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

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Executive Summary

Stock

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

Catches

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

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

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

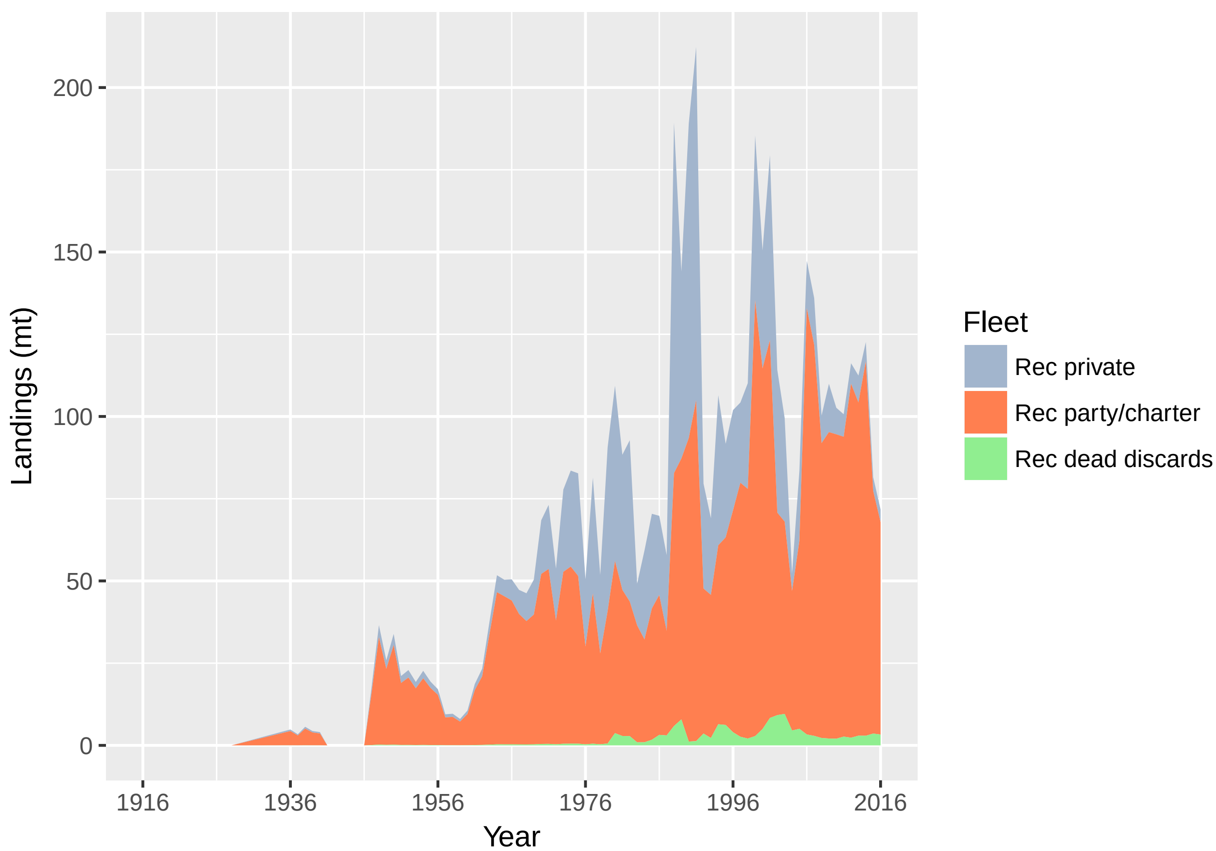

Figure a: California scorpionfish catch history for the recreational fleets.

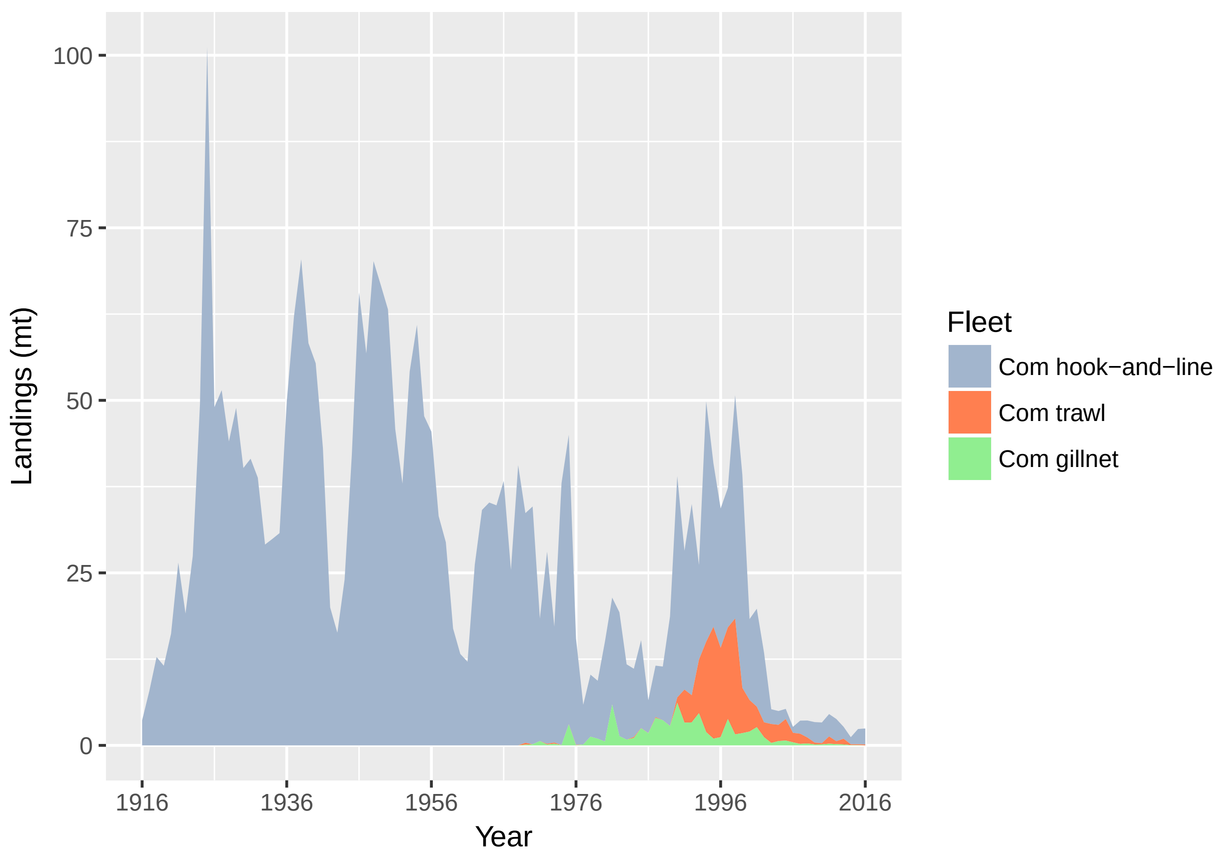

Figure b: Stacked line plot of California scorpionfish catch history for the commercial fleets.

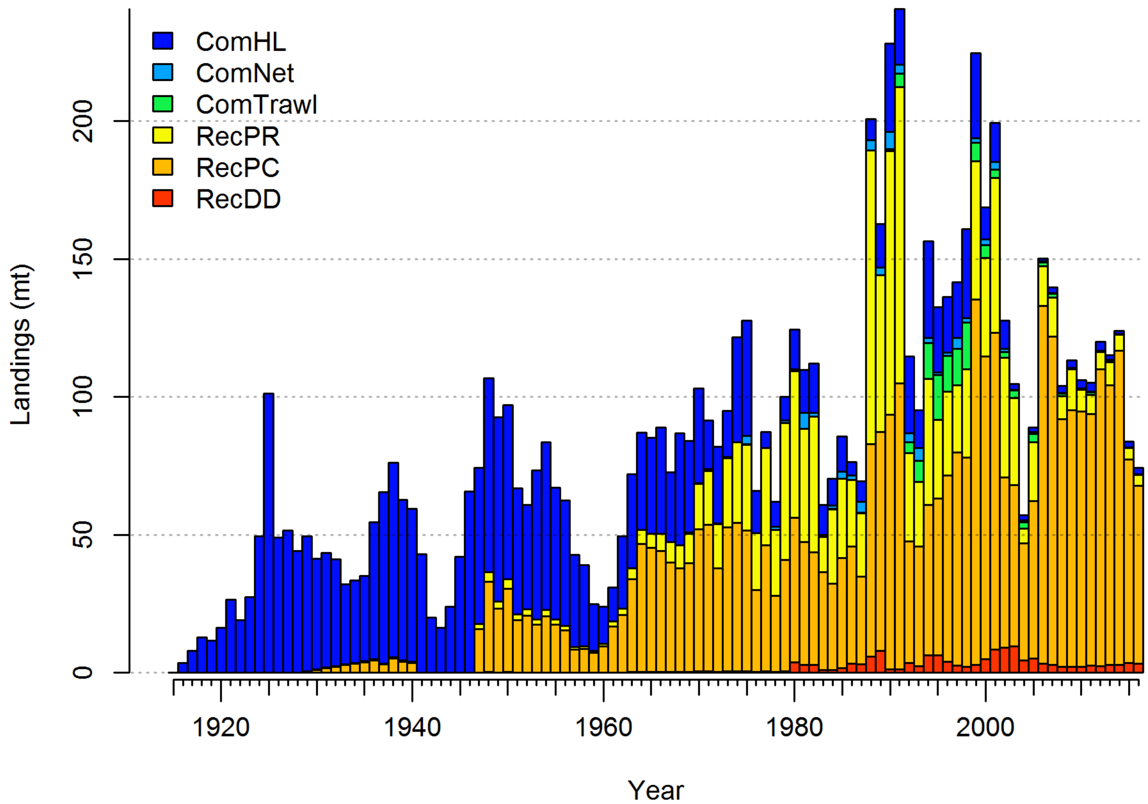

Figure c: Catch history of California scorpionfish in the base model.

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

Data and Assessment

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

All of the data sources for California scorpionfish have been re-evaluated for 2016, including the historical fishery catch-per-unit effort time-series. The landings history has been updated and extended back to 1916. Harvest was negligible prior to that year. Survey data from five sources were used to develop indices of abundance: 1) Publicly Owned Treatment Works (POTW) trawl surveys, 2) the NWFSC trawl survey, 3) a fishery-independent gill net survey, 4) the Southern California Bight regional monitoring program trawl survey, and 5) the onboard observer survey for retained catch. Length compositions were also created for each fishery-dependent and -independent data source, including a nuclear power generating station impingement survey that did not have an associated index of abundance. Conditional age-at-length information were available from the NWFSC trawl survey.

The definition of fishing fleets has changed from those in the 2005 assessment. Six fishing fleets were specified within this model: 1) a combined commercial hook-and-line, fish pot, and "other gear" fleet, 2) the commercial gill net fleet, 3) the commercial trawl fleet, 4) the recreational party/charter boat fleet (retained catch only), 5) the recreational private boat fleet (retained catch only), and 6) a discard fleet that combined the estimated discards from the recreational party/charter and private boat fleets.

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

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

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

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

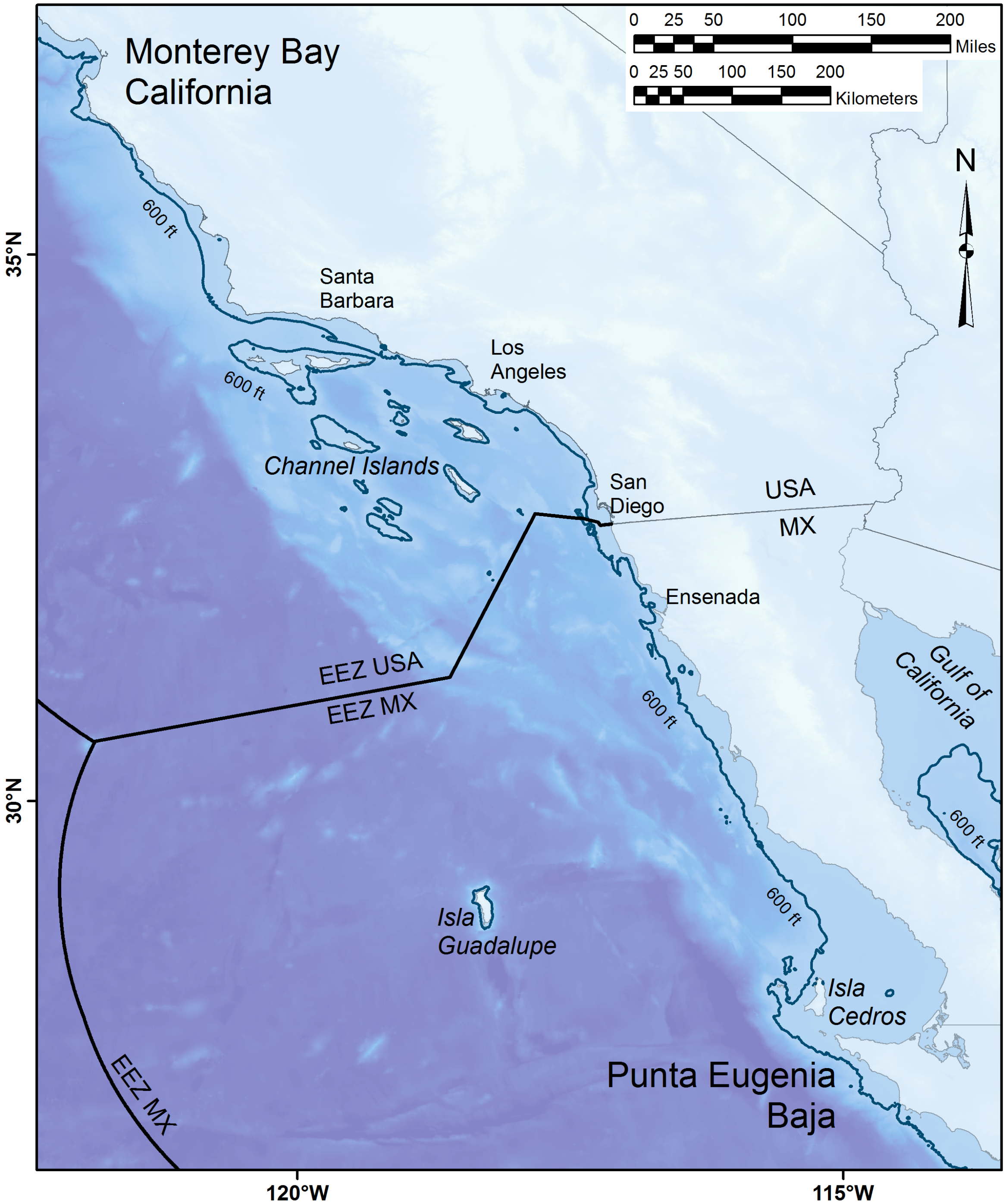

Figure d: Map depicting the distribution of California scorpionfish out to 600 ft. The stock assessment is bounded at Pt. Conception in the north to the U.S./Mexico border in the south.

Stock Biomass

The predicted spawning biomass from the base model generally showed a slight decline prior to 1965, when information on recruitment variability became available (Figure e and Table b). A short, but sharp decline occurred between 1965 and 1985, followed by a period cyclical variation in spawning biomass, and then a decline from 2000 to 2015. The stock showed increases in stock size in 2015 due to a combination of strong recruitment and smaller catches in 2015 and 2016. The 2016 estimated spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass at 54.3% (95% asymptotic interval: ± 43%-65.7%) (Figure f). Approximate confidence intervals based on the asymptotic variance 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	1144.500	(654.46-1634.54)	0.705	(0.573-0.836)
2009	1090.480	(629.78-1551.18)	0.671	(0.55-0.793)
2010	1029.330	(597.2-1461.46)	0.634	(0.521-0.746)
2011	980.130	(571.79-1388.47)	0.603	(0.5-0.707)
2012	943.555	(553.81-1333.3)	0.581	(0.485-0.677)
2013	890.084	(518.85-1261.32)	0.548	(0.456-0.64)
2014	810.223	(462.86-1157.59)	0.499	(0.41-0.587)
2015	746.227	(412.08-1080.38)	0.459	(0.371-0.548)
2016	774.813	(426.28-1123.35)	0.477	(0.381-0.572)
2017	882.457	(484.21-1280.71)	0.543	(0.43-0.657)

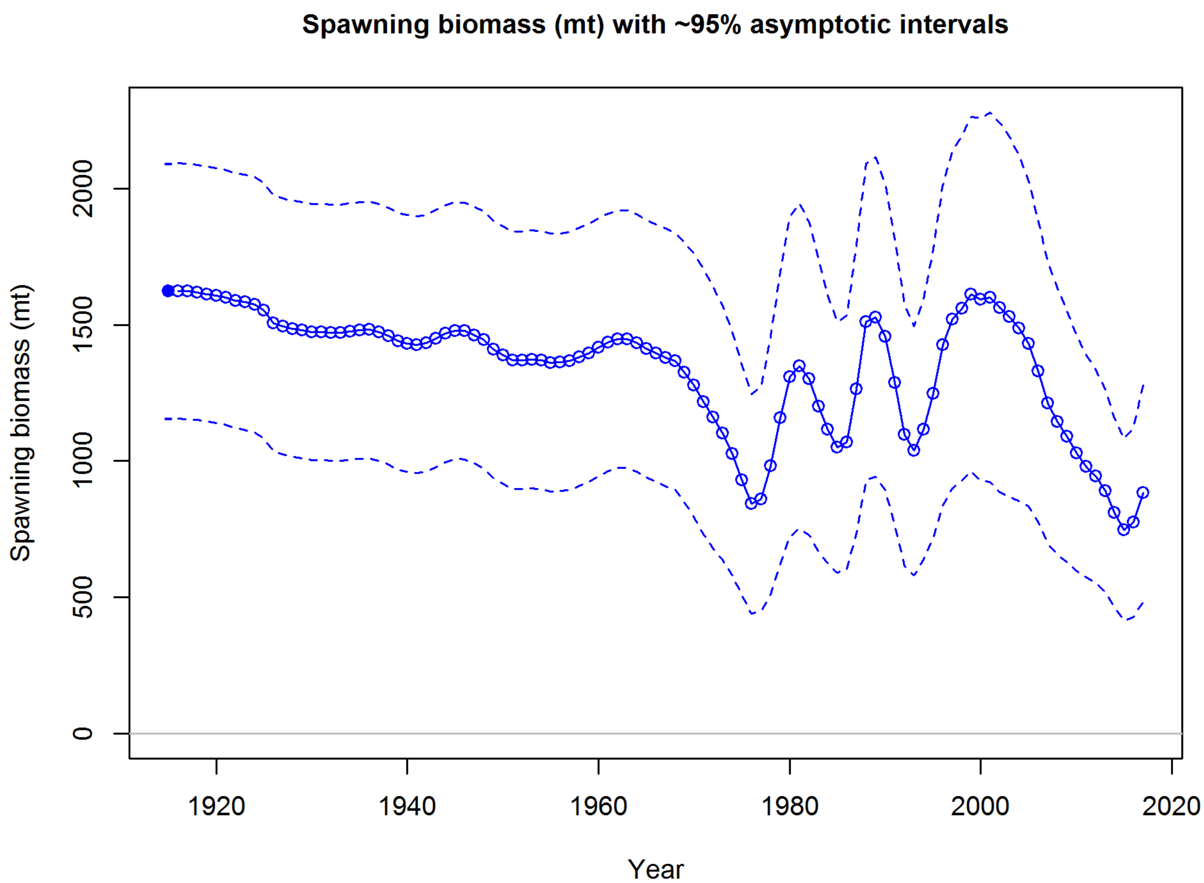

Figure e: Time series of spawning biomass trajectory (circles and line: median; light broken lines: 95% credibility intervals) for the base case assessment model.

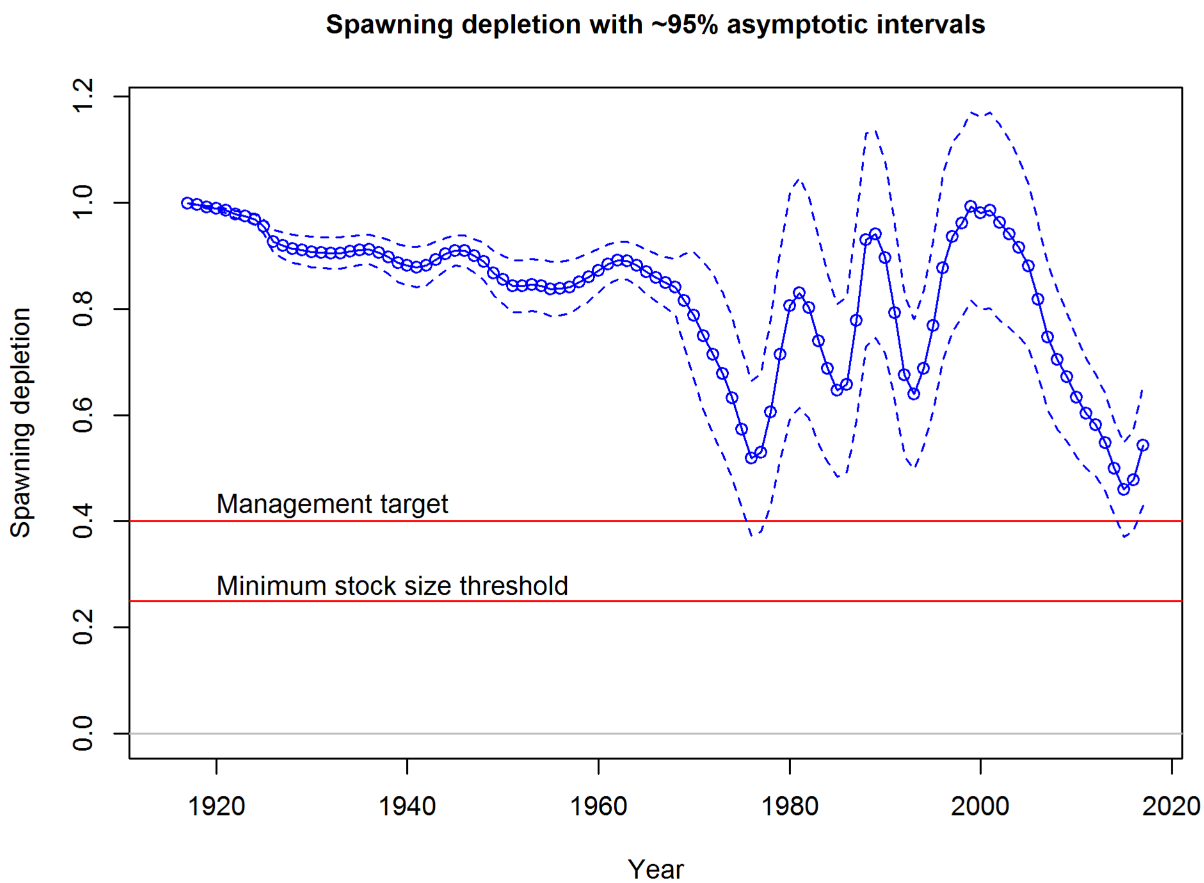

Figure f: Estimated relative depletion with approximate 95% asymptotic confidence intervals (dashed lines) for the base case assessment model.

Recruitment

Recruitment deviations were estimated from 1965-2016 (Figure g and Table c). Historically, there are estimates of large recruitment from 1975-1977, 1984-1985 and in 1993 and 1996. There is early evidence of a strong recruitment in 2013. The four lowest recruitment estimated 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	2288.15	(1198.27 - 4369.33)
2009	2589.07	(1388.65 - 4827.18)
2010	2483.75	(1330.55 - 4636.43)
2011	1178.81	(541.36 - 2566.83)
2012	1112.10	(509.72 - 2426.35)
2013	3747.47	(2048.29 - 6856.23)
2014	3529.05	(1626.81 - 7655.6)
2015	7585.54	(3389.96 - 16973.8)
2016	3268.02	(1063.03 - 10046.74)
2017	3343.81	(1088.44 - 10272.52)

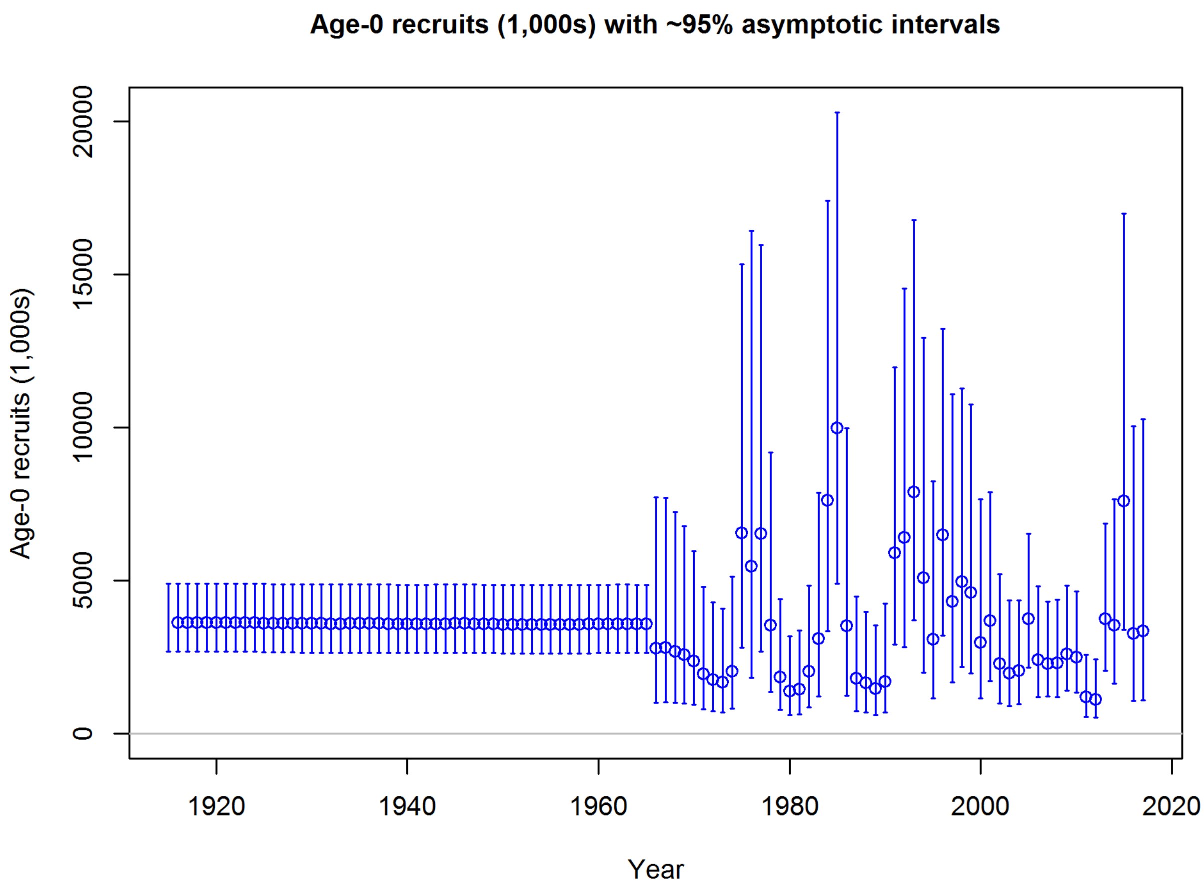

Figure g: Time series of estimated California scorpionfish recruitments for the base-case model with 95% confidence or credibility intervals.

Exploitation status

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

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

Year	Estimated (1-SPR)/(1-SPR50%)	95% confidence interval	Harvest rate (ratio)	95% confidence interval
2007	0.50	(0.33-0.66)	0.06	(0.04-0.08)
2008	0.43	(0.27-0.58)	0.05	(0.03-0.07)
2009	0.47	(0.31-0.63)	0.06	(0.03-0.08)
2010	0.47	(0.31-0.63)	0.05	(0.03-0.08)
2011	0.49	(0.32-0.65)	0.06	(0.03-0.08)
2012	0.55	(0.38-0.73)	0.07	(0.04-0.09)
2013	0.56	(0.38-0.74)	0.07	(0.04-0.1)
2014	0.61	(0.43-0.8)	0.08	(0.05-0.11)
2015	0.50	(0.33-0.67)	0.05	(0.03-0.08)
2016	0.47	(0.3-0.64)	0.04	(0.02-0.06)

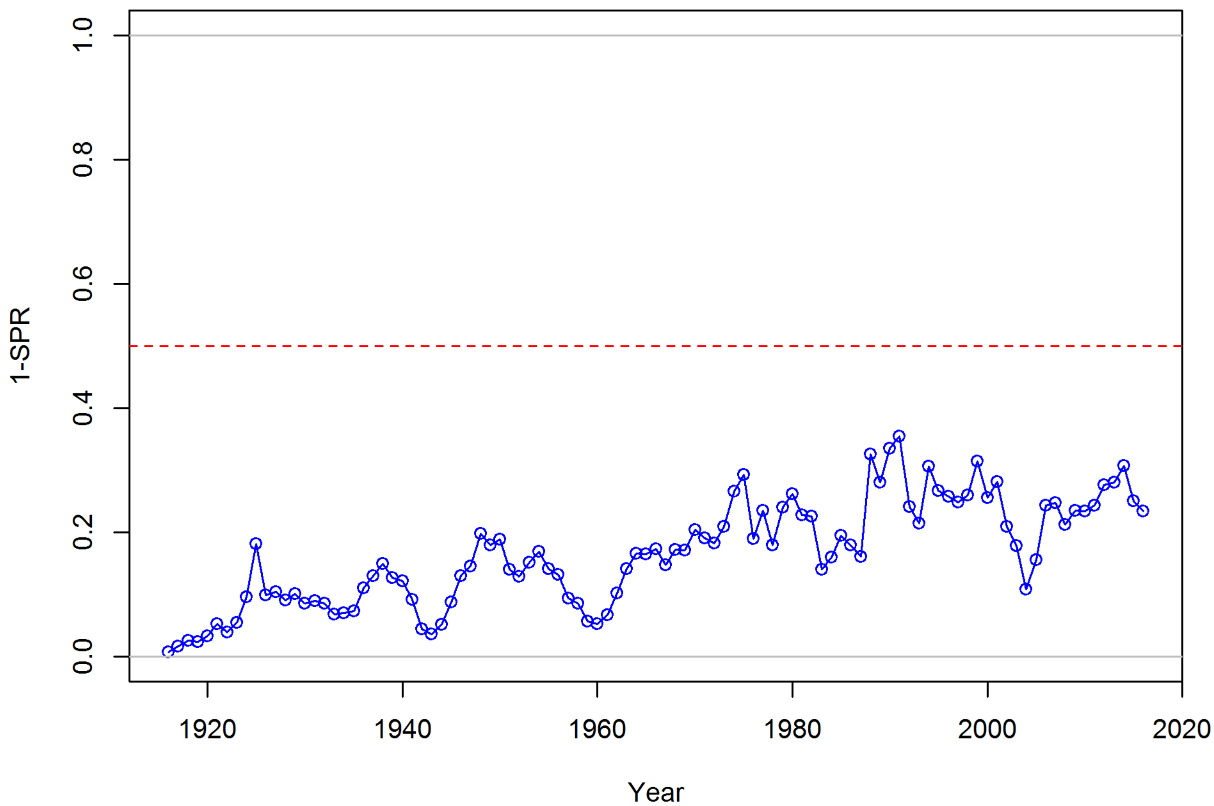

Figure h: Estimated spawning potential ratio (SPR) for the base-case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing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

Ecosystem Considerations

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

Reference Points

This stock assessment estimates that California scorpionfish in the base model is above the biomass target ($SB_{40\%}$), and well above the minimum stock size threshold ($SB_{25\%}$). The estimated relative depletion level for the base model in 2017 is 54.3% (95% asymptotic interval: $\pm$ 43%-65.7%, corresponding to an unfished spawning biomass of 882.457 mt (95% asymptotic interval: 484.21-1280.71 mt) of spawning biomass in the base model (Table e). Unfished age 1+ biomass was estimated to be 2921.9 mt in the base case model. The target spawning biomass ($SB_{40\%}$) is 649.8 mt, which corresponds with an equilibrium yield of 247.2 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 232.4 mt (Figure i).

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

Quantity	Estimate	~95% Confidence Interval
Unfished spawning biomass (mt)	1624.4	(1156.4-2092.5)
Unfished age 1+ biomass (mt)	2921.9	(2052.8-3791.1)
Unfished recruitment (R_0)	3619.8	(2518.6-4721)
Spawning biomass (2017, mt)	882.5	(484.2-1280.7)
Depletion (2017)	0.5432	(0.4299-0.6565)
Reference points based on $\mathbf{SB_{40\%}}$		
Proxy spawning biomass ($B_{40\%}$)	649.8	(462.5-837)
SPR resulting in $B_{40\%}$ ($SPR_{B40\%}$)	0.4589	(0.4589-0.4589)
Exploitation rate resulting in $B_{40\%}$	0.1741	(0.1601-0.1882)
Yield with $SPR_{B40\%}$ at $B_{40\%}$ (mt)	247.2	(168.6-325.9)
Reference points based on SPR proxy for MSY		
Spawning biomass	723.8	(515.2-932.3)
SPR_{proxy}	0.5	
Exploitation rate corresponding to SPR_{proxy}	0.1502	(0.1383-0.1621)
Yield with SPR_{proxy} at SB_{SPR} (mt)	232.4	(158.5-306.4)
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY})	358.8	(250.6-467)
SPR_{MSY}	0.2974	(0.2857-0.3091)
Exploitation rate at MSY	0.3236	(0.2917-0.3554)
MSY (mt)	281.3	(192.2-370.4)

Management Performance

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

Unresolved Problems and Major Uncertainties

As in most/all stock assessments, the appropriate value for stock-recruit steepness remains a major uncertainty for California scorpionfish. In this assessment a prior value from a meta-analysis of West Coast rockfish was used.

Assessment results for the base model are sensitive to natural mortality. When the natural mortality parameter is estimated by the model, the result is a value of female natural mortality that is higher than the STAT believed is biologically plausible. At the high value of female

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	-

natural mortality also produced a stock with an estimated lnR_0 an order of magnitude higher than when natural mortality was fixed at the prior. Additional analyses and studies should be conducted to determine an appropriate prior distribution for California scorpionfish.

The time series of recruitment deviations is driving the trend in abundance in the base model. Initial explorations of mapping the estimated recruitment deviations to the CalCOFI sea surface temperature indicated correlations may be present. Additional research should be conducted to explore the environmental drivers related to California scorpionfish recruitment.

The NMFS shelf-slope survey was the only available source of otoliths for California scorpionfish. It it unknown if the age and length distribution of the California scorpionfish deeper than 55 m (survey area) is the similar to that in waters shallower than 55 m. The majority of California scorpionfish aged were males, and it is unknown if that was driven by the depth distribution, time of sampling, or other factors.

The current term of reference for stock assessment require development of a single decision table with states of nature ranging along the dominant axis of uncertainty. This presumes that uncertainty is consequential only for a single variable or estimated quantity, such as natural mortality, steepness, or ending biomass. This approach may fail to capture important elements of uncertainty that should be communicated to the Council and its advisory bodies. Additional flexibility in the development of decision tables is needed.

Decision Table

The forecasts of stock abundance and yield were developed using the final base model, with the forecasted projections of the OFL presented in Table g. The total catches in 2017 and 2018 are set to the PFMC adopted California scorpionfish ACL of 150 mt.

Uncertainty in the forecasts is based upon the three states of nature agreed upon at the STAR panel and are based on a low value of M, 0.164, the base model value of M, 0.235, and a high value, 0.2745. The decision table based sigma was larger than the value for a category one species of 0.36. Therfore, the sigma was estimated as 0.582 from $(ln(BaseSpawnOut2017) - ln(LowSpawnOut2017))/1.15$. The resulting buffer, given a $p^* = 0.45$, was 0.929. The total catches in 2017 and 2018 are set to the average annual catch from 2015-2016 (79.03) and not the ABC or OFL due recent trends in total catch being significantly lower than the OFL and ABC. The average of 2015-2016 catch by fleet was used to distribute catches in forecasted years. Current medium-term forecasts based on the alternative states of nature project that the stock, under the current control rule as applied to the base model, will decline towards the target stock size Table h. The current control rule under the low state of nature results in a stock decline into the precautionary zone, while the high state of nature maintains the stock at nearer unfished levels. Removing the high M catches under the base model M and high M states of nature results in the population going remaining at a level of spawning biomass during the projection period, and higher initial values of lnR_0.

Table g: Projections of potential OFL (mt) using the base model forecast and assuming a total catch of 150 mt in 2017 and 2018. The control rule target is set to 0.956.

Year	OFL
2017	274.71
2018	297.86
2019	336.59
2020	332.51
2021	317.30
2022	300.78
2023	286.95
2024	276.30
2025	268.27
2026	262.21
2027	257.60
2028	254.09

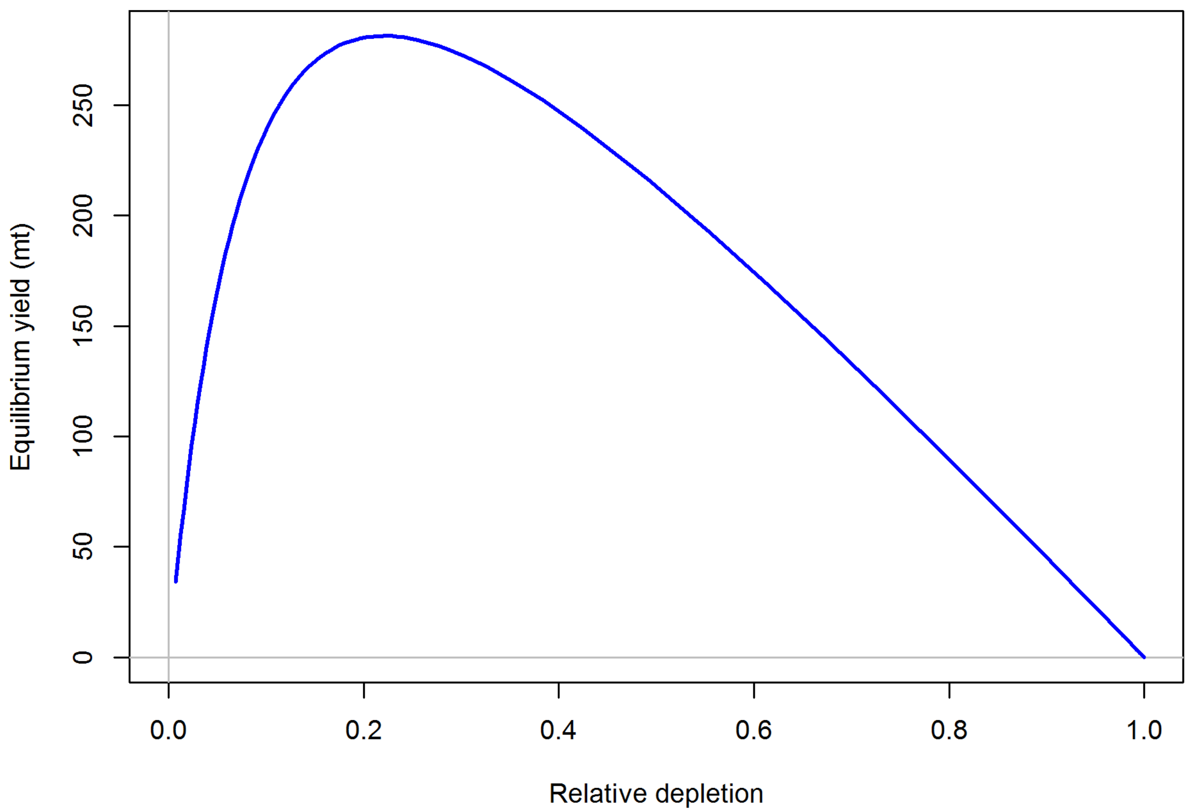

Figure i: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.718.

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 0.164		Base M 0.235		High M 0.2745	
	Year	Catch	Spawning biomass	Depletion	Spawning biomass	Depletion	Spawning biomass	Depletion
Constant Catch	2019	150.00	587.05	0.47	1154.73	0.71	2252.89	0.84
	2020	150.00	584.87	0.47	1174.89	0.72	2312.02	0.86
	2021	150.00	574.64	0.46	1176.29	0.72	2331.33	0.87
	2022	150.00	561.72	0.45	1169.09	0.72	2330.83	0.87
	2023	150.00	548.66	0.44	1158.79	0.71	2321.64	0.86
	2024	150.00	536.43	0.43	1148.13	0.71	2309.70	0.86
	2025	150.00	525.20	0.42	1138.24	0.70	2297.82	0.86
	2026	150.00	514.89	0.41	1129.45	0.70	2287.10	0.85
	2027	150.00	505.35	0.40	1121.77	0.69	2277.85	0.85
	2028	150.00	496.46	0.40	1115.12	0.69	2270.05	0.85
Estimated MSY	2019	232.40	587.05	0.46	1154.73	0.71	2252.89	0.83
	2020	232.40	539.94	0.43	1129.81	0.69	2267.62	0.84
	2021	232.40	488.83	0.38	1091.54	0.67	2248.79	0.83
	2022	232.40	440.88	0.35	1051.19	0.64	2217.13	0.82
	2023	232.40	398.12	0.31	1013.73	0.62	2183.03	0.81
	2024	232.40	360.29	0.28	980.74	0.60	2151.29	0.80
	2025	232.40	325.87	0.25	952.17	0.58	2123.53	0.79
	2026	232.40	293.92	0.23	927.43	0.57	2099.95	0.78
	2027	232.40	263.85	0.21	905.91	0.55	2080.12	0.77
	2028	232.40	235.33	0.18	887.07	0.54	2063.54	0.76
ACL = ABC	2019	337.40	587.05	0.47	1154.73	0.71	2252.89	0.84
	2020	326.81	484.09	0.39	1073.09	0.66	2211.40	0.82
	2021	307.52	390.83	0.31	991.72	0.61	2150.46	0.80
	2022	288.62	320.06	0.26	926.68	0.57	2095.21	0.78
	2023	273.50	269.27	0.21	879.51	0.54	2052.75	0.76
	2024	262.14	230.32	0.18	846.34	0.52	2022.64	0.75
	2025	253.68	197.08	0.16	822.85	0.51	2002.27	0.75
	2026	247.35	167.13	0.13	805.86	0.50	1989.02	0.74
	2027	242.56	139.73	0.11	793.31	0.49	1980.76	0.74
	2028	238.90	114.30	0.09	783.94	0.48	1976.01	0.74

Table i: Base case results summary.

Quantity	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Landings (mt)										
Total Est. Catch (mt)										
OFL (mt)										
ACL (mt)										
(1-SPR)(1-$SPR_{50\%}$)	0.43	0.47	0.47	0.49	0.55	0.56	0.61	0.50	0.47	
Exploitation rate	0.05	0.06	0.05	0.06	0.07	0.07	0.08	0.05	0.04	
Age 1+ biomass (mt)	2306.33	2156.96	2047.95	1948.44	1869.84	1768.52	1630.70	1556.37	1534.81	1713.25
Spawning biomass	1144.500	1090.480	1029.330	980.130	943.555	890.084	810.223	746.227	774.813	882.457
95% CI	(654.46-1634.54)	(629.78-1551.18)	(597.2-1461.46)	(571.79-1388.47)	(553.81-1333.3)	(518.85-1261.32)	(462.86-1157.59)	(412.08-1080.38)	(426.28-1123.35)	(484.21-1280.71)
Depletion	0.705	0.671	0.634	0.603	0.581	0.548	0.499	0.459	0.477	0.543
95% CI	(0.573-0.836)	(0.55-0.793)	(0.521-0.746)	(0.5-0.707)	(0.485-0.677)	(0.456-0.64)	(0.41-0.587)	(0.371-0.548)	(0.381-0.572)	(0.43-0.657)
Recruits	2288.15	2589.07	2483.75	1178.81	1112.10	3747.47	3529.05	7585.54	3268.02	3343.81
95% CI	(1198.27 - 4369.33)	(1388.65 - 4827.18)	(1330.55 - 4636.43)	(541.36 - 2566.83)	(509.72 - 2426.35)	(2048.29 - 6856.23)	(1626.81 - 7655.6)	(3389.96 - 16973.8)	(1063.03 - 10046.74)	(1088.44 - 10272.52)

Research and Data Needs

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

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

1. **Natural mortality**: Both natural mortality and steepness were fixed in the base model. The natural mortality estimate used the assessment was based on maximum age. The collection of age data for older females may improve the ability to estimate female natural mortality in the model. The NWFSC trawl survey was the only available source of age data for this assessment, of which there were a number of age-1 fish and the data were dominated by males. It may also be possible to evaluate mortality by quantifying predation by major predators of scorpionfish, such as octopus.

   A tagging study to estimate natural mortality for scorpionfish should be considered. This project could be designed as a cooperative research project with the charter fleet in southern California.

2. **Steepness**: California scorpionfish has not been fished to a level where information on steepness is available. A meta-analysis of steepness should be done for species with the same reproductive strategy as scorpionfish.

3. **Stock south of the U.S. border**: No available information on the status of California scorpionfish in Mexico could be found. A number of emails were sent to researchers in Mexico and none were returned. It is known that a portion of the stock resides in Mexico and that boat leaving from San Diego target California scorpionfish off the Coronado Islands.

4. **Sex ratio**: The sex ratio in the only published work by Love et al. (1987) and samples from the NWFSC trawl survey were skewed towards males. Data on sex ratios from the recreational or commercial fisheries would help in determining the sex ratio of the population.

5. **Aggregating behavior**: Aggregative behavior in both spawning and non-spawning seasons of California scorpionfish is not well understood. Studies are needed to evaluate the environmental or ecological conditions that govern this behavior.

6. **Fecundity/maturity**: A reproductive biology study of California scorpionfish is needed.There are currently no estimates of fecundity for California scorpionfish. The hard copies of data from the only estimates of maturity for California scorpionfish by Love et al. (1987) are no longer available. Some data on the spatial distribution of the eggs are available from CalCOFI, but were not keypunched to the species level. California scorpionfish mature at a young age, and additional data can help inform the maturity ogive.

No studies have been done of the relationship between weight and reproductive output. California scorpionfish have a different reproductive strategy than rockfish, and seasonal protection of spawning areas may help maintain reproductive capacity of the stock.

7. **Discard mortality**: Many scorpionfish are discarded at sea. The assessment used estimates of discard mortality of a distantly related species (lingcod) in a different ecological setting (Karpov 1996). Studies of discard mortality are needed to parametrize the assessment model.

8. **Environmental covariates**: The relationship between environmental conditions and recruitment for scorpionfish should be further explored. Preliminary exploration using CalCOFI temperature data suggested that a relationship existed, but other time series may correlate more strongly given that scorpionfish are a near-shore species. Scorpionfish appear to be a relatively hardy and adaptable species and may expand northward in a warming climate.

9. **Stephens and MacCall filtering**: Ad hoc criteria are used to identify a threshold when applying the Stephens and MacCall method of selecting records for CPUE index development. Further research is needed to determine whether threshold selection criteria can be optimized.

10. **Discard fleet modeling**: Modeling discard as a separate fleet, as was done for California scorpionfish, is a simple and intuitive approach, but the strengths and weaknesses of this approach are unclear. This method should be compared to the more standard approach of modeling discard with retention curves to ensure the model results are not strongly affected by the method used.

11. **MCMC in Stock Synthesis**: The Markov chain Monte Carlo (MCMC) method implemented in Stock Synthesis is not reliable in many cases. Characterizing uncertainty of the final assessment model is important, and MCMC offers advantages over asymptotic approximations using the Hessian or likelihood profiles.

12. **Decision tables**: Several alternative approaches were used this year to construct decision tables and some approaches may be better than others. The stock assessment TOR should outline the various methods that can be used, and provide recommendations if possible on preferred approaches.

13. **POTW trawl surveys**: Additional biological information (sex, otoliths, depth distribution) should be collected for California scorpionfish during the Publicly Owned Treatment Works (POTWs) trawl survey and the Southern California Bight Regional Monitoring Project (SCCWRP) trawl survey.

14. **Age validation**: An age validation study is needed for California scorpionfish.

15. **CalCOFI**: CalCOFI ichthyoplankton surveys in southern California do not currently identify scorpionfish eggs to species, though it is possible to do this in southern California waters. Species-specific identification of scorpionfish eggs is recommended to develop spawning output index for use in the next stock assessment.

1 Introduction

1.1 Basic Information and Life History

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

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

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

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

1.2 Early Life History

California scorpionfish utilize the "explosive breeding assemblage" reproductive mode in which fish migrate to, and aggregate at traditional spawning sites for brief periods (Love et al. 1987). California scorpionfish migrate to deeper waters (120-360 ft) to spawn during May-August, with peak spawning occurring July. The species is oviparous, producing floating, gelatinous egg masses in which the eggs are embedded in a single layer (Orton 1955) and it is believed that spawning takes place just before, and perhaps after dawn, in the water column (Love et al. 1987). Love et al. (1987) tagged California scorpionfish and recaptures suggested individuals return to the same spawning site, but information is not available on non-spawning season site fidelity.

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

1.3 Map

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

1.4 Ecosystem Considerations

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

1.5 Fishery Information

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

California scorpionfish comprise a minor part of the Californian sport and commercial fisheries (Love et al. 1987). Historically, California scorpionfish were taken commercially by hook and line and, occasionally, by round haul nets (Daugherty 1949). Scorpionfish were commonly caught around Santa Catalina Island during the late 19th Century with gill nets (Jordan 1887). The 1937 Bureau of Commercial Fisheries report noted that California scorpionfish had been a fairly important commercial species for a long time. The species was targeted by a few fishermen during the summer months, and was also taken as a bycatch in the rockfish fisheries. By 1949, the Bureau of Marine Fisheries reported "[Scorpionfish] will even come to the surface to lights at night" and were also taken in round haul nets. At that time, scorpionfish were rarely targeted by fishermen except by a few specialists.

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

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

Aggregate mortality has been far below the Annual Catch Limits (ACL) established by the 2005 stock assessment. The ACL projections from the 2005 assessment assumed that the entire ACL was being taken each year and as a result, the ACL for each subsequent year declined despite under-attainment in reality. In addition, in 2014, recreational catch was higher than expected. As a result, in 2014, the combined recreational and commercial catch exceeded the OFL by 2mt (1%) resulting from assumption that the ACL had been attained. Subsequently, action was taken to decrease the recreational season by four months (September 1 - December 31). A catch only update of the stock was undertaken in 2015 (Wallace and Budrick 2015) that imputed the actual catch values since the last assessment, resulting in significant increase in the OFL and ACL. Retrospectively, the catch in 2014 was well below the OFL as well as the ACL that would have been in place had the ACL values from the actual attainment been in place in 2014. Thus the stock has not been subject to overfishing since the original assessment or been in an overfished condition historically and is considered healthy. The season restriction in the recreational fishery remained in place as a precautionary measure until the full assessment was completed to better inform the current status of the stock, catch limits and regulations given the perspective provided.

1.6 Summary of Management History

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

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

Beginning in 1997, California scorpionfish was managed as part of the *Sebastes* complex-south, Other Rockfish category. *Sebastes* complex-south included the Eureka, Monterey, and Conception areas while *Sebastes* complex-north included the Vancouver and Columbia areas.) The PFMC's rockfish management structure changed significantly in 2000 with the replacement of the *Sebastes* complex -north and -south areas with Minor Rockfish North (now covering the Vancouver, Columbia, and Eureka areas) and Minor Rockfish South (now Monterey and Conception areas only). The OY for these two groups (which continued to be calculated as 0.50 of the ABC) was further divided (between north and south of 40°10′ N. latitude) into nearshore, shelf, and slope rockfish categories with allocations set for Limited Entry and Open Access fisheries within each of these three categories (January 4, 2000, 65 FR 221; PFMC (2002), Tables 54-55). Because of its depth range and southern distribution, California scorpionfish was included within the Minor Rockfish South, Other Rockfish ABC and managed under the south of 40°10′ N. latitude nearshore rockfish OY and trip limits (PFMC (2002), Table 29).

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

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

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

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

Although the Nearshore FMP provided for the management of the nearshore rockfish and California scorpionfish, management authority for these species continued to reside with the Council. Even so, for the 2003 and subsequent fishery seasons, the State provided recommendations to the Council specific to the nearshore species that followed the directives set out in the Nearshore FMP. These recommendations, which the Council incorporated into the 2003 management specifications, included a recalculated OY for Minor Rockfish South

- Nearshore, division of the Minor Rockfish South - Nearshore into three groups (shallow nearshore rockfish; deeper nearshore rockfish; and California scorpionfish), and specific harvest targets and recreational and commercial allocations for each of these groups.

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

1.7 Management Performance

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

1.8 Fisheries Off Mexico

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

2 Assessment

2.1 Data

Data used in the California scorpionfish assessment are summarized in Figure 3. Descriptions of the data sources are in the following sections.

2.1.1 Commercial Fishery Landings

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

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

Statewide annual commercial landings are available for California scorpionfish from 1916 to 1925, and are assumed to be taken by hook-and-line. Data by area and month are given in a series of bulletins, each bulletin usually providing information for a single year. Data by region and month is available for 1926 to 1986. The Santa Barbara region includes San Luis Obispo, Santa Barbara and Ventura counties. Catches from this region were included in the catch history and comprised less than 10 mt for the period from 1926-1968 (the period when data at the regional scale are available). Catches from Mexico can be separated from the total catch starting in 1931, although the CDFG Bulletins do not report catches originating from Mexican waters available for all years, e.g., 1932-1934. It is assumed that before 1931 there was no catch taken from Mexican waters landed in California.

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

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

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

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

2.1.2 Commercial Discards

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

2.1.3 Commercial Fishery Length and Age Data

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

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

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

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

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

2.1.4 Sport Fishery Removals and Discards

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

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

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

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

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

For all other modes, the MRFSS (1980-2003) and CRFS (2004-2017) based estimates of retained catch and discard mortality were used. There was a lapse in MRFSS sampling from 1990 through 1992, for which retained catch and discard mortality were estimated using the average of values three years before and three years after the lapse for all modes other than the party/charter mode. For the party/charter mode, estimates of numbers of fish were available from logbook data and average weight from the three years before and after this period were applied to provide estimates for the party/charter mode.

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

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

2.1.5 Fishery-Dependent Indices of Abundance

CRFS Private Boat Dockside Intercept Survey

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

The survey records the number of contributing anglers (number of anglers on the vessel for the private mode), but does not contain data on hours fished. For this index, angler-day was the assumed effort. The data were filtered to trips fishing with hook-and-line gear in southern California. Trips with a primary fishing area of Mexico were also removed. The CRFS dockside private boat records with these broad filters include 44,128 trips of which 3,802 caught California scorpionfish (8.6%).

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

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 (Figure 4). Potentially informative species for the Stephens-MacCall analysis were limited to species caught in at least one percent of all trips and caught in at least five years. Some of these never occurred with California scorpionfish (strong 'counter-indicators') and records with these species were removed from the data prior to estimation of the index. Strong counter-indicators for the CRFS private boat index included yellowfin tuna and dolphinfish.

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

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

Model selection procedures selected the covariates *2-month wave* and *county* as important for both the catch occurrence and positive catch component models for all data sets, along with the categorical year factor used for the index of abundance (Table 7). The Q-Q goodness of fit plot for the lognormal portion of the model shows a moderate fit to the data (Figure 7). The final index indicates a decrease in relative abundance from 2006 to 2010, at which point the index is relatively flat (Figure 8 and Table 8).

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

CRFS CPFV Logbook Index

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

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

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

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

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

MRFSS Party/Charter Boat Dockside Index

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

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

Since recreational fishing trips target a wide variety of species, standardization of the catch rates requires selecting trips that are likely to have fished in habitats containing California scorpionfish. The Stephens-MacCall (2004) filtering approach was used to identify trips with a high probability of catching California scorpionfish, based on the species composition of the catch in a given trip. Prior to applying the Stephens-MacCall filter, we identified potentially informative predictor species, i.e., species with sufficient sample sizes and temporal coverage (at least 30 positive trips total, distributed across at least 10 years of the index) to inform 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" equals "false negatives." The trips selected using this criteria were compared to an alternative method including all the "false positive" trips, regardless of the probability of encountering a California scorpionfish. This assumes that if California scorpionfish were caught, the vessel must have fished in appropriate habitat during the trip. 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 contrary 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 anomalous result and the low sample size, trips from 1989 were excluded from analysis.

The percentage of trips that retained California scorpionfish was 20.8% (828/3,968) prior to filtering with the Stephens-MacCall method, and 71.0% (828/,1167) with the filter set to 0.27 and 26.7% (828/3,099) with the filter set to 0.10, filtered data set. Residual-based model diagnostics for the positive component of the index suggest the data generally met the assumptions of the GLM (Figure 12). The resulting index is highly variable for both thresholds, with consistent peaks in 1984 and 1998 (Figure 10). Application of the 0.27 threshold holds the potential of biasing the resulting index values high by excluding false positive trips while including positive trips with equivalent probability of encountering California scorpionfish. The 0.1 threshold removes a high proportion of trips with shelf rockfish species indicative of effort exerted in deeper depths than are commonly occupied by California scorpionfish, while retaining false positive trips with equivalent probabilities of capture to true positives and thus was retained for further analysis. The resulting jackknifed mean index values, standard error, coefficient of variation and confidence intervals for the 0.1 threshold model, excluding 1989, with year, month and county effects are provided in Table 14.

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

Party/Charter Dockside Length Measurements

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

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

From 1985-1987 Ally et al. (1991) conducted an onboard observer program in southern California, and measured both retained and discarded fish. Additional unpublished years (1984, 1988-1999) from this onboard observer sampling program were provided by CDFW

(Paulo Serpa). From 1984-1989, the onboard observer program measured 11,892 retained California scorpionfish compared to the 1,981 measurements in RecFIN. It is almost certain, but cannot be verified, that some of the lengths from the onboard observer program were input in RecFIN. Therefore, the onboard observer measurements from 1984-1989 are used instead of those from RecFIN for these years.

Onboard Observer Party/Charter Boat

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

CDFW implemented a regulation of three hooks in 2000, which was reduced to (and remains at) two hooks in 2001. CDFW also implemented a 10 inch size limit for California scorpionfish in 2000. Prior to 2001, there were no depth restrictions for the southern California recreational fishery. Given these regulation changes, the data from 1999 and 2000 are excluded from the index.

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

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

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

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

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

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

Onboard Observer Discarded Catch Index

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

Discarded Catch Length Composition

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

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

Onboard Observer Retained Catch Index

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

2.1.6 Fishery-Independent Data Sources

Publicly Owned Treatment Works (POTWs) Monitoring Trawl Survey

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

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

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

Orange County.

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

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

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

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

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

Sanitation Districts of Los Angeles County.

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

City of San Diego Ocean Monitoring Program.

The City of San Diego's Ocean Monitoring Program is conducted by Environmental Monitoring & Technical Services Division of the Public Utilities Department (City of San Diego Public Utilities Department). The City of San Diego holds three NPDES that require monitoring of the areas potentially impacted by the discharge of wastewater into the Pacific Ocean via the Point Loma Ocean Outfall and South Bay Ocean Outfall (Timothy Stebbins, personal communication, City of San Diego Public Utilities Department). One permit is for the City's Point Loma Wastewater Treatment Plant discharge via the Point Loma Ocean Outfall. A second permit is for discharge via the South Bay Ocean Outfall from the City's South Bay Water Reclamation Plant. The third permit is also for discharge via the South Bay Ocean Outfall, but from the South Bay International Wastewater Treatment Plant operated by the U.S. Section of the International Boundary & Water Commission (USIBWC). Effluent from the two South Bay treatment facilities commingle before discharge to the ocean, so a single monitoring program is conducted by the City and USIBWC to meet those requirements (i.e., the City conducts the joint program under contract to the USIBWC). For purposes of this assessment, any trawls conducted in Mexican water, were excluded from analyses.

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

POTWs Index Standardization

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

The data were filtered for each POTW independently. The filters applied are described in the sections above and summarized in Table 22. The covariates considered for the lognormal and binomial models were *year* (47 levels), *quarter* (4 levels), and *station* (52 levels). A lognormal model for the positives was select over a gamma model by a delta AIC of 619. AIC model select was used for both the lognormal and binomial models and all three covariates were selected for both (Table 23). The standardized index shows a large spike in relative CPUE in 1981, varies within a range of 0.1 to 0.25 from 1989 to 2009, and then 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 POTWs had low sample sizes in some years. The general trend in relative CPUE is similar across POTWs (Figures 21).

POTWs Length Composition

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

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

NWFSC Trawl Survey Index

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

The proportions of positive catch haul and the raw catch rates of positive hauls by depth and latitude are shown in Figure 25 and Figure 27, respectively. These figures show that more scorpionfish were caught at shallow depth zones and in the southern latitude zones. Box plots of length summary data by depth and sex (Figure 29) and by latitude and sex (Figure 29) show no evidences of different spatial distributions (by depth and latitude) by length or by sex.
The numbers of total hauls and percentages of positive catch hauls by depth and latitude zones are presented in Tables 27 and 28, respectively. Summaries of raw catch data by year are listed in Table 29. Overall, catches of scorpionfish by the survey were very low with less than 1mt fish caught during the entire 14 years of the survey. Bubble plots of length frequency distribution by year and sex are presented in Figure 30.

Summaries of age data by year and sex are presented in Table 30. There were more males (n = 529) aged than females (n = 340), presumably indicating that there are more males than females in the area surveyed. The table also shows that mean ages and mean lengths for both sexes decreased in recent years. Table 31 show five percentiles of fish aged by sex, indicating more older males in the population. All aged data from the survey were used as conditional age-at-length matrix in the assessment model. The mean age-at-length indicates males and females to have similar growth patterns until around age three, at which time, females are larger than males (Table 32).

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

CSUN/VRG Gillnet Survey Index

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

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

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

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

Southern California Bight Regional Monitoring Project Trawl Survey

The southern California Coast Water Research Project SCCWRP works to bring together over 60 agencies in southern California, including all of the aforementioned POTWs, that conduct monitoring of aquatic environments. One of the monitoring programs in the Southern California Bight (SCB) is a trawl survey conducted every five years. The pilot year of the survey was 1994. Data from each of the survey years (1994, 1998, 2003, 2008, and 2013) were provided by the SCCWRP (Shelly Moore, SCCWRP).

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

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

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

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

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

Generating Station Impingement Surveys

Data from the southern California generating station surveys were provided by Eric Miller (MBC Applied Environmental Sciences). The generating stations all draw in seawater through an intake system for once-through cooling water. There are five generating stations that conduct normal operation and heat treatment surveys with observations of California scorpionfish: Scattergood Generating Station (SGS), El Segundo Generating Station (ESGS), Redondo Beach Generating Station (RBGS), Huntington Beach Generating Station (HBGS), and San Onofre Generation Station (SONGS). Each generating station draws in water from different depths and distances from shore: SGS draws from 500 m offshore at 6 m depth, ESBS draws from 700 m offshore at 9.8 m depth, RBGS draws from 289 m offshore at 13.7 m depth, HBGS draws from 500 m offshore at 5 m depth, and SONGS has two intake systems 960 m and 900 m offshore and at 9 m and 8 m depth, respectively (Miller et al. 2009).

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

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

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

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

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

California scorpionfish larvae encounters from CalCOFI surveys were provided by Noelle Bowlin (NMFS SWFSC). Only 16 positive bongo tows in the core area (lines 77-93) encountered California scorpionfish. The majority of the 335 positive bongo tows occurred in Mexico, south of Punta Eugenia Baja California and are likely a combination of California scorpionfish and other *Scorpaena* species. The California scorpionfish egg masses are encountered in the CalCOFI surveys, but because California scorpionfish is not a target species they are entered in the database as "unidentified eggs" (William Watson, NMFS SWFSC). An index of abundance was not developed for the CalCOFI data due to the small sample sizes.

2.1.7 Biological Parameters and Data

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

Standard and total lengths of 163 California scorpionfish were available from a halibut trawl survey in southern California (Steve Wertz, CDFW). The conversion from SL to TL from these data was estimated at $TL = 1.2225SL + 0.7773$. The conversion originating from the halibut trawl data was used in this assessment due to the fact that the original data from Love et al. (1987) are not available. The majority of available length composition data were measured to total length, except for the POTW trawl surveys, the Southern California Bight Regional Monitoring Program trawl survey, and the CSUN/VRG gillnet survey (gillnet survey). Maunder et al. (2005) converted all data to standard length due to clumping of data when length data are only available to the nearest centimeter. However, the same is true for the conversion from TL to SL when data were available to the nearest centimeter. All length data for this assessment are in TL. The Orange County Sanitation District and the VRG gillnet study measured SL to the nearest mm.

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

Length and Age Compositions

Length compositions were provided from the following sources:

- CDFW market category study (*commercial dead fish*, 1996-2003)
- CALCOM (*commercial dead fish*, 2013-2016)
- CDFW onboard observer (*recreational charter discards*, 2003-2016)
- Ally onboard observer study (*recreational charter discards*, 1984-1989)
- California recreational sources combined (*recreational charter retained catch*)
  - CDFW and Ally onboard observer surveys (1984-1989)
  - Collins and Crooke onboard observer surveys (1975-1978)
  - 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, i.e., females grow faster than males (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 (Figure 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. Ageing error was estimated using publicly available software (Thorson et al. 2012). The software setting for bias and standard deviation were the same for both readers, unbiased and curvilinear increase in standard deviation with age, respectively (Figure 49). Two fish with estimated age greater than 21 (plus group age) were excluded from the ageing error estimation. The resulting estimate indicated a standard deviation in age readings increasing from 0.001 years to a standard deviation of 1.79 years at age 22.

Weight-Length

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

Sex-specific weight-length relationships were estimated from the NWFSC trawl survey data. Length and weight data were available for 340 females and 530 males. The estimated parameters for females are $\alpha = 1.553983e^{-05}$ and $\beta = 3.057654$, and for males $\alpha = 1.9104e^{-05}$ and $\beta = 2.980548$. Love et al. (1987) found males to be heavier at a given length than females, whereas the NWFSC data suggests the opposite (Figure 50).

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

Sex Ratio, Maturity, and Fecundity

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

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

No new data on maturity or fecundity for California scorpionfish are available since the publication of the 2005 stock assessment. Love et al. (1987) found few California scorpionfish to be mature at age-1, 50% of males were mature at 17 cm TL and over 50% of females were mature by 18 cm TL, or two years of age. All fish were mature by 22 cm TL. This assessment used size at 50% maturity for females of 18 cm TL, with maturity asymptoting to 1.0 for larger fish.

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

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

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

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

2.1.8 Environmental or Ecosystem Data Included in the Assessment

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

2.2 Previous Assessments

2.2.1 History of Modeling Approaches Used for this Stock

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

2.2.2 2005 Assessment Recommendations

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

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

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

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

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

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

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

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

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

2.3 Model Description

The mode descriptions in the following sections reflect decisions and modelling choices the STAT team made prior to the STAR panel. Changes from the pre-STAR base model to the final post-STAR base model are documented in the "Responses to the Current STAR Panel Requests" section. None of the data changed during the STAR panel, and the figures and tables reflect the post-STAR final base model.

2.3.1 Transition to the Current Stock Assessment

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

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

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

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

The way growth is modeled for age-0 fish has changed. More recent versions of Stock Synthesis model length-at-age for fish below the first reference age (Amin) as linearly increasing from the initial length bin to the length given by the L_at_Amin parameter. Since small California scorpionfish are selected in the POTW trawl survey data, the change in modeled growth has the potential to affect estimates of recruitment. We took the following approach in order to mimic the methods of SS2 version 1.8:

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

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

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

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

The recreational catches differed from the catch history used in the previous assessment. In 2010 a catch reconstruction was completed for California (Ralston et al. 2010). Methods provided were applied in reconstructing the catch of California scorpionfish for this assessment. Both assessments utilized similar data sources including CPFV logbooks and MRFSS data providing catch estimates, with the addition of data from the CRFS program for 2004-2016. The main difference resides with accounting for discard mortality as well as landed catch allowing discards to be modeled as a separate fleet making use of length distribution data for discards for 2003-2016. In addition, the recreational catch time series terminated in 1928 for the current assessment, as specified for rockfish catch reconstructions in the historical catch reconstruction document, rather than in 1916. The ratio of catches for the party-charter boat mode to the private and rental boat mode from the MRFSS period were used in combination with catch estimates from the CPFV logbook estimates back to 1932 in both assessments to approximate mortality the private rental boat mode prior to 1980. A ramp accounting for the increase relative contribution of the private boat mode relative to the party charter mode from the mid 1965 to 1980, as conducted for rockfish in the historical catch reconstruction document. A constant ratio of catch compared to the party charter boat mode was applied for man-made and beach and bank modes to provide an estimate of catch back to 1936 as was done for the private and rental boat mode in the previous assessment. The CPFV logbook data terminated in 1935 and a linear ramp was used to approximate catch from 1936 back to zero in 1928 for each mode as compared to 1916 in the 2005 assessment.

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

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

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

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

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

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

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

Maturity was changed for this assessment. The Love et al. (1987) study is the only study that estimated the maturity ogive. The CDFW cross-shelf halibut survey used in the 2005 assessment to estimate the GSI were not used in this study as GSI is not an indicator of fecundity. Fecundity estimates are available for a number of rockfish species (Dick et al. 2017), but there is currently no information on fecundity available for California scorpionfish. This assessment uses the assumption that eggs are equivalent to spawning biomass.

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

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

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

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

2.3.2 Summary of Data for Fleets and Areas

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

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

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

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

2.3.3 Other Specifications

Stock synthesis has a broad suite of structural options available. Where possible, the 'default' or most commonly used approaches are applied to this stock assessment. The assessment is sex-specific, including the estimation of separate growth curves, and natural mortality. Sex-specific length-weight parameters were input as fixed values. The assessment only tracks female spawning biomass for use in calculating stock status.

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

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

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

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

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

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

2.3.4 Modeling Software

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

2.3.5 Data Weighting

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

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

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

2.3.6 Priors

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

The prior for steepness (h) assumes a beta distribution with parameters based on an update for the Thorson-Dorn rockfish prior (Dorn, M. and Thorson, J., pers. comm.), which was endorsed by the Science and Statistical Committee in 2017. The prior is a beta distribution with mu=0.718 and $sigma$=0.158. Steepness is fixed in the base model at the mean of the prior. The priors were applied in sensitivity analyses where these parameters were estimated.

2.3.7 Estimated and Fixed Parameters

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

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

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

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

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

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

Natural Mortality. Natural mortality is fixed for females at the value provided by the Hamel (Hamel 2015) analysis described above. Natural mortality for males is estimated as an offset from the fixed female natural mortality in the pre-STAR base model. Natural mortality parameters for females and males are the same and fixed in the post-STAR base model.

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

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

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

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

This assessment includes discards for the recreational fleet, so time was spent investigating changes in selectivity and the most prudent way to incorporate discards. Length composition of discards from two recreational party/charter onboard observer programs and sensitivities to estimates of female natural mortality were explored by fixing other key parameters, i.e., steepness. Male natural mortality is still reasonably well estimated, but the estimates of $lnR0$ and female M are not well estimated. The previous assessment fixed female and male M, where male M was an offset. The previous model had two breakpoints for natural mortality, but the natural mortality for older fish was set to the same as for younger fish. This model uses one parameter for natural mortality for each sex.

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

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

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

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

2.4 Model Selection and Evaluation

2.4.1 Key Assumptions and Structural Choices

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

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

2.4.2 Alternate Models Considered

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

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

Runs of the base case model estimating steepness were also considered, when female natural mortality was fixed. Steepness was estimated at approximately 0.8. No data exist to inform this parameter for California scorpionfish, and the decision was made to fix steepness at the mean of the prior developed from a meta-analysis of West Coast groundfish.

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

2.4.3 Convergence

Model convergence was determined by starting the minimization process from dispersed values of the maximum likelihood estimates to determine if the model found a better minimum. Jitter is a SS option that generates random starting values from a normal distribution logistically transformed into each parameter's range (Methot 2015). This was repeated 100 times and the minimum was reached in 56% of the runs (Table 41). The model did not experience convergence issues, e.g., final gradient was below 0.0001, when reasonable starting values were used and there were no difficulties in inverting the Hessian to obtain estimates of variability. We did sensitivity runs for convergence by changing the phases for key estimated parameters; neither the total log-likelihood nor the parameter estimates changed.

2.5 Response to the Current STAR Panel Requests

Request No. 1: Add time blocks (1916-1999, 2000-2005, 2006-2017) for the Recreational Dead Discard fleet same as for the Recreational Retained fleets.

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

Request No. 2: Combine retained and discarded catches in the Recreational index (use the number of CA scorpionfish encountered per angler hour as the CPUE metric). Include retained and discarded catches and length compositions in this new fleet with appropriate weights. Make the CPFV logbook index a survey.

Rationale: Concern with modeling discards as a separate fleet.

STAT Response: This turned out to be more difficult than the STAR panel anticipated 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 thresholds in the Stephens-MacCall filtering by halving the false positives and alternatively halving the false negatives. Retain the true and false positives in each of these runs.

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 generic rockfish relationship from Dick et al. (2017)

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 model models fecundity as proportional to weight. The model was run with the alternative where fecundity is proportional to length to the power 4.043 (Dick et al. 2017). 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 for a normal descending selex pattern.

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

Request No. 6: Investigate the commercial net length data sources to see if they are representative of the different mesh sizes used. For a sensitivity analysis, turn off the selex mirroring to the hook-and-line fleet and estimate a fleet-specific selex. An additional sensitivity analysis, remove the length comps. from this fleet and continue to mirror the selex to the hook-and-line fleet.

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

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

Request No. 7: Turn off the mirroring of the gillnet survey to the POTW survey selex and allow the model to estimate a survey-specific selex.

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

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

Request No. 8: Plot the CalCOFI sea surface temperature index for Pacific sardine with the estimated CA scorpionfish recruitment deviations.

Rationale: To investigate the hypothesis of warmer water influencing positive recruitment.

STAT Response: The annual CalCOFI sea surface temperature index was correlated with the model estimated recruitment deviations (Figure 57). This helps explain the pattern of alternating periods of positive and negative recruitment deviations in the model. The panel recommends further investigation of possible predictors with the goal of finding a better indicator of California scorpionfish recruitment to be considered for use within a model and for forecasting.

Request No. 9: Provide a model run where recruitment deviations are not estimated. Also, provide a model run with a lower sigma-r (0.3).

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

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

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

- Model the commercial net fishery with its own selex curve with two selex blocks matching the other commercial fisheries. Peak selex parameter needs to be fixed (not estimated)
- Model the impingement data with a descending selex pattern, including estimation of the peak parameter
- Drop the Gillnet survey from the model
- Fix M for both sexes combined based on a max. age of 23 years (M = 0.235) (determined by averaging the third oldest estimated ages of each sex)

- Retune and jitter
- Evaluate diagnostics to ensure this is a sound model.

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

STAT Response: These changes consitute a new base model.

Request No. 11: Building on the new base model, prepare bracketing runs on M that use the 12.5% (M = 0.164) and 87.5% (M = 0.335) quantiles of the Hamel prior distribution.

Rationale: To consider for a decision table.

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

Request No. 12: For the high state of nature, explore an M such that the ratio of ending SSB in the high state of nature to the base case is equal to that ratio from the base case (M = 0.235) to the low state of nature (M = 0.164).

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

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

Request No. 13: Provide a draft decision table with the 3 states of nature assuming the following harvest control rule for a catch stream: ACL = ABC, $P*$=0.45, sigma = 0.36; ABC buffer = 4.4% (i.e., ABC is $0.956*OFL$).

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

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

2.6 Base Case Model Results

The following description of the model results reflects a base model that incorporates all of the changes made during the STAR panel (see previous section). The base model parameter estimates and their approximate asymptotic standard errors are shown in Table 42 and the likelihood components are in Table 43. Estimates of derived reference points and approximate 95% asymptotic confidence intervals are shown in Table e. Time-series of estimated stock size over time are shown in Table 44.

The base model is sex-specific for the growth parameters. Key productivity parameters are fixed at measures of central tendency from prior distributions endorsed by the PFMC's SSC due to the models' inabilities to estimate reasonable parameter values. Specifically, steepness of the assumed Beverton-Holt stock-recruitment relationship was fixed at 0.718. In the final base models the instantaneous rate of annual natural mortality was fixed at 0.235 for females and males.

2.6.1 Parameter Estimates

The base model produces reasonable estimates of growth parameters, for both males and females (Figure 47). The von Bertalanffy growth coefficient k for females was estimated close to the external estimate, 0.2496 externally and 0.2503 within SS. For males, the von Bertalanffy k parameter was estimated at 0.2325 externally and 0.1864 within SS. The female estimated L_{inf} was 33.312 and 28.4207 for males. Females grow faster than males and reach a maximum size greater than the males.

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

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

The additional survey variability (process error added directly to each year's input variability) for all surveys was estimated within the model. The model estimated a small added variances for the recreational private mode of 0.012 and the recreational party/charter discard fleet of 0.067. The estimated added variance was highest for the recreational party/charter retained-catch fleet (0.258), the POTW trawl survey (0.217), and the NWFSC trawl survey (0.253).

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

The stock-recruit curve resulting from a fixed value of steepness is shown in Figure 66 with estimated recruitments also shown. The stock is predicted to have never fallen to low enough levels that the steepness is obvious. Steepness was not estimated in this model, but sensitivities to an alternative value of steepness is discussed below.

2.6.2 Fits to the Data

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

The fits to the four fishery CPUE and four survey indices are shown in Figures 67 - 73. Extra standard error was estimated for all eight of the indices. The indices for the recreational private mode and dead-discard fleets were fit relatively well by the model. The recreational party/charter retained-catch index was fit moderately well in parts of the time series, but did not capture the increases observed in the late 1990s. The extra variability added to this index was also large. The onboard observer retained-only catch index was fit well by the model except for the two lowest years, 2003 and 2015.

The POTW trawl survey index was fit well by the model, except for the highest four years from 1979-1982, where the fit is estimated lower than the added uncertainty. The NWFSC trawl survey index is flat and fit well by the model, except for in 2013, the highest year in the index, with also high uncertainty. The gillnet survey index was not well fit by the model; the model fit did not capture the trend observed in the standardized index. The decision was made during the STAR panel to exclude the gillnet survey and associated length data from the base model. The Southern California Bight trawl survey, conducted every 5 years, was also not well fit by the model. The standardized index from the Bight trawl survey showed peaks in 1994 and 2004, which were not fit by the model.

Fits to the length data are shown based on the proportions of lengths observed by year and the Pearson residuals-at-length for all fleets. Detailed fits to the length data by year and fleet are provided in Appendix 8. Aggregate fits by fleet are shown in Figure 74. Overall, the length composition data for the commercial hook-and-line, commercial trawl, POTW trawl survey, recreational private, and party/charter fleets all fit well. The fits to the recreational discard fleet by year were variable, and were worse in years with small sample sizes; however, the aggregate fit is reasonable. The sample sizes by year for each of the gillnet, impingement, and Bight trawl surveys were small compared to the fisheries. The fit to the data varies by year and does not capture the high proportion of small fish observed in the impingement survey, especially in 2013.

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

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

The observed and expected conditional age-at-length fits are shown in Figure 75 for the NWFSC trawl survey observations. The fits generally match the observations for fish smaller than 30 cm. Some outliers are apparent with large residuals.

The age data were also weighted according to Francis weighting which adjust the weight given to a data set based on the fit to the mean age by year. The mean ages from the fishery appear to have declined in recent years which could be due to incoming cohorts (Figure 76). Smaller fish were also observed in the POTW trawl and impingement surveys in the (Figures 77 and 78). The mean length in the recreational private and party/charter fleets increased over time (Figures 79 and 80). The length composition of the recreational fleet discards was smaller in the 1980s and hovers around the 10-in minimum size limit in the 2000s (Figure 81).

2.6.3 Uncertainty and Sensitivity Analyses

A number of sensitivity analyses were conducted, including:

1. Data weighting according to the harmonic mean.
2. Removal of the POTW trawl survey index (axis of uncertainty from the 2005 assessment)
3. Dome-shaped selectivity for the NWFSC trawl survey and gillnet survey

4. Estimating female natural mortality
5. Estimating steepness
6. Assume the same fixed natural mortality for males and females
7. Drop data sources, one at a time

A number of changes were made since the 2005 assessment, and sensitivities to the current base model included changing or fixing a number of parameters to the same as the 2005 assessment, as well as a number of sensitivities to modelling choices made in developing the current base model (Tables 45 and 46). A number of metrics (SB_0, SB_{2017}, SB_{2017}/SB_0, and $Yield_{SPR}$) relative to the pre-STAR base model are presented in Figure 82 and show that the impingement length composition data are the data source to which the model is most sensitive. The model is also sensitive to the choice of data weighting.

Data weighting is an area of uncertainty for stock assessment and research is ongoing to determine the effects of data weighting and the most appropriate initial sample sizes for length and age composition data. The base model used the Stewart sample sizes for the fishery data and number of trips for all survey sample sizes. Weighting the data by the harmonic mean resulted in a model with a total likelihood between the base model, which uses the Francis method for weighting, and the model with default weights. The Francis weights in the base model were stable, and did not tend to serially decrease (downweight) any of the datasets, which has been seen in other assessments.

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

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

Sensitivity of the base model to each of the data sources was also explored (Figures 85 and 85). The time series of spawning biomass was most sensitive to the impingement survey length composition. Without the impingement length composition, the relative time series is the same, but the total biomass is almost double the base model. However, dropping the impingement index and estimating a single natural mortality rate for both sexes reduces the total biomass towards the base model. Natural mortality is also reasonably estimated at 0.19. In the sensitivity run where both natural mortality (0.19, same for males and females) and steepness (0.88) were estimated produces both a reasonable estimate for natural mortality and a value of steepness that was high, but not estimated at the parameter bound.

2.6.4 Retrospective Analysis

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

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

2.6.5 Likelihood Profiles

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

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

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

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

The negative log-likelihood was minimized at a natural mortality value of 0.38, the profile is relatively flat for the priors, index data, and recruitment (Figure 94). The age data likelihood contribution was minimized at natural mortality values ranging from 0.035-0.40, and the length data contribution was minimized as the largest value of M run, 0.40 (Table 50). The virgin biomass was estimated at unreasonable levels ($\tilde{}2e^{12}$) when M was fixed at 0.33 and greater. The impingement survey was the only fleet for which the likelihood profile over M was not relatively flat (Figure 95). The relative depletion for California scorpionfish ranged from 0.48-0.80 across alternative values of natural mortality (Figure 96).

2.6.6 Reference Points

Reference points were calculated using the estimated selectivities and catch distribution among fleets in the most recent year of the model, (2015). Sustainable total yield (landings plus discards) were 232.4 mt when using an $SPR_{50\%}$ reference harvest rate and with a 95% confidence interval of (158.5-306.4) mt based on estimates of uncertainty. The spawning biomass equivalent to 40% of the unfished level ($SB_{40\%}$) was 649.8 mt.

The predicted spawning biomass from the base model shows an initial decline starting in 1970, with two year of low spawning biomass in 1976 and 1977. From the late 1970s to the mid-2000s the population follows a cyclical pattern (driven by recruitment pulses) and then declines until 2015. The last two years of the model indicate an increase in spawning biomass. (Figure 97). Since 2015, the spawning biomass has been increased due to lower catches and a high recruitment pulse in 2015. The 2016 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished levels (Figure 98). The relative fishing intensity, $(1 - SPR)/(1 - SPR_{50\%})$, has been well below the management target for the entire time series of the model.

Table e shows the full suite of estimated reference points for the base model and Figure 99 shows the equilibrium curve based on a steepness value fixed at 0.718.

3 Harvest Projections and Decision Tables

The forecasts of stock abundance and yield were developed using the final base model, with the forecasted projections of the OFL presented in Table g. The total catches in 2017 and 2018 are set to the average annual catch from 2015-2016 and not the ABC or OFL due recent trends in total catch being significantly lower than the OFL and ABC. CDFW also allocated 75% of the ACL to the recreational fisheries and 25% to the commercial fisheries. The exploitation rate for 2019 and beyond is based upon an SPR harvest rate of 50%. The average of 2015-2016 catch by fleet was used to distribute catches in forecasted years. The forecasted projections of the OFL for each model are presented in Table h.

Uncertainty in the forecasts is based upon the three states of nature agreed upon at the STAR panel and are based on a low value of M, 0.164, the base model value of M, 0.235, and a high value, 0.2745. The total catches in 2017 and 2018 are set to the average annual catch from 2015-2016 (79.03) and not the ABC or OFL due recent trends in total catch being significantly lower than the OFL and ABC. The average of 2015-2016 catch by fleet was used to distribute catches in forecasted years. Current medium-term forecasts based on the alternative states of nature project that the stock, under the current control rule as applied to the base model, will decline towards the target stock size Table h. The current control rule under the low state of nature results in a stock decline into the precautionary zone, while the high state of nature maintains the stock at nearer unfished levels.

4 Regional Management Considerations

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

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

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

5 Research Needs

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

1. **Natural mortality**: Both natural mortality and steepness were fixed in the base model. The natural mortality estimate used the assessment was based on maximum age. The collection of age data for older females may improve the ability to estimate female natural mortality in the model. The NWFSC trawl survey was the only available source of age data for this assessment, of which there were a number of age-1 fish and the data were dominated by males. It may also be possible to evaluate mortality by quantifying predation by major predators of scorpionfish, such as octopus.

   A tagging study to estimate natural mortality for scorpionfish should be considered. This project could be designed as a cooperative research project with the charter fleet in southern California.

2. **Steepness**: California scorpionfish has not been fished to a level where information on steepness is available. A meta-analysis for species with similar breeding strategies to California scorpionfish could be conducted if data are available. A meta-analysis of steepness should be done for species with the same reproductive strategy as scorpionfish.

3. **Stock south of the U.S. border**: No available information on the status of California scorpionfish in Mexico could be found. A number of emails were sent to researchers in Mexico and none were responded to. It is known that a portion of the stock resides in Mexico and that boat leaving from San Diego target California scorpionfish off the Coronado Islands.

4. **Sex ratio**: The sex ratio in the only published work by Love et al. (1987) and samples from the NWFSC trawl survey were skewed towards males. Data on sex ratios from the recreational or commercial fisheries would help in determining the sex ratio of the population.

5. **Aggregating behavior**: Aggregative behavior in both spawning and non-spawning seasons of California scorpionfish is not well understood. Studies are needed to evaluate the environmental or ecological conditions that govern this behavior.

6. **Fecundity/maturity**: A reproductive biology study of California scorpionfish is needed.There are currently no estimates of fecundity for California scorpionfish. The hard copies of data from the only estimates of maturity for California scorpionfish by Love et al. (1987) are no longer available. Some data on the spatial distribution of the eggs are available from CalCOFI, but were not keypunched to the species level. California scorpionfish mature at a young age, and additional data can help inform the maturity ogive.

   No studies have been done of the relationship between weight and reproductive output. California scorpionfish have a different reproductive strategy than rockfish, and seasonal protection of spawning areas may help maintain reproductive capacity of the stock.

7. **Discard mortality**: Many scorpionfish are discarded at sea. The assessment used estimates of discard mortality of a distantly related species (lingcod) in a different ecological setting (Karpov 1996). Studies of discard mortality are needed to parametrize the assessment model.

8. **Environmental covariates**: The relationship between environmental conditions and recruitment for scorpionfish should be further explored. Preliminary exploration using CalCOFI temperature data suggested that a relationship existed, but other time series may correlate more strongly given that scorpionfish are a near-shore species. Scorpionfish appear to be a relatively hardy and adaptable species and may expand northward in a warming climate.

9. **Stephens and MacCall filtering**: Ad hoc criteria are used to identify a threshold when applying the Stephens and MacCall method of selecting records for CPUE index development. Further research is needed to determine whether threshold selection criteria can be optimized.

10. **Discard fleet modeling**: Modeling discard as a separate fleet, as was done for California scorpionfish, is a simple and intuitive approach, but the strengths and weaknesses of this approach are unclear. This method should be compared to the more standard approach of modeling discard with retention curves to ensure the model results are not strongly affected by the method used.

11. **MCMC in Stock Synthesis**: The Markov chain Monte Carlo (MCMC) method implemented in Stock Synthesis is not reliable in many cases. Characterizing uncertainty of the final assessment model is important, and MCMC offers advantages over asymptotic approximations using the Hessian or likelihood profiles.

12. **Decision tables**: Several alternative approaches were used this year to construct decision tables and some approaches may be better than others. The stock assessment TOR should outline the various methods that can be used, and provide recommendations if possible on preferred approaches.

13. **POTW trawl surveys**: Additional biological information (sex, otoliths, depth distribution) should be collected for California scorpionfish during the Publicly Owned Treatment Works (POTWs) trawl survey and the Southern California Bight Regional Monitoring Project (SCCWRP) trawl survey.

14. **Age validation**: An age validation study is needed for California scorpionfish.

15. **CalCOFI**: CalCOFI ichthyoplankton surveys in southern California do not currently identify scorpionfish eggs to species, though it is possible to do this in southern California waters. Species-specific identification of scorpionfish eggs is recommended to develop spawning output index for use in the next stock assessment.

6 Acknowledgments

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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

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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
1951	45.85	0.00	0.00	0.16	45.85	CDFG Bulletins
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

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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
1988	7.77	0.00	3.65	0.00	11.42	CFIS
1989	15.87	0.02	2.80	0.00	18.69	CFIS
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

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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
1967	7.34	39.64	0.29	47.27
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

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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
2005	21.34	57.15	5.04	83.53
2006	14.44	129.58	3.31	147.33
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 index 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 (*Seriola lalandi*); 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 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 Califronia scorpionfish by 25 m interval depth zones from NWFSC trawl survey between 2003 and 2016.

Depth zone (m)	Total catch (kg)	Raw CPUE (kg/ha)
50-74	304.80	1.71
75-99	568.20	1.98
100-124	34.10	0.22
125-149	3.80	0.04
150-174	46.90	0.41
175-199	1.10	0.01
200-225	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 row shows total numbers of fish aged by sex.

	Female			Male		
Year	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.

	Female		Male	
Age	Mean length	No. of Fish	Mean length	No. of 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	0.235	-3	(0.01, 1)			Log_Norm (-1.3581, 0.438438)
2	L_at_Amin_Fem_GP_1	11.925	2	(2, 30)	OK	0.675	None
3	L_at_Amax_Fem_GP_1	31.886	2	(30, 50)	OK	0.680	None
4	VonBert_K_Fem_GP_1	0.292	2	(0.05, 0.5)	OK	0.030	None
5	CV_young_Fem_GP_1	0.088	3	(0.02, 0.5)	OK	0.020	None
6	CV_old_Fem_GP_1	0.119	3	(0.02, 0.75)	OK	0.007	None
7	Wtlen_1_Fem	0.000	-3	(-3, 3)			None
8	Wtlen_2_Fem	3.058	-3	(2, 4)			None
9	Mat50%_Fem	18.000	-3	(10, 30)			None
10	Mat_slope_Fem	-1.200	-3	(-3, 3)			None
11	Eggs/kg_inter_Fem	1.000	-3	(-3, 3)			None
12	Eggs/kg_slope_wt_Fem	0.000	-3	(-3, 3)			None
13	NatM_p_1_Mal_GP_1	0.000	-2	(-1, 1)			Normal (0, 99)
14	L_at_Amin_Mal_GP_1	0.000	-2	(-3, 3)			None
15	L_at_Amax_Mal_GP_1	-0.143	2	(-3, 3)	OK	0.024	None
16	VonBert_K_Mal_GP_1	-0.080	2	(-3, 3)	OK	0.144	None
17	CV_young_Mal_GP_1	1.318	3	(-3, 3)	OK	0.229	None
18	CV_old_Mal_GP_1	-0.495	3	(-3, 3)	OK	0.121	None
19	Wtlen_1_Mal	0.000	-5	(0, 1)			None
20	Wtlen_2_Mal	2.981	-5	(2, 4)			None
24	CohortGrowDev	1.000	-1	(1, 1)			None
25	FracFemale_GP_1	0.500	-4	(0.000001, 0.999999)			None
26	SR_LN(R0)	8.194	1	(0, 31)	OK	0.155	None
27	SR_BH_steep	0.718	-2	(0.21, 0.99)			Full_Beta (0.718, 0.158)
28	SR_sigmaR	0.600	-2	(0, 2)			None
29	SR_regime	0.000	-4	(-5, 5)			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)	-6.847	-1	(-15, 15)			None
107	Q_extraSD_RecPR(4)	0.012	4	(0.0001, 1)	OK	0.022	None
108	LnQ_base_RecPC(5)	-11.255	-1	(-15, 15)			None
109	Q_extraSD_RecPC(5)	0.258	4	(0.0001, 1)	OK	0.047	None
110	LnQ_base_RecDD(6)	-10.578	-1	(-15, 15)			None
111	Q_extraSD_RecDD(6)	0.067	4	(0.0001, 1)	OK	0.043	None
112	LnQ_base_Sanitation(7)	-10.614	-1	(-15, 15)			None
113	Q_extraSD_Sanitation(7)	0.217	4	(0.0001, 1)	OK	0.047	None
114	LnQ_base_NWFSCTrawl(8)	-1.086	-1	(-15, 15)			None
115	Q_extraSD_NWFSCTrawl(8)	0.253	4	(0.0001, 1)	OK	0.145	None
116	LnQ_base_SCBSurvey(11)	-11.143	-1	(-15, 15)			None
117	Q_extraSD_SCBSurvey(11)	0.159	4	(0.0001, 1)	OK	0.139	None
118	LnQ_base_RecPCOBR(12)	-10.209	-1	(-15, 15)			None
119	Q_extraSD_RecPCOBR(12)	0.136	4	(0.0001, 1)	OK	0.046	None
120	SizeSel_P1_ComHL(1)	24.436	5	(13, 44)	OK	1.166	None
121	SizeSel_P2_ComHL(1)	15.000	-3	(-10, 16)			None
122	SizeSel_P3_ComHL(1)	2.119	5	(-1, 10)	OK	0.619	None
123	SizeSel_P4_ComHL(1)	15.000	-3	(-1, 16)			None
124	SizeSel_P5_ComHL(1)	-15.537	5	(-25, -1)	OK	128.790	None
125	SizeSel_P6_ComHL(1)	10.000	-3	(-5, 11)			None
126	SizeSel_P1_ComNet(2)	44.000	-5	(13, 44)			None
127	SizeSel_P2_ComNet(2)	15.000	-3	(-10, 16)			None
128	SizeSel_P3_ComNet(2)	5.146	5	(-1, 10)	OK	0.234	None
129	SizeSel_P4_ComNet(2)	15.000	-3	(-1, 16)			None
130	SizeSel_P5_ComNet(2)	-16.400	5	(-25, -1)	OK	119.734	None
131	SizeSel_P6_ComNet(2)	10.000	-3	(-5, 11)			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_ComTrawl(3)	1.000	-2	(1, 45)			None
133	SizeSel_P2_ComTrawl(3)	45.000	-3	(1, 45)			None
134	SizeSel_P1_RecPR(4)	42.043	5	(13, 44)	OK	2.423	None
135	SizeSel_P2_RecPR(4)	15.000	-3	(-10, 16)			None
136	SizeSel_P3_RecPR(4)	4.572	5	(-1, 10)	OK	0.181	None
137	SizeSel_P4_RecPR(4)	15.000	-3	(-1, 16)			None
138	SizeSel_P5_RecPR(4)	-8.075	5	(-25, -1)	OK	0.792	None
139	SizeSel_P6_RecPR(4)	10.000	-3	(-5, 11)			None
140	SizeSel_P1_RecPC(5)	37.769	5	(13, 44)	OK	1.567	None
141	SizeSel_P2_RecPC(5)	15.000	-3	(-10, 16)			None
142	SizeSel_P3_RecPC(5)	4.609	5	(-1, 10)	OK	0.168	None
143	SizeSel_P4_RecPC(5)	15.000	-3	(-1, 16)			None
144	SizeSel_P5_RecPC(5)	-8.370	5	(-25, -1)	OK	2.026	None
145	SizeSel_P6_RecPC(5)	10.000	-3	(-5, 11)			None
146	SizeSel_P1_RecDD(6)	22.469	5	(13, 44)	OK	0.091	None
147	SizeSel_P2_RecDD(6)	-11.207	4	(-15, 16)	OK	57.911	None
148	SizeSel_P3_RecDD(6)	3.684	4	(-1, 10)	OK	0.490	None
149	SizeSel_P4_RecDD(6)	-10.915	4	(-20, 5)	OK	48.055	None
150	SizeSel_P5_RecDD(6)	-2.632	5	(-25, 3)	OK	0.390	None
151	SizeSel_P6_RecDD(6)	-2.583	4	(-5, 11)	OK	0.405	None
152	SizeSel_P1_Sanitation(7)	23.678	4	(13, 44)	OK	0.487	None
153	SizeSel_P2_Sanitation(7)	15.000	-3	(-10, 16)			None
154	SizeSel_P3_Sanitation(7)	3.005	4	(-1, 10)	OK	0.158	None
155	SizeSel_P4_Sanitation(7)	15.000	-3	(-1, 16)			None
156	SizeSel_P5_Sanitation(7)	-4.582	4	(-25, 5)	OK	0.606	None
157	SizeSel_P6_Sanitation(7)	10.000	-3	(-5, 11)			None
158	SizeSel_P1_NWFSCTrawl(8)	23.098	4	(13, 44)	OK	2.213	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_P2_NWFSCTrawl(8)	15.000	-3	(-10, 16)			None
160	SizeSel_P3_NWFSCTrawl(8)	3.443	4	(-1, 10)	OK	0.616	None
161	SizeSel_P4_NWFSCTrawl(8)	15.000	-3	(-1, 16)			None
162	SizeSel_P5_NWFSCTrawl(8)	-12.730	4	(-25, 5)	OK	169.330	None
163	SizeSel_P6_NWFSCTrawl(8)	10.000	-3	(-5, 11)			None
164	SizeSel_P1_GillnetSurvey(9)	1.000	-2	(1, 45)			None
165	SizeSel_P2_GillnetSurvey(9)	45.000	-3	(1, 45)			None
166	SizeSel_P1_Impingement(10)	18.012	-3	(13, 44)			None
167	SizeSel_P2_Impingement(10)	-5.928	4	(-15, 16)	OK	27.411	None
168	SizeSel_P3_Impingement(10)	2.137	-4	(-1, 10)			None
169	SizeSel_P4_Impingement(10)	2.701	4	(-20, 5)	OK	1.173	None
170	SizeSel_P5_Impingement(10)	8.275	-3	(-25, 10)			None
171	SizeSel_P6_Impingement(10)	-0.611	4	(-5, 11)	OK	0.476	None
172	SizeSel_P1_SCBSurvey(11)	1.000	-2	(1, 45)			None
173	SizeSel_P2_SCBSurvey(11)	45.000	-3	(1, 45)			None
174	SizeSel_P1_RecPCOBR(12)	1.000	-2	(1, 45)			None
175	SizeSel_P2_RecPCOBR(12)	45.000	-3	(1, 45)			None
176	SizeSel_P1_ComHL(1)_BLK1repl_1999	28.427	6	(13, 44)	OK	0.583	None
177	SizeSel_P3_ComHL(1)_BLK1repl_1999	2.029	6	(-1, 10)	OK	0.301	None
178	SizeSel_P1_ComNet(2)_BLK1repl_1999	44.000	-6	(13, 44)			None
179	SizeSel_P3_ComNet(2)_BLK1repl_1999	4.203	6	(-1, 10)	OK	0.145	None
180	SizeSel_P1_RecPR(4)_BLK2repl_2000	36.672	6	(13, 44)	OK	1.143	None
181	SizeSel_P1_RecPR(4)_BLK2repl_2006	35.765	6	(13, 44)	OK	0.727	None
182	SizeSel_P3_RecPR(4)_BLK2repl_2000	3.616	6	(-1, 10)	OK	0.183	None
183	SizeSel_P3_RecPR(4)_BLK2repl_2006	3.462	6	(-1, 10)	OK	0.122	None
184	SizeSel_P1_RecPC(5)_BLK2repl_2000	32.756	6	(13, 44)	OK	1.481	None
185	SizeSel_P1_RecPC(5)_BLK2repl_2006	26.999	6	(13, 44)	OK	0.484	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)
186	SizeSel_P3_RecPC(5)_BLK2repl_2000	3.270	6	(-1, 10)	OK	0.403	None
187	SizeSel_P3_RecPC(5)_BLK2repl_2006	1.161	6	(-1, 10)	OK	0.410	None
188	SizeSel_P1_RecDD(6)_BLK2repl_2000	44.000	-6	(13, 44)			None
189	SizeSel_P1_RecDD(6)_BLK2repl_2006	24.513	6	(13, 44)	OK	0.044	None
190	SizeSel_P3_RecDD(6)_BLK2repl_2000	5.535	6	(-1, 10)	OK	0.166	None
191	SizeSel_P3_RecDD(6)_BLK2repl_2006	2.154	6	(-1, 10)	OK	0.312	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
Parmeter soft bounds	0.01

Table 44: Time-series of population estimates from the base-case model. Relative exploitation rate is $(1 - SPR)/(1 - SPR_{50\%})$.

Year	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1916	2922	1624	0.000	3620	4	0.00	0.99
1917	2919	1622	0.999	3619	8	0.00	0.98
1918	2912	1618	0.996	3618	13	0.00	0.97
1919	2903	1612	0.992	3617	12	0.00	0.98
1920	2895	1607	0.989	3616	16	0.01	0.97
1921	2885	1600	0.985	3614	26	0.01	0.95
1922	2867	1588	0.978	3612	19	0.01	0.96
1923	2859	1583	0.974	3610	27	0.01	0.95
1924	2844	1573	0.968	3608	49	0.02	0.90
1925	2813	1552	0.956	3603	101	0.04	0.82
1926	2741	1505	0.927	3592	49	0.02	0.90
1927	2724	1494	0.920	3589	51	0.02	0.90
1928	2709	1484	0.913	3586	44	0.02	0.91
1929	2702	1480	0.911	3585	50	0.02	0.90
1930	2692	1473	0.907	3584	41	0.02	0.91
1931	2691	1472	0.906	3583	43	0.02	0.91
1932	2688	1471	0.905	3583	41	0.02	0.91
1933	2688	1470	0.905	3583	32	0.01	0.93
1934	2696	1476	0.908	3584	34	0.01	0.93
1935	2702	1479	0.911	3585	35	0.01	0.93
1936	2705	1482	0.912	3586	55	0.02	0.89
1937	2692	1472	0.906	3583	66	0.02	0.87
1938	2670	1458	0.898	3580	76	0.03	0.85
1939	2642	1440	0.886	3575	63	0.02	0.87
1940	2630	1432	0.881	3573	59	0.02	0.88
1941	2622	1427	0.878	3571	43	0.02	0.91
1942	2630	1432	0.882	3573	20	0.01	0.96
1943	2657	1450	0.892	3578	16	0.01	0.96
1944	2683	1467	0.903	3582	24	0.01	0.95
1945	2699	1478	0.910	3585	42	0.02	0.91
1946	2697	1477	0.909	3585	66	0.02	0.87
1947	2675	1462	0.900	3581	74	0.03	0.85
1948	2649	1444	0.889	3576	107	0.04	0.80
1949	2600	1410	0.868	3567	93	0.04	0.82
1950	2570	1389	0.855	3561	97	0.04	0.81
1951	2541	1369	0.843	3555	67	0.03	0.86
1952	2542	1369	0.843	3555	61	0.02	0.87
1953	2548	1373	0.845	3556	73	0.03	0.85

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Table 44: Time-series of population estimates from the base-case model. Relative exploitation rate is $(1 - SPR)/(1 - SPR_{50\%})$.

Year	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1954	2542	1370	0.843	3555	84	0.03	0.83
1955	2529	1361	0.838	3552	67	0.03	0.86
1956	2531	1362	0.839	3553	63	0.02	0.87
1957	2537	1367	0.841	3554	43	0.02	0.91
1958	2559	1381	0.850	3558	39	0.02	0.91
1959	2581	1396	0.860	3563	25	0.01	0.94
1960	2611	1417	0.872	3569	24	0.01	0.95
1961	2639	1436	0.884	3574	31	0.01	0.93
1962	2658	1447	0.891	3577	50	0.02	0.90
1963	2658	1447	0.891	3577	72	0.03	0.86
1964	2639	1433	0.882	3573	87	0.03	0.83
1965	2611	1412	0.869	3567	85	0.03	0.83
1966	2589	1396	0.859	2782	89	0.03	0.83
1967	2544	1380	0.849	2805	73	0.03	0.85
1968	2497	1366	0.841	2684	87	0.03	0.83
1969	2420	1325	0.816	2579	84	0.03	0.83
1970	2336	1279	0.787	2361	103	0.04	0.80
1971	2227	1217	0.749	1941	91	0.04	0.81
1972	2117	1160	0.714	1758	82	0.04	0.82
1973	2000	1102	0.678	1672	95	0.05	0.79
1974	1865	1026	0.632	2031	122	0.07	0.73
1975	1719	931	0.573	6549	128	0.07	0.71
1976	1717	842	0.518	5453	66	0.04	0.81
1977	1878	859	0.529	6529	87	0.05	0.77
1978	2127	983	0.605	3528	62	0.03	0.82
1979	2371	1159	0.714	1828	100	0.04	0.76
1980	2479	1309	0.806	1373	124	0.05	0.74
1981	2442	1349	0.830	1443	110	0.04	0.77
1982	2323	1302	0.802	2018	112	0.05	0.77
1983	2161	1201	0.739	3088	61	0.03	0.86
1984	2064	1117	0.688	7618	70	0.03	0.84
1985	2126	1050	0.647	9970	86	0.04	0.81
1986	2400	1068	0.658	3500	76	0.03	0.82
1987	2678	1264	0.778	1796	69	0.03	0.84
1988	2844	1510	0.930	1645	201	0.07	0.67
1989	2766	1528	0.940	1462	163	0.06	0.72
1990	2603	1456	0.896	1695	228	0.09	0.67
1991	2331	1288	0.793	5899	241	0.10	0.65

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Table 44: Time-series of population estimates from the base-case model. Relative exploitation rate is $(1 - SPR)/(1 - SPR_{50\%})$.

Year	Total biomass (mt)	Spawning biomass (mt)	Depletion	Age-0 recruits	Total catch (mt)	Relative exploitation rate	SPR
1992	2155	1097	0.675	6399	115	0.05	0.76
1993	2215	1038	0.639	7882	95	0.04	0.79
1994	2445	1117	0.687	5072	156	0.06	0.69
1995	2651	1248	0.768	3072	133	0.05	0.73
1996	2805	1426	0.878	6491	136	0.05	0.74
1997	2957	1520	0.935	4313	142	0.05	0.75
1998	3053	1561	0.961	4950	161	0.05	0.74
1999	3107	1613	0.993	4597	225	0.07	0.69
2000	3087	1593	0.981	2975	169	0.05	0.74
2001	3057	1601	0.986	3680	199	0.07	0.72
2002	2969	1564	0.963	2267	128	0.04	0.79
2003	2876	1529	0.941	1965	105	0.04	0.82
2004	2743	1488	0.916	2040	57	0.02	0.89
2005	2608	1430	0.880	3742	89	0.03	0.84
2006	2480	1329	0.818	2391	150	0.06	0.76
2007	2306	1213	0.747	2285	140	0.06	0.75
2008	2157	1144	0.705	2288	104	0.05	0.79
2009	2048	1090	0.671	2589	113	0.06	0.76
2010	1949	1029	0.634	2484	106	0.05	0.77
2011	1870	980	0.603	1179	105	0.06	0.76
2012	1769	944	0.581	1112	120	0.07	0.72
2013	1631	890	0.548	3747	115	0.07	0.72
2014	1557	810	0.499	3529	124	0.08	0.69
2015	1535	746	0.459	7586	84	0.05	0.75
2016	1713	775	0.477	3268	74	0.04	0.77
2017	1915	882	0.543	3344			

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	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
lnR0	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	0.59	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	113.00	114.00	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
Equililibrium 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 Impingement data	Drop Impingement data and est. one M	Drop Impingement data and est. one M and h	Drop Impingement data and est. M
Female natural mortality	0.26	0.26	0.26	0.26	0.26	0.26	0.26	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
lnR0	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
Equililibrium 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	2006-2016	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. The base model includes all of the data. Retro1 removes the last year of data (2016), Retro2 removes the last two years of data, Retro3 removes three years and Retro4 removes four years.

Label	Base	Retro1	Retro2	Retro3	Retro4
Female natural mortality	0.26	0.26	0.26	0.26	0.26
Steepness	0.72	0.72	0.72	0.72	0.72
lnR0	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
Equililibrium 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 (lnR0) 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
lnR0	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	9753570000000.00
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	274.712	79.030	1915.220	882.457	0.543
2018	310.882	79.030	2090.750	1055.040	0.649
2019	360.718	337.391	2223.110	1154.730	0.711
2020	349.351	326.810	2114.540	1073.030	0.661
2021	328.699	307.516	2004.000	991.437	0.610
2022	308.514	288.623	1908.890	926.191	0.570
2023	292.375	273.507	1833.970	878.827	0.541
2024	280.243	262.140	1776.960	845.442	0.520
2025	271.216	253.683	1733.920	821.710	0.506
2026	264.456	247.349	1701.300	804.465	0.495
2027	259.341	242.558	1676.440	791.670	0.487
2028	255.439	238.903	1657.390	782.044	0.481

8 Figures

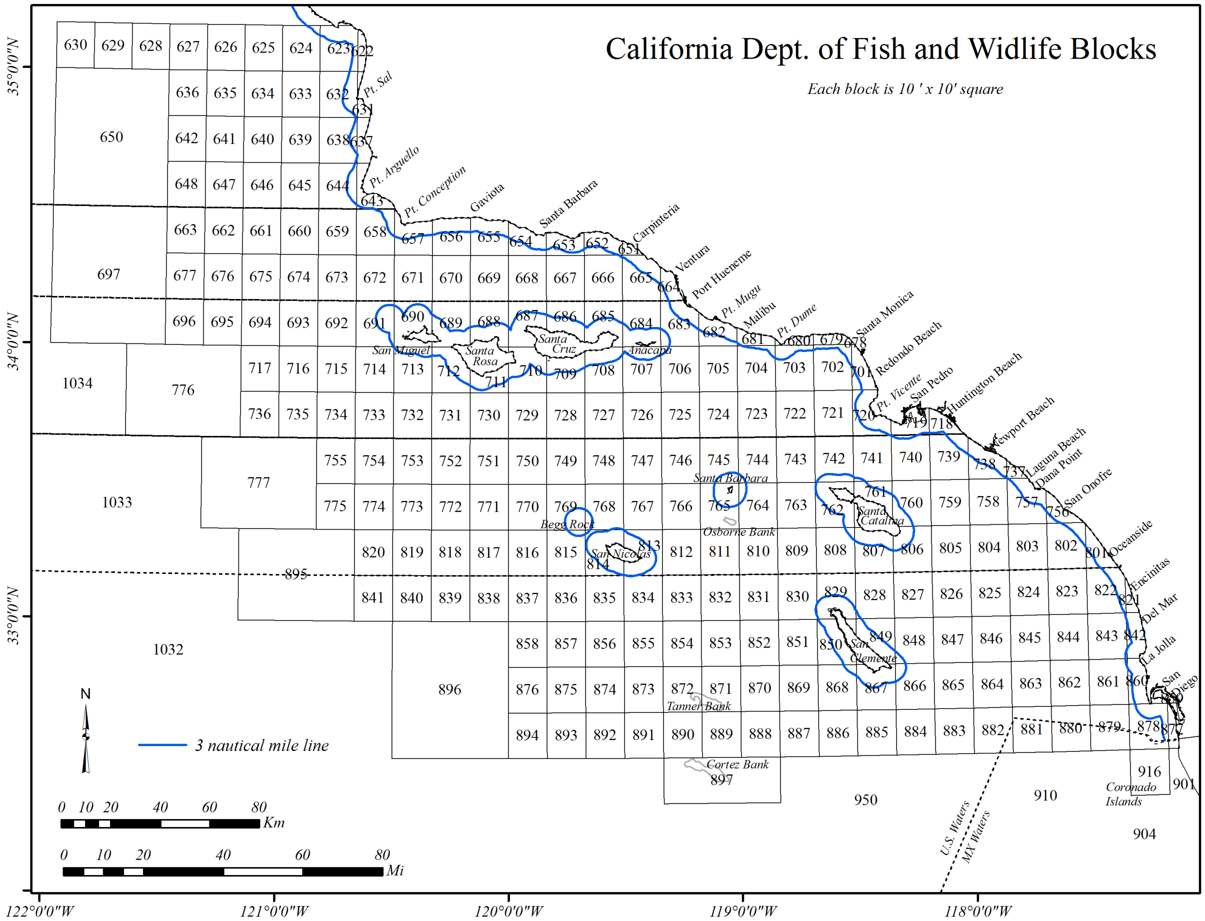


Figure 1: Map showing the state boundary lines for management of the recreational fishing fleets

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.

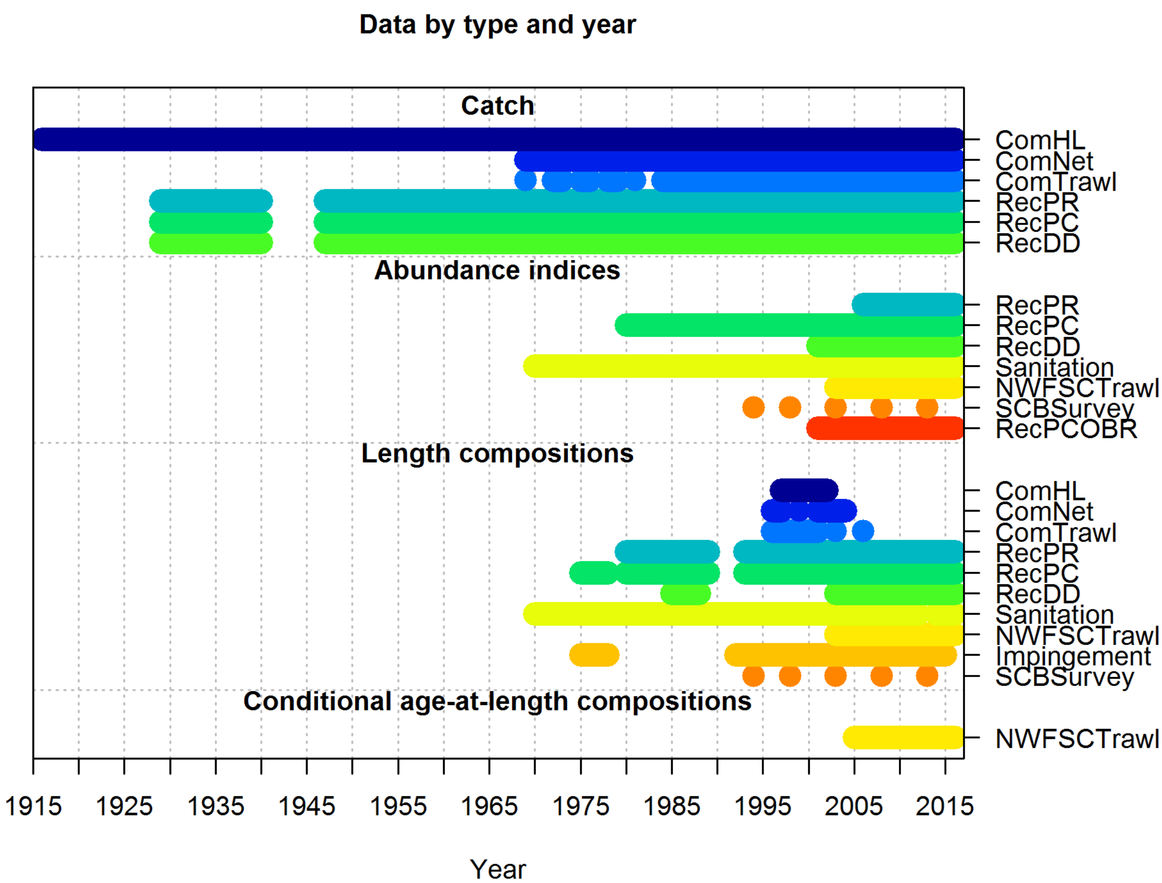


Figure 3: Summary of data sources used in the base model.

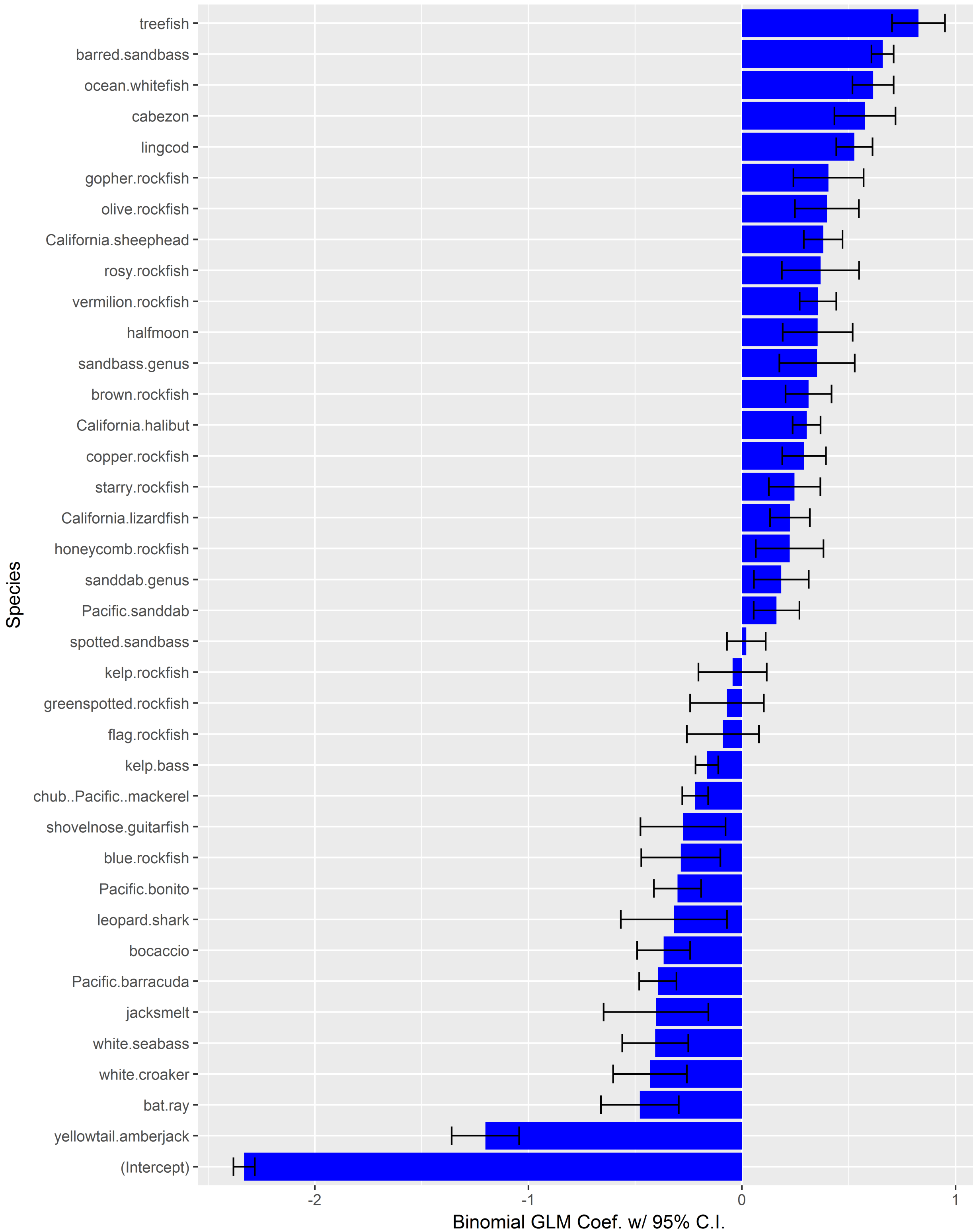


Figure 4: Species coefficients from the binomial GLM for presence/absence of California scorpionfish in the Marine Recreational Fisheries Statistics Survey (MRFSS) private mode dockside survey data set. Horizontal bars are 95% confidence intervals.

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1999	open	open	open	open	open	open	open	open	open	open	open	open
2000	open	open	open	open	open	open	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.

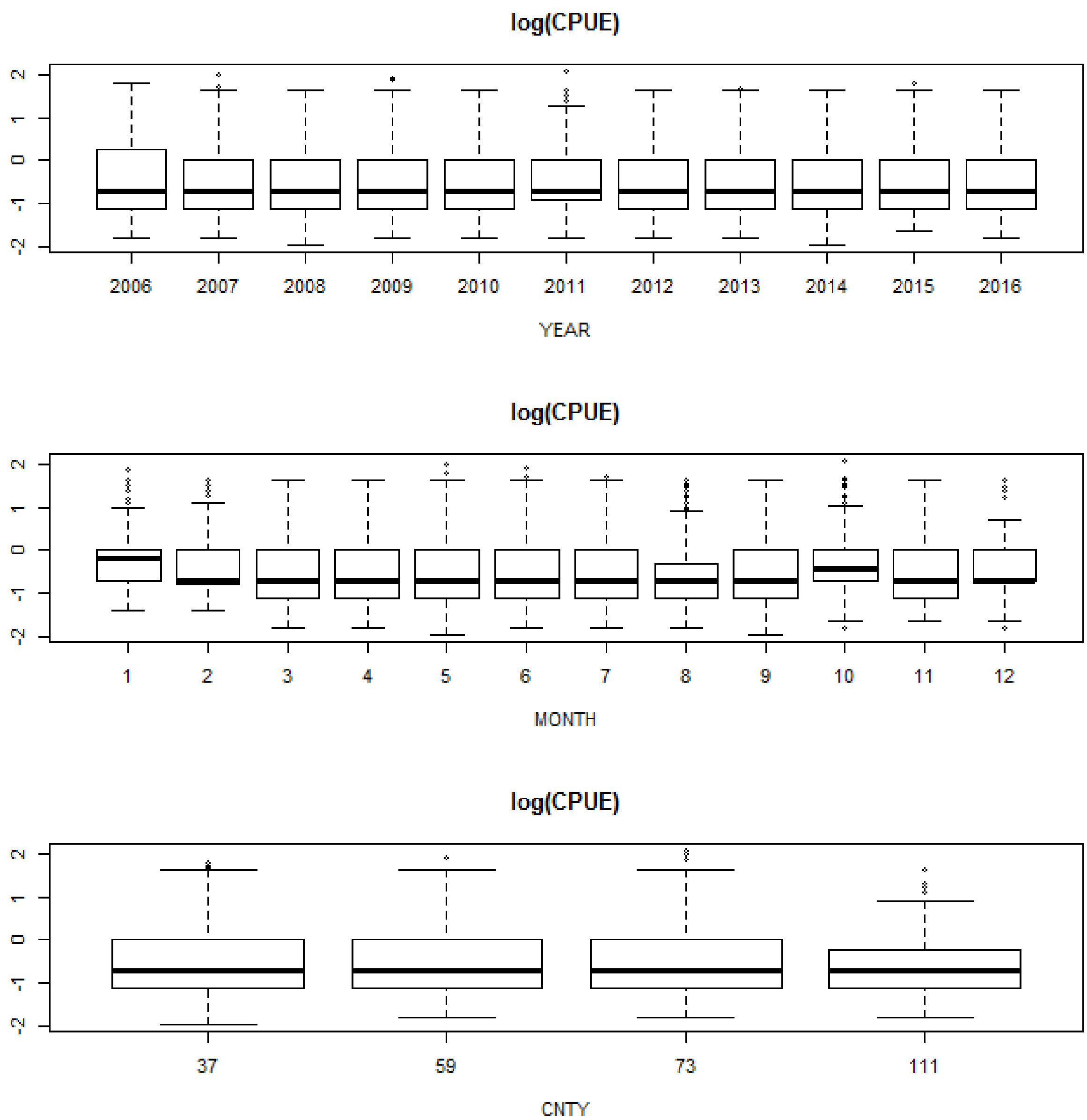


Figure 6: Boxplots of the raw log CPUE by year for each of the three factors considered in the deltaGLM model, county, month and year.

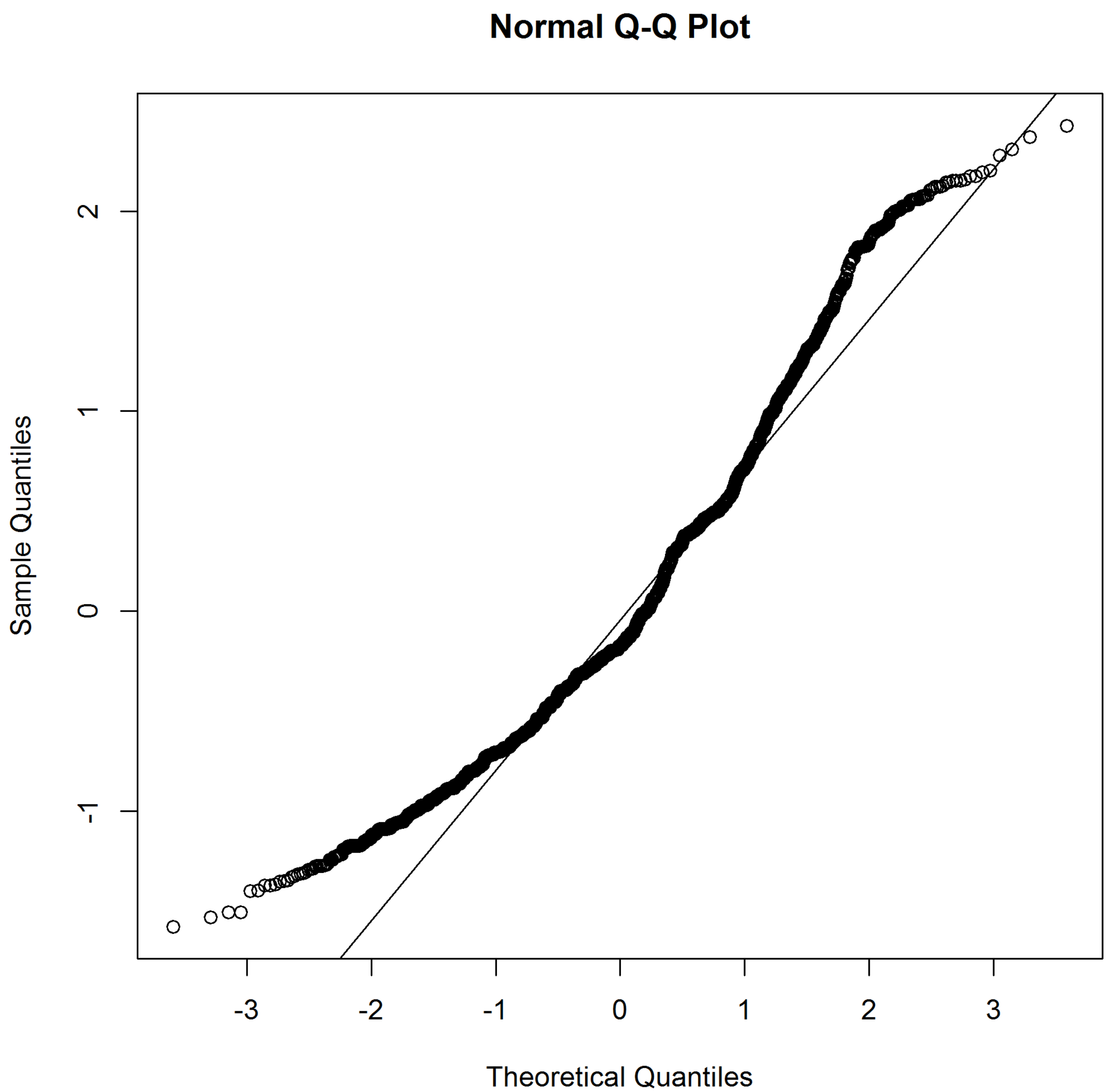


Figure 7: Q-Q plot used to evaluate the fit of the lognormal (positive encounters) of California scorpionfish from the California Recreational Fisheries Statistics Survey (CRFS) private mode dockside survey data set.

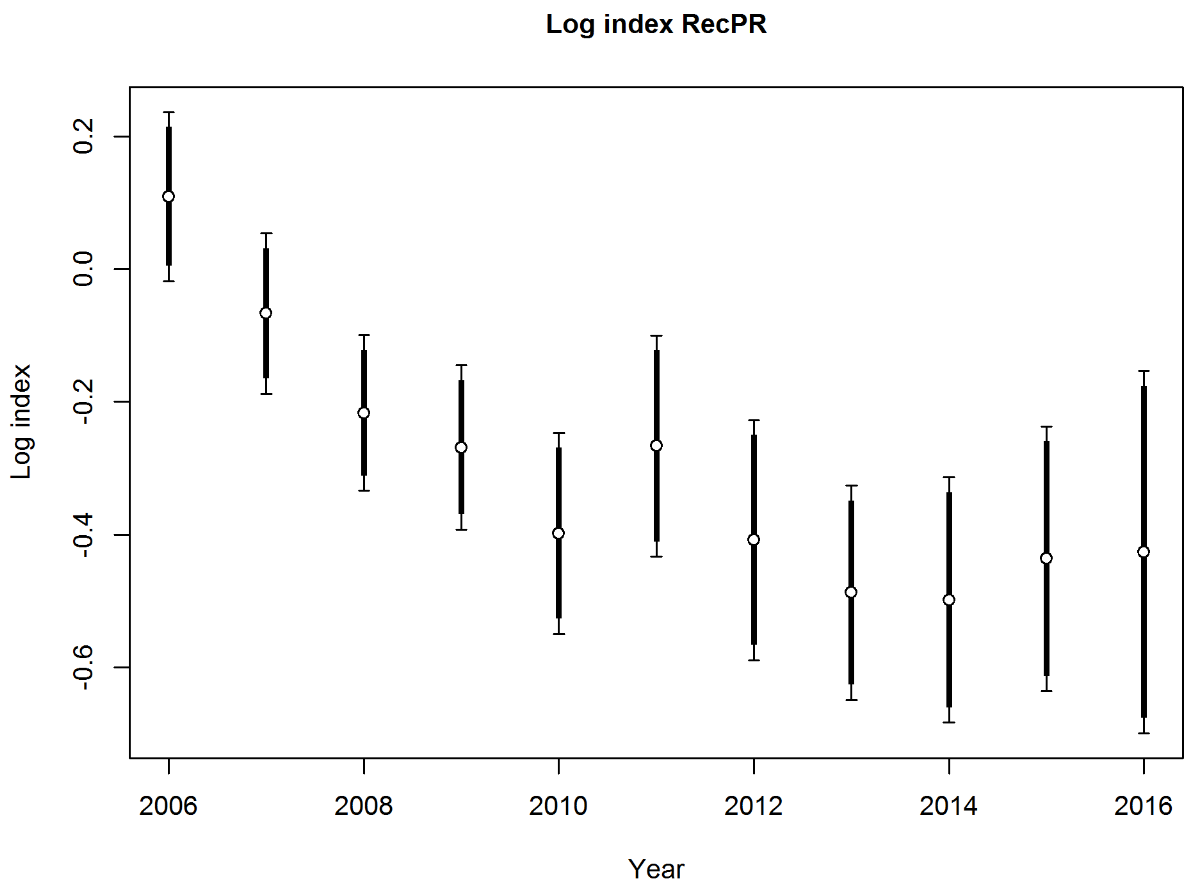


Figure 8: Standardized index on log scale for the recreational private mode dockside survey data set. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

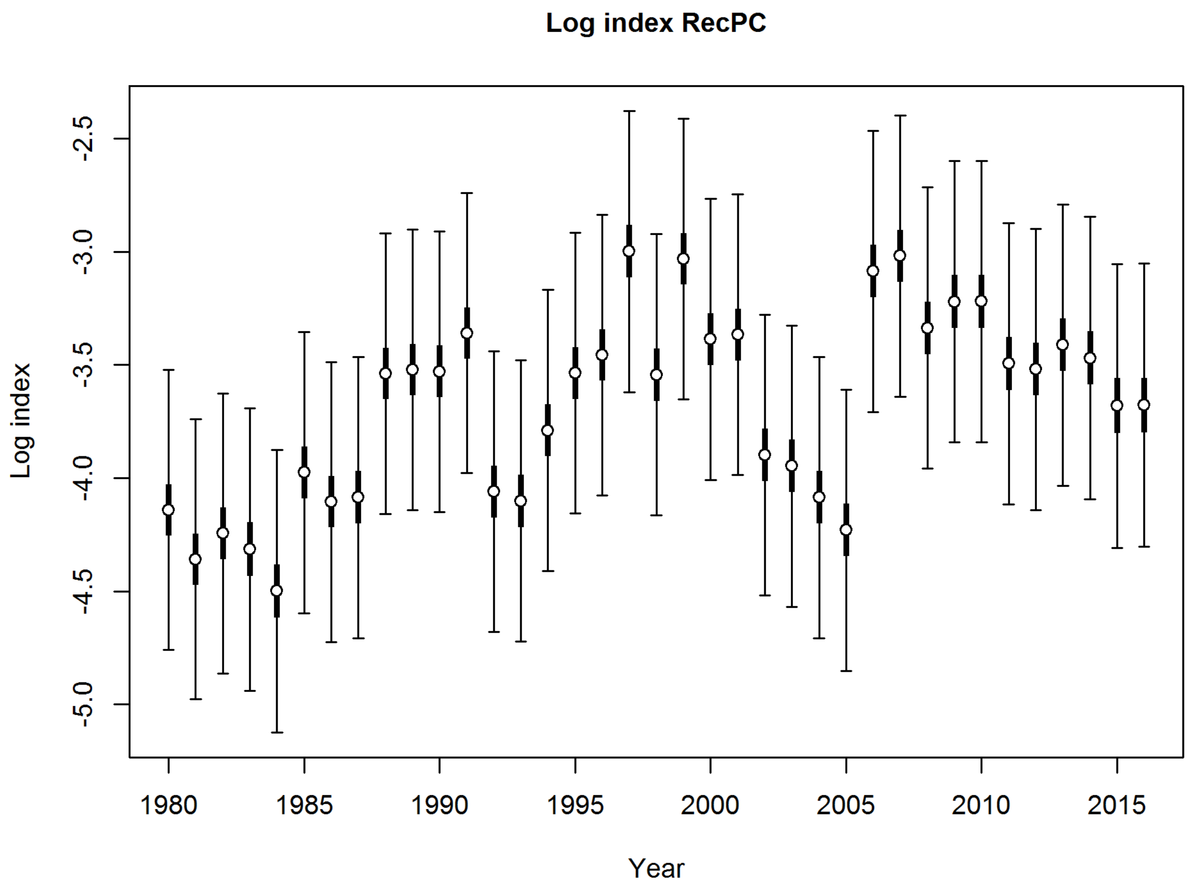


Figure 9: Standardized index on the log scale for the recreational CPFV logbook retained catches. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

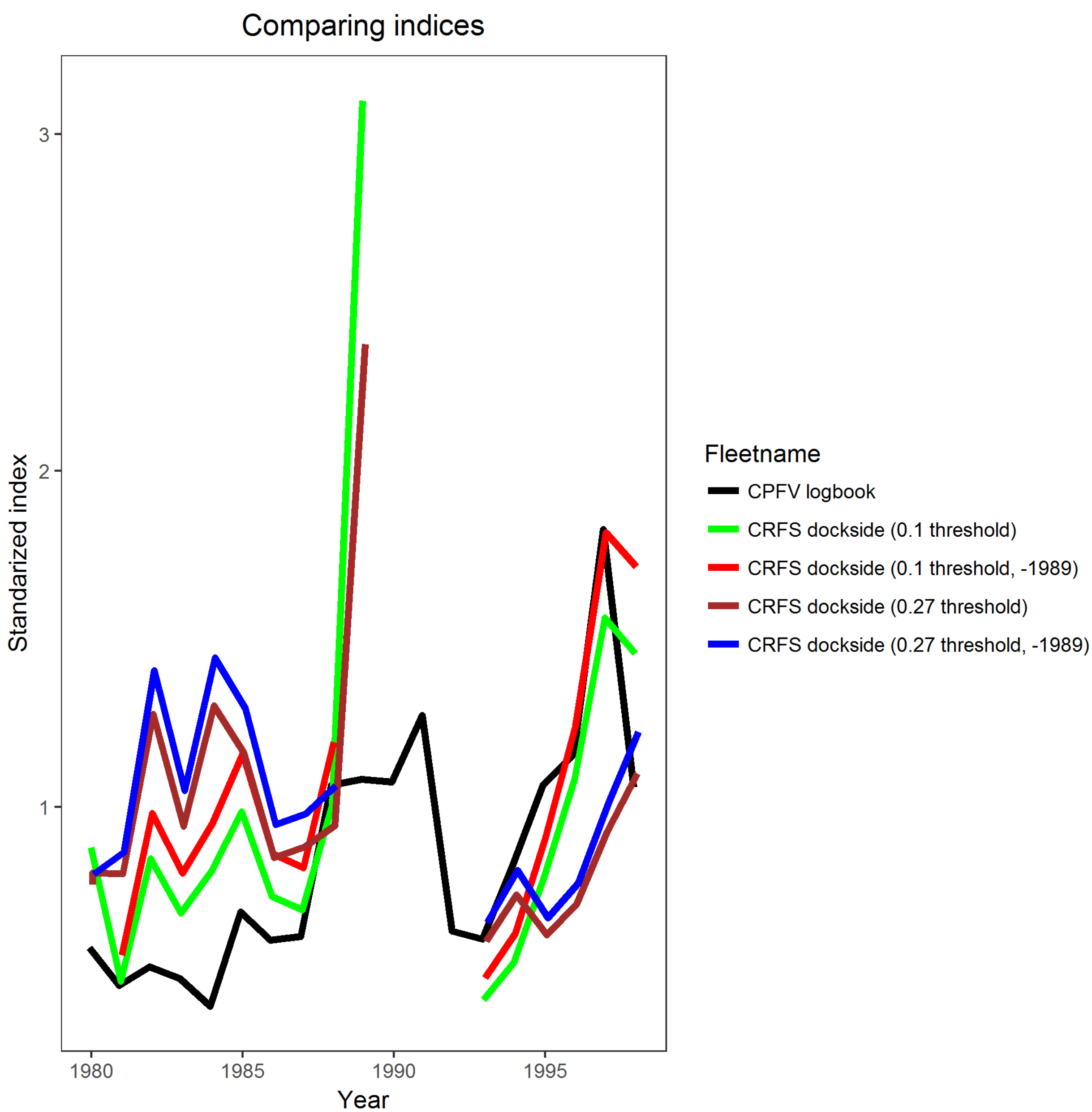


Figure 10: Comparison of standardized indices using two different threshold levels (0.27 and 0.1) from the Stephens-MacCall filtering, and including or excluding the year 1989.

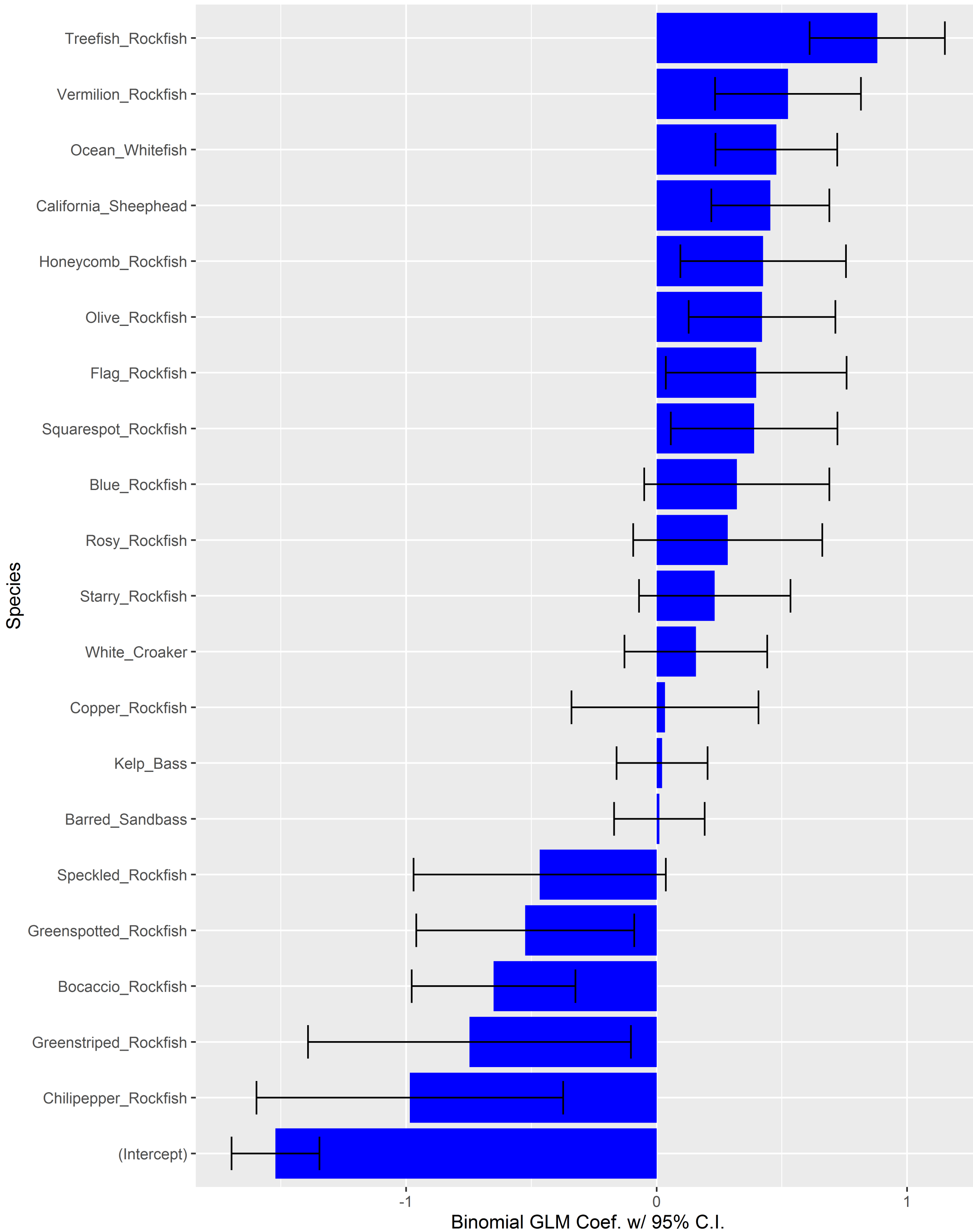


Figure 11: Species coefficients from the binomial GLM for presence/absence of California scorpionfish in the Marine Recreational Fisheries Statistics Survey (MRFSS) party/charter mode dockside survey data set. Horizontal bars are 95% confidence intervals.

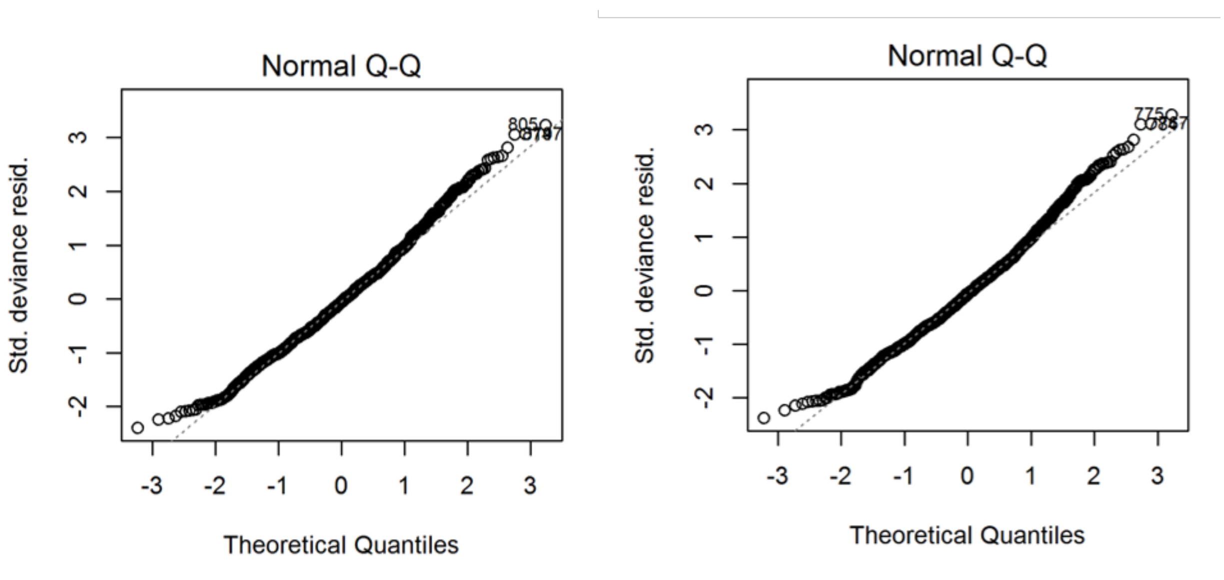


Figure 12: Q-Q plot used to validate the goodness of fit of the lognormal portion (positive catch) of the Marine Recreational Fisheries Statistics Survey (MRFSS) party/charter dockside survey, for thresholds of 0.27 (left) and 0.10 (right) from the Stephens-MacCall filter.

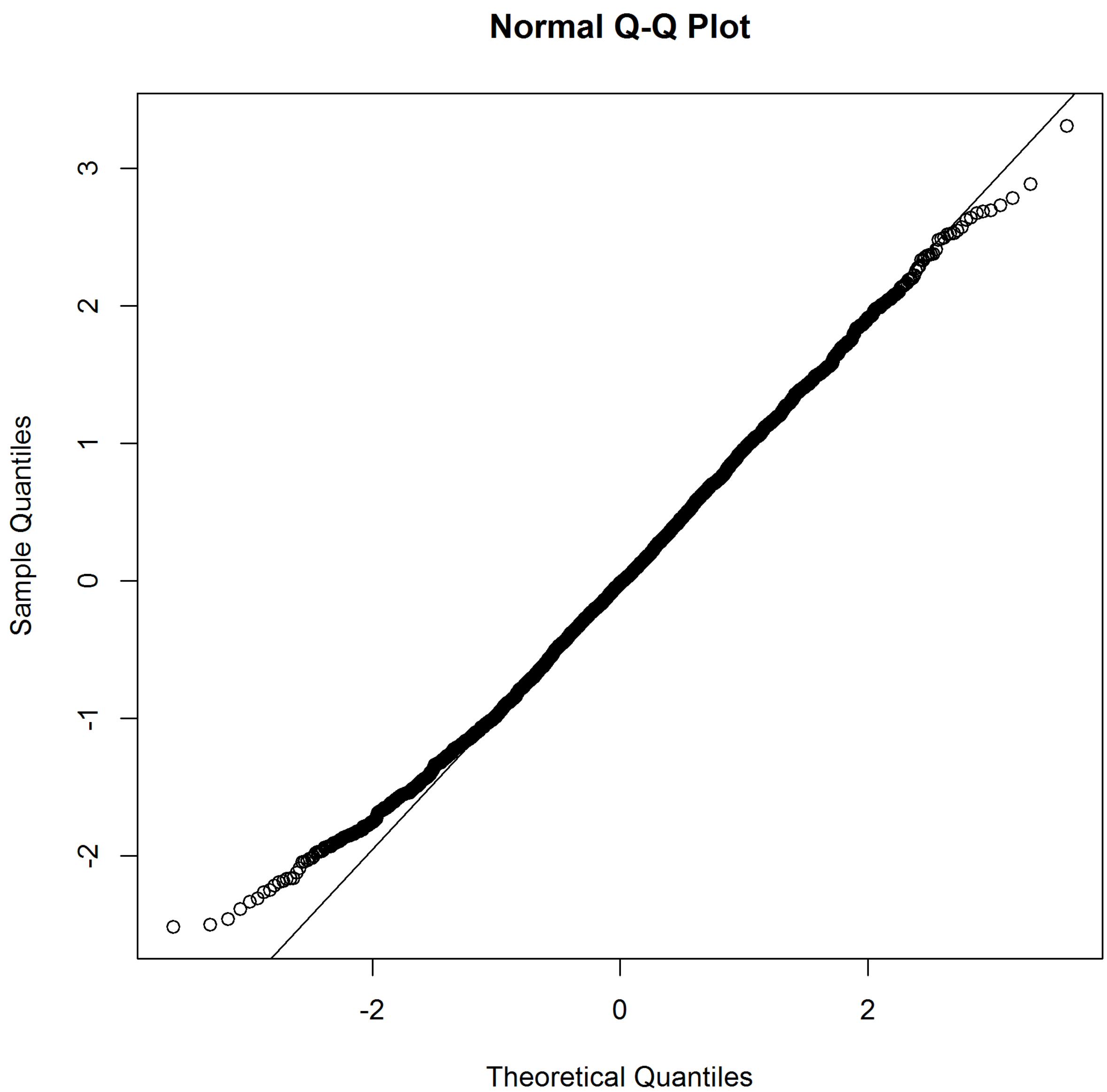


Figure 13: Q-Q plot used to validate the goodness of fit of the lognormal model for the CPFV onboard observer discarded only catch.

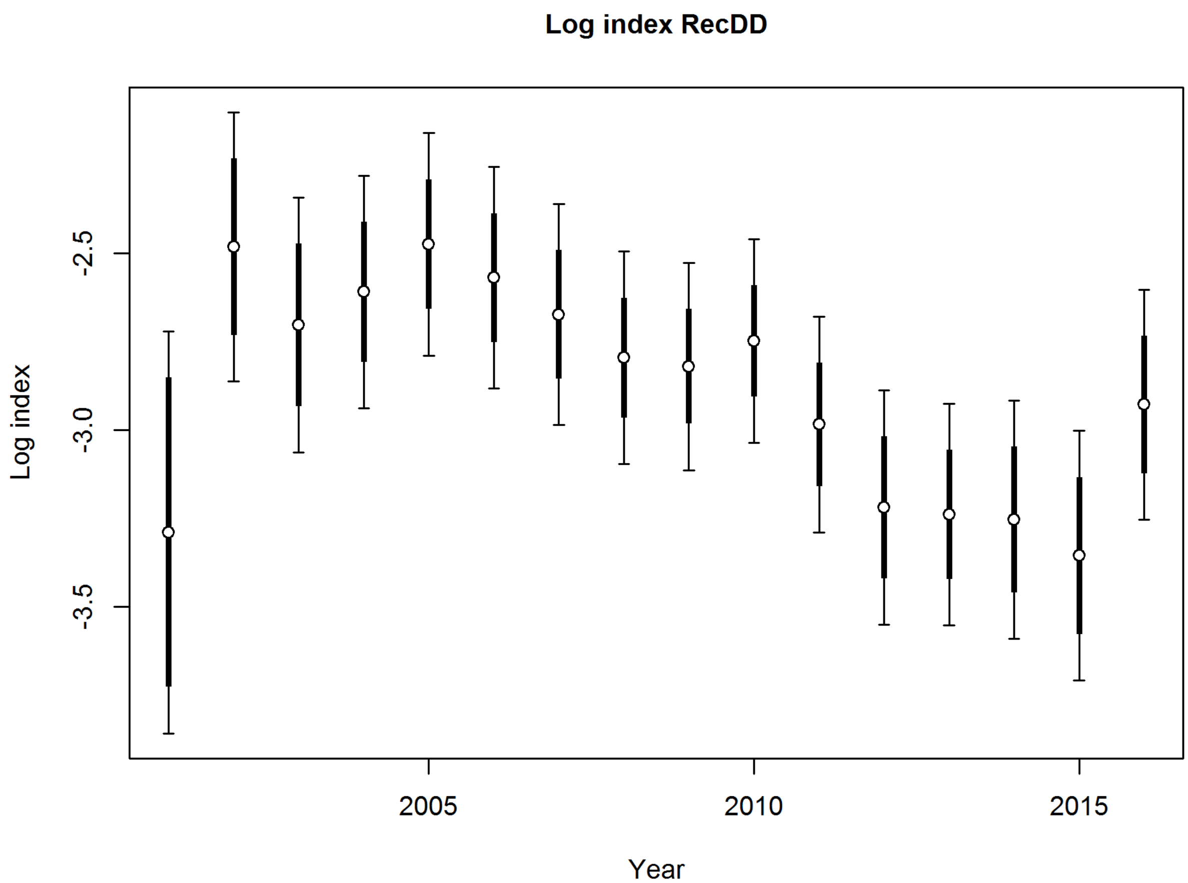


Figure 14: Standardized index on the log scale for the recreational CPFV onboard observer discarded catch index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

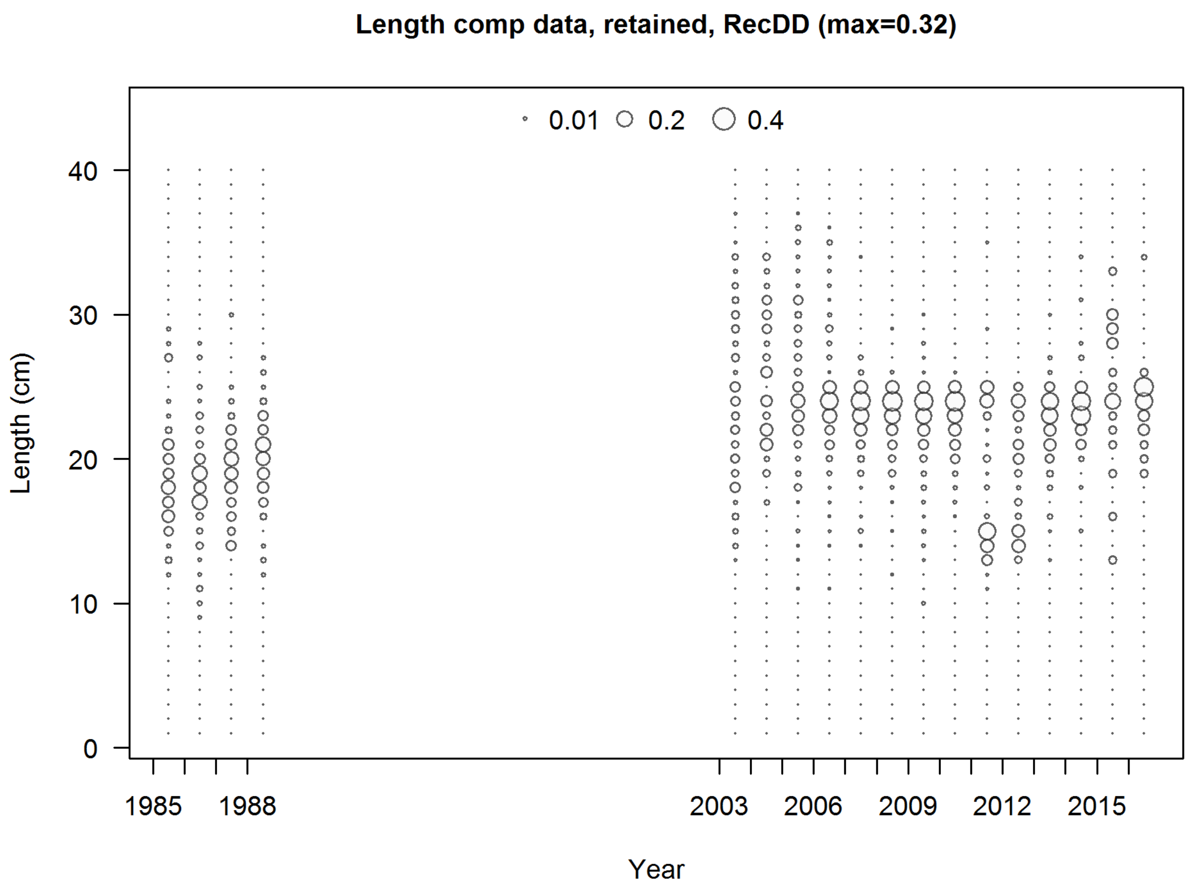


Figure 15: Length frequency distributions from the onboard observer discard-only catch.

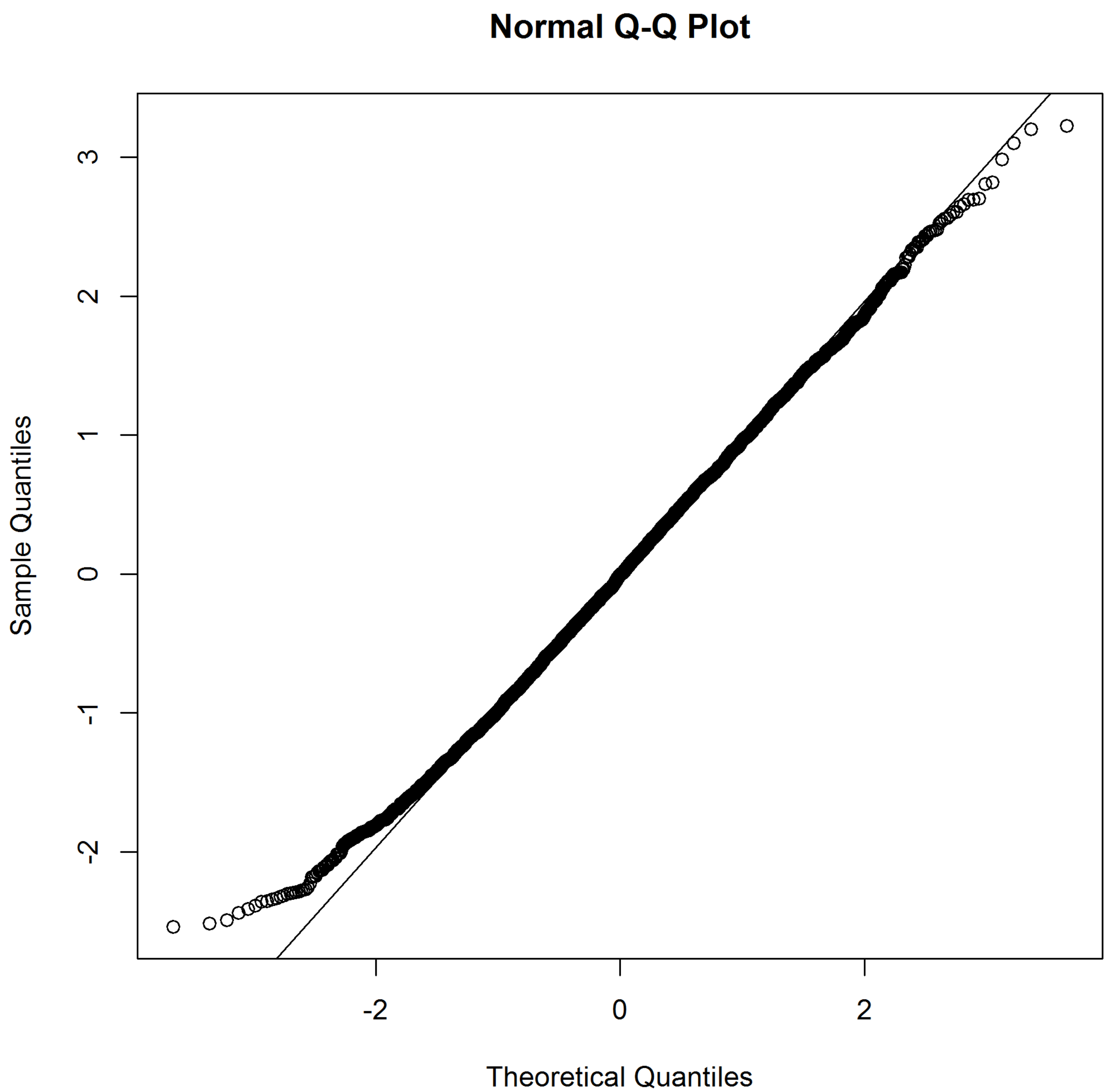


Figure 16: Q-Q plot used to validate the goodness of fit of the lognormal model for the CPFV onboard observer retained only catch.

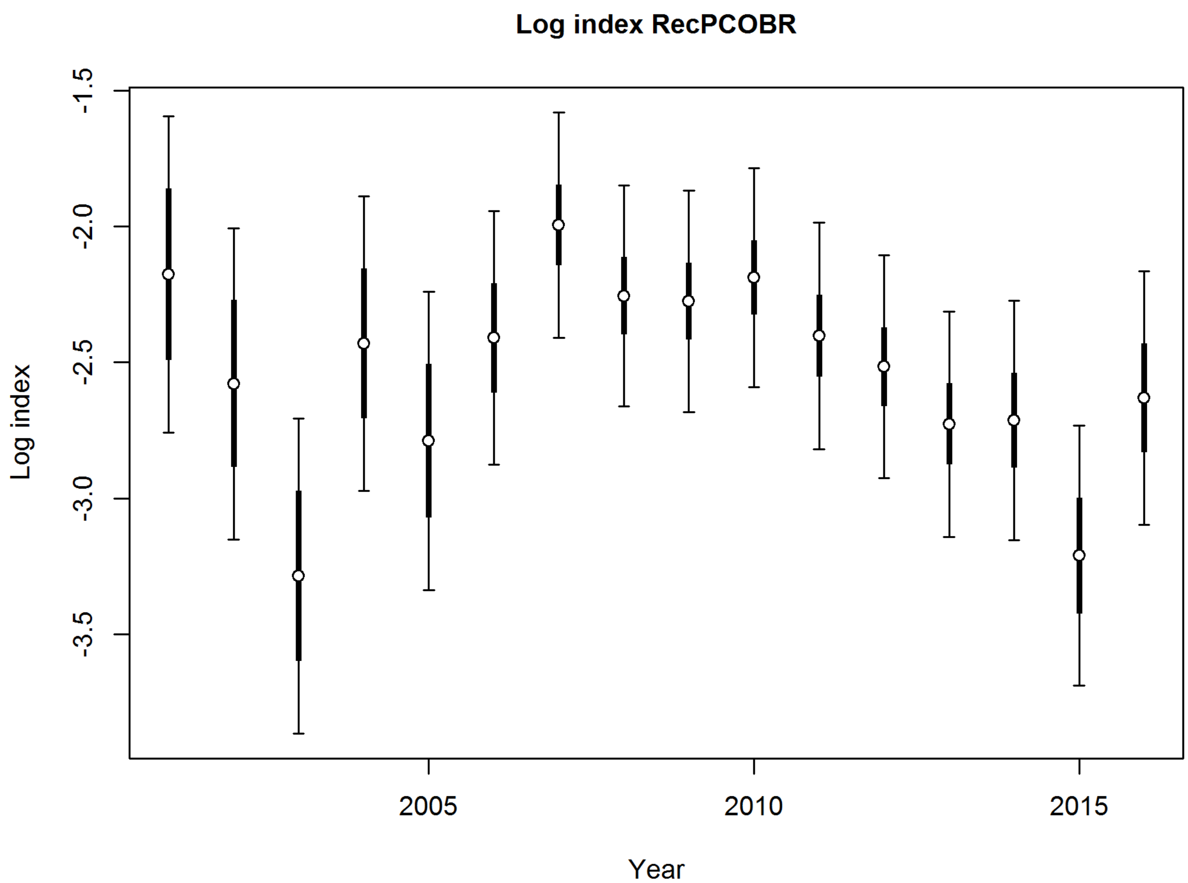


Figure 17: Standardized index on the log scale for the recreational CPFV onboard observer retained catch index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

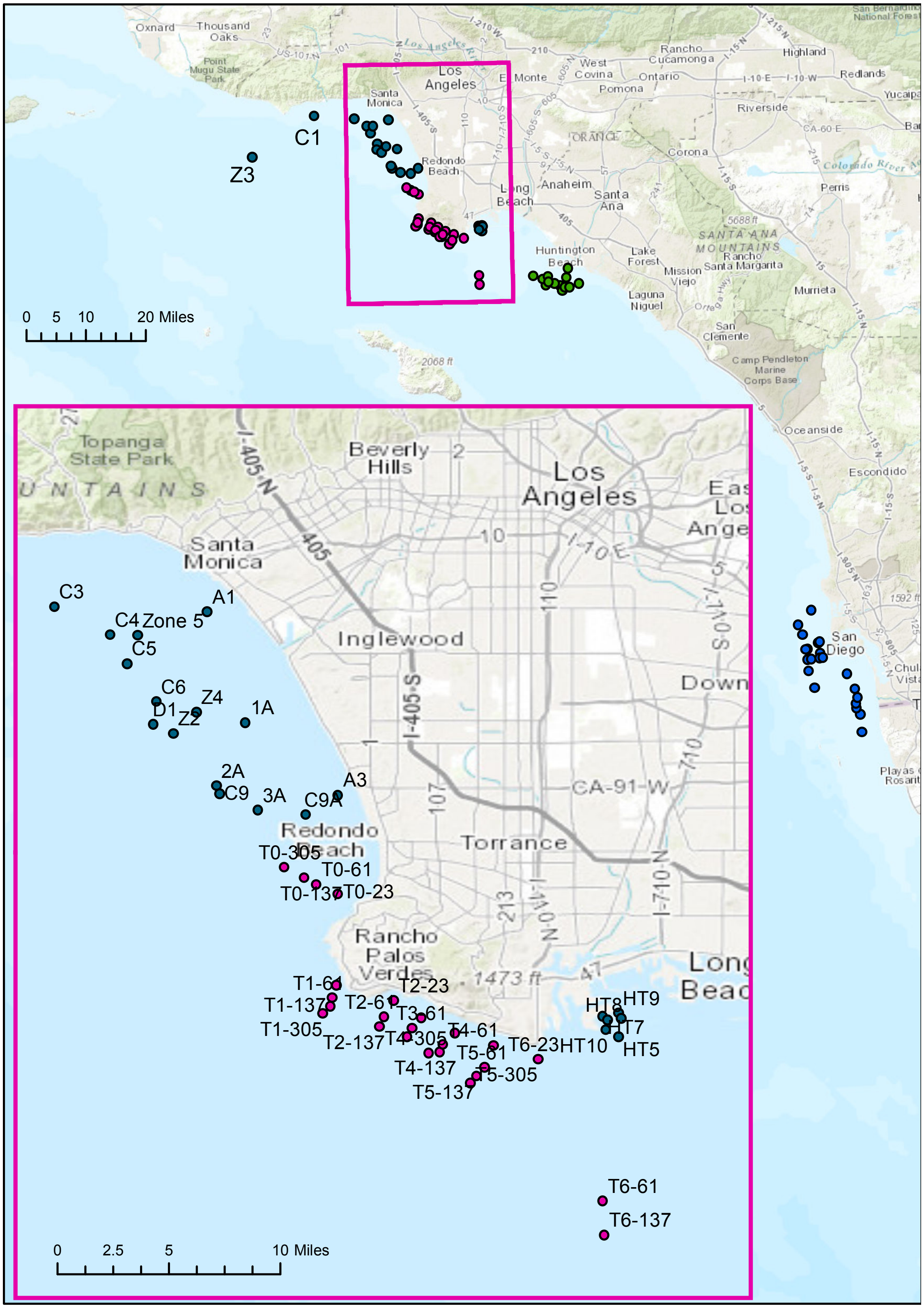


Figure 18: Map of stations sampled in at least 5 years by the Sanitation Districts of Los Angeles County (magenta) and the City of Los Angeles Environmental Monitoring Division (blue)

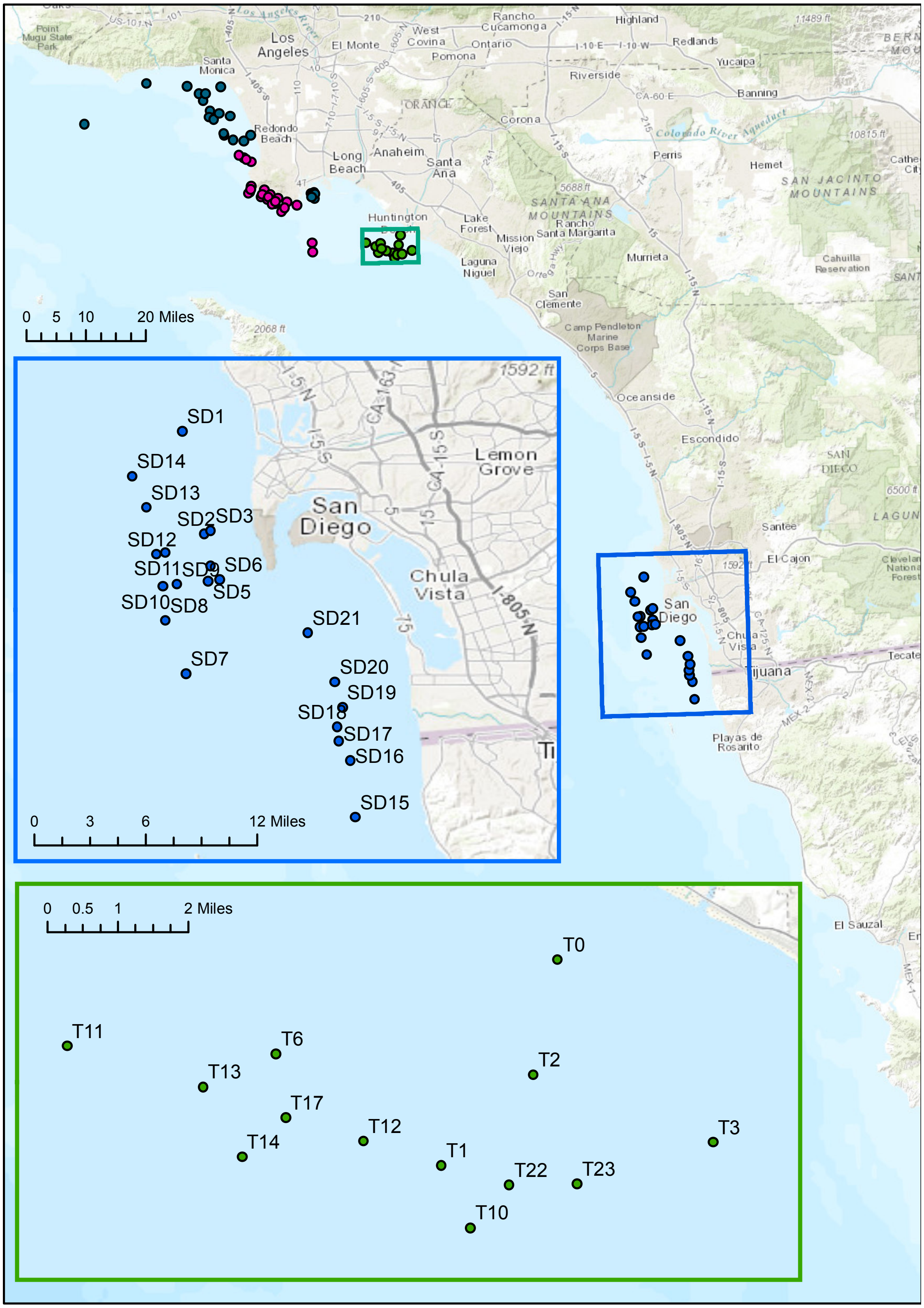


Figure 19: Map of stations sampled in at least 5 years by the Orange County Sanitation District (green) and the City of San Diego Public Utilities Ocean Monitoring Program (blue)

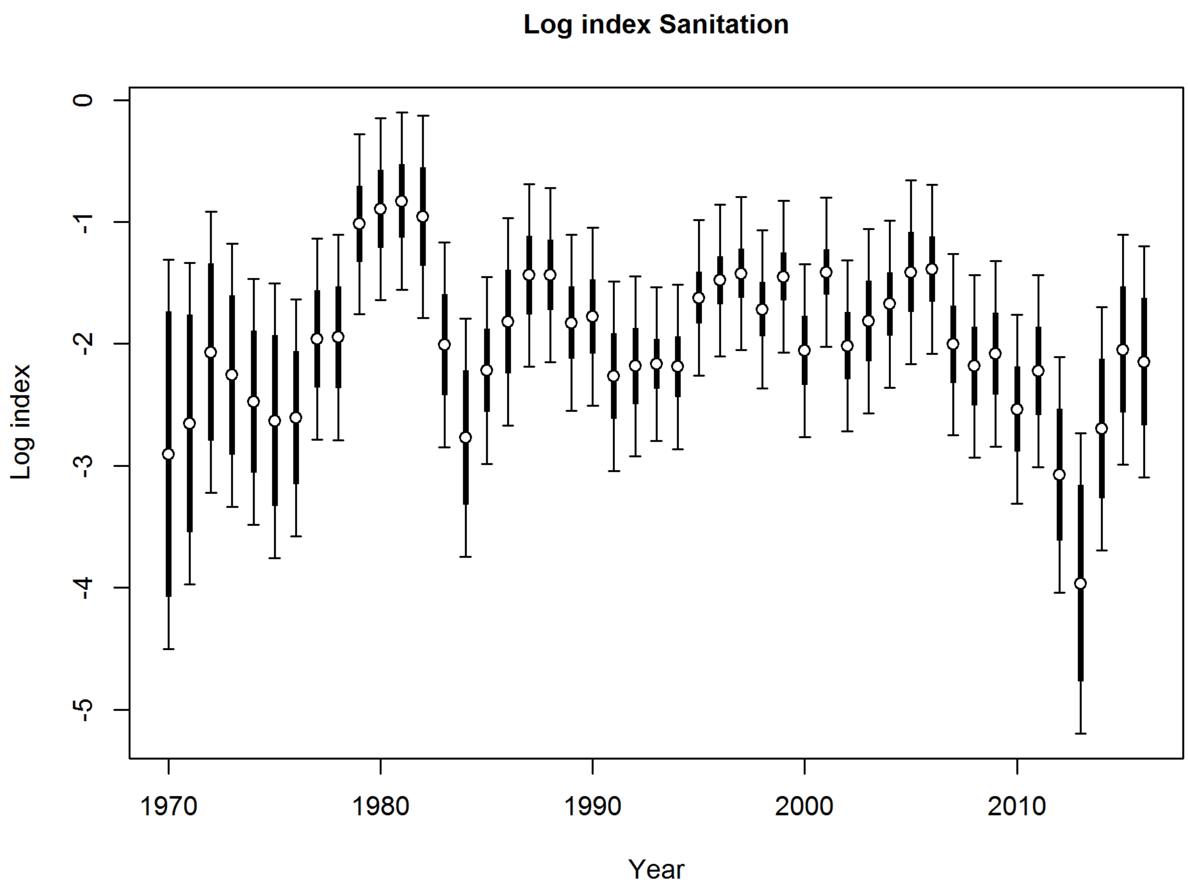


Figure 20: Standardized index on log scale for the Publicly Owned Treatment Works monitoring programs trawl index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

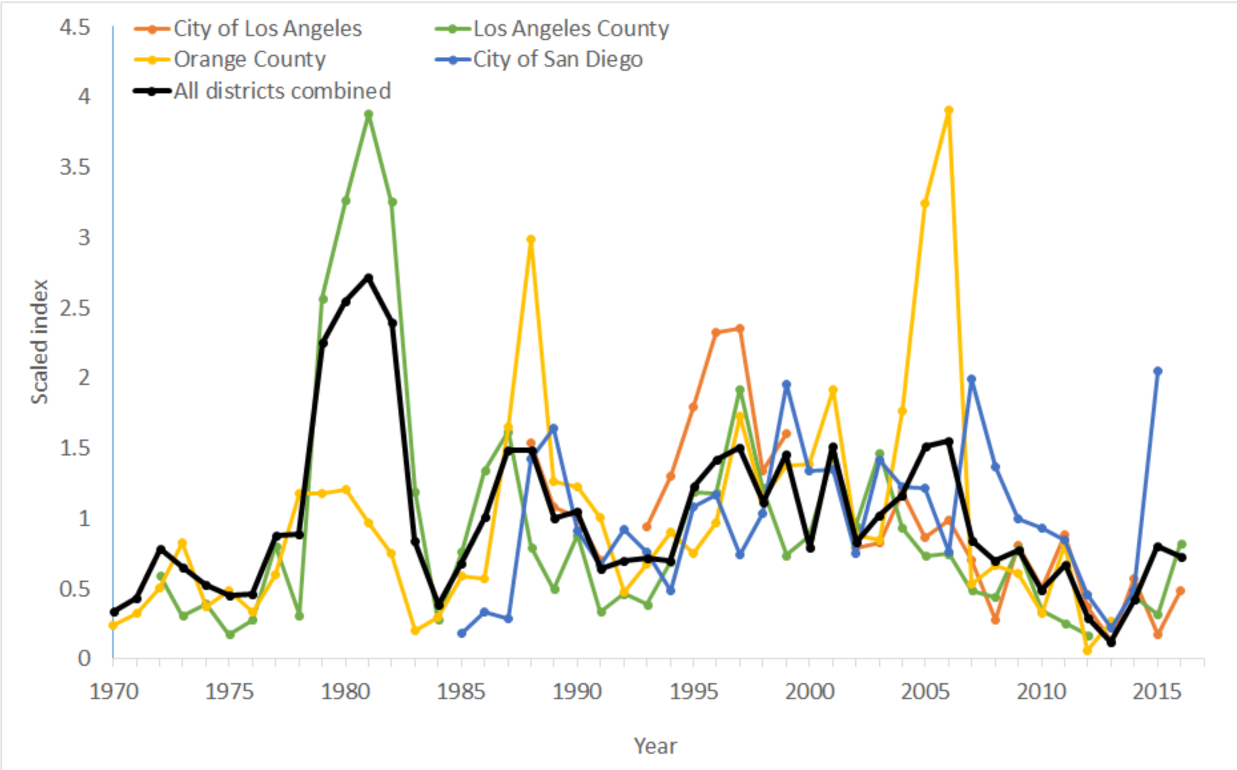


Figure 21: Comparison of standardized indices for each Publicly Owned Treatment Works monitoring program independently and with data from all Publicly Owned Treatment Works programs combined.

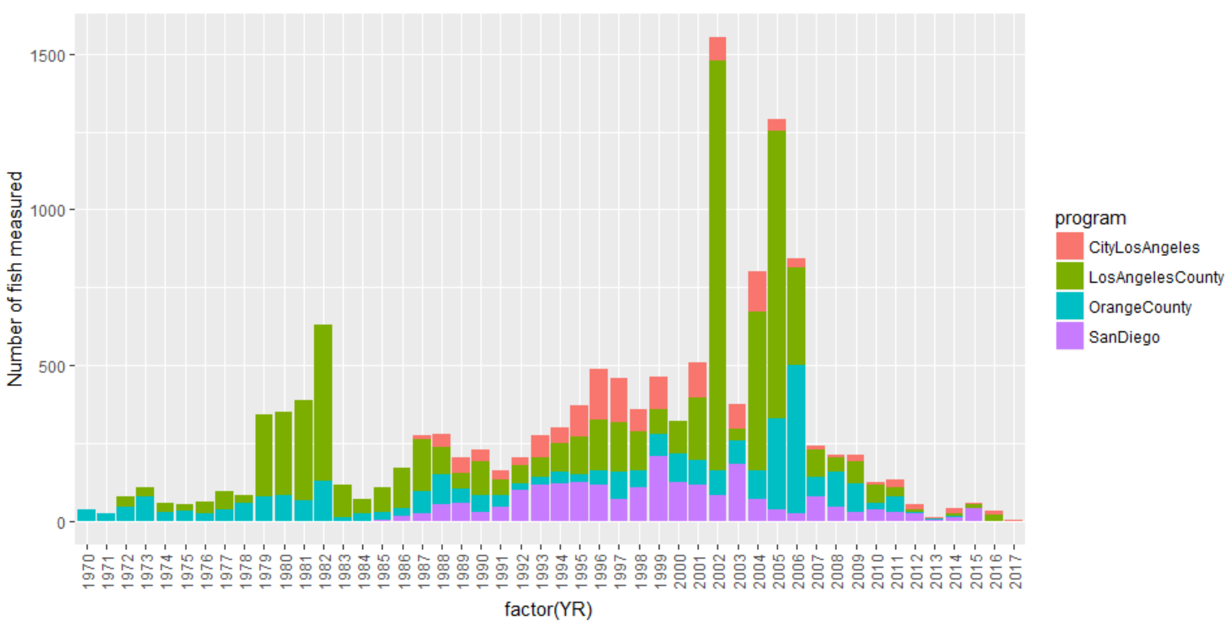


Figure 22: Sample sizes of measured California scorpionfish by Publicly Owned Treatment Works monitoring program and year.

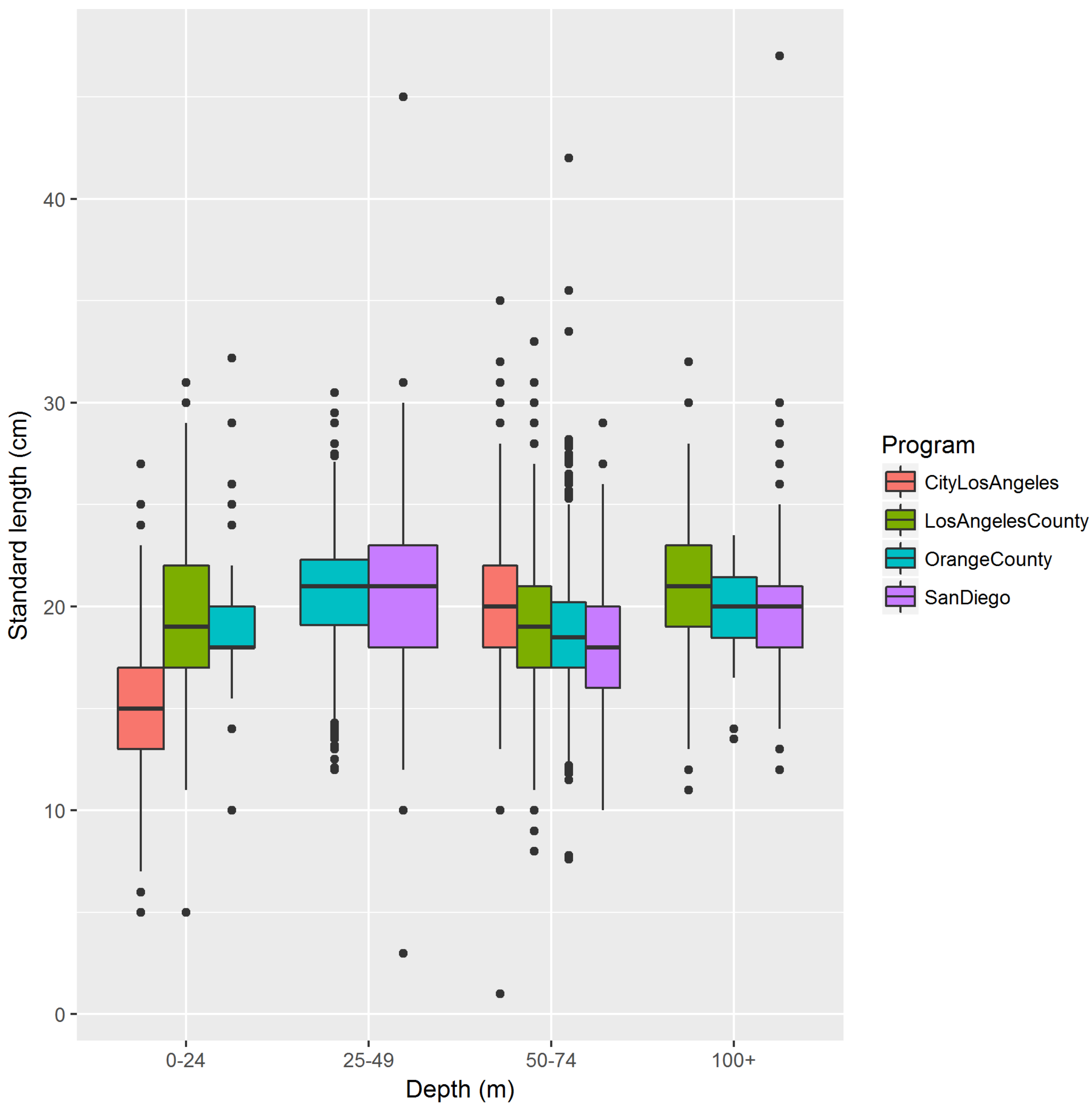


Figure 23: Boxplots of measured California scorpionfish from the Publicly Owned Treatment Works monitoring surveys by program and 25 m depth bins.

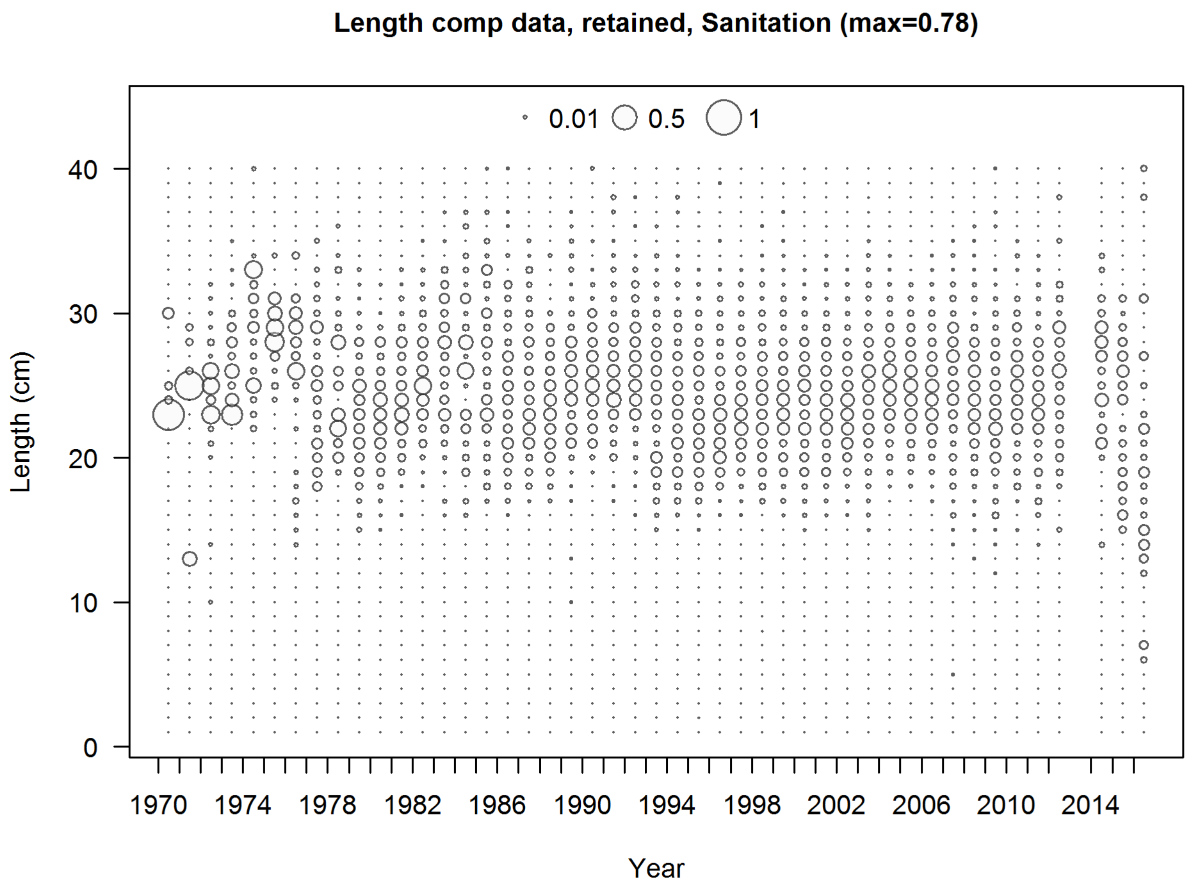


Figure 24: Length frequency distributions from the Publicly Owned Treatment Works monitoring trawl surveys.

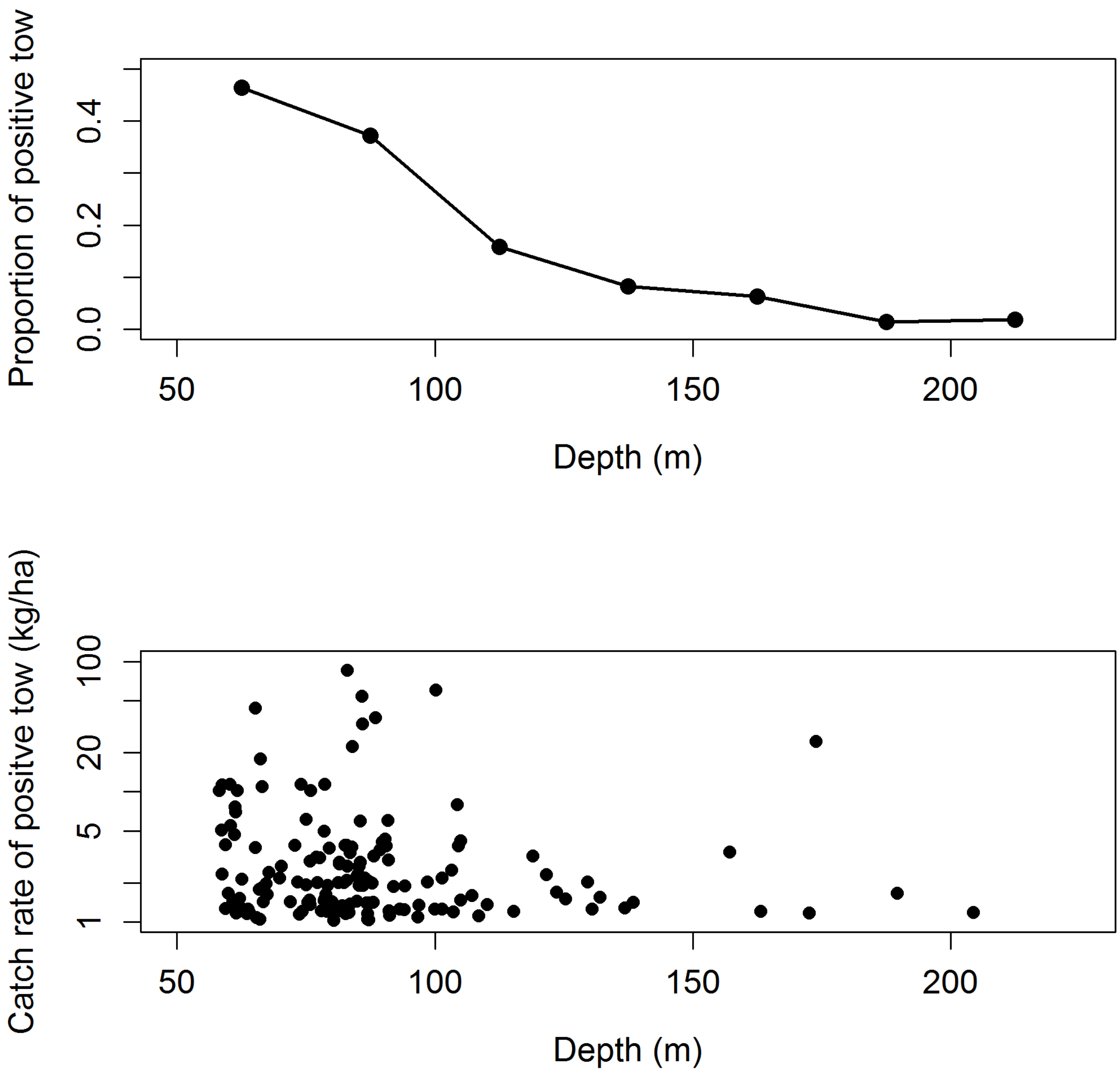


Figure 25: Plots of the proportion of positive tows (top panel) and the raw catch rates of positive tows (bottom panel) by depth zones (25 m interval) for NWFSC trawl survey.

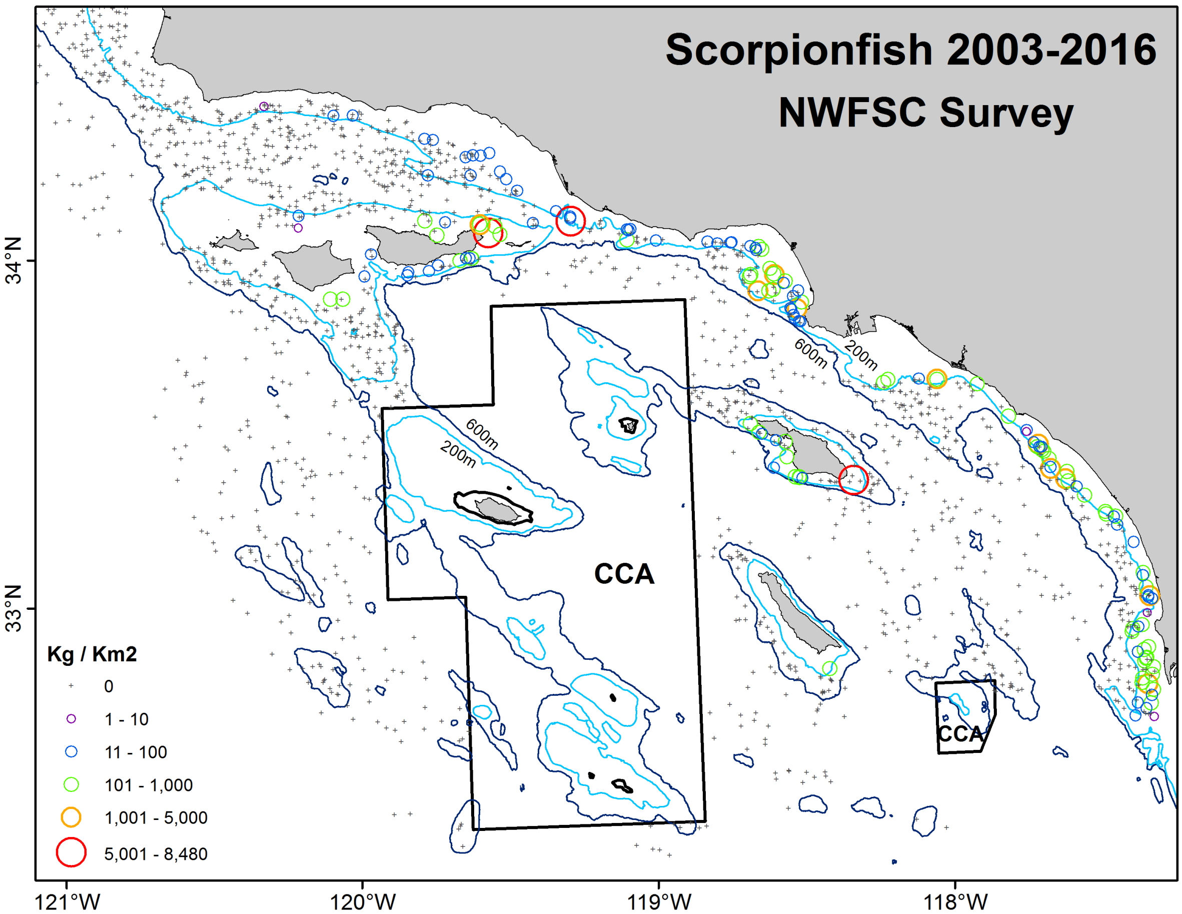


Figure 26: Spatial distribution of raw catch rates of Scorpionfish from NWFSC trawl survey between 2003 and 2016. Depth contour lines of 200 m and 600 m and the CCA areas are shown. Note that sizes and colors of circles represent catch rate in log scales (Credit of Rebecca Miller, SWFSC).

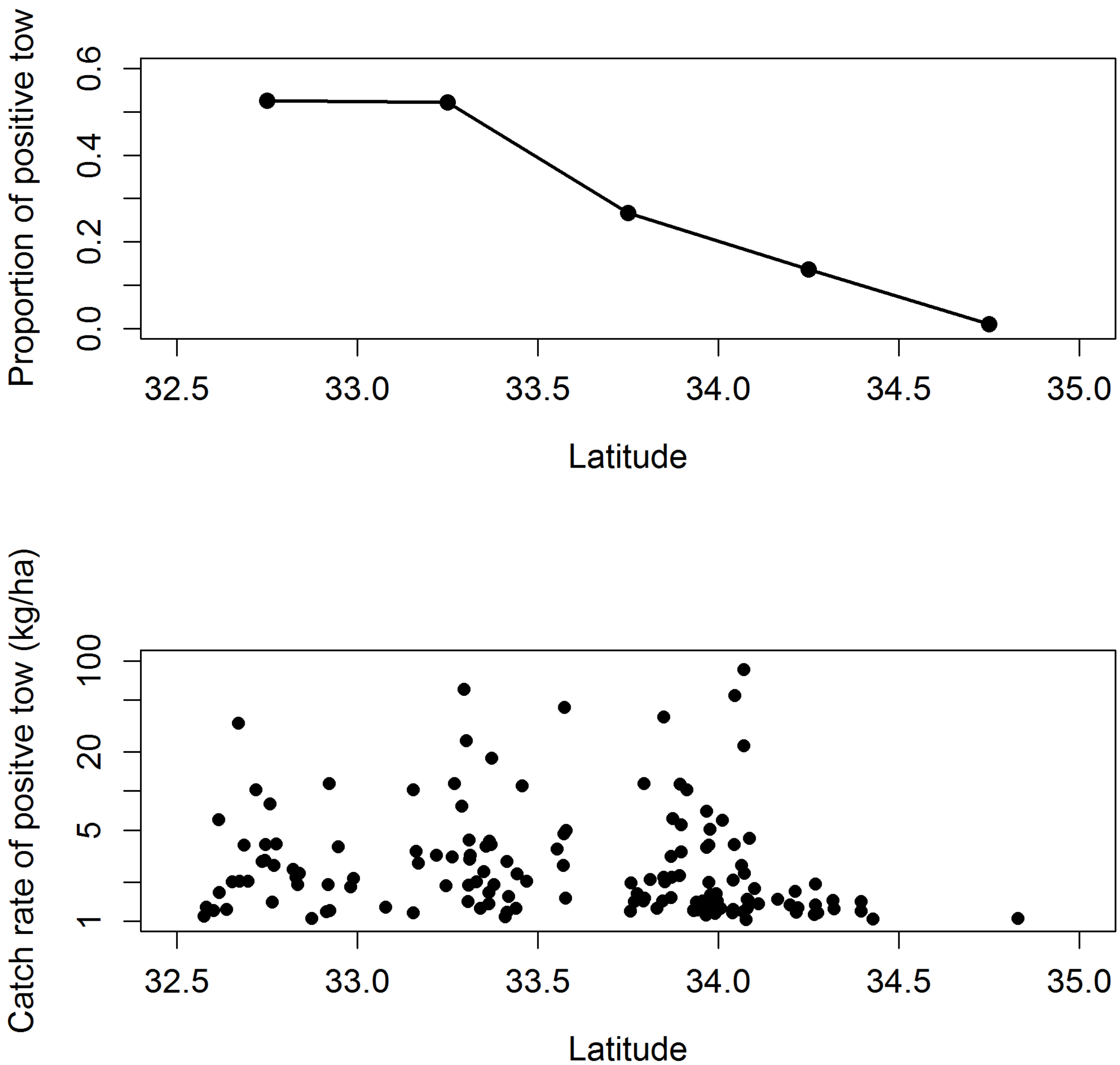


Figure 27: Plots of the proportion of positive tows (top panel) and the raw catch rates of positive tows (bottom panel) by latitude zones (0.5 degree interval) for NWFSC trawl survey.

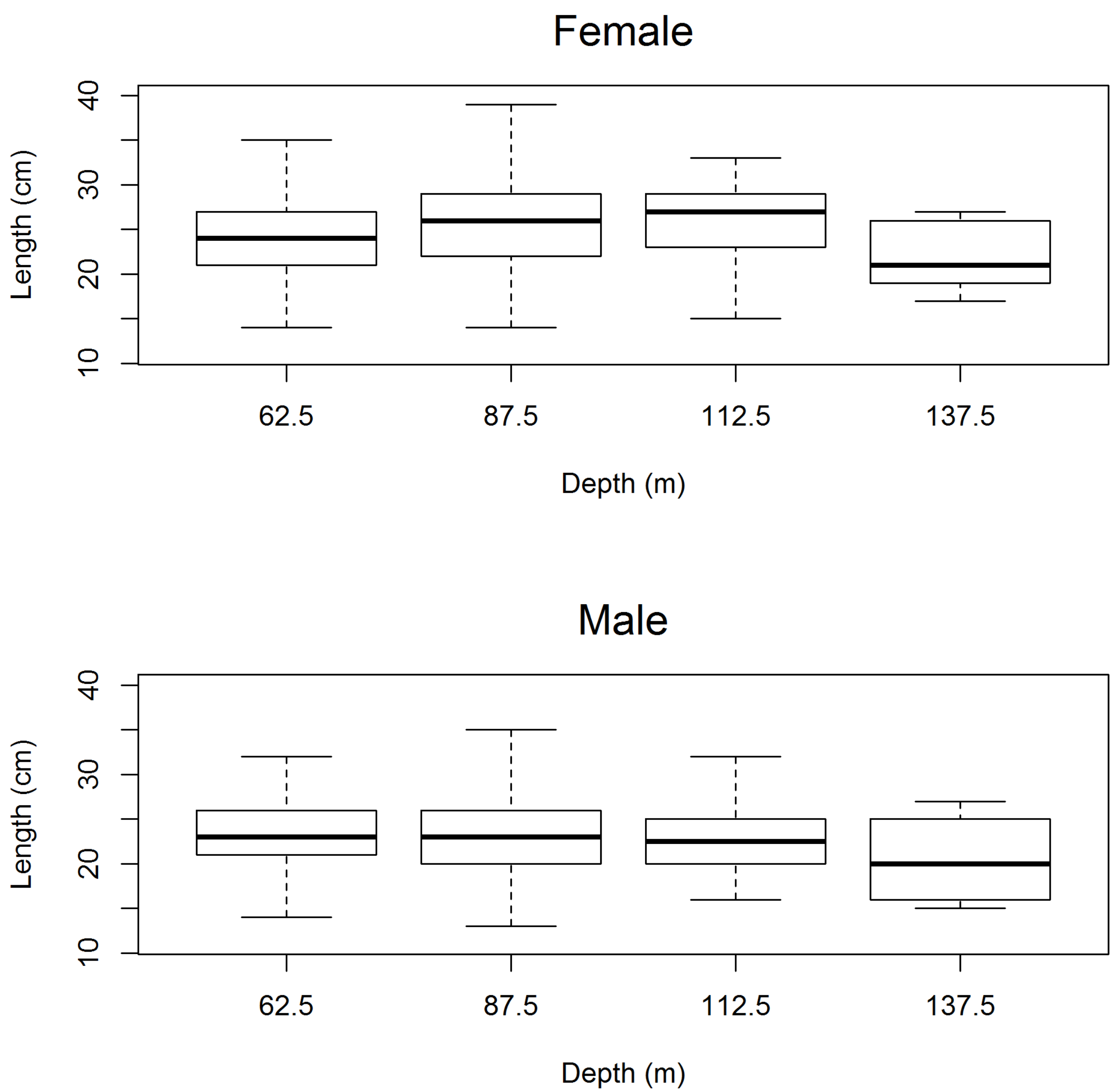


Figure 28: Comparison box plots of raw length data from NWFSC trawl survey by depth zone and sex.

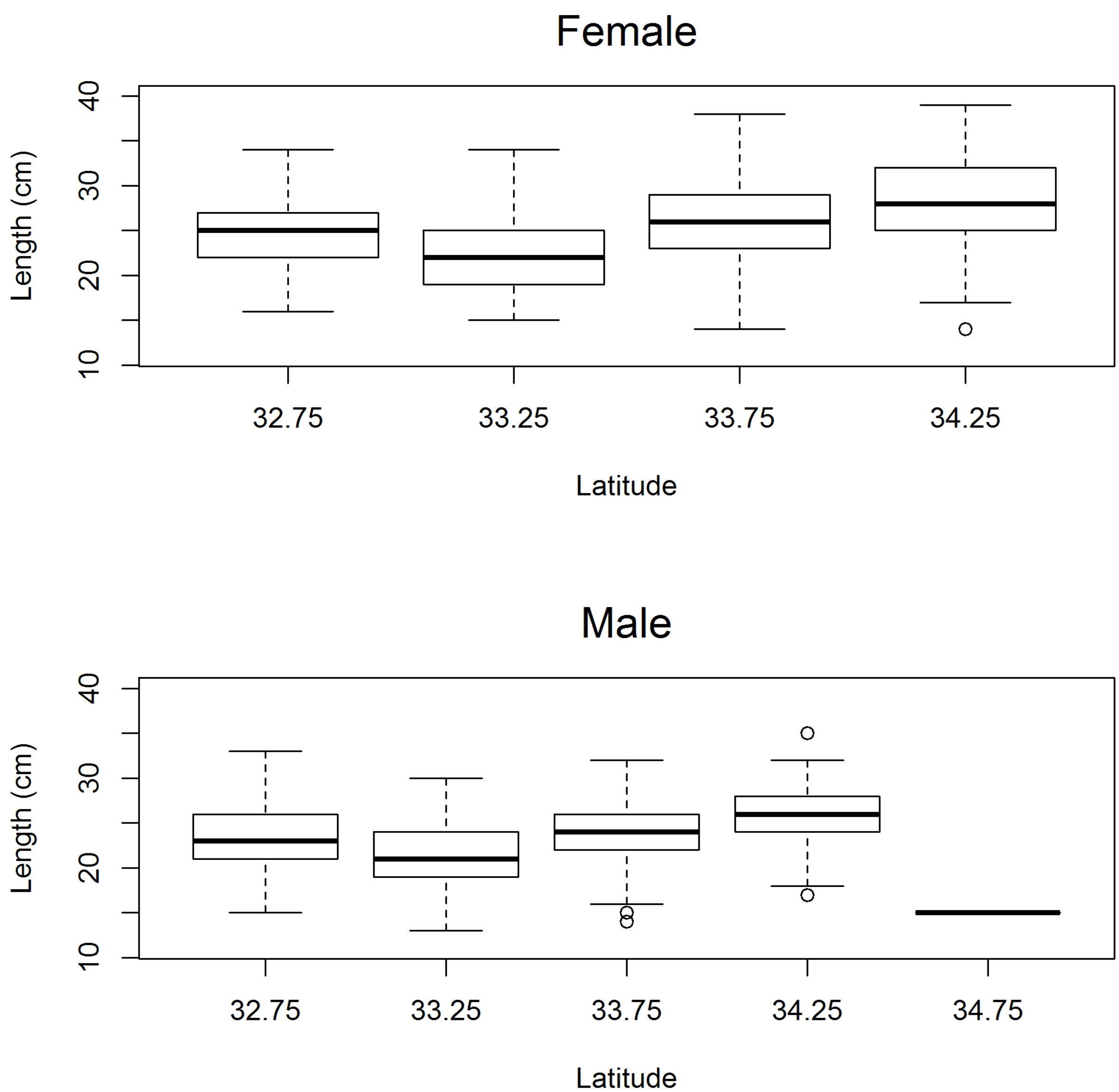


Figure 29: Comparison box plots of raw length data from NWFSC trawl survey by latitude zone and sex.

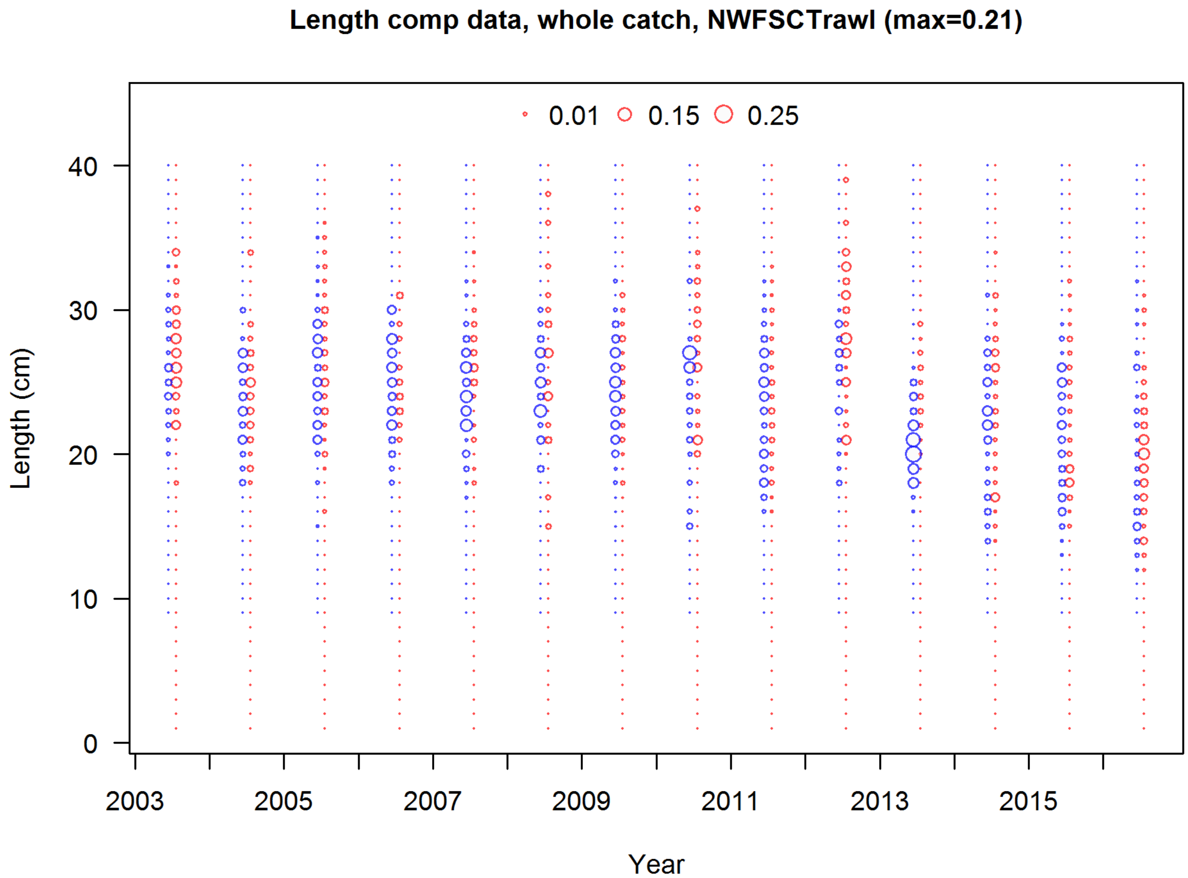


Figure 30: Length frequency distributions of females (red) and male (blue) from the NWFSC trawl survey between 2003 and 2016.

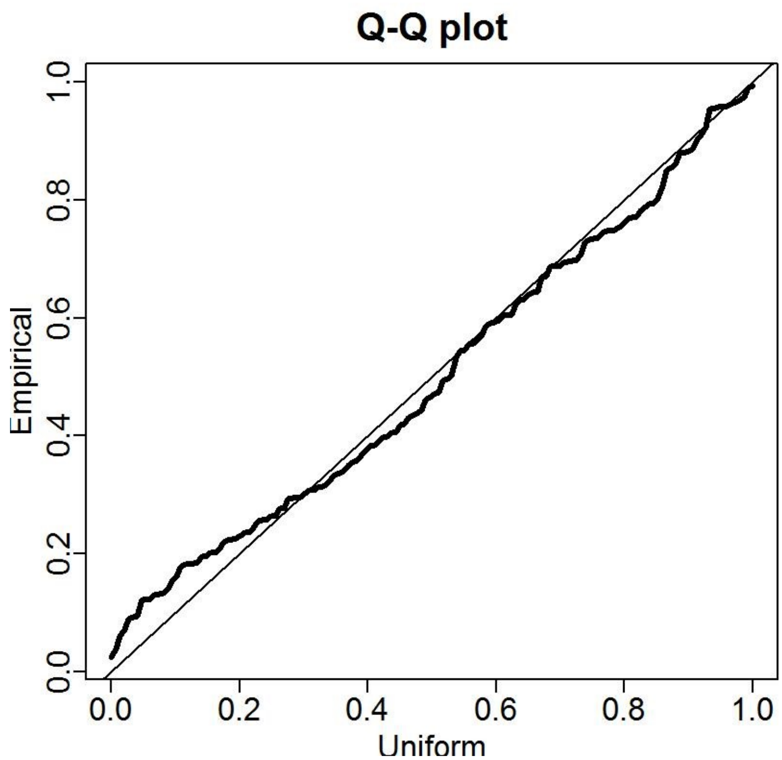


Figure 31: Q-Q plot used to validate the goodness of fit of the VAST analysis for the NWFSC trawl survey between 2003 and 2016.

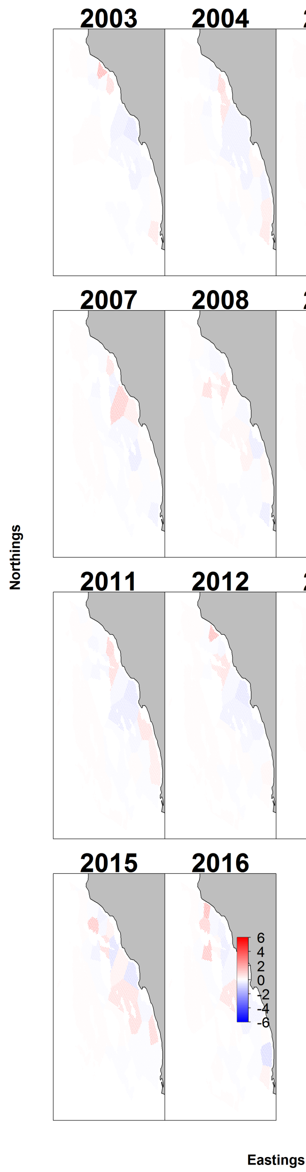


Figure 32: NWFSC survey index encounter probability Pearson residuals

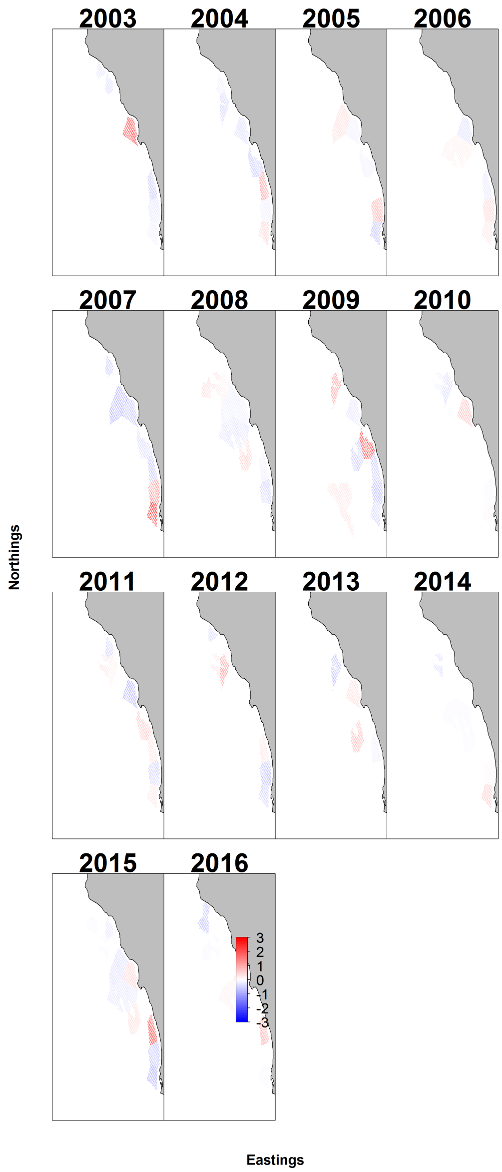


Figure 33: NWFSC survey index positive catch rate probability Pearson residuals

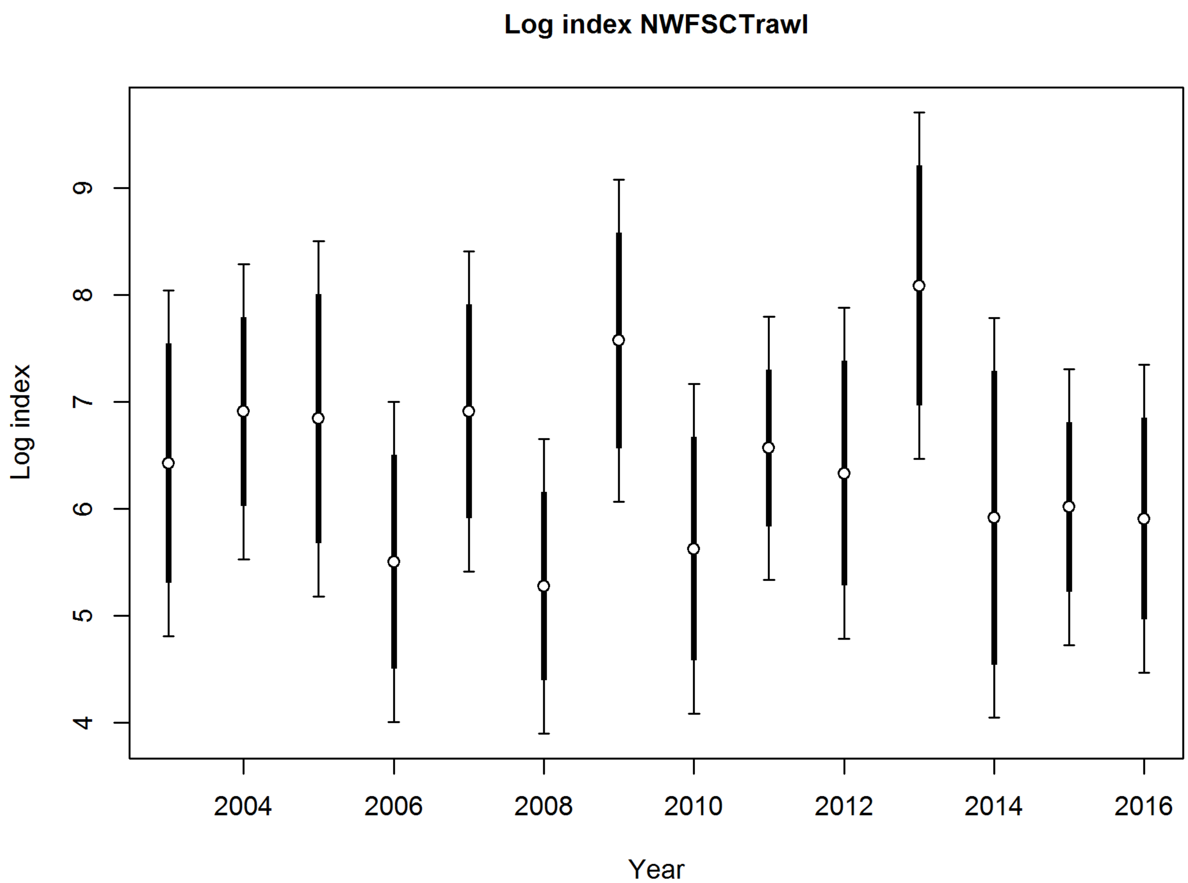


Figure 34: Standardized index on the log scale for the NWFSC trawl survey from the VAST analysis from 2003-2016. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

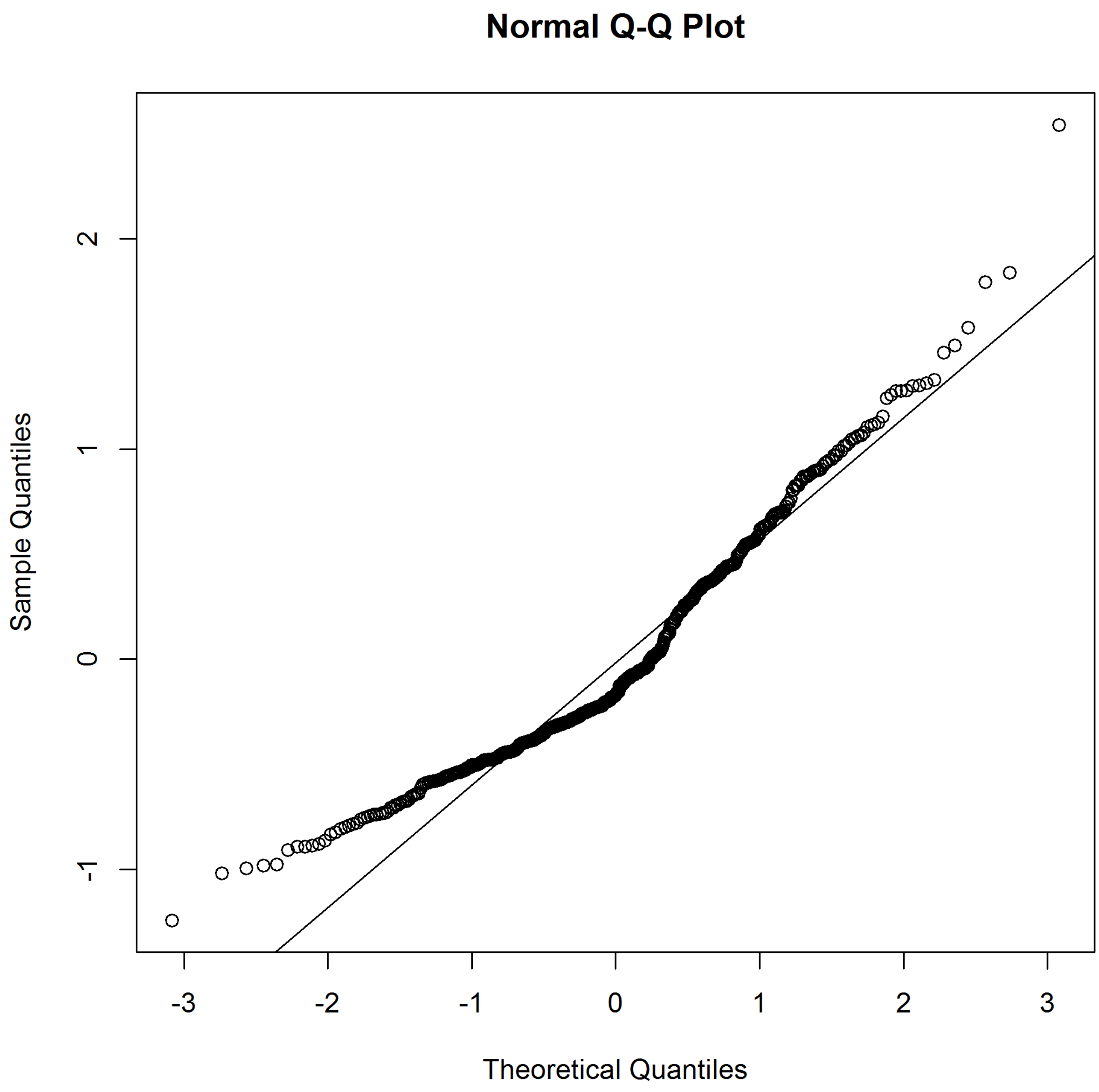


Figure 35: Q-Q plot used to validate the goodness of fit of the lognormal model for the CSUN/VRG gillnet survey from 1995-2008.

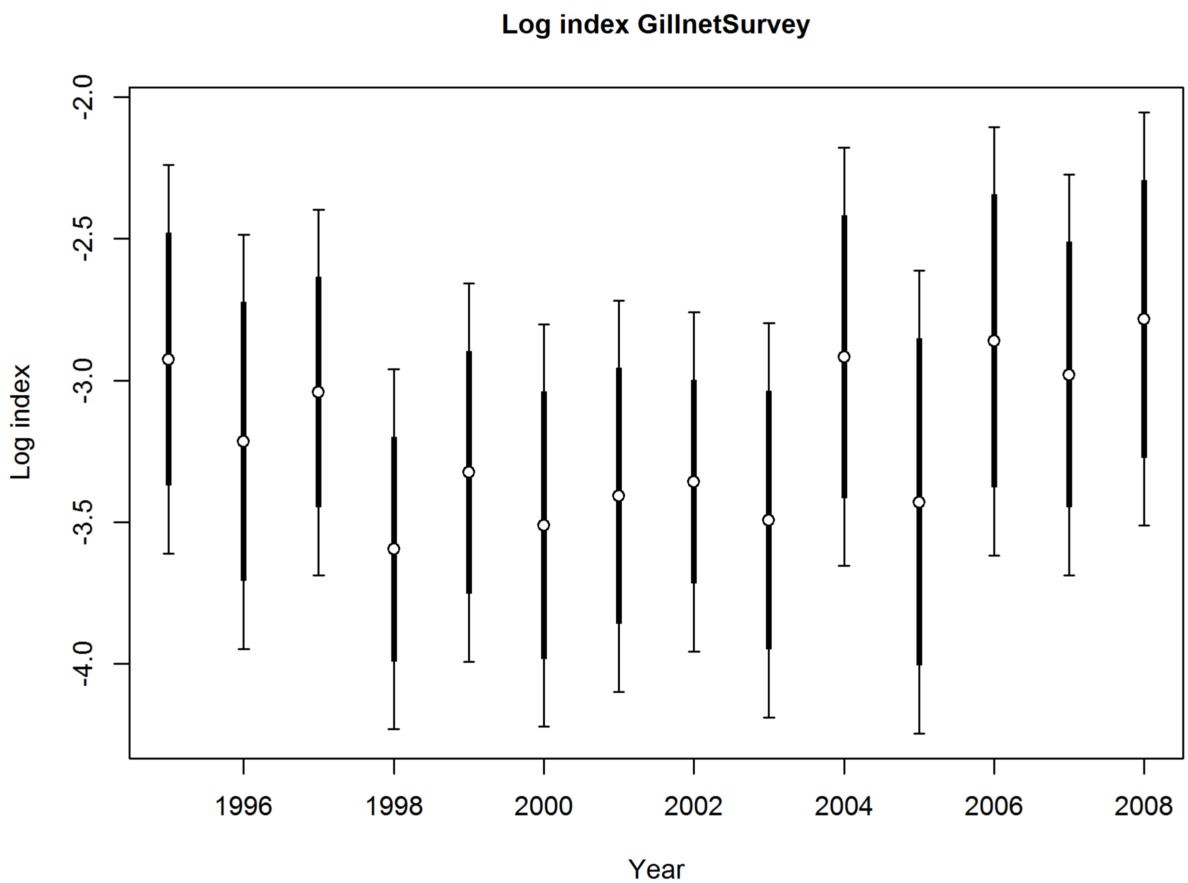


Figure 36: Standardized index on the log scale for the recreational CSUN/VRG gillnet survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

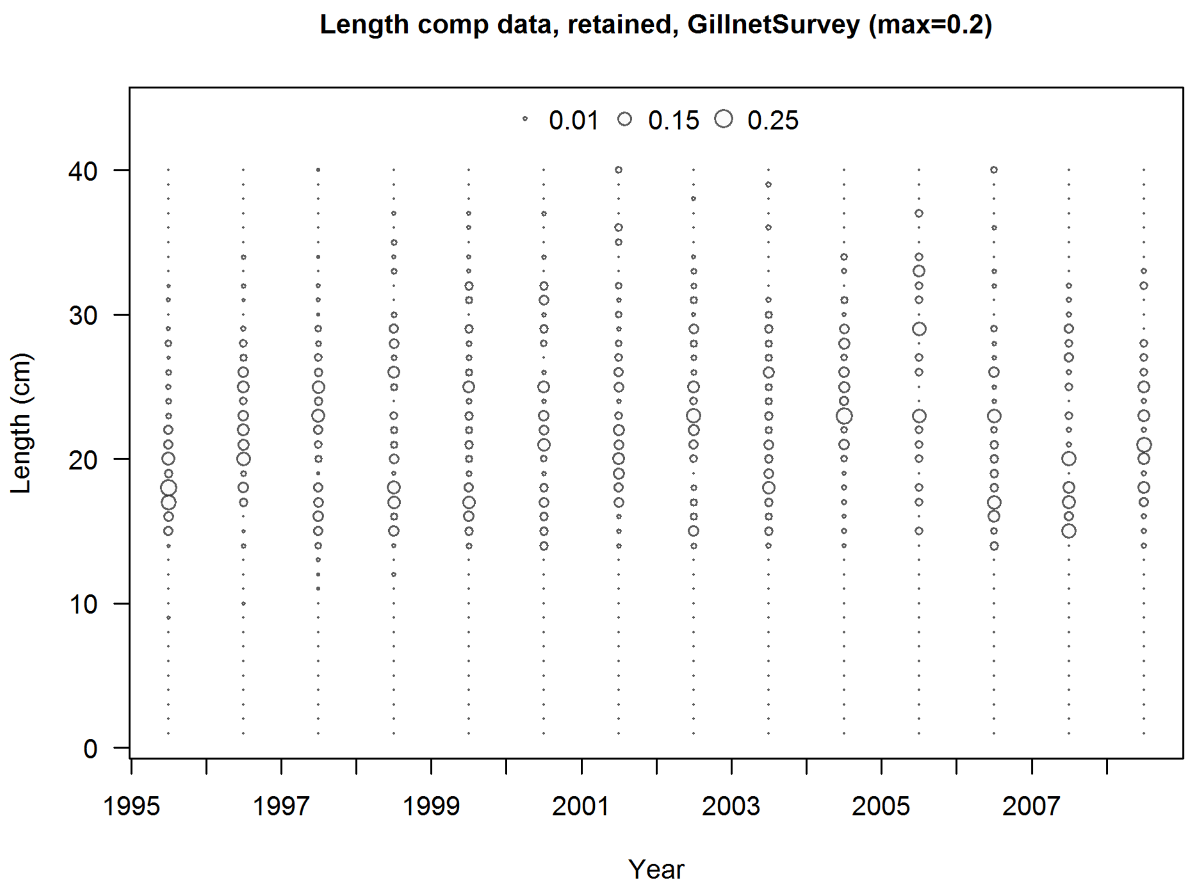


Figure 37: Length frequency distributions from the gill net surveys.

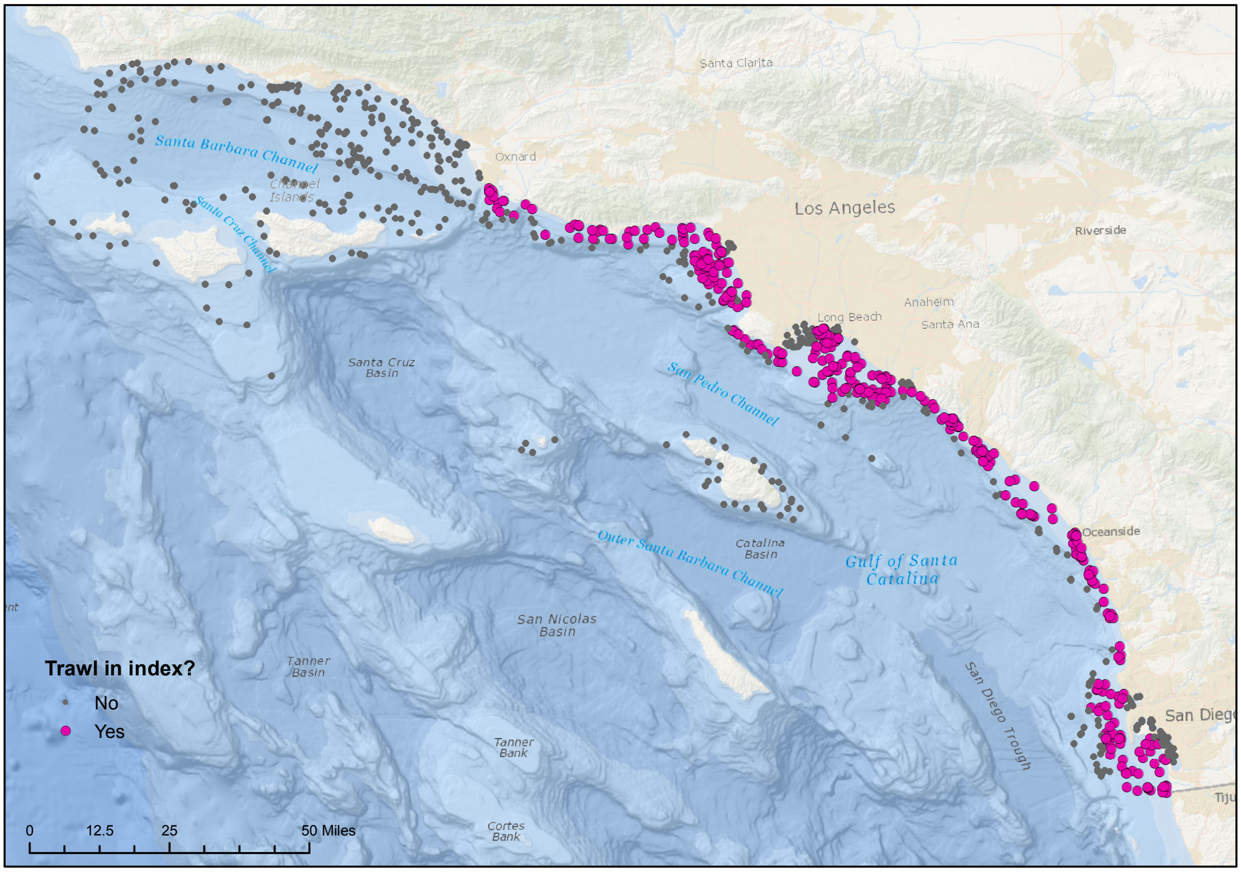


Figure 38: Map of the stations from the Southern California Coastal Water Research Project regional monitoring trawl survey from 1994, 1998, 2003, 2008, and 2013. Stations used in the index of abundance are colored magenta.

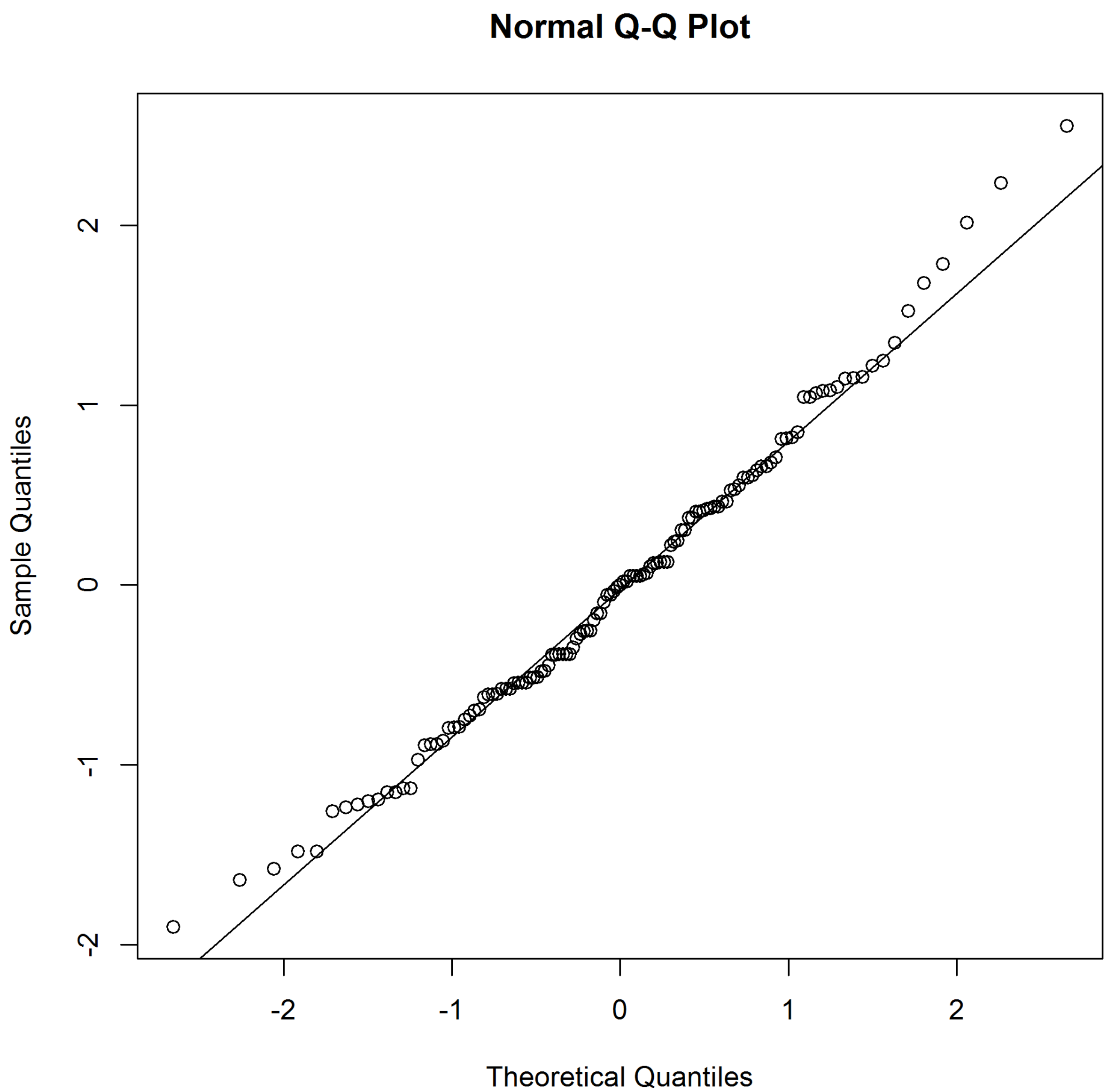


Figure 39: Q-Q plot used to validate the goodness of fit of the lognormal model for the Southern California Bight monitoring program trawl survey.

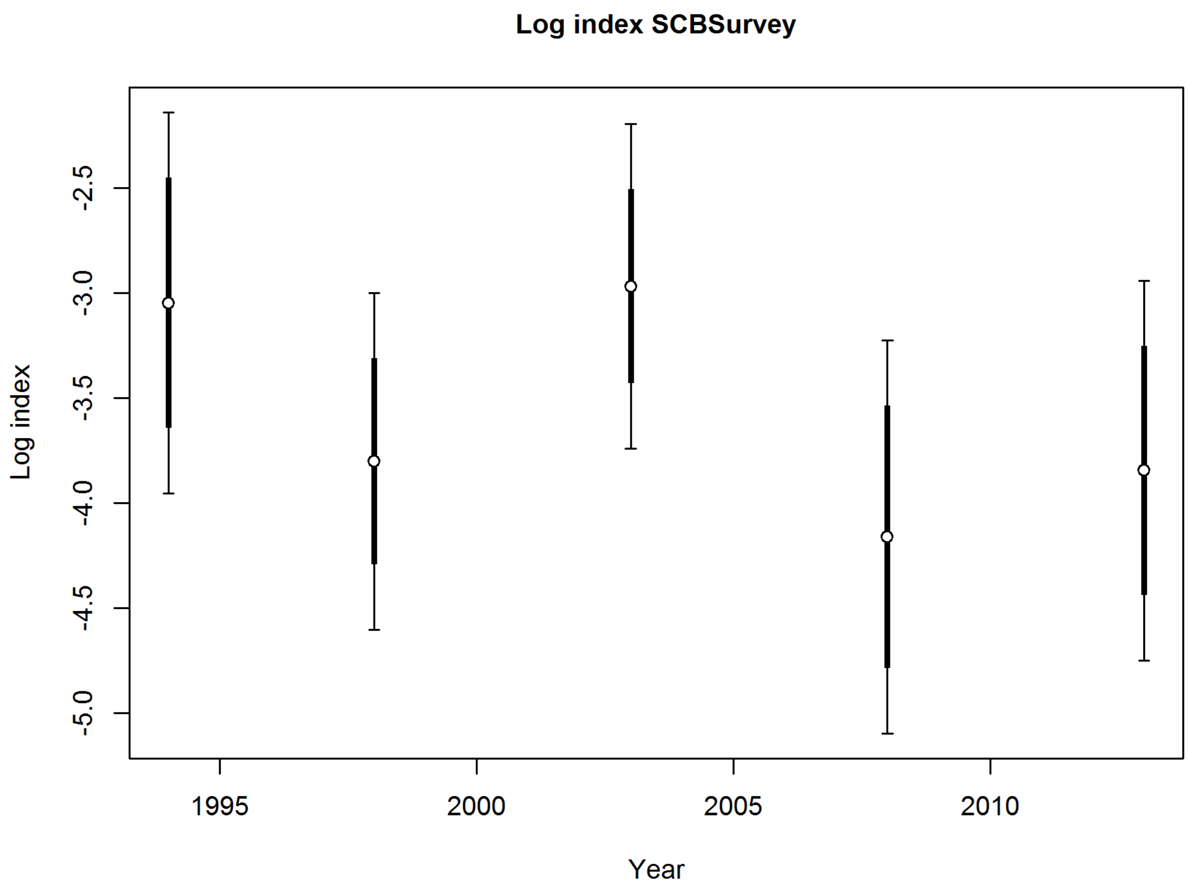


Figure 40: Standardized index on the log scale for the recreational Southern California Bight trawl survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

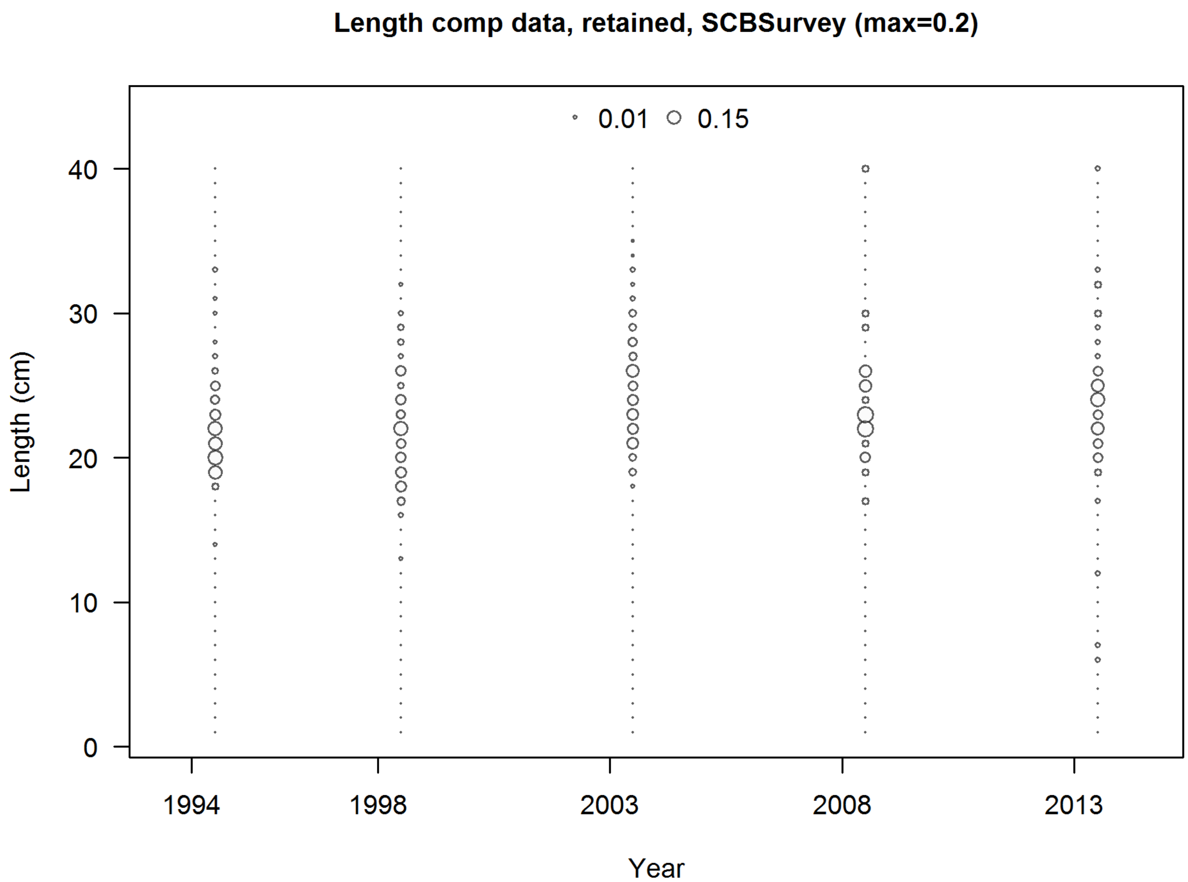


Figure 41: Length frequency distributions from the Southern California Bight regional monitoring program trawl surveys.

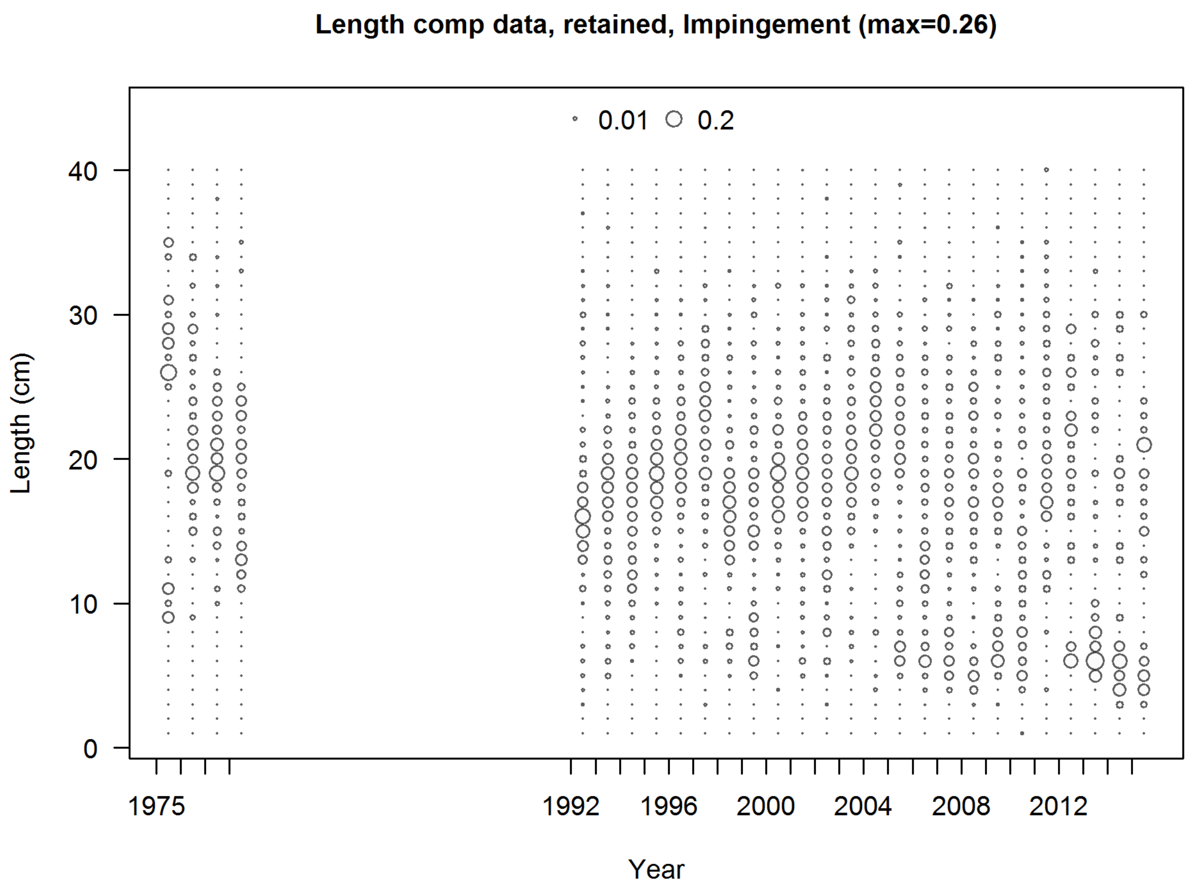


Figure 42: Length frequency distributions from the Impingement surveys.

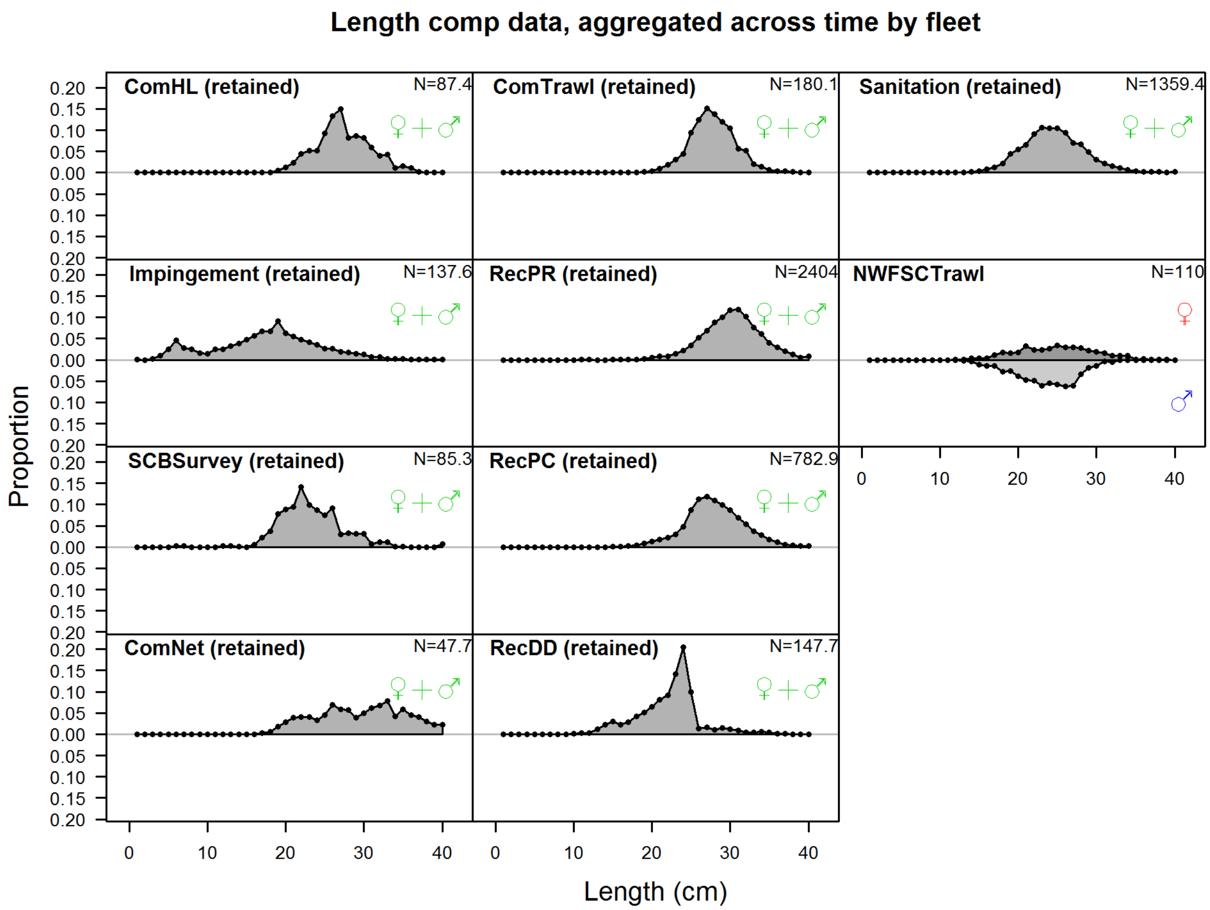


Figure 43: Length comp data, aggregated across time by fleet. Labels 'retained' and 'discard' indicate discarded or retained sampled for each fleet. Panels without this designation represent the whole catch.

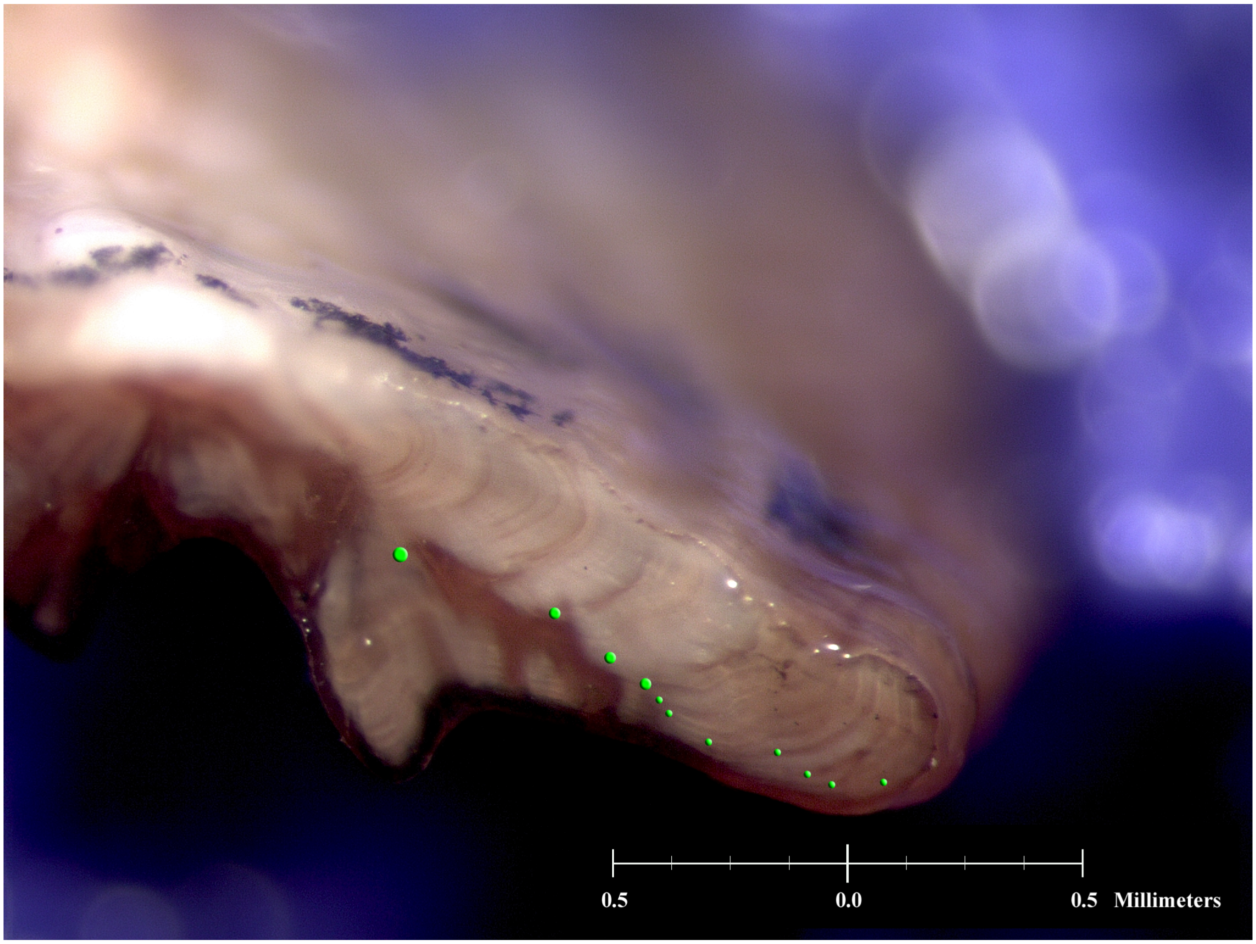


Figure 44: Cross-section of broken and burned California scorpionfish otolith showing. The green dots indicate the number of increments (photo courtesy Lance Sullivan, NWFSC).

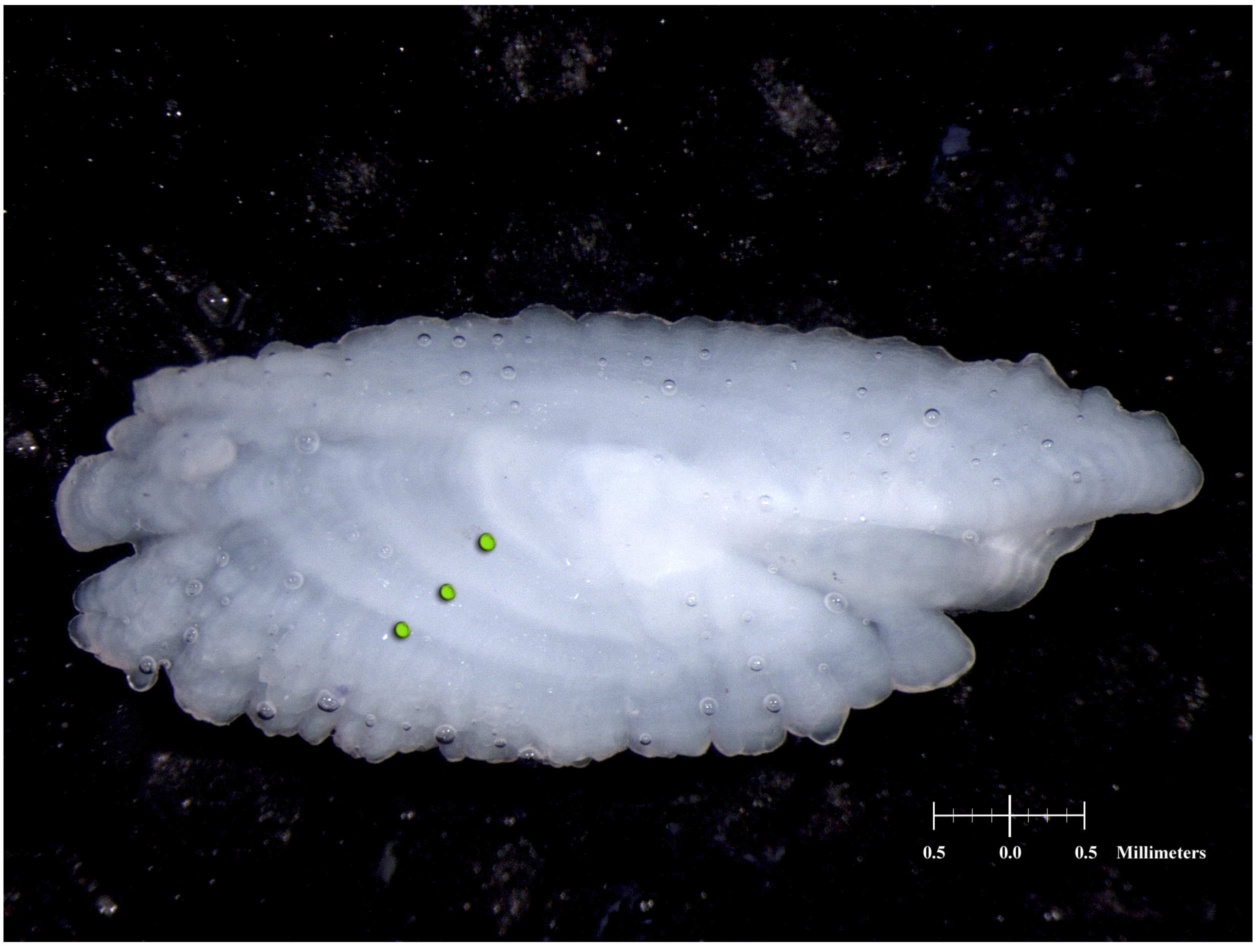


Figure 45: California scorpionfish otolith (photo courtesy Lance Sullivan, NWFSC).

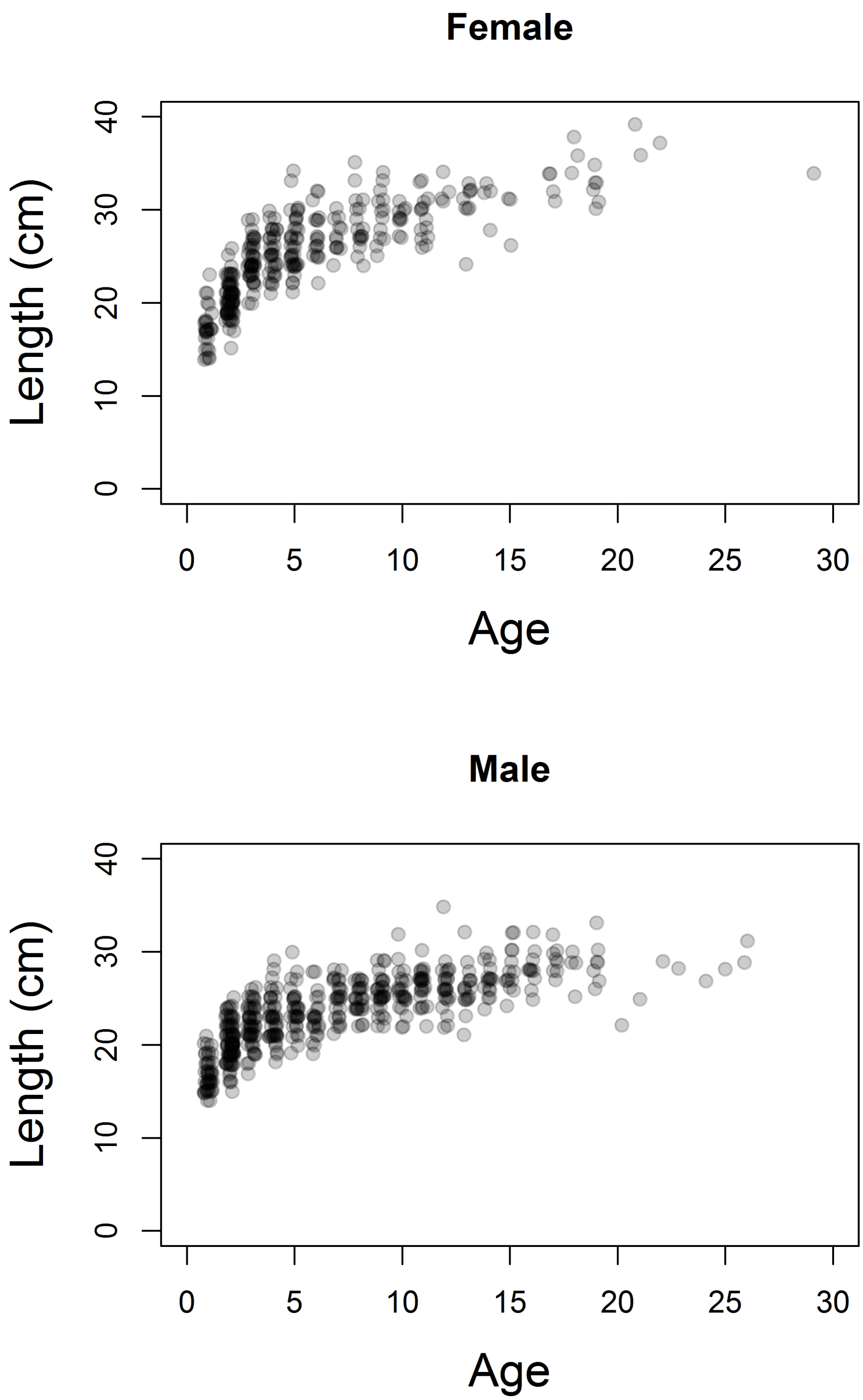


Figure 46: Length at age by sex for California scorpionfish collected from the NWFSC trawl survey.

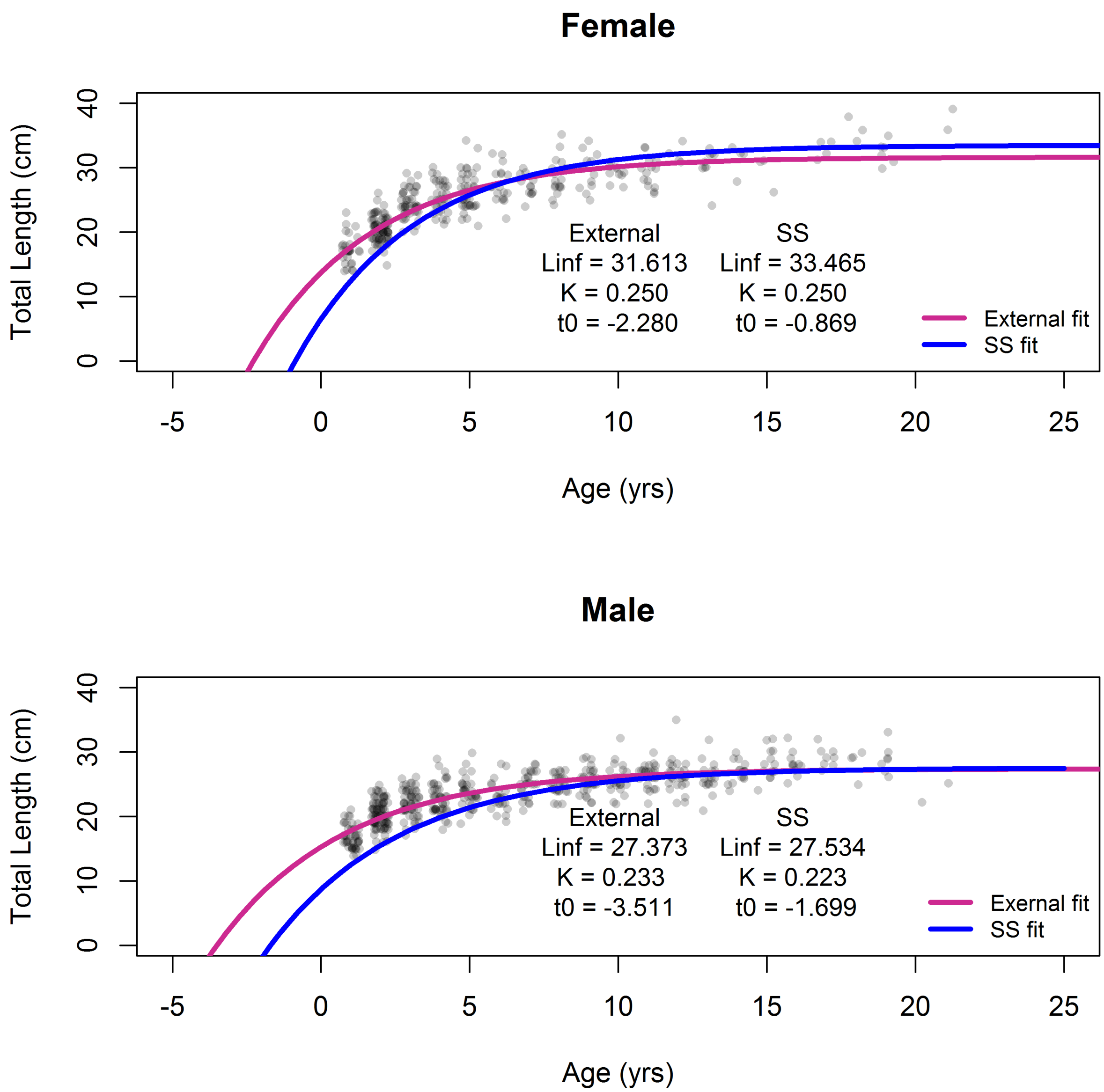


Figure 47: Fitted (external to SS) von Bertalanffy growth by sex for California scorpionfish collected from the NWFSC trawl survey.

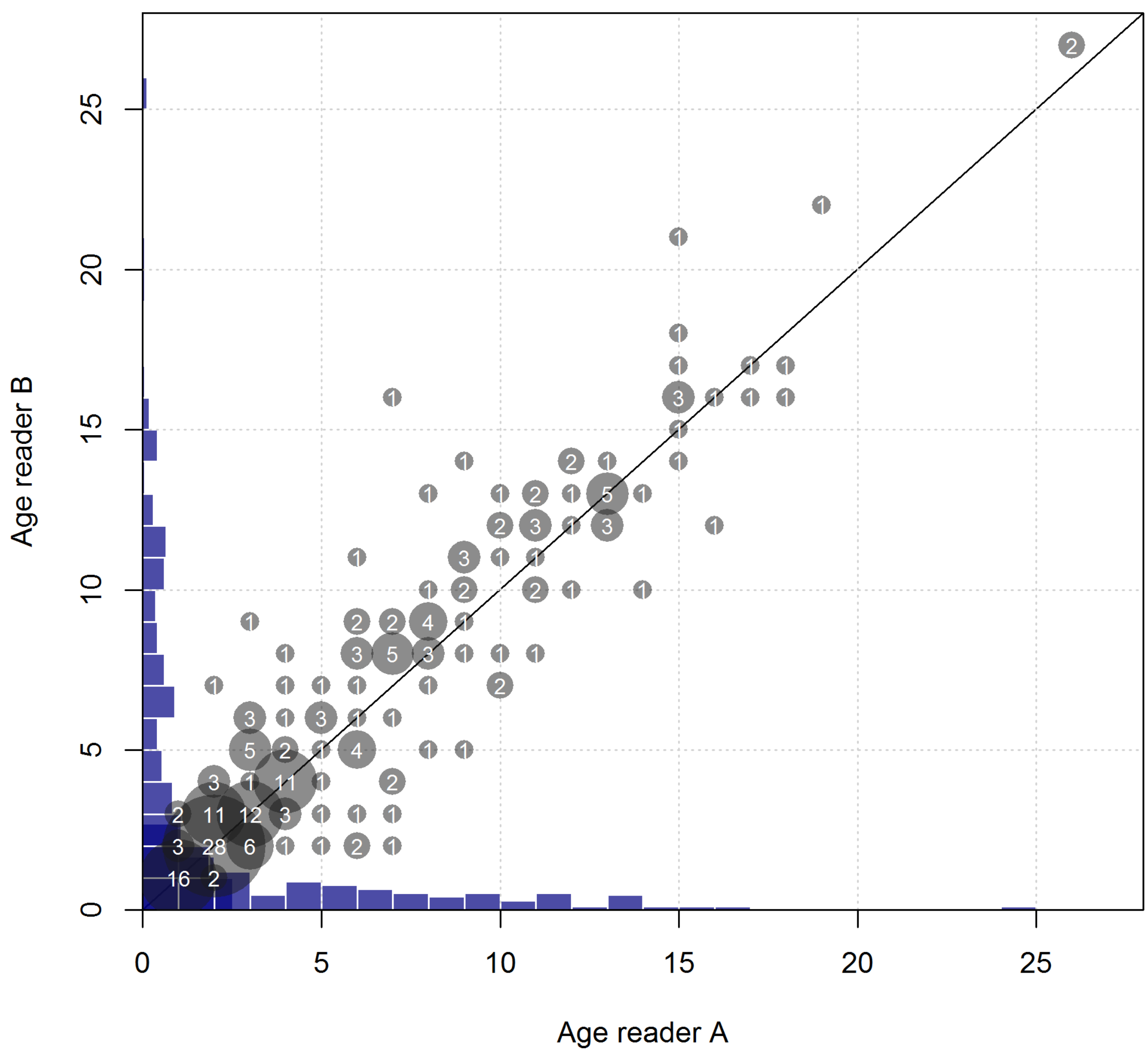


Figure 48: Aging precision between two current age readers at the NWFSC. Numbers in the bubbles are the sample sizes of otoliths cross-read.

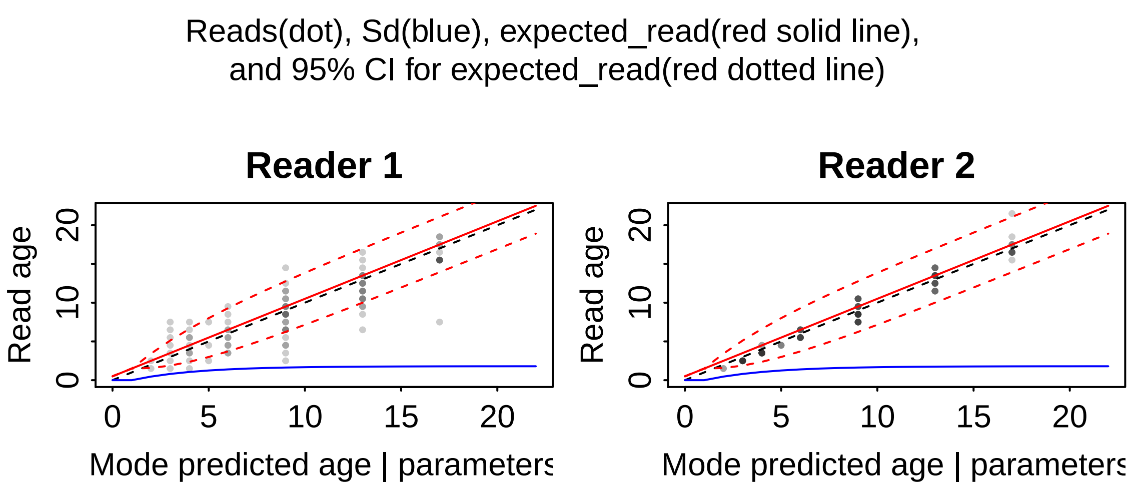


Figure 49: True versus predicted age for two current age readers at the NWFSC from the ageing error software with unbiased reads and curvilinear standard deviation for both readers.

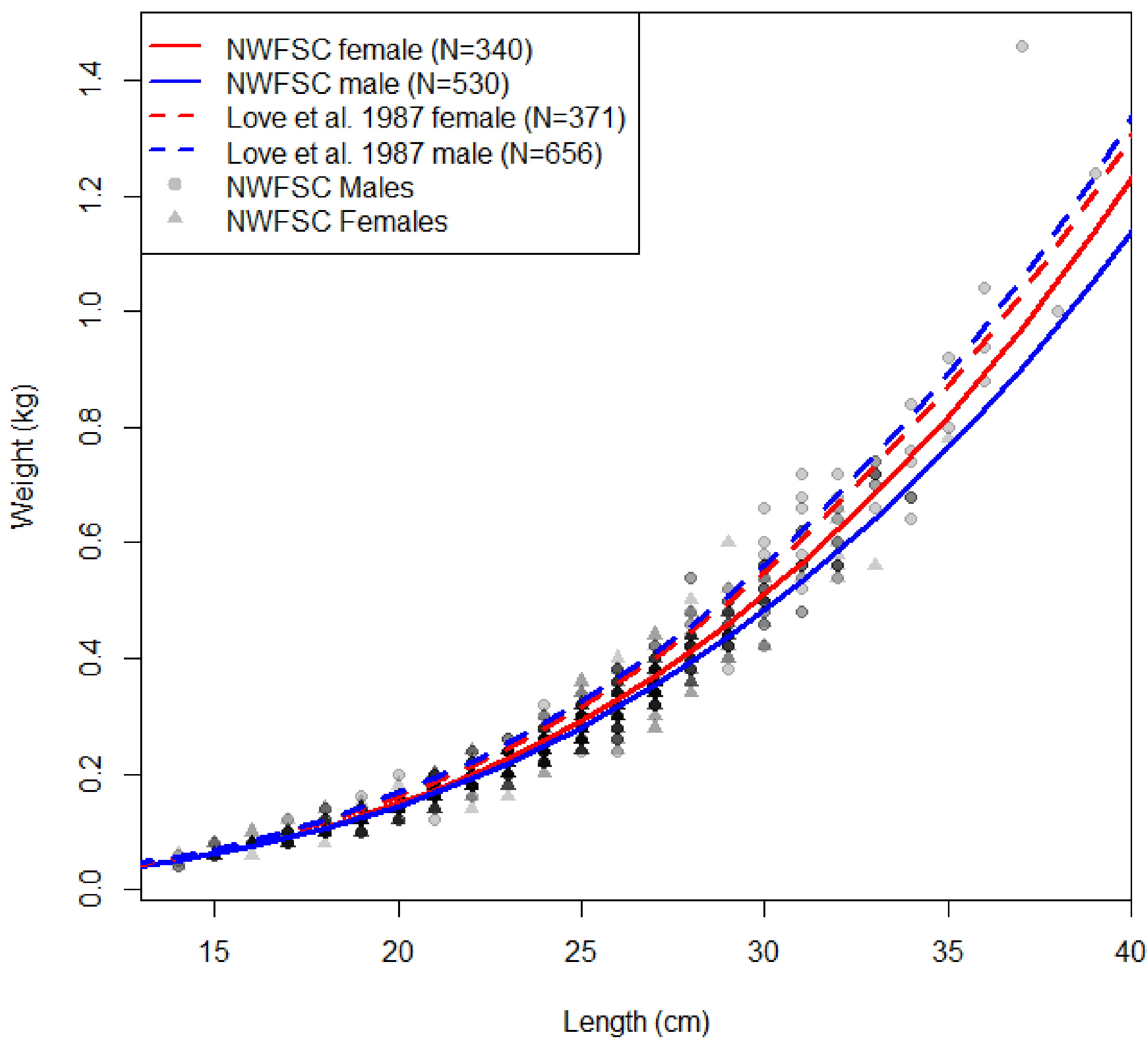


Figure 50: Comparison of the California scorpionfish weight-length curves from Love et al. (1987) and those estimated from the NWFSC trawl survey. The latter is used in this assessment.

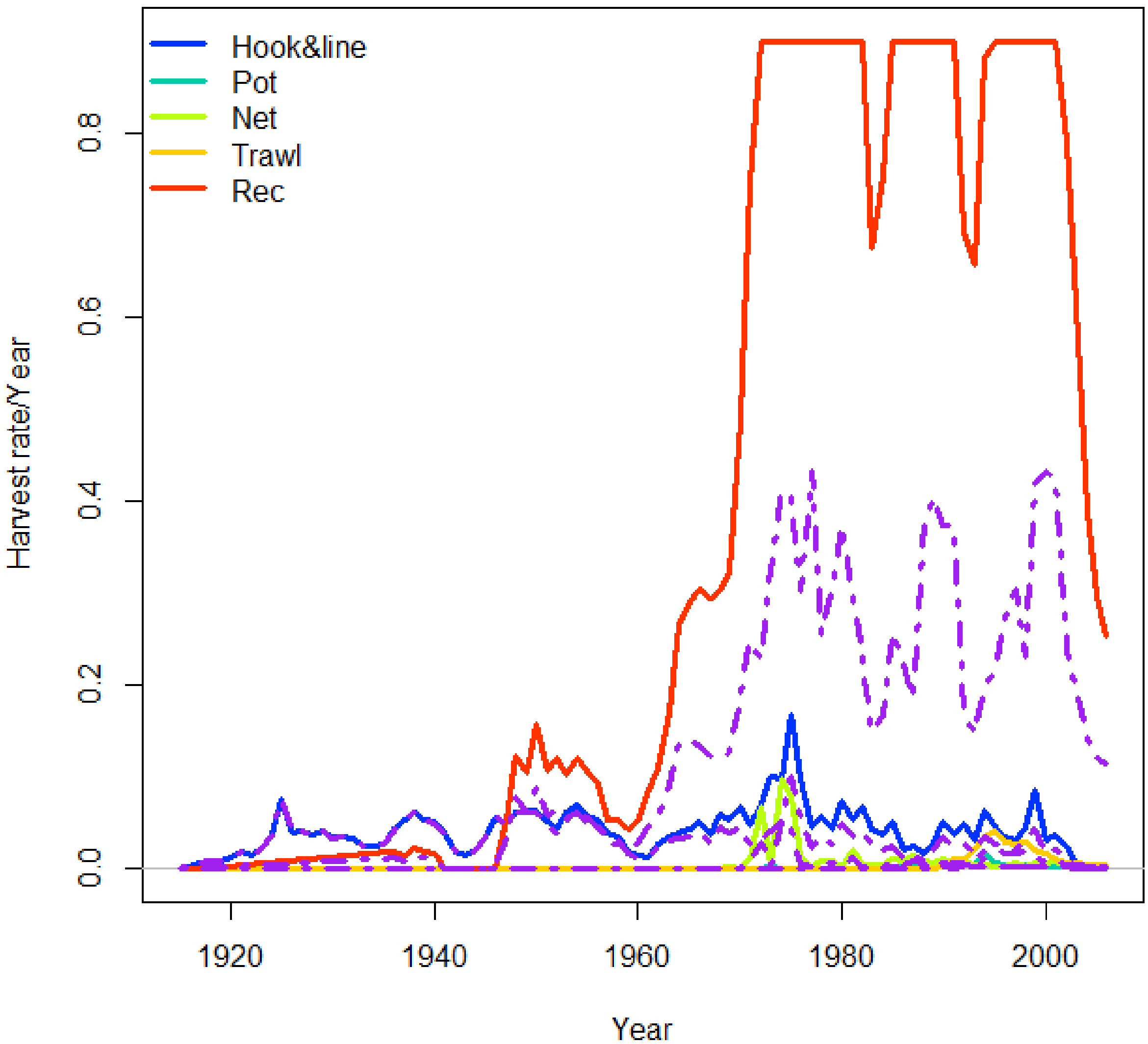


Figure 51: Time series of harvest rates by fleet from the 2005 model where the harvest rate for the recreational fleet hit the boundary of 0.9.

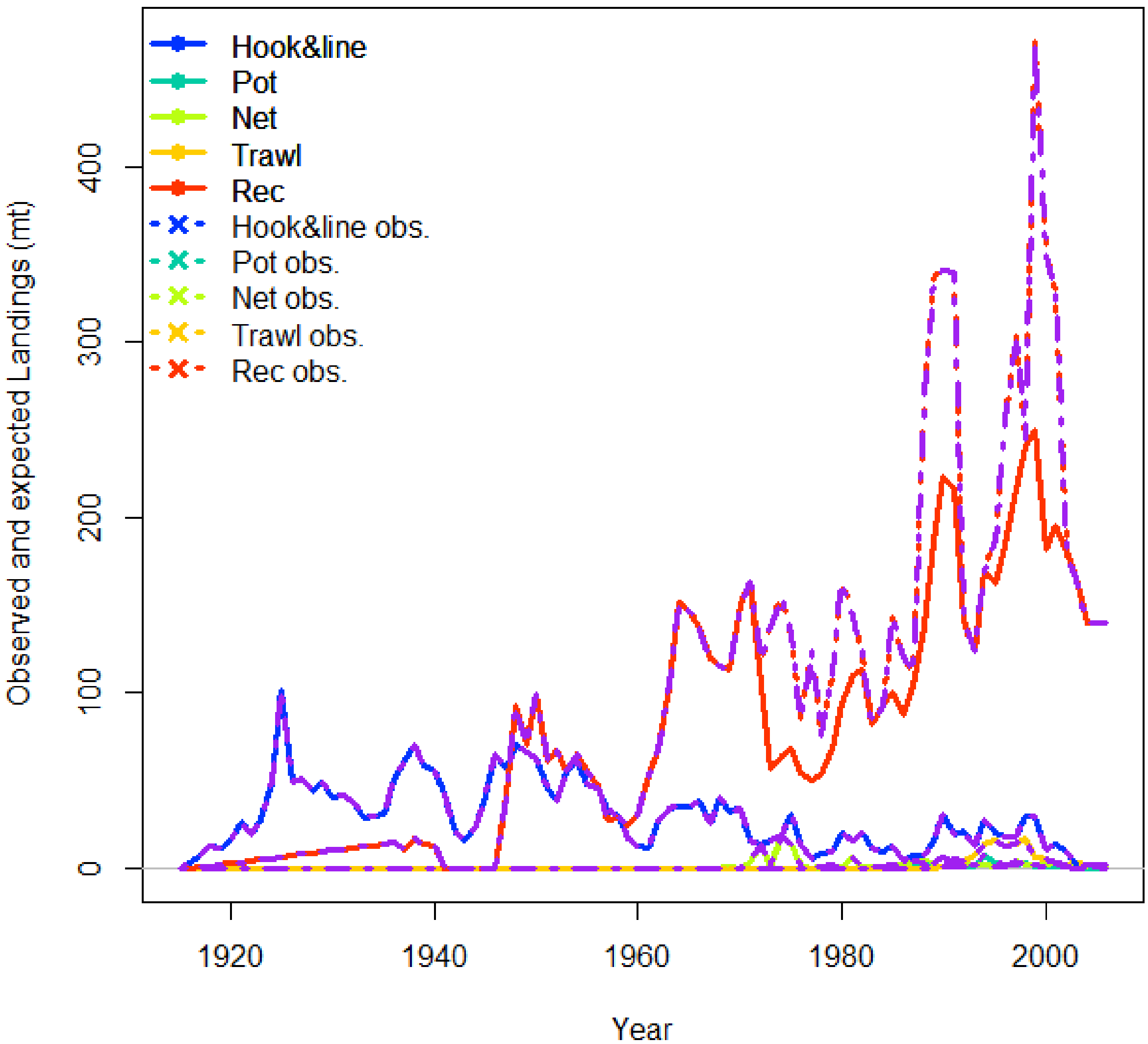


Figure 52: Time series of observed and expected landings by fleet from the 2005 model. The model was not able to remove all of the recreational catches starting around 1970.

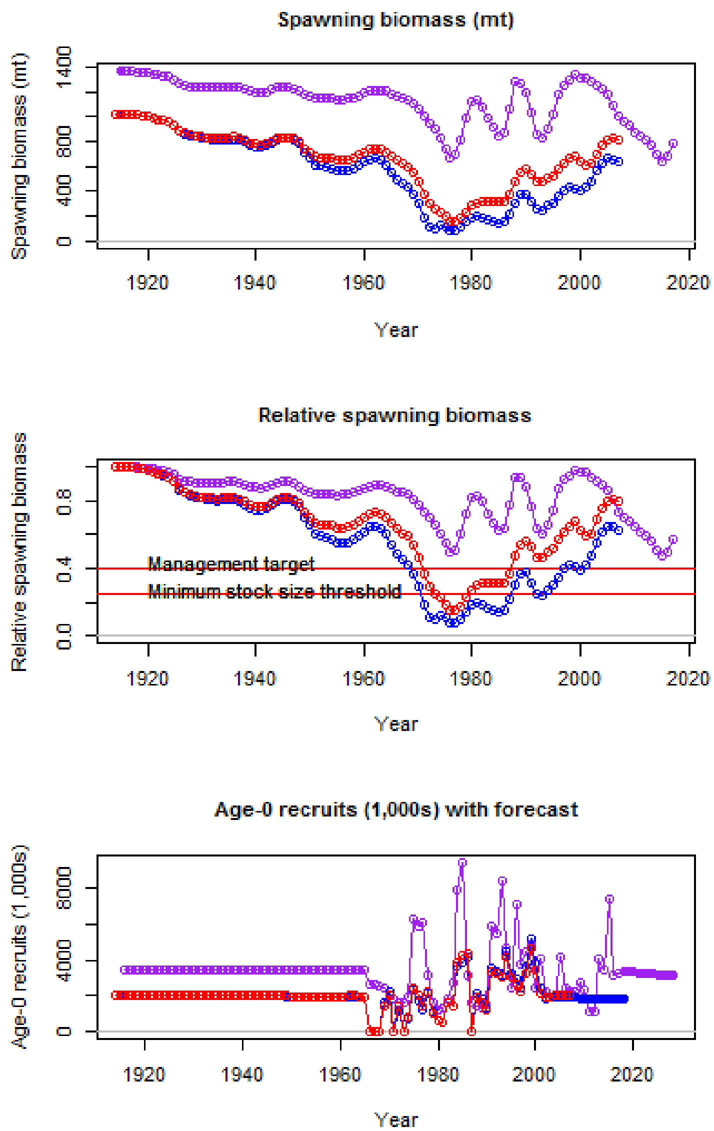


Figure 53: Comparison of spawning output, total biomass, and recruits from the 2005 model (solid red lines) using SS2, the 2005 model converted to SS3.24z (blue lines), and the pre-STAR base model from this assessment (purple lines). Note: The 2005 assessment was found to have an error, and therefore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

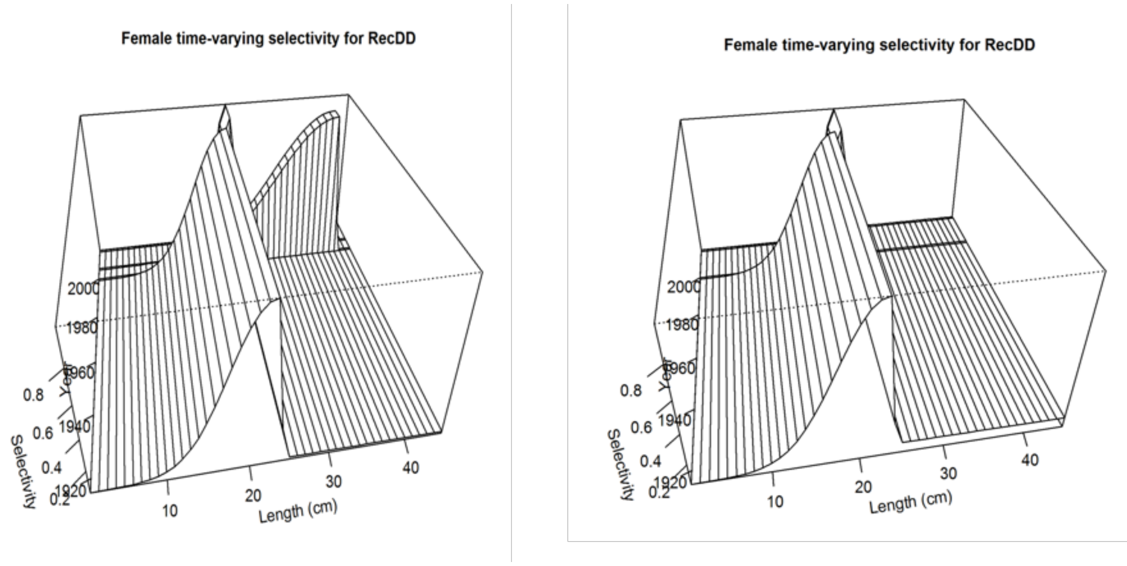


Figure 54: Selectivity curves for the dead discard fleet with three (left) or two (right) time blocks.

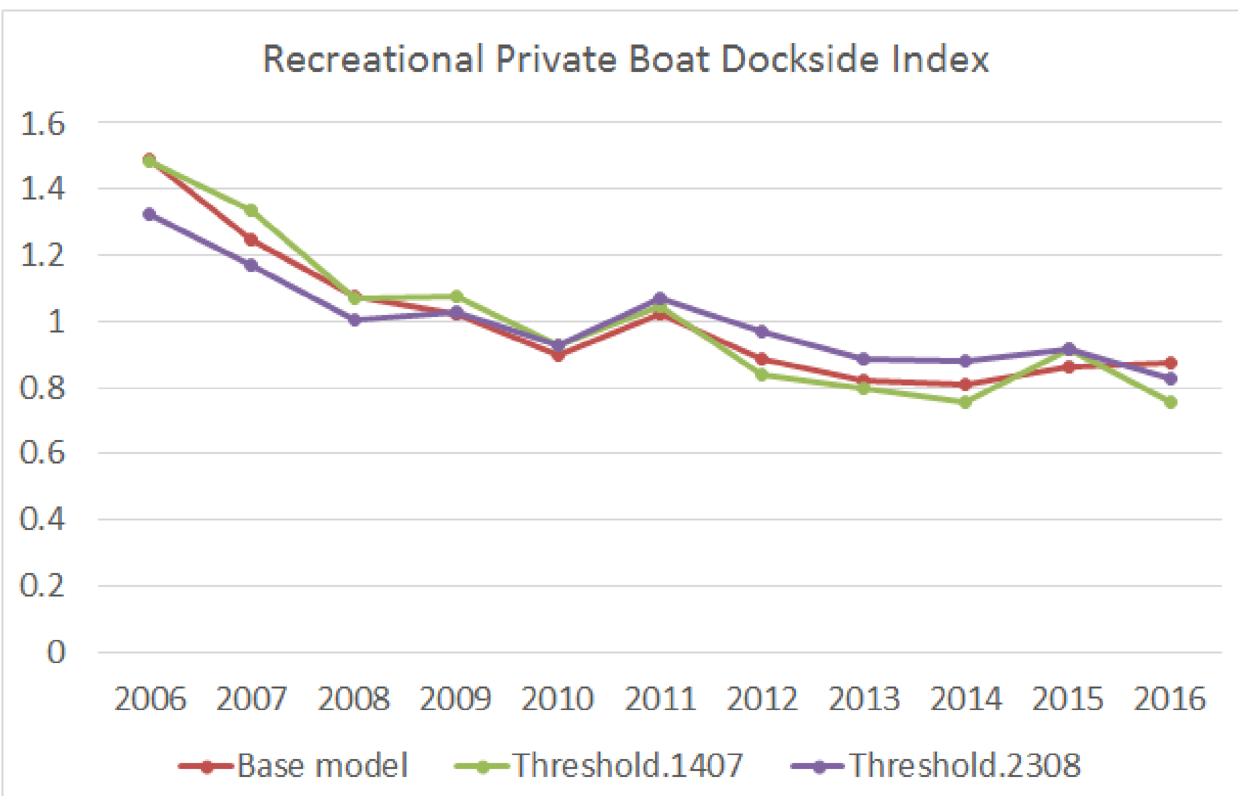


Figure 55: Comparison of the recreational private mode dockside index using three different thresholds for the Stephens-MacCall filter.

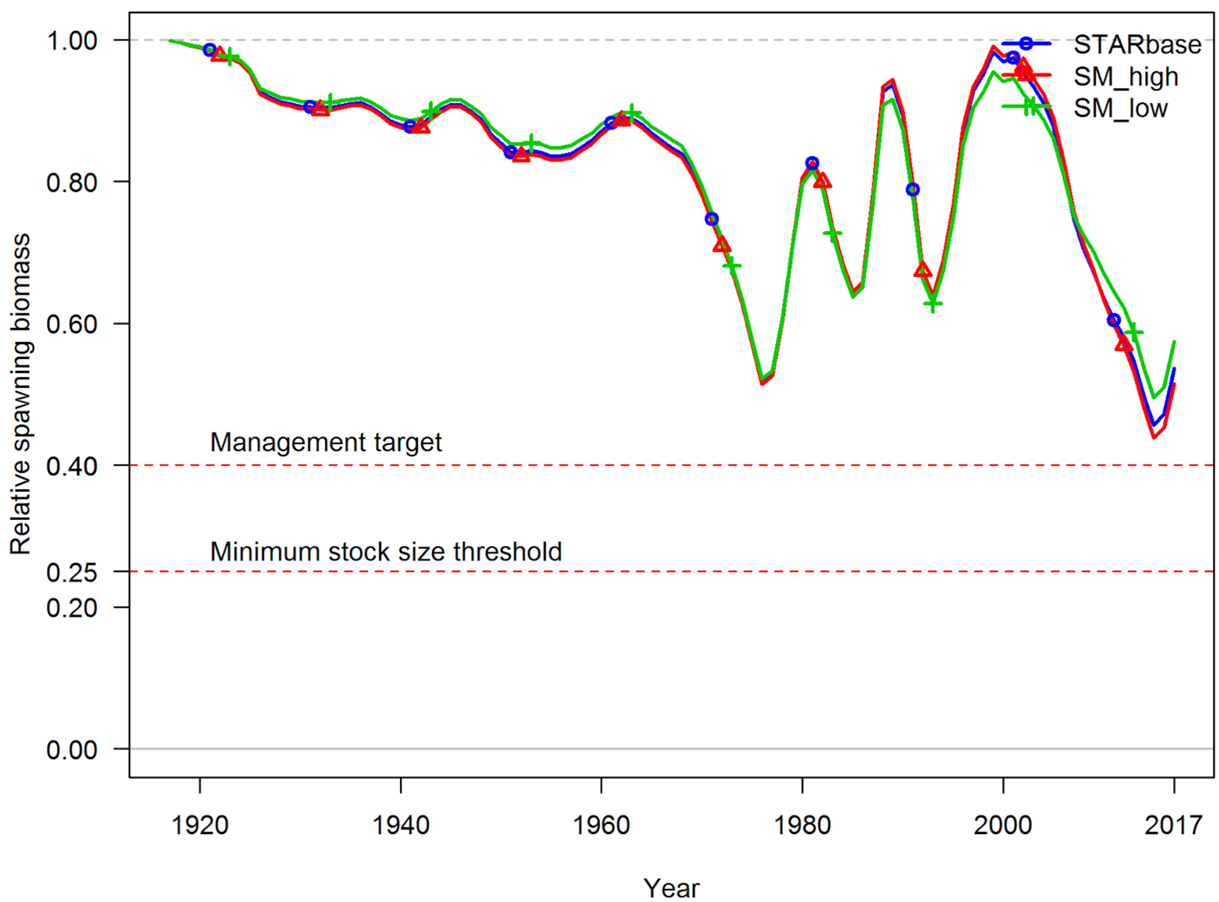


Figure 56: Comparisons of the base model using the index developed for the recreational private mode dockside index using three different thresholds for the Stephens-MacCall filter.

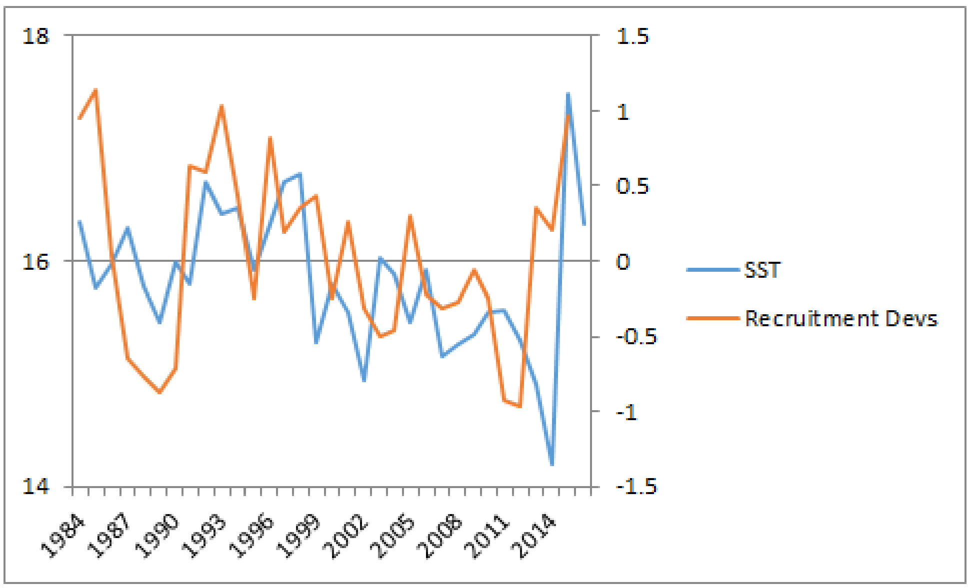


Figure 57: Time series of estimated recruitment deviations from the base model and the CalCOFI sea surface temperature.

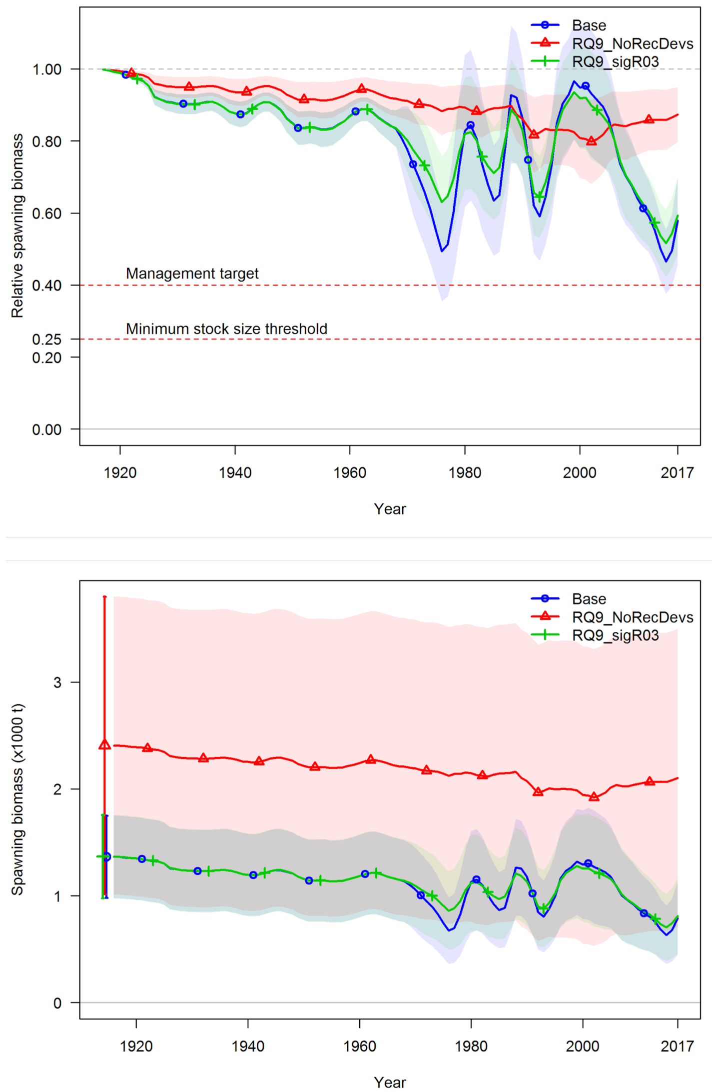
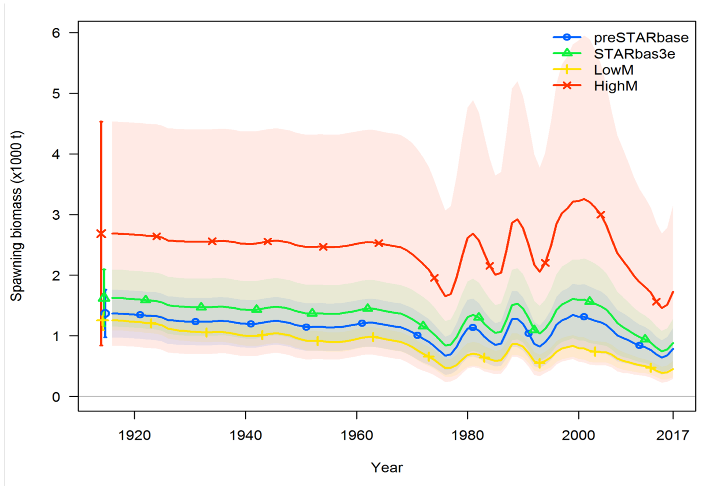


Figure 58: Time series of relative spawning biomass (top) and spawning biomass (bottom) from the base model compared to a model with no recruitment deviations and a sigma-r of 0.3.



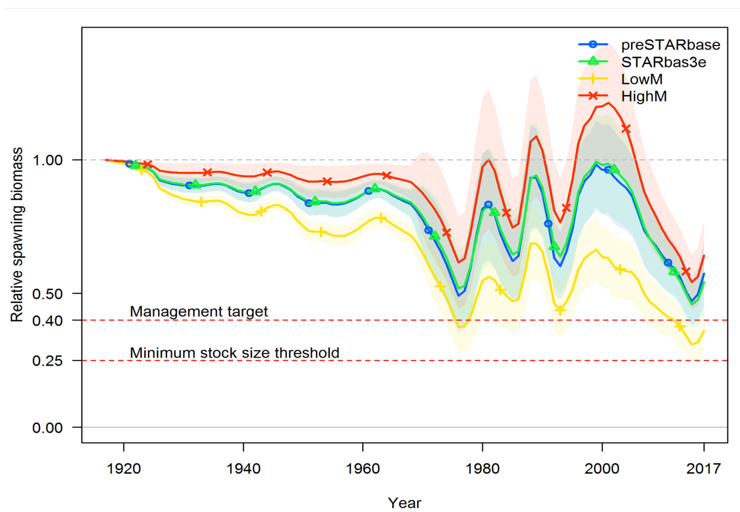


Figure 59: Time series of spawning biomass (top) and relative spawning biomass (bottom) from the pre-STAR base model (M fixed at 0.257 for females and estimated for males) compared to the STAR panel base model (one M = 0.235), and the two states of nature of natural mortality of 0.165 and 0.2745.

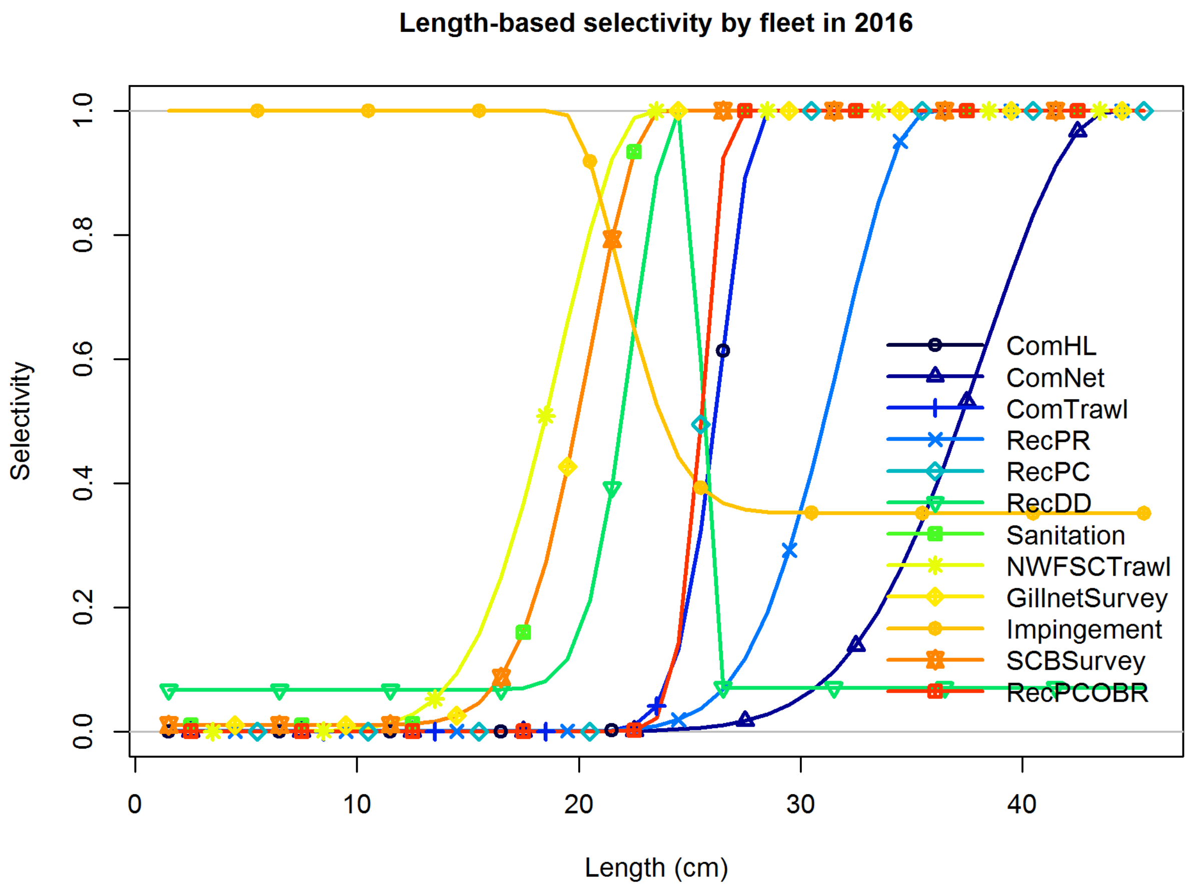


Figure 60: Selectivity at length for all of the fleets in the base model.

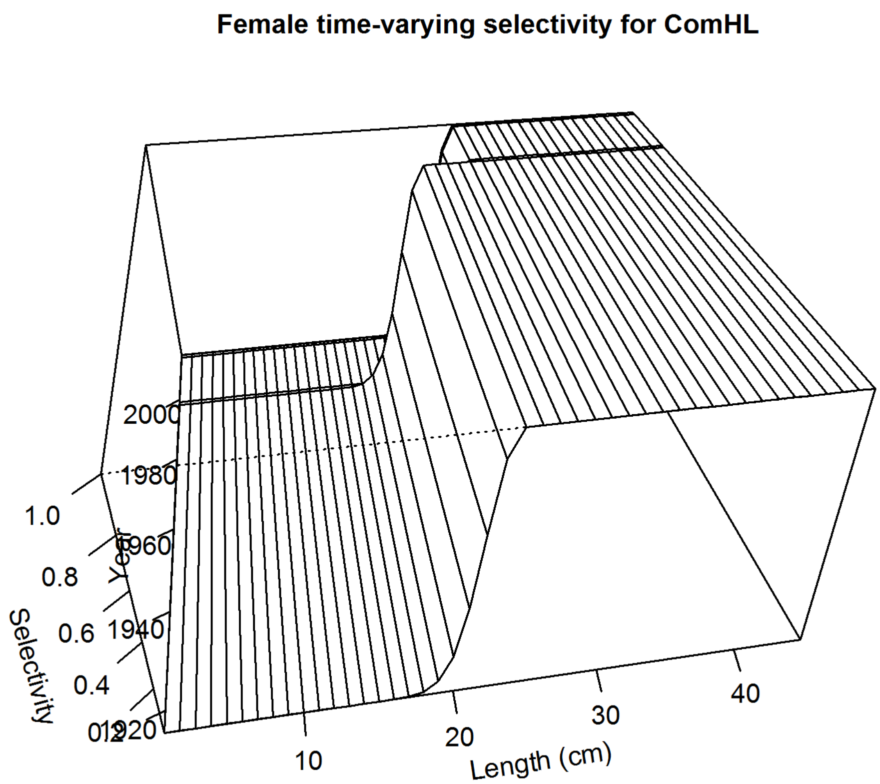


Figure 61: Surface plot of Female time-varying selectivity for the commercial hook-and-line fleet, with time blocks from 1916-1998 and 1999-2016.

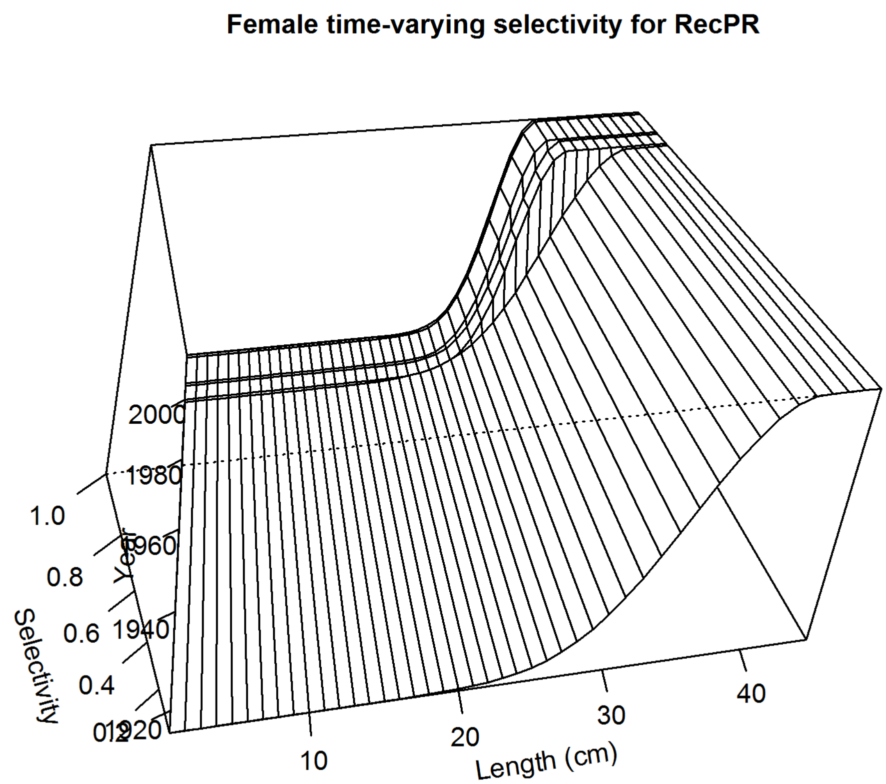


Figure 62: Surface plot of Female time-varying selectivity for the recreational private boat fleet, with time blocks from 1916-2000, 2001-2005, and 2006-2016.

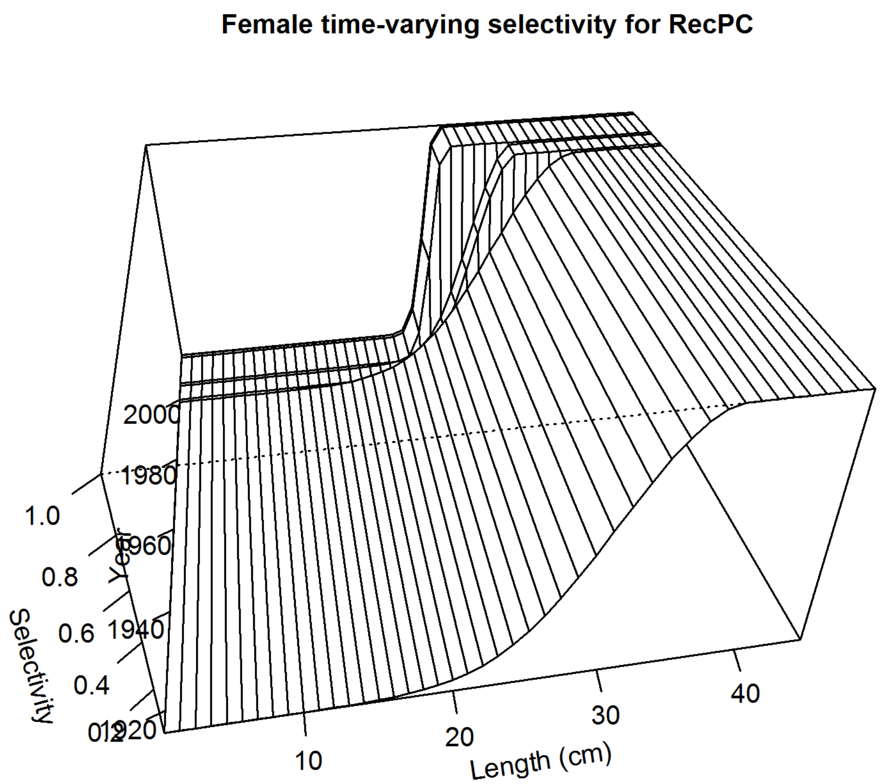


Figure 63: Surface plot of Female time-varying selectivity for the recreational party/charter retained-only catch fleet, with time blocks from 1916-2000, 2001-2005, and 2006-2016.

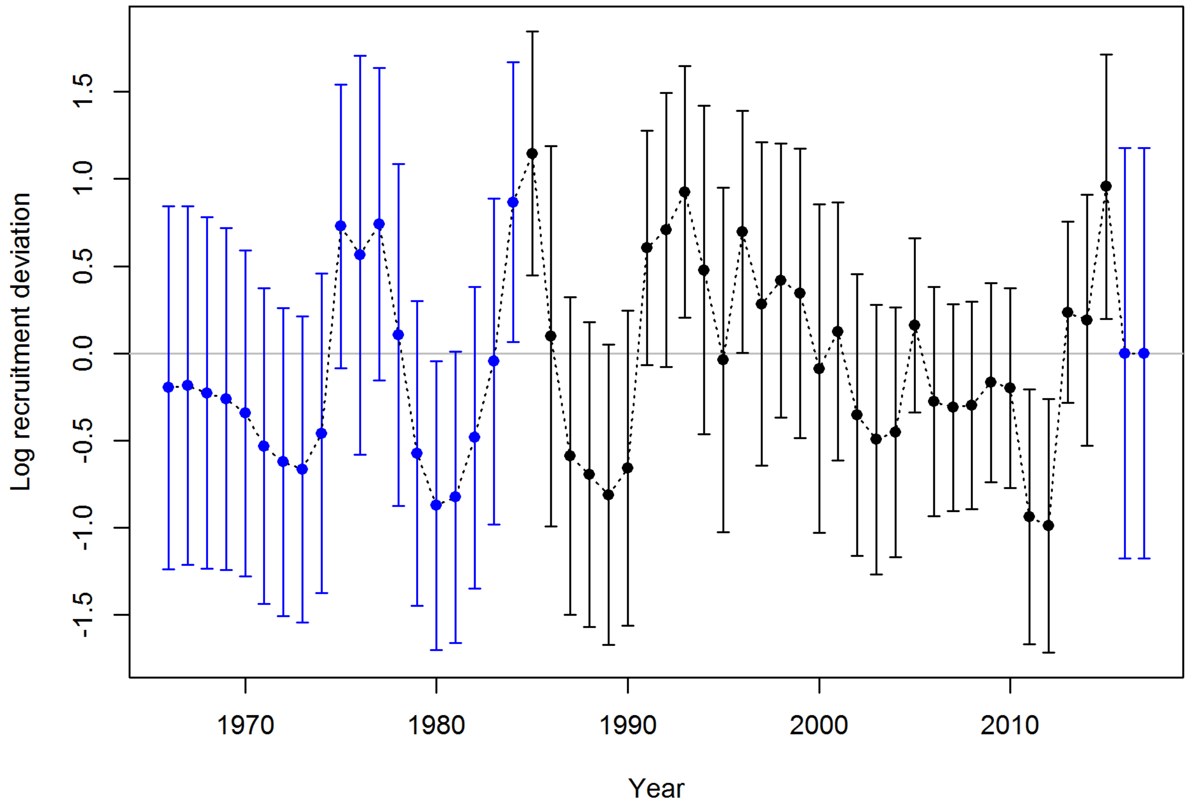


Figure 64: Estimated time-series of recruitment deviations for California scorpionfish with 95% intervals.

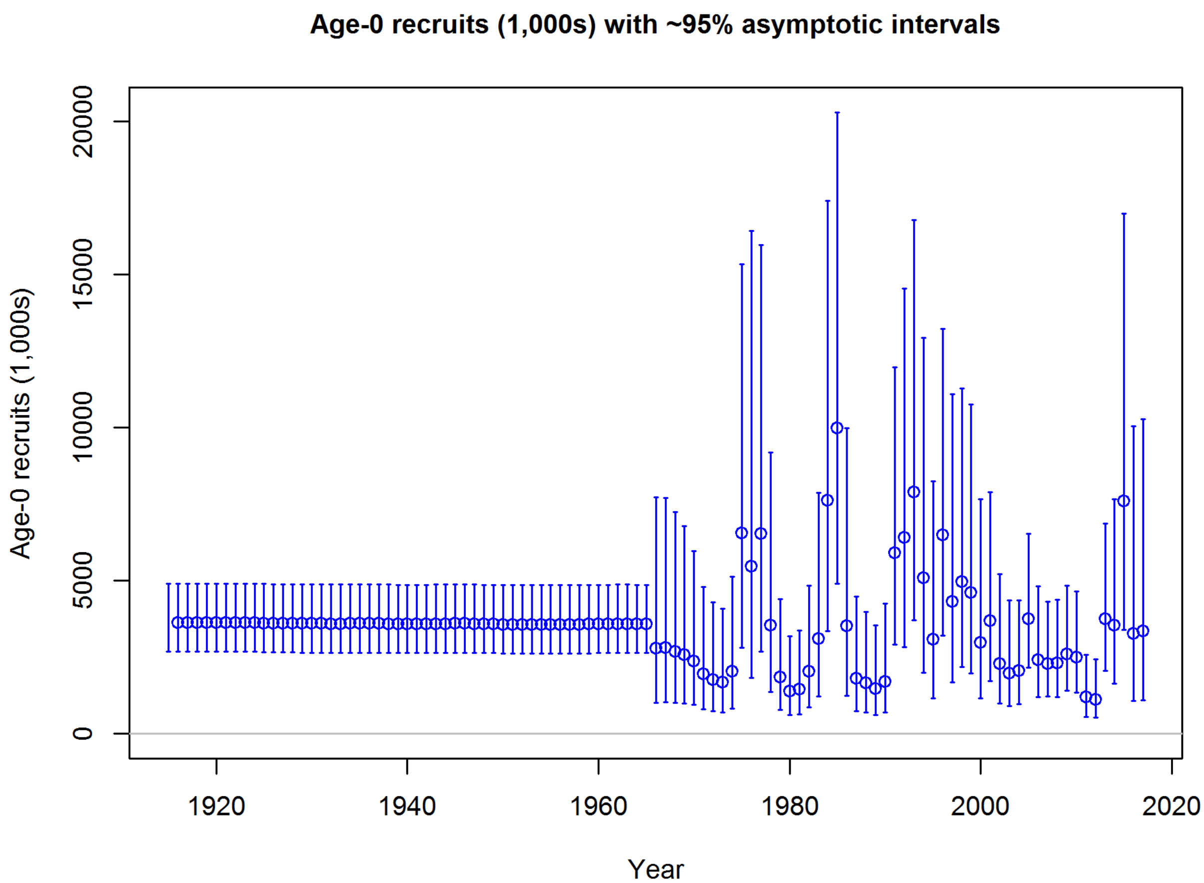


Figure 65: Estimated time-series of recruitment for California scorpionfish.

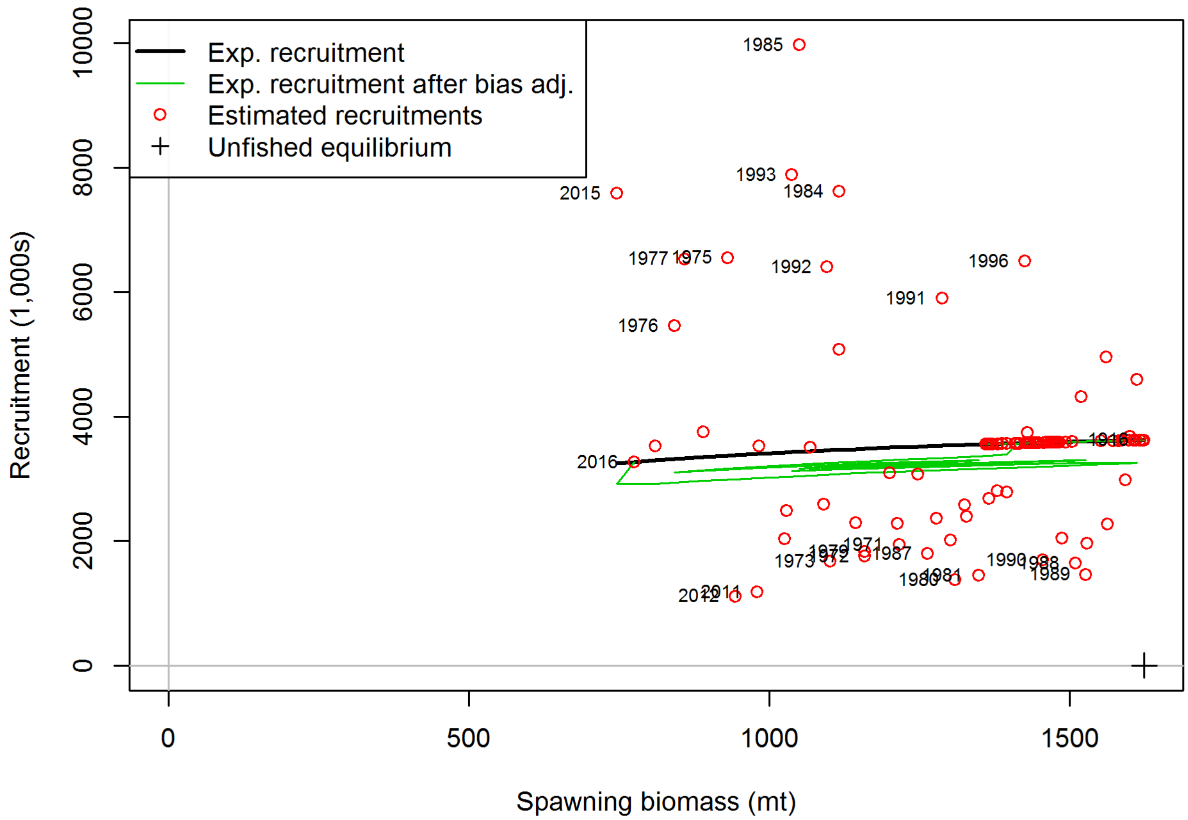


Figure 66: Estimated recruitment (red circles) and the assumed stock-recruit relationship (black line) for California scorpionfish. The green line shows the effect of the bias correction for the lognormal distribution.

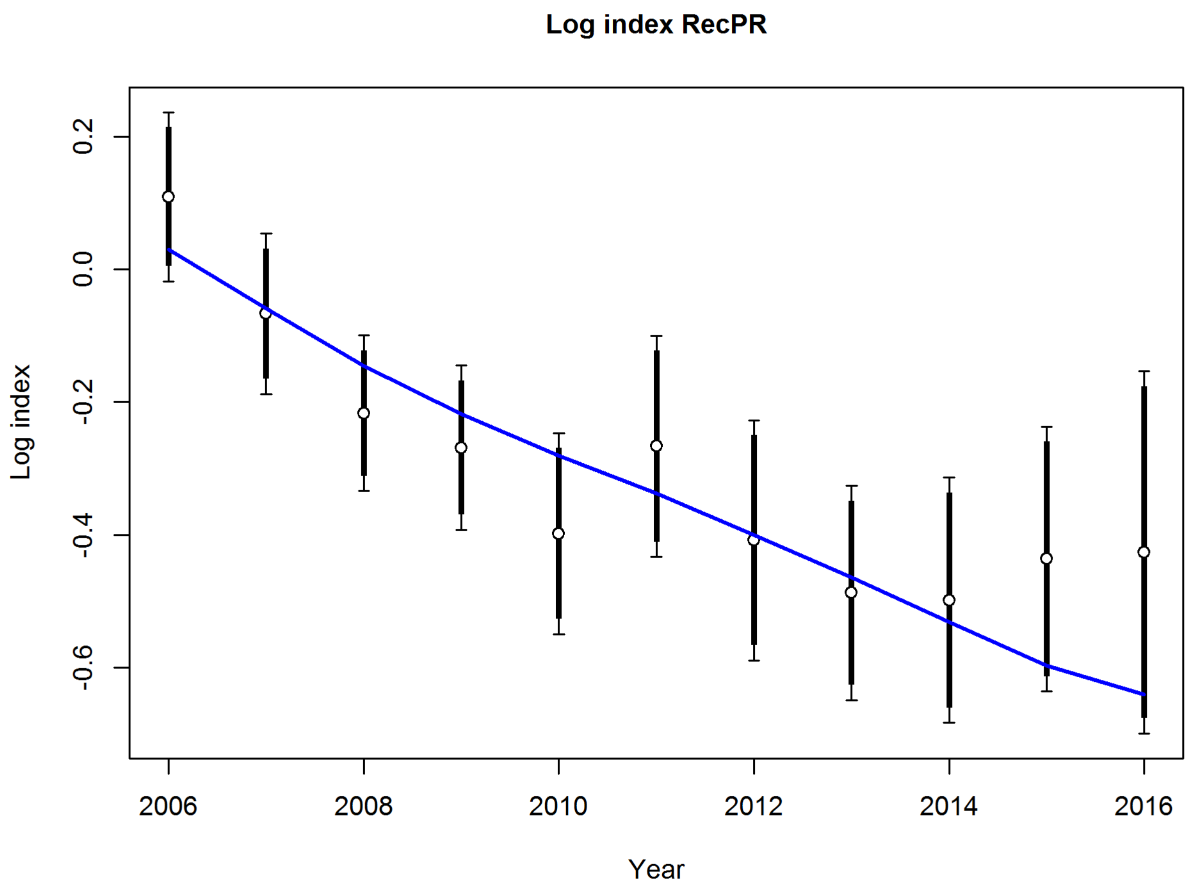


Figure 67: Fit to log index data on log scale for the CRFS recreational private mode fishery. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

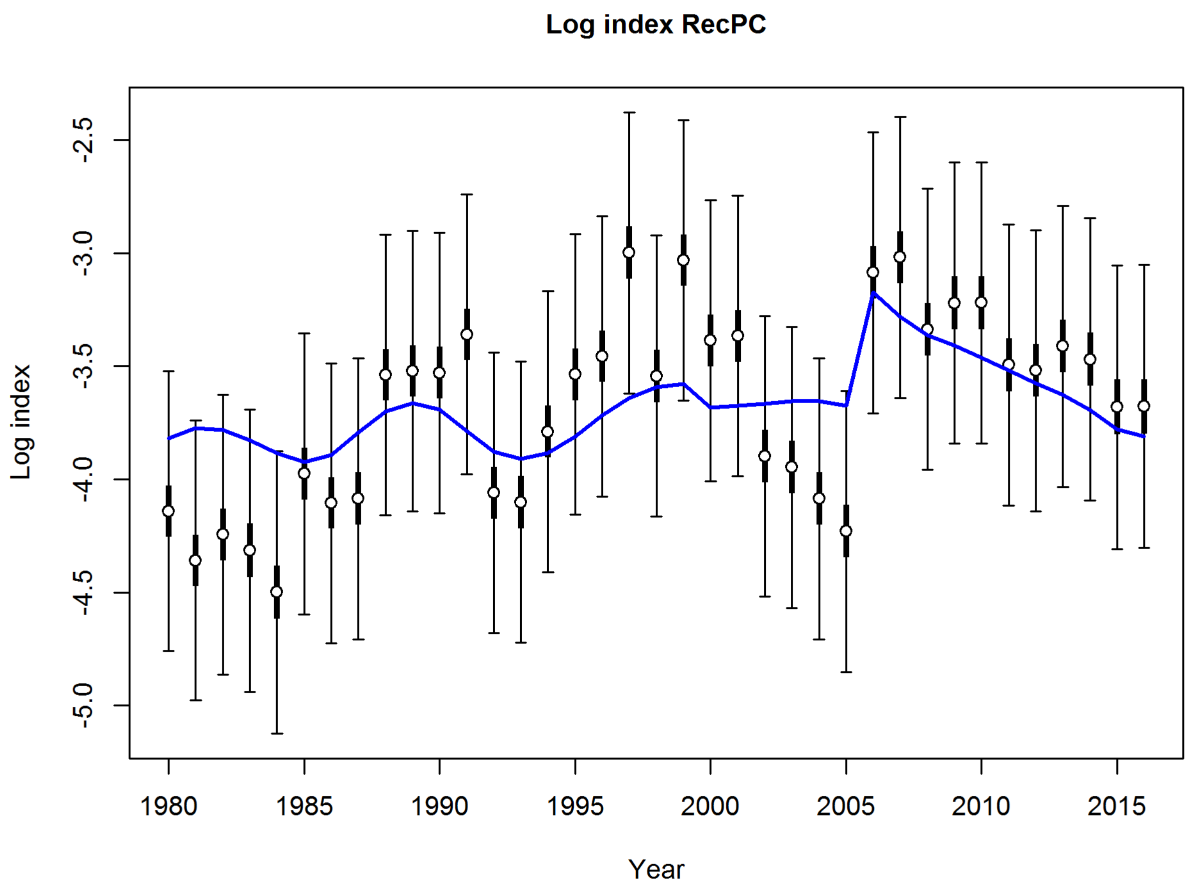


Figure 68: Fit to log index data on log scale for the recreational CPFV logbook retained catches. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

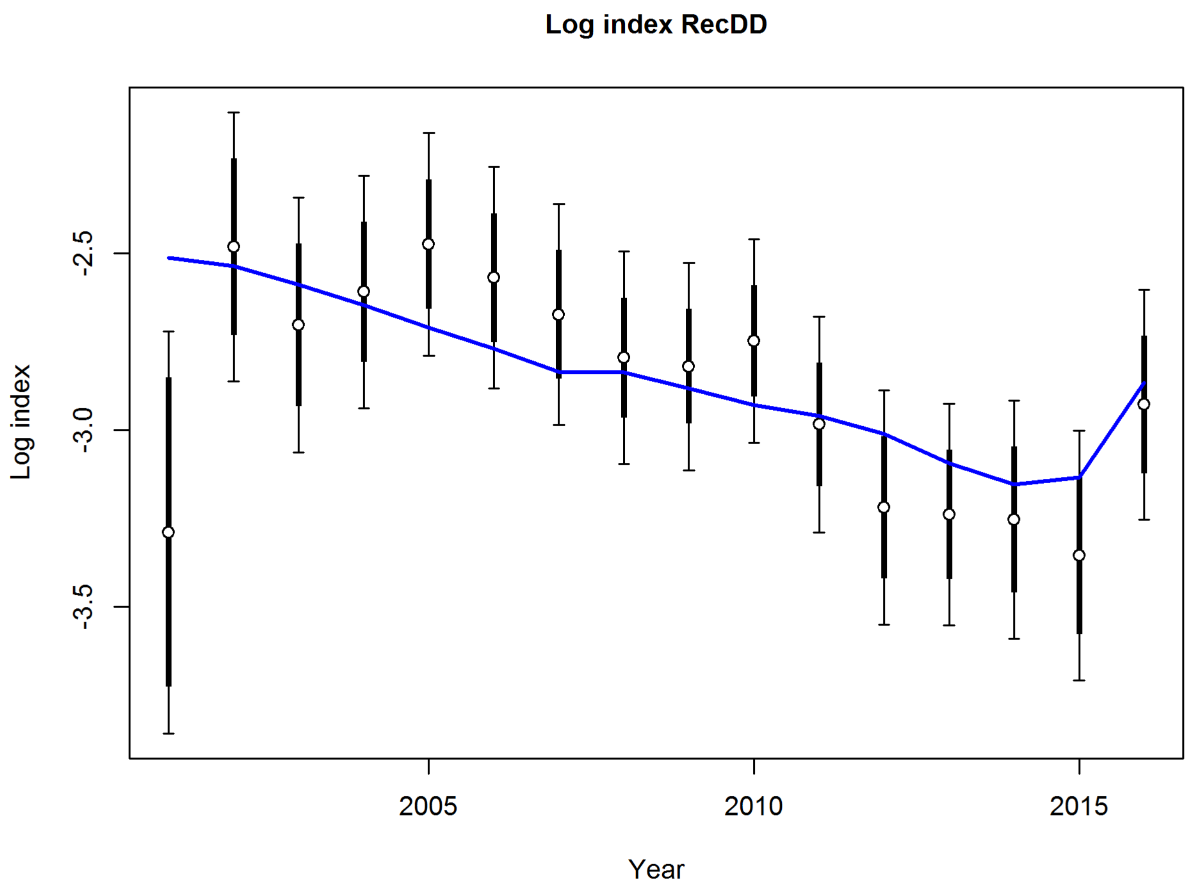


Figure 69: Fit to log index data on log scale for the recreational CPFV onboard observer discard catch index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

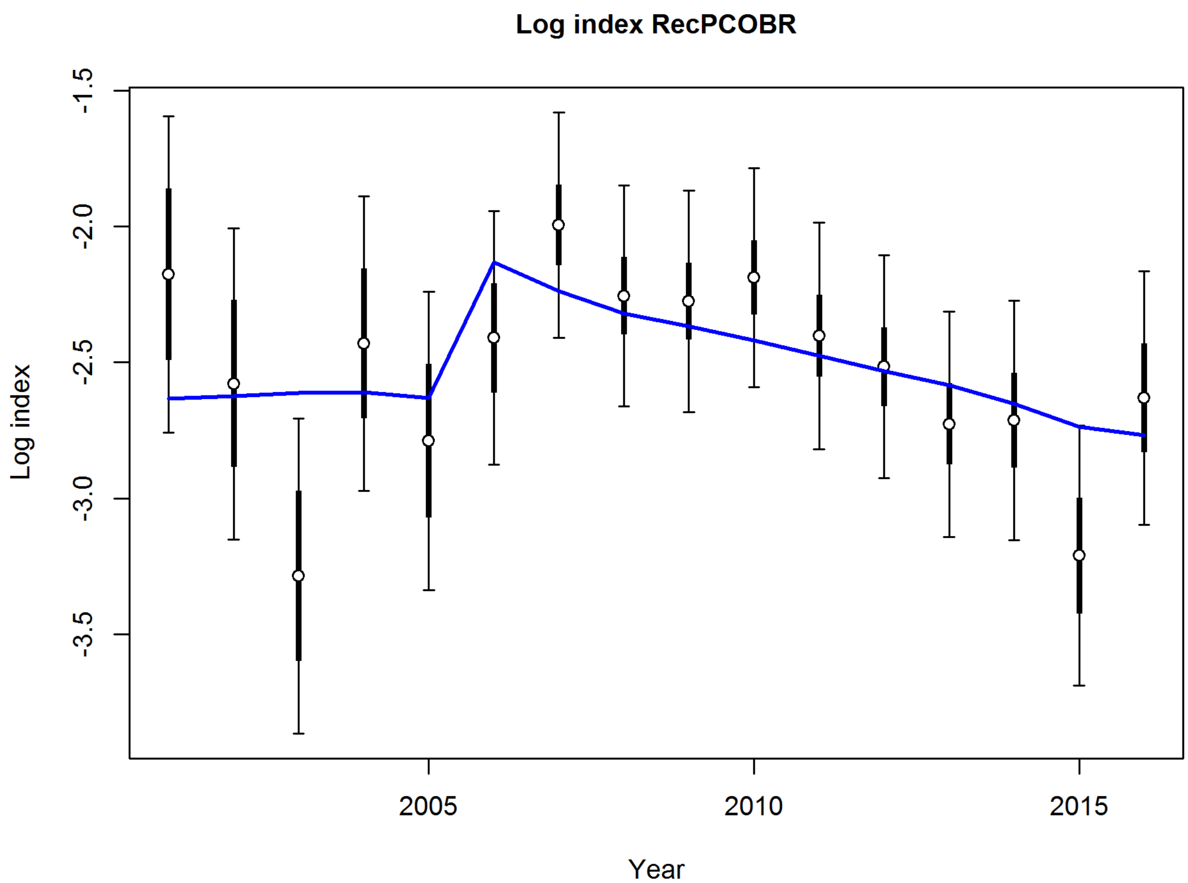


Figure 70: Fit to log index data on log scale for the recreational CPFV onboard observer retained catch index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

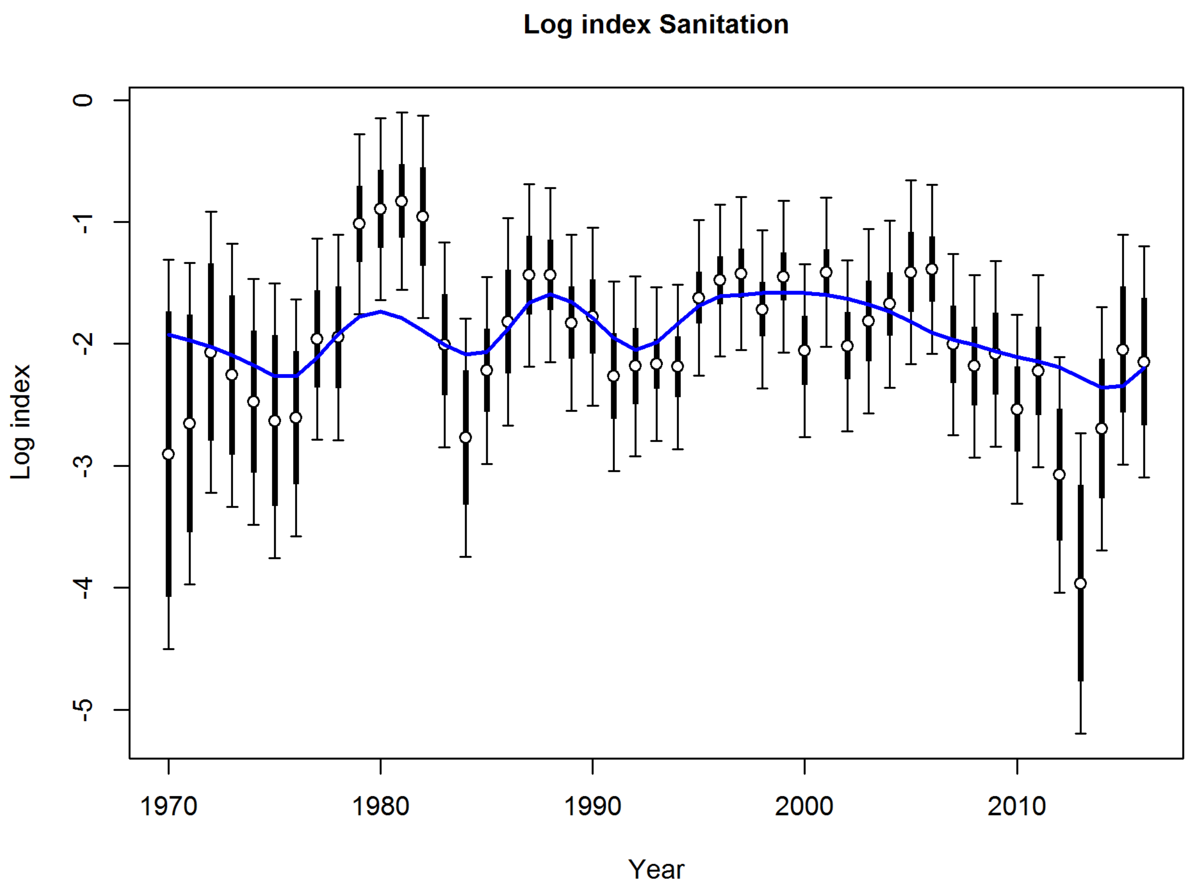


Figure 71: Fit to log index data on log scale for the POTW trawl index. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

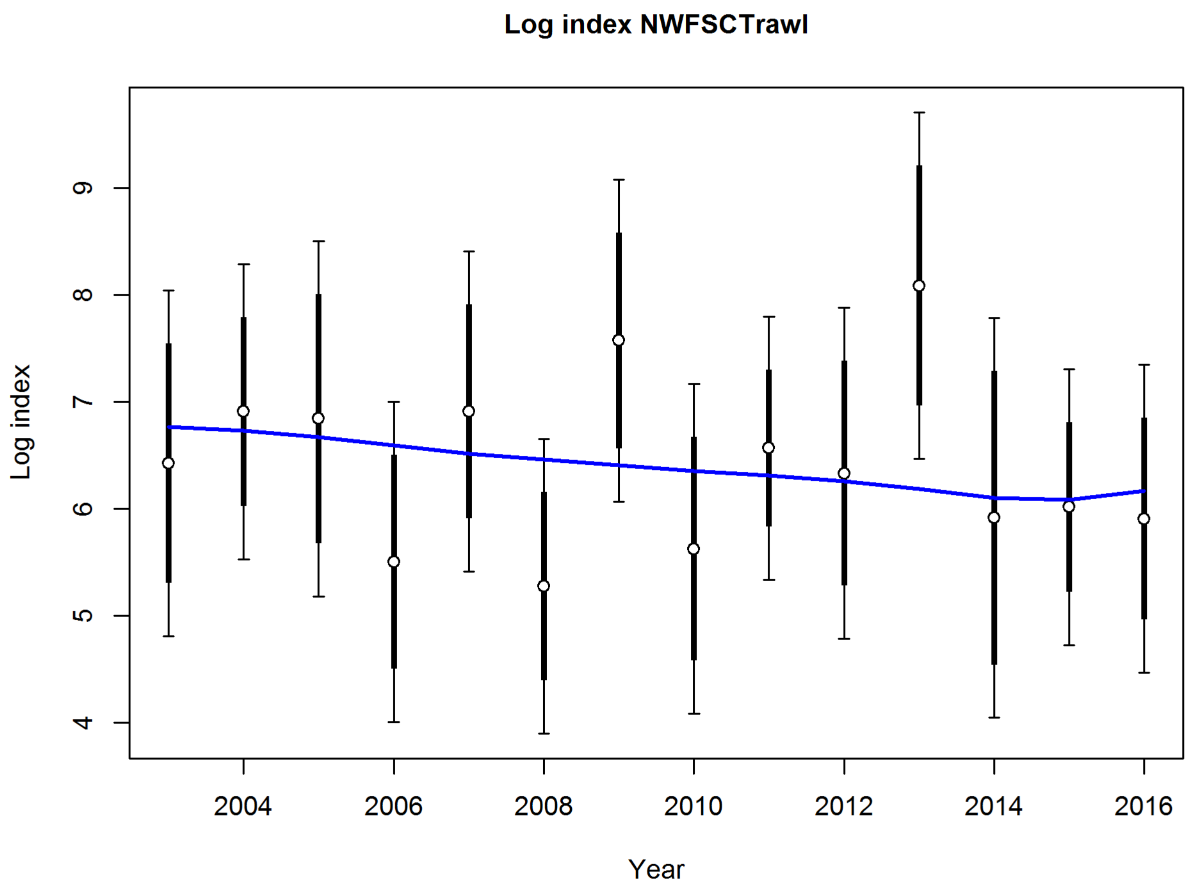


Figure 72: Fit to log index data on log scale for the NWFSC trawl survey from the VAST analysis from 2003-2016. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

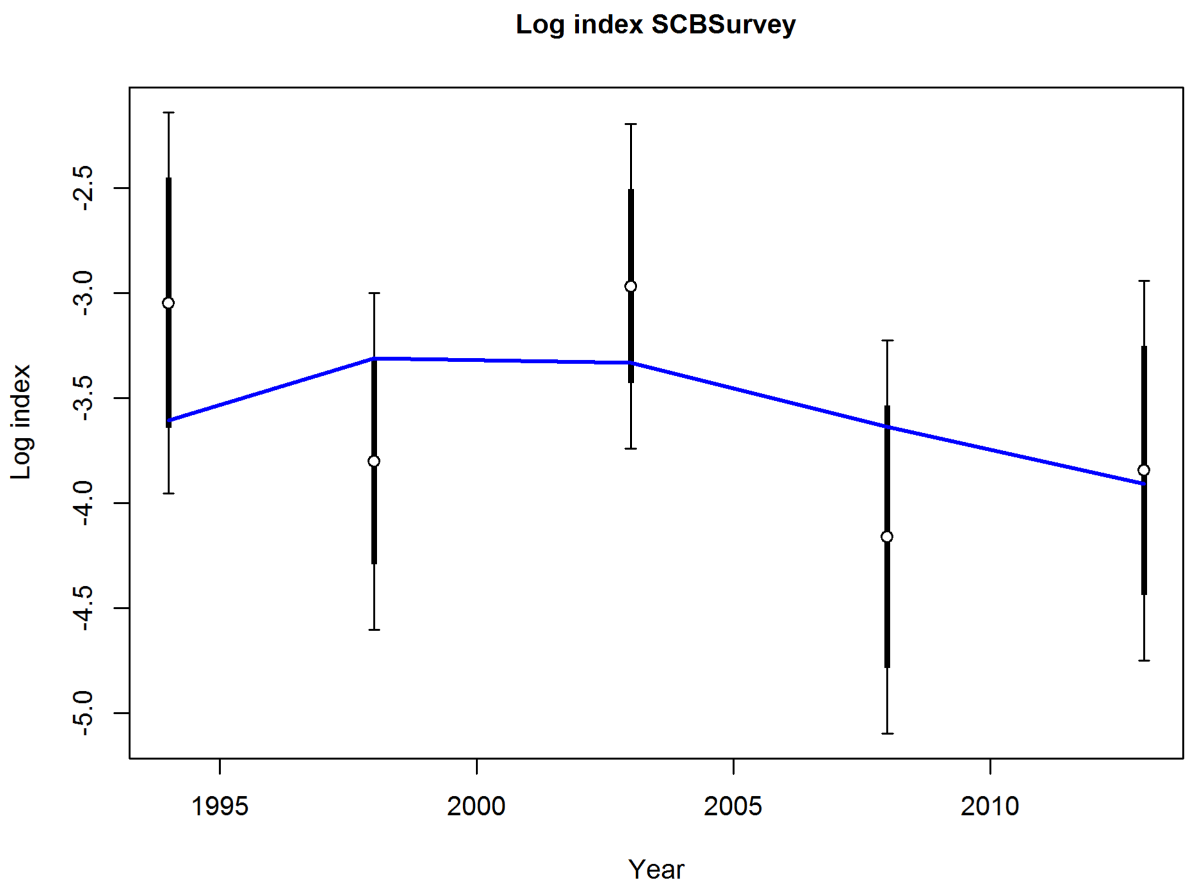


Figure 73: Fit to log index data on log scale for the recreational Southern California Bight trawl survey. Lines indicate 95% uncertainty interval around index values. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

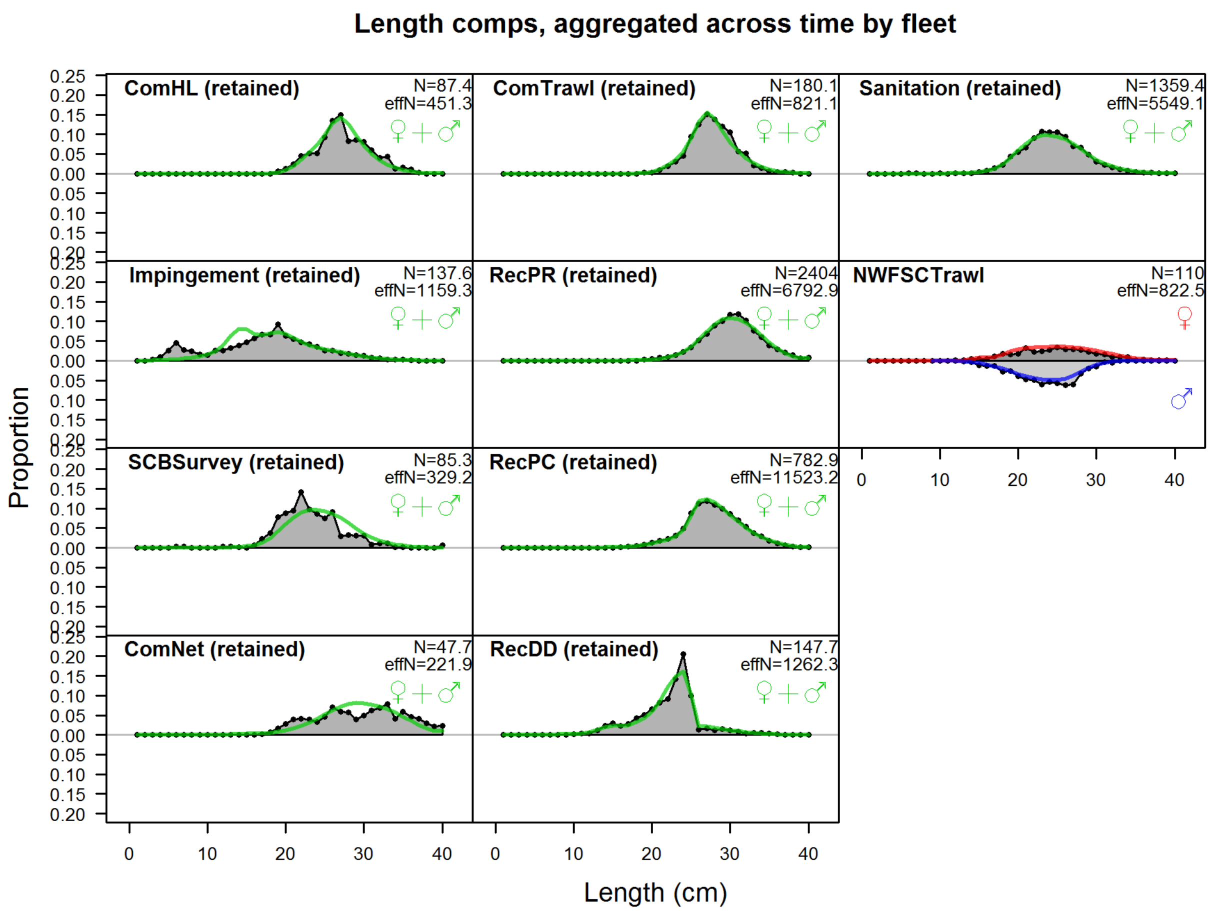


Figure 74: Length compositions aggregated across time by fleet. Labels ‘retained’ and ‘discard’ indicate retained or discarded samples for each fleet. Panels without this designation represent the whole catch.

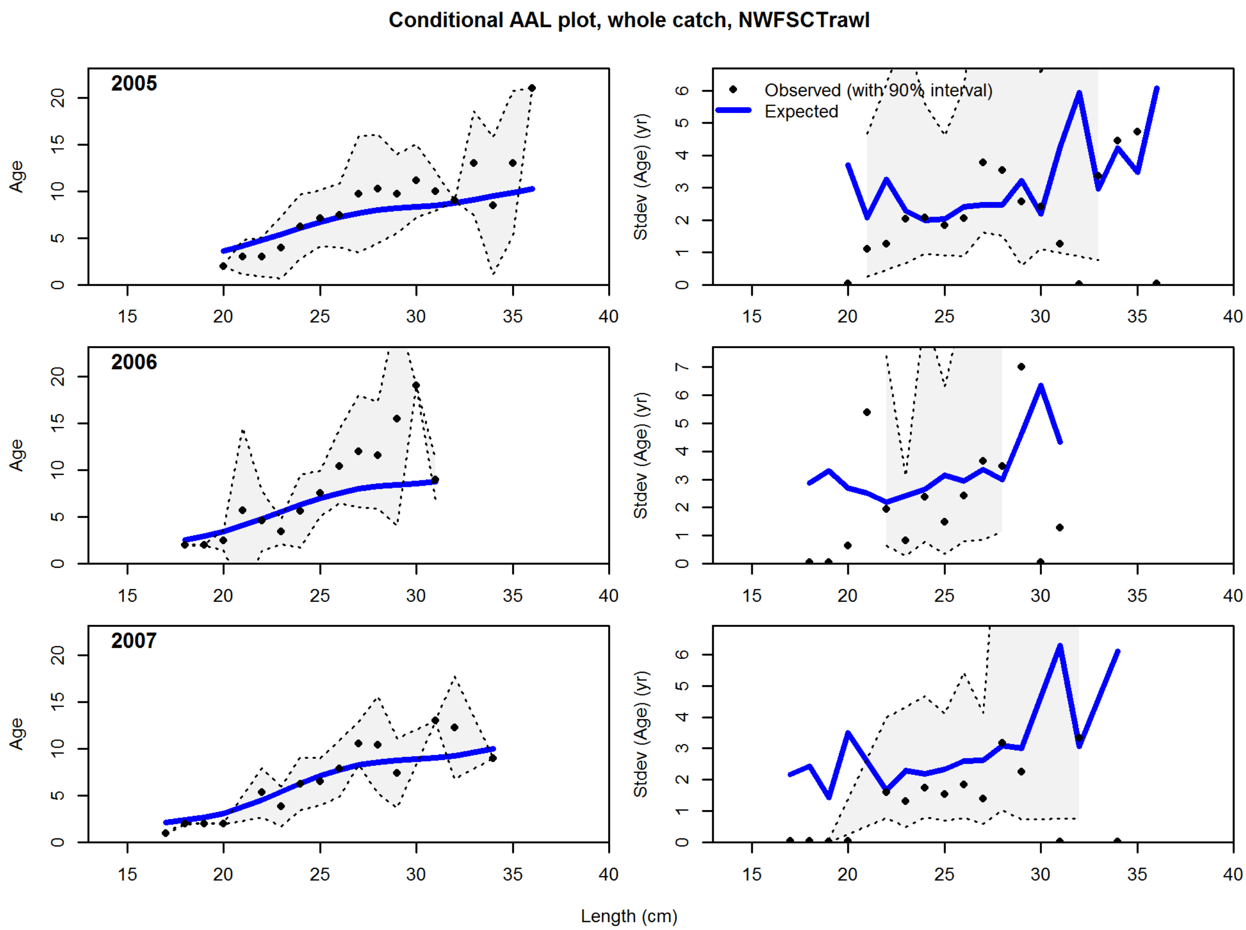
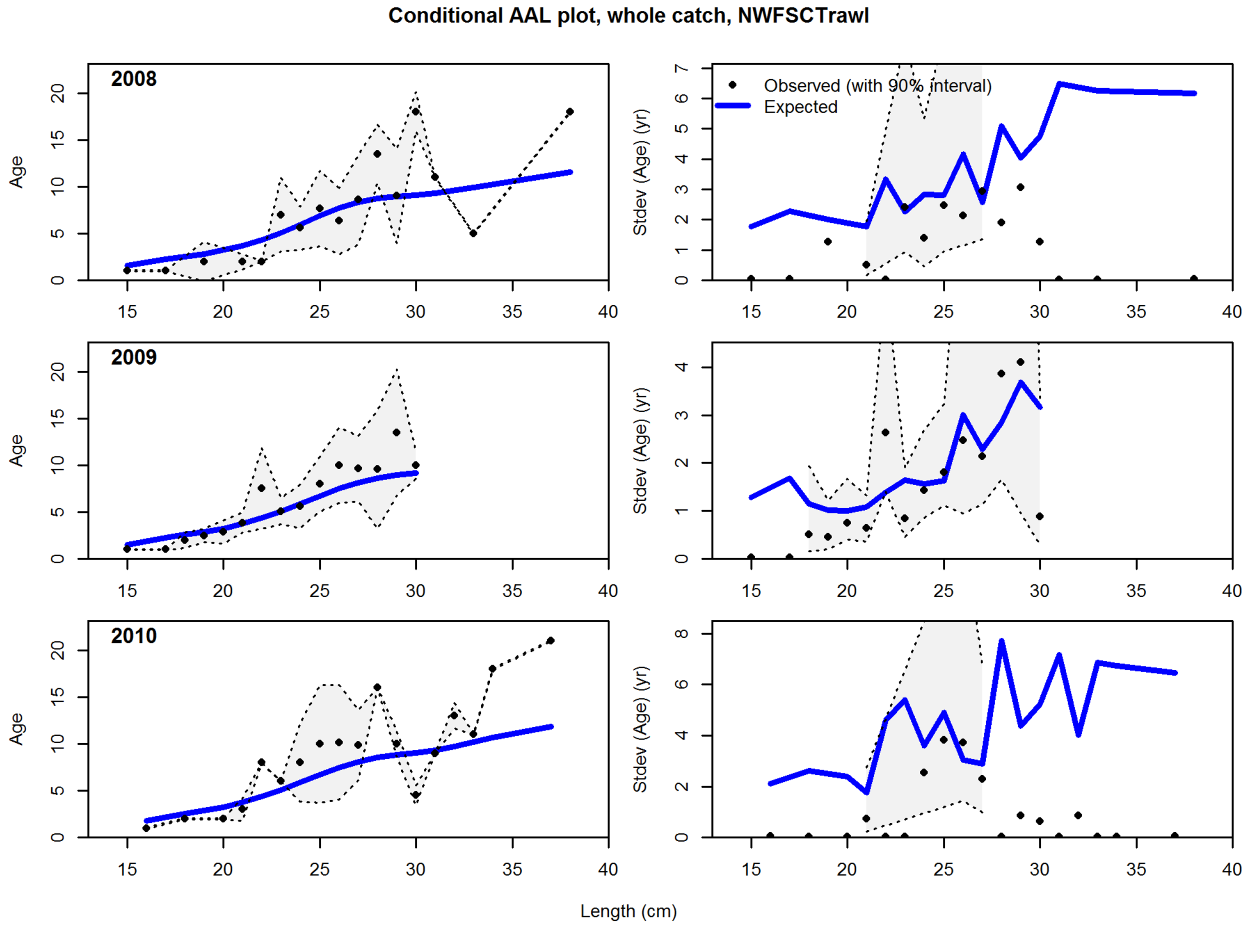


Figure 75: Conditional AAL plot, whole catch, NWFSCTrawl (plot 1 of 4) These plots show mean age and std. dev. in conditional AAL. Left plots are mean AAL by size_class (obs. and pred.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean AAL (obs. and pred.) with 90% CIs based on the chi_square distribution.



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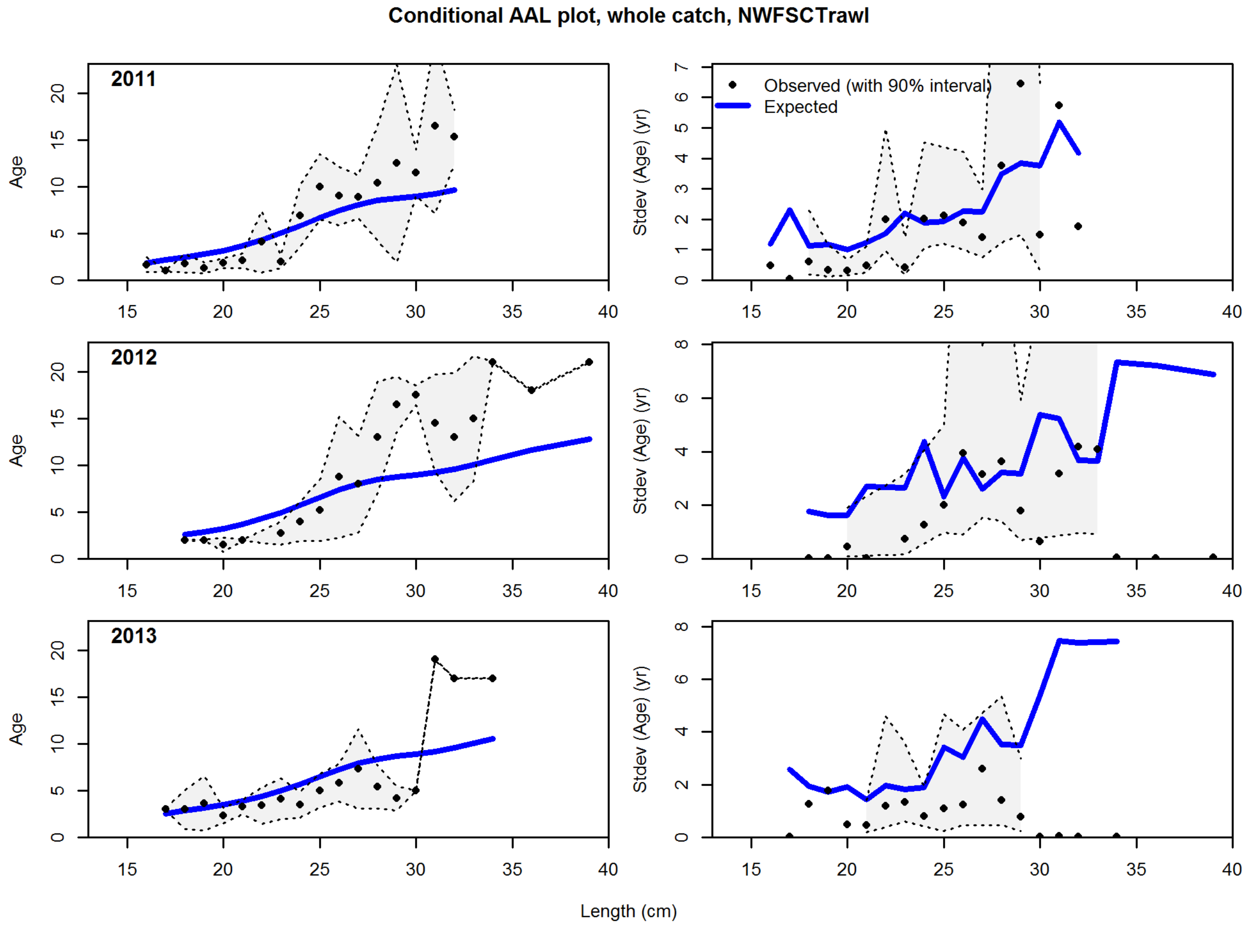

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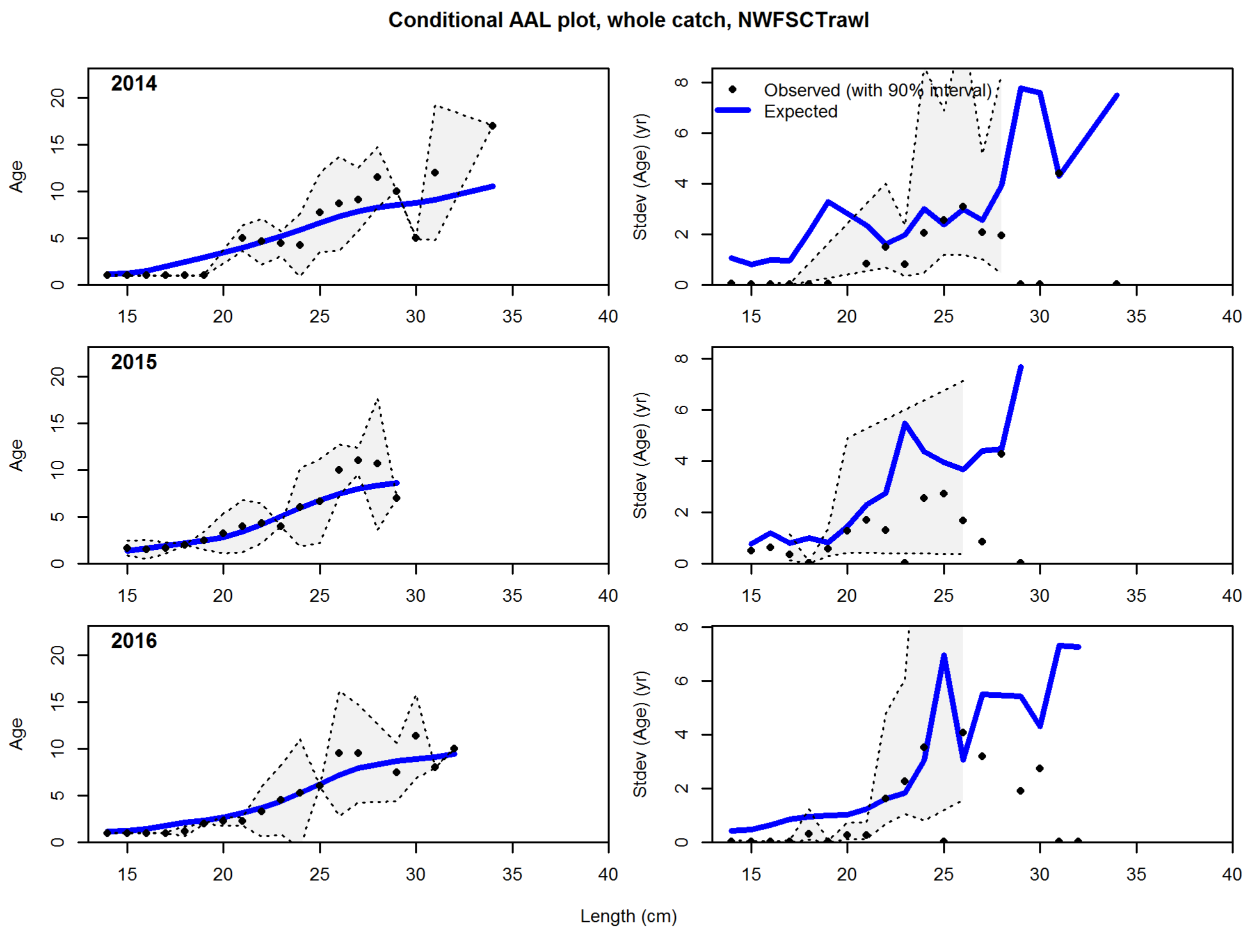

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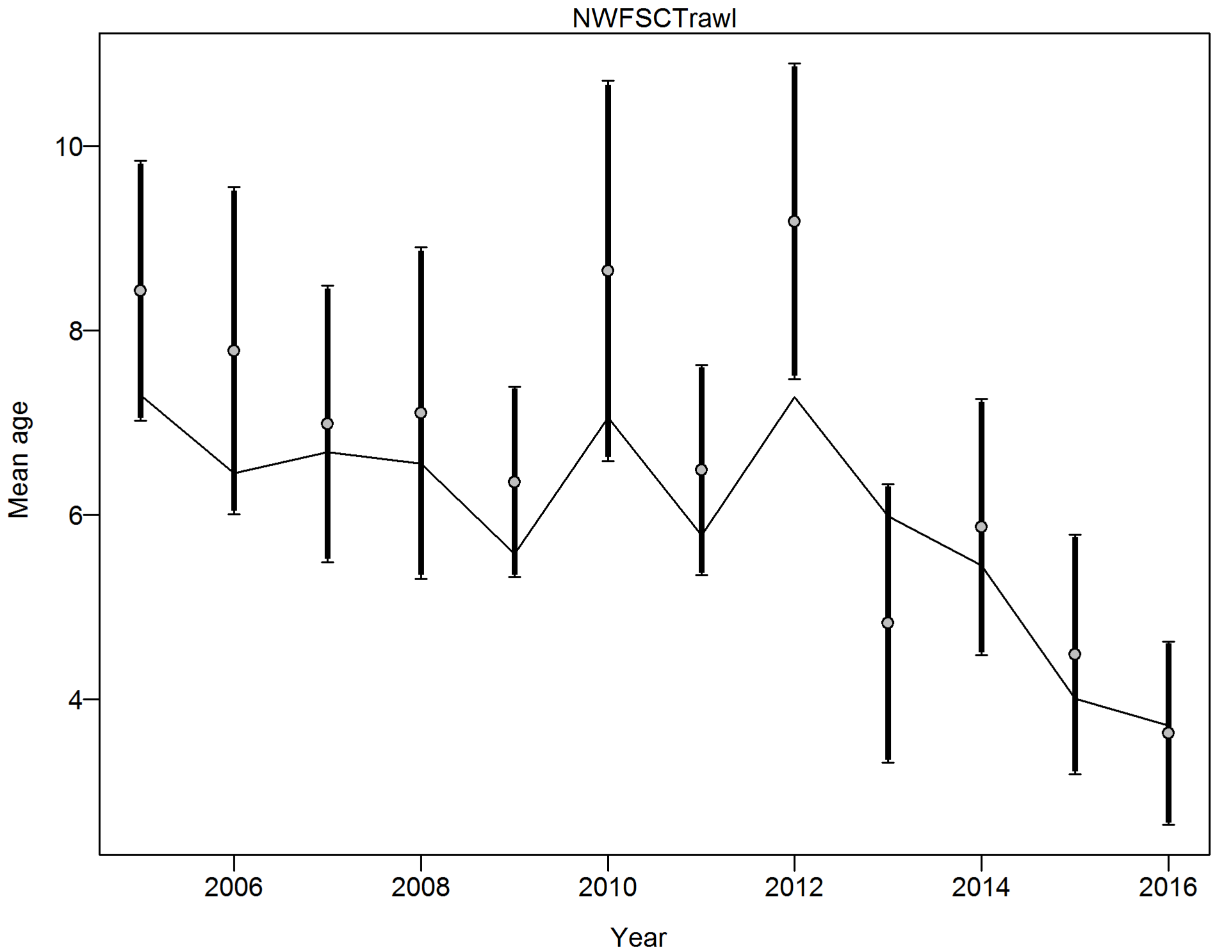


Figure 76: Mean age for NWFSC trawl survey with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.325612 (0.162855-1.289125). For more info, see Francis et al. (2011).

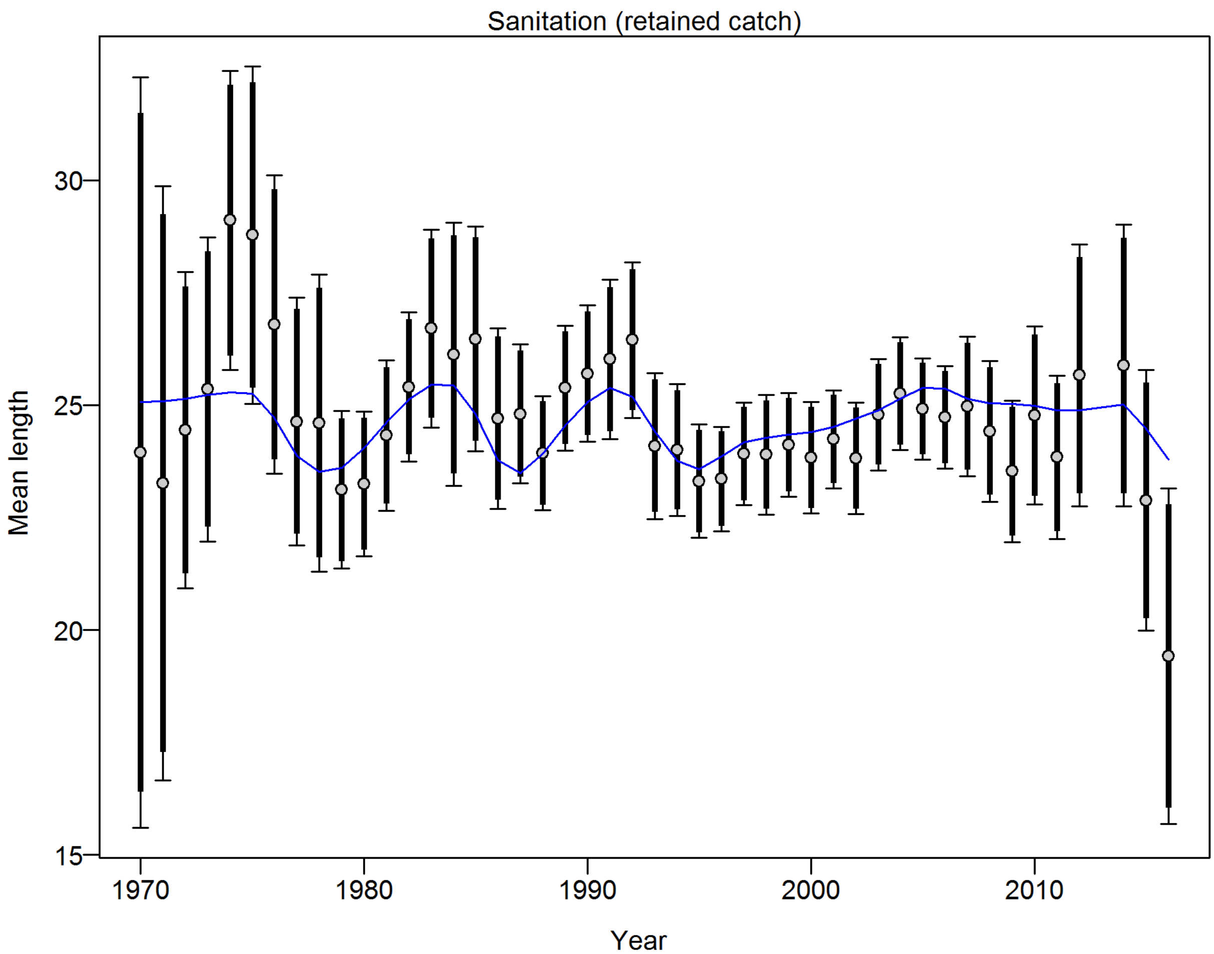


Figure 77: Mean length for the POTW trawl surveys with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.26669 (0.188917-0.430652). For more info, see Francis et al. (2011).

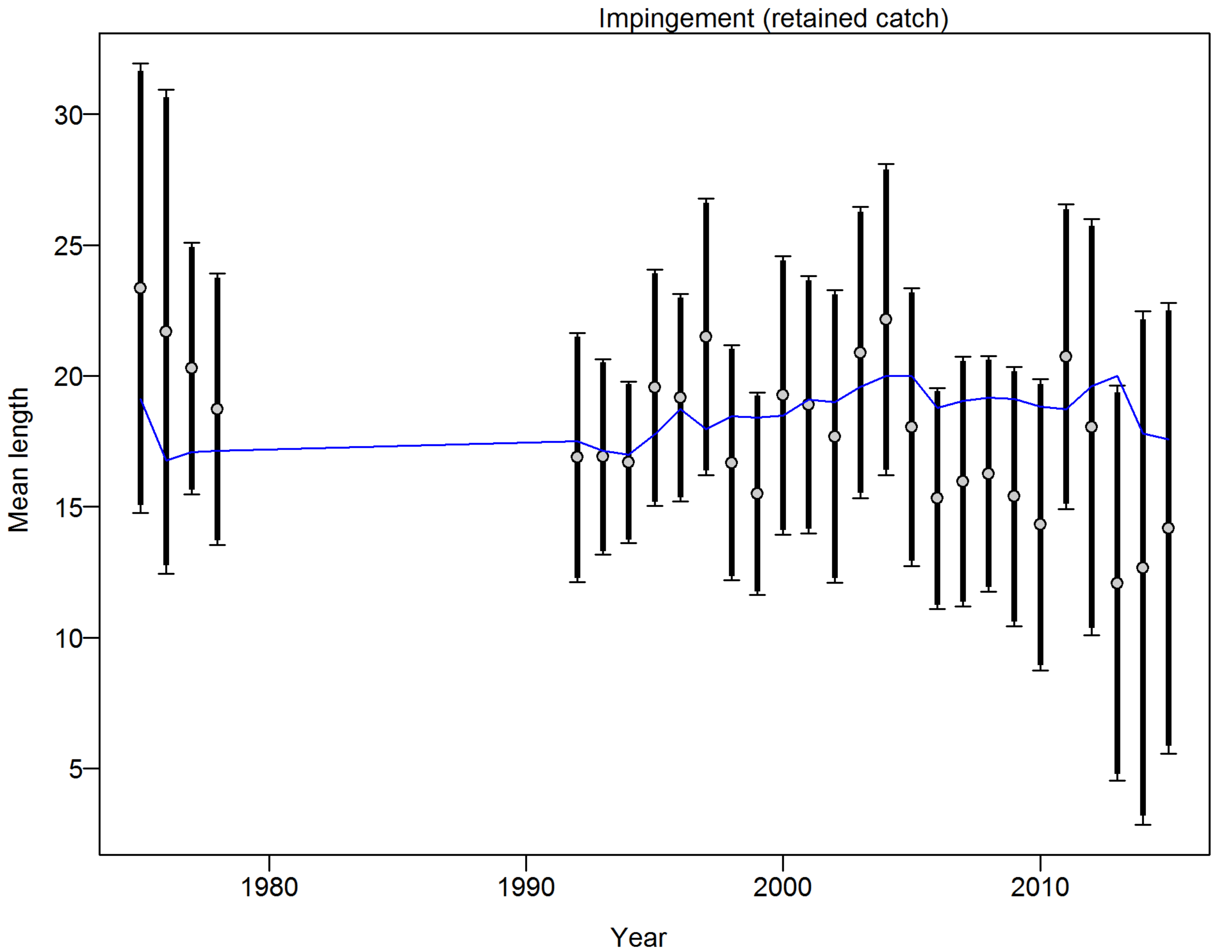


Figure 78: Mean length for the Impingement surveys with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.169729 (0.128089-0.263479). For more info, see Francis et al. (2011).

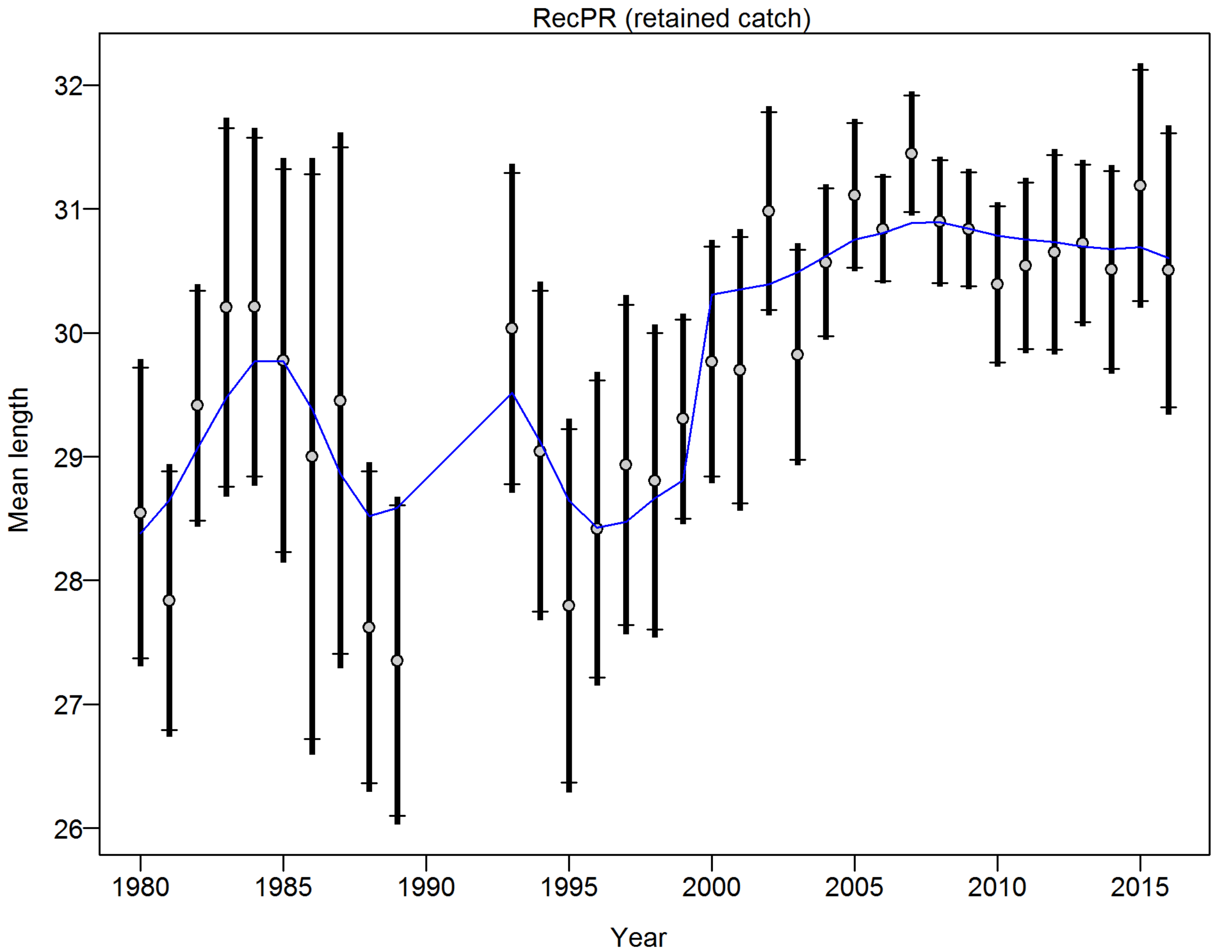


Figure 79: Mean length for the recreational private boat fleet with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.72827 (0.526118-1.183978). For more info, see Francis et al. (2011).

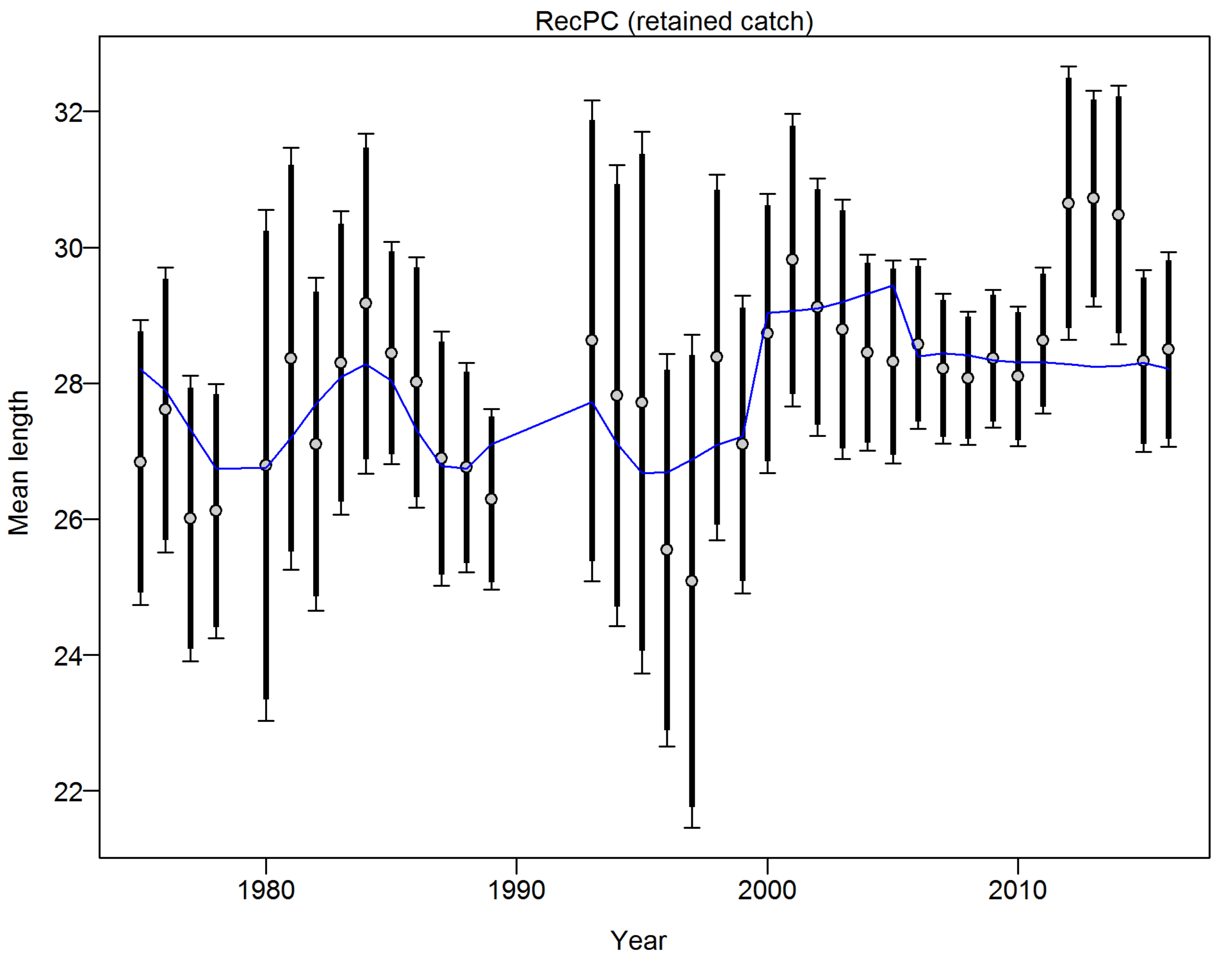


Figure 80: Mean age for recreational party/charter retained-catch fleet with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.135779 (0.087286-0.281298). For more info, see Francis et al. (2011).

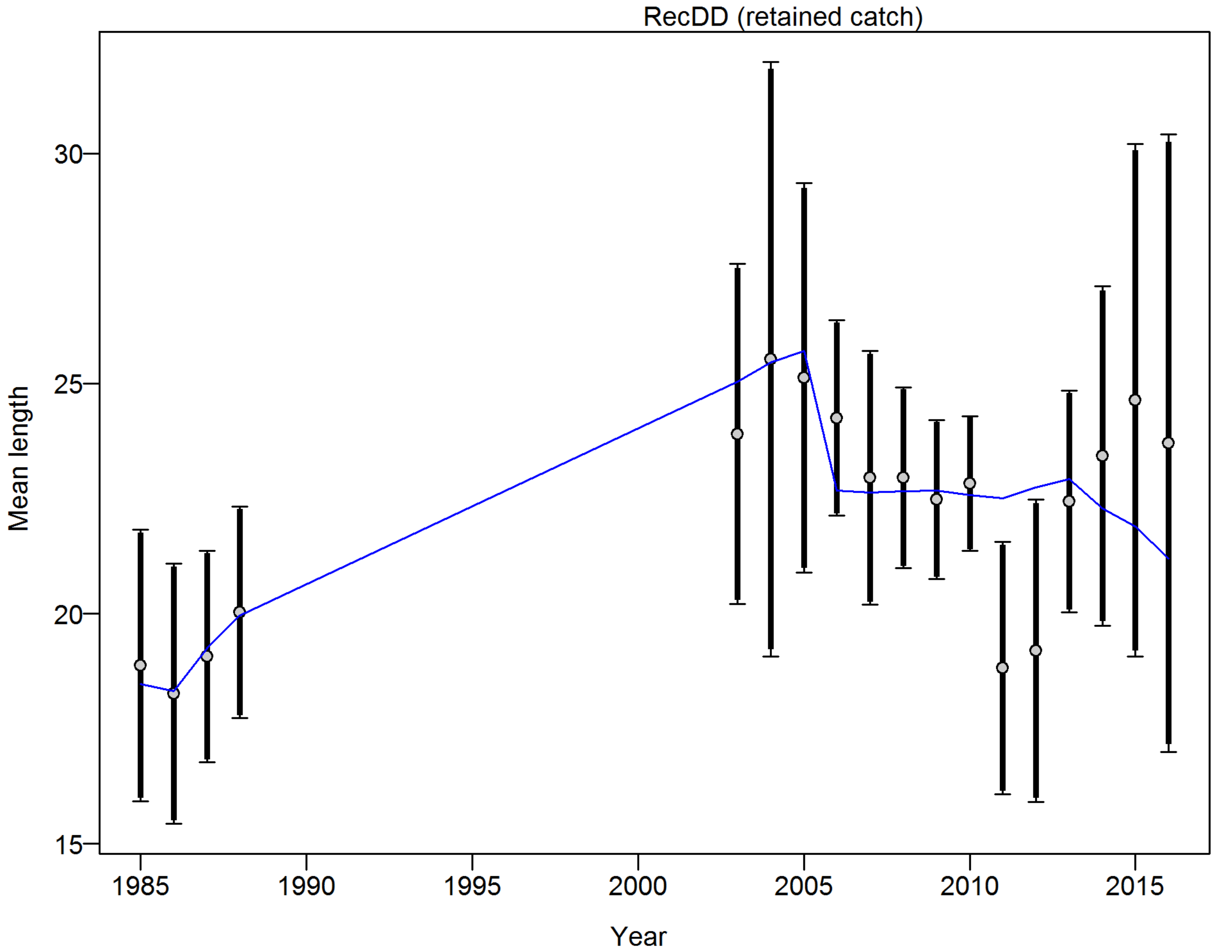


Figure 81: Mean age for recreational discard-catch fleett with 95% confidence intervals based on current samples sizes. Francis data weighting method TA1.8: thinner intervals (with capped ends) show result of further adjusting sample sizes based on suggested multiplier (with 95% interval) is 0.13574 (0.104322-0.257617). For more info, see Francis et al. (2011).

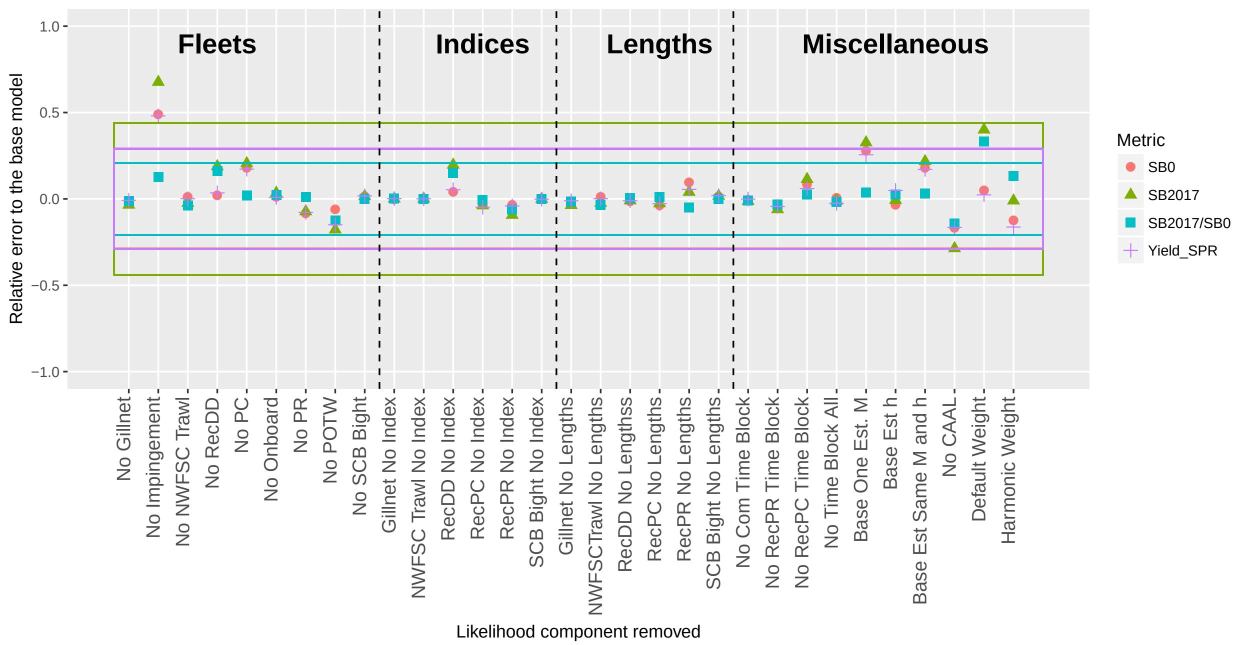


Figure 82: Sensitivity of the pre-STAR base model to SB_0, SB_{2017}, SB_{2017}/SB_0, and $Yield_{SPR}$ when likelihood components are removed. The boxes represent the 95% CIs from the base model. The CI for SB_0 is the same at that for yield and no visible in the figure.

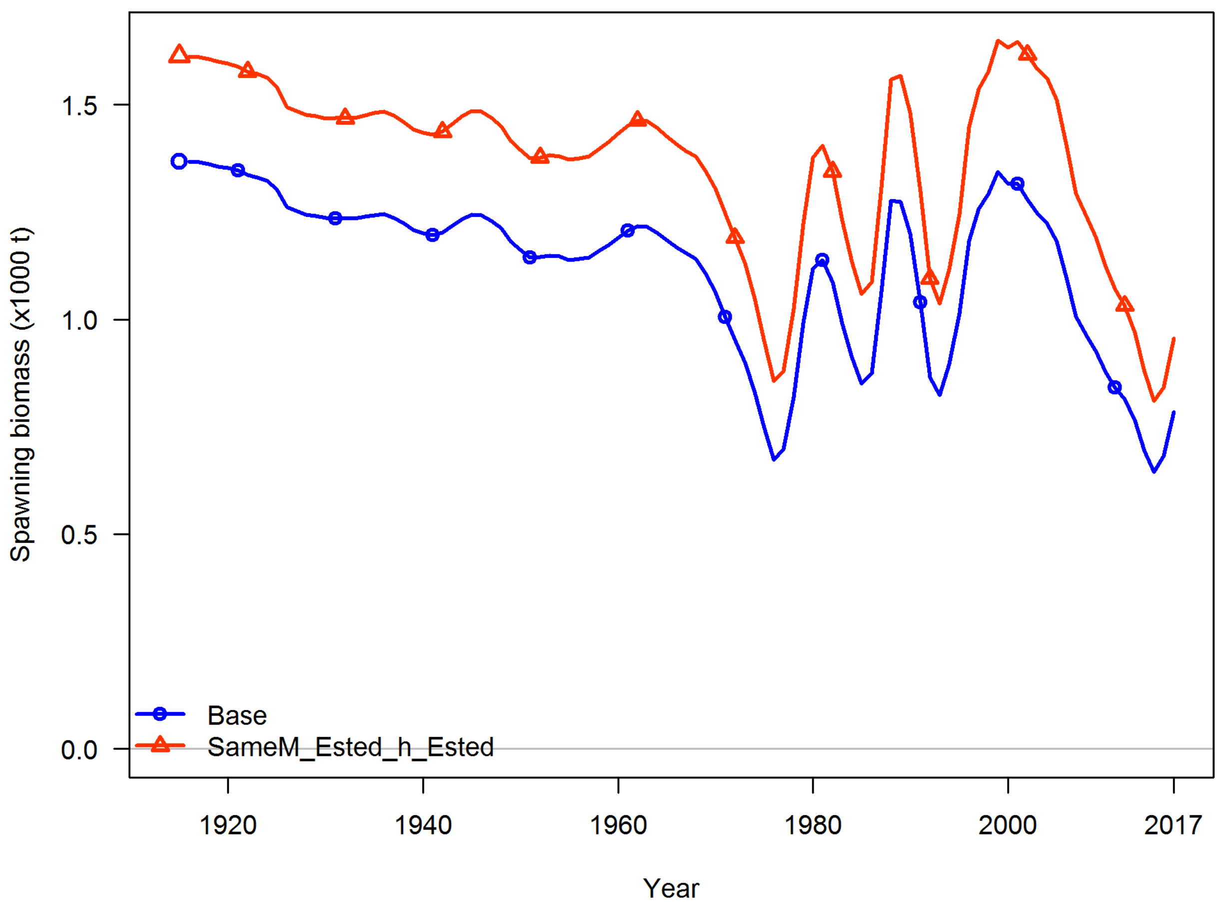


Figure 83: Sensitivity of the spawning biomass to estimating the same natural mortality for males and females and estimating steepness, as compared to the pre-STAR base model, which has fixed female natural mortality and steepness.

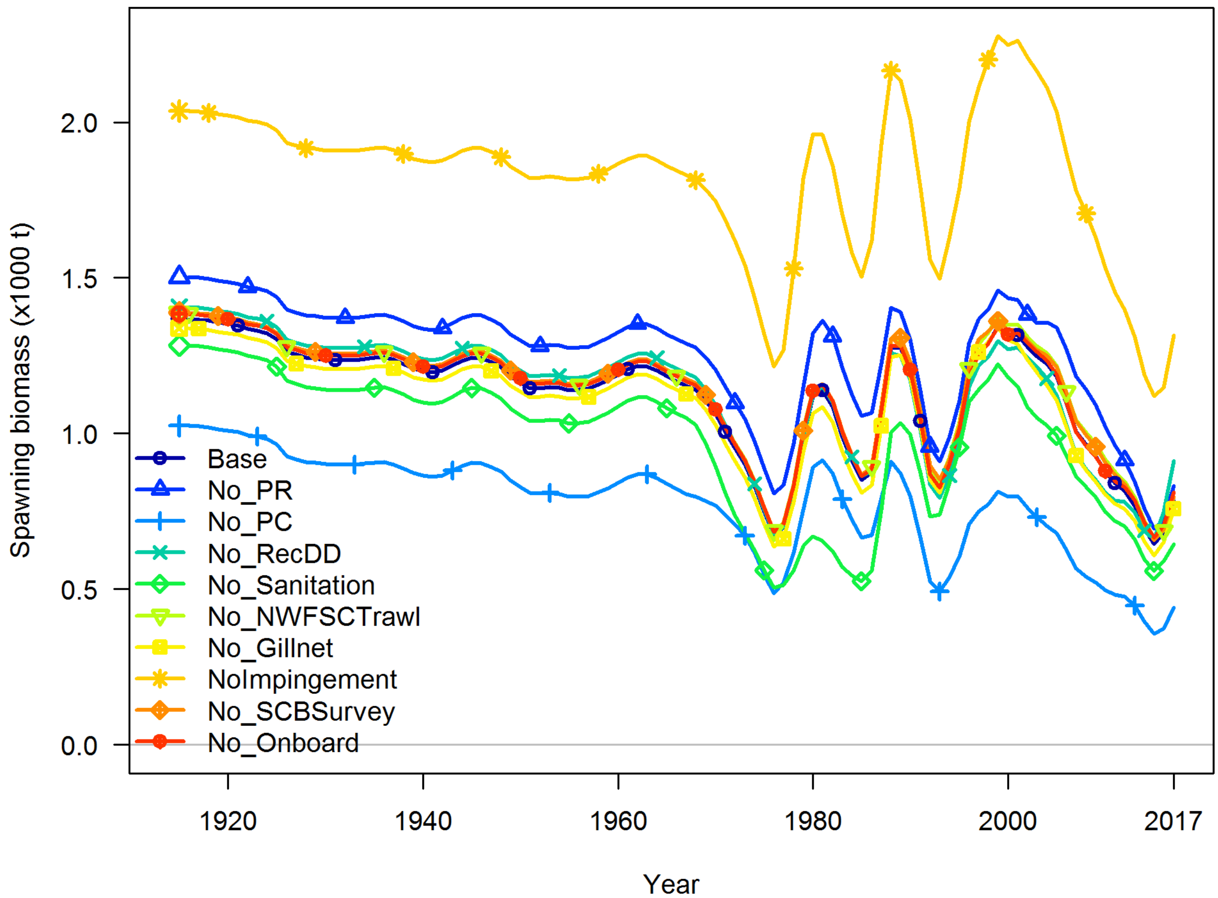


Figure 84: Sensitivity of the spawning biomass to dropping one data source at a time as compared to the pre-STAR base model.

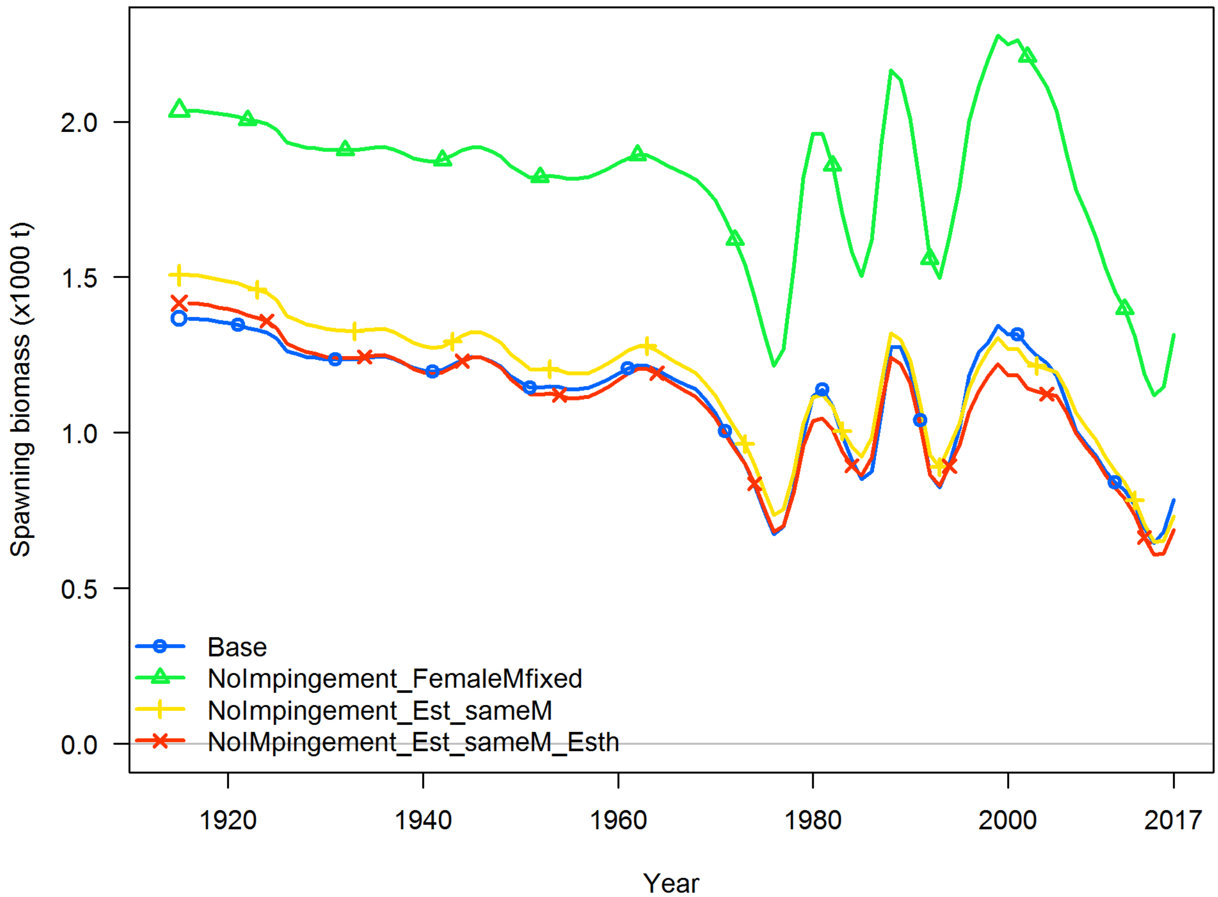


Figure 85: Sensitivity of the spawning biomass to dropping the impingement length composition and either fixing female natural mortality, estimating the same natural mortality for males and females, or estimating the same natural mortality for males and females and estimating steepness, as compared to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

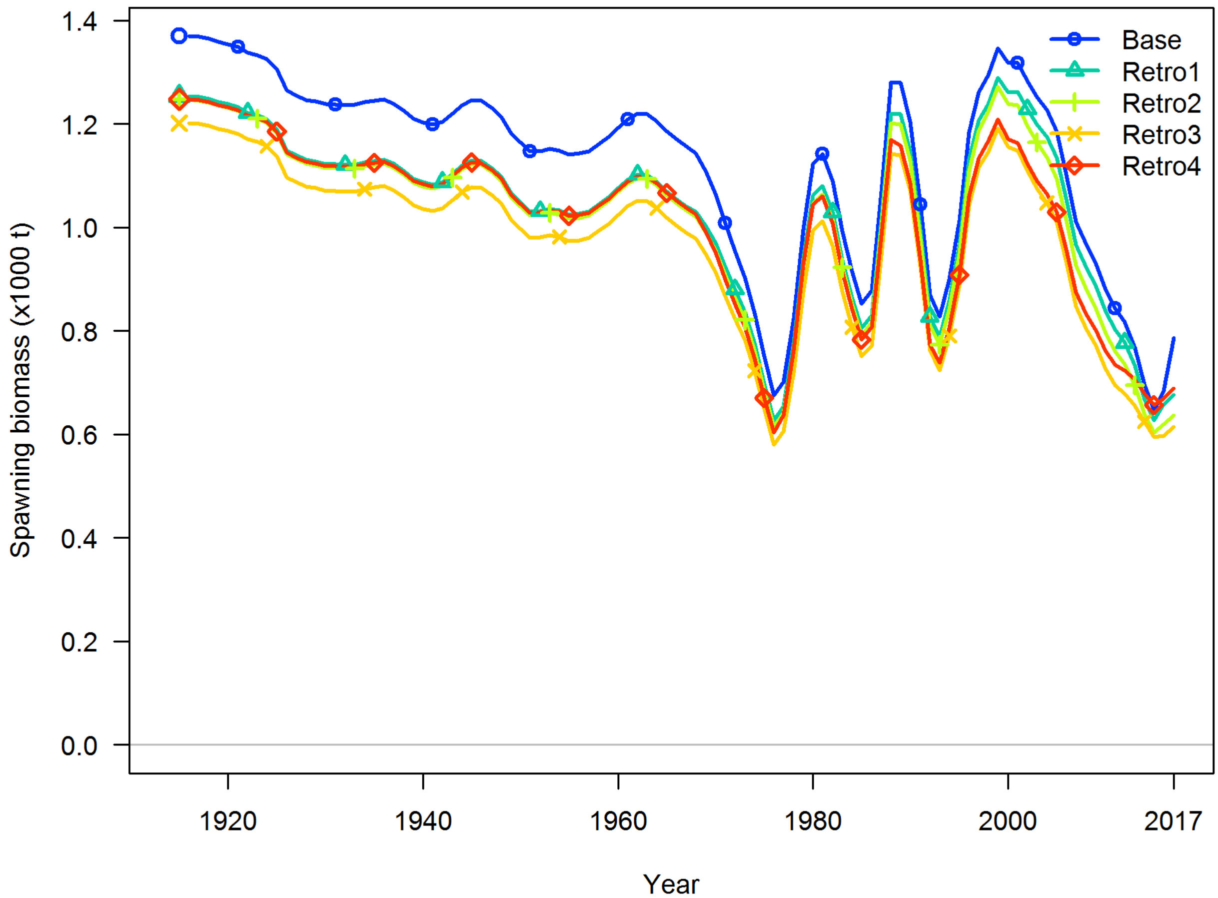


Figure 86: Retrospective pattern for spawning output.

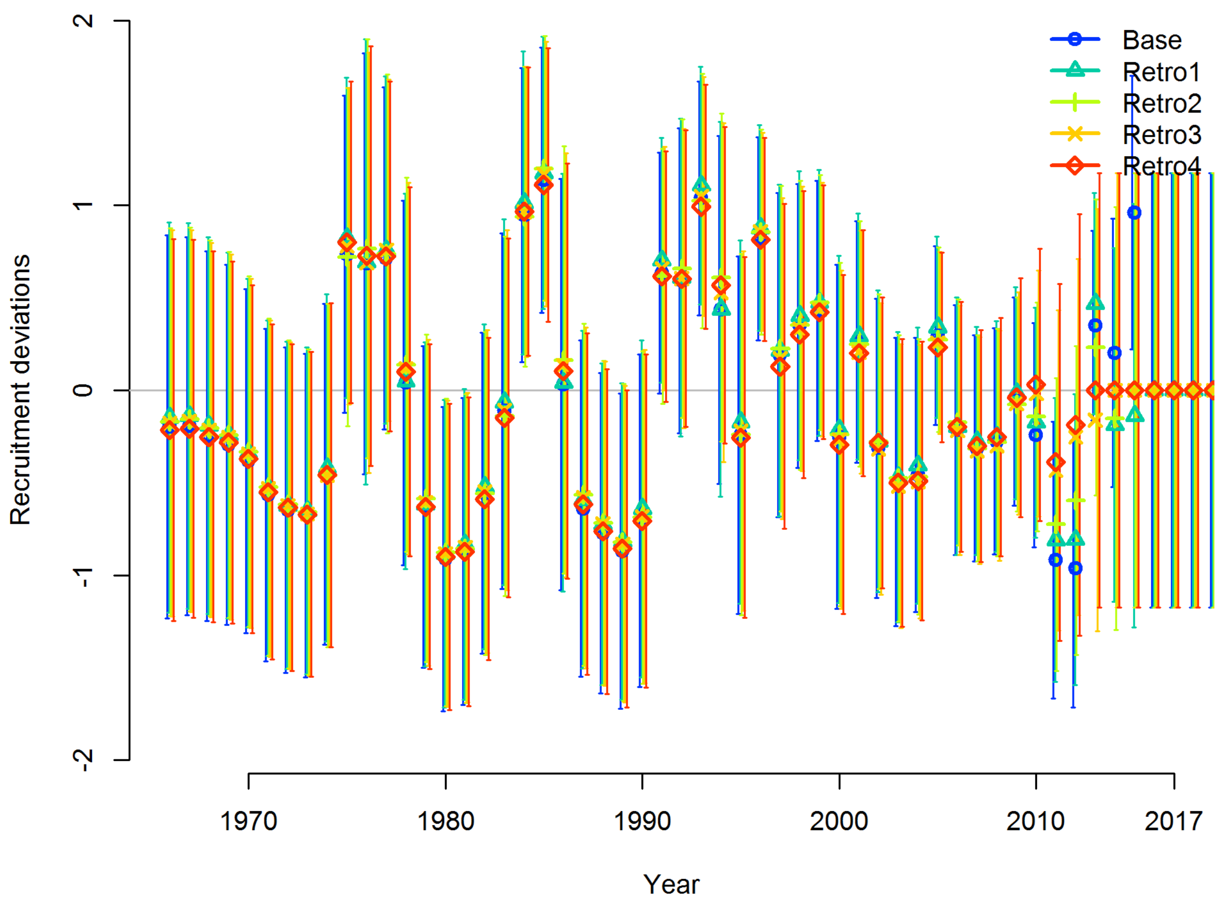


Figure 87: Retrospective pattern for estimated recruitment deviations.

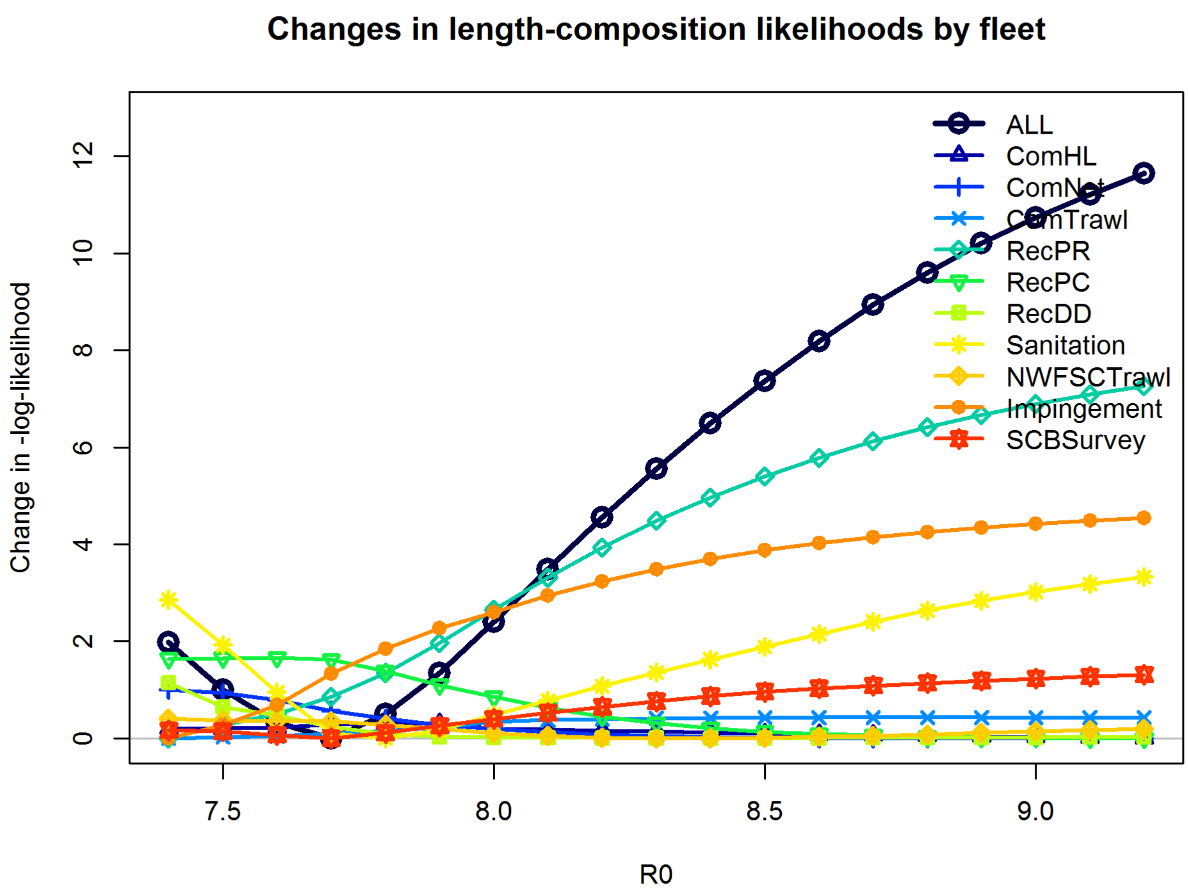


Figure 88: Likelihood profile across R_0 values by fleet.

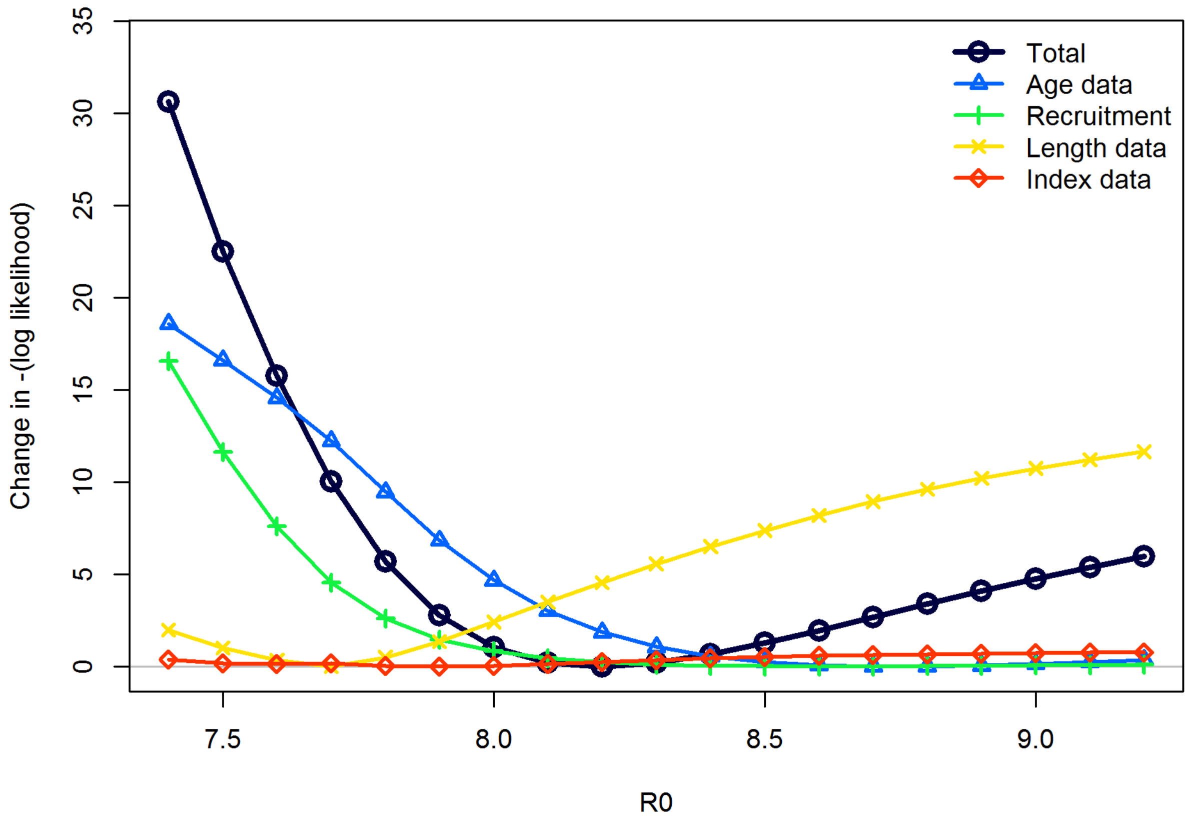


Figure 89: Likelihood profile across R_0 values for each data type.

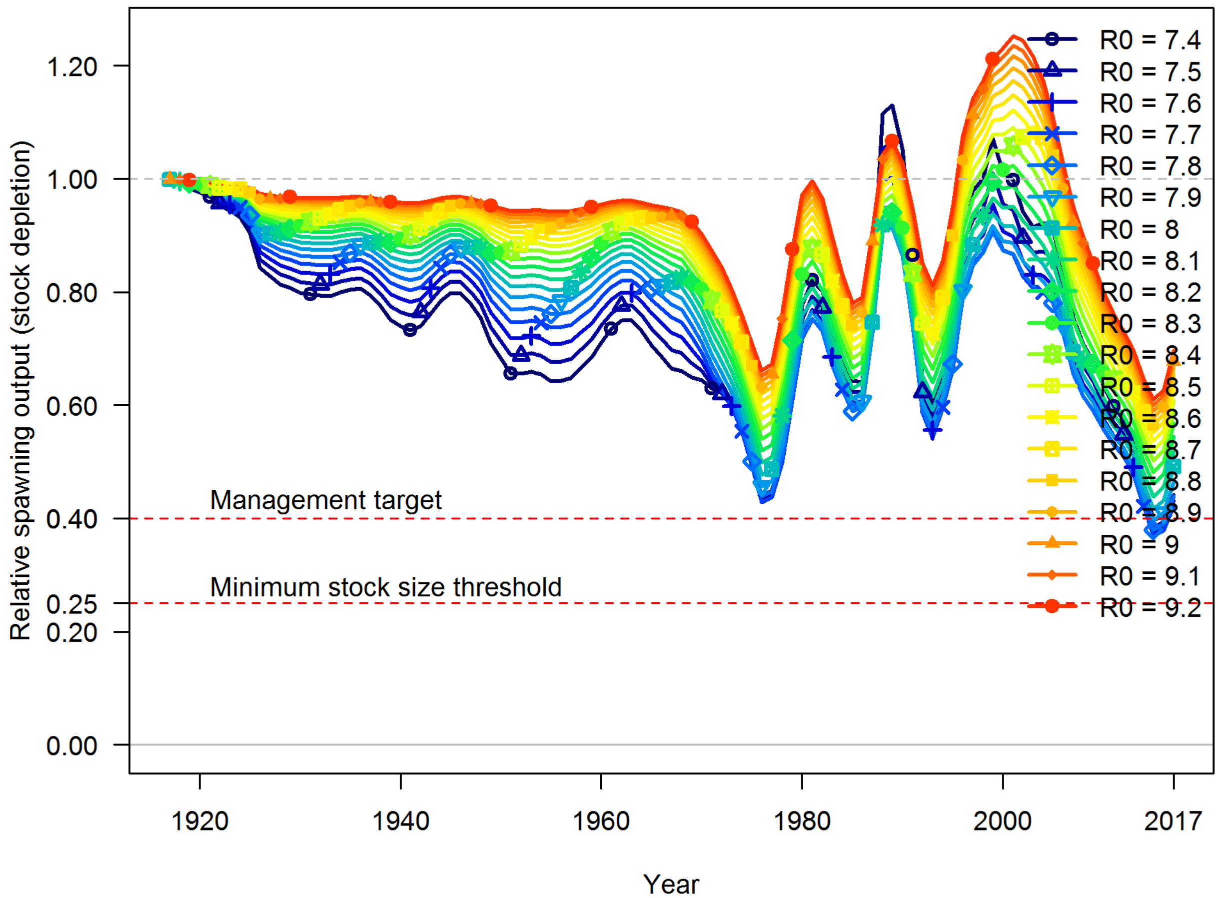


Figure 90: Trajectories of depletion across values of R_0.

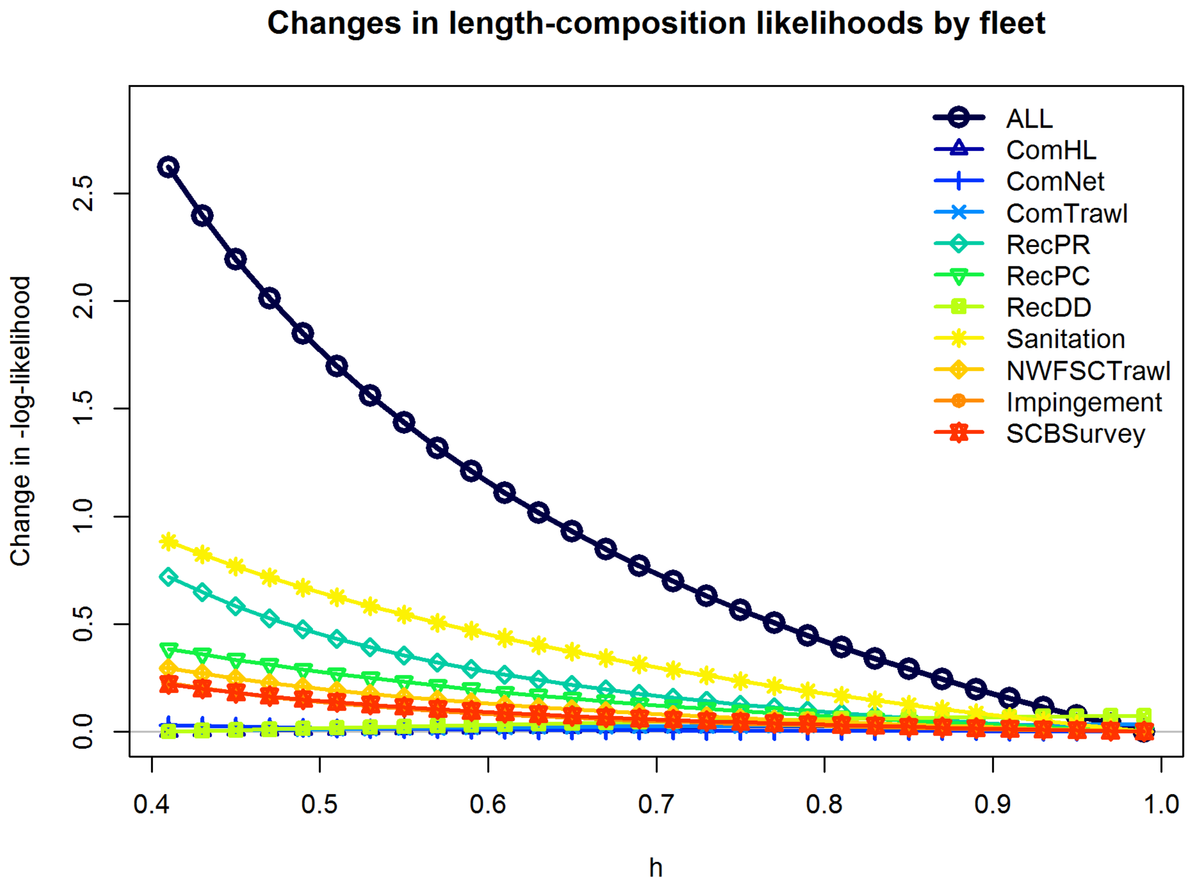


Figure 91: Likelihood profile across steepness values by fleet.

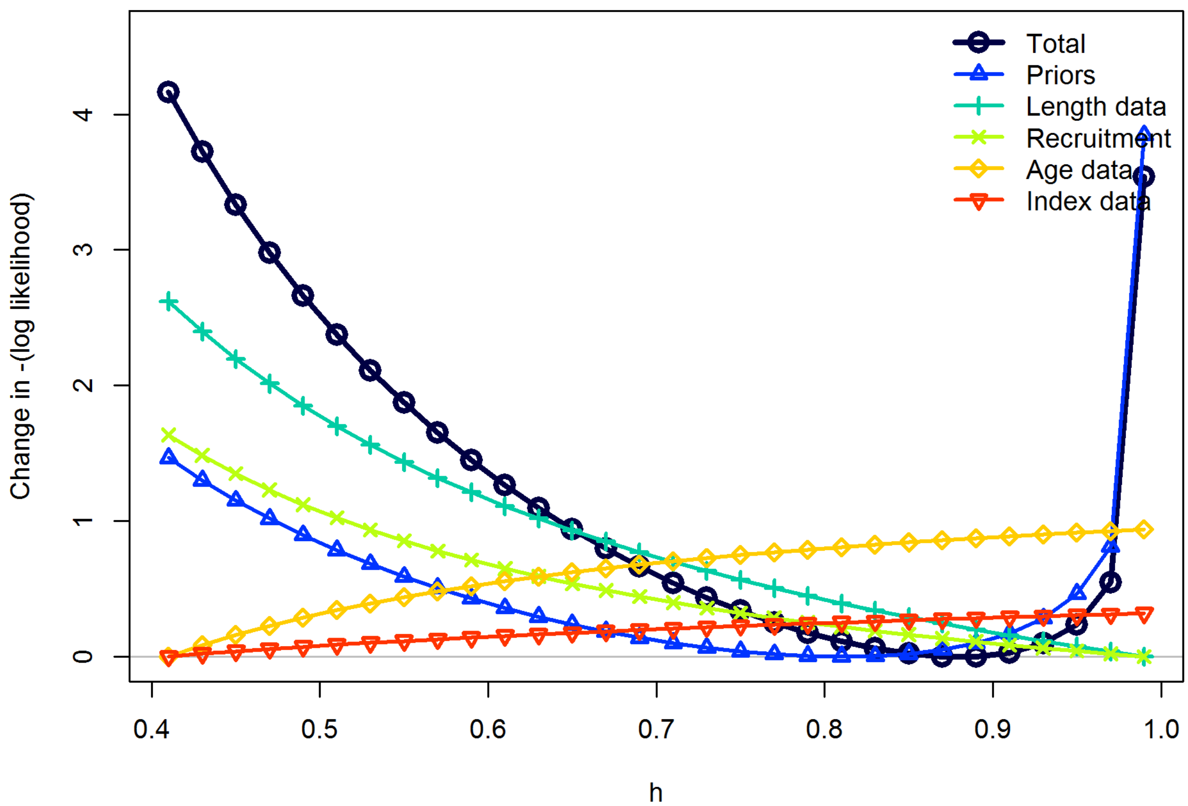


Figure 92: Likelihood profile across steepness values for each data type.

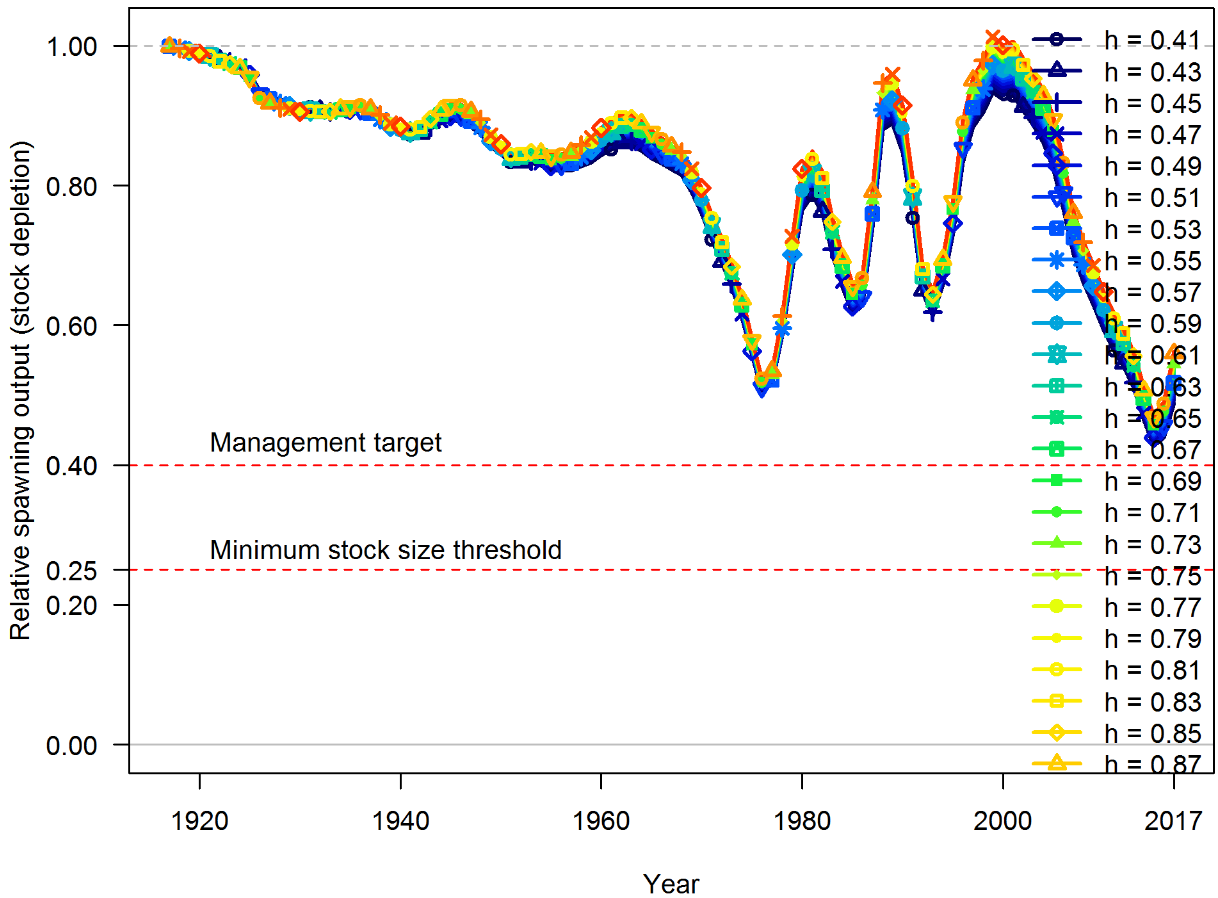


Figure 93: Trajectories of depletion across values of steepness.

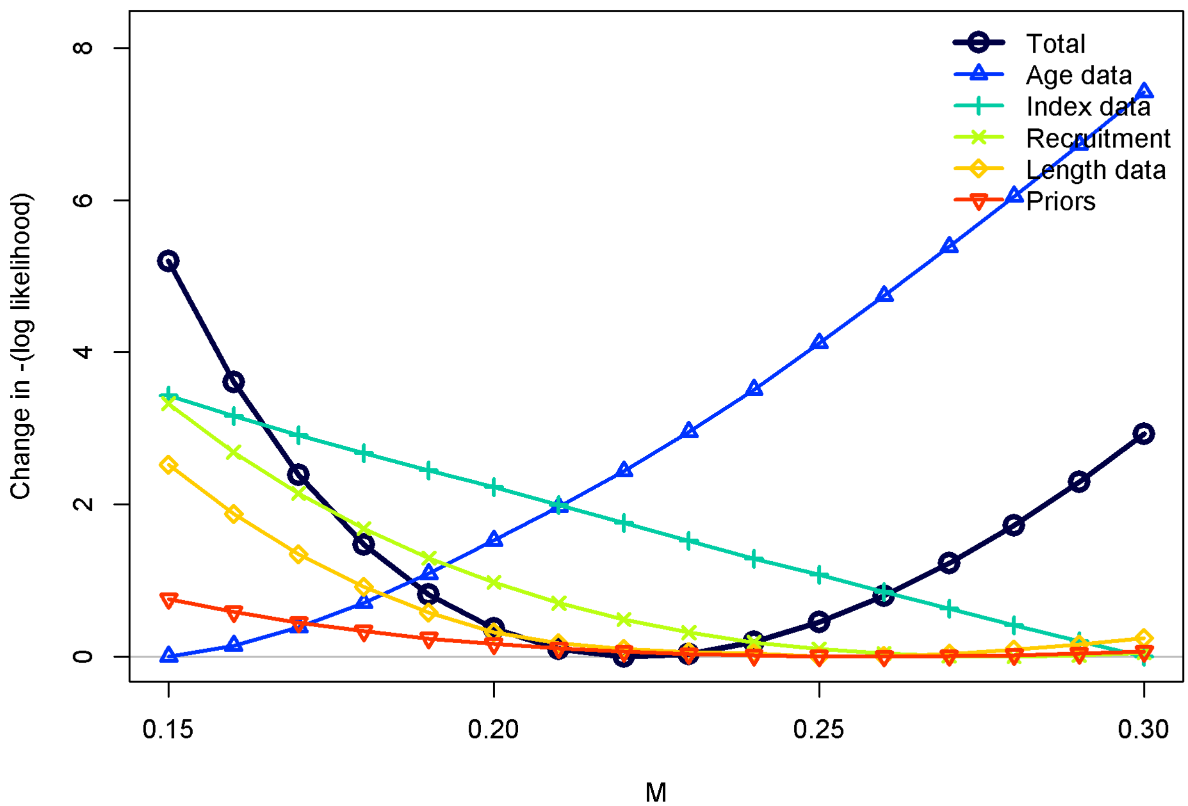


Figure 94: Likelihood profile across female natural mortality values for each data type.

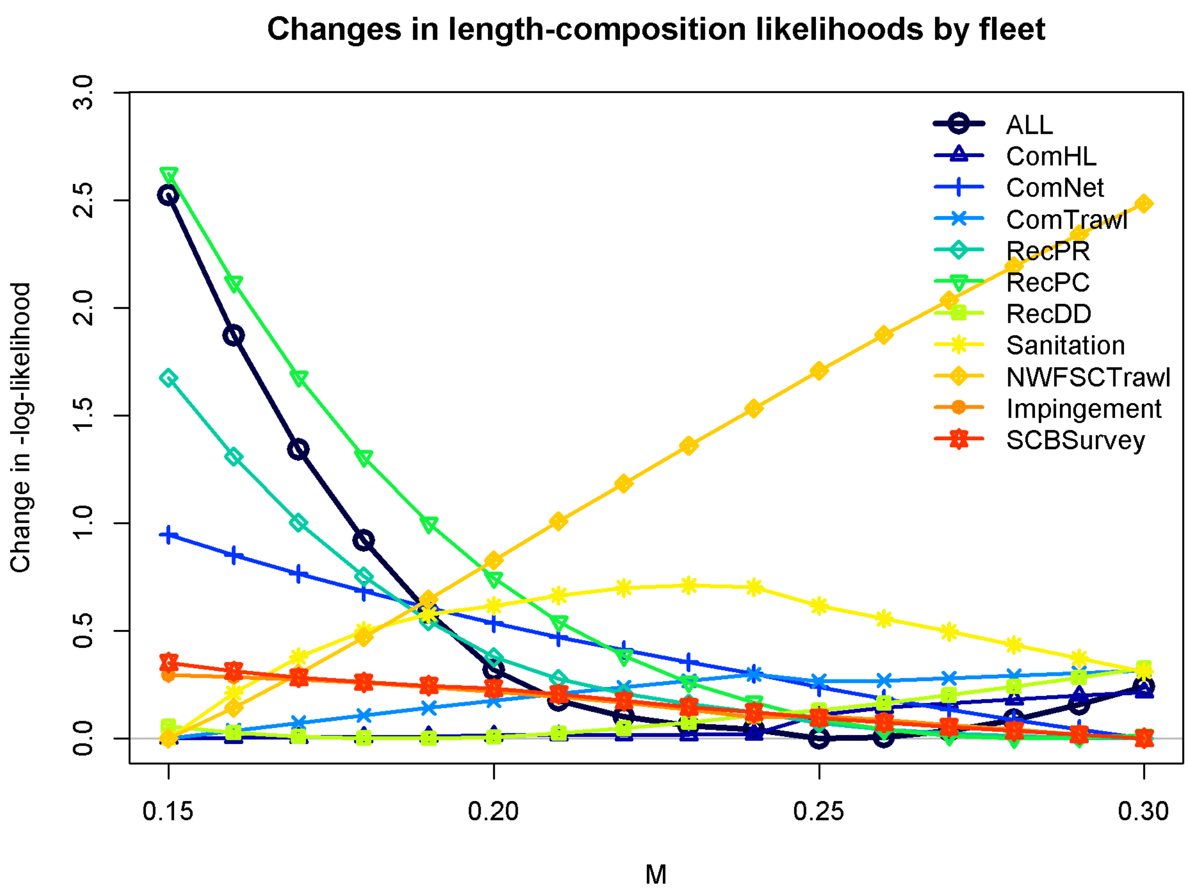


Figure 95: Likelihood profile across female natural mortality values by fleet.

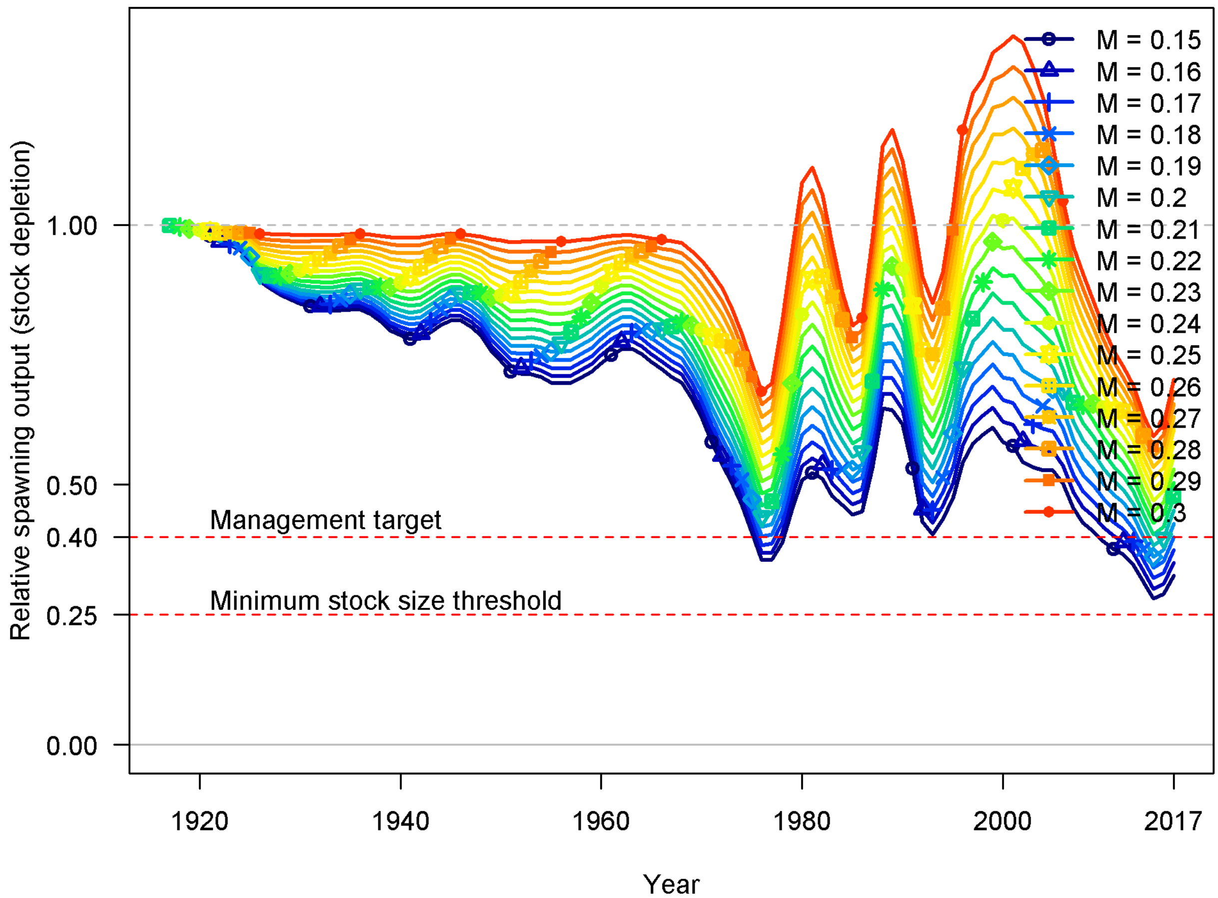


Figure 96: Trajectories of depletion across values of female natural mortality.

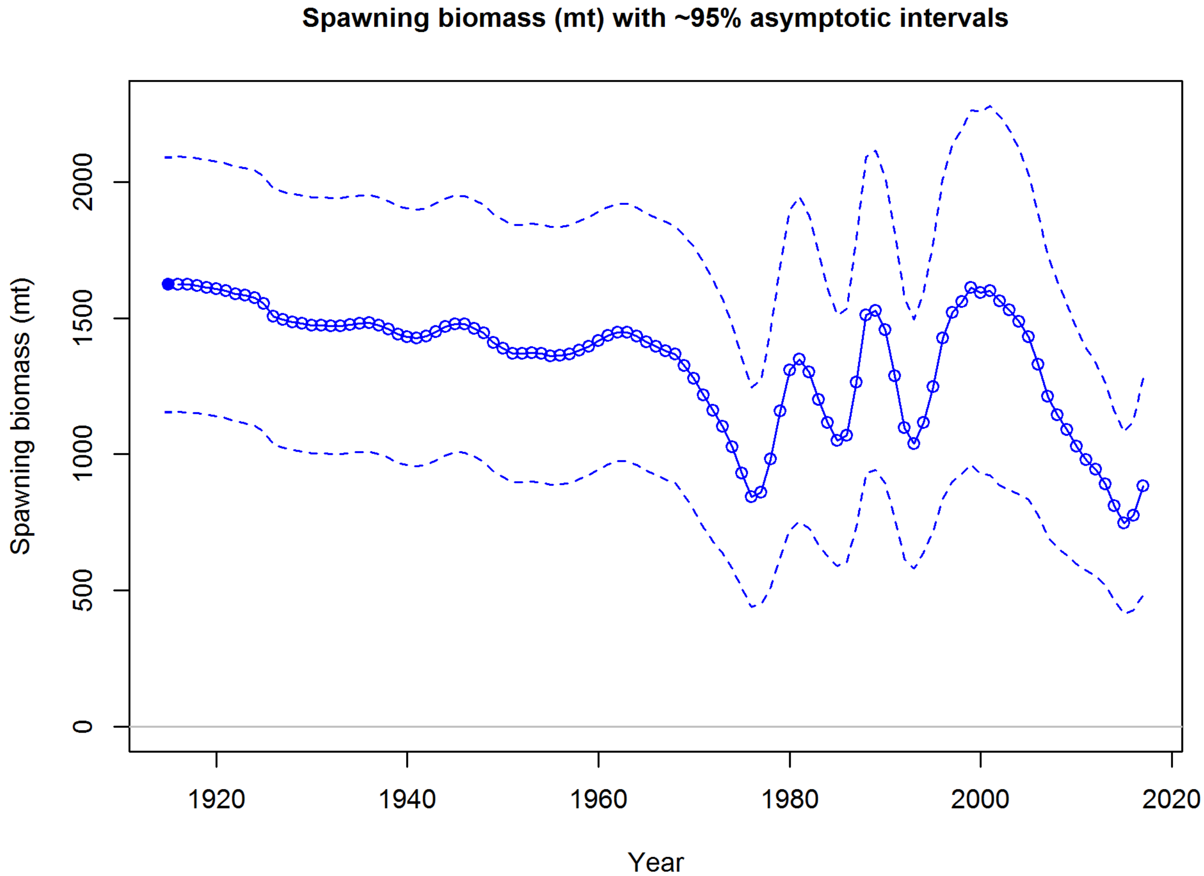


Figure 97: Estimated spawning biomass (mt) with approximate 95% asymptotic intervals.

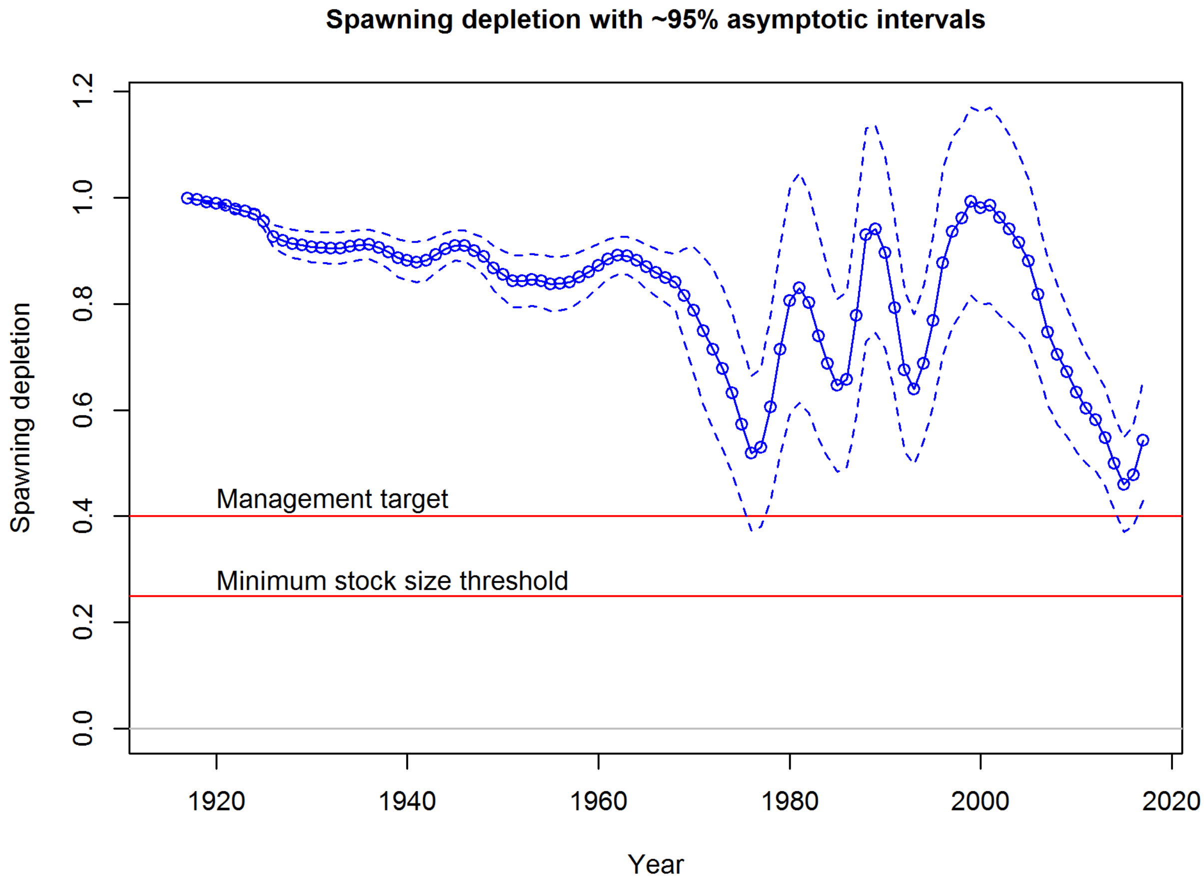


Figure 98: Estimated spawning depletion with approximate 95% asymptotic intervals.

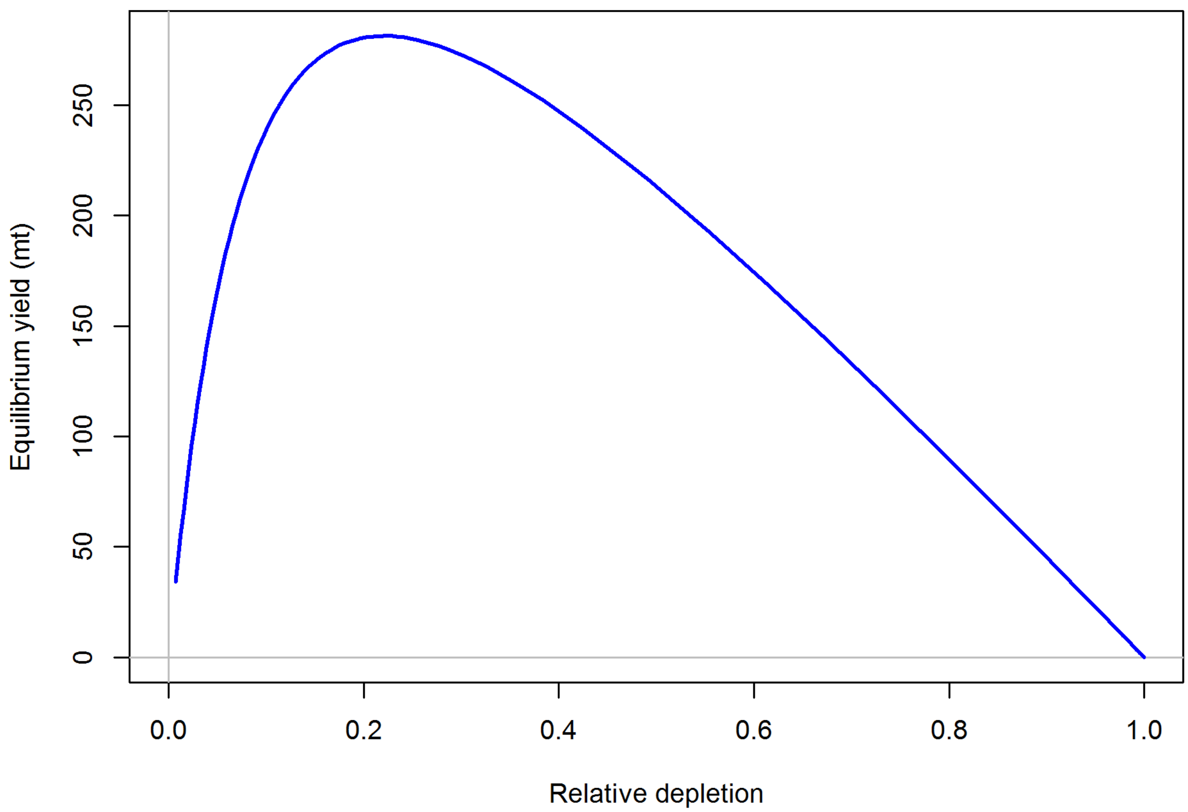


Figure 99: Equilibrium yield curve for the base case model. Values are based on the 2016 fishery selectivity and with steepness fixed at 0.718.

Appendix A. Detailed fits to length composition data

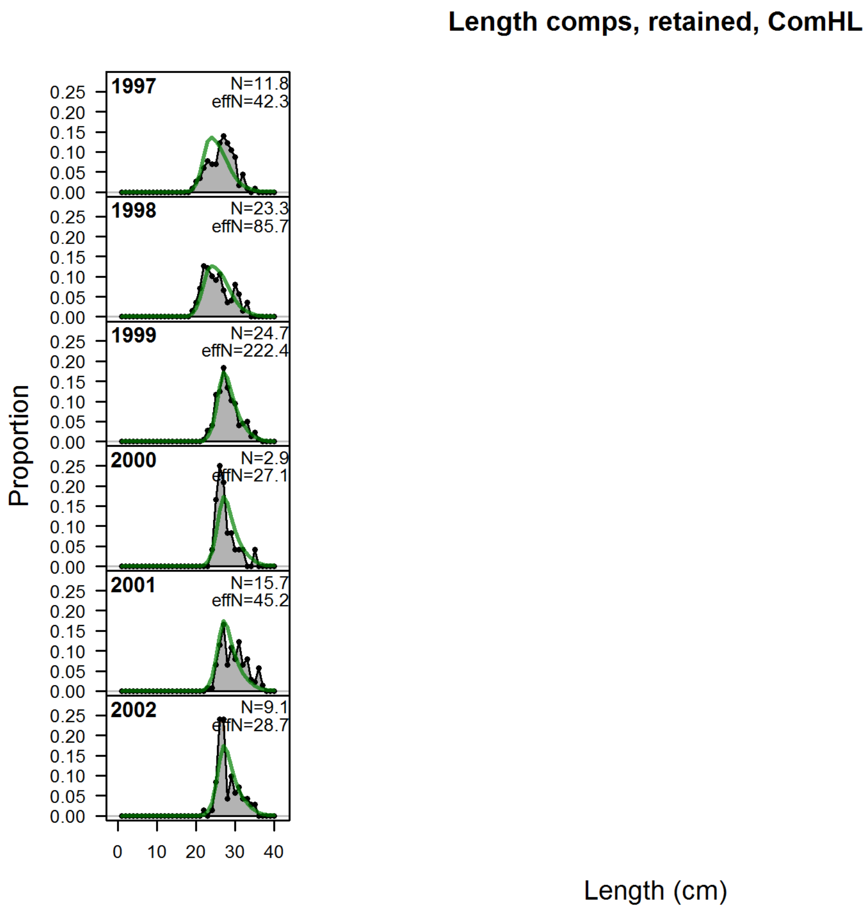


Figure A100: Length comps, retained, ComHL

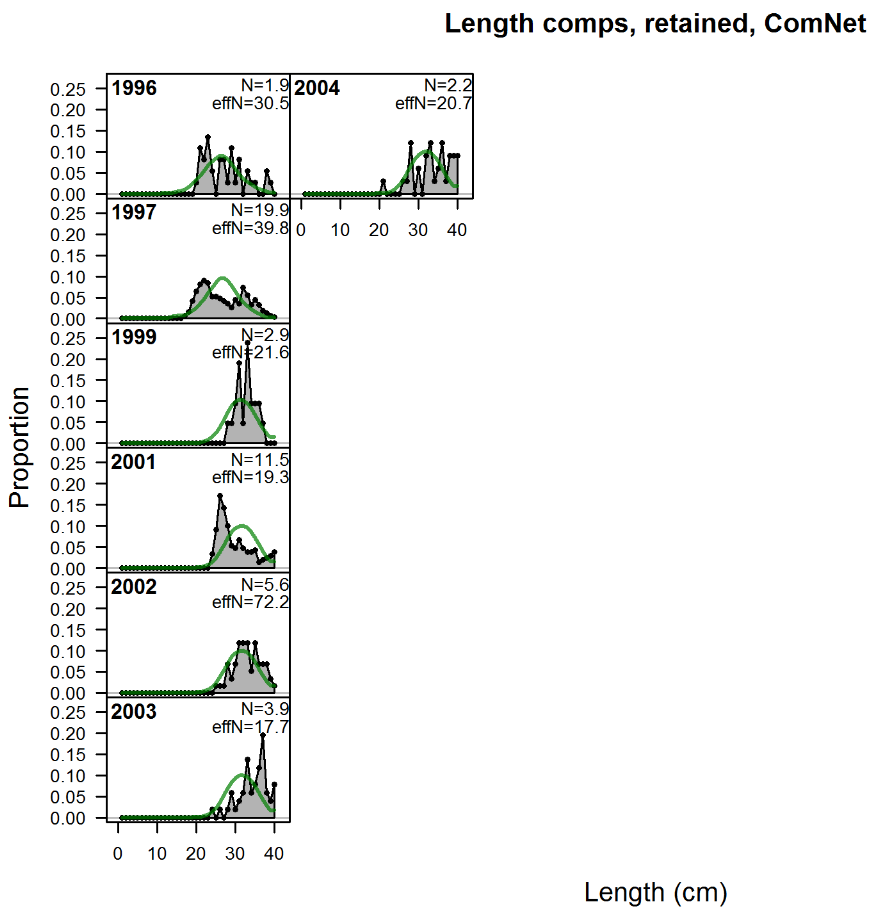


Figure A101: Length comps, retained, ComNet

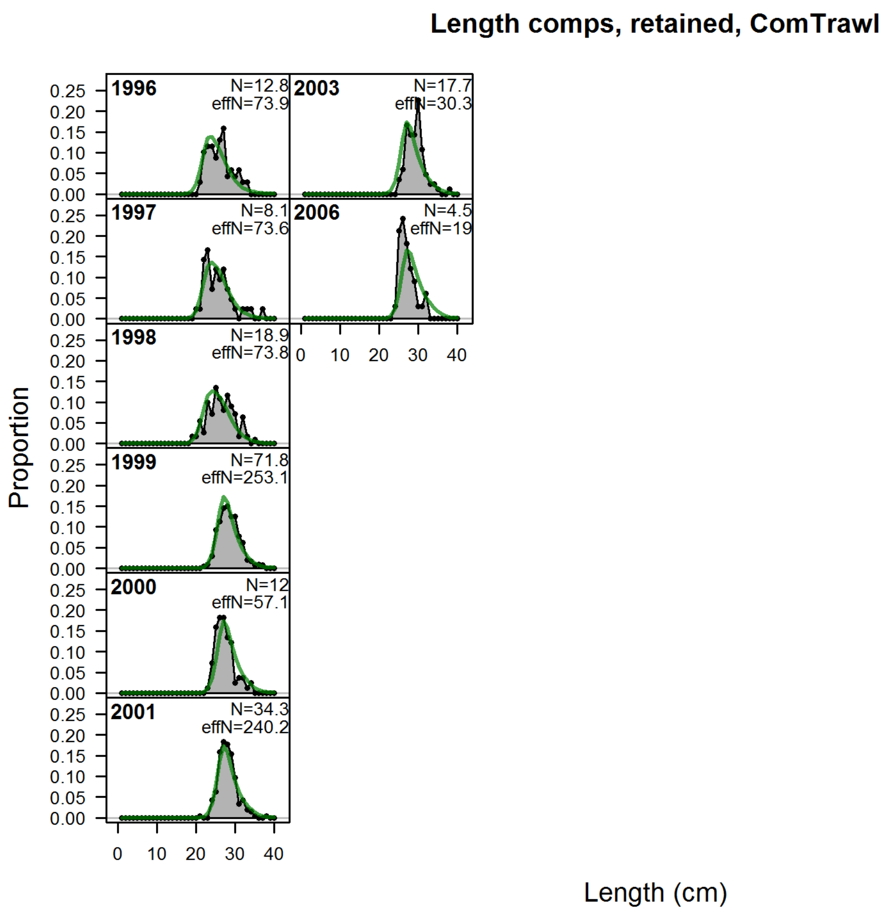


Figure A102: Length comps, retained, ComTrawl

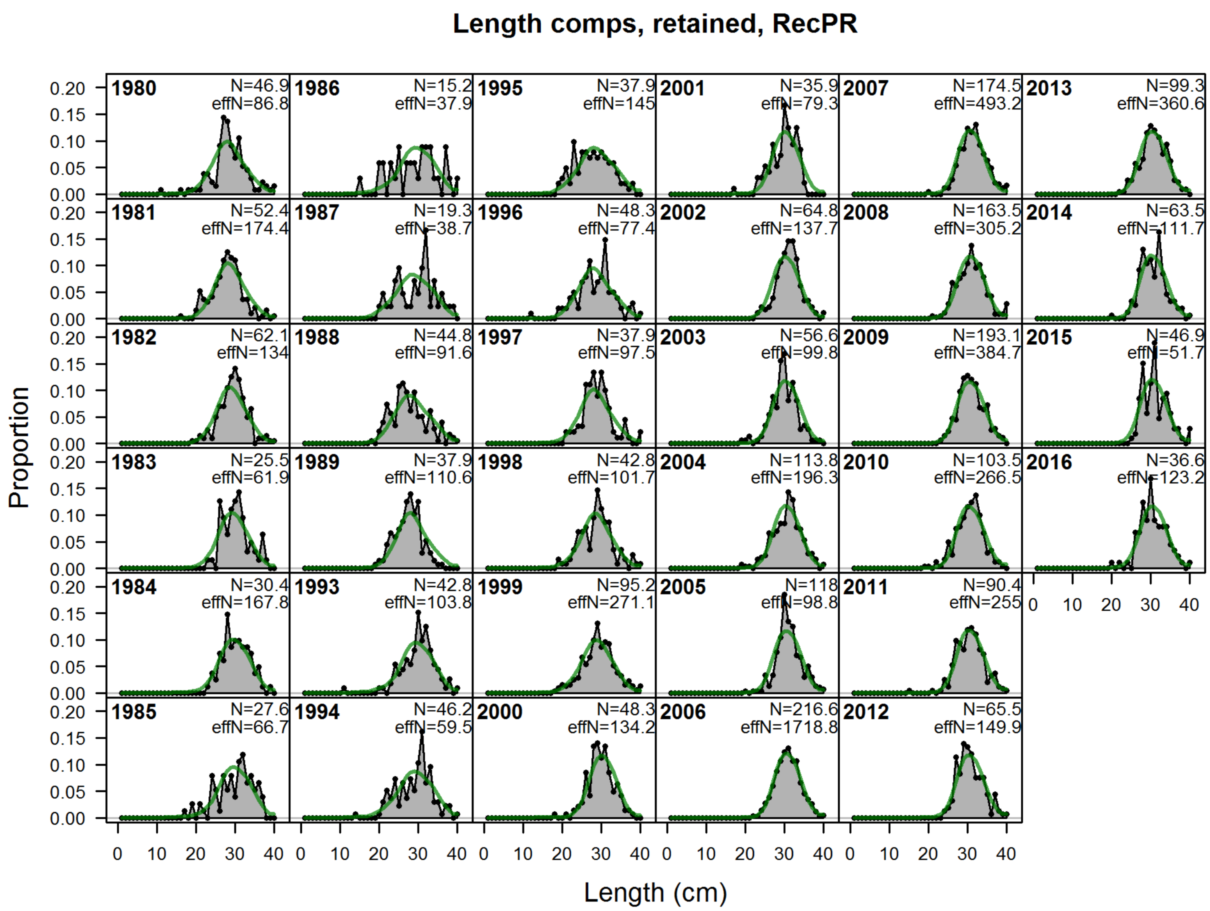


Figure A103: Length comps, retained, RecPR

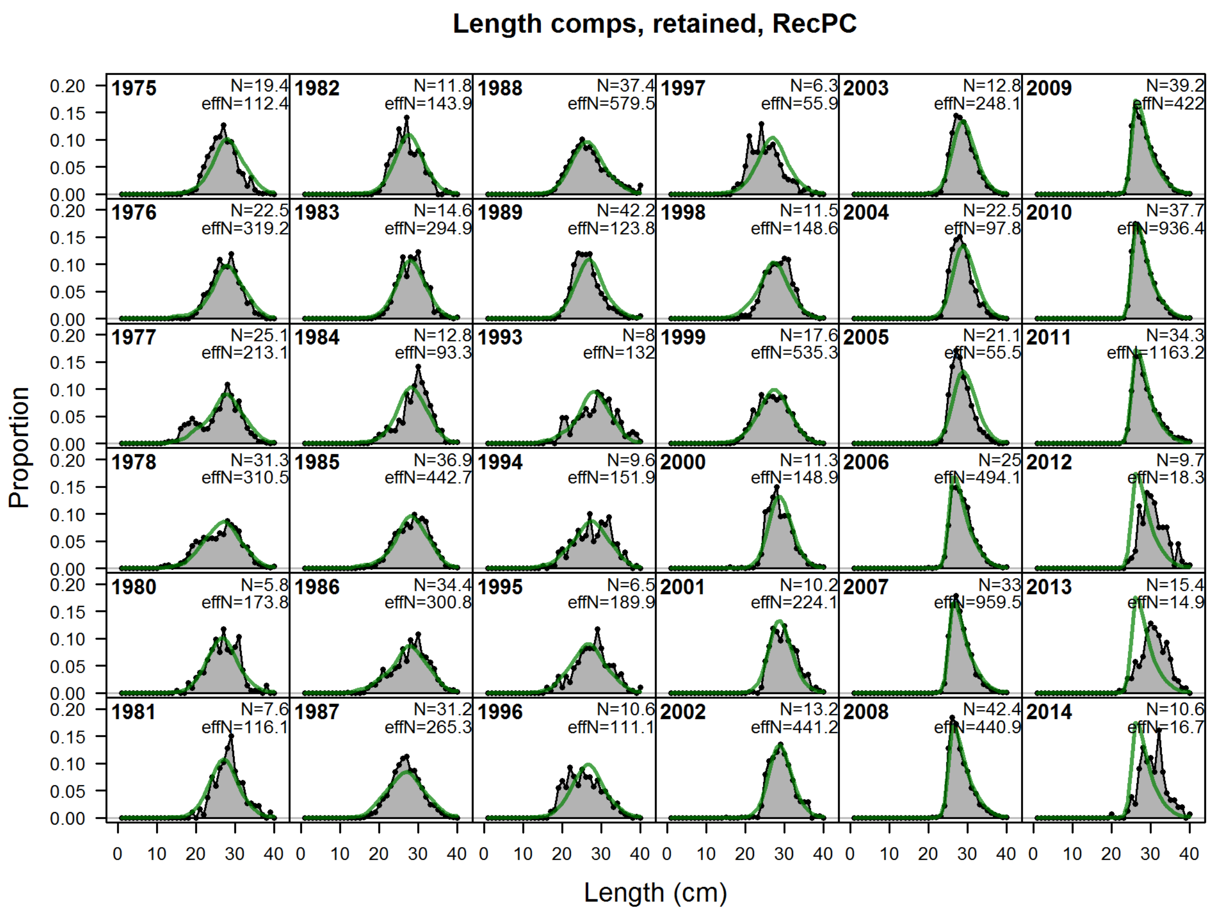
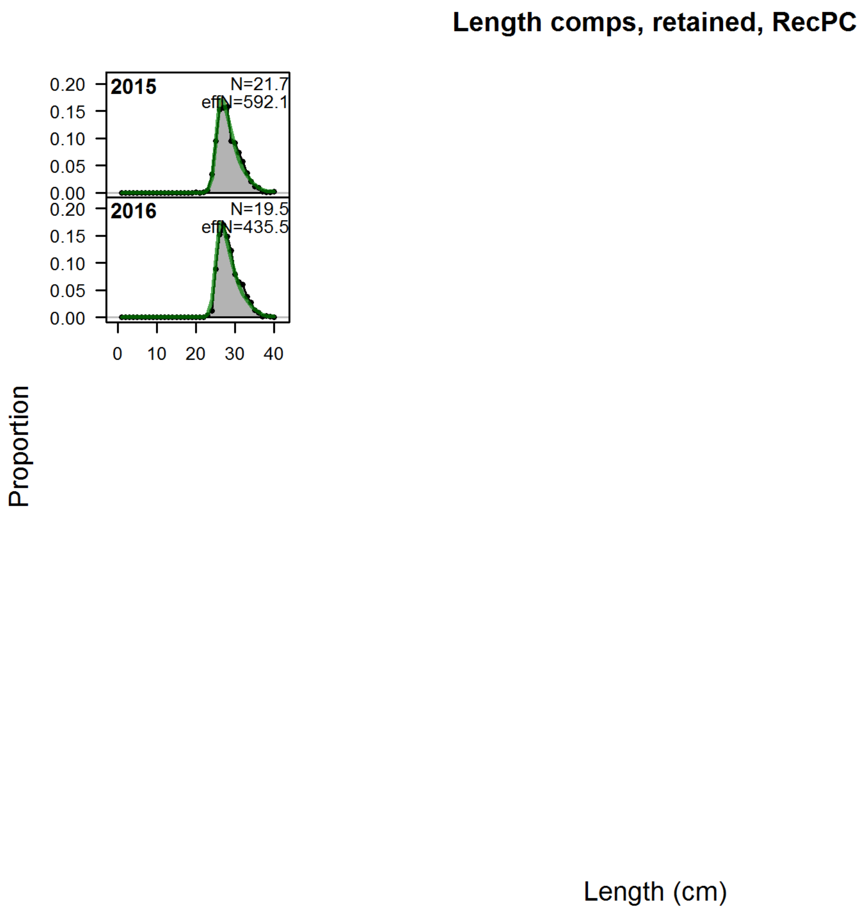


Figure A104: Length comps, retained, RecPC (plot 1 of 2)



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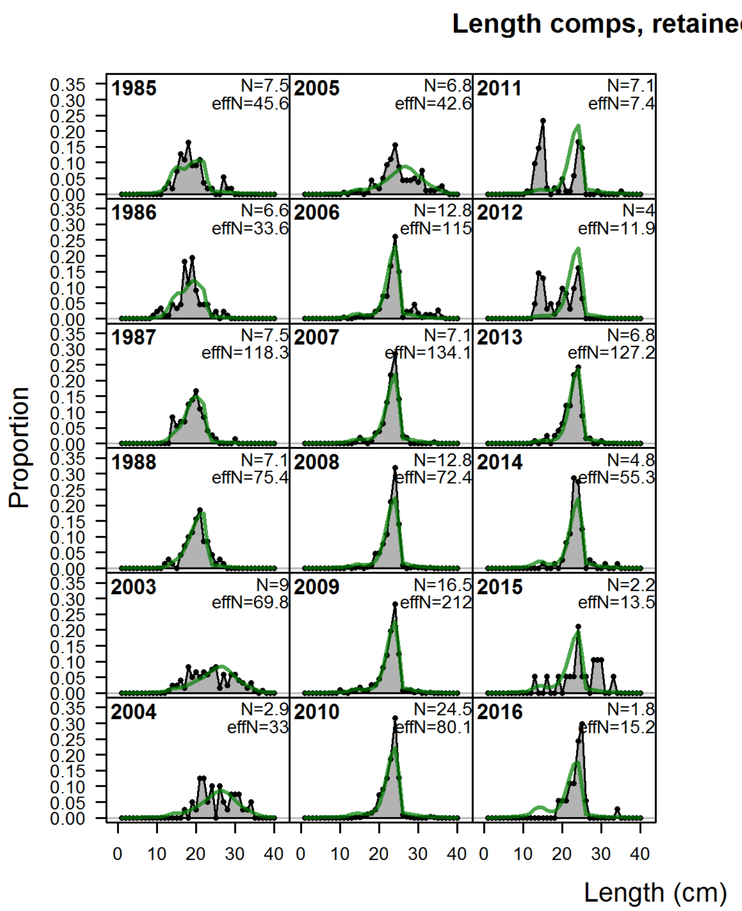


Figure A105: Length comps, retained, RecDD

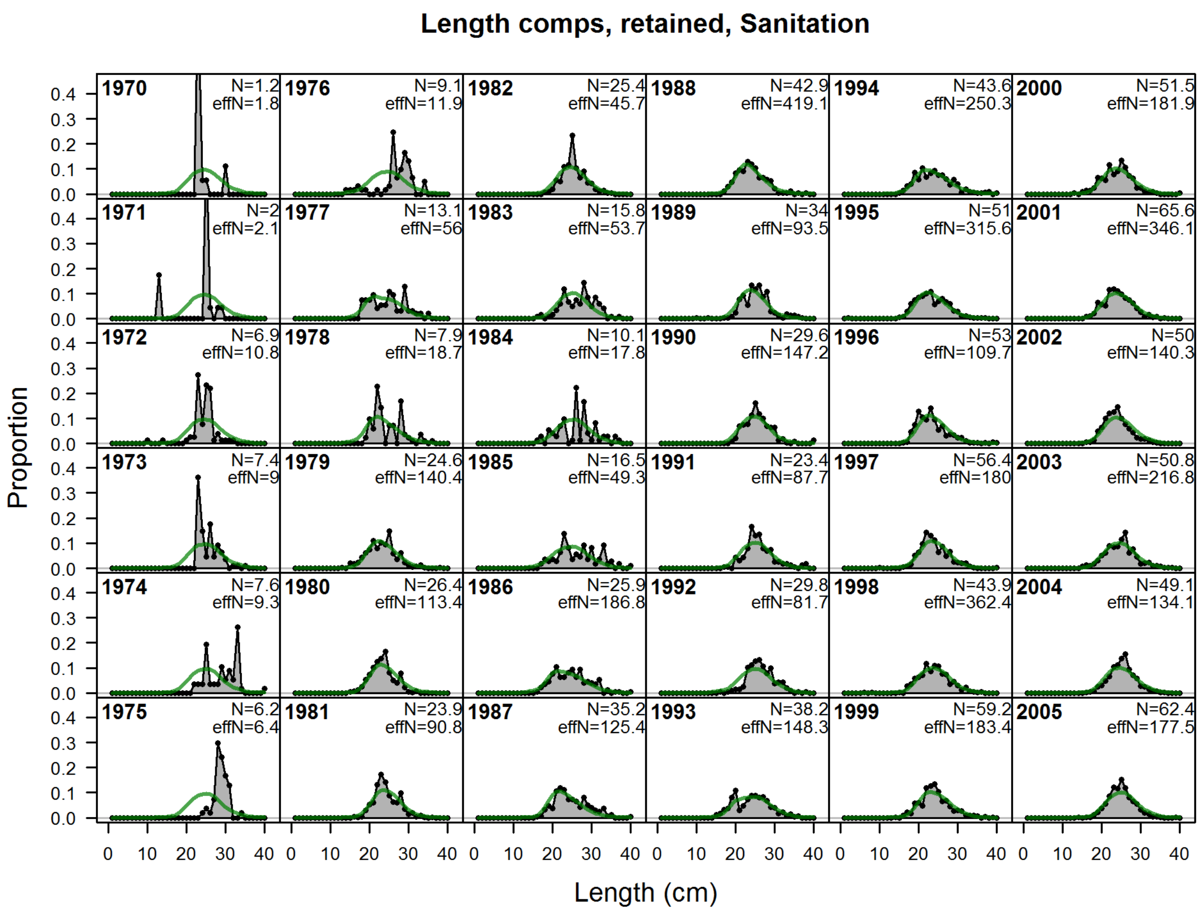
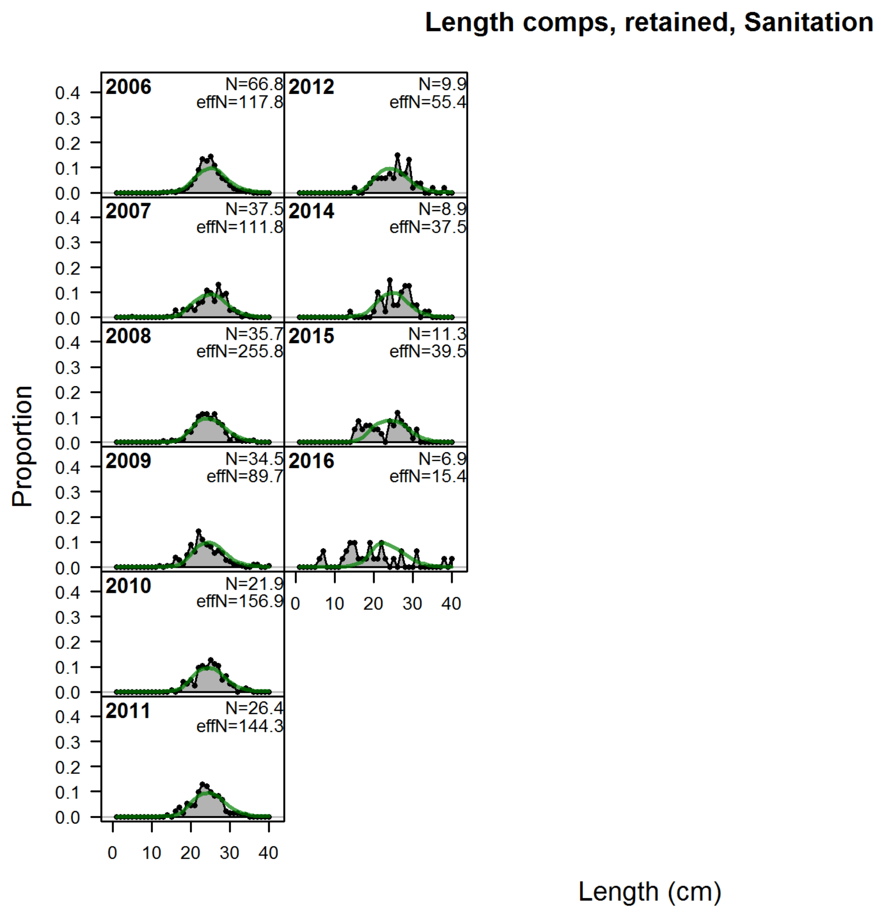


Figure A106: Length comps, retained, Sanitation (plot 1 of 2)



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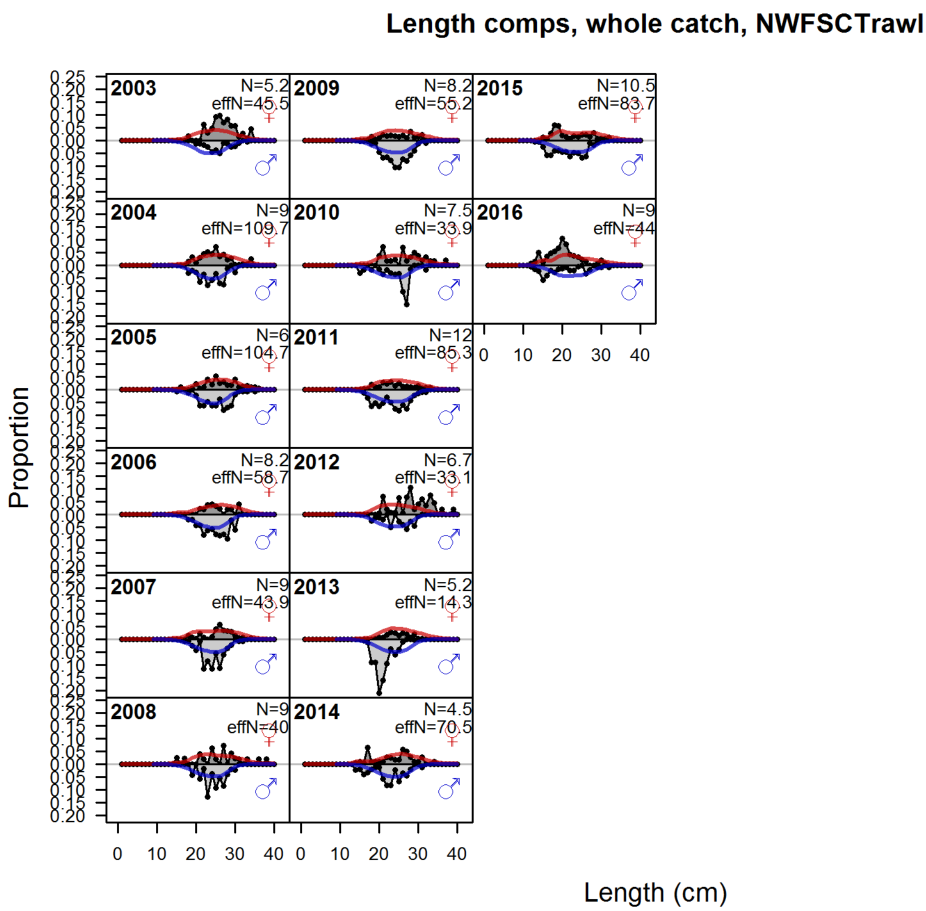

Figure A107: Length comps, whole catch, NWFSCTrawl

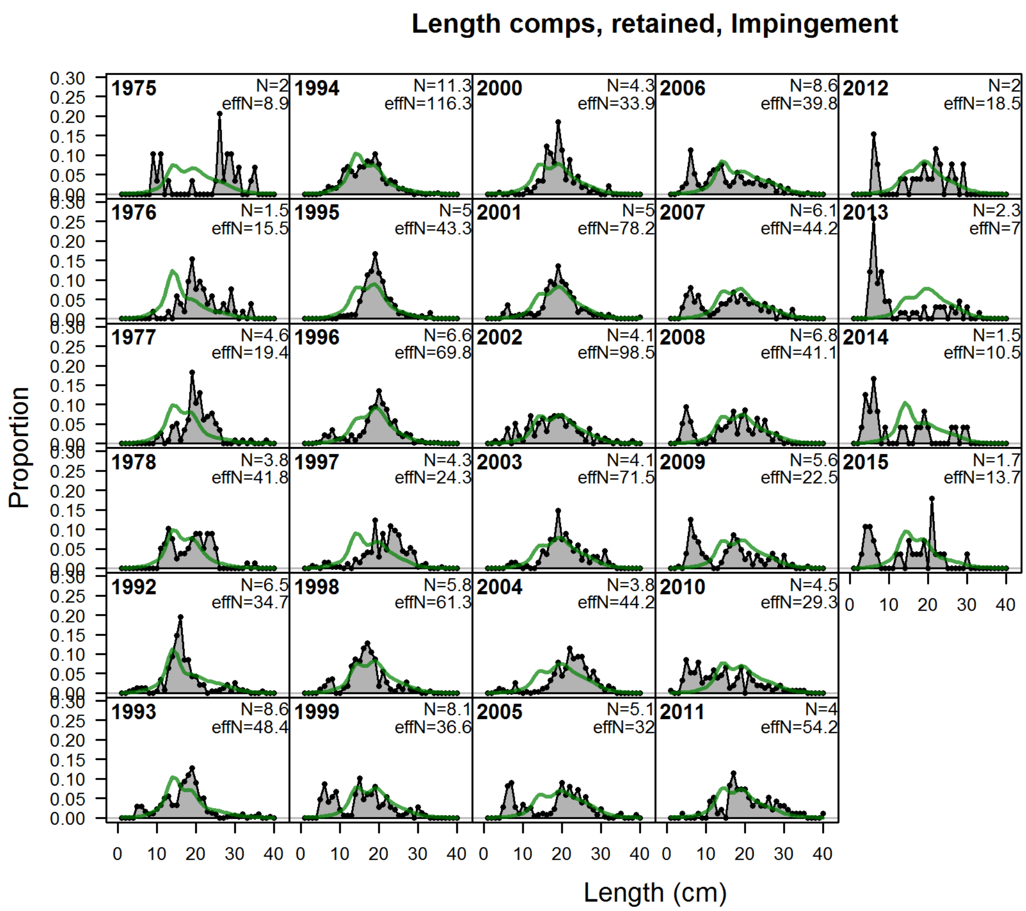

Figure A108: Length comps, retained, Impingement

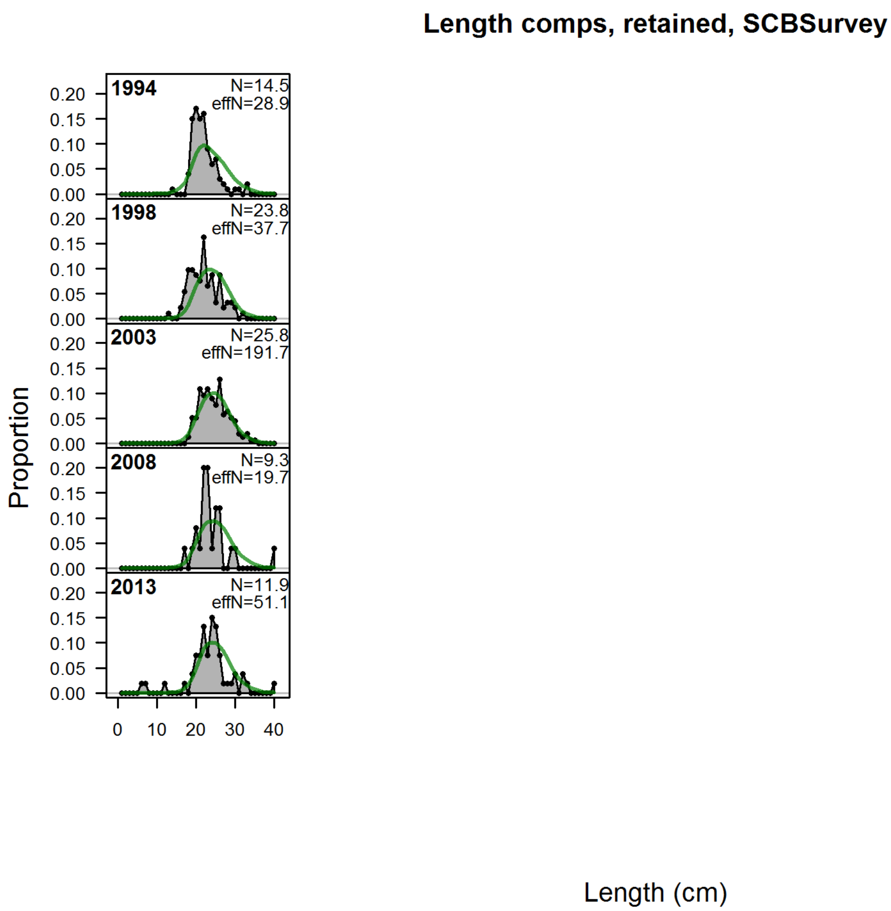

Figure A109: Length comps, retained, SCBSurvey

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