DRAFT Status of quillback rockfish (*Sebastes maliger*) in U.S. waters off the coast of California in 2021 using catch and length data

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1 Introduction

1.1 Basic Information

This assessment reports the status of quillback rockfish (*Sebastes maliger*) off the California coast using data through 2020.

The stock off the California coast was assessed as a separate stock from other populations off the U.S. West Coast based on the fairly sedentary nature of quillback rockfish (Hannah and Rankin 2011; Tolimieri et al. 2009), which likely limits movement of fish between California and Oregon. Additionally, the exploitation history and magnitude of removals off the California coast differ from those in Oregon. Although the population of quillback rockfish in California is assessed statewide, given the range of quillback rockfish, this assessment is primarily of quillback rockfish north of Point Conception. Catches of quillback rockfish south of Point Conception were rare, however, where available, these data were used within this assessment.

1.2 Life History

Quillback rockfish are a medium- to large-sized nearshore rockfish found from southern California to the Gulf of Alaska (Love, Yoklavich, and Thorsteinson 2002). Off the U.S. West Coast quillback rockfish are primarily located north of central California, with few observations south of Point Conception. Quillback rockfish have historically been part of both commercial and recreational fisheries throughout their range.

Quillback rockfish are found in waters less than 274 meters in depth in nearshore kelp forests and rocky habitat (Love, Yoklavich, and Thorsteinson 2002). The diets of quillback rockfish consist primarily of benthic and pelagic crustaceans and fish (Murie 1995). The body coloring of adult quillback rockfish is brown with yellow to orange blotching and light-colored dorsal saddle patches (Love, Yoklavich, and Thorsteinson 2002). As their name suggests, quillback rockfish have long dorsal fin spines.

Limited studies have evaluated genetic variation in quillback rockfish across the U.S. West Coast. Genetic work has revealed significant differences between Puget Sound and coastal stocks of quillback rockfish (Seeb 1998; Stout et al. 2001), however Seeb (1998) did not find significant differentiation in populations of quillback rockfish between coastal Washington and Alaska. Significant population sub-division along the U.S. West Coast has been detected for the closely related, and more well-studied copper rockfish (*Sebastes caurinus*), indicating limited oceanographic exchange among geographically proximate locations (Seeb 1998; Buonaccorsi et al. 2002; Johansson et al. 2008). High site-fidelity (Hannah and Rankin 2011) and relatively small home ranges (Tolimieri et al. 2009) for quillback rockfish suggests patterns of isolation-by-distance as found for other rockfish. Quillback rockfish are a long-lived rockfish estimated to live up to 95 years (Love, Yoklavich, and Thorsteinson 2002; Yamanako and Lacko 2001). Quillback rockfish was determined to have a vulnerability (V = 2.22) of major concern 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 characterized by how the stock is likely affected by the fishery in question.

1.3 Historical and Current Fishery Information

Commercial

Quillback rockfish off the coast of California is caught in both the recreational and commercial fisheries. Recreational removals are the largest source of fishing mortality and represent approximately 70 percent of the total removals of quillback rockfish across all years (Table 1 and Figure 1). The majority of the commercial landings for quillback rockfish occurred between 1990 and 2008, and apart from 1945-1946, in 1984, and in the last four years, commercial landings for quillback rockfish have been less than 2 mt per year.

Prior to the development of the live-fish market in the 1980s, commercial catches of quillback rockfish were relatively low, and quillback rockfish were often landed dead for a relatively low ex-vessel price per pound. Most fish were caught using hook and line gear, though some were caught using traps, gill nets, and in some instances, trawl gear. Trawling within three miles of shore, where most of their habitat is found, has been prohibited since 1953, and gill nets were banned within three miles of shore in 1994. Whether from directed effort in the nearshore or as incidental catch while targeting other more valuable stocks such as lingcod, catches were below 0.5 mt from 1916 to 1980, with the exception of four of five years from 1944-1948.

With the development and expansion of the nearshore live-fish fishery during the late 1980s and early 1990s, new entrants in this open access fishery were drawn by premium ex-vessel prices 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, Larinto, and Key 2014). In 2003, the CDFW implemented a Nearshore Restricted Access Permit system, including a requirement of a Deeper Nearshore Fishery Species Permit to retain quillback rockfish, with the overall goal of reducing the number of participants to a more sustainable level, and with permit issuance based on historical landings history by a 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, seasonal closures in March and April and depth restrictions were implemented to address bycatch of overfished species and associated constraints from these species low ACLs.

As overfished shelf rockfish have rebuilt, resumed access to deeper depths has been allowed for Nearshore Permit holders as well as open access fisheries. While depth restrictions for waters deeper than 75 fm were implemented in 2019 south of Point Conception where yelloweye rockfish are uncommon, access in constrained north of Point Conception where, since 2003, depth restrictions at a range of depths starting between 20 and 40 fm, depending on the management area, have prohibited fishing in deeper waters (see separately provided Regulation History addendum).

As open access fisheries are allowed to retain shelf rockfish species co-occurring with nearshore rockfish species within the open depths, there is growing concern regarding increased encounters by non-permit holders and greater discard mortality from bycatch in deeper depths given that discard mortality is 100% in depths greater than 30 fm. This is of particular concern given both increased trip limits for shelf rockfish species and less constraining depth restrictions allow increased access to these species, as well as drive increased participation in the open access fishery, and therefore increased total mortality. In addition, coverage rates for observers from the WCGOP on small vessels participating in these fisheries provide limited data to inform bycatch rates. Under National Standard 8, reduction of bycatch is a priority and increased observer coverage rates would improve data on discards as the open access fishery for shelf rockfish expands.

Recreational

The California recreational fishery in the early part of the 1900s was focused on nearshore waters near ports, but expanded further from port and into deeper depths over time (Miller et al. 2014). Prior to the groundfish fishery disaster being declared in 2000, there was no time or areas closures for fishing groundfish. During this period, access to deeper depths led to effort being spread over a larger area and filled bag limits with a greater diversity of species from the shelf as well as the nearshore. This resulted in lower catch rates for nearshore rockfish relative to the period after 2000 when depth restrictions at a range of depths starting between 20 to 50 fm were put in place in various management areas north of Point Conception where quillback rockfish are commonly found. This shift of effort into the nearshore kept catch levels high for nearshore rockfish, including quillback rockfish (Figure 1), despite greatly reduced seasons. While the part of the stock that was available to the fishery in shallower depths was subject to higher fishing effort, the remainder of the stock (see Appendix A for estimates of density at depth based on remotely operated vehicle observations) was subject to reduced fishing effort during more than a decade of depth restrictions in waters deeper than 20 to 30 fm that were put in place to facilitate rebuilding of yelloweye rockfish.

As the yelloweye rockfish stock continues to rebuild, depth restrictions are expected to lessen, increasing access to more of the habitat for quillback rockfish. Once fishing is allowed in waters up to 60 fm, effort for quillback rockfish may decrease as overall effort shifts to the shelf and away from waters where quillback rockfish are most prevalent. Marine Protected Areas (MPAs) instituted between 2003 and 2012 now encompass 20-30% of the rocky reef habitat within 3 miles of shore in state waters (see Appendix B for details), and provide refugia to spawning stock in a network designed to seed areas outside the MPAs.

1.4 Summary of Management History and Performance

Quillback rockfish is managed by the Pacific Fishery Management Council (PFMC) as a part of the Minor Nearshore Rockfish North and Minor Nearshore Rockfish South complexes. The North and South complexes are split at N. 40° 10' Lat. off the U.S. West Coast. Each complex is managed based on a complex-level overfishing limit (OFL) and annual catch limit (ACL) that are determined by summing the species-specific OFL and ACL (ACLs set equal to the Acceptable Biological Catch) contributions for all stocks managed in the complex. Removals for species within each complex are managed and tracked against the complex total OFL and ACL, rather than on a species by species basis.

Quillback rockfish was most recently assessed in 2010 using Depletion-Based Stock Reduction Analysis (DB-SRA) to provide estimates of coastwide OFLs (Dick and MacCall 2010). The coastwide OFL was then apportioned to each management area based on the proportion of historical catches North and South of N. 40° 10' Lat. DB-SRA does not assess overfished status, but rather assumes that current depletion is distributed around the management target (e.g. 40%). The 2010 assessment found there was a 52% chance that quillback rockfish was experiencing overfishing, as recent coastwide catch of quillback rockfish slightly exceeded the median coastwide OFL estimate at the time.

The current OFL contribution and implied ACL contribution for quillback rockfish South and North of 40° 10' Lat. N., the state specific ACL allocation (all of the South and 28.7% of the North contribution for California; Groundfish Management Team, pers. comm.), and the total removals are shown in Table 2.

2 Data

The following types and sources of data were used in this assessment. Fishery catch and composition data were specific to California, however biological data were estimated coastwide and included Oregon, Washington, and California sources.

- 1. Commercial landings, and length and weight data obtained from PacFIN, and the CDFW. Weight data were used to estimate biological parameters which were fixed inputs to the model.
- 2. Estimates of commercial discard length frequencies and fraction discarded in the fishery obtained from the West Coast Groundfish Observer Program (WCGOP).
- 3. Recreational landings, discards, and length and weight data obtained from the Marine Recreational Fisheries Statistics Survey (MRFSS) and the California Recreational Fisheries Survey (CRFS), which are available on the Recreational Fisheries Information Network (RecFIN). Weight data were used to estimate biological parameters which were fixed inputs to the model.

- Historical reconstruction of commercial and recreational landings from Ralston et al. (2010).
- 5. Fishery independent biological data (length, weight, and age) from the Northwest Fisheries Science Center (NWFSC) West Coast Groundfish Bottom Trawl Survey (WCGBTS). These data were used to estimate biological parameters which were fixed inputs to the model.
- 6. Estimates of fecundity, maturity, and natural mortality from various sources.

A description of each data type is provided below, with timing of catch and composition data used in the base model shown in Figure 2.

2.1 Fishery-Dependent Data

2.1.1 Commercial Fishery

2.1.1.1 Landings

Commercial landings for quillback rockfish were combined into a single fleet by aggregating across gear types and fish landed live vs. dead. This choice was driven by the limited length composition data for each gear type, and the fact that length distributions were similar by gear type. Additionally, commercial length data available in the Pacific Fisheries Information Network (PacFIN) database for California did not have the needed information to identify samples from live vs. dead fish (e.g., condition code), preventing the ability to evaluate the data based on live vs. dead landings.

Commercial landings estimates for 1916 - 1969 from the California Catch Reconstruction (Ralston et al. 2010) were queried from the Southwest Fisheries Science Center (SWFSC) catch reconstruction database. Landings in this database are divided into trawl, 'non-trawl', and 'unknown' gear categories, for various regions within California. Additional catches between 1948-1968 landed at California ports but caught off Oregon and Washington were added to the landings from the catch reconstruction to represent total catches landed at California ports. Estimated catches of quillback rockfish from this additional analysis were very small and totaled approximately 0.30 mt over all years, with no more than 0.08 mt in any one year.

In September 2005, the California Cooperative Groundfish Survey (CCGS) 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 and past assessments as the best available landings for the time period 1969 - 1979 for all port complexes. Catches during this time for quillback rockfish are negligible. See Appendix A of Dick et al. (2007) for further details.

Commercial fishery landings from 1984-2020 were obtained from PacFIN (extracted 2/21/2021). There were no quillback rockfish catches in PacFIN from 1981-1983 so landings of quillback rockfish from 1981-1983 were set equal to the average landings from the three years before (1978 - 1980) and after (1984 - 1986) this time period.

The input catches in the model represent total removals, which equal landings plus discards (Table 1 and Figure 1). Discards totals for the commercial fleet from 2002 - 2019 were determined based on WCGOP data provided in the Groundfish Expanded Mortality Multiyear (GEMM) product. The total coastwide observed discards were allocated to state and area based on the total observed landings observed by WCGOP. Discards were added to landings to obtain total removals for 2002-2019. Total removals prior to 2002, and for 2020 where no WCGOP data were yet available, were calculated using the average discard rates from WCGOP in 2002-2018 for California (3.6 percent).

2.1.1.2 Length Compositions

Length data of quillback rockfish collected from commercial fisheries from 1978-2020 was extracted from PacFIN (Table 3, extracted 2/23/2021). Samples were very sparse prior to 1991 and consisted of only three samples, one each in 1978, 1984, and 1987, which were not used in model fitting (i.e. used as a 'ghost' fleet, not fit by the model but implied fits reflected in diagnostic output). Length samples were most numerous during the 1990s, while since 2002 the number of length samples has been relatively low. The sizes observed from 1991 - 2002 were relatively broad, ranging from approximately 20 - 50 cm (the largest data bin; Figure 3). Since approximately 2003, the range of sizes observed have shrunk to around 30 - 45 cm, while tending toward larger sizes over time. This shift in observed sizes is also reflected in the mean lengths observed by year, which have increased from around 35 cm to above 40 cm since 2003 (Figure 4). The shift in mean size could be due to shifts in fishery behavior, sampling, changes in the population demographics (e.g., lack of strong recruitment), or a combination of multiple factors.

The input sample sizes for the commercial length data were calculated via the Stewart method (Ian Stewart, personal communication) which incorporate the number of trips and fish by year:

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

2.1.2 Recreational / Sport Fishery

2.1.2.1 Landings

Recreational landings from 1928 - 1980 were obtained from the historical reconstruction (Ralston et al. 2010). Recreational removals from 1981 - 1989 were obtained from MRFSS.

The MRFSS dataset also includes removals in 1980, however Ralston et al. (2010) considered their 1980 estimate to be more reliable than that of MRFSS, so landings from the historical reconstructions were preferred for 1980. The total removals for the missing years between the MRFSS and CRFS datasets, 1990 - 1992, were assumed by applying a linear ramp in removals between the 1989 and 1993 values. Removals in 1993 were some of the largest for the recreational fleet across all years, so the effects of assuming an average catch from 1989 and 1994 for 1993, and altering the ramp was explored as a Sensitivity (see Section 3.5.4 for details). Both data sources, MRFSS and CRFS, provide total mortality which combined observed landings plus estimates of discarded fish. Discard estimates for the recreational fleet for years between 1928 - 1980 were calculated based on the discard rate (1.7 percent) from the MRFSS and CRFS data in years 1980-2004. A direct breakdown of the landed and discarded fish by weight was not available for these years, so the proportion by number of total dead catch that was unavailable to the sampler, which included dead discarded fish, was calculated and averaged across years.

The recreational fishery is the main source of mortality for quillback rockfish in California (Table 1 and Figure 1). Recreational removals peaked in the late 1970s and early 1980s, with two years of exceptionally large catches in 1984 and 1993. Removals declined sharply in 1994, but increased to levels similar to the late 1970s and early 1980s in the mid 2000s and again in recent years.

2.1.2.2 Length Compositions

Recreational length samples from MRFSS for years 1980 - 2003 and from CRFS for years 2004 - 2020 were obtained from the RecFIN website. Lengths of fish measured by samplers onboard Commercial Passenger Fishing Vessels (CPFV) prior to being released (Type 3d data) were also obtained from 2003 to 2020, however released samples (n = 23) were not used in length compositions for the base model. The number of length observations by year are shown in Table 4, with the highest number of samples occurring in years since 2004. The distribution of lengths of quillback rockfish observed by the recreational fleet have generally ranged between 20 and 50 cm (the maximum length data bin size) across all available years (Figure 5). Samples in years prior to 1989 generally were more uniformly distributed and had smaller samples sizes than in more recent years. The mean length observed each year was more variable within and among years prior to the mid 1990s, ranging from slightly above 40 cm to slightly below 30 cm (Figure 6). Since 2005, mean length has been less variable across years, between 35 and 40 cm, with less variation within each year as well.

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

2.2 Fishery-Independent Data

No fishery-independent data sources that are commonly incorporated in West Coast groundfish assessments (as required by the data moderate Terms of Reference) had adequate sample size of quillback rockfish off the California coast to include abundance indices for this assessment. The WCGBTS, the Hook and Line survey, and the Triennial survey collect data off the California coast on rockfish biology and abundance. There were no more than ten positive tows of quillback rockfish in any one year coastwide in the WCGBTS, and typically fewer than five. Similarly there were no more than five positive tows of quillback rockfish in any one year coastwide for the Triennial survey. No quillback rockfish were captured in the Hook and Line survey. Given that indices of abundance were not calculated due to small sample sizes, length composition data from the WCGBTS (n = 91) and Triennial Survey (n = 42) off California were not included in the model. Biological data from the WCGBTS survey was used in external calculations of biological parameters, including growth and weight-at-length relationships. No ages or weights for quillback rockfish were available from the Triennial survey.

2.3 Biological Data

This assessment modeled quillback rockfish as a single sex. Growth and length-weight relationships were similar across sexes, and the literature provided limited evidence of sexual dimorphism in length (Lenarz and Echeverria 1991). The sections below therefore describe combined male and female biological data.

2.3.1 Natural Mortality

Hamel (2015) developed a method for combining meta-analytic approaches relating instantaneous natural mortality rate (M) to other life-history parameters such as longevity, size, growth rate, and reproductive effort to provide a prior on M. Then et al. (2015) provided an updated data set of estimates of M and related life history parameters across a large number of fish species from which to develop an M estimator for fish species in general. They concluded by recommending M estimates be based on maximum age alone, based on an updated Hoenig non-linear least-squares estimator $M = 4.899 A_{max}^{-0.916}$. The approach of basing M priors on maximum age alone was one that was already being used for West Coast rockfish assessments. However, in fitting the alternative model forms relating M to $A_{\rm max}$, Then et al. (2015) did not consistently apply their transformation. In particular, in real space, one would expect substantial heteroscedasticity in both the observation and process error associated with the observed relationship of M to A_{\max} . Therefore, it would be reasonable to fit all models under a log transformation. This was not done. Re-evaluating the data used in Then et al. (2015) by fitting the one-parameter A_{max} model under a log-log transformation (such that the slope is forced to be -1 in the transformed space Hamel (2015)), the point estimate for M is:

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

The above is also the median of the prior suggested by Hamel (2015). The prior is defined as a log-normal distribution with parameters $\mu = ln(5.4/A_{\text{max}})$ and $\sigma = 0.438$. Using a maximum age of 95 years, the point estimate and median of the prior for M is 0.057 per year.

The maximum age assumed for calculating natural mortality in the base model was 95 years. The maximum age of 95 years was based on literature values for the U.S. West Coast examining the longevity of female quillback rockfish (Love, Yoklavich, and Thorsteinson 2002; Palsson et al. 2009; Yamanako and Lacko 2001). Yamanaka and Lacko (2001) found male longevity to be 76 years. Literature estimates were larger than the oldest aged quillback rockfish (73, 70, and 69) among data used in this assessment. These ages were from fish caught off the coast of Washington in 1999.

2.3.2 Maturation and Fecundity

Maturity-at-length estimates were based on the work of Hannah and Blume (2014) which estimated the 50% size-at-maturity of 29.2 cm off the coast of Oregon with maturity asymptoting to 1.0 for larger fish (Figure 7). A length at 50% maturity of 29.2 cm is consistent with other studies for quillback rockfish, which provide a range of 26-32 cm (Echeverria 1987; Rosenthal et al. 1982).

The fecundity-at-length was based on research by Dick et al. (2017). The fecundity relationship for quillback rockfish was estimated equal to $3.93e-07L^{3.7}$ in millions of eggs where L is length in cm. Fecundity-at-length is shown in Figure 8.

2.3.3 Length-Weight Relationship

The length-weight relationship for quillback rockfish was estimated outside the model using available coastwide biological data collected from fishery-independent and fishery-dependent data sources (Figure 9). Sources included the WCGBTS, and recreational and commercial samples from all states (Table 5). Only directly measured weight and length values were used; any values with more than two decimal places were assumed to be calculated from another measurement and were excluded. This occurred for 32 percent of lengths and 20 percent of the weights in the MRFSS-era recreational samples. Weights from Oregon special projects samples taken from the Oregon recreational and commercial fleets (n = 241) were not included. The estimated length-weight relationship for quillback rockfish was W=1.963e - 05L^{3.02} where L is fork length in cm and W is weight in kg (Figures 10).

2.3.4 Growth (Length-at-Age)

The length-at-age relationship for quillback rockfish was estimated outside the model using data collected from fishery-dependent sources off the coast of Oregon and Washington collected between 1998-2019, and from a single coastwide fishery-independent source (WCGBTS) collected between 2005-2019 (Table 6). Ages from Oregon special projects samples taken from the Oregon commercial fleet (n = 30) were not included. Age data were generally

sparse for quillback rockfish from any one source (Figure 11). The fishery-dependent data had limited observations of young fish less than 5 years of age, but had observations of fish up to 73 years of age. The fishery-independent data had limited observations of old fish greater than 40 years of age, but had observations of fish as young as one year of age. Growth parameters for quillback rockfish were estimated at the following values:

 $L_{\infty} = 43.04 \text{ cm}; k = 0.199; t0 = -0.067 \text{ cm}$

These values were fixed within the base model. The coefficient of variation (CV) around young and old fish was fixed at a value of 0.10. The length-at-age curve with the CV around length-at-age is shown in Figure 12. The estimate of L_{∞} is comparable to literature values, while the estimate of k is on the higher side of literature values which vary from 0.06 - 0.19 (Yamanako and Lacko 2001; Palsson et al. 2009; West, Helser, and O'Neill 2014).

Table 7 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.

3 Assessment Model

3.1 Summary of Previous Assessments

Quillback rockfish was last assessed in 2010 (Dick and MacCall 2010). The stock was assessed using Depletion-Based Stock Reduction Analysis (DB-SRA) which is a data-limited approach that incorporates catch data with priors on select parameters including natural mortality, the ratio of fishing mortality at maximum sustainable yield to natural mortality, current depletion, and the depletion at maximum sustainable yield to estimate overfishing status, but not overfished status. Quillback rockfish was assessed as a single coastwide stock to generate an overall OFL that was then apportioned to each management area based on the proportion of historical catches North and South of 40° 10' Lat. N.. Assuming that current depletion was at the management target on average (e.g. 40%), the 2010 assessment found that quillback rockfish had a 52% chance of experiencing overfishing coastwide.

3.1.1 Bridging Analysis

A direct bridging analysis was not conducted because the previous assessment was structured as a single coastwide model. The previous assessment also used DB-SRA, which uses different assumptions and data than the model used for this assessment, making a direct bridging analysis intractable.

3.2 Model Structure and Assumptions

California quillback rockfish was assessed using a one-sex model with life history parameters combined across sexes. The model assumed two fleets: 1) commercial and 2) recreational fleets with removals beginning in 1916. Selectivity for the commercial and recreational fleets was specified to be asymptotic using a six-parameter double normal parameterization. The ascending width and beginning size of maximum selectivity parameters were estimated for each fleet. Annual recruitment deviations were estimated within the base model.

3.2.1 Modeling Platform and Structure

Stock Synthesis (SS) version 3.30.16 was used to estimate the parameters in the model (Methot and Wetzel 2013). The R package r4ss, version 1.41.0 (Taylor et al. 2021), along with R version 4.0.2 (R Core Team 2020) were used to investigate and plot model fits. The NWFSC developed R packages nwfscSurvey_2.0 and PacFIN.Utilities_0.0.2.0000 were used for synthesis and processing of data for use in Stock Synthesis.

3.2.2 Priors

Fixed parameter values for natural mortality and steepness, based on prior distributions, were used 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 95 years. The prior assumed a log-normal distribution for natural mortality with a median of 0.057 and a standard deviation of 0.438.

The prior for steepness assumed a beta distribution with mean of 0.72 and standard deviation of 0.158. 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 Section 2.1.1 (Table 3). The input sample size for the recreational fishery length composition data was set equal to the number of length samples by year (Table 4). The base model was weighted using the McAllister-Ianelli method, which is based on equation 2.5 and 2.6 in Appendix 2 of McAllister et al. (1997)). The weightings applied using the McAllister-Ianelli method are provided in Table 8. This formulation accounts for a lack of independence in sampled fish by downweighting the number of samples. The amount of downweighting for a data set is calculated as the harmonic mean of the effective sample sizes across years. This method does not account for correlation in the data among years. Sensitivities were performed examining the difference in weighting using equation TA1.8 in Francis (2011) and the Dirichlet Multinomial Weighting (Thorson et al. (2017)).

3.2.4 Estimated and Fixed Parameters

There were 98 estimated parameters in the base model. These included one parameter for R_0 , 4 parameters for selectivity, 81 annual recruitment deviations, and 12 forecast recruitment deviations (Table 9).

Fixed parameters in the model were as follows. Steepness was fixed at 0.72, and natural mortality was fixed at 0.057, as described above in Section 3.2.2. Growth, maturity-at-length, and length-at-weight were fixed as described above in Section 2.3. The standard deviation of recruitment deviates was fixed at 0.6. Likelihood profiles were performed for steepness, natural mortality, length at maximum size, vonBertalanffy growth coefficient, and the CV at maximum length.

Selectivity in the recreational and commercial fleets was fixed to be asymptotic with only ascending width and beginning size of maximum selectivity being estimated. During initial model development, the descending width and width of maximum selectivity parameters for the recreational and commercial fleets were estimated to identify appropriate fixed values consistent with the data, and then fixed at those estimates. Dome-shaped selectivity was explored for all fleets within the model as sensitivities (see Sensitivity Analyses section). Older quillback rockfish are often found in deeper waters and may move into areas that limit their availability to fishing gear. Dome shaped selectivity can also occur under heterogeneous fishing pressure across space by fleets (Waterhouse et al. 2014).

Given the depth closures in the recreational fishery off California it was initially assumed that large quillback rockfish would not be caught in the fishery indicating dome-shaped selectivity. However, lengths at depth of quillback rockfish from Remote Operated Vehicle data suggested larger quillback rockfish occur across depths and are not limited to depths closed to fishing (see Appendix A for details). This information lead to the assumption of asymptotic selectivity for the recreational fleet for the base model.

3.3 Model Selection and Evaluation

The base assessment model for quillback rockfish was developed to balance parsimony and realism, with the goal of estimating a spawning output trajectory for the population of

quillback rockfish off California. The model contains many assumptions to achieve parsimony and uses many different sources of data to estimate reality. A series of investigative model runs were done to achieve the final base model.

3.4 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 value for $\ln(R_0)$ was estimated at 3.17. The selectivity curves for the commercial and recreational fleet are shown in Figure 13. The selectivity was assumed to be asymptotic for the commercial fleet with an estimated peak in maximum selectivity starting at 41.6 cm. The selectivity for the recreational fleet was also assumed to be asymptotic with an estimated peak of the selectivity curve starting at 33.4 cm. Sensitivities to the shape of the commercial and recreational selectivity form and potential time blocking of the recreational fleet was explored (see below in Section 3.5.4).

The estimated annual recruitment and recruitment deviations are shown in Figures 14 and 15. Strong recruitment events were estimated prior to 2000 and in 2011. Recruitment deviations in 1987, 1996, and 1999 were particularly strong and resulted in an increase in biomass during the early 2000s. While the largest recruitment deviations were estimated to have occurred in these three specific years, the surrounding years in the 1980s and 1990s also have above average recruitment estimated. Recruitment deviations in the 1980s and 1990s however were highly uncertain, with standard errors extending above the value of σ_R (0.6), suggesting recruitment during these years is not strongly informed by the data. Recruitment deviations for 1996 and 1999 were less uncertain, with standard errors below that of $\[mathbb{s}\]_R$, suggesting these two recruitments were more informed by the data. Below average recruitment was estimated in all years since 2000, with the exception of 2011. Bias adjustment was applied to the annual estimates of recruitment deviations following the pattern of transformed variances in recent years as shown in Figure 16.

The general pattern in recruitment deviations showed fairly close coherence with the recruitment deviations estimated in the separate Oregon model. The Oregon base model estimated above average recruitment in the late 1990s, though for fewer years, and a strong recruitment pulse in 2012. This may potentially suggest that quillback rockfish off the coast of California and Oregon experience similar drivers in recruitment.

The large recruitment pulses in the 1980s and 1990s primarily show up in the composition data for the commercial and recreational fleets as a steady range of sizes across years, but

also as a pulse of young fish around 2000 and 2001 for the commercial and recreational fleets. The recruitment pulse in 1999 does not clearly show up as a single pulse of young fish in later years but is probably aggregated with the 1996 recruitment pulse to support the trend of increasing mean size for both the commercial and recreational fleets. The increasing mean size in the recreational and commercial fleet after 2005 along with minimal catches of smaller fish in the composition data supports the below average recruitment in the 2000s. The 2011 recruitment pulse shows up primarily in the composition data for the recreational fleet as pulses of smaller fish in 2015-2017 that are also reflected by declines in mean size. The commercial fleet also shows some pulses of smaller fish in 2017-2018 along with declines in mean size, with the later time frame likely being due to a right shifted selectivity curve compared to the recreational fleet.

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 each of the commercial and recreational fleets. Fits to the length composition data by year are provided in Appendix C.

The Pearson residuals for the commercial fishery have no discernible pattern of misfit to the length data across cohorts but show areas of misfit over time (Figure 17). The residuals show that the peak of the composition is being underfit in many years since 2001, where sample sizes are lower and the distributions have a prominent peak (see Appendix C for details). The mean lengths observed by the commercial fishery were variable by year, with higher variation since 2004 given smaller sample size, and showed an increase in mean length starting in 2007 and a decline after 2014 (Figure 18). The increase in mean size estimated by the model was substantially less than the increase in mean size observed in the data, and likely a consequence of smaller sample size for commercial lengths compared to recreational lengths during this time.

The Pearson residuals for the recreational length data were variable by year and indicate no discernible pattern of misfit to the length data (Figure 19). Positive residuals at the edges of the distribution in years before 2004, which are the largest residuals, are indicative of widely spread distributions with lower sample size. In years since 2004, there are periods of positive and negative residuals in clusters over two to five years. The positive residuals indicate underfitting of peaked distributions (e.g. in 2006-2010, or in 2012-2014), whereas negative residuals indicate overfitting of the distribution as it skews to the left or right (e.g. 2005-2007 or 2015-2019; see Appendix C for details). The mean length decreased from a high around 40cm in the early 1980s through the 1990s to under 30cm, and then increased slightly through 2004. After 2004, the variation in mean length was reduced, and mean length varied around 35 cm, with increases through 2013 and decline in 2015 and 2016 (Figure 20). The mean length was highly variable in 2002 due to low sample size (Table 4) and a flat length distribution.

Aggregate fits by fleet are shown in Figure 21. The model fits the aggregated lengths for both the commercial and recreational fleet well. Both fleets show similar ranges of sizes caught and a central tendency of 36 cm. The commercial fleet is more peaked compared to the recreational fleet, which has a more rounded peak around its central tendency and slight shift toward smaller sizes. The model expects a slightly higher proportion of the largest fish for both fleets relative to the data. This may indicate that the true selectivity of the recreational and commercial fleets may have some level of reduced selectivity for the largest fish (i.e. dome-shape). Sensitivities examining dome-shaped selectivity form were performed and presented in the Sensitivity Analyses section below.

3.4.3 Population Trajectory

The predicted spawning output (in millions of eggs) is given in Table 12 and plotted in Figure 22. The predicted spawning output from the base model declines steadily until 1999, with the exception of a slight increase around 1990, and then increases due to several above average recruitment events that occurred in the to mid- to late-1990s. The population then increases until 2007 after which it remains level until 2016 and then declines through 2020. The estimate of total biomass over time is shown in Figure 23.

The 2020 spawning output relative to unfished equilibrium spawning output is below the threshold of 25 percent of unfished spawning output (0.14, Figure 24). Approximate confidence intervals based on the asymptotic variance estimates show that the uncertainty in the estimated spawning output ranges between approximately 5 - 25 percent of unfished equilibrium spawning output. The standard deviation of the log of the spawning output in 2020 is 0.39.

The stock-recruit curve resulting from a value of steepness fixed at 0.72 is shown in Figure 25. The estimated annual recruitment is shown in Figure 14.

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 and adjusting phases of the estimated parameters to determine if the model found a better minimum. Starting parameters were first jittered by 10 percent. This was repeated 100 times with 64 out of 100 runs returning to the base model likelihood. A lower negative log-likelihood model fit was not found and all runs converged. When parameters were jittered by 25 percent, 57 of 100 runs returned to the base model likelihood. A lower negative log-likelihood model fit was again not found. Through the jittering done as explained and likelihood profiles (described below), 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 throughout initial model attempts and all explorations resulted in a positive-definite Hessian.

3.5.2 Likelihood Profiles

Likelihood profiles were conducted for R_0 , steepness, natural mortality, L_{∞} , growth coefficient (k), and CV at maximum length values separately. These likelihood profiles were conducted by fixing the parameter at specific values and estimating the remaining parameters based on the fixed parameter value.

In regards to values of R_0 , the negative log-likelihood was minimized at a $\ln(R_0)$ of 3.17 (Figure 26). The commercial data supported lower $\ln(R_0)$ values around 2.75 whereas the recreational data supported $\ln(R_0)$ near the base model value. Increasing R_0 relative to the base model value resulted in an increase in stock scale (Figure 27) and status (Figure 28).

For steepness, values at the upper bound of 1.0 had the lowest negative log-likelihood (Figure 29). Assuming higher or lower steepness values than the fixed base model value of 0.72 affected spawning output estimates by approximately 20% at most (Figure 30), and had relatively little effect on stock status for all but the highest values (Figure 31). The estimated relative final stock status was below 0.25 for all but the highest value of steepness.

The negative log-likelihood profile across natural mortality supported values at the upper range of profiled values (0.12; Figure 32). The estimated stock trajectories assuming lower or higher natural mortality values than the base model value of 0.057 varied up to 20% of the unfished and recent spawning output (Figures 33). Higher values of M reduced unfished spawning output but increased recent spawning output so the range of stock status varied from below the management precautionary zone (between 0.25 - 0.40) for lower values of Mto within and above the management precautionary zone for higher values of M (Figure 34).

A profile across a range of L_{∞} values was also conducted. The negative log-likelihood was minimized at 42 cm, near the fixed value of 43.04, though the negative log-likelihood for both 41 cm and 43 were greater than two units from the minimum (Figure 35). The commercial data supported lower L_{∞} values, at the edge of the profiled range. The stock scale varied across alternative L_{∞} values where assuming lower values resulted in increased recent spawning output and assuming higher values resulted in increased unfished spawning output but decreased recent spawning output (Figure 36). Lower values of L_{∞} compared to the base resulted in a range of stock status from within, and above the management precautionary zone whereas higher L_{∞} resulted in greater levels of depletion (Figure 37).

The negative log-likelihood profile across values of k showed support for values between 0.11 and 0.14, and was minimized at 0.13, which is lower than the fixed value of 0.199 (Figure 38). The commercial data suggested lower estimate of k to minimize negative log-likelihood but supported estimates between 0.10 and 0.16 while the recreational data suggested a minimum at 0.19, but supported values ranging from 0.12 to 0.23. The stock scale (Figure 39) and status (Figure 40) increased under lower k values.

Profiles for L_{∞} and k indicate there may be information in the data to estimate growth parameters given that well defined minimums for each parameter exist among the profile values. Sensitivities estimating growth were performed and presented in the Sensitivity Analyses section below.

The negative log-likelihood profile across values for the CV at maximum length showed support for 0.08 and 0.09, with a minimum at 0.08, slightly lower than the base model value of 0.1 (Figure 41). The commercial data supported 0.08, while the recreational data supported 0.09. Higher variation around maximum length (i.e. higher values of CV) resulted in smaller unfished and recent spawning output (Figure 42), and greater depletion (Figure 43), though differences with the base model were relatively small across profiled values.

3.5.3 Retrospective Analysis

A five-year retrospective analysis was conducted by running the model using data up to 2015, 2016, 2017, 2018, and 2019. The estimated spawning output (Figures 44) and stock status (Figure 45) declined in comparison with the base model as recent years of data were removed. Removing years of data resulted in a steady decline is spawning output relative to the base model likely due to reducing the amount of information in the length comps about above average recruitment pulses (Figures 46).

3.5.4 Sensitivity Analyses

A number of sensitivity analyses were conducted. Sensitivities were conducted as a single exploration from the base model assumptions and/or data, and were not performed in a cumulative fashion.

- 1. Deterministic recruitment from the stock recruitment curve.
- 2. Data weighting according to the Francis method (Francis DW) using the weighting values shown in Table 8.
- 3. Data weighting according to the Dirichlet Multinomial method (DM DW) where the estimated parameters are shown in Table 8.
- 4. Estimate L_{∞} .
- 5. Estimate k.
- 6. Estimate L_{∞} and k.
- 7. Estimate the coefficient of variation in length of older fishes.
- 8. Estimate natural mortality.
- 9. Exclude composition data prior to 2004 for recreational fleet
- 10. Exclude composition data prior to 1994 for recreational fleet
- 11. Allow recreational selectivity form to be dome-shaped.

- 12. Allow commercial selectivity form to be dome-shaped.
- 13. Estimate recreational selectivity block: 1979-1993 and 1994-2020 with asymptotic selectivity.
- 14. Adjust extreme catches for the commercial (in 1991) and recreational (in 1983 and 1993) fleets based on the average of the three years before and three years after the year of high catch. Adjusting recreational catches in 1993 results in changes to interpolated values in 1990-1992.

Likelihood values and estimates of key parameters from each sensitivity are available in Table 13. Plots of the estimated time-series of spawning output, relative spawning output, and recruitment are shown in Figures 47, 48, and 49, respectively.

The largest change from the base model occurred where large catches were adjusted downward, and when estimating natural mortality. Estimating M resulted in a 24 percent lower estimate for initial spawning output and over two-fold higher estimate for recent spawning output compared to the base model. Stock status increased to above the management target of 0.4. The estimate for M was 0.11, which according to the prior of Hamel (2015) would translate to a max age of around 50 years. Lowering the magnitude of large catches resulted in a 28 percent decline in unfished spawning output, but with a similar decline in recent spawning output such that stock status was similar.

Six other sensitivities had either changes in initial spawning output near 10 percent or more, or resulted in depletion estimates within the precautionary zone (between 0.25 - 0.40). The sensitivities where recruitment deterministically followed the stock recruitment curve, and where data weighting was with the Dirichlet-Multinomial resulted in unfished spawning output increasing 10 percent, and declining 8 percent respectively, but similar stock status compared to the base model. Results for assuming deterministic recruitment were similar regardless of whether data weighting was updated. Estimating L_{∞} , k, and L_{∞} and k resulted in comparable estimates of unfished spawning output to that of the base model but higher recent spawning output. The two sensitivities estimating k resulted in stock status between the target and threshold ratios, whereas the sensitivity estimating L_{∞} was slightly below 0.25 and more similar to the base model.

All other sensitivities, including those estimating dome-shaped recruitment, resulted in similar estimates of unfished and recent spawning output, and thus had similar stock status, compared to the base model.

3.5.5 Unresolved Problems and Major Uncertainties

A primary uncertainty for the California quillback rockfish model is in treatment of growth parameters. The fixed value for k for quillback rockfish is on the higher end of other published studies, ranging between 0.06-0.19, and results in a low M/k ratio. Profiles and sensitivities for L_{∞} and k suggest estimating these parameters is possible, both separately and together, and result in estimates of k nearer to the middle of the range of literature values and estimates

of L_{∞} near to the fixed value. The choice also matters in the sense that estimating growth parameters results in a different stock status compared to the base model. Despite well defined profiles for k and L_{∞} , we decided to keep the fixed values in the base model given the relatively limited length composition data, concerns over whether length data on its own without age data can inform k, that the curve of estimated k and L_{∞} values poorly fit the age and length data, and that growth estimates used in the model were based on data with young fish from the surveys to inform the estimate of k.

Variation in recruitment deviations remains an unresolved problem. Recruitment deviations in the 1980s and 1990s were highly variable, and variance was higher than the assumed value for sigmaR. We explored numerous ways to account for this, with the only solution reducing recruitment deviations to below the value of sigmaR was by reducing the variability in size at older ages to very small values (~0.01). Under such a scenario, the trajectory of the population was very similar to the base model as was the pattern of stronger than average recruitment deviations in the 1980s and 1990s followed by weaker than average recruitment deviations in the 2000s. Consequently, this remains an unresolved problem that does not appear to greatly affect model results.

Lastly, catches of quillback rockfish were particularly high in a few years for both the recreational and commercial fleets. Although not affecting estimates of depletion, averaging out these high years of catches affected model scale and therefore estimates of sustainable yield. Changes to catches affecting model scale is true of all models that assume catch is well known, however for quillback rockfish in California the magnitude of the reduction in catch for these years was approximately 20 percent of the total removals. Better understanding the factors contributing to these high catches as well as potential resolutions, should they be needed, would aid in ensuring catch time series and resulting estimates of sustainable yield are accurate.

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). Sustainable total yields were 8.41 mt when using an $SPR_{50\%}$ reference harvest rate. The spawning output equivalent to 40 percent of the unfished spawning output ($SB_{40\%}$) was 24.58 millions of eggs.

The 2020 spawning output relative to unfished equilibrium spawning output is below the threshold of 25 percent of unfished spawning output (Figure 24). The fishing intensity, 1 - SPR, has been above the harvest rate limit $(SPR_{50\%})$ in all years but four years from 1975-2009, and in all but three years since (Table 12 and Figure 50). Figure 51 shows the phase plot of relative spawning output and fishing intensity. Table 11 shows the full suite of

estimated reference points for the base model and Figure 52 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 was estimated for years 2023-2032, with catches equal to the estimated Acceptable Biological Catch (ABC) based on the category 2 timevarying sigma and $P^* = 0.45$ (Table 14). The removals in 2021 and 2022 were set based on the adopted ACLs for the southern management area and the percent allocation (28.7 percent) for California in the northern management area provided by the PFMC Groundfish Management Team (GMT, personal communication). ACLs were apportioned to recreational and commercial catches based on the average proportion from 2018-2020 each fleet contributes to the total catch.

The decision table uncertainty axes and catch levels are to be determined later.

4.3 Evaluation of Scientific Uncertainty

The estimated uncertainty in the base model around the 2021 spawning output is $\sigma = 0.39$ and the uncertainty in the base model around the 2021 OFL is $\sigma = 0.37$. The estimated model uncertainty was less than the category 2 groundfish data moderate assessment default value of $\sigma = 1.0$.

4.4 Research and Data Needs

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

- At the time of the assessment due to issues in California data in PacFIN (i.e., condition code) length samples landed live vs. dead from the commercial were unable to be identified. The ability to examine sample sizes and lengths from each type of landings would allow for future assessments to account for a greater range of commercial fishing behavior.
- Improved understanding of where recreational fishing is commonly occurring (areas and depths) and the range of sizes available by depth would better inform the selectivity form, which currently is the near the shape for maturity.
- Age data were predominantly from Oregon and Washington waters. Collecting length and otolith samples from recreational and commercial catches in California would result in samples from the entire U.S. West Coast informing growth.

- Recruitment patterns showed lower than average recruitment in the 2000s. Additional data to support such patterns in recruitment would provide additional support for model estimates.
- Catches of quillback rockfish were particularly high in a few years for both the recreational and commercial fleet. Better understanding the factors contributing to these high catches as well as potential resolutions, should they be needed, would aid in ensuring catch time series are accurate.

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6 References

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7 Tables

Year	\mathbf{CA}	\mathbf{CA}	Total Catch
	Commercial	Recreational	
1916	0.02	0.00	0.02
1917	0.03	0.00	0.03
1918	0.07	0.00	0.07
1919	0.02	0.00	0.02
1920	0.02	0.00	0.02
1921	0.03	0.00	0.03
1922	0.03	0.00	0.03
1923	0.01	0.00	0.01
1924	0.02	0.00	0.02
1925	0.08	0.00	0.08
1926	0.07	0.00	0.07
1927	0.14	0.00	0.14
1928	0.12	0.06	0.18
1929	0.11	0.12	0.24
1930	0.18	0.14	0.32
1931	0.25	0.19	0.44
1932	0.18	0.23	0.42
1933	0.14	0.28	0.42
1934	0.13	0.33	0.45
1935	0.23	0.37	0.61
1936	0.22	0.42	0.64
1937	0.15	0.50	0.65
1938	0.21	0.49	0.70
1939	0.20	0.43	0.63
1940	0.08	0.62	0.70
1941	0.14	0.57	0.71
1942	0.13	0.30	0.44
1943	0.18	0.29	0.47
1944	0.92	0.24	1.16
1945	2.27	0.32	2.59
1946	2.38	0.55	2.92
1947	0.48	0.43	0.91
1948	1.00	0.86	1.86
1949	0.35	1.12	1.47
1950	0.18	1.36	1.54
1951	0.33	1.66	1.98
1952	0.28	1.44	1.72
1953	0.16	1.23	1.39
1954	0.40	1.52	1.92
1955	0.02	1.82	1.83
1956	0.04	2.03	2.07
1957	0.06	2.02	2.08

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

Year	CA Commercial	CA Recreational	Total Catch
1050	0.10	0.51	0.61
1958	0.10	3.51	3.61
1959	0.05	2.63	2.67
1960	0.02	2.19	2.21
1901	0.02	1.59	1.01
1962	0.02	1.80	1.82
1963	0.06	2.07	2.74
1964	0.03	2.20	2.23
1965	0.10	3.73	3.83
1966	0.04	4.25	4.29
1967	0.08	4.76	4.84
1968	0.07	4.88	4.95
1969	0.00	5.47	5.47
1970	0.00	7.45	7.45
1971	0.00	6.62	6.62
1972	0.00	9.47	9.47
1973	0.00	10.23	10.23
1974	0.00	11.31	11.31
1975	0.00	11.27	11.27
1976	0.00	12.83	12.83
1977	0.00	13.56	13.56
1978	0.12	13.08	13.19
1979	0.00	14.02	14.02
1980	0.00	15.13	15.13
1981	0.56	4.89	5.45
1982	0.56	5.04	5.60
1983	0.56	40.00	40.56
1984	3.17	10.40	13.56
1985	0.00	12.25	12.25
1986	0.08	13.18	13.26
1987	0.15	5.51	5.66
1988	0.29	1.84	2.13
1989	1.87	9.71	11.58
1990	1.32	16.22	17.55
1991	51.17	22.73	73.90
1992	6.16	29.25	35.41
1993	4.92	35.76	40.67
1994	19.87	4.04	23.90
1995	9.63	3.03	12.66
1996	12.01	3.56	15.56
1997	19.64	3.35	22.98
1998	12.30	2.68	14.98
1999	8.47	5.34	13.81
2000	6.51	6.80	13.31
2001	12.50	3.60	16.10

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

Year	\mathbf{CA}	\mathbf{CA}	Total Catch
	Commercial	Recreational	
2002	4.78	1.17	5.96
2003	2.04	11.88	13.92
2004	2.46	3.18	5.64
2005	4.90	5.70	10.59
2006	4.42	10.13	14.55
2007	6.60	12.71	19.32
2008	6.33	4.72	11.05
2009	1.16	5.72	6.88
2010	0.88	2.68	3.56
2011	0.95	4.50	5.45
2012	1.69	6.30	7.99
2013	0.68	2.89	3.57
2014	0.45	2.52	2.97
2015	1.12	7.43	8.55
2016	0.98	8.48	9.46
2017	2.76	9.76	12.52
2018	2.73	10.11	12.84
2019	4.56	11.46	16.02
2020	4.36	7.97	12.34

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

Year	OFL North	ACL North	OFL South	ACL South	CA ACL	CA Removals
2011	8.70	7.26	6.35	5.30	7.38	5.45
2012	8.70	7.26	6.35	5.30	7.38	7.99
2013	7.37	6.15	5.39	4.49	6.26	3.57
2014	7.37	6.15	5.39	4.49	6.26	2.97
2015	7.37	6.15	5.39	4.49	6.26	8.55
2016	7.37	6.15	5.39	4.49	6.26	9.46
2017	7.37	6.15	5.39	4.49	6.26	12.52
2018	7.37	6.15	5.39	4.49	6.26	12.84
2019	7.37	6.15	5.39	4.49	6.26	16.02
2020	7.37	6.15	5.39	4.49	6.26	12.34

Table 2: The OFL and ACL for quillback rockfish within the Minor Nearshore Rockfish North and South complexes, the ACL allocated to California across both complexes, and the total removals.

Year	N Trips	N Fish Female	N Fish Male	N Fish
				Ulisexed
1978	1	0	2	0
1984	1	0	1	0
1987	1	0	1	0
1991	7	0	3	155
1992	32	0	0	260
1993	14	0	0	93
1994	20	0	0	284
1995	16	1	1	123
1996	22	0	0	132
1997	21	0	0	150
1998	3	0	0	16
1999	50	0	1	579
2000	12	0	0	41
2001	33	1	0	321
2002	6	0	0	17
2004	4	0	4	10
2005	2	0	0	16
2006	3	0	0	19
2007	20	14	13	111
2008	17	0	0	108
2009	10	0	0	39
2010	6	0	0	16
2011	5	0	2	5
2012	9	3	2	10
2013	5	0	0	13
2014	5	0	0	5
2015	14	0	0	20
2016	10	0	0	16
2017	14	0	0	49
2018	8	0	0	31
2019	7	26	49	11
2020	10	35	39	0

Table 3: Summary of the commercial length samples by number of trips and lengths by sexper year.

Year	All Fish	Sexed Fish	Unsexed Fish
1980	11	0	11
1981	7	0	7
1982	8	0	8
1983	62	0	62
1984	28	0	28
1985	36	0	36
1986	44	0	44
1987	8	0	8
1988	7	0	7
1989	51	0	51
1993	57	0	57
1994	29	0	29
1995	18	0	18
1996	43	0	43
1997	79	0	79
1998	60	0	60
1999	72	0	72
2000	46	0	46
2001	32	0	32
2002	5	0	5
2003	56	0	56
2004	119	0	119
2005	215	0	215
2006	417	0	417
2007	552	0	552
2008	327	1	326
2009	317	0	317
2010	144	0	144
2011	205	0	205
2012	270	0	270
2013	189	3	186
2014	126	0	126
2015	375	0	375
2016	439	0	439
2017	456	0	456
2018	419	0	419
2019	463	0	463

 Table 4: Summary of the recreational length samples used in the stock assessment.

	CA	CA Rec	OR	OR	OR Rec	WA	WA	WA
	NWFSC		Com	NWFSC		Com	NWFSC	Rec
	WCG-			WCG-			WCG-	
	BTS			BTS			BTS	
1993	0	50	0	0	47	0	0	0
1994	0	28	0	0	43	0	0	0
1995	0	17	0	0	16	0	0	0
1996	0	37	0	0	13	0	0	0
1997	0	9	0	0	49	0	0	0
1998	0	7	0	0	115	0	0	0
1999	0	21	0	0	152	0	0	0
2000	0	38	20	0	59	0	0	0
2001	0	11	8	0	372	0	0	0
2002	0	4	45	0	811	0	0	18
2003	0	14	17	0	882	0	0	16
2004	0	21	65	0	498	0	0	26
2005	0	82	20	0	930	0	2	67
2006	0	118	73	2	1033	0	1	73
2007	15	203	127	1	1074	0	0	41
2008	0	163	56	22	1115	0	0	21
2009	0	119	59	3	824	0	0	10
2010	0	49	63	1	918	0	1	0
2011	0	70	191	6	1044	0	0	0
2012	0	173	129	0	1238	0	26	0
2013	0	167	211	1	752	0	0	0
2014	4	61	157	4	484	0	17	65
2015	0	113	102	5	10	0	3	14
2016	0	148	72	8	0	0	1	33
2017	2	385	214	5	724	0	9	10
2018	0	367	199	16	1341	8	5	25
2019	0	364	351	11	1206	1	5	61
2020	0	0	216	0	39	0	0	0

Table 5: Summary of the number of samples by year from the NWFSC WCGBTS, and the commercial (com) and recreational (rec) fisheries by state used to estimate weight-at-length parameters.
	CA NWFSC WCG- BTS	OR Com	OR NWFSC WCG- BTS	OR Rec	WA Com	WA NWFSC WCG- BTS	WA Rec
1998	0	0	0	0	0	0	50
1999	0	0	0	0	0	0	162
2000	0	0	0	0	0	0	26
2002	0	2	0	0	0	0	0
2003	0	9	0	0	0	0	0
2004	0	63	0	0	0	0	0
2005	0	1	0	91	0	2	0
2006	0	63	2	336	0	1	0
2007	15	0	1	0	0	0	0
2008	0	0	22	356	0	0	0
2009	0	0	3	0	0	0	0
2010	0	0	1	0	0	1	0
2011	0	0	6	0	0	0	0
2012	0	0	0	0	0	26	0
2013	0	0	1	0	0	0	0
2014	4	0	3	0	0	17	0
2015	0	0	5	0	0	3	0
2016	0	0	8	0	0	1	0
2017	2	0	5	0	9	9	0
2018	0	0	16	0	4	5	0
2019	0	0	11	0	19	5	0

Table 6: Summary of the number of samples by year from the NWFSC WCGBTS, and the commercial (com) and recreational (rec) fisheries by state used to estimate length-at-age parameters.

Age	Length (cm)	Weight (kg)	Maturity	Spawning Output
0	4.00	0.00	0.00	0.00
1	8.23	0.01	0.00	0.00
2	14.51	0.06	0.00	0.00
3	19.66	0.16	0.00	0.00
4	23.88	0.29	0.05	0.00
5	27.34	0.44	0.30	0.03
6	30.17	0.59	0.60	0.09
7	32.49	0.73	0.79	0.14
8	34.40	0.87	0.89	0.19
9	35.96	1.00	0.94	0.23
10	37.23	1.11	0.97	0.27
11	38.28	1.20	0.98	0.30
12	39.14	1.29	0.98	0.32
13	39.84	1.36	0.99	0.35
14	40.42	1.42	1.00	0.37
15	40.89	1.47	1.00	0.38
16	41.28	1.51	1.00	0.40
17	41.60	1.55	1.00	0.41
18	41.86	1.58	1.00	0.42
19	42.07	1.60	1.00	0.42
20	42.25	1.62	1.00	0.43
21	42.39	1.64	1.00	0.44
22	42.51	1.65	1.00	0.44
23	42.60	1.66	1.00	0.44
24	42.68	1.67	1.00	0.45
25	42.75	1.68	1.00	0.45
26	42.80	1.68	1.00	0.45
27	42.84	1.69	1.00	0.45
28	42.88	1.69	1.00	0.46
29	42.91	1.70	1.00	0.46
30	42.93	1.70	1.00	0.46
31	42.95	1.70	1.00	0.46
32	42.97	1.70	1.00	0.46
33	42.98	1.71	1.00	0.46
34	42.99	1.71	1.00	0.46
35	43.00	1.71	1.00	0.46
36	43.01	1.71	1.00	0.46
37	43.01	1.71	1.00	0.46
38	43.02	1.71	1.00	0.46
39	43.02	1.71	1.00	0.46
40	43.03	1.71	1.00	0.46
41	43.03	1.71	1.00	0.46

Table 7: Age, length, weight, maturity, and spawning output by age (product of maturity and fecundity) at the start of the year. Output for ages 51-95 is truncated as these ages have the same length, weight, maturity, and spawning output as at age 50.

Age	Length (cm)	Weight (kg)	Maturity	Spawning Output
42	43.03	1.71	1.00	0.46
43	43.03	1.71	1.00	0.46
44	43.03	1.71	1.00	0.46
45	43.03	1.71	1.00	0.46
46	43.04	1.71	1.00	0.46
47	43.04	1.71	1.00	0.46
48	43.04	1.71	1.00	0.46
49	43.04	1.71	1.00	0.46
50	43.04	1.71	1.00	0.46

Table 7: Age, length, weight, maturity, and spawning output by age (product of maturity and fecundity) at the start of the year. Output for ages 51-95 is truncated as these ages have the same length, weight, maturity, and spawning output as at age 50. *(continued)*

Method	Commercial Lengths	Recreational Lengths
McAllister-Ianelli Francis Dirichlet Multinomial	$0.3826330 \\ 0.2778310 \\ 0.9819261$	$0.1243430 \\ 0.0975810 \\ 0.5121594$

Table 8: Data weights applied by each alternative data weighting method. The Dirichlet Multinomial weight is theta/(1+theta)

Parameter	Value	Phase	Bounds	Status	SD	Prior (Exp.Val, SD)
NatM p 1 Fem GP 1	0.057	-2	(0.01, 0.2)	NA	NA	Log Norm (-2.8647, 0.48)
L at Amin Fem GP 1	8.230	-2	(0, 10)	NA	NA	None
L at Amax Fem GP 1	43.040	-2	(25, 60)	NA	NA	None
VonBert K Fem GP 1	0.199	-2	(0.03, 0.3)	NA	NA	None
CV young Fem GP 1	0.100	-2	(0.01, 1)	NA	NA	None
CV old Fem GP 1	0.100	-2	(0.01, 1)	NA	NA	None
Wtlen 1 Fem GP 1	1.963e-05	-9	(0, 0.1)	NA	NA	None
Wtlen 2 Fem GP 1	3.016	-9	(2, 4)	NA	NA	None
Mat50Mat slope Fem GP 1	-0.800	-9	(-2, 0)	NA	NA	None
Eggs scalar Fem GP 1	0.000	-9	(-3, 3)	NA	NA	None
Eggs exp len Fem GP 1	3.702	-9	(0, 6)	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)	3.168	1	(1, 20)	OK	0.0770772	None
SR BH steep	0.720	-7	(0.2, 1)	NA	NA	Full Beta $(0.72, 0.158)$
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 1940	-0.084	5	(-5, 5)	act	0.5765370	dev (NA, NA)
Early RecrDev 1941	-0.087	5	(-5, 5)	act	0.5755490	dev (NA, NA)
Early RecrDev 1942	-0.091	5	(-5, 5)	act	0.5745270	dev (NA, NA)
Early RecrDev 1943	-0.095	5	(-5, 5)	act	0.5734730	dev (NA, NA)
Early RecrDev 1944	-0.099	5	(-5, 5)	act	0.5723900	dev (NA, NA)
Early RecrDev 1945	-0.104	5	(-5, 5)	act	0.5712770	dev (NA, NA)
Early RecrDev 1946	-0.108	5	(-5, 5)	act	0.5701370	dev (NA, NA)
Early RecrDev 1947	-0.113	5	(-5, 5)	act	0.5689660	dev (NA, NA)
Early RecrDev 1948	-0.117	5	(-5, 5)	act	0.5677500	dev (NA, NA)
Early RecrDev 1949	-0.122	5	(-5, 5)	act	0.5665130	dev (NA, NA)
Early RecrDev 1950	-0.127	5	(-5, 5)	act	0.5652440	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).

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 1951	-0.132	5	(-5, 5)	act	0.5639410	dev (NA, NA)
Early RecrDev 1952	-0.138	5	(-5, 5)	act	0.5626030	dev (NA, NA)
Early RecrDev 1953	-0.143	5	(-5, 5)	act	0.5612200	dev (NA, NA)
Early RecrDev 1954	-0.149	5	(-5, 5)	act	0.5597900	dev (NA, NA)
Early RecrDev 1955	-0.155	5	(-5, 5)	act	0.5583270	dev (NA, NA)
Early RecrDev 1956	-0.161	5	(-5, 5)	act	0.5568470	dev (NA, NA)
Early RecrDev 1957	-0.167	5	(-5, 5)	act	0.5553640	dev (NA, NA)
Early RecrDev 1958	-0.173	5	(-5, 5)	act	0.5538650	dev (NA, NA)
Early RecrDev 1959	-0.179	5	(-5, 5)	act	0.5523490	dev (NA, NA)
Early RecrDev 1960	-0.186	5	(-5, 5)	act	0.5507760	dev (NA, NA)
Early RecrDev 1961	-0.193	5	(-5, 5)	act	0.5491360	dev (NA, NA)
Early RecrDev 1962	-0.201	5	(-5, 5)	act	0.5474030	dev (NA, NA)
Early RecrDev 1963	-0.209	5	(-5, 5)	act	0.5455740	dev (NA, NA)
Early RecrDev 1964	-0.217	5	(-5, 5)	act	0.5436460	dev (NA, NA)
Early RecrDev 1965	-0.227	5	(-5, 5)	act	0.5415690	dev (NA, NA)
Early RecrDev 1966	-0.238	5	(-5, 5)	act	0.5393220	dev (NA, NA)
Early RecrDev 1967	-0.249	5	(-5, 5)	act	0.5368470	dev (NA, NA)
Early RecrDev 1968	-0.263	5	(-5, 5)	act	0.5341080	dev (NA, NA)
Early RecrDev 1969	-0.278	5	(-5, 5)	act	0.5310710	dev (NA, NA)
Early RecrDev 1970	-0.294	5	(-5, 5)	act	0.5277930	dev (NA, NA)
Early RecrDev 1971	-0.311	5	(-5, 5)	act	0.5244520	dev (NA, NA)
Early RecrDev 1972	-0.327	5	(-5, 5)	act	0.5212750	dev (NA, NA)
Early RecrDev 1973	-0.338	5	(-5, 5)	act	0.5188300	dev (NA, NA)
Early RecrDev 1974	-0.337	5	(-5, 5)	act	0.5176710	dev (NA, NA)
Early RecrDev 1975	-0.318	5	(-5, 5)	act	0.5175340	dev (NA, NA)
Early RecrDev 1976	-0.309	5	(-5, 5)	act	0.5173650	dev (NA, NA)
Early RecrDev 1977	-0.312	5	(-5, 5)	act	0.5172770	dev (NA, NA)
Main RecrDev 1978	-0.534	2	(-5, 5)	act	0.5332130	dev (NA, NA)
Main RecrDev 1979	-0.432	2	(-5, 5)	act	0.5476160	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	$\overline{\text{Prior}(\text{Exp.Val}, \text{SD})}$
Main RecrDev 1980	-0.280	2	(-5, 5)	act	0.5697850	dev (NA, NA)
Main RecrDev 1981	-0.220	2	(-5, 5)	act	0.5818810	dev (NA, NA)
Main RecrDev 1982	-0.259	2	(-5, 5)	act	0.5866670	dev (NA, NA)
Main RecrDev 1983	-0.114	2	(-5, 5)	act	0.6362140	dev (NA, NA)
Main RecrDev 1984	0.209	2	(-5, 5)	act	0.7592310	dev (NA, NA)
Main RecrDev 1985	0.424	2	(-5, 5)	act	0.8586760	dev (NA, NA)
Main RecrDev 1986	0.243	2	(-5, 5)	act	0.8878220	dev (NA, NA)
Main RecrDev 1987	1.320	2	(-5, 5)	act	0.6410710	dev (NA, NA)
Main RecrDev 1988	0.142	2	(-5, 5)	act	0.7857140	dev (NA, NA)
Main RecrDev 1989	0.081	2	(-5, 5)	act	0.6363950	dev (NA, NA)
Main RecrDev 1990	0.045	2	(-5, 5)	act	0.6687210	dev (NA, NA)
Main RecrDev 1991	0.603	2	(-5, 5)	act	0.7970220	dev (NA, NA)
Main RecrDev 1992	0.719	2	(-5, 5)	act	0.9165650	dev (NA, NA)
Main RecrDev 1993	0.455	2	(-5, 5)	act	0.9926700	dev (NA, NA)
Main RecrDev 1994	1.081	2	(-5, 5)	act	0.7119440	dev (NA, NA)
Main RecrDev 1995	0.341	2	(-5, 5)	act	0.9701030	dev (NA, NA)
Main RecrDev 1996	1.677	2	(-5, 5)	act	0.4381810	dev (NA, NA)
Main RecrDev 1997	-0.015	2	(-5, 5)	act	0.7002820	dev (NA, NA)
Main RecrDev 1998	0.087	2	(-5, 5)	act	0.7606940	dev (NA, NA)
Main RecrDev 1999	1.970	2	(-5, 5)	act	0.3034810	dev (NA, NA)
Main RecrDev 2000	-0.225	2	(-5, 5)	act	0.6211900	dev (NA, NA)
Main RecrDev 2001	-0.393	2	(-5, 5)	act	0.5500170	dev (NA, NA)
Main RecrDev 2002	-0.474	2	(-5, 5)	act	0.5208930	dev (NA, NA)
Main RecrDev 2003	-0.349	2	(-5, 5)	act	0.5245180	dev (NA, NA)
Main RecrDev 2004	-0.062	2	(-5, 5)	act	0.5431810	dev (NA, NA)
Main RecrDev 2005	0.038	2	(-5, 5)	act	0.5014010	dev (NA, NA)
Main RecrDev 2006	-0.521	2	(-5, 5)	act	0.5020880	dev (NA, NA)
Main RecrDev 2007	-0.789	2	(-5, 5)	act	0.4708870	dev (NA, NA)
Main RecrDev 2008	-0.826	2	(-5, 5)	act	0.4649180	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 2009	-0.700	2	(-5, 5)	act	0.4845610	dev (NA, NA)
Main RecrDev 2010	-0.277	2	(-5, 5)	act	0.5397700	dev (NA, NA)
Main RecrDev 2011	0.533	2	(-5, 5)	act	0.4310130	dev (NA, NA)
Main RecrDev 2012	-0.100	2	(-5, 5)	act	0.5199760	dev (NA, NA)
Main RecrDev 2013	-0.606	2	(-5, 5)	act	0.4766590	dev (NA, NA)
Main RecrDev 2014	-0.887	2	(-5, 5)	act	0.4600950	dev (NA, NA)
Main RecrDev 2015	-0.889	2	(-5, 5)	act	0.4712850	dev (NA, NA)
Main RecrDev 2016	-0.632	2	(-5, 5)	act	0.5173470	dev (NA, NA)
Main RecrDev 2017	-0.385	2	(-5, 5)	act	0.5736820	dev (NA, NA)
Late RecrDev 2018	-0.005	6	(-5, 5)	act	0.5983400	dev (NA, NA)
Late RecrDev 2019	0.000	6	(-5, 5)	act	0.5999750	dev (NA, NA)
Late RecrDev 2020	0.000	6	(-5, 5)	act	0.6000000	dev (NA, NA)
Size DblN peak CA Commercial(1)	41.568	2	(15, 50)	OK	1.8873100	None
Size DblN top logit CA Commercial(1)	-1.274	-2	(-7, 7)	NA	NA	None
Size DblN ascend se CA $Commercial(1)$	4.708	3	(-10, 10)	OK	0.2086120	None
Size DblN descend se CA Commercial(1)	-0.517	-4	(-10, 10)	NA	NA	None
Size DblN start logit CA Commercial(1)	-20.000	-9	(-20, 30)	NA	NA	None
Size DblN end logit CA Commercial(1)	10.000	-3	(-10, 10)	NA	NA	None
Size DblN peak CA Recreational(2)	33.365	2	(15, 50)	OK	1.0225400	None
Size DblN top logit CA Recreational(2)	-0.364	-2	(-7, 7)	NA	NA	None
Size DblN ascend se CA Recreational (2)	3.946	3	(-10, 10)	OK	0.2288940	None
Size DblN descend se CA Recreational(2)	-0.207	-4	(-10, 10)	NA	NA	None
Size DblN start logit CA Recreational(2)	-20.000	-9	(-20, 30)	NA	NA	None
Size DblN end logit CA $Recreational(2)$	10.000	-3	(-10, 10)	NA	NA	None

Label	Total
TOTAL	186.85
Catch	0.00
Equil catch	0.00
Length comp	163.10
Recruitment	23.75
InitEQ Regime	0.00
Forecast Recruitment	0.00
Parm priors	0.00
Parm softbounds	0.00
Parm devs	0.00
Crash Pen	0.00

 Table 10:
 Likelihood components by source.

	Estimate	Lower Interval	Upper Interval
Unfished Spawning Output	55.08	46.76	63.4
Unfished Age $3+$ Biomass (mt)	443.01	376.09	509.94
Unfished Recruitment (R0)	23.76	20.17	27.36
Spawning Output (2021)	7.75	1.65	13.84
Fraction Unfished (2021)	0.14	0.04	0.24
Reference Points Based SB40%	-	-	-
Proxy Spawning Output SB40%	22.03	18.7	25.36
SPR Resulting in SB40%	0.46	0.46	0.46
Exploitation Rate Resulting in SB40%	0.05	0.05	0.05
Yield with SPR Based On SB40% (mt)	8.8	7.49	10.11
Reference Points Based on SPR Proxy for MSY	-	-	-
Proxy Spawning Output (SPR50)	24.58	20.86	28.29
Exploitation Rate Corresponding to SPR50	0.04	0.04	0.04
Yield with SPR50 at SB SPR (mt)	8.41	7.15	9.66
Reference Points Based on Estimated MSY Values	-	-	-
Spawning Output at MSY (SB MSY)	15.44	13.1	17.77
SPR MSY	0.35	0.35	0.35
Exploitation Rate Corresponding to SPR MSY	0.07	0.07	0.07
MSY (mt)	9.3	7.91	10.69

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

Year	Total	Spawn-	Total	Frac-	Age-0	Total	1-SPR	Ex-
	Biomass	ing	Biomass	tion	Re-	Mortal-		ploita-
	(mt)	Output	3+ (mt)	Un-	cruits	ity (mt)		tion
				fished				Rate
1916	444.71	55.08	443.01	1.00	23.77	0.02	0.00	0.00
1917	444.70	55.08	443.00	1.00	23.77	0.03	0.00	0.00
1918	444.67	55.08	442.97	1.00	23.77	0.07	0.00	0.00
1919	444.60	55.07	442.90	1.00	23.77	0.02	0.00	0.00
1920	444.59	55.07	442.89	1.00	23.77	0.02	0.00	0.00
1921	444.57	55.06	442.87	1.00	23.77	0.03	0.00	0.00
1922	444.55	55.06	442.85	1.00	23.77	0.03	0.00	0.00
1923	444.53	55.06	442.83	1.00	23.77	0.01	0.00	0.00
1924	444.53	55.06	442.83	1.00	23.77	0.02	0.00	0.00
1925	444.52	55.06	442.82	1.00	23.77	0.08	0.00	0.00
1926	444.46	55.05	442.76	1.00	23.77	0.07	0.00	0.00
1927	444.40	55.04	442.70	1.00	23.77	0.14	0.01	0.00
1928	444.29	55.03	442.58	1.00	23.77	0.18	0.01	0.00
1929	444.13	55.00	442.43	1.00	23.77	0.24	0.01	0.00
1930	443.92	54.98	442.22	1.00	23.76	0.32	0.02	0.00
1931	443.64	54.94	441.94	1.00	23.76	0.44	0.02	0.00
1932	443.26	54.89	441.56	1.00	23.76	0.42	0.02	0.00
1933	442.91	54.85	441.21	1.00	23.76	0.42	0.02	0.00
1934	442.57	54.80	440.87	0.99	23.76	0.45	0.02	0.00
1935	442.21	54.75	440.50	0.99	23.76	0.61	0.03	0.00
1936	441.71	54.69	440.01	0.99	23.75	0.64	0.03	0.00
1937	441.20	54.62	439.49	0.99	23.75	0.65	0.03	0.00
1938	440.69	54.55	438.99	0.99	23.75	0.70	0.03	0.00
1939	440.15	54.48	438.45	0.99	23.74	0.63	0.03	0.00
1940	439.70	54.42	438.01	0.99	21.84	0.70	0.03	0.00
1941	439.19	54.36	437.51	0.99	21.75	0.71	0.03	0.00
1942	438.59	54.30	437.03	0.99	21.67	0.44	0.02	0.00
1943	438.13	54.27	436.57	0.99	21.58	0.47	0.02	0.00
1944	437.45	54.24	435.90	0.98	21.49	1.16	0.05	0.00
1945	435.93	54.10	434.39	0.98	21.39	2.59	0.11	0.01
1946	432.88	53.75	431.35	0.98	21.29	2.92	0.13	0.01
1947	429.41	53.34	427.88	0.97	21.17	0.91	0.04	0.00
1948	427.78	53.15	426.26	0.96	21.07	1.86	0.09	0.00
1949	425.13	52.84	423.62	0.96	20.95	1.47	0.07	0.00
1950	422.79	52.55	421.28	0.95	20.84	1.54	0.08	0.00
1951	420.32	52.25	418.82	0.95	20.72	1.98	0.10	0.00
1952	417.39	51.89	415.90	0.94	20.59	1.72	0.08	0.00
1953	414.70	51.56	413.22	0.94	20.47	1.39	0.07	0.00
1954	412.33	51.27	410.86	0.93	20.34	1.92	0.09	0.00
1955	409.43	50.91	407.96	0.92	20.20	1.83	0.09	0.00
1956	406.61	50.55	405.16	0.92	20.07	2.07	0.10	0.01
1957	403.57	50.17	402.13	0.91	19.93	2.08	0.10	0.01

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

Year	Total	Spawn-	Total	Frac-	Age-0	Total	$1\text{-}\mathrm{SPR}$	Ex-
	Biomass	ing	Biomass	tion	Re-	Mortal-		ploita-
	(mt)	Output	3 + (mt)	Un-	cruits	ity (mt)		tion
				fished				Rate
1958	400.54	49.80	399.11	0.90	19.79	3.61	0.17	0.01
1959	396.03	49.22	394.60	0.89	19.64	2.67	0.13	0.01
1960	392.48	48.78	391.07	0.89	19.49	2.21	0.11	0.01
1961	389.43	48.39	388.03	0.88	19.34	1.61	0.09	0.00
1962	387.00	48.09	385.61	0.87	19.18	1.82	0.10	0.00
1963	384.38	47.76	383.00	0.87	19.01	2.74	0.14	0.01
1964	380.86	47.32	379.49	0.86	18.82	2.23	0.12	0.01
1965	377.86	46.95	376.51	0.85	18.63	3.83	0.19	0.01
1966	373.31	46.38	371.97	0.84	18.41	4.29	0.21	0.01
1967	368.35	45.75	367.02	0.83	18.16	4.84	0.23	0.01
1968	362.91	45.06	361.59	0.82	17.89	4.95	0.24	0.01
1969	357.42	44.37	356.12	0.81	17.59	5.47	0.27	0.02
1970	351.47	43.62	350.20	0.79	17.27	7.45	0.34	0.02
1971	343.66	42.63	342.40	0.77	16.93	6.62	0.32	0.02
1972	336.76	41.75	335.53	0.76	16.62	9.47	0.41	0.03
1973	327.14	40.53	325.93	0.74	16.38	10.23	0.44	0.03
1974	316.91	39.24	315.73	0.71	16.33	11.31	0.47	0.04
1975	305.79	37.82	304.62	0.69	16.56	11.27	0.48	0.04
1976	294.93	36.43	293.75	0.66	16.63	12.83	0.53	0.04
1977	282.77	34.87	281.58	0.63	16.47	13.56	0.56	0.05
1978	270.21	33.25	269.03	0.60	13.10	13.19	0.56	0.05
1979	258.36	31.70	257.22	0.58	14.40	14.02	0.60	0.05
1980	245.94	30.10	244.98	0.55	16.63	15.13	0.63	0.06
1981	232.67	28.41	231.61	0.52	17.49	5.45	0.36	0.02
1982	229.28	27.98	228.08	0.51	16.78	5.60	0.37	0.02
1983	226.04	27.54	224.79	0.50	19.34	40.56	0.88	0.18
1984	188.81	22.73	187.56	0.41	25.74	13.56	0.67	0.07
1985	179.32	21.37	177.84	0.39	31.50	12.25	0.66	0.07
1986	172.18	20.26	170.27	0.37	25.98	13.26	0.70	0.08
1987	165.67	19.13	163.36	0.35	75.32	5.66	0.47	0.03
1988	168.47	19.05	166.06	0.35	23.16	2.13	0.23	0.01
1989	177.90	19.60	173.22	0.36	21.95	11.58	0.65	0.07
1990	180.53	19.28	178.89	0.35	21.09	17.55	0.76	0.10
1991	178.59	18.54	176.99	0.34	36.48	73.90	0.96	0.42
1992	123.22	11.85	121.50	0.22	36.10	35.41	0.94	0.29
1993	103.81	9.92	101.23	0.18	26.07	40.67	0.96	0.40
1994	78.69	7.12	76.20	0.13	42.59	23.90	0.93	0.31
1995	70.28	5.81	68.24	0.11	18.48	12.66	0.89	0.19
1996	73.59	5.85	70.74	0.11	70.50	15.56	0.91	0.22
1997	75.08	5.88	73.19	0.11	13.02	22.98	0.94	0.31
1998	71.18	5.29	66.93	0.10	13.66	14.98	0.91	0.22
1999	75.16	5.56	74.02	0.10	92.17	13.81	0.90	0.19
2000	80.00	6.02	78.15	0.11	10.68	13.31	0.88	0.17

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

Year	Total	Spawn-	Total	Frac-	Age-0	Total	1-SPR	Ex-
	Biomass	ing	Biomass	tion	Re-	Mortal-		ploita-
	(mt)	Output	3 + (mt)	Un-	cruits	ity (mt)		tion
				fished				Rate
2001	86.73	6.82	81.26	0.12	9.57	16.10	0.89	0.20
2002	91.47	7.39	90.73	0.13	8.86	5.96	0.70	0.07
2003	104.93	8.76	104.25	0.16	10.45	13.92	0.84	0.13
2004	108.84	9.75	108.18	0.18	14.50	5.64	0.60	0.05
2005	118.38	11.76	117.57	0.21	17.11	10.59	0.73	0.09
2006	121.11	12.85	120.05	0.23	10.06	14.55	0.79	0.12
2007	117.91	12.90	116.79	0.23	7.71	19.32	0.85	0.17
2008	108.25	11.93	107.56	0.22	7.25	11.05	0.75	0.10
2009	105.22	11.66	104.67	0.21	8.16	6.88	0.64	0.07
2010	104.97	11.80	104.42	0.21	12.50	3.56	0.46	0.03
2011	107.13	12.27	106.44	0.22	28.47	5.45	0.57	0.05
2012	106.95	12.39	105.87	0.22	15.17	7.99	0.68	0.08
2013	104.56	12.04	102.72	0.22	9.06	3.57	0.46	0.03
2014	106.98	12.13	105.99	0.22	6.86	2.97	0.41	0.03
2015	110.22	12.30	109.61	0.22	6.87	8.55	0.70	0.08
2016	107.80	12.00	107.30	0.22	9.00	9.46	0.73	0.09
2017	103.96	11.74	103.43	0.21	11.69	12.52	0.79	0.12
2018	96.59	11.06	95.90	0.20	17.10	12.84	0.81	0.13
2019	88.55	10.19	87.64	0.18	16.70	16.02	0.87	0.18
2020	77.52	8.78	76.30	0.16	15.78	12.34	0.85	0.16
2021	70.60	7.75	69.42	0.14	14.99	5.83	0.71	0.08
2022	70.71	7.52	69.59	0.14	14.81	5.84	0.72	0.08
2023	71.49	7.43	70.42	0.13	14.73	0.82	0.22	0.01
2024	77.74	8.08	76.68	0.15	15.26	1.08	0.26	0.01
2025	84.18	8.83	83.11	0.16	15.82	1.38	0.29	0.02
2026	90.64	9.62	89.53	0.17	16.35	1.69	0.32	0.02
2027	97.01	10.41	95.87	0.19	16.83	1.98	0.34	0.02
2028	103.24	11.18	102.06	0.20	17.25	2.26	0.35	0.02
2029	109.32	11.91	108.11	0.22	17.62	2.52	0.36	0.02
2030	115.25	12.63	114.01	0.23	17.96	2.76	0.37	0.02
2031	121.03	13.33	119.76	0.24	18.26	2.99	0.38	0.02
2032	126.66	14.00	125.37	0.25	18.53	3.21	0.39	0.03

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

 Table 13:
 Sensitivities relative to the base model.

	Base	No	DW	DW	Est	Est	Est	Est	Est	No	No	Rec	Com	Rec	Adjust extreme catches
	model	rec	Fran-	DM	Linf	Linf,	Κ	Old	Μ	pre-	pre-	dome	dome	block	
		devs	cis			Κ		CV		2004	1993	se-	se-	selex.	
										rec	rec	lex.	lex.	1993	
										comps	comps				
Total Likelihood	186.85	257.08	134.93	815.35	184.34	180.81	179.54	183.09	175.14	148.11	169.06	185.48	184.48	186.25	192.96
Length Likelihood	163.10	257.08	119.57	764.51	162.65	161.13	160.35	160.95	158.71	127.34	147.12	161.93	161.80	162.74	163.12
Recruitment Likelihood	23.75	0.00	15.35	48.41	21.69	19.68	19.19	22.14	15.32	20.77	21.94	23.54	22.68	23.52	29.84
Forecast Recruitment Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parameter Priors Likelihood	0.00	0.00	0.00	2.43	0.00	0.00	0.00	0.00	1.11	0.00	0.00	0.00	0.00	0.00	0.00
Parameter Bounds Likelihood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\log(\mathrm{R0})$	3.17	3.26	3.21	3.09	3.24	3.36	3.40	3.20	4.01	3.16	3.17	3.19	3.18	3.18	2.84
SB Virgin	55.08	60.48	57.42	50.86	54.42	55.37	55.24	56.15	42.06	54.75	55.08	56.26	55.91	55.57	39.56
SB 2020	7.75	12.06	8.03	8.59	11.49	14.22	16.35	8.33	18.05	7.95	8.06	8.89	8.35	7.80	4.59
Fraction Unfished 2021	0.14	0.20	0.14	0.17	0.21	0.26	0.30	0.15	0.43	0.15	0.15	0.16	0.15	0.14	0.12
Total Yield at SPR 50	8.41	9.05	8.72	7.81	8.49	8.25	8.20	8.52	11.99	8.39	8.44	8.41	8.41	8.49	6.02
Steepness	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Natural Mortality	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.11	0.06	0.06	0.06	0.06	0.06	0.06
Length at Amin	8.23	8.23	8.23	8.23	8.23	8.23	8.23	8.23	8.23	8.23	8.23	8.23	8.23	8.23	8.23
Length at Amax	43.04	43.04	43.04	43.04	42.09	43.02	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04	43.04
Von Bert. k	0.20	0.20	0.20	0.20	0.20	0.14	0.13	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
CV young	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
CV old	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.08	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Peak recreational selex	41.57	35.55	40.24	43.30	41.62	42.00	42.28	41.32	43.73	41.48	41.56	41.08	41.80	41.49	41.17
Peak commercial selex	33.36	33.60	33.40	34.94	32.74	33.35	33.39	32.86	34.43	33.24	33.68	33.19	33.27	33.36	33.15

Table 14: Projections of potential OFLs (mt), ABCs (mt), the assumed removals based on 2021 and 2022 adopted ACL values, estimated spawning output, and fraction unfished. The OFL South and ACL South for 2021 and 2022 reflect adopted management limits for quillback rockfish for the area south of 40.10 Latitude N. The OFL North is the year specific total OFL for quillback rockfish, and the CA ACL North is the California specific allocation of the total ACL for 2021 and 2022 north of 40.10 Latitude N. Total CA ACL is the sum of the ACL South and CA ACL North values.

Year	OFL South	ACL South	OFL North	CA ACL North	Total CA ACL	As- sumed re- movals	OFL	ABC	Buffer	Spawn- ing Out- put	Frac- tion Un- fished
2021	5.39	4.19	7.37	1.65	5.84	5.83	-	-	-	7.75	0.14
2022	5.39	4.19	7.37	1.65	5.84	5.84	-	-	-	7.52	0.14
2023	-	-	-	-	-	-	2.67	0.82	0.306	7.43	0.13
2024	-	-	-	-	-	-	2.92	1.08	0.372	8.08	0.15
2025	-	-	-	-	-	-	3.18	1.38	0.434	8.83	0.16
2026	-	-	-	-	-	-	3.45	1.69	0.488	9.62	0.17
2027	-	-	-	-	-	-	3.72	1.98	0.532	10.41	0.19
2028	-	-	-	-	-	-	3.98	2.26	0.567	11.18	0.20
2029	-	-	-	-	-	-	4.23	2.52	0.595	11.91	0.22
2030	-	-	-	-	-	-	4.47	2.76	0.618	12.63	0.23
2031	-	-	-	-	-	-	4.7	2.99	0.636	13.33	0.24
2032	-	-	-	-	-	-	4.93	3.21	0.652	14.00	0.25

8 Figures



Figure 1: Total removals (mt) by fleet used in the base model.



Figure 2: Summary of data sources used in the base model.



Figure 3: Length composition data from the commercial fleet.



Figure 4: Mean length for commercial fleet with 95 percent confidence intervals.



Figure 5: Length composition data from the recreational fleet.



Figure 6: Mean length for recreational fleet with 95 percent confidence intervals.



Figure 7: Maturity as a function of length.



Figure 8: Fecundity as a function of length.



Figure 9: Observed sex-specific weight-at-length data from the individual sources with length and weight data, along with all sources combined with the estimated weight-at-length curves.



Figure 10: Weight-at-length relationship used in the model.



Figure 11: Observed sex-specific length-at-age data from the individual sources with length and age data, along with all sources combined with the estimated length-at-age curves.



Figure 12: Length at age in the beginning of the year in the ending year of the model.



Length-based selectivity by fleet in 2020

Figure 13: Selectivity at length by fleet.



Age-0 recruits (1,000s) with ~95% asymptotic intervals

Figure 14: Estimated time series of age-0 recruits (1000s).



Figure 15: Estimated time series of recruitment deviations.



Figure 16: Recruitment bias adjustment applied in the base model.



Figure 17: Pearson residuals for commercial fleet. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



Figure 18: Model estimated mean length in cm (blue line) overlaid on mean length of commercial lengths (gray circles) with 95 percent confidence intervals (thick bars) based on current samples sizes. The thin bars indicate the confidence interval if Francis weighting were used instead.



Figure 19: Pearson residuals for recreational fleet. Closed bubble are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).



Figure 20: Model estimated mean length in cm (blue line) overlaid on mean length for recreational lengths (gray circles) with 95 percent confidence intervals (thick bars) based on current samples sizes. The thin bars indicate the confidence interval if Francis weighting were used instead.



Figure 21: Aggregated length comps over all years.


Figure 22: Estimated time series of spawning output.



Total biomass (mt)

Figure 23: Estimated time series of total biomass.



Relative spawning output: B/B_0 with ~95% asymptotic intervals

Figure 24: Estimated time series of relative spawning output.



Figure 25: Stock-recruit curve. Point colors indicate year, with warmer colors indicating earlier years and cooler colors in showing later years.







Figure 26: Change in the negative log-likelihood across a range of $\ln(R0)$ values.



Figure 27: Change in the estimate of spawning output across a range of $\ln(R0)$ values.



Figure 28: Change in the estimate of fraction unfished across a range of $\ln(R0)$ values.





Figure 29: Change in the negative log-likelihood across a range of steepness values.



Figure 30: Change in the estimate of spawning output across a range of steepness values.



Figure 31: Change in the estimate of fraction unfished across a range of steepness values.



Figure 32: Change in the negative log-likelihood across a range of natural mortality values.



Figure 33: Change in the estimate of spawning output across a range of natural mortality values.



Figure 34: Change in the estimate of fraction unfished across a range of natural mortality values.



Figure 35: Change in the negative log-likelihood across a range of maximum length values.



Figure 36: Change in the estimate of spawning output across a range of maximum length values.



Figure 37: Change in the estimate of fraction unfished across a range of maximum length values.



Changes in total likelihood





Figure 38: Change in the negative log-likelihood across a range of k values.



Figure 39: Change in the estimate of spawning output across a range of k values.



Figure 40: Change in the estimate of fraction unfished across a range of k values.



Figure 41: Change in the negative log-likelihood across a range of CV at maximum length values.

0.10

CV_old_Fem_GP_1

0.12

0.06

0.08

Т

0.14



Figure 42: Change in the estimate of spawning output across a range of CV at maximum length values.



Figure 43: Change in the estimate of fraction unfished across a range of CV at maximum length values.



Figure 44: Change in the estimate of spawning output when the most recent 5 years of data are removed sequentially.



Figure 45: Change in the estimate of fraction unfished when the most recent 5 years of data are removed sequentially.



Figure 46: Change in the estimate of annual recruitment deviations when the most recent 5 years of data are removed sequentially.



Figure 47: Change in estimated spawning output by sensitivity.



Figure 48: Change in estimated fraction unfished by sensitivity.



Figure 49: Change in estimated annual recruitment deviation.



Figure 50: Estimated 1 - relative spawning ratio (SPR) by year.



Figure 51: Phase plot showing the fraction unfished versus fishing intensity for each year. Each point shows the spawning output relative to the unfished spawning output and the SPR ratio for each year. Lines through the final point show the 95 percent confidence intervals based on the asymptotic uncertainty for each dimension. The shaded ellipse is a 95 percent confidence region which accounts for the estimated correlations between the spawning output and SPR ratios.



Figure 52: 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 Appendix A: California ROV Survey Data Informing Selectivity

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 quillback rockfish biomass (Table 15).

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. The length frequency distribution by depth is provided in Figure 53. In reviewing both the density by depth and length by depth relative to ontogenetic migration, the patterns may not reflect the smaller fish using shallow rocky reef as juveniles in less than 10 fm, and only reflect the density and composition in deeper depths where ontogenetic migration to deeper depths has already taken place for nearshore species and is not as apparent.

When examining the length composition data by depth inside and outside of MPAs north of Point Conception (Figure 53), no extreme differences in composition were observed, which is not surprising given the relatively recent implementation of MPAs north of Point Conception between 2007 and 2012. The MPAs make up 20-30% of the rocky reef habitat in state waters within three miles of shore and are intended to preserve the larger individuals as biomass accumulates in MPAs over time. The combination of MPAs and RCAs restrict a larger portion of habitat to fishing (see Appendix B for details).

The percentage of fish in 5 cm size categories among 10 fm depths bins north of Point Conception did not show clear signs of increasing size with depth in greater than 10 fm in either region or protected vs. reference sites (Figure 54). This may be in part due to the fish having already moved from shallow kelp forest habitat where the ROV cannot operate to the adult depth distribution in greater than 10 fm by the time they are observed. Only in the shallower depth bins is there higher proportion of smaller individuals. This would indicate that selectivity may not be domed shaped as would be considered if the depth restrictions protected a larger proportion of adult biomass.

Depth (fm)	Observed Area (m2)	Quillback Rockfish Observed	Quillback Rockfish Density (fish/m2)	Percent Relative Density
0-10	2905	0	0	0
10-20	124611	54	0.00043	0.17
20-30	106708	92	0.00086	0.34
30-40	86149	67	0.00078	0.3
40-50	49896	21	0.00042	0.16
50-60	16972	1	0.00006	0.02
60-70	1379	0	0	0
70-80	970	0	0	0
80-90	947	0	0	0
90-100	1257	0	0	0
100-110	608	0	0	0
110-120	696	0	0	0
120-130	415	0	0	0
130 - 140	777	0	0	0
140 - 150	1633	0	0	0
150 - 160	908	0	0	0
160 - 170	860	0	0	0
170 - 180	1268	0	0	0
180-190	912	0	0	0
190-200	735	0	0	0
200-210	604	0	0	0
210-220	167	0	0	0
220-230	54	0	0	0
230-240	100	0	0	0
Total	401535	235	-	-

Table 15: Counts of fish, areas surveyed by the ROV, density (fish/meter square) and percent relative density by 10 fm depth



Figure 53: Length frequency distribution of in each 10 fm depth bin for quillback rockfish sampled by the ROV in reference locations open to fishing north of Point Conception (above) and State Marine Reserves prohibiting take (below).



Figure 54: Percent composition of quillback 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 retention is allowed (above) and in State Marine Reserves where retention is prohibited (below).
9.2 Appendix B: Percent Area Closed to Fishing in the RCAs and MPAs over time

MPAs were instituted at various times from 2003 to 2012 as the area selection process was undertaken on a regional process. The existence of no take MPAs in some of the areas selected prior to expansion of the MPAs to encompass approximately 20-30% of rocky reef habitat in state waters, duration of existence of new areas, degree of effort prior to protection or criteria for selection including productivity of the reef may have contributed to the current patterns in composition and density inside vs. outside MPAs. As biomass accrues inside MPAs, 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 the MPAs.

The percentage area closed to fishing in MPAs and Rockfish Conservation Areas (RCAs) north of Point Conception from 2001 to 2021 are shown in Table 16. The percentage closed to fishing provides a buffer against uncertainty through protection of a portion of the population. The percent 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. Areas closed to fishing prior to the implementation of the present MPA network were also accounted for. 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. The presence of each type of closure in each assessment region and year was converted to tables of Boolean fields allowing GIS algorithms estimating the area open and closed to fishing. The distribution and area of rocky reef habitat was determined using the GIS layers rendering the results of the side scanning sonar from the California Seafloor Mapping Project to identify hard bottom at varying levels of resolution from two square meters to ten meters based on the depth surveyed due to cone width of the sonar. The area of rocky reef habitat closed to fishing within the depth distribution of the focal species was converted to a percentage of the total habitat.

Year	Percent Habitat Protected by MPA	Percent Habitat Protected by RCA	Percent Habitat Open to Fishing
2001	4	0	96
2002	4	0	96
2003	4	38	59
2004	7	23	70
2005	7	29	64
2006	7	29	64
2007	7	27	66
2008	14	27	59

Table 16: Percent of rocky reef habitat protected for quillback and copper rockfish north or Point Conception by MPAs and RCAs, and the total percent habitat open to fishing.

Year	Percent Habitat Protected by MPA	Percent Habitat Protected by RCA	Percent Habitat Open to Fishing
2009	14	27	59
2010	14	32	54
2011	21	30	49
2012	23	30	47
2013	26	30	44
2014	26	30	44
2015	26	27	47
2016	26	27	47
2017	26	16	58
2018	26	16	58
2019	26	13	61
2020	26	13	61
2021	26	6	68

Table 16: Percent of rocky reef habitat protected for quillback and copper rockfish north or Point Conception by MPAs and RCAs, and the total percent habitat open to fishing. *(continued)*



9.3 Appendix C: Detailed Fit to Annual Length Composition Data

Figure 55: Length comps, whole catch, CA_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 56: Length comps, whole catch, CA_Commercial (plot 2 of 2).



Figure 57: Length comps, whole catch, CA_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 58: Length comps, whole catch, CA_Recreational (plot 2 of 3).



Length (cm)

Figure 59: Length comps, whole catch, CA_Recreational (plot 3 of 3).



Length (cm)

Figure 60: Ghost length comps, whole catch, CA_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.