

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

by  
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# 1 Introduction

## 1.1 Basic Information

This assessment reports the status of copper rockfish (*Sebastes caurinus*) off the California coast, north 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, north of Point Conception, copper rockfish is caught in both

commercial and recreational fisheries. Recreational removals have been the largest source of fishing mortality, comprising nearly 85 percent of total removals of copper rockfish across all years (Table 1 and Figure 1). The landings from the commercial fishery have been minimal by year, except for a brief period between the mid-1980s and early-2000s.

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.

Copper rockfish residing between Point Conception and the California/Oregon border are assessed here as a single, separate stock (Figure 2). This designation was made based on oceanographic, geographic, and fishery conditions. The copper rockfish population in California waters was split at Point Conception due to water circulation patterns that create a natural barrier between nearshore rockfish populations to the north and south. The northern border for this assessment was defined as the California/Oregon border due to substantial differences in historical and current exploitation levels. Additionally, the fairly sedentary nature of adult copper rockfish, likely limits flow of fish between northern California and areas to the north.

Analysis that summarized current research to inform stock structure in copper rockfish off the West Coast and evaluated the available information to guide the selection of the management area relative to the assessment area is presented in Wetzal et al. (2021).

### **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, north 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 and fish landed live or dead (Table 1 and Figure 1). The grouping of all commercial landings into a single fleet was driven by the limited length composition data available per gear type. Additionally, commercial length data available in PacFIN database for California did not have the needed information to identify samples from live versus dead fish (i.e., condition code) preventing the ability to evaluate the data based on live versus dead landing.

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. Catches from Region 6 were allocated to the areas north and south of Point Conception following an approach developed by Dick et al. (2007) for the assessment of cowcod. Specifically, port-specific landings of total rockfish from the California Department of Fish and Wildlife (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, this was the best available option given the absence of port-specific species composition data. Years with no data were imputed using the average of ratio estimates from adjacent years. Annual catches from unknown locations 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 1969-1979 into the 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 assessment, as they have in past assessments as the best available landings for the time period 1969 - 1979 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 (extracted 2/22/2021). Landings were separated for the area north 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 WCGOP discards were allocated to state and area based on the total observed landings by WCGOP. An average commercial discard mortality rate of 4.4 percent, based on the WCGOP data from 2002 - 2019, was applied to adjust historical landings data to account for total removals

### **2.1.1.2 Length Compositions**

Biological data were extracted from the PacFIN Biological Data System on February 21, 2001. The quantity of length samples from the commercial fishery were low until 1991 (Table 4). Due to low annual sample sizes, years prior to 1991 were not used in model fitting (entered as a ‘ghost fleet’ observations to see the implied fit). When used during model

development, the noisy distribution of years with low sample size prior to 1991, impacted the estimation of selectivity, reducing the fits to the later more informed data years. Length samples were highest during the 1990s, while the number of lengths samples by year have been relatively low since 2002. The range of sizes observed from 1991 - 2007 was relatively broad, encompassing approximately 25 - 54 cm (Figure 4). Since 2008, the frequency of sizes observed has shifted to smaller lengths, centered around 30 cm, with larger fish still being observed in the data. This shift in observed sizes is also reflected in the mean lengths observed by year (Figure 5), which could be due to shifts in fishery behavior, changes in the population demographics (e.g., incoming strong recruitments), or a combination of multiple factors.

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

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

## 2.1.2 Recreational Fishery

### 2.1.2.1 Landings

The recreational fishery is the main source of exploitation of copper rockfish. Recreational catches of copper rockfish in California waters north of Point Conception peaked in the late 1970s and early 1980s. Removals declined sharply in the 1990s and early 2000s. The removals remained relatively low until 2015.

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 added to recreational removals for north 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 all 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 catches 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 for MRFSS (1980-2003) and CRFS (2004-2019) were downloaded from the RecFIN website. The number of length observation by year are shown in Table 5. The highest number of samples occurred within the last 15 years of the modeled period. A broad range of sizes, between 20 - 50 cm, have been observed from the recreational fishery across available data years (Figure 6). The recreational length data show a pulse of smaller fish starting around 2010, which appears at greater lengths in subsequent years, perhaps indicating of a strong recruitment event. The mean size observed across years ranged from 30 to approximately 38 cm (Figure 7).

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

## **2.2 Fishery-Independent Data**

### **2.2.1 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 are limited. The number of tows where copper rockfish were observed in California waters north of Point Conception are shown in Table 6. The limited number of tows by year within this area prevented the calculation of an index of abundance for copper rockfish. Additionally, observations using trawl gear may not be informative of population trends for rocky-habitat associated species such as copper rockfish. With limited observations and in the absence of an index of abundance to link associated length 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  $M = 4.899A_{\max}^{-0.916}$ . 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:

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

where  $A_{\max}$  is the maximum age. The prior is defined as a lognormal distribution with mean  $\ln(5.4/A_{\max})$  and standard error = 0.438. Using a maximum age of 50, the point estimate and median of the prior is 0.108 yr<sup>-1</sup>. 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 8). The estimated length-weight relationship for female fish was  $W = 9.56e-06L^{3.19}$  and males  $1.08e-05L^{3.15}$  where  $L$  is length in cm and  $W$  is weight in kilograms (Figure 9).

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

Length-at-age was estimated for male and female copper rockfish using data collected from fishery-dependent data sources off the coasts of Oregon and Washington, collected between 1998-2019 (Table 7). The available fishery-dependent data from Oregon and Washington included limited observations of young fish (less than 4 years of age), which presented challenges for estimating growth. Attempting to estimate growth in the absence of data to inform the rate of growth ( $k$ ) and the size-at-age 0 ( $t_0$ ) could result in biased estimates of all parameters including the size-at-maximum length ( $L_\infty$ ). A published growth study for copper rockfish by Lea et al. (1999) had 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. The simulated data for young fish appeared consistent with the data for older fish observed off the Oregon and Washington coast (Figure 10). This combined data set was used to estimate growth curves for male and female copper rockfish that were used in this assessment. Ideally, growth would be estimated using data collected from similar sources. However, the bias from using data from different sources was considered to be less than the bias that may arise from estimating growth from observations that did not cover the range of ages.

The estimated growth used in this assessment had females reach marginally larger asymptotic sizes compared to males. Sex-specific growth parameters were estimated at the following values:

$$\text{Females } L_\infty = 48.4 \text{ cm; } k = 0.206$$

$$\text{Males } L_\infty = 47.2 \text{ cm; } k = 0.231$$

These values were fixed within the base model for male and female copper rockfish. While the growth differences between sexes was limited for copper rockfish, sex-specific parameterization was used in the hopes that it would allow the length data to be the most informative within the assessment. 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 based 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 11.

In contrast to the current approach, 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  $L_\infty$  from Lea et al. (1999) by sex were quite a bit larger than those estimated for this assessment using recent length and age data off the coast of Oregon and Washington. In the Lea et al. (1999) young fish were well sampled, however, there were very few observations of fish older than 12 years of age (fewer than 5 total), which appears to have led to a poorly informed estimate of  $L_\infty$ .

For the sake of parsimony, the length-age samples were pooled across sources to estimate a single length-at-age curve for copper rockfish in California north of Point Conception, Oregon, and Washington. In the future, if adequate area-based length-age samples across a range of fishery-dependent and -independent source are available, copper rockfish growth should be re-evaluated for possible area-specific variation.

#### **2.3.4 Maturation and Fecundity**

Maturity-at-length is based upon the work of Hannah (2014) who estimated the 50 percent size-at-maturity of 34.8 cm and slope of -0.6 for copper rockfish off the coast of Oregon, with maturity reaching the asymptote of 1.0 for larger fish (Figure 12).

The fecundity-at-length was based on research from Dick et al. (2017). The fecundity relationship for copper rockfish was estimated equal to  $3.362e-07L^{3.68}$  in millions of eggs where  $L$  is length in cm. Fecundity-at-length is shown in Figure 13.

Table 8 shows the length-at-age, weight-at-age, maturity-at-age, and spawning output (the product of fecundity and maturity) assumed in the base model.

#### **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 14 and 15. 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 that 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, the area south of Point Conception off the California coast and the area north of Point Conception to the Washington/Canadian border. The 2013 assessment estimated the stock south of Point Conception at 75 percent of unfished spawning biomass and the stock north of Point Conception at 48 percent of unfished spawning biomass.

#### **3.1.1 Bridging Analysis**

A direct bridging analysis was not conducted because the previous assessment was structured to include the area from north of Point Conception to the Washington/Canadian border. The data types used in the 2013 assessment were catches and indices of abundance. Matching the 2013 data was not straightforward aside from the challenges already posed from the alternative model platform (XDB-SRA) and area grouping. First, the 2013 assessment document did not report catches on a state and source level (not atypical for grouped state or area assessments). Secondly, some of the recreational indices used in 2013 were calculated based on multi-state data. All of these items created significant challenges of how to conduct an effective, logical, and informative bridging analysis for the assessment north of Point Conception.

### **3.2 Model Structure and Assumptions**

Copper rockfish north of Point Conception off the coast of California are assessed using a two-sex model with sex-specific life history parameters. The model assumed two fleets: 1) commercial and 2) recreational with removals beginning in 1916. Selectivity was specified using the double normal parameterization within Stock Synthesis for both the commercial and recreational fleets. The commercial selectivity applied two time blocks for selectivity: 1916 - 2008 and 2009 - 2020. The commercial selectivity block from 1916 - 2008 was fixed to be asymptotic, while the selectivity block from 2009 - 2020 was allowed to be dome-shaped. The recreational fleet selectivity was constant across the model years, 1916 - 2020, and fixed to be asymptotic, although dome-shaped selectivity was explored during model development. Annual recruitment deviations were estimated for all years.



### 3.2.1 Modeling Platform and Structure

The assessment was conducted using Stock Synthesis version 3.30.16 developed by Dr. Richard Methot at the NOAA, NWFSC (Methot and Wetzel 2013). This most recent version was used because it included improvements and corrections to older model versions. The 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  $0.108 \text{ yr}^{-1}$  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 length composition data was set equal to the number of length samples by year.

The base model weighted length data for each fleet using the “Francis method” which was based on equation TA1.8 in Francis (2011). This formulation looks at the mean length or age and its associated standard error, and determines if, across years, the model is able to adequately match the data. If the model predictions do not adequately match the mean lengths given the associated standard errors, then that data source should be down-weighted (equivalently, the standard errors are increased). This method accounts for correlation in the data (i.e., the multinomial distribution). Sensitivities were performed examining the

difference in results due to weighting using McAllister-Ianelli Harmonic Mean Weighting (McAllister and Ianelli 1997) and the Dirichlet-Multinomial Weighting (Thorson et al. 2017).

### 3.2.4 Estimated and Fixed Parameters

There were 123 estimated parameters in the base model. These included one parameter for  $\log(R_0)$ , 5 parameters for selectivity and time blocking of the fleets, 105 recruitment deviations, and 12 forecast recruitment deviations.

Fixed parameters in the model were as follows. Steepness was fixed at 0.72, the mean of the prior. Natural mortality was fixed at  $0.108 \text{ yr}^{-1}$  for both sexes, the median of the prior. The standard deviation of recruitment deviates was fixed at 0.6. Growth, maturity-at-length, and length-at-weight were fixed as described above in Section 2.3.

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, there was little support for dome-shaped selectivity the recreational fleet and the final selectivity form was fixed to be asymptotic. Selectivity for the recreational fleet was estimated using the double normal parameterization where the ascending width and the size at peak selectivity were estimated.

For the commercial fleet in order to fit a shift in observed lengths, two blocks of selectivity were estimated: 1916 - 2008 and 2009 - 2020. Selectivity in each time block was estimated using the double normal parameterization where selectivity was assumed asymptotic from 1916 - 2008, estimating the ascending width and the size at peak selectivity, with the shape of selectivity estimated to be dome-shaped from 2009 - 2020 by estimating the final selectivity parameter for this period.

## 3.3 Model Selection and Evaluation

The base assessment model for copper rockfish was developed to balance parsimony and realism, with the goal of estimating a spawning output trajectory for the population of copper rockfish off the California coast north 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 developed 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 9 and the likelihood components are shown in Table 10. Estimates of derived reference points and approximate 95 percent asymptotic confidence intervals are shown in Table 11. 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 9. The  $\log(R_0)$  was estimated at 6.03. The selectivity curves for the commercial and recreational fleet are shown in Figure 16. The commercial selectivity was estimated in two blocks of time; 1916 - 2008 and 2009 - 2020. The block in selectivity was aimed to capture the shift in observations of smaller fish in recent years (Figure 4). The early block estimated a gradual slope of increasing selectivity across lengths with selectivity reaching 1.0 at the largest sizes, with the parameter hitting the upper bound of 55 cm. To reduce problems in convergence the final model fixed this parameter at 55 cm, just below the upper bound. In recent years, commercial selectivity shifted left-ward, resulting in increased selectivity of smaller fish with peak selectivity occurring at 26.3 cm. The cause of this shift in selectivity is not entirely clear but may be related to management changes shifting effort into shallower depths, the live fish fishery which favors age 3 fish (Dan Platt, personal communication), and or combined with a strong recruitment event entering the fishery that could have resulted in a shift in size targeted by the fishery.

Selectivity in the recreational fishery was assumed constant across the modeled period with maximum selectivity occurring for fish of 32.1 cm and greater. The peak selectivity for both fleets, commercial and recreational fishery, is less than the length-at-50 percent maturity (34.83 cm).

The estimated annual recruitment and recruitment deviations are shown in Figures 17 and 18. The bias adjustment applied to the annual recruitment deviations across time is shown in Figure 19. Strong recruitments are estimated to have occurred in 2008, 2009, and 2010. While there could have been three above average recruitments occurring in subsequent years, alternatively there may have been a single year with high recruitment that the model is unable to accurately assign to a single year due to the variability in length data. Above average recruitment in 2008 has been estimated in other rockfish assessments off the West Coast (Gertseva et al. 2015; Hicks and Wetzel 2015; Wetzel et al. 2017). The stock-recruit curve resulting from a value of steepness fixed at 0.72 is shown in Figure 20.

#### 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 and recreational fleets. Annual length composition fits are shown in the Appendix, Section 9.1.

The Pearson residuals for the commercial fishery length data area shown in Figure 21. The observations of larger fish, greater than 45 cm, are minimally greater than the model expectations prior to 2009. Starting in 2009, the commercial length data shifts to smaller fish with observations greater than model expectations for fish between 25 - 30 cm. The mean length observed in the commercial lengths were generally stable between 1990 - 2003, slightly increasing between 2004 - 2007, and then decreasing to smaller sizes to a low in mean lengths occurring in 2011 (Figure 22). The observed decline in mean lengths was not fit well by the model using only recruitment deviations, leading to the decision to also allow for a shift in commercial selectivity.

The Pearson residuals for the recreational length data are variable by year (Figure 23). Pearson residuals were positive, observations greater than expected, for small fish prior to 1997 and are generally variable showing no clear misfit in the model in recent years. In model development, an additional selectivity block for years prior to 1997 were explored to address the pattern in the Pearson residual. These model explorations did estimate a left-ward shift in selectivity for the recreational fleet by approximately 2-3 cm, but had little impact on the overall model results. In the aims of parsimony and simplicity a single selectivity pattern was assumed in the base model. The mean length by year for the recreational fleet was highly variable across years (Figure 24). The recreational lengths show a decrease in the mean length observed around 2011, similar to the commercial data.

Aggregate fits by fleet are shown in Figure 25. The model fits the aggregated lengths for the recreational fleet length data generally well. The aggregated lengths for the commercial fleet reflected a wide selection across sizes, with the model under-predicting the selection for both small and large fish. Multiple sensitivities were conducted to explore alternative parameterization of commercial selectivity.

### **3.4.3 Population Trajectory**

The predicted spawning output (in millions of eggs) is given in Table 12 and shown in Figure 26. The estimated spawning output decreases sharply in the late-1970s and continues to decline until reaching low levels in the late-1990s. The spawning output slowly increases between 2000 - 2010 with the rate of population growth increasing after 2011 as fish from recent strong year-classes begin to mature. The estimate of total biomass over time is shown in Figure 27.

The model estimates that the spawning output relative the unfished equilibrium spawning output declined below the management limit of 25 percent around 1984 and remained below

the limit until 2015 (Figure 28). The estimated relative stock status of 39.3 percent at the start of 2021 is just below the rockfish relative biomass management target of 40 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 78 out of 100 runs returning 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 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 conducted 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. Deterministic recruitment with annual recruitment based on the stock recruitment curve.
2. Data weighting according to the McAllister-Ianelli method (MI DW) using the weighting values shown in Table 15.
3. Data weighting according to the Dirichlet Multinomial method (DM DW) where the estimated parameters are shown in Table 15.
4. Estimate  $L_{\infty}$  for both sexes.
5. Estimate the coefficient of variation of length-at-age for older fish for both sexes.
6. Estimate natural mortality for females only.
7. Fix the commercial fleet selectivity to be asymptotic in the late block.

8. Parameterize commercial selectivity using a cubic spline to fit the commercial composition data.
9. Remove the block in commercial selectivity and estimate a single asymptotic selectivity curve.
10. Add selectivity block for the recreational fleet for 1916 - 1997.
11. Add the onboard Commercial Passenger Fishing Vessel (CPFV) index of abundance from northern California used in the 2013 assessment. Sensitivity was allowed to estimate added variance to the index of abundance.
12. Add additional early CPFV lengths collected during onboard sampling (referred to as the Deb Wilson-Vanderberg survey) that were not included in the base model due to not being received until after the assessment review.
13. 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, 2003-2007, 2008-2016, and 2017-2020. 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 13 and 14. Plots of the estimated time series of spawning output and relative spawning output are shown in Figures 29 - 32. The majority of sensitivities estimated the final stock status within the precautionary zone, between 25 and 40 percent of unfished spawning output, or just about the management target of 40 percent. Assuming deterministic recruitment, annual recruitment from the stock recruitment curve, estimated a more pessimistic final stock status with the final stock status below the management threshold of 25 percent of unfished. The sensitivity that estimated female natural mortality estimated a higher unfished spawning output but a similar final stock size, relative to the base model, resulting in a final stock status below the management threshold.

The sensitivities that examined alternative parameterization of the commercial selectivity, asymptotic or spline selectivity, estimated similar initial stock size but lower stock size and status in 2021 relative to the base model. Fixing the commercial selectivity to be asymptotic and a single selectivity curve resulted in a less depleted stock relative to the base model (Figure 32). The estimates from this sensitivity were primarily driven by the model estimating a selectivity curve that was between the selectivities by time block within the base model. Given the magnitude of difference in final estimates relative to the base model, additional explorations were conducted. Typically, sensitivity runs assume the same data weighting applied in the base model that allows for direct comparison on the negative log-likelihood across models. Updating the data weighting to this sensitivity resulted in a model that was similar to the base model (Figure 32).

The sensitivity that used the onboard CPFV index of abundance resulted in a slightly higher estimated spawning output and fraction unfished relative to the base model (Figures 31 and

32). The sensitivity was allowed to estimate additional added variance for the input standard deviation for the index time series, which is typical practice in West Coast groundfish stock assessments. The estimated added variance for this index of abundance was relatively high, with 0.17 added.

### 3.5.3 Likelihood Profiles

Likelihood profiles were constructed for  $\log(R_0)$ , steepness ( $h$ ), female  $L_\infty$ , female natural mortality ( $M$ ) 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 estimating the remaining parameters based on the fixed parameter value.

The  $\log(R_0)$  negative log-likelihood was minimized at approximately  $\log(R_0)$  of 6.03 (Figure 33). The likelihood component driving the estimate of the  $\log(R_0)$  was attributed to the recruitment deviations in the base model, with the length data having little to no influence on the estimate. However, length data are the only data in the base model and those data are driving the estimate of annual recruitment deviations. Conducting a profile across  $\log(R_0)$  with recruitment deviations not estimated in the base model results in a profile where all influence on the estimated parameter is attributed to the length data supporting a similar parameter estimate for  $\log(R_0)$ . This confirms that the length data are the key source of information for the estimate of  $\log(R_0)$  in the base model. Assuming higher or lower values of  $R_0$  result in large fluctuations in the scale of the stock and final stock status (Figures 34 and 35).

For steepness, values from approximately 0.60 to 0.80 were supported by the negative log-likelihood (Figure 36). The main source of informing the likelihood across parameter values were the recreational length data. Assuming higher or lower steepness values had a large impact on the unfished and spawning output estimated (Figure 37). The estimated relative final stock status ranged between 0 - 1.0+. Values of steepness of 0.60 and 0.80, have similar support by the data, resulted in relative stock status that was either well below the minimum threshold or a bit above the target stock status (Figure 38).

The negative log-likelihood profile across female natural mortality supported values below  $0.115 \text{ yr}^{-1}$ , which includes the fixed value in the base model  $0.108 \text{ yr}^{-1}$  (Figure 39). The range of value explored in the profile resulted in a large change in the unfished stock size and a range of final stock status between 10 - 80 percent of unfished (Figures 40 and 41).

A profile across a range of female  $L_\infty$  values was also conducted (Figure 42). The negative log-likelihood showed support for values between approximately 45.5 - 49 cm. The  $L_\infty$  value for female fish in the model was fixed at 48.43 cm based on external model estimates using

length-at-age data collected off the Oregon and Washington coast. The stock scale and status was quite variable across alternative  $L_\infty$  values where assuming lower values resulted in sharp increases in stock scale and status (Figures 43 and 44).

A profile across a range of female  $k$  showed support for values from 0.18 - 0.25  $\text{yr}^{-1}$  (Figure 45). The  $k$  value for female fish in the model was fixed at 0.206. The stock scale and status increased under lower  $k$  values decreased in under higher  $k$  value (Figure 46 and 47).

The profile across a range of coefficient of variation ( $CV_2$ ) for older females supported  $CV_2$  values ranging between 0.05 - 0.085 (Figure 48). Assuming lower or higher  $CV_2$  values had little impact on the unfished spawning output (Figure 49). However, the estimated final spawning output and fraction unfished was more optimistic if lower  $CV_2$  values were assumed (Figures 49 and 50).

### 3.5.4 Length-Based Spawner-per-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) based on the observed recreational lengths. This analysis indicated the copper rockfish were 50 percent selected around 25 - 30 cm with full selection typically between 35 - 40 cm (excluding 2017, Figure 51). The median estimates of SPR by year ranged between 0.10 - 0.30 from 2012 - 2019 (lower values of SPR indicate higher exploitation levels). This type of analysis can provide insight on the fishing effort based on life history and observed length data in the absence of an integrated assessment model. Examining the length data by year in isolation, assuming deterministic recruitment, indicating that SPR by year has been lower (and thus the fishing impact has been higher) than the proxy rockfish SPR target (0.50) with 50 percent selectivity occurring before the length of 50 percent maturity.

### 3.5.5 Retrospective Analysis

A ten-year retrospective analysis was conducted by peeling back a year of data from the model from 2020 (e.g., Data -1 Years) to 2010 (e.g. Data -10 Years). The estimated spawning output was generally consistent with the base model when recent years of data were removed with the largest departure from the base model when the largest number of data years were removed (Figures 52 and 53). Figure 54 shows the change in estimated annual recruitment deviations as subsequent years data are removed during the retrospective run.



### 3.5.6 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 55 with Oregon and Washington shown in Figure 56. The fraction unfished across all West Coast stocks shown in Figure 57. 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.

## 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 11). The estimated sustainable total yield was 106.19 mt when using an  $SPR_{50\%}$  reference harvest rate. The spawning output equivalent to 40 percent of the unfished spawning output ( $SB_{40\%}$ ) was 166.33 million eggs.

The estimated fraction unfished in 2021 of 39.3 percent is just below the rockfish relative biomass management target of 40 percent (Figure 28). The fishing intensity,  $1 - SPR$ , was above the harvest rate limit ( $SPR_{50\%}$ ) between the early 1970s and late-2000s and has been both above and below the target over the final 10 years of the model (Table 12 and Figure 58). In recent years the stock status has been below the management target with the fishing intensity above and below the target in different years (Figure 59). Table 11 shows the full suite of estimated reference points for the base model and Figure 60 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  $\sigma$  with  $P^* = 0.45$  for years

2023-2032 (Table 16). Since the stock is estimated to be below the management target of 40 percent the buffer value in Table 16 reflects both the 40-10 harvest control rule adjustment and the time-varying scientific uncertainty buffer.

The area assumed in this assessment does not align with the PMFC management regions that define copper rockfish ACL allocation, north and south of 40° 10' Lat. N. To determine the amount of the 2021 and 2021 ACL for the California portion of the stock north of Point Conception the total ACL that would be allocated to the state of California was determined by summing the S. 40° 10' Lat. N. ACL and the percent of the N. 40° 10' Lat. N. allocated to California (25 percent, PFMC Groundfish Management team personal communication). Once the total ACLs for California were determined the portion of the ACL allocated to the area north 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.

The axes of uncertainty in the decision table is based on the uncertainty around the spawning biomass in 2021 ( $\sigma = 0.301$ ) via natural mortality parameter. The  $\sigma$  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 natural mortality values were done to attain the current year spawning biomass values. The natural mortality values that corresponded with the lower and upper percentiles were 0.098 and 0.123 yr<sup>-1</sup>.

Across the low and high states of nature and across alternative future harvest scenarios the fraction of unfished ranges between 0.31 - 0.60 by the end of the 10 year projection period (Table 17). The fraction unfished across the state of natures assuming the full ABC removals all increase over the projection period from the fraction unfished in 2023.

### 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 18.

#### 4.4 Evaluation of Scientific Uncertainty

The estimated uncertainty in the base model around the 2021 spawning output is  $\sigma = 0.3$  and the uncertainty in the base model around the 2021 OFL is  $\sigma = 0.28$ . The estimated model uncertainty was less than the category 2 groundfish data-moderate assessment default value of  $\sigma = 1.0$ .

#### 4.5 Research and Data Needs

The ability to estimate additional process and biological parameters for copper rockfish was limited by data. Collecting the following data would be beneficial to future assessments of the stock:

1. The recreational and commercial length data indicated that selection of copper rockfish occurs at sizes that were below the length at 50 percent maturity assumed in the base model. Developing area-specific estimates of the length- or age-at-maturity of copper rockfish in California waters north of Point Conception would provide additional understanding of the potential impact of size selectivity by each fleet.
2. Length samples could not be divided between live versus dead copper rockfish for the commercial fishery data. This was due to issues with the California data in PacFIN (i.e., condition code not available). The ability to examine sample sizes and lengths from each type of landing would allow for future assessments to better account for the range of commercial fishing behavior.
3. Otoliths should be or continue to be collected from the commercial and recreational fisheries. Additional age data from both fishery-dependent and -independent sources would provide insight of area-specific growth of copper rockfish. These data would support future assessments and would also allow for assessments to better capture uncertainty through the estimation of growth parameters within the model. Following the review of the base model during the June 2021 Groundfish Subcommittee meeting of the Scientific and Statistical Committee (GFSC-SSC) otoliths collected north of Point Conception in California from the following sources were provided for ageing: CDFW Commercial collections ( $N = 102$ ), California Collaborative Fisheries Research Program ( $N = 54$ ), and Southwest Fisheries Science Center Research Survey ( $N = 423$ ). These otoliths were aged and the creation of area-specific growth curve was attempted. Unfortunately, the sampling coverage across ages and sizes was inadequate for the development of an area specific growth curve, emphasizing the continued need for otolith collection in the area.
4. California Department of Fish and Wildlife provided additional length observation data that was not available for use in the base models 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 1987 - 1998 and included a total of 6,347 additional length observations. 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.

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## 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.
- 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.
- 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 Wetzell, 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.
- 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., and Council, E. 2015. Status of the darkblotched rockfish resource off the continental U.S. Pacific Coast in 2015. Pacific Fishery Management Council,

Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.

- 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.
- Hicks, A.C., and Wetzel, C.R. 2015. The status of Widow Rockfish (*Sebastes entomelas*) along the U.S. West coast in 2015. Pacific Fishery Management Council, Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.
- Horodyk, 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.
- 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.
- 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.
- Method, 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.
- 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 Administration, National Marine.

- 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.
- Wetzel, C.R., Cronin-Fine, L., and Johnson, K.F. 2017. Status of Pacific ocean perch (*Sebastes alutus*) along the US west coast in 2017. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220.
- Wetzel, C.R., Langseth, B.J., Cope, J.M., and Budrick, J. 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. Pacific Fishery Management Council, Portland, Oregon.
- 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.

## 7 Tables



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

Year	CA N Commercial	CA N Recreational	Total Catch
1916	4.02	0.00	4.02
1917	6.31	0.00	6.31
1918	7.60	0.00	7.60
1919	4.97	0.00	4.97
1920	5.13	0.00	5.13
1921	4.37	0.00	4.37
1922	3.75	0.00	3.75
1923	3.94	0.00	3.94
1924	2.60	0.00	2.60
1925	3.89	0.00	3.89
1926	4.96	0.00	4.96
1927	3.69	0.00	3.69
1928	3.68	1.58	5.26
1929	3.07	3.16	6.23
1930	5.40	3.64	9.04
1931	6.39	4.85	11.24
1932	5.77	6.06	11.83
1933	4.92	7.27	12.19
1934	3.60	8.49	12.09
1935	5.76	9.70	15.46
1936	5.28	10.91	16.19
1937	5.97	12.93	18.90
1938	5.33	12.72	18.05
1939	5.05	11.12	16.17
1940	4.88	16.02	20.90
1941	5.30	14.81	20.11
1942	1.83	7.86	9.69
1943	2.94	7.52	10.46
1944	8.78	6.18	14.96
1945	21.68	8.23	29.91
1946	24.23	14.17	38.40
1947	7.26	11.21	18.47
1948	9.75	22.38	32.13
1949	5.29	29.00	34.29
1950	4.15	35.34	39.49
1951	9.16	45.17	54.33
1952	6.04	39.31	45.35
1953	2.99	33.47	36.46
1954	5.53	41.61	47.14
1955	2.99	49.61	52.60

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

Year	CA N Commercial	CA N Recreational	Total Catch
1956	4.96	55.39	60.35
1957	5.69	52.83	58.52
1958	6.67	92.97	99.64
1959	7.57	73.07	80.64
1960	10.12	58.51	68.63
1961	7.48	43.89	51.37
1962	5.34	58.55	63.89
1963	6.31	73.33	79.64
1964	4.28	66.72	71.00
1965	4.66	100.67	105.33
1966	5.58	115.90	121.48
1967	6.34	122.53	128.87
1968	3.43	133.08	136.51
1969	2.46	143.84	146.30
1970	2.53	179.23	181.76
1971	4.46	165.24	169.70
1972	6.96	208.97	215.93
1973	6.76	240.35	247.11
1974	15.91	255.47	271.38
1975	8.54	260.32	268.86
1976	16.11	281.40	297.51
1977	14.07	293.10	307.17
1978	2.50	279.85	282.35
1979	2.81	290.90	293.71
1980	40.15	266.37	306.52
1981	9.78	425.88	435.66
1982	13.12	272.91	286.03
1983	69.96	138.46	208.42
1984	43.75	143.08	186.83
1985	25.77	180.88	206.65
1986	10.57	154.79	165.36
1987	14.03	86.69	100.72
1988	18.18	94.95	113.13
1989	34.30	88.25	122.55
1990	43.85	83.98	127.83
1991	53.13	79.71	132.84
1992	72.30	75.43	147.73
1993	69.69	71.16	140.85
1994	31.86	44.97	76.83
1995	43.35	21.60	64.95

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

Year	CA N Commercial	CA N Recreational	Total Catch
1996	54.55	30.20	84.75
1997	46.36	34.48	80.84
1998	28.96	16.32	45.28
1999	16.05	21.19	37.24
2000	7.77	24.24	32.01
2001	11.89	17.21	29.10
2002	9.37	12.58	21.95
2003	2.61	20.56	23.17
2004	3.49	15.61	19.10
2005	3.65	31.20	34.85
2006	2.88	33.25	36.13
2007	5.14	36.25	41.39
2008	4.77	26.75	31.52
2009	2.49	36.72	39.21
2010	1.74	25.76	27.50
2011	2.45	23.43	25.88
2012	3.19	31.69	34.88
2013	2.94	22.83	25.77
2014	3.26	33.73	36.99
2015	3.65	62.00	65.65
2016	3.44	62.92	66.36
2017	6.07	132.61	138.68
2018	9.87	92.98	102.85
2019	12.48	92.54	105.02
2020	14.63	51.58	66.21

**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 (mt) allocated to California, and the total removals (mt) from north 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	25.88
2012	-	-	155.96	130.15	-	-	28.61	5.97	136.12	34.88
2013	-	-	141.50	118.01	-	-	25.96	5.41	123.42	25.77
2014	-	-	141.50	118.01	-	-	25.96	5.41	123.42	36.99
2015	-	-	301.11	274.91	-	69	10.64	2.43	277.34	65.65
2016	-	-	284.34	259.60	-	69	10.33	2.36	261.96	66.36
2017	1329.25	1163	310.86	283.83	118.39	105	11.24	2.56	286.40	138.68
2018	1344.47	1179	316.71	289.16	118.6	105	11.59	2.64	291.80	102.85
2019	1299.65	1142	322.09	294.07	91	81	11.91	2.72	296.79	105.02
2020	1322	1163	327.26	298.79	92	82	12.24	2.80	301.59	66.21

**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
1978	1	0	0	2
1979	3	0	0	26
1980	4	0	0	34
1981	2	0	0	4
1982	3	0	0	6
1983	5	0	0	13
1984	2	0	0	25
1985	1	0	0	1
1986	1	0	0	2
1987	2	0	0	2
1988	3	0	0	4
1990	2	0	0	2
1991	6	0	0	126
1992	106	0	0	662
1993	169	0	0	808
1994	88	0	0	342
1995	70	0	0	263
1996	94	0	0	363
1997	28	0	0	116
1998	21	0	0	37
1999	81	0	0	459
2000	32	0	0	70
2001	44	0	0	233
2002	8	0	0	29
2003	6	0	0	27
2004	8	0	0	36
2005	2	0	0	19
2006	2	0	0	4
2007	19	0	0	74
2008	17	0	0	72
2009	14	0	0	27
2010	20	0	0	32
2011	26	0	0	51
2012	25	0	0	62
2013	14	0	0	28
2014	10	0	0	24
2015	15	0	0	22
2016	29	0	0	47
2017	25	0	0	70

**Table 4:** Summary of the commercial length samples by number of trips and lengths by sex per year. (*continued*)

Year	N Trips	N Fish Females	N Fish Males	N Fish Unsexed
2018	28	0	0	102
2019	26	0	0	84
2020	29	0	0	85



**Table 5:** Summary of the available recreational length samples.

Year	All Fish	Sexed Fish	Unsexed Fish
1980	372	0	372
1981	360	0	360
1982	368	0	368
1983	287	0	287
1984	409	0	409
1985	489	0	489
1986	505	0	505
1987	201	0	201
1988	151	0	151
1989	242	0	242
1993	465	0	465
1994	299	0	299
1995	151	0	151
1996	270	0	270
1997	546	0	546
1998	142	0	142
1999	244	0	244
2000	104	0	104
2001	112	0	112
2002	127	0	127
2003	167	0	167
2004	578	0	578
2005	1236	0	1236
2006	1777	0	1777
2007	1985	0	1985
2008	1536	0	1536
2009	1481	1	1480
2010	1359	0	1359
2011	1328	0	1328
2012	1442	0	1442
2013	1779	2	1777
2014	1910	1	1909
2015	2925	0	2925
2016	2825	0	2825
2017	3992	2	3990
2018	3032	3	3029
2019	2815	1	2814

**Table 6:** 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	4	12	12	0	9
2004	4	49	49	0	9
2005	2	9	9	0	4
2006	2	7	7	0	4
2007	1	1	1	0	1
2008	6	26	26	0	14
2009	5	6	6	0	6
2010	6	12	11	1	12
2011	1	1	1	0	1
2012	3	4	4	0	4
2013	3	8	8	0	7
2014	1	23	23	0	2
2015	4	10	8	2	9
2016	1	2	2	0	2
2017	2	11	11	0	4
2018	5	12	12	0	11
2019	3	10	10	0	7

**Table 7:** Summary of the number of samples by year from commercial (Com.) and recreational (Rec.) fisheries by state used to estimate length-at-age parameters.

	OR Com.	OR Rec.	WA Com.	WA Rec.
1998	0	0	0	46
1999	0	0	0	136
2000	0	0	0	26
2001	0	0	0	32
2002	1	0	0	19
2003	9	0	0	0
2004	26	0	0	188
2005	0	58	0	225
2006	1	150	0	65
2007	1	188	0	86
2008	1	217	0	65
2009	0	156	0	35
2010	6	273	0	24
2011	0	235	0	27
2012	11	216	0	35
2013	31	158	0	8
2014	25	121	0	123
2015	10	0	0	74
2016	25	0	0	169
2017	40	177	1	101
2018	44	175	0	176
2019	102	174	0	274

**Table 8:** 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	13.46	0.04	0.00	0.00
2	19.97	0.14	0.00	0.00
3	25.27	0.30	0.01	0.00
4	29.58	0.49	0.11	0.01
5	33.09	0.70	0.35	0.06
6	35.95	0.91	0.60	0.13
7	38.27	1.11	0.76	0.20
8	40.16	1.29	0.86	0.26
9	41.70	1.46	0.91	0.31
10	42.95	1.60	0.94	0.35
11	43.97	1.73	0.96	0.38
12	44.80	1.83	0.97	0.41
13	45.48	1.92	0.97	0.44
14	46.03	2.00	0.98	0.46
15	46.47	2.06	0.98	0.48
16	46.84	2.11	0.98	0.49
17	47.13	2.16	0.99	0.50
18	47.38	2.19	0.99	0.51
19	47.57	2.22	0.99	0.52
20	47.73	2.24	0.99	0.53
21	47.86	2.26	0.99	0.53
22	47.97	2.28	0.99	0.54
23	48.05	2.29	0.99	0.54
24	48.12	2.30	0.99	0.54
25	48.18	2.31	0.99	0.55
26	48.23	2.32	0.99	0.55
27	48.26	2.32	1.00	0.55
28	48.30	2.33	1.00	0.55
29	48.32	2.33	1.00	0.55
30	48.34	2.33	1.00	0.55
31	48.36	2.34	1.00	0.55
32	48.37	2.34	1.00	0.55
33	48.38	2.34	1.00	0.55
34	48.39	2.34	1.00	0.55
35	48.40	2.34	1.00	0.55
36	48.40	2.34	1.00	0.56
37	48.41	2.35	1.00	0.56
38	48.41	2.35	1.00	0.56

**Table 8:** 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	48.42	2.35	1.00	0.56
40	48.42	2.35	1.00	0.56
41	48.42	2.35	1.00	0.56
42	48.42	2.35	1.00	0.56
43	48.42	2.35	1.00	0.56
44	48.42	2.35	1.00	0.56
45	48.43	2.35	1.00	0.56
46	48.43	2.35	1.00	0.56
47	48.43	2.35	1.00	0.56
48	48.43	2.35	1.00	0.56
49	48.43	2.35	1.00	0.56
50	48.43	2.35	1.00	0.56

**Table 9:** 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	13.460	-2	(3, 25)	NA	NA	None
L at Amax Fem GP 1	48.430	-2	(35, 60)	NA	NA	None
VonBert K Fem GP 1	0.206	-2	(0.03, 0.3)	NA	NA	None
CV young Fem GP 1	0.100	-2	(0.01, 0.3)	NA	NA	None
CV old Fem GP 1	0.100	-2	(0.01, 0.3)	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	34.830	-9	(10, 60)	NA	NA	None
Mat slope Fem GP 1	-0.600	-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	8.500	-2	(3, 25)	NA	NA	None
L at Amax Mal GP 1	47.240	-2	(35, 60)	NA	NA	None
VonBert K Mal GP 1	0.231	-2	(0.03, 0.3)	NA	NA	None
CV young Mal GP 1	0.100	-2	(0.01, 0.3)	NA	NA	None
CV old Mal GP 1	0.100	-2	(0.01, 0.3)	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)	6.028	1	(2, 20)	OK	0.1017490	None
SR BH steep	0.720	-7	(0.22, 1)	NA	NA	Normal (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
Early RecrDev 1916	0.005	5	(-5, 5)	act	0.6015090	dev (NA, NA)

**Table 9:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Early RecrDev 1917	0.006	5	(-5, 5)	act	0.6016440	dev (NA, NA)
Early RecrDev 1918	0.006	5	(-5, 5)	act	0.6017910	dev (NA, NA)
Early RecrDev 1919	0.007	5	(-5, 5)	act	0.6019510	dev (NA, NA)
Early RecrDev 1920	0.007	5	(-5, 5)	act	0.6021250	dev (NA, NA)
Early RecrDev 1921	0.008	5	(-5, 5)	act	0.6023140	dev (NA, NA)
Early RecrDev 1922	0.009	5	(-5, 5)	act	0.6025200	dev (NA, NA)
Early RecrDev 1923	0.009	5	(-5, 5)	act	0.6027430	dev (NA, NA)
Early RecrDev 1924	0.010	5	(-5, 5)	act	0.6029860	dev (NA, NA)
Early RecrDev 1925	0.011	5	(-5, 5)	act	0.6032510	dev (NA, NA)
Early RecrDev 1926	0.012	5	(-5, 5)	act	0.6035380	dev (NA, NA)
Early RecrDev 1927	0.013	5	(-5, 5)	act	0.6038510	dev (NA, NA)
Early RecrDev 1928	0.014	5	(-5, 5)	act	0.6041910	dev (NA, NA)
Early RecrDev 1929	0.016	5	(-5, 5)	act	0.6045620	dev (NA, NA)
Early RecrDev 1930	0.017	5	(-5, 5)	act	0.6049650	dev (NA, NA)
Early RecrDev 1931	0.019	5	(-5, 5)	act	0.6054040	dev (NA, NA)
Early RecrDev 1932	0.020	5	(-5, 5)	act	0.6058820	dev (NA, NA)
Early RecrDev 1933	0.022	5	(-5, 5)	act	0.6064030	dev (NA, NA)
Early RecrDev 1934	0.024	5	(-5, 5)	act	0.6069710	dev (NA, NA)
Early RecrDev 1935	0.026	5	(-5, 5)	act	0.6075910	dev (NA, NA)
Early RecrDev 1936	0.028	5	(-5, 5)	act	0.6082650	dev (NA, NA)
Early RecrDev 1937	0.031	5	(-5, 5)	act	0.6089990	dev (NA, NA)
Early RecrDev 1938	0.033	5	(-5, 5)	act	0.6098000	dev (NA, NA)
Early RecrDev 1939	0.036	5	(-5, 5)	act	0.6106700	dev (NA, NA)
Early RecrDev 1940	0.039	5	(-5, 5)	act	0.6116080	dev (NA, NA)
Early RecrDev 1941	0.043	5	(-5, 5)	act	0.6126220	dev (NA, NA)
Early RecrDev 1942	0.046	5	(-5, 5)	act	0.6137180	dev (NA, NA)
Early RecrDev 1943	0.050	5	(-5, 5)	act	0.6149080	dev (NA, NA)
Early RecrDev 1944	0.055	5	(-5, 5)	act	0.6161950	dev (NA, NA)
Early RecrDev 1945	0.059	5	(-5, 5)	act	0.6175830	dev (NA, NA)

**Table 9:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Early RecrDev 1946	0.064	5	(-5, 5)	act	0.6190910	dev (NA, NA)
Early RecrDev 1947	0.069	5	(-5, 5)	act	0.6207380	dev (NA, NA)
Early RecrDev 1948	0.075	5	(-5, 5)	act	0.6225590	dev (NA, NA)
Early RecrDev 1949	0.081	5	(-5, 5)	act	0.6245370	dev (NA, NA)
Early RecrDev 1950	0.088	5	(-5, 5)	act	0.6266640	dev (NA, NA)
Early RecrDev 1951	0.095	5	(-5, 5)	act	0.6289450	dev (NA, NA)
Early RecrDev 1952	0.103	5	(-5, 5)	act	0.6314200	dev (NA, NA)
Early RecrDev 1953	0.111	5	(-5, 5)	act	0.6341480	dev (NA, NA)
Early RecrDev 1954	0.120	5	(-5, 5)	act	0.6371650	dev (NA, NA)
Early RecrDev 1955	0.130	5	(-5, 5)	act	0.6405320	dev (NA, NA)
Early RecrDev 1956	0.141	5	(-5, 5)	act	0.6443310	dev (NA, NA)
Early RecrDev 1957	0.153	5	(-5, 5)	act	0.6484190	dev (NA, NA)
Early RecrDev 1958	0.165	5	(-5, 5)	act	0.6527100	dev (NA, NA)
Early RecrDev 1959	0.178	5	(-5, 5)	act	0.6571480	dev (NA, NA)
Early RecrDev 1960	0.191	5	(-5, 5)	act	0.6619970	dev (NA, NA)
Early RecrDev 1961	0.205	5	(-5, 5)	act	0.6673030	dev (NA, NA)
Early RecrDev 1962	0.221	5	(-5, 5)	act	0.6731600	dev (NA, NA)
Early RecrDev 1963	0.238	5	(-5, 5)	act	0.6797240	dev (NA, NA)
Early RecrDev 1964	0.256	5	(-5, 5)	act	0.6869850	dev (NA, NA)
Early RecrDev 1965	0.276	5	(-5, 5)	act	0.6948980	dev (NA, NA)
Early RecrDev 1966	0.297	5	(-5, 5)	act	0.7029680	dev (NA, NA)
Early RecrDev 1967	0.316	5	(-5, 5)	act	0.7104580	dev (NA, NA)
Early RecrDev 1968	0.329	5	(-5, 5)	act	0.7151080	dev (NA, NA)
Early RecrDev 1969	0.326	5	(-5, 5)	act	0.7121580	dev (NA, NA)
Early RecrDev 1970	0.295	5	(-5, 5)	act	0.6955140	dev (NA, NA)
Early RecrDev 1971	0.218	5	(-5, 5)	act	0.6612080	dev (NA, NA)
Early RecrDev 1972	0.092	5	(-5, 5)	act	0.6143660	dev (NA, NA)
Early RecrDev 1973	-0.069	5	(-5, 5)	act	0.5661060	dev (NA, NA)
Early RecrDev 1974	-0.225	5	(-5, 5)	act	0.5267420	dev (NA, NA)



**Table 9:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Main RecrDev 1975	-0.206	2	(-5, 5)	act	0.4788220	dev (NA, NA)
Main RecrDev 1976	-0.190	2	(-5, 5)	act	0.4495010	dev (NA, NA)
Main RecrDev 1977	-0.212	2	(-5, 5)	act	0.4248740	dev (NA, NA)
Main RecrDev 1978	-0.257	2	(-5, 5)	act	0.3978990	dev (NA, NA)
Main RecrDev 1979	-0.420	2	(-5, 5)	act	0.3776260	dev (NA, NA)
Main RecrDev 1980	-0.723	2	(-5, 5)	act	0.3859000	dev (NA, NA)
Main RecrDev 1981	-0.626	2	(-5, 5)	act	0.3732310	dev (NA, NA)
Main RecrDev 1982	-0.305	2	(-5, 5)	act	0.3470360	dev (NA, NA)
Main RecrDev 1983	-0.407	2	(-5, 5)	act	0.3832460	dev (NA, NA)
Main RecrDev 1984	-0.297	2	(-5, 5)	act	0.4158560	dev (NA, NA)
Main RecrDev 1985	0.147	2	(-5, 5)	act	0.4003100	dev (NA, NA)
Main RecrDev 1986	0.173	2	(-5, 5)	act	0.4108870	dev (NA, NA)
Main RecrDev 1987	-0.112	2	(-5, 5)	act	0.4369960	dev (NA, NA)
Main RecrDev 1988	-0.279	2	(-5, 5)	act	0.4093850	dev (NA, NA)
Main RecrDev 1989	-0.288	2	(-5, 5)	act	0.3908630	dev (NA, NA)
Main RecrDev 1990	0.100	2	(-5, 5)	act	0.3203520	dev (NA, NA)
Main RecrDev 1991	0.376	2	(-5, 5)	act	0.2734610	dev (NA, NA)
Main RecrDev 1992	-0.156	2	(-5, 5)	act	0.3718660	dev (NA, NA)
Main RecrDev 1993	-0.228	2	(-5, 5)	act	0.3939270	dev (NA, NA)
Main RecrDev 1994	0.203	2	(-5, 5)	act	0.3668680	dev (NA, NA)
Main RecrDev 1995	0.205	2	(-5, 5)	act	0.4086460	dev (NA, NA)
Main RecrDev 1996	0.143	2	(-5, 5)	act	0.4377610	dev (NA, NA)
Main RecrDev 1997	0.126	2	(-5, 5)	act	0.4518840	dev (NA, NA)
Main RecrDev 1998	0.107	2	(-5, 5)	act	0.4769070	dev (NA, NA)
Main RecrDev 1999	0.139	2	(-5, 5)	act	0.4850410	dev (NA, NA)
Main RecrDev 2000	0.378	2	(-5, 5)	act	0.3848460	dev (NA, NA)
Main RecrDev 2001	-0.093	2	(-5, 5)	act	0.4079250	dev (NA, NA)
Main RecrDev 2002	-0.135	2	(-5, 5)	act	0.3485630	dev (NA, NA)
Main RecrDev 2003	-0.099	2	(-5, 5)	act	0.3177690	dev (NA, NA)

**Table 9:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Main RecrDev 2004	-0.028	2	(-5, 5)	act	0.2855640	dev (NA, NA)
Main RecrDev 2005	-0.368	2	(-5, 5)	act	0.3202780	dev (NA, NA)
Main RecrDev 2006	-0.721	2	(-5, 5)	act	0.3674310	dev (NA, NA)
Main RecrDev 2007	0.198	2	(-5, 5)	act	0.2864230	dev (NA, NA)
Main RecrDev 2008	0.775	2	(-5, 5)	act	0.2722080	dev (NA, NA)
Main RecrDev 2009	1.017	2	(-5, 5)	act	0.2703160	dev (NA, NA)
Main RecrDev 2010	1.222	2	(-5, 5)	act	0.2237820	dev (NA, NA)
Main RecrDev 2011	-0.081	2	(-5, 5)	act	0.4265340	dev (NA, NA)
Main RecrDev 2012	0.468	2	(-5, 5)	act	0.2879570	dev (NA, NA)
Main RecrDev 2013	0.588	2	(-5, 5)	act	0.2655520	dev (NA, NA)
Main RecrDev 2014	0.225	2	(-5, 5)	act	0.3119530	dev (NA, NA)
Main RecrDev 2015	0.043	2	(-5, 5)	act	0.3289970	dev (NA, NA)
Main RecrDev 2016	-0.097	2	(-5, 5)	act	0.3588210	dev (NA, NA)
Main RecrDev 2017	-0.306	2	(-5, 5)	act	0.4386560	dev (NA, NA)
Late RecrDev 2018	-0.134	6	(-5, 5)	act	0.5612430	dev (NA, NA)
Late RecrDev 2019	0.000	6	(-5, 5)	act	0.5999950	dev (NA, NA)
Late RecrDev 2020	0.000	6	(-5, 5)	act	0.6000000	dev (NA, NA)
Size DblN peak CA N Commercial(1)	26.343	1	(15, 55)	OK	0.6574890	None
Size DblN top logit CA N Commercial(1)	-3.965	-3	(-7, 7)	NA	NA	None
Size DblN ascend se CA N Commercial(1)	0.877	3	(-10, 10)	OK	0.8229510	None
Size DblN descend se CA N Commercial(1)	2.158	4	(-10, 10)	OK	0.7933850	None
Size DblN start logit CA N Commercial(1)	-20.000	-5	(-20, 30)	NA	NA	None
Size DblN end logit CA N Commercial(1)	-0.997	4	(-10, 10)	OK	0.3560040	None
Size DblN peak CA N Recreational(2)	32.117	2	(15, 55)	OK	0.5464370	None
Size DblN top logit CA N Recreational(2)	-1.047	-3	(-7, 7)	NA	NA	None
Size DblN ascend se CA N Recreational(2)	3.803	3	(-10, 10)	OK	0.1216640	None
Size DblN descend se CA N Recreational(2)	4.653	-4	(-10, 10)	NA	NA	None
Size DblN start logit CA N Recreational(2)	-20.000	-9	(-20, 30)	NA	NA	None
Size DblN end logit CA N Recreational(2)	10.000	-4	(-10, 10)	NA	NA	None

**Table 9:** List of parameters used in the base model, including estimated values and standard deviations (SD), bounds (minimum and maximum), estimation phase (negative values not estimated), status (indicates if parameters are near bounds), and prior type information (mean and SD). (*continued*)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
Size DblN peak CA N Commercial(1) BLK1repl 1916	54.999	-2	(15, 55)	NA	NA	None
Size DblN top logit CA N Commercial(1) BLK1repl 1916	-0.020	-3	(-7, 7)	NA	NA	None
Size DblN ascend se CA N Commercial(1) BLK1repl 1916	5.579	3	(-10, 10)	OK	0.0822682	None
Size DblN end logit CA N Commercial(1) BLK1repl 1916	10.000	-4	(-10, 10)	NA	NA	None

**Table 10:** Likelihood components by source.

Label	Total
TOTAL	188.81
Catch	0.00
Equil catch	0.00
Length comp	191.47
Recruitment	-2.69
InitEQ Regime	0.00
Forecast Recruitment	0.03
Parm priors	0.00
Parm softbounds	0.00
Parm devs	0.00
Crash Pen	0.00

**Table 11:** Summary of reference points and management quantities, including estimates of the 95 percent intervals.

	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output	415.81	332.89	498.74
Unfished Age 3+ Biomass (mt)	3889.83	3114.10	4665.56
Unfished Recruitment ( $R_0$ )	414.80	332.08	497.52
Spawning Output (2021)	163.51	64.75	262.27
Fraction Unfished (2021)	0.39	0.21	0.57
Reference Points Based $SB_{40\%}$			
Proxy Spawning Output $SB_{40\%}$	166.33	133.16	199.50
SPR Resulting in $SB_{40\%}$	0.46	0.46	0.46
Exploitation Rate Resulting in $SB_{40\%}$	0.06	0.06	0.07
Yield with SPR Based On $SB_{40\%}$ (mt)	110.85	88.66	133.04
Reference Points Based on $SPR_{50}$ for MSY			
Proxy Spawning Output ( $SPR_{50}$ )	185.52	148.52	222.51
$SPR_{50}$	0.50		
Exploitation Rate Corresponding to $SPR_{50}$	0.06	0.05	0.06
Yield with $SPR_{50}$ at SB SPR (mt)	106.19	84.94	127.44
Reference Points Based on Estimated MSY Values			
Spawning Output at MSY ( $SB_{MSY}$ )	119.04	95.26	142.82
$SB_{MSY}$	0.36	0.35	0.36
Exploitation Rate Corresponding to $SB_{MSY}$	0.09	0.09	0.09
MSY (mt)	116.37	93.06	139.67

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

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3+ (mt)	Fraction Un-fished	Age-0 Re-cruits	Total Catch (mt)	1-SPR	Exploitation Rate
1916	3935.85	415.81	3889.83	1.00	416.97	4.02	0.01	0.00
1917	3932.32	415.38	3886.26	1.00	417.12	6.31	0.02	0.00
1918	3927.13	414.73	3880.88	1.00	417.27	7.60	0.02	0.00
1919	3921.39	413.98	3875.12	1.00	417.42	4.97	0.01	0.00
1920	3918.69	413.57	3872.40	0.99	417.63	5.13	0.02	0.00
1921	3916.39	413.20	3870.08	0.99	417.87	4.37	0.01	0.00
1922	3915.26	412.99	3868.93	0.99	418.14	3.75	0.01	0.00
1923	3915.10	412.91	3868.74	0.99	418.45	3.94	0.01	0.00
1924	3915.10	412.85	3868.71	0.99	418.80	2.60	0.01	0.00
1925	3916.58	412.97	3870.16	0.99	419.19	3.89	0.01	0.00
1926	3917.11	412.98	3870.64	0.99	419.60	4.96	0.01	0.00
1927	3916.92	412.90	3870.41	0.99	420.04	3.69	0.01	0.00
1928	3918.15	412.99	3871.59	0.99	420.54	5.26	0.02	0.00
1929	3918.06	412.94	3871.45	0.99	421.07	6.23	0.02	0.00
1930	3917.22	412.80	3870.56	0.99	421.63	9.04	0.03	0.00
1931	3914.15	412.38	3867.43	0.99	422.22	11.24	0.04	0.00
1932	3909.49	411.77	3862.71	0.99	422.84	11.83	0.04	0.00
1933	3904.81	411.15	3857.96	0.99	423.53	12.19	0.04	0.00
1934	3900.35	410.55	3853.43	0.99	424.29	12.09	0.04	0.00
1935	3896.55	410.02	3849.55	0.99	425.12	15.46	0.05	0.00
1936	3890.31	409.20	3843.22	0.98	426.01	16.19	0.05	0.00
1937	3884.17	408.38	3836.99	0.98	426.98	18.90	0.06	0.00
1938	3876.36	407.35	3829.08	0.98	428.02	18.05	0.06	0.00
1939	3870.38	406.51	3822.99	0.98	429.19	16.17	0.05	0.00
1940	3867.27	405.99	3819.76	0.98	430.48	20.90	0.07	0.01
1941	3860.50	405.06	3812.86	0.97	431.83	20.11	0.07	0.01
1942	3855.71	404.32	3807.92	0.97	433.32	9.69	0.03	0.00
1943	3861.99	404.83	3814.05	0.97	435.08	10.46	0.04	0.00
1944	3868.38	405.35	3820.27	0.97	436.97	14.96	0.05	0.00
1945	3871.67	405.50	3823.36	0.98	438.96	29.91	0.09	0.01
1946	3862.49	404.16	3813.97	0.97	440.96	38.40	0.12	0.01
1947	3847.03	402.10	3798.29	0.97	443.08	18.47	0.06	0.00
1948	3851.75	402.37	3802.78	0.97	445.70	32.13	0.10	0.01
1949	3844.49	401.30	3795.28	0.97	448.38	34.29	0.11	0.01
1950	3836.41	400.14	3786.90	0.96	451.25	39.49	0.13	0.01
1951	3824.90	398.57	3775.09	0.96	454.28	54.33	0.17	0.01
1952	3801.37	395.58	3751.24	0.95	457.40	45.35	0.15	0.01
1953	3789.19	393.78	3738.72	0.95	461.00	36.46	0.12	0.01

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

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3+ (mt)	Fraction Un-fished	Age-0 Re-cruits	Total Catch (mt)	1-SPR	Exploitation Rate
1954	3788.14	393.19	3737.31	0.95	465.15	47.14	0.15	0.01
1955	3779.30	391.72	3728.05	0.94	469.68	52.60	0.17	0.01
1956	3767.72	389.95	3716.01	0.94	474.75	60.35	0.19	0.02
1957	3751.80	387.63	3699.57	0.93	480.10	58.52	0.19	0.02
1958	3741.29	385.83	3688.49	0.93	485.74	99.64	0.29	0.03
1959	3694.22	379.98	3640.82	0.91	490.99	80.64	0.25	0.02
1960	3670.94	376.56	3616.93	0.91	497.07	68.63	0.22	0.02
1961	3664.68	374.91	3610.06	0.90	503.96	51.37	0.17	0.01
1962	3679.94	375.64	3624.63	0.90	511.93	63.89	0.21	0.02
1963	3686.90	375.56	3630.80	0.90	520.73	79.64	0.25	0.02
1964	3682.76	374.29	3625.76	0.90	530.31	71.00	0.23	0.02
1965	3691.72	374.38	3633.72	0.90	541.01	105.33	0.31	0.03
1966	3671.74	371.29	3612.65	0.89	551.58	121.48	0.35	0.03
1967	3641.80	366.95	3581.53	0.88	561.45	128.87	0.36	0.04
1968	3611.42	362.38	3550.00	0.87	568.10	136.51	0.38	0.04
1969	3580.57	357.66	3518.14	0.86	565.94	146.30	0.40	0.04
1970	3547.23	352.64	3484.31	0.85	547.42	181.76	0.47	0.05
1971	3485.26	344.71	3423.01	0.83	505.60	169.70	0.45	0.05
1972	3439.65	338.84	3380.04	0.81	444.78	215.93	0.53	0.06
1973	3348.33	328.96	3293.83	0.79	377.41	247.11	0.58	0.08
1974	3220.31	316.36	3172.70	0.76	313.88	271.38	0.62	0.09
1975	3057.40	301.24	3017.07	0.72	310.82	268.86	0.63	0.09
1976	2880.94	285.72	2846.22	0.69	306.31	297.51	0.68	0.10
1977	2661.50	265.76	2627.17	0.64	289.63	307.17	0.71	0.12
1978	2420.86	242.71	2387.33	0.58	267.00	282.35	0.72	0.12
1979	2196.67	220.21	2165.17	0.53	223.18	293.71	0.76	0.14
1980	1956.88	195.23	1928.44	0.47	161.30	306.52	0.79	0.16
1981	1704.28	168.51	1681.00	0.41	172.71	435.66	0.90	0.26
1982	1318.73	128.65	1300.51	0.31	223.45	286.03	0.87	0.22
1983	1080.49	104.02	1060.20	0.25	190.21	208.42	0.82	0.20
1984	927.34	87.13	903.36	0.21	200.76	186.83	0.84	0.21
1985	800.06	72.65	778.58	0.17	292.95	206.65	0.90	0.27
1986	659.73	56.82	635.33	0.14	271.83	165.36	0.90	0.26
1987	569.26	45.88	537.46	0.11	185.10	100.72	0.83	0.19
1988	553.37	41.70	525.38	0.10	149.34	113.13	0.86	0.22
1989	531.24	37.85	511.60	0.09	140.56	122.55	0.87	0.24
1990	498.90	34.82	482.47	0.08	197.86	127.83	0.89	0.26
1991	456.30	32.15	439.28	0.08	249.34	132.84	0.91	0.30
1992	406.14	28.39	383.20	0.07	135.96	147.73	0.93	0.39

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

Year	Total Biomass (mt)	Spawning Output	Total Biomass 3+ (mt)	Fraction Un-fished	Age-0 Re-cruits	Total Catch (mt)	1-SPR	Exp-loitation Rate
1993	343.08	22.16	318.24	0.05	108.00	140.85	0.95	0.44
1994	284.73	16.05	270.32	0.04	132.67	76.83	0.90	0.28
1995	281.10	15.60	268.55	0.04	130.19	64.95	0.87	0.24
1996	286.51	16.79	271.88	0.04	129.18	84.75	0.91	0.31
1997	270.34	16.41	255.96	0.04	124.97	80.84	0.91	0.32
1998	253.75	15.44	239.56	0.04	117.17	45.28	0.82	0.19
1999	268.87	16.75	255.19	0.04	128.43	37.24	0.77	0.15
2000	290.90	18.93	277.57	0.05	177.89	32.01	0.71	0.12
2001	318.30	21.74	302.98	0.05	122.10	29.10	0.65	0.10
2002	351.31	24.84	332.91	0.06	127.75	21.95	0.54	0.07
2003	392.93	28.64	379.23	0.07	144.78	23.17	0.51	0.06
2004	433.20	32.70	418.58	0.08	168.04	19.10	0.43	0.05
2005	477.66	37.57	461.12	0.09	129.20	34.85	0.57	0.08
2006	506.51	41.04	488.86	0.10	95.19	36.13	0.57	0.07
2007	532.13	44.00	518.36	0.11	247.28	41.39	0.59	0.08
2008	551.53	46.33	537.00	0.11	451.84	31.52	0.50	0.06
2009	588.79	49.58	556.25	0.12	594.57	39.21	0.56	0.07
2010	642.55	51.80	588.79	0.12	744.93	27.50	0.43	0.05
2011	748.99	55.04	680.36	0.13	208.08	25.88	0.37	0.04
2012	899.93	60.66	829.84	0.15	375.56	34.88	0.40	0.04
2013	1064.62	70.63	1037.42	0.17	450.80	25.77	0.27	0.02
2014	1244.51	88.01	1201.24	0.21	339.33	36.99	0.32	0.03
2015	1410.63	109.29	1363.35	0.26	302.70	65.65	0.44	0.05
2016	1536.67	127.02	1499.96	0.31	274.43	66.36	0.42	0.04
2017	1643.31	141.90	1610.49	0.34	228.86	138.68	0.62	0.09
2018	1654.28	147.97	1624.80	0.36	308.42	102.85	0.53	0.06
2019	1676.44	154.78	1649.08	0.37	356.42	105.02	0.53	0.06
2020	1679.80	158.56	1644.45	0.38	358.34	66.21	0.40	0.04
2021	1713.88	163.51	1674.30	0.39	360.74	115.60	0.56	0.07
2022	1698.14	161.34	1658.35	0.39	359.70	113.10	0.56	0.07
2023	1687.39	158.68	1647.41	0.38	358.39	78.76	0.45	0.05
2024	1713.86	160.12	1674.00	0.39	359.10	79.57	0.45	0.05
2025	1742.45	162.35	1702.68	0.39	360.18	80.59	0.45	0.05
2026	1771.99	165.13	1732.13	0.40	361.50	81.67	0.45	0.05
2027	1801.52	168.18	1761.54	0.40	362.90	82.42	0.45	0.05
2028	1830.65	171.31	1790.53	0.41	364.30	82.93	0.44	0.05
2029	1859.16	174.43	1818.87	0.42	365.65	83.48	0.44	0.05
2030	1886.68	177.46	1846.24	0.43	366.93	83.86	0.44	0.05
2031	1913.20	180.39	1872.61	0.43	368.13	84.17	0.44	0.04



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

Year	Total Biomass (mt)	Spawn- ing Output	Total Biomass 3+ (mt)	Frac- tion Un- fished	Age-0 Re- cruits	Total Catch (mt)	1-SPR	Ex- ploita- tion Rate
2032	1938.69	183.21	1897.97	0.44	369.26	84.51	0.43	0.04

**Table 13:** Sensitivities relative to the base model.

	Base Model	No Rec. Devs.	MI DW	DM DW	Estimate Linf	Estimate CV Old	Estimate M (f)	2013 CPFV Onboard Index
Total Likelihood	188.812	304.705	224.377	1287.910	187.405	182.039	187.575	175.597
Survey Likelihood	NA	NA	NA	NA	NA	NA	NA	-14.218
Length Likelihood	191.474	304.704	224.915	1281.740	188.750	184.871	191.228	192.002
Recruitment Likelihood	-2.687	0.000	-0.558	5.733	-1.360	-2.854	-3.826	-2.209
Forecast Recruitment Likelihood	0.025	0.000	0.020	0.069	0.014	0.020	0.049	0.021
Parameter Priors Likelihood	0.000	0.000	0.000	0.363	0.000	0.000	0.123	0.000
log(R0)	6.028	6.060	6.006	5.929	6.098	6.054	5.915	6.072
SB Virgin	415.814	429.356	406.757	376.539	397.926	415.363	566.201	434.730
SB 2020	163.510	99.542	160.528	168.809	222.337	188.542	88.541	196.601
Fraction Unfished 2021	0.393	0.232	0.395	0.448	0.559	0.454	0.156	0.452
Total Yield - SPR 50	106.189	111.020	104.026	96.823	107.133	107.371	102.742	110.690
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	0.085	0.108
Length at Amin - Female	13.460	13.460	13.460	13.460	13.460	13.460	13.460	13.460
Length at Amax - Female	48.430	48.430	48.430	48.430	47.134	48.430	48.430	48.430
Von Bert. k - Female	0.206	0.206	0.206	0.206	0.206	0.206	0.206	0.206
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	0.056	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	8.500	8.500	8.500	8.500	8.500	8.500	8.500	8.500
Length at Amax - Male	47.240	47.240	47.240	47.240	46.869	47.240	47.240	47.240
Von Bert. k - Male	0.231	0.231	0.231	0.231	0.231	0.231	0.231	0.231
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	0.108	0.100	0.100

**Table 14:** 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. Select.	Com. Spline Select.	Com. No Blocks and Asym.	Early Block in Rec. Selectivity	Early CPFV Lengths	Early CPFV Lengths and Selectivity Blocks
Total Likelihood	188.812	200.950	182.581	247.839	188.812	258.993	219.987
Survey Likelihood	NA	NA	NA	NA	NA	NA	NA
Length Likelihood	191.474	203.931	185.028	246.934	191.474	259.293	223.384
Recruitment Likelihood	-2.687	-2.996	-2.477	0.901	-2.687	-0.320	-3.405
Forecast Recruitment Likelihood	0.025	0.014	0.027	0.002	0.025	0.019	0.001
Parameter Priors Likelihood	0.000	0.000	0.000	0.000	0.000	0.000	0.000
log(R0)	6.028	6.015	6.023	5.993	6.028	5.958	5.984
SB Virgin	415.814	410.329	413.951	401.644	415.814	387.910	397.925
SB 2020	163.510	145.276	146.441	227.910	163.510	169.236	184.740
Fraction Unfished 2021	0.393	0.354	0.354	0.567	0.393	0.436	0.464
Total Yield - SPR 50	106.189	109.472	108.401	107.689	106.189	99.943	101.971
Steepness	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
Length at Amin - Female	13.460	13.460	13.460	13.460	13.460	13.460	13.460
Length at Amax - Female	48.430	48.430	48.430	48.430	48.430	48.430	48.430
Von Bert. k - Female	0.206	0.206	0.206	0.206	0.206	0.206	0.206
CV young - Female	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
Natural Mortality - Male	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Length at Amin - Male	8.500	8.500	8.500	8.500	8.500	8.500	8.500
Length at Amax - Male	47.240	47.240	47.240	47.240	47.240	47.240	47.240
Von Bert. k - Male	0.231	0.231	0.231	0.231	0.231	0.231	0.231
CV young - Male	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

**Table 15:** Data weights applied by each alternative data weighting method.

Method	Commercial Lengths	Recreational Lengths
Francis	0.2330	0.0765
McAllister-Ianelli	0.1813	0.1164
Dirichlet Multinomial	0.5810	0.4020

**Table 16:** Projections of potential OFLs (mt), ABCs (mt), the assumed removals based on 2021 and 2022 adopted ACL (mt) values, estimated spawning output, and fraction unfished. The OFL S. 40.10 and ACL S. 40.10 for 2021 and 2022 reflect adopted management limits for the area south of 40.10 Latitude N. The OFL N. 40.10 is the year specific total OFL for 2021 and 2021 and the CA ACL N. 40.10 is the California specific allocation of the total ACL N. 40.10

Year	OFL - S. 40.10	ACL - S. 40.10	OFL - N. 40.10	CA ACL - N. 40.10	Total CA ACL	Assumed Removals	OFL	ABC	Buffer	Spawning Output	Fraction Unfished
2021	327.26	204.38	12.24	2.03	206.41	115.6	-	-	-	163.51	0.39
2022	247.43	202.03	9.83	2.02	204.05	113.1	-	-	-	161.34	0.39
2023	-	-	-	-	-	-	91.55	78.76	0.86	158.68	0.38
2024	-	-	-	-	-	-	93.16	79.57	0.854	160.12	0.39
2025	-	-	-	-	-	-	94.8	80.59	0.85	162.35	0.39
2026	-	-	-	-	-	-	96.42	81.67	0.847	165.13	0.40
2027	-	-	-	-	-	-	98	82.42	0.841	168.18	0.40
2028	-	-	-	-	-	-	99.55	82.93	0.833	171.31	0.41
2029	-	-	-	-	-	-	101.06	83.48	0.826	174.43	0.42
2030	-	-	-	-	-	-	102.51	83.86	0.818	177.46	0.43
2031	-	-	-	-	-	-	103.91	84.17	0.81	180.39	0.43
2032	-	-	-	-	-	-	105.25	84.51	0.803	183.21	0.44

**Table 17:** 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.

		M = 0.09 $yr^{-1}$			M = 0.108 $yr^{-1}$		M = 0.123 $yr^{-1}$	
	Year	Catch	Spawning Biomass	Fraction Unfished	Spawning Biomass	Fraction Unfished	Spawning Biomass	Fraction Unfished
	2021	115.60	115.88	0.259	163.51	0.393	230.01	0.607
	2022	113.10	112.53	0.251	161.34	0.388	227.55	0.601
	2023	78.76	109.35	0.244	158.68	0.382	223.59	0.590
	2024	79.57	110.52	0.247	160.12	0.385	222.98	0.589
ACL	2025	80.59	112.87	0.252	162.35	0.390	222.84	0.588
P*=	2026	81.67	116.08	0.259	165.13	0.397	223.14	0.589
0.45	2027	82.42	119.75	0.268	168.18	0.404	223.69	0.591
	2028	82.93	123.60	0.276	171.31	0.412	224.37	0.592
	2029	83.48	127.51	0.285	174.43	0.419	225.09	0.594
	2030	83.86	131.39	0.294	177.46	0.427	225.79	0.596
	2031	84.17	135.22	0.302	180.39	0.434	226.45	0.598
	2032	84.51	139.02	0.311	183.21	0.441	227.07	0.600

**Table 18:** 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 18:** 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*)

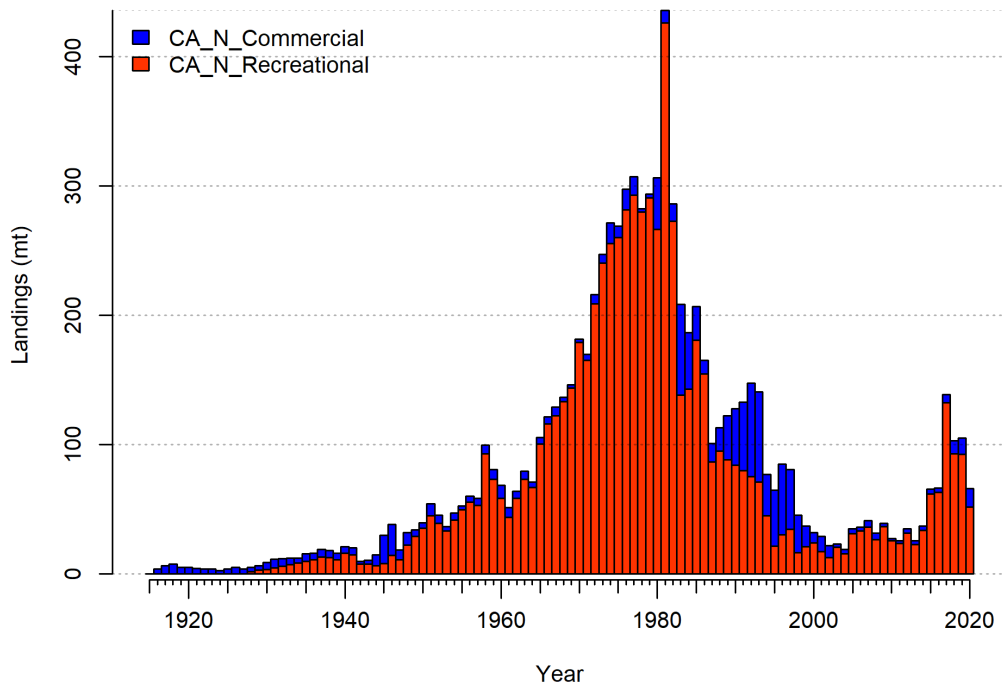
Year	SO-North	SO-South	SO-CA	Rel. SO-North	Rel. SO-South	Rel. SO-CA
1952	395.58	231.04	626.62	0.951	0.991	0.966
1953	393.78	230.55	624.34	0.947	0.989	0.962
1954	393.19	230.11	623.30	0.946	0.987	0.961
1955	391.72	229.22	620.94	0.942	0.984	0.957
1956	389.95	227.43	617.38	0.938	0.976	0.951
1957	387.63	225.39	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



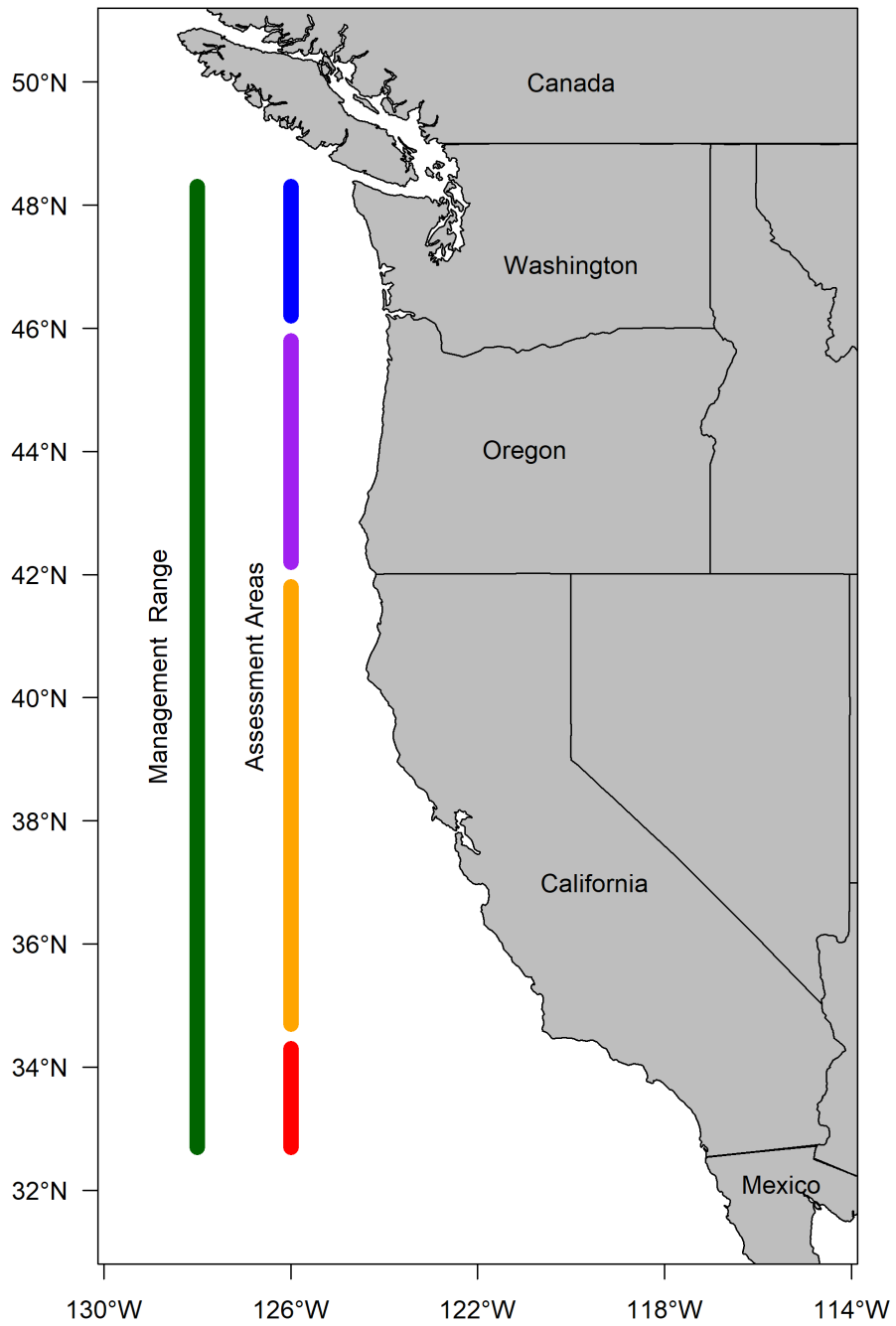
**Table 18:** Spawning output (SO) south and north of Point Conception in California, total spawning output across California, relative spawning output (Rel. SO) north and south of Point Conception, and relative spawning output across California. (*continued*)

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

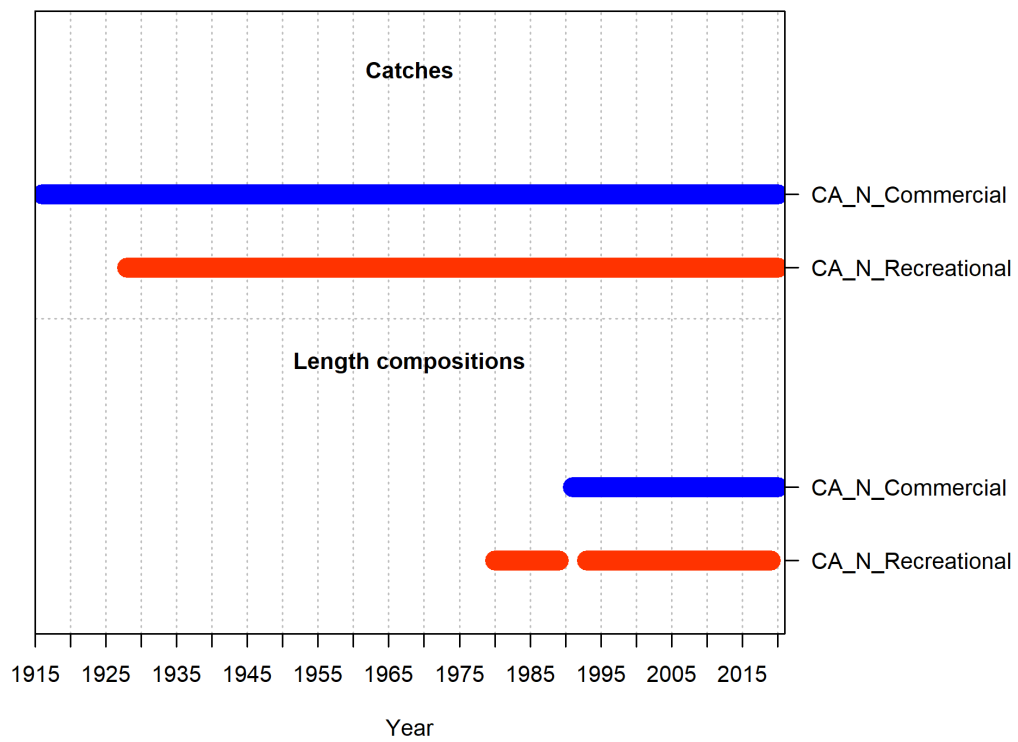
## 8 Figures



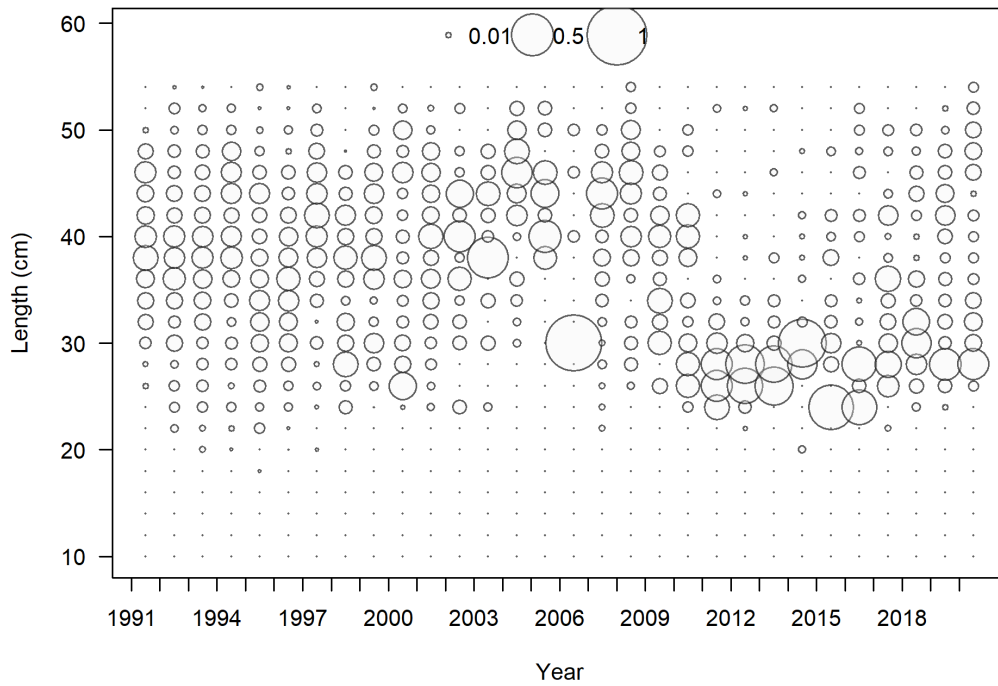
**Figure 1:** Catches by fleet used in the base model.



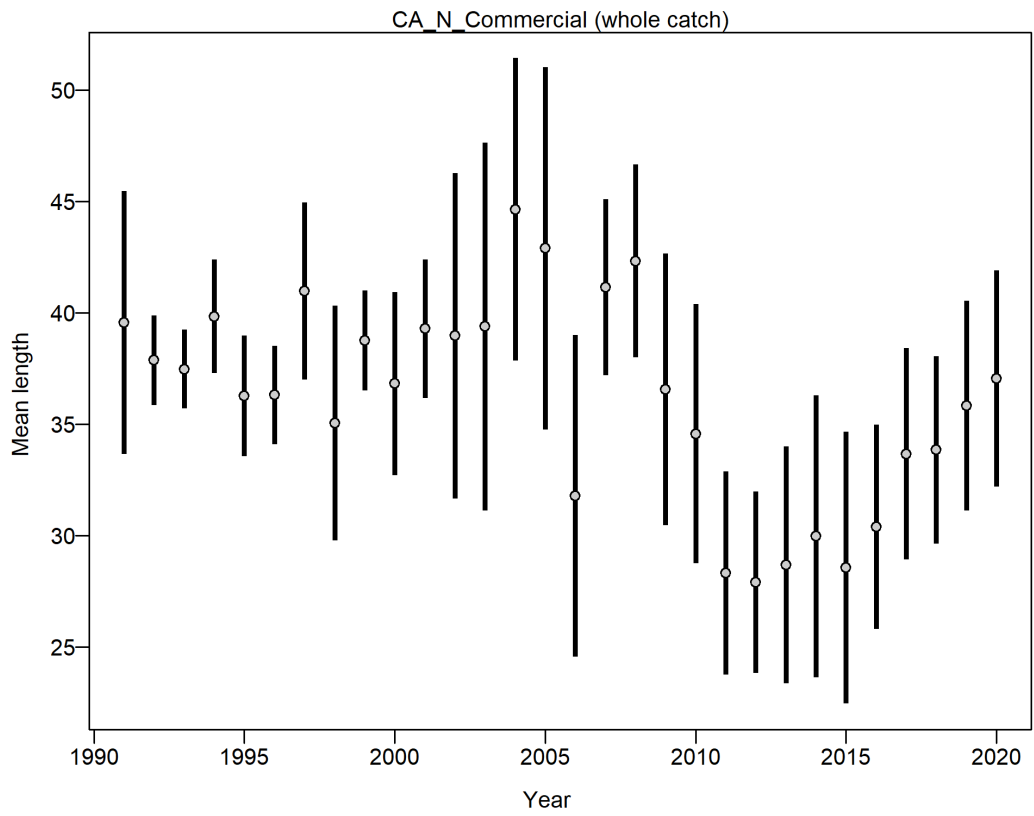
**Figure 2:** Map of management area and assessments areas for copper rockfish with the assessment area north of Point Conception shown in orange.



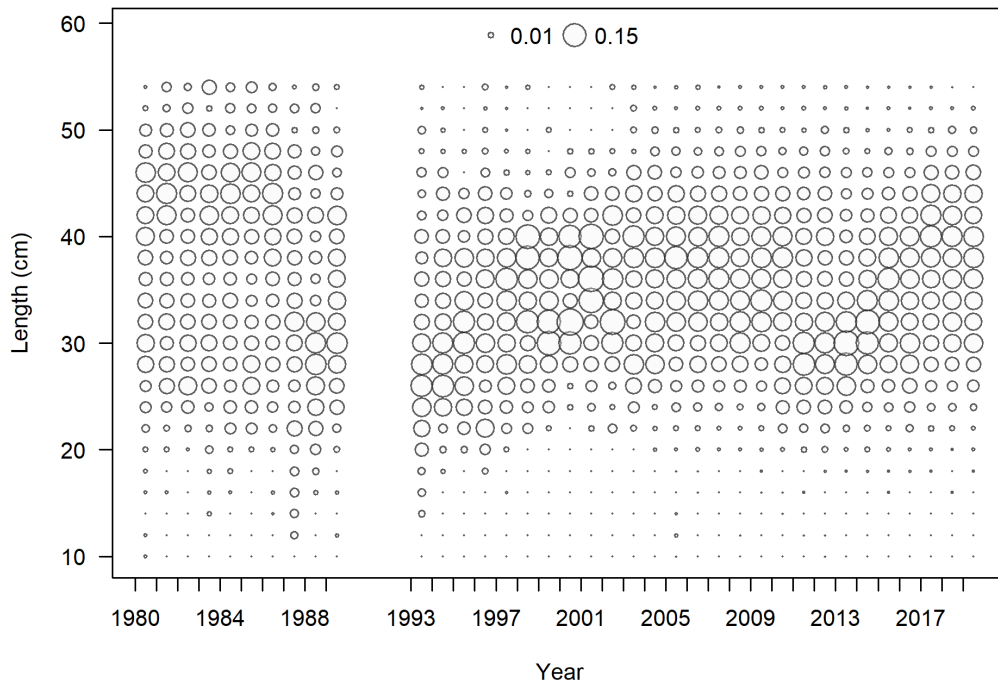
**Figure 3:** Summary of data sources used in the base model.



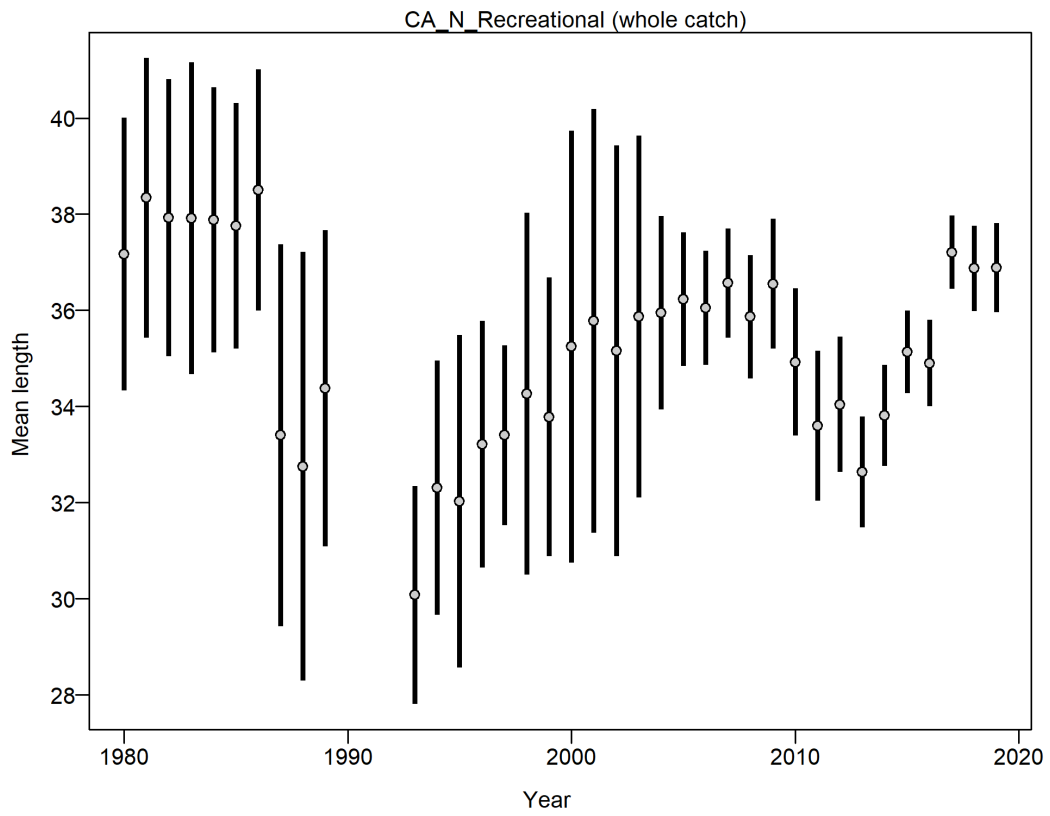
**Figure 4:** Length composition data from the commercial fleet.



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

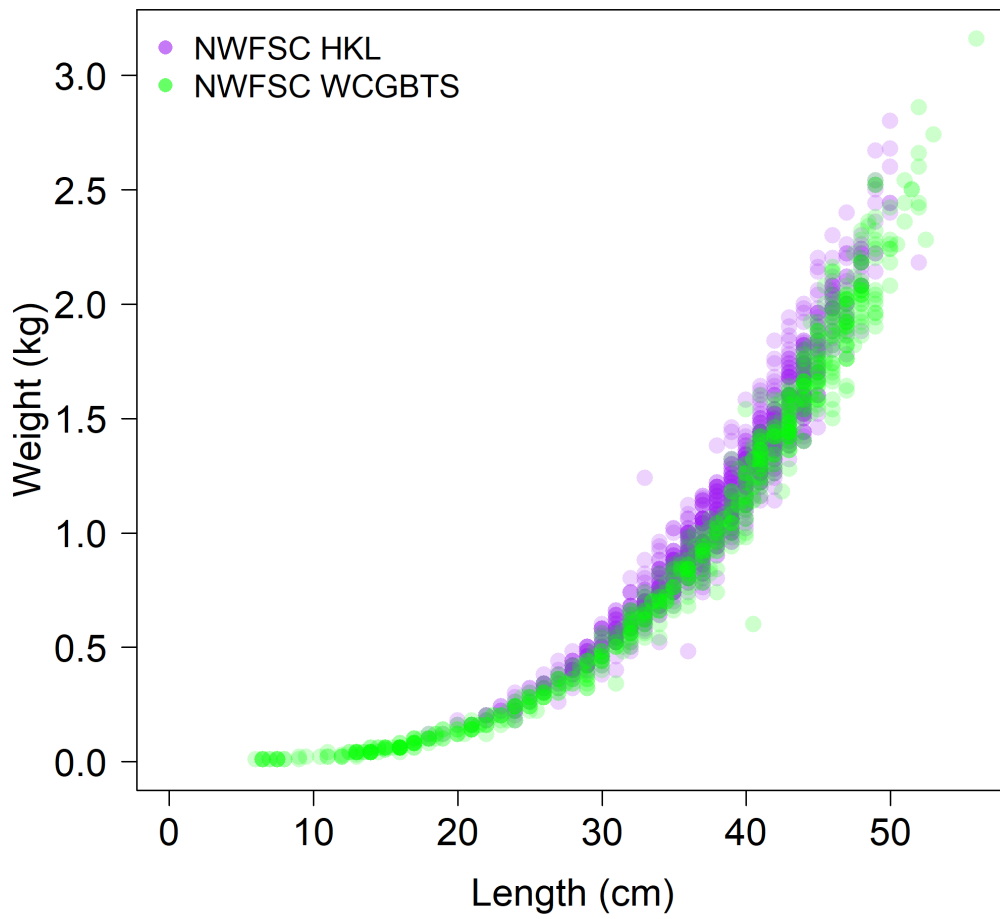


**Figure 6:** Length composition data from the recreational fleet.

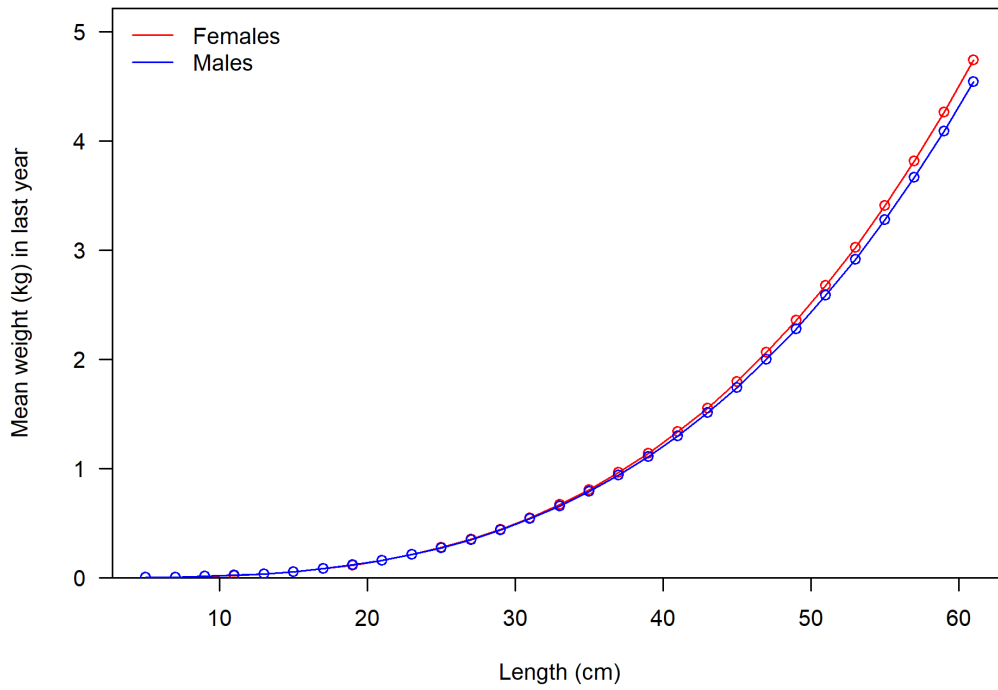


**Figure 7:** Mean length for recreational fleet with 95 percent confidence intervals.

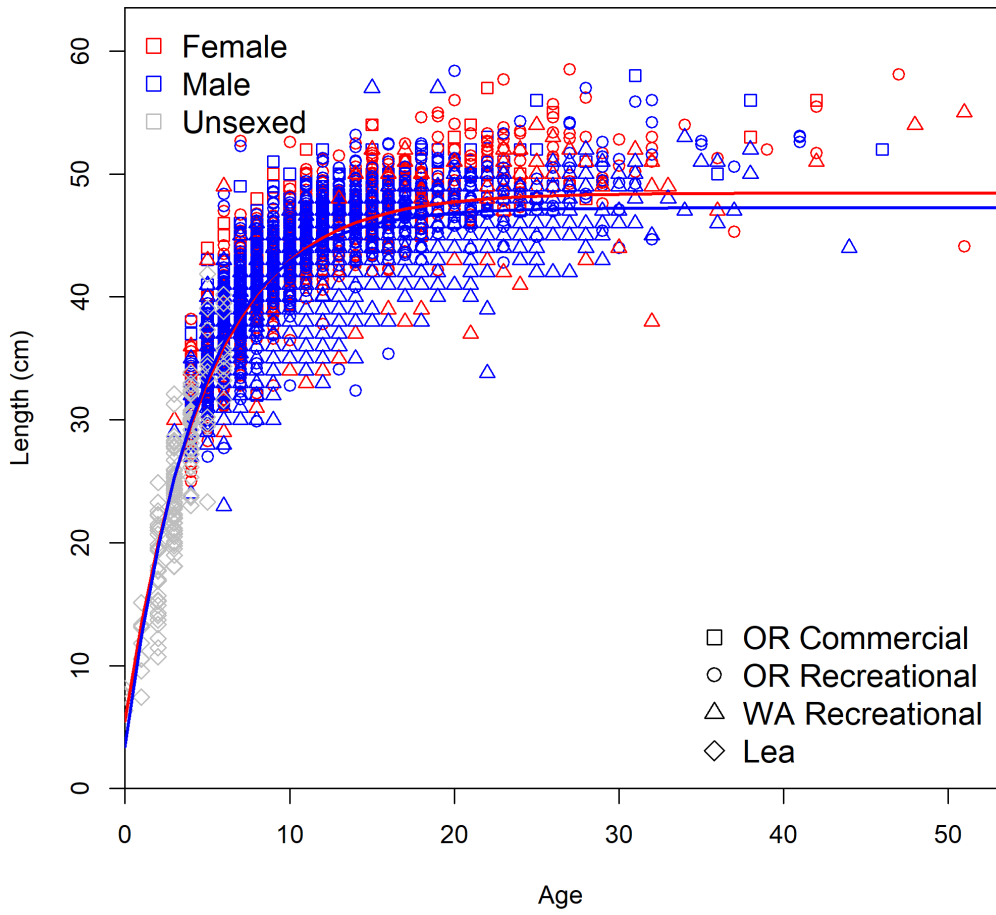




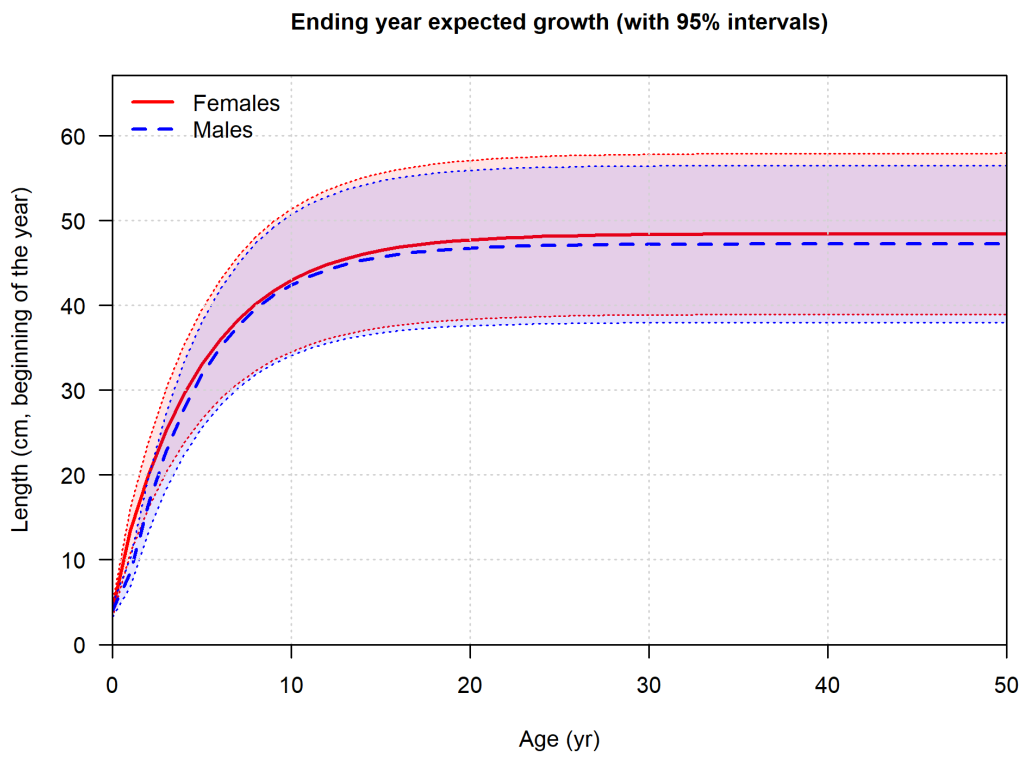
**Figure 8:** Comparison of the length-at-weight data from the NWFSC Hook and Line and the NWFSC WCGBT surveys.



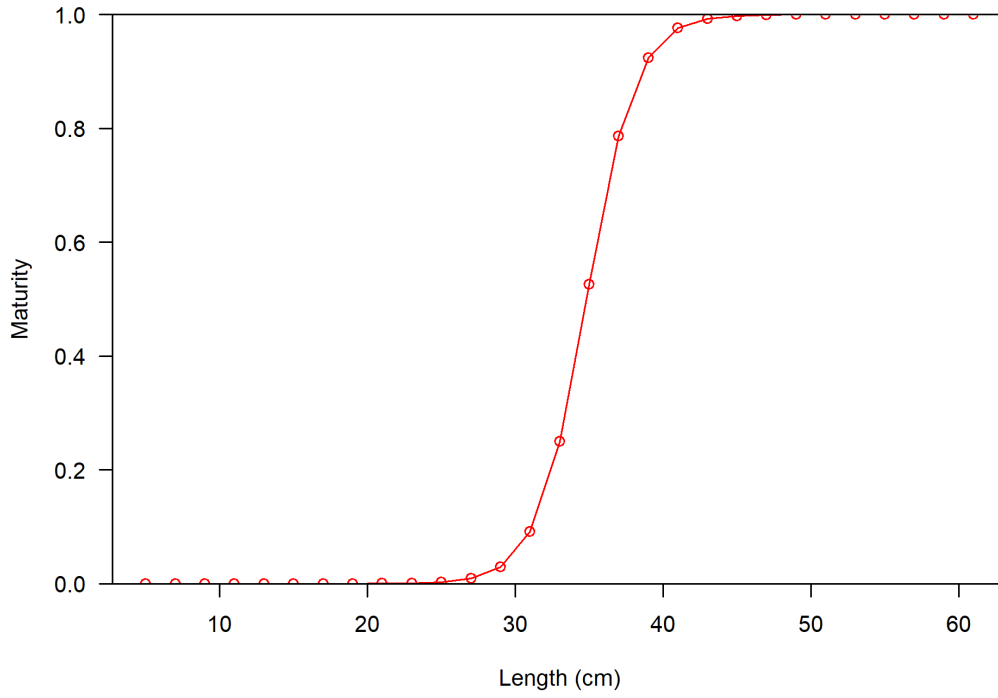
**Figure 9:** Weight-at-length by sex used in the model.



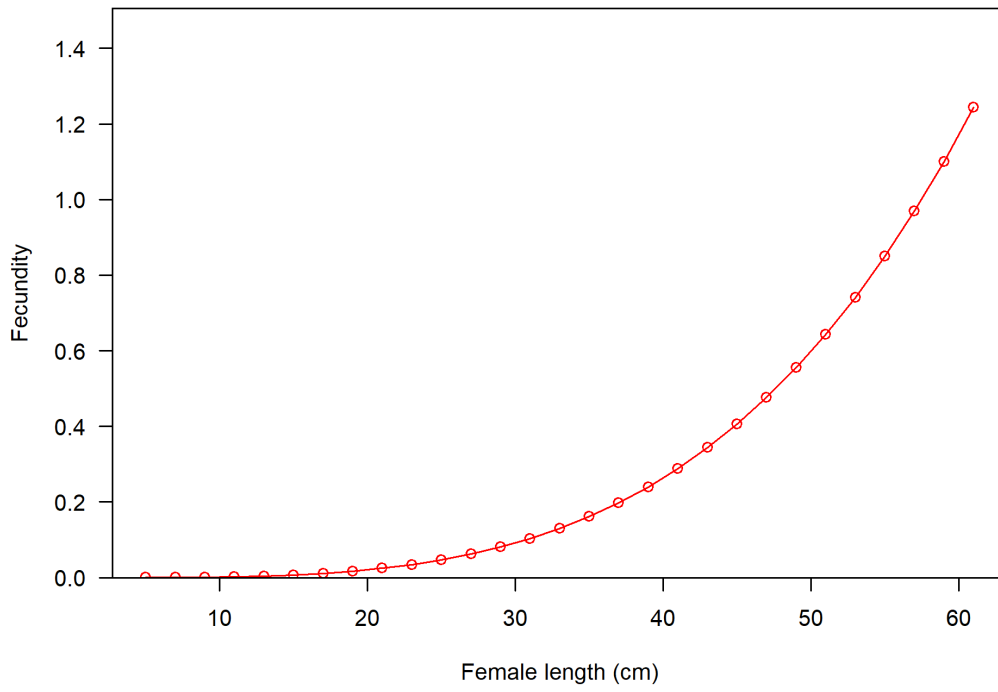
**Figure 10:** Observed sex-specific length-at-age by data source with the estimate length-at-age curve.



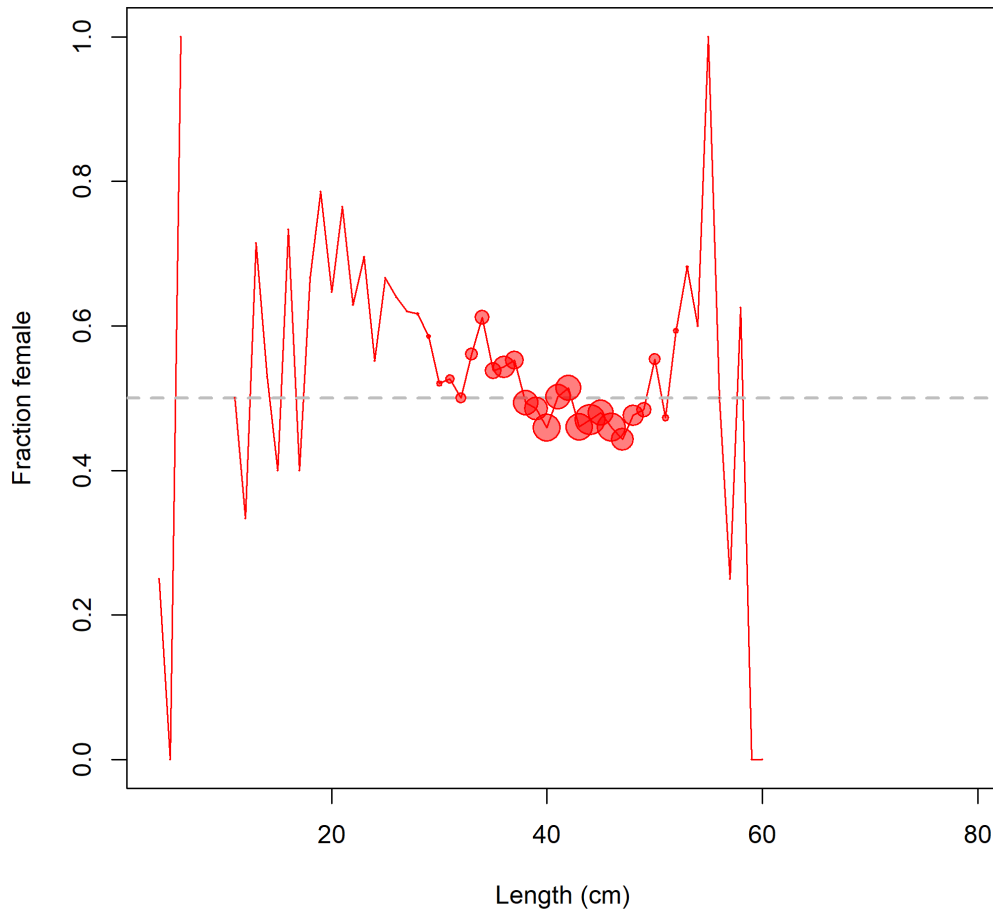
**Figure 11:** Length at age in the start of the year in the ending year of the model.



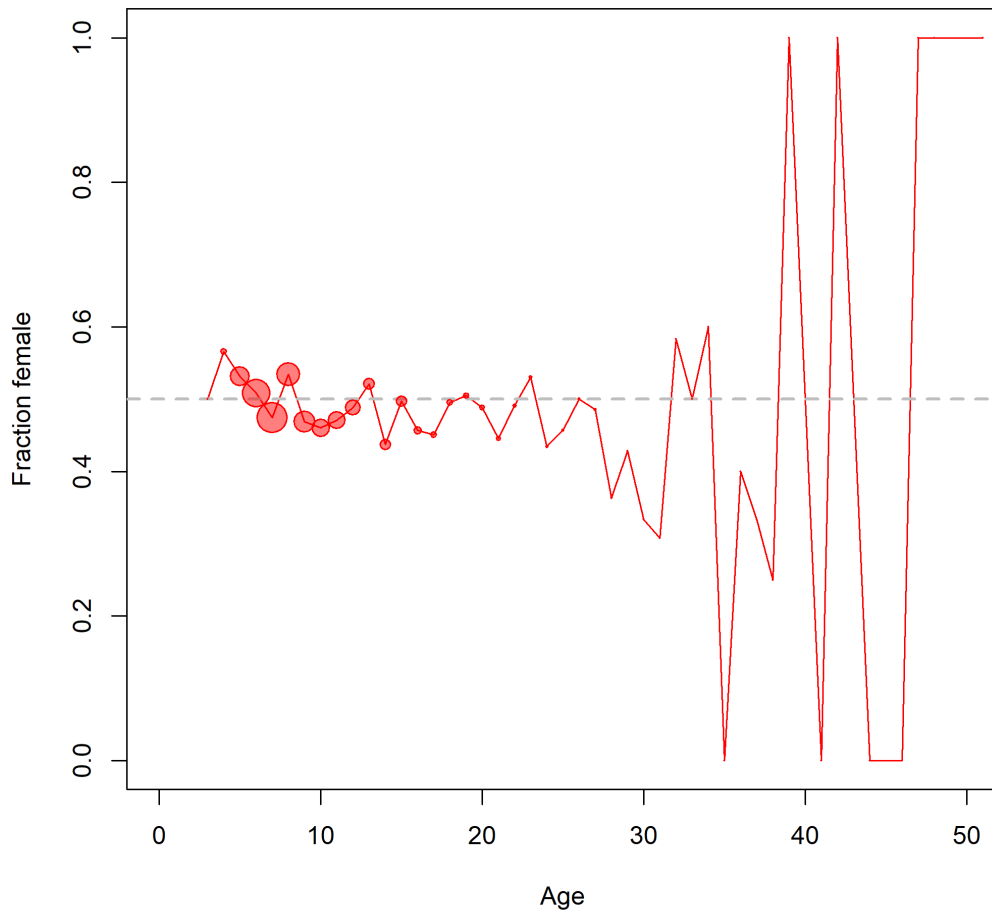
**Figure 12:** Maturity as a function of length.



**Figure 13:** Fecundity as a function of length.



**Figure 14:** 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 15:** 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.



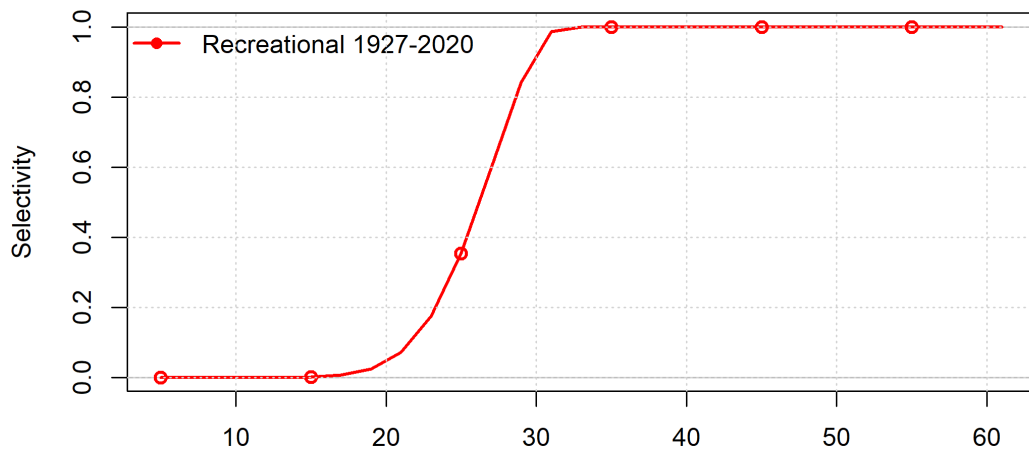
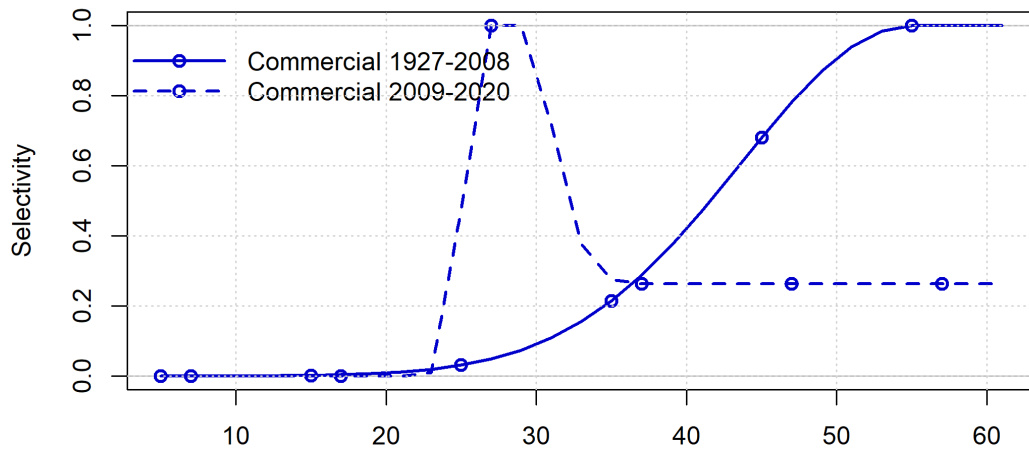
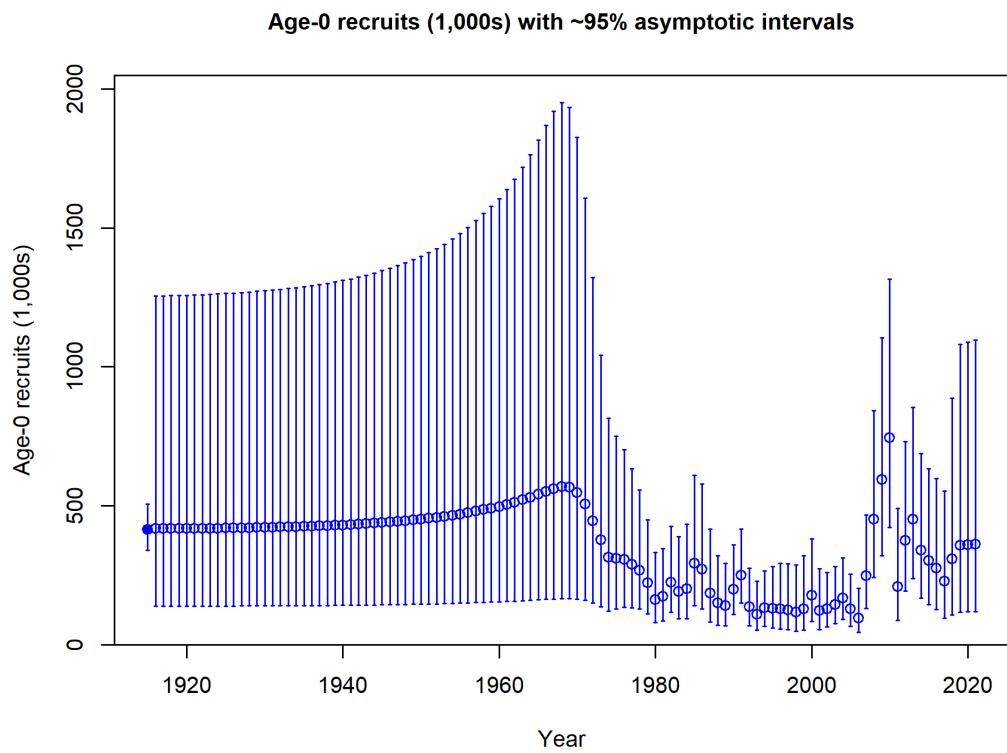
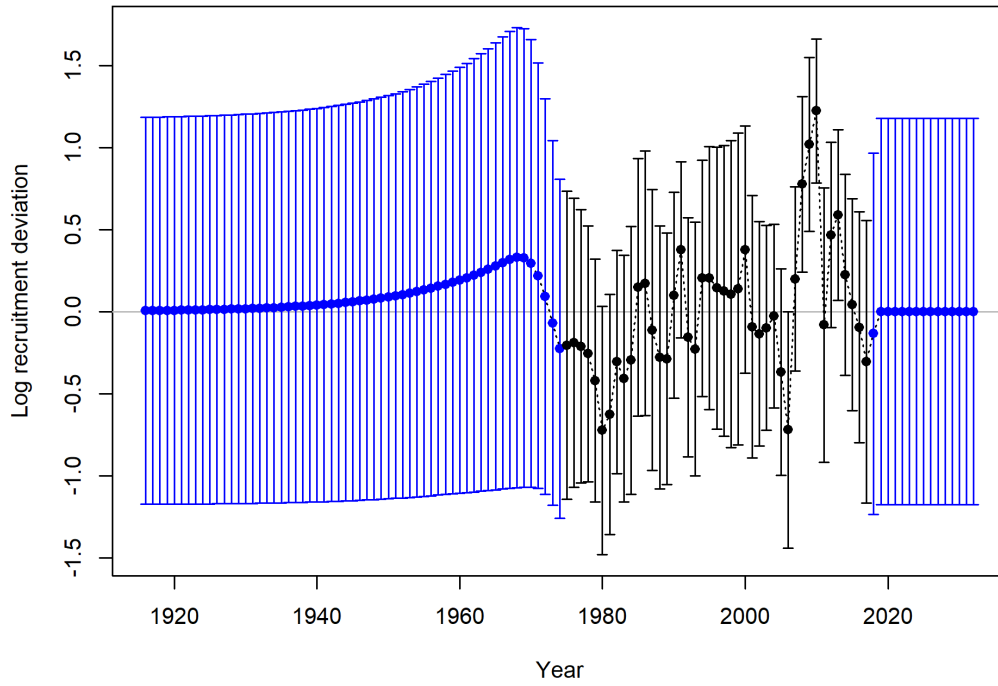


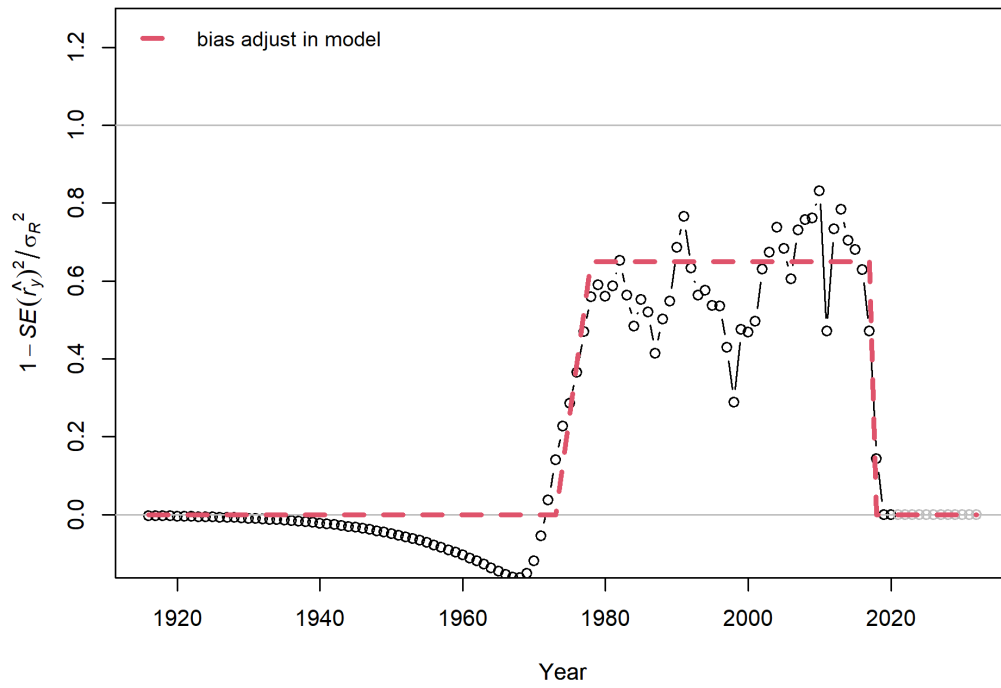
Figure 16: Selectivity at length by fleet.



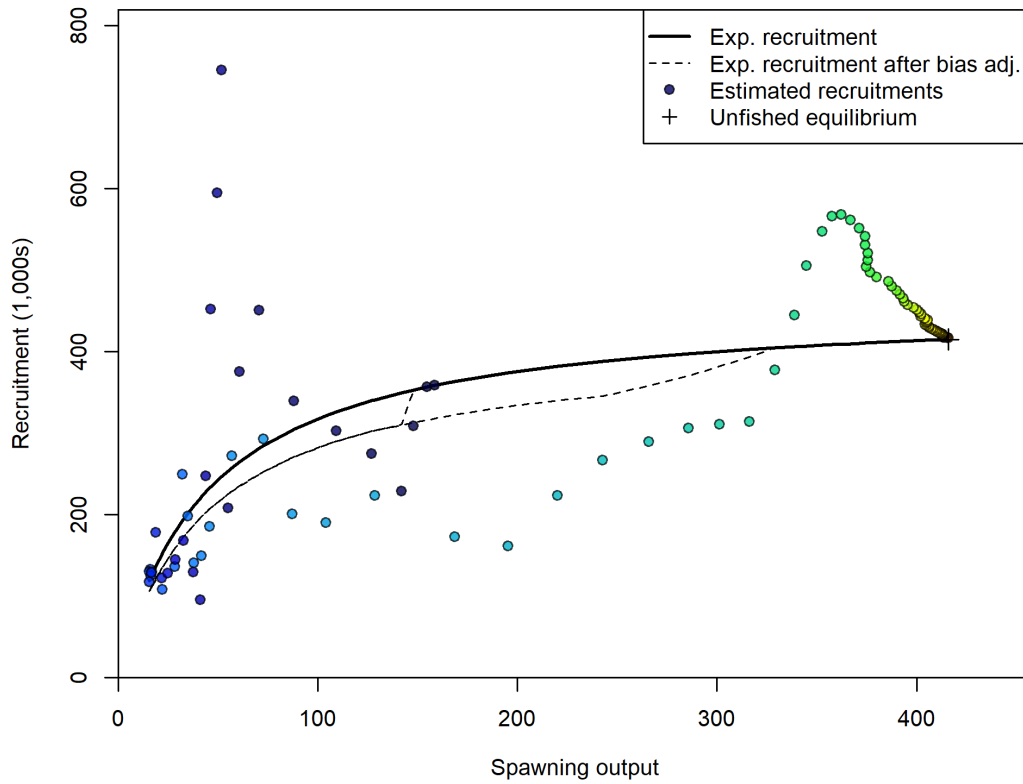
**Figure 17:** Estimated time series of age-0 recruits (1000s).



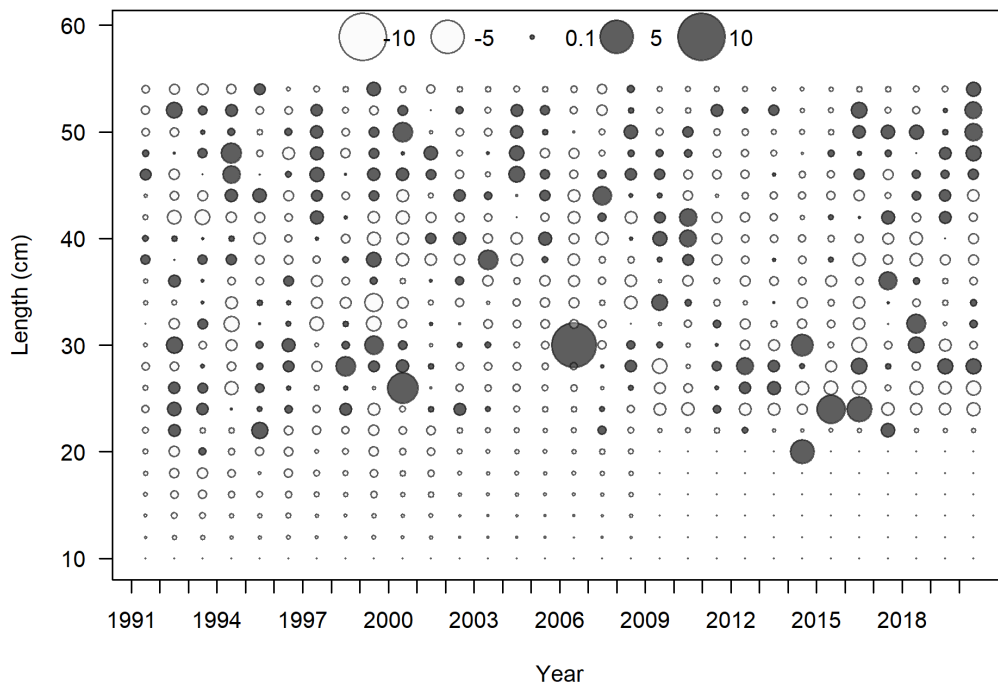
**Figure 18:** Estimated time series of recruitment deviations.



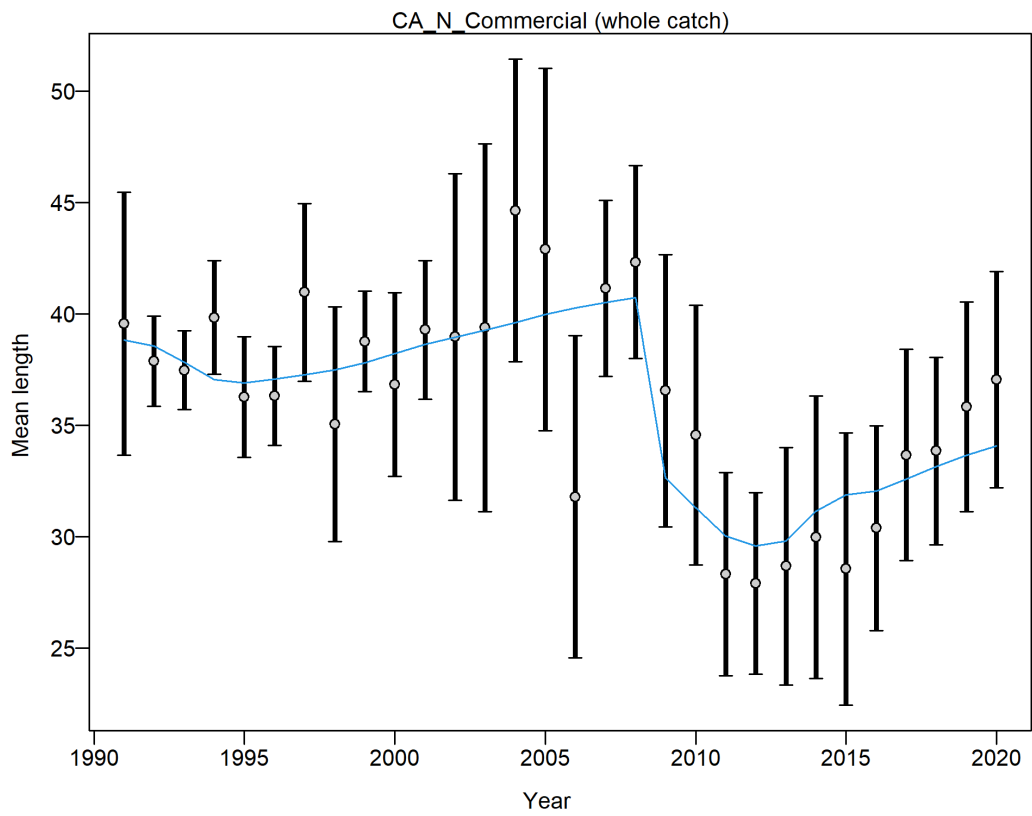
**Figure 19:** Recruitment bias adjustment applied in the base model.



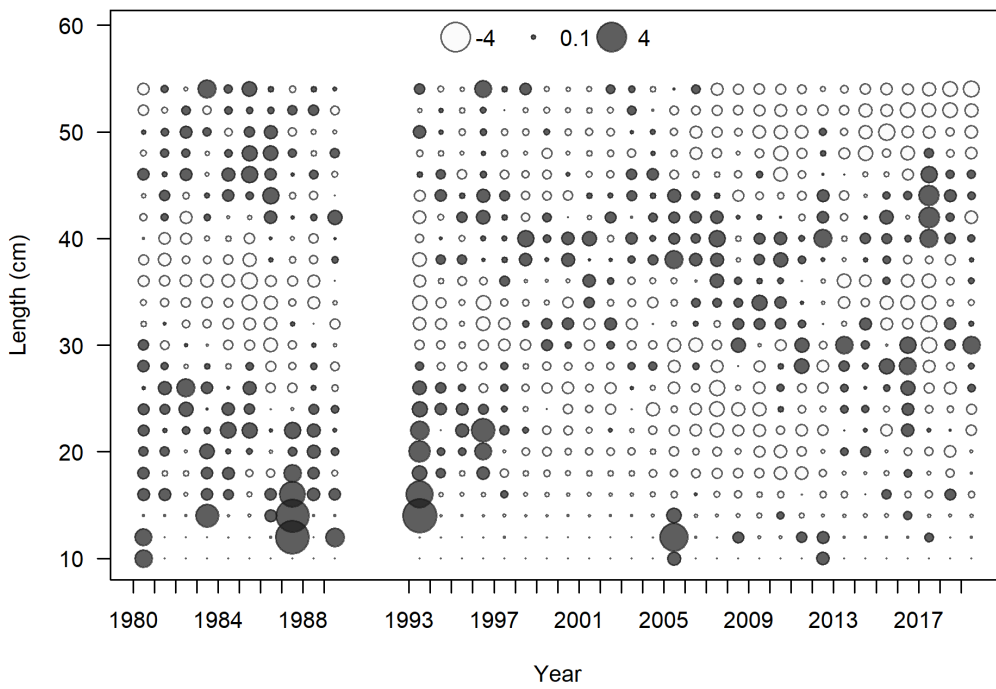
**Figure 20:** Stock-recruit curve. Point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years.



**Figure 21:** Pearson residuals for commercial fleet. Closed bubble are positive residuals (observed > expected) and the open bubbles are negative residuals (observed < expected).

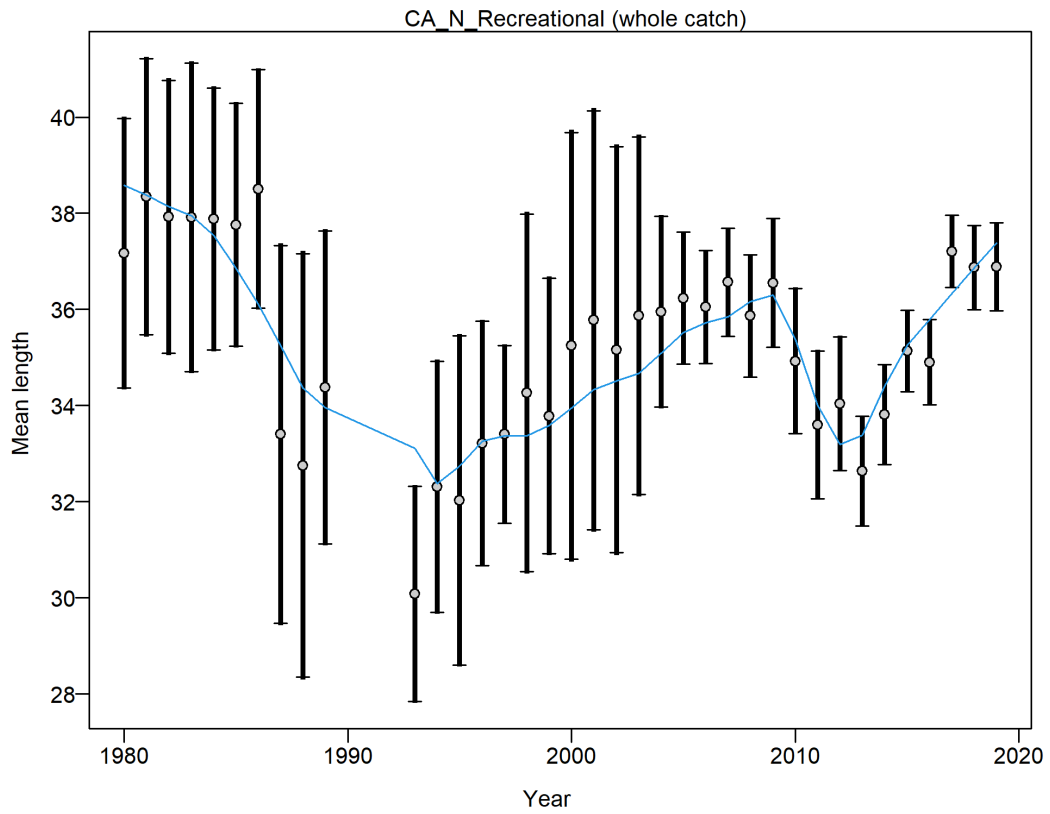


**Figure 22:** Mean length for commercial lengths with 95 percent confidence intervals based on current samples sizes.

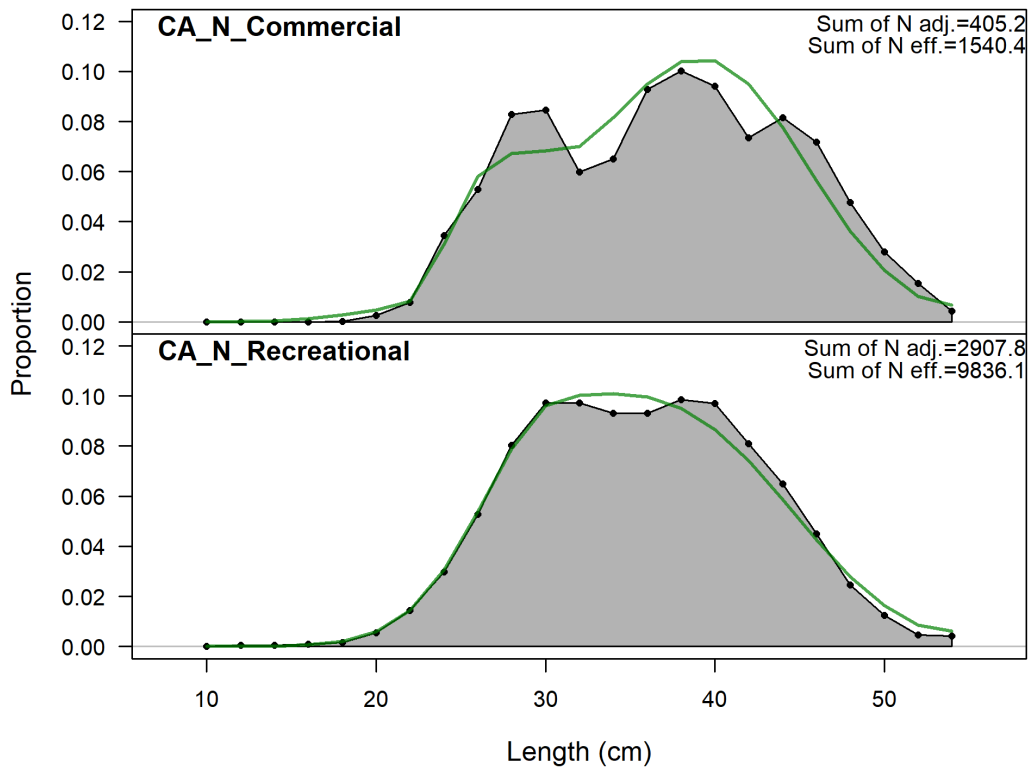


**Figure 23:** Pearson residuals for recreational fleet. Closed bubble are positive residuals (observed > expected) and the open bubbles are negative residuals (observed < expected).

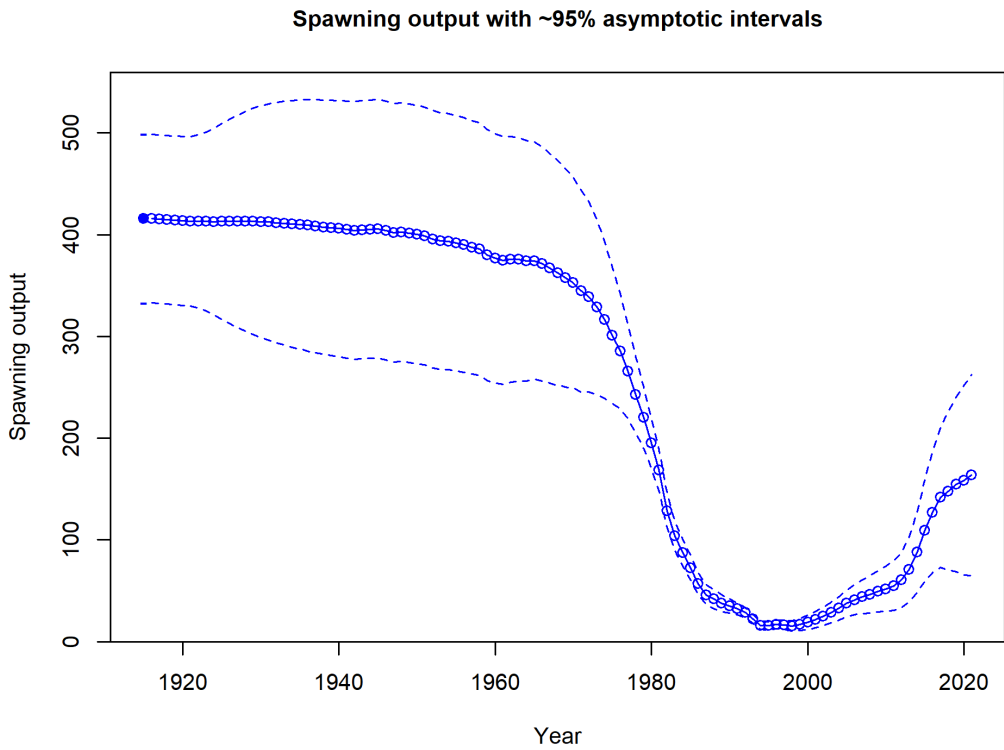




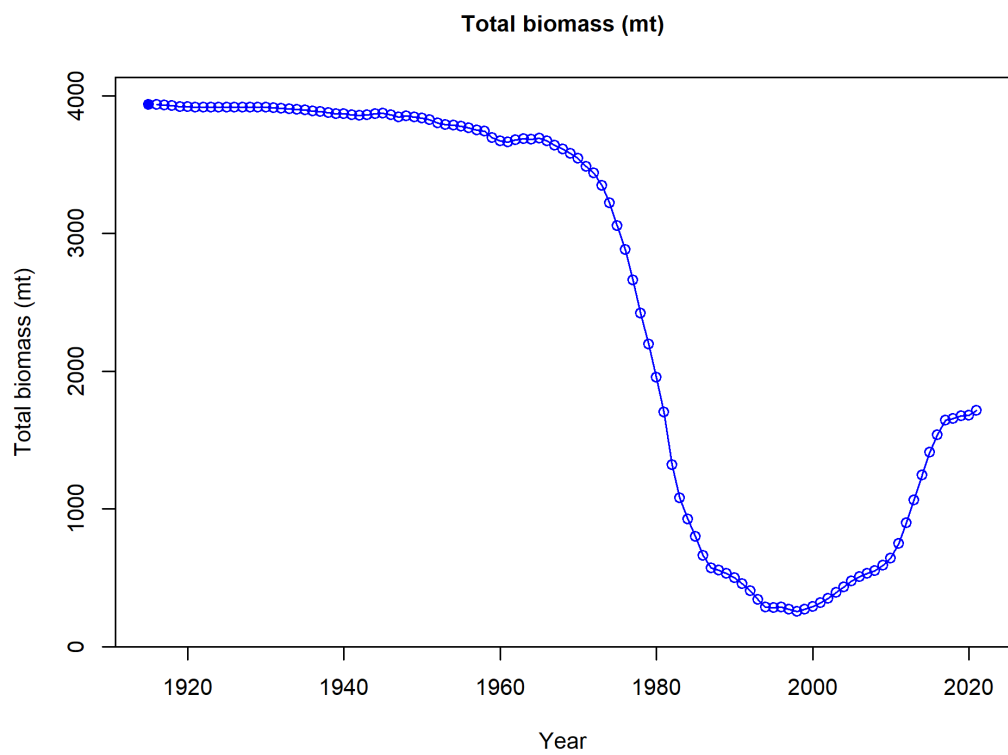
**Figure 24:** Mean length for recreational lengths with 95 percent confidence intervals based on current samples sizes.



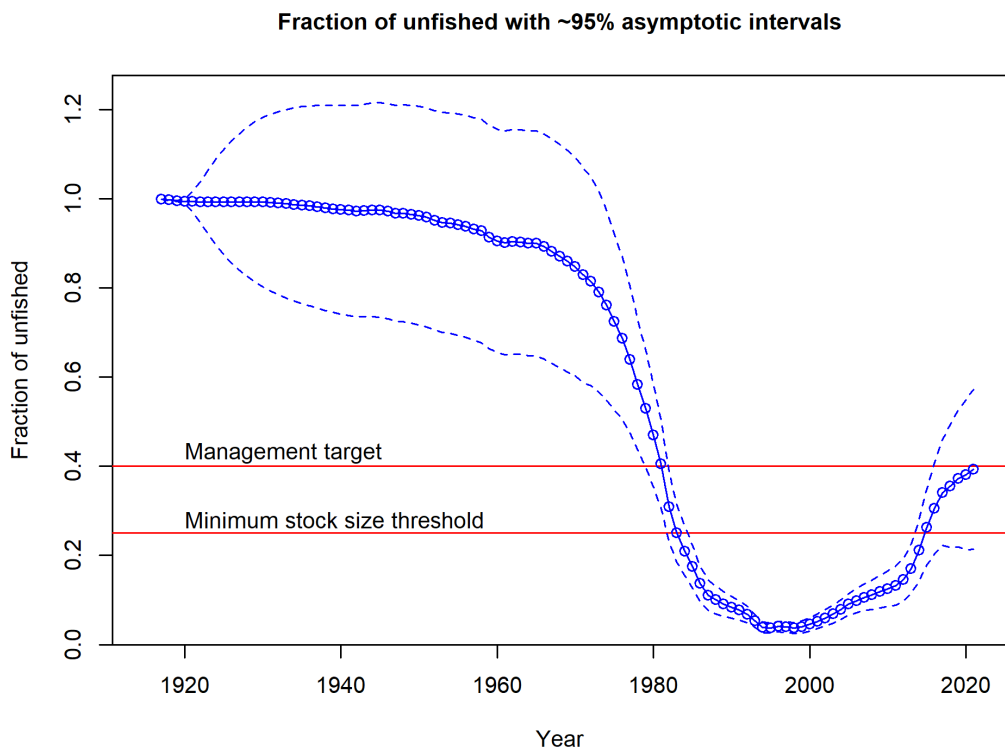
**Figure 25:** Aggregated length comps across all years.



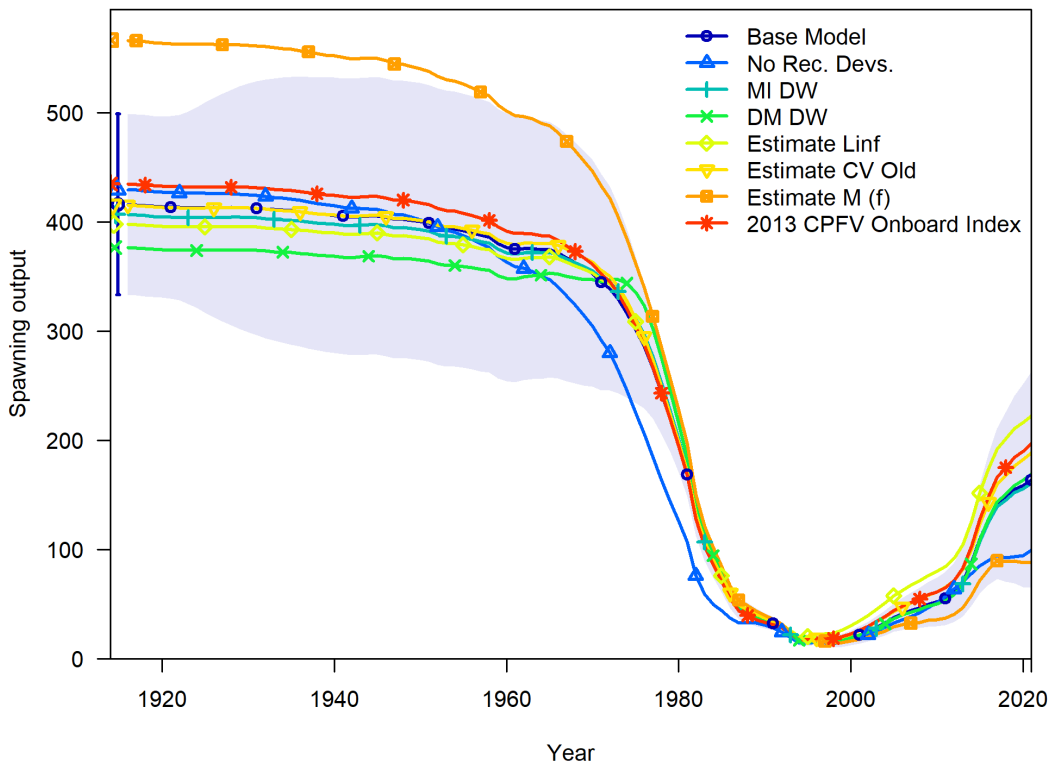
**Figure 26:** Estimated time series of spawning output.



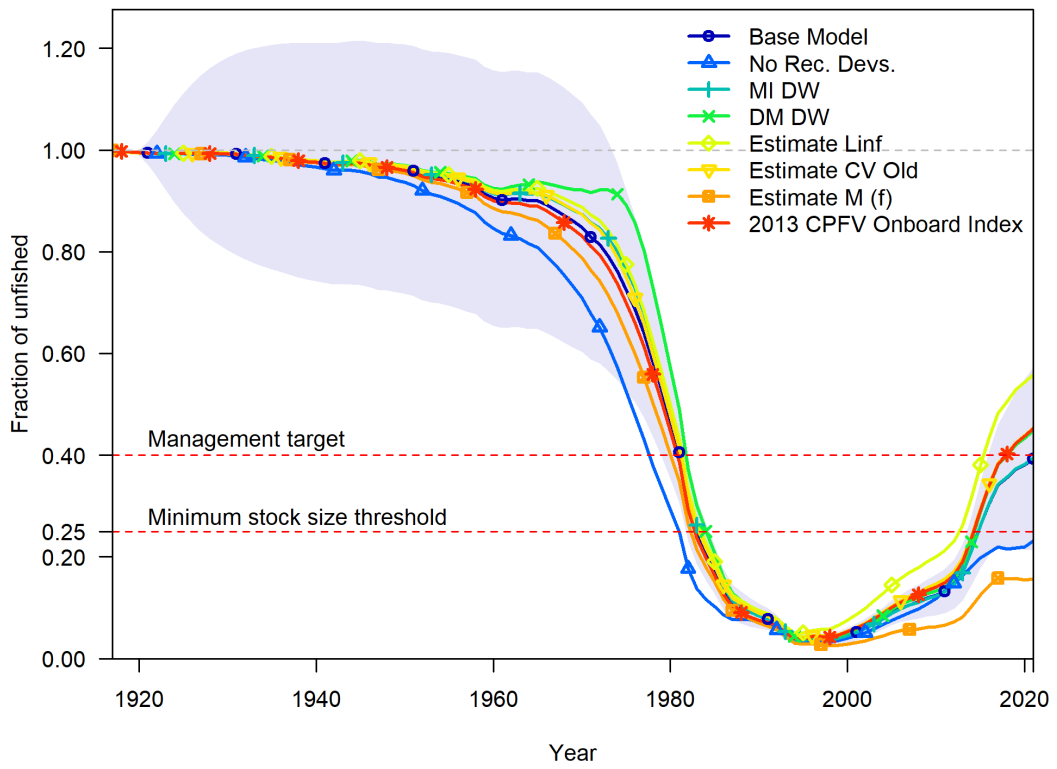
**Figure 27:** Estimated time series of total biomass.



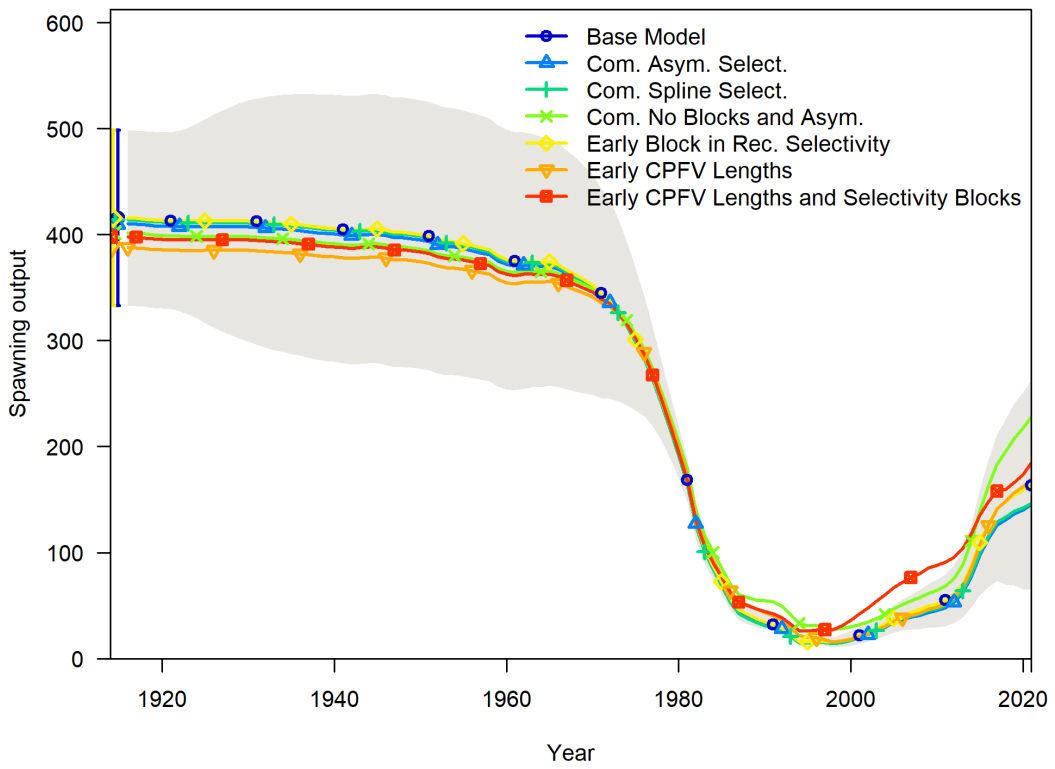
**Figure 28:** Estimated time series of fraction of unfished spawning output.



**Figure 29:** Change in estimated spawning output by sensitivity.

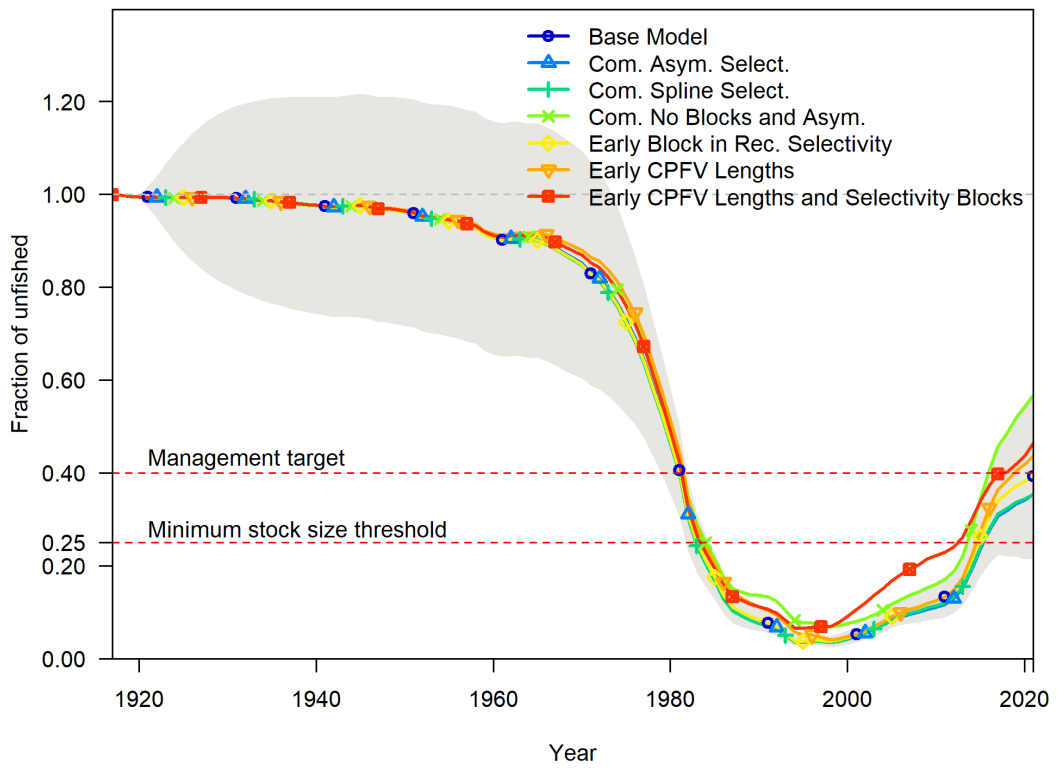


**Figure 30:** Change in estimated fraction unfished by sensitivity.

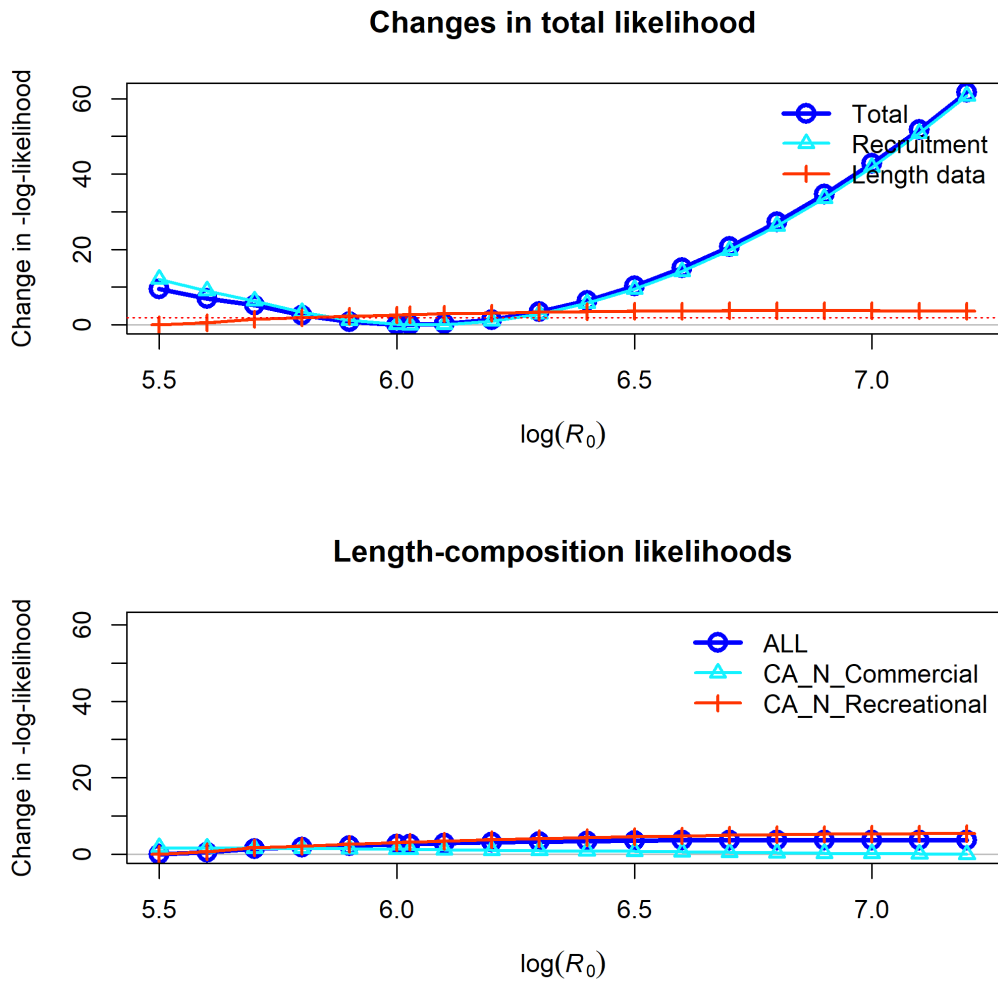


**Figure 31:** Change in estimated spawning output by sensitivity.

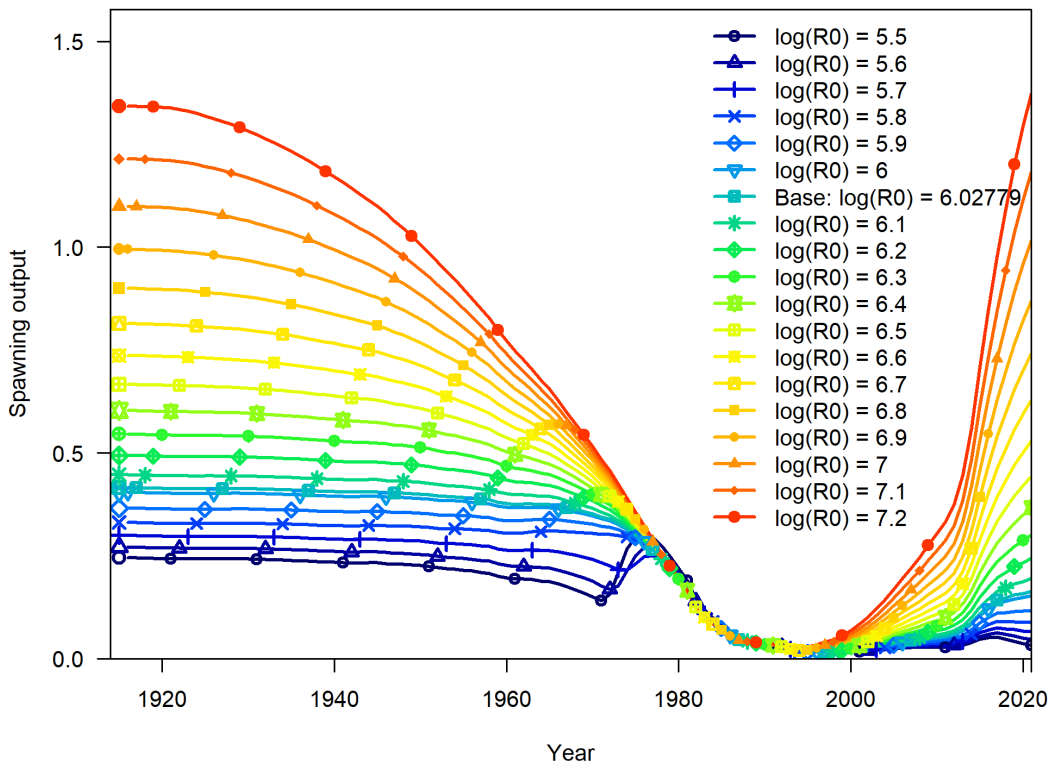




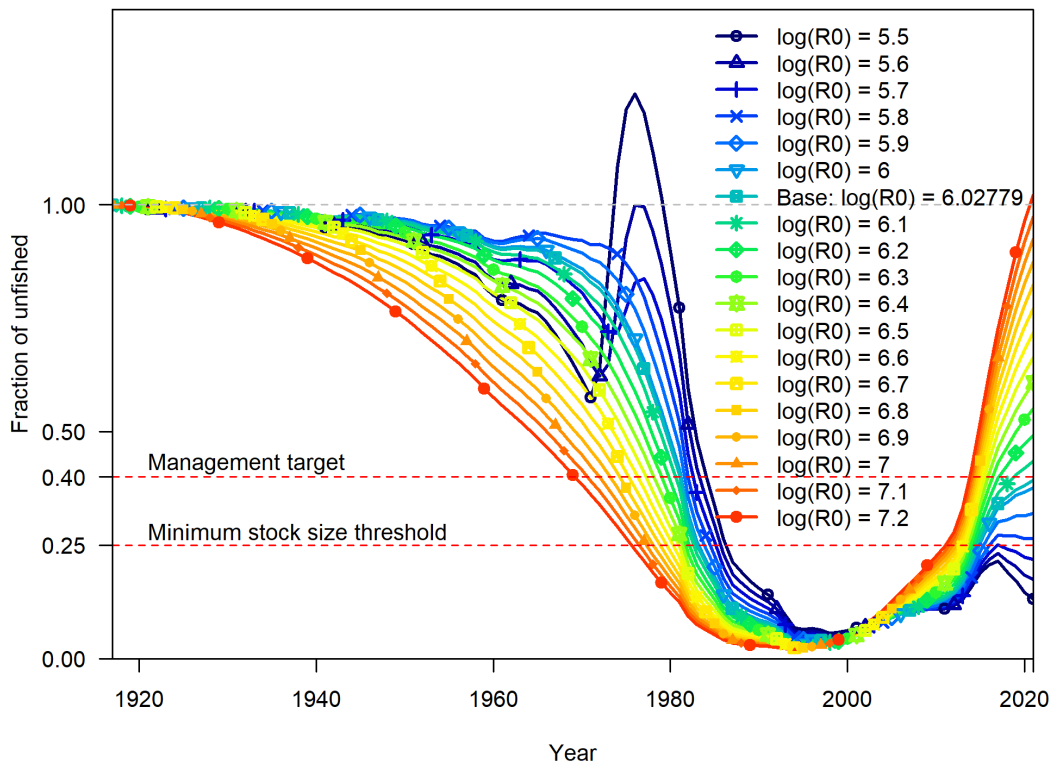
**Figure 32:** Change in estimated fraction unfished by sensitivity.



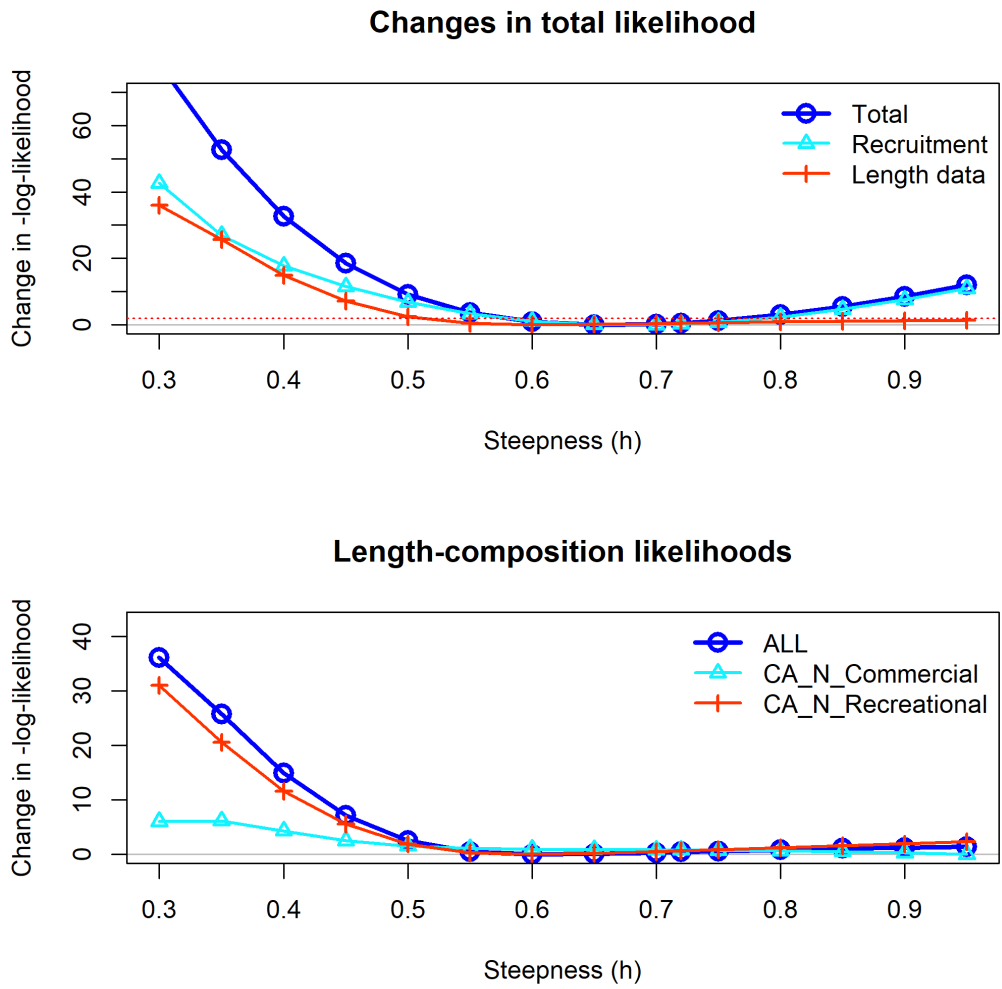
**Figure 33:** Change in the negative log-likelihood across a range of  $\log(R_0)$  values.



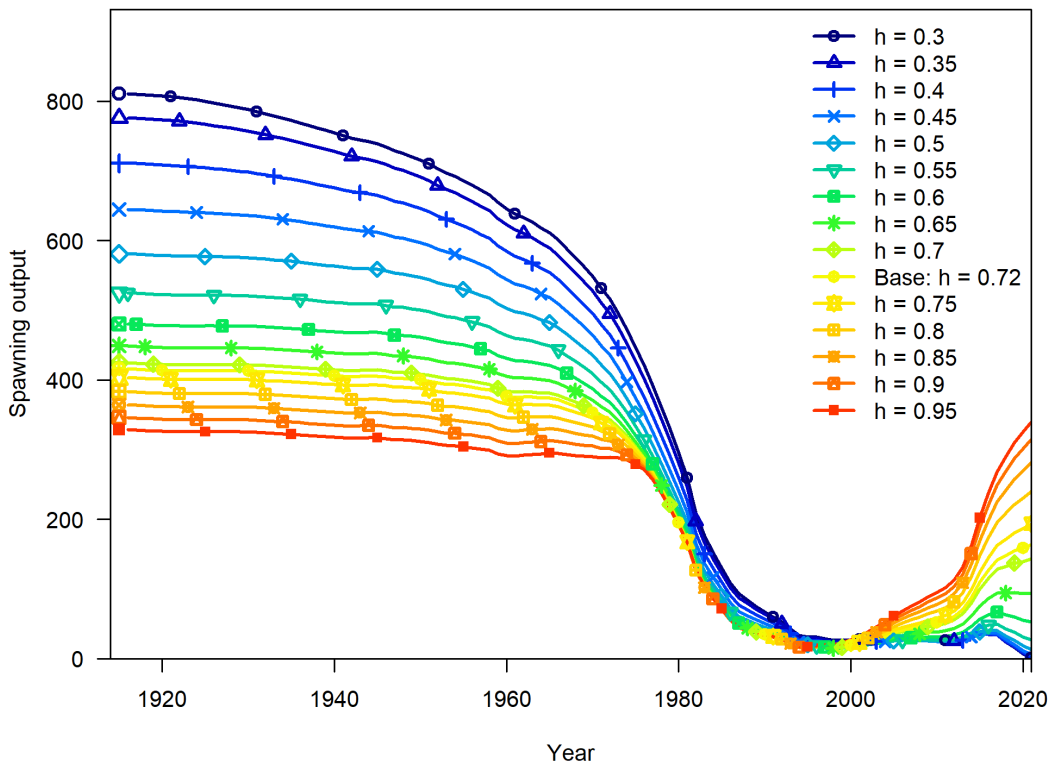
**Figure 34:** Change in the estimate of spawning output across a range of  $\log(R_0)$  values.



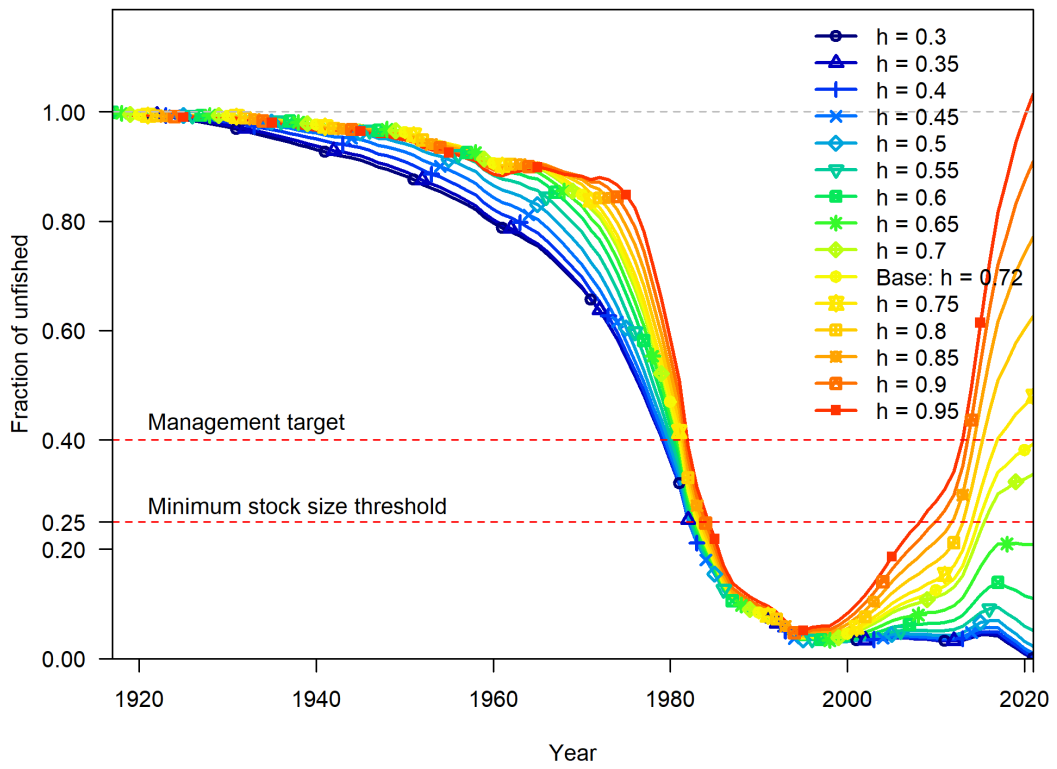
**Figure 35:** Change in the estimate of fraction unfished across a range of  $\log(R_0)$  values.



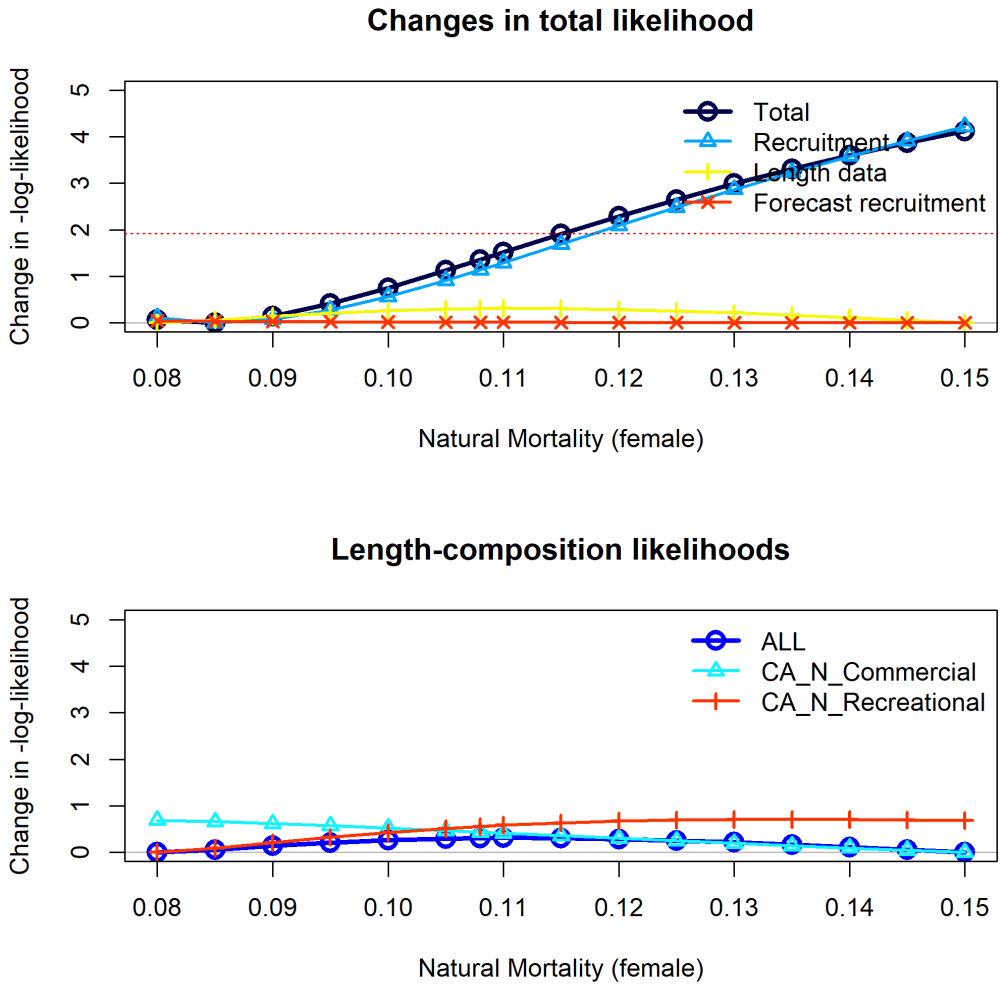
**Figure 36:** Change in the negative log-likelihood across a range of steepness values.



**Figure 37:** Change in the estimate of spawning output across a range of steepness values.

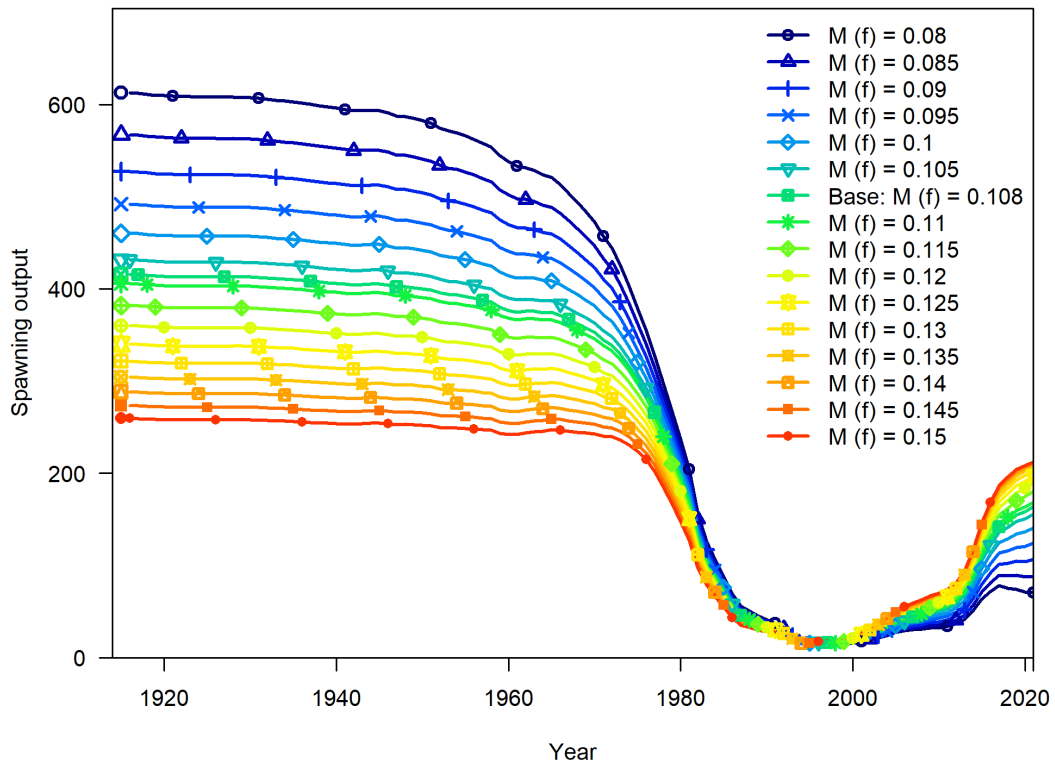


**Figure 38:** Change in the estimate of fraction unfished across a range of steepness values.

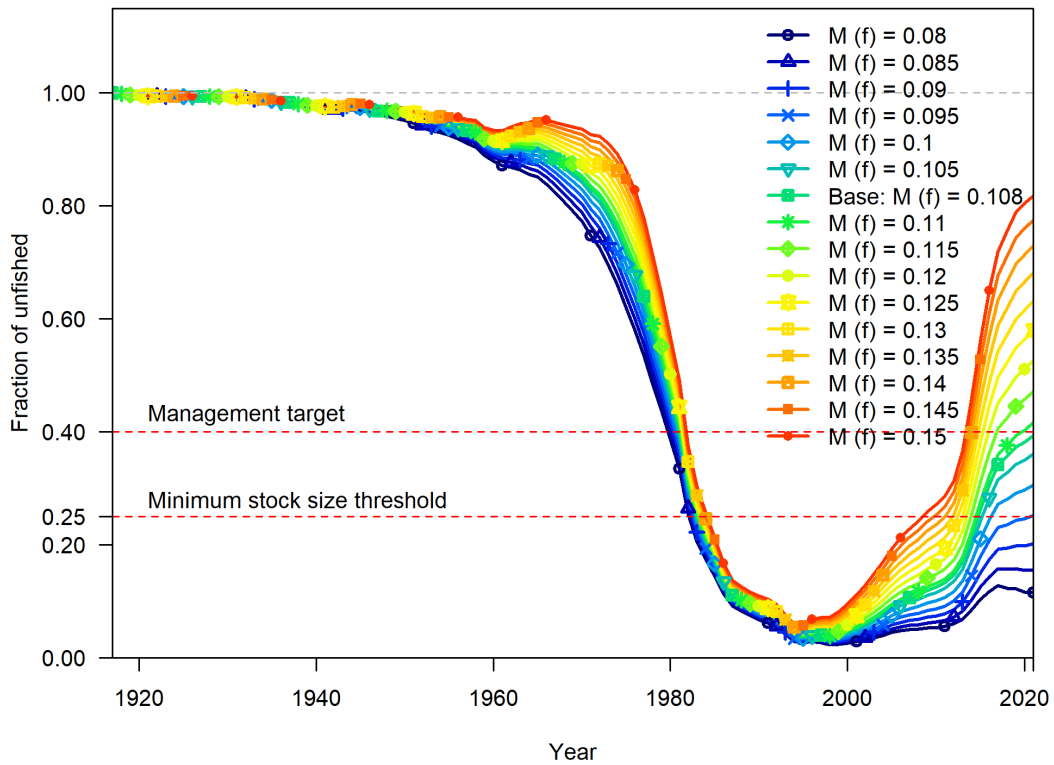


**Figure 39:** Change in the negative log-likelihood across a range of female natural mortality values.

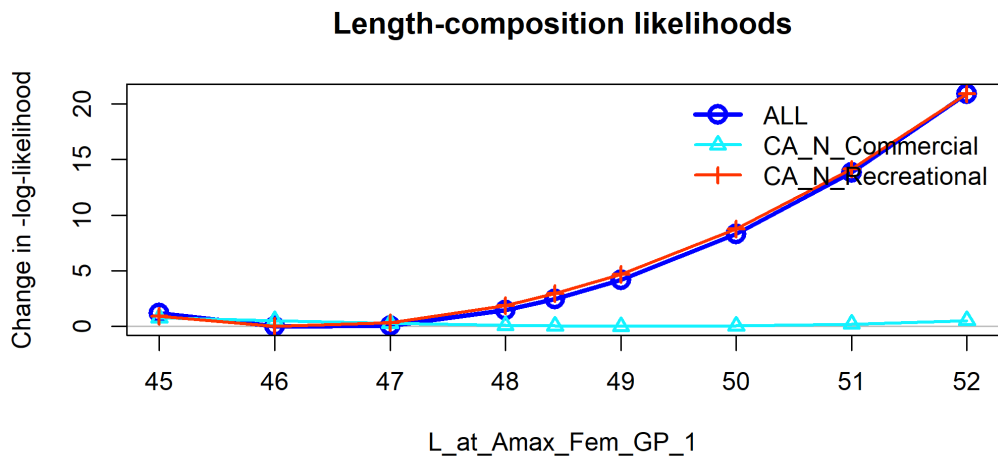
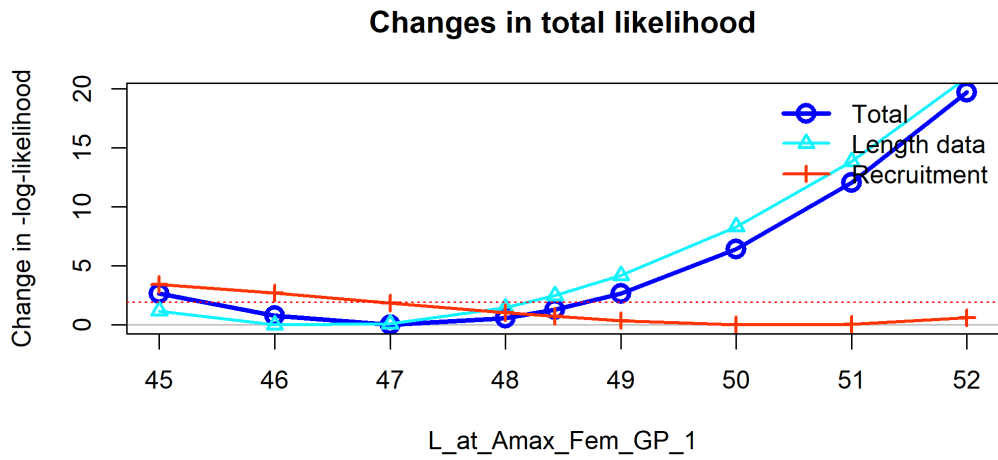




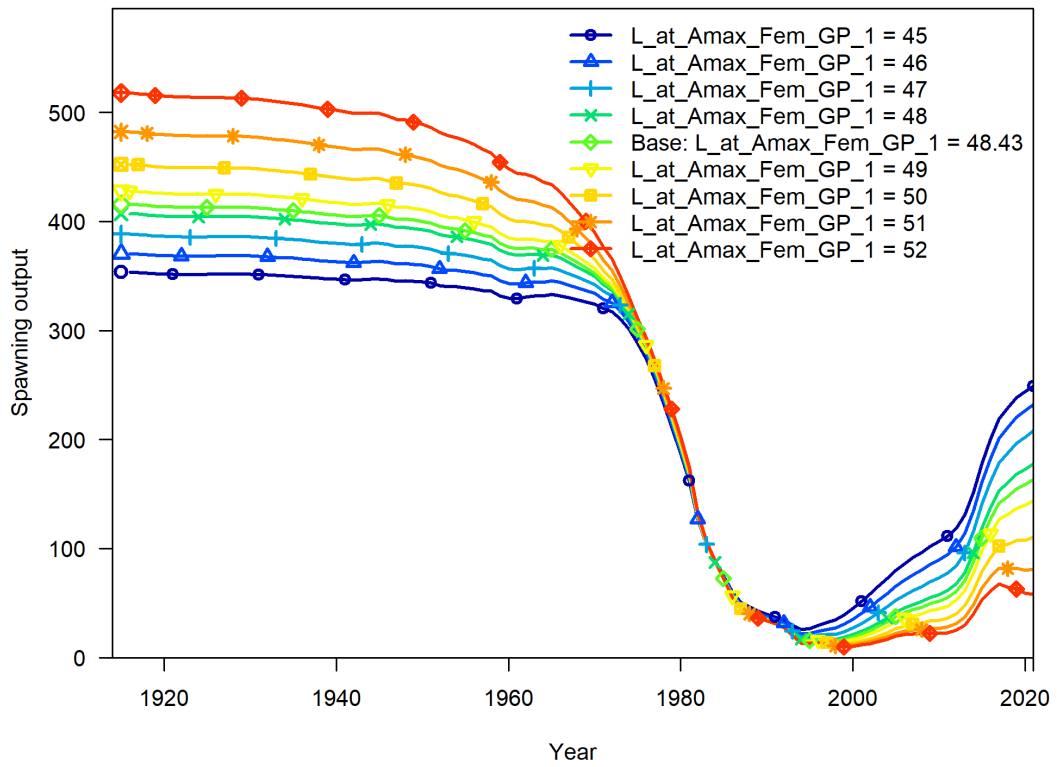
**Figure 40:** Change in the estimate of spawning output across a range of female natural mortality values.



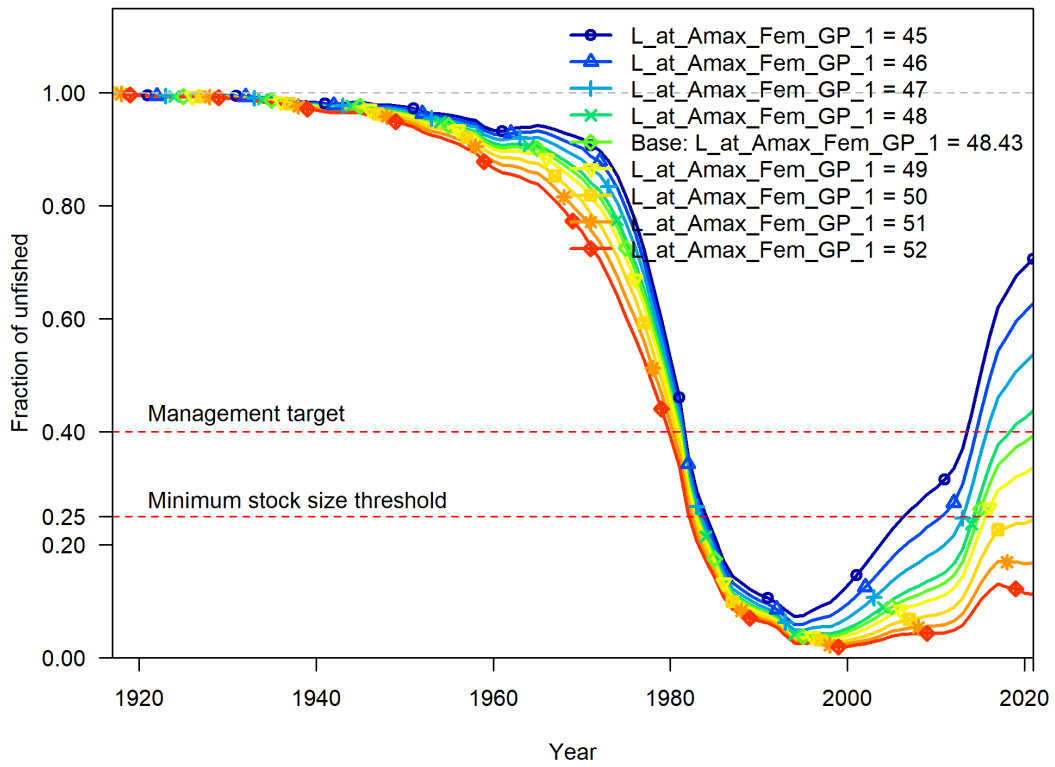
**Figure 41:** Change in the estimate of fraction unfished across a range of female natural values.



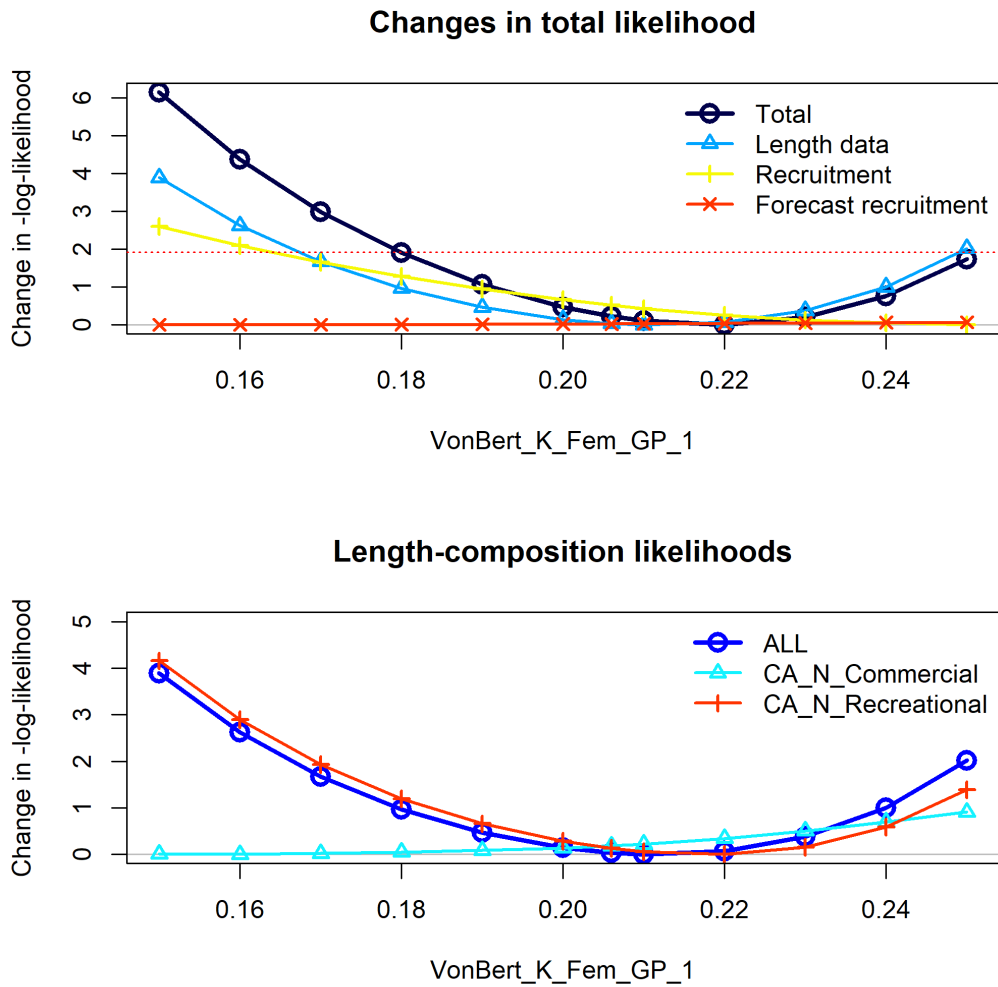
**Figure 42:** Change in the negative log-likelihood across a range of female maximum length values.



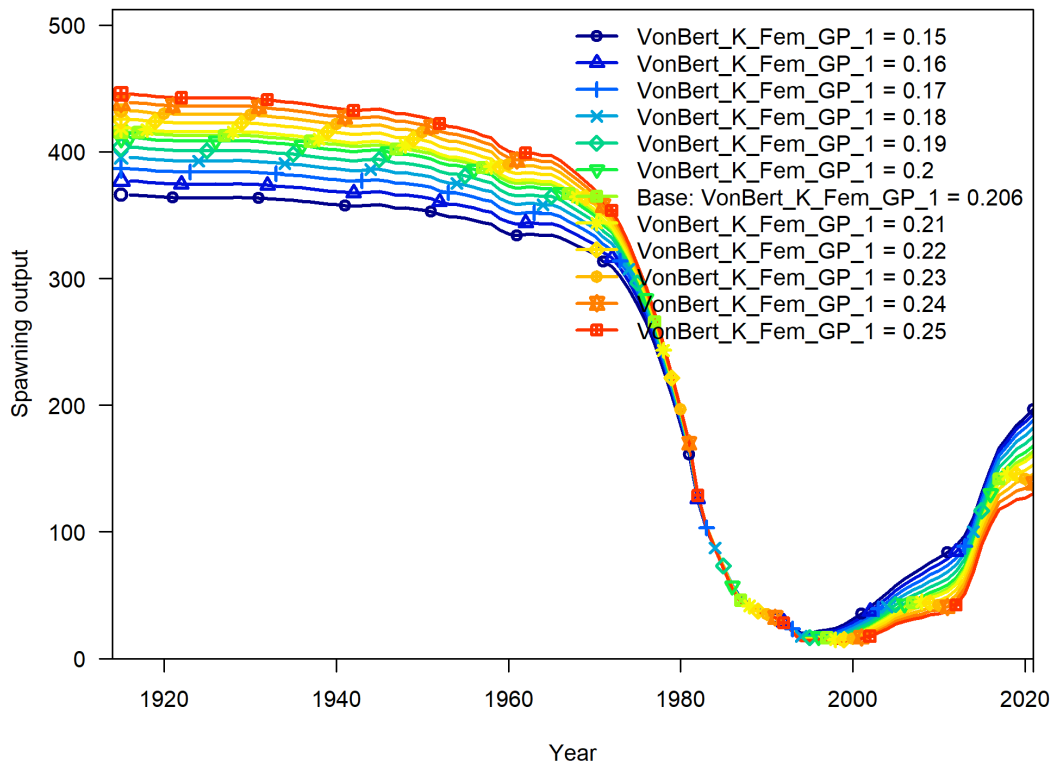
**Figure 43:** Change in the estimate of spawning output across a range of female maximum length values.



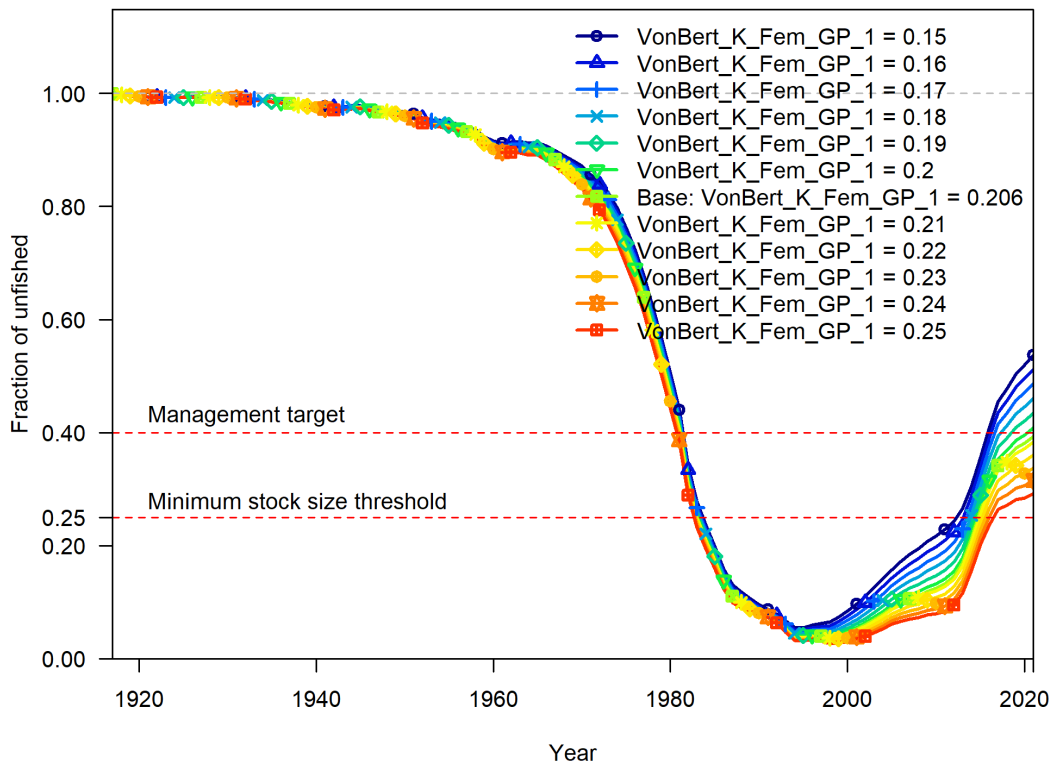
**Figure 44:** Change in the estimate of fraction unfished across a range of female maximum length values.



**Figure 45:** Change in the negative log-likelihood across a range of female k values.

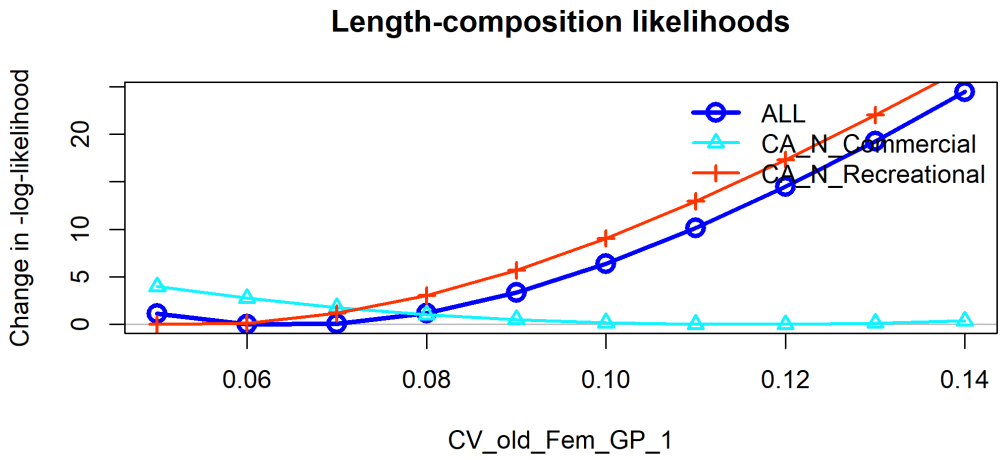
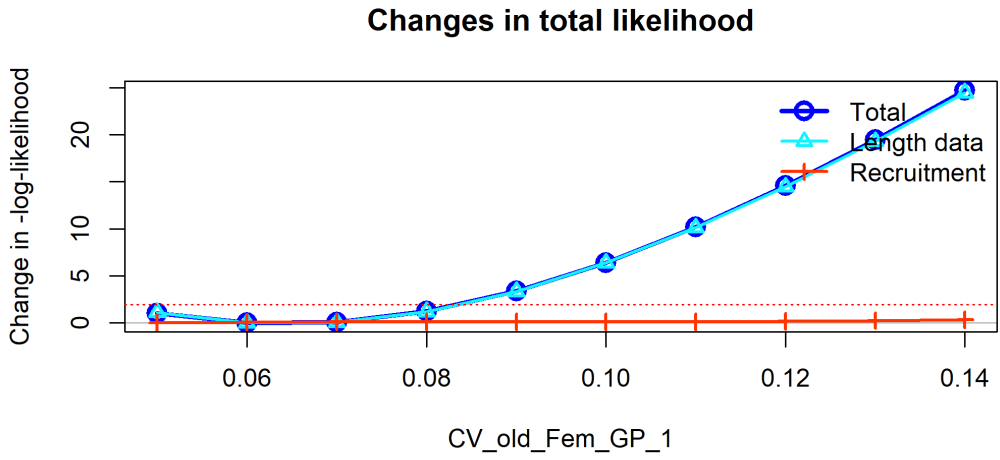


**Figure 46:** Change in the estimate of spawning output across a range of female k values.

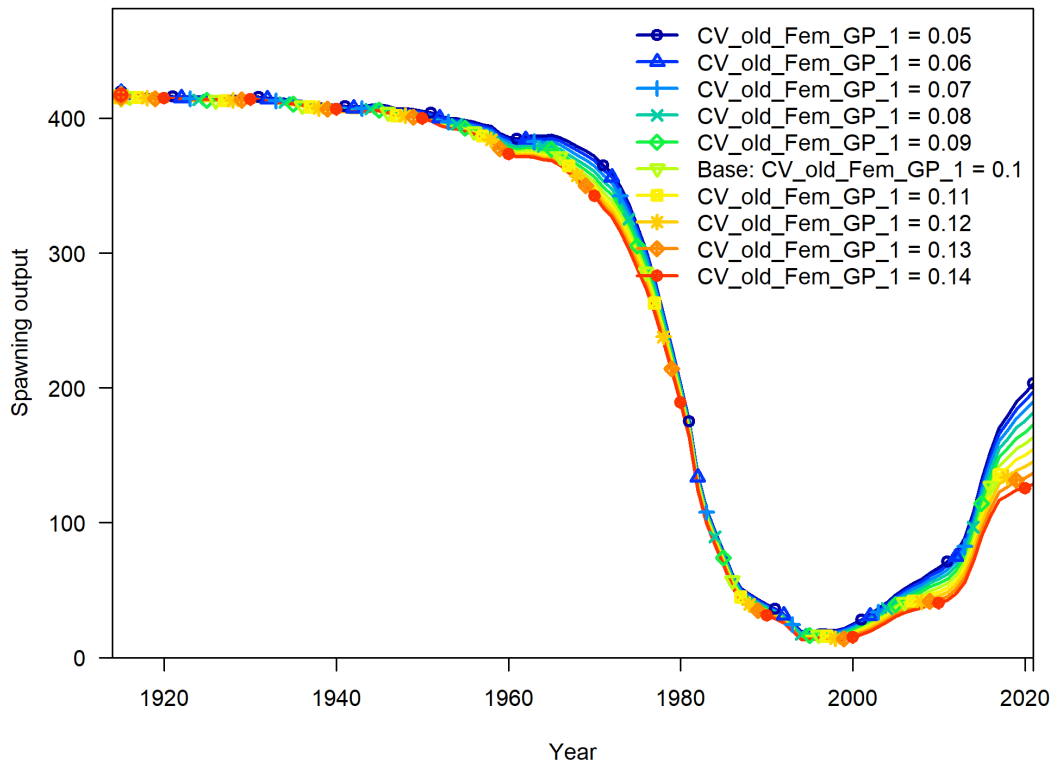


**Figure 47:** Change in the estimate of fraction unfished across a range of female  $k$  values.

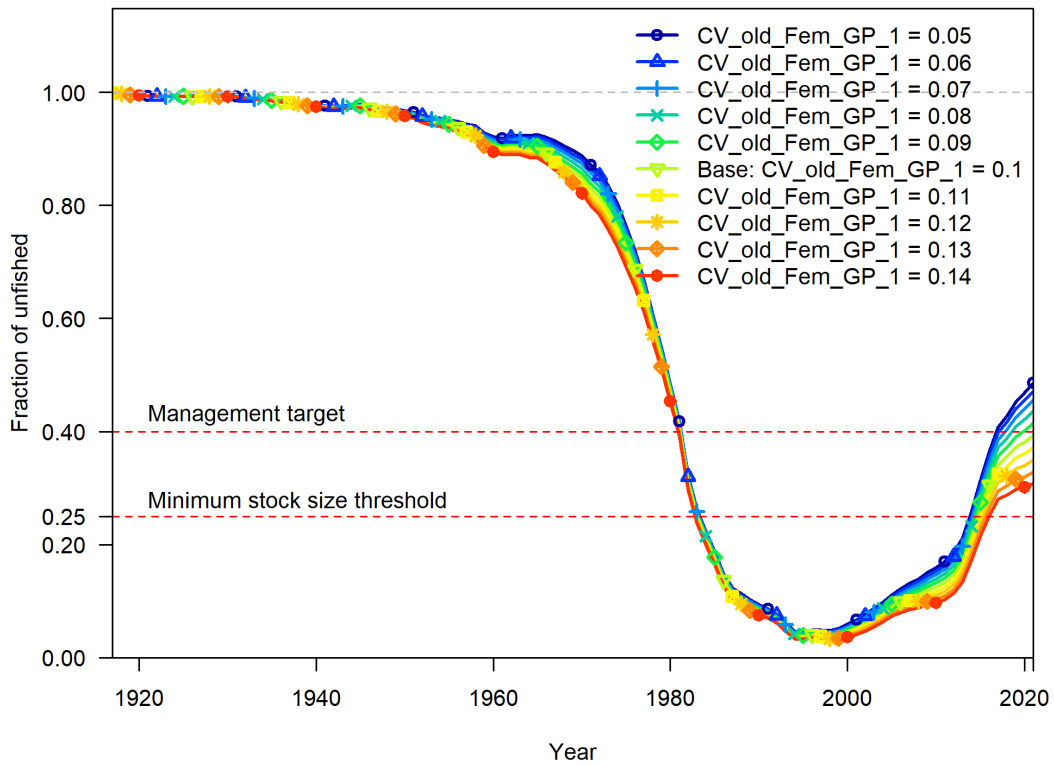




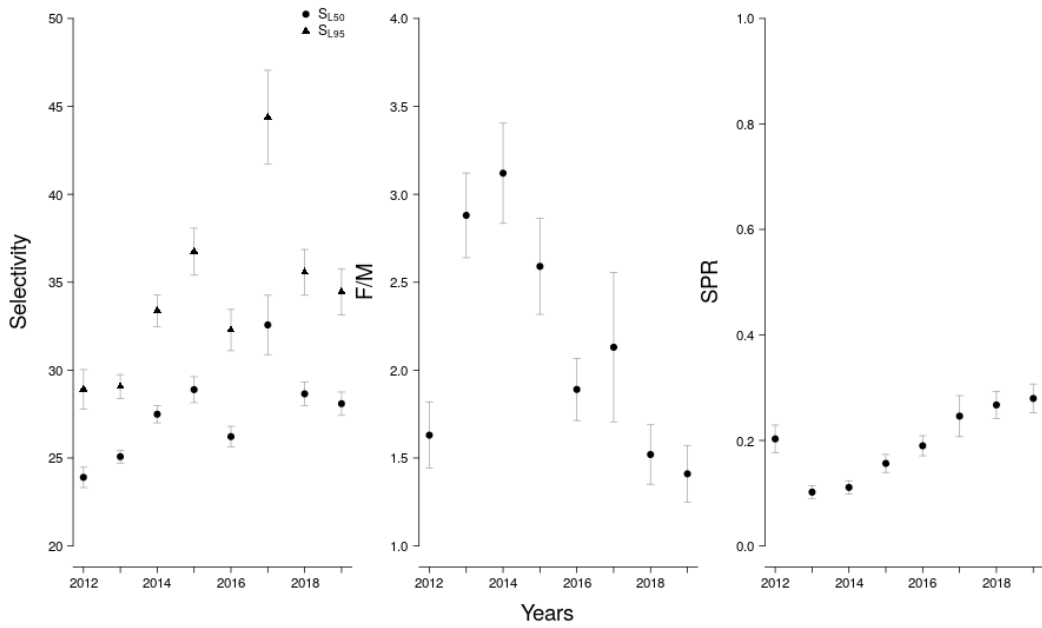
**Figure 48:** Change in the negative log-likelihood across a range of female coefficient of variation for older ages.



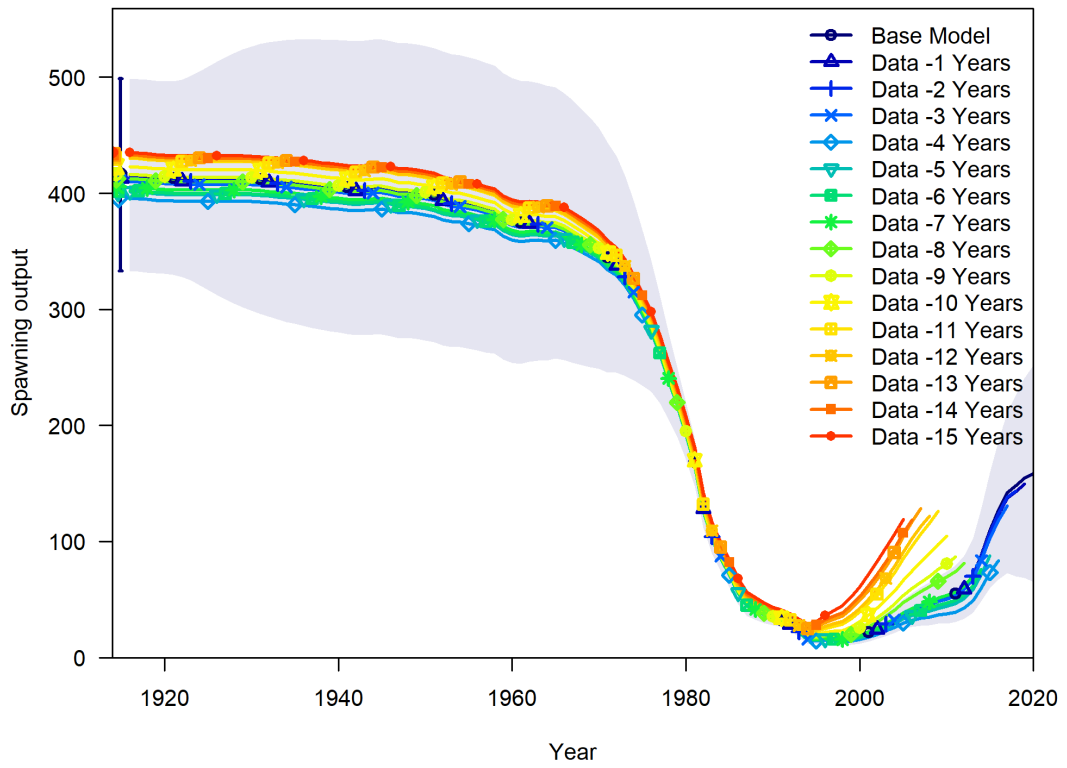
**Figure 49:** Change in the estimate of spawning output across a range of female coefficient of variation for older ages.



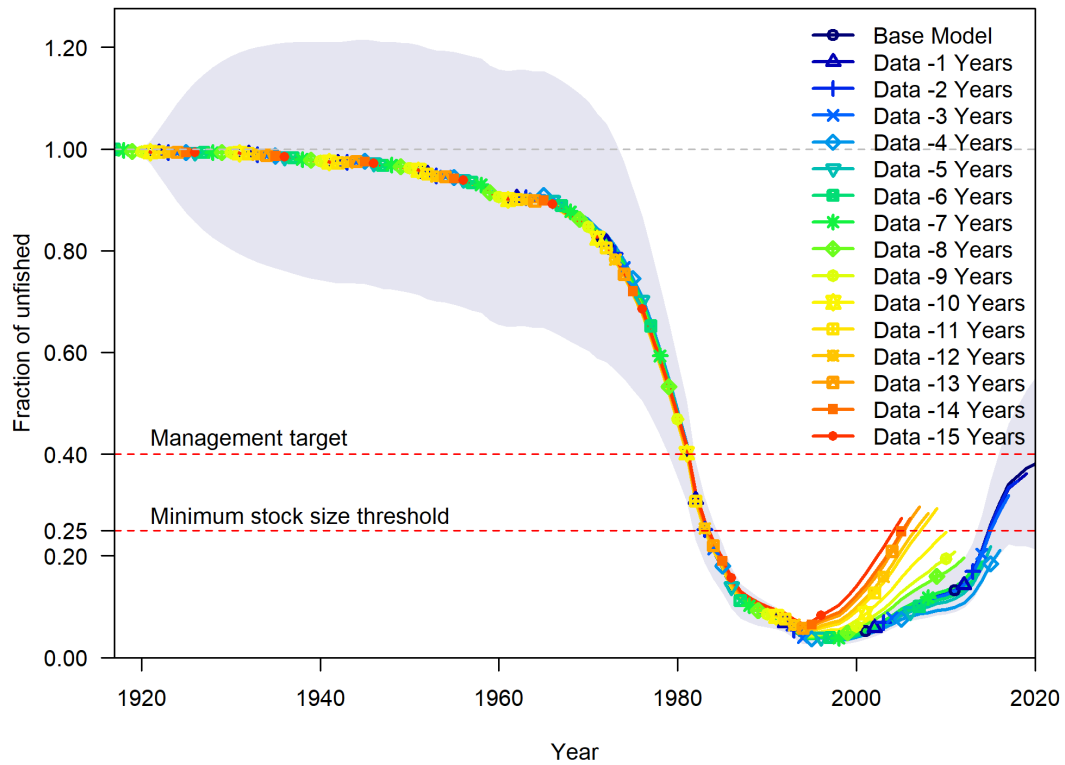
**Figure 50:** Change in the estimate of fraction unfished across a range of female coefficient of variation for older ages.



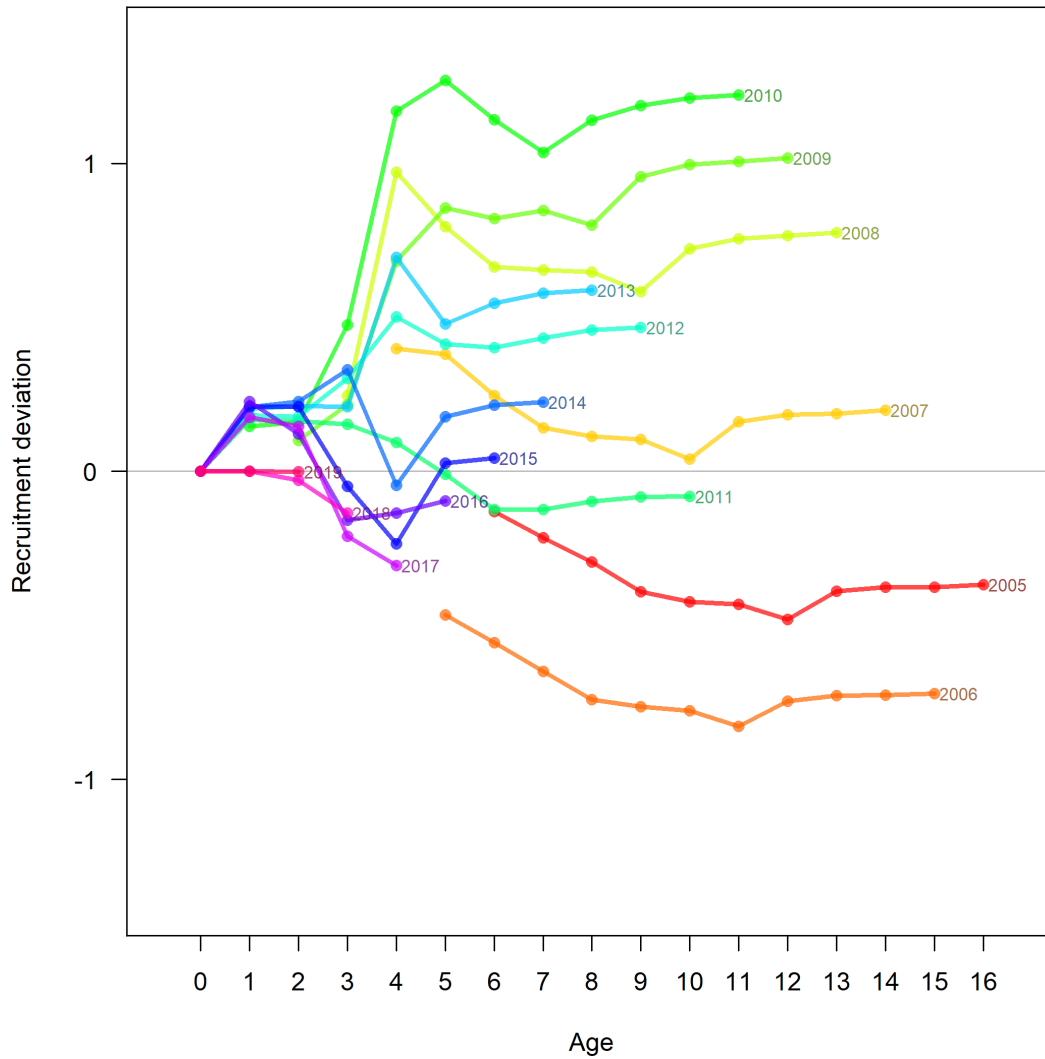
**Figure 51:** LB-SPR yearly estimates of selectivity, the ratio of fishing intensity to natural mortality (F/M), and annual spawner-per-recruit (SPR) values.



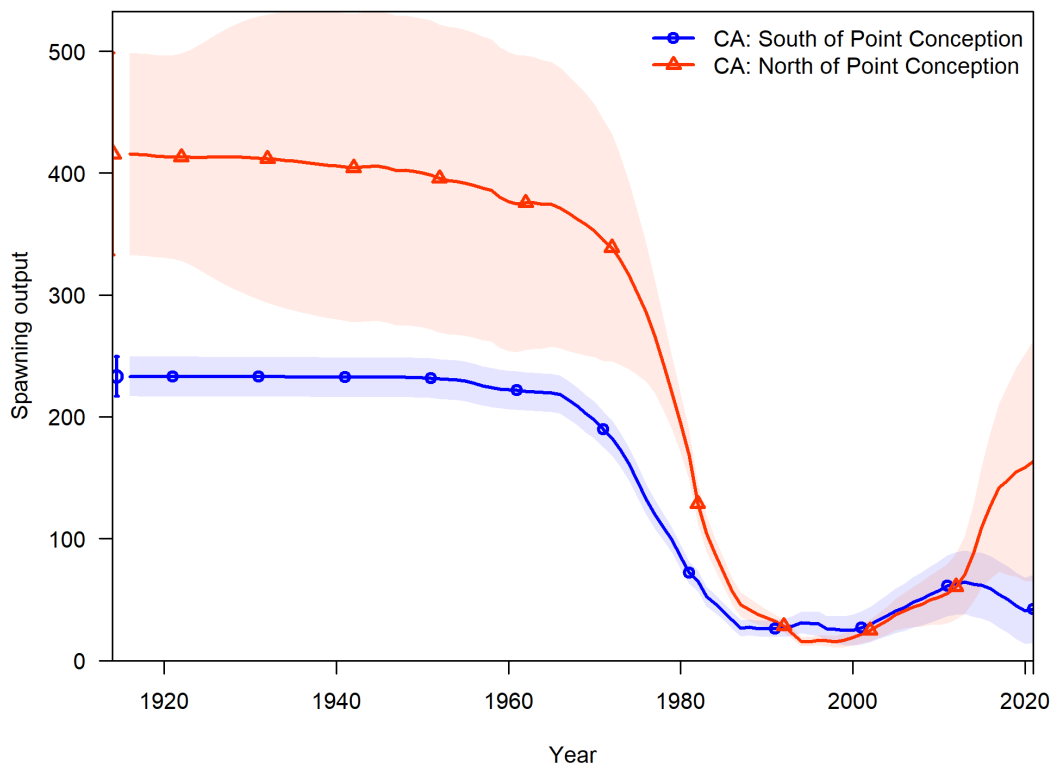
**Figure 52:** Change in the estimate of spawning output when the most recent 10 years of data are removed sequentially.



**Figure 53:** Change in the estimate of fraction unfished when the most recent 10 years of data are removed sequentially.

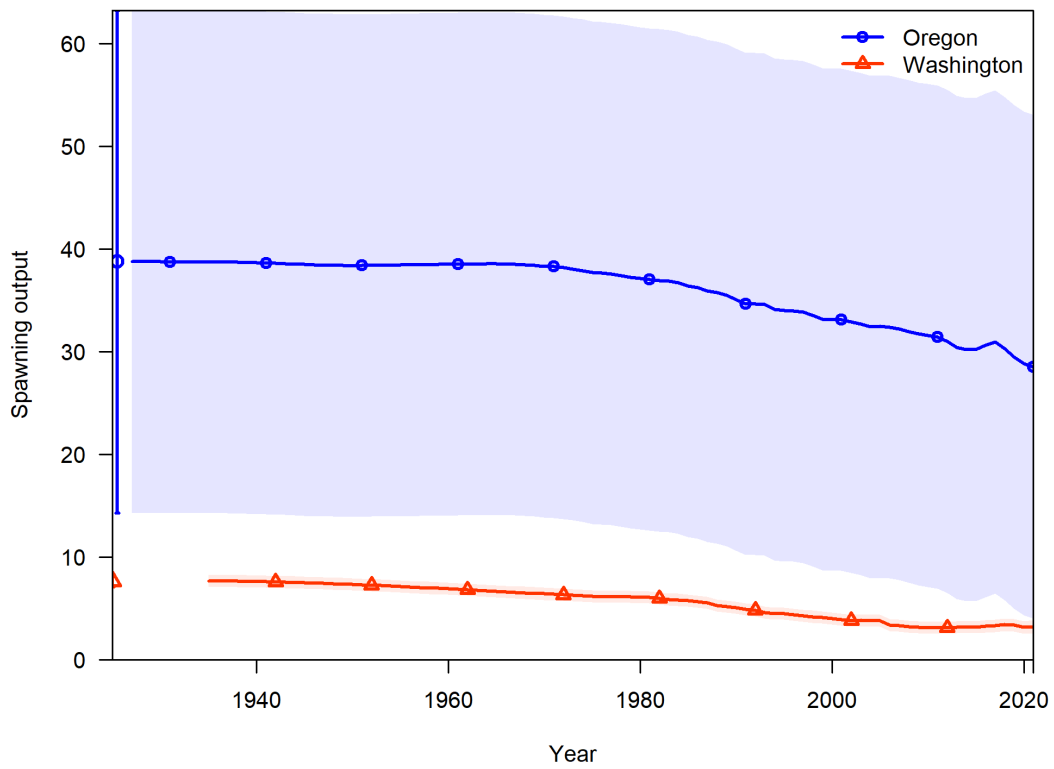


**Figure 54:** The change in estimated recruitment deviations by year as additional years of data are removed during a retrospective run.

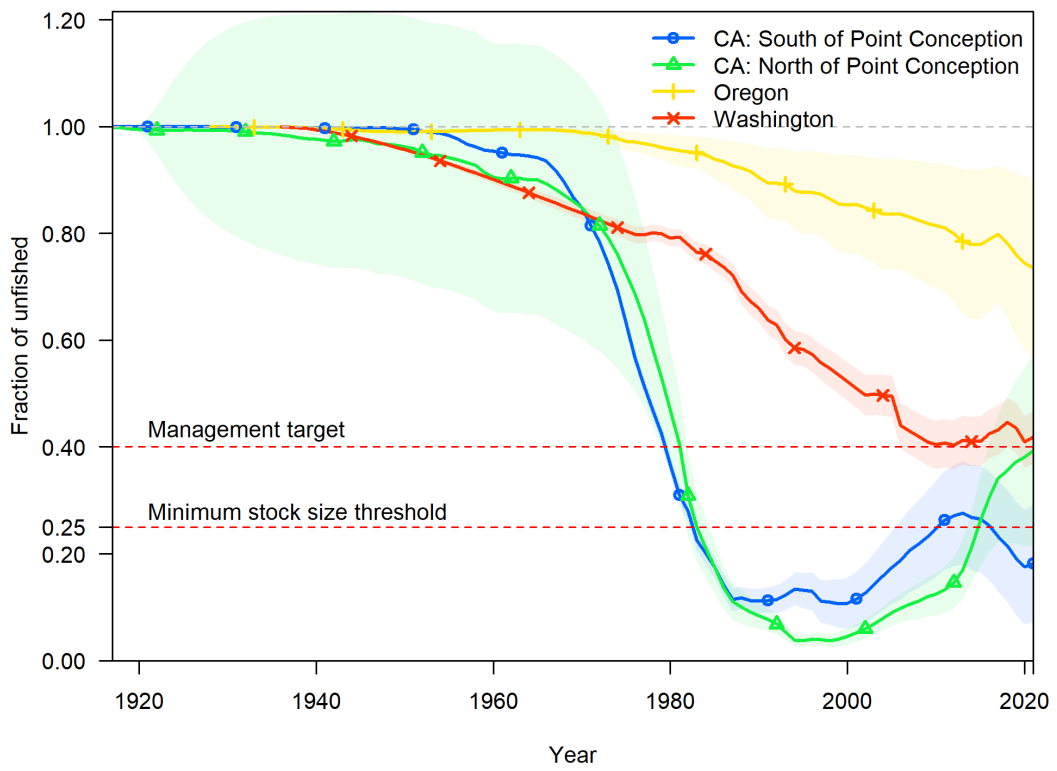


**Figure 55:** Estimated spawning output time series for the California stocks north and south of Point Conception.

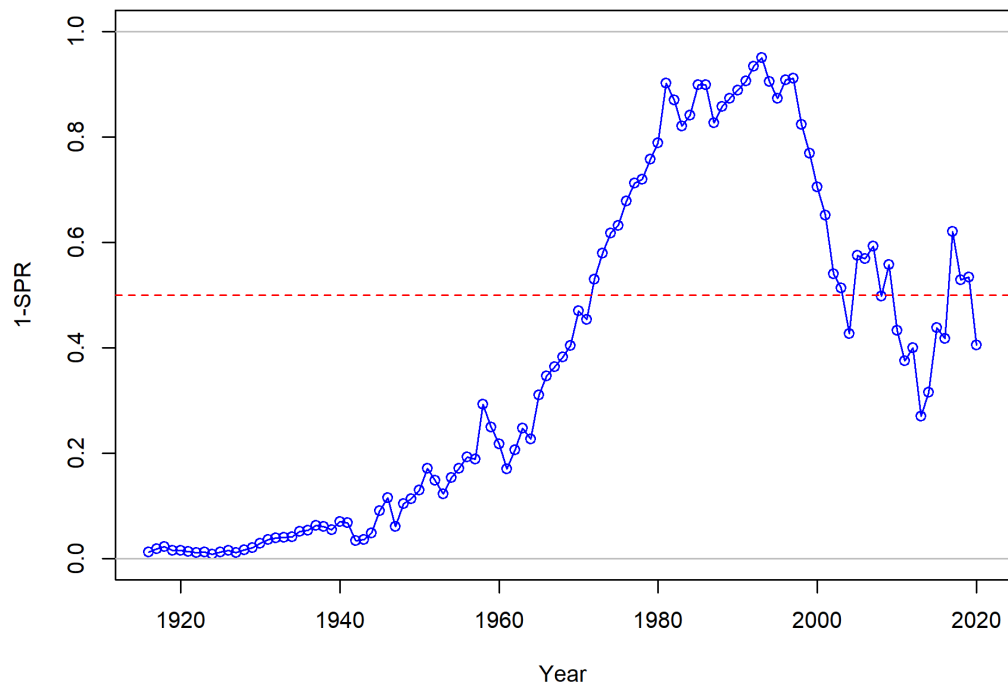




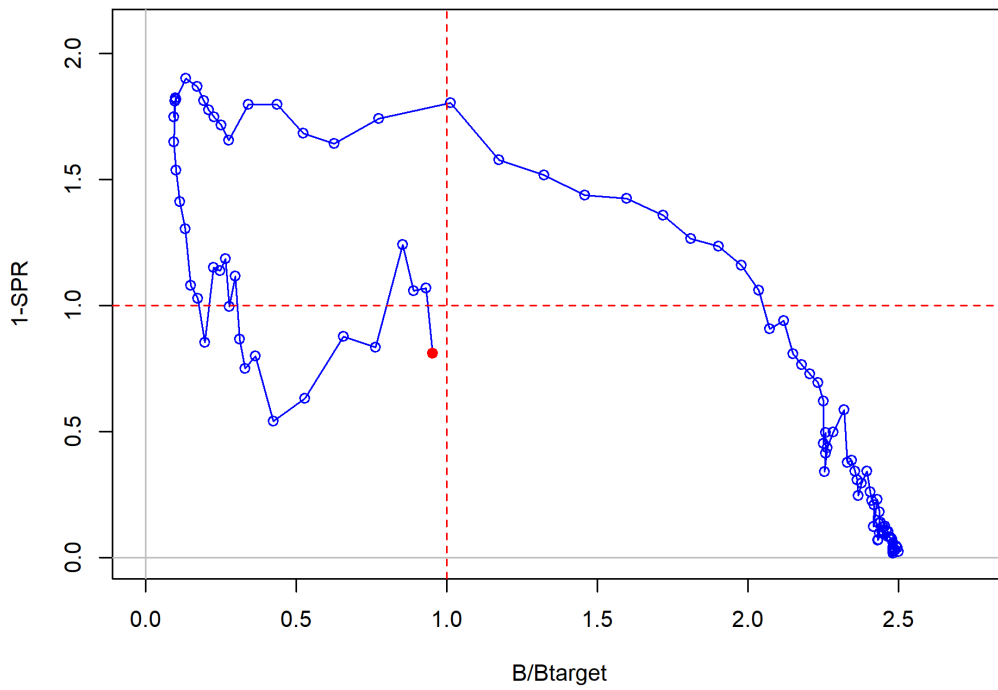
**Figure 56:** Estimated spawning output time series for the stocks off the Oregon and Washington coast.



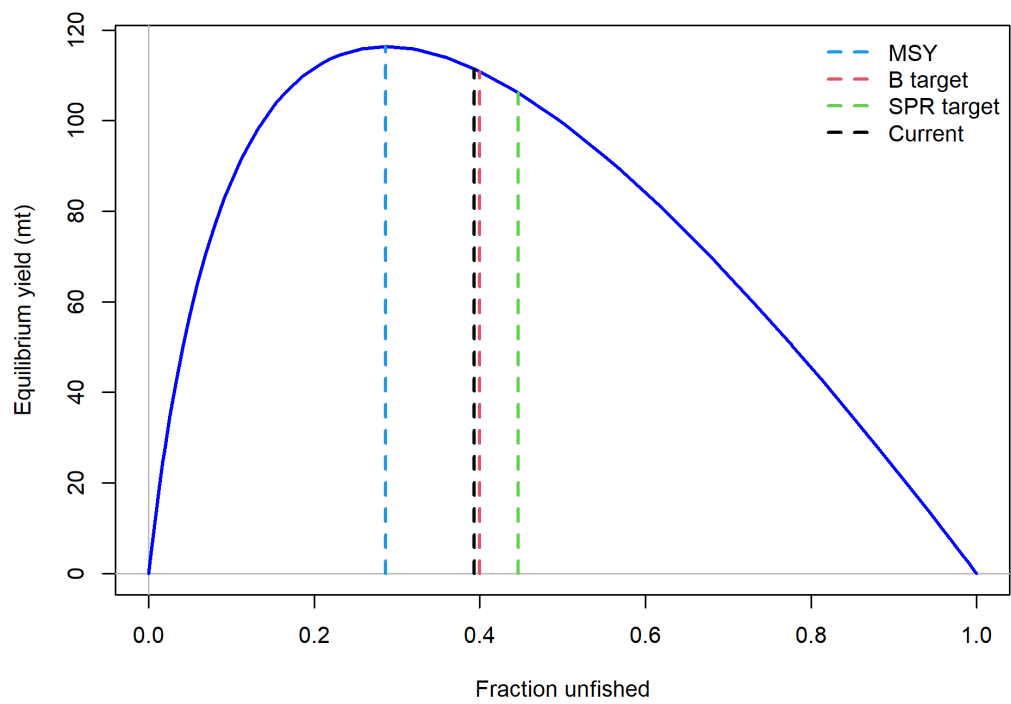
**Figure 57:** Estimated fraction unfished time series for all West Coast stocks.



**Figure 58:** Estimated 1 - relative spawning ratio (SPR) by year.



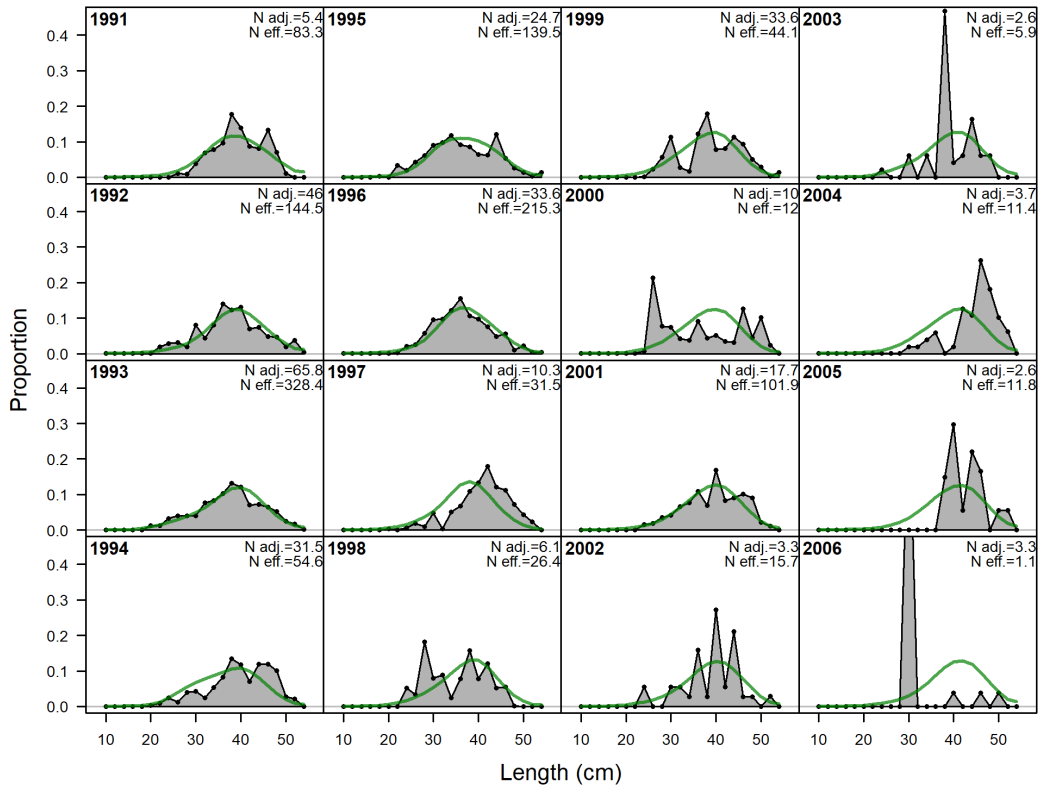
**Figure 59:** Phase plot of the relative biomass (also referred to as fraction unfished) versus the SPR ratio where each point represents the biomass ratio at the start of the year and the relative fishing intensity in that same year.



**Figure 60:** 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 61:** Length comps, whole catch, CA\_N\_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.

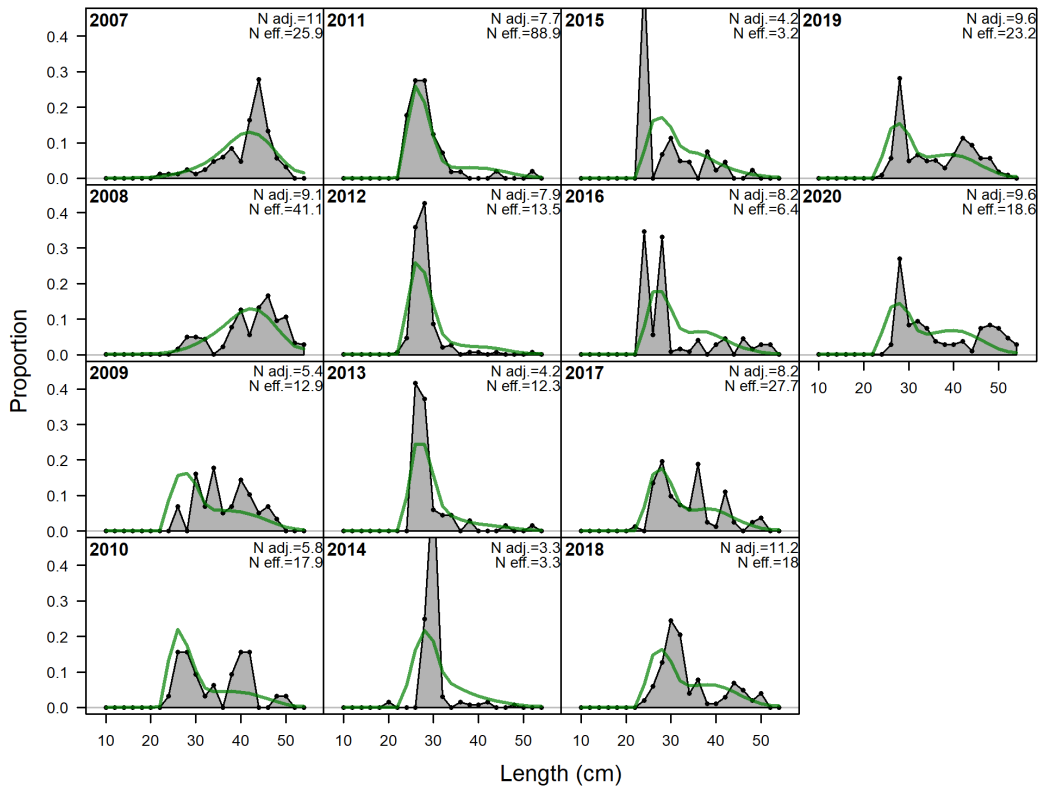
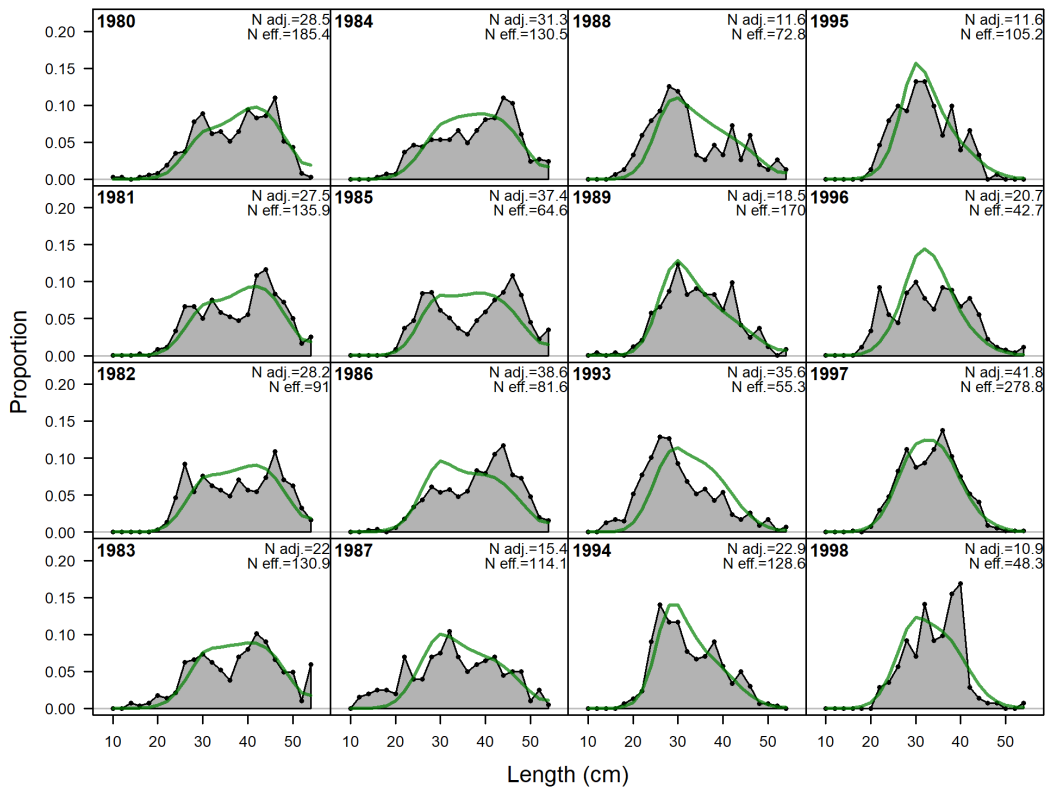


Figure 62: Length comps, whole catch, CA\_N\_Commercial (plot 2 of 2).



**Figure 63:** Length comps, whole catch, CA\_N\_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.



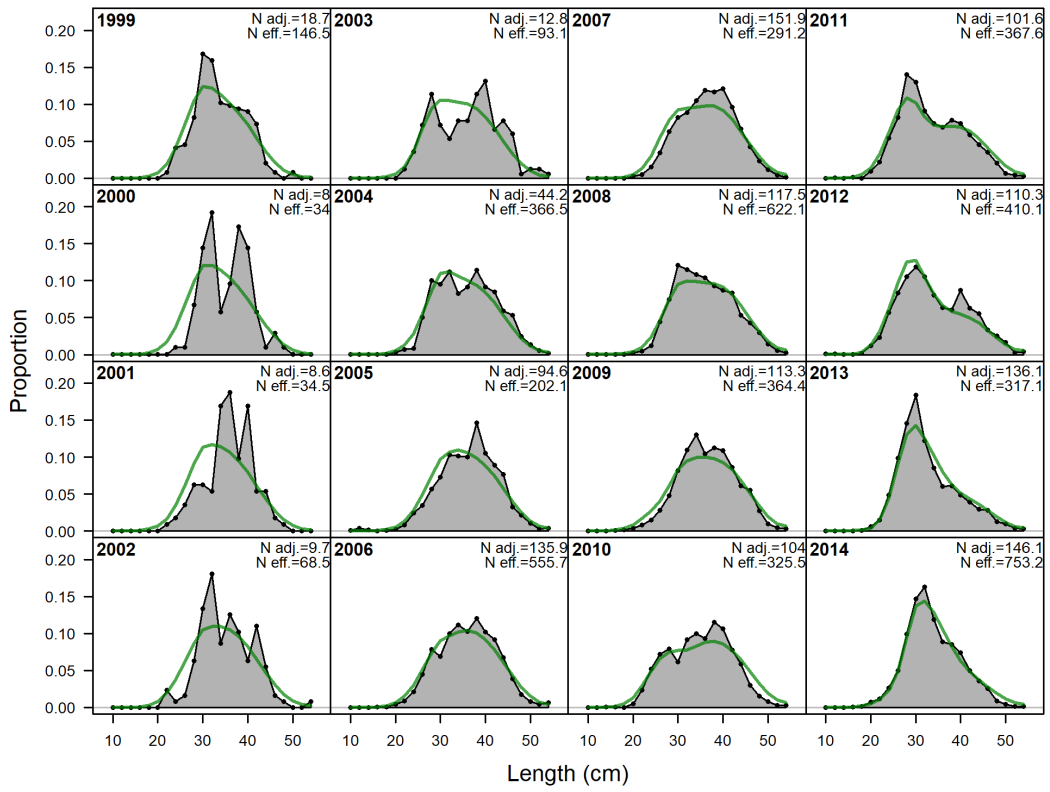
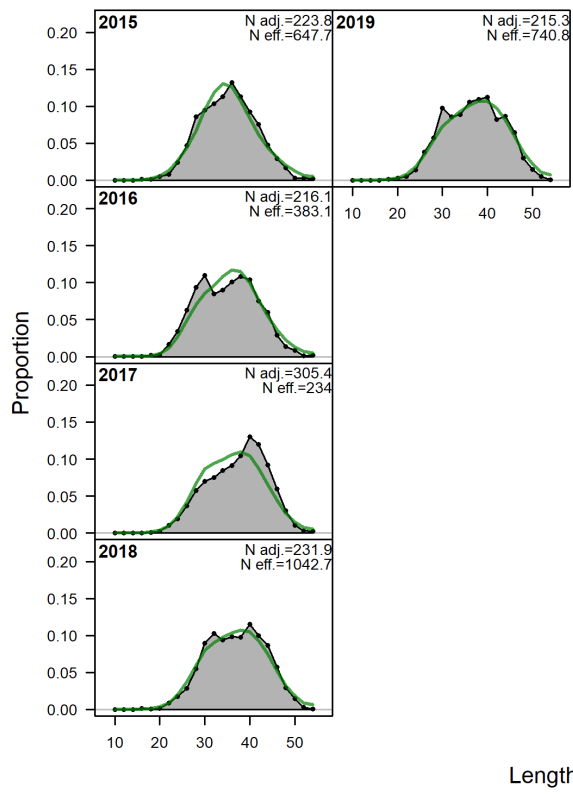


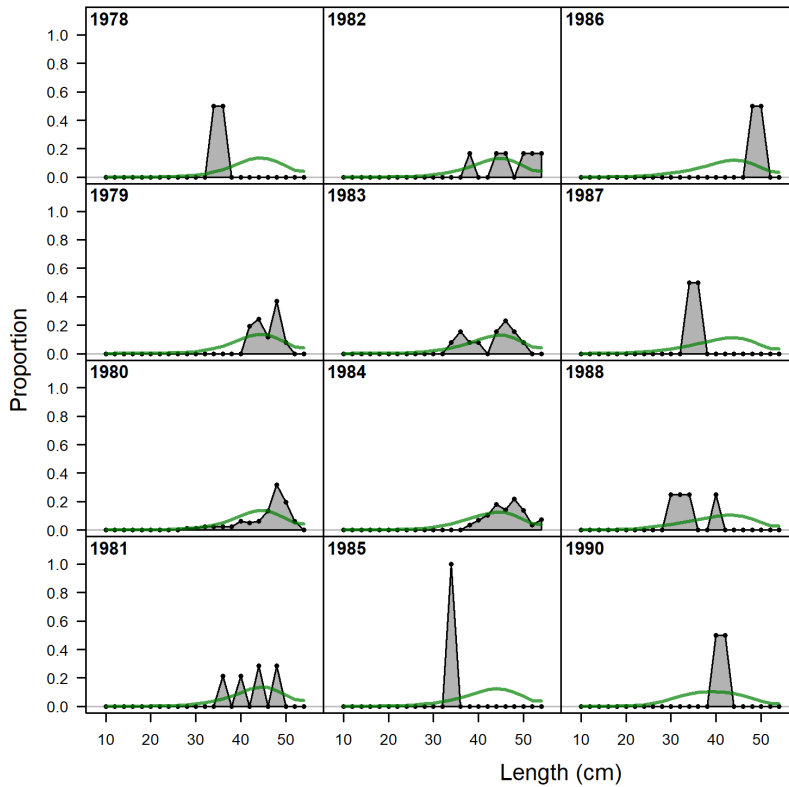
Figure 64: Length comps, whole catch, CA\_N\_Recreational (plot 2 of 3).



**Figure 65:** Length comps, whole catch, CA\_N\_Recreational (plot 3 of 3).

## 9.2 Implied Fit to Commercial ‘Ghost’ Fleet Length Data

The ‘ghost’ fleet data consist of commercial length samples collected prior to 1999 which were not used in the base model due to low sample sizes which resulted in noisy length distributions.



**Figure 66:** Ghost length comps, whole catch, CA\_N\_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.

## 9.3 Allocation of Yield Among Federal Management Areas

The 2021 northern California base model for copper rockfish represents U.S. waters between 34° 27’ N. lat. and the California-Oregon border 42° 00’ N. lat. Federal management of the nearshore rockfish complex, that includes copper rockfish, is based on areas north and south of 40° 10’ N. lat. Therefore, yield estimates from the California base model must be divided between the norther and southern management areas in order to determine the contribution of copper rockfish to the nearshore rockfish overfishing limit (OFL).

Ideally, allocation by area would be based on calculations of habitat by area and/or estimates of biomass by area. Unfortunately neither of these estimates were available for copper rockfish to inform allocations by area. In lieu of this information, historical catches by each region were used to recommend allocation percents by area. Total removals from the recreational and commercial fleets between 2005 - 2020 by areas north and south of 40° 10' N. lat. were calculated. During this period a total of 3.9 percent of all removals were from areas north of 40° 10' N. lat. Based on this the recommend allocations of the OFLs from the northern California model 3.9 percent should be allocated to the north nearshore rockfish complex with 96.1 percent to the southern complex.

#### **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 overlaid 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 19) and south of Point Conception (Table 20). 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 67) and various regions along the state in Figures 68 - 71.

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 19:** 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

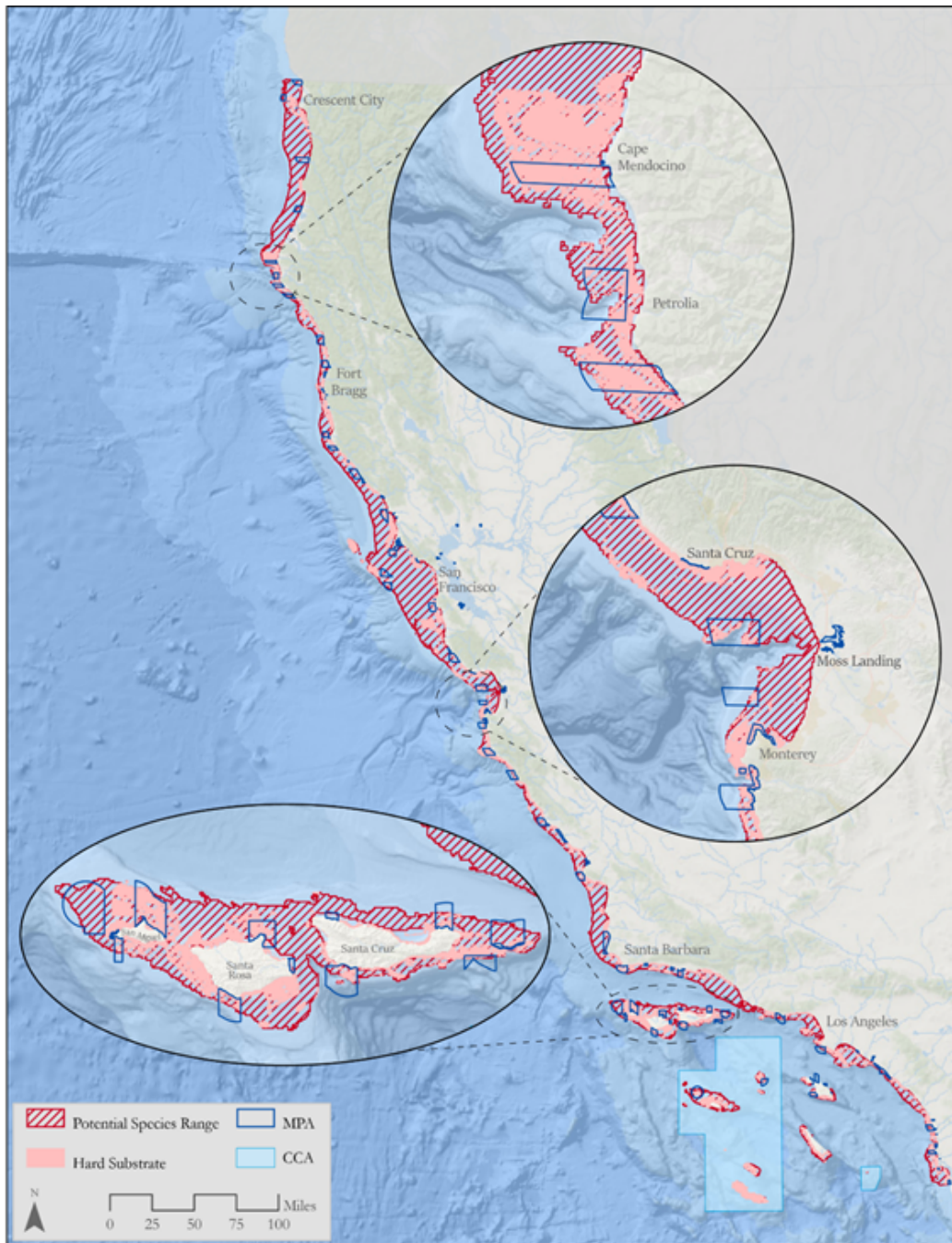
**Table 20:** Percent of rocky reef habitat within 100 meters in MPAs, RCAs, CCAs closed to fishing for groundfish and waters open to fishing in California south of Point Conception

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

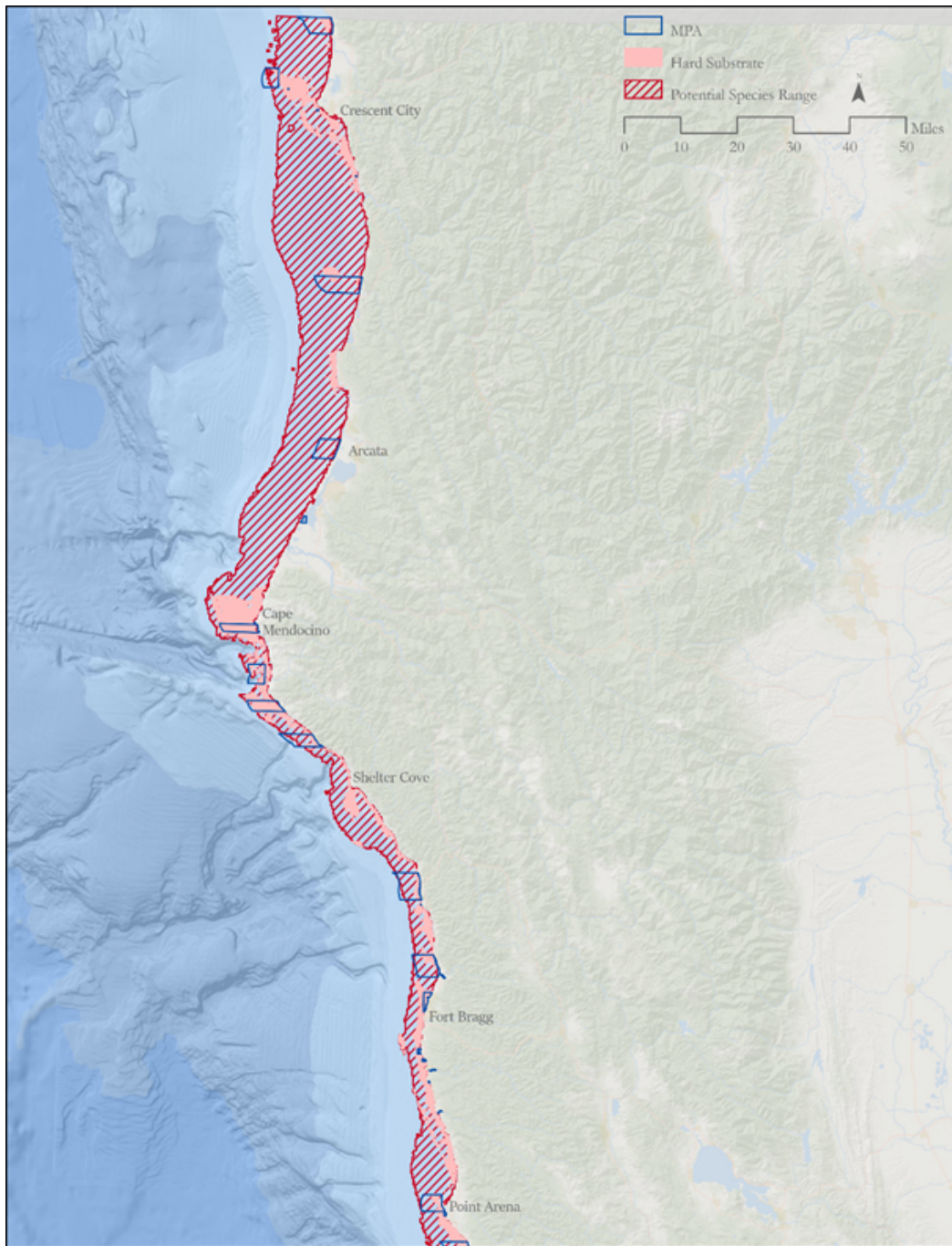


**Table 20:** Percent of rocky reef habitat within 100 meters in MPAs, RCAs, CCAs closed to fishing for groundfish and waters open to fishing in California south of Point Conception (*continued*)

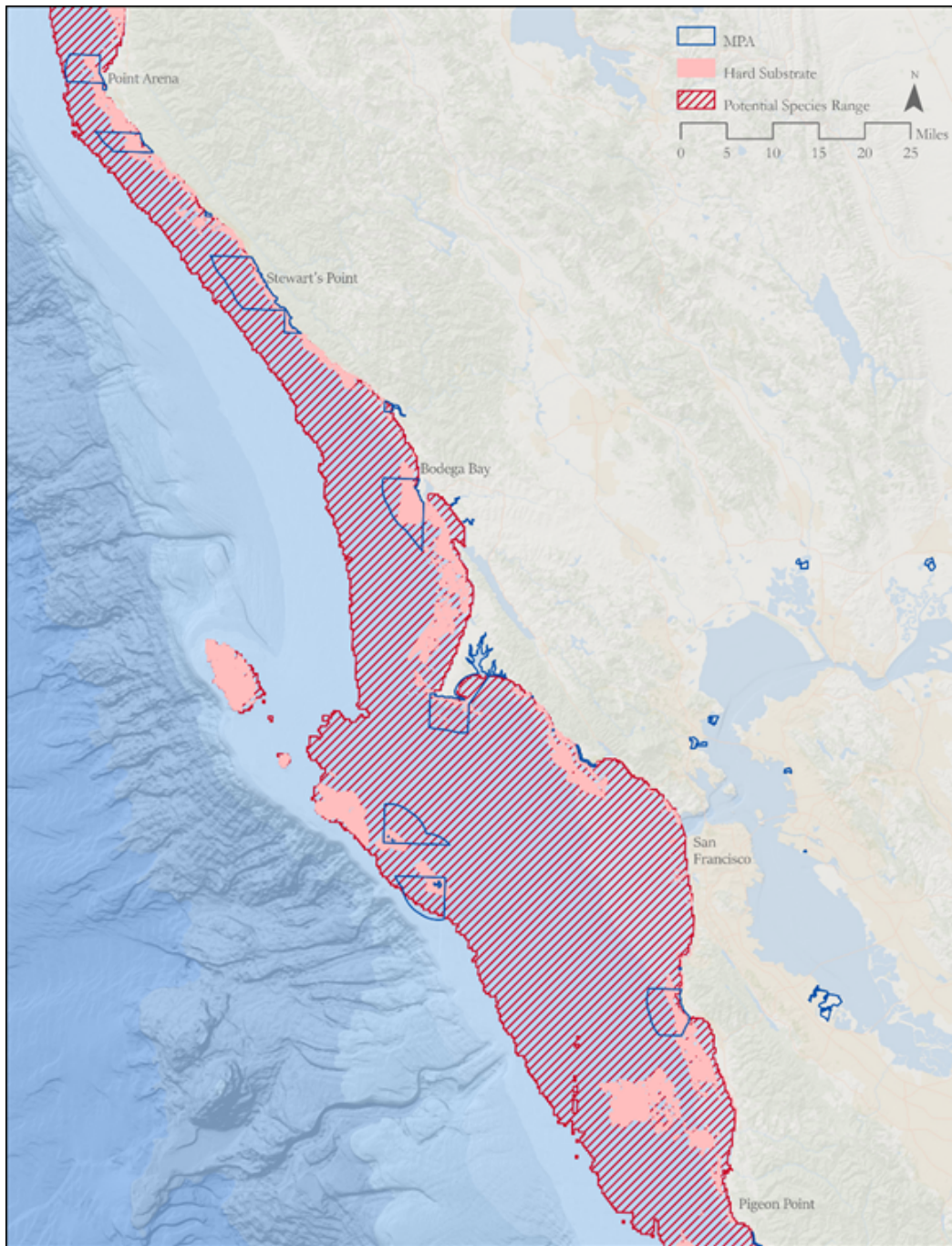
Year	Percent Protected by MPA	Percent Protected by RCA	Percent Protected by CCA	Percent Open to Fishing
2010	0.04	0.10	0.34	0.52
2011	0.04	0.10	0.34	0.52
2012	0.08	0.10	0.34	0.48
2013	0.08	0.10	0.34	0.48
2014	0.08	0.10	0.34	0.48
2015	0.08	0.10	0.34	0.48
2016	0.08	0.10	0.34	0.48
2017	0.08	0.10	0.34	0.48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



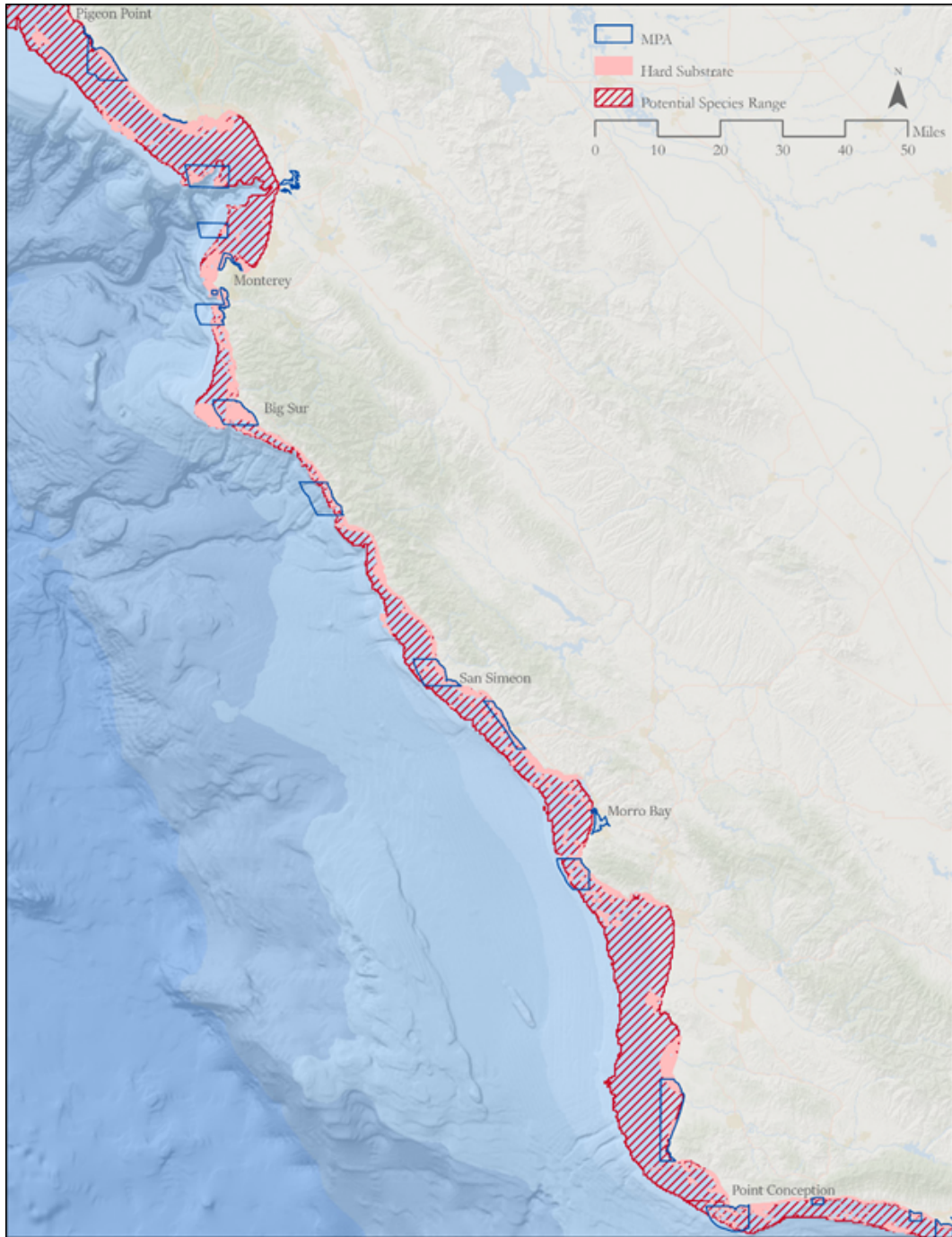
**Figure 67:** Copper and quillback rockfish potential depth range off California in red hatched polygon, hard substrate occurring within the potential range in pink, MPAs in dark blue outline, and the CCAs in light blue.



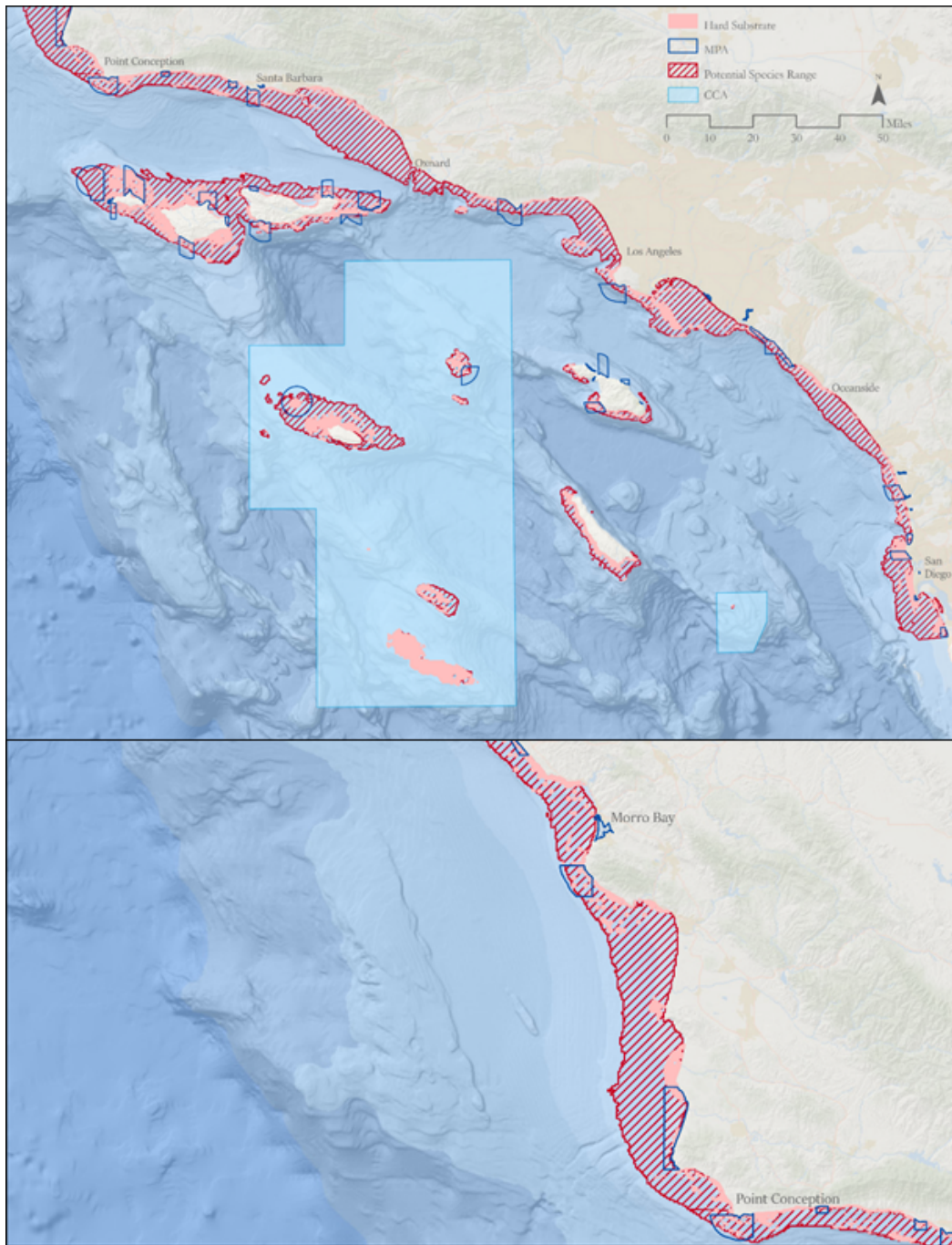
**Figure 68:** Copper and quillback rockfish potential depth range in red hatched polygon, hard substrate occurring within the potential range in pink and MPAs in dark blue outline between the Oregon/California border and Point Arena, California.



**Figure 69:** 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 70:** 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 71:** . 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

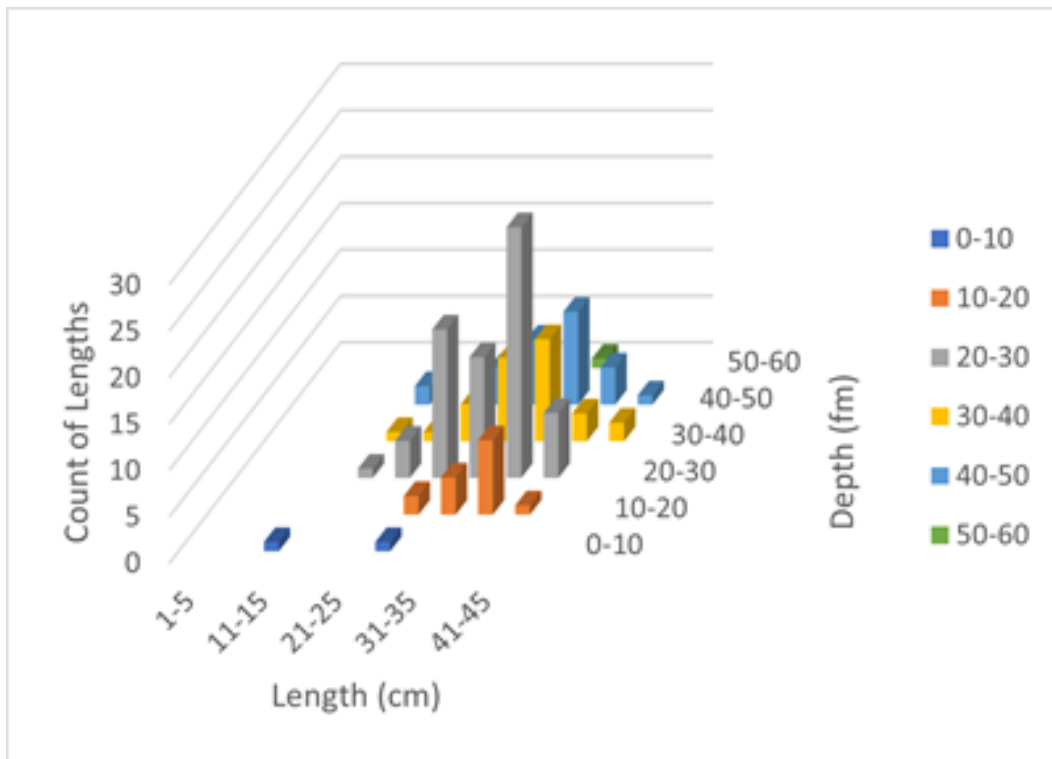
From 2013-2015, the CDFW in collaboration with Marine Applied Research and Exploration (MARE), conducted Remote Operated Vehicle (ROV) surveys along the full length of the California coastline inside MPAs and in reference sites outside for comparison. Density estimates were produced from the ratio of 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. Depth restrictions north of Point Conception varied from 20 to 40 fm for most of the last two decades. Densities were highest in the depths of 10 to 50 fm. Therefore, fish occur at depths greater than those that are open to fishing, indicating depth restrictions offer protection of copper rockfish biomass (Table 21).

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 distribution for copper rockfish sampled by the ROV in reference locations open to fishing north of Point Conception show the majority of observations occurring between 10 - 30 fathoms with peak observations between 31 - 35 cm (Figure 72). 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 73). A reduced range of sizes, percent of copper rockfish by length bin, were observed across depths in open areas (Figure 74) versus closed areas (Figure 75).

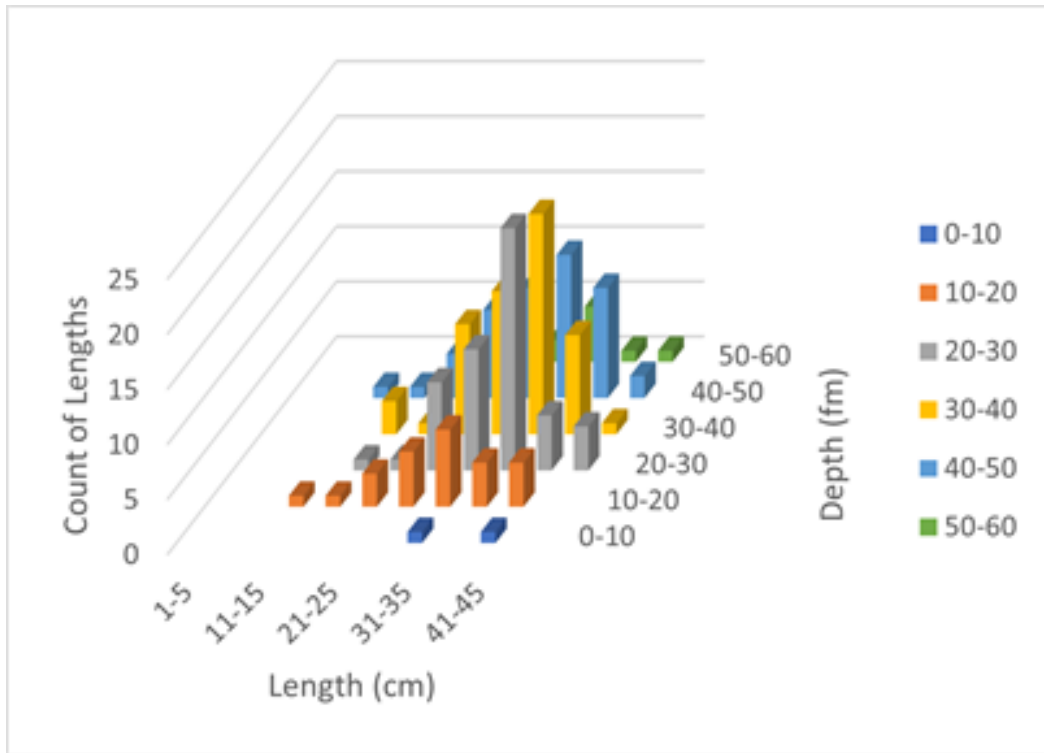
**Table 21:** Counts of fish, areas surveyed by the ROV, and density.

Depth (fm)	Observed Area (m2)	Copper Rockfish Observed	Copper Rockfish Density (fish/m2)
0-10	2905	0	0.0000
10-20	124611	44	0.0004
20-30	106708	84	0.0008
30-40	86149	76	0.0009
40-50	49896	68	0.0014
50-60	16972	18	0.0011
60-70	1379	0	0.0000
70-80	970	0	0.0000
80-90	947	0	0.0000
90-100	1257	0	0.0000
100-110	608	0	0.0000
110-120	696	0	0.0000
120-130	415	0	0.0000
130-140	777	0	0.0000
140-150	1633	0	0.0000
150-160	908	0	0.0000
160-170	860	0	0.0000
170-180	1268	0	0.0000
180-190	912	0	0.0000
190-200	735	0	0.0000
200-210	604	0	0.0000
210-220	167	0	0.0000
220-230	54	0	0.0000
230-240	100	0	0.0000
Total	401535	209	-

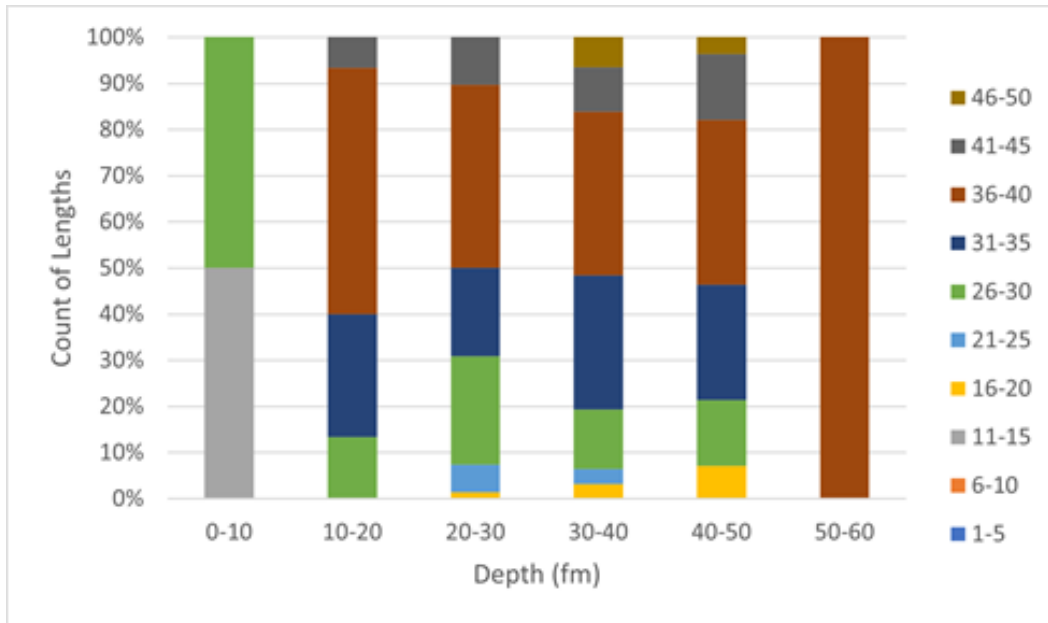




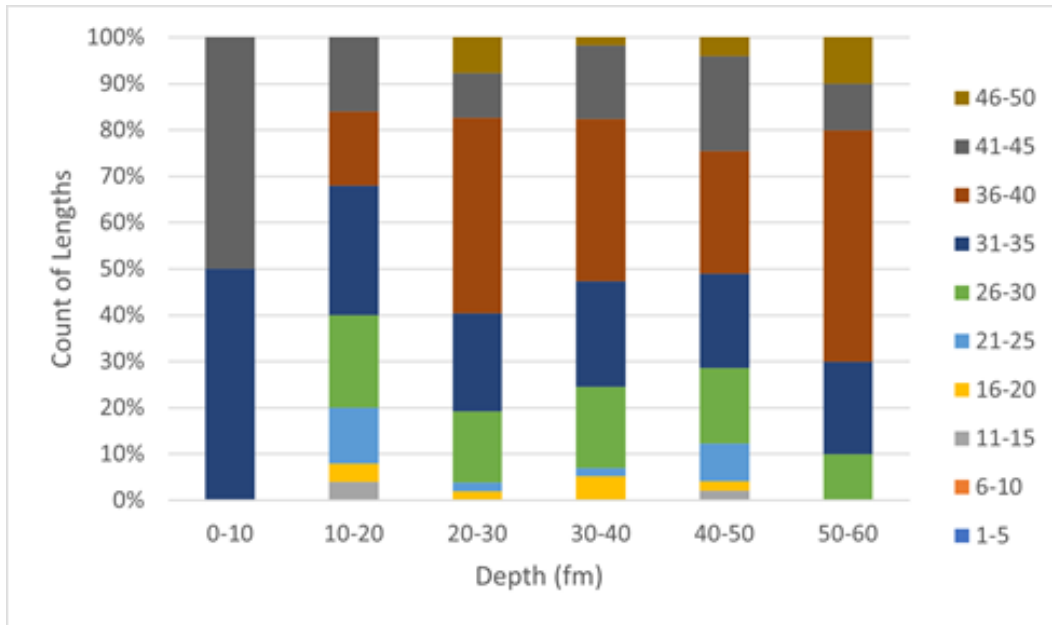
**Figure 72:** Length frequency distribution in each 10 fm depth bin for copper rockfish sampled by the ROV in reference locations open to fishing north of Point Conception.



**Figure 73:** 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.

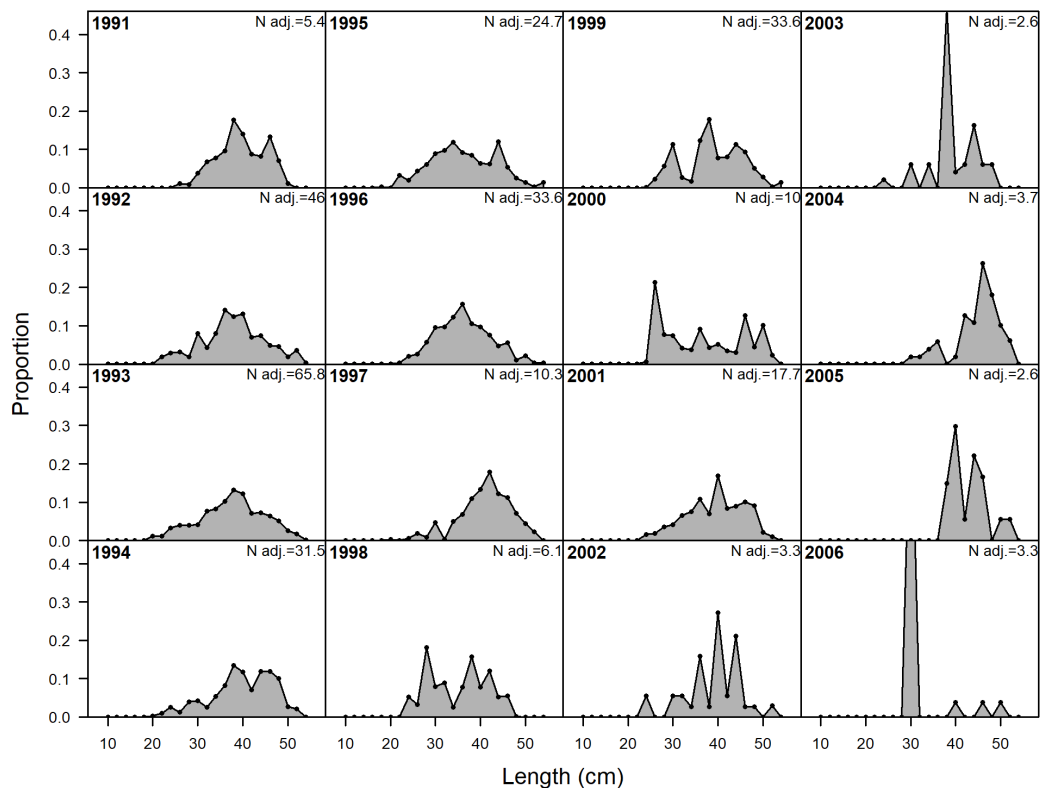


**Figure 74:** Percent composition of copper rockfish length frequency in 5 cm size classes for each 10 fm depth bin from ROV observations north of Point Conception in reference locations where where fishing for groundfish is allowed.

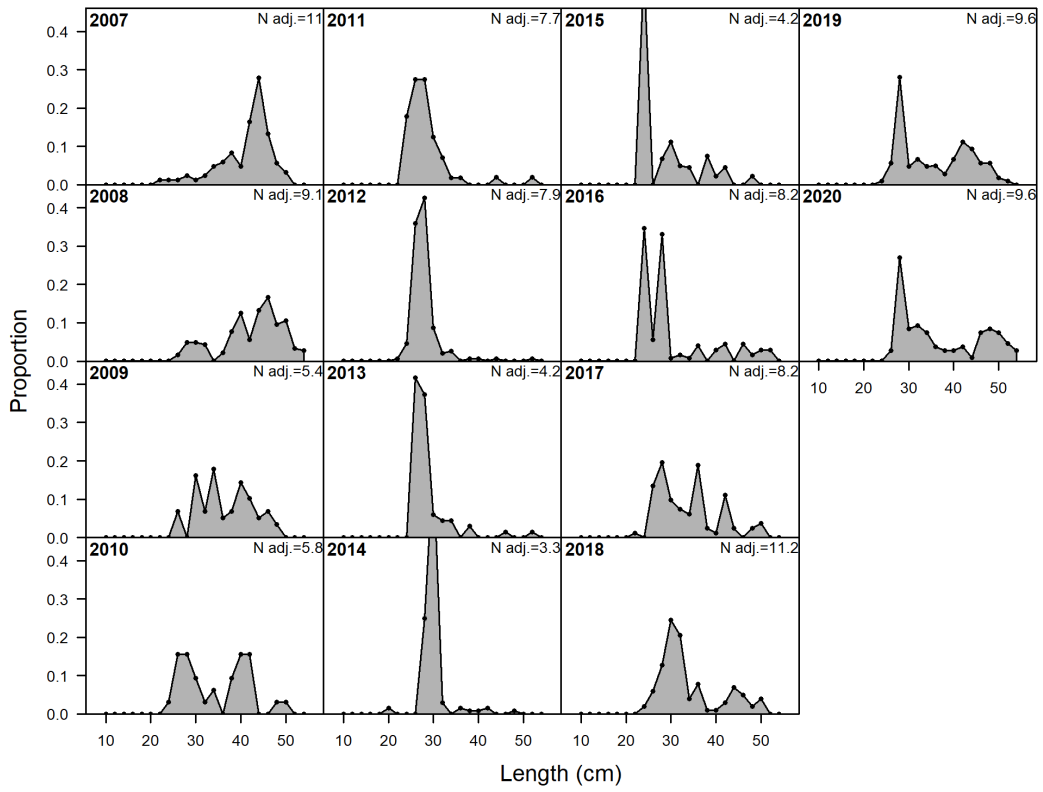


**Figure 75:** Percent composition of copper rockfish length frequency in 5 cm size classes for each 10 fm depth bin from ROV observations north of Point Conception in marine protected areas where where fishing for groundfish is prohibited.

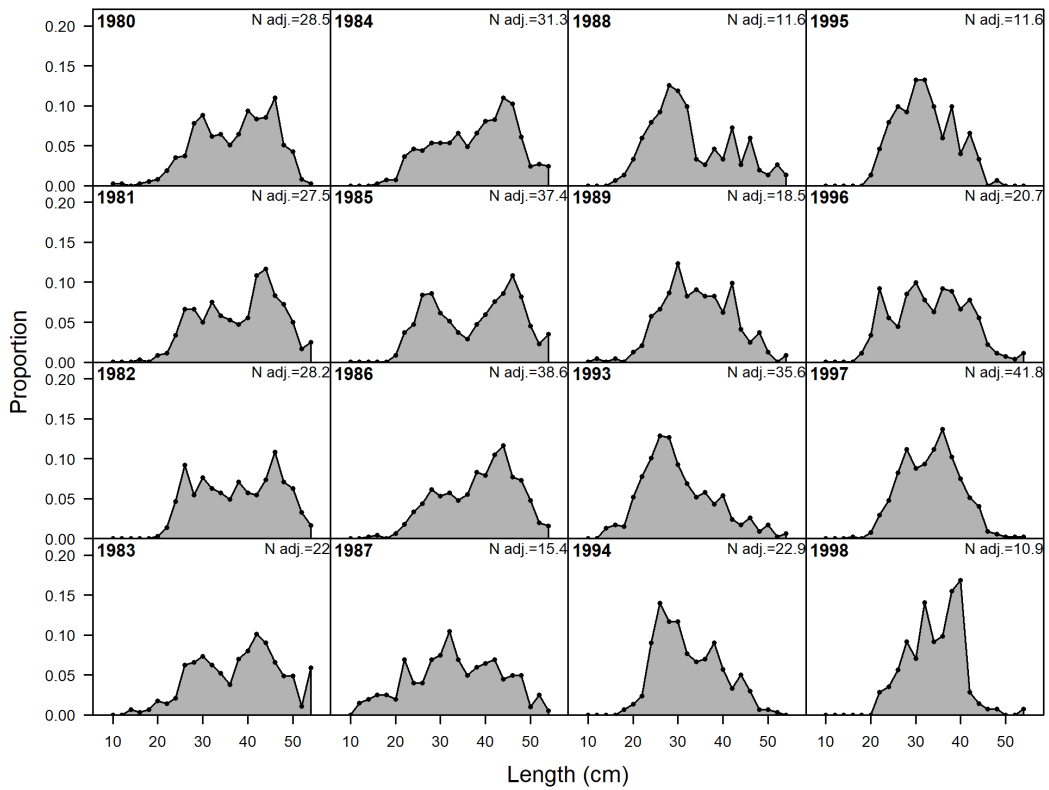
## 9.7 Annual Length Composition Data



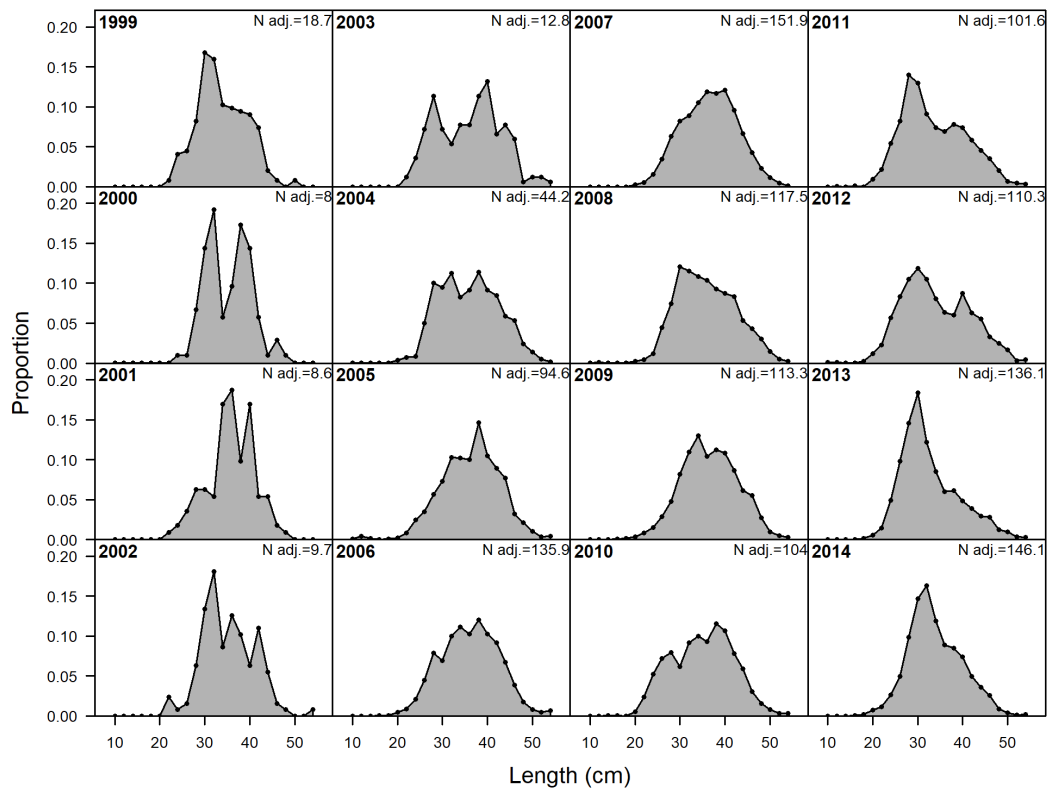
**Figure 76:** Length comp data, whole catch, CA\_N\_Commercial (plot 1 of 2): 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.



**Figure 77:** Length comp data, whole catch, CA\_N\_Commercial (plot 2 of 2).

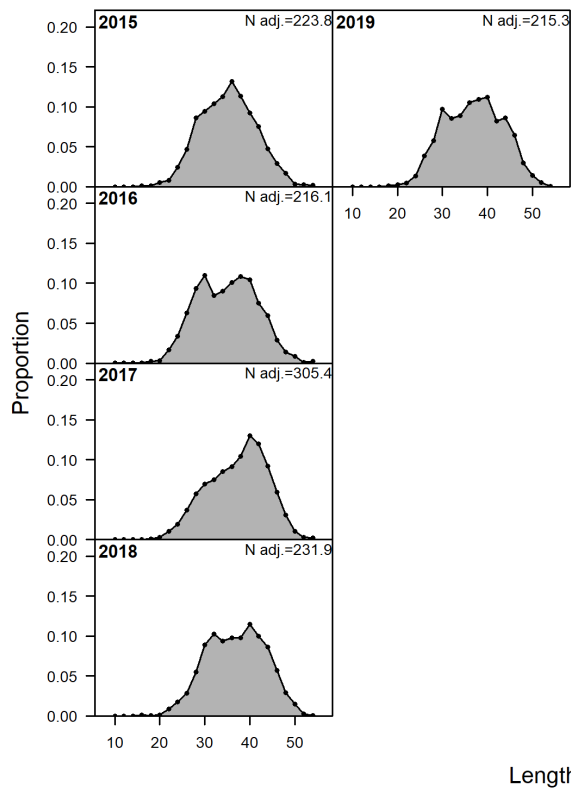


**Figure 78:** Length comp data, whole catch, CA\_N\_Recreational (plot 1 of 3); 'N adj.' is the input sample size after data-weighting adjustment. N eff. is the calculated effective sample size used in the McAllister-Iannelli tuning method.



**Figure 79:** Length comp data, whole catch, CA\_N\_Recreational (plot 2 of 3).





**Figure 80:** Length comp data, whole catch, CA\_N\_Recreational (plot 3 of 3).