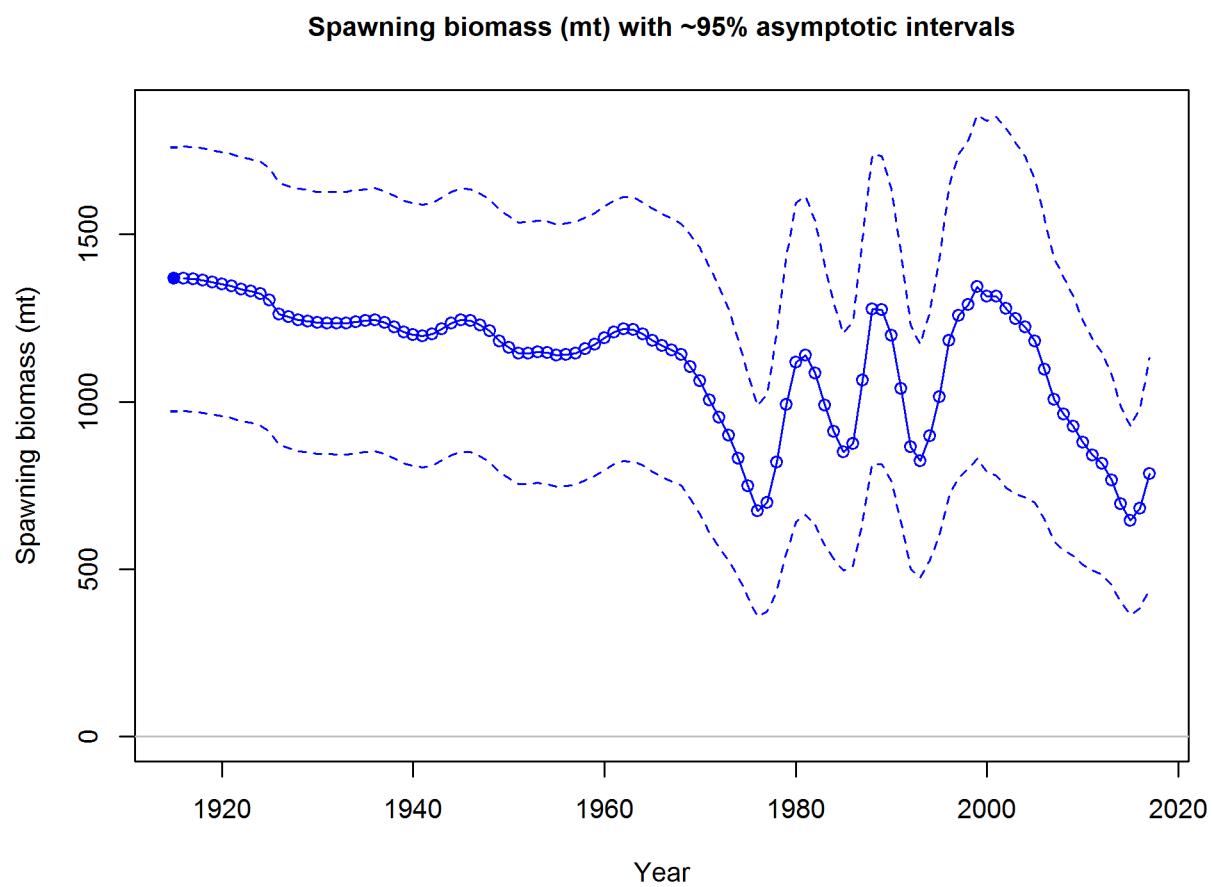


Figure f: Time series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model.

Spawning depletion with ~95% asymptotic intervals

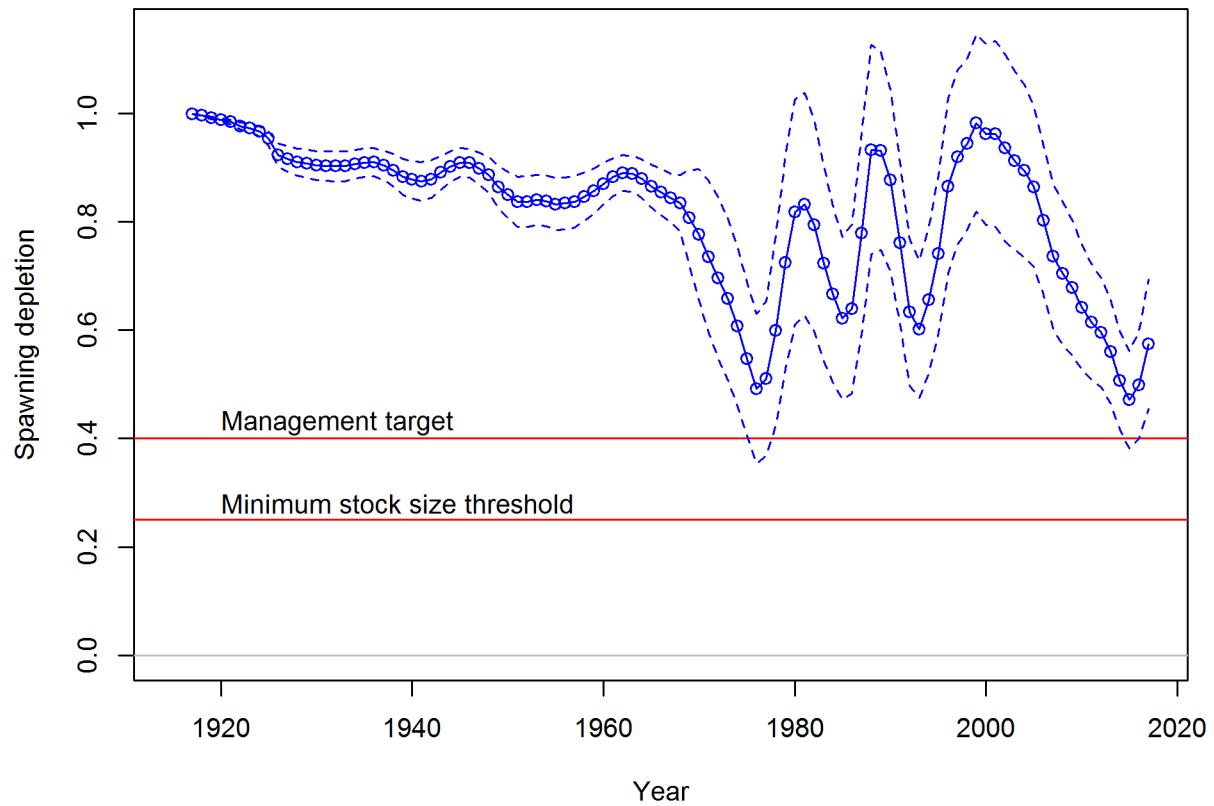


Figure g: Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

¹⁶⁷ **Recruitment**

¹⁶⁸ Recruitment deviations were estimated from 1965-2016 (Figure [h](#) and Table [c](#)). Historically,
¹⁶⁹ there are estimates of large recruitment from 1975-1977, 1984-1985 and in 1993 and 1996.
¹⁷⁰ There is early evidence of a strong recruitment in 2013. The four lowest recruitment estimated
¹⁷¹ within the model (in ascending order) occurred in 2012, 2011, 1989, and 1988.

Table c: Recent recruitment for the base model.

Year	Estimated Recruitment (1,000s)	~ 95% confidence interval
2008	2260.15	(1164.5 - 4386.66)
2009	2784.55	(1503.55 - 5156.93)
2010	2304.22	(1195.21 - 4442.24)
2011	1163.87	(527.22 - 2569.29)
2012	1107.90	(496.15 - 2473.94)
2013	4073.40	(2239.71 - 7408.36)
2014	3459.51	(1590.35 - 7525.52)
2015	7382.85	(3333.93 - 16349.03)
2016	3183.32	(1035.73 - 9783.91)
2017	3260.47	(1061.6 - 10013.79)

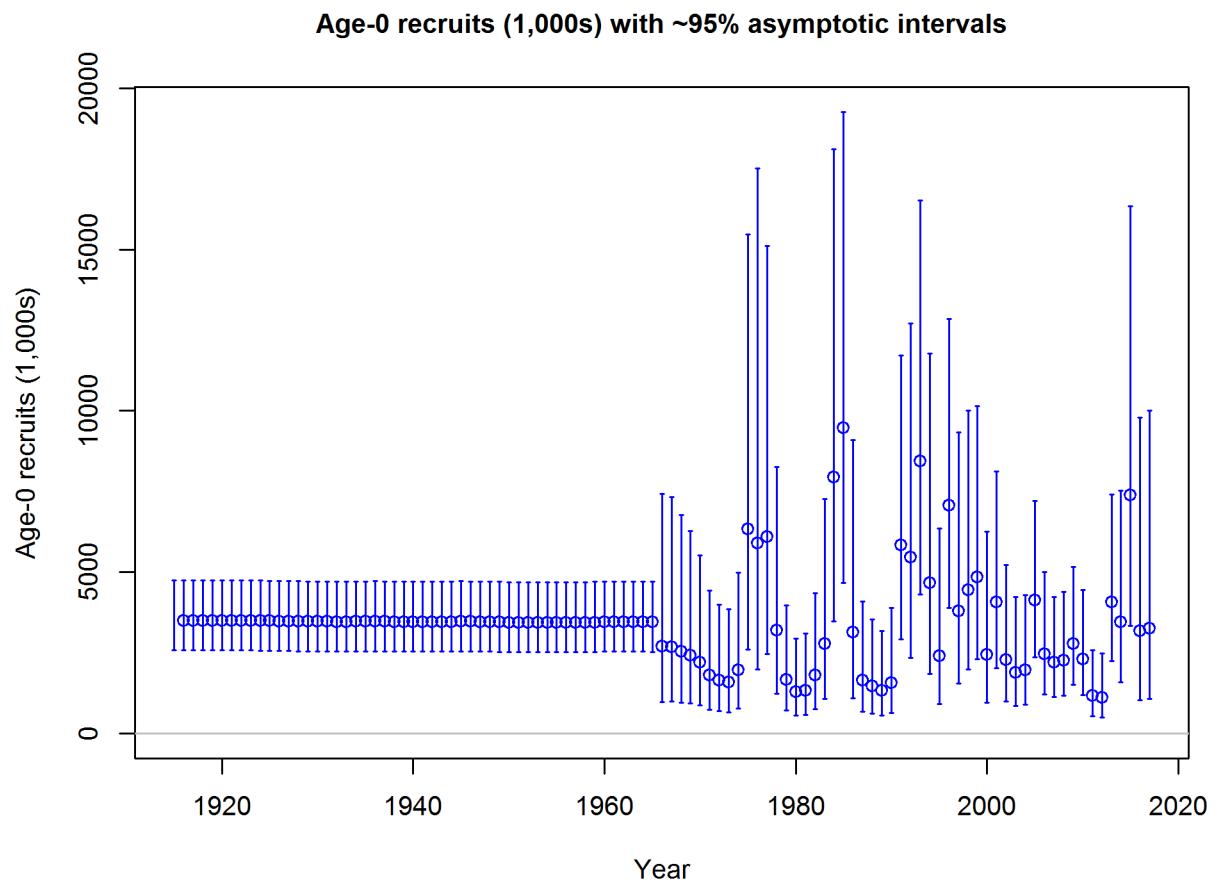


Figure h: Time series of estimated California scorpionfish recruitments for the base-case model with 95% confidence or credibility intervals.

¹⁷² **Exploitation status**

¹⁷³ Harvest rates estimated by the base model have never exceeded management target levels
¹⁷⁴ (Table d and Figure i). Recent harvest rates have been relatively constant for the last decade.
¹⁷⁵ The estimated relative depletion is currently greater than the 40% unfished spawning output
¹⁷⁶ target. Recent exploitation rates on California scorpionfish were predicted to be significantly
¹⁷⁷ below target levels.

Table d: Recent trend in spawning potential ratio and exploitation for California scorpionfish in the base model. Fishing intensity is (1-SPR) divided by 50% (the SPR target) and exploitation is F divided by F_{SPR} .

Year	Fishing intensity	~ 95% confidence interval	Exploitation rate	~ 95% confidence interval
2007	0.51	(0.35-0.66)	0.06	(0.04-0.09)
2008	0.43	(0.29-0.57)	0.05	(0.03-0.07)
2009	0.47	(0.32-0.62)	0.06	(0.04-0.08)
2010	0.47	(0.32-0.61)	0.05	(0.03-0.08)
2011	0.48	(0.33-0.63)	0.06	(0.04-0.08)
2012	0.55	(0.39-0.71)	0.07	(0.04-0.09)
2013	0.55	(0.39-0.72)	0.07	(0.04-0.1)
2014	0.61	(0.43-0.78)	0.08	(0.05-0.11)
2015	0.49	(0.33-0.65)	0.05	(0.03-0.08)
2016	0.46	(0.31-0.62)	0.04	(0.03-0.06)

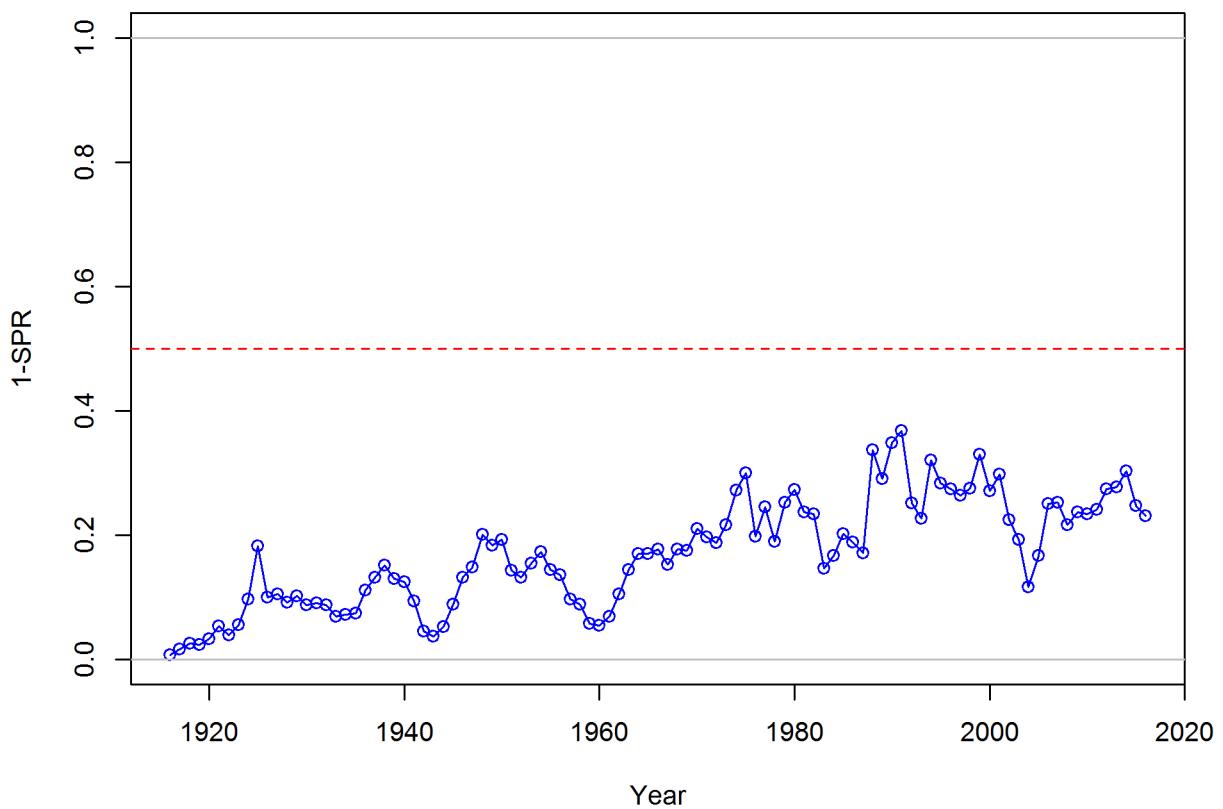


Figure i: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR_{50%} harvest rate. The last year in the time series is 2016.

¹⁷⁸ **Ecosystem Considerations**

¹⁷⁹ In this assessment, ecosystem considerations were not explicitly included in the analysis.
¹⁸⁰ This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere)
¹⁸¹ that could contribute ecosystem-related quantitative information for the assessment.

¹⁸² **Reference Points**

¹⁸³ This stock assessment estimates that California scorpionfish in the base model is above the
¹⁸⁴ biomass target ($SB_{40\%}$), and well above the minimum stock size threshold ($SB_{40\%}$). The
¹⁸⁵ estimated relative depletion level for the base model in 2017 is 57.4% (~95% asymptotic
¹⁸⁶ interval: \pm 45.5%-69.4%, corresponding to an unfished spawning biomass of 785.329 mt
¹⁸⁷ (~95% asymptotic interval: 439.85-1130.8 mt) of spawning biomass in the base model (Table
¹⁸⁸ e). Unfished age 1+ biomass was estimated to be 2796.9 mt in the base case model. The
¹⁸⁹ target spawning biomass ($SB_{40\%}$) is 547.2 mt, which corresponds with an equilibrium yield
¹⁹⁰ of 235.1 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is
¹⁹¹ 221.2 mt (Figure j).

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

Quantity	Estimate	95% Confidence Interval
Unfished spawning biomass (mt)	1367.9	(973.1-1762.7)
Unfished age 1+ biomass (mt)	2796.9	(2030.7-3563)
Unfished recruitment (R_0)	3497.9	(2424.5-4571.3)
Spawning biomass (2017, mt)	785.3	(439.9-1130.8)
Depletion (2017)	0.5741	(0.4546-0.6936)
Reference points based on SB_{40%}		
Proxy spawning biomass ($B_{40\%}$)	547.2	(389.2-705.1)
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.4589	(0.4589-0.4589)
Exploitation rate resulting in $B_{40\%}$	0.1745	(0.1613-0.1877)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	235.1	(166.7-303.5)
Reference points based on SPR proxy for MSY		
Spawning biomass	609.5	(433.6-785.4)
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.1506	(0.1394-0.1617)
Yield with SPR_{proxy} at SB_{SPR} (mt)	221.2	(156.9-285.5)
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY})	301.8	(213-390.6)
SPR_{MSY}	0.2971	(0.2861-0.3082)
Exploitation rate at MSY	0.3268	(0.2944-0.3592)
MSY (mt)	267.5	(189.6-345.4)

192 Management Performance

193 California scorpionfish has been managed as a single-species outside of a complex since 2003.
 194 The estimated catch of California scorpionfish north below the ACL in all years (2007-2017)
 195 except for in 2014 when the catch exceeded the ACL (and ABC) by 6.8 mt. A summary of
 196 these values as well as other base case summary results can be found in Table f.

197 Unresolved Problems and Major Uncertainties

198 TBD after STAR panel

Table f: Recent trend in total catch (mt) relative to the harvest specifications. Estimated total catch reflect the commercial and recreational removals. The OFL was termed the ABC prior to implementation of the FMP Amendment 23 in 2011. Likewise, the ACL was termed OY prior to 2011 and the ABC was redefined to reflect the uncertainty in estimating the OFL.

Year	OFL (mt; ABC prior to 2011)	ABC (mt)	ACL (mt; OY prior to 2011)	ACT	Estimated total catch (mt)
2007	219		175		139.583
2008	219		175		103.887
2009	175		175		113.318
2010	155		155		105.968
2011	141	135	135		105.215
2012	132	126	126		120.008
2013	126	120	120		115.142
2014	122	117	117		123.822
2015	119	114	114		83.8908
2016	117	111	111		74.1613
2017	289	264	150	110	-
2018	278	254	150	110	-

¹⁹⁹ Decision Table

- ²⁰⁰ The forecasted projections of the OFL for each model are presented in Table [g](#) and will be
²⁰¹ finalized after the STAR panel.
- ²⁰² Decision table to be added after the STAR panel (Table [h](#)).

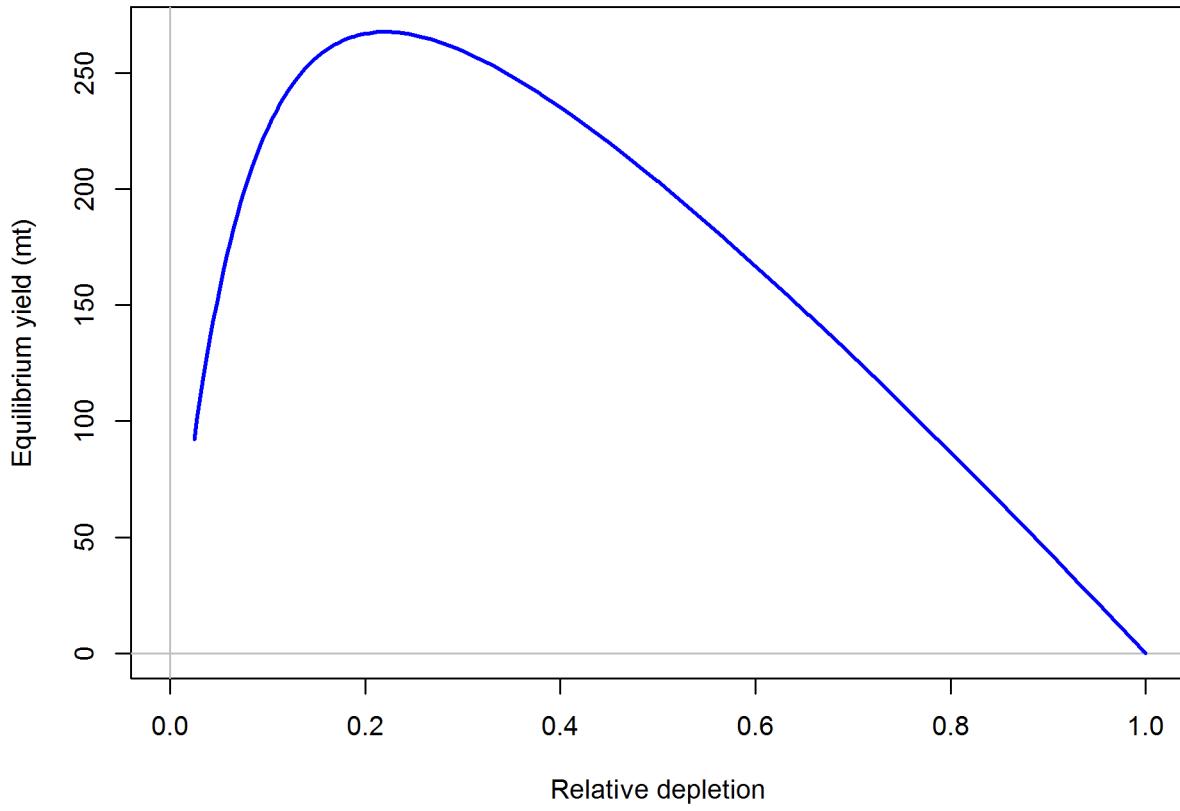


Figure j: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.718.

Table g: Projections of potential OFL (mt) for each model, using the base model forecast.

Year	OFL
2017	282.78
2018	300.05
2019	334.00
2020	326.57
2021	309.69
2022	292.99
2023	279.64
2024	269.39
2025	261.42
2026	255.14
2027	250.17
2028	246.26

Table h: Summary of 10-year projections beginning in 2018 for alternate states of nature based on an axis of uncertainty for the base model. Columns range over low, mid, and high states of nature, and rows range over different assumptions of catch levels. An entry of “-” indicates that the stock is driven to very low abundance under the particular scenario.

		States of nature					
		Low M 0.05		Base M 0.07		High M 0.09	
	Year	Catch	Spawning biomass	Depletion	Spawning biomass	Depletion	Spawning biomass
40-10 Rule, Low M	2019	-	-	-	-	-	-
	2020	-	-	-	-	-	-
	2021	-	-	-	-	-	-
	2022	-	-	-	-	-	-
	2023	-	-	-	-	-	-
	2024	-	-	-	-	-	-
	2025	-	-	-	-	-	-
	2026	-	-	-	-	-	-
	2027	-	-	-	-	-	-
	2028	-	-	-	-	-	-
40-10 Rule	2019	-	-	-	-	-	-
	2020	-	-	-	-	-	-
	2021	-	-	-	-	-	-
	2022	-	-	-	-	-	-
	2023	-	-	-	-	-	-
	2024	-	-	-	-	-	-
	2025	-	-	-	-	-	-
	2026	-	-	-	-	-	-
	2027	-	-	-	-	-	-
	2028	-	-	-	-	-	-
40-10 Rule, High M	2019	-	-	-	-	-	-
	2020	-	-	-	-	-	-
	2021	-	-	-	-	-	-
	2022	-	-	-	-	-	-
	2023	-	-	-	-	-	-
	2024	-	-	-	-	-	-
	2025	-	-	-	-	-	-
	2026	-	-	-	-	-	-
	2027	-	-	-	-	-	-
	2028	-	-	-	-	-	-
Average Catch	2019	-	-	-	-	-	-
	2020	-	-	-	-	-	-
	2021	-	-	-	-	-	-
	2022	-	-	-	-	-	-
	2023	-	-	-	-	-	-
	2024	-	-	-	-	-	-
	2025	-	-	-	-	-	-
	2026	-	-	-	-	-	-
	2027	-	-	-	-	-	-
	2028	-	-	-	-	-	-

Table i: Base case results summary.

	Quantity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Laudlings (mt)											
Total Est. Catch (mt)											
OFL (mt)											
ACL (mt)											
(1- SFR)(1- $SPB_{0.0\%}$)	0.43	0.47	0.47	0.48	0.48	0.55	0.55	0.61	0.49	0.46	0.46
Exploitation rate	0.05	0.06	0.05	0.06	0.07	0.07	0.07	0.08	0.05	0.04	0.04
Age 1+ biomass (mt)	2240.78	2110.60	2015.33	1933.13	1858.78	1753.79	1616.09	1566.71	1552.41	1737.27	
Spawning biomass	963.6	927.1	878.2	841.1	814.9	765.8	693.8	644.5	681.7	785.3	
95% CI	(555.81-1371.32)	(539.76-1314.38)	(513.26-1243.07)	(494.98-1187.31)	(483.41-1146.34)	(451.39-1080.3)	(401.18-986.46)	(362.67-926.31)	(382.78-980.56)	(439.85-1130.8)	
Depletion	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.6	0.6
95% CI	(0.572-0.837)	(0.554-0.802)	(0.526-0.758)	(0.508-0.722)	(0.495-0.696)	(0.465-0.655)	(0.417-0.598)	(0.382-0.561)	(0.399-0.597)	(0.455-0.694)	
Recruits	2260.15	2784.55	2304.22	1163.87	1107.90	4073.40	3459.51	7382.85	3183.32	3260.47	
95% CI	(1164.5 - 4386.66)	(1503.55 - 5156.93)	(1195.21 - 4442.24)	(527.22 - 2569.29)	(496.15 - 2473.94)	(2239.71 - 7408.36)	(1590.35 - 7325.52)	(3333.93 - 16349.03)	(1035.73 - 9783.91)	(1061.6 - 10013.79)	

²⁰³ **Research and Data Needs**

²⁰⁴ We recommend the following research be conducted before the next assessment:

²⁰⁵ 1. List item No. 1 in the list

²⁰⁶ 2. List item No. 2 in the list, etc.

207 **1 Introduction**

208 **1.1 Basic Information and Life History**

209 California scorpionfish (*Scorpaena guttata*), also known as sculpin, originates from the Greek
210 word for scorpionfishes and *guttata* is Latin for speckled. California scorpionfish is a medium-
211 bodied fish and like other species in the genus *Scorpaena*, it produces a toxin in its dorsal,
212 anal, and pectoral fin spines, which produces intense, painful wounds (Love et al. 1987).
213 Scorpionfish are very resistant to hooking mortality and have shown survival under extreme
214 conditions.

215 Its range extends from central California (Santa Cruz) to the Gulf of California, although
216 within U.S. waters they are most common in the Southern California Bight (Eschmeyer et al.
217 1983, Love et al. 1987). The species generally inhabits rocky reefs, caves and crevices, but in
218 certain areas and seasons it aggregates over sandy or muddy substrate (Frey 1971, Love et
219 al. 1987). California scorpionfish have been observed from the intertidal to 600 ft with a
220 preferred depth range from 20-450 ft. Little is known about the aggregating behaviors of
221 California scorpionfish. Marine Applied Research and Exploration (MARE) has observed
222 California scorpionfish aggregations during the spawning season (June 2014) and also in
223 the late fall (November 2012) from video transects in southern California. The November
224 spawning aggregation was observed at a small rocky feature near La Jolla and the June
225 aggregation was at a sandy area adjacent to the Farnsworth MPAs (Andy Lauermann, MARE,
226 personal communication).

227 Males and females show different growth rates, with females growing to a larger size than
228 males, and the sexes exhibit different length-weight relationships (Love et al. 1987). Few
229 California scorpionfish are mature at one year old (14 cm total length). Fifty-percent of fish
230 mature at 17-18 cm (2 years old) and all by 22 cm (4 years old) (Love et al. 1987).

231 California scorpionfish feed on a wide variety of mobile prey, including crabs, fishes (e.g.,
232 include northern anchovy, spotted cusk-eel), octopi, isopods and shrimp, (Taylor 1963, Quast
233 1968, Turner et al. 1969, Love et al. 1987). The species is nocturnal, but have been observed
234 feeding during the day. Predation on scorpionfish is believed to be low, but one individual
235 was found in the gut of a leopard shark (Milton Love, personal communication, UC Santa
236 Barbara).

237 **1.2 Early Life History**

238 California scorpionfish utilize the “explosive breeding assemblage” reproductive mode in
239 which fish migrate to, and aggregate at traditional spawning sites for brief periods (Love
240 et al. 1987). California scorpionfish migrate to deeper waters (120-360 ft) to spawn during
241 May-August, with peak spawning occurring July. The species is oviparous, producing floating,

²⁴² gelatinous egg masses in which the eggs are embedded in a single layer (Orton [1955](#)) and
²⁴³ it is believed that spawning takes place just before, and perhaps after dawn, in the water
²⁴⁴ column (Love et al. [1987](#)). Love et al. ([1987](#)) tagged California scorpionfish and recaptures
²⁴⁵ suggested individuals return to the same spawning site, but information is not available on
²⁴⁶ non-spawning season site fidelity.

²⁴⁷ California scorpionfish have been observed in the California Cooperative Oceanic Fisheries
²⁴⁸ Investigations (CalCOFI) survey, the zooplankton and ichthyoplankton survey of the California
²⁴⁹ Current System. The CalCOFI survey observed 463 California scorpionfish larvae from 1977-
²⁵⁰ 2000, with the majority at station close to Oxnard (east of the Channel Islands) (Moser et al.
²⁵¹ [2002](#)). Higher densities of larvae have been observed in the CalCOFI stations throughout
²⁵² Baja, peaking south of Punta Eugenia from July to September. The hatching length is
²⁵³ reported as 1.9-2.0 mm (Washington et al. [1984](#)) and transformation length of greater than
²⁵⁴ 1.3 cm (Washington et al. [1984](#)) less than 2.1 cm (Moser [1996](#)).

²⁵⁵ 1.3 Map

²⁵⁶ A map showing the scope of the assessment and depicting boundaries for fisheries or data
²⁵⁷ collection strata is provided in Figure 1.

²⁵⁸ 1.4 Ecosystem Considerations

²⁵⁹ In this assessment, ecosystem considerations were not explicitly included in the analysis.
²⁶⁰ This is primarily due to a lack of relevant data and results of analyses (conducted elsewhere)
²⁶¹ that could contribute ecosystem-related quantitative information for the assessment.

²⁶² 1.5 Fishery Information

²⁶³ The hook-and-line fishery off California developed in the late 19th century (Love et al. [2002](#)).
²⁶⁴ The rockfish trawl fishery was established in the early 1940s, when the United States became
²⁶⁵ involved in World War II and wartime shortage of red meat created an increased demand for
²⁶⁶ other sources of protein (Harry and Morgan [1961](#), Alverson et al. [1964](#)).

²⁶⁷ California scorpionfish comprise a minor part of the Californian sport and commercial fisheries
²⁶⁸ (Love et al. [1987](#)). Historically, California scorpionfish were taken commercially by hook and
²⁶⁹ line and, occasionally, by round haul nets (Daugherty [1949](#)). Scorpionfish were commonly
²⁷⁰ caught around Santa Catalina Island during the late 19th Century with gill nets (Jordan
²⁷¹ [1887](#)). The 1937 Bureau of Commercial Fisheries report noted that California scorpionfish
²⁷² had been a fairly important commercial species for a long time. The species was targeted by

273 a few fishermen during the summer months, and was also taken as a bycatch in the rockfish
274 fisheries. By 1949, the Bureau of Marine Fisheries reported “[Scorpionfish] will even come
275 to the surface to lights at night” and were also taken in round haul nets. At that time,
276 scorpionfish were rarely targeted by fishermen except by a few specialists.

277 More recently, commercial bottom longlines have been used to target spawning aggregations
278 offshore of Long Beach (Love et al. 1987). Since the early 1990s, trawl catch has been
279 a substantial component of the commercial catch. Commercial landings have fluctuated
280 substantially over time, which could, in part, be due to changes in targeting and El Niño
281 events (Love et al. 1987). A high proportion of the catch landed in California during the
282 1960s and 1970s was taken from Mexican waters. In recent years, most of the catch has come
283 from around the Los Angeles region. In general, the majority of the commercial catch has
284 come from the Los Angeles region, except in the 1960s and 1970s when the majority of the
285 catch came from the San Diego region and Mexican waters.

286 California scorpionfish are most often taken by boat fishermen, but fairly large numbers are
287 caught from piers, jettys, and rocky shorelines in the recreational fishery. The Commercial
288 Passenger Fishing Vessel (CPFV; also referred to as the recreational party/charter or PC
289 mode) effort has remained relatively constant over a long period (1959-1998) (Dotson and
290 Charter 2003). However, there appears to be a shift in effort towards less utilized species,
291 such as California scorpionfish, over the past decade (Dotson and Charter 2003). Especially
292 as catch limits for rockfish have become more restricted commercial passenger fishing vessels
293 (CPFV) operators target California scorpionfish spawning aggregations during spring and
294 summer (Love et al. 1987), and also target California scorpionfish in the winter when other
295 fisheries are closed. California scorpionfish become a target species for day boats during the
296 spawning months when spawning aggregations can be located. There are a small number
297 of boats that specialize in targeting these aggregations. The spawning aggregations occur
298 in deeper waters, often times outside of the three nautical mile state jurisdiction. It is also
299 unknown what fraction of the population aggregates during the spawning season, e.g., all
300 mature fish.

301 Aggregate mortality has been far below the Annual Catch Limits (ACL) established by the
302 2005 stock assessment. The ACL projections from the 2005 assessment assumed that the
303 entire ACL was being taken each year and as a result, the ACL for each subsequent year
304 declined despite under-attainment in reality. In addition, in 2014, recreational catch was
305 higher than expected. As a result, in 2014, the combined recreational and commercial catch
306 exceeded the OFL by 2mt (1%) resulting from assumption that the ACL had been attained.
307 Subsequently, action was taken to decrease the recreational season by four months (September
308 1 - December 31). A catch only update of the stock was undertaken in 2015 (Wallace and
309 Budrick 2015) that imputed the actual catch values since the last assessment, resulting in
310 significant increase in the OFL and ACL.

311 Retrospectively, the catch in 2014 was well below the OFL as well as the ACL that would
312 have been in place had the ACL values from the actual attainment been in place in 2014.
313 Thus the stock has not been subject to overfishing since the original assessment or been in
314 an overfished condition historically and is considered healthy.

³¹⁵ The season restriction in the recreational fishery remained in place as a precautionary measure
³¹⁶ until the full assessment was completed to better inform the current status of the stock, catch
³¹⁷ limits and regulations given the perspective provided.

³¹⁸ 1.6 Summary of Management History

³¹⁹ Prior to the adoption of the Pacific Coast Groundfish Fishery Management Plan (FMP) in
³²⁰ 1982, California scorpionfish (*Scorpaena guttata*) was managed through a regulatory process
³²¹ that included the California Department of Fish and Wildlife (CDFW) along with either
³²² the California State Legislature or the Fish and Game Commission (FGC) depending on
³²³ the sector (recreation or commercial) and fishery. With implementation of the Pacific Coast
³²⁴ Groundfish FMP, California scorpionfish came under the management authority of the Pacific
³²⁵ Fishery Management Council (PFMC), being incorporated, along with all genera and species
³²⁶ of the family Scorpidae, into a federal rockfish classification and managed as part of
³²⁷ “Remaining Rockfish” under the larger heading of “Other Rockfish” (PFMC (2002, 2004),
³²⁸ Tables 31-39).

³²⁹ The ABCs provided by the PFMC’s Groundfish Management Team (GMT) in the 1980s were
³³⁰ based on an analysis of commercial landings from the 1960s and 1970s. For this analysis,
³³¹ most of the rockfishes were lumped into one large group. This analysis indicated that the
³³² landings for rockfish in the Monterey-Conception area were at or near ABC levels (Pacific
³³³ Fishery Management Council 1993). To keep landings within these adopted harvest targets,
³³⁴ the Pacific Coast Groundfish FMP provided the Council with a variety of management tools
³³⁵ including area closures, season closures, gear restrictions, and, for the commercial sector,
³³⁶ cumulative limits (generally for two-month periods). With the implementation of a federal
³³⁷ groundfish restricted access program in 1994, allocations of total catch and cumulative limits
³³⁸ began to be specifically set for open access (including most of California’s commercial fisheries
³³⁹ that target California scorpionfish in Southern California) and limited entry fisheries (Figure
³⁴⁰ 2) (Pacific Fishery Management Council 2002, 2004). As a result, in the later 1990s as
³⁴¹ commercial landings decreased and recreational harvest became a greater proportion of the
³⁴² available harvest.

³⁴³ Beginning in 1997, California scorpionfish was managed as part of the *Sebastodes* complex-
³⁴⁴ south, Other Rockfish category. *Sebastodes* complex-south included the Eureka, Monterey,
³⁴⁵ and Conception areas while *Sebastodes* complex-north included the Vancouver and Columbia
³⁴⁶ areas.) The PFMC’s rockfish management structure changed significantly in 2000 with the
³⁴⁷ replacement of the *Sebastodes* complex -north and -south areas with Minor Rockfish North
³⁴⁸ (now covering the Vancouver, Columbia, and Eureka areas) and Minor Rockfish South (now
³⁴⁹ Monterey and Conception areas only). The OY for these two groups (which continued to be
³⁵⁰ calculated as 0.50 of the ABC) was further divided (between north and south of 40°10' N.
³⁵¹ latitude) into nearshore, shelf, and slope rockfish categories with allocations set for Limited
³⁵² Entry and Open Access fisheries within each of these three categories (January 4, 2000, 65
³⁵³ FR 221; PFMC (2002), Tables 54-55). Because of its depth range and southern distribution,

³⁵⁴ California scorpionfish was included within the Minor Rockfish South, Other Rockfish ABC
³⁵⁵ and managed under the south of 40°10' N. latitude nearshore rockfish OY and trip limits
³⁵⁶ (PFMC ([2002](#)), Table 29).

³⁵⁷ Along with the above changes, in 2000 the southern area divided into two separate management
³⁵⁸ areas at Point Lopez, 36°00' N. latitude. This was followed in 2001 with the implementation
³⁵⁹ of the northern rockfish and lingcod management area between (40°10' N. latitude) and Point
³⁶⁰ Conception (34°27' N. latitude); and the southern rockfish and lingcod management area
³⁶¹ between Point Conception and the U.S.- Mexico border. These were later revised starting
³⁶² in 2004 with the northern rockfish and lingcod management area redefined as ocean waters
³⁶³ from the Oregon-California border (42°00' N. latitude) to 40°10' N. latitude, the central
³⁶⁴ rockfish and lingcod management area defined as ocean waters from 40°10' N. latitude to
³⁶⁵ Point Conception, and the southern rockfish and management area continuing to be defined
³⁶⁶ as ocean waters from Point Conception to the U.S.-Mexico border.

³⁶⁷ Cowcod Conservation Areas (CCAs) also were established in 2001 to reduce fishing effort
³⁶⁸ in areas with high encounter rates of cowcod rockfish (PFMC ([2002](#)), Table 29). These
³⁶⁹ areas were closed to all recreational and commercial fishing for groundfish except for minor
³⁷⁰ nearshore rockfish (including California scorpionfish) within waters less than 20 fathoms.
³⁷¹ The California Rockfish Conservation Area (CRCA) was defined as those ocean waters south
³⁷² 40°10' N. latitude to the U.S.-Mexico border with different depth zones specified for the areas
³⁷³ north and south of Pt. Reyes (37°59.73' N. latitude).

³⁷⁴ During the late 1990s and early 2000s, major changes also occurred in the way that California
³⁷⁵ managed its nearshore fishery. The Marine Life Management Act (MLMA), which was passed
³⁷⁶ in 1998 by the California Legislature and enacted in 1999, required that the FGC adopt
³⁷⁷ an FMP for nearshore finfish. It also gave authority to the FGC to regulate commercial
³⁷⁸ and recreational nearshore fisheries through FMPs and provided broad authority to adopt
³⁷⁹ regulations for the nearshore fishery during the time prior to adoption of the nearshore finfish
³⁸⁰ FMP. Within this legislation, the Legislature also included commercial size limits for nine
³⁸¹ nearshore species including California scorpionfish (10-inch minimum size) and a requirement
³⁸² that commercial fishermen landing these nine nearshore species possess a nearshore permit.

³⁸³ Following adoption of the Nearshore FMP and accompanying regulations by the FGC in fall
³⁸⁴ of 2002, the FGC adopted regulations in November 2002 which established a set of marine
³⁸⁵ reserves around the Channel Islands in southern California (which became effective April
³⁸⁶ 2003). The FGC also adopted a nearshore restricted access program in December 2002 (which
³⁸⁷ included the establishment of a Deeper Nearshore Permit) to be effective starting in the 2003
³⁸⁸ fishing year.

³⁸⁹ Although the Nearshore FMP provided for the management of the nearshore rockfish and
³⁹⁰ California scorpionfish, management authority for these species continued to reside with
³⁹¹ the Council. Even so, for the 2003 and subsequent fishery seasons, the State provided
³⁹² recommendations to the Council specific to the nearshore species that followed the directives
³⁹³ set out in the Nearshore FMP. These recommendations, which the Council incorporated into

³⁹⁴ the 2003 management specifications, included a recalculated OY for Minor Rockfish South
³⁹⁵ - Nearshore, division of the Minor Rockfish South - Nearshore into three groups (shallow
³⁹⁶ nearshore rockfish; deeper nearshore rockfish; and California scorpionfish), and specific harvest
³⁹⁷ targets and recreational and commercial allocations for each of these groups.

³⁹⁸ Also, since the enactment of the MLMA, the Council and State in a coordinated effort
³⁹⁹ developed and adopted various management specifications to keep harvest within the harvest
⁴⁰⁰ targets, including seasonal and area closures (e.g. the CCAs; a closure of Cordell Banks
⁴⁰¹ to specific fishing), depth restrictions, minimum size limits, and bag limits to regulate the
⁴⁰² recreational fishery and license and permit regulations, finfish trap permits, gear restrictions,
⁴⁰³ seasonal and area closures (e.g. the RCAs and CCAs; a closure of Cordell Banks to specific
⁴⁰⁴ fishing), depth restrictions, trip limits, and minimum size limits to regulate the commercial
⁴⁰⁵ fishery.

⁴⁰⁶ 1.7 Management Performance

⁴⁰⁷ Management performance table: (Table [f](#))
⁴⁰⁸ A summary of these values as well as other base case summary results can be found in Table
⁴⁰⁹ [i](#).

⁴¹⁰ 1.8 Fisheries Off Mexico

⁴¹¹ The California scorpionfish's range extends into to Punta Abreojos, Baja California Sur,
⁴¹² Mexico. The species is also found in the northern Gulf of California and Guadalupe Island.
⁴¹³ No formal stock assessments have been conducted for California scorpionfish in Mexican
⁴¹⁴ waters.

⁴¹⁵ 2 Assessment

⁴¹⁶ 2.1 Data

⁴¹⁷ Data used in the California scorpionfish assessment are summarized in Figure [3](#).
⁴¹⁸ A description of each data source is below.

⁴¹⁹ 2.1.1 Commercial Fishery Landings

⁴²⁰ Commercial catches of California scorpionfish (often landed as "sculpin") are available back
⁴²¹ to 1916. Landings from 1916 to 1935 are presented in CDFG Fish Bulletin No. 49 and

422 Bulletin No. 149 provides tabulated data from 1916 to 1968. Over 99% of the commercial
423 catches of California scorpionfish are from south of Pt. Conception. Whenever possible,
424 catches from north of Pt. Conception and also caught in Mexico but landed in the U.S. were
425 excluded from the commercial catch histories. [California Explores the Ocean \(CEO\)](#) provides
426 landings data taken from the CDFG Fish Bulletins in electronic form, as well as electronic
427 copies of all CDFG Fish Bulletins.

428 Statewide annual commercial landings are available for California scorpionfish from 1916 to
429 1925, and are assumed to be taken by hook-and-line. Data by area and month are given in
430 a series of bulletins, each bulletin usually providing information for a single year. Data by
431 region and month is available for 1926 to 1986. The Santa Barbara region includes San Luis
432 Obispo, Santa Barbara and Ventura counties. Catches from this region were included in the
433 catch history and comprised less than 10 mt for the period from 1926-1968 (the period when
434 data at the regional scale are available).

435 Catches from Mexico can be separated from the total catch starting in 1931, although the
436 CDFG Bulletins do not report catches originating from Mexican waters available for all years,
437 e.g., 1932-1934. It is assumed that before 1931 there was no catch taken from Mexican waters
438 landed in California.

439 The [CALCOM](#) database was queried (March 7, 2017) for commercial landing estimates of
440 California scorpionfish in California, 1969-2016. Landings were stratified by year, quarter,
441 live/dead, market category, gear group, port complex, and source of species composition
442 data (actual port samples, borrowed samples, or assumed nominal market category). All
443 CALCOM California scorpionfish landing data are either actual port samples or the nominal
444 California scorpionfish market category. However, catches in CALCOM do not separate out
445 catches originating from Mexican waters and landed at U.S. ports.

446 The Commercial Fisheries Information System (CFIS; maintained by CDFW) contains
447 California catch in pounds by gear and port for 1969 to 2016. The CFIS data come from
448 landing receipts or “fish tickets” filled out by the markets or fish buyers as required by the
449 state for all commercial landings. The fish tickets include the CDFW block in which the
450 majority of the landings were caught. Landings reported from a block solely in Mexican
451 waters (blocks >900) were removed from the catch history. Landings with reported blocks
452 877-882 with area in both U.S. and Mexican waters were retained in the catch histories.

453 The commercial catch is dominated by the hook-and-line fishery (89% of total catches).
454 The catch by reported gear types: hook-and-line, fish pot, trawl, gill net, and other can be
455 found in Table 1. Catch taken by fish pot and other gears is added to the hook-and-line
456 catch in the stock assessment (30.6 mt from fish pot and 93.9 mt from other gears).

457 In the assessment, catch for 1916 to 1968 is taken from the CDFG Fish Bulletins. Catch by
458 gear for 1969 to 2004 is taken from CFIS.

459 **2.1.2 Commercial Discards**

460 Information on commercial discards from the West Coast Groundfish Observer Program
461 (WCGOP) are available starting in 2004. The commercial fishery for California scorpionfish
462 has been minimal since the early 2003 (averaging 3.5 mt per year). The available length
463 composition data from the observed discards is minimal, with 151 fish measured from 2004-
464 2015, and less than half a metric ton. Given the discard mortality of only 7%, and the small
465 total catches in the recent years, discards from the commercial fleet are not considered in the
466 assessment.

467 **2.1.3 Commercial Fishery Length and Age Data**

468 Biological data from commercial fisheries that caught California scorpionfish were extracted
469 from CALCOM on March 7, 2017. Samples from the hook and line fishery were available
470 from 1999 (1 trip) and 2013-2015 (1 trip per year), and for 1999 (1 trip) and 2006 (2 trips)
471 from the trawl fishery. A total of 87 fish were measured and length compositions were based
472 on expanded catch-weighted landings. The samples from 1999 for both fisheries were replaced
473 by samples from the market category study described below.

474 The CDFW conducted a market study from 1990-2004 in southern California (Laughlin
475 and Ugoretz 1998) to monitor and summarize local commercial catches. The ports sampled
476 included San Diego, Santa Barbara/Ventura and Long Beach/San Pedro. Very few of the
477 samples from Santa Barbara and San Diego (four samples each from the hook-and-line and
478 trawl fisheries Santa Barbara, and one sample from the hook-and-line fishery in San Diego)
479 reported California scorpionfish, and are excluded from the length composition data. Length
480 composition for California scorpionfish are available from the Long Beach samples for the
481 hook-and-line (Table 2), gillnet (Table 3), and trawl fisheries (Table 4). Length samples
482 from both groundfish (otter) trawls and single-rigged shrimp trawls were available from the
483 market study. The average size of fish from the otter trawls (26.5 cm) was smaller than from
484 the shrimp trawl samples (28.1 cm). Over 70% of California scorpionfish catch from the
485 trawl sector was landed from single-rigged shrimp trawls, which best represent the length
486 composition of the trawl fleet (CALCOM).

487 The input sample sizes were calculated via the Stewart Method (Ian Stewart, personal
488 communication, IPHC):

$$489 \text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is } < 44$$

$$490 \text{Input effN} = 7.06 * N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is } \geq 44$$

491 **2.1.4 Sport Fishery Removals and Discards**

492 Data used in reconstructing the retained catch and discarded mortality for California scor-
493 pionfish in the California recreational fishery are from the Commercial Passenger Fishing
494 Vessel (CPFV), i.e., charter or for-hire boats, logbooks (1932-2017), the Marine Recreational
495 Fishery Statistical Survey (MRFSS, 1980-2003) and the California Recreational Fishery
496 Survey (CRFS, 2004-2017). Total catch was accounted for including retained catch as well
497 as the estimate of fish discarded dead assuming a 7% discard mortality rate approved for
498 use in management in the regulatory specifications for 2009-2010 (Pacific Fishery Manage-
499 ment Council 2008). The MRFSS and CRFS data provide estimates of mortality for four
500 recreational fishing modes: party/charter boats, private/rental boats, fishing from man-made
501 structures,e.g., piers and jetties, and fishing from the beach or banks.

502 The Coastal County Household Telephone Survey was used to estimate fishing effort for
503 the MRFSS survey from 1980-2003 and was subject to potential positive avidity bias in
504 participation by those contacted by the survey. The party/charter phone survey was used to
505 estimate effort for CRFS between 2004 and 2010. The phone survey participation rates were
506 low in the area south of Pt. Conception, introducing a negative bias in the effort estimates.

507 Estimates of mortality from the party/charter sector were derived from the CPFV logbook
508 data from 1932-2010 and CRFS from 2011-2017. Estimated mortality from the logbook
509 data is consistent with the catch-based update conducted in 2015 as well as the 2005 stock
510 assessment.

511 An under-reporting adjustment (assuming an 80% reporting rate) was applied to the logbook
512 data, which is the same as in the 2005 stock assessment was confirmed as the approximate
513 level of reporting in conversation with the CRFS program director (Connie Ryan, personal
514 communication, CDFW). The logbook catch was inflated by 20% from 1936 to 2010. Annual
515 average weights for the party/charter boat retained catch were derived from the MRFSS
516 or CRFS estimates for 1980-2010 and the average weight from 1980-1984 was applied to
517 preceding years.

518 To estimate discard mortality for the party/charter mode, the annual average weight was
519 applied from lengths collected sampling onboard CPFVs; CRFS survey from 2004-2010.
520 The annual average weight from was applied to discards reported in CPFV logbooks from
521 2004-2010 and the overall and the average weight was applied to discards from 1995-2003.
522 For the period between 1980 and 1994, the MRFSS estimates for discards were used to reflect
523 discarding due to the paucity of data on the number of discards from party/charter logbooks
524 prior to 1995.

525 For all other modes, the MRFSS (1980-2003) and CRFS (2004-2017) based estimates of
526 retained catch and discard mortality were used. There was a lapse in MRFSS sampling from
527 1990 through 1992, for which retained catch and discard mortality were estimated using
528 the average of values three years before and three years after the lapse for all modes other
529 than the party/charter mode. For the party/charter mode, estimates of numbers of fish were

530 available from logbook data and average weight from the three years before and after this
531 period were applied to provide estimates for the party/charter mode.

532 Estimates of retained catch and discards were not available from the non-party/charter modes
533 prior to 1980, thus the ratio of catch in the party/charter mode to the other modes for
534 1980 through 1985 was used to provide an estimate of catch in the other modes in the years
535 1932-1979. In the case of the private/rental mode, a linear ramp in the ratio adjustment
536 between party/charter and private/rental modes was applied between 1966 and 1979 from 0.55
537 in 1980 to 0.10 in 1965, reflecting the increase in the relative proportion of catch contributed
538 by the private/rental mode with time as more individuals anglers purchased vessels, as
539 recommended in the California Catch Reconstruction (Ralston et al. 2010), and the ratio of
540 0.10 was assumed for all years prior. The ratio of party/charter estimates to the MM and BB
541 modes was assumed to constant and the average between 1980 and 1989 was applied from
542 1932 to 1979. Catch estimates from CPFV logbooks were not available during the World
543 War II era from 1941 until 1946 and catch was assumed to be zero for all modes during this
544 period. Estimates for retained catch and discarded mortality for 1928 to 3528 were estimated
545 using a linear ramp from the value for 1936 to zero in 1928 for the party/charter mode and
546 ratios party/charter compared to other modes were used to proxy estimates for other modes
547 based on the resulting ramped values for the party/charter mode. The final time series of
548 landings and discard mortality are in Table 5.

549 Biological samples from the recreational fleets are described in the sections below.

550 2.1.5 Fishery-Dependent Indices of Abundance

551 CRFS Private Boat Dockside Intercept Survey

552 The CDFW provided the CRFS private boat dockside sampling fisheries data from 2004
553 to 2016. The data went through several data quality checks to identify the best subset of
554 available data that are consistent over the time series and provide a representative relative
555 index of abundance once standardized. The dockside sampling of the private/rental mode
556 consists of samples from a primary series of ports (PR1) where the majority of fishing effort
557 for this mode originates and a secondary series of ports with historically low effort (PR2).
558 Only PR1 samples were used for this index as the sampling forms for the PR2 index have
559 changed over time and the data could not reliably be collapsed to the trip level. The dockside
560 data consist of two types of data; Type 2 data contain records of angler-reported catch, i.e.,
561 catch that was not observed by the sampler and Type 3 data includes sampler-examined
562 retained catch. Of the Type 2 reported catch for scorpionfish, less than one percent were
563 reported “thrown back dead” and five percent reported as retained to eat. Given that the
564 reported retained catch is a small fraction of the catch overall and discard mortality of
565 California scorpionfish is low, only the Type 3 examined catch are used in the index.

566 The survey records the number of contributing anglers (number of anglers on the vessel for
567 the private mode), but does not contain data on hours fished. For this index, angler-day

568 was the assumed effort. The data were filtered to trips fishing with hook-and-line gear in
569 southern California. Trips with a primary fishing area of Mexico were also removed. The
570 CRFS dockside private boat records with these broad filters include 44,128 trips of which
571 3,802 caught California scorpionfish (8.6%).

572 The Stephens-MacCall approach was used to identify trips with a high probability of catching
573 California scorpionfish (Stephens and MacCall 2004). Prior to using the Stephens-MacCall
574 approach to select relevant trips a number of other filters were applied to the data. Over the
575 course of the time series only 45 trips from Santa Barbara county encountered California
576 scorpionfish, ranging from 0-10 trips a year. The Stephens-MacCall approach was applied
577 with and without trips from Santa Barbara and the same species were identified as indicators
578 and counter-indicators. For the final model prior to Stephens-MacCall, trips from Santa
579 Barbara were excluded, leaving 41,235 trips, and 3,747 of those caught California scorpionfish
580 (Table 6).

581 Coefficients from the Stephens-MacCall analysis (a binomial GLM) are positive for species
582 which co-occur with California scorpionfish, and negative for species that are not caught with
583 California scorpionfish (Figure 4). Potentially informative species for the Stephens-MacCall
584 analysis were limited to species caught in at least one percent of all trips and caught in at
585 least five years. Some of these never occurred with California scorpionfish (strong ‘counter-
586 indicators’) and records with these species were removed from the data prior to estimation
587 of the index. Strong counter-indicators for the CRFS private boat index included yellowfin
588 tuna and dolphinfish.

589 A total of 8,590 trips were retained following the Stephens-MacCall filter, with 3,056 all
590 positive California scorpionfish trips retained. The California scorpionfish recreational fishery
591 in the southern management area was closed for eight months in 2004 and nine months in
592 2005. The majority of records from 2004 and 2005 are from the period when the fishery
593 was closed and were removed from the analysis (Figure 5). Records from months when the
594 fishery was closed from 2006-2016 were also excluded from the index since this index relies
595 on sampler-examined retained catch.

596 Catch per unit effort was modeled using a delta-GLM approach, where the catch occurrence
597 (binomial) component was modeled using a logit link function and the positive catch compo-
598 nent was modeled after log-transformation of the response variable, according to a normal
599 distribution with an identity link function. The units for CPUE are fish landed/anglers. A
600 gamma distribution for the positive catch component was also explored, but model selection
601 favored the lognormal model. The raw CPUE of factors considered in the model by year are
602 shown in Figure 6.

603 Model selection procedures selected the covariates *2-month wave* and *county* as important
604 for both the catch occurrence and positive catch component models for all data sets, along
605 with the categorical year factor used for the index of abundance (Table 7).

606 The Q-Q goodness of fit plot for the lognormal portion of the model shows a moderate fit to
607 the data (Figure 7). The final index indicates a decrease in relative abundance from 2006 to
608 2010, at which point the index is relatively flat (Figure 8 and Table 8).

609 Biological samples from trips retaining California scorpionfish were collected during the
610 dockside surveys. Lengths of California scorpionfish from 1980-2016 for the private mode
611 were provided from the Recreational Fisheries Information Network (RecFIN) by Edward
612 Hibscher (PSMFC) on November 29, 2016. Length measurements from the private mode were
613 provided directly from CDFW for the years 2004-2016 Table 9. The number of trips is the
614 number of unique ID_CODEs from RecFIN for 1980-2003. Starting in 2004 with the CRFS
615 program, the number of unique trips sampled in the private boat mode was recorded. The
616 recreational private fleet tends to select larger fish than the recreational party/charter fleet,
617 which is one reason the private and party/charter fleets were maintained as two separate
618 fleets in the base model. No length data for discarded fish from the recreational private mode
619 fleet are available.

620 CRFS CPFV Logbook Index

621 CPFV operators have been required to submit written catch logs with daily trips records of
622 catches to CDFW since 1935. The logbook data from 1936-1979 are available as monthly
623 summaries, which do not contain the level of detail needed for an index of abundance. CDFW
624 provided the CPFV logbook data from 1980-2016 (Charlene Calac, CDFW). Logbook data
625 from 1980-2016 contain records for each trip, including the fishing date, port of landing,
626 vessel name and number, CDFG block area fished (Figure 1), angler effort, number of fish
627 kept and discarded by species. As of 1994, operators were required to report the number
628 of fish discarded and lost to seals. Prior to 1994, it is assumed that all reported fish were
629 retained. Details and additional information on the historical logbook database can be found
630 in Hill and Schneider (1999).

631 The number of anglers on board the vessel and the hours fished are included in the database
632 for all years. Only retained fish are included in the index of abundance the unit of effort
633 is angler hours. A number of data filters were applied to the data to account for possible
634 mis-reporting, e.g., trips reporting retained California scorpionfish in top 1% of the data
635 (>325 fish). Trips fishing outside of California scorpionfish habitat (reported as targeting
636 pelagic species) or trips reporting a block with a minimum depth deeper than 140 m were
637 also filtered out.

638 Because California scorpionfish is not a primary target species, boats with fewer than 10
639 trips retaining California scorpionfish were removed from the analysis. Data were also filtered
640 to only include catches reported from blocks South of Pt. Conception and north of the U.S.-
641 Mexico border (Figure 1), and blocks with at least 100 trips retaining California scorpionfish
642 and a total of 500 trips. A full description of the data filters is in Table 10. A total of
643 432,868 trips were retained for the index of abundance, 202,937 of which caught California
644 scorpionfish.

645 Two different area factors were considered for the standardization, block and region.
646 The 60 retained blocks were split into nearshore regions north and south of San Pedro and
647 the northern and southern islands, for four regions. Both a delta model and a negative
648 binomial model were considered for index standardization. However, due to the large number
649 of records, the traditional jackknife routine to estimate uncertainty was not possible.

650 California scorpionfish were present in 47% of all trips, and standardized with a negative
651 binomial model. Factors considered were *year*, *month*, and *area* (either block or region). A
652 model with blocks and was selected over a model with region by 39,180 AIC. The final model
653 includes *year*, *month*, and *block* with a log link and effort as an offset (Table 11).
654 The standardized index shows a cyclic pattern, with period of higher CPUE (late 1980's to
655 early 1990's and late 1990s) and has shown a general downward trend since 2008 (Figure
656 9 and Table 12). An interesting note is the similarity in standardized CPUE between the
657 CPFV logbook index and the CPFV dockside index (not used in the stock assessment model)
658 from 1992-1997 (for a Stephens-MacCall threshold of 0.1) (Figure 10).

659 MRFSS Party/Charter Boat Dockside Index

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

672 Initial trip filters included eliminating trips targeting species caught near the surface waters
673 for all or part of the trip, including trips with catch of bluefin tuna, yellowfin tuna, dorado,
674 Pacific bonito, skipjack, albacore, chinook salmon, coho salmon and bigeye tuna. Trips with
675 catch of yellowtail amberjack were also removed since effort on such trips can often be focused
676 in the surface and mid-water where California scorpionfish do not occur. In addition, trips
677 with aggregate effort below and above 95% percentile (less than 2 and over 109.5 hours) were
678 removed to exclude trips for which either too little effort was exerted to be informative or
679 longer trips that may make an excessive contribution to the effort likely distributed over
680 a number of target species, only some of which may co-occur with California scorpionfish.
681 Trips in Santa Barbara County were removed due the low number of positive trips retaining
682 California scorpionfish.

683 Since recreational fishing trips target a wide variety of species, standardization of the catch
684 rates requires selecting trips that are likely to have fished in habitats containing California
685 scorpionfish. The Stephens-MacCall (2004) filtering approach was used to identify trips with
686 a high probability of catching California scorpionfish, based on the species composition of the
687 catch in a given trip. Prior to applying the Stephens-MacCall filter, we identified potentially
688 informative predictor species, i.e., species with sufficient sample sizes and temporal coverage
689 (at least 30 positive trips total, distributed across at least 10 years of the index) to inform
690 the binomial model. Coefficients from the Stephens-MacCall analysis (a binomial GLM) are

positive for species which co-occur with California scorpionfish, and negative for species that are not caught with California scorpionfish. Each of these filtering steps and the resulting number of trips remaining in the sampling frame are provided in Table 13.

Prior to the Stephens-MacCall filter, a total of 3,968 trips were retained for the analysis. Species that composed less than 5% of the catch were excluded from analysis, which included Chub mackerel, Pacific mackerel and barracuda. As expected, positive indicators of California scorpionfish trips include several species of nearshore rockfish, California sheephead, California halibut, Pacific sanddabs and seabasses and counter-indicators include several species of deep-water rockfish (Figure 11). While the filter is useful in identifying co-occurring or non-occurring species assuming all effort was exerted in pursuit of a single target, the targeting of more than one target species can result in co-occurrence of species in the catch that do not truly co-occur in terms of habitat associations informative for an index of abundance.

Two levels of filtering were applied using the Stephens-MacCall Filter. The Stephens-MacCall filtering method identified the probability of occurrence (in this case 0.27) at which the rate of false positives and false negatives for the presence of California scorpionfish. The trips from this criteria for selection was compared to an alternative method including the false positive trips as well as all positive trips for California scorpionfish supported by the assumption that if California scorpionfish were caught in such trips, they must constitute appropriate habitat justifying their inclusion. In addition, the false positives from a lower probability of occurrence (0.10) was considered to reflect a less stringent threshold inclusive of more trips including a higher proportion of the false positive trips combined with the positive trips from the entire data set was evaluated for comparison.

Catch per angler hour (CPUE; number of fish per angler hour) was modelled using a delta model (Lo et al. 1992, Stefnsson 1996). Model selection using Akaike Information Criterion (AIC) and Bayesian Information Criteria (BIC) supported inclusion of year and region effects in both the binomial and lognormal components of the index for both the model with false positives using the 0.27 threshold and the 0.10 threshold. The addition of month effects (to allow for seasonal changes in CPUE) did not improve model fit in the lognormal model, but the full model including month, year and county was supported for the binomial model (Table 14). The difference in AIC values for the full model compared to the model with only year and county was greater for the binomial model (201.5) favoring the full modal compared to the small difference for the lognormal model favoring the model with only year and county (8.3). As a result, the full model including year, county and month effects was selected for further analysis.

The resulting index values for 1989 were anomalously high compared to other years. In addition, the less stringent filter of 0.1 resulted in a higher index value than 0.27, which was antithetical to the expectation that including trips with fewer positive trips would decrease the CPUE. Further examination of the number of California scorpionfish per trip by year showed a lower number of trips for this year than others and a lower proportion of low catch trips explaining why exclusion of low catch trips through application of the 0.27 index reduced the relative magnitude of the 1989 index value relative to other years. As a result of this

732 anomalous result and the low sample size, trips from 1989 were excluded from analysis.

733 The percentage of trips that retained California scorpionfish was 20.8% (828/3,968) prior
734 to filtering with the Stephens-MacCall method, and 71.0% (828/1,167) with the filter set
735 to 0.27 and 26.7% (828/3,099) with the filter set to 0.10, filtered data set. Residual-based
736 model diagnostics for the positive component of the index suggest the data generally met the
737 assumptions of the GLM (Figure 12). The resulting index is highly variable for both thresholds,
738 with consistent peaks in 1984 and 1998 (Figure 10). Application of the 0.27 threshold holds
739 the potential of biasing the resulting index values high by excluding false positive trips while
740 including positive trips with equivalent probability of encountering California scorpionfish.
741 The 0.1 threshold removes a high proportion of trips with shelf rockfish species indicative of
742 effort exerted in deeper depths than are commonly occupied by California scorpionfish, while
743 retaining false positive trips with equivalent probabilities of capture to true positives and
744 thus was retained for further analysis. The resulting jackknifed mean index values, standard
745 error, coefficient of variation and confidence intervals for the 0.1 threshold model, excluding
746 1989, with year, month and county effects are provided in Table 14.

747 The results of the models with each of the thresholds provided similar trends seen in Figure 10
748 along with the results from the CPFV logbook index. The trends differ from those resulting
749 from the CPFV logbook index early in the time series, but both show an increase in the
750 mid to late 1990s. The PC dockside index was excluded from further analysis in the model
751 given that the CPFV logbook index represents the same sector of the fishery and presumably
752 contains data from the some of the same trips, utilizes data for many thousands more trips,
753 and provides data from 1989 to 1992 omitted from the MRFSS data as a result of filtering
754 out 1989 and a lapse of sampling from 1990-1992.

755 *Party/Charter Dockside Length Measurements*

756 The retained catch for the recreational party/charter mode has been measured during the
757 dockside interviews since 1980, and also by two different onboard observer programs in
758 southern California by Collins and Crooke (n.d.) a combination of unpublished data and
759 a study by Ally et al. (1991) from 1984-1989 (Table 15). The length measurements from
760 Collins and Crooke (n.d.) are assumed to all be from retained fish.

761 Length measurements for California scorpionfish from 1980-2016 were provided from RecFIN
762 by Edward Hirsch (PSMFC) on November 29, 2016. The number of trips from 1980-2003
763 is the number of trips with observer catch of California scorpionfish as outlined in the
764 Supplemental Material (“Identifying Trips in RecFIN”). However, the algorithm used to
765 determine the number of trips has not been applied to RecFIN data past 2003. The number
766 of trips for 2004 and 2005, was taken as the ratio of the number of interviews (ID_CODE) in
767 RecFIN to the number of known trips for years with complete data. The number of individual
768 ID_CODEs was reduced by 38% for 2004 and 2005, and gives reasonable sample sizes. From
769 2004-2016 the number of trips from which the samples were taken is known.

770 From 1985-1987 Ally et al. (1991) conducted an onboard observer program in southern
771 California, and measured both retained and discarded fish. Additional unpublished years

772 (1984, 1988-1999) from this onboard observer sampling program were provided by CDFW
773 (Paulo Serpa). From 1984-1989, the onboard observer program measured 11,892 retained
774 California scorpionfish compared to the 1,981 measurements in RecFIN. It is almost certain,
775 but cannot be verified, that some of the lengths from the onboard observer program were
776 input in RecFIN. Therefore, the onboard observer measurements from 1984-1989 are used
777 instead of those from RecFIN for these years.

778 Onboard Observer Party/Charter Boat

779 California implemented a statewide Onboard Observer Sampling Program in 1999, and began
780 measuring discarded fish in 2003 (Monk et al. 2014). The goal of the Onboard Observer
781 Sampling Program is to collect data including charter boat fishing locations, catch and discard
782 of observed fish by species, and lengths of discarded fish. The program samples the CPFV
783 fleet, i.e., charter boats or for-hire boats, and collects drift-specific information at each fishing
784 stop on an observed trip. At each fishing stop recorded information includes start and end
785 times, start and end location (latitude/longitude), start and end depth, number of observed
786 anglers (a subset of the total anglers), and the catch (retained and discarded) by species of
787 the observed anglers.

788 CDFW implemented a regulation of three hooks in 2000, which was reduced to (and remains
789 at) two hooks in 2001. CDFW also implemented a 10 inch size limit for California scorpionfish
790 in 2000. The length composition of retained in discarded California scorpionfish (both before
791 and after the minimum size restriction). Prior to 2001, there were no depth restrictions for
792 the southern California recreational fishery. Given these regulation changes, the data from
793 1999 and 2000 are excluded from the index.

794 From 2002 to 2005, the California scorpionfish fishery was closed from four to nine months of
795 the year. During these years, California scorpionfish were still encountered, but all discarded.
796 The onboard observer program provides the only available information on discards because
797 the sampler records both the retained and discarded catch at each fishing stop. The onboard
798 observer data are used to create two indices of abundance, one using only the discarded catch
799 and one using only the retained catch. The index of discarded catch is used as an index of
800 abundance for the recreational discard fleet, and the index derived from the retained catch is
801 treated a survey in the assessment model.

802 The entire dataset was filtered as one, regardless of retained or discarded, due to the fact that
803 discarding can occur for a number of reasons, e.g., angler preference, size limit, bag limit,
804 etc., and California scorpionfish are often retained and discarded on the same fishing drift.

805 Prior to any analyses, drifts with erroneous or missing data were removed from the data
806 considered for the California scorpionfish index. The locations of positive encounters (retained
807 + discarded) were mapped, using the drift starting locations. Regions of suitable habitat
808 were defined by creating detailed hulls (similar to an alpha hull) with a 0.01 decimal degree
809 buffer around a location or cluster of locations. Any portion of a region that intersected
810 with land was removed. Drifts that did not intersect with one of these areas were considered
811 structural zeroes, i.e., outside of the species habitat, and not used in analyses.

812 Five areas were retained based on sample sizes, 1) nearshore area from the U.S./Mexico
813 border to Oceanside, 2) nearshore Oceanside to Newport Beach, 3) Newport Beach to Palos
814 Verdes, 4) Palos Verdes to Point Magu, and 4) drifts from Santa Cruz Island, Santa Barbara
815 and Anacapa Islands, Santa Catalina Island, and San Clemente Islands were combined.
816 Drifts encountering California scorpionfish north of Point Magu were rare (<5% positive
817 encounters).

818 Drift locations within the Cowcod Conservation Area (CCA) or in Mexican waters were also
819 filtered out of the dataset. The years 1999 and 2000 were removed from the index due to
820 changes in hook and gear regulations during those years. California adopted a 3-hook and
821 1-line regulation in 2000, which changed to 2-hooks and 1-line in 2001. California scorpionfish
822 is not a common target species for the CPFV fleet, but if often a fallback species, for trips
823 targeting seabass or rockfish. California scorpionfish are targeted more often in January
824 and February when the rockfish/cabezon/greenling complex is closed. Boat identifiers were
825 available for all trips in the onboard observer database. Approximately 1,000 drifts were
826 filtered out after accounting for boats that were identified as not encountering scorpionfish
827 (Table 16). A total of 26,733 drifts for the analysis were retained. Of these, 5,507 encountered
828 scorpionfish, with 3,249 discarding California scorpionfish and 3,867 retaining California
829 scorpionfish.

830 The drift-level effort cannot be parsed out between the retained and discarded catch. The
831 effort represents the total angler hours fished by the subset of observed anglers for a particular
832 drift, and is the same for both the discard-only and retained-only indices. Both of the indices
833 derived from this dataset were standardized using a delta modeling approach (Lo et al. 1992).

834 *Onboard Observer Discarded Catch Index*

835 Covariates considered in the full model included *year*, *area* (5 levels), *month* (12 levels), and
836 *20 m depth bins* (5 levels). All covariates were specified as categorical variables. A lognormal
837 model for the positives was selected by AIC over a gamma model (delta-AIC of 482.28).
838 Model selection for both the lognormal and binomial models retained all covariates (Table
839 17). The Q-Q plot for the positive catch lognormal model looks reasonable (Figure 13). The
840 final index shows a lower CPUE of the discards in 2001 and an increase from 2002-2005 when
841 the California scorpionfish recreational fishery was restricted by depth or closed (Table 18
842 and Figure 14). The relative CPUE of the discards decreases from 2006 to 2015.

843 *Discarded Catch Length Composition*

844 As of 2003, Onboard Observer program has taken length measurements for discarded fish.
845 The retained catch is measured during the dockside (angler intercept) surveys, and cannot
846 necessarily be matched to a trip with the discard lengths prior to 2012. Additional discarded
847 length measurements were available from both CDFW unpublished data (1984, 1988-1989)
848 and the Ally et al. (1991) onboard observer program from 1985-1987. The sample sizes of
849 measured discarded fish in the 1980s is small. The mean length of discarded fish is smaller
850 than for years when the length restriction was in place (Table 19 and Figure 15).

851 The discard length composition reflects the California scorpionfish seasonal closures from
852 2002-2005. Anglers encountered and discarded fish greater than the size limit of 10 inches
853 during these years. When the fishery is open, anglers are most often only discarded California
854 scorpionfish that are smaller than the legal size. This also holds true for the length composition
855 of discarded California scorpionfish in the 1980s before there was a size limit.

856 *Onboard Observer Retained Catch Index*

857 The index of relative abundance using the retained-only catch from the onboard observer
858 program is a separate survey fleet in the base model and has no lengths associated with it.
859 Covariates considered in the full model included *year*, *area* (5 levels), *month* (12 levels), and
860 *20 m depth bins* (5 levels). All covariates were specified as categorical variables. A lognormal
861 model was selected by AIC over a gamma model for the positives (delta-AIC of 534.9). Model
862 selection for both the lognormal and binomial models retained all covariates (Table 20). The
863 Q-Q plot for the positive catch lognormal model looks reasonable (Figure 16). The final index
864 shows a lower CPUE of the retained catch from 2002 and 2003 (Table 21 and Figure 17). The
865 relative CPUE of the retained catch shows a decline from 2007-2015, and an increase in 2016.

866 **2.1.6 Fishery-Independent Data Sources**

867 **Publicly Owned Treatment Works (POTWs) Monitoring Trawl Survey**

868 Publicly Owned Treatment Works (POTWs; referred to the sanitation index in the stock
869 assessment model and associated plots) that discharge into coastal waters are required to
870 conduct trawl surveys to monitor the demersal fish community in the vicinity of the discharge
871 sites as a condition of the
872 National Pollutant Discharge Elimination System (NPDES) permits, issued by the Environmental
873 Protection Agency if the discharge is to federal waters, and the State Water Resources
874 Control Board if discharge is into state waters. All POTWs holding NPDES permits in southern
875 California were contacted for trawl data. The two northernmost districts, Goleta and the
876 City of Oxnard, provided data (via Aquatic Bioassay & Consulting Laboratories, Inc.), but
877 California scorpionfish have not been encountered in either district's trawl surveys. The four
878 other POTWs, Orange County, The City of Los Angeles Environmental Monitoring Division
879 (CLAEMD), Los Angeles County, and the City of San Diego Public Utilities Department all
880 encounter California scorpionfish and provided trawl data (Figures 18 and 19).

881 All of the POTWs sample using the same protocols and gear as the Southern California Bight
882 Regional Monitoring Program. The trawl net is a 7.6 m wide Marinovich, semi-balloon otter
883 trawl (2.54 cm mesh) with a 0.64 cm mesh cod-end liner.

884 A description of the data provided by each POTW is provided. In contrast to the inverse
885 variance weighted index from the 2005 assessment, trawls from all POTWs were combined to
886 develop a single index of abundance.

887 *Orange County.*

888 The Orange County Sanitation District provided trawl data from 1970-2015 (Jeff Armstrong,
889 Orange County Sanitation District). Fixed stations are sampled either annually (summer) or
890 semi-annually in the winter and summer, Quarters 1 and 3 (Jan-March and July-September).
891 From 1970-1985 Quarter 2, trawl effort was based on a 10 minute tow time. As of 1985 Quarter
892 3, trawls were towed a distance of 450 m. Tow time was not available for approximately half
893 of the tows from 1985 Quarter 3 to 2016, and was imputed based on the mean tow time of
894 the sampling station.

895 Eleven stations (T0-T6,T10-T13) sampled in at least 11 years and with California scorpionfish
896 present in at least 5% of trawls were retained for the analysis (1,490 trawls). For hauls with
897 fewer than 30 California scorpionfish, each fish was measured to the nearest mm (standard
898 length). In hauls with more than 30 California scorpionfish, they were tallied by size class
899 (nearest cm). Six hauls, all from station T3, caught more than 30 California scorpionfish.
900 From these six hauls, 30 California scorpionfish were measured to the nearest mm, and the
901 remainder were binned to cm size classes.

902 *The City of Los Angeles Environmental Monitoring Division (CLAEMD).*

903 The CLAEMD provided trawl data from 1986-2016 (Craig Campbell, Lost Angeles City).
904 The CLAEMD follows the same sampling protocols as the Southern California Bight Regional
905 Monitoring Program trawl survey. Stations within Los Angeles Harbor were excluded from
906 the dataset. Years with fewer than ten total hauls were removed from the analysis (1986,
907 1987, and 1992), as were station sampled in fewer than 10 years. Ten stations (A1, A3, C1,
908 C3, C6, C9A, D1T, Z2, Z3, Z4), total 921 hauls, were retained for the index of abundance.

909 Tow times were recorded starting in 1999, and assumed to be 10 minutes prior to 1999. Haul
910 depth was missing for approximately half of the hauls, and was imputed as the mean depth
911 of other hauls at that station. All California scorpionfish encountered were measured to the
912 nearest cm (standard length).

913 *Sanitation Districts of Los Angeles County.*

914 The Sanitation Districts of Los Angeles County provided quarterly trawl data from 1972-2016
915 (Shelly Walther, Sanitation Districts of Los Angeles County) and follow the same sampling
916 protocols as the Southern California Bight Regional Monitoring Program. Trawl survey
917 stations sampled in fewer than 10 years or at 305 m where California scorpionfish were never
918 observed were removed from the analysis. Non-standard and special study trawls were also
919 removed, e.g., night trawl study in 1987. Hauls were based on a 10 minute tow time and that
920 is assumed as the effort for all hauls. Twelve stations (stations at 23 m, 61 m, and 137 m for
921 T0, T1, T4, and T5), totaling 1,848 hauls were retained after initial filtering. All California
922 scorpionfish encountered were measured to the nearest cm (standard length).

923 *City of San Diego Ocean Monitoring Program.*

924 The City of San Diego's Ocean Monitoring Program is conducted by Environmental Monitoring
925 & Technical Services Division of the Public Utilities Department (City of San Diego Public
926 Utilities Department). The City of San Diego holds three NPDES that require monitoring
927 of the areas potentially impacted by the discharge of wastewater into the Pacific Ocean via
928 the Point Loma Ocean Outfall and South Bay Ocean Outfall (Timothy Stebbins, personal
929 communication, City of San Diego Public Utilities Department). One permit is for the City's
930 Point Loma Wastewater Treatment Plant discharge via the Point Loma Ocean Outfall. A
931 second permit is for discharge via the South Bay Ocean Outfall from the City's South Bay
932 Water Reclamation Plant. The third permit is also for discharge via the South Bay Ocean
933 Outfall, but from the South Bay International Wastewater Treatment Plant operated by the
934 U.S. Section of the International Boundary & Water Commission (USIBWC).

935 Effluent from the two South Bay treatment facilities commingle before discharge to the
936 ocean, so a single monitoring program is conducted by the City and USIBWC to meet those
937 requirements (i.e., the City conducts the joint program under contract to the USIBWC). For
938 purposes of this assessment, any trawls conducted in Mexican water, were excluded from
939 analyses.

940 The City of San Diego Public Utilities Department provided trawl data from 1985-2015 (Ami
941 Latker and Robin Gartman, City of San Diego Public Utilities Department) and follow the
942 same sampling protocols as the Southern California Bight Regional Monitoring Program.
943 Stations sampled in fewer than 15 years were filtered from the dataset. Fourteen stations
944 from the Point Loma Ocean Outfall (SD1-SD14) and five stations from the South Bay Ocean
945 Outfall were retained (SD17-21), totaling 1,180 hauls. A tow time of 10 minutes is assumed
946 for all trawls. All California scorpionfish encountered were measured to the nearest cm
947 (standard length).

948 *POTWs Index Standardization*

949 Trawls from all POTWs were combined to standardize the index of relative abundance. This
950 is in contrast to the 2005 assessment that standardized each of the sanitation district indices
951 independently and combined them using an inverse variance weighting approach (Maunder
952 et al. 2005). One reason for this was that the 2005 base model going into the STAR panel
953 was five sub-models for the southern California Bight. Taking into consideration that the
954 2017 base model is a one-area model, all of the sanitation districts follow the same sampling
955 protocols and the sampling design is a fixed station approach, the decision was made to
956 develop a single index. The index was standardized using a delta-GLM approach.

957 The data were filtered for each sanitation district independently. The filters applied are
958 described in the sections above and summarized in Table 22. The covariates considered for
959 the lognormal and binomial models were *year* (47 levels), *quarter* (4 levels), and *station* (52
960 levels). A lognormal model for the positives was select over a gamma model by a delta AIC
961 of 619. AIC model select was used for both the lognormal and binomial models and all three
962 covariates were selected for both (Table 23). The standardized index shows a large spike
963 in relative CPUE in 1981, varies within a range of 0.1 to 0.25 from 1989 to 2009, and then
964 declines until 2013 (Figure 20). The last three years of the index show an increase in relative

abundance. The final standardized index and log-standard error can be found in Table 24.
We did explore standardizing the indices independently. However, this results in a loss of
data, as some sanitation district had low sample sizes in some years. The general trend in
relative CPUE is similar across sanitation districts (Figures 21).

969 *POTWs Length Composition*

970 Each district measures every fish encountered in their survey. Orange County Sanitation
971 District was the only program sampling in 1970 and 1971 and encountered a small number
972 of California scorpionfish in those years (Figure 22). Los Angeles County has encountered
973 pulses of large numbers of California scorpionfish in 2002, 2004 and 2005. Figure 23 shows
974 the distribution of lengths for California scorpionfish by 25 m depth bins and Sanitation
975 District. The median length
976 of fish from the CLAEMD trawls is smaller than the other two districts. However, there are
977 only 120 fish encountered in that depth range, compared to 1,372 fish encountered in the
978 50-74 m depth range (Table 25).

979 The length composition indicates a fairly consistent size range of fish encountered in the
980 trawl surveys, with a handful of smaller fish in 2016 (Figure 24). Length measurements from
981 all 5,525 hauls of the POTWs were combined across POTWs. The number of California
982 scorpionfish was slowest during the first few years of the time series, and also declines starting
983 in 2012 (Table 26).

984 **NWFSC Trawl Survey Index**

985 The Northwest Fishery Science Center has conducted combined shelf and slope trawl surveys
986 (hereafter referred as NWFSC trawl survey) since 2003, based on a random-grid design from
987 depths of 55 to 1280 meters. Additional details on this survey and design are available in
988 the abundance and distribution reports by Keller et al. (2008). The haul locations and raw
989 catch rates (in log scale) are shown in Figure 25.

990 The proportions of positive catch haul and the raw catch rates of positive hauls by depth and
991 latitude are shown in Figure 25 and Figure 27, respectively. These figures show that more
992 scorpionfish were caught at shallow depth zones and in the southern latitude zones. Box
993 plots of length summary data by depth and sex (Figure 29) and by latitude and sex (Figure
994 29) show no evidences of different spatial distributions (by depth and latitude) by length or
995 by sex.

996 The numbers of total hauls and percentages of positive catch hauls by depth and latitude
997 zones are presented in Tables 27 and 28, respectively. Summaries of raw catch data by year
998 are listed in Table 29. Overall, catches of scorpionfish by the survey were very low with
999 less than 1mt fish caught during the entire 14 years of the survey. Bubble plots of length
1000 frequency distribution by year and sex are presented in Figure 30.

1001 Summaries of age data by year and sex are presented in Table 30. There were more males (n
1002 = 529) aged than females (n = 340), presumably indicating that there are more males than

1003 females in the populations. The table also shows that mean ages and mean lengths for both
1004 sexes decreased in recent years. Table 31 show five percentiles of fish aged by sex, indicating
1005 more older males in the population. All aged data from the survey were used as conditional
1006 age-at-length matrix in the assessment model. The mean age-at-length indicates males and
1007 females to have similar growth patterns until around age three, at which time, females are
1008 larger than males (Table 32).

1009 Total biomass estimates from the survey were analyzed using the VAST program (Thorson
1010 and Barnett 2017). The Q-Q goodness of fit plot, maps of the Pearson residuals for encounter
1011 probability and positive catch rates, and time series of total biomass estimates are shown in
1012 Figures 31, 32, 33, and 34, respectively. The Q-Q plots shows generally good fits and the time
1013 series of biomass estimates indicates no significant trend with relatively large uncertainties
1014 from the survey. The final survey index and log standard error used in the assessment model
1015 are in Table 33.

1016 CSUN/VRG Gillnet Survey Index

1017 California State University Northridge with Vantuna Research Group (CSUN/VRG) con-
1018 ducted a gillnet survey from 1995-2008 (Daniel Pondella, VRG). Sites along the coast from
1019 Santa Barbara to Newport were consistently sampled for the time series, as well as Catalina
1020 Island. Gillnet sets from within Marina Del Rey and Catalina Harbor were removed from the
1021 analysis.

1022 All gillnets were the same length with six-25' panels (150' in length).
1023 The standard sampling gillnet had 1“, 1.5“, 2 square mesh, with each mesh on two panels.
1024 Samples were excluded if they were collected using a net other than the standard sampling
1025 gear. Other data filters included remove months that were not consistently sampled (Table
1026 34).

1027 Five covariates were considered in the model standardization, *year* (14 levels), *month* (8
1028 levels), *site* (8 levels indicating the sampling site location), *float* (2 levels indicate if floats
1029 were used on the gillnet), and *perp/para* (2 levels indicate if the net was set perpendicular or
1030 parallel to shore). A lognormal was select over a gamma model for the positive encounters
1031 by a delta AIC of 108.29. Covariates selected via AIC for both the lognormal and binomial
1032 models included *year*, *site*, and *perp/para* (Table 35, Figure 35). The standardized index
1033 decreases from 1995-1998 and remains flat until through the early 2000's with three high
1034 years at the end of the time series (Figure 36).

1035 The survey measured (standard length) every California scorpionfish encountered, totaling
1036 1,130 fish. The majority of fish encountered were between 14 and 33 cm total length, with no
1037 strong trends or patterns in age classes during the time period (Figure 37)

1038 Southern California Bight Regional Monitoring Project Trawl Survey

1039 The southern California Coast Water Research Project SCCWRP works to bring together
1040 over 60 agencies in southern California, including all of the aforementioned POTWs, that

1041 conduct monitoring of aquatic environments. One of the monitoring programs in the Southern
1042 California Bight (SCB) is a trawl survey conducted every five years. The pilot year of the
1043 survey was 1994. Data from each of the survey years (1994, 1998, 2003, 2008, and 2013) were
1044 provided by the SCCWRP (Shelly Moore, SCCWRP).

1045 In each of the five years of the study, sampling stations were chosen via a stratified random
1046 sampling design (Bight '98 Steering Committee 1998) (Figure 38). All participating agencies
1047 follow the same protocols (net is towed 10 minutes at a speed of 1.0 m/sec) and use the same
1048 net (semiballoon otter trawl). All fish and invertebrates are identified, counted, batch-weighed,
1049 and measured (standard length to the nearest cm).

1050 A series of data filters were applied to the dataset (Table 37). Only two scorpionfish were
1051 encountered in hauls deeper than 450 m. Ninety-five percent of the data were retained for
1052 hauls in shallower than 97 m, which was set as a filter. Stations in harbors (2/114 positive
1053 hauls), north of Ventura (6/190 positive hauls) and the islands (16/117 positive hauls) were
1054 excluded due to low encounters of California scorpionfish. The final dataset included 398
1055 hauls, 129 of which encountered California scorpionfish. The unit of effort for this survey is
1056 in kg per tow time (minutes).

1057 Covariates considered for the delta-GLM model were *year* (5 levels), *area* (4 regions), and
1058 *month* (3 levels; July-September). Sampling stations were assigned to one of four regions, 1)
1059 Ventura to Long Beach, 2) Long Beach to Dana Point, 3) Dana Point to San Diego, and 4)
1060 San Diego to the U.S./Mexico Border. A lognormal model was selected over a gamma model
1061 for the positives by a delta AIC of 30. Depth (20-m depth bins) were considered, but none
1062 of the levels were significant in a full lognormal or binomial model and was not considered
1063 further. AIC selection for both the lognormal and binomial models selected all covariates
1064 for the final model (Table 38). The Q-Q plot used to evaluate the goodness-of-fit of the
1065 lognormal portion of the model is in Figures 39.

1066 The standardized index of abundance indicates higher relative CPUE in 1994 and 2003, with
1067 the other three years lower (Figure 40). The fact that the survey is conducted every five years
1068 (4 years between the pilot and the 1998 survey), may preclude drawing any firm conclusions
1069 on trends in abundance from this data.

1070 The survey measured a total of 427 fish, with the last two years of the survey (2008 and
1071 2013) only encountering 25 and 53 California scorpionfish, respectively.
1072 However, the smallest fish observed in this survey were in 2013 (Figure 41).

1073 Generating Station Impingement Surveys

1074 Data from the southern California generating station surveys were provided by Eric Miller
1075 (MBC Applied Environmental Sciences). The generating stations all draw in seawater
1076 through an intake system for once-through cooling water. There are five generating stations
1077 that conduct normal operation and heat treatment surveys with observations of California
1078 scorpionfish: Scattergood Generating Station (SGS), El Segundo Generating Station (ESGS),

1079 Redondo Beach Generating Station (RBGS), Huntington Beach Generating Station (HBGS),
1080 and San Onofre Generation Station (SONGS). Each generating station draws in water from
1081 different depths and distances from shore: SGS draws from 500 m offshore at 6 m depth,
1082 ESBS draws from 700 m offshore at 9.8 m depth, RBGS draws from 289 m offshore at 13.7 m
1083 depth, HBGS draws from 500 m offshore at 5 m depth, and SONGS has two intake systems
1084 960 m and 900 m offshore and at 9 m and 8 m depth, respectively (Miller et al. 2009).

1085 The two surveys conducted are normal operations surveys and heat treatment surveys. For
1086 normal operations surveys, the intake screens are rotated and cleaned to start the survey.
1087 All of the impinged fish are washed off the screen at this time and discarded. When the
1088 intake screens stop running, the survey begins. The generating station then operates as
1089 normal for 24 hours, which includes operating and washing the screens as usual (typically
1090 every eight hours). The screens are then operated and washed again after a second 24 hours
1091 has elapsed. Any specimens washed off the screens during the 48 hour study period are
1092 retained. The total sample is processed to identify, count, weigh, and measure the fish and
1093 macroinvertebrates. There is often no information on the water flow collected during the
1094 48 hour period of the normal operations survey. Most fish enter the generating station and
1095 swim in the sedimentation basin until either getting exhausted or impinged. The SONGS
1096 generating station also has a fish elevator that releases a fraction of the fish back to the ocean.

1097 At each generating station, cooling water, i.e., seawater, is pumped into the generating station
1098 where it reaches a sedimentation basin. Water flow is one-directional, and fish can reside
1099 in this area, but not escape. During a heat treatment, water in the sedimentation basin is
1100 heated to over 38 degrees Celsius, killing all fish and invertebrates, and impinging them on
1101 the travelling screens.

1102 The screens are operated and washed off per normal operating procedures right up until the
1103 heat treatment takes place. Therefore, only the fish remaining in the sedimentation basin
1104 and those impinged since the last screen rotation are counted in the heat treatment survey.
1105 The total flow between heat treatments has previously been used to standardize indices in
1106 previous reports. However, this is not representative of the flow relating to fish impinged
1107 during the heat treatment. The water flows vary widely among heat treatments, time of
1108 year (higher in summer when energy demands increase), and generating stations. Therefore,
1109 the generating station impingement surveys were not used to develop indices of abundance.
1110 However, length composition data from the impingement surveys were used.

1111 The length composition data from the impingement show a higher proportion of smaller (<10
1112 cm) fish since 2012 (Figure 42)

1113 *California Cooperative Oceanic Fisheries Investigations (CalCOFI) Survey* UCSD Scripps
1114 Institution of Oceanography, CDFG, and the National Marine Fisheries Service have carried
1115 out a plankton survey on a regular basis since 1951 (Moser et al. 1993). Prior to 1965,
1116 *Scorpaena* samples were not speciated.

1117 California scorpionfish larvae encounters from CalCOFI surveys were provided by Noelle
1118 Bowlin (NMFS SWFSC). Only 16 positive bongo tows in the core area (lines 77-93) encoun-

1119 tered California scorpionfish. The majority of the 335 positive bongo tows occurred in Mexico,
1120 south of Punta Eugenia Baja California and are likely a combination of California scorpionfish
1121 and other *Scorpaena* species. The California scorpionfish egg masses are encountered in
1122 the CalCOFI surveys, but because California scorpionfish is not a target species they are
1123 entered in the database as “unidentified eggs” (William Watson, NMFS SWFSC). An index
1124 of abundance was not developed for the CalCOFI data due to the small sample sizes.

1125 2.1.7 Biological Parameters and Data

1126 California scorpionfish do not have a forked tail, therefore total length and fork length are
1127 equal. Love et al. (1987) provide conversion factors between standard length (SL) and total
1128 length (TL): $TL = 1.21SL + 1.02$ and $SL = 0.82TL - 0.69$.

1129 Standard and total lengths of 163 California scorpionfish were available from a halibut trawl
1130 survey in southern California (Steve Wertz, CDFW). The conversion from SL to TL from
1131 these data was estimated at $TL = 1.2225SL + 0.7773$.

1132 The conversion originating from the halibut trawl data was used in this assessment due to
1133 the fact that the original data from Love et al. (1987) are not available. The majority of
1134 available length composition data were measured to total length, except for the POTW trawl
1135 surveys, the Southern California Bight Regional Monitoring Program trawl survey, and the
1136 CSUN/VRG gillnet survey (gillnet survey). Maunder et al. (2005) converted all data to
1137 standard length due to clumping of data when length data are only available to the nearest
1138 centimeter. However, the same is true for the conversion from TL to SL when data were
1139 available to the nearest centimeter. All length data for this assessment are in TL. The Orange
1140 County Sanitation District and the VRG gillnet study measured SL to the nearest mm.

1141 To avoid missing length bins (specifically 18, 23, 29 cm) in the conversion from SL to TL,
1142 0.5 was first subtracted from each SL and a random uniform number ($U[0, 1]$) was added to
1143 the SL measurement. All TL measurements were rounded to the nearest length centimeter
1144 length bin. A comparison of the length distributions

1145 Length and Age Compositions

1146 Length compositions were provided from the following sources:

- 1147 • CDFW market category study (*commercial dead fish*, 1996-2003)
- 1148 • CALCOM (*commercial dead fish*, 2013-2016)
- 1149 • CDFW onboard observer (*recreational charter discards*, 2003-2016)
- 1150 • Ally onboard observer study (*recreational charter discards*, 1984-1989)
- 1151 • California recreational sources combined (*recreational charter retained catch*)
 - 1152 – CDFW and Ally onboard observer surveys (1984-1989)
 - 1153 – Collins and Crooke onboard observer surveys (1975-1978)
 - 1154 – MRFSS (1980-2003)

- CRFS (2004-2014)
 - California recreational sources combined (*private mode retained catch*)
 - MRFSS (1980-2003)
 - CRFS (2004-2016)
 - POTW trawl surveys (*research*, 1970-2016)
 - CSUN/VRG gillnet survey (*research*, 1995-2008)
 - Power plant impingement surveys (*research*, 1974-2016)
 - Southern California Bight trawl survey (*research*, 1994, 1998, 2003, 2008, 2013)
- The length composition of all fisheries aggregated across time by fleet is in Figure 43.
 Descriptions and details of the length composition data are in the above section for each fleet or survey.

Recreational: California MRFSS and CRFS Length Composition Data

Individual fish lengths recorded by MRFSS (1980-2003) and CRFS (2004-2011) samplers were downloaded from the RecFIN website (www.recfin.org). CRFS data from 2012-2014 were obtained directly from CDFW.

Age Structures

Age data were provided from the NWFSC trawl survey from 2005-2016, and all of the otoliths collected from the survey were aged. Figures 44 and 45 provide examples of California scorpionfish otoliths read (including double-reads) by the Cooperative Ageing Project (CAP) in Newport, Oregon.

A total of 879 otoliths were read, and ranged from 0-29 years of age. Fewer than 1% (8 fish) were aged 22 years or older, and only one age-0 fish was in the sample (Figure 46).

Males and females exhibit different growth patterns with females growing to be larger at a smaller age (Figure 46). Sex-specific length-at-age was initially estimated external to the population dynamics models using the von Bertalanffy growth curve (Bertalanffy 1938), $L_i = L_\infty e^{(-k[t-t_0])}$, where L_i is the length (cm) at age i , t is age in years, k is rate of increase in growth, t_0 is the intercept, and L_∞ is the asymptotic length. The external parameter estimates for females were $L_\infty = 31.613$, $k = 0.250$, $t_0 = -2.280$, and for males $L_\infty = 27.374$, $k = 0.233$, $t_0 = -2.092$ (Figure 47).

Aging Precision and Bias

Uncertainty in ageing error was estimated using a collection of 200 California scorpionfish otoliths with two age reads (48).

Age-composition data used in the model were all from the NWFSC trawl survey and were from otoliths reads aged by the Cooperative Ageing Project (CAP) in Newport, Oregon. All of the otolith reads were from Age Reader A, and double reads were read by Age Reader B.

1190 Ageing error was estimated using publicly available software (Thorson et al. 2012).
1191 The software setting for bias and standard deviation were the same for both readers, unbiased
1192 and curvilinear increase in standard deviation with age, respectively (Figure 49). Two fish
1193 with estimated age greater than 21 (plus group age) were excluded from the ageing error
1194 estimation. The resulting estimate indicated a standard deviation in age readings increasing
1195 from 0.001 years to a standard deviation of 1.79 years at age 22.

1196 Weight-Length

1197 The weight-length relationship is based on the standard power function: $W = \alpha(L^\beta)$ where
1198 W is individual weight (kg), L is length (cm), and α and β are coefficients used as constants.
1199 Sex-specific weight-length relationships were estimated from the NWFSC trawl survey data.
1200 Length and weight data were available for 340 females and 530 males. The estimated
1201 parameters for females are $\alpha = 1.553983e^{-05}$ and $\beta = 3.057654$, and for males $\alpha = 1.9104e^{-05}$
1202 and $\beta = 2.980548$. Love et al. (1987) found males to be heavier at a given length than
1203 females, whereas the NWFSC data suggests the opposite (Figure 50).

1204 The original data from Love et al. (1987) are no longer available (Milton Love, personal
1205 communication, UC Santa Barbara) to re-examine the trends. The weight-length relationships
1206 estimated from the NWFSC survey are consistent with the sex-specific growth rates and are
1207 used in the assessment model.

1208 Sex Ratio, Maturity, and Fecundity

1209 The NWFSC trawl survey is the only study available with raw data on sex ratios by age.
1210 Across all ages, the sex ratio from the aged California scorpionfish from the NWFSC trawl
1211 survey was 60% males and 40% females (Table 40). At age-1, 39% of the aged fish were female
1212 (29 of 85), but the sex of 10 fish was unknown. For ages two to five, the percent of female
1213 fish ranged from 45-54%, with aged fish older than five dominated by males. The assessment
1214 assumed a sex ratio at birth was 1:1. The NWFSC trawl survey samples a minimum depth
1215 of 55 m and no information on sex ratios was available from other surveys.

1216 Love et al. (1987) conducted the only published life history study of California scorpionfish,
1217 but did not report information on sex ratios. Differing numbers of sample sizes (males and
1218 females) were used for each part of the study (ex. maturity and length-at-age). The raw data
1219 from this study are no longer available, and we were not able to determine raw samples sizes
1220 by sex.

1221 No new data on maturity or fecundity for California scorpionfish are available since the
1222 publication of the 2005 stock assessment. Love et al. (1987) found few California scorpionfish
1223 to be mature at age-1, 50% of males were mature at 17 cm TL and over 50% of females were
1224 mature by 18 cm TL, or two years of age. All fish were mature by 22 cm TL. This assessment

1225 used size at 50% maturity for females of 18 cm TL, with maturity asymptoting to 1.0 for
1226 larger fish.

1227 The 2005 assessment model combined information from estimated linear gonadal somatic
1228 index and maturity based on standard length (Maunder et al. 2005). However, the study used
1229 to estimate the GSI, was a halibut targeted trawl study using a mesh size of 10.2 cm (Steven
1230 Wertz, personal communication, CDFW). This assessment assumed linear relationship for
1231 eggs per kilogram.

1232 **Natural Mortality** Hamel (2015) developed a method for combining meta-analytic ap-
1233 proaches to relating the natural mortality rate M to other life-history parameters such as
1234 longevity, size, growth rate and reproductive effort, to provide a prior on M . In that same
1235 issue of ICESJMS, Then et al. (2015), provided an updated data set of estimates of M and
1236 related life history parameters across a large number of fish species, from which to develop
1237 an M estimator for fish species in general. They concluded by recommending M estimates
1238 be based on maximum age alone, based on an updated Hoenig non-linear least squares
1239 (nls) estimator $M = 4.899 * A_{max}^{-0.916}$. The approach of basing M priors on maximum age
1240 alone was one that was already being used for west coast rockfish assessments. However,
1241 in fitting the alternative model forms relating $-0.916M$ to A_{max} , Then et al. (2015) did
1242 not consistently apply their transformation. In particular, in real space, one would expect
1243 substantial heteroscedasticity in both the observation and process error associated with the
1244 observed relationship of M to A_{max} . Therefore, it would be reasonable to fit all models under
1245 a log transformation. This was not done. Reevaluating the data used in Then et al. (2015) by
1246 fitting the one-parameter A_{max} model under a log-log transformation (such that the slope is
1247 forced to be -1 in the transformed space (as in Hamel (2015)), the point estimate for M is:

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

1248 The above is also the median of the prior. The prior is defined as a lognormal with mean
1249 $\ln \frac{5.4}{A_{max}}$ and SE = 0.4384343. Using a maximum age of 21 the point estimate and median of
1250 the prior is 0.2545, which is used as a prior for females in the assessment model.

1251 2.1.8 Environmental or Ecosystem Data Included in the Assessment

1252 In this assessment, neither environmental nor ecosystem considerations were explicitly included
1253 in the analysis. This is primarily due to a lack of relevant data and results of analyses
1254 (conducted elsewhere) that could contribute ecosystem-related quantitative information for
1255 the assessment.

1256 **2.2 Previous Assessments**

1257 **2.2.1 History of Modeling Approaches Used for this Stock**

1258 California scorpionfish was first assessed in 2005 (Maunder et al. 2005) using SS2 (version
1259 1.18). The 2005 model was a one-area model for the population south of Pt. Conception to
1260 the U.S.-Mexico border. The assessment was sensitive to the inclusion of the POTW trawl
1261 survey index of abundance and the STAT team provided reference points for a model that
1262 included the POTW trawl survey index and one excluding it. The stock was found to be
1263 at 80% of unfished levels for the model with the POTW trawl survey index and 58% for
1264 the model without the POTW trawl survey index. The 2015 catch-only projections used
1265 the same version of SS2 as the 2005 assessment model. The 2005 model assumed removals
1266 equivalent to the ACL in all years from 2004-2016. The 2015 model included catch estimates
1267 from 2004-2014, and the ACLs for 2015 and 2016 were assumed to be attained. Maunder
1268 et al. (2005) assumed no discard mortality, while the 2015 update applied a 7% discard
1269 mortality rate derived by the Groundfish Management Team (GMT) (2009-2010 SPEX EIS,
1270 Chapter 4, pg. 290) was applied to the estimate of discards to provide an estimate of discard
1271 mortality for the recreational fleet.

1272 **2.2.2 2005 Assessment Recommendations**

1273 **Recommendation 1:** The POTW trawl surveys (referred to as sanitation district
1274 surveys in teh 2005 assessment) conducted to track the impact of sewage
1275 outfall provided a fishery independent index of abundance for scorpionfish.
1276 This data source should be more fully explored for other nearshore species
1277 of recreational or commercial interest. Methods should be developed to
1278 produce a more statistically rigorous index from the separate surveys.

1279
1280 STAT response: Data from all large POTWs in southern California were obtained for
1281 this assessment. All of the data were pooled across surveys to develop one index of
1282 abundance using the delta-GLM method

1283 **Recommendation 2:** An age, growth and maturity study for scorpionfish is
1284 needed. Although there has been previous research on scorpionfish age and
1285 growth, the available information is not appropriate for stock assessment
1286 modeling.

1287
1288 STAT response: Age data are available from the NWFSC trawl survey from 2005-2016.
1289 There have been no additional studies on growth or maturity for California scorpionfish
1290 since the 2005 assessment.

1291 **Recommendation 3:** Location information for the historic groundfish data of all
1292 species is currently available, in hard copy form only, from the California

1293 **Department of Fish and Game.** Putting this information into electronic
1294 format would greatly improve the ability to assign catches of all species to
1295 specific stocks on a trip-by-trip basis.

1296
1297 STAT response: The location-specific catches referred to above have been key-punched
1298 and are available in electronic form from the SWFSC, Santa Cruz.

1299 **Recommendation 4:** The SS2 model should be modified to allow for projections
1300 of user-specified recruitment at user defined values. It would be most
1301 helpful if the default harvest policies were then recalculated automatically
1302 for these user-specified recruitments.

1303
1304 STAT response: The status of this within Stock Synthesis is unknown.

1305 2.3 Model Description

1306 2.3.1 Transition to the Current Stock Assessment

1307 The first formal stock assessment for California scorpionfish was conducted in 2005 (Maunder
1308 et al. 2005). The 2005 model conducted in SS2 version 1.18 was first transitioned to SS3.24z
1309 as a bridge model, before moving forward to SS3.30. During the model transition to SS3.24z
1310 an error was found in the 2005 model. The harvest rate was estimated at the upper limit of
1311 0.9 and could not remove all of the input catch (Figure 51).

1312 The older SS2 output did not include separate columns for the observed (input) catch and
1313 dead removals by the model (output), which would have prevented the 2005 STAT team from
1314 discovering that the two time series differed (Figure 52). The recreational fishery selects the
1315 largest fish and removes the highest biomass of California scorpionfish. When the harvest rate
1316 hit the upper bounds as in the 1970s, there were not enough fish estimated in the population
1317 to support the large removals, i.e., stock estimated at 500 mt and the recreational catch was
1318 100 mt. The stock was not productive enough to sustain the observed catch. A comparison
1319 of time series from the 2005 model, the SS3.24z transition model, and the base model from
1320 this assessment are in Figure 53.

1321 Below, we describe the most important changes made since the last full assessment in 2005
1322 and explain rationale for each change. Some of these items are changes due to structure
1323 changes with Stock Synthesis, and some denote parameters chosen for options that were not
1324 available in SS2 (version 1.18).

1325 Changes in the bridge model from SS2 version 1.8 to SS3.24z and SS3.30.03.05 include:

1326 The way growth is modeled for age-0 fish has changed. More recent versions of Stock Synthesis
1327 model length-at-age for fish below the first reference age (Amin) as linearly increasing from

1328 the initial length bin to the length given by the L_at_Amin parameter. Since small California
1329 scorpionfish are selected in the POTW trawl survey data, the change in modeled growth has
1330 the potential to affect estimates of recruitment. We took the following approach in order to
1331 mimic the methods of SS2 version 1.8:

- 1332 1. Replaced initial value of length at minimum age for females with 7.26567 (the Length
1333 begin value for age 0 from the SS2.rep file).
- 1334 2. Replaced initial value of length at minimum age for males with 0.35366 (=
1335 LN(10.3483/7.26567), the log of the ratio of Male to Female length at age 0 from the
1336 SS2.rep file)

1337 This assessment aggregated the catches from the commercial fish pot fleet with the hook-
1338 and-line fleet. There were no measured California scorpionfish from the fish pot fleet and
1339 overall catches were minimal. The commercial trawl and gillnet fleets were disaggregated as
1340 in the 2005 model. The current model also assumes no discards in the commercial fishery.
1341 The previous assessment combined the recreational party/charter and private modes into a
1342 single fishery. This assessment disaggregates the two sectors of the recreational fishery and
1343 adds a fleet to represent the discards (party/charter and private modes combined) from the
1344 recreational fleet

1345 The 2005 model was a length-based model. This assessment uses conditional age-at-length
1346 from fish aged from the NWFSC trawl survey.

1347 The historical commercial catches were the same as those used in the previous assessment
1348 and were updated using CFIS data from 2005-2016. The CFIS database was used instead of
1349 CALCOM because landings in CALCOM included catches from Mexican waters.

1350 The recreational catches differed from the catch history used in the previous assessment. In
1351 2010 a catch reconstruction was completed for California (Ralston et al. 2010). Methods
1352 provided were applied in reconstructing the catch of California scorpionfish for this assessment.
1353 Both assessments utilized similar data sources including CPFV logbooks and MRFSS data
1354 providing catch estimates, with the addition of data from the CRFS program for 2004-2016.
1355 The main difference resides with accounting for discard mortality as well as landed catch
1356 allowing discards to be modeled as a separate fleet making use of length distribution data for
1357 discards for 2003-2016. In addition, the recreational catch time series terminated in 1928 for
1358 the current assessment, as specified for rockfish catch reconstructions in the historical catch
1359 reconstruction document, rather than in 1916. The ratio of catches for the party-charter boat
1360 mode to the private and rental boat mode from the MRFSS period were used in combination
1361 with catch estimates from the CPFV logbook estimates back to 1932 in both assessments to
1362 approximate mortality the private rental boat mode prior to 1980. A ramp accounting for
1363 the increase relative contribution of the private boat mode relative to the party charter mode
1364 from the mid 1965 to 1980, as conducted for rockfish in the historical catch reconstruction
1365 document. A constant ratio of catch compared to the party charter boat mode was applied

1366 for man-made and beach and bank modes to provide an estimate of catch back to 1936 as was
1367 done for the private and rental boat mode in the previous assessment. The CPFV logbook
1368 data terminated in 1935 and a linear ramp was used to approximate catch from 1936 back to
1369 zero in 1928 for each mode as compared to 1916 in the 2005 assessment.

1370 The bias adjustment for recruitment deviations did not exist in SS2 (version 1.198). We set
1371 1965-2015 as the range of years with full bias adjustment in SS3.24z to span the time series
1372 that was modeled.

1373 Length composition data was updated and sources added for this assessment. The 2005
1374 assessment used the same source for length compositions for the commercial fisheries, the
1375 CDFW market category study. The length compositions from CALCOM were all from single
1376 trips within a year and are not used in the assessment. The measured fish from RecFIN
1377 (dockside intercept surveys) were disaggregated to the party/charter and private modes.
1378 Preliminary analyses indicated the recreational private and rental boat mode selects larger
1379 fish than the party and charter boat mode (add plot).

1380 The 2005 assessment converted all length parameters to SL, which prevented comparisons
1381 with some of the growth parameters. The values in the SS files from the previous assessment
1382 also did not match those in the written document. The current model uses TL for all length
1383 compositions and growth parameters.

1384 The previous assessment modeled selectivity using the double logistic, with defined peak,
1385 and smooth joiners for all fleets with estimated selectivity. Two parameters were estimated
1386 for each selectivity curve, the size at which selectivity is halfway between the selectivity at
1387 length bin = 1 and one, and the slope of the left side of the selectivity curve. This selectivity
1388 pattern has since been discontinued in SS. All of the double logistic selectivity patterns in
1389 the 2005 assessment were asymptotic and are the same in this assessment. Selectivity in this
1390 model is assumed to be length-based and is modeled as double-normal for all fleets that were
1391 also in the previous assessment. This assessment mirrors the selectivity for the trawl and
1392 gillnet commercial fisheries to the commercial hook-and-line fishery. The 2005 assessment
1393 included two surveys, the CPFV logbook and POTW trawl surveys. The length composition
1394 measurement for the CPFV logbook survey are from the dockside intercept surveys in RecFIN
1395 and were updated to double normal selectivity in this model.

1396 The time blocks for the commercial fishery is the same as in the previous assessment (1916-
1397 1998 and 1999-2017). There have been no additional major changes to the commercial
1398 regulations since the 10-inch minimum size limit and the catches from the commercial fleets in
1399 the last 10 years have been minimal compared to historical catches. The time blocks for the
1400 recreational fleets were updated to include a third time block from 2000-2005, when closures
1401 of the recreational fishery fluctuated annually. Since 2006, the recreational regulations have
1402 remained fairly consistent.

1403 The 2005 assessment considered six candidate indices of abundance (fishery-dependent: CPFV
1404 logbook, CDFW monthly block summaries, RecFIN dockside intercept survey, trawl logbook;

1405 fishery-independent: POTW trawl survey, CalCOFI, but only included two in the final model
1406 (CPFV logbook and POTW trawl surveys). The POTW trawl surveys ended up being the
1407 basis for the decision table in the 2005 assessment, with more weight given to the model
1408 without the POTW trawl survey. All indices were re-evaluated and updated through 2016 for
1409 this assessment. As in the 2005 assessment, we did not consider the CaCOFI index, CDFW
1410 monthly block summaries, or the trawl survey for the current model. The current model
1411 includes four fishery-dependent indices and four fishery-independent indices. The RecFIN
1412 party/charter mode dockside intercept survey was not available at the trip-level in 2005 and
1413 it is unclear how the 2005 assessment treated data record entries from RecFIN; however,
1414 the RecFIN index was sensitive to the. The RecFIN private mode index is currently only
1415 available at the trip-level for the CRFS sampling period, 2004-2016. The onboard observer
1416 database was also not available for the 2005 assessment and is used here as both retained-only
1417 and discard-only indices. The CPFV logbook data was updated and reevaluated from the
1418 2005 assessment.

1419 The fishery-independent indices are all new for this assessment, except for the POTW trawl
1420 surveys.

1421 Maturity was changed for this assessment. The Love et al. (1987) study is the only study
1422 that estimated the maturity ogive. The CDFW cross-shelf halibut survey used in the 2005
1423 assessment to estimate the GSI were not used in this study as GSI is an indicator of fecundity.
1424 No information on fecundity is available for California scorpionfish. This assessment uses the
1425 assumption that eggs are equivalent to spawning biomass.

1426 In this assessment, steepness was set at 0.718, the mean of the beta prior developed from
1427 a meta-analysis of West Coast groundfish and updated in 2017 (James Thorson, personal
1428 communication, NWFSC, NOAA).

1429 The prior for female natural mortality was updated to the median of the prior from a meta-
1430 analysis conducted by Owen Hamel (personal communication, NWFSC, NOAA).
1431 Assuming a maximum age of 21 years, the median of the prior is 0.2547, close to the fixed
1432 value for younger fish in the 2005 assessment of 0.25.

1433 Due to the fact that the 2005 model was erroneous, a bridge from the 2014 catch update,
1434 which used SS2 version 1.8 and the 2005 model, was not developed.

1435 Changes in the bridge model from the SS3.24z model closely matched with the SS2 version
1436 1.8 model to SS3.30.

1437 2.3.2 Summary of Data for Fleets and Areas

1438 There are twelve fleets in the base model. They include:

¹⁴³⁹ *Commercial:* The commercial fleets include three separate fleets, one each for the hook-and-
¹⁴⁴⁰ line, gillnet, and trawl fisheries. The catch from all other commercial gears is included in the
¹⁴⁴¹ hook-and-line catch.

¹⁴⁴² *Recreational:* The recreational fleets include three separate fleets, one each for retained catch
¹⁴⁴³ from the recreational party/charter boat and private boat modes, and one for the dead
¹⁴⁴⁴ discards from the recreational party/charter boat and private boat modes combined.

¹⁴⁴⁵ *Research:* There are six sources of fishery-independent data available for California scorp-
¹⁴⁴⁶ onfish, including the POTW trawl surveys, NWFSC trawl survey, the CSUN/VRG gillnet
¹⁴⁴⁷ survey, the generating stations surveys, Southern California Bight regional monitoring trawl
¹⁴⁴⁸ survey, and the recreational party/charter onboard observer retained-only catch data.

¹⁴⁴⁹ 2.3.3 Other Specifications

¹⁴⁵⁰ Stock synthesis has a broad suite of structural options available. Where possible, the ‘default’
¹⁴⁵¹ or most commonly used approaches are applied to this stock assessment.

¹⁴⁵² The assessment is sex-specific, including the estimation of separate growth curves, and natural
¹⁴⁵³ mortality. Sex-specific length-weight parameters were input as fixed values. The assessment
¹⁴⁵⁴ only tracks female spawning biomass for use in calculating stock status.

¹⁴⁵⁵ The selectivity for the generation station impingement surveys was set to 1.0 for all sizes
¹⁴⁵⁶ (SS pattern 0). As an example, the cooling intake pipes at SONGS are 18-foot in diameter
¹⁴⁵⁷ and draw in seawater at a rate of hundreds of thousands of gallons per minute. The water
¹⁴⁵⁸ flow once in the generating station is one directional and organisms cannot escape, unless
¹⁴⁵⁹ removed via a fish return system. Flow rates for the cooling water intake range from 0.27-1.2
¹⁴⁶⁰ m/s (MBC 2005, 2007, Electric Power Research Institute 2008) and would not allow a fish of
¹⁴⁶¹ any size evade intake cooling pipes.

¹⁴⁶² The length composition data for some years and fleets was small, and may not have been
¹⁴⁶³ representative of the total catch. Length composition data were removed from the model if
¹⁴⁶⁴ less than one trip sampled and fewer than 20 fish were measured in a given year and fleet.
¹⁴⁶⁵ From 1985-1989, two surveys measured fish from the recreational party/charter fleet, the
¹⁴⁶⁶ Ally et al. (Ally et al. 1991) onboard observer survey and the dockside intercept survey. The
¹⁴⁶⁷ number of trips and fish sampled by the onboard observer survey was far greater than the
¹⁴⁶⁸ RecFIN survey and were used in the model.

¹⁴⁶⁹ The time-series of landings begins in 1916 for the commercial fleet and in 1929 for the
¹⁴⁷⁰ recreational fleet. This captures the inception of the fishery, so the stock is assumed to be in
¹⁴⁷¹ equilibrium at the beginning of the modeled period.

¹⁴⁷² The internal population dynamics model tracks ages 0-21, where age 21 is the ‘plus-group.’
¹⁴⁷³ There are relatively few observations in the age compositions that are greater than age 21.

¹⁴⁷⁴ The following likelihood components are included in this model: catch, indices, discards,
¹⁴⁷⁵ length compositions, age compositions, recruitments, parameter priors, and parameter soft
¹⁴⁷⁶ bounds. See the SS technical documentation for details (Methot [2015](#)).

¹⁴⁷⁷ Electronic SS model files including the data, control, starter, and forecast files can be found
¹⁴⁷⁸ on the [PFMC ftp site](#).

¹⁴⁷⁹ 2.3.4 Modeling Software

¹⁴⁸⁰ The STAT team used Stock Synthesis 3 version 3.30.05.03 by Dr. Richard Methot at the
¹⁴⁸¹ NWFSC. This most recent version was used, since it included improvements and corrections to
¹⁴⁸² older versions. The r4SS package (GitHub release number v1.27.0) was used to post-processing
¹⁴⁸³ output data from Stock Synthesis.

¹⁴⁸⁴ 2.3.5 Data Weighting

¹⁴⁸⁵ Length composition and conditional-age-at-length (CAAL) compositions sample sizes for the
¹⁴⁸⁶ base model were tuned by the “Francis method,” based on equation TA1.8 in Francis
¹⁴⁸⁷ ([2011](#)), and implemented in the r4ss package. This approach involves comparing the residuals
¹⁴⁸⁸ in the model’s expected mean length with respect to the observed mean length and associated
¹⁴⁸⁹ uncertainty derived from the composition vectors and their associated input sample sizes.
¹⁴⁹⁰ The sample sizes are then tuned so that the observed and expected variability are consistent.
¹⁴⁹¹ After adjustment to the sample sizes, models were not re-tuned if the bootstrap uncertainty
¹⁴⁹² value around the tuning factor overlapped 1.0.

¹⁴⁹³ As outlined in the Best Practices, a sensitivity run was conducted with length and conditional-
¹⁴⁹⁴ age-at-length (CAAL) compositions were re-weighted using the Ianelli-McAllister harmonic
¹⁴⁹⁵ mean method (McAllister and Ianelli [1997](#)).

¹⁴⁹⁶ Extra variability parameters were estimated and added to the input variance for all surveys
¹⁴⁹⁷ and CPUE indices.

¹⁴⁹⁸ 2.3.6 Priors

¹⁴⁹⁹ The log-normal prior for female natural mortality were based on a meta-analysis completed
¹⁵⁰⁰ by Hamel ([2015](#)), as described under “Natural Mortality.” Female natural mortality was
¹⁵⁰¹ fixed at the median of the prior, 0.257 for an assumed maximum age of 21. An uninformative
¹⁵⁰² prior was used for the male offset natural mortality, which was estimated.

¹⁵⁰³ The prior for steepness (h) assumes a beta distribution with parameters based on an update
¹⁵⁰⁴ for the Thorson-Dorn rockfish prior (Dorn, M. and Thorson, J., pers. comm.), which was

1505 endorsed by the Science and Statistical Committee in 2017. The prior is a beta distribution
1506 with $mu=0.718$ and $sigma=0.158$.
1507 Steepness is fixed in the base model at the mean of the prior. The priors were applied in
1508 sensitivity analyses where these parameters were estimated.

1509 2.3.7 Estimated and Fixed Parameters

1510 A full list of all estimated and fixed parameters is provided in Tables 42. Time-invariant,
1511 sex-specific growth is estimated in this assessment, with all SS growth parameters being
1512 estimated. The log of the unexploited recruitment level for the Beverton-Holt stock-recruit
1513 function is treated as an estimated parameter. Annual recruitment deviations are estimated
1514 beginning in 1985, just after the first sets of length composition data enter the model. The
1515 survey catchability parameters are calculated analytically (set as scaling factors) such that the
1516 estimate is median unbiased, which is comparable to the way q is treated in most groundfish
1517 assessments.

1518 The base model has a total of 113 estimated parameters in the following categories:

- 1519 • Equilibrium recruitment (R_0) and 54 recruitment deviations,
- 1520 • Nine growth parameters
- 1521 • Eight index extra standard deviation parameter, and
- 1522 • 31 selectivity parameters

1523 The estimated parameters are described in greater detail below and a full list of all estimated
1524 and parameters is provided in Table 42.

1525 *Growth.* Five growth parameters were estimated for females: 3 von Bertalanffy parameters
1526 and 2 parameters for CV as a function of length at age related to variability in length at age
1527 for small and large fish.

1528 Four parameters are estimated for male growth as offset from female growth. The length at
1529 Amin was set equal to the female estimate.

1530 *Natural Mortality.* Natural mortality is fixed for females at the value provided by the Hamel
1531 (Hamel 2015) analysis described above. Natural mortality for males is estimated as an offset
1532 from the fixed female natural mortality.

1533 *Selectivity.* Selectivity for all fleets (except the impingement survey) was estimated as
1534 double-normal. The recreational dead discard fleet has a dome-shaped selectivity and all 6
1535 parameters were estimable.

1536 For all fleets where the estimated parameters were asymptotic, parameters related to the
1537 dome were fixed, leaving only the position of the peak, the ascending slope, and selectivity at
1538 the first length bin as estimated parameters. Ten selectivity parameters related to the time
1539 blocks were also estimated.

1540 *Other Estimated Parameters.* Recruitment deviations for the base model are estimated from
1541 1984 to 2015. The base model also included estimated recruitment deviations for the forecast
1542 years, although these have no impact on the model estimates for the current year.

1543 A number of alternate model were explored before the final base model was reached.
1544 Many variations of the base case model were explored during this analysis. Sensitivities
1545 to asymptotic vs. domed selectivity were explored for the appropriate fisheries, e.g. trawl
1546 and gillnet fisheries, as well as estimating selectivity and mirroring fleet selectivities. Time
1547 blocked selectivity without the time block from 2005-2015 for the recreational fisheries was
1548 investigated. We also considered a model with an additional time block for the commercial
1549 fishery, but the length composition data were sparse.

1550 This assessment includes discards for the recreational fleet, so time was spent investigating
1551 changes in selectivity and the most prudent way to incorporate discards.

1552 Length composition of discards from two recreational party/charter onboard observer programs
1553 and

1554 Sensitivities to estimates of female natural mortality were explored by fixing other key
1555 parameters, i.e., steepness. Male natural mortality is still reasonably well estimated, but
1556 the estimates of $\ln R_0$ and female M are not well estimated. The previous assessment fixed
1557 female and male M , where male M was an offset. The previous model had two breakpoints
1558 for natural mortality, but the natural mortality for older fish was set to the same as for
1559 younger fish. This model uses one parameter for natural mortality for each sex.

1560 Much time was also spent tuning the advanced recruitment bias adjustment options, which
1561 were new as of SS 3.24. Sensitivities were performed to each of the thirteen advanced options
1562 for recruitment, e.g., early recruitment deviation start year, early recruitment deviation phase,
1563 years with bias adjustments, and maximum bias adjustment. The final base model sets the
1564 first year of recruitment deviations just prior to when length composition are available.

1565 Several models were also investigated where steepness was either estimated, fixed at the prior,
1566 or at an alternate value.

1567 Sensitivities of the model to the spawning and settlement months were also explored.
1568 The base model originally set spawning month to June and settlement month to July.
1569 California scorpionfish are summer spawners and settle at a small size. However, a potential
1570 bug in how recruits move into the numbers-at-age matrix was discovered (Richard Methot,
1571 personal communication, NWFSC). The final base model sets both the spawning month
1572 and settlement month to January, which is the equivalent to the settings available in
1573 SS3.24z. Parameters for extra standard deviation were added to all survey indices in the model
1574 because they were not exceptionally well fit by the models considered.

1575 *Other Fixed Parameters.* The stock-recruitment steepness is fixed at the SSC approved
1576 steepness prior for rockfish of 0.718. The initial recommendation for steepness was to explore
1577 the available estimates of steepness from Myers et al. (1999). Myers (Myers et al. 1999)
1578 provides estimates of steepness for three species in the family Scorpaenidae, of which California
1579 scorpionfish is a member: chilipepper (*Sebastodes goodei*), 0.35; Pacific ocean perch (*Sebastodes*
1580 *alutus*) 0.43; and deepwater redfish (*Sebastodes mentella*), 0.47. The estimate of steepness for
1581 the family was 0.48. Information for steepness is not available for California scorpionfish and
1582 there is little information from related species that could be considered as a good proxy. A
1583 value of 0.718 (the updated 2017 prior) was assumed for the assessment.

1584 2.4 Model Selection and Evaluation

1585 2.4.1 Key Assumptions and Structural Choices

1586 Key assumptions in the model were that the population is a single-stock in the Southern
1587 California Bight. No information is available on the portion of the population in Mexican
1588 waters. The San Diego recreational party/charter fleet is known to fish for California
1589 scorpionfish at the Coronado Island in Mexican waters. All catches from Mexican waters and
1590 landed in the U.S. were removed from the base model data streams.

1591 Female natural mortality and steepness are both fixed in the base model, and sensitivities
1592 were conducted estimating these parameters. Structurally, the model assumed that the
1593 landings from each fleet were representative of the population in southern California and
1594 fishing mortality prior to 1916 was negligible. It is also assumed that commercial discards
1595 have been negligible and are not included in the base model.

1596 2.4.2 Alternate Models Considered

1597 Due to the error in the 2005 model, the population from the base case of this assessment is
1598 larger in scale. The majority of the alternate models considered were to estimate parameters,
1599 such as natural mortality and steepness.

1600 The base model is age structured, but 60% of those ages are from males, and a number of
1601 ages were from younger fish. Models that attempted to estimate female natural mortality
1602 were considered. However, female natural mortality was estimated at 0.38, much too high
1603 to be considered a reasonable value. The age data needed to estimate natural mortality
1604 (especially for older fish) is not yet available. Male natural mortality was estimable as an
1605 offset from female natural mortality.

1606 Runs of the base case model estimating steepness were also considered, when female natural
1607 mortality was fixed. Steepness was estimated at approximately 0.8. No data exist to inform

1608 this parameter for California scorpionfish, and the decision was made to fix steepness at the
1609 mean of the prior developed from a meta-analysis of West Coast groundfish.

1610 Additional models considered and run for sensitivity analyses can be found in the Sensitivity
1611 Analysis Section of this document.

1612 **2.4.3 Convergence**

1613 Model convergence was determined by starting the minimization process from dispersed values
1614 of the maximum likelihood estimates to determine if the model found a better minimum.
1615 Jitter is a SS option that generates random starting values from a normal distribution
1616 logistically transformed into each parameter's range (Methot 2015). This was repeated 100
1617 times and the minimum was reached in 56% of the runs (Table 41).

1618 The model did not experience convergence issues, e.g., final gradient was below 0.0001, when
1619 reasonable starting values were used and there were no difficulties in inverting the Hessian
1620 to obtain estimates of variability. We did sensitivity runs for convergence by changing the
1621 phases for key estimated parameters and the total log-likelihood did not change nor the
1622 parameter estimates.

1623 **2.5 Response to the Current STAR Panel Requests**

1624 **Request No. 1: Add time blocks (1916-1999, 2000-2005, 2006-2017) for the Recreational De**

1625

1626

1627 **Rationale:** Changes in selectivity of retained fish likely reflect changes in the retention
1628 of discarded fish.

1629 **STAT Response:** The model was run with the 3 requested blocks, or with only
1630 two (-1999 and 2000-2017) and the second block encompassing 6 years has only 3
1631 years of data (2003-2005) on which to estimate selectivity (Figure 54). The three
1632 blocks reflected the changes in management better (the closed years 2000-2006 show a
1633 selectivity reflective of the retained catch in other years) than two blocks and fit the
1634 data better (1 to 2 blocks change of 8.7 log likelihood units, 2 to 3 blocks change of
1635 5.7 units). Overall, the total biomass in 2017 changed by less than 0.1% and depletion
1636 changed from 0.574 to 0.582 with the addition of the two extra time blocks.

1637 **Request No. 2: Combine retained and discarded catches in the Recreational index (use the**

1638

1639

1640 **Rationale:** Concern with modeling discards as a separate fleet.

1641 **STAT Response:** This turned out to be more difficult than the STAR panel antici-
1642 pated the "discard fleet includes discard amounts from two fisheries, but only one has

composition data associated with it. So while one fleet could combine the retained and discarded in the compositions with appropriate weighting, the other would still only be based on the retained compositions (or "borrow" information from the other fleet). Given the small amounts of dead discard overall and the finding of virtually no impact of Request 1 on the model (while fitting the discard compositions better), this request was dropped by the STAR panel.

Request No. 3: Explore the sensitivity of the Recreational Dockside PR mode index to the

Rationale: The current thresholds are ad hoc.

STAT Response: The original cutoff used for Stephens-MacCall filtering was a rounded value of an 0.17 probability of catching California scorpionfish in a trip. This resulted in something close to 2,300 each of false negatives and false positives. Halving these values was achieved by using probabilities of 0.1407 and 0.2308 respectively. The changes had relatively minor effects on the index, but moderate effect on the overall stock size, especially for the lower probability which included many more false positives, adding approximately 1600 points to the CPUE standardization set, which resulted in a model with nearly 10% more spawning biomass (both unfished and current) than the base. However, the overall pattern was unchanged (Figures 55-56). Since it is not clear which set is most appropriate, there was no recommendation arising from this analysis for the current assessment. Rather this highlights the need for more research into this topic.

Request No. 4: Do a sensitivity to the relationship between weight and fecundity. Use a ge

Rationale: There is a lack of information on this relationship in the assessment and the sensitivity of the model to this relationship needs to be understood.

STAT Response: The base models fecundity as proportional to weight. The model was run with this alternative where fecundity is proportional to length to the power 4.043. This model had a slightly lower depletion level (0.531 vs. 0.579, measured in spawning output rather than spawning biomass) and a slightly higher unfished equilibrium biomass estimate (by about 1%). While more research into this topic is warranted, its effect on the model outcome will likely be moderate.

Request No. 5: Evaluate the selectivity for the impingement length compositions by allowing

Rationale: There is a strong residual pattern with fits to length compositions suggesting an alternative selex pattern for this index.

STAT Response: Allowing for a descending selectivity pattern resulted in a reduction in the residual pattern. The run conducted, however, did not estimate the size at the "peak" selectivity (representing here where the start of the downturn would be) and

1684 the downward slope was quite steep. Estimating this value resulted in a change from
1685 about 20 to 17 cm for this value and better overall fit of the model the length and age
1686 composition data (by about 5 log likelihood points apiece vs. the constant selectivity
1687 assumption). The scale of the population increased by approximately 15% and the
1688 2017 depletion increased to 0.598 (vs. 0.579). The resulting selectivity pattern is close
1689 to an inverse logistic with a non-zero lower asymptote. The STAR panel and STAT
1690 agreed that this pattern is more realistic and fits the data better than the model with
1691 full selectivity at all ages and sizes, and should be included in the final base model.

1692 **Request No. 6: Investigate the commercial net length data sources to see if they are repres**

1693

1694

1695 **Rationale:** These lengths do not fit well in the current model. It is not clear if the
1696 length comps. match the temporal changes in allowable mesh sizes.

1697 **STAT Response:** When estimated independently for the commercial net fleet, the
1698 selectivity pattern moved far to the right of that for the hook and line fleet. Depletion
1699 (0.575 vs 0.579) and stock size decreased slightly with this change, and the fit to length
1700 composition data improved by 20 log likelihood points. Since there is relatively little
1701 length data from the commercial net fishery, dropping that length data and continuing
1702 to mirror selectivity made little change from the base model, but the resulting model
1703 does not accurately reflect the apparent selectivity of the net fleet. The STAR panel
1704 and STAT agreed that the independently estimated selectivity for the net fleet is more
1705 realistic and fits the data better, and should be included in the final base model. Since
1706 the peak value parameter hit the upper bound, it should be fixed in the final model.

1707 **Request No. 7: Turn off the mirroring of the gillnet survey to the POTW survey selex and**

1708

1709

1710 **Rationale:** The length comps. do not fit well in the current model.

1711 **STAT Response:** The model run following this change did result in a very different
1712 selectivity pattern (nearly a straight diagonal line up from zero to the 40 cm), however,
1713 the hessian did not converge. Dropping the gillnet data altogether had very little
1714 impact on the model. It was agreed to drop this fleet from the final base model, and
1715 recommend further investigation of this data for future use.

1716 **Request No. 8: Plot the CalCOFI sea surface temperature index for Pacific sardine with the**

1717

1718

1719 **Rationale:** To investigate the hypothesis of warmer water influencing positive recruit-
1720 ment.

1721 **STAT Response:** The annual CalCOFI sea surface temperature index was correlated
1722 with the model estimated recruitment deviations (Figure 57). This helps explain the
1723 pattern of alternating periods of positive and negative recruitment deviations in the
1724 model. The panel recommends further investigation of possible predictors with the goal

1725 of finding a better indicator of California scorpionfish recruitment to be considered for
1726 use within a model and for forecasting.

1727 **Request No. 9: Provide a model run where recruitment deviations are not estimated. Also,**

1728

1729

1730 **Rationale:** There is concern that the higher recruitment deviations are not realistic
1731 and they sustain the trends we see in stock size regardless of removals.

1732 **STAT Response:** A run with no recruitment deviations resulted in a higher unfished
1733 equilibrium biomass, but did not fit the data nearly as well (by over 110 log likelihood
1734 units). With half the sigma-r value, the overall scale of the stock did not change from
1735 the base, but the variation over time was suppressed somewhat (Figure 58). Since
1736 the results of Request 8 indicated potential underlying environmental drivers for the
1737 recruitment patterns in the base model, it was agreed that the original sigma-r (0.6)
1738 was reasonable.

1739 **Request No. 10: Prepare a new base model that changes July 26 base model as follows:**

1740

1741

- 1742 • Model the commercial net fishery with its own selex curve with two selex blocks
1743 matching the other commercial fisheries. Peak selex parameter needs to be fixed
1744 (not estimated)
- 1745 • Model the impingement data with a descending selex pattern, including estimation
1746 of the peak parameter
- 1747 • Drop the Gillnet survey from the model
- 1748 • Fix M for both sexes combined based on a max. age of 23 years ($M = 0.235$)
1749 (determined by averaging the third oldest estimated ages of each sex)
- 1750 • Retune and jitter
- 1751 • Evaluate diagnostics to ensure this is a sound model.

1752 **Rationale:** These changes were agreed to by the STAT and STAR Panel.

1753 **STAT Response:** These changes constitute a new base model.

1754 **Request No. 11: Building on the new base model, prepare bracketing runs on M that use t**

1755

1756

1757 **Rationale:** To consider for a decision table.

1758 **STAT Response:** While the low value for M produced a reasonable result, the high
1759 value resulted in an incredibly large biomass. This request was modified below.

1760 Request No. 12: For the high state of nature, explore an M such that the ratio of ending S

1761

1762

1763 **Rationale:** The first exploration of a high state of nature in a potential decision
1764 table provided unrealistic results and a narrower range of Ms did not provide adequate
1765 contrast between states of nature.

1766 **STAT Response:** The high value of M which meets the above criteria was found to be
1767 0.2745. This, along with the low value ($M = 0.164$) results in a reasonable bracketing
1768 of the uncertainty (Figure 59).

1769 Request No. 13: Provide a draft decision table with the 3 states of nature assuming the fol

1770

1771

1772 **Rationale:** This is a reasonable catch stream to demonstrate the outcomes of a
1773 potential decision table.

1774 **STAT Response:** See the final decision table for appropriate values.

1775 2.6 Base Case Model Results

1776 The base model parameter estimates and their approximate asymptotic standard errors are
1777 shown in Table 42 and the likelihood components are in Table 43. Estimates of derived
1778 reference points and approximate 95% asymptotic confidence intervals are shown in Table e.
1779 Time-series of estimated stock size over time are shown in Table 44.

1780 The base model is sex-specific for all biological parameters. Key productivity parameters
1781 are fixed at measures of central tendency from prior distributions endorsed by the PFMC's
1782 SSC due to the models' inabilities to estimate reasonable parameter values. Specifically,
1783 steepness of the assumed Beverton-Holt stock-recruitment relationship was fixed at 0.718. In
1784 the final base models the instantaneous rate of annual natural mortality was fixed at 0.2547
1785 for females, and estimated as 0.2078 for males.

1786 2.6.1 Parameter Estimates

1787 The base model produces reasonable estimates of growth parameters, for both males and
1788 females (Figure 47). The von Bertalanffy growth coefficient k for females was estimated
1789 close to the external estimate, 0.2496 externally and 0.2503 within SS. For males, the von
1790 Bertalanffy k parameter was estimated at 0.2325 externally and 0.1864 within SS. The female
1791 estimated $\$L_{\{\inf\}}$ was 33.312 and 28.4207 for males.

1792 Females grow faster than males and reach a maximum size greater than the males.

1793 Selectivity curves were estimated for the fishery and survey fleets. The estimated selectivities
1794 for all fleets within the model are shown in Figure 60. The commercial fishery selectivities
1795 are all asymptotic with the trawl and gillnet fisheries mirroring the hook-and-line fishery.
1796 Maximum selectivity for the commercial fleet is reached at about 26 cm from 1916-1998 and
1797 28 cm from 1999-2016 (Figure 61). The shift in selectivity is due to the implementation
1798 of the 10-inch size limit for the commercial fishery in 1999. The recreational private mode
1799 sector selects the largest fish, with full selectivity at 41 cm. The time blocked selectivity does
1800 not show a major shift in selectivity when the fishery was closed for portions of 2001-2005
1801 (Figure 62. This can be explained by the fact the length composition data from the dockside
1802 intercept survey contains a large number of observed fish when the fishery was closed. The
1803 recreational private mode also selects the largest fish, and there is no available information
1804 on discards from this fleet. There is a distinct shift in the selectivity for the retained-catch
1805 recreational party/charter fleet, with the onboard observer retained-catch fleet mirrored to
1806 the other recreational party/charter fleet. Prior to the implementation of a 10-in minimum
1807 size limit the size at maximum selectivity was 36 cm, from 2001-2005 it was 31 cm and since
1808 2006 the size at maximum selectivity is at 26 cm (Figure 63). The recreational party/charter
1809 mode discard-catch dome-shaped selectivity reflects the discarding of small fish due to the
1810 size limit and also the discarding of smaller fish prior to the 10-in minimum size limit due to
1811 angler preference for larger fish. The selectivity of the discard fleet does not go to 0, because
1812 some larger fish are still discarded, either due to angler preference, bag limits, and/or fishery
1813 closure. The onboard observer data also indicates that there are higher discards when an
1814 aggregation of California scorpionfish was found, i.e., hundreds of fish may be caught at a
1815 single fishing stop and some are discarded.

1816 All of the survey selectivity curves were asymptotic and none had time blocks. The Southern
1817 California Bight regional monitoring trawl survey uses the same gear as the POTW trawl
1818 surveys. All of the three trawl surveys reach full selectivity around 24 cm. The selectivity for
1819 the gillnet survey is mirrored to the trawl survey because small 1"-2" mesh sizes were used.

1820 The additional survey variability (process error added directly to each year's input variability)
1821 for all surveys was estimated within the model. The model estimated a small added variances
1822 for the recreational private mode of 0.013 and the recreational party/charter discard fleet
1823 of 0.078. The estimated added variance was highest for the recreational party/charter
1824 retained-catch fleet (0.267), the POTW trawl survey (0.225), and the NWFSC trawl survey
1825 (0.25).

1826 Recruitment deviations were estimated from 1965 to 2015 (Figure 64). Estimates of re-
1827 cruitment suggest that the California scorpionfish population is characterized by variable
1828 recruitment with occasional strong recruitments and periods of low recruitment (Figures 65
1829 and 64). The four lowest recruitments (in ascending order) occurred in 2012, 2011, 1981, and
1830 1973. There are large estimates of recruitment in 1985, 1993, and 2015. The 2015 recruitment
1831 event can be observed in the length and conditional length at age compositions from the
1832 survey data.

1833 The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 66

¹⁸³⁴ with estimated recruitments also shown. The stock is predicted to have never fallen to low
¹⁸³⁵ enough levels that the steepness is obvious. Steepness was not estimated in this model, but
¹⁸³⁶ sensitivities to an alternative value of steepness is discussed below.

¹⁸³⁷ **2.6.2 Fits to the Data**

¹⁸³⁸ Model fits to the indices of abundance, fishery length composition, survey length composition,
¹⁸³⁹ and conditional age-at-length observations from the NWFSC trawl survey are all discussed
¹⁸⁴⁰ below.

¹⁸⁴¹ The fits to the four fishery CPUE and four survey indices are shown in Figures 67 - 74. Extra
¹⁸⁴² standard error was estimated for all eight of the indices. The indices for the recreational
¹⁸⁴³ private mode and dead-discard fleets were fit relatively well by the model. The recreational
¹⁸⁴⁴ party/charter retained-catch index was fit moderately well in parts of the time series, but
¹⁸⁴⁵ did not capture the increases observed in the late 1990s. The extra variability added to this
¹⁸⁴⁶ index was also large. The onboard observer retained-only catch index was fit well by the
¹⁸⁴⁷ model except for the two lowest years, 2003 and 2015.

¹⁸⁴⁸ The POTW trawl survey index was fit well by the model, except for the highest four years
¹⁸⁴⁹ from 1979-1982, where the fit is estimated lower than the added uncertainty.

¹⁸⁵⁰ The NWFSC trawl survey index is flat and fit well by the model, except for in 2013, the
¹⁸⁵¹ highest year in the index, with also high uncertainty. The gillnet survey was not well fit by
¹⁸⁵² the model and did not capture the trend observed in the standardized index. The Southern
¹⁸⁵³ California Bight trawl survey, conducted every 5 years, was also not well fit by the model.
¹⁸⁵⁴ The standardized index from the Bight trawl survey showed peaks in 1994 and 2004, which
¹⁸⁵⁵ were not fit by the model.

¹⁸⁵⁶ Fits to the length data are shown based on the proportions of lengths observed by year and
¹⁸⁵⁷ the Pearson residuals-at-length for all fleets. Detailed fits to the length data by year and
¹⁸⁵⁸ fleet are provided in Appendix 8. Aggregate fits by fleet are shown in Figure 75. Overall, the
¹⁸⁵⁹ length composition data for the commercial hook-and-line, commercial trawl, POTW trawl
¹⁸⁶⁰ survey, recreational private, and party/charter fleets all fit well. The fits to the recreational
¹⁸⁶¹ discard fleet by year were variable, and were worse in years with small sample sizes; however,
¹⁸⁶² the aggregate fit is reasonable. The sample sizes by year for each of the gillnet, impingement,
¹⁸⁶³ and Bight trawl surveys were small compared to the fisheries. The fit to the data varies by
¹⁸⁶⁴ year and does not capture the high proportion of small fish observed in the impingement
¹⁸⁶⁵ survey, especially in 2013.

¹⁸⁶⁶ Fits to the aggregated and yearly length composition data from the gillnet fishery are not
¹⁸⁶⁷ well fit. The selectivity for this fishery is mirrored to the commercial hook-and-line fishery
¹⁸⁶⁸ and the sample sizes of the number of measured fish and trips is small compared to other
¹⁸⁶⁹ fleets. California scorpionfish are also not a target species for the gillnet fishery, but are
¹⁸⁷⁰ retained most commonly by the seabass and halibut fisheries as bycatch. The minimum mesh
¹⁸⁷¹ size for the gillnet fishery ranges from 3.5 - 6 inches depending on the year and season.

1872 The NWFSC trawl survey lengths were well estimated for males and females in aggregate by
1873 the model. California scorpionfish are not one of the more common species observed in this
1874 survey, with sample size all under 10 hauls per year.

1875 The observed and expected conditional age-at-length fits are shown in Figure 76 for the
1876 NWFSC trawl survey observations. The fits generally match the observations for fish smaller
1877 than 30 cm. Some outliers are apparent with large residuals.

1878 The age data were also weighted according to Francis weighting which adjust the weight
1879 given to a data set based on the fit to the mean age by year. The mean ages from the fishery
1880 appear to have declined in recent years which could be due to incoming cohorts (Figure 77).
1881 Smaller fish were also observed in the POTW trawl and impingement surveys in the (Figures
1882 78 and 79). The mean length in the recreational private and party/charter fleets increased
1883 over time (Figures 80 and 81). The length composition of the recreational fleet discards was
1884 smaller in the 1980s and hovers around the 10-in minimum size limit in the 2000s (Figure 82).

1885 2.6.3 Uncertainty and Sensitivity Analyses

1886 A number of sensitivity analyses were conducted, including:

- 1887 1. Data weighting according to the harmonic mean.
- 1888 2. Removal of the POTW trawl survey index (axis of uncertainty from the 2005 assessment)
- 1889 3. Dome-shaped selectivity for the NWFSC trawl survey and gillnet survey - TBD
- 1890 4. Estimating female natural mortality
- 1891 5. Estimating steepness
- 1892 6. Assume the same fixed natural mortality for males and females
- 1893 7. Drop data sources, one at a time

1894 A number of changes were made since the 2005 assessment, and sensitivities to the current
1895 base model included changing or fixing a number of parameters to the same as the 2005
1896 assessment, as well as a number of sentivities to modelling choices made in developing the
1897 current base model (Tables 45 and 46).

1898 Data weighting is an area of uncertainty for stock assessment and research is ongoing to
1899 determine the effects of data weighting and the most appropriate initial sample sizes for
1900 length and age composition data. A model run with default weighting increased the total
1901 likelihood by 2,692 and resulted in a final depletion of 0.771. The base model used the Stewart
1902 sample sizes for the fishery data and number of trips for all survey sample sizes. Weighting

1903 the data by the harmonic mean resulted in a model with a total likelihood between the base
1904 model, which uses the Francis method for weighting, and the model with default weights.
1905 The Francis weights in the base model were stable, and did not tend to serially decrease
1906 (downweight) any of the datasets, which has been seen in other assessments.

1907 The POTW trawl survey index was the axis of uncertainty in the 2005 assessment.
1908 The stock was estimated to be at 80% depletion in 2005 with the POTW trawl survey index
1909 and at 58% without the index. The current assessment has a number of new data sources,
1910 including new indices, length data, and conditional age-at-length data available. Removing
1911 the POTW trawl survey index and length composition data from the current base model did
1912 not have a large effect on the model. Depletion dropped from 0.574 to 0.53, but this is a
1913 fairly small change compared to the effect on the 2005 model.

1914 The 2005 assessment fixed natural mortality at 0.25 for males and females, and steepness at
1915 0.7. A sensitivity of fixing male and female natural mortality to 0.257, increased depletion
1916 from 0.574 to 0.594, but did not have a large overall effect on the model. A sensitivity was
1917 also run estimating a single natural mortality rate (0.252) and steepness (0.88) Figure 83.

1918 Sensitivity of the base model to each of the data sources was also explored (Figures 85 and
1919 85). The time series of spawning biomass was most sensitive to the impingement survey
1920 lenght composition.

1921 Without the impingement length composition, the relative time series is the same, but the
1922 total biomass is almost double the base model. However, dropping the impingement index and
1923 estimating a single natural mortality rate for both sexes reduces the total biomass towards
1924 the base model. Natural moratlity is also reasonably estimated at 0.19. In the sensitivity run
1925 where both natural mortality (0.19,same for males and females) and steepness (0.88) were
1926 estimated produces both a reasonable estimate for natural mortality and a value of steepness
1927 that was high, but not estimated at the parameter bound.

1928 and dropping the recreational party/charter index decreases the stock size, whic is the major
1929 fishery for this species.

1930 2.6.4 Retrospective Analysis

1931 A 4-year retrospective analysis was conducted by running the model using data only through
1932 2012, 2013, 2014, and 2015, progressively (Table 48). The initial population size and estimation
1933 of trends in spawning biomass in the retrospective runs were slightly lower than the base
1934 model (Figure 86). The initial scale of the spawning population was basically unchanged for
1935 all of these retrospectives.

1936 The recruitment deviations in the more recent years shrink towards zero the more years are
1937 removed from the model (Figure 87).

1938 **2.6.5 Likelihood Profiles**

1939 Likelihood profiles were conducted for R_0 , steepness, and over natural mortality values
1940 separately. These likelihood profiles were conducted by fixing the parameter at specific values
1941 and estimated the remaining parameters based on the fixed parameter value.

1942 In regards to values of R_0 , the negative log-likelihood was minimized at approximately $\log(R_0)$
1943 of 8.0 (Table 50). The recreational private mode fishery minimized at a smaller value of R_0
1944 whereas the gillnet survey, recreational discard and commercial gillnet fisheries indicated a
1945 higher value of R_0 (Figure 88). The age and recruitment data indicated a higher value of R_0
1946 and were minimized at the highest value in the profile (Figure 89). Over the range of values
1947 of R_0 , depletion ranged from 0.53-0.70 (Figure 90).

1948 For steepness, the negative log-likelihood was essentially flat between values of 0.57-0.87
1949 (Figure 91 and Table 50).

1950 Likelihood components by data source show that the fishery age data support a low steepness
1951 value, but the other data sources higher value for steepness (Figure 92). The impingement,
1952 POTW trawl survey, and recreational private mode fleets support higher values of steepness
1953 while the other surveys are relatively uninformative. The relative depletion for California
1954 scorpionfish changes very little (0.51-0.60) across different assumed values of steepness (Figure
1955 93).

1956 The negative log-likelihood was minimized at a natural mortality value of 0.38, the profile
1957 is relatively flat for the priors, index data, and recruitment (Figure 94). The age data
1958 likelihood contribution was minimized at natural mortality values ranging from 0.035-0.40,
1959 and the length data contribution was minimized as the largest value of M run, 0.40 (Table
1960 50). The impingement survey was the only fleet for which the likelihood profile over M was
1961 not relatively flat (Figure 95) The relative depletion for California scorpionfish ranged from
1962 0.48-0.80 across alternative values of natural mortality (Figure 96).

1963 **2.6.6 Reference Points**

1964 Reference points were calculated using the estimated selectivities and catch distribution
1965 among fleets in the most recent year of the model, (2015). Sustainable total yield (landings
1966 plus discards) were 221.2 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95%
1967 confidence interval of (156.9-285.5) mt based on estimates of uncertainty. The spawning
1968 biomass equivalent to 40% of the unfished level ($SB_{40\%}$) was 547.2 mt.

1969 The predicted spawning biomass from the base model shows an initial decline starting in
1970 1970, with two years of low spawning biomass in 1976 and 1977. From the late 1970s to the
1971 mid-2000s the population follows a cyclical pattern (driven by recruitment pulses) and then
1972 declines until 2015. The last two years of the model indicate an increase in spawning biomass.

1973 (Figure 97). Since 2015, the spawning biomass has been increased due to lower catches and a
1974 high recruitment pulse in 2015. The 2016 spawning biomass relative to unfished equilibrium
1975 spawning biomass is above the target of 40% of unfished levels (Figure 98). The relative
1976 fishing intensity, $(1 - SPR)/(1 - SPR_{50\%})$, has been well below the management target for
1977 the entire time series of the model.

1978 Table e shows the full suite of estimated reference points for the base model and Figure 99
1979 shows the equilibrium curve based on a steepness value fixed at .

1980 **3 Harvest Projections and Decision Tables**

1981 The forecasts of stock abundance and yield were developed using the final base model. The
1982 total catches in 2017 and 2018 are set to the PFMC adopted California scorpionfish ACLs
1983 (Table \ref{tab:mnmgt_perform}). CDFW allocated 75% of the ACL to the recreational
1984 fisheries and 25% to the commercial fisheries. The catches were divided among the fleets
1985 within each the commercial and recreational fisheries by taking the ratio of the average
1986 catches from 2012-2016. The average of 2012-2016 catch by fleet was used to distribute
1987 catches in forecasted years. The research catch harvest guideline for 2017-2018 was set at
1988 0.2 mt. The average research catch from the NWFSC trawl survey averaged 0.077 mt from
1989 2012-2016, which was used in the forecast.

1990 **Projections and Decision Table**

1991 Forecasts (Table 51) and decision tables (Table h) to be completed during and/or after the
1992 STAR panel

1993 **4 Regional Management Considerations**

1994 While the proportion of the stock residing within U.S. waters is unknown, the assessment
1995 provides an adequate geographic representation of the portion assessed for management
1996 purposes. Collaboration with Mexico in conducting future assessments may be mutually
1997 beneficial. No genetic information is available to inform whether separate stocks or population
1998 structure pertinent to management exists. Given the relatively small area in the waters off
1999 of California where this species occurs south of Point Conception, there is relatively little
2000 concern regarding exploitation in proportion to the regional distribution of abundance in the
2001 area assessed in this study.

2002 While the species does aggregate during the spawning season making harvest of the stock
2003 more efficient during this period, removals have been well within the harvest limits and the
2004 stock has not been overfished or subject to overfishing as a whole.

2005 Routine sampling of commercial and recreational fisheries provides mortality estimates to
2006 monitor catch during the course of season to prevent overfishing should effort increase in
2007 the future. Analysis of CPUE of areas known to be spawning aggregations over time using
2008 data from sampling onboard CPFVs and comparison to the trajectory of the population as
2009 a whole could provide information in determining whether localized depletion is occurring.
2010 Eggs and larvae are expected to travel substantial distance before settling, thus such areas
2011 should be repopulated from adjacent areas. Time/area closures could be considered where
2012 deemed beneficial in maintaining a minimum CPUE the remainder of the year, but are not
2013 necessary to keep aggregate harvest within the current harvest limits.

2014 5 Research Needs

2015 There are a number of areas of research that could improve the stock assessment for California
2016 scorpionfish. Below are issues identified by the STAT team:

- 2017 1. **Natural mortality:** Both female natural mortality and steepness were fixed in the
2018 base model. The collection of age data for older females may improve the ability to
2019 estimate female natural mortality in the model. The NWFSC trawl survey was the
2020 only available source of age data for this assessment, of which there were a number of
2021 age-1 fish and the data were dominated by males.
- 2022 2. **Steepness:** California scorpionfish has not been fished to a level where information on
2023 steepness is available. A meta-analysis for species with similar breeding strategies to
2024 California scorpionfish could be conducted if data are available.
- 2025 3. **Stock in Mexico:** No available information on the status of California scorpionfish in
2026 Mexico could be found. A number of emails were sent to researchers in Mexico and
2027 none were returned. It is known that a portion of the stock resides in Mexico and that
2028 boat leaving from San Diego target California scorpionfish off the Coronado Islands.
- 2029 4. **Sex ratio:** The sex ratio in both Love et al. [@Love1987] and samples from the NWFSC
2030 trawl survey were skewed towards males. Data on sex ratios from the recreational or
2031 commercial fisheries would help in determining the sex ratio of the population.
- 2032 5. **Aggregating behavior:** Little is known about the aggregating behavior of California
2033 scorpionfish. California scorpionfish are known to aggregate in both the spawning
2034 and non-spawning seasons. The location and timing of the aggregations would aid in
2035 modelling the high catch events.
- 2036 6. **Fecundity/Maturity:** There are currently no estimates of fecundity for California
2037 scorpionfish. Love et al. [@Love1987] has published the only estimates of maturity for
2038 California scorpionfish, but the original copies of the data are no longer available. Some
2039 data on the spatial distribution of the eggs are available from CalCOFI, but were not
2040 keypunched to the species level. California scorpionfish mature at a young age, and
2041 additional data can help inform the maturity curve.

2042 **6 Acknowledgments**

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2055 Project for compiling and sharing their trawl survey data, and to Eric Miller for providing
2056 the generating station impingement data. Thank you to everyone who answered my countless
2057 emails regarding your survey methodologies and datasets.

7 Tables

Table 1: Commercial landings (mt) from the commercial fisheries. Data sources are the CDFG Fishery Bulletins (available from California Explores the Ocean) and the California Fisheries Information System (CFIS)

Year	Hook-and-line (plus pot and other)	Trawl	Gillnet	Mexico	Total U.S. Commercial Removals	Source
1916	3.64	0.00	0.00	0.00	3.64	CDFG Bulletins
1917	7.90	0.00	0.00	0.00	7.90	CDFG Bulletins
1918	12.81	0.00	0.00	0.00	12.81	CDFG Bulletins
1919	11.54	0.00	0.00	0.00	11.54	CDFG Bulletins
1920	16.18	0.00	0.00	0.00	16.18	CDFG Bulletins
1921	26.48	0.00	0.00	0.00	26.48	CDFG Bulletins
1922	19.11	0.00	0.00	0.00	19.11	CDFG Bulletins
1923	27.43	0.00	0.00	0.00	27.43	CDFG Bulletins
1924	49.47	0.00	0.00	0.00	49.47	CDFG Bulletins
1925	101.20	0.00	0.00	0.00	101.20	CDFG Bulletins
1926	49.02	0.00	0.00	0.00	49.02	CDFG Bulletins
1927	51.46	0.00	0.00	0.00	51.46	CDFG Bulletins
1928	44.04	0.00	0.00	0.00	44.04	CDFG Bulletins
1929	48.90	0.00	0.00	0.00	48.90	CDFG Bulletins
1930	40.19	0.00	0.00	0.00	40.19	CDFG Bulletins
1931	41.54	0.00	0.00	0.05	41.54	CDFG Bulletins
1932	38.78	0.00	0.00	0.00	38.78	CDFG Bulletins
1933	29.10	0.00	0.00	0.00	29.10	CDFG Bulletins
1934	29.91	0.00	0.00	0.00	29.91	CDFG Bulletins
1935	30.76	0.00	0.00	0.79	30.76	CDFG Bulletins
1936	49.75	0.00	0.00	0.34	49.75	CDFG Bulletins
1937	62.19	0.00	0.00	0.09	62.19	CDFG Bulletins
1938	70.44	0.00	0.00	0.05	70.44	CDFG Bulletins
1939	58.29	0.00	0.00	0.06	58.29	CDFG Bulletins
1940	55.37	0.00	0.00	0.03	55.37	CDFG Bulletins
1941	43.07	0.00	0.00	0.14	43.07	CDFG Bulletins
1942	20.00	0.00	0.00	0.11	20.00	CDFG Bulletins
1943	16.32	0.00	0.00	2.98	16.32	CDFG Bulletins
1944	24.03	0.00	0.00	1.95	24.03	CDFG Bulletins
1945	42.13	0.00	0.00	0.81	42.13	CDFG Bulletins
1946	65.63	0.00	0.00	0.16	65.63	CDFG Bulletins
1947	56.79	0.00	0.00	0.84	56.79	CDFG Bulletins
1948	70.17	0.00	0.00	0.18	70.17	CDFG Bulletins
1949	66.72	0.00	0.00	0.58	66.72	CDFG Bulletins
1950	63.16	0.00	0.00	0.12	63.16	CDFG Bulletins
1951	45.85	0.00	0.00	0.16	45.85	CDFG Bulletins

Table 1: Commercial landings (mt) from the commercial fisheries. Data sources are the CDFG Fishery Bulletins (available from California Explores the Ocean) and the California Fisheries Information System (CFIS)

Year	Hook-and-line (plus pot and other)	Trawl	Gillnet	Mexico	Total U.S. Commercial Removals	Source
1952	37.93	0.00	0.00	0.00	37.93	CDFG Bulletins
1953	54.17	0.00	0.00	0.05	54.17	CDFG Bulletins
1954	60.92	0.00	0.00	0.00	60.92	CDFG Bulletins
1955	47.71	0.00	0.00	1.29	47.71	CDFG Bulletins
1956	45.47	0.00	0.00	0.00	45.47	CDFG Bulletins
1957	33.23	0.00	0.00	0.00	33.23	CDFG Bulletins
1958	29.43	0.00	0.00	0.00	29.43	CDFG Bulletins
1959	16.94	0.00	0.00	0.00	16.94	CDFG Bulletins
1960	13.25	0.00	0.00	0.00	13.25	CDFG Bulletins
1961	12.12	0.00	0.00	0.00	12.12	CDFG Bulletins
1962	26.18	0.00	0.00	0.11	26.18	CDFG Bulletins
1963	34.11	0.00	0.00	0.14	34.11	CDFG Bulletins
1964	35.19	0.00	0.00	7.55	35.19	CDFG Bulletins
1965	34.78	0.00	0.00	2.75	34.78	CDFG Bulletins
1966	38.31	0.00	0.00	10.90	38.31	CDFG Bulletins
1967	25.42	0.00	0.00	12.07	25.42	CDFG Bulletins
1968	40.60	0.00	0.00	16.18	40.60	CDFG Bulletins
1969	33.28	0.28	0.10	18.72	33.66	CFIS
1970	34.45	0.00	0.16	35.67	34.62	CFIS
1971	17.76	0.00	0.63	40.41	18.38	CFIS
1972	27.84	0.11	0.13	31.81	28.08	CFIS
1973	16.80	0.17	0.24	54.85	17.21	CFIS
1974	37.94	0.00	0.06	33.59	38.00	CFIS
1975	41.95	0.02	3.03	33.64	45.01	CFIS
1976	15.41	0.06	0.01	63.29	15.49	CFIS
1977	5.75	0.00	0.13	47.07	5.88	CFIS
1978	8.99	0.00	1.26	21.62	10.25	CFIS
1979	8.40	0.00	0.97	5.43	9.37	CFIS
1980	14.47	0.00	0.56	11.72	15.03	CFIS
1981	15.48	0.01	5.93	4.09	21.41	CFIS
1982	17.95	0.00	1.34	8.46	19.29	CFIS
1983	10.91	0.00	0.83	2.31	11.74	CFIS
1984	9.89	0.15	1.07	0.08	11.11	CFIS
1985	12.73	0.02	2.48	0.00	15.24	CFIS
1986	4.76	0.02	1.76	0.11	6.54	CFIS
1987	7.46	0.11	3.99	0.00	11.56	CFIS
1988	7.77	0.00	3.65	0.00	11.42	CFIS
1989	15.87	0.02	2.80	0.00	18.69	CFIS

Table 1: Commercial landings (mt) from the commercial fisheries. Data sources are the CDFG Fishery Bulletins (available from California Explores the Ocean) and the California Fisheries Information System (CFIS)

Year	Hook-and-line (plus pot and other)	Trawl	Gillnet	Mexico	Total U.S. Commercial Removals	Source
1990	32.07	0.78	6.17	0.00	39.01	CFIS
1991	20.12	4.80	3.29	0.00	28.20	CFIS
1992	27.71	3.94	3.33	0.00	34.98	CFIS
1993	13.72	7.76	4.66	0.22	26.14	CFIS
1994	34.85	13.08	1.92	0.00	49.86	CFIS
1995	23.69	16.20	0.98	0.13	40.87	CFIS
1996	20.17	12.97	1.19	0.00	34.33	CFIS
1997	20.22	13.28	3.82	0.00	37.31	CFIS
1998	32.34	16.80	1.59	0.00	50.72	CFIS
1999	30.88	6.56	1.78	0.00	39.22	CFIS
2000	11.74	4.57	2.00	0.00	18.30	CFIS
2001	14.18	2.98	2.64	0.00	19.80	CFIS
2002	10.09	2.16	1.18	0.00	13.43	CFIS
2003	2.13	2.75	0.35	0.00	5.24	CFIS
2004	2.00	2.36	0.62	0.00	4.98	CFIS
2005	1.47	3.12	0.70	0.00	5.29	CFIS
2006	0.86	1.38	0.44	0.00	2.68	CFIS
2007	1.90	1.48	0.21	0.00	3.59	CFIS
2008	2.46	0.86	0.28	0.00	3.61	CFIS
2009	2.97	0.27	0.13	0.00	3.38	CFIS
2010	2.99	0.18	0.14	0.00	3.32	CFIS
2011	3.24	1.05	0.24	0.00	4.54	CFIS
2012	3.22	0.43	0.18	0.00	3.82	CFIS
2013	1.73	0.83	0.14	0.00	2.70	CFIS
2014	1.03	0.13	0.04	0.00	1.19	CFIS
2015	2.21	0.13	0.03	0.00	2.37	CFIS
2016	2.32	0.13	0.00	0.00	2.45	CFIS

Table 2: The annual number of California scorpionfish sampled from the the commercial hook-and-line fleet for lengths. Sample size is calculated using Stewarts method (see text for detail)

Year	Fish	Trips	Sample size	Mean length (cm)
1996	25	1	4.45	22
1997	115	6	21.87	27
1998	197	16	43.19	26
1999	224	15	45.91	28
2000	24	2	5.31	28
2001	139	10	29.18	30
2002	71	7	16.80	28
2003	6	1	1.83	32
2013	244	1	7.06	29
2014	46	1	7.06	30
2015	163	1	7.06	29

Table 3: The annual number of California scorpionfish sampled from the the commercial gillnet fleet for lengths. Sample size is calculated using Stewarts method (see text for detail)

Year	Fish	Trips	Sample size	Mean length (cm)
1996	37	4	9.11	28
1997	310	54	96.78	27
1998	13	4	5.79	32
1999	21	11	13.90	33
2000	15	5	7.07	30
2001	209	27	55.84	30
2002	59	19	27.14	34
2003	51	12	19.04	35
2004	33	6	10.55	34

Table 4: The annual number of California scorpionfish sampled from the the commercial trawl fleet for lengths. Sample size is calculated using Stewarts method (see text for detail)

Year	Fish	Trips	Sample size	Mean length (cm)
1996	69	9	18.52	26
1997	42	6	11.80	26
1998	111	12	27.32	27
1999	399	49	104.06	29
2000	82	6	17.32	28
2001	208	21	49.70	28
2003	84	14	25.59	30
2004	22	1	4.04	28
2006	33	2	6.55	28

Table 5: Recreational removals (mt) from the party/charter and private vessels. Removals from man-made and beach/bank modes were included in the private mode removals. Dead discards include all modes. CDFW provided all data. Note: A discard mortality rate of seven percent was applied to the dead discard removals.

Year	Private	Party/charter	Dead Discard (all modes)	Total Removals
1929	0.06	0.54	0.00	0.61
1930	0.12	1.08	0.01	1.21
1931	0.18	1.62	0.01	1.81
1932	0.24	2.16	0.01	2.42
1933	0.30	2.70	0.02	3.02
1934	0.36	3.24	0.02	3.63
1935	0.42	3.78	0.03	4.23
1936	0.48	4.33	0.03	4.84
1937	0.34	3.01	0.02	3.37
1938	0.56	5.06	0.04	5.66
1939	0.44	3.90	0.03	4.36
1940	0.40	3.61	0.02	4.04
1941	0.00	0.00	0.00	0.00
1942	0.00	0.00	0.00	0.00
1943	0.00	0.00	0.00	0.00
1944	0.00	0.00	0.00	0.00
1945	0.00	0.00	0.00	0.00
1946	0.00	0.00	0.00	0.00
1947	1.76	15.73	0.11	17.60
1948	3.65	32.67	0.23	36.55
1949	2.58	23.12	0.16	25.86
1950	3.38	30.29	0.21	33.89
1951	2.11	18.84	0.13	21.08
1952	2.29	20.48	0.14	22.91
1953	1.93	17.24	0.12	19.28
1954	2.26	20.27	0.14	22.67
1955	1.93	17.33	0.12	19.38
1956	1.70	15.26	0.11	17.07
1957	0.94	8.44	0.06	9.44
1958	0.96	8.60	0.06	9.62
1959	0.80	7.19	0.05	8.04
1960	1.06	9.47	0.07	10.59
1961	1.86	16.71	0.12	18.69
1962	2.33	20.87	0.14	23.34
1963	3.77	33.75	0.23	37.75
1964	5.16	46.25	0.32	51.73
1965	5.02	45.03	0.31	50.36
1966	6.44	43.74	0.31	50.48
1967	7.34	39.64	0.29	47.27

Table 5: Recreational removals (mt) from the party/charter and private vessels. Removals from man-made and beach/bank modes were included in the private mode removals. Dead discards include all modes. CDFW provided all data. Note: A discard mortality rate of seven percent was applied to the dead discard removals.

Year	Private	Party/charter	Dead	Discard (all modes)	Total	Removals
1968	8.46	37.50		0.29		46.25
1969	10.62	39.47		0.32		50.41
1970	16.32	51.69		0.43		68.44
1971	19.46	53.19		0.46		73.10
1972	15.80	37.62		0.34		53.76
1973	25.01	52.28		0.49		77.78
1974	29.18	53.84		0.52		83.55
1975	31.19	51.01		0.52		82.72
1976	20.44	29.75		0.32		50.50
1977	35.19	45.69		0.51		81.39
1978	23.82	27.63		0.33		51.77
1979	49.76	40.23		0.58		90.57
1980	53.27	52.35		3.72		109.35
1981	41.08	44.42		2.85		88.36
1982	49.04	40.92		2.81		92.77
1983	12.65	35.56		0.93		49.14
1984	27.06	31.25		0.96		59.27
1985	28.77	39.93		1.71		70.41
1986	24.07	42.53		3.19		69.79
1987	23.05	31.78		3.02		57.85
1988	106.56	76.88		5.89		189.34
1989	56.79	79.32		7.90		144.00
1990	95.63	92.27		1.16		189.06
1991	107.40	103.63		1.30		212.34
1992	31.91	44.10		3.60		79.60
1993	23.31	43.49		2.26		69.07
1994	45.62	54.40		6.42		106.45
1995	28.44	57.03		6.21		91.68
1996	30.46	67.48		4.00		101.93
1997	24.39	77.23		2.62		104.24
1998	32.12	75.91		2.08		110.11
1999	50.11	132.50		2.83		185.43
2000	35.86	109.64		4.97		150.47
2001	56.20	114.90		8.33		179.43
2002	43.39	61.57		9.20		114.15
2003	31.49	58.46		9.56		99.52
2004	5.29	42.42		4.53		52.24
2005	21.34	57.15		5.04		83.53
2006	14.44	129.58		3.31		147.33

Table 5: Recreational removals (mt) from the party/charter and private vessels. Removals from man-made and beach/bank modes were included in the private mode removals. Dead discards include all modes. CDFW provided all data. Note: A discard mortality rate of seven percent was applied to the dead discard removals.

Year	Private	Party/charter	Dead	Discard (all modes)	Total	Removals
2007	14.24	118.87		2.89		135.99
2008	8.38	89.65		2.25		100.28
2009	14.68	93.16		2.09		109.93
2010	8.07	92.55		2.03		102.65
2011	6.84	91.18		2.66		100.68
2012	6.22	107.63		2.34		116.18
2013	8.18	101.31		2.94		112.44
2014	5.88	113.83		2.93		122.63
2015	4.15	73.78		3.59		81.52
2016	3.86	64.56		3.29		71.71

Table 6: Recreational private mode dockside data sample sizes at each data filtering step. The bold value indicates the final sample size used for delta-GLM analysis.

Filter	Criteria	Sample size (no. positive trips)	Sample size (no. of trips)
Entire dataset			108,171
General data filters	CRFS-PR1 survey only, Southern California only (sub_reg = 1), Hook and line gear only (geara = 'H'), Ocean only (Area_X = 1 or 2)	3,802	43,956
Region	Remove trips from Santa Barbara	3,757	42,956
Year	Remove 2004-2005; fishery closed majority of year	3,094	33,770
Closed fishery	Remove remaining trips when fishery closed	3,056	32,236
Rare and co-occurring species	Remove trips with yellowfin tuna and dolphinfish and species present in <1% of all trips and in at least 5 years of data	3,056	30,033
Stephens-MacCall	Retain all positive trips, plus "False Positives" (trips predicted to be in California scorpionfish habitat, but with no California scorpionfish retained)	3,056	8,590

Table 7: AIC values for each model in the recreational private mode dockside sample index.

Model	Binomial	Lognormal
Year	6182	8103
Year + County	5862	8003
Year + Wave	6091	8092
Year + County + Wave	5792	8000

Table 8: The recreational private mode dockside sample index.

Year	Index	Log-scale SE
2006	1.1154	0.0533
2007	0.9353	0.0500
2008	0.8052	0.0481
2009	0.7645	0.0516
2010	0.6716	0.0657
2011	0.7660	0.0734
2012	0.6651	0.0807
2013	0.6143	0.0708
2014	0.6076	0.0826
2015	0.6465	0.0901
2016	0.6530	0.1275

Table 9: The annual number of California scorpionfish sampled from the the recreational private mode fleet for lengths. Data from 1980-2003 were downloaded from RecFIN and from CDFW for 2004-2016. The number of trips is the number of unique ID Codes from 1980-2003 and the number of trips from 2004-2016.

Year	N.measured	N.trips	Mean.length
1980	132	68	26.57
1981	191	76	25.84
1982	199	90	27.43
1983	63	37	28.21
1984	81	44	28.21
1985	76	40	27.78
1986	34	22	27.03
1987	42	28	27.45
1988	177	65	25.63
1989	136	55	25.35
1993	112	62	28.05
1994	136	67	26.96
1995	102	55	25.79
1996	101	70	26.44
1997	90	55	26.93
1998	116	62	26.80
1999	312	138	27.32
2000	142	70	27.77
2001	96	52	27.70
2002	178	94	28.98
2003	148	82	27.82
2004	286	165	30.58
2005	297	171	31.13
2006	663	314	30.85
2007	412	253	31.47
2008	356	237	30.91
2009	471	280	30.84
2010	241	150	30.39
2011	244	131	30.55
2012	158	95	30.65
2013	226	144	30.72
2014	153	92	30.52
2015	106	68	31.27
2016	89	53	30.51

Table 10: Recreational CPFV logbook sample sizes at each data filtering step. The bold value indicates the final sample size used for delta-GLM analysis.

Filter	Criteria	Sample size (no. of trips)
All CA data	No filter	1,164,662
Gear	Remove trips reported as diving, mooching or trolling	959,740
Effort or missing data	Remove trips with missing effort or species information	930,233
Year	Remove 2017, remaining years 1980-2016	929,781
Region	Remove trips north of Pt. Conception and in Mexico	568,222
Fish encountered	Remove trips reporting number of retained fish greater than in the 99% quantile (>325 fish)	564,433
Target species	Remove trips targeting sharks, striped bass, sturgeon, tuna, misc. bay, and potluck	558,872
Single-species trips	Filter trips reporting catches of only species and that one species in <100 trips	558,833
Offshore trips	Remove trips catching yellowtail, tunas, and dolphinfish that were not designated as offshore trips	475,492
Vessel	Remove trips by vessels that had fewer than 10 trips catching scorpionfish	466,023
Anglers	Remove trips with number of anglers < the 1% and > the 99% quantile (retain 5-75 anglers)	452,938
Depth	Remove trips in blocks with a minimum depth of >140m	443,929
Scorpionfish targets	Blocks with at least 100 scorpionfish trips	433,248
Sample size	Blocks with at least 500 trips	432,868

Table 11: AIC values for each model in the recreational CPFV logbook sample index.

Model	Negative Binomial
Year	1918470
Year+ Month	1901592
Year + Block	1872224
Year+ Month + Block	1854652

Table 12: The recreational CPFV logbook sample index.

Year	Index	Log-scale SE
1980	0.0159	0.0579
1981	0.0128	0.0580
1982	0.0143	0.0583
1983	0.0134	0.0610
1984	0.0111	0.0605
1985	0.0188	0.0588
1986	0.0165	0.0579
1987	0.0168	0.0593
1988	0.0291	0.0584
1989	0.0296	0.0581
1990	0.0293	0.0585
1991	0.0348	0.0579
1992	0.0172	0.0587
1993	0.0166	0.0590
1994	0.0226	0.0588
1995	0.0291	0.0587
1996	0.0316	0.0583
1997	0.0498	0.0592
1998	0.0289	0.0595
1999	0.0482	0.0583
2000	0.0338	0.0587
2001	0.0345	0.0586
2002	0.0203	0.0588
2003	0.0193	0.0593
2004	0.0168	0.0595
2005	0.0146	0.0592
2006	0.0457	0.0592
2007	0.0489	0.0589
2008	0.0355	0.0593
2009	0.0399	0.0595
2010	0.0400	0.0597
2011	0.0304	0.0593
2012	0.0296	0.0591
2013	0.0330	0.0592
2014	0.0311	0.0602
2015	0.0252	0.0622
2016	0.0253	0.0615

Table 13: Recreational CPFV dockside sample sizes at each data filtering step. The bold value indicates the final sample size used for delta-GLM analysis.

Filter	Criteria	Sample size (no. of trips)
All southern CA data	No filter	6295
Offshore trips	Remove trips with catch of yellowfin tuna, bluefin tuna, albacore, chinook salmon, coho salmon, bigeye tuna and skipjack	6180
Species	Remove trips with catch of Pacific bonito	4718
County	Remove trips from Santa Barbara County	4338
Effort	Remove trips with lower and upper 2.5% of angler hours (± 2 or ± 109.5).	4117
Second species filter	Remove trips with catch of yellowtail (<i>Seriola lalandi</i>); remove chub/Pacific mackerel and barracuda as predictors	3968
Stephens-MacCall	Retained all trips with California scorpionfish as well as trips identified as false negatives and probability of encounter of 0.10	3176
Year	Removed trips from 1989 due to anomalous results and low sample size	3,099

Table 14: AIC values for each model in the recreational CPFV logbook sample index, including all positive trips and false positive trips selected with a Stephens-MacCall filter threshold encounter probability of 0.1.

Model	Binomial	Lognormal
Year	3516	2479
Year + Month	3123	2488
Year + County	3293	2436
Year + Month + County	3091	2444

Table 15: The annual number of retained California scorpionfish sampled from the the recreational party/charter mode fleet for lengths. Length measurements from 1980-1983 and 1993-2016 were downloaded from RecFIN. Length measurements from 1984-1989 were from an onboard observer program that measured both retained and discarded fish.

Year	Fish	Trips	Mean length (cm)	Source
1975	935	150	27	Collins and Crooke (unpublished)
1976	941	174	28	Collins and Crooke (unpublished)
1977	1373	194	26	Collins and Crooke (unpublished)
1978	1729	242	26	Collins and Crooke (unpublished)
1980	212	45	27	MRFSS
1981	187	59	28	MRFSS
1982	277	91	27	MRFSS
1983	318	113	28	MRFSS
1984	472	99	29	CDFW (unpublished)
1985	1089	285	28	Ally et al. (1991)
1986	955	266	28	Ally et al. (1991)
1987	1500	241	27	Ally et al. (1991)
1988	3358	289	27	CDFW (unpublished)
1989	4518	326	26	CDFW (unpublished)
1993	233	62	29	MRFSS
1994	201	74	28	MRFSS
1995	196	50	28	MRFSS
1996	698	82	26	MRFSS
1997	373	49	25	MRFSS
1998	656	89	28	MRFSS
1999	2057	136	27	MRFSS
2000	875	87	29	MRFSS
2001	479	79	30	MRFSS
2002	816	102	29	MRFSS
2003	1026	99	29	MRFSS
2004	1497	174	28	CRFS
2005	1493	163	28	CRFS
2006	3054	193	29	CRFS
2007	4143	255	28	CRFS
2008	4971	328	28	CRFS
2009	4118	303	28	CRFS
2010	4773	291	28	CRFS
2011	2763	265	29	CRFS
2012	3440	75	28	CRFS
2013	3299	119	28	CRFS
2014	2564	82	28	CRFS
2015	1734	168	28	CRFS
2016	1922	151	28	CRFS

Table 16: Recreational onboard observer data sample sizes at each data filtering step. The bold value indicates the final sample size used for delta-GLM analysis. The same sample data were used for the discard-only index and the retained-only catch indices

Filter	Criteria	Sample size (no. positive drifts)	Sample size (no. of drifts)
Initial SQL filtering		6,475	59,192
Habitat filter	Remove drifts >1000 m of alpha hull buffer, remove "reefs" with <0 drifts or 5% positives, or in CCA	6,365	30,987
Exclude 1999 and 2000	Management changes (depth and gear restrictions)	5,986	29,577
Depth	Remove upper and lower 1% of data (retain 26-330ft)	5,921	29,002
Minutes Fished	Remove upper and lower 1% of data (retain 4 - 155 minutes)	5,780	28,460
Observed Anglers	Remove upper and lower 1% of data (retain 4 - 15 anglers)	5,679	27,946
Boats	Include boats encountering scorpionfish in at least 3 years; at least 30 drifts and 10 with scorpionfish	5,509	26,805
Second depth filter	Remove anything >100 m after looking at 20 m depth bins	5,507	26,733

Table 17: AIC values for each model in the The recreational CPFV onboard observer discard-only catch index.

Model	Binomial	Lognormal
Year	19619	9177
Year + Reef	18677	9177
Year + Depth	19374	8860
Year + Depth + Reef	18392	8778
Year + Month + Reef + Depth	18318	8769

Table 18: The recreational CPFV onboard observer discard-only catch sample index.

Year	Index	Log-scale SE
2001	0.0373	0.0373
2002	0.0836	0.0834
2003	0.0670	0.0670
2004	0.0736	0.0735
2005	0.0842	0.0840
2006	0.0766	0.0765
2007	0.0691	0.0690
2008	0.0611	0.0610
2009	0.0596	0.0596
2010	0.0640	0.0640
2011	0.0506	0.0506
2012	0.0400	0.0400
2013	0.0392	0.0392
2014	0.0387	0.0386
2015	0.0349	0.0349
2016	0.0535	0.0535

Table 19: The annual number of discarded California scorpionfish sampled from the the recreational party/charter mode fleet for lengths. Length measurements from 2003-2016 were provided by CDFW. Length measurements from 1984-1989 were from an onboard observer program that measured both retained and discarded fish.

Year	Fish	Trips	Mean length (cm)	Source
1984	6	5	20	CDFW unpublished
1985	55	34	19	Ally et al. (1991)
1986	88	30	18	Ally et al. (1991)
1987	72	34	19	Ally et al. (1991)
1988	70	32	20	CDFW unpublished
1989	11	11	23	CDFW unpublished
2003	121	41	24	Onboard Observer
2004	40	13	26	Onboard Observer
2005	161	31	25	Onboard Observer
2006	222	58	24	Onboard Observer
2007	207	32	23	Onboard Observer
2008	455	58	23	Onboard Observer
2009	396	75	22	Onboard Observer
2010	873	111	23	Onboard Observer
2011	103	32	19	Onboard Observer
2012	62	18	19	Onboard Observer
2013	124	31	22	Onboard Observer
2014	73	22	23	Onboard Observer
2015	19	10	25	Onboard Observer
2016	37	8	24	Onboard Observer

Table 20: The AIC values for each model in the The recreational CPFV onboard observer retained-only catch index.

Model	Binomial	Lognormal
Year	21826	11507
Year + Reef	21192	11325
Year + Depth	21265	10704
Year + Depth + Reef	20691	10619
Year + Month + Reef + Depth	20453	10599

Table 21: The recreational CPFV onboard observer retained-only catch sample index.

Year	Index	Log-scale SE
2001	0.1134	0.1611
2002	0.0759	0.1566
2003	0.0374	0.1600
2004	0.0880	0.1410
2005	0.0615	0.1444
2006	0.0898	0.1025
2007	0.1360	0.0760
2008	0.1048	0.0722
2009	0.1027	0.0723
2010	0.1121	0.0701
2011	0.0905	0.0775
2012	0.0807	0.0736
2013	0.0654	0.0763
2014	0.0663	0.0895
2015	0.0403	0.1088
2016	0.0720	0.1026

Table 22: The trawl sample sizes for each Publicly Owned Treatment Works trawl survey data at each data filtering step. The bold value indicates the final sample size used for delta-GLM analysis.

Filter	Criteria	City of LA	LA County	Orange County	City of San Diego	Total trawls
General	Erroneous and missing data, harbors or Mexican waters	1,496	2,321	1,671	1,180	6,668
District-specific filters	Stations sampled >29 years or <305 ft		1,848			
	Stations sampled >9 years	930			998	
	Stations sampled >13 years			1,558		
	Stations sampled >11 years					
Station	Stations encountering scorpionfish >4% of trawls	930	1,848	1,500	998	
Tow time and depth	Stations with tow times >4 minutes and <24 ft	921				
	Tow distance 100-599 m (target tow distance 400 m)			1,490		
Final data		921	1,848	1,490	998	5,257

Table 23: AIC values for each model in the Publicly Owned Treatment Works trawl sample index.

Model	Binomial	Lognormal
Year	7330	6748
Year + Quarter	7179	6642
Year + Station	6321	6372
Year + Station + Quarter	6130	6252

Table 24: The Publicly Owned Treatment Works trawl sample index.

Year	Index	Log-scale SE
1970	0.0548	0.5975
1971	0.0703	0.4554
1972	0.1261	0.3709
1973	0.1047	0.3344
1974	0.0841	0.2973
1975	0.0719	0.3571
1976	0.0737	0.2780
1977	0.1408	0.2035
1978	0.1426	0.2135
1979	0.3617	0.1598
1980	0.4085	0.1645
1981	0.4360	0.1543
1982	0.3841	0.2056
1983	0.1343	0.2110
1984	0.0627	0.2817
1985	0.1087	0.1745
1986	0.1624	0.2172
1987	0.2377	0.1644
1988	0.2382	0.1471
1989	0.1605	0.1513
1990	0.1691	0.1551
1991	0.1037	0.1801
1992	0.1126	0.1595
1993	0.1147	0.1055
1994	0.1120	0.1267
1995	0.1970	0.1083
1996	0.2276	0.1006
1997	0.2407	0.1036
1998	0.1795	0.1148
1999	0.2343	0.1001
2000	0.1281	0.1439
2001	0.2433	0.0947
2002	0.1329	0.1411
2003	0.1632	0.1688
2004	0.1873	0.1320
2005	0.2435	0.1673
2006	0.2497	0.1368
2007	0.1347	0.1615
2008	0.1126	0.1643
2009	0.1246	0.1717
2010	0.0791	0.1772
2011	0.1081	0.1851
2012	0.0462	0.2760
2013	0.0190	0.4105
2014	0.0674	0.2917
2015	0.1290	0.2641
2016	0.1167	0.2660

Table 25: Number of fish measured by 25 m depth bin and Publicly Owned Treatment Works program.

Program	0-24 m	25-49 m	50-74 m	100+ m	Total
City of Los Angeles	120	0	1372	0	1492
Los Angeles County	687	0	5879	450	7016
Orange County	161	669	2157	48	3035
City of San Diego	0	404	333	829	1566

Table 26: Sample sizes and mean length (cm) by year for the Publicly Owned Treatment Works trawl surveys, all Publicly Owned Treatment Works programs combined

Year	Fish	Trips	Mean length
1970	36	5	24
1971	23	8	23
1972	77	28	25
1973	108	30	25
1974	57	31	29
1975	54	25	29
1976	61	37	27
1977	93	53	25
1978	83	32	24
1979	340	100	23
1980	352	107	23
1981	388	97	24
1982	631	103	25
1983	118	64	27
1984	72	41	26
1985	109	67	26
1986	171	105	25
1987	276	143	25
1988	278	174	24
1989	203	138	25
1990	230	120	26
1991	162	95	26
1992	204	121	26
1993	275	155	24
1994	299	177	24
1995	371	207	23
1996	489	215	23
1997	458	229	24
1998	358	178	24
1999	461	240	24
2000	319	209	24
2001	510	266	24
2002	1552	203	24
2003	376	206	25
2004	801	199	25
2005	1292	253	25
2006	844	271	25
2007	242	152	25
2008	212	145	24
2009	211	140	24
2010	125	89	25
2011	131	107	24
2012	53	40	26
2013	11	11	24
2014	40	36	26
2015	59	46	23
2016	31	28	20

Table 27: Summaries of catch statistics of California scorpionfish by 25 m interval depth zones from NWFSC trawl survey between 2003 and 2016.

Depth zone	Total catch (kg)	Raw CPUE (kg/ha)
62.50	304.80	1.71
87.50	568.20	1.98
112.50	34.10	0.22
137.50	3.80	0.04
162.50	46.90	0.41
187.50	1.10	0.01
212.50	0.40	0.00

Table 28: Summaries of catch statistics of California scorpionfish by latitude zones from NWFSC trawl survey between 2003 and 2016.

Latitude zone	Total catch (kg)	Raw CPUE (kg/ha)
32.50	156.30	1.59
33.00	274.90	2.60
33.50	257.70	0.93
34.00	270.10	0.73
34.50	0.10	0.00

Table 29: Summaries of haul statistics of California scorpionfish from NWFSC trawl survey between 2003 and 2016.

Year	No. hauls	No. positive hauls	Percent positive hauls	Total catch (kg)	Raw CPUE (kg/ha)
2003	33	9	27.30	28.20	0.51
2004	37	12	32.40	73.20	1.02
2005	37	8	21.60	58.50	0.90
2006	42	11	26.20	15.10	0.23
2007	50	12	24.00	81.30	1.03
2008	51	12	23.50	16.20	0.22
2009	58	10	17.20	217.50	2.60
2010	53	10	18.90	20.00	0.23
2011	51	16	31.40	64.00	0.93
2012	61	9	14.80	102.40	1.07
2013	25	8	32.00	182.70	4.85
2014	49	6	12.20	23.00	0.32
2015	50	14	28.00	52.50	0.59
2016	58	12	20.70	24.70	0.28

Table 30: Summary statistics of age data by year and sex from NWFSC trawl survey between 2005 and 2016. The last raw shows total numbers of fish aged by sex.

Year	Female			Male		
	No. aged	Mean age (year)	Mean length (cm)	No. aged	Mean age (year)	Mean length (cm)
2005	38	8	28	37	9	26
2006	12	6	26	33	9	24
2007	19	7	26	49	7	25
2008	19	6	26	30	8	24
2009	33	4	24	97	7	23
2010	20	8	28	22	9	25
2011	42	5	24	74	8	24
2012	30	10	29	36	9	25
2013	28	6	27	39	4	22
2014	32	6	24	41	6	22
2015	20	3	20	34	5	21
2016	47	3	21	37	5	21
Sum	340			529		

Table 31: Ages at five percentiles by sex from NWFSC trawl survey between 2005 and 2016, indicating more older males in the population.

Percentile	Female age at percentile	Male age at percentile
50	4	6
90	12	14
95	15	17
98	19	19
99	20	22

Table 32: Mean age at length (cm) and number of fish aged by sex for California scorpionfish from the NWFSC trawl survey.

Age	Female		Male	
	Mean length	Fish	Mean length	Fish
1	17	29	17	46
2	20	72	20	87
3	24	45	22	54
4	25	33	23	44
5	26	38	24	32
6	27	18	23	23
7	27	12	25	26
8	29	17	25	27
9	29	13	25	31
10	29	10	26	23
11	29	14	26	25
12	32	4	26	24
13	30	9	26	17
14	31	4	27	16
15	29	3	28	14
16			28	11
17	33	4	29	8
18	36	3	28	4
19	32	6	29	7
20			22	1
21	38	2	25	1

Table 33: The NWFSC trawl survey index.

Year	Index	Log-scale SE
2003	615.6453	0.5708
2004	1000.1240	0.4503
2005	936.2185	0.5943
2006	245.5559	0.5092
2007	1001.1330	0.5099
2008	195.6025	0.4484
2009	1940.3440	0.5137
2010	277.3953	0.5338
2011	710.0569	0.3744
2012	561.1833	0.5361
2013	3243.2760	0.5728
2014	370.3868	0.7000
2015	409.8495	0.4045
2016	366.7447	0.4809

Table 34: Recreational private mode dockside data sample sizes at each data filtering step. The bold value indicates the final sample size used for delta-GLM analysis.

Filter	Criteria	Sample size (no. positive trips)	Sample size (no. of trips)
Entire dataset		325	3,558
General data filters	Samples with no net failures	269	3,515
Net type	Samples using a net type 1", 1.5" and 2" mesh	269	2,815
Sites	Sites frequently sampled	266	2,170
Month	Months sampled consistently (April, June, August, October)	259	2,019

Table 35: AIC values for each model in the recreational private mode dockside sample index.

Model	Binomial	Lognormal
Year + month + site + perp_para + floats	1983	1008
Year + site + perp_para + floats	2000	1004
Year + month + perp_para + floats	2349	1264
Year + site + perp_para	2010	1004

Table 36: The recreational private mode dockside sample index.

Year	Index	Log-scale SE
1995	0	0
1996	0	0
1997	0	0
1998	0	0
1999	0	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
2004	0	0
2005	0	0
2006	0	0
2007	0	0
2008	0	0

Table 37: Southern California Bight regional monitoring trawl survey data sample sizes at each data filtering step. The bold value indicates the final sample size used for delta-GLM analysis.

Filter	Criteria	Sample size (no. positive trips)	Sample size (no. of trips)
All trawls	No filter	158	944
Depth	Trawls < 98 m (retains 95% of all data)	149	662
Region	Exclude trawls in harbors, north of Ventura and islands (few scorpionfish)	129	398

Table 38: AIC values for each model in the Southern California Bight regional monitoring trawl survey sample index.

Model	Binomial	Lognormal
Year	494.73	339.56
Year + Region	490.24	343.16
Year + Month	493.02	336.68
Year + Month + Region	486.55	337.87

Table 39: Southern California Bight regional monitoring trawl survey sample index.

Year	Index	Log-scale SE
1994	0.0475	0.3042
1998	0.0223	0.2499
2003	0.0514	0.2356
2008	0.0156	0.3187
2013	0.0214	0.3021

Table 40: Number of fish by sex and age from the NWFSC trawl survey

Age	Female	Male	Unknown	Total
0	0	0	1	1
1	29	46	10	85
2	72	86	2	160
3	45	52	1	98
4	33	44	0	77
5	38	32	0	70
6	18	23	0	41
7	12	25	0	37
8	18	29	0	47
9	13	31	0	44
10	11	24	0	35
11	14	25	0	39
12	4	25	0	29
13	9	17	0	26
14	4	17	0	21
15	3	15	0	18
16	0	11	0	11
17	4	8	0	12
18	3	4	0	7
19	6	7	0	13
20	0	1	0	1
21	4	7	0	11
22	1	1	0	2
23	0	1	0	1
24	0	1	0	1
25	0	1	0	1
26	0	2	0	2
29	1	0	0	1

Table 41: Results from 100 jitters from the base case model.

Description	Value
Minimum likelihood	1097.30
Maximum likelihood	1111.98
Likelihood difference	14.68
Minimum MGC	0.00
Maximum MGC	0.00
Depletion at minimum likelihood percent	57.41
Depletion at maximum likelihood percent	82.99
Difference in depletion percent	25.58
Number of jitters	50.00
Proportion of runs at mimimum likelihood	0.56
Proportion of runs at maximum likelihood	0.02

Table 42: 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	0.257	-3	(0.01, 1) (2, 30)	OK	0.626	Log_Norm (-1.3581, 0.438438)
2	Lat_Amin_Fem_GP_1	12.434	2	(30, 50)	OK	0.720	None
3	Lat_Amax_Fem_GP_1	33.312	2	(0.05, 0.5)	OK	0.024	None
4	VonBert_K_Fem_GP_1	0.250	2	(0.02, 0.5)	OK	0.019	None
5	CV_young_Fem_GP_1	0.089	3	(0.02, 0.75)	OK	0.008	None
6	CV_old_Fem_GP_1	0.112	3	(-3, 3)	None	None	None
7	Wtlen_1_Fem	0.000	-3	(2, 4)	None	None	None
8	Wtlen_2_Fem	3.058	-3	(10, 30)	None	None	None
9	Mat50%_Fem	18.000	-3	(-3, 3)	None	None	None
10	Mat_slope_Fem	-1.200	-3	(-3, 3)	None	None	None
11	Eggs/kg_inter_Fem	1.000	-3	(-3, 3)	None	None	None
12	Eggs/kg_slope_wt_Fem	0.000	-3	(-3, 3)	None	None	None
13	NatM_p_1_Mal_GP_1	-0.213	2	(-1, 1)	OK	0.049	Normal (0, 99)
14	Lat_Amin_Mal_GP_1	0.000	-2	(-3, 3)	None	None	None
15	Lat_Amax_Mal_GP_1	-0.159	2	(-3, 3)	OK	0.026	None
16	VonBert_K_Mal_GP_1	-0.295	2	(-3, 3)	OK	0.183	None
17	CV_young_Mal_GP_1	1.300	3	(-3, 3)	OK	0.218	None
18	CV_old_Mal_GP_1	-0.452	3	(-3, 3)	OK	0.158	None
19	Wtlen_1_Mal	0.000	-5	(0, 1)	None	None	None
20	Wtlen_2_Mal	2.981	-5	(2, 4)	None	None	None
24	CohortGrowDev	1.000	-1	(1, 1)	None	None	None
25	FracFemale_GP_1	0.500	-4	(0.000001, 0.999999)	OK	0.157	Full_Beta (0.718, 0.158)
26	SR_LN(R0)	8.160	1	(0, 31)	None	None	None
27	SR_BH_stEEP	0.718	-2	(0.21, 0.99)	None	None	None
28	SR_sigmar	0.600	-2	(0, 2)	None	None	None
29	SR_regime	0.000	-4	(-5, 5)	None	None	None

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Table 42: 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)
30	SR.autocorr	0.000	-3	(0, 0.5)			None
106	LnQ_base_RecPR(4)	-6.775	-1	(-15, 15)	OK	0.020	None
107	Q_extraSD_RecPR(4)	0.013	4	(0.0001, 1)			None
108	LnQ_base_RecPC(5)	-11.223	-1	(-15, 15)	OK	0.047	None
109	Q_extraSD_RecPC(5)	0.267	4	(0.0001, 1)			None
110	LnQ_base_RecDD(6)	-10.894	-1	(-15, 15)	OK	0.044	None
111	Q_extraSD_RecDD(6)	0.078	4	(0.0001, 1)			None
112	LnQ_base_Sanitation(7)	-10.544	-1	(-15, 15)	OK	0.047	None
113	Q_extraSD_Sanitation(7)	0.225	4	(0.0001, 1)			None
114	LnQ_base_NWFSC_Trawl(8)	-1.023	-1	(-15, 15)	OK	0.145	None
115	Q_extraSD_NWFSC_Trawl(8)	0.250	4	(0.0001, 1)			None
116	LnQ_base_GillnetSurvey(9)	-12.050	-1	(-15, 15)	OK	0.070	None
117	Q_extraSD_GillnetSurvey(9)	0.122	4	(0.0001, 1)			None
118	LnQ_base_SCBSSurvey(11)	-11.052	-1	(-15, 15)	OK	0.142	None
119	Q_extraSD_SCBSSurvey(11)	0.166	4	(0.0001, 1)			None
120	LnQ_base_RecPCOBR(12)	-10.171	-1	(-15, 15)	OK	0.046	None
121	Q_extraSD_RecPCOBR(12)	0.140	4	(0.0001, 1)			None
122	SizeSel_P1_CoMHL(1)	25.963	5	(13, 44)	OK	2.868	None
123	SizeSel_P2_CoMHL(1)	15.000	-3	(-10, 16)	OK		None
124	SizeSel_P3_CoMHL(1)	2.761	5	(-1, 10)	OK	0.954	None
125	SizeSel_P4_CoMHL(1)	15.000	-3	(-1, 16)	OK	121.578	None
126	SizeSel_P5_CoMHL(1)	-15.902	5	(-25, -1)			None
127	SizeSel_P6_CoMHL(1)	10.000	-3	(-5, 11)			None
128	SizeSel_P1_CoMNet(2)	1.000	-2	(1, 45)			None
129	SizeSel_P2_CoMNet(2)	45.000	-3	(1, 45)			None
130	SizeSel_P1_CoM_Trawl(3)	1.000	-2	(1, 45)			None
131	SizeSel_P2_CoM_Trawl(3)	45.000	-3	(1, 45)			None

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Table 42: 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)
132	SizeSel_P1_RecPR(4)	41.212	5	(13, 44)	OK	2.054	None
133	SizeSel_P2_RecPR(4)	15.000	-3	(-10, 16)	OK	0.163	None
134	SizeSel_P3_RecPR(4)	4.493	5	(-1, 10)	OK	0.163	None
135	SizeSel_P4_RecPR(4)	15.000	-3	(-1, 16)	OK	0.784	None
136	SizeSel_P5_RecPR(4)	-8.340	5	(-25, -1)	OK	0.784	None
137	SizeSel_P6_RecPR(4)	10.000	-3	(-5, 11)	OK	1.358	None
138	SizeSel_P1_RecPC(5)	36.624	5	(13, 44)	OK	1.358	None
139	SizeSel_P2_RecPC(5)	15.000	-3	(-10, 16)	OK	None	None
140	SizeSel_P3_RecPC(5)	4.473	5	(-1, 10)	OK	0.158	None
141	SizeSel_P4_RecPC(5)	15.000	-3	(-1, 16)	OK	None	None
142	SizeSel_P5_RecPC(5)	-8.344	5	(-25, -1)	OK	1.872	None
143	SizeSel_P6_RecPC(5)	10.000	-3	(-5, 11)	OK	0.074	None
144	SizeSel_P1_RecDD(6)	24.530	5	(13, 44)	OK	57.708	None
145	SizeSel_P2_RecDD(6)	-11.238	4	(-15, 16)	OK	0.518	None
146	SizeSel_P3_RecDD(6)	2.727	4	(-1, 10)	OK	65.524	None
147	SizeSel_P4_RecDD(6)	-9.302	4	(-20, 5)	OK	0.472	None
148	SizeSel_P5_RecDD(6)	-2.156	5	(-25, 3)	OK	0.457	None
149	SizeSel_P6_RecDD(6)	-1.709	4	(-5, 11)	OK	0.580	None
150	SizeSel_P1_Sanitation(7)	24.627	4	(13, 44)	OK	None	None
151	SizeSel_P2_Sanitation(7)	15.000	-3	(-10, 16)	OK	0.140	None
152	SizeSel_P3_Sanitation(7)	3.388	4	(-1, 10)	OK	0.633	None
153	SizeSel_P4_Sanitation(7)	15.000	-3	(-1, 16)	OK	2.258	None
154	SizeSel_P5_Sanitation(7)	-4.618	4	(-25, 5)	OK	None	None
155	SizeSel_P6_Sanitation(7)	10.000	-3	(-5, 11)	OK	None	None
156	SizeSel_P1_NWFSCCTrawl(8)	24.306	4	(13, 44)	OK	None	None
157	SizeSel_P2_NWFSCCTrawl(8)	15.000	-3	(-10, 16)	OK	None	None
158	SizeSel_P3_NWFSCCTrawl(8)	3.652	4	(-1, 10)	OK	0.558	None

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Table 42: 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)
159	SizeSel_P4_NWFSTrawl(8)	15.000	-3	(-1, 16)			None
160	SizeSel_P5_NWFSTrawl(8)	-12.844	4	(-25, 5)	OK	166.385	None
161	SizeSel_P6_NWFSTrawl(8)	10.000	-3	(-5, 11)			None
162	SizeSel_P1_GilnetSurvey(9)	1.000	-2	(1, 45)			None
163	SizeSel_P2_GilnetSurvey(9)	45.000	-3	(1, 45)			None
164	SizeSel_P1_SCBSurvey(11)	1.000	-2	(1, 45)			None
165	SizeSel_P2_SCBSurvey(11)	45.000	-3	(1, 45)			None
166	SizeSel_P1_RecPCOBR(12)	1.000	-2	(1, 45)			None
167	SizeSel_P2_RecPCOBR(12)	45.000	-3	(1, 45)			None
168	SizeSel_P1_CoMHL(1)_BLK1rep1_1999	28.442	6	(13, 44)	OK	0.489	None
169	SizeSel_P3_CoMHL(1)_BLK1rep1_1999	2.007	6	(-1, 10)	OK	0.251	None
170	SizeSel_P1_RecPR(4)_BLK2rep1_2000	36.584	6	(13, 44)	OK	1.031	None
171	SizeSel_P1_RecPR(4)_BLK2rep1_2006	35.815	6	(13, 44)	OK	0.652	None
172	SizeSel_P3_RecPR(4)_BLK2rep1_2000	3.602	6	(-1, 10)	OK	0.165	None
173	SizeSel_P3_RecPR(4)_BLK2rep1_2006	3.463	6	(-1, 10)	OK	0.110	None
174	SizeSel_P1_RecPC(5)_BLK2rep1_2000	31.799	6	(13, 44)	OK	1.370	None
175	SizeSel_P1_RecPC(5)_BLK2rep1_2006	26.886	6	(13, 44)	OK	0.464	None
176	SizeSel_P3_RecPC(5)_BLK2rep1_2000	3.041	6	(-1, 10)	OK	0.417	None
177	SizeSel_P3_RecPC(5)_BLK2rep1_2006	1.066	6	(-1, 10)	OK	0.412	None

Table 43: Likelihood components from the base model.

Likelihood component	Value
TOTAL	1097.30
Catch	0.00
Survey	-98.12
Length composition	763.02
Age composition	421.52
Recruitment	10.88
Forecast recruitment	0.00
Parameter priors	0.00
Parameter soft bounds	0.01

Table 44: Time-series of population estimates from the base-case model.

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative ex- ploitation rate	SPR
1916	2797	1368	0.000	3498	4	0.00	0.99
1917	2794	1366	0.999	3497	8	0.00	0.98
1918	2787	1362	0.996	3496	13	0.00	0.97
1919	2778	1356	0.992	3495	12	0.00	0.98
1920	2771	1352	0.989	3494	16	0.01	0.97
1921	2760	1346	0.984	3492	26	0.01	0.95
1922	2743	1336	0.977	3490	19	0.01	0.96
1923	2734	1331	0.973	3488	27	0.01	0.94
1924	2720	1323	0.967	3486	49	0.02	0.90
1925	2689	1304	0.953	3481	101	0.04	0.82
1926	2618	1262	0.923	3469	49	0.02	0.90
1927	2602	1253	0.916	3467	51	0.02	0.90
1928	2586	1245	0.910	3464	44	0.02	0.91
1929	2579	1241	0.907	3463	50	0.02	0.90
1930	2569	1236	0.904	3462	41	0.02	0.91
1931	2567	1236	0.903	3462	43	0.02	0.91
1932	2564	1235	0.902	3461	41	0.02	0.91
1933	2564	1235	0.903	3461	32	0.01	0.93
1934	2571	1239	0.906	3463	34	0.01	0.93
1935	2577	1243	0.909	3464	35	0.01	0.93
1936	2580	1245	0.910	3464	55	0.02	0.89
1937	2566	1237	0.904	3462	66	0.03	0.87
1938	2545	1224	0.895	3458	76	0.03	0.85
1939	2518	1208	0.883	3453	63	0.02	0.87
1940	2506	1201	0.878	3451	59	0.02	0.88
1941	2498	1197	0.875	3449	43	0.02	0.91
1942	2505	1202	0.879	3451	20	0.01	0.95
1943	2531	1218	0.890	3456	16	0.01	0.96
1944	2557	1234	0.902	3461	24	0.01	0.95
1945	2573	1244	0.909	3464	42	0.02	0.91
1946	2571	1242	0.908	3464	66	0.03	0.87
1947	2549	1229	0.898	3460	74	0.03	0.85
1948	2524	1212	0.886	3454	107	0.04	0.80
1949	2476	1181	0.863	3444	93	0.04	0.82
1950	2446	1162	0.850	3438	97	0.04	0.81
1951	2417	1145	0.837	3432	67	0.03	0.86
1952	2417	1145	0.837	3432	61	0.03	0.87
1953	2423	1149	0.840	3434	73	0.03	0.85
1954	2417	1146	0.838	3433	84	0.03	0.83
1955	2404	1139	0.832	3430	67	0.03	0.86

Table 44: Time-series of population estimates from the base-case model.

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative ex- ploitation rate	SPR
1956	2406	1140	0.834	3431	63	0.03	0.86
1957	2411	1144	0.837	3432	43	0.02	0.90
1958	2432	1158	0.847	3437	39	0.02	0.91
1959	2454	1172	0.857	3441	25	0.01	0.94
1960	2484	1191	0.870	3448	24	0.01	0.95
1961	2512	1207	0.882	3453	31	0.01	0.93
1962	2530	1217	0.890	3456	50	0.02	0.90
1963	2530	1216	0.889	3456	72	0.03	0.86
1964	2512	1203	0.879	3451	87	0.03	0.83
1965	2484	1184	0.865	3445	85	0.03	0.83
1966	2462	1169	0.854	2688	89	0.04	0.82
1967	2416	1154	0.844	2686	73	0.03	0.85
1968	2369	1142	0.835	2539	87	0.04	0.82
1969	2296	1105	0.808	2410	84	0.04	0.82
1970	2214	1062	0.777	2194	103	0.05	0.79
1971	2107	1006	0.735	1810	91	0.04	0.80
1972	1996	953	0.696	1652	82	0.04	0.81
1973	1883	900	0.658	1590	95	0.05	0.78
1974	1753	831	0.607	1963	122	0.07	0.73
1975	1617	748	0.547	6328	128	0.08	0.70
1976	1636	673	0.492	5892	66	0.04	0.80
1977	1808	698	0.510	6099	87	0.05	0.75
1978	2042	820	0.599	3189	62	0.03	0.81
1979	2245	991	0.725	1671	100	0.04	0.75
1980	2316	1118	0.817	1278	124	0.05	0.73
1981	2267	1138	0.832	1331	110	0.05	0.76
1982	2155	1086	0.794	1811	112	0.05	0.77
1983	2010	989	0.723	2786	61	0.03	0.85
1984	1928	912	0.667	7937	70	0.04	0.83
1985	2028	850	0.621	9469	86	0.04	0.80
1986	2305	874	0.639	3143	76	0.03	0.81
1987	2523	1065	0.778	1649	69	0.03	0.83
1988	2641	1276	0.933	1473	201	0.08	0.66
1989	2545	1274	0.932	1333	163	0.06	0.71
1990	2390	1199	0.876	1556	228	0.10	0.65
1991	2139	1040	0.760	5837	241	0.11	0.63
1992	2006	866	0.633	5455	115	0.06	0.75
1993	2060	823	0.602	8431	95	0.05	0.77
1994	2297	897	0.656	4667	156	0.07	0.68
1995	2470	1014	0.741	2404	133	0.05	0.72

Table 44: Time-series of population estimates from the base-case model.

Yr	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative ex- ploitation rate	SPR
1996	2577	1183	0.865	7073	136	0.05	0.73
1997	2745	1258	0.919	3787	142	0.05	0.74
1998	2831	1291	0.944	4445	161	0.06	0.73
1999	2876	1344	0.982	4832	225	0.08	0.67
2000	2864	1315	0.962	2435	169	0.06	0.73
2001	2821	1316	0.962	4058	199	0.07	0.70
2002	2754	1280	0.935	2274	128	0.05	0.78
2003	2680	1248	0.913	1889	105	0.04	0.81
2004	2572	1223	0.894	1953	57	0.02	0.88
2005	2466	1182	0.864	4123	89	0.04	0.83
2006	2384	1098	0.802	2454	150	0.06	0.75
2007	2241	1007	0.736	2191	140	0.06	0.75
2008	2111	964	0.704	2260	104	0.05	0.78
2009	2016	927	0.678	2785	113	0.06	0.76
2010	1933	878	0.642	2304	106	0.05	0.77
2011	1859	841	0.615	1164	105	0.06	0.76
2012	1754	815	0.596	1108	120	0.07	0.73
2013	1616	766	0.560	4073	115	0.07	0.72
2014	1567	694	0.507	3460	124	0.08	0.70
2015	1553	644	0.471	7383	84	0.05	0.75
2016	1737	682	0.498	3183	74	0.04	0.77
2017	1902	785	0.574	3260			

Table 45: Sensitivity of the base model to dropping or down-weighting data sources and alternative assumptions about growth.

Label	Base (Francis weights)	Default weights	Harmonic mean weights	Estimate equal M and h	Estimate equal M and h	Drop PR data	Drop PC data	Drop RecDD data
Female natural mortality	0.26	0.26	0.26	0.26	0.25	0.26	0.26	0.26
Male natural mortality	0.21	0.21	0.19	0.26	0.25	0.21	0.19	0.21
Steepness	0.72	0.72	0.72	0.72	0.88	0.72	0.72	0.72
InR0	8.16	8.26	8.03	8.43	8.34	8.26	7.86	8.20
Total Biomass (mt)	2796.86	2856.03	2429.68	3110.57	2904.86	3075.03	2221.83	2885.61
Depletion	0.57	0.76	0.65	59.12	0.59	0.55	0.43	0.65
SPR ratio	0.72	0.62	0.79	0.64	0.68	0.70	1.02	0.69
Female Lmin	12.43	12.32	12.32	11.98	11.98	11.63	12.29	12.08
Female Lmax	33.31	33.77	34.55	32.47	32.49	33.20	33.38	33.08
Female K	0.25	0.22	0.22	0.26	0.26	0.27	0.26	0.26
Male Lmin (offset)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Male Lmax (offset)	-0.16	-0.17	-0.17	-0.14	-0.14	-0.17	-0.15	-0.15
Male K (offset)	-0.29	-0.37	-0.83	-0.16	-0.16	-0.09	-0.38	-0.29
Negative log-likelihood								
No. parameters	113.00	113.00	113.00	114.00	113.00	113.00	113.00	113.00
TOTAL	1097.30	3788.31	2302.18	1108.05	1107.55	918.80	1056.73	1078.36
Catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Equilibrium catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Survey	-98.12	-87.71	-87.94	-98.42	-98.34	-79.46	-78.37	-80.19
Length composition	763.02	2523.37	1684.19	765.37	765.10	571.45	704.57	727.28
Age composition	421.52	1320.36	682.93	430.55	430.50	418.51	421.37	419.66
Recruitment	10.88	32.28	23.00	10.54	10.30	8.29	9.15	11.59
Forecast Recruitment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parameter priors	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00
Parameter softbounds	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.02
Parameter devs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crash Pen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 46: Sensitivity of the base model to dropping data sources and alternative assumptions about growth.

Label	Base (Francis weights)	Drop Sanitation data	Drop NWFSC Trawl index and lengths	Drop Gillnet data	Drop SCB survey data	Drop Onboard retained catch index	Drop Im- pingement data and est. one M and h	Drop Im- pingement data and est. one M	Drop Im- pingement data and est. M	Drop Im- pingement data and est. M
Female natural mortality	0.26	0.26	0.26	0.26	0.26	0.26	0.20	0.20	0.19	0.32
Male natural mortality	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.19	0.25
Steepness	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.89	0.72
InR0	8.16	8.09	8.17	8.15	8.17	8.17	8.50	7.72	7.61	30.77
Total Biomass (mt)	2796.86	2518.67	2798.21	2748.12	2842.37	2824.12	4329.79	2639.65	2469.87	14000000000000.00
Depletion	0.57	0.50	0.55	0.57	0.57	0.59	0.65	0.48	0.49	0.80
SPR ratio	0.72	0.83	0.72	0.74	0.71	0.71	0.50	0.93	0.97	0.00
Female Lmin	12.43	13.01	12.65	12.14	12.43	12.41	14.09	14.01	14.00	14.06
Female Lmax	33.31	34.42	33.30	33.11	33.29	33.34	33.34	32.46	32.49	33.52
Female K	0.25	0.21	0.25	0.26	0.25	0.25	0.24	0.26	0.26	0.24
Male Lmin (offset)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Male Lmax (offset)	-0.16	-0.15	-0.15	-0.16	-0.16	-0.16	-0.17	-0.16	-0.16	-0.17
Male K (offset)	-0.29	-0.77	-0.35	-0.26	-0.29	-0.29	-0.01	0.01	0.01	-0.06
Negative log-likelihood										
No. parameters	1097.30	109.00	113.00	113.00	113.00	113.00	113.00	113.00	114.00	114.00
TOTAL	0.00	899.14	1053.68	1004.53	1070.73	1111.06	995.14	1004.90	1004.31	993.80
Catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Equilibrium catch	-98.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Survey	763.02	-93.00	-101.81	-92.02	-97.20	-82.66	-98.50	-98.54	-98.51	-98.36
Length composition	421.52	550.37	722.00	664.99	736.19	761.73	685.20	688.37	688.00	683.99
Age composition	10.88	432.29	423.28	420.63	420.94	421.15	398.89	404.88	404.78	398.66
Recruitment	0.00	9.48	10.20	10.92	10.79	10.85	9.55	10.00	9.80	9.38
Forecast Recruitment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parameter priors	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.23	0.13
Parameter softbounds	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Parameter devs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crash Pen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 47: Summary of the biomass/abundance time series used in the stock assessment.

Fleet	Years	Name	Fishery ind.	Filtering	Method	Endorsed
4	2004-2016	Recreational PR dockside CPUE	No	trip, area, regulations, Stephens-MacCall	delta-GLM (bin-lognormal)	SSC
5	1980-2016	CPFV logbook CPUE	No	trip, gear, effort, species, depth, sample size	negative binomial	SSC
6	2002-2016	Onboard observer discard catch CPUE	No	habitat ,regulations, effort, boats	delta-GLM (bin-lognormal)	SSC
7	1970-2016	Sanitation district CPUE	Yes	sample size, depth, tow times	delta-GLM (bin-lognormal)	SSC
8	2003-2016	NWFSC trawl survey CPUE	Yes	depth, area	VAST	SSC
9	1995-2008	CSUN/VRG Gillnet survey CPUE	Yes	gear, site, month	delta-GLM (bin-lognormal)	SSC
11	1994; 1998; 2003; 2008; 2013	Southern California Bight trawl survey CPUE	Yes	depth, area	delta-GLM (bin-lognormal)	SSC
12	2002-2016	Onboard observer retained catch CPUE	No	habitat, regulations, effort, boats	delta-GLM (bin-lognormal)	SSC

Table 48: Summaries of key assessment outputs and likelihood values from the retrospective analysis. Note that male growth parameters are exponential offsets from female parameters, and depletion and SPR ratio are for the year of 2017.

Label	Base	Retro1	Retro2	Retro3	Retro4
Female natural mortality	0.26	0.26	0.26	0.26	0.26
Steepness	0.72	0.72	0.72	0.72	0.72
InR0	8.16	8.09	8.07	8.04	8.08
Total Biomass (mt)	2796.86	2593.78	2568.77	2498.07	2650.36
Depletion	57.41	53.57	50.74	50.72	54.78
SPR ratio	0.72	0.76	0.79	0.80	0.74
Female Lmin	12.43	12.45	12.90	12.63	13.03
Female Lmax	33.31	33.50	33.39	33.37	33.46
Female K	0.25	0.24	0.24	0.25	0.23
Male Lmin (offset)	0.00	0.00	0.00	0.00	0.00
Male Lmax (offset)	-0.16	-0.16	-0.15	-0.16	-0.15
Male K (offset)	-0.29	-0.30	-0.43	-0.41	-0.56
Negative log-likelihood	1097.30	1047.56	1009.37	961.81	897.04
No. parameters	0.00	0.00	0.00	0.00	0.00
TOTAL	0.00	0.00	0.00	0.00	0.00
Equilibrium catch	-98.12	-92.00	-89.12	-81.75	-80.59
Survey	763.02	739.90	720.39	700.10	670.66
Length composition	421.52	390.56	369.97	336.26	299.84
Age composition	10.88	9.09	8.12	7.20	7.12
Recruitment	0.00	0.00	0.00	0.00	0.00
Forecast Recruitment	0.00	0.00	0.00	0.00	0.00
Parameter priors	0.01	0.01	0.01	0.01	0.01

Table 49: Summaries of key assessment outputs and likelihood values from selected likelihood profile runs on virgin recruitment ($\ln R_0$) and steepness. Note that male growth parameters are exponential offsets from female parameters, and depletion and SPR ratio are for the year of 2017.

Label	R07400	R07800	R08200	R08600	R09000	h0410	h0570	h0710	h0870	h0990
Female M	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Steepness	0.72	0.72	0.72	0.72	0.72	0.41	0.57	0.71	0.87	0.99
$\ln R_0$	7.40	7.80	8.20	8.60	9.00	8.34	8.21	8.16	8.13	8.11
Total biomass (m)	1623.19	2113.03	2894.72	4173.95	6142.97	3313.42	2943.85	2802.69	2712.12	2667.97
Depletion (%)	46.83	49.83	58.31	66.23	71.80	51.20	55.27	57.32	58.81	59.60
SPR ratio	1.05	0.91	0.70	0.49	0.34	0.68	0.71	0.72	0.72	0.73
Female Lmin	12.16	12.41	12.43	12.39	12.36	12.43	12.44	12.43	12.43	12.43
Female Lmax	34.29	33.83	33.26	32.76	32.42	33.19	33.28	33.31	33.33	33.34
Female K	0.24	0.25	0.25	0.26	0.26	0.25	0.25	0.25	0.25	0.25
Male Lmin (offset)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Male Lmax (offset)	-0.18	-0.17	-0.16	-0.15	-0.15	-0.16	-0.16	-0.16	-0.16	-0.16
Male K (offset)	-0.22	-0.31	-0.29	-0.24	-0.21	-0.27	-0.29	-0.29	-0.30	-0.30
Negative log-likelihood										
TOTAL	1117.15	1101.02	1097.33	1099.69	1102.95	1101.35	1098.58	1097.35	1096.72	1100.21
Catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Equil_catch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Survey	-100.10	-99.20	-97.99	-97.00	-96.37	-98.27	-98.18	-98.12	-98.06	-98.03
Length_comp	761.18	760.12	763.44	767.61	770.76	765.11	763.69	763.05	762.58	762.33
Age_comp	437.32	427.37	421.09	418.57	417.98	420.58	421.24	421.51	421.68	421.77
Recruitment	18.74	12.72	10.80	10.50	10.58	12.55	11.40	10.90	10.56	10.38
Forecast_Recruitment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parm_priors	0.00	0.00	0.00	0.00	0.00	1.38	0.42	0.01	-0.04	3.76
Parm_softbounds	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Parm_devs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crash_Pen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 50: Summaries of key assessment outputs and likelihood values from selected likelihood profile runs on female natural mortality. Note that male growth parameters are exponential offsets from female parameters, and depletion and SPR ratio are for the year of 2017.

Label	M0220	M0260	M0300	M0350	M0400
Female M	0.22	0.26	0.30	0.35	0.40
Steepness	0.72	0.72	0.72	0.72	0.72
lnR0	7.67	8.20	8.95	12.21	31.00
Total biomass (m)	2259.39	2861.79	4632.81	89473.50	975357000000.00
Depletion (%)	47.72	58.15	68.08	79.27	79.74
SPR ratio	0.97	0.70	0.41	0.02	0.00
Female Lmin	12.39	12.44	12.43	12.39	12.24
Female Lmax	33.23	33.31	33.31	33.25	33.73
Female K	0.25	0.25	0.25	0.25	0.24
Male Lmin (offset)	0.00	0.00	0.00	0.00	0.00
Male Lmax (offset)	-0.16	-0.16	-0.15	-0.15	-0.15
Male K (offset)	-0.27	-0.30	-0.31	-0.32	-0.36
Negative log-likelihood					
TOTAL	1102.66	1096.96	1092.96	1089.92	1091.52
Catch	0.00	0.00	0.00	0.00	0.00
Equil_catch	0.00	0.00	0.00	0.00	0.00
Survey	-97.79	-98.14	-98.33	-98.33	-98.95
Length_comp	765.50	762.85	760.88	759.19	755.26
Age_comp	422.97	421.41	420.05	418.75	425.16
Recruitment	11.91	10.82	10.30	10.05	9.54
Forecast_Recruitment	0.00	0.00	0.00	0.00	0.00
Parm_priors	0.06	0.00	0.06	0.25	0.51
Parm_softbounds	0.01	0.01	0.01	0.00	0.00
Parm_devs	0.00	0.00	0.00	0.00	0.00
Crash_Pen	0.00	0.00	0.00	0.00	0.00

Table 51: Projection of potential OFL, spawning biomass, and depletion for the base case model.

Yr	OFL contribution (mt)	ACL landings (mt)	Age 5+ biomass (mt)	Spawning Biomass (mt)	Depletion
2017	282.776	150.000	1902.000	785.329	0.574
2018	300.049	150.000	1990.340	900.794	0.659
2019	333.999	307.627	2054.400	952.718	0.696
2020	326.566	300.835	1970.570	891.407	0.652
2021	309.686	285.301	1882.730	825.947	0.604
2022	292.990	269.898	1805.680	772.904	0.565
2023	279.639	257.575	1743.360	734.781	0.537
2024	269.391	248.119	1694.170	708.350	0.518
2025	261.422	240.769	1655.480	689.845	0.504
2026	255.138	234.974	1625.110	676.550	0.495
2027	250.168	230.390	1601.360	666.773	0.487
2028	246.265	226.790	1582.910	659.478	0.482

8 Figures

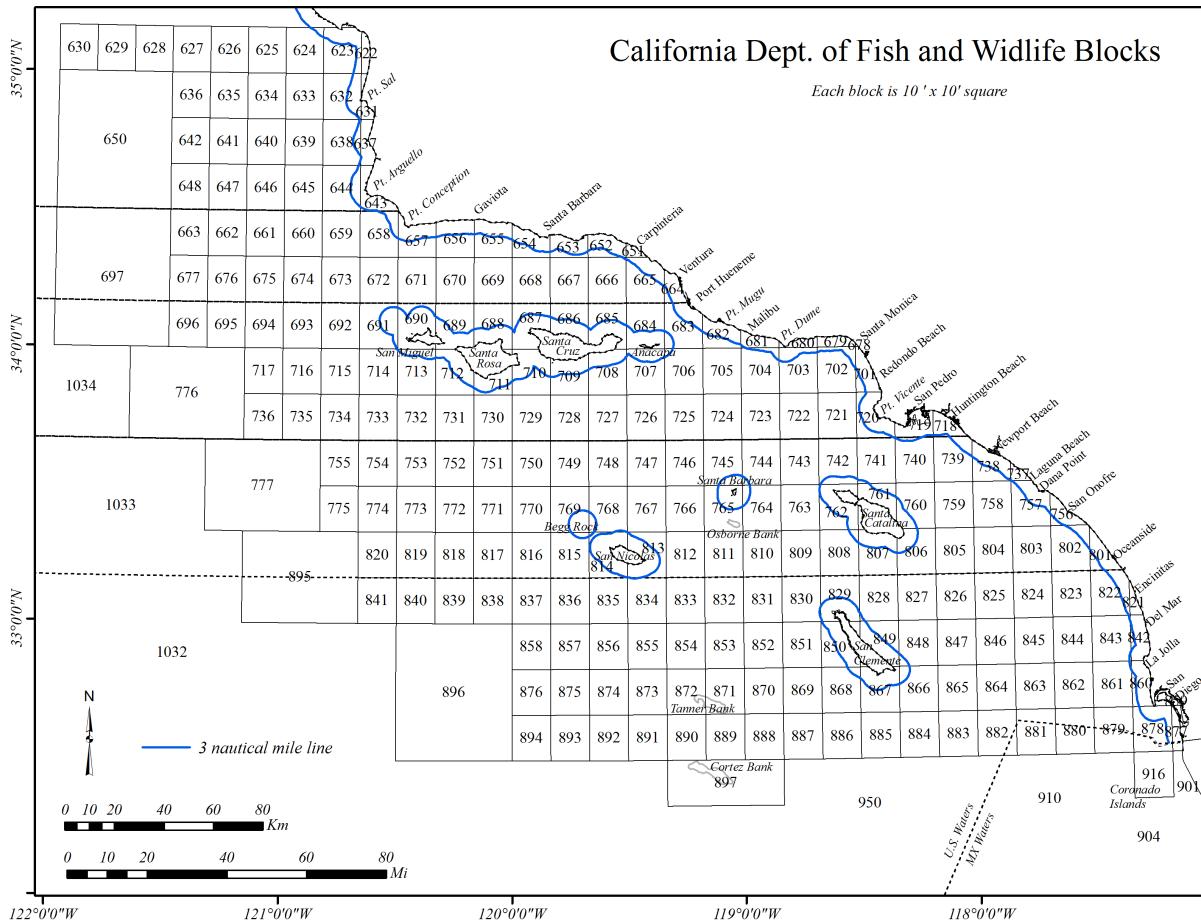


Figure 1: Map showing the state boundary lines for management of the recreational fishing fleets

Year	JAN-FEB	MAR-APR	MAY-JUN	JUL-AUG	SEP-OCT	NOV-DEC
1994						
1995						
1996						
1997			LE = 80,000 lb/ month; OA = 40,000 lb/ month			
1998						
1999						
2000		CLOSED				
2001		CLOSED				
2002		CLOSED				
2003	800	CLOSED	800	800	CLOSED	CLOSED
2004	300	CLOSED	300	400	400	300
2005	300	CLOSED	300	400	400	300
2006	300	CLOSED	300	400	400	300
2007	600	CLOSED	600	800	800	600
2008	600	CLOSED	600	800	800	600
2009	600	CLOSED	600	1,200	1,200	1,200
2010	600	CLOSED	600	1,200	1,200	1,200
2011	600	CLOSED	1,200	1,200	1,200	1,200
2012	1,200	CLOSED	1,200	1,200	1,200	1,200
2013	1,200	CLOSED	1,200	1,200	1,200	1,200
2014	1,200	CLOSED	1,200	1,200	1,200	1,200
2015	1,200	CLOSED	1,200	1,200	1,200	1,200
2016	1,200	CLOSED	1,200	1,200	1,200	1,200
2017	1,500	CLOSED	1,500	1,500	1,500	1,500

Figure 2: Commercial fishery regulations pertaining to limited entry (LE) and open access (OA) fisheries in southern California. Blocks with a numeric value indicate the bi-monthly trip limit for both LE and OA fisheries.

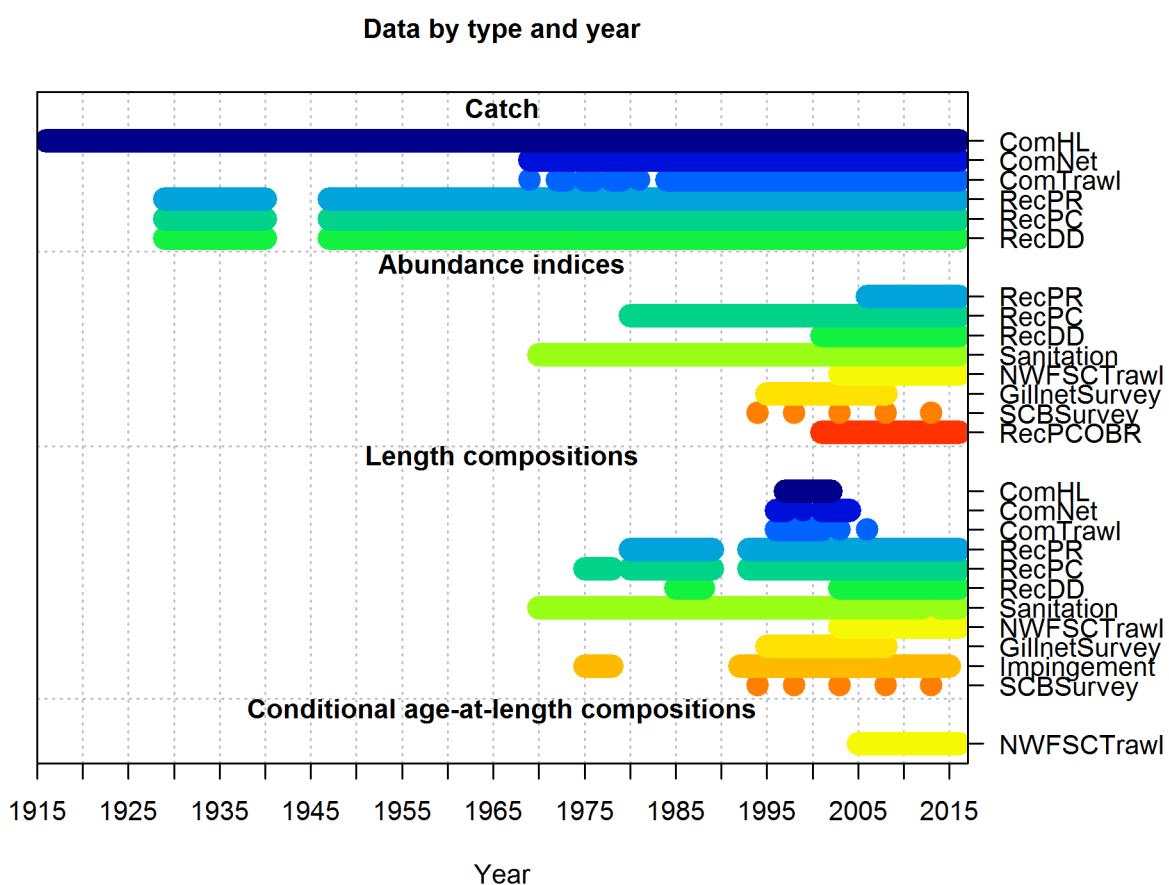


Figure 3: Summary of data sources used in the base model.

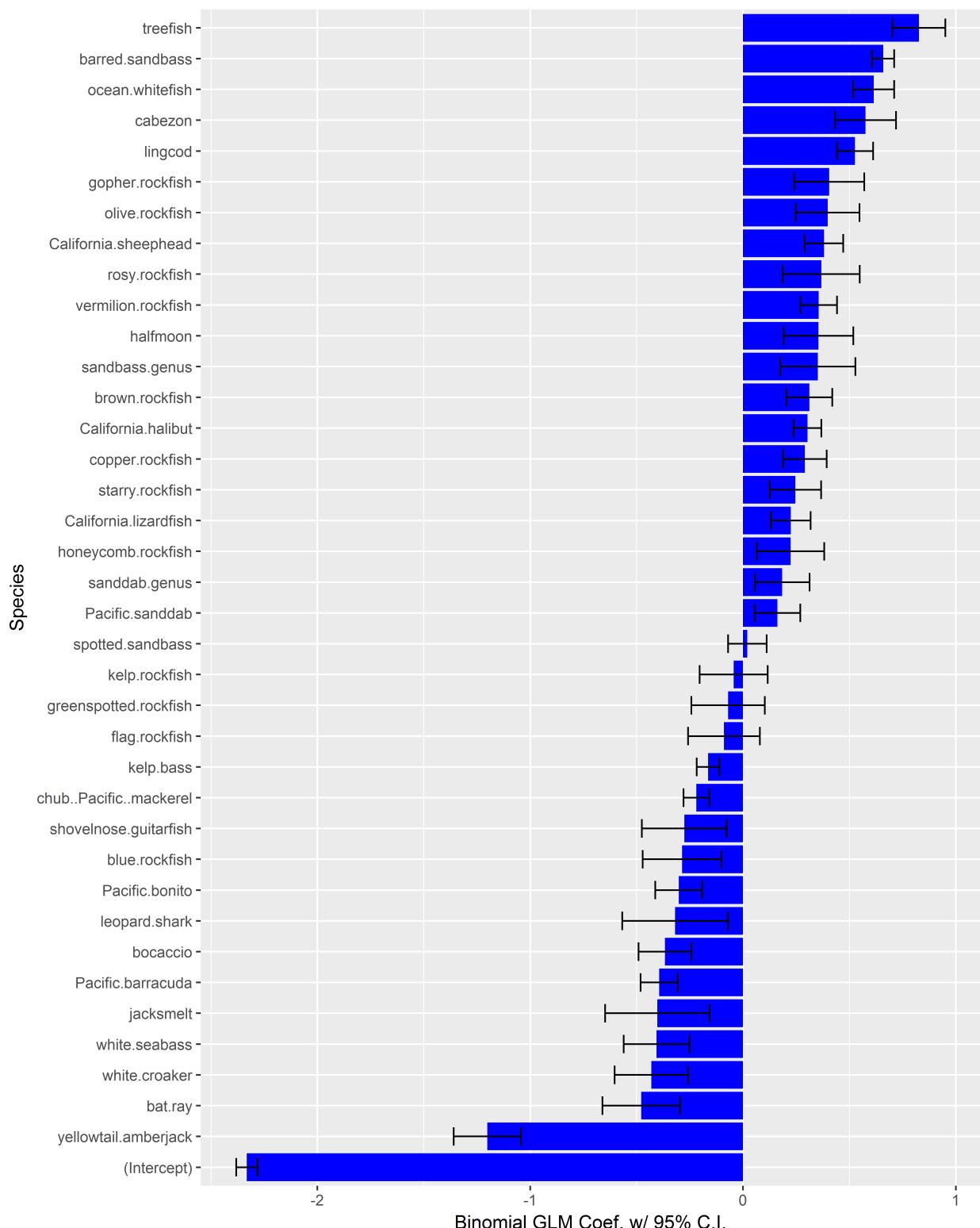


Figure 4: Species coefficients from the binomial GLM for presence/absence of California scorpionfish in the Marine Recreational Fisheries Statistics Survey (MRFSS) private mode dockside survey data set. Horizontal bars are 95% confidence intervals.

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1999	open	open	open	open	open	open						
2000	open	open	open	open	open	open						
2001	20	20	open	open	open	open	open	open	open	open	20	20
2002			open	open	open	open	20	20	20	20		
2003	20	20					20	20	30	30	30	
2004			60	60							60	60
2005										30	60	60
2006			60	60	60	60	60	60	60	60	60	60
2007	40	40	60	60	60	60	60	60	60	60	60	60
2008	40	40	60	60	60	60	60	60	60	60	60	60
2009	40	40	60	60	60	60	60	60	60	60	60	60
2010	40	40	60	60	60	60	60	60	60	60	60	60
2011	60	60	60	60	60	60	60	60	60	60	60	60
2012	60	60	60	60	60	60	60	60	60	60	50	50
2013	50	50	50	50	50	50	50	50	50	50	50	50
2014	50	50	50	50	50	50	50	50	50	50	50*	
2015	60	60	60	60	60	60	60	60				
2016	60	60	60	60	60	60	60	60				

Figure 5: A summary of the monthly recreational regulations for California scorpionfish in southern California. Cells with “open” indicate no depth restriction, black cells indicate the fishery is closed, and cells with a number indicate the depth restriction in fathoms, e.g., 20 = retained catch allowed in less than 20 fathoms. *Fishery closed on November 15, 2014.

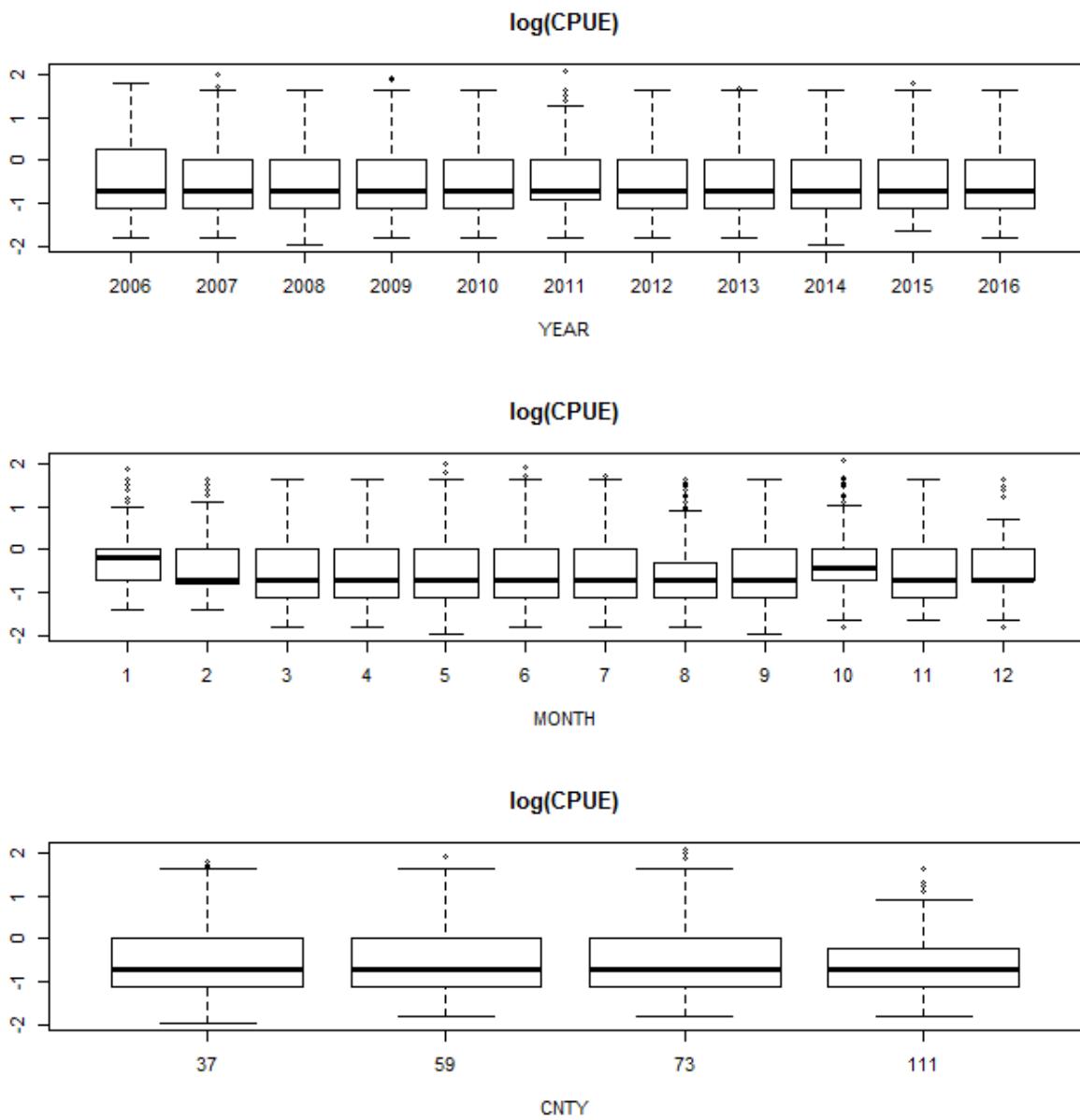


Figure 6: Boxplots of the raw log CPUE by year for each of the three factors considered in the deltaGLM model, county, month and year.

Normal Q-Q Plot

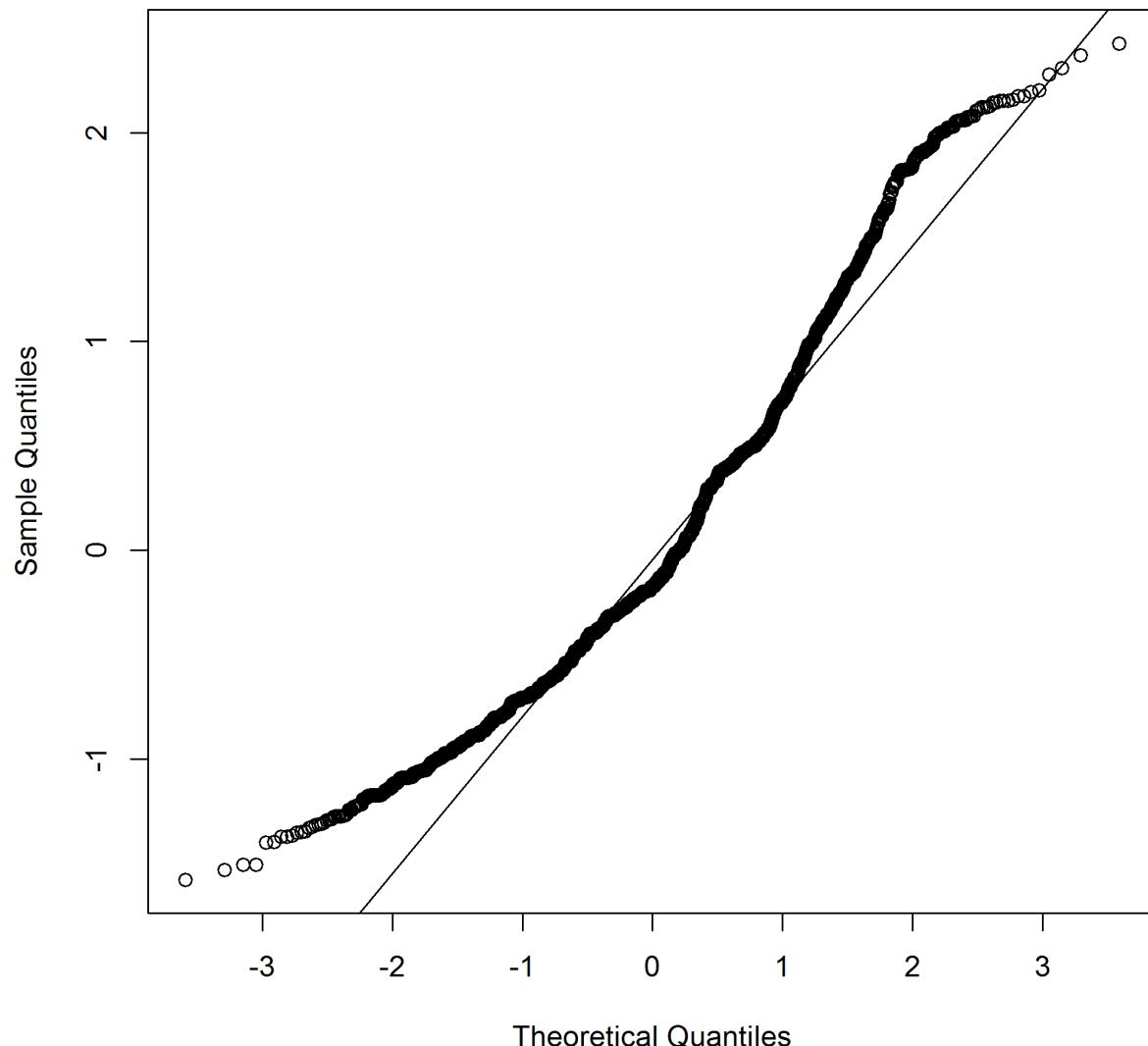


Figure 7: Q-Q plot used to evaluate the fit of the lognormal (positive encounters) of California scorpionfish from the California Recreational Fisheries Statistics Survey (CRFS) private mode dockside survey data set.

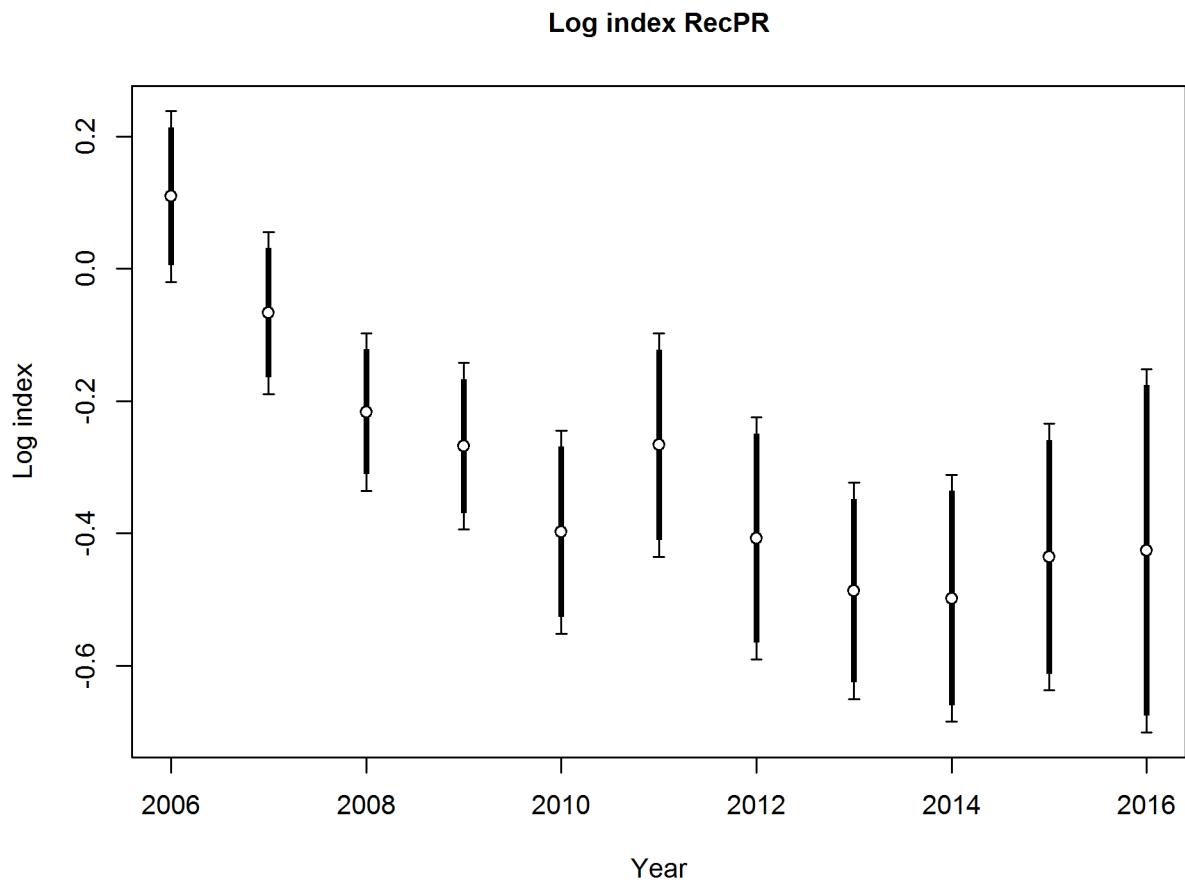


Figure 8: Standardized index on log scale for the recreational CPFV logbook retained catches. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

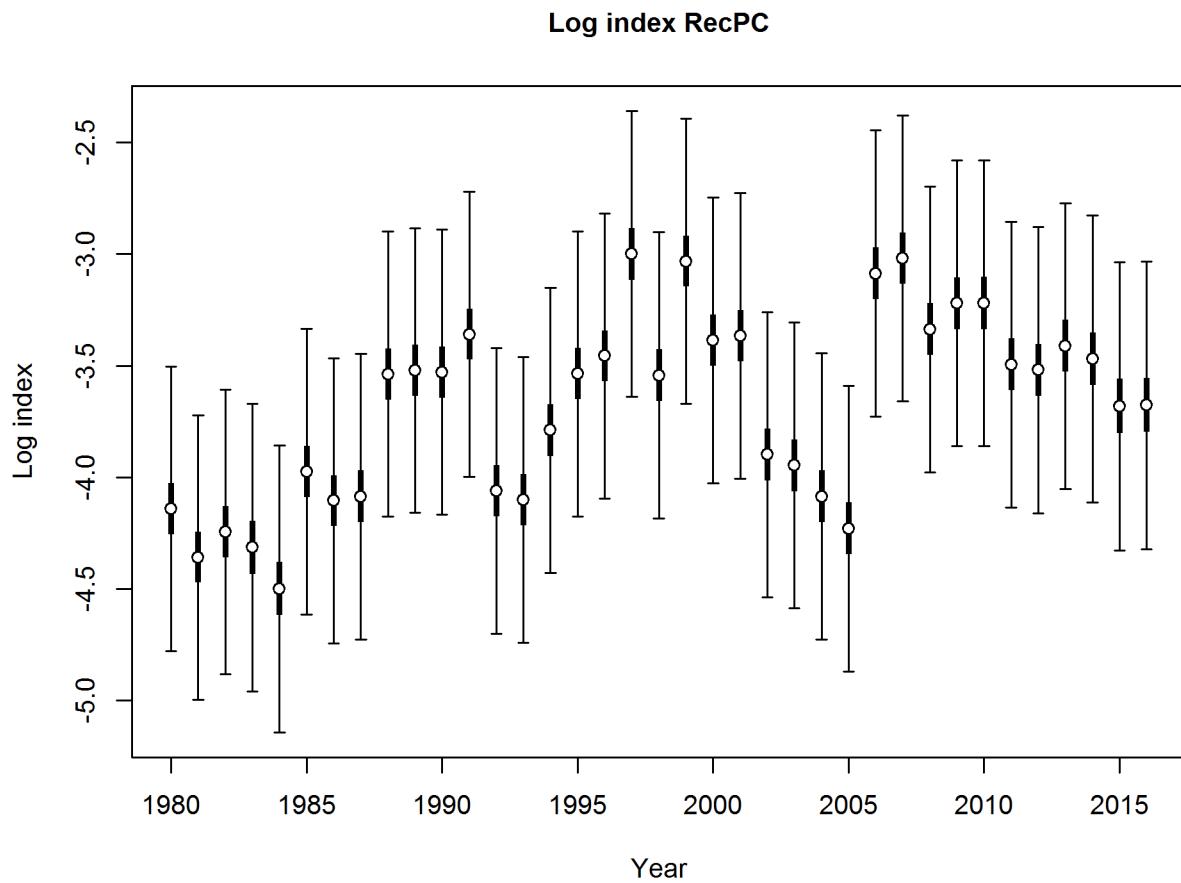


Figure 9: Standardized index on the log scale for the recreational CPFV logbook retained catches. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

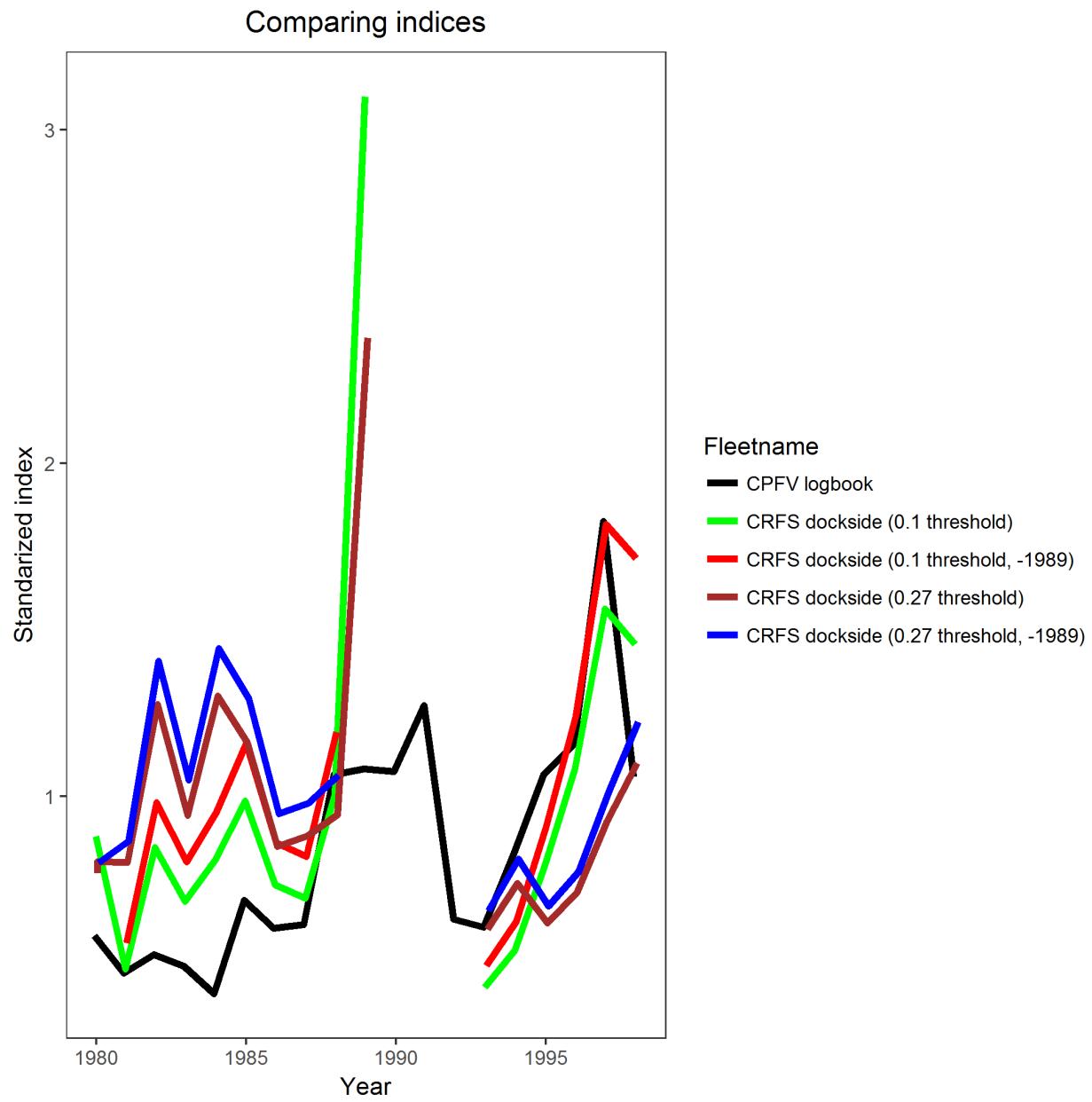


Figure 10: Comparison of standardized indices using two different threshold levels (0.27 and 0.1) from the Stephens-MacCall filtering, and including or excluding the year 1989.

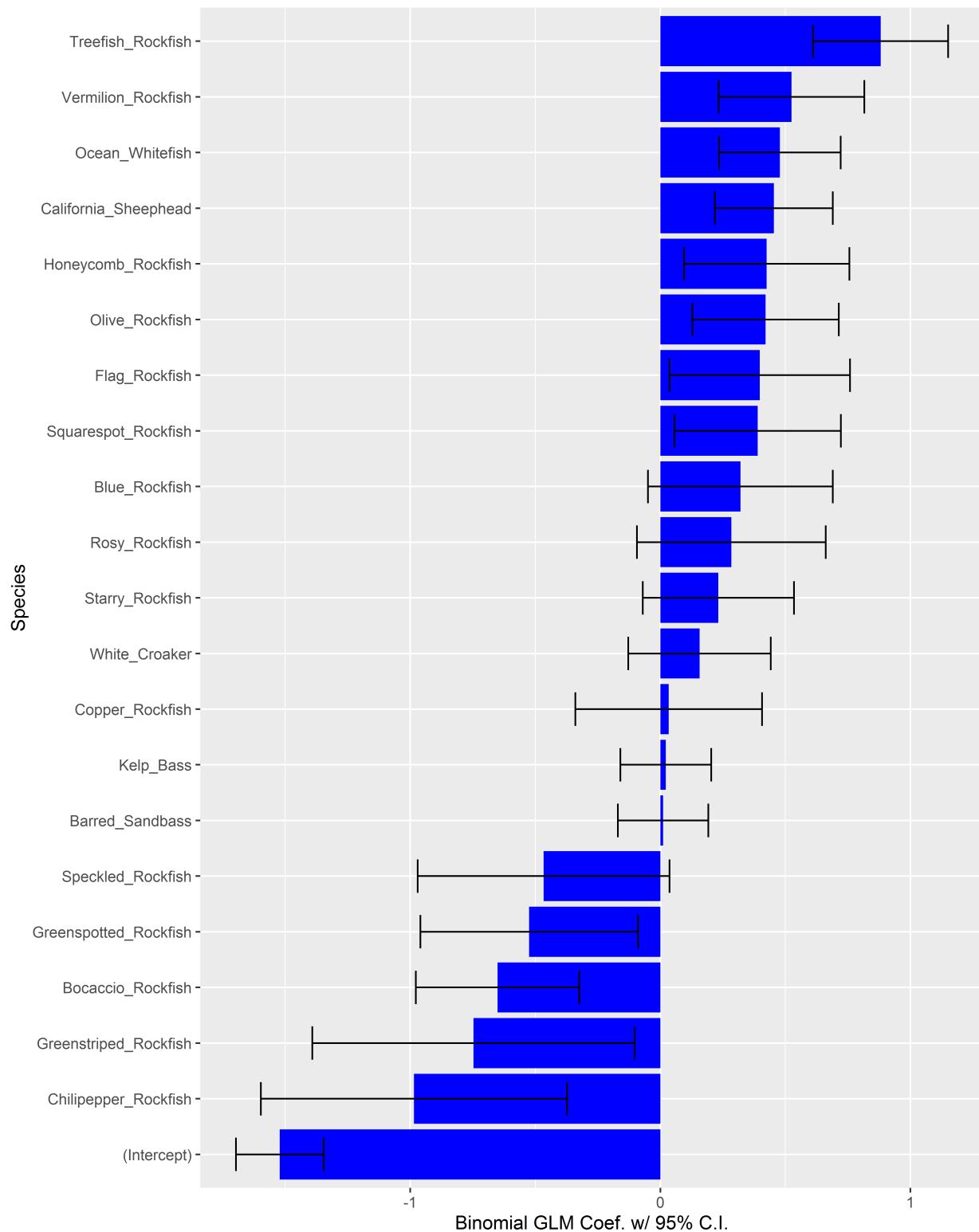


Figure 11: Species coefficients from the binomial GLM for presence/absence of California scorpionfish in the Marine Recreational Fisheries Statistics Survey (MRFSS) party/charter mode dockside survey data set. Horizontal bars are 95% confidence intervals.

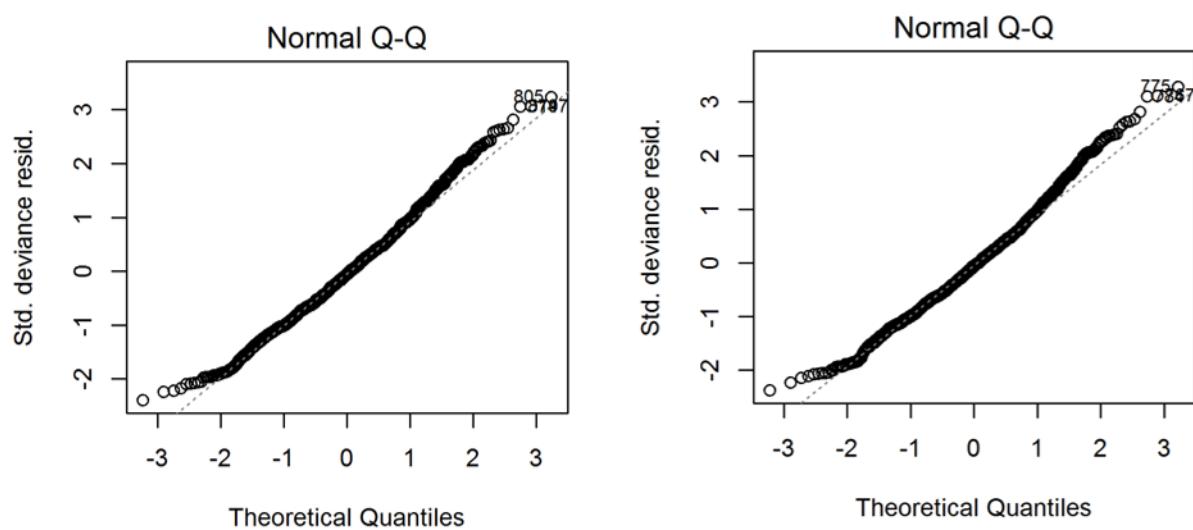


Figure 12: Q-Q plot used to validate the goodness of fit of the lognormal portion (positive catch) of the Marine Recreational Fisheries Statistics Survey (MRFSS) party/charter dockside survey, for thresholds of 0.27 (left) and 0.10 (right) from the Stephens-MacCall filter.

Normal Q-Q Plot

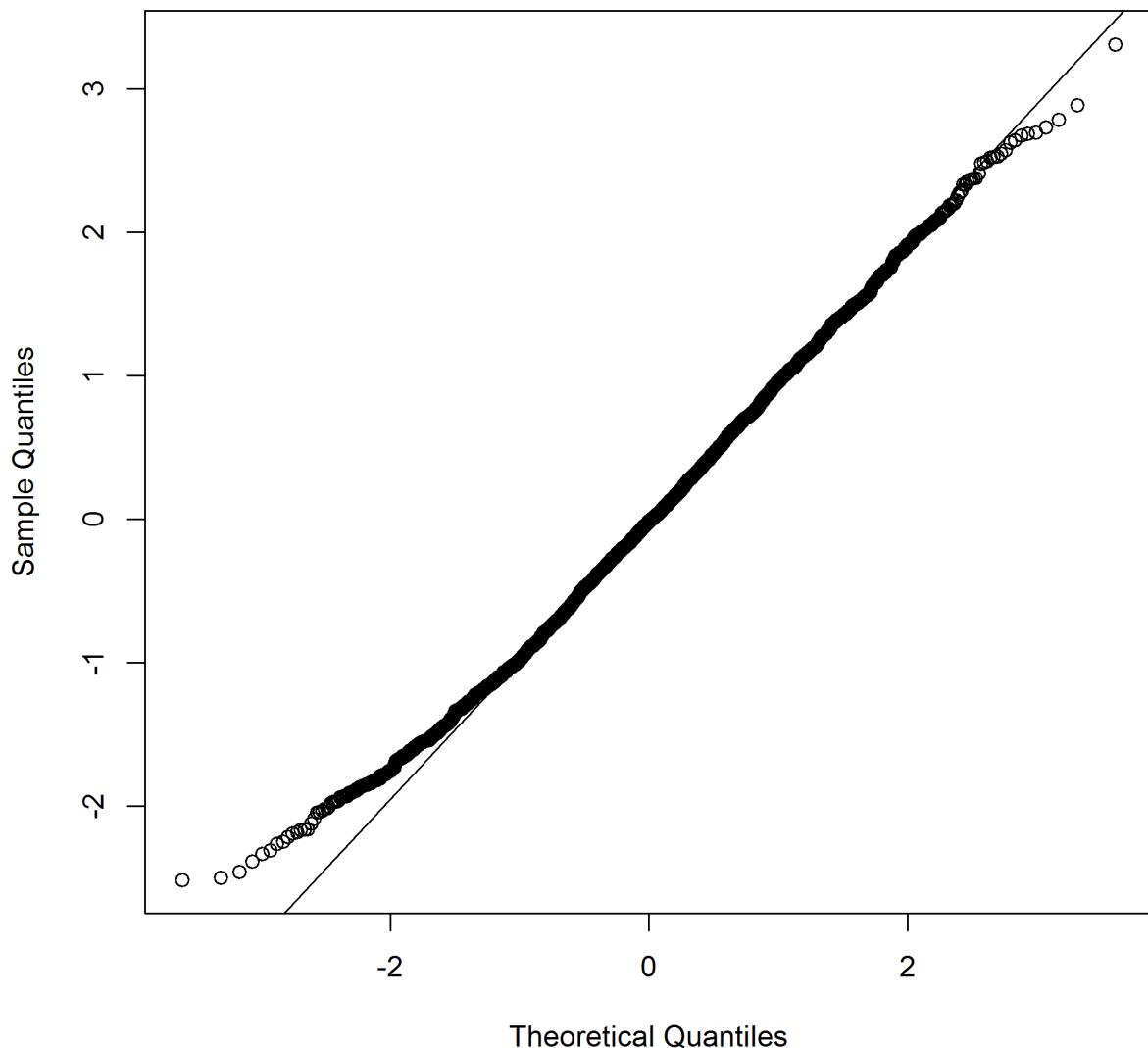


Figure 13: Q-Q plot used to validate the goodness of fit of the lognormal model for the CPFV onboard observer discarded only catch.

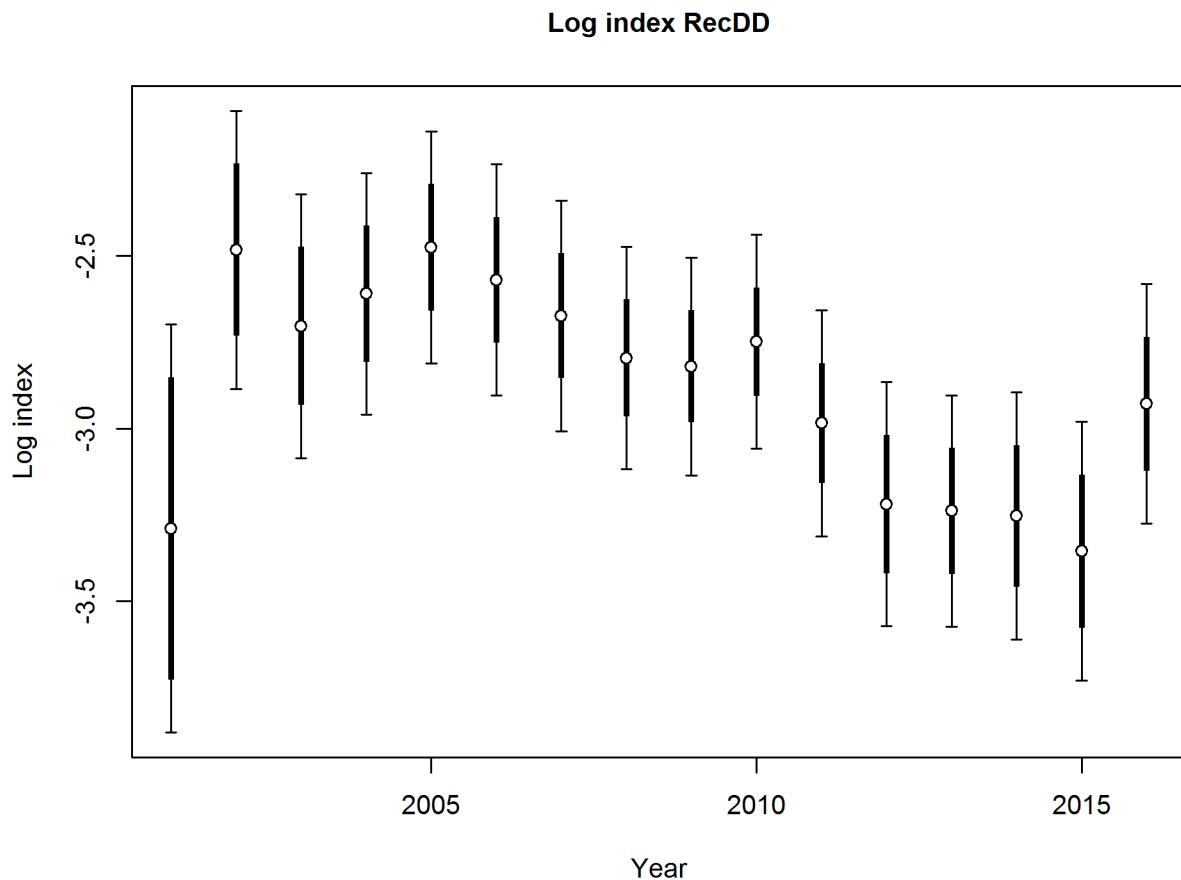


Figure 14: Standardized index on the log scale for the recreational CPFV onboard observer discarded catch index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

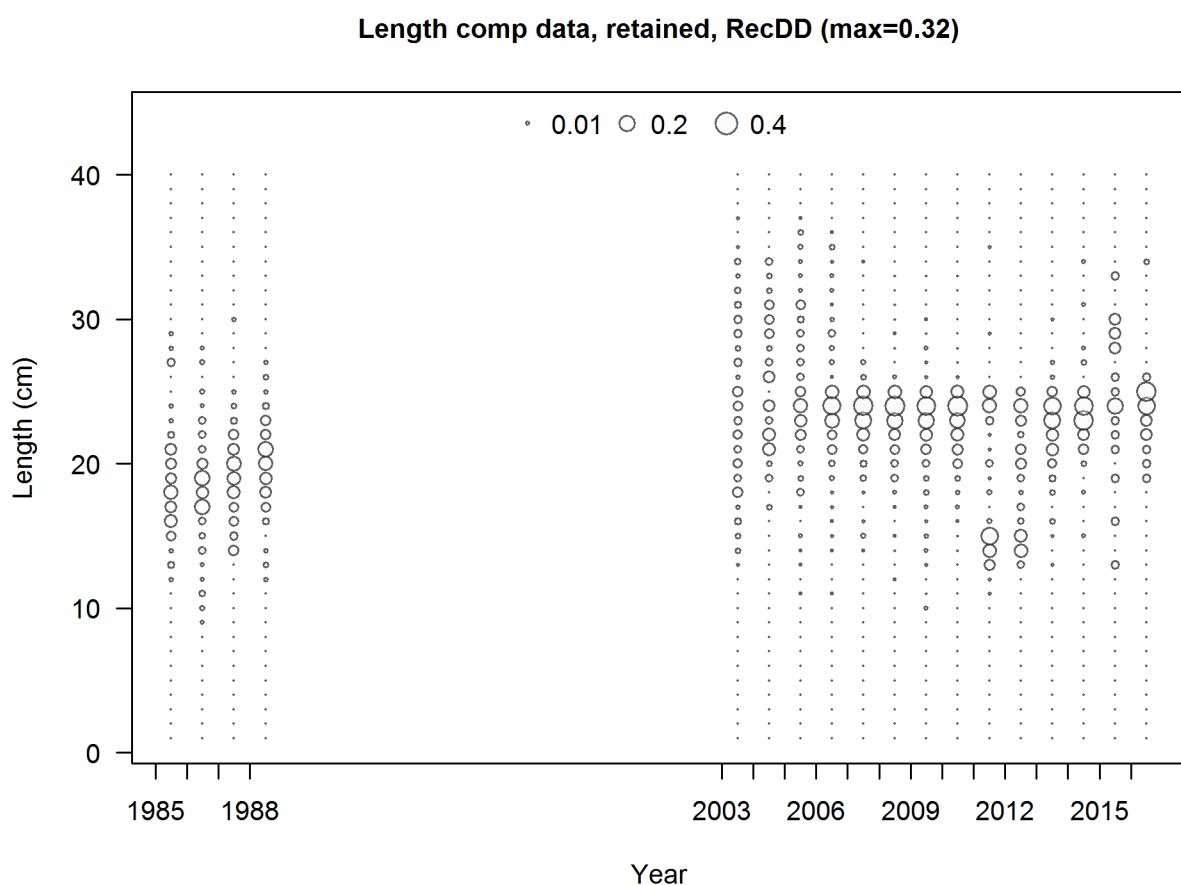


Figure 15: Length frequency distributions from the onboard observer discard-only catch.

Normal Q-Q Plot

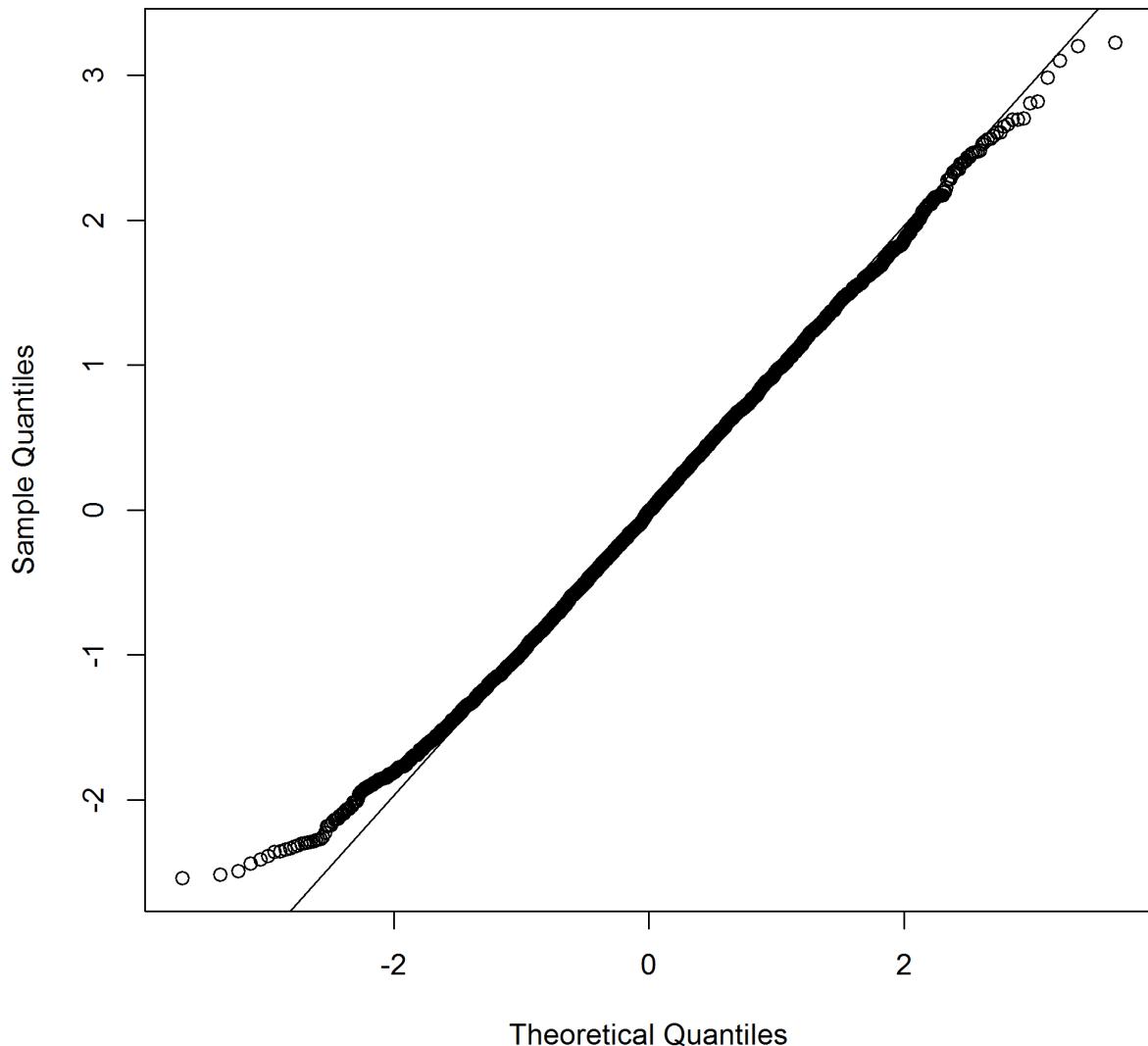


Figure 16: Q-Q plot used to validate the goodness of fit of the lognormal model for the CPFV onboard observer retained only catch.

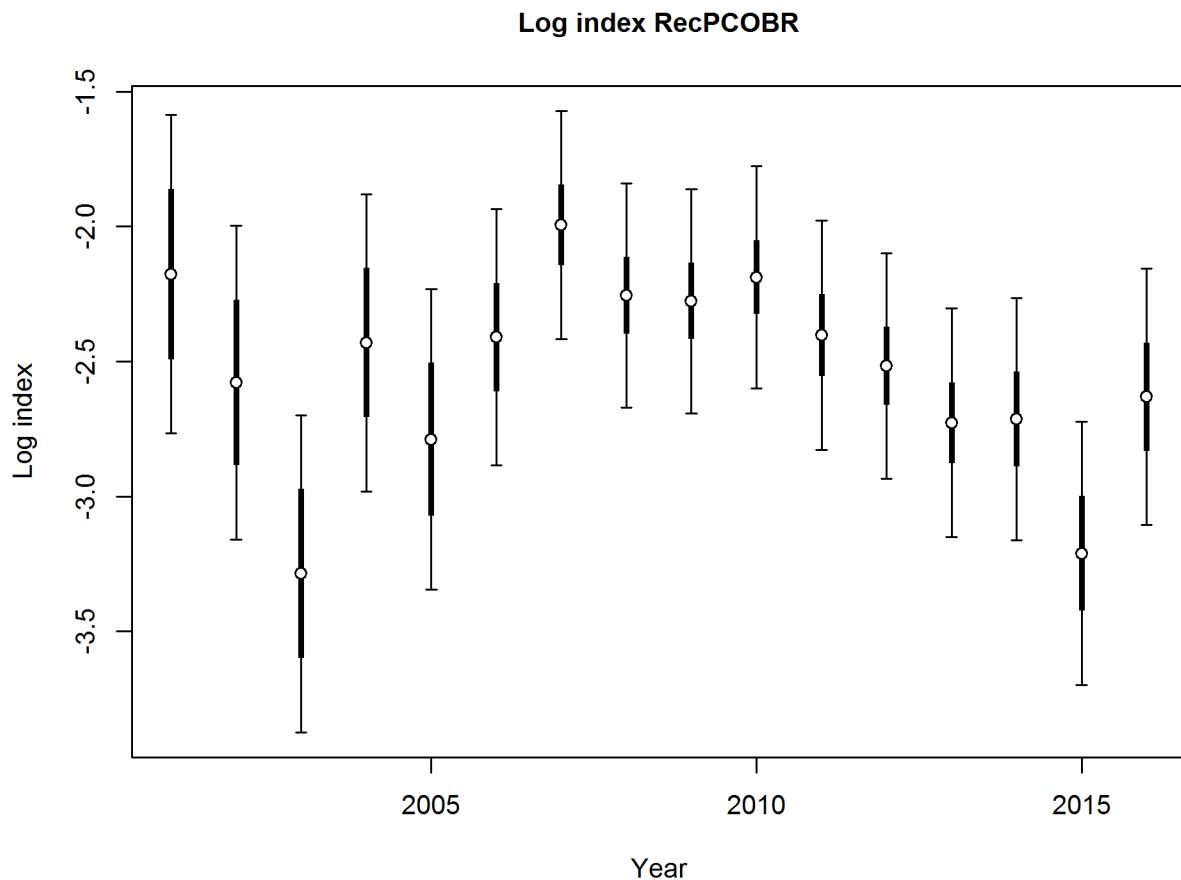


Figure 17: Standardized index on the log scale for the recreational CPFV onboard observer retained catch index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

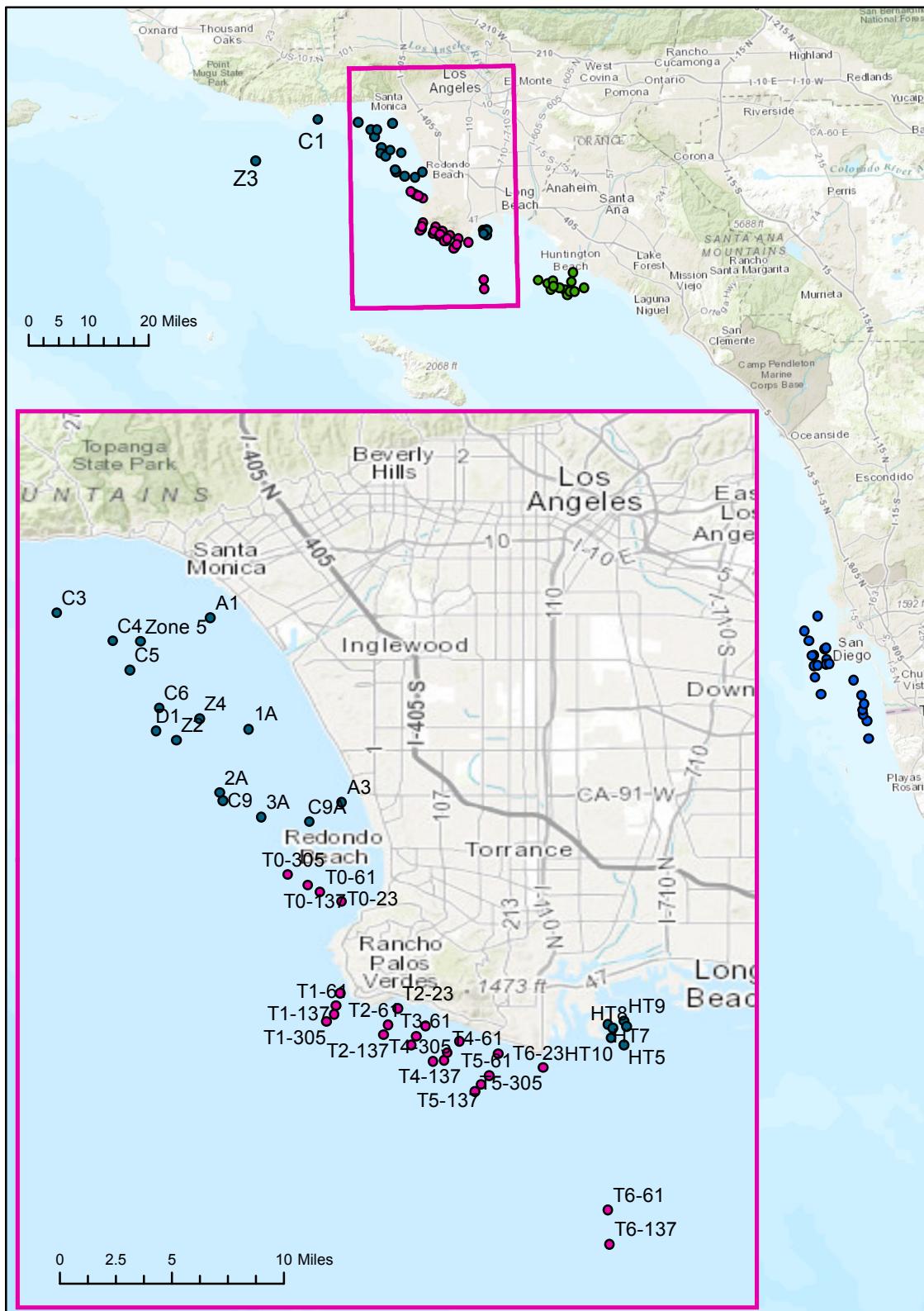


Figure 18: Map of stations sampled in at least 5 years by the Sanitation Districts of Los Angeles County (magenta) and the City of Los Angeles Environmental Monitoring Division (blue)

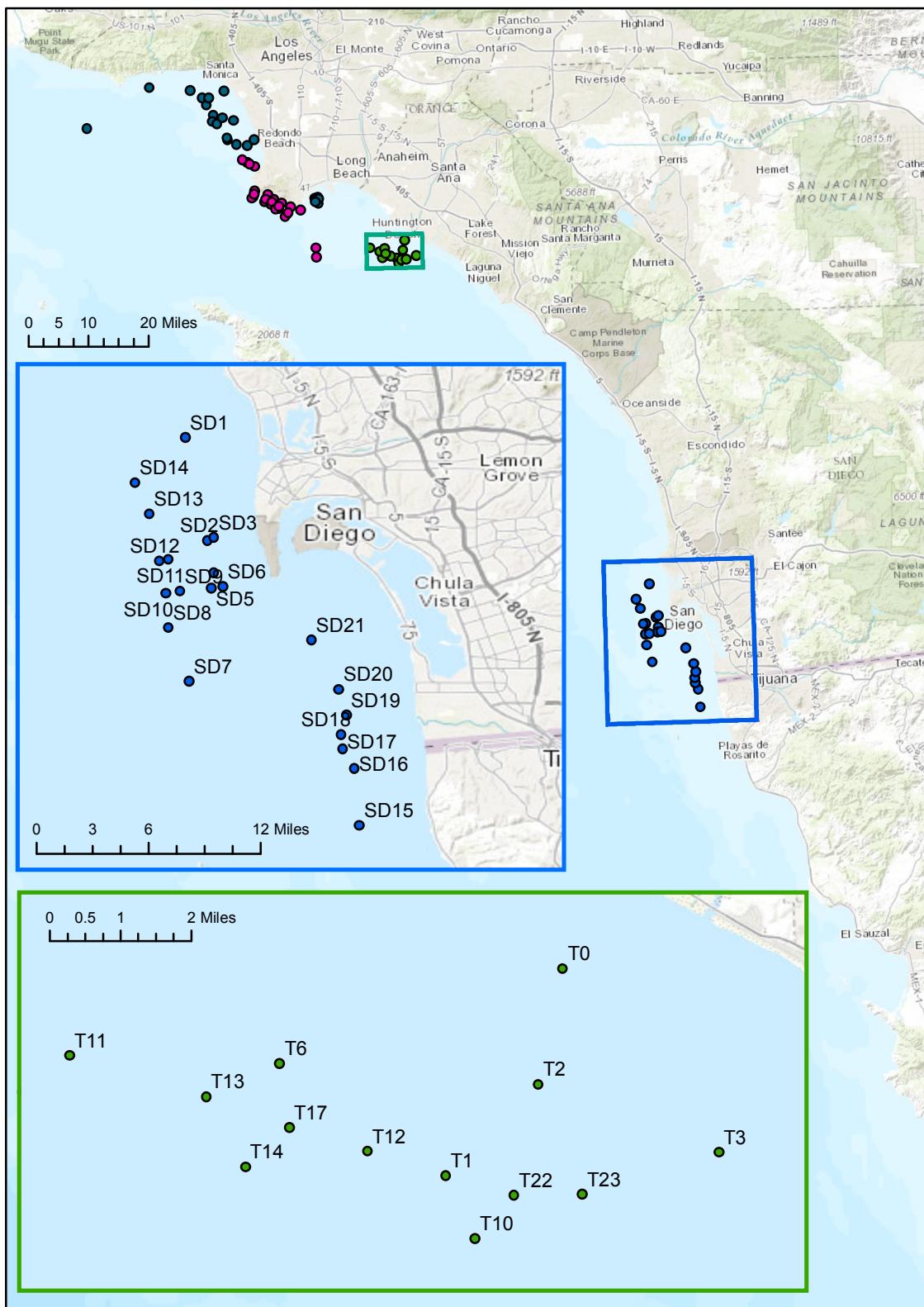


Figure 19: Map of stations sampled in at least 5 years by the Orange County Sanitation District (green) and the City of San Diego Public Utilities Ocean Monitoring Program (blue)

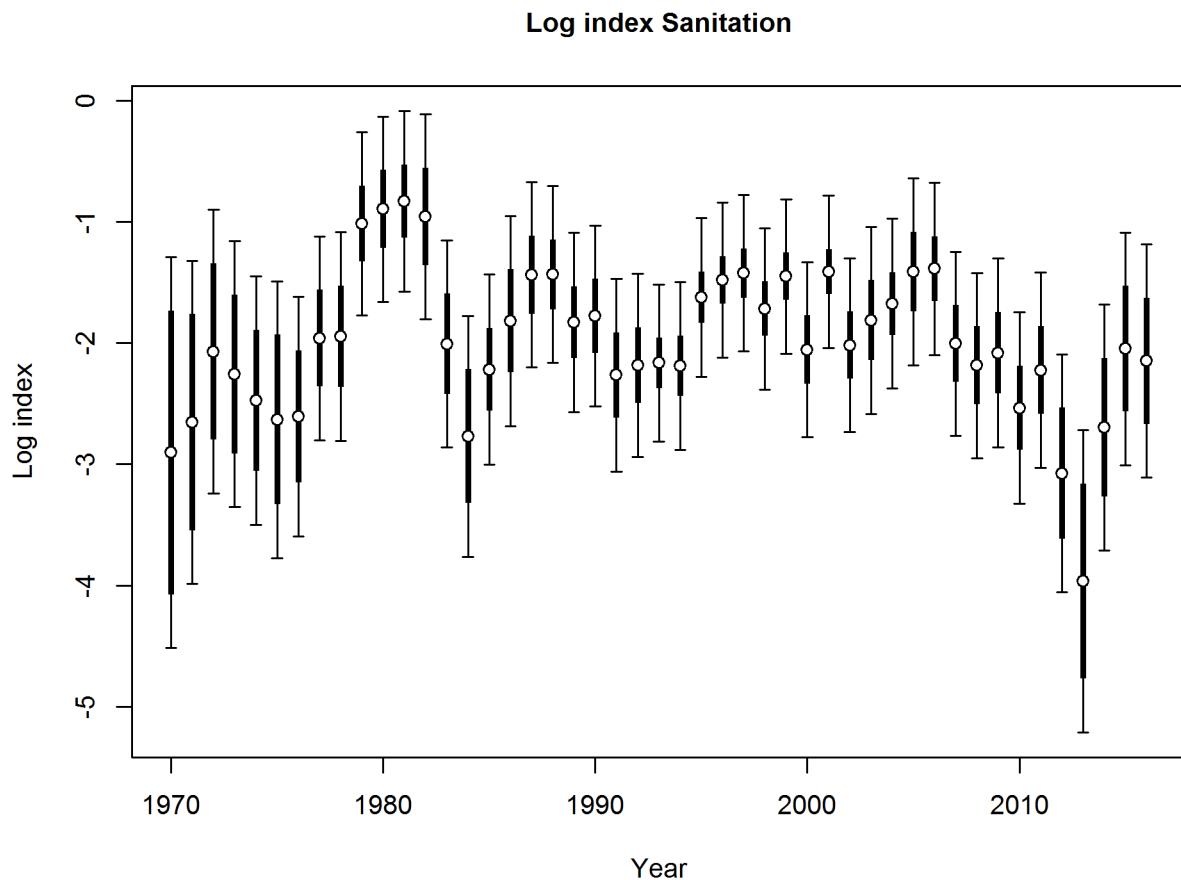


Figure 20: Standardized index on log scale for the Publicly Owned Treatment Works monitoring programs trawl index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

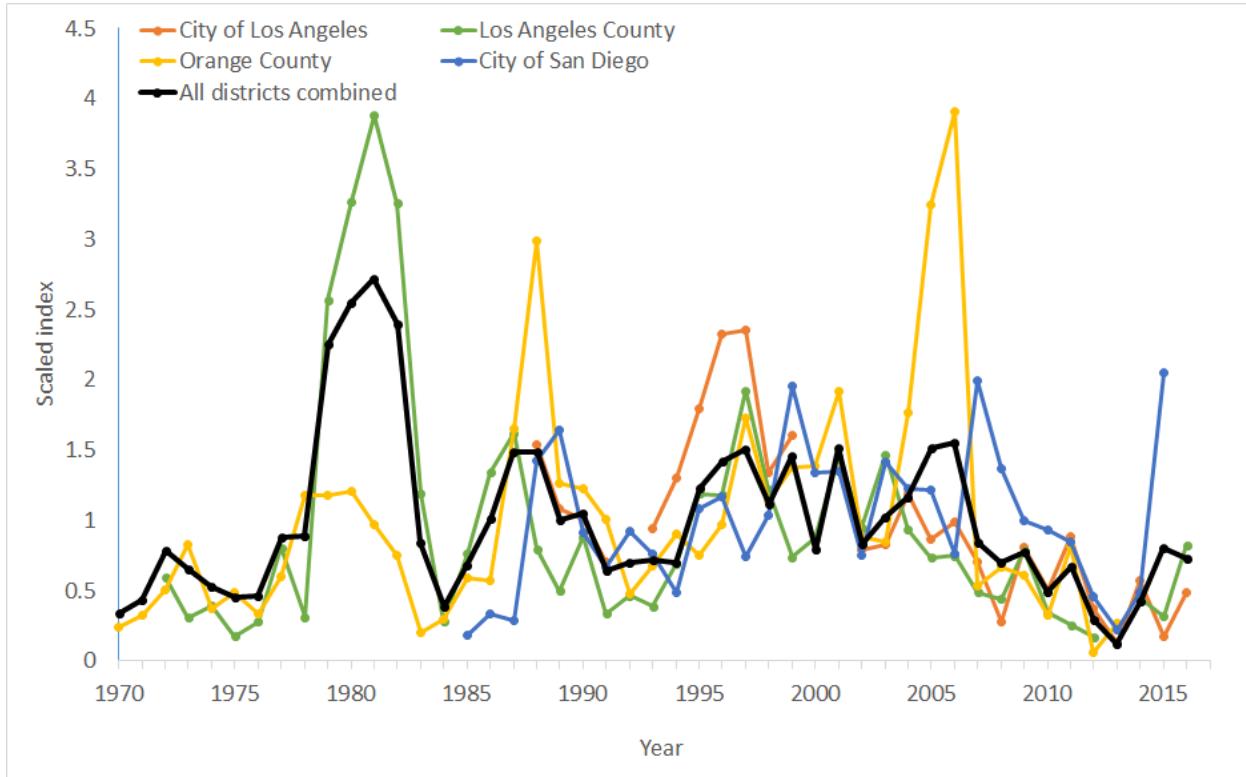


Figure 21: Comparison of standardized indices for each Publicly Owned Treatment Works monitoring program independently and with data from all Publicly Owned Treatment Works programs combined.

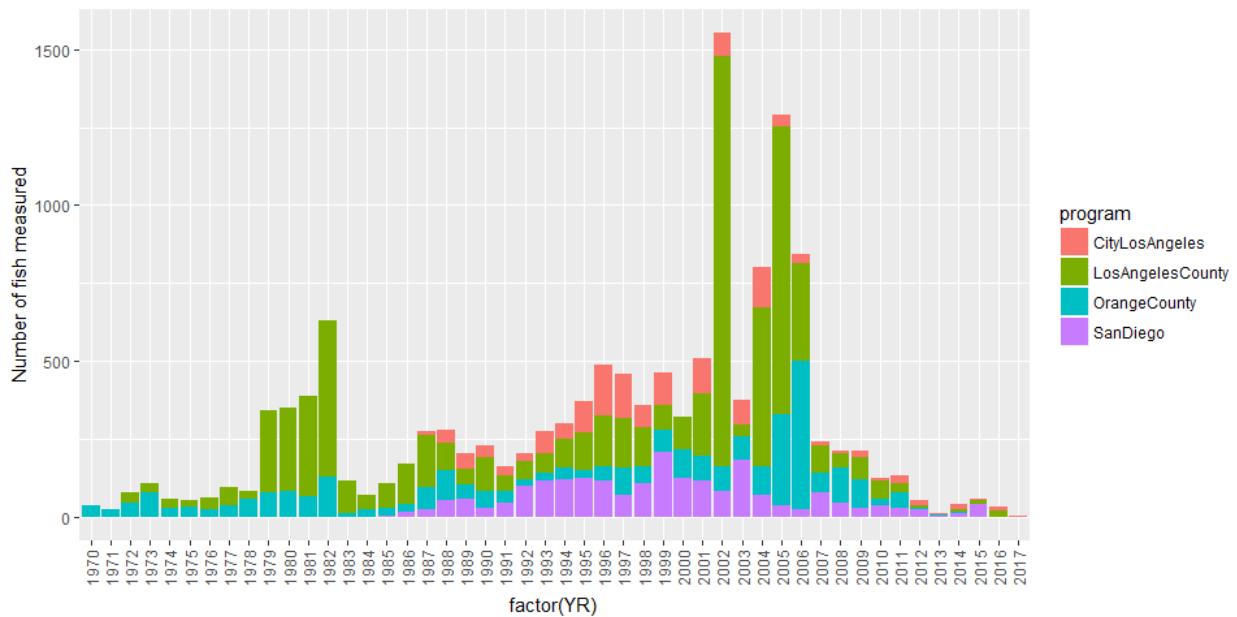


Figure 22: Sample sizes of measured California scorpionfish by Publicly Owned Treatment Works monitoring program and year.

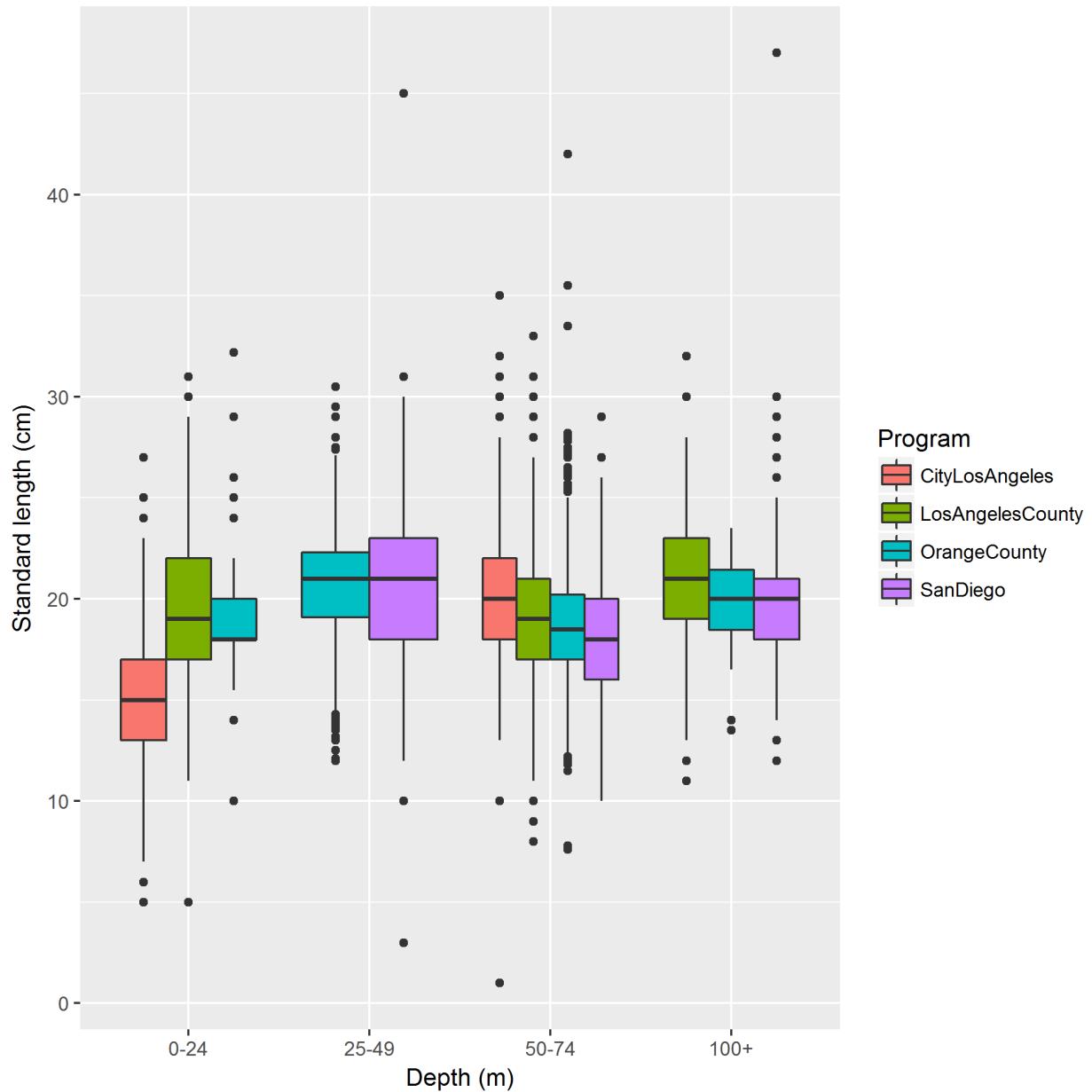


Figure 23: Boxplots of measured California scorpionfish from the Publicly Owned Treatment Works monitoring surveys by program and 25 m depth bins.

Length comp data, retained, Sanitation (max=0.78)

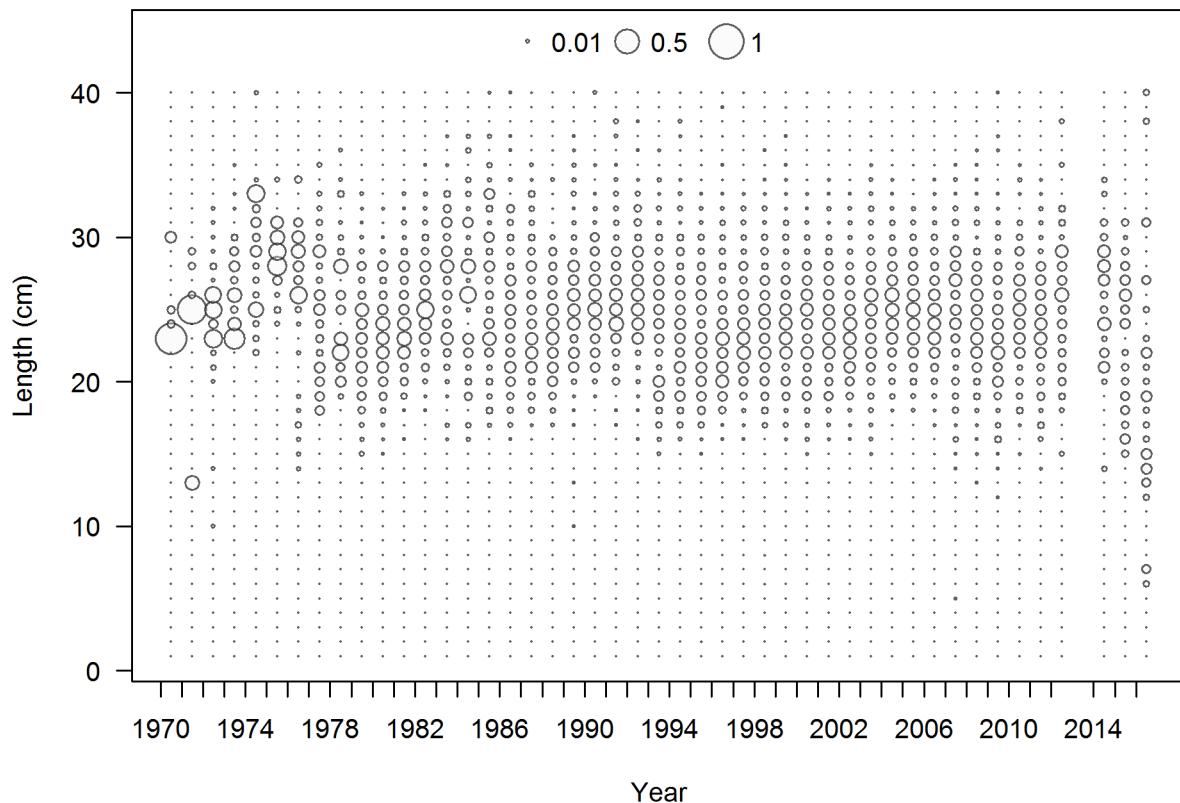


Figure 24: Length frequency distributions from the Publicly Owned Treatment Works monitoring trawl surveys.

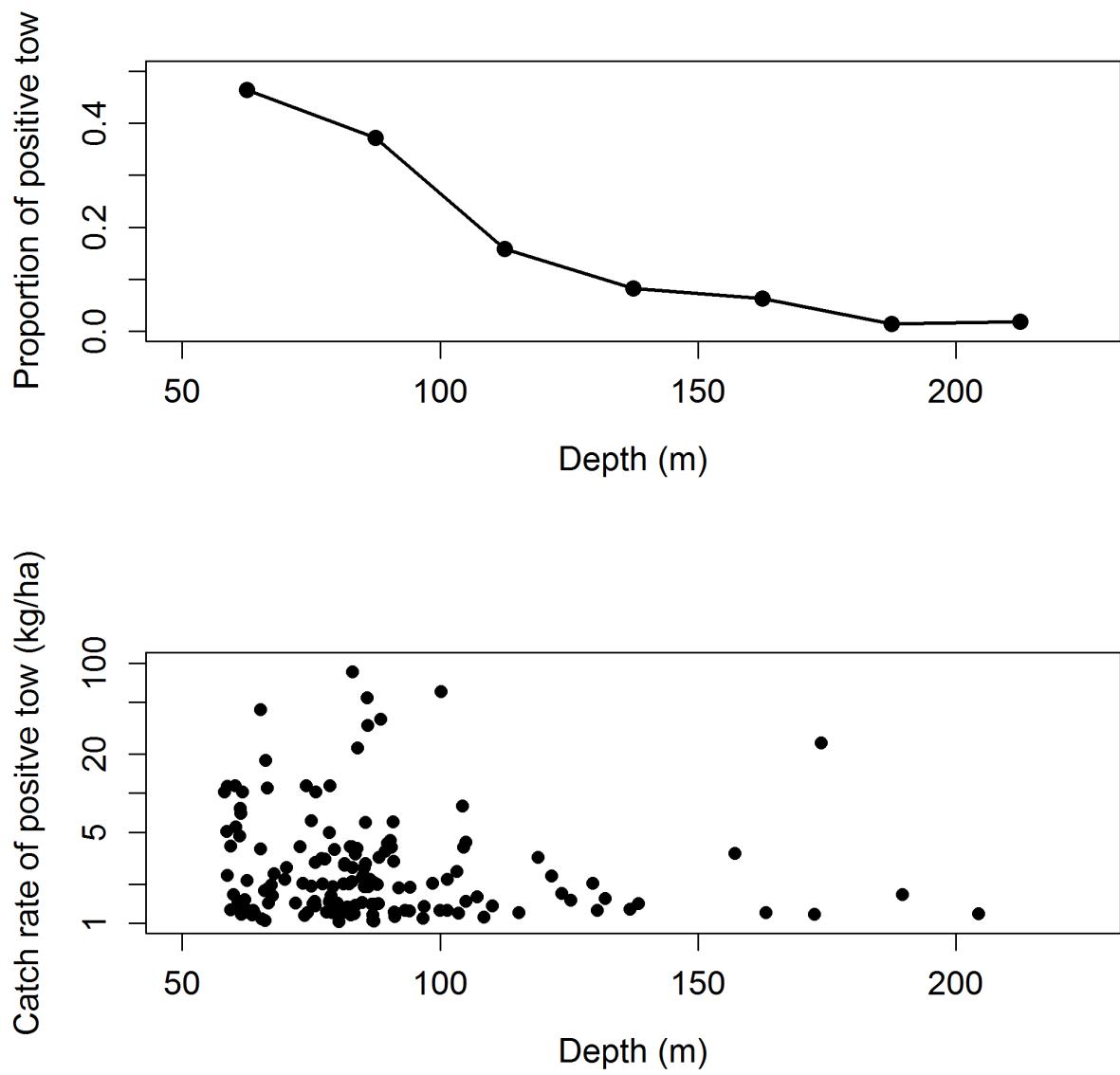


Figure 25: Plots of the proportion of positive tows (top panel) and the raw catch rates of positive tows (bottom panel) by depth zones (25 m interval) for NWFSC trawl survey.

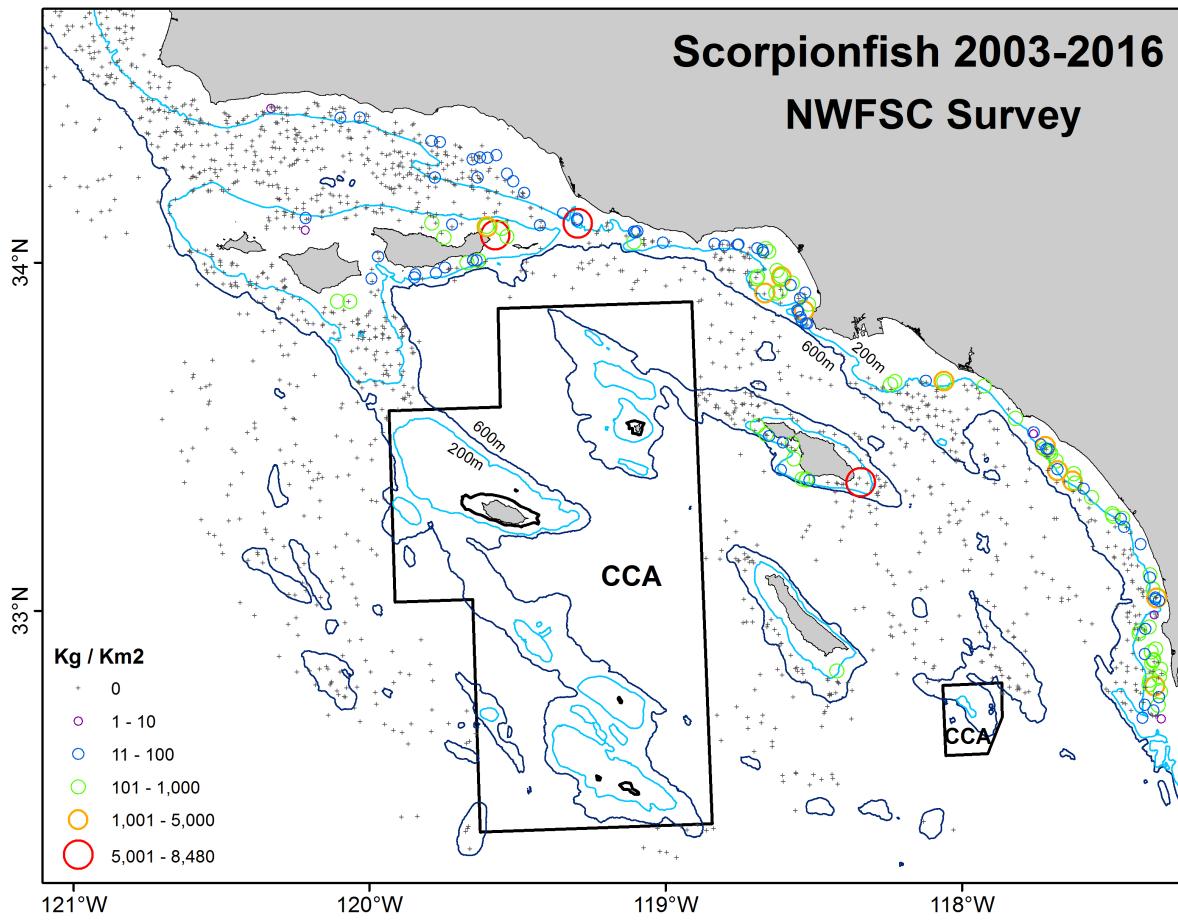


Figure 26: Spatial distribution of raw catch rates of Scorpionfish from NWFSC trawl survey between 2003 and 2016. Depth contour lines of 200 m and 600 m and the CCA areas are shown. Note that sizes and colors of circles represent catch rate in log scales (Credit of Rebecca Miller, SWFSC).

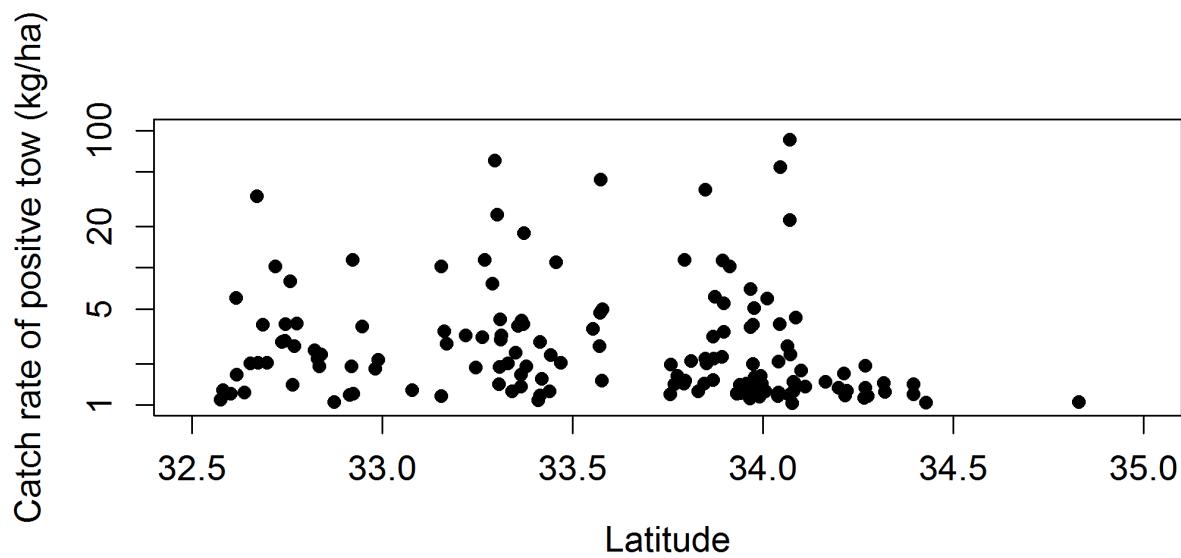
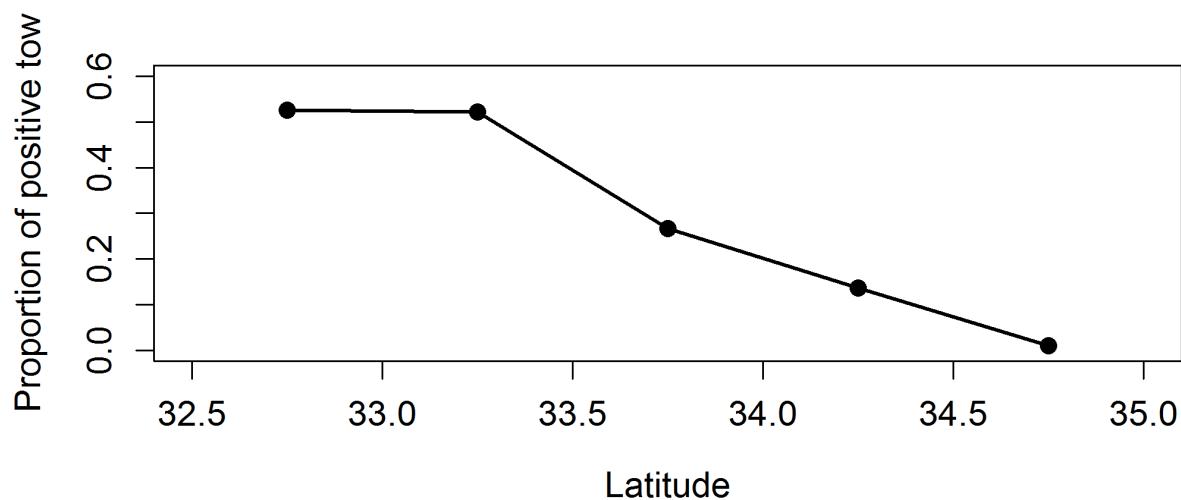


Figure 27: Plots of the proportion of positive tows (top panel) and the raw catch rates of positive tows (bottom panel) by latitude zones (0.5 degree interval) for NWFSC trawl survey.

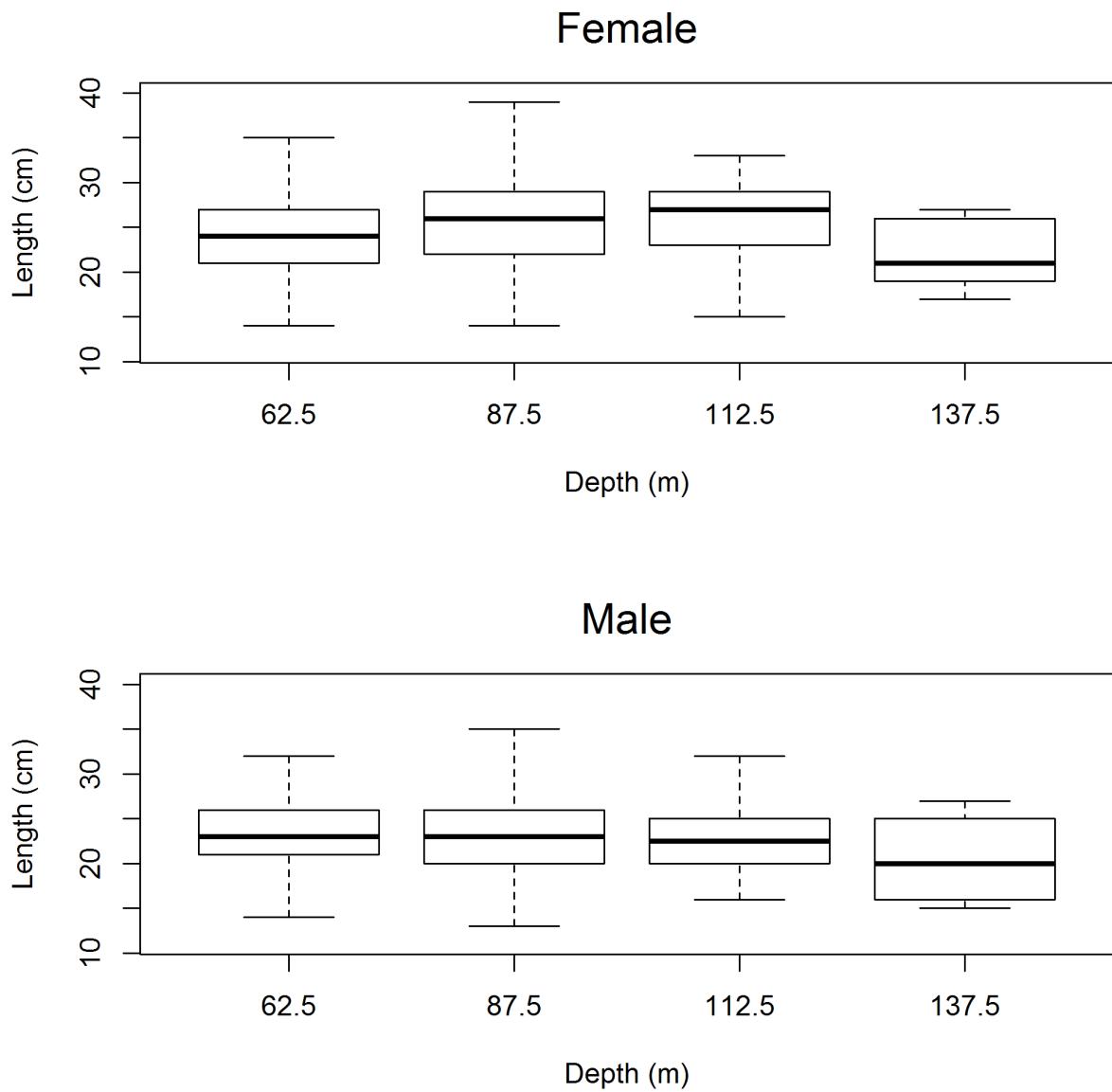


Figure 28: Comparison box plots of raw length data from NWFSC trawl survey by depth zone and sex.

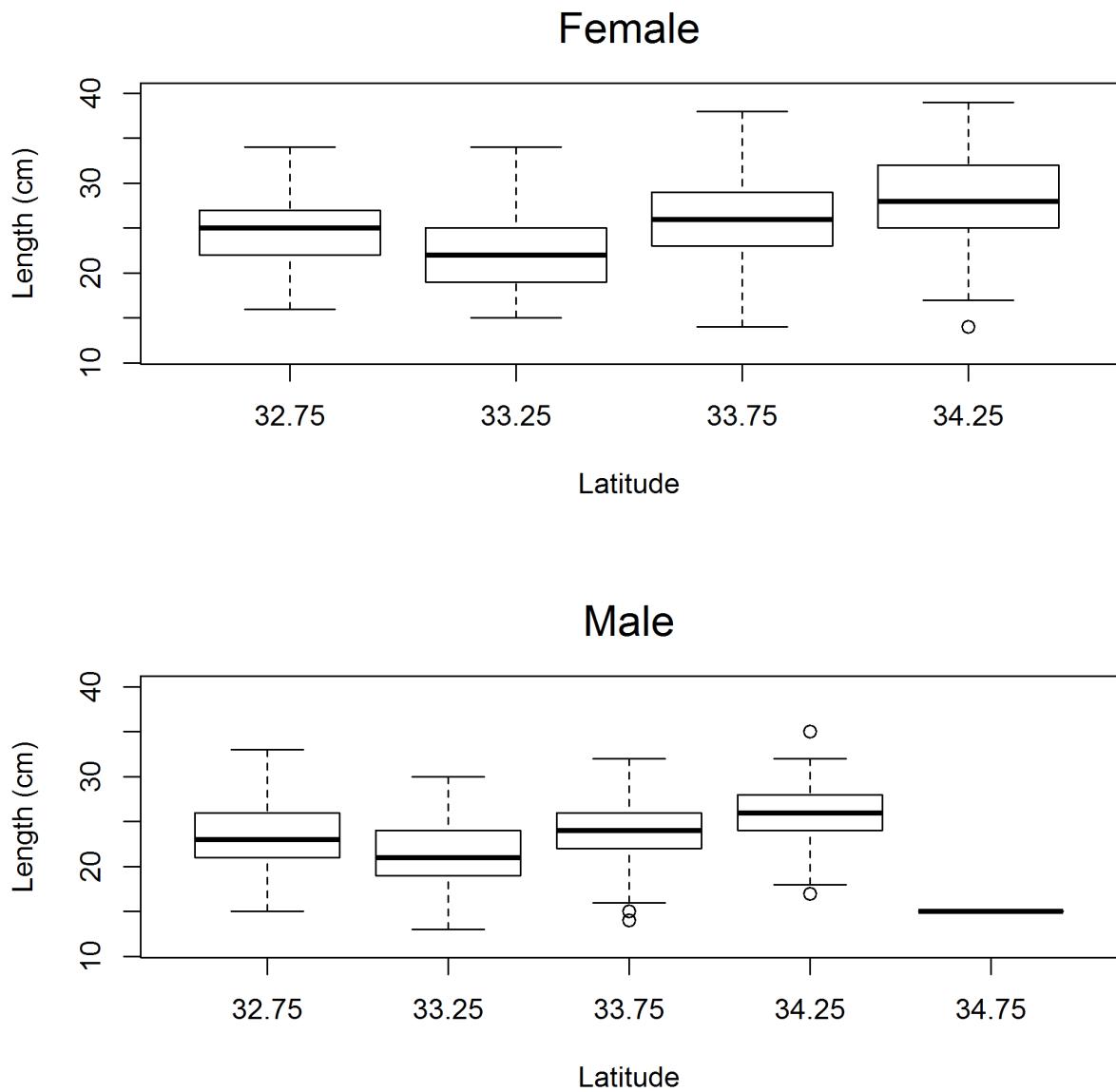


Figure 29: Comparison box plots of raw length data from NWFSC trawl survey by latitude zone and sex.

Length comp data, whole catch, NWFSC Trawl (max=0.21)

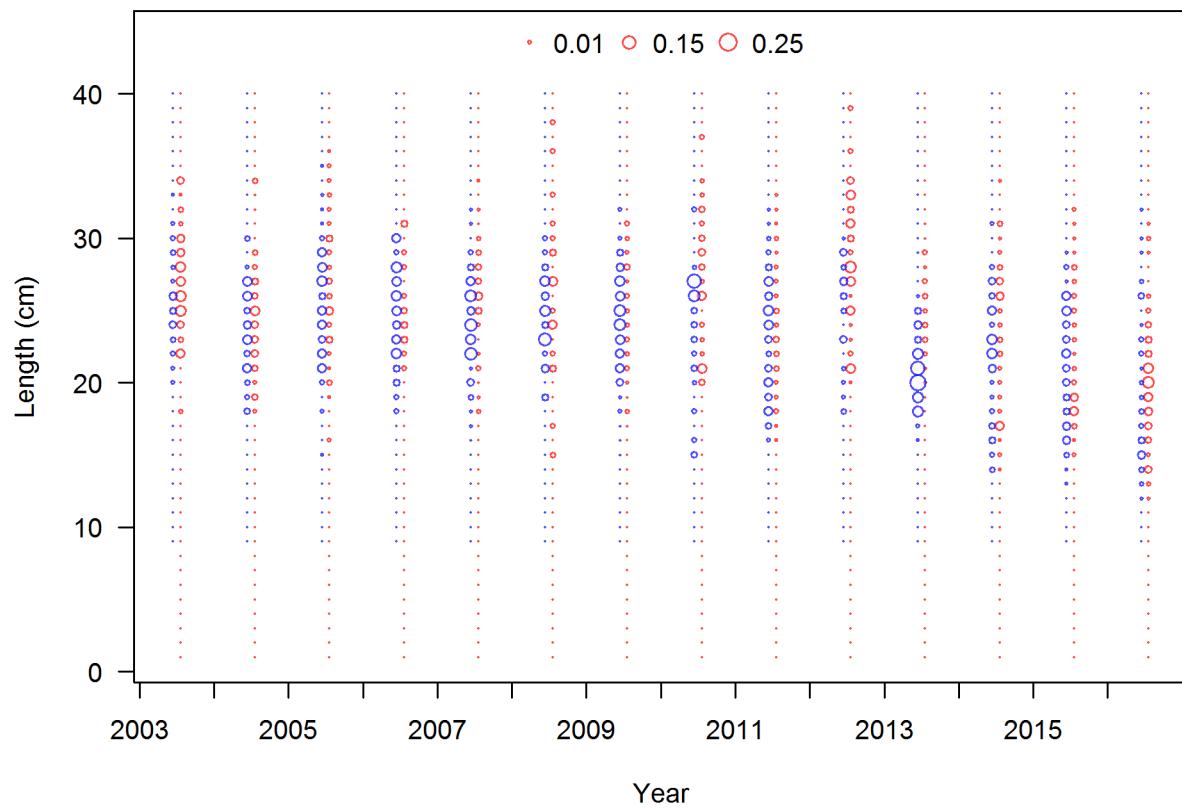


Figure 30: Length frequency distributions of females (red) and male (blue) from the NWFSC trawl survey between 2003 and 2016.

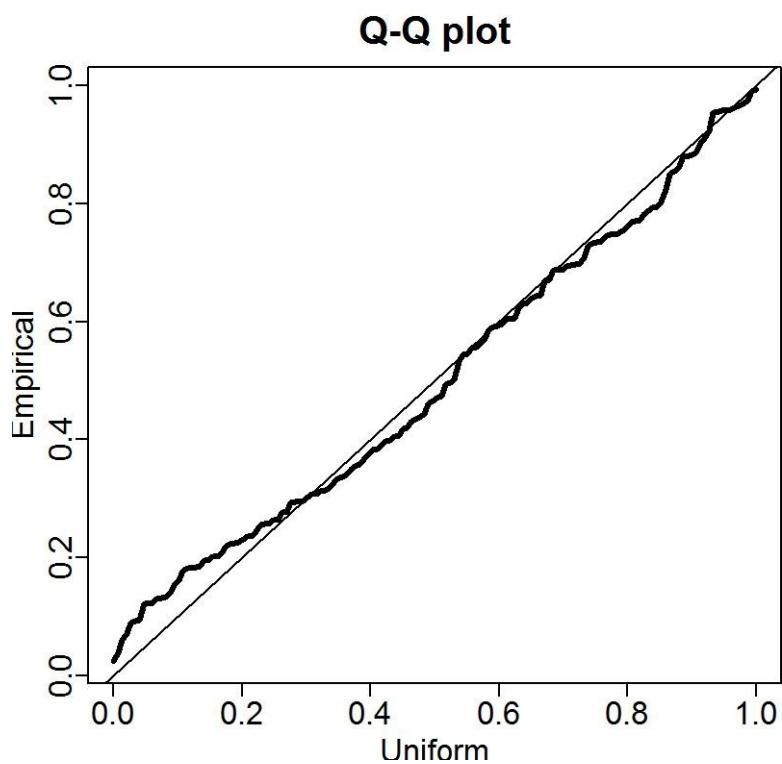


Figure 31: Q-Q plot used to validate the goodness of fit of the VAST analysis for the NWFSC trawl survey between 2003 and 2016.

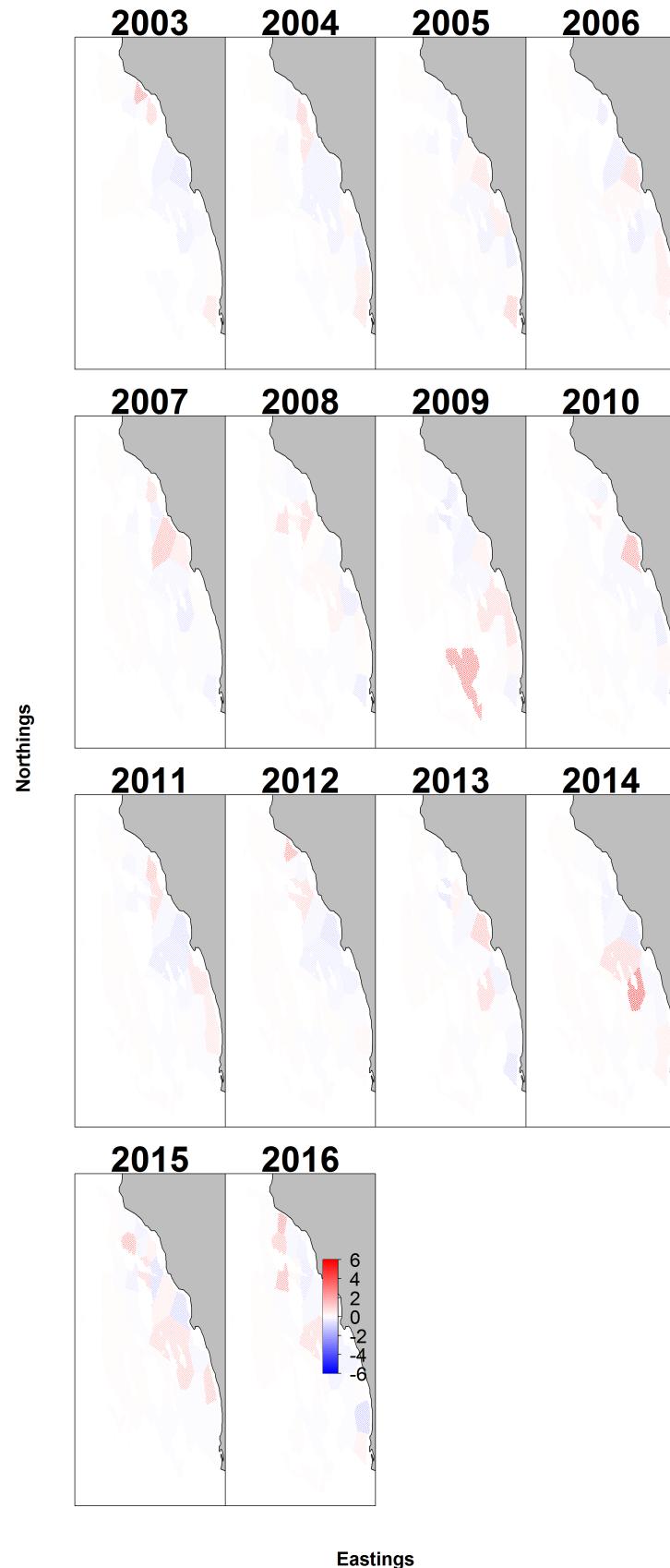


Figure 32: NWFSC survey index encounter probability Pearson residuals
128

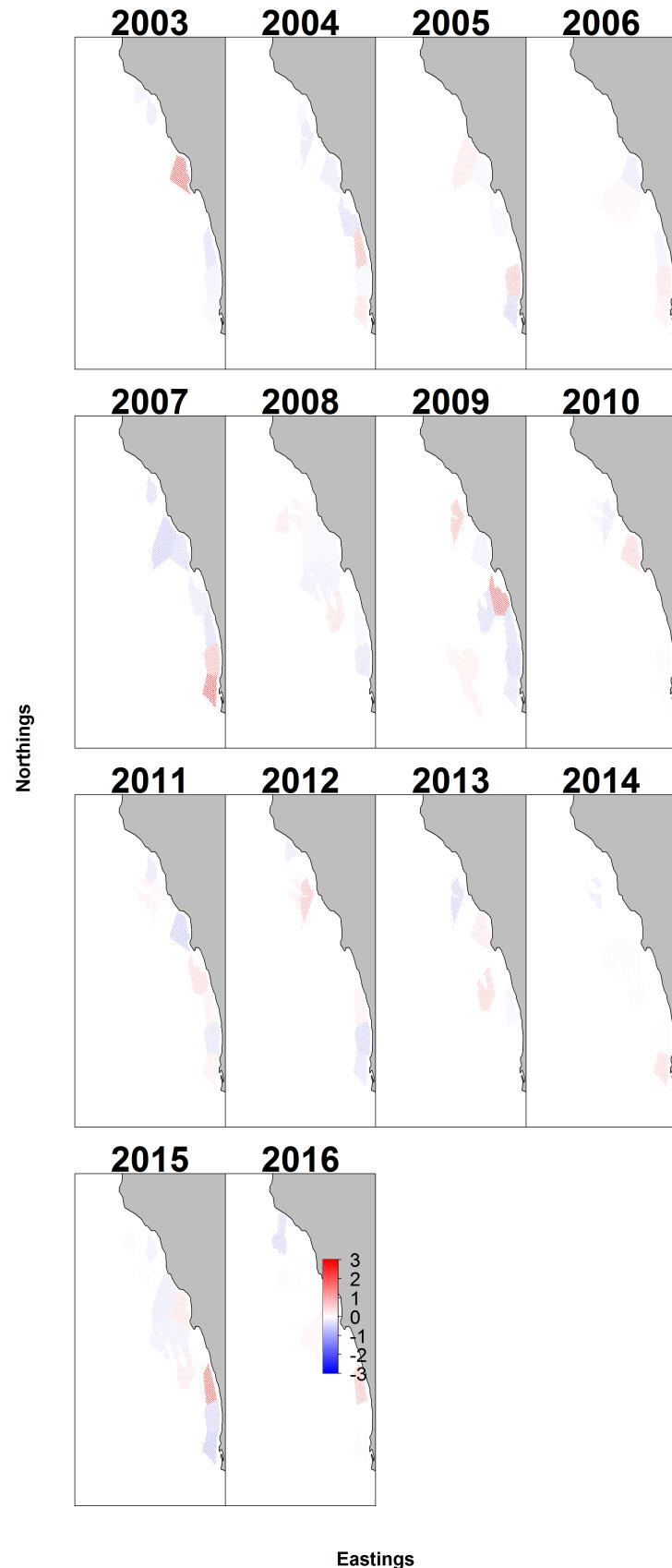


Figure 33: NWFSC survey index positive catch rate probability Pearson residuals
129

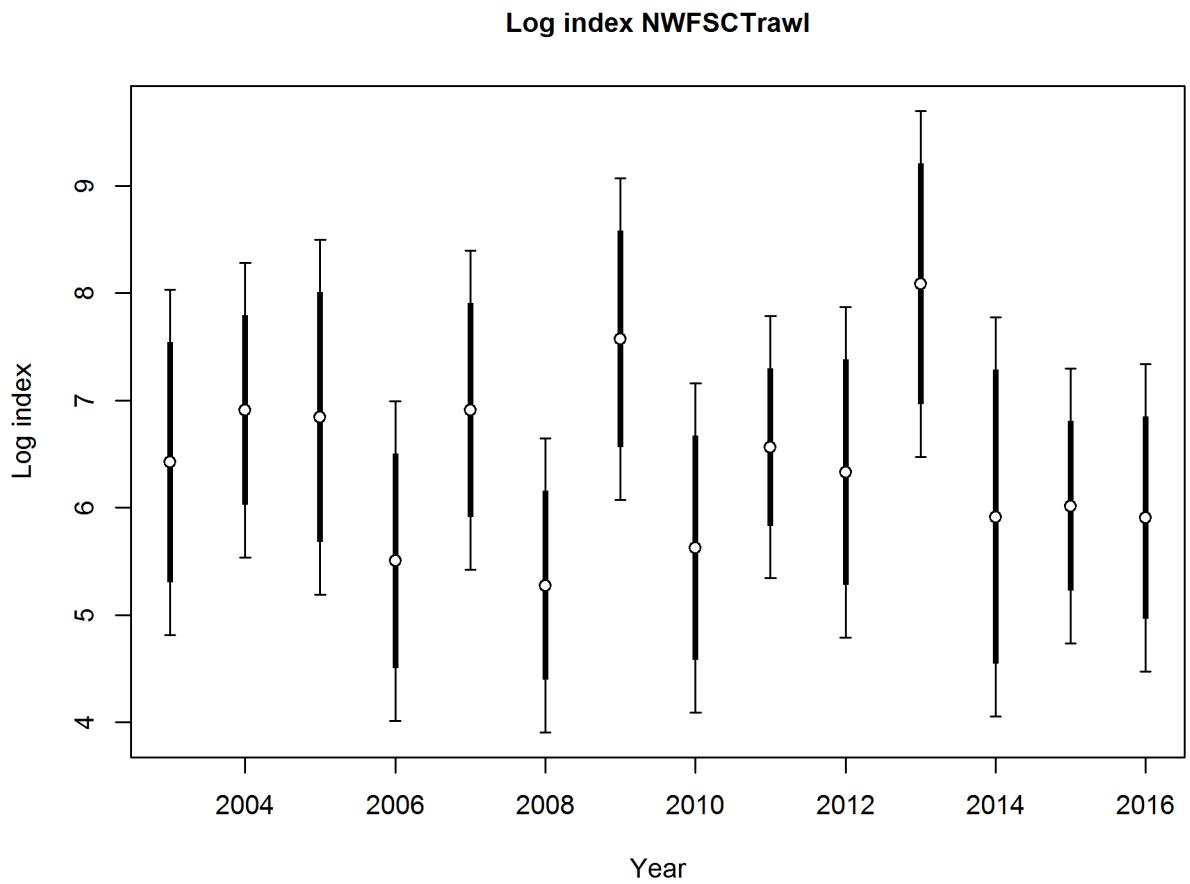


Figure 34: Standardized index on the log scale for the NWFSC trawl survey from the VAST analysis from 2003-2016. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

Normal Q-Q Plot

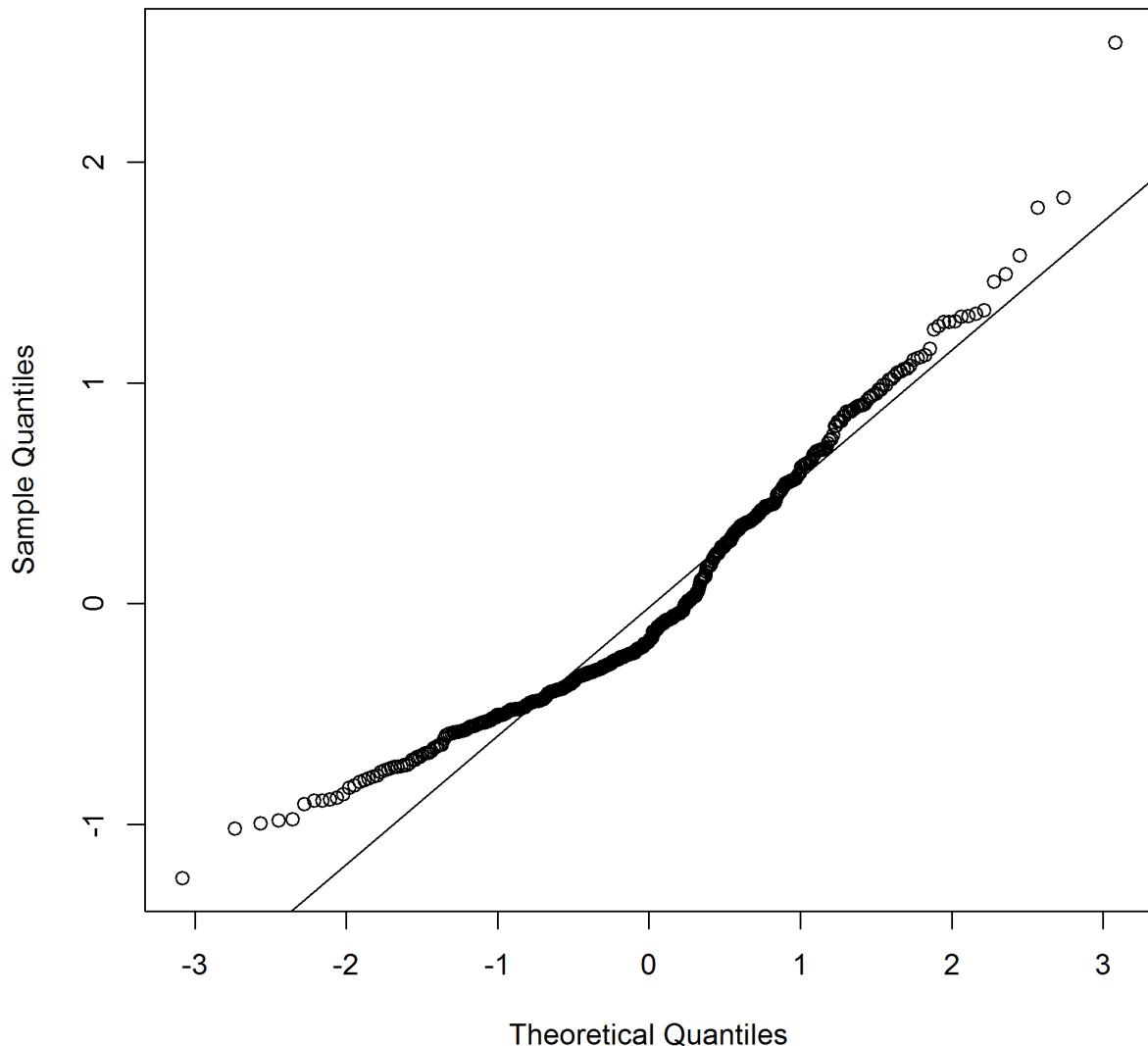


Figure 35: Q-Q plot used to validate the goodness of fit of the lognormal model for the CSUN/VRG gillnet survey from 1995-2008.

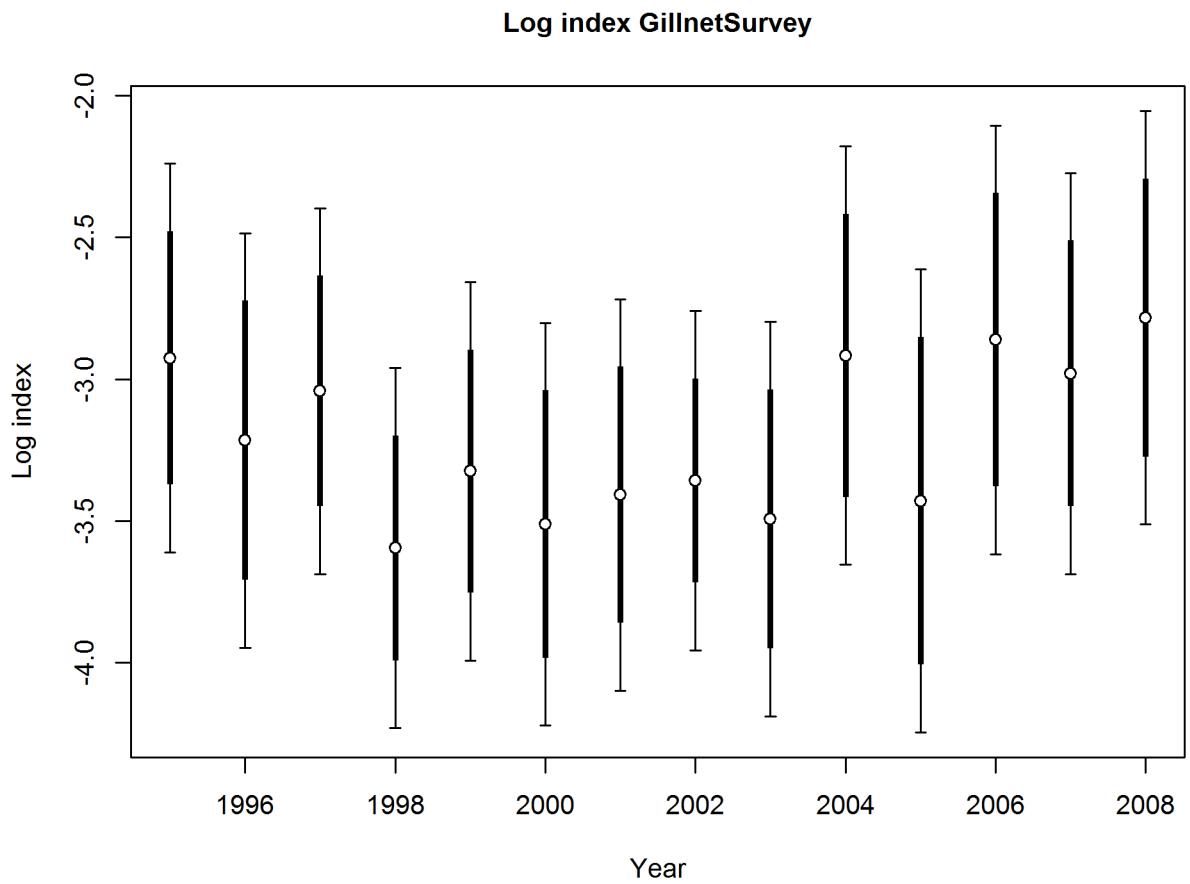


Figure 36: Standardized index on the log scale for the recreational CSUN/VRG gillnet survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

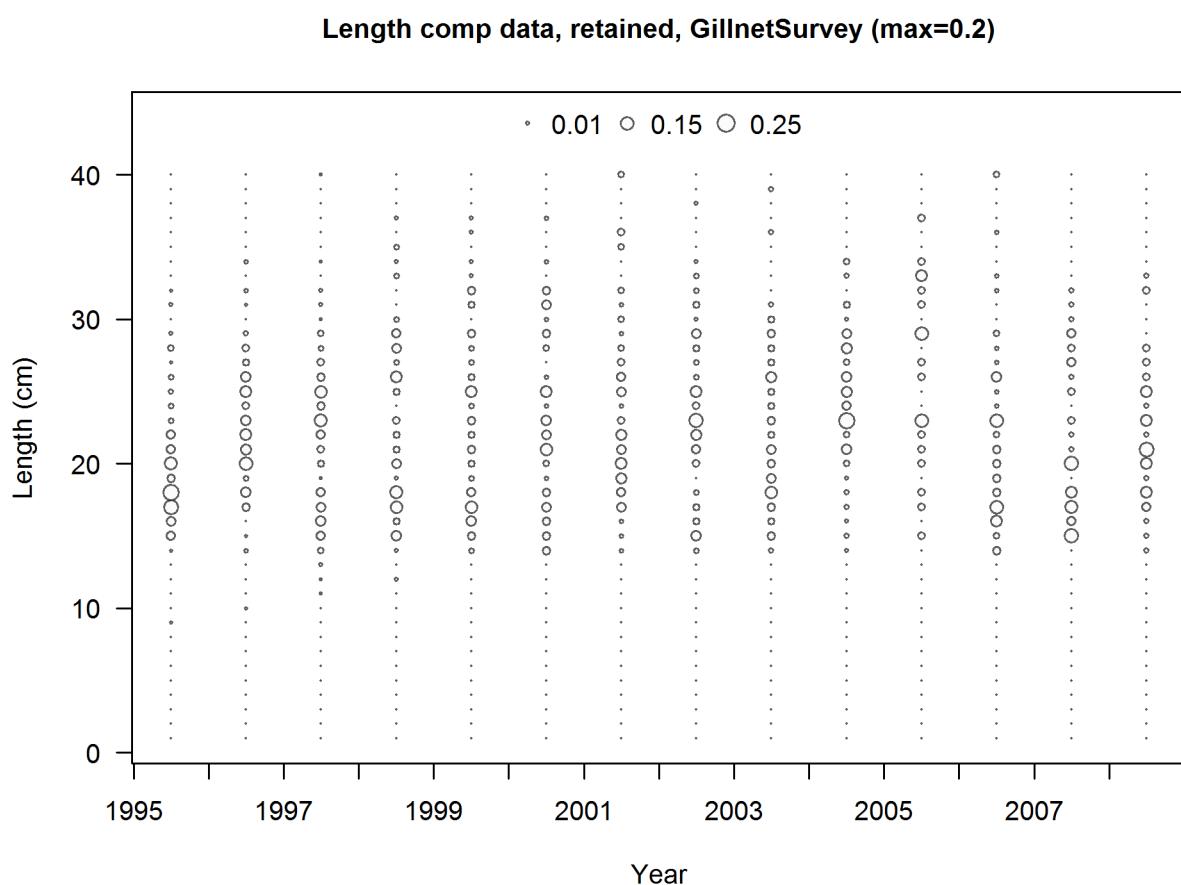


Figure 37: Length frequency distributions from the gill net surveys.

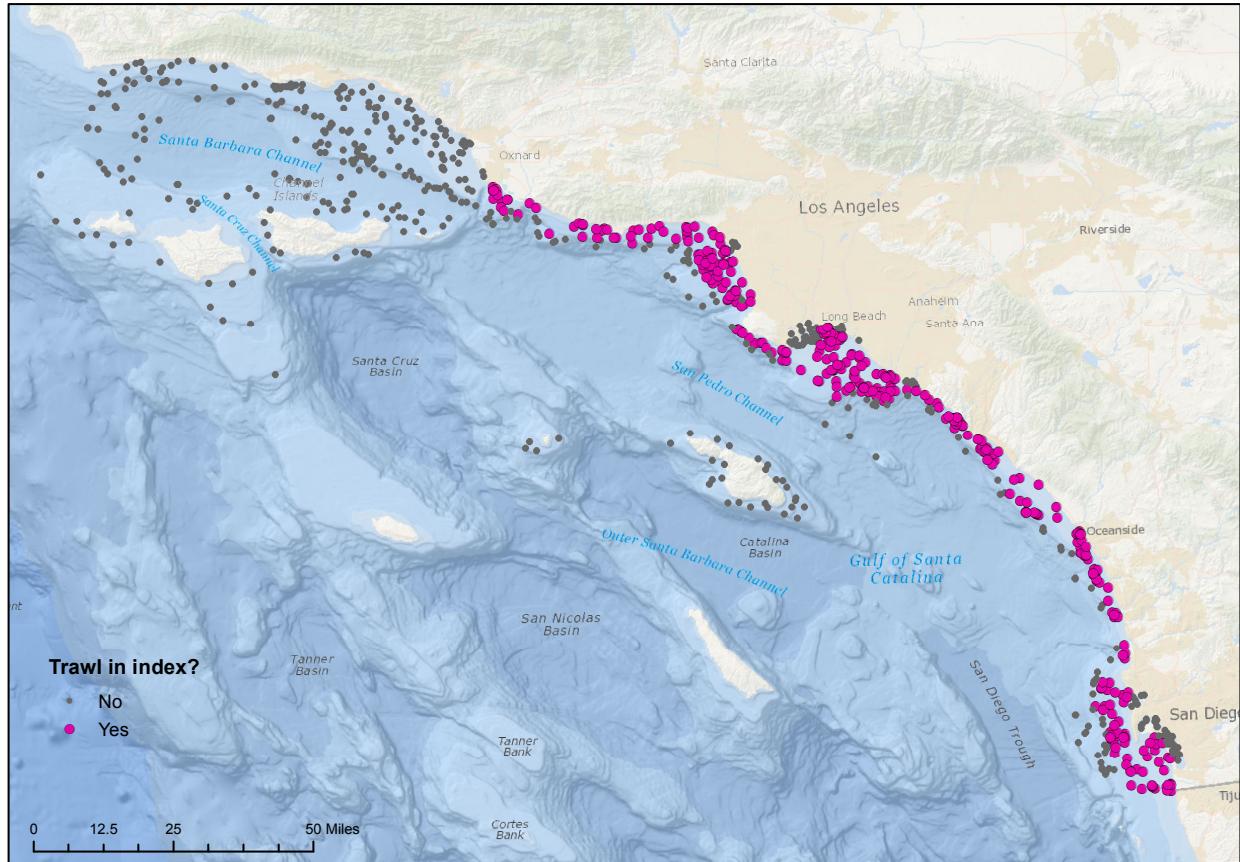


Figure 38: Map of the stations from the Southern California Coastal Water Research Project regional monitoring trawl survey from 1994, 1998, 2003, 2008, and 2013. Stations used in the index of abundance are colored magenta.

Normal Q-Q Plot

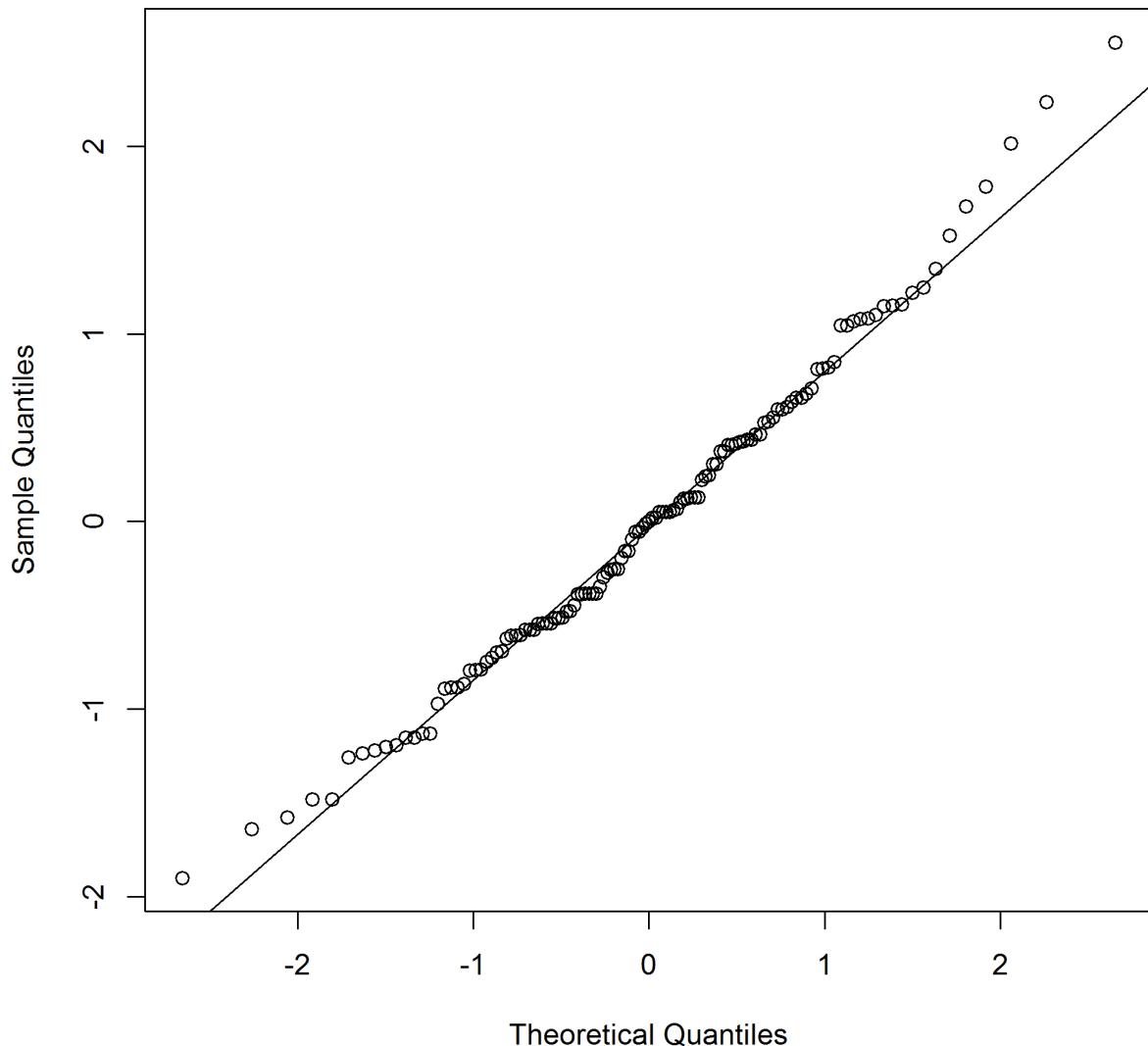


Figure 39: Q-Q plot used to validate the goodness of fit of the lognormal model for the Southern California Bight monitoring program trawl survey.

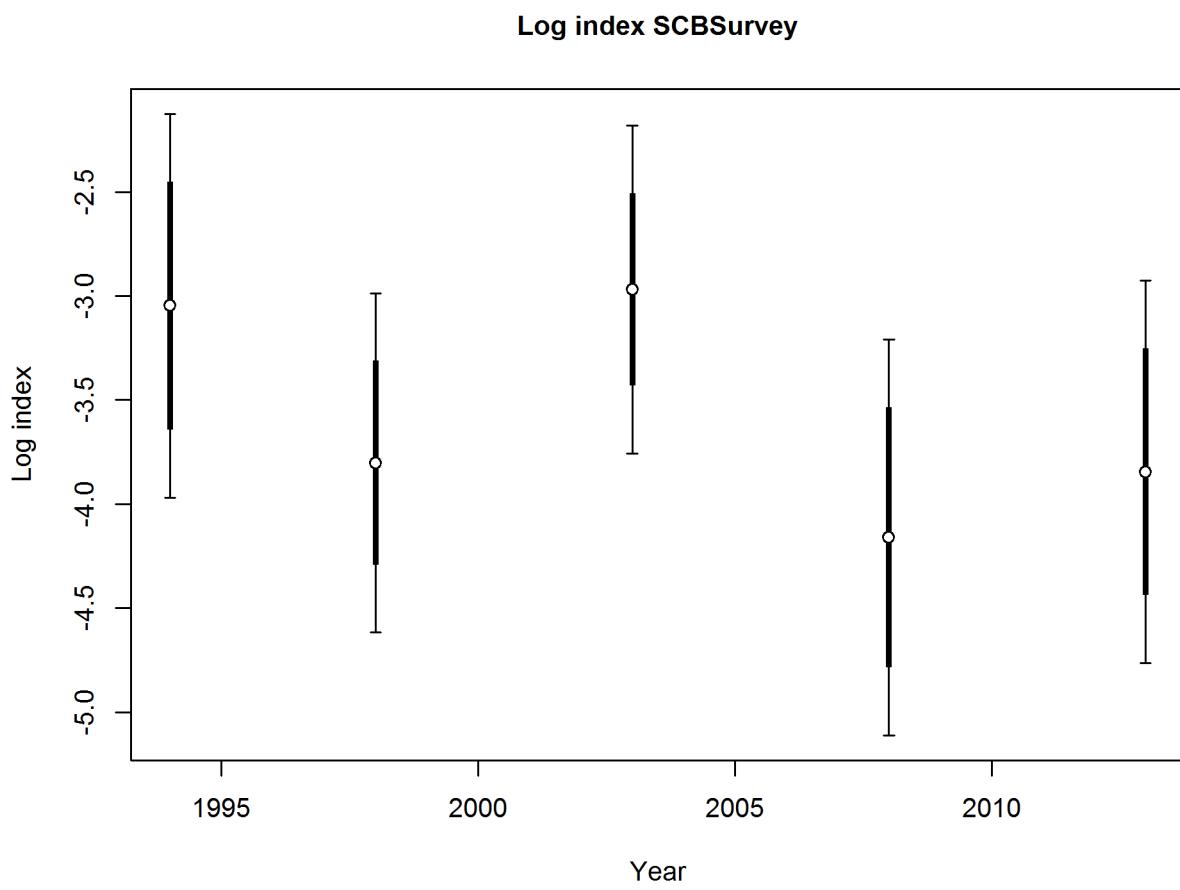


Figure 40: Standardized index on the log scale for the recreational Southern California Bight trawl survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

Length comp data, retained, SCBSurvey (max=0.2)

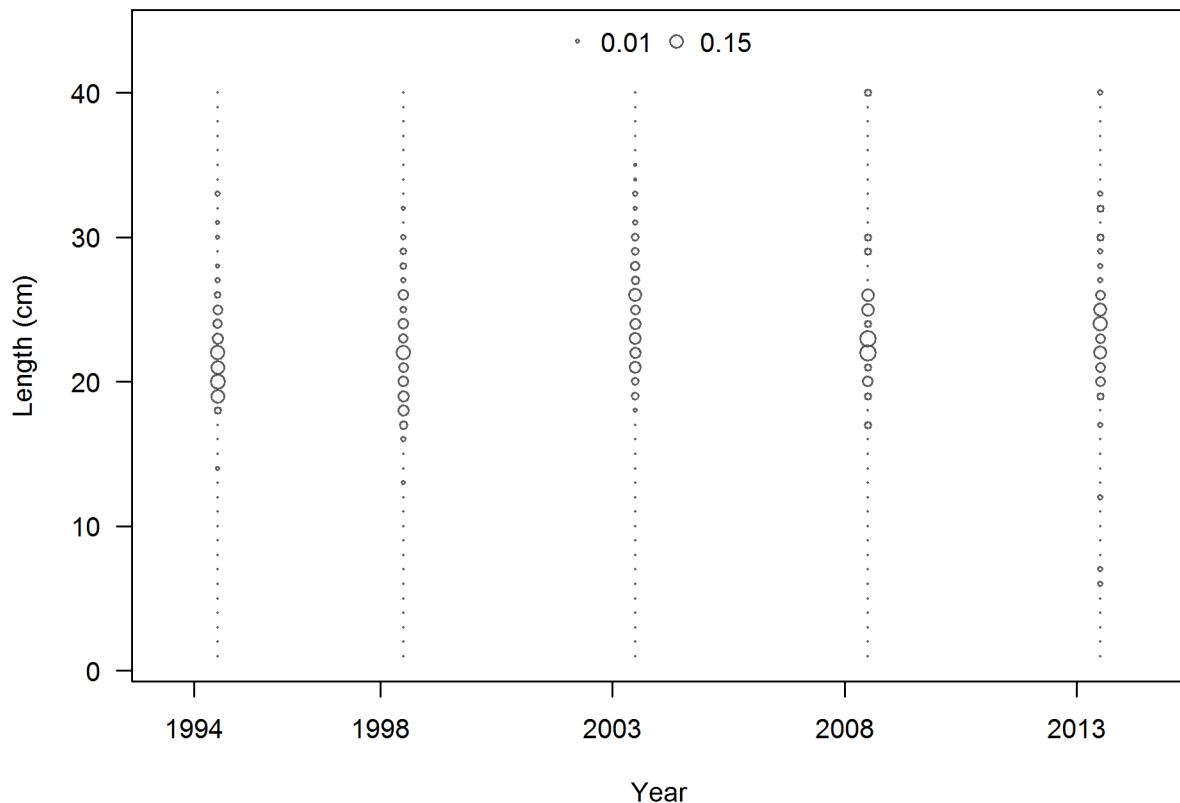


Figure 41: Length frequency distributions from the Southern California Bight regional monitoring program trawl surveys.

Length comp data, retained, Impingement (max=0.26)

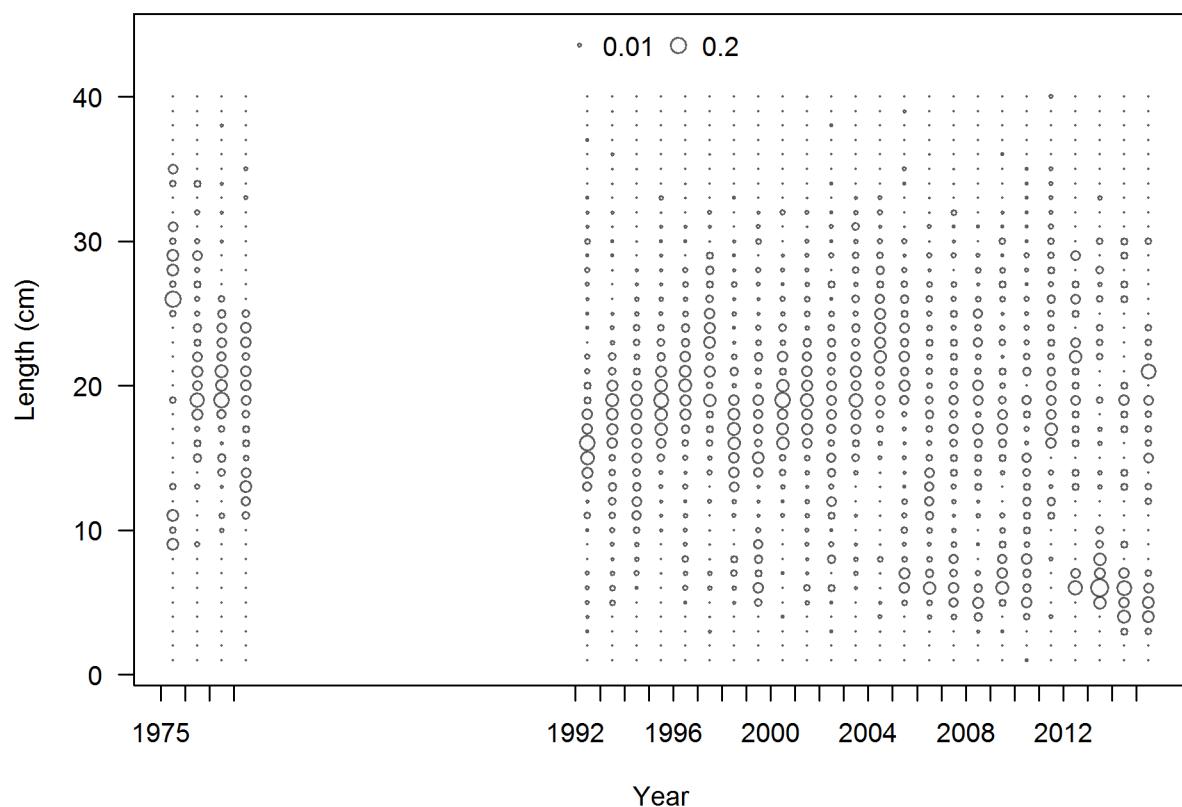


Figure 42: Length frequency distributions from the Impingement surveys.

Length comp data, aggregated across time by fleet

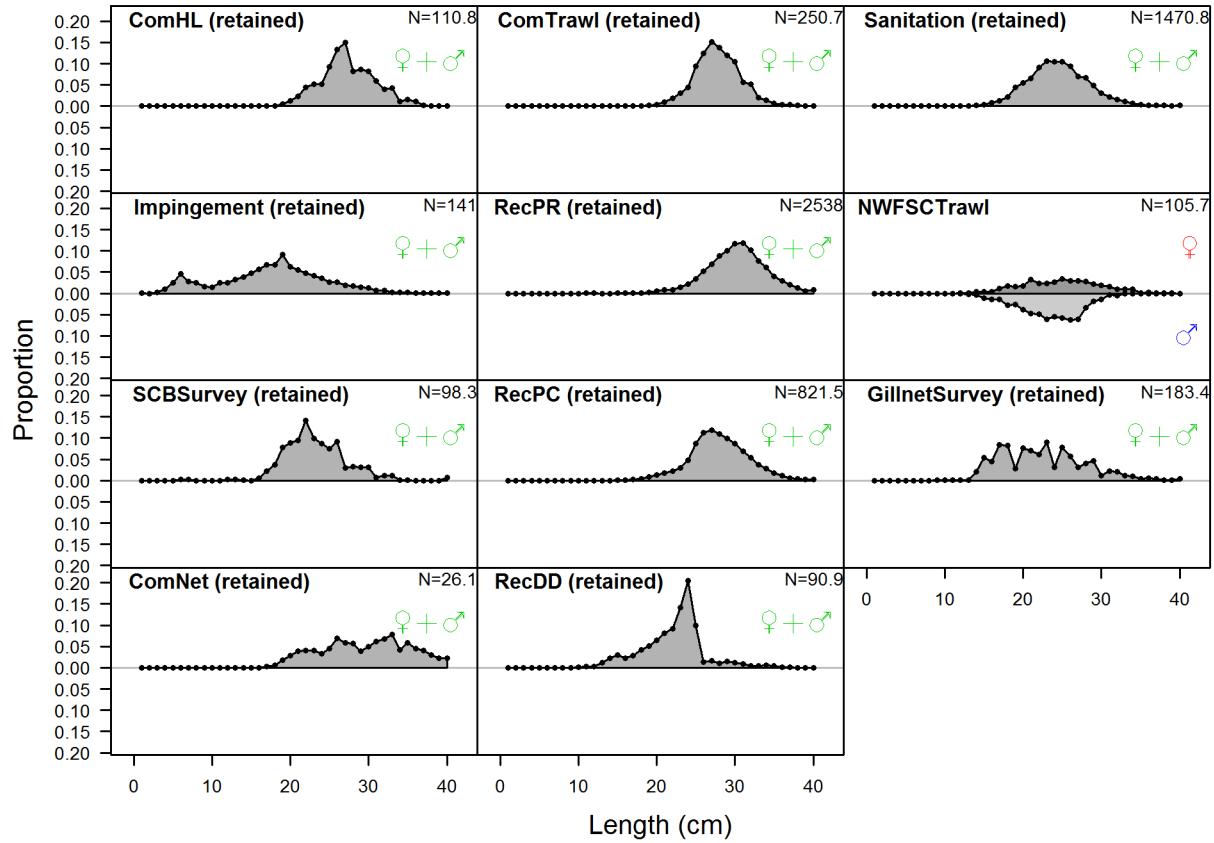


Figure 43: Length comp data, aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

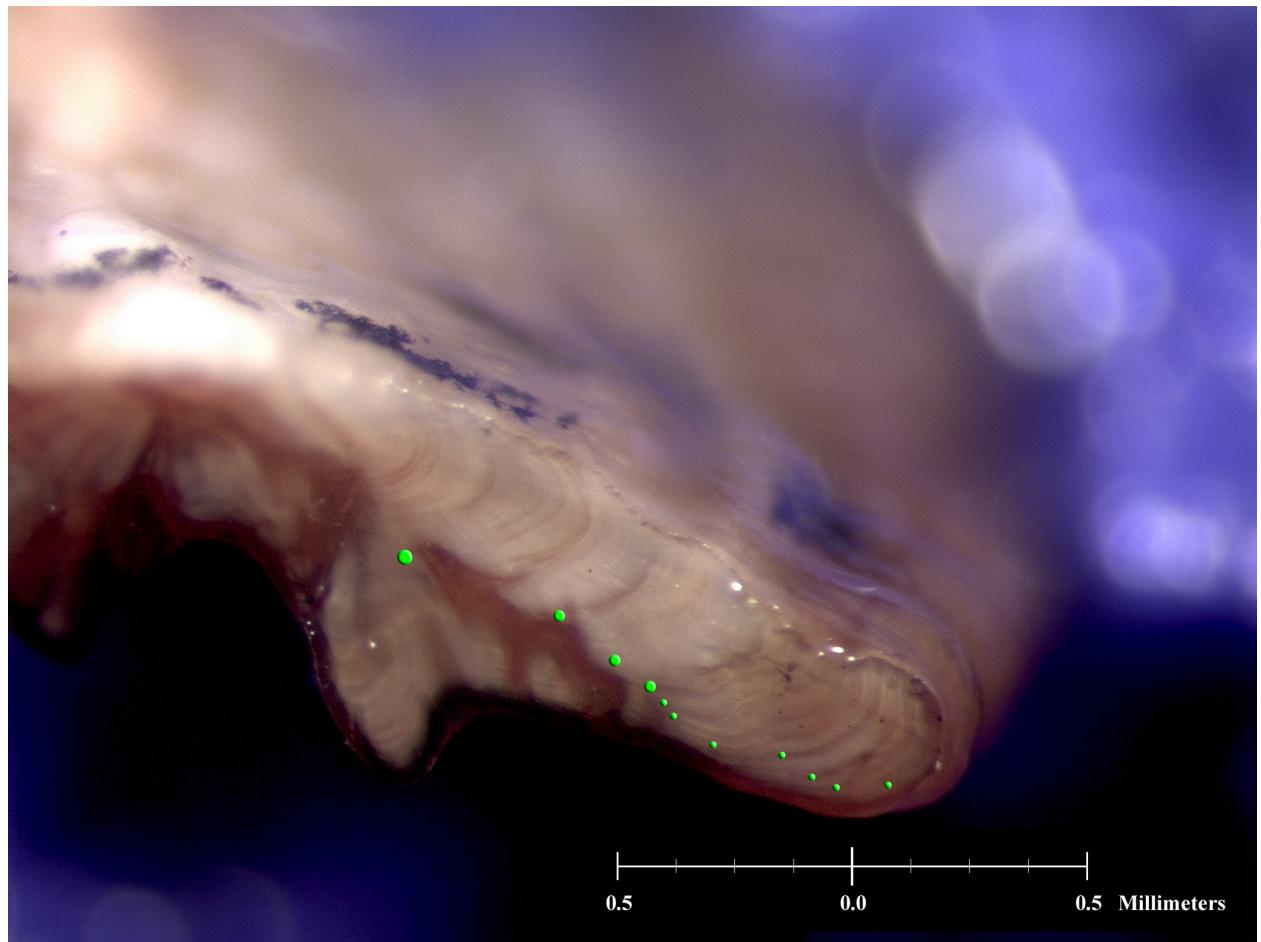


Figure 44: Cross-section of broken and burned California scorpionfish otolith showing. The green dots indicate the number of increments (photo courtesy Lance Sullivan, NWFSC).

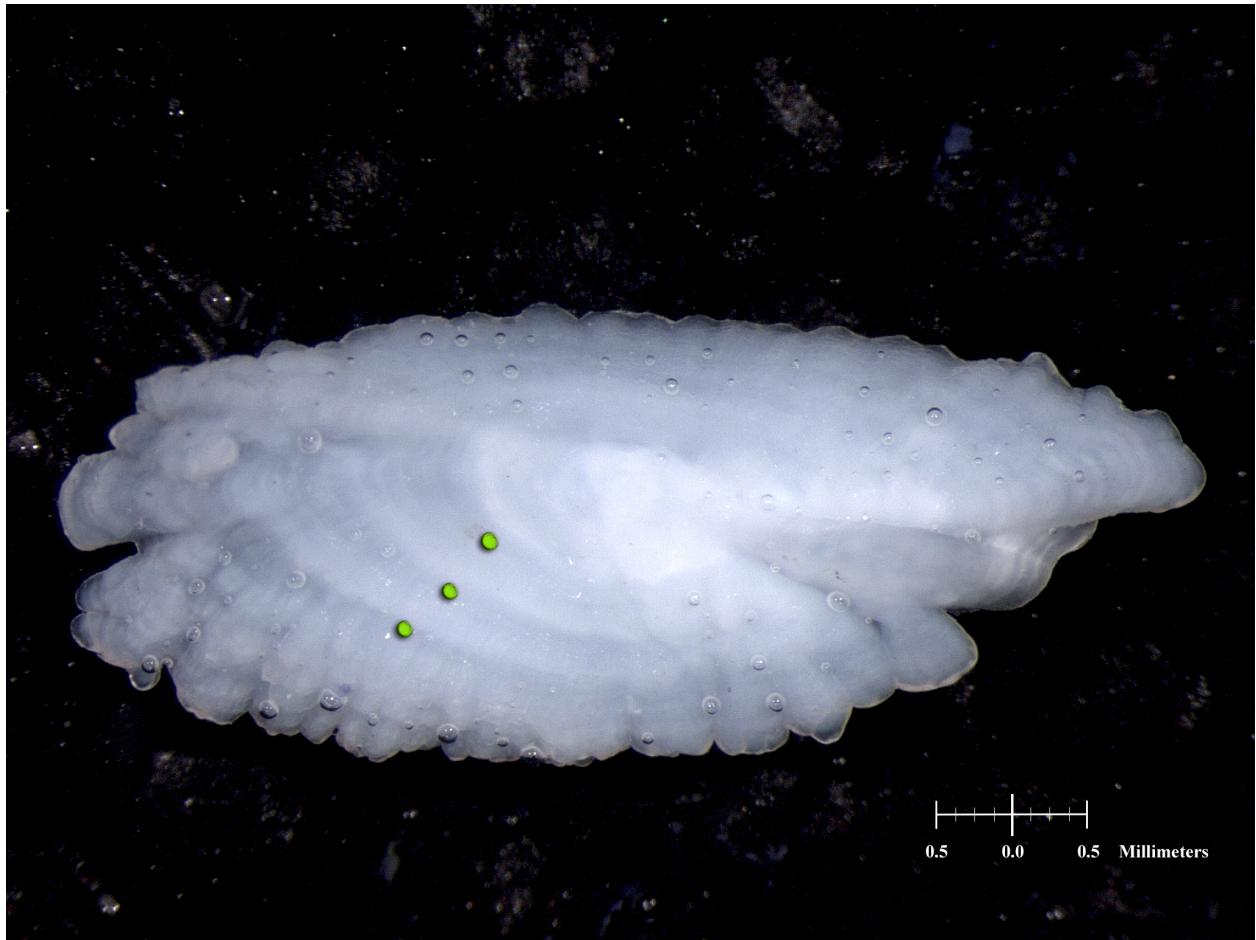
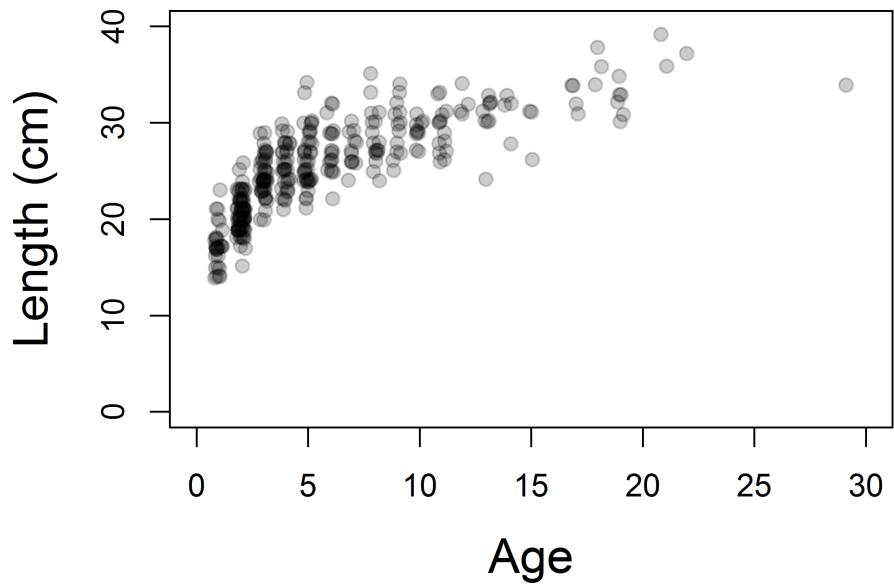


Figure 45: California scorpionfish otolith (photo courtesy Lance Sullivan, NWFSC).

Female



Male

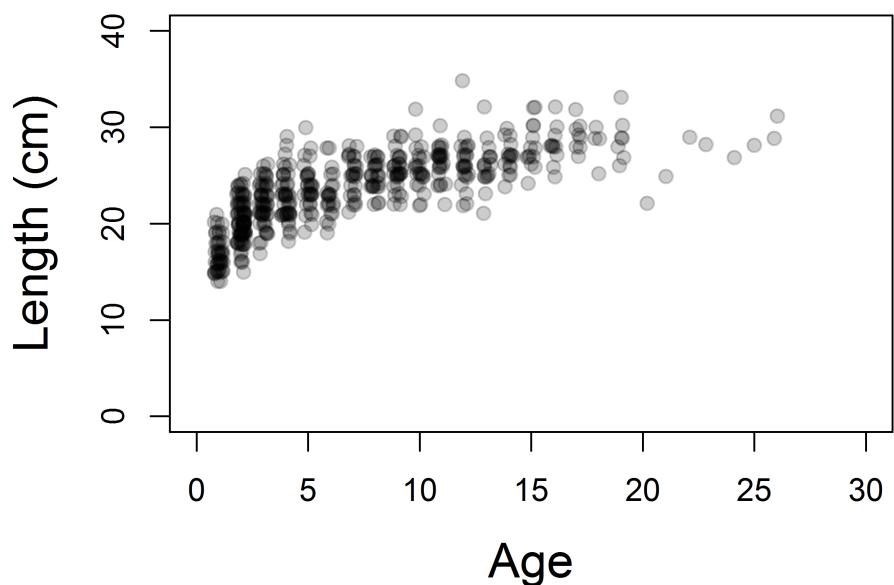
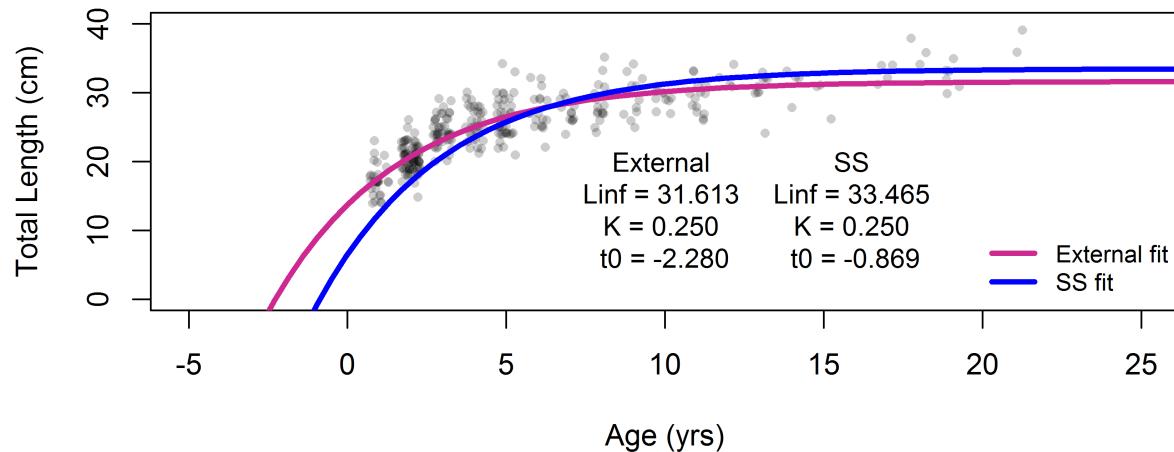


Figure 46: Length at age by sex for California scorpionfish collected from the NWFSC trawl survey.

Female



Male

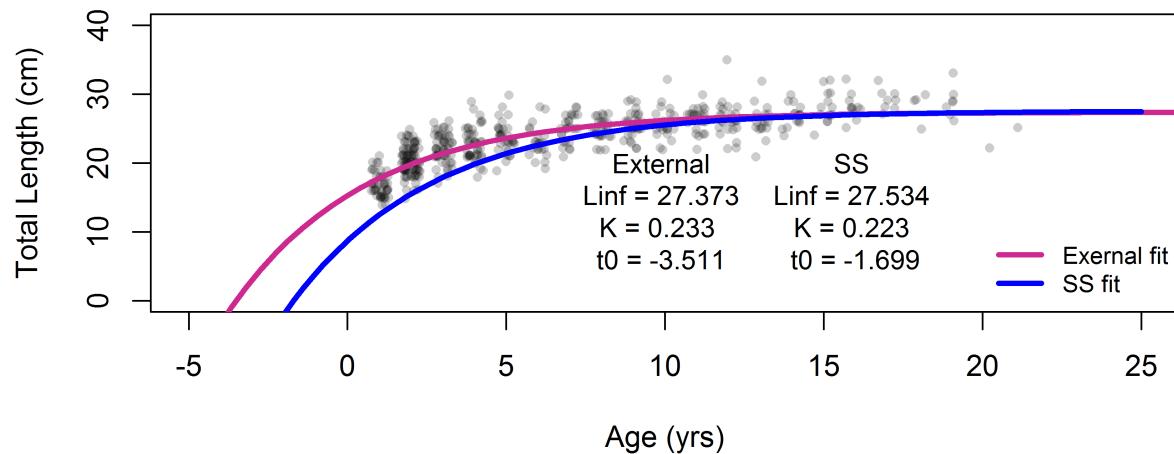


Figure 47: Fitted (external to SS) von Bertalanffy growth by sex for California scorpionfish collected from the NWFSC trawl survey.

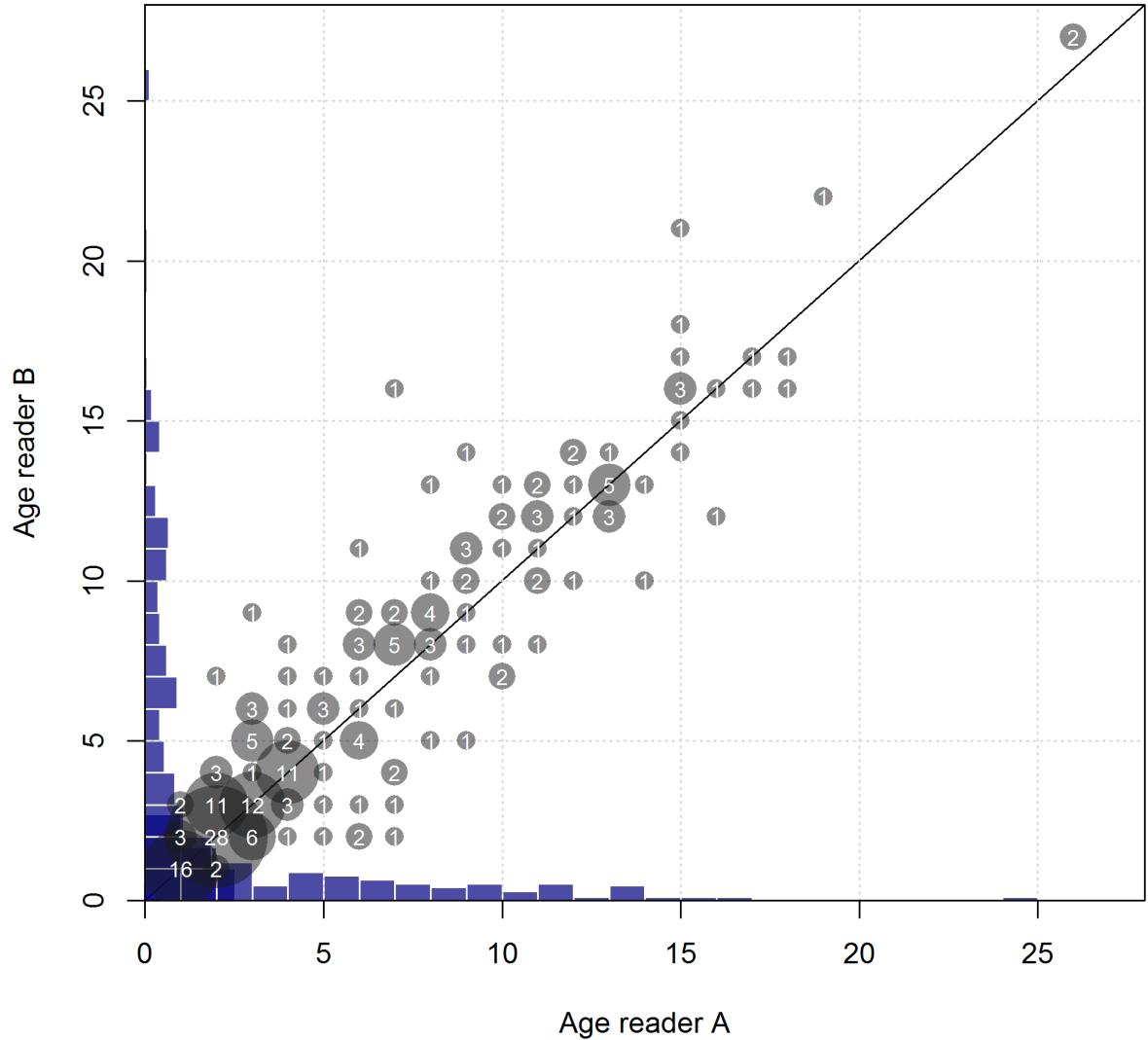


Figure 48: Aging precision between two current age readers at the NWFSC. Numbers in the bubbles are the sample sizes of otoliths cross-read.

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

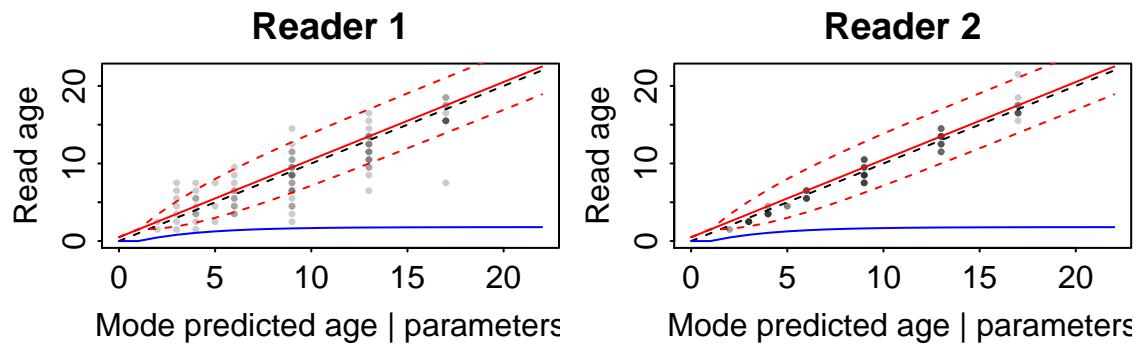


Figure 49: True versus predicted age for two current age readers at the NWFSC from the ageing error software with unbiased reads and curvilinear standard deviation for both readers.

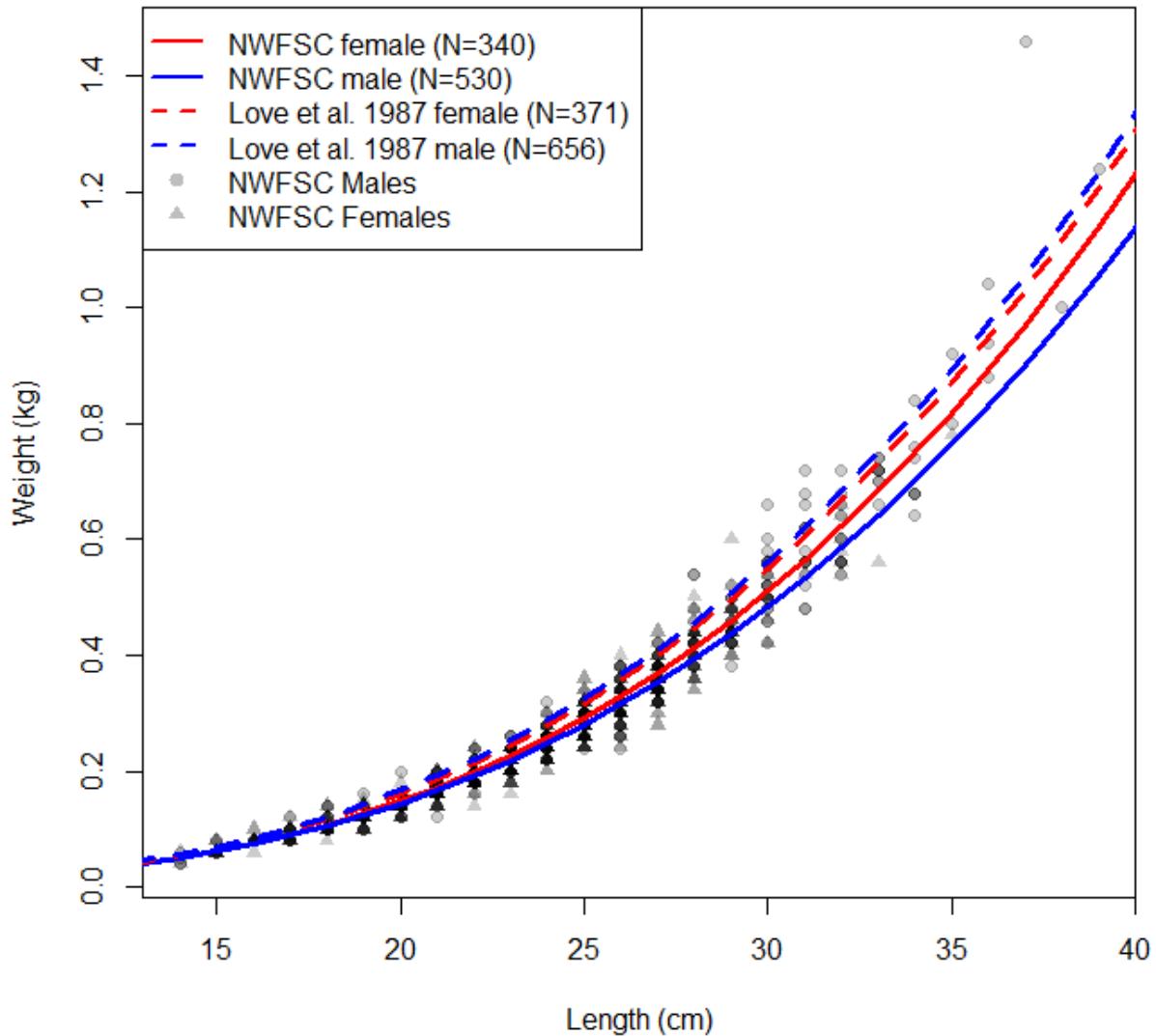


Figure 50: Comparison of the California scorpionfish weight-length curves from Love et al. (1987) and those estimated from the NWFSC trawl survey. The latter is used in this assessment.

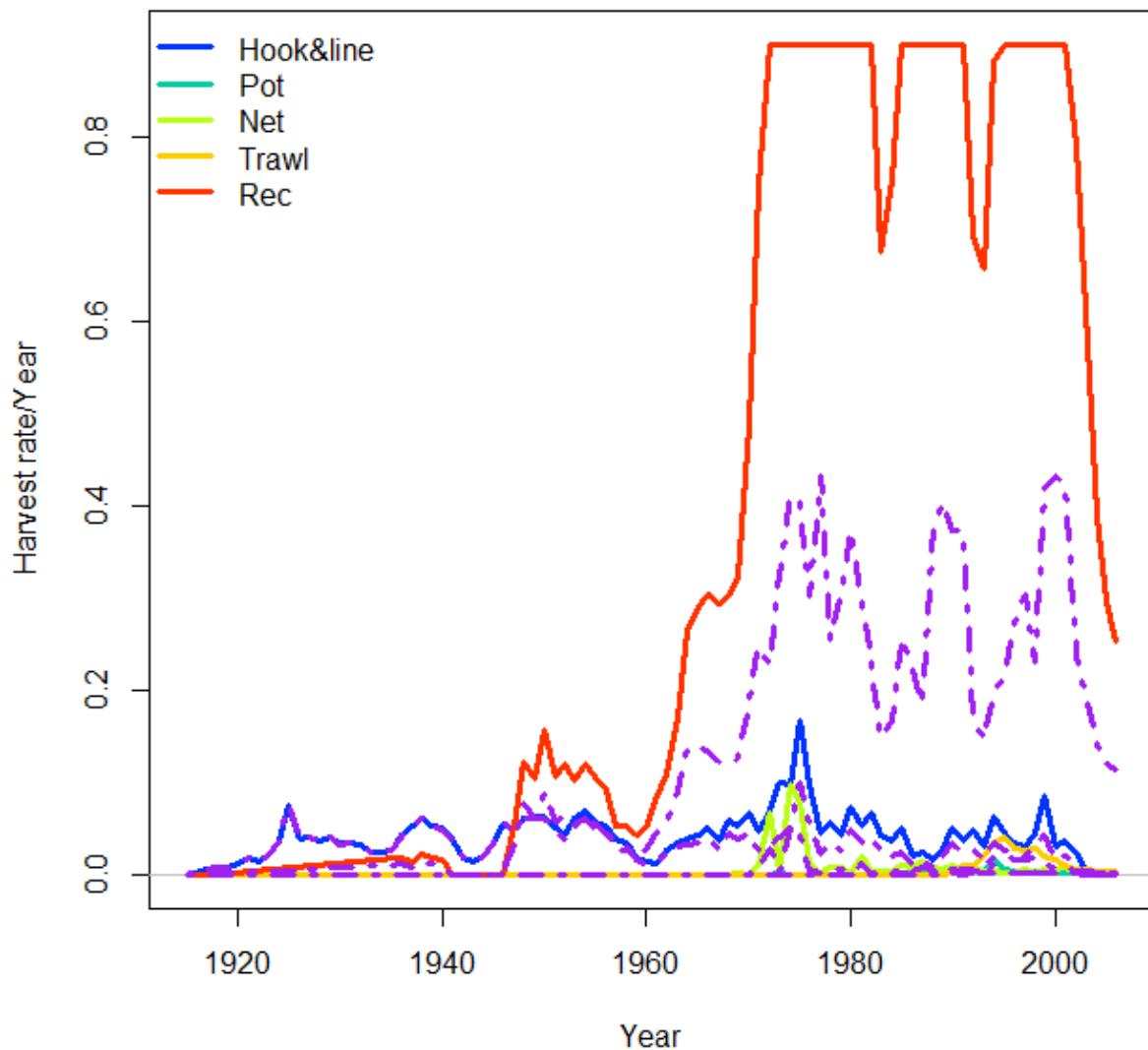


Figure 51: Time series of harvest rates by fleet from the 2005 model where the harvest rate for the recreational fleet hit the boundary of 0.9.

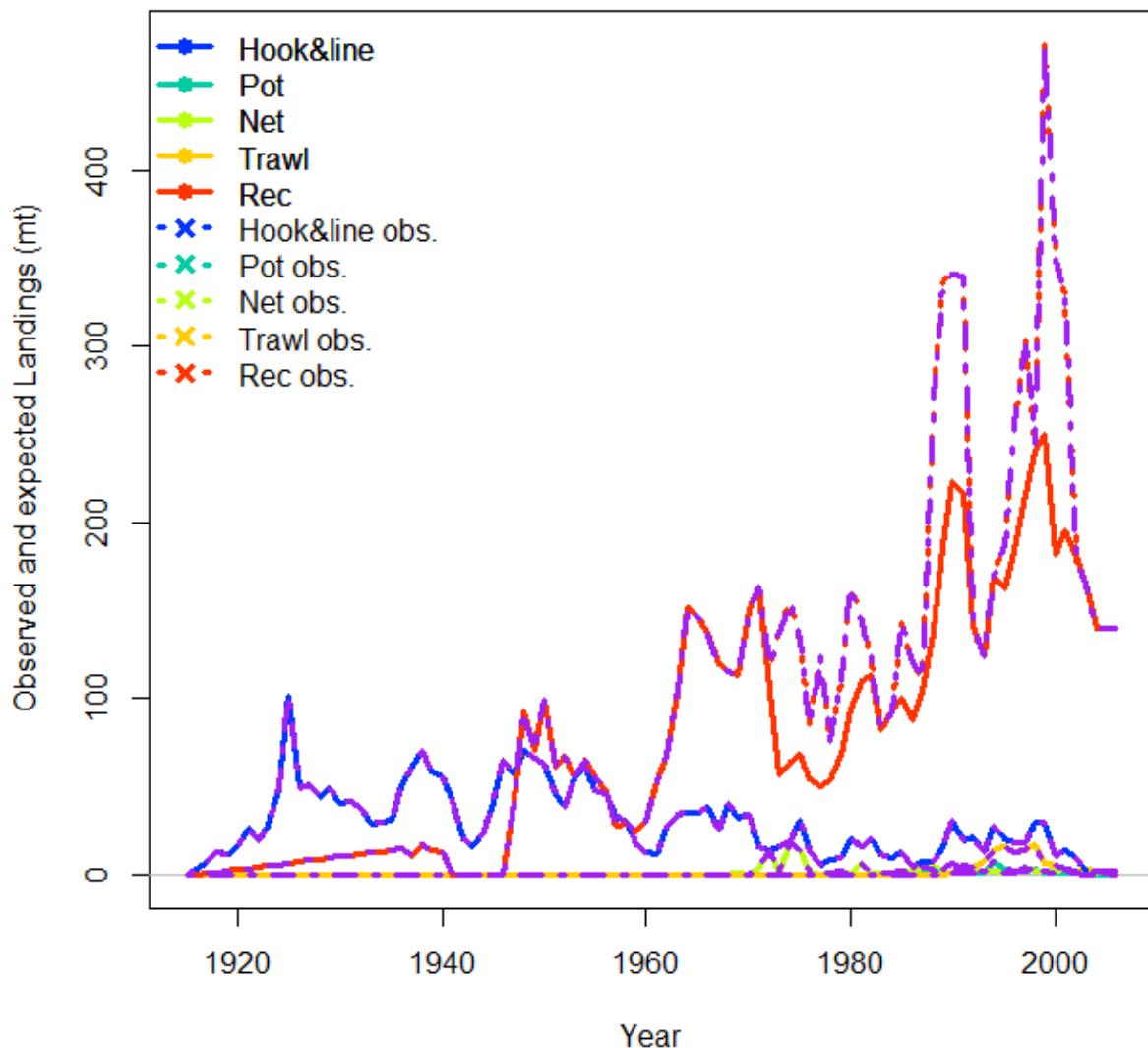


Figure 52: Time series of observed and expected landings by fleet from the 2005 model. The model was not able to remove all of the recreational catches starting around 1970.

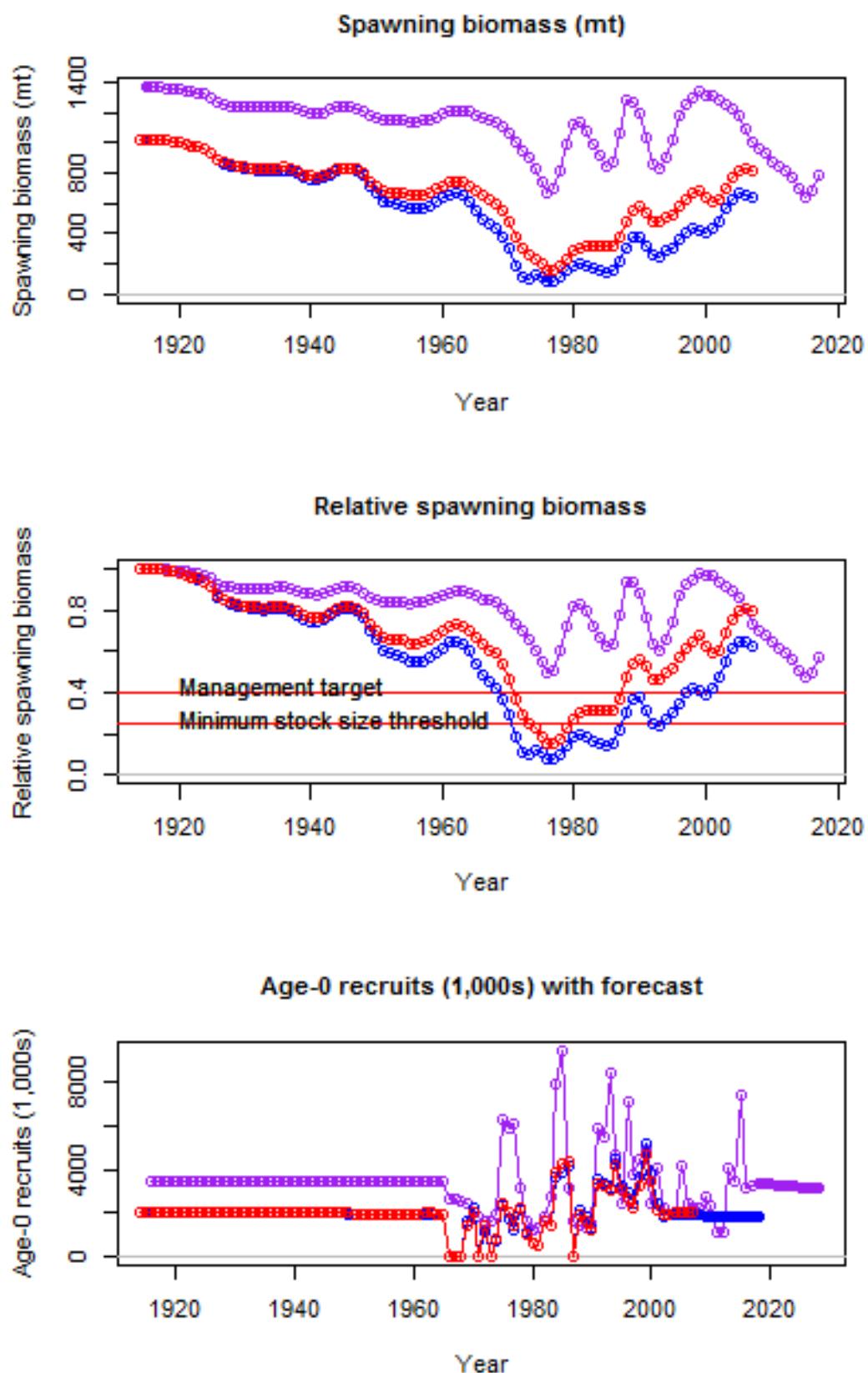


Figure 53: Comparison of spawning output, total biomass, and recruits from the 2005 model (solid red lines) using SS2, the 2005 model converted to SS3.24z (blue lines), and the base model from this assessment (purple lines). Note: The 2005 assessment was found to have an error, and therefore the time series for the model to SS3.24 will not match perfectly.

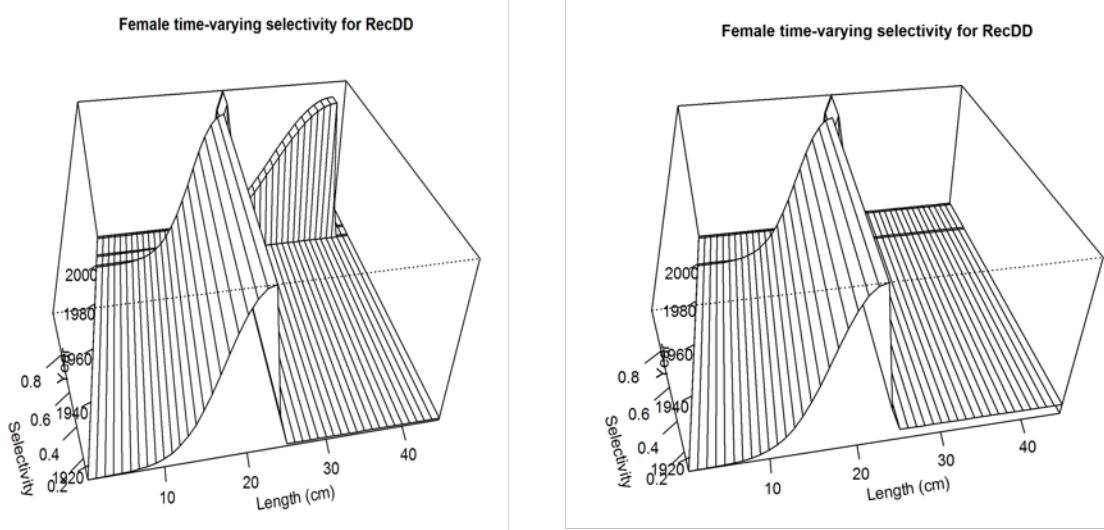


Figure 54: Selectivity curves for the dead discard fleet with three (left) or tow (right) time blocks.

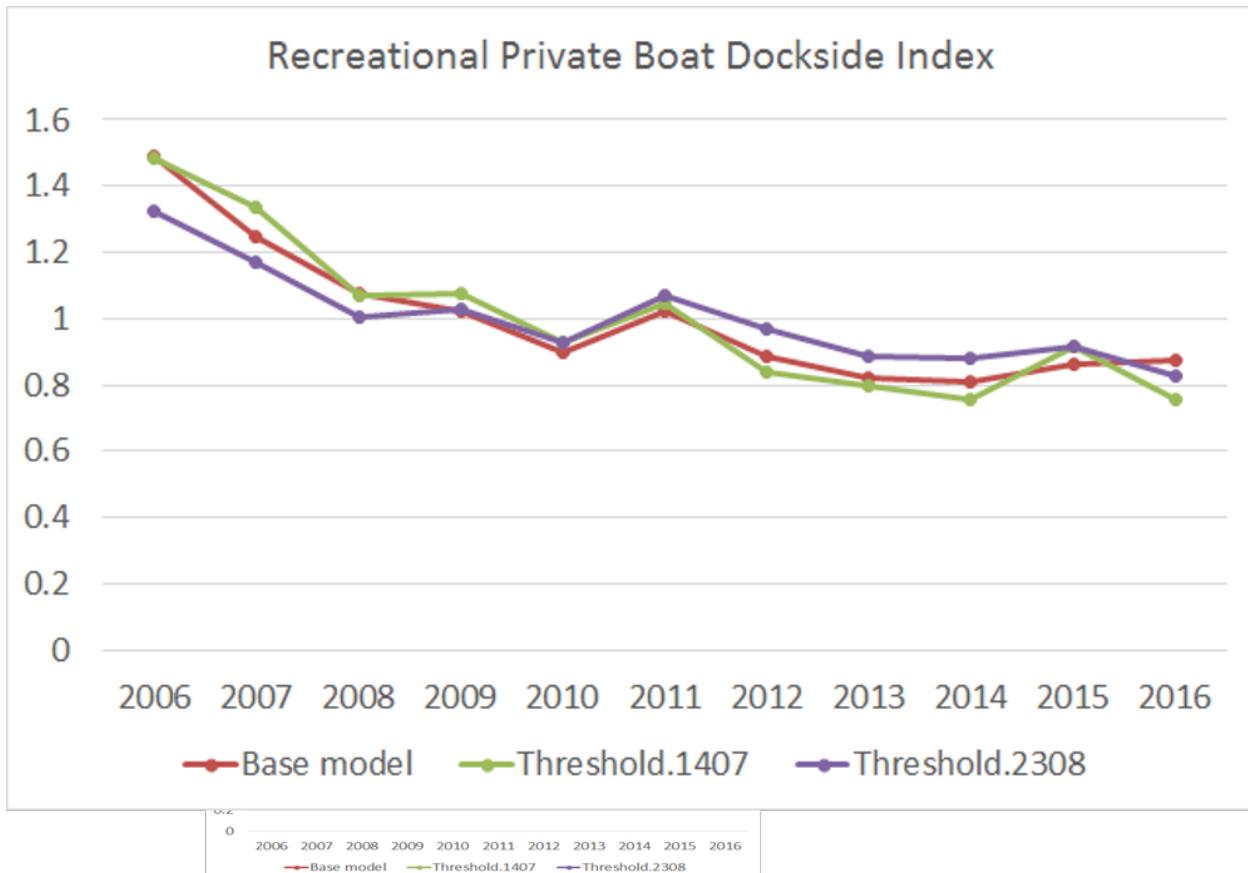


Figure 55: Comparison of the recreational private mode dockside index using three different thresholds for the Stephens-MacCall filter.

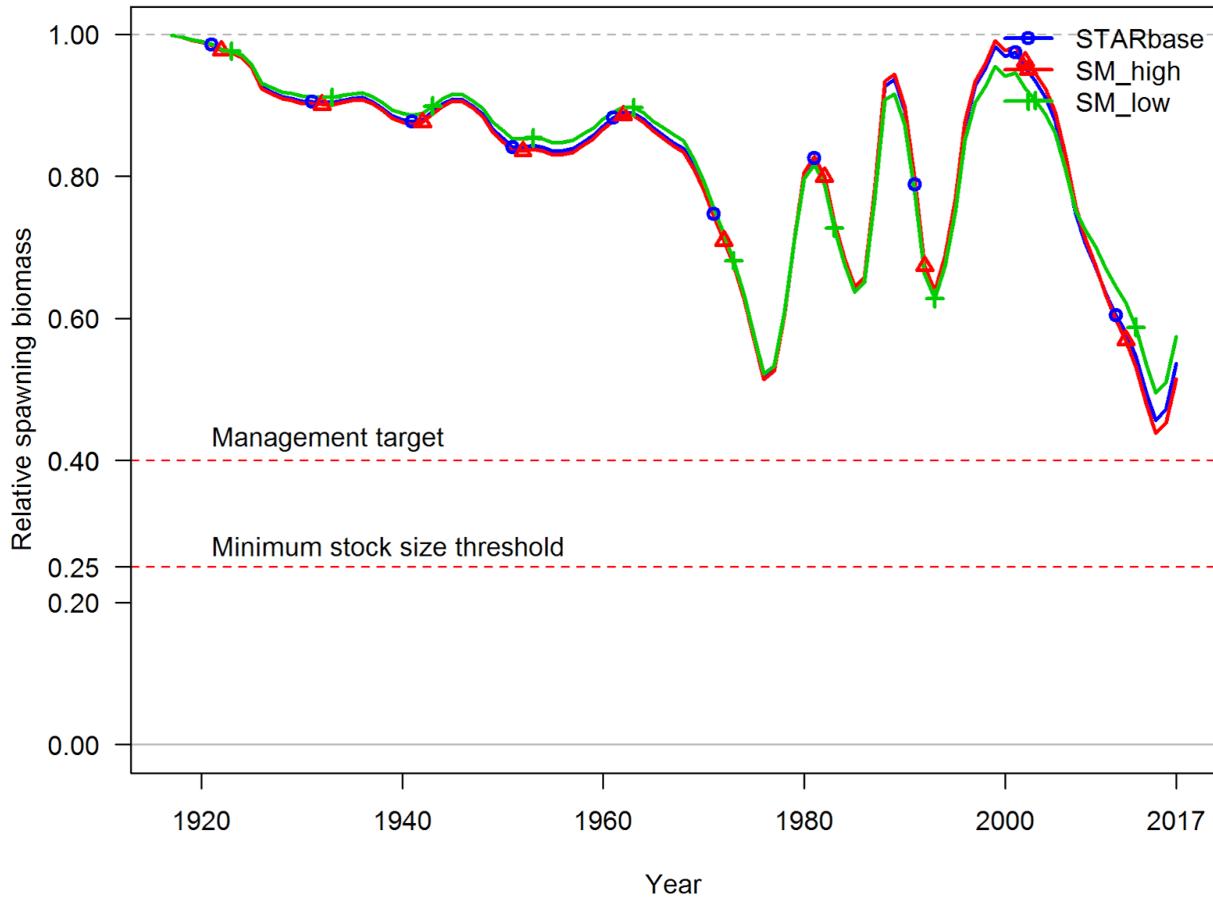


Figure 56: Comparisons of the base model using the index developed for the recreational private mode dockside index using three different thresholds for the Stephens-MacCall filter.

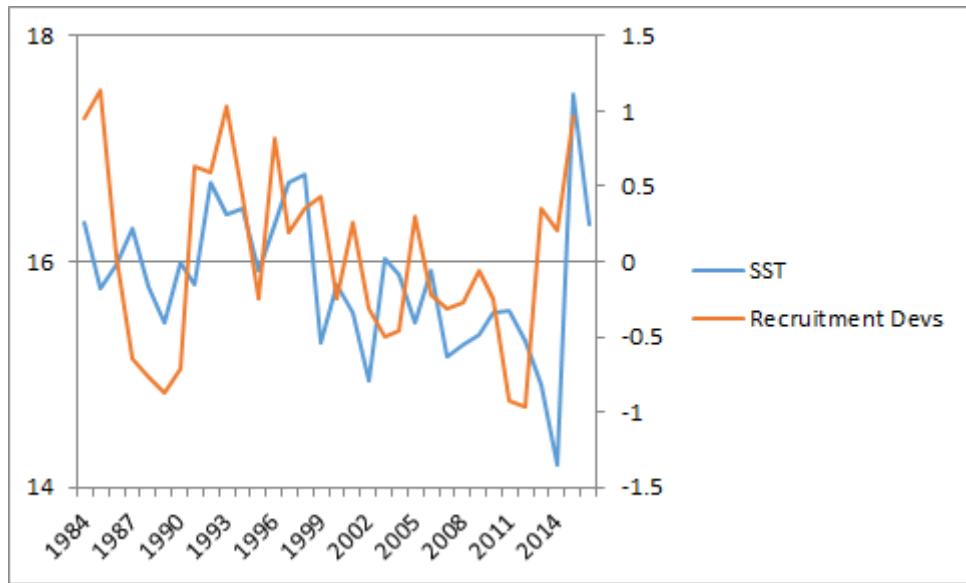


Figure 57: Time series of estimated recruitment deviations from the base model and the CalCOFI sea surface temperature

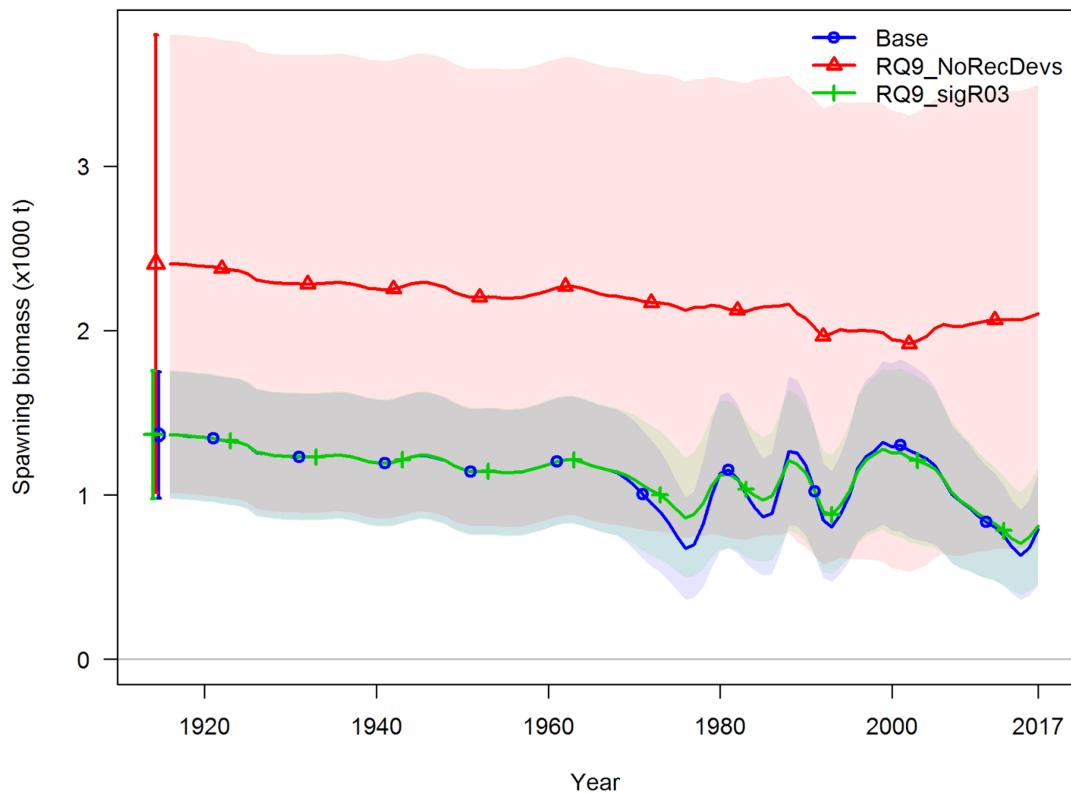
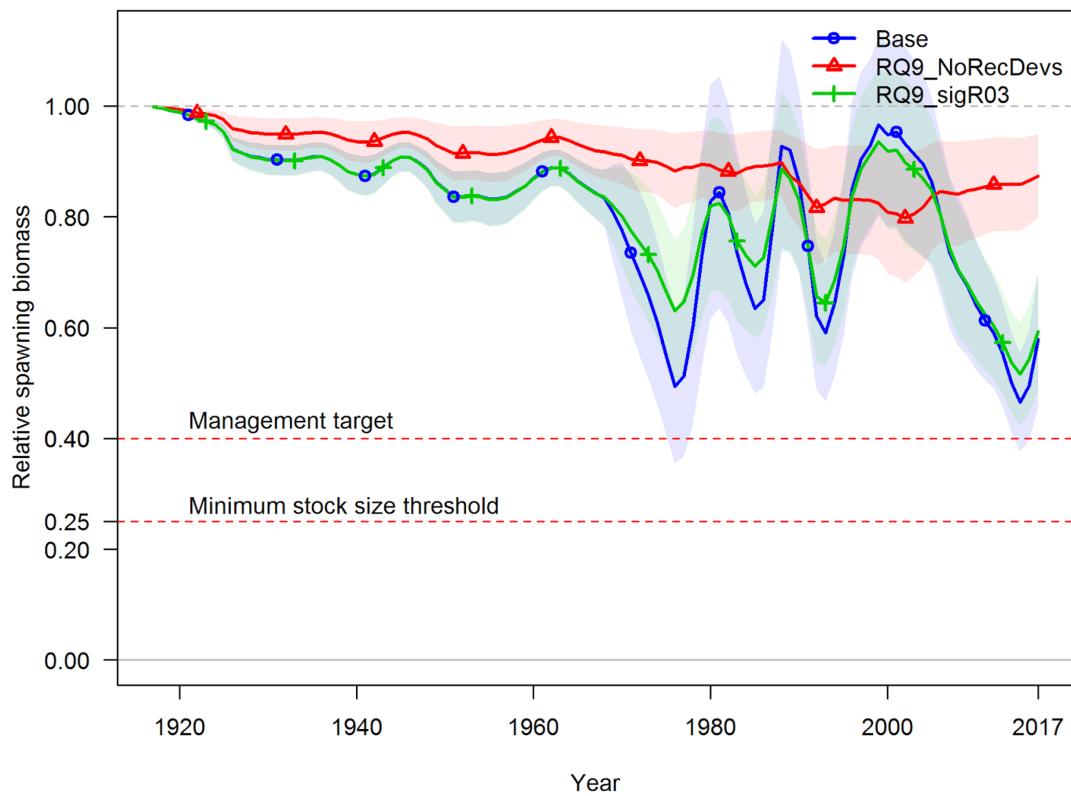


Figure 58: Time series of relative spawning biomass (top) and spawning biomass (bottom) from the base model compared to a model with no recruitment deviations and a sigma-r of 0.3.
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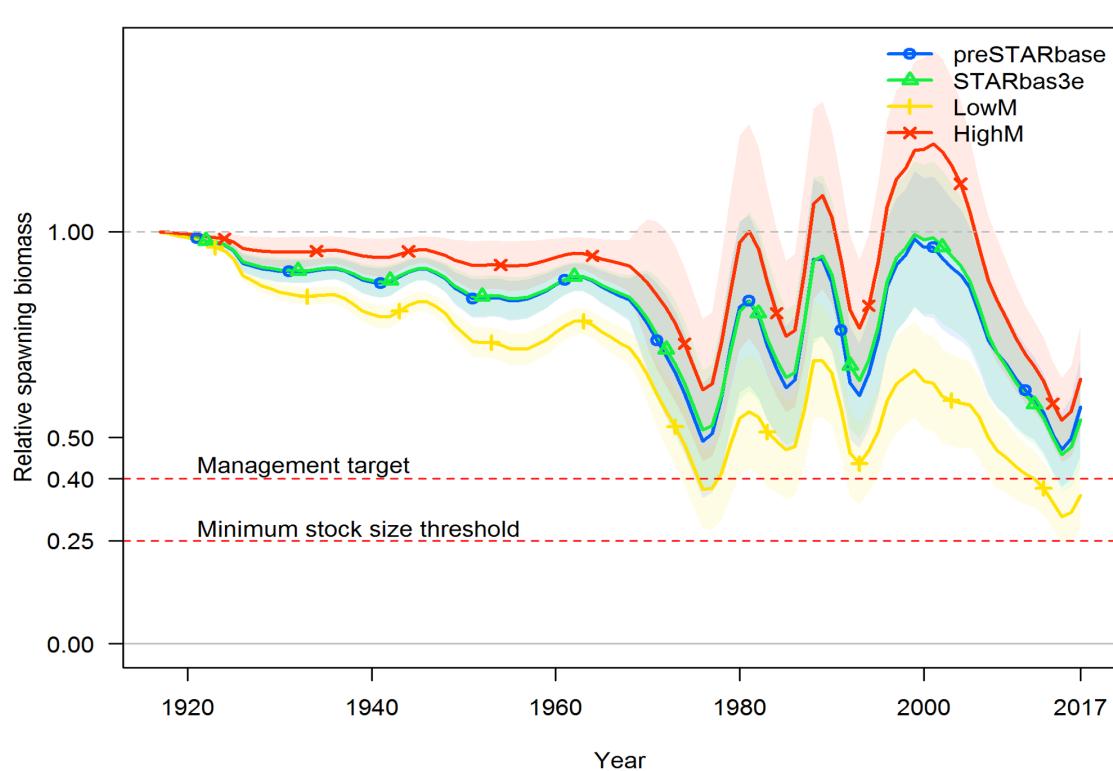
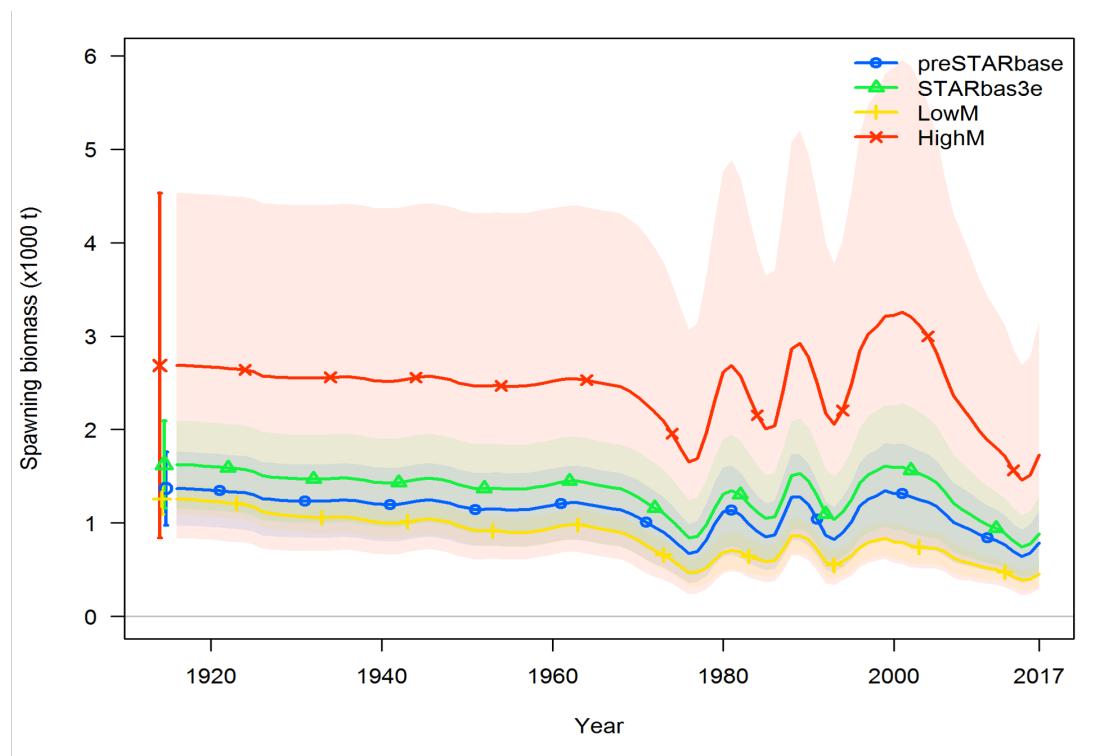


Figure 59: Time series of spawning biomass (top) and relative spawning biomass (bottom) from the pre-STAR base model (M fixed at 0.257 for females and estimated for males) compared to the STAR panel base model (one $M = 0.235$), and the two states of nature of natural mortality of 0.165 and 0.2745 .

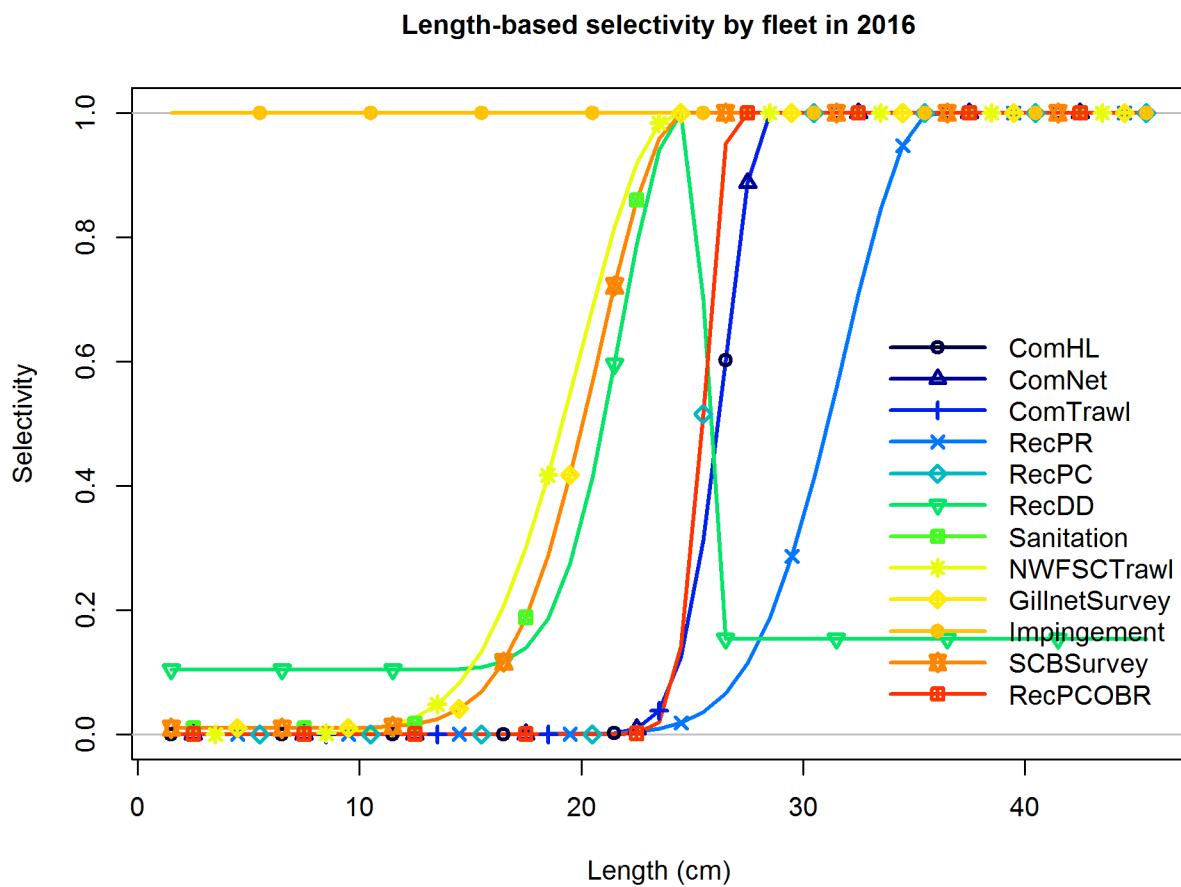


Figure 60: Selectivity at length for all of the fleets in the base model.

Female time-varying selectivity for ComHL

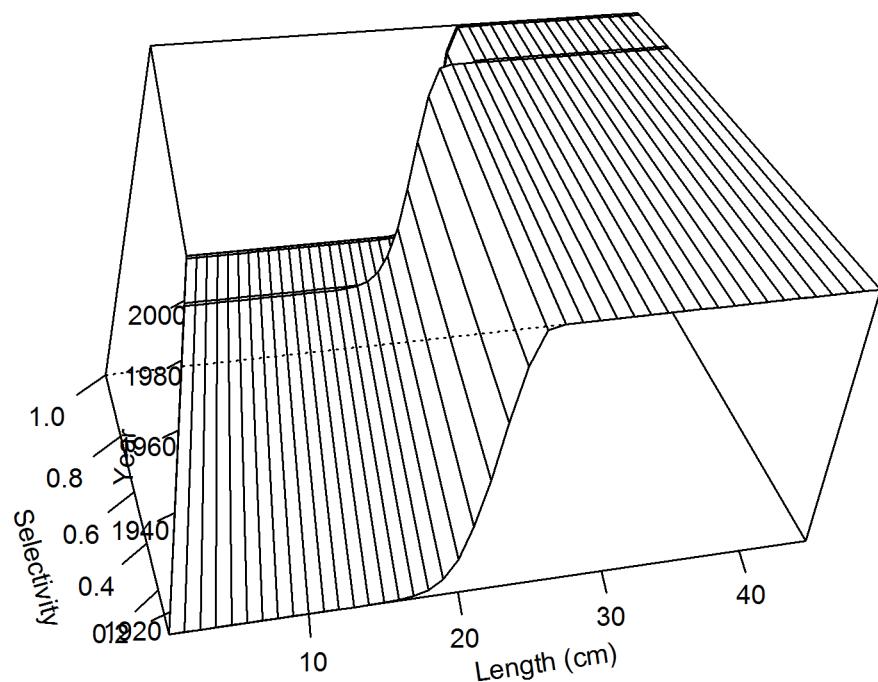


Figure 61: Surface plot of Female time-varying selectivity for the commercial hook-and-line fleet, with time blocks from 1916-1998 and 1999-2016.

Female time-varying selectivity for RecPR

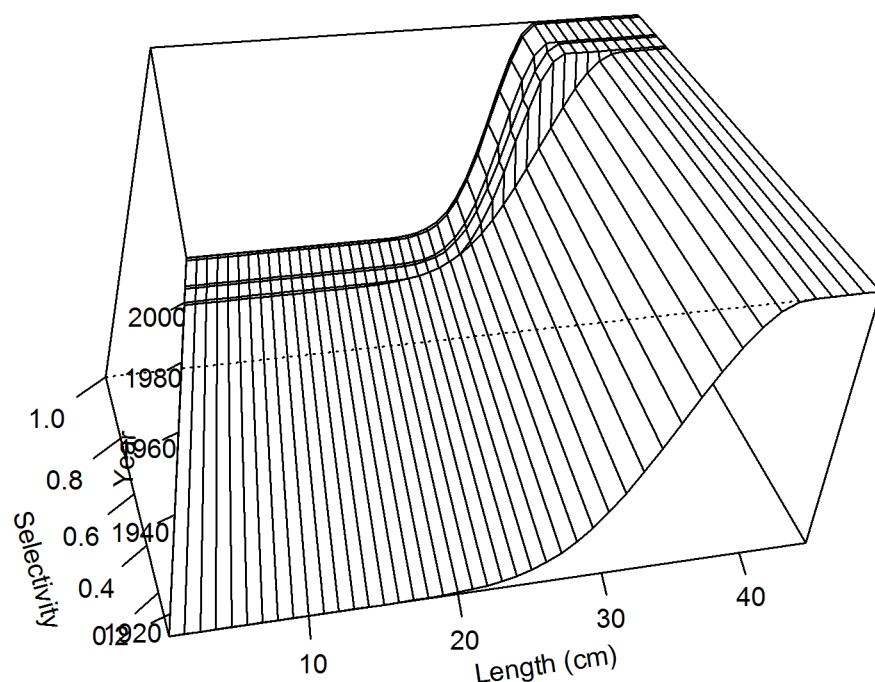


Figure 62: Surface plot of Female time-varying selectivity for the recreational private boat fleet, with time blocks from 1916-2000, 2001-2005, and 2006-2016.

Female time-varying selectivity for RecPC

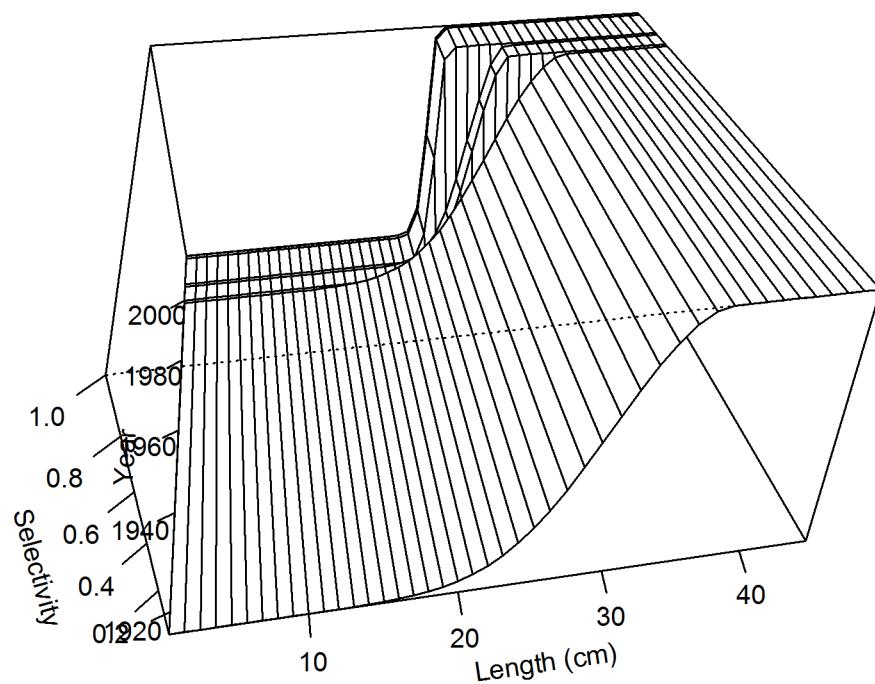


Figure 63: Surface plot of Female time-varying selectivity for the recreational party/charter retained-only catch fleet, with time blocks from 1916-2000, 2001-2005, and 2006-2016.

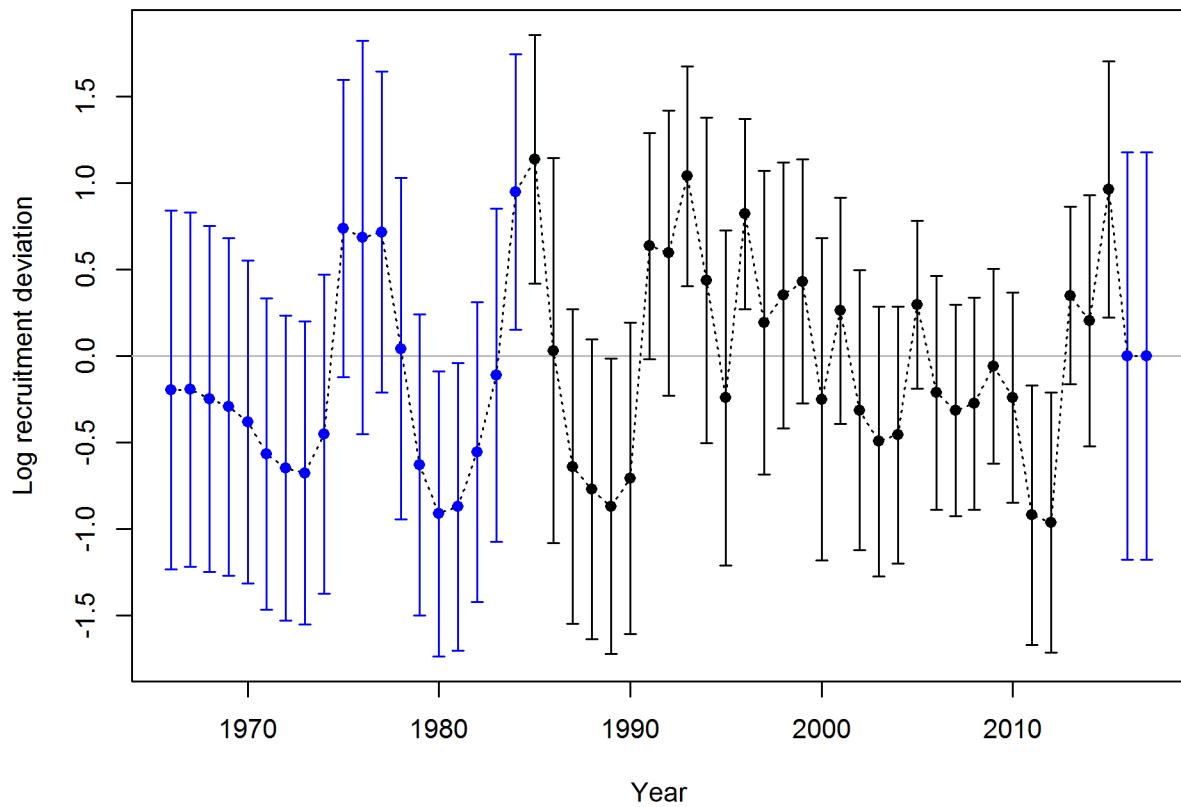


Figure 64: Estimated time-series of recruitment deviations for California scorpionfish with 95% intervals.

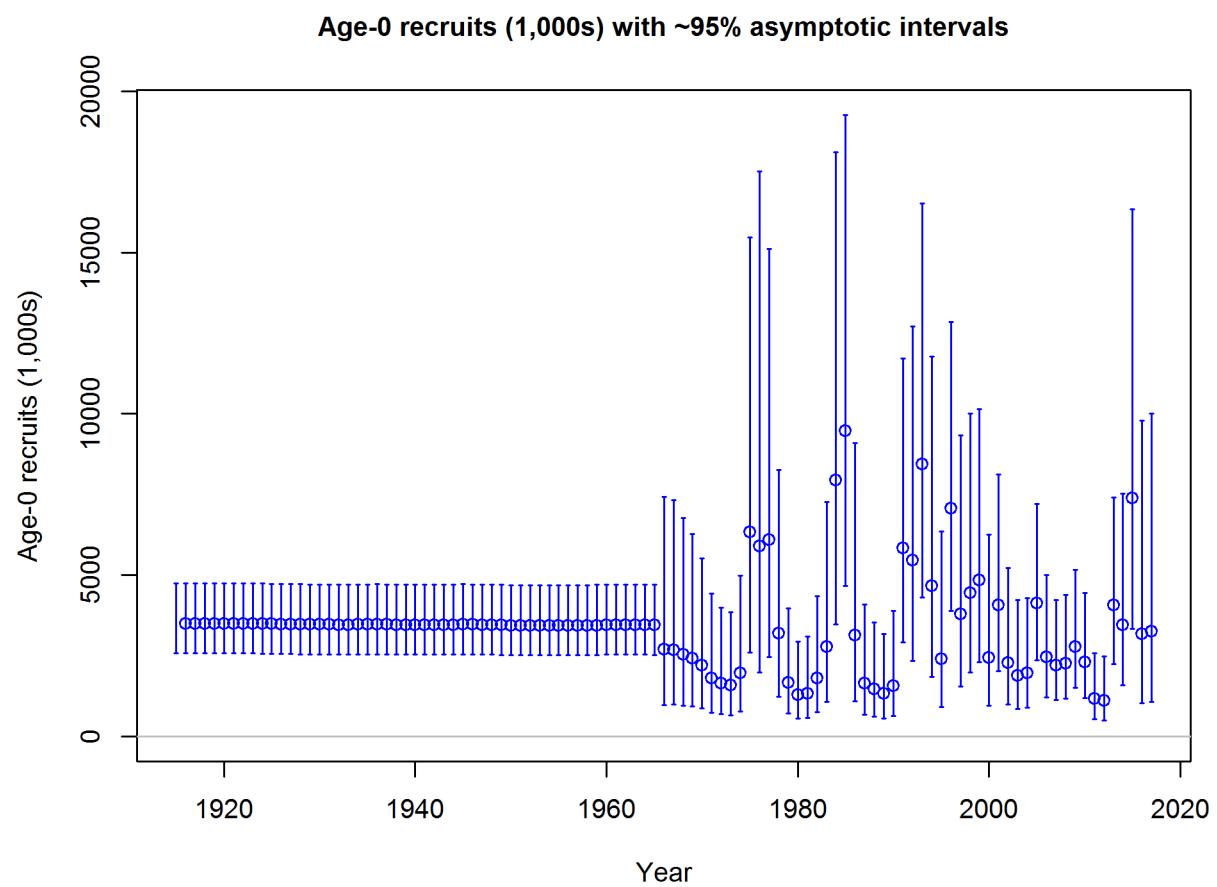


Figure 65: Estimated time-series of recruitment for California scorpionfish.

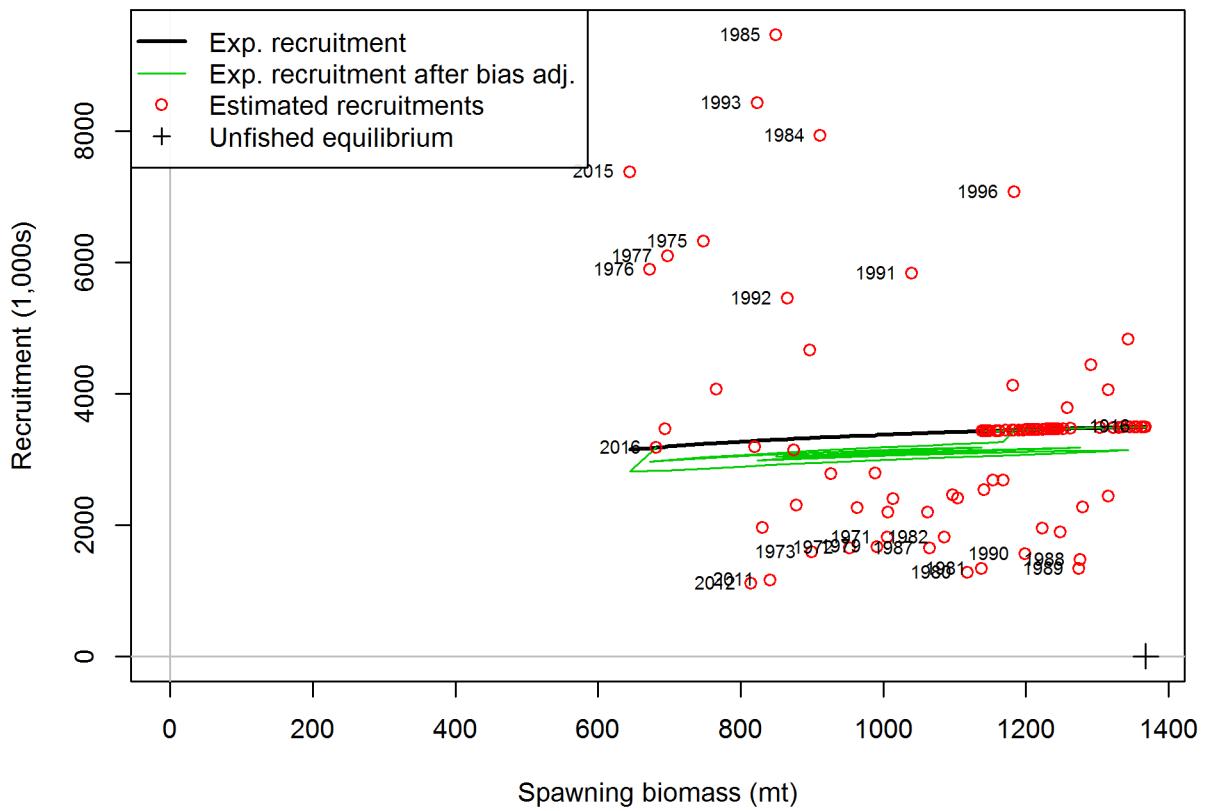


Figure 66: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line) for California scorpionfish. The green line shows the effect of the bias correction for the lognormal distribution.

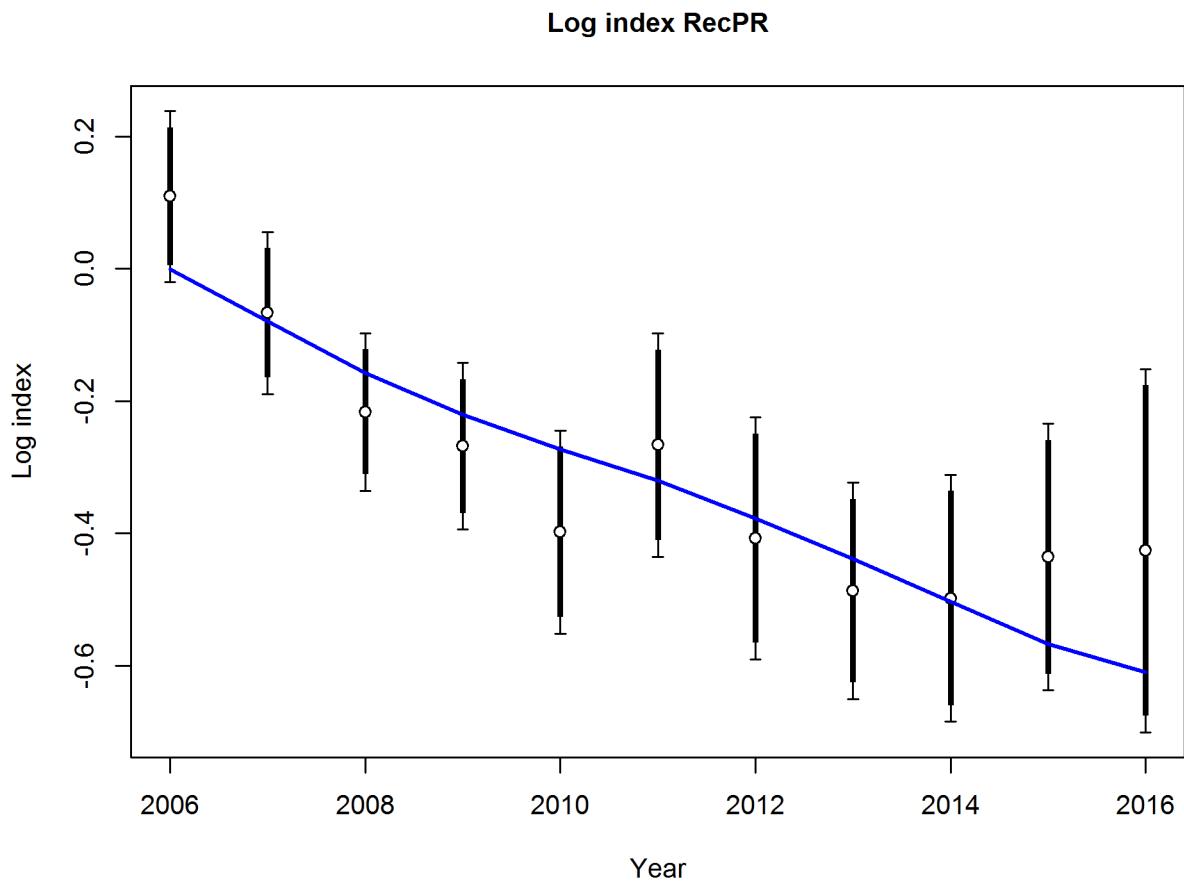


Figure 67: Fit to log index data on log scale for the recreational CPFV logbook retained catches. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

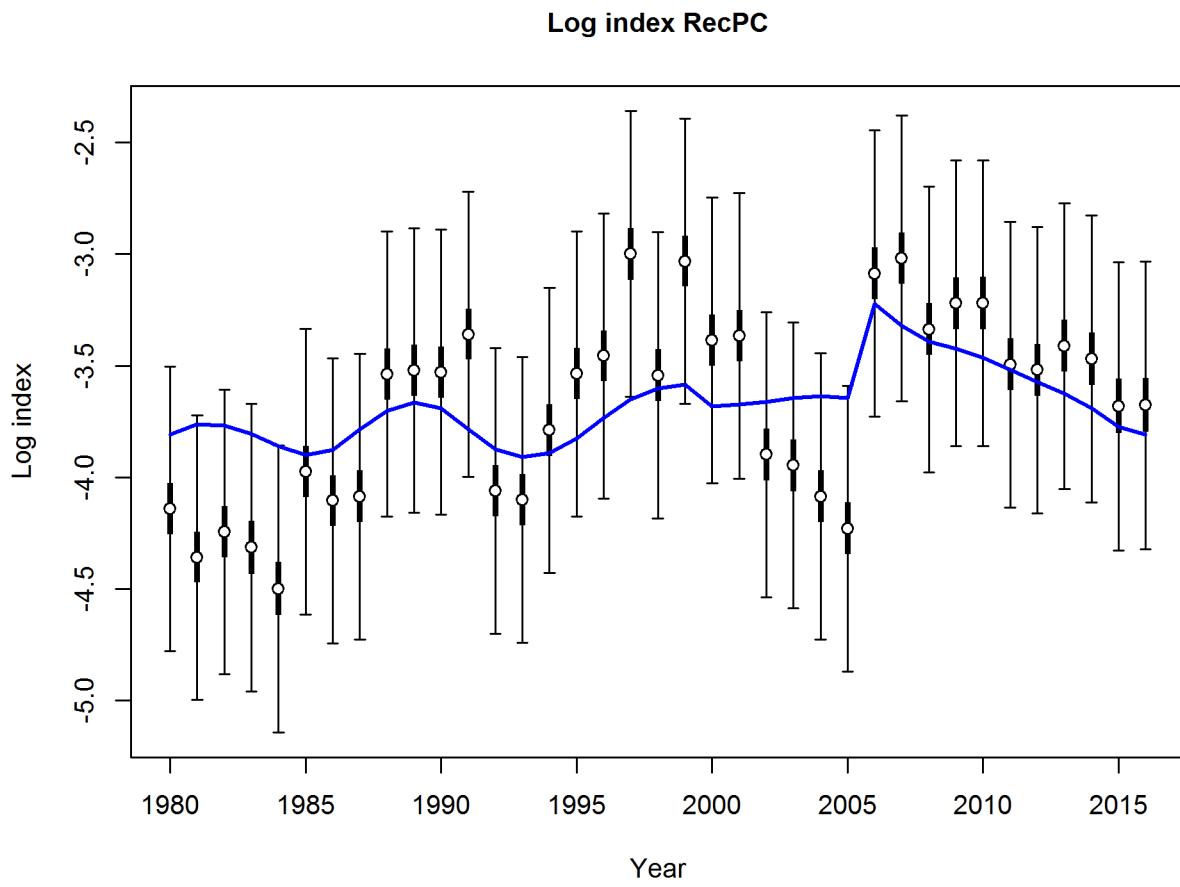


Figure 68: Fit to log index data on log scale for the recreational CPFV logbook retained catches. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

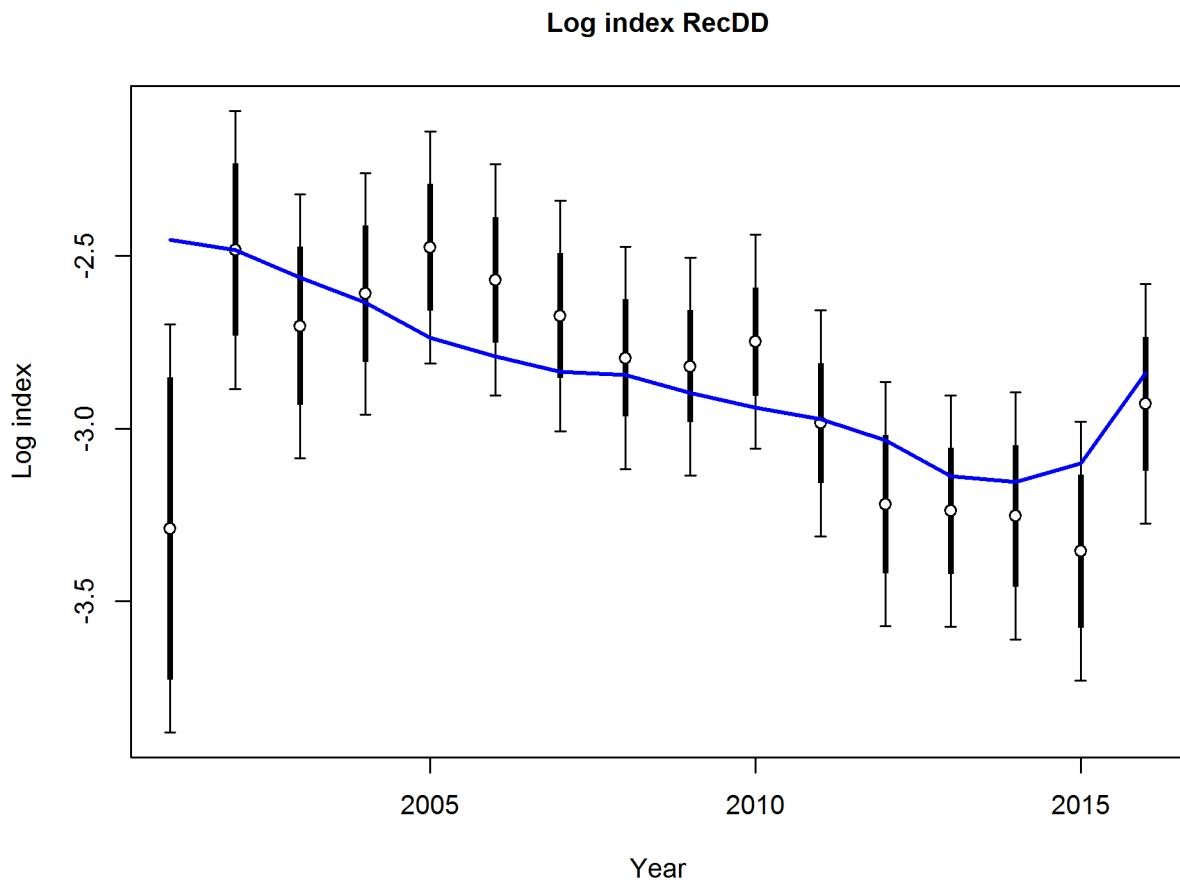


Figure 69: Fit to log index data on log scale for the recreational CPFV onboard observer discard catch index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

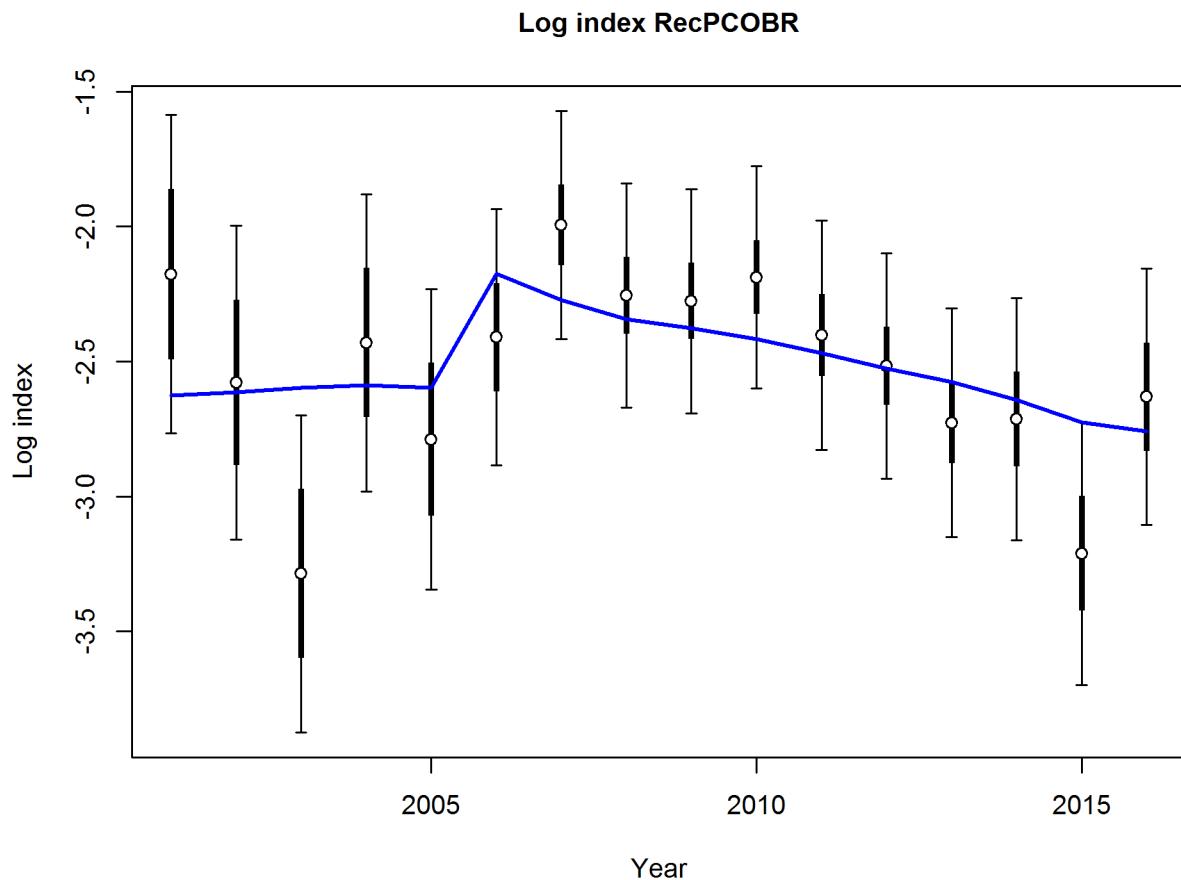


Figure 70: Fit to log index data on log scale for the recreational CPFV onboard observer retained catch index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

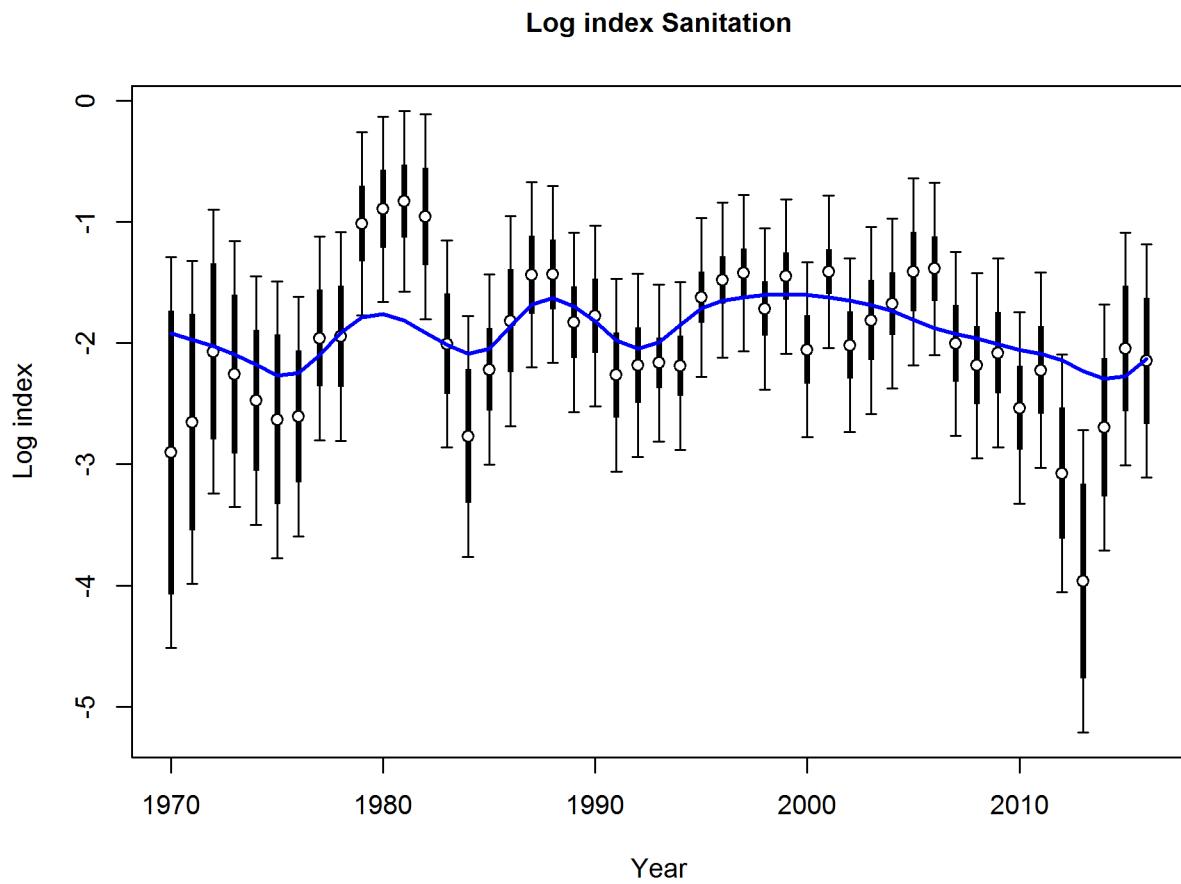


Figure 71: Fit to log index data on log scale for the POTW trawl index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

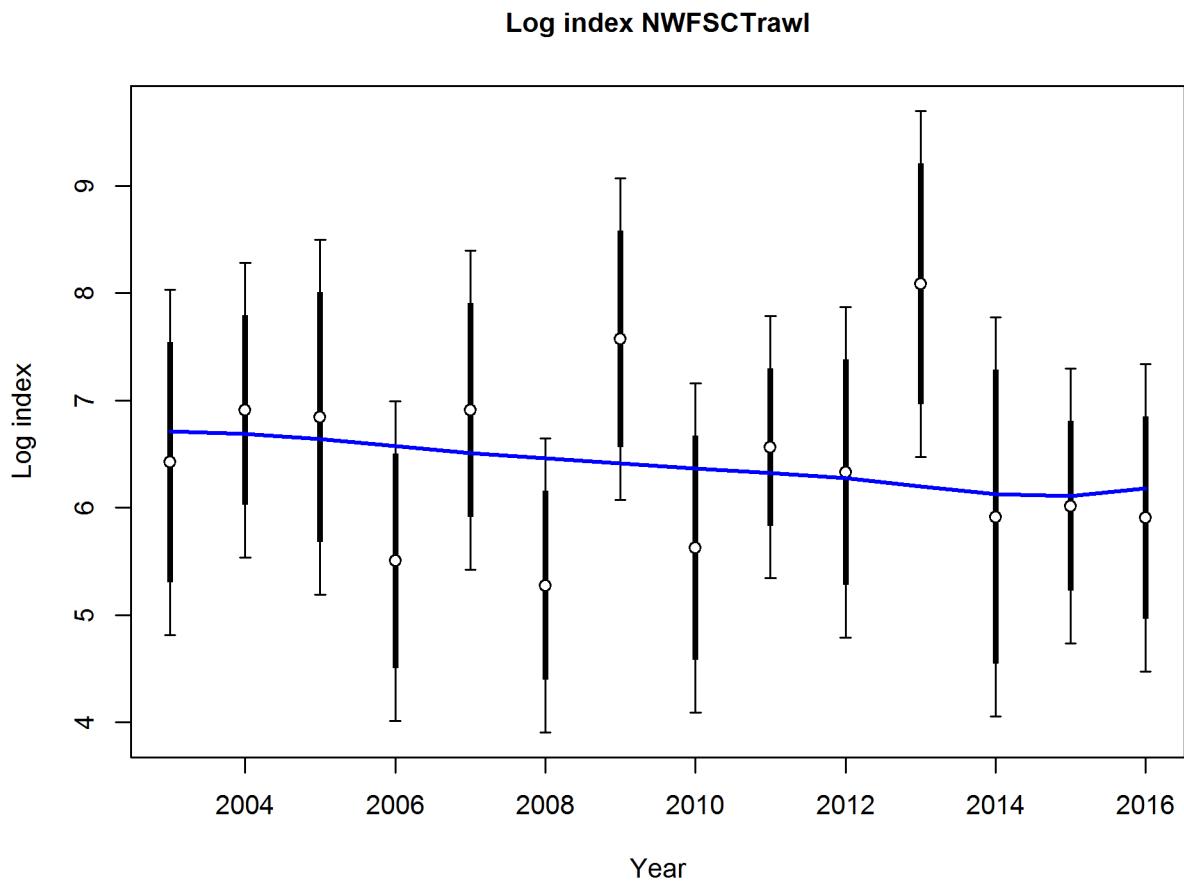


Figure 72: Fit to log index data on log scale for the NWFSC trawl survey from the VAST analysis from 2003-2016. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

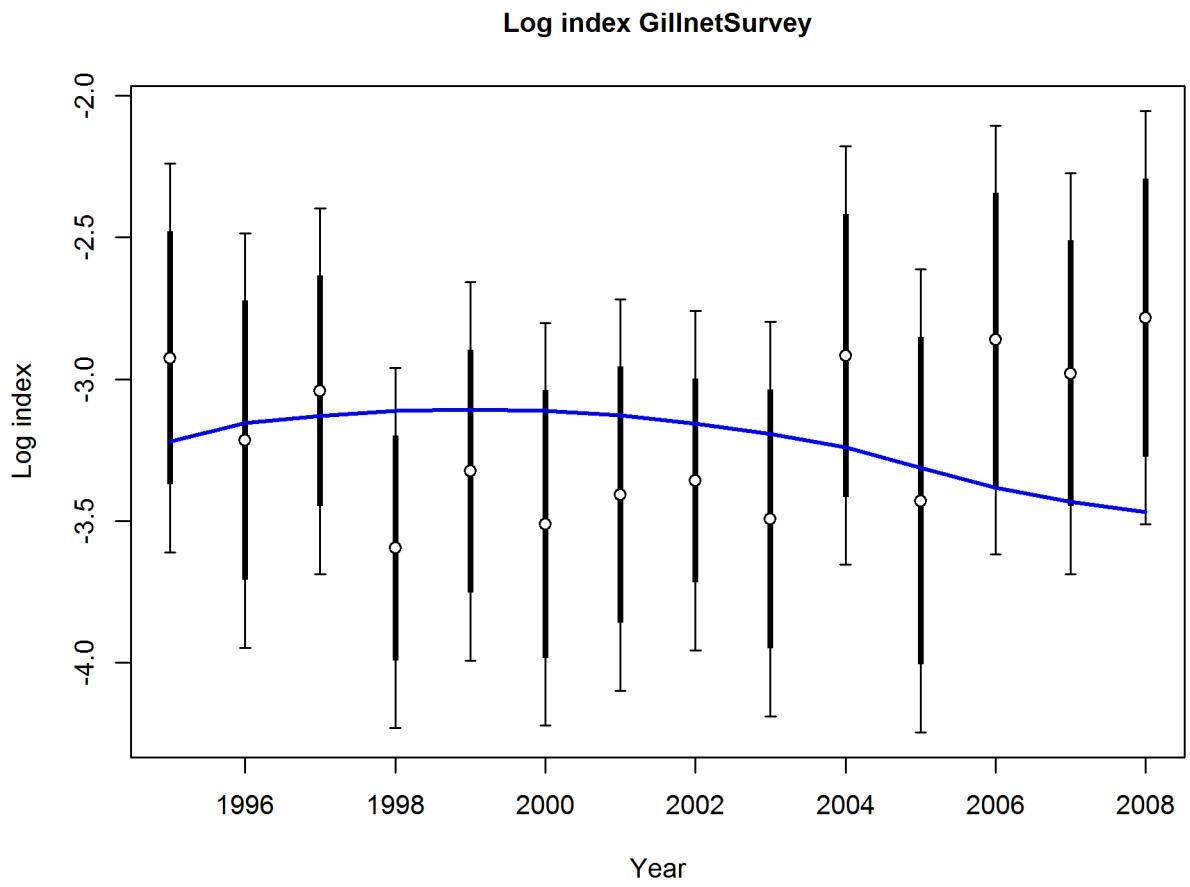


Figure 73: Fit to log index data on log scale for the recreational CSUN/VRG gillnet survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

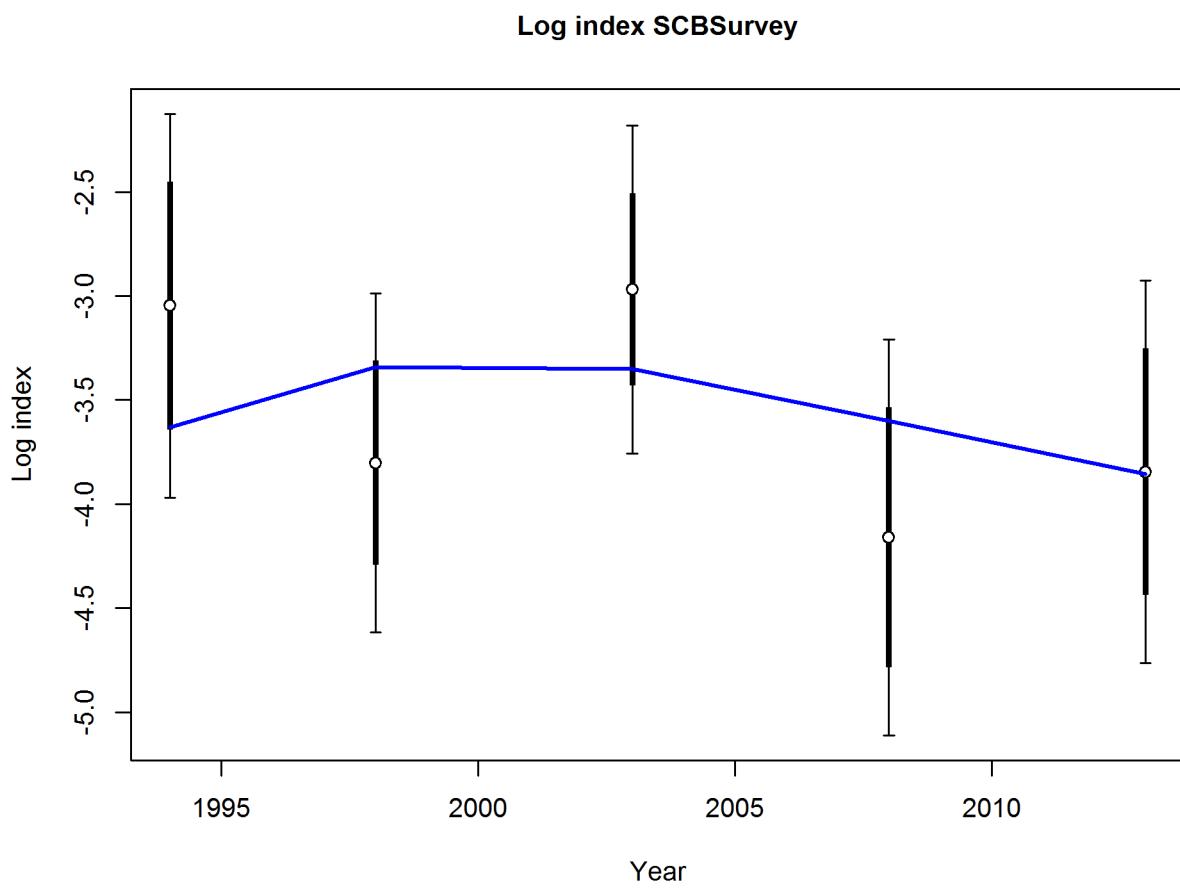


Figure 74: Fit to log index data on log scale for the recreational Southern California Bight trawl survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

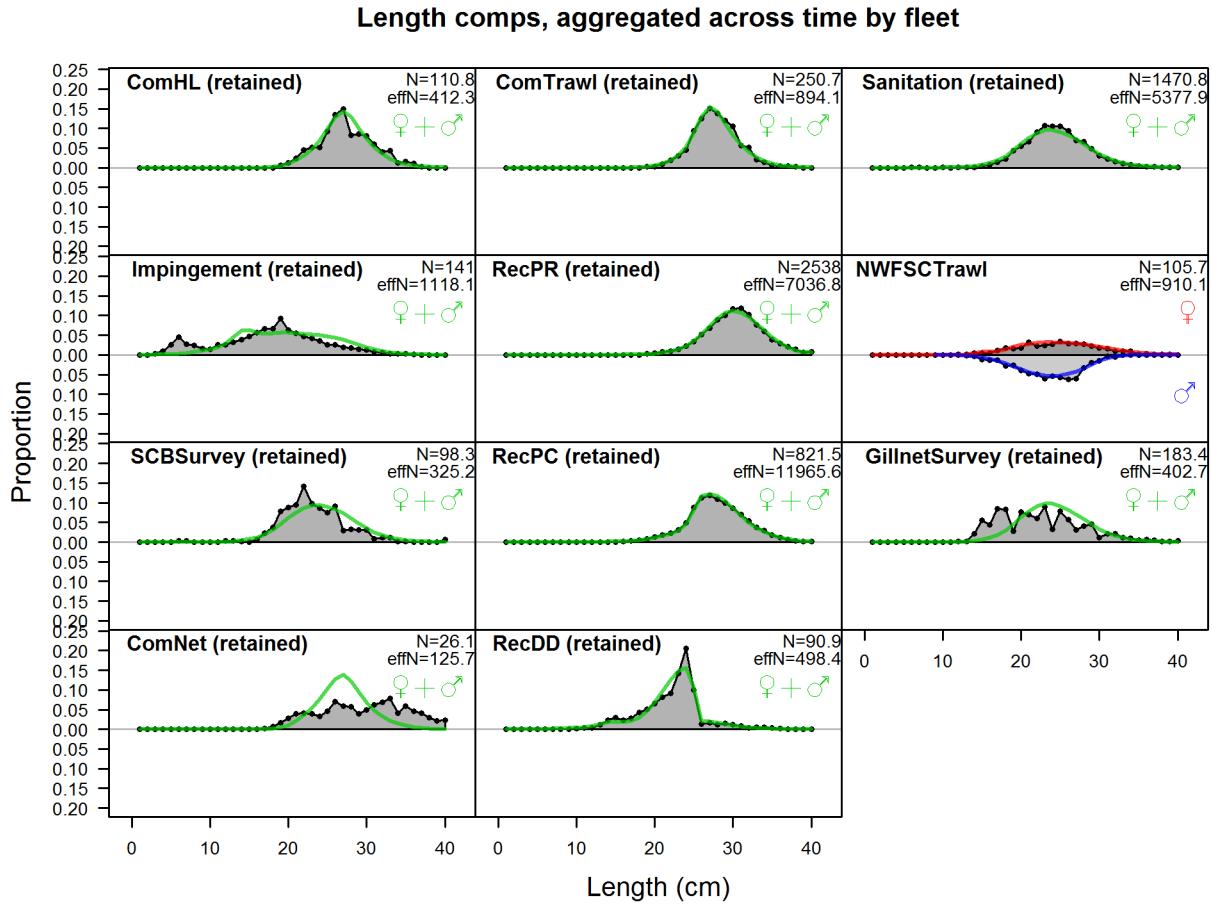


Figure 75: Length compositions aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch.

Conditional AAL plot, whole catch, NWFSC Trawl

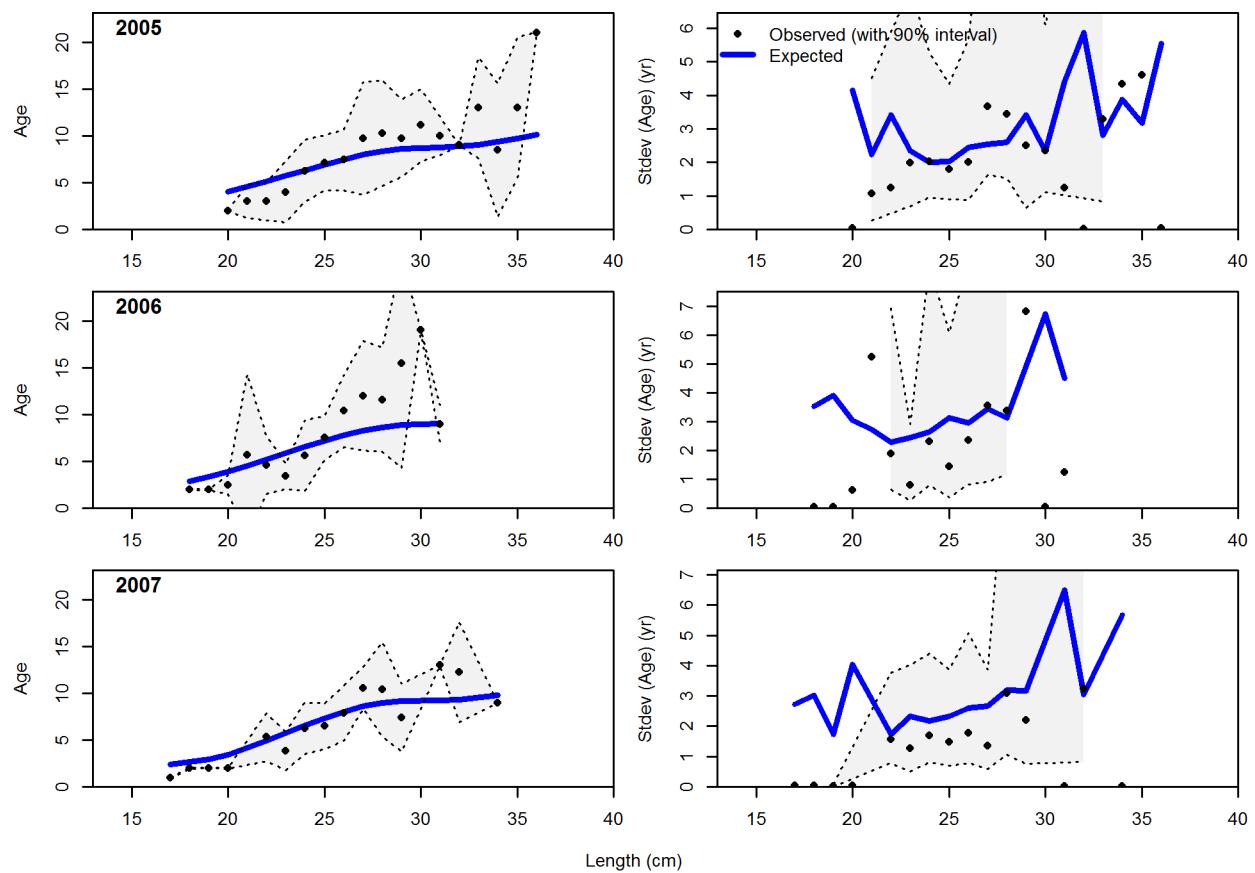
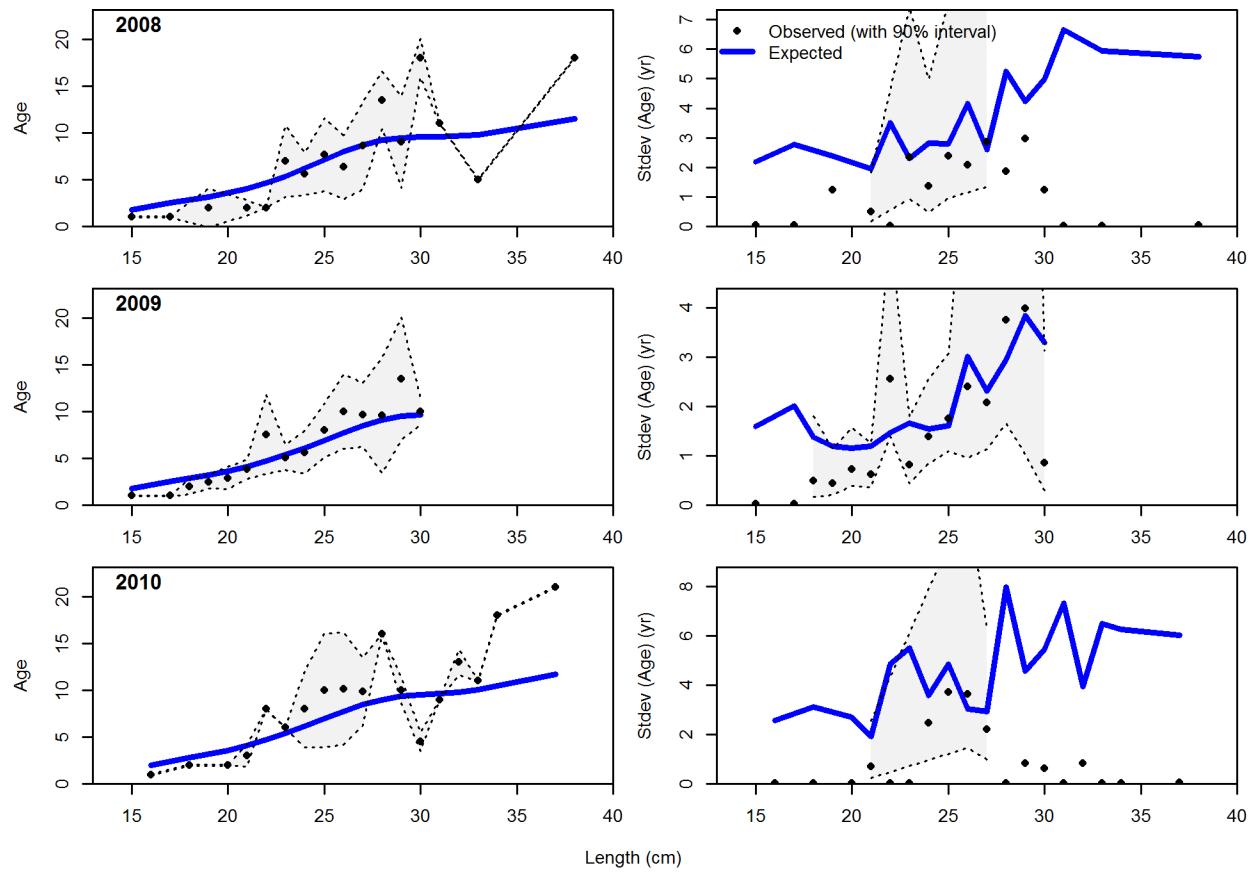


Figure 76: Conditional AAL plot, whole catch, NWFSC Trawl (plot 1 of 4) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution.

Conditional AAL plot, whole catch, NWFSC Trawl

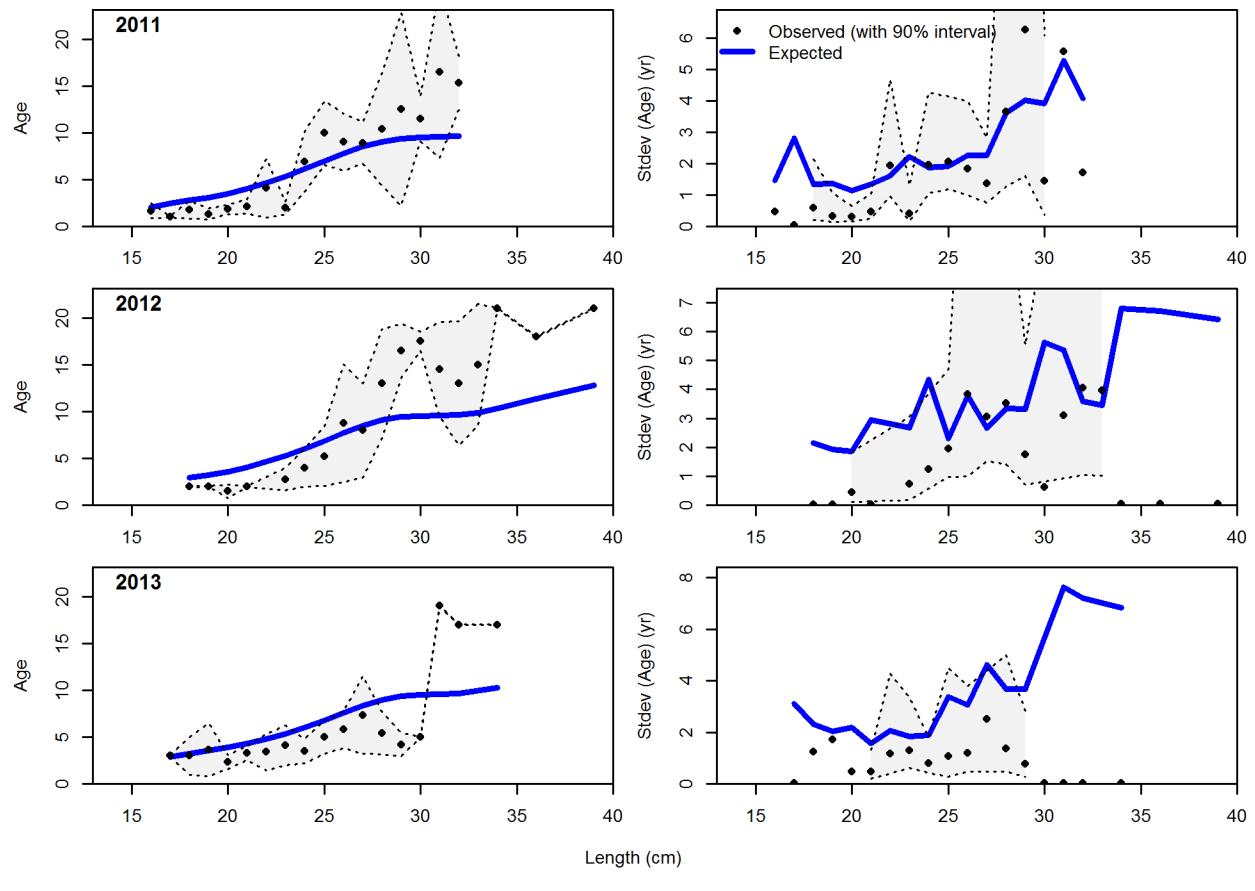


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Conditional AAL plot, whole catch, NWFSC Trawl

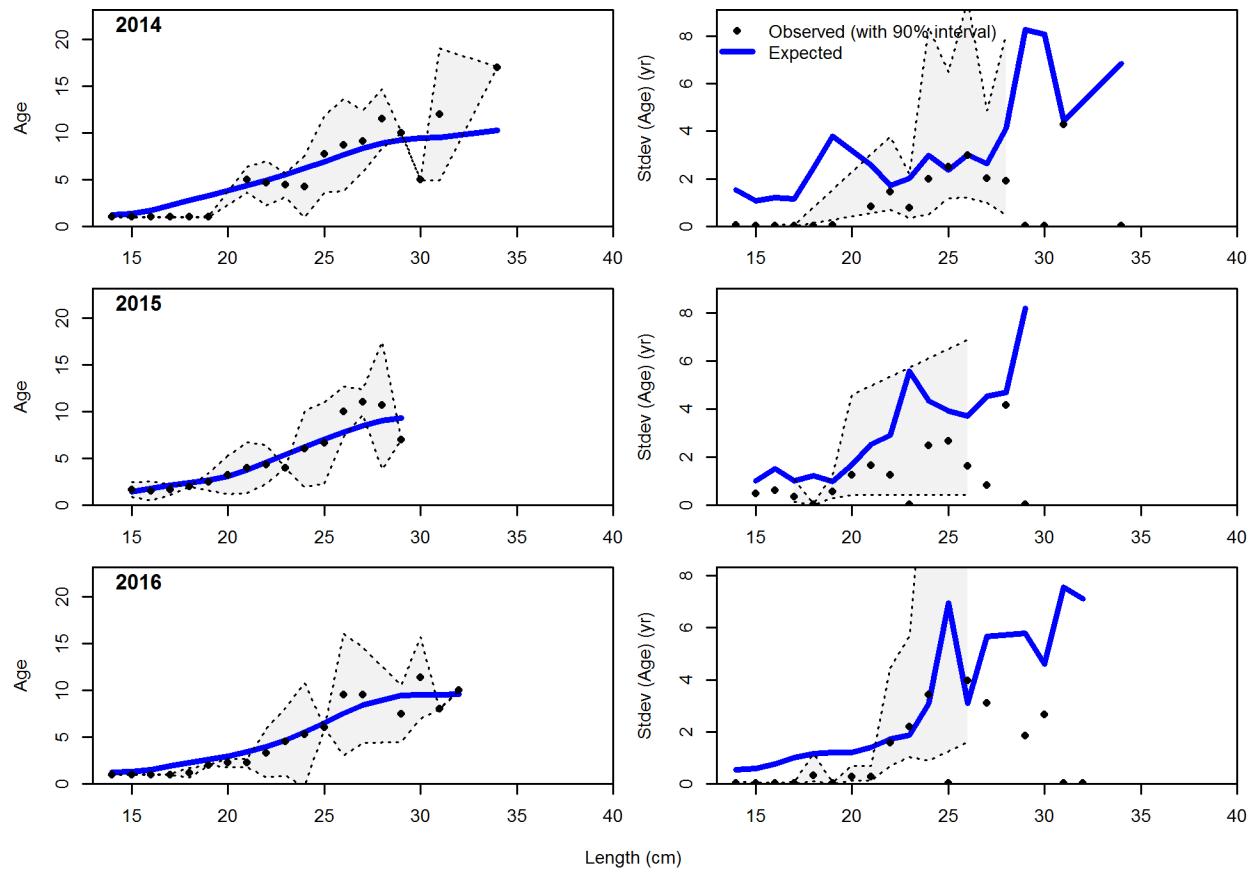


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Conditional AAL plot, whole catch, NWFSC Trawl



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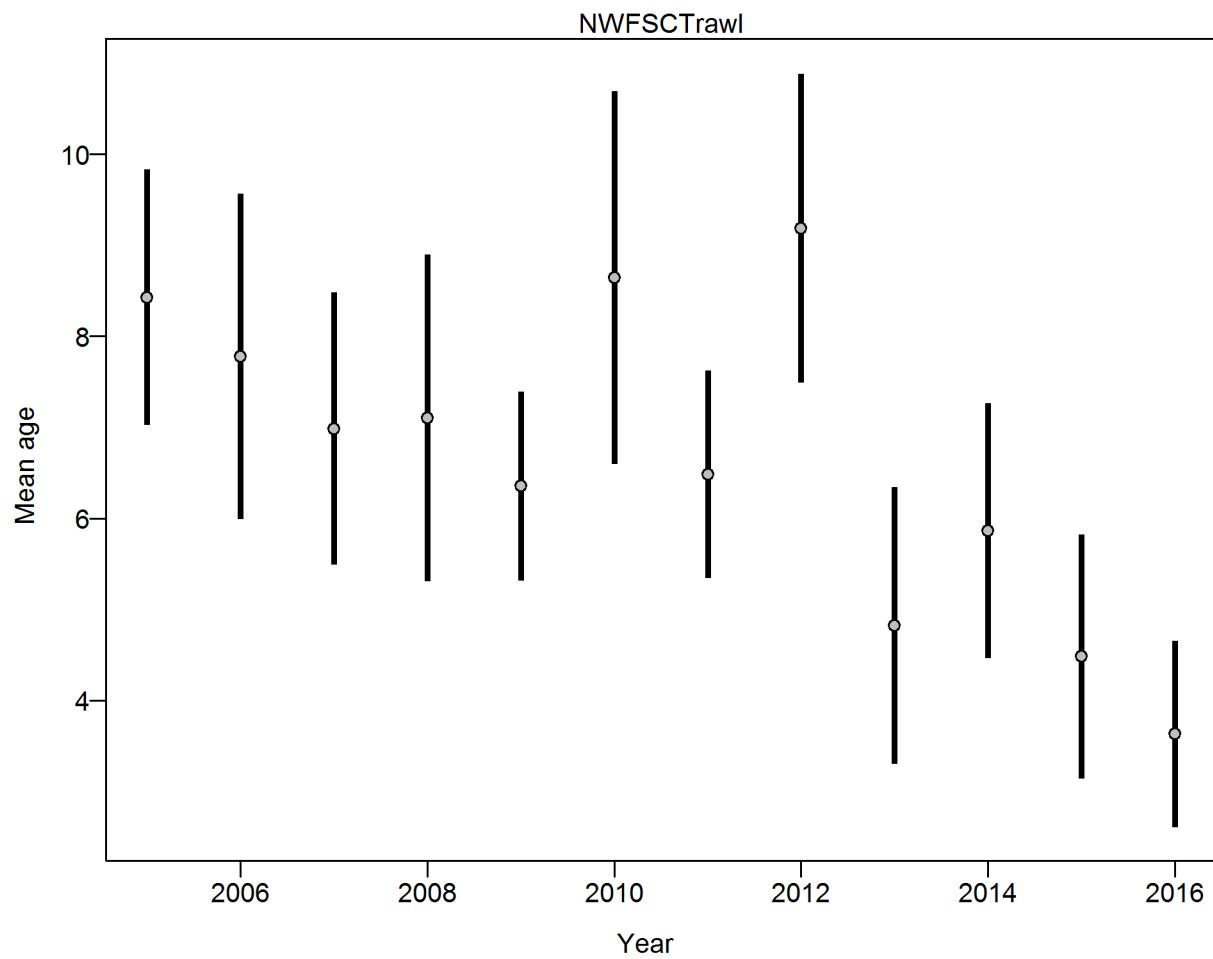


Figure 77: Francis data weighting method TA1.8 for conditional age data from the NWFSC trawl survey. Suggested sample size adjustment (with 95% interval) for conditional age-at-length data from NWFSC trawl is 0.325612 (0.162855-1.289125). For more info, see Francis et al. (2011).

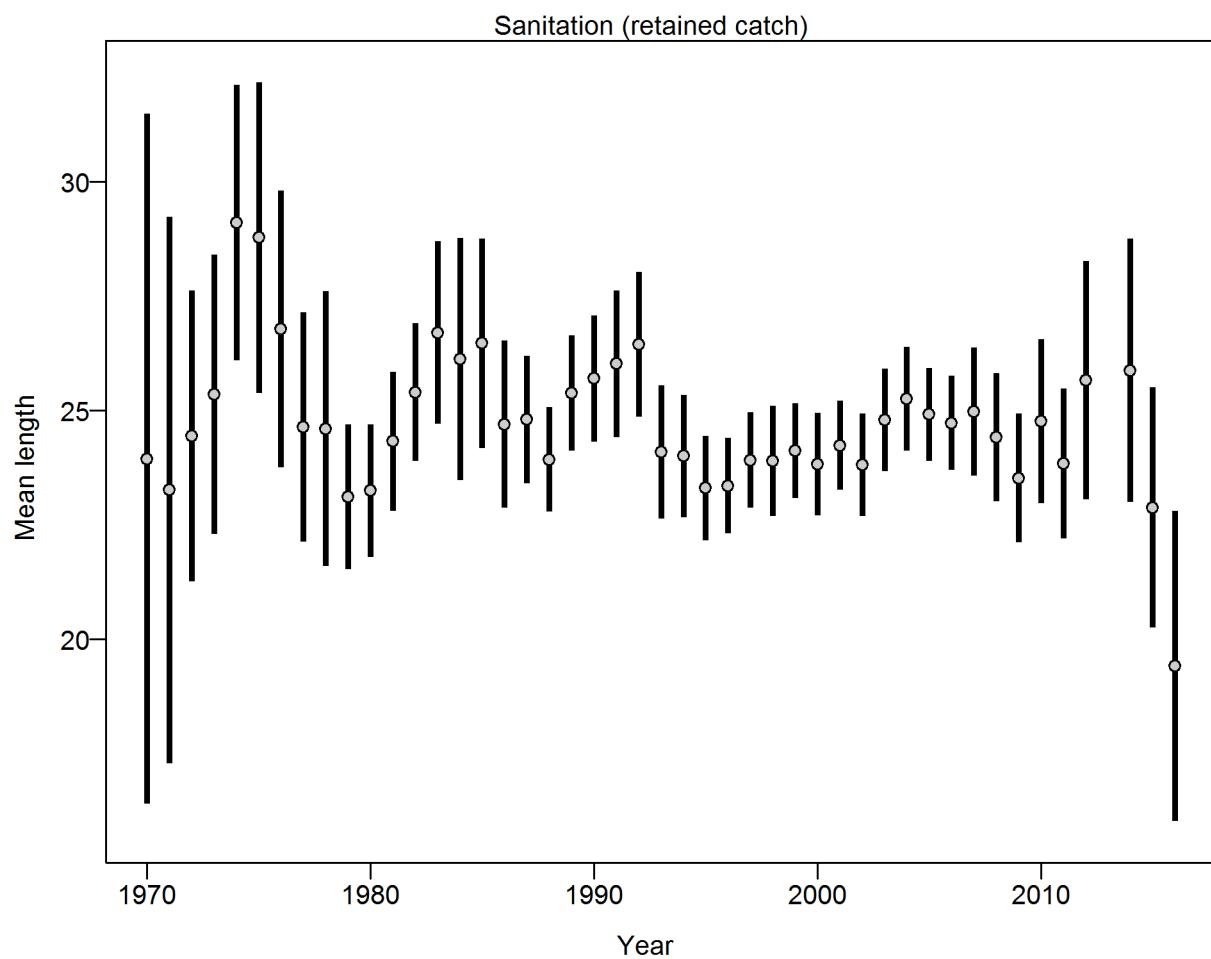


Figure 78: Francis data weighting method TA1.8 for length composition data from the POTW trawl surveys. Suggested sample size adjustment (with 95% interval) for length data from Sanitation surveys is 0.26669 (0.188917-0.430652). For more info, see Francis et al. (2011).

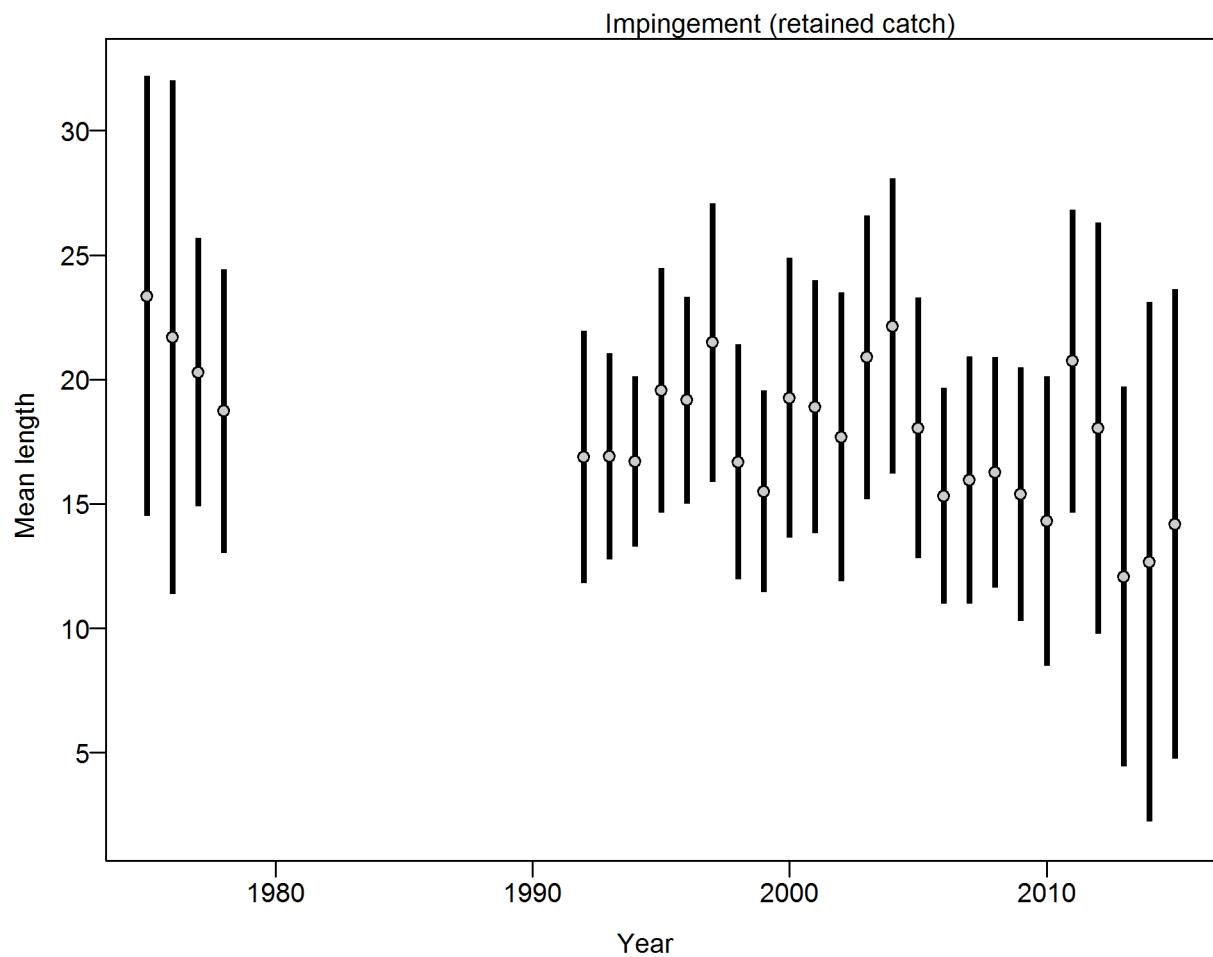


Figure 79: Francis data weighting method TA1.8 for length composition data from the Impingement surveys. Suggested sample size adjustment (with 95% interval) for the length data from the Impingement surveys is 0.169729 (0.128089-0.263479). For more info, see Francis et al. (2011).

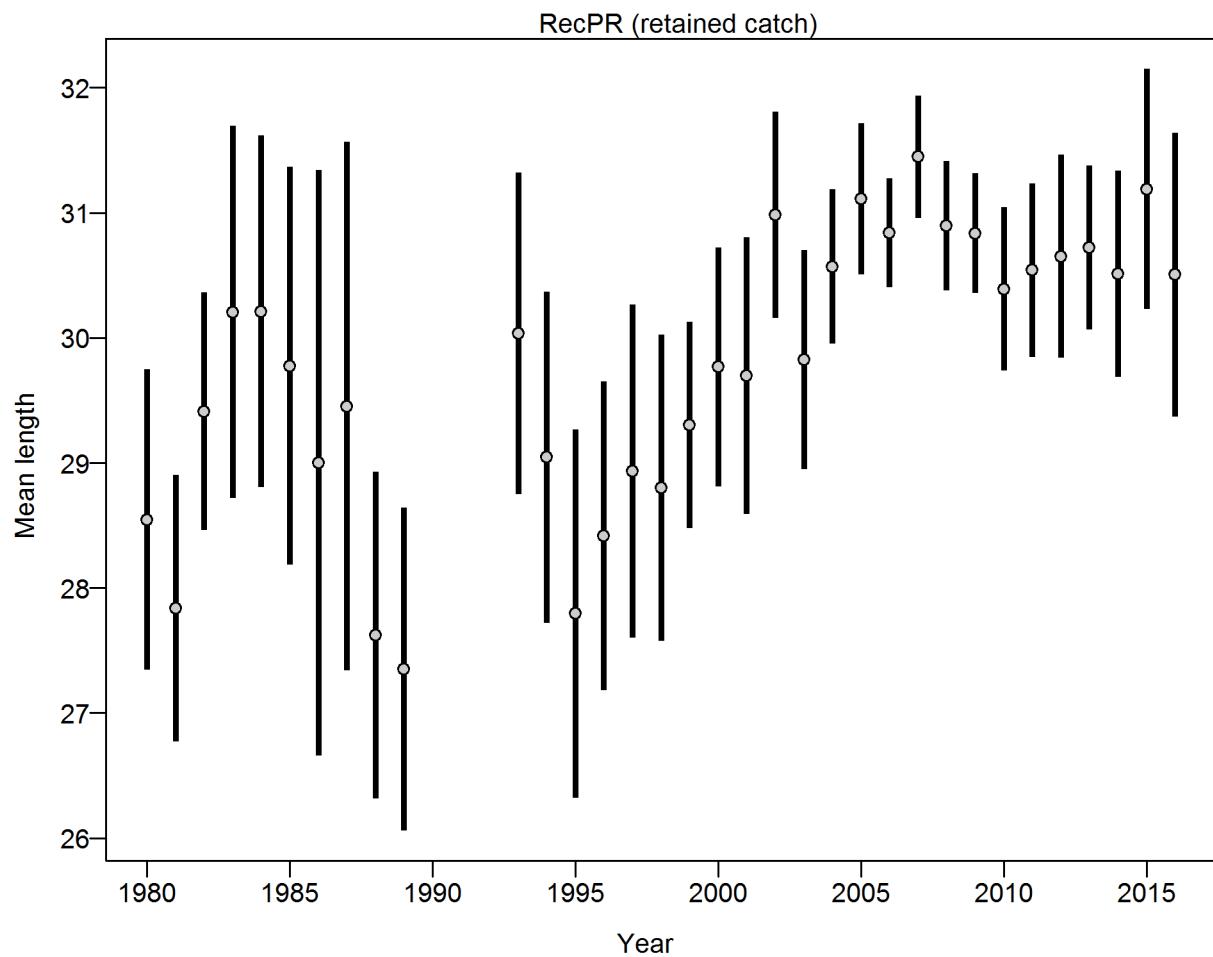


Figure 80: Francis data weighting method TA1.8 for length composition data from the recreational private boat fleet. Suggested sample size adjustment (with 95% interval) for the length data from the recreational private boat fleet is 0.72827 (0.526118-1.183978). For more info, see Francis et al. (2011).

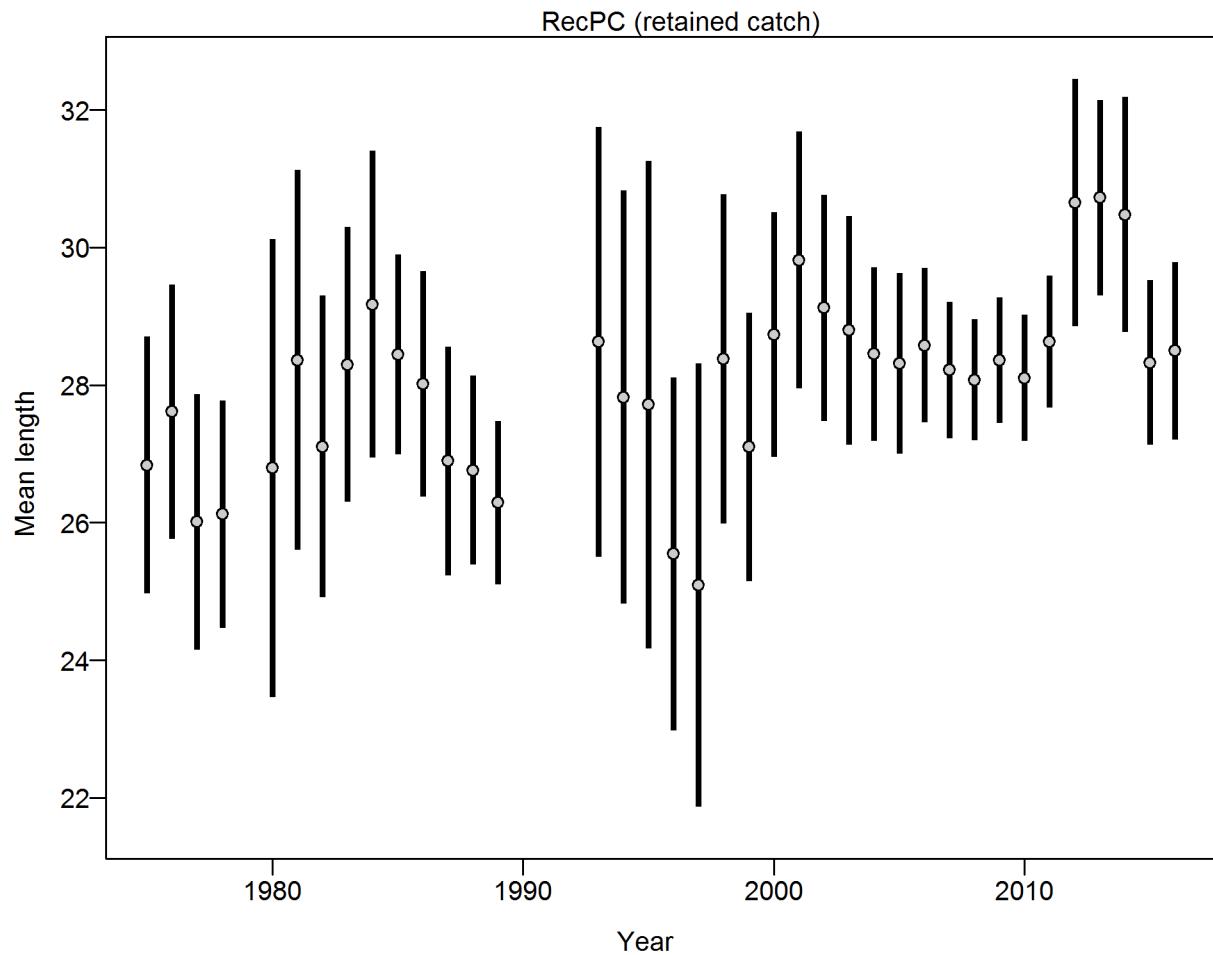


Figure 81: Francis data weighting method TA1.8 for conditional age data from the recreational party/charter retained-catch fleet. Suggested sample size adjustment (with 95% interval) for the length data from the recreational party/charter retained-catch fleet is 0.135779 (0.087286-0.281298). For more info, see Francis et al. (2011).

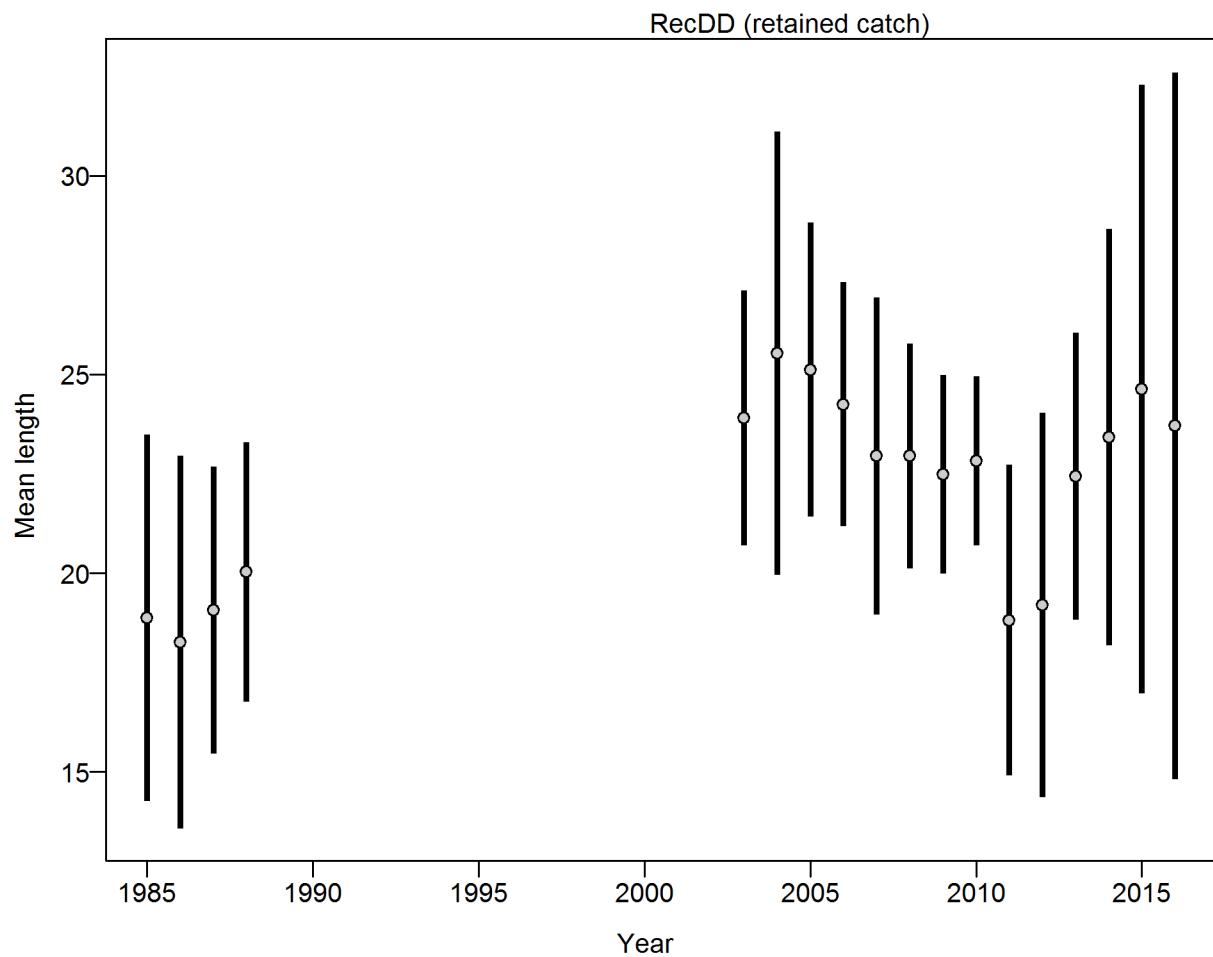


Figure 82: Francis data weighting method TA1.8 for conditional age data from the recreational discard-catch fleet. Suggested sample size adjustment (with 95% interval) for the length data from the recreational discard-catch fleet is 0.13574 (0.104322-0.257617). For more info, see Francis et al. (2011).

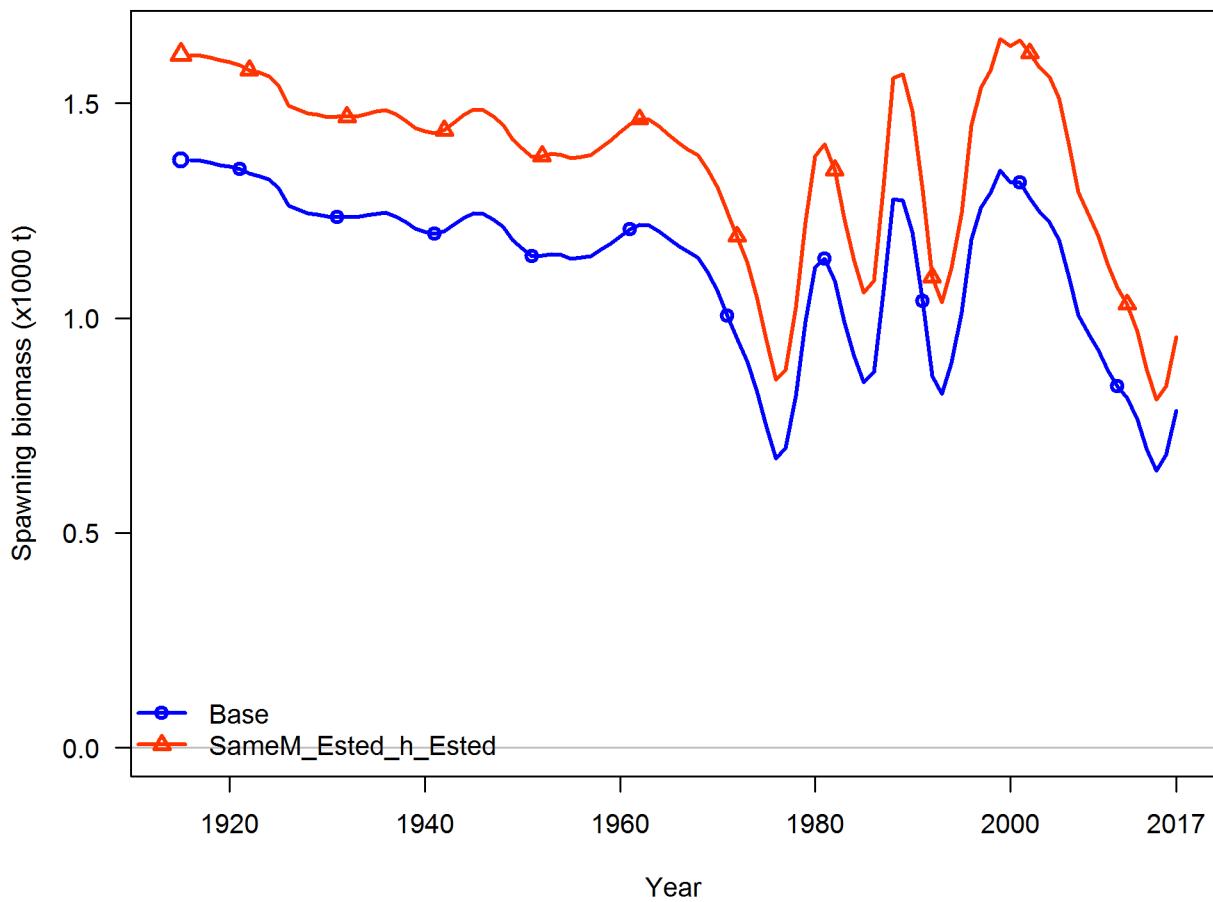


Figure 83: Sensitivity of the spawning biomass to estimating the same natural mortality for males and females and estimating steepness, as compared to the pre-STAR base model, which has fixed female natural mortality and steepness.

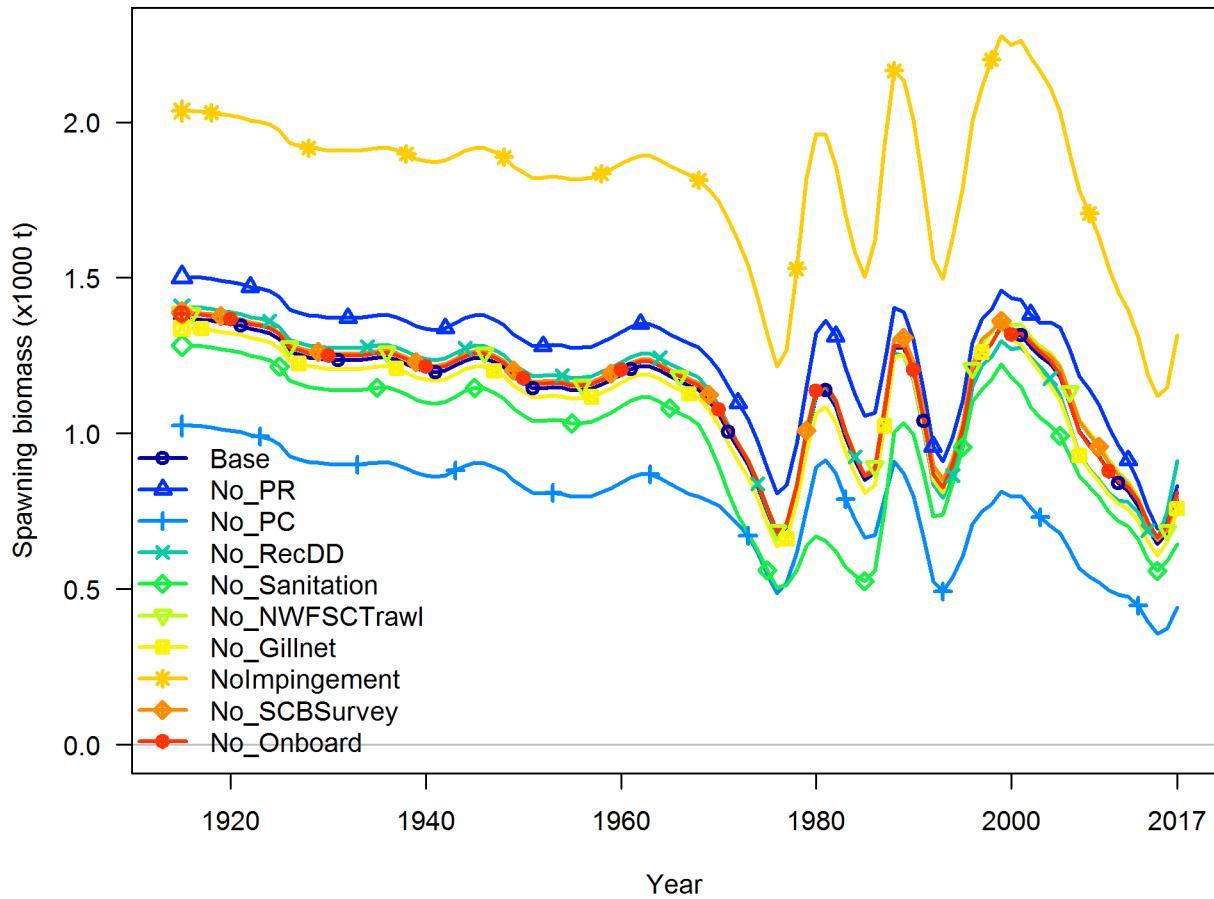


Figure 84: Sensitivity of the spawning biomass to dropping one data source at a time as compared to the pre-STAR base model.

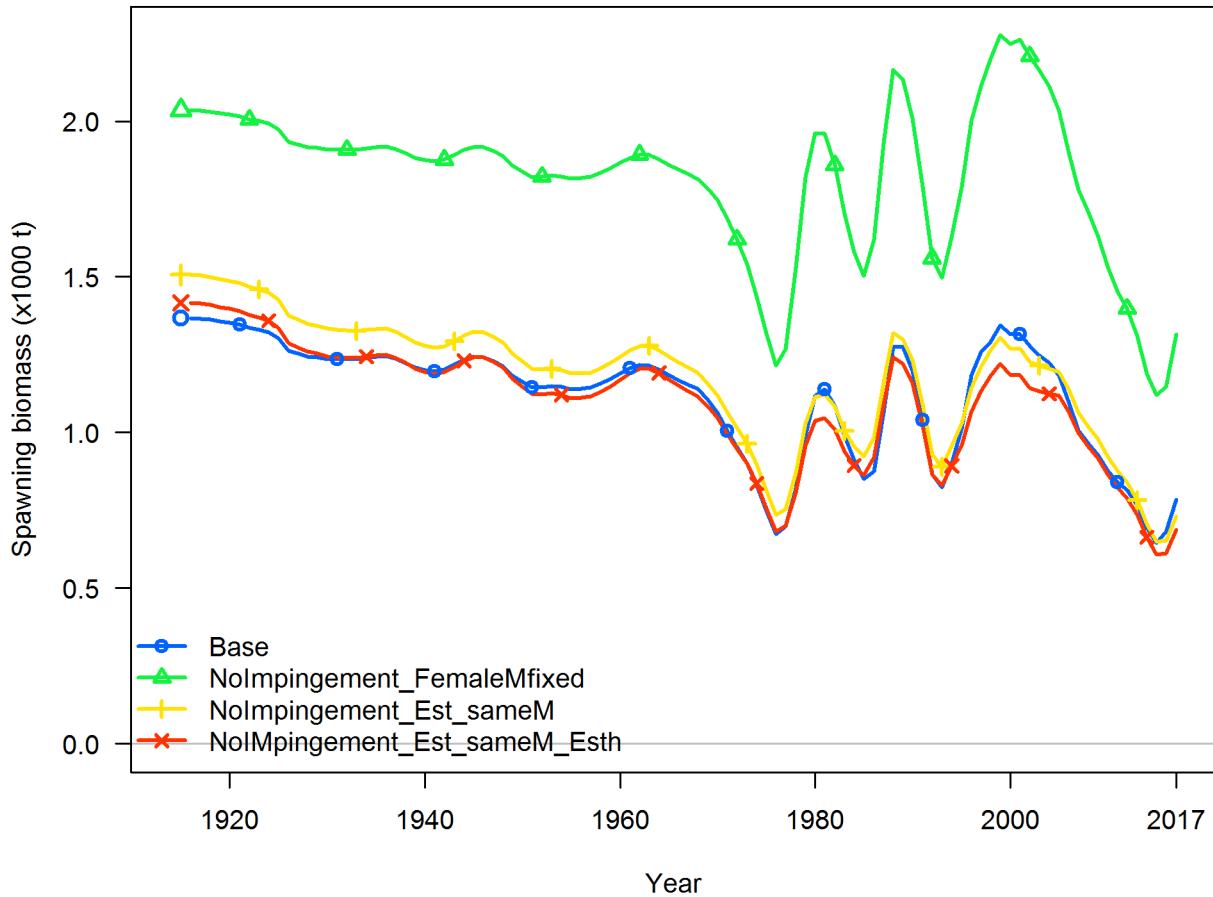


Figure 85: Sensitivity of the spawning biomass to dropping the impingement length composition and either fixing female natural mortality, estimating the same natural mortality for males and females, or estimating the same natural mortality for males and females and estimating steepness, as compared to the pre-STAR base model, which has fixed female natural mortality.

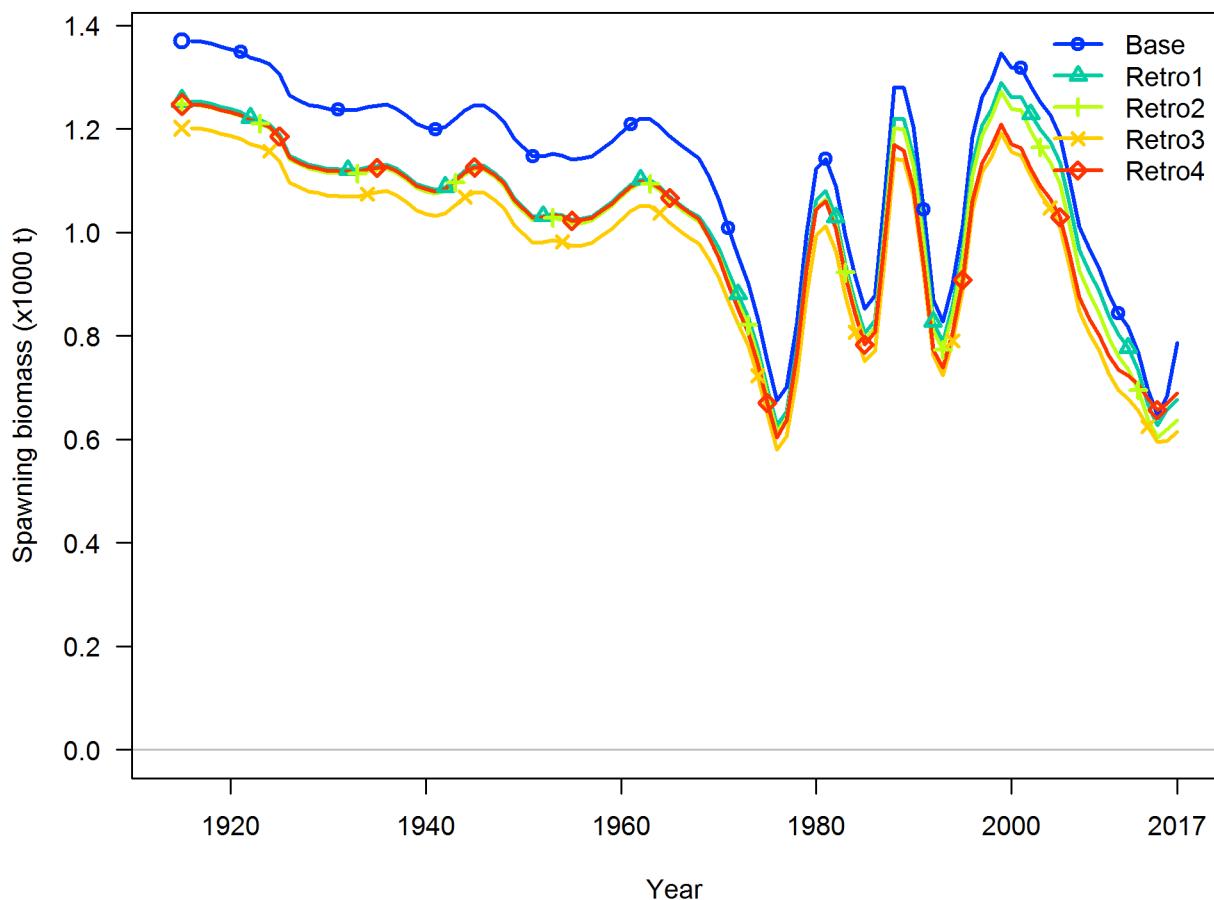


Figure 86: Retrospective pattern for spawning output.

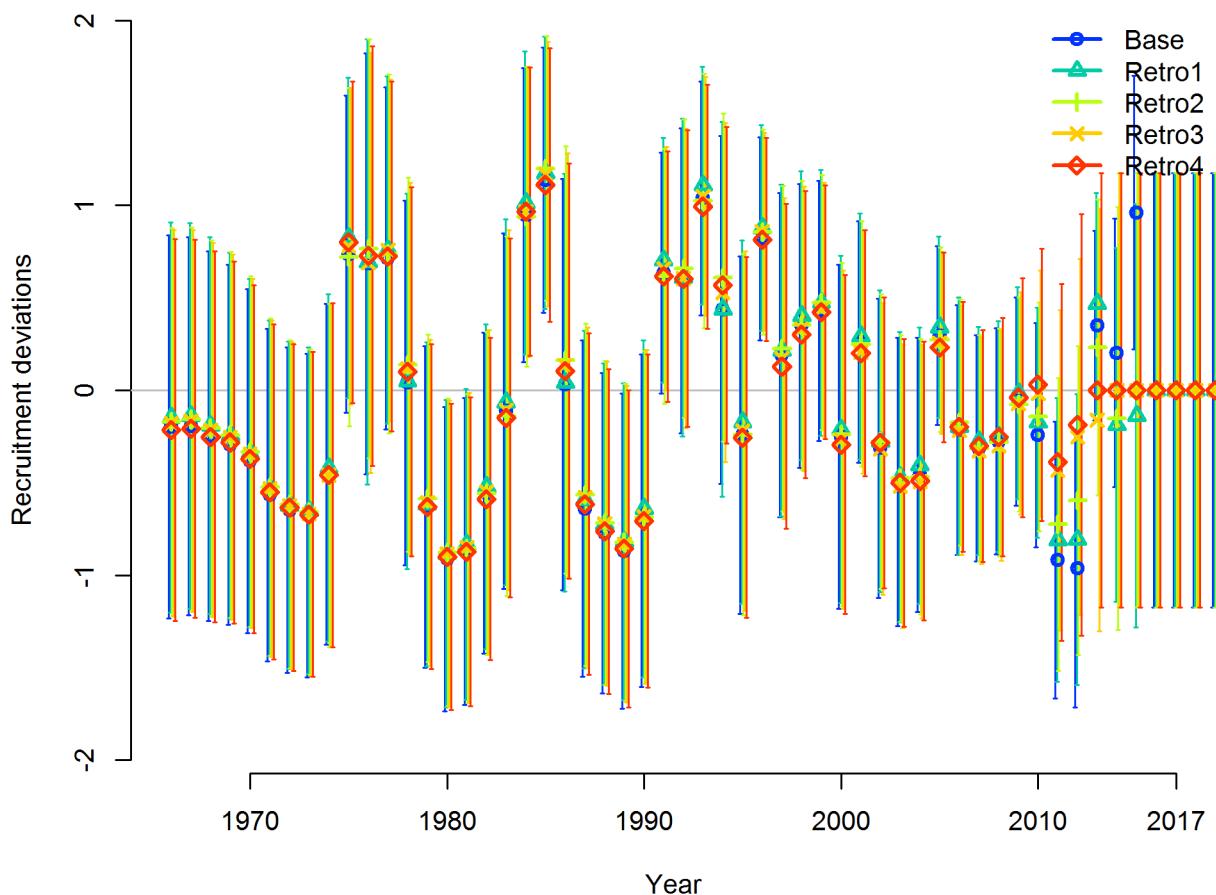


Figure 87: Retrospective pattern for estimated recruitment deviations.

Changes in length-composition likelihoods by fleet

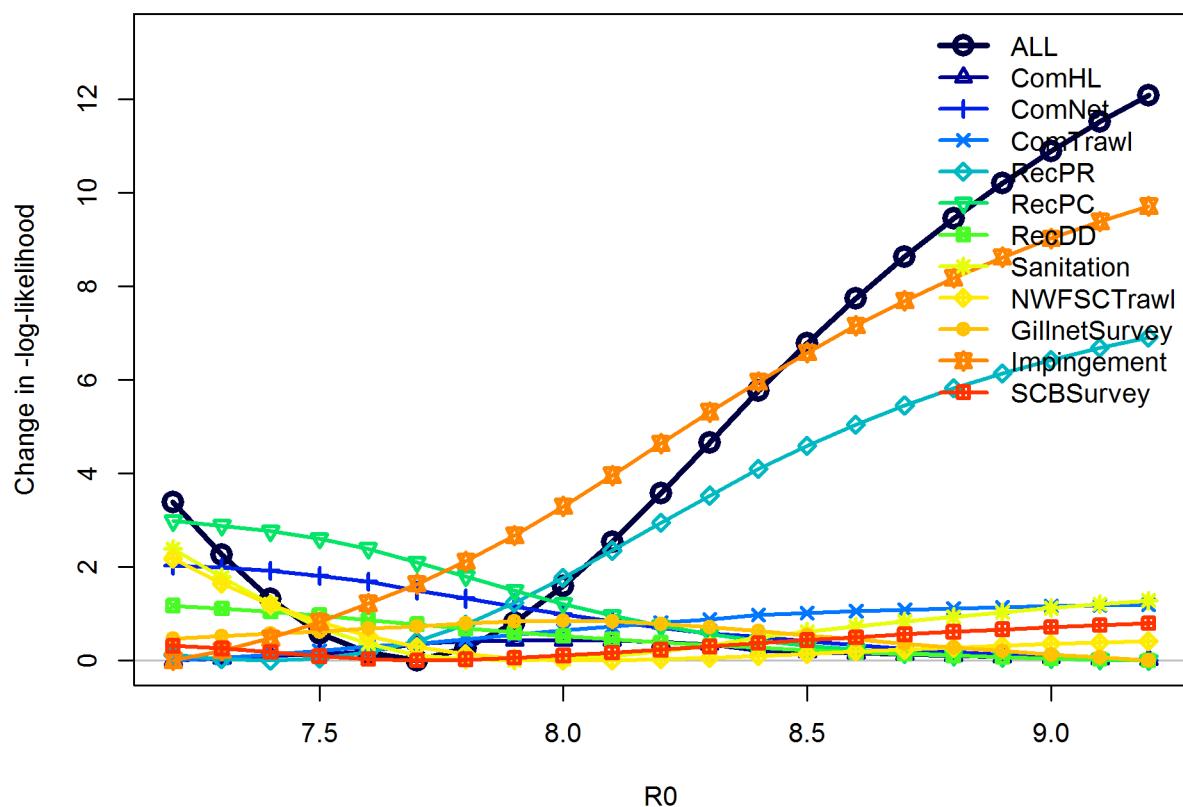


Figure 88: Likelihood profile across R_0 values by fleet.

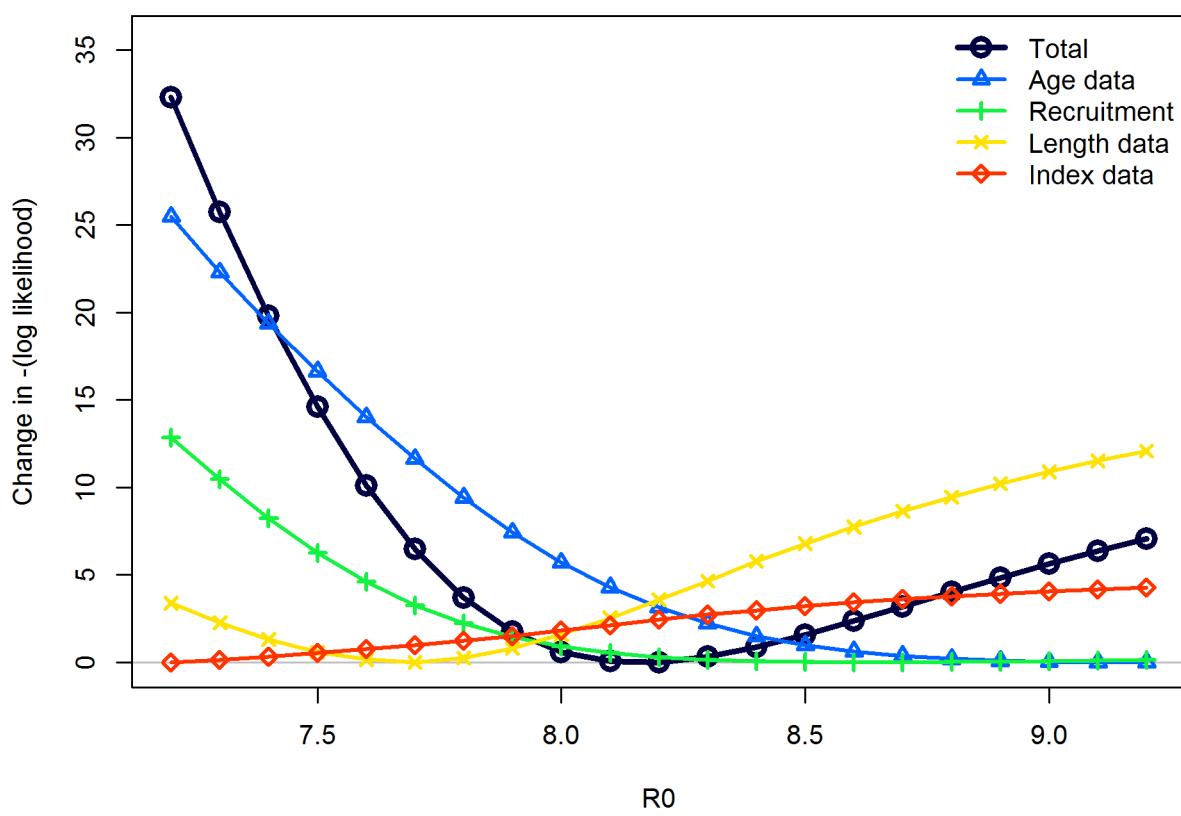


Figure 89: Likelihood profile across R_0 values for each data type.

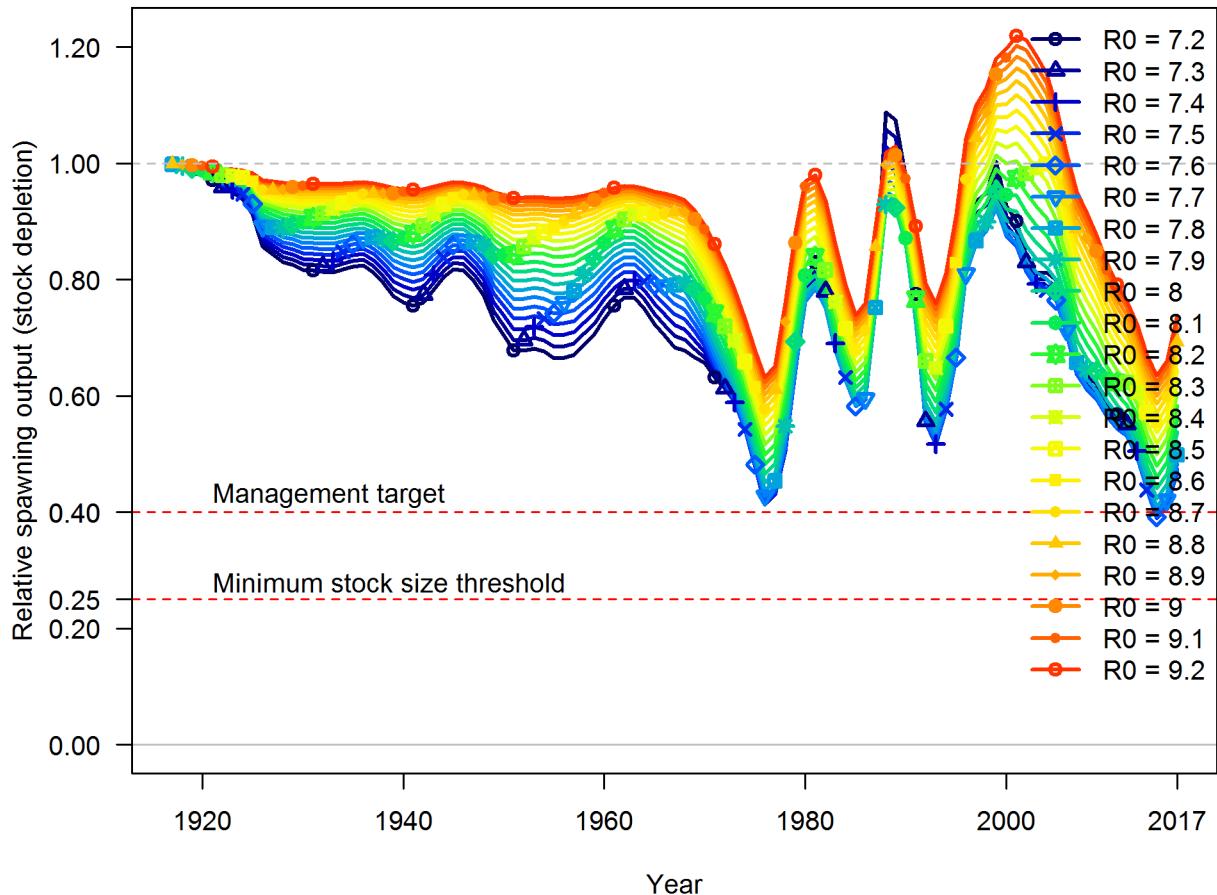


Figure 90: Trajectories of depletion across values of R_0 .

Changes in length-composition likelihoods by fleet

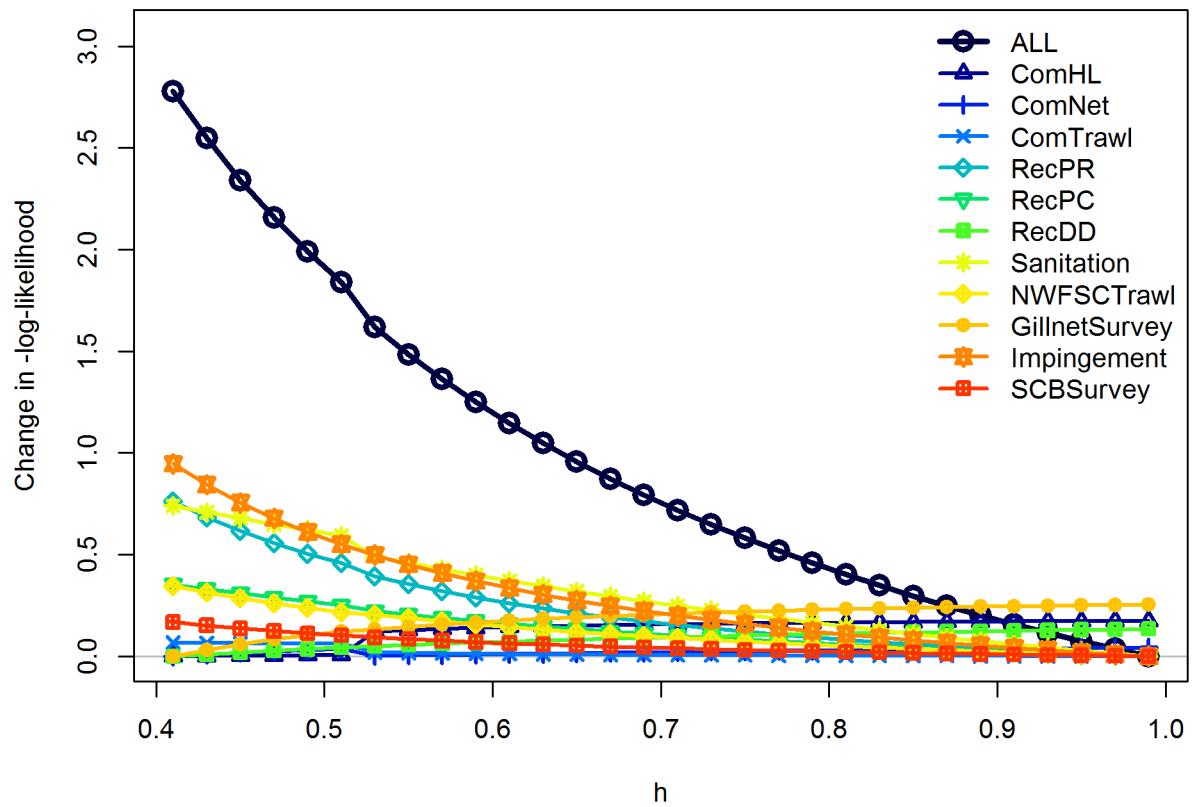


Figure 91: Likelihood profile across steepness values by fleet.

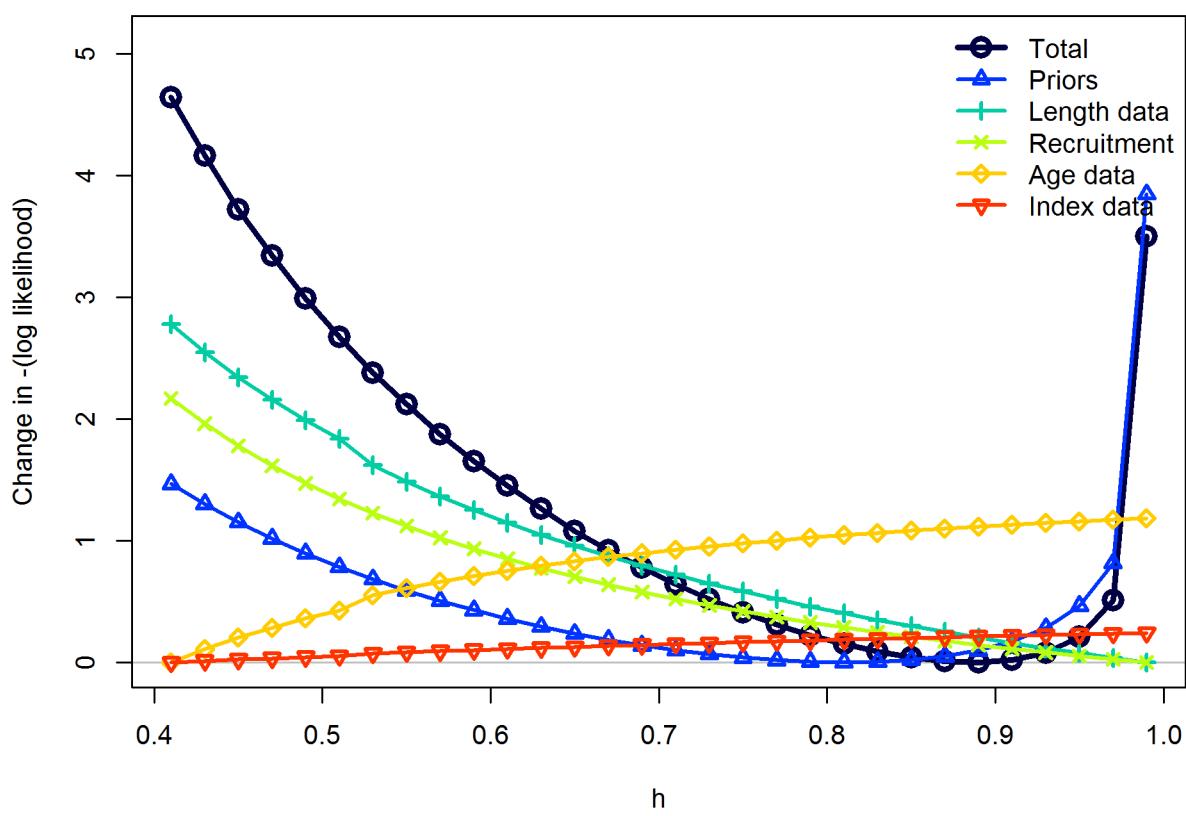


Figure 92: Likelihood profile across steepness values for each data type.

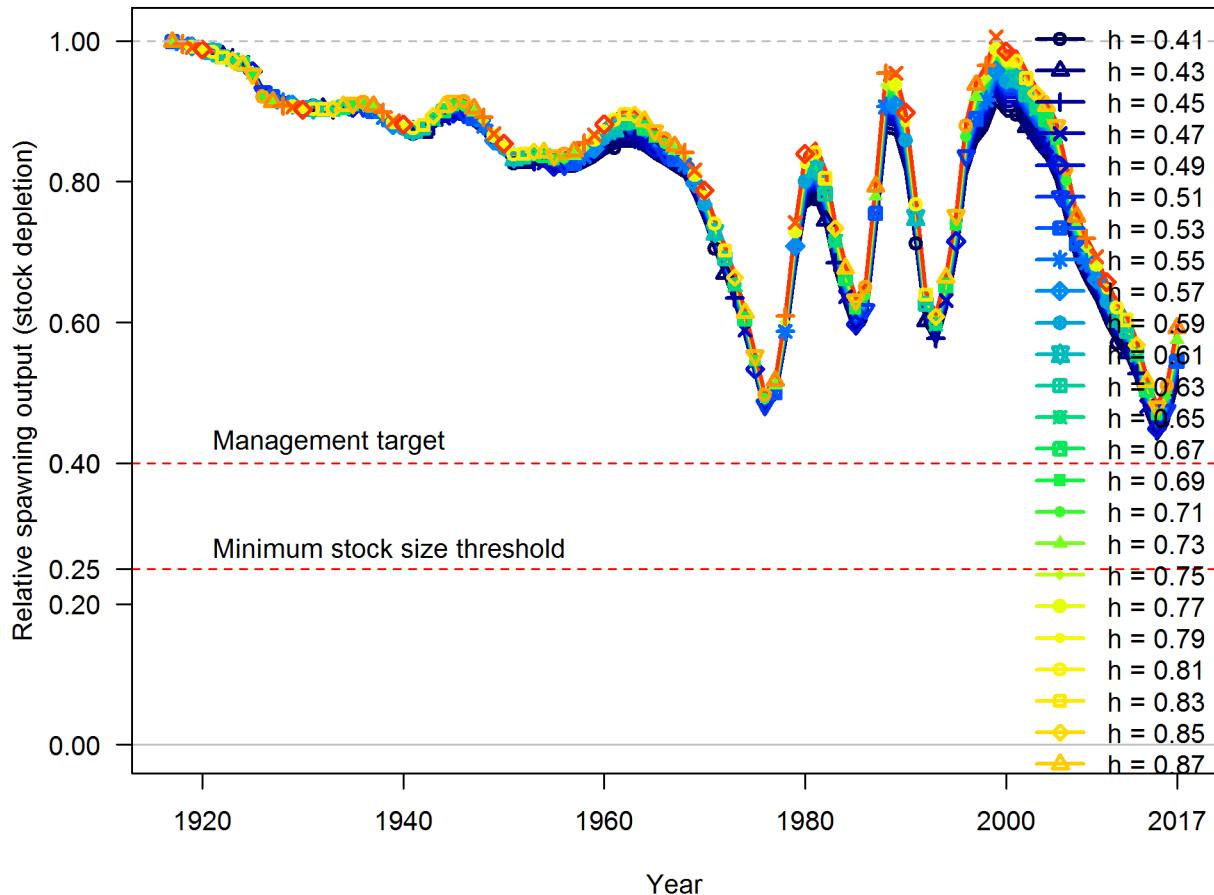


Figure 93: Trajectories of depletion across values of steepness.

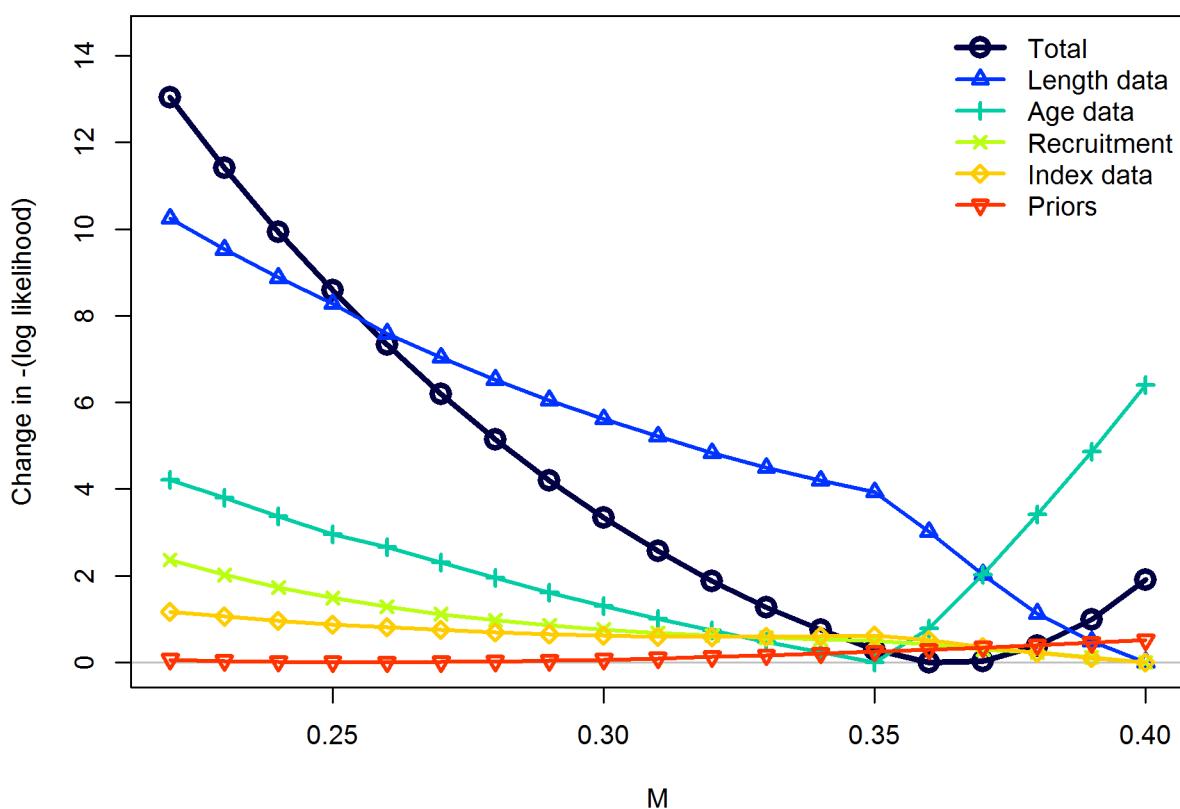


Figure 94: Likelihood profile across female natural mortality values for each data type.

Changes in length-composition likelihoods by fleet

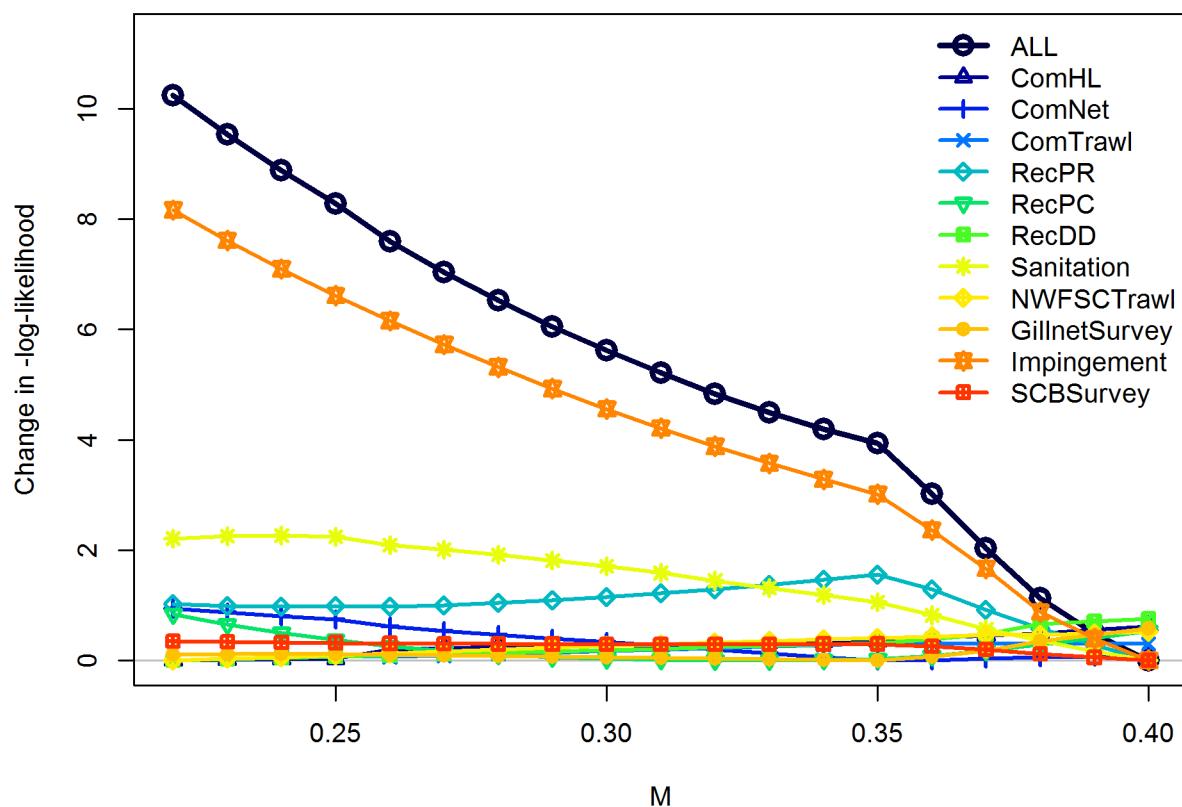


Figure 95: Likelihood profile across female natural mortality values by fleet.

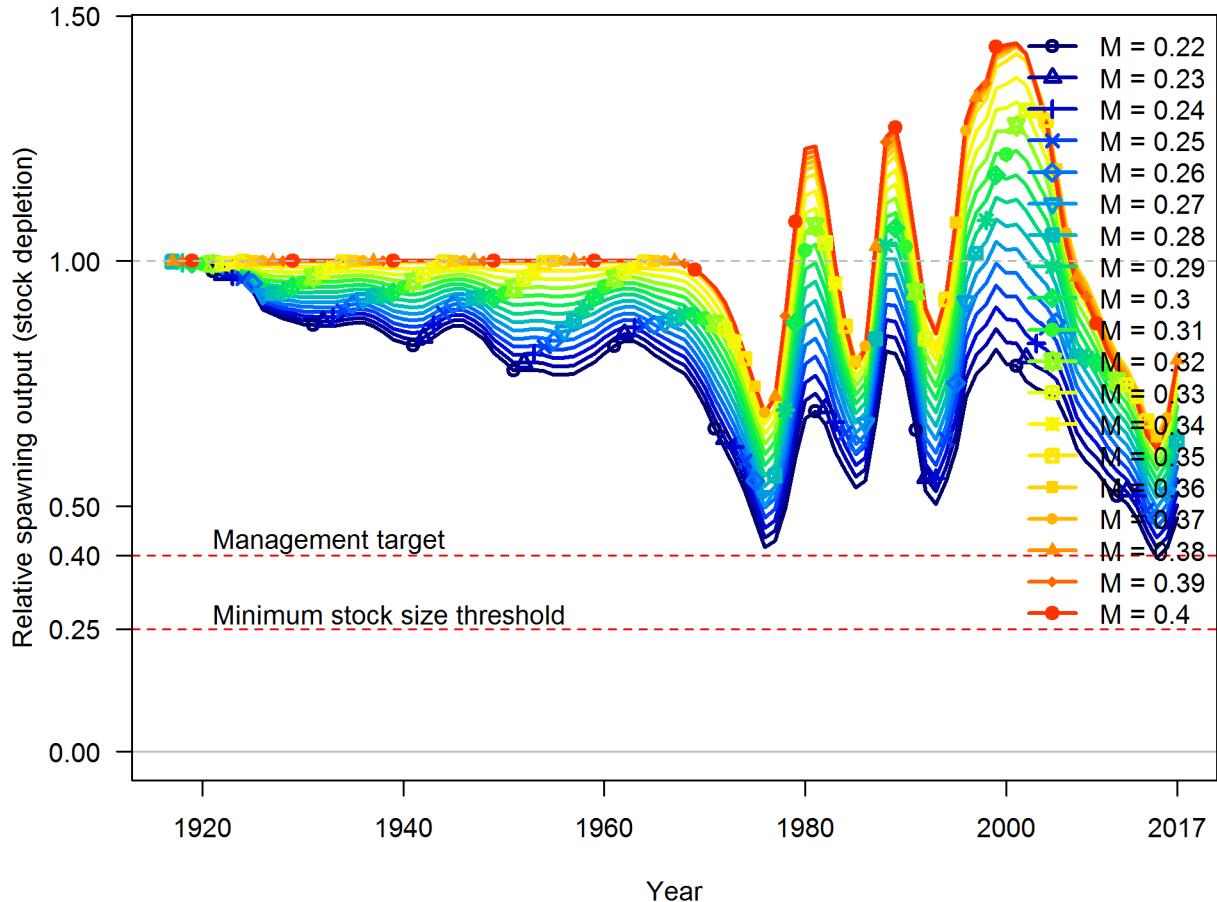


Figure 96: Trajectories of depletion across values of female natural mortality.

Spawning biomass (mt) with ~95% asymptotic intervals

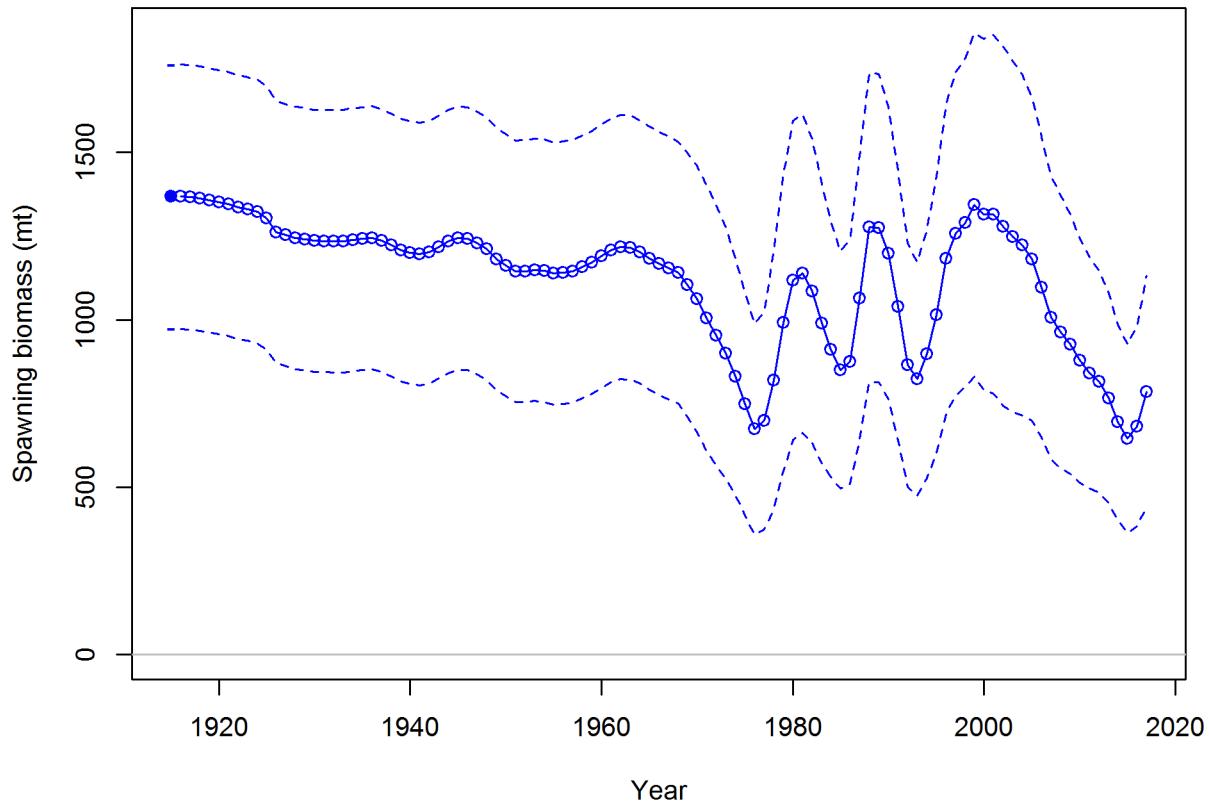


Figure 97: Estimated spawning biomass (mt) with approximate 95% asymptotic intervals.

Spawning depletion with ~95% asymptotic intervals

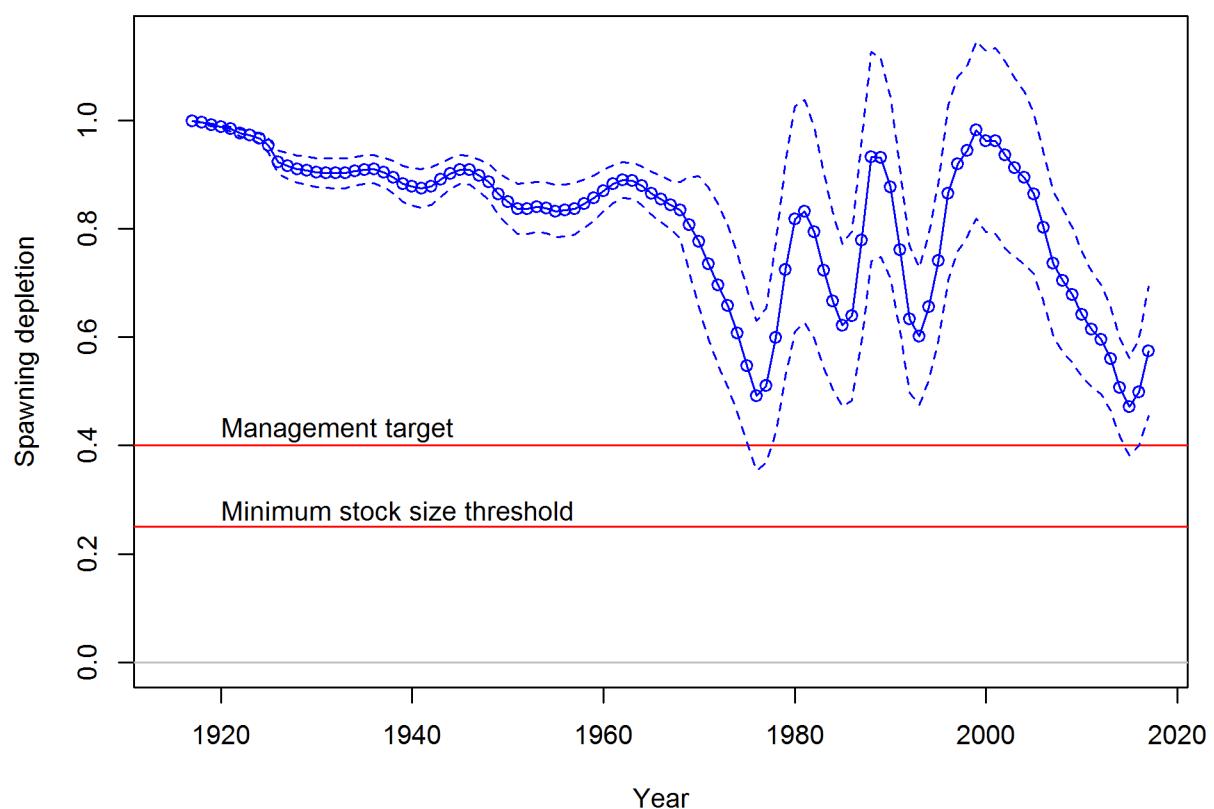


Figure 98: Estimated spawning depletion with approximate 95% asymptotic intervals.

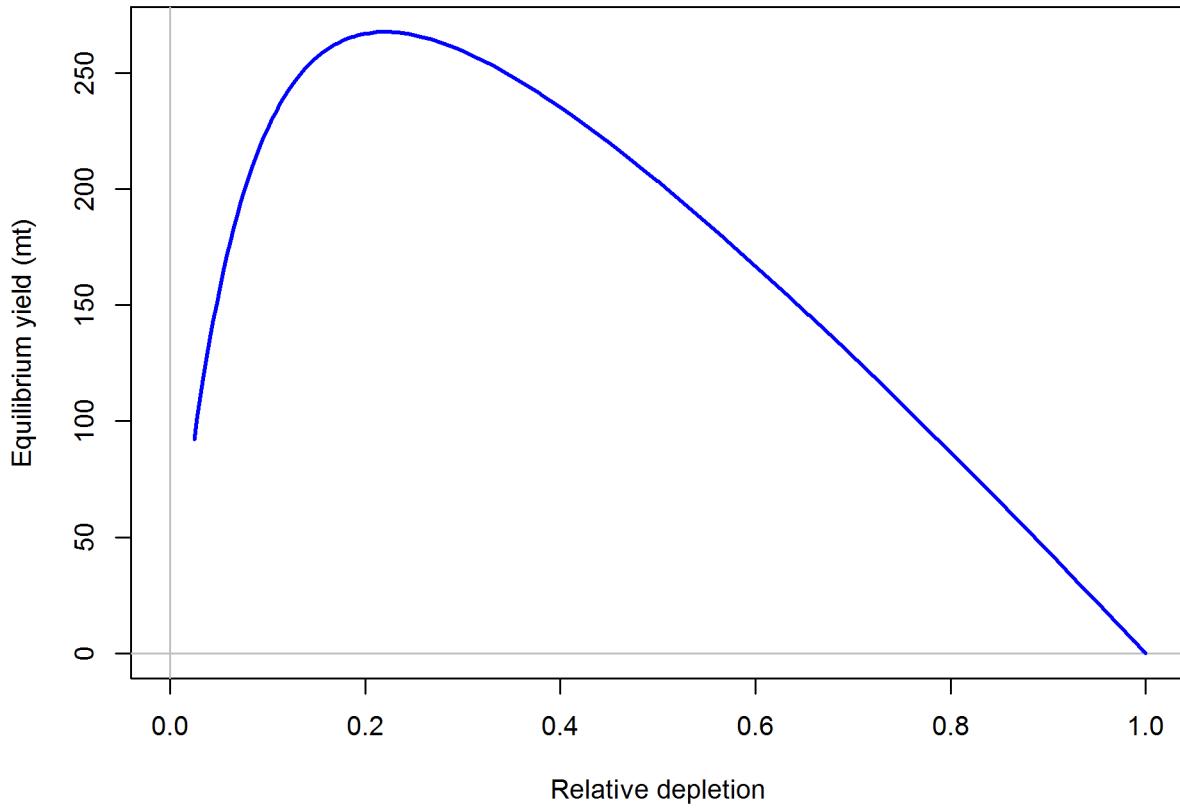


Figure 99: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.718.

2066 **Appendix A. Detailed fits to length composition data**

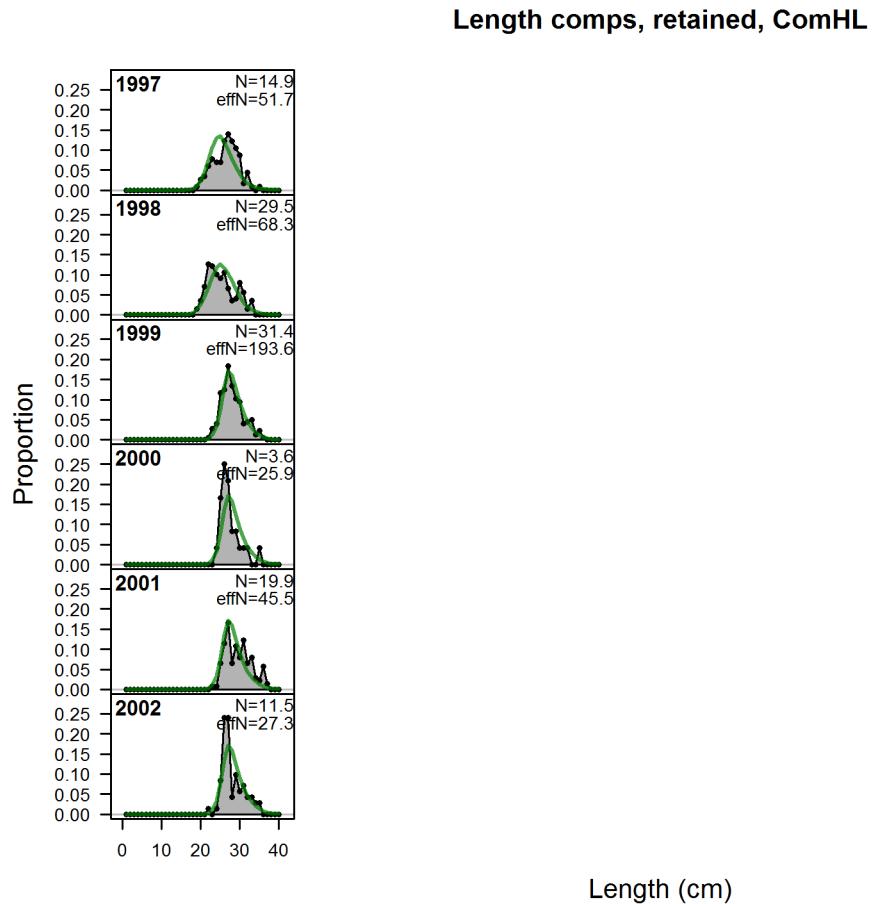


Figure A100: Length comps, retained, ComHL

Length comps, retained, ComNet

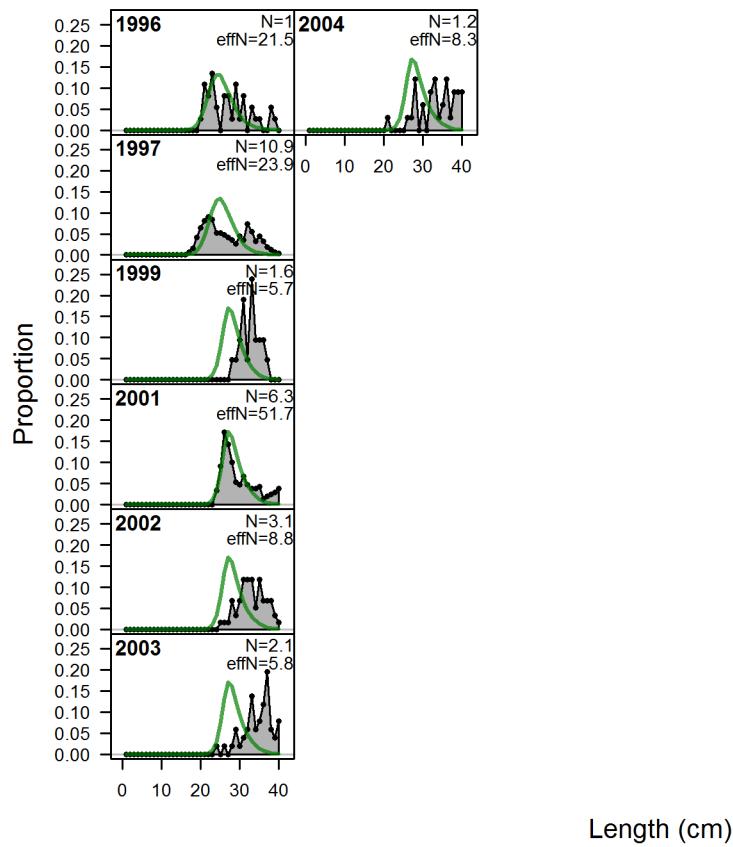


Figure A101: Length comps, retained, ComNet

Length comps, retained, ComTrawl

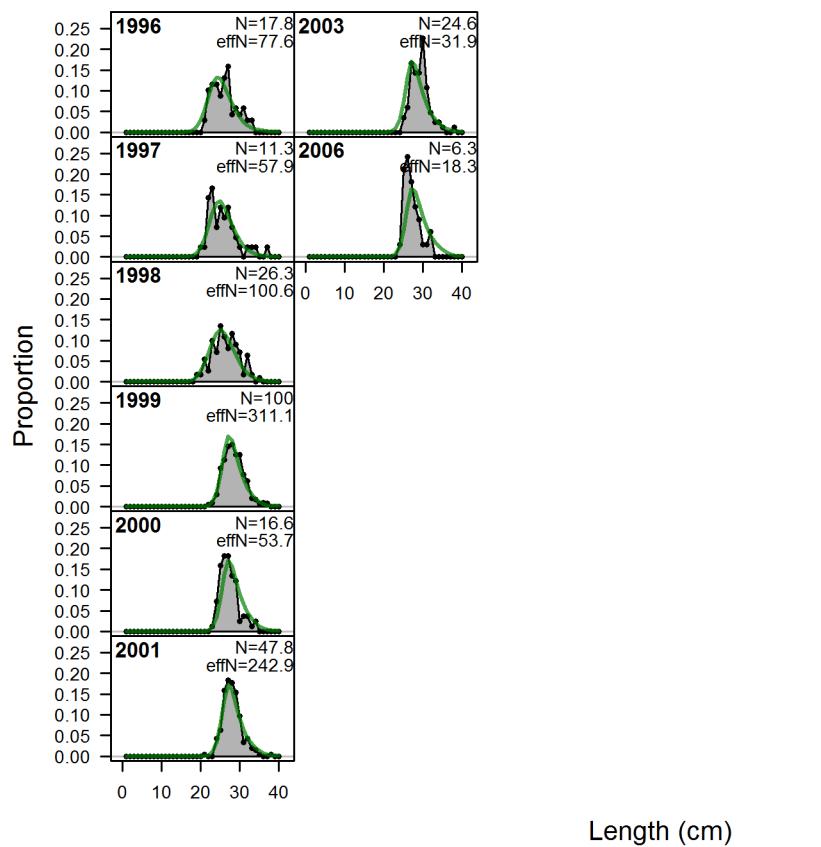


Figure A102: Length comps, retained, ComTrawl

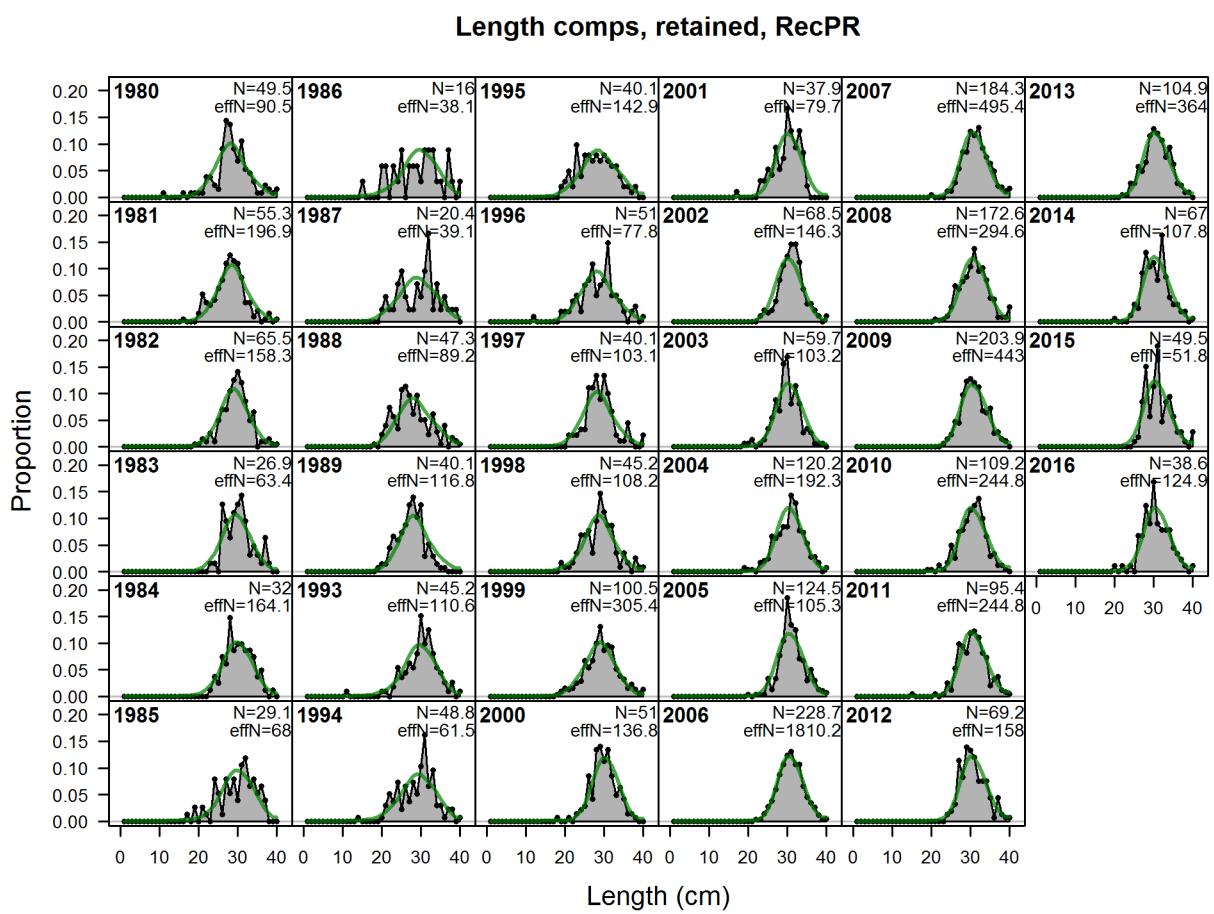


Figure A103: Length comps, retained, RecPR

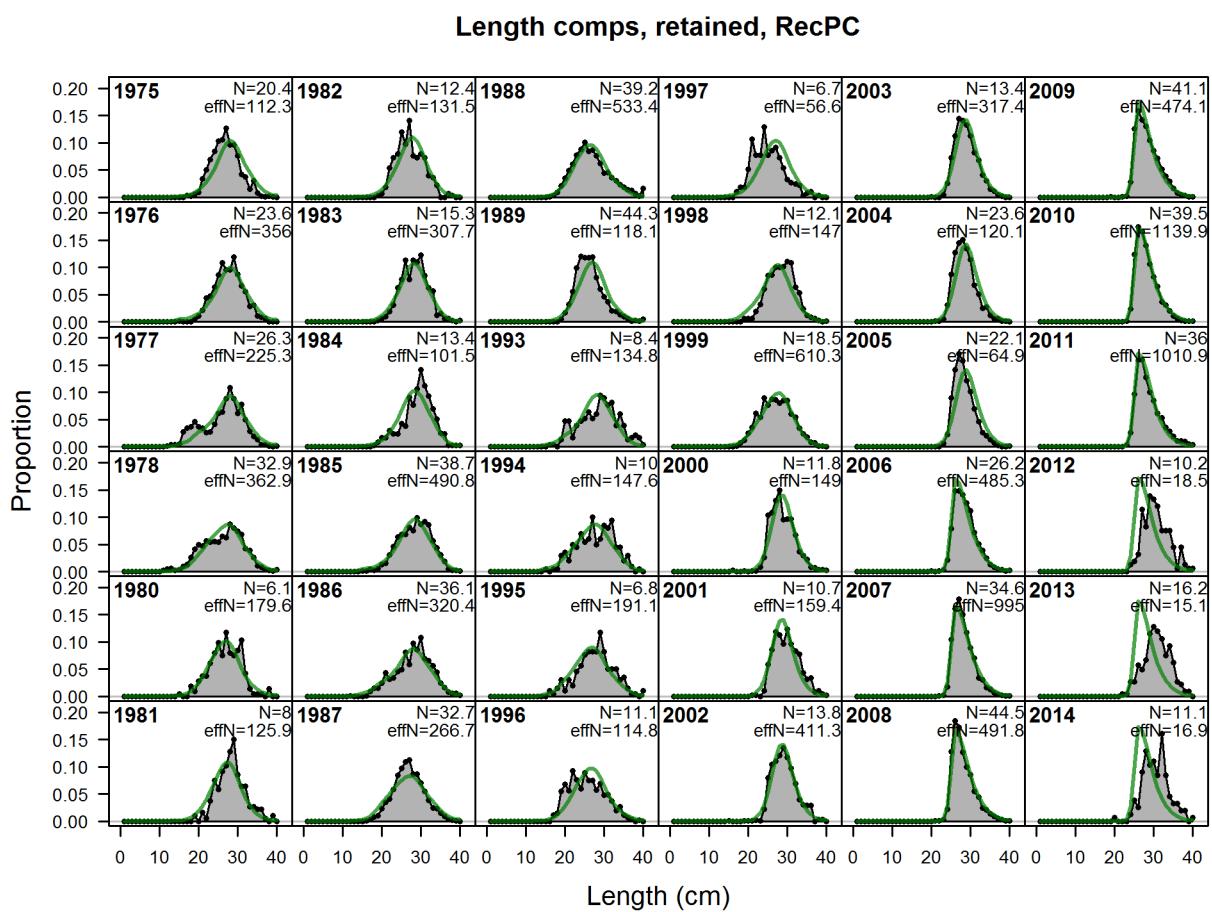
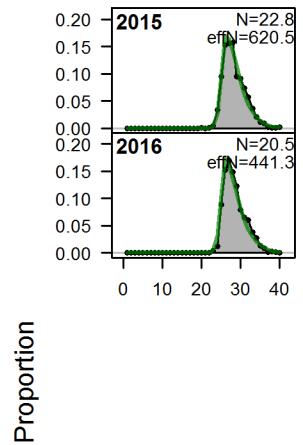


Figure A104: Length comps, retained, RecPC (plot 1 of 2)

Length comps, retained, RecPC



Length (cm)

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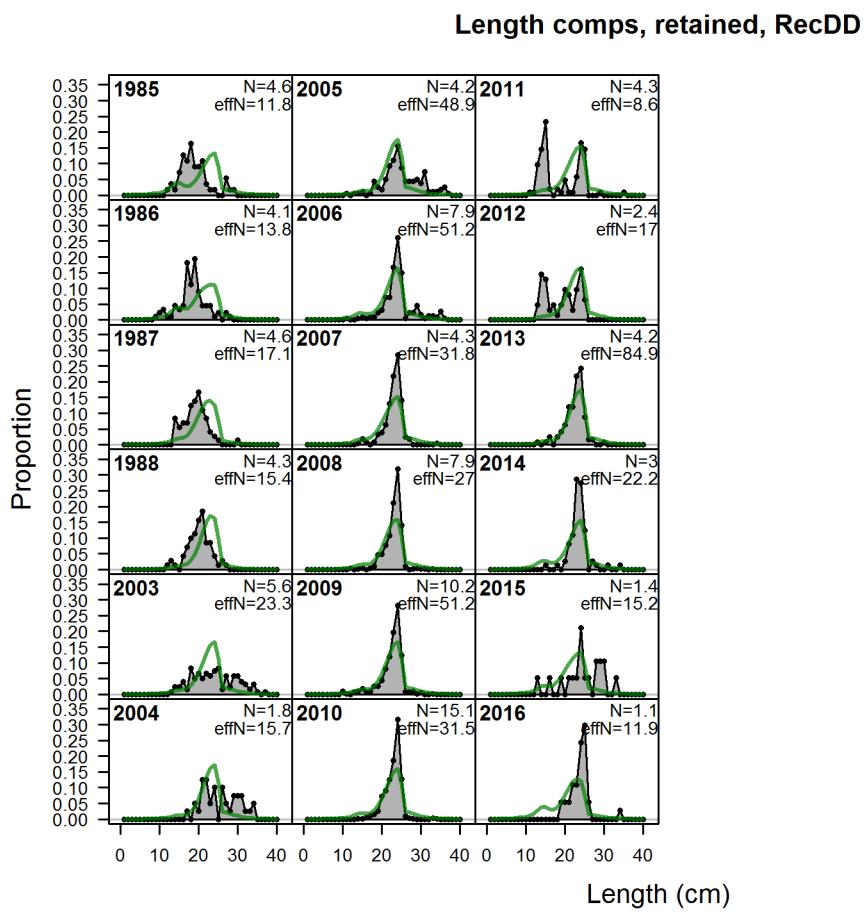


Figure A105: Length comps, retained, RecDD

Length comps, retained, Sanitation

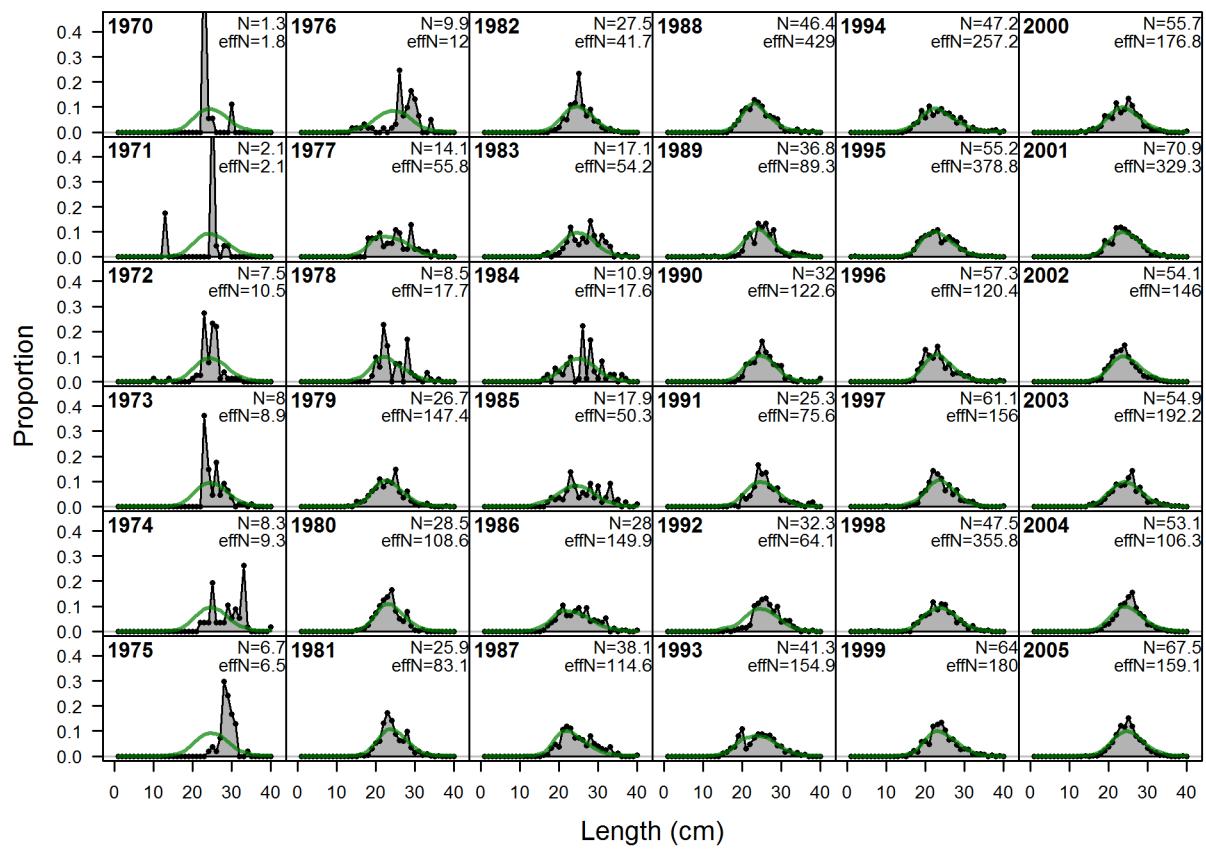
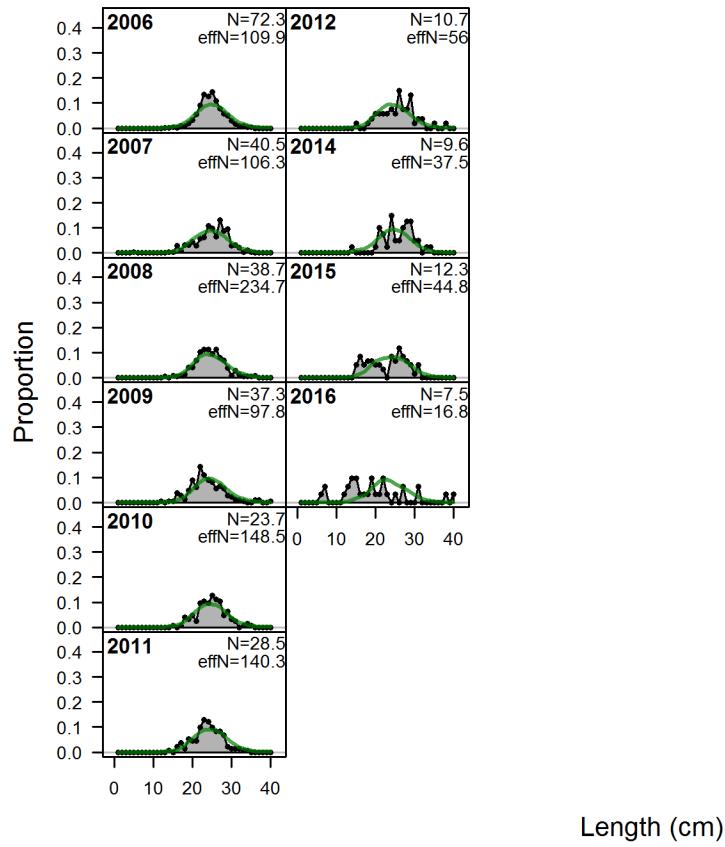


Figure A106: Length comps, retained, Sanitation (plot 1 of 2)

Length comps, retained, Sanitation



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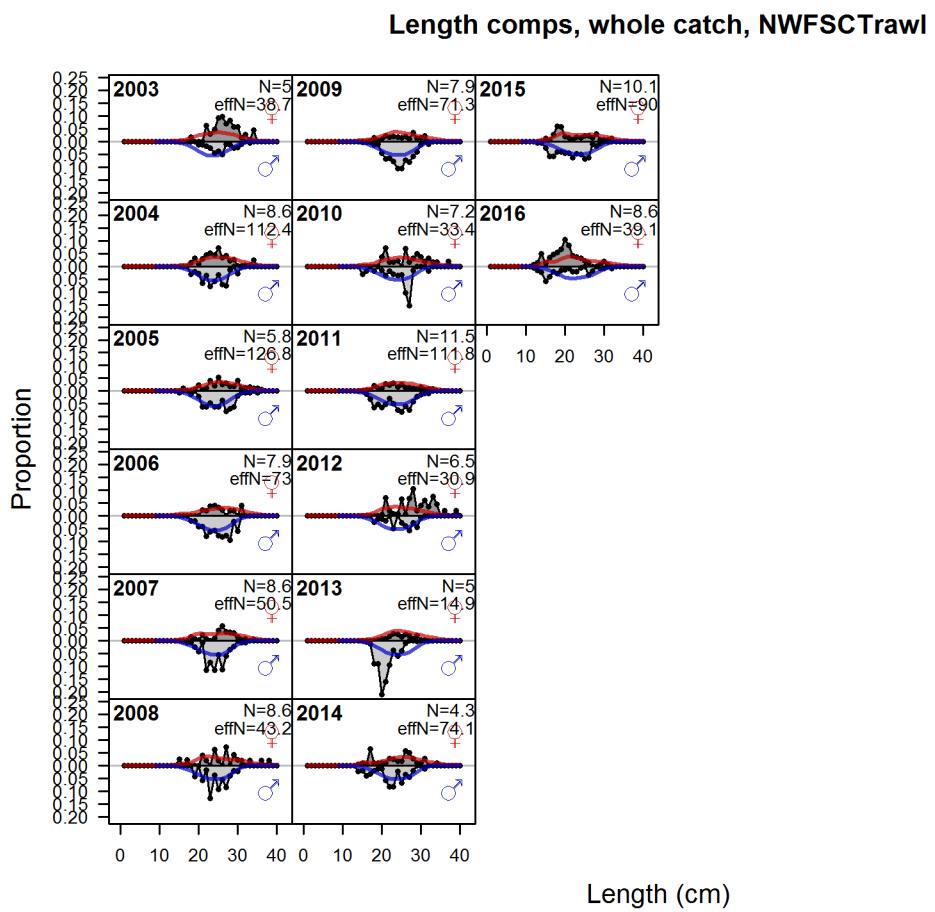


Figure A107: Length comps, whole catch, NWFSC Trawl

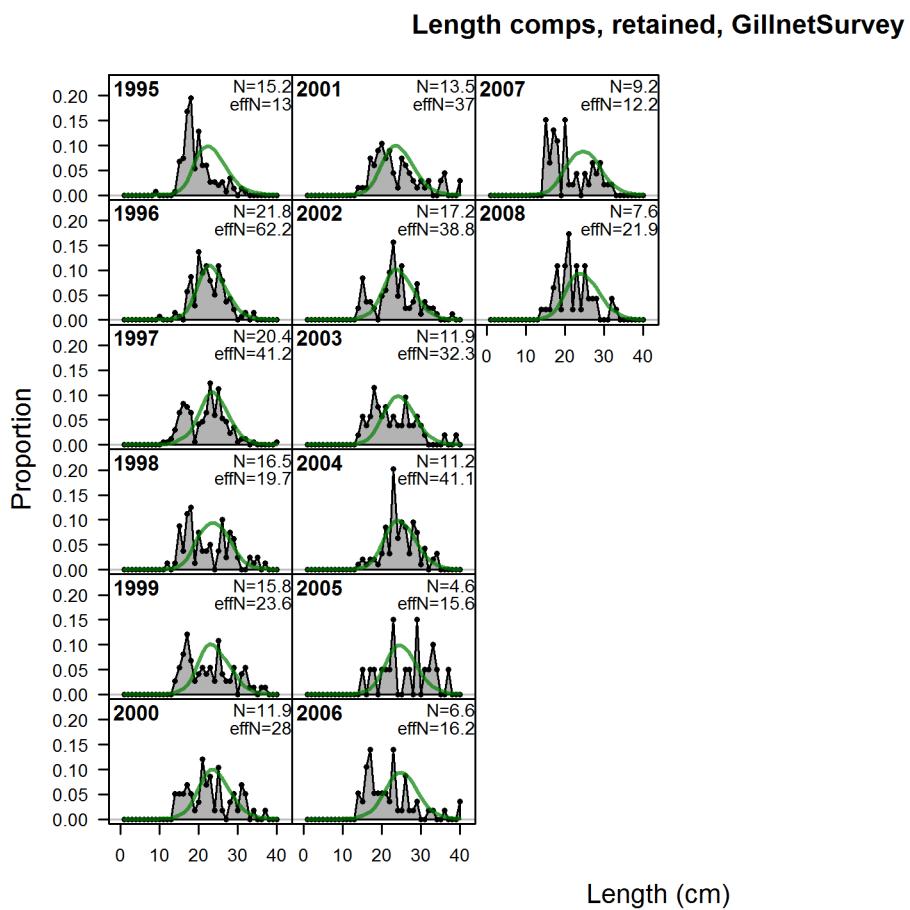


Figure A108: Length comps, retained, GillnetSurvey

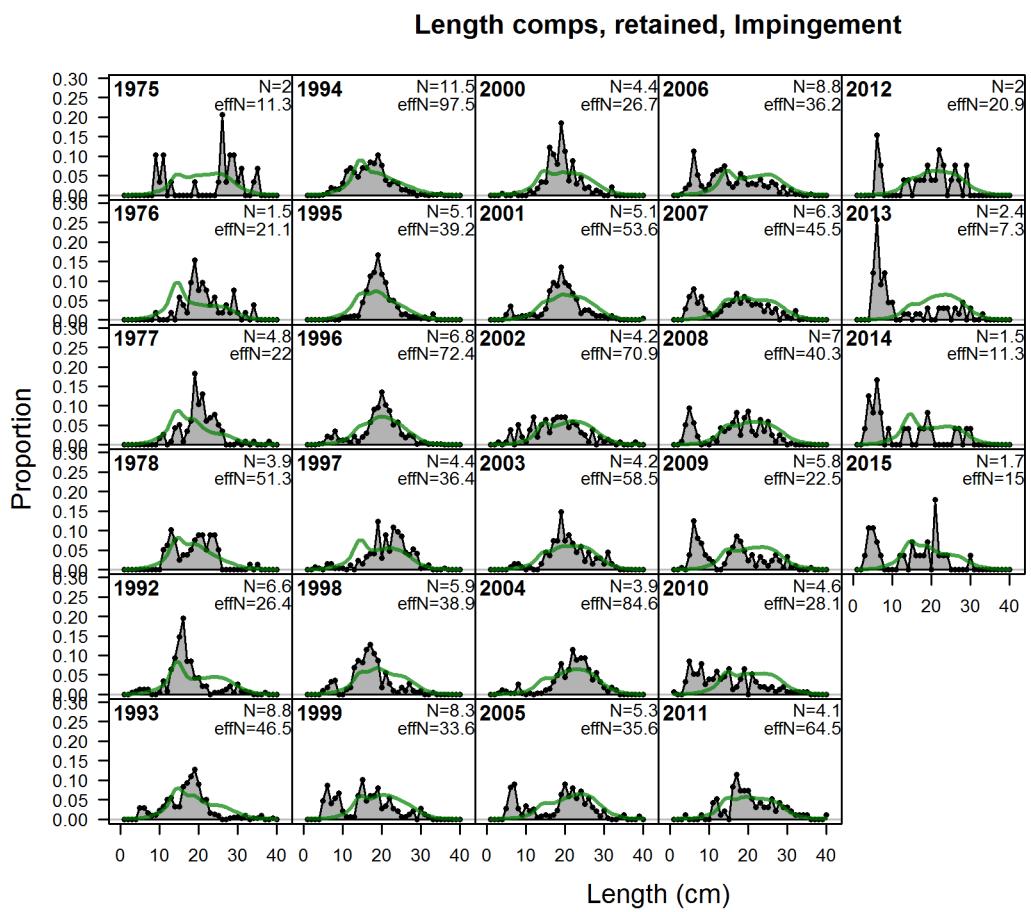


Figure A109: Length comps, retained, Impingement

Length comps, retained, SCBSurvey

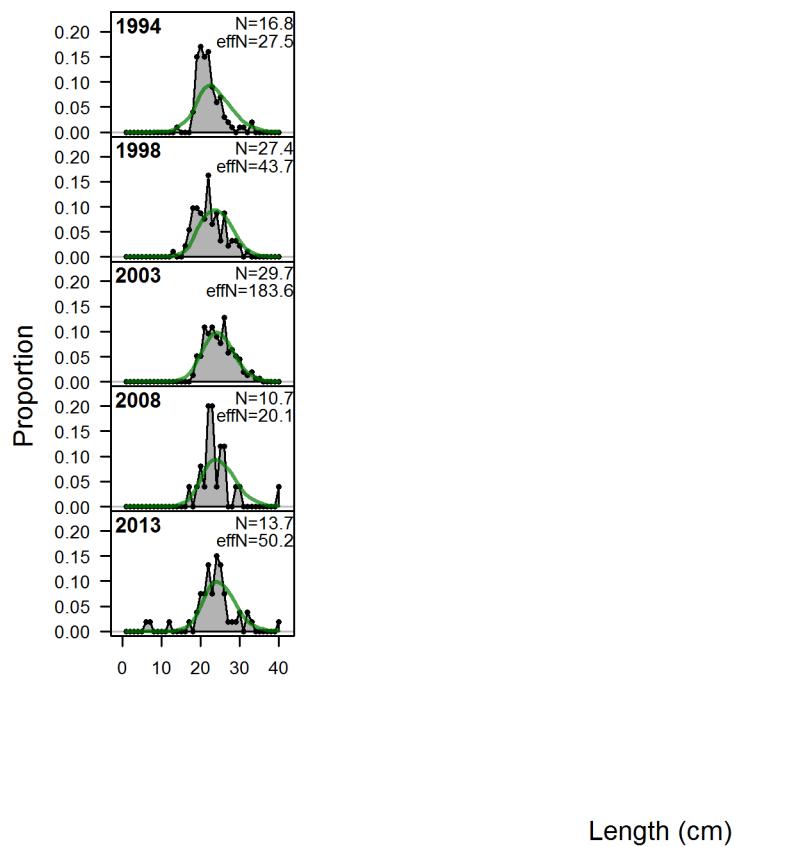


Figure A110: Length comps, retained, SCBSurvey

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