The status of copper rockfish (*Sebastes caurinus*) in U.S. waters off the coast of California south of Point Conception in 2021 using catch and length data

by
Chantel R. Wetzel[1]
Brian J. Langseth[1]
Jason M. Cope[1]
John E. Budrick[2]

[1]Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, Washington 98112
[2]California Department of Fish and Wildlife, 1123 Industrial Rd., Suite 300, San Carlos, California 94070

December 2021

Correct citation for this publication:

Wetzel, C.R., B.J. Langseth, J.M. Cope, J.E. Budrick. 2021. The status of copper rockfish (*Sebastes caurinus*) in U.S. waters off the coast of California south of Point Conception in 2021 using catch and length data. , Portland, Oregon. 177 p.

Contents

1 Introduction

1.1 Basic Information

This assessment reports the status of copper rockfish (*Sebastes caurinus*) off the California coast, south of Point Conception, using data through 2020.

Copper rockfish is a medium- to large-sized nearshore rockfish found from Mexico to Alaska. The core range is comparatively large, from northern Baja Mexico to the Gulf of Alaska, as well as in Puget Sound. Copper rockfish have historically been a part of both commercial and recreational fisheries throughout its range.

Copper rockfish are commonly found in waters less than 130 meters in depth in nearshore kelp forests and rocky habitat (Love 1996). The diets of copper rockfish consist primarily of crustaceans, mollusks, and fish (Lea et al. 1999; Bizzarro et al. 2017). The body coloring of copper rockfish varies across the West Coast with northern fish often exhibiting dark brown to olive with southern fish exhibiting yellow to olive-pink variations in color (Miller and Lea 1972), which initially led to them being designated as two separate species (*S. caurinus* and *S. vexillaris*).

Numerous genetic studies have been performed looking for genetic variation in copper rockfish, with variable outcomes. Genetic work has revealed significant differences between Puget Sound and coastal stocks (Dick et al. 2014). Stocks along the West Coast have not been determined to be genetically distinct populations, but significant population subdivision has been detected, indicating limited oceanographic exchange among geographically proximate locations (Buonaccorsi et al. 2002; Johansson et al. 2008). A specific study examining copper rockfish populations off the coast of Santa Barbara and Monterey California identified a genetic break between the north and south, with moderate differentiation (Sivasundar and Palumbi 2010).

Copper rockfish are a relatively long-lived rockfish, estimated to live at least 50 years (Love 1996). Copper rockfish was 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.

1.2 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 1). The recreational fishery is comprised of individual recreational fishers and charter recreational private vessels 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 a 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 when 20 to 60 fm depth restrictions ranging from 20 fm in the Northern Management Area to 60 fm in the Southern Management Area were put in place in various management area delineations along the state (see Appendix Section 9.4). This shifting effort onto the nearshore, concomitantly increased catch rates for nearshore rockfish including copper rockfish in the remaining open depths, though season lengths were greatly curtailed.

Following all previously overfished groundfish species, other than yelloweye rockfish, being declared rebuilt by 2019, deeper depth restrictions were offered in the Southern Management area allowing resumed access to shelf rockfish in less than 75 fm and are currently 100 fm as of 2021. The increased access to deeper depths south of Point Conception with the rebuilding of cowcod is expected to reduce the effort in nearshore waters where copper rockfish is most prevalent. To the north of Point Conception where yelloweye rockfish are prevalent, depth constraints persist and effort remains focused on the nearshore in 30 to 50 fm depending on the management area. As yelloweye rockfish continues to rebuild, incremental increases in access to deeper depths are expected, which will likely further reduce the effort in nearshore waters where copper rockfish is most prevalent.

Prior to development of the live fish market in the 1980s, there was very little commercial catch of copper rockfish, with dead copper rockfish fetching 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. Copper rockfish were caught along with other rockfish to some degree in the nearshore or caught as bycatch by vessels targeting other more valuable stocks such as lingcod.

In the late 1980s and early 1990s a market for fish landed live arose out of Los Angeles and the 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 -7 per fish (Bill James, personal communication). 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 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 Nearshore Fisheries Management Plan (Wilson-Vandenberg et al. 2014). In 2003, the CDFW implemented a Nearshore Restricted Access Permit system, including the requirement of a Deeper Nearshore Fishery Species Permit to retain copper rockfish, with the overall goal of reducing the number of participants to a more sustainable level, with permit issuance based on historical landings history by the retrospective qualifying date. The result was a reduction in permits issued from 1,127 in 1999 to 505 in 2003, greatly reducing catch levels. 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.

The population of copper rockfish south of Point Conception to the U.S./Mexico border is assessed here as a separate stock (Figure 2). This decision was made based on oceanographic conditions and previous assessments of copper rockfish. The stock split in California waters at Point Conception accounts for water circulation patterns that create a natural barrier between nearshore rockfish population north and south of the area. An additional analysis is presented in the Appendix, Section 9.7, that summarized current research to inform of stock structure in copper rockfish off the West Coast and evaluated the available information to guide selection of the management area relative to the assessment area.

1.3 Summary of Management History and Performance

Copper rockfish is managed by the Pacific Fishery Management Council (PFMC) as a part of the Nearshore Rockfish North and Nearshore Rockfish South complexes, split at 40° 10’ N. lat. off the West Coast. Each complex, comprised of nearshore rockfish species, is managed based on a complex level overfishing limit (OFL) and annual catch limit (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 complex (North or South). Removals for species within the Nearshore Rockfish North and South complexes are managed and tracked against the complex total OFL and ACL, rather than on a species by species basis.

Table 2 shows the Nearshore Rockfish North and South complex level OFLs and ACLs, the copper rockfish OFL and ACL contributions amounts for both areas, the state-specific allocations of the copper rockfish ACL contribution (the south copper rockfish ACL plus 25 percent allocated to California from the north ACL), and the total removals for California, south of Point Conception.

2 Data

A description of each data source is provided below (Figure 3).

2.1 Fishery-Dependent Data

2.1.1 Commercial Fishery

2.1.1.1 Landings

The commercial removals were extracted from the The Pacific Fisheries Information Network (PacFIN) database for 1981-2020 on February 21, 2021. Commercial removals for copper rockfish were combined into a single fleet by aggregating across gear types (Table 1 and Figure 1). Commercial landings prior to 1969 were extracted from the SWFSC catch 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 Southern California. Region 6 in Ralston et al. (2010) includes Santa Barbara County (mainly south of Point Conception), plus some major ports north of Point Conception. To allocate catches 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 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 catch in Region 6 is not ideal, we see this as the best available option in the absence of port-specific species composition data. Years with no data were imputed using ratio estimates from adjacent years. Annual catches from unknown locations (Region 0) and unknown gear types were allocated proportional to the catches from known regions and gears.

Catches from known regions, but unknown gears, were allocated proportional to catches by known gears within the same region. In this way, total annual removals in California were kept consistent with those reported by Ralston et al. (2010), and assigned to the assessment areas north and south of Point Conception.

In September 2005, the California Cooperative Groundfish Survey (CCGS CALCOM) incorporated newly acquired commercial landings statistics from 1969-80 into CALCOM database. 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 1981-2020 were extracted from the PacFIN database (extracted February 22, 2021). Landings were separated for the area south of Point Conception based on port of landing. The input catches in the model represent total removals: landings plus discards. Discards totals for the commercial fleet from 2002-2019 were determined based on West Coast Groundfish Observer Program (WCGOP) data provided in the Groundfish Expanded Mortality Multiyear (GEMM) product. The total coastwide observed discards were allocated to state and area based on the total observed landings observed by WCGOP. The historical commercial discard mortality used to adjust the landings data to account for total removals was calculated based on the average coastwide discard rates from WCGOP of 4.4 percent.

2.1.1.2 Length Compositions

Biological data were extracted from the PacFIN Biological Data System on February 21, 2001. 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 (Table 4). The number of total lengths available was highly variable ranging from 2 to 542 samples per year. The samples prior to 1995 were sparse and variable across sizes. During model explorations these low sample years appeared to have a disproportionate impact on selectivity estimates and were therefore removed from the base model (treated as a 'ghost' fleet, see Appendix A for implied fits to these lengths).

The majority of lengths observed by the commercial fleet were between approximately 25 - 45 cm (Figure 4), with relatively low observations of fish larger than 45 cm (detailed length compositions by year can be found in the Appendix, Section 9.2. The mean length observed by year ranged between 32 - 39 cm (Figure 5). The mean length across commercial lengths was the smallest in 2014 (around 32 cm) and has generally incrementally increased in the subsequent years.

The input sample sizes were calculated via the Stewart method (Ian Stewart, personal communication) based on a combination of trips and fish sampled:

$$\text{Input effN} = N_{\text{trips}} + 0.138 * N_{\text{fish}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} < 44$$
$$\text{Input effN} = 7.06 * N_{\text{trips}} \text{ if } N_{\text{fish}}/N_{\text{trips}} \text{ is} \geq 44$$

2.1.2 Recreational Fishery

2.1.2.1 Landings

The recreational fishery is the main source of exploitation of copper rockfish. The recreational catches of copper rockfish south of Point Conception in California waters peaked in the late 1970s and early 1980s. Removals declined in the 1990s and early 2000s. The removals remained relatively low until 2015 and after. The increase in removals in 2015 was likely due to new Annual Catch Limits being updated based on the 2013 assessment (Cope et al. 2013).

Recreational removal estimates from 1928 to 1980 were obtained from the historical reconstruction (Ralston et al. 2010), which were available split north and south of Point Conception. Recreational removals from 1981 - 1989 and 1993 - 2003 were obtained from Marine Recreational Fisheries Statistics Survey (MRFSS). 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 removals from Ralston et al. (2010) was used.

The MRFSS definition of "Southern California" included San Luis Obispo County from 1981 - 1989, requiring the catches from this county to be split out and removed from the recreational removals south of 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 County. The ratio of catches (0.316) in San Luis Obispo to the total removals calculated based on the data from Albin et al. (1993) was estimated and used to adjust the MRFSS catches to account for the removals north of Point Conception.

There are three years without removals, 1990 - 1992, available in the MRFSS data. Removals for the missing years were filled in by applying a linear ramp in removals between the 1989 and 1993 values.

Recreational landings from 2004 - 2020 were obtained from California Recreational Fisheries Survey (CRFS available on the Recreational Fisheries Information Network, RecFIN). Both data sources, MRFSS and CRFS, provide total mortality which combined observed landings plus estimates of discarded fish.

The recreational removals from the historical reconstruction from 1928 - 1980 account for only landed fish. A historical discard rate of 3 percent based on Miller and Gotshall (1965) was used to estimate total catches for this period. MRSS and CRFS each provide estimates of total mortality so no additional discard assumptions were made.

2.1.2.2 Length Compositions

Length data for retained catch from MRFSS (1980-2003) and CRFS (2004-2020) were downloaded from the RecFIN website. Recreational length data were available starting in 1980 (Table 5). The length data from the recreational fleet generally ranged between 25 to approximately 45 cm (Figure 6), with limited observations of fish greater than 45 cm. The annual mean length observed was relatively stable between 2004 and 2011, followed by a minor dip in mean size and slight increase in recent years (Figure 7). Detailed length compositions by year can be found in the Appendix, Section 9.2.

The input sample sizes for the recreational length data were set equal to the number of length samples available by year.

2.2 Fishery-Independent Data

2.2.1 NWFSC Hook and Line Survey

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 8) 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).

Copper rockfish have been observed at multiple sampling sites by the NWFSC Hook and Line Survey each year between 2004 - 2019 (Table 6). Starting in 2014 the NWFSC Hook and Line Survey added sampling sites located within the cowcod conservation area (CCA). Across all sample years and sample sites the NWFSC Hook and Line Survey has observed a total of 1,117 copper rockfish. Copper rockfish have been observed both outside and inside the CCA (Figures 9 and 10). However, the limited number of copper rockfish observations within the CCA constrained the ability to determine whether the CCA impacted the frequency and or sizes observed compared to the other areas sampled (non-CCA sampling sites). Copper rockfish were observed at sites with depth ranging between 40 - 120 m with only the largest sizes being observed at the greatest depths (Figure 11).

Copper rockfish caught in the NWFSC Hook and Line Survey were generally between 30 and 50 cm for both sexes (Figure 12). The mean length observed by year was variable with an appreciable drop in the mean sized observed in 2012 but has gradually increased in the subsequent years (Figure 13). Detailed length compositions by year can be found in the Appendix, Section 9.2. The input sample sizes for the composition data were set equal to the number of length samples available by year.

While copper rockfish are not observed in large numbers similar to vermilion/sunset rockfish (N = 23,110), greenspotted rockfish (N = 4,432), or bocaccio (N = 16,519) in the NWFSC Hook and Line Survey, there are observations per year to support an index of abundance although it may be uncertain. An annual index of abundance was calculated from the NWFSC Hook and Line Survey data following the methods put Harms et al. (2010) based on the AIC criterion. The index of abundance was calculated using a binomial generalized-linear model. The final index includes year, site, number of hooks, fisher, drop number, and swell height as covariates. The single index of abundance was calculated using observations from both outside and within the CCA (Table 7 and Figure 14). Due to the limited number of copper rockfish observations within the CCA, calculating an index of abundance using only data collected outside the CCAs was similar in trend and variance to the index calculated when using all available data. The diagnostics for the binomial generalized-linear model are shown in Figure 15.

2.2.2 NWFSC West Coast Groundfish Bottom Trawl Survey

The NWFSC West Coast Groundfish Bottom Trawl Survey (WCGBTS) 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 WCGBTS were limited (Table 8). The WCGBTS 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 closely associated with rock substrate. The WCGBTS had limited tows by year where copper rockfish were observed within this area, preventing the calculation of an index of abundance for copper rockfish. With limited length observations and in the absence of an index of abundance to link these data to, this data set was not used in the base model.

2.3 Biological Data

2.3.1 Natural Mortality

The current method for developing a prior on natural mortality for West Coast groundfish stock assessments is based on Hamel (2015), a method for combining 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. This approach modifies work done by Then et al. (2015) who estimated M and related life history parameters across a large number of fish species from which to develop an M estimator for fish species in general. They concluded by recommending M estimates be based on maximum age alone, based on an updated Hoenig non-linear least squares estimator $M = 4.899A_{\text{max}}^{-0.916}$. Hamel (personal communication) 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:

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

where A_{max} is the maximum age. The prior is defined as a lognormal distribution with mean $ln(5.4/A_{\text{max}})$ and standard error = 0.438. Using a maximum age of 50, the point estimate and median of the prior is 0.108 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 was 51 years with two observations, one each off of the coast of Washington and Oregon in 2019. The maximum age in the model was set at 50 years. This selection was consistent with the literature examining the longevity of copper rockfish (Love 1996) and was supported by the observed ages that had multiple observations of fish between 44 and 51 years of age.

2.3.2 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 WCGBTS and the NWFSC Hook and Line survey (Figure 16). The estimated length-weight relationship for female fish was W = 9.56e-06$L^{3.19}$ and males 1.08e-05$L^{3.15}$ where L is length in cm and W is weight in kilograms (Figure 17).

2.3.3 Growth (Length-at-Age)

The length-at-age was estimated for male and female copper rockfish south of Point Conception using data combined across multiple sources. Given variable oceangraphic conditions north and south of Point Conception, among other factors, differences in growth patterns in the same species among areas may occur. Ideally a full area-specific growth curve would be externally estimated by sex (parameters k, L_∞, $L1$, and $L2$ within Stock Synthesis) based on a single age and growth study. However, given limitations in ageing capacity a targeted sampling approach was applied. The Cooperative Ageing Program (CAP) selected a subsample of larger (greater than 35 cm) of copper rockfish observed by both the NWFSC Hook and Line Survey and the WCGBTS (Figure 18). These observations were combined with simulated data based on a published growth study for copper rockfish by Lea et al. (1999). Fishes sampled by Lea et al. (1999) study were for the most part collected off central California between July 1978 through December 1985. This study included numerous observations of young fish and also reported the mean length, the number of observations, and the standard deviation of the length observations by age. These pieces of information were used to simulate length-at-age data that would be representative of the study's data for fish younger than 5 years of age (since data on individual fish were not reported). The simulated data for young fish appeared consistent with data from older fish observed in the survey data sources (Figure 19). This combined data set was used to calculate the growth curves for male and female copper rockfish that were used in this assessment. The length-at-age observations from the surveys show minimal differences to those collected off the Oregon and Washington coast from fishery-dependent sources (Figure 20).

The calculated growth parameters used in this assessment indicated females and males have similar, if not identical, growth trajectories. Sex-specific growth parameters were estimated at the following values:

$$\text{Females } L_\infty = 47.4 \text{ cm}; k = 0.231$$
$$\text{Males } L_\infty = 47.1 \text{ cm}; k = 0.238$$

These values were fixed within the base model for male and female copper rockfish. The coefficient of variation (CV) around young and old fish was fixed at a value of 0.10 for both sexes, a value that was base on values observed across other groundfish stocks. The length-at-age curve with the CV around length-at-age by sex is shown in Figure 21.

In contrast, the length-at-age values cited in the 2013 data-moderate assessment (Cope et al. 2013) for copper rockfish (although not directly used by the data-moderate model) were from Lea et al. (1999). The L_∞ from Lea et al. (1999) by sex were quite a bit larger than those estimated for this assessment. In Lea et al. (1999), young fish were well sampled; however, there were fewer than 5 observations of fish older than 12 years of age, which appears to have led to a poorly informed estimate of L_∞.

2.3.4 Maturation and Fecundity

Maturity-at-length was based on maturity reads conducted by Melissa Head at the NWFSC examining a total of 111 samples collected south of Point Conception by the NWFSC Hook and Line Survey and WCGBTS. 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 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 was estimated at 34.3 cm and slope of -0.37 (Figure 22). This area-specific maturity-at-length estimate is relatively similar to the biological maturity curve assumed for copper rockfish north of Point Conception based on the work of Hannah (2014) which estimated the 50 percent size-at-maturity of 34.8 cm 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 equal to 3.362e-07$L^{3.68}$ in millions of eggs where L is length in cm. Fecundity-at-length is shown in Figure 23.

2.3.5 Sex Ratio

There were limited sex-specific observations by length or age across biological data sources.

The sex ratio of copper rockfish by length and age across all available data sources off the West Coast are shown in Figures 24 and 25. The sex ratio of young fish was assumed to be 1:1.

3 Assessment Model

3.1 Summary of Previous Assessments

Copper rockfish was last assessed in 2013 (Cope et al. 2013). The stock was assessed 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 of maximum productivity). Copper rockfish was assessed as two separated stocks, split north and south of Point Conception. 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.

3.1.1 Bridging Analysis

A bridging analysis was conducted to replicate the results from XDB-SRA. XDB-SRA is a delay-difference model that uses a production function to define biomass and dynamics of a stock. XDB-SRA does not explicitly parameterize weight-at-length and length-at-age. The bridge Stock Synthesis model assumed a structure similar to XDB-SRA: single-sex, deterministic recruitment, and knife-edged selectivity equal to 50 percent maturity-at-length. The growth in the bridge Stock Synthesis model was based on the biological values provided in the 2013 assessment for copper rockfish (Cope et al. 2013), although the XDB-SRA does not explicitly define growth. The bridge model used the data from the XDB-SRA model: catches and indices, the median parameter values from XDB-SRA: depletion in the year 2000, natural mortality, and productivity (steepness). The bridge model used the 3-parameter Ricker-Power stock-recruitment function which can replicate the stock recruitment relationship with XDB-SRA.

The bridge model estimated a stock status time series that matched the estimate from XDB-SRA but estimated a reduced stock size across time compared to XDB-SRA (Figure 26, red line). This mis-match in scale alone implied a difference in the implied growth (all mature biomass assumed equal) within XDB-SRA versus the weight-at-length parameterization for the bridge model. The female weight-at-length was adjusted within the bridge model to produce a stock trajectory that matched in scale the results from XDB-SRA (Figures 26 and 27).

Once the matching bridge structure was identified, the parameterization of the model was updated in a step-wise fashion by the following steps:

1. Remove the depletion ”survey” for the year 2000.
2. Update all biology to match those applied in the base model (natural mortality, length-weight, length-at-age, fecundity, and maturity).
3. Switch to a Beverton-Holt stock-recruitment relationship with a steepness value of 0.72, the value in the base model.
4. Update catches through 2012, lumped into a single fleet.
5. Add all lengths to the model through 2012, lumped into a single fleet. Allow for asymptotic selectivity estimation using the double normal selectivity parameterization.
6. Remove the indices of abundance used in the 2013 XDB-SRA model.
7. Add in the NWFSC Hook and Line Suvey index of abundance, length data, and fleet specific selectivity curve.
8. Separate catches and lengths into the fleet structure assumed in the base model. Allow for fleet-specific selectivity estimation.
9. Turn on annual recruitment deviations.

Removing the depletion “survey” resulted in a shift upward in scale and stock status in 2013 (Figures 28 and 29). Updating the biology included changing the length-weight, length-at-age, maturity, and transitioning the fecundity assumption from being equal to spawning biomass to being in terms of eggs and body size (spawning output). Figure 30 shows only the time series in terms of spawning output for ease of visibility. The comparable quantity, stock status, was more pessimistic relative to the 2013 XDB-SRA model (Figure 29). All subsequent changes or additions to the 2013 model resulted in a more pessimistic view of the stock (Figure 29). The largest changes resulted when the length composition data was added and the 2013 fishery-dependent indices removed. The fishery-dependent indices used in the 2013 copper rockfish south model were variable but had a slight increasing trend (see Figure 69 in Cope et al. (2013)). The length data from the recreational fishery, the main source of removals, has limited observation of larger copper rockfish, with the peak of the length data distribution around 30 cm. The observed length distribution combined with an asymptotic selectivity assumption resulted in a highly pessimistic estimate of stock status.

The bridge model was modified from this point to determine the base model by extending the catches, extending fishery and survey lengths to 2020, adding a survey fleet for the NWFSC Hook and Line Survey with an index of abundance and length compositions, and updating and/or changing model assumptions based upon fits to the data.

3.2 Model Structure and Assumptions

Copper rockfish south of Point Conception were assessed using a two-sex model with sex-specific life history parameters. The model assumed two fishing fleets: 1) commercial and 2) recreational fleets with removals beginning in 1916 and one survey fleet, the NWFSC Hook and Line Survey. Selectivity was specified for all fleets in the model using the double normal parameterization within Stock Synthesis. The selectivity for the commercial and recreational fleets were allowed to estimate dome-shaped selectivity and the NWFSC Hook and Line Survey selectivity was fixed to be asymptotic.

3.2.1 Modeling Platform and Structure

The assessment was conducted using Stock Synthesis version 3.30.16 developed by Dr. Richard Methot at NOAA, NWFSC (Methot and Wetzel 2013). This most recent version was used because it included improvements and corrections to older model versions. 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 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 (2015) 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 yr^{-1} and a standard error of 0.438.

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.

3.2.3 Data Weighting

Length composition data for the commercial fishery started with a sample size determined from the equation listed in Sections 2.1.1. The input sample size for the recreational fishery and NWFSC Hook and Line Survey length composition data were set equal to the number of length samples by year.

The base model was weighted using the "Francis method", which was based on equation TA1.8 in Francis (2011). 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). Sensitivities were performed examining the difference results due to in weighting using McAllister-Ianelli Harmonic Mean Weighting (1997) and the Dirichlet Multinomial Weighting (2017).

3.2.4 Estimated and Fixed Parameters

There were 12 estimated parameters in the base model. These included 1 parameter for R_0, 1 for estimated added variance for the NWFSC Hook and Line Survey index of abundance, and 10 parameters for selectivity. The estimation of annual recruitment deviations were explored but were not included in the base model due to correlation with high catches during periods of estimated low stock abundance.

Fixed parameters in the model were as follows. Steepness was fixed at 0.72, the mean of the prior. Natural mortality was fixed at 0.108 yr^{-1} for females and males, the median of the prior. Annual recruitment was deterministic predicted from the stock-recruitment curve. Growth, maturity-at-length, and length-at-weight was fixed as described above in Section 2.3. Likelihood profiles were conducted across steepness, natural mortality, and growth parameters to examine the impact of the selected fixed values in the model.

Dome-shaped selectivity was explored for all fleets within the model. Older copper rockfish are often found in deeper waters and may move into areas that limit their availability to fishing gear. After explorations, the commercial and recreational fleets were both allowed to estimate dome-shaped selectivity due to extreme model estimates (highly pessimistic) when forced to be asymptotic. Selectivity for both fleets used a double normal selectivity parameterization where the ascending width, the size at peak, and the final selectivity parameters estimated in the base model. Estimating the descending width was explored during model explorations and was fixed in the base model based on these explorations.

The selectivity for the NWFSC Hook and Line Survey was also modeled using a double normal parameterization with selectivity fixed to be asymptotic. The ascending width and the size at peak selectivity were estimated in the base model.

3.3 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 south of Point Conception. The model contains many assumptions to achieve parsimony and uses many sources of data to estimate reality. A series of investigative model runs was conducted to achieve the final base model.

3.4 Base Model Results

The base model parameter estimates along with approximate asymptotic standard errors are shown in Table 10 and the likelihood components are shown in Table 11. Estimates of derived reference points and approximate 95 percent asymptotic confidence intervals are shown in Table 16. Estimates of stock size and status over time are shown in Table 12.

3.4.1 Parameter Estimates

Estimated parameter values are provided in Table 10. The $\log(R_0)$ was estimated at 5.5. The selectivity curves for the commercial and recreational fleets are shown in Figure 31. The selectivity for both the commercial and recreational fleets were estimated to be dome-shaped, with reduced selectivity for larger copper rockfish. However, a dome-shaped selectivity was not anticipated *a priori* but forcing one or both of the fleets to have asymptotic selectivity resulted in an extremely depleted stock status (~3 percent when both fleets assumed asymptotic selectivity). The highly pessimistic stock status was deemed to have limited plausibility given the ongoing high removals of copper rockfish in recent years. Multiple sensitivities were performed to examine the assumption of dome-shaped selectivity in the base model (see Section 3.5.2).

The commercial fleet selectivity peaked at 35.5 cm and decreased to low selectivity rates for larger copper rockfish (Figure 31). The recreational fleet selectivity peaked at smaller sizes relative to the commercial fleet with full selectivity occurring at 29.6 cm. The esimated peak selectivities for the commercial and recreational fleets were less than the length-at-50 percent maturity (34.3 cm).

The NWFSC Hook and Line Survey was fixed to have asymptotic selectivity with selectivity peaking at 38.5 cm (Figure 31). The NWFSC Hook and Line Survey selectivity is markedly different compared to the commercial and recreational fleets. This difference was speculated to be due to two factors: 1) the survey sampling deeper waters that, until recently, the recreational fishery did not have access to where larger copper rockfish are commonly found, and 2) many of the observations of large copper rockfish by the NWFSC Hook and Line Survey were around areas that would likely require at least a 3/4 day trip (i.e., Santa Rosa Island, San Miguel Island) which would put them out of range of the more typical 1/2 day trip recreational fishing efforts (John Harms, personal communication, NOAA, NWFSC).

The stock-recruit curve resulting from a value of steepness fixed at 0.72 is shown in Figure 32. Annual recruitment deviations were not estimated in the base model due to confounding between recent high catches, estimated low stock abundance, and recruitment deviations. A rise in catches could be related to above average recruitment. However, when recruitment deviations were allowed to be estimated, the estimates of annual recruitment deviations were positively biased in recent years presumably for the model to maintain the population biomass greater than 0 (not extinct). This issue was identified by conducting a 20 year retrospective analysis combined with a plot that reflects the model estimated recruitment strength by year as data were removed. When all data were removed that would inform recent recruitment, the recruitment deviations did not decline to 0, but remained positive (Figure 33). Based on this, recruitment deviations were not estimated in the base model. The stock-recruit curve resulting from a value of steepness fixed at 0.72 is shown in Figure 32. Annual recruitment estimated directly from the stock-recruitment curve are shown in Figure 34.

3.4.2 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 commercial, recreational, and NWFSC Hook and Line Survey fleets. Annual length composition fits are shown in the Appendix, Section 9.1.

The Pearson residuals for the commercial fishery length data are shown in Figure 35. There are limited patterns in the Pearson residuals but there is potential evidence of an above average recruitment moving through the population in recent years. The mean length observed by year from the commercial fleet were uncertain but with a relatively stable mean size until 2014 when the mean length declined and then slowly increase in the subsequent years (Figure 36).

The Pearson residuals for the recreational length data are variable by year (Figure 37). Pearson residuals were positive, observations greater than expected, for larger fish prior to 2000. Adding a block in selectivity for this period was explored during model development but there was little support in the data for the added model complexity (i.e., similar fits to the data). In recent years, there are residual patterns in the length data that likely indicate above average recruitments moving through the population age structure, which the model was unable to capture with deterministic recruitment. The mean length in the early period of data ranged between 28 - 38 cm, with a decline and stabilizing of the mean observed length in recent years around 30 cm (Figure 38).

The Pearson residuals for the NWFSC Hook and Line Survey were variable by year and by sex (Figure 39). Similar to the other data sources in the model there appears to be a pattern of observations greater than the model expectations moving through the population possibly supporting an above average recruitment event prior to 2011 and 2013. The mean length observed by year from the NWFSC Hook and Line Survey varied by year ranging between 35 - 40 cm (Figure 40).

Aggregate fits by fleet are shown in Figure 41. The model fits the aggregated lengths for the commercial and recreational fleet length data generally well.

The fit to the NWFSC Hook and Line Survey index of abundance is shown in Figure 42. The index of abundance was relatively flat between 2004 - 2009, dropped in 2010, and then slowly increases until 2015. The model was unable to capture these trends in the index of abundance and estimated a slightly increasing stock until 2013 and then declining in the final years. The index of abundance had relatively high uncertainty intervals (uncertainty estimated in the index development) by years likely due to the limited observations of copper rockfish in the survey. In order to fit the index of abundance the base model estimated added variance (0.2) which is reflected by the thin bars on Figure 42. The catchability calculated for the NWFSC Hook and Line Survey was 6.14×10^{-5}. Multiple sensitivities (e.g., selectivity shape, no added variance, upweighting the index while downweighting other data sources, estimating annual recruitment deviations) were conducted attempting to produce a better fit to the index of abundance. The only sensitivity that was identified to improve the fit to the index of abundance was estimating annual recruitment deviations. However, adding annual recruitment deviations to the base model was not done due to correlations between recent high catches and recruitment estimates.

3.4.3 Population Trajectory

The predicted spawning output (in millions of eggs) is given in Table 12 and plotted in Figure 43. The estimated spawning output decreases sharply in the mid-1970s reaching a low around 2000. The spawning output slowly increases between 2000 - 2013 and then begins declining in recent years due to an increase in removals starting in 2013. The estimate of total biomass shows a similar pattern over time (Figure 44). Estimates of the unavailable spawning output across time are shown in Figure 45.

The model estimates of spawning output relative the unfished equilibrium declined below the current management threshold limit of 25 percent around 1983 and remained below the limit until 2011, and then drop below the limit once again in 2016 (Figure 46). The fraction unfished at the start of 2021 is estimated to be 18.1 percent, below the rockfish relative biomass target of 40 percent as well as below the management threshold limit of 25 percent.

3.5 Model Diagnostics

3.5.1 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 by 10 percent. This was repeated 100 times with 90 out of 100 runs returned to the base model likelihood. A better, lower negative log-likelihood, model fit was not found. The model did not experience convergence issues when provided with reasonable starting values. Through the jittering done as explained and 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.

3.5.2 Sensitivity Analyses

Several sensitivity analyses were conducted. The majority of the sensitivities conducted was a single exploration from the base model assumptions and/or data, and were not performed in a cumulative fashion.

1. Estimate female natural mortality.
2. Estimate the coefficient of variation of length-at-age for older fish by sex.
3. Estimate annual recruitment deviations.
4. Data weighting according to the McAllister-Ianelli method using the weighting values shown in Table 13.
5. Data weighting according to the Dirichlet method where the estimated parameters are shown in Table 13.
6. Fix selectivity for the commercial fleet to be asymptotic.
7. Fix selectivity for the recreational fleet to be asymptotic.
8. Fix selectivity for both the commercial and recreational fleets to be asymptotic.

9. Remove the NWFSC Hook and Line Survey length and index data.
10. Fit to the dockside RecFIN (1980 - 1988 and 1993 - 2003) and CPFV (1999-2011) indices of abundance used in the 2013 assessment with no estimated added variance.
11. Add additional early CPFV lengths collected during onboard sampling from that were not included in the base model due to not being received until after the assessment review.
12. Include the CPFV lengths prior the previous sensitivity and include additional flexibility in selectivity for both the commercial and recreational fishery allowing for selectivity time blocks that would allow dome-shaped selectivity (if estimated): 1916-2000, 2001-2002, 2003-2011, 2012-2018, and 2019-2020. The time blocks for selectivity were designed to capture changes in percentage of area open to fishing.

Likelihood values and estimates of key parameters from each sensitivity are available in Tables 14 and 15. Plots of the estimated time series of spawning output and relative spawning output are shown in Figures 47 - 50. The majority of sensitivities estimated the final stock status to be below the management threshold limit of 25 percent of unfished spawning output, similar to the base model. Estimating annual recruitment deviations from the stock recruitment curve resulted in a more pessimistic final stock status relative to the base model (Figure 48). The sensitivity that estimated female natural mortality estimated a lower unfished spawning output but a similar final stock size to the base model (Figures 47 and 48).

The two sensitivities that examined alternative parameterization of the recreational selectivity (forced to be asymptotic) estimated a relative stock status of 3 percent in the final year of the model (Figure 50). Fixing the only the commercial selectivity to be asymptotic resulted in slightly more depleted stock relative to the base model (Figure 50). The sensitivity that included the onboard CPFV index of abundance from the 2013 assessment estimated a similar stock size and status relative to the base model (Figures 49 and 50). The sensitivity that included the recreational indices of abundance from the 2013 index-only data-moderate assessment estimated a slightly larger initial spawning output and higher relative biomass compared to the base model, but still below the management threshold of 0.25 (Figures 49 and 50).

The sensitivity of removing the NWFSC Hook and Line Survey length and index data is not shown due to the model estimating a $\log(R_0)$ value at the upper bound ($\log(R_0)$ of 20). This is due to slight shifts in the recreational and commercial selectivity curves. Fixing the selectivity parameters at the values of the base model (estimating $\log(R_0)$ only) resulted in a similar estimate of the unfished spawning output but a more depleted final status in 2021 (0.17) relative to the base model. Splitting the NWFSC Hook and Line Survey data between samples inside and outside the CCA for the index of abundance and compositions data were also explored. However, since there were limited samples of copper rockfish inside the CCAs the estimates from this sensitivity were the same as the base model.

The sensitivity that included the additional CPFV lengths and the increase in selectivity estimation for the commercial and recreational fleet was relatively similar to the base model (Table 15 and Figures 49 and 50). The model estimated dome-shaped selectivity for each block for both fleets with only minimal shifts in the dome-peak and the level of final selectivity for the largest fish.

3.5.3 Area-Based Sensitivity Analyses

Along the coast of California, over the last couple of decades, several marine protected areas that prohibited retention have been created (see Appendix Section 9.5). During model development there was much discussion concerning the model results and whether they reflected the copper rockfish population south of Point Conception as a whole or only reflect the status of the stock in fished areas. In order to understand how the results could possibly vary if a portion of the population was protected from fishing, some simple area-based sensitivities were conducted. These sensitivities make some strong and generous assumptions that do not match the real world system. The first major assumption is that the protected areas have experienced no fishing pressure across all model years (known to not match the true implementation of protected areas). The second assumption is that annual recruitment by year is pooled across both protected and fished areas with the proportion of recruitment settling to each area equal to the area protected (e.g., if 20 percent of the population is protected then 20 percent of annual recruitment settles in that area). Three sensitivities were conducted where the percent of protected area was either 10, 15, or 20 percent of the total population.

The estimated spawning output and fraction unfished for each sensitivity is shown in Figures 51 and 52. All sensitivities that assumed two-areas estimated a lower initial spawning output relative to the base model. The 10 and 20 percent area protected sensitivities estimated the fraction unfished in the final year that were either above or below the base model and the 15 percent protected area sensitivity estimating a similar status to the base model (Figure 52).

3.5.4 Likelihood Profiles

Likelihood profiles were constructed for R_0, steepness, female L_∞, female natural mortality values, female coefficient of variation for older fish (CV_2), and female growth coefficient k separately. These likelihood profiles were constructed by fixing the parameter at specific values and estimated the remaining parameters based on the fixed parameter value.

The $\log(R_0)$ negative log-likelihood was minimized at approximately $\log(R_0)$ of 5.5 (Figure 53). The likelihood component driving the estimate of the $\log(R_0)$ were the length data.

The length data from recreational fleet was the most informative to the estimate of $\log(R_0)$. Assuming higher of lower values of R_0 result in large fluctuations in the scale of the stock and final stock status (Figures 54 and 55). Values of $\log(R_0)$ lower than 5.25 resulted in a crashed population and were not explored further.

For steepness, values from approximately 0.50 to 0.80 were supported by the negative log-likelihood (Figure 56). The information content in the length data by source was variable, with the NWFSC Hook and Line Survey data supporting higher steepness values and the commercial and recreational fleets supporting lower values. Assuming higher steepness values estimated lower initial spawning output and a lower stock status relative to the base model where values greater than 0.85 resulted in a crashed population (Figures 57 and 58).

The negative log-likelihood profile across female natural mortality supported a wide range of values, 0.095 - 0.14 yr^{-1}, compared to the fixed value in the base model 0.108 yr^{-1} (Figure 59). The range of values explored in the profile resulted in large changes to the unfished stock size and but very similar stock status trajectories compared to the base model (Figures 60 and 61).

A profile across a range of female L_∞ values was also conducted (Figure 62). The negative log-likelihood showed support for lower L_∞ values. The L_∞ value for female fish in the model was fixed at 47.36 cm based on external model estimates using length-at-age data. The stock scale and status was quite variable across alternative L_∞ values where assuming the lowest value profiled, 44 cm, resulted in sharp increases status (Figures 63 and 64).

A profile across a range of female k showed support for values from 0.16 - 0.24 yr^{-1} (Figure 65). The k value for female fish in the model was fixed at 0.231 yr^{-1}. The unfished spawning output decreased under lower k values, however, the relative stock status were relatively similar across k values (Figures 66 and 67).

The profile across a range of CV_2 for older females supported CV_2 values from 0.11 and lower (Figure 68). Assuming lower or higher CV_2 values impacted on the unfished spawning output but had very little impact on the the estimated final spawning and output and fraction unfised (Figures 69 and 70).

3.5.5 Length-Based Spawner Recruit Analysis

An exploratory length-based spawner-per-recruit (LB-SPR) analysis using the approach developed by Hordyk et al. (2015) was conducted. This approach assumes asymptotic selectivity and deterministic recruitment to produce independent estimates by year of selectivity and spawner-per-recruit (SPR) effort based on the observed recreational lengths. This analysis indicated the copper rockfish were 50 percent selected size around 25 cm with full selection between 31 - 32 cm (Figure 71). For comparison, the size at 50 percent length-at-maturity was fixed at 34.3 cm south of Point Conception based on the maturity curve developed for this assessment. The LB-SPR estimate of the size at 50 percent selection assuming asymptotic selectivity was consistent with the base model estimates which estimated the peak of selectivity (although allowed to be domed) at sizes less than 50 percent maturity (Figure 31).

3.5.6 Retrospective Analysis

A ten-year retrospective analysis was conducted by running the model using data only through 2010 - 2020 (e.g., Data -10 Year reflects data through 2010). A longer retrospective analysis was conducted to cover years prior to the last assessment in 2013. As years of data were removed the estimates of stock size in recent years declines relative to the base model with the retrospective runs with at least 3 years of removed data having similar stock trajectories (Figures 72 and 73).

3.5.7 Comparison with Other West Coast Stocks

Copper rockfish is assessed as four distinct stocks off the U.S. west coast: south of Point Conception in California; north of Point Conception in California; Oregon; and Washington. The area north of Point Conception off the coast of California was estimated to have the largest unfished spawning output of copper rockfish off the West Coast. The stocks off of the Oregon and Washington coast are smaller in size compared to the California stocks, with the stock off the coast of Washington estimated to have the smallest unfished spawning output. Comparison of the estimated spawning output trajectories for the California stocks are shown in Figure 74 with Oregon and Washington shown in Figure 75. The fraction unfished across all West Coast stocks shown in Figure 76. The California stocks are estimated to be the most depleted, with the stock south of Point Conception estimated below the management threshold of 25 percent of unfished and the stock north of Point Conception estimated to be in the precautionary zone (less than the management target of 40 percent but above the management threshold). The stock off the coast of Washington is estimated to be just above the management target and the Oregon stock well above the target.

3.5.8 Historical Analysis

The estimated spawning output from the previous assessment conducted in 2013 and the base model are shown in Figure 77 and the estimated fraction unfished are shown in Figure

78. The scale of the stock is substantially lower compared to the 2013 assessment. This is due to both a change in units from spawning biomass (2013) to spawning output in terms of millions of eggs (2021) and from changes in length-at-age and weight-at-length parameters (not explicitly defined in 2013). The base model has a significantly more pessimistic view of the relative stock status compared to the 2013 assessment, with the base model estimating that the stock has been below the minimum stock biomass threshold for the majority of years since the early 1980s (the stock was above the threshold briefly between 2011 - 2015).

4 Management

4.1 Reference Points

Reference points were calculated using the estimated selectivity and catch distributions among fleets in the most recent year of the model (2020, Table 16). The estimated sustainable total yields were 51.84 mt when using an $\mathrm{SPR}_{50\%}$ reference harvest rate. The spawning output equivalent to 40 percent of unfished spawning output ($\mathrm{SB}_{40\%}$) was 93.22 million eggs.

The 2020 spawning output relative to unfished equilibrium spawning output, 18.1 percent, is below the management threshold limit of 25 percent of unfished spawning output (Figure 46). The fishing intensity, $1-\mathrm{SPR}$, has been above the harvest rate limit ($\mathrm{SPR}_{50\%}$) in recent years, except 2020 when overall removals declined due to impacts of COVID-19 which reduced recreational fishing effort (Table 12 and Figure 79). The stock is estimated to be below the management target with fishing intensity exceeding the target across recent years (Figure 80). Table 16 shows the full suite of estimated reference points for the base model and Figure 81 shows the equilibrium curve based on a steepness value fixed at 0.72.

4.2 Harvest Projections and Decision Tables

A ten year projection of the base model with catches equal to the estimated Acceptable Biological Catch (ABC) based on the category 2 time-varying σ with $P^* = 0.45$ for years 2023-2032 (Table 17). Since the stock is estimated to be below the management target of 40 percent the buffer value in Table 17 reflects both the 40-10 harvest control rule adjustment and the time-varying scientific uncertainty buffer.

The removals in 2021 and 2022 were initially determined by first summing the adopted ACLs South of 40° 10' Lat. N. and the portion of the North of 40° 10' Lat. N. allocated to California (25 percent - PFMC Groundfish Management Team pers. comm.). Once the total

ACLs for California were determined the portion of the ACL allocated to the area south of Point Conception was based on the percentage of total removals in each area of California (north and south of Point Conception) from 2017 - 2019 based on recommendations from the Grounfish Management Team. At the November 2021 Pacific Fishery Management Council Meeting adopted proposed inseason actions to reduce copper rockfish mortality for 2022 to 73.1 mt for the area south of Point Conception. The projections in Table 17 were update to reflect the new 2022 removal assumptions. The decision table was not updated to reflect these new removal assumptions; however, the change was minimal enough to not impact the interpretation of risk across alternative states of nature.

The axes of uncertainty in the decision table is based on the uncertainty around the spawning biomass in 2021 ($\sigma = 0.327$) via the $\log(R_0)$ parameter. The σ value was used to identify the 12.5 and 87.5 percentiles of the asymptotic standard deviation for the current year, 2021, spawning biomass from the base model to identify the low and high states of nature (i.e., 1.15 standard deviations corresponding to the 12.5 and 87.5 percentiles). Once the 2021 spawning biomass for the low and high states of nature were identified a search across $\log(R_0)$ values were done to attain the current year spawning biomass values. The $\log(R_0)$ values that corresponded with the lower and upper percentiles were 5.44 and 5.55.

Across the low and high states of nature and across alternative future harvest scenarios the fraction of unfished ranges between 0.21 - 0.39 by the end of the 10 year projection period (Table 18). The fraction unfished across the state of natures assuming the ACL removals (the ABC adjusted by the 40:10 harvest control rule) remains below the management target.

4.3 Summary of Copper Rockfish in California Waters

Copper rockfish off the coast of California was assessed as two separate sub-stocks split at Point Conception. However, the stock status for management decisions was based on combined estimates of stock size and status from both of the California area assessments. The combined stock status in 2021 of copper rockfish in California was 31.7 percent. The spawning output by area and summed across California along with the relative spawning outputs for each area are provided in Table 19.

4.4 Evaluation of Scientific Uncertainty

The estimated uncertainty in the base model around the 2021 spawning output is $\sigma = 0.33$ and the uncertainty in the base model around the 2021 OFL is $\sigma = 0.23$. The estimated model uncertainty was less than the category 2 groundfish data-moderate assessment default value of $\sigma = 1.0$.

4.5 Future Research and Data Needs

There were some major sources of uncertainty within this assessment. To improve our understanding of the copper rockfish stock south of Point Conception the following research and data collection should be prioritized:

1. The commercial and recreational fisheries had limited observations of larger copper rockfish. It is unclear whether this was due to lack of access to larger individuals or a truncation of the length/age distribution due to fishing effort. Fishery-independent survey information collected by either hook and line or remotely operated vehicles (ROVs) targeting areas that are subject to recreational and commercial fishing could improve our understanding the availability of copper rockfish.
2. The assessment area 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 lower levels, and rocky reefs that fall within marine protect areas. 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. There are very limited age data for copper rockfish south of Point Conception. The NWFSC Hook and Line Survey was the main source of otoliths read for constructing a age-at-length curve for copper rockfish. Collection otoliths from the recreational fishery, a large source of mortality in the area, would support future assessments and would improve the understanding of the population structure and life history of copper rockfish.
4. California Department of Fish and Wildlife (CDFW) provided additional length observation data that were not available for use in the base model reviewed in the June 2021 Groundfish Subcommittee meeting of the Scientific and Statistical Committee (GFSC-SSC). These data were collected from the recreational fishery commercial passenger fishing vessels (CPFV; aka 'party' and 'charter') between the 1970s - 1990s. A total of 3,499 additional length observations collected between 1975 - 1989 were provided for the area south of Point Conception. A model sensitivity was performed looking at the inclusion of these data which showed that they only had a minimal impact on the base model. However, these data should be provided and included in future assessments of copper rockfish. Additionally, it was noted during the GFSC meeting that there are additional lengths in these data sets that were not included in the sensitvities due to early copper rockfish samples being recorded as 'whitebelly rockfish' that should also be considered in future assessments.

5 Acknowledgments

Many people were instrumental in the successful completion of this assessment and their contribution is greatly appreciated. We are very grateful to all the agers at WDFW, ODFW, and the CAP lab for their hard work reading numerous otoliths and availability to answer questions when needed. Jason Jannot and Kayleigh Sommers assisted with data from the WCGOP and entertained our many questions. We would like to acknowledge our survey team and their dedication to improving the assessments we do. Peter Frey and John Harms were incredibly helpful in helping the STAT team to understand the data and as to why and when each of our assessments either encounter or do not copper rockfish along the coast. Melissa Head provided an area specific maturity estimate for copper rockfish and provided insight in the complex biological processes that govern maturity processes.

All of the data-moderate assessment assessments this year were greatly benefited by the numerous individuals who took the time to participate in the pre-assessment data webinar. Gerry Richter, Merit McCrea, Louis Zimm, Bill James, and Daniel Platt provided insight to the data and the complexities of the commercial and recreational fisheries off the West Coast of the U.S. which were essential in the production of all of the copper rockfish assessments conducted this year.

6 References

Albin, D.P., Karpov, K.A., and Van Buskirk, W.H. 1993. Effort and catch estimates for Northern and Central California marine recreational fisheries, 1981-1986. State of California The Resources Agency Department of Fish; Game.

Berger, A.M., Deroba, J.J., Bosley, K.M., Goethel, D.R., Langseth, B.J., Schueller, A.M., and Hanselman, D.H. 2021. Incoherent dimensionality in fisheries management: Consequences of misaligned stock assessment and population boundaries. ICES Journal of Marine Science 78(1): 155–171.

Bizzarro, J.J., Yoklavich, M.M., and Wakefield, W.W. 2017. Diet composition and foraging ecology of U.S. Pacific Coast groundfishes with applications for fisheries management. Environmental Biology of Fishes 100(4): 375–393.

Bosley, K.M., Goethel, D.R., Berger, A.M., Deroba, J.J., Fenske, K.H., Hanselman, D.H., Langseth, B.J., and Schueller, A.M. 2019. Overcoming challenges of harvest quota allocation in spatially structured populations. Fisheries Research 220: 105344.

Bradburn, M.J., Keller, A.A., and Horness, B.H. 2011. The 2003 to 2008 US West Coast bottom trawl surveys of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, length, and age composition. US Department of Commerce, National Oceanic; Atmospheric Administration, National Marine Fisheries Service.

Budrick, J.E., Ryley, L., and Prall, M. 2019. Methods for using remotely operated vehicle survey data in assessment of nearshore groundfish stocks along the California coast. Pacific Fishery Management Council, Portland, Oregon.

Buonaccorsi, V.P., Kimbrell, C.A., Lynn, E.A., and Vetter, R.D. 2002. Population structure of copper rockfish (*Sebastes caurinus*) reflects postglacial colonization and contemporary patterns of larval dispersal. Canadian Journal of Fisheries and Aquatic Sciences 59(8): 1374–1384.

Cope, J., Dick, E.J., MacCall, A., Monk, M., Soper, B., and Wetzel, C. 2013. Data-moderate stock assessments for brown, China, copper, sharpchin, stripetail, and yellowtail rockfishes and English and rex soles in 2013. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR.

Cope, J.M., DeVore, J., Dick, E.J., Ames, K., Budrick, J., Erickson, D.L., Grebel, J., Hanshew, G., Jones, R., Mattes, L., Niles, C., and Williams, S. 2011. An approach to defining stock complexes for U.S. West Coast groundfishes using vulnerabilities and ecological distributions. North American Journal of Fisheries Management 31(4): 589–604.

Dick, E.J., Beyer, S., Mangel, M., and Ralston, S. 2017. A meta-analysis of fecundity in rockfishes (genus *sebastes*). Fisheries Research 187: 73–85.

Dick, E.J., Ralston, S., and Pearson, D.E. 2007. Status of cowcod, *Sebastes levis*, in the Southern California Bight. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.

Dick, S., Shurin, J.B., and Taylor, E.B. 2014. Replicate divergence between and within sounds in a marine fish: The copper rockfish (*Sebastes caurinus*). Molecular Ecology 23(3): 575–590.

Field, J.C., Miller, R.R., Santora, J.A., Tolimieri, N., Haltuch, M.A., Brodeur, R.D., Auth, T.D., Dick, E.J., Monk, M.H., Sakuma, K.M., and Wells, B.K. 2021. Spatiotemporal patterns of variability in the abundance and distribution of winter-spawned pelagic juvenile rockfish in the California Current. PLOS ONE 16(5): e0251638.

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68(6): 1124–1138.

Gertseva, V., Matson, S.E., and Cope, J. 2017. Spatial growth variability in marine fish: Example from Northeast Pacific groundfish. ICES Journal of Marine Science 74(6): 1602–1613.

Hamel, O.S. 2015. A method for calculating a meta-analytical prior for the natural mortality rate using multiple life history correlates. ICES Journal of Marine Science: Journal du Conseil 72(1): 62–69.

Hannah, R.W. 2014. Length and age at maturity of female copper rockfish (*Sebastes caurinus*) from Oregon waters based on histological evaluation of ovaries. Information Reports, Oregon Department of Fish; Wildlife.

Harms, J., Benante, J., and Barnhart, R.M. 2008. The 2004-2007 hook and line survey of shelf rockfish in the southern California Bight: Estimates of distribution, abundance, and length composition. {NOAA} {Technical} {Memorandum}, U.S. Department of Commerce.

Harms, J.H., Wallace, J.R., and Stewart, I.J. 2010. Analysis of fishery-independent hook and line-based data for use in the stock assessment of bocaccio rockfish (*Sebastes paucispinis*). Fisheries Research 106(3): 298–309.

Hordyk, A., Ono, K., Valencia, S., Loneragan, N., and Prince, J. 2015. A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. ICES Journal of Marine Science: Journal du Conseil 72(1): 217–231.

Johansson, M.L., Banks, M.A., Glunt, K.D., Hassel-Finnegan, H.M., and Buonaccorsi, V.P. 2008. Influence of habitat discontinuity, geographical distance, and oceanography on fine-scale population genetic structure of copper rockfish (*Sebastes caurinus*). Molecular Ecology 17(13): 3051–3061.

Keller, A.A., Molton, K.J., Hicks, A.C., Haltuch, M., and Wetzel, C. 2012. Variation in age and growth of greenstriped rockfish (Sebastes elongatus) along the U.S. West coast (Washington to California). Fisheries Research 119-120: 80–88.

Keller, A., Frey, P., Wallace, J., Head, M., Wetzel, C., Cope, J., and Harms, J. 2018. Canary rockfishes *Sebastes pinniger* return from the brink: Catch, distribution and life history along the US west coast (Washington to California). Marine Ecology Progress Series 599: 181–200.

Lea, R.N., McAllister, R.D., and VenTresca, D.A. 1999. Biological aspects of nearshore rockfishes of the genus *sebastes* from Central California with notes on ecologically related sport fishes. State of California The Resources Agency Department of Fish; Game.

Love, M. 1996. Probably more than you want to know about the fishes of the Pacific Coast. Really Big Press, Santa Barbara, California.

Love, M.S., Yoklavich, M.M., and Thorsteinson, L. 2002. Rockfishes of the Northeast Pacific. University of California Press, Berkeley, CA.

Lowe, C.G., Anthony, K.M., Jarvis, E.T., Bellquist, L.F., and Love, M.S. 2009. Site fidelity and movement patterns of groundfish associated with offshore petroleum platforms in the Santa Barbara Channel. Marine and Coastal Fisheries 1(1): 71–89.

Markel, R.W. 2011. Rockfish recruitment and trophic dynamics on the west coast of vancouver island: Fishing, ocean, climate, and sea otters. Dissertation, University of British Columbia: 146.

McAllister, M.K., and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling - importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences 54: 284–300.

McGilliard, C.R., Punt, A.E., Methot, R.D., and Hilborn, R. 2015. Accounting for marine reserves using spatial stock assessments. Canadian Journal of Fisheries and Aquatic Sciences 72(2): 262–280.

Methot, R.D., and Wetzel, C.R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142: 86–99.

Miller, D.J., and Gotshall, D. 1965. Ocean sportfish catch and effort from Oregon to Point Arguello, California July 1, 1957–June 30, 196. California Department of Fish; Game.

Miller, D.J., and Lea, R.N. 1972. Guide to coastal marine fishes of California. State of California Department of Fish; Game Bureau of Marine Fisheries.

Miller, R.R., Field, J.C., Santora, J.A., Schroeder, I.D., Huff, D.D., Key, M., Pearson, D.E., and MacCall, A.D. 2014. A spatially distinct history of the development of California groundfish fisheries. PLoS ONE 9(6): e99758.

Punt, A.E. 2019. Spatial stock assessment methods: A viewpoint on current issues and assumptions. Fisheries Research 213: 132–143.

Punt, A.E., Haddon, M., and Tuck, G.N. 2015. Which assessment configurations perform best in the face of spatial heterogeneity in fishing mortality, growth and recruitment? A case study based on pink ling in Australia. Fisheries Research 168: 85–99.

Ralston, S., Pearson, D.E., Field, J.C., and Key, M. 2010. Documentation of the California catch reconstruction project. US Department of Commerce, National Oceanic; Atmospheric Adminstration, National Marine.

Reynolds, B.F., Powers, S.P., and Bishop, M.A. 2010. Application of acoustic telemetry to assess residency and movements of rockfish and lingcod at created and natural habitats in Prince William Sound. PLoS ONE 5(8): e12130.

Sivasundar, A., and Palumbi, S.R. 2010. Life history, ecology and the biogeography of strong genetic breaks among 15 species of Pacific rockfish, Sebastes. Marine Biology 157(7): 1433–1452.

Then, A.Y., Hoenig, J.M., Hall, N.G., and Hewitt, D.A. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science 72(1): 82–92.

Thorson, J.T., Johnson, K.F., Methot, R.D., and Taylor, I.G. 2017. Model-based estimates of effective sample size in stock assessment models using the Dirichlet-multinomial distribution. Fisheries Research 192: 84–93.

Tolimieri, N., Andrews, K., Williams, G., Katz, S., and Levin, P. 2009. Home range size and patterns of space use by lingcod, copper rockfish and quillback rockfish in relation to diel and tidal cycles. Marine Ecology Progress Series 380: 229–243.

Waples, R.S., and Gaggiotti, O. 2006. What is a population? An empirical evaluation of some genetic methods for identifying the number of gene pools and their degree of connectivity. Molecular Ecology 15(6): 1419–1439.

Wilson-Vandenberg, D., Larinto, T., and Key, M. 2014. Implementing California's nearshore fishery management plan — twelve years later. California Department of Fish and Game 100(2): 32.

Ying, Y., Chen, Y., Lin, L., Gao, T., and Quinn, T. 2011. Risks of ignoring fish population spatial structure in fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 68(12): 2101–2120.

7 Tables

Table 1: Catches (mt) by fleet for all years and total catches (mt) by year summed by year.

Year	CA S Commercial	CA S Recreational	Total Catch
1916	0.12	0.00	0.12
1917	0.20	0.00	0.20
1918	0.18	0.00	0.18
1919	0.11	0.00	0.11
1920	0.12	0.00	0.12
1921	0.10	0.00	0.10
1922	0.10	0.00	0.10
1923	0.13	0.00	0.13
1924	0.18	0.00	0.18
1925	0.20	0.00	0.20
1926	0.25	0.00	0.25
1927	0.20	0.00	0.20
1928	0.17	0.03	0.20
1929	0.18	0.05	0.23
1930	0.18	0.08	0.26
1931	0.15	0.10	0.25
1932	0.21	0.13	0.34
1933	0.05	0.15	0.20
1934	0.12	0.18	0.30
1935	0.39	0.21	0.60
1936	0.23	0.21	0.44
1937	0.93	0.27	1.20
1938	0.42	0.28	0.70
1939	0.23	0.25	0.48
1940	0.34	0.18	0.52
1941	0.41	0.16	0.57
1942	0.04	0.09	0.13
1943	0.10	0.08	0.18
1944	0.02	0.07	0.09
1945	0.07	0.09	0.16
1946	0.05	0.16	0.21
1947	0.03	0.72	0.75
1948	0.06	1.72	1.78
1949	0.16	2.17	2.33
1950	0.25	2.90	3.15
1951	3.53	2.19	5.72
1952	1.45	2.97	4.42
1953	0.44	3.67	4.11
1954	0.24	8.34	8.58
1955	0.03	16.74	16.77

Table 1: Catches (mt) by fleet for all years and total catches (mt) by year summed by year. *(continued)*

Year	CA S Commercial	CA S Recreational	Total Catch
1956	0.21	18.14	18.35
1957	0.43	10.41	10.84
1958	0.75	10.10	10.85
1959	0.52	5.38	5.90
1960	0.78	5.99	6.77
1961	2.44	7.15	9.59
1962	1.37	5.14	6.51
1963	1.19	5.80	6.99
1964	0.63	11.16	11.79
1965	1.39	15.98	17.37
1966	1.11	42.75	43.86
1967	2.65	48.11	50.76
1968	1.44	57.91	59.35
1969	0.32	46.79	47.11
1970	0.21	69.55	69.76
1971	0.40	66.63	67.03
1972	0.50	91.97	92.47
1973	0.59	111.22	111.81
1974	0.80	137.75	138.55
1975	1.53	141.02	142.55
1976	2.02	115.23	117.25
1977	2.08	107.26	109.34
1978	2.75	105.57	108.32
1979	4.96	147.23	152.19
1980	4.44	143.93	148.37
1981	4.34	79.93	84.27
1982	5.57	151.18	156.75
1983	4.43	77.95	82.38
1984	3.70	87.75	91.45
1985	4.11	111.66	115.77
1986	4.05	96.85	100.90
1987	3.56	8.55	12.11
1988	4.95	49.76	54.71
1989	3.81	46.54	50.35
1990	2.82	38.96	41.78
1991	8.84	31.38	40.22
1992	3.44	23.80	27.24
1993	3.62	16.22	19.84
1994	7.39	55.16	62.55
1995	31.93	18.51	50.44

Table 1: Catches (mt) by fleet for all years and total catches (mt) by year summed by year. *(continued)*

Year	CA S Commercial	CA S Recreational	Total Catch
1996	36.33	61.21	97.54
1997	36.96	6.32	43.28
1998	28.65	26.60	55.25
1999	0.79	49.56	50.35
2000	4.85	22.42	27.27
2001	3.77	16.77	20.54
2002	4.23	10.11	14.34
2003	0.47	16.55	17.02
2004	2.64	13.69	16.33
2005	1.61	28.14	29.75
2006	1.02	12.61	13.63
2007	0.69	31.45	32.14
2008	0.81	26.03	26.84
2009	1.89	22.95	24.84
2010	1.51	21.82	23.33
2011	1.33	43.40	44.73
2012	2.69	48.21	50.90
2013	3.87	75.61	79.48
2014	4.01	57.63	61.64
2015	5.86	75.97	81.83
2016	5.53	93.28	98.81
2017	4.47	82.30	86.77
2018	5.21	96.18	101.39
2019	5.61	74.91	80.52
2020	6.42	13.12	19.54

Table 2: The complex level OFL (mt) and ACL (mt) for Nearshore Rockfish north and south of 40.10 Latitude N., the copper rockfish OFL (mt) and ACL (mt) contributions, the total ACL allocated to California, and the total removals (mt) from south of Point Conception.

Year	Complex OFL - S.	Complex ACL - S.	OFL - S.	ACL - S.	Complex OFL - N.	Complex ACL - N.	OFL - N.	CA ACL - N.	CA ACL Total	N. CA Removals
2011	-	-	155.96	130.15	-	-	28.61	5.97	136.12	44.73
2012	-	-	155.96	130.15	-	-	28.61	5.97	136.12	50.90
2013	-	-	141.50	118.01	-	-	25.96	5.41	123.42	79.48
2014	-	-	141.50	118.01	-	-	25.96	5.41	123.42	61.64
2015	-	-	301.11	274.91	-	69	10.64	2.43	277.34	81.83
2016	-	-	284.34	259.60	-	69	10.33	2.36	261.96	98.81
2017	1329.25	1163	310.86	283.83	118.39	105	11.24	2.56	286.40	86.77
2018	1344.47	1179	316.71	289.16	118.6	105	11.59	2.64	291.80	101.39
2019	1299.65	1142	322.09	294.07	91	81	11.91	2.72	296.79	80.52
2020	1322	1163	327.26	298.79	92	82	12.24	2.80	301.59	19.54

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

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
1954	0.14	data
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 commercial length samples by number of trips and lengths by sex per year.

Year	N Trips	N Fish Females	N Fish Males	N Fish Unsexed
1983	1	0	0	2
1984	5	0	0	18
1985	5	0	0	27
1986	9	0	0	34
1987	5	0	0	20
1988	2	0	0	23
1989	6	0	0	24
1992	1	0	0	2
1994	3	0	0	12
1995	20	0	0	187
1996	16	0	0	116
1997	29	0	0	409
1998	41	0	0	542
1999	8	0	0	108
2000	1	0	0	21
2001	1	0	0	12
2002	4	0	0	47
2003	3	0	0	63
2006	1	0	0	15
2009	1	0	0	25
2010	2	0	0	51
2011	1	0	0	16
2012	4	0	0	11
2013	5	0	0	19
2014	10	0	0	56
2015	15	0	0	212
2016	13	0	0	218
2017	12	0	0	253
2018	6	0	0	68
2019	6	0	0	49
2020	2	0	0	4

Table 5: Summary of the recreational length samples used in the base model.

Year	All Fish	Sexed Fish	Unsexed Fish
1980	455	0	455
1981	169	0	169
1982	301	0	301
1983	227	0	227
1984	153	0	153
1985	223	0	223
1986	168	0	168
1987	6	0	6
1988	132	0	132
1989	13	0	13
1993	53	0	53
1994	184	0	184
1995	75	0	75
1996	181	0	181
1997	19	0	19
1998	183	0	183
1999	433	0	433
2000	210	0	210
2001	76	0	76
2002	121	0	121
2003	330	0	330
2004	389	0	389
2005	804	0	804
2006	1211	1	1211
2007	1763	0	1763
2008	1742	0	1742
2009	1280	0	1280
2010	790	0	790
2011	1507	0	1507
2012	2494	0	2494
2013	3804	0	3804
2014	2188	0	2188
2015	2180	0	2180
2016	2138	0	2138
2017	1709	0	1709
2018	1590	0	1590
2019	1416	2	1416
2020	95	0	95

Table 6: Summary of the NWFSC Hook and Line survey length samples by number of sites and lengths by sex per year.

Year	Sites	All Fish	Sexed Fish	Unsexed Fish
2004	11	33	33	0
2005	14	70	70	0
2006	12	58	58	0
2007	17	77	77	0
2008	22	67	67	0
2009	21	104	104	0
2010	14	24	24	0
2011	23	56	56	0
2012	22	63	63	0
2013	29	46	46	0
2014	29	53	52	1
2015	38	99	99	0
2016	39	109	108	1
2017	31	75	75	0
2018	30	108	108	0
2019	32	65	64	1

Table 7: Summary of the NWFSC Hook and Line relative biomass/abundance time series observations and input standard error used in the stock assessment.

Year	Observation	Standard Error
2004	0.0268	0.3332
2005	0.0312	0.2924
2006	0.0280	0.3601
2007	0.0401	0.2096
2008	0.0287	0.2232
2009	0.0428	0.1878
2010	0.0102	0.2909
2011	0.0200	0.2117
2012	0.0303	0.1998
2013	0.0253	0.2225
2014	0.0253	0.2100
2015	0.0381	0.1821
2016	0.0488	0.1733
2017	0.0433	0.1925
2018	0.0472	0.1886
2019	0.0327	0.2234

Table 8: Summary of the NWFSC WCGBTS length samples by number of trips and lengths by sex per year.

Year	Tows	All Fish	Sexed Fish	Unsexed Fish	Sample Size
2003	3	13	13	0	7
2004	1	22	22	0	2
2005	3	13	10	3	7
2006	1	3	3	0	2
2007	4	12	12	0	9
2008	5	18	18	0	11
2009	2	21	21	0	4
2010	4	6	6	0	6
2011	3	11	11	0	7
2012	16	237	230	7	38
2013	6	90	90	0	14
2014	7	17	17	0	16
2015	5	103	103	0	11
2016	8	94	51	43	19
2017	10	115	114	1	23
2018	6	50	50	0	14
2019	4	22	22	0	9

Table 9: Age, length, weight, maturity, and spawning output by age (product of maturity and fecundity) at the start of the year for female fish.

Age	Length (cm)	Weight (kg)	Maturity	Spawning Output
0	4.00	0.00	0.00	0.00
1	11.68	0.03	0.00	0.00
2	19.04	0.12	0.00	0.00
3	24.88	0.28	0.04	0.00
4	29.52	0.48	0.19	0.02
5	33.20	0.70	0.42	0.07
6	36.12	0.92	0.62	0.13
7	38.44	1.12	0.75	0.20
8	40.28	1.31	0.83	0.25
9	41.74	1.46	0.88	0.30
10	42.90	1.60	0.91	0.34
11	43.82	1.71	0.93	0.37
12	44.55	1.80	0.94	0.40
13	45.13	1.88	0.95	0.42
14	45.59	1.94	0.95	0.44
15	45.95	1.99	0.96	0.45
16	46.24	2.03	0.96	0.46
17	46.47	2.06	0.96	0.47
18	46.66	2.09	0.97	0.48
19	46.80	2.11	0.97	0.48
20	46.92	2.12	0.97	0.49
21	47.01	2.14	0.97	0.49
22	47.08	2.15	0.97	0.49
23	47.14	2.16	0.97	0.50
24	47.18	2.16	0.97	0.50
25	47.22	2.17	0.97	0.50
26	47.25	2.17	0.97	0.50
27	47.27	2.18	0.97	0.50
28	47.29	2.18	0.97	0.50
29	47.30	2.18	0.97	0.50
30	47.32	2.18	0.97	0.50
31	47.33	2.18	0.97	0.50
32	47.33	2.18	0.97	0.51
33	47.34	2.18	0.97	0.51
34	47.34	2.19	0.97	0.51
35	47.35	2.19	0.97	0.51
36	47.35	2.19	0.97	0.51
37	47.35	2.19	0.97	0.51
38	47.35	2.19	0.97	0.51

Table 9: Age, length, weight, maturity, and spawning output by age (product of maturity and fecundity) at the start of the year for female fish. *(continued)*

Age	Length (cm)	Weight (kg)	Maturity	Spawning Output
39	47.35	2.19	0.97	0.51
40	47.36	2.19	0.97	0.51
41	47.36	2.19	0.97	0.51
42	47.36	2.19	0.97	0.51
43	47.36	2.19	0.97	0.51
44	47.36	2.19	0.97	0.51
45	47.36	2.19	0.97	0.51
46	47.36	2.19	0.97	0.51
47	47.36	2.19	0.97	0.51
48	47.36	2.19	0.97	0.51
49	47.36	2.19	0.97	0.51
50	47.36	2.19	0.97	0.51

Table 10: 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 p 1 Fem GP 1	0.108	-2	(0.05, 0.4)	NA	NA	Log Norm (-2.2256, 0.48)
L at Amin Fem GP 1	11.680	-2	(3, 25)	NA	NA	None
L at Amax Fem GP 1	47.360	-2	(35, 60)	NA	NA	None
VonBert K Fem GP 1	0.231	-2	(0.03, 0.3)	NA	NA	None
CV young Fem GP 1	0.100	-2	(0.01, 1)	NA	NA	None
CV old Fem GP 1	0.100	-2	(0.01, 1)	NA	NA	None
Wtlen 1 Fem GP 1	0.000	-9	(0, 0.1)	NA	NA	None
Wtlen 2 Fem GP 1	3.190	-9	(2, 4)	NA	NA	None
Mat50% Fem GP 1	34.315	-9	(10, 60)	NA	NA	None
Mat slope Fem GP 1	-0.369	-9	(-1, 0)	NA	NA	None
Eggs scalar Fem GP 1	0.000	-9	(-3, 3)	NA	NA	None
Eggs exp len Fem GP 1	3.679	-9	(-3, 3)	NA	NA	None
NatM p 1 Mal GP 1	0.108	-2	(0.05, 0.4)	NA	NA	Log Norm (-2.2256, 0.48)
L at Amin Mal GP 1	11.390	-2	(3, 25)	NA	NA	None
L at Amax Mal GP 1	47.090	-2	(35, 60)	NA	NA	None
VonBert K Mal GP 1	0.238	-2	(0.03, 0.3)	NA	NA	None
CV young Mal GP 1	0.100	-2	(0.01, 1)	NA	NA	None
CV old Mal GP 1	0.100	-2	(0.01, 1)	NA	NA	None
Wtlen 1 Mal GP 1	0.000	-9	(0, 0.1)	NA	NA	None
Wtlen 2 Mal GP 1	3.150	-9	(2, 4)	NA	NA	None
CohortGrowDev	1.000	-9	(0, 1)	NA	NA	None
FracFemale GP 1	0.500	-9	(0.01, 0.99)	NA	NA	None
SR LN(R0)	5.496	1	(2, 20)	OK	0.0357108	None
SR BH steep	0.720	-7	(0.22, 1)	NA	NA	Full Beta (0.72, 0.16)
SR sigmaR	0.600	-99	(0.15, 0.9)	NA	NA	None
SR regime	0.000	-99	(-2, 2)	NA	NA	None
SR autocorr	0.000	-99	(0, 0)	NA	NA	None
Late RecrDev 2018	0.000	NA	(NA, NA)	NA	NA	dev (NA, NA)

Table 10: 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)
Late RecrDev 2019	0.000	NA	(NA, NA)	NA	NA	dev (NA, NA)
Late RecrDev 2020	0.000	NA	(NA, NA)	NA	NA	dev (NA, NA)
LnQ base NWFSC HKL(3)	-9.698	-1	(-15, 15)	NA	NA	None
Q extraSD NWFSC HKL(3)	0.203	4	(0.001, 0.5)	OK	0.0796341	None
Size DblN peak CA S Commercial(1)	35.544	1	(15, 55)	OK	1.2174200	None
Size DblN top logit CA S Commercial(1)	-6.842	-3	(-7, 7)	NA	NA	None
Size DblN ascend se CA S Commercial(1)	3.740	3	(-10, 10)	OK	0.2930470	None
Size DblN descend se CA S Commercial(1)	3.799	4	(-10, 10)	OK	0.7828100	None
Size DblN start logit CA S Commercial(1)	-20.000	-9	(-20, 30)	NA	NA	None
Size DblN end logit CA S Commercial(1)	-2.076	4	(-10, 10)	OK	1.3282800	None
Size DblN peak CA S Recreational(2)	29.567	2	(15, 55)	OK	0.7120620	None
Size DblN top logit CA S Recreational(2)	-6.935	-3	(-7, 7)	NA	NA	None
Size DblN ascend se CA S Recreational(2)	3.679	3	(-10, 10)	OK	0.1819020	None
Size DblN descend se CA S Recreational(2)	4.574	4	(-10, 10)	OK	0.2657820	None
Size DblN start logit CA S Recreational(2)	-8.243	-9	(-20, 30)	NA	NA	None
Size DblN end logit CA S Recreational(2)	-2.632	4	(-10, 10)	OK	0.7387730	None
Size DblN peak NWFSC HKL(3)	38.504	2	(15, 55)	OK	1.7869300	None
Size DblN top logit NWFSC HKL(3)	-6.891	-3	(-7, 7)	NA	NA	None
Size DblN ascend se NWFSC HKL(3)	4.466	3	(-10, 10)	OK	0.2901930	None
Size DblN descend se NWFSC HKL(3)	-9.703	-4	(-10, 10)	NA	NA	None
Size DblN start logit NWFSC HKL(3)	-20.000	-9	(-20, 30)	NA	NA	None
Size DblN end logit NWFSC HKL(3)	10.000	-4	(-10, 10)	NA	NA	None

Table 11: Likelihood components by source.

Label	Total
TOTAL	156.07
Catch	0.00
Equil catch	0.00
Survey	-5.32
Length comp	161.39
Recruitment	0.00
InitEQ Regime	0.00
Forecast Recruitment	0.00
Parm priors	0.00
Parm softbounds	0.00
Parm devs	0.00
Crash Pen	0.00

Table 12: Time series of population estimates from the base model.

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3+ (mt)	Fraction Unfished	Age-0 Recruits	Total Mortality (mt)	1-SPR	Exploitation Rate
1916	2324.15	233.04	2294.94	1.00	243.72	0.12	0.00	0.00
1917	2324.01	233.03	2294.80	1.00	243.71	0.20	0.00	0.00
1918	2323.79	233.00	2294.58	1.00	243.71	0.18	0.00	0.00
1919	2323.60	232.98	2294.39	1.00	243.71	0.11	0.00	0.00
1920	2323.50	232.97	2294.29	1.00	243.71	0.12	0.00	0.00
1921	2323.39	232.96	2294.18	1.00	243.71	0.10	0.00	0.00
1922	2323.32	232.95	2294.11	1.00	243.71	0.10	0.00	0.00
1923	2323.26	232.94	2294.05	1.00	243.71	0.13	0.00	0.00
1924	2323.16	232.93	2293.95	1.00	243.71	0.18	0.00	0.00
1925	2323.02	232.92	2293.81	1.00	243.70	0.20	0.00	0.00
1926	2322.87	232.90	2293.66	1.00	243.70	0.25	0.00	0.00
1927	2322.66	232.88	2293.45	1.00	243.70	0.20	0.00	0.00
1928	2322.52	232.86	2293.32	1.00	243.70	0.20	0.00	0.00
1929	2322.39	232.85	2293.19	1.00	243.70	0.23	0.00	0.00
1930	2322.24	232.83	2293.03	1.00	243.70	0.26	0.00	0.00
1931	2322.06	232.81	2292.85	1.00	243.69	0.25	0.00	0.00
1932	2321.89	232.79	2292.68	1.00	243.69	0.34	0.00	0.00
1933	2321.63	232.77	2292.42	1.00	243.69	0.20	0.00	0.00
1934	2321.53	232.76	2292.33	1.00	243.69	0.30	0.00	0.00
1935	2321.33	232.74	2292.13	1.00	243.68	0.60	0.00	0.00
1936	2320.80	232.68	2291.59	1.00	243.68	0.44	0.00	0.00
1937	2320.46	232.65	2291.25	1.00	243.68	1.20	0.01	0.00
1938	2319.28	232.52	2290.07	1.00	243.66	0.70	0.01	0.00
1939	2318.69	232.46	2289.49	1.00	243.66	0.48	0.00	0.00
1940	2318.39	232.42	2289.19	1.00	243.65	0.52	0.00	0.00
1941	2318.08	232.38	2288.88	1.00	243.65	0.57	0.00	0.00
1942	2317.75	232.35	2288.55	1.00	243.65	0.13	0.00	0.00
1943	2317.94	232.36	2288.74	1.00	243.65	0.18	0.00	0.00
1944	2318.11	232.37	2288.91	1.00	243.65	0.09	0.00	0.00
1945	2318.38	232.40	2289.18	1.00	243.65	0.16	0.00	0.00
1946	2318.59	232.42	2289.38	1.00	243.65	0.21	0.00	0.00
1947	2318.73	232.44	2289.52	1.00	243.65	0.75	0.01	0.00
1948	2318.22	232.39	2289.02	1.00	243.65	1.78	0.01	0.00
1949	2316.49	232.24	2287.29	1.00	243.63	2.33	0.02	0.00
1950	2314.08	232.01	2284.88	1.00	243.61	3.15	0.03	0.00
1951	2310.71	231.68	2281.51	0.99	243.58	5.72	0.04	0.00
1952	2304.50	231.04	2275.31	0.99	243.51	4.42	0.04	0.00
1953	2299.90	230.55	2270.71	0.99	243.46	4.11	0.03	0.00

Table 12: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3+ (mt)	Fraction Unfished	Age-0 Recruits	Total Mortality (mt)	1-SPR	Exploitation Rate
1954	2295.79	230.11	2266.61	0.99	243.42	8.58	0.07	0.00
1955	2286.63	229.22	2257.45	0.98	243.32	16.77	0.13	0.01
1956	2267.95	227.43	2238.78	0.98	243.13	18.35	0.15	0.01
1957	2247.40	225.39	2218.25	0.97	242.92	10.84	0.09	0.00
1958	2235.91	224.09	2206.78	0.96	242.77	10.85	0.09	0.00
1959	2225.24	222.85	2196.13	0.96	242.64	5.90	0.05	0.00
1960	2221.19	222.23	2192.10	0.95	242.57	6.77	0.06	0.00
1961	2217.10	221.65	2188.02	0.95	242.51	9.59	0.08	0.00
1962	2210.54	220.89	2181.47	0.95	242.42	6.51	0.05	0.00
1963	2208.12	220.53	2179.06	0.95	242.38	6.99	0.06	0.00
1964	2205.70	220.21	2176.65	0.94	242.34	11.79	0.10	0.01
1965	2198.06	219.45	2169.02	0.94	242.26	17.37	0.14	0.01
1966	2184.07	218.10	2155.04	0.94	242.10	43.86	0.32	0.02
1967	2139.20	213.92	2110.19	0.92	241.62	50.76	0.37	0.02
1968	2085.81	208.73	2056.82	0.90	240.99	59.35	0.42	0.03
1969	2022.62	202.44	1993.70	0.87	240.19	47.11	0.36	0.02
1970	1974.56	197.30	1945.72	0.85	239.50	69.76	0.49	0.04
1971	1902.15	189.91	1873.41	0.81	238.46	67.03	0.49	0.04
1972	1834.59	182.81	1805.95	0.78	237.38	92.47	0.62	0.05
1973	1739.87	173.21	1711.36	0.74	235.80	111.81	0.70	0.07
1974	1624.63	161.58	1596.28	0.69	233.68	138.55	0.80	0.09
1975	1480.54	147.14	1452.40	0.63	230.64	142.55	0.83	0.10
1976	1334.27	132.18	1306.43	0.57	226.90	117.25	0.81	0.09
1977	1221.21	119.95	1193.73	0.51	223.27	109.34	0.81	0.09
1978	1122.91	109.12	1095.88	0.47	219.51	108.32	0.82	0.10
1979	1031.27	99.11	1004.68	0.43	215.45	152.19	0.92	0.15
1980	893.58	85.44	867.49	0.37	208.72	148.37	0.94	0.17
1981	761.64	72.17	736.12	0.31	200.37	84.27	0.85	0.11
1982	705.92	65.18	681.18	0.28	194.99	156.75	0.97	0.23
1983	572.93	52.56	549.22	0.23	182.82	82.38	0.90	0.15
1984	523.48	46.53	500.51	0.20	175.49	91.45	0.93	0.18
1985	468.20	40.60	446.57	0.17	166.99	115.77	0.97	0.26
1986	386.09	33.06	365.42	0.14	153.66	100.90	0.97	0.28
1987	317.90	26.58	298.36	0.11	139.11	12.11	0.43	0.04
1988	349.60	27.31	331.54	0.12	140.93	54.71	0.86	0.17
1989	341.12	26.31	324.45	0.11	138.41	50.35	0.83	0.16
1990	336.47	25.95	319.69	0.11	137.50	41.78	0.78	0.13
1991	340.72	26.30	324.18	0.11	138.40	40.22	0.76	0.12
1992	347.46	26.79	330.99	0.11	139.63	27.24	0.61	0.08

Table 12: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3+ (mt)	Fraction Unfished	Age-0 Recruits	Total Mortality (mt)	1-SPR	Exploitation Rate
1993	369.52	28.53	352.92	0.12	143.85	19.84	0.48	0.06
1994	401.94	31.21	385.11	0.13	149.84	62.55	0.84	0.16
1995	387.86	30.65	370.53	0.13	148.64	50.44	0.78	0.14
1996	386.58	30.29	368.67	0.13	147.85	97.54	0.94	0.26
1997	333.16	25.95	315.45	0.11	137.50	43.28	0.78	0.14
1998	338.36	25.45	320.89	0.11	136.19	55.25	0.84	0.17
1999	333.13	24.76	316.71	0.11	134.33	50.35	0.83	0.16
2000	331.15	24.98	314.92	0.11	134.92	27.27	0.62	0.09
2001	353.49	26.83	337.39	0.12	139.74	20.54	0.50	0.06
2002	384.90	29.53	368.62	0.13	146.16	14.34	0.36	0.04
2003	425.33	33.08	408.42	0.14	153.71	17.02	0.39	0.04
2004	464.76	36.82	447.07	0.16	160.70	16.33	0.35	0.04
2005	506.66	40.76	488.07	0.17	167.23	29.75	0.52	0.06
2006	534.74	43.68	515.34	0.19	171.59	13.63	0.28	0.03
2007	581.68	47.92	561.53	0.21	177.29	32.14	0.52	0.06
2008	609.46	50.77	588.77	0.22	180.76	26.84	0.45	0.05
2009	643.39	54.01	622.08	0.23	184.42	24.84	0.41	0.04
2010	680.54	57.50	658.80	0.25	188.02	23.33	0.37	0.04
2011	720.43	61.25	698.25	0.26	191.58	44.73	0.57	0.06
2012	736.44	63.22	713.85	0.27	193.33	50.90	0.62	0.07
2013	744.04	64.35	721.07	0.28	194.29	79.48	0.77	0.11
2014	717.40	62.52	694.26	0.27	192.72	61.64	0.71	0.09
2015	708.41	61.70	685.20	0.26	191.99	81.83	0.80	0.12
2016	676.00	58.89	652.98	0.25	189.38	98.81	0.87	0.15
2017	622.30	54.21	599.44	0.23	184.63	86.77	0.86	0.14
2018	579.95	50.17	557.45	0.22	180.06	101.39	0.91	0.18
2019	520.12	44.70	498.20	0.19	173.02	80.52	0.89	0.16
2020	482.35	40.81	461.02	0.18	167.31	19.54	0.44	0.04
2021	515.21	42.28	494.62	0.18	169.55	90.80	0.90	0.18
2022	472.44	38.97	452.42	0.17	164.37	73.10	0.87	0.16
2023	445.55	36.65	425.42	0.16	160.41	9.93	0.26	0.02
2024	490.04	39.48	470.43	0.17	165.21	12.67	0.29	0.03
2025	537.50	43.13	518.15	0.19	170.79	15.78	0.31	0.03
2026	585.16	47.39	565.22	0.20	176.61	18.83	0.34	0.03
2027	631.40	51.89	610.79	0.22	182.06	21.53	0.35	0.04
2028	675.60	56.32	654.31	0.24	186.84	23.84	0.37	0.04
2029	717.69	60.56	695.76	0.26	190.95	25.87	0.38	0.04
2030	757.73	64.58	735.25	0.28	194.49	27.64	0.39	0.04
2031	795.85	68.41	772.89	0.29	197.57	29.23	0.39	0.04

Table 12: Time series of population estimates from the base model. *(continued)*

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3+ (mt)	Fraction Unfished	Age-0 Recruits	Total Mortality (mt)	1-SPR	Exploitation Rate
2032	832.12	72.06	808.74	0.31	200.29	30.71	0.40	0.04

Table 13: Data weights applied by each alternative data weighting method.

Method	Commercial Lengths	Recreational Lengths	NWFSC Hook and Line
Francis	0.343	0.023	0.198
McAllister-Ianelli	0.808	0.029	0.606
Dirichlet Multinomial	0.991	0.193	0.827

Table 14: Sensitivities relative to the base model.

	Base Model	Est. M (f)	Est. CV Old	Est. Rec. Devs.	DM DW	DM MI
Total Likelihood	156.072	170.590	204.097	140.371	107.393	172.412
Survey Likelihood	-5.318	-3.872	1.066	-3.260	0.000	11.464
Length Likelihood	161.389	174.460	203.030	143.624	107.393	160.946
Recruitment Likelihood	0.000	0.000	0.000	0.000	0.000	0.000
Forecast Recruitment Likelihood	0.000	0.000	0.000	0.000	0.000	0.000
Parameter Priors Likelihood	0.000	0.000	0.000	0.000	0.000	0.000
log(R0)	5.496	5.445	5.215	5.057	5.431	5.523
SB Virgin	233.041	221.565	175.932	150.298	218.382	239.318
SB 2020	42.281	25.163	6.150	18.906	17.334	53.111
Fraction Unfished 2021	0.181	0.114	0.035	0.126	0.079	0.222
Total Yield - SPR 50	51.842	53.908	48.367	49.336	53.778	52.382
Steepness	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
Length at Amin - Female	11.680	11.680	11.680	11.680	11.680	11.680
Length at Amax - Female	47.360	47.360	47.360	47.360	47.360	47.360
Von Bert. k - Female	0.231	0.231	0.231	0.231	0.231	0.231
CV young - Female	0.100	0.100	0.100	0.100	0.100	0.100
CV old - Female	0.100	0.100	0.100	0.100	0.100	0.100
Natural Mortality - Male	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Male	11.390	11.390	11.390	11.390	11.390	11.390
Length at Amax - Male	47.090	47.090	47.090	47.090	47.090	47.090
Von Bert. k - Male	0.238	0.238	0.238	0.238	0.238	0.238
CV young - Male	0.100	0.100	0.100	0.100	0.100	0.100
CV old - Male	0.100	0.100	0.100	0.100	0.100	0.100

Table 15: Sensitivities relative to the base model. The negative log-likelihood for the Early CPFV Lengths and the Early CPFV Lengths and Selectivity Blocks sensitivities are not comparable with the base model since these sensitivities include additional data.

	Base Model	Com. Asym. Sel.	Rec. Asym. Sel.	Com. and Rec. Asym. Sel.	Remove HKL Survey	2013 RecFIN and CPFV Indices	Additional CPFV Lengths	CPFV Lengths and Sel. Blocks
Total Likelihood	156.072	170.590	204.097	219.384	107.393	172.412	171.232	152.608
Survey Likelihood	-5.318	-3.872	1.066	1.637	0.000	11.464	-4.915	-4.593
Length Likelihood	161.389	174.460	203.030	217.746	107.393	160.946	176.145	157.197
Recruitment Likelihood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Forecast Recruitment Likelihood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Parameter Priors Likelihood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
log(R0)	5.496	5.445	5.215	5.208	5.431	5.523	5.472	5.434
SB Virgin	233.041	221.565	175.932	174.728	218.382	239.318	227.521	219.094
SB 2020	42.281	25.163	6.150	5.166	17.334	53.111	35.864	36.790
Fraction Unfished 2021	0.181	0.114	0.035	0.030	0.079	0.222	0.158	0.168
Total Yield - SPR 50	51.842	53.908	48.367	50.395	53.778	52.382	51.513	56.498
Steepness	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
Length at Amin - Female	11.680	11.680	11.680	11.680	11.680	11.680	11.680	11.680
Length at Amax - Female	47.360	47.360	47.360	47.360	47.360	47.360	47.360	47.360
Von Bert. k - Female	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
CV young - Female	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
CV old - Female	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Natural Mortality - Male	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Male	11.390	11.390	11.390	11.390	11.390	11.390	11.390	11.390
Length at Amax - Male	47.090	47.090	47.090	47.090	47.090	47.090	47.090	47.090
Von Bert. k - Male	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238
CV young - Male	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
CV old - Male	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100

Table 16: Summary of reference points and management quantities, including estimates of the 95 percent intervals.

	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output	233.04	216.73	249.35
Unfished Age 3+ Biomass (mt)	2294.94	2134.31	2455.57
Unfished Recruitment (R_0)	243.71	226.65	260.76
Spawning Output (2021)	42.28	14.46	70.10
Fraction Unfished (2021)	0.18	0.07	0.29
Reference Points Based $SB_{40\%}$			
Proxy Spawning Output $SB_{40\%}$	93.22	86.69	99.74
SPR Resulting in $SB_{40\%}$	0.46	0.46	0.46
Exploitation Rate Resulting in $SB_{40\%}$	0.05	0.05	0.06
Yield with SPR Based On $SB_{40\%}$ (mt)	54.40	52.78	56.01
Reference Points Based on SPR_{50} for MSY			
Proxy Spawning Output (SPR_{50})	103.97	96.69	111.25
SPR_{50}	0.50		
Exploitation Rate Corresponding to SPR_{50}	0.05	0.04	0.05
Yield with SPR_{50} at SB SPR (mt)	51.84	50.31	53.38
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY (SB_{MSY})	62.60	58.44	66.77
SB_{MSY}	0.34	0.34	0.34
Exploitation Rate Corresponding to SB_{MSY}	0.08	0.08	0.09
MSY (mt)	58.08	56.31	59.84

Table 17: Projections of potential OFLs (mt), ABCs (mt), the assumed removals based on 2021 and 2022 adopted ACL values, estimated spawning output, and fraction unfished. The OFLs and ACLs reflect adopted species-specific contribution for copper rockfish by area. The California (CA) ACL is the sum of the species-specific ACL for south of 40.10 N. Lat. and the percent of the species-specific ACL for north of 40.10 N. Lat. allocated to California.

Year	OFL - S. 40.10	ACL - S. 40.10	OFL - N. 40.10	CA ACL - N. 40.10	Total CA ACL	Removals	OFL	ABC	Buffer	ACL	Spawning Output	Fraction Unfished
2021	327.3	204.4	12.2	2	206.4	90.8	-	-	-	-	42.28	0.18
2022	247.4	202	9.8	2	204	73.1	-	-	-	-	38.97	0.17
2023	-	-	-	-	-	-	23	20.09	0.874	9.93	36.65	0.16
2024	-	-	-	-	-	-	26.4	22.85	0.865	12.67	39.48	0.17
2025	-	-	-	-	-	-	29.66	25.43	0.857	15.78	43.13	0.19
2026	-	-	-	-	-	-	32.37	27.49	0.849	18.83	47.39	0.20
2027	-	-	-	-	-	-	34.54	29.06	0.841	21.53	51.89	0.22
2028	-	-	-	-	-	-	36.35	30.29	0.833	23.84	56.32	0.24
2029	-	-	-	-	-	-	37.95	31.34	0.826	25.87	60.56	0.26
2030	-	-	-	-	-	-	39.46	32.27	0.818	27.64	64.58	0.28
2031	-	-	-	-	-	-	40.89	33.13	0.81	29.23	68.41	0.29
2032	-	-	-	-	-	-	42.26	33.92	0.803	30.71	72.06	0.31

Table 18: Decision table summary of 10 year projections beginning in 2023 for alternative states of nature based on an axis of uncertainty around initial stock size. Columns range over low, mid, and high states of nature and rows range over different catch level assumptions.

			$\log(R_0)$=5.44		$\log(R_0)$=5.50		$\log(R_0)$=5.55	
	Year	Catch	Spawning Biomass	Fraction Unfished	Spawning Biomass	Fraction Unfished	Spawning Biomass	Fraction Unfished
	2021	90.80	28.79	0.130	42.28	0.181	62.04	0.253
	2022	88.90	25.30	0.114	38.97	0.167	58.74	0.240
	2023	8.79	21.29	0.096	35.28	0.151	55.19	0.225
	2024	11.44	23.29	0.105	37.92	0.163	58.32	0.238
ACL	2025	14.58	26.06	0.118	41.44	0.178	62.38	0.255
P*=	2026	17.74	29.41	0.133	45.68	0.196	67.16	0.274
0.45	2027	20.56	32.94	0.149	50.24	0.216	72.26	0.295
	2028	22.97	36.31	0.164	54.75	0.235	77.34	0.316
	2029	25.08	39.44	0.178	59.07	0.253	82.19	0.336
	2030	26.91	42.36	0.192	63.17	0.271	86.75	0.354
	2031	28.57	45.15	0.204	67.06	0.288	90.99	0.372
	2032	30.10	47.85	0.216	70.78	0.304	94.92	0.388

Table 19: Spawning output (SO) south and north of Point Conception in California, total spawning output across California, relative spawning output (Rel. SO) north and south of Point Conception, and relative spawning output across California.

Year	SO-North	SO-South	SO-CA	Rel. SO-North	Rel. SO-South	Rel. SO-CA
1914	415.81	233.04	648.86	1.000	1.000	1.000
1915	415.81	233.04	648.86	1.000	1.000	1.000
1916	415.81	233.04	648.86	1.000	1.000	1.000
1917	415.38	233.03	648.41	0.999	1.000	0.999
1918	414.73	233.00	647.74	0.997	1.000	0.998
1919	413.98	232.98	646.97	0.996	1.000	0.997
1920	413.57	232.97	646.54	0.995	1.000	0.996
1921	413.20	232.96	646.16	0.994	1.000	0.996
1922	412.99	232.95	645.94	0.993	1.000	0.996
1923	412.91	232.94	645.85	0.993	1.000	0.995
1924	412.85	232.93	645.78	0.993	1.000	0.995
1925	412.97	232.92	645.89	0.993	0.999	0.995
1926	412.98	232.90	645.88	0.993	0.999	0.995
1927	412.90	232.88	645.78	0.993	0.999	0.995
1928	412.99	232.86	645.86	0.993	0.999	0.995
1929	412.94	232.85	645.79	0.993	0.999	0.995
1930	412.80	232.83	645.63	0.993	0.999	0.995
1931	412.38	232.81	645.20	0.992	0.999	0.994
1932	411.77	232.79	644.57	0.990	0.999	0.993
1933	411.15	232.77	643.92	0.989	0.999	0.992
1934	410.55	232.76	643.31	0.987	0.999	0.991
1935	410.02	232.74	642.76	0.986	0.999	0.991
1936	409.20	232.68	641.88	0.984	0.998	0.989
1937	408.38	232.65	641.02	0.982	0.998	0.988
1938	407.35	232.52	639.88	0.980	0.998	0.986
1939	406.51	232.46	638.97	0.978	0.998	0.985
1940	405.99	232.42	638.41	0.976	0.997	0.984
1941	405.06	232.38	637.44	0.974	0.997	0.982
1942	404.32	232.35	636.67	0.972	0.997	0.981
1943	404.83	232.36	637.19	0.974	0.997	0.982
1944	405.35	232.37	637.72	0.975	0.997	0.983
1945	405.50	232.40	637.89	0.975	0.997	0.983
1946	404.16	232.42	636.58	0.972	0.997	0.981
1947	402.10	232.44	634.53	0.967	0.997	0.978
1948	402.37	232.39	634.76	0.968	0.997	0.978
1949	401.30	232.24	633.54	0.965	0.997	0.976
1950	400.14	232.01	632.15	0.962	0.996	0.974
1951	398.57	231.68	630.25	0.959	0.994	0.971

Table 19: Spawning output (SO) south and north of Point Conception in California, total spawning output across California, relative spawning output (Rel. SO) north and south of Point Conception, and relative spawning output across California. *(continued)*

Year	SO-North	SO-South	SO-CA	Rel. SO-North	Rel. SO-South	Rel. SO-CA
1952	395.58	231.04	626.62	0.951	0.991	0.966
1953	393.78	230.55	624.34	0.947	0.989	0.962
1954	393.19	230.11	623.30	0.946	0.987	0.961
1955	391.72	229.22	620.94	0.942	0.984	0.957
1956	389.95	227.43	617.38	0.938	0.976	0.951
1957	387.63	225.39	613.02	0.932	0.967	0.945
1958	385.83	224.09	609.92	0.928	0.962	0.940
1959	379.98	222.85	602.83	0.914	0.956	0.929
1960	376.56	222.23	598.79	0.906	0.954	0.923
1961	374.91	221.65	596.57	0.902	0.951	0.919
1962	375.64	220.89	596.52	0.903	0.948	0.919
1963	375.56	220.53	596.09	0.903	0.946	0.919
1964	374.29	220.21	594.50	0.900	0.945	0.916
1965	374.38	219.45	593.83	0.900	0.942	0.915
1966	371.29	218.10	589.39	0.893	0.936	0.908
1967	366.95	213.92	580.87	0.882	0.918	0.895
1968	362.38	208.73	571.11	0.872	0.896	0.880
1969	357.66	202.44	560.10	0.860	0.869	0.863
1970	352.64	197.30	549.94	0.848	0.847	0.848
1971	344.71	189.91	534.62	0.829	0.815	0.824
1972	338.84	182.81	521.65	0.815	0.784	0.804
1973	328.96	173.21	502.17	0.791	0.743	0.774
1974	316.36	161.58	477.94	0.761	0.693	0.737
1975	301.24	147.14	448.38	0.724	0.631	0.691
1976	285.72	132.18	417.90	0.687	0.567	0.644
1977	265.76	119.95	385.70	0.639	0.515	0.594
1978	242.71	109.12	351.84	0.584	0.468	0.542
1979	220.21	99.11	319.32	0.530	0.425	0.492
1980	195.23	85.44	280.68	0.470	0.367	0.433
1981	168.51	72.17	240.68	0.405	0.310	0.371
1982	128.65	65.18	193.83	0.309	0.280	0.299
1983	104.02	52.56	156.58	0.250	0.226	0.241
1984	87.13	46.53	133.66	0.210	0.200	0.206
1985	72.65	40.60	113.25	0.175	0.174	0.175
1986	56.82	33.06	89.88	0.137	0.142	0.139
1987	45.88	26.58	72.46	0.110	0.114	0.112
1988	41.70	27.31	69.01	0.100	0.117	0.106
1989	37.85	26.31	64.15	0.091	0.113	0.099
1990	34.82	25.95	60.77	0.084	0.111	0.094

Table 19: Spawning output (SO) south and north of Point Conception in California, total spawning output across California, relative spawning output (Rel. SO) north and south of Point Conception, and relative spawning output across California. *(continued)*

Year	SO-North	SO-South	SO-CA	Rel. SO-North	Rel. SO-South	Rel. SO-CA
1991	32.15	26.30	58.45	0.077	0.113	0.090
1992	28.39	26.79	55.18	0.068	0.115	0.085
1993	22.16	28.53	50.69	0.053	0.122	0.078
1994	16.05	31.21	47.26	0.039	0.134	0.073
1995	15.60	30.65	46.25	0.038	0.132	0.071
1996	16.79	30.29	47.08	0.040	0.130	0.073
1997	16.41	25.95	42.37	0.039	0.111	0.065
1998	15.44	25.45	40.89	0.037	0.109	0.063
1999	16.75	24.76	41.51	0.040	0.106	0.064
2000	18.93	24.98	43.90	0.046	0.107	0.068
2001	21.74	26.83	48.57	0.052	0.115	0.075
2002	24.84	29.53	54.38	0.060	0.127	0.084
2003	28.64	33.08	61.72	0.069	0.142	0.095
2004	32.70	36.82	69.52	0.079	0.158	0.107
2005	37.57	40.76	78.33	0.090	0.175	0.121
2006	41.04	43.68	84.72	0.099	0.187	0.131
2007	44.00	47.92	91.92	0.106	0.206	0.142
2008	46.33	50.77	97.10	0.111	0.218	0.150
2009	49.58	54.01	103.59	0.119	0.232	0.160
2010	51.80	57.50	109.30	0.125	0.247	0.168
2011	55.04	61.25	116.29	0.132	0.263	0.179
2012	60.66	63.22	123.88	0.146	0.271	0.191
2013	70.63	64.35	134.98	0.170	0.276	0.208
2014	88.01	62.52	150.53	0.212	0.268	0.232
2015	109.29	61.70	170.99	0.263	0.265	0.264
2016	127.02	58.89	185.91	0.305	0.253	0.287
2017	141.90	54.21	196.11	0.341	0.233	0.302
2018	147.97	50.17	198.14	0.356	0.215	0.305
2019	154.78	44.70	199.48	0.372	0.192	0.307
2020	158.56	40.81	199.37	0.381	0.175	0.307
2021	163.51	42.28	205.79	0.393	0.181	0.317

8 Figures

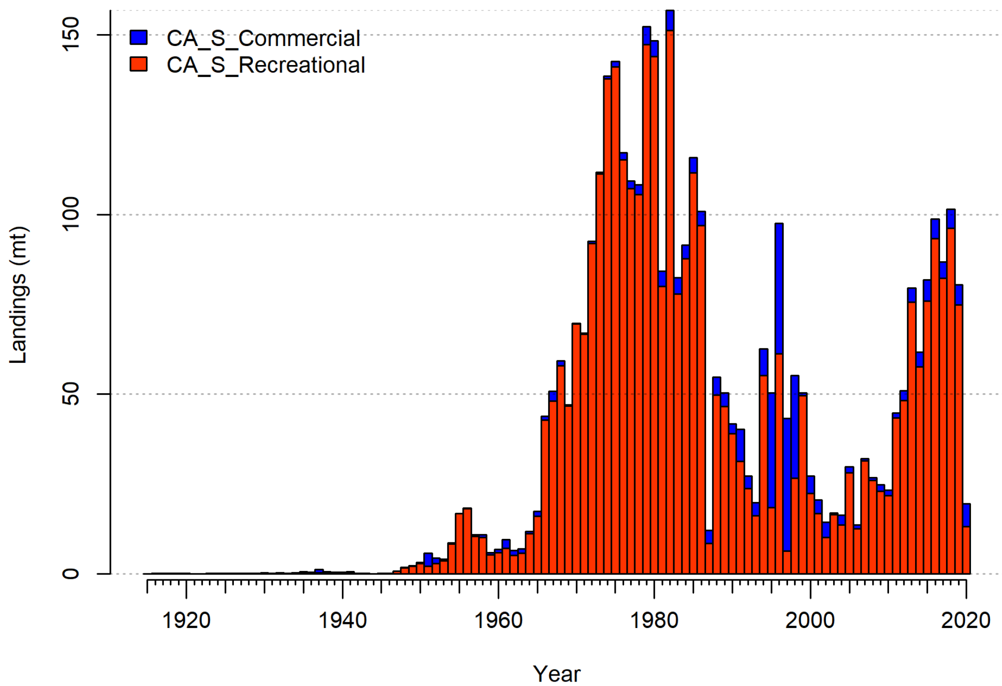

Figure 1: Catches by fleet used in the base model.

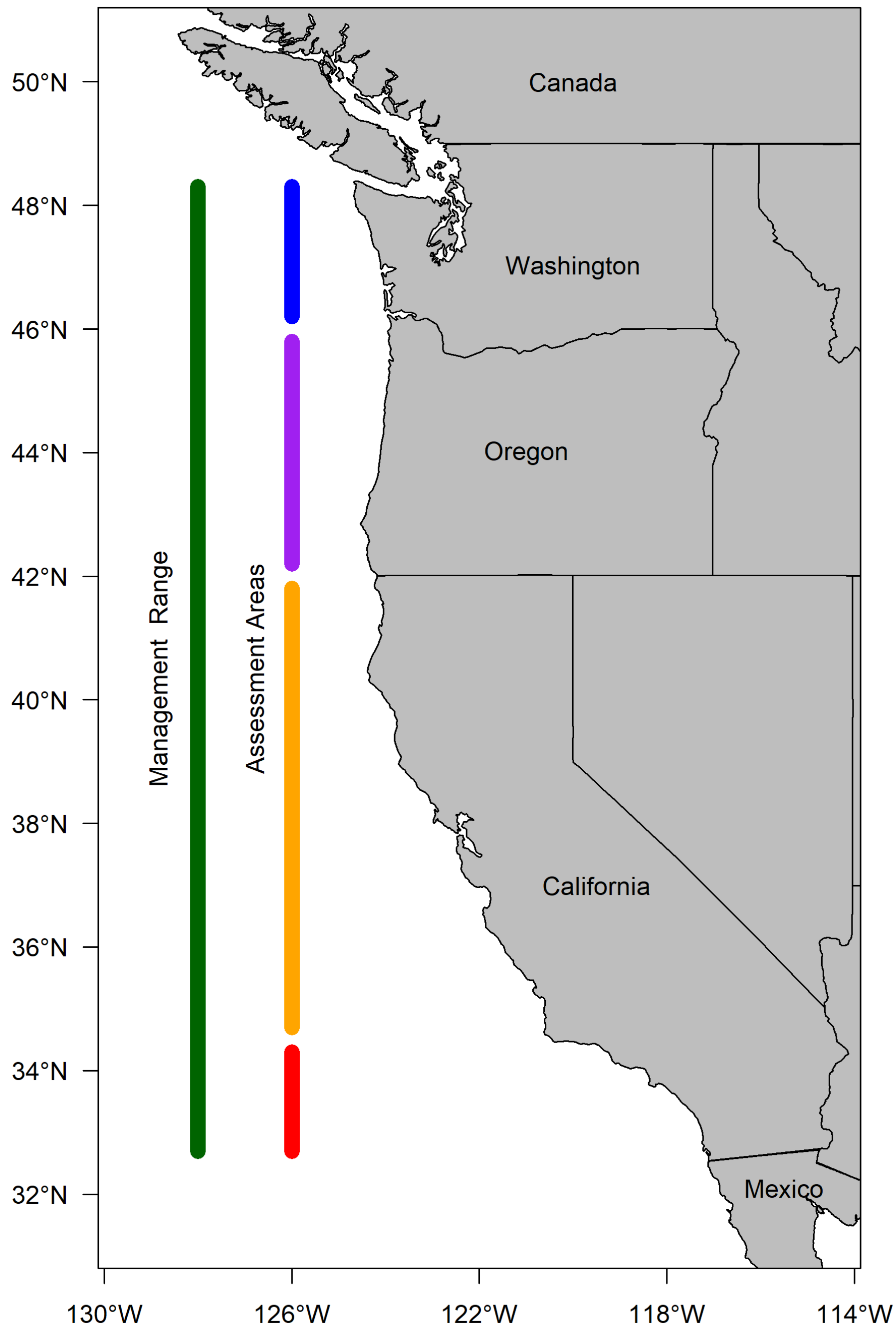

Figure 2: Map of management area and assessments areas for copper rockfish with the assessment area south of Point Conception shown in red.

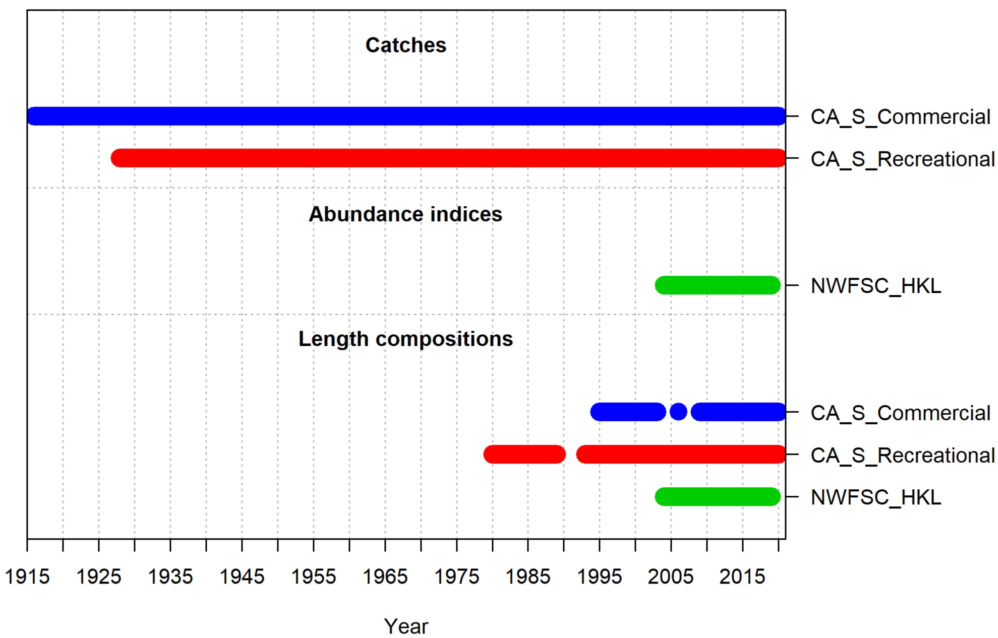

Figure 3: Summary of data sources used in the base model.

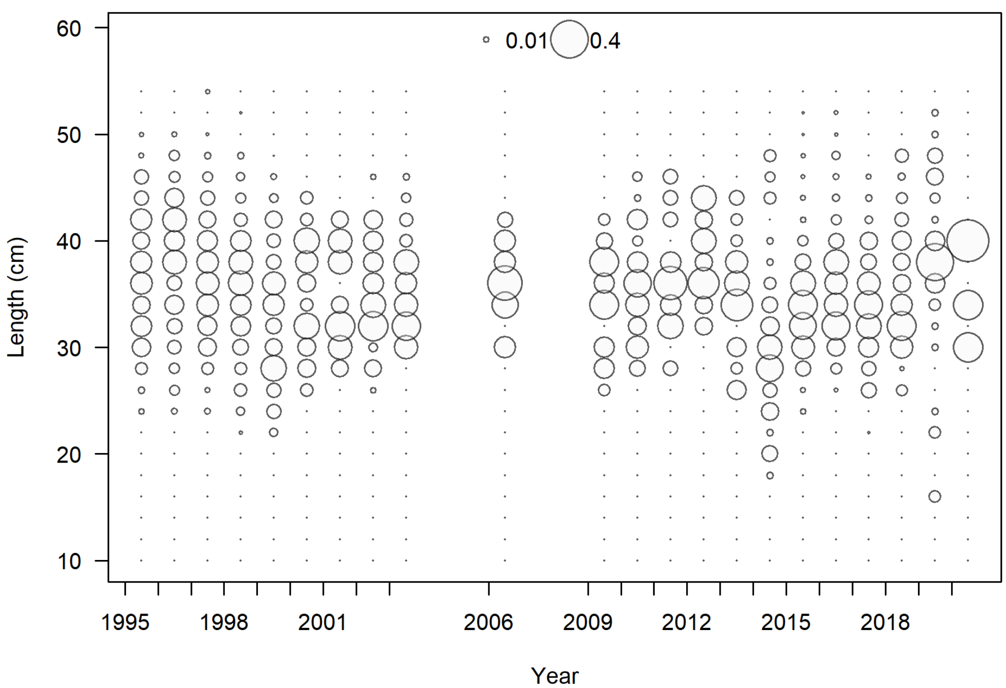

Figure 4: Length composition data from the commercial fleet.

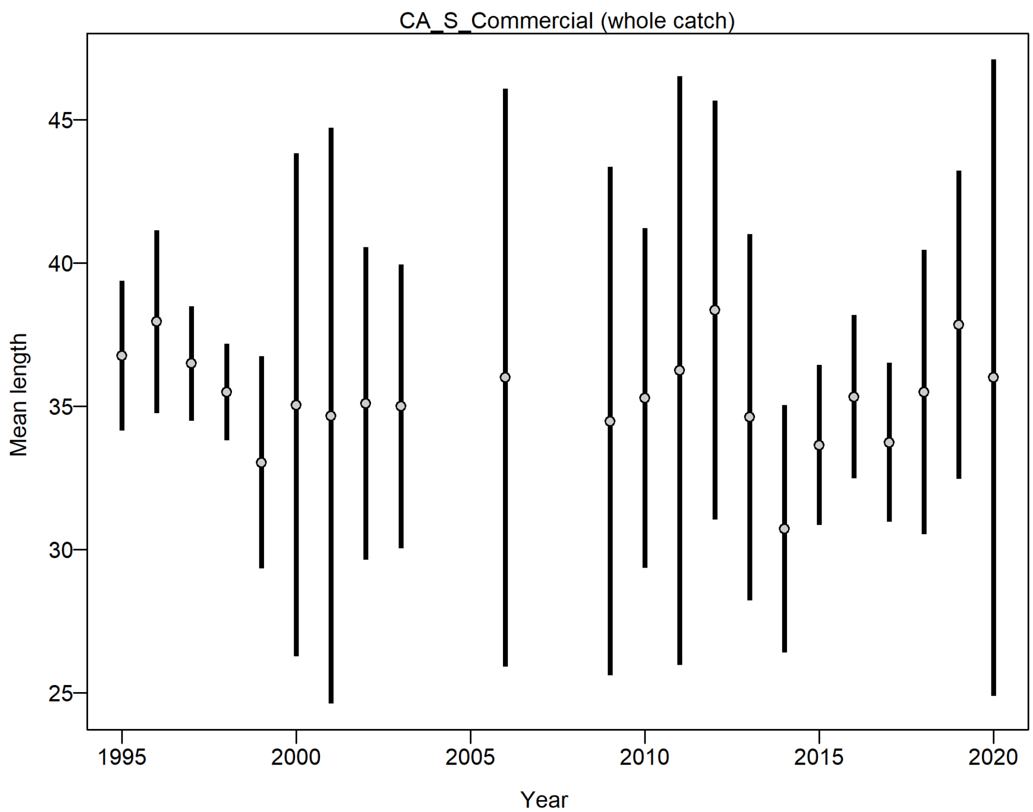

Figure 5: Mean length for commercial fleet with 95 percent confidence intervals.

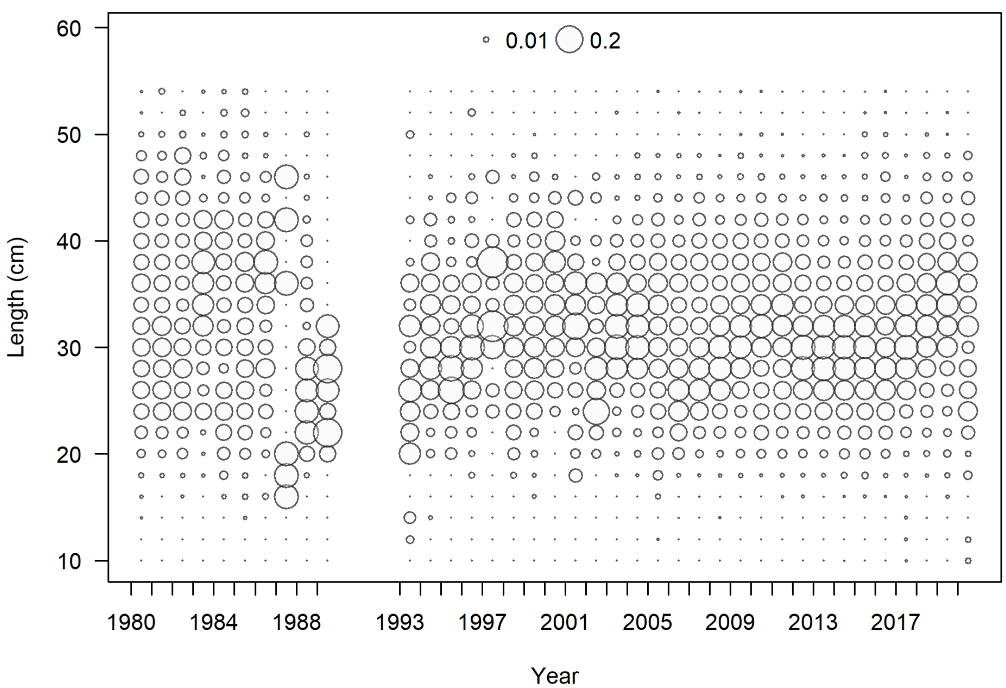

Figure 6: Length composition data from the recreational fleet.

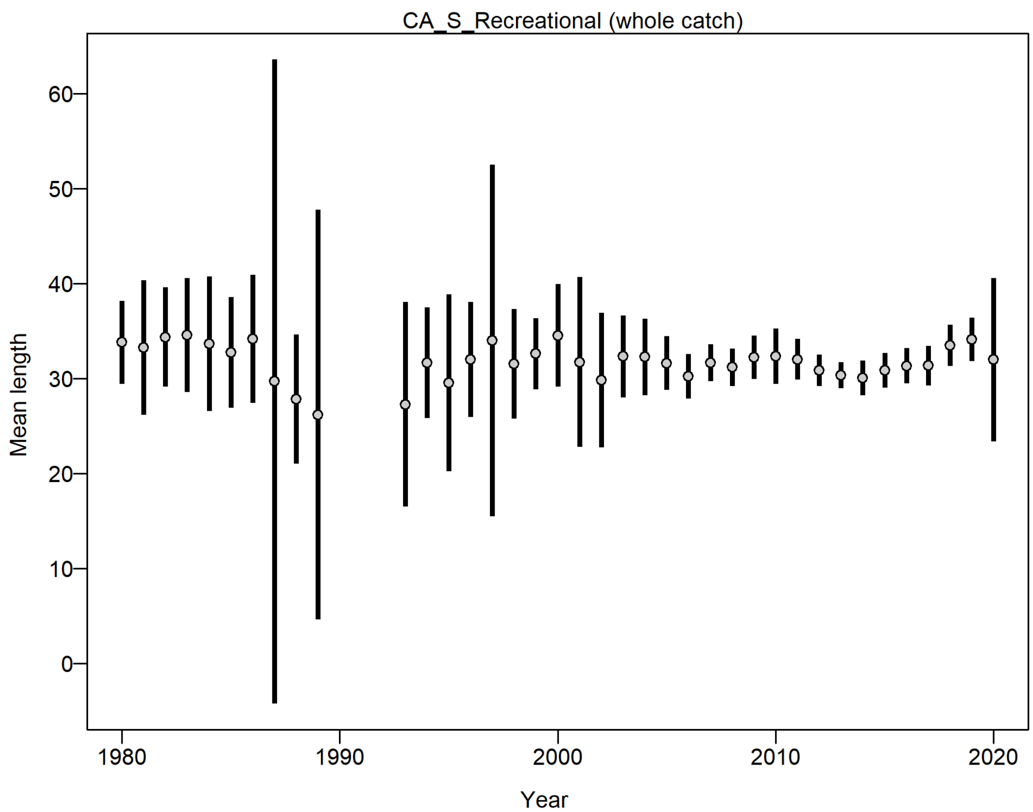

Figure 7: Mean length for recreational fleet with 95 percent confidence intervals.

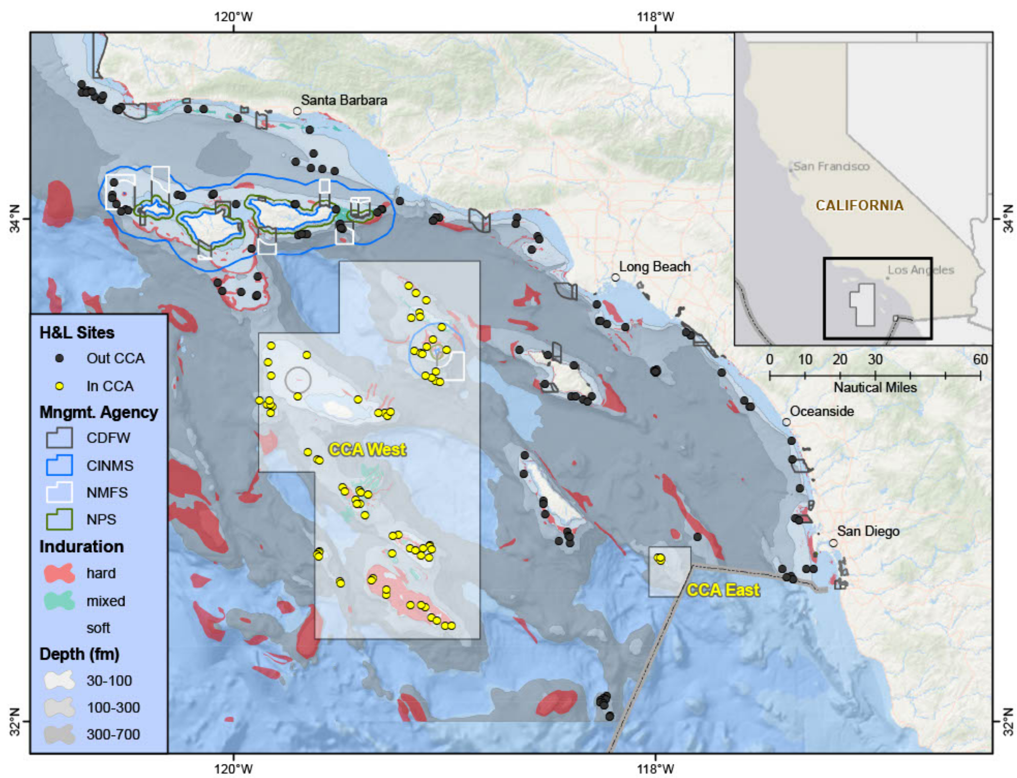

Figure 8: NWFSC Hook and Line survey sampling sites where yellow sites indicate locations inside Cowcod Conservation Areas. Additionally, known substrate structure, depths, and areas under various management regulations are shown for the area south of Point Conception.

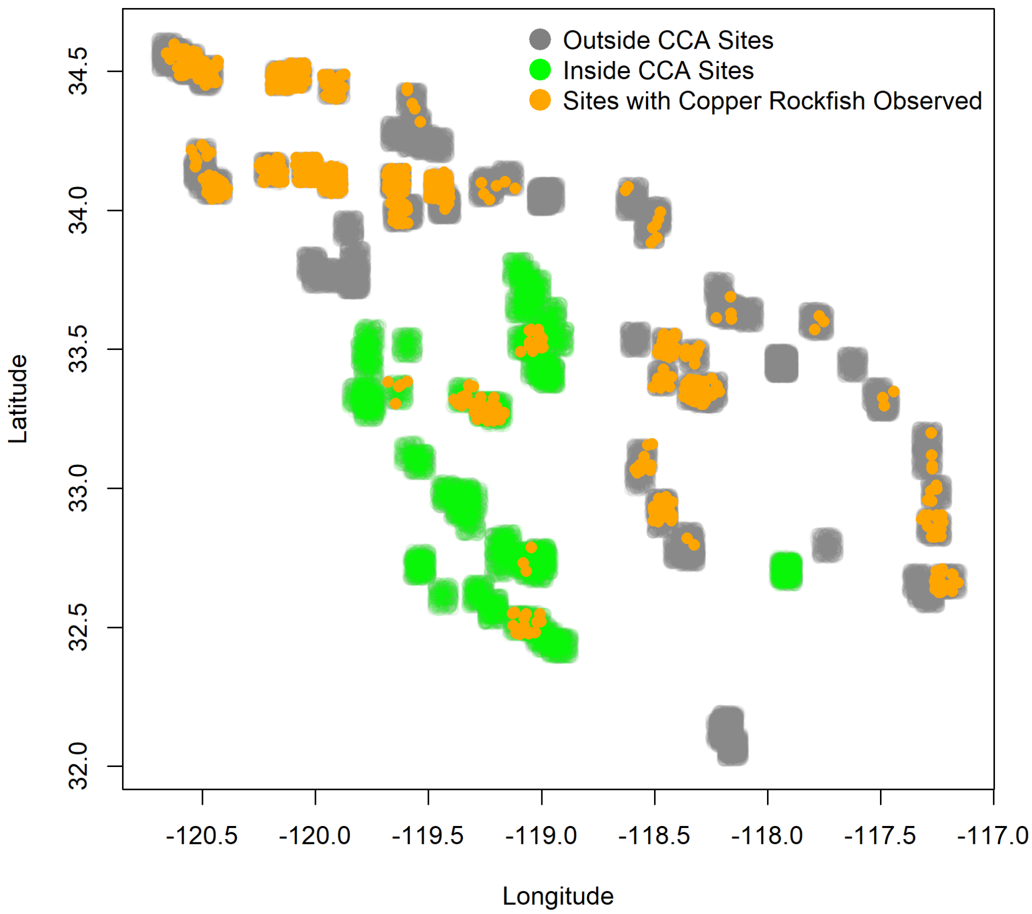

Figure 9: NWFSC Hook and Line survey sample sites inside and outside the CCA and sites with observations of copper rockfish.

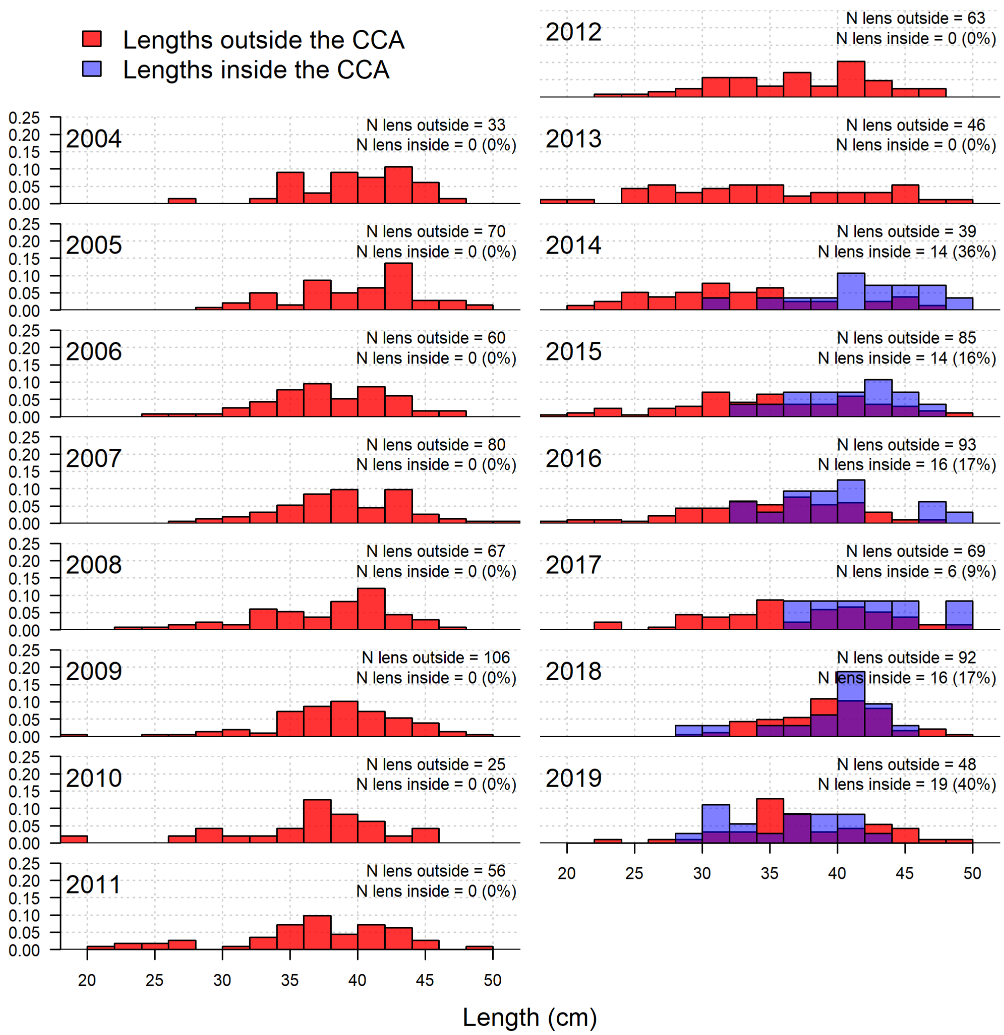

Figure 10: NWFSC Hook and Line survey observations by year outside and inside the cowcod conservation area.

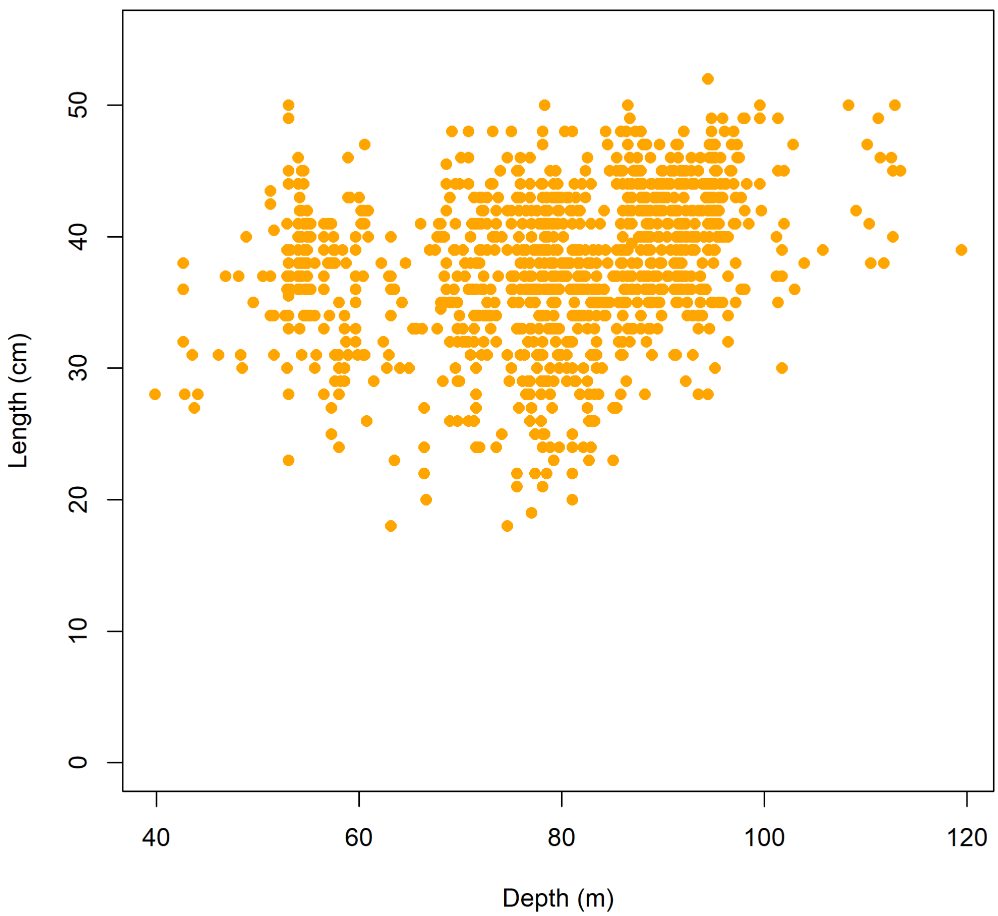

Figure 11: Lengths observations by depth in the NWFSC Hook and Line survey data.

Figure 12: Length composition data from the NWFSC Hook and Line survey.

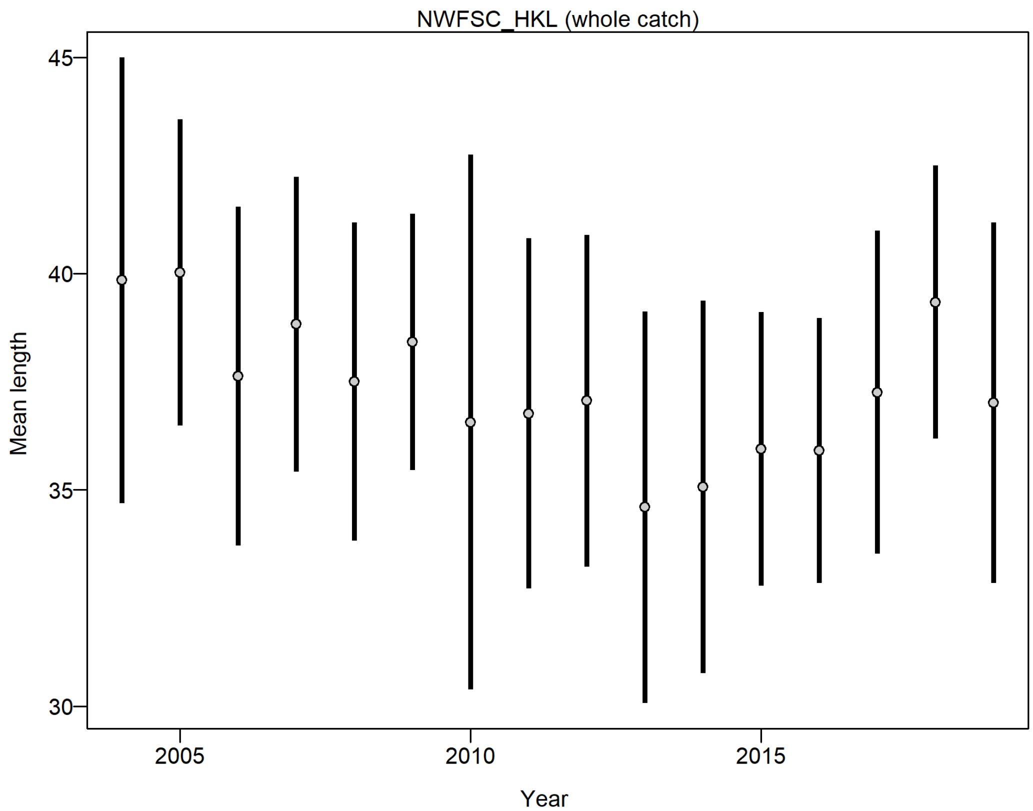

Figure 13: Mean length for NWFSC Hook and Line survey with 95 percent confidence intervals.

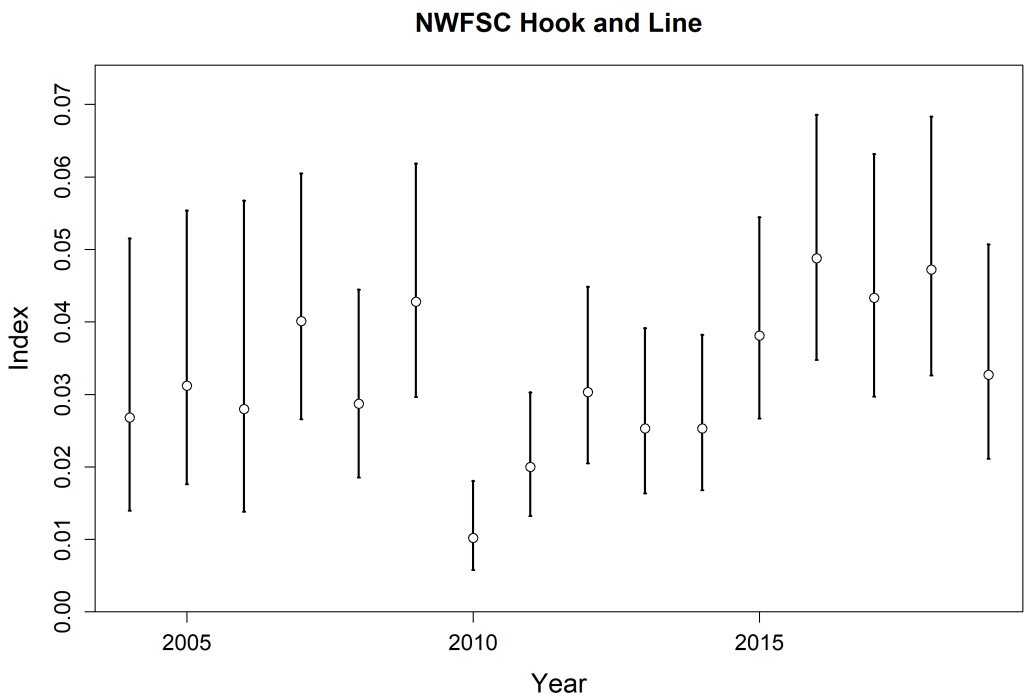

Figure 14: Index of abundance for the NWFSC Hook and Line survey. Lines indicate 95 percent uncertainty interval around index values based on the model assumption of lognormal error. Thicker lines indicate input uncertainty before addition of estimated additional uncertainty parameter.

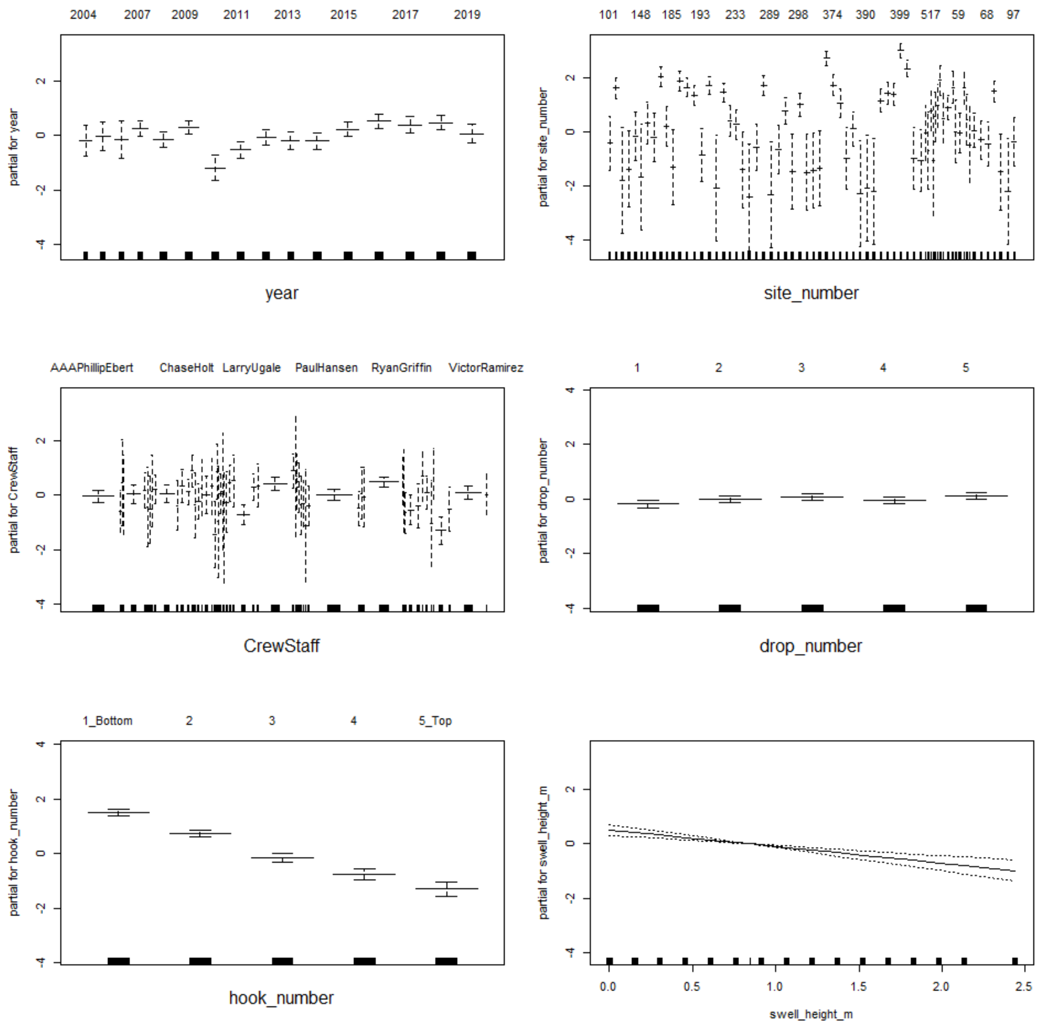

Figure 15: Diagnostics for the binomial generalized-linear model.

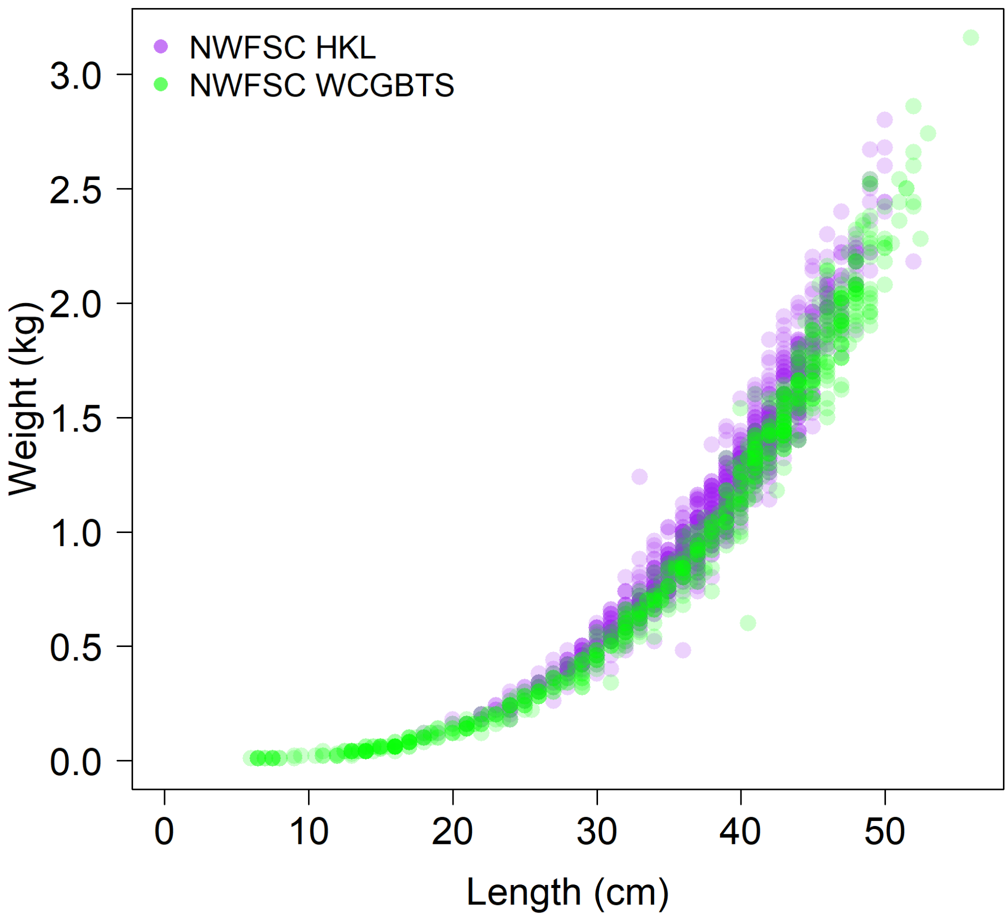

Figure 16: Comparison of the length-at-weight data from the NWFSC Hook and Line and the NWFSC WCGBT surveys.

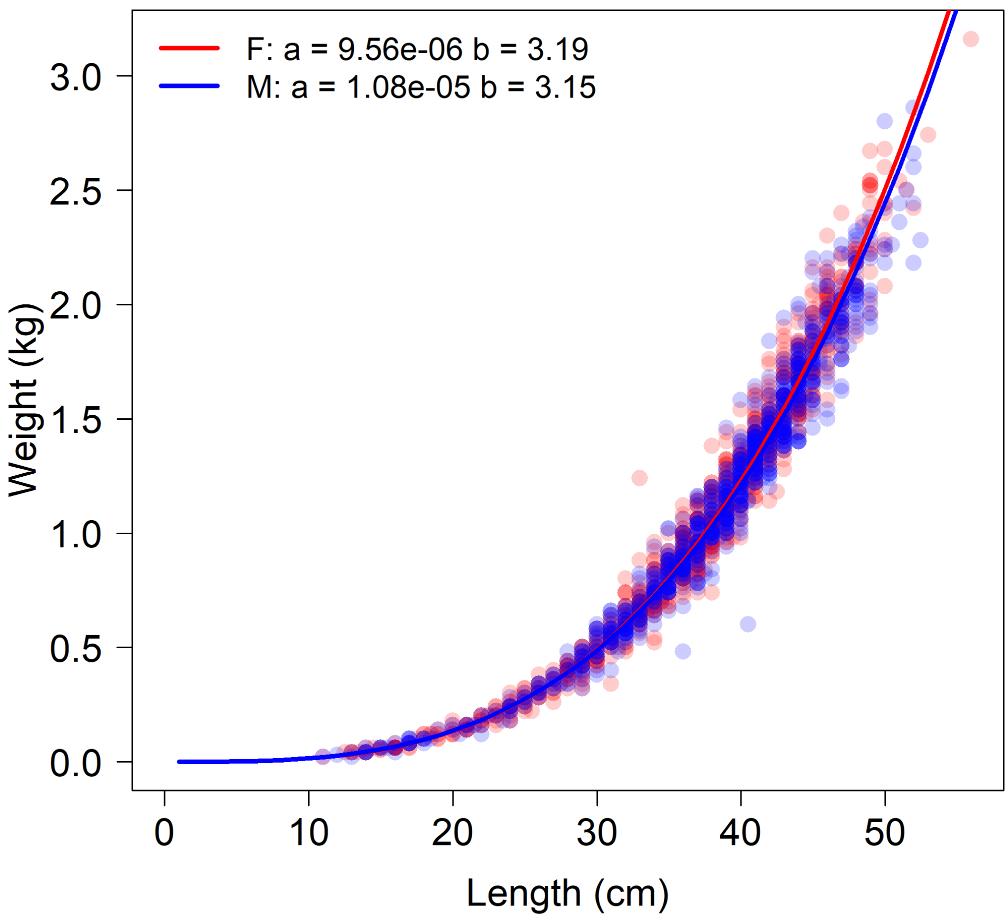

Figure 17: All available survey length-at-weight data with sex specific estimated fits.

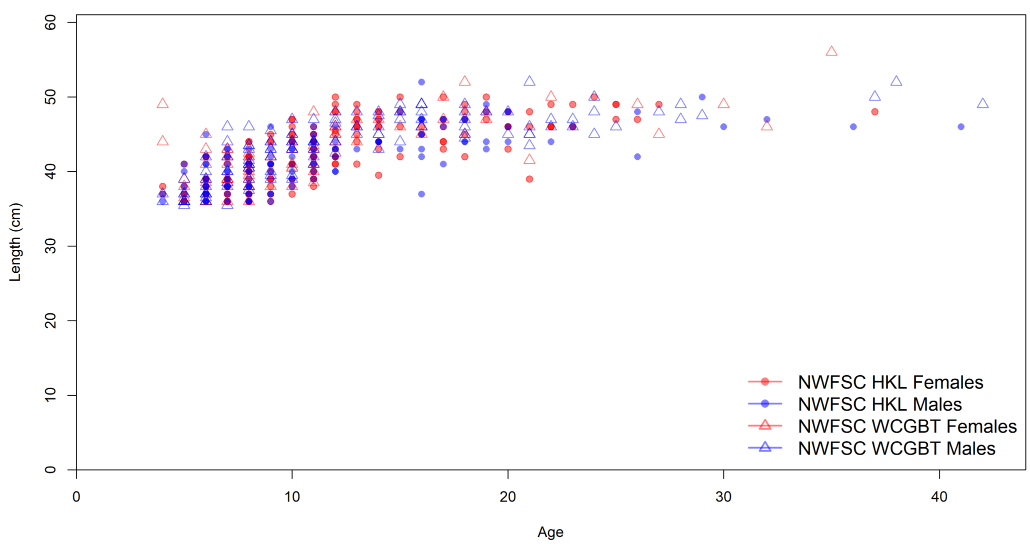

Figure 18: Length-at-age for non-randomly sampled larger fish observed by the NWFSC Hook and Line and WCGBT surveys.

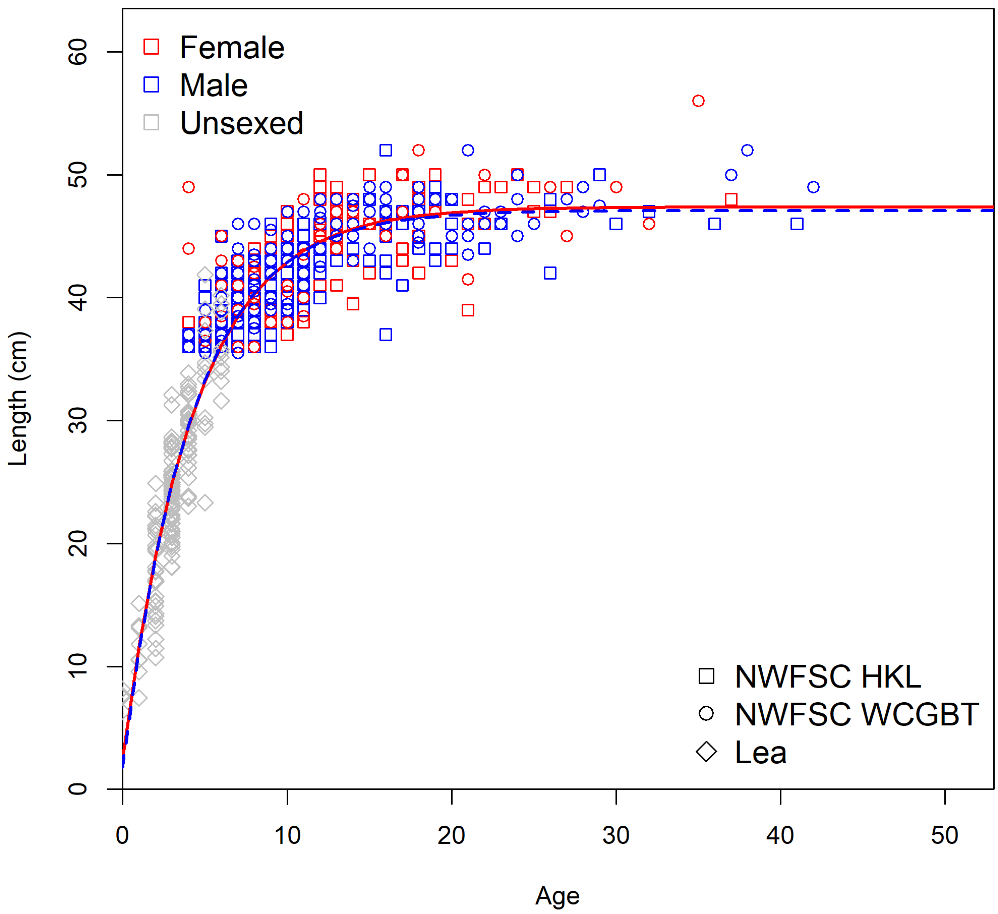

Figure 19: Length-at-age for non-randomly sampled larger fish observed by the NWFSC Hook and Line and WCGBT surveys and young fish from Lea.

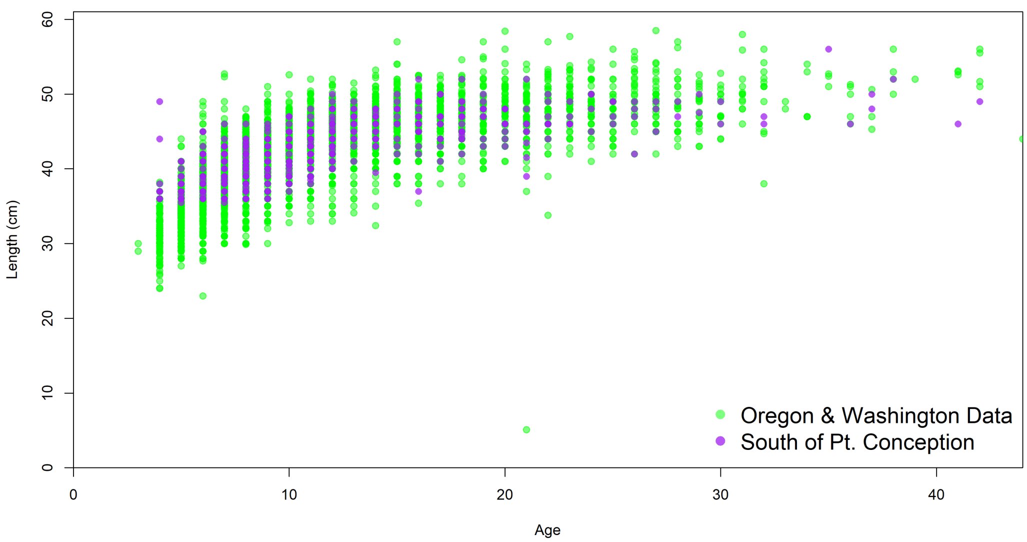

Figure 20: Length-at-age comparisons between survey collected fish south of Point Conception and to those observed off the coast of Oregon and Washington.

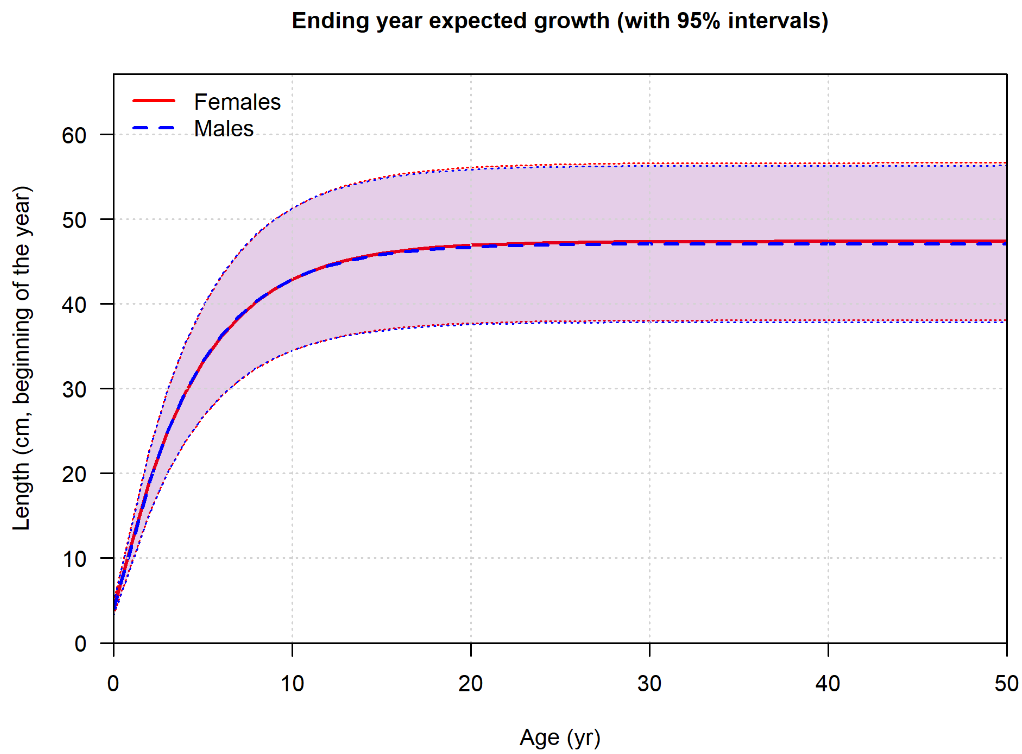

Figure 21: Length-at-age in the beginning of the year with the coefficient of variation by age within the model.

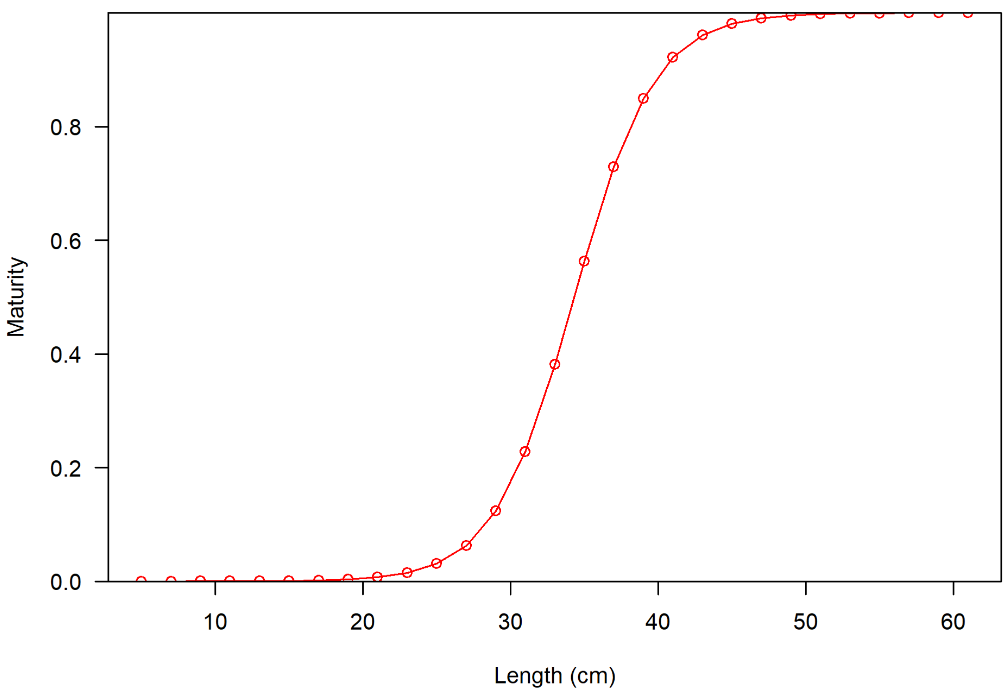

Figure 22: Maturity as a function of length.

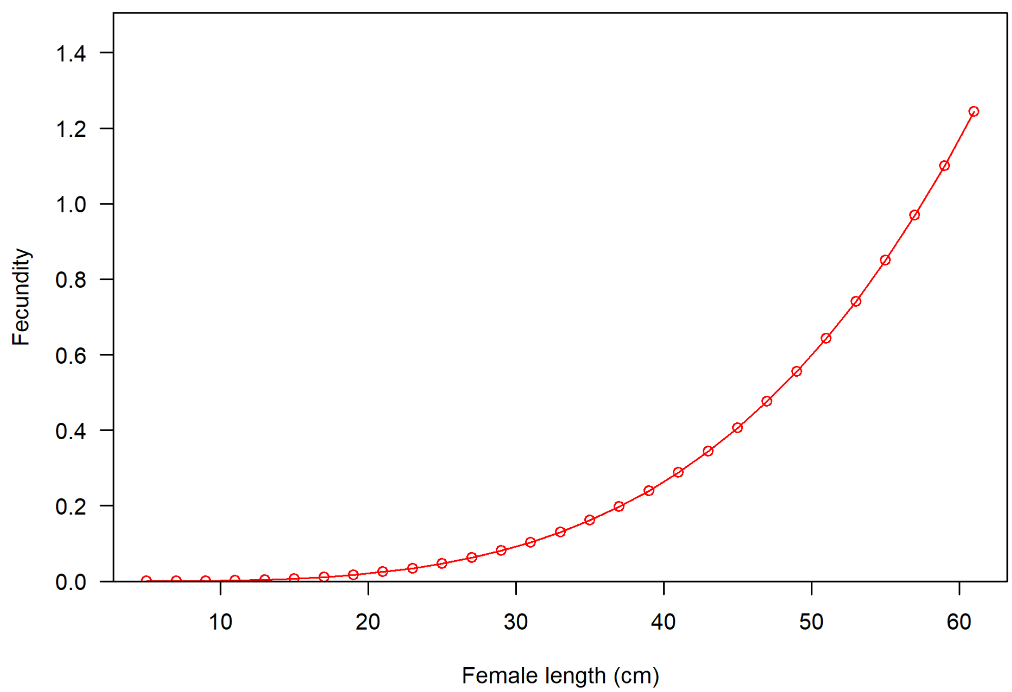

Figure 23: Fecundity as a function of length.

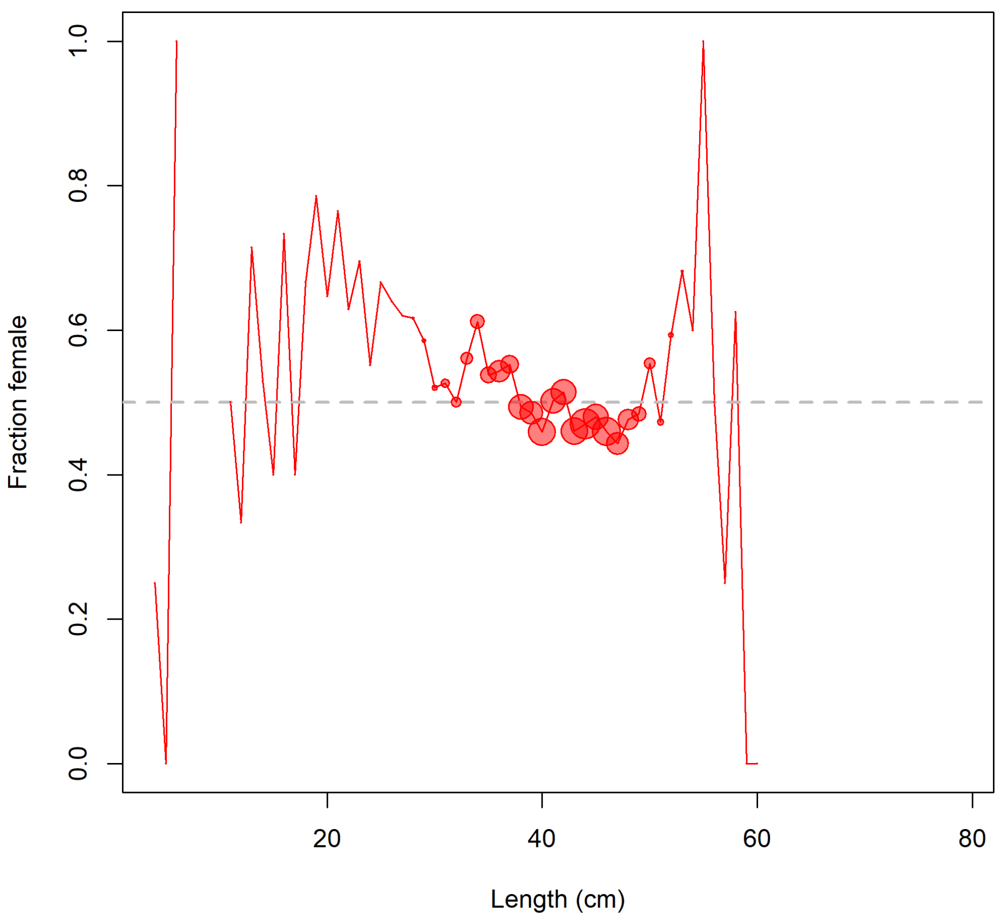

Figure 24: Fraction female by length across all available data sources where the size of red circles are based on the number of observations by length where larger circles indicate more observations.

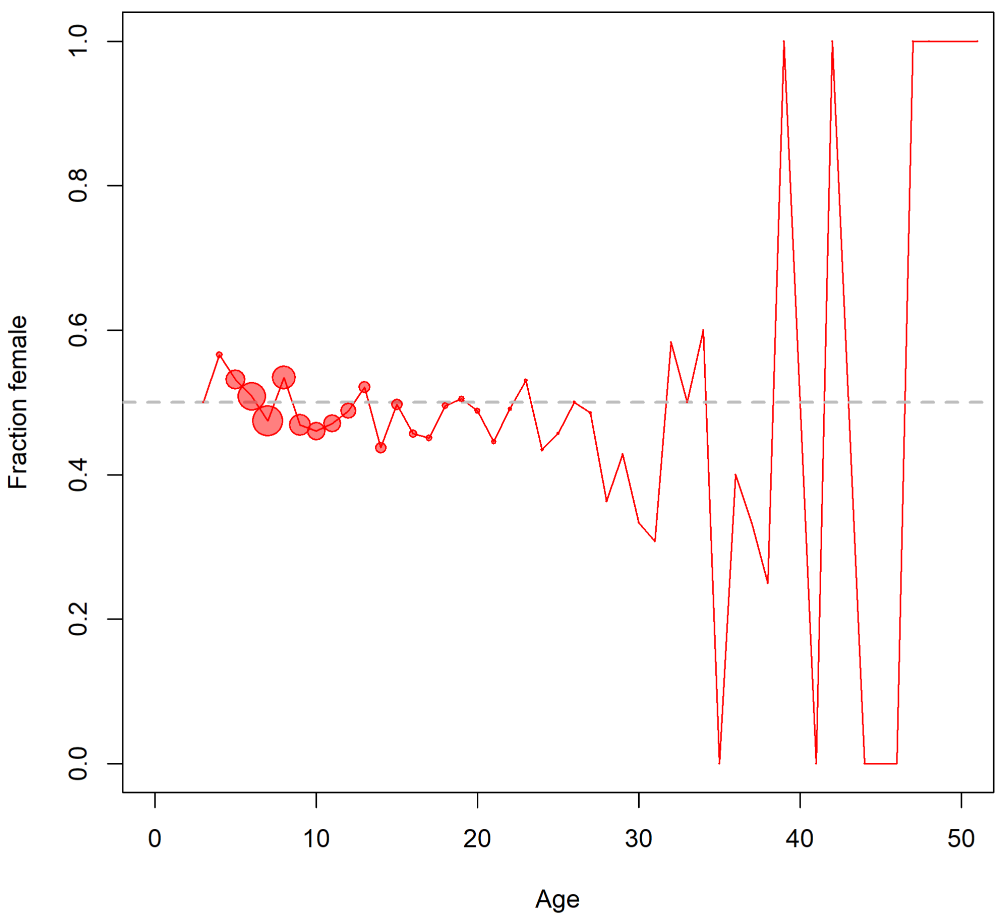

Figure 25: Fraction female by age across all available data sources where the size of red circles are based on the number of observations by age where larger circles indicate more observations.

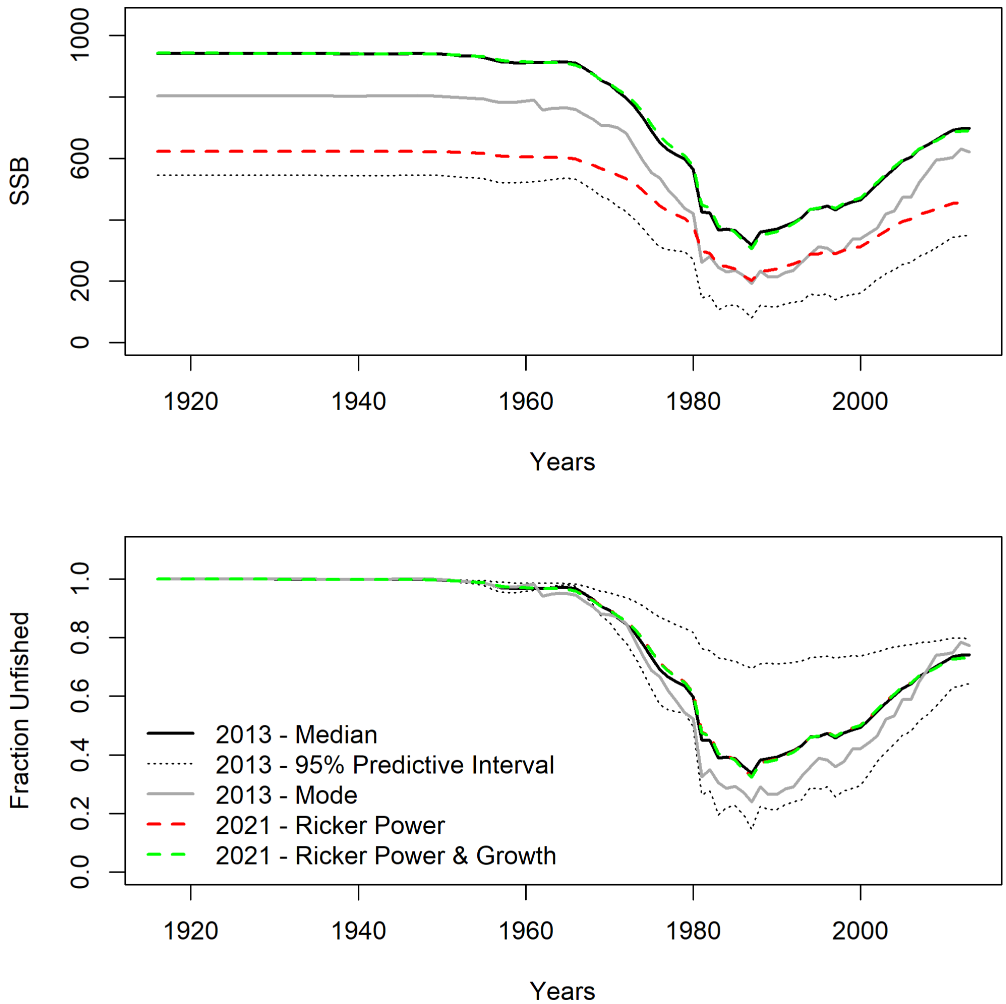

Figure 26: Comparison between SS bridge model and the results from the 2013 XDB-SRA model.

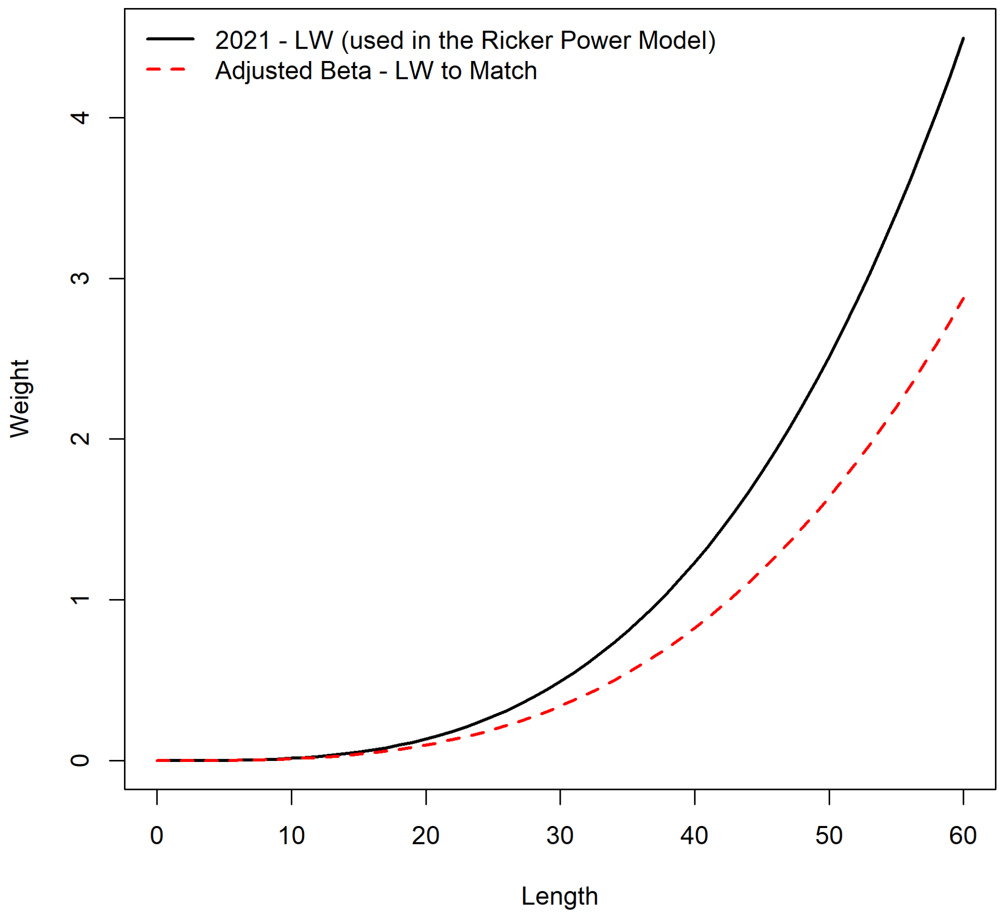

Figure 27: Adjustment to SS female weight-at-length curve to create a match in stock scale to XDB-SRA.

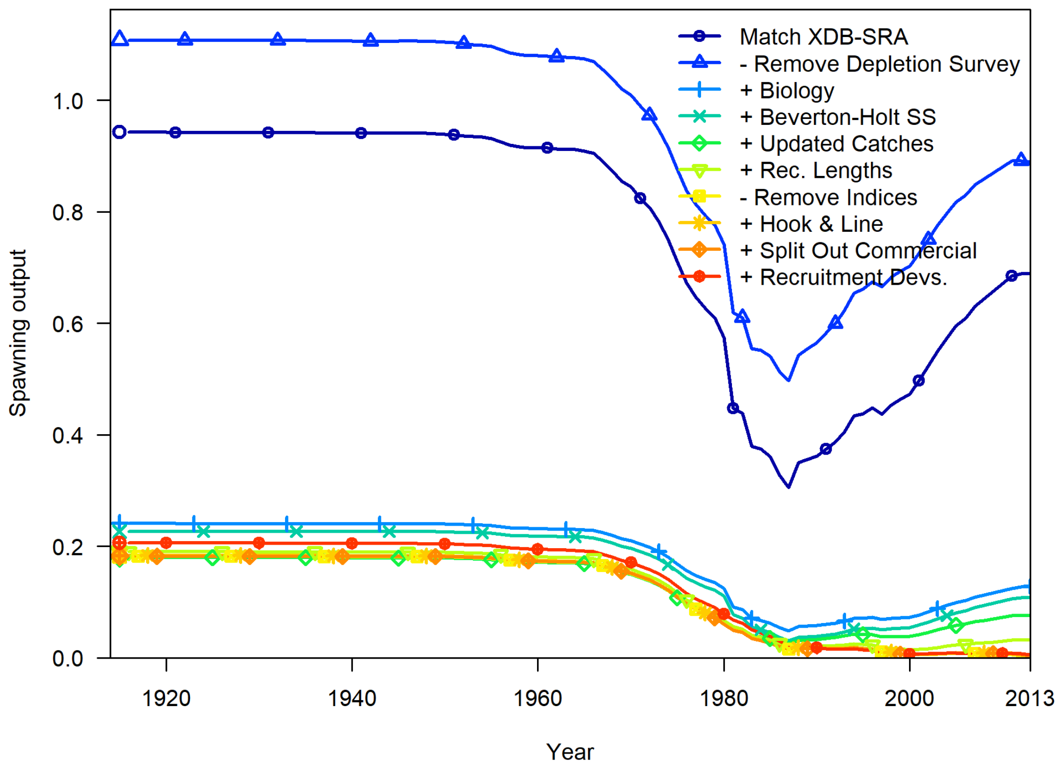

Figure 28: The time series of spawning biomass (or output) for updates to the 2013 model.

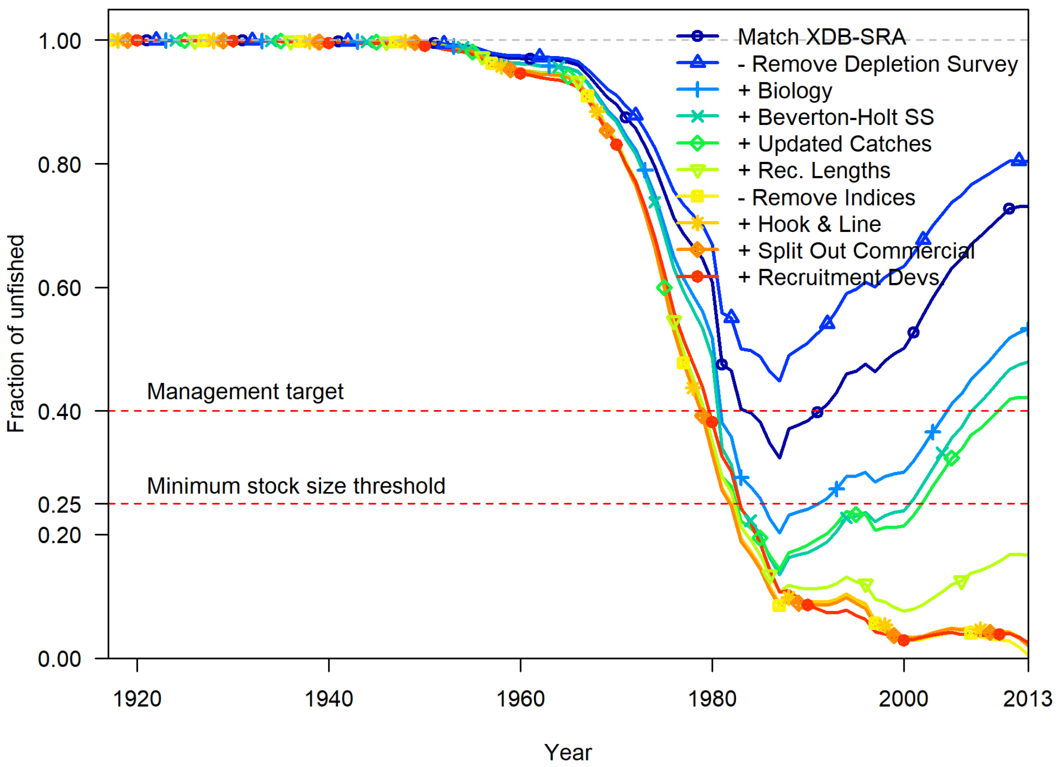

Figure 29: The time series of fraction unfished for updates to the 2013 model.

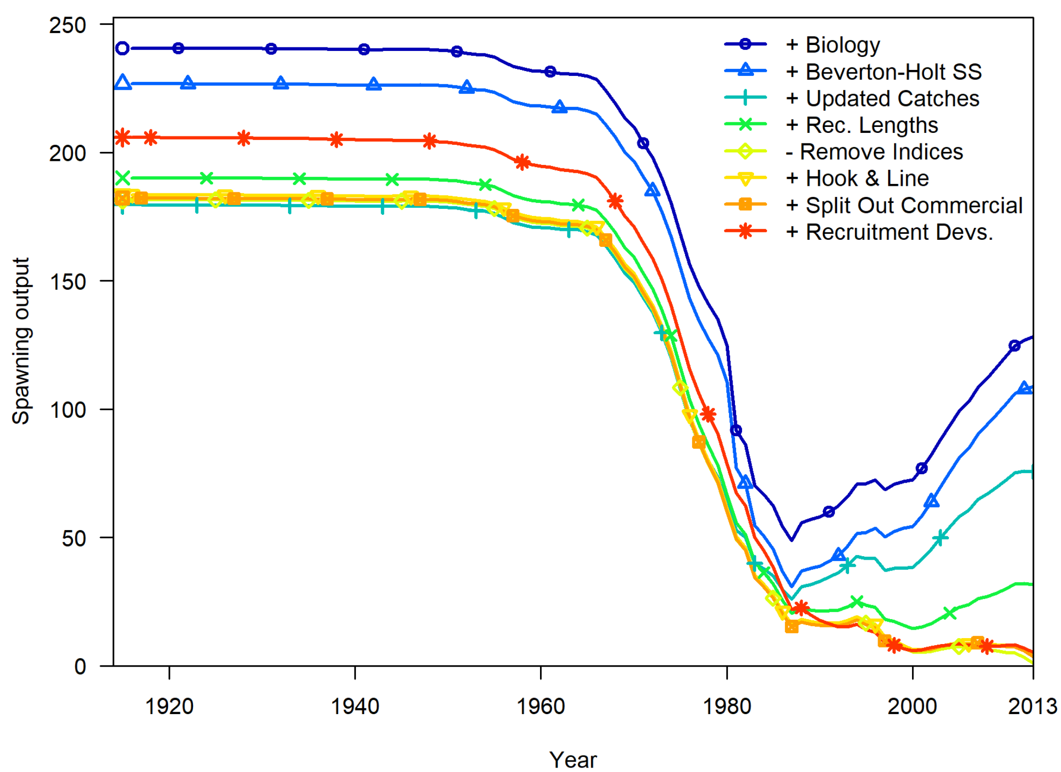

Figure 30: The time series of spawning output for the subset of bridge models with the updated fecundity relationship.

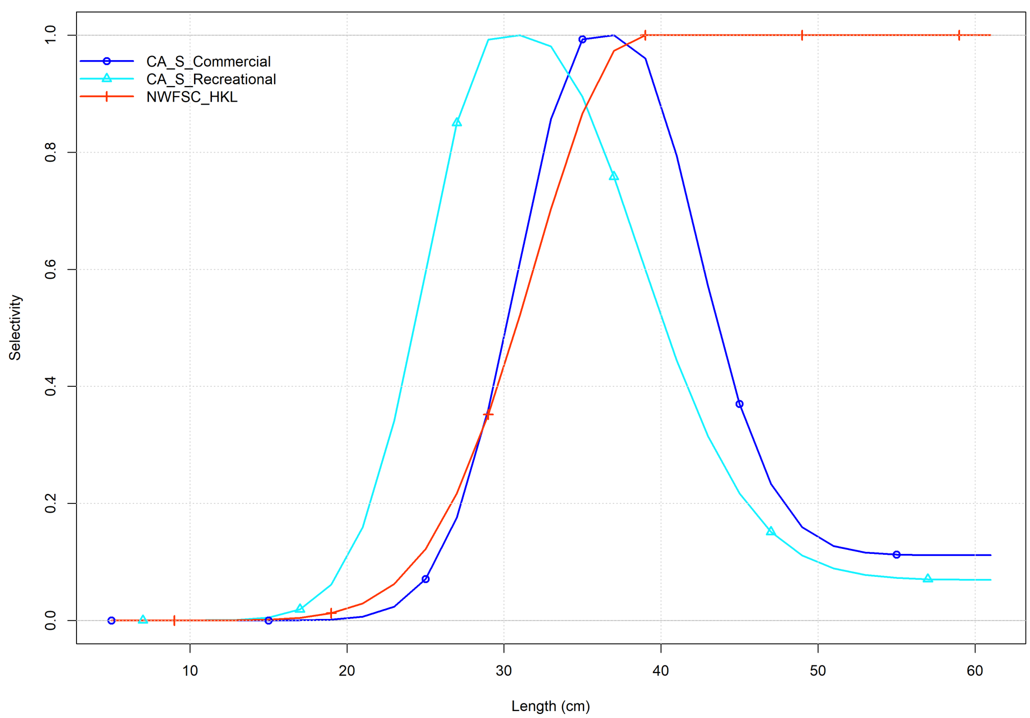

Figure 31: Selectivity at length by fleet.

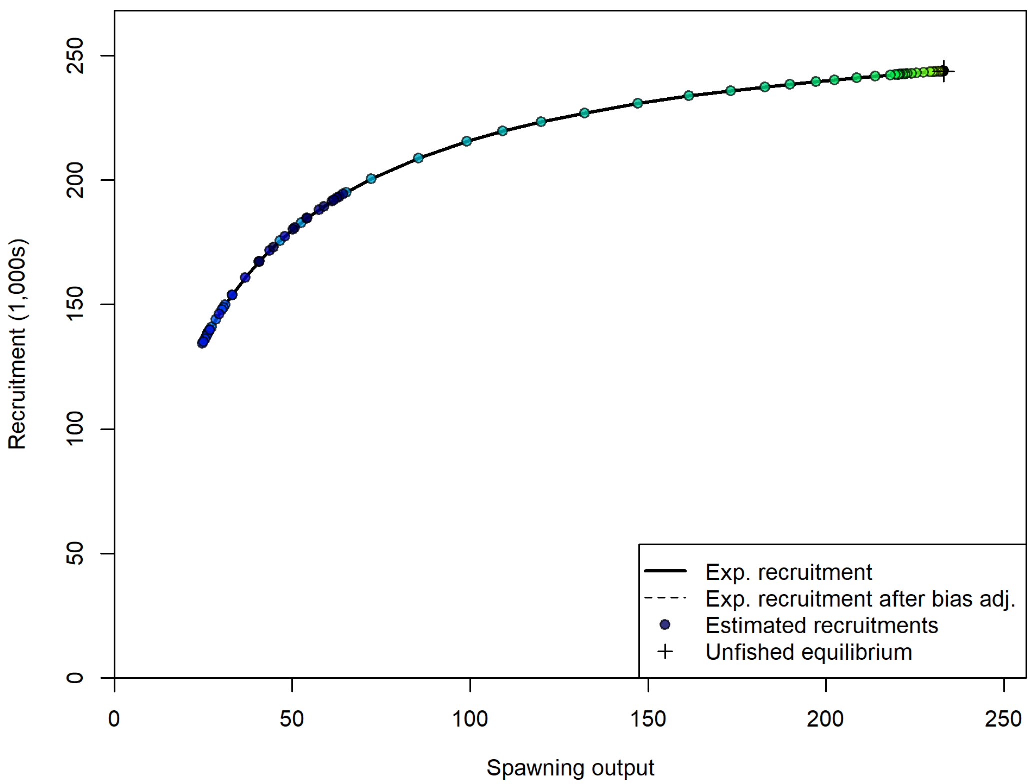

Figure 32: Stock-recruit curve. Point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years.

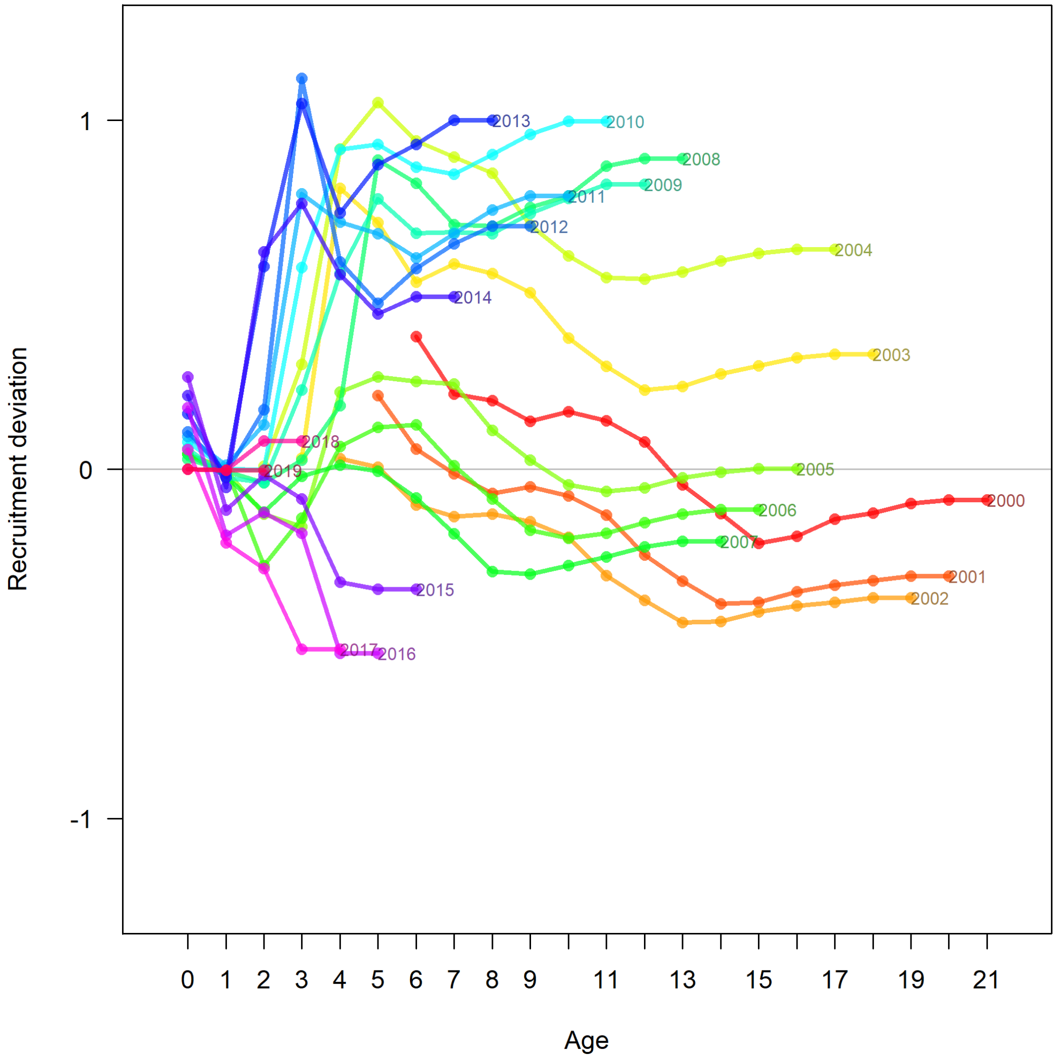

Figure 33: The estimated recruitment deviations as additional years of data are removed during a retrospective run. Select years of estimated recruitment deviations remain greater than 0 after all informative data are removed.

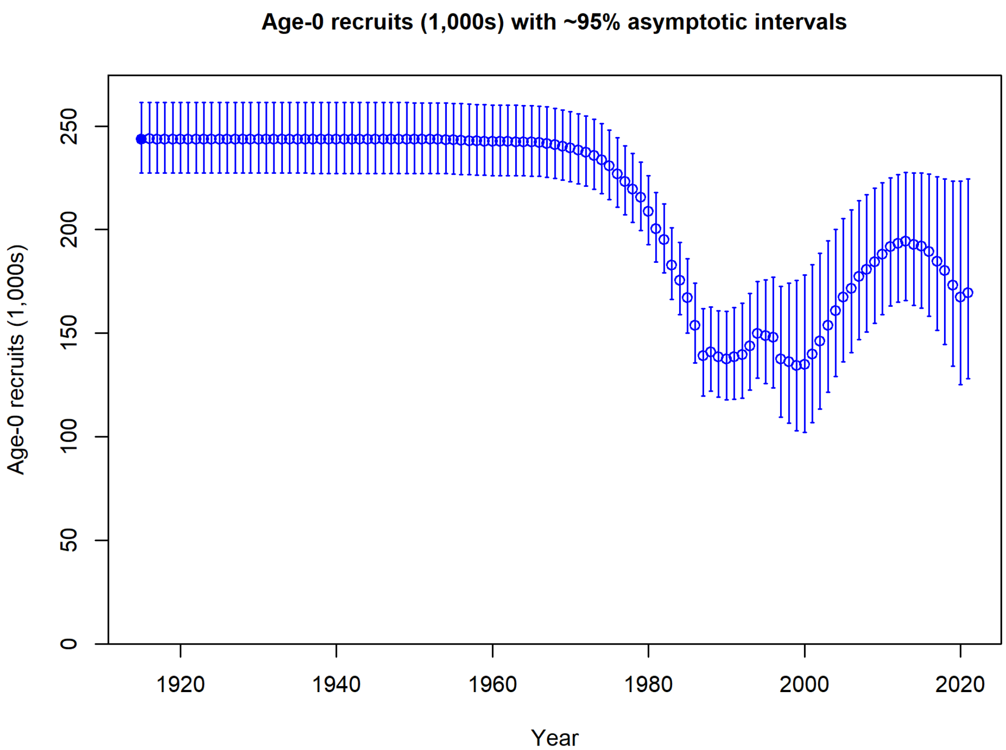

Figure 34: Estimated time series of age-0 recruits (1000s).

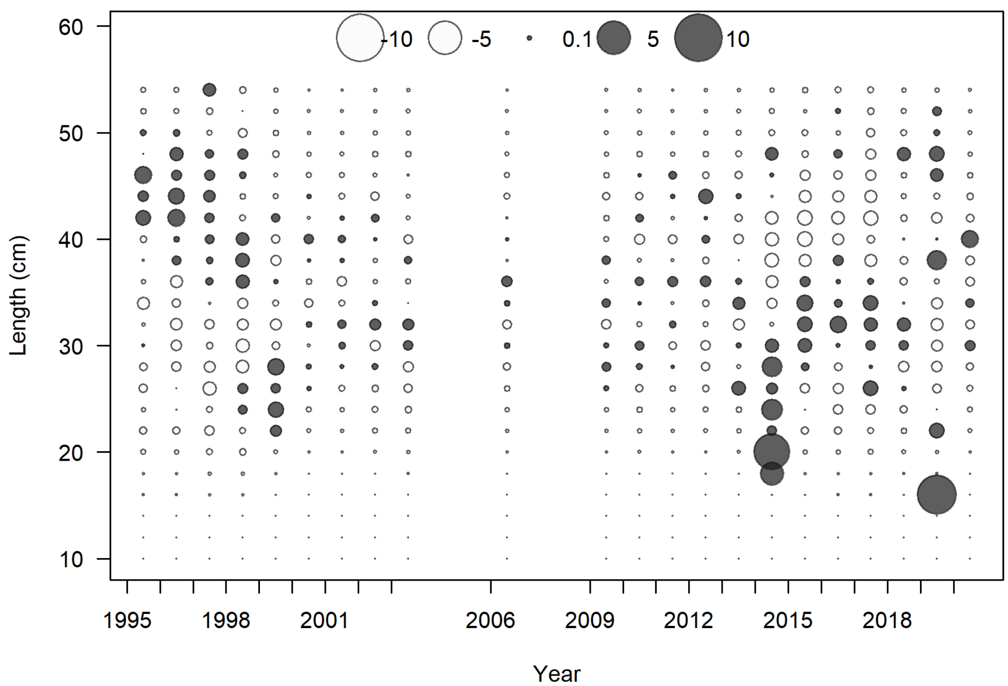

Figure 35: Pearson residuals for commercial fleet. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

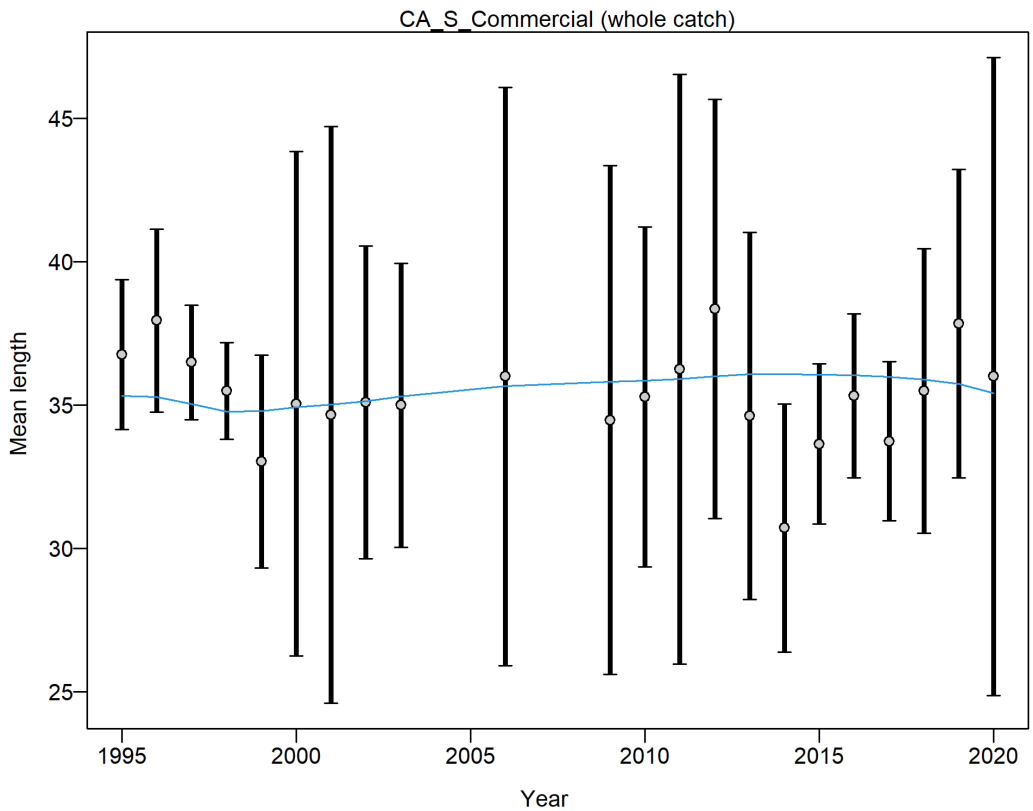

Figure 36: Mean length for commercial lengths with 95 percent confidence intervals based on current samples sizes.

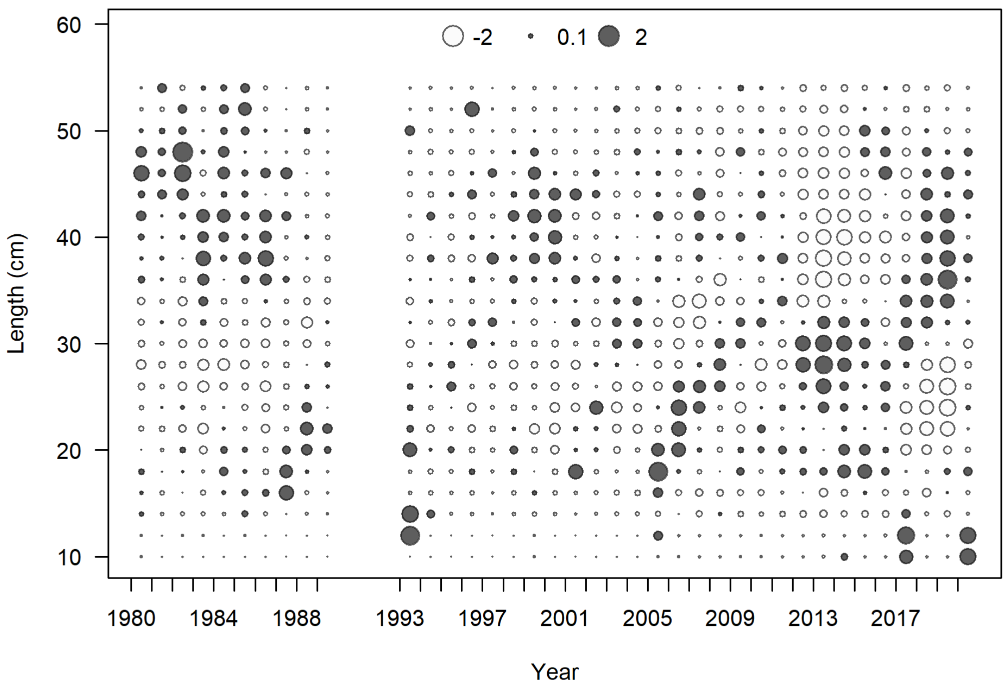

Figure 37: Pearson residuals for recreational fleet. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

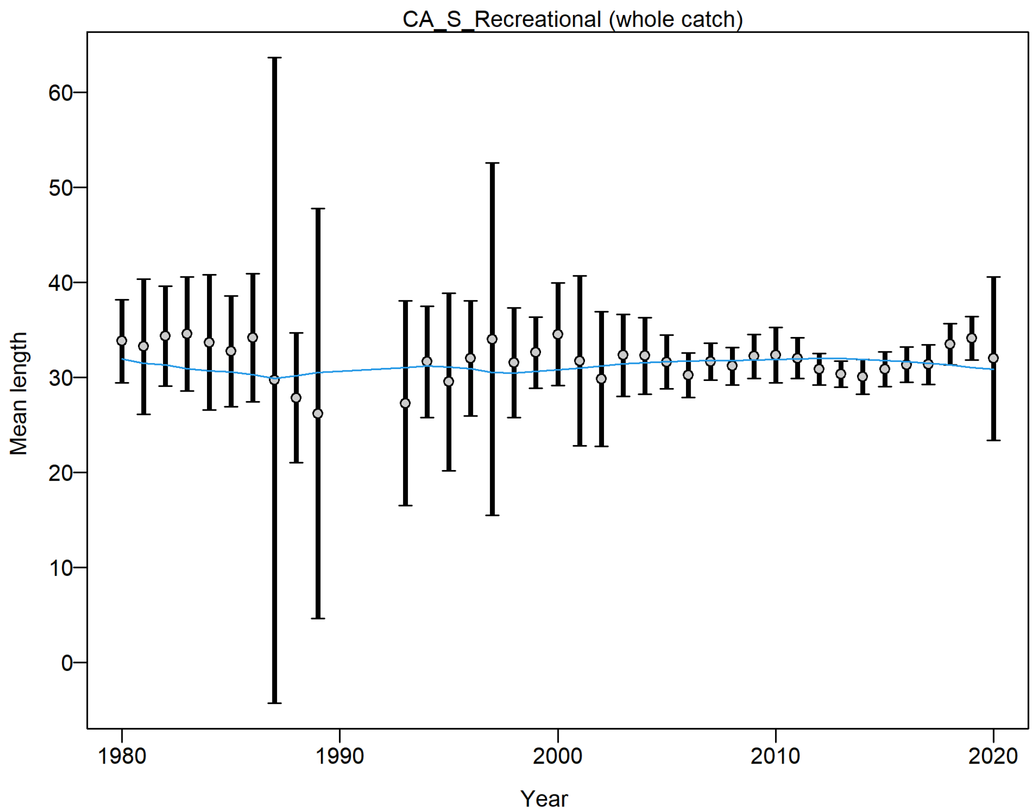

Figure 38: Mean length for recreational lengths with 95 percent confidence intervals based on current samples sizes.

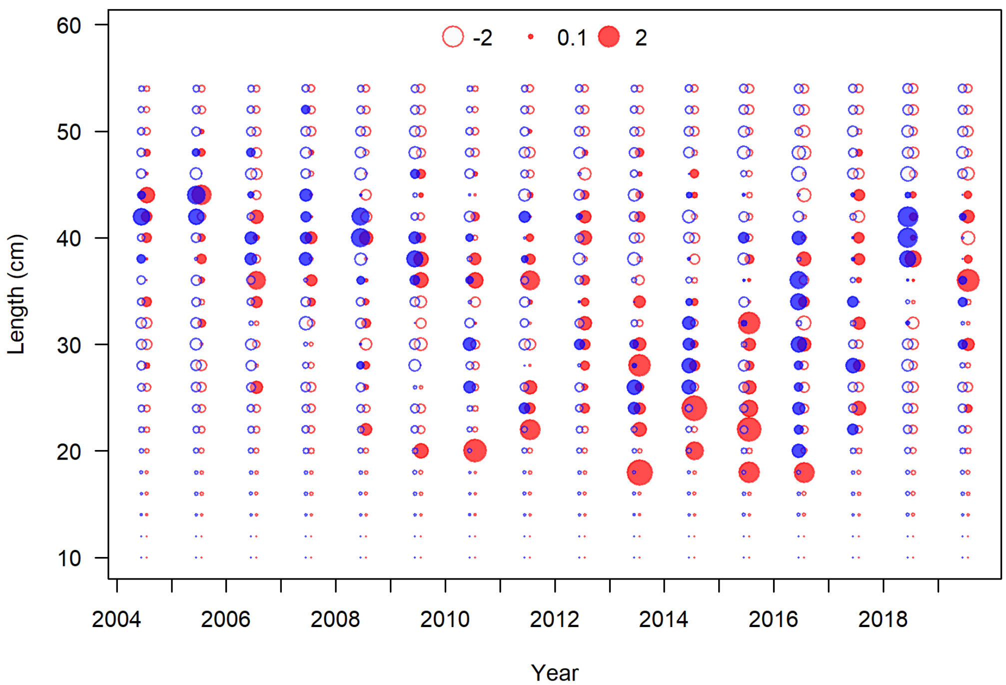

Figure 39: Pearson residuals for NWFSC Hook and Line survey. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

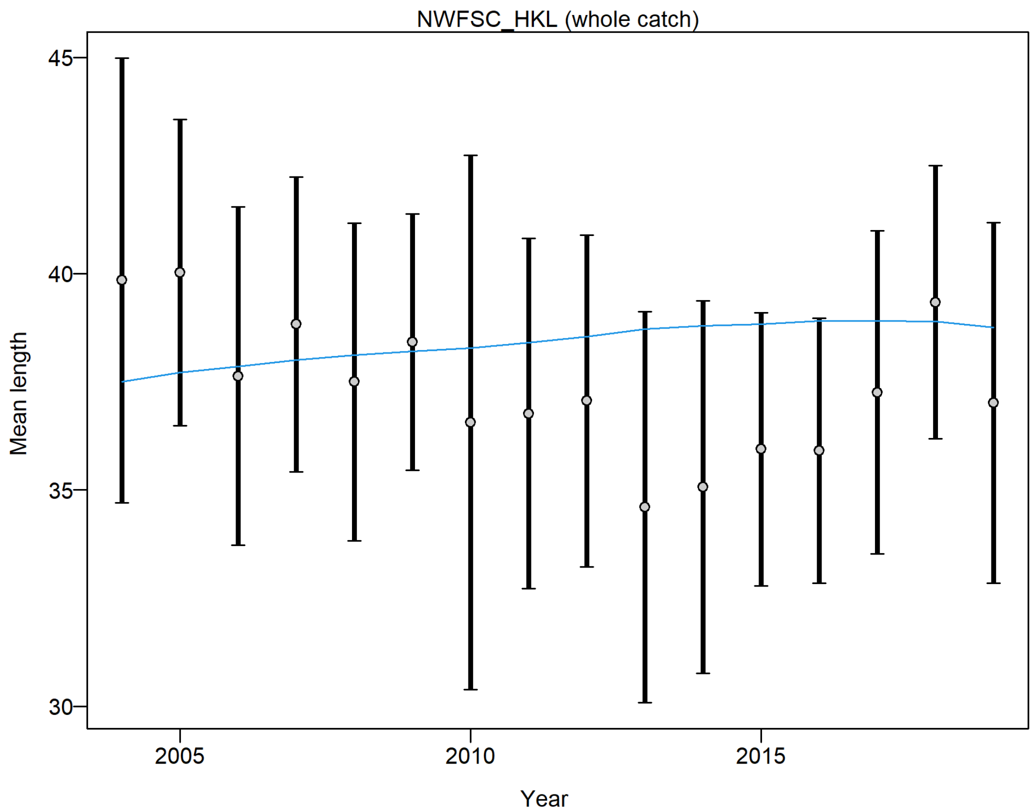

Figure 40: Mean length for NWFSC Hook and Line survey lengths with 95 percent confidence intervals based on current samples sizes.

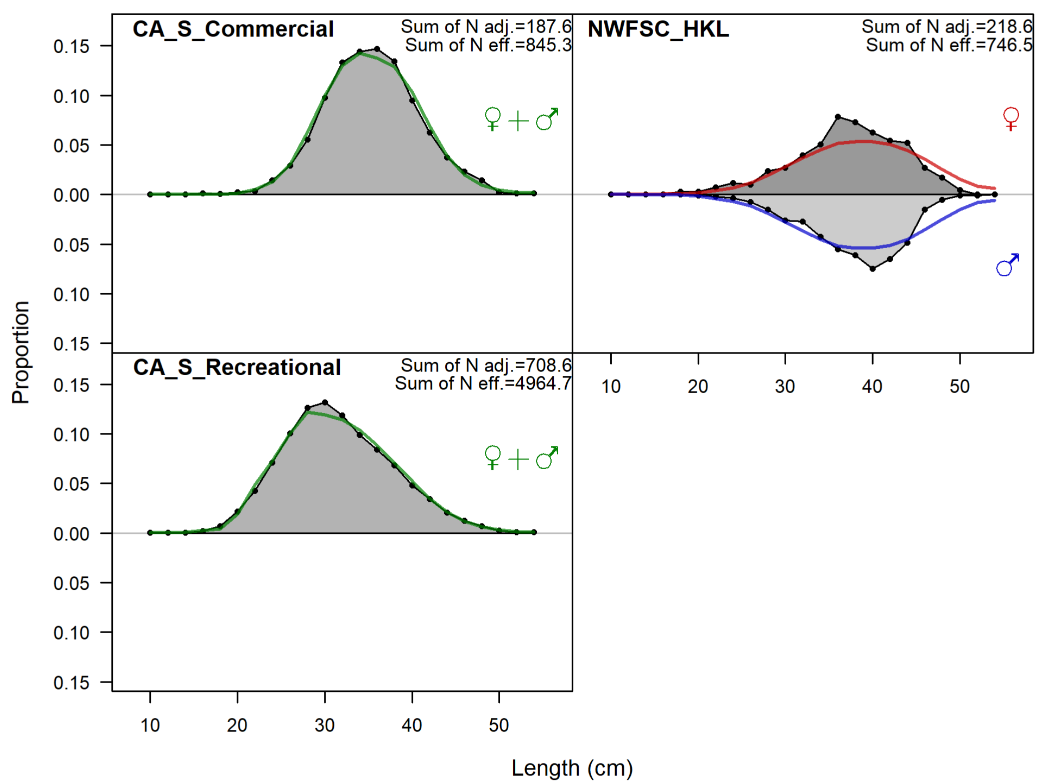

Figure 41: Aggregated length comps over all years.

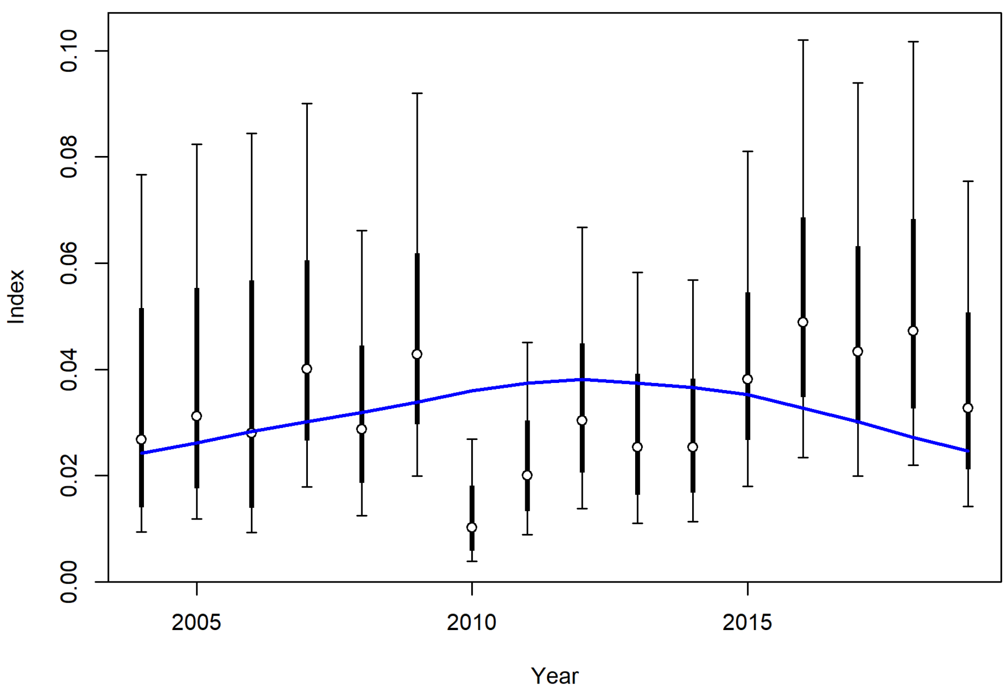

Figure 42: Fit to index data for the NWFSC Hook and Line survey.

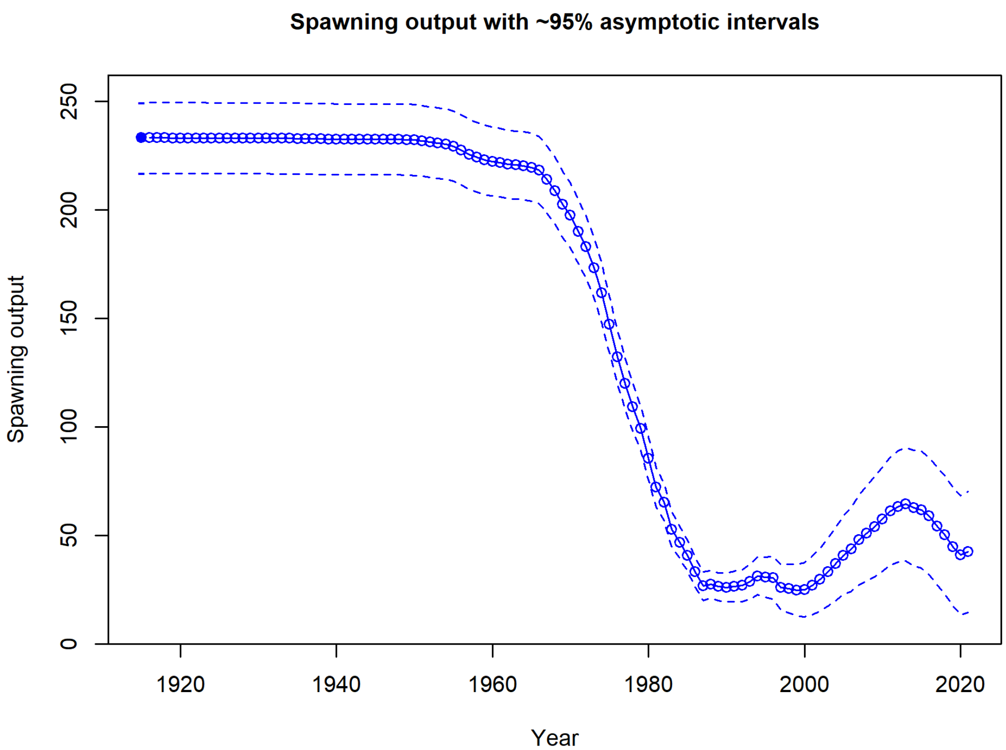

Figure 43: Estimated time series of spawning output.

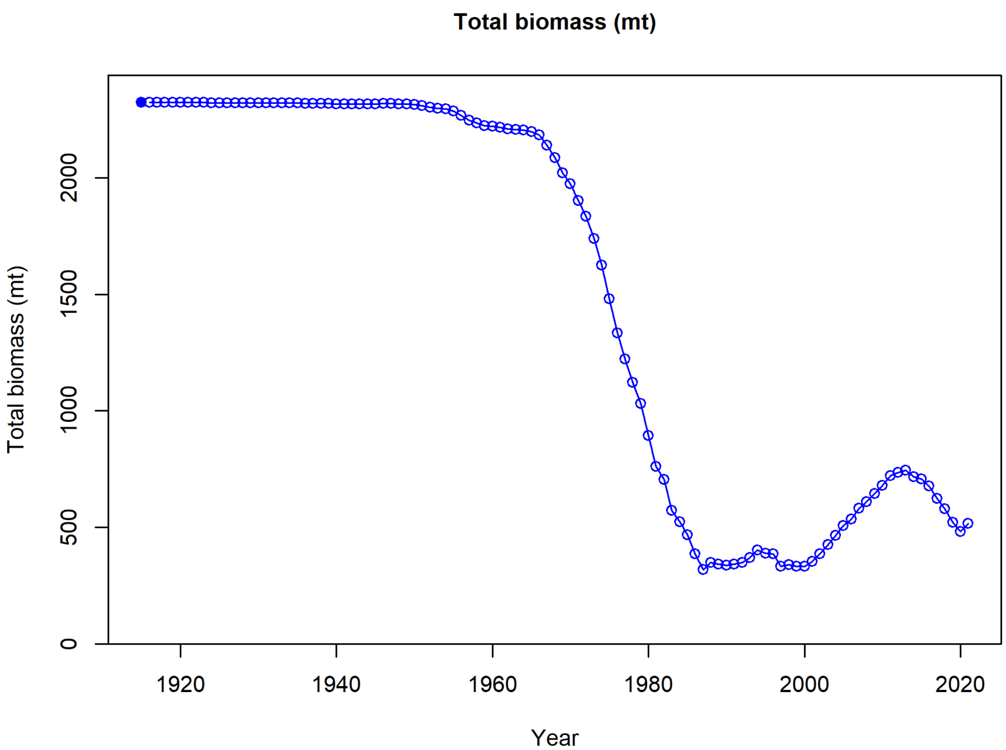

Figure 44: Estimated time series of total biomass.

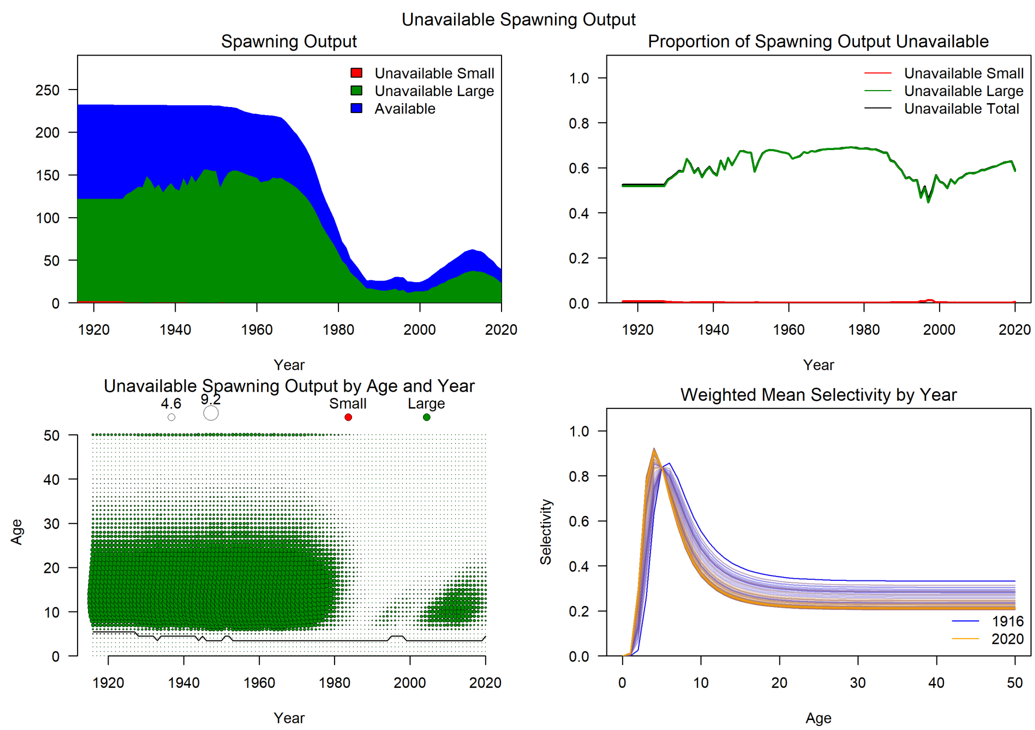

Figure 45: Estimated time series of unavailable spawning output.

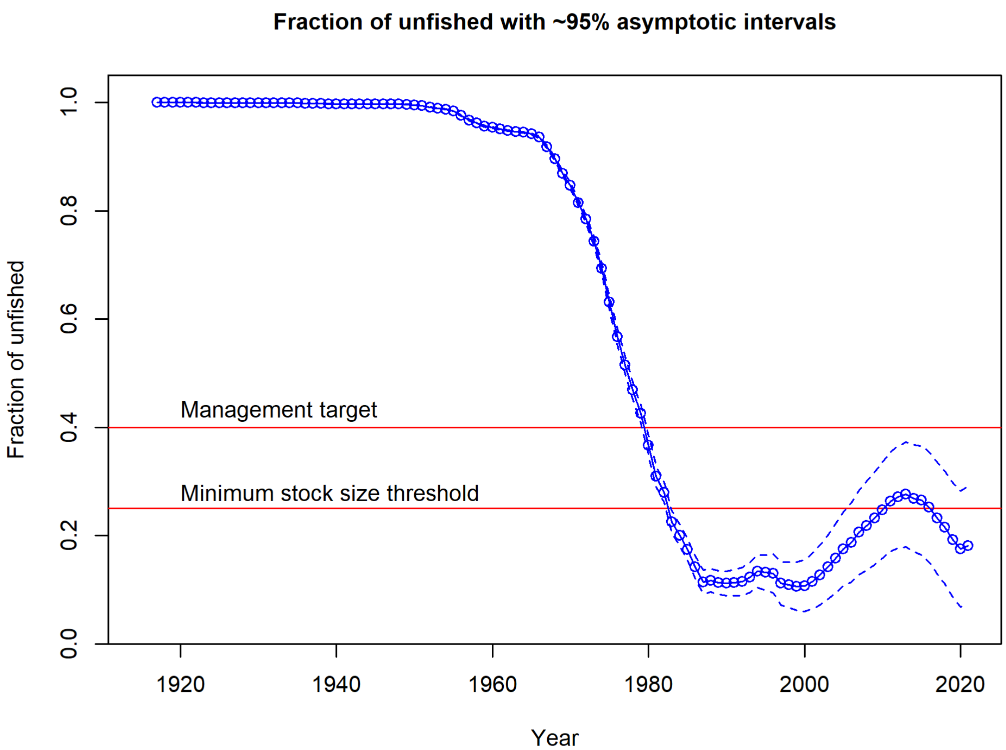

Figure 46: Estimated time series of fraction of unfished spawning output.

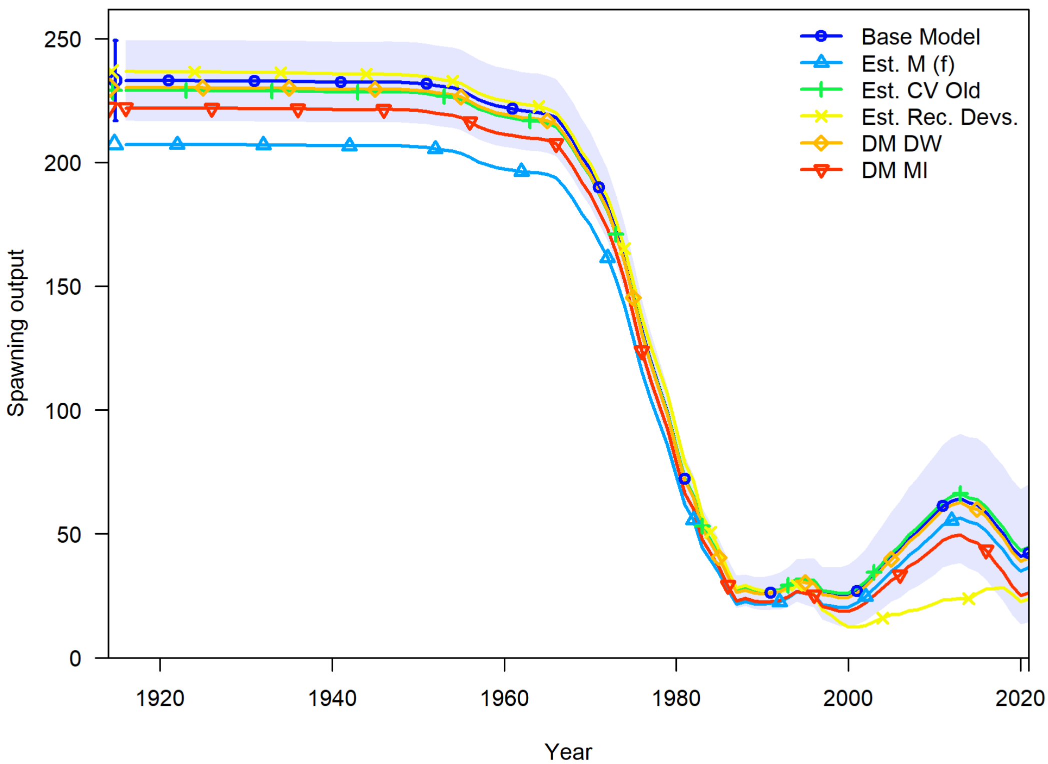

Figure 47: Change in estimated spawning output by sensitivity.

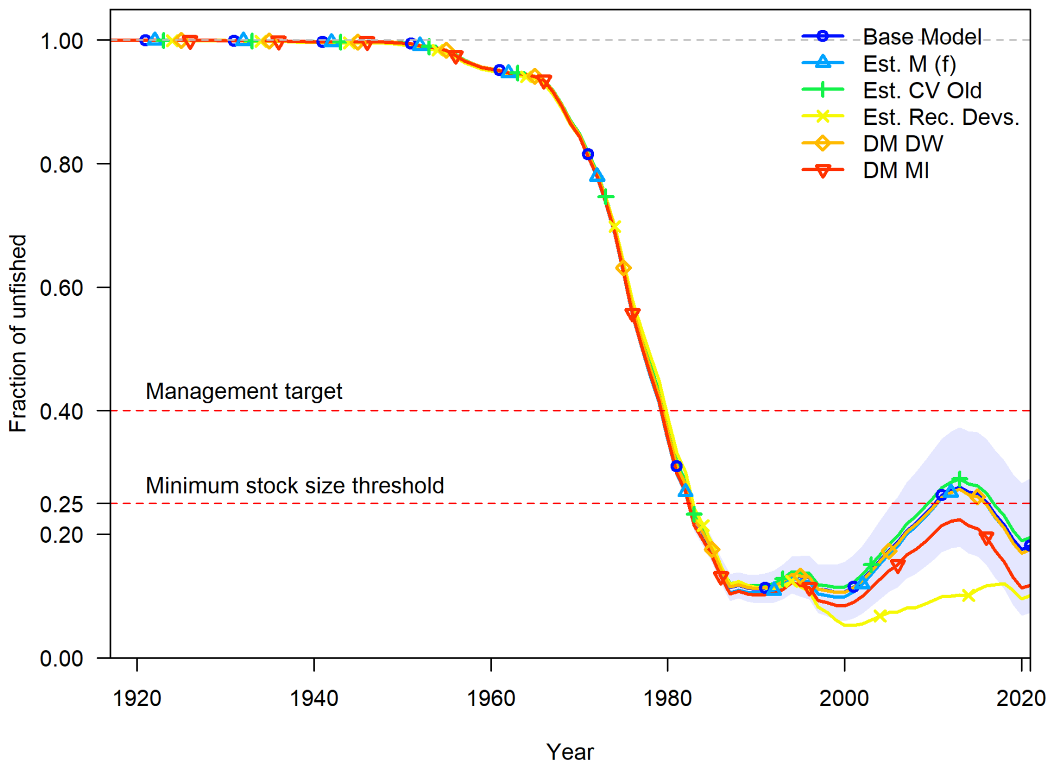

Figure 48: Change in estimated fraction unfished by sensitivity.

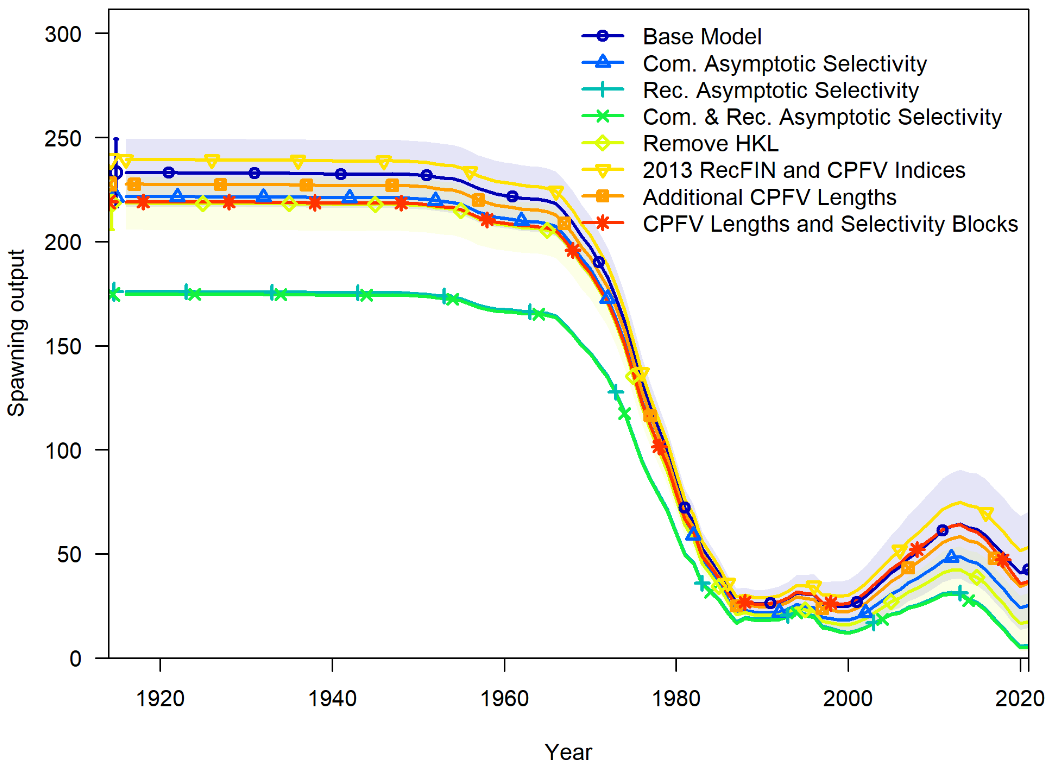

Figure 49: Change in estimated spawning output by sensitivity.

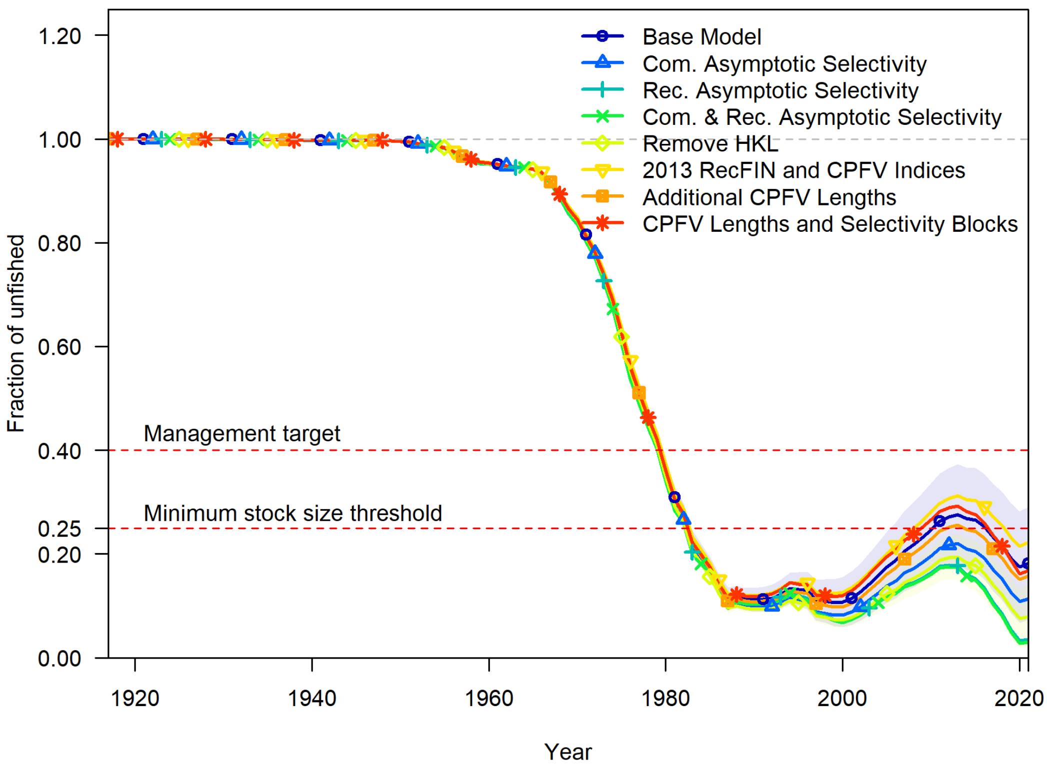

Figure 50: Change in estimated fraction unfished by sensitivity.

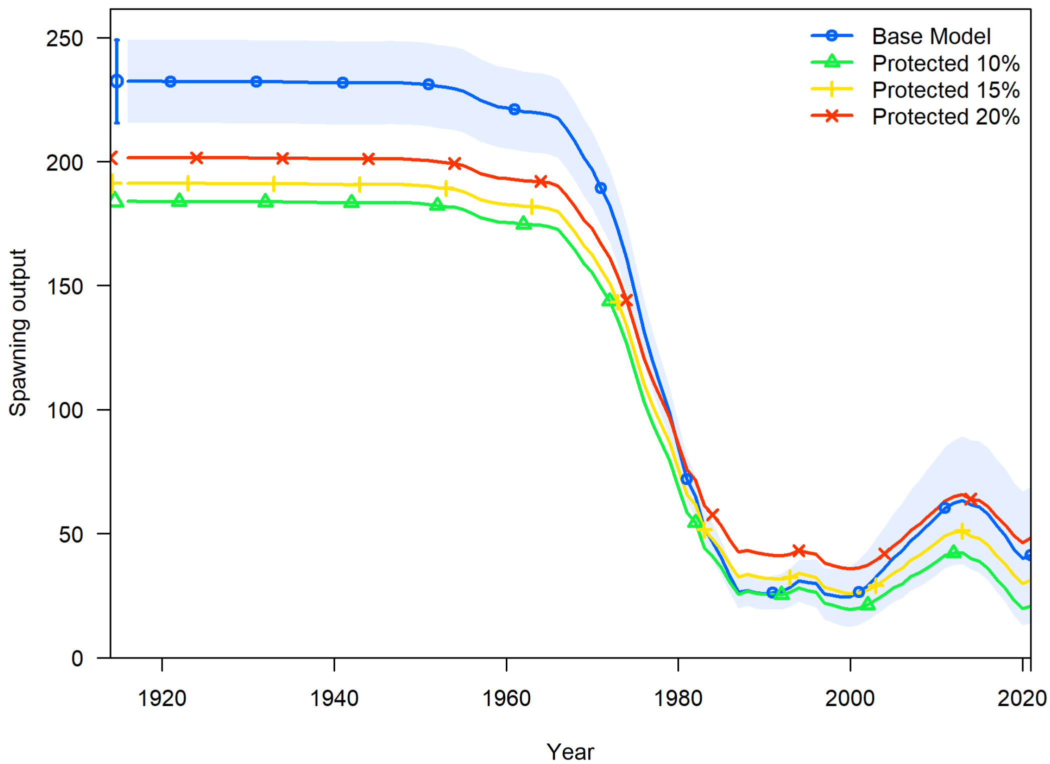

Figure 51: Change in estimated spawning output by sensitivity examining alternative percent of the population protected from fishing.

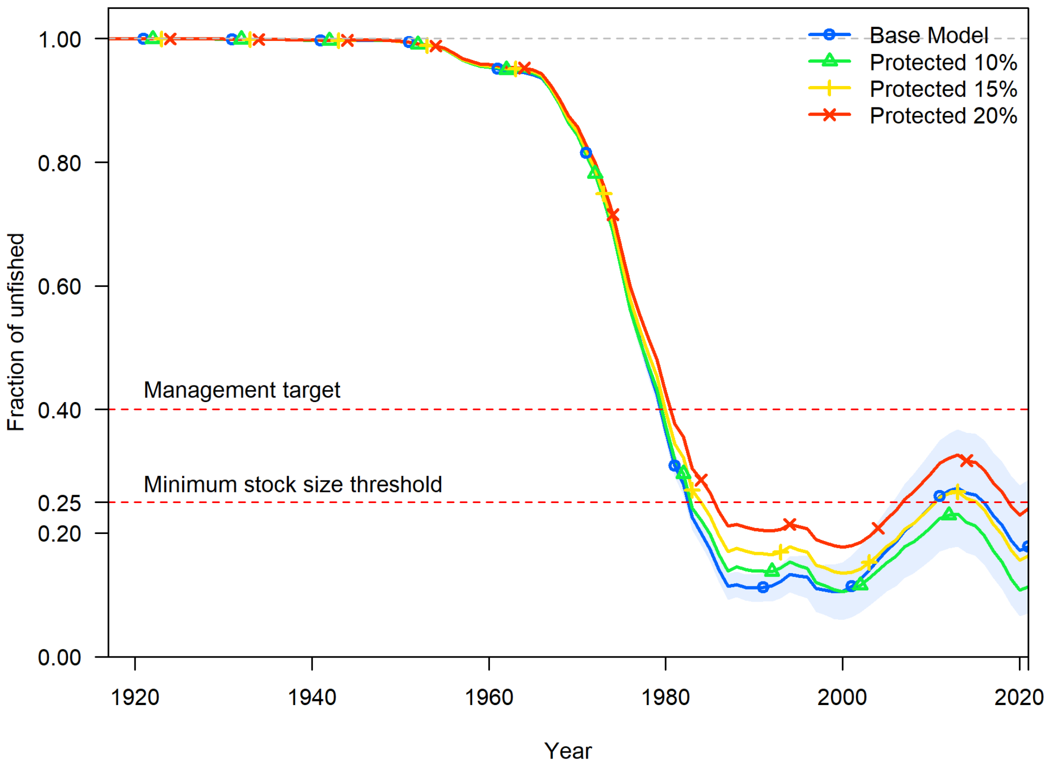

Figure 52: Change in estimated fraction unfished by sensitivity examining alternative percent of the population protected from fishing.

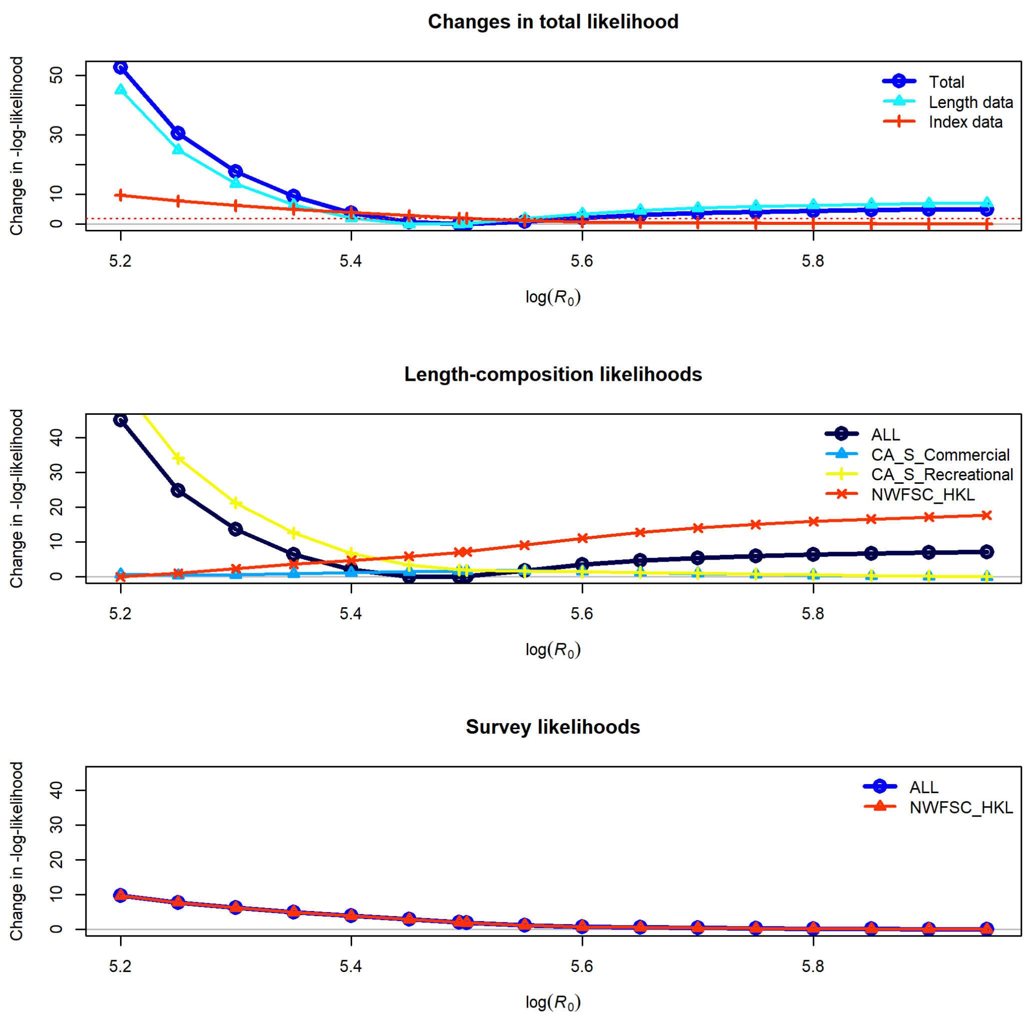

Figure 53: Change in the negative log-likelihood across a range of log(R_0) values.

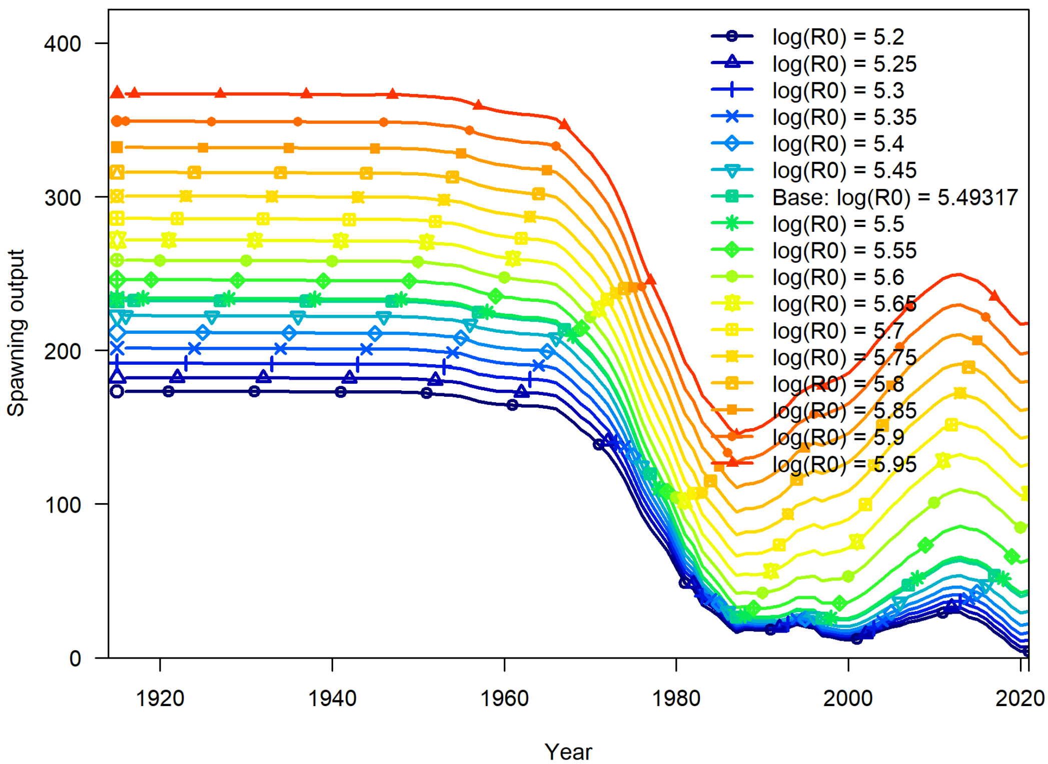

Figure 54: Change in the estimate of spawning output across a range of $\log(R_0)$ values.

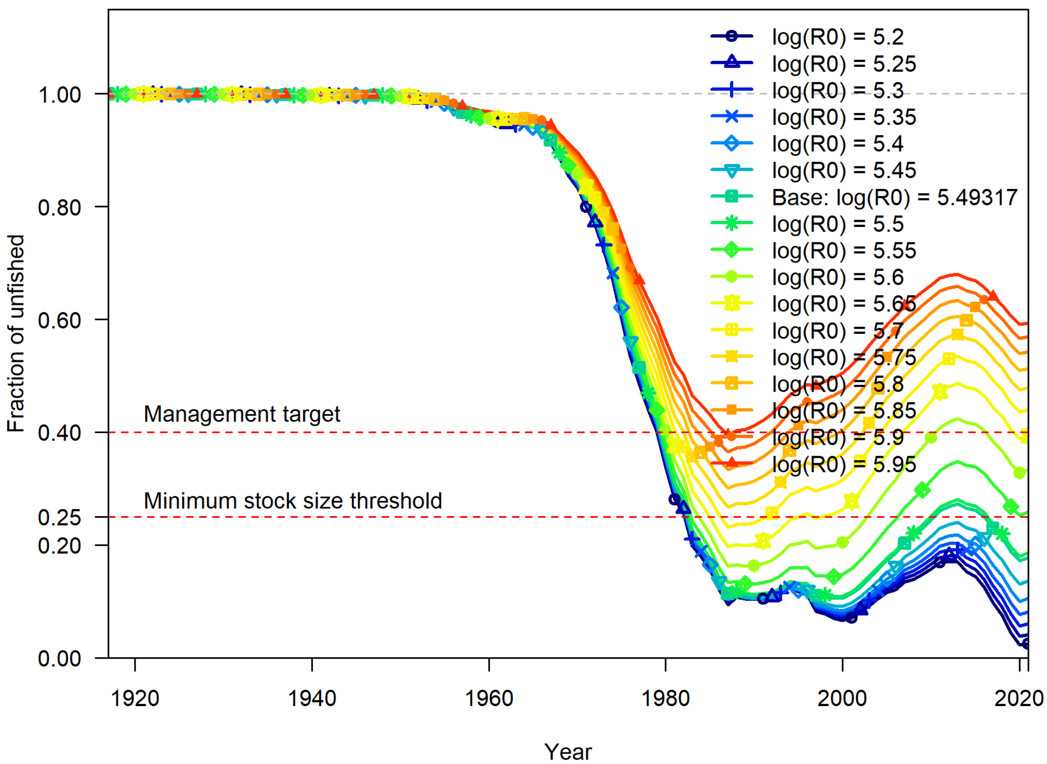

Figure 55: Change in the estimate of fraction unfished across a range of $\log(R_0)$ values.

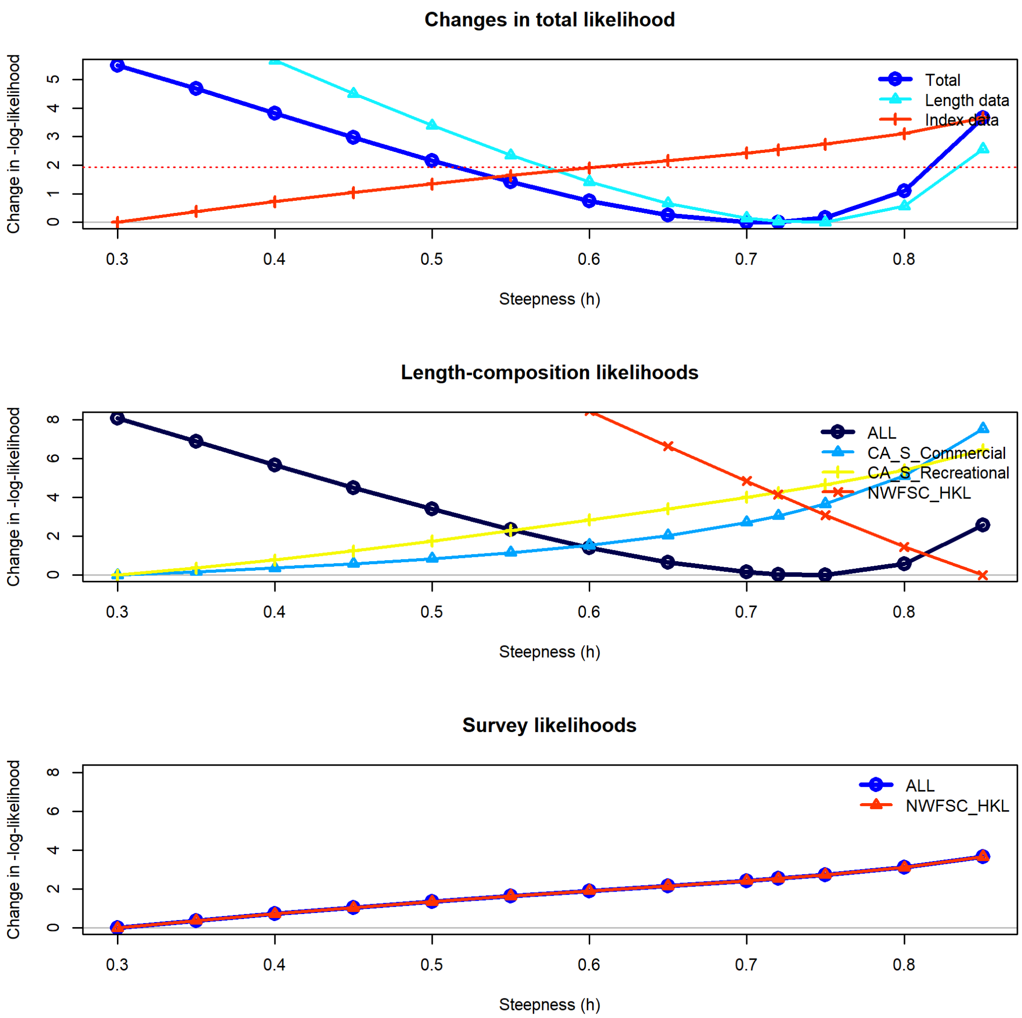

Figure 56: Change in the negative log-likelihood across a range of steepness values.

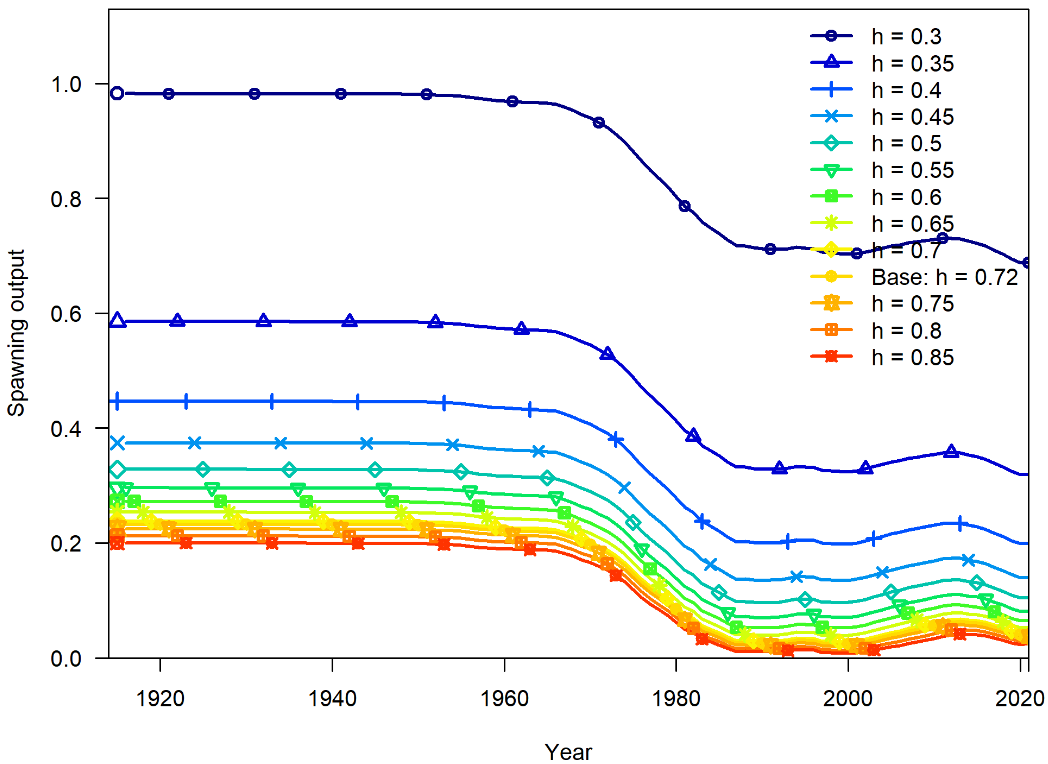

Figure 57: Change in the estimate of spawning output across a range of steepness values.

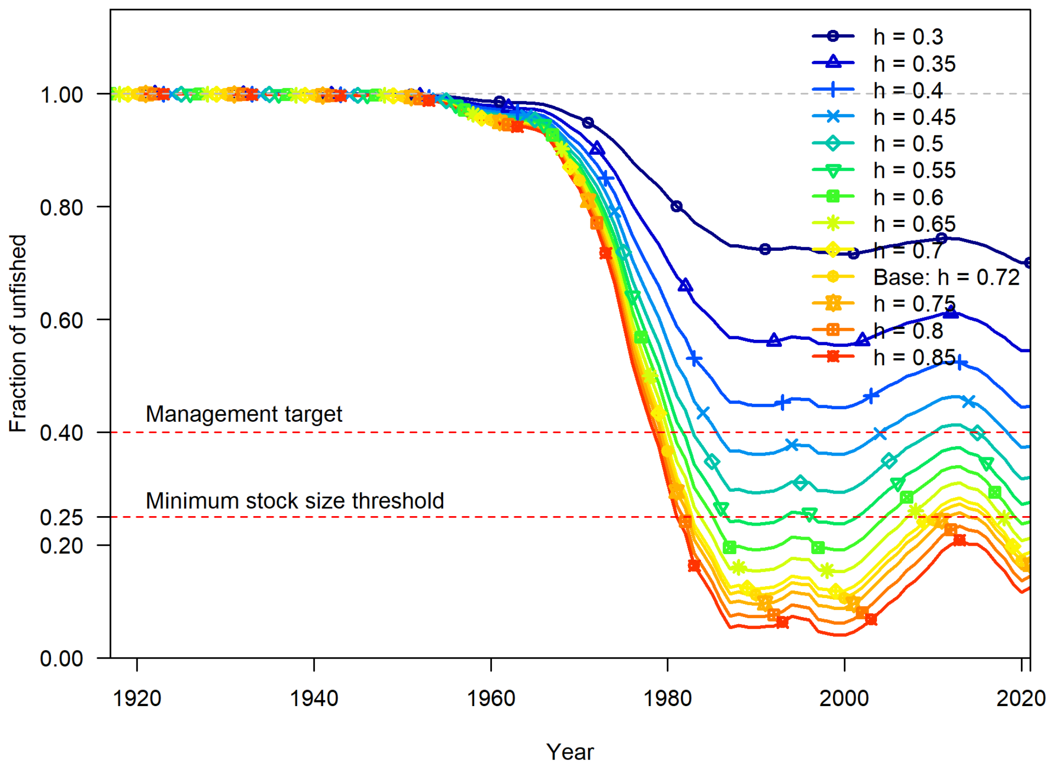

Figure 58: Change in the estimate of fraction unfished across a range of steepness values.

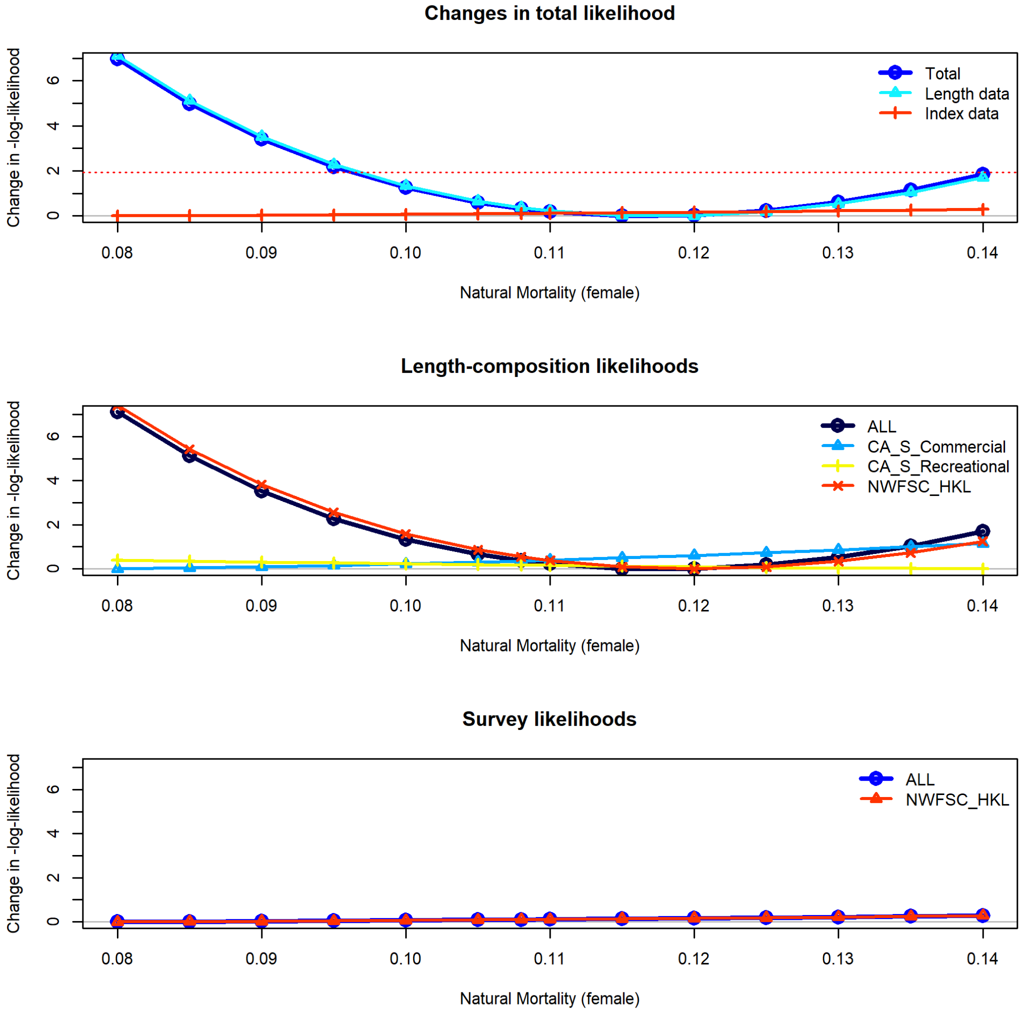

Figure 59: Change in the negative log-likelihood across a range of female natural mortality values.

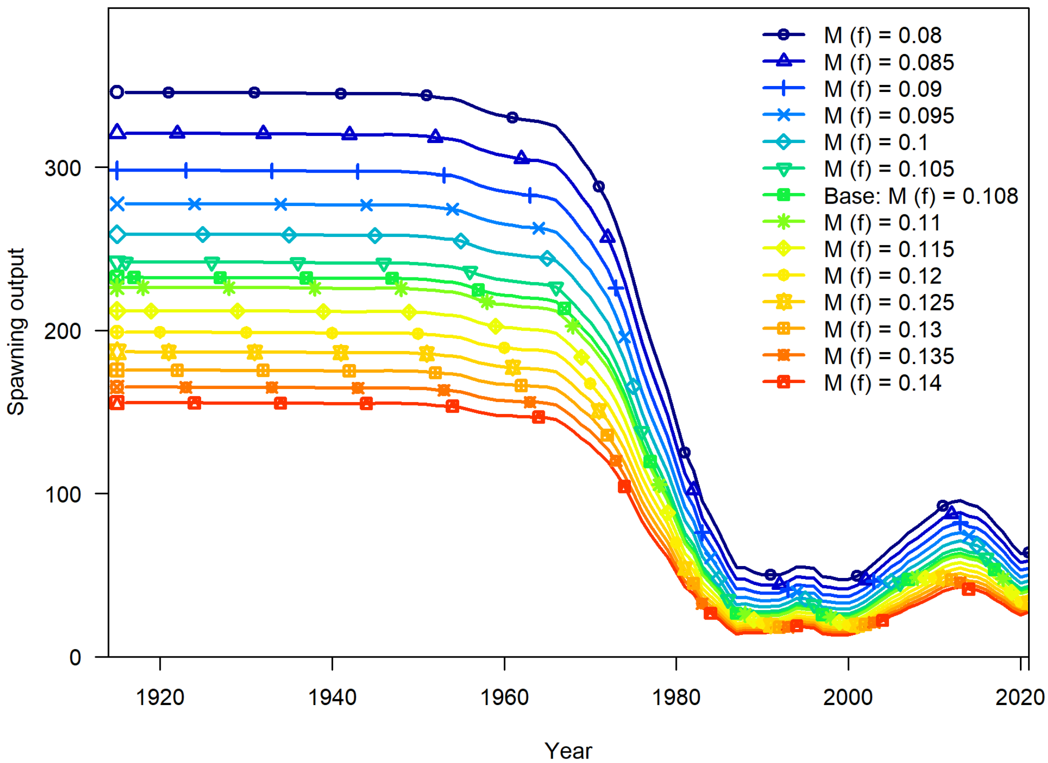

Figure 60: Change in the estimate of spawning output across a range of female natural mortality values.

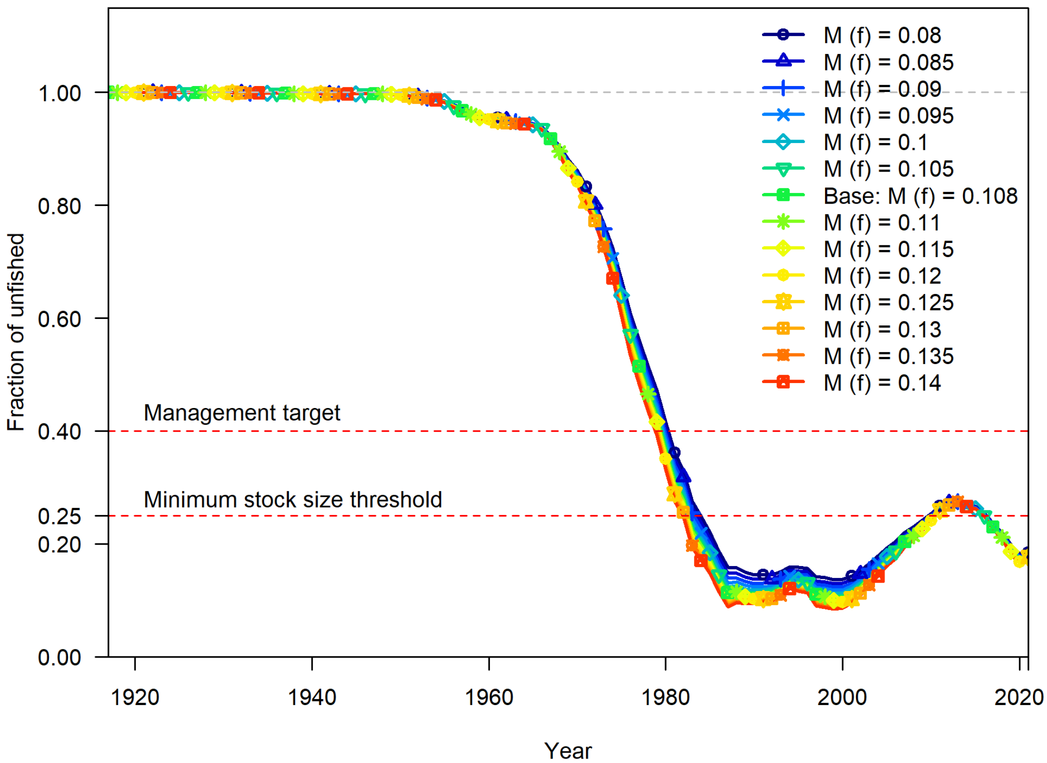

Figure 61: Change in the estimate of fraction unfished across a range of female natural values.

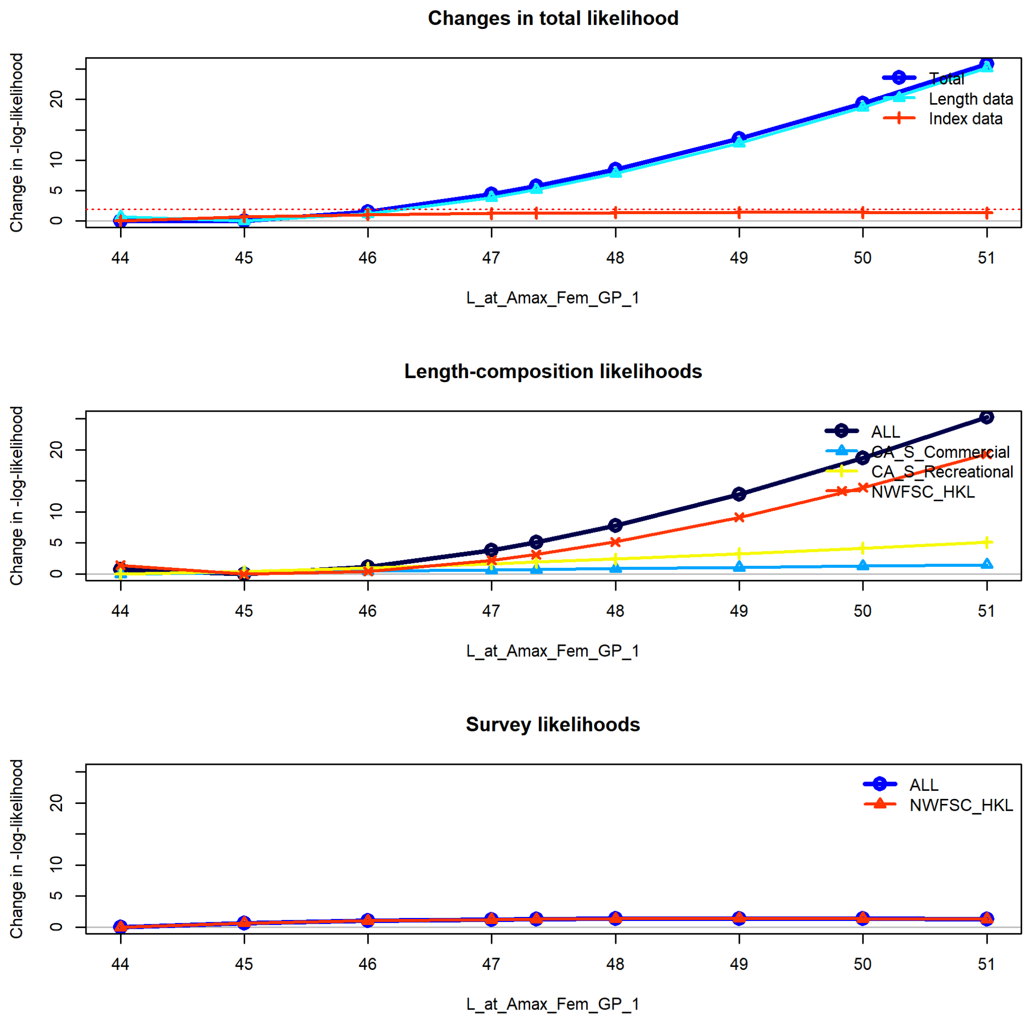

Figure 62: Change in the negative log-likelihood across a range of female maximum length values.

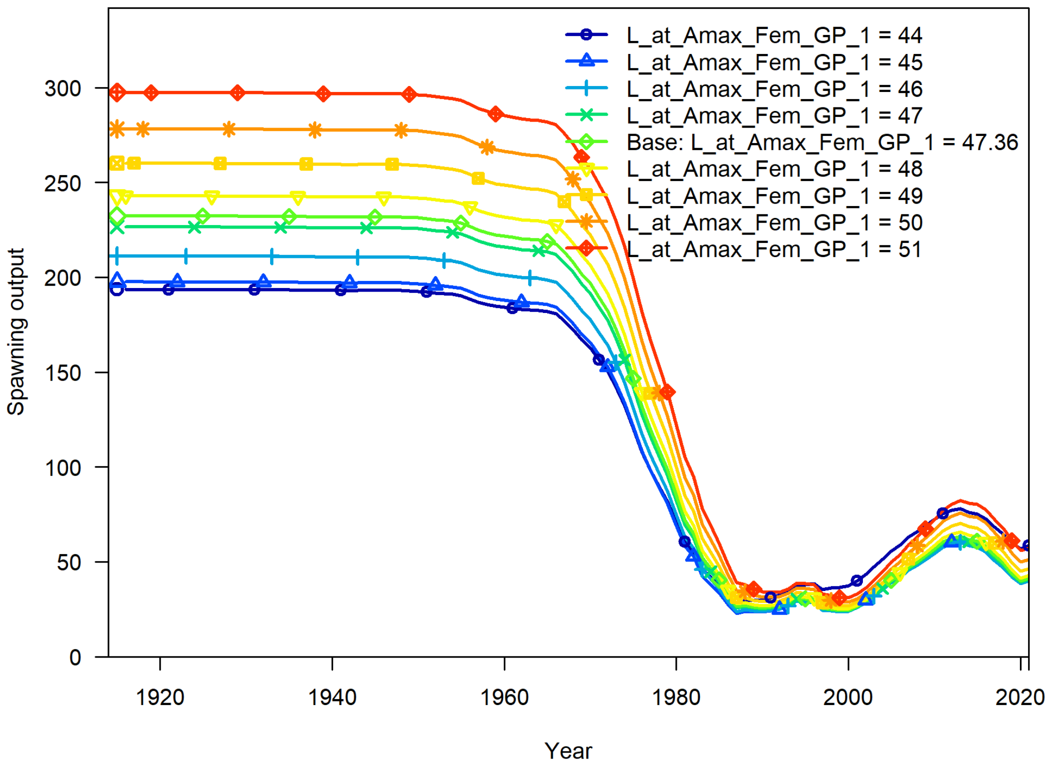

Figure 63: Change in the estimate of spawning output across a range of female maximum length values.

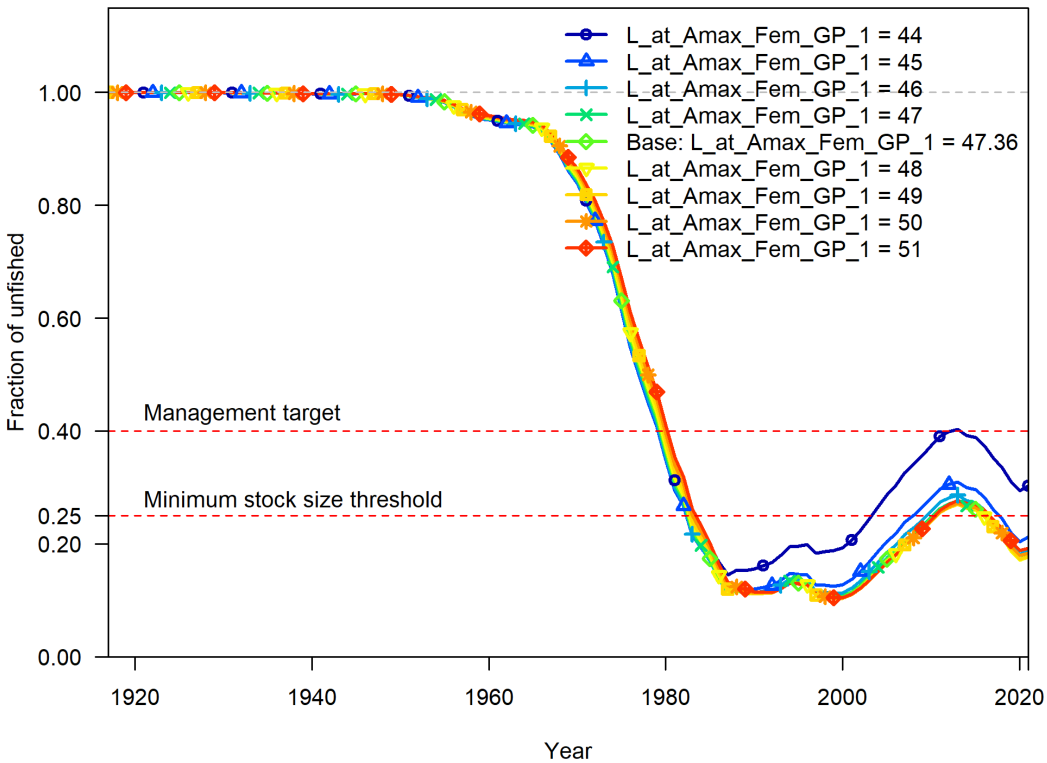

Figure 64: Change in the estimate of fraction unfished across a range of female maximum length values.

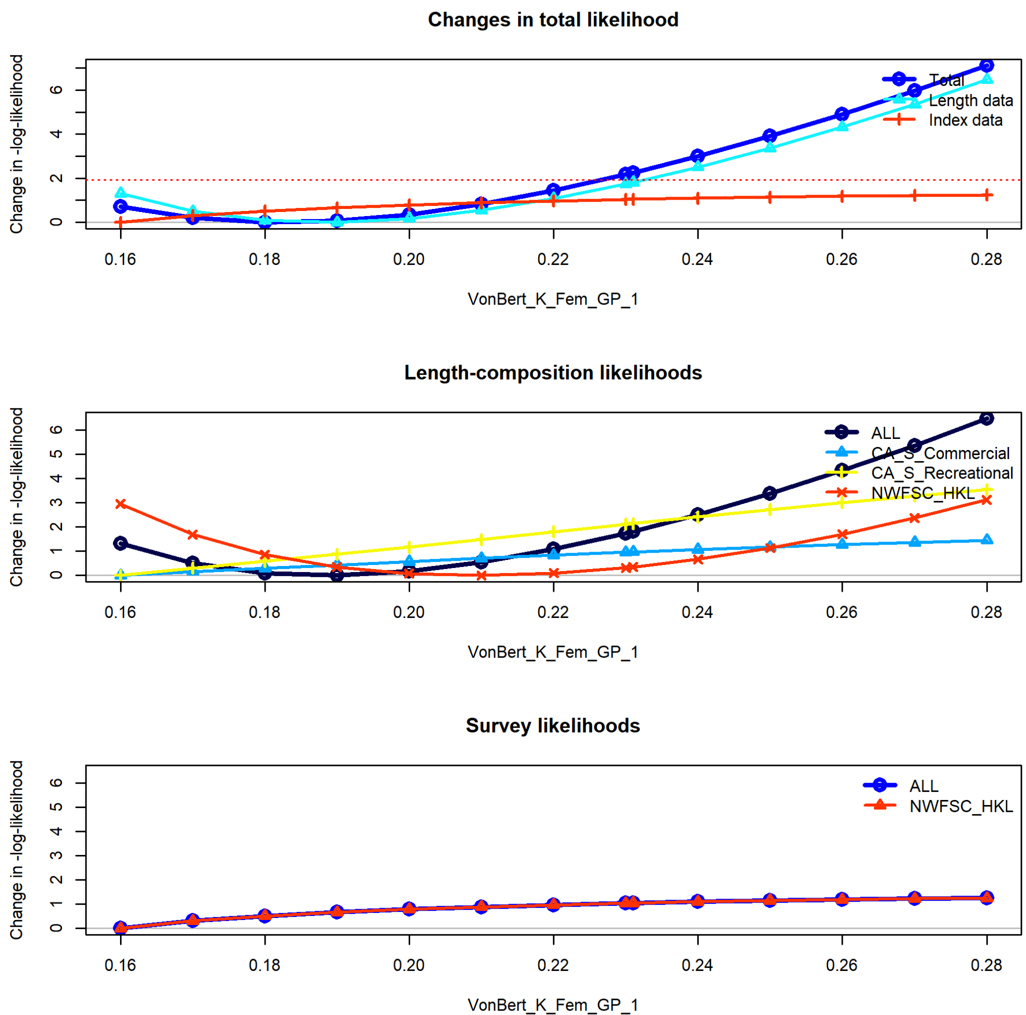

Figure 65: Change in the negative log-likelihood across a range of female k values.

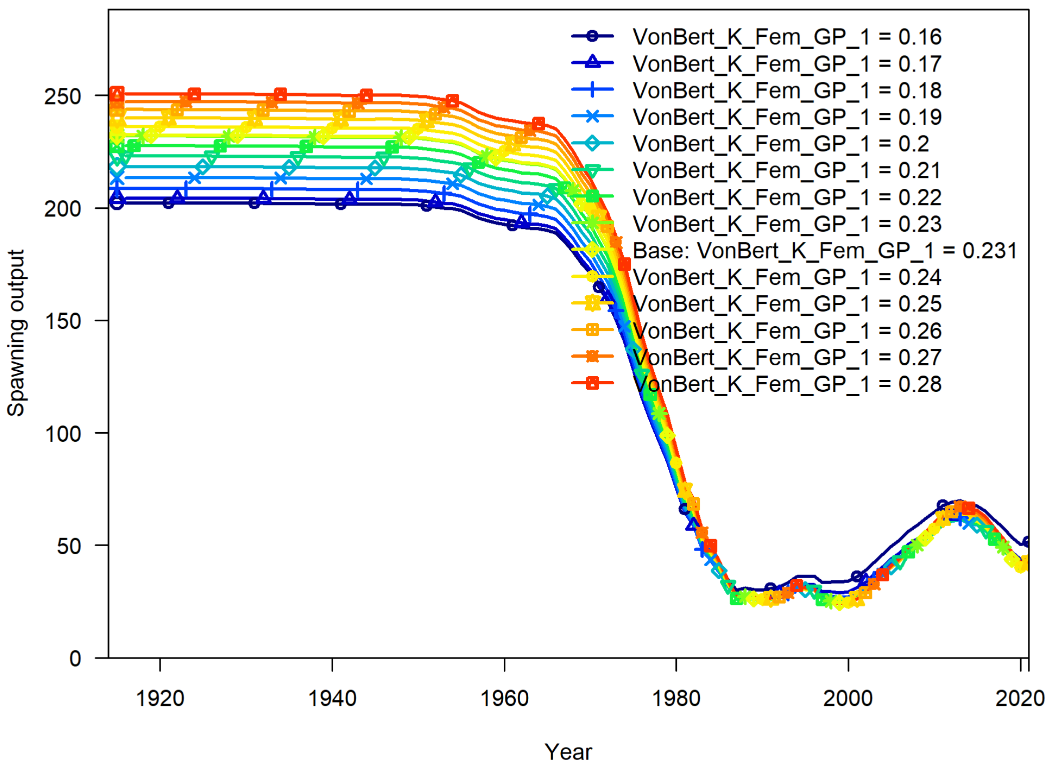

Figure 66: Change in the estimate of spawning output across a range of female k values.

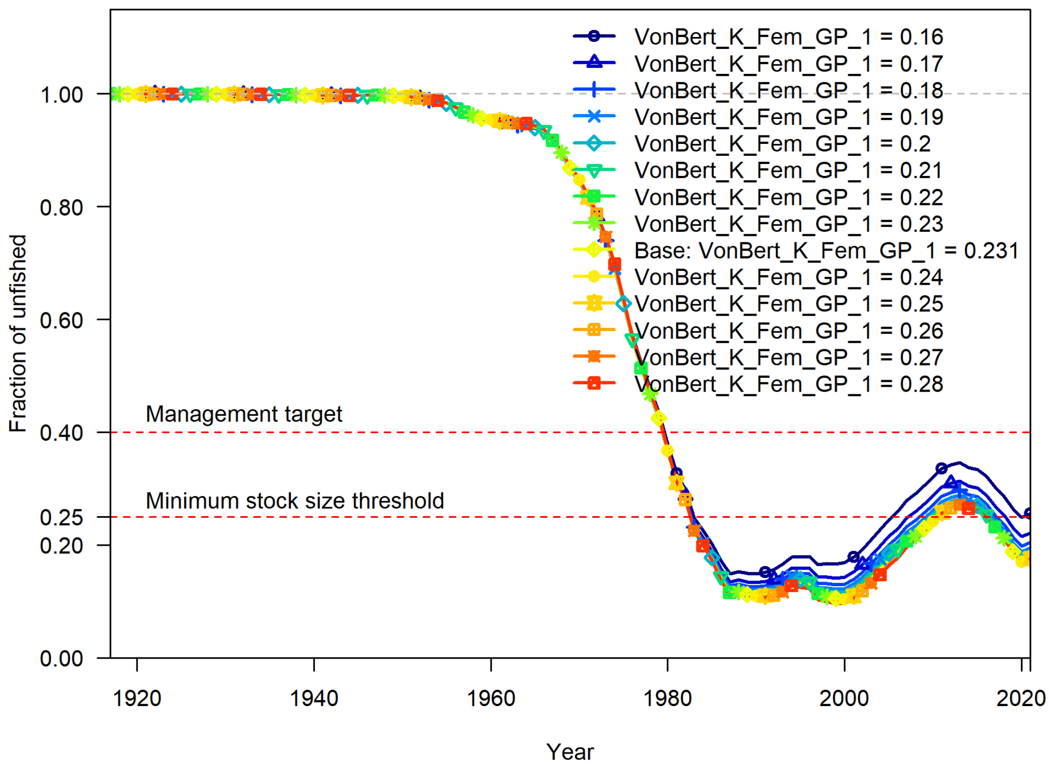

Figure 67: Change in the estimate of fraction unfished across a range of female k values.

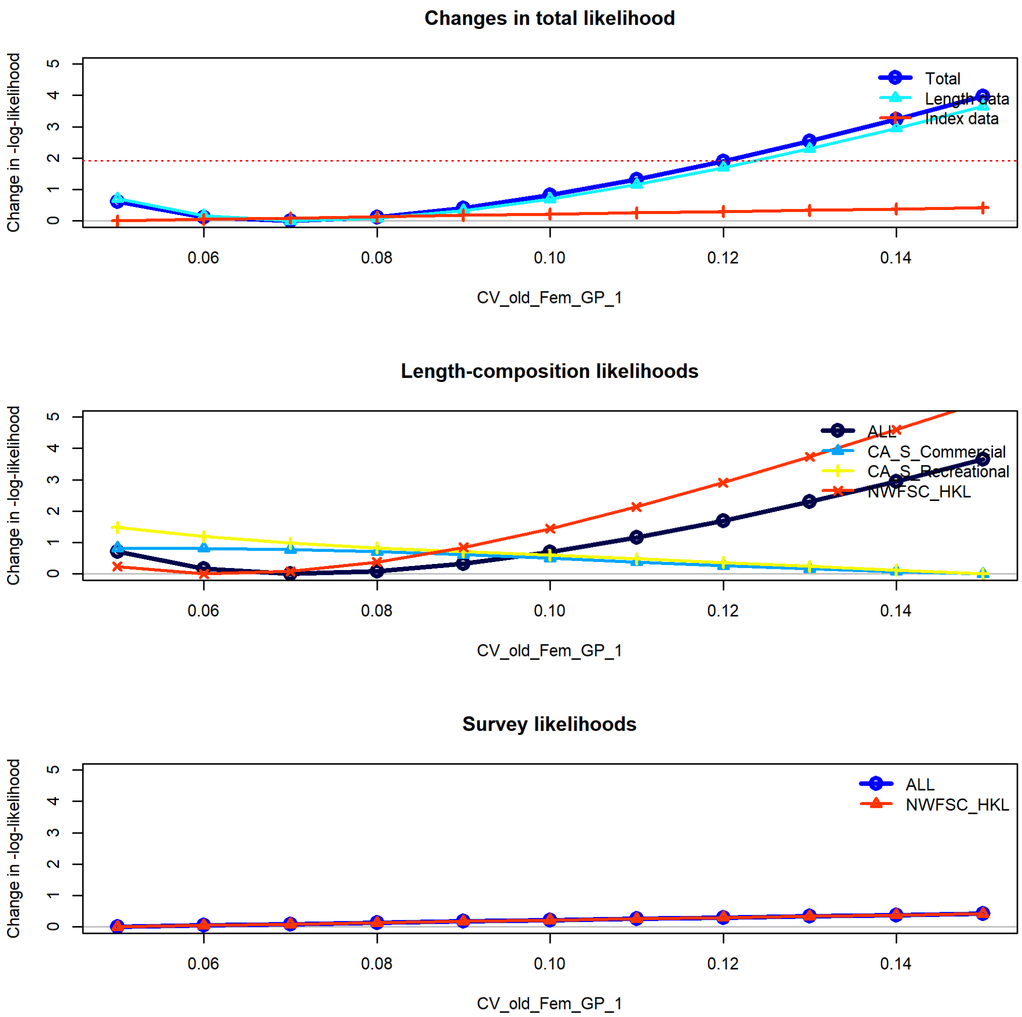

Figure 68: Change in the negative log-likelihood across a range of female coefficient of variation for older ages.

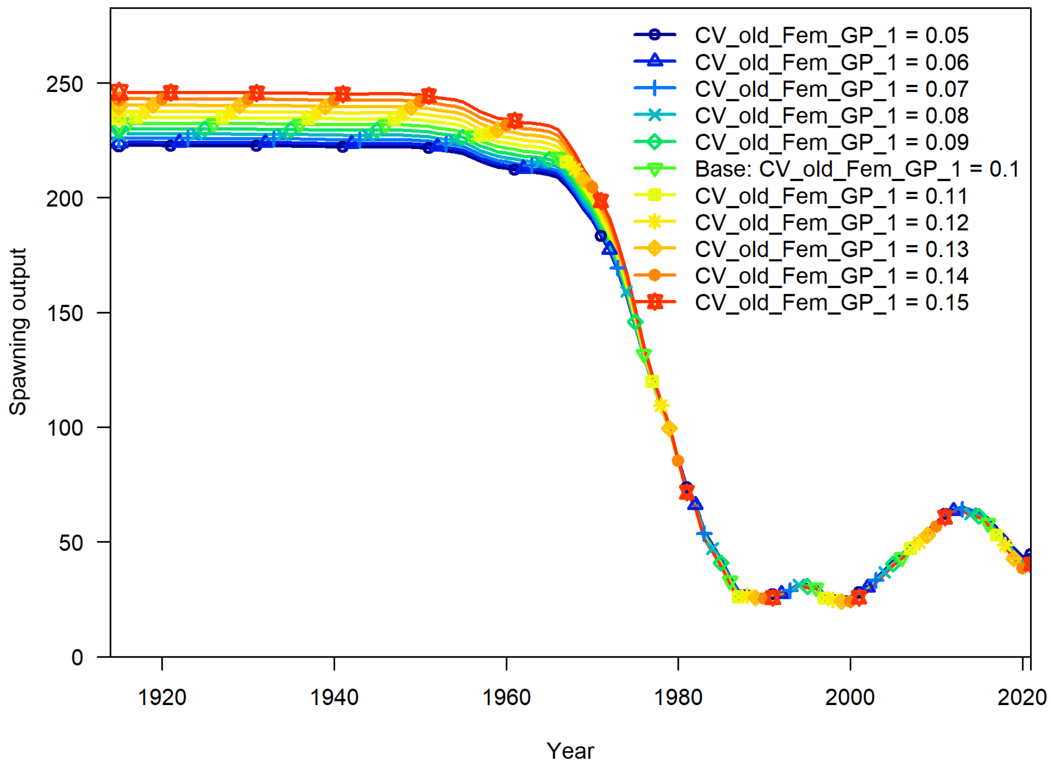

Figure 69: Change in the estimate of spawning output across a range of female coefficient of variation for older ages.

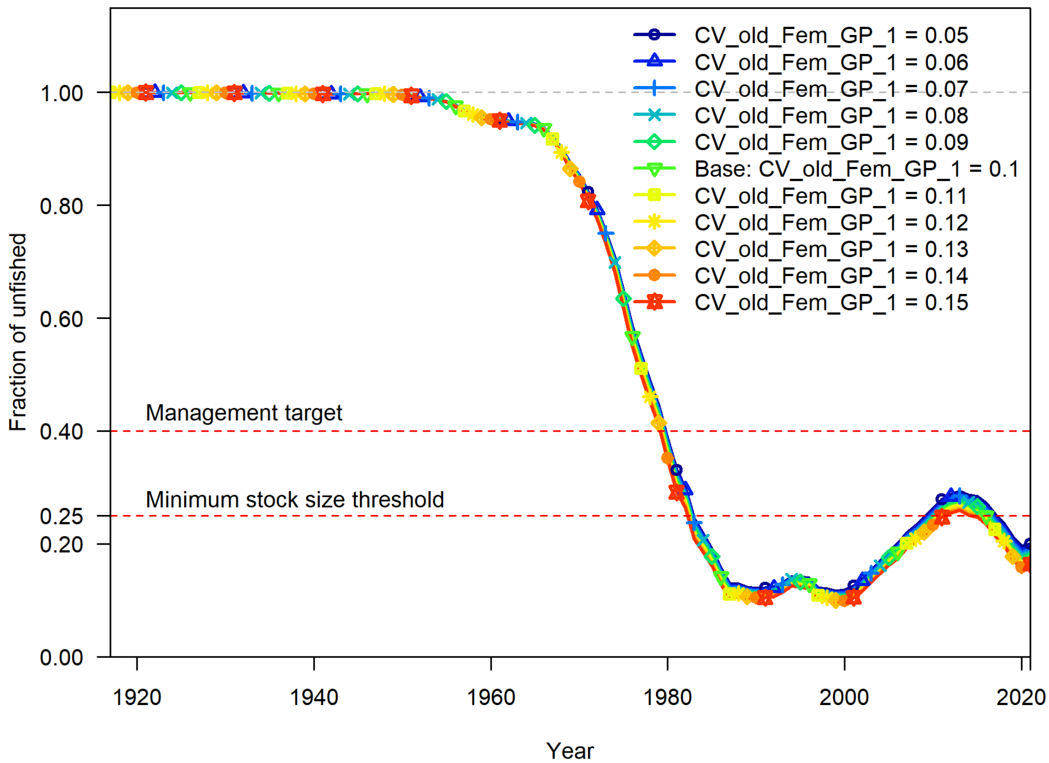

Figure 70: Change in the estimate of fraction unfished across a range of female coefficient of variation for older ages.

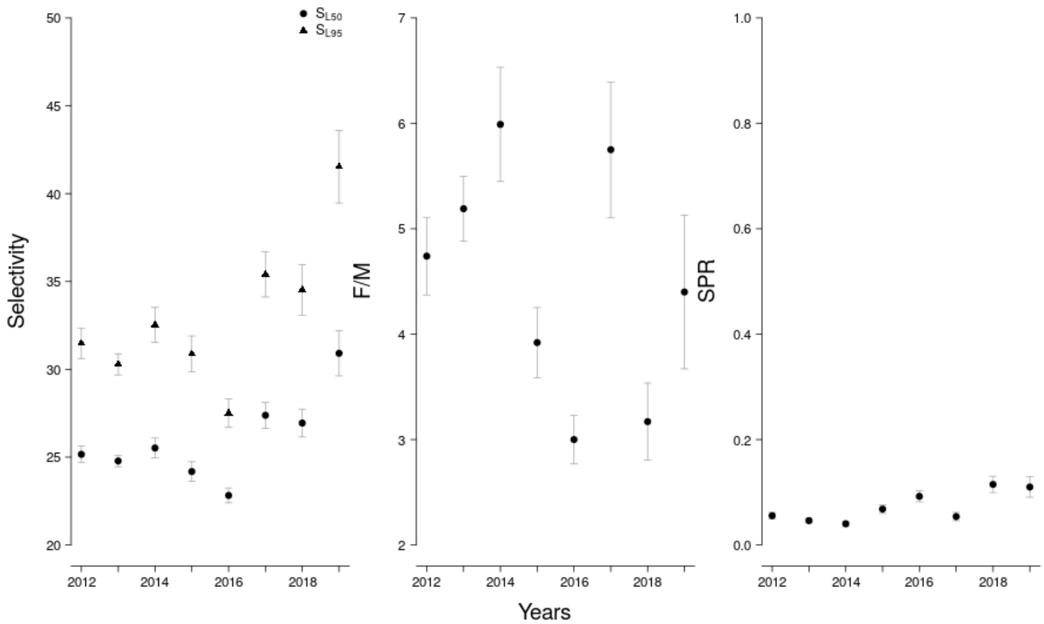

Figure 71: LB-SPR yearly estimates of selectivity, the ratio of fishing intensity to natural mortality (F/M), and annual spawner-per-recruit (SPR) values.

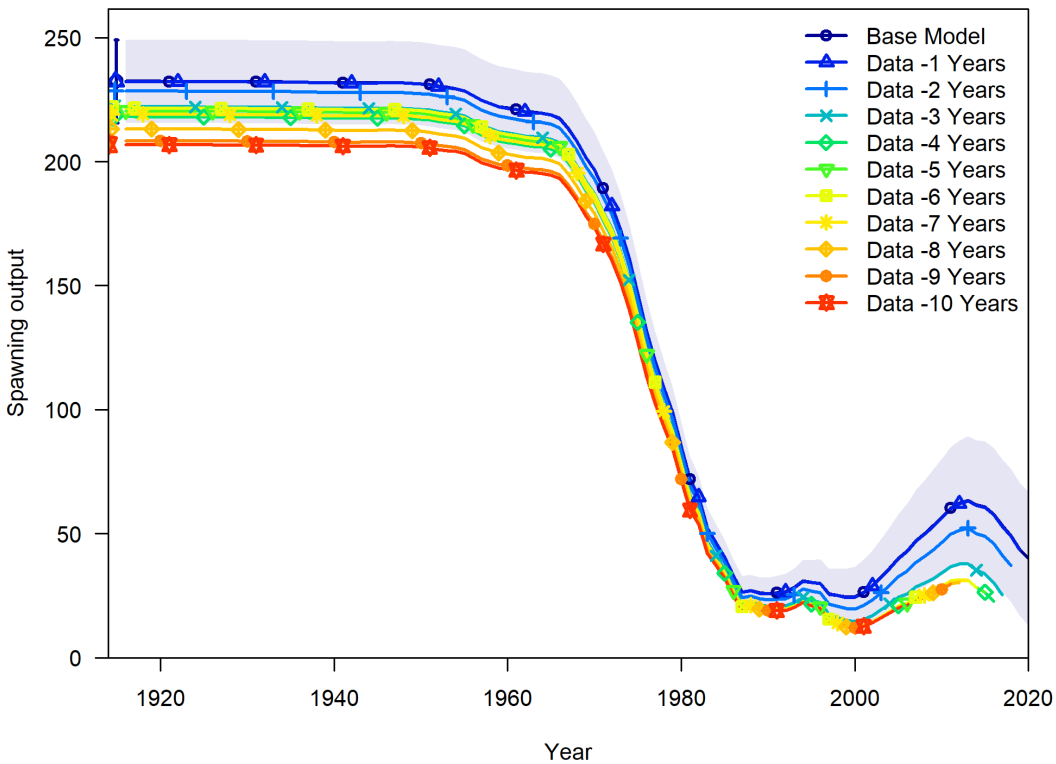

Figure 72: Change in the estimate of spawning output when the most recent 10 years of data area removed sequentially.

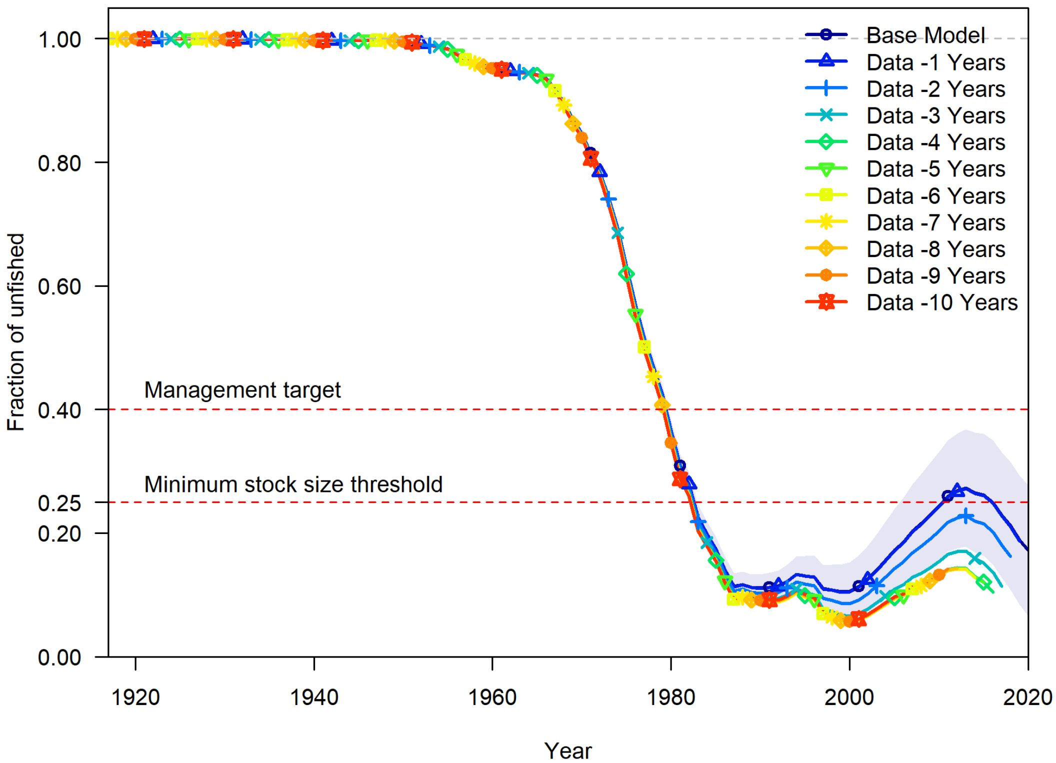

Figure 73: Change in the estimate of fraction unfished when the most recent 10 years of data area removed sequentially.

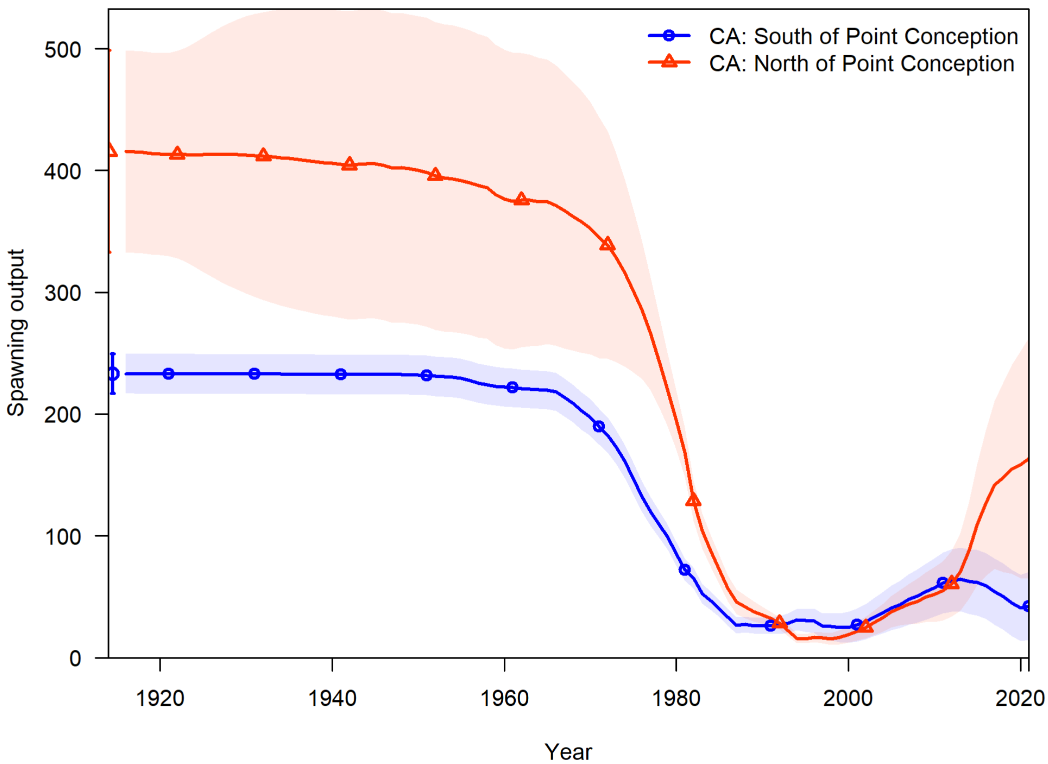

Figure 74: Estimated spawning output time series for the California stocks north and south of Point Conception.

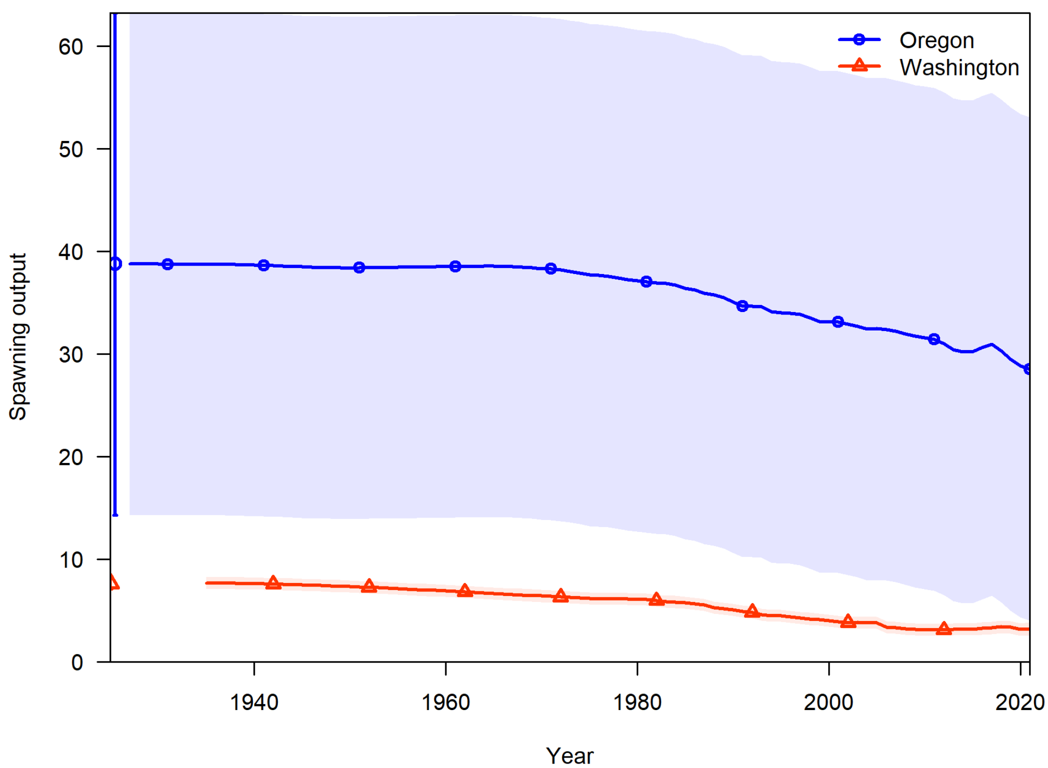

Figure 75: Estimated spawning output time series for the stocks off the Oregon and Washington coast.

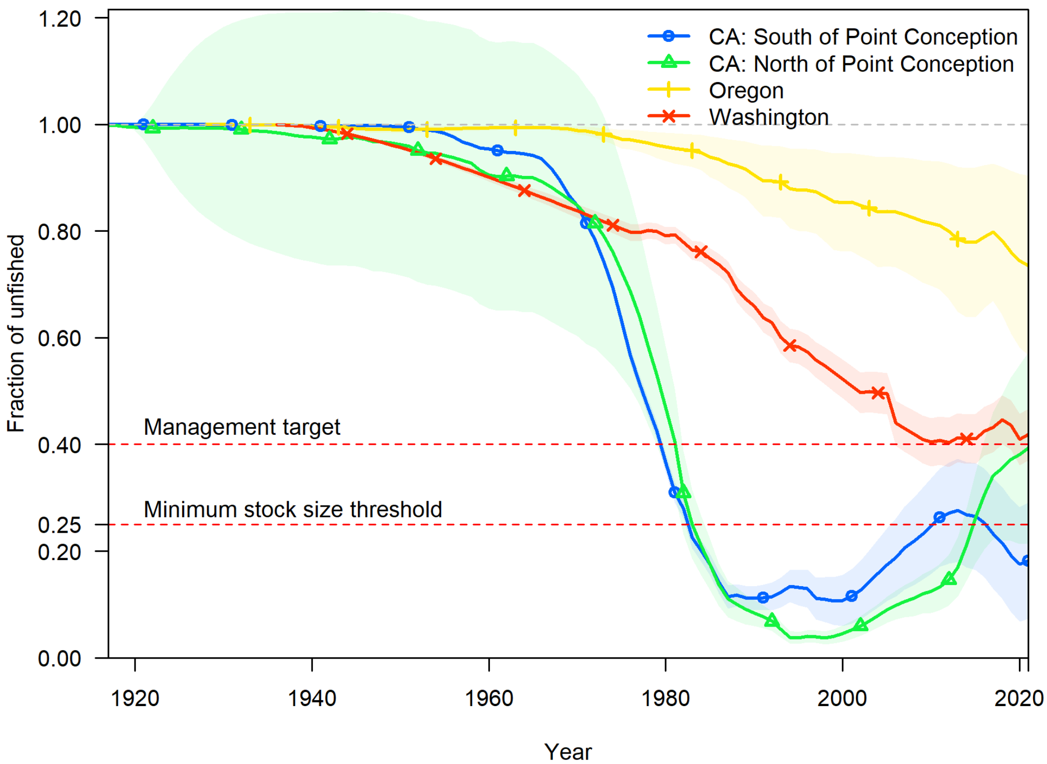

Figure 76: Estimated fraction unfished time series for all West Coast stocks.

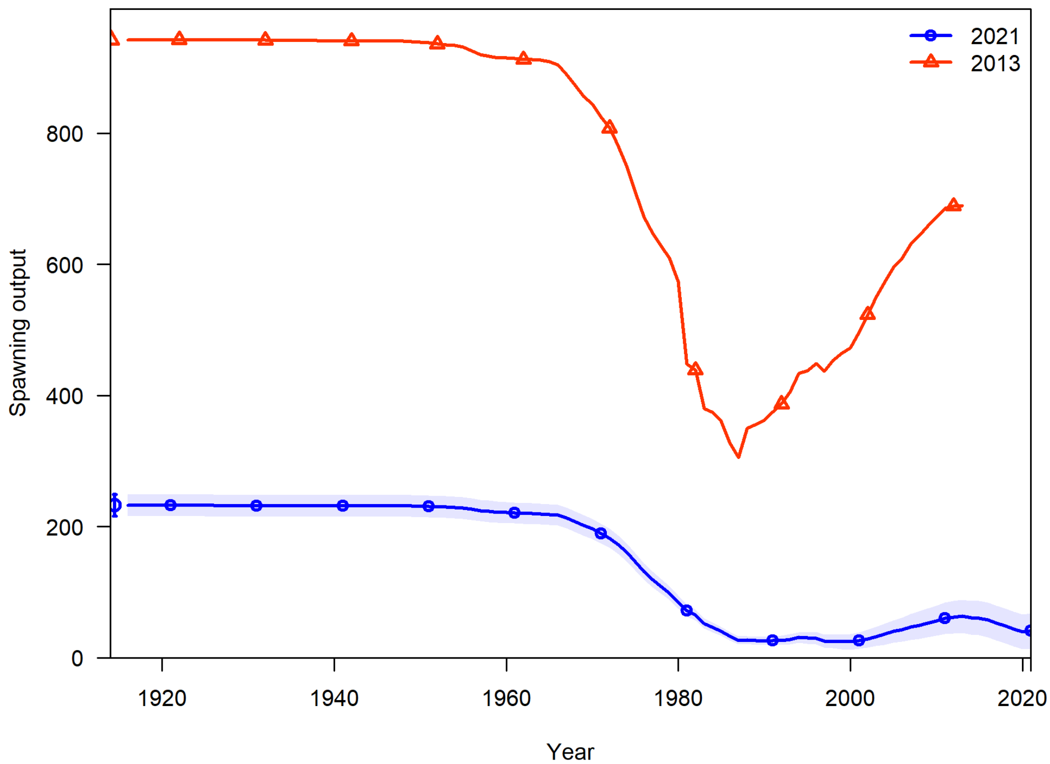

Figure 77: The estimated spawning output from the base model and the 2013 assessment. The 2013 model estimated spawning biomass (mt) and the 2021 assessment is terms of spawning output (millions of eggs).

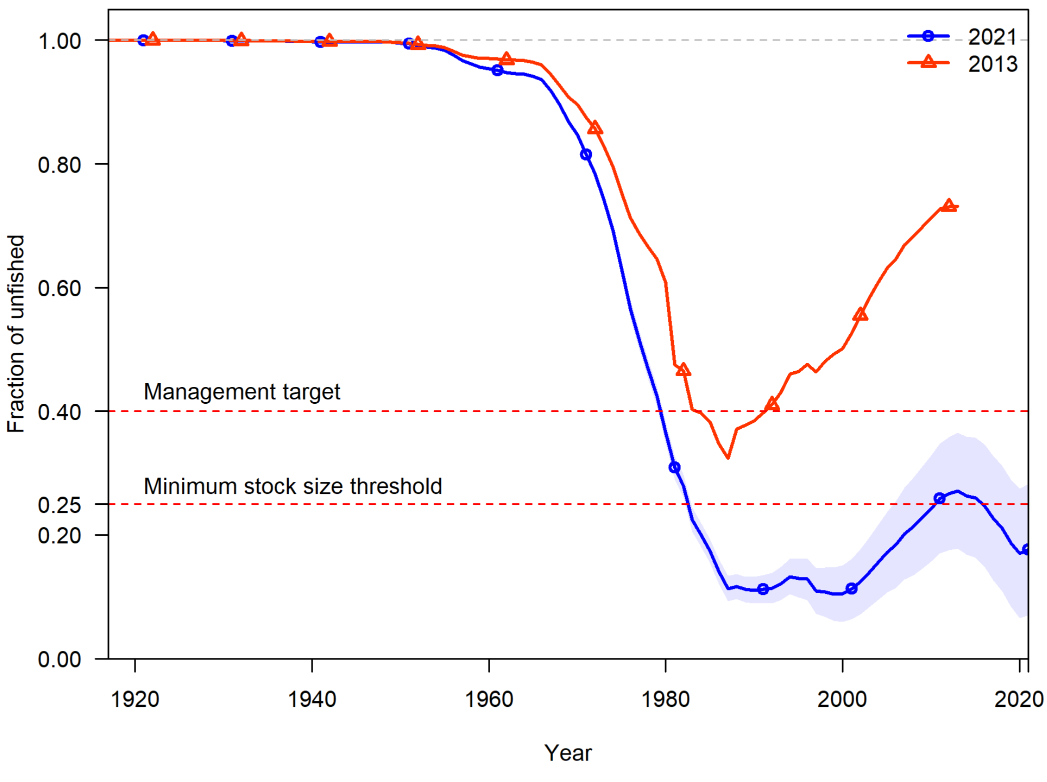

Figure 78: The estimated fraction unfished from the base model and the 2013 assessment.

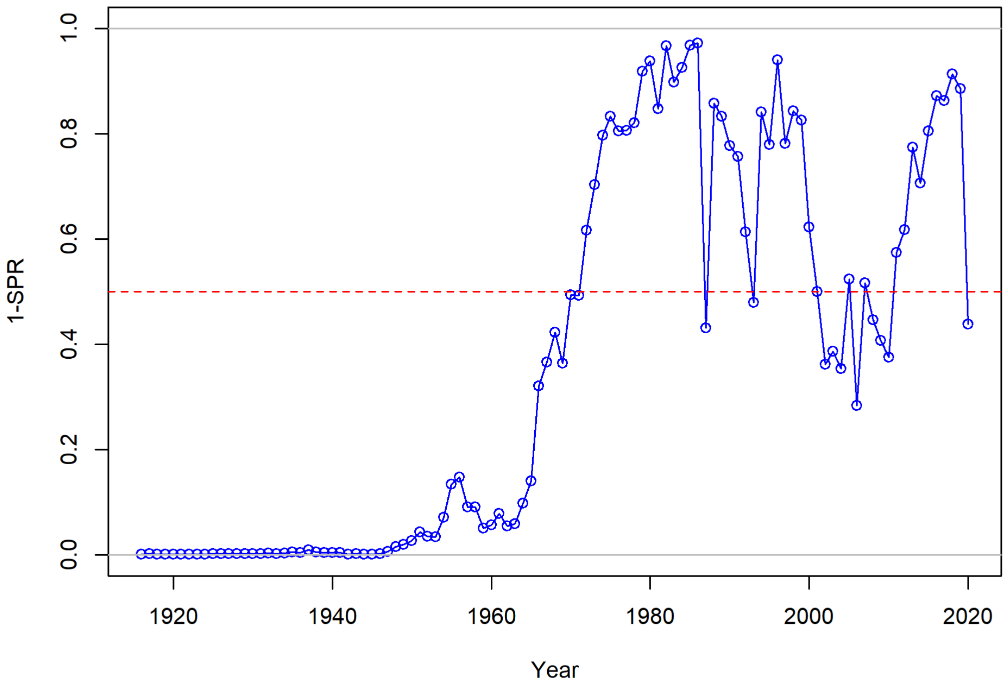

Figure 79: Estimated 1 - relative spawning ratio (SPR) by year.

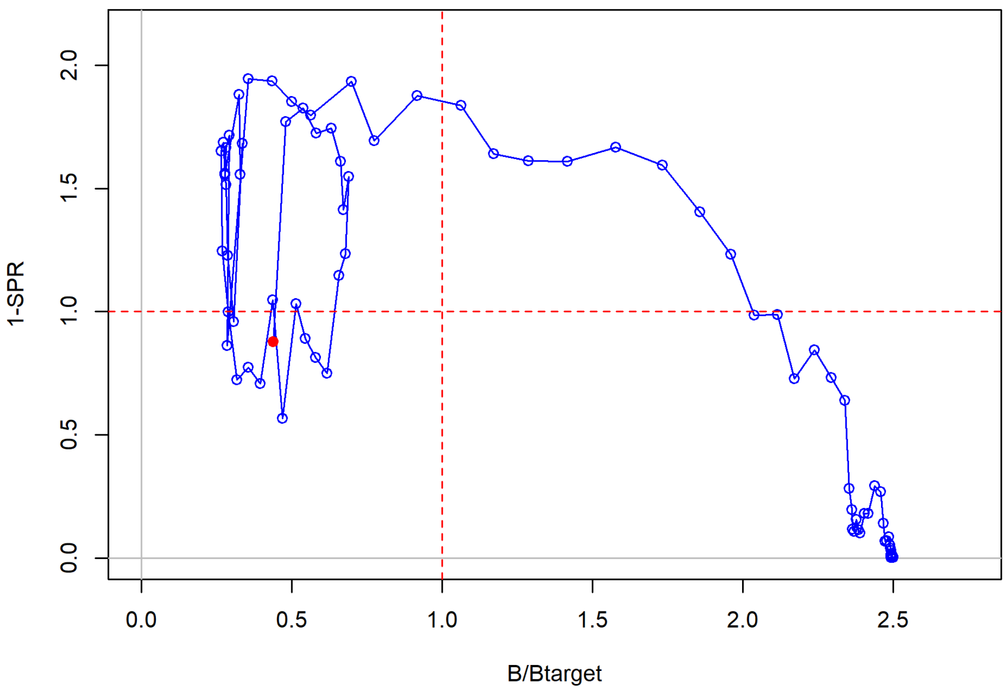

Figure 80: Phase plot of the relative biomass (also referred to as fraction unfished) versus the SPR ratio where each point represents the biomass ratio at the start of the year and the relative fishing intensity in that same year.

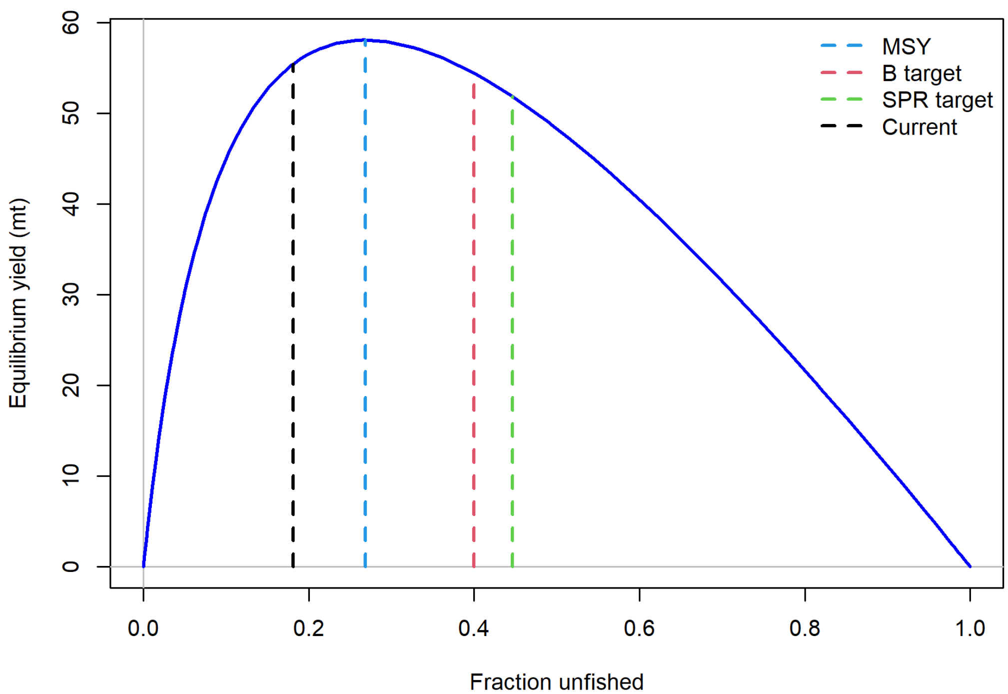

Figure 81: Equilibrium yield curve for the base case model. Values are based on the 2020 fishery selectivity and with steepness fixed at 0.72.

9 Appendix

9.1 Detailed Fit to Length Composition Data

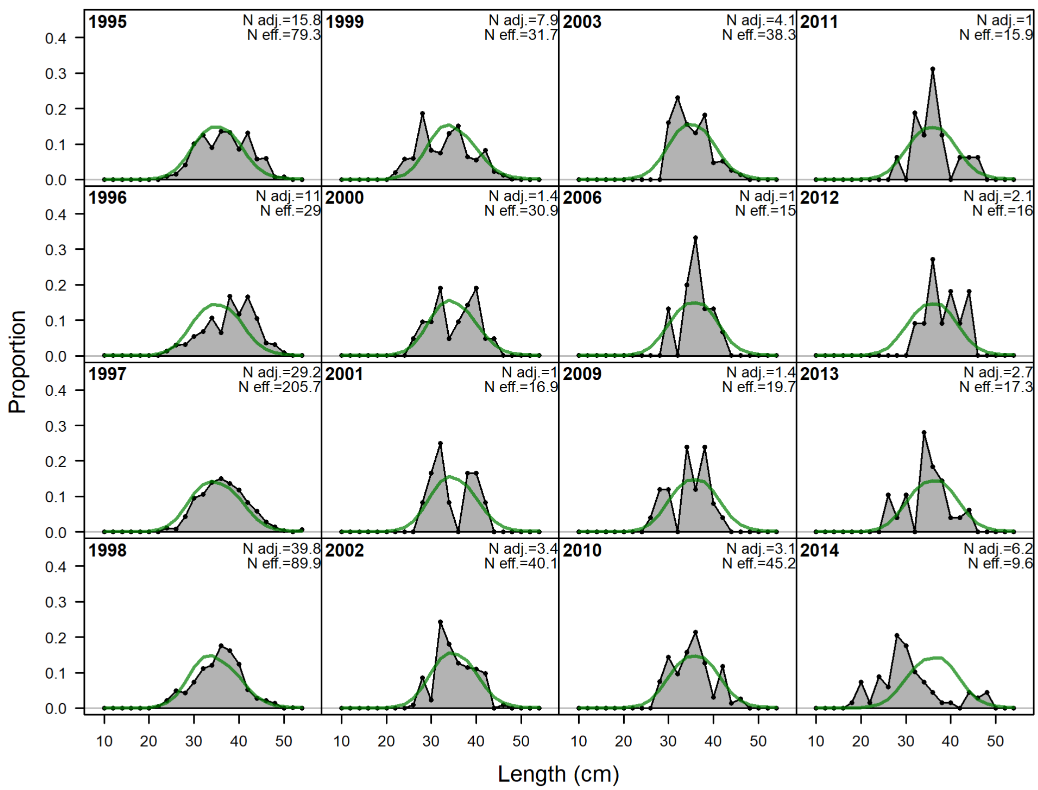

Figure 82: Length comps, whole catch, CA_S_Commercial (plot 1 of 2).'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.

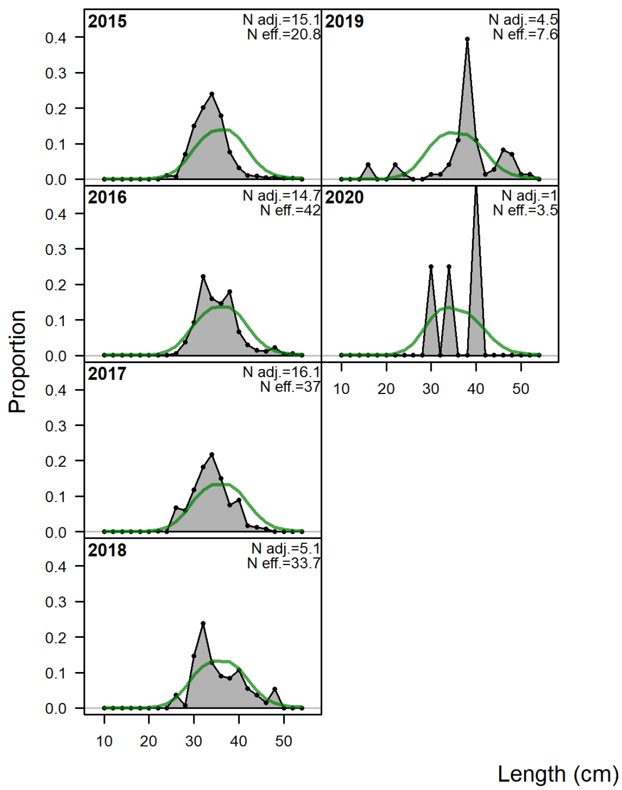

Figure 83: Length comps, whole catch, CA_S_Commercial (plot 2 of 2).

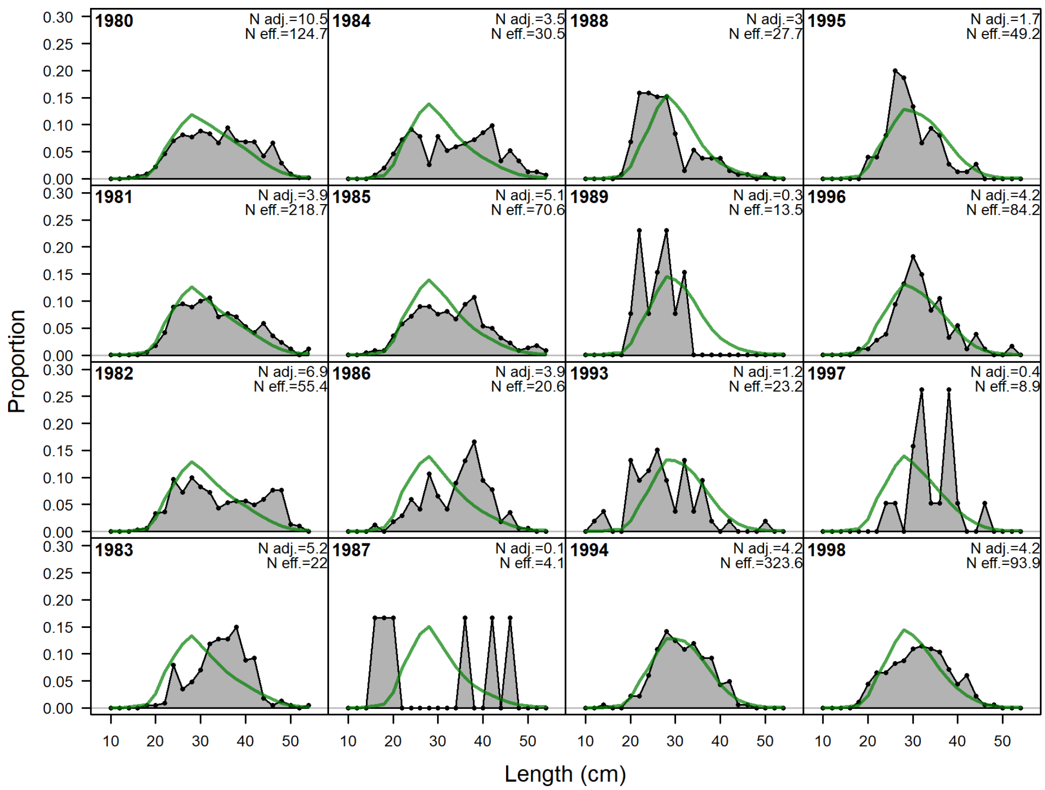

Figure 84: Length comps, whole catch, CA_S_Recreational (plot 1 of 3).'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.

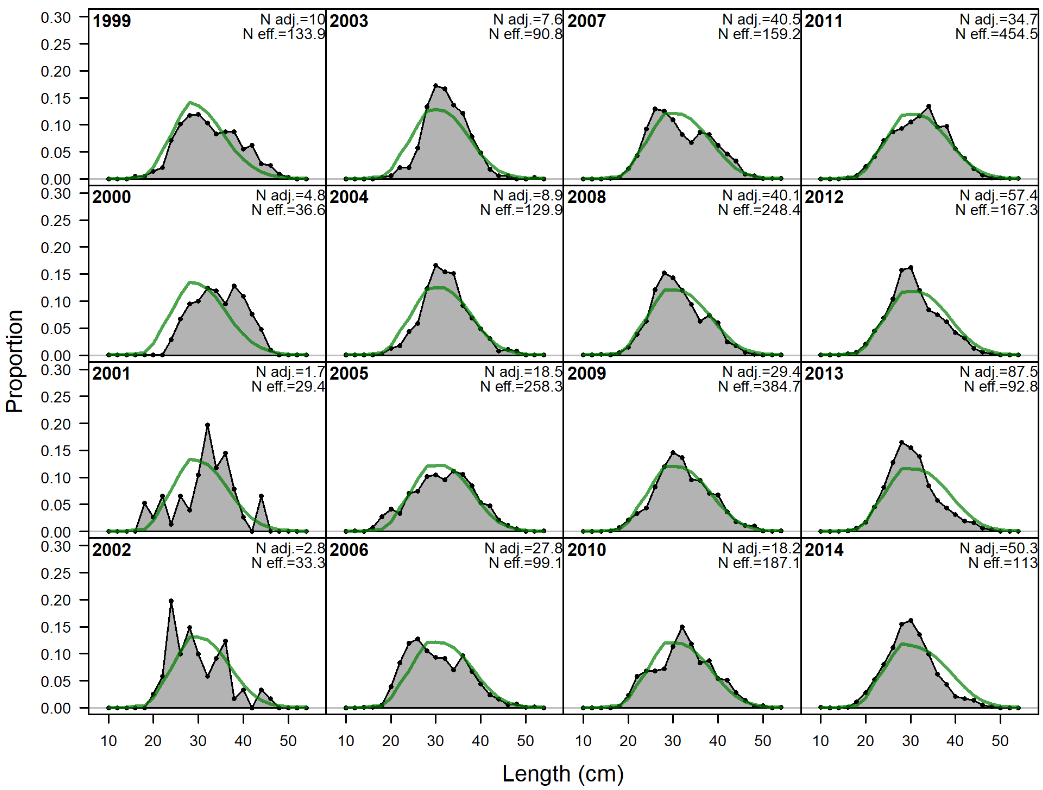

Figure 85: Length comps, whole catch, CA_S_Recreational (plot 2 of 3).

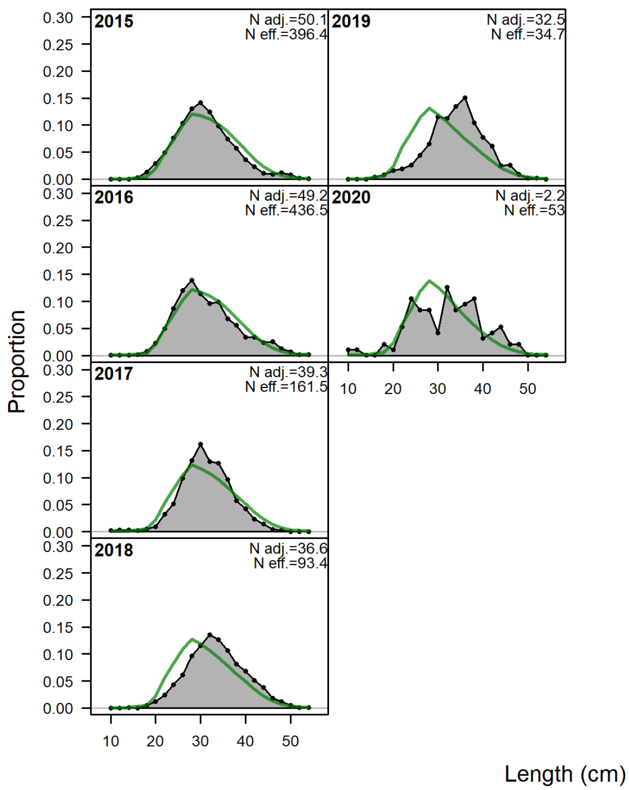

Figure 86: Length comps, whole catch, CA_S_Recreational (plot 3 of 3).

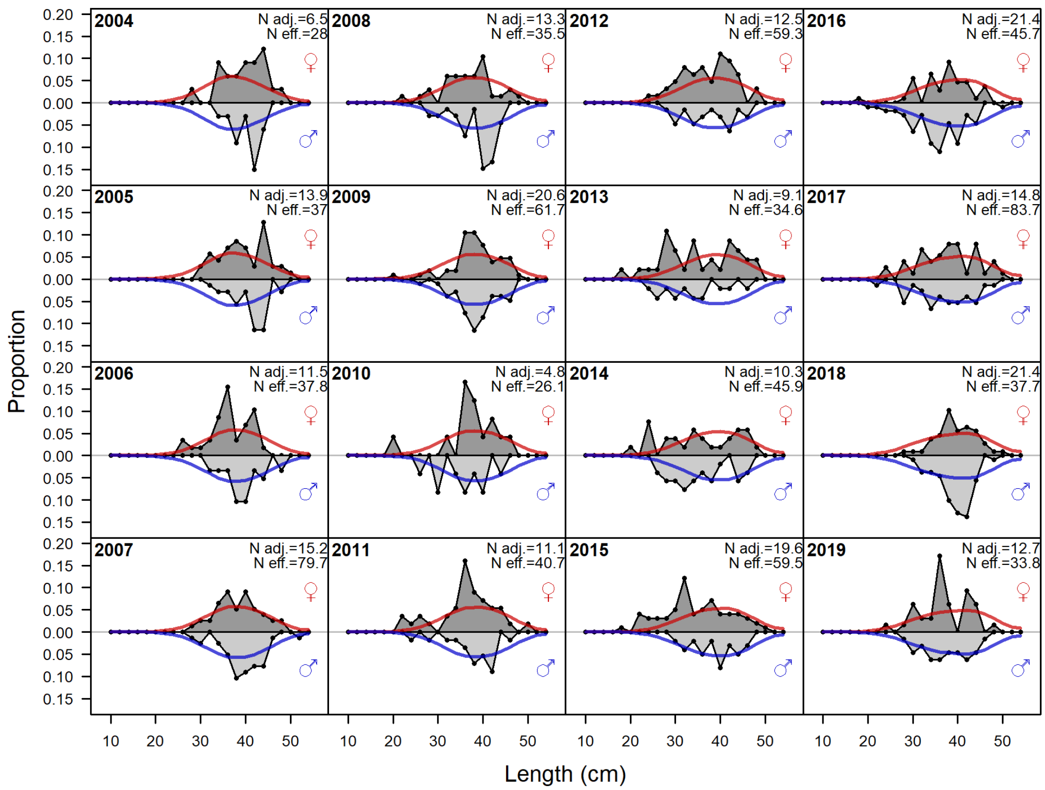

Figure 87: Length comps, whole catch, NWFSC_HKL.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.

9.2 Annual Length Composition Data

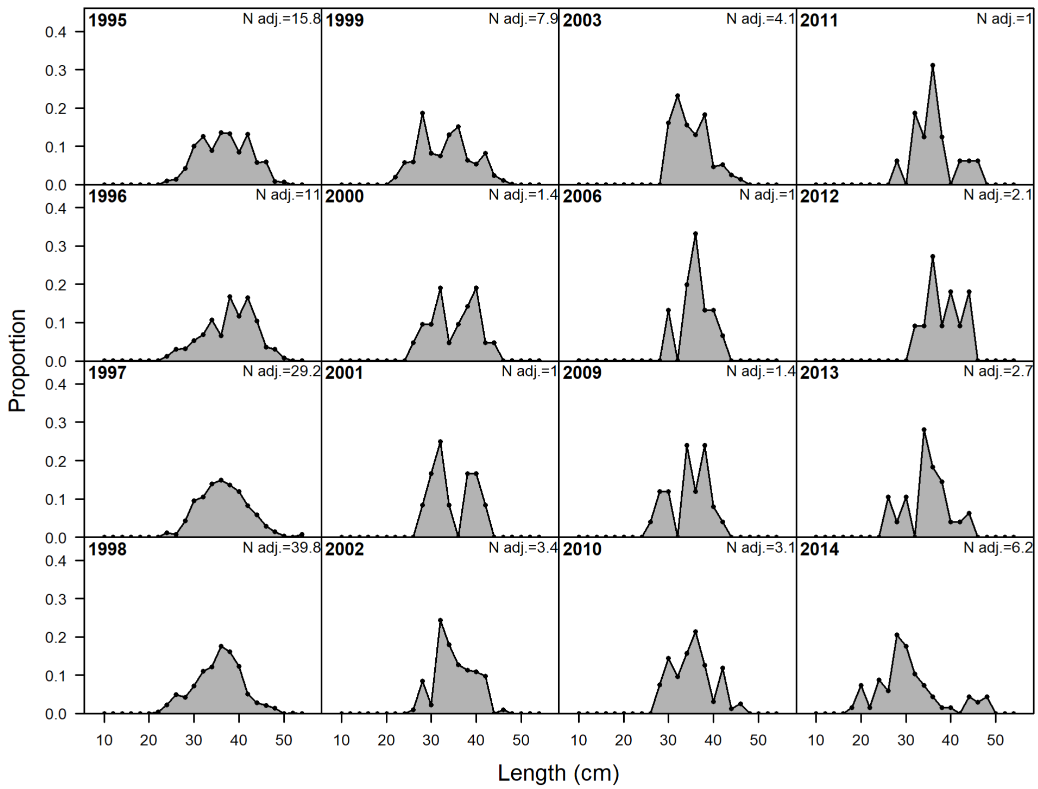

Figure 88: Length comp data, whole catch, CA_S_Commercial (plot 1 of 2).'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.

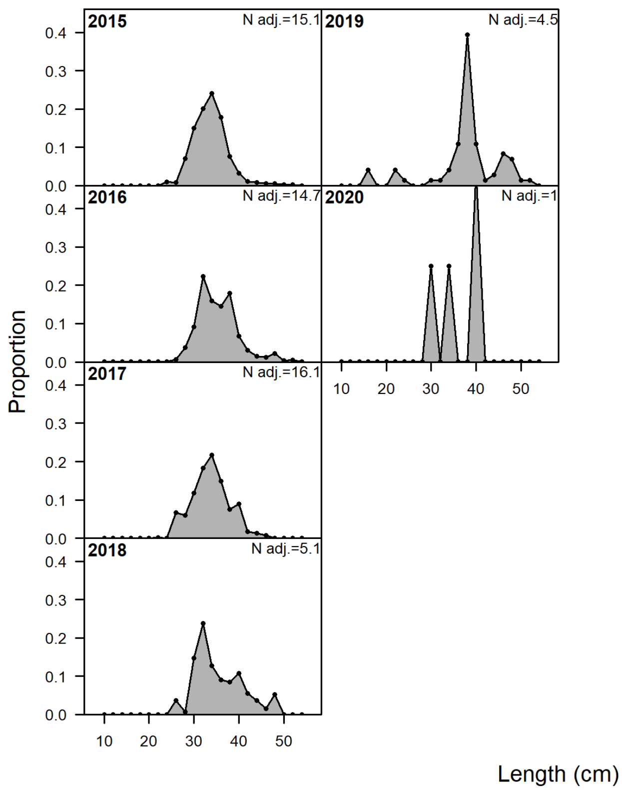

Figure 89: Length comp data, whole catch, CA_S_Commercial (plot 2 of 2).

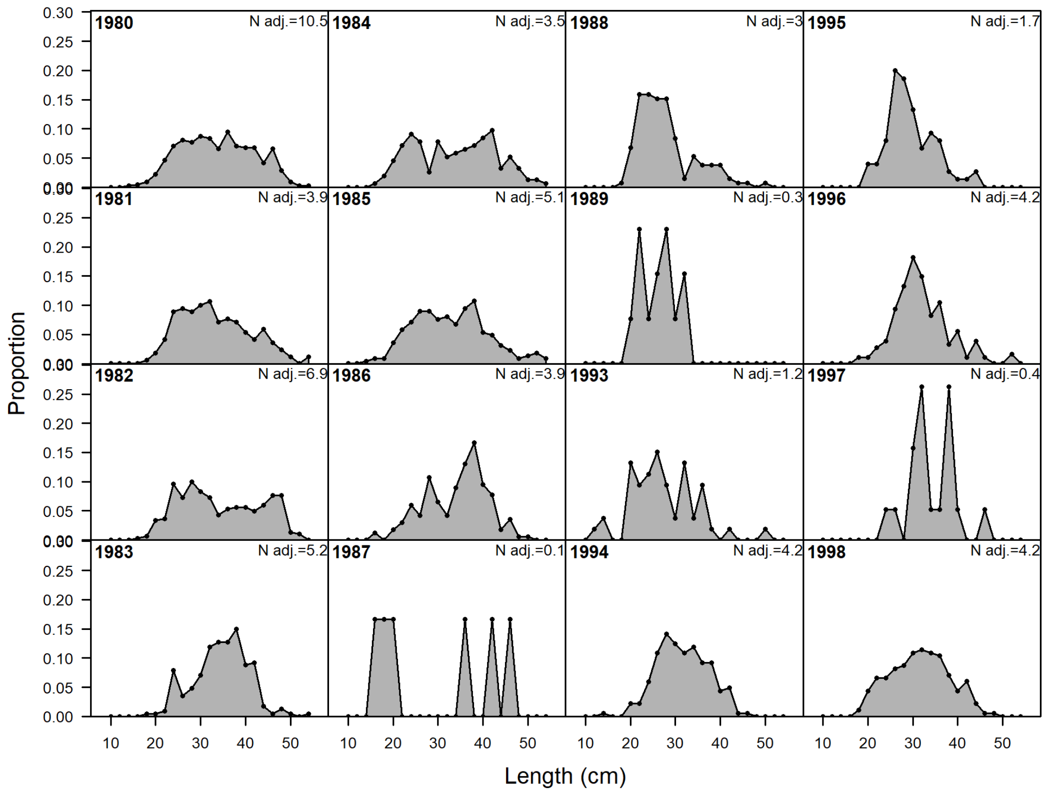

Figure 90: Length comp data, whole catch, CA_S_Recreational (plot 1 of 3).'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.

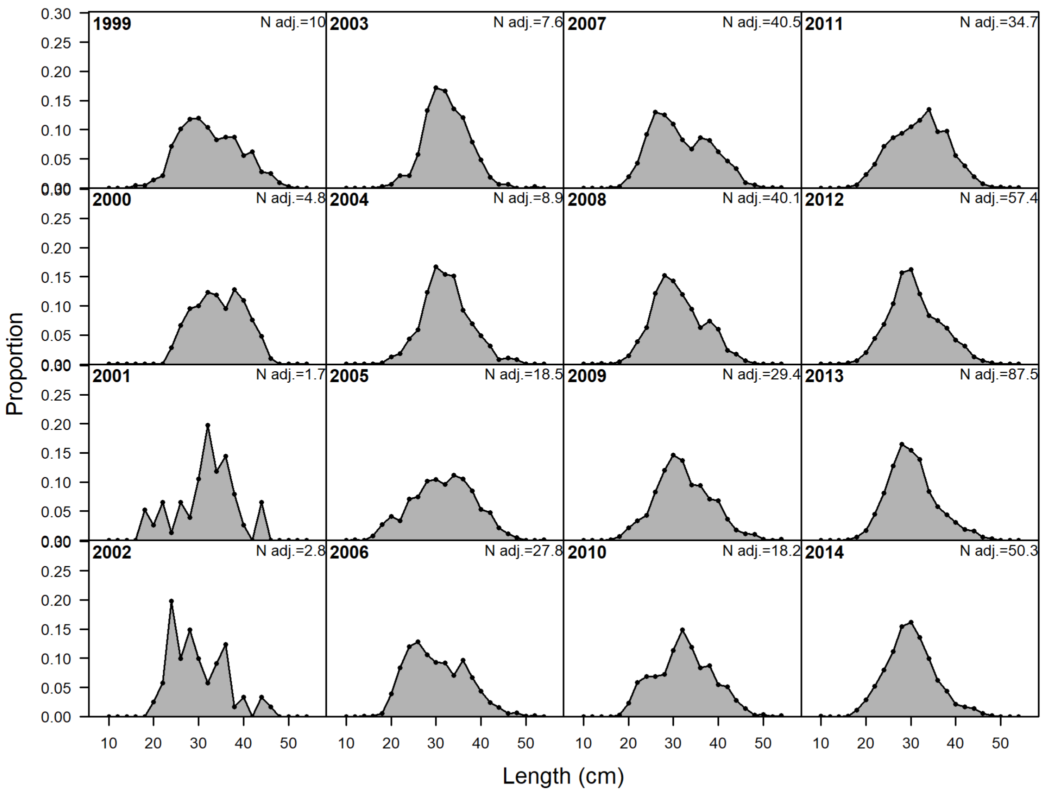

Figure 91: Length comp data, whole catch, CA_S_Recreational (plot 2 of 3).

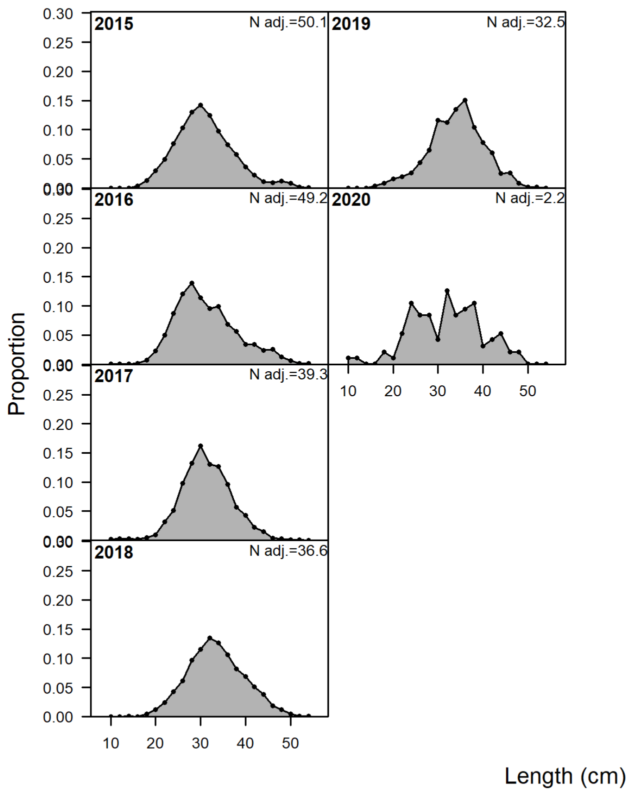

Figure 92: Length comp data, whole catch, CA_S_Recreational (plot 3 of 3).

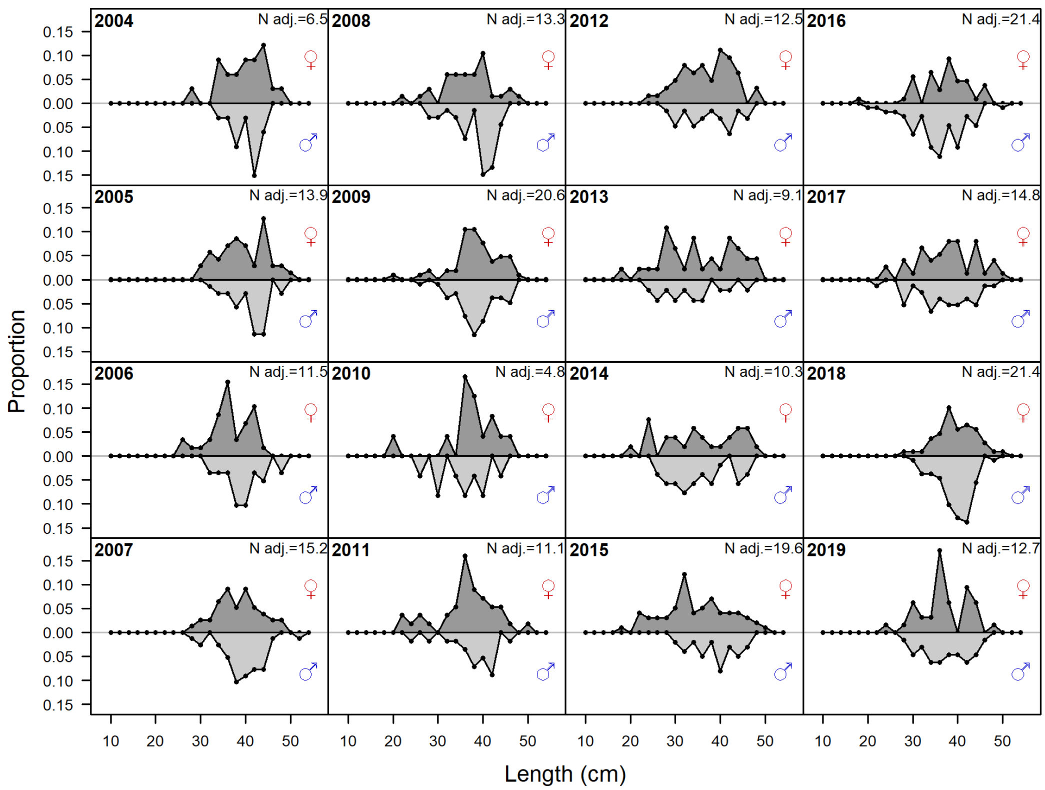

Figure 93: Length comp data, whole catch, NWFSC_HKL.'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.

9.3 Implied Fit to Commercial ‘Ghost’ Fleet Length Data

The ‘ghost’ fleet data consist of commercial length samples collected prior to 1995 which were not used in the base model due to low sample sizes which resulted in noisy length distributions.

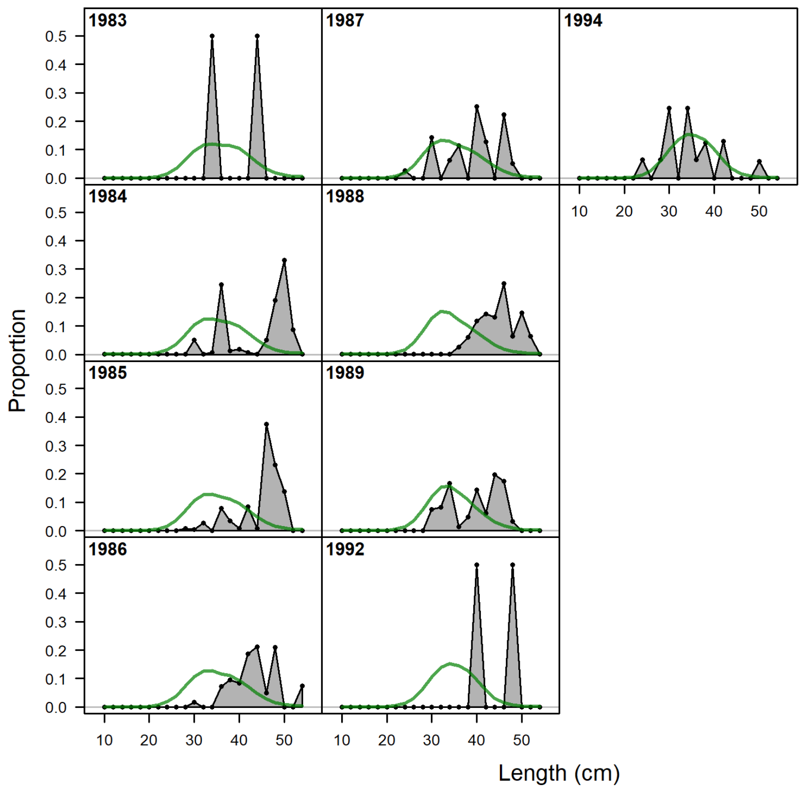

Figure 94: Ghost length comps, whole catch, CA_S_Commercial.‘N adj.’ is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.

9.4 Summary of California Management Measures

Information on changes to California management measures across time can be found in the separate file “California Nearshore Regulation History-Data Moderate Accompanying Material.pdf”.

9.5 Percent of Habitat Area Closed to Fishing for Groundfish in the Rockfish Conservation Areas, Cowcod Conservation Areas, and Marine Protected Areas in California from 2001-2021

At present, stock assessments reliant on fishery-dependent data only represent the areas open to fishing, unless there is a fishery-independent data source providing information on the relative abundance and length composition in closed areas. A network of marine protected areas (MPAs) was established between 2003 to 2012 through a regional siting process. The length composition and relative abundance inside and outside MPAs in part results from the presence of MPAs prohibiting take of groundfish established prior to expansion of the current network, duration of existence of new areas, degree of effort prior to protection and criteria for selection focusing on high productivity reefs. These areas are established in perpetuity and will provide substantial protections to nearshore fish stocks for the foreseeable future.

In addition to MPAs, extensive Rockfish Conservation Areas (RCAs) of varying depths over time and space, as well as the two cowcod conservation areas (CCAs) encompassing 4200 square miles of water area since 2001, were established to facilitate rebuilding of overfished species. While the depth restrictions in these closed areas can change or be eliminated, the areas closed become refugia that reduce fishing mortality, allowing accumulation of biomass within them. There has long been interest in quantifying the area of reef habitat for each assessed species that resides in protected areas, but until very recently, there was insufficient data on the distribution of rocky reef habitat. This analysis provides the percentage of habitat area for copper and quillback rockfish closed to fishing in MPAs, RCAs and CCAs where the take of groundfish was prohibited in each year from 2001 to 2021.

9.5.1 Methods

9.5.1.1 Descriptions of the habitat layers

A predictive substrate layer that identifies hard and soft substrate was used to analyze seafloor coverage within the 3 nautical miles from California's shore. Substrate types were generated algorithmically using rugosity analysis, to identify areas likely to have rocky reefs. This layer was derived from bathymetric data of 2, 5 and 10 m resolution and bathymetric data were collected by California Seafloor Mapping Project (CSMP). Potential issues with this rugosity analysis include noise and artifacts resulting from unusual substrate structure, original mapping data, and steep slopes. In addition, hard substrate might be underestimated in areas with canyon slopes, deep water, over smooth rock and where sediments cover rock.

Data from the CSMP is known to have nearshore data gaps referred to as the white zone. Contributors from The University of California Santa Cruz, California Ocean Science Trust, and California Department of Fish and Wildlife (CDFW) conducted a 30 m resolution interpolation analysis to estimate hard and soft substrate within the white zone. The interpolation analysis utilized data from the CSMP and National Oceanic and the National Oceanic and Atmospheric Administration Environmental Sensitivity Index (ESI). Accuracy of the interpolation is estimated to be best where the white zone bands are narrowest and worst where the white zone bands are widest. In addition, metadata indicates the interpolation is questionable at scales finer than 100 m.

Substrate data developed for an Essential Fish Habitat Review was incorporated into this analysis for seafloor occurring outside of California State Waters (3 nautical miles). This dataset was generated by Joe Bizarro of the National Marine Fisheries Service, Southwest Fisheries Science Center in Santa Cruz and was created by combining multiple sources of bathymetric data with varying resolutions including multibeam sonar, sidescan sonar, sediment grabs, core samples seismic reflection profiles, still photos and video. This habitat data are subject to georeferencing errors and data resolution errors. Currently, this is the best available data that represents hard and soft substrate types offshore for the areas outside of California State waters.

9.5.1.2 Boundaries of the CCAs, RCAs and MPAs

Regulation histories for each type of closure were converted to Boolean fields with zeros and ones indicating absence and implementation, respectively from 2001-2020. The corresponding GIS layers were either available from previous CDFW GIS staff projects or approximated by the depth contour where specific weigh points were unavailable. The area in MPAs prohibiting take by the recreational and commercial fisheries were included in the estimates of area closed to fishing from the first year in which the MPA was in place for a full calendar year. The Western CCA area accounted for waters around islands and banks open to take of a limited suite of groundfish species including copper rockfish. The RCAs for commercial and recreational fisheries were based on the deeper of the depth restrictions for the sectors to reflect only areas where take was prohibited for both. Where the RCA lines for the stock in question were not available, depth contours were used to approximate the percent of area closed.

9.5.1.3 Delineating Habitat in Restricted Areas and Open to Fishing

The depth range of habitat for copper and quillback rockfish was between shore to 100 m, covering the primary depth distribution of both stocks observed in the CDFW ROV survey (Budrick et al. 2019) or noted in Love et al. (2002). The latitudinal range was set from the California/Mexican border to the California/Oregon border (42° N. lat.), which was stratified north and south Point Conception (34° 27' N. lat.). Quillback rockfish are relatively rare south of Point Conception, thus only estimates for the area north of Point Conception are pertinent to this stock, while copper rockfish are found in both areas.

The distribution and area of rocky reef habitat within a species range was delineated in ArcGIS Pro (2.6) by extracting specific values from a 10 m bathymetric raster based on species depth and latitudinal ranges. The resulting raster layer was converted into a shapefile and merged with a coastal boundary of California to account for gaps in the bathymetric raster. Hard habitat within the species range was identified and isolated using the intersect tool to create species range shapefile. This process was repeated to identify overlapping coverage between the species range and hard substrate, as well as intersecting the species range with a combination of different types of regulatory boundaries.

The areas of the resulting shapefiles were calculated in GIS and exported into tables using Python script. The combination of area closures in a given year were overlayed on the habitat maps, with the area in MPAs and CCAs extracted first, then the habitat in the remaining RCAs estimated. The residual habitat still open to fishing after accounting for the closed areas was then estimated. The area of rocky reef habitat closed to fishing within a species range was converted to a percentage of the total habitat. This process for identifying overlapping boundaries and calculating areas were scripted in Python to reduce the possibility of human error.

9.5.1.4 Examination of bottom type coverage relative to habitat

The extent of existing substrate data within a given species range was examined through geospatial analysis. This included hard, soft, and unknown substrate for data from California Seafloor Mapping Project, and hard, mixed, and soft data from the EFH project. Both datasets were merged within the species range for copper and quillback rockfish. The resulting combination of substrate data was erased from the species range.

9.5.2 Results

The tables reflecting the percent of habitat area in RCAs, MPAs, CCAs closed to fishing for groundfish and waters open to fishing are provided for north of Point Conception (Table 20) and south of Point Conception (Table 21). The potential habitat within the depth primary depth range of the species, rocky reef habitat within the potential habitat, MPAs and CCAs are depicted for the entire state (Figure 95) and various regions along the state in Figures 96 - 99.

We found minimal voids in coverage in habitat layers across the species range, with 0.13 square miles missing north of Point Conception and 4.95 square miles missing from the south of Point Conception.

9.5.3 Discussion

Current assessments do not account for length/age composition and differing fishing mortality rates inside and outside MPAs or waters in long-established CCAs and RCAs. As biomass accrues inside these areas, accounting for protections through area-based assessment methods or effects on selectivity should be considered as fishery dependent data will only reflect the length composition and density outside. There is the potential for future assessments to account for differences in length composition, fishing mortality and relative abundance in a two-area model in Stock Synthesis with available data from long-term MPA monitoring.

Additional high resolution side scan sonar data in waters seaward of the CSMP coverage would improve coverage and resolution of habitat data. Similar analyses for each nearshore or shallower distributed shelf rockfish species (i.e., vermilion rockfish) would be a helpful addition to stock assessments to inform time blocking and selectivity considerations. The extent and design of the network to function in this way is unique to California and it's efforts to conserve nearshore stocks. Until the closed areas can be accounted for explicitly in stock assessments, the substantial areas in MPAs should be taken into consideration as a buffer against overfishing, since they were established in the interest of preserving spawning stock to seed areas outside and other MPAs in the network.

Table 20: Percent of rocky reef habitat within 100 meters in MPAs, RCAs closed to fishing for groundfish and waters open to fishing in California north of Point Conception

Year	Percent Protected by MPA	Percent Protected by RCA	Percent Open to Fishing
2001	0.03	0.00	0.97
2002	0.03	0.00	0.97
2003	0.03	0.41	0.55
2004	0.03	0.23	0.73
2005	0.03	0.30	0.67
2006	0.03	0.30	0.67
2007	0.03	0.28	0.69
2008	0.11	0.27	0.62
2009	0.11	0.27	0.62
2010	0.11	0.33	0.56
2011	0.17	0.29	0.54
2012	0.17	0.29	0.54
2013	0.20	0.27	0.53
2014	0.20	0.27	0.53
2015	0.20	0.24	0.56
2016	0.20	0.24	0.56
2017	0.20	0.14	0.66
2018	0.20	0.14	0.66
2019	0.20	0.11	0.68
2020	0.20	0.13	0.67
2021	0.20	0.05	0.75

Table 21: Percent of rocky reef habitat within 100 meters in MPAs, RCAs, CCAs closed to fishing for groundfish and waters open to fishing in California south of Point Conception

Year	Percent Protected by MPA	Percent Protected by RCA	Percent Protected by CCA	Percent Open to Fishing
2001	0.01	0.00	0.34	0.65
2002	0.01	0.00	0.34	0.65
2003	0.01	0.16	0.34	0.49
2004	0.04	0.10	0.34	0.52
2005	0.04	0.10	0.34	0.52
2006	0.04	0.10	0.34	0.52
2007	0.04	0.10	0.34	0.52
2008	0.04	0.10	0.34	0.52
2009	0.04	0.10	0.34	0.52

Table 21: Percent of rocky reef habitat within 100 meters in MPAs, RCAs, CCAs closed to fishing for groundfish and waters open to fishing in California south of Point Conception *(continued)*

Year	Percent Protected by MPA	Percent Protected by RCA	Percent Protected by CCA	Percent Open to Fishing
2010	0.04	0.10	0.34	0.52
2011	0.04	0.10	0.34	0.52
2012	0.08	0.10	0.34	0.48
2013	0.08	0.10	0.34	0.48
2014	0.08	0.10	0.34	0.48
2015	0.08	0.10	0.34	0.48
2016	0.08	0.10	0.34	0.48
2017	0.08	0.10	0.34	0.48
2018	0.08	0.10	0.34	0.48
2019	0.08	0.10	0.25	0.57
2020	0.08	0.10	0.25	0.57
2021	0.08	0.10	0.25	0.57

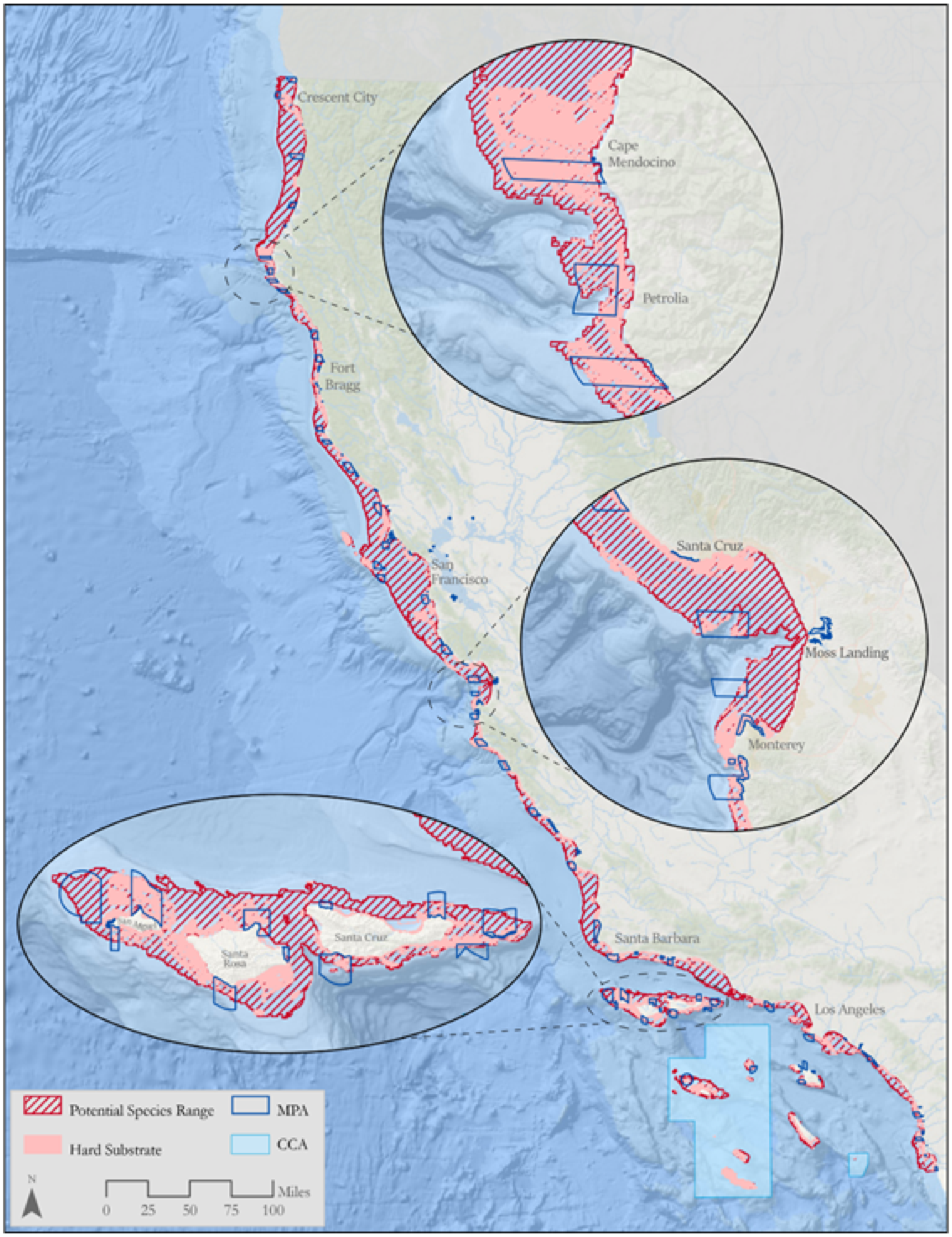

Figure 95: Copper and quillback rockfish potential depth range off California in red hatched polygon, hard substrate occurring within the potential range in pink, MPAs in dark blue outline, and the CCAs in light blue.

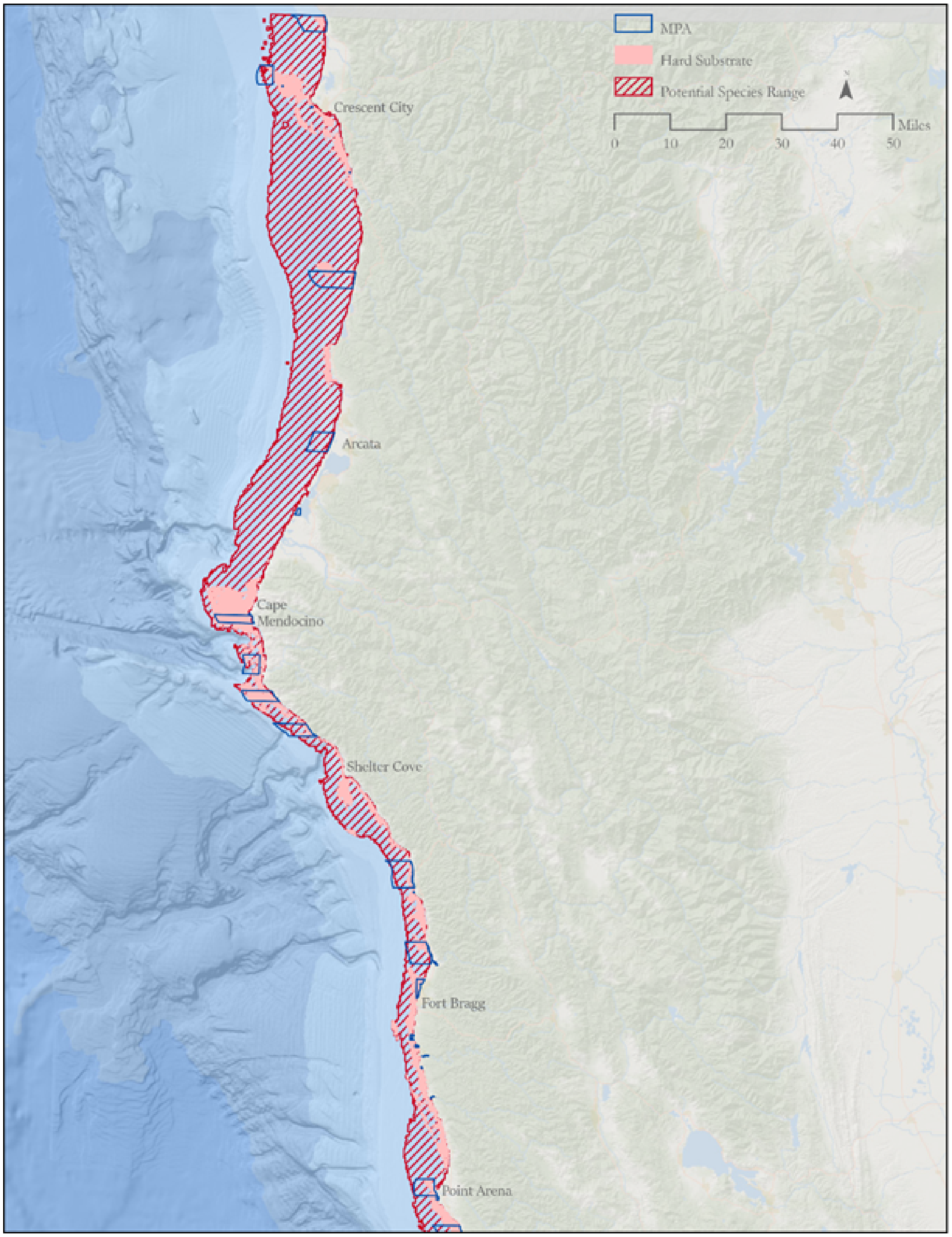

Figure 96: Copper and quillback rockfish potential depth range in red hatched polygon, hard substrate occurring within the potential range in pink and MPAs in dark blue outline between the Oregon/California border and Point Arena, California.

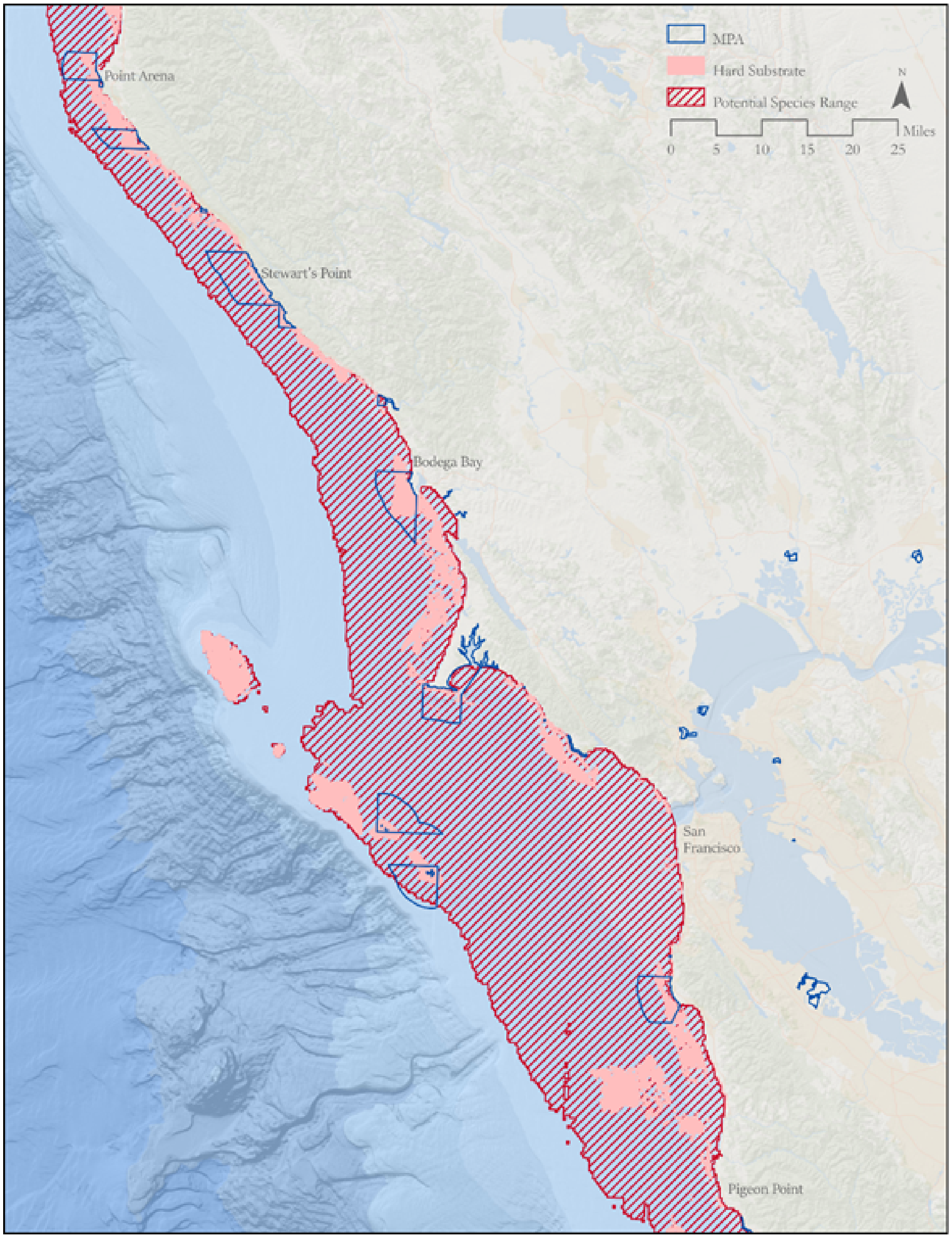

Figure 97: Copper and quillback rockfish potential depth range in red hatched polygon, hard substrate occurring within the potential range in pink and MPAs in dark blue outline between Point Arena and Pigeon Point, California.

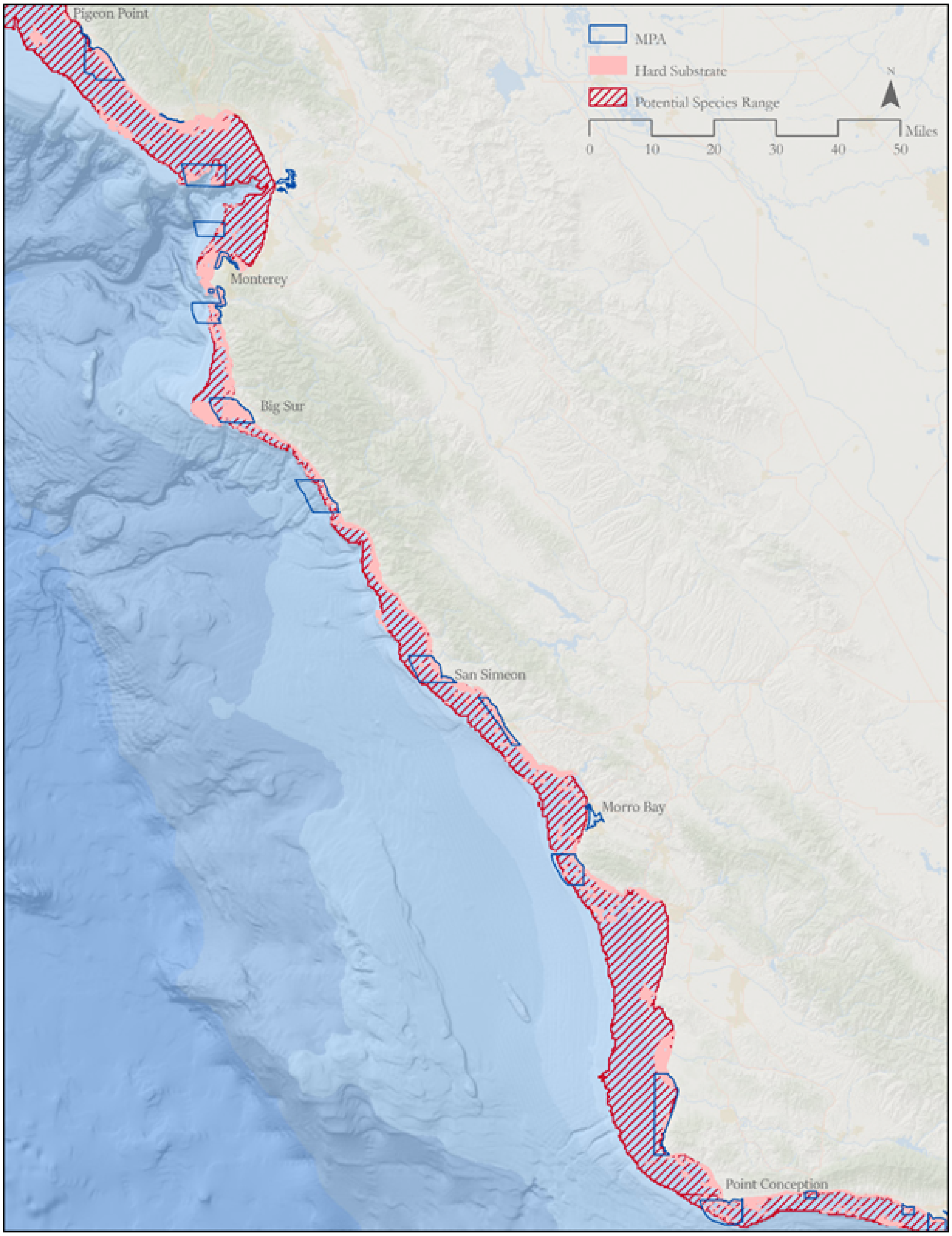

Figure 98: Copper and quillback rockfish potential depth range in red hatched polygon, hard substrate occurring within the potential range in pink and MPAs in dark blue outline between Pigeon Point and Point Conception, California.

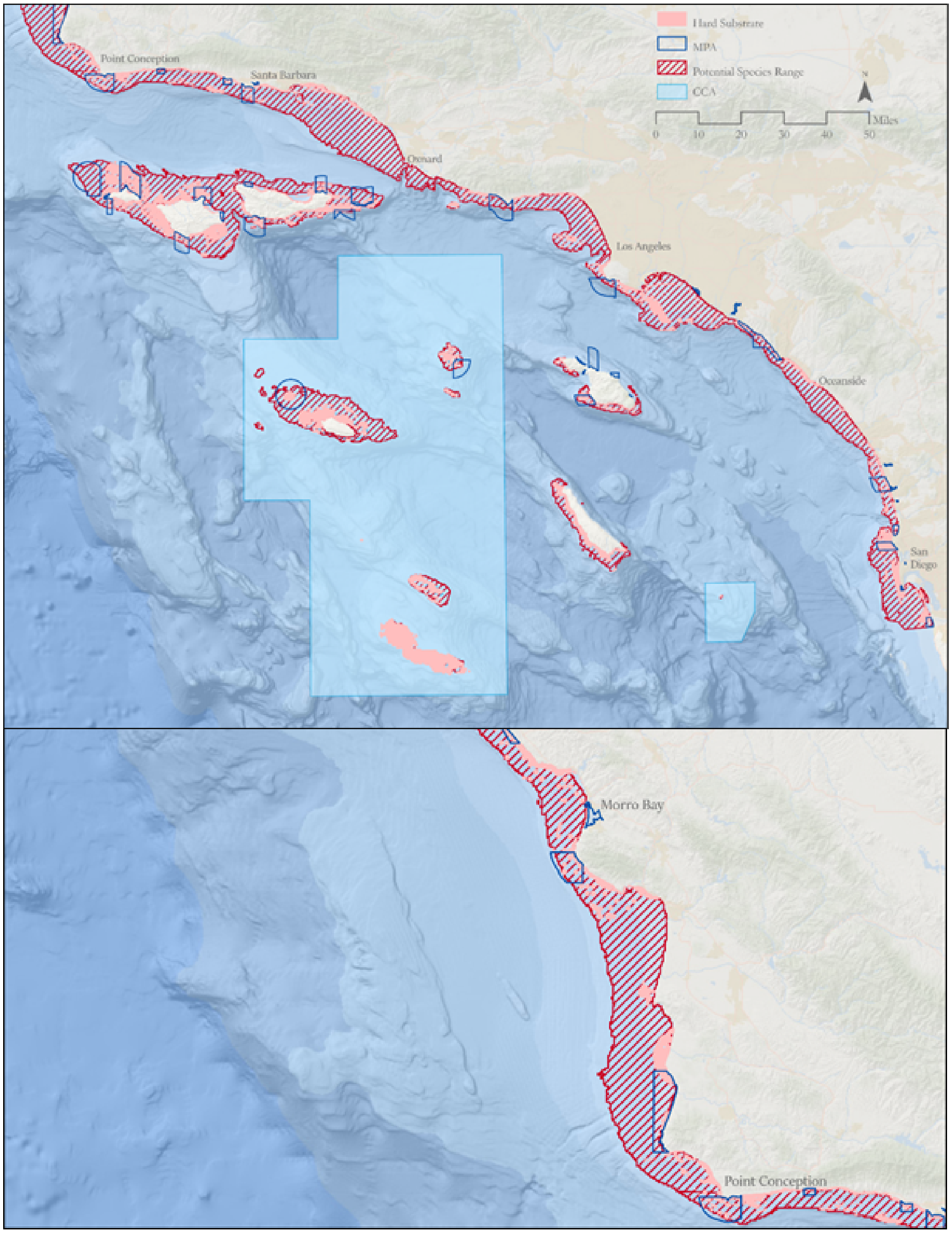

Figure 99: . Copper rockfish potential depth range in red hatched polygon, hard substrate occurring within the potential range in pink, MPAs in dark blue outline, and the CCA in light blue between the Point Conception, California and the U.S./Mexican border. .

9.6 California Remotely Operated Vehicle Data

From 2013-2015, the CDFW in collaboration with Marine Applied Research and Exploration (MARE), conducted Remote Operated Vehicle (ROV) surveys along the full length of the California coastline inside MPAs and in reference sites outside for comparison. Density estimates were produced from the ratio of observed fish per unit area observed over the area of seafloor observed by the ROV in fish per meter squared. The percent relative density reflecting the proportion of the density observed in each depth bin was estimated relative to the sum of the density values in observed depths. A particular advantage of ROV data compared to other data sources is the accuracy of the depth of encounter of individual fish, providing useful information regarding selectivity of fishing gear relative to the depth distribution of fish observed by the ROV.

In addition, length frequency distributions by depth were determined from fish observed by the ROV based on visual approximations using the distance between paired lasers. While future efforts to increase the precision of length estimates include using stereo-camera data and programs estimating length from trigonometric calculations, the trends in approximate length distribution with depth still provides useful information. Length frequency distributions for copper rockfish sampled by the ROV in reference locations open to fishing south of Point Conception show the majority of observations occurring between 10 - 20 fathoms with peak observations between 20 - 40 cm (Figure 100). The observations in closed areas, marine protected areas where retention is prohibited, had higher number of observations of copper rockfish across sizes and depths (Figure 101). Smaller sizes were observed in higher proportions across depth in open areas (Figure 102) versus closed areas (Figure 103).

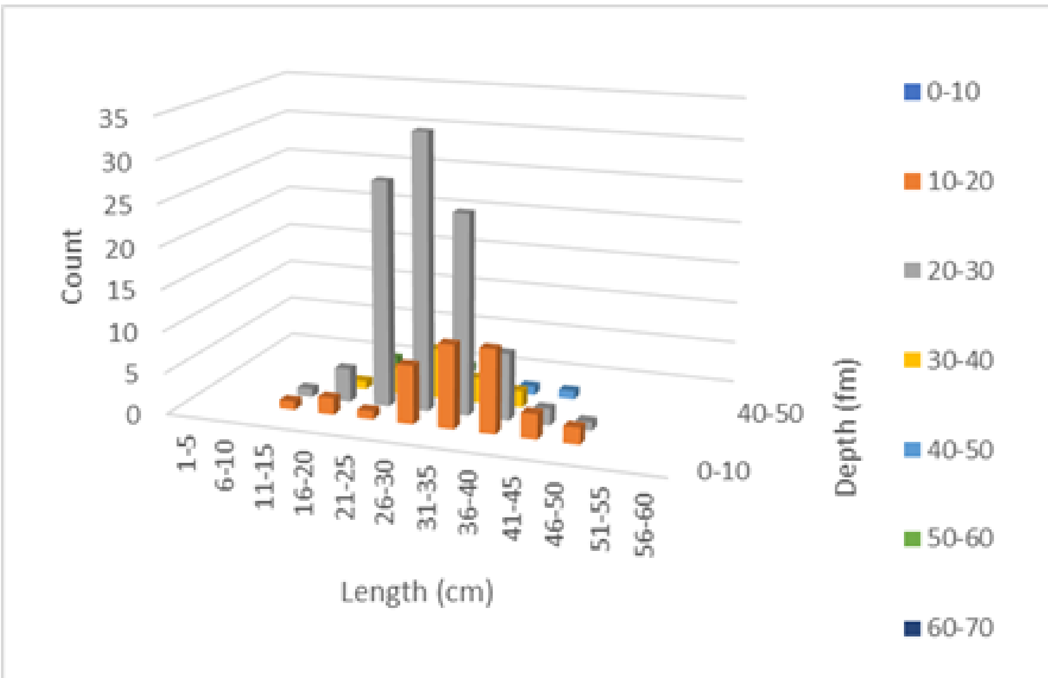

Figure 100: Length frequency distribution in each 10 fm depth bin for copper rockfish sampled by the ROV in reference locations open to fishing south of Point Conception.

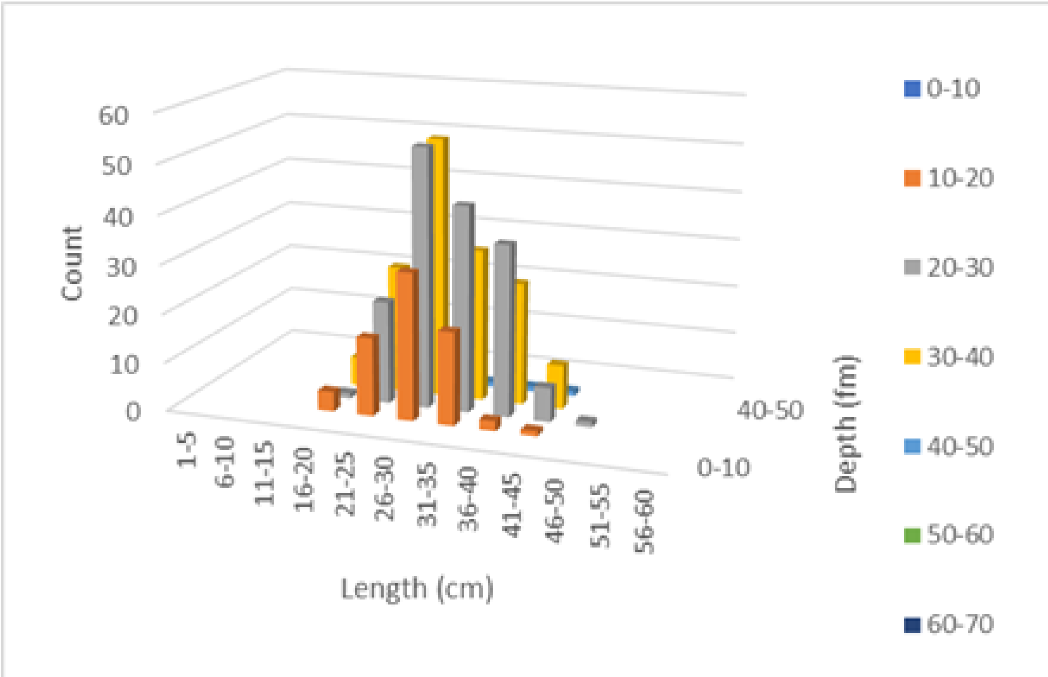

Figure 101: Length frequency distribution in each 10 fm depth bin for copper rockfish sampled by the ROV in marine protected areas where fishing for groundfish is prohibited.

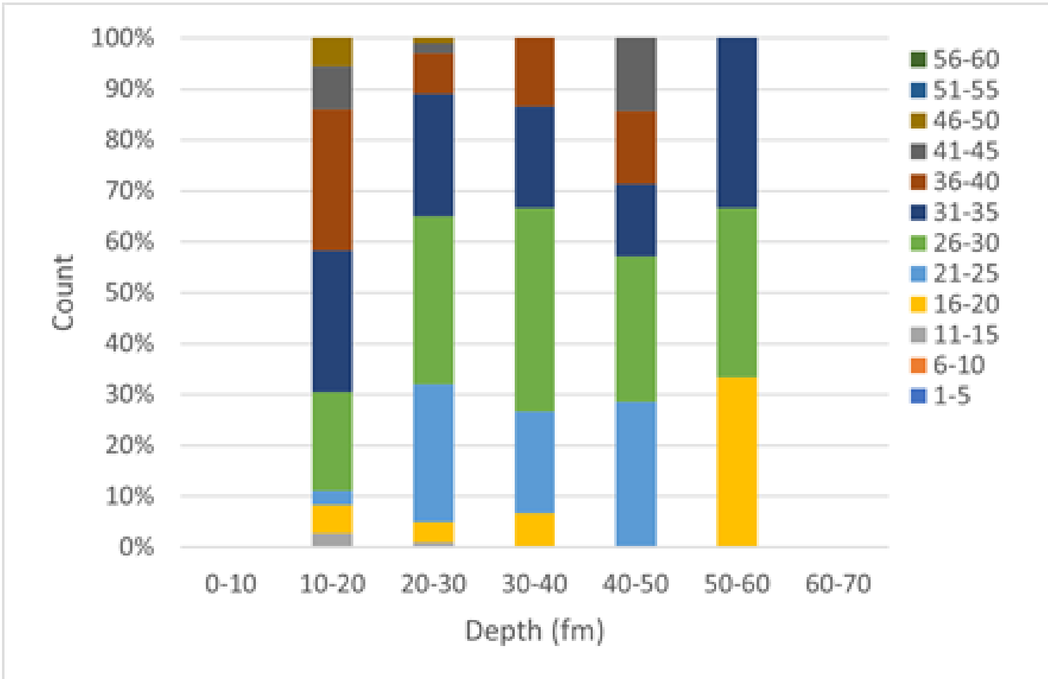

Figure 102: Percent composition of copper rockfish length frequency in 5 cm size classes for each 10 fm depth bin from ROV observations south of Point Conception in reference locations where fishing for groundfish is allowed.

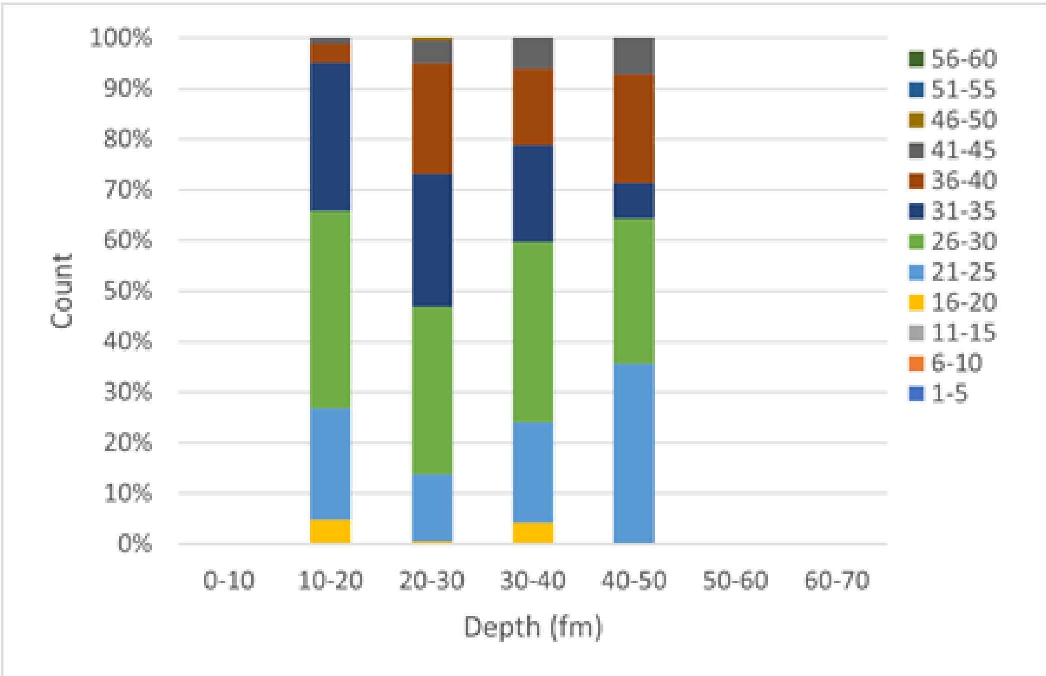

Figure 103: Percent composition of copper rockfish length frequency in 5 cm size classes for each 10 fm depth bin from ROV observations south of Point Conception in marine protected areas where fishing for groundfish is prohibited.

9.7 Evaluating available information to determine stock management delineation for copper rockfish (***Sebastes caurinus***) off the U.S. West Coast

The following analysis examines the available literature that could inform the selection of management areas for stocks that are assessd at finer regional scales such as copper rockfish. This analysis was presented at the Groundfish Sub-committee of the Scientific and Statiscal Committee held on September 29, 2021.

9.7.1 Dispersal

9.7.1.1 Recruitment and Dispersal

Evidence for Managing at Assessment Scale

Markel (2011) - Observed significant differences of recruitment among sites and years which were not consistent, indicating spatial differences in recruitment intensity during year of high recruitment within the Barkley Sound, British Columbia.

Buonaccorsi et al. (2002): Estimated the dispersal distance of copper rockfish recruits as 13km or less based on a stepping stone model. Caveat: This value can be highly sensitive to the ratio of total population size to effective population size.

While annual recruitment deviations were not estimated in the base model for the area south of Point Conception, model sensitivities to estimating annual recruitment deviations appeared to be little coherence with strong or weak recruitment years between the models south and north of Point Conception. The base model for the area south of Point Conception opted to not estimate annual recruitment deviations due to correlations with recent high catch years (i.e., estimated a series of years [2008 - 2014] with high recruitment proceeding recent years with high catches between). *Caveat*: length data may not be fully informative on recruitment and variation in growth can result in low or high recruitment years being attributed to multiple years.

Evidence for Alternative Management Scale

Field et al. (2021) - Determined that rockfish strong recruitments observed between 2014-2016 were largely coastwide events.

9.7.1.2 Adult Movement

Evidence for Managing at Assessment Scale

Lea et al (1999): Summarized tagging data that reported copper rockfish to have low to moderate degrees of movement and high site fidelity. Of 32 tagged copper rockfish that were recaptured the distance moved ranged between 0-1.5 nautical miles after 2-1,017 days at liberty.

Reynolds et al. (Reynolds et al. 2010): Tagged copper rockfish in nearshore waters of Prince William Sound, Alaska exhibited long periods of residency with limited movements.

Tolimieri et al. (2009): Observed home ranges of copper rockfish in Puget Sound was relatively small (~1500 to ~2500m^2). Caveat: movement of copper rockfish in the Puget Sound may not be representative of movement of coastal populations.

Evidence for Alternative Management Scale

Lowe et al. (2009): Copper rockfish exhibited low degrees of site fidelity and had high variation in the percentage of days on which individuals were detected based on 7 tagged fish at petroleum platforms in the Santa Barbara Channel.

McGilliard et al. (2015): Fisheries managed by area closures impose spatial heterogeneity in fishing mortality, and simulations from generic operating models suggest that the accuracy of conventional stock assessments depends on movement rates.

9.7.2 Geographic variation

9.7.2.1 Variation in Genetic Composition

Evidence for Managing at Assessment Scale

Sivasundar and Palumbi (2010): Measured moderate differentiation mtDNA structure but no nuclear structure in coastal copper rockfish populations.

Buonaccorsi et al. (2002): Identified significant divergence along the U.S. West Coast when measured as variance in allele frequency or mean repeat number, indicting a substantial isolation between regions. Examined samples from Queen Charlotte, Puget Sound, Canadian Gulf Islands, Crescent City, Big Creek, San Miguel Island.

Johansson et al. (2008): Identified isolation by distance in coastal copper rockfish populations (F_{ST} = 0.006) similar to Buonaccorsi et al. (2002) (F_{ST} = 0.008). However, concluded that some of the genetic divergence may be related to habitat patchiness and not distance alone.

Evidence for Alternative Management Scale

Sivasundar and Palumbi (2010): The Oregon and Monterey Bay populations were both genetically differentiated from the Santa Barbara populations for mtDNA but the Monterey Bay and Oregon populations could not be distinguished from each other. This could indicate that there is limited differentiation between northern California and Oregon copper rockfish populations indicating mixing between the areas.

Caveat

Waples and Gaggiotti (Waples and Gaggiotti 2006): Significant differences in neutral genetic characters indicate that the populations have been re-productively isolated for many generations,which is far longer than the ecological time scales that are relevant to stock assessment or fishery management.

9.7.2.2 Variation in Phenotypic Traits

Evidence for Managing at Assessment Scale

Minor differences measured in maturity-at-length between two areas of the coast: Oregon (Hannah 2014) and South of Point Conception (Melissa Head, NWFSC).

Punt et al.(2015): Conventional stock assessments produced significantly biased estimates when applied to an operating model of pink ling fisheries with spatial heterogeneity in fishing mortality, growth, and recruitment.

Evidence for Alternative Management Scale

Limited growth differences measured based on original age-length estimates between fish off the Oregon and Washington coast to those sample south of Point Conception. Caveat:

Spatial gradients of growth across the coast are commonly observed in rockfish or other fish species along the U.S. west coast (Keller et al. 2012; Gertseva et al. 2017; Keller et al. 2018) and lack of measure growth variation may be due lack of spatial coverage of otoliths samples across the California coast.

9.7.3 Other Considerations

9.7.3.1 Abundance Trends

Evidence for Managing at Assessment Scale

Ying et al. (2011): The performance of stock assessments using an operating model to represent three connected sub-populations of small yellow croaker and observed that assessing and managing each sub-population as a unit led to overfishing and managing the metapopulation as a unit stock often led to local depletion.

The separate models for the areas south and north of Point Conception estimated two distinct stock trajectories with the stock in the north over recent years from low levels to at or around the management target and the stock in the south increasing from low levels between 2001 - 2014 and decreasing in recent years to levels below the minimum stock size threshold. The model for the area south of Point Conception did not estimate annual recruitment deviations which could contribute to stock trajectory differences to the stock to the north where strong recent recruitments have led to increases in stock size. However, in the model sensitivity for the south of Point Conception model that estimated annual recruitment deviations the stock trajectory remaining low (below the minimum stock size threshold) and did not show similar stock increases as observed in the north.

The trajectories across all model areas showed varying trajectories (Figure 76).

Evidence for Alternative Management Scale

The areas of true population variation in relative stock size may not align with the assessment boundaries as currently defined. State based management is likely not the only factor impacting relative stock sizes across the coast where movement and recruitment patterns likely also influence potential differences in relative stock size.

Cope and Punt (2013): Conventional stock assessments failed to estimate differing spatial patterns and exploitation (localized depletion) but adequately estimated the overall stock status.

9.7.3.2 Size and Age Composition

Evidence for Managing at Assessment Scale

Distinct selectivity curves estimated between the recreational and commercial fisheries north and south of Point Conception. While to a lesser degree, the selectivity in Oregon and Washington commercial and recreation fleets also varied from selectivity estimated in other areas.

Bosely et al. (2019): Specifying the correct form spatial population structure may not e as critical as understanding movement patterns and spatial heterogeneity in fishery selectivity and life-history variation when developing reference points for management.

Berger et al. (2021): Aligning management assessment areas with with underlying population structure and processes is important, especially when fishing mortality is disproportionate to vulnerable biomass among management areas, demographic parameters (growth and maturity) are not homogeneous within management areas, and connectivity (via recruitment or movement) unknowingly exists among management areas. Bias and risk were greater for assessments that incorrectly span multiple population segments compared to assessments that cover a subset of a population segment, and these results were exacerbated when there was connectivity between population segments. Caveat: The variation is growth and connectivity between areas via recruitment for copper rockfish off the West Coast is currently unknown or uncertain.

Caveat

Rather than creating separate assessments to account for variation in exploitation or life-history variation across areas a more integrated approach could be to apply a spatial assessment that can provide both area- and coastwide population estimates. However, spatial assessments come at the cost of a larger number of parameters to estimate, but general guidance around the key decisions exists when moving to spatial assessments (Punt (2019)). This approach should be evaluated to understand the trade-offs between adding parameters that may be poorly informed (e.g., movement, recruitment by area) via a spatial assessment approach versus either conducting separate assessments or applying the "fleets-as-areas" approach.