

Status of copper rockfish (*Sebastes caurinus*) along the U.S.  
California coast south of Point Conception in 2023



by  
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## Disclaimer

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## Executive summary

### Stock

This assessment reports the status of copper rockfish (*Sebastes caurinus*) off the California coast in U.S. waters, using data through 2022. The stock of copper rockfish in California waters was assessed using two sub-area models that captured distinct inter-stock dynamics split north and south of Point Conception, 34° 27' N. lat. The estimated dynamics for each assessed sub-area area described here along with the combined stock status for the California stock. This assessment does not account for populations located in Mexican waters or other areas off the U.S. West Coast and assumes that these southern and northern populations do not contribute to nor take from the population being assessed here.

### Catches

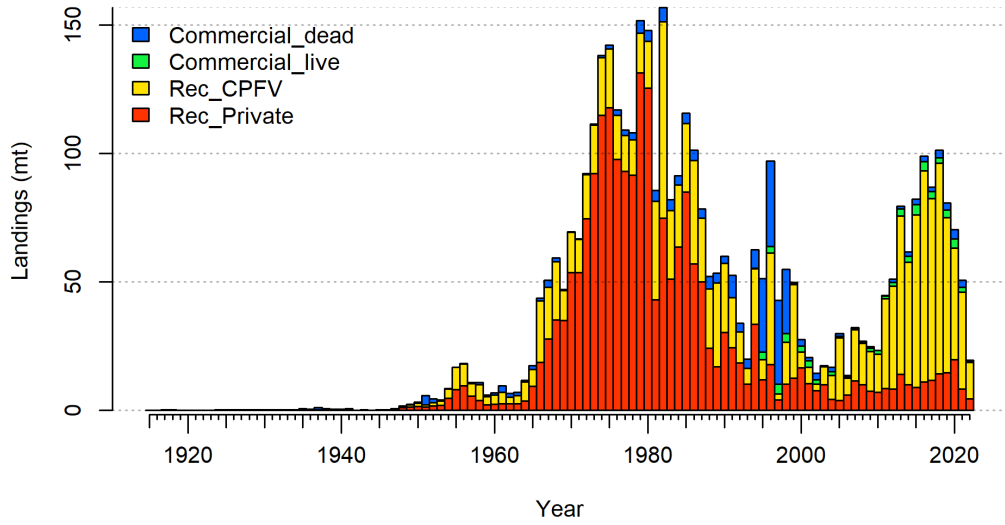
Catches of copper rockfish off the coast of California began slowly in the 1910s with catches steadily increasing in the 1940s north of Point Conception and with catches ramping up south of Point Conception in the 1960s (Figures i and ii). The recreational fishery in California is the primary source of mortality for copper rockfish where private/rental (PR) vessels are the primary source of historical removals across the state. Catches by commercial passenger fishing vessels (CPFV) ramped up between the 1960s to the 1980s across the state. In recent years, the recreational removals in the north of Point Conception have been split between CPFV and PR vessels. In contrast, the CPFV fleet south of Point Conception is the primary source of mortality for copper rockfish. Since 2013, catches south of Point Conception peaked in 2018 and sharply declined in 2022 due to the sub-bag limit of one copper rockfish in response to the 2021 assessments of copper rockfish in California waters (Table i). North of Point Conception total catch has fluctuated with the lowest catches in 2013 of just over 25 mt, a peak in 2017 at greater than 138 mt, and decreased removals in 2022 due to the sub-bag limit of one copper rockfish implemented in January 2022 (Table ii).

**Table i:** Recent catches (mt) by fleet and total catch (mt) summed across fleets for the sub-area model south of Point Conception.

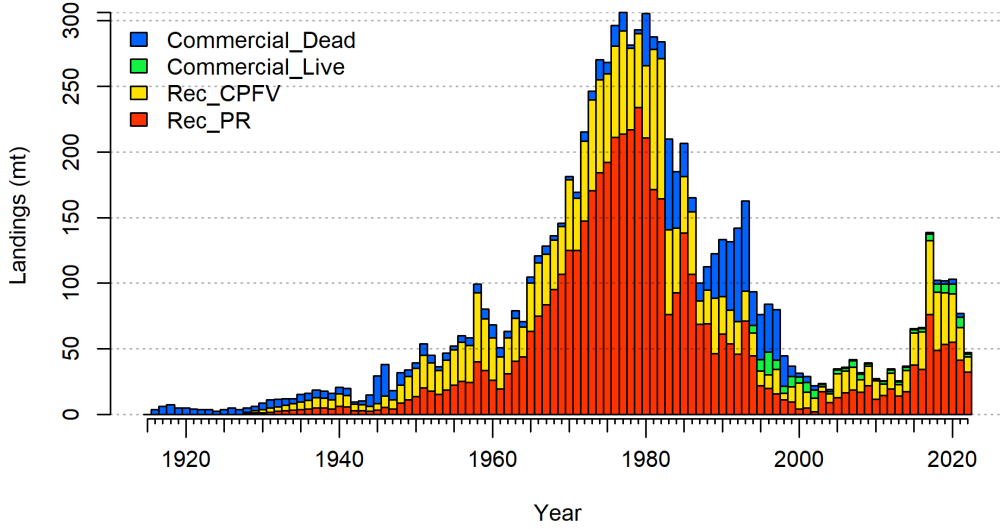
Year	Commercial Dead	Commercial Live	Rec CPFV	Rec PR	Total Catch
2013	1.26	2.67	61.65	13.96	79.54
2014	1.79	2.29	47.58	10.04	61.71
2015	2.11	4.09	67.00	8.97	82.18
2016	2.11	3.57	82.20	11.07	98.95
2017	1.74	2.82	70.58	11.72	86.86
2018	2.93	2.20	81.97	14.21	101.31
2019	2.71	3.08	60.25	14.66	80.70
2020	3.54	3.58	43.43	19.71	70.26
2021	2.74	1.94	37.78	8.28	50.73
2022	0.69	0.21	14.12	4.50	19.52

**Table ii:** Recent catches (mt) by fleet and total catch (mt) summed across fleets for the sub-area model north of Point Conception.

Year	Commercial Dead	Commercial Live	Rec CPFV	Rec PR	Total Catch
2013	0.70	2.11	8.83	14.00	25.64
2014	0.74	2.47	16.10	17.63	36.94
2015	0.78	2.69	24.22	37.77	65.46
2016	0.83	2.57	28.69	34.23	66.32
2017	1.41	4.60	56.48	76.13	138.62
2018	3.04	6.36	43.97	49.01	102.38
2019	2.49	6.85	39.16	53.39	101.89
2020	3.90	7.55	36.55	55.17	103.17
2021	3.10	7.55	24.98	41.42	77.05
2022	1.19	1.92	11.50	32.53	47.15



**Figure i:** Catches by fleet used in the base model for the area south of Point Conception where catches in metric tons by fleet are stacked.



**Figure ii:** Catches by fleet used in the base model for the area north of Point Conception where catches in metric tons by fleet are stacked.

## Data and Assessment

Length-based data-moderate assessments were conducted in 2021 for copper rockfish off the U.S. West Coast. The population was assessed regionally with four separate population models for Washington, Oregon, and south and north of Point Conception in California. Only the stock off the coast of California is being assessed in 2023 with two sub-area models split at Point Conception ( $34^{\circ} 27' \text{ N. lat.}$ ). This assessment uses Stock Synthesis 3 (version 3.30.21.00). Each assessment model is a two-sex age-structured model operating on an annual time step covering the period 1916 to 2022, with a twelve-year projection, and assumes an unfished population prior to 1916. Population dynamics are modeled for ages 0 through 50, with age 50 being the accumulator age. The model is conditioned on catch from two sectors, commercial and recreational, divided among four fleets, and is informed by both fishery-dependent and fishery-independent indices of abundance. The sub-area models are fit to length composition data from fishery-independent and fishery-dependent sources, as well as age compositions conditioned on length. Discards from the commercial and recreational fleets were estimated externally and added to landings to represent total catch. The commercial fishery is sub-divided based on the landed condition of copper rockfish, live or dead. The recreational fishery is split into two fleets, a PR and the CPFV boat modes. The model also incorporates an updated length-based maturity schedule and externally estimated length-weight relationship and fecundity-at-length function. The assessment fixes values for natural mortality of females and males at the median of the prior ( $0.108 \text{ yr}^{-1}$ ) and estimates sex-specific growth parameters. Year-class strength is estimated as deviations from

a Beverton-Holt stock-recruitment relationship beginning in 1965 in the south and in 1970 north of Point Conception. Steepness of the Beverton-Holt stock-recruitment relationship is fixed at the mean of the prior, 0.72.

All the data sources included in each sub-area model for copper rockfish in California have been re-evaluated for these assessments, including improvements and updates in the data (and associated analyses) that were used in the previous assessments. New data types and sources were included in these assessment compared to the 2021 assessments which included a limited scope of data types and sources. One fishery-independent data source was added to these assessments, the California Collaborative Fisheries Research Program (CCFRP) Hook and Line survey. The CCFRP Hook and Line survey data (indices, lengths, and ages) have been included in other nearshore assessments in the past (e.g., vermilion rockfish). These assessments also include fishery-dependent indices of abundance from the CPFV and PR fleets, north and south of Point Conception, that were not included in the 2021 assessments. Finally, this is the first assessment to include age composition data to support estimates of growth and population dynamics within the base models.

Within model uncertainty is explicitly included in this assessment by parameter estimation uncertainty, while among model uncertainty is explored through sensitivity analyses addressing alternative input assumptions such as data treatment and weighted, and model specification sensitivity to the treatment of life history parameters, selectivity, and recruitment. Base models were selected that best fit the observed data while concomitantly balancing the desire to capture the central tendency across those sources of uncertainty, ensure model realism and tractability, and promote robustness to potential model mis-specification.

## Stock Output and Dynamics

Spawning output of copper rockfish was estimated within each sub-area model and is reported here for each area (Tables iii and iv) and the combined estimates for the California stock (Table v). Uncertainty is estimated within each model and is reported for the model area results south and north of Point Conception. The spawning output, in terms of billions of eggs, south of Point Conception was estimated at 32.06 in 2023 and an unfished spawning output of 201.06. The spawning output north of Point Conception was estimated at 208.74 in 2023 and unfished spawning output of 456.05. Across California the stock for copper rockfish has a combined spawning output of 240.8, unfished spawning output of 657.11, and a relative spawning output of 36.6 percent. The stock is estimated to be above the management target at the start of 2023 (Figures iii and iv).

The spawning output declined for each sub-area from the early 1970s through the mid-1990s (Figures v and vi). South of Point Conception, the population remained at very low levels until the early 2000s at which point the population began slowly increasing up until 2019, with the spawning output declining in the final years of the time series. In contrast, the portion of the stock north of Point Conception has been continually increasing since the sub-area low point in spawning output in the 1990s.

**Table iii:** Estimated recent trend in spawning output and the fraction unfished and the 95 percent intervals for the sub-area model south of Point Conception.

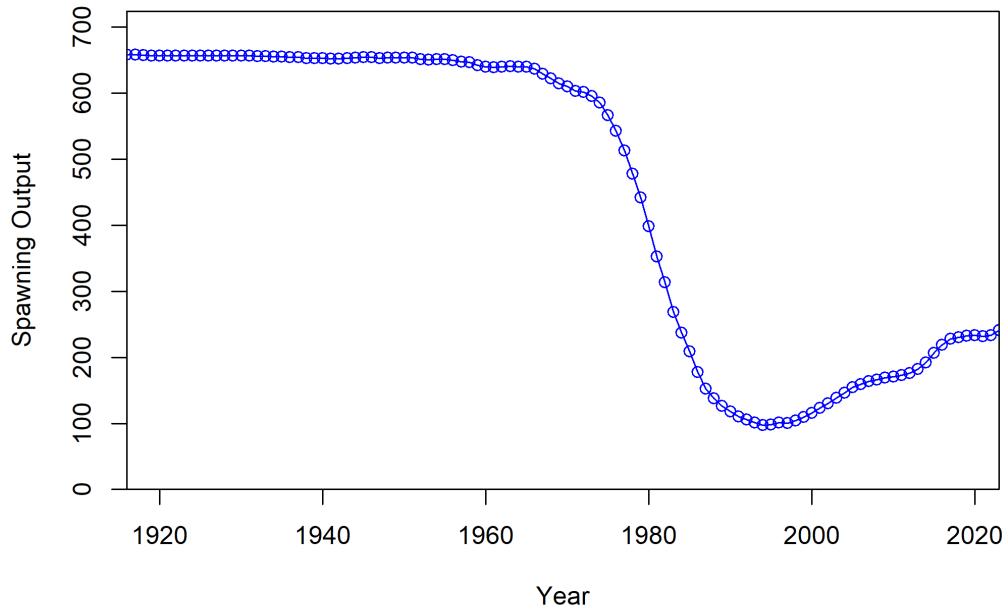
Year	Spawning Output	Lower Interval	Upper Interval	Fraction Unfished	Lower Interval	Upper Interval
2013	30.41	21.69	39.14	0.15	0.10	0.20
2014	31.23	21.96	40.51	0.16	0.10	0.21
2015	34.70	24.45	44.95	0.17	0.12	0.23
2016	37.53	26.11	48.96	0.19	0.13	0.25
2017	39.19	26.45	51.94	0.19	0.13	0.26
2018	41.13	26.90	55.35	0.20	0.13	0.28
2019	40.17	24.51	55.82	0.20	0.12	0.28
2020	38.24	21.30	55.18	0.19	0.10	0.28
2021	35.22	17.23	53.20	0.18	0.09	0.26
2022	32.58	13.79	51.37	0.16	0.07	0.25
2023	32.06	12.70	51.42	0.16	0.06	0.25

**Table iv:** Estimated recent trend in spawning output and the fraction unfished and the 95 percent intervals for the sub-area model north of Point Conception.

Year	Spawning Output	Lower Interval	Upper Interval	Fraction Unfished	Lower Interval	Upper Interval
2013	151.35	77.12	225.59	0.33	0.21	0.46
2014	161.15	82.41	239.88	0.35	0.22	0.48
2015	172.25	87.89	256.61	0.38	0.24	0.52
2016	181.11	90.77	271.45	0.40	0.25	0.55
2017	189.01	92.73	285.30	0.41	0.25	0.57
2018	189.15	86.95	291.35	0.41	0.24	0.59
2019	192.23	84.08	300.38	0.42	0.24	0.61
2020	194.90	80.88	308.92	0.43	0.23	0.62
2021	196.80	77.10	316.49	0.43	0.22	0.64
2022	201.06	75.66	326.45	0.44	0.22	0.66
2023	208.74	77.33	340.15	0.46	0.23	0.69

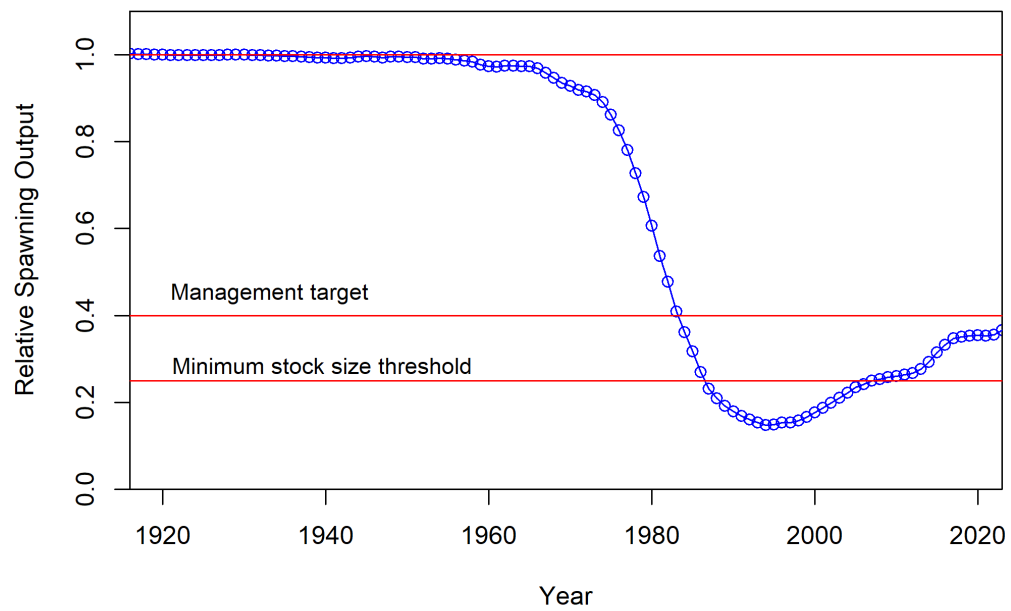
**Table v:** The estimated total biomass (mt), total biomass age 3+ (mt), age-0 recruits, and spawning output in number of billions of eggs across California and fraction unfished by year.

Year	Total Biomass (mt)	Total Biomass 3+ (mt)	Age-0 Recruits	Spawning Output	Fraction Unfished
2013	2289.25	2253.87	947.06	181.77	0.277
2014	2428.11	2379.05	532.16	192.38	0.293
2015	2575.68	2525.46	561.77	206.95	0.315
2016	2668.29	2640.24	378.21	218.64	0.333
2017	2720.50	2693.81	813.33	228.21	0.347
2018	2687.50	2662.11	589.84	230.28	0.350
2019	2649.99	2612.81	364.71	232.40	0.354
2020	2620.84	2594.05	559.06	233.14	0.355
2021	2591.82	2570.81	639.19	232.01	0.353
2022	2601.31	2571.41	636.27	233.63	0.356
2023	2672.65	2638.28	638.71	240.80	0.366

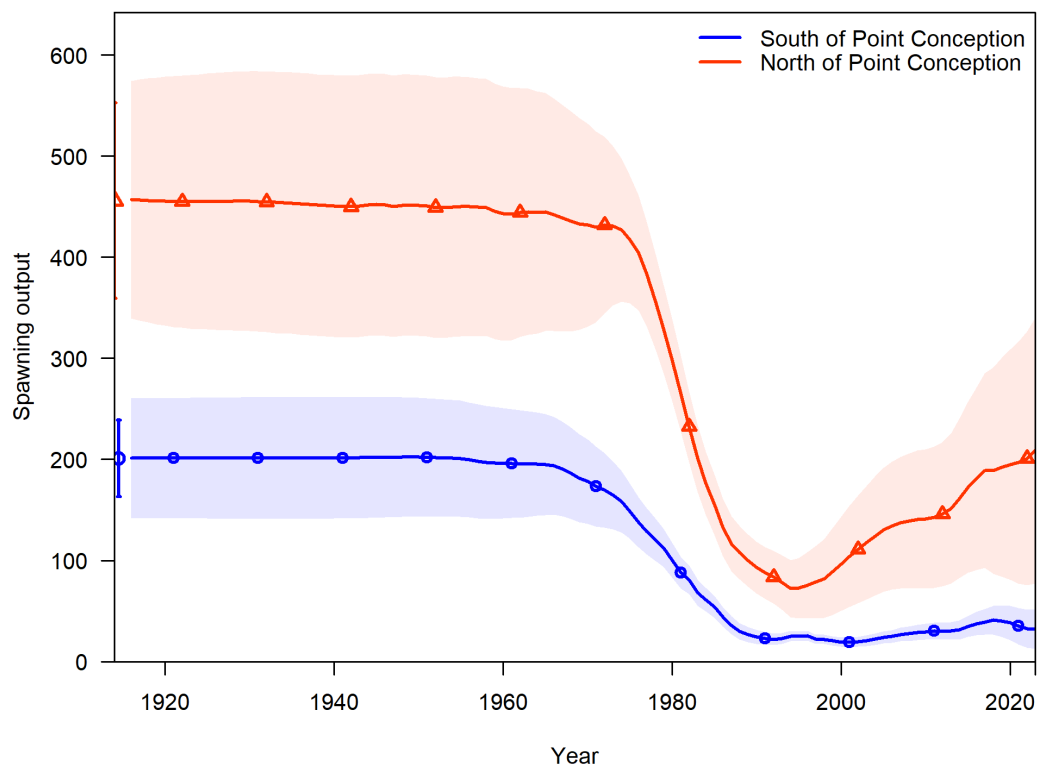


**Figure iii:** Estimated combined time series of spawning output for copper rockfish in California waters.

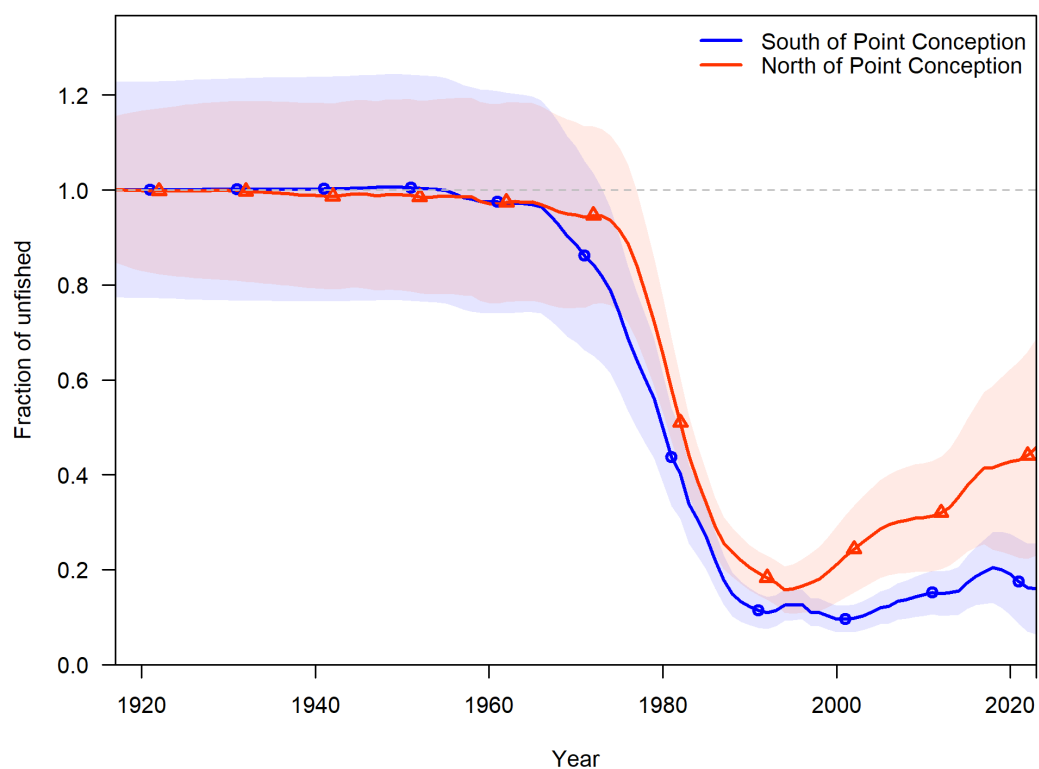




**Figure iv:** Estimated combined time series of fraction of relative spawning output for copper rockfish in California waters.



**Figure v:** Estimated time series of spawning output (circles and line: median; light broken lines: 95 percent intervals) for the model areas south and north of Point Conception.



**Figure vi:** Estimated time series of fraction of relative spawning output (circles and line: median; light broken lines: 95 percent intervals) for the model areas south and north of Point Conception.

## Recruitment

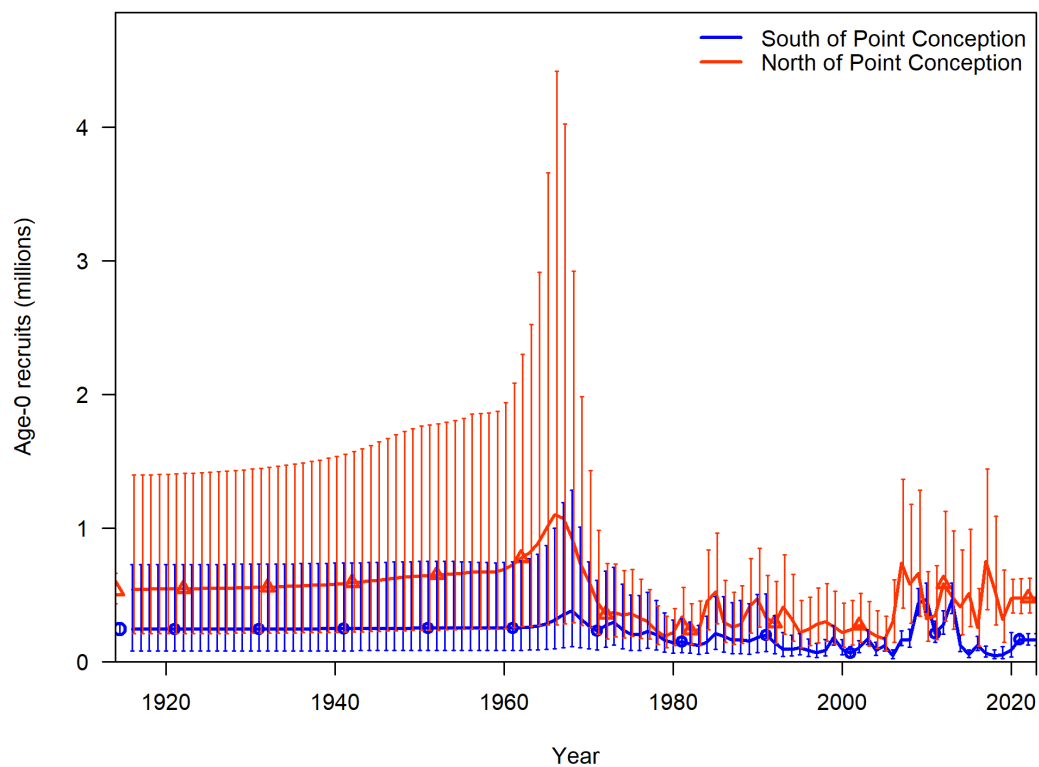
Recruitment deviations were estimated from 1965-2020 south of Point Conception and from 1970-2019 north of Point Conception. The estimated magnitude of recruitment deviations and years of strong or weak recruitment varied for each sub-area. The base model south of Point Conception estimated strong recruitment in 2009, 2010, and 2013 with multiple poor recruitment years at the end of the time series (Table vi and Figures vii and viii). The sub-area model north of Point Conception estimated the largest recent recruitment deviations in 2007, 2009, and 2017 with series of poor recruitment occurring in the late 1990s and early 2000s (Table vii and Figures vii and viii). The magnitude of overall estimated relative recruitment variation, highs and lows, was greater in the sub-area south of Point Conception compared to the sub-area north of Point Conception.

**Table vi:** Estimated recent trend in recruitment and recruitment deviations and the 95 percent intervals for the sub-area model south of Point Conception.

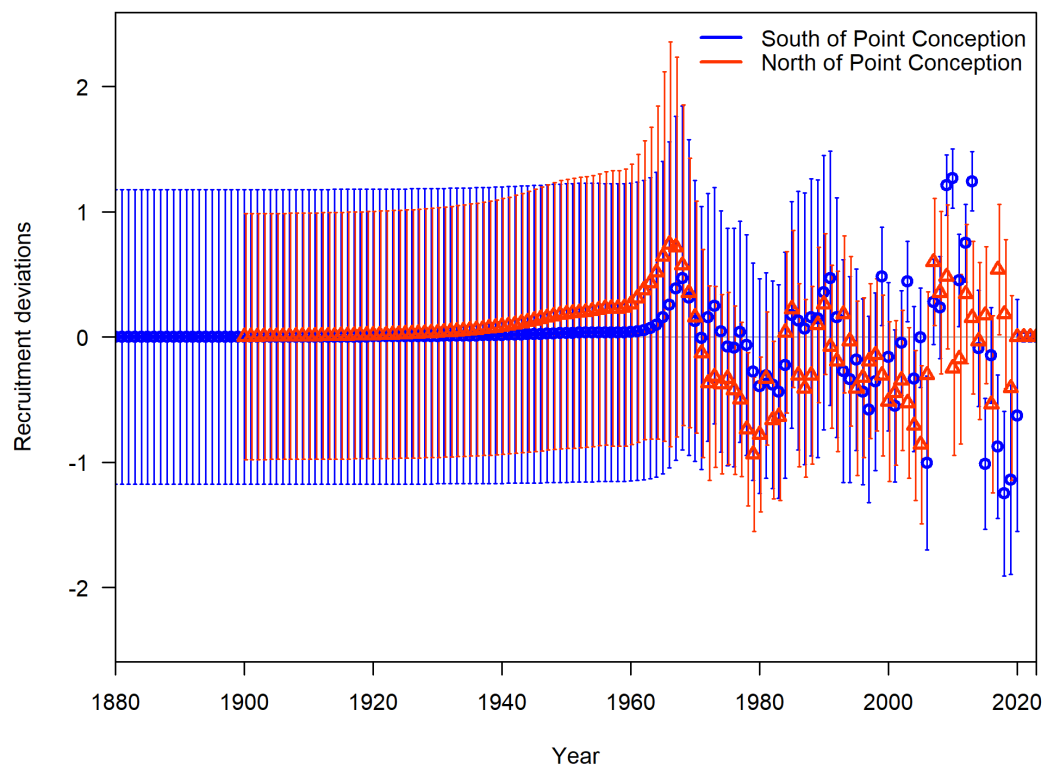
Year	Recruit- ment	Lower Interval	Upper Interval	Recruit- ment Devia- tions	Lower Interval	Upper Interval
2013	460.73	361.13	587.80	1.24	1.01	1.48
2014	122.60	76.54	196.38	-0.09	-0.56	0.37
2015	50.87	29.98	86.31	-1.01	-1.53	-0.49
2016	124.48	81.84	189.32	-0.15	-0.53	0.24
2017	62.66	34.31	114.43	-0.88	-1.45	-0.30
2018	45.02	22.72	89.22	-1.25	-1.91	-0.59
2019	51.27	23.69	110.97	-1.14	-1.89	-0.39
2020	86.40	34.59	215.82	-0.63	-1.55	0.30
2021	165.61	130.37	210.38	0.00	0.00	0.00
2022	160.68	122.78	210.27	0.00	0.00	0.00
2023	159.66	120.60	211.38	0.00	0.00	0.00

**Table vii:** Estimated recent trend in recruitment and recruitment deviations and the 95 percent intervals for the sub-area model north of Point Conception.

Year	Recruit- ment	Lower Interval	Upper Interval	Recruit- ment Devia- tions	Lower Interval	Upper Interval
2013	486.33	242.04	977.19	0.15	-0.46	0.77
2014	409.56	201.09	834.19	-0.03	-0.66	0.60
2015	510.90	263.41	990.93	0.17	-0.37	0.72
2016	253.74	117.60	547.46	-0.54	-1.24	0.17
2017	750.67	390.60	1442.66	0.54	0.02	1.06
2018	544.82	272.78	1088.16	0.18	-0.41	0.78
2019	313.44	143.31	685.52	-0.41	-1.15	0.33
2020	472.66	362.64	616.07	0.00	0.00	0.00
2021	473.58	362.02	619.52	0.00	0.00	0.00
2022	475.59	362.99	623.12	0.00	0.00	0.00
2023	479.05	366.01	627.00	0.00	0.00	0.00



**Figure vii:** Estimated time series of age-0 recruits (1000s) for the model areas south and north of Point Conception with 95 percent intervals.



**Figure viii:** Estimated time series of recruitment deviations for the model areas south and north of Point Conception.

## Exploitation status

Trends in fishing intensity (1 - SPR) for both sub-areas dramatically increased in the 1970s, exceeded the management target  $SPR_{50\%}$ , and remained high until at least the late 1990s (Figure ix). The fishing intensity south of Point Conception declined in the early 2000s but remained above the target for the rest of the time series except for 2006 (Table viii). The fishing intensity sharply decreased around 2000 north of Point Conception with fishing intensity remaining below the management target since, excluding a recent spike in 2017 (Table ix).

As a percentage of biomass (ages 3+), harvest rates south of Point Conception between 2013-2021 ranged between 0.13-0.19, with harvest rates declining in 2022 to 0.06 based on inseason management actions by California Department of Fish and Wildlife (CDFW) that reduced the sub-bag limit for copper rockfish to one fish across the state (Table viii). The harvest rates in the sub-area north of Point Conception since 2013 have ranged between 0.01-0.07 (Table ix).

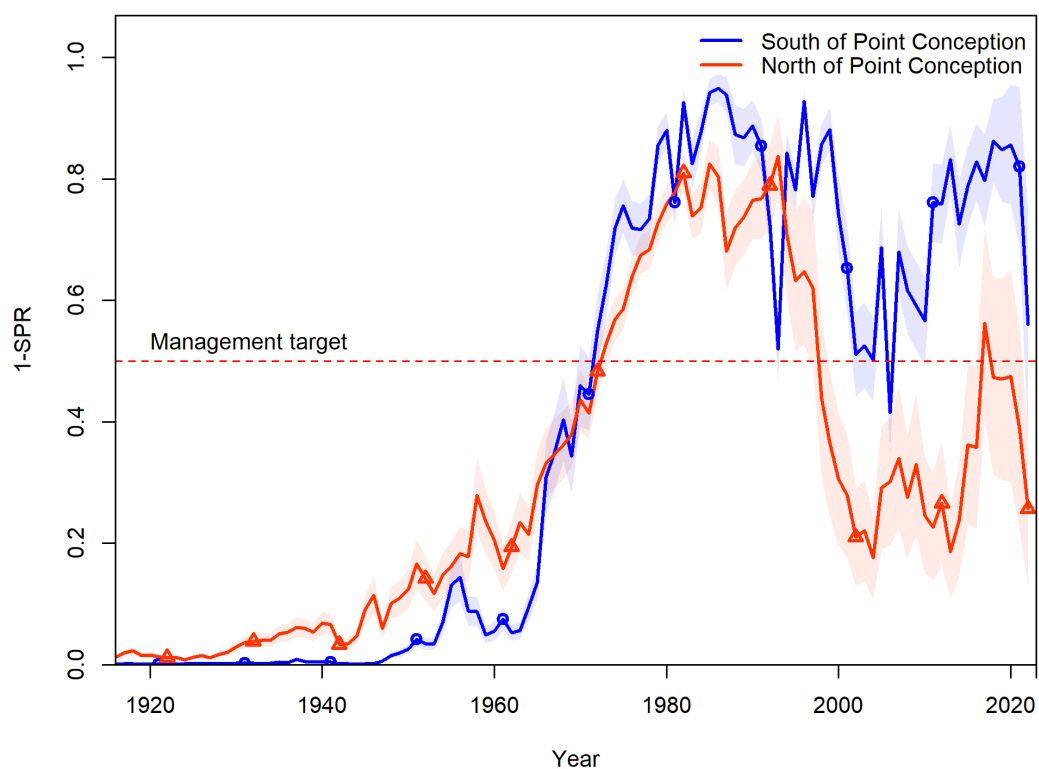
**Table viii:** Estimated recent trend in the 1-SPR where SPR is the spawning potential ratio the exploitation rate, and the 95 percent intervals for the sub-area model south of Point Conception.

Year	1-SPR	Lower Interval	Upper Interval	Exploita- tion Rate	Lower Interval	Upper Interval
2013	0.83	0.78	0.89	0.17	0.13	0.21
2014	0.73	0.65	0.80	0.13	0.10	0.16
2015	0.79	0.72	0.85	0.16	0.12	0.19
2016	0.83	0.76	0.89	0.17	0.13	0.22
2017	0.80	0.72	0.87	0.15	0.11	0.20
2018	0.86	0.79	0.93	0.19	0.13	0.25
2019	0.85	0.76	0.93	0.17	0.11	0.23
2020	0.86	0.76	0.95	0.16	0.09	0.23
2021	0.82	0.69	0.95	0.13	0.07	0.20
2022	0.56	0.37	0.75	0.06	0.02	0.09



**Table ix:** Estimated recent trend in the 1-SPR where SPR is the spawning potential ratio the exploitation rate, and the 95 percent intervals for the sub-area model north of Point Conception.

Year	1-SPR	Lower Interval	Upper Interval	Exploita- tion Rate	Lower Interval	Upper Interval
2013	0.19	0.11	0.26	0.01	0.01	0.02
2014	0.24	0.14	0.33	0.02	0.01	0.03
2015	0.36	0.23	0.49	0.03	0.02	0.05
2016	0.36	0.22	0.49	0.03	0.02	0.05
2017	0.56	0.41	0.72	0.07	0.03	0.10
2018	0.47	0.31	0.63	0.05	0.02	0.07
2019	0.47	0.30	0.64	0.05	0.02	0.07
2020	0.47	0.30	0.65	0.05	0.02	0.08
2021	0.39	0.22	0.55	0.04	0.01	0.06
2022	0.26	0.13	0.38	0.02	0.01	0.03



**Figure ix:** Estimated 1 - relative spawning ratio (SPR) by year for the model areas south and north of Point Conception. The management target is plotted as a red horizontal line and values above this reflect harvest in excess of the proxy harvest rate.

## Ecosystem considerations

This stock assessment does not explicitly incorporate trophic interactions, habitat factors (other than as they inform relative abundance indices) or environmental factors into the assessment model, but a brief description of likely or potential ecosystem considerations is provided below.

As with most other rockfish and groundfish in the California Current, recruitment or cohort (year-class) strength appears to be highly variable for copper rockfish, with only a modest apparent relationship to estimated levels of spawning output. Oceanographic and ecosystem factors are widely recognized to be key drivers of recruitment variability for most species of groundfish, as well as most elements of California Current food webs. Empirical estimates of recruitment from pelagic juvenile rockfish surveys have been used to inform incoming year class strength for some of these stocks, however copper rockfish are infrequently encountered in these surveys. Between 1998 and 2013 the California Cooperative Oceanic Fisheries Investigation (CalCOFI) survey had 34 positive observations of copper rockfish out of over 500 bongo net tows.

## Reference points

Reference points were calculated using the estimated selectivities and catch distribution among fleets in the final year of each sub-area model, 2022. Reference points are presented in Tables x and xi for each sub-model area and are informational only. Copper rockfish off the California coast are managed as a single stock by the Pacific Fishery Management Council. Combined reference point quantities for the California stock are shown in Table xii.

Sustainable total yield (landings plus discards) across California is estimated to 164.24 mt when using an  $SPR_{50\%}$  reference harvest rate. The spawning output equivalent to 40 percent of the unfished level ( $SO_{40\%}$ ) was 262.8 billions of eggs.

The 2022 combined California spawning output relative to unfished equilibrium spawning biomass is at 36.6 percent of unfished, below the management target of 40 percent (Table v). The fishing intensity,  $1 - SPR$ , for each model area varied where the portion of the stock north of Point Conception has been below that target in recent years (Figures ix and x). In contrast, the fishing intensity south of Point Conception has been estimated to be above the target in recent years.

Tables x and xi show the full suite of estimated reference points for each sub-area model and Figures xi and xii show the equilibrium yield curves and net production based on a steepness value fixed at 0.72.

**Table x:** Summary of reference points and management quantities, including estimates of the 95 percent intervals for the sub-area model south of Point Conception.

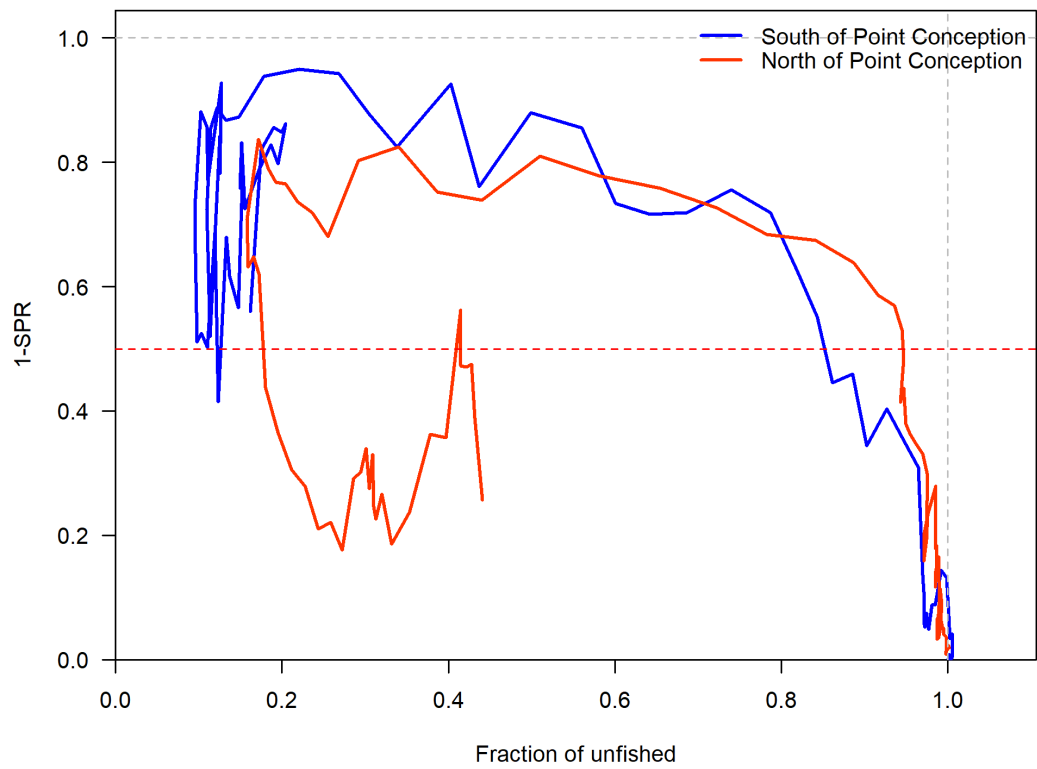
	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output	201.06	163.43	238.70
Unfished Age 3+ Biomass (mt)	1999.51	1624.90	2374.12
Unfished Recruitment (R0)	241.18	196.04	286.32
Spawning Output (2023)	32.06	12.70	51.42
Fraction Unfished (2023)	0.16	0.06	0.25
Reference Points Based SO40%			
Proxy Spawning Output SO40%	80.43	65.37	95.48
SPR Resulting in SO40%	0.46	0.46	0.46
Exploitation Rate Resulting in SO40%	0.06	0.05	0.06
Yield with SPR Based On SO40% (mt)	49.99	40.74	59.25
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Output (SPR50)	89.71	72.92	106.50
SPR50	0.50	-	-
Exploitation Rate Corresponding to SPR50	0.05	0.05	0.05
Yield with SPR50 at SB SPR (mt)	47.78	38.93	56.62
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY (SB MSY)	55.51	45.15	65.87
SPR MSY	0.35	0.34	0.35
Exploitation Rate Corresponding to SPR MSY	0.08	0.08	0.08
MSY (mt)	52.94	43.14	62.74

**Table xi:** Summary of reference points and management quantities, including estimates of the 95 percent intervals for the sub-area model north of Point Conception.

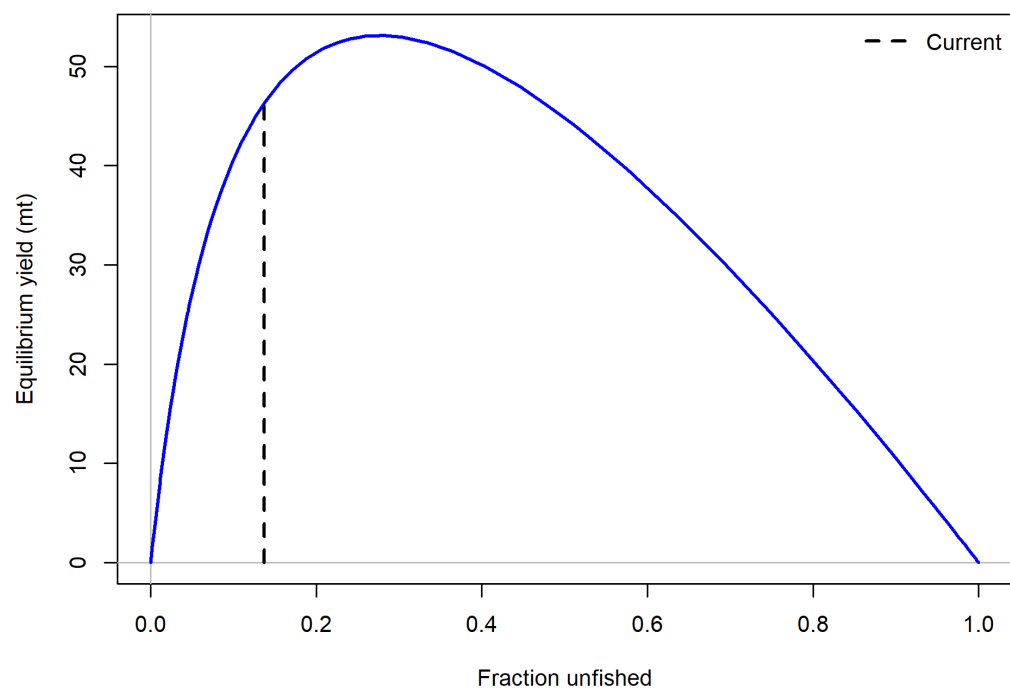
	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output	456.05	359.98	552.11
Unfished Age 3+ Biomass (mt)	4431.19	3511.38	5351.00
Unfished Recruitment (R0)	534.18	421.66	646.70
Spawning Output (2023)	208.74	77.33	340.15
Fraction Unfished (2023)	0.46	0.23	0.69
Reference Points Based SO40%			
Proxy Spawning Output SO40%	182.42	143.99	220.84
SPR Resulting in SO40%	0.46	0.46	0.46
Exploitation Rate Resulting in SO40%	0.06	0.06	0.06
Yield with SPR Based On SO40% (mt)	121.92	96.86	146.99
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Output (SPR50)	203.47	160.61	246.33
SPR50	0.50	-	-
Exploitation Rate Corresponding to SPR50	0.05	0.05	0.05
Yield with SPR50 at SB SPR (mt)	116.46	92.51	140.41
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY (SB MSY)	125.80	99.21	152.39
SPR MSY	0.35	0.34	0.35
Exploitation Rate Corresponding to SPR MSY	0.09	0.08	0.09
MSY (mt)	129.20	102.65	155.75

**Table xii:** Summary of reference points and management quantities for copper rockfish in California waters

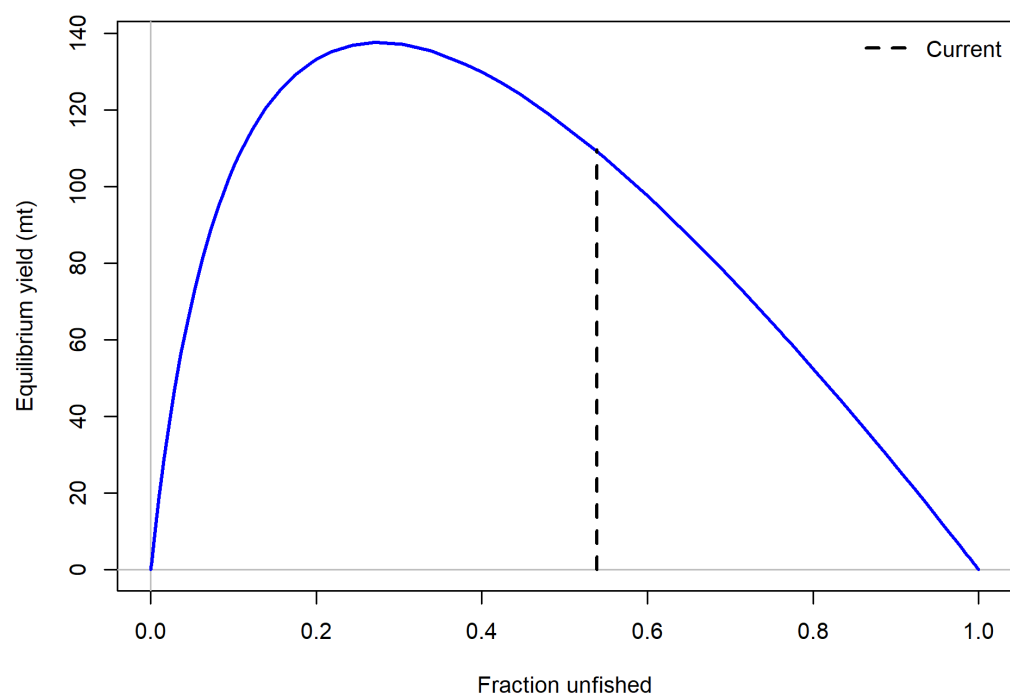
Quantity	Estimate
Unfished Spawning Output	657.11
Unfished Age 3+ Biomass (mt)	6430.7
Unfished Recruitment	775.36
Spawning Output (2023)	240.8
Relative Spawning Output (2023)	0.366
Proxy Spawning Output (SO40%)	262.84
Yield with SPR Based on SO40% (mt)	171.92
Proxy Spawning Output (SPR50)	293.17
Yield with SPR50 (mt)	164.24
Spawning Output at MSY	181.31
MSY (mt)	182.14



**Figure x:** Phase plot of estimated 1-SPR versus fraction unfished for the model areas south and north of Point Conception.



**Figure xi:** Equilibrium yield curve for the base case model south of Point Conception. Values are based on the 2022 fishery selectivities and with steepness fixed at 0.72.



**Figure xii:** Equilibrium yield curve for the base case model north of Point Conception. Values are based on the 2022 fishery selectivities and with steepness fixed at 0.72.



## Management performance

Copper rockfish are currently managed within two Nearshore Rockfish Complexes, split north and south of 40° 10' N. lat. The complexes are managed based on overfishing limits (OFL) and annual catch limits (ACL) that are determined by summing the species-specific OFLs and ACLs (ACLs set equal to the Acceptable Biological Catches [ABCs]) contributions for all stocks managed in the complexes. Limits are shared among all commercial and recreational fleets with the various management procedures intended to maintain removals below the total OFL and ACL for the Nearshore Rockfish north and south complexes as a whole, rather than on a species by species basis.

The species-specific OFL and ACL contribution for copper rockfish that is allocated to California waters, Nearshore Rockfish South and 25 percent of the Nearshore Rockfish North, is shown in Table xiii as well as the total catch across California. Over the last ten years the catches of copper rockfish have been below the species-specific ACLs in California. In 2021 all U.S. West Coast stocks of copper rockfish were assessed that informed the 2023-24 harvest specifications species-specific OFLs and ACLs. In California waters the new OFLs and ACLs for the 2023-24 management cycle were significantly lower than early years, resulting in in-season management action by CDFW for 2022 to reduce removals based on the latest stock assessment.

**Table xiii:** The species-specific Overfishing Limit (OFL) and Annual Catch Limit (ACL) allocated to California and the total catch (mt) in California waters by year.

Year	OFL (mt)	ACL (mt)	Catch (mt)
2012	163.2	136.2	86.0
2013	148.0	123.4	105.2
2014	148.0	123.4	98.7
2015	303.8	277.3	147.6
2016	286.9	262.0	165.3
2017	313.7	286.4	225.5
2018	319.6	291.8	203.7
2019	325.1	296.8	182.6
2020	330.4	301.6	173.4
2021	249.8	206.4	127.8
2022	249.5	204.0	66.7

## Unresolved problems and major uncertainties

This assessment models the sub-areas north and south of Point Conception as separate non-mixing sub-populations, but there is likely larval or juvenile dispersal, and potentially some adult movement among these areas. Dispersal and movement rates are not well known. Improved understanding around the dispersal rates of copper rockfish across California, particularly around Point Conception, are needed to support spatial modeling of the stock.

The primary fishery-independent survey for West Coast groundfish, the Northwest Fisheries Science Center (NWFSC) West Coast Groundfish Bottom Trawl (WCGBT) survey, does

not sample rocky habitats where most copper rockfish are found, and thus does not provide a robust index of abundance. An alternative survey, the CCFRP Hook and Line survey, provides a reasonable signal for copper rockfish, including relative abundance and demographic structure inside and outside a number of Marine Protect Areas (MPAs).

Age data are limited and consequently growth estimates are uncertain and the available age data contained little to no information to support the estimation of natural mortality. There is some tension among limited data sources and types inferred by the likelihood profiles, with age data suggesting a higher natural mortality rate and length data suggesting a lower value, particularly for the area north of Point Conception. Conflicting signals in the information between length and age data is commonly encountered for many West Coast groundfish stock assessments. The mechanisms driving these differences are uncertain.

Each of the sub-area models estimates high recruitment events over the most recent decade, especially relative to previous time periods. The base model for the sub-area north of Point Conception estimated overall lower variation in recruitment relative to the model south of Point Conception. Oceanographic conditions likely drive periods of either poor or above average recruitment, particularly for rockfish species. However, it is unclear what conditions may be contributing to the differing levels of recruitment variation across the California coast.

## Decision table and projections

A ten-year projection using the combined estimates from each sub-area base model, south and north of Point Conception in California, with catches equal to the estimated Annual Catch Limit (ACL) based on the category 1 time-varying  $\sigma$  with  $P^* = 0.45$  for years 2025-2034 is shown in Table xiv (i.e., termed the “buffer”). The removals in 2023 and 2024 were set equal to the portion of copper rockfish species-specific adopted ACLs for California determined by summing the adopted ACLs south of 40° 10' N. lat. and the portion of the north of 40° 10' N. lat. allocated to California (25 percent - PFMC Groundfish Management Team pers. comm.). The portion of ACL to allocate to each sub-area for 2023-24 was determined based on the proportion of the total removals by area in 2022 (71 percent north and 29 percent south) as recommended by the GMT (Mel Mandrup, CDFW, personal communication). The projections were conducted in an iterative fashion based on the combined estimates of spawning output, relative spawning output, OFL, ABC, and ACL for each year. The estimated proportion of the ACL removed from each sub-area model was based on the proportion of the contribution to the total annual OFL estimate.

At the end of the projection period, 2034, the projected ACL removals result in the California stock increasing to be above the biomass target at 40.9 percent of the relative spawning output, with the portion of the stock south at 24.5 percent of the sub-area estimated relative spawning output and north of Point Conception at 48.2 percent.

The axes of uncertainty in the decision table are based on the uncertainty around steepness. The estimated uncertainty around the 2023 OFL was used to identify the low and high states of nature that would align with the 12.5 and 87.5 percentiles from the base model where the base model is assigned a 50 percent probability of being the true state of nature and both the low and high states of nature being assigned a 25 percent probability. A search across

steepness ( $h$ ) values for each sub-area model was conducted to identify the corresponding steepness values that would create the low and high states of nature relative to the base model. The sub-area north of Point Conception applied values of  $h$  of: 0.655, 0.72, and 0.859. The sub-area south of Point Conception applied values of  $h$  of: 0.54, 0.72, and 0.929. The proposed decision table assumes full ACL removal during the projection period under P\* alternative catch stream (Table xv).

**Table xiv:** The estimated OFL (mt), ABC (mt), ACL (mt), buffer, spawning output in billions of eggs across California, and relative spawning output by year along with the sub-area allocations of the ACL south of Point Conception (south, 34°27' N. lat.), north of Point Conception to 40°10' N. lat. (central), and 40°10' to 42° N. lat. (north).

Year	Assumed Catch (mt)	OFL (mt)	ABC (mt)	ACL (mt)	Buffer	Spawning Output	Fraction Unfished	Sub-ACL South (mt)	Sub-ACL Central (mt)	Sub-ACL North (mt)
2023	91.5	-	-	-	-	240.80	0.366	-	-	-
2024	94.7	-	-	-	-	245.88	0.374	-	-	-
2025	-	143.5	134.1	131.9	0.935	250.60	0.381	15.8	109.2	6.8
2026	-	145.3	135.2	133.1	0.93	251.62	0.383	18	108.4	6.7
2027	-	147.2	136.3	134.5	0.926	252.91	0.385	20.1	107.7	6.7
2028	-	148.9	137.3	135.8	0.922	254.64	0.388	22	107.1	6.7
2029	-	150.4	137.9	136.7	0.917	256.75	0.391	23.5	106.6	6.6
2030	-	151.6	138.5	137.7	0.913	259.10	0.394	24.8	106.3	6.6
2031	-	152.8	138.9	138.6	0.909	261.54	0.398	26	106	6.6
2032	-	153.9	139.1	139.1	0.904	264.02	0.402	27	105.6	6.6
2033	-	155	139.5	139.5	0.9	266.52	0.406	27.9	105.1	6.5
2034	-	156.2	139.9	139.9	0.896	269.04	0.409	28.8	104.6	6.5

**Table xv:** Decision table summary of 10 year projections beginning in 2025 for alternative states of nature based on an axis of uncertainty around steepness for both California sub-area models. Columns range over low, mid, and high states of nature and rows range over different catch P\* values.

	Year	Catch	Low Steepness		Base Steepness		High Steepness	
			Spawning Output	Fraction Unfished	Spawning Output	Fraction Unfished	Spawning Output	Fraction Unfished
ACL P* 0.45	2023	91.5	176.2	0.255	240.8	0.366	337.3	0.533
	2024	94.7	178.2	0.258	245.9	0.374	345.7	0.546
	2025	131.9	180.2	0.261	250.6	0.381	352.9	0.558
	2026	133.1	178.9	0.259	251.6	0.382	355.4	0.562
	2027	134.5	178.2	0.258	252.9	0.384	357.3	0.564
	2028	135.8	178.0	0.258	254.6	0.387	358.9	0.567
	2029	136.7	178.3	0.258	256.7	0.390	360.4	0.569
	2030	137.7	178.9	0.259	259.1	0.394	361.8	0.572
	2031	138.6	179.6	0.260	261.5	0.397	363.1	0.574
	2032	139.1	180.4	0.261	264.0	0.401	364.3	0.575
	2033	139.5	181.2	0.262	266.5	0.405	365.3	0.577
	2034	139.9	182.0	0.264	269.0	0.409	366.2	0.578
ACL P* 0.40	2023	91.5	176.2	0.255	240.8	0.366	337.3	0.533
	2024	94.7	178.2	0.258	245.9	0.374	345.7	0.546
	2025	123.1	180.2	0.261	250.6	0.381	352.9	0.558
	2026	124.2	179.7	0.260	252.4	0.384	356.3	0.563
	2027	125.4	179.9	0.261	254.6	0.387	359.1	0.567
	2028	126.5	180.7	0.262	257.3	0.391	361.6	0.571
	2029	127.4	181.9	0.263	260.3	0.396	364.1	0.575
	2030	128.1	183.4	0.266	263.6	0.401	366.4	0.579
	2031	128.2	185.1	0.268	267.1	0.406	368.7	0.582
	2032	128.4	186.9	0.271	270.6	0.411	370.8	0.586
	2033	128.4	188.8	0.273	274.1	0.416	372.8	0.589
	2034	128.5	190.7	0.276	277.7	0.422	374.7	0.592
ACL P* 0.35	2023	91.5	176.2	0.255	240.8	0.366	337.3	0.533
	2024	94.7	178.2	0.258	245.9	0.374	345.7	0.546
	2025	114.7	180.2	0.261	250.6	0.381	352.9	0.558
	2026	115.6	180.5	0.261	253.3	0.385	357.1	0.564
	2027	116.7	181.5	0.263	256.3	0.389	360.7	0.570
	2028	117.5	183.2	0.265	259.8	0.395	364.2	0.575
	2029	118.2	185.3	0.268	263.8	0.401	367.6	0.581
	2030	118.1	187.8	0.272	268.1	0.407	370.9	0.586
	2031	118.0	190.5	0.276	272.5	0.414	374.1	0.591
	2032	117.9	193.4	0.280	277.0	0.421	377.2	0.596
	2033	117.6	196.3	0.284	281.5	0.428	380.2	0.601
	2034	117.4	199.2	0.289	286.1	0.435	383.1	0.605

## Scientific uncertainty

The model estimated uncertainty around the 2023 spawning output for the sub-area model south of Point Conception is  $\sigma = 0.3$  and the uncertainty for the sub-area model north of Point Conception is  $\sigma = 0.31$ . The uncertainty around the OFL south and north of Point Conception was  $\sigma = 0.28$  and  $0.3$ , respectively. Each of these are likely underestimates of overall uncertainty due to the necessity to fix several key population dynamics parameters (e.g., steepness, recruitment variance, natural mortality) and also because there is no explicit incorporation of model structural uncertainty (although see the decision table for alternative states of nature).

## Research and data needs

There were some major sources of uncertainty within the assessments for copper rockfish. To improve our understanding of the copper rockfish stock in California waters the following research and data collection should be prioritized:

1. The NWFSC Hook and Line survey is the only long-term fishery-independent survey in rocky (untrawlable) habitat in the Southern California Bight. Efforts should continue to explore how best to model hook and line catch data to develop indices of abundance. We also recommend evaluating how to structure the NWFSC Hook and Line survey index, given its expansion into the CCAs and increase in sites within designated MPAs, and independent analysis of information content in NWFSC Hook and Line survey across observed species. Finally, increased spatiotemporal sampling around Point Conception would aid in identifying stock boundaries.
2. The assessment area south of Point Conception appears to have a mixture of observations from areas experiencing variable fishing mortality. In the region there are likely a mixture of areas: open access rocky reefs that are close to port that are heavily fished, open access rocky reefs that are inaccessible via day-trips that are fished but likely at lower levels, and rocky reefs that fall within marine protected areas (MPAs). A spatially-explicit assessment model may be able to capture this complexity but will require data (indices of abundance and composition data) from each of the regions.
3. Future nearshore assessments would greatly benefit from additional CDFW ROV surveys which could increase the power of these data to inform assessments.
4. There are very limited age data for copper rockfish across California arising from fishery-dependent sources. Establishing regular collections of otoliths from the recreational fishery, a large source of mortality, would support future assessments and would improve the understanding of the population structure and life history of copper rockfish.
5. There is limited information for copper rockfish on maturity and fecundity and the variability of these parameters with increasing latitude. The NWFSC WCGBT and Hook and Line surveys provided the only available information on the maturity ogive and the timing of these surveys does not overlap with the expected peak spawning season. The Southwest Fisheries Science Center has egg samples from a total of ten copper rockfish, which is too few to draw conclusions regarding fecundity.

6. Some of the PR mode recreational data that should be available via RecFIN were found to contain information in that database inconsistent with datasheets available from CDFW. There is also a question if length data collected by the Deb Wilson-Vandenberg onboard observer survey is duplicated within RecFIN and attributed to MRFSS dockside samples of the CPFV fleet.
7. The interpreted substrate data for the areas north of Point Conception within state waters is incomplete. Additional data needs include high resolution interpreted substrate maps for areas outside of state waters. The available interpreted bathymetry data from south of Point Conception is incomplete within state waters around the northern and southern Channel Islands. This poses a challenge for estimating available rocky substrate both by district and also inside and outside closed areas.
8. The genetic stock structure of copper rockfish warrants further investigation to ensure appropriate management of copper rockfish along the West Coast.
9. The Marine Recreational Fisheries Statistics Survey (MRFSS) index was excluded from both California assessment models. The standardized trends in abundance were marked by extreme peaks in the data throughout the time series. The STAT was unable to identify what may driving extreme changes fishing behavior in these select years. These data should be reviewed to better understand whether these data reflect true changes in fishing behavior in those years or errors in data collection.
10. Additional research on the effect of the MPA network on copper rockfish and other nearshore rockfish species needs to be conducted. The trend inside the MPAs in northern California exhibited an increasing trend compared to outside the MPAs, similar to what was observed during the 2021 assessment of vermilion/sunset rockfish. However, the trends inside MPAs south of Point Conception varied by location with a number of sites showing flat or declining trends.
11. Further investigations of other available fishery-independent data such as the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) kelp forest index would benefit future assessments of nearshore species, including copper rockfish.
12. Larval and smaller young-of-the-year copper rockfish can only be identified with certainty genetically. Existing sources of data (CalCOFI and Standard Monitoring Units for the Recruitment of Fishes [SMURFs]) where genetic samples can be analyzed would provide key information to inform spawning output estimates for copper rockfish.
13. Continue to improve historical catch reconstructions, including attempting to quantify uncertainty with these and other historical data.
14. Existing catch estimates within Recreational Fisheries Information Network (RecFIN) that are currently assigned only to "rockfish, general" should be investigated to determine if these removals can be assigned to specific species.

# 1 Introduction

This assessment report describes the sub-area population of copper rockfish (*Sebastes caurinus*) off the California coast south of Point Conception in U.S. waters, using data through 2022. The sub-area population north of Point Conception in California waters was also evaluated and is described in a separate assessment report. The copper rockfish status for the California stock of copper rockfish is determined by the combined estimates of spawning output from both sub-areas and is detailed in Management, Section 4. This assessment does not account for populations located in Mexican waters or other areas off the U.S. West Coast and assumes that these southern and northern populations do not contribute to nor take from the population being assessed here.

## 1.1 Basic Information and Life History

Copper rockfish have historically been a part of both commercial and recreational fisheries throughout its range. Copper rockfish are a demersal, relatively nearshore species within the subgenus *Pteropodus*. The core range of copper rockfish is comparatively large, ranging from northern Baja Mexico to the Gulf of Alaska, with copper rockfish also found in Puget Sound. Copper rockfish range from the sub-tidal (as juveniles) to depths of around 180 m (Love et al. 2002). Copper rockfish are commonly found in waters less than 100 m in depth inhabiting nearshore kelp forests and complex low-relief rocky habitat (Love 1996). Adult copper rockfish have high site fidelity and are thought to not make long-range movements. An acoustic telemetry study displaced copper rockfish 4 km from their capture location to an artificial reef and within 10 days, half of the copper rockfish returned to the original capture location (Reynolds et al. 2010).

Copper rockfish have a clearly defined long white band the posterior two-thirds of the lateral line. Copper rockfish have high variation in coloration throughout its range, taking on coloration from dark brown, olive, orange-red and pink, with patches of yellow and pink (Miller and Lea 1972). In general, the copper rockfish towards the northern part of the range are often darker in color than fish encountered in southern California. The distinct change in coloration resulted in copper rockfish initially being described as two separate species, copper rockfish (*S. caurinus*) and whitebelly rockfish (*S. vexillaris*).

The *Sebastes* genus is viviparous with internal fertilization, many species exhibit dimorphic growth with females larger at size-at-age than males, and a number of species have reproductive strategies that vary with latitude. There are very few fecundity samples from copper rockfish available from California, although copper rockfish are assumed to produce a single brood annually during the winter months.

The pelagic larvae are encountered in the California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys, but neither larval nor young-of-the-year can be identified visually (Thompson et al. 2017). The size at birth ranges from 5-6 mm and the larvae remain pelagic until approximately 22-23 mm standard length at which time they recruit to the kelp forest canopy (Anderson 1983).



Juvenile copper rockfish are indistinguishable from kelp (*S. atrovirens*), black-and-yellow (*S. chrysomelas*), and gopher (*S. carnatus*) rockfishes, all of which recruit to the kelp forest canopy in the spring months. Copper rockfish is the first of the species group to recruit to the kelp forest from April to May and can be distinguished from the other species once it reaches a size around 5 cm standard length (Anderson 1983). Baetscher et al. (2019) genetically identified young-of-the-year rockfish from surveys in Carmel and Monterey Bays in California and provided the authors with the length and genotyped species identifications from her study. The average total length of young-of-the-year copper rockfish in July was 3-4 cm (Figure 1). Anderson (1983) observed benthic copper rockfish nocturnally active over sandy bottom outside the kelp forest.

Copper rockfish are a relatively long-lived rockfish, estimated to live at least 50 years (Love 1996). Copper rockfish were determined to have the highest vulnerability ( $V = 2.27$ ) of any West Coast groundfish stock evaluated in a productivity susceptibility analysis (Cope et al. 2011). This analysis calculated species-specific vulnerability scores based on two dimensions: productivity characterized by the life history and susceptibility that characterized how the stock could be impacted by fisheries and other activities.

Copper rockfish are opportunistic carnivores and commonly consume crustaceans, mollusks, and fish whole (Lea et al. 1999; Bizzarro et al. 2017). Prince (1972) observed a shift in a diet dominated by arthropods in age 0 and 1 fish to a more diverse diet including molluscs and fish as they aged. The study also noted that juvenile copper rockfish were preyed upon by harbor seals and lingcod. Two tagging studies of copper rockfish indicated that most individuals have a small home range, with 91 percent of recaptures from CCFRP (unpublished data) and 49 percent of individuals from Hanan (2012) within 1 km (straight line distance) of the original release site. Of the 117 recaptures from Hanan (2012), four traveled greater than 50 km, with a maximum distance of 488 km (1,222 days at liberty), and four individuals crossed the biogeographic boundary of Point Conception. Of the 133 copper rockfish recaptures from CCFRP, four traveled greater than 50 km, and the maximum distance traveled was 169 km by two different fish (291 and 524 days at liberty).

There is currently little evidence of significant stock structure from genetic studies of copper rockfish across the west coast. Buonaccorsi et al. (2002) looked at genetic variation across six microsatellite DNA loci from samples ranging from British Columbia to southern California. Significant population subdivision was detected between the Puget Sound and coastal samples which supports the model of isolation-by-distance for copper rockfish. Sivasundar and Palumbi (2010) conducted a genetic study to determine the potential for biogeographic boundaries to prohibit gene flow for 15 *Sebastes* species. The study included 45 observations of copper rockfish with samples from Oregon ( $N = 18$ ), Monterey Bay ( $N = 18$ ), and Santa Barbara ( $N = 9$ ). Sivasundar and Palumbi (2010) used mtDNA and could differentiate samples from Santa Barbara from those collected in Oregon and Monterey Bay, but the Monterey Bay and Oregon samples could not be distinguished. Microsatellite data did not reveal any genetic differentiation among the samples from the three locations for copper rockfish and suggests low genetic differentiation coastwide. An earlier genetic analysis of copper rockfish was conducted by Johansson et al. (2008). The study included 749 samples from

along the west coast ranging from Neah Bay, Washington to San Diego, California with the majority of sampling locations clustered north of Cape Mendocino in northern California. The study included 185 samples collected within California. Eleven microsatellite DNA loci were analyzed. The study found significant evidence to support isolation by distance at the coast wide scale. Weak, but significant, genetic structure was identified from samples collected along the Oregon coast suggesting that habitat barriers may limit larval dispersal.

## 1.2 Ecosystem Considerations

This stock assessment does not explicitly incorporate trophic interactions, habitat factors (other than as they inform relative abundance indices) or environmental factors into the assessment model, but a brief description of likely or potential ecosystem considerations is provided below.

As with most other rockfish and groundfish in the California Current, recruitment or cohort (year-class) strength appears to be highly variable for copper rockfish, with only a modest apparent relationship to estimated levels of spawning output. Oceanographic and ecosystem factors are widely recognized to be key drivers of recruitment variability for most species of groundfish, as well as most elements of California Current food webs. Empirical estimates of recruitment from pelagic juvenile rockfish surveys have been used to inform incoming year class strength for some of these stocks, however copper rockfish are infrequently encountered in these surveys. Between 1998 and 2013 the California Cooperative Oceanic Fisheries Investigation (CalCOFI) survey had 34 positive observations of copper rockfish out of over 500 bongo net tows.

## 1.3 Historical and Current Fishery Information

Off the coast of California south of Point Conception copper rockfish is caught in both commercial and recreational fisheries. Recreational removals have been the largest source of fishing mortality of copper rockfish across all years (Table 1 and Figure 2). The recreational fishery is comprised of individual recreational fishers (Private/Rental, PR) and commercial passenger fishing vessels (CPFV) also known as party/charter (PC) which take groups of individuals out for day fishing trips. Across both types of recreational fishing the majority of effort occurs around rocky reefs that can be accessed via day-trips.

The recreational fishery in the early part of the 20th century was focused on nearshore waters near ports, with expanded activity further from port and into deeper depths over time (Miller et al. 2014). Prior to the groundfish fishery being declared a federal disaster in 2000, and the subsequent rebuilding period, there were no time or area closures for groundfish. Access to deeper depths during this period spread effort over a larger area and filled bag limits with a greater diversity of species from both the shelf and nearshore. This resulted in lower catch of nearshore rockfish relative to the period after 2000. Between 1999 and 2002, gear regulations went from unlimited hooks and lines to one line per person with no more than two hooks, the current 10 rockfish, cabezon, greenling (RCG) bag limit was enacted, and CDFW created management areas to restrict fishing shoreward of the 20 to 60 fathoms (fm). Depth

restrictions ranged from 20 fm in the Northern Management Area (California/Oregon Border to 40° 10' N. lat.) to 60 fm in the Southern Management Area (south of Point Conception, 34° 27' N. lat.). The latitudinal boundaries of the management areas and depth closures have fluctuated since 2002, but have remained fairly consistent since 2011. This shifting effort onto the nearshore, concomitantly increased catch rates for nearshore rockfish including copper rockfish in the remaining open depths. California's network of Marine Protected Areas (MPAs) also closed approximately 20 to 27 percent of state waters to recreational fishing, with the majority of MPAs developed in 2007.

The depth restrictions have slowly been relaxed following the rebuilding of all previously overfished groundfish species as of 2019, other than yelloweye rockfish (*S. ruberrimus*). The Southern Management area gained access to a depth of 75 fm in 2019, and out to 100 fm in 2021 and 2022. To the north of Point Conception, where yelloweye rockfish are more prevalent, depth constraints persist with most northern areas limited to 30 fm and shallower and more southern areas limited to fishing 50 fm and shallower through 2022. The recreational regulations for 2023 differ from the most recent years and are described in the management section.

Prior to development of the live fish market in the 1980s, there was very little commercial catch of copper rockfish, with dead copper rockfish yielding a low ex-vessel price per pound. Copper rockfish were targeted along with other rockfish to some degree in the nearshore or caught as incidental catch by vessels targeting other more valuable stocks such as lingcod. Most fish were caught using hook and line gear, though some were caught using traps, gill nets and, rarely, trawl gear. Trawling was prohibited within three miles of shore in 1953 and gill netting within three miles of shore was prohibited in 1994, preventing access to a high proportion of the species habitat with these gear types.

In the late 1980s and early 1990s a market for fish landed live arose out of Los Angeles and the San Francisco Bay area, driven by demand from Asian restaurants and markets. The growth of the live fish market was driven by consumers willing to pay a higher price for live fish, ideally plate-sized (12 - 14 inches or 30.5 - 35.6 cm). Live fish landed for the restaurant market are lumped into two categories, small (1 - 3 lbs.) or large (3 - 6 lbs.), with small, plate-sized, fish fetching higher prices at market ranging between \$5 - 8 per fish (Bill James, personal communication, 2021). Copper rockfish is one of the many rockfish species that is included in the commercial live fish fishery. The proportion of copper rockfish being landed live vs. dead since 2000 by California commercial fleets ranges between 50 to greater than 70 percent in the southern and northern areas, respectively.

With the development and expansion of the nearshore live fish fishery during the 1980s and 1990s, new entrants in this open access fishery were drawn by a premium ex-vessel price per pound for live fish, resulting in over-capitalization of the fishery. Since 2002, the California Department of Fish and Wildlife (CDFW) has managed 19 nearshore species in accordance with the Nearshore Fisheries Management Plan (Wilson-Vandenberg et al. 2014). In 2003, CDFW implemented a Nearshore Restricted Access Permit system, including the requirement of a Deeper Nearshore Fishery Species Permit to retain copper rockfish. Permits were issued

based on prior landings history and the overall goal of reducing the number of participants to a more sustainable level. The result was a reduction in permits issued from 1,127 in 1999 to 505 in 2003. In addition, reduced trip limits, season closures in March and April, and depth restrictions were implemented to address bycatch of overfished species and associated constraints from their low catch limits.

Copper rockfish residing between Point Conception and the Mexico/U.S. border are assessed here as a separate sub-area (Figure 3). This designation was made based on oceanographic, geographic, and fishery conditions. The copper rockfish population in California waters was split at Point Conception due to water circulation patterns that create a natural barrier between nearshore rockfish populations to the north and south. Additionally, the fairly sedentary nature of adult copper rockfish likely limits flow of fish between south and north of Point Conception.

#### **1.4 Summary of Management History and Performance**

Prior to the adoption of the Pacific Coast Groundfish Fishery Management Plan (FMP) in 1982, copper rockfish were managed through a regulatory process that included the California Department of Fish and Wildlife (CDFW), the California State Legislature, and the Fish and Game Commission (FGC). With implementation of the Pacific Coast Groundfish FMP, copper rockfish came under the management authority of the Pacific Fishery Management Council (PFMC) and were managed as part of the *Sebastes* complex. Because copper rockfish had not undergone rigorous stock assessment and did not compose a large fraction of the landings it was classified and managed as part of the “Minor Nearshore Rockfish” group (PFMC 2008).

Since the early 1980s, a number of federal regulatory measures have been used to manage the commercial rockfish fishery including cumulative trip limits (generally for two- month periods) and seasons. Starting in 1994 the commercial groundfish fishery sector was divided into two components: limited entry and open access with specific regulations designed for each component. Limited entry programs were designed in part to limit bottom contact gears and the open access sector includes gears not making bottom contact, e.g., hook and line. Other regulatory actions for the general rockfish categories included area closures and gear restrictions set for the four different commercial sectors - limited entry fixed gear, limited entry trawl, open access trawl, and open access non-trawl (which includes the nearshore fishery).

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

requirement that commercial fishermen landing nearshore species possess a nearshore fishery permit.

In 2000, the PFMC's rockfish management structure changed significantly with the replacement of the *Sebastes* complex -north and -south areas with Minor Rockfish North (Vancouver, Columbia, and Eureka, International North Pacific Fisheries Commission (INPFC) areas) and Minor Rockfish South (Monterey and Conception INPFC areas only). The optimum yield for these two groups was further divided (between north and south of 40° 10' N. lat., near Cape Mendocino, California) into nearshore, shelf, and slope rockfish categories with allocations set for Limited Entry and Open Access fisheries within each of these three categories. Species were parceled into these new categories depending on primary catch depths and geographical distribution. Copper rockfish was included in the nearshore rockfish category.

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 protected areas (MPAs) around the Channel Islands in southern California (which became effective April 2003). The FGC also adopted a restricted access program in December 2002 which established the Deeper Nearshore Species Fishery Permit, to be effective starting in the 2003 fishing year. Also, since the enactment of the MLMA, the PFMC and State coordinated to develop and adopt various management specifications to keep harvest within the harvest targets, including seasonal and area closures, depth restrictions, and bag limits to regulate the recreational fishery and license and permit regulations, finfish trap permits, gear restrictions, seasonal and area closures, depth restrictions, trip limits, and minimum size limits to regulate the commercial fishery. The MPAs were later expanded under authority of the Marine Life Protection Act (MLPA) enacted in 1999, creating a network of MPAs which went into place in phases beginning with the central coast in 2007, north central coast in 2010, and the south and north coasts in 2012. The implementation of the cowcod conservation area (CCA) in 2001 closed a large area of the Southern California Bight west of Santa Catalina and San Clemente Islands and offshore of San Diego. The CCA prohibited retention of groundfish, except for some take of nearshore species in depths less than 20 fm around islands and banks, and later, less than 40 fm. The rockfish conservation areas (RCAs) are seasonally adjusted depth limits impacting trawl and non-trawl gears that were initially established in 2002 to protect overfished species. The RCAs also restricted catch of nearshore species to depths less than 30 fm, and in some areas along California to less than 20 fm. Thus, the MPAs, CCAs and RCAs represent three types of spatial and/or depth closures impacting rockfish.

The state of California has adopted regulatory measures to manage the nearshore fishery based on the harvest guidelines set by the PFMC for the minor nearshore rockfish complexes north and south of 40° 10' N. lat.. The complexes are managed based on overfishing limits (OFL) and annual catch limits (ACL) that are determined by summing the species-specific OFLs and ACLs (ACLs set equal to the Acceptable Biological Catches) contributions for all stocks managed in the complexes. Limits are shared among all commercial and recreational fleets with the various management procedures intended to maintain removals below the total OFL and ACL for the nearshore rockfish north and south complexes as a whole, rather

than on a species by species basis. The nearshore commercial fishery is managed based on bimonthly allowable catches per vessel, that have ranged from 200 pounds to 2,000 pounds per two months since 2000. The limited entry trawl fleet is managed on monthly limits on an annual basis. Since 2011, the limit has been 300 pounds per month for non-IFQ species, such as nearshore rockfish.

The species-specific OFL and ACL contribution for copper rockfish that is allocated to California waters, Nearshore Rockfish South and 25 percent of the Nearshore Rockfish North, is shown in Table 2 as well as the total catch, south and north of Point Conception in California combined, for the last ten years. Over the last ten years the catches of copper rockfish have been below the species-specific ACLs. In 2021 all U.S. West Coast stocks of copper rockfish were assessed that informed the 2023-24 harvest specifications species-specific OFLs and ACLs for copper rockfish. In California waters the new OFLs and ACLs for the 2023-24 management cycle were significantly lower than earlier years, resulting in inseason management action by CDFW for 2022 to reduce removals based on the latest stock assessment. January 1, 2022, a statewide commercial sub-trip limit of 75 lbs. per 2-month and statewide recreational sub-bag limit of 1 fish within the overall 10 fish allowed for the RCG complex went into effect. No change in recreational seasons or depth limits occurred in 2022 but changes were implemented in 2023. In 2022, the Northern and Mendocino management areas were closed January through April and allowed fishing to 30 fathoms May through October and at all depths November through December. The San Francisco and Central management areas were closed January through March and allowed fishing to 50 fathoms the remainder of the year. The Southern management area was closed January and February and allowed fishing to 100 fathoms the remainder of the year. Beginning in 2023, closed seasons are extended in all management areas. Depth restrictions are eased during some months and tightened in others. These new recreational depth restrictions will be particularly impactful to the CPFV fleet south of Point Conception where it represents the majority of recreational catch.

## 1.5 Foreign Fisheries

Copper rockfish have not been formally assessed in Mexican waters. Landings data are collected by the federal government agency Mexican National Commission of Fisheries and Aquaculture (CONAPESCA), but catch statistics are not available for individual species. All rockfish are pooled together into the Rocoto group. A recent publication by Saldaña-Ruiz et al. (2022) conducted a productivity-susceptibility analysis of 531 species found in Mexico. They identified copper rockfish in the “low” vulnerability category and as having moderate data quality. The determination of low vulnerability for copper rockfish in Mexican waters is in contrast to the findings of a high vulnerability by the U.S. West Coast productivity susceptibility analysis (Cope et al. 2011). Catches in Mexican waters by U.S. fleets are not included in this assessment.

Copper rockfish in Canadian waters are managed as a part of a species complex termed “Inshore Rockfish”. Inshore Rockfish are a group of *Sebastes* species that are caught by hook and line gear in subsistence, recreational, and commercial fisheries. The species included

in this management group are yellow, quillback, copper, China, black, and tiger rockfishes. Fisheries and Oceans Canada implement a system of rockfish conservation areas in British Columbia as part of a Rockfish Conservation Strategy. The abundance of rockfish within the Inshore Complex is currently unknown.

Copper rockfish extend into the Gulf of Alaska at the northern edge of their range where they are assessed as part of an Other Rockfish stock complex that includes 27 *Sebastes* species (Tribuzio and Omori 2021). Within that complex, copper rockfish is apart of a sub-complex group termed Demersal Shelf Rockfish with canary, China, quillback, rosethorn, tiger, and yelloweye rockfishes. The most recent assessment conducted in 2021 recommended a reduction in the ABC and OFL for the complex but noted that overfishing was not occurring.

Off the U.S. West Coast, the portions of the populations of copper rockfish off Washington and Oregon were last assessed in 2021 (Wetzel et al. 2021d, 2021c). The estimated unfished spawning output for these areas are substantially lower than the estimated population size off California. In 2021, the Washington and Oregon populations were estimated to be at 42 and 71 percent of the unfished spawning output, respectively.

## 2 Data

Data comprise the foundational components of stock assessment models. The decision to include or exclude particular data sources in an assessment model depends on many factors. These factors often include, but are not limited to, the way in which data were collected (e.g., measurement method and consistency); the spatial and temporal coverage of the data; the quantity of data available per desired sampling unit; the representativeness of the data to inform the modeled processes of importance; timing of when the data were provided; limitations imposed by the Pacific Fishery Management Council Groundfish Terms of Reference; and the presence of an avenue for the inclusion of the data in the assessment model. Attributes associated with a data source can change through time, as can the applicability of the data source when different modeling approaches are explored (e.g., stock structure or time-varying processes). Therefore, the specific data sources included or excluded from this assessment should not necessarily constrain the selection of data sources applicable to future stock assessments for copper rockfish. Even if a data source is not directly used in the stock assessment they can provide valuable insights into biology, fishery behavior, or localized dynamics.

Data from a wide range of programs were available for possible inclusion in the current assessment model. Descriptions of each data source included in the model (Figure 4) and sources that were explored but not included in the base model are provided below. Data that were excluded from the base model were excluded only after being explicitly explored during the development of this stock assessment and found to be inappropriate for use or had not changed since their past exploration in a previous copper rockfish stock assessment when they were not used. In some cases, the inclusion of excluded data sources were explored through sensitivity analyses (see Section 3).

## **2.1 Fishery-Dependent Data**

### **2.1.1 Commercial Fishery**

#### **2.1.1.1 Landings and Discards**

Commercial landings prior to 1969 were extracted from the Southwest Fisheries Science Center (SWFSC) landings reconstruction database for estimates from the California Catch Reconstruction (Ralston et al. 2010). Landings in this database are divided into trawl, non-trawl, and unknown gear categories. Regions 7 and 8 as defined by Ralston et al. (2010) were assigned to south of Point Conception in California. Regions 2, 4, and 5 are associated with areas north of Point Conception. Region 6 in Ralston et al. (2010) included Santa Barbara County (mainly south of Point Conception), plus some major ports north of Point Conception. To allocate landings from Region 6 to the areas north and south of Point Conception, we followed an approach used by Dick et al. (2007) for the assessment of cowcod. Specifically, port-specific landings of total rockfish from the CDFW Fish Bulletin series were used to determine the annual fraction of landings in Region 6 that was north and south of Point Conception (Table 3). Rockfish landings at that time were not reported at the species level. Although the use of total rockfish landings to partition landings in Region 6 is not ideal, we see this as the best available option in the absence of port-specific species composition data. Landings from unknown locations (Region 0) were allocated proportional to the landings from known regions.

In September 2005, the California Cooperative Groundfish Survey (CCGS) incorporated newly acquired commercial landings statistics from 1969-1980 into the CALCOM database (Pearson et al. 2008). The data consisted of landing receipts (“fish tickets”), including mixed species categories for rockfish. In order to assign rockfish landings to individual species, the earliest available species composition samples were applied to the fish ticket data by port, gear, and quarter. These ‘ratio estimator’ landings are coded (internally) as market category 977 in the CALCOM database, and are used in this and past assessments as the best available landings for the time period 1969-1980 for all port complexes. See Appendix A of Dick et al. (2007) for further details.

Commercial fishery landings from 1981-2022 were extracted from the Pacific Fisheries Information Network (PacFIN) database (extracted February 6, 2023). Landings were separated north and south of Point Conception based on port of landing. Commercial landings for copper rockfish were split into two fleets based on the fish landed condition, live or dead, and aggregated across gear types (Table 1 and Figure 2). The selection of this fleet structure was based on potential differences in selectivity by the fishery based on fish landed condition where the live fish fishery may be targeting fish of particular sizes (i.e., plate sized). The first year where fish were observed to be landed live for copper rockfish in the area south of Point Conception was 1994.

Discarding was not estimated within the model. The commercial catches, landings plus discards, were estimated external to the model based on data from the West Coast Groundfish



Observer Program (WCGOP) data provided in the Groundfish Expanded Mortality Multiyear (GEMM) product. The GEMM provides expanded estimates of landings, discard, and catches based on observed trips by sector split north and south of 40° 10' N. lat. for the commercial fishery. Estimated landings and discards south of 40° 10' N. lat. from select sectors (Limited Entry Fixed Gear Daily Trip Limit - Hook and Line, Nearshore, Catch Share - Hook and Line, Open Access Fixed Gear - Hook and Line, Open Access Fixed Gear - Pot, and Limited Entry Fixed Gear Daily Trip Limit - Pot) were used to calculate a discard rate (total discard divided by the sum of landings and discards by year) for 2002-2021. The annual discard rates were applied to the total landings by year to calculate catches for both areas south and north of Point Conception. The median discard rate south of 40° 10' N. lat. from the select sectors between 2002-2021 in the GEMM was 3 percent. This discard rate was applied to landings between 1916-2001 and 2022 to determine catch by year. The assumptions around the estimated total discards by year had limited impact to the assumed total catches given the limited scale of removals by the commercial fishery for copper rockfish.

#### **2.1.1.2 Composition Data**

Biological data were extracted from the PacFIN Biological Data System on March 20, 2023. Length data for the commercial fleet were extracted from the PacFIN Biological Data System (BDS) with samples for south of Point Conception beginning in 1983 (Tables 4 and 5). The commercial data was split by landed condition, live or dead, with the first data for the live fish fishery beginning in 1999. The number of length samples by fleet were highly variable with the largest number of samples by year being recorded in the mid- to late-1990s for the dead fish fishery. In recent years, the number of length samples by year are limited for both fleets. The number of samples prior to 1995 and in the 2000s for the dead fish fishery were sparse and variable across sizes. During model explorations any year with less than 20 sampled fish were considered too sparse to accurately reflect the fleet selectivity for that year (see Appendix A for implied fits to these lengths).

The majority of lengths sampled from the commercial fleet landing dead copper rockfish ranged between approximately 25 - 45 cm starting in the early 1990s with some additional observations of larger fish in earlier years (Figure 5, detailed length compositions by year can be found in the Appendix, Section 9.1.1). The mean length observed by year ranged between approximately 35 - 45 cm (Figure 6). The mean observed length in the earliest data is variable ranging between 40 -45 cm, declining in the 1990s to less than 40 cm, then increasing to slightly larger mean size across the sparse data of the early 2000s, and then increasing again in the most recent years. There were only a few age samples (8 total) from the commercial dead fleet that were collected in 2022 (Figure 7). By chance, all of these ages were from female fish. These data were incorporated into the model as marginal age data associated with this fleet.

The observed distribution of sizes sampled from the commercial live fish fleet were generally variable based on the more limited sample sizes but ranging between 30 - 40 cm with missing years of data across different time periods (Figure 8). The observed mean length of fish

landed live was highly variable with means often below 35 cm with the smallest observed mean size being observed in the final year of data (Figure 9).

The input sample sizes for all commercial data initially were calculated based on a combination of trips and fish sampled:

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

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

During initial model evaluations alternative data weighting approaches suggested potentially high up-weighting the samples from the commercial live fish fishery. In order to ensure that the data were not up-weighted beyond the total annual sample size the input sample size was revised to be equal to the number of lengths samples.

## 2.1.2 Recreational Fishery

### 2.1.2.1 Landings and Discards

The recreational fishery is the main source of exploitation of copper rockfish across California. The recreational catches of copper rockfish in California waters peaked in the late 1970s and early 1980s. Catches declined in the 1990s and early 2000s (Table 1 and Figure 2). The removals remained relatively low until the mid-2010s, at which point they began to increase over the last decade, and then sharply declined in 2021 and relatively low in 2022 due to implementation of the sub-bag limit in California for copper rockfish. The recreational fishery was split into two fleets based on fishing type (termed ‘modes’), a commercial passenger fishing vessel (CPFV, party/charter mode) fleet and a combined private or rental boats (PR mode). Shoreside fishing (man-made and beach/bank modes) was combined with the PR mode. The catches associated with the shoreside mode for copper rockfish are limited and did not justify a separate fishing fleet within the model.

Recreational landing estimates from 1928 to 1980 were obtained from the historical reconstruction (Ralston et al. 2010). The historical landings reconstruction split removals north and south of Point Conception and by recreational modes. CPFV landings of all rockfish were based on logbook data (which do not report rockfish to the species level), scaled by compliance estimates, while total recreational landings from PR vessels were based on a combination of the relative catch rates observed in the CPFV fleet and a linear ramp between catch estimates in the early 1960s and those in the early 1980s (as described in Ralston et al. (2010)). The species composition of rockfish landings was estimated using a combination of the 1980s Marine Recreational Fisheries Statistics Survey (MRFSS) data as well as limited CPFV mode species composition data from onboard observer programs in the late 1970s (south of Point Conception) and dockside recreational creel surveys in the late 1950s and early 1960s (north of Point Conception).

Recreational removals from 1981-1989 and 1993-2003 were obtained from MRFSS downloaded from the Recreational Fisheries Information Network (RecFIN). Historically, copper rockfish were occasionally referred to as whitebelly rockfish in select California areas. MRFSS catches were pulled for both species names and for all ocean areas. MRFSS includes estimates of removals for 1980. However, due to inconsistencies in the estimates of this year in MRFSS, likely due to it being the first year of the survey with low sample sizes, the value for recreational landings from the historical reconstruction were used (2010).

Some known issues with the MRFSS estimates include 1) a change in the spatial definition of California subregions after 1989, 2) missing or imprecise estimates of catch in weight for some strata that reported catch in numbers, and 3) a hiatus in sampling from 1990-1992 (all modes) and also 1993-1995 in the party/charter mode north of Point Conception. The Stock Assessment Team Members (STAT) attempted to address each of these issues, as described below. The CDFW California Recreational Fisheries Survey (CRFS) estimates from 2004 were also included in the MRFSS analysis, as they were not available on the current RecFIN website but are included with the MRFSS catch estimate tables

The MRFSS definition of “Southern California” included San Luis Obispo County between 1981-1989, requiring the catches from this county to be split out and removed from the recreational catch south of Point Conception. The MRFSS catches between southern and northern California were adjusted in a similar fashion as previous assessments split at Point Conception. Albin et al. (1993) used MRFSS data to estimate catch at a finer spatial scale from the California/Oregon border to the southern edge of San Luis Obispo (SLO) County. Over the period 1981-1986, numbers of copper rockfish landed in SLO County were found to be approximately one third (0.317) of the numbers of copper rockfish landed in all California counties north of SLO County (Albin et al. 1993). Therefore, to approximate catches north and south of Point Conception from 1980-1989, the STAT reduced the ‘southern’ subregion annual catch (which included SLO County) from 1980-1989 by 0.317 during the same period, and added this amount to the northern subregion catch. On average, this ‘moves’ the estimated SLO County catch from the southern region to the northern region from 1980-1989, creating a spatially consistent time series of landings over the entire time series.

The STAT chose to use catch in terms of weight (WGT\_AB1 column) within MRFSS. The catch weights were converted from kilograms to metric tons and any records with missing catch weights were examined. The number of records with missing catch weights for copper rockfish in MRFSS were limited (only 18 out of 713). The missing catch weights were imputed based on the number of fish (TOT\_CAT column) and the calculated average fish weight by year and area north and south of Point Conception.

MRFSS sampling was halted from 1990-1992 due to funding issues. The survey resumed in 1993 in all modes, except for the PC boat mode which resumed in 1996 for counties north of Santa Barbara County. To produce catch estimates for the missing subregion, mode, and year combinations linear interpolations were used to fill in the missing data.

Two additional revisions were applied to select years and modes in the MRFSS data based

on conversations with California Department of Fish and Wildlife (CDFW). The catches for the PR mode north of Point Conception in MRFSS for 1981 were 50 to 90 percent greater than the catches in 1980 and 1982, respectively. The high catches in this year were assumed to be a result of issues in the catch expansions due to limited sampling. The catches for the PR fleet were revised downward to be equal to the average removals in surrounding years (1979, 1980, 1982, and 1983). The catches in MRFSS south of Point Conception in 1987 were identified as abnormally low by CDFW (John Budrick, pers. communication, 13 to 27 percent of catches in 1986 and 1988) which was due to no catch information for waves 1-3 (January - June) for either mode. Absence of data in 1987 for these waves was not observed across other rockfish species in southern California indicating that the absence of catch data was likely not due to closures in the fishery. The catches for this year and mode were set equal to the average catch by mode 2 years before and after 1987.

Recreational landings from 2004-2022 were obtained from CRFS available on RecFIN for for all ocean areas. This survey improves upon the MRFSS sampling design, employing higher sampling rates and producing estimates with finer spatial and temporal resolution. CRFS also employs onboard CPFV observers, providing spatially referenced, drift-level estimates of catch and discard for a subset of anglers on observed groundfish trips. Any CRFS records of fish caught in Mexican waters were removed and catch estimates were split north and south of Point Conception for each fleet. Due to database issues, catches for 2004 are currently not available on RecFIN. The catches for this year were set equal to data pulled in 2021 for the previous assessment of copper rockfish.

Adjustments to the recreational catches for 2020-2022 were provided directly by CDFW to account for sampling issues due to COVID-19. During 2020, dockside sampling by observers was halted April through June leading to missing catch data within the CRFS database for this period. CDFW provided proxy catch values for these months directly by CRFS district (personal communication, Melanie Parker, CDFW). The total proxy catches south of Point Conception (districts 1 and 2) for these months were 18.9 mt and 15.0 mt north of Point Conception in California (districts 3 - 6). These catches were split by mode (CPFV and PR) equally for both areas, noting that effort by mode during this period varied across district based on varying COVID-19 restrictions. When sampling resumed in 2020 a large number of rockfish catches were not identified to species, and rather were recorded as *Sebastes* genus, for the remainder of 2020 and 2021 due to social distancing for health and safety. The second adjustment to catches was to allocate some of those unidentified rockfish catches to specific species. CDFW provided estimates of catch values that allocated a subset of the *Sebastes* genus removals by recreational mode north and south of Point Conception for these years to copper rockfish. Finally, the completed catch estimates for 2022 were not available within CRFS on RecFIN by the data deadline for this assessment and estimates were provided directly to the STAT from CDFW.

MRFSS and CRFS both provide estimates of total mortality which combine observed landings plus estimates of discarded fish using depth-dependent mortality rates. While the recreational removals from the historical reconstruction from 1928-1980 account for only landed fish. There is limited information on historical discarding in the recreational fishery. A report

by Miller and Gotshall (1965) looked at the number of retained and discarded fish in the recreational fishery in California for a select year which showed essentially no discarding of copper rockfish. Based on this information, no additional discards were applied to the historical data between 1926-1980.

Recreational catch data is reported by district in CRFS where district 1 (aka South) and district 2 (aka Channel) are located south of Point Conception. The proportion of removals by the CPFV fleet since 2004 by district are shown in Table 6 (see the Appendix, Section 9.4, for additional information about sampling and data by CDFW districts)

#### **2.1.2.2 Indices of Abundance**

A number of indices of abundance were explored for the recreational fleet (Figure 10). Discarded catch is available from onboard observer surveys, but was not included in indices. Indices developed for the assessment include:

- CDFW CPFV/PC onboard observer index (2005-2019)
- CRFS PR1 sites dockside survey (2004-2019)

Due to limited sampling during 2020 due to the COVID-19 pandemic and inseason action taken by CDFW for 2022 reducing sub-bag limits for copper rockfish across California, both recreational fishery indices of abundance excluded data collected after 2019.

The state of California implemented a statewide onboard observer sampling program in 1999 (Monk et al. 2014). California Polytechnic State University (Cal Poly) has conducted an independent onboard sampling program as of 2003 for boats in Port San Luis and Morro Bay, and follows the protocols established in Reilly et al. (1998). During an onboard observer trip the sampler rides along on the CPFV and records location-specific catch and discard information to the species level for a subset of anglers onboard the vessel. The subset of observed anglers is usually a maximum of 15 people and the observed anglers change during each fishing stop.

The catch cannot be linked to an individual, but rather to a specific fishing location. The sampler also records the starting and ending time, number of anglers observed, starting and ending depth, and measures discarded fish. The fine-scale catch and effort data allow us to better filter the data for indices to fishing stops within suitable habitat for copper rockfish. Cal Poly has modified protocols to reflect sampling changes that CDFW has also adopted, e.g., observing fish as they are encountered instead of at the level of a fisher's bag. Therefore, the Cal Poly data are incorporated in the same index as the CDFW data. The only difference is that Cal Poly measures the length of both retained and discarded fish.

The CRFS CPFV index of abundance was low in the early years of the time-series between 2005-2004 and then began to increase with variability among years until 2013, and declined

in the final years (Figure 11). See the Appendix Section 9.3.1 for details on the data filtering, processing, and model selection.

Catch and effort data from CRFS dockside sampling of private boats, 2004-2019, and 2021-2022, were provided by CDFW for use in this assessment. The data include catch (number of fish) by species, number of anglers (i.e., effort units are angler trips), angler-reported distance from shore (Area X: inside/outside of 3 nm), county, port, interview site, year, month, and CRFS district. Only data through 2019 were used to develop an index of abundance due to potential changes in angler behavior in 2021 and management changes in 2022. See Appendix Section 9.3.2 for details on the data filtering, processing, and model selection. The CRFS PR index of abundance generally increased between 2004-2016, with the final years of the index stabilizing or slightly declining (Figure 12).

### 2.1.2.3 Composition Data

Length compositions were available from the following sources:

- Recreational party/charter mode (CPFV/PC)
  - Collins and Crooke onboard observer survey (1975-1978)
  - MRFSS CPFV/PC dockside survey (1980-1989, 1993-2003)
  - Ally onboard observer survey (1984-1989)
  - CRFS CPFV/PC onboard dockside survey (2004-2022)
- Recreational private/rental mode (PR)
  - MRFSS dockside PR survey (1980-1989, 1993-2003)
  - CRFS dockside PR survey (2004-2022)

The number of available fish and unique trips by year and fleet are in Table 7. MRFSS historical biological data were downloaded from the RecFIN website in December 2022. CRFS biological data were also downloaded from RecFIN on February 18, 2023. The Collins and Crooke and Ally recreational survey data were downloaded from the SWFSC databases on February 12, 2023. In the CRFS era which reports samples by CDFW district the majority of length samples south of Point Conception arise from CDFW district 2 (Channel Islands, Table 8).

Nearly all of the length samples for both recreational fleets, CPFV and PR, were unsexed (only two sexed fish in the CPFV data were added to the unsexed data). A wide range of lengths from the recreational CPFV fleet were observed across all years with lengths generally ranging between 20 - 40 cm except for the late 1970s and early 1980s where a higher proportion of larger fish were sampled (Figure 13). The mean of lengths observed in the recreational CPFV fleet is variable with mean length increasing until the early 1980s, decreasing until the mid-1990s, increasing until 2000, stabilizing with some variability through the early 2010s, and then slowly increasing in the most recent years of data (Figure 14). The

length distribution by CDFW district from the CPFV fleet since 2004 are shown in Figure 16. The range of lengths sampled from the recreational PR fleet are similar to those from the CPFV fleet with lengths in recent years ranging between 20 - 40 cm (Figures 17 and 18).

Age data collected by the recreational CPFV fleet were collected in two separate years, 1975 and 2022. The historical age data were from a total of 84 unsexed fish and were incorporated in the model as marginal age data (Figure 7). In 2022, a total of 508 age samples were collected by a cooperative collection program between the a subset of boats from the CPFV fleet and the the SWFSC. These data were collected by four CPFV vessels that operate south of Point Conception following random sampling protocols. The four vessels participating in this collection program are included among the vessels sampled by the CRFS onboard sampling program. However, the otoliths collections done in 2022 were collected by a separate program outside the CRFS sampling and are not included in the RecFIN database. In theory, the lengths sampled by CRFS and this collection program would be comparable if the samples were representative of the population south of Point Conception given random sampling. The lengths collected associated with fish sampled by the cooperative collection program for aging were compared to all the CPFV lengths collected by the CRFS sampling program (Figure 15). This comparison revealed that there were distinct differences in the length of fish in these two data sets where the cooperative collected data tended to have a larger proportion of large fish. The CRFS length data sample size was less than half of the sample size of cooperative age data collection (CRFS sampled 243 from 78 trips, Table 7). The source of these differences is not entirely clear, but could be arising from a difference in sampling areas within the region south of Point Conception where there appear to be size and abundance differences in the more southern areas compared to areas around the Channel Islands. Given the differences in the age samples to the lengths sampled by the CRFS program, these ages were not linked to the CPFV fleet in the model. However, these data are an important source of age-length information for copper rockfish, so these data were added to a growth fleet in the model (see the Growth Data section)

The approach to determine the number of unique trips by data source varied. Only Collins and Crook data had unique trip numbers within the data. Other data sources that lacked clear trip identifier applied a similar methodology as developed by Brian Soper that combines multiple fields of information to attempt to estimate trips sampled. The number of trips for MRFSS data was estimated using the year, wave, ID code, sampling site (INSITE), area, and mode. A similar methodology was done for CRFS that used data, county, water area, interview site, and mode. Finally, trips for the Ally survey data were based on year, complex, landing, and district.

## 2.2 Fishery-Independent Data

Three fishery-independent data sources with indices of abundance were included in the base model. These surveys sampled rocky habitat across the area south of Point Conception and sampled both areas opens to fishing (termed reference areas) and Marine Protected Areas (MPAs, Figure 19). Figure 19 indicate CDFW area blocks by grey grid lines with areas that copper rockfish would be expected to be found based (Merit McCrea, personal

communication).

## **2.2.1 California Collaborative Fisheries Research Program**

### **2.2.1.1 Index of Abundance**

Since 2007, the California Collaborative Fisheries Research Program (CCFRP) has monitored several areas in California to evaluate the performance of Marine Protected Areas (MPAs) and understand nearshore fish populations (Wendt and Starr 2009a; Starr et al. 2015b). In 2017, the survey expanded beyond the four MPAs in central California (Año Nuevo, Point Lobos, Point Buchon, and Piedras Blancas) to include the entire California coast. Fish are collected by volunteer anglers aboard commercial passenger fishing vessels (CPFVs) guided by one of the following academic institutions based on proximity to fishing location: Humboldt State University; Bodega Marine Laboratories; Moss Landing Marine Laboratories; Cal Poly San Luis Obispo; University of California, Santa Barbara; and Scripps Institution of Oceanography.

The survey consists of fishing with hook and line gear for 30-45 minutes within randomly chosen 500 by 500-m grid cells within and outside MPAs. Prior to 2017, all fish were measured for length and release or descended to depth; since then, some were sampled for otoliths and fin clips.

The estimated index of abundance was weighted based on sample locations outside (reference) and inside MPAs (73 and 80 percent of areas open to fishing in the north and south, respectively, see Appendix Section 9.3.3 for additional information about the development of rocky habitat estimates). Interpreted bathymetry classifying substrate as rock or sand is available at high resolution for state waters north of Point Conception, but is not complete for southern California (Figure 20). The highest index point is associated with the first index year, 2017, varies between 2018-2021, and has the lowest value in 2022 (Figure 21, see Appendix Section 9.3.3 for additional information on the development of the index).

### **2.2.1.2 Composition Data**

Length measurements were available each year the CCFRP Hook and Line survey has operated south of Point Conception and age data were collected in 2022 by the survey (Table 9). The length data by designation, MPA and Reference, were weighted based on the estimated rocky habitat within each designation north and south of Point Conception (73 and 80 percent of areas open to fishing in the north and south, respectively, see Appendix Section 9.3.3 for additional information). The lengths observed by the survey ranged between 20-45 cm across the sample years with the mean lengths observed ranging between 33-36 cm (Figures 22 and 23). The survey collected age data from a subset of fish sampled in 2022 (Figure 24). The read ages from these sampled fish ranged between 4-24 years of age.



## 2.2.2 Northwest Fisheries Science Center Hook and Line

### 2.2.2.1 Index of Abundance

Since 2004, the Northwest Fisheries Science Center (NWFSC) has conducted an annual hook and line survey targeting shelf rockfish in the genus *Sebastes* at fixed stations (e.g., sites, Figure 25) in the Southern California Bight. Key species of rockfish targeted by the NWFSC Hook and Line survey are bocaccio (*S. paucispinis*), cowcod (*S. levis*), greenspotted (*S. chlorostictus*), and vermilion/sunset (*S. miniatus* and *S. crocotulus*) rockfishes, although a wide range of rockfish species have been observed by this survey. During each site visit, three deckhands simultaneously deploy 5-hook sampling rigs (this is referred to as a single drop) for a maximum of 5 minutes per line, but individual lines may be retrieved sooner at the angler's discretion (e.g., to avoid losing fish). Five drops are attempted at each site for a maximum possible catch of 75 fish per site per year (3 anglers fishing with a line with 5 hooks across a total of 5 drops per site). Further details regarding the sample frame, site selection, and survey methodology are described by Harms et al. (2008).

From 2004 through 2013, sampling was conducted only outside the Cowcod Conservation Areas (CCAs). Beginning in 2014, 40 sites inside the CCAs were sampled, and roughly another 40 sites have been added in subsequent years inside the CCAs. It is important to note that some portions of the CCAs allow take for select species at depths less than 73 meters. The survey currently has 201 sites (79 inside and 122 outside the CCAs). Additionally, there are 16 stations within the original sample design that have been converted into either state or federal MPAs between 2007 - 2011 and continue to be sampled annually.

While copper rockfish have not been encountered in large numbers similar to some of the other commonly encountered species (vermillion/sunset, bocaccio, greenspotted rockfish) in the NWFSC Hook and Line survey, copper rockfish has been observed every year that the survey has been conducted (Table 10). Observations of copper rockfish commonly occur across a range of depths between 30 - 120 m with observations peaking around 80 m (Table 11 and Figure 28). Across all sample years and sample sites the NWFSC Hook and Line survey has observed a total of 1,213 copper rockfish. While copper rockfish have been observed both outside and inside the CCAs in areas that restrict take or MPAs (Figures 26), the vast majority of observations of copper rockfish have been outside the CCAs (1,060 observations, Tables 12). The number of copper rockfish observations within the no take areas of the CCAs or MPA and open areas was explored to determine if the catch rates of copper rockfish differed among the areas which determined there was not a substantial difference in the observations among these areas (Table and 13). Additionally, the data from the NWFSC Hook and Line survey was broken out into three regions: mainland, Northern Channel Islands, and Southern Channel Islands. The highest catch rate of copper rockfish was observed around the Northern Channel Islands (Figure 27).

The STAT explored alternative model structures to generate a standardized index of relative abundance. The final model selected was a model with a delta-lognormal error structure

with factors of year, region, drop, covariates of number of vermillion and bocaccio observed, year/region interaction, and with random site effects. Finally, the index was weighted by the estimated proportion of rocky habitat by region. A single index of abundance was calculated using all observations from this survey (Figure 29). Details regarding the index of abundance, sample sizes and model selection can be found in the Appendix Section 9.3.4.

The composition and index of abundance data from the NWFSC Hook and Line survey have been included in other nearshore assessments using various approaches. For species where the expansion of the survey into the CCAs was expected to impact the size of fish observed by this survey (e.g., vermillion/sunset rockfish and cowcod), one approach has been to estimate a single index of abundance for the whole time series but to only associate composition data collected by the survey (lengths and ages) from 2014 onward to estimate a single selectivity curve representative of the expansion of the survey, with composition data collected prior to 2014 being added to a separate fleet in the model. Since the initial analysis of the data did not indicate large changes in the catch rates or size of fish observed pre- and post-survey expansion for copper rockfish all composition data were used within the base model but a sensitivity that used this approach was conducted (see the Sensitivities Section below).

#### **2.2.2.2 Composition Data**

Copper rockfish caught in the NWFSC Hook and Line survey were generally between 30 and 50 cm for both sexes (Figures 30 and 31). The number of lengths and ages collected by the survey are shown in Table 14 and the length-at-age by sex is shown in Figure 32. The mean length observed by year was variable with an appreciable drop in the mean size observed in 2012 but has gradually increased in the subsequent years (Figure 33).

#### **2.2.3 Growth Data**

A substantial amount of additional age-at-length data not associated with fishery fleets or surveys incorporated in the model were available for copper rockfish. These age data were collected by three programs south of Point Conception since 2004: 621 otoliths from the NWFSC WCGBT survey, 33 otoliths from a research survey conducted by Don Pearson, and 506 otoliths from a cooperative research survey by the SWFSC and CPFV funded by the Sportfishing Association of California (Table 15). Numerous explorations were conducted to evaluate how best to incorporate these data within the base model. These data were split into two growth fleets based on the collection method. The samples from the NWFSC WCGBT survey were split into their own growth fleet and the lengths associated with the ages were added to the model to estimate a length-based selectivity for these samples collected via trawl gear (Figures 34 and 35). The ages collected by Pearson and the CPFV cooperative research samples were combined into a second growth fleet. The lengths associated with these fish were included in the model to estimate a length-based selectivity (Figures 36 and 37). These collections had a wide distribution of length and ages observed (Figures 38 and 39).

## 2.3 Additional Considered Data Sources

### 2.3.1 Partnership for Interdisciplinary Studies of Coastal Oceans

The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) is an academic consortium conducting monitoring of coastal ecosystems in California as well as research to support marine protected area design. Their work includes SCUBA surveys and fish recruitment monitoring within rocky reef habitats at a suite of sites across the state using standardized protocols so that multiple participating universities collect compatible data.

The PISCO kelp forest fish survey data were downloaded from DataONE. We examined fish transect data collected by participating PISCO researchers at the University of California Santa Cruz (UCSC), University of California Santa Barbara (UCSB), the Vantuna Research Group (VRG) and Humboldt State University (HSU, now Cal Poly Humboldt) for potential development of a fishery-independent abundance index for use in the assessment model. We ultimately concluded that the number of detections of copper rockfish on transects was too low to be representative of relative abundance over time and the spatial distribution of sites having copper rockfish were not well distributed across the coast. Below we outline the structure of PISCO fish transect data, the procedure we used to filter to include copper rockfish habitat, and resulting sample sizes. Each fish transect location is surveyed by divers who count fish within a 30 x 2 x 2-m volume on the bottom, mid-way up the water column, and near the surface just below the kelp canopy. Three replicate transects are performed within inner, inner-mid, outer-mid, and deep zones of the reef corresponding to depths between 5 and 20 m. This results in 12 transect locations per reef site and 36 transect swims incorporating the three levels. Divers count fish by species and estimate sizes. Survey sites are typically grouped within a geographic area, i.e., there are three sites on Naples reef near Santa Barbara (Naples Central, Naples East, and Naples West).

The full dataset was filtered for quality and habitat appropriate for copper rockfish. Data was limited to surveys conducted by UCSC and UCSB because copper rockfish were not observed by HSU and sites surveyed by VRG typically either saw very few copper rockfish or were not consistently sampled across the time series. The UCSC and UCSB campus sites were separated to develop two indices for the northern and southern models. We eliminated sites that were sampled in less than 80 percent of the survey years for each campus. Copper rockfish were only observed on bottom transects and so mid-water and canopy transects were removed. The inner reef (shallow) transects were removed due to rare copper rockfish observations. Divers noted approximate water visibility and transects with visibility less than 3 m were removed. We also retained only fish greater than 17 cm to construct an adult index.

Early years with less consistent sampling were eliminated such that the time series for UCSB began in 2004 and extended through 2021. Sites surveyed by UCSB were mixed in distribution inside and outside MPA locations and therefore were not filtered for this criterion. After filtering, sites that remained in the UCSC dataset were centered around the northern Channel Islands with a few on the Santa Barbara Channel mainland. Sample sizes

of copper rockfish observed by year at all retained sites ranged from 15 to 39 fish for UCSB (Table 16).

The PISCO program also conducts larval fish recruitment monitoring by sampling artificial settlement substrates called Standard Monitoring Units for Recruitment of Fishes (SMURFs). Similar to the SCUBA surveys, SMURF surveys are conducted by multiple universities using standardized protocols. We examined data collected by the UCSB and UCSC campuses in southern and central California. Surveys by UCSB were conducted between 2000 and 2018 and by UCSC between 1999 and 2016. Juvenile copper rockfish are difficult to distinguish from juvenile gopher rockfish (*Sebastes carnatus*) and the data from UCSB combines counts of these species into a complex. For this reason, we determined this data to be inappropriate for construction of a copper rockfish recruitment index to be used within the assessment. While data from UCSC reports distinct counts of copper and gopher rockfish, the concern remains that the copper rockfish counts may not be accurate due to this morphological identification difficulty. Additionally, collections of copper rockfish in this data set were very sparse with many years seeing none. However, an extremely high number were recorded for 2016.

### **2.3.2 Reef Check**

Reef Check is an international non-profit organization utilizing citizen scientists to monitor reef habitats. Data from SCUBA surveys of fish in California are available since 2006. Given the low proportion of copper rockfish detections on PISCO surveys, we did not dedicate time to analysis of Reef Check survey data for the purpose of abundance index development.

### **2.3.3 Visual Surveys**

The SWFSC and UCSB both conduct visual surveys using ROVs and submersible vehicles. We used the observations of copper rockfish from these data to inform our understanding of the species' distribution (Figure 40). We also used these data as a visualization of data gaps that can inform future research. The visual surveys ranged from 1993 to 2018 from Monterey south to the California/Mexico border. A total of 3,976 individual copper rockfish were observed at average transect depths ranging from 20 to 156 m, with an average of 67 m. The depth ranges of these surveys, especially dives from the 2007 submersible survey of the Southern California Bight extended into much deeper waters to cover the depth range of cowcod (Yoklavich et al. 2007). The UCSB submersible survey sampled the natural reefs and the oil platforms southern California from 1995-2011 and could be explored as an index of abundance for copper rockfish in the future (Love et al. 2006).

### **2.3.4 MRFSS Dockside Survey of CPFV/PC Vessels**

From 1980 to 2003 the MRFSS program conducted dockside intercept surveys of the recreational CPFV fishing fleet. No MRFSS CPUE data are available for the years 1990-1992, due to a hiatus in sampling related to funding issues. Sampling of California CPFVs north of Point Conception was further delayed, and CPFV samples in 1993 and 1994 are limited to San Luis Obispo County. For the purposes of this assessment, the MRFSS time series

was truncated at 1999 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). The onboard observer data provide higher resolution data of retained and discarded catch.

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.

The data were filtered to identify rockfish trips, standardized across the time series, and modeled to estimate and index of abundance for copper rockfish. The MRFSS CPFV index of abundance between 1980-1999 is generally variable but with a flat trend in abundance except for three years that spike in abundance estimates (Figure 162). These same patterns in sharp increases in the index for select years were also observed in the raw data. Given the limited information in the data to understand what was behind these unexpected spikes in the time series, the MRFSS index of abundance was not used in the final base model.

### **2.3.5 CDFW ROV Survey**

The California Department of Fish and Wildlife (CDFW) in collaboration with Marine Applied Research and Exploration (MARE) have been conducting remotely operated vehicle (ROV) surveys along the California coast in Marine Protected Areas (MPAs) and reference sites adjacent to them since 2004 for the purposes of long-term monitoring of changes in size, density (fish/square meter) and length of fish and invertebrate species along the California coast. Surveys of the entire coast have now been undertaken twice, each taking three years to complete, during 2014-2016 and again in 2019-2021. The survey conducted multiple 500 meter transects across rocky reef survey sites. Transect locations within a site were selected by first randomly selecting the deepest transect at a given site, then placing additional transects on a constant interval into shallower depths. Transects were designed to be oriented parallel to general depth contours, though they were carried out using a fixed bearing that crossed depths in some cases.

Given that each pass of the California coast took a three year period, the STAT initially opted to explore using the data either by year or grouping it into super years. The selected super years were 2015 and 2020, the middle year of the time grouped sampling efforts. Based on the life history of copper rockfish and the generally limited movement of adult copper rockfish, the super year approach was considered to generate separate indices for north and south of Point Conception. The two sub-area models for copper rockfish represent disparate proportions of the California coast where the model south of Point Conception has a greatly reduced spatial range compared to the model area north of Point Conception. South of Point Conception, nearly all sampling locations were visited either three or four times within the six year sampling period (only one reference location only visited one year) while sampling locations north of Point Conception were visited between two to four times

within the six sampling years. These differences in sampling frequency and the areas being sampled informed the decision to attempt to model these data differently by area. The data south of Point Conception were modeled using the sample year, while the data north of Point Conception were modeled using super years.

Revised data for the CDFW ROV survey were provided to the STAT late on Thursday May 18, 2023. CDFW determined that the line identifiers for the 500m transects, which we used to represent a sample, were not unique as previously described in the original data delivery on February 24, 2023. A small subset of transects were identified to have disparate 10 m sampling segments aggregated to incorrect transects (i.e., data collected across separate transects were combined into incorrect transects). This issue was identified in a total of 12 transects across all years and areas and when corrected resulted in 12 revised transects and 12 newly identified transects. Unfortunately, a clear summary of the number of 10 m segments, which transect they were subtracted or added from and which transects were impacted by area, year, and sites were not provided by CDFW. The STAT examined the number of unique transects by year north and south of Point Conception in the revised data. The new data south of Point Conception contains a total of 894 transects across all years with 2 new transects in both 2014 and 2019. North of Point Conception there were a total of 916 transects with a total of 8 new transects, 3 in both 2016 and 2020 and 1 new transect in both 2019 and 2021. The number of transects impacted by area was relatively small and was not expected to result in a meaningful change in the estimated indices of abundance. However, when the revised data were analyzed there was a non-negligible shift in the estimated scale of the index of abundance south of Point Conception. This change in scale was not expected given the limited changes in the data described by CDFW. There was no significant change in the index north of Point Conception, which may be a result of using super-years and the sparser sampling. Further analysis of the data there revealed non-trivial changes in attributes for each transect, e.g., proportion substrate type, depth, effort estimated through usable transect area. The STAT observed these changes across transects that should not have been modified given the description that the revised data affected only 8 transects south of Point Conception (4 new and 4 revised transects). The STAT communicated these unexpected findings to CDFW on May 24, 2023. The response provided by CDFW on May 26th indicated that the estimates of the proportion of substrate types did differ from the original values based on an alternative calculation but the differences would be expected to be trivial. A description of the alternative calculations was provided, however, the STAT was unable to calculate matching values to those in the original dataset.

Given the limited time to properly review and analyze any potential data corrections and fully understand the changes to the data, the STAT decided the decision to remove the CDFW ROV data from both sub-area models. While the STAT identified significant issues with the revised data only south of Point Conception, there were overall concerns that all of the CDFW ROV data requires additional quality control, further descriptions of variable calculations, and further description and analyses of the aggregation of 10 m segments to the 500 m sampling unit to ensure that the data are accurate. The STAT is supportive of considering these data in future assessments of copper rockfish or other nearshore species once the issues identified this assessment cycle have been adequately addressed.

A sensitivity to including the original dataset with errors estimated index of abundance and length compositions is provided in the Sensitivities Section 3.4.2.

### **2.3.6 Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey**

The NWFSC West Coast Groundfish Bottom Trawl (WCGBT) survey is based on a random-grid design; covering the coastal waters from a depth of 55-1,280 m (Bradburn et al. 2011). This design generally uses four industry-chartered vessels per year assigned to a roughly equal number of randomly selected grid cells and divided into two ‘passes’ of the coast. Two vessels fish from north to south during each pass between late May to early October. This design therefore incorporates both vessel-to-vessel differences in catchability, as well as variance associated with selecting a relatively small number (approximately 700) of possible cells from a very large set of possible cells spread from the Mexican to the Canadian borders.

The observations of copper rockfish by the NWFSC WCGBT survey are limited. The NWFSC WCGBT survey uses trawl gear to sample sandy bottom areas off the West Coast and *a priori* it would not be expected to be an informative data source for copper rockfish, which are generally more closely associated with rock substrate. The NWFSC WCGBT survey had limited positive tows by year that observed copper rockfish within this area, preventing the calculation of an index of abundance for copper rockfish (Table 17). The catch-per-unit-effort across all years for the NWFSC WCGBT survey is generally small, excluding one single tow from 2012 where 1.9 mt of copper rockfish were caught (Figure 41). The observations of copper rockfish by the NWFSC WCGBT survey commonly occur between 50 - 120 meters (Figure 42). The NWFSC WCGBT survey has regularly collected length and age samples from positive tows for copper rockfish south of Point Conception (Figure 43). These data were used as conditional-age-at-length data to inform the estimation of growth within the model. See the Length-at-Age section for data used to inform growth estimation.

### **2.3.7 California Cooperative Oceanic Fisheries Investigations**

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) survey began in 1951 and conducts quarterly cruises off southern and central California, collecting a suite of hydrographic and biological data at fixed stations and while underway; ichthyoplankton sampling with a paired bongo started in 1978. Data on larval abundance from the CalCOFI Ichthyoplankton survey have been used in stock assessments of several species, including bocaccio, cowcod and shortbelly rockfish. Although the long-term dataset is limited to a subset of species for which morphological identification of larvae has been possible, recent research has been successful at identifying a broader range of species based on genetic identification of larvae (Thompson et al. 2016). Larval fish were enumerated from winter samples from 1998 to 2013. Out of 36 sites, 12 observed a larval copper rockfish at least once, predominantly around the northern Channel Islands. After selecting for only those sites that observed copper rockfish, we examined the proportion of positive net tows by year and the average number of copper rockfish observed per tow. Given that these values were

low and the sites observing copper rockfish were not well distributed, we did not use these data to develop a spawning output index for use in the assessment.

### 2.3.8 Southern California Bight Publicly Owned Treatment Works

In the Southern California Bight, a number of monitoring programs exist to evaluate the potential consequences of effluent discharges from waste water treatment facilities on the coastal marine environment. As over 20 million people live within an hour’s drive of the ocean in this region, a major impact to this ecosystem includes a cumulative total of 1.5 billion liters of treated effluent released each day to the ocean, originating from 17 major waste water treatment plants. Most of these publicly owned treatment works support monitoring programs to evaluate the impacts on water and sediment quality, and associated ecological communities. For several, this includes bottom trawl surveys of coastal habitats, representing some of the longest running trawl surveys available in the region. Despite being limited spatially to waters close to population centers, these data have previously been used in stock assessments of cowcod (*Sebastes levis*) (Dick and He 2019) and California scorpionfish (*Scorpaena guttata*) (Monk et al. 2017). Investigations indicated the copper rockfish are rarely observed in this survey and did not support the development of an index for this assessment.

## 2.4 Biological Data

### 2.4.1 Natural Mortality

Natural mortality was not directly measured, so life-history based empirical relationships were used. The Natural Mortality Tool (NMT), a Shiny-based graphical user interface allowing for the application of a variety of natural mortality estimators based on measures such as longevity, size, age and growth, and maturity, was used to obtain estimates of natural mortality (Cope and Hamel 2022). The NMT currently provides 19 options, including the Hamel and Cope (2022) method, which is a corrected form of the Then et al. (2015) functional regression model and is a commonly applied method for West Coast groundfish. The NMT also allows for the construction of a natural mortality prior weighted across methods by the user.

The Hamel and Cope (2022) method for developing a prior on natural mortality for West Coast groundfish stock assessments combines meta-analytic approaches relating the  $M$  rate to other life-history parameters such as longevity, size, growth rate, and reproductive effort to provide a prior for  $M$ . The Hamel and Cope (2022) method re-evaluated the data used by 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 (Hamel 2015), the point estimate and median of the prior for  $M$  is:

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

where  $A_{\max}$  is the maximum age. The prior is defined as a lognormal distribution with



median  $\ln(5.4/A_{\max})$  and standard error = 0.31. Using a maximum age of 50, the point estimate and median of the prior is  $0.108 \text{ yr}^{-1}$ . The maximum age was selected based on available age data from all West Coast data sources and literature values. The oldest aged copper rockfish observed in California waters was 52 years of age sampled in 2020 in northern California with 15 additional fish aged to be 40 years and older across all data sources.

The maximum age in the model was set at 50 years. This selection was consistent with the literature examining the longevity of copper rockfish within California (Love 1996) and was supported by the observed ages that had multiple observations of fish between 40 and 52 years of age. The 2021 data moderate stock assessments for copper rockfish off the coasts of Washington, Oregon, and California all assumed a maximum age of 50 years (Wetzel et al. 2021a, 2021b, 2021d, 2021c). The oldest aged copper rockfish from the 2021 assessment data was 51 years with two observations, one each off the coast of Washington and Oregon in 2019. Additionally, coastwide there are a total of 31 observations of copper rockfish aged to be between the 40-51 comprised of 4 within Washington, 10 within Oregon, and 17 within California waters (5 south and 12 north of Point Conception). Densities of aged fish from the West Coast and 25 age fish from the Gulf of Alaska are shown in Figure 44.

## 2.4.2 Maturation and Fecundity

Maturity-at-length was based on maturity reads conducted by Melissa Head at the NWFSC examining a total of 112 samples (4 north of Point Conception and 105 south of Point Conception) collected across California by the NWFSC Hook and Line survey and the NWFSC WCGBT surveys in September and October. Given the limited sample size north of Point Conception, all samples were pooled across California to inform maturity north of Point Conception, while only samples south of Point Conception were used to inform maturity in this region.

The maturity-at-length curve is based on an estimate of functional maturity rather than biological maturity. Biological maturity can include multiple behaviors that functional maturity will exclude (e.g., abortive maturation and skip spawning). Biological maturity indicates that some energy reserves were used to create vitellogenin, but it does not mean that eggs will continue to develop and successfully spawn. This includes juvenile abortive maturation. Female rockfish commonly go through the first stages of spawning the year before they reach actual spawning capability. This is most likely a factor related to their complicated reproductive process of releasing live young. A subset of oocytes will develop early yolk, and then get aborted during the spawning season. Biological maturity also does not account for the proportion of oocytes in atresia (cellular breakdown and reabsorption), which means that fish that were skipping spawning for the season could be listed as biologically mature and functionally immature (Melissa Head, personal communication, NWFSC, NOAA).

The 50 percent size-at-maturity for copper rockfish south of Point Conception was estimated at 34.05 cm with a slope of -0.42 (Figure 45). This area-specific maturity-at-length estimate is the same to the biological maturity curve assumed for copper rockfish north of Point Conception using all maturity samples. Additionally, these values are both slightly smaller

than estimates by Hannah (2014) for fish observed in Oregon waters (34.8 cm) which estimated the 50 percent size-at-maturity of and slope of -0.60.

The fecundity-at-length was based on research from Dick et al. (2017). The fecundity relationship for copper rockfish was estimated to be equal to  $3.36e-07L^{3.68}$  in billions of eggs where  $L$  is length in cm. Fecundity-at-length is shown in Figure 46.

### 2.4.3 Sex Ratio

There were limited sex-specific observations by length or age of young fish across biological data sources. The NWFSC WCGBT survey had the highest frequency of small fish observed. However, many of the small fish observed by the survey were too small for sex determination (Figure 47). In the absence of evidence of a differential sex ratio at birth the sex ratio of young fish was assumed to be 1:1.

### 2.4.4 Length-Weight Relationship

The length-weight relationship for copper rockfish was estimated outside the model using all coastwide biological data available from fishery-independent data from the NWFSC WCGBT and the NWFSC Hook and Line surveys. The estimated length-weight relationship for female fish was  $W = 9.6e-06L^{3.19}$  and males  $1.11e-05L^{3.15}$  where  $L$  is length in cm and  $W$  is weight in kilograms (Figure 48).

### 2.4.5 Growth (Length-at-Age)

Length-at-age was estimated for male and female copper rockfish informed by age data from the fisheries, the CCFRP survey, and independent efforts from four south of Point Conception programs since 2002: 207 otoliths collected by the NWFSC WCGBT survey, 427 otoliths collected by a research survey conducted by Don Pearson, 77 from a research survey conducted by Abrams, and 508 otoliths collected by a cooperative research survey by the SWFSC and CPFV funded by the Sportfishing Association of California (Table 15). The ages collected by these three sources were included in the model as a “growth” fleet that was not associated with removals or an index of abundance.

Sex-specific growth parameters south of Point Conception were initially estimated external to the model using the von Bertalanffy growth curve as parameterized within Stock Synthesis at the following values:

$$\text{Females } L_{age=2} = 19.8 \text{ cm; } L_{age=20} = 44.9 \text{ cm; } k = 0.243 \text{ per year}$$

$$\text{Males } L_{age=2} = 20.4 \text{ cm; } L_{age=20} = 44.2 \text{ cm; } k = 0.279 \text{ per year}$$

These values were used as starting parameter values within the base model prior to estimating each parameter for male and female copper rockfish.

#### 2.4.6 Ageing Precision and Bias

Uncertainty surrounding the age-reading process for copper rockfish was incorporated by estimating ageing error by age. Age composition data used in the model were from break-and-burn otolith reads. Aged copper rockfish used in the assessment were aged by the Cooperative Ageing Project (CAP) in Newport, Oregon. Within-lab ageing error was estimated by the CAP based on one primary age reader and a second reader producing double reads from 875 otoliths provided by the CAP lab (Figure 49).

An ageing error estimate was made based on these double reads using a computational tool specifically developed for estimating ageing error (Punt et al. 2008) and using release 1.1.0 of the R package `nwfscAgeingError` (Thorson et al. 2012) for input and output diagnostics. A linear standard error was estimated by age where there is more variability in the age of older fish (Figures 50 and 51). Sensitivities to alternative ageing error estimates were conducted during model development and the model was relatively insensitive to alternative ageing error assumptions.

### 2.5 Environmental and Ecosystem Data

This assessment did not explicitly incorporate environmental data.

## 3 Assessment Model

### 3.1 Summary of Previous Assessments and Reviews

#### 3.1.1 History of Modeling Approaches

Copper rockfish was first assessed in 2013 (Cope et al. 2013) using extended depletion-based stock reduction analysis (XDB-SRA), a data-moderate approach, which incorporated catch and index data with priors on select parameters (natural mortality, stock status in a specified year, productivity, and the relative status). Copper rockfish was assessed as two separate stocks, split north and south of Point Conception where the population north of Point Conception included the population off California, Oregon, and Washington. The 2013 assessment estimated the stock south of Point Conception at 75 percent of unfished spawning output and the stock north of Point Conception at 48 percent of unfished spawning output.

Copper rockfish was most recently assessed in 2021 using a length-based data-moderate assessment approach that included catch, fishery-independent index data, and length composition data (Wetzel et al. 2021a, 2021b). The 2021 assessments comprised four regional assessment models for copper rockfish with two model-areas within California split north and south of Point Conception. The 2021 assessments estimated  $R_0$  and select selectivity parameters with fixed growth and deterministic annual recruitment for the proportion of the population south of Point Conception and annual recruitment deviations estimated in the model for California north of Point Conception. The estimated stock status in 2021 for the portion of the population south of Point Concept was 18 percent of unfished spawning

output, while the California portion of the population north of Point Conception was 39 percent of unfished spawning output.

### 3.1.2 Most Recent STAR Panel and SSC Recommendations

This is the first benchmark assessment for copper rockfish off the coast of California. The previous assessment of this species was a data-moderate assessment conducted in 2021 that was reviewed by the Scientific and Statistical Committee. The following items were identified at that time for future assessments of copper rockfish to consider:

**Issue:** The model for Northern California estimated a pattern of high recruitment during the 1960s and lower recruitment during the 1970s, which is not consistent with trends in the recruitment for other rockfishes during that time.

**Response:** The estimated recruitment deviations for the model area north of Point Conception in California for this assessment also estimates a similar pattern despite the addition of historical recreational length and ages. The assessment for the sub-area north of Point Conception estimated a series of positive recruitment deviations in the early 1960s that are not well informed by data.

**Issue:** Concerns were raised regarding the declining trend in the recent time period of the Southern California model, which is inconsistent with population trends from other southern California stocks for which data are available (e.g., bocaccio, cowcod), most of which have seen signs of strong recruitment over the past decade.

**Response:** The previous data-moderate assessment that incorporated catch, length, and survey indices was unable to estimate annual recruitment deviations in the south of Point Conception model due to lack of information in the data to inform these estimates. This assessment included additional data sources including available age data that supported the estimation of annual recruitment. The south of Point Conception model estimated high recruitment since 2010 similar to trends observed for other rockfish species that have been recently assessed (bocaccio, vermilion/sunset rockfish). Estimates of recruitment were not compared to the most recent cowcod assessment since this model did not estimate annual recruitment deviations.

**Issue:** Age-length estimates (and hence the growth curve) for northern California may not be representative because they rely on data from Oregon and Washington where water temperatures are different and growth may differ as a result.

**Response:** Available age data from a range of sources were included within each sub-area model to support area-specific growth for copper rockfish. The majority of the age data that were available to support estimation of growth within the model in the area north of Point Conception (e.g., otoliths collected by the CPFV fleet within a cooperative sampling program coordinated by the SWFSC) were not available for consideration in 2021.

**Issue:** The fit to the [NWFSC] hook-and-line survey in the Southern California assessment was poor. This likely reflects differences in the composition from the fishery disproportionately reflecting areas open to fishing closer to port as compared to the more spatially balanced sampling of the survey, more equally representing habitat offshore and in the Cowcod Conservation Areas (CCAs) and in the Rockfish Conservation Areas (RCAs).

**Response:** It is important to note that the 2021 assessment of copper rockfish south of Point Conception did not estimate annual recruitment deviations which likely limited the ability to fit the variable trends in the index of abundance from the NWFSC Hook and Line survey. However, the NWFSC Hook and Line survey data did appear to see the largest proportion of larger sizes compared to the other surveys and was the only survey with asymptotic selectivity. This survey does include a number of sampling sites that are protected from fishing and other sampling sites that may experience lower fishing pressure due to locations that would require overnight trips to access from many mainland ports. Analysis of the data from the NWFSC Hook and Line survey for copper rockfish did not identify significant differences in the catch rate between areas open and closed to fishing. This should be revisited in subsequent assessments to determine if catch rates do increase in closed areas given longer periods of closures.

**Issue:** California Department of Fish and Wildlife (CDFW) quantified the percent of habitat in Marine Protected Areas (MPAs), CCAs and RCAs, along with charts for further consideration to make clear the amount of habitat that is not represented in recent years. Data from the recreational fishery only represents areas open to fishing, potentially making the stock appear more depleted than it is as a whole. Two-area models, estimates of biomass from recently reviewed CDFW remotely operated vehicle (ROV) surveys, and inclusion of the California Collaborative Fisheries Research Program that sample in MPAs can be incorporated in future assessments to help reflect differences in composition and fishing mortality in open and closed areas. Additional data to represent the composition in closed areas would be beneficial.

**Response:** Data from the CDFW ROV survey were not available for consideration in 2021. Additionally, estimates of the percent of habitat within and outside of MPAs and CCAs were provided by CDFW the date of the SSC review in 2021 which precluded their consideration for how to process available data or model sensitivities for copper rockfish in 2021. This assessment was able to include survey data from the CCFRP Hook and Lin survey that does sampling inside and outside of MPAs. Additionally, a sensitivity was conducted that included CDFW ROV survey index of abundance and length data that sampled both inside and outside MPAs. In order to properly weight composition data and abundance data collected within and outside MPAs estimates of rocky habitat were developed for the area south of Point Conception from partial seafloor mapping data (see Appendix Section 9.3.3 for detailed information). The area north of Point Conception has complete seafloor mapping data which has been used to inform data weighting as was done in the 2021 assessment of vermilion/sunset rockfish.

### **3.1.3 Response to Groundfish Subcommittee Requests**

To be completed after the SSC Groundfish Subcommittee meeting.

## **3.2 Model Structure and Assumptions**

### **3.2.1 Modeling Platform and Structure**

The assessment was conducted using Stock Synthesis version 3.30.21.00 developed by Dr. Richard Methot at the NOAA, NWFSC (Methot and Wetzel 2013). This most recent version was used because it included improvements and corrections to older model versions. The previous assessment of copper rockfish also used Stock Synthesis but an earlier version, 3.30.16.00; model bridging was performed between both versions of Stock Synthesis and is discussed below. The R package r4ss, version 1.38.0, along with R version 4.0.1 were used to investigate and plot model fits.

### **3.2.2 Model Selection and Evaluation**

The base assessment model for copper rockfish was developed to balance parsimony and realism, and the goal was to estimate a spawning output trajectory for the population of copper rockfish off the coast of California, north and south of Point Conception. The model contains many assumptions to achieve parsimony and uses many different sources of data to estimate reality. A series of investigative model runs were done to achieve the final base model.

### **3.2.3 Model Changes from the Last Assessment**

The assessment model structures for both the sub-area south and north of Point Conception have been substantially changed from the structure used in the 2021 assessments. The 2021 assessments were length-based data-moderate assessments which, per the Terms of Reference, assume a more simplified structure and limited data sources. The changes between the 2021 and the base models identified in 2023 are described below.

First, the fishery fleets were broken out into four specific fleets: commercial fishery that lands dead fish, commercial fishery that lands fish for the live market, recreational fishery CPFV vessels, and private/rental recreational anglers. This fleet structure is in contrast to the combined commercial and recreational fleets used in the 2021 assessment. The more disaggregated fleet structure used for the 2023 assessments allowed the model structure to account for varying selectivity and historical management actions that may have impacted the fishery and the available data in specific ways.

This assessment also included one additional survey dataset that were not included in the 2021 assessments: the CCFRP Hook and Line survey. This survey collect data in areas that are open to fishing and MPAs. These data were weighted according the estimates of the percentage of rocky habitat area within open and MPA areas. Using these data in the assessment allowed it to account for dynamics that may not be reflected in the fishery data alone and give a more informed picture of the whole population.

A major change relative to the 2021 assessment is the estimation of biological parameters. Since the 2021 assessments used length-based data-moderate models that did not include age data within the models, growth parameters were externally estimated and fixed within the models. This assessment estimates all growth parameters in the model except for the  $L_{age=2}$  parameter which was fixed in the model north of Point Conception at the estimated values due to limited observations of length-at-age of young fish leading to high uncertainty within the model. Additionally, the maturity-at-length parameters were updated from the values used in the 2021 assessments. Maturity estimates conducted by Melissa Head (NWFSC) in 2021 were re-evaluated limiting the samples to the fall months when copper rockfish are preparing for spawning. The updated length-at-50-percent maturity was marginally smaller for each assessment area compared to the values used in the 2021 assessments.

### 3.2.4 Bridging Analysis

The exploration of models began by bridging from the 2021 data-moderate assessment to Stock Synthesis version 3.30.21, which produced the same estimates for spawning output and the relative spawning output across the time series (Figures 52 and 53). Additional bridging analysis was conducted examining the impact of a revised model structure, updating existing data sources, and adding new data into the model. First, the fishery fleet structure was modified from the 2021 structure where the new assessment separated commercial data into two fleets based on fish landed condition, dead or live, and the recreational data into two fleets, CPFV and PR. The 2021 recreational and commercial data were reprocessed into the new model structure through 2021 and new selectivity parameters were added to the 2021 for the newly split data. The new data available for this assessment were then added to the model retaining the same model structure where feasible in the following order:

1. Update externally estimated biology parameters for length-at-age, weight-at-age, and maturity.
2. Add new catch data for all fishery fleets.
3. Add all updated commercial and recreational length and age data.
4. Add the new fishery-dependent indices of abundance.
5. Add the CDFW ROV survey index of abundance and length data. Note that due to late revisions to this dataset by CDFW, this survey and the associated length composition data was not included in the final base model. A sensitivity to including the estimated index of abundance from the original uncorrected data set is included in the Sensitivities Section 3.4.2.
6. Add the CCFRP Hook and Line survey index of abundance, length, and age data.
7. Add the updated NWFSC Hook and Line survey index of abundance, length, and age data.
8. Add selectivity blocks for the commercial and recreational fishing fleets.
9. Turn on the estimation of annual recruitment deviations.
10. Add conditional-age-at-length data for the growth fleet and estimate growth parameters for both sexes.

The data bridging models are shown in Figures 54-57. Revising the model structure, updating

biology, removals, length data, adding ages, and fishery-dependent indices results in small changes to the estimated spawning output and stock status (Figures 54 and 55). Adding and updating survey data, adding selectivity blocks, and estimating annual recruitment deviations and growth resulted in larger revisions in the population estimates. The largest changes in the new model relative to the 2021 assessment occurred when annual recruitment deviations were estimates resulting in a decrease in spawning output and relative spawning output at the end of the time series (Figures 56 and 57). Similar estimates were observed in 2021 assessment that included a sensitivity that estimated annual recruitment deviations.

To arrive at a final base model additional revisions to the model structure, selectivity blocks, and selectivity parameterizations were made in order to determine the best fit to the data.

### 3.2.5 Key Assumptions and Structural Choices

A decision was made by the STAT after discussions with the Pacific Fishery Management Council’s Groundfish Management Team and Groundfish Advisory Panel to model the areas north and south of Point Conception independently for a number of reasons. These included a discussion of the evidence of a change in growth with latitude and the fundamental differences in the fisheries north and south of Point Conception. The preliminary exploration of length data also suggested that the size composition of landed fish north and south of Point Conception differed in both the commercial and recreational fleets. The STAT maintained consistency across the two models when the data supported the decisions, i.e., maintaining the same recreational and commercial fleet structures and sharing biological data across models when appropriate.

The specifications of the assessment are listed in Table 18. The structure of the California models north and south of Point Conception are very similar. Population dynamics in both regions operate on an annual time step and are initialized from an unfished equilibrium condition in 1916. The model is a two-sex, age-structured model with an accumulated age group at 50 years. Growth and natural mortality were assumed time invariant with constant growth estimated and natural mortality fixed at the median of the prior for both sexes. Sex-specific age and length structure is modeled from age 0 (recruitment age) to an accumulator age (plus group) of 50, with 1-cm population length bins ranging from 10-54 cm in the south and 10-58 cm in the north. Length data bins are 2-cm wide, and range from 10-54 cm for both model areas. Expected recruitment is assumed to follow a Beverton-Holt function of spawning output, with lognormally-distributed recruitment deviations.

Stock Synthesis estimates growth in the age and size plus group. To avoid issues with additional estimated growth in the plus groups, the selection of the maximum age and length bins was made to ensure that the numbers of fish in the plus group would be low. Growth (male and female) is modeled using the Schnute parameterization of von Bertalanffy growth, with two estimated lengths (ages 2 and 20) and a growth rate coefficient ( $k$ ). The major differences between the two models are the availability of fishery-independent data sources that are region-specific, and the parameterization of male growth and mortality parameters (details below).



The models in both regions are conditioned on catches from the commercial and recreational sectors. The commercial sector is divided into two fleets, one representing fish landed for the live-fish market and the second representing all other landings. The recreational fleets were divided into two groups according to boat mode: CPFV (party/charter) and PR (private/rental/shoreside) and includes both estimated retained and discarded catch.

Copper rockfish is a desirable species and discards are a small component of total fishing mortality in both the commercial and recreational sectors. Estimated discards based on WCGOP were used to estimate discard mortality for both commercial fleets and were added to the landings to estimate total catch. The size distribution of recreational discards from the CDFW and Cal Poly onboard observer programs represented smaller fish than those retained prior to the one fish sub-bag for copper rockfish enacted in January 2023. The estimates of discard mortality available in RecFIN were combined with retained catch to estimate total recreational landings.

The southern California model is fit to two fishery-dependent indices of relative abundance: 1) CDFW CRFS onboard observer survey, and 2) CDFW CRFS private/rentals PR1 dockside survey. Additionally, a MRFSS CPFV dockside index was generated but due to data concerns was not included in the base model (lambda adjustment to the likelihood contribution set equal to 0 but retained in the model in order to see implied fits). The CDFW onboard observer index represents the same recreational party/charter fleet and includes both retained and discarded fish. The onboard index is specified as a separate “survey” fleet in the model because it overlaps in time with the MRFSS dockside time series. The CRFS onboard index uses the recreational party/charter (CPFV) fleet’s selectivity curve to define vulnerable size classes. The CRFS PR1 dockside index is linked to the recreational private/rental (PR) fleet, and used a different selectivity curve from the party/charter fleet. The indices were assumed to have a lognormal distribution standard error structure.

Recreational length measurements are included as marginal length compositions (numbers at length, sexes combined) by year starting in 1975 and 1980 for the CPFV and PR modes, respectively. Fishery-dependent length composition data are also included for the commercial fleets. Available age data for copper rockfish south of Point Conception from either the commercial or recreational fisheries are limited and were only available in 1975 for the recreational CPFV fleet and in 2022 in the commercial dead fleet. Age data from the fisheries were input as marginal ages.

Fishery-independent data sources in the southern California model are organized into two fleets: 1) the NWFSC Hook and Line survey and 2) CCFRP Hook and Line survey. Each of the survey data sources were used to create an index of relative abundance and included marginal length compositions by sex and year. Age data from the NWFSC Hook and Line survey and CCFRP Hook and Line survey were included as conditional-age-at-length data by sex and year.

Additional available age structures that could not be linked to one of the fleets above or represented a subset of information from a fleet were included in the two growth fleets. The

NWFSC WCGBT survey was not considered for an index of abundance, but is a source of conditional-age-at-length data and associated marginal length comps, both by sex and year, within the NWFSC WCGBT survey growth fleet. The second growth fleet combined limited ages from a Pearson Research Study between 2005 - 2007 and ages from the CPFV cooperative collection program in 2022. All composition data were fit with a multinomial error structure.

Time blocks on selectivity were explored extensively when setting up the initial model structure. A range of management changes to the commercial fishery were considered when determining periods when selectivity may have been expected to change. Commercial removals for copper rockfish are relatively low when compared to recreational removals for this species which limited the amount of composition data available to support the estimation of changes in selectivity. Given this and the limited evidence in the available length data, time-invariant selectivity was selected for both the commercial dead and live fish fleets. Identical time block structures were assumed for the recreational CPFV and PR fleets based on gear restrictions and depth closures. Selectivity was blocked into three periods: 1916-1999, 2000-2003, and 2004-2022. In 2022 the sub-bag limit in the California recreational fishery was reduced to only allow one copper rockfish. However, the amount of length samples in 2022 were not informative about a change in selectivity. The STAT examined depth restrictions in the area south of Point Conception across time to understand the potential selectivity shape by time block for both of the recreational fleets. Since 2004, the majority of depths have been open for recreational anglers (Figure 58). However, the PR fleets operating in both CRFS district 1 and 2 and the CPFV fleet out of district 1 have a higher frequency of shorter trips (e.g., half day trips) and given the required travel time to reach the deeper depths within copper rockfish range, the number of trips to deeper waters farther from port are likely limited for PR vessels and a portion of the CPFV fleets (see Appendix Section 9.4 for additional information). Given this, the parameterization of selectivities for both the recreational fleets was allowed to estimate some level of dome-shape. Finally, model exploration revealed that that selectivity in the first and third time blocks (1916-1999 and 2004-2022) for both the CPFV and PR fleets were highly similar so these two time periods were set to have equal selectivity.

A change in selectivity was explored for the NWFSC Hook and Line survey between 2012-2014, years where the number of MPA and CCA sites increased within the survey. The selectivity for both time blocks were estimated to be asymptotic or practically asymptotic (very slight dome only at the largest lengths) with little change in model fits to the data (change in negative log-likelihood less than 2 units). In the aim of parsimony, the selectivity for this survey was parameterized to have a single selectivity curve across all years.

The specification of when to estimate recruitment deviations is an assumption that affects the estimate of early model uncertainty around stock scale and status. Recruitment deviations were estimated from 1880 - 2020 to appropriately quantify uncertainty in the early model years. The earliest length- and age-composition data occur in 1975 but age data were not available consistently on a yearly basis until 2003. The most informed years for estimating recruitment deviations were from about the mid-1990s to 2018. The period from 1880 - 1964

was fit using an early recruitment deviation series with little or no bias adjustment, the main period of recruitment deviates occurred from 1965 - 2020 with an upward and downward ramping of bias adjustment, and 2021 onward recruitment deviations were assumed to be 0 due to limited information at the end of the time series. Methot and Taylor (2011) summarize the reasoning behind varying levels of bias adjustment based on the information available to estimate the deviates. The standard deviation of recruitment variability was assumed to be 0.60 based on the estimated variation in recruitment from the base model. Annual recruitment deviations were not forced to be fully zero centered during the main recruitment period in order to allow the data to fully inform the estimation and to avoid this constraint altering the annual estimates. Model explorations revealed that the selection of recruitment deviation estimation, zero-centered or not, had little to no impact on the annual estimated deviations.

### 3.2.6 Priors

Priors were used to determine fixed parameter values for natural mortality and steepness in the base model. The prior distribution for natural mortality was based on the Hamel and Cope (2022) meta-analytic approach with an assumed maximum age of 50 years. The prior assumed a log normal distribution for natural mortality. The log normal prior has a median of  $0.108 \text{ yr}^{-1}$  and a standard error of 0.31.

The prior for steepness assumed a beta distribution with mean of 0.72 and standard error of 0.15. The prior parameters are based on the Thorson-Dorn rockfish prior (commonly used in past West Coast rockfish assessments) conducted by James Thorson (personal communication, NWFSC, NOAA), which was reviewed and endorsed by the Scientific and Statistical Committee (SSC) in 2017. However, this approach was subsequently rejected for future analysis in 2019 when the new meta-analysis resulted in a mean value of approximately 0.95. In the absence of a new method for generating a prior for steepness the default approach reverts to the previously endorsed method, the 2017 value.

### 3.2.7 Data Weighting

Length composition data for the commercial fishery started with a sample size determined from the equation listed in Section 2.1.1. The input sample size for the length composition data from recreational fishery was determined based on the number of estimated trips (described in Sections 2.1.2), both the CCFRP and NWFSC Hook and Line surveys were set equal to the number of positive drops by year, the NWFSC WCGBT survey was set equal to the number of fish, and the Pearson Research survey and CPFV cooperative collection program set equal to the number of trips. The majority of age-composition data were input as conditional-age-at-length with input sample size equal to the number of ages. The age-composition data from both the commercial dead and historical CPFV samples were used as marginal age-composition with the input sample size set equal to the number of ages.

The base model was weighted using the “Francis method”, which was based on equation TA1.8 in Francis (2011) which was selected based on model stability and consistency to

identify the minimum likelihood estimate (MLE). This formulation looks at the mean length or age and the variance of the mean to determine if across years, the variability is explained by the model. If the variability around the mean does not encompass the model predictions, then that data source should be down-weighted. This method accounts for correlation in the data (i.e., the multinomial distribution). Since Francis data weighting is determined by the mean and variance in observations across years, a subset of data types that had only one year of composition data were weighted based on recommended values from the McAllister-Ianelli Harmonic Mean Weight (1997). These data sources were the marginal ages from the commercial dead and CPFV fleet and the conditional-age-at-length data from the CCFRP Hook and Line survey. One iteration of the Francis method resulted in converged estimates. The weighting of the length composition was allowed to exceed 1.0, but age composition data were constrained to 1.0 due to the fact that the sample sizes of conditional-age-at-length data were a direct count of the number of available ages.

Sensitivities were performed examining the difference in the model fits and results due to weighting using McAllister-Ianelli Harmonic Mean Weighting and the Dirichlet Multinomial Weighting (2017).

### 3.2.8 Model Parameters

There were 182 estimated parameters in the base model. These included one parameter for  $R_0$ , 10 parameters for growth, 4 parameters for extra variability for the fishery and survey indices, 26 parameters for length-based selectivity and time blocking of the fleets and the surveys, and 141 recruitment deviations including 35 pre-model estimates (Table 19).

Fixed parameters in the model were as follows. Steepness was fixed at 0.72, the mean of the prior. A sensitivity analysis and a likelihood profile were performed for steepness. Natural mortality was fixed at  $0.108 \text{ yr}^{-1}$  for females and males, the median of the prior. Estimation of natural mortality was explored during model development. The estimate of natural mortality was uncertain and poorly informed by the data. When estimated, natural mortality was low (around  $0.095 - 0.099 \text{ yr}^{-1}$ ), relative to the median of the prior which was based on maximum age; however, well within the prior distribution ( $SE = 0.31$ ). The observations of fish greater than 50 years of age across the West Coast, not only this assessment area, is rare, so a natural mortality that would be associated with a maximum around 55 years of age did not seem fully supported given the available age data. Natural mortality was fixed in the base model but estimation of this parameter for both sexes was explored via sensitivities.

The standard deviation of recruitment deviates was fixed at 0.60 ( $\sigma_R$ ). Maturity-at-length was fixed as described above in Section 2.4.2. A single California sex-specific length-weight relationship was fixed at externally derived estimates using the NWFSC Hook and Line survey and NWFSC WCGBT survey length-weight observations (Figure 48).

## 3.3 Base Model Results

The base model described here is only for the portion of the copper rockfish stock in California south of Point Conception,  $34^\circ 27' \text{ N. lat.}$ . Descriptions of the summed total

biomass, spawning output, and stock status for the full California stock of copper rockfish are described in later sections.

The base model parameter estimates along with approximate asymptotic standard errors (SD column) are shown in Table 19 and the likelihood components are shown in Table 20. The estimated data weights by the Francis method are shown in Table 21. Estimates of the copper rockfish population size south of Point Conception over time are shown in Table 22.

The full r4ss plotting output is available in the supplementary material on the Pacific Fishery Management Council website (these figures will not be available until the assessment is finalized).

### 3.3.1 Parameter Estimates

The estimates of growth parameters by sex varied relative to the externally estimated starting values. The length-at-age 2 and the length-at-age 20 estimates for both sexes were slightly less than the external estimates but were well within the 95 percent confidence interval given the estimated uncertainty (Table 19 and Figure 59). The estimated  $k$  for females was greater than the values estimated externally using the survey age data while the male value was similar to the external estimate ( $0.194 \text{ yr}^{-1}$  for females and  $0.218 \text{ yr}^{-1}$  for males). The majority of female and male copper rockfish growth occurs at younger ages, reaching near maximum length by age 10-15, with female copper rockfish reaching marginally larger maximum lengths (Figure 59).

Length-based selectivity curves were estimated for the fishery and survey fleets. The majority of fishery and survey fleets were parameterized using the double normal selectivity parameterization in SS3 except for the commercial dead and NWFSC Hook and Line survey fleets that were parameterized as logistic asymptotic selectivity. The estimated selectivities are shown in Figure 60. The selectivity for the commercial dead fleet was estimated to be asymptotic and constant across the model period. The commercial live fish fishery selects fish at small sizes with dome-shaped selectivity. Both recreational fleets were estimated to have dome-shaped selectivity for each selectivity period with the CPFV fleet selecting a higher portion of large fish in the final time block relative to the PR fleet. The peak in selectivity for both the CPFV and PR fleets in the final time block were estimated at 30.3 and 30.7, respectively. While the recreational fleets select a wide range of sizes, the estimated peak of selectivity for both fleets were notably less than the size-at-50 percent maturity of 34.1 cm.

The CCFRP Hook and Line estimated peak selectivity around 40 cm with selectivity decreasing for larger fish. The NWFSC Hook and Line survey estimated asymptotic selectivity only reaching maximum selectivity for the largest fish. The NWFSC WCGBT survey which samples soft bottom via trawl gear had relatively low selectivity for the majority of sizes with only selectivity peaking at the largest sizes. Finally, the estimated length-based selectivity from the CPFV cooperative collection and Pearson Research study was asymptotic with full selectivity for fish of 35 cm and larger. Both of these last two fleets included only lengths and ages to inform growth estimation. As noted in the Growth Data, Section 2.2.3, that

describes these data, the estimated selectivity for the samples collected by the CPFV vessels participating in the cooperative sampling program was distinctly different than that from the CPFV fleet operating south of Point Conception as a whole. This is likely due to the areas accessible and trip type (half-day, three-quarter day, or overnight) between the CRFS districts 1 and 2 within this area where all vessels participating in the collaborative collections operating out of district 2 (see Appendix Section 9.4 for additional information about the CPFV trip types across California).

The catchability for each of the surveys was analytically solved comparing observed to expected vulnerable biomass across all years. The analytical values for catchability were very small given the survey methodologies and are reported in Table 19 in log-space. Additional fishery and survey index variability, process error added directly to each year's input standard deviation for the were estimated within the model. The model estimated the largest added variance of 0.193 for the recreational PR fishery index. In contrast the model estimated only limited additional variability in order to fit the recreational CRFS CPFV fishery-dependent index of abundance (0.083). The model fit the trends in the NWFSC Hook and Line survey index of abundance relatively well with only a small amount of added variance being estimated to fit this time series (0.035). The model estimated an added variance of 0.042 to the index from the CCFRP Hook and Line survey.

The time series of estimated recruitments and annual recruitment deviations are shown in Figures 61 and 62. Years with the highest recruitment deviations were estimated to have occurred in 2010 and 2013 with the lowest being estimated in 2018 and 2019. There is limited information regarding recruitment prior to 1980 but are estimated in the base model to account for uncertainty around the unfished condition. The historical age data from the CPFV fleet from 1975 were identified to have a disproportional influence on estimated recruitment in the late 1960s relative to all other data sources in the model. These data resulted in a sharp spike in recruitment during these years that was substantially higher than any other year in the model. Given that these estimates were extreme and appeared to be informed by limited data, the decision was made to reduce the influence of this one year of limited age data for model stability (lambda value of 0.10 for these data). Sensitivities showed that the overall ending model estimates were not impacted by this decision (show below in Sensitivities Section 3.4.2). Estimated recruitment deviations during the early years when compositional data began, 1975 - 1995, have relatively high uncertainty intervals indicating lack of support for clear strong or poor recruitment years across data sources. Recruitment deviations after 2017 are relatively uncertain but with large negative recruitment deviations. Recruitment in 2021 and 2022 are not estimated and fixed to be equal to the spawner-recruit curve values (Figure 63). The recruitment bias adjustment applied within the model across years is shown in Figure 64.

### 3.3.2 Fits to the Data

Fits to the length data are shown based on the Pearson residuals-at-length, the annual mean lengths, and aggregated length composition data for the fishery and survey fleets in the model. Annual length composition fits are shown in the Appendix, Section 9.1.1.

The aggregated fit to the length composition data by fleet is shown in Figure 65. The majority of the length compositions from the commercial dead fleet were unsexed fish with sexed fish only occurring for select years for limited samples (1986, 1987, and 2022). On aggregate the model fit the unsexed length composition well with the single asymptotic selectivity curve. Pearson residuals for the commercial dead fishery length data are shown in Figure 66. The data across time are limited making it difficult to discern patterns in the Pearson residuals across time. Temporal patterns are additionally difficult to discern since the data were not sufficient to support the estimation of time-varying selectivity which would be expected given changes in management. The mean lengths observed by year from the commercial fleet were uncertain but showed a relatively stable mean size in the final years of the model and a larger mean size in the available data prior to 1990 (Figure 67). There were only limited ages available from the commercial dead fleet in 2022 with rather large Pearson residuals (Figures 68 and 69), noting that there were only 8 ages available that happened to all be female. The Pearson residuals for the commercial live fish fishery did not appear to have patterns or periods of misfit to the data (Figure 70) and the model appeared to fit the mean size across time which was highly variable (Figure 71).

The length composition data aggregated across years from the CPFV fleet was fit well by model (Figure 65). The Pearson residuals for the recreational CPFV length data are variable by year (Figure 72). Pearson residuals were positive, with observations greater than expected, for larger fish in the earliest data. Additionally, there appears to be a series of diagonal positive residuals moving across years starting around 2005 which may be a year-class moving through the population that the model is under-estimating. These under fits to the data could align with the positive recruitment deviation being estimated in 2003 for the population. Explorations of alternative selectivity forms failed to resolve this pattern in residuals. The mean length observed by the CPFV fleet was fit relatively well by the model with the largest mean size being observed in the early years of the data with the mean size roughly stabilizing between the late 1980s though 2010, after which there was a decline in the mean size, which then slowly increased at the end of the model period (Figure 73). Age data were available for the CPFV fleet only in 1975 with all ages being unsexed fish (Figure 68). The peak of the distribution of these ages was under-fit by the model (Figure 74). These ages were highly influential in the model, leading to a large recruitment deviation that was significantly higher than any other year estimated. All data weighting approaches explored indicated these data should be significantly up-weighted (e.g., suggested weights of greater than 1.0 where the input sample size was equal to the number of fish). Due to the highly influential nature of this single year these data were down-weighted in the model. Model explorations showed that down-weighting of these data did not affect the ending model estimates but resulted in a more stable model.

The aggregate length composition data from the PR fleet had a more defined peak around 30 cm with fewer observations of larger fish relative to the CPFV fleet and was fit well by the model (Figure 65). The Pearson residuals for the recreational PR length data are variable by year (Figure 75). Similar to the CPFV length data, there appears to be a series of diagonal positive residuals moving across years starting around 2005 which may be a year-class moving through the population that the model is under-estimating and that were not able to be

resolved. The mean length observed by the PR fleet was highly variable prior to 2001 with the model estimated mean length being either below or above the observed mean length (Figure 76). After 2001, the variability around the mean length decreases with the model approximately fitting the decrease in mean length after 2010, although the model estimating a larger decline in mean length (Figure 76). The increase in mean length at the end of the time series observed in the data generally aligns with the model predictions for this period.

The CCFRP Hook and Line survey aggregated lengths had a sharp peak between 30-40 cm that the model was not able to fit but fit the ascending and descending length observations for this survey well (Figure 65). There was no clear pattern in the Pearson residuals for this data source (Figure 77). The model estimated mean length was increasing between 2017-2021, while the CCFRP Hook and Line data had a declining trend in mean length observed for this period (Figure 78). However, the estimated model fit was well within the variance in the observed lengths by this survey and this data source was given an intermediate data weight (Table 21). Only a limited number of age data were available in 2022 from the CCFRP Hook and Line survey and were input as conditional-age-at-length data. This data source had a slightly higher proportion of fish observed at small sizes and intermediate ages than the model expectation given the estimated growth (Figure 79)

The aggregated sexed length composition data from the NWFSC Hook and Line survey was fit relatively well by the model (Figure 65). The Pearson residuals by sex did not show any clear patterns of poor fit (Figure 80). Notably, there were no clear pattern of residuals at the larger sizes starting between 2012-2014 indicating that there was not a clear shift in larger fish being observed as the number of MPAs and sites within the CCAs began to be sampled. The trend in mean lengths was fit well by the model with both the data and model showing a decline in mean lengths in the mid-2010s and an increase in mean length in recent years (Figure 81). The Pearson residuals for the conditional-age-at-length data did not show any clear patterns of poor fits, excluding select positive residuals for single fish observations with length-age combinations (e.g., old-large male in 2012 or older female of intermediate size in 2016, Figures 82-84). The pattern in the mean ages is generally fit by the model, except for the 2021, which the model underestimates (Figure 85).

The NWFSC WCGBT survey across years selected limited numbers of copper rockfish of all sizes with the observations of sexed fish being generally well fit by the model (Figure 65). The Pearson residuals did not show patterns of poor fit across years with the largest residuals arising for small unsexed fish observed in 2016 (Figure 86). The mean size observed across years was generally stable, although data through 2011 had high variability in the observed length, and was fit well by the model (Figure 87). The conditional-age-at-length data were fit well by the model (Figures 88 and 90). The mean age across years was fit well by the model with the Francis data weighting recommending data weights greater than one (i.e., the data weights were capped at one to equal the number of fish, Table 21 and Figure 91).

The Pearson residuals for the Pearson Research and CPFV cooperative collection length data were greatest for the Pearson Research lengths (2005-2007) but the sample sizes across the three years were limited (31 fish total, Figure 92). The variance around the mean lengths



observed in 2022 was limited but fit well by the model (Figure 93). The conditional-at-length data from the CPFV cooperative collection were highly variable with positive residuals of smaller than average size-at-age fish compared to other data sources (Figure 94). The mean age of 12 for fish observed in 2022 was under-fit by the model which may be due to the fact that these age data came only from CRFS district 2 rather than both district 1 and 2 (Figure 95).

The model estimates generally followed similar trends in both the recreational CFRS CPFV onboard and CRFS PR dockside indices of abundance (Figures 96 and 97). The model estimated vulnerable biomass for the CRFS CPFV onboard index follows the observed trend of lower estimates in the beginning of the time series, increasing after 2010, and a subtle decline in the final years of the index. However, the model under-fits select years that increased relative to the surrounding years (e.g., 2007-2008, 2013, and 2018) resulting in the model adding additional variance in order to fit these years. The CRFS PR index of abundance had a similar trend as that of the CRFS CPFV index and was fit well excluding the 2007-2008 and the 2012 data points which were under and over estimated, respectively (Figure 97).

The model estimated a subtle decline at the end of the time series that fit all but one of the years from the CCFRP Hook and Line survey index of abundance (Figure 98). The NWFSC Hook and Line survey, the longest fishery-independent time series included in the model, the model fit the overall trend of the index well, excluding the 2005 and 2006 data points that were higher than the surrounding years (Figure 99).

### 3.3.3 Population Trajectory in the Modeled Area

The estimated spawning output (in billions of eggs) for the portion of the stock south of Point Conception is shown in Table 22 and Figure 100. The spawning output time series shows a slow decline in spawning output from the 1960s through the mid-1970s as catches ramped up (Figure 2). The spawning output sharply decreases until the early 1990s around when catches started to decline from their peak. The spawning output stabilized at low levels through the early 2000s when the population slowly began to slightly increase until the final years of the model when spawning output is declining. The estimated total biomass follows the same general trend as observed in the spawning output but with a more pronounced increase between the early 2000s up until 2018 (Figure 101). The estimated spawning output relative to the unfished equilibrium spawning output for the sub-area south of Point Conception has remained relatively low since the late 1980s, peaking in recent years at 20.5 percent in 2018 (Figure 102).

### 3.3.4 Population Trajectory for the Stock

The predicted spawning output (in billions of eggs) for the California stock of copper rockfish is given in Table 23 and shown in Figure 103. The predicted trajectory of spawning output for the stock is generally similar to the trend observed for each area north and south of Point Conception with spawning output declining starting late 1970s when catches across California

peaked. The spawning output of the stock declined to the lowest level in the mid-1990s and then began to steadily increase through the end of the time series. The spawning output relative to unfished spawning output declined to the stock's lowest point in 1994 at 14.8 percent (Figure 104). After hitting a low in 1994, the relative spawning output of the stock has steadily increased with an estimated final stock status of 36.6 percent of unfished in 2023.

### 3.4 Model Diagnostics

#### 3.4.1 Convergence

Proper 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. Starting parameters were jittered using the jitter function built into Stock Synthesis, using a jitter input of 0.10. This was repeated 100 times with 17 out of 100 runs returning to the base model likelihood. A better, lower negative log-likelihood, model fit was not found. In the jittering analysis, models with similar log-likelihood values (21 models with difference  $< 0.50$  units) were found with little difference in overall model estimates, indicating a somewhat flat likelihood surface around the maximum likelihood estimate. Additionally, jitters using a smaller jitter value yielded an increased frequency of runs returning to the base model with no models finding a better fit to the data. Through the jittering and the likelihood profiles, we are confident that the base model, as presented, represents the best fit to the data given the assumptions made. There were no difficulties in inverting the Hessian to obtain estimates of variability, although much of the early model investigation was done without attempting to estimate a Hessian.

#### 3.4.2 Sensitivity Analyses

Sensitivity analyses were conducted to examine the relative influence of specific changes to data inputs and model structural assumptions to further address uncertainty associated with the base model estimates and derived management quantities. The majority of the sensitivity models are the result of a single change relative to base model (i.e., they are not the result of cumulative changes such as the modeling approach used with the bridging analysis). Comparisons of likelihood values and estimates of key parameters from the sensitivity analyses are shown in Tables 24-26. Comparison of all sensitivities relative to the base model are shown in Figures 105 and 106 comparing only select derived quantities relative to the base model. Figures 107-112 show the change in spawning output and the relative spawning output trajectories compared to the base model. Many additional sensitivity runs were explored during development and testing of the base model that are not included here. This section focuses on the main data and structural sensitivity model runs and includes the following:

##### Structural Sensitivities

1. Estimate natural mortality ( $M$ ) for each sex.
2. Estimate steepness ( $h$ ).

3. Estimate  $M$  for each sex and  $h$ .
4. Fix recruitment to be equal to the stock-recruitment curve (no recruitment deviations).
5. Set the CPFV selectivity to be asymptotic for the period of 2004-2022.
6. Add growth platoons that can account for size-dependent survivorship.
7. Remove added variance from all fishery-dependent and -independent indices of abundance (fixed equal to 0.01).
8. Apply Dirichlet data weights.
9. Apply McAllister-Ianelli data weights.

#### Data Sensitivities

1. Reduce the PR catch between 1970-1982 to half of the fleet's average catch for that period of time.
2. Eliminate down weighting of the historical CPFV ages ( $\lambda = 1.0$ ).
3. Remove all age data and fix growth at the estimates.
4. Remove the CPFV cooperative collection ages in 2022.
5. Move the CPFV cooperative collection ages to the CPFV fleet and set  $\lambda = 1.0$  for CPFV ages.
6. Remove the NWFSC WCGBT survey lengths and ages.
7. Add the NWFSC WCGBT survey index of abundance.
8. Remove all fishery-dependent indices of abundance.
9. Remove the CCFRP Hook and Line survey data (index, lengths, and ages).
10. Add the CDFW ROV survey data (index and lengths).
11. Remove the NWFSC Hook and Line survey data (index, lengths, and ages).
12. Remove the NWFSC Hook and Line survey age data only.
13. Remove the NWFSC Hook and Line survey length and age data (retain only the index of abundance).
14. Move NWFSC Hook and Line survey data prior to the sampling expansion to include CCAs in 2014 to be associated with the Pearson Research Cooperative Collection growth fleet. This approach has been applied in other assessments where the expansion into the CCA were thought to impact the size and age of fish being encountered by the survey.
15. Remove the NWFSC Hook and Line survey index of abundance (retain the lengths and ages).

16. Remove the NWFSC Hook and Line and CCFRP Hook and Line survey (indices, lengths, and ages).

Across all the sensitivities conducted only a subset resulted in distinct changes in the model estimates and the discussion here will focus on the sensitivities that were identified in Figures 105 and 106. The sensitivity that did not estimate annual recruitment deviations and predicted recruitment directly from the stock-recruitment curve resulted in the model estimating a higher initial unfished recruitment ( $R_0$ ), a higher spawning output in the final model year, and a less depleted population south of Point Conception (Table 24, Figures 107 and 108). The dynamics of copper rockfish south of Point Conception appear to be driven by strong or weak recruitment variations combined with exploitation. In order to fit the data in the absence of recruitment variation the model needs to adjust the derived quantities accordingly.

Both sensitivities that explored the impact of alternative data weighting methodologies resulted in differences relative to the base model in derived final spawning output and relative spawning output (Table 24, Figures 107 and 108). The suggested data weights from the Dirichlet methodology for most data types hit the upper bound on data-weighting of 1.0 (Table 21). These suggested data weights for the length data may be due to the input sample sizes not being equal to the number of fish sampled and if the data processing were revised, the suggested data weights may be less than those estimated here. However, the Dirichlet data weighting approach also estimated data weights at the upper bound of 1.0 for the majority of age data sources which in most instances had an input sample size equal to the number of fish. Similar behavior in data weights suggested by the Dirichlet method have been encountered by sensitivities for other groundfish assessments (e.g. petrale sole in 2019, copper rockfish in 2021). In order to understand what is behind this behavior, additional simulation work should be conducted to inform how this approach should be best applied. The other data weighting approach, McAllister-Ianelli, also estimated a higher final spawning output and relative status compared to the base model (Table 24, Figures 107 and 108). Much of the exploratory modeling work conducted for this assessment used either Francis or McAllister-Ianelli. Models that used the McAllister-Ianelli data-weighting for copper rockfish south of Point Conception seemed to generally have issues converging to the true maximum likelihood estimate (MLE, e.g., jitter commonly identified a model with a lower MLE) with this issue also extending to challenges when conducting likelihood profiles. These issues were encountered when running diagnostics for this alternative model where the jittering revealed an inability of the MLE being repeatedly identified (i.e., out of 100 jitters run at a level of 0.10, only one run returned to the true MLE) and likelihood profiles across parameters failing to converge to a reasonable model across parameter values.

The model showed sensitivity to a range of data sources (Figure 106). Removing the length and age data from the NWFSC WCGBT survey resulted in a larger estimate of final spawning output and a less depleted population (Table 25, Figures 109 and 110). These data had a number of observations from age-0 and age-1 copper rockfish and when removed from the model the size-at-age 2 increased for female fish relative to the base model resulting in a meaningful change in the growth curve. Removing both CRFS CPFV and PR indices of

abundance from the model also resulted in the sensitivity estimating a larger final spawning output (Table 25, Figures 109 and 110). The majority of the indices included in the model included a slight downturn at the end of the time series (Figure 10) indicating that each of these indices have some level of contribution to the estimates at the end of the time series.

The base model was most sensitive to the removal of the NWFSC Hook and Line survey data (i.e., indices, lengths, and ages, Figure 106). The NWFSC Hook and Line survey is the only major data source in the model that had asymptotic selectivity (i.e., the commercial dead fleet selectivity was also asymptotic but given the low removals was not a influential fleet in the model, Table 26, Figures 111 and 112). Removing all data from this survey allows the model to estimate a lower size-at-age 20 for both male and female fish which may allow the model to estimate a less depleted population. Explorations that removed the age data from this survey indicated that the change in model estimates relative to the base model are largely being driven by the age-composition data from this survey.

### 3.4.3 Retrospective Analysis

A five-year retrospective analysis was conducted by successively removing years of data ranging from 2017 - 2021 (i.e., “Data -1 Years” corresponds to data through 2021). The estimated spawning output for all retrospectives was higher at the start of the time series and lower for the final model years (Figure 113). There are a substantial number of ages only available in 2022 which may be a contributing factor leading to this slight decline in estimated spawning output when the most recent data were removed. Additionally, removing five years of data removes all but one year of data from the CCFRP Hook and Line survey. The estimates of relative spawning output to unfished for the population south of Point Conception decreased with each subsequent data peel compared to the base model but were within the uncertainty intervals (Figure 114).

### 3.4.4 Likelihood Profiles

Likelihood profiles were conducted for  $R_0$ , steepness, and female natural mortality values separately. These likelihood profiles were conducted by fixing the parameter at specific values and estimating the remaining parameters based on the fixed parameter value. The priors for all parameters, including the parameter being profiled, were included in every likelihood model. For example, including the prior on natural mortality across the profiled values of natural mortality provides information on the likelihood contribution of that prior as if it were estimated in the model.

The negative-log-likelihood was minimized at a  $\log(R_0)$  value of 5.49 (Figure 115). The likelihood profile for  $R_0$  was most informed by the recruitment likelihood contribution within the model. The information about  $R_0$  across the other data sources was limited with the age data having the greatest information supporting lower values of  $R_0$ . Across the range of  $\log(R_0)$  values profiled the spawning output at the end of the time series were similar with the largest differences occurring around the estimates of unfished spawning output (Figure 116). The varying estimates of unfished spawning output across values of  $\log(R_0)$

translated to variations in the ending fraction unfished (11-24 percent), although all of the profile trajectories ended in a similar relative spawning output range as the base model (Figure 117).

The majority of data types included in the model contained limited information on steepness (Figure 118). The minimum identified by the profile of approximately 0.69, was very similar to the fixed value in the model (0.72) based on the mean of the prior but values between approximately 0.60-0.80 had similar support from the data. The sensitivity that explored estimating steepness indicated little to no change in the negative-log-likelihood relative to the base model that fixes this parameter (Table 24). Similar to the profile over  $\log(R_0)$ , fixing steepness in the model at values ranging between 0.30-0.95 had the largest impact on the derived unfished spawning output resulting in a range of relative spawning outputs between 11-27 percent of unfished for the sub-area south of Point Conception (Figures 119 and 120).

Parameter profiles across a range of female natural mortality values indicated that the negative-log-likelihood was minimized around values below the model fixed value of 0.108  $\text{yr}^{-1}$  (Figure 121). The length data were the most informative around this parameter with the length data from NWFSC Hook and Line survey contributing the most information about natural mortality. The information in the age data by source was more limited but the aggregate information across data sources supported values greater than 0.09  $\text{yr}^{-1}$ . Relative to the other parameter profiles the assumed value of female natural mortality had a reduced impact on the estimates of spawning output and the relative status (Figures 122-123). The range of relative spawning output at the end of the time series was between 10-21 percent of unfished spawning output across natural mortality values between 0.08-0.13  $\text{yr}^{-1}$ .

Throughout model explorations estimates of both steepness and natural mortality were made. A decision to not estimate these parameters in the base model was based on the change in the negative-log-likelihood of only 1.5 units when the three additional parameters were estimated. Additionally, these parameters were not well informed by the data and appeared to lead to issues with the model correctly identifying the best fit to the data.

### 3.4.5 Historical Analysis

The estimated spawning output from both the 2013 and 2021 assessments for the portion of copper rockfish south of Point Conception compared to the base model are shown in Figures 124 and 125. The model structure and the approach used in the 2013, index-based data-moderate assessment using Extended-Depletion-Based Stock Reduction Analysis, was substantially different both from the 2021 and this assessment. The 2013 assessment assumed fecundity was equal to weight-at-length while the 2021 assessment and the base model sets fecundity in numbers of eggs as a function of length, so estimates of total biomass are shown in Figure 124 to allow comparability. The estimated scale of the population and relative fraction of spawning output among the 2021 and this base model were consistent despite the number of additional data sources, changes in biology (estimated vs. fixed at external estimates), and recruitment dynamics (estimation of annual recruitment deviations in the base model which were fixed to 0 in the 2021 assessment).

## 4 Management

### 4.1 Reference Points

Reference points were calculated using the estimated selectivities and catch distribution among fleets in the final year of each sub-area model, 2022. Reference points are presented in Tables 27 and 28 for each sub-model area and are informational only. Copper rockfish off the California coast are managed as a single stock by the Pacific Fishery Management Council. Combined reference point quantities for the California stock are shown in Table 29.

Sustainable total yield (landings plus discards) across California is estimated to be 164.24 mt when using an  $SPR_{50\%}$  reference harvest rate. The spawning output equivalent to 40 percent of the unfished level ( $SO_{40\%}$ ) was 262.8 billions of eggs.

The 2022 combined California spawning biomass relative to unfished equilibrium spawning output at 36.6 percent, below the management target of 40 percent (Table 23 and Figures 103 and 104). The fishing intensity,  $1 - SPR$ , for each model area varied where the portion of the stock north of Point Conception has been below that target in recent years (Figures 126 and 127). In contrast, the fishing intensity south of Point Conception has been estimated to be above the target in recent years.

Tables 27 and 28 shows the full suite of estimated reference points for each sub-area model and Figures 128 and 129 show the equilibrium yield curves and net production based on a steepness value fixed at 0.72.

### 4.2 Evaluation of Scientific Uncertainty

The model estimated uncertainty around the 2023 spawning output for the sub-area model south of Point Conception is  $\sigma = 0.3$  and the uncertainty for the sub-area model north of Point Conception is  $\sigma = 0.31$ . The uncertainty around the OFL south and north of Point Conception was  $\sigma = 0.28$  and 0.3, respectively. Each of these are likely underestimates of overall uncertainty due to the necessity to fix several key population dynamics parameters (e.g., steepness, recruitment variance, natural mortality) and also because there is no explicit incorporation of model structural uncertainty (although see the decision table for alternative states of nature).

### 4.3 Harvest Projections and Decision Tables

A ten-year projection using the combined estimates from each sub-area base model, south and north of Point Conception in California, with catches equal to the estimated Annual Catch Limit (ACL) based on the category 1 time-varying  $\sigma$  with  $P^* = 0.45$  for years 2025-2034 is shown in Table 30 (i.e., termed the “buffer”). The removals in 2023 and 2024 were set equal to the portion of copper rockfish species-specific adopted ACLs for California determined by summing the adopted ACLs South of 40° 10' N. lat. and the portion of the North of 40° 10' N. lat. allocated to California (25 percent - PFMC Groundfish Management Team pers. comm.). The portion of ACL to allocate to each sub-area for 2023-24 was determined based

on the proportion of the total removals by area in 2022 (71 percent north and 29 percent south) as recommended by the GMT (Mel Mandrup, CDFW, personal communication). The projections were conducted in an iterative fashion based on the combined estimates of spawning output, relative spawning output, OFL, ABC, and ACL for each year. The estimated proportion of the ACL removed from each sub-area model based on the proportion of the contribution to the total annual OFL estimate.

At the end of the projection period, 2034, the projected ACL removals result in the California stock increasing to be above the biomass target at 40.9 percent of the relative spawning output, with the portion of the stock south at 24.5 percent of the sub-area estimated relative spawning output and north of Point Conception at 48.2 percent.

The axes of uncertainty in the decision table are based on the uncertainty around steepness. The estimated uncertainty around the 2023 OFL was used to identify the low and high states of nature that would align with the 12.5 and 87.5 percentiles from the base model where the base model is assigned a 50 percent probability of being the true state of nature and both the low and high states of nature being assigned a 25 percent probability. A search across steepness ( $h$ ) values for each sub-area model was conducted to identify the corresponding steepness values that would create the low and high states of nature relative to the base model. The sub-area north of Point Conception applied values of  $h$  of: 0.655, 0.72, and 0.859. The sub-area south of Point Conception applied values of  $h$  of: 0.54, 0.72, and 0.929. The proposed decision table assumes full ACL removal during the projection period under P\* alternative catch stream (Table 31).

#### **4.4 Regional Management and Spatial Management Considerations**

Over the last several decades, spatially explicit management measures at both the state and Federal/Management Council level have been implemented to achieve a wide range of marine resource and fishery management objectives. Depth restrictions to commercial and recreational fisheries in the Rockfish Conservation Areas (RCAs) and the Cowcod Conservation Areas (CCAs) are key among those, as are the suite of total and partial exclusion of commercial and recreational fishing activities in the California statewide network of Marine Protected Areas (MPAs). While the former are associated with explicit fisheries management objectives, the latter have a suite of ecological and economic objectives, most of which are not specific to, nor integrated across, the fisheries management arena. Despite this, both types of spatial management measures are expected to result in various biological, ecological, and socioeconomic effects within and adjacent to their boundaries. All of these effects have the potential to influence the nature and quality of the data used to inform stock assessments of species that reside in these areas, including copper rockfish.

Regardless of the management objective, spatial closures are expected to increase the spatial heterogeneity in abundance and size or age structure of fished stocks. This greater spatial variability can complicate the assumptions made in stock assessment models, particularly the assumption that the densities and demographic structure of assessed populations are relatively homogeneous, at least across predictable habitat types such as bathymetric gradients or



substrate types (Punt and Methot 2004; Berger et al. 2017). Although a wide range of factors above and beyond spatial management measures can also lead to violations of those assumptions, and the challenge is intuitively less problematic for populations with high movement rates and/or high population turnover, the challenge can be particularly important for longer lived populations with lower movement rates. The challenge can best be summarized by the result that the more effective MPAs or other closed areas are at protecting populations within them, the more likely it is that traditional assessment approaches will be biased or more uncertain.

If the spatial closures also prevent fisheries independent surveys from evaluating the relative abundance and demographic structure of managed populations, the challenges in developing robust population models, and thus robust management advice, become even more severe. While spatially explicit assessment models provide a means of more explicitly addressing these challenges, such models are computationally intensive, require robust data from the specific areas being modeled, and may also require detailed information regarding movement and dispersal rates (McGilliard et al. 2014; Berger et al. 2017; Cadrin 2020; Punt et al. 2020). Moreover, the complexity of these spatial models increases substantially if the size and location of closed areas changes over time, as many of the more “fisheries management based” closures (e.g., RCAs) have in California groundfish fisheries. Thus, such approaches may be less feasible for more data limited stocks, such as northern and southern copper rockfish, at least in the near term. However, the fact that both the northern and southern assessment models are informed by fishery-independent surveys that include habitats both inside and outside area closures provides some hope for greater recognition of spatial factors in future assessments.

#### **4.5 Unresolved Problems and Major Uncertainties**

This assessment models the sub-areas north and south of Point Conception as separate non-mixing sub-populations, but there is likely larval or juvenile dispersal, and potentially some adult movement among these areas. Dispersal and movement rates are not well known. Improved understanding around the dispersal rates of copper rockfish across California, particularly around Point Conception, are needed to support spatial modeling of the stock.

The primary fishery-independent survey for West Coast groundfish, the Northwest Fisheries Science Center (NWFS) West Coast Groundfish Bottom Trawl (WCGBT) survey, does not sample rocky habitats where most copper rockfish are found, and thus does not provide a robust index of abundance. An alternative survey, the CCFRP Hook and Line survey, provides a reasonable signal for copper rockfish, including relative abundance and demographic structure inside and outside a number of Marine Protected Areas (MPAs).

Age data are limited and consequently growth estimates are uncertain and the available age data contained little to no information to support the estimation of natural mortality. There is some tension among limited data sources and types inferred by the likelihood profiles, with age data suggesting a higher natural mortality rate and length data suggesting a lower value, particularly for the area north of Point Conception. Conflicting signals in the information

between length and age data is commonly encountered for many West Coast groundfish stock assessments. The mechanisms driving these differences are uncertain.

Each of the sub-area models estimates high recruitment events over the most recent decade, especially relative to previous time periods. The base model for the sub-area north of Point Conception estimated overall lower variation in recruitment relative to the model south of Point Conception. Oceanographic conditions likely drive periods of either poor or above average recruitment, particularly for rockfish species. However, it is unclear what conditions may be contributing to the differing levels of recruitment variation across the California coast.

## 4.6 Research and Data Needs

There were some major sources of uncertainty within the assessments for copper rockfish. To improve our understanding of the copper rockfish stock in California waters the following research and data collection should be prioritized:

1. The NWFSC Hook and Line survey is the only long-term fishery-independent survey in rocky (untrawlable) habitat in the Southern California Bight. Efforts should continue to explore how best to model hook and line catch data to develop indices of abundance. We also recommend evaluating how to structure the NWFSC Hook and Line survey index, given its expansion into the CCAs and increase in sites within designated MPAs, and independent analysis of information content in NWFSC Hook and Line survey across observed species. Finally, increased spatiotemporal sampling around Point Conception would aid in identifying stock boundaries.
2. The assessment area south of Point Conception appears to have a mixture of observations from areas experiencing variable fishing mortality. In the region there are likely a mixture of areas: open access rocky reefs that are close to port that are heavily fished, open access rocky reefs that are inaccessible via day-trips that are fished but likely at lower levels, and rocky reefs that fall within marine protected areas (MPAs). A spatially-explicit assessment model may be able to capture this complexity but will require data (indices of abundance and composition data) from each of the regions.
3. Future nearshore assessments would greatly benefit from additional CDFW ROV surveys which could increase the power of these data to inform assessments.
4. There are very limited age data for copper rockfish across California arising from fishery-dependent sources. Establishing regular collections of otoliths from the recreational fishery, a large source of mortality, would support future assessments and would improve the understanding of the population structure and life history of copper rockfish.
5. There is limited information for copper rockfish on maturity and fecundity and the variability of these parameters with increasing latitude. The NWFSC WCGBT and Hook and Line surveys provided the only available information on the maturity ogive and the timing of these surveys does not overlap with the expected peak spawning season. The Southwest Fisheries Science Center has egg samples from a total of ten copper rockfish, which is too few to draw conclusions regarding fecundity.

6. Some of the PR mode recreational data that should be available via RecFIN were found to contain information in that database inconsistent with datasheets available from CDFW. There is also a question if length data collected by the Deb Wilson-Vandenberg onboard observer survey is duplicated within RecFIN and attributed to MRFSS dockside samples of the CPFV fleet.
7. The interpreted substrate data for the areas north of Point Conception within state waters is incomplete. Additional data needs include high resolution interpreted substrate maps for areas outside of state waters. The available interpreted bathymetry data from south of Point Conception is incomplete within state waters around the northern and southern Channel Islands. This poses a challenge for estimating available rocky substrate both by district and also inside and outside closed areas.
8. The genetic stock structure of copper rockfish warrants further investigation to ensure appropriate management of copper rockfish along the West Coast.
9. The Marine Recreational Fisheries Statistics Survey (MRFSS) index was excluded from both California assessment models. The standardized trends in abundance were marked by extreme peaks in the data throughout the time series. The STAT was unable to identify what may driving extreme changes fishing behavior in these select years. These data should be reviewed to better understand whether these data reflect true changes in fishing behavior in those years or errors in data collection.
10. Additional research on the effect of the MPA network on copper rockfish and other nearshore rockfish species needs to be conducted. The trend inside the MPAs in northern California exhibited an increasing trend compared to outside the MPAs, similar to what was observed during the 2021 assessment of vermilion/sunset rockfish. However, the trends inside MPAs south of Point Conception varied by location with a number of sites showing flat or declining trends.
11. Further investigations of other available fishery-independent data such as the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) kelp forest index would benefit future assessments of nearshore species, including copper rockfish.
12. Larval and smaller young-of-the-year copper rockfish can only be identified with certainty genetically. Existing sources of data (CalCOFI and Standard Monitoring Units for the Recruitment of Fishes [SMURFs]) where genetic samples can be analyzed would provide key information to inform spawning output estimates for copper rockfish.
13. Continue to improve historical catch reconstructions, including attempting to quantify uncertainty with these and other historical data.
14. Existing catch estimates within Recreational Fisheries Information Network (RecFIN) that are currently assigned only to "rockfish, general" should be investigated to determine if these removals can be assigned to specific species.

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## 7 Tables

**Table 1:** Catch (mt) by fleet and the summed total catch (mt).

Year	Commercial Dead	Commercial Live	CPFV	PR	Total Catch
1916	0.1	0.0	0.0	0.0	0.1
1917	0.2	0.0	0.0	0.0	0.2
1918	0.2	0.0	0.0	0.0	0.2
1919	0.1	0.0	0.0	0.0	0.1
1920	0.1	0.0	0.0	0.0	0.1
1921	0.1	0.0	0.0	0.0	0.1
1922	0.1	0.0	0.0	0.0	0.1
1923	0.1	0.0	0.0	0.0	0.1
1924	0.2	0.0	0.0	0.0	0.2
1925	0.2	0.0	0.0	0.0	0.2
1926	0.2	0.0	0.0	0.0	0.2
1927	0.2	0.0	0.0	0.0	0.2
1928	0.2	0.0	0.0	0.0	0.2
1929	0.2	0.0	0.0	0.0	0.2
1930	0.2	0.0	0.0	0.1	0.3
1931	0.2	0.0	0.0	0.1	0.3
1932	0.2	0.0	0.0	0.1	0.3
1933	0.0	0.0	0.0	0.1	0.2
1934	0.1	0.0	0.0	0.1	0.3
1935	0.4	0.0	0.0	0.2	0.6
1936	0.2	0.0	0.0	0.2	0.4
1937	0.9	0.0	0.0	0.2	1.2
1938	0.4	0.0	0.1	0.2	0.7
1939	0.2	0.0	0.1	0.2	0.5
1940	0.4	0.0	0.0	0.1	0.5
1941	0.4	0.0	0.0	0.1	0.6
1942	0.0	0.0	0.0	0.1	0.1
1943	0.1	0.0	0.0	0.1	0.2
1944	0.0	0.0	0.0	0.0	0.1
1945	0.1	0.0	0.0	0.1	0.2
1946	0.0	0.0	0.0	0.1	0.2
1947	0.0	0.0	0.3	0.4	0.7
1948	0.1	0.0	0.7	1.1	1.8
1949	0.2	0.0	0.8	1.3	2.3
1950	0.3	0.0	1.3	1.6	3.2
1951	3.7	0.0	0.8	1.4	5.8
1952	1.5	0.0	1.2	1.7	4.5
1953	0.5	0.0	1.6	2.0	4.1
1954	0.2	0.0	3.7	4.6	8.6

**Table 1:** Catch (mt) by fleet and the summed total catch (mt). (*continued*)

Year	Commercial Dead	Commercial Live	CPFV	PR	Total Catch
1955	0.0	0.0	8.5	8.2	16.7
1956	0.2	0.0	8.6	9.5	18.3
1957	0.4	0.0	4.8	5.6	10.8
1958	0.8	0.0	6.3	3.8	10.9
1959	0.5	0.0	3.2	2.2	5.9
1960	0.8	0.0	3.7	2.3	6.8
1961	2.5	0.0	4.5	2.6	9.6
1962	1.4	0.0	2.6	2.5	6.5
1963	1.2	0.0	3.2	2.5	7.0
1964	0.6	0.0	7.6	3.6	11.8
1965	1.4	0.0	6.6	9.3	17.3
1966	1.1	0.0	24.0	18.6	43.7
1967	2.7	0.0	20.2	27.8	50.6
1968	1.5	0.0	22.6	35.1	59.2
1969	0.3	0.0	11.7	34.9	47.0
1970	0.2	0.0	15.8	53.5	69.5
1971	0.4	0.0	12.9	53.5	66.8
1972	0.5	0.0	17.2	74.5	92.2
1973	0.6	0.0	18.8	92.1	111.5
1974	0.8	0.0	22.6	114.8	138.1
1975	1.5	0.0	22.8	117.8	142.1
1976	2.0	0.0	17.3	97.6	116.9
1977	2.1	0.0	14.0	93.0	109.0
1978	2.7	0.0	13.8	91.4	108.0
1979	4.9	0.0	15.5	131.3	151.7
1980	4.4	0.0	18.1	125.4	147.9
1981	4.3	0.0	38.3	43.0	85.6
1982	5.5	0.0	76.3	74.9	156.7
1983	4.4	0.0	26.6	51.0	82.0
1984	3.7	0.0	24.1	63.6	91.4
1985	4.1	0.0	26.6	85.0	115.7
1986	4.0	0.0	40.2	57.0	101.2
1987	3.5	0.0	24.8	50.0	78.3
1988	4.9	0.0	23.1	24.2	52.2
1989	3.8	0.0	32.8	16.9	53.4
1990	2.8	0.0	26.9	30.4	60.0
1991	8.7	0.0	19.4	24.4	52.6
1992	3.4	0.0	11.9	18.5	33.8
1993	3.6	0.0	6.2	10.2	20.0
1994	7.2	0.1	21.8	33.4	62.5
1995	28.5	3.0	7.8	11.9	51.2

**Table 1:** Catch (mt) by fleet and the summed total catch (mt). *(continued)*

Year	Commercial Dead	Commercial Live	CPFV	PR	Total Catch
1996	33.3	2.6	43.4	17.9	97.1
1997	32.6	3.9	2.2	4.1	42.8
1998	25.0	3.3	16.3	10.2	54.8
1999	0.3	0.5	36.5	12.5	49.8
2000	2.4	2.3	6.1	16.6	27.5
2001	1.2	2.5	6.4	10.4	20.5
2002	2.5	1.7	2.5	7.6	14.4
2003	0.2	0.3	7.1	9.9	17.5
2004	1.7	1.4	9.5	4.2	16.8
2005	1.0	0.7	24.3	3.8	29.8
2006	0.5	0.6	6.6	6.0	13.7
2007	0.4	0.4	20.1	11.4	32.3
2008	0.5	0.4	16.0	10.0	26.9
2009	0.6	1.3	15.5	7.5	24.9
2010	0.1	1.4	14.7	7.1	23.4
2011	0.2	1.2	34.9	8.5	44.8
2012	1.2	1.7	39.9	8.3	51.0
2013	1.3	2.7	61.6	14.0	79.5
2014	1.8	2.3	47.6	10.0	61.7
2015	2.1	4.1	67.0	9.0	82.2
2016	2.1	3.6	82.2	11.1	99.0
2017	1.7	2.8	70.6	11.7	86.9
2018	2.9	2.2	82.0	14.2	101.3
2019	2.7	3.1	60.2	14.7	80.7
2020	3.5	3.6	43.4	19.7	70.3
2021	2.7	1.9	37.8	8.3	50.7
2022	0.7	0.2	14.1	4.5	19.5

**Table 2:** The species-specific Overfishing Limit (OFL) and Annual Catch Limit (ACL) allocated to California and the total catch (mt) in California waters by year.

Year	OFL (mt)	ACL (mt)	Catch (mt)
2012	163.2	136.2	86.0
2013	148.0	123.4	105.2
2014	148.0	123.4	98.7
2015	303.8	277.3	147.6
2016	286.9	262.0	165.3
2017	313.7	286.4	225.5
2018	319.6	291.8	203.7
2019	325.1	296.8	182.6
2020	330.4	301.6	173.4
2021	249.8	206.4	127.8
2022	249.5	204.0	66.7

**Table 3:** Ratio estimates of total rockfish landings north and south of Point Conception. "Ratio years" are the range of years over which ratio estimates were calculated. Sources include the NMFS SWFSC ERD Live Access Server and several volumes of the CDFG Fish Bulletin series.

Year	Ratio	Ratio Years
1916	0.33	1928-33
1917	0.33	1928-33
1918	0.33	1928-33
1919	0.33	1928-33
1920	0.33	1928-33
1921	0.33	1928-33
1922	0.33	1928-33
1923	0.33	1928-33
1924	0.33	1928-33
1925	0.33	1928-33
1926	0.33	1928-33
1927	0.33	1928-33
1928	0.33	1949-51
1929	0.33	1949-51
1930	0.33	1949-51
1931	0.33	1949-51
1932	0.33	1949-51
1933	0.33	1949-51
1934	0.33	1949-51
1935	0.33	1949-51
1936	0.33	1949-51
1937	0.33	1949-51
1938	0.33	1949-51
1939	0.33	1949-51
1940	0.33	1949-51
1941	0.33	1949-51
1942	0.33	1949-51
1943	0.33	1949-51
1944	0.33	1949-51
1945	0.33	1949-51
1946	0.33	1949-51
1947	0.33	1949-51
1948	0.33	1949-51
1949	0.30	data
1950	0.19	data
1951	0.44	data
1952	0.46	1949-51
1953	0.31	1954-57
1954	0.14	data

**Table 3:** Ratio estimates of total rockfish landings north and south of Point Conception. "Ratio years" are the range of years over which ratio estimates were calculated. Sources include the NMFS SWFSC ERD Live Access Server and several volumes of the CDFG Fish Bulletin series. (*continued*)

Year	Ratio	Ratio Years
1955	0.01	data
1956	0.06	data
1957	0.10	data
1958	0.14	1954-57
1959	0.24	1954-57
1960	0.23	1954-57
1961	0.44	1954-57
1962	0.28	data
1963	0.25	data
1964	0.19	data
1965	0.37	data
1966	0.27	data
1967	0.38	data
1968	0.46	data



**Table 4:** Summary of the number of trips and length samples for fish landed dead by commercial fisheries.

Year	Trips	Lengths
1983	1	2
1984	5	18
1985	5	27
1986	9	34
1987	5	20
1988	2	23
1989	6	24
1992	1	2
1994	3	12
1995	20	187
1996	16	116
1997	29	409
1998	41	542
1999	6	88
2000	1	21
2002	2	31
2003	1	22
2006	1	15
2012	2	5
2013	5	19
2014	10	56
2015	9	76
2016	10	145
2017	7	119
2018	5	45
2019	6	49
2020	2	4
2021	3	24
2022	5	27

**Table 5:** Summary of the number of trips and length samples for fish landed live by commercial fisheries.

Year	Trips	Lengths
1999	2	20
2001	1	12
2002	2	16
2003	2	41
2009	1	25
2010	2	51
2011	1	16
2012	2	6
2015	6	136
2016	3	73
2017	5	134
2018	1	23
2022	1	4

**Table 6:** Summary of the CPFV catch data in CRFS by CDFW district south of Point Conception.

Year	District 2 (Channel)	District 1 (South)	Percent District 2	Percent District 1
2005	18.2	6.1	0.75	0.25
2006	4.3	2.4	0.64	0.36
2007	17.3	2.8	0.86	0.14
2008	13.3	2.6	0.83	0.17
2009	12.5	3.0	0.81	0.19
2010	12.8	1.9	0.87	0.13
2011	28.6	6.3	0.82	0.18
2012	34.4	5.5	0.86	0.14
2013	50.3	11.4	0.82	0.18
2014	39.7	7.9	0.83	0.17
2015	56.5	10.5	0.84	0.16
2016	68.5	13.7	0.83	0.17
2017	59.7	10.9	0.85	0.15
2018	75.5	6.5	0.92	0.08
2019	41.7	18.6	0.69	0.31
2020	3.3	7.0	0.32	0.68
2021	8.8	2.4	0.79	0.21
2022	12.0	2.1	0.85	0.15

**Table 7:** Summary of the recreational length samples and estimated trips for the CPFV and PR fleets.

Year	Source	CPFV Trips	CPFV Samples	PR Trips	PR Samples
1975	COLLINS-CROOKE	87	346	-	-
1976	COLLINS-CROOKE	123	441	-	-
1977	COLLINS-CROOKE	98	377	-	-
1978	COLLINS-CROOKE	118	1041	-	-
1980	MRFSS	91	226	80	231
1981	MRFSS	53	71	32	105
1982	MRFSS	63	111	65	190
1983	MRFSS	59	147	27	80
1984	ALLY	10	163	-	-
1984	MRFSS	70	106	20	47
1985	ALLY	14	399	-	-
1985	MRFSS	77	131	34	92
1986	ALLY	15	313	-	-
1986	MRFSS	61	105	16	63
1987	ALLY	16	806	-	-
1987	MRFSS	5	5	1	1
1988	ALLY	17	471	-	-
1988	MRFSS	40	84	17	48
1989	ALLY	19	732	-	-
1989	MRFSS	6	6	4	7
1993	MRFSS	29	36	13	17
1994	MRFSS	29	100	27	84
1995	MRFSS	21	31	15	44
1996	MRFSS	91	140	20	41
1997	MRFSS	9	10	8	9
1998	MRFSS	98	157	11	26
1999	MRFSS	208	383	31	50
2000	MRFSS	99	159	21	51
2001	MRFSS	50	57	12	19
2002	MRFSS	72	89	15	32
2003	MRFSS	118	266	36	64
2004	CRFS	68	189	83	208
2005	CRFS	96	449	109	360
2006	CRFS	187	686	169	545
2007	CRFS	205	943	193	830
2008	CRFS	195	1026	154	722
2009	CRFS	181	827	142	459
2010	CRFS	159	580	102	251
2011	CRFS	234	1287	99	235
2012	CRFS	218	2320	83	193
2013	CRFS	291	3345	182	489
2014	CRFS	230	1806	157	391
2015	CRFS	208	1958	110	228

**Table 7:** Summary of the recreational length samples and estimated trips for the CPFV and PR fleets. (*continued*)

Year	Source	CPFV Trips	CPFV Samples	PR Trips	PR Samples
2016	CRFS	193	1783	162	360
2017	CRFS	175	1411	132	300
2018	CRFS	139	1305	120	285
2019	CRFS	145	1125	139	296
2020	CRFS	8	82	7	13
2021	CRFS	54	183	33	69
2022	CRFS	78	243	65	141

**Table 8:** Summary of the total CPFV recreational length samples and percentage collected in district 1 and 2.

Year	District 2 (Channel)	District 1 (South)	District 2 Percent	District 1 Percent
2004	130	59	0.69	0.31
2005	305	144	0.68	0.32
2006	432	255	0.63	0.37
2007	661	282	0.70	0.30
2008	675	351	0.66	0.34
2009	537	290	0.65	0.35
2010	393	187	0.68	0.32
2011	999	288	0.78	0.22
2012	2031	289	0.88	0.12
2013	2604	741	0.78	0.22
2014	1287	519	0.71	0.29
2015	1405	553	0.72	0.28
2016	1255	528	0.70	0.30
2017	1033	378	0.73	0.27
2018	1045	260	0.80	0.20
2019	843	282	0.75	0.25
2020	42	40	0.51	0.49
2021	109	74	0.60	0.40
2022	154	89	0.63	0.37

**Table 9:** The total number of drifts, length, and age samples collected by year from the CCFRP Hook and Line survey south of Point Conception.

Year	Drifts	Lengths	Ages
2017	44	289	0
2018	61	400	0
2019	62	454	0
2020	84	489	0
2021	84	402	0
2022	64	271	52

**Table 10:** Positive samples of copper rockfish in the NWFSC Hook and Line survey by year where the number of samples is equal to the total number of sets across all sites sampled that year.

Year	Positive Samples	Samples	Percent Positive
2004	33	373	9%
2005	70	447	16%
2006	60	453	13%
2007	80	495	16%
2008	67	596	11%
2009	106	597	18%
2010	25	604	4%
2011	56	551	10%
2012	63	604	10%
2013	46	599	8%
2014	53	803	7%
2015	99	950	10%
2016	109	918	12%
2017	75	985	8%
2018	108	1004	11%
2019	67	1004	7%
2021	34	988	3%
2022	62	988	6%



**Table 11:** Positive samples of copper rockfish in the NWFSC Hook and Line survey by depth bin (m) where the value in the depth column is the lower depth bound.

Depth (m)	Positive Samples	Samples	Percent Positive
(0-30]	1	7	14%
(30-40]	15	376	4%
(40-50]	150	310	48%
(50-60]	100	428	23%
(60-70]	300	1512	20%
(70-80]	338	1856	18%
(80-90]	275	1498	18%
(90-100]	17	1269	1%
(100-110]	16	809	2%
(110-120]	1	1046	0%
(120-130]	0	853	0%
(130-140]	0	619	0%
(140-150]	0	685	0%
(150-160]	0	572	0%
(160-170]	0	374	0%
(170-180]	0	225	0%
(180-190]	0	210	0%
(190-200]	0	112	0%
(200-201]	0	84	0%
(210-220]	0	40	0%
(220-230]	0	68	0%
(230-240]	0	4	0%
240+	0	2	0%

**Table 12:** Summary of the number of observations by year and unique drops between sites outside the CCAs and inside the CCAs for copper rockfish from the NWFSC Hook and Line survey.

Year	Drops	Observations - Outside	Observations - CCA
2004	25	33	-
2005	32	70	-
2006	31	58	-
2007	35	77	-
2008	45	67	-
2009	51	104	-
2010	19	24	-
2011	43	56	-
2012	40	63	-
2013	39	46	-
2014	13	-	14
2014	30	38	-
2015	12	-	14
2015	60	84	-
2016	14	-	16
2016	62	92	-
2017	6	-	6
2017	49	69	-
2018	13	-	16
2018	43	88	-
2019	16	-	18
2019	37	46	-
2021	7	-	9
2021	23	25	-
2022	5	-	8
2022	41	53	-

**Table 13:** Summary of the number of observations by year and unique drops between sites open to fishing (outside) and sites within either CCA areas with no take or MPAs (closed) for copper rockfish from the NWFSC Hook and Line survey.

Year	Drops	Observations - Outside	Observations - Closed
2004	25	33	-
2005	32	70	-
2006	31	58	-
2007	35	77	-
2008	45	67	-
2009	51	104	-
2010	19	24	-
2011	1	-	1
2011	42	55	-
2012	11	-	12
2012	29	51	-
2013	12	-	14
2013	27	32	-
2014	9	-	10
2014	34	42	-
2015	13	-	21
2015	59	77	-
2016	13	-	15
2016	63	93	-
2017	15	-	20
2017	40	55	-
2018	13	-	14
2018	43	90	-
2019	12	-	13
2019	41	51	-
2021	12	-	14
2021	18	20	-
2022	10	-	12
2022	36	49	-

**Table 14:** Number of length and age samples collected by year and the calculated effective sample size based on the number of positive drops by site for the NWFSC Hook and Line survey.

Year	Effective Sample Size	Lengths	Ages
2004	25	33	33
2005	32	70	68
2006	31	58	58
2007	35	77	75
2008	45	67	67
2009	51	104	101
2010	19	24	23
2011	43	56	53
2012	40	63	57
2013	39	46	46
2014	43	52	47
2015	72	98	95
2016	76	108	107
2017	55	75	69
2018	56	104	101
2019	53	64	61
2021	30	34	31
2022	46	61	59

**Table 15:** Available age data by year and source used in the growth fleets.

Year	Source	Number of Ages
2004	NWFSC WCGBT	22
2005	NWFSC WCGBT	13
2005	Pearson Research	3
2006	NWFSC WCGBT	3
2006	Pearson Research	10
2007	NWFSC WCGBT	9
2007	Pearson Research	20
2008	NWFSC WCGBT	18
2009	NWFSC WCGBT	21
2010	NWFSC WCGBT	6
2011	NWFSC WCGBT	11
2012	NWFSC WCGBT	99
2013	NWFSC WCGBT	26
2014	NWFSC WCGBT	16
2015	NWFSC WCGBT	28
2016	NWFSC WCGBT	75
2017	NWFSC WCGBT	90
2018	NWFSC WCGBT	40
2019	NWFSC WCGBT	20
2021	NWFSC WCGBT	78
2022	NWFSC WCGBT	46
2022	SWFSC/CPFV Coop.	506

**Table 16:** All and filtered observations by year and sampling institution for PISCO.

Year	UCSC Raw Count	UCSC Filtered Count	UCSB Raw Count	UCSB Filtered Count
1999	2	NA	7	NA
2000	1	NA	11	NA
2001	6	4	4	NA
2002	25	21	8	NA
2003	34	25	73	NA
2004	30	9	65	19
2005	40	6	45	18
2006	27	12	51	25
2007	17	4	58	19
2008	21	5	44	22
2009	20	7	60	29
2010	34	10	85	32
2011	36	1	44	20
2012	9	4	77	39
2013	40	17	59	23
2014	50	28	50	39
2015	51	16	18	15
2016	29	17	51	45
2017	30	11	28	22
2018	37	15	42	28
2019	26	15	41	37
2020	58	26	35	29
2021	23	12	37	27

**Table 17:** The total number of tows, positive tows, estimated number of copper rockfish caught, and the number of lengths and ages collected by year south of Point Conception by the NWFSC WCGBT survey.

Year	Tows	Positive Tows	Numbers Caught	Lengths	Ages
2003	21	4	14	13	0
2004	25	1	22	22	22
2005	33	3	13	13	13
2006	32	1	3	3	3
2007	38	4	12	12	11
2008	37	4	17	17	17
2009	39	2	21	21	21
2010	36	4	6	6	6
2011	37	3	11	11	11
2012	42	16	1408	237	99
2013	19	6	90	90	26
2014	32	7	17	17	17
2015	37	5	109	103	29
2016	38	8	94	94	75
2017	32	10	116	115	90
2018	38	6	50	50	41
2019	20	4	22	22	20
2021	44	10	78	78	78
2022	40	8	46	46	46

**Table 18:** Specifications and structure of the base model.

Model Setup	Base Model
Starting year	1916
<u>Population characteristics</u>	
Maximum age	50
Sex	2
Population lengths	4-54 cm by 1 cm bins
Summary biomass (mt)	Age 3+
<u>Data characteristics</u>	
Data lengths	10-54 cm by 2 cm bins
Data ages	0-50 ages
Minimum age for growth calculations	2
Maximum age for growth calculations	20
First mature age	0
Starting year of estimated recruitment in main period	1965
<u>Fishery characteristics</u>	
Fishing mortality method	Hybrid F
Maximum F	3.5
Catchability	Analytical estimate
Commercial Dead Selectivity	Length-Based Logistic
Commercial Live Selectivity	Length-Based Double Normal
Recreational CPFV Selectivity	Length-Based Double Normal
Recreational PR Selectivity	Length-Based Double Normal
CCFRP Selectivity	Length-Based Double Normal
NWFSC Hook and Line Selectivity	Length-Based Logistic
WCGBT Growth Selectivity	Length-Based Double Normal
Coop. Growth Selectivity	Length-Based Double Normal
<u>Fishery time blocks</u>	
Recreational CPFV	1916-1999, 2000-2003, 2004-2022
Recreational PR	1916-1999, 2000-2003, 2004-2022



**Table 19:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD).

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM uniform Fem GP 1	0.108	-2	(0.05, 0.4)	NA	NA	Log Norm (-2.2256, 0.31)
L at Amin Fem GP 1	15.349	2	(10, 25)	OK	0.586	None
L at Amax Fem GP 1	46.829	2	(35, 54)	OK	0.328	None
VonBert K Fem GP 1	0.194	2	(0.03, 0.35)	OK	0.010	None
CV young Fem GP 1	0.197	2	(0.01, 1)	OK	0.011	None
CV old Fem GP 1	0.059	2	(0.01, 1)	OK	0.004	None
Wtlen 1 Fem GP 1	9.6e-06	-9	(0, 0.1)	NA	NA	None
Wtlen 2 Fem GP 1	3.19	-9	(2, 4)	NA	NA	None
Mat50% Fem GP 1	34.05	-9	(10, 54)	NA	NA	None
Mat slope Fem GP 1	-0.425	-9	(-1, 0)	NA	NA	None
Eggs scalar Fem GP 1	3.36e-07	-9	(-3, 3)	NA	NA	None
Eggs exp len Fem GP 1	3.679	-9	(-3, 4)	NA	NA	None
NatM uniform Mal GP 1	0.108	-2	(0.05, 0.4)	NA	NA	Log Norm (-2.2256, 0.31)
L at Amin Mal GP 1	15.722	2	(10, 25)	OK	0.639	None
L at Amax Mal GP 1	45.415	2	(35, 54)	OK	0.331	None
VonBert K Mal GP 1	0.218	2	(0.03, 0.35)	OK	0.012	None
CV young Mal GP 1	0.203	2	(0.01, 1)	OK	0.012	None
CV old Mal GP 1	0.06	2	(0.01, 1)	OK	0.004	None
Wtlen 1 Mal GP 1	1.11e-05	-9	(0, 0.1)	NA	NA	None
Wtlen 2 Mal GP 1	3.15	-9	(2, 4)	NA	NA	None
CohortGrowDev	1	-9	(0, 1)	NA	NA	None
FracFemale GP 1	0.5	-9	(0.01, 0.99)	NA	NA	None
SR LN(R0)	5.486	1	(2, 20)	OK	0.095	None
SR BH steep	0.72	-7	(0.22, 1)	NA	NA	Full Beta (0.72, 0.16)
SR sigmaR	0.6	-99	(0.05, 1.5)	NA	NA	None
SR regime	0	-99	(-2, 2)	NA	NA	None
SR autocorr	0	-99	(0, 0)	NA	NA	None
Early InitAge 36	0	2	(-5, 5)	act	0.600	dev (NA, NA)

**Table 19:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Early InitAge 35	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 34	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 33	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 32	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 31	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 30	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 29	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 28	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 27	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 26	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 25	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 24	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 23	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 22	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 21	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 20	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 19	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 18	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 17	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 16	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 15	0	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 14	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 13	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 12	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 11	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 10	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 9	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 8	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 7	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)

**Table 19:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Early InitAge 6	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 5	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 4	0.001	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 3	0.002	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 2	0.002	2	(-5, 5)	act	0.600	dev (NA, NA)
Early InitAge 1	0.002	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1916	0.002	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1917	0.002	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1918	0.002	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1919	0.003	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1920	0.003	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1921	0.003	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1922	0.003	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1923	0.004	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1924	0.004	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1925	0.004	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1926	0.005	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1927	0.005	2	(-5, 5)	act	0.601	dev (NA, NA)
Early RecrDev 1928	0.005	2	(-5, 5)	act	0.602	dev (NA, NA)
Early RecrDev 1929	0.006	2	(-5, 5)	act	0.602	dev (NA, NA)
Early RecrDev 1930	0.006	2	(-5, 5)	act	0.602	dev (NA, NA)
Early RecrDev 1931	0.007	2	(-5, 5)	act	0.602	dev (NA, NA)
Early RecrDev 1932	0.008	2	(-5, 5)	act	0.602	dev (NA, NA)
Early RecrDev 1933	0.008	2	(-5, 5)	act	0.602	dev (NA, NA)
Early RecrDev 1934	0.009	2	(-5, 5)	act	0.603	dev (NA, NA)
Early RecrDev 1935	0.01	2	(-5, 5)	act	0.603	dev (NA, NA)
Early RecrDev 1936	0.011	2	(-5, 5)	act	0.603	dev (NA, NA)
Early RecrDev 1937	0.012	2	(-5, 5)	act	0.603	dev (NA, NA)
Early RecrDev 1938	0.013	2	(-5, 5)	act	0.604	dev (NA, NA)

**Table 19:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Early RecrDev 1939	0.014	2	(-5, 5)	act	0.604	dev (NA, NA)
Early RecrDev 1940	0.015	2	(-5, 5)	act	0.604	dev (NA, NA)
Early RecrDev 1941	0.016	2	(-5, 5)	act	0.604	dev (NA, NA)
Early RecrDev 1942	0.018	2	(-5, 5)	act	0.605	dev (NA, NA)
Early RecrDev 1943	0.019	2	(-5, 5)	act	0.605	dev (NA, NA)
Early RecrDev 1944	0.021	2	(-5, 5)	act	0.606	dev (NA, NA)
Early RecrDev 1945	0.022	2	(-5, 5)	act	0.606	dev (NA, NA)
Early RecrDev 1946	0.024	2	(-5, 5)	act	0.606	dev (NA, NA)
Early RecrDev 1947	0.026	2	(-5, 5)	act	0.607	dev (NA, NA)
Early RecrDev 1948	0.028	2	(-5, 5)	act	0.607	dev (NA, NA)
Early RecrDev 1949	0.029	2	(-5, 5)	act	0.608	dev (NA, NA)
Early RecrDev 1950	0.031	2	(-5, 5)	act	0.608	dev (NA, NA)
Early RecrDev 1951	0.033	2	(-5, 5)	act	0.608	dev (NA, NA)
Early RecrDev 1952	0.034	2	(-5, 5)	act	0.608	dev (NA, NA)
Early RecrDev 1953	0.035	2	(-5, 5)	act	0.608	dev (NA, NA)
Early RecrDev 1954	0.036	2	(-5, 5)	act	0.608	dev (NA, NA)
Early RecrDev 1955	0.036	2	(-5, 5)	act	0.608	dev (NA, NA)
Early RecrDev 1956	0.035	2	(-5, 5)	act	0.607	dev (NA, NA)
Early RecrDev 1957	0.034	2	(-5, 5)	act	0.607	dev (NA, NA)
Early RecrDev 1958	0.034	2	(-5, 5)	act	0.606	dev (NA, NA)
Early RecrDev 1959	0.035	2	(-5, 5)	act	0.606	dev (NA, NA)
Early RecrDev 1960	0.039	2	(-5, 5)	act	0.606	dev (NA, NA)
Early RecrDev 1961	0.045	2	(-5, 5)	act	0.608	dev (NA, NA)
Early RecrDev 1962	0.054	2	(-5, 5)	act	0.610	dev (NA, NA)
Early RecrDev 1963	0.069	2	(-5, 5)	act	0.614	dev (NA, NA)
Early RecrDev 1964	0.098	2	(-5, 5)	act	0.621	dev (NA, NA)
Main RecrDev 1965	0.156	2	(-5, 5)	act	0.637	dev (NA, NA)
Main RecrDev 1966	0.255	2	(-5, 5)	act	0.664	dev (NA, NA)
Main RecrDev 1967	0.387	2	(-5, 5)	act	0.701	dev (NA, NA)

**Table 19:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Main RecrDev 1968	0.469	2	(-5, 5)	act	0.701	dev (NA, NA)
Main RecrDev 1969	0.314	2	(-5, 5)	act	0.643	dev (NA, NA)
Main RecrDev 1970	0.127	2	(-5, 5)	act	0.573	dev (NA, NA)
Main RecrDev 1971	-0.01	2	(-5, 5)	act	0.536	dev (NA, NA)
Main RecrDev 1972	0.156	2	(-5, 5)	act	0.505	dev (NA, NA)
Main RecrDev 1973	0.25	2	(-5, 5)	act	0.482	dev (NA, NA)
Main RecrDev 1974	0.044	2	(-5, 5)	act	0.492	dev (NA, NA)
Main RecrDev 1975	-0.08	2	(-5, 5)	act	0.483	dev (NA, NA)
Main RecrDev 1976	-0.085	2	(-5, 5)	act	0.485	dev (NA, NA)
Main RecrDev 1977	0.041	2	(-5, 5)	act	0.450	dev (NA, NA)
Main RecrDev 1978	-0.066	2	(-5, 5)	act	0.449	dev (NA, NA)
Main RecrDev 1979	-0.277	2	(-5, 5)	act	0.443	dev (NA, NA)
Main RecrDev 1980	-0.393	2	(-5, 5)	act	0.437	dev (NA, NA)
Main RecrDev 1981	-0.309	2	(-5, 5)	act	0.418	dev (NA, NA)
Main RecrDev 1982	-0.38	2	(-5, 5)	act	0.423	dev (NA, NA)
Main RecrDev 1983	-0.437	2	(-5, 5)	act	0.435	dev (NA, NA)
Main RecrDev 1984	-0.226	2	(-5, 5)	act	0.461	dev (NA, NA)
Main RecrDev 1985	0.176	2	(-5, 5)	act	0.461	dev (NA, NA)
Main RecrDev 1986	0.132	2	(-5, 5)	act	0.527	dev (NA, NA)
Main RecrDev 1987	0.065	2	(-5, 5)	act	0.554	dev (NA, NA)
Main RecrDev 1988	0.156	2	(-5, 5)	act	0.564	dev (NA, NA)
Main RecrDev 1989	0.146	2	(-5, 5)	act	0.565	dev (NA, NA)
Main RecrDev 1990	0.355	2	(-5, 5)	act	0.559	dev (NA, NA)
Main RecrDev 1991	0.469	2	(-5, 5)	act	0.517	dev (NA, NA)
Main RecrDev 1992	0.155	2	(-5, 5)	act	0.488	dev (NA, NA)
Main RecrDev 1993	-0.271	2	(-5, 5)	act	0.454	dev (NA, NA)
Main RecrDev 1994	-0.34	2	(-5, 5)	act	0.420	dev (NA, NA)
Main RecrDev 1995	-0.181	2	(-5, 5)	act	0.369	dev (NA, NA)
Main RecrDev 1996	-0.436	2	(-5, 5)	act	0.379	dev (NA, NA)

**Table 19:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Main RecrDev 1997	-0.58	2	(-5, 5)	act	0.380	dev (NA, NA)
Main RecrDev 1998	-0.355	2	(-5, 5)	act	0.362	dev (NA, NA)
Main RecrDev 1999	0.483	2	(-5, 5)	act	0.200	dev (NA, NA)
Main RecrDev 2000	-0.158	2	(-5, 5)	act	0.302	dev (NA, NA)
Main RecrDev 2001	-0.552	2	(-5, 5)	act	0.310	dev (NA, NA)
Main RecrDev 2002	-0.049	2	(-5, 5)	act	0.214	dev (NA, NA)
Main RecrDev 2003	0.443	2	(-5, 5)	act	0.163	dev (NA, NA)
Main RecrDev 2004	-0.335	2	(-5, 5)	act	0.296	dev (NA, NA)
Main RecrDev 2005	-0.005	2	(-5, 5)	act	0.203	dev (NA, NA)
Main RecrDev 2006	-1.007	2	(-5, 5)	act	0.354	dev (NA, NA)
Main RecrDev 2007	0.28	2	(-5, 5)	act	0.175	dev (NA, NA)
Main RecrDev 2008	0.236	2	(-5, 5)	act	0.208	dev (NA, NA)
Main RecrDev 2009	1.213	2	(-5, 5)	act	0.122	dev (NA, NA)
Main RecrDev 2010	1.266	2	(-5, 5)	act	0.121	dev (NA, NA)
Main RecrDev 2011	0.452	2	(-5, 5)	act	0.189	dev (NA, NA)
Main RecrDev 2012	0.749	2	(-5, 5)	act	0.159	dev (NA, NA)
Main RecrDev 2013	1.243	2	(-5, 5)	act	0.121	dev (NA, NA)
Main RecrDev 2014	-0.092	2	(-5, 5)	act	0.237	dev (NA, NA)
Main RecrDev 2015	-1.013	2	(-5, 5)	act	0.266	dev (NA, NA)
Main RecrDev 2016	-0.147	2	(-5, 5)	act	0.196	dev (NA, NA)
Main RecrDev 2017	-0.876	2	(-5, 5)	act	0.292	dev (NA, NA)
Main RecrDev 2018	-1.251	2	(-5, 5)	act	0.335	dev (NA, NA)
Main RecrDev 2019	-1.139	2	(-5, 5)	act	0.385	dev (NA, NA)
Main RecrDev 2020	-0.627	2	(-5, 5)	act	0.473	dev (NA, NA)
Late RecrDev 2021	0	NA	(NA, NA)	NA	NA	dev (NA, NA)
Late RecrDev 2022	0	NA	(NA, NA)	NA	NA	dev (NA, NA)
LnQ base Rec Private(4)	-8.16	-1	(-15, 15)	NA	NA	None
Q extraSD Rec Private(4)	0.193	4	(0.001, 0.5)	OK	0.056	None
LnQ base CCFRP(5)	-11.287	-1	(-15, 15)	NA	NA	None

**Table 19:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Q extraSD CCFRP(5)	0.042	4	(0.001, 0.5)	OK	0.092	None
LnQ base NWFSC HKL(7)	-5.928	-1	(-15, 15)	NA	NA	None
Q extraSD NWFSC HKL(7)	0.035	4	(0.001, 0.5)	OK	0.086	None
LnQ base CRFS CPFV(8)	-10.346	-1	(-15, 15)	NA	NA	None
Q extraSD CRFS CPFV(8)	0.083	4	(0.001, 0.5)	OK	0.040	None
Size inflection Commercial dead(1)	30.756	4	(20, 53)	OK	1.097	None
Size 95%width Commercial dead(1)	7.311	4	(0.001, 50)	OK	1.410	None
Size DbLN peak Commercial live(2)	34.211	2	(15, 53)	OK	0.599	None
Size DbLN top logit Commercial live(2)	-6.842	-3	(-7, 7)	NA	NA	None
Size DbLN ascend se Commercial live(2)	3.038	3	(-10, 10)	OK	0.211	None
Size DbLN descend se Commercial live(2)	3.468	4	(-10, 10)	OK	0.259	None
Size DbLN start logit Commercial live(2)	-20	-9	(-20, 30)	NA	NA	None
Size DbLN end logit Commercial live(2)	-2.886	-4	(-10, 10)	NA	NA	None
Size DbLN peak Rec CPFV(3)	30.281	1	(15, 53)	OK	0.875	None
Size DbLN top logit Rec CPFV(3)	-6.935	-3	(-7, 7)	NA	NA	None
Size DbLN ascend se Rec CPFV(3)	3.988	3	(-10, 10)	OK	0.183	None
Size DbLN descend se Rec CPFV(3)	4.725	3	(-10, 10)	OK	0.352	None
Size DbLN start logit Rec CPFV(3)	-8.243	-9	(-20, 30)	NA	NA	None
Size DbLN end logit Rec CPFV(3)	-1.3	2	(-10, 10)	OK	0.402	None
Size DbLN peak Rec Private(4)	30.696	2	(15, 53)	OK	0.589	None
Size DbLN top logit Rec Private(4)	-6.935	-3	(-7, 7)	NA	NA	None
Size DbLN ascend se Rec Private(4)	3.62	3	(-10, 10)	OK	0.155	None
Size DbLN descend se Rec Private(4)	4.311	4	(-10, 10)	OK	0.268	None
Size DbLN start logit Rec Private(4)	-8.243	-9	(-20, 30)	NA	NA	None
Size DbLN end logit Rec Private(4)	-1.494	4	(-10, 10)	OK	0.348	None
Size DbLN peak CCFRP(5)	35.953	3	(15, 53)	OK	1.151	Normal (39.5, 3)
Size DbLN top logit CCFRP(5)	-6.898	-3	(-7, 7)	NA	NA	None
Size DbLN ascend se CCFRP(5)	4.456	3	(-10, 10)	OK	0.298	None
Size DbLN descend se CCFRP(5)	3.258	4	(-10, 10)	OK	0.436	None

**Table 19:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Size DblN start logit CCFRP(5)	-20	-9	(-20, 30)	NA	NA	None
Size DblN end logit CCFRP(5)	-4.186	-4	(-10, 10)	NA	NA	None
Size inflection NWFSC HKL(7)	33.444	4	(20, 53)	OK	0.920	None
Size 95%width NWFSC HKL(7)	9.492	4	(0.001, 50)	OK	0.863	None
Size DblN peak WCGBT Growth(9)	52.99	-2	(10, 53)	NA	NA	None
Size DblN top logit WCGBT Growth(9)	-0.189	-3	(-7, 7)	NA	NA	None
Size DblN ascend se WCGBT Growth(9)	4.904	3	(-10, 10)	OK	0.371	None
Size DblN descend se WCGBT Growth(9)	0.291	-4	(-10, 10)	NA	NA	None
Size DblN start logit WCGBT Growth(9)	-2.568	-4	(-20, 30)	NA	NA	None
Size DblN end logit WCGBT Growth(9)	10	-4	(-10, 10)	NA	NA	None
Size DblN peak COOP Growth(10)	29.177	2	(10, 53)	OK	11.566	None
Size DblN top logit COOP Growth(10)	-5.767	-3	(-7, 7)	NA	NA	None
Size DblN ascend se COOP Growth(10)	-1.205	3	(-10, 10)	OK	34.422	None
Size DblN descend se COOP Growth(10)	10	-4	(-10, 10)	NA	NA	None
Size DblN start logit COOP Growth(10)	-10.73	-4	(-20, 30)	NA	NA	None
Size DblN end logit COOP Growth(10)	10	-4	(-10, 10)	NA	NA	None
Size DblN peak Rec CPFV(3) BLK5repl 2000	33.78	3	(15, 55)	OK	2.028	None
Size DblN ascend se Rec CPFV(3) BLK5repl 2000	4.242	4	(-10, 10)	OK	0.410	None
Size DblN descend se Rec CPFV(3) BLK5repl 2000	3.989	5	(-10, 10)	OK	0.628	None
Size DblN end logit Rec CPFV(3) BLK5repl 2000	-3.702	-5	(-10, 10)	NA	NA	None
Size DblN peak Rec Private(4) BLK5repl 2000	31.592	3	(15, 55)	OK	1.625	None
Size DblN ascend se Rec Private(4) BLK5repl 2000	3.174	6	(-10, 10)	OK	0.708	None
Size DblN descend se Rec Private(4) BLK5repl 2000	3.604	-6	(-10, 10)	NA	NA	None
Size DblN end logit Rec Private(4) BLK5repl 2000	-2.024	-6	(-10, 10)	NA	NA	None



**Table 20:** Likelihood components by source.

Label	Total
TOTAL	2832.68
Catch	0.00
Equil catch	0.00
Survey	-33.42
Length comp	540.05
Age comp	2319.93
Recruitment	5.41
InitEQ Regime	0.00
Forecast Recruitment	0.00
Parm priors	0.70
Parm softbounds	0.00
Parm devs	0.00
Crash Pen	0.00

**Table 21:** Suggested data weights for each data weighting methodology by fleet and data type.

Fleet	Data Type	Francis	MI	Dirichlet
Commercial Dead	Lengths	0.42	0.65	0.99
Commercial Live	Lengths	0.81	0.55	0.97
CPFV	Lengths	0.22	0.55	0.99
PR	Lengths	0.35	0.59	0.99
CCFRP	Lengths	0.56	2.50	0.98
NWFSC HKL	Lengths	0.67	1.12	0.98
WCGBT Growth	Lengths	0.05	0.14	0.50
Coop. Growth	Lengths	2.63	0.48	0.98
Commercial Dead	Ages	0.53	0.53	0.89
CPFV	Ages	0.45	0.44	0.52
CCFRP	Ages	0.58	0.58	0.99
NWFSC HKL	Ages	1.00	0.62	0.99
WCGBT Growth	Ages	1.00	0.62	0.99
Coop. Growth	Ages	0.21	0.15	0.99

**Table 22:** Time series of population estimates from the base model for the sub-area south of Point Conception.

Year	Total Biomass (mt)	Spawn- ing Output	Total Biomass 3+ (mt)	Frac- tion Un- fished	Age-0 Re- cruits	Total Mortal- ity (mt)	1-SPR	Ex- ploita- tion Rate
1916	2018.26	201.16	2000.72	1.00	241.67	0.12	0.00	0.00
1917	2018.26	201.16	2000.73	1.00	241.71	0.19	0.00	0.00
1918	2018.22	201.15	2000.68	1.00	241.75	0.18	0.00	0.00
1919	2018.21	201.15	2000.67	1.00	241.80	0.11	0.00	0.00
1920	2018.30	201.15	2000.75	1.00	241.86	0.12	0.00	0.00
1921	2018.39	201.16	2000.84	1.00	241.92	0.10	0.00	0.00
1922	2018.53	201.17	2000.97	1.00	241.98	0.10	0.00	0.00
1923	2018.69	201.18	2001.13	1.00	242.05	0.13	0.00	0.00
1924	2018.84	201.19	2001.27	1.00	242.13	0.18	0.00	0.00
1925	2018.97	201.20	2001.40	1.00	242.21	0.20	0.00	0.00
1926	2019.11	201.20	2001.54	1.00	242.30	0.24	0.00	0.00
1927	2019.24	201.21	2001.66	1.00	242.40	0.20	0.00	0.00
1928	2019.44	201.22	2001.86	1.00	242.51	0.20	0.00	0.00
1929	2019.68	201.24	2002.08	1.00	242.63	0.22	0.00	0.00
1930	2019.93	201.26	2002.32	1.00	242.76	0.26	0.00	0.00
1931	2020.18	201.28	2002.57	1.00	242.90	0.25	0.00	0.00
1932	2020.47	201.30	2002.85	1.00	243.05	0.34	0.00	0.00
1933	2020.73	201.31	2003.10	1.00	243.21	0.21	0.00	0.00
1934	2021.15	201.35	2003.51	1.00	243.40	0.30	0.00	0.00
1935	2021.54	201.38	2003.88	1.00	243.59	0.60	0.00	0.00
1936	2021.69	201.38	2004.02	1.00	243.80	0.44	0.00	0.00
1937	2022.07	201.40	2004.39	1.00	244.03	1.19	0.01	0.00
1938	2021.80	201.35	2004.10	1.00	244.27	0.71	0.01	0.00
1939	2022.10	201.37	2004.38	1.00	244.54	0.49	0.00	0.00
1940	2022.71	201.41	2004.98	1.00	244.84	0.53	0.00	0.00
1941	2023.38	201.45	2005.63	1.00	245.16	0.59	0.00	0.00
1942	2024.11	201.50	2006.33	1.00	245.50	0.14	0.00	0.00
1943	2025.39	201.61	2007.59	1.00	245.87	0.20	0.00	0.00
1944	2026.71	201.72	2008.89	1.00	246.27	0.08	0.00	0.00
1945	2028.25	201.85	2010.40	1.00	246.69	0.16	0.00	0.00
1946	2029.82	201.99	2011.94	1.00	247.14	0.20	0.00	0.00
1947	2031.46	202.13	2013.55	1.01	247.60	0.74	0.01	0.00
1948	2032.64	202.23	2014.69	1.01	248.06	1.78	0.01	0.00
1949	2032.84	202.24	2014.86	1.01	248.51	2.32	0.02	0.00
1950	2032.61	202.20	2014.60	1.01	248.93	3.15	0.03	0.00
1951	2031.68	202.08	2013.64	1.01	249.31	5.84	0.04	0.00
1952	2028.44	201.69	2010.37	1.00	249.62	4.47	0.03	0.00

**Table 22:** Time series of population estimates from the base model for the sub-area south of Point Conception. (*continued*)

Year	Total Biomass (mt)	Spawn- ing Output	Total Biomass 3+ (mt)	Frac- tion Un- fished	Age-0 Re- cruits	Total Mortal- ity (mt)	1-SPR	Ex- ploita- tion Rate
1953	2026.82	201.48	2008.72	1.00	249.88	4.13	0.03	0.00
1954	2025.76	201.33	2007.64	1.00	250.01	8.56	0.07	0.00
1955	2020.28	200.78	2002.14	1.00	249.91	16.72	0.13	0.01
1956	2006.39	199.46	1988.24	0.99	249.62	18.31	0.14	0.01
1957	1991.05	197.96	1972.92	0.98	249.22	10.82	0.09	0.01
1958	1984.02	197.14	1965.91	0.98	249.03	10.86	0.09	0.01
1959	1977.58	196.36	1959.50	0.98	249.16	5.91	0.05	0.00
1960	1976.91	196.13	1958.84	0.98	250.11	6.77	0.06	0.00
1961	1975.93	195.92	1957.83	0.97	251.69	9.63	0.08	0.00
1962	1972.60	195.49	1954.42	0.97	253.93	6.55	0.05	0.00
1963	1972.97	195.42	1954.66	0.97	257.76	6.98	0.06	0.00
1964	1973.52	195.37	1955.02	0.97	265.18	11.76	0.09	0.01
1965	1969.87	194.91	1951.02	0.97	280.98	17.35	0.14	0.01
1966	1961.71	193.95	1942.18	0.96	310.06	43.74	0.31	0.02
1967	1928.28	190.51	1907.37	0.95	351.68	50.62	0.35	0.03
1968	1892.08	186.35	1868.89	0.93	379.34	59.24	0.40	0.03
1969	1854.19	181.46	1828.31	0.90	322.60	46.97	0.34	0.03
1970	1838.45	178.00	1811.89	0.89	265.86	69.55	0.46	0.04
1971	1807.30	173.18	1784.84	0.86	230.02	66.83	0.45	0.04
1972	1781.84	169.51	1763.07	0.84	269.84	92.19	0.55	0.05
1973	1727.76	164.57	1710.41	0.82	293.91	111.47	0.63	0.07
1974	1648.68	158.18	1628.80	0.79	237.21	138.13	0.72	0.08
1975	1538.02	148.78	1517.64	0.74	207.02	142.10	0.76	0.09
1976	1421.29	137.99	1404.56	0.69	203.10	116.88	0.72	0.08
1977	1329.42	128.99	1314.43	0.64	227.12	108.99	0.72	0.08
1978	1244.26	120.76	1229.18	0.60	201.28	107.97	0.73	0.09
1979	1159.14	112.64	1143.13	0.56	160.56	151.67	0.86	0.13
1980	1028.10	100.28	1014.18	0.50	139.53	147.88	0.88	0.15
1981	899.69	87.84	888.37	0.44	147.42	85.59	0.76	0.10
1982	834.50	80.95	824.28	0.40	134.35	156.68	0.93	0.19
1983	694.53	67.96	684.08	0.34	121.52	82.04	0.82	0.12
1984	629.67	61.30	620.10	0.30	145.55	91.40	0.88	0.15
1985	556.12	53.88	546.84	0.27	209.24	115.71	0.94	0.21
1986	459.52	44.29	447.98	0.22	187.71	101.22	0.95	0.23
1987	382.58	35.86	367.79	0.18	162.29	78.32	0.94	0.21
1988	337.12	29.75	323.92	0.15	164.29	52.22	0.87	0.16
1989	325.82	26.60	314.03	0.13	154.36	53.42	0.87	0.17
1990	318.38	24.55	306.60	0.12	182.50	60.04	0.89	0.20

**Table 22:** Time series of population estimates from the base model for the sub-area south of Point Conception. (*continued*)

Year	Total Biomass (mt)	Spawn- ing Output	Total Biomass 3+ (mt)	Frac- tion Un- fished	Age-0 Re- cruits	Total Mortal- ity (mt)	1-SPR	Ex- ploita- tion Rate
1991	306.38	22.90	294.72	0.11	197.14	52.57	0.85	0.18
1992	303.82	21.99	290.43	0.11	140.63	33.83	0.72	0.12
1993	323.26	22.84	309.92	0.11	93.08	19.98	0.52	0.06
1994	359.87	25.19	350.42	0.13	90.61	62.47	0.84	0.18
1995	351.58	25.15	344.85	0.13	105.71	51.23	0.78	0.15
1996	349.30	25.55	342.52	0.13	82.12	97.06	0.93	0.28
1997	293.19	22.26	285.93	0.11	66.36	42.80	0.77	0.15
1998	286.36	22.05	280.63	0.11	82.30	54.84	0.86	0.20
1999	263.51	20.61	258.31	0.10	183.23	49.76	0.88	0.19
2000	241.05	19.33	233.61	0.10	92.92	27.50	0.74	0.12
2001	241.70	19.30	229.88	0.10	62.34	20.50	0.65	0.09
2002	253.19	19.66	246.88	0.10	103.65	14.40	0.51	0.06
2003	273.13	20.70	267.86	0.10	173.39	17.50	0.53	0.07
2004	290.60	22.20	282.10	0.11	82.45	16.76	0.50	0.06
2005	310.14	24.00	298.95	0.12	119.10	29.84	0.69	0.10
2006	317.64	24.78	311.18	0.12	44.39	13.69	0.42	0.04
2007	341.06	26.75	333.44	0.13	166.37	32.28	0.68	0.10
2008	344.01	27.50	338.86	0.14	161.17	26.87	0.62	0.08
2009	351.32	28.59	338.96	0.14	435.34	24.86	0.59	0.07
2010	367.03	29.59	350.94	0.15	466.17	23.38	0.57	0.07
2011	400.46	30.51	368.74	0.15	209.16	44.79	0.76	0.12
2012	435.81	30.06	406.00	0.15	279.78	51.04	0.76	0.13
2013	483.96	30.41	467.44	0.15	460.73	79.54	0.83	0.17
2014	511.42	31.23	488.72	0.16	122.60	61.71	0.73	0.13
2015	557.65	34.70	529.71	0.17	50.87	82.18	0.79	0.16
2016	580.43	37.53	572.58	0.19	124.48	98.95	0.83	0.17
2017	569.50	39.19	564.72	0.19	62.66	86.86	0.80	0.15
2018	547.67	41.13	539.65	0.20	45.02	101.31	0.86	0.19
2019	489.84	40.17	485.57	0.20	51.27	80.70	0.85	0.17
2020	436.46	38.24	433.05	0.19	86.40	70.26	0.86	0.16
2021	383.10	35.22	378.72	0.18	165.61	50.73	0.82	0.13
2022	345.79	32.58	338.28	0.16	160.68	19.52	0.56	0.06
2023	343.79	32.06	331.85	0.16	159.66	26.80	0.68	0.08
2024	341.81	30.58	330.18	0.15	156.62	27.70	0.69	0.08
2025	347.37	29.30	335.84	0.15	153.84	15.84	0.47	0.05
2026	372.22	29.75	360.90	0.15	154.84	17.97	0.47	0.05
2027	400.56	31.07	389.38	0.15	157.63	20.09	0.47	0.05
2028	430.27	33.12	418.98	0.16	161.73	21.97	0.47	0.05

**Table 22:** Time series of population estimates from the base model for the sub-area south of Point Conception. (*continued*)

Year	Total Biomass (mt)	Spawn- ing Output	Total Biomass 3+ (mt)	Frac- tion Un- fished	Age-0 Re- cruits	Total Mortal- ity (mt)	1-SPR	Ex- ploita- tion Rate
2029	460.03	35.65	448.52	0.18	166.37	23.52	0.47	0.05
2030	489.28	38.39	477.47	0.19	170.97	24.82	0.47	0.05
2031	517.82	41.18	505.67	0.20	175.24	25.99	0.47	0.05
2032	545.62	43.92	533.15	0.22	179.07	27.00	0.47	0.05
2033	572.80	46.58	560.02	0.23	182.50	27.94	0.46	0.05
2034	599.40	49.17	586.35	0.24	185.58	28.84	0.46	-

**Table 23:** The estimated total biomass (mt), total biomass age 3+ (mt), age-0 recruits, and spawning output in number of billions of eggs across California and fraction unfished by year.

Year	Total Biomass (mt)	Total Biomass 3+ (mt)	Age-0 Recruits	Spawning Output	Fraction Unfished
1916	6487.70	6444.62	782.05	658.16	1.002
1917	6485.61	6442.53	782.58	657.88	1.001
1918	6481.65	6438.53	783.13	657.37	1.000
1919	6476.97	6433.82	783.72	656.76	0.999
1920	6475.37	6432.18	784.40	656.49	0.999
1921	6474.04	6430.83	785.15	656.24	0.999
1922	6473.91	6430.66	785.97	656.12	0.998
1923	6474.77	6431.48	786.88	656.12	0.998
1924	6475.80	6432.47	787.86	656.13	0.999
1925	6478.43	6435.06	788.94	656.32	0.999
1926	6480.16	6436.74	790.09	656.40	0.999
1927	6481.25	6437.77	791.33	656.41	0.999
1928	6484.02	6440.49	792.70	656.60	0.999
1929	6485.63	6442.03	794.35	656.66	0.999
1930	6486.67	6443.00	796.15	656.67	0.999
1931	6485.53	6441.78	798.08	656.41	0.999
1932	6482.95	6439.11	800.17	655.98	0.998
1933	6480.53	6436.59	802.44	655.55	0.998
1934	6478.73	6434.69	804.88	655.17	0.997
1935	6477.88	6433.72	807.60	654.87	0.997
1936	6474.56	6430.28	810.49	654.27	0.996
1937	6471.90	6427.49	813.62	653.72	0.995
1938	6467.23	6422.67	817.03	652.93	0.994
1939	6465.41	6420.69	820.84	652.40	0.993
1940	6467.30	6422.42	825.16	652.23	0.993
1941	6466.04	6420.96	830.01	651.72	0.992
1942	6467.40	6422.09	835.57	651.45	0.991
1943	6481.34	6435.79	842.00	652.46	0.993
1944	6496.26	6450.43	849.10	653.56	0.995
1945	6509.01	6462.86	856.70	654.36	0.996
1946	6509.74	6463.24	864.37	653.77	0.995
1947	6505.06	6458.19	871.87	652.56	0.993
1948	6522.11	6474.85	879.27	653.68	0.995
1949	6527.29	6479.68	885.58	653.54	0.995
1950	6532.65	6484.69	890.70	653.42	0.994
1951	6535.09	6486.83	894.60	652.97	0.994
1952	6523.94	6475.45	897.58	651.02	0.991
1953	6526.53	6477.85	901.24	650.48	0.990

**Table 23:** The estimated total biomass (mt), total biomass age 3+ (mt), age-0 recruits, and spawning output in number of billions of eggs across California and fraction unfished by year.  
(continued)

Year	Total Biomass (mt)	Total Biomass 3+ (mt)	Age-0 Recruits	Spawning Output	Fraction Unfished
1954	6541.36	6492.53	906.40	651.24	0.991
1955	6543.68	6494.65	912.37	650.86	0.990
1956	6534.35	6485.05	920.52	649.49	0.988
1957	6518.21	6468.63	919.46	647.40	0.985
1958	6514.75	6464.90	919.44	646.42	0.984
1959	6473.12	6423.31	923.23	641.59	0.976
1960	6459.46	6409.60	940.54	639.38	0.973
1961	6460.66	6410.43	977.35	638.64	0.972
1962	6479.98	6428.66	1028.65	639.77	0.974
1963	6494.25	6440.98	1074.50	640.38	0.975
1964	6498.87	6443.13	1150.43	639.68	0.973
1965	6517.08	6458.65	1281.29	639.69	0.973
1966	6509.21	6446.35	1408.91	636.17	0.968
1967	6477.99	6408.65	1421.35	629.20	0.958
1968	6459.92	6385.24	1299.89	621.82	0.946
1969	6457.10	6382.52	1056.46	614.53	0.935
1970	6485.08	6417.23	867.73	609.87	0.928
1971	6467.13	6411.62	678.96	603.14	0.918
1972	6455.51	6410.10	622.54	601.34	0.915
1973	6342.36	6304.83	663.68	595.57	0.906
1974	6135.34	6098.60	583.76	585.01	0.890
1975	5832.09	5794.45	567.23	566.43	0.862
1976	5488.67	5455.43	529.24	542.49	0.826
1977	5113.57	5081.96	526.87	512.50	0.780
1978	4716.78	4686.65	434.09	477.62	0.727
1979	4333.41	4304.03	348.50	441.90	0.672
1980	3886.17	3861.71	356.94	398.56	0.607
1981	3427.17	3406.47	481.56	352.49	0.536
1982	3047.31	3025.60	369.19	313.46	0.477
1983	2602.36	2577.22	356.57	268.54	0.409
1984	2321.68	2300.72	593.15	237.41	0.361
1985	2070.48	2047.58	732.81	208.89	0.318
1986	1790.39	1757.11	484.67	177.25	0.270
1987	1591.45	1554.50	420.06	152.37	0.232
1988	1510.19	1483.35	443.86	137.57	0.209
1989	1463.86	1439.46	562.22	126.43	0.192
1990	1419.26	1392.72	652.29	117.70	0.179
1991	1365.20	1333.72	524.75	110.70	0.168



**Table 23:** The estimated total biomass (mt), total biomass age 3+ (mt), age-0 recruits, and spawning output in number of billions of eggs across California and fraction unfished by year.  
(continued)

Year	Total Biomass (mt)	Total Biomass 3+ (mt)	Age-0 Recruits	Spawning Output	Fraction Unfished
1992	1329.62	1295.66	427.01	105.49	0.161
1993	1315.53	1287.00	500.09	101.25	0.154
1994	1302.48	1278.23	408.27	97.27	0.148
1995	1312.84	1287.98	324.59	97.82	0.149
1996	1349.02	1328.30	323.69	101.12	0.154
1997	1322.44	1304.52	346.34	100.79	0.153
1998	1343.56	1325.94	381.39	104.17	0.159
1999	1376.52	1357.90	445.15	109.61	0.167
2000	1411.75	1390.63	311.59	115.90	0.176
2001	1470.27	1446.52	302.21	123.30	0.188
2002	1536.63	1519.69	374.54	130.54	0.199
2003	1611.45	1594.53	403.51	138.54	0.211
2004	1674.58	1653.75	277.49	146.37	0.223
2005	1738.43	1716.77	288.73	154.34	0.235
2006	1766.57	1751.00	342.41	159.03	0.242
2007	1802.17	1784.51	905.84	163.97	0.250
2008	1809.04	1784.99	742.42	166.42	0.253
2009	1839.67	1794.01	1097.49	169.44	0.258
2010	1894.56	1850.48	785.14	170.89	0.260
2011	2005.28	1946.07	553.35	173.20	0.264
2012	2141.10	2095.60	861.66	175.88	0.268
2013	2289.25	2253.87	947.06	181.77	0.277
2014	2428.11	2379.05	532.16	192.38	0.293
2015	2575.68	2525.46	561.77	206.95	0.315
2016	2668.29	2640.24	378.21	218.64	0.333
2017	2720.50	2693.81	813.33	228.21	0.347
2018	2687.50	2662.11	589.84	230.28	0.350
2019	2649.99	2612.81	364.71	232.40	0.354
2020	2620.84	2594.05	559.06	233.14	0.355
2021	2591.82	2570.81	639.19	232.01	0.353
2022	2601.31	2571.41	636.27	233.63	0.356
2023	2672.65	2638.28	638.71	240.80	0.366

**Table 24:** Sensitivities relative to the base model.

	Base Model	Esti- mate M	Esti- mate h	Esti- mate M & h	No Rec. Devs.	CPFV Selec- tivity Asym.	Growth Pla- toons	No Added Vari- ance	Dirich- let DW	McAllister- Ianelli DW
Total Likelihood	2832.680	2831.460	2832.560	2831.200	3134.870	2837.370	2835.120	2859.380	5634.510	2316.530
Survey Likelihood	-33.416	-33.610	-33.475	-33.580	-17.454	-33.386	-32.849	-7.966	-33.326	-32.072
Length Likelihood	540.049	539.701	540.255	539.450	648.502	545.436	539.845	541.527	2392.660	849.416
Age Likelihood	2319.930	2318.690	2319.460	2318.810	2503.460	2319.170	2322.670	2320.270	3227.620	1494.460
Recruitment Likelihood	5.415	5.876	5.559	5.635	0.000	5.484	4.744	4.837	5.228	3.761
Forecast Recruitment Likelihood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Parameter Priors Likelihood	0.699	0.797	0.754	0.884	0.355	0.663	0.706	0.715	42.252	0.957
log(R0)	5.486	5.360	5.518	5.240	5.555	5.484	5.488	5.497	5.509	5.514
SO Virgin	201.064	223.878	207.620	220.131	215.440	200.889	199.748	203.487	202.753	206.429
SO 2023	32.063	27.727	30.860	27.140	51.364	29.578	39.604	38.632	37.136	42.858
Fraction Unfished 2023	0.159	0.124	0.149	0.123	0.238	0.147	0.198	0.190	0.183	0.208
Total Yield - SPR 50	47.777	46.211	48.183	44.538	52.380	47.773	48.561	48.169	48.260	48.853
Steepness	0.720	0.720	0.687	0.780	0.720	0.720	0.720	0.720	0.720	0.720
Natural Mortality - Female	0.108	0.095	0.108	0.090	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Female	15.349	15.394	15.347	15.402	14.524	15.379	15.419	15.271	15.210	15.867
Length at Amax - Female	46.829	46.809	46.829	46.801	46.528	46.874	46.503	46.829	46.429	46.751
Von Bert. k - Female	0.194	0.194	0.194	0.193	0.211	0.193	0.203	0.195	0.203	0.192
CV young - Female	0.197	0.196	0.197	0.196	0.202	0.198	0.217	0.198	0.192	0.187
CV old - Female	0.059	0.059	0.059	0.060	0.060	0.058	0.066	0.059	0.068	0.065
Natural Mortality - Male	0.108	0.098	0.108	0.093	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Male	15.722	15.699	15.726	15.703	15.435	15.843	15.652	15.609	15.737	15.371
Length at Amax - Male	45.415	45.391	45.411	45.393	45.498	45.562	44.870	45.421	45.153	45.125
Von Bert. k - Male	0.218	0.218	0.218	0.218	0.223	0.213	0.234	0.218	0.223	0.228
CV young - Male	0.203	0.203	0.203	0.203	0.220	0.202	0.225	0.205	0.201	0.194
CV old - Male	0.060	0.060	0.060	0.060	0.060	0.060	0.067	0.060	0.066	0.066

**Table 25:** Sensitivities relative to the base model.

	Base Model	Reduce PR Catch 1970-82	Hist. CPFV Ages Lambda = 1	Rm. All Ages	Rm. Coop. Ages	Add Coop. Ages to CPFV	Rm. WCGBT Ages	Add WCGBT Index	Rm. CPFV & PR Indices
Total Likelihood	2832.680	2831.350	2839.860	1789.560	2746.700	2913.810	1896.690	2843.830	2858.280
Survey Likelihood	-33.416	-33.526	-33.482	-32.462	-33.365	-33.504	-32.113	-22.121	-8.020
Length Likelihood	540.049	540.854	540.582	533.008	542.899	539.304	487.111	539.727	539.571
Age Likelihood	2319.930	2318.290	2324.450	1287.810	2232.770	2397.540	1438.300	2320.530	2320.280
Recruitment Likelihood	5.415	5.022	7.609	0.578	3.769	9.678	2.442	4.968	5.772
Forecast Recruitment Likelihood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Parameter Priors Likelihood	0.699	0.702	0.695	0.621	0.621	0.781	0.953	0.722	0.671
log(R0)	5.486	5.307	5.439	5.512	5.481	5.440	5.533	5.492	5.477
SO Virgin	201.064	168.330	192.252	206.500	204.013	189.556	207.561	202.498	199.362
SO 2023	32.063	30.709	31.756	31.690	30.142	34.005	47.007	36.142	27.612
Fraction Unfished 2023	0.159	0.182	0.165	0.153	0.148	0.179	0.226	0.178	0.139
Total Yield - SPR 50	47.777	39.916	45.494	49.855	48.233	44.981	49.603	48.062	47.508
Steepness	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
Natural Mortality - Female	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Female	15.349	15.327	15.346	15.349	15.281	15.400	17.169	15.348	15.369
Length at Amax - Female	46.829	46.831	46.857	46.829	47.097	46.644	46.401	46.819	46.839
Von Bert. k - Female	0.194	0.195	0.194	0.194	0.194	0.195	0.193	0.195	0.194
CV young - Female	0.197	0.197	0.197	0.197	0.197	0.197	0.150	0.197	0.196
CV old - Female	0.059	0.059	0.059	0.059	0.055	0.062	0.067	0.059	0.059
Natural Mortality - Male	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Male	15.722	15.746	15.738	15.722	15.566	15.827	15.649	15.718	15.746
Length at Amax - Male	45.415	45.424	45.458	45.415	45.616	45.279	44.468	45.402	45.427
Von Bert. k - Male	0.218	0.217	0.217	0.218	0.218	0.217	0.245	0.218	0.217
CV young - Male	0.203	0.203	0.204	0.203	0.206	0.201	0.173	0.203	0.203
CV old - Male	0.060	0.060	0.059	0.060	0.055	0.063	0.069	0.060	0.060

**Table 26:** Sensitivities relative to the base model.

	Base Model	Rm. CCFRP	Add CDFW ROV Survey	Rm. NWFSC HKL All	Rm. NWFSC HKL Ages	Rm. NWFSC HKL Lens. & Ages	Rm. NWFSC HKL Index	Move NWFSC HKL Data Before 2014	Rm. All Surveys
Total Likelihood	2832.680	2763.640	2830.550	1379.710	1529.870	1377.270	2836.050	2718.710	1315.760
Survey Likelihood	-33.416	-29.661	-35.632	-29.493	-32.653	-32.401	-29.806	-33.786	-25.732
Length Likelihood	540.049	530.746	540.192	383.346	532.298	383.718	539.694	721.904	373.522
Age Likelihood	2319.930	2257.490	2319.670	1023.930	1027.120	1023.450	2321.010	2025.620	966.632
Recruitment Likelihood	5.415	5.058	5.617	1.190	2.367	1.812	4.404	4.366	1.331
Forecast Recruitment Likelihood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Parameter Priors Likelihood	0.699	0.000	0.700	0.733	0.741	0.692	0.743	0.601	0.000
log(R0)	5.486	5.481	5.483	5.576	5.547	5.548	5.503	5.494	5.555
SO Virgin	201.064	201.628	200.611	216.348	205.104	210.422	204.603	195.923	214.888
SO 2023	32.063	29.328	30.791	66.186	44.561	49.663	42.180	25.415	57.169
Fraction Unfished 2023	0.159	0.145	0.153	0.306	0.217	0.236	0.206	0.130	0.266
Total Yield - SPR 50	47.777	47.784	47.682	51.185	49.253	49.874	48.504	48.104	50.412
Steepness	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
Natural Mortality - Female	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Female	15.349	15.459	15.347	13.716	15.793	13.776	15.347	15.839	14.088
Length at Amax - Female	46.829	47.009	46.833	46.569	46.486	46.622	46.810	46.429	46.986
Von Bert. k - Female	0.194	0.190	0.194	0.204	0.182	0.202	0.195	0.191	0.192
CV young - Female	0.197	0.198	0.197	0.191	0.224	0.191	0.197	0.197	0.195
CV old - Female	0.059	0.058	0.059	0.076	0.066	0.076	0.059	0.061	0.074
Natural Mortality - Male	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Male	15.722	15.580	15.722	16.280	14.724	16.285	15.709	15.438	16.109
Length at Amax - Male	45.415	45.567	45.421	45.340	44.751	45.393	45.388	45.167	45.824
Von Bert. k - Male	0.218	0.219	0.217	0.200	0.229	0.198	0.219	0.220	0.200
CV young - Male	0.203	0.206	0.203	0.222	0.200	0.222	0.203	0.203	0.225
CV old - Male	0.060	0.055	0.060	0.065	0.068	0.065	0.060	0.059	0.055

**Table 27:** Summary of reference points and management quantities, including estimates of the 95 percent intervals for the sub-area model south of Point Conception.

	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output	201.06	163.43	238.70
Unfished Age 3+ Biomass (mt)	1999.51	1624.90	2374.12
Unfished Recruitment (R0)	241.18	196.04	286.32
Spawning Output (2023)	32.06	12.70	51.42
Fraction Unfished (2023)	0.16	0.06	0.25
Reference Points Based SO40%			
Proxy Spawning Output SO40%	80.43	65.37	95.48
SPR Resulting in SO40%	0.46	0.46	0.46
Exploitation Rate Resulting in SO40%	0.06	0.05	0.06
Yield with SPR Based On SO40% (mt)	49.99	40.74	59.25
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Output (SPR50)	89.71	72.92	106.50
SPR50	0.50	-	-
Exploitation Rate Corresponding to SPR50	0.05	0.05	0.05
Yield with SPR50 at SB SPR (mt)	47.78	38.93	56.62
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY (SB MSY)	55.51	45.15	65.87
SPR MSY	0.35	0.34	0.35
Exploitation Rate Corresponding to SPR MSY	0.08	0.08	0.08
MSY (mt)	52.94	43.14	62.74

**Table 28:** Summary of reference points and management quantities, including estimates of the 95 percent intervals for the sub-area model north of Point Conception.

	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output	456.05	359.98	552.11
Unfished Age 3+ Biomass (mt)	4431.19	3511.38	5351.00
Unfished Recruitment (R0)	534.18	421.66	646.70
Spawning Output (2023)	208.74	77.33	340.15
Fraction Unfished (2023)	0.46	0.23	0.69
Reference Points Based SO40%			
Proxy Spawning Output SO40%	182.42	143.99	220.84
SPR Resulting in SO40%	0.46	0.46	0.46
Exploitation Rate Resulting in SO40%	0.06	0.06	0.06
Yield with SPR Based On SO40% (mt)	121.92	96.86	146.99
Reference Points Based on SPR Proxy for MSY			
Proxy Spawning Output (SPR50)	203.47	160.61	246.33
SPR50	0.50	-	-
Exploitation Rate Corresponding to SPR50	0.05	0.05	0.05
Yield with SPR50 at SB SPR (mt)	116.46	92.51	140.41
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY (SB MSY)	125.80	99.21	152.39
SPR MSY	0.35	0.34	0.35
Exploitation Rate Corresponding to SPR MSY	0.09	0.08	0.09
MSY (mt)	129.20	102.65	155.75

**Table 29:** Summary of reference points and management quantities for copper rockfish in California waters

Quantity	Estimate
Unfished Spawning Output	657.11
Unfished Age 3+ Biomass (mt)	6430.7
Unfished Recruitment	775.36
Spawning Output (2023)	240.8
Relative Spawning Output (2023)	0.366
Proxy Spawning Output (SO40%)	262.84
Yield with SPR Based on SO40% (mt)	171.92
Proxy Spawning Output (SPR50)	293.17
Yield with SPR50 (mt)	164.24
Spawning Output at MSY	181.31
MSY (mt)	182.14

**Table 30:** The estimated OFL (mt), ABC (mt), ACL (mt), buffer, spawning output in billions of eggs across California, and relative spawning output by year along with the sub-area allocations of the ACL south of Point Conception (south, 34°27' N. lat.), north of Point Conception to 40°10' N. lat. (central), and 40°10' to 42° N. lat. (north).

Year	Assumed Catch (mt)	OFL (mt)	ABC (mt)	ACL (mt)	Buffer	Spawning Output	Fraction Unfished	Sub-ACL South (mt)	Sub-ACL Central (mt)	Sub-ACL North (mt)
2023	91.53	-	-	-	-	240.80	0.366	-	-	-
2024	94.69	-	-	-	-	245.88	0.374	-	-	-
2025	-	143.5	134.1	131.9	0.935	250.60	0.381	15.8	109.2	6.8
2026	-	145.3	135.2	133.1	0.93	251.62	0.383	18	108.4	6.7
2027	-	147.2	136.3	134.5	0.926	252.91	0.385	20.1	107.7	6.7
2028	-	148.9	137.3	135.8	0.922	254.64	0.388	22	107.1	6.7
2029	-	150.4	137.9	136.7	0.917	256.75	0.391	23.5	106.6	6.6
2030	-	151.6	138.5	137.7	0.913	259.10	0.394	24.8	106.3	6.6
2031	-	152.8	138.9	138.6	0.909	261.54	0.398	26	106	6.6
2032	-	153.9	139.1	139.1	0.904	264.02	0.402	27	105.6	6.6
2033	-	155	139.5	139.5	0.9	266.52	0.406	27.9	105.1	6.5
2034	-	156.2	139.9	139.9	0.896	269.04	0.409	28.8	104.6	6.5

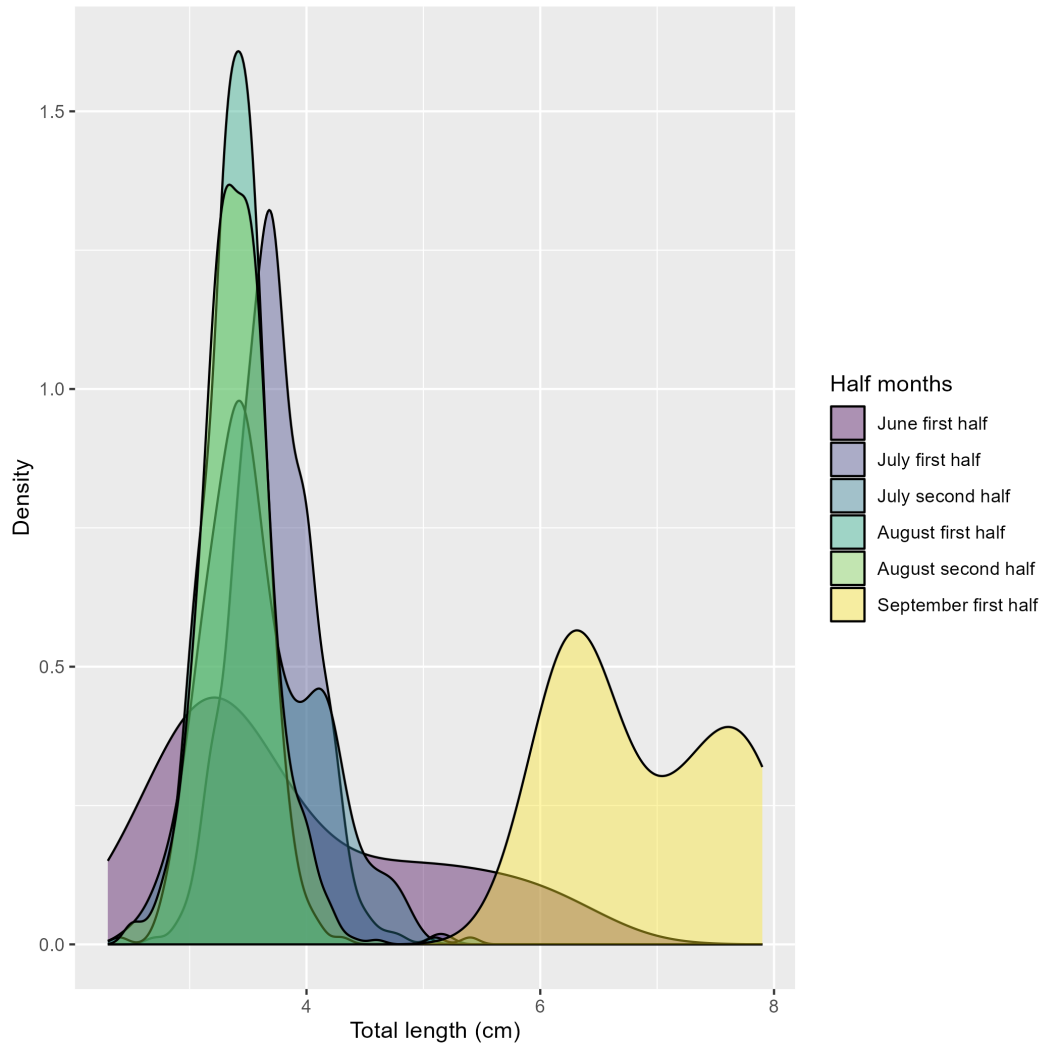


**Table 31:** Decision table summary of 10 year projections beginning in 2025 for alternative states of nature based on an axis of uncertainty around steepness for both California sub-area models. Columns range over low, mid, and high states of nature and rows range over different catch P\* values.

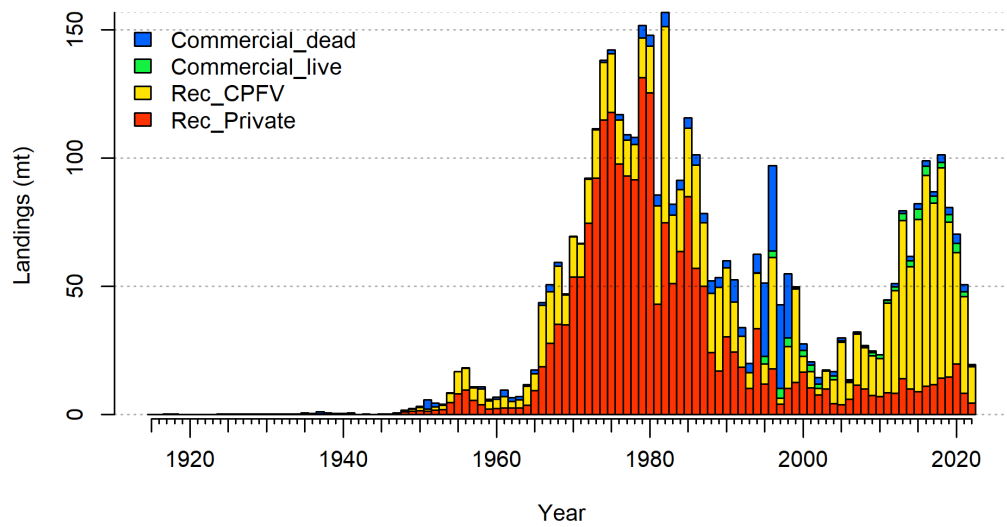
	Year	Catch	Low Steepness		Base Steepness		High Steepness	
			Spawning Output	Fraction Unfished	Spawning Output	Fraction Unfished	Spawning Output	Fraction Unfished
ACL P* 0.45	2023	91.5	176.2	0.255	240.8	0.366	337.3	0.533
	2024	94.7	178.2	0.258	245.9	0.374	345.7	0.546
	2025	131.9	180.2	0.261	250.6	0.381	352.9	0.558
	2026	133.1	178.9	0.259	251.6	0.382	355.4	0.562
	2027	134.5	178.2	0.258	252.9	0.384	357.3	0.564
	2028	135.8	178.0	0.258	254.6	0.387	358.9	0.567
	2029	136.7	178.3	0.258	256.7	0.390	360.4	0.569
	2030	137.7	178.9	0.259	259.1	0.394	361.8	0.572
	2031	138.6	179.6	0.260	261.5	0.397	363.1	0.574
	2032	139.1	180.4	0.261	264.0	0.401	364.3	0.575
	2033	139.5	181.2	0.262	266.5	0.405	365.3	0.577
	2034	139.9	182.0	0.264	269.0	0.409	366.2	0.578
ACL P* 0.40	2023	91.5	176.2	0.255	240.8	0.366	337.3	0.533
	2024	94.7	178.2	0.258	245.9	0.374	345.7	0.546
	2025	123.1	180.2	0.261	250.6	0.381	352.9	0.558
	2026	124.2	179.7	0.260	252.4	0.384	356.3	0.563
	2027	125.4	179.9	0.261	254.6	0.387	359.1	0.567
	2028	126.5	180.7	0.262	257.3	0.391	361.6	0.571
	2029	127.4	181.9	0.263	260.3	0.396	364.1	0.575
	2030	128.1	183.4	0.266	263.6	0.401	366.4	0.579
	2031	128.2	185.1	0.268	267.1	0.406	368.7	0.582
	2032	128.4	186.9	0.271	270.6	0.411	370.8	0.586
	2033	128.4	188.8	0.273	274.1	0.416	372.8	0.589
	2034	128.5	190.7	0.276	277.7	0.422	374.7	0.592
ACL P* 0.35	2023	91.5	176.2	0.255	240.8	0.366	337.3	0.533
	2024	94.7	178.2	0.258	245.9	0.374	345.7	0.546
	2025	114.7	180.2	0.261	250.6	0.381	352.9	0.558
	2026	115.6	180.5	0.261	253.3	0.385	357.1	0.564
	2027	116.7	181.5	0.263	256.3	0.389	360.7	0.570
	2028	117.5	183.2	0.265	259.8	0.395	364.2	0.575
	2029	118.2	185.3	0.268	263.8	0.401	367.6	0.581
	2030	118.1	187.8	0.272	268.1	0.407	370.9	0.586
	2031	118.0	190.5	0.276	272.5	0.414	374.1	0.591
	2032	117.9	193.4	0.280	277.0	0.421	377.2	0.596
	2033	117.6	196.3	0.284	281.5	0.428	380.2	0.601
	2034	117.4	199.2	0.289	286.1	0.435	383.1	0.605

## 8 Figures

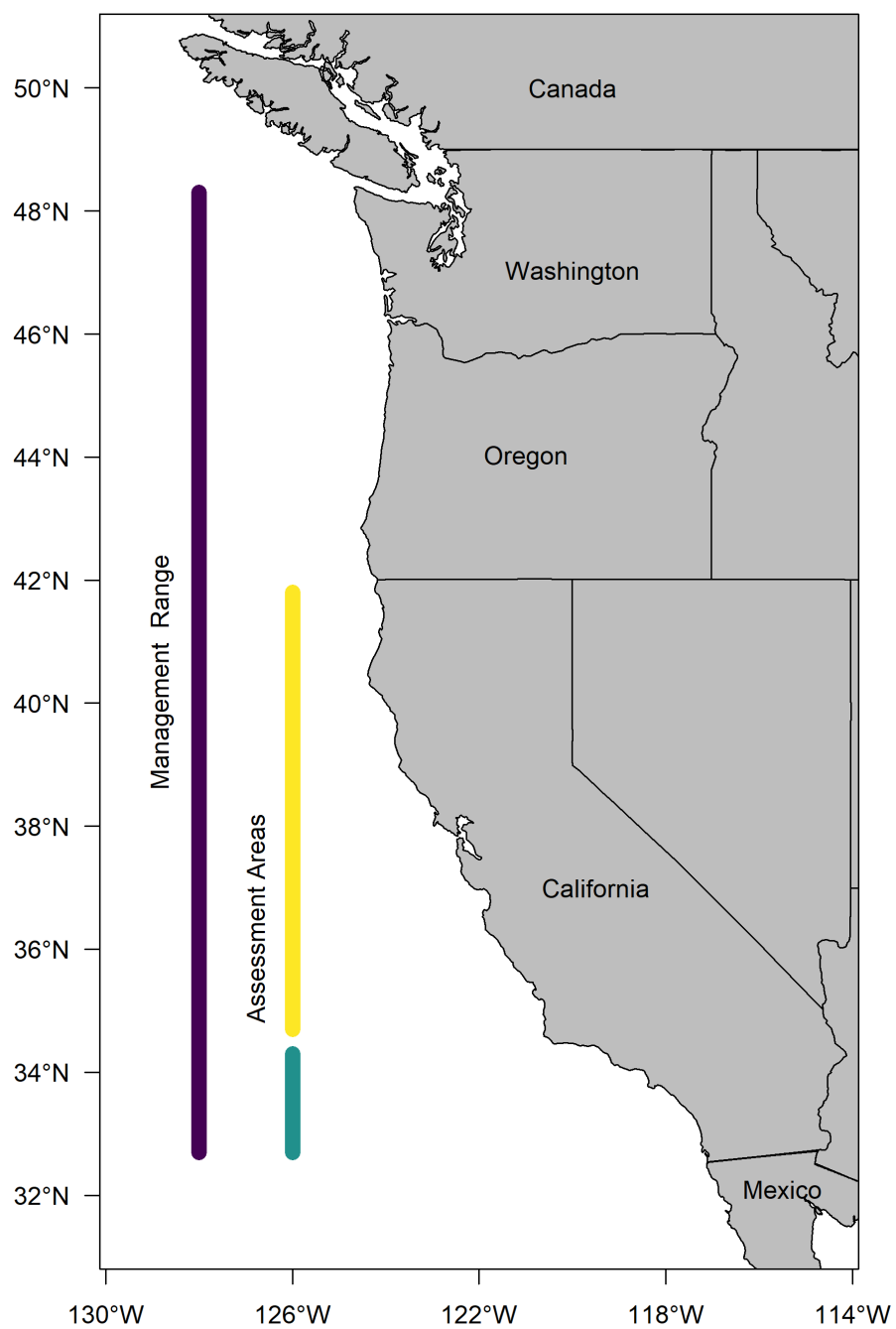
### 8.1 Data



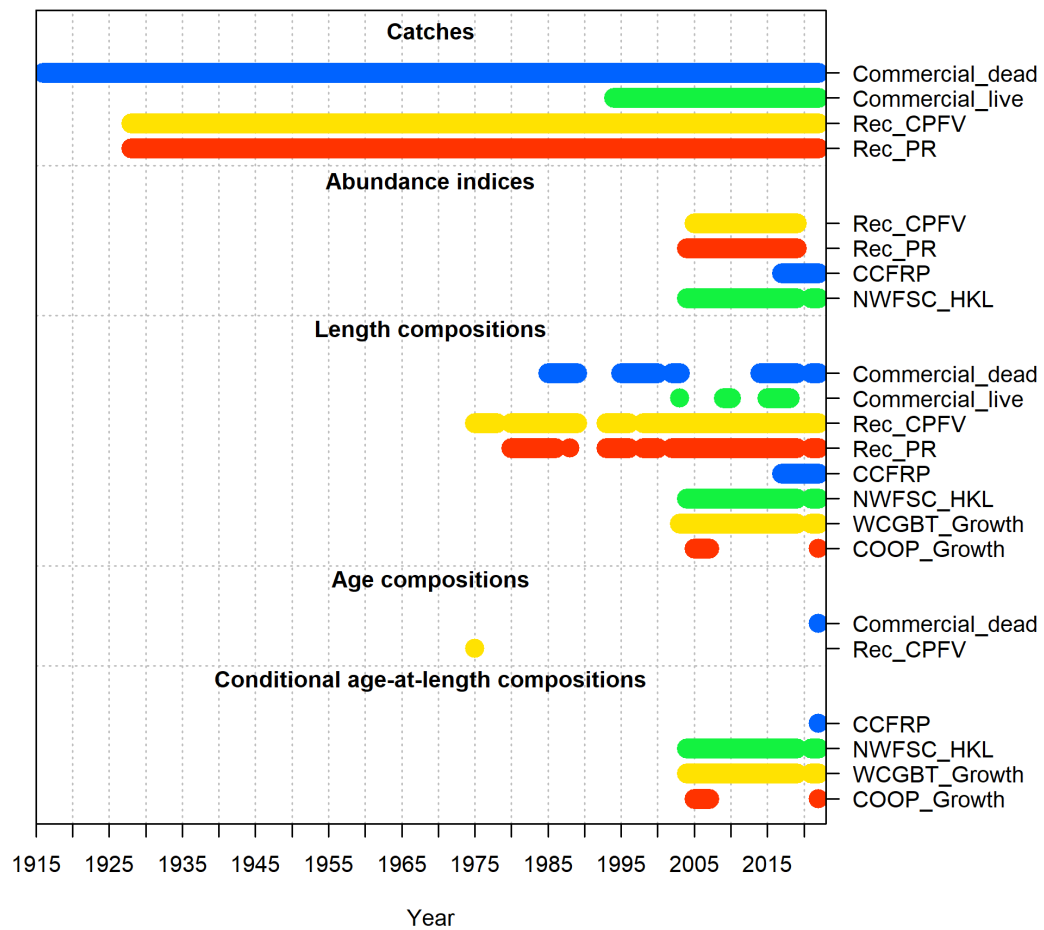
**Figure 1:** Distribution of young-of-the-year copper rockfish lengths from fish genetically identified from D. Baetscher.



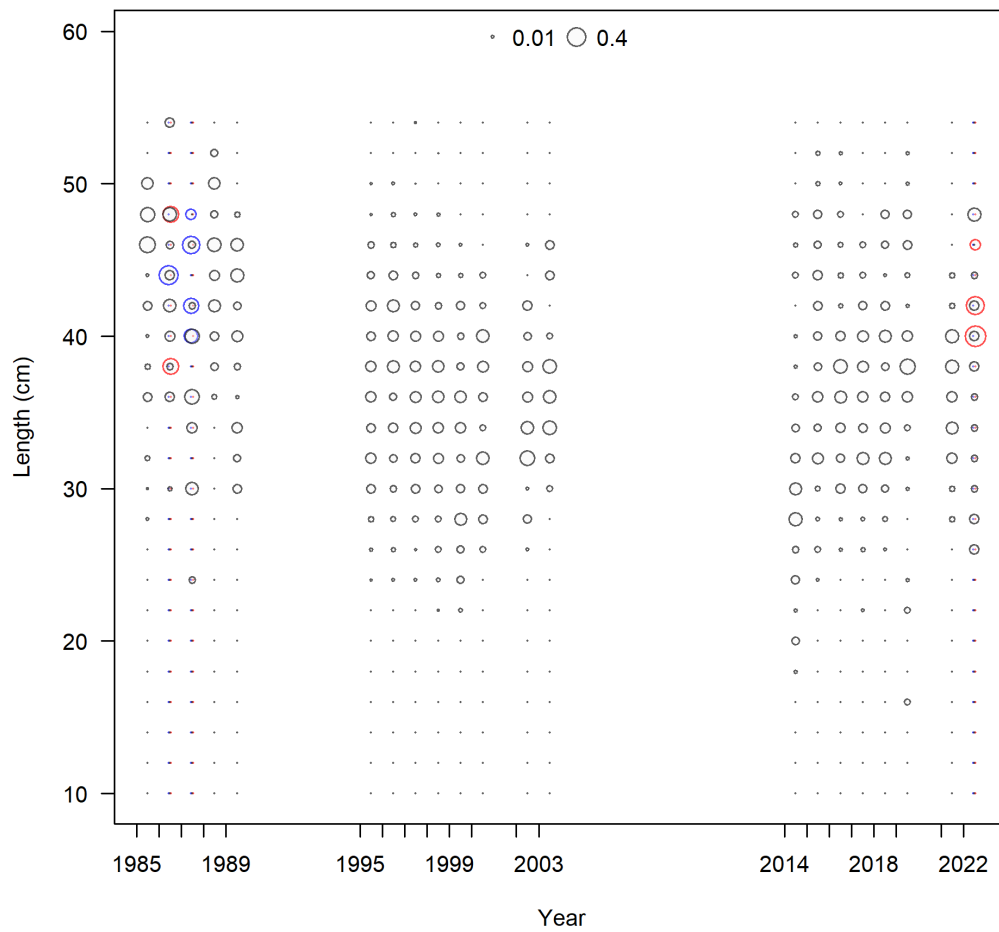
**Figure 2:** Landings by fleet used in the base model where catches in metric tons by fleet are stacked.



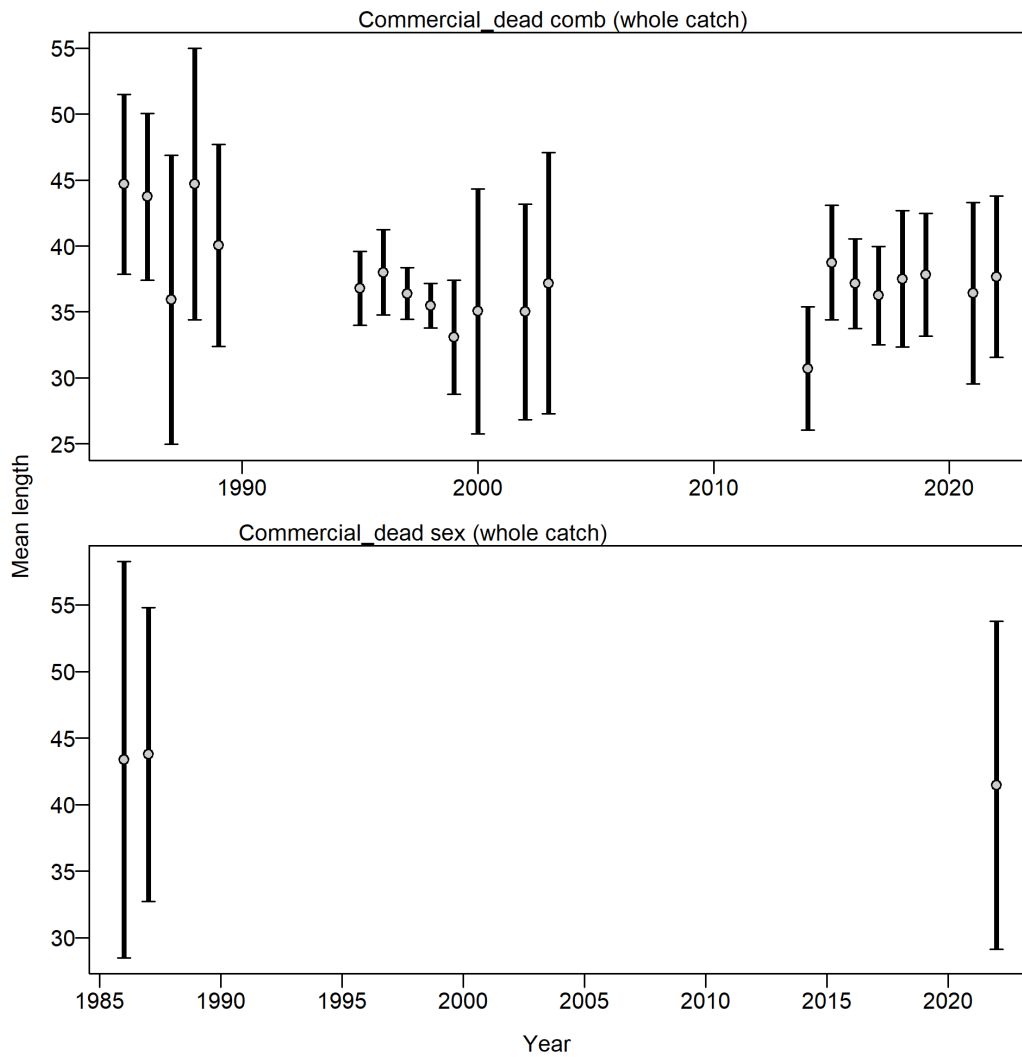
**Figure 3:** Map of management area and the 2023 assessment areas for copper rockfish.



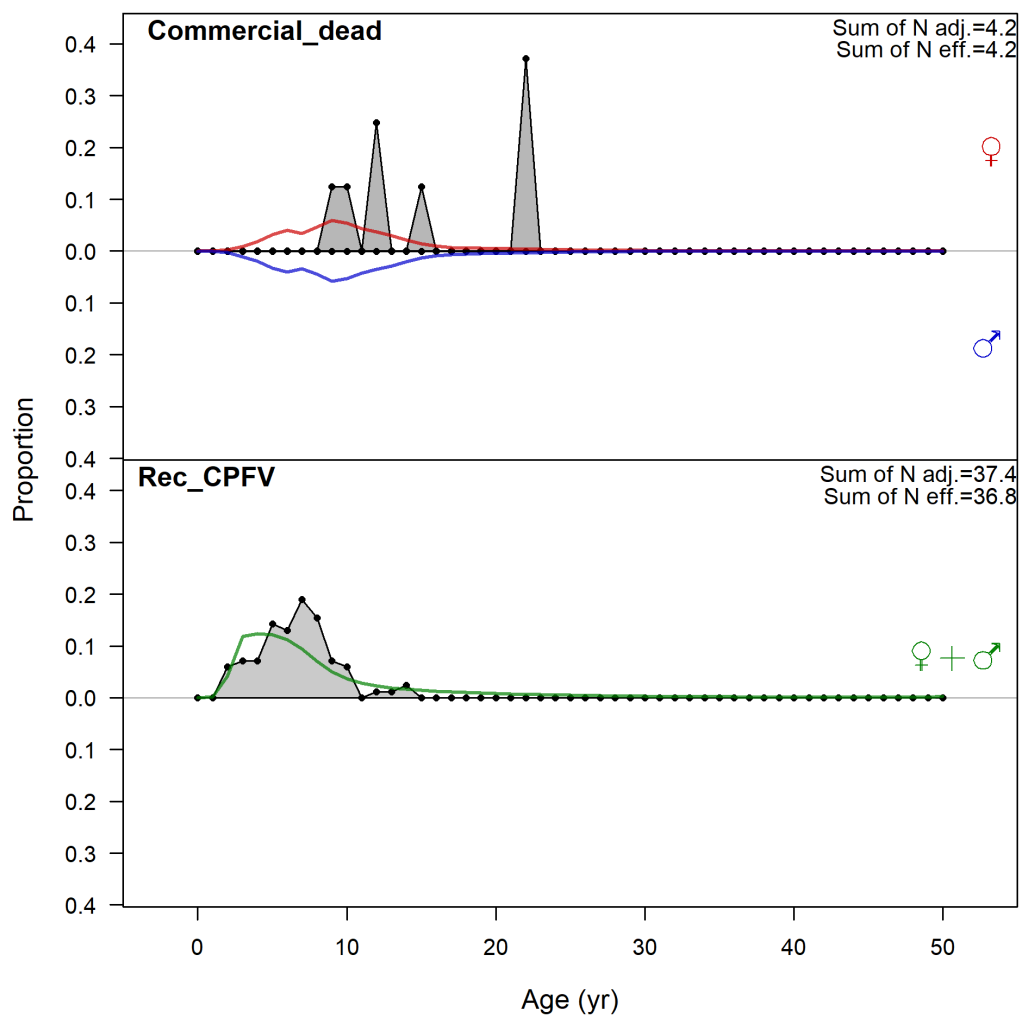
**Figure 4:** Summary of data sources used in the base model.



**Figure 5:** Length composition data from the commercial dead fleet.

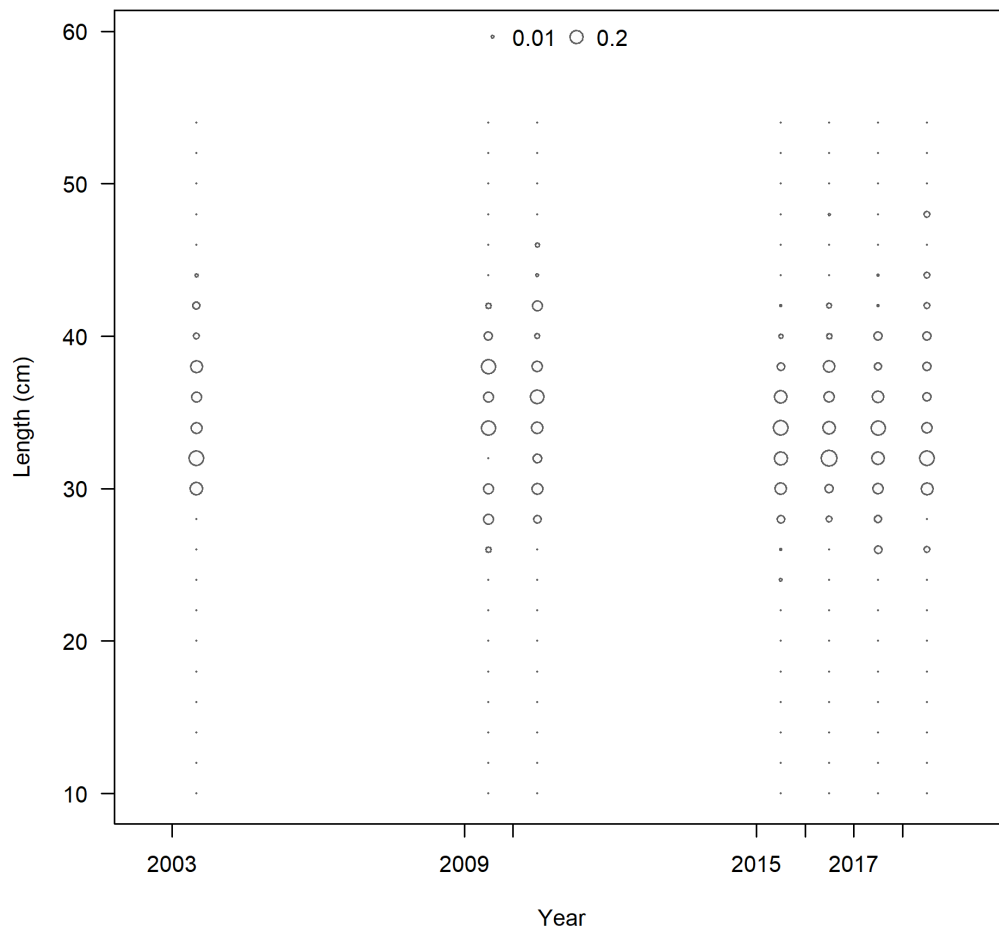


**Figure 6:** Mean length for commercial dead fleet with 95 percent confidence intervals.

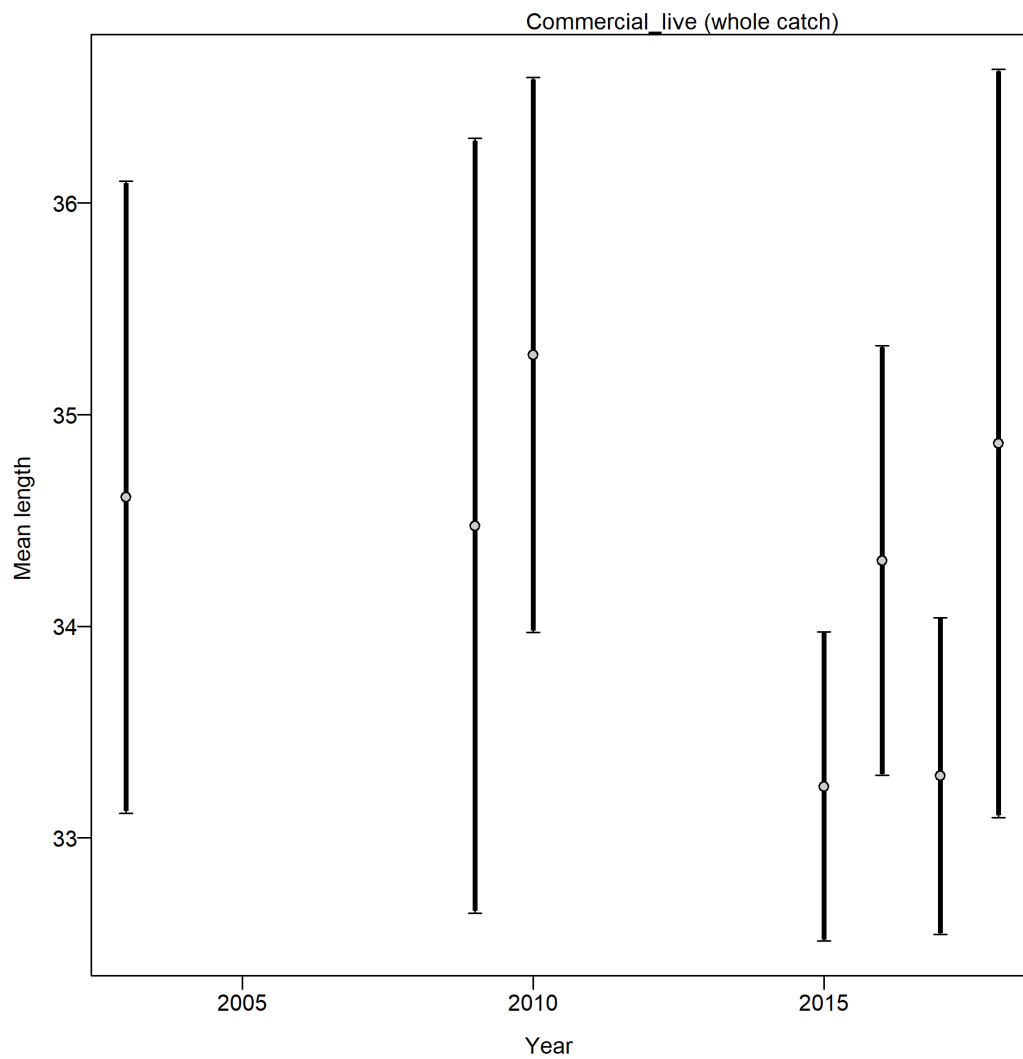


**Figure 7:** Age composition data from the commercial dead and recreational CPFV fleets. The commercial samples were all from 2022 and the CPFV samples were all from 1975.

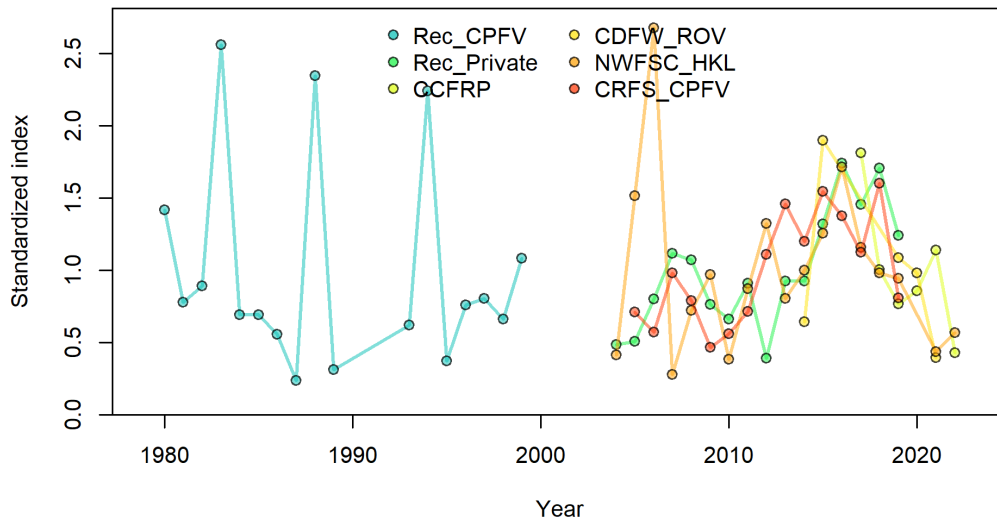




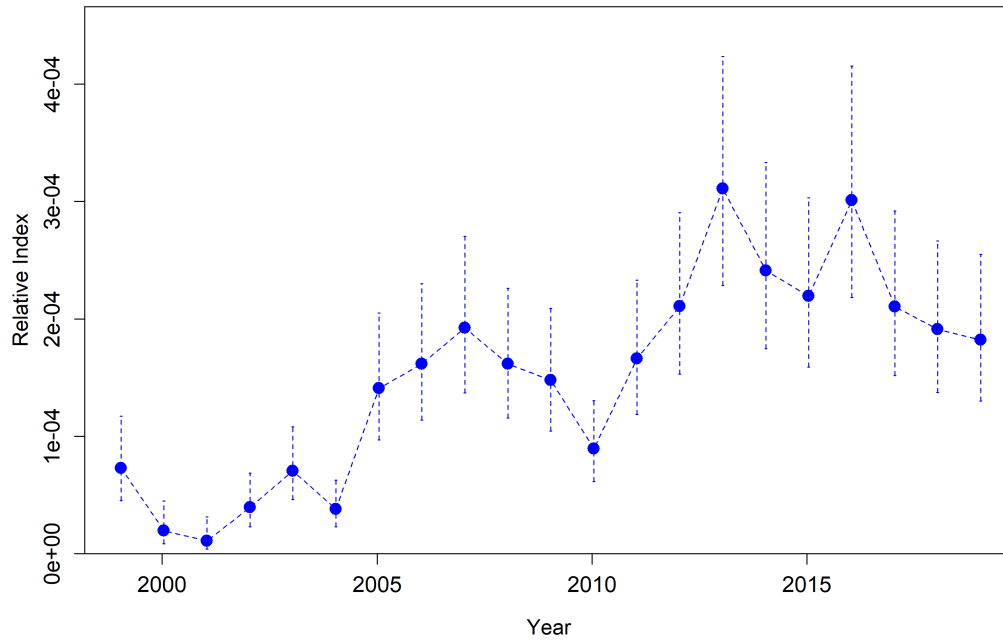
**Figure 8:** Length composition data from the commercial live fleet.



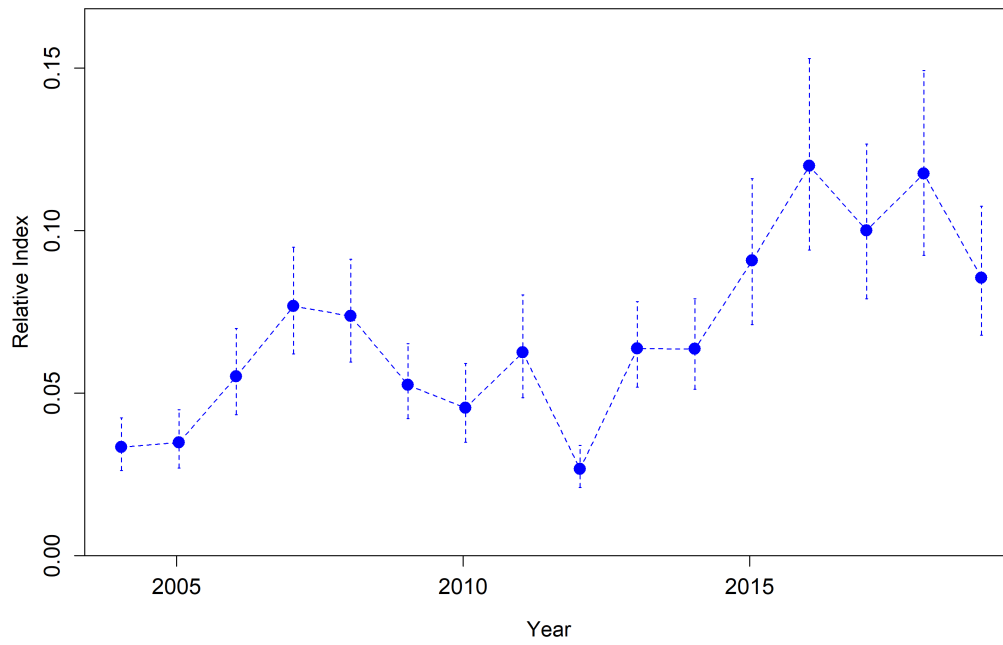
**Figure 9:** Mean length for commercial live fleet with 95 percent confidence intervals.



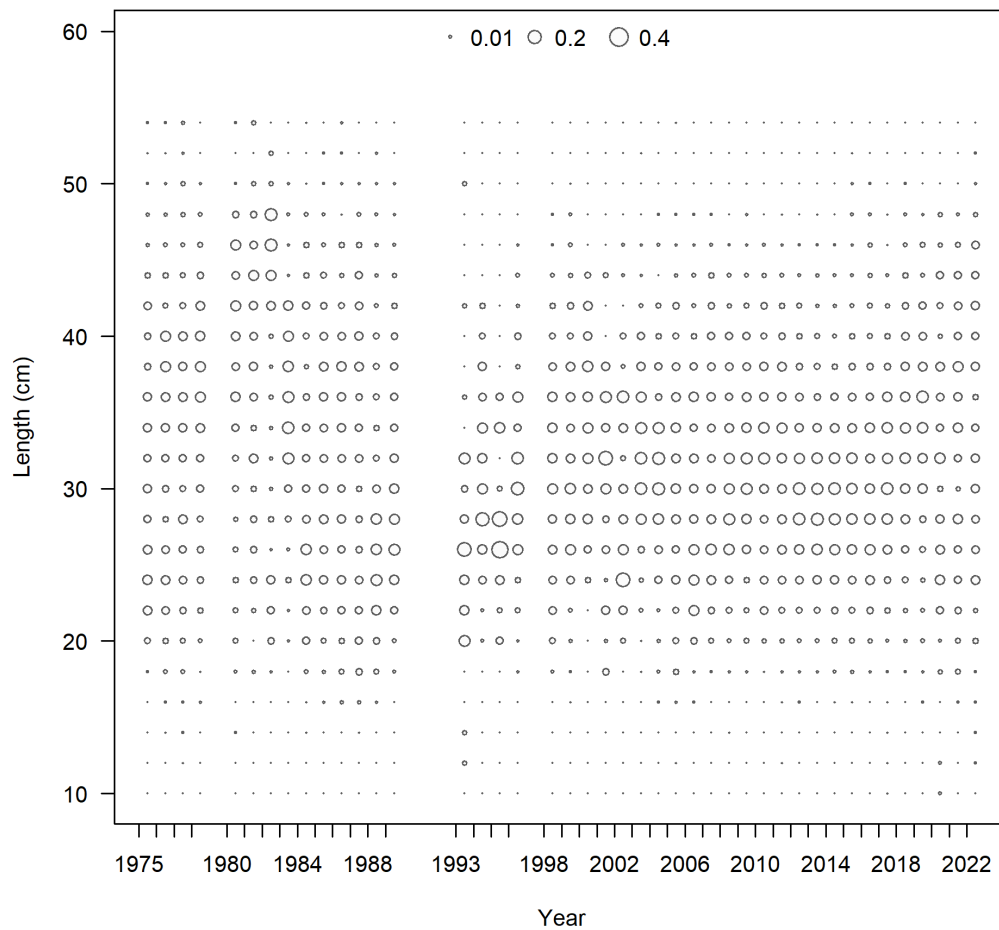
**Figure 10:** Standardized indices overlaid with each index rescaled to have a mean observation equal to 1.0. Note, the MRFSS CPFV (Rec\_CPFV) fishery-dependent and CDFW ROV fishery-independent indices of abundance were not fit in the model but are included here for illustration.



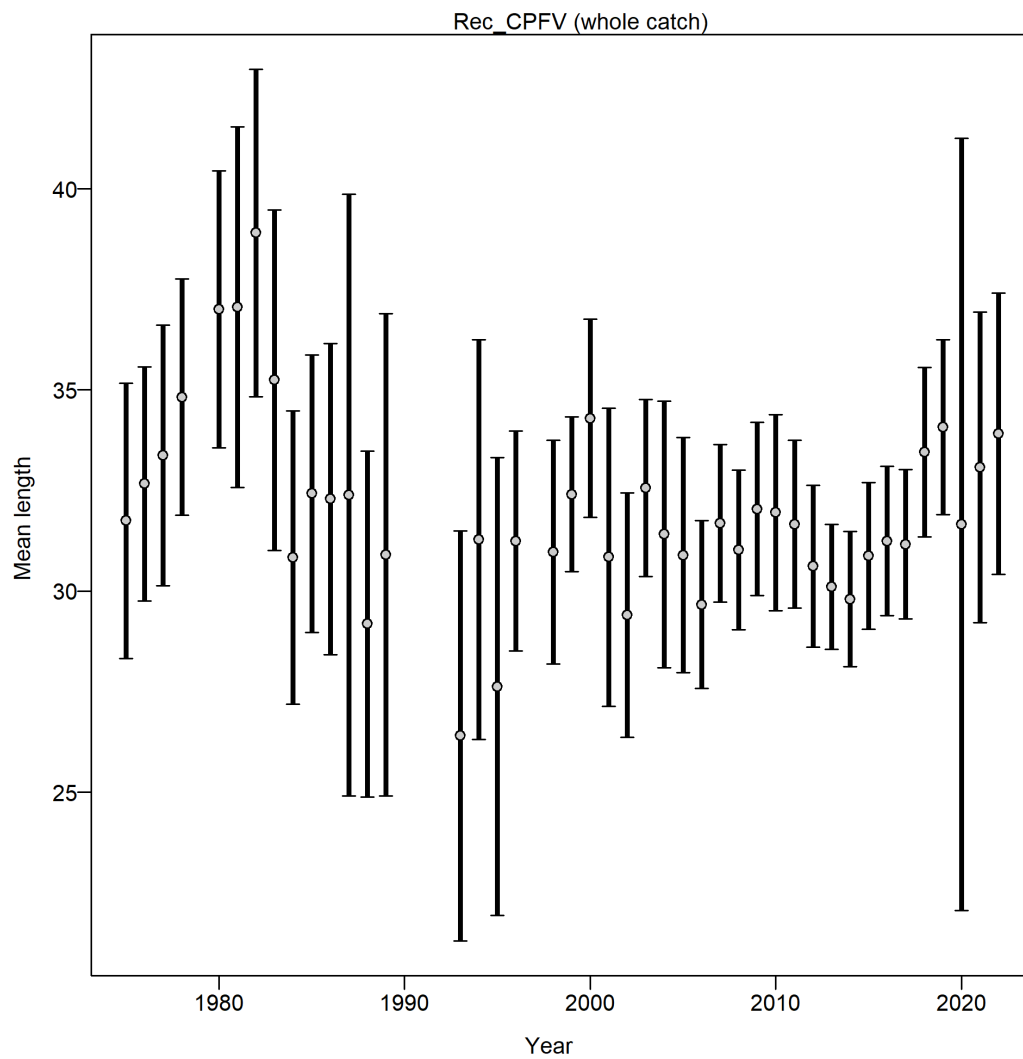
**Figure 11:** Estimated annual index of abundances for the recreational CPFV fleet based on CRFS survey data.



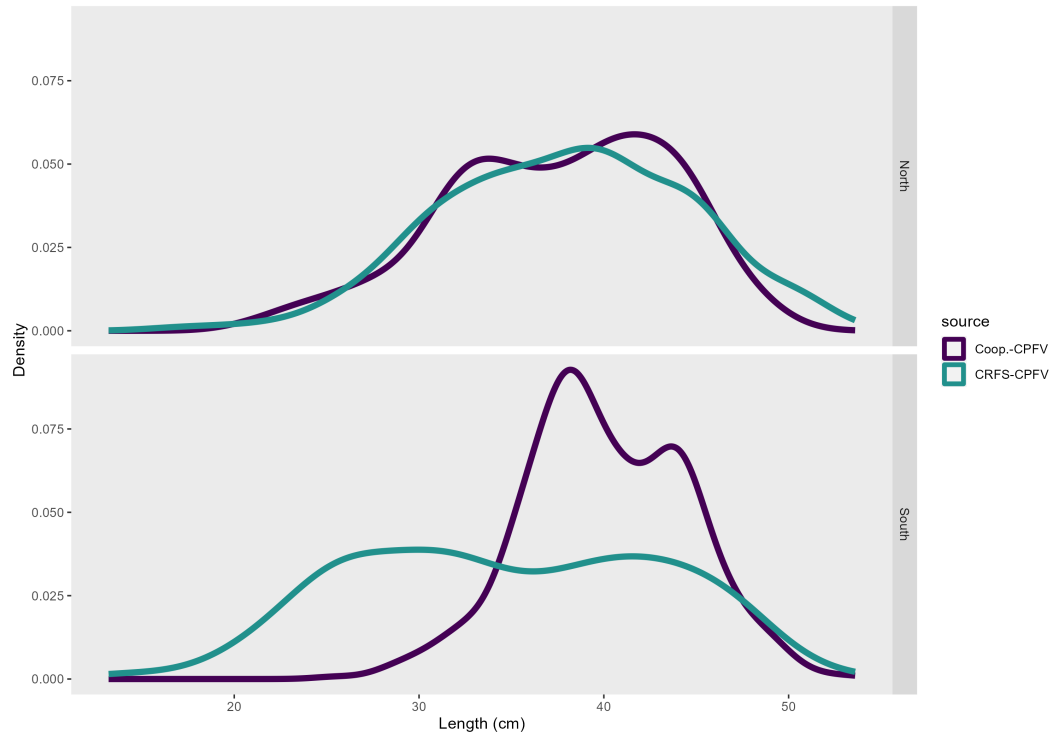
**Figure 12:** Estimated annual index of abundances for the recreational PR fleet based on CRFS survey data.



**Figure 13:** Length composition data from the recreational CPFV fleet.

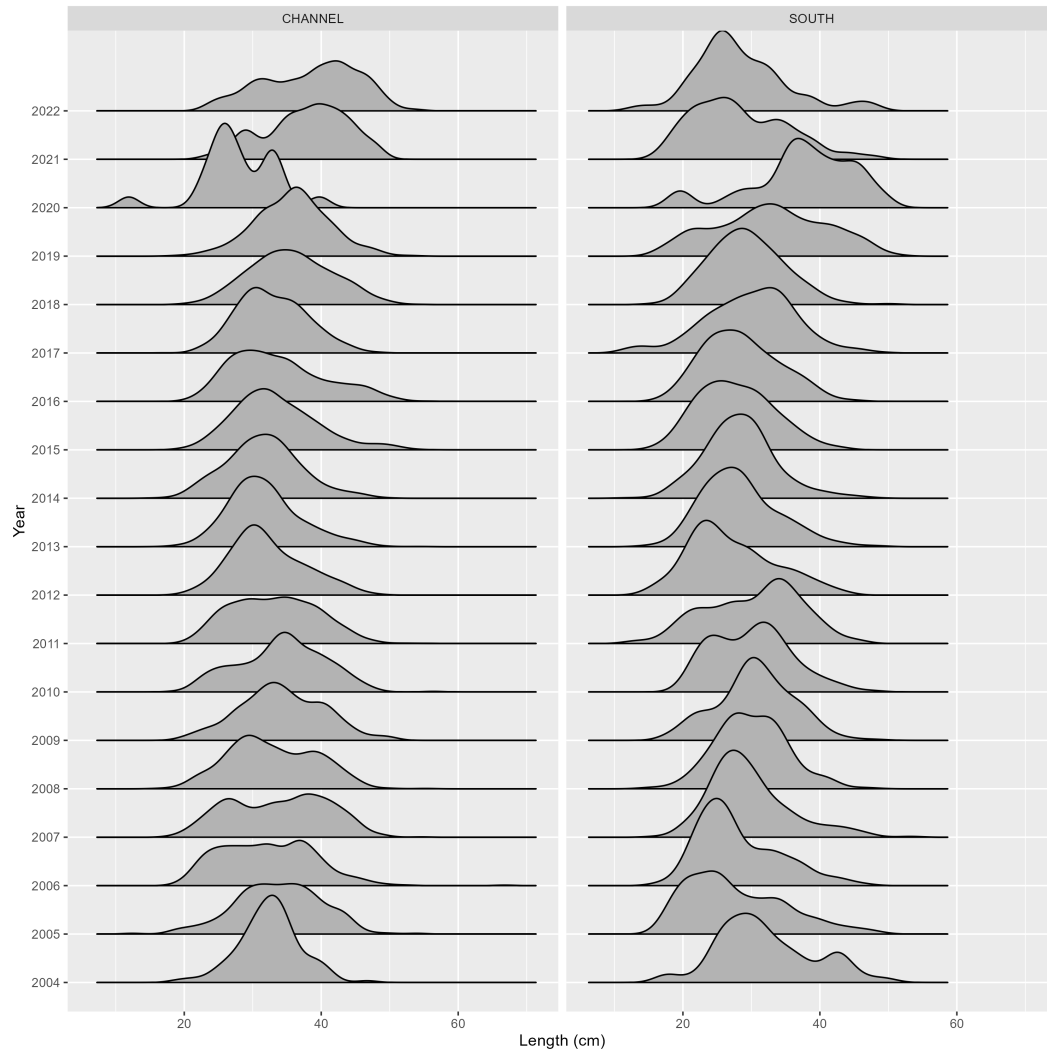


**Figure 14:** Mean length for recreational CPFV fleet with 95 percent confidence intervals.

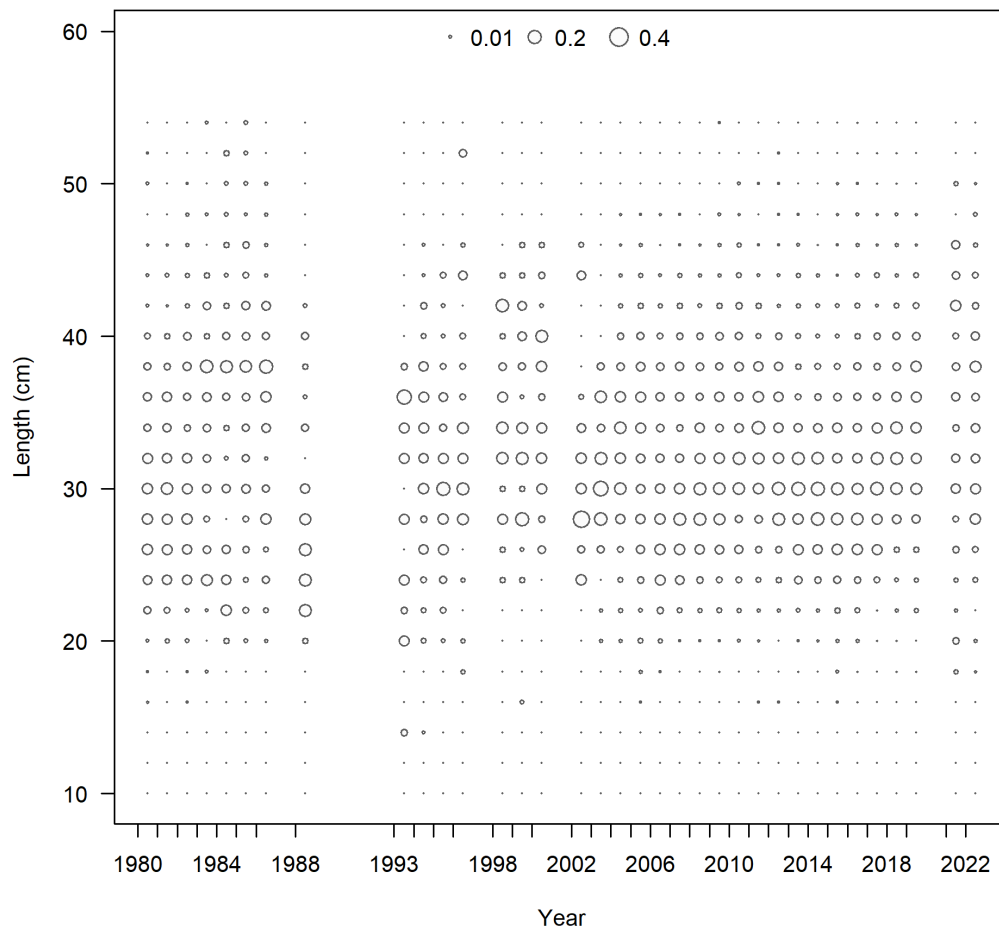


**Figure 15:** Comparison of all length collected by the CRFS sampling program for the CPFV fleet to the lengths from the fish with ages from the cooperative sampling program north and south of Point Conception. The length distributions in the area north of Point Conception are in general agreement while the distribution of lengths south of Point Conception collected by this program does not align with the length samples from CRFS.

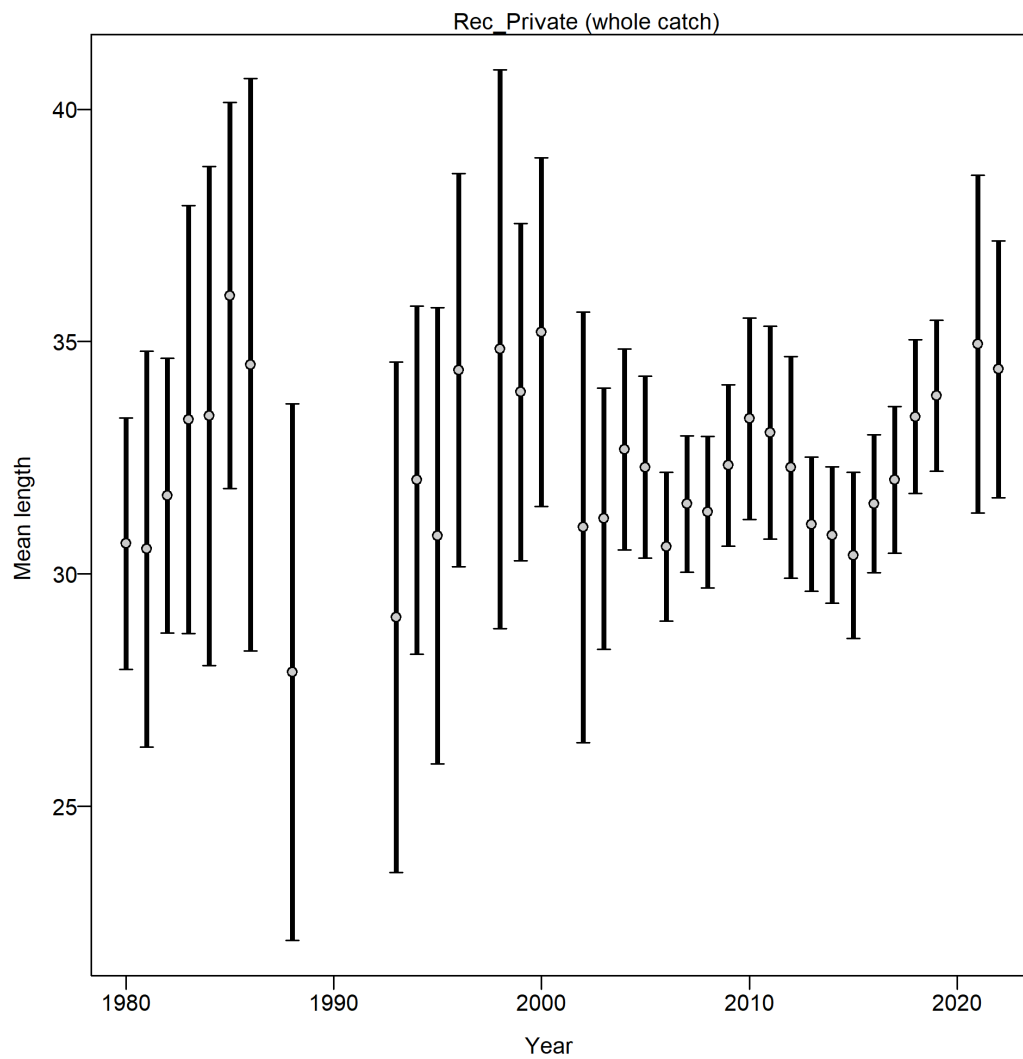




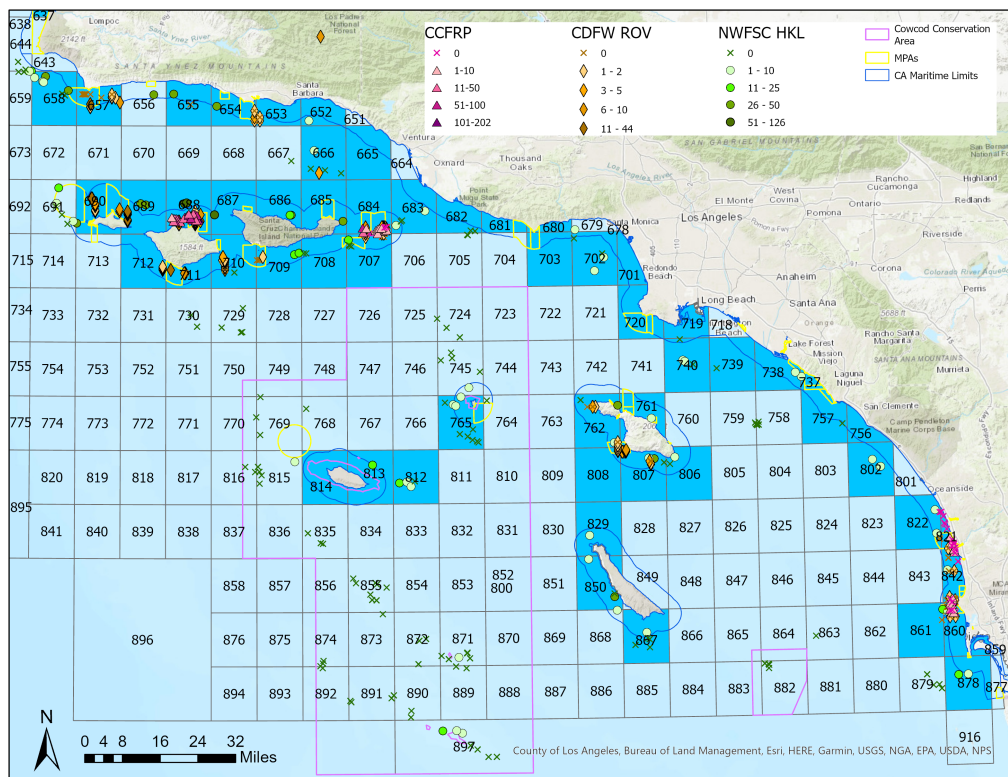
**Figure 16:** Length distributions observed in the CPFV fleet by CDFW district 1 (South) and 2 (Channel) since 2004.



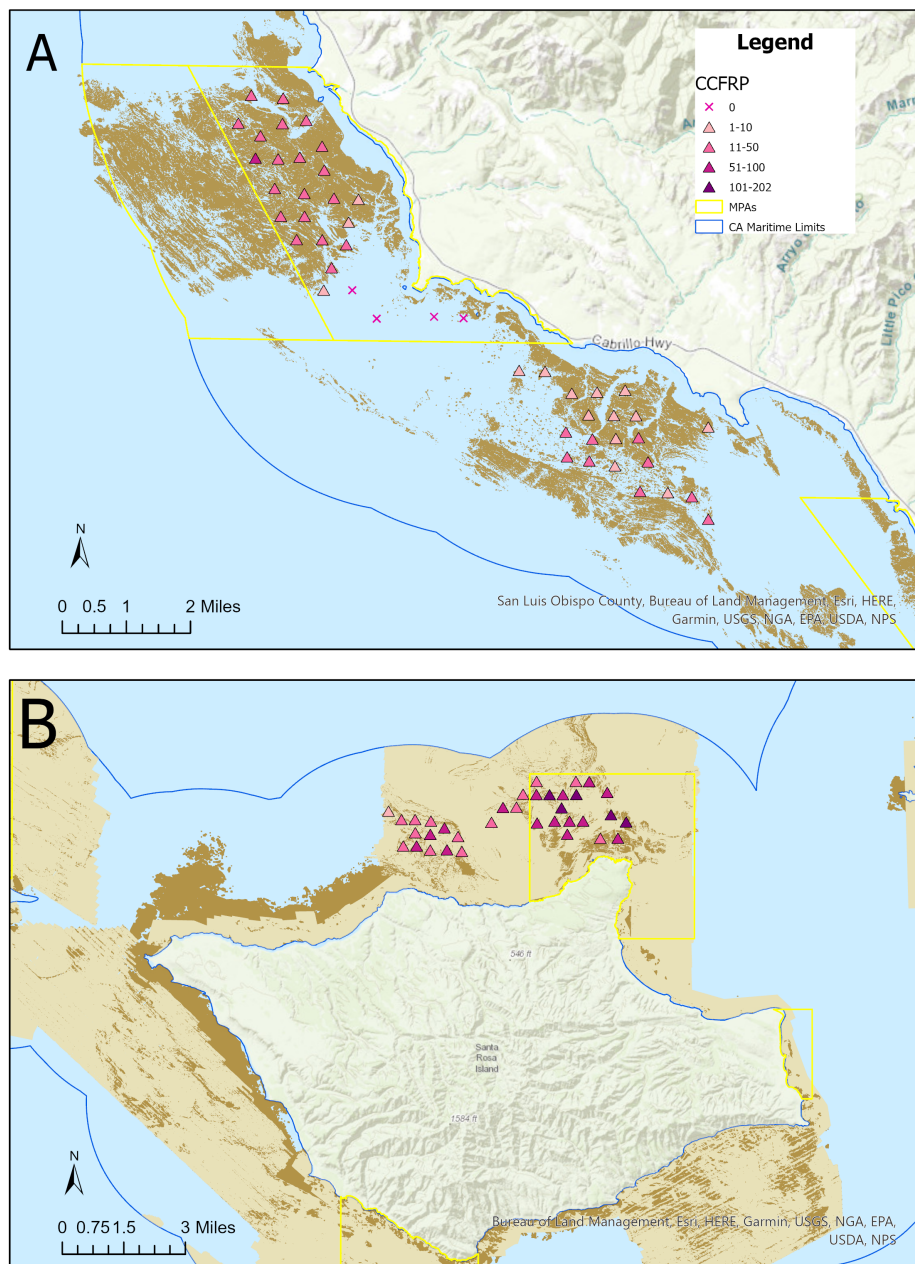
**Figure 17:** Length composition data from the recreational PR fleet.



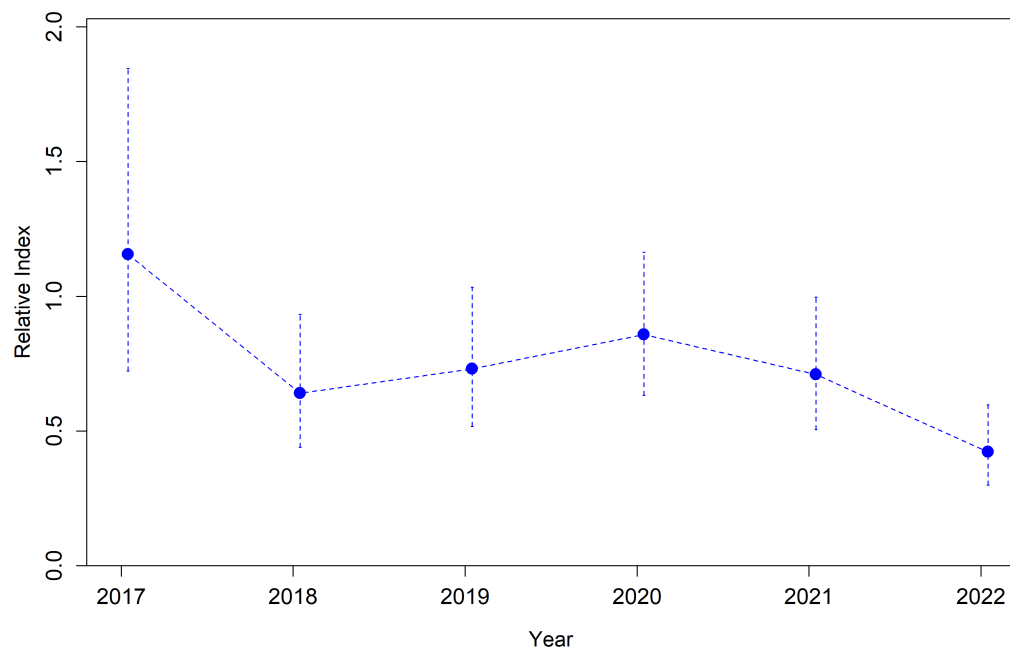
**Figure 18:** Mean length for recreational PR fleet with 95 percent confidence intervals.



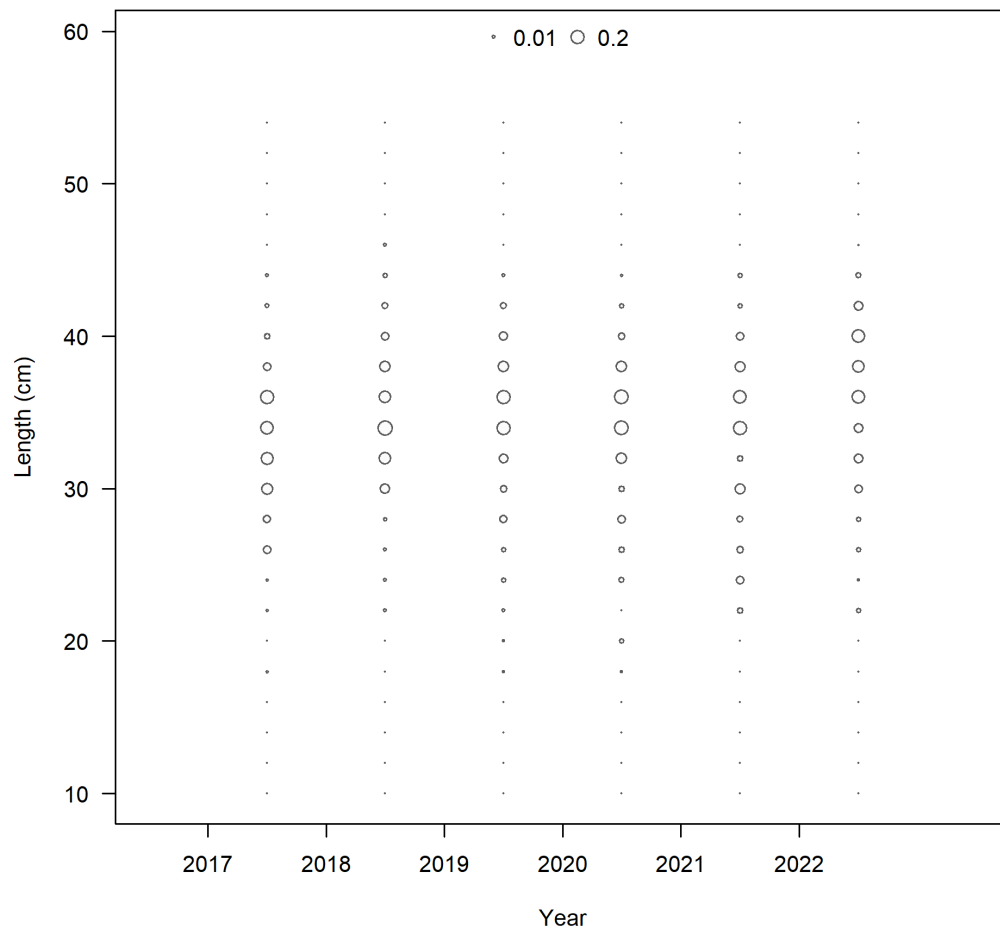
**Figure 19:** Sample locations from each of the fishery-independent data source indicating the number of observations across all years. The yellow outline indicates the location of MPAs. The CDFW area blocks are indicated by the numerical values inside each grid area with blocks where copper rockfish would be expected to be found are shaded darker blue.



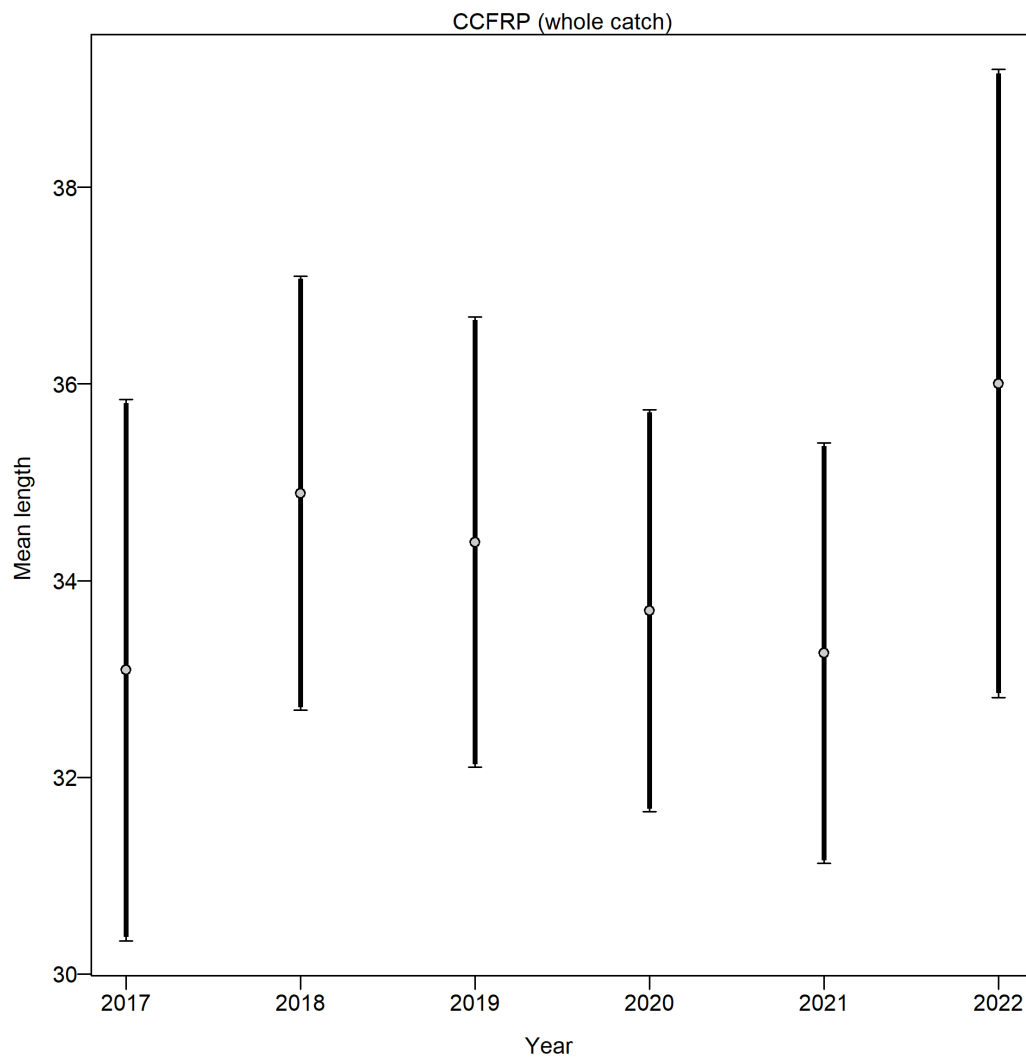
**Figure 20:** Map depicting copper rockfish observations from the Piedras Blancas MPA and reference sites for CCFRP in northern California (A) and the Carrington Point MPA and reference sites in southern California. The examples from each area show the differences in the available interpreted rocky substrate. Rocky habitat (in brown) is depicted for northern California and the areas that have been interpreted for the area shown in southern California are in tan with the rocky substrate in brown. The lower resolution rocky substrate (outside the tan areas) depicted in southern California represents interpreted substrate from coarser bathymetry data.



**Figure 21:** Estimated CCFRP Hook and Line survey index of abundance for copper rockfish.

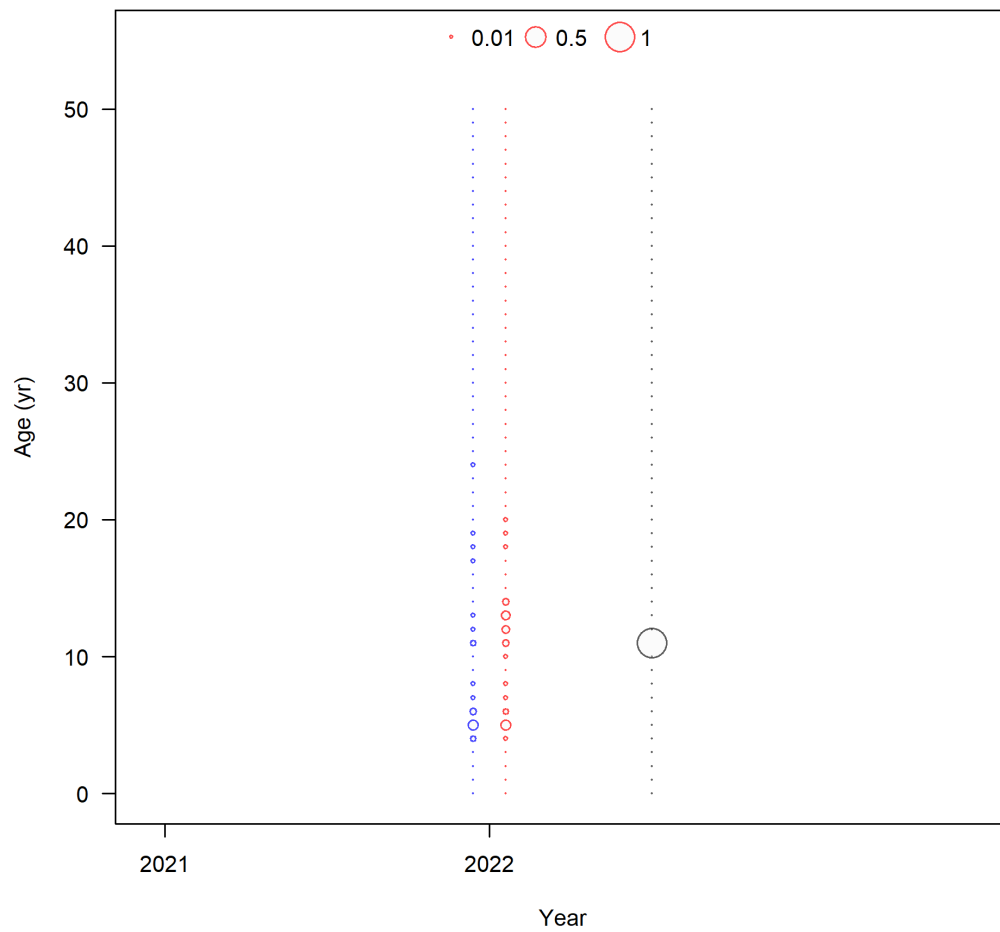


**Figure 22:** Length composition data from the CCFRP Hook and Line survey.

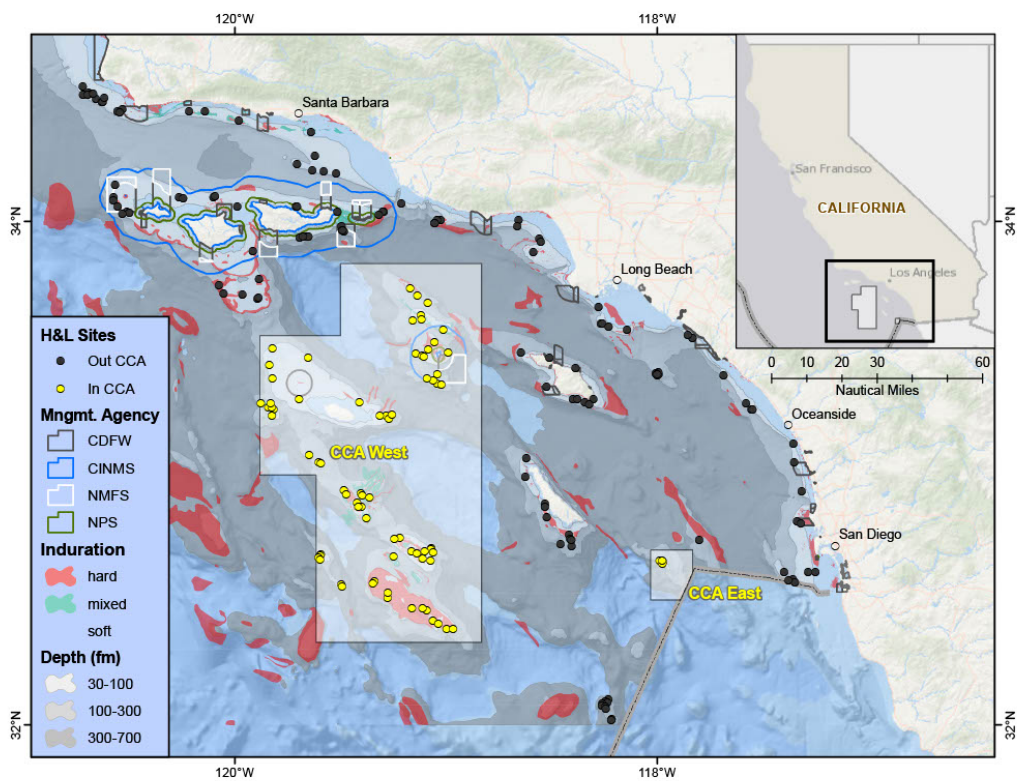


**Figure 23:** Mean length for the CCFRP Hook and Line survey with 95 percent confidence intervals.

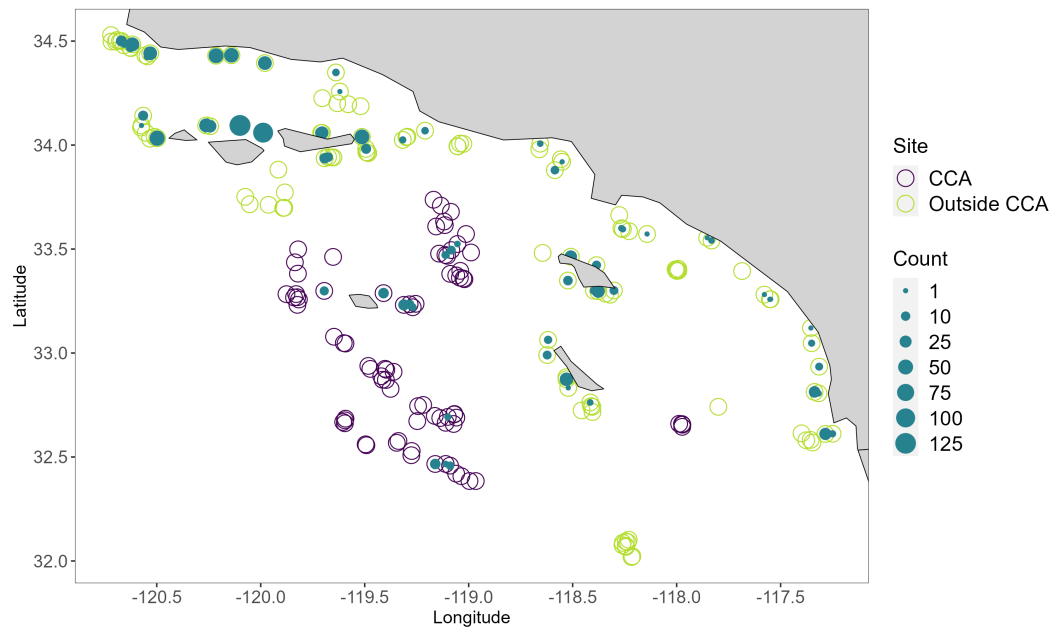




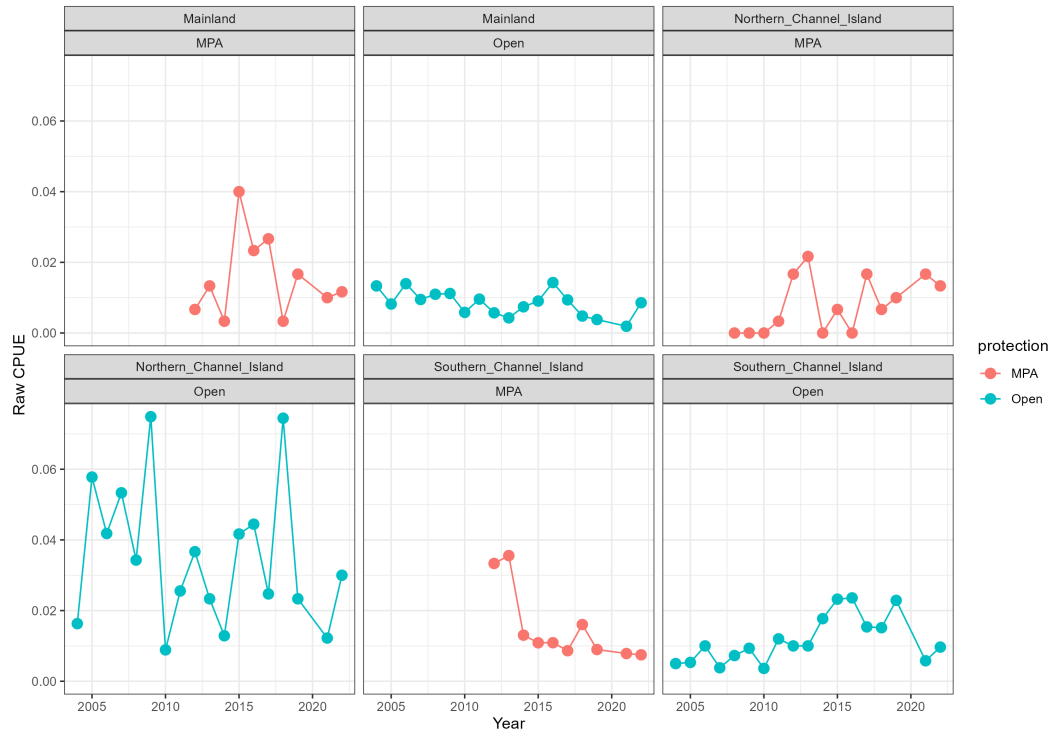
**Figure 24:** Age composition data from the CCFRP Hook and Line survey.



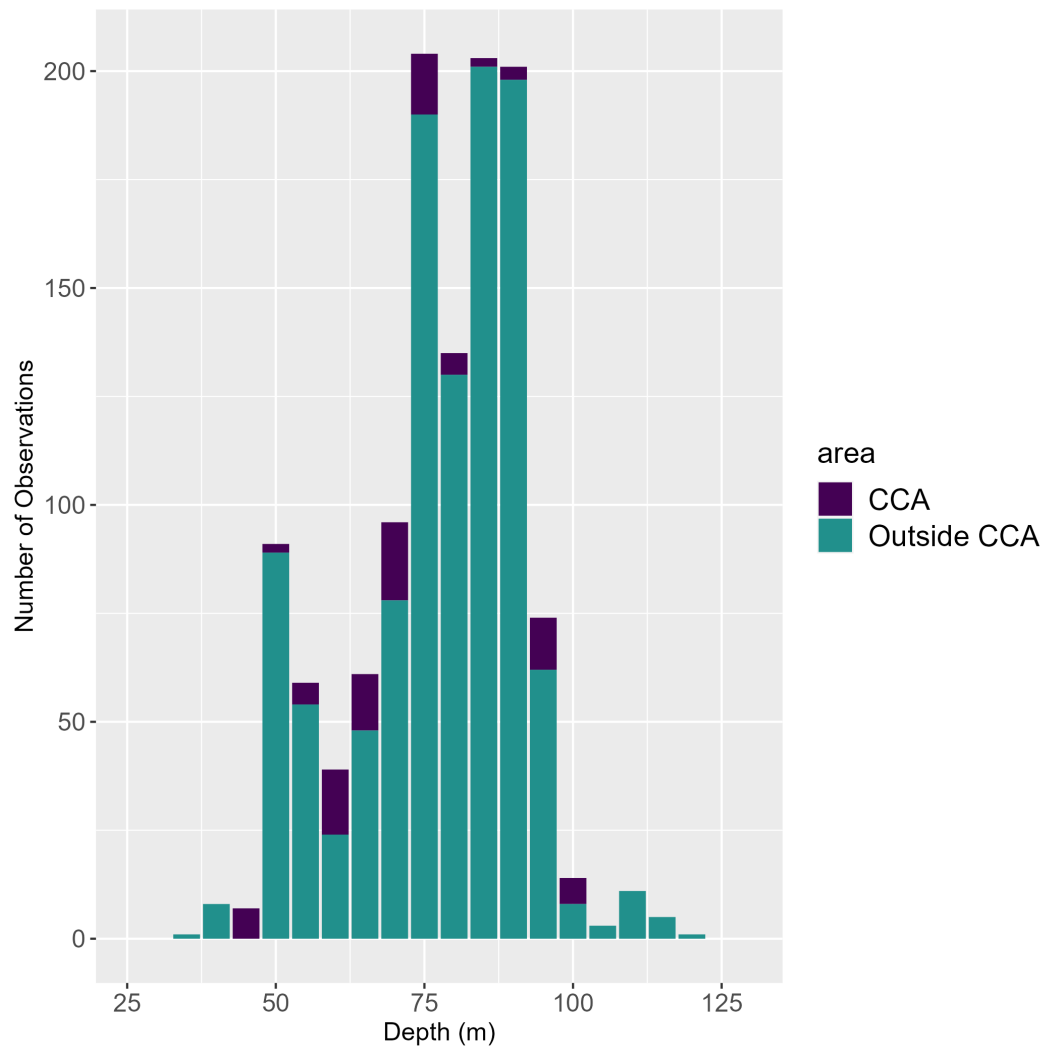
**Figure 25:** Area sampled by the NWFSC Hook and Line survey.



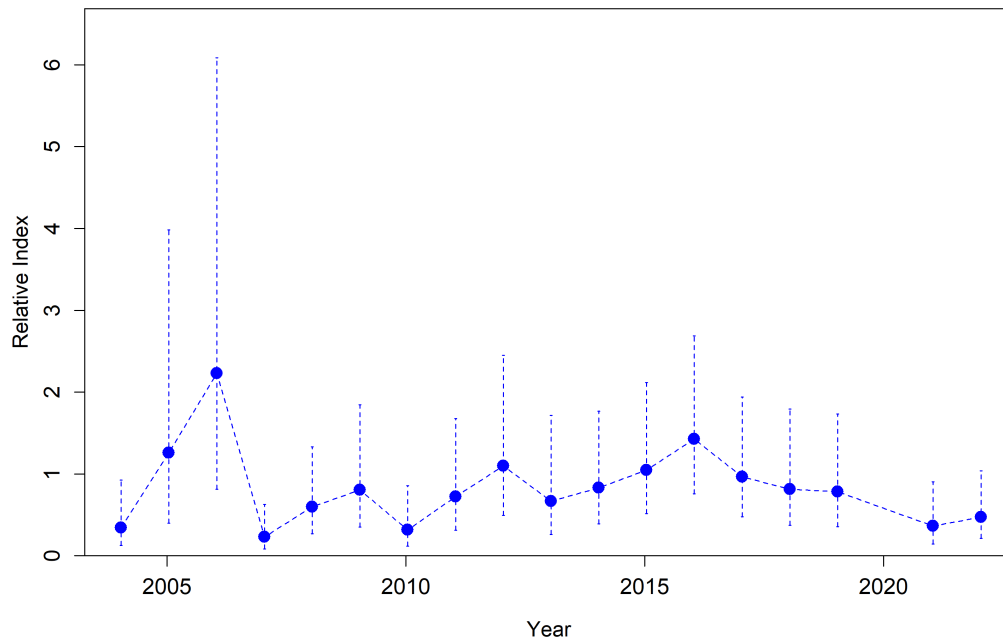
**Figure 26:** Observations of copper rockfish by the NWFSC Hook and Line survey by sample area, inside and outside Cowcod Conservation areas (CCA).



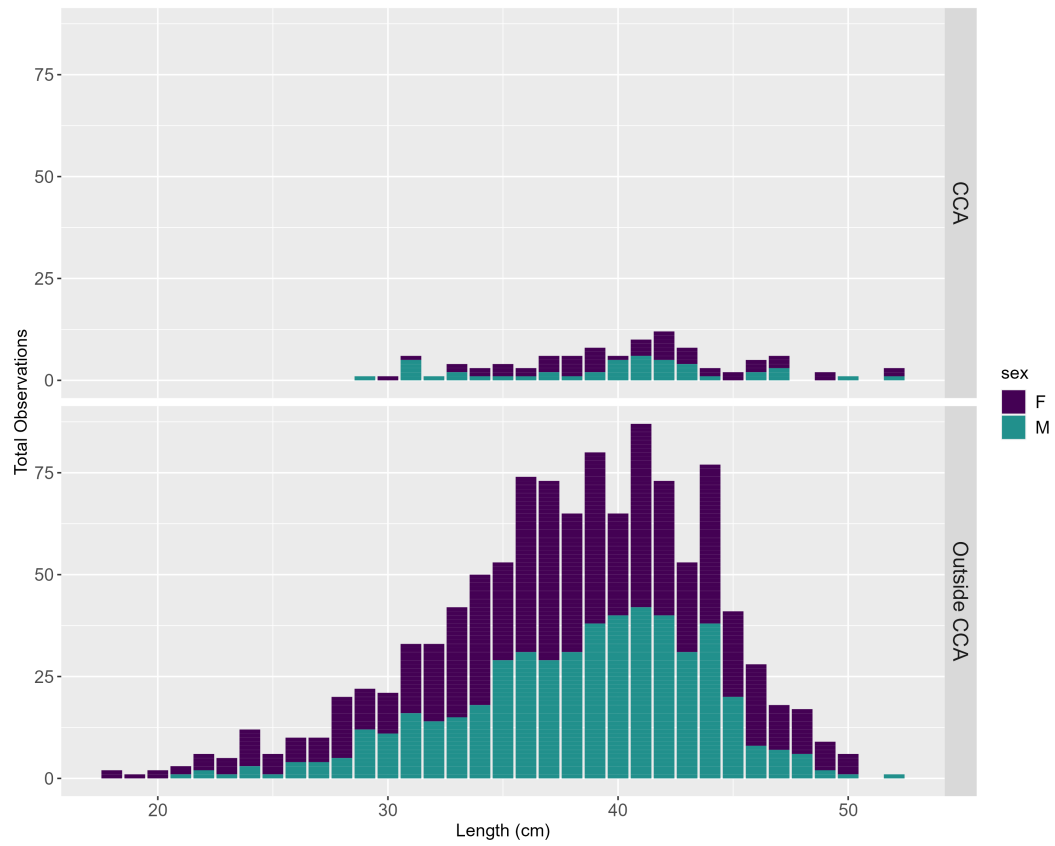
**Figure 27:** Raw CPUE inside and outside protected areas by region sampled by the NWFSC Hook and Line survey.



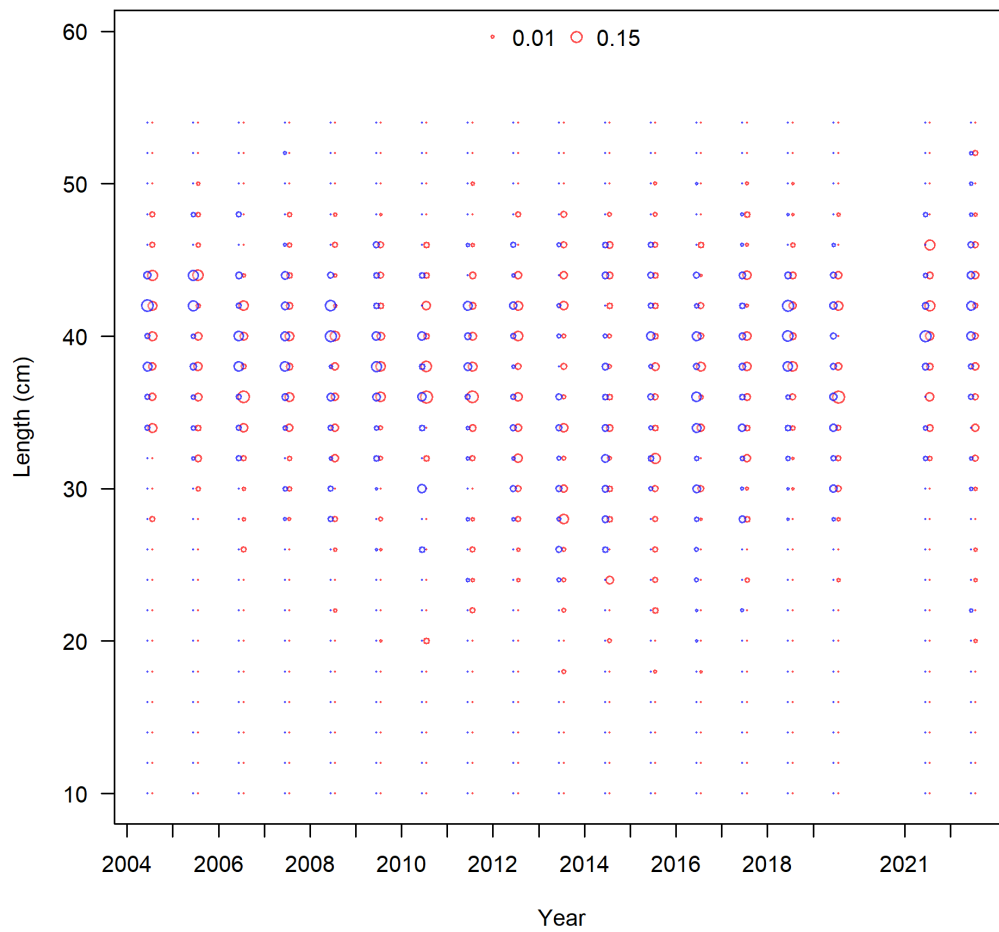
**Figure 28:** Number of observations by depth (m) inside and outside the CCAs by the NWFSC Hook and Line survey.



**Figure 29:** Estimated NWFSC Hook and Line survey index of abundance for copper rockfish.

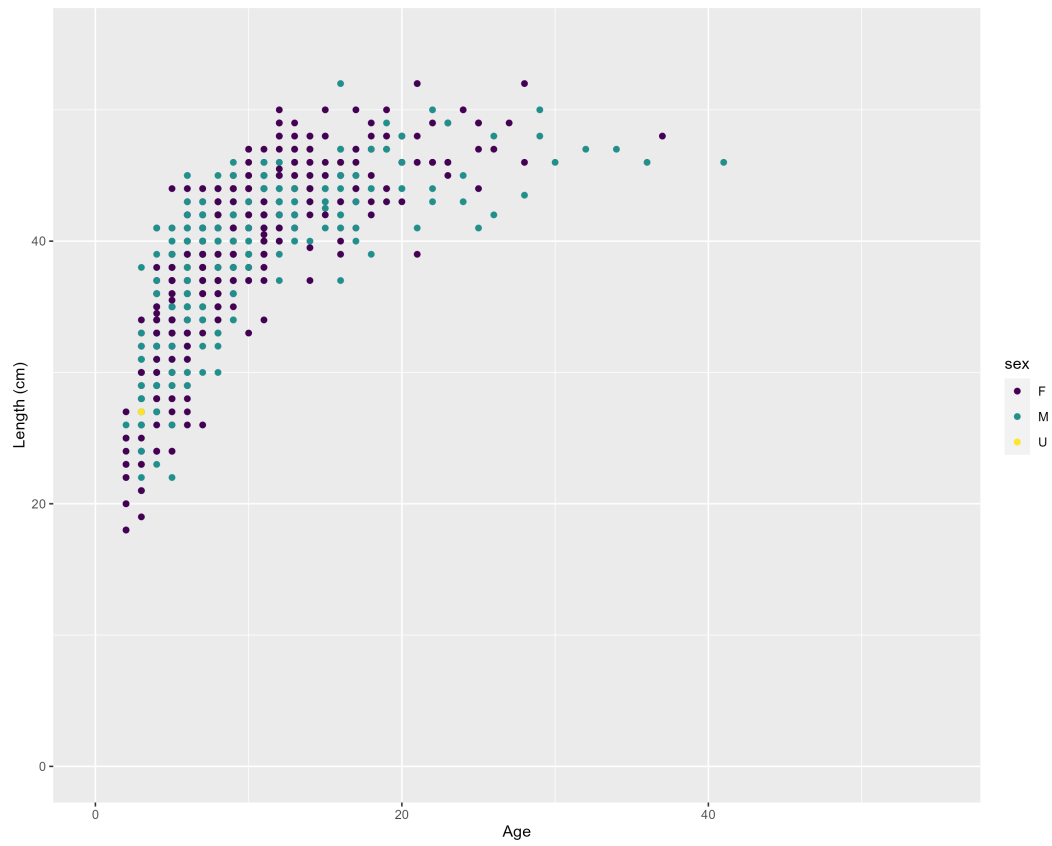


**Figure 30:** Observed length (cm) distribution of copper rockfish by the NWFSC Hook and Line survey by sample area, inside and outside Cowcod Conservation areas (CCA).

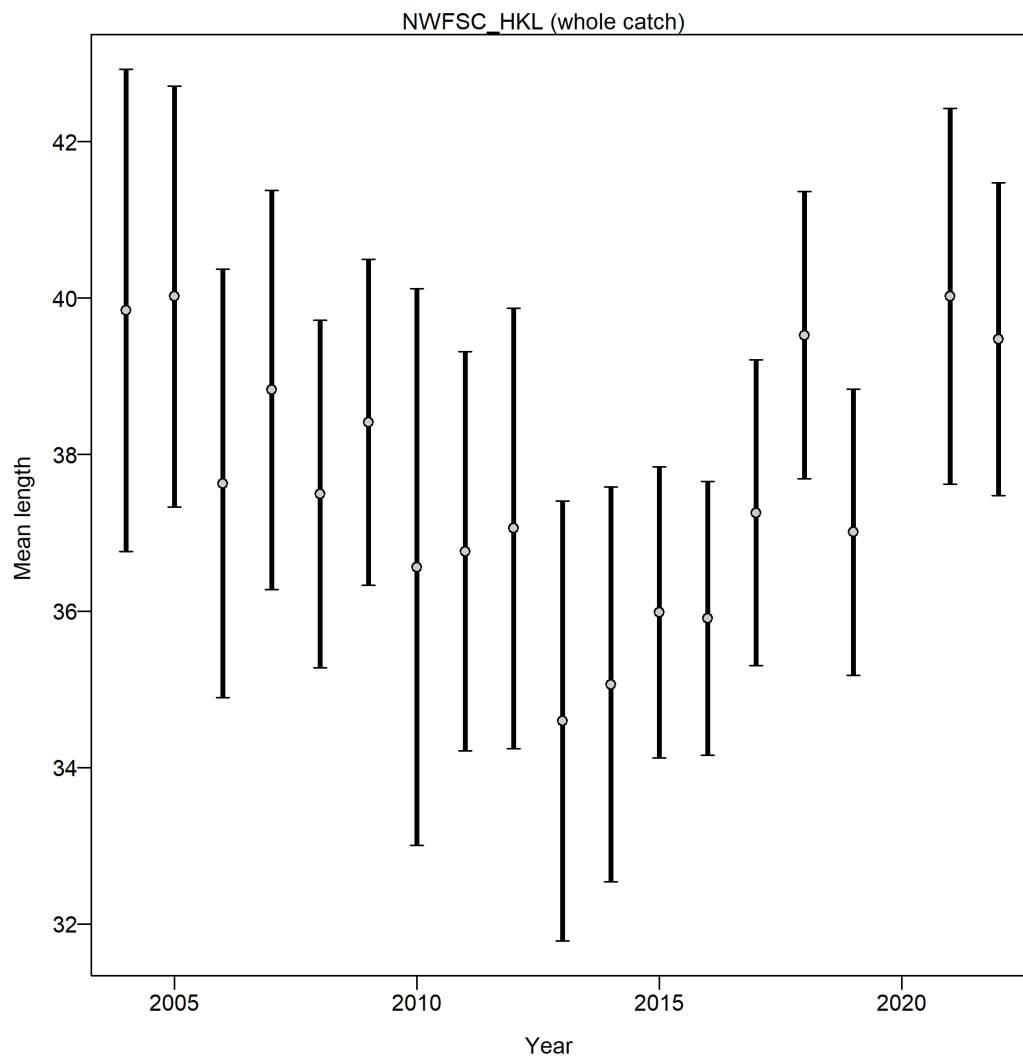


**Figure 31:** Length composition data from the NWFSC Hook and Line survey.

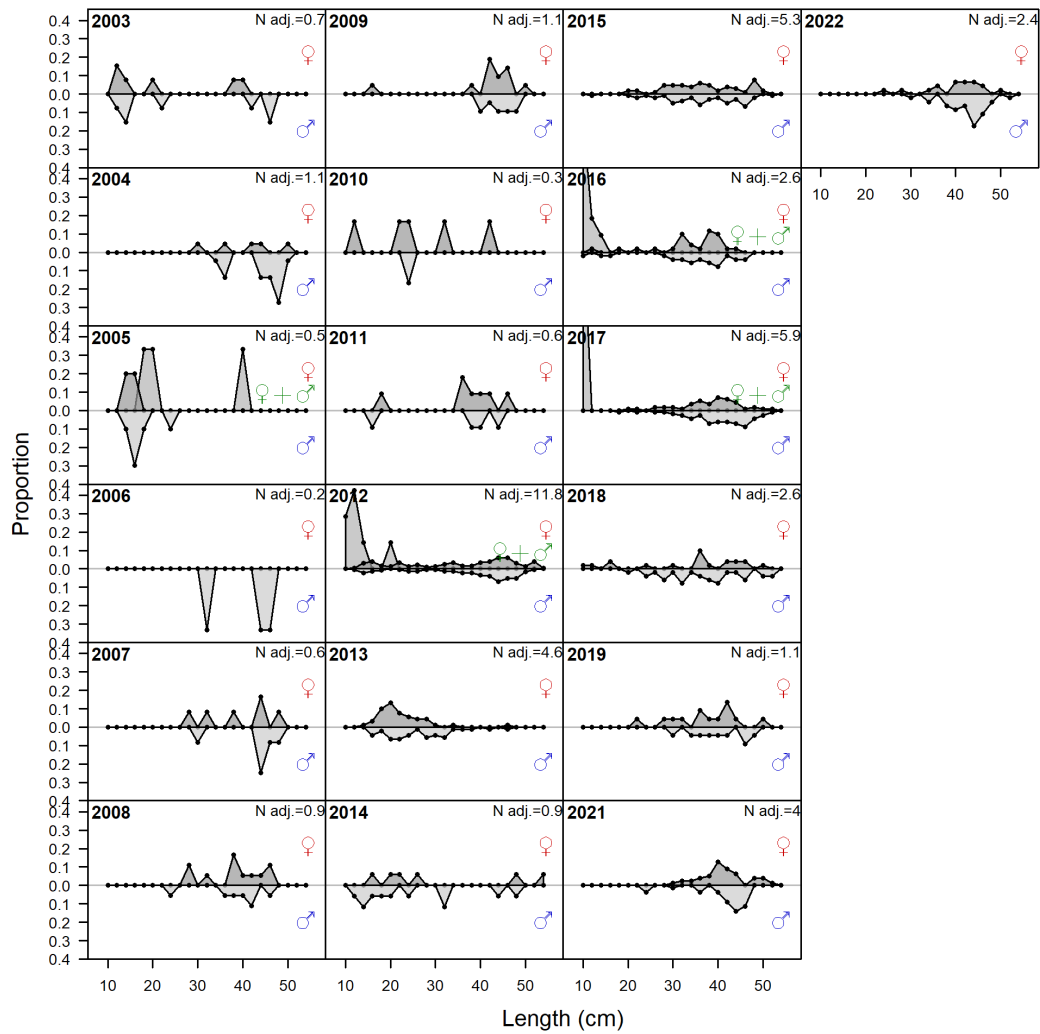




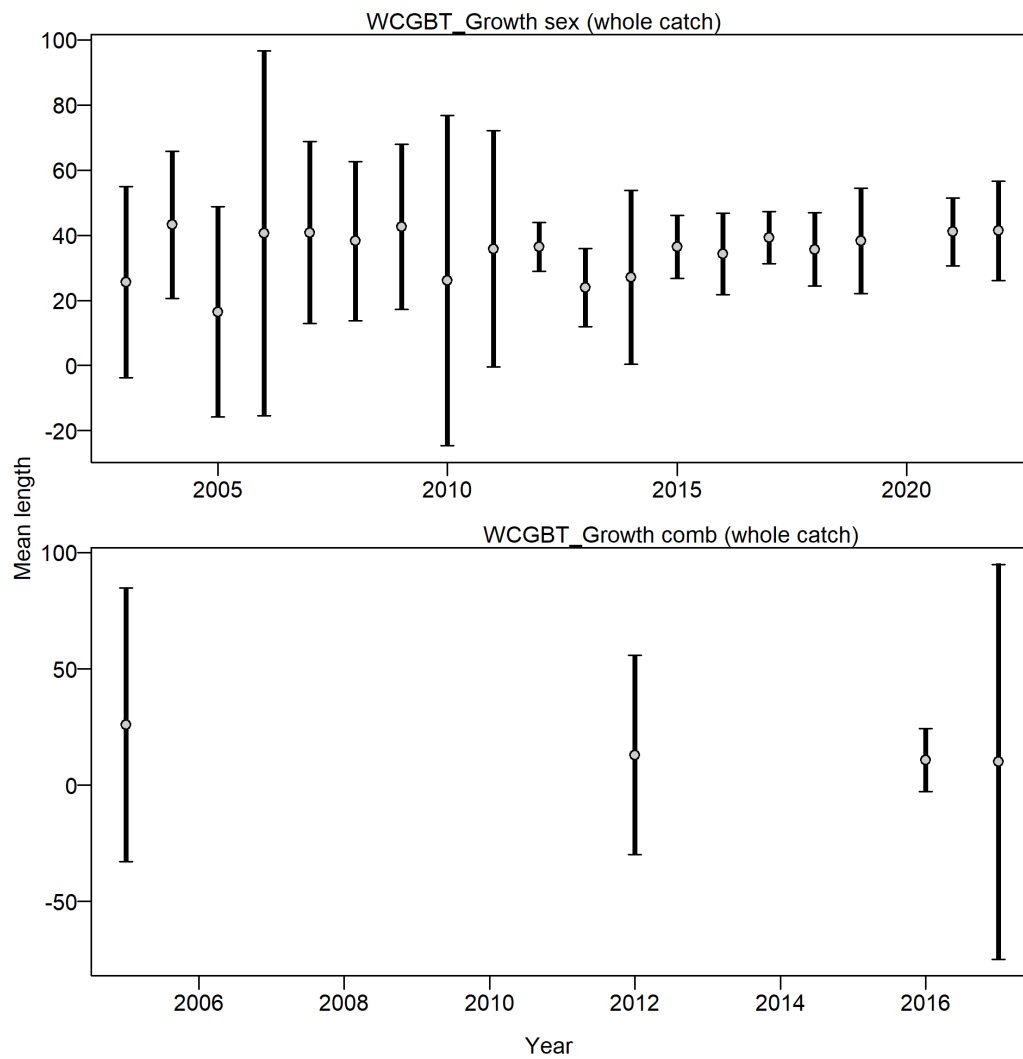
**Figure 32:** Age and length by sex for copper rockfish in the NWFSC Hook and Line survey.



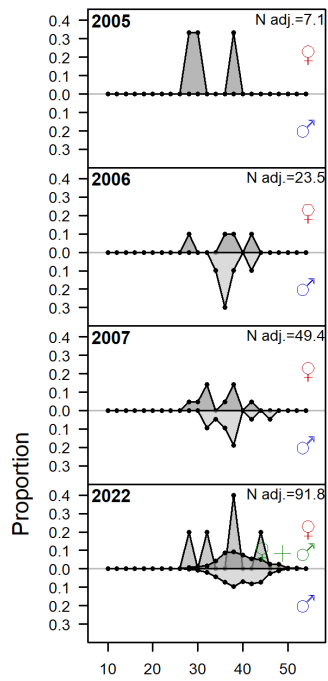
**Figure 33:** Mean length for NWFSC Hook and Line survey with 95 percent confidence intervals.



**Figure 34:** Length distribution by year for fish sampled by the NWFSC WCGBT survey.

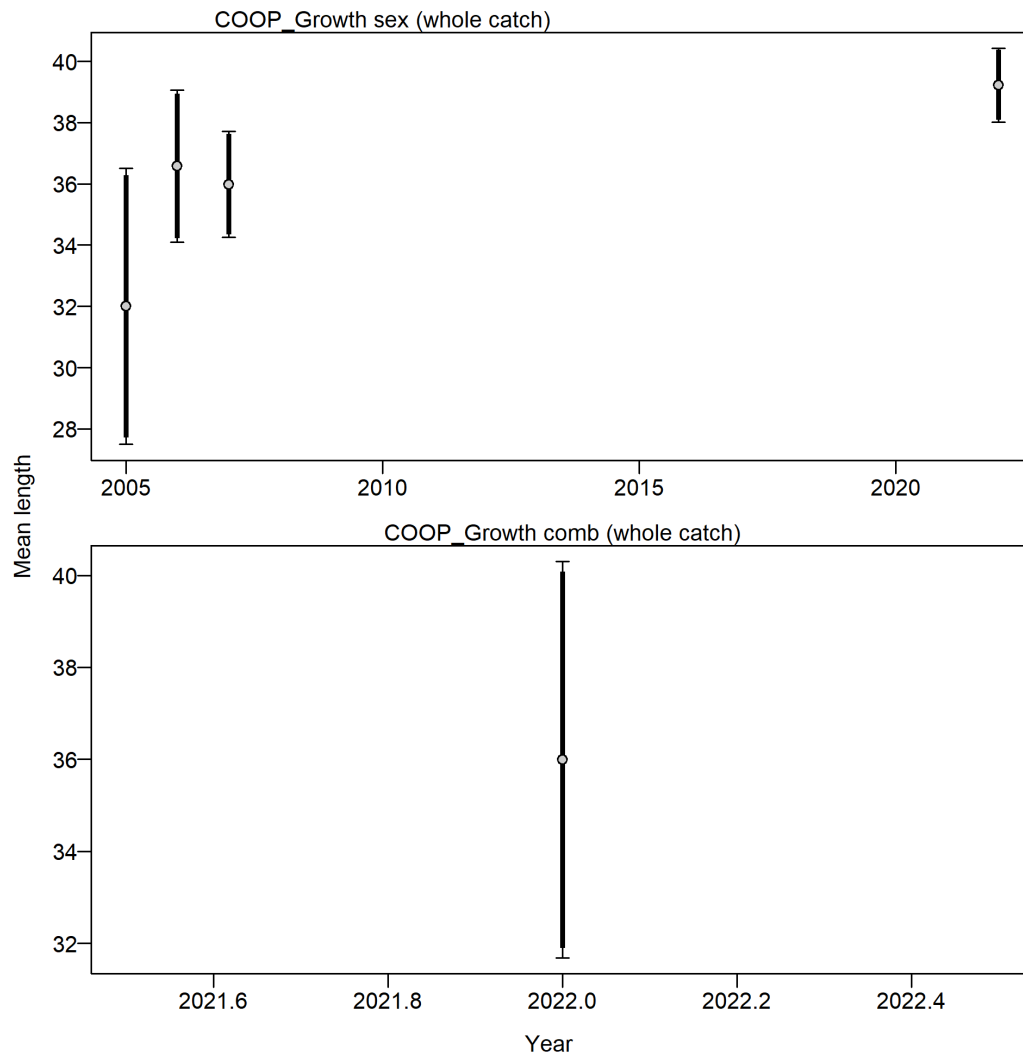


**Figure 35:** Mean length distribution by year for fish sampled by the NWFSC WCGBT survey.

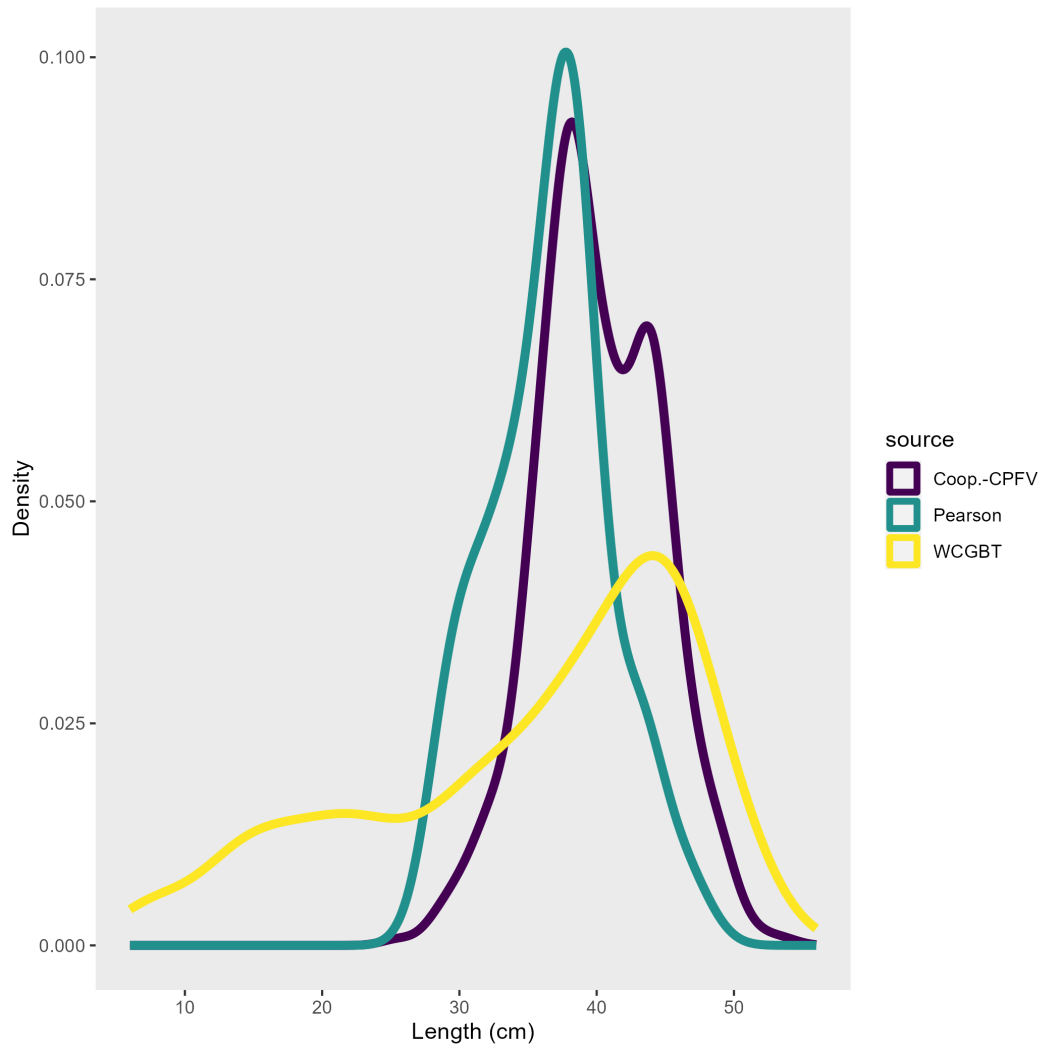


Length (cm)

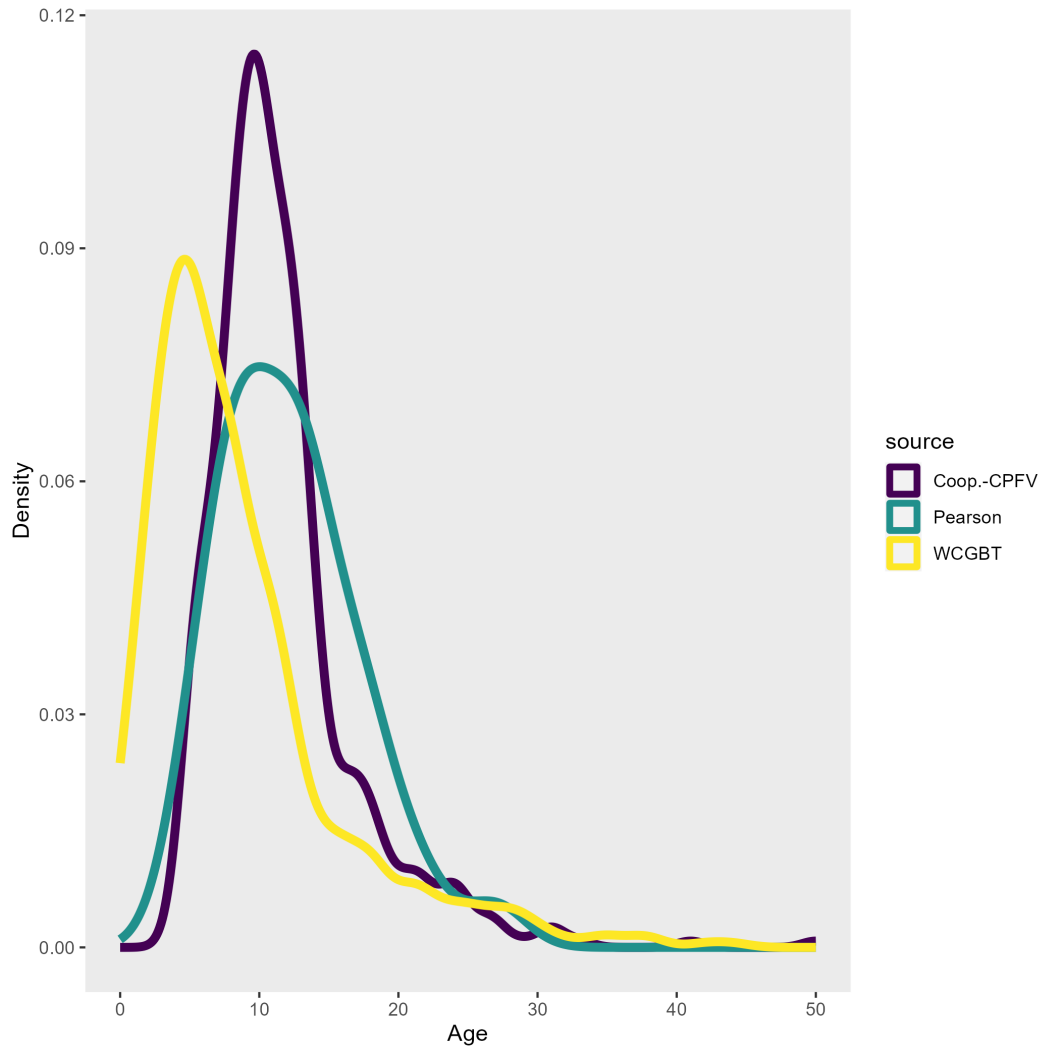
**Figure 36:** Length distribution by year for fish sampled by the Pearson Research study (2005-2007) and the CPFV cooperative collection program (2022).



**Figure 37:** Mean length distribution by year for fish sampled by the Pearson Research Program (2005-2007) and the CPFV cooperative collection program (2022).

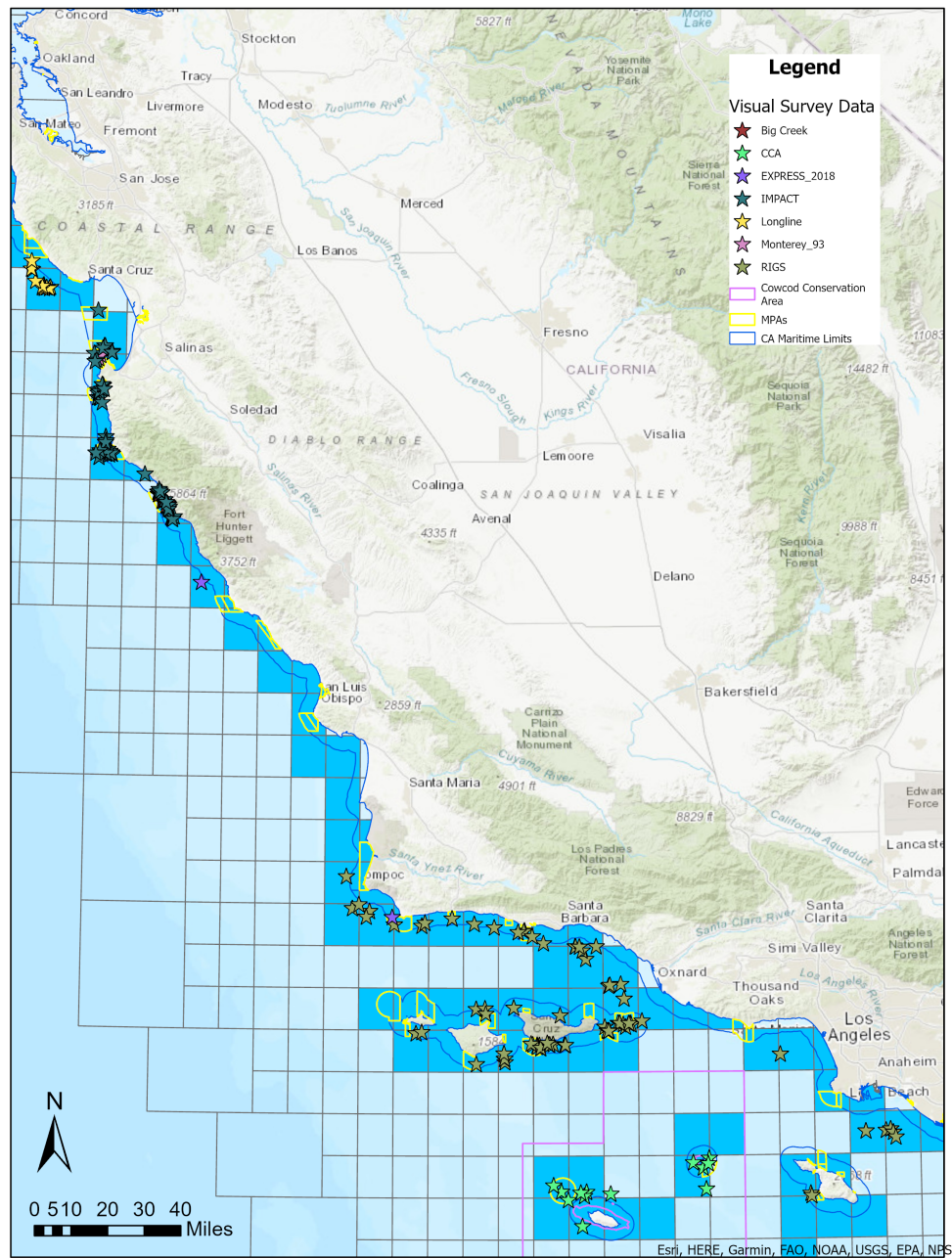


**Figure 38:** Length (cm) distribution of fish by collection source that were used as conditional age-at-length data in the growth fleets.

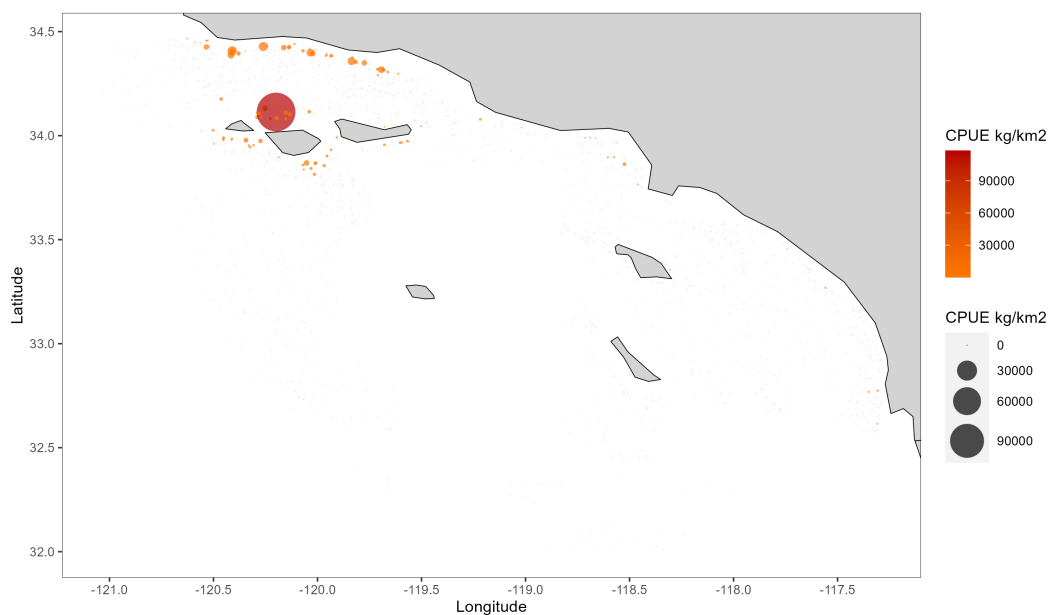


**Figure 39:** Age (year) distribution of fish by collection source that were used as conditional age-at-length data in the growth fleets.

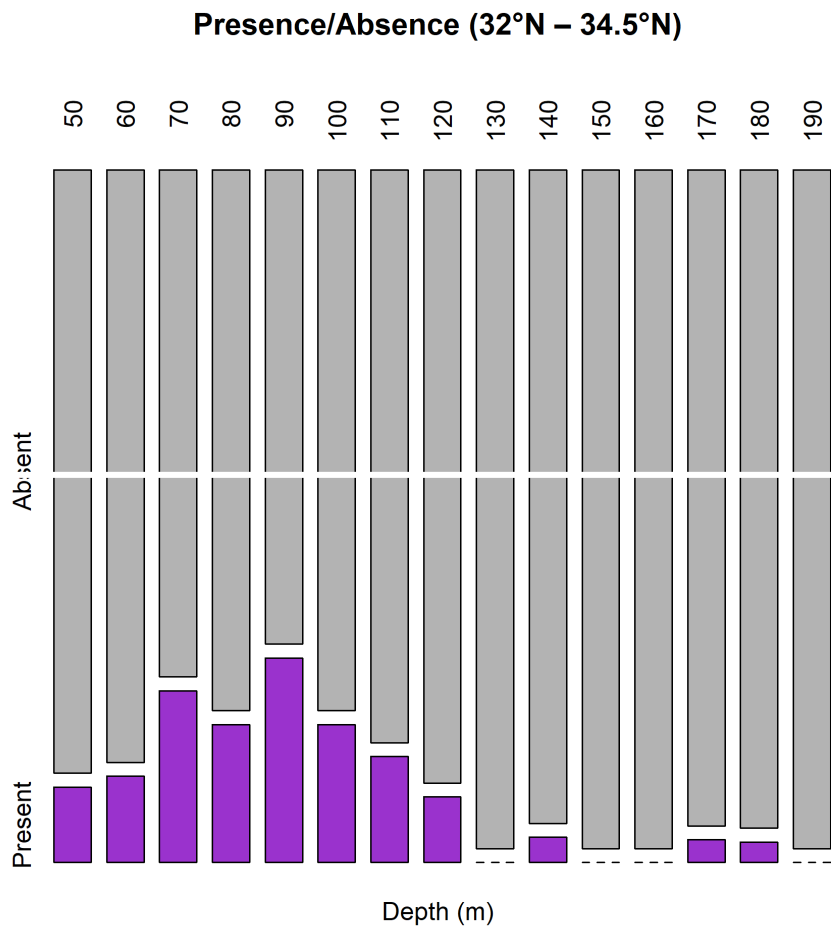




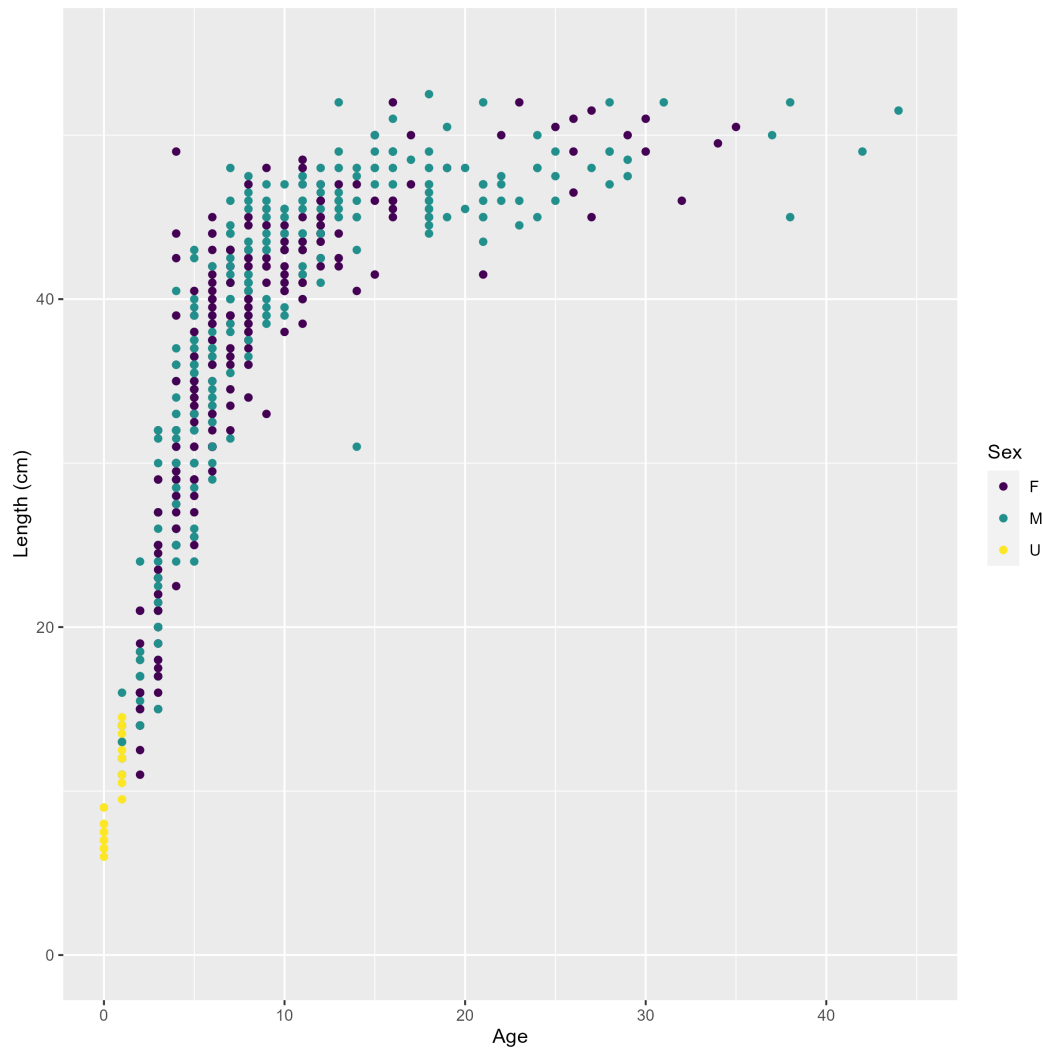
**Figure 40:** Locations copper rockfish were observed from visual surveys from Milton Love's submersible survey of natural reefs and oil platforms (RIGS) and additional visual surveys conducted by the SWFSC.



**Figure 41:** Location and catch-per-unit-effort (CPUE) measured in kilograms (kg) by kilometers-squared by location south of Point Conception by the NWFSC WCGBT survey.

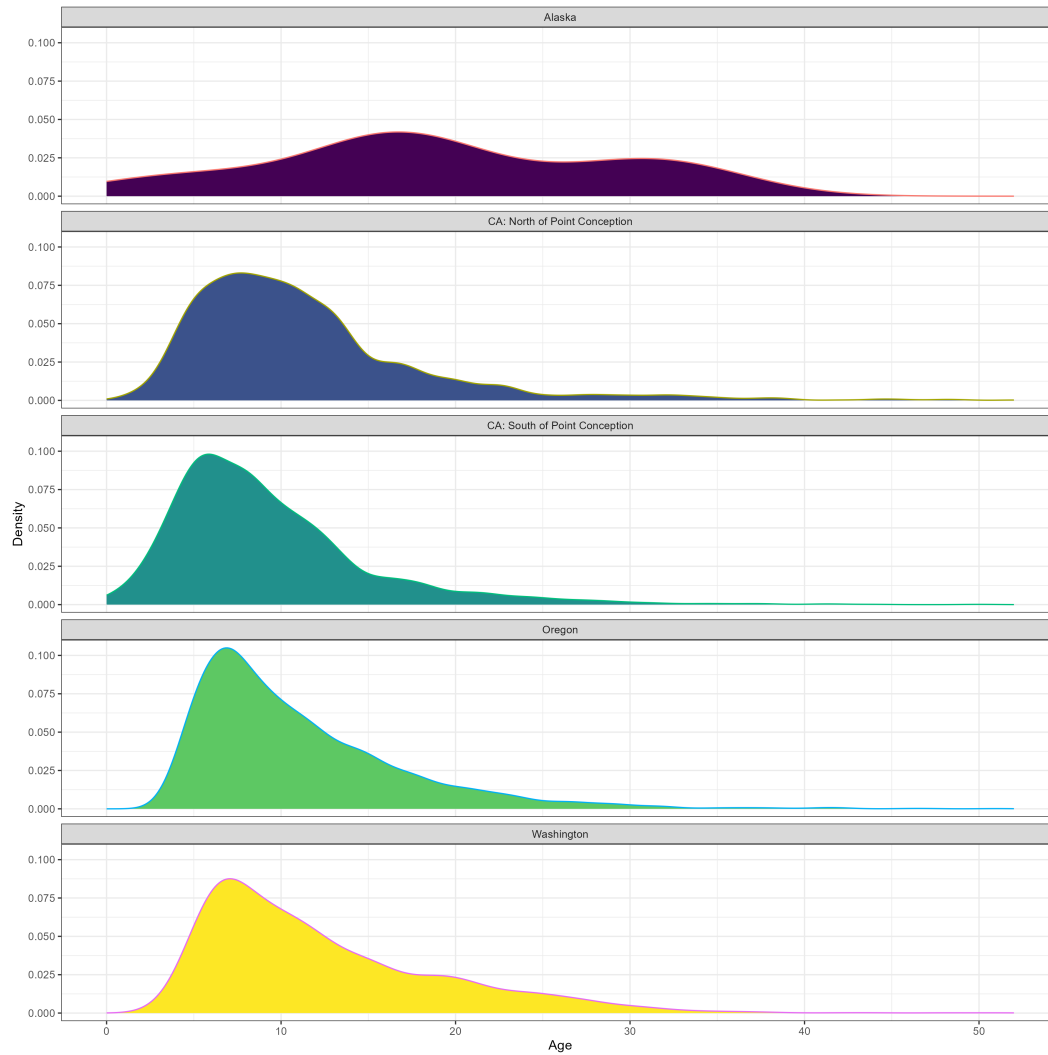


**Figure 42:** Proportion of positive tows from the NWFSC WCGBT survey across all years by depth in meters.

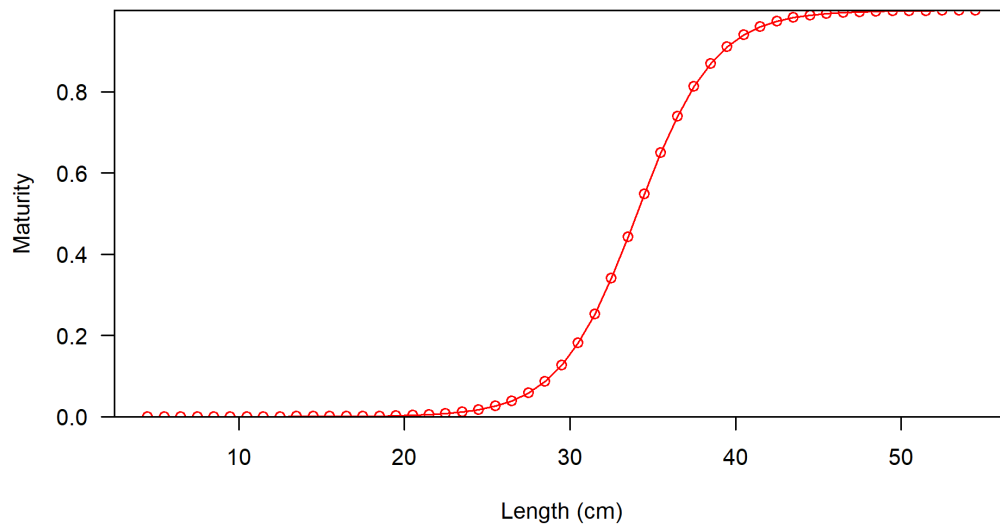


**Figure 43:** Age and length by sex for copper rockfish caught south of Point Conception by the NWFSC WCGBT survey.

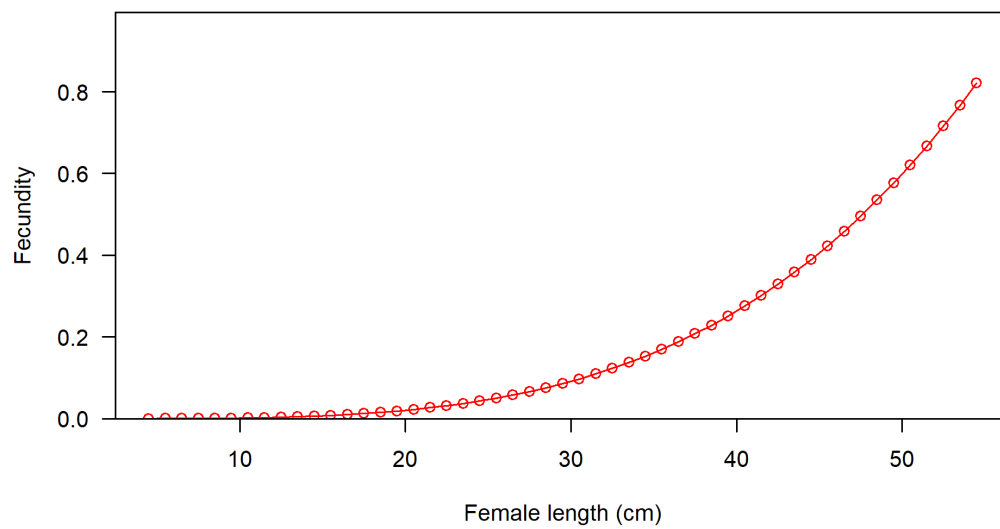
## 8.2 Biology



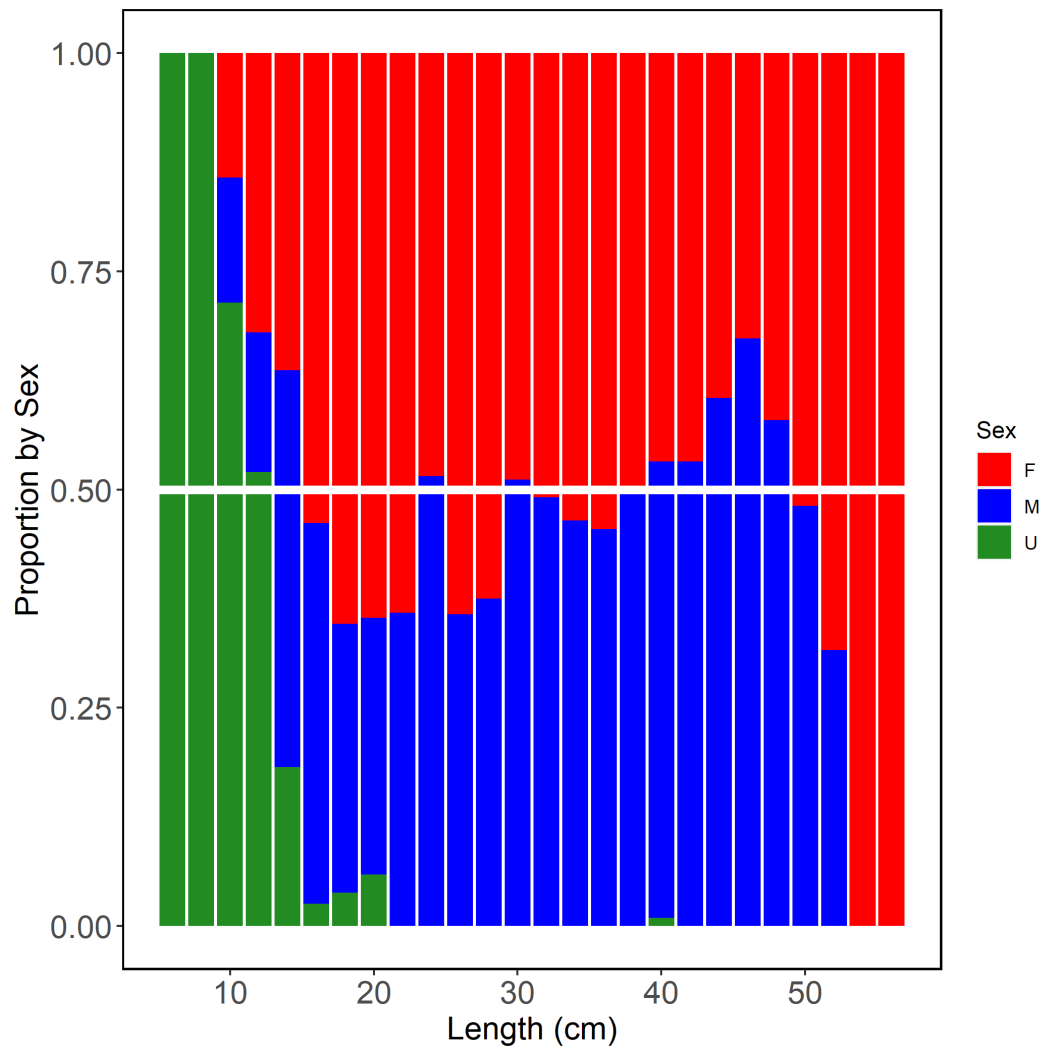
**Figure 44:** Densities of aged copper rockfish by West Coast collection area and limited samples from the Gulf of Alaska (25 fish).



**Figure 45:** Maturity as a function of length.

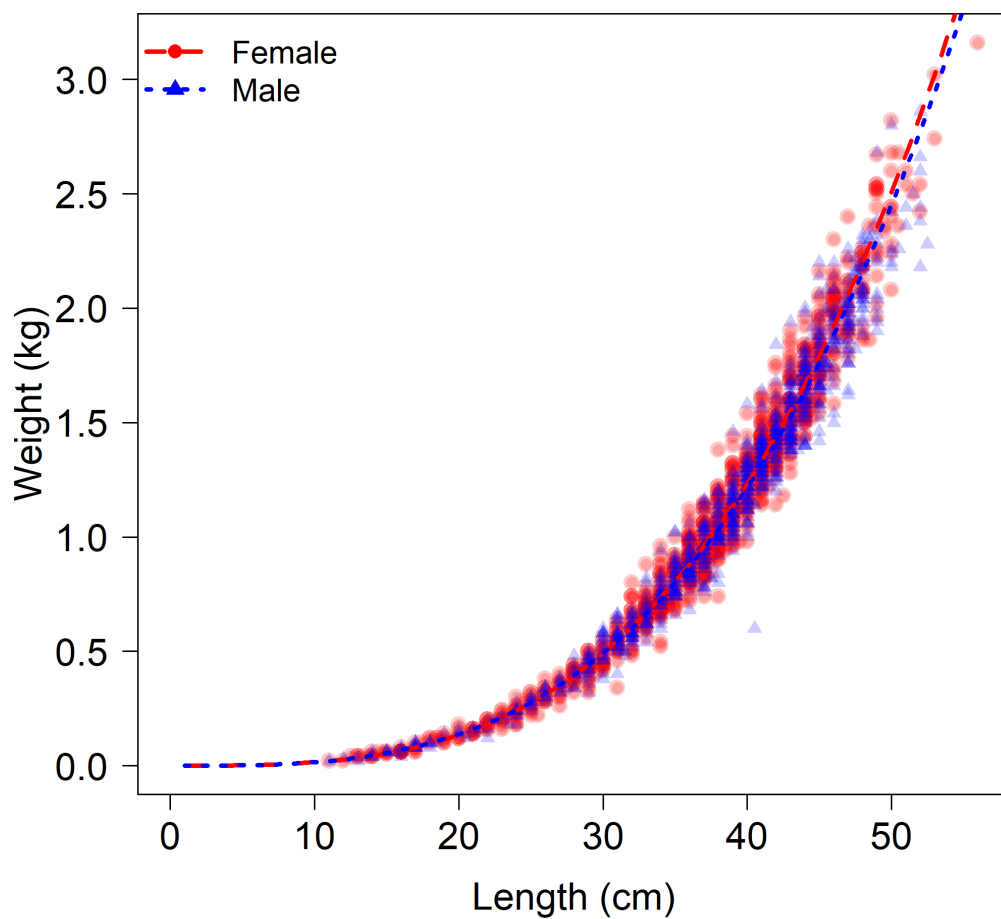


**Figure 46:** Fecundity as a function of length.

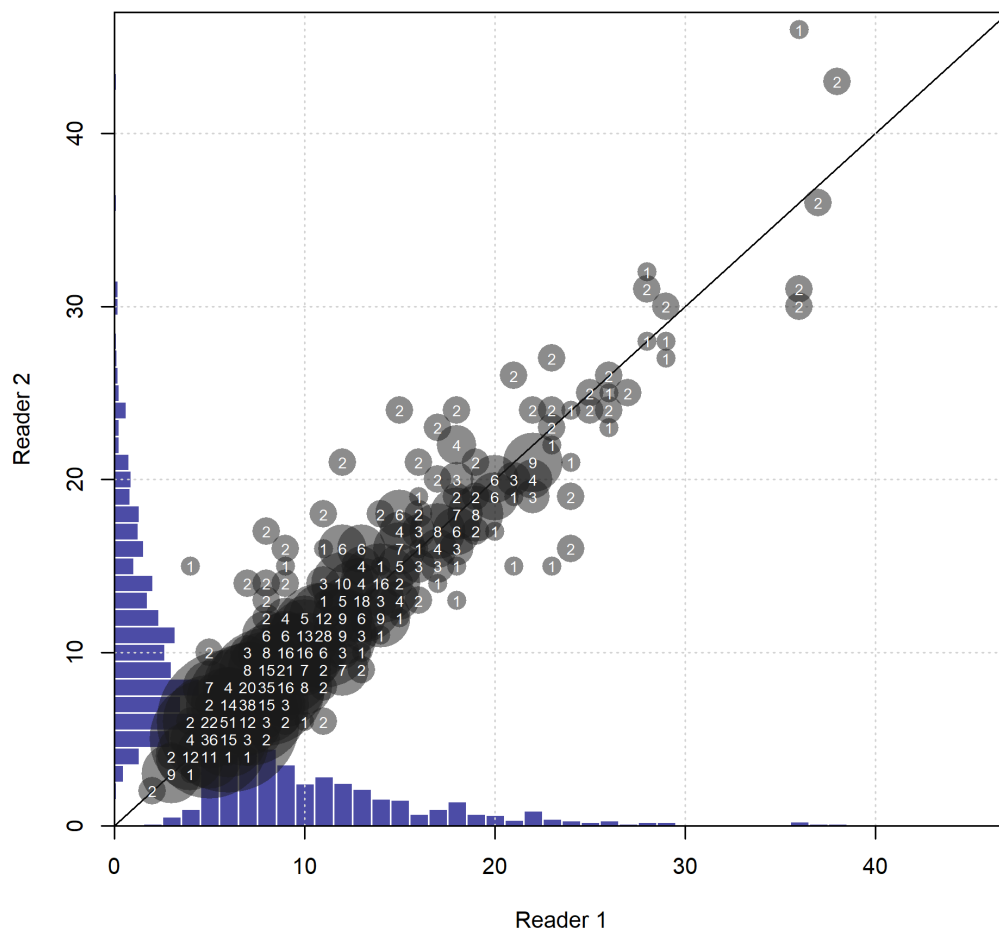


**Figure 47:** Fraction of each sex by length observed by the NWFSC WCGBT survey.

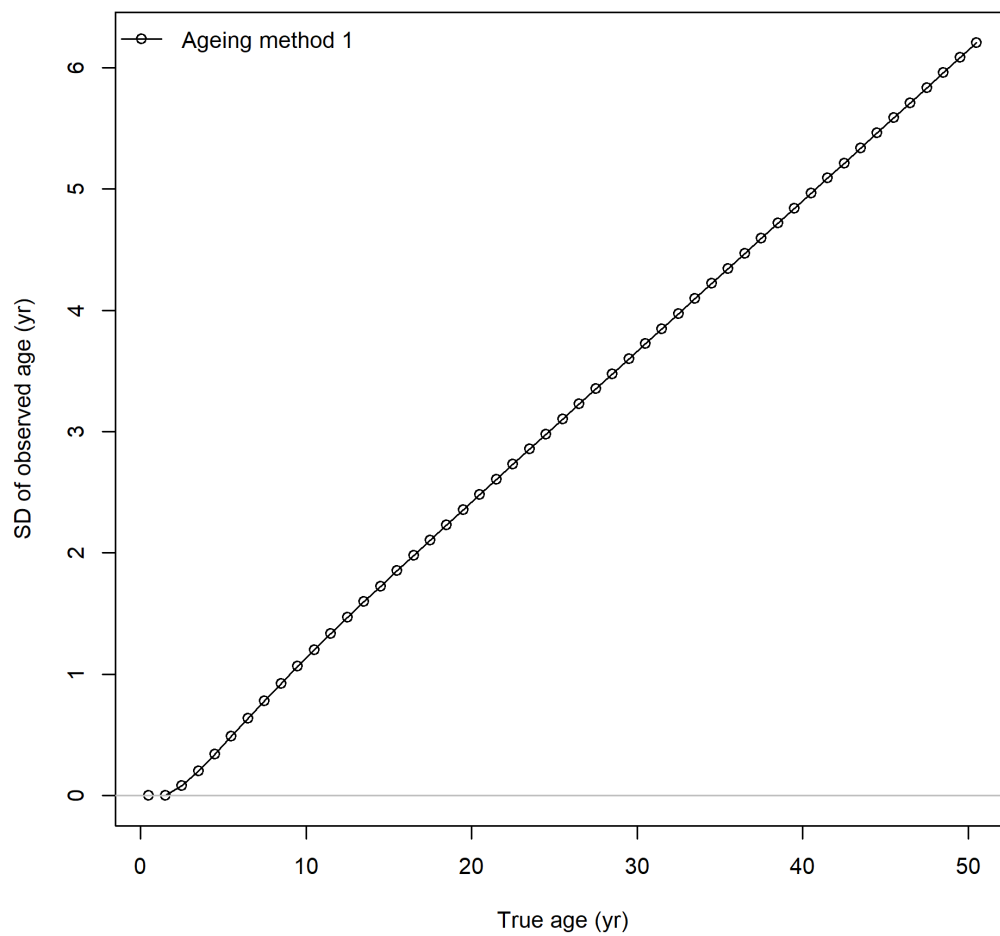




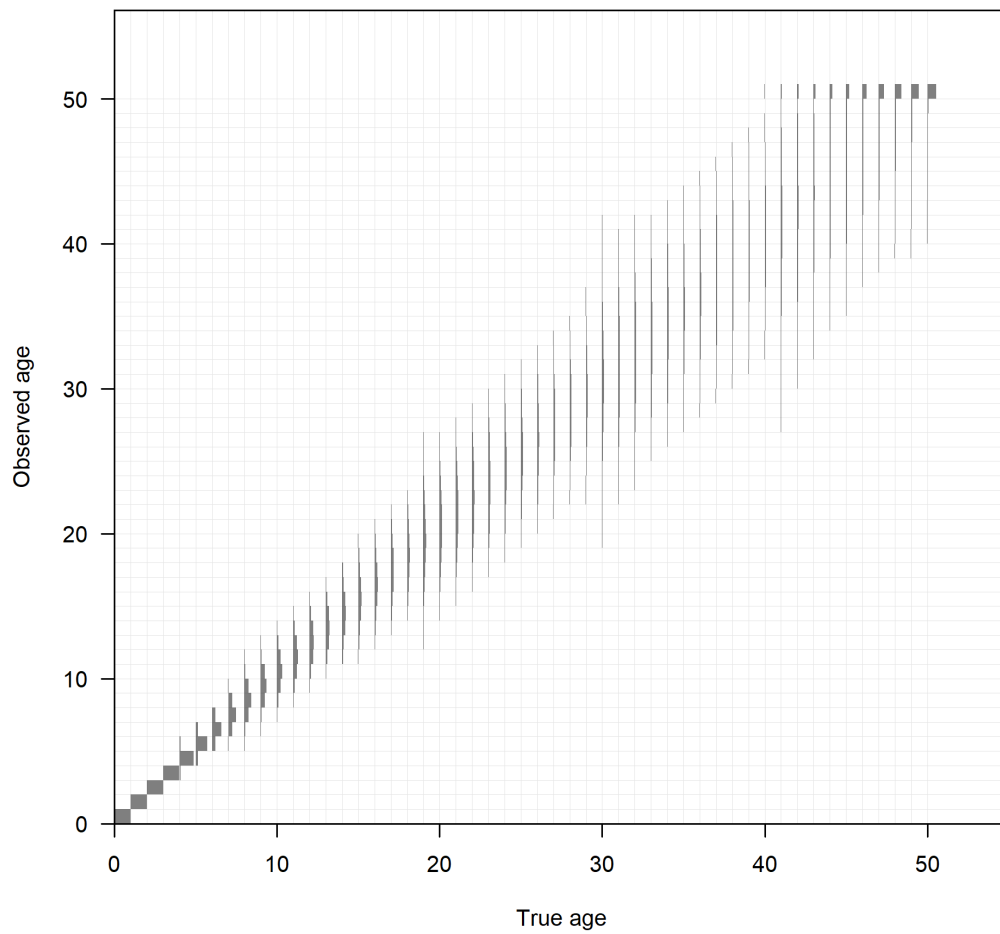
**Figure 48:** Estimated weight-at-length using data from the NWFSC Hook and Line and WCGBT surveys.



**Figure 49:** Distribution of double reads between age reader 1 and 2.



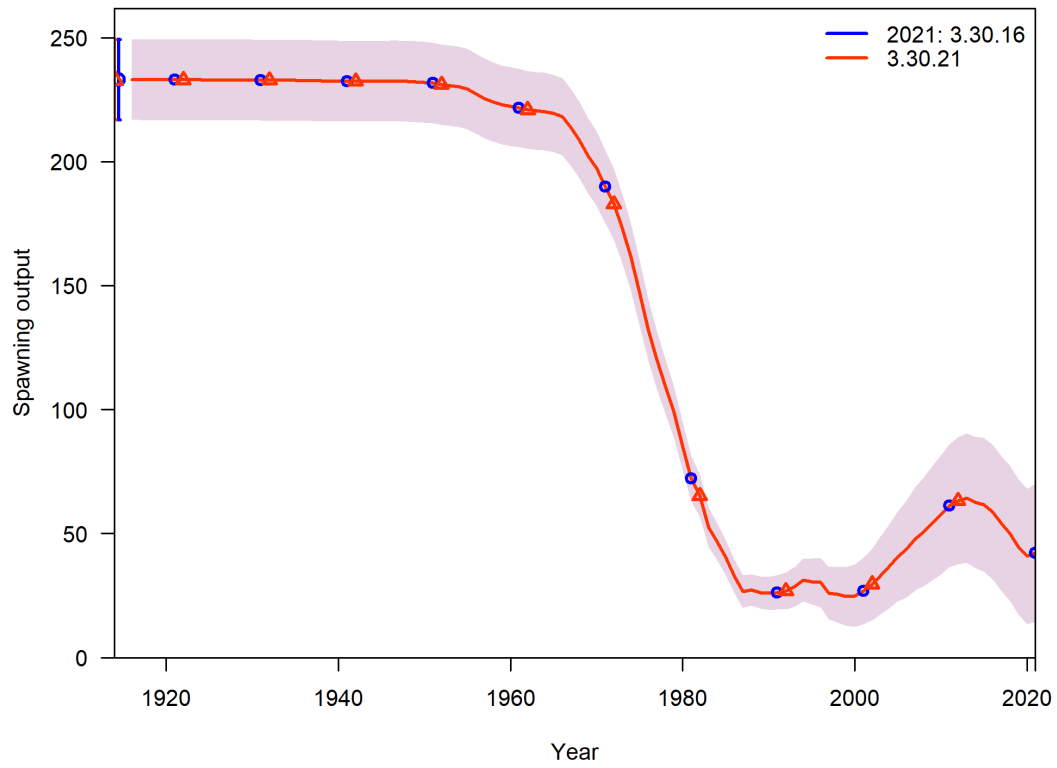
**Figure 50:** Ageing imprecision standard deviation of observed age in years.



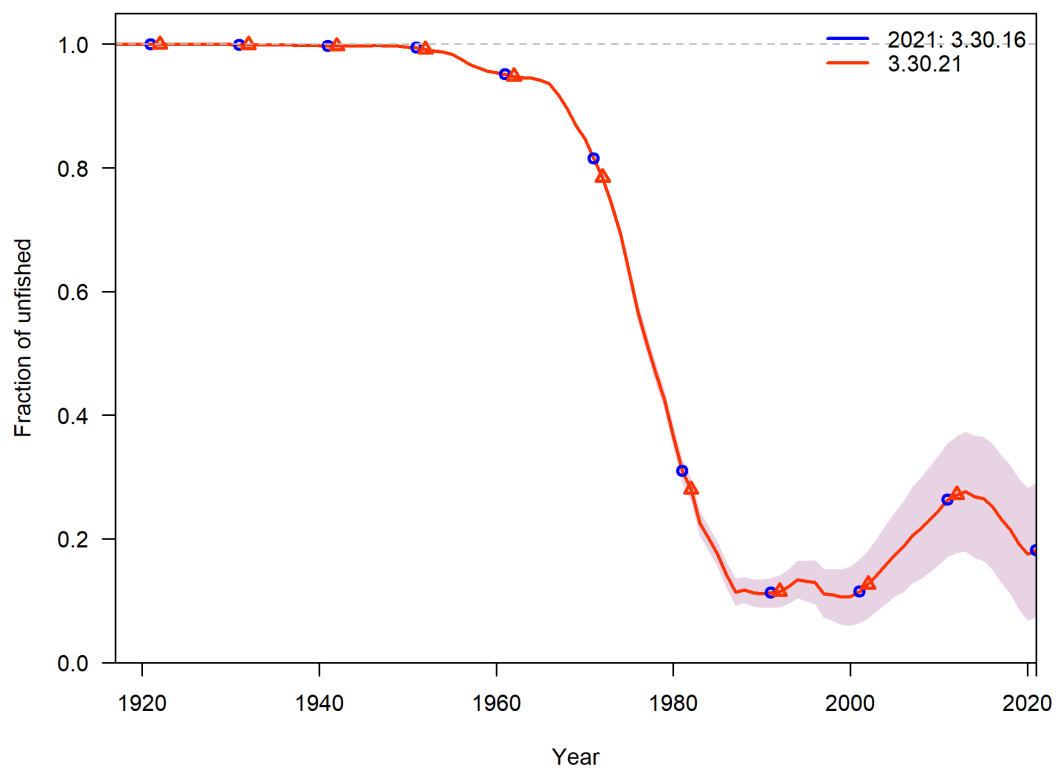
**Figure 51:** Distribution of observed age at true age for ageing error type 1.

## 8.3 Model Results

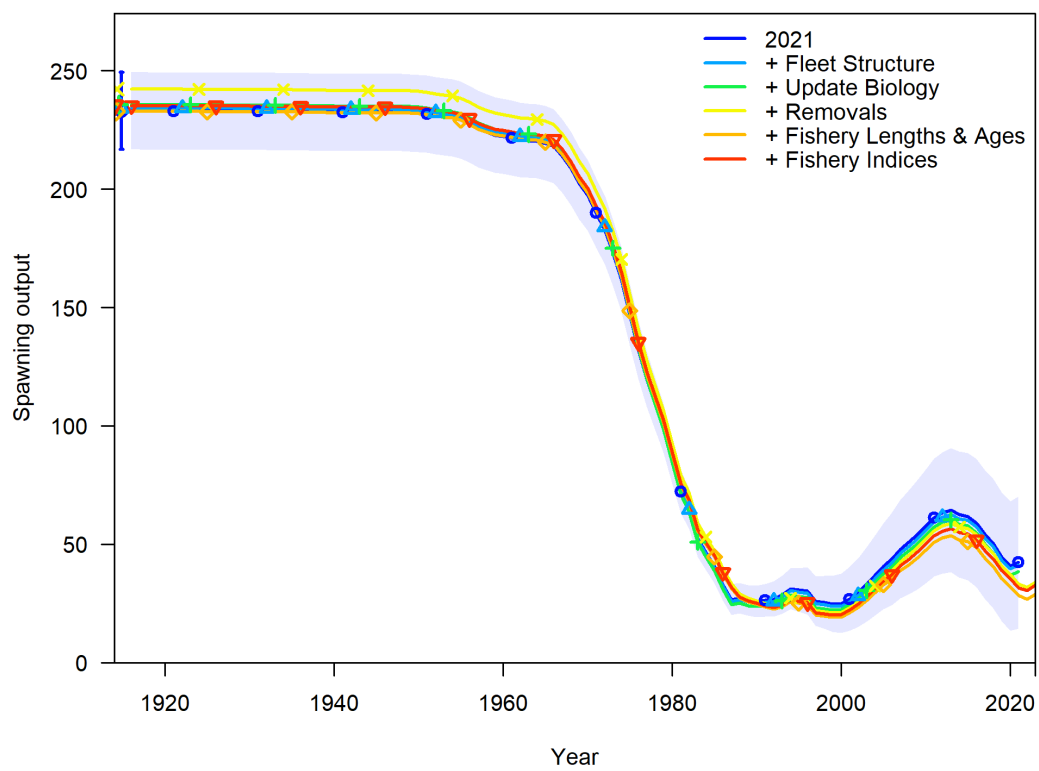
### 8.3.1 Bridging



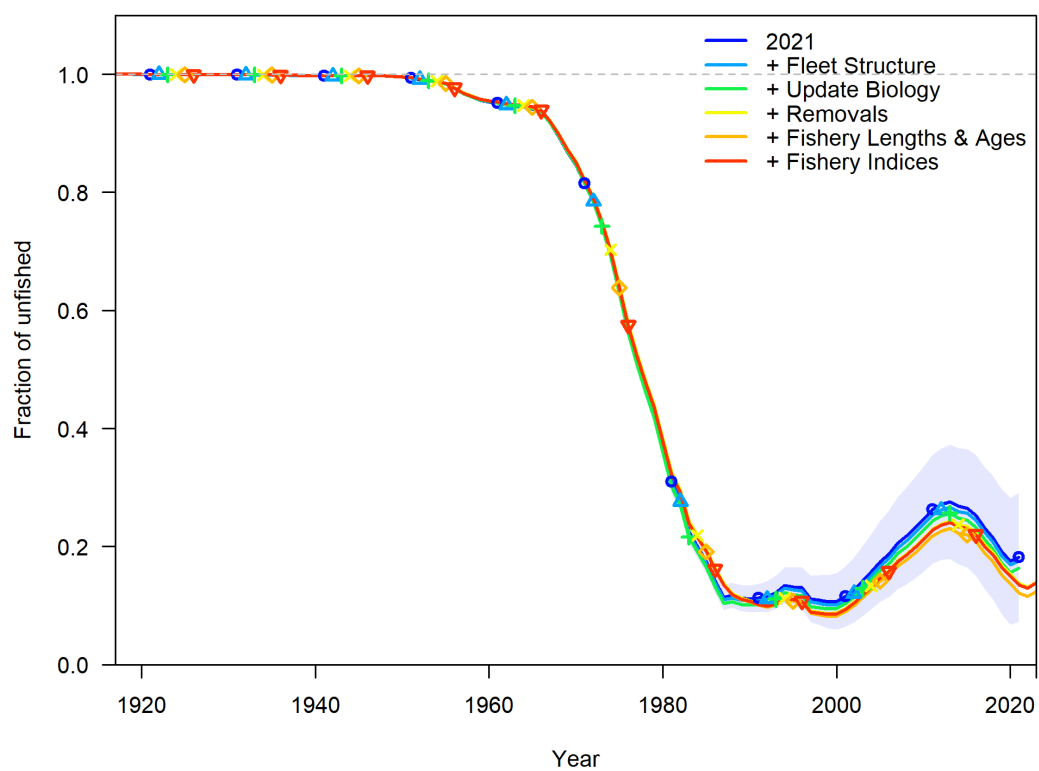
**Figure 52:** Stock Synthesis version bridge model comparison of estimated spawning output.



**Figure 53:** Stock Synthesis version bridge model comparison of estimated fraction unfished.

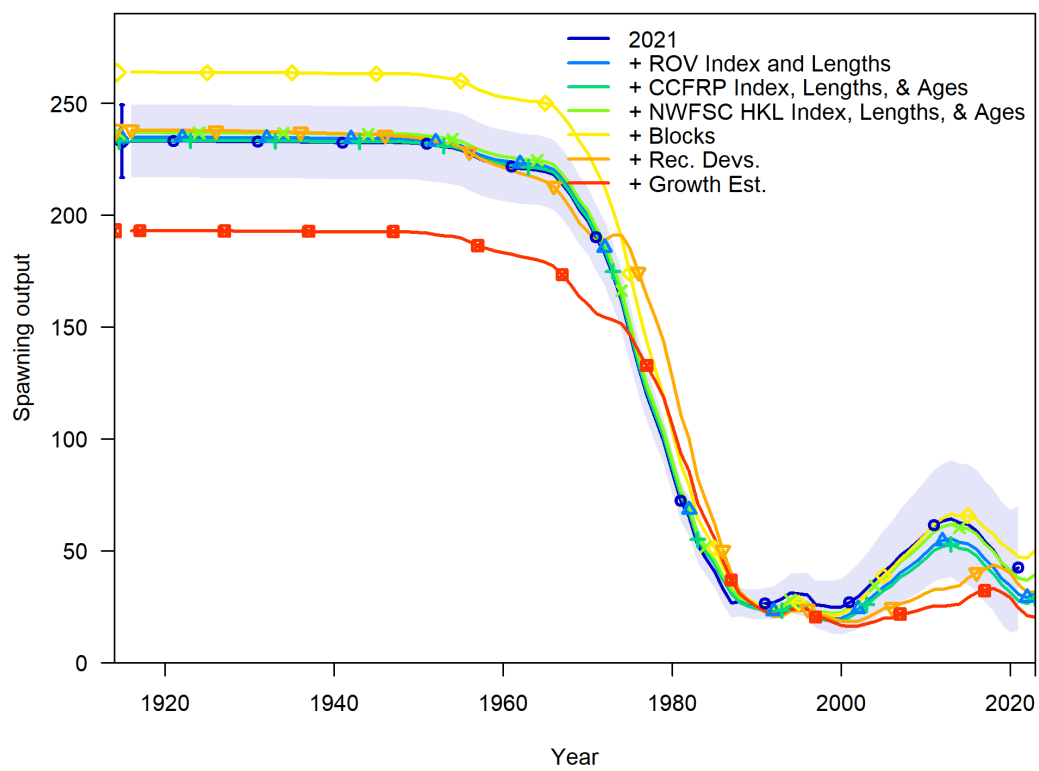


**Figure 54:** Model structure and data bridging comparison of estimated spawning output.

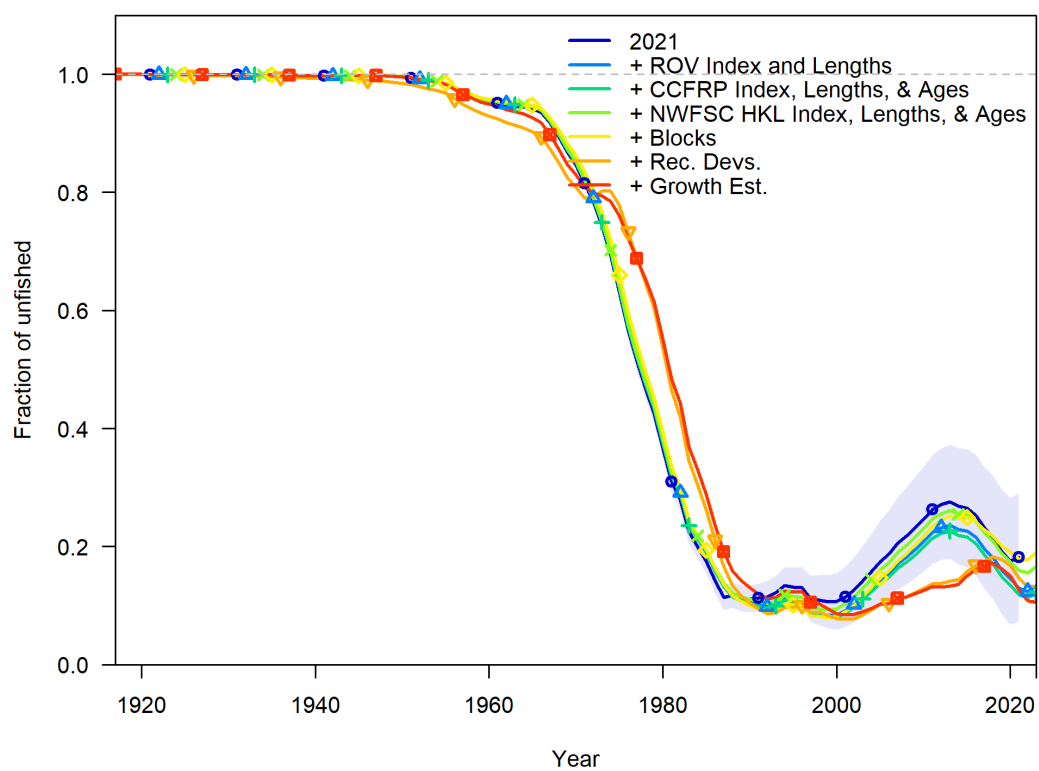


**Figure 55:** Model structure and data bridging comparison of estimated fraction unfished.



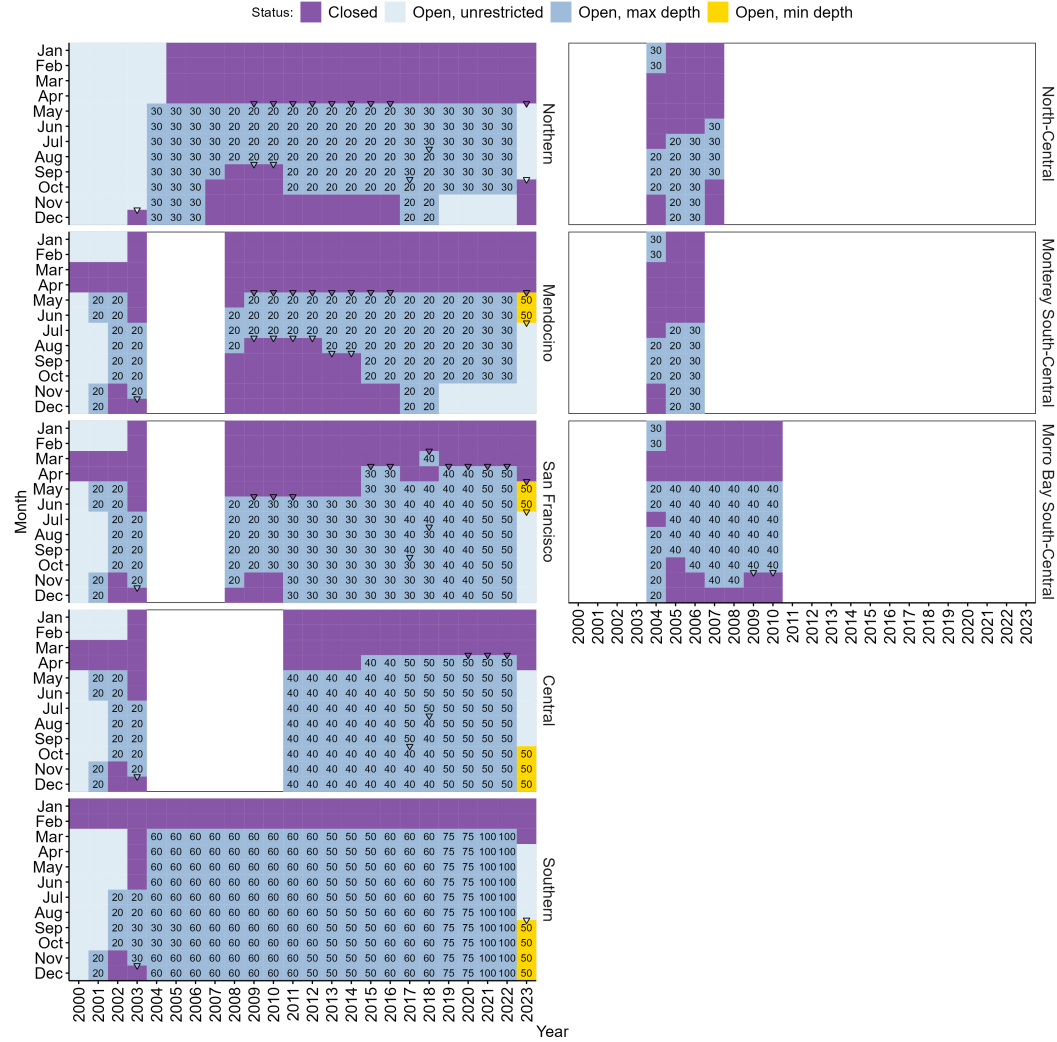


**Figure 56:** Model structure and data bridging comparison of estimated spawning output.



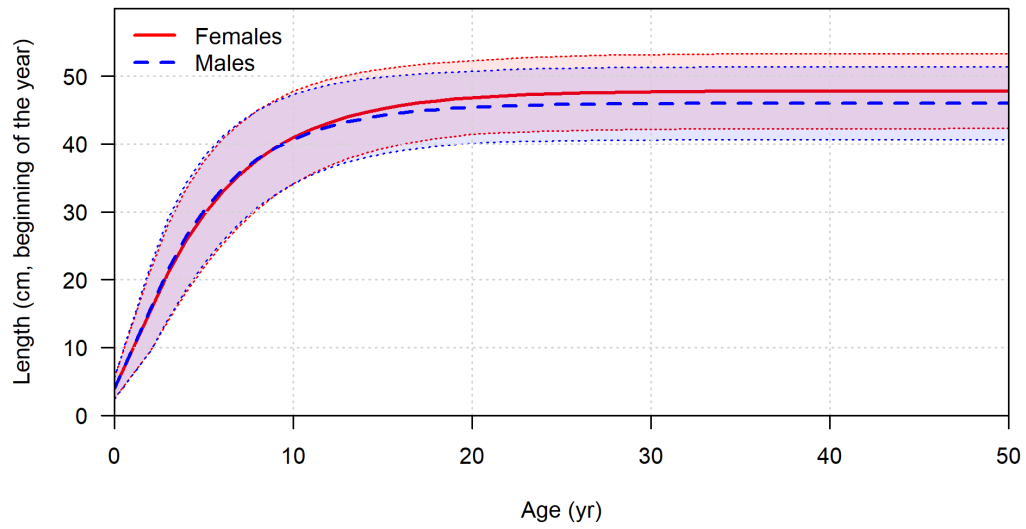
**Figure 57:** Model structure and data bridging comparison of estimated fraction unfished.

### 8.3.2 Model Structure



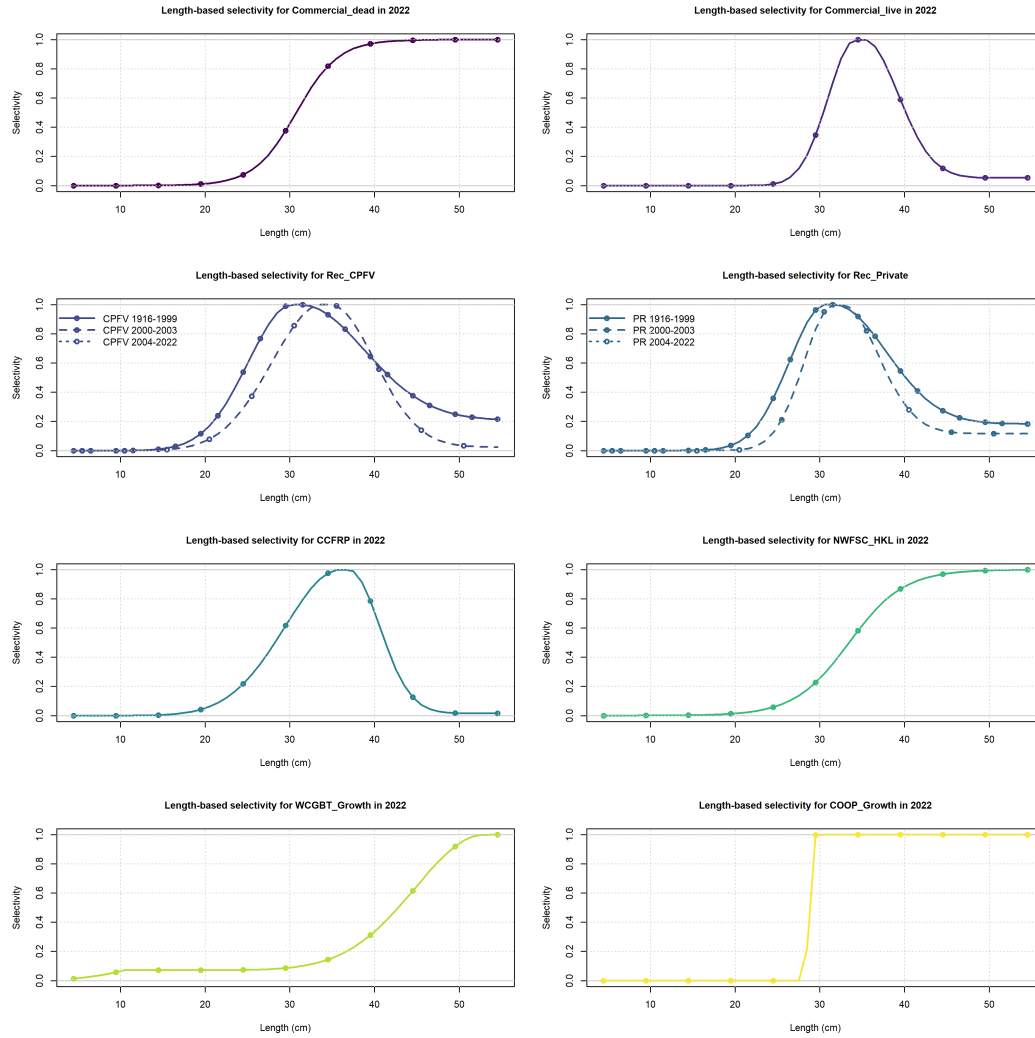
**Figure 58:** The CDFW recreational season length and depth restriction for nearshore rockfish by month from 2000 to 2003. A triangle indicates a regulation change mid-month. The regions defined base on the following latitudes: Northern ( $42^{\circ}00'$  N. lat. to  $40^{\circ}10'$  N. lat.), Mendocino ( $40^{\circ}10'$  N. lat. to  $38^{\circ}57'$  N. lat.), San Francisco ( $38^{\circ}57'$  N. lat. to  $37^{\circ}11'$  N. lat.), Central ( $37^{\circ}11'$  N. lat. to  $34^{\circ}27'$  N. lat.), Southern ( $34^{\circ}27'$  N. lat. to U.S./Mexico border). Not all management areas have been consistently defined over time. The northern and southern management areas have remained the same. From 2001-2003 the Central management area was defined as  $40^{\circ}10'$  N. lat. to  $34^{\circ}27'$  N. lat. In 2004, the Central area was split into a North-Central and South-Central areas at  $36^{\circ}00'$  N. lat. In 2005, the regions from  $40^{\circ}10'$  N. lat. to  $34^{\circ}27'$  N. lat. were redefined. The North-Central encompasses  $40^{\circ}10'$  N. lat. to  $37^{\circ}11'$  N. lat., Monterey South-Central from  $37^{\circ}11'$  N. lat. to  $36^{\circ}00'$  N. lat., and Morro Bay South-Central from  $36^{\circ}00'$  N. lat. to  $34^{\circ}27'$  N. lat.

### 8.3.3 Estimated Biology



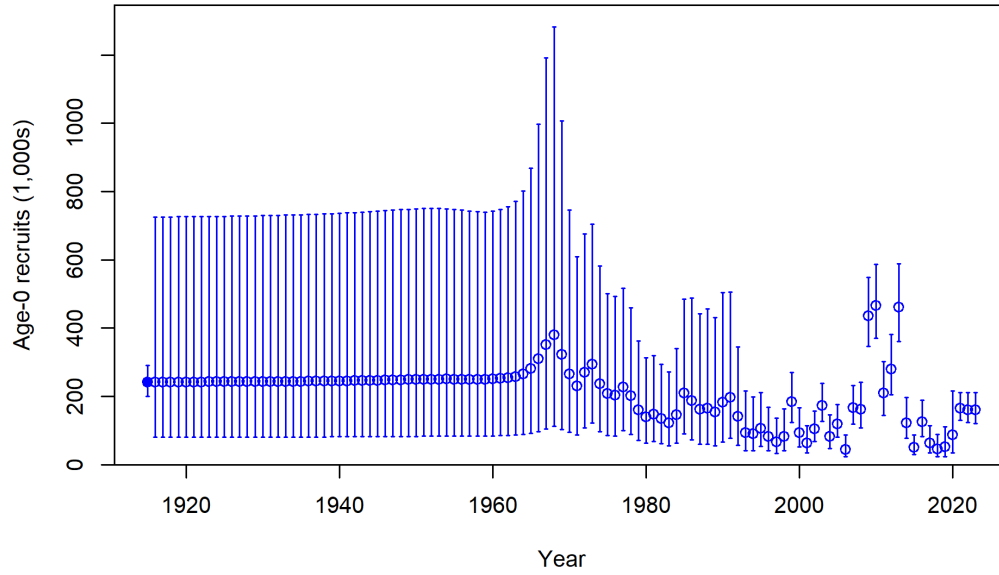
**Figure 59:** Model estimated length-at-age in the beginning of the year. Shaded area indicates 95 percent distribution of length-at-age around the estimated growth curve.

### 8.3.4 Selectivity

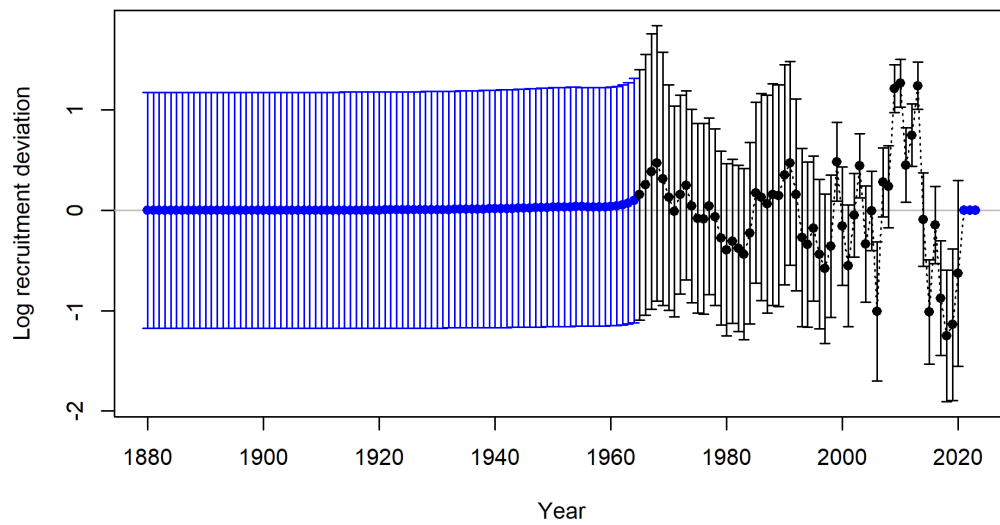


**Figure 60:** Estimated selectivity for each fleet and survey in the base model.

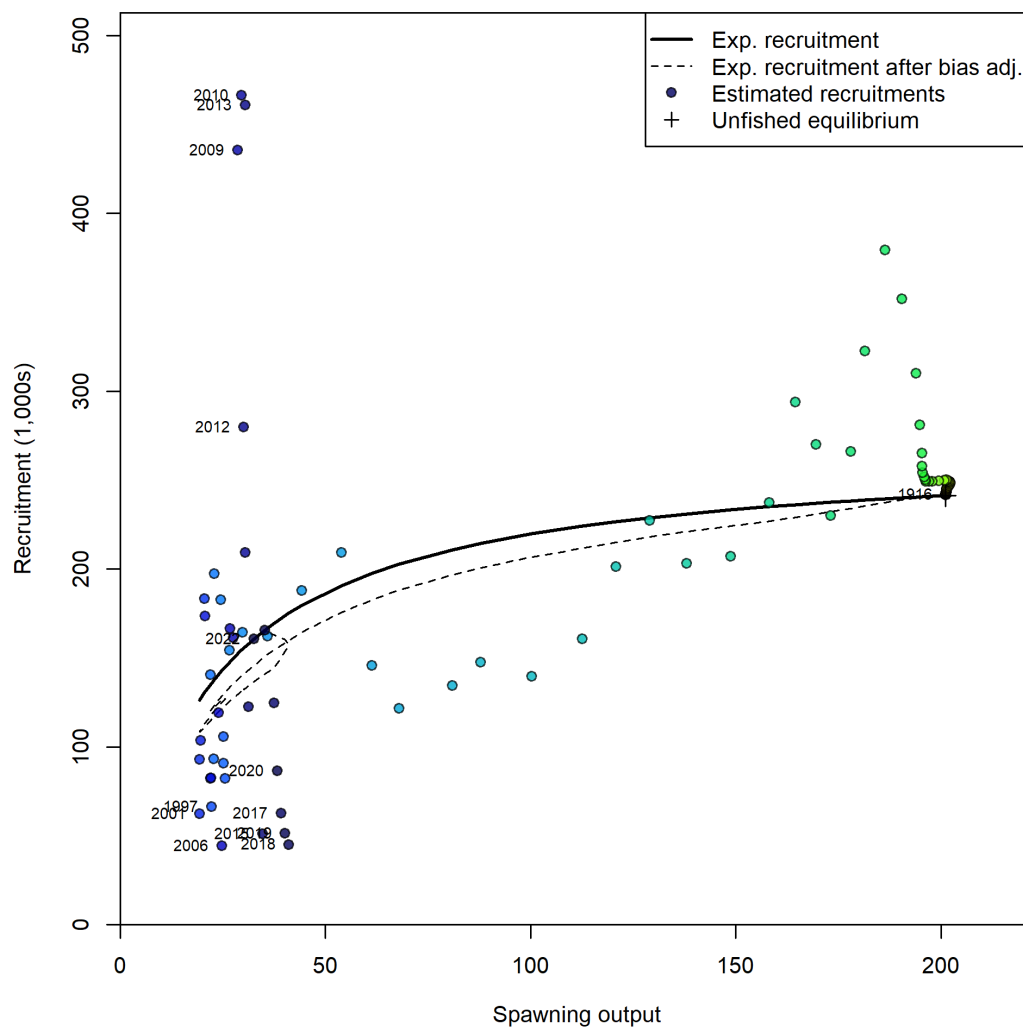
### 8.3.5 Recruitment



**Figure 61:** Estimated time series of age-0 recruits (1000s).

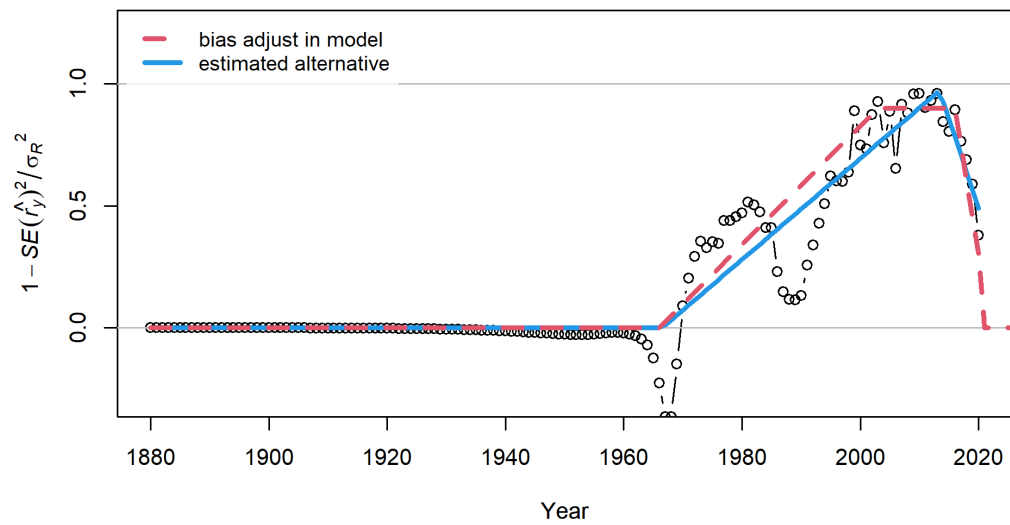


**Figure 62:** Estimated time series of recruitment deviations.



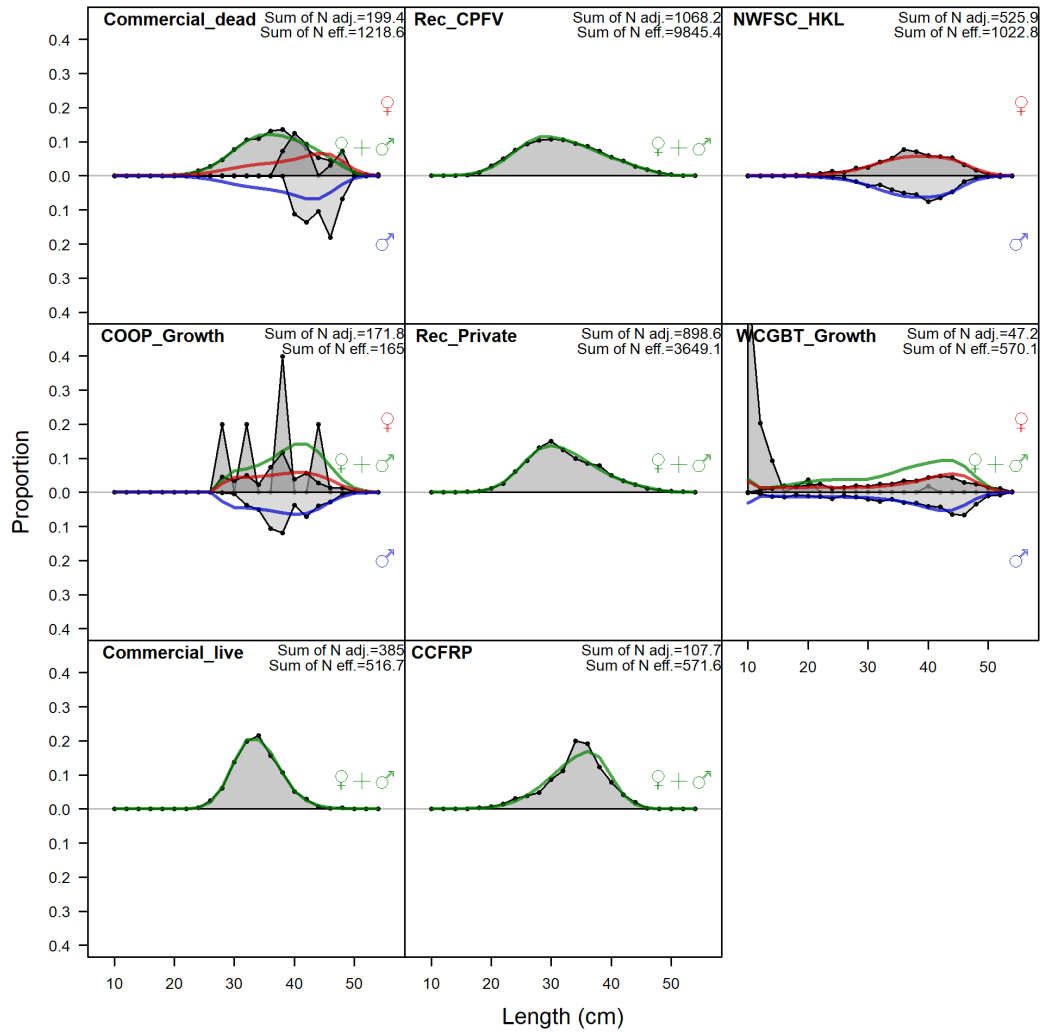
**Figure 63:** Stock-recruit curve with labels on first, last, and years with log-deviations greater than 0.50. Point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years.



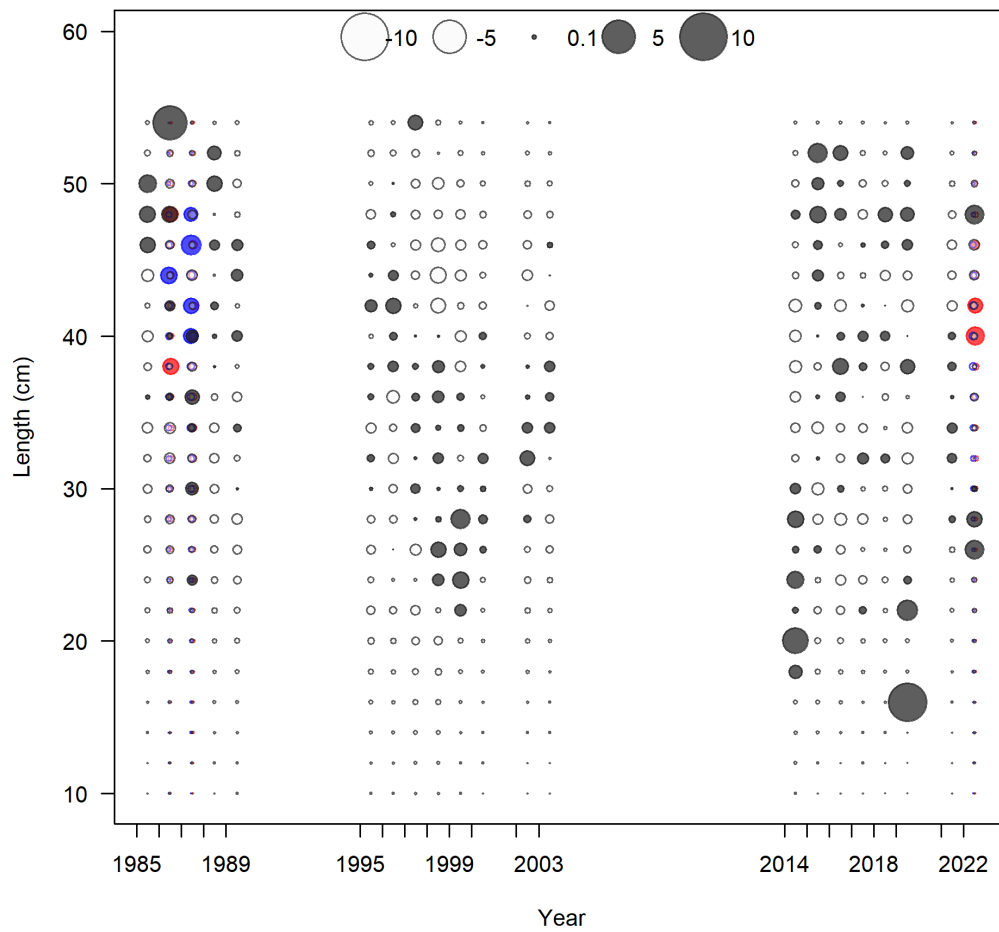


**Figure 64:** Points are transformed variances. Red line shows current settings for bias adjustment specified in control file. Blue line shows least squares estimate of alternative bias adjustment relationship for recruitment deviations (which may or may not be an improvement).

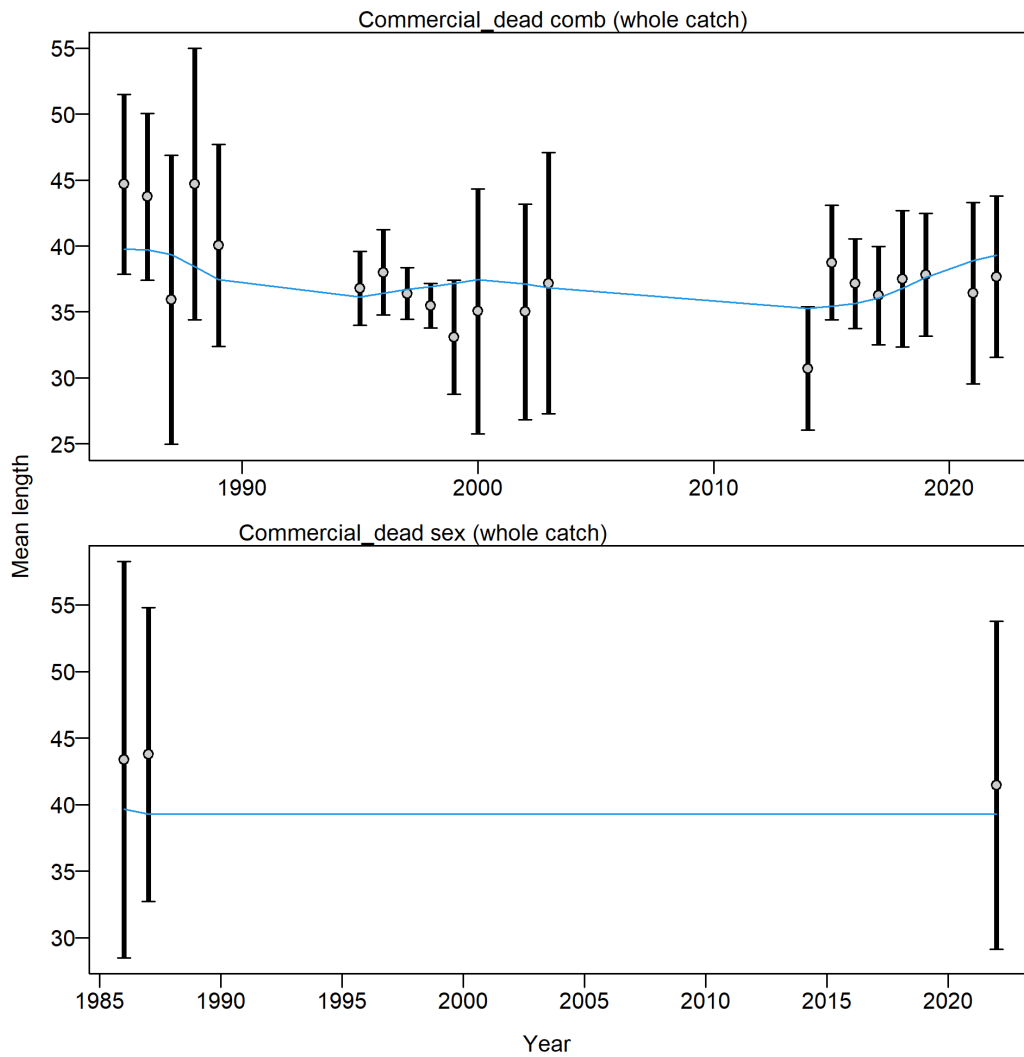
### 8.3.6 Fits to Data



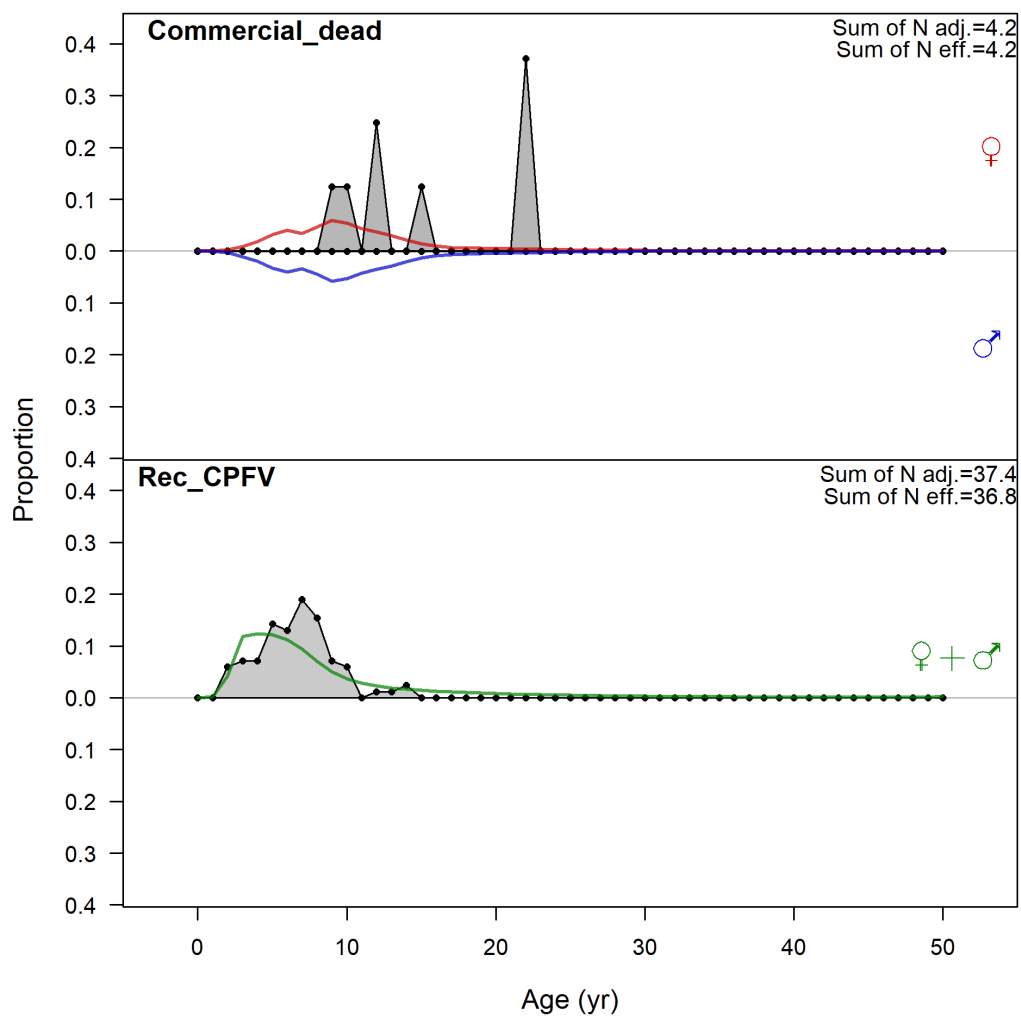
**Figure 65:** Length composition aggregated across years by fleet with the model estimated fit to the data by sex (green unsexed, red female, and blue male).



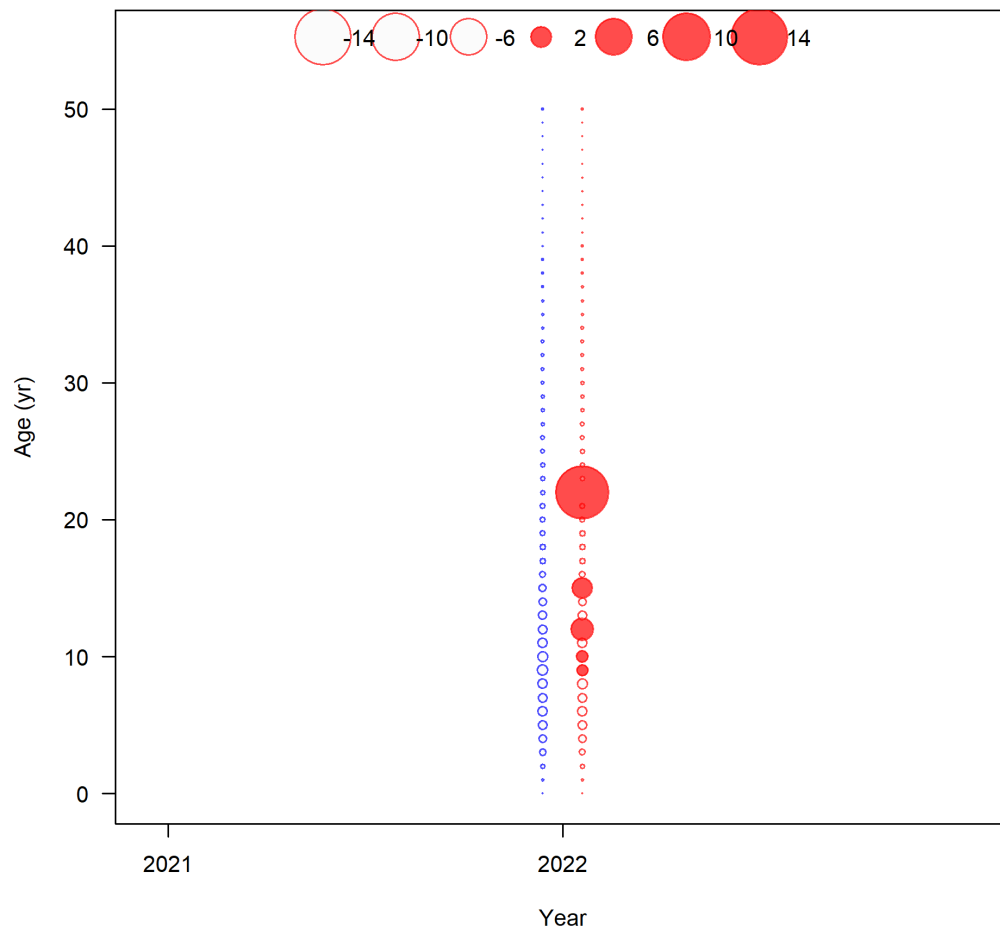
**Figure 66:** Pearson residuals for commercial fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



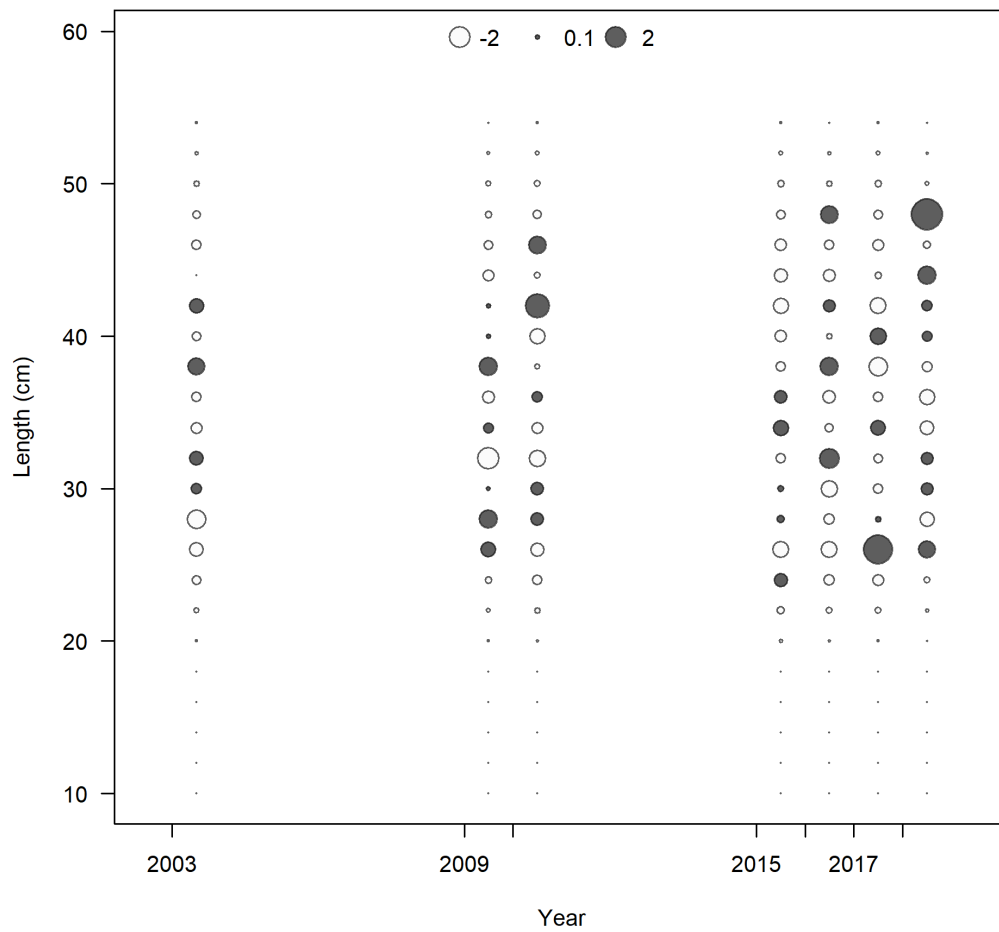
**Figure 67:** Mean length for commercial dead lengths with 95 percent confidence intervals based on current samples sizes.



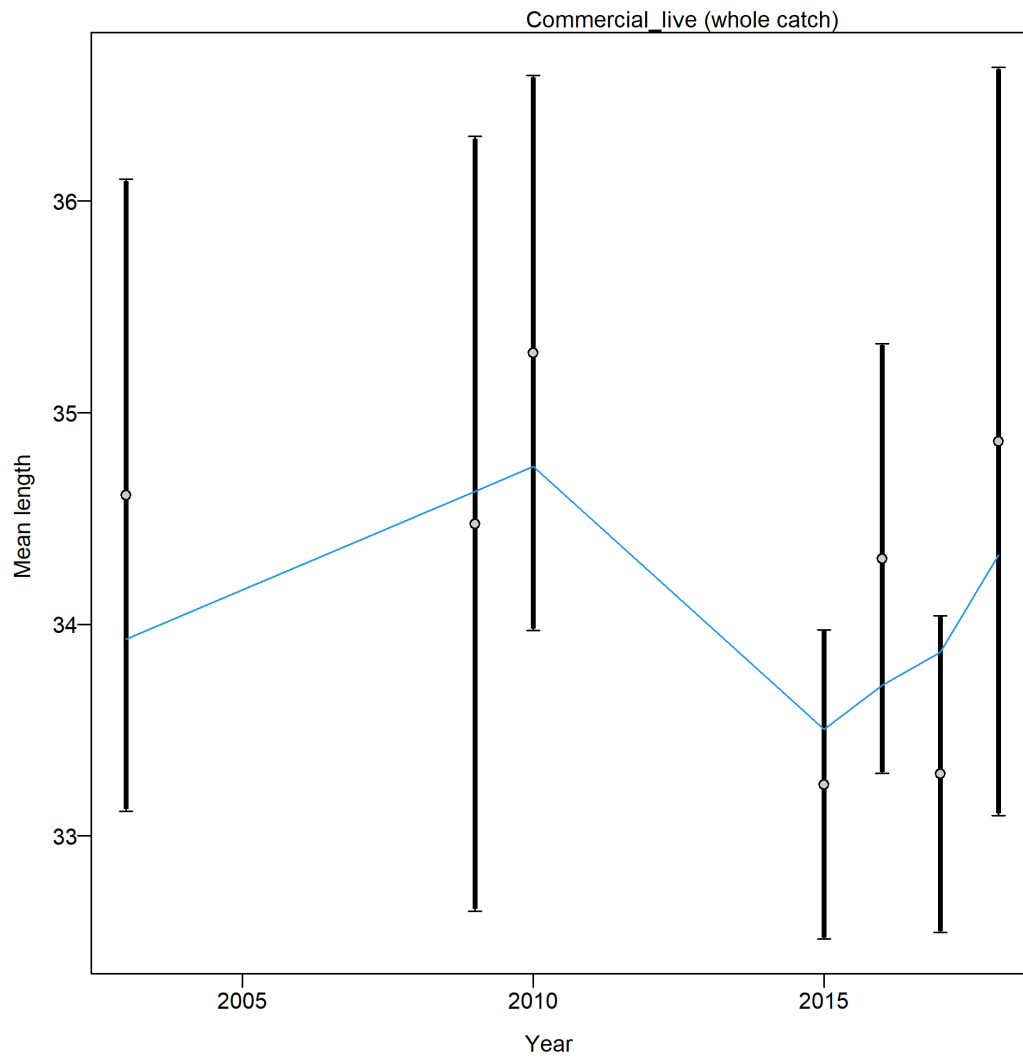
**Figure 68:** Age composition data aggregated across time by fleet.



**Figure 69:** Pearson residuals for commercial dead age data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

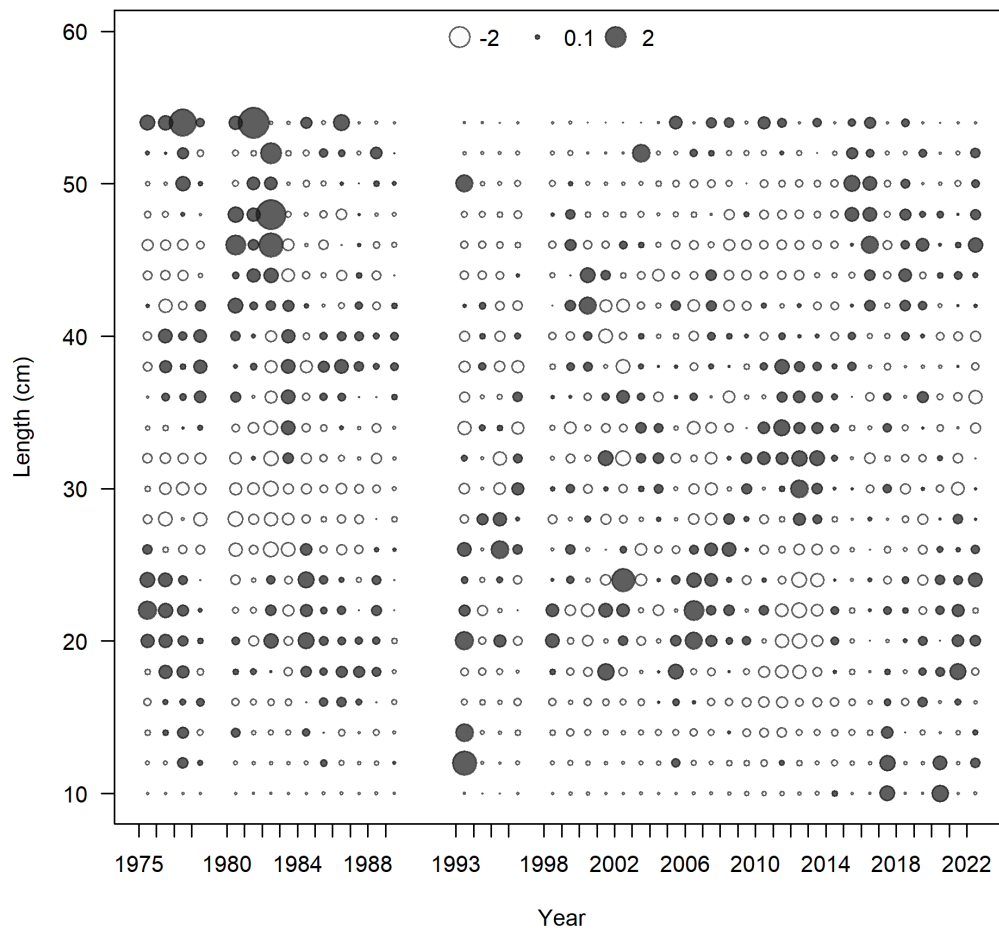


**Figure 70:** Pearson residuals for commercial live fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

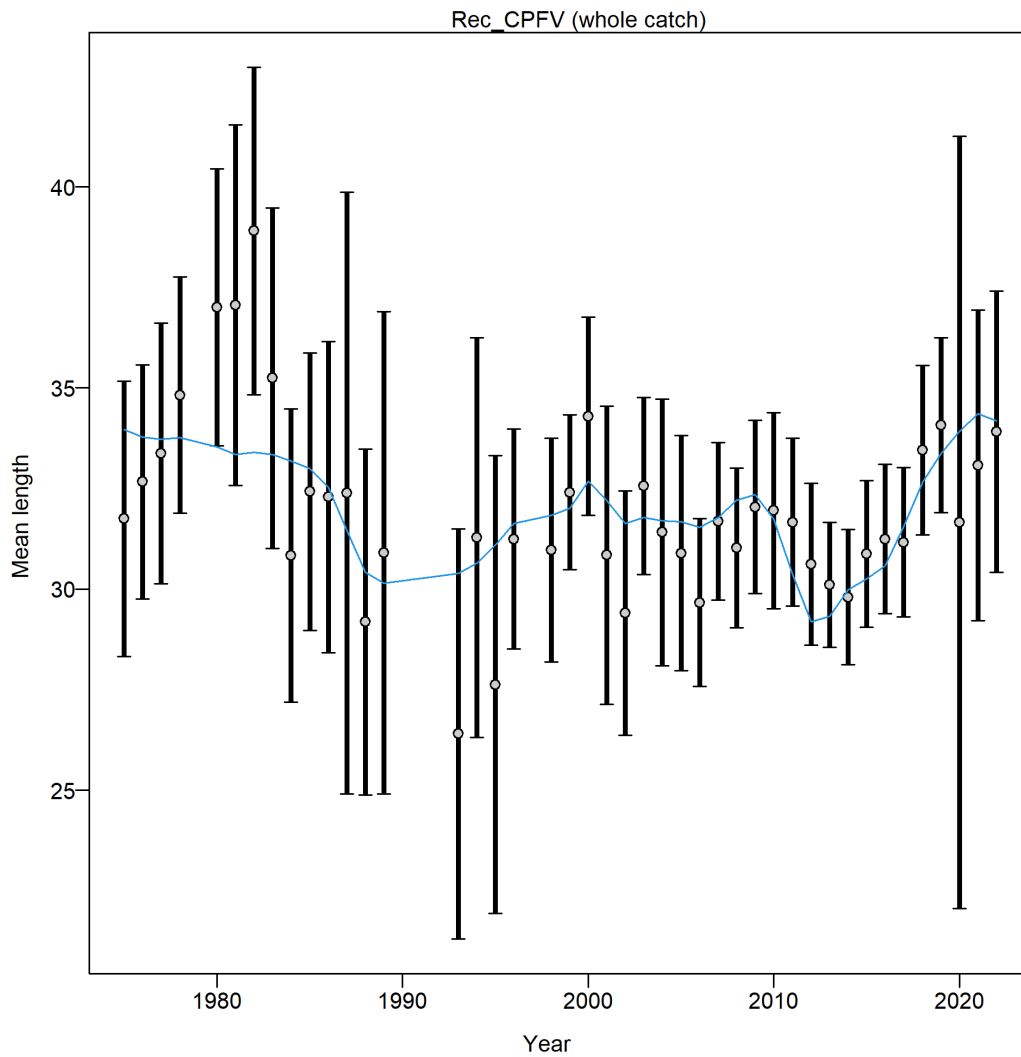


**Figure 71:** Mean length for commercial live fish lengths with 95 percent confidence intervals based on current samples sizes.

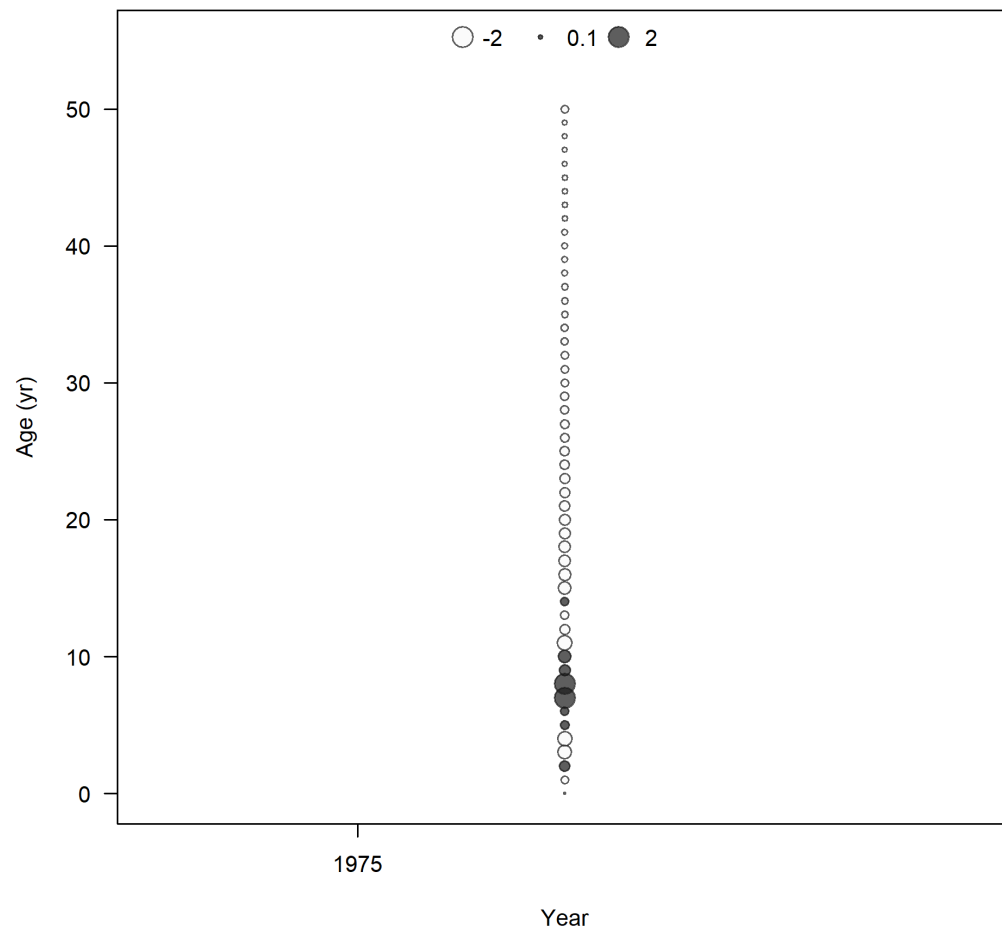




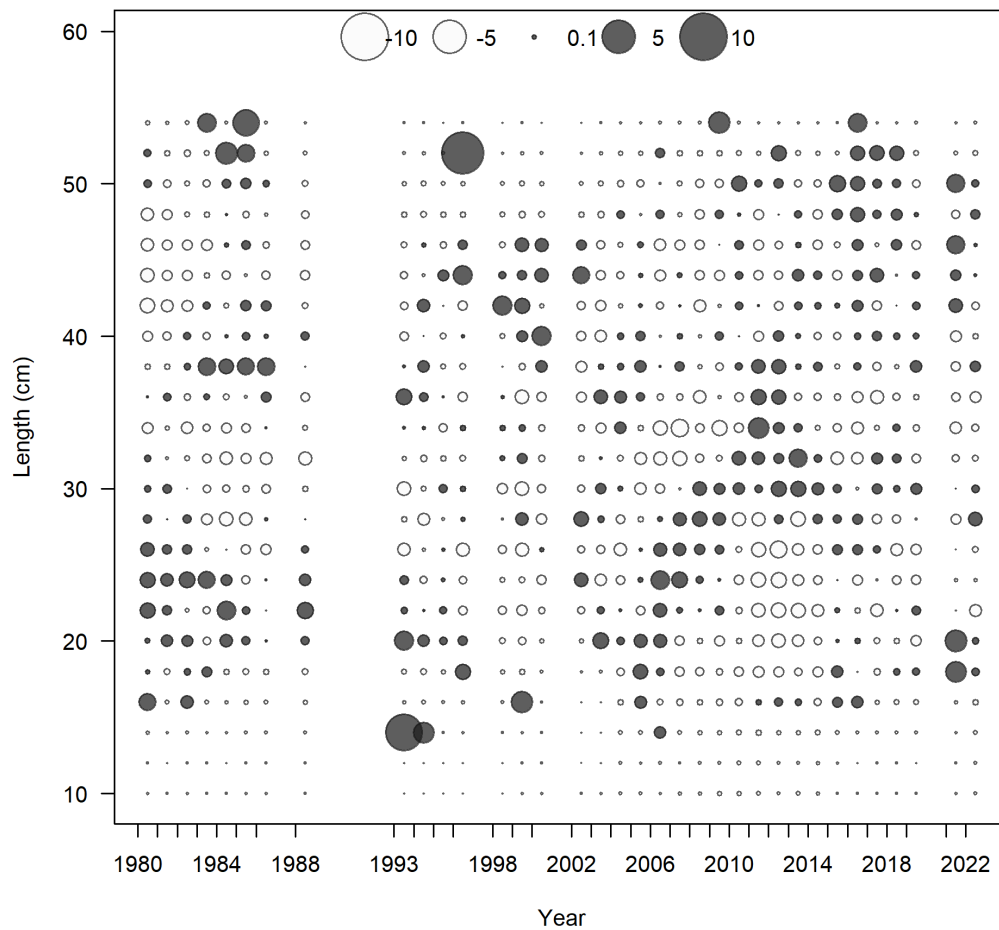
**Figure 72:** Pearson residuals for recreational CPFV fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



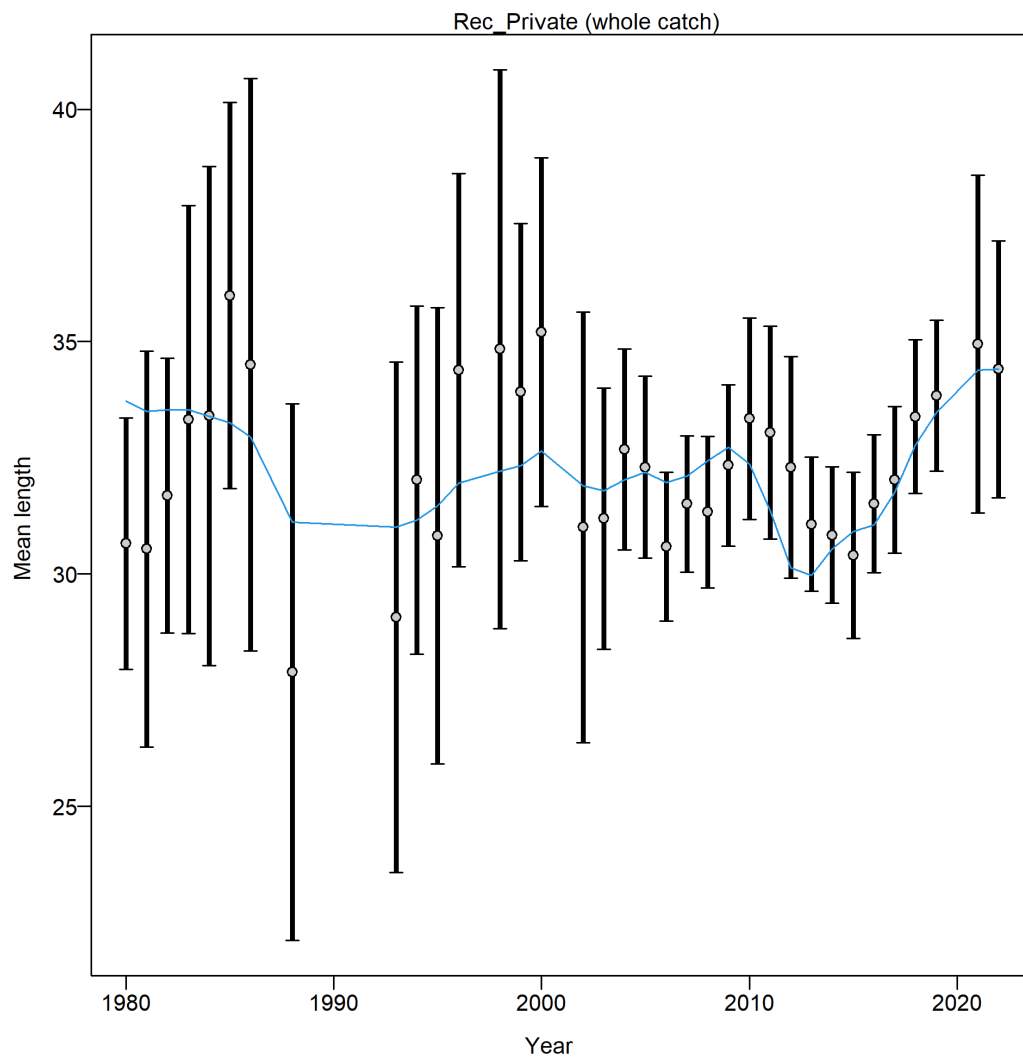
**Figure 73:** Mean length for recreational CPFV lengths with 95 percent confidence intervals based on current samples sizes.



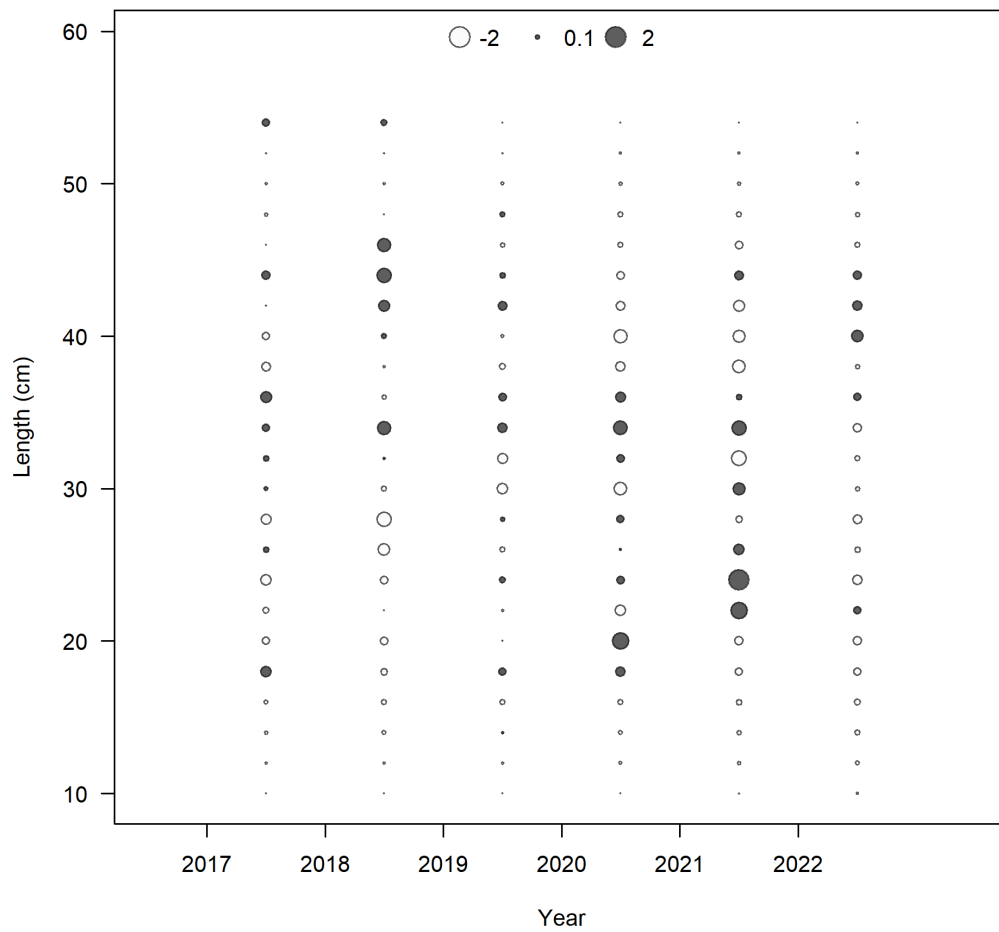
**Figure 74:** Pearson residuals for recreational CPFV age data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



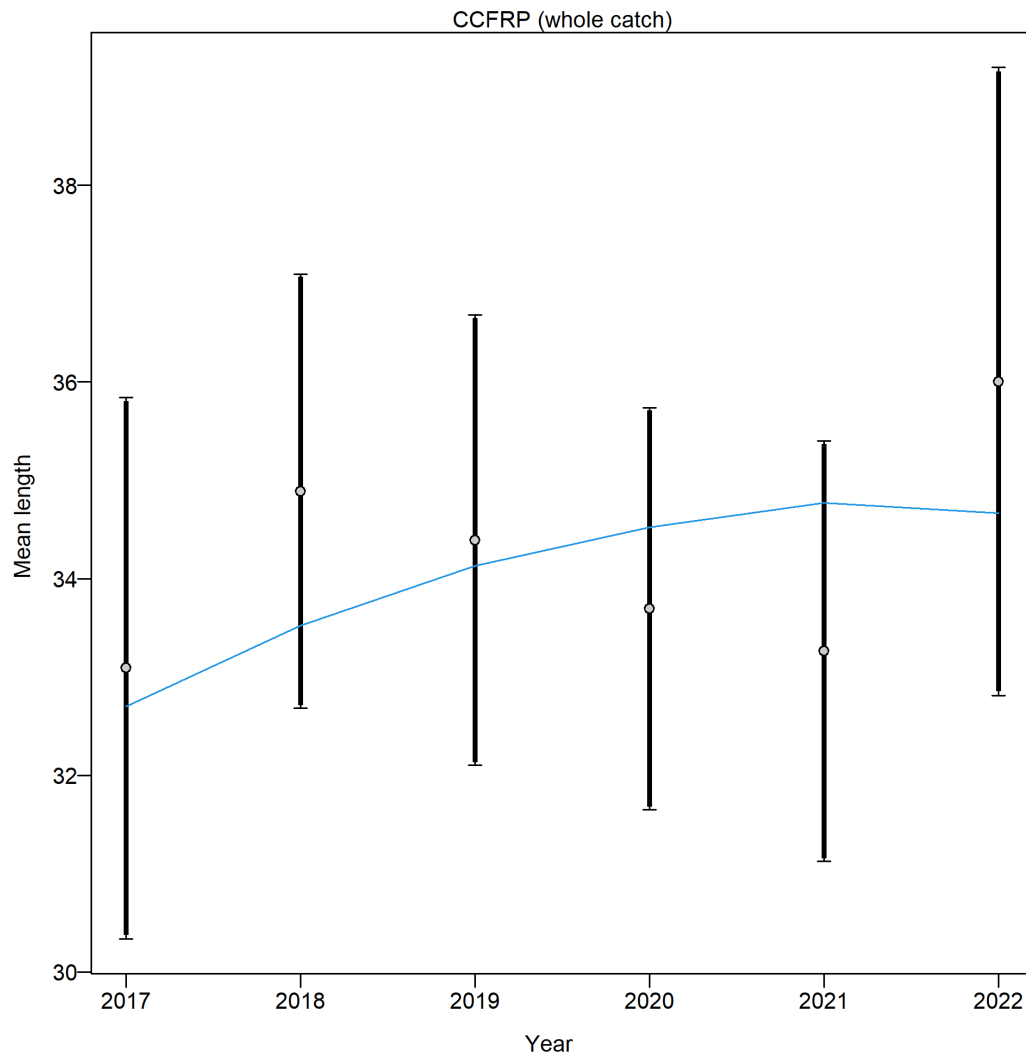
**Figure 75:** Pearson residuals for recreational PR fleet. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



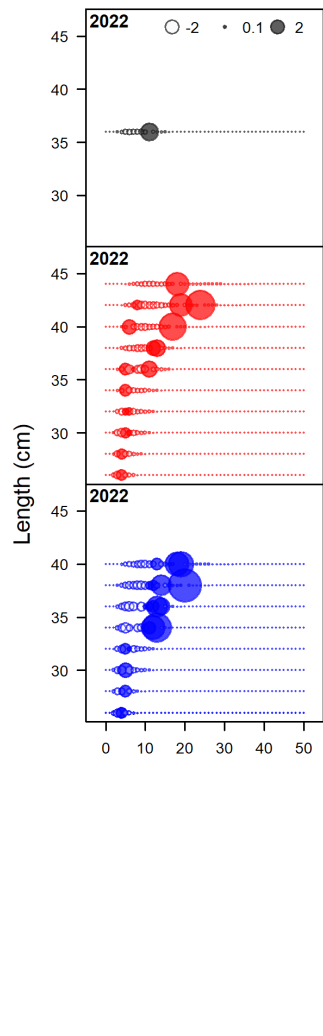
**Figure 76:** Mean length for recreational PR lengths with 95 percent confidence intervals based on current samples sizes.



**Figure 77:** Pearson residuals for CCFRP Hook and Line survey length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

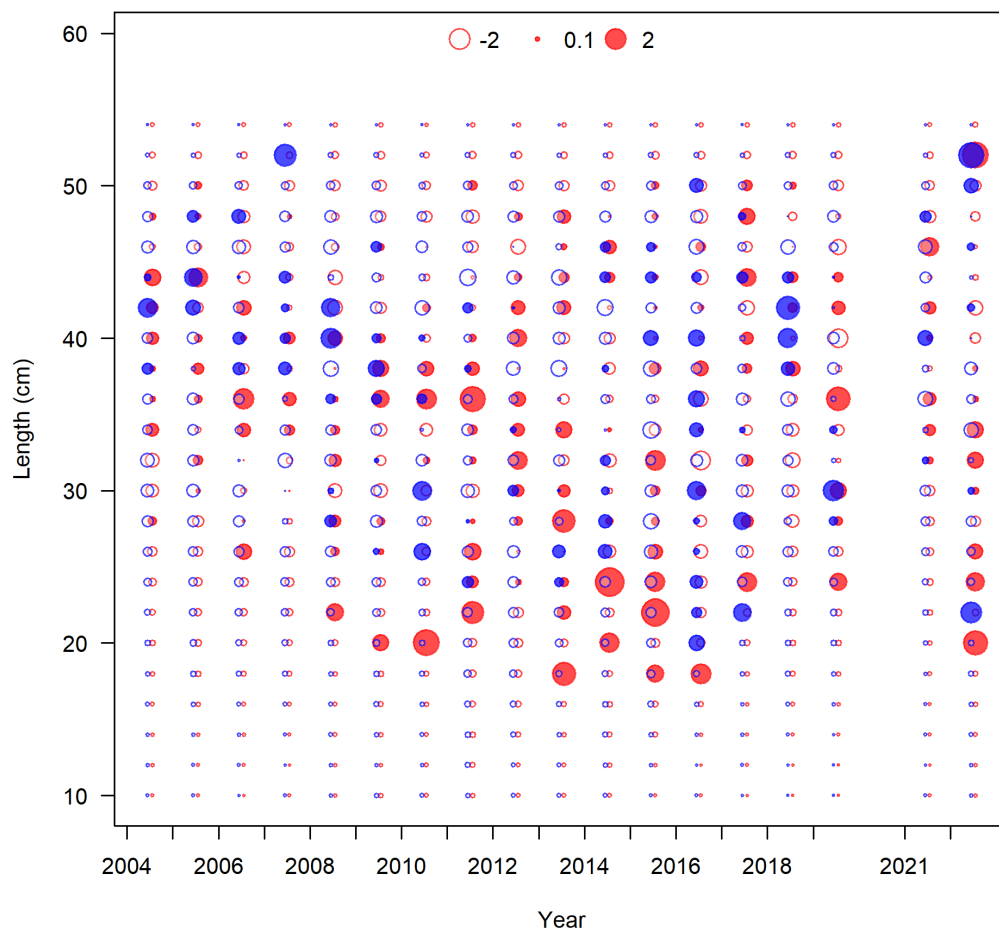


**Figure 78:** Mean length for CCFRP Hook and Line survey lengths with 95 percent confidence intervals based on current samples sizes.

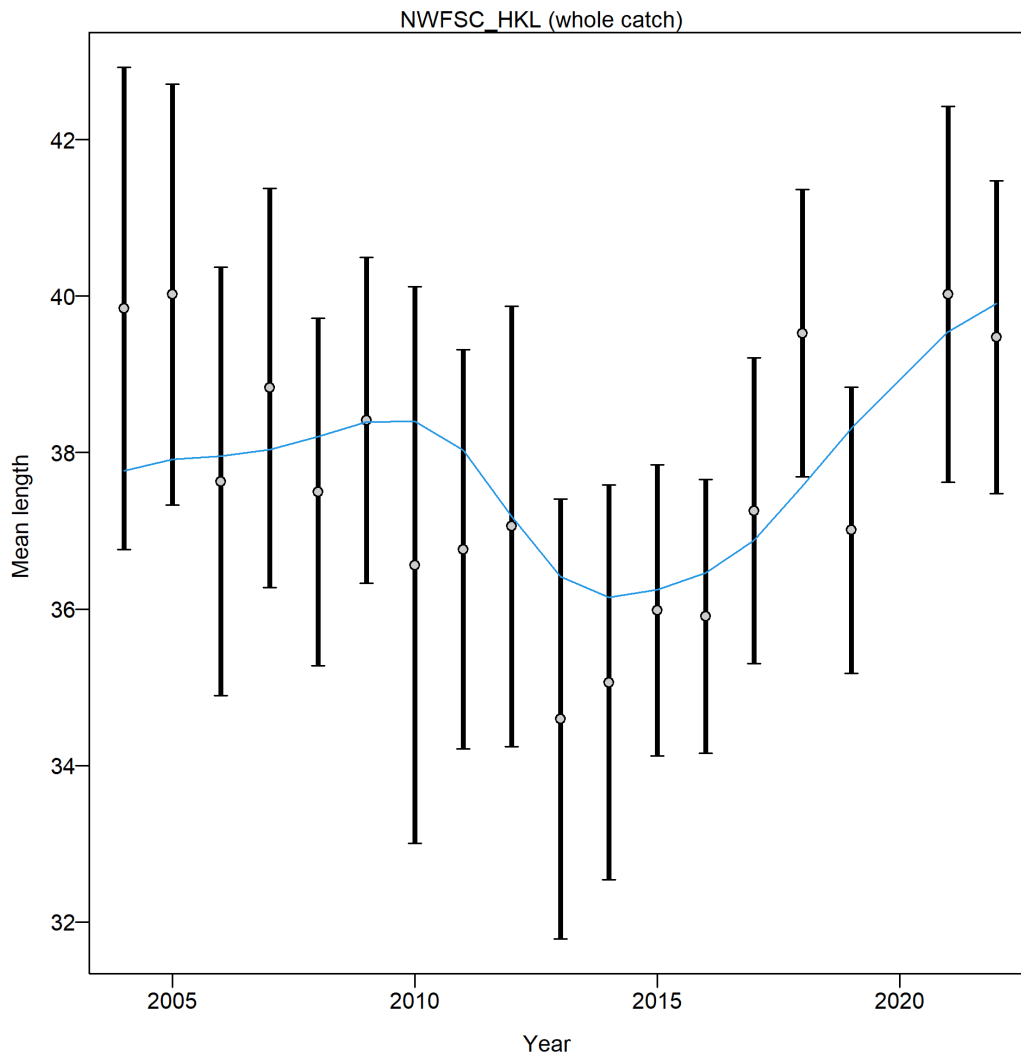


**Figure 79:** Pearson residuals for CCFRP Hook and Line survey conditional-age-at-length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

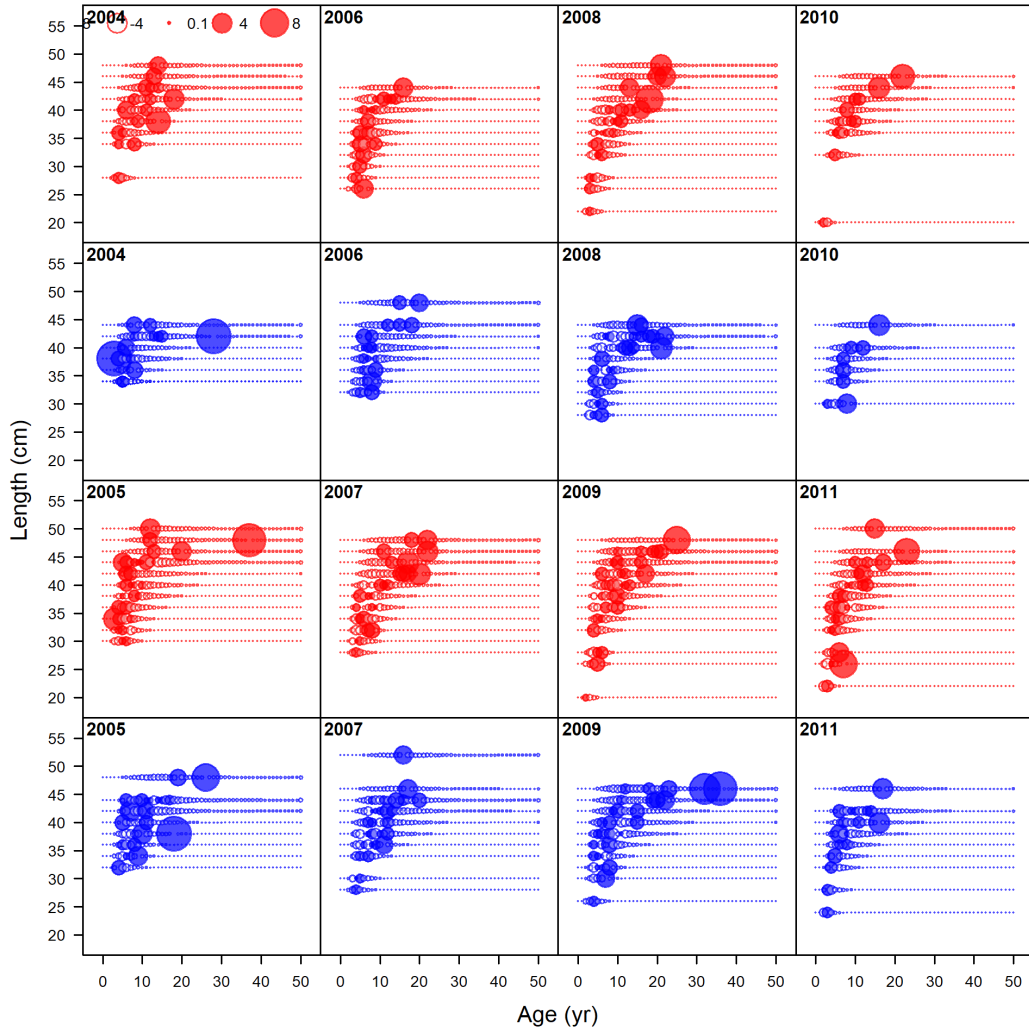




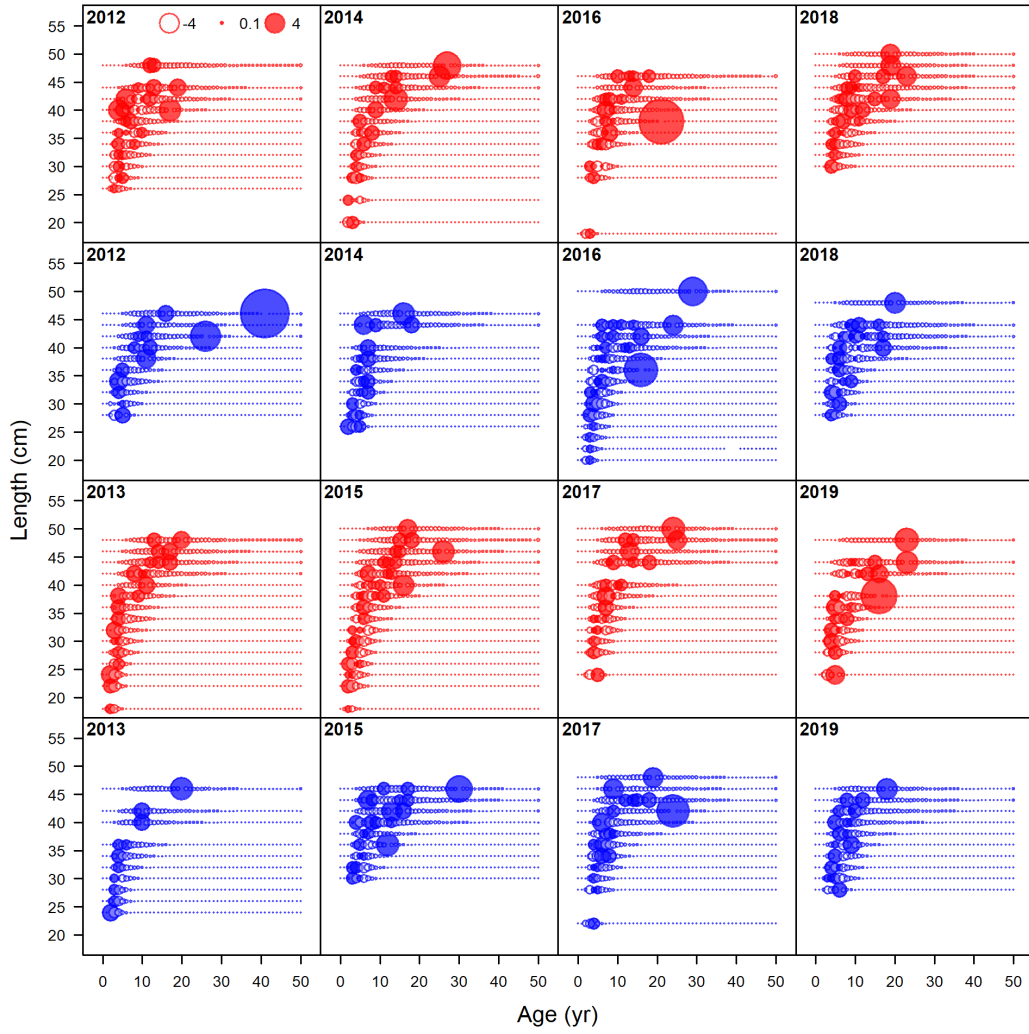
**Figure 80:** Pearson residuals for NWFSC Hook and Line survey length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



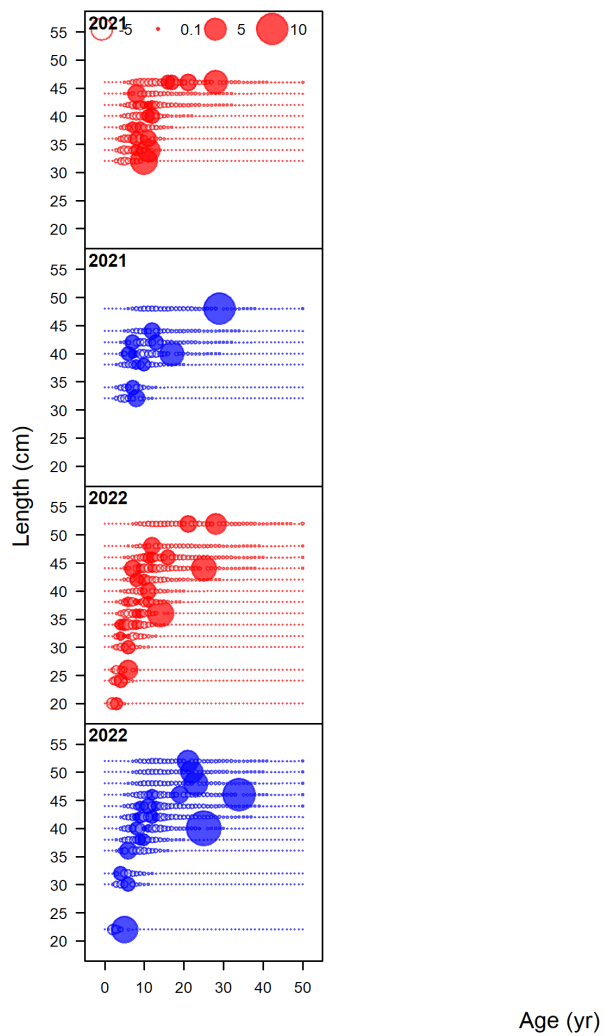
**Figure 81:** Mean length for NWFSC Hook and Line survey lengths with 95 percent confidence intervals based on current samples sizes.



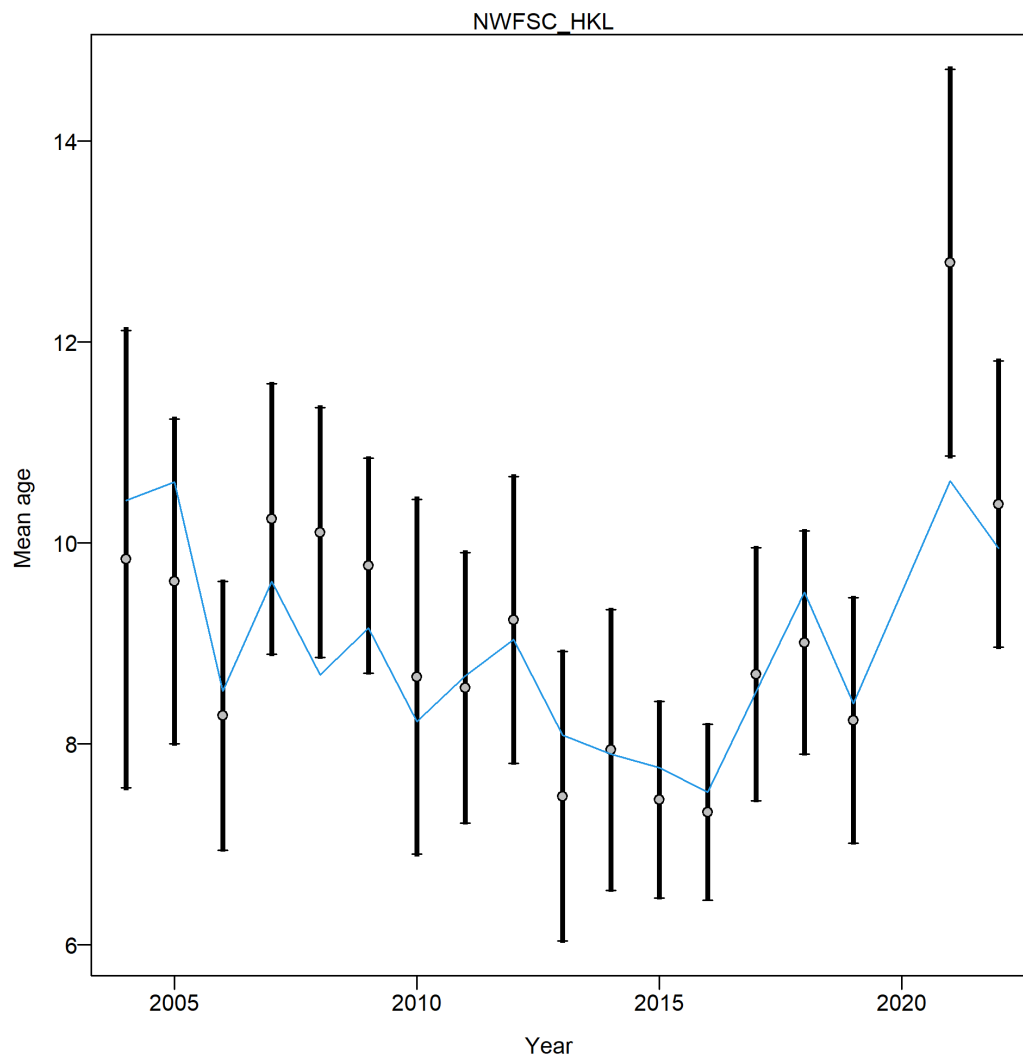
**Figure 82:** Pearson residuals for NWFSC Hook and Line survey conditional-age-at-length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



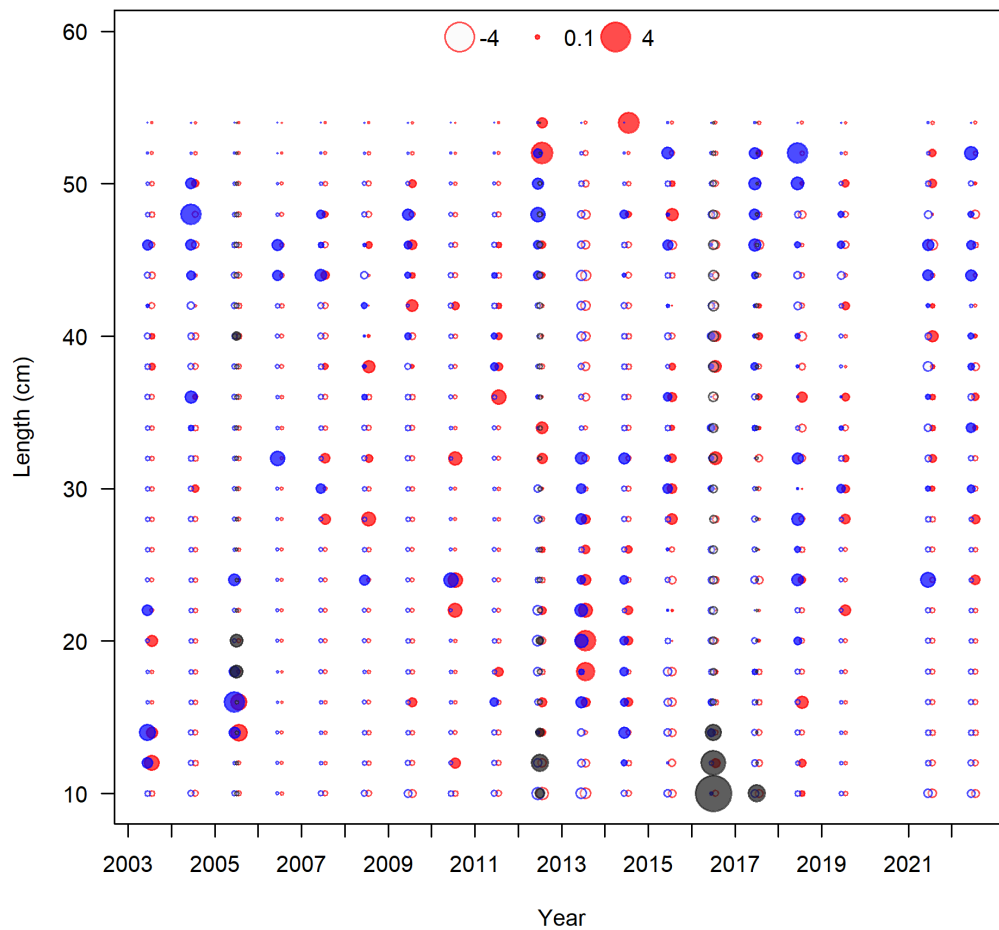
**Figure 83:** Pearson residuals for NWFSC Hook and Line survey conditional-age-at-length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



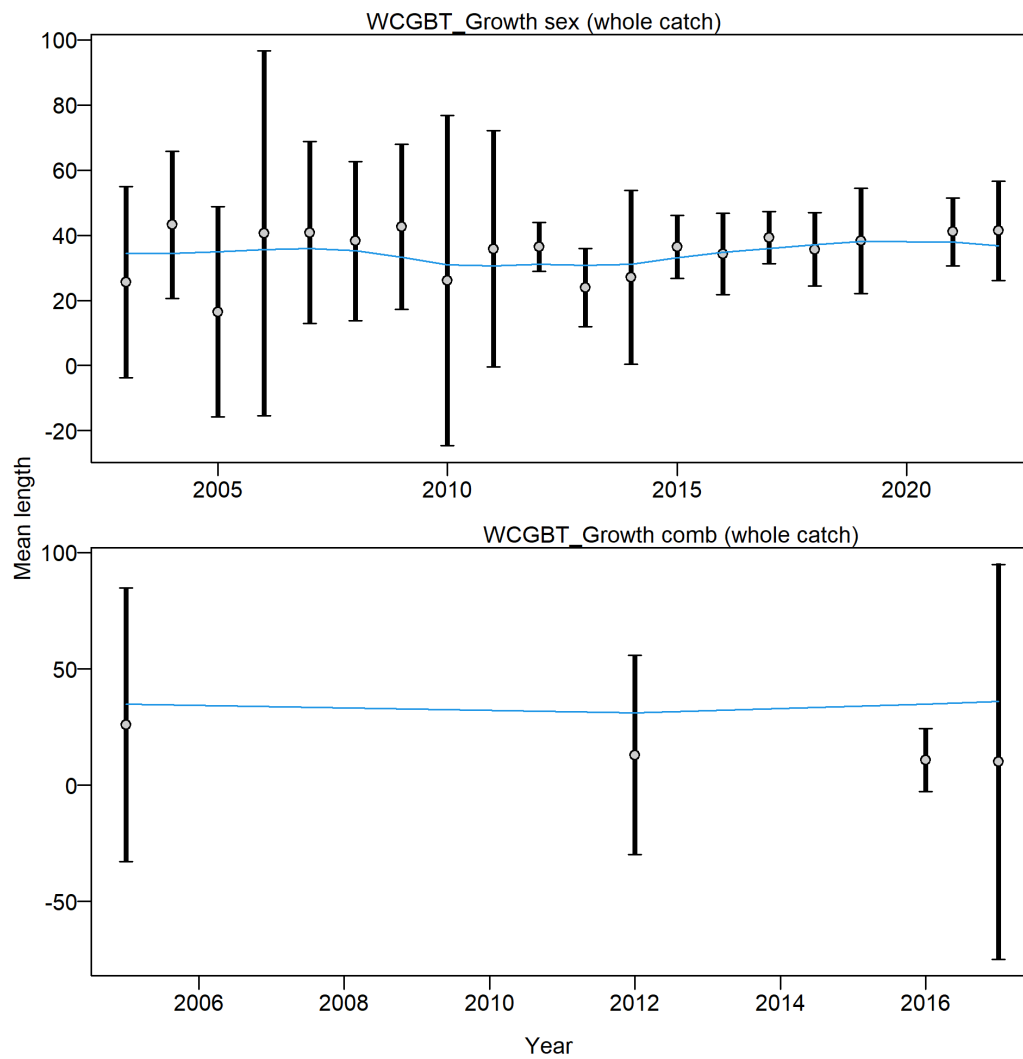
**Figure 84:** Pearson residuals for NWFSC Hook and Line survey conditional-age-at-length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



**Figure 85:** Mean age for NWFSC Hook and Line survey age data with 95 percent confidence intervals based on current samples sizes.

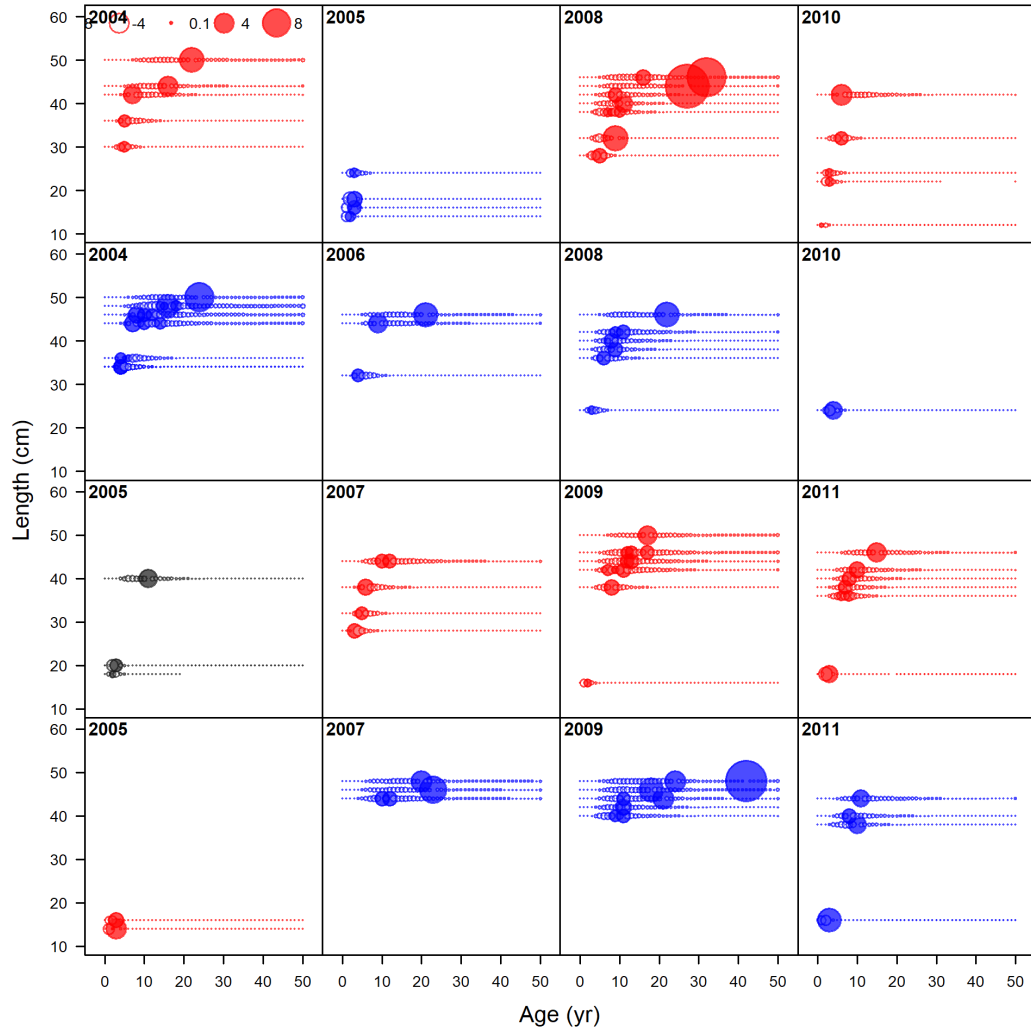


**Figure 86:** Pearson residuals for NWFSC WCGBT survey fleet length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

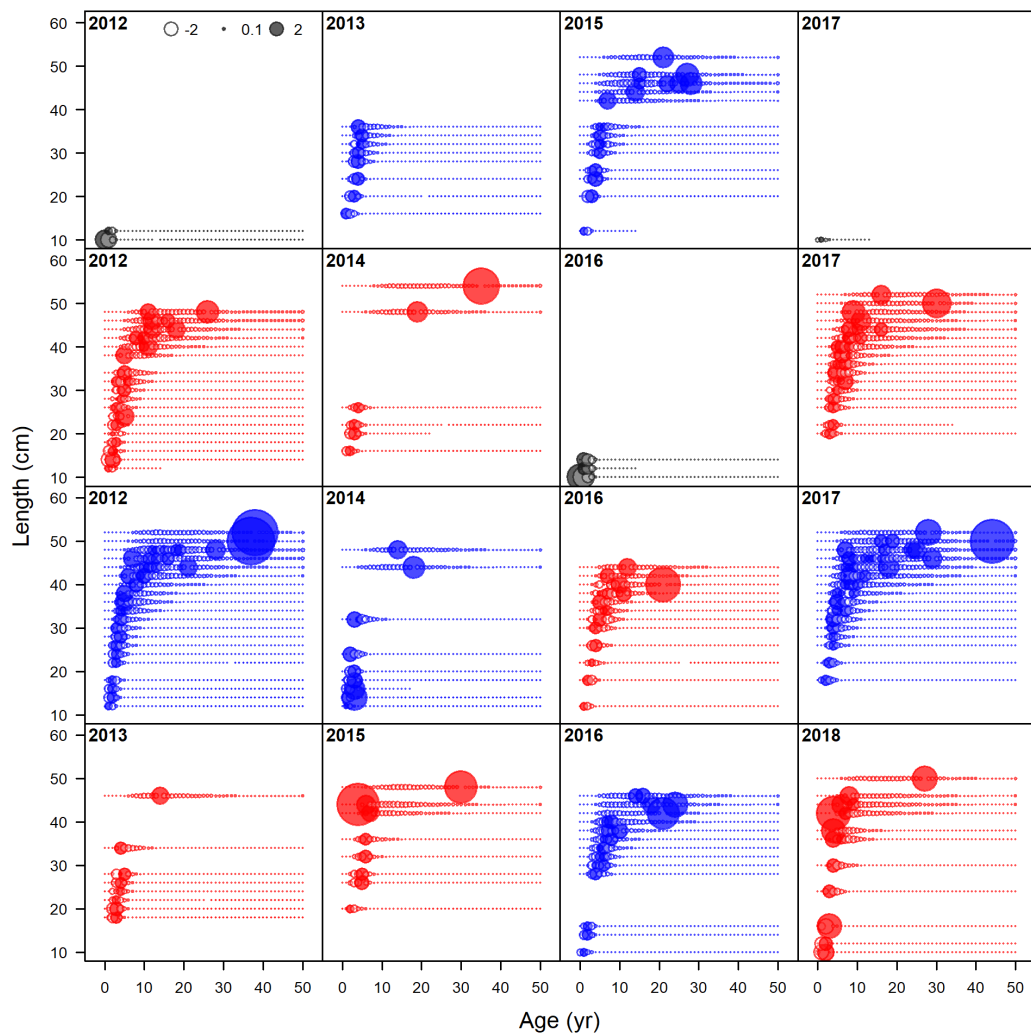


**Figure 87:** Mean length for the NWFSC WCGBT survey lengths with 95 percent confidence intervals based on current samples sizes.

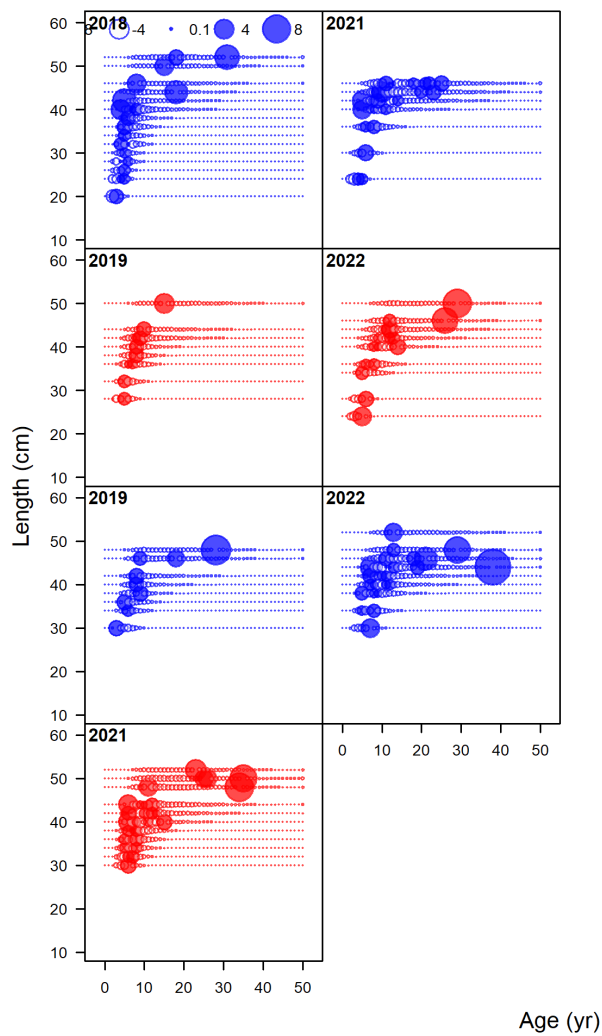




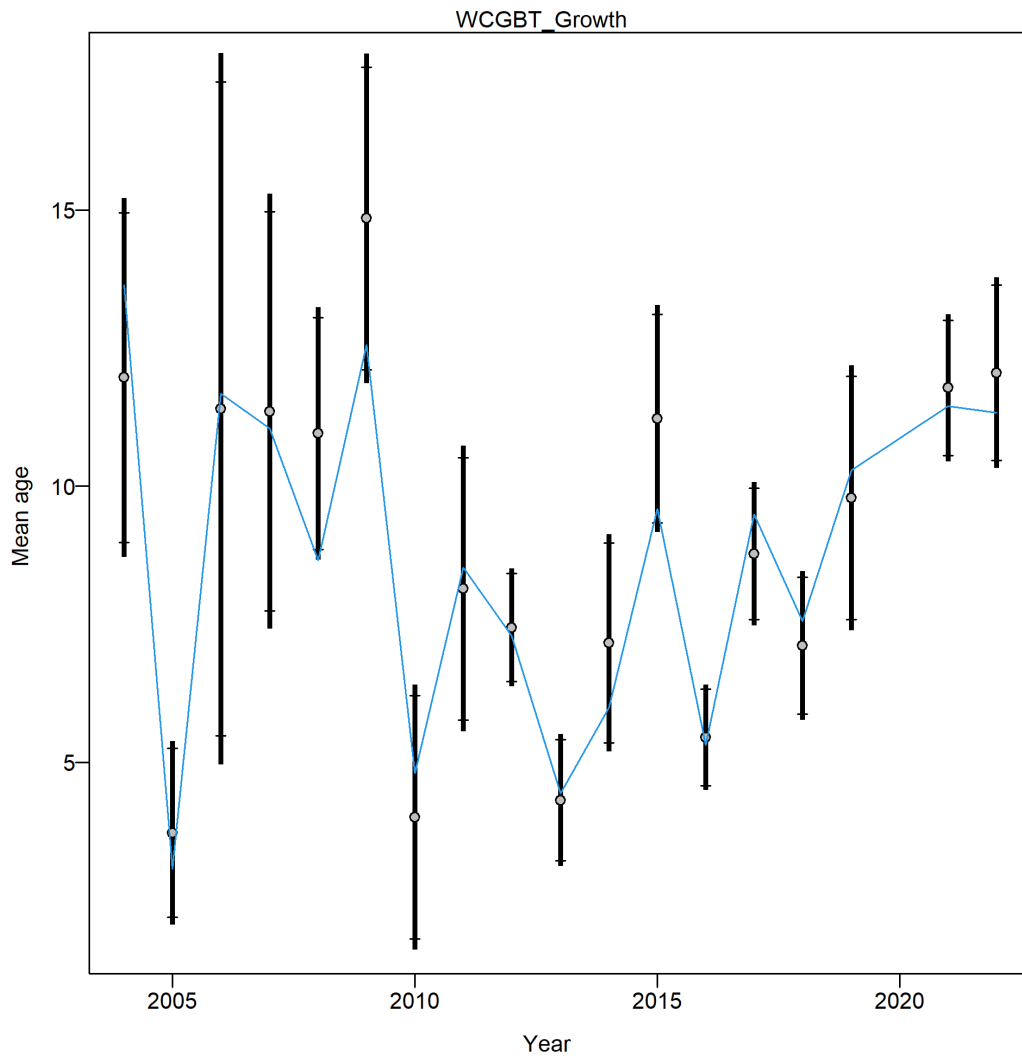
**Figure 88:** Pearson residuals for the NWFSC WCGBT survey conditional-age-at-length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



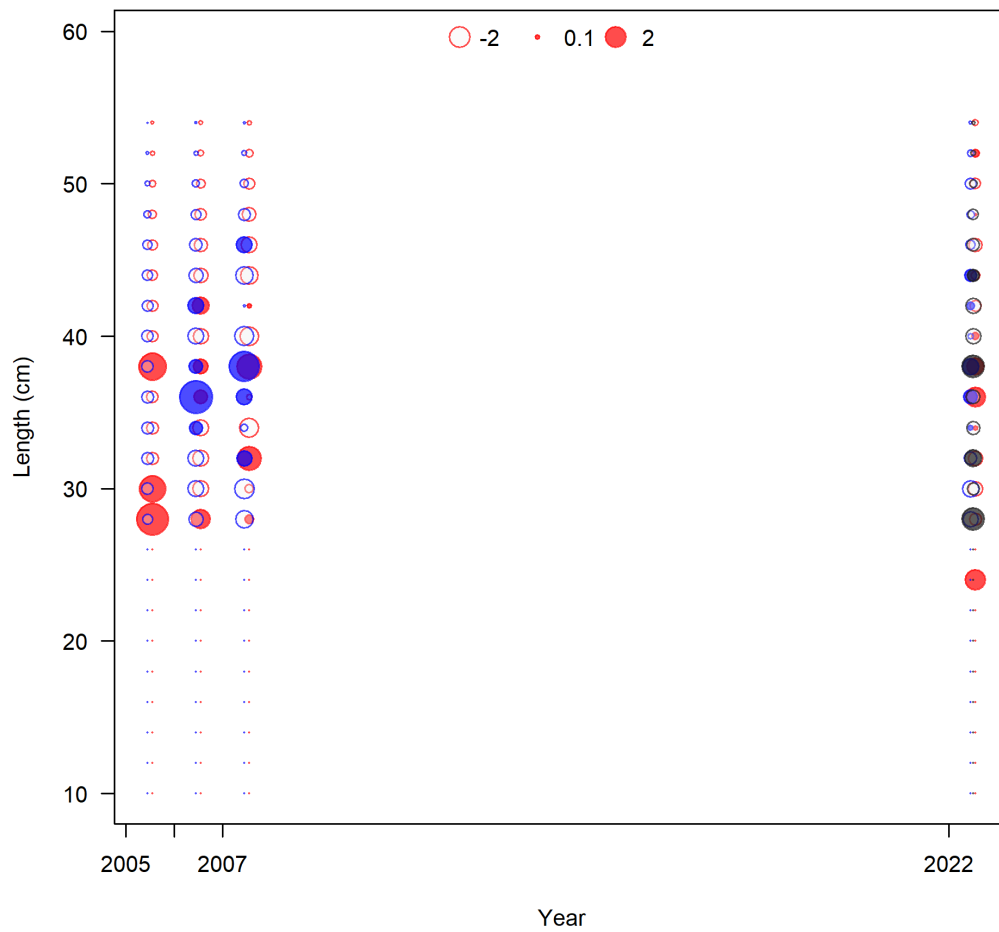
**Figure 89:** Pearson residuals for the NWFSC WCGBT survey conditional-age-at-length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



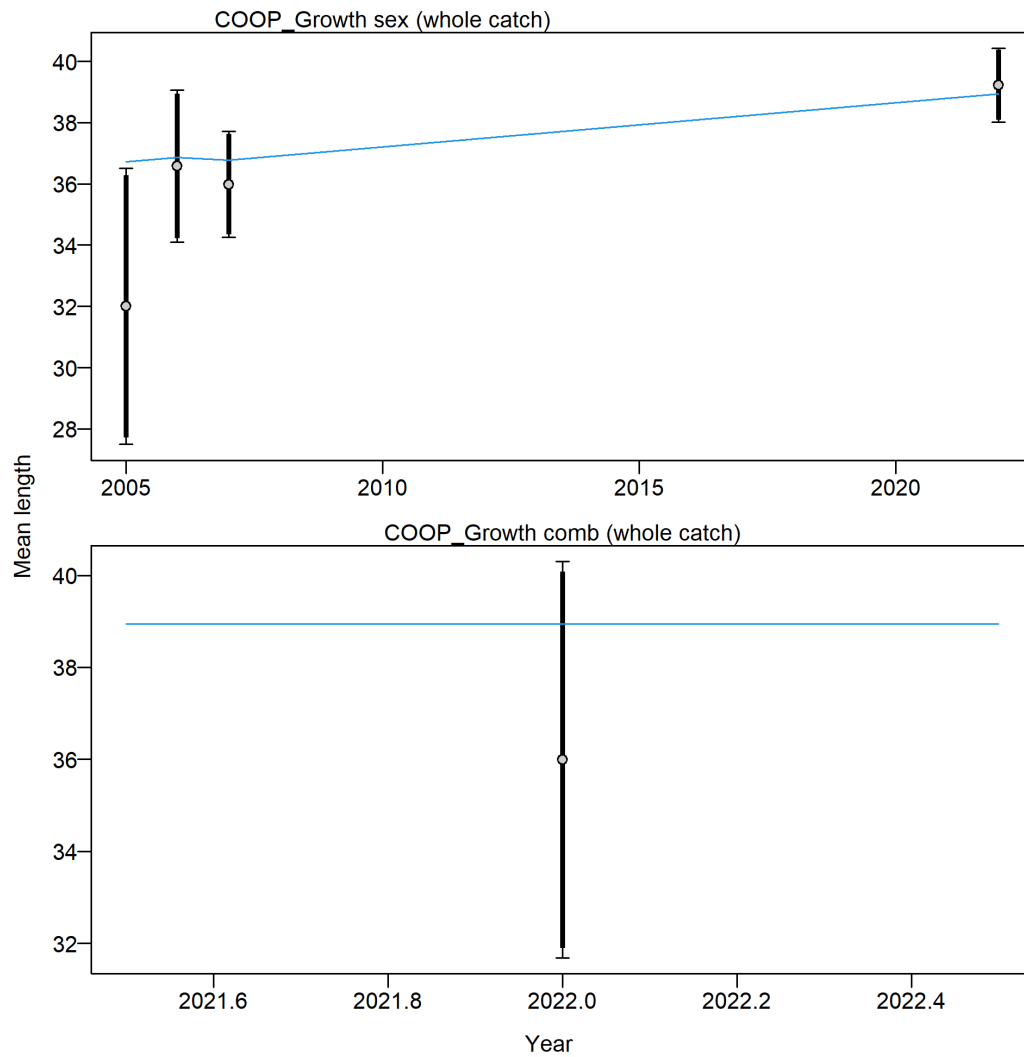
**Figure 90:** Pearson residuals for the NWFSC WCGBT survey conditional-age-at-length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



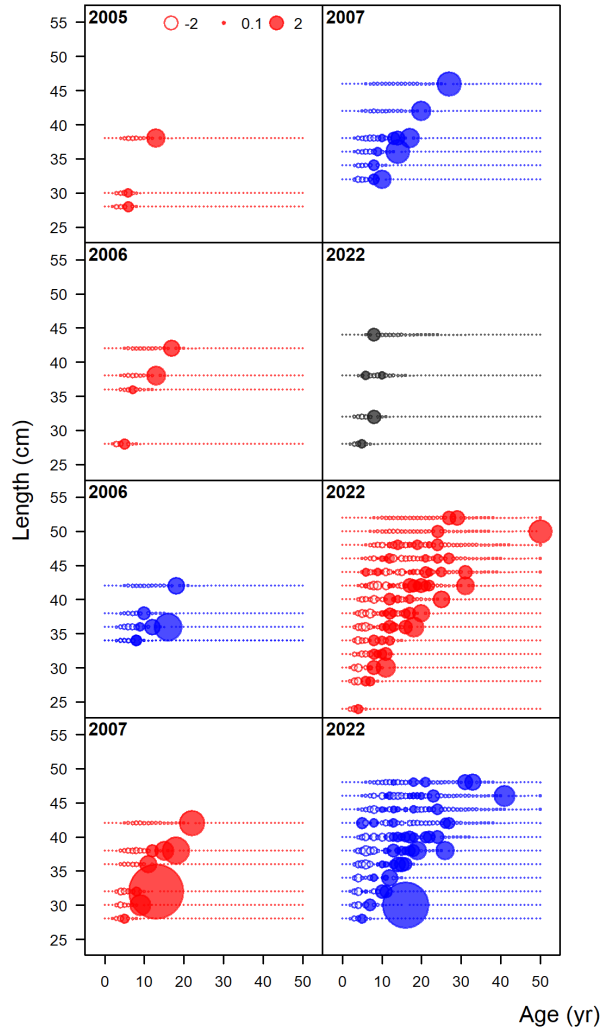
**Figure 91:** Mean age for the NWFSC WCGBT survey age data with 95 percent confidence intervals based on current samples sizes.



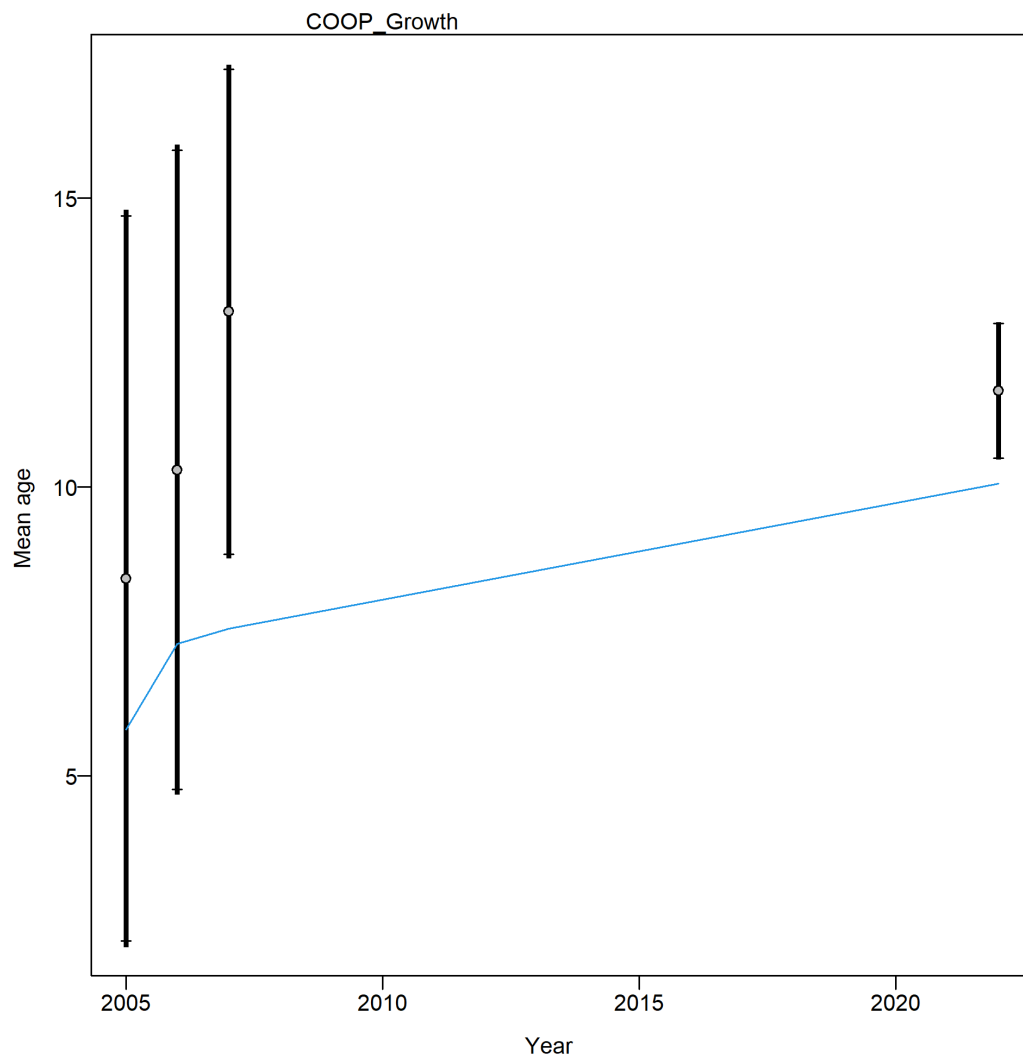
**Figure 92:** Pearson residuals for Pearson and CPFV cooperative collection length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



**Figure 93:** Mean length for the Pearson and CPFV cooperative collection lengths with 95 percent confidence intervals based on current samples sizes.

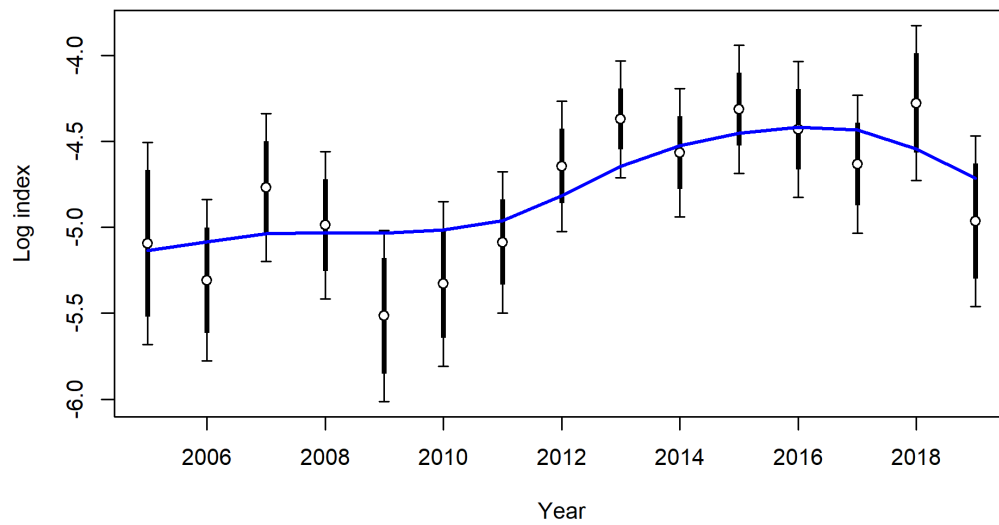


**Figure 94:** Pearson residuals for the Pearson and CPFV cooperative collection conditional-age-at-length data. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

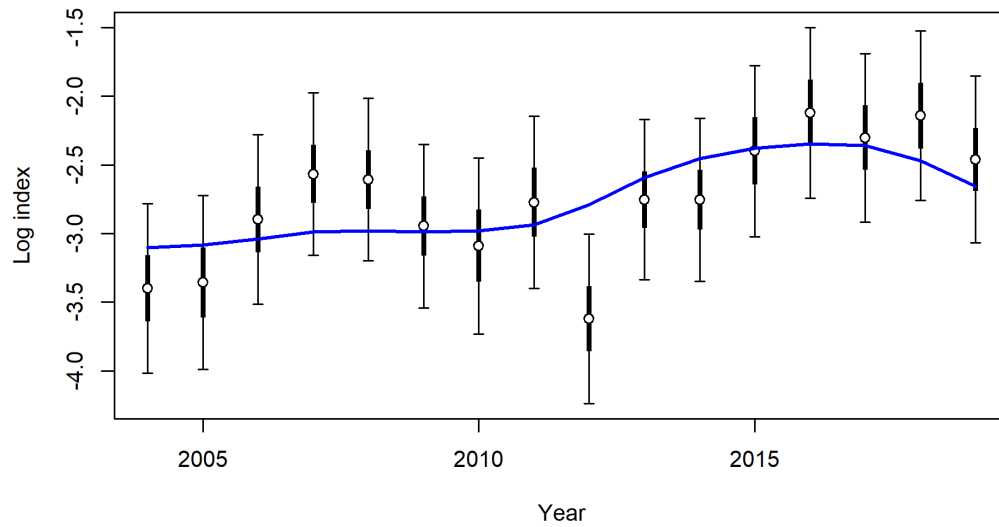


**Figure 95:** Mean age for the Pearson and CPFV cooperative collection age data with 95 percent confidence intervals based on current samples sizes.

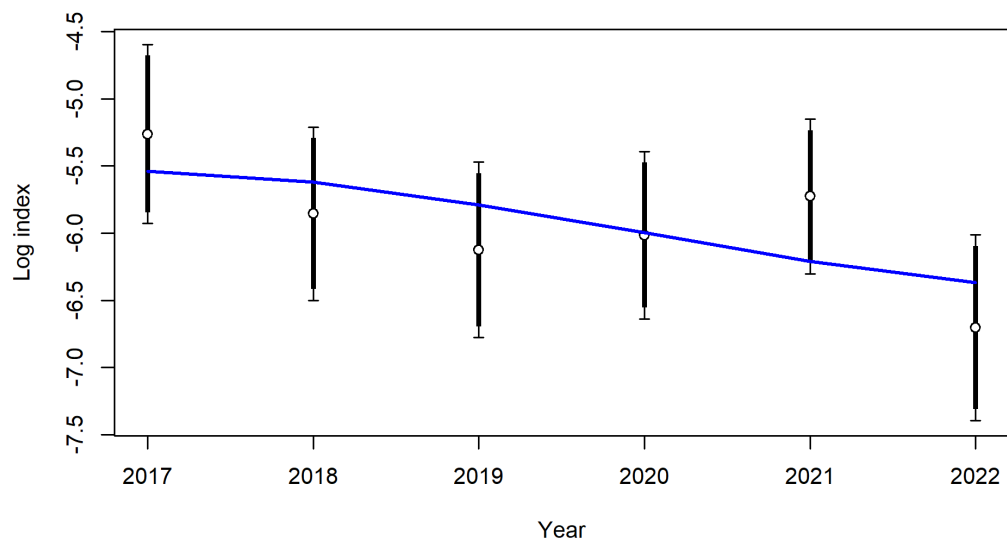




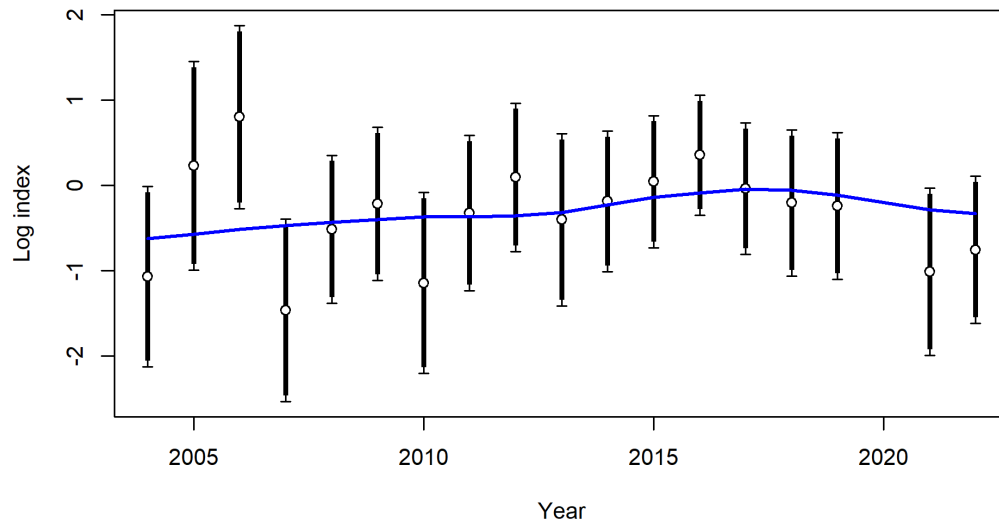
**Figure 96:** Fit to log index data on log scale for the recreational CRFS CPFV index of abundance. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.



**Figure 97:** Fit to log index data on log scale for the recreational PR index of abundance. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

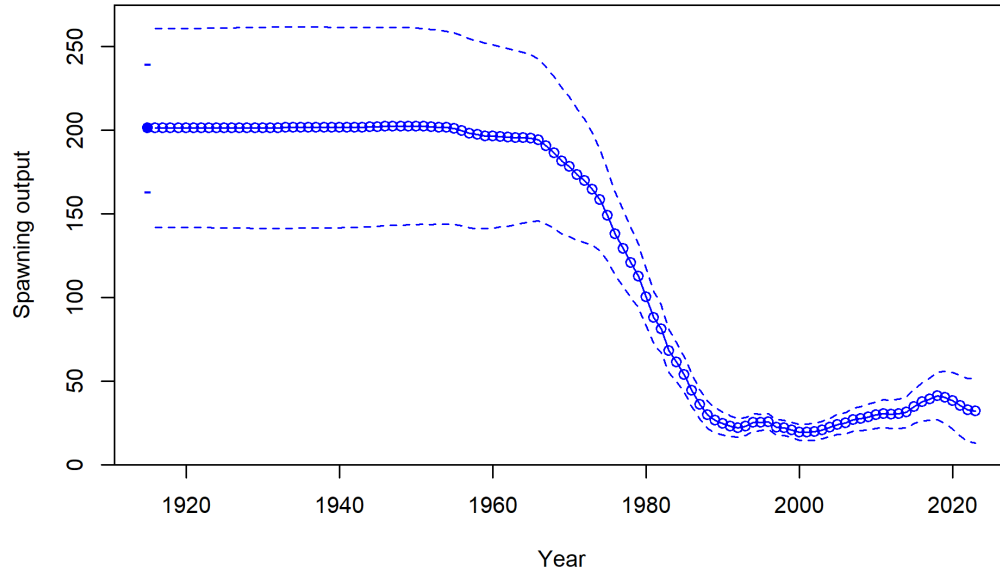


**Figure 98:** Fit to log index data on log scale for the CCFRP Hook and Line survey index of abundance. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

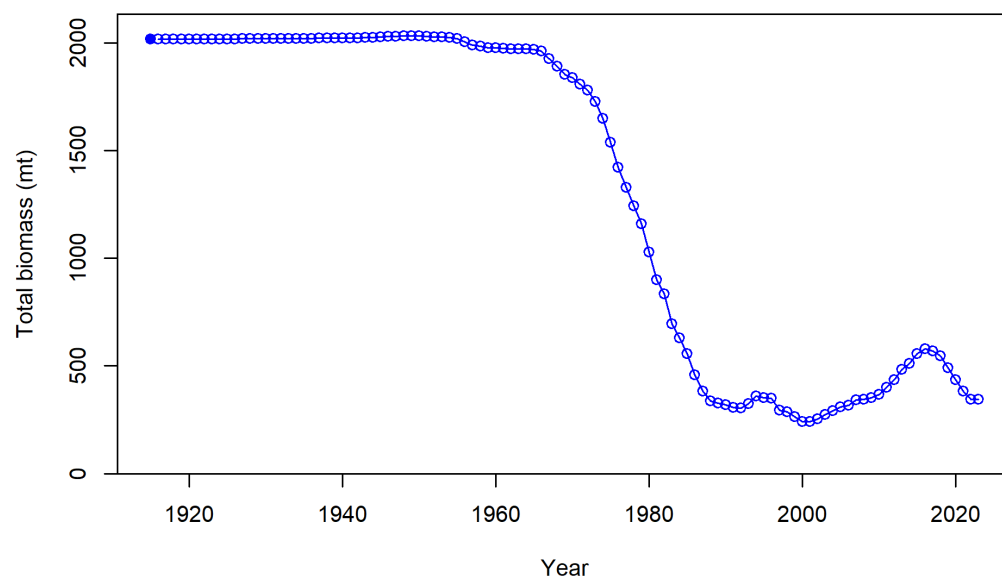


**Figure 99:** Fit to log index data on log scale for the NWFSC Hook and Line index of abundance. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

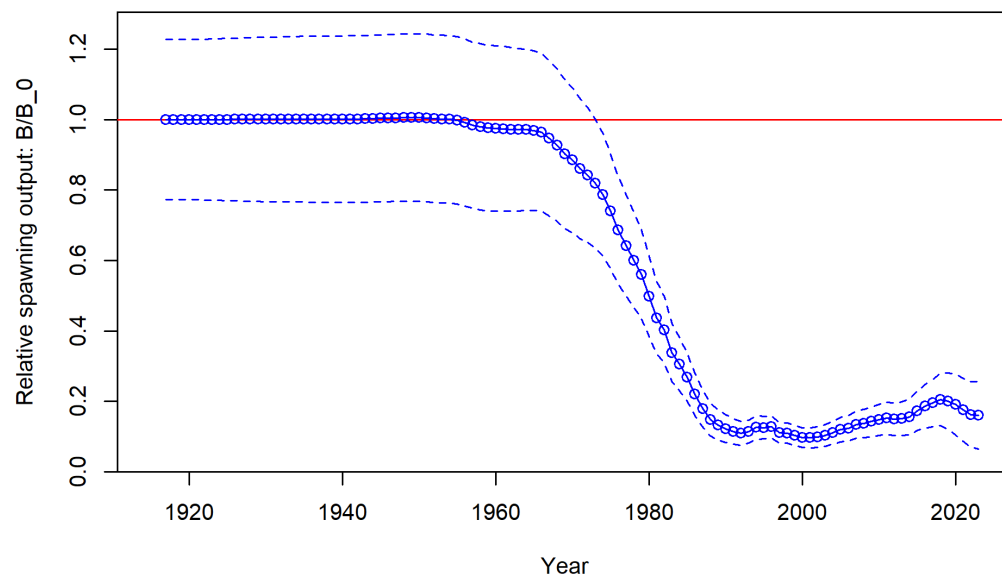
### 8.3.7 Time Series



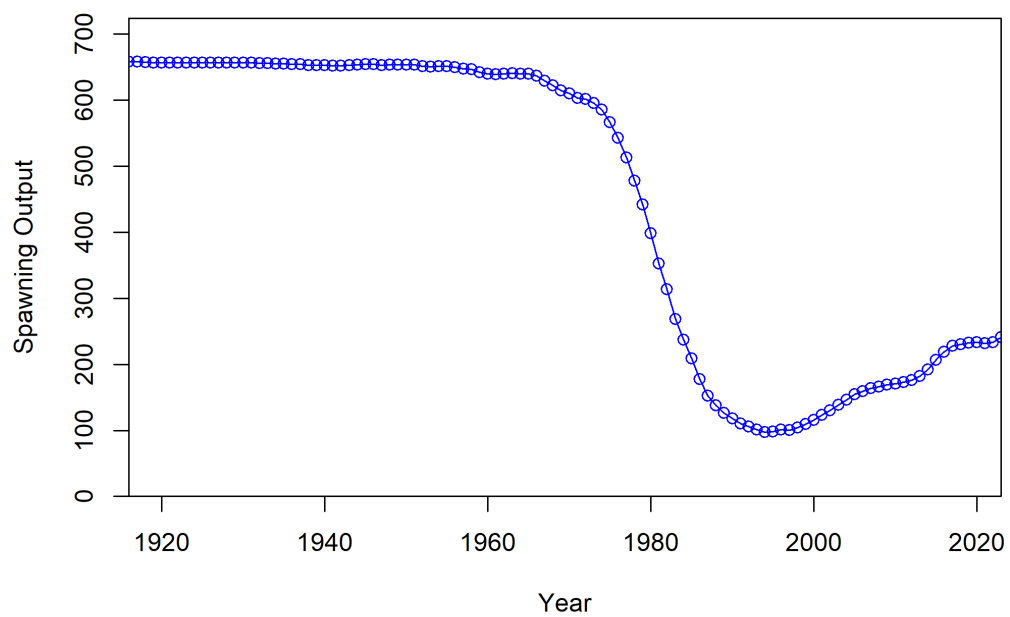
**Figure 100:** Estimated time series of spawning output for the area south of Point Conception in California.



**Figure 101:** Estimated time series of total biomass for the area south of Point Conception in California.

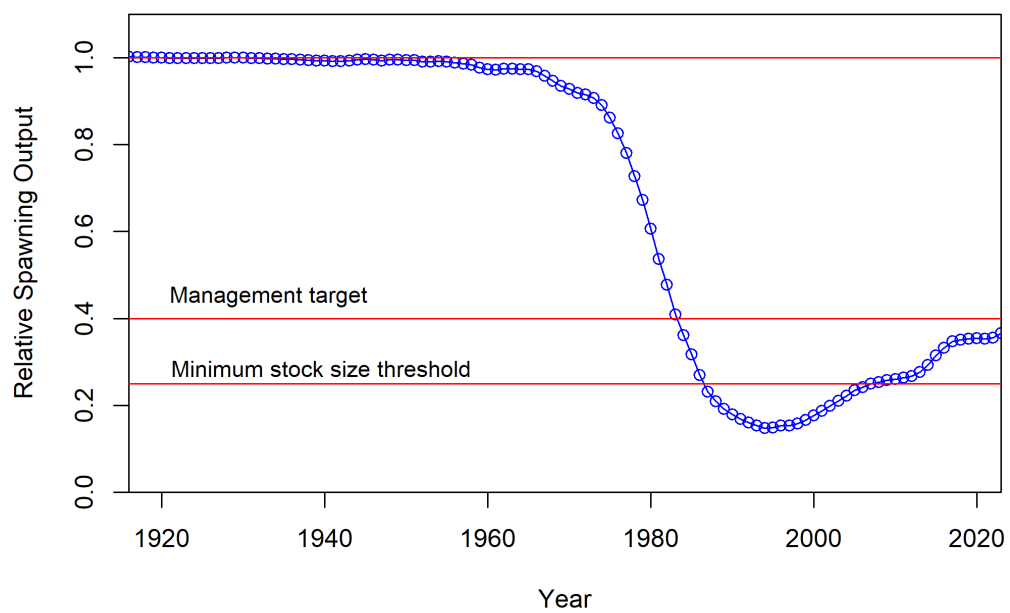


**Figure 102:** Estimated time series of relative spawning output for the area south of Point Conception in California.



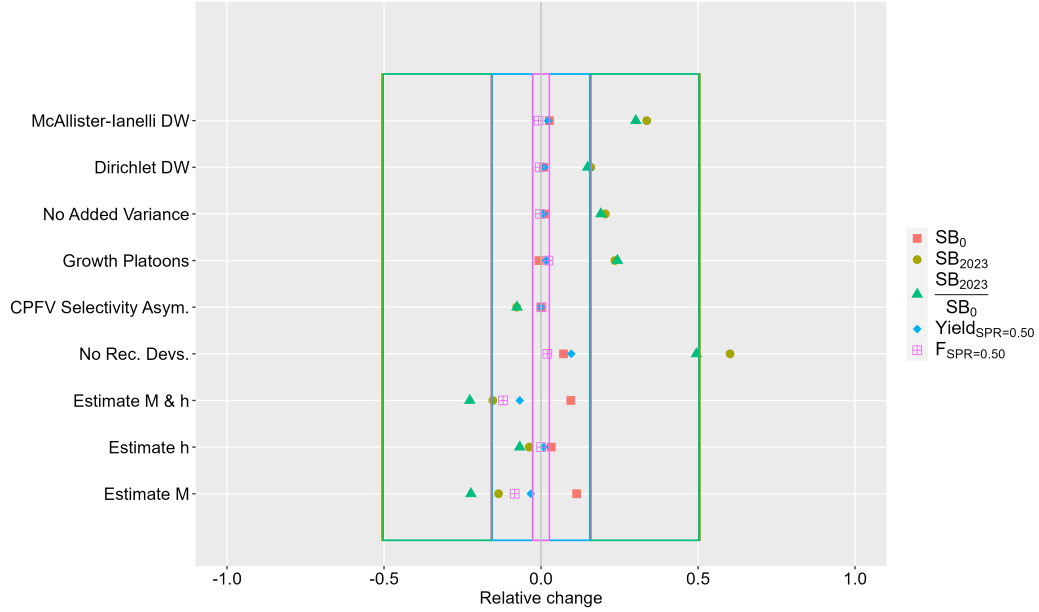
**Figure 103:** Estimated combined time series of spawning output for copper rockfish in California waters.



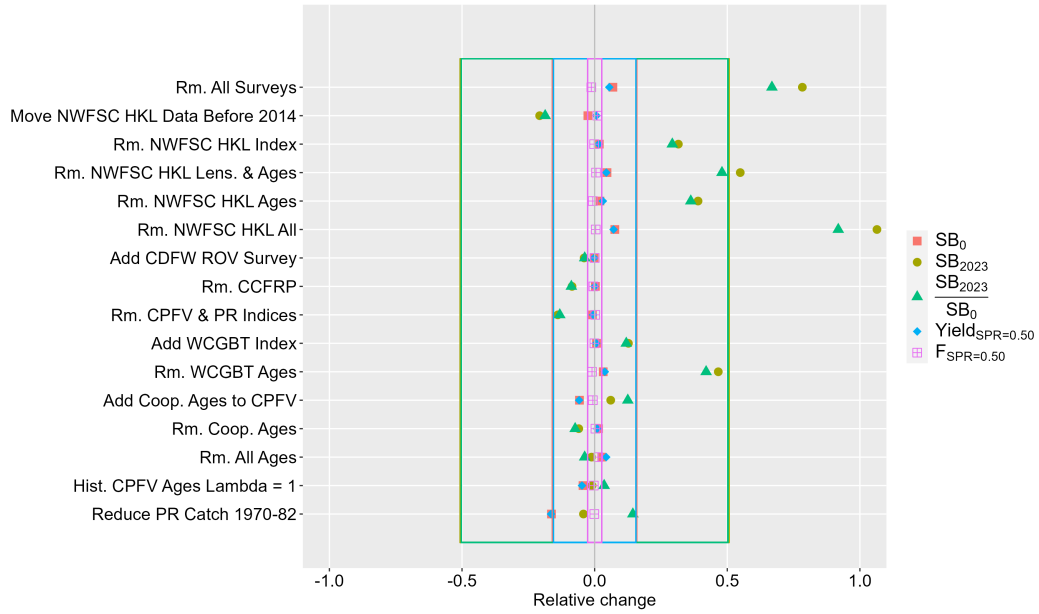


**Figure 104:** Estimated combined time series of relative spawning output for copper rockfish in California waters.

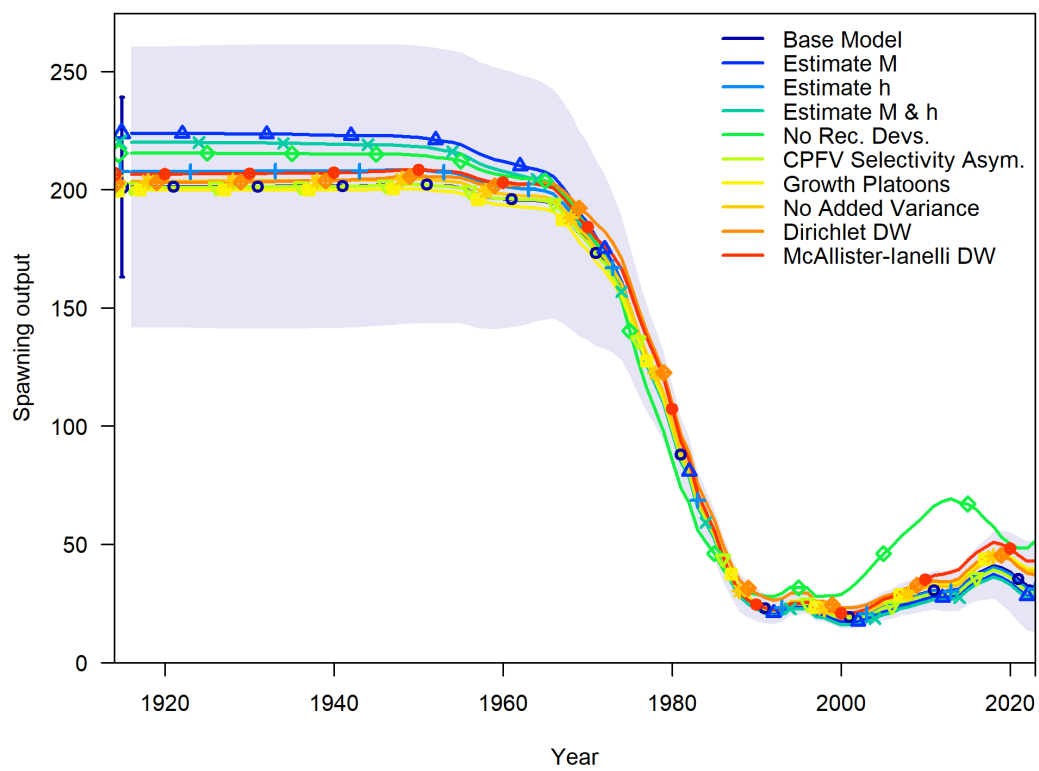
### 8.3.8 Sensitivity Analyses and Retrospectives



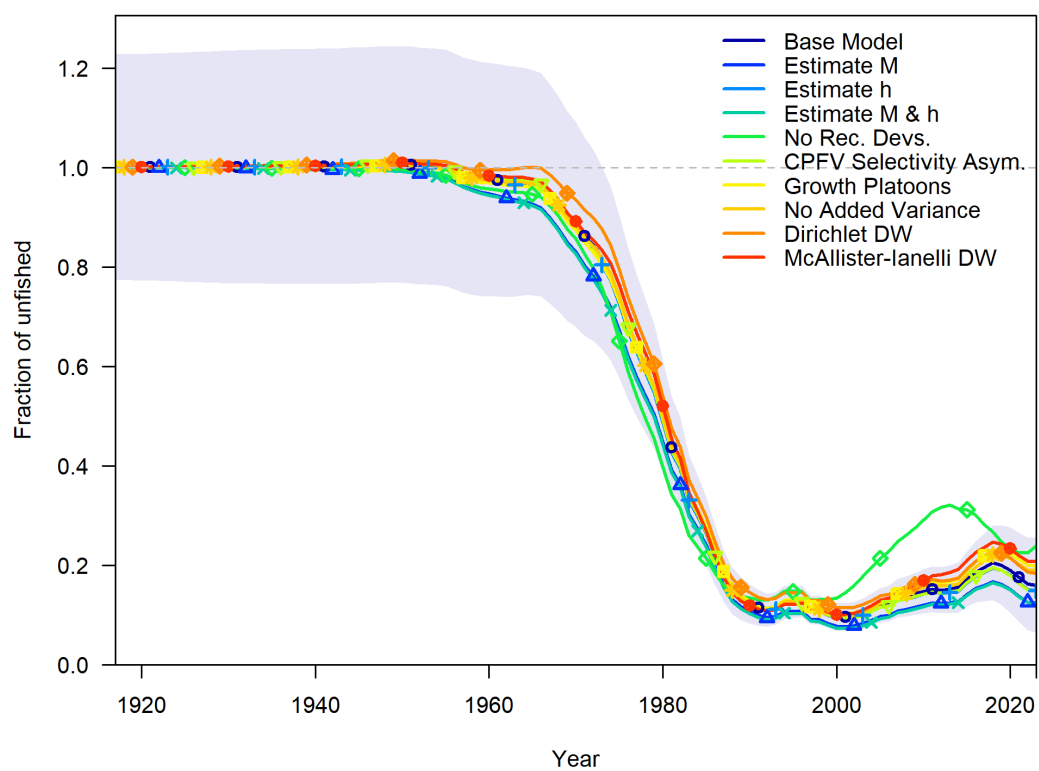
**Figure 105:** Comparison of the relative change in estimated management quantities as compared to the base model for structural sensitivities. The quantities compared are the estimate of unfished spawning output ( $SB_0$ ), spawning output in 2023 ( $SB_{2023}$ ), the relative spawning output ( $SB_{2023}/SB_0$ ), the yield based on a spawner per recruit harvest rate ( $Yield_{SPR=0.50}$ ), and the fishing mortality at that harvest rate ( $F_{SPR=0.50}$ ). The colored boxes indicate the 95 percent confidence interval around the point estimate of the quantity from the base model where each color corresponds with a specific quantity in the legend. A model with matching estimates as the base model would reflect a relative change of 0, a model with estimates less than the base model would have a negative relative change, and a model with estimates greater than the base model would have a positive relative change.



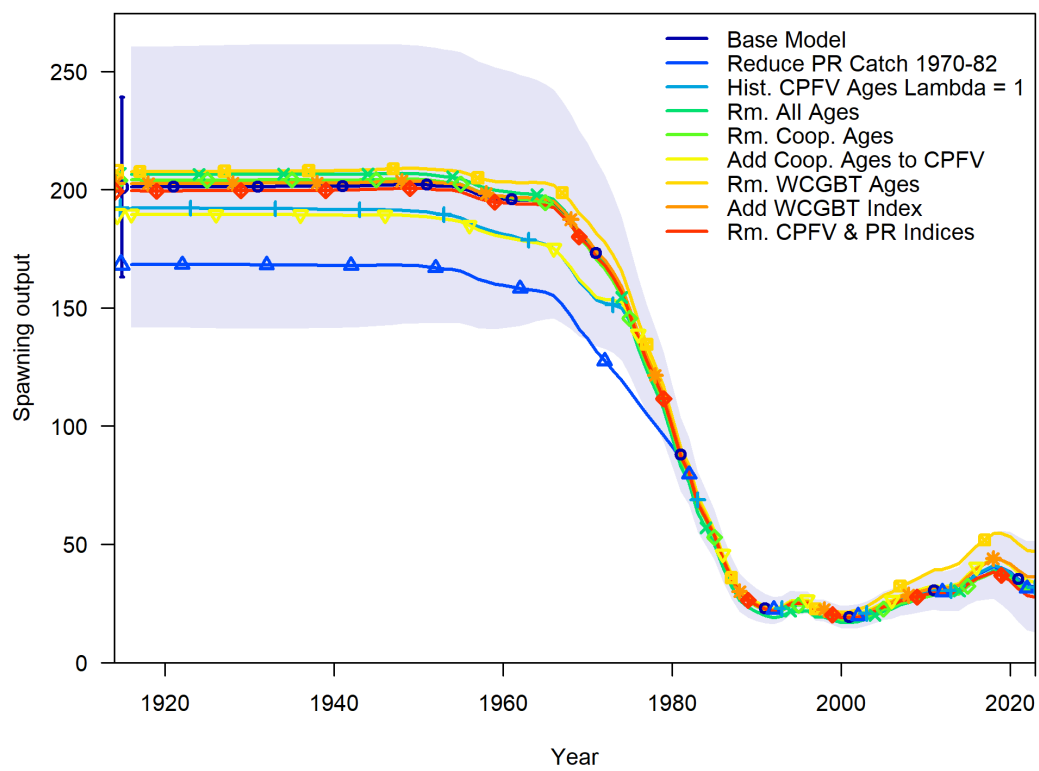
**Figure 106:** Comparison of the relative change in estimated management quantities as compared to the base model for data sensitivities. The quantities compared are the estimate of unfished spawning output ( $SB_0$ ), spawning output in 2023 ( $SB_{2023}$ ), the relative spawning output ( $SB_{2023}/SB_0$ ), the yield based on a spawner per recruit harvest rate ( $Yield_{SPR=0.50}$ ), and the fishing mortality at that harvest rate ( $F_{SPR=0.50}$ ). The colored boxes indicate the 95 percent confidence interval around the point estimate of the quantity from the base model where each color corresponds with a specific quantity in the legend. A model with matching estimates as the base model would reflect a relative change of 0, a model with estimates less than the base model would have a negative relative change, and a model with estimates greater than the base model would have a positive relative change.



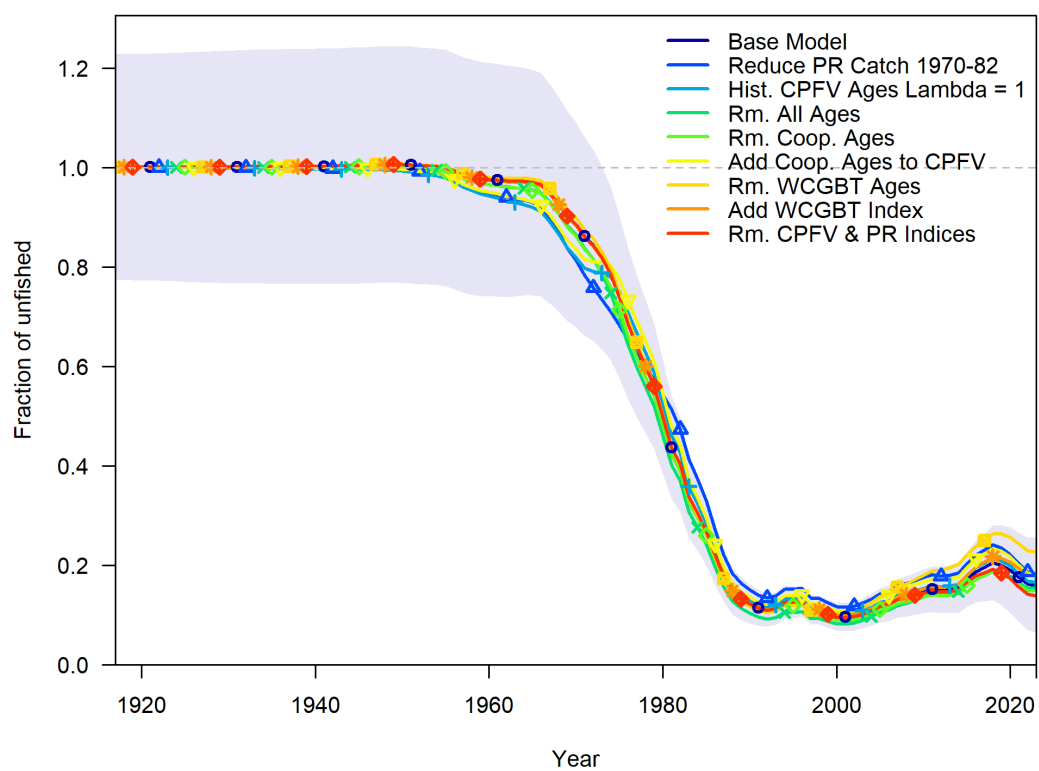
**Figure 107:** Change in estimated spawning output by sensitivity.



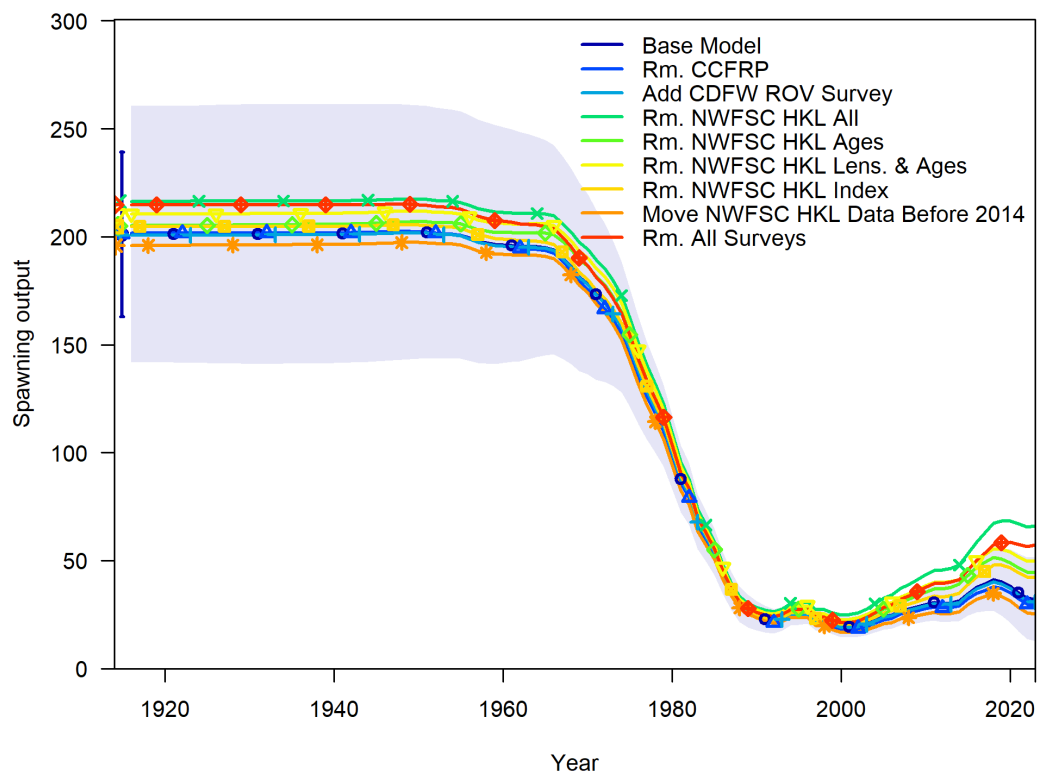
**Figure 108:** Change in estimated fraction unfished by sensitivity.



**Figure 109:** Change in estimated spawning output by sensitivity.

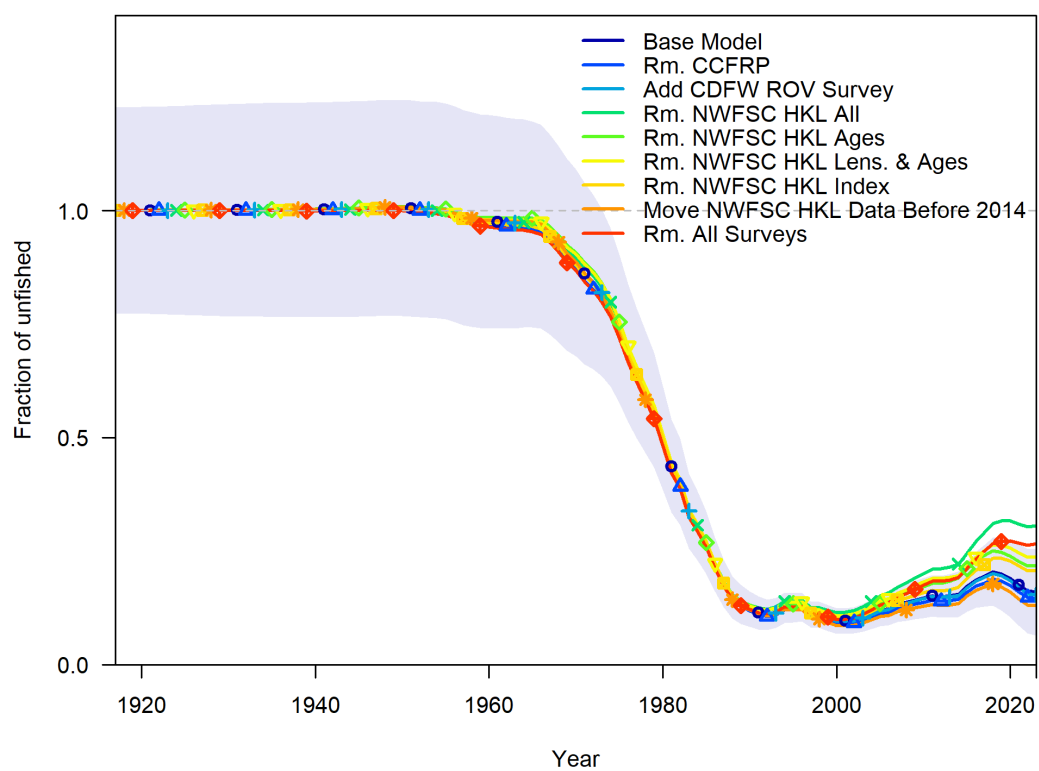


**Figure 110:** Change in estimated fraction unfished by sensitivity.

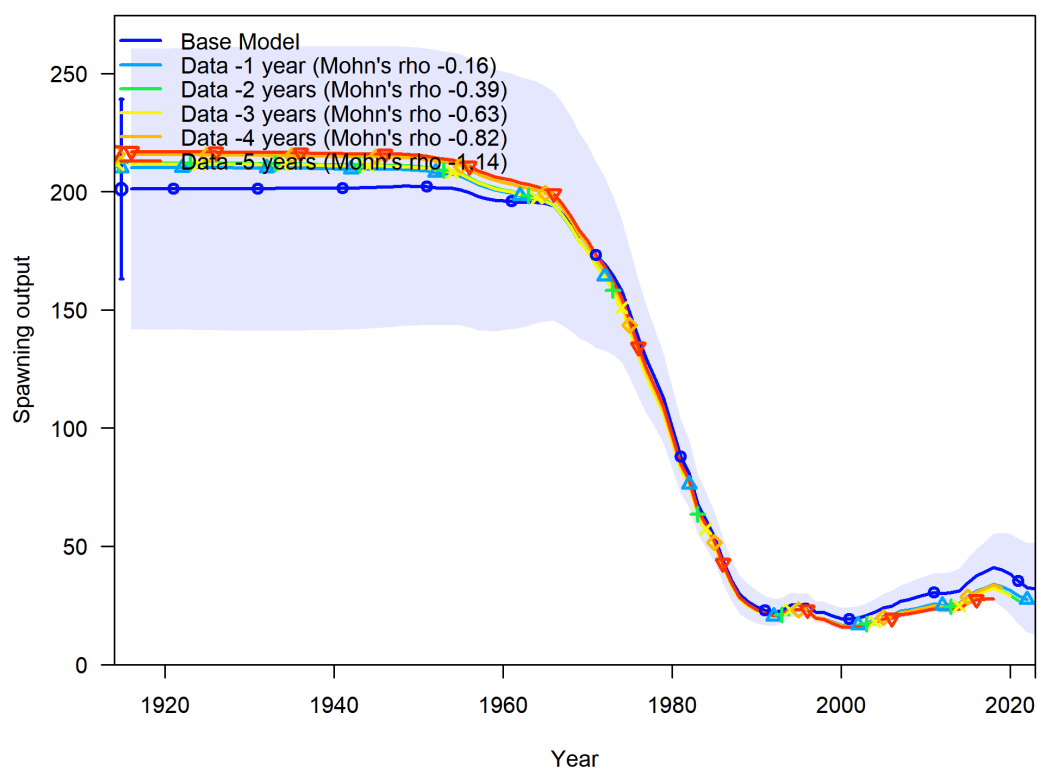


**Figure 111:** Change in estimated spawning output by sensitivity.

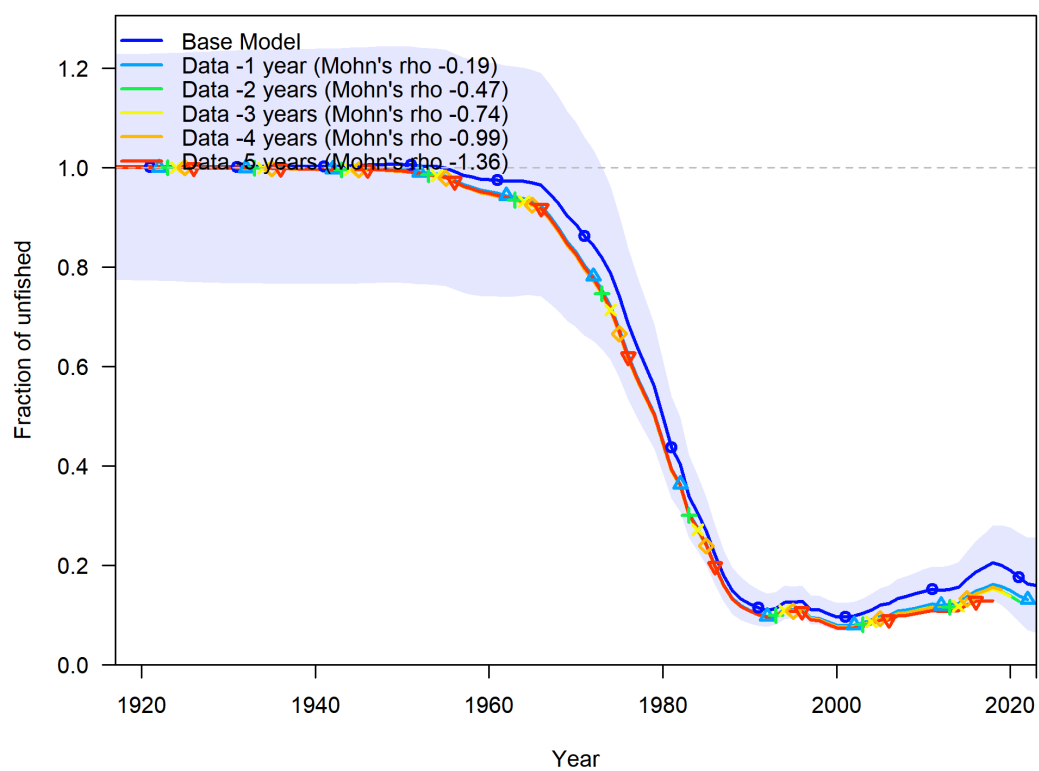




**Figure 112:** Change in estimated fraction unfished by sensitivity.

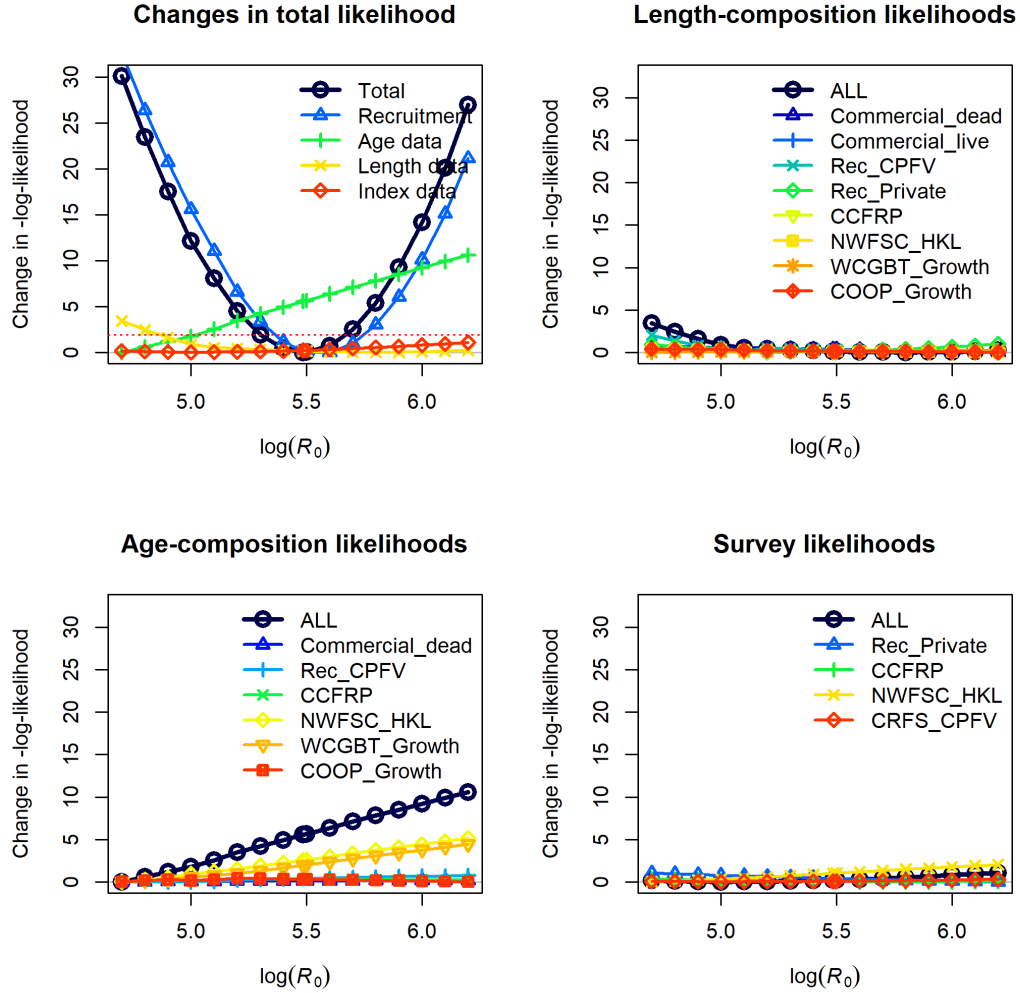


**Figure 113:** Change in the estimate of spawning output when the most recent 5 years of data area removed sequentially.

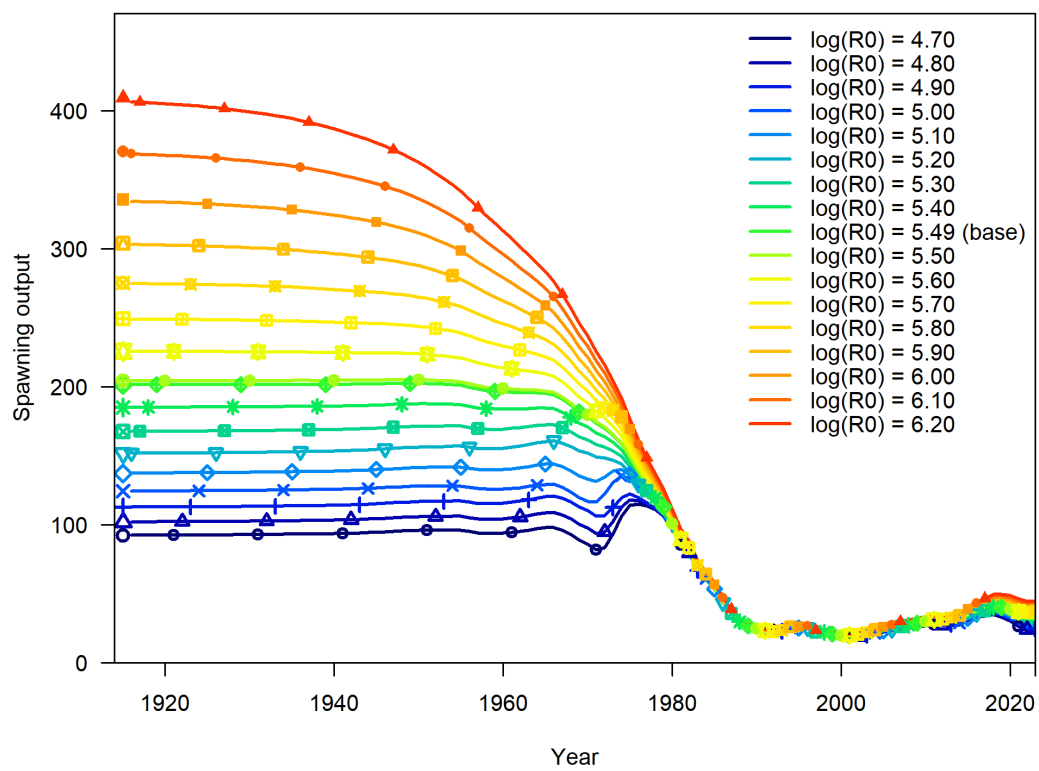


**Figure 114:** Change in the estimate of fraction unfished when the most recent 5 years of data area removed sequentially.

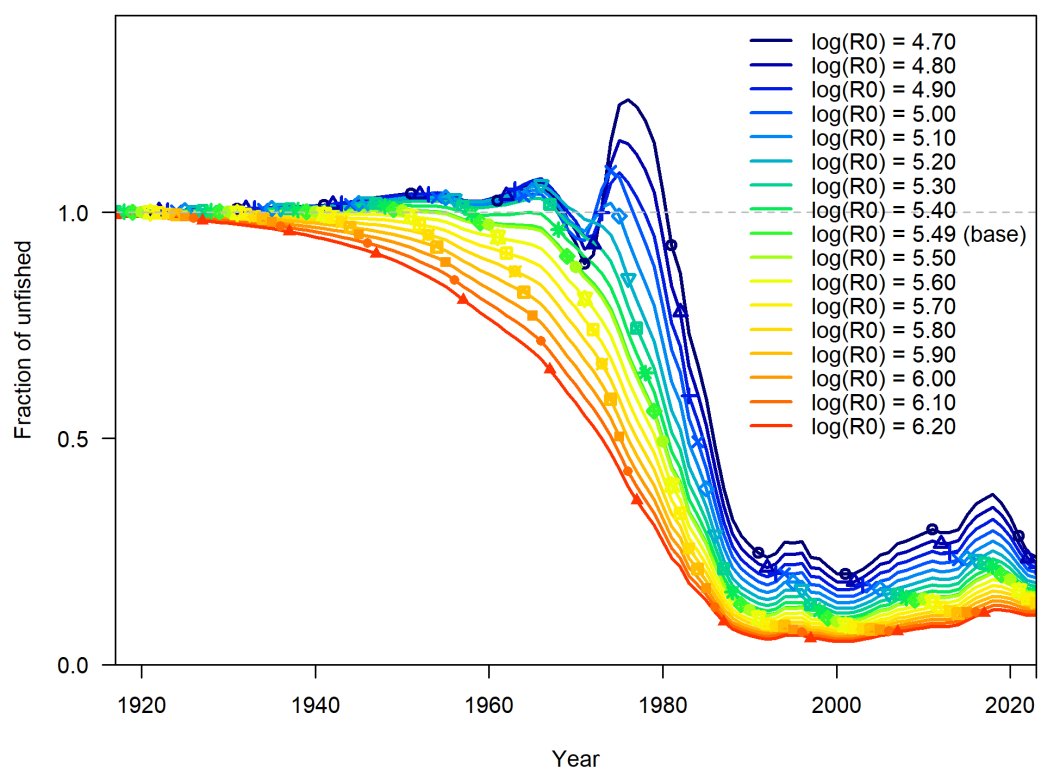
### 8.3.9 Likelihood Profiles



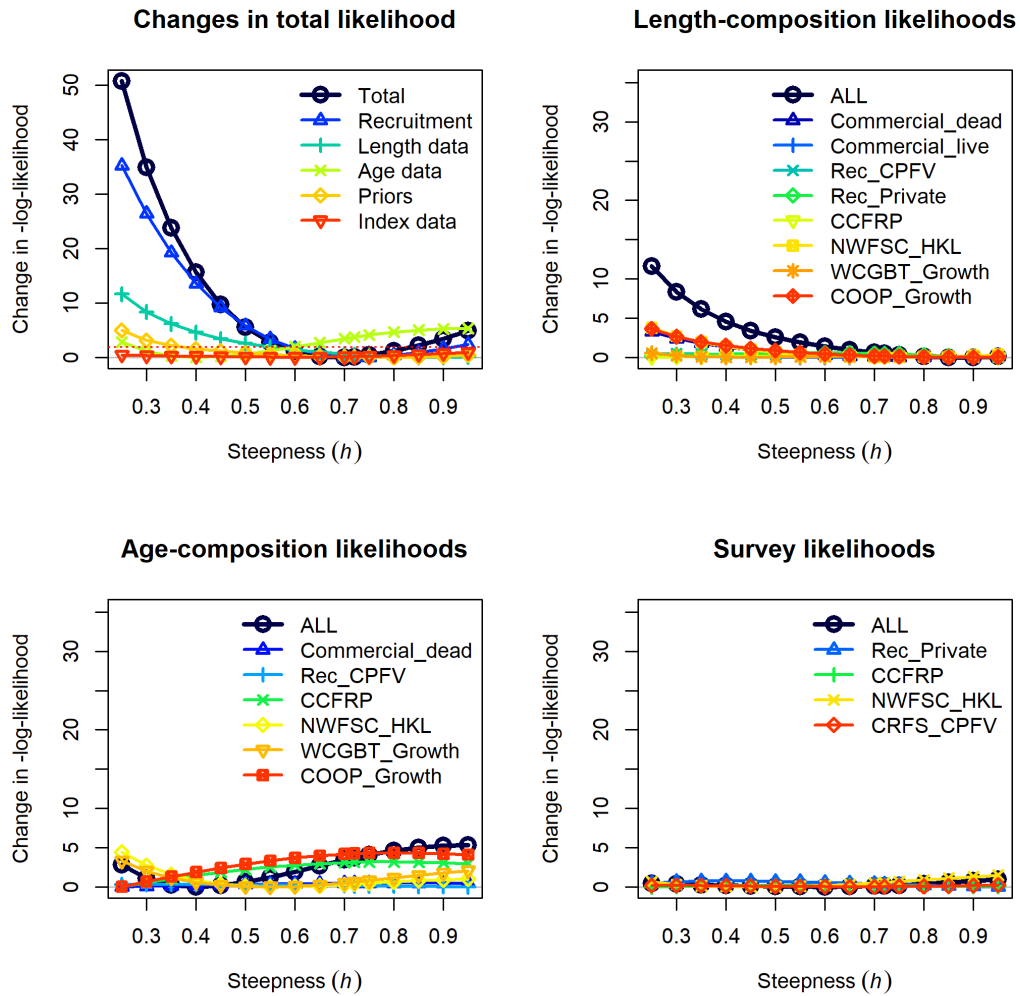
**Figure 115:** Change in the negative log-likelihood across a range of  $\log(R_0)$  values.



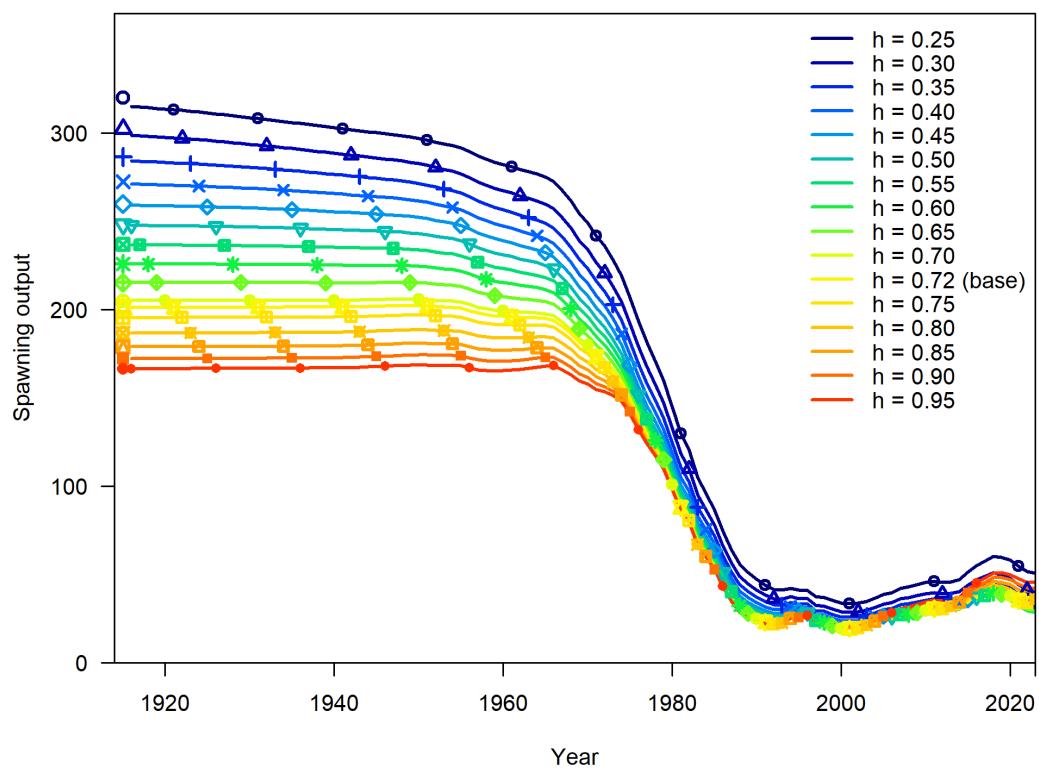
**Figure 116:** Change in the estimate of spawning output across a range of  $\log(R_0)$  values.



**Figure 117:** Change in the estimate of fraction unfished across a range of  $\log(R_0)$  values.

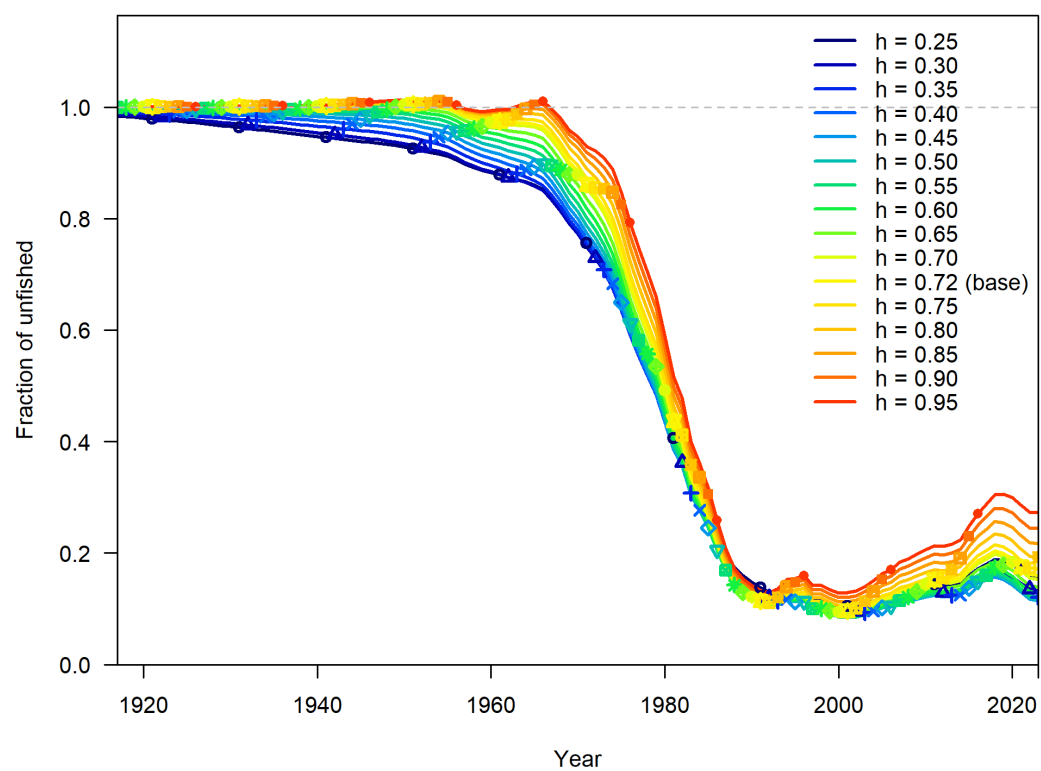


**Figure 118:** Change in the negative log-likelihood across a range of steepness ( $h$ ) values.

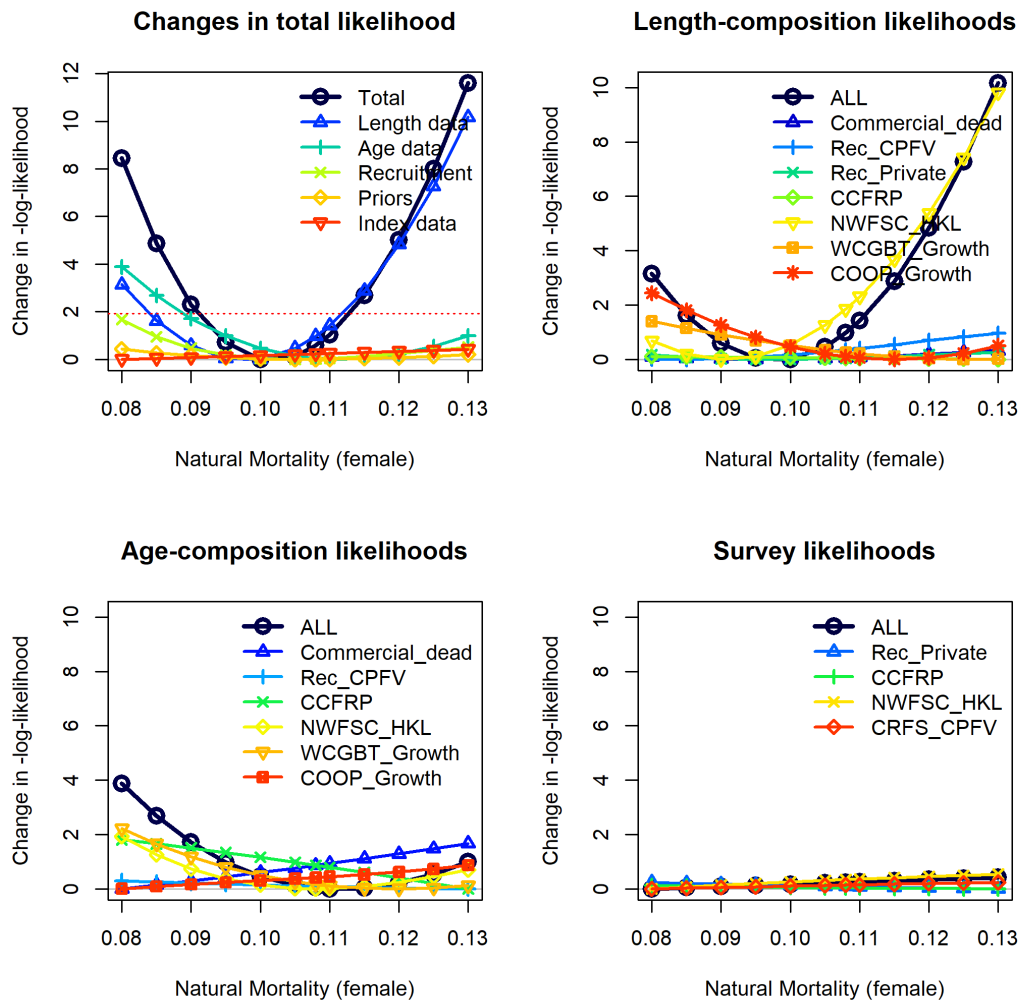


**Figure 119:** Change in the estimate of spawning output across a range of steepness ( $h$ ) values.

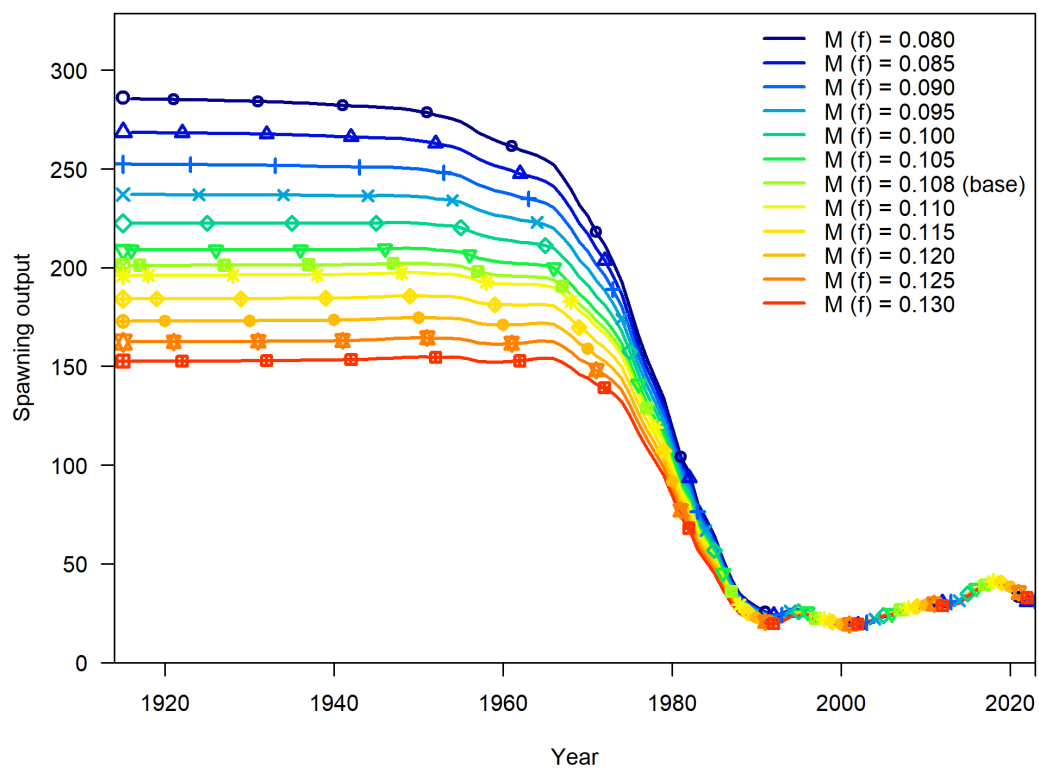




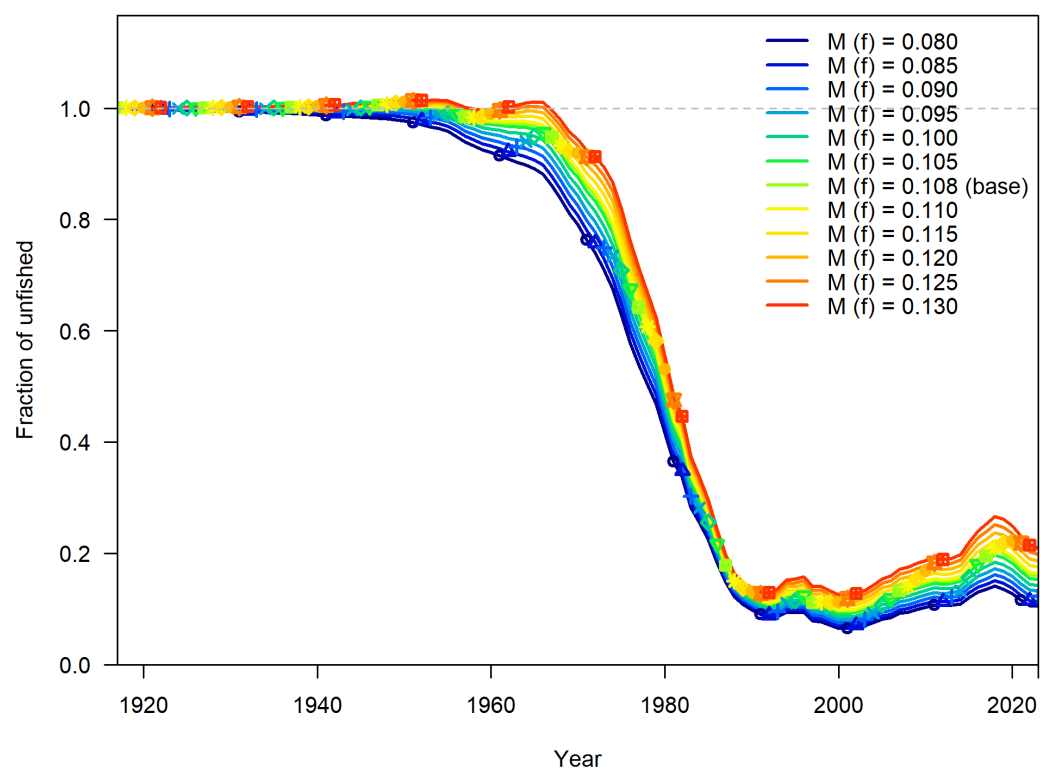
**Figure 120:** Change in the estimate of fraction unfished across a range of steepness ( $h$ ) values.



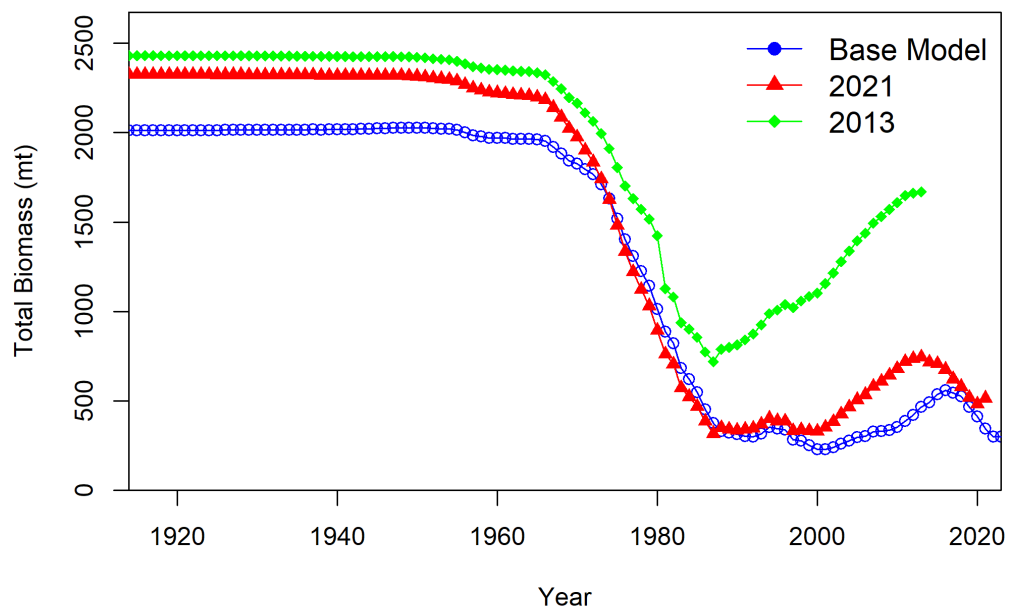
**Figure 121:** Change in the negative log-likelihood across a range of female natural mortality (M) values.



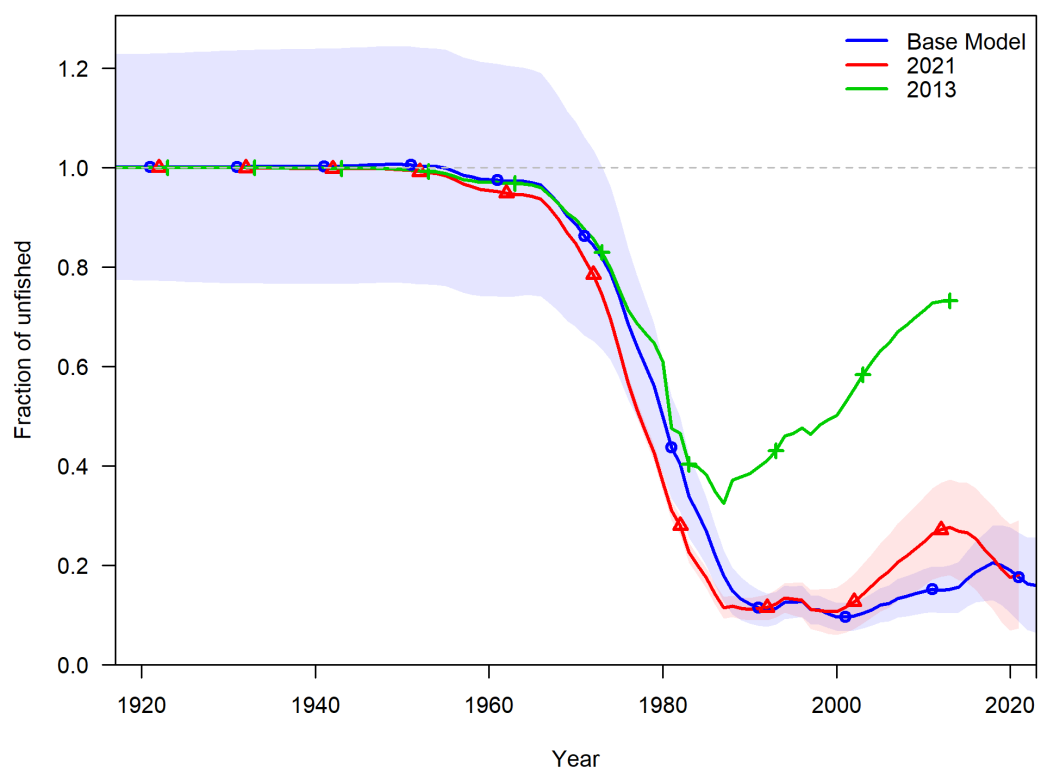
**Figure 122:** Change in the estimate of spawning output across a range of female natural mortality ( $M$ ) values.



**Figure 123:** Change in the estimate of fraction unfished across a range of female natural mortality ( $M$ ) values.

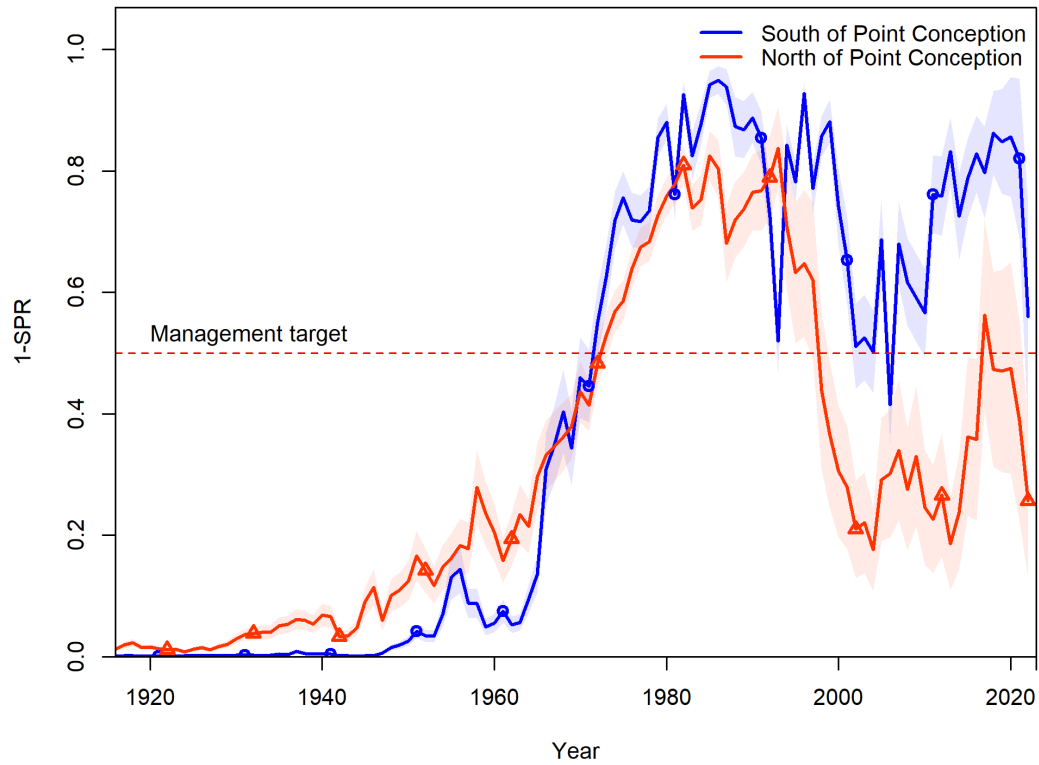


**Figure 124:** Comparison of the estimated total biomass (mt) for the base model to previous assessments in 2021 and 2013.

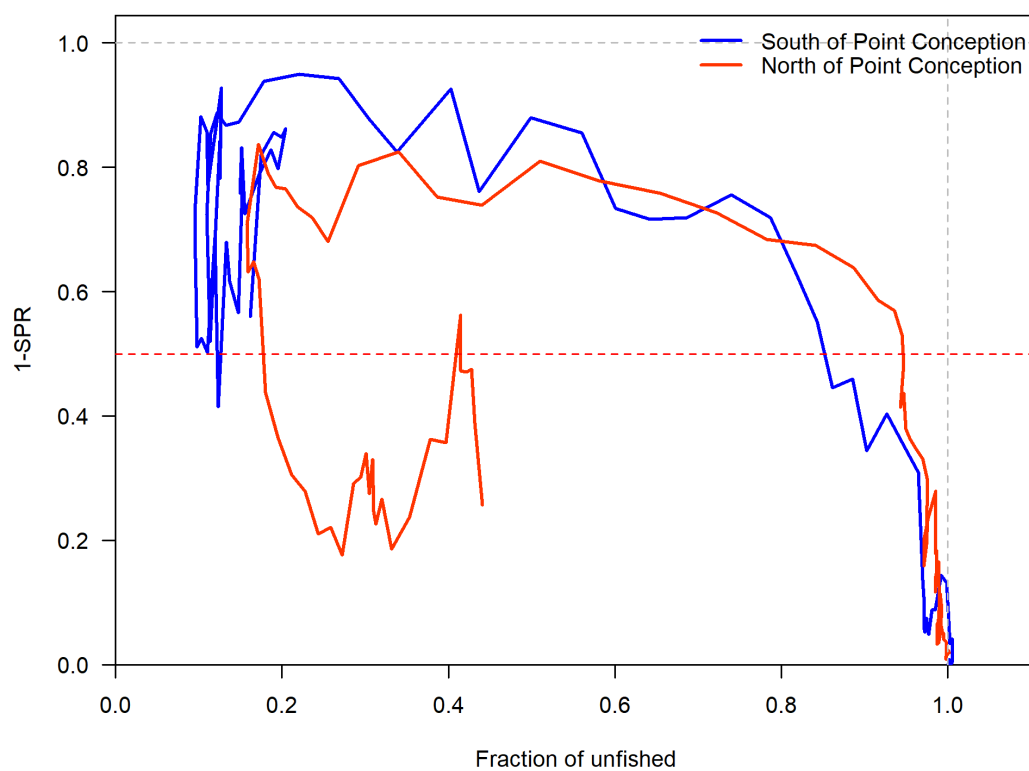


**Figure 125:** Comparison of the estimated fraction unfished for the base model to previous assessments in 2021 and 2013.

### 8.3.10 Reference Points and Forecasts

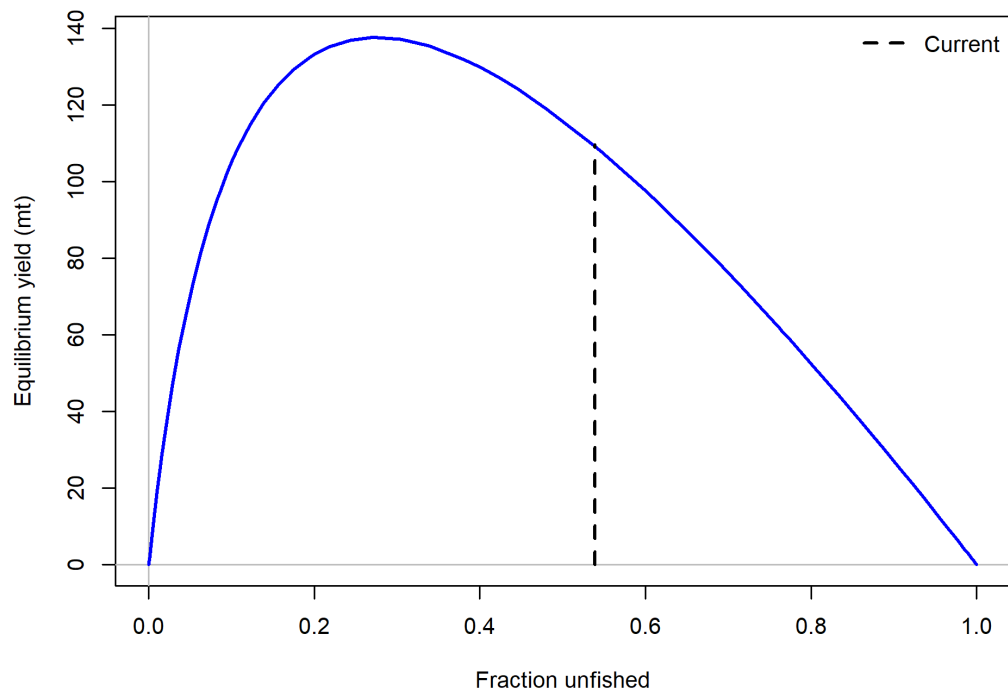


**Figure 126:** Estimated 1 - relative spawning ratio (SPR) by year for both sub-area models south and north of Point Conception.

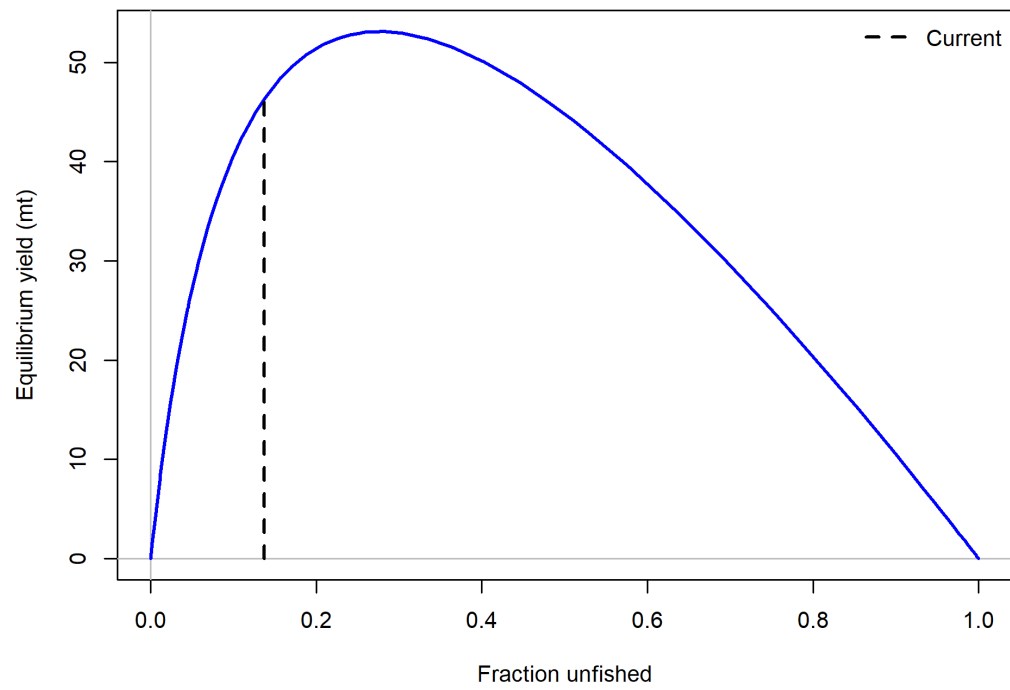


**Figure 127:** Phase plot of the relative biomass (also referred to as fraction unfished) versus the SPR ratio where each point represents the biomass ratio at the start of the year and the relative fishing intensity in that same year. Lines through the final point show the 95 percent intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95 percent region which accounts for the estimated correlations between the biomass ratio and SPR ratio.





**Figure 128:** Equilibrium yield curve for the base case model north of Point Conception. Values are based on the 2022 fishery selectivities and with steepness fixed at 0.72.

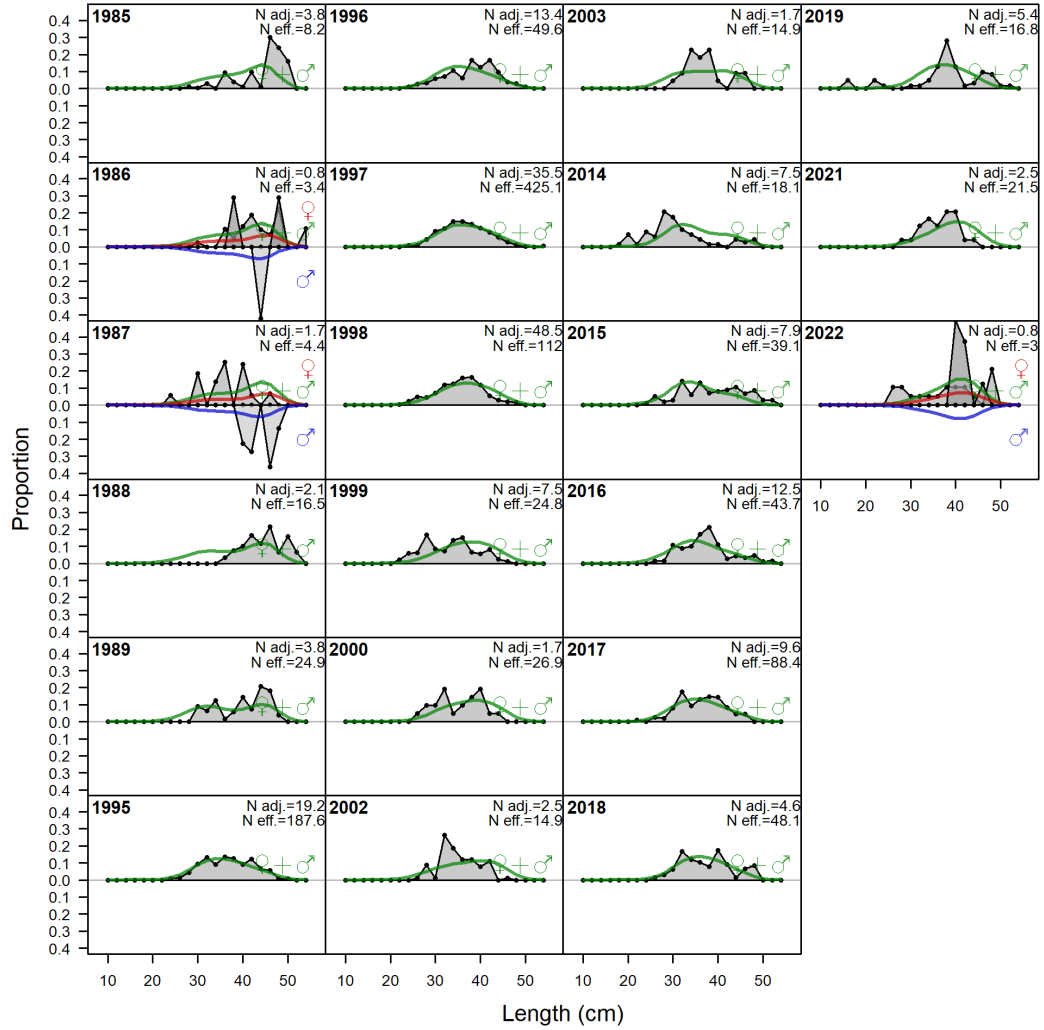


**Figure 129:** Equilibrium yield curve for the base case model south of Point Conception. Values are based on the 2022 fishery selectivities and with steepness fixed at 0.72.

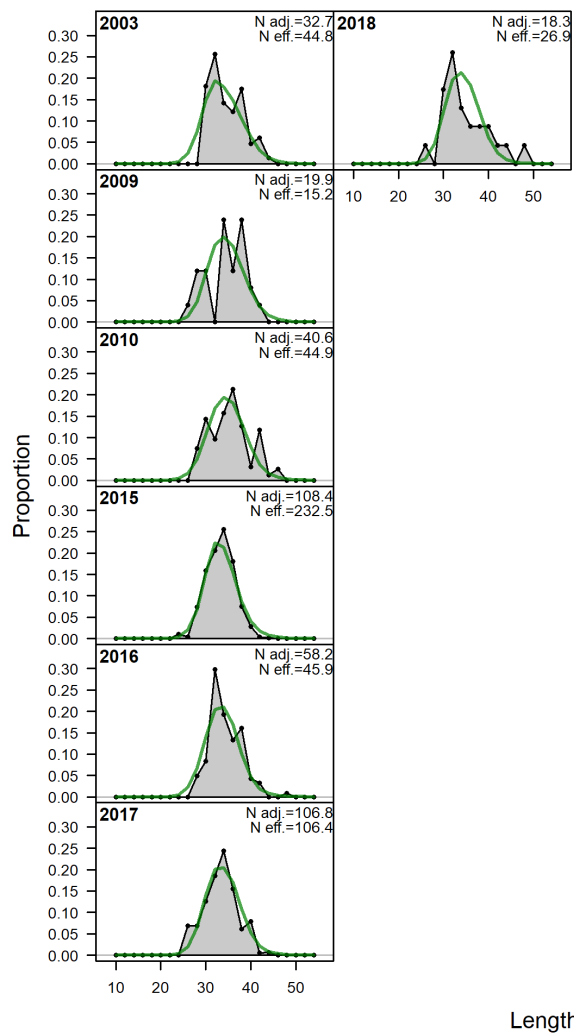
## 9 Appendices

### 9.1 Detailed Fits to Composition Data

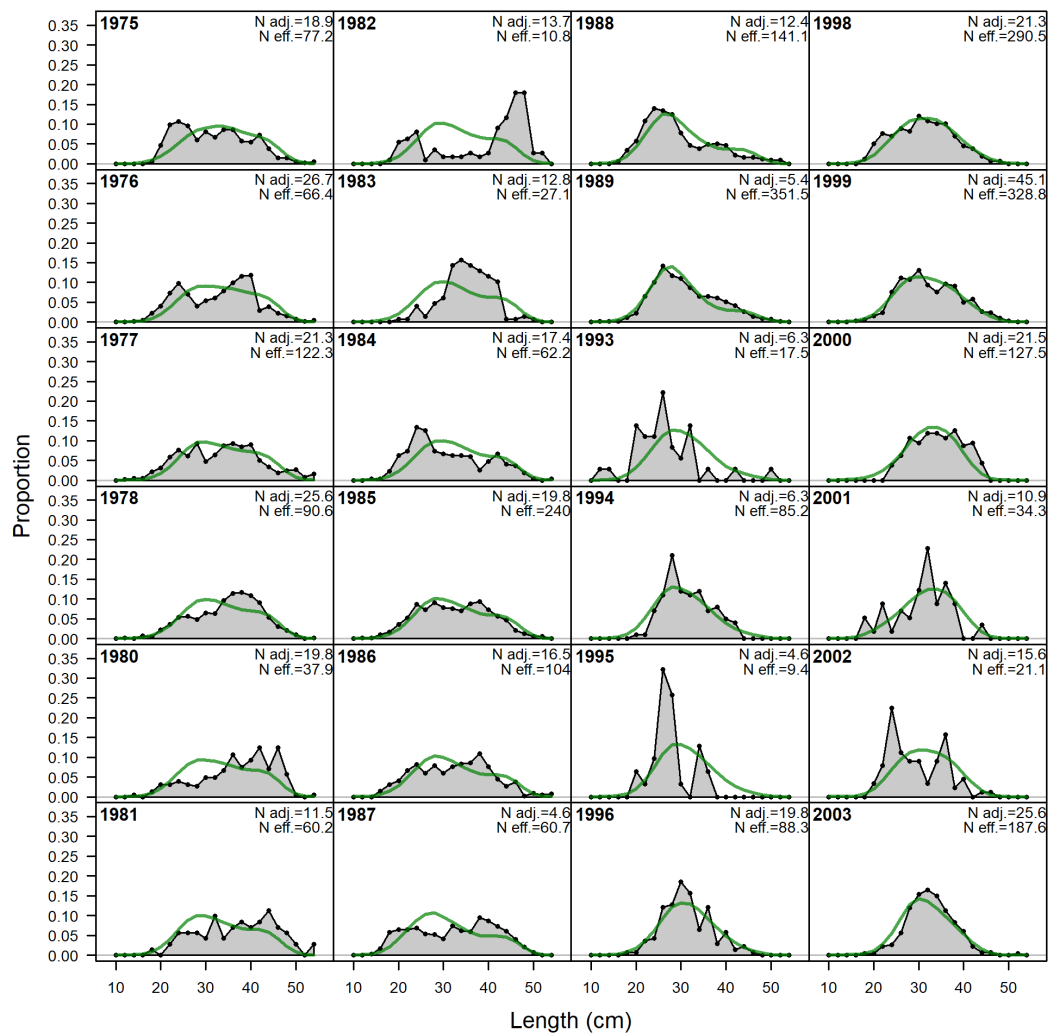
#### 9.1.1 Length Composition Data



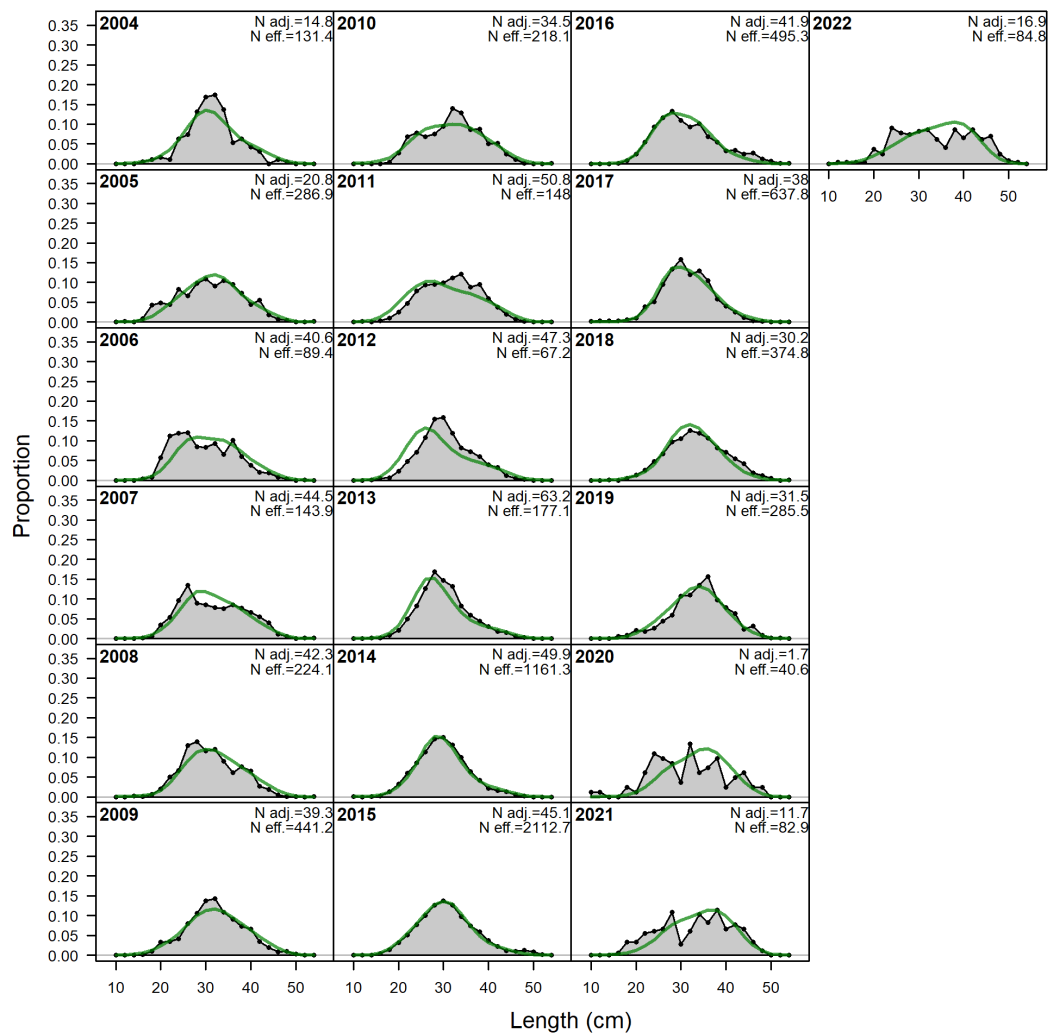
**Figure 130:** Length comps, whole catch, Commercial \_dead. 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



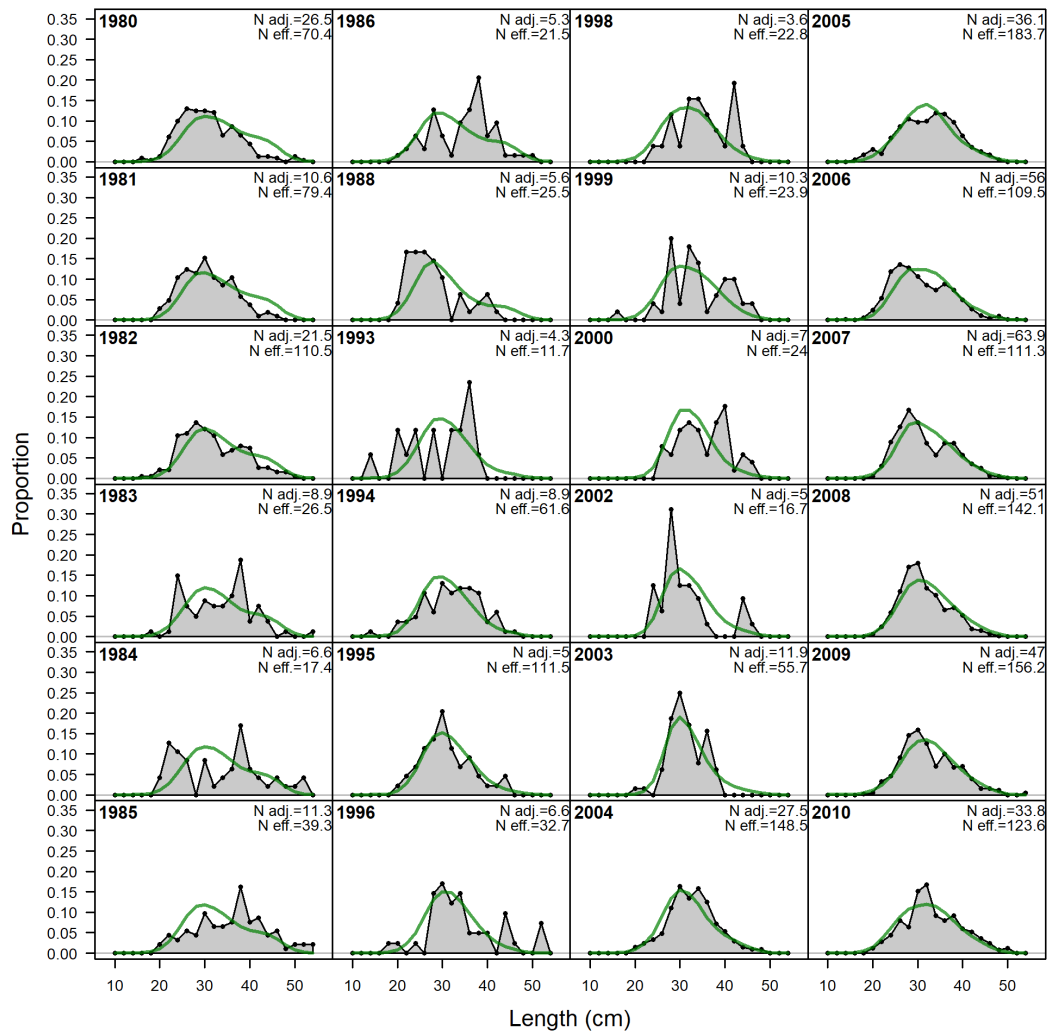
**Figure 131:** Length comps, whole catch, Commercial\_live. 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



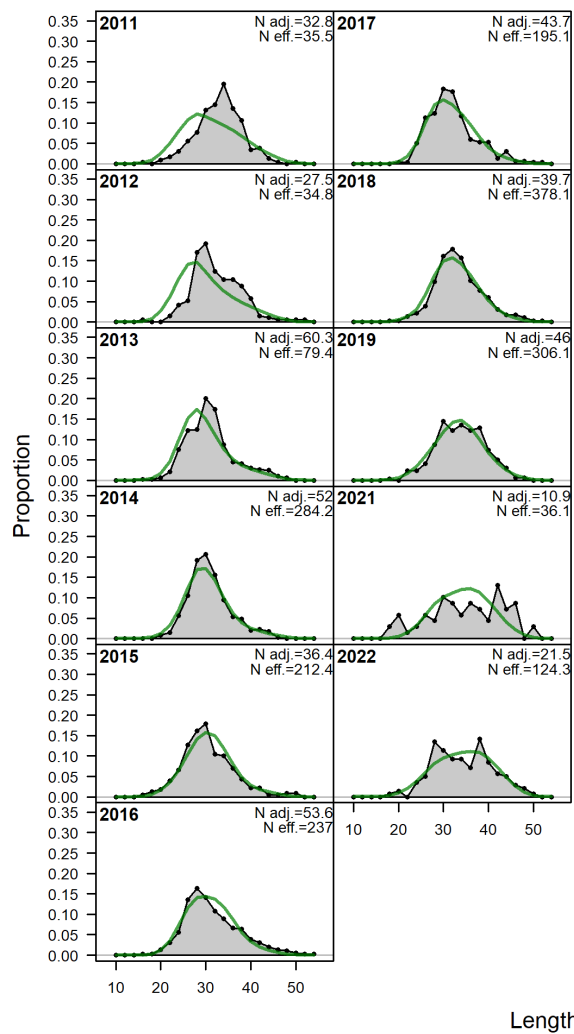
**Figure 132:** Length comps, whole catch, Rec\_CPFV (plot 1 of 2). 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



**Figure 133:** Length comps, whole catch, Rec\_CPFV (plot 1 of 2). 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method. (plot 2 of 2).

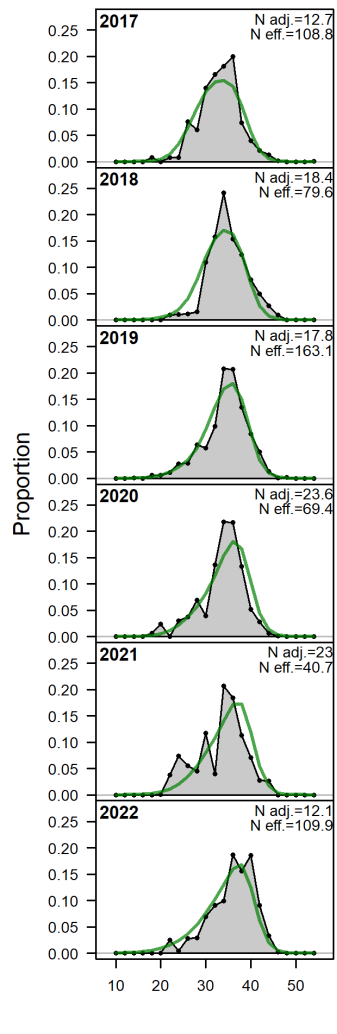


**Figure 134:** Length comps, whole catch, Rec\_Private (plot 1 of 2): 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

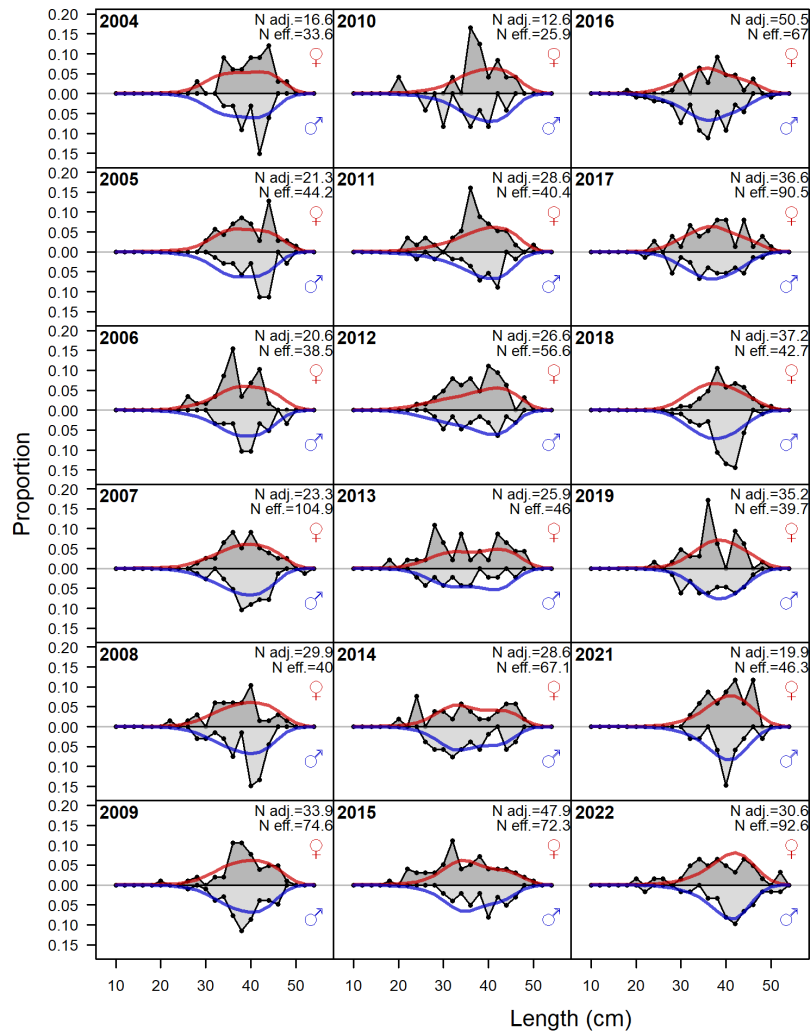


**Figure 135:** Length comps, whole catch, Rec\_Private (plot 1 of 2): 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method. (plot 2 of 2).

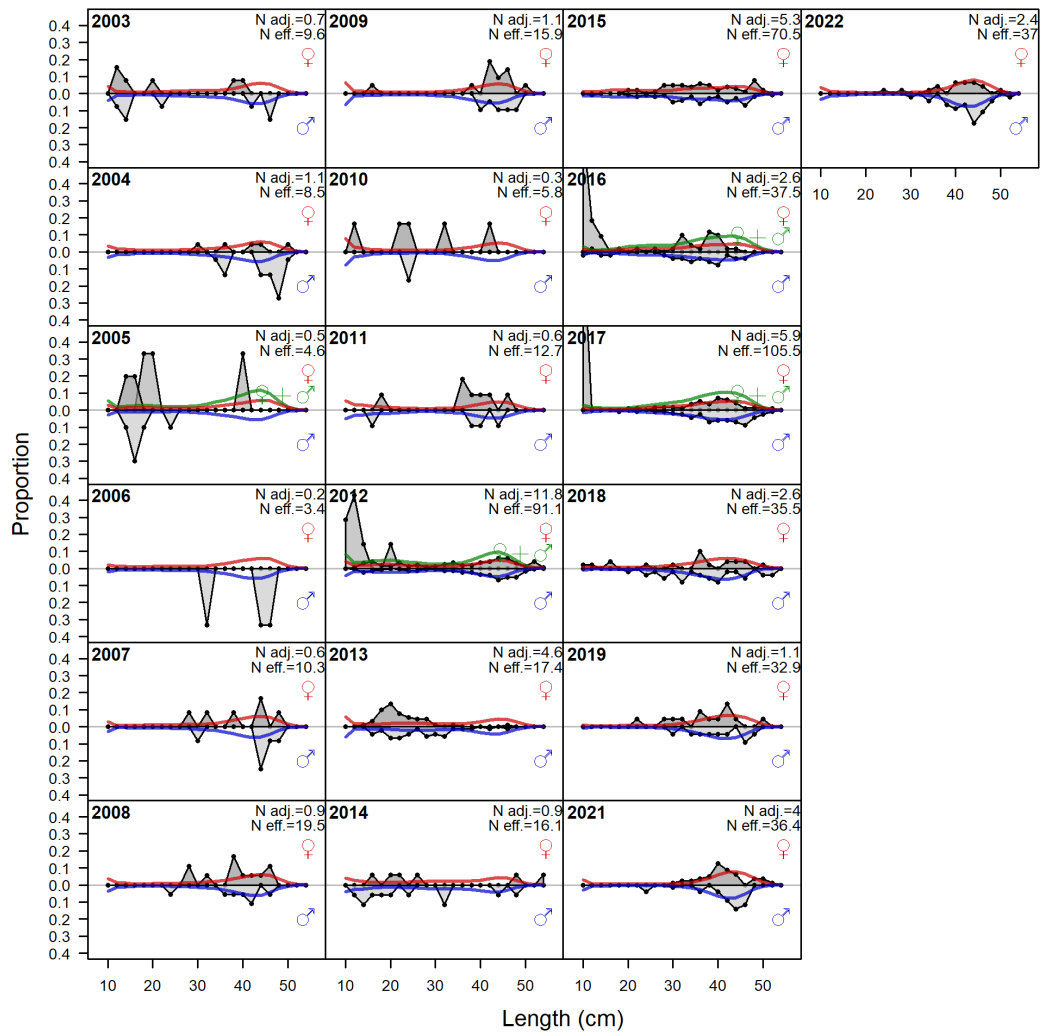




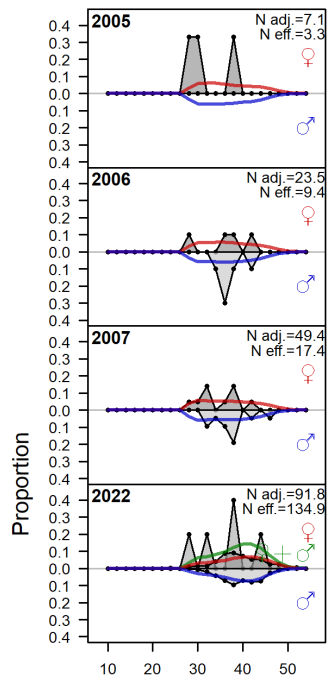
**Figure 136:** Length comps, whole catch, CCFRP: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



**Figure 137:** Length comps, whole catch, NWFSC\_HKL.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



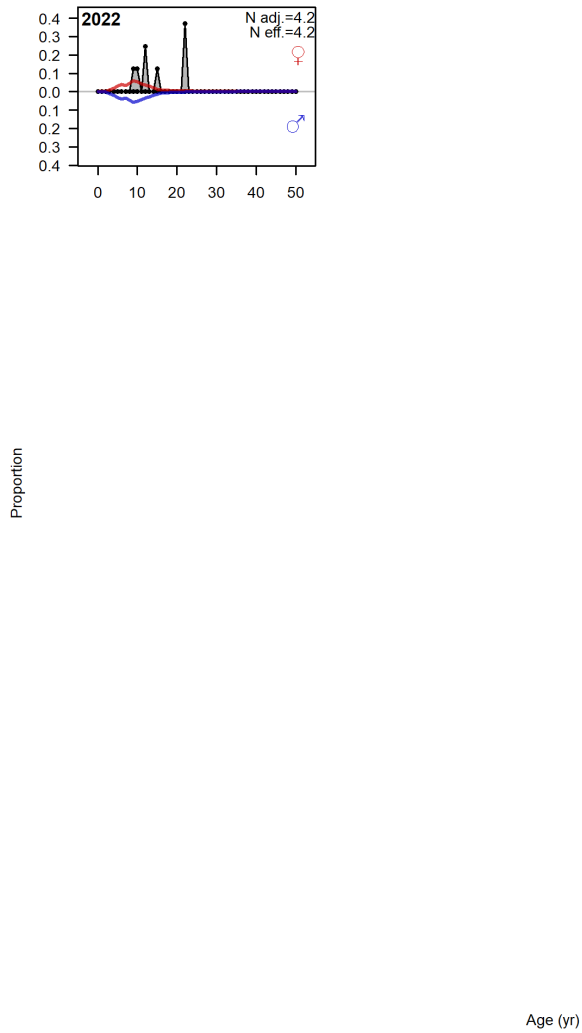
**Figure 138:** Length comps, whole catch, WCGBT\_Growth: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



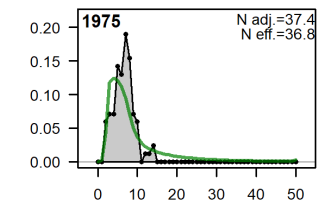
Length (cm)

**Figure 139:** Length comps, whole catch, COOP\_Growth. 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

### 9.1.2 Age Composition Data

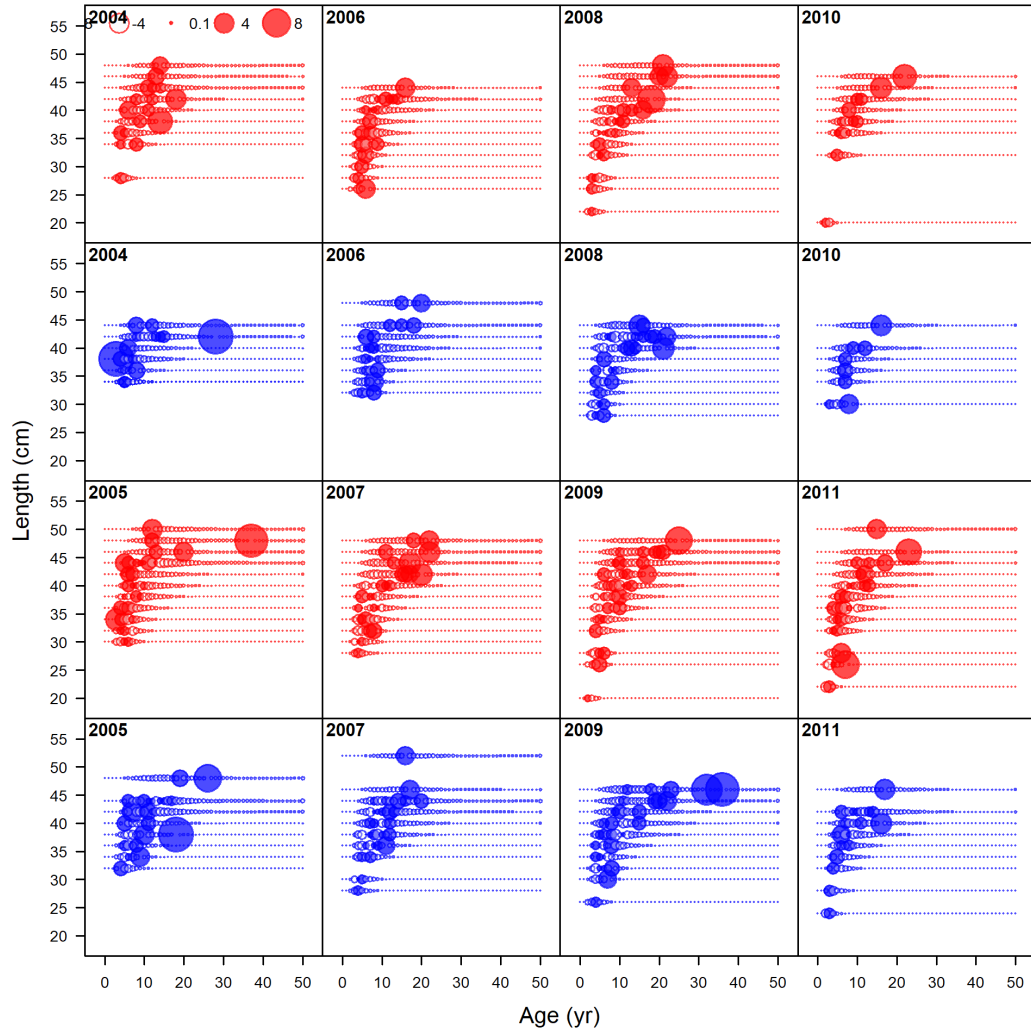


**Figure 140:** Age comps, whole catch, Commercial\_dead: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

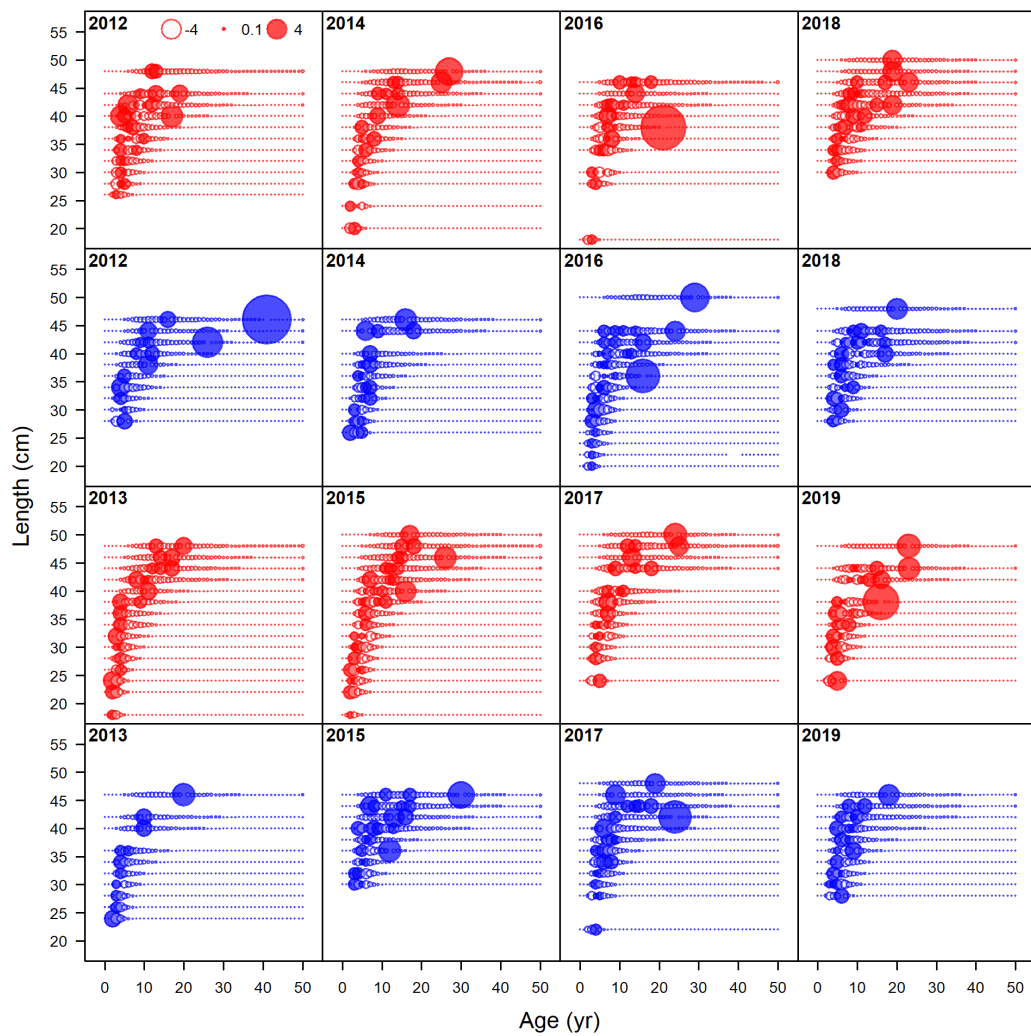


**Figure 141:** Age comps, whole catch, Rec\_CPFV: 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

### 9.1.3 Conditional-Age-at-Length Composition Data

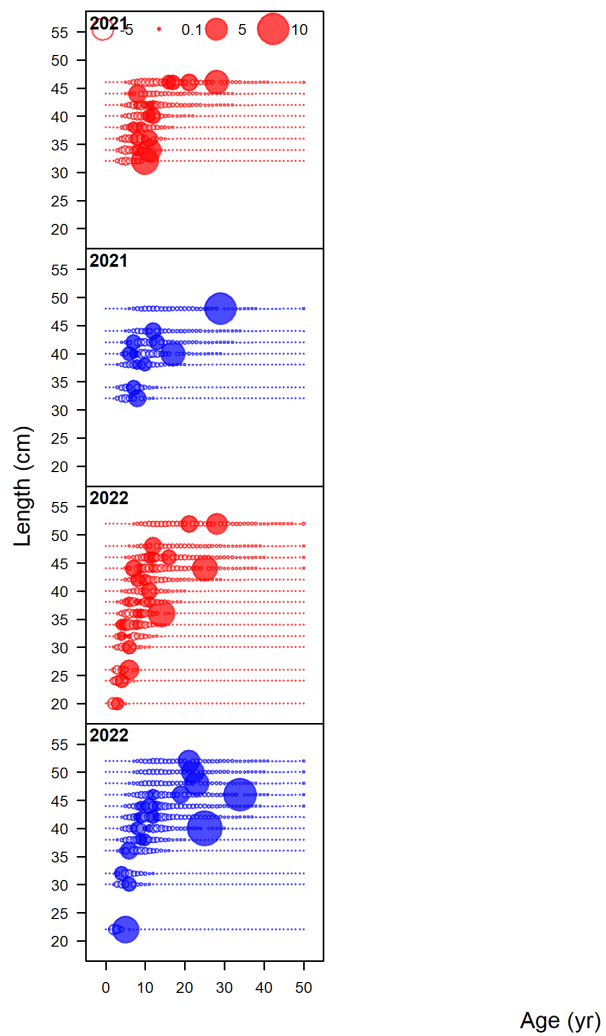


**Figure 142:** Pearson residuals, whole catch, NWFSC\_HKL (max=24.41) (plot 1 of 3).

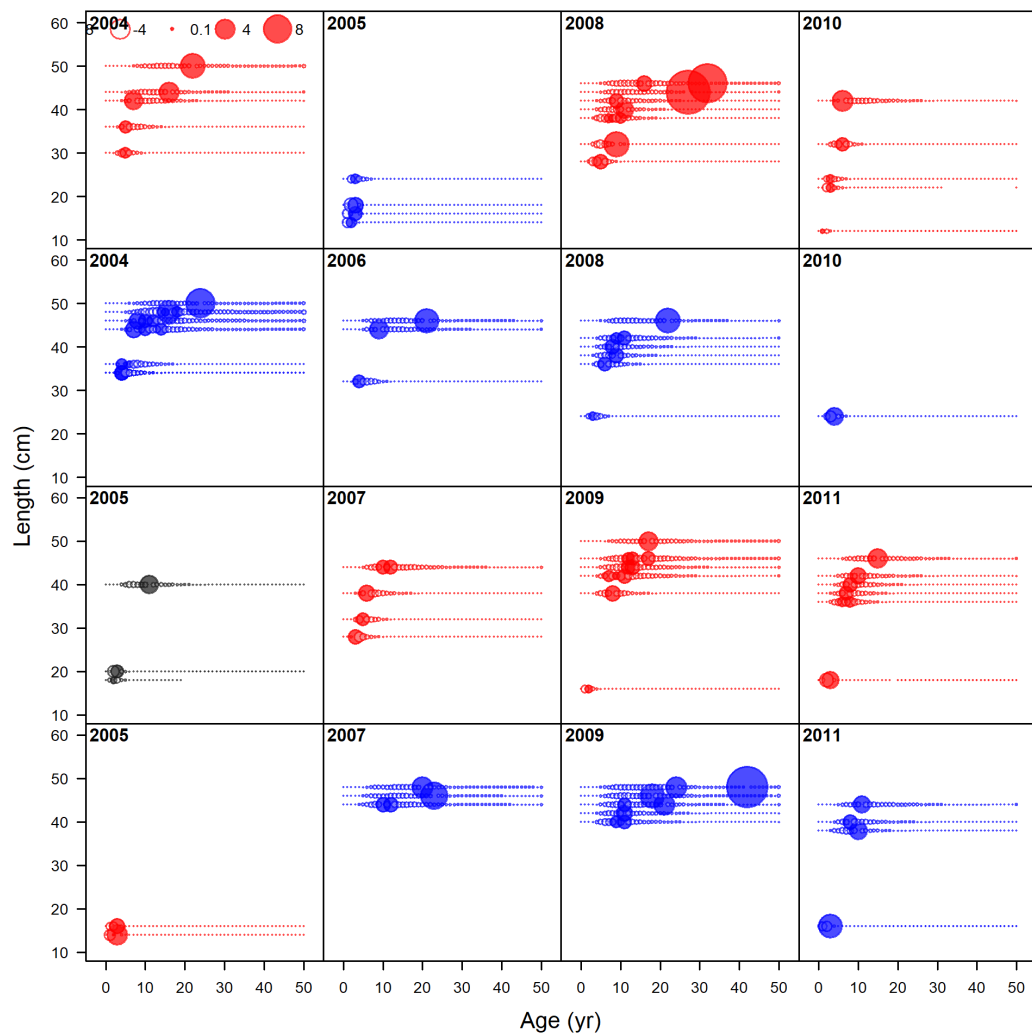


**Figure 143:** Pearson residuals, whole catch, NWFSC\_HKL (max=24.41) (plot 2 of 3).

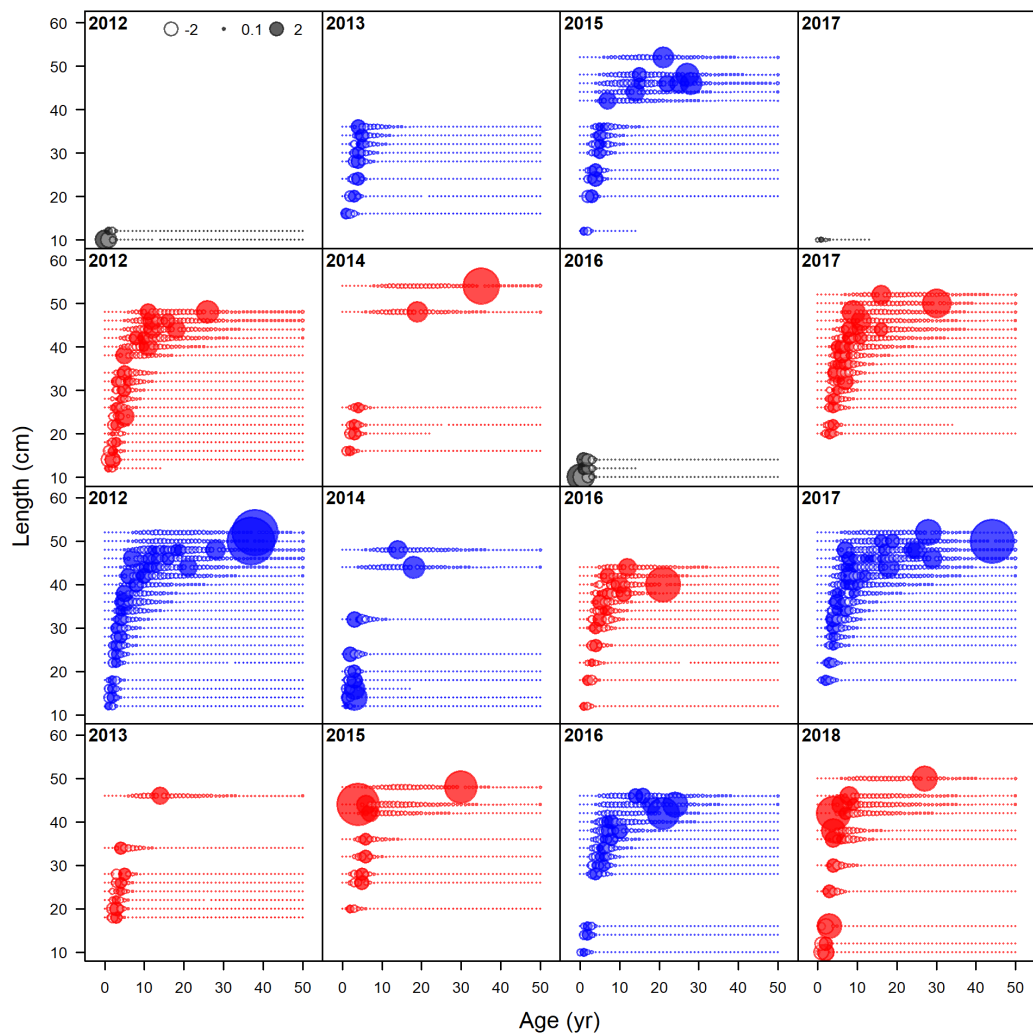




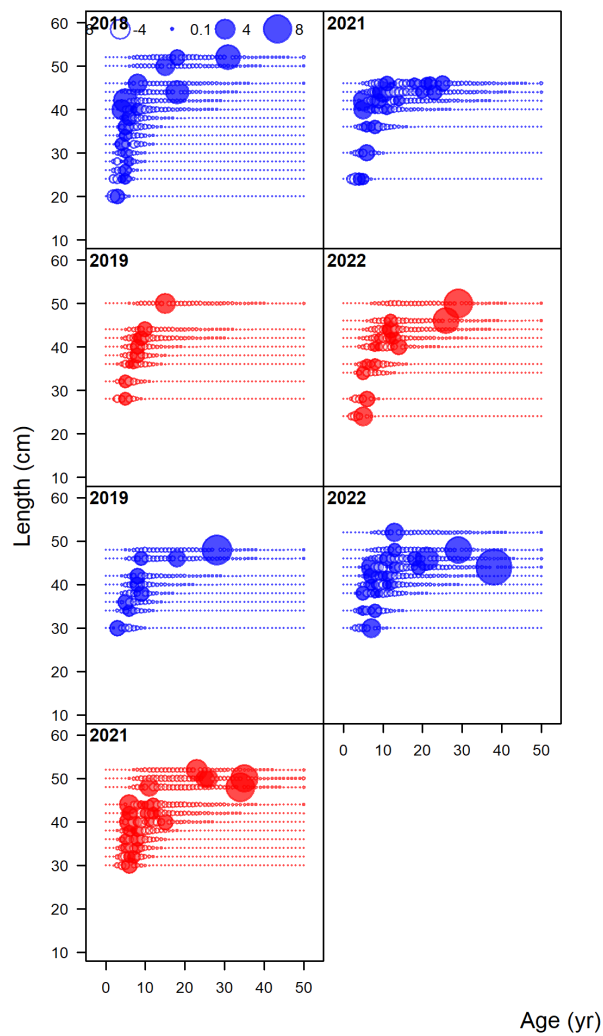
**Figure 144:** Pearson residuals, whole catch, NWFSC\_HKL (max=24.41) (plot 3 of 3).



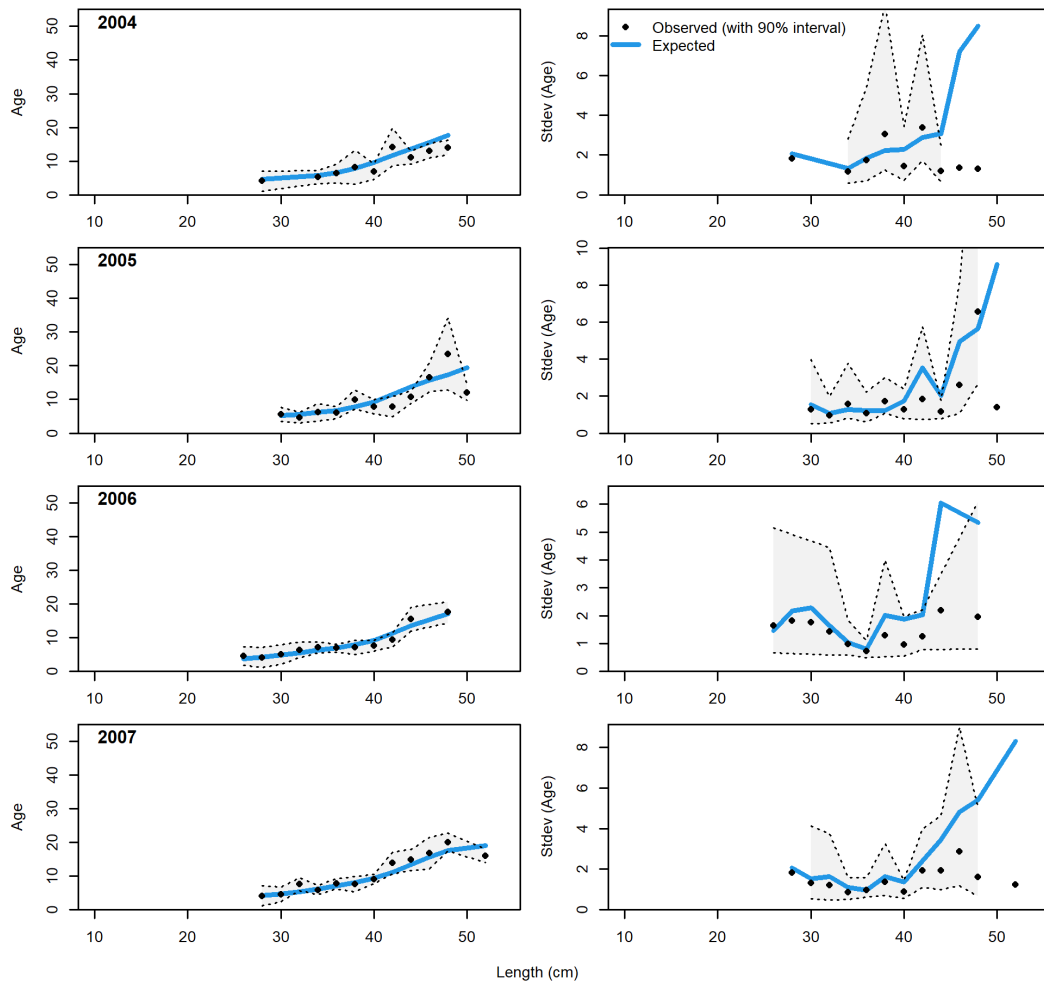
**Figure 145:** Pearson residuals, whole catch, WGBT\_Growth (max=22.95) (plot 1 of 4).



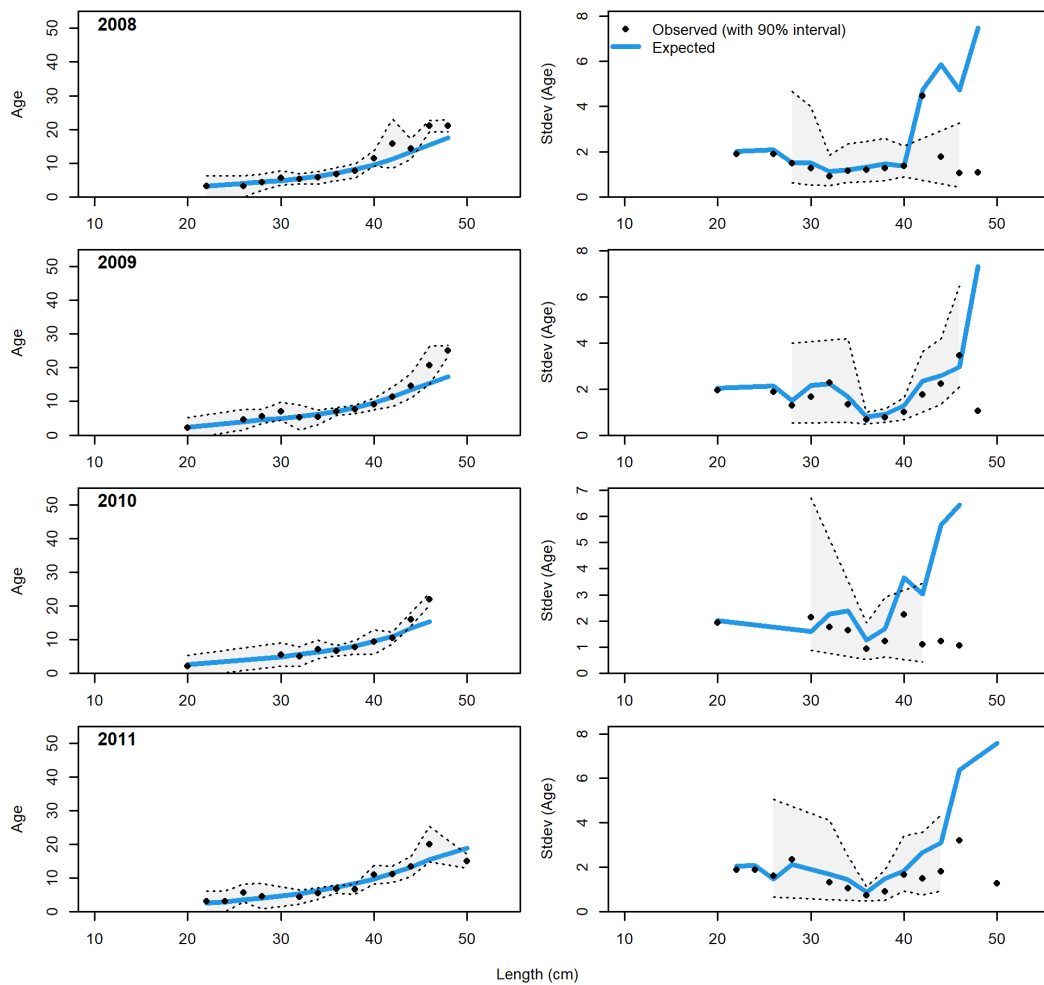
**Figure 146:** Pearson residuals, whole catch, WCGBT\_Growth (max=22.95) (plot 2 of 4).



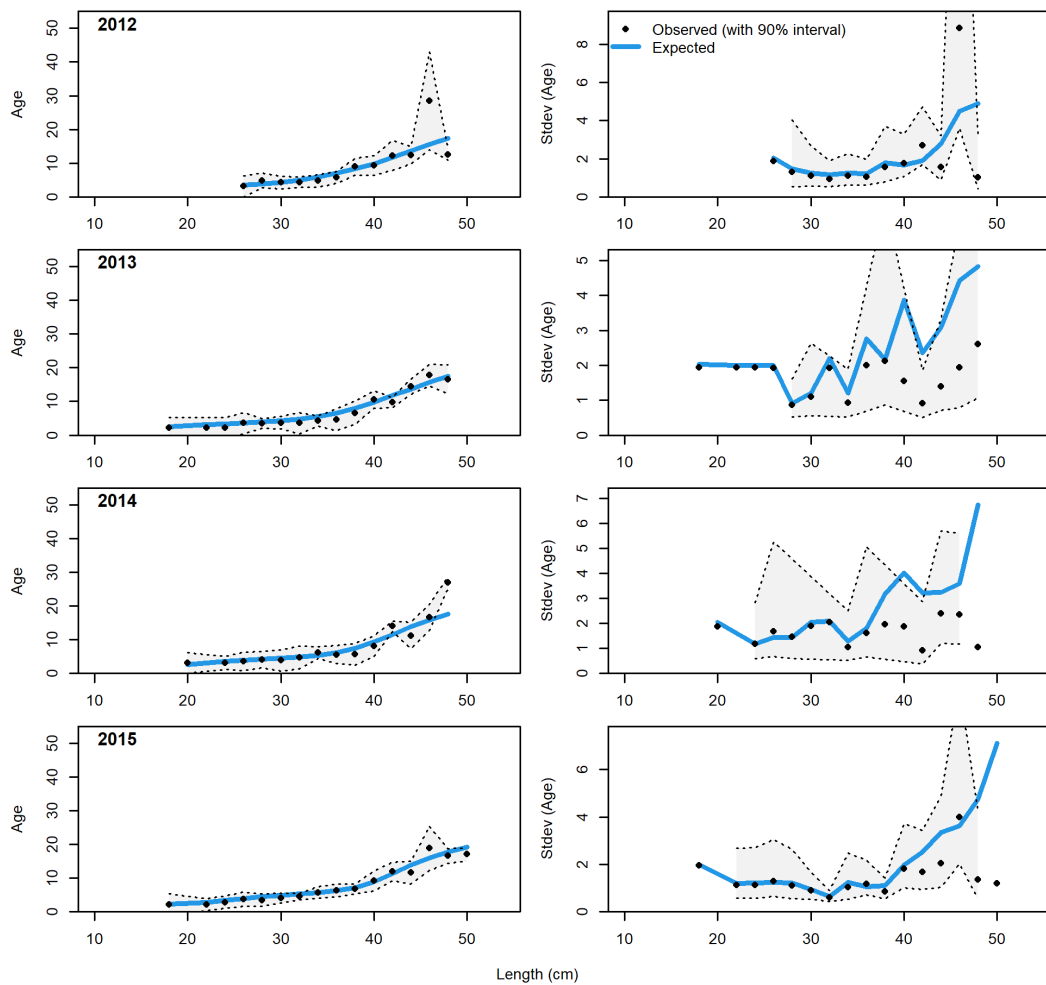
**Figure 147:** Pearson residuals, whole catch, WCGBT\_Growth (max=22.95) (plot 3 of 4).



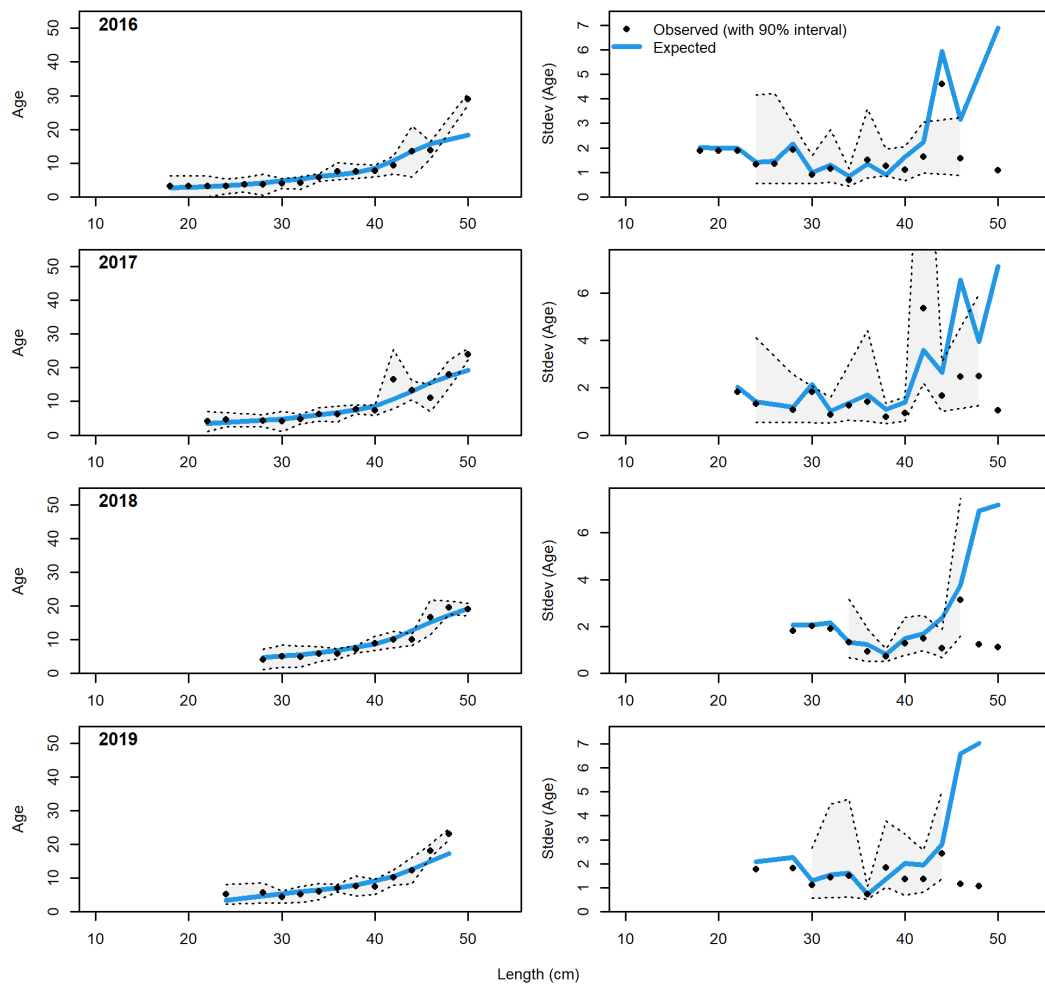
**Figure 148:** Conditional AAL plot, whole catch, NWFSC\_HKL (plot 1 of 5) These plots show mean age and std. dev. in conditional A@L. Left plots are mean A@L by size-class (obs. and exp.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean A@L (obs. and exp.) with 90% CIs based on the chi-square distribution.



**Figure 149:** Conditional AAL plot, whole catch, NWFSC\_HKL (plot 2 of 5).

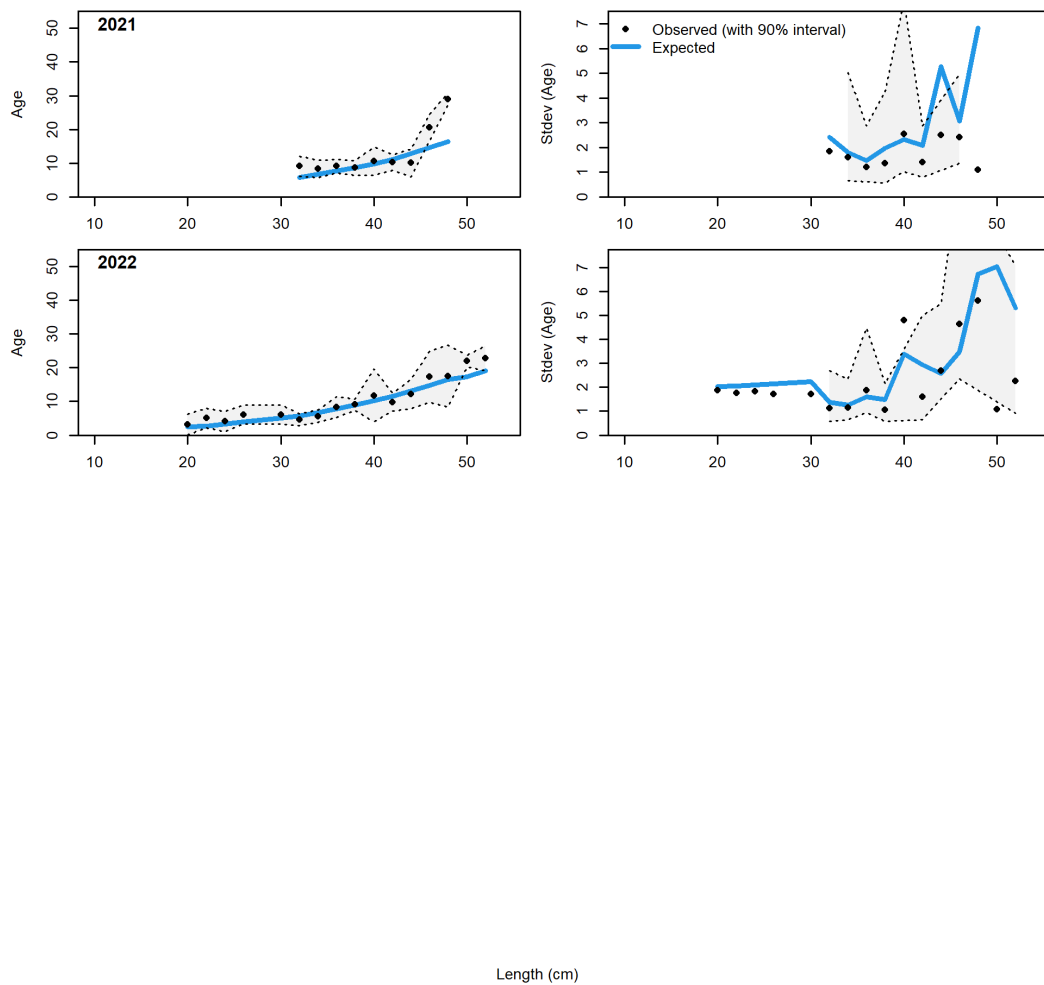


**Figure 150:** Conditional AAL plot, whole catch, NWFSC\_HKL (plot 3 of 5).

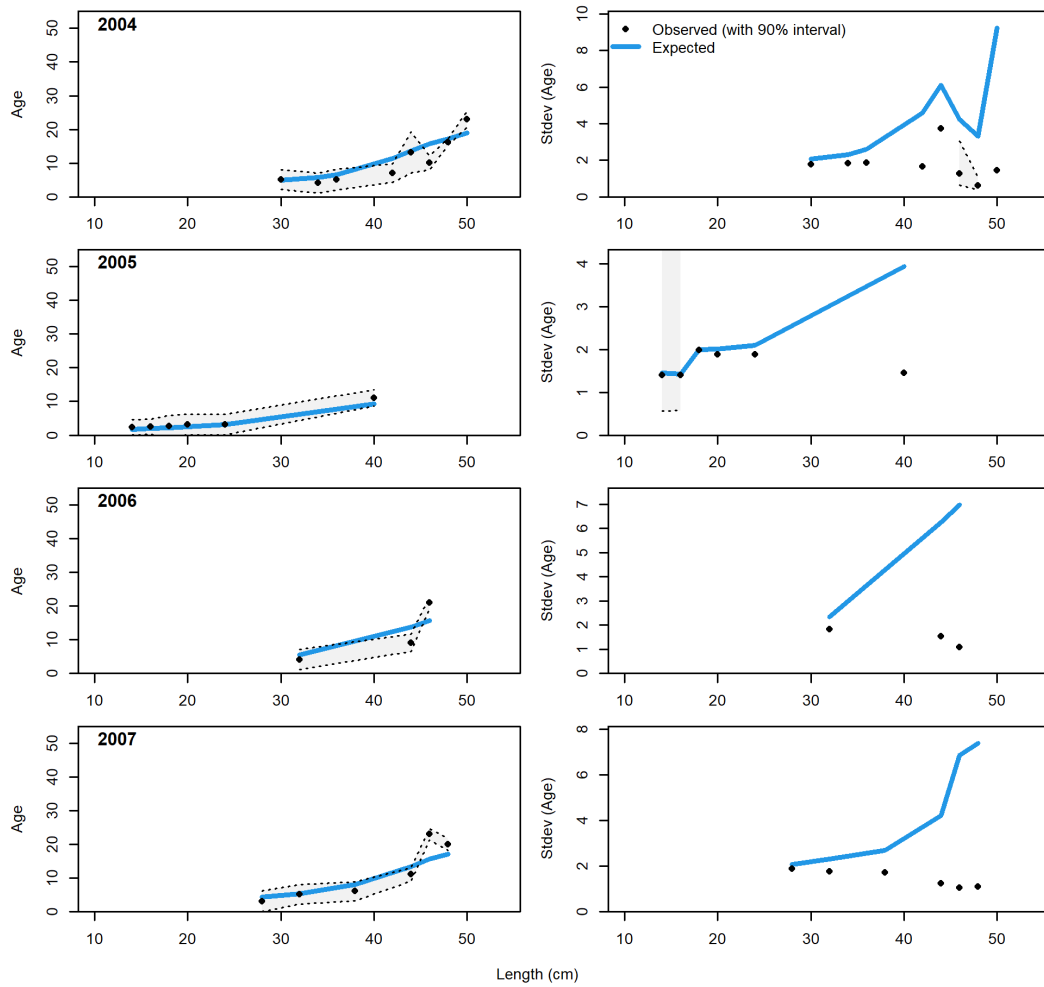


**Figure 151:** Conditional AAL plot, whole catch, NWFSC\_HKL (plot 4 of 5).

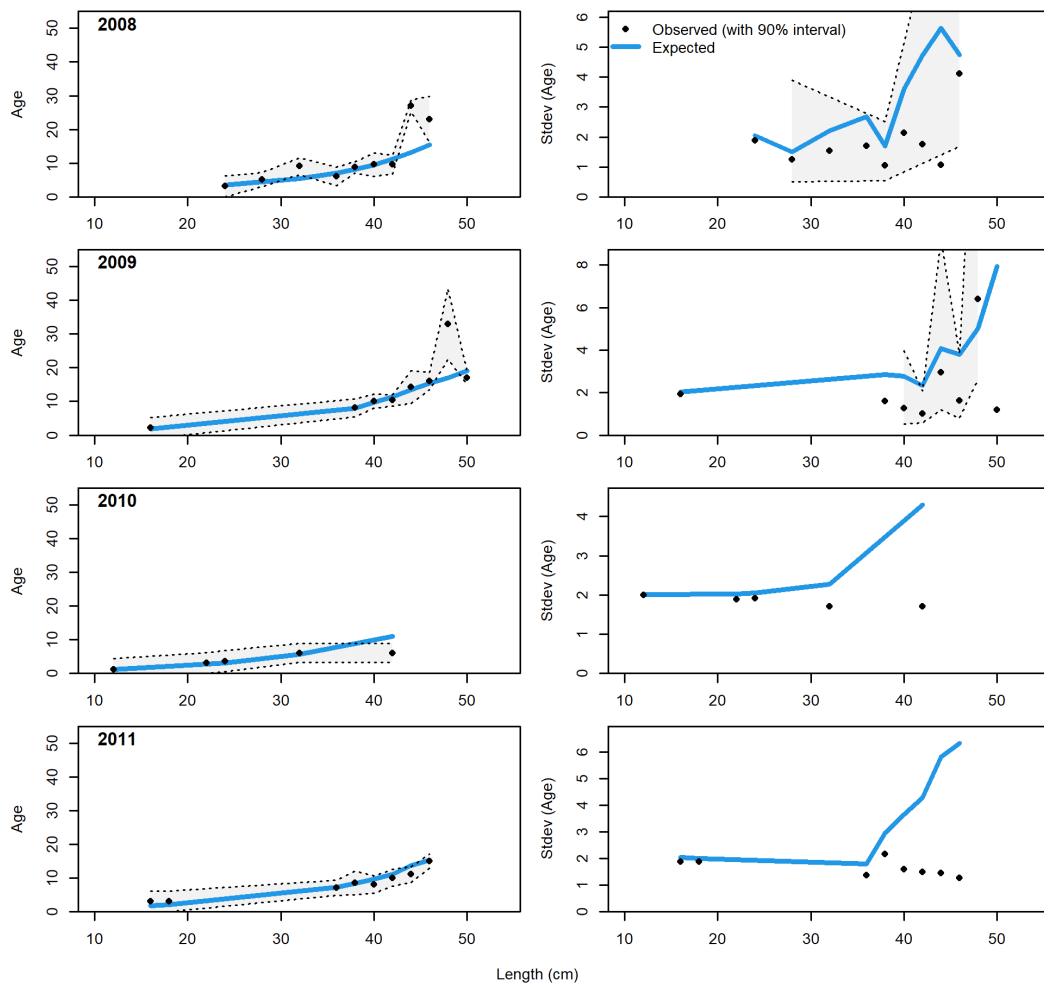




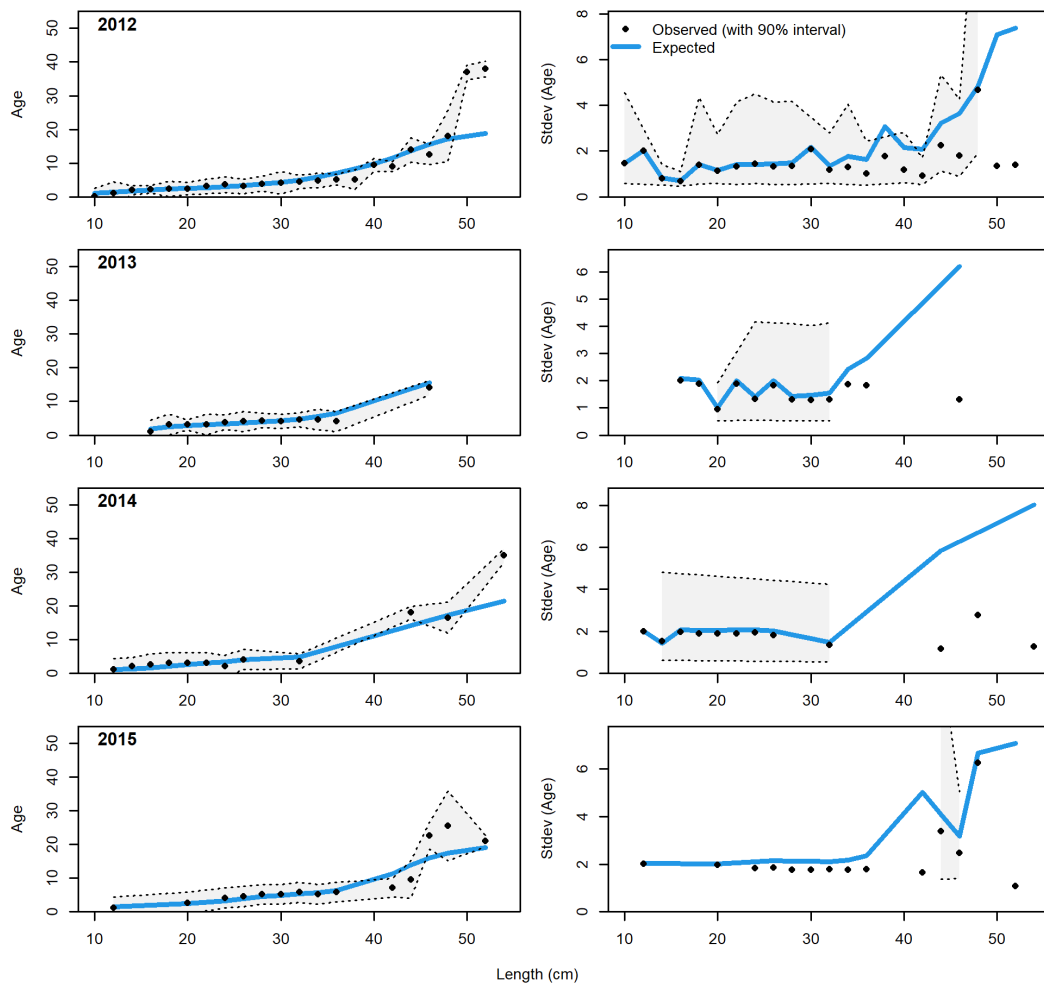
**Figure 152:** Conditional AAL plot, whole catch, NWFSC\_HKL (plot 5 of 5).



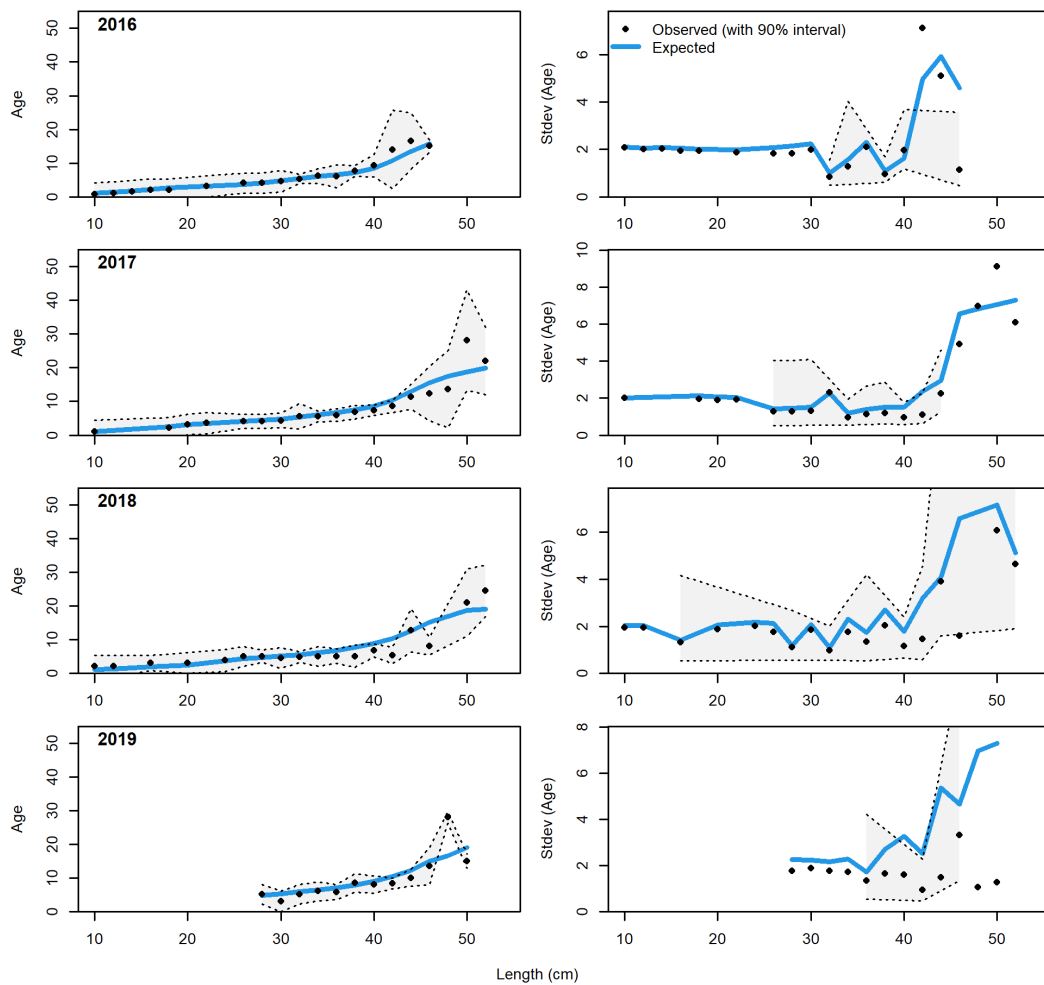
**Figure 153:** Conditional AAL plot, whole catch, WCGBT\_Growth (plot 1 of 5) These plots show mean age and std. dev. in conditional A@L. Left plots are mean A@L by size-class (obs. and exp.) with 90% CIs based on adding 1.64 SE of mean to the data. Right plots in each pair are SE of mean A@L (obs. and exp.) with 90% CIs based on the chi-square distribution.



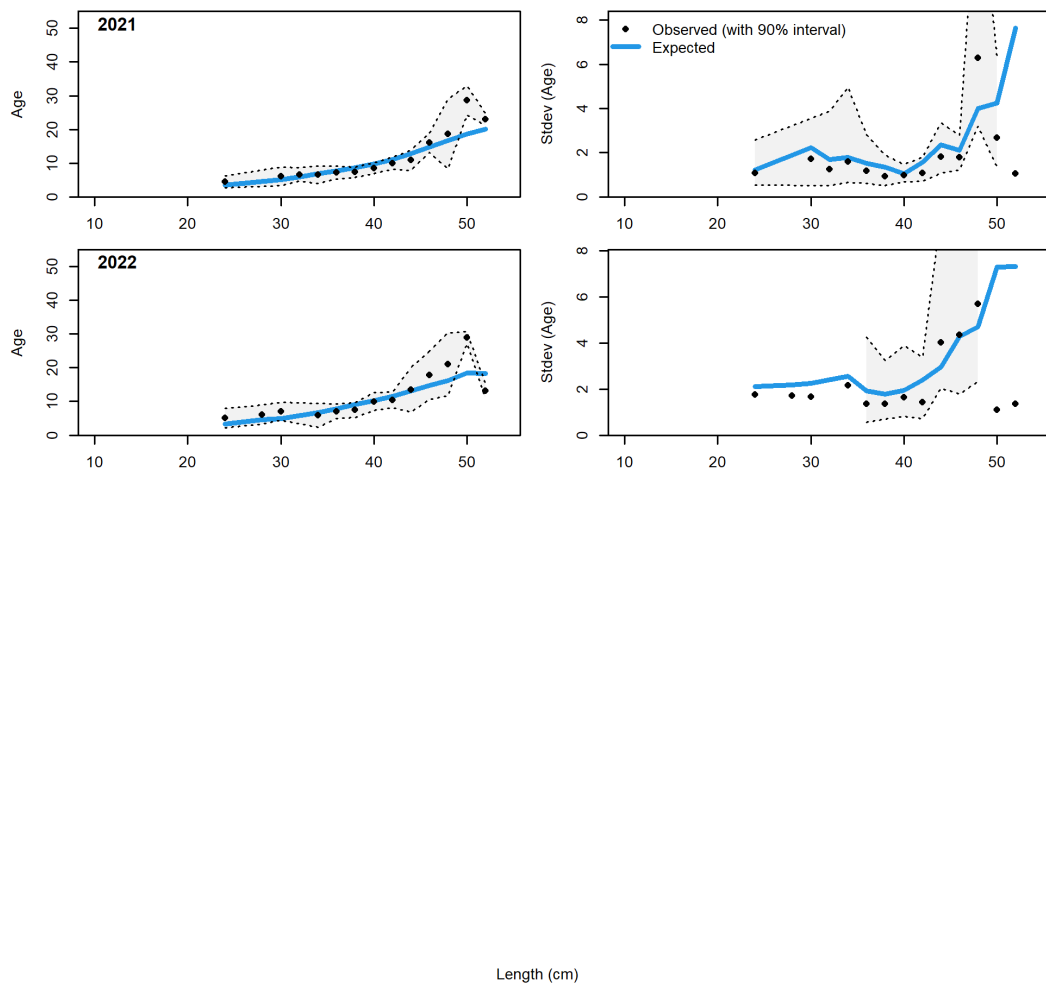
**Figure 154:** Conditional AAL plot, whole catch, WCGBT\_Growth (plot 2 of 5).



**Figure 155:** Conditional AAL plot, whole catch, WCGBT\_Growth (plot 3 of 5).



**Figure 156:** Conditional AAL plot, whole catch, WCGBT\_Growth (plot 4 of 5).

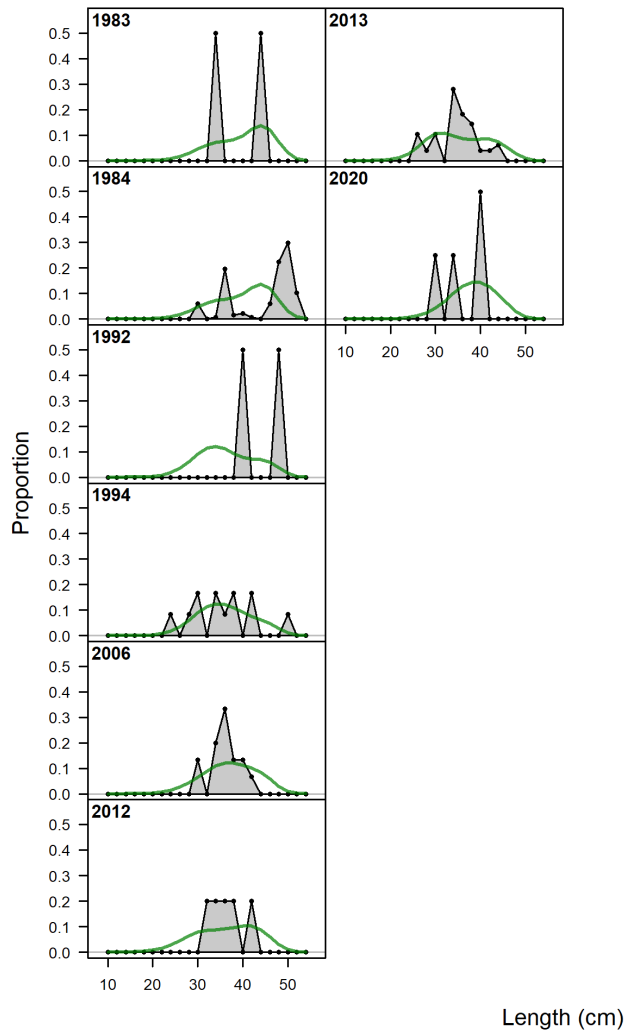


**Figure 157:** Conditional AAL plot, whole catch, WCGBT\_Growth (plot 5 of 5).

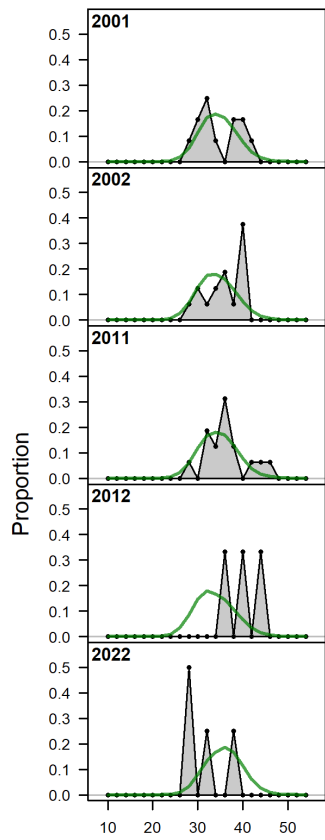
## 9.2 Implied Fits to Excluded Data

### 9.2.1 Length Data

The implied fits to the data not included in the base model due to low annual sample size are shown below.



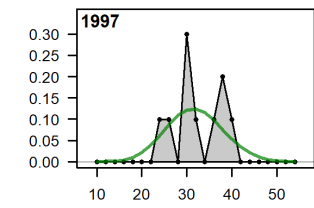
**Figure 158:** Excluded length comps, whole catch, Commercial\_dead:'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



Length (cm)

**Figure 159:** Excluded length comps, whole catch, Commercial\_live.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

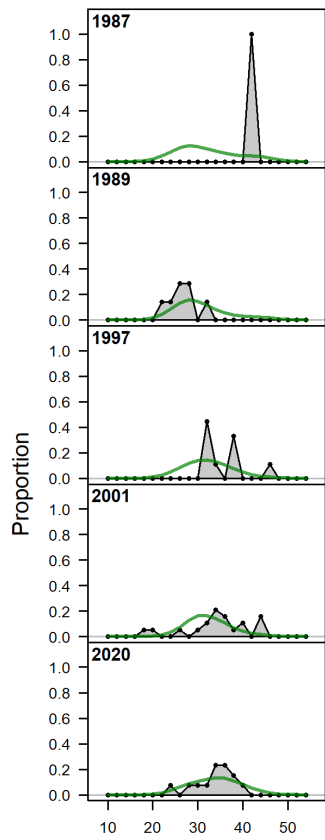




Proportion

Length (cm)

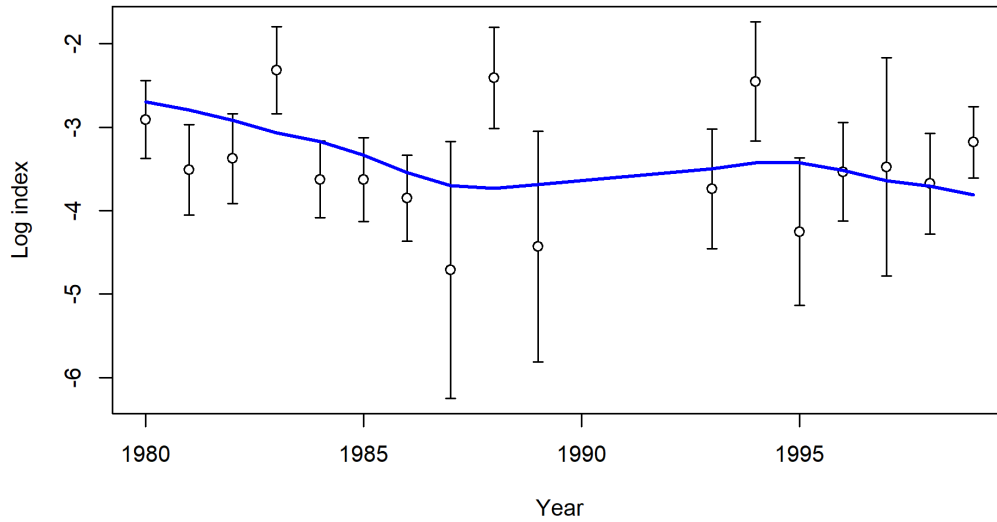
**Figure 160:** Excluded length comps, whole catch, Rec\_CPFV:'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.



Length (cm)

**Figure 161:** Excluded length comps, whole catch, Rec\_Private.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Ianelli tuning method.

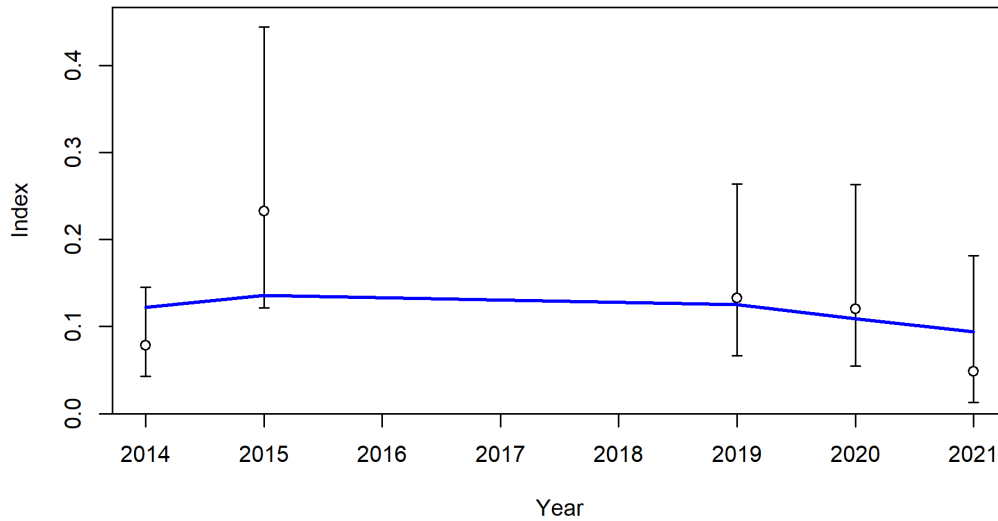
### 9.2.2 MRFSS CPFV Fishery-Dependent Indices of Abundance



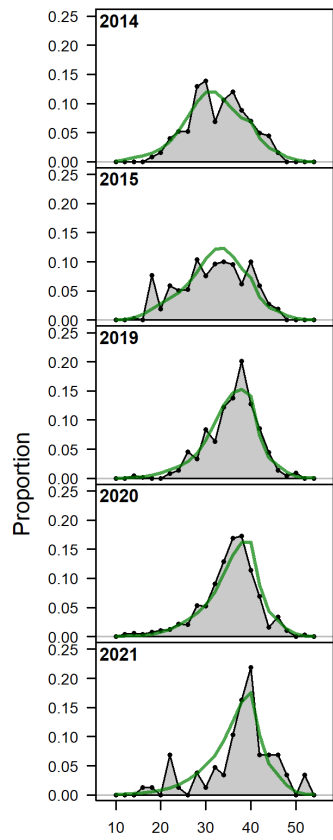
**Figure 162:** Implied fit to log index data on log scale for the recreational (MRFSS) CPFV index of abundance. Lines indicate 95% uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines (if present) indicate input uncertainty before addition of estimated additional uncertainty parameter.

### 9.2.3 CDFW ROV Survey

Data from the CDFW ROV survey were not included in the base model. A sensitivity to the inclusion of these data were included in the Sensitivities Section 3.4.2. The estimated index of abundance from the uncorrected data (see Section 2.3.5 for additional information) is shown below with a plot of the length composition data by year south of Point Conception.



**Figure 163:** The estimated weighted relative index of abundance for the CDFW ROV survey and the implied fit to the index from the model.

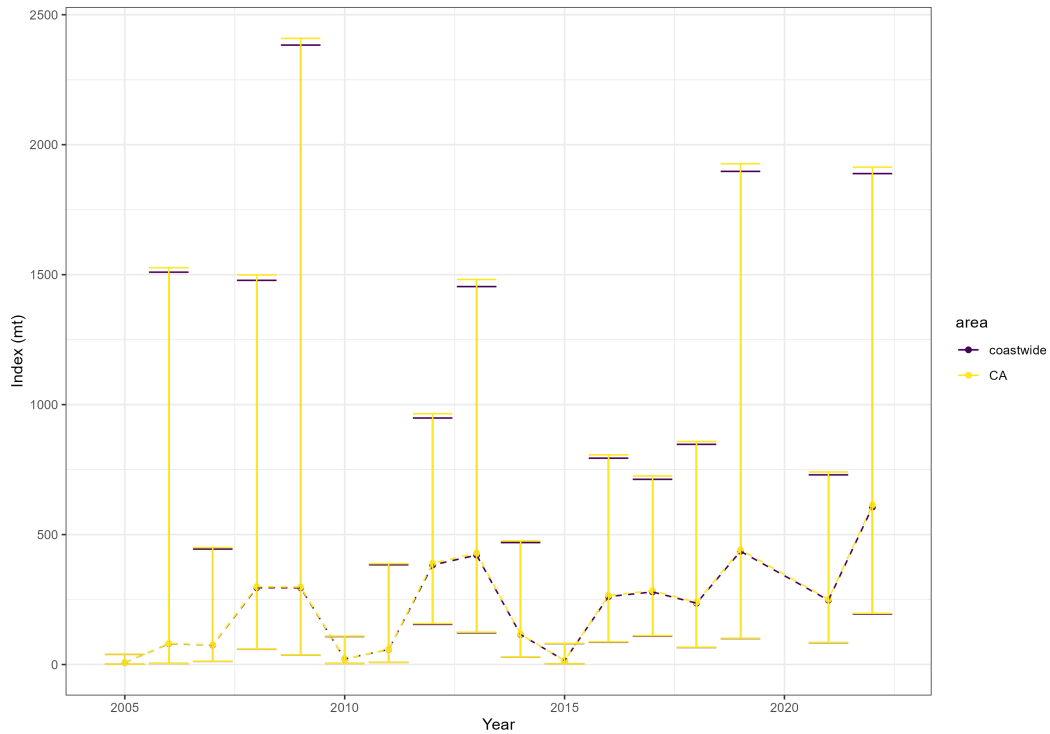


Length (cm)

**Figure 164:** Annual length composition data from the CDFW ROV survey south of Point Conception and the implied model fit given a fixed selectivity curve.

### 9.2.4 NWFSC WCGBT Survey Index of Abundance

Data from the NWFSC WCGBT survey were not used in the base model to develop an index of abundance. A sensitivity to the base model explored including the estimated index of abundance shown below



**Figure 165:** Estimated index of abundance based on NWFSC WCGBT survey data starting in 2005 and limiting to observations between 55-110 m where CA is the area south of Point Conception and coastwide is all data within California.

## 9.3 Development of Indices of Abundance

### 9.3.1 California Onboard CPFV Index of Abundance

The state of California implemented a statewide onboard observer sampling program in 1999 (Monk et al. 2014). California Polytechnic State University (Cal Poly) has conducted an independent onboard sampling program as of 2003 for boats in Port San Luis and Morro Bay, and follows the protocols established in Reilly et al. (1998). During an onboard observer trip the sampler rides along on the CPFV and records location-specific catch and discard information to the species level for a subset of anglers onboard the vessel. The subset of observed anglers is usually a maximum of 15 people and the observed anglers change during each fishing stop.

The catch cannot be linked to an individual, but rather to a specific fishing location. The sampler also records the starting and ending time, number of anglers observed, starting and ending depth, and measures discarded fish. The fine-scale catch and effort data allow us to better filter the data for indices to fishing stops within suitable habitat for copper rockfish. Cal Poly has modified protocols to reflect sampling changes that CDFW has also adopted, e.g., observing fish as they are encountered instead of at the level of a fisher's bag. Therefore, the Cal Poly data are incorporated in the same index as the CDFW data. The only difference is that Cal Poly measures the length of both retained and discarded fish.

We applied a number of data filters to the available data presented in Table 35. The onboard CPFV index restricts the time series to 2005-2019. The onboard observer survey began in 1999, but the sample sizes were small during the first year of the program. The years 1999-2004 also represent years where a number of regulations changed including gear limits, bag limits, and spatial closures. Due to COVID-19, no onboard sampling took place in 2020. In 2021, the onboard sampling resumed in August, at which point a large portion of the southern California fleet had switched target species to fish highly migratory species. The 2021 stock assessment for copper rockfish had also been released by August 2021 indicating the portion of the population south of Point Conception was depleted, estimated to be below the management threshold of 25 percent of unfished. The southern California CPFV fleet began an organized effort to avoid copper rockfish and encourage their clientele to release and descend copper rockfish when encountered. In 2022, the CDFW implemented the one copper rockfish sub-bag limit and combined with avoidance by the fleet, the data in this year does not represent the available copper rockfish biomass.

The data filters also included the removal of the number of observed anglers and time fished at the tail ends of the distributions, and removal of drifts occurring in depths outside the expected range of copper rockfish (Table 35 and Figure 167). The availability of high resolution data were lacking for the area south of Point Conception, hence, we retained all drifts from within a CDFW block that had at least 100 drifts and at least 5 percent of those encountered copper rockfish. A total of 17,605 drifts were retained for index standardization with 3,035 of those drifts encountered copper rockfish (Table 34).

In the assessment model, the recreational CPFV fleet is modeled as retained plus discarded fish. The proportion of observed discarded copper rockfish is small, averaging 4 percent over the time series (Table 32) and are included in the index. We modeled catch per angler minutes fished (CPUE) by fishing drift. Prior to any modeling, the SWFSC QA/QC'd the data to ensure the location information was correct. Each drift was overlaid in ArcPro with the available interpreted substrate layer that characterizes rocky and hard substrate, assigned to a rocky reef and the distance of the drift start location calculated. In addition, the depth of the start location was interpreted from the 2 m resolution bathymetry as well as 90 m resolution bathymetry layer for comparison. For drifts missing depth location, we assigned depth based on the best available depth based on the bathymetry.

To appropriately weight the onboard observer survey index by the available rocky substrate within a region, each drift was assigned to the closest area of rocky habitat. Hard bottom was extracted from the California Seafloor Mapping Project, along the mainland coast of southern California. These data were collected in state waters at a resolution of two meters, but did not extend into state waters

past the mainland coast. Additional interpreted bathymetric data classifying the bottom type as rock or soft bottom were compiled by analysts at the University of California Santa Cruz and are now also available from CDFW's website. We used the available interpreted rocky substrate data to expand the known area of rocky substrate to areas in southern California that lack substrate type. This expansion of the estimated rocky substrate assumes that the proportions of rocky substrate within and outside state waters are similar. Copper rockfish are a nearshore species and the majority of observed encounters were within state waters (Table 33). This is, of course, an estimation of the amount of rocky substrate, and represents the best available data. The calculations can be found in the online supplementary material.

The covariates explored for model selection included year and four categorical region levels (District 1 mainland, District 2 mainland, Southern Channel Islands and Northern Channel Islands), a year and area interaction, a categorical variable for month, and continuous depth and depth-squared. Trends in the average CPUE by region were similar in the filtered data set (Figure 168). A year and region interaction was included after visualizing the trends in average CPUE over time. The full model was selected by AICc (Table 36). In southern California, whether a trip is a half-day or three-quarter-day or overnight trip has a significant impact on the available fishing grounds. The half-day CPFV vessels fish in the shallower, nearshore waters along the along the mainland coast. The three-quarter and overnight or multi-day vessels are able to access the same areas of the Northern Channel Islands, where as the southern Channel Islands are further offshore and the observations are predominantly from overnight trips. The overnight and multi-day trips may target multiple target species, i.e., tuna and rockfish, depending on the time of the year.

Indices were fit via MLE from the sdmTMB package in R. The Q-Q plot for the negative binomial model indicated a poor fit to the data, which as not surprising given the low percent of observed drifts encountering copper rockfish. A delta-lognormal error distribution was selected over a delta-gamma based on AIC. The Q-Q plot indicated a much improved fit compared to the negative binomial model (Table 170).

The final index was weighted based on the estimates of rocky substrate within each of the four regions. The relative abundance increases during the first part of the time series (Table 37 and Figure 169).



**Table 32:** Number of observed copper rockfish retained and discarded by year.

Year	Number Kept	Number Discarded	Proportion discarded
1999	188	2	1.1%
2000	87	1	1.1%
2001	20	2	9.1%
2002	57	14	19.7%
2003	109	8	6.8%
2004	142	6	4.1%
2005	231	20	8.0%
2006	277	51	15.5%
2007	387	38	8.9%
2008	388	21	5.1%
2009	347	21	5.7%
2010	409	7	1.7%
2011	566	18	3.1%
2012	865	69	7.4%
2013	1227	159	11.5%
2014	652	52	7.4%
2015	716	40	5.3%
2016	742	33	4.3%
2017	598	19	3.1%
2018	575	19	3.2%
2019	449	17	3.6%

**Table 33:** Number of observed drifts inside and outside of state waters.

District	Year	Inside State Waters	Outside State Waters	Percent Inside
1	2005	19	8	70.40%
1	2006	52	27	65.80%
1	2007	62	27	69.70%
1	2008	55	29	65.50%
1	2009	59	15	79.70%
1	2010	38	21	64.40%
1	2011	57	40	58.80%
1	2012	68	32	68.00%
1	2013	112	59	65.50%
1	2014	80	43	65.00%
1	2015	84	33	71.80%
1	2016	113	48	70.20%
1	2017	75	41	64.70%
1	2018	56	26	68.30%
1	2019	39	28	58.20%
2	2005	39	18	68.40%
2	2006	56	1	98.20%
2	2007	86	21	80.40%
2	2008	96	4	96.00%
2	2009	68	5	93.20%
2	2010	68	1	98.60%
2	2011	138	14	90.80%
2	2012	266	31	89.60%
2	2013	328	18	94.80%
2	2014	192	24	88.90%
2	2015	140	72	66.00%
2	2016	143	26	84.60%
2	2017	125	13	90.60%
2	2018	150	53	73.90%
2	2019	92	30	75.40%

**Table 34:** Retain trips and the number of trips with target species for the onboard CPFV survey.

Year	Trips with Target	Trips without Target	Total trips	Percent with Target
2005	79	767	846	9.3%
2006	123	994	1117	11.0%
2007	191	1144	1335	14.3%
2008	180	1422	1602	11.2%
2009	146	1501	1647	8.9%
2010	128	1439	1567	8.2%
2011	244	1527	1771	13.8%
2012	378	1537	1915	19.7%
2013	498	1805	2303	21.6%
2014	330	1480	1810	18.2%
2015	321	1530	1851	17.3%
2016	323	1525	1848	17.5%
2017	250	1427	1677	14.9%
2018	279	1219	1498	18.6%
2019	185	1247	1432	12.9%

**Table 35:** Data filtering steps for the onboard CPFV survey.

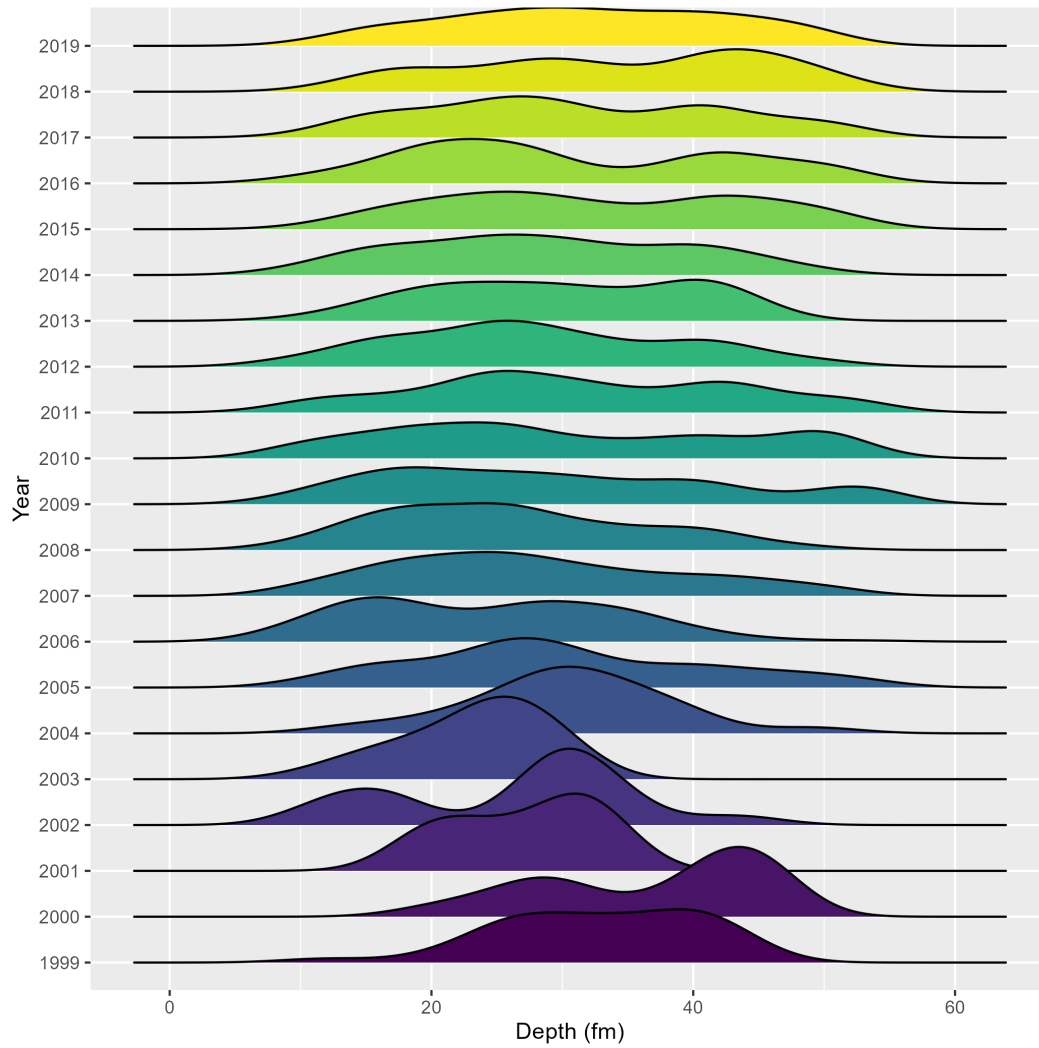
Filter	Description	Number of Samples	Positive Samples
All data	All data	56276	4861
Years	Start time series in 2005 due to sparse data	46125	4523
Errors and Missing Data	Remove drifts with missing data and identified errors	41837	4319
Area fished	Remove drifts in bays and Mexico (if applicable)	39081	4235
Months fished	Remove Jan-Feb; recreational rockfish fishery closed	35123	4112
Depth	Remove drifts in depths greater than 60 fathoms	33724	4094
Observed anglers	Remove upper and lower 2.5% of observed anglers; Remaining data: Observed anglers 4-14	32603	3977
Time fished	Remove upper and lower 2.5% time fished and time fished; Remaining drifts with 5-102 minutes time fished	29641	3773
Inferred habitat	Retain drifts within the alpha hulls from positive observations	24219	3764

**Table 36:** Model selection for the onboard CPFV survey.

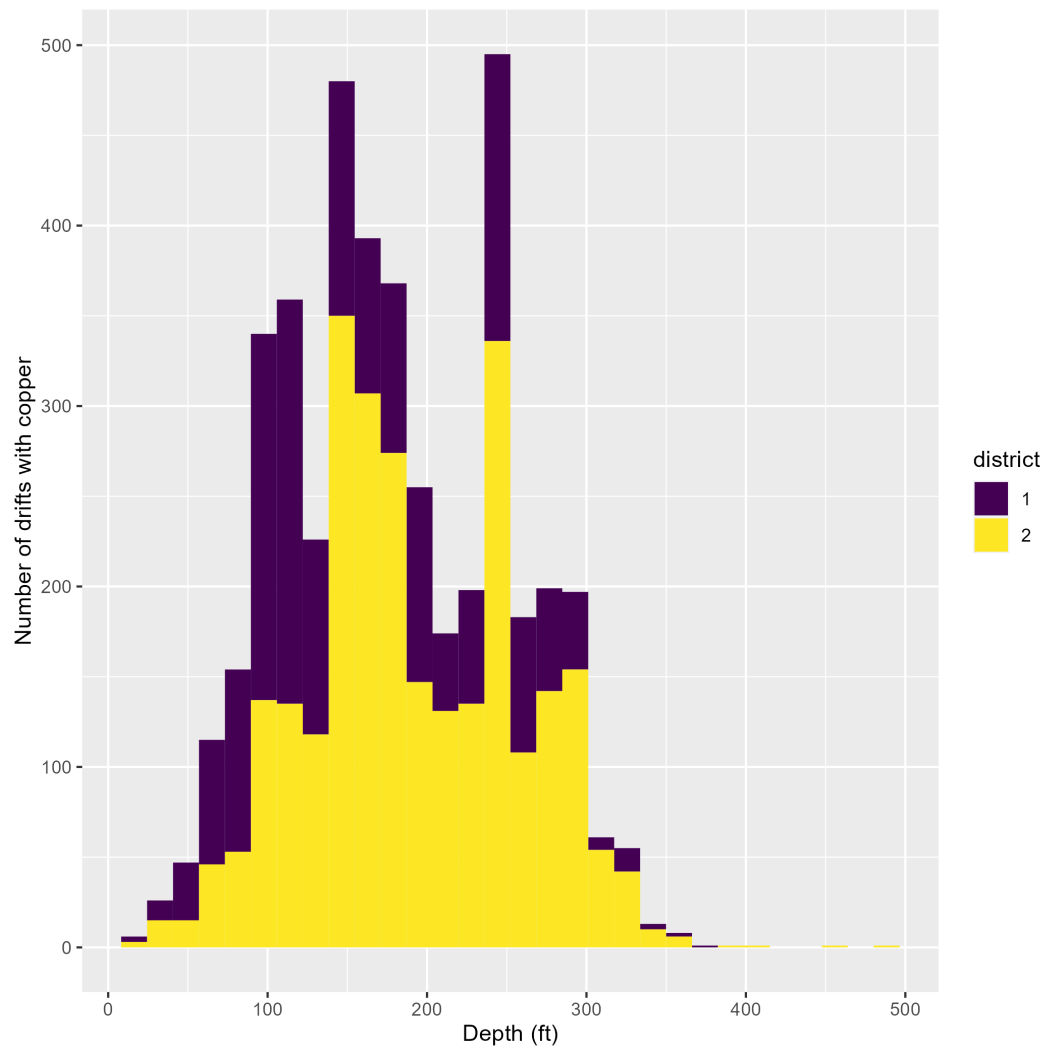
Depth	Month	Region	Year	Effort.Offset	Df	Log.Likeli- hood	AICc	Delta
0.035	+	+	+	+	35	-13212.2	26494.6	0.0
0.040	NA	+	+	+	26	-13368.2	26788.4	293.8
NA	+	+	+	+	34	-13418.5	26905.2	410.6
NA	NA	+	+	+	25	-13653.7	27357.5	862.9
0.060	+	NA	+	+	32	-14764.8	29593.7	3099.1
0.062	NA	NA	+	+	23	-14824.1	29694.2	3199.7
NA	+	NA	+	+	31	-15196.4	30454.9	3960.3
NA	NA	NA	+	+	22	-15289.1	30622.3	4127.8

**Table 37:** Estimated relative index of abundance for the onboard CPFV survey.

Year	Estimate	logSE
2005	0.0061	0.2173
2006	0.0049	0.1568
2007	0.0085	0.1369
2008	0.0068	0.1363
2009	0.0040	0.1715
2010	0.0049	0.1617
2011	0.0062	0.1265
2012	0.0096	0.1109
2013	0.0126	0.0904
2014	0.0104	0.1083
2015	0.0134	0.1080
2016	0.0119	0.1193
2017	0.0097	0.1223
2018	0.0139	0.1474
2019	0.0070	0.1707

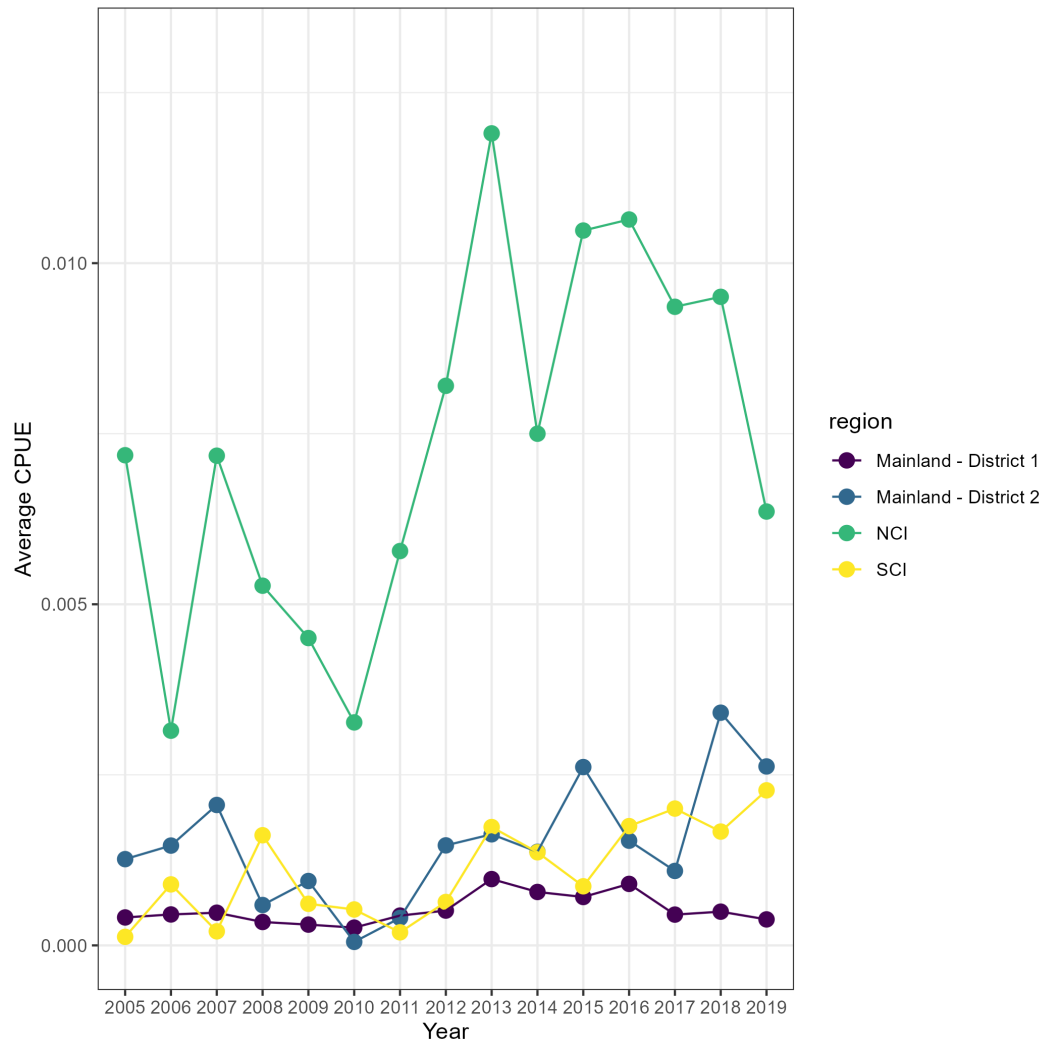


**Figure 166:** Distribution by year of depths where copper rockfish observed.



**Figure 167:** Stacked bar plot of the depth of observed copper rockfish by district.

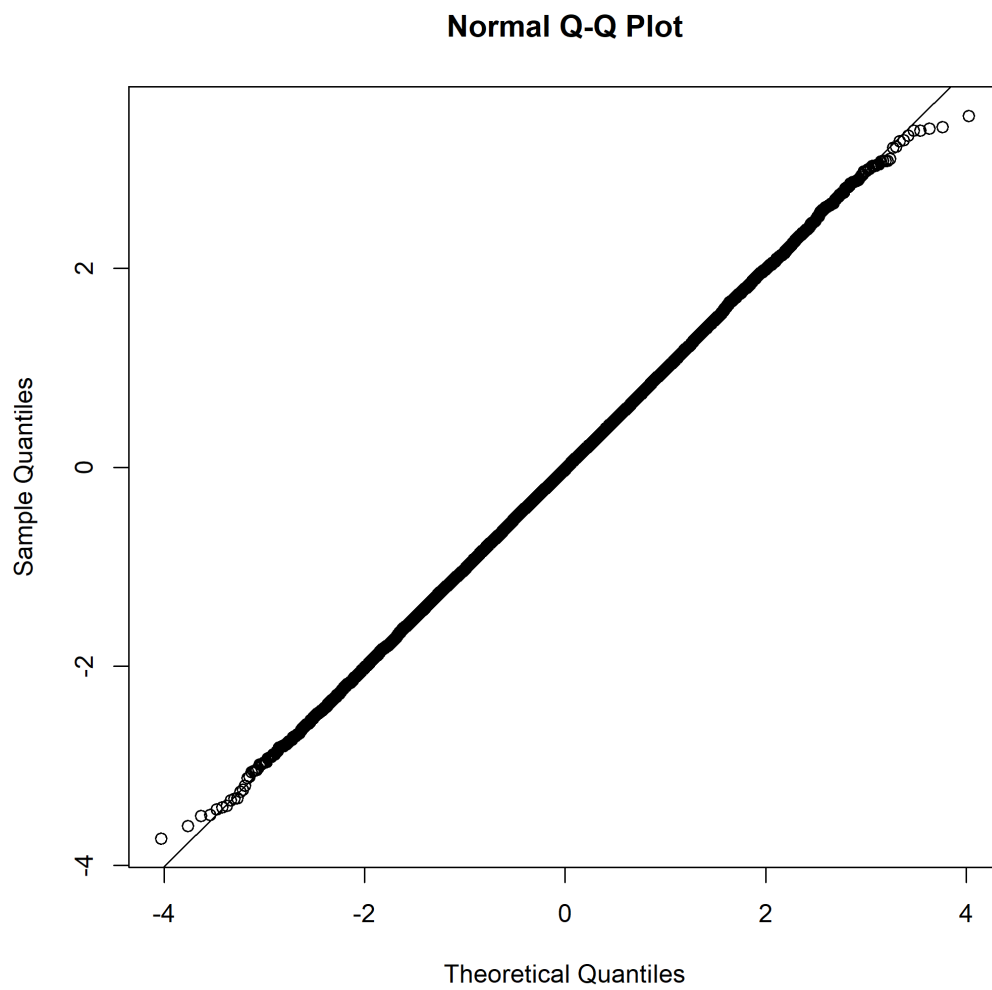




**Figure 168:** Average CPUE by region prior to standardization.



**Figure 169:** Relative index of abundance for the onboard CPFV survey.



**Figure 170:** Q-Q plot for the onboard CPFV survey.

### 9.3.2 CRFS PR Dockside Index of Abundance

Catch and effort data from CRFS dockside sampling of private boats, 2004-2022, were provided by CDFW for use in this assessment. The PR dockside data housed on the Recreational Fisheries Information Network (RecFIN) were determined to include a number of complexities that precluded the ability to use them for the development of an index of abundance. For the time period from 2004-2014 the STAT re-created the interview, or trip level, data from the “i” sample files. For 2015-2022 the STAT used files provided by CDFW from the CRFS dockside sampling program.

The data for both time periods included catch by species, number of anglers contributing to the catch, angler-reported area of fishing, gear, county, port, interview site, year, month, and CRFS district. The catch included the number of fish observed by the CRFS sample, the number of unobserved retained fish reported by the angler, and the number of discarded and descended fish reported by the angler. The sample size of the unfiltered private boat data is much larger than the CPFV onboard observer data set, with 256,738 samples statewide from 2004-2022, 169,912 south of Point Conception and 86,826 north of Point Conception.

Records were limited to the primary private and rental boats public-access sites, PR1 sites, which encompasses over 90 percent of the total private boat effort (Table 41). The CRFS interviews contain a small fraction (407 trips over the entire time series) of samples where the retained catch for rockfish is over the daily bag limit of 10 fish per person. We did not remove these data from the index, but did only include sampler examined catch. Rockfish species can be difficult to distinguish and there have not been any verification studies conducted to determine the uncertainty in angler reported unobserved catch. Additional data filters included the exclusion of any samples from January and February, since those months have been closed to the recreational fishery south of Point Conception since 2005. The time series was also restricted to 2004-2019. Sampling during the COVID-19 period (2020-2021) resulted in a higher fraction of the sampler examined catch in the “rockfish, general” category due to the social distancing requirements (Table 39). The CDFW implemented a one fish sub-bag limit for copper rockfish in 2022 and the quantiles and distribution of CPUE suggest that this regulation change impacted fishing behavior in the private boat fleet (Table 38 and Figure 171).

The angler reported water area was restricted to ocean areas in U.S. waters and a reported primary gear of hook and line or troll gear. A number of trips reporting troll as the primary gear reported a secondary gear of hook and line. To determine if the angler(s) interviewed targeted rockfish and fished in rocky habitat, we retained trips if the angler reported the primary target species as rockfish or bottomfish or if rockfish was reported as the secondary target species. This filter replaced the Stephens-MacCall (Stephens and MacCall 2004) filtering approach that have been used for some assessment in the past. This filtering retained 13,340 angler interviews for index standardization, with 3,739 including sampled examined copper rockfish (Table 41).

We modeled retained catch per angler days with a negative binomial generalized linear model in the R package *sdmTMB*. The Q-Q plots indicate a reasonable fit (Figure 174). There are a handful of samples with higher than average CPUE and the authors checked with CDFW to determine whether the samples should still be included. CDFW indicated data sheets were not available prior to 2012, but the catches were less than the bag limits, and should be assumed to be correct. Indices with a year and district interaction were not considered in model selection due to the fact that fishing locations are unknown; the scale of the relative abundance of copper rockfish is higher in District 2, but there is some overlap in the fishing locations accessed by this fleet (Figure 172).

Based on AICc values from maximum likelihood fits (Table 42), a main effects model including year, month and primary target species as categorical covariates was selected (Table 43 and Figure 173).

**Table 38:** Summary of the copper rockfish CPUE, number of fish retained per angler day, by year.

Year	Minimum	Q1	Q2	Q3	Maximum
2015	0.12	0.50	0.67	1.25	10.00
2016	0.14	0.50	0.67	1.50	10.00
2017	0.11	0.50	1.00	2.00	10.00
2018	0.14	0.50	1.00	1.60	20.00
2019	0.11	0.50	0.92	1.50	10.00
2020	0.17	0.50	0.67	1.00	7.50
2021	0.11	0.50	0.67	1.25	8.57
2022	0.12	0.33	0.50	1.00	6.33

**Table 39:** Summary of the number of speciated and unspeciated (RFGEN) rockfish per year across all of California.

Year	Unspeciated	Speciated	Percent unspeciated
2015	5816	93285	5.9%
2016	5153	71835	6.7%
2017	6015	80123	7.0%
2018	4767	79348	5.7%
2019	3597	92228	3.8%
2020	27522	59999	31.4%
2021	13439	90050	13.0%
2022	3559	83804	4.1%

**Table 40:** Number of samples and percent positive for the dockside PR survey.

Year	Trips with Target	Trips without Target	Total trips	Percent with Target
2004	189	601	790	23.9%
2005	160	494	654	24.5%
2006	241	526	767	31.4%
2007	325	705	1030	31.6%
2008	269	754	1023	26.3%
2009	213	862	1075	19.8%
2010	117	466	583	20.1%
2011	150	501	651	23.0%
2012	143	931	1074	13.3%
2013	363	1104	1467	24.7%
2014	279	818	1097	25.4%
2015	227	335	562	40.4%
2016	246	321	567	43.4%
2017	265	378	643	41.2%
2018	274	314	588	46.6%
2019	278	491	769	36.2%

**Table 41:** Data filtering steps for the onboard CPFV survey.

Filter	Description	Number of Samples	Positive Samples
All data	All data	56276	4861
Years	Start time series in 2005 due to sparse data	46125	4523
Errors and Missing Data	Remove drifts with missing data and identified errors	41837	4319
Area fished	Remove drifts in bays and Mexico (if applicable)	39081	4235
Months fished	Remove Jan-Feb; recreational rockfish fishery closed	35123	4112
Depth	Remove drifts in depths greater than 60 fathoms	33724	4094
Observed anglers	Remove upper and lower 2.5% of observed anglers; Remaining data: Observed anglers 4-14	32603	3977
Time fished	Remove upper and lower 2.5% time fished and time fished; Remaining drifts with 5-102 minutes time fished	29641	3773
Inferred habitat	Retain drifts within the alpha hulls from positive observations	24219	3764

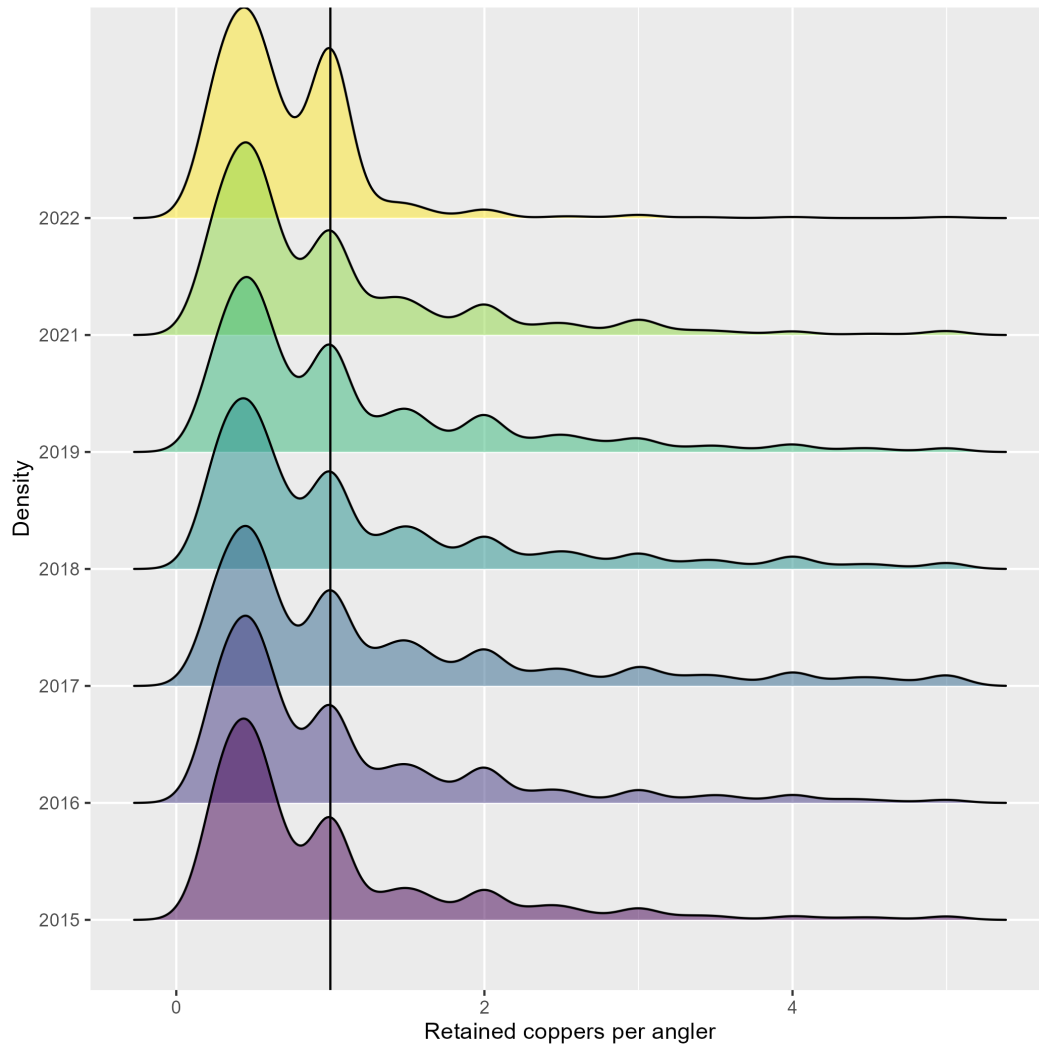


**Table 42:** Model selection for the dockside PR survey.

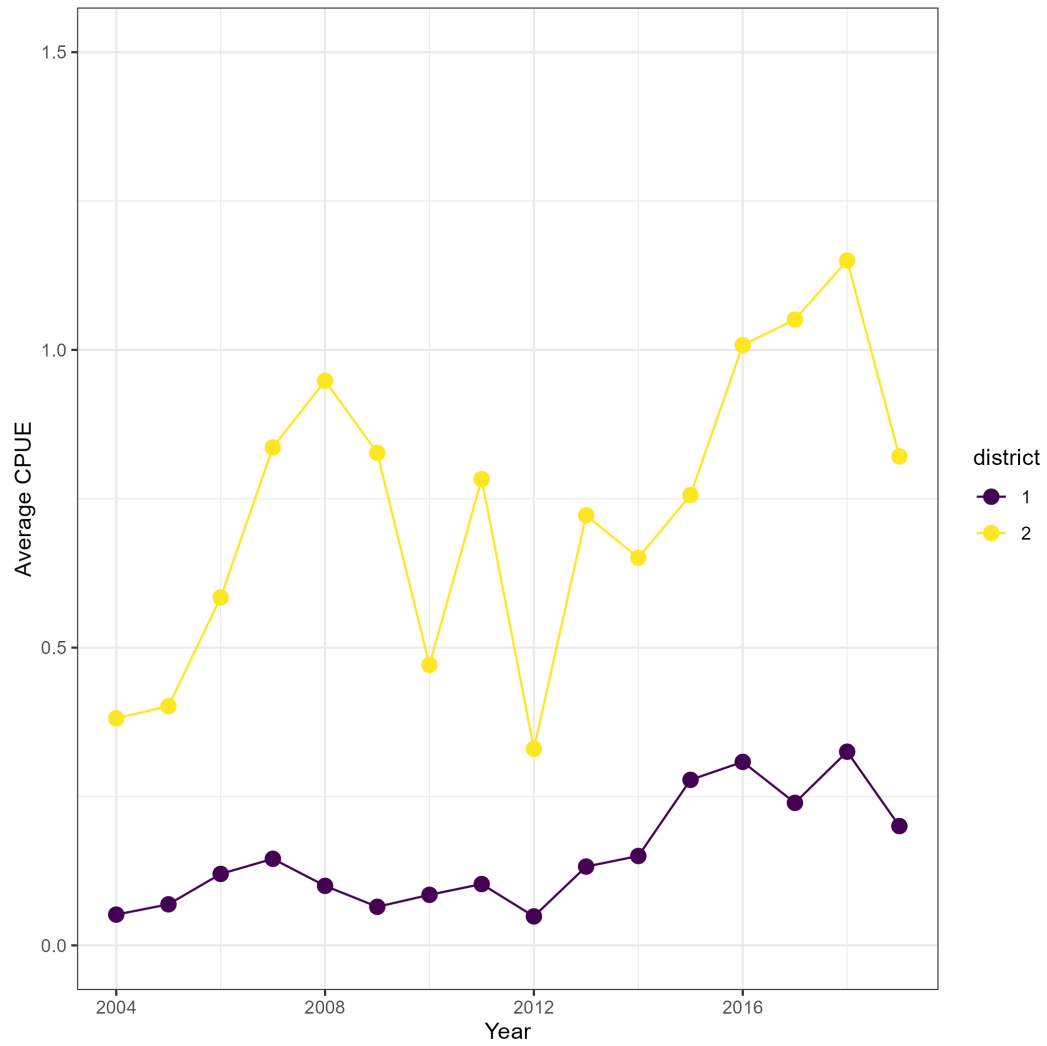
District	Month	Primary.Tar- get.Species	Year	Effort.Offset	Df	Log.Likeli- hood	AICc	Delta
+	+	+	+	+	29	-14494.1	29046.3	0.0
+	NA	+	+	+	20	-14515.9	29071.8	25.5
+	+	NA	+	+	27	-14576.7	29207.5	161.2
+	NA	NA	+	+	18	-14603.1	29242.2	195.9
NA	+	+	+	+	28	-15132.3	30320.8	1274.5
NA	NA	+	+	+	19	-15147.5	30333.0	1286.7
NA	+	NA	+	+	26	-15354.8	30761.7	1715.4
NA	NA	NA	+	+	17	-15369.6	30773.2	1726.9

**Table 43:** Estimated relative index of abundance for the dockside PR survey.

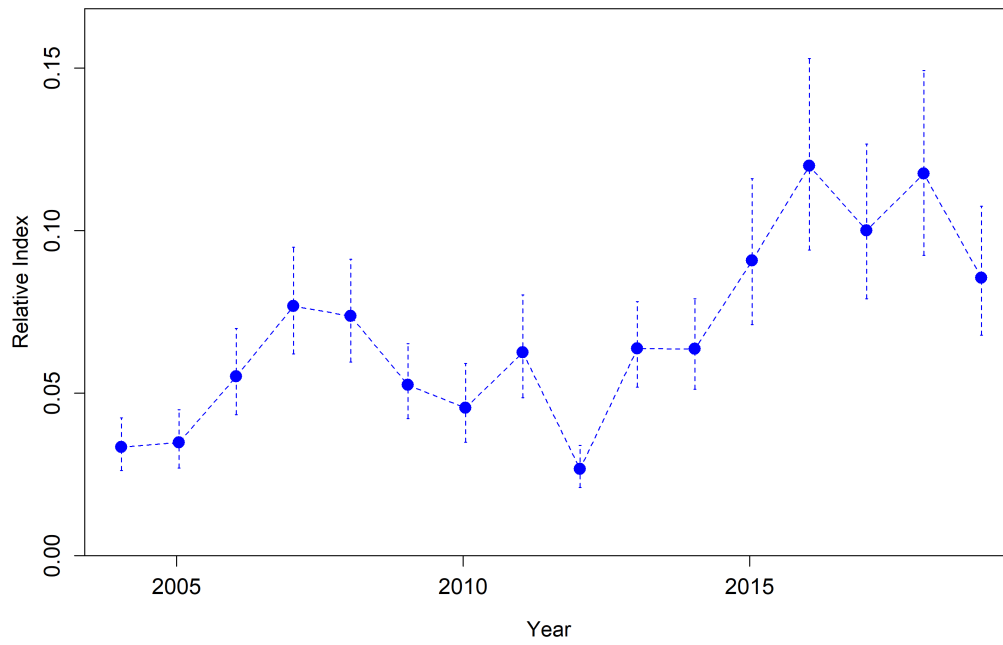
Year	Estimate	logSE
2004	0.0334	0.1226
2005	0.0348	0.1301
2006	0.0551	0.1217
2007	0.0767	0.1083
2008	0.0737	0.1087
2009	0.0525	0.1110
2010	0.0455	0.1340
2011	0.0625	0.1275
2012	0.0267	0.1214
2013	0.0637	0.1049
2014	0.0636	0.1105
2015	0.0908	0.1247
2016	0.1199	0.1240
2017	0.1000	0.1203
2018	0.1175	0.1221
2019	0.0854	0.1171



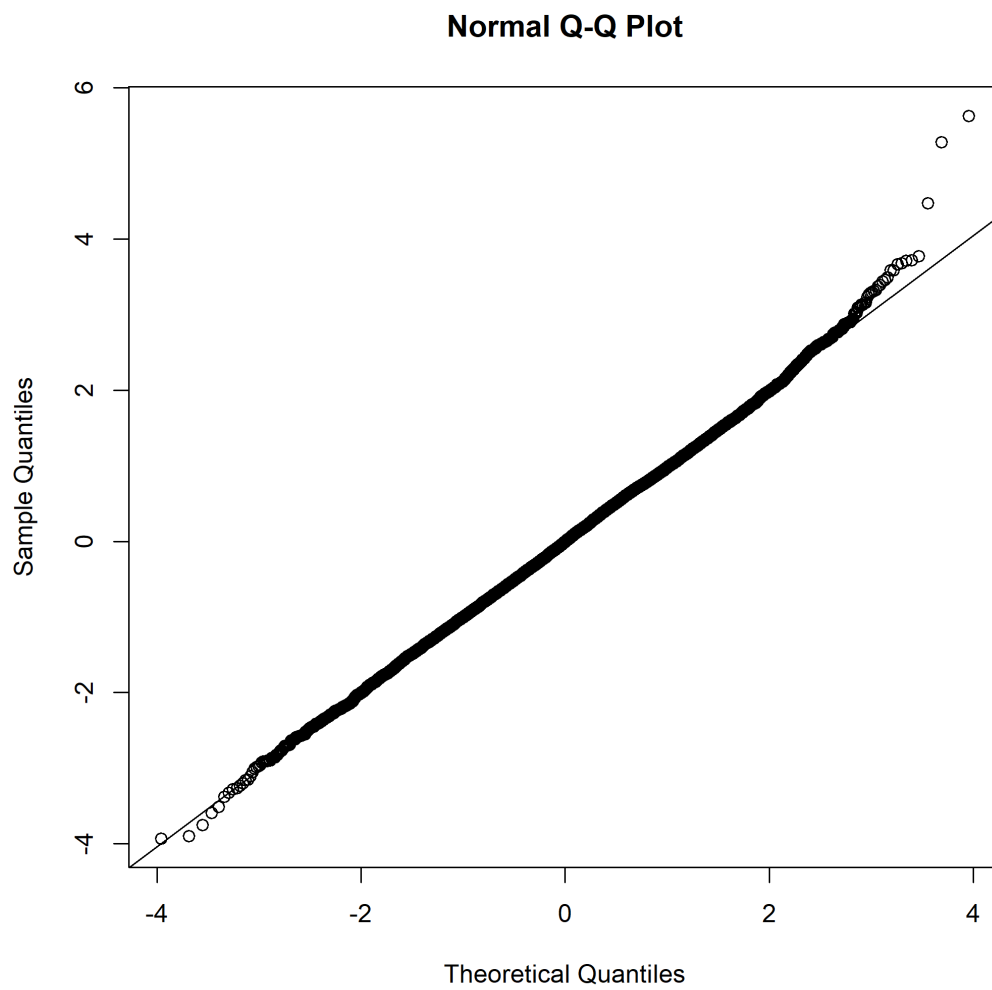
**Figure 171:** Distribution by year of the number of copper rockfish retained per angler. This includes sampler observed and angler reported catch. The vertical line at 1 represents the sub-bag limit implemented in 2022.



**Figure 172:** Average CPUE by district prior to standardization.



**Figure 173:** Relative index of abundance for the dockside PR survey.



**Figure 174:** Q-Q plot for the dockside PR survey.

### 9.3.3 CCFRP Index of Abundance

The California Collaborative Fisheries Research Program, CCFRP, is a fishery-independent hook and line survey designed to monitor nearshore fish populations at a series of sampling locations both inside and adjacent to MPAs (Wendt and Starr 2009b; Starr et al. 2015a). The CCFRP survey began in 2007 along the central coast of California and was designed in collaboration with academics, NMFS scientists and fishermen. From 2007-2016 the CCFRP project was focused on the central California coast, and has monitored four MPAs consistently. In 2017, the CCFRP expanded coastwide within California. The University of California Santa Barbara and Scripps Institute of Oceanography conduct the southern California CCFRP sampling and monitor MPA and reference paired sites.

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

The CCFRP data are quality controlled at the time they are key punched and little filtering was needed for the index. Cells not consistently sampled over time were excluded as well as cells that never encountered copper rockfish. Copper rockfish were observed at the South La Jolla, Carrington Point and Anacapa Island MPAs in the area south of Point Conception. After applying filters to remove drifts from sites that were not consistently sampled, marked for exclusion in the data, or did not fish a minimum of two minute, 856 drifts remained for index standardization, with 399 drifts encountering copper rockfish.

We modeled retained catch per angler hour (CPUE; number of fish per angler hour). Plots of the average CPUE inside (MPA) and outside (REF) MPAs at each site are shown in Figure 175. The average CPUE at Carrington Point, the location with the highest CPUE for the survey, from inside and outside MPAs by distinct show a trend of decreasing average CPUE during the time series. Trends among the two other paired sampling locations, Anacapa Island and South La Jolla, had much lower estimated CPUEs with potentially decreasing CPUE for the reference locations and potentially the MPA site at South La Jolla. On average, across all sampling locations south of Point Conception, the trends in average CPUE over the six year time series inside and outside of the MPA both show a decline in copper rockfish observations.

A negative binomial model was fit to the drift-level data (catch with a log offset for angler hours) using the *sdmTMB* R package. Because the average observed CPUE among the MPAs indicated differing trends, we explore a region:year interaction, which was not significant. The model selected by AICc included depth, depth squared, region and MPA or reference site (Table 45). The final model included year, mpa/reference categorization, depth, depth squared, and a year:mpa/reference interaction. The Q-Q plots indicate a reasonable fit (Figure 177). The final index (Table 46) represents a similar trend to the unstandardized average CPUE (Figure 176).

Based on work completed at the SWFSC, we estimated that the percent of rocky reef habitat from Point Conception to the California/Mexican border within state waters is  $892 \text{ km}^2$ , of which approximately 23 percent is in MPAs that prohibit the harvest of groundfish (pers comm. Rebecca Miller, UCSC). There is recreational fishing outside of state waters, but habitat maps are not available at the same 2-meter resolution and do not allow for direct comparisons. To estimate the area of rocky substrate south of Point Conception, we separated the southern California Bight into four areas, 1) CRFS District 1 along the mainland coast, 2) CRFS District 2 along the mainland coast, 3) state waters encompassing the southern Channel Islands, and 4) state waters encompassing the northern Channel Islands. We calculated the total area in each of the four regions, as well as the

total area with available interpreted substrate. By also calculating the total area open and closed to fishing, i.e., MPAs and CCAs, we expanded the known fraction of rocky substrate to the areas within state waters where no substrate interpreted maps exist. This resulted in an estimate of 27 percent of the available rocky substrate within areas closed to fishing in southern California state waters.



**Table 44:** Data filtering for the CCFRP Hook and Line survey.

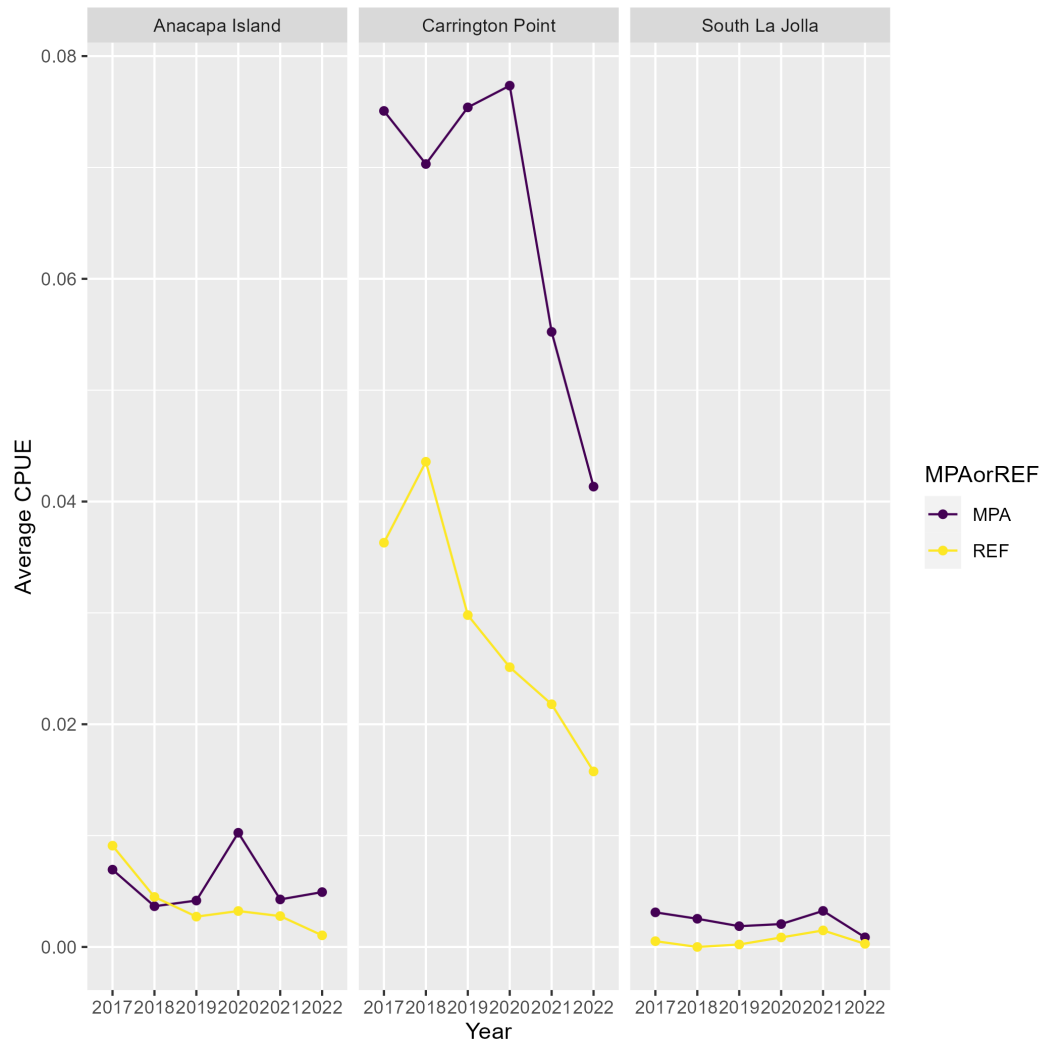
Filter	Description	Samples	Positive_Samples
All data		1783	501
Sampling frequency	Remove locations and cells not well sampled and drifts marked for exclusion	1445	410
Location	Remove Swami's; only 5 coppers caught	1049	405
Location	Remove grid cells that never observed the target species	875	405
Time fished	Remove drifts less than two minutes and cells fished less than 15 minutes during a sampling event	856	399

**Table 45:** Model selection for the CCFRP Hook and Line survey.

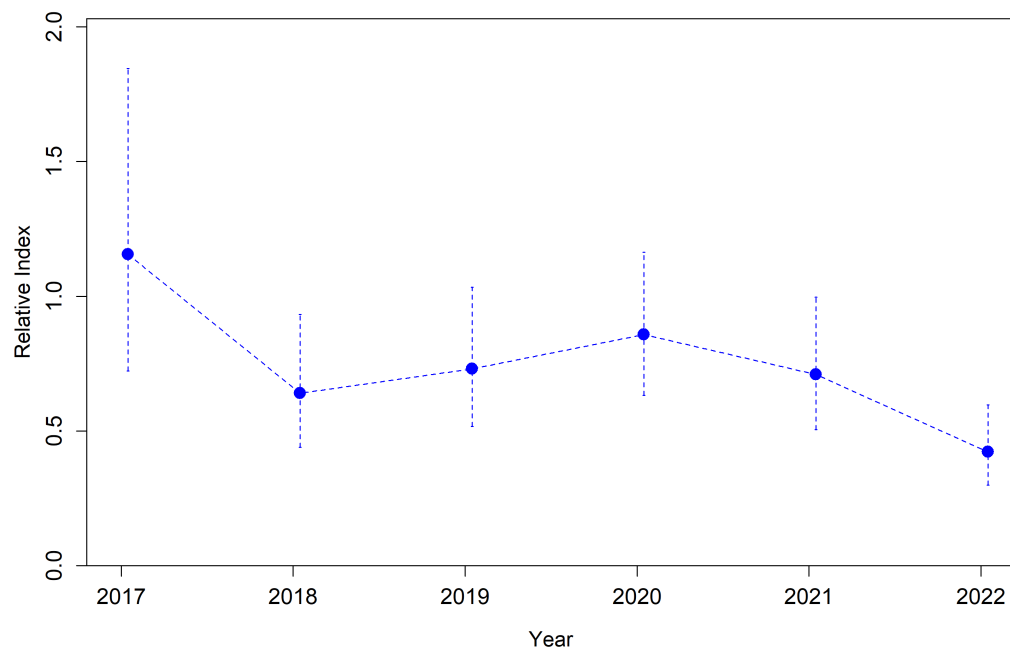
Intercept	Depth	Depth2	Region	Offset	DF	Log-likelihood	AICc	Delta
-8.33	0.22	-0.01	+	+	5	-1475.66	2961.40	0.00
-6.94	0.02	NA	+	+	4	-1485.64	2979.32	17.92
-6.72	NA	NA	+	+	3	-1486.65	2979.33	17.93
-6.74	NA	0.00	+	+	4	-1486.63	2981.31	19.91
-7.19	0.37	-0.01	NA	+	4	-1593.78	3195.60	234.20
-5.08	0.07	NA	NA	+	3	-1616.77	3239.56	278.16
-4.32	NA	0.00	NA	+	3	-1623.94	3253.91	292.51
-4.01	NA	NA	NA	+	2	-1627.18	3258.38	296.98

**Table 46:** Estimated relative index of abundance for the CCFRP Hook and Line survey.

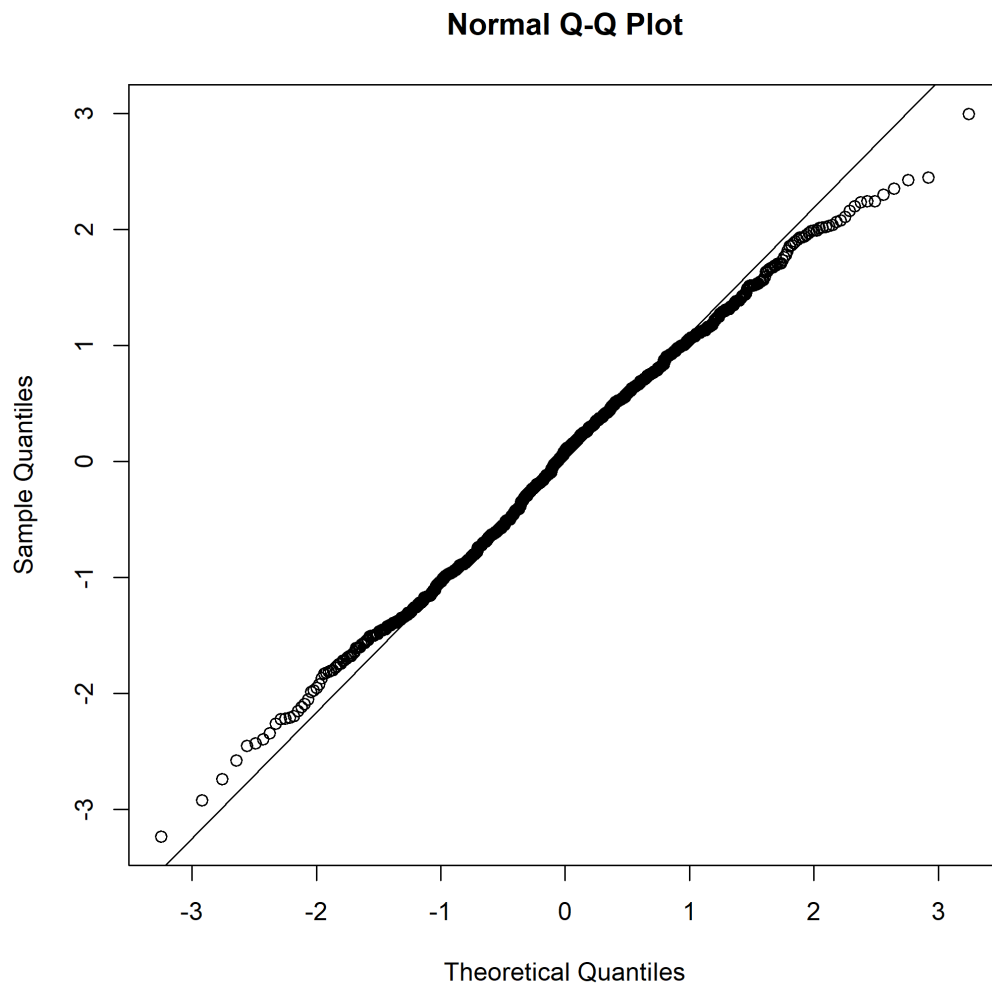
Year	Estimate	logSE
2017	1.1551	0.2389
2018	0.6400	0.1921
2019	0.7311	0.1764
2020	0.8575	0.1556
2021	0.7096	0.1732
2022	0.4225	0.1760



**Figure 175:** Average CPUE by site with trends prior to standardization in the MPA and REF areas for the CCFRP Hook and Line survey.



**Figure 176:** The weighted relative index of abundance for the CCFRP Hook and Line survey.



**Figure 177:** Q-Q plot for the CCFRP Hook and Line survey.

### 9.3.4 NWFSC Hook and Line Index of Abundance

Since 2004, the NWFSC has conducted an annual hook and line survey targeting shelf rockfish in the genus *Sebastes* at fixed stations (e.g., sites, Figure 25) in the Southern California Bight. Key species of rockfish targeted by the NWFSC Hook and Line survey are bocaccio (*S. paucispinis*), cowcod (*S. levis*), greenspotted (*S. chlorostictus*), and vermilion/sunset (*S. miniatus* and *S. crocotulus*) rockfishes, although a wide range of rockfish species have been observed by this survey. During each site visit, three deckhands simultaneously deploy 5-hook sampling rigs (this is referred to as a single drop) for a maximum of 5 minutes per line, but individual lines may be retrieved sooner at the angler's discretion (e.g., to avoid losing fish). Five drops are attempted at each site for a maximum possible catch of 75 fish per site per year (3 anglers x 5 hooks x 5 drops). Further details regarding the sample frame, site selection, and survey methodology are described by Harms et al. (2008).

Over time, select sampling sites in the original survey design have been converted to either federal or state MPAs beginning around 2011. Additionally, the survey began sampling in two cowcod conservation areas (CCA) in the California Bight starting in 2014 which has portions of depth where take is prohibited. The data were examined for potential impact of catch rates of copper rockfish in the NWFSC Hook and Line survey between open and protected areas in order to best understand how to model these data. The catch-per-unit-effort of copper rockfish was calculated for protected and open sites in three regions: mainland, Northern Channel Island, and Southern Channel Island (Figure 178). An exploratory negative binomial model determined that the catch rates of copper rockfish between open and protected areas were not significantly different so the decision was made to use all data for copper rockfish to generate an index of abundance in a manner that did not specifically account for open and protected sites.

The sites considered for the creation of a relative index of abundance were limited to sites that have caught at least 1 copper rockfish across all years. To appropriately weight the survey index by the available rocky substrate by region in the California Bight, each site was assigned as mainland, Northern Channel Island, or Southern Channel Island. Estimates of hard bottom were extracted from the California Seafloor Mapping Project for each of these regions. These data were collected in state waters at a resolution of two meters. South of Point Conception, additional interpreted bathymetric data classifying the bottom type as rock or soft bottom were compiled by Emily Saarman (University of California Santa Cruz) and also available from CDFW's website. The estimates of rocky substrate for each of these regions were 19.5, 36.5, and 44.1 percent in the mainland, Southern Channel Islands, and Northern Channel Islands, respectively.

A range of alternative model structures were explored to generate an index of abundance. This included alternative levels of aggregation (hook, drop, or site), probability distributions (negative binomial, delta-gamma, or delta-lognormal), and covariates (year, site, depth, swell height, region, year-region interaction, and/or the number of vermilion/sunset or bocaccio rockfishes observed, Table 47). The overall trends in the index of abundance were highly similar across the explored probability distributions and model configurations. Based on Q-Q plots, residuals, and AIC the delta-lognormal distribution was selected for the final model using sdmTMB with covariates for year, region, drop, polynomial depth term, number of bocaccio, number of vermilion, year-region interaction, and site as a random-effect (Anderson et al. 2022) (Figures 180, 181, and 182).

**Table 47:** Model selection for the NWFSC Hook and Line survey.

Area	Bo- caccio	Depth	Depth2	Drop	Swell	Ver- mil- ion	Year	Area- Year	Offset log(ef- fort)	DF	AICc	Delta
+	-0.07	-0.62	-0.35	+	NA	0.14	+	NA	+	29	5322.5	0.0
+	-0.08	-0.61	-0.35	+	NA	0.13	+	+	+	63	5324.2	1.6
+	-0.07	-0.62	-0.35	+	-0.02	0.14	+	NA	+	30	5324.5	2.0
+	-0.08	-0.61	-0.35	+	0.03	0.13	+	+	+	64	5326.1	3.6
+	NA	-0.64	-0.34	+	NA	0.14	+	NA	+	28	5330.3	7.7
+	NA	-0.63	-0.34	+	-0.03	0.14	+	NA	+	29	5332.2	9.7
+	NA	-0.62	-0.34	+	NA	0.13	+	+	+	62	5333.3	10.7
+	NA	-0.62	-0.34	+	0.01	0.13	+	+	+	63	5335.3	12.8
+	-0.07	-0.38	-0.30	+	NA	NA	+	+	+	62	5416.5	94.0
+	-0.07	-0.39	-0.30	+	0.14	NA	+	+	+	63	5417.3	94.8
+	-0.05	-0.37	NA	+	NA	0.11	+	NA	+	28	5418.8	96.2
+	-0.05	-0.36	NA	+	-0.16	0.12	+	NA	+	29	5418.8	96.2
+	NA	-0.37	NA	+	-0.17	0.12	+	NA	+	28	5421.6	99.0
+	NA	-0.39	NA	+	NA	0.11	+	NA	+	27	5421.7	99.2
+	NA	-0.39	-0.29	+	NA	NA	+	+	+	61	5423.0	100.4

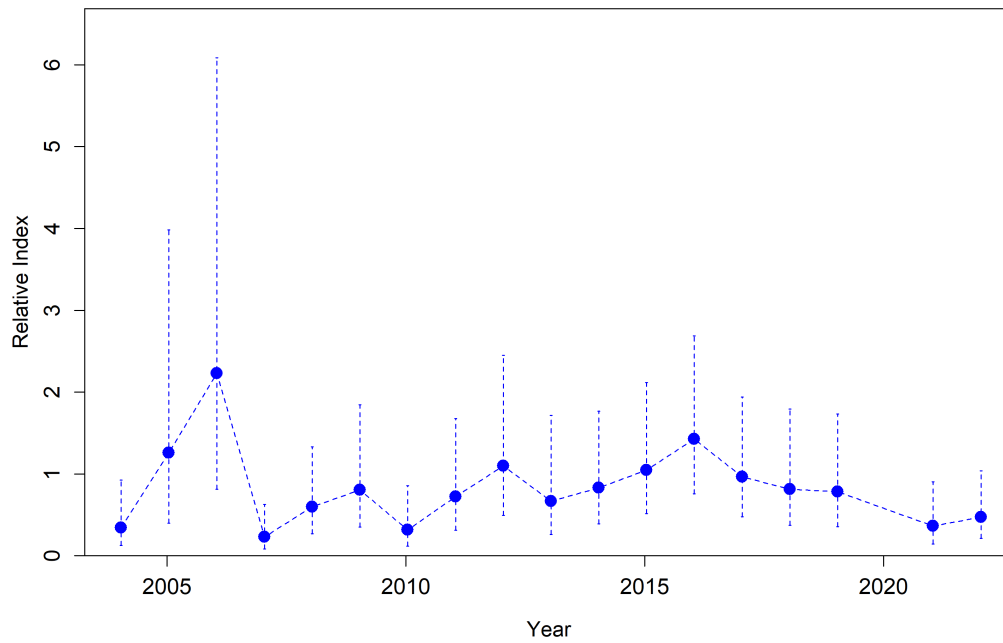


**Table 48:** The estimated index by year and the log-standard errorr.

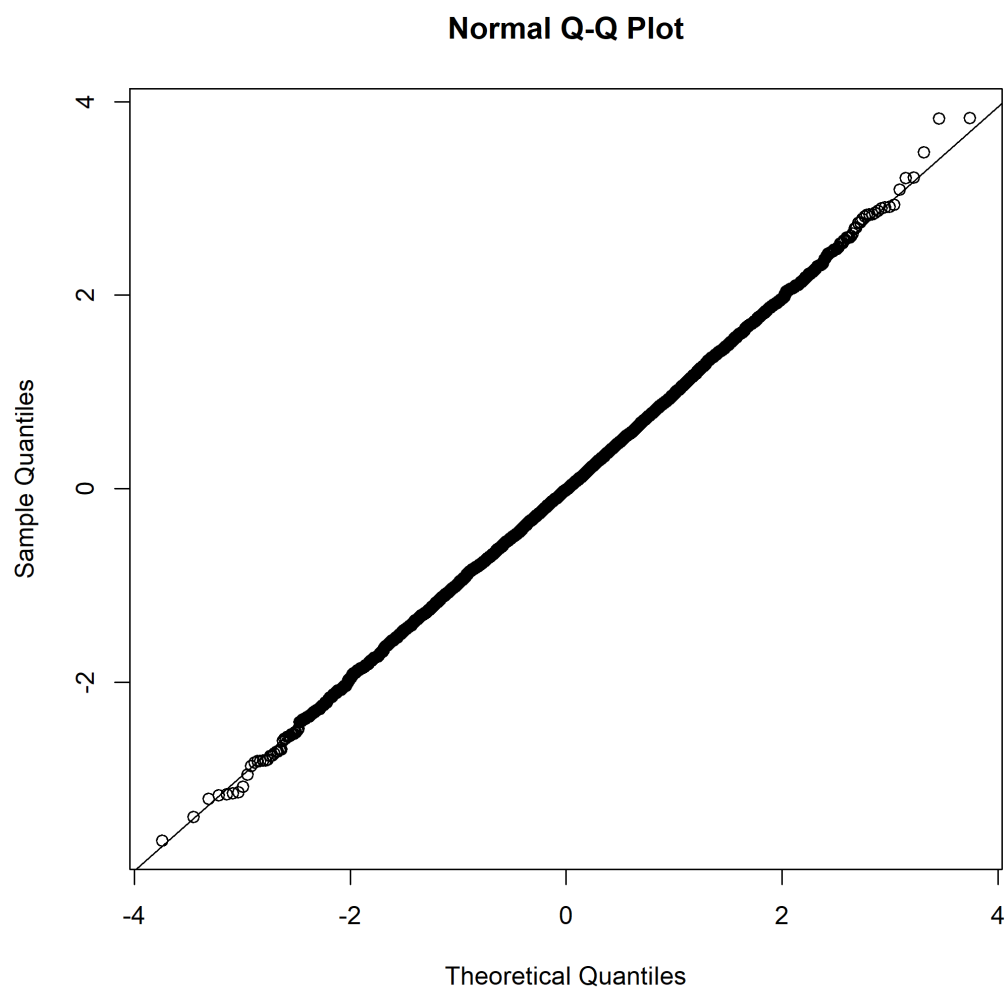
Year	Est	LogSE
2004	0.34	0.50
2005	1.26	0.59
2006	2.23	0.51
2007	0.23	0.51
2008	0.60	0.41
2009	0.81	0.42
2010	0.32	0.50
2011	0.72	0.43
2012	1.10	0.41
2013	0.67	0.48
2014	0.83	0.38
2015	1.04	0.36
2016	1.43	0.32
2017	0.96	0.36
2018	0.82	0.40
2019	0.79	0.40
2021	0.36	0.47
2022	0.47	0.40



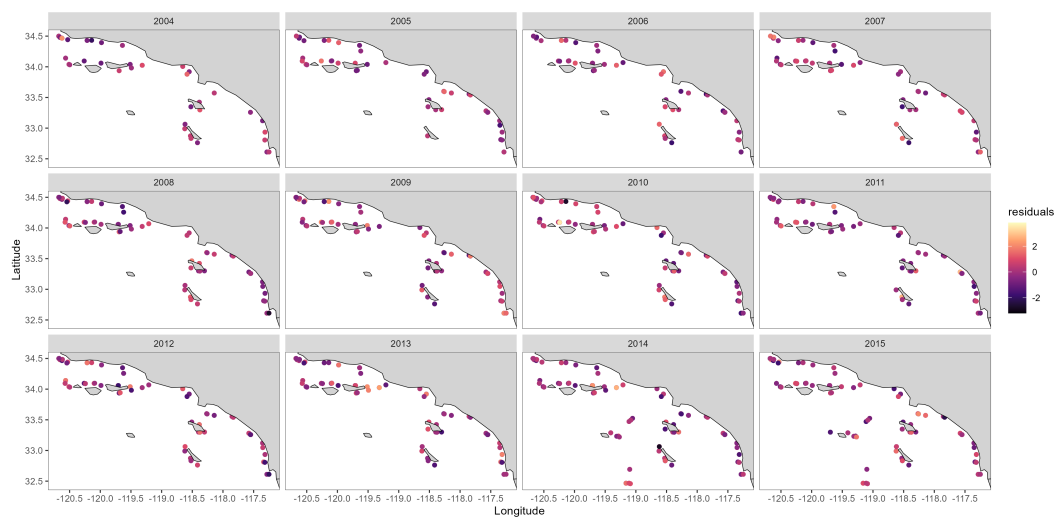
**Figure 178:** Raw catch-per-unit-effort by region and area protection for the NWFSC Hook and Line survey.



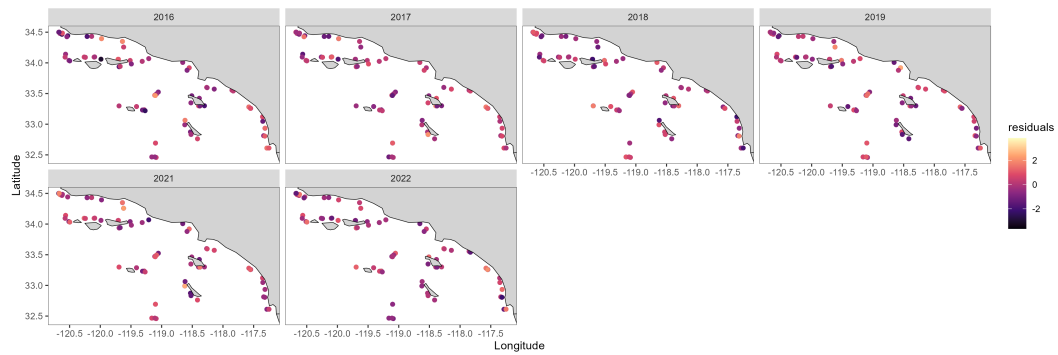
**Figure 179:** Estimated relative index of abundance by the NWFSC Hook and Line survey for copper rockfish.



**Figure 180:** Q-Q plot for the NWFSC Hook and Line survey.



**Figure 181:** Residuals by sample location and year NWFSC Hook and Line survey.



**Figure 182:** Residuals by sample location and year for the NWFSC Hook and Line survey.

## 9.4 CPFV Fleet Description, Trip Types, and Sampling

During the 2021 copper rockfish stock assessment review meeting and during the pre-assessment workshop for the 2023 groundfish assessments, concern was raised regarding possible biases in the available data from the CPFV fleet. This appendix describes the CPFV fleet, including the differences between the fleet north and south of Point Conception and why sampling by trip type was raised as a concern in southern California. The goal of this exploratory analysis was to compare the CPFV logbook data and the onboard observer sampled trips to describe the proportion of sampled trips by trip type and the distribution of copper rockfish catches across trip types. We then used CPFV data from the two most recent years pre-COVID (2018 and 2019) to illustrate how the distribution of sampling effort compares to the distribution of fishing effort and catches of copper rockfish.

*CPFV Fleet Description:* The CPFV fleets north and south of Point Conception are fundamentally different in terms of the size of the vessels, available target species, and accessible areas and depths. The CPFVs north of Point Conception targeting groundfish do not typically target other species on the same trip, with the exception being a half-day groundfish trip mixed with a half-day of Dungeness crab pot fishing. Overnight trips are extremely rare in northern California and weather is a more constraining factor as you move north along the coast. There are few Coast Guard inspected vessels north of Bodega Bay, California and the recreational fleet is dominated by smaller six-pack vessels with limited capacity.

In southern California, the diversity of target species is higher and includes several state-managed gamefish, coastal pelagics, and highly migratory species. There are three distinct trip types in southern California. The shortest of these is a half-day trip where a CPFV will run two trips a day. The three-quarter to full-day trips are able to access fishing grounds further offshore, such as the Channel Islands. Overnight and multi-day access areas including remote destinations such as San Nicholas Island and may target a combination of species, i.e., trips targeting tunas, but also catching rockfish. A number of CPFVs in southern California also transit to fish in Mexican waters for rockfish. The diversity of trip types and variety target species within a CPFV trip in southern California pose a challenge for both sampling and managing the fisheries. If either catch rates or size compositions vary across trip, in the absence of representative sampling, stock assessments may not be able to accurately account for that variability resulting in the possibility that selectivity and the input catches may be biased.

*Available CPFV Catch and Effort Data:* The components of the CDFW sampling programs used in this analysis are the CRFS CPFV onboard observer survey, CRFS angler interviews, and the mandatory, self-reported CPFV logbooks.

The CRFS program divides California into six districts, and these represent the finest spatial stratification of catch and effort estimates for stock assessments and management (Figure 183). The CRFS sampling manual outlines the sampling methodologies for each survey component. The California Fisheries Recreational Fisheries Survey Methods indicates the CPFV mode “sampling goal is to sample onboard at the historical sampling frequency of two to five percent of estimated CPFV trips of interest (e.g., trips targeting groundfish, inshore and coastal pelagic species) at each CPFV landing and to sample other CPFV trip types dockside.”

The CRFS data collected onboard are a key component to obtaining species-specific information from the CPFV fleet because the state of California allows the filleting of fish at sea. To accurately identify rockfish species and obtain measurements of whole fish, the majority of CPFV angler interviews occur onboard the vessel.

The CPFV logbooks include information on the the general location fished, number of anglers, number of fish retained and discarded, use of descending devices, as examples. The CPFV fleet, in the absense of an onboard observer, is not required to speciate the catch and only one CDFW block number (i.e., location identifying grid system) is recorded per entry. For these reasons the CPFV logbook data are not often used to develop an index of abundance for groundfish species. However,

the CPFV logbook data provide insight into the spatial distribution of fishing effort and changes in effort over time.

*Data Summaries from 2018-2019:* In order to maintain confidentiality, we aggregated data within each dataset across 2018 and 2019, and across districts four and six (i.e., no trips were observed onboard in CRFS District 5 during 2018-2019).

We filtered the CPFV logbook data to trips that recorded at least one rockfish and the CPFV onboard observer data to trips that encountered at least 1 percent groundfish species. Additional filters were applied to the CPFV logbook data such as removing trips that recorded the primary fishing location in Mexican waters (6 percent of all trips). We also removed a small fraction (less than 10 trips) recorded as multi-day trips, but that reported a fishing location along the mainland of southern California.

The combined onboard observer sampling rate for 2018-2019 was 3 percent of all CPFV trips statewide in the filtered data. No trips were observed onboard in CRFS District 5 during 2018-2019. However, 1,051 CPFV logbooks were submitted from District 5 ports that recorded at least one rockfish. When we grouped the data by the modeled areas north and south of Point Conception, we found that 2 percent of all trips in northern California were sampled onboard. In southern California, 4 percent of single-day trips were observed and less than 1 percent of multi-day trips were observed.

We then explored the southern California data further to look at sampling effort by trip type. The CPFV logbooks indicated if a trip was a single- or multi-day, but the logbooks do not differentiate between a half-day or three-quarter day trip. We assigned each CPFV logbook trip from southern California to a sub-region (District 1 mainland, District 2 mainland, northern Channel Islands, Southern Channel Islands, and Offshore) based upon the recorded block number (Table 53). The trips assigned to “Southern CA Offshore” were a catch-all that included blocks outside the range of a half-day trip, but not within the vicinity of an island. We separated out the “Southern CA Offshore” trips because it is likely their target species was not rockfish. Approximately 16 percent of the CPFV logbooks in southern California were from multi-day trips. As expected, the trips recording a CDFW block near the mainland were recorded as half-day trips. More than twice as many trips to the northern Channel Islands were single-day trips versus multi-day trips. The vessels in District 2 typically offer fewer half-day day trips and fish the nearshore when weather precludes crossing the channel to the northern Channel Islands on a three-quarter day trip.

To put these sampling rates in context for copper rockfish, we looked at the total estimated mortality by district related to the distribution of sampling. The total mortality of copper rockfish in metric tons from 2018-2019 from the CPFV fleet by CRFS District is shown in Table 49. Fifty-two percent of the total copper rockfish mortality was from northern California and 48 percent from southern California. Within northern California, 50 percent of the total mortality originated from District 3, and in southern California, 81 percent of the total mortality originated from District 2.

From the onboard observer trips in District 1, 37 percent of the observed copper rockfish were from half-day day trips, 42 percent from three-quarter to full-day trips, and 21 percent of the observed copper rockfish were from the five observed multi-day trips (Table 50).

In District 2, 17 percent of the observed copper rockfish were from half-day day trips, 75 percent from the three-quarter to full day trips, and 8 percent from multi-day trips. When weather allows, the northern Channel Islands can be accessed from CRFS District 2 during a three-quarter to full-day trip or a multi-day trip, depending on the port. For instance, the CPFVs from Channel Islands Sportfishing in Oxnard, California access the northern Channel Islands during multi-day trips, and the same areas are accessed by the three-quarter to full-day trips out of Santa Barbara Landing.

The majority of length samples for the CPFV fleet are taken onboard the observed trips. The shift in the distribution of lengths from each trip type is evident from the overnight trips from District 1 with larger fish encountered on the overnight trips (Figure 184). The average length of fish

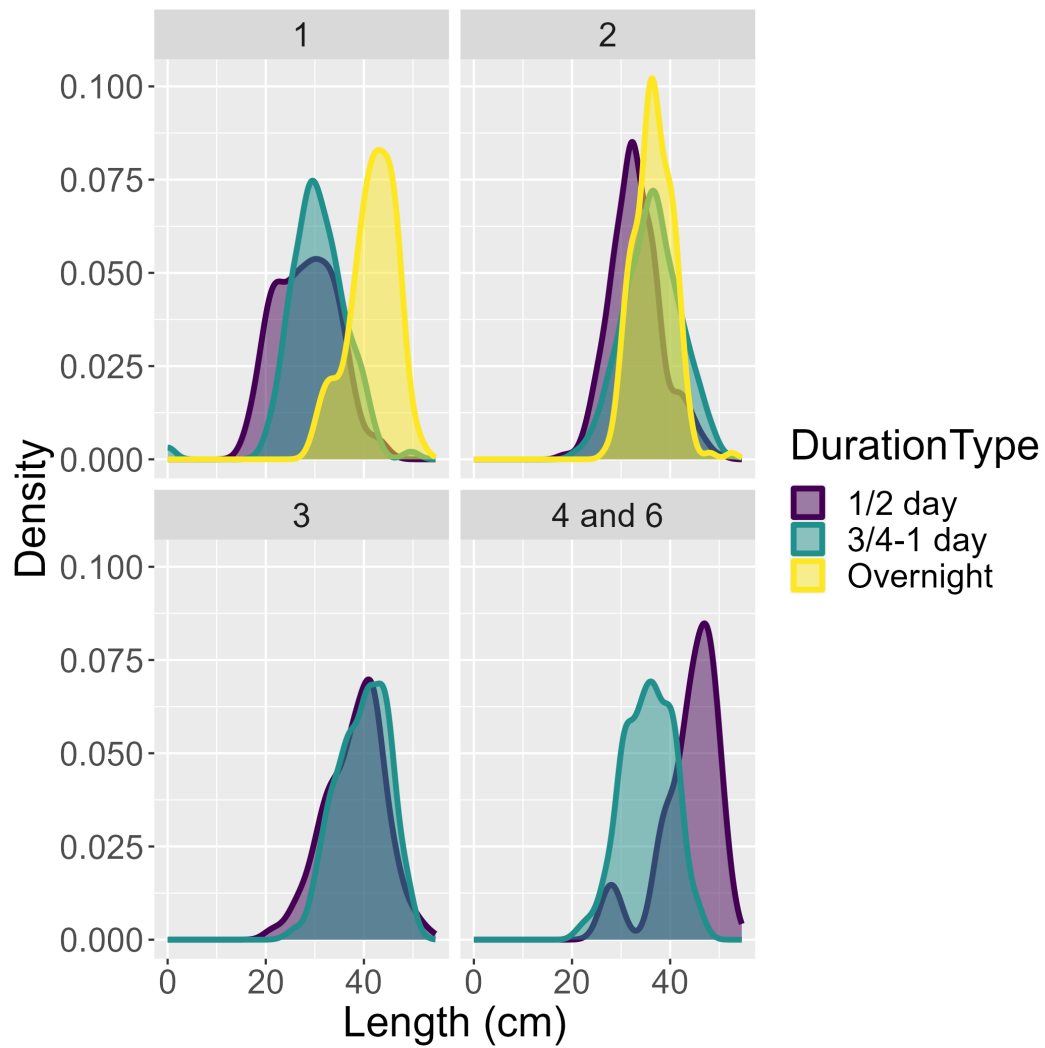


encountered on half-day trips out of District 2 is 33.1 cm compared to 36.3 for three-quarter day trips and 36.6 for overnight trips.

To account for the differences in the the differences in catch rates and size compositions observed across trip types and areas, we would need to collect estimates of catch and effort at a finer-scale than the CRFS district. While the logbooks are not perfect, and there is a fraction of non-compliance, they highlight the intense fishing pressure in some areas and may help identify the how to distribute sampling efforts. For example, increased sampling in Districts 4-6 would also provide information on the length composition of the fish encountered by the CPFV fleet, especially considering the increase in average length with latitude (Figure 184). The increased sampling in District 4-6 would also provide the data needed to create an accurate index of relative abundance from the onboard observer data, which can easily be considered one of the most valuable fishery-dependent data sources available. Based on additional data from the logbooks it may be possible to identify an approximate fraction of half-day to three-quarter day trips. The lengths in Table 51 are currently all weighted equally in the length compositions within the current assessment models. Future research is needed to determine the effects of the changing size composition by trip type within stock assessment models, especially for southern California where larger fish are encountered on longer trips. Weighting the length composition data by the catch from each trip type is one possible method to account for the differences observed in Figure 184.



**Figure 183:** Map of the CDFW CRFS sampling Districts.



**Figure 184:** Distribution of the lengths of copper rockfish measured from 2018-2019 from dockside angler interviews by district.

**Table 49:** Total mortality in metric tons of copper rockfish from 2018 and 2019 from the CPFV fleet by CRFS District.

District	2018	2019	Total
1	9.2	23.1	32.3
2	87.0	51.8	138.8
3	49.3	44.3	93.6
4	30.0	27.9	57.9
5	7.7	13.1	20.7
6	6.0	7.3	13.2

**Table 50:** Number of copper rockfish observed during the CPFV trips sampled onboard by district and trip type from 2018-2019.

District	1/2 day trips	3/4-1 day trips	Overnight trips
1	111	123	62
2	136	588	59
3	140	351	NA
4 and 6	12	138	NA

**Table 51:** Number of copper rockfish measured by district and trip type from the angler interviews in 2018-2019.

District	1/2 day trips	3/4-1 day trips	Overnight trips
1	240	240	69
2	388	1311	189
3	313	664	NA
4 and 6	12	302	NA

**Table 52:** Number of CPFV trips sampled as part of the onboard observer survey during 2018-2019, the percent of trips with copper rockfish observed, and the total number of recorded copper rockfish by trip type and District. District 4 and 6 were combined to retain confidentiality. No trips from District 5 were sampled.

District	1/2 day trips	3/4-1 day trips	Overnight trips	Percent trips with copper rockfish	Total number of copper rock- fishobserved
1	435	119	5	21%	296
2	36	93	4	72%	783
3	86	55	0	67%	864
4 and 6	10	69	0	61%	150
Percent of trips encountering copper rockfish	26%	60%	89%	-	-
Copper rockfish observed	399	1,200	121	-	-

**Table 53:** Number of CPFV logbook entries with at least one rockfish, grouped by region fished and trip type from 2018-2019.

Region	Multi-day	Single-day
Mexico	223	636
District 1 mainland	0	8324
Southern Channel Islands	1170	1572
District 2 mainland	0	663
Northern Channel Islands	1135	2600
Southern CA Offshore	119	2243
District 3	58	5195
District 4	0	3156
District 5	0	1051
District 6	0	1189

## 9.5 Information Provided by the Commercial and Recreational Fleet Representatives

The copper rockfish STAT held the following three informal virtual meetings with stakeholders as part of the data exploration process:

1. Copper Rockfish and the Commercial Fisheries on January 10, 2023 (24 attendees)
2. Copper Rockfish and the Recreational Fishery South of Point Conception on January 23, 2023 (17 attendees)
3. Copper Rockfish and the Recreational Fishery North of Point Conception on January 30, 2023 (19 attendees)

A summary of the information learned from these meetings is provided here. We would like to thank everyone who participated in our virtual meetings for their willingness to participate in the stock assessment process and provide additional insight into the fisheries for copper rockfish.

### 9.5.1 Preferred Habitat and Life History Notes

Copper rockfish are “king” of the reef and appear to push other species off of the best habitat within a reef. The STAT consistently heard from all fishermen that copper rockfish are not caught in areas of high relief. Copper rockfish prefer areas of flatter or broken hard bottom, and also venture out over soft bottom habitat. Larger fish are often caught over soft bottom where they are feeding on sanddabs. Copper rockfish do not feed on pyrosomes as frequently as other rockfish species. Copper rockfish will follow prey targets, including pelagic red crabs that have been observed farther north than usual. In general, rockfish catches decreased when prey (anchovies, squid, myctophids, pyrosomes, etc.) are hyper-abundant. Fishermen notice ontogenetic shifts, as well as seasonal and weather related movements of copper rockfish. Copper rockfish also tend to move based on weather conditions. North of Point Conception (34° 27' N. lat.), copper rockfish cannot be found during bad weather and seem to move to deeper waters. This appears true of all rockfish in general with respect to long period swells that create heavy bottom surge, increased turbulence and suspend flocculant materials near the bottom.

### 9.5.2 Commercial Fishery

A Deeper Nearshore permit is needed to fish copper rockfish commercially in California. The trip limits of 75 pounds per two-month period, in combination with depth restrictions, have negatively impacted the commercial targeting of copper rockfish. The fleet reported releasing (by descending back to depth) more fish in 2022 with the current lower quota of 75 pounds per two-month period. Copper rockfish are a component of the live fish fishery in both northern and southern California. They are most often targeted to be sold live, but those fish that do not survive well are sold dead at a much lower price. Copper rockfish are encountered at an average depth of 45 fm, but can be found out to 60 fm.

The live fish market is constantly in flux and can be difficult to predict. In southern California, a large portion of the live-fish fishery collapsed during the COVID-19 pandemic and has not returned. A fisherman’s market in San Diego has allowed individual fishermen to sell fish directly to the public. Many of the live fish buyers in central California transport live fish to Las Vegas, Nevada or Los Angeles and San Jose in California.

North of Point Conception, copper rockfish is a target of the commercial fleet. North of Cape Mendocino (40° 10' N. lat.), live copper rockfish sell for 3-4 times the price of dead. For fishermen targeting black rockfish in the north, copper rockfish are an incidental catch of value. Out of Morro Bay, copper rockfish ranging between 1 to 6 pounds are most common in the 10-15 fm range and also sell for \$7 to \$8 per pound. In shallow waters, fishermen will use traps within the live-fish fleet

and vertical gear for deeper waters. In Central California (near Morro Bay) the nearshore live-fish target species live in the kelp beds and larger copper rockfish are on the outside edges of the reef. Larger coppers are typically found on isolated outcrops. It's rare for the commercial live fleet to fish deeper than 15 fm, and in central California it's harder to keep fish exhibiting barotrauma alive. The price of live fish is much higher.

Commercial fishermen from multiple areas along the coast emphasized that the price differential for copper by size is not as pronounced as it is for other species landed in the live-fish fishery. North of San Francisco, the commercial fleet encounters larger copper rockfish (~ 7 pounds) in general. Fish smaller than 2.5 - 3 pounds (approximately 14-17 inches) are desired by the live-fish buyers and the restaurant market and thus will sell for a higher price. The larger fish can be retailed to the general public.

South of Point Conception, copper rockfish are not generally a target species for the live-fish fishery and have been difficult to market. The fleet is now marketing copper rockfish in Southern California as a species similar to the popular "grouper" (bocaccio rockfish, *S. paucispinis*) and demand is increasing. The majority of commercially caught copper rockfish in Southern California are sold dead. The price of a dead copper in San Diego is around \$6 per pound. The fleet can keep copper alive from depths as deep as 60 fathoms with no issue. Coppers seem to be the hardiest of the rockfish species.

### 9.5.3 Recreational Fishery

In 1997 there were approximately 295 CPFVs in California and in 2022 that number was reduced to 193 active Coast Guard inspected CPFVs, defined as vessels that can carry seven or more passengers. Of the 193 CPFVs in the state, 78 fish offshore exclusively. The number of active six-pack vessels is much less.

During the COVID-19 pandemic, reduced loads were required on the CPFVs to maintain distancing among passengers. Customers preferred the reduced loads that resulted in a less crowded vessel and have been willing to pay the increased charter costs to maintain the reduced loads post-COVID. This is true along the entire coast of California for Coast Guard inspected vessels.

**9.5.3.1 North of Point Conception** The majority of vessels north of Bodega Bay are six-packs. Vessels fishing out of Eureka generally fish closer to shore due to weather and fuel costs. The primary target in this area is salmon, and vessels will switch to rockfish especially if salmon are not biting or salmon season is closed.

Larger copper rockfish can be found in 40-60 feet of water and swell is a good indicator for the presence of copper rockfish. If there is swell, the copper rockfish remain close to the bottom and are not as active, i.e., there is a reduced chance of catching copper rockfish. In Eureka, copper rockfish are a desirable species in the recreational fleet due to their larger average size. Copper rockfish would not be caught more than 5-10 feet off the bottom.

In central California, small copper rockfish can be found in 100+ feet of water at the edge of the Farallon Islands. The last two to three weeks of December, fishermen out of Emeryville, California find aggregations of copper rockfish on shale beds where they are not usually present.

Small copper rockfish have been caught off the the jetties in Humboldt, Pillar Point Harbor, and San Francisco, California. In the Half Moon Bay CFPV fleet, copper rockfish are rarely observed shallower than 35 fathoms and they tend to only bite the bottom hook. Stakeholder reported that the gear regulations from unlimited hooks to two hooks per line and a one pole limit in 1999-2000 resulted in increased loss of fish to sea lions.



**9.5.3.2 South of Point Conception** After the depth restrictions and other closures, the fleet moved to different fishing grounds and the desire for copper rockfish increased retention. Over half of the habitat regularly fished by the 1/2-day vessels out of Mission Bay in San Diego is now within in protected areas closed to fishing, and the depth closures moved effort from offshore to inshore (<50-60fa) starting in 2001. During the summer months the effort of the fleet in southern California shifts to pelagic species and kelp and sand bass, the timing of which is dependent on ocean temperatures. There is more pressure on the rockfish stocks during cold water years.

The business of the recreational fleet is tied to the state of the economy. When fuel prices are high there are fewer boats fishing. Around 2014-2015, as the economy recovered, business started increasing. Beginning in 2022, the CPFV fleet in southern California made a concerted effort to avoid copper rockfish grounds, and when copper rockfish were encountered, encouraged their clients to release and descend copper rockfish back to depth. Anglers who were not catching as many fish were more interested in retaining their copper rockfish.

In general, there is less rocky habitat in southern California compared to northern California. In southern California towards San Diego, coppers are typically found in less than 35 fm with juveniles in less than 10 fm. In some areas, size classes of coppers are mixed and are not caught deeper than 60 fm.

A portion of the U.S. fleet fishes rockfish in Mexican waters where there are some known areas of higher copper rockfish density. At the Coronado Islands in Mexico, coppers are typically found in 28-35 fm on low-relief habitat. Fishing is more consistent in Mexican waters.

The activity of private vessels is dependent on ocean conditions, the vessel's size, range and fuel costs. Private vessels of >25 ft are usually focused on pelagic species and may fish rockfish during the transit to or from highly migratory species grounds. It's difficult for the private anglers to access offshore waters at depths of 50+ fm.

#### **9.5.4 Additional Notes of Interest**

Some of the meeting attendees participate in Cooperative Research, such as the NWFSC and the CCFRP Hook and Line surveys and the SWFSC Cooperative Sampling Program.

During the NWFSC Hook and Line survey, there have been times when the vermilion and widow rockfishes are abundant and the lines are reeled in before even reaching the bottom where copper rockfish may be encountered. Anglers who previously participated in ROV studies with NMFS observed rockfish species moving to the bottom and hiding in crevices when the ground swell reached 6-7 ft. There is interest in participation in future ROV surveys.

We heard interest from the CPFV fleet in deploying conductivity, temperature, and depth (CTD) devices during their trips. Fishermen are interested in tagging fish they release.

The number one question posed to the STAT at all meetings was, "How will the stock assessment account for closed areas?" The fleet would like to see some accounting for these areas in the assessment models.