The Combined Status of Blue and Deacon Rockfishes in U.S. Waters off California and Oregon in 2017

Blue Rockfish (*Sebastes mystinus*)

Deacon Rockfish (*Sebastes diaconus*)

January 2018

Prepared by

E.J. Dick[1,*], Aaron Berger[2,*], Joe Bizzarro[3,1], Katelyn Bosley[2], Jason Cope[4], John Field[1], Libby Gilbert-Horvath[1], Nicholas Grunloh[3,1], Morgan Ivens-Duran[5], Rebecca Miller[3,1], Kristin Privitera-Johnson[6], Brett T. Rodomsky[7]

[*] Corresponding authors: edward.dick@noaa.gov and aaron.berger@noaa.gov

[1] Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 110 McAllister Way, Santa Cruz, CA 95060.
[2] Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 2032 SE OSU Dr., Newport, OR 97365
[3] University of California, Santa Cruz, Cooperative Institute for Marine Ecosystems and Climate, Award Number NA150AR4320071, 1156 High Street, Santa Cruz, CA 95064, USA.
[4] Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 2725 Montlake Boulevard East, Seattle, WA 98112
[5] California Department of Fish and Wildlife, 20 Lower Ragsdale Drive, Suite 100, Monterey, CA 93940
[6] University of Washington, School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195
[7] Oregon Department of Fish and Wildlife, 2040 SE Marine Science Drive, Newport, OR 97365

This report may be cited as:

Dick, E.J., A. Berger, J. Bizzarro, K. Bosley, J. Cope, J. Field, L. Gilbert-Horvath, N. Grunloh, M. Ivens-Duran, R. Miller, K. Privitera-Johnson, and B.T. Rodomsky. 2017. The Combined Status of Blue and Deacon Rockfishes in U.S. Waters off California and Oregon in 2017. Pacific Fishery Management Council, Portland, OR. Available from http://www.pcouncil.org/groundfish/stock-assessments/

Photo credits:

Photos of Blue and Deacon Rockfishes were downloaded from the RecFIN website (http://www.recfin.org/resources/fishid/) and taken by Vicky Okimura (WDFW).

Glossary of Acronyms:

ABC: Acceptable Biological Catch
ACL: Annual Catch Limit
BDR: Blue and Deacon Rockfish(es)
CAAL: Conditional age at length
CalCOFI: California Cooperative Oceanic Fisheries Investigations
CALCOM: California Cooperative Groundfish Survey
CDFW (CDFG): California Department of Fish and Wildlife (formerly Fish and Game)
CPFV: Commercial Passenger Fishing Vessel (aka “party” or “charter” boats)
CPAH: Catch-per-angler-hour
CPUE: Catch-per-unit-effort
CRFS: California Recreational Fisheries Survey
MRFSS: Marine Recreational Fisheries Statistics Survey
NMFS: National Marine Fisheries Service
NWFSC: Northwest Fisheries Science Center
ODFW: Oregon Department of Fish and Wildlife
OFL: Overfishing Limit
ORBS: Oregon Recreational Boat Survey
PacFIN: Pacific Fisheries Information Network
PFMC: Pacific Fishery Management Council
PISCO: Partnership for the Interdisciplinary Study of Coastal Oceans
PSMFC: Pacific States Marine Fisheries Commission
RecFIN: Recreational Fisheries Information Network
SEBS: Shore Estuary Boat Survey
SPR: Spawning Potential Ratio
STAR: Stock Assessment Review (Panel)
STAT: Stock Assessment Team
SWFSC: Southwest Fisheries Science Center
WCGOP: West Coast Groundfish Observer Program
WDFW: Washington Department of Fish and Wildlife
YOY: Young-of-the-year

Table of Contents

Executive Summary

Stock

This assessment reports the status of the Blue Rockfish (*Sebastes mystinus*) and the recently described Deacon Rockfish (*Sebastes diaconus*; Frabel et al. 2015) as a stock complex in U.S. waters off the coast of California and Oregon. The complex is modeled with two independent stock assessments to approximate spatial variation in species composition, exploitation history, and other factors affecting stock dynamics. The California model represents the stock complex in U.S. waters from Point Conception (34° 27′ North latitude) to the California-Oregon border (42° N. lat.), and the Oregon model includes all U.S. waters off the coast of Oregon. Recent genetic analyses (see Appendix A) suggest that Blue Rockfish may be the dominant species south of Monterey Bay, CA, with an increasing fraction of Deacon Rockfish north of Monterey and into Oregon. Historical data streams did not separate the two species or estimate removals at a spatial scale small enough to evaluate assessment boundaries near Monterey Bay, but future assessments may wish to consider alternative spatial structures should long-term, species-specific data become available.

Catches

California

Over the past decade, Blue and Deacon Rockfish (BDR) off California have been caught primarily by the recreational fishery (Table ES1). Over this time period, the commercial passenger fishing vessel (CPFV) fleet accounted for over 50% of the total removals and the private boat fleet accounted for over 30%, with the remainder largely taken by commercial hook and line gears. Since 1900, recreational fisheries account for roughly 80% of cumulative removals in waters north of Point Conception. BDR landings from all sectors have historically been recorded as “Blue Rockfish” and recreational sampling in California currently does not differentiate between the two species.

Table ES1: Recent catches (mt) in California, north of Point Conception, by sector. Commercial landings are aggregated (see main text for disaggregated estimates) and minor removals by recreational shore modes are included with private boat landings.

Year	Recreational CPFV	Recreational Private	Recreational Discard	Commercial Landings	Commercial Discard	Total Removals
2005	209.25	62.44	5.43	17.77	9.00	303.89
2006	174.21	109.94	5.68	18.77	9.50	318.10
2007	95.03	39.88	2.70	13.40	6.78	157.79
2008	47.11	28.77	1.52	26.33	13.33	117.06
2009	21.49	16.89	0.77	7.35	3.72	50.22
2010	28.93	21.56	1.01	4.93	2.49	58.92
2011	34.97	23.53	1.17	7.12	3.60	70.39
2012	30.12	18.54	0.97	6.64	3.36	59.63
2013	66.84	35.95	2.06	6.10	3.09	114.04
2014	64.38	49.37	2.27	5.90	2.99	124.91
2015	91.73	63.91	3.11	9.18	4.65	172.58
2016	81.23	41.79	2.46	7.16	3.62	136.26

Recreational removals in California prior to 2004 were only estimated at large spatial scales -- north and south of Point Conception -- following the design of the Marine Recreational Fisheries Statistics Survey (MRFSS). Recent sampling (2004 – present) by the California Recreational Fisheries Survey (CRFS) produces estimates of BDR landings and discard at a finer spatial resolution. Total removals north of Point Conception increased steadily following World War II, peaking in the late 1970s and early 1980s with annual removals exceeding 600 mt per year (Figure ES1). This was followed by a decline in catch until about 2010. Recent years have seen a steady increase in landings, but total removals remain low relative to historical levels.

Oregon

BDR in Oregon is predominantly caught using hook-and-line gear by recreational fishermen and by hook-and-line or longline gear by commercial fishermen. Several other gear types harvest incidental amounts of BDR (including troll and trawl gear). Catch of BDR is almost all incidental as these species regularly school with Black Rockfish, the main target of Oregon nearshore fisheries. Only a small number of recreational and commercial fishermen target these fish regularly, generally in winter and spring months when catch rates tend to be higher.

Total landings have generally increased through time up until the late-1990s when landings returned to levels in the 2000s that more consistent with those observed in the 1980s (Figure ES2). Since the implementation of management limits on the commercial fishery in 2004 (fleet size limit, annual landing caps, and daily and period landing limits) and on the recreational fishery since 2001 (bag limit reductions), landings have reduced and have been generally stable. Recent landings continue to be dominated by the recreational landing fishery (Table ES2).

Table ES2: Recent catches (mt) for BDR in Oregon by fleet.

Year	Commercial Landings Fleet	Commercial Discards Fleet	Recreational Landings Ocean Fleet	Recreational Discards Ocean Fleet	Recreational Shore Fleet	Total Removals
2005	5.18	1.28	31.10	0.76	2.17	40.49
2006	4.68	1.16	11.52	0.30	1.06	18.72
2007	4.26	1.05	16.16	0.56	1.07	23.10
2008	2.74	0.68	15.14	0.68	1.08	20.32
2009	2.85	0.70	15.28	0.94	1.09	20.86
2010	4.04	1.00	21.17	0.79	1.09	28.09
2011	6.58	1.62	20.44	0.76	1.10	30.50
2012	6.84	1.69	25.12	0.71	1.11	35.47
2013	5.15	1.27	23.06	0.78	1.12	31.38
2014	3.97	0.98	18.11	0.62	1.12	24.80
2015	1.51	0.37	28.04	1.68	1.13	32.73
2016	2.06	0.51	19.95	0.71	1.14	24.37

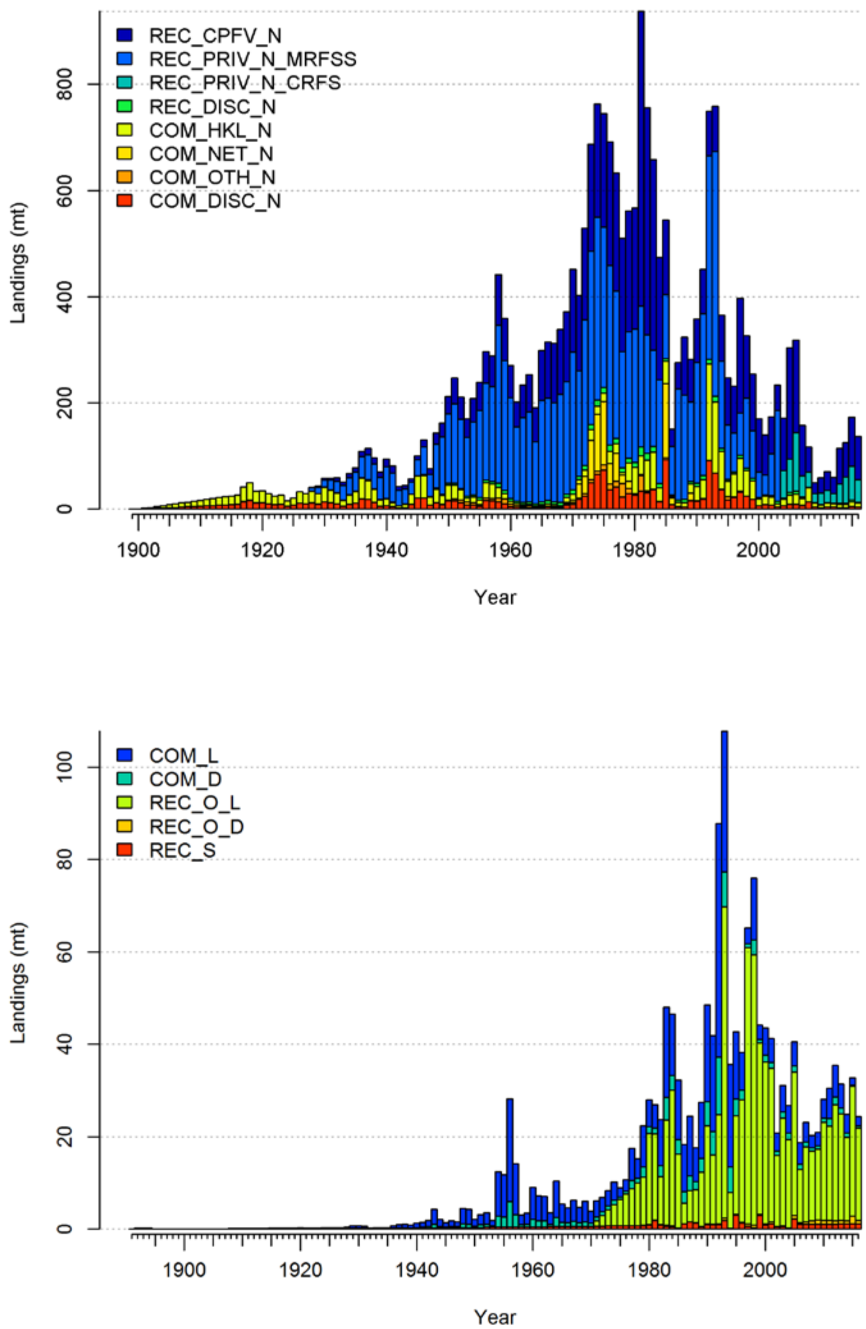


Figure ES1: Catch histories by fleet in the base models for California (upper panel) and Oregon (lower panel).

Data and assessment

<u>California</u>

"Blue Rockfish" (now known to include both Blue and Deacon Rockfishes) was last assessed in 2007, and estimated to be at 29% of unfished spawning output (Key et al. 2008). The 2017 assessment of BDR uses Stock Synthesis 3 (version V3.30.03.07). The assessment is structured as a single, sex-disaggregated, unit population, spanning U.S. waters from Point Conception to the California-Oregon border. The assessment model operates on an annual time step covering the period 1900 to 2017 (not including forecast years) and assumes an unfished population prior to 1900. Population dynamics are modeled for ages 0 through 35, with age-35 being the accumulator age. The maximum observed age was 39 for males and 43 for females. The model is conditioned on catch from two sectors (commercial and recreational) divided among eight fleets, and is informed by five abundance indices (one fishery-independent survey, two CPUE indices from shore-based sampling programs, and two CPUE indices from onboard observer programs). Size composition data include lengths from multiple fleets spanning the period 1959-2016, but a very limited number of age structures were available for California, specifically from the recreational fishery (1980-1984) and two research programs conducted in 2010-2011. The assessment estimates parameters for natural mortality of females and males, steepness of the Beverton-Holt stock-recruitment relationship, and gender-specific growth parameters. Year class strength is estimated as deviations from the expected stock-recruitment relationship beginning in 1950.

<u>Oregon</u>

This is the first full assessment for BDR in Oregon waters so no direct transition from a previous assessment was possible. However, there was a transition from the 2007 Blue Rockfish assessment conducted in California waters (Key et al. 2008) to the current California BDR assessment. The base modeling assumptions used in the final transition step for the California model were used as a starting point for evaluating Oregon assessment models and building the Oregon BDR base case model.

The Oregon assessment uses the same recent version of Stock Synthesis 3 (version V3.30.03.07) as the California assessment. The Oregon assessment is structured as a single, sex-disaggregated, unit population, spanning Oregon coastal waters, and operates on an annual time step covering the period 1892 to 2017. Fleets were specified for recreational and commercial sectors. Three recreational fishing fleets are used in this assessment: 1) ocean-boats (Private Boat and Rental (PBR) and Commercial Passenger Fishing Vessel (CPFV) boat types) that landed BDR, 2) ocean-boats that discarded BDR, and 3) landings from shore (beach/bank and man-made structure types) and estuary-boats (PBR boat type). Two commercial fishing fleets are used in this assessment: 1) combined hook-and-line and longline gear type landed BDR, and 2) combined hook-and-line and longline gear type discarded BDR. Data used in the assessment includes time-series of commercial and recreational landings, four fishery-dependent abundance indices (catch-per-unit-effort or CPUE), length compositions for each fleet, and age compositions from the recreational ocean-boat landings fleet, the commercial landings fleet, and a collection of research survey ages.

Stock biomass

The terms “spawning output” and “spawning biomass” are used interchangeably in this document, in reference to total egg production. Egg production is assumed to be proportional to larval production.

California

Spawning output of BDR in California was estimated to be 812 million eggs in 2017 (~95% asymptotic intervals: 0-1,661 million eggs), or 37% of unfished spawning output (“depletion,” ~95% asymptotic intervals: 0-78.5%; Table ES3). Depletion is a ratio of the estimated spawning output in a particular year relative to estimated unfished, equilibrium spawning output. In California, spawning output declined rapidly in the 1970s and early 1980s, falling below the minimum stock size threshold in the early 1980s, followed by a steady recovery since the late 2000s (Figures ES2 and ES3). The trend in spawning output in 2017 is approaching the management target (40% of unfished spawning output), but the precision of that estimate is low relative to other management reference points (e.g. the $SPR_{50\%}$ proxies for target spawning output and maximum yield).

Oregon

BDR spawningoutput was estimated to be 296 million eggs in 2017 (~95% asymptotic intervals: 64-527 million eggs), which when compared to unfished spawning output equates to a depletion level of 69% (~95% asymptotic intervals: 0.52-0.85; Table ES4) in 2017. In general, spawning output has been trending slightly downwards, with the exception of an increase in the 1990s due to several high recruitment years (Figure ES2). Stock size is estimated to be at the lowest level throughout the historic time series in 2017, but the stock is estimated to be well above the management target of $B_{40\%}$ (Figure ES3).

Table ES3: Recent trends in the beginning of the year biomass and depletion for BDR in California waters. Asymptotic confidence intervals truncated at zero.

Year	Spawning Output (eggs x 10^6)	~ 95% confidence intervals	Estimated depletion (%)	~ 95% confidence intervals
2005	383	85–682	17.6	2.8–32.4
2006	362	47–678	16.6	1.1–32.2
2007	340	5–675	15.6	0–32.0
2008	351	0–712	16.1	0–33.7
2009	375	0–768	17.2	0–36.3
2010	416	0–846	19.1	0–40.0
2011	459	0–930	21.1	0–44.0
2012	509	0–1,028	23.4	0–48.7
2013	573	0–1,152	26.3	0–54.5
2014	638	0–1,285	29.3	0–60.8
2015	703	0–1,421	32.3	0–67.3
2016	757	0–1,542	34.7	0–73.0
2017	812	0–1,661	37.3	0–78.5

Table ES4: Recent trends in the beginning of the year biomass and depletion for BDR in Oregon waters.

Year	Spawning Output (eggs x 10^6)	~ 95% confidence intervals	Estimated depletion	~ 95% confidence intervals
2005	386	107–665	89.6	72.3–106.9
2006	370	98–643	86.0	68.5–103.4
2007	358	94–621	83.0	66.0–99.9
2008	344	89–600	79.8	63.3–96.4
2009	337	86–587	78.1	61.9–94.4
2010	334	85–583	77.6	61.4–93.7
2011	330	82–578	76.5	60.3–92.7
2012	322	78–566	74.6	58.4–90.9
2013	312	72–553	72.5	56.1–88.9
2014	307	69–545	71.2	54.7–87.7
2015	304	68–540	70.5	54.2–86.8
2016	299	65–533	69.3	52.8–85.8
2017	296	64–527	68.6	52.2–84.9

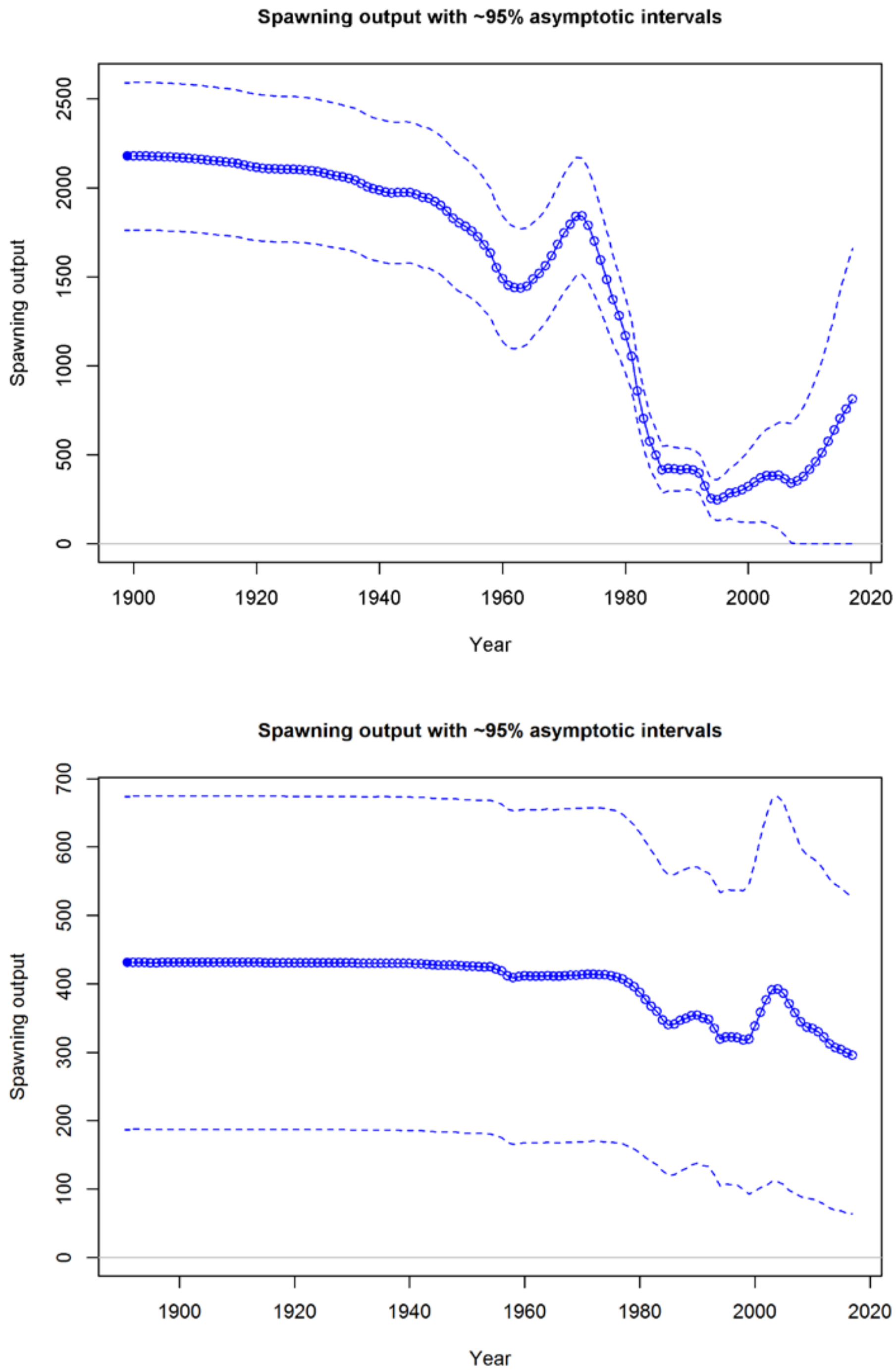
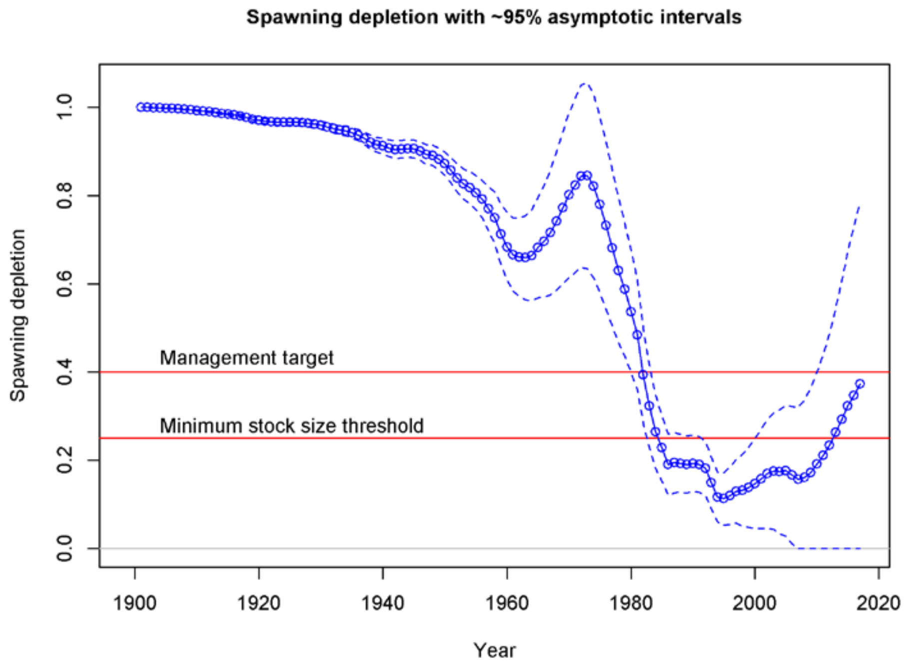


Figure ES2: Recent trends in the beginning of the year spawning output (millions of eggs) for BDR in California waters (upper panel) and Oregon waters (lower panel).



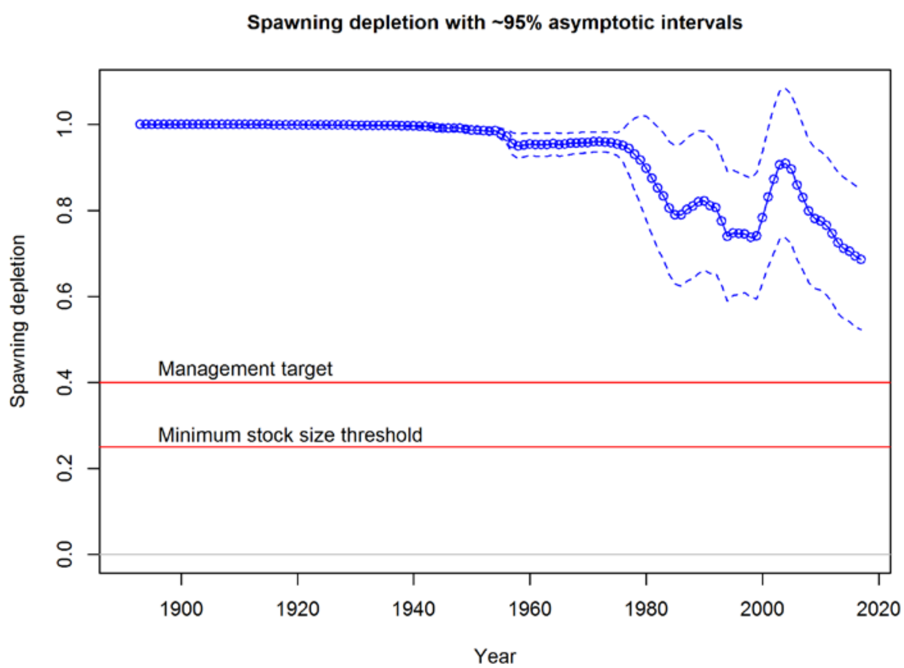


Figure ES3: Estimated relative depletion (spawning output relative to unfished spawning output) with approximate 95% asymptotic confidence intervals (dashed lines) for BDR in California (upper panel) and Oregon (lower panel).

Recruitment

<u>California</u>

A recent, strong recruitment in 2013 has contributed to the recent increase in BDR biomass in California (Table ES5; Figure ES4). This recruitment is informed by several independent data sets, was observed by multiple juvenile rockfish surveys, and is also supported by length composition data in the model. Above-average recruitments in 2008 and 2009 are largely driven by recent age data covering the years 2010-2011, but the 2007 recruitment appears to be supported by multiple data sources, as well. Overall, variability in recruitment is average (to low) relative to other rockfish species, with an RMSE of 0.47 for the main period of recruitment deviations.

<u>Oregon</u>

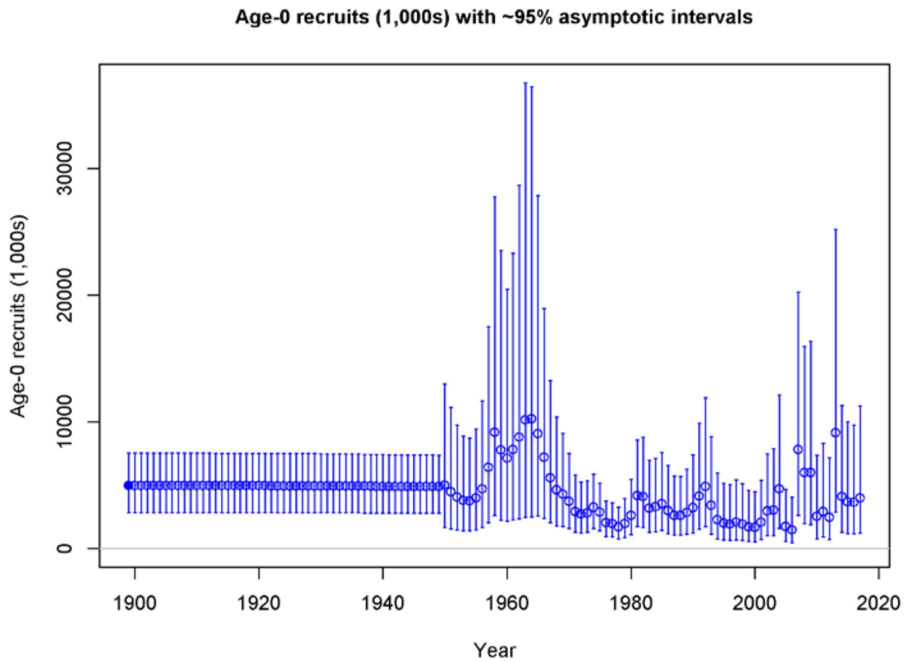
Recruitment variability was dynamic for BDR (Table ES6, Figure ES4) and indicated well above average recruitment in 2013. Other years with relatively high estimates of recruitment were 1993, 1994, and 1995. The BDR stock in Oregon has not been depleted to levels that would provide information on how recruitment changes with spawning output at low spawning output levels (i.e., inform the steepness parameter).

Table ES5: Recent trend in estimated recruitment for BDR in U.S. waters off California and north of Point Conception.

Year	Estimated Recruitment (1,000s)	~ 95% confidence intervals	Estimated Recruitment Deviations	~ 95% confidence intervals
2005	1,623	567–4,644	-0.49	-1.068–0.088
2006	1,364	462–4,028	-0.637	-1.256–-0.017
2007	7,249	2,601–20,201	1.065	0.695–1.436
2008	5,571	1,949–15,926	0.786	0.356–1.215
2009	5,568	1,896–16,351	0.753	0.263–1.243
2010	2,362	759–7,349	-0.153	-0.869–0.564
2011	2,722	895–8,285	-0.055	-0.770–0.660
2012	2,269	719–7,159	-0.28	-1.108–0.547
2013	8,510	2,875–25,190	0.995	0.323–1.667
2014	3,791	1,275–11,269	0.144	-0.635–0.922
2015	3,410	1,163–9,997	-0.01	-0.804–0.785
2016	3,376	1,170–9,739	-0.058	-0.870–0.755
2017	3,707	1,222–11,248	0	-0.980–0.980

Table ES6: Recent trend in estimated recruitment for BDR in Oregon waters.

Year	Estimated Recruitment (1,000s)	~ 95% confidence intervals	Estimated Recruitment Deviations	~ 95% confidence intervals
2005	1,039	525–2,057	0.017	-0.294–0.328
2006	369	172–792	-1.015	-1.506–-0.523
2007	959	483–1,903	-0.055	-0.383–0.272
2008	1,290	651–2,553	0.246	-0.078–0.570
2009	591	271–1,290	-0.531	-1.061–-0.001
2010	1,211	572–2,564	0.187	-0.276–0.649
2011	654	280–1,528	-0.433	-1.072–0.206
2012	738	304–1,797	-0.314	-1.021–0.393
2013	2,233	942–5,292	0.791	0.122–1.461
2014	1,054	387–2,871	0.037	-0.854–0.928
2015	960	339–2,718	-0.06	-1.009–0.888
2016	1,095	618–1,939	0	0.000–0.000
2017	1,093	617–1,937	0	0.000–0.000



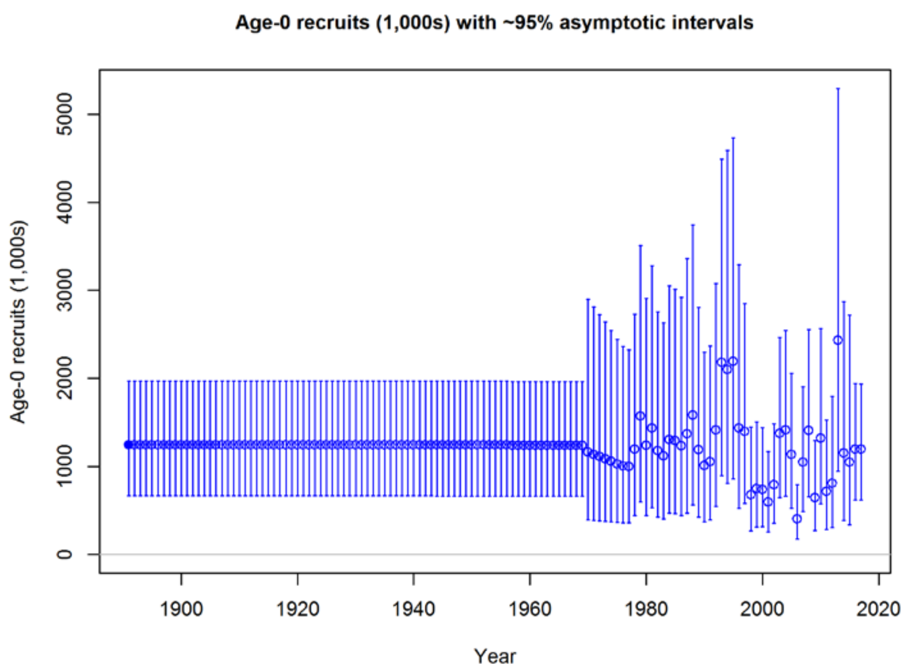


Figure ES4: Recent trend in estimated recruitment for BDR in U.S. waters off California (upper panel) and Oregon (lower panel).

Exploitation status

California

The annual (equilibrium) SPR harvest rate for BDR in California has been below target since 2008 (Table ES7, Figure ES5). Prior to 2008, the harvest rate exceeded the target for over 30 years, regularly reaching levels 50% above target in the 1980s and 1990s (Figure ES5). As with current estimates of spawning output, recent estimates of exploitation status are highly uncertain, ranging from 13% to 120% of target in 2016 (Table ES7). As a percentage of total biomass (ages 0+), California harvest rates peaked at 15-20% in the 1980s and 1990s, but have since declined to levels below 3% for the past decade (Figure ES6). Harvest rates in California are currently below target, and the stock is approaching the proxy target biomass (Figure ES7). Estimates of maximum sustainable yield for the California portion of the stock are 3 to 4 times larger than the Oregon stock (Figure ES8).

Oregon

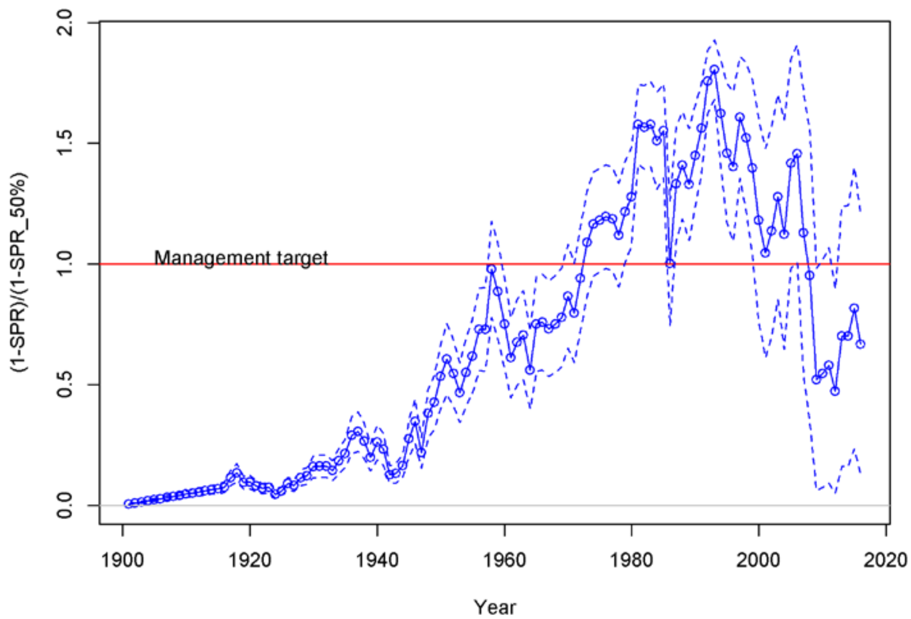
Harvest rates in Oregon have generally increased through time until the mid-1990s when harvest was reduced to a relatively stable level beginning in the 2000s. The maximum relative harvest rate was 0.92 in 1993 (or 92% of the target level) before declining again to around 0.40 in recent years (Table ES8, Figure ES5). Summary fishing mortality rates have been around 0.02 in recent years (Figure ES6). Fishing intensity is estimated to have been below the target throughout the time series [(1-SPR) / (1-$SPR_{50\%}$) < 1]. In 2016, Oregon BDR biomass is estimated to have been 1.73 times higher than the target biomass level, and fishing intensity remains lower than the SPR fishing intensity target (Figure ES7). The equilibrium curve is shifted left, as expected from the high fixed steepness, showing a more productive stock than the SPR50% reference point would suggest (Figure ES8).

Table ES7. Recent trend in spawning potential ratio (entered as 1-SPR / 1-SPR50%) and exploitation for BDR in California waters. Estimates for 2017 assume catch is equal to the average of 2015-2016 catches.

Year	Estimated (1-SPR) / (1-$SPR50_{\%}$)	~ 95% confidence intervals	Harvest rate (ratio)	~ 95% confidence intervals
2005	141.69	98.22–185.16	0.09	0.020–0.167
2006	145.70	100.49–190.91	0.10	0.014–0.181
2007	112.86	54.07–171.65	0.05	0.004–0.094
2008	95.20	34.80–155.60	0.04	0.002–0.067
2009	52.14	6.09–98.20	0.01	0.000–0.026
2010	54.67	7.53–101.81	0.01	0.000–0.027
2011	57.99	9.29–106.70	0.02	0.000–0.029
2012	47.31	5.01–89.60	0.01	0.000–0.023
2013	70.08	16.23–123.93	0.02	0.001–0.042
2014	70.11	16.00–124.23	0.02	0.001–0.043
2015	81.77	23.49–140.05	0.03	0.001–0.056
2016	66.78	13.20–120.37	0.02	0.000–0.042
2017	93.96	72.84–115.08	0.04	0.015–0.060

Table ES8. Recent trend in spawning potential ratio (entered as 1-SPR / 1-SPR50%) and exploitation for BDR in Oregon waters. Estimates for 2017 assume catch is equal to the average of 2015-2016 catches.

Year	Estimated (1-SPR) / (1-SPR$_{50\%}$)	~ 95% confidence intervals	Harvest rate (ratio)	~ 95% confidence intervals
2005	43.34	18.51–68.16	0.02	0.007–0.036
2006	23.17	8.25–38.10	0.01	0.003–0.017
2007	28.78	10.71–46.85	0.01	0.004–0.021
2008	26.36	9.50–43.23	0.01	0.004–0.019
2009	27.37	9.87–44.87	0.01	0.004–0.020
2010	35.81	13.80–57.82	0.02	0.005–0.027
2011	38.95	15.27–62.63	0.02	0.005–0.030
2012	44.81	18.22–71.40	0.02	0.006–0.035
2013	41.26	16.00–66.53	0.02	0.006–0.032
2014	34.31	12.36–56.27	0.02	0.004–0.026
2015	43.66	17.18–70.13	0.02	0.006–0.033
2016	34.58	12.34–56.81	0.01	0.004–0.024
2017	95.3	95.12–95.48	0.06	0.049–0.064



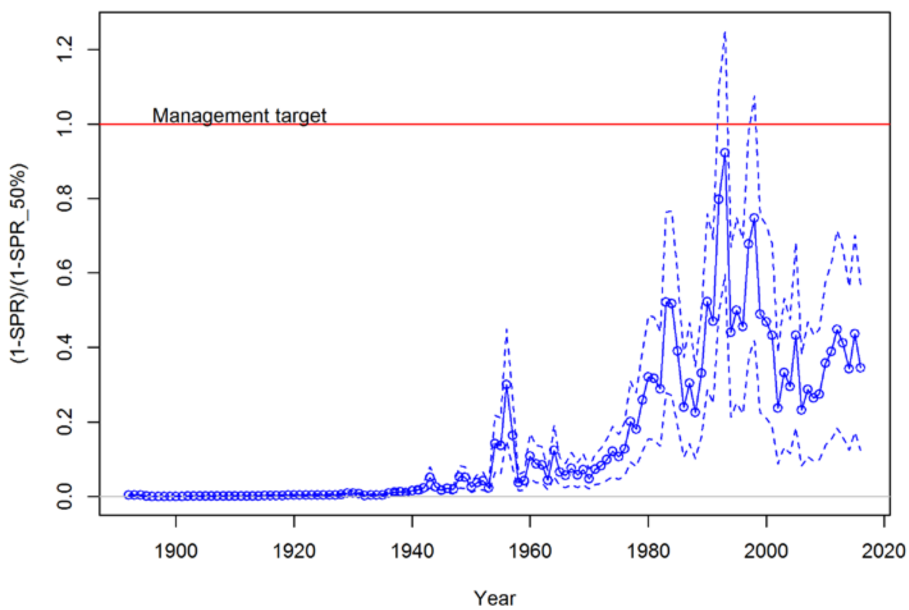


Figure ES5. Estimated spawning potential ratio (SPR) for the base case models with approximate 95% asymptotic confidence intervals (upper panel: California; lower panel: Oregon). One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{50\%}$.

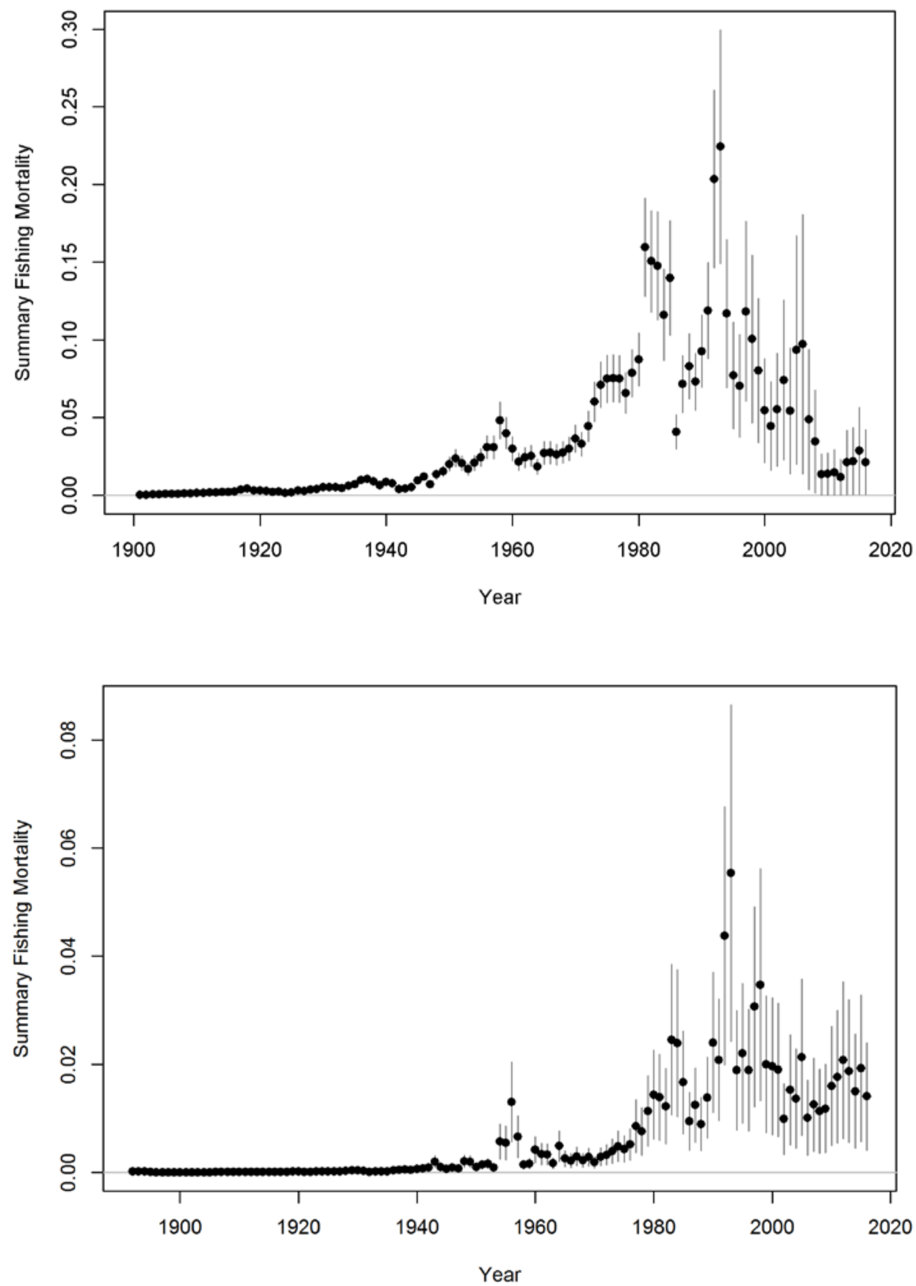


Figure ES6. Time-series of estimated summary harvest rate (total catch divided by age-0 and older biomass) for the base case models (California, upper panel; Oregon, lower panel) with approximate 95% asymptotic confidence intervals (grey lines).

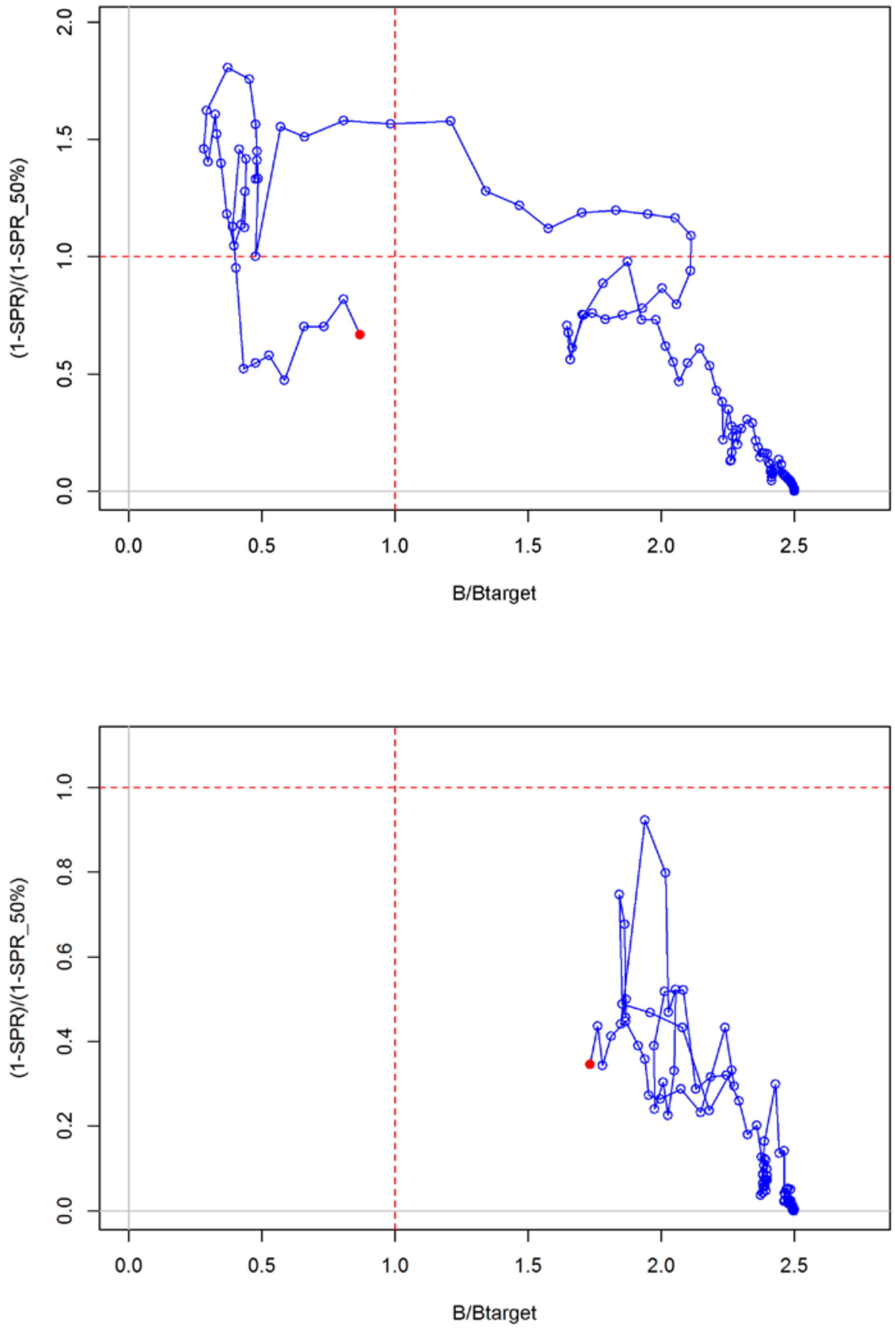


Figure ES7. Phase plot of estimated relative (1-SPR) vs. relative spawning output for the base case models (California, upper panel; Oregon, lower panel). The relative (1-SPR) is (1-SPR) divided by 0.5 (the SPR target). Relative depletion is the annual spawning output divided by the spawning output corresponding to 40% of the unfished spawning output. The red point indicates the year 2016.

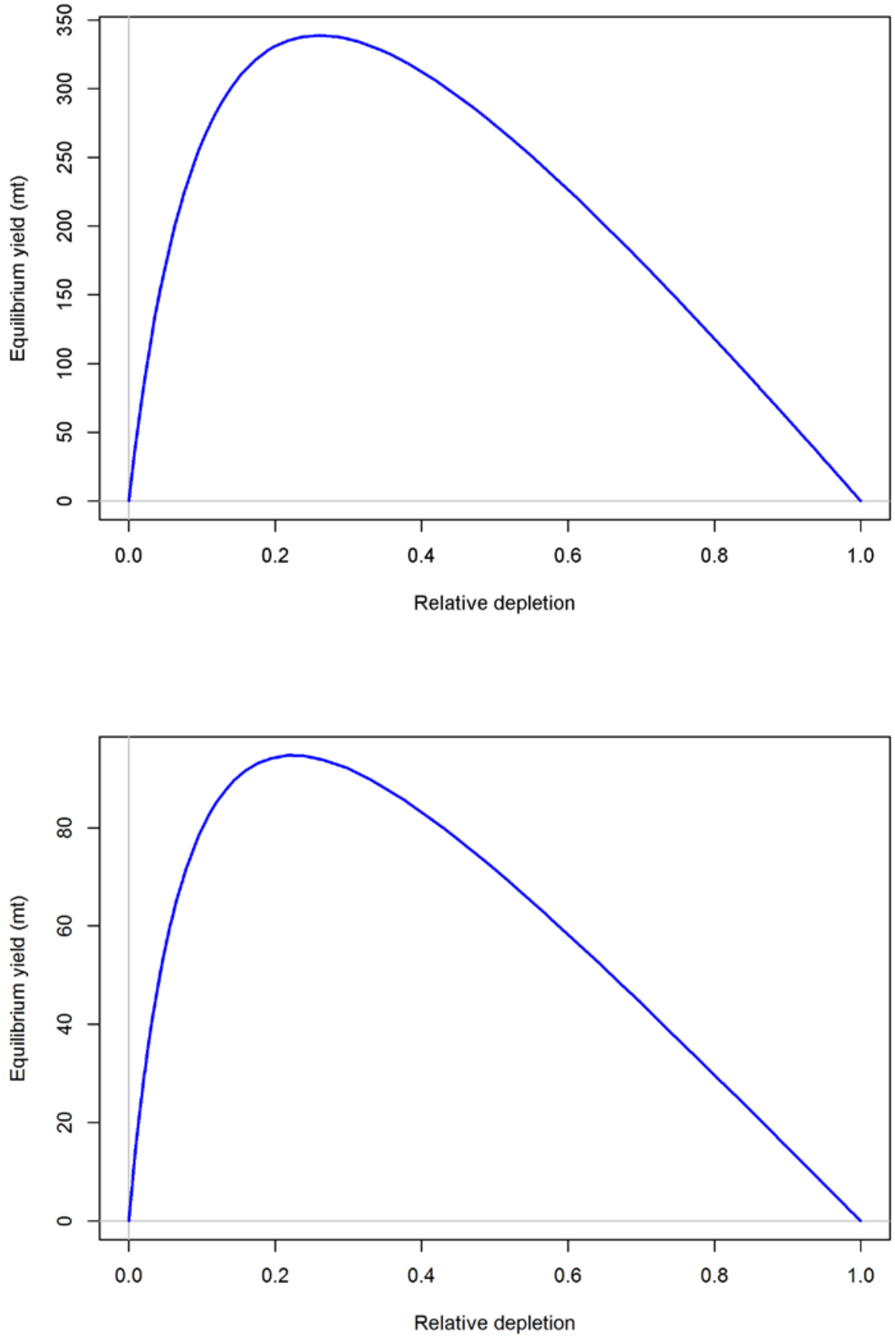


Figure ES8. Equilibrium yield curve (derived from reference point values reported in Table e) for the base case models (California, upper panel; Oregon, lower panel). The depletion is relative to unfished spawning output.

Ecosystem considerations

Ecosystem data were not explicitly included in either assessment model. Trophic relationships and habitat associations of Blue Rockfish are relatively well described among rockfishes; however, the recent discovery of a cryptic species (Deacon Rockfish) necessitates that historical information is considered for the Blue/Deacon Rockfish complex as a whole. Habitat associations vary ontogenetically for BDR but all post-larval stages occur in nearshore waters, often in association with kelp beds. Early juveniles are benthic, but BDR become more pelagic with ontogeny. Adult BDR do not typically move more than 100 m from their core home range, which is often centered on rock pinnacles and cliffs, but do commonly shift their home ranges, especially during the upwelling season. Large-scale climactic conditions (e.g., ENSO warming events) can influence adult reproductive condition. BDR are largely planktivorous species that feed on midwater organisms. BDR are important prey species for a variety of nearshore marine vertebrates.

Reference points

California

Reference points and management quantities for the California BDR base case model are listed in Table ES9. In 2017, spawning output relative to unfished spawning output ("depletion") is estimated at 37% (~95% asymptotic intervals = 0%-79%). Unfished spawning output was estimated at 2,178 million eggs (~95% asymptotic intervals = 1,763-2,593; Table ES9), and spawning output at the beginning of 2017 was estimated to be 812 million eggs (~95% asymptotic intervals = 0-1,661 mt). The target spawning output (*SB*40%) is 871 million eggs, compared to an equilibrium spawning output of 915 million eggs associated with the proxy $SPR_{50\%}$ harvest rate. Yield at the SPR proxy biomass and harvest rate is 306 mt per year (~95% asymptotic intervals = 230-381 mt). Estimates of MSY (and its proxies) for the California stock are considerably more precise than estimates of current OFL due to uncertainty in recent biomass levels.

Table ES9. Summary of reference points and management quantities for the California BDR base case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning Output (millions of eggs)	2,178	1,763–2,593
Unfished Age 0+ Biomass (mt)	11,536	9,140–13,932
Spawning Output (2017, millions of eggs)	812	0–1,661
Unfished recruitment (R0, thousands of recruits)	4,617	2,328–6,907
Depletion -- (2017, % of unfished spawning output)	37	0–78.54
Reference points based on SB $_{40\%}$		
Proxy spawning output ($B_{40\%}$, millions of eggs)	871	705–1,037
SPR resulting in $B_{40\%}$	0.483	0.402–0.563
Exploitation rate resulting in $B_{40\%}$	0.048	0.036–0.059
Yield at $B_{40\%}$ (mt)	312	222–402
Reference points based on SPR proxy for MSY		
Proxy spawning output ($SPR_{50\%}$, millions of eggs)	915	722–1,108
$SPR_{50\%}$	0.5	NA
Exploitation rate corresponding to $SPR_{50\%}$	0.045	0.040–0.051
Yield with $SPR_{50\%}$ at $SB_{SPR50\%}$ (mt)	306	230–381
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY}, millions of eggs)	567	286–847
SPR_{MSY}	0.362	0.180–0.544
Exploitation rate corresponding to SPR_{MSY}	0.069	0.032–0.105
MSY (mt)	339	216–461

Oregon

Reference points and management quantities for the Oregon BDR base case model are listed in Table ES10. Spawning output has generally declined throughout the time series, but there were increases in the early-1990s due to large recruitment events associated with increased catch levels and in the early 2000s. Stock status has remained above the biomass target reference point (40%), though is trending towards the target since the mid-2000s, and is estimated to be at 69% (~95% asymptotic intervals = 52%-85%) in 2017. Unfished spawning output was estimated at 431 million eggs (~95% asymptotic intervals = 187-675 mt; Table ES10), and spawning output at the beginning of 2017 was estimated to be 296 million eggs (~95% asymptotic intervals = 64-527 mt). The target spawning output based on the biomass target (*SB*40%) is 172 million eggs, which corresponds to a catch of 83 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{50\%}$ is 78 mt.

Table ES10. Summary of reference points and management quantities for the Oregon BDR base case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning Output (millions of eggs)	431	187–675
Unfished Age 0+ Biomass (mt)	2,199	963–3,435
Spawning Output (2017, millions of eggs)	296	64–527
Unfished recruitment (R0, thousands of recruits)	1142	508–1,777
Depletion (2017, % of unfished spawning output)	68.56	52.25–84.87
Reference points based on SB $_{40\%}$		
Proxy spawning output ($B_{40\%}$, millions of eggs)	172	75–270
SPR resulting in $B_{40\%}$	0.459	0.459–0.459
Exploitation rate resulting in $B_{40\%}$	0.063	0.060–0.066
Yield at $B_{40\%}$ (mt)	83	36–130
Reference points based on SPR proxy for MSY		
Proxy spawning output ($SPR_{50\%}$, millions of eggs)	192	84–301
$SPR_{50\%}$	0.50	NA
Exploitation rate corresponding to $SPR_{50\%}$	0.056	0.053–0.058
Yield with $SPR_{50\%}$ at $SB_{SPR50\%}$ (mt)	78	34–123
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY}, millions of eggs)	97	41–152
SPR_{MSY}	0.3	0.296–0.305
Exploitation rate corresponding to SPR_{MSY}	0.1	0.097–0.104
MSY (mt)	95	41–148

Management performance

The contribution of BDR to the Minor Nearshore Rockfish OFLs is currently derived from three sources: 1) forecasts from Key et al. (2008), allocated north and south of Cape Mendocino, 2) Depletion Corrected Average Catch (DCAC; MacCall, 2009) for the area south of Point Conception, and 3) a DCAC estimate of yield for waters off Oregon and Washington. Since 2011, total mortality of BDR has not exceeded the component OFL for "Blue Rockfish" and total mortality of Minor Nearshore Rockfishes has not exceeded the ACL or OFL in either the northern or southern areas (Table ES11).

Table ES11. Evaluation of Management Performance for "Blue Rockfish" (Blue and Deacon Rockfishes, combined). Total Mortality estimates are based on annual reports from the NMFS NWFSC.

Area	Year	"Blue Rockfish" (BDR)			Minor Nearshore Rockfish		
		NWFSC Total Mortality	ABC/ACL Contribution [1] (CA + OR/WA)	OFL Contribution [1] (CA + OR/WA)	Total Mortality	ACL	OFL
North of 40° 10'	2011	44.0	*25.3 + 27.6 = 52.9*	*27.7 + 33.1 = 60.8*	99.0	99	116
	2012	43.6	*25.1 + 27.6 = 52.7*	*27.5 + 33.1 = 60.6*	96.0	99	116
	2013	36.5	*22.2 + 26.9 = 49.1*	*27.4 + 32.3 = 59.7*	75.0	94	110
	2014	29.4	*22.2 + 26.9 = 49.1*	*27.4 + 32.3 = 59.7*	59.0	94	110
	2015	41.6	*17.0 + 26.9 = 43.9*	*27.4 + 32.3 = 59.7*	64.3	69	88
	2016	TBD	*17.5 + 26.9 = 44.4*	*27.7 + 32.3 = 60.0*	TBD	69	88
South of 40° 10'			**(S + N of 34°27' N lat.)**	**(S + N of 34°27' N lat.)**			
	2011	58.3	*61.8 + 156.3 = 218.1*	*74.0 + 191.3 = 265.3*	436	1,001	1,156
	2012	50.7	*61.8 + 154.5 = 216.3*	*74.0 + 189.5 = 263.5*	445	1,001	1,145
	2013	107.6	*60.8 + 152.8 = 213.6*	*72.9 + 187.8 = 260.7*	495	990	1,164
	2014	138.8	*60.8 + 152.8 = 213.6*	*72.9 + 187.8 = 260.7*	596	990	1,160
	2015	181.9	*60.8 + 116.6 = 177.4*	*72.9 + 188.6 = 261.5*	676	1,114	1,313
	2016	TBD	*60.8 + 120.0 = 180.8*	*72.9 + 190.3 = 263.2*	TBD	1,006	1,288

1 - Harvest contributions to the Minor Nearshore Rockfish complexes are not management limits; management limits are specified at the complex level. ACL = ABC for these contributions with a 40-10 adjustment to the ACLs for those areas assessed in 2007 by Key et al. (off CA north of 34°27' N lat.).

The status of BDR off Oregon has never previously been fully assessed leaving only the DCAC (Depletion Corrected Adjusted Catch) data-poor method estimates to inform harvest limits. However, the harvest limit for the federally designated "northern nearshore rockfish" management complex, of which includes BDR, is calculated by summing the contributing component limits to a complex-level harvest control rule (Table ES12). While harvest levels for the northern nearshore rockfish have never exceeded the ACL, the complex attainment in 2011 was 100% and in recent years BDR harvest levels have exceeded the Oregon allocation of 29.6 mt for these species (Table ES12). At the state level, annual harvest limits for both the recreational and commercial fisheries have been in regulation since 2004 to maintain impacts within federal ACLs.

Table ES12. Summary of recent management history for the northern nearshore rockfish (40°10' N) complex relative to harvest limits (mt).

Year	Control Rule	Harvest Limit	Complex Impacts (mt)	Blue/Deacon Impacts (mt)	Blue/Deacon % of Complex Impacts	Complex Impacts % of Limit
2008	OY	142	97	30	31	68
2009	OY	155	63	30	47	41
2010	OY	155	75	40	54	48
2011	ACL	99	99	44	44	100
2012	ACL	99	96	44	45	97
2013	ACL	94	75	37	49	80
2014	ACL	94	59	29	50	63
2015	ACL	69	64	42	65	93
2016	ACL	69	*	*	*	*
2017	ACL	105	*	*	*	*

* - Totals not yet available from the West Coast Groundfish Observer Program

Unresolved problems and major uncertainties

California

The 2017 BDR assessment for California is generally consistent with the results of the 2007 assessment (see section 2.10.4). The scale of the stock is similar, and proxy ($SPR_{50\%}$) estimates of maximum sustainable yield are similar (275 mt per the 2007 assessment and 306 mt per the 2017 assessment). However, estimates of recent stock size based on the 2017 assessment are imprecise (Table ES3, Figure ES2), which results in imprecise forecasts of yield. The 2017 assessment is sensitive to the removal of age data, because only seven years of age data (1980-1984 and 2010-2011) are currently available to inform the assessment. Since recreational fisheries account for the majority of removals, collection of age structures from California recreational fisheries is a priority for improving stock assessments of BDR. Calibration and validation of age estimates is also needed, as there was some evidence of bias among agers. Collection of additional age data would assist with estimation of natural mortality rate, a major source of uncertainty in current stock status, and improve the precision of gender-specific estimates of the natural mortality rate. Similar to natural mortality, uncertainty in the Beverton-Holt steepness parameter contributes to the imprecision of recent BDR biomass. However, population scale (unfished spawning output) in the California model is robust to changes in these parameters, relative to the Oregon model. Catches of Blue and Deacon Rockfish are strongly skewed toward females. The current assessment accounts for this through gender-specific growth and natural mortality. An alternative (or parallel) hypothesis is that males are less vulnerable to the fishery (i.e. have a gender-specific selectivity). Although the STAT explored this possibility by profiling over the apical value of the male selectivity curve, the model was not able to estimate gender-specific selectivity curves given the available data.

Oregon

The most significant uncertainty for the OR BDR model is the size of population scale, the treatment and value of natural mortality, and gender-specific selectivity. The development of a comprehensive fishery-independent index of abundance will help to resolve uncertainty in population scale. The treatment of selectivity and natural mortality was a major structural consideration that was explored in the development of the base case model. In particular, alternative approaches to estimating female and male natural mortality and gender specific selectivity were evaluated to account for differences in male selectivity (gear retention for the slower growing males) and availability (for sex-ratio reasons other than that attributed to natural mortality) relative to females in the catch. There was little information in the data to estimate gender-specific selectivity patterns, and most modeling attempts resulted in non-convergence or unrealistic results. The catch history for recreational fishing modes in years prior to 1979 and for the shore (and estuary) mode in recent years (2006-2014) is quite uncertain. In this assessment, historical catch reconstructions for these fleets included using a simple linear ramp, proportional fishing license sales ramp, and an extrapolation based on information available in the time series. Steepness, while fixed, is still highly uncertain for rockfishes and currently is mismatched to the MSY proxy. Stock structure and its relationship to the current political/management boundaries are also not fully understood.

Decision table and forecasts

California

Projections of OFL (mt), ABC (mt), age 0+ biomass (mt), spawning output (millions of eggs), and depletion (% of unfished spawning output), are shown for two catch scenarios: 1) the default harvest control rule (Table ES13), and 2) constant catch equal to average catch over the period 2015-2016 (Table ES14).

Table ES13. Projection of OFL, default harvest control rule catch (ABC = ACL above 40% SSB), biomass, and depletion using the California BDR base case model with 2017-2018 catches set equal to 2015-2016 average catch (154.4 mt).

Year	OFL (mt)	ABC Catch (mt)	Age 0+ Biomass (mt)	Spawning Output (eggs x 10^6)	Depletion (% of SB_0)
2017	278.7	154.4*	6654	812	37.3
2018	294.6	154.4*	6830	864	39.7
2019	309.8	281.4	6984	917	42.1
2020	316.8	287.8	7015	943	43.3
2021	321.9	292.4	7032	963	44.2
2022	325.1	295.4	7039	976	44.8
2023	326.7	296.8	7039	984	45.2
2024	327.1	297.2	7036	987	45.3
2025	326.8	296.9	7031	987	45.3
2026	326.2	296.4	7027	987	45.3
2027	325.6	295.8	7024	985	45.2
2028	325.0	295.2	7023	984	45.2

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.783, for a multiplier of 0.906 applied to the OFL. *Average catch, 2015-2016.*

Table ES14. Projection of OFL, constant catch (2015-2016 average catch), biomass, and depletion using the California BDR base case model with 2017-2018 catches set equal to 2015-2016 average catch (154.4 mt).

Year	OFL	ABC Catch	Age 0+ Biomass	Spawning Output	Depletion (%)
2017	278.7	154.4	6654	812	37.3
2018	294.6	154.4	6830	864	39.7
2019	309.8	154.4	6984	917	42.1
2020	323.9	154.4	7124	968	44.5
2021	336.4	154.4	7250	1014	46.6
2022	347.1	154.4	7365	1055	48.4
2023	356.1	154.4	7470	1089	50.0
2024	363.6	154.4	7569	1119	51.4
2025	370.1	154.4	7663	1145	52.6
2026	375.8	154.4	7752	1168	53.6
2027	381.1	154.4	7838	1189	54.6
2028	386.1	154.4	7920	1209	55.5

During the STAR Panel review, it was agreed that uncertainty in the BDR assessment for California would be represented by quantiles of spawning output (sometimes referred to as spawning stock biomass, or SSB). Specifically, the 12.5 and 87.5 percentiles of SSB were chose as “low” and “high” alternative states of nature. Catch streams based on the default harvest control rule were generated under each state of nature. Each of these catch streams (low, base, and high) were then applied to all three states of nature, bracketing the range of management decisions and uncertainty in current stock size in California (Table ES15). Forecasts based on two “constant” catch streams were also completed: one with catch equal to the $SPR_{50\%}$ proxy yield multiplied by 0.906 (the buffer resulting from σ = 0.783 and P* = 0.45), and another set equal to average catch over the period 2015-2016. The estimate of σ was derived from the decision table using the following equation:

$$\sigma = \frac{\{ln(SB2017_{base\ state}) - ln(SB2017_{low\ state})\}}{1.15}$$

Table ES15: Decision table summarizing 12-year projections (2017 – 2028) for California BDR based on three alternative states of nature spanning quantiles of spawning output in 2017. Columns range over low, medium, and high state of nature, and rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2017 and 2018 are fixed at 2015-2016 average catch, and allocated to each fleet based on the percentage of landing for each fleet averaged over the same period.

[see next page]

		State of nature (percentiles of spawning output in 2017)								
		Low			Base case			High		
Percentile of Spawning Output		12.5%			50%			87.5%		
Estimated steepness and M_{fem}		h = 0.555, M = 0.113			h = 0.645, M = 0.119			h = 0.702, M = 0.131		
Management decision	Year	Catch (mt)	Spawning Output (eggs x 10^6)	Depletion (% of SB_0)	Catch (mt)	Spawning Output (eggs x 10^6)	Depletion (% of SB_0)	Catch (mt)	Spawning Output (eggs x 10^6)	Depletion (% of SB_0)
Catches from low SSB, Default Harvest Control Rule (40-10)	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	51.1	355	15%	51.1	917	42%	51.1	1564	72%
	2020	63.4	388	17%	63.4	988	45%	63.4	1659	77%
	2021	74.6	418	18%	74.6	1053	48%	74.6	1739	80%
	2022	84.5	445	19%	84.5	1109	51%	84.5	1802	83%
	2023	93.2	470	20%	93.2	1157	53%	93.2	1849	85%
	2024	100.9	491	21%	100.9	1198	55%	100.9	1882	87%
	2025	108.0	511	22%	108.0	1233	57%	108.0	1903	88%
	2026	114.5	529	23%	114.5	1263	58%	114.5	1915	89%
	2027	120.8	547	24%	120.8	1289	59%	120.8	1920	89%
	2028	127.0	564	25%	127.0	1312	60%	127.0	1919	89%
Catches from median (base case) SSB, Default Harvest Control Rule (40-10)	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	281.4	355	15%	281.4	917	42%	281.4	1564	72%
	2020	287.8	346	15%	287.8	943	43%	287.8	1613	75%
	2021	292.4	335	15%	292.4	963	44%	292.4	1649	76%
	2022	295.4	323	14%	295.4	976	45%	295.4	1669	77%
	2023	296.8	310	13%	296.8	984	45%	296.8	1676	77%
	2024	297.2	297	13%	297.2	987	45%	297.2	1672	77%
	2025	296.9	285	12%	296.9	987	45%	296.9	1661	77%
	2026	296.4	274	12%	296.4	987	45%	296.4	1644	76%
	2027	295.8	264	11%	295.8	985	45%	295.8	1624	75%
	2028	295.2	254	11%	295.2	984	45%	295.2	1602	74%
Catches from high SSB, Default Harvest Control Rule (40-10)	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	522.4	355	15%	522.4	917	42%	522.4	1564	72%
	2020	520.7	304	13%	520.7	897	41%	520.7	1565	72%
	2021	515.5	255	11%	515.5	872	40%	515.5	1555	72%
	2022	507.0	208	9%	507.0	844	39%	507.0	1533	71%
	2023	495.9	167	7%	495.9	813	37%	495.9	1501	69%
	2024	483.3	133	6%	483.3	782	36%	483.3	1464	68%
	2025	470.0	105	5%	470.0	754	35%	470.0	1423	66%
	2026	457.0	82	4%	457.0	729	33%	457.0	1383	64%
	2027	444.7	62	3%	444.7	708	32%	444.7	1344	62%
	2028	433.5	42	2%	433.5	689	32%	433.5	1308	60%
Constant Catch, base model MSY ($F_{SPR50\%}$) proxy with buffer (σ=0.72, P*=0.45)	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	279.0	355	15%	279.0	917	42%	279.0	1564	72%
	2020	279.0	347	15%	279.0	944	43%	279.0	1614	75%
	2021	279.0	337	15%	279.0	966	44%	279.0	1651	76%
	2022	279.0	327	14%	279.0	981	45%	279.0	1674	77%
	2023	279.0	317	14%	279.0	992	46%	279.0	1684	78%
	2024	279.0	307	13%	279.0	999	46%	279.0	1684	78%
	2025	279.0	297	13%	279.0	1002	46%	279.0	1676	77%
	2026	279.0	289	13%	279.0	1005	46%	279.0	1662	77%
	2027	279.0	281	12%	279.0	1006	46%	279.0	1645	76%
	2028	279.0	274	12%	279.0	1007	46%	279.0	1625	75%
Constant Catch, average catch from 2015-2016	2017	154.4	330	14%	154.4	812	37%	154.4	1401	65%
	2018	154.4	342	15%	154.4	864	40%	154.4	1484	69%
	2019	154.4	355	15%	154.4	917	42%	154.4	1564	72%
	2020	154.4	369	16%	154.4	968	44%	154.4	1638	76%
	2021	154.4	382	17%	154.4	1014	47%	154.4	1700	79%
	2022	154.4	394	17%	154.4	1055	48%	154.4	1748	81%
	2023	154.4	406	18%	154.4	1089	50%	154.4	1782	82%
	2024	154.4	416	18%	154.4	1119	51%	154.4	1804	83%
	2025	154.4	427	19%	154.4	1145	53%	154.4	1817	84%
	2026	154.4	438	19%	154.4	1168	54%	154.4	1823	84%
	2027	154.4	449	20%	154.4	1189	55%	154.4	1824	84%
	2028	154.4	461	20%	154.4	1209	56%	154.4	1822	84%

Oregon

The Oregon BDR assessment would be considered a category 2 stock assessment according to SSC established policy, because it is an assessment of a species complex. Therefore, projections and decision tables use a P* = 0.45 and a minimum sigma of 0.72, resulting in a multiplier on the OFL of 0.9135. At the request of the SSC, sigma was later revised to 0.803, in order to better reflect the range of states of nature in the decision table (see below) and the equation

$$\sigma = \frac{\{ln(SB2017_{base\ state}) - ln(SB2017_{low\ state})\}}{1.15}.$$

The OFL, ABC, and ACL for each forecast scenario is calculated following the rockfish MSY proxy of F_{SPR}=50% along with the 40-10 harvest control rule. Two harvest projections are provided based on alternative assumptions of catch during the forecast period (2019-2028), where catch during the current management cycle (2017-2018) was set to the average over the most recent two years (2015-2016). The first uses the catch specified by the F_{SPR}=50% MSY proxy following the 40:10 harvest control rule, where the ABC = ACL (Table ES16). The second uses a constant catch value specified by the STAR panel GMT representative. The constant catch was set at the average historical catch from 2005-2014, prior to newly implemented regulations in 2015 (Table ES17).

Uncertainty in management quantities for the Oregon model was characterized by exploring different values of equilibrium recruitment, $ln(R_0)$. There was considerable discussion at the STAR panel about capturing the appropriate range of uncertainty relative to population scale. In response, the STAT and STAR panel agreed that the high and low states of nature should be based on ±1.15 * the asymptotic SE of $ln(R_0)$ using the sensitivity model that estimated female natural mortality with a fixed male offset value (offset set to the average of the Hamel prior offset and the Then growth offset, see section 3.4.1). This model was chosen to develop the range of $ln(R_0)$ because there were concerns that the base model did not capture the full range of uncertainty in $ln(R_0)$ when natural mortality was fixed. This approach resulted in low ($ln(R_0)$ = 6.453) and high ($ln(R_0)$ = 7.641) states of nature relative to the base model ($ln(R_0)$ = 7.047) that were used to characterize uncertainty in the decision table (Table ES18).

Table ES16. Projection of BDR OFL, catch, biomass, and depletion using the Oregon BDR base case model projected with total projected catch equal to 28.6 mt for 2017 and 2018. The predicted OFL is the calculated total catch determined by FSPR=50% (ABC=ACL). Total catch in 2017 and 2018 were set to the average over the most recent two years (2015 – 2016).

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 0+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	109.1	28.6	1773	295.51	0.686
2018	110.1	28.6	1801	294.04	0.682
2019	112.3	103.0	1824	300.59	0.697
2020	108.8	99.8	1776	289.61	0.672
2021	105.7	96.9	1734	278.67	0.647
2022	102.6	94.1	1696	267.80	0.621
2023	99.7	91.4	1664	257.97	0.598
2024	97.2	89.1	1637	249.51	0.579
2025	95.0	87.1	1614	242.46	0.563
2026	93.2	85.5	1594	236.65	0.549
2027	91.7	84.1	1577	231.88	0.538
2028	90.4	82.9	1562	227.93	0.529

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.72 with a multiplier of 0.9135 applied to the OFL.*

Table ES17. Projection of BDR OFL, catch, biomass, and depletion using the Oregon BDR base case model projected with total projected catch equal to 28.6 mt for 2017 and 2018. The predicted OFL is the calculated total catch determined by the catch levels specified by the STAR panel GMT representative (i.e., 2019-2028 catches set to average historical, 2005-2014, catch level). Total catch in 2017 and 2018 were set to the average over the most recent two years (2015 – 2016).

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 0+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	109.1	28.6	1773	295.51	0.686
2018	110.1	28.6	1801	294.04	0.682
2019	112.3	27.4	1824	300.59	0.697
2020	115.1	27.4	1842	309.95	0.719
2021	117.5	27.4	1857	317.07	0.736
2022	119.3	27.4	1869	322.07	0.747
2023	120.6	27.4	1879	325.87	0.756
2024	121.6	27.4	1887	328.89	0.763
2025	122.3	27.4	1895	331.35	0.769
2026	122.9	27.4	1901	333.41	0.774
2027	123.5	27.4	1907	335.19	0.778
2028	123.9	27.4	1912	336.75	0.781

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.72 with a multiplier of 0.9135 applied to the OFL.*

Table ES18. Decision table summarizing 12-year projections (2017 – 2028) for Oregon BDR according to three alternative states of nature based on equilibrium unfished recruitment. Columns range over low, medium, and high state of nature, and rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2017 and 2018 are allocated to each fleet based on the percentage of landing for each fleet averaged over the period 2015-2016.

			State of nature					
			Low		Base case		High	
			$\ln(R_0) = 6.453$		$\ln(R_0) = 7.041$		$\ln(R_0) = 7.641$	
Relative probability of states of nature:			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning Biomass (mt)	Depletion	Spawning Biomass (mt)	Depletion	Spawning Biomass (mt)	Depletion
Catches from low SSB, Default Harvest Control Rule (40-10)	2017	28.6	117	0.49	296	0.69	636	0.80
	2018	28.6	115	0.48	294	0.68	633	0.80
	2019	41.7	116	0.49	301	0.70	645	0.82
	2020	41.4	115	0.49	306	0.71	657	0.83
	2021	41.2	114	0.48	310	0.72	665	0.84
	2022	41.0	113	0.48	311	0.72	669	0.85
	2023	40.9	112	0.47	312	0.72	672	0.85
	2024	40.9	112	0.47	313	0.73	673	0.85
	2025	40.9	112	0.47	313	0.73	674	0.85
	2026	41.0	112	0.47	313	0.73	674	0.85
	2027	41.1	112	0.47	313	0.73	674	0.85
	2028	41.1	112	0.47	313	0.73	674	0.85
Catches from median (base case) SSB, Default Harvest Control Rule (40-10)	2017	28.6	117	0.49	296	0.69	636	0.80
	2018	28.6	115	0.48	294	0.68	633	0.80
	2019	103.0	116	0.49	301	0.70	645	0.82
	2020	99.8	100	0.42	290	0.67	640	0.81
	2021	96.9	86	0.36	279	0.65	633	0.80
	2022	94.1	74	0.31	268	0.62	624	0.79
	2023	91.4	64	0.27	259	0.60	615	0.78
	2024	89.1	57	0.24	250	0.58	608	0.77
	2025	87.1	52	0.22	243	0.56	601	0.76
	2026	85.5	48	0.20	238	0.55	595	0.75
	2027	84.1	44	0.19	233	0.54	590	0.75
	2028	82.9	41	0.17	229	0.53	586	0.74
Catches from high SSB, Default Harvest Control Rule (40-10)	2017	28.6	117	0.49	296	0.69	636	0.80
	2018	28.6	115	0.48	294	0.68	633	0.80
	2019	214.6	116	0.49	301	0.70	645	0.82
	2020	204.8	73	0.31	260	0.60	610	0.77
	2021	196.0	42	0.17	224	0.52	577	0.73
	2022	187.7	21	0.09	193	0.45	546	0.69
	2023	180.4	10	0.04	167	0.39	519	0.66
	2024	174.1	4	0.02	147	0.34	496	0.63
	2025	168.8	2	0.01	130	0.30	477	0.60
	2026	164.5	0	0.00	117	0.27	462	0.58
	2027	160.9	0	0.00	107	0.25	449	0.57
	2028	157.9	0	0.00	98	0.23	439	0.55
Constant Catch, average catch from 2005-2014	2017	28.6	117	0.49	296	0.69	636	0.80
	2018	28.6	115	0.48	294	0.68	633	0.80
	2019	27.4	116	0.49	301	0.70	645	0.82
	2020	27.4	119	0.50	310	0.72	661	0.84
	2021	27.4	121	0.51	317	0.74	673	0.85
	2022	27.4	123	0.52	322	0.75	680	0.86
	2023	27.4	125	0.52	326	0.76	685	0.87
	2024	27.4	127	0.53	329	0.76	690	0.87
	2025	27.4	129	0.54	331	0.77	693	0.88
	2026	27.4	131	0.55	333	0.77	695	0.88
	2027	27.4	133	0.56	335	0.78	697	0.88
	2028	27.4	135	0.57	337	0.78	699	0.88

Research and data needs

There are several areas for further research that were identified while conducting this assessment that could result in information useful to future Blue and/or Deacon Rockfish assessments. The list below is believed to represent strategic pieces of information that would likely help to resolve key uncertainties associated with assessing BDR. Many would provide the necessary information to evaluate basic life history parameters and spatiotemporal population and fleet dynamics.

1. Nearshore survey. A fisheries-independent nearshore survey should be supported to improve estimates of abundance trends (not having to rely on fisheries data for such trends) and, if possible, absolute abundance. Population scale has proven difficult to estimate for many nearshore species without informative data.

2. Collection of gender- and species-specific data. Gender- and species-specific information from the recreational fishery should be collected for BDR given differences in growth and natural mortality by gender and the importance of this fishery to overall catches. This information should continue to be collected for commercial fisheries. For California, collection of age data (particularly from the recreational fishery) is a priority for stock assessment of BDR and other species important to recreational fisheries.

3. A study of the stock structure of Blue and Deacon Rockfish. Stock structure for Blue Rockfish and Deacon Rockfish needs further study and the results accounted for in future assessments. In particular, ontogenetic and gender-related movement according to offshore depth and spawning seems plausible, and data to inform tests of that hypothesis would be beneficial for future assessments given the lack of larger/older males in the fisheries data. Given that the vast majority of catches for BDR are in the nearshore waters, the intersection of seasonal movements to offshore habitat coupled with fleet dynamics could play an important role determining vulnerability. Alternative sub-stock boundaries, those that do not lie on political borders, should also be explored.

4. Further analyses on natural mortality values for females and males. This will help resolve the extent to which gender-based selectivity (e.g., dome-shaped or relative male-to-female scales) may be occurring, and whether natural mortality and such complex selectivity patterns can be estimated (and when they cannot).

5. Historical catch reconstructions for recreational fleets in Oregon. Ocean-boat landings comprise the vast majority of landings for BDR, but there has been no rigorous attempt at a catch reconstruction beyond linking catch to license sales (as was done for this assessment).

6. Accurate accounting of removals for recreational shore fleet (estuary-boat and shore fishing modes). Fisheries exploited by the recreational sector are traditionally hard to monitor. Since 2005, there has been no comprehensive information collected about catch or effort or biological information from estuary-boat and shore fishing modes. Although these modes do not represent major fisheries for BDR in terms of landed catch, they do tend to catch smaller individuals. Biological data on smaller individual is a data gap for this and many other nearshore rockfish species.

7. Calibration and validation of BDR ages. Formal ageing criteria for BDR should be developed and standardized and ages validated.

8. Control rules for stocks managed as part of a stock complex. BDR is currently managed as part of two "Minor Nearshore Rockfish" stock complexes (each representing over 10 stocks), north and south of 40° 10′ N. latitude. The contribution of BDR (currently "Blue Rockfish") to the northern complex OFL in 2017 is over half the yield (roughly 56% of the combined OFL), and 23% of the OFL for the southern complex. The STAT recommends research on the risks associated with management of stocks in a complex (e.g. the probability of overfishing component stocks), as a function of the degree of variability in the OFL contribution of each stock. Stocks that are managed as part of a complex and determined to be above target biomass are of particular concern, as their OFL contribution may exceed MSY (or its proxy). In the absence of a species-specific catch limit, alternative measures could be evaluated using management strategy evaluation, including alternative control rules for stocks managed within a complex (e.g. a "40-10" harvest control rule combined with a yield cap set equal to MSY or its proxy; see also Froese et al. 2010).

9. Mandatory port sampling. In California, commercial port samplers can be refused access to landings. This could result in biased estimates of species, length, and age compositions, as well as estimates of commercial landings, particularly if catch that is made available to the sampler is not representative of the total catch in a sampling stratum.

Table ES19. Summary of base case model results for BDR in California waters. The unit for spawning output is millions of eggs.

Quantity	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total landings (mt)	289.46	302.92	148.31	102.21	45.73	55.42	65.62	55.30	108.89	119.65	164.82	130.18	
Total removals (mt)	303.89	318.10	157.79	117.06	50.22	58.92	70.39	59.63	114.04	124.91	172.58	136.26	
(1-SPR) / (1-$SPR_{50\%}$)	1.42	1.46	1.13	0.95	0.52	0.55	0.58	0.47	0.70	0.70	0.82	0.67	NA
Exploitation rate	0.09	0.10	0.05	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.02	NA
Age 0+ biomass (mt)	3,273	3,287	3,326	3,457	3,810	4,312	4,789	5,149	5,490	5,725	6,093	6,421	6654
Spawning Output	383	362	340	351	375	416	459	509	573	638	703	757	812
~95% CI	85–682	47–678	5–675	0–712	0–768	0–846	0–930	0–1028	0–1152	0–1285	0–1421	0–1542	0–1661
Recruitment (1000s)	1,623	1,364	7,249	5,571	5,568	2,362	2,722	2,269	8,510	3,791	3,410	3,376	3,707
~95% CI	567–4644	462–4028	2601–20201	1949–15926	1896–16351	759–7349	895–8285	719–7159	2875–25190	1275–11269	1163–9997	1170–9739	1222–11248
Depletion (%)	17.60	16.60	15.60	16.10	17.20	19.10	21.10	23.40	26.30	29.30	32.30	34.70	37.30
~95% CI	2.8–32.4	1.1–32.2	0–32.0	0–33.7	0–36.3	0–40.0	0–44.0	0–48.7	0–54.5	0–60.8	0–67.3	0–73.0	0–78.5

Table ES20. Summary of base case model results for BDR in Oregon waters. The unit for spawning output is millions of eggs.

Quantity	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total landings (mt)	38.44	17.26	21.49	18.96	19.21	26.30	28.12	33.06	29.33	23.21	30.68	23.15	
Total removals (mt)	40.48	18.71	23.10	20.31	20.86	28.08	30.51	35.46	31.38	24.81	32.74	24.37	
(1-SPR)/(1-$SPR_{50\%}$)	0.43	0.23	0.29	0.26	0.27	0.36	0.39	0.45	0.41	0.34	0.44	0.35	NA
Exploitation rate	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.01	NA
Age 0+ biomass (mt)	1,898	1,856	1,841	1,799	1,770	1,758	1,726	1,711	1,677	1,654	1,702	1,737	1773
Spawning Output	386	370	358	344	337	334	330	322	312	307	304	299	296
~95% CI	107–665	98–643	94–621	89–600	86–587	85–583	82–578	78–566	72–553	69–545	68–540	65–533	64–527
Recruitment (1,000s)	1,039	369	959	1,290	591	1,211	654	738	2,233	1,054	960	1,095	1,093
~95% CI	525–2,057	172–792	483–1,903	651–2,553	271–1,290	572–2,564	280–1,528	304–1,797	942–5,292	387–2,871	339–2,718	618–1,939	617–1,937
Depletion (%)	89.60	86.00	83.00	79.80	78.10	77.60	76.50	74.60	72.50	71.20	70.50	69.30	68.60
~95% CI	72.3–106.9	68.5–103.4	66.0–99.9	63.3–96.4	61.9–94.4	61.4–93.7	60.3–92.7	58.4–90.9	56.1–88.9	54.7–87.7	54.2–86.8	52.8–85.8	52.2–84.9

1 Introduction

1.1 Basic Information

Blue and Deacon Rockfishes (BDR; *Sebastes mystinus* and *S. diaconus* [Jordan and Gilbert 1881; Frable et al. 2015]) are small to medium sized members of the genus *Sebastes* within the family Scorpanenide. These are two of the 65 rockfish species managed under the Pacific Fishery Management Council (PFMC) Groundfish Fishery Management Plan (GFMP). Until 2015, these species were thought to be one species, "Blue Rockfish (*S. mystinus*)". Deacon Rockfish was formally separated from Blue Rockfish based on morphometric and microsatellite genetic analyses by Frable et al. (2015). Thus, this document provides an assessment of the "Blue and Deacon Rockfish" complex as was done in the 2007 California Blue Rockfish assessment (Key et al. 2008), because almost all of the historical data available consist of mixed BDR in unknown proportions.

Both Blue and Deacon Rockfishes share many common physical characters that contributed to combining these two species with a few notable differences emerging from recent studies. Pigmentation in both is gray-blue to blue-black. This coloration was the impetus for the Blue Rockfish species name, *mystinus*, and later for Deacon Rockfish, *diaconus,* as the dark color is reminiscent of the robes worn by priests and deacons (Frable et al. 2015). The two species are differentiated by the pattern of this pigmentation as the Blue Rockfish is blotched while the Deacon Rockfish pigmentation is solid (see cover photo). Deacon Rockfish are further differentiated possessing a prominent symphyseal knob, a flatter ventrum, and longer first and second anal spines (Frable et al. 2015). Internally, female Deacon Rockfish have pink-cream colored ovaries while ovaries of Blue Rockfish are bright yellow (Hannah et al. 2015). These species are also commonly confused with Black Rockfish, but Blue and Deacon Rockfishes have smaller mouths, no dorsal fin spots, and lack a rounded anal fin.

BDR inhabit nearshore and offshore rocky reef and kelp habitats ranging from Baja California Sur, Mexico to British Columbia, Canada (Love 2011). These two species are sympatric from northern California to central Oregon (Frable et al. 2015). BDR can occupy depths from the shallow intertidal zones out to 149 m at Stonewall Banks (Hannah and Blume 2016), but are also found 500 km west of Washington at Cobb seamount where depths range from 33 – 820 m (Douglas 2011). However, these fish are most commonly encountered in depths from 0- 55 m (Love 2011) as schools can surface feed. BDR are schooling semi-pelagic species commonly found aggregating with Black Rockfish, Canary Rockfish, Widow Rockfish, Yellowtail Rockfish, Olive Rockfish and Blacksmiths.

Summary of Blue and Deacon Rockfish Genetic Analyses

Subsequent to the 2007 Blue Rockfish (*Sebastes mystinus*) stock assessment (Key et al. 2008), new research using microsatellite analysis and mitochondrial and nuclear sequencing showed that what were previously believed to be northern and southern sub-populations of *mystinus* are actually two cryptic species (Burford et al. 2006, 2011a; Burford and Bernardi 2008). Differences between species in coloration, the size of the symphyseal knob, ventrum shape, and length of anal-fin spines align with genetic distinction at six microsatellite loci (Burford and Bernardi 2008; Frable et al. 2015). The two species are now officially distinguished as the Deacon Rockfish (*S. diaconus*) and the Blue Rockfish (*S. mystinus*, lectotype; Frable et al. 2015). It is believed that these species diverged allopatrically approximately 500 Kya (± 200k) during a glacial event prior to the last glacial maximum (Burford 2009). *Diaconus*, which derived from *mystinus*, has been a comparatively more stable population and has shown a general increasing overall trend in abundance over time (Cope 2002, 2004).

In addition to morphological and genetic differentiation, the “two species of blues” exhibit differences in geographic distribution and possibly depth. *Diaconus* has commonly been reported at depths of 8–72 m (but have been observed in deeper water associated with the Cobb Seamount) and ranges from Morro Bay, central California to Vancouver Island, British Columbia (Frable et al. 2015; M. Love, pers. comm.). *Mystinus* occurs from tide pools and surface waters to depths of at least 156 m (Love 2011; M. Love, pers. comm.), with its known range extending from northern Baja California (32.5° N) and farther south (roughly 30° N to 31.5° N; Phillips 1957; Klingbeil and Knaggs 1976) to central Oregon (44.5° N) (Frable et al., 2015). Frable et al. (2015) report anecdotal evidence that adult *diaconus* are more frequently found offshore in deeper water than adult *mystinus*. Additional research also suggests that *diaconus* are the dominant species from Neah Bay, WA to Cape Arago, OR, whereas *mystinus* dominate from Cape Mendocino to Santa Cruz Island, CA. Because of range expansion over time, there is a high degree of spatial overlap and similar abundance in the ~450 km stretch of coast between Cape Arago and Cape Mendocino (Burford 2009; Burford et al. 2011b; Schmidt 2014). Cope (2004) found that fish at the Farallon Islands (CA) are more closely related to *diaconus* than *mystinus* and suggested they could be either a sub-population of *diaconus* or a third “blue” species that diverged from *mystinus* (Cope 2004). Burford et al. (2011b) found evidence of a southward range shift for juvenile *diaconus*, indicating either a range expansion in colder years, range adjustment due to upwelling, or different patterns for juveniles and adults.

To better inform spatial, temporal, and ontogenetic patterns in species distribution, this assessment includes results of extensive genetic analyses (see Appendix A) conducted by E. Gilbert-Horvath at the NMFS, SWFSC, Fisheries Ecology Division in Santa Cruz, California. Gilbert-Horvath examined DNA sources derived from modern fin tissues as well as historical otolith samples, and confirmed that visual identification of BDR to species is highly accurate, with 97% concordance between high-confidence genetic IDs and visual IDs. Approximately 70% of samples taken in Half Moon Bay, California were Deacon Rockfish, with an increasing trend in relative abundance of Deacon to the north. Blue Rockfish were more common from Monterey Bay, California (~73% of samples), and increased in relative abundance to the south. Within species, very little geographic structure was detected (Figure 1 and Figure O in Appendix A).

Despite partial range overlap and a three to six month long larval phase (Laidig 2010; Love et al. 2011), species integrity and range stratification for *diaconus* and *mystinus* have been maintained over time. Potential reasons for the maintenance of these distinctions are: 1) larvae not dispersing as far as previously expected (Miller and Shanks 2004), 2) strong site fidelity and potential homing ability (Lea et al. 1999), and 3) differences in the timing of parturition (Sivasundar and Palumbi 2010, Kashef et al. 2014). There is also the potential that physical segregation acts as a mechanism for reproductive isolation. For other cryptic rockfishes (e.g., Vermilion Rockfish, *S. miniatus*), speciation has been mainly attributed to depth segregation (Williams and Ralston 2002; Hyde et al. 2008; Ingram, 2011). The lack of interbreeding and high degree of genetic distinctiveness in sympatric areas suggests that maintenance of these two genetically distinct populations is likely due to pre-zygotic reproductive barriers (Burford et al. 2006; Burford and Bernardi 2008; Burford 2009) such as differential mating strategies (e.g., timing) or mate choice (Hyde and Vetter 2007). Helvey (1982) found that Blue Rockfish in southern California (and therefore assumed to be *mystinus*) have a patterned courtship behavior involving active males and relatively inactive females. One action performed by the male is to brush the female’s snout with his ventral side. Given different relative symphyseal knob sizes for *diaconus* and *mystinus*, the males may be able to identify conspecifics through this courtship encounter. Helvey (1982) also describes the courtship as being dependent upon female inactivity. Hypothetically then, during this interaction, if a female *diaconus* did not maintain the stillness required for the patterned courtship, it could terminate a mating attempt by a male *mystinus*. While these pre-zygotic barriers might prevent interbreeding, they do not preclude the possibility. Burford et al. (2011a) found higher rates of hybridization in areas where one species was found in relatively low abundance. Pre-zygotic barriers therefore may not be fixed and may be overcome with increased encounter rates or with a substantial disparity in relative abundance (Burford et al. 2011a).

Although Blue Rockfish and Deacon Rockfish represent distinct species, prior research and the paucity of reliable species-specific life history, distribution, and abundance data supports the assessment of *diaconus* and *mystinus* stocks as a "complex". Evaluating spatial patterns in the data could eventually allow species-specific trends in abundance to be highlighted given the known latitudinal differences between species. In analyzing the Blue Complex, Laidig et al. (2003) found that growth parameter estimates differed significantly between California and Oregon populations. These regional differences may be a proxy for species-level differences, given the known differences in distribution between species. A combined stock assessment is further supported by the difficulty in accurately distinguishing species throughout ontogeny (Schmidt 2014; Frable et al. 2015) given their similar coloration and morphology. Misidentification of the two species could lead to erroneous results if the fishes were assessed individually. In addition, life history parameter estimates and patterns have been relatively consistent for the complex (Miller et al. 1967; Wyllie-Echeverria 1987; Laidig et al. 2003; Key et al. 2008) and appear to be similar between species (Schmidt, 2014; Hannah et al., 2015). Hannah et al. (2015) found that females of both species grew slower but reached larger maximum sizes than males in Oregon. They also found that both species have similar timing for parturition and reach approximately the same asymptotic sizes (both sexes). The most notable life history difference detected by Hannah et al. (2015) was that *mystinus* was smaller and younger at 50% maturity than *diaconus* (Hannah et al. 2015). In California, Schmidt (2014) similarly found that size at maturity of female and male *mystinus* was significantly smaller than that of *diaconus* and that female *mystinus* had smaller lengths at age than *diaconus* females. No significant interspecific differences in age at maturity or length-fecundity relationships were detected (Schmidt 2014). Schmidt (2014) did, however, find temporal and spatial variation with respect to catch composition, length-fecundity relationships, maximum size, and length and age at maturity. Despite the noted interspecific variation, Schmidt (2014) recommended combining the species for stock assessment purposes given the potential for misidentification and because variation in life history characteristics is not substantial.

Several authors have emphasized the importance of conducting genetic and life history analysis to detect cryptic species and sub-populations within a species and ensure that rockfish are managed in appropriate units (Buonaccorsi et al. 2005; Tuckey et al. 2007). *Sebastes* is a diverse genus that radiated with the establishment of upwelling systems in the late Miocene (Hyde and Vetter 2007). There are currently 106 described *Sebastes* species (Frable et al. 2015), 65 of which occur in the eastern North Pacific (Hyde and Vetter 2007). It is highly likely that more cryptic species remain unidentified given that similar morphology among species can conceal differences in genetic structure. For example, what was considered one species of *S. aleutianus* (Rougheye Rockfish) has been revealed to be two genetically distinct forms (Blackspotted Rockfish, *S. melanostictus*; Gharrett et al., 2005, 2006; Hicks et al. 2014), and oceanic and deep-sea populations of *S. mentella* (Beaked Redfish) exhibit genetic differences (Johansen et al. 2000). Similarly, microsatellite analysis indicated that *S. miniatus* (Vermilion Rockfish) contains a cryptic species (Sunset Rockfish, *S. crocotulus*; Hyde et al. 2008), and that Dark-Banded Rockfish, *S. inermis*, is in fact three recently evolved species that probably separated because of ecological preferences (Kai et al. 2002). The emerging understanding of cryptic speciation in rockfishes can have major implications for stock designation and assessments. The ability to differentiate of species and stocks for assessments is largely contingent on the quality and quantity of available demographic data and the reliability of distinguishing different stocks in the fishery and should therefore be determined on a case by case basis. For the purposes of this assessment, we refer to the combined complex of Blue Rockfish and Deacon Rockfish as "BDR" (Blue-Deacon Rockfish).

We model the population dynamics of BDR as two independent stocks, one in U.S. waters off the coast of California, USA, and the other in U.S. waters off the coast of Oregon, USA. Prior to the recent description of Deacon Rockfish as a separate species (Frable et al. 2015), historical removals of Blue and Deacon rockfish were identified as Blue rockfish. Our assessment makes no attempt to partition historical removals among Blue and Deacon Rockfish.

1.2 Map

A map of the assessment region with selected coastal features is provided as Figure 2.

1.3 Life History

Larval BDR are spawned from October-March with a peak during December-February (Wales 1952; Moser 1996; Lea et al. 1999; Love 2011). Fertilized ovaries ripen in winter months with peak parturition occurring in January and February (Hannah et al. 2015) during oceanographic conditions when relaxed upwelling and shoreward winds help retain larvae nearshore (Parish et al. 1981). The number of developing ova ranges from about 50,000–525,000, with a strong positive relationship between female body size and fecundity (Miller and Geibel 1973; Love et al. 2002; Dick et al. 2017). Birth (total) length (TL) is ~3.8 mm and larvae transform to pelagic juveniles at 2.1 cm TL (Moser 1996). BDR larvae and pelagic juveniles spend 3–6 months in the plankton and occur at deeper depths (commonly to > 100 m) than those of most rockfishes (Lenarz et al. 1991; Moser 1996; Love et al. 2002). However, Laidig (2010) estimated age at settlement to be 68-69 days off Central California, with birth and settlement dates occurring later in Mendocino relative to Monterey. Pelagic juveniles recruit to the rocky, benthic regions during April-June at total lengths ≥ 3.1 cm (typically 3.5–4.0 cm; Love et al. 2002) and form dense aggregations, occasionally with Olive or Black Rockfish (Anderson 1983; Carr 1991). Mean length of YOY BDR off the central California coast, 1987-1992, were between 6-7 cm total length in July (VenTresca et al. 1996). The number of recruits is highly variable between years and strongly linked to the favorability of environmental conditions during the planktonic phase (Love et al. 2002; Ralston et al. 2013). Natural mortality estimates of YOY BDR, as estimated from catch curves, ranged from 0.001-0.008/day and were generally consistent among northern California study sites (Adams and Howard 1996). Reproductive condition is negatively impacted by ENSO warming events (VenTresca et al. 1995).

Life history traits are sexually dimorphic, as is common among rockfishes (Love et al. 2002). The two sexes can be differentiated by examining the genital papilla, which in males is forward-facing and in females faces backwards. Female BDR mature more slowly than males but ultimately reach larger sizes (maximum TL of BDR = 53.3 cm TL, Phillips 1957). Greater fin area and eye size occur in male BDR (Echeverria 1986). Size at first maturity has been reported at 19.6 cm TL for females and 21.9 cm TL for males (Lea et al. 1999), which corresponds to four years for males and five years for females (Laidig et al. 2003). All male fish are mature by 32 cm TL (9 years) whereas 100% maturity in females is attained by 35 cm TL (11 years) (Love et al. 2002). Maternal age and size positively influence the quality and quantity (but not the size) of larvae through increased lipid provisioning, greater weight-specific fecundity, and earlier timing of parturition (Sogard et al. 2008). As observed in other rockfish species, older and larger females may therefore contribute disproportionally to larval recruitment (Sogard et al. 2008). After maturation, females are larger than males at any given age (Love et al. 2002), and reach larger maximum lengths than males (Laidig et al. 2003). The oldest aged BDR, a male, was 44 years old, and the oldest aged female was 41 years old (Laidig et al. 2003). Fish from northern and central California have similar maximum sizes, maximum ages, and growth model parameters (Laidig et al. 2003).

In the California Current Large Marine Ecosystem food web, BDR are important planktivores, but prey on many organisms. Their small mouths are well adapted for planktivory with adults limited to prey ≤ 5 mm during dives off Sonoma, CA (Hobson 1996). Primary prey included thaliaceans (44.5%), gastropods (24.4%), ctenophores (2.3%), polychaetas (1.3%), and pelagic hydrozoans (0.5%). Many of these prey organisms reside offshore, but are pushed inshore with surface water during relaxed upwelling events. Hobson (1996) also noted plants, *Nereocystis luetkeana* (21.2%) and *Porphyra* spp. (0.5%), as dietary components. Prey can also include crustaceans, arrow worms, and other fish and squid for adults (Love 2011). Many organisms prey upon BDR (see section 1.4), particularly in the nearshore on young-of-the-year fish. Piscivorous fish including Olive, Kelp and Gopher Rockfishes are common predators as are Lingcod, Kelp Greenling and Chinook Salmon. Seabirds and California sea lions also prey on these rockfish.

1.4 Ecosystem Considerations

Ecosystem data were not explicitly included in this assessment. Trophic relationships and habitat associations of Blue Rockfish are relatively well described among rockfishes; however, the recent discovery of a cryptic species (Deacon Rockfish, *Sebastes diaconus*; Frable et al. 2005) necessitates that historical information is considered for the Blue/Deacon Rockfish complex as a whole. We refer to both species simply as "BDR" for convenience and consistency in describing habitat associations and predator/prey interactions. More research is needed to elucidate the distinct ecological roles of Blue and Deacon Rockfish in the California Current Large Marine Ecosystem and to describe differences in spatial associations and trophic relationships between species.

Habitat associations vary ontogenetically for BDR, but all post-larval stages occur in nearshore waters often in association with kelp beds. BDR can recruit to nearshore rocky habitats (Anderson 1983), sometimes preceded by a brief respite in surface canopies of kelp (Love et al. 2002). Oil platforms also serve as habitat for recruits in offshore waters (Love et al. 2007). Smaller numbers of BDR can recruit to tide pools (Moring 1972; Studebaker et al. 2009) and rarely to bays and estuaries (Fletcher 1981; Gallagher and Heppell 2010). Early juveniles are benthic, but BDR become more pelagic with ontogeny. Pelagic excursions are confined to daylight hours; however, as all life stages of BDR seek shelter in rocky reefs after dark. Adult BDR do not typically move more than 100 m from their core home range, which is centered on rock pinnacles (Jorgensen et al. 2006) and cliffs. However, BDR commonly shift their home ranges, especially during the upwelling season, and tagged fish have moved up to 43 km (Love et al. 2002; Green et al. 2014). BDR prefer kelp beds to similar nearshore regions without kelp and are a dominant member of kelp bed communities off central and southern California (Miller and Geibel 1973; Jorgensen et al. 2006; Love 2011). Large-scale climactic conditions (e.g., ENSO warming events) can influence adult reproductive condition (VenTresca et al. 1995).

BDR are largely planktivorous species that feed on midwater organisms (Hobson and Chess 1988; Lea et al. 1999; Love 2011). Diet of young-of-the-year (YOY) includes small tunicates, harpacticoid and calanoid copepods, crustacean larvae, polychaetes, mysids, algae, and gammarid amphipods (Singer 1985). Food habit studies on combined juvenile and adult individuals indicate a diverse diet consisting largely of crustaceans (e.g., amphipods, crab larvae, copepods, pelagic red crabs during ENSO events), gelatinous zooplankton (e.g., larvaceans, siphonophores, pteropods, medusa, ctenophores), and chaetognaths, with small fishes (e.g., larvae, YOY rockfish, northern anchovies, sardines), algae, and hydroids also commonly taken and polychaetes, bivalve siphons, and squids occasionally consumed (Gothsall et al. 1965, Love and Ebeling 1978, Lea et al. 1999). Juveniles, which mainly prey on small, midwater crustaceans and gelatinous zooplankton, can significantly reduce local plankton densities (Gaines and Roughgarden 1987, Love et al. 2002). Consumption of gelatinous zooplankton, pelagic gastropods, drift vegetation, squids, and fishes increases with size (Gotshall et al. 1965; Love et al. 2002). BDR are adapted to feeding opportunities created by alternating, episodic periods of strong upwelling and strong downwelling (Hobson and Chess 1988). It is most abundant off central and northern California, where these conditions are best developed (Hobson and Chess 1988; Love et al. 2002).

BDR are important prey species for a variety of nearshore marine vertebrates. YOY and pelagic juveniles are eaten by Kelp Rockfish (Larson 1972; Lea et al. 1999), Olive Rockfish (M.S. Love, unpub. data), Pigeon guillemot (Follett and Ainley 1976), Rhinoceros Auklet, and Chinook Salmon (Mills et al. 2007). Gopher Rockfish prey on small, benthic juveniles (Larson 1972) whereas Lingcod (Wyllie-Echeverria, unpub. data), Kelp Greenling (Whipple et al. 1991), California Sea Lion (M. Lowry, unpub. data), and Harbor Seal (Love et al. 2002) consume older juveniles and adults. In years when they are particularly abundant, YOY BDR dominates the diets of several nearshore fishes (e.g., rockfishes, Lingcod, Kelp Greenling), pinnipeds, and marine birds (Love 2011).

1.5 Fishery Information

1.5.1 California

Prior to the recent description of Deacon Rockfish as a separate species (Frable et al. 2015), historical removals of Blue and Deacon Rockfish (BDR) were identified as Blue Rockfish. Therefore, it is not possible at this time to examine historical patterns of exploitation by species. In recent years, some state agencies have begun estimating landings for both species, but methods vary by state and sector. The current assessment makes no attempt to partition historical removals between Blue and Deacon Rockfish.

BDR are taken by recreational and commercial fleets in California, but recreational fisheries have accounted for the vast majority of statewide cumulative removals (Figure 3). Within the recreational sector, landings are dominated by the “boat modes” (i.e., private/rental boats and party/charter boats), with only minor contributions from shore-based fishing modes. Party/charter boats in California often are referred to as Commercial Passenger Fishing Vessels (CPFVs), and the terms “party boat,” “charter,” and “CPFV” are used interchangeably in this assessment.

The great majority of historic BDR fishery landings have been contributed by the recreational sector (Reilly 2001; CALCOM; RecFIN). “Blue Rockfish” is one of the most important recreational species in California and has historically been the most numerically abundant rockfish in recreational fisheries off northern California (Phillips 1957; Miller and Geibel 1973; Mason 1995; Reilly 2001). BDR has also been an important recreational fishery target in southern California. During 1975–1978, BDR was the second most abundant rockfish caught in a survey of CPFVs in the northern Channel Islands (Love et al. 1985). Rapid expansion of recreational fishing effort on rockfishes occurred during the 1950s in response to population declines of traditional target species both south (California Barracuda, Lenarz 1986) and north (salmon, Lea et al. 1999) of Point Conception. Throughout California waters, CPFV landings of BDR increased from 9% of the total catch during 1947 to 55% of the total catch during 1955 (Phillips 1957). Although BDR is caught mainly by CPFVs and private/rental boats, it also is commonly landed by shore-based anglers, which tend to catch a larger proportion of juveniles (Miller and Geibel 1973; Love 2011). BDR is also are among the most frequent species taken by California spear divers (Karpov et al. 1995; Reilly 2001).

Recreational landings of BDR peaked in both northern and southern California during the early 1980s and have since declined in both regions (RecFIN). Prior to 1929, landings of BDR were trivial throughout California. Landings of BDR in northern California increased steadily thereafter until declining in association with changing priorities and targets during World War II (Young 1969). Following the war, there was a marked expansion in the CPFV fishing industry throughout the state (Young 1969), and a substantial increase in landings was observed in northern California (RecFIN). Southern California recreational landings of BDR began to increase in the mid-1950s and then ramped up substantially during the early 1960s. Recreational fisheries in both regions continued to rapidly expand with some temporal variability, especially in northern California, until the early 1980s. In northern California, annual recreational fishing effort and associated landings of BDR doubled between 1957–1961 and 1981–1986 (Heimann and Miller 1960; Karpov et al. 1995). Although averaged landings from the latter time period indicate increased productivity, they mask a trend of precipitous declines in landings from both regions (Karpov et al. 1995; Love et al. 1998). In northern California, landings declined 85.4% between 1981 and 1985, when they were lower than those of southern California for the only time in the history of the recreational fishery. Recreational landings from southern California peaked in 1982 before declining by 99.7% to a modern low in 2001 (RecFIN). Fishery production rebounded in northern California, peaking at a relatively lower level in 1993, before declining steadily but erratically thereafter (RecFIN). BDR landings from southern California remained at a reduced level during the same time period (RecFIN).

In addition to the noted declines in overall recreational landings, the contribution of BDR to recreational landings and the size of landed specimens also have declined (Mason 1998; Love et al. 1998). There are several possible reasons for the apparent reduction in California populations of BDR. BDR typically aggregate in nearshore regions during daylight hours, making them ideal targets for CPFVs (Miller and Geibel 1973; Wilson et al. 1996). Recruitment of BDR is strongly linked to oceanic conditions during larval development; therefore, population fluctuations, including local differences among populations, are common (Miller and Geibel 1973; Jarvis et al. 2004; Burford et al. 2011b). The onset of a protracted period of relatively warm oceanic conditions, especially in southern California, appears to have resulted in generally poor recruitment for BDR (Love et al. 2002; Jarvis et al. 2004; Laidig et al. 2007). BDR also are relatively long lived among marine fishes, with life history traits and behaviors that limit the species overall productivity and ability to rebound from added fishing mortality (Miller and Geibel 1973; Lea et al. 1999; Laidig et al. 2003). Finally, the implementation of increasingly strict fishing regulations also may have resulted in reduced landings.

Current recreational fisheries for BDR are concentrated north of Point Conception and are of relatively low magnitude compared to historic levels (RecFIN, 2017). Although recreational landings increased substantially during 2014–2016, they remain at their lowest recorded levels since the onset of fisheries expansion (Figure 3). Recreational fishery landings continue to dominate total landings of BDR (average contribution = 91.1% during 2007–2016; 88.1% during 1900–2006). Most of the recreational BDR catch in California (82.1%) is currently landed north of Point Conception, which represents an increase over historic levels (70.1%).

Commercial fisheries for BDR have been relatively minor compared to those of other rockfishes and to the recreational fishery for BDR (Phillips 1958; Reilly 2001). The drab coloration and relatively small size of BDR among rockfishes are considered the primary reasons that BDR has been of historically low commercial importance (Wales et al. 1952; Miller and Geibel 1973). Rockfish were landed commercially as early as 1875 (Phillips 1957); and throughout the nineteenth century, BDR were the most abundant rockfish in San Francisco and San Diego markets (Love et al. 2002). This early dominance in commercial landings probably is a result of the nearshore abundance of BDR and the lack of an industrialized groundfish fleet. Until 1943, when the balloon trawl was introduced (Phillips 1949), the great majority of rockfish landings (~95%) were taken by longline (Phillips 1958; Lenarz 1986). Since 1944, trawl landings have dominated the commercial rockfish fishery; although relatively minor longline, gillnet, and hook and line fisheries also have been prosecuted (Phillips 1958; Lenarz 1986; Reilly 2001). BDR are a minor component of the live fish fishery that developed in the early 1990s (Reilly 2001; Pearson et al. 2008). For example, during 1996–1998 in Morro Bay, ~1% of live fish landings were BDR, and about four times as many BDR were landed dead (or sold freshly dead, market as “premium”) than alive (Reilly 2001). This was mostly due to the fact that Blue Rockfish do not survive well after capture (J. Cope, pers. comm.). Overall, historic southern California commercial landings of BDR are trivial, with a brief expansion during 1992–1995, possibly as a result of live fish landings although live landings were not consistently identified on landing receipts (Pearson et al. 2008). BDR commercial landings north of Point

Conception in California increased steadily during the early 1900s but remained at relatively low and variable levels of productivity until the late 1960s (CALCOM). Although trawl fisheries for rockfishes increased substantially in Morro Bay during the 1950s, BDR were not reported among these landings and this trend was not evident in northern California landings (Heimann and Miller 1960; CALCOM, 2017). Commercial BDR fisheries in northern California expanded rapidly from 1969–1975, and then remained highly erratic at relatively higher levels of productivity than those prior to expansion until the late 1990s. Commercial fisheries for BDR in northern California declined thereafter to levels comparable to or lower than those reported prior to expansion (CALCOM, 2017).

Commercial fishery landings of BDR remain at extremely low levels when compared to peak years of production (Figure 3). The modern commercial fishery for BDR is of trivial importance in southern California, which has constituted less than 1% of combined commercial and recreational landings during the last decade (CALCOM, 2017). However, landings of BDR have steadily increased in northern California since the late 2000s. Because BDR and Black Rockfish can be difficult to distinguish, landings of these species often have been misassigned between market categories (Pearson et al. 2008). This problem is especially pronounced for trawl landings, where BDR are rarely captured but occasionally reported in large quantities (Pearson et al. 2008). Conversely, in some instances BDR landings are underreported because they may be landed as “unspecified rockfish” or “group small rockfish” (Reilly 2001). Based on these factors, Pearson et al. (2008) concluded that BDR landing estimates are generally unreliable from at least 1969–2006. Given the added confusion of a cryptic species (Deacon Rockfish, Frable et al. 2015), it is unlikely that this situation improved during the last decade.

1.5.2 Oregon

Blue and Deacon Rockfishes are harvested in both recreational and commercial fisheries primarily with hook and line but also with troll and trawl gears. In these fisheries, catch of BDR is almost all incidental as these species regularly school with Black Rockfish, the main target of Oregon nearshore fisheries. Landings of BDR tend to peak at two seasonal time periods, in the summer when overall effort is high and in winter months when effort is low but catch rates are higher. Only a small number of recreational and commercial fishermen target these fish regularly, generally in winter and spring months when they tend to move inshore (pers. comm. T. Tyler, GAP member and charter captain; T. Thompson, commercial nearshore fishermen). Ocean conditions are challenging for small vessels during winter months when BDR catch rates are highest shoreward of the RCA, which is one of the reasons for low seasonal effort in targeting BDR. Historically, landings and species compositions of “Blue Rockfish” prior to 2016 are complex level “nominal Blue Rockfish,” consisting of unknown proportions of Blue and Deacon Rockfish (see section 1.3).

In Oregon’s recreational fishery, BDR have not been a main target species historically. However, this fishery has accounted for the overwhelming majority of BDR catch due to incidental take, on the order of four to five times that of annual commercial landings (Figure 156). As far back as 1979, Oregon’s ORBS sampling program has collected species composition samples from rockfish landed by ocean boats focused on targeting salmon. These compositions contain records of nominal Blue Rockfish including length samples. As salmon opportunities declined in the 1980’s and newly dredged bars allowed more ocean access, recreational fishermen began targeting nearshore rockfish such as Canary and Black Rockfishes and incidentally impacting BDR. By the mid-1990s, Coho Salmon opportunities were mostly eliminated and recreational fishermen were attaining their Pacific Halibut quota by early in the fishing season (Schindler et al. 2012). All these factors shifted recreational fishing targets to nearshore groundfish species and by the late 1990s landings of BDR rose substantially. Since 2000, bag limits have dropped and overall effort has increased, resulting in inter-annual fluctuations in landings. However, the average annual landing rate since 2000 of nearly 0.5 BDR per angler-trip indicates that bag limits haven’t been directly limiting BDR catch, although catch could be influenced indirectly by targeting preferences. Effort in the recreational fishery is concentrated on Oregon's northern and central coast.

Blue and Deacon Rockfishes are also not a main component of Oregon commercial fisheries. Significant amounts of landed unidentified nearshore rockfish occurred during the early days of trawl fishing, but species composition samples during that time do not include Blue Rockfish. Commercial boats targeting other nearshore species for the live- and fresh- (dead) fish markets on Oregon's southern coast comprise the majority of the commercial catch. BDR can occur in mixed schools with Black Rockfish in large numbers such that preferred Black Rockfish can be difficult to target and catch (pers. comm., T. Obteshka, commercial nearshore fishermen). As such, these species are often caught and landed by commercial nearshore fishermen. The year-to-year magnitude of overall commercial landings has been variable depending on fishery effort, regulations, market forces, and availability of other species. However, BDR have poor survival for the live-fish market such that over 90% of the fish that are landed are sold to fresh markets (Rodomsky et al. 2016). Prior to 2015 regulation changes, retaining BDR came as a trade-off with retaining the more valuable Black Rockfish, because these three species have been State managed as a complex under a single trip limit (see Management History). Many commercial fishermen were motivated to retain Black Rockfish over BDR, which led to discarding of BDR. Of the retained BDR, over 90% are female. This is mainly due to sexual dimorphism with males growing to a smaller maximum size, relative to females, driving size distributions that result in few marketable male fish.

1.6 Summary of Management History

1.6.1 California

Key et al. (2008) summarized relevant management actions through 2006. At that time, *S. diaconus* had not been described, so historical references to management of "Blue Rockfish" or *S. mystinus* should be interpreted as affecting both *S. mystinus* and *S. diaconus*. The management summary by Key et al. (2008) is repeated below for convenience, followed by additional details and aspects of recent management (2007-2016) that are relevant to this assessment.

> "Prior to the adoption of the Pacific Coast Groundfish Fishery Management Plan (FMP) in 1982, blue rockfish (*Sebastes mystinus*) were managed through a regulatory process that included the California Department of Fish and Game (CDFG) along with either the California State Legislature or the Fish and Game Commission (FGC) depending on the fishery and sector (recreational or commercial). With implementation of the Pacific Coast Groundfish FMP, blue rockfish came under the management authority of the Pacific Fishery Management Council (PFMC), being incorporated, along with all genera and species of the family *Scorpaenidae*, into a federal rockfish classification (PFMC 2004) and was then jointly managed with the state.
>
> Under the Pacific Coast Groundfish FMP, groundfish species and species groups were managed using estimates of Allowable Biological Catch (ABC). Starting in 1992, some of the rockfish species and species groups also began to be managed using harvest guidelines followed in 1999 by the use of Optimum Yields (OY). To keep landings within these adopted harvest targets, the Pacific Coast Groundfish FMP provided the Council with a variety of management tools including area closures, season closures, gear restrictions, and, for the commercial sector, cumulative limits (generally for two-month periods). With the implementation of a federal groundfish restricted access program in 1994, allocations of total catch and cumulative limits began to be specifically set for open access (including most of

California's commercial fisheries that target nearshore rockfish) and limited entry fisheries (PFMC 2002; 2004).

During most of this time frame, management also concentrated on the commercial groundfish sector primarily because harvest from the recreational sector was considerably smaller than that from the commercial sector. This approach began to change in the later 1990's as commercial landings decreased and recreational harvest became a greater proportion of the available harvest.

The PFMC's rockfish management structure changed significantly in 2000 with the replacement of the *Sebastes* complex –north and –south areas with Minor Rockfish North (Vancouver, Columbia, and Eureka, International North Pacific Fisheries Commission (INPFC) areas) and Minor Rockfish South (Monterey and Conception INPFC areas only). The OY for these two groups was further divided (between north and south of 40º10' N. lat. ~ Cape Mendocino, Humboldt County, California) into nearshore, shelf, and slope rockfish categories with allocations set for Limited Entry and Open Access fisheries within each of these three categories (January 4, 2000, 65 FR 221; PFMC 2002, Tables 54-55). Species were parceled into these new categories depending on primary catch depths and geographical distribution.

Also, in 2000, seasonal 2-month closures were adopted in California for the first time for both commercial and recreational fisheries. In addition, the bag limit in California for rockfish was reduced from 15 to 10 rockfish, in combination, and recreational gear was limited to one line with three hooks.

Cowcod Conservation Areas (CCAs) were established in 2001 to reduce fishing effort for cowcod rockfish in southern California (PFMC 2002, [see Table 29 in Key et al. 2008]). More importantly for blue rockfish management, Rockfish Conservation Areas (RCAs) were established in 2003 to allow for the closure of large areas based on depth for particular fishing sectors or gears. The trawl and non-trawl gear RCAs were two of these groundfish conservation areas established in 2003 with the purpose of reducing fishing effort on shelf and slope rockfish, including overfished species such as canary rockfish, while providing some limited bottom fishing opportunities in adjacent waters.

During the late 1990's and early 2000's, major changes also occurred in the way that California managed its nearshore fishery. The Marine Life Management Act (MLMA), which was enacted in 1999, gave authority to the FGC to regulate commercial and recreational nearshore fisheries through FMPs and provided broad authority to adopt regulations for the nearshore fishery during the time prior to adoption of a nearshore finfish FMP.

Following adoption of the Nearshore FMP in fall of 2002, the FGC adopted a nearshore restricted access program for the commercial fishery to be effective starting in the 2003 fishing year, including the establishment of a Deeper Nearshore Permit (DNP). Since blue rockfish was categorized in the Nearshore FMP as a deeper nearshore rockfish, commercial fishermen taking this species were required to possess a DNP.

Although the Nearshore FMP provided for the management of the nearshore rockfish, joint management authority for these species continued to reside with the Council and the State. Even so, for the 2003 and subsequent fishery seasons, the State provided recommendations to the Council specific to the nearshore species that followed the directives set out in the Nearshore FMP. These recommendations, which the Council incorporated into the 2003 management specifications, included a division of the Minor Rockfish North – Nearshore into two groups (black and blue rockfish; and other nearshore rockfish), recalculation and division of the OY for Minor Rockfish South - Nearshore into three groups (shallow nearshore rockfish; deeper nearshore rockfish; and California scorpionfish). The Council also incorporated specific harvest targets and recreational and commercial allocations for each of the above groups and adopted various management specifications to keep harvest within harvest targets.

Starting in 2004, management specifications adopted by the Council and State also included recreational RCAs which limited the maximum allowable fishing depth such as the California Rockfish Conservation Area (CRCA) (for more information on the CRCA, see Title 14 of the California Code of Regulations, Section 27.51). Also in 2004, black rockfish were removed from both the Minor Rockfish North and Minor Rockfish South ABCs and OYs. As a consequence, the groupings and harvest targets for the Minor Rockfish North – Nearshore changed; the blue rockfish proportion of the black and blue rockfish group harvest target was combined with that from the other nearshore rockfish and placed under a new group category, minor nearshore rockfish."

Key et al. (2008) created a timeline of California regulations from 1990-2006 (their Table 1, reproduced here as Figure 4). Prior to 2000, recreational fisheries had few regulations apart from bag limits. A 20 rockfish daily limit was in effect as early as 1958 (CDFG, 1958), and was replaced with a 15 fish limit in March, 1971. In 2000, the rockfish bag limit was again reduced to 10 fish per day, but the effects of this change are confounded with the introduction of depth restrictions and area closures (Figure 5). Depth and area restrictions varied considerably from 2001-2006, followed by a relatively stable spatial and temporal pattern of management, with southern parts of the state generally having access to deeper depths and longer fishing seasons. Gear restrictions for sport fishermen were first implemented in 2000, allowing no more than one line with three hooks (Figure 4). The following year, the number of hooks per line was reduced from three to two, and this limit is still in effect as of the time of writing.

A coastal network of Marine Protected Areas (MPAs) was implemented in California state waters (within 3nm of shore) over a period of approximately 5 years beginning in 2007 with the Central Coast Region (Pigeon Point to Point Conception). Statewide, roughly 16% (852 sq. miles) of state waters are afforded some level of protection, including approximately 9% of state waters designated as State Marine Reserves (SMRs), which prohibit all take and consumptive use. Additional details about California MPAs can be found online at https://www.wildlife.ca.gov/Conservation/Marine/MPAs. A recent study found little change in effect sizes (catch rate and average length) between MPA and reference sites over the course of seven years, but cautioned that longer time periods may be necessary to detect MPA effects (Starr et al. 2015). This assessment does not explicitly account for MPAs in the model structure.

Blue Rockfish (now known to include Deacon Rockfish) have been managed as part of various species assemblages (stock complexes) over time. Since 2011, Annual Catch Limits (ACLs) have been required for all federally-managed stocks and stock complexes. Blue Rockfish is currently managed as part of two minor nearshore rockfish complexes, north and south of 40° 10' North Latitude (see Management Performance section, below). A selection of commercial management actions affecting Blue (and Deacon) Rockfish through 2006 were reported by Key et al. (2008; Figure 4). See Appendix B for a detailed table of Federal management actions relevant to commercial fisheries targeting stock complexes that have included Blue (and Deacon) Rockfish.

1.6.2 Oregon

The management of BDR in the State of Oregon began in 1976 with the recreational fishery, when the first daily harvest limits on these species were implemented under Oregon's 25 fish aggregate daily bag limit for the 'Other Fish' complex of which BDR were a part. By 1978, the daily bag limit for 'Other Fish' dropped to 15 fish. Since 1978, the state management grouping and recreational bag limit for these species have changed multiple times (Table 1). BDR has always been recreationally managed with other species as part of an aggregate bag limit. In additions to bag limits, in 2004 ODFW implemented an annual 41 mt soft-cap harvest limit on BDR based on historical catch that was in place through 2014. In 2015, ODFW implemented a sub-bag limit of three BDR and an annual harvest limit of 26 mt for Blue, Deacon and Other Nearshore Rockfishes, combined. These more restrictive regulations were set to maintain impacts within the 69 mt ACL for northern nearshore rockfish which had dropped 27% from the 2014 ACL (Table 2).

Management of Oregon's commercial fishery for BDR began with the rapid development of a live-fish fishery on the southern coast in the late 1990s and early 2000s. At that time, effort was shifting away from offshore stocks adversely affected by the West Coast groundfish crisis. In 1997, live fish were landed by 44 vessels and sold to 27 buyers, whereas by 2000, open access effort increased to 102 vessels delivering live fish to 45 buyers (ODFW 2002). This effort expansion prompted fishery participants to urge ODFW to establish a management system that capped participation. ODFW implemented an interim fishery management plan (ODFW 2002) and placed BDR in a Developmental Fisheries Program with Black Rockfish and 21 other nearshore species with the goal of reducing effort by at least 50%. In 2003, the state first adopted bimonthly trip limits for BDR, in combination with Black Rockfish. In 2004, the state legislature passed House Bill 3108 which established limited-entry management of the Black and Blue Rockfish permitted fixed gear fishery with 144 permits. This new management system allowed permitted vessels access to full bimonthly trip limits of BDR for six annual bimonthly periods (Table 3), while non-permitted trips and gear types were restricted to small incidental landing limits. From 2004 – 2014, BDR were managed by the state in a complex with Black Rockfish. Commercial harvest limits for this complex included an aggregated state bimonthly trip limit and a soft cap annual harvest limit of four metric tons added to the Black Rockfish limit. In 2015, BDR were separated from Black Rockfish and placed into a "Blue Rockfish" only state management complex and managed with state-level Other Nearshore Rockfish under a 10.4 mt harvest limit. In addition, ODFW implemented a BDR-only bimonthly limit which was two-orders of magnitude lower than the previous combined Black and Blue Rockfish trip limit. This new restrictive bimonthly limit specific to BDR was necessary to keep impacts within the reduced federal northern nearshore rockfish complex ACL (Table 2).

Currently, BDR are managed under both state and federal jurisdictions. At the federal level, these species are managed under the federal Groundfish Fishery Management Plan (GFMP). Prior to 2000, BDR were managed as part of the federal *Sebastes* complex that included various less commercially important rockfish species. In 2000, federal management of BDR was shifted into the "minor nearshore rockfish" complex that was renamed the "nearshore rockfish" during the 2015 harvest specifications cycle.
The nearshore rockfish complex is subdivided geographically at 40°10' N into two groups, northern and southern nearshore rockfish. BDR in Oregon waters are part of the northern nearshore rockfish. The northern nearshore rockfish consist of 13 assessed and unassessed species and are managed together because of scientific uncertainty and management convenience. The overfishing limit (OFL) for this complex is determined by summing the individual species OFL contributions, amounting to 118 mt for 40°10' N in 2017. The current contribution of BDR to the nearshore rockfish complex OFL is based on a depletion-corrected average catch (DCAC) assessment for both Oregon and Washington amounting to 32.3 mt combined for both states with an ACL of 26.9 mt at a P*=0.45. These individual component species ACLs are treated as soft caps under the hard capped northern nearshore rockfish complex ACL harvest control rule. Harvest of BDR from Oregon's waters counts against this northern nearshore

rockfish complex along with harvest levels from Washington and northern California. The shared Oregon and Washington BDR OFL and ACL are the largest components contributing to the northern nearshore complex harvest limits.

BDR have semi-pelagic life histories and broad depth distributions, such that these fish are caught in the nearshore and further offshore (more so than many other nearshore rockfish species). This fact prompted the Council to consider removing these species from the nearshore rockfish complex during the 2009-10 harvest specification cycle (PFMC 2016). However, given the regular interaction of these species with nearshore fisheries and the scientific uncertainty about life history characters, the Council decided continued management in the nearshore rockfish complex was most appropriate. BDR regularly compose a substantial portion of the impacts under the harvest control rule for northern nearshore rockfish (Table 2).

1.7 Management Performance

The contribution of BDR to the Minor Nearshore Rockfish OFLs is currently derived from three sources: 1) forecasts from Key et al. (2008), allocated north and south of Cape Mendocino, 2) Depletion Corrected Average Catch (DCAC; MacCall, 2009) for the area south of Point Conception, and 3) a DCAC estimate of yield for waters off Oregon and Washington. Estimates of "Blue Rockfish" total mortality by sector, year, and area are shown in Table 4. We compared recent estimates of BDR total mortality, "Blue Rockfish" component OFLs, and the total mortalities, ACLs and OFLs for the Minor Nearshore Rockfish complexes north and south of 40° 10′ N. latitude (Table 5). Total mortality of BDR has not exceeded the component OFL for "Blue Rockfish" and total mortality of Minor Nearshore Rockfishes has not exceeded the ACL or OFL in either the northern or southern areas.

The status of BDR off Oregon has never been fully assessed leaving only the DCAC (Depletion Corrected Adjusted Catch) data-poor method estimates to inform harvest limits (See section 1.6.2). However, the harvest limit for the federally designated "Northern Nearshore Rockfish" management complex, which includes BDR, is calculated by summing the contributing component limits to a complex-level harvest control rule. A history of Northern Nearshore Rockfish harvest limits, complex impacts, and BDR impacts are detailed in Table 2. Harvest levels for the Northern Nearshore Rockfish complex have never exceeded the ACL, the complex attainment in 2011 was 100%. While the OFL and ACL contributions of BDR in the Northern and Southern Nearshore Rockfish complexes were not used as management limits (the harvest specifications at the complex level are the management limits), the ACL contributions were exceeded in the north in all years from 2011-2015 and in the south in 2015 (Table 5). Given that BDR in the area assessed in 2007 (California north of 34°27' N lat.) were estimated to be in the precautionary zone, a California statewide harvest guideline (HG) was specified, which was calculated using the projected 40-10 adjusted ACL from the assessment plus the DCAC estimated ABC/ACL for the area south of 34°27' N lat. This HG was not exceeded since it was first implemented in 2009.

At the Oregon state level, annual harvest limits for both the recreational and commercial fisheries have been in regulation since 2004 to maintain impacts within federal ACLs. For the recreational fishery, the 2004-14 limit of 41 mt was never exceeded. In 2015, the state recreational limit was combined with the state-level Other Nearshore Rockfish and dropped to 26 mt to curtail impacts in response to the 27% ACL reduction. The impacts of BDR and Other Nearshore Rockfish that year totaled 31.9 mt, exceeding the state harvest limit. However, due to the fact that these fish are ultimately held to a complex-level ACL shared among California and Washington, the 2015 overage did not cause the Northern Nearshore Rockfish to exceed the ACL. By 2016, recreational impacts had dropped to 21.3 mt. For the commercial fishery, the four metric ton state soft cap in place from 2004-14 was exceeded in 2004, 2011, 2012, and 2013. These overages to the commercial limit did not cause the fishery to exceed either the state combined Black and Blue Rockfish limit or the federal ACL for Northern Nearshore Rockfish. In 2015, the commercial fishery had a soft cap harvest limit of 10.4 mt for BDR and state-level Other Nearshore Rockfish. Regulations that year held landings of this state complex to less than seven metric tons, but the large amount of discard mortality due to high discard rates from reduced trip limits (see section 1.6.2) drove commercial impacts above the 10.4 mt soft cap. Similar to the recreational fishery, the 2015 overage by the commercial fleet did not drive impacts to federally managed Northern Nearshore Rockfish complex over the ACL. Attainment in 2015 for the Northern Nearshore Rockfish complex was 64 mt, 93% of the 69 mt ACL (Table 2).

1.8 Fisheries off Canada, Alaska, and/or Mexico

Only minor fisheries for BDR exist beyond the U.S. Pacific Coast. The range of BDR extends to northern Baja California, Mexico, where the local species is considered to be *S. mystinus* (Frable et al. 2015). Party boats from the San Diego area have a long history of fishing excursions to these waters to target a variety of species, including rockfishes (Heiman et al. 1968). Landings from the commercial rockfish fishery in Southern California are trivial but historically have been derived from both U.S. and Mexican waters and presumably include BDR (Heinman et al. 1968). BDR landings have been reported from a Mexican sportfish fishery in Bahia de Todos Santos, Ensenada (Rodríguez-Medrano 1993) but commercial fishery information was not obtained. BDR rockfish abundance declines off British Columbia, Canada (Love 2011), where the local species is believed to be *S. diaconus* (Frable et al. 2015). BDR are considered “non-quota” species for commercial fisheries operating off British Columbia and are a minor component of the “inshore rockfish species” assemblage for recreational fisheries (DFO 2007, 2016). Rockfish conservation areas were established in 2002 throughout British Columbia waters to rebuild declining stocks, and inshore rockfish are protected from fishing mortality within these regions (DFO 2007). The range of BDR may extend into the waters of Southeast Alaska, but purported specimens of BDR in other regions of the Gulf of Alaska and Bering Sea are based on misidentifications, typically of *S. ciliatus* (Frable et al. 2015). As a consequence, commercial and recreational fishery landings of BDR in Alaskan waters are unreliable.

2 California Assessment

The STAT presented an overview of available data sources for California and Oregon during the 2017 Groundfish Pre-Assessment Workshop held March 21-22, 2017, in Portland, OR. The STAT also arranged for separate meetings with the PFMC’s Groundfish Management Team (GMT) and Groundfish Advisory Subpanel (GAP) on April 10, 2017, to discuss their concerns about available data and modeling choices. Notable comments from the GAP include that the lack of males in the retained catch is likely due, in part, to a higher discard rate (less desirable size). Alternative proposed mechanisms included segregation by sex, females out-competing males for hooks, or sex-specific diet preferences. The STAT was not able to find studies examining gender effects on diet or hook competition. A search of primary literature cited by Love et al. (2002) in the species account for Blue Rockfish did not reveal any evidence supporting or eliminating segregation by sex among the set of possible mechanisms that could account for the high observed proportion of females in the catch (i.e. dimorphic growth and size-based selectivity or differences in natural mortality).

2.1 Commercial Fisheries Data

Commercial data sources used in the Northern California base model span the period 1916 – 2016 (Figure 6).

2.1.1 Commercial Landings and Discard

Commercial landings in California are based on two primary data sources: a cooperative port sampling program (California Cooperative Groundfish Survey) that collects information including species composition data (i.e. the proportion of species landed in a sampling stratum), and landing receipts (sometimes called "fish tickets") that are a record of pounds landed in a given stratum. Strata in California are defined by market category, year, quarter, gear group, port complex, and disposition (live or dead). Although many market categories are named after actual species, catch in a given market category can consist of several species. For example, Key et al. (2008) found that BDR make up 88% of the "Blue Rockfish" market category (665), as well as 10% of the "Black Rockfish" market category (252). All landings used in this assessment are "expanded" landings, i.e. species composition data collected by port samplers were used to allocate pounds recorded on landing receipts to species. Use of the "Blue Rockfish" market category (665) alone to represent actual landings of BDR would not be accurate. See Pearson et al. (2008, Appendix C) for a simple example of the expansion calculations. Data from the California Cooperative Groundfish Survey, species compositions, and expanded landings estimates are stored in the CALCOM database, and also uploaded to PacFIN, a central repository of commercial landings data for the U.S. West Coast.

We queried the CALCOM database for expanded BDR landings estimates in metric tons, 1969-2016 (Table 6, query date May 29, 2017). In recent years, commercial port samplers have begun identifying Blue and Deacon Rockfishes to species, so we aggregated species codes "BDRK," "BLUR," and "DEAC" in the query. Landings were stratified by gear group: hook and line (HKL), net gears (NET), trawl (TWL; bottom and mid-water combined), and 'other' (all other gears). Port complexes south of Point Conception (San Diego, Los Angeles, and Santa Barbara) were combined into a "Southern California" region, and all others were combined into "Northern California." Data from individual quarters were aggregated at the year level. Fish landed live or dead were combined, due to changes over time in the reliability of condition information (D. Pearson, pers. comm.). Data from the recent query almost exactly matched the landings data used in the 2007 assessment (Figure 7).

For commercial landings prior to 1969, we queried the CALCOM database for estimates from the California Catch Reconstruction (Ralston et al. 2010). Landings in this database are divided into trawl and 'non-trawl.' Since commercial hook and line gear catch the majority of BDR, we assigned estimated catch in the 'non-trawl' category to hook and line (Table 6). A minor adjustment (<4mt total over the period 1948-68) was made to correct for a recently discovered database error. Regions 7 and 8 as defined by Ralston et al. were assigned to Southern California. Northern California non-trawl landings in 1916 (the first year of reconstructed catches) were 17.6 mt, so a linear interpolation was used to approximate Northern California hook and line landings from 1900 to 1915 (Table 6).

The West Coast Groundfish Observer Program (WCGOP) provides observer data on discarding practices across sectors since 2003. The rates of discarding for groundfish species by fishing gear and area is calculated based on the ratio of observed discard to the total of all discard and retained observations for individually managed species. In the case of species managed as part of a complex (e.g. BDR), the calculation of this rate is no longer appropriate. The value of retained fish recorded in the WCGOP database represents the amount of retained fish from the whole complex rather than that of a single species resulting in a discard rate that is not representative of the species of interest. . In consultation with WCGOP staff, the STAT developed estimates of discard mortality ratios based on WCGOP's Groundfish Expanded Mortality Multiyear (GEMM) report. Due to high levels of inter-annual variability, dead discard was estimated as a fixed percentage of landings (Figure 8; 50.63% in California and 24.71% in Oregon) based on available data from management areas north and south of 40° 10′ N. latitude (roughly

Cape Mendocino, CA). Estimated landings for California and discard percentages (CA and OR) were provided to the GMT for review on May 5th and 15th, 2017, respectively.

2.1.2 Commercial Length and Age Compositions

Commercial length data are largely unchanged since the last assessment, with the exception of additional years' data and the use of discard length composition data from the West Coast Groundfish Observer Program (WCGOP). Catch-weighted length composition data ("expanded" length compositions) are available from CALCOM, and are the source of all commercial lengths in the California base model. We aggregated lengths into 2-cm bins by year, gear, and region (north/south of Point Conception). The vast majority (97%) of commercial length samples were of unknown sex. Sex-specific length compositions would be useful for the assessment of BDR due to sexually dimorphic growth patterns. Of the sexed samples, 85% were female, but due to small sample sizes these were combined with the unsexed samples. Most commercial samples in the Northern California base model come from hook and line gear types, with a small number of samples from net gears (Table 7). Length compositions of discarded fish in the commercial fishery were obtained from WCGOP for the years 2004-2015.

Sampling of lengths from the commercial hook and line fishery in Southern California has been sporadic and limited, with only 32 trips sampled over the period 1995-2016. Similarly, only 2 trips (20 fish) were sampled from net gear landings in Southern California. Fewer than 10 discarded fish per year were measured in the Southern California area, so commercial length compositions for discarded fish south of Point Conception were not evaluated in the base model.

Available age composition data from commercial fisheries in California were too sparse to be considered for the assessment (76 females and 5 males from 2011-2012). Approximately 200 other California commercial otoliths were not aged due to missing data associated with the structure (e.g. sex, length, collection date and/or location).

2.2 Recreational Fisheries Data

Recreational data sources used in the Northern California base model span the period 1928 – 2016 (Figure 6).

2.2.1 Recreational Landings and Discard

Estimates of recreational landings and discard in this assessment are derived from three primary sources, described below, and summarized by year, boat mode, and region in Table 8.

Historical recreational landings and discard, 1928-1980

Ralston et al. (2010) reconstructed estimates of recreational rockfish catch and discard in California, 1928-1980. Reported landings of total rockfish were allocated to species based on several sources of species composition data. Estimates of BDR landings and discard (combined) from 1928-1980 are available from the CALCOM database. For this assessment, historical recreational catch was stratified by year, area (north and south of Point Conception), and boat mode (Table 8).

Marine Recreational Fisheries Statistics Survey (MRFSS), 1980-2003

From 1980-2003, the Marine Recreational Fisheries Statistics Survey (MRFSS) executed a dockside (angler intercept) sampling program in Washington, Oregon, and California. Data from this survey are available from the Recreational Fisheries Information Network (RecFIN). RecFIN serves as a repository for recreational fishery data for California, Oregon, and Washington (www.recfin.org). RecFIN is currently undergoing a transition to a relational database design. Catch estimates for years 1980-2003 were downloaded prior to the transition (August 16, 2016), and are consistent with the previous assessment (Key et al. 2008).

MRFSS-era recreational removals for California were estimated for two regions: north and south of Point Conception. No finer-scale estimates of landings are available for this period. Catches were downloaded in numbers and weight. Catch in weight is sometimes missing from the database due to missing average weight estimates. We estimated average weights based on adjacent strata as needed, although the effect was minor (<2 mt over all years). MRFSS sampling was temporarily suspended from 1990-1992, and we used linear interpolation to fill the missing years. Sampling of CPFVs in Northern California was further delayed, and the linear interpolation spans the period 1990-1995 for this boat mode and region. An estimate for Southern California in 1997 was also missing and interpolated. Recreational fishing modes other than boat modes contributed approximately 1% of total recreational removals and were combined with the private boat data.

We stratified the resulting estimates of BDR landings and discard (catch types A+B1, in metric tons) by year, boat mode, and region (Table 8). Catch type A refers to estimates of catch based on sampler-examined catch. Catch type B1 includes mainly angler-reported discard, but also angler-reported retained fish that were unavailable to the sampler during the interview (e.g. filets).

California Recreational Fisheries Survey (CRFS), 2004-2016

MRFSS was replaced with the California Recreational Fisheries Survey (CRFS) beginning January 1, 2004. Among other improvements to MRFSS, CRFS provides higher sampling intensity, finer spatial resolution (6 districts vs. 2 regions), and onboard CPFV sampling. Estimates of catch from 2004-2014 were downloaded from the RecFIN database at the same time as the MRFSS data (August 16, 2016), while catch estimates for 2015 and 2016 were obtained from the newly restructured RecFIN website (downloaded April 30, 2017). We queried and aggregated CRFS data to match the structure of the MRFSS data, by year, mode, and region (Table 8).

Recreational Discard

Methods used to determine recreational discard mortality have changed significantly over time. Under MRFSS, catch estimates were stratified into sampler-examined retained catch (Type A), angler-reported dead discard and otherwise unavailable retained catch (Type B1), and angler-reported fish that were discarded live (Type B2). The reliability of angler-reported catch and disposition (live/dead) is unknown for this data set. Under CRFS, catch estimates since 2005 are adjusted to account for estimates of depth-dependent discard mortality. These methods have changed over time, as well, and following discussion with CDFW (J. Budrick, pers. comm.), it was agreed to approximate total recreational dead discard using a fixed percentage that could be varied to understand the sensitivity of the model to alternative levels of assumed total discard mortality.

Miller and Gotshall (1965, their Table 8) reported the number of "Blue Rockfish" discarded at sea in 1960 based on observer data from six ports between Bodega Bay and Avila, California. Of the 7070 Blue Rockfish caught, 483 (6.8%) were discarded. Ally et al. (1991, their Table 41) conducted onboard CPFV sampling in Southern California from 1985-1987, and reported variable annual discard rates (0.3% to 3.6%) with a catch-weighted average of 2.5%. These historical studies did not account for post-release mortality rates. Based on an analysis of CRFS data with estimates of retained catch [mt] and dead discard

[mt] over the period 2005 – 2016, we estimate discard using a constant 2% rate for the recreational boat modes (Table 9, Figure 9).

2.2.2 Recreational Length and Age Compositions

Recreational length composition samples for California were obtained from several sources, depending on the time period and boat mode. This assessment makes use of a much longer time series of length composition data, relative to the previous assessment, as described below. Input sample sizes for recreational length composition data were based on the number of observed trips, when available. Other proxies that were used to estimate the number of trips are described below.

CPFV length composition data, 1959-1972

The earliest available length data for this assessment were described by Karpov et al. (1995), who assembled a time series (1959-1972) of available California CPFV length data north of Point Conception (made available courtesy of W. Van Buskirk). Data from private boats were also reported, but for smaller groups of ports and over shorter time periods. A total of 45,773 unsexed measurements of retained fish (no discards) were included in the assessment (Table 7). Sampling of these length data did not follow consistent protocol over time and areas (data are unweighted), and therefore may not be representative of total catch. Since the number of trips sampled was not reported by Karpov et al. (1995), we assume the number of sampled trips is proportional to the number of measured fish in each year, and estimated the number of trips using the ratio of fish measured per trip in the MRFSS data (roughly 30 fish per trip). All lengths obtained in units of total length (TL) were converted to fork length (FL) using the equation FL = -2.164+0.962(TL) (Echeverria and Lenarz, 1984).

California Cooperative Groundfish Survey CPFV Sampling, 1978-1984

Commercial port samplers with the California Cooperative Groundfish Survey sampled landings from CPFVs operating north of Point Conception in the late 1970s and early 1980s. A total of 7,384 fish lengths and 909 trips were sampled over this time period (Table 7). This data set represents one of the few sources of sex-specific length information available for BDR in California. Key et al. (2008) prepared length frequency distributions from the raw length data, and their results are used without modification in this assessment.

The cooperative survey collected age composition data (by year and gender) from CPFVs in California, north of Point Conception (Table 10). These data were the only age information in the previous assessment (Key et al. 2008), and are the earliest age data (1980-1984) included in our base model. Outliers in the data were re-examined (D. Pearson, pers. comm.) on the basis of otolith size given the reported length (a small number of BDR with assigned ages of 6-7 years were recorded as having lengths equal to or greater than 40 cm. These are likely errors in sample data recording and were removed from the data set used in the California assessment.

MRFSS Recreational Length Data, 1980-1989 and 1993-2003

Unsexed length data of retained fish were collected by MRFSS dockside samplers and downloaded from the RecFIN website. As noted by Key et al. (2008), an analysis of length types revealed that some length measurements were converted from weights. We determined that some of the lengths excluded by Key et al. were valid conversions from total length, particularly lengths prior to 1993. We identified a subset of lengths that were converted from weight measurements, and these were excluded from the final data set. Using county and interview site information, we assigned MRFSS-era length data to CRFS Districts 1-6 (map: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=121237&inline) and plotted length distributions by CRFS district and mode for years 1980-2013 (Figure 10). Lengths north of Point Conception (roughly CRFS districts 3-6) showed slight differences between modes in some districts, but were otherwise similar. Districts 1 and 2 (Southern California) had much smaller mean lengths, but also smaller sample sizes, with District 2 lengths more similar to areas north of Point Conception. MRFSS sample sizes (numbers of measured fish and trips) by year and mode are in Table 7. For MRFSS length data (1980-2003) the number of CPFV trips was determined from the trip-level MRFS CPFV database (see section 2.2.3.1) and the number of private boat trips was determined based on unique combinations of the variables "ASSNID" ,"ID_CODE", "MODE_FX", "AREA_X", "DIST", "INTSITE", "HRSF", "CNTRBTRS", "SUB_REG", "WAVE", "YEAR", and "CNTY" in the Type 3 (sampler-examined catch) data.

CRFS Recreational Length Data, 2004-2016

Retained catch: Recreational length data (unsexed, retained fish) from the CRFS sampling program were obtained from CDFW (K. Hitchcock, pers. comm.). Sampling intensity increased under CRFS relative to MRFSS, and the number of trips observed for the private boat fleet increased by roughly an order of magnitude (Table 7). This led to the definition of a separate private boat fleet in the base model, as described in section 2.7.1.

Discarded catch: CRFS sampling includes length measurements of discarded fish collected by onboard observers on CPFVs. Samples of discard lengths are used to estimate average weight of discarded fish in the catch estimates, but the length composition data can also be used to inform stock assessments of the size composition of discarded catch. Monk et al. (2014) describe a relational database of onboard observer data for the years 1999-2011, but discarded fish lengths prior to 2003 were not considered due to small sample sizes. Length compositions of discarded fish from 2012-2016 were provided by CDFW (J. Rimpo, pers. comm.). A total of 9317 discarded fish lengths from 706 observed CPFV trips, 2003-2016, were used in the base model (Table 7).

Sampling effort for recreational fisheries is often allocated proportional to fishing effort. This was the case for all MRFSS data, and is the current basis for CRFS sampling of the CPFV fleet. The MRFSS survey stratified landings estimates into only two regions in California, one of which (Northern California) spans the area from Point Conception to the California-Oregon border. Therefore, it is not possible to develop landings estimates or catch-weighted length compositions at a finer spatial scale prior to 2004. However, since effort is likely correlated with catch, the MRFSS samples (both boat modes), and CRFS CPFV samples are an approximation of a catch-weighed sample. Private boat sampling under CRFS has a minimum target sampling rate of 20% of the available primary sampling units, i.e. days in each strata and time period.

2.2.3 Recreational Abundance Indices (Catch per Unit Effort)

Aside from those discussed in this document (e.g., PISCO, CCFRP), no large-scale fishery independent surveys currently sample nearshore, rocky reef habitat off California. Therefore, this assessment makes extensive use of time series of relative abundance derived from recreational fishery catch-per-unit-effort (CPUE). We developed four indices of relative abundance from recreational catch rate data, each of which spans either a different time period of the fishery or different components of the recreational fleet (CPFV vs. private boat).

2.2.3.1 MRFSS Dockside CPFV Index, 1980-1999

Trip-level catch-per-unit-effort data (“Type 3 data”) from MRFSS dockside sampling of CPFVs was downloaded from the NMFS SWFSC on 5/31/2017. These data are derived from fish sampled in angler bags following completion of a trip, aggregated to the trip level using an algorithm developed by Braden Soper (University of California, Santa Cruz). The methodology for aggregating the data to the trip level was reviewed and approved by the PFMC Scientific and Statistical Committee in March of 2013 (PFMC, 2013). The database contains information on catch by species (number of retained fish), effort (angler hours), sample location (county and interview site), date, and distance from shore (inside/outside of 3nm from shore).

MRFSS CPUE Index: Data Preparation, Filtering, and Sample Sizes

In order to define effective fishing effort (i.e. identify trips that were likely to catch BDR), we used the method of Stephens and MacCall (2004) to predict the probability of catching a BDR given the occurrence of other species in the catch. Since the species composition of catch in California varies greatly with latitude, we partitioned the data into areas north and south of Point Conception and applied the method separately to each data set.

For Northern California, the unfiltered data set contained 2923 trips. Species that are rarely encountered will provide little information about the likelihood of catching a BDR, so we identified 42 “indicator” species that were caught in at least 30 trips within the subset of Northern California data. One of these was “rockfish genus,” a catch-all category for rockfish that was excluded from the set of indicator species. Catch of these commonly-encountered species in a given trip was coded as presence/absence (1/0) and treated as a categorical variable in the Stephens-MacCall logistic regression analysis. Next, we flagged commonly-caught species that never co-occurred with BDR (“extreme counter-indicators”). For Northern California, albacore tuna was the only species in the data set that was caught in at least 30 trips that never co-occurred with BDR. This would produce an undefined ($-\infty$) coefficient, i.e. a predicted probability of exactly zero, in the logistic regression so we removed 40 trips that caught albacore tuna from the Northern California CPUE data set.

The Stephens-MacCall logistic regression was fit to the remaining set of 40 indicator species (Figure 11). The top five species with high probability of co-occurrence with BDR north of Point Conception include Olive, Kelp, Gopher, Yellowtail, and China Rockfishes, all of which are associated with rocky reef and kelp habitats in nearshore waters. The association with Kelp Rockfish, although ranked second in magnitude, was not significantly different from zero at the alpha = 0.05 level (two-tailed z-test, p = 0.076). The five species with the lowest probability of co-occurrence were Albacore Tuna (never co-occurred with BDR, as noted above), Chinook Salmon, Greenspotted Rockfish, Striped Bass, and Petrale Sole. These species are not commonly caught during the same trip as BDR, presumably due to different habitat associations and fishing techniques. The Area Under the Characteristic curve (AUC) for this model is 0.911, a significant improvement over a random classifier (AUC = 0.5). AUC represents the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence (Figure 12).

Stephens and MacCall proposed filtering (excluding) trips from the index standardization based on a criterion of balancing the number of false positives and false negatives. False positives (FP) are trips that are predicted to catch a BDR based on the species composition of the catch, but did not. False negatives (FN) are trips that were not predicted to catch a BDR, given the catch composition, but caught at least one. For the MRFSS Northern California data set, the threshold probability that balances FP and FN excludes 1216 trips that did not catch a BDR (42% of the trips), and 220 trips (7.6% of the data) that caught a BDR. We retained the latter set of trips (FN), assuming that catching a BDR indicates that a non-negligible fraction of the fishing effort occurred in habitat where BDR occur. Only “true negatives” (the 1216 trips that neither caught BDR, nor were predicted to catch them by the model) were excluded from the index standardization.

No MRFSS CPUE data are available for the years 1990-1992, due to a hiatus in sampling related to funding issues. Sampling of California CPFVs north of Point Conception was further delayed, and CPFV samples in 1993 and 1994 are limited to San Luis Obispo County. These years were removed from the index due to insufficient spatial coverage. Catch rates in 1997 and 1998 were anomalously high, as previously noted by Key et al. (2008), and the RecFIN data manager in 2007 recommended that those years be excluded from the index (W. VanBuskirk, pers. comm., cited in Key et al. 2008, p. 26). Although MRFSS CPUE data are available through 2003, years after 1999 were excluded from the index due to regulatory changes that may affect catch rates. In 2000, anglers targeting rockfish were limited to one line with three hooks, and the number of hooks per line was reduced to two in 2001 (Figure 4). Significant depth restrictions were introduced in 2001 (Figure 5), potentially changing catch rates relative to data from 1980-1999, when there were no gear or depth restrictions in place. The bag limit remained unchanged (15 fish) from 1980-1999. The previous assessment included MRFSS data after 1999, but broke the time series into two separate indices to account for regulatory changes. In this assessment, trends in abundance after 1999 are informed by an improved, onboard CPFV sampling program (Section 2.2.3.4) and dockside private boat index (Section 2.2.3.2). The final, filtered data set consisted of 1086 trips (Table 11).

The same data filtering approach was applied to data from Southern California, but the result of the Stephens-MacCall analysis excluded >90% of the data. For this reason, we did not develop a MRFSS CPUE index for the area south of Point Conception.

MRFSS CPUE Index: Model Selection, Fits, and Diagnostics

Data at the county level were sometimes sparse, so we assigned trips from adjacent counties to ‘subregions’ (Table 12). The proportion of positive trips varied by year and subregion, with 84% of all trips encountering a BDR (Table 13). Apart from differences in catch rate among subregion and year, we also considered changes associated with season (2-month “waves”) and a course measure of distance from shore (“Area_X” in the MRFSS data). This distance variable is a categorical variable indicating whether most of the fishing took place inside or outside 3 nautical miles from shore, as reported by anglers during each interview. Raw catch rate data suggested that trends in CPUE over time may vary by subregion (Figure 13), so we included a model with an interaction between year and subregion in the set of candidate models.

Based on the Akaike Information Criterion (AIC), we selected a model with an interaction between year and subregion as the best predictor of MRFSS catch rates (Table 14). The seasonal “wave” variable did not reduce the AIC score and therefore was not included in the index, but distance from shore (“Area_X”) was retained. Predicted means, by stratum, from the best-AIC model were consistent with the observed means (Figure 14). Residuals from a negative binomial (NB) regression are not expected to be normally distributed except under very specific conditions, so we simulated quantile residuals (Dunn and Smyth, 1996) using the R package “DHARMa” (Hartig 2017). A quantile-quantile plot of the simulated residuals suggests that the negative binomial distribution is a reasonable approximation of the data (Figure 15, left panel). The final standardization model does a good job at reproducing intermediate and high catch rates, but predictions associated with low catch rates are higher than the observed rates (Figure 16).

In order to construct the final index of abundance for the MRFSS catch-rate data, we needed to assign relative weights to the subregions in the model. Treating CPUE as proportional to density, we multiplied annual predicted CPUE in each subregion by the area in that subregion to obtain an estimate of relative abundance. Summing across subregions within each year produces an area-weighted (integrated) time series of relative abundance. R. Miller (NMFS SWFSC) provided area estimates of rocky reef habitat derived from 2-meter resolution bathymetric data available from the California Seafloor Mapping Program (CSMP; https://walrus.wr.usgs.gov/mapping/csmp/). Total reef area in each subregion was normalized to sum to one, with roughly 14% found off Mendocino and Sonoma Counties, 10% off of Monterey and Santa Cruz Counties, 50% off of counties near San Francisco County, and 26% in San Luis Obispo County.

To estimate uncertainty in the final index of abundance it is necessary to account for the correlation structure between parameters of the negative binomial regression, as well as the use of weights in the area-integrated index. We used the “rstanarm” package (Stan Development Team, 2016) in R to replicate the interaction model using diffuse prior distributions that replicated point estimates from the maximum likelihood fits. The advantage of this approach is that calculation of the index (summing relevant model parameters and applying area weights) can be applied to posterior draws, preserving the correlation structure and propagating uncertainty into the final index (Table 15, Figure 17). As an additional diagnostic, we generated replicate data sets from the posterior predictive distribution, and compared the distribution of the proportion of zeros in the replicate data sets to the observed proportion of zeros. The negative binomial model is able to reproduce the observed proportion of zeros in the data (Figure 18), similar to the delta-GLM approach (Lo et al., 1992; Stefánsson 1996) but requiring fewer parameters. Strata with all positive observations are easily handled by the NB model, whereas the binomial portion of a delta-GLM model will produce an undefined coefficient (estimate goes to infinity). In this index, several strata have all positive observations (Table 13), which would complicate the estimation of uncertainty using the delta-GLM approach.

2.2.3.2 CRFS Dockside Private Boat Index, 2004-2016

Catch and effort data from CRFS dockside sampling of private boats, 2004-2016, were provided by CDFW (K. Hitchcock, pers. comm.) for use in this assessment. The data include catch (number of fish) by species, number of anglers (i.e. effort units are angler trips), ‘Area_X’ (angler-reported distance from shore, inside/outside of 3nm), county, port, interview site, year, month, and CRFS district. We created a 2-month “wave” variable, and subregions (groups of counties) identical to the MRFSS dockside CPFV index (Table 12). We also created a subregion representing Del Norte and Humboldt counties, since this data set contains adequate samples to estimate trends in that area. The sample size of the unfiltered private boat CPUE data is much larger than the MRFSS CPFV data set, with over 109000 trips statewide, approximately 47000 in southern California (south of Point Conception), and 62000 north of Point Conception. Records were limited to “PR1” sites, and only the hook-and-line gear type.

Northern California CRFS Private Boat Index: Data Preparation, Filtering, and Sample Sizes

Since this is a dockside index lacking precise fishing location information, we again used the method of Stephens and MacCall (2004) to predict the probability of catching a BDR given the occurrence of other species in the catch. Similar to the MRFSS index, we partitioned the data into areas north and south of Point Conception and applied the method separately to each data set.

Beginning with unfiltered Northern California data (62178 trips), we identified 51 “indicator” species (other than BDR), defined as species caught in at least 100 trips. We increased the minimum number of trips for indicator species for the CRFS private boat index, relative to the MRFSS index, due to the large sample size. All trips that caught albacore or Pacific Bonito (958 trips) were removed from the data set, as these are likely mixed trips. Catch-all categories (“rockfish genus” and “sanddab genus”) were excluded from the set of indicator species.

The Stephens-MacCall logistic regression was fit to the remaining set of 47 indicator species (Figure 19). The top five species with high probability of co-occurrence with BDR north of Point Conception include Olive, Yellowtail, and Widow Rockfishes, Chub Mackerel, and Kelp Rockfish. The five species with the lowest probability of co-occurrence were striped bass, bat ray, Pacific Halibut, Leopard Shark, and White

Seabass. The Area Under the Characteristic curve (AUC) for this model is 0.756, a moderate improvement over a random classifier (AUC = 0.5). AUC represents the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence (Figure 20).

For the CRFS private boat data from Northern California, the threshold probability that balances FP and FN excludes 33495 trips that did not catch a BDR (54.7% of the remaining 61220 trips), and 8346 trips that caught a BDR (13.6% of the data). We retained the latter set of trips (FN), assuming that catching a BDR indicates that a non-negligible fraction of the fishing effort occurred in habitat where BDR occur (see sensitivity, below). Only "true negatives" (the 33495 trips that neither caught BDR, nor were predicted to catch them by the logistic regression model) were excluded from the index standardization.

Waves 1 and 2 (months January through April) were not sampled in most years (2005-2013), and were dropped from the analysis. The "Area_X" variable (angler reported distance from shore; inside/outside 3nm) had no samples in the "outside 3 nm" category (Area_X = 2) from 2004-2011, so trips with Area_X=2 were excluded from the index standardization. The final, filtered data set consisted of 26981 private boat trips (Table 16).

Northern California CRFS Private Boat Index: Model Selection, Fits, and Diagnostics

Similar to the MRFSS CPFV index, CRFS private boat data at the county level were combined into 'subregions' (Table 17). The proportion of positive trips varied by year and subregion, with 70% of all trips encountering a BDR (Table 18). Apart from differences in catch rate among subregion and year, we also considered changes associated with season (2-month "waves"). Raw catch rate data suggested that trends in CPUE over time were generally consistent, but varied slightly by subregion in early years (Figure 21), so we included a model with an interaction between year and subregion in the set of candidate models.

Based on the Akaike Information Criterion, we selected a model with an interaction between year and subregion as the best predictor of MRFSS catch rates (Table 19). Predicted means, by stratum, from the best-AIC model were consistent with the observed means (Figure 22). A quantile-quantile plot of the simulated residuals suggests that the negative binomial distribution is a reasonable approximation of the data (Figure 23, left panel). There was no evidence of strong residual patterns when plotted against the link-scale fitted values (Figure 24).

Treating CPUE as proportional to density, we multiplied annual predicted CPUE in each subregion by the area in that subregion to obtain an estimate of relative abundance (Table 20). Summing across subregions within each year produces an area-weighted (integrated) time series of relative abundance. To estimate uncertainty in the final index of abundance, we used the "rstanarm" package (Stan Development Team, 2016) in R to replicate the interaction model using diffuse prior distributions that replicated point estimates from the maximum likelihood fits (Figure 25). We again generated replicate data sets from the posterior predictive distribution, and compared the distribution of the proportion of zeros in the replicate data sets to the observed proportion of zeros. The negative binomial model is able to reproduce the observed proportion of zeros in the data (Figure 26).

As a sensitivity analysis of the Northern California CRFS private boat index, we removed the false negative observations (trips that caught BDR, but were not predicted to), and estimated the index with equal area weights (i.e. set all area weights = 1, but retaining the year-area interaction term). There is a shift in CPUE associated with removing the positive observations, but the trend in the index is almost identical regardless of area weights due to the similar trends in each subregion (Figure 27).

Southern California CRFS Private Boat Index

Of the 46958 private boat trips sampled in Southern California between 2004 and 2016, more than 78% occurred in San Diego, Orange, and Los Angeles counties. Only 109 (0.3%) of those trips caught a BDR. The remaining trips that were sampled in Ventura and Santa Barbara counties caught at least one BDR in 1130 out of 10125 trips (11% of unfiltered trips). Give this difference in the proportion of positive sampled trips, we developed a CRFS private boat index for Ventura and Santa Barbara counties.

Following the methods described above for Northern California, we identified indicator species and fit Stephens-MacCall logistic regression (Figure 28, Figure 29). We dropped trips that caught Yellowtail Amberjack and Pacific bonito, and excluded the “rockfish genus” and “sanddab genus” categories from the list of indicator species. We excluded Wave 1 (Jan-Feb; only 4 sampled trips), and trips fishing farther than 3 nm from shore (Area_X=2; no samples from 2004-2011). Final sample size in the filtered data set was 1669 trips (Table 21), with the majority of samples coming from Ventura County (Table 22) and 63% of all trips in the filtered data set catching at least one BDR (Table 23).

We examined models with year, county, wave, and distance from shore (“Area_X”) effects. Mean CPAH had a similar overall trend in both Santa Barbara and Ventura counties (Figure 30), but a model with a year-county interaction term had the best fit to the data (Table 24). Although the year-area interaction model had the best fit according to AIC, we selected a model with only additive year effects because 1) trends in both counties are very similar, and 2) habitat data for Southern California is incomplete at the time of writing. Residual diagnostics for the main effects model are show consistency with the NB distribution based on quantile-quantile plots, but indicate some lack of fit, particularly in the tails of the distribution of predicted values (Figure 31, Figure 32). Similar to the Northern California index, the Southern index shows a declining trend until 2012-13, with an increasing trend after 2013, although the rate of increase appears to be higher in the Southern index (Table 25, Figure 33; also compare Figure 27 and Figure 25). The main effects NB model suggests that roughly 36-44% trips do not catch BDR based on simulated data from the posterior predictive distribution, compared to an observed 37% (Figure 34).

2.2.3.3 Central California Onboard CPFV Observer Index, 1988-1998

In addition to the two dockside indices (MRFSS CPFV and CRFS private boat) described above, this assessment makes use of two indices derived from onboard CPFV observer data and collected during different time periods of the fishery. The primary advantage of onboard observer data is that catch and effort data are based on individual fishing stops (or “drifts”), rather than aggregated at the trip level, and information about actual fishing locations is available, rather than port of landing or interview site. This location information, when combined with recent maps of rocky reef habitat, allows us to associate catch rates with reefs of known area and produce habitat area-weighted CPUE indices.

The CDFW (formerly CDFG) Central California Marine Sport Fish Project sampled the Northern and Central California CPFV fleet using onboard observers from 1987-1998. Observers recorded the total catch (kept and released fish) of a subset of anglers during each fishing drift. Catches from drifts occurring at a single CDFW fishing site were aggregated into a “fishing stop.” Each stop in the database is associated with the closest reef structure. Retained fish were measured at the end of the fishing day. Additional details about the survey design, data collected, spatial associations between fishing stops and reef habitat, and the structure of the relational database are described by Monk et al. (2016).

Central CA Onboard CPFV Index: Data Preparation, Filtering, and Sample Sizes

Catch and effort data by fishing stop (7192 records) were downloaded on 5/17/2017 from the SWFSC relational database. Catch is number of Blue/Deacon Rockfish caught at a fishing stop, but only retained fish were included in this index because associated length compositions were derived from retained catch at the end of the day. Effort is in units of angler-hours, based on the subset of observed anglers at each fishing stop. Blue/Deacon rockfish were caught at 54% of stops in the unfiltered data set.

As noted by Monk et al. (2016), samples in 1987 were only collected in Santa Cruz and Monterey counties, so we excluded 1987 from the index. The relational database contains information on over 100 individual reefs, and catch is associated with the nearest reef structure. The data are too sparse at the level of individual reefs to estimated changes in catch rate over time, so we aggregated reefs into 8 “mega reefs” from Point Conception (34° 27′ N. latitude) to the California/Oregon border (42° N. latitude). Mega-reefs 1-7 are numbered from south to north, and mega-reef 8 represents offshore reefs (Figure 35). The number of samples by year and mega-reef varies (Table 26), and only 22 samples were taken north of Cape Mendocino (mega reef 7). For this reason, the area north of Cape Mendocino was excluded from the index. We further aggregated mega reefs 1 and 2 into a single category, and mega reefs 5 and 6 into another, ending with 5 spatial regions over the time period 1988-1998 (Table 27). The proportion fishing stops that encountered a Blue/Deacon Rockfish (“proportion positive”) was 59% overall, but varied by year and area (Table 28).

Only 7 fishing stops (out of 7192) caught Blue/Deacon Rockfish in depths greater than 110 meters (360 feet, or 60 fathoms), and three stops had unusually high catch rates of >50 fish per angler hour (Figure 36). We excluded these stops from the index standardization model. Depths fished varied over time and region (Figure 37), so we created a categorical variable with depths binned into 15-fathom increments to account for the effect of depth on catch rates. Months were binned into 2-month “waves” to evaluate seasonal patterns in catch rate. Trends in average catch-per-angler-hour (CPAH) vary by reef area (Figure 38), so we included a model with a year-area interaction in the set of candidate models.

Central CA Onboard CPFV Index: Model Selection, Fits, and Diagnostics

We fit catch of BDR (number of fish) at each fishing stop using a negative binomial (NB) regression with effort (angler hours) as an offset and a log link function. Model-selection based on AIC supported the following covariates: year, reef area, depth (15 fathom bins), wave (2-month interval), and the interaction between year and reef area (64 parameters; Table 29). Predicted means, by stratum, from the best-AIC model were not able to reproduce the highest observed means, although the majority of those strata contained fewer than 10 observations (Figure 39).Quantile-quantile plots of the simulated residuals indicate that while expected quantiles from the NB model are consistent with the observed (Figure 40, left panel), a residual pattern relative to fitted values suggests either a missing covariate or other form of model misspecification (Figure 40, right panel; Figure 41).

Similar to the methods used for the MRFSS index (Section 2.2.3.1), we constructed an area-weighted index from the year-area interaction model using posterior draws from an identically structured Bayesian model with diffuse priors (Table 30, Figure 42). Area weights were calculated as the sum of individual reef areas based on 2-meter resolution CSMP bathymetry data within each “mega reef” (Figure 43). The NB model generated data sets with roughly 34-38% zeros, compared to the observed 41% (Figure 44). Although not a formal comparison, we plotted the trend of the negative binomial model against a delta-GLM model (Figure 45). The delta model treats region as a main effect, and therefore does not use area weights or account for spatial differences in catch rate trends. However, the two models produce qualitatively similar time series, both highly variable with an increasing trend in later years.

2.2.3.4 CDFW Onboard CPFV Observer Index, 2001-2016

We queried a database of California onboard CPFV observer data, spanning the years 1999-2016 (Monk et al. 2014). Each observation included a unique trip and drift identifier, and a subset of anglers was observed at each drift. Drift-level information included catch of Blue Rockfish in numbers (kept and discarded) including zeros, number of observed anglers, time fished (in minutes), location where drift began (latitude and longitude), year, month, county, CRFS district, depth (in feet), distance from nearest reef habitat (in meters), and unique reef identifier.

Initial sample size (number of drifts) was 21897, with 44.4% of drifts catching at least one BDR. 74% of drifts were over a reef (i.e. distance to reef variable = 0), and 50% of those caught at least one Blue Rockfish. Using logistic regression, we modeled the probability of catching at least one Blue Rockfish on a drift as a function of distance to the nearest reef (Figure 46). Based on this, we removed all drifts farther than 1km from reef, excluding 1061 observations, only 36 of which caught a BDR. Data from 1999-2000 were excluded due to changes in regulations (a reduction in the rockfish bag limit and number of hooks per line). Catch rates also vary by depth (Figure 47), so we excluded drifts deeper than 45 fathoms and shallower than 2 fathoms. Additional filters included removal of trips that caught <50% groundfish, drifts lasting less than 3 minutes or greater than 100 minutes, and drifts sampled from January to April due to poor sampling coverage (Table 31). To ensure complete spatial and temporal coverage in the final data set, we aggregated reef areas 1-2, as well as 5-7 (Table 32). The proportion of drifts that caught at least one BDR was 48.1% of all drifts, but varied by year and region (Table 33). Trends among regions were fairly consistent, showing a peak in catch rates in the early 2000s, followed by a decline and slow recovery (Figure 48).

We fit catch of BDR (number of fish) at each drift using a negative binomial (NB) regression with effort (angler hours) as an offset and a log link function. Model-selection based on AIC supported the following covariates: year, reef, depth (2-20 fm, 20-30 fm, and 30-45 fm bins), wave (2-month interval), and the interaction between year and reef area (86 parameters; Table 34). Predicted means, by stratum, from the best-AIC model were not able to reproduce the highest observed means, although the majority of those strata contained fewer than 10 observations (Figure 49).Quantile-quantile plots of the simulated residuals indicate that expected quantiles from the NB model are consistent with the observed (Figure 50, left panel) and no strong residual patterns are apparent relative to fitted values (Figure 51).

Similar to the methods used for the MRFSS index (Section 2.2.3.1), we constructed an area-weighted index from the year-area interaction model using posterior draws from an identically structured Bayesian model with diffuse priors (Figure 52, Table 35). This trend is similar to that observed in the CRFS private boat index for the years 2004-2016 (Figure 25). Reef area weights were derived from GIS layers (Figure 35). The NB model generated data sets with roughly 48-51% zeros, compared to the observed 52% (Figure 53).

2.3 Fishery-Independent Data

2.3.1 NMFS SWFSC Pelagic Juvenile Rockfish Index

The Fishery Ecology Division of the Southwest Fishery Science Center has conducted a standardized pelagic juvenile trawl survey during May-June every year since 1983 (Ralston et al. 2013; Sakuma et al. 2016; Field et al. 2017). A primary purpose of the survey is to estimate the abundance of pelagic juvenile rockfishes (*Sebastes* spp.) and to develop indices of year-class strength for use in groundfish stock assessments on the U. S. West Coast. This is possible because the survey samples young-of-the-year rockfish when they are ~100 days old, an ontogenetic stage that occurs after year-class strength is established, but well before cohorts recruit to commercial and recreational fisheries. This survey has encountered tremendous interannual variability in the abundance of the ten species that are routinely indexed, as well as high apparent synchrony in abundance among the ten most frequently encountered species. Past assessments have used this survey as an index of year-class strength, including assessments for Blue Rockfish (Key et al. 2008), Widow Rockfish (He et al. 2005), Pacific Hake (Helser et al. 2006), Shortbelly Rockfish (Field et al. 2007) and Chilipepper Rockfish (Field 2008).

Historically, the survey was conducted between 36°30' and 38°20' N latitude (approximately Carmel to just north of Point Reyes, CA), but starting in 2004 the spatial coverage expanded to cover from Cape Mendocino in the north to the U.S./Mexico border. Additionally, since 2001 juvenile rockfish data are available from a comparable survey conducted by the Pacific Whiting Conservation Cooperative and the Northwest Fisheries Science Center (spanning from just south of Monterey Bay to Westport, WA; see Sakuma et al. 2006). Comparison of the coastwide data have revealed two types of shifts in the distribution of most pelagic species, in which species characterized by a more southerly geographic range (e.g., Bocaccio, Shortbelly, and Squarespot Rockfish) were caught in relatively large numbers south of Point Conception, while species with more northerly distributions (widow, canary, and yellowtail rockfish) were caught in moderate numbers north of Cape Mendocino. Thus the near absence of fish in the core survey area during the 2005-2007 period, which saw two of the lowest abundance levels of juvenile rockfish ever observed in the core area time series, was associated with an apparent redistribution of fish, both to the north and the south (Ralston and Stewart, 2013). The survey index is calculated after the raw catch data are adjusted to a common age of 100 days to account for interannual differences in age structure. As the core area index seems to have failed to capture the magnitude of the 1999 year class for most stocks, the recommendations from the juvenile rockfish survey workshop held in 2005 were to exclude the core juvenile indices unless a convincing case could be made otherwise.

Index model structure

Catch of a particular species is a function of latitude, year, depth, period, and vessel. Due to the zero-inflated, and non-negative, nature of catch observations among these strata (Table 36), catch was modeled using the Δ-GLM modeling approach (Lo et al. 1992; Stefánsson 1996). The positive observation model was best modeled via a log-normal GLMM and the presence/absence model was modeled as a mixed effects logistic regression. In both models, latitude (in 2 degree bins), year, depth, period, and vessel were used as categorical predictors of catch, however the structure of the random effects in each of the positive and presence/absence models differ slightly. In the positive model, depth and period are treated as fixed effects, while vessel is treated as a random effect in which the variance between vessels is estimated from the data. Furthermore, latitude and year are included in the positive model via year:latitude interaction terms which are treated as random effects to estimate a single variance among all of the year:latitude parameters. In the presence/absence model, depth and period are again treated as fixed effects. Again vessel is treated as a random effect in which the variance between vessels is estimated from the data. Finally, latitude and year are included in the presence/absence model via year:latitude interactions, however in the presence/absence model these year:latitude interactions are treated as fixed effects due to drastically different behavior in stratum containing only zeros. These models were formulated as weakly informative Bayesian hierarchical model, and fit using the R package rstanarm (Stan Development Team, 2016).

To produce an index of abundance which summarizes the aggregate spatial behavior in each year, we consider only the year:latitude interaction terms from each of the Δ-GLM models. Vessel, depth, and period effects are included in these models only as control variables. From the presence/absence model we are interested in the inverse logit of the year:latitude interaction terms to estimate the proportion of non-zero catch in each stratum, p_{jk}. From the positive model we transform the Log-Normal scale year:latitude interaction terms (μ_{jk}) to the arithmetic scale (m_{jk}) via the transformation, $m = e^{\mu+\frac{\sigma^2}{2}}$(Mood et. al., 1974). Thus the Δ-GLM yearly index amounts to aggregating across space, by summing the product of $p_{jk}$and m_{jk}across latitude in each year, $\sum^k p_{jk}\, m_{jk}$.

The area-integrated pelagic juvenile index for BDR suggests a strong year class in 2013 (Table 37, Figure 54). Two years (2006 and 2012) with CVs greater than 100% were replaced with values equal to one-half the minimum observed value, and CVs equal to the maximum CV.

2.3.2 CalCOFI Larval Abundance Index

Larval (ichthyoplankton) abundance of numerous fish species data have been routinely collected from California Cooperative Oceanic and Fisheries Investigations (CalCOFI) surveys since the early 1950s (details in McClatchie 2014). Ichthyoplankton data from this program have been used to support assessments and life history studies of coastal pelagic species (e.g., Jacobson and Lo 1994, Hill et al. 2007), as well several groundfish assessments of southern rockfish species (He et al. 2015, Dick and MacCall 2014). The use of these data to support rockfish assessments has historically been limited to those few species for which larvae are identifiable using morphometric methods, such as Bocaccio, Cowcod, Shortbelly and Chilipepper (Moser et al. 1977, Moser et al. 2000). However, in recent years the methods have been developed to use molecular methods to identify larvae to the species level from more recent (1998-2013) ichthyoplankton collections for which samples were also archived in ethanol (versus formalin used for historical collections; Taylor et al. 2004, Thompson et al. 2015). Although the results of an analysis of 16 years of such data demonstrate that the rockfish ichthyoplankton assemblage in this region is dominated by small and short-lived *Sebastes* species, such as Shortbelly, Squarespot (*S. hopkinsi*) and Pygmy (*S. wilsoni*) Rockfish, there are also catches for a number of stocks of commercial and recreational importance, such as Blue (*S. mystinus*), Bank (*S. rufus*), Speckled (*S. ovaliis*) and Widow (*S. entomelas*) Rockfish.

Data from the Thompson et al. (2016) analysis for the period 1998-2013 were made available for this assessment, for which Table 38 provides the number of tows by year, the number of positive tows for Blue Rockfish, and total number of larvae collected. Preservation problems in 2003 led to no data being available for that year. Figure 55 shows the stations for which data were available, and the percentage of those stations that had positive observations over the duration of the time period. Catch rates tended to be highest in the northern part of the Southern California Bight (and just north of Point Conception) and closest to the shorelines of the northern mainland and the Northern Channel Islands. The number of positive observations was very low in the early part of the time period and increased over time, a pattern consistent with other trends in an ongoing analysis of the comprehensive results for all of the species (Thompson, unpublished data), as well as with other indices used in this assessment. The index was modeled consistent with the approach from past assessments, in which catch data are standardized to the volume of water sampled, and we use tow specific information and a delta-GLM approach (with a log-normal distribution for the positive observations) to derive an index of spawning output (such that selectivity is based on model fecundity). Fixed effects in the model included year and line-station effects, as all samples were taken during the winter (January-February) surveys there was no need for a month or season effect. A jackknife routine to estimate an index coefficient of variation; as the minimum number of positive observations necessary to run this routine is two for any given year, years with less than two positive observations were excluded, leading to only ten of the 16 years of observations having an index value in the resulting index (Figure 56, Table 39).

2.3.3 Abrams Thesis

Jeff Abrams (2014) conducted a research study aboard recreational charter boats from Crescent City Harbor, Trinidad Bay and the Noyo River Harbor. Rocky habitat was identified from high resolution bathymetric data and gridded into 500 m by 500 m cells (California Seafloor Mapping Project, data available from: http://seafloor.otterlabs.org/index.html). During a sampling event, cells were randomly selected to fish. Fish were captured via hook-and-line by researchers, students, or recreational fishers. The charter boat captain was not allowed to search and target fish within the cell. Fishing drifts started at the upcurrent/wind side of the cell and drifted to the opposite edge of the cell, then stopped the clock and reset for another drift (Jeff Abrams, pers. comm.) If it was certain that fishing was occurring over sand, the captain would generally reset. However, because cells were selected with a minimum area of rocky habitat, this was rare. This study provided 408 otoliths collected in 2010-2011 that were used as Conditional Age-at-Length (CAAL) data in the California model (Table 10).

2.3.4 Schmidt Thesis

Katherine Schmidt (2014) examined differences in life history characteristics (growth, maturity, and fecundity) between BDR caught historically (1960s and 1980s) and in recent years (2010-2012), as well as between Blue (“Type 2”) and Deacon (“Type 1” or “Northern Blue”) Rockfishes caught between 2010-2012. The majority of samples were caught with hook and line gear consistent with that used by recreational fleets, plus a small number of fish taken by spear fishermen. A total of 776 BDR samples were collected, 81% of which were female. Only 10 samples were collected in 2012 and these were excluded due to small sample size. Samples were obtained from three California ports: Half Moon Bay (36%), Monterey (44%), and Morro Bay (19%). Females were sampled at a minimum target rate of 10 fish per 10 mm size bin from 150-350 mm total length. Males were sampled opportunistically due to being underrepresented in the catch. A total of 758 age estimates were obtained from otoliths collected in 2010-2011 and used as CAAL data in the California model (Table 10).

Similar to Hannah et al. (2015), Schmidt found that Deacon Rockfish mature at larger sizes than Blue Rockfish. Schmidt also found no difference between species in fecundity at length based on analysis of covariance of log-transformed fecundity-length data for 106 Blue and 53 Deacon Rockfishes.

2.4 Biological Data

2.4.1 Natural Mortality

Key et al. (2008) estimated the natural mortality rate (*M*) for Blue Rockfish using the method of Hoenig (1983) based on maximum ages of 41 years for females and 44 years for males (Laidig et al. 2003). The 2007 assessment was unable to estimate natural mortality from the data, and the final base model fixed female *M* at 0.10 and male *M* at 0.12. Prior to the 2007 assessment, Tenera (2000) had reported an estimate of 0.14 yr^{-1}.

Hamel (2015) developed a method for combining meta-analytic approaches to relating the natural mortality rate *M* to other life-history parameters such as longevity, size, growth rate and reproductive effort, to provide a prior on *M*. In that same issue of ICESJMS, Then et al. (2015), provided an updated data set of estimates of *M* and related life history parameters across a large number of fish species, from which to develop an *M* estimator for fish species in general. They concluded by recommending *M* estimates be based on maximum age (A_{max}) alone, based on an updated Hoenig non-linear least squares (nls) estimator $M = 4.899A_{max}^{-0.916}$. 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_{max}, Then et al. did not consistently apply their transformation. In particular, in real space, one would expect substantial heteroscedasticity in both the observation and process error associated with the observed relationship of M to A_{max}. Therefore, it would be reasonable to fit all models under a log transformation. This was not done.

Revaluating the data used in Then et al. (2015) by fitting the one-parameter A_{max} model under a log-log transformation (such that the slope is forced to be -1 in the transformed space (as in Hamel 2015)), the point estimate for M is:

$$M = 5.4/A_{max}$$

The above is also the median of the prior. The prior is defined as a lognormal with mean ln ($5.4/A_{max}$) and SE = 0.4384343. Using a female maximum age of 41 the point estimate and median of the prior is 0.1317 (with a log-space value of -2.02717). Natural mortality of males was modeled as an exponential offset with no prior.

2.4.2 Growth

Numerous studies evaluated growth of BDR prior to the description of Deacon Rockfish as a separate species, using alternative structures (e.g. scales) and methodologies (surface ages vs. break and burn). See Laidig et al. (2003) for a review. For this assessment, age and length data for all species, sex, and regional comparisons were initially fit external to the population dynamics model using the von Bertalanffy growth equation (von Bertalanffy 1957),

$$L_t = L_\infty (1-e^{-k(t-t_0)});$$

where L_t = fork length (mm) of fish at a given age t (years), L_∞ = theoretical average maximum length (mm), k = growth constant (per year), and t_0 = theoretical age at size zero. The parameters L_∞, k, and t_0 were estimated using the nonlinear least squares function in R (R Core Team 2016). Schnute's (1981) parameterization of each model was computed for comparison with von Bertalanffy results. Akaike's Information Criterion was used to evaluate the relative fit of different regression models (Akaike 1974).

Four separate comparisons were made to assess potential sources of variability in age and growth parameters. Data for California were limited to the set of high-confidence genetic IDs to minimize misidentification of species. Data for Oregon were visually assigned to species, a reasonable approximation given the large sample sizes from Oregon and a high concordance between genetic and visual IDs (see Appendix A). The initial baseline analysis pooled species (Blue Rockfish, Deacon Rockfish) and regions (Oregon, California) and compared only sexes (Female, Male). Subsequent analyses added categorical covariates for species (Blue/Deacon) and then region (California/Oregon) to the original model. Finally, to assess spatial differences in age and growth of female Blue Rockfish collected north and south of Point Conception in recent years, we evaluated data from Schmidt (2014) and the NWFSC Hook and Line Survey (see Harms et al. 2008 for a description of survey methods), respectively.

Growth parameters of BDR (species and regions combined) differed substantially by sex, with females reaching larger sizes and exhibiting slower growth rates (Table 40, Figure 57). Female and male length-at-age was similar until ages 4-5, after which females were estimated to be substantially larger at the same age. Predicted maximum length for the model that pooled data across species and regions was 37.5 cm FL for females and 30.1 cm FL for males.

Growth rates differed only slightly when sexes were further subdivided by species, however this is likely due to the large sample sizes in Oregon relative to California. This model suggests that Deacon females grow to slightly larger sizes at faster growth rates than Blue females (Table 40, Figure 58). Predicted maximum FL and growth rates of Blue and Deacon rockfish males were nearly identical. Model selection using AIC supported the sex-only model (AIC = 23,455.3) over the species-sex model (AIC = 23,579.5).

The best fit model for the full age and length data set included species, sex, and region (AIC = 22,036.3; $\Delta AIC_{sex\text{-}only}$ = 419; $\Delta AIC_{species\text{-}sex}$ = 543). California males of both species grew slower and reached larger maximum sizes than their counterparts from Oregon (Table 40, Figure 59). Oregon males of both species had extremely similar growth parameters. Oregon females of both species also had very similar estimated growth rates and maximum fork lengths, which were slower and larger than those of Oregon males, respectively. In California waters, both sexes of Deacon rockfish grew to larger sizes at slower rates than comparable sexes of Blue rockfish (Table 40, Figure 59).

The most striking difference between regions (states) is the similarity of growth between species in Oregon, relative to California. Unlike Oregon, the State of California currently does not regularly collect otoliths as a part of its CRFS sampling program. Although this assessment includes substantially more age information than the previous model (Key et al. 2008), age data are limited to three temporally and spatially disconnected data sets. California age data used in this assessment, while the best available, are based on an opportunistic sample and may be subject to biases associated with differences in sampling method, location, and/or time. As noted in the STAR panel report from the last assessment, the STAT highly recommends that collection of otoliths from California's recreational fisheries begin on a regular basis, with adequate spatial coverage, to improve the quality of assessments for species important to recreational fisheries, such as Blue and Deacon Rockfishes.

Although Laidig et al. (2003) found no difference in BDR length at age between central and northern California (all north of Point Conception), our data suggest that Blue Rockfish females north of Point Conception grew slower and reached larger maximum sizes than Blue Rockfish females south of Point Conception (Table 40, Figure 60); however, the more parsimonious model combined fish from both regions and had an AIC value 60 points lower than the model with region as a covariate. The combined region model was heavily influenced by the more abundant northern California data set, and the growth parameter estimates of the combined and northern California models were nearly the same (Table 40). In addition, age and growth data only were available from one source in each region; therefore, any biases inherent to processing and ageing techniques may also have influenced results.

Analysis of ageing error

Otoliths for California were read by Don Pearson (NMFS, SWFSC, Fisheries Ecology Division). To evaluate within-reader ageing error, 587 otoliths were aged twice (blind reads), with 63% agreement to the year and 86% agreement to within 1 year (Figure 61, Figure 62). Among-reader error was evaluated based on a sample of 257 otoliths, with independent reads by D. Pearson and L. Kautzi (ODFW). There is some evidence of relative bias between readers (Figure 63), although the range and distribution of ages were similar (Figure 64).

Length-weight relationships in the California base model are identical to those used by Key et al. (2008), and based on gender-specific equations published by Lea et al. (1999).

2.4.3 Maturity and Fecundity

Using the results of Key et al. (2008), we model the proportion of mature BDR females as a function of length based on the analysis of Wyllie Echeverria (1987). Wyllie Echeverria found that 50% of "Blue

Rockfish" (now know to be BDR) mature at 29cm TL (26cm FL) and 6 years old, and 100% were mature at 35cm TL (32cm FL) and 11 years old.

This assessment makes the assumption that fecundity is a power function of female body length, $F = aL^b$. Values for b (4.816) and a ($1.14e^{-08}$) were taken from Dick et al. (2017). Since the exponent of the fecundity-length relationship is greater than the exponent of the fecundity-weight relationship, weight-specific fecundity (eggs or larvae per gram female body weight) also increases with size.

2.5 Data sources evaluated, but not used in the California assessment

2.5.1 Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)

Data from subtidal SCUBA surveys along most of the California Coastline were obtained from the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO). PISCO is a long-term ecosystem research and monitoring program, for which subtidal SCUBA surveys have been conducted in summer and fall from 1999 through 2015 (ongoing, data currently only available through 2015) for a large number of sites along the California Coastline. At designated sampling locations, biologist conduct SCUBA surveys in bottom, midwater and kelp canopy habitats, enumerating the abundance and size of over 100 species of fish and invertebrates. At each location, divers sample a range of depth zones (typically 5, 10, 15 and 20m), across a range of cells and as possible, conduct several transects. Transects are typically two meters wide by two meters tall, by 30 meters long (each transect takes approximately 6-10 minutes, several may be conducted per dive). Additional details can be found at the PISCO website (www.piscoweb.org) and in published manuscripts describing PISCO results (Hamilton et al. 2010, Johnson 2006).

Young-of-the-year (YOY) as well as juvenile and adult Blue Rockfish are among the most frequently occurring species in this survey; with individuals ranging from 4 to 50 cm in length; YOY ranging in size from approximately 4-10 cm are the most frequently occurring size class. We focused on selected locations that had been sampled each year for at least 10 of the 17 years between 1999 and 2015 (see Table 41 and Table 42 for summary of data by site and year). On exploration of the length composition data and index of abundance of all sizes, we determined that due to relatively shallow depths of the surveys and noisy length composition data, an index of YOY alone (by region) would be the most appropriate way to evaluate these data in the model. Year, location, depth zone and dive type were treated as categorical variables in a delta-GLM, and all were found to be significant factors based on AIC. Index CVs were estimated with a jackknife routine. The final PISCO index for Northern California (Table 43, Figure 65) suggested a minor peak in 2002 followed by several years of poor recruitment, 2005-2012. A large spike in recruitment was observed in 2013, followed by the second-largest estimate in the time series in 2014 (similar magnitude to 2002).

The PISCO dive survey was excluded from the final base model because the model was unable to match the degree of variability in recruitment in the survey. The estimated additive (log-scale) standard deviation parameter (i.e. variance added to the input variances) for this index was greater than 1, indicating that the index was not consistent with structural assumptions of the model and/or other data sources.

The Tenera dive survey (section 2.5.2) also observed a spike in BDR YOY abundance in 2013, causing the model to estimate a large additive variance parameter. Given the consistency between juvenile indices regarding the strength of the 2013 year class (see also the SWFSC juvenile index), we conclude that the model structure does not adequately capture the processes observed by the dive surveys, and future research is recommended regarding incorporation of subtidal dive surveys into stock assessments.

2.5.2 Tenera Dive Surveys

Survey Methodology

Tenera Environmental Group has conducted subtidal monitoring of nearshore fishes near the Diablo Canyon Nuclear Power Plant (near Avila Beach in San Luis Obispo County, California) under contract from Pacific Gas and Electric since 1976. Benthic and midwater surveys are conducted four times per year at locations impacted by the power plant thermal discharge (North Diablo Cove and South Diablo Cove), and locations with very little (Field's Cove), or no influence from the discharge (Patton's Cove). There are three sampling sites with benthic and midwater transects at each location. Each sampling site consists of a benthic transect 50m long by 4m wide by 1m above the bottom, and a 50m long by 4m diameter midwater transect located above and parallel to the benthic transect. Each survey is conducted by a pair of SCUBA divers, who swim the 50m transects in opposite directions while recording the length, maturity stage, and species of all fish encountered. The "counts" reported for each transect are the average of the counts recorded by each diver. Size information could not be released for external use due to data quality-control concerns.

Through 1992, divers distinguished between two maturity stages: "juvenile" and "adult". Maturity was largely determined by size, with the dividing line around 18-20cm. Starting in 1993, divers began distinguishing between YOY and juvenile rockfish, with the dividing line around 9cm.

Data Preparation Prior to Analysis

Given the change in maturity identification in 1993, it wasn't possible to utilize the full time series in a YOY-only index. Rather than only using the data from 1993 on (which would truncate the data series by 17 years), a new factor (YOYJuvCount) was created that was equal to the juvenile counts through 1992 and equal to the sum of the YOY and juvenile counts from 1993 on. In addition, since the "counts" are actually averages, not all values are integers. Using the round function in R (which rounds to the nearest even digit) produced a new factor (YOYJuvCount_Int) in which all values are integers, allowing use of a negative binomial GLM model.

The number of observed transects varied by year and period (Table 44). Further analysis revealed that for 7 settlement years (1983, 1994, 1995, 1996, 1997, 2006, and 2007) no YOY/juvenile Blue Rockfish were encountered (i.e. for all surveys YOYJuvCount_Int = 0). To improve model fit, those years were removed from subsequent analysis.

Two temporal factors were created: SetYear and SetPer. SetYear defines the Settlement Year during which the count occurred. Each SetYear runs from March of the calendar year during which the survey was conducted through February of the following calendar year (e.g. the 2016 Settlement Year would include transects from March 2016 to February 2017). SetPer divides each SetYear into two periods, "early" (March - August) and "late" (Sept - Feb).

Model Selection

Due to the large number of zeros in the data, we modeled fish per transect (rounded means) using maximum likelihood and Bayesian negative binomial regression. Models incorporating temporal (SetYear, SetPer) and geographic (LocType, LocSite) factors were evaluated, along with relevant interaction terms. Based on AIC values from maximum likelihood fits (Table 2), four models were selected for additional exploration using the "rstanarm" R package (version 2.13.1): a main effects model with SetYear and LocSite, a main effects model with SetYear and LocSite (treating LocSite as a random effect), an interaction model including only SetYear*LocSite (treating the interaction term as a random effect), and an interaction model with SetYear, LocSite, and SetYear*LocSite (treating the interaction term as a random effect). The results of leave-one-out cross-validation ("looic") suggest the first main effects model (SetYear + LocSite as fixed effects) best predicted the data (Table 45). Diagnostic checks of the Bayesian model fit (N_{eff}, Rhat, and Monte Carlo standard error values) were all reasonable.

Final time series of relative juvenile abundance

The model-based estimates of relative juvenile abundance suggest that average recruitment from 1977-92 was higher than during the period 1993-2012 (Table 46, Figure 66). The largest observed abundance of juveniles was in 2013, which was followed by another strong year (relative to historical levels) in 2014. Model predictions are generally correlated with observed means in each stratum, with the exception of 1997/North stratum (Figure 67). The model predicts a higher mean abundance in this stratum due, in part, to the additive model structure. As mentioned above, however, our exploration of a model with random-effect interaction terms did not produce a better fit relative to the final additive model.

Similar to the PISCO survey, the Tenera dive survey was excluded from the final base model because the model was unable to match the degree of variability in recruitment in the survey. The PISCO survey, which covers a much larger area, also observed a spike in BDR YOY abundance in 2013, causing the model to estimate a large additive variance parameter. Given the consistency between juvenile indices regarding the strength of the 2013 year class (see also the SWFSC juvenile index), we conclude that the model structure does not adequately capture the processes observed by the dive surveys, and future research is recommended regarding incorporation of subtidal dive surveys into stock assessments.

2.5.3 CDFW/VenTresca Dive Surveys

Survey Methodology

The California Department of Fish and Wildlife (CDFW; then Fish and Game) initiated SCUBA surveys along the central California coast in 1990 in an effort to collect information on nearshore rockfish populations that could inform subsequent designation of marine life refuges. Surveys were conducted between Santa Cruz County and San Luis Obispo County and targeted young-of-the-year (YOY) and juvenile nearshore reef fishes. Surveys continued through 1999, however sampling effort began to decline in 1994. The geographic spread of sampling in any given temporal strata (year or year*month) was dictated by the availability of field personnel.

One of three methods was used for each survey: timed transects, permanent transects, or measured transects. Timed transects were modeled after the methods of Hobson et al. (1986); transects were randomly stratified by depth and habitat type and divers counted all fish within a 2m*2m window as they followed a pre-determined compass bearing at a swim rate of 20m/minute. Fish counts were reported for each minute of the transect, with an average transect duration of 5 minutes. Permanent transects were established within rocky habitat at a single location (Otter Point), and were simultaneously surveyed by 2 divers, each recording fish counts for an area 2m*2m on their side of the 60m transect. Fish counts were reported separately for three 20m segments. Measured transects took advantage of a modified retractable "dog leash" (Ugoretz et al. 1997) to establish temporary 10m transects, along which two divers counted fish in an area 1m*2m on their side of the transect. All three types of transects were conducted along the benthos. Timed and permanent transects were also conducted in the midwater, and timed and measured transects were also conducted in the kelp canopy.

Divers recorded counts separately by maturity stage and identified to species whenever possible. The distinctive coloration of YOY Blue (and presumably Deacon) rockfish enabled consistent identification to the Blue/Deacon complex level

Data Preparation Prior to Analysis

The raw data did not include a unique identifier for each transect, and included separate records for each observation parameter (e.g. transect segment, species observed, etc.). Thus, we created a new field (TRANS_ID) which defined a transect as all records sharing the same survey date (YYYYMMDD), location code, and transect number (e.g. first transect of the day at that location).

Two filters were applied to the data prior to further analysis: transect type and maturity stage (Table 47). Timed transects were the only method where effort could be ascribed to fish counts, so we excluded both permanent and measured transects. Since YOY Blue Rockfish are known to preferentially aggregate near the benthos (Love et al. 2002), midwater and canopy transects were also excluded from further analysis. Counts of non-YOY fish (i.e. juvenile, subadult, or adult) were also excluded.

Each survey location was designated by a LOCA code. These codes are used across multiple spatially-explicit sampling efforts by CDFW, including the historic CPFV on-board sampling program (see Monk et al. 2016 for additional information). Based on the recorded LOCA code, transects were aggregated at two geographic levels- “Site Cluster” and “Region”. Site Clusters included North Monterey Bay, South Monterey Bay, Cypress Point, Carmel Bay, Big Creek, Piedras Blancas, Morro Bay, Point Buchon, and Avila. The “North” region included site cluster from Carmel Bay north to Santa Cruz, and the “South” region included site clusters surveys from Big Sur south to Avila.

Since counts were recorded separately for each transect segment (per minute, for the timed transects), both the effort (number of minutes) and Blue Rockfish catch (sum of the counts for all Blue Rockfish records) associated with each transect were calculated.

Model Selection

Due to limited sample sizes at the Site Cluster level, Region was the only spatial factor analyzed for inclusion in the model (Table 48). Two negative binomial models were evaluated; a main effects model (with catch modeled as an additive function of year and region, with an offset term for effort) and an interaction model (with catch as a function of year, region, and year*region, and effort offset). While AIC values suggested a year*region interaction exists (reduced the AIC by >60 points), the main effects model was used to generate the index due to the unbalanced nature of the data. A Bayesian negative binomial regression model (rstanarm R package, version 2.13.1) was used to test performance of the main effects model and to generate estimates of uncertainty for the index (Figure 68). Bayesian model diagnostics (N_{eff}, Rhat, and mcse values) were all reasonable. Predicted means by stratum (Year and Region) were strongly correlated with observed means, suggesting a reasonable fit to the data (Figure 69).

The CDFW/VenTresca dive survey was excluded from the final base model because the additive (log-scale) standard deviation parameter for this index was estimated to be very large (greater than 1), indicating that the index was not consistent with structural assumptions of the model and/or other data sources.

2.5.4 NMFS Fishery-Independent Trawl Surveys

BDR are poorly sampled in fishery-independent bottom trawl surveys. BDR were only reported in 14 of 16,917 trawl sets (0.08%) conducted from 1977-2015 during Groundfish Shelf, Groundfish Slope, Groundfish Triennial Shelf, and Groundfish Slope and Shelf Combination (i.e., the current "West Coast Groundfish Bottom Trawl Survey") surveys. Four-hundred and one BDR were collected in these 14 tows, which were conducted from 33.79-42.60° N at average depths ranging of 60-132 m.

Black Rockfish also are poorly sampled in fishery-independent trawl surveys. Black Rockfish only were reported in 41 of 16,917 trawl sets (0.24%) conducted from 1977-2015 during Groundfish Shelf, Groundfish Slope, Groundfish Triennial Shelf, and Groundfish Slope and Shelf Combination surveys. Two-hundred and seventy-one Black Rockfish were collected in these 41 tows, which were conducted from 35.15-48.59° N, at average depths ranging of 59-146 m.

None of the tows containing BDR and Black Rockfish overlapped; these species were never caught in the same tow.

2.5.5 California Collaborative Fisheries Research Program (CCFRP)

The California Collaborative Fisheries Research Program (CCFRP), created by Rick Starr (Sea Grant and Moss Landing Marine Laboratory) and Dean Wendt (Cal Poly San Luis Obispo), monitors marine protected areas (MPAs) and gathers information useful for fisheries management through hook-and-line surveys (Starr et al. 2015). This program has been running in Central California since 2007 and information regarding the program can be found at https://seagrant.mlml.calstate.edu/research/ccfrp/.

The CCFRP survey was not evaluated as an index of CPUE because protocols for the survey include a maximum depth of 120 feet (20 fathoms) to improve survivorship of released fish. The survey was designed to detect changes in catch rate and size compositions associated with Marine Protected Areas, relative to reference sites. CCFRP data was used to help describe spatial patterns in the proportion of catch by species (Blue vs. Deacon) at CCFRP sampling sites (Figure 1, inset).

2.5.6 NWFSC Southern California Shelf Rockfish Hook and Line Survey

Although the NWFSC Hook and Line Survey targets deeper (shelf) habitats than are typically occupied by BDR, the survey provided 446 otoliths and tissue samples of BDR from the Southern California Bight for this assessment. The majority of samples were determined to be Blue Rockfish (*S. mystinus*) based on genetic identification (see Appendix A). Additional details of the survey can be found online.

Although an index of abundance could not be constructed due to small sample sizes, the STAT used ages from the hook and line survey to evaluate spatial differences in growth for female Blue Rockfish in California (see section 2.4.2).

2.5.7 Laidig et al. (2003) dive surveys

Laidig et al. (2003) examined growth of BDR sampled using SCUBA off Sonoma and Mendocino Counties in California from 1988-1998. Females were targeted for fecundity studies, and the sex ratio of the age compositions was therefore not a random sample (T. Laidig, pers. comm.). This caused the model to estimate unrealistic growth trajectories for males in an attempt to match the artificially skewed sex ratio.

2.5.8 Beyer et al. age data

Similar to the Laidig et al. (2003) study, we excluded CAAL data provided by S. Beyer (UCSC, NMFS SWFSC) after learning that the sex ratio was skewed toward females due to preferential retention of females for a fecundity study.

2.6 California Model

2.6.1 History of Modeling Approaches Used for this Stock

The first stock assessment of Blue Rockfish (*Sebastes mystinus*) off the U.S. West Coast was completed in 2007 using Stock Synthesis version 2.00c (Key et al. 2008). Key et al. assumed a single, well-mixed stock in U.S. waters between Point Conception, CA, and the California-Oregon border (roughly 34° 27′ to 42° North latitude) and modeled stock dynamics from an unfished condition starting in 1916. The model allowed for gender-specific differences in growth, natural mortality, and size-dependent vulnerability to the fishery ("selectivity"). Recreational fishing mortality was represented as a single fleet, and commercial removals were split into two fleets representing the hook-and-line and setnet sectors. Deviations from a Beverton-Holt stock-recruitment curve were estimated from 1960-2006, and informed by an index of age-0 juvenile abundance from 2001-2006 (NMFS, SWFSC). An index of relative abundance was developed from dockside intercept surveys of recreational CPFVs (split into two time periods, 1980-1999 and 2000-2006, due to regulatory changes), as well as an index estimated from onboard CPFV observer data in central California (1987-1998). Length composition data from the recreational CPFV and private boat fleets were combined, while commercial length data suggested differences in catch size distributions between the hook-and-line and setnet fisheries. Conditional age-at-length data from the 1980s allowed for estimation of certain length-at-age parameters within the assessment.

In response to the 2011 mandate for Annual Catch Limits (ACLs), catch-based models (DCAC; MacCall 2009) were used to estimate sustainable yields for Blue Rockfish in U.S. waters south of Point Conception and north of the California-Oregon border (Dick and MacCall, 2010).

2.6.2 Response to STAR Panel Recommendations from Previous Assessment

The STAR Panel report from the 2007 Blue Rockfish assessment documents several unresolved problems and major uncertainties. We list these below, and provide updated information on the status of relevant research.

The assessment area is based on management boundaries and not on population structure. The assessment covers only the core of the species range. Blue rockfish south of Point Conception were not assessed, but anecdotal information suggests that they have declined steeply, potentially in response to climate change and loss of kelp forest habitat. The status of Blue Rockfish off Oregon (and further north) is unknown.

Since the 2007 assessment, estimates of sustainable yield based on DCAC (MacCall 2009) have been the basis of Southern California's contribution to the southern Minor Nearshore Rockfish OFL. This assessment recognizes the challenges associated with modeling Southern California either as a separate population (due to data limitations), or including Southern California in a statewide model for BDR (due to potential differences in stock dynamics north and south of Point Conception). As a Pre-STAR sensitivity, the STAT presented the latter option, evaluating a model that includes landings and abundance indices from Southern California (a "fleets as areas" approach), while assuming that length and age compositions, as well as trends in recruitment, from the north are representative of the southern region. As noted by Key et al. (2008), there is evidence (long-term fluctuations in temperature and associated habitat, e.g. kelp biomass) that declines in catches in Southern California may be due to a combination of factors (fishing and the environment). Therefore, this approach is provided as sensitivity analysis, and not as the current base model for California.

Recent genetic studies suggest that Blue Rockfish is two closely-related species that intermix in the area covered by the assessment.

This assessment attempts to evaluate differences between the newly described Deacon Rockfish (*S. diaconus*) and Blue Rockfish (*S. mystinus*) and to consider, where possible, the implications of assessing and managing the two species as a complex.

Historical catches of Blue Rockfish are highly uncertain.

California and Oregon have completed reconstructions of historical catches for commercial and recreational fisheries since the last assessment (Ralston et al. 2010, Karnowski et al. 2014). These analyses are incorporated into the revised assessment, and uncertainty evaluated through sensitivity analysis.

Natural mortality is highly uncertain and cannot be reliably estimated. The scarcity of males in the landings could be either due higher male natural mortality or lower fishery selectivity for the males.

Natural mortality is estimable in the revised assessment, and consistent with newly developed prior distributions. There is no additional evidence that male natural mortality has a different functional form to that of females, so the approach in this assessment to estimate males as an offset to females seems consistent with other life history traits (e.g., the VBGF growth coefficient).

The assumed value of stock-recruit steepness was based on Dorn's meta-analysis of steepness and represents average for all West Coast rockfish. The assessment itself provides little indication of the appropriate value of steepness for Blue Rockfish. Consequently, how the stock will respond to the Council's harvest policy for rockfish is not well known.

Steepness, *h*, in the 2017 California base model is estimated at a value (h=0.645) that is lower, but within one standard deviation of, the current prior mean (mean=0.718, SD=0.158). The model is sensitive to the value of the steepness parameter (particularly with respect to ending year spawning output), and estimating the parameter integrates uncertainty associated with steepness into model outputs including management reference points.

Growth of Blue Rockfish shows complex spatial and temporal patterns. Data are not available to adequately describe these patterns.

Our external analyses of growth suggest that recent patterns of growth in Blue and Deacon rockfish are similar, within gender, in Oregon. Patterns of growth in California are more complex. See section 2.4.2 for a description of growth patterns by sex, species, and location.

Assessment results depend on an assumption of a constant proportionality between recreational fishery CPUE and stock abundance.

Our analyses of recreational catch and effort data treat CPUE as proportional to density, rather than abundance. We use estimates of habitat area based on high-resolution bathymetry to create area-weighted indices of relative abundance. Although this is an improvement over the assumption of proportionality to stock abundance, additional research is needed to evaluate the relationship between CPUE and local fish density.

2.6.3 Transition to the Current Stock Assessment

We were able to closely reproduce the results of Key et al. (2008) using more recent versions of Stock Synthesis (ending with version V3.30.03.07). Log likelihood values were similar among versions (Table 49), and the spawning output trajectories were nearly identical (Figure 70), with differences in end-year depletion smaller than 0.3%. Differences in model structure between the 2007 assessment and the current base model are described in section 2.6.4.

2.6.4 Model Specifications

The assessment is structured as a single, sex-disaggregated population, spanning U.S. waters from Point Conception to the California-Oregon border. The assessment model operates on an annual time step covering the period 1900 to 2017 (not including forecast years) and assumes an unfished equilibrium population prior to 1900. Population dynamics are modeled for ages 0 through 35, with age-35 being the accumulator age. The maximum observed age was 39 for males and 43 for females. Population bins were set every 1 cm from 7 to 54 cm, and data bins were set every 2 cm from 10 to 52 cm. The model is conditioned on catch from two sectors (commercial and recreational) divided among eight fleets, and is informed by five abundance indices (one fishery-independent survey, two CPUE indices from shore-based sampling programs, and two CPUE indices from onboard observer programs). Size and age composition data include lengths from 1959-2016 and ages from 1980-1984 and 2010-2011. Recruitment is related to spawning output using the Beverton-Holt stock recruitment relationship with log-normally distributed, bias corrected process error. Growth was modeled across a range of ages from 0 through 35. All catch was assumed to be known without error.

Fleets were specified for recreational and commercial sectors. While the previous assessment combined all recreational fishing modes, we split the recreational sector into four main fleets according to fishing type (CPFV or private boat) and catch type (retained or discarded). The private boat fleet is further divided into time periods (before 2004, and 2004-2016) based on changes in sampling intensity (MRFSS vs. CRFS). All recreational shore modes were combined with the private boat fleet due to their small contribution to overall BDR catch. The commercial sector was represented by four fleets: a hook-and-line and longline gear type, a net gear type, 'other' gears (including trawl), and a fleet for commercial BDR discards. Fleet selectivity was assumed to be asymptotic for all retained catch fleets, and dome shaped for the recreational and commercial discard fleets. Sensitivity to these selectivity assumptions were explored during model development and relative to the base model.

The time-series of data used in the California assessment are summarized in Figure 6. Sample sizes for length and age compositions are also summarized (Table 7, Table 10). For yearly length-composition data, initial sample sizes for recreational fleets were set at the number of sampled trips, or a proxy based on the ratio of fish landed per trip in similar fleets. For the commercial fleet, the initial sample size was set to the number of trips. Length composition sample sizes were then tuned in the base assessment model using the Francis weighting method (Francis 2011). The Francis method resulted in down-weighting of all recreational fleet sample sizes, except for the ocean-boat discard fleet was up-weighted slightly (Table 50).

Conditional age-at-length data were used in the assessment model to inform estimation of growth and to alleviate the potential lack of independence among dual age and length-composition information for the same sample. Age-at-length composition sample sizes were set at the number of aged fish in each population bin. These data were weighted according to the harmonic mean effective sample size (McAllister and Ianelli 1997) by using tuning scalars that are generated using the r4ss package in program R (https://github.com/r4ss/r4ss). The harmonic mean approach resulted in a down-weighting of recreational, commercial, and research age sample sizes (Table 50). Alternative approaches to weighting were explored through sensitivity evaluations (see section 2.10.1).

Among data source weights (or emphasis factors) can also be specified in Stock Synthesis (i.e., “lambdas”). In this assessment, there was no clear reason to down-weight (up-weight) particular data sources relative to each other, so all were assumed to have equal emphasis in the base case model.

A prior distribution was specified for male and female natural mortality following the Hamel (2015) meta-analytic approach (see section 2.4.1 for more details). A lognormal prior for natural mortality was applied when estimating female (mean = -2.0272, standard deviation = 0.438) natural mortality, and male natural mortality was modeled as an exponential offset with no prior. A beta prior (mean=0.718, SD=0.158) was applied when estimating steepness of the stock recruitment curve. The steepness prior was developed from a west coast groundfish meta-analysis (Dorn et al. 2002; Thorson et al. in press).

Likelihood components that were minimized in the overall fitting procedure include fleet-specific catch, length composition, and conditional age-at-length composition and also survey, recruitment deviate, parameter prior, and parameter soft-bound components. Initial model explorations utilized individual and combined likelihood values to assist in model development.

This assessment used a recent version of Stock Synthesis 3 (version V3.30.03.07), which was provided by Rick Methot (NOAA-NWFSC) and Teresa Amar (NOAA-OST). The basic population dynamic equations used in Stock Synthesis 3 can be found in Methot and Wetzel (2013). The relevant input files (starter.ss, data.ss, ctl.ss, and forecast.ss) necessary to run the stock assessment can be found on the Pacific Fisheries Management council website (http://www.pcouncil.org/groundfish/stock-assessments/).

2.6.5 Model Parameters

The population dynamics model has many parameters, some estimated using the available data in the assessment and some fixed at values either external to the assessment or informed by the available data. A summary of all estimated and fixed parameter values, including associated properties, are listed in Table 51.

A total of 110 parameters were estimated in the base model, including recruitment deviations from 1950-2016. Time-invariant growth parameters (Brody growth coefficient, lengths at age 2 and age 30, and CV old/young) using the Schnute parameterization of the von Bertalanffy growth function were estimated for each gender, where males were estimated as an offset of female parameters. The CV of the distribution of length-at-age, CV(L), in the base model is estimated at the lower and upper ages specified in the Schnute parameterization of von Bertalanffy growth, and a linear interpolation between these 2 parameters is a function of age. This choice was based on visual inspection of the relationship between CV(L) and age, by sex, for ages with sample sizes greater than or equal to 30 (Figure 71). Natural mortality was estimated for females and informed by a prior distribution, and estimated for males as an exponential offset with no prior (see section 2.4.1). Selectivity was assumed to be asymptotic and related to length by a normal cumulative density function for all retained catch fleets, and domed for discard fleets with initial and final selectivity fixed at zero. All selectivity parameters were assumed to be time-invariant, except time blocks were used to capture changes in peak selectivity associated with bag limit changes in 1971 (CPFV) and 2000 (CPFV and private boat). No data are in the model to estimate a selectivity block for the private fleet in 1971. Recruitment deviates were estimated in the base model from 1950 – 2015. Initial (equilibrium) recruitment was also estimated. Coefficients of variation about the abundance indices derived from posterior predictive intervals (or other resampling techniques) may greatly underestimate the true uncertainty regarding the relationship between these indices and biomass. Thus, extra standard deviation parameters were estimated for each abundance index.

The Post-STAR panel base model estimated the Beverton-Holt steepness parameter at 0.645 (SE=0.114), which is lower than the prior mean (0.718), but within 1 standard deviation (SD=0.158) (Dorn et al. 2002; Thorson et al. in press). Recruitment variation about the stock recruitment curve was fixed at 0.5, a value tuned to the estimated recruitment deviation RMSE plus a slight adjustment upward to account for unmeasured process error. Functional forms from Key et al. (2008) were retained to specify the female maturity ogive and gender-specific weight-length relationships. Parameters for fecundity were fixed at estimates following methods in Dick et al. (2017). Several of the parameterization decisions were further examined through sensitivity analysis (section 2.10).

2.7 California Base Model Selection and Evaluation

2.7.1 Key Assumptions and Structural Choices

Many of the key assumptions and structural choices made in this assessment were evaluated through sensitivity analysis (section 2.10). For consistency, model structural choices were made that were likely to result in the most parsimonious treatment of the available data, either a priori determined or through the evaluation of model goodness of fit. The major structural choices in this assessment were the use of a single closed area (U.S. waters off California from Point Conception to the California-Oregon border) to adequately describe gender-specific population dynamics of BDR, and that gender-specific differences in natural mortality account for sex-ratio differences in the observed catches.

Major structural assumptions included estimating the steepness stock recruitment parameter and gender-specific natural mortality parameters, but assuming gender invariant selectivity parameters. Female natural mortality was estimated using the prior distribution following methods of Hamel (2015). The California model estimates male natural mortality as an offset to female natural mortality with no prior, as joint priors for female and male natural mortality parameters are not currently available (either directly estimated or as an offset). Selectivity was assumed to be asymptotic following a normal cumulative distribution function (similar to a logistic) for all retention fleets, and was assumed to be dome-shaped for the commercial and recreational discard fleets. Male and female selectivity curves were assumed to be equivalent in the base case model. Sensitivity model runs that include differences in selectivity by gender were evaluated at the STAR panel. There was sufficient information in the data to produce reasonable estimates for selectivity, but there was some difficulty fitting to the largest observed fish. The California base model was not sensitive to the shape of the selectivity curves (i.e. more flexible, "double-normal" selectivity curves were often estimated as asymptotic, and/or had little effect on model results). A time block was used to capture changes in selectivity as a result of the implementation of a bag limits (recreational fleets) in 1971 (20 fish to 15 fish) and 2000 (15 fish to 10 fish), which influenced the size of fish landed in the observed data. It was not possible to model the effect of bag limit changes on discard size compositions due to lack of discard length data before 2003.

2.7.2 Evaluation of Model Parameters

Model parameters were evaluated for stability, precision, along likelihood profile gradients (section 2.10), and against the main assumptions in the base case model (section 2.7.1). Stability was examined by ensuring that model parameters were not up against a lower or upper bound (Table 51), and that the addition or removal of parameters associated with dome-shaped selectivity did not substantially improve model fit. Parameter precision was also monitored by looking at estimated standard deviations to assess the variability associated with point estimates.

2.7.3 Residual Analysis

Residuals to length composition and age composition fits to the model were explored during model development. The identification of residual patterns helped to sort out which set of a priori selectivity blocks were the most appropriate given the data. Alternative model configurations were also explored during model development in an attempt to minimize residual trends. The base model produced reasonable fits in general to length and age composition data. Across all years, the fit to length composition information was best for the CRFS private boat and onboard CPFV 1988-1998 fleets, which had the largest sample sizes among length data sources (Table 7).

In general, annual fits to time-aggregated length composition information were adequate (Figure 72) with the exception of larger fish (particularly males) in the length comps associated with the cooperative survey CPFV data (Figure 73). The more recent sources of sex-specific marginal length composition data had smaller residuals (Figure 74, Figure 75), but the expected relative proportion of females to males was best matched by the Abrams data. Pearson residuals for the unsexed length compositions did not indicate gross lack of fit (Figure 76, Figure 77, Figure 78, Figure 79, Figure 80, Figure 81, Figure 82, Figure 83). The model was able to track mean length well for the onboard CPFV observer data from 1988-1998 (Figure 84) and the combined sex recreational CPFV data (Figure 85, upper panel), but a slight decline in predicted mean length did not follow a slight increase observed in the cooperative survey samples of CPFVs (Figure 85, lower panel). Mean length for the recreational private boat fleets also followed the main trends through time (Figure 86, Figure 87), but the model essentially had a smoothing effect over other data because of the smaller sample sizes (Figure 88, Figure 89, Figure 90, Figure 91, Figure 92).

Age compositions that resulted from fitting conditional age-at-length data matched reasonably well with the observed marginal age compositions from the recreational CPFV fleet (Figure 93). The model predicted a higher proportion of young fish (less than ~7 years old) than were observed in years 1983 and 1984. The K. Schmidt research ages indicated a lower proportion of 4- and 5-year-old fish in 2010, and 5- and 6-year-old fish in 2011, which was captured by the model (Figure 94). This 'gap' in observed ages also appeared in the Abrams research data, suggesting that it is not an artifact of sampling (Figure 95). Fits to the recreational CPFV conditional age at length (CAAL) data show generally good agreement between observed and expected ages at length (Figure 96). Fits to the Schmidt research CAAL data are also reasonable (Figure 97), with a slight tendency for the model to predict older fish at length than were observed in the Abrams data, specifically for fish greater than 20cm (Figure 98). The model did not track a slightly increasing trend in mean age for the CPFV fleet (Figure 99), but predictions were consistently within 1-2 years of the observed mean age. The best fit to mean ages was seen with the Schmidt data, which had the largest sample sizes in recent years (Figure 100). As noted earlier, the expected mean age for the Abrams data was larger than observed, but the increasing trend from 2010 to 2011 was captured by the model (Figure 101).

Some patterns are visible in the Pearson residuals for the conditional age-at-length data. The ages from the CPFV fleet in 1983 and 1984 observed a greater number of old fish than the model predicts (Figure 102). Although the model reproduces the cohorts observed in the two research age data sources (Figure 94, Figure 95), it is not able to match the magnitude of the peaks, leading to slight patterns in the CAAL Pearson residuals (Figure 103, Figure 104).

2.7.4 Convergence

Model convergence was checked during development of a base model by ensuring that the final gradient of the likelihood surface was less than 0.0001 and produced asymptotic standard deviations. All estimated parameter values were also checked to ensure they were not hitting a minimum or maximum bound. To reduce the chance that the optimization arrived at a local (rather than global) minimum on the likelihood surface, additional explorations for a consistent likelihood minimum were performed using jittered (0.1) starting values. A total of 30 jittered runs were performed for each model. Across all jittered runs, the model found no minima lower than the base case (Figure 105).

2.8 Response to STAR Panel Recommendations

1. Shift both early and main start year for estimating recruitment deviations ±10 yrs. and ±20 yrs. from the base case. Recalculate the ramp. If the start of the main recruitment devs. seems implausible, feel free to shift.
   Rationale: There is a period of higher recruitment early in the time series that does not seem to be informed by the data.

   Response: The runs were conducted. Relatively modest differences in model results and fit with earlier start to recruitments, but very substantial impact when recruitment deviations were started later than the base model (Figure 106). This manifests through a much higher estimate of natural mortality (approximately 0.22 in both later-starting cases) that scales biomass, and ending year depletion, dramatically upwards. Fit degrades by about 10 – 20 likelihood units in these runs. Fits were modestly (less than one likelihood unit) improved with earlier start (slight increase in estimate of M, to 0.123-0.125). When M was fixed at base model point estimate and rec devs started in 1980, result is more comparable to base model, however fit still degraded (about 20 likelihood units).

2. Do the "drop one" analysis for the data components informing the CPFV and private fleets (i.e., indices, length comps., and age comps.).
   Rationale: To better understand what data are driving the weird recruitment time series in the original base case model.

   Response: The California model is most sensitive to removal of 1) sources of age data with the largest sample sizes, i.e. CPFV 1980-1984 and Schmidt 2010-2011, and 2) large portions of the CPFV length compositions (Figure 107). Without both the CPFV and Schmidt ages, the model often hits the upper bound of R0. Removal of the Karpov et al. (1995) CPFV length composition data reduces recruitment variability in the early part of the time series, but has minimal effect on the scale or current status of the stock. The Schmidt CAAL data appear to inform the large 2008-2009 recruitment deviations, relative to 2013, while a strong 2007 recruitment is supported by other data. Although unfished biomass was relatively stable, stock status in 2017 was sensitive to four data sources: 1) Schmidt age and length data (removal resulted in a severely depleted stock), 2) MRFSS private boat length compositions, 3) MRFSS CPFV index, and 4) 1988-1998 onboard CPFV observer index. Removal of the recreational discard length composition data significantly reduced the strength of the 2013 year class (although still well above average).

3. Explore the sensitivity of the MRFSS CPFV dockside and CRFS dockside indices to the thresholds in the Stephens-MacCall filtering by halving the false positives and alternatively halving the false negatives.
   Rationale: The current thresholds are somewhat ad hoc.

   Response: Two new indices were produced, halving the number of false positives (FPs), then halving the number of false negatives (FNs) for the dockside MRFSS CPFV index. Contingency tables, model selection criteria, and indices scaled to a unit mean were presented to illustrate the effect of the Stephens-MacCall threshold choice on index standardization. Trends in the MRFSS index were not sensitive to the choice of threshold.

4. Produce a table like Table 5 in the 2015 black rockfish assessment (in the OR and CA assessments; except for the final 2 columns).
Rationale: To concisely understand how the different indices were constructed.

Response: See Table 53.

5. Provide a run where the discard fleet is removed. Add the estimated discards to the total removals for affected fleets.
Rationale: To understand sensitivity to that model structure.

Response: Length composition data from the CRFS onboard CPFV and WCGOP observer programs were removed (neg. fleet value in SS), and discard fleet selectivities mirrored to the CPFV and Hook and Line fleets, respectively. The effect was modest, but larger than the STAT anticipated given that discards represent a small fraction of total removals (e.g. 6.2% in last 10 years). This is due, in part, to the information about recent recruitments in the rec discard composition data (see STAT response to request #2, part 1).

6. Provide a run where both zero years in the juvenile recruitment index have half the value of the lowest year in the index.
Rationale: No BDR were observed in these years and therefore the index should be less than any of the other years. That information should be captured in the model.

Response: We explored both including those years with the Rstan estimated point estimates and CVs, as well as using half of the lowest value for years that did have positive observations, with the CV set to the largest estimated CV for those years. There was negligible (verging on undetectable) change in the base model result, as the predicted recruitments are already low for these years so recruitment estimates do not change substantively. Change is logical, and consistent with how the index had been developed in the past (prior to the application of Rstan to develop the index). The STAT and STAR panel agreed to incorporate this change in the revised base model.

7. Consider whether implementation of MPAs in central CA in 2007 caused the change in the onboard CPFV index trends after 2007. Reconstruct the index by removing all the historical drifts that occurred in current MPAs.
Rationale: Implementation of MPAs may have affected index trends.

Response: The STAT calculated catch rates from 2001-2006 inside areas that were later classified as MPAs. CPUE "inside" was larger than outside the (eventual) MPAs (Figure 108). However, a relatively small proportion of observed drifts occurred "inside," and the effect on the index is minor, based on a comparison of area-weighted point estimates (MLEs).

8. Rerun the corrected base model with the reconstructed CPFV index that excludes drifts inside of MPAs.
Rationale: This conceptually improves the index since the same areas accessible to the fleet are consistent through the entire time series.

Response: The STAT replaced the original index with the revised area-weighted MLEs, using the log-scale standard errors from the base case index. The change had little effect on model results.

9. Reproduce the table displaying the bivariate profile over M and h showing the depletion and ending biomass with a CI defined by a 75% chi square bivariate CI equivalent to a 1.386 change in likelihood.
   Rationale: To explore these axes of uncertainty for a decision table.

   Response: The results of the bivariate profile over M & h were modified to reflect the change in confidence region from 95% to 75%, to mirror the percentile range customarily displayed in decision tables (12.5% to 87.5%). See section 2.10.2for updated results with the post-STAR panel base model.

10. Prepare a new base model as follows:
    - Estimate h and M with the priors included;
    - Include the revised juv. rockfish time series;
    - Fix the gap in the hook-and-line catch time series;
    - For alternative states of nature in a decision table, use the 12.5 and 87.5 percentiles of the ending biomass assuming a normal distribution;
    - Retune and jitter the base model.

    Rationale: The STAT and STAR Panel agreed on this model configuration.

    Response: The STAT fit and retuned the revised base model as specified in Request #10. Alternative states of nature were estimated by creating a "survey" in the model (fleet #14, "SSB_Survey_2017) with survey year 2016, timing 12.999 (essentially Jan. 1, 2017), and log-scale SD of 0.001. The survey selectivity was set equal to spawning output (survey units option #30 in Stock Synthesis), with catchability fixed equal to 1. Values of the 12.5 and 87.5 percentiles of SSB in 2017 were determined from the base case model using the point estimate of SSB in 2017 (812.487) and adding/subtracting the product of its estimated asymptotic standard deviation (432.669) and 1.15035, the approximate value of the 87.5 percentile point of the normal distribution. See section 2.9 for additional details.

11. If time permits, run a jitter to start from the following extreme states of nature: 1) h = 0.3 and M = 0.15 and an analogous high h and low M state of nature.
    Rationale: An extreme test for the global minimum.

    Response: the STAT was unable to complete this request during the panel.

2.9 California Base-Model Results

The California base case model estimated reasonable growth parameters (*k*, length at minimum and maximum age, and CV young/old; Table 52). The CV of length at age for male BDR was similar to that estimated for females at age 2 (the lower age in the Schnute parameterization), but was estimated to be twice that of females at age 30 (Figure 109). Asymptotic length was estimated to be 37.3 cm for females and 30.4 cm for males (Table 52, Figure 109).

The fit to the MRFSS CPFV dockside index captured the declining trend in CPUE from the 1980s to the 1990s (Figure 110). The more recent CPUE indices (CRFS private boat and CRFS onboard CPFV) both had patterns of a peak in 2006, followed by a decline and subsequent increase since roughly 2012, but the model fit showed a flat to increasing trend over this time period (Figure 111, Figure 112). Estimates of the additive variance parameters for these two indices were large (0.56 and 0.69, Table 51), in part due to large sample sizes and very small input CVs (usually <10%) relative to other indices in the model (Table 20, Table 35). As in the last assessment, the model was not able to match the observed rate of increase suggested by the final years of the onboard CPFV index (1988-1998; Figure 113), but the model estimated the smallest additional variance for this index (0.18, Table 51), suggesting that the index and associated uncertainty estimates were not inconsistent with model predictions of vulnerable biomass. Lastly, the SWFSC juvenile rockfish recruitment index was well-fit by the model, with a small additive variance estimate (0.20) and predictions matching the observed peak in YOY abundance in 2013 (Figure 114). The model also predicted somewhat strong year classes in 2007-2009, likely due to the large proportion of young fish in the recent CAAL data from Schmidt and Abrams (see section 2.7.3). Due to the limited temporal and spatial coverage of recent age data sources, it is possible that localized recruitment events are over-represented in the data, contributing to uncertainty in the relative strength of individual cohorts. Comprehensive sampling of age structures from the recreational fishery would help inform the relative strength of individual year classes, as well as improve our ability to estimate growth in the model.

Length-based selectivity curves were estimated for nine of the13 fleets (Figure 115, Figure 116). The recent (2004-2016) private boat selectivity was assumed equal (‘mirrored’) to the estimated values for the earlier (pre-2004) private boat. An asymptotic curve following the normal cumulative distribution function was used for all recreational and commercial landings, and descending limbs of the selectivity curves were estimated for discard fleets. Shifts in the peak of the length-based selectivity curves were estimated in years when changes in bag limits went into effect (1971 and 2000; Table 51; Figure 117, Figure 118).The base model assumes that length-based selectivity is equal for males and females. Therefore, the model matches the low observed percentages of males through gender-specific differences in estimated growth and natural mortality. It is possible that males are less vulnerable to the gear. The current base model is able to estimate reasonable values of natural mortality and growth for both males and females given equal selectivity. The STAT considers this to be the most parsimonious structure for the observed data. The effects of gender-specific selectivity are evaluated in section 2.10.5.

BDR spawning output in California was estimated to be 812 million eggs in 2017 (~95% asymptotic intervals: 0-1661; Table 54), which equates to a depletion level of 37% (~95% asymptotic intervals: 0%-79%; Table 54; Figure 119, Figure 120) in 2017. Depletion is a ratio of the estimated spawning output in a particular year relative to estimated unfished, equilibrium spawning output. Spawning output in California (north of Point Conception) declined rapidly throughout the 1970s and 1980s to a level below the Minimum Stock Size Threshold (MSST), but catches decreased enough in the late 1980s for the stock to reach a stable level of spawning output (Table 55, Figure 120). Stock size is estimated to have been at the lowest level in the mid-1990s, but has since increased, in part due to a strong recruitment in 2013. The stock is estimated to have been below the management target of B40% for several decades (Figure 120). Recruitments in California may be poorly estimated in the base model due to limited spatial and temporal coverage of age data, but the model picks up a strong 2013 year class observed in several YOY and juvenile surveys (Figure 54, Figure 65, Figure 66).Other years with relatively high estimates of recruitment were 2007, 2008, and 2009 (Figure 121, Figure 122). Relative exploitation rates [(1-SPR) / (1-$SPR_{50\%}$)] increased through time, exceeding target levels from the mid-1970s through the early 2000s. Exploitation over the past 8 years has been below target (Figure 123). In 2016, BDR biomass is estimated to have been near the target biomass level, while experiencing fishing intensity below the SPR fishing intensity target (Figure 124). The equilibrium yield curve is shifted left, as expected from the Beverton-Holt steepness estimate (h=0.645), showing a more productive stock than the $SPR_{50\%}$ reference point would suggest (Figure 125).

2.10 Evaluation of Uncertainty

2.10.1 Sensitivity to Assumptions, Data, and Weighting

We evaluated sensitivity of the California model to specific data sources using a 'one-off' approach (remove one data source relative to the base model) analyses to clearly identify the impact of a single piece of information or structural assumption. For the pre-STAR California base model, data were removed initially by fleet (i.e. all composition and trend data associated with a particular fleet), and subsequently by individual data source (see STAR Panel request #2). Other sensitivity tests include:

- Estimating dome-shaped selectivity curves for recreational fleets
- Estimating dome-shaped selectivity curves for commercial fleets
- Using the Francis (2011) method of data-weighting for all composition data
- Using the harmonic mean (McAllister and Ianelli, 1997) method of data-weighting for all composition data
- Fixing steepness at the mean of the recommended prior distribution (mean=0.718, SD=0.158)
- Add removals and indices from Southern California (see section 2.10.5)
- Use alternative ageing error matrix that assumes SWFSC reader is biased relative to ODFW
- Gender-specific selectivity curves (alternative hypothesis for skewed sex ratio; see section 2.10.5)
- Deterministic stock-recruitment (turn off estimation of recruitment deviations)

In general, the base case model was relatively stable with respect to population scale across most "one-off" scenarios examined (Table 56, Figure 126, Figure 107). Population trends were fairly robust across 'one-off' runs except for the two scenarios that removed the recreational fleets and the removal of the 2010-2011 Schmidt age data. See the response to STAR Panel request #2 (section2.8). The removal of the CPFV and private boat data (i.e. the majority of length data, and the only early age data) resulted in predictions of a severely depleted stock (Figure 126), as did the removal of the K. Schmidt data (Figure 107). This highlights the sensitivity of the model to the small amount of available age data (see research recommendations, section 7).

Allowing for dome-shaped selectivity curves in the California recreational fleets (CPFV and private) or the commercial fleets (hook and line, net gears) had little effect on the model results (Table 57, Figure 127). The selectivity for the recreational CPFV fleet remained asymptotic despite the more flexible parameterization, and the private boat fleet estimated a sharply domed curve, but with only a slight reduction in selectivity at large sizes that had little effect on population scale or trend (Figure 127). Similarly, estimating parameters using more flexible selectivity curves for the commercial fleets resulted in no change for the hook and line fleet (remained asymptotic), and a domed curve for the net gear fleet (Table 57). Since the net gear curve was already only selecting the largest individuals, the effect of the dome shape on population scale and status was almost imperceptible (Figure 127).

The California model is sensitive to the approach used to weight composition data. The base model uses the Francis method to weight length composition data, and the harmonic mean method for age composition data. When the Francis method (Table 58) is used to weigh all composition data in the pre-STAR base (lengths and ages), the estimate of unfished population size decreases, but not the current biomass estimate, resulting in a less depleted stock (Figure 128). However, the estimated CV of length at age 30 for males becomes unreasonably large, and the estimate of annual natural mortality rate (*M*) increased from 0.12 yr^{-1} in the base model to 0.17 yr^{-1} (Table 57). When harmonic mean weights were used for all composition data (Table 59, Figure 129), the model estimated a much smaller, more depleted stock (8% of unfished), with lower natural mortality (0.09 yr^{-1}).

There was some evidence of bias between agers, with younger age estimates from ODFW's reader relative to the SWFSC reader (Figure 63). Use of an ageing error matrix that assumes the ODFW reader is unbiased resulted in a more depleted stock (Figure 130). The STAT recommends that age calibration and validation studies be conducted for future assessments of BDR.

Estimation of recruitment deviations had a large influence on model results, with a deterministic recruitment model suggesting a much more depleted stock relative to the pre-STAR base (Figure 131). Relatively speaking, changes to length at 50% maturity (+/- 2 cm) had little effect on model output (Figure 132).

2.10.2 Parameter Uncertainty

Likelihood profiles were performed across three major sources of uncertainty: natural mortality (M), initial recruitment (R0), and steepness (h). In addition, a bivariate profile over steepness and female natural mortality was performed. An individual profile was completed for each data type (e.g. lengths, ages, indices) and parameter combination to derive the relative importance of each data set to parameter estimation.

The profile over female natural mortality (M) was conducted across a range of values (0.08 – 0.18 yr^{-1}) while estimating the offset of male natural mortality to female natural mortality (Figure 133). The age data tend to favor higher values in the range, whereas length and recruitment data are better fit by smaller female M values in the profile range. Indices appear to have a bi-modal distribution, with the best agreement occurring at the bounds of the profile space (Figure 133). The value of M has a much larger effect on terminal biomass than it does on unfished biomass in the model, suggesting that unfished population scale is relatively well-defined for the California model (Figure 134). The range of depletion estimates for likely values of M spans stock sizes below the Minimum Stock Size Threshold to above target biomass (Figure 135). Results from a similar analysis using the pre-STAR base model suggest that estimates of male natural mortality in the California model are consistently larger and positively correlated with female M, but the relationship is not strictly proportional (Figure 136), although this relationship was conditional on a fixed value of the Beverton-Holt steepness parameter (0.718).

The profile over the initial scale of the California population (R0) indicated a reasonably well determined estimate for the base model, formed mainly by length and age composition data sources (Figure 137). Indices appear to again have a bimodal distribution, and are best fit (as a group) by smaller estimates of R0. Examination of profiles for likelihood components of individual indices reveals that earlier data sets (the MRFSS CPFV index and the onboard CPFV index from 1988-1998) favor higher values of R0, and more recent indices (CRFS onboard CPFV, CRFS private boat, and SWFSC YOY) favor smaller values (Figure 138).As with the profile over natural mortality, the scale of the unfished California population varied relatively less with R0 than did the estimate of terminal biomass (Figure 139). The range of R0 values in the profile resulted in depletion estimates that spanned values below and above the minimum stock size threshold and target biomass levels, respectively (Figure 140).

Profiles over the Beverton-Holt steepness parameter (*h*) indicated that steepness was difficult to determine given the available data, and profile runs for steepness greater than 0.8 did not converge. (Figure 141). Similar to the profiles over ln(R0) and M, steepness had relatively little effect on estimates of unfished population size, with the exception of very low values (h<=0.3) (Figure 142). However, stock status is greatly affected by the value of steepness, with steepness values below 0.6 resulting in a severely depleted stock (Figure 143). When steepness was estimated in the pre-STAR California model, the estimated value (0.649) produces time series similar to the post-STAR base case model, with greater uncertainty in the estimate of ending depletion and spawning output (Figure 144, Figure 145). The post-

STAR base model (which estimates steepness) had nearly identical results to the pre-STAR model with estimated steepness (h=0.645 in the post-STAR model).

A bivariate profile over female natural mortality and Beverton-Holt steepness parameter was presented during the star panel (see STAR panel request #9). This analysis was repeated for the post-STAR base model, with the same parameter values presented during the STAR panel, and showing a 75% bivariate confidence region (1.386 likelihood points above the minimum negative log likelihood; panel 'a' in Table 60). Estimates of depletion within the 75% confidence region (coarsely defined by this grid) ranged from 7% to 67% of unfished spawning output (panel 'b' in Table 60). This uncertainty in stock status is mainly due to uncertainty in 2017 biomass (panel 'c' in Table 60), rather than unfished spawning output, as noted earlier. This uncertainty in terminal biomass is reflected in estimates of the OFL for the year 2017, which vary by an order of magnitude, whereas uncertainty in estimates of (proxy) MSY are relatively more precise (Table 61). Given the uncertainty in terminal biomass, forecasted yields that are greater than the proxy MSY yield (i.e. those associated with biomass estimates above the target) should be considered with caution.

2.10.3 Retrospective Analysis

A retrospective analysis was conducted by sequentially removing 1 through 5 years of data from the base model starting with 2016. Since the most recent age data in the model was in years 2010-2011, the removal of 5 years' data had little effect on model results (Figure 146, Figure 147). This is an artifact of a data-limited situation, with respect to ages.

2.10.4 Historical Analysis

Comparisons of "depletion," spawning output, and recruitment deviations from the 2007 and 2017 assessments are shown as Figure 148, Figure 149, and Figure 150, respectively.

2.10.5 Alternate Models

The California base model explains scarcity of males in the catches using a higher natural mortality rate and smaller size at age. An alternative hypothesis is that males are less vulnerable to the fishery, relative to females, at a given size. This could be due to targeting of schools with larger average size (and therefore a larger fraction of females), or numerous other mechanisms relating to selectivity. This is consistent with the 2007 assessment (Key et al. 2008), which fixed peak male selectivity at a value less than 1, in addition to specifying gender-specific natural mortality (fixed) and gender-specific growth (some parameters fixed).

The STAT evaluated this hypothesis by profiling over values of the maximum value male selectivity could take, from 1.0 (the base model assumption), down to 30% of the female maximum (i.e. setting the 'apical' male parameter in Stock Synthesis equal to 0.3). The apical parameter was not estimable in the base model. As the apical male selectivity parameter was reduced, estimates of male length at age 30 increased, along with a decline in the difference in estimated natural mortality rate of both genders (Table 62). Total log-likelihood was minimized for an apical value of 0.5.

As noted by Key et al. (2008) BDR removals in Southern California (i.e. south of Point Conception) declined rapidly in the 1980s and have remained low, relative to historical catch, since 2000 (Figure 3). Key et al. (2008) concluded that the apparent reduction in stock size, given relatively small changes in total effort over the same time period, was likely due to environmental conditions, and pointed to a decrease in kelp abundance as a potential mechanism. The relative influence of fishing and changes in productivity south of Point Conception are not well known. The potential for spatial differences in factors affecting stock productivity (growth, recruitment) north and south of Point Conception led the current STAT to adopt the same spatial structure for the base case model as used in the previous assessment.

Currently, estimates of OFL for Southern California are based on Depletion-Corrected Average Catch (MacCall, 2009). As a sensitivity run, we added removals and indices from the region south of Point Conception to the base case model. This makes a strong assumption that all factors affecting productivity are identical in both regions. Also, the reduction in removals in Southern California since 2000 will be associated with recruitment dynamics inferred from the northern portion of the stock. If recruitment is responsible for the reduction of stock size south of Point Conception, this model run will not recognize the change and the model will predict an increasing stock size due to the reduction in total fishing mortality since 2000. As such, this sensitivity should be considered a "high biomass" scenario for the statewide stock, and interpreted with caution.

The sensitivity runs that included Southern California data were done in two steps. Catch and discard mirroring the Northern California fleet structure were added first, followed by the addition of three abundance indices. An index was calculated from dockside sampling of private boats (see section 2.2.3.2), CalCOFI data were included as an index of spawning output, with selectivity set equal to fecundity (see section 2.3.2), and onboard CPFV observer data was analyzed to generate another time series of relative abundance (see section 2.2.3.4). As expected, the addition of Southern California removals increases the overall scale of the stock (Figure 151), and results in a slightly less depleted stock due to the issues noted above (Figure 152). The effect of adding indices was minor, and fits to the Southern California indices do not match initial declines suggested by the two CPUE time series (Figure 153, Figure 154). However, recent reported increases in BDR catch rates appear to be picked up in both time series. The CalCOFI index is consistent (but variable) with the predicted increase in spawning output since 2000 (Figure 155).

3 Oregon Assessment

3.1 Commercial Fisheries Data

3.1.1 Commercial Landings and Discards – 1892 to 2016

Commercial landings of BDR were obtained from historical catch reconstructions for U.S. West Coast groundfish (1892-1986, Karnowski et al. 2014) and from the Pacific Fishery Information System (PacFIN; 1987-2016; Table 63, Figure 156). Prior to 1987, the data collection system for monitoring commercial fishery landings did not track the landings of individual rockfish species, largely because many rockfish species have similar market characteristics and therefore were landed as an unsorted mix of species. BDR are a nearshore species and much less abundant than many of the offshore rockfish species, and so when landed were included in mixed-species categories. As a consequence, the historical records do not provide a detailed accounting of the landings of BDR. The basic approach taken to develop the historical landings series in this assessment (Karnowski et al. 2014) was to apply values for the proportion of BDR sampled in mixed-rockfish landings. Data on the proportions of BDR are sparse, with the consequence that the landings reconstructions are highly uncertain.

Landings data from PacFIN, which is a central repository for U.S. West Coast groundfish landings and auxiliary information collected by ODFW and other agencies, were used from 1987 onwards. A description of basic state data collection systems and overview of PacFIN is provided in Sampson and Crone (1997). The PacFIN database includes four species identification names pertaining to BDR. The first data set consisted of direct estimates of BDR landings in Oregon waters (described as BLUR in PacFIN; 1991-2016), which were derived estimates from fish tickets, species composition estimates, and trawl-logbooks provided by ODFW. The second data set consisted of landings of BDR that were nominally landed in the Blue Rockfish market category (described as BLU1 in PacFIN; 2000-2016) that was first initiated in 2000. The third data set (DEAC in PacFIN; 2015-2016) identifies landings of Deacon Rockfish. The separation of Deacon Rockfish from Blue Rockfish landings was initiated in 2015 after observations and analyses identified that they were in fact separate species (e.g., see Hannah et al. 2015). The final PacFIN data set (URCK in PacFIN; 1987-1999) was derived from landings of rockfish for which species composition sample estimates were unavailable, but which might feasibly contain some BDR. This derivation involved applying estimates of the percentages of BDR to the landings of unspecified rockfish. Small amounts of BLUR and BLU1 that were caught in Oregon waters but brought to port in California were also included in total commercial landings (Table 63).

Commercial fishermen use two main gear types that capture BDR in Oregon waters: hook-and-line gear (jig, dingle bar, and cable, though most BDR are caught with jig gear) and longline gear. Since 2000, hook-and-line and longline gear have been used to take more than 99% (on average) of the overall BDR harvest by weight. Several other gear types harvest incidental amounts of BDR (including fish pot, troll gear, and trawl gear). Landings from these gear types were negligible and were not included in this assessment.

The onset of a readily available market for live fish, along with attractive ex-vessel prices, has been the main driving force for many nearshore species such as Black Rockfish and Kelp Greenling. However, BDR are not a main target species for nearshore commercial fishermen, and are predominantly landed as incidental catch because BDR ex-vessel value is low owing to their inability to survive to the live-fish market and market preferences for other species in the dead-fish market. The majority of commercial landings occur along the southern Oregon coastline (83%), due to the presence of a growing nearshore species live-fish market. There are a few fishermen who target BDR along the northern Oregon coastline. Total commercial landings were highest in the 1980s and 1990s, and peaked at 50.5 mt in 1993. Since 2000, landings have been fairly steady at around 5 mt per year. This stability is partially a result of state regulations (e.g., fleet size limit, trip and period landing limits, and minimum fish size limit) implemented for the Black Rockfish and BDR complex by ODFW in 2004 to limit overall commercial harvest (Rodomsky et. al. 2014; Table 3).

The amount of discarded BDR relative to retained BDR was estimated by the Groundfish Expanded Mortality Multiyear (GEMM) report. Discard ratios were available from 2002 to 2015 for the nearshore fixed-gear fishery (in waters < 50 fathoms). Mortality rates associated with discarded BDR are specified by depth bins following the approved levels specified by the Pacific Fisheries Management Council – Groundfish Management Team (see Somers et al. 2016). The average dead discard rate for BDR was 24.7% for the management area north of 40°10' north latitude (Figure 8). This value was used to calculate total discarded catch by multiplying 0.247 by annual estimates of commercial landings over the time series (1892-2016).

3.1.2 Commercial Length and Age Compositions

Commercial length and age composition data were extracted from PacFIN on May 24, 2017. These data were collected from the landed catch by port biologists from hook-and-line fisheries following a stratified, multistage sampling design. Raw length compositions were expanded to the sample level (individual port sample) to account for unmeasured fish and then to the trip level to account for inter-trip variation in landing size. Length compositions were reported in fork length and then tabulated for each gender by 2-cm length bins ranging from 10 cm to 52 cm, with accumulator bins at each end. The initial annual sample sizes used in the assessment for the commercial fishery length-composition data were the number of trips (Table 64).

Commercial discard length composition data (unsexed) were also available through the West Coast Groundfish Observer Program (WCGOP) from 2004 to 2015. Observers on commercial hook-and-line vessels measured the fork length of discarded BDR. Initial length compositions were tabulated according to the northern and the southern Oregon coasts. Final compositions were achieved by weighting area-specific compositions by catch biomass. This approach ensures that the final composition data are representative of the overall catch. The initial annual sample sizes for the commercial discard fleet were the number of trips (Table 64).

There were some differences in the aggregate length composition data between landed fish and discarded fish. Thus, we included the discard portion of commercial catch as a separate fleet. There is little evidence in any of the length composition data of distinct modes or successions of modes from one year to the next that might represent strong year-classes.

Age compositions were available for the commercial landings fleet in 2000, 2003, 2005, 2007, 2009, 2011, and 2013 to 2015. In conjunction with the ODFW ageing lab, we elected to space out years with ageing reads rather than ageing all individuals working backwards from present, given time constraints on age readers. A total of 261 males and 1,943 females were aged for developing compositional data. The initial sample sizes used in the assessment for each year were the number of aged fish by gender (Table 65). Conditional age-at-length compositions were created from the age-composition data and used as model input to facilitate internal estimation of growth parameters and to account for the lack of independence between age- and length-compositional data. Marginal age composition data were also input into the assessment model as a diagnostic to evaluate marginal fits to the age data, but these data were not included in the likelihood function when fitting the model.

3.1.3 Commercial Logbook CPUE Index, 2004-2014

In Oregon, commercial nearshore fishers are required to submit to ODFW a logbook detailing catch from all fishing trips. The state logbook program began in 2004 and data from all years through 2015 were available for this assessment. Data from 2016 were not yet available at the time of this assessment. Compliance with this logbook program has fluctuated year-to-year including a low of 65% in 2007 to averaging greater than 90% over the last five years. The completeness and quality of data recorded also varies between fishers and from year to year. The logbook database contains information on catch by species (number of retained fish), effort (hook hours), sample location (port), date, vessel, fishing depth, fishing gear, fishing permit, number of fishers, and harvest trip limits.

Logbook CPUE Data Preparation, Filtering, and Sample Sizes

Because of completeness and quality issues intrinsic to these fisher-reported data, filters were applied to extract consistent records representative of the fishery to best estimate the relative abundance trend through time. Filtering criteria and resulting sample size changes from each filtering step are summarized in Table 66. In general, data filters that were applied included eliminating records with missing or unrealistic values, including permitted trips using only hook and line jig gear from ports with appreciable data, and using only vessels that fished in at least 3 (not necessarily contiguous) years over the logbook history. Vessel operators may have changed through time as we only filtered by vessel name. The final dataset included 13,280 compliant trips (44.8% of the submitted logbook data set) which represented 61.4% of recorded catch from 121 vessels (Figure 157).

Initial data analyses identified levels or limits of filtering variables to identify trips representative of BDR catch while maintaining adequate sample sizes. Ports retained in the data were Tillamook (Garibaldi), Pacific City, Depoe Bay, Newport, Port Orford, Gold Beach and Brookings as these ports accounted for over 99% of BDR records. Trips using only hook and line jig gear were included because this gear was used to commercially catch 82% of BDR in the data set. Only limited-entry permitted trips were retained because these trips are allowed to keep more than incidental amounts of these species. Data after 2014 were excluded because a large drop (two-orders of magnitude) in the bimonthly limit occurred in 2015, and this regulation change could have influenced targeting or other changes in catchability. After filters, these data were considered representative trips for BDR catch using jigs, the main gear type used to catch BDR in Oregon's commercial fishery.

Logbook CPUE Standardization: Model Selection, Fits, and Diagnostics

The full model considered the covariates month, wave (or period which is equivalent to two-month seasonal intervals), vessel, depth bin, permit type, subregion, rugosity, and number of crew (Figure 158). All covariates were specified as categorical variables except for rugosity, which was continuous. Rugosity was included in the model to account for variation in the bathymetric reef structure where these species congregate. Month was included to account for seasonal variation in catch rates observed by commercial fishers (see Oregon Fishery Information, section 3.1.1). Permit type was included to consider differences in fishing and target strategies associated with different levels of access to nearshore species. Number of crew was included to account for differences in fishing efficiency and potential hook oversaturation. Data at the port level were sparse for all months and years, so we assigned trips to north and south 'subregions' in order to facilitate data categories conducive to exploring interactions between subregion and year. Raw catch rate data suggested that trends in CPUE over time were not similar by subregion, so we included a model with an interaction between year and subregion in the set of candidate models. Model covariates were selected with standard information criterion for relative goodness of fit (Akaike Information Criterion, AICc). Covariates were retained in the model if the overall model fit was improved by more than 2 AIC units relative to the model without the covariate.

A delta-Generalized Linear Model (GLM) approach was used to model CPUE. The binomial component for catch occurrence was modeled using a logit link function while the log of positive CPUE was modeled with a Gaussian distribution and an identity link function. Total catch was calculated by summing fishers' estimates of retained pounds and released catch counts of fish multiplied by an estimated discard weight of one pound. Effort was defined by multiplying the number of hooks by hours fished. A gamma distribution for the positive catch component was also explored, but based on graphical diagnostics it did not provide a better fit to the data. An attempt was made to specify vessel as a random effect using a delta-GLMM (generalized linear mixed model), but that model had difficulty with convergence presumably due to the large number of vessels in the data set.

Based on the Akaike Information Criterion, we selected a model with year, month, subregion, number of crew, and depth bin as the best predictor of commercial logbook catch rates (Table 67**).** Residuals from the binomial component of the delta-model are not expected to be normally distributed, so we simulated quantile residuals (Dunn and Smyth, 1996) using the R package "DHARMa." A quantile-quantile plot of the simulated residuals suggests that the binomial component of the delta-model that fits to encounters (presence/absence) is a reasonable approximation of the data (Figure 159, left panel). The lognormal component of the model that fits to positive catches also fit the data well (Figure 160).

In order to construct the final index of abundance for the commercial logbook catch-rate data, we needed to assign relative weights to the subregions in the model (following procedures outlined in 3.2.3.1). To estimate uncertainty in the final index of abundance it is necessary to account for the correlation structure between parameters within the binomial and lognormal components of the model, as well as with the combined (binomial and lognormal components) delta-model and the use of weights in the area-integrated index. We used the rstanarm package in R to replicate the best model using diffuse prior distributions that replicated point estimates from the maximum likelihood fits. The advantage of this approach is that the calculation of the index (summing relevant model parameters, combining model components, and applying area weights) can be applied to posterior draws, preserving the correlation structure and propagating uncertainty into the final index (Figure 161; Table 68). As an additional diagnostic, we generated replicate data sets from the posterior predictive distribution, and compared the maximum likelihood estimates from the positive model component to the median estimates from the posterior distribution (Figure 162). As expected, this model matches well the distribution from replicate data (Figure 163).

3.2 Recreational Fisheries Data

3.2.1 Recreational Landings and Discards – 1915 to 2016

Reconstructing Recreational Removals

Three recreational fishing fleets are used in this assessment: 1) ocean-boats (Private Boat and Rental (PBR) and Commercial Passenger Fishing Vessel (CPFV) boat types) that landed BDR, 2) ocean-boats that discarded BDR), and 3) fishing from shore (beach/bank and man-made structure types) and estuary-boats (PBR boat type). Ocean-boat catches were separated into a landings fleet and a discard fleet based on differences in the length composition data for landed BDR versus discarded BDR. The shore fleet (shore and estuary combined) was also distinguished because of differences in length composition of the sampled catch and potential differences in selectivity. For example, estuary-boat and shore fishing modes generally catch smaller individuals than ocean-boats, and there is differential access to BDR habitat that naturally occurs between shore and estuary-based modes and ocean-boats.

Total BDR landings for Oregon recreational fishing modes are provided in Table 69 and Figure 156. For the ocean-boat fleet, total landings from 1979 to 2016 were obtained from ODFW and informed by the Oregon Recreational Boat Survey (ORBS). For the shore fleet, total landings from 1980 to 1989 and 1993 to 2005 were obtained from ODFW and informed by the Marine Recreational Fisheries Statistics Survey (MRFSS). To address survey biases, spatial and temporal under-coverage, and other known errors, ODFW reconstructed both the ORBS and MRFSS historical landings for BDR (methods described below). Ocean-boat landings peaked in 1993 at over 67 mt before declining back down to a recent (from 2007 to 2016) average of 20 mt per year. Shore fleet landings have remained low in comparison, averaging around 1 mt annually, with a peak landing of 3 mt in 1999. There has been a downward overall trend in total recreational landings for BDR since the large episodic catches in the 1990s.

Recreational discards for the ocean-boat fleet were obtained from the ORBS data base from 2002 to 2016, and were based on data collected by observers on charter boat trips and information collected from ORBS dockside interviews. For dockside collections, BDR were examined by dockside samplers while discarded fish were angler reported. The dead discard rate was calculated as the proportion of discarded to retained fish multiplied by the assumed discard mortality rate by depth bin that has been approved by the Pacific Fisheries Management Council Groundfish Management Team. Dead discard estimates indicated relatively low levels of discarding, averaging less than 1 mt (or 3% of landings; Table 69 and Figure 156). However, there was a substantial increase in the dead discard rate in 2015 and, to a lesser extent, in 2016 as a result of bag limit changes (Table 1). Discard levels prior to 2002 were reconstructed (see below). This assessment assumed no discarding in the shore fleet.

Ocean-boat Landings Reconstruction (1970 – 2016)

Total landings of BDR from ocean-boats were obtained from estimates produced by ORBS. ORBS applies catch rates from a subsample of vessels (from dockside interviews) to total effort counts at fine levels of stratification (i.e., by week, port, fishery, and type of boat) to estimate total landed catch. Effort is computed by using visual counts to estimate private boat trips (i.e., number of vessels crossing the ocean bar or trailer counts) and through a census of charter boat logbooks. Since 2001, ORBS has produced comprehensive year-round estimates of catch and effort for all developed Oregon ports (and these estimates are available in RecFIN). However, prior to 2001, ORBS sampling was typically conducted at only major ports during peak months of sport fishing activity, and no estimates of catch were made for unsampled ports and during certain times of day. Therefore, ODFW reconstructed historic ORBS estimates for BDR to account for these known biases and errors (not yet available on RecFIN).

The ocean-boat reconstruction addressed four spatial and temporal coverage biases identified during an external review of ORBS by the RecFIN Statistical Subcommittee (Van Vorhees et al. 2000): (1) “major ports” that were sampled each year were not sampled during the winter months; (2) “minor ports” were not sampled at all during some years; (3) effort counts for private boats excluded afternoon and night trips; and (4) undeveloped launch sites (e.g., beaches) were never sampled. The ocean-boat reconstruction utilized ratio estimators, based on years with complete sampling, to expand catches from years with partial sampling. For instance, the contribution of winter catch to total catch during years with complete sampling was used to expand catches for years with missing winter catch. Similarly, the contribution of catch from a minor port to that of the major ports during years with complete sampling was used to expand catches to years for which the minor port was not sampled. Given these corrections, total landings from ocean-boats are considered to be reasonably comprehensive.

Landings were reconstructed from 1970 to 1978 through the use of a linear ramp. No direct information was available to estimate catch from ocean-boat fleets so catches were assumed to be zero in 1970 and then linearly increase to the catch level in 1979, the first year of catch data for this fleet. Prior to 1970, recreational ocean-boat fishermen were mainly targeting salmon, where incidental catch of BDR would have been negligible. Nonetheless, there remains significant uncertainty around historical ocean-boat landings.

Dead discards from 1979 to 2001 were reconstructed by multiplying the estimated landed catch by a constant proportion (0.0087). This proportion was estimated by using the relationship, as determined by linear regression, between annual dead discard rates and daily bag limits from the observed time series (2002-2016) to predict the reconstructed discard rate (when the bag limit was 15 rockfish). Dead discards were assumed negligible prior to 1979.

Shore Fleet Landings Reconstruction (1915 – 2016)

ODFW conducted a landed catch reconstruction for estuary-boat and shore fishing modes using two approaches. The first was to correct for known biases in the MRFSS dataset, and the second was to estimate landings for years not covered by MRFSS. Estimates of BDR landings from estuary-boat and shore fishing modes were obtained from MRFSS (1980 – 1989; 1993 - 2005). Like ORBS, MRFSS also utilized a dockside angler intercept survey component to obtain catch rates; however, MRFSS used a random-digit phone survey of residents in coastal and adjacent counties to estimate total effort. Although MRFSS had comprehensive spatial and temporal coverage, MRFSS estimates were determined to contain bias (Van Vorhees et al. 2000). The first bias was the inclusion of freshwater fishing trips in effort counts for marine fisheries that caused boat (and presumably shore-based) estimates to be overestimated by 17%. Specifically, trips conducted in zip codes that were not adjacent to the ocean were being recorded as marine trips in the phone survey. Therefore, the reconstruction applied a scaling factor to both the shore and estuary-boat estimates to remove this freshwater bias.

The second identified bias in MRFSS was a result of sampling area. Ocean-boat landings were deemed to be overestimated by 23% at the expense (underestimation) of estuary-boats. Although MRFSS estimates boat catch (by boat type), they were not stratified by area. The total (coastwide) estimates were partitioned to inland (estuary) and ocean areas based on ratios observed in the dockside survey. In order for the area partitioned estimates to be correct, the MRFSS dockside samples would have to have been representative. However, it was determined that MRFSS had oversampled the central and southern parts of Oregon that tend to have a larger proportion of ocean trips than in the north, where there is a larger proportion of estuary trips. Therefore, another scaling factor was applied to the estuary-boat estimates to account for this boat area bias. This scaling factor did not affect the shore fishing mode.

In addition to using scaling factors to account for MRFSS biases, this reconstruction also corrected for errors in weights of individual fish that were used to convert numbers of fish (measure produced by MRFSS) to metric tons. The magnitude of these errors was not inconsequential.

A reconstruction of landings outside the temporal scope of MRFSS (1915-1980; 2005-2014) was conducted through extrapolation. For years prior to 1980, no direct information was available to estimate catch from estuary-boat and shore fishing modes. Therefore, historic sales of fishing licenses were obtained from ODFW and used as an indirect measure of fishing pressure to scale landings from 1915 to 1980. There is also missing catch information in recent years (2006-2016) for shore and estuary-boat fishing modes. Since the end of the MRFSS (and ODFW sponsored equivalent program; Shore and Estuary Boat Survey, SEBS) programs in 2005, there has been no catch or effort information collected from these nearshore fishing modes. For these recent missing years, an extrapolation from a simple linear regression of the landings from 1980-2005 was used. Although the regression captured the general trend well, this approach was unable to predict the high level of inter-annual variability seen during the available data period for the shore fleet. There remains significant uncertainty around total landings for the shore fleet, but this fleet only comprises a small percentage (< 3% on average over the most recent 10 years of observed data, 1996-2005) of total BDR landings.

3.2.2 Recreational Length and Age Compositions

Recreational length composition samples for Oregon were obtained and considered from 3 sources: RecFIN (MRFSS), ODFW-ORBS, and independent ODFW length-age sampling. For 1980-1989 and 1993-2003, the MRFSS program collected unsexed individual fish lengths from both ocean and inland (estuary) areas. From 1980-1989, MRFSS collected total lengths, but after a hiatus from 1990-1992, the renewed MRFSS program began collecting fork lengths. ODFW provided data extracted from RecFIN, and included an identifier column indicating whether lengths were measured directly or converted from weights. Only lengths that were measured directly were used in this assessment. From 2003-2005, the state managed SEBS program collected fork length data from shore modes in both ocean and inland areas, and from boat modes only in inland areas. Sample sizes and number of trips by year, and fishery used to generate the effective sample size for inputs are shown in Table 64.

From 2001 through the present, the state managed ORBS program has collected unsexed groundfish fork length data from recreational boats, primarily from ocean fisheries but with a handful of samples from boats fishing in inland waters. For this assessment, ORBS length data from 2001-2014 were obtained from ODFW (Table 64). Shore based modes are not sampled by ORBS.

Age compositions were available for the recreational ocean-boat landing fleet for 1999, 2004, and 2008 through 2015. A decision was made to age BDR from a few earlier years in the time series (1999 and 2004) instead of stepping back chronologically to age fish from 2007 and 2006. This was done in an attempt to gain information on age structure further back in the time series. A total of 2,861 female, 1,205 male, and 66 unknown genders of BDR were aged for developing compositional data. The initial sample sizes used in the assessment for each year for the ocean-boat fleet were the number of aged fish by gender (Table 65). Conditional age-at-length compositions were created from the age-composition data as model input to facilitate internal estimation of growth parameters and to account for the lack of independence between age- and length-compositional data.

3.2.3 Recreational Abundance Indices (Catch per Unit Effort)

3.2.3.1 MRFSS Dockside CPFV CPUE Index, 1980-2000

Trip-level catch-per-unit-effort data (“Type 3 data”) from MRFSS dockside sampling of CPFVs (“party boats”) was downloaded from the NMFS SWFSC on 3/30/2017. These data are derived from fish sampled in angler bags following completion of a trip, aggregated to the trip level using an algorithm developed by Braden Soper (University of California, Santa Cruz). The methodology for aggregating the data to the trip level was reviewed and approved by the PFMC Scientific and Statistical Committee in March of 2013 (PFMC, 2013). A preliminary analysis conducted by ODFW indicated that the Soper algorithm may be underestimating the number of trips. However, a final determination with updated information was unavailable at the time of this assessment, so the previously approved approach was retained. The database contains information on catch by species (number of retained fish), effort (angler hours), sample location (county and interview site), date, and distance from shore (inside/outside of 3nm from shore).

MRFSS CPUE Data Preparation, Filtering, and Sample Sizes

In order to define effective fishing effort for BDR (i.e. identify trips that were likely to catch BDR), we used the method of Stephens and MacCall (2004) to predict the probability of catching a BDR given the occurrence of other species in the catch. The unfiltered data set contained 1831 trips. Species that are rarely encountered will provide little information about the likelihood of catching a BDR, so we identified 22 “indicator” species that were caught in at least 30 Oregon trips (Figure 164). Catch of these commonly-encountered species in a given trip was coded as presence/absence (1/0) and treated as a categorical variable in the Stephens-MacCall logistic regression analysis. The top five species with high probability of co-occurrence with BDR include Black rockfish, Widow Rockfish, Yellowtail Rockfish, Canary Rockfish, and Kelp Greenling, all of which are associated with rocky reef and kelp habitats in nearshore waters. These five species were all strongly associated with BDR (significantly different from zero at the alpha = 0.05 level). The five species with the lowest probability of co-occurrence were Greenstriped Rockfish, Coho Salmon, Chinook Salmon, Bocaccio, and Yelloweye Rockfish. These species are not commonly caught during the same trip as BDR, presumably due to different habitat associations and fishing techniques. The Area Under the Characteristic curve (AUC) for this model is 0.797 (Figure 165), a significant improvement over a random classifier (AUC = 0.5). AUC represents the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence.

Stephens and MacCall (2004) proposed filtering (excluding) trips from the index standardization based on a criterion of balancing the number of false positives and false negatives. False positives (FP) are trips that are predicted to catch a BDR based on the species composition of the catch, but did not. False negatives (FN) are trips that were not predicted to catch a BDR, given the catch composition, but caught at least one. The threshold probability that balances FP and FN excludes 444 trips that did not catch a BDR (24% of the trips), and 199 trips (10.9% of the data) that caught a BDR. We retained the latter set of trips (FN), assuming that catching a BDR indicates that a non-negligible fraction of the fishing effort occurred in habitat where BDR occur. Only “true negatives” (the 444 trips that neither caught BDR, nor were predicted to catch them by the model) were excluded from the index standardization.

No MRFSS CPUE data are available for the years 1990-1992, due to a hiatus in sampling related to funding issues. Although sampling of Oregon CPFVs through MRFSS lasted until 2003, the years 2001 through 2003 were removed from the index due to a bag limit change from 15 to 10 fish beginning in 2001 which could affect catch rates. The bag limit remained unchanged (15 fish) from 1980-2000.

Sample size was also very low in 2003 with insufficient spatial coverage. Other minor filters were applied to the final data set that was used to model CPUE trend (Table 70).

MRFSS CPUE Standardization: Model Selection, Fits, and Diagnostics

Data at the county level were sometimes sparse, so we assigned trips to north and south 'subregions' (Figure 166). Apart from differences in catch rate among subregion and year, we also considered changes associated with 2-month "waves" and a coarse measure of distance from shore ("Area_X" in the MRFSS data; Figure 167). This distance variable is a categorical variable indicating whether most of the fishing took place inside (Nearshore) or outside (Offshore) of 3 nautical miles from shore, as reported by anglers during each interview. Raw catch rate data suggested that trends in CPUE over time were mostly similar by subregion, but we included a model with an interaction between year and subregion in the set of candidate models.

Based on the Akaike Information Criterion, we selected a model with year, wave (or period) and subregion as the best predictor of MRFSS catch rates (Table 71**).** The variable nearshore area ("Area_X") did not reduce the AIC score by more than 2 AIC units and therefore was not included in the index. Predicted means from the best-AIC model were consistent with the observed means (Figure 168). Residuals from a negative binomial regression are not expected to be normally distributed except under very specific conditions, so we simulated quantile residuals (Dunn and Smyth, 1996) using the R package "DHARMa." A quantile-quantile plot of the simulated residuals suggests that the negative binomial distribution is a reasonable approximation of the data (Figure 169, left panel).

In order to construct the final index of abundance for the MRFSS catch-rate data, we needed to assign relative weights to the subregions in the model. Treating CPUE as proportional to density, we multiplied annual predicted CPUE in each subregion by the area in that subregion to obtain an estimate of relative abundance. Summing across subregions within each year produces an area-weighted (integrated) time series of relative abundance. R. Miller (NMFS SWFSC) provided area estimates of rocky reef habitat derived from 100-meter resolution bathymetric data available from the Active Tectonics Seafloor Mapping Lab (http://activetectonics.coas.oregonstate.edu/). Total reef area in each subregion was defined by boulder, cobble, cobble mix, hard rock, and rock mix substrates and then normalized to sum to one, with roughly 82% found in northern nearshore waters (north of Lane County, OR) and 18% found in southern Oregon nearshore waters.

To estimate uncertainty in the final index of abundance it is necessary to account for the correlation structure between parameters of the negative binomial regression, as well as the use of weights in the area-integrated index. We used the rstanarm package in R to replicate the best model using diffuse prior distributions that replicated point estimates from the maximum likelihood fits. The advantage of this approach is that the calculation of the index (summing relevant model parameters and applying area weights) can be applied to posterior draws, preserving the correlation structure and propagating uncertainty into the final index (Figure 170; Table 68). As an additional diagnostic, we generated replicate data sets from the posterior predictive distribution, and compared the distribution of the proportion of zeros in the replicate data sets to the observed proportion of zeros. The negative binomial model is able to reproduce the observed proportion of zeros in the data (Figure 171), similar to the delta-GLM approach (Stefánsson 1996) but requiring fewer parameters.

3.2.3.2 ORBS Dockside CPUE Index, 2001-2016

The Oregon Recreational Boat Survey (ORBS) data series does not include full species composition information for most years. The analysis of these data was restricted to the years 2001-2016, when species composition of the catch is available. Trip-level catch-per-unit-effort data from ORBS dockside sampling was obtained from ODFW on 3/6/2017. To mitigate the confounding of hourly effort associated with these trips with travel, the travel time was subtracted from the hours fished. Travel time was stratified by boat type (charter and private) and was calculated as boat type-specific speeds (13 mph for charter boat trips and 18 mph for private boat trips) multiplied by twice the distance between the port of origin and the reef fished. CPUE, expressed in terms of fish per angler-hour, was calculated by multiplying the number of anglers and the adjusted effort. The database contains information on catch by species (number of retained fish), effort (angler hours), sample location (port where data collected), date, bag limits, boat type (charter or private), and trip type (e.g., bottom associated fish).

ORBS CPUE Data Preparation, Filtering, and Sample Sizes

In order to define effective fishing effort for BDR (i.e. identify trips that were likely to catch BDR), we used the method of Stephens and MacCall (2004) to predict the probability of catching a BDR given the occurrence of other species in the catch. The unfiltered data set contained 575,113 trips, but after several initial filters to remove outliers and data not suitable for a BDR index 69,520 trips remained (Table 72) for applying the Stephens and MacCall method. Species that are rarely encountered will provide little information about the likelihood of catching a BDR, so we identified 41 "indicator" species that were caught in at least 30 Oregon trips (Figure 172). Catch of these commonly-encountered species in a given trip was coded as presence/absence (1/0) and treated as a categorical variable in the Stephens-MacCall logistic regression analysis. The top five species with high probability of co-occurrence with BDR include Black Rockfish, Yellowtail Rockfish, Rosy Rockfish, Gopher rockfish, and Smelt, the first four of which are commonly associated with rocky reef and kelp habitats in nearshore waters. The top four species were all strongly associated with BDR (significantly different from zero at the alpha = 0.05 level), while Smelt was more variable. The five species with the lowest probability of co-occurrence were Greenstriped Rockfish, Pacific Halibut, Boccaccio, Grass Rockfish, and Striped Surfperch. These species are not commonly caught during the same trip as BDR, presumably due to different habitat associations and fishing techniques. The Area Under the Characteristic curve (AUC) for this model is 0.746 (Figure 173), a significant improvement over a random classifier (AUC = 0.5). AUC represents the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence.

Stephens and MacCall proposed filtering (excluding) trips from the index standardization based on a criterion of balancing the number of false positives and false negatives. The threshold probability that balances FP and FN excludes 39,463 trips that did not catch a BDR (57% of the trips), and 9,470 trips (13.6% of the data) that caught a BDR. We retained the latter set of trips (FN), assuming that catching a BDR indicates that a non-negligible fraction of the fishing effort occurred in habitat where BDR occur. Only "true negatives" (the 39,463 trips that neither caught BDR, nor were predicted to catch them by the model) were excluded from the index standardization.

After filtering for species composition, further filters were applied to port, effort, bag limit, and catch rate attributes (Table 72). Removed from the final data set were ports with sparse data, outlying and irrational effort reporting, and extreme catch rates. Trips where the total catch of BDR was greater than or equal to the bag limit for all anglers were removed to minimize trips with inflated fishing effort for BDR as a result of target switching.

ORBS CPUE Standardization: Model Selection, Fits, and Diagnostics

Data at the port level were sparse for all months and years, so we assigned trips to north and south 'subregions' and to season (a compilation of winter and summer months; Figure 174) in order to facilitate data categories conducive to exploring interactions between subregion and year. Apart from differences in catch rate among subregion, season and year, we also considered changes associated with boat type (charter and private; Figure 175). Raw catch rate data suggested that trends in CPUE over time were not similar by subregion, so we included a model with an interaction between year and subregion in the set of candidate models.

Based on the Akaike Information Criterion, we selected a model with year, season, subregion, boat type, and a year by subregion interaction as the best predictor of ORBS catch rates (Table 73**).** Predicted means from the best-AIC model were consistent with the observed means (Figure 176). Residuals from a negative binomial regression are not expected to be normally distributed except under very specific conditions, so we simulated quantile residuals (Dunn and Smyth, 1996) using the R package "DHARMa." A quantile-quantile plot of the simulated residuals suggests that the negative binomial distribution is a reasonable approximation of the data (Figure 177, left panel).

In order to construct the final index of abundance for the ORBS catch-rate data, we needed to assign relative weights to the subregions in the model (following procedures outlined in 3.2.3.1). To estimate uncertainty in the final index of abundance it is necessary to account for the correlation structure between parameters of the negative binomial regression, as well as the use of weights in the area-integrated index. We used the rstanarm package in R to replicate the best model using diffuse prior distributions that replicated point estimates from the maximum likelihood fits. The advantage of this approach is that the calculation of the index (summing relevant model parameters and applying area weights) can be applied to posterior draws, preserving the correlation structure and propagating uncertainty into the final index (Figure 178; Table 68). As an additional diagnostic, we generated replicate data sets from the posterior predictive distribution, and compared the distribution of the proportion of zeros in the replicate data sets to the observed proportion of zeros. The negative binomial model is able to nearly reproduce the observed proportion of zeros in the data (Figure 179). Differences are due to the large amount of data associated with the ORBS index, which produces very fine mean distributions.

3.2.3.3 OR Onboard Observer Index, 2001 and 2003-2016

The onboard observer program in Oregon collects drift-level information for each observed fishing trip. Information recorded during each fishing drift includes start and end times, start and end depth, start and end location (latitude/longitude), number of observed anglers (a subset of the total anglers), and the catch (both retained and discarded) by species of the observed anglers. The onboard observer program was initiated by ODFW in 2001 and became a yearly sampling program in 2003 (Monk et al. 2013), therefore no data was obtained in 2002. The onboard sampling data for Oregon are through 2016. Data for the onboard observer (OBO) index were analyzed at the drift-level and catch was calculated as the sum of observed retained and discarded fish.

OR OBO CPUE Data Preparation, Filtering, and Sample Sizes

A number of different filters were applied to the OBO data in order to define effective fishing effort. The unfiltered data set included 13,501 drifts but after several filters were applied to the data, 11,701 drifts remained for the analysis, 2,359 of which (20.2%) had a positive catch for BDR. The filters excluded drifts based on distance from reef center, distance from shore, depth and species composition. A logistic regression was used to estimate the decay rate of BDR catch as fishing moved away from known reefs. The majority of drifts that caught BDR were within 1000 m of a reef, so drifts further than 1000 meters from reef center were excluded. Other filtering criteria and resulting change to sample sizes are described in Table 74**.** Excluded records were primarily for drifts that did not catch BDR, eliminating only 33 positive catch drifts from a total of 1,800 removed.

Data were divided spatially into categorical variables for area (SUBREGION; 2 levels representing mega reefs north and south of Florence) and temporally by YEAR (15 levels), MONTH (12 levels), SEASON

(2 levels, Mar-Jun, July-Oct) and two month blocks (WAVE; 4 levels, Mar-Apr, May-Jun, Jul-Aug, Sep-Oct). Depths were divided into three bins (DEPTH_BIN; 0-20 m, 21 – 40m, 41-79 m). In nearshore waters, the region south of Florence comprised a larger total reef area representing 80% of the area where BDR were encountered with 20% occurring in the northern subregion. These area proportions were used as weights to calculate the area-weighted CPUE indices.

OR OBO CPUE Standardization: Model Selection, Fits, and Diagnostics

A negative binomial regression analysis was used to model CPUE with log-transformed angler hours specified as an offset parameter. Model covariates were selected using AIC as the criteria for evaluating goodness of fit. Catch rates were best predicted with a model containing year, month, subregion, depth bin and a year by subregion interaction term (Table 75). Predicted means from the best model output are consistent with observed the means from the data (Figure 180). Evaluation of model variance was conducted with methods similar to those used for the MRFSS index (described above). Quantile residuals were simulated using the R package "DHARMa." (Dunn and Smyth, 1996) and visual inspection of the quantile-quantile plot of simulated residuals suggests that the negative binomial distribution is a reasonable approximation of the data (Figure 181, left panel).

Construction of the final index of abundance for the Oregon onboard observer data requires assignment of relative weights to the subregions in the model. This was completed by multiplying the annual predicted CPUE in each subregion by its area to obtain an estimate of relative abundance then summing across subregions within each year to produce an area-weighted (integrated) time series of relative abundance. To estimate uncertainty in the final index of abundance it was necessary to account for the correlation structure between parameters of the negative binomial regression model, as well as the use of weights in the area-integrated index. The rstanarm package in R was used to replicate the best model using diffuse prior distributions to approximate point estimates from the maximum likelihood fits (Figure 182; Table 68). As an additional diagnostic, replicate data sets were generated from the posterior predictive distribution. The distribution of the proportion of zeros in the replicate data sets was then compared to the distribution of proportion of zeros from the observed data. This comparison indicated that the negative binomial model is effective in reproducing the proportion of zeros in the observed catch rate data (Figure 183).

A summary of the characteristics of abundance indices in the BDR base models is provided as Table 53.

3.3 Fishery-Independent Data

3.3.1 ODFW Research Sampling for Small Fish, 2016-2017

Targeted research sampling was conducted by ODFW in December 2016 and February 2017 to collect small-sized BDR rockfish for ageing. Preliminary data summaries indicated a lack of information on size-at-age for BDR younger than 4 years old. Without information on length and age of small BDR, estimates of species- and sex-specific growth, especially the rising limb of the von Bertalanffy growth curve, was quite uncertain (Hannah et al. 2015). In response, ODFW sought out small BDR by fishing herring jigs in BDR habitat near Seal Rock and Stonewall Bank. These efforts lead to 124 additional samples of length and age (57 females, 53 males, and 14 with gender unknown) that were incorporated into the BDR assessment as conditional age-at-length data to help inform growth (Table 65). This data set included lengths spanning from 8-27 cm and ages from 0-9 years.

3.4 Biological Data

3.4.1 Natural Mortality

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

Revaluating the data used in Then et al. (2015) by fitting the one-parameter A_{max} model under a log-log transformation (such that the slope is forced to be -1 in the transformed space (as in Hamel 2015)), the point estimate for *M* is:

$$M = \frac{5.4}{Amax}$$

The above result is also the median of the prior distribution for each gender, depending on the specified maximum age for males and females. The prior is defined as a lognormal with mean $\ln(\frac{5.4}{Amax})$ and SE = 0.438. Using a maximum age of 34 for females and 29 for males, the point estimate and median of the prior are 0.159 for females and 0.186 for males.

For the base model, female and male natural mortality were fixed at the median of the prior (values specified above). Sensitivity runs were conducted that estimated female and male natural mortality and estimated female natural mortality with alternative male fixed offset values. The fixed offset values were based on Then et al. 2015 von Bertalanffy growth function approach offset value (offset = 0.5242), and the average of the Hamel (2015) prior offset value and the Then et al. 2015 von Bertalanffy growth function approach offset value (offset = 0.3416). The growth parameters used for the Then et al. 2015 approach were estimated outside of the assessment model (Figure 184).

3.4.2 Growth

Only a few studies have examined the age and growth of BDR. Laidig et al. (2003) presented gender-specific von Bertalanffy growth estimates from California samples, but those may not be applicable to Oregon waters. Blue Rockfish growth was also discussed in McClure (1982) from samples taken off of Newport, Oregon, but that study estimated much faster growth rates (*k* = 0.23 and 0.31 for males and females, respectively) than previously seen for this species (Laidig et al. 203). A recent study conducted by Hannah et al. (2015) estimated BDR growth by gender and species (Deacon female: *Linf* = 37.90, *k* = 0.24, *t0* = -0.70; Deacon male: *Linf* = 29.54, *k* = 0.41, *t0* = -0.31; Blue female: *Linf* = 40.79, *k* = 0.11, *t0* = -6.36; Blue male: *Linf* = 31.21, *k* = 0.10, *t0* = -12.00), except this study lacked data on small sized (aged) fish which increased uncertainty in predictions. In response, ODFW targeted small BDR with herring jigs in December of 2016 and February of 2017 to supplement available age-length data to facilitate estimating growth curves (see section 3.3.1). This additional data was appended to the Hannah et al.

(2015) data set, totaling 2,152 Deacon female ages, 1,030 Deacon male ages, 615 Blue female ages, and 117 Blue male ages. We then re-estimated the von Bertalanffy growth parameters and explicitly evaluated whether there were differences in the parameters between gender and species (see Section 2.4.2 for further details). In summary, the results from the general linear model indicated that the best fit to the data included differences in growth between males and females in Oregon waters (AIC = 16633.1), but not the additional difference between species (AIC=16638.6; Figure 184). Parameter estimates were 0.21 and 0.4 for female and male *k*, respectively, and 37.90 and 29.89 for *Linf*.

The lack of observing larger male fish could be the result of increased natural mortality, relative to females, the fishery not selecting for slower growing males due to size-based gear selectivity, or that larger males are unavailable to the fishing gear (either emigrating beyond the nearshore fishery or become non-aggressive to jig gear). Whatever the mechanism, there is a disproportionate amount of larger female BDR being retained relative to larger male BDR.

3.4.3 Maturity and Fecundity

BDR maturity is based on length for this assessment. Maturity ogives were estimated for each species (193 Deacon Rockfish; 120 Blue Rockfish) using logistic regression on a combination of macroscopically- and histologically-determined maturity stage samples (Hannah et al. 2015). Age and length at 50% maturity estimates for female Blue Rockfish were 4.3 years and 26 cm, and were 5.7 years and 29 cm for Deacon Rockfish (Hannah et al. 2015). A single maturity curve for BDR was needed for this assessment, so species-specific curves were combined by weighting individual species logistic regression parameter estimates by estimates of species composition from 8,844 samples identified to species (instead of complex) in the commercial and recreational fisheries. The input parameters for length at 50% maturity and the logistic regression slope are 28.80 and -0.98, respectively (Figure 185).

This assessment makes the assumption that fecundity is a power function of female body length, $F = aL^{b}$. Values for b (4.816) and a ($1.14e^{-08}$) were taken from Dick et al. (2017). Since the exponent of the fecundity-length relationship is greater than the exponent of the fecundity-weight relationship, weight-specific fecundity (eggs or larvae per gram female body weight) also increases with size.

3.4.4 Length-Weight Relationship

Length-weight relationships for BDR were estimated outside of the assessment model using data from the Oregon Sport Boat Survey (ORBS) biological database. The weight-length parameters for combined females and males were estimated from 54,980 individual BDR are $\alpha = 2.67x10^{-5}$ and $\beta = 2.90$, following the standard power function formulation $W = \alpha(L^{\beta})$ where weight is in kilograms and length is in centimeters (Figure 186).

3.4.5 Stock-Recruitment Relationship

The Oregon BDR assessment assumes a Beverton-Holt stock-recruit relationship (Beverton-Holt 1957) following the parameterization that uses steepness. Steepness is defined as the proportion of average recruitment for an unfished population expected for a population at 20% of unfished spawning output. The value of steepness provides an indication of stock productivity and resilience to fishing pressure. Because steepness is a difficult parameter to estimate, there have been several attempts to estimate Bayesian prior distributions based on meta-analytic approaches (Myers et al. 1995; Dorn 2002; Thorson et al. in press). The 2017 updated prior predictive distribution based on the Thorson et al. (in press) approach, which builds upon Dorn's earlier work, is a mean of 0.718 with a standard deviation of 0.158. We attempted to estimate steepness, but a lack of contrast in exploitation lead to little information about steepness so the influence of alternative fixed steepness values was assessed using likelihood profiles.

3.4.6 Age Structures

Otoliths from BDR were collected from the recreational ocean-boat fleet, the commercial fleet (mainly hook-and-line), and from ODFW research samples (Table 65). Otoliths were aged using a combination of the break and burn method and surface reads by the ODFW ageing lab, however all final age determinations (except for a few otoliths collected from small individuals) were from the break and burn method. This method is more precise than surface reads (Beamish 1979, Kimura et al. 1979). A total of 4,132 BDR were aged from the recreational ocean boat fishery (1999, 2004, and 2008-2015), 2,204 from the commercial fishery (2000, 2003, 2005, 2007, 2009, 2011, and 2013-2015), and 124 from ODFW research collections (2016-2017) that were used for this assessment. Very few fish under 24 cm (and none under 18 cm) were collected from the fisheries for ageing, making it difficult to reliably estimate growth (namely predicting the length at ages 0 to 3 and growth coefficients parameters). In response to this knowledge gap, ODFW aged an additional set of male and female Blue Rockfish and Deacon Rockfish collected from targeted survey trips in December of 2016 and February of 2017. The research age-length data were assumed to be collected in 2016 and incorporated into the assessment to inform the male and female growth curves.

Ageing error was incorporated into the assessment as a source of observation error by analyzing otoliths that had been independently read twice by the same age reader (within reader variation) and by two different age readers (across reader variation). The latter approach also evaluated potential ageing error bias across ageing laboratories. The Punt et al. (2008) method and ageing error software (Thorson et al. 2012) was used to determine the underlying true age distribution and resultant imprecision. The first reader in all comparisons was assumed unbiased, but as mentioned, alternative reader bias configurations were evaluated. The functional form of the bias was specified as curvilinear. Within reader variation was assessed by comparing 1,123 internally double read otoliths by the ODFW ageing lab (i.e., same age reader blindly reading otoliths twice). This approach assumes that the ODFW ageing lab is unbiased, but accounts for internal ageing lab observation error (Figure 187). A comparison of 257 inter-lab double reads (CA and OR ageing labs) showed differences in ageing among labs (Figure 188; Figure 189). Therefore, a second ageing matrix was estimated where the OR ageing lab was assumed biased relative to the CA ageing lab. The base case assessment model assumed that the ODFW ageing lab was unbiased and used the ageing error matrix pertaining to within reader variation (Table 76). A sensitivity model run was evaluated that assumed the ODFW ageing lab was biased (CA ageing lab was unbiased) and used the ageing error matrix pertaining to across reader variation.

3.5 Data Considered for the Oregon Assessment but not Used

<u>Fishery-Independent Data</u>

NMFS Fishery-Independent Trawl Surveys
BDR are poorly sampled in fishery-independent bottom trawl surveys. BDR only were reported in 14 of 16,917 trawl sets (0.08%) conducted from 1977-2015 during Groundfish Shelf, Groundfish Slope, Groundfish Triennial Shelf, and Groundfish Slope and Shelf Combination (i.e., the current “West Coast Groundfish Bottom Trawl Survey) surveys. A total of 401 BDR were collected in these 14 tows, which were conducted from 33.79-42.60° N at average depths ranging of 60-132 m.

Black Rockfish also are poorly sampled in fishery-independent trawl surveys. Black Rockfish only were reported in 41 of 16,917 trawl sets (0.24%) conducted from 1977-2015 during Groundfish Shelf, Groundfish Slope, Groundfish Triennial Shelf, and Groundfish Slope and Shelf Combination surveys. A total of 271 Black Rockfish were collected in these 41 tows, which were conducted from 35.15-48.59° N, at average depths ranging of 59-146 m.

None of the tows containing BDR and Black Rockfish overlapped; these species were never caught in the same tow.

NMFS SWFSC Pelagic Juvenile Rockfish Index

The Fishery Ecology Division of the Southwest Fishery Science Center has conducted a standardized pelagic juvenile trawl survey during May-June every year since 1983 (Ralston et al. 2013; Sakuma et al. 2016; Field et al. 2017). However, catches are sufficiently rare for this species off of Oregon and Washington (only 30 positive hauls in six years over 14 years of sampling, such that eight years have no positive observations for either Blue or Deacon Rockfish), that the development of a robust index was not tractable.

Oregon Department of Fish and Wildlife ROV camera surveys

Since 1995, ODFW has conducted surveys used to enumerate fish densities at sampled reefs (or reef complexes). These surveys have limited spatial and temporal coverage, but do provide some information on BDR density at those sites. However, ROV surveys are typically not conducive to evaluating species found in the water column. Methods to evaluate detection/sighting probabilities and camera happy/shy behavior are being explored.

Oregon Department of Fish and Wildlife nearshore acoustic surveys

A pilot acoustic survey is currently underway in the Seal Rock nearshore area of the Oregon coast to evaluate the ability of using acoustics to develop absolute abundance estimates for species found in the water column, such as Black Rockfish and BDR. This survey shows potential and survey methods should be reviewed. The pilot nature of the survey study offers limited spatial and temporal coverage for use in the current assessment, and the acoustic methods for such a survey are currently in the developmental stage.

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)

SCUBA transects and hook-and-line sampling was conducted at reef sites predominantly in California waters, but some along Oregon nearshore coastal waters. This data set was explored as an index of abundance, but ultimately wasn't used in the base case assessment model (see section 2.5 for further details).

<u>Fishery-Dependent Data</u>

Pikitch study

The primary goal of the Pikitch study (Pikitch et al. 1988) was to collect retained and discarded catch information from trawl fleets (bottom, midwater, and shrimp trawl gears) operating near the Columbia INPFC area (1985 – 1987). BDR are poorly sampled using trawl gear and have been rarely encountered by the trawl fleet historically, thus this data set was not used in this assessment.

Enhanced Data Collection Project (EDCP)

ODFW collected bycatch and discard information for groundfish species caught using trawl gear off the coast of Oregon (1995 – 1999). BDR are not targeted using trawl gear and have been rarely encountered by the trawl fleet historically, thus this data set was not used in this assessment.

Oregon Model

3.5.1 History of Modeling Approaches Used for this Stock

This stock assessment represents the first for BDR in Oregon waters. Previously, BDR contributions to the northern nearshore rockfish complex OFL have been based on the data-limited depletion-corrected average catch (DCAC) method (see section 1.6.2). A full stock assessment was conducted for Blue Rockfish in California waters in 2007 (Key et al. 2008). A summary of the modelling approaches used for that assessment can be found in section 2.6.1.

3.5.2 Response to STAR Panel Recommendations from Previous Assessment

Although this is the first full stock assessment for BDR in Oregon waters, several of the STAR panel recommendations for the 2007 Blue Rockfish assessment in California waters are relevant. We briefly respond to those recommendations below that were deemed likely to be pertinent to BDR in Oregon.

Construct a catch history for Blue Rockfish as far back as feasible

A catch reconstruction was completed for each fleet in Oregon. The commercial fleet catch reconstruction was based on work by Karnowski et al. (2014; further information is available in section 3.1.1) and spanned the years (1892 to 1986) before reliable data were available. Catches from the recreational ocean boat fleet (1928-1978) were reconstructed in proportion to the State of Oregon fishing license sales (see section 3.2.1). The recreational shore (and estuary) fleet catches were reconstructed from 1915 to 1979, 1990-1993, and 2006-2016 using information from license sales (first two time periods) and recent average catches (last time period; see section 3.2.1 for further details)

There needs to be increased biological sampling for Blue Rockfish ages

We have included 6,460 ages in this Oregon assessment, spanning the commercial and recreational fleets, survey samples, and the years 1999 to 2015

The Blue Rockfish model should incorporate ages as conditional age-at-length data

This assessment utilizes all age data in the form of conditional-age-at-length information

There needs to be adequate justification for including gender-specific (e.g., male) selectivity patterns

The Oregon base case model specifies selectivity as gender invariant. However, alternative hypotheses have been developed (and models evaluated) about why large males do not appear in the catch. This disappearance could be a result of higher male natural mortality (base case assumption) or different selectivity patterns (e.g., larger males are unavailable to the gear due to movement away from nearshore fishing grounds). Further models are being developed and will be presented at the 2017 STAR panel

Further analyses of Blue Rockfish growth patterns are needed, because growth appears to show complex patterns

We conducted separate growth analyses (outside of the assessment) using the most current data available. The results show that for Oregon waters, growth is mostly consistent by region (northern coast compared to the southern coast) and by species (Blue and Deacon Rockfish), but does vary considerably by gender. The base model incorporates these results into the parameterization of growth (i.e., different growth patterns for male and females).

The development of fishery-independent time series for use as an index of abundance would be beneficial to the assessment

Although we fully agree with this recommendation, unfortunately a temporally and spatially representative fishery-independent survey that could be used in assessments has not been initiated for nearshore species in Oregon

3.5.3 Transition to the Current Stock Assessment

This is the first full assessment for BDR in Oregon waters so no direct transition from a previous assessment was possible. However, there was a transition from the 2007 Blue Rockfish assessment conducted in California waters (Key et al. 2008) to the current California BDR assessment (see section 2.6.3**)**. The base modeling assumptions used in the final transition step for the California model was used as a starting point for evaluating Oregon assessment models and building the base case model.

3.5.4 Model Specifications

The assessment is structured as a single, sex-disaggregated, unit population, spanning Oregon marine waters. There is little information available on BDR movement rates within Oregon or among adjacent states, although BDR are rarely encountered north of Astoria, OR. From 13 tagged fish in central California, Blue Rockfish predominantly displayed site fidelity over the course of one year and had home ranges less than half a square kilometer (Green et al. 2014).

The assessment model operates on an annual time step covering the period 1892 to 2017 (not including forecast years), assumes negligible catch prior to that time, and thus assumes a stable equilibrium population prior to 1892. Population dynamics are modeled for ages 0 through 35, with age-35 being the accumulator age. The maximum observed age was 37 for males and 35 for females; however, ninety-nine percent of observed male ages were below age-26 and below-28 for females. Population bins were set every 1 cm from 0 to 60 cm, and data bins were set every 2 cm from 6 to 46 cm. The model tracks catch across two sectors (commercial and recreational) and five fleets, and is informed by 4 separate abundance indices. Recruitment was related to spawning output using the Beverton-Holt stock recruitment relationship with log-normally distributed, bias corrected process error. Growth was modeled across a range of ages from 1 through 30. All catch was assumed to be known without error. Model sensitivity to alternative catch histories was explored.

Fleets were specified for recreational and commercial sectors. The recreational sector was split into three main fleets: an ocean-boat fleet for landed BDR, an ocean-boat fleet for discarded BDR, and a shore fleet for landed BDR. The shore fleet is a compilation of fishing by boat in estuaries, fishing from manmade structures on shore, and fishing from beach and banks along the shore. The commercial sector was represented by two fleets: a hook-and-line and longline gear type commercial fleet for landed BDR and one for discarded BDR. Landings and discards (when available) were separated into different fleets for the recreational ocean-boat and commercial sectors to accommodate differences in the observed length composition of retained versus discarded BDR. Fleet selectivity was assumed to be asymptotic for the recreational ocean landings fleet and the commercial landing fleet, dome-shaped for the commercial and recreational discard fleets and the shore fleet, and was gender invariant. The recreational ocean-boat and commercial landings fleets were specified as asymptotic because larger BDR should be vulnerable to hook sizes that are typically used with jig and longline gear that targets nearshore species. Sensitivity to these selectivity assumptions were explored during model development and relative to the base model (see section 3.9).

The time-series of data used in this assessment is summarized in Figure 190. Sample sizes for length composition, age composition, and mean body weights are also summarized (Table 64, Table 65, and Table 77). For yearly length-composition data, initial sample sizes for recreational fleets were set at the number of sampled trips. For the commercial fleet, the initial sample size was set to the number of hauls. Length composition sample sizes were then tuned in the base assessment model using the Francis weighting method (Francis 2011). The Francis method resulted in down-weighting of all recreational fleet sample sizes, except for the ocean-boat discard fleet was up-weighted slightly (Table 78).

Conditional age-at-length data were used in the assessment model to inform estimation of growth and to alleviate the potential lack of independence among dual age and length-composition information for the same sample. Age-at-length composition sample sizes were set at the number of aged fish in each population bin. These data were weighted according to the harmonic mean effective sample size (McAllister and Ianelli 1997) by using tuning scalars that are generated using the r4ss package in program R (https://github.com/r4ss/r4ss). The harmonic mean approach resulted in a down-weighting of recreational, commercial, and research age sample sizes (Table 78). Alternative approaches to weighting were explored through sensitivity evaluations (see section 3.9.1).

Among data source weights (or emphasis factors) can also be specified in Stock Synthesis (i.e., “lambdas”). In this assessment, there was no clear reason to down-weight (up-weight) particular data sources relative to each other, so all were assumed to have equal emphasis in the base case model.

A prior distribution was specified for male and female natural mortality following the Hamel (2015) meta-analytic approach (see section 3.4.1 for more details). A lognormal prior for natural mortality was applied when attempting to estimate female (mean = -1.84, standard deviation = 0.438) and male (-1.68, 0.438) natural mortality (Figure 191). A beta prior was applied when attempting to estimate steepness of the stock recruitment curve (0.718, 0.158) during sensitivity evaluations. The steepness prior was developed from a west coast groundfish meta-analysis (Dorn et al. 2002; Thorson et al. in press).

Likelihood components that were minimized in the overall fitting procedure include fleet-specific catch, length composition, and conditional age-at-length composition and also survey, recruitment deviate, parameter prior, and parameter soft-bound components. Initial model explorations utilized individual and combined likelihood values to assist in model development.

This assessment used a recent version of Stock Synthesis 3 (version V3.30.03.07), which was provided by Rick Methot (NOAA-NWFSC) and Teresa Amar (NOAA-OST). The basic population dynamic equations used in Stock Synthesis 3 can be found in Methot and Wetzel (2013). The relevant input files (starter.ss, data.ss, ctl.ss, and forecast.ss) necessary to run the stock assessment can be found on the Pacific Fisheries Management council website (http://www.pcouncil.org/groundfish/stock-assessments/).

3.5.5 Model Parameters

The population dynamics model has many parameters, some estimated using the available data in the assessment and some fixed at values either external to the assessment or informed by the available data. A summary of all estimated and fixed parameter values, including associated properties, are listed in Table 79.

A total of 72 parameters were estimated in the base model. Time-invariant growth parameters (Brody growth coefficient, length at minimum age, and CV old/young) using the Schnute parameterization of the von Bertalanffy growth function were estimated for each gender, where males were estimated as an offset of female parameters. The exceptions were: the CV associated with young (length at minimum age) males was fixed at the value estimated for females; the CV associated with old (length at maximum age) males was fixed at the value estimated in the California BDR model; and the male length at minimum age was fixed to that estimated for females. Selectivity was assumed to be asymptotic and related to length by a logistic function for the recreational ocean landings fleet and the commercial landings fleet, and dome-shaped for the commercial and recreational discard fleets and the recreational shore fleet. Selectivity for the ODFW research survey assumed that all small BDR were fully selected so no parameters were estimated for this data source. All selectivity parameters were assumed to be time-invariant, except a time block was used to capture changes in selectivity as a result of the implementation of reduced bag and trip limits for BDR in 2015. Recruitment deviates were estimated in the base model from 1970 – 2015. Initial (equilibrium) recruitment was also estimated. Coefficients of variation about the abundance indices derived from posterior predictive intervals (or other resampling techniques) may underestimate the true uncertainty regarding the relationship between these indices and biomass. Thus, extra standard deviation parameters were estimated for each abundance index.

The base model assumed a stock-recruitment steepness of 0.718, which is the mean of the posterior predictive distribution based on a west coast groundfish meta-analysis (Dorn et al. 2002; Thorson et al. in press). Natural mortality was fixed at the Hamel (2015) median of the prior distribution (see section 3.4.1). Recruitment variation about the stock recruitment curve was fixed at 0.50, a value tuned to the estimated recruitment deviation RMSE plus a slight adjustment upward to account for unmeasured process error. Estimates from the Hannah et al. (2015) study were used to specify the maturity ogive, and weight-length relationships were derived from recreational samples from 2001-2016. Parameters for fecundity were fixed at estimates following methods in Dick et al. 2017. Several of the parameterization decisions were further examined through sensitivity analysis (section 3.9).

3.6 Oregon Base Model Selection and Evaluation

3.6.1 Key Assumptions and Structural Choices

Many of the key assumptions and structural choices made in this assessment were evaluated through sensitivity analysis (section 3.9). For consistency, model structural choices were made that were likely to result in the most parsimonious treatment of the available data, either *a priori* determined or through the evaluation of model goodness of fit. The major structural choices in this assessment were the use of a single closed area (Oregon marine waters) to adequately describe gender-specific population dynamics of BDR, and gender-specific differences in natural mortality to account for sex-ratio differences in the observed catches. Data inputs available for this assessment arise from fisheries that predominantly occur in the nearshore zone (< 40 fathoms), while observations suggest BDR also inhabit offshore areas (> 40 fathoms).

Major assumptions included fixing the steepness stock recruitment parameter and the variability parameter associated with recruitment deviations (sigma-R), including fixed gender-specific natural mortality parameters, and gender invariant selectivity parameters (Table 79). Female and male natural mortality were fixed at the median of the prior predictive distribution following methods of Hamel (2015). The median of the calculated prior distribution was 0.159 for females, and the specified offset for males was 0.159 (equivalent to 0.186 once back-transformed), which is reasonably different from that used in the 2007 California Blue Rockfish assessment (0.12 for females and 0.10 for males). Selectivity was assumed to be asymptotic following a logistic function for the commercial and recreational ocean-boat landing fleets, and was assumed to be dome-shaped for the commercial and recreational ocean-boat discard fleets and the shore fleet. Male and female selectivity curves were assumed to be equivalent in the base case model. Sensitivity model runs were conducted that included differences in selectivity by gender. There was sufficient information in the data to produce reasonable estimates for selectivity, but there was some difficulty fitting to the largest observed fish. As expected, the base model was sensitive to the shape of the selectivity curves. A time block was used to capture changes in selectivity as a result of the implementation of a bag limits (recreational fleets) and trip limits (commercial fleets) in 2015, which influenced the size of fish landed and discarded in the observed data. The reconstruction of the historical catch time series for the shore fleet (1915-1979; 1990-1992; 2006-2016), the ocean-boat landing fleet (1970-1978), and the commercial discard fleet (1892-2002) were based on particular assumptions including: catch proportional to Oregon fishing license sales, linear ramp of catch, catch equal to recent average catch, and discards a constant proportion of landings (see section 3.2.1).

3.6.2 Evaluation of Model Parameters

Model parameters were evaluated for stability, precision, along likelihood profile gradients (section 3.9.2), and against the main assumptions in the base case model (section 3.6.1). Stability was examined by ensuring that model parameters were not up against a lower or upper bound (Table 79), and that the addition or removal of parameters associated with dome-shaped selectivity improved model fit. During model development, the commercial discard fleet was changed from being dome-shaped to asymptotic, because the inclusion of the additional parameter to produce a dome-shaped selectivity curve was ambiguous in terms of improving model fit. Thus, the more parsimonious approach (asymptotic) was taken for this fleet. Parameter precision was also monitored by looking at estimated standard deviations to assess the variability associated with point estimates.

3.6.3 Residual Analysis

Residuals to length composition and age composition fits to the model were explored during model development. The identification of residual patterns helped to sort out which set of *a priori* selectivity blocks were the most appropriate given the data. Alternative model configurations were also explored during model development in an attempt to minimize residual trends. The base model produced reasonable fits in general to length and age composition data. Across all years, the fit to length composition information was best for the recreational ocean-boat landings fleet and the commercial landings fleet, which is not surprising because a large proportion of the composition data comes from these two fleets (Table 64).

In general, annual fits to length composition information were adequate, with the average observed distribution matching well the predicted distribution (Figure 192). The main exceptions were the fit of the largest male BDR observed in the commercial fishery relative to females and smaller males (Figure 193), and the largest individuals (unsexed; greater than >46 cm) in the recreational fishery were also not fit as well as those less than 46 cm (Figure 194). The commercial discard fleet, the recreational discard fleet, and the shore fleet had small composition sample sizes, which resulted in lack of fit in some years (Figure 195, Figure 196, and Figure 197). The model was able to track mean length well for the recreational ocean landing fleet (Figure 198), which had more than an order of magnitude larger sample size compared to the other fleets in the most recent 10 years, and is the largest contributing sector in terms of catch biomass. Mean length for the remaining fleets followed the main trends through time, but the model essentially had a smoothing effect over these data because of the small sample sizes (Figure 199, Figure 200, Figure 201, and Figure 202).

Age compositions that resulted from fitting conditional age-at-length data matched reasonably well with the observed age compositions from the recreational ocean-boat landing fleet (Figure 203) and from the commercial landing fleet (Figure 204) during years with reasonable amounts of observations (2007 – 2015). The model also fit the research survey data well during 2016 (Figure 205). Fits to the recreational ocean-boat landings conditional age composition data shows generally good agreement between observed and expected ages at length (Figure 206). Fits to commercial conditional age composition data were also reasonable given lower sample sizes prior to 2011 (Figure 207). The model was able to track mean age for the ocean-boat fleet moderately well. The model fit was above the observed mean age in 2013 and

2014 and was below in 2015, but still within the range of uncertainty around mean age (Figure 208). Mean age for the commercial fleet tracked reasonably well during years with adequate sample sizes (2009 – 2015; Figure 209). No abnormal patterns were apparent in the residuals for the recreational ocean-boat conditional age-at-length fits (Figure 210), nor for the commercial conditional age-at-length fits (Figure 211). There was a large residual in 2011 (commercial landing fleet) and 2012 (recreational landing fleet) as the model had difficulty fitting those unusually large fish for their age. The fit to the research special project age data was also reasonable (Figure 212).

3.6.4 Convergence

Model convergence was checked for all models during development of a base model by ensuring that the final gradient of the likelihood surface was less than 0.001 and produced asymptotic standard deviations. All estimated parameter values were also checked to ensure they were not hitting a minimum or maximum bound. To reduce the chance that the parameter estimation process (i.e., setting initial parameter values and the sequence of parameter estimation through phasing) resulted in a converged gradient at a local (rather than the desired global) minima on the likelihood surface, additional explorations for a consistent likelihood minimum were performed using jittered (0.1) starting values. A total of 100 jittered runs were performed for each model. Across all jittered runs, the lowest likelihoods of each respective model matched the base case likelihood (Figure 213).

3.7 Response to STAR Panel Recommendations

During the course of the STAR panel, several requests were made to further explore model behavior and results. The following is a list of those requests/recommendations and the author's response. Further information, including relevant tables and graphics, can be found in the Stock Assessment Review (STAR) Panel Report for Blue and Deacon Rockfish (http://www.pcouncil.org/groundfish/stock-assessments/by-species/).

1. Create a proxy survey with absolute numbers in the ending year of the assessment, then profile over values of that number ranging from the current ending estimate of numbers of fish to the ending estimate of numbers of fish in the 2015 black rockfish assessment. Fix catchability to 1 and assume full selectivity of age 3+ and specify the survey as numbers of fish. Provide likelihood components, biomass estimates, and depletion. Maintain the current configuration of the base model.
   Response: The model was run assuming that the point of that proxy survey was equal to a proportion of the total population of the black rockfish ranging from 0.2 to 1. As expected, the population scale of BDR was pinned to that of Black Rockfish. However, there is considerable uncertainty in the 2015 Black Rockfish assessment and with defining an appropriate scalar between Black Rockfish and BDR in Oregon waters.

2. Evaluate how a linear ramp in historical recreational catches from 1970 affects model results.
   Response: The results showed that there is a small change in the stock size for that period (1970-80), but the current stock status remained almost unchanged. Despite not making a large difference, this change should be included in a new base case model because comments by the advisory participants indicating that this change was more realistic.

3. Reduce the compression age bin to age 25+.
   Response: The compression of the age plus bin to 25 did not lead to a noticeable change in the residual patterns in the age compositions for each fleet. Alternatively, compressing the length plus bin to 42 cm and 46cm did lead to an improved length composition residual pattern. Compressing both plus groups to 30 years and 42 cm did not change the overall results further.

4. Set the coefficient of variation for the length at maximum age for the male growth curve to the value calculated in the California assessment.
   Response: This change affected the scale, but the depletion pattern remained largely the same. Incorporating this change and compressing the length plus bin to 46 cm produced better residual patterns for commercial fishery length composition and recreational ocean fishery length composition. These changes are considered improvements and should be incorporated into the new base model.

5. Fix natural mortality for males and females in the model based on the Hamel prior. Alternatively, fix male and female natural mortality based on the values in the California assessment.
   Response: These alternatives led to changes in both scale and relative depletion of the population. Fixing female and male natural mortality at the Hamel median of the prior is perhaps the best approach given the uncertainty associated with natural mortality and population scale. There is not much contrast in the input data to help the model produce a robust estimate of natural mortality.

6. Provide a model run where all the indices are dropped.
   Response: Results of dropping all indices showed that the indices had negligible influence on the overall model results, confirming that the model is being driven by the catch and composition data. These fishery-dependent indices are rather uninformative, which is perhaps not surprising given the relative low BDR exploitation rate and that BDR are predominantly non-target species.

7. Provide a model run where the research survey selectivity is fixed at 1.0 for all ages and lengths.
   Response: This resulted in a small change in the scale of the stock and a slightly less depleted stock. This change should be incorporated in to the new base model as it is a more appropriate way to model the research survey selectivity. The previous selectivity had inadvertently had a descending limb associated with it.

8. Use the onboard observer data to compare black rockfish and Blue/Deacon Rockfish indices for Oregon calculated by multiplying the predicted catch rate from the GLM by the amount of suitable habitat in each sub region (north and south). Report the results by sub region.
   Response: Raw CPUE data were used for this request, because standardized CPUE between Black Rockfish and BDR would not be directly comparable because the standardization procedure was different between them. A table was produced showing the raw CPUE time series, which was then used in association with available habitat data to produce a relative density estimate for Black Rockfish and BDR biomass for 2001 and 2003-2014. Two alternatives were explored for defining habitat: species-specific habitat as used in their respective area-weighted standardization procedure, and an assumed same amount of habitat for these similar species. Population scalars between Black Rockfish and BDR were produced and then used as a proxy survey by scaling the 2015 Black rockfish biomass estimate. Neither approach to specifying habitat resulted in drastically different indicators of stock status. This approach relied on the 2015 Black Rockfish biomass estimate being known without error, and many other assumptions regarding catchability between Black Rockfish and BDR when interpreting CPUE data.

9. Update the table of reported parameters from the base model to show the standard errors for estimated parameters.
   Response: Done and included in assessment document.

10. Provide the graphs for total biomass for the different apical parameter runs.
    Response: Done and included in assessment document (Figure 214, Figure 215).

11. Provide a model run where the prior for $\ln(R_0)$ is set equal to the estimate of $\ln(R_0)$ in the 2015 black rockfish assessment with double the standard error as estimated in the 2015 black rockfish assessment.
    Response: Results were presented across several alternative prior SDs, but development of a prior using the Black Rockfish assessment information is not straightforward. When the Black Rockfish informed prior was less restricted, the BDR data preferred a lower abundance, suggesting that the model does have some information supporting a smaller stock size than that for Black Rockfish.

12. If time permits, use the habitat-weighted ratios of Blue/Deacon Rockfish to black rockfish in the onboard observer CPUE index in recent years to develop a proxy survey based on the biomass of black rockfish times the ratio. Evaluate this in the new base model.
    Response: See response to #8 above.

13. If possible, produce the likelihood profiles over $\ln(R_0)$ of the individual indices.
    Response: Done and included in assessment document. In general, there are no major conflicts among fishery-dependent index data sources, and none contain much information about population scale (see Figure 216).

14. Produce a table of SEs for $\ln(R_0)$, SSB, and depletion for the models in Request 5 (former base, the natural mortality set equal to the median of the Hamel prior, and the natural mortality set equal to the values in California Blue/Deacon Rockfish assessment.
    Response: Done and these values were helpful in determining alternative states of nature in the decision table.

15. Provide the new base case model.
    Response: A presentation of the new base case model was given, which included the changes specified in the paragraphs that follow.

16. To document the differences between the initial base model and the new base model, provide a run with all the changes in Request 15 except setting the male and female natural mortality at the median of the Hamel prior; instead allow the model to estimate natural mortality. Provide plots showing the spawning output time series and the $\ln(R_0)$ distributions for the three model runs (initial base, new base, and this intermediate case).
    Response: Graphs showing the requested parameters were provided. The value of female M when estimated was 0.144, which was slightly different from the originally estimated value for female M. The value of female M associated with the Hamel prior was 0.158, which is somewhat different from the M value the model prefers. When comparing the $\ln(R_0)$ asymptotic distributions for these cases, the new base model with fixed natural mortality at the Hamel prior included the mean value of ln(R0) when female natural mortality was estimated (Figure 217).

17. Use the default harvest control rule (ACL = ABC; P* = 0.45; sigma = 0.72; ABC buffer = 0.9135*OFL) for the new base model as described above to produce decision tables with the following alternative approaches:
    a. Find the $\ln(R_0)$ values for which the likelihood is 0.66 units from the base in either direction;
    b. ±1.15 * the asymptotic SE of ln(R0) to the value of $\ln(R_0)$ for the base case
    Response: The calculations were conducted and presented. It was determined that the boundaries were insufficiently wide to capture uncertainty, because it did not encompass the mean of the

model that estimated female natural mortality with a fixed male offset (i.e. the base model initially presented to the STAR panel). New decision tables were then presented that used high and low states of nature based on ±1.15 * the asymptotic SE of $\ln(R_0)$ using the sensitivity model that estimated female natural mortality with a fixed male offset value, and applying that value to the new base model. This larger range now captures the mean value as desired (see Figure 217).

Several other recommendations were made by the STAR panel for consideration in future assessments and for future research. Those can be found in the Stock Assessment Review (STAR) Panel Report for Blue and Deacon Rockfish (http://www.pcouncil.org/groundfish/stock-assessments/by-species/).

A new base case model was developed through discussion with the STAT and STAR panel, which included a few changes to the base case model presented to the STAR panel. Results from the new base case model are presented in this document. These changes include:

- the recreational ocean boat catch time series was ramped up linearly starting at zero in 1970 to 1979 to better reflect historical removals;
- growth curve parameter CV at the maximum age was borrowed from the California assessment rather than set equal to the Oregon female CV;
- upper tail of the length bins was compressed to the 46 cm length bin for model fitting;
- research survey was set to full selectivity for all ages and lengths;
- male and female natural mortalities were fixed at the median of the Hamel prior distribution; and
- the male growth parameter for the length at minimum age was set equal to equivalent female growth parameter.

3.8 Oregon Base-Model Results

The base case model estimated reasonable growth parameters (*k*, length at minimum and maximum age, and CV young/old) for ages 1 and older fish. Male parameters were an offset of female parameters, with the exception that the CV on young fish and the length at minimum age was set equal to the value for females, and the CV on old fish was fixed at the California male estimate. Growth was estimated beginning at age-1, because there was information in the conditional age-at-length data from the ODFW research collections. Asymptotic length was estimated to be 38.1 cm for females and 29.5 (offset = -0.26) cm for males (Table 80, Figure 218).

The fit to the abundance indices was reasonable for the commercial logbook index (Figure 161), recreational onboard observer index (Figure 182), and the ORBS index (Figure 178). From 2004 to 2014, the fit to these indices showed a slight downward trend in abundance, though the latter two recreational indices indicated a stabilizing period from 2015 to 2016. The fit to the recreational MRFSS index was flat and mostly uninformative (Figure 170). The model estimated an additional standard deviation for each index (0.04, 0.07, 0.15, and 0.59 for logbook, onboard observer, ORBS, and MRFSS based indices, respectively).

The base model produced reasonable fits in general to length and age composition data, with the exception of the oldest males (see section 3.6.3). Length composition fits are good for the recreational ocean-boat landings fishery and the commercial landings fishery, which combined represent the bulk of the data and BDR catch. The fits were not as good for the larger male fish in the recreational ocean-boat discard fleet and for one year (1993) in the recreational shore fleet. Fits to the weighted conditional age-at-length compositions show generally good agreement between observed and expected values (see section 3.6.3).

Selectivity curves were estimated for all five fleets (Figure 219, Figure 220), whereas survey abundance index selectivity was mirrored to the relevant fleet. An asymptotic curve following the logistic function was used for the recreational ocean landings fleet and the commercial landings fleet. Dome-shaped selectivity was estimated for the commercial discard fleet, the recreational ocean-boat discard fleet, and the shore fleet. However, it was determined during model development that the model preferred a logistic selectivity for the commercial discard fleet. A time block on selectivity to adjust for the large decrease in bag (recreational) and trip (commercial) limits in 2015 indicated a slight shift in the length at peak selectivity for the landings fleets, and a sizeable shift (from a peak of 29.6 cm to 26.2 cm) in the recreational discard fleet. The shore fleet selectivity pattern was consistent with fisheries that tend to catch smaller fish in areas where larger fish are generally less available for capture.

BDR spawning output was estimated to be 296 million eggs in 2017 (~95% asymptotic intervals: 64-527 mt), which when compared to unfished spawning output equates to a depletion level of 69% (~95% asymptotic intervals: 0.52-0.85; Table 81) in 2017. Depletion is a ratio of the estimated spawning output in a particular year relative to estimated unfished, equilibrium spawning output. In general, spawning output has been trending slightly downwards, with the exception of an increase in the 1990s due to several high recruitment years (Figure 221). Stock size is estimated to be at the lowest level throughout the historic time series in 2017, but the stock is estimated to be well above the management target of $B_{40\%}$ (Figure 222).

Recruitment variability was dynamic for BDR (Table 82, Figure 223) and indicated well above average recruitment in 2013. Other years with relatively high estimates of recruitment were 1993, 1994, and 1995. The BDR stock in Oregon has not been depleted to levels that would provide information on how recruitment changes with spawning output (Figure 224) at low spawning output levels (i.e., inform the steepness parameter).

Harvest rates have generally increased through time until the mid-1990s when harvest was reduced to a relatively stable level beginning in the 2000s. The maximum relative harvest rate was 0.92 in 1993 before declining to around 0.40 in recent years (Table 82, Figure 225). Fishing intensity is estimated to have been below the target throughout the time series [(1-SPR) / (1-$SPR_{50\%}$) < 1]. In 2016, Oregon BDR biomass is estimated to have been 1.73 times higher than the target biomass level, while experiencing fishing intensity 2.86 times lower than the SPR fishing intensity target (Figure 226). The equilibrium yield curve associated with the base model is shown in Figure 227.

3.9 Evaluation of Uncertainty

3.9.1 Sensitivity to Assumptions, Data, and Weighting

Sensitivity to the main sources of uncertainty was structured as ‘one-off’ (remove one data source or change one structural assumption relative to the base model) analyses to clearly identify the impact of a single piece of information or structural assumption. Several model sensitivities were evaluated. In general, these fell under four categories: removal of an index of abundance time series (runs 1-4), removal of length or age composition data (runs 5-12), evaluation of structural (parameterization) assumptions, and alternative assumptions about catch history time series (Table 84**)**. The following is a list of the specific structural assumptions and alternative catch histories examined (model number corresponds to those in Table 84):

13. Tuning the model to compositional weights based on the harmonic mean approach only
14. Tuning the model to compositional weights based on the Francis method only
15. Estimate female natural mortality, male natural mortality fixed at the ‘average’ offset value
16. Estimate female natural mortality, male natural mortality fixed at the ‘high’ offset value
17. Estimate female and male natural mortality

18. Specify all commercial fleets as dome-shaped selectivity
19. Specify all recreational fleets as dome-shaped selectivity
20. Estimate male selectivity separate from females for the commercial and recreational landings fleets
21. Turn off the estimation of all recruitment deviations
22. Turn off the estimation of all pre-2010 recruitment deviations
23. Use ageing error that assumes ODFW ageing lab is biased
24. Double the historical catch time series (pre-1980 catches) for all fleets
25. Halve the historical catch time series (pre-1980) for all fleets
26. Double the shore fleet catches during the recent interpolation period (2006-2016)
27. Estimate steepness using the west coast groundfish prior distribution (mean=0.718, SD = 0.158)

In general, the base case model was sensitive to population scale across most scenarios examined. Population trends were fairly robust across scenarios, but equilibrium recruitment (R_0) was quite sensitive. The sensitivity runs that had the largest influence on population scale, relative to the base case model, were when either the commercial age composition data or the recreational length composition data were removed (Figure 228), recruitment was deterministic according to the stock recruitment curve (Figure 230), and to alternative assumptions for natural mortality (Figure 231). In terms of depletion, the base model was the most sensitive to the case when natural mortality was either fixed at alternative offset values or was estimated (Figure 231), the use of recreational deviates (Figure 230), and age composition data (Figure 228). Current depletion levels predominantly ranged from 60% to 75% across sensitivity scenarios. However, current depletion was 37% when natural mortality was estimated for females and set at the higher offset value for males, and 90% when no recruitment deviations were estimated. Assuming recruitment is deterministic according to the stock-recruitment curve resulted in a larger overall population scale and higher estimates of current depletion. The estimated high recruitment in 2013 remained robust to the removal of any one data source, though was lessened with the removal of recreational ocean boat discard length data (Figure 228), and to alternative tuning approaches (Figure 232).

The approach to weighting length composition data (Francis method in the base case model) and age composition data (harmonic mean in the base case model) was slightly influential for the most recent estimates of depletion and the overall population scale (Figure 232). When all composition data sources (length and age) were weighted using the Francis approach, results were slightly more optimistic, with 2017 depletion estimated at 70% compared to 69% when using only the harmonic mean method. For the abundance indices, the ORBS index had the most influence on relative depletion (73% compared to 69% for the base model).

There is uncertainty associated with historical (mostly pre-1980) catch levels, especially for the recreational ocean-boat fleet which has not undergone a rigorous catch reconstruction like that available for the commercial fleet. The ocean-boat fleet has been the largest contributor to overall catch (Figure 156). There is also no direct information about shore fleet landings from 2006-2016. Doubling historical (pre-1980) catch for all fleets, halving the historical catch across all fleets, and doubling the recent (albeit low) catch of the shore fleet all had little influence on current depletion (Figure 233).

3.9.2 Parameter Uncertainty

Likelihood profiles were performed across three major sources of uncertainty: natural mortality (M), steepness (h), and initial recruitment (R_0). An individual profile was completed for each data source and parameter combination to derive the relative importance of each data set to parameter estimation. The profile over the initial scale of the population (R_0) indicated a relative low gradient from a ln(R_0) value of

6.5 to 8.0 (Figure 236). Length and age composition data sources were the most influential (Figure 237). The influence of R_0 on derived quantities for absolute levels of biomass was nonlinear, with large changes in biomass predicted from small changes in R_0 (Figure 236). The R_0 values between 6.7 and 7.7 spanned the range within two likelihood units of the base model, which covered a range of current depletion estimates from 58% to 81% (Figure 238). Fishery-dependent indices had little influence on population scale, and there was not considerable conflict among them (Figure 216).

Profiles over the steepness parameter (h) indicated that steepness was difficult to determine given the available data, and was primarily driven by specified prior information (Figure 239). Steepness was fixed at 0.718 in the base model, which is the mean of the prior distribution based on a west coast groundfish meta-analysis on steepness. The values of steepness within 2 likelihood units from the base model all resulted in 2017 depletion being above the management target (Figure 240).

Although female and male natural mortality were fixed in the base model, several profiles were examined across alternative female and male parameter values. A profile over female natural mortality (M) was conducted across a range of values while maintaining the same offset of male natural mortality to female natural mortality as that used in the base model (namely the median of the Hamel prior distribution for males). Natural mortality was influenced mostly by age composition and index data, with some contrast with length composition data (Figure 241). Current estimates of depletion were linearly-related to the estimate of natural mortality (Figure 242). The values of female natural mortality within 2 likelihood units from the base model were 0.15 to 0.20, and these values all resulted in 2017 depletion being above the management target (Figure 243). There was less information in the data to determine female natural mortality when the male offset was also allowed to be estimated in the model (Figure 244). Additional scenarios were examined where the offset between male and female natural mortality was set at alternative values than that used in the base model. Results were then compared with a profile over female natural mortality where the male natural mortality offset was estimated (Figure 245).

3.9.3 Retrospective Analysis

A retrospective analysis was conducted by sequentially removing 1 through 5 years of data from the base model starting with 2016. The base model was generally centered within the range of stock size and depletion estimates from models with sequentially less data (Figure 246). The large predicted recruitment event in 2013 was first estimated in 2014, but the estimated recruitment deviate has positively increased each year since 2014 (Figure 246). The overall population trend remained largely robust to the inclusion/omission of recent data; however, the retrospective analysis also highlights the uncertainty associated with overall stock size.

3.9.4 Alternate Models

Many other model parameterizations were explored (e.g., gender-specific and shape of selectivity curves and the estimation of growth and natural mortality parameters) during the development of the base case and for sensitivity analysis relative to the base model (section 3.9). In general, model sensitivity to the parameterization and estimation of growth, natural mortality, steepness, selectivity, recruitment deviates, ageing error, abundance indices, composition data, composition weighting, and the historical catch time series were explored. Alternative catch scenarios provided insight into the highly uncertain catch histories.

The treatment of selectivity and natural mortality was a major structural consideration that was explored in the development of the base case model. In particular, alternative approaches to estimating female and male natural mortality, including male offset values, bracketed this source of uncertainty and, ultimately, natural mortality parameters were fixed in the base model during the STAR panel. Many alternative models that explored gender specific selectivity were evaluated to account for differences in male selectivity (gear retention for the slower growing males) and availability (for sex-ratio reasons other than that attributed to natural mortality) relative to females in the catch. There was little information in the data to estimate the male 'apical' parameter (ratio of maximum male selectivity relative to female selectivity) and these modeling attempts resulted in non-convergence or irrational results (Table 83). There was some success with estimating male selectivity parameters as dome-shaped, one of these is presented as a sensitivity (Table 84).

During the STAR panel, several other alternative models were explored. Some of these include the following, but see section 3.7 for further details.

- Several alternative approaches to incorporating a proxy survey data point to pin Oregon BDR abundance relative to Oregon Black Rockfish abundance.
- Alternative catch history scenarios for the recreational ocean boat fleet catch reconstruction.
- Evaluating alternative fixed values for the male apical selectivity parameter across all fleets.

4 Reference Points

4.1 California

Trends in spawning output (millions of eggs or larvae) during the "data-rich" period of the model suggest a strong decline throughout the 1970s and early 1980s, followed by a rapid increase beginning in the late 2000s (Figure 119). Fluctuations in stock size prior to the 1980s are based on limited data, and may not be reliable. The distribution of stock status in 2017 is centered near target biomass (40% of unfished spawning output) with an increasing trend, after four decades below the target reference point. The California stock is estimated to be at 37% (~95% asymptotic intervals = 0%-79%) in 2017 (Figure 120). Unfished spawning output was estimated at 2178 million eggs (~95% asymptotic intervals = 1,763-2,593 million eggs; Table 54), and spawning output at the beginning of 2017 was estimated to be 812 million eggs (~95% asymptotic intervals = 0-1661 million eggs; Table 54). BDR recruitment in recent years supports a strong 2013 year class (consistent with several YOY and juvenile indices evaluated for this assessment). Strong recent recruitments in 2007-2009 may reflect patterns in local recruitment associated with limited age data collected primarily in the northern part of the state (Figure 121, Figure 122). Fishing intensity was above the SPR50% rate from the 1970s through the 2000s, but below the relative SPR target for the past decade, as shown in Figure 123. The phase plot shows the relationship between fishing intensity and stock size, both relative to their target values of equilibrium $F(SPR_{50\%})$ and 40% of unfished biomass, respectively (Figure 124). The equilibrium yield curve is shifted left, as expected from the high fixed steepness, showing a more productive stock than the SPR50% reference point would suggest (Figure 125). The target stock size based on the biomass target (SB40%) is 871 million eggs, which corresponds to a catch of 312 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $F(SPR_{50\%})$ is 306 mt.

4.2 Oregon

Spawning output (millions of eggs or larvae) has generally declined throughout the time series, but there were increases in the early-1990s due to large recruitment events associated with increased catch levels and in the early 2000s (Figure 221). Stock status has remained above the biomass target reference point (40%), though is trending towards the target since the mid-2000s, and is estimated to be at 69% (~95% asymptotic intervals = 52%-85%) in 2017 (Figure 222). Unfished spawning output was estimated at 431 million eggs (~95% asymptotic intervals = 187-675 million eggs; Table 81), and spawning output at the beginning of 2017 was estimated to be 296 million eggs (~95% asymptotic intervals = 64-527 million eggs). BDR recruitment has fluctuated over the last 37 years, with a general pattern of above average recruitment earlier in the time series and below average recruitment later in the time series except for the large estimated 2013 year-class (Figure 223, Figure 224). Fishing intensity has been below the SPR50% rate throughout the time series (or equivalently, above the relative SPR target as shown in Figure 225). The phase plot shows the interaction of fishing intensity and biomass targets (Figure 226), and shows that spawning output in 2016 is estimated to have been 1.73 times higher than the target level, while experiencing fishing intensity 2.86 times lower than the SPR fishing intensity target. The equilibrium curve is shifted left, as expected from the high fixed steepness, showing a more productive stock than the SPR50% reference point would suggest (Figure 227). The target stock size based on the spawning output target (*SB*40%) is 172 million eggs, which corresponds to a catch of 83 mt. Equilibrium yield at the proxy *FMSY* harvest rate corresponding to *SPR50*% is 78 mt.

5 Harvest Projections and Decision Tables

5.1 California

Projections of OFL (mt), ABC (mt), age 0+ biomass (mt), spawning output (millions of eggs), and depletion (% of unfished spawning output), are shown for two catch scenarios: 1) the default harvest control rule (See Executive Summary; Table ES13), and 2) constant catch equal to average catch over the period 2015-2016 (See Executive Summary; Table ES14).

During the STAR Panel review, it was agreed that uncertainty in the BDR assessment for California would be represented by quantiles of spawning output (sometimes referred to as spawning stock biomass, or SSB). Specifically, the 12.5 and 87.5 percentiles of SSB were chose as “low” and “high” alternative states of nature. Catch streams based on the default harvest control rule were generated under each state of nature. Each of these catch streams (low, base, and high) were then applied to all three states of nature, bracketing the range of management decisions and uncertainty in current stock size in California (See Executive Summary; Table ES15). Forecasts based on two “constant” catch streams were also completed: one with catch equal to the $SPR_{50\%}$ proxy for MSY, and another set equal to average catch over the period 2015-2016.

5.2 Oregon

The Oregon BDR assessment is considered a category 2 stock assessment, because it is used to assess a species complex. Therefore, projections and decision tables use a P* = 0.45 and a sigma = 0.72, resulting in a multiplier on the OFL of 0.9135. The OFL, ABC, and ACL for each forecast scenario is calculated following the rockfish MSY proxy of F_{SPR}=50% along with the 40-10 harvest control rule.

Two harvest projections are provided based on alternative assumptions of catch during the forecast period (2019-2028), where catch during the current management cycle (2017-2018) was set to the average over the most recent two years (2015-2016). The first uses the catch specified by the F_{SPR}=50% MSY proxy following the 40:10 harvest control rule, where the ABC = ACL (Table 85). The second uses a constant catch value specified by the STAR panel GMT representative. The constant catch was set at the average historical catch from 2005-2014, prior to newly implemented regulations in 2015 (Table 86).

Uncertainty in management quantities for the Oregon model was characterized by exploring different values of $\ln(R_0)$. There was considerable discussion at the STAR panel about capturing the appropriate range of uncertainty relative to population scale. In response, the STAT and STAR panel agreed that the high and low states of nature should be based on ±1.15 * the asymptotic SE of $\ln(R_0)$ using the sensitivity model that estimated female natural mortality with a fixed male offset value (offset set to the average of the Hamel prior offset and the Then growth offset, see section 3.4.1). This model was chosen to develop the range of $\ln(R_0)$ because there were concerns that the base model did not capture the full range of uncertainty in $\ln(R_0)$ when natural mortality was fixed. This approach resulted in low ($\ln(R_0) = 6.453$) and high ($\ln(R_0) = 7.641$) states of nature relative to the base model ($\ln(R_0) = 7.047$) that were used to characterize uncertainty in the decision table (Table 87).

6 Regional Management Considerations

Current practice for BDR is to allocate harvests by Federal management area, as it is managed as part of the northern and southern minor nearshore rockfish complexes. The STAT proposes a new method of allocating harvests based on the estimation of relative biomass from fishery-dependent CPUE and estimates of habitat area in each region. Details of this approach, and recommendations for allocation of BDR OFL estimates in California are provided as Appendix D.

7 Research Needs

1. Nearshore survey. A fisheries-independent nearshore survey should be supported to improve estimates of abundance trends (not having to rely on fisheries data for such trends) and, if possible, absolute abundance. Population scale has proven difficult to estimate for many nearshore species without informative data.

2. Collection of gender- and species-specific data. Gender- and species-specific information from the recreational fishery should be collected for BDR given differences in growth and natural mortality by gender and the importance of this fishery to overall catches. This information should continue to be collected for commercial fisheries. For California, collection of age data (particularly from the recreational fishery) is a priority for stock assessment of BDR and other species important to recreational fisheries.

3. A study of the stock structure of Blue and Deacon Rockfish. Stock structure for Blue Rockfish and Deacon Rockfish needs further study and the results accounted for in future assessments. In particular, ontogenetic and gender-related movement according to offshore depth and spawning seems plausible, and data to inform tests of that hypothesis would be beneficial for future assessments given the lack of larger/older males in the fisheries data. Given that the vast majority of catches for BDR are in the nearshore waters, the intersection of seasonal movements to offshore habitat coupled with fleet dynamics could play an important role determining vulnerability. Alternative sub-stock boundaries, those that do not lie on political borders, should also be explored.

4. Further analyses on natural mortality values for females and males. This will help resolve the extent to which gender-based selectivity (e.g., dome-shaped or relative male-to-female scales) may be occurring, and whether natural mortality and such complex selectivity patterns can be estimated (and when they cannot).

5. Historical catch reconstructions for recreational fleets in Oregon. Ocean-boat landings comprise the vast majority of landings for BDR, but there has been no rigorous attempt at a catch reconstruction beyond linking catch to license sales (as was done for this assessment).

6. Accurate accounting of removals for recreational shore fleet (estuary-boat and shore fishing modes). Fisheries exploited by the recreational sector are traditionally hard to monitor. Since 2005, there has been no comprehensive information collected about catch or effort or biological information from estuary-boat and shore fishing modes. Although these modes do not represent

major fisheries for BDR in terms of landed catch, they do tend to catch smaller individuals. Biological data on smaller individual is a data gap for this and many other nearshore rockfish species.

7. Calibration and validation of BDR ages. Formal ageing criteria for BDR should be developed and standardized and ages validated.

8. Control rules for stocks managed as part of a stock complex. BDR are currently managed as part of two "Minor Nearshore Rockfish" stock complexes (each representing over 10 stocks), north and south of 40° 10′ N. latitude. The contribution of BDR (currently "Blue Rockfish") to the northern complex OFL in 2017 is over half the yield (roughly 56% of the combined OFL), and 23% of the OFL for the southern complex. The STAT recommends research on the risks associated with management of stocks in a complex (e.g. the probability of overfishing component stocks), as a function of the degree of variability in the OFL contribution of each stock. Stocks that are managed as part of a complex and determined to be above target biomass are of particular concern, as their OFL contribution may exceed MSY (or its proxy). In the absence of a species-specific catch limit, alternative measures could be evaluated using management strategy evaluation, including alternative control rules for stocks managed within a complex (e.g. a "40-10" harvest control rule combined with a yield cap set equal to MSY or its proxy; see also Froese et al. 2010).

9. Mandatory port sampling. In California, commercial port samplers can be refused access to landings. This could result in biased estimates of species, length, and age compositions, as well as estimates of commercial landings, particularly if catch that is made available to the sampler is not representative of the total catch in a sampling stratum.

8 Acknowledgments

The STAT thanks the STAR panel for their helpful comments and suggestions (Martin Dorn, STAR panel chair, NMFS/AFSC; Panayiota Apostolaki, CIE; Robin Cook, CIE; and Owen Hamel, NMFS/NWFSC). STAR Panel Advisors Patrick Mirick (GMT representative), Louie Zimm (GAP representative), and John DeVore (Council Staff) also provided valuable information and assistance during the review. Other contributions to the assessment were equally appreciated, but too numerous to describe in detail. Persons contributing to the assessment include Jeff Abrams, Teresa A'mar, Sabrina Beyer, John Budrick, Troy Buell, Mark Carr, Alison Dauble, Xi He, Kenyon Hensel, Kevin Hitchcock, Bob Ingles, Jason Jannot, Lisa Kautzi, Tom Laidig, Dan Malone, Melissa Monk, Don Pearson, Gerry Richter, Keith Sakuma, Katie Schmidt, Andi Stephens, Ian Taylor, Tenera Environmental, John Wallace, Chantel Wetzel, Deb Wilson-Vandenberg, and Noelle Yochum.

9 Literature Cited

Abrams, J. 2014. The effect of local fishing pressure on the size and age structure of fishes associated with rocky habitats along California's north coast. Master's thesis, Humboldt State University. 148 p.

Adams, P.B., and Howard, D.F. 1996. Natural mortality of blue rockfish, Sebastes mystinus, during their first year in the nearshore benthic habitats. Fishery Bulletin 94: 156–162.

Anderson, T.W. 1983. Identification and development of nearshore juvenile rockfishes (genus *Sebastes*) in central California kelp forests. M.S. Thesis. California State University, Fresno.

Beamish, R. 1979. New information on the longevity of Pacific ocean perch (*Sebastes alutus*). Journal of the Fisheries Board of Canada 36, 1395–1400.

Buonaccorsi, V.P., Kimbrell, C.A., Lynn, E.A., and Vetter, R.D. 2005. Limited realized dispersal and introgressive hybridization influence genetic structure and conservation strategies for brown rockfish, *Sebastes auriculatus*. Conservation Genetics 6: 697–713.

Burford, M.O. 2009. Demographic history, geographical distribution and reproductive isolation of distinct lineages of blue rockfish (*Sebastes mystinus*), a marine fish with a high dispersal potential. Journal of Evolutionary Biology 22: 1471–1486.

Burford, M.O., Bernardi, G., 2008. Incipient speciation within a subgenus of rockfish (*Sebastosomus*) provides evidence of recent radiations within an ancient species flock. Marine Biology 154, 701–717.

Burford, M.O., Bernardi, G., and Carr, M.H. 2011a. Analysis of individual year-classes of a marine fish reveals little evidence of first-generation hybrids between cryptic species in sympatric regions. Marine Biology 158: 1815–1827.

Burford, M., Carr, M., and Bernardi, G. 2006. Speciation and genetic structure in a marine fish with an extended pelagic larval phase: an analysis of both the juvenile and adult populations of blue rockfish (*Sebastes mystinus*). University of California Marine Council. Coastal Environmental Quality Initiative. Paper 039.

Burford, M.O., Carr, M.H., Bernardi, G. 2011b. Age-structured genetic analysis reveals temporal and geographic variation within and between two cryptic rockfish species. Marine Ecology Progress Series 442, 201–215.

Carr, M.H. 1991. Habitat selection and recruitment of an assemblage of temperate zone reef fishes. J. Exp. Mar. Biol. Ecol. 146: 113-137.

CDFG. 1958. Fish Bulletin No. 105. The Marine Fish Catch of California For the Years 1955 and 1956 with Rockfish Review. Scripps Institution of Oceanography Library. UC San Diego: UC San Diego Library – Scripps Collection. Retrieved from: https://escholarship.org/uc/item/6d51q168

Cope, J.M. 2002. Phylodemography of the blue rockfish (*Sebastes mystinus*) from California to Washington. San Francisco State University.

Cope, J.M. 2004. Population genetics and phylogeography of the blue rockfish (*Sebastes mystinus*) from Washington to California. Canadian Journal of Fisheries and Aquatic Sciences 61: 332–342.

Department of Fisheries and Oceans (DFO) Canada. 2007. Rockfish Conservation Areas. Fisheries and Oceans Canada, Pacific Region.

Department of Fisheries and Oceans (DFO) Canada. 2016. Pacific Region Integrated Fisheries Management Plan: Groundfish. Fisheries and Oceans Canada, Pacific Region.

Dick, E.J. and A.D. MacCall. 2014. Status and Productivity of Cowcod, *Sebastes levis*, in the Southern California Bight, 2013. Pacific Fishery Management Council, Portland, Oregon. http://www.pcouncil.org/wp-content/uploads/Cowcod_Assessment_140820.pdf

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

Douglas, D.A. 2011. The Oregon Shore-Based Cobb Seamount Fishery, 1991-2003: Catch Summaries and Biological Observations. Oregon Dept. of Fish and Wildl. Information Rept. Ser. No. 2011-03. 28 pp. https://nrimp.dfw.state.or.us/CRL/Reports/Info/2011-03.pdf

Dunn, K. P., and Smyth, G. K. (1996). Randomized quantile residuals. Journal of Computational and Graphical Statistics 5, 1-10.

Echeverria, T.W. 1986. Sexual dimorphism in four species of rockfish genus *Sebastes* (Scorpaenidae). Environmental Biology of Fishes 15: 181–190.

Echeverria, T. and W.H. Lenarz. 1984. Conversions between total, fork, and standard lengths in 35 species of *Sebastes* from California. Fish. Bull., U.S. 82:249–251.

Field, J., E.J. Dick, N. Grunloh, X. He, K. Sakuma and S. Ralston. 2017. Appendix B. Coastwide Pre-Recruit Indices from SWFSC and NWFSC/PWCC Midwater trawl Surveys (2001-2016). in He, X. and J. Field, Stock Assessment Update: Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2017. Online (under agenda item F4) at http://www.pcouncil.org/resources/archives/briefing-books/june-2017-briefing-book/#gfJun2017

Fletcher V. E. 1981. A comparative analysis of the behavioral ecology, agonistic behavior and sound production in two species of inshore eastern pacific rockfish (genus *Sebastes*). M.S. Thesis. University of Victoria, British Columbia.

Follett, W. I., and Ainley, D. G.1976. Fishes collected by pigeon guillemots, *Cepphus columba* (Pallas), nesting on southeast Farallon Island, California. California Fish and Game 62: 28–31.

Frable, B.W., Wagman, D.W., Frierson, T.N., Aquilar, A., and Sidlauskas, B.L. 2015. A new species of *Sebastes* (Scorpaeniformes: Sebastidae) from the northeastern Pacific, with a redescription of the blue rockfish, *S. mystinus* (Jordan and Gilbert, 1881). Fishery Bulletin 113: 355–377.

Francis, R. 2011. Data weighting in statistical fisheries stock assessment models. Canadian 2487 Journal of Fisheries and Aquatic Sciences 68: 1124–1138.

Froese, R., T. Branch, A. Proelβ, M. Quaas, K. Sainsbury, and C. Zimmerman. 2010. Generic harvest control rules for European fisheries. Fish and Fisheries 12: 340–351.

Gaines, S.D., and Roughgarden, J. 1987. Fish in offshore kelp forests affect recruitment to intertidal barnacle populations. Science 235: 479–481.

Gallagher, M.B., and Heppell, S.H. 2010. Essential habitat identification for Age-0 rockfish along the Central Oregon Coast. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 2: 62–72.

Gharrett, A.J., Matala, A.P., Peterson, E.L., Gray, A.K., Li, Z., Heifetz, J., 2005. Two genetically distinct forms of rougheye rockfish are different species. Transactions of the American Fisheries Society 134: 242–260.

Gharrett, A.J., Mecklenburg, C.W., Seeb, L.W., Li, Z., Matala, A.P., Gray, A.K., Heifetz, J., 2006. Do genetically distinct rougheye rockfish sibling species differ phenotypically? Transactions of the American Fisheries Society 135: 792–800.

Gotshall, D.W., J.G. Smith, and Holbert, A. 1965. Food of the blue rockfish *Sebastodes mystinus*. California Fish and Game 51: 147–162.

Green, K.M., Greenley, A.P., and Starr, R.M. 2014. Movements of blue rockfish (*Sebastes mystinus*) off Central California with comparisons to similar species. PLOS ONE 9.6.e98976.

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

Hamilton, S.L., Caselle, J.E., Malone, D.P. and Carr, M.H., 2010. Incorporating biogeography into evaluations of the Channel Islands marine reserve network. Proceedings of the National Academy of Sciences, 107(43), pp.18272-18277.

Hannah, R.W., Wagman, D.W., Kautzi, L.A., 2015. Cryptic speciation in the blue rockfish (*Sebastes mystinus*): age, growth and female maturity of the blue-sided rockfish, a newly identified species, from Oregon waters. Oregon Department of Fish and Wildlife. Information Reports 2015-01.

Hannah, R.W. and M.T.O. Blume. 2016. Variation in the Effective Range of a Stereo-Video Lander in Relation to Near-Seafloor Water Clarity, Ambient Light and Fish Length. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science. 8:62-69. http://www.tandfonline.com/doi/abs/10.1080/19425120.2015.1135222

Harms, J.H., Benante, J.A., and Barnhart, R.M. 2008. The 2004–2007 hook and line survey of shelf rockfish in the Southern California Bight: Estimates of distribution, abundance, and length composition. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-95.

Hartig, F. 2017. DHARMa: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models. R package version 0.1.5. http://florianhartig.github.io/DHARMa/

He, X., J.C. Field, D.E. Pearson, L. Lefebvre and S. Lindley. 2017. Status of Bocaccio, *Sebastes paucispinis*, in the Conception, Monterey and Eureka INPFC areas for 2015. Pacific Fishery Management Council Stock Assessment and Fishery Evaluation. http://www.pcouncil.org/groundfish/stock-assessments/by-species/bocaccio-rockfish/

Heimann, R.F.G., and Miller, D.J. 1960. The Morro Bay otter trawl and party boat fisheries, August 1957 to September 1958. Calif. 46: 35–58.

Heimann, R.F.G., Frey, H.W., and Roedel, P.M. 1968. The California marine fish catch for 1966 California-based fisheries off the West Coast of Mexico for temperature tunas, market fish, and sport fish. California Department of Fish and Game. Fish Bulletin 138.

Helvey, M. 1982. First observations of courtship behavior in rockfish, Genus Sebastes. Copeia 1982: 763–770.

Hicks, A., Wetzel, C., and Harms, J. 2014. The status of rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*) as a complex along the U.S. West Coast in 2013. Pacific Fishery Management Council, Portland, OR.

Hill, K.T., E. Dorval, N.C.H. Lo, B.J. Macewicz, C. Show, and R. Felix-Uraga. 2008. Assessment of the Pacific sardine resource in 2007 for U.S. management in 2008. NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-413. 176 p. http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-413.PDF

Hobson, E.S., and Chess, J.R. 1988. Trophic relations of the blue rockfish, *Sebastes mystinus,* in a coastal upwelling system off northern California. Fishery Bulletin 86: 715–743.

Hobson, E.S., J.R. Chess, and D.F. Howard. 1996. Zooplankters consumed by Blue Rockfish during brief access to a current off California's Sonoma Coast.

Hoenig, J.M., 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82(1):898-905.

Hyde, J.R., and Vetter, R.D. 2007. The origin, evolution, and diversification of rockfishes of the genus *Sebastes* (Cuvier). Molecular Phylogenetics and Evolution 44: 790–811.

Hyde, J.R., Kimbrell, C.A., Budrick, J.E., Lynn, E.A., and Vetter, R.D. 2008. Cryptic speciation in the vermilion rockfish (*Sebastes miniatus*) and the role of bathymetry in the speciation process. Molecular Ecology 17: 1122–1136.

Ingram, T., 2011. Speciation along a depth gradient in a marine adaptive radiation. Proceedings of the Royal Society B: Biological Sciences 278: 613–618.

Jacobson, L. D., S. Ralston, and A. D. MacCall. 1996. Historical larval abundance indices for bocaccio rockfish (*Sebastes paucispinus*) from CalCOFI data. NMFS SWFSC Administrative Report LJ-96-06.

Jarvis, E.T., Allen, M.J., and Smith, R.T. 2004. Comparison of recreational fish catch trends to environment-species relationships and fishery-independent data in the southern California Bight. CalCOFI Rep. 45: 167-–179.

Johansen, T., Danielsdottir, A.K., Meland, K., and Naevdal, G., 2000. Studies of the genetic relationship between deep-sea and oceanic *Sebastes mentella* in the Irminger Sea. Fisheries Research 49: 179–192.

Johnson, D.W. 2006. Predation, habitat complexity, and variation in density dependent mortality of temperate reef fishes. Ecology 87(5): 1179-1188.

Jorgensen, S.J., Kaplan, D.M., Klimley, P.A., Morgan, S.G., O'Farrell, M.R., and Botsford, L.W. 2006. Limited movement in blue rockfish *Sebastes mystinus*: internal structure. Marine Ecology Progress Series 327: 249–258.

Kai, Y., Nakayama, K., and Nakabo, T. 2002. Genetic differences among three colour morphotypes of the black rockfish, *Sebastes inermis*, inferred from mtDNA and AFLP analyses. Molecular Ecology 11: 2591–2598.

Karnowski, M., V. Gertseva, and A. Stephens. 2014. Historical reconstruction of Oregon's commercial fisheries landings. Oregon Department of Fish and Wildlife, Info. Rep. No. 2014-02.

Karpov, K.A., Albin, D.P., and Van Buskirk, W.H. 1995. The marine recreational fishery in northern California and central California: a historical comparison (1958–86), status of stocks (1980–1986), and effects of changes in the California Current. Calif. Dep. Fish Game Fish Bull. 176.

Kashef, N.S., Sogard, S.M., Fisher, R., and Largier, J.L. 2014. Ontogeny of critical swimming speeds for larval and pelagic juvenile rockfishes (*Sebastes* spp., family Scorpaenidae). Marine Ecology Progress Series 500: 231–243.

Key, M., MacCall, A.D., Field, J.C., Aseltine-Neilson, D., and Lynn, K. 2008. The 2007 assessment of blue rockfish (*Sebastes mystinus*) in California. Pacific Fishery Management Council.

Kimura, D., R. Mandapat, and S. Oxford. 1979. Method, validity, and variability in the age determination of yellowtail rockfish (*Sebastes flavidus*), using otoliths. Journal of the Fisheries Research Board of Canada 35, 377–383.

Klingbeil, R.A., and Knaggs, E.H. 1976. Southern range extensions of the blue rockfish, *Sebastes mystinus*, the flag rockfish, *S. rubrivinctus*, and the shortbelly rockfish, *S. jordani*. Cal. Dept. Fish Game 62: 160.

Laidig, T.E., Pearson, D.E., and Sinclair, L.L. 2003. Age and growth of blue rockfish (*Sebastes mystinus*) from central and northern California. Fishery Bulletin 101: 800–808.

Laidig, T.E., Chess, J.R., and Howard, D.F. 2007. Relationship between abundance of juvenile rockfishes (*Sebastes* spp.) and environmental variables documented off northern California and potential mechanisms for the covariation. Fishery Bulletin 105(1):39-48.

Laidig, T.E. 2010. Influence of ocean conditions on the timing of early life history events for blue rockfish (*Sebastes mystinus*) off California. Fishery Bulletin 108:442–449.

Larson, R.J. 1972. The food habits of four kelp-bed rockfishes (Scorpaenidae, *Sebastes*) off Santa Barbara, California. M.S. Thesis. University of California, Santa Barbara. 65 p.

Lea, R.N., McAllister, R.D., and VenTresca, D.A. 1999. Biological aspects of nearshore rockfishes of the genus Sebastes from central California. California Department of Fish and Game. Fish Bulletin 177.

Lenarz, W.H. 1986. A history of California rockfish fisheries, p. 35-41. In: Proc. Int. Rockfish Symp. Anchorage, AK. Lowell Wakefield Fish. Symp. Ser. 5. Alaska Sea Grant and University of Alaska, Fairbanks.

Lenarz, W.H., Larson, R.J., and Ralston, S. 1991. Depth distributions of late larvae and pelagic juveniles of some fishes of the California Current. CalCOFI Rep. 32: 41–46.

Lo, N., Jacobson, L.D., and Squire, J.L. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Sciences 49: 2515–2526.

Love, M.S., and Ebeling, A.W. 1978. Food and habitat of three switch-feeding fishes in the kelp forests off Santa Barbara, California. Fishery Bulletin 76: 257–271.

Love, M.S., Westphal, W., and Collins, R.A. 1985. Distributional patterns of fishes captures aboard commercial passenger vessels along the northern Channel Islands, California. Fishery Bulletin 83: 243–251.

Love, M.S., Caselle, J.E., and Van Buskirk, W. 1998. A severe decline in the commercial passenger fishing vessel rockfish (Sebastes spp.) catch in the southern California Bight, 1980-1986. CalCOFI Rep. 39: 180–195.

Love, M.S., Yoklavich, M.M., and Thorseinson, L. 2002. The rockfishes of the Northeast Pacific. University of California Press. Berkeley, CA.

Love, M.S. 2011. Certainly more than you want to know about the fishes of the Pacific Coast (a postmodern experience). Really Big Press. Santa Barbara, CA.

Mason, J.E. 1995. Species trends in sport fisheries, Monterey Bay, Calif., 1959-1986. Marine Fisheries Review 57: 1–16.

Mason, J.E. 1998. Declining rockfish lengths in the Monterey Bay, California, recreational fishery, 1959-1994. Marine Fisheries Review 60: 15–28.

McAllister, M.K. and J.N. Ianelli 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Can. J. Fish. Aquatic Sci. 54: 284-300.

McClatchie, S. 2014. Regional Fisheries Oceanography of the California Current System. Springer:Netherlands.

McClure, R. E. 1982. Neritic reef fishes off central Oregon: aspects of life histories and recreational fishery. M.S. thesis, 94 p. Oregon State Univ., Corvallis, OR.

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

Miller, D.J., and Gotshall, D. 1965. Ocean sportfish catch from Oregon to Point Arguello, California. Calif. Dept. Fish Game. Fish Bulletin 130.

Miller, D.J., Odemar, M.W., and Gotshall, D.W. 1967. Life history and catch analysis of the blue rockfish (*Sebastes mystinus*) off central California, 1961-1965. California Department of Fish and Game. Marine Resources Operations Reference No. 67-14.

Miller, D.J., and Geibel, J.J. 1973. Summary of blue rockfish and lingcod life histories: a reef ecology study, and giant kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California. California Department of Fish and Game. Fish Bulletin 158.

Miller, J.A., and Shanks, A.L. 2004. Evidence for limited larval dispersal in black rockfish (*Sebastes melanops*): implications for population structure and marine-reserve design. Canadian Journal of Fisheries and Aquatic Sciences 61: 1723–1735.

Mills, K.L., Laidig, T., Ralston, S., and Sydeman, W.J. 2007. Diets of top predators indicate pelagic juvenile rockfish (*Sebastes* spp.) abundance in the California Current System. Fisheries Oceanography 16: 273–283.

Monk, M., E.J. Dick, T. Buell, L. ZumBrunnen, A. Dauble, and D. Pearson. 2013. Documentation of a relational database for the Oregon Sport Groundfish Onboard Sampling Program. NOAA-TM-NMFS-SWFSC-519.

Moring, J. R. 1972. Check list of intertidal fishes of Trinidad Bay, California, and adjacent areas. Calif. Fish Game 58: 315–320.

Moser, H. G. (editor). 1996. The early stages of fishes in the California Current region. California Cooperative Oceanic Fisheries Investigations Atlas No. 33. U.S. Department of Commerce. NOAA, NMFS, Southwest Fisheries Science Center. La Jolla, California.

Moser, H.G., E.H. Ahlstrom and E.M. Sandknop. 1977. Guide to the identification of Scorpionfish larvae (Family Scorpaenidae) in the eastern Pacific with comparative notes on 75 species of *Sebastes* and *Helicolenus* from other oceans. NOAA Technical Report NMFS Circular 402; 71 pp.

Moser, H. G., R. L. Charter, W. Watson, D. A. Ambrose, J. L. Butler, S. R. Charter, and E. M. Sandknop. 2000. Abundance and distribution of rockfish (*Sebastes*) larvae in the Southern California Bight in relation to environmental conditions and fishery exploitation. CalCOFI Reports 41: 132-147.

ODFW. 2002. An Interim Management Plan of Oregon's Nearshore Commercial Fisheries. Oregon Department of Fish and Wildlife. Newport, OR. Pp. 109. http://www.dfw.state.or.us/MRP/publications/docs/northshore_comm_fisheries.pdf

Parish, R.H., C.S. Nelson, and A. Bakun. 1981. Transport mechanisms and reproductive success of fishes in the California Current. Biol. Oceangr. 1:175-203.

Pearson, D.E., Erwin, B., and Key, M. 2008. Reliability of California's groundfish landings estimates from 1969-2006. NOAA/NMFS Tech Memo. NOAA-TM-NMFS-SWFSC-431.

PFMC. 2013. Scientific and Statistical Committee Draft Summary Minutes, April, 2017. Pacific Fishery Management Council, Portland, Oregon. 22 p. Available online: http://www.pcouncil.org/wp-content/uploads/SSC_DRAFT_MAR13MIN_APR2013BB.pdf

PFMC. 2016. Status of the Pacific Coast Groundfish Fishery: Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council. Portland, OR. Pp. 310. http://www.pcouncil.org/wp-content/uploads/2017/02/SAFE_Dec2016_02_28_2017.pdf

Phillips, J. B. 1957. A review of the rockfishes of California. Calif. Dep. Fish Game Fish Bull. 104.

Phillips, J.B. 1958. Rockfish review. In: The marine fish catch of California for the years 1955 and 1956. Calif. Dept. Fish and Game. Fish Bulletin 105.

Punt, A.E., Smith, D.C., KrusicGolub, K., and Robertson, S. 2008. Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia's southern and eastern scalefish and shark fishery. Can. J. Fish. Aquat. Sci. 65: 1991–2005.

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. http:www.R-project.org/

Ralston, S., D.E. Pearson, J. Field, and M. Key. 2010. Documentation of the California Catch NOAA Technical Memorandum NMFS-SWFSC 461.

Ralston, S., Sakuma, K.M., and Field, J.C. 2013. Interannual variation in pelagic juvenile rockfish (*Sebastes* spp.) abundance – going with the flow. Fisheries Oceanography 22: 288–308.

Ralston, S. and Stewart, I.J., 2013. Anomalous distributions of pelagic juvenile rockfish on the US west coast in 2005 and 2006. California Cooper. Ocean. Fish. Invest. Rep, 54, pp.155-166.

Reilly, P. 2001. Blue Rockfish, p. 165–167. In: California's marine living resources: a status report. Leet, W.S., Dewees, C.M., Klingbell, R., and Larson, E.J., eds. Calif. Dept. Fish and Game and California Sea Grant Extension Program.

Rodomsky, B.T., T.R. Calavan, and A.L. Carpenter. 2016. The Oregon Commercial Nearshore Fishery Summary: 2015. Oregon Department of Fish and Wildlife. Newport, OR. Pp. 51. http://www.dfw.state.or.us/MRP/publications/docs/2015%20Commercial%20Nearshore%20Summary%20final.pdf

Rodríguez-Medrano, M.C. 1993. Descripción y análisis biólogico de la pesca deportiva en Bahía Todos Santos, Ensenada, B.C. M.S. Thesis. Centro de Investigación Cientifica y Educación Superior de Ensenada Baja California.

Sakuma, K.M., Field, J.C., Mantua, N.J., Ralston, S., Marinovic, B.B. and C.N. Carrion. 2016. Anomalous epipelagic micronekton assemblage patterns in the neritic waters of the California Current in spring 2015 during a period of extreme ocean conditions. CalCOFI Reports 57:163-183.

Sampson, D.B. and P.R. Crone. 1997. Commercial fisheries data collection procedures for the U.S. Pacific coast groundfish. NOAA Technical Memorandum NMFS-NWFSC-31.

Schindler, E., M. Freeman and B. Wright. 2012. Sampling design of the Oregon Department of Fish and Wildlife's Ocean Recreational Boat Survey (ORBS). Oregon Department of Fish and Wildlife. Pp. 27. http://www.dfw.state.or.us/mrp/salmon/docs/ORBS_Design.pdf

Schmidt, K.T., 2014. Life history changes in female blue rockfish, *Sebastes mystinus*, before and after overfishing in central California. California State University, Monterey Bay.

Schnute, J. 1981. A versatile growth model with statistically stable parameters. Canadian Journal of Fisheries and Aquatic Sciences 38:1128–1140.

Singer, M.M. 1985. Food habits of juvenile rockfishes (*Sebastes*) in a central California kelp forest. Fishery Bulletin 83: 531–541.

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

Somers, K.A., Y.-W. Lee, J. Jannot, N.B. Riley, V. Tuttle, and J. McVeigh. 2016. Estimated discard and catch of groundfish species in the 2015 U.S. west coast fisheries. NOAA Fisheries, NWFSC Observer Program, 2725 Montlake Blvd E., Seattle, WA 98112.

Stan Development Team. 2016. rstanarm: Bayesian applied regression modeling via Stan. R package version 2.13.1. http://mc-stan.org/.

Starr RM, Wendt DE, Barnes CL, Marks CI, Malone D, Waltz G, et al. 2015. Variation in Responses of Fishes across Multiple Reserves within a Network of Marine Protected Areas in Temperate Waters. PLoS ONE 10(3): e0118502. https://doi.org/10.1371/journal.pone.0118502

Stefánsson, G. 1996. Analysis of ground fish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Science 53:577–596.

Studebaker, R. S., K. N. Cox, and T. J. Mulligan. 2009. Recent and historical spatial distribution of juvenile rockfish species in rocky intertidal tide pools, with emphasis on black rockfish. Trans. Amer. Fish. Soc. 138: 645–651.

Taylor, C.A., W. Watson, T. Chereskin, J. Hyde and R. Vetter. 2004. Retention of larval rockfishes, Sebastes, near natal habitat in the Southern California Bight, as indicated by molecular identification methods. CalCOFI Reports 45: 152−166.

Tenera Environmental Services. 2000. Diablo Canyon Power Plant 316(b) Demonstration Report. Document No. E9-055.0. Tenera Environmental Services, P.O. Box 400, Avila Beach, California, 93424.

Then, A.Y., J.M. Hoenig, N.G. Hall, and D.A. Hewitt. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES J. of Mar. Sci. 72, 82-92.

Thorson, James T, Stewart, Ian J, and Punt, Andre E. 2012. nwfscAgeingError: a user interface in R for the Punt et al. (2008) method for calculating ageing error and imprecision. Available from: http://github.com/nwfsc-assess/nwfscAgeingError/.

Thompson, A.R., Hyde, J.R., Watson, W., Chen, D.C. and L.W. Guo. 2016. Rockfish assemblage structure and spawning locations in southern California identified through larval sampling. Marine Ecology Progress Series 547: 177-192.

Tuckey, T., Yochum, N., Hoenig, J., Lucy, J., and Cimino, J., 2007. Evaluating localized vs. large-scale management: the example of tautog in Virginia. Fisheries 32: 21–28.

Van Voorhees, D., Hoffman, A., Lowther, A., Van Buskirk, W., Weinstein, J., and White, J. 2000. An evaluation of alternative estimators of ocean-boat fish effort and catch in Oregon. The Pacific RecFIN Statistics Subcommittee, http://old.recfin.org/lib/RecFIN_ORBS_ MRFSS_Comparison.PDF.

VenTresca, D.A., Parrish, R.H., Houk, J.L., Gingras, M.L., Short, S.D., and Crane, N.L. 1995. El Nino effects on the somatic and reproductive condition of blue rockfish, Sebastes mystinus. CalCOFI Reports 36: 167–174.

VenTresca, D., J. Houk, M. Paddack, M. Gingras, N. Crane, and S. Short. 1996. Early life-history studies of nearshore rockfishes and lingcod off Central California, 1987-1992. Marine Resources Division Administrative Report 96-4, California Department of Fish and Game. 78 p.

von Bertalanffy, L. 1957. Quantitative laws in metabolism and growth. Quarterly Review Biology 32: 217–231.

Wales, J.H., 1952. Life history of the blue rockfish *Sebastodes mystinus*. California Fish and Game 38: 485–498.

Whipple, J. 1991. Progress in rockfish recruitment studies. NMFS-SWFSC Administrative Report T-91-01.

Williams, E.H., and Ralston, S. 2002. Distribution and co-occurrence of rockfishes (family: Sebastidae) over trawlable shelf and slope habitats of California and southern Oregon. Fishery Bulletin 100: 836–855.

Wilson, C.E., Halko, L.A., Wilson-Vandenberg, D., and Reilly, P.N. 1996. Onboard sampling of the rockfish and lingcod commercial passenger fishing vessel industry in northern and central California, 1992. California Department of Fish and Game. Marine Resources Division Administrative Report 96-2.

Wyllie-Echeverria, T. 1987. Thirty-four species of California rockfishes: maturity and seasonality of reproduction. Fishery Bulletin 85: 229–250.

Young, P. 1969. The California Partyboat Fishery, Fish Bulletin 145, California Dept. of Fish and Game, 91 p.

10 Auxiliary Files

Files archived with the California assessment

B17.ctl
B17.dat
forecast.ss
starter.ss
ss.exe

Files archived with the Oregon assessment

BDR_OR17.ctl
BDR_OR17.dat
forecast.ss
starter.ss
ss.exe

11 Tables

Table 1: History of recreational bag limits and Oregon state management groups for Blue and Deacon Rockfishes.

Year	Blue / Deacon Rockfishes State Management Group	Daily Bag Limit
Pre-1976	N/A	N/A
1976	Other Fish	25
1978	Other Fish	15
1986	Rockfish, Cabezon and Greenling	15
1994	Rockfish	15
2000	Rockfish	10
2003	Rockfish, Cabezon, Greenling, Flounder, and Other Marine Species	10
2005	Rockfish, Cabezon, Greenling, Flounder, and Other Marine Species	8
2006	Rockfish, Cabezon, Greenling, Flounder, and Other Marine Species	6
2010	Rockfish, Cabezon, Greenling, and Other Marine Species	7
2015	Rockfish, Cabezon, Greenling, and Other Marine Species	3*
2017	Rockfish, Cabezon, Greenling, and Other Marine Species	4*

* - sub-bag limits from a 7 fish aggregate bag limit

Table 2: Summary of recent management history for the northern nearshore rockfish (40°10' N) complex relative to harvest limits (mt).

Year	Control Rule	Harvest Limit	Complex Impacts (mt)	Blue/Deacon Impacts (mt)	Blue/Deacon % of Complex Impacts	Complex Impacts % of Limit
2008	OY	142	97	30	31	68
2009	OY	155	63	30	47	41
2010	OY	155	75	40	54	48
2011	ACL	99	99	44	44	100
2012	ACL	99	96	44	45	97
2013	ACL	94	75	37	49	80
2014	ACL	94	59	29	50	63
2015	ACL	69	64	42	65	93
2016	ACL	69	*	*	*	*
2017	ACL	105	*	*	*	*

* - Totals not yet available from the West Coast Groundfish Observer Program

Table 3: State of Oregon bimonthly period trip limit history for Blue and Deacon Rockfishes. Inseason changes implemented are in parentheses.

Year	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
2003 [1]	-	-	-	3,000	3,000	3,000
2004	3,000	3,000	3,000	3,000 (1,500)	3,000 (Closed)	3,000 (Closed)
2005	1,000	1,000	1,500	1,500 (700)	800 (500)	500
2006 [2]	300	600	600	600	300	250
2007	600	800	1,600	1,600	1,600 (2,000)	800 (Closed)
2008	600	800	1,600	1,600 (1,200)	1,600 (1,200)	800 (400)
2009	800	1,000	1,600	1,600	1,200	1,000 (400)
2010	800	1,000	1,400	1,400 (1,600)	1,000 (1,400)	800 (1,200)
2011	800	1,000	1,400	1,400 (1,600)	1,000 (1,400)	800 (1,200)
2012	800	1,000	1,400 (1,800)	1,400 (1,800)	1,000 (2,100)	800 (2,100)
2013	1,000	1,200	1,700	1,600	1,200 (2,100)	1,000 (1,800)
2014	1,000	1,400	1,700	1,600	1,400 (1,600)	1,000 (1,200)
2015	15	15	15	15	15 (50)	15 (50)
2016	30	30	30	30 (50)	30 (150)	30 (150)

[1] - State trip limits for Blue/Deacon Rockfishes began on 7/16/2003.

[2] - limits presented for 2006 were one month limits (e.g. Period 1 limits = 300 lbs for Jan. and 300 lbs for Feb.)

Table 4: Total mortality of "Blue Rockfish" (Blue and Deacon Rockfishes, combined) from the NWFSC Total Mortality reports.

Area	Year	Commercial fisheries		Recreational fishing mortality			Research	Estimated Total Fishing Mortality
		Nearshore fixed gear	All other gears	WA	OR	CA		
North of 40°10' N. lat.	2015	9.76	0.01	1.13	26.81	3.93	0.01	41.65
	2014	7.50	0.04	0.56	19.82	1.45	--	29.38
	2013	9.37	0.04	0.80	23.96	2.33	0.01	36.51
	2012	12.28	0.08	1.27	27.12	2.86	0.03	43.64
	2011	15.20	0.00	1.30	27.47	--	--	43.97
	2010	10.90	--	2.58	23.00	3.65	0.03	40.17
	2009	9.10	--	0.70	16.80	3.20	0.00	29.70
South of 40°10' N. lat.	2015	9.18	0.23	--	--	172.42	0.03	181.86
	2014	6.06	0.12	--	--	132.59	0.05	138.83
	2013	3.56	0.01	--	--	103.88	0.17	107.62
	2012	1.41	0.02	--	--	48.90	0.38	50.70
	2011	3.94	0.04	--	--	54.30	0.02	58.31
	2010	3.14	0.00	--	--	42.33	0.02	45.49
	2009	3.30	0.00	--	--	41.60	0.00	44.90

Table 5: Evaluation of Management Performance for "Blue Rockfish" (Blue and Deacon Rockfishes, combined). Total Mortality estimates are based on annual reports from the NMFS NWFSC.

Area	Year	"Blue Rockfish" (BDR)			Minor Nearshore Rockfish		
		NWFSC Total Mortality	ABC/ACL Contribution [1] (CA + OR/WA)	OFL Contribution [1] (CA + OR/WA)	Total Mortality	ACL	OFL
North of 40° 10'	2011	44.0	*25.3 + 27.6 = 52.9*	*27.7 + 33.1 = 60.8*	99.0	99	116
	2012	43.6	*25.1 + 27.6 = 52.7*	*27.5 + 33.1 = 60.6*	96.0	99	116
	2013	36.5	*22.2 + 26.9 = 49.1*	*27.4 + 32.3 = 59.7*	75.0	94	110
	2014	29.4	*22.2 + 26.9 = 49.1*	*27.4 + 32.3 = 59.7*	59.0	94	110
	2015	41.6	*17.0 + 26.9 = 43.9*	*27.4 + 32.3 = 59.7*	64.3	69	88
	2016	TBD	*17.5 + 26.9 = 44.4*	*27.7 + 32.3 = 60.0*	TBD	69	88
South of 40° 10'			**(S + N of 34°27' N lat.)**	**(S + N of 34°27' N lat.)**			
	2011	58.3	*61.8 + 156.3 = 218.1*	*74.0 + 191.3 = 265.3*	436	1,001	1,156
	2012	50.7	*61.8 + 154.5 = 216.3*	*74.0 + 189.5 = 263.5*	445	1,001	1,145
	2013	107.6	*60.8 + 152.8 = 213.6*	*72.9 + 187.8 = 260.7*	495	990	1,164
	2014	138.8	*60.8 + 152.8 = 213.6*	*72.9 + 187.8 = 260.7*	596	990	1,160
	2015	181.9	*60.8 + 116.6 = 177.4*	*72.9 + 188.6 = 261.5*	676	1,114	1,313
	2016	TBD	*60.8 + 120.0 = 180.8*	*72.9 + 190.3 = 263.2*	TBD	1,006	1,288

1 - Harvest contributions to the Minor Nearshore Rockfish complexes are not management limits; management limits are specified at the complex level. ACL = ABC for these contributions with a 40-10 adjustment to the ACLs for those areas assessed in 2007 by Key et al. (off CA north of 34°27' N lat.).

Table 6: Estimated California commercial landings and discard by year, area, and fleet.

	Northern California				Southern California			Commercial Totals		
Year	Hook and Line	Net	Trawl/Other	Discard	Hook and Line	Net	Discard	North	South	All
1900	0.00			0.00				0.00		0.00
1901	1.10			0.56				1.66		1.66
1902	2.21			1.12				3.32		3.32
1903	3.31			1.67				4.98		4.98
1904	4.41			2.23				6.64		6.64
1905	5.51			2.79				8.30		8.30
1906	6.62			3.35				9.97		9.97
1907	7.72			3.91				11.63		11.63
1908	8.82			4.47				13.29		13.29
1909	9.92			5.02				14.95		14.95
1910	11.03			5.58				16.61		16.61
1911	12.13			6.14				18.27		18.27
1912	13.23			6.70				19.93		19.93
1913	14.33			7.26				21.59		21.59
1914	15.44			7.82				23.25		23.25
1915	16.54			8.37				24.91		24.91
1916	17.64		0.166	9.02	0.07		0.03	26.82	0.10	26.92
1917	27.52		0.258	14.07	0.11		0.05	41.85	0.16	42.01
1918	32.73		0.301	16.72	0.10		0.05	49.75	0.15	49.90
1919	22.19		0.209	11.34	0.06		0.03	33.74	0.09	33.83
1920	22.73		0.214	11.62	0.06		0.03	34.56	0.09	34.66
1921	19.02		0.176	9.72	0.05		0.03	28.92	0.08	29.01
1922	16.31		0.152	8.34	0.05		0.03	24.80	0.08	24.88
1923	17.35		0.164	8.87	0.07		0.04	26.39	0.11	26.49
1924	10.43		0.094	5.33	0.10		0.05	15.85	0.15	16.00
1925	13.78		0.117	7.04	0.11		0.05	20.94	0.16	21.10
1926	21.32		0.191	10.89	0.13		0.07	32.41	0.20	32.61
1927	19.41		0.162	9.91	0.11		0.06	29.48	0.16	29.64
1928	22.13		0.200	11.31	0.09		0.05	33.64	0.14	33.78
1929	18.91		0.162	9.66	0.09		0.05	28.73	0.14	28.87
1930	26.98		0.231	13.78	0.10		0.05	40.99	0.14	41.14
1931	23.59		0.101	12.00	0.18		0.09	35.69	0.26	35.95
1932	19.74		0.249	10.12	0.02		0.01	30.11	0.03	30.14
1933	10.94		0.253	5.67	0.10		0.05	16.86	0.16	17.02
1934	17.62		0.171	9.01	0.02		0.01	26.80	0.04	26.84
1935	21.62		0.096	10.99	0.02		0.01	32.71	0.03	32.74
1936	38.17		0.140	19.40	0.03		0.01	57.71	0.04	57.75
1937	35.44		0.251	18.07	0.02		0.01	53.76	0.04	53.79
1938	24.63		0.206	12.57	0.02		0.01	37.41	0.03	37.43
1939	11.47		0.150	5.88	0.02		0.01	17.50	0.03	17.54
1940	12.49		0.081	6.36	0.02		0.01	18.93	0.03	18.97
1941	8.10		0.108	4.15	0.02		0.01	12.36	0.02	12.38
1942	4.02		0.012	2.04	0.00		0.00	6.07	0.01	6.08
1943	6.34		0.022	3.22	0.00		0.00	9.59	0.01	9.60
1944	18.47		0.007	9.35	0.00		0.00	27.82	0.00	27.83
1945	41.23		0.019	20.88	0.00		0.00	62.13	0.00	62.14
1946	42.21		0.014	21.38	0.00		0.00	63.59	0.01	63.60
1947	15.17		0.117	7.74	0.01		0.00	23.03	0.01	23.04
1948	25.24		0.087	12.82	0.01		0.01	38.15	0.02	38.17
1949	16.68		0.534	8.72	0.03		0.01	25.93	0.04	25.97
1950	28.38		1.988	15.38	0.02		0.01	45.75	0.03	45.78
1951	26.16		3.985	15.26	0.01		0.01	45.41	0.02	45.43
1952	18.46		5.571	12.16	0.01		0.00	36.19	0.01	36.20
1953	7.16		7.054	7.20	0.01		0.01	21.41	0.02	21.43
1954	10.93		4.496	7.81	0.02		0.01	23.24	0.03	23.27
1955	9.16		2.549	5.93	0.02		0.01	17.64	0.03	17.67
1956	28.85		4.167	16.72	0.03		0.02	49.73	0.05	49.78
1957	26.87		4.423	15.84	0.03		0.01	47.14	0.04	47.18

Table 6 (continued). Estimated California commercial landings and discard by year, area, and fleet.

	Northern California				Southern California			Commercial Totals		
Year	Hook and Line	Net	Trawl/Other	Discard*	Hook and Line	Net	Discard	North	South	All
1958	20.01		7.45	13.90	0.04		0.02	41.35	0.06	41.41
1959	10.08		9.13	9.73	0.05		0.02	28.94	0.07	29.01
1960	4.61		5.21	4.97	0.05		0.02	14.79	0.07	14.86
1961	3.15		4.00	3.62	0.06		0.03	10.76	0.08	10.85
1962	2.19		3.29	2.77	0.04		0.02	8.25	0.06	8.31
1963	2.57		3.52	3.09	0.06		0.03	9.18	0.08	9.27
1964	1.72		2.38	2.08	0.05		0.02	6.18	0.07	6.25
1965	2.97		2.51	2.77	0.06		0.03	8.25	0.09	8.34
1966	4.16		2.58	3.41	0.09		0.05	10.15	0.14	10.29
1967	3.84		1.59	2.75	0.09		0.05	8.18	0.14	8.31
1968	2.98		1.29	2.16	0.06		0.03	6.42	0.10	6.52
1969	8.49	3.46	2.47	7.30	0.31	0.03	0.17	21.73	0.51	22.24
1970	10.48	4.48	3.50	9.35	0.21	0.01	0.11	27.81	0.34	28.15
1971	7.80	25.94	2.86	18.53	0.24	0.01	0.13	55.13	0.38	55.51
1972	12.23	32.18	4.48	24.75	0.36	0.01	0.19	73.64	0.56	74.19
1973	19.29	74.65	5.06	50.12	0.33	0.06	0.20	149.12	0.59	149.71
1974	15.61	106.45	6.61	65.15	0.29	0.24	0.26	193.81	0.79	194.60
1975	15.97	119.17	9.79	73.38	0.52	0.21	0.37	218.32	1.09	219.41
1976	22.22	39.11	10.82	36.53	0.64	0.23	0.44	108.68	1.30	109.99
1977	18.24	52.18	11.42	41.43	0.53	0.23	0.39	123.27	1.15	124.42
1978	4.58	16.60	24.64	23.20	0.74	0.34	0.54	69.03	1.62	70.65
1979	34.67	13.25	9.76	29.20	1.20	0.67	0.95	86.89	2.82	89.70
1980	49.55	2.30	0.30	26.40	1.11	0.47	0.80	78.55	2.37	80.92
1981	35.87	1.16	29.86	33.87	1.08	0.87	0.99	100.76	2.94	103.71
1982	57.79	0.47	2.85	30.94	1.68	0.72	1.21	92.04	3.61	95.65
1983	70.22	0.83	0.18	36.06	1.01	0.63	0.83	107.29	2.47	109.76
1984	24.64	1.32	0.32	13.31	0.20	0.62	0.42	39.60	1.24	40.83
1985	41.91	139.34	3.47	93.52	1.16	1.14	1.17	278.24	3.47	281.71
1986	2.81	12.78	0.28	8.04	1.26	1.59	1.44	23.91	4.29	28.20
1987	7.78	0.42	0.05	4.18	0.25	0.02	0.14	12.42	0.41	12.83
1988	7.71	0.13	0.01	3.97	1.73	0.20	0.98	11.82	2.91	14.73
1989	17.15	14.10	0.21	15.93	1.53	0.00	0.78	47.38	2.31	49.69
1990	26.85	1.52	0.07	14.40	0.55	0.66	0.61	42.85	1.83	44.67
1991	35.39	1.43	0.01	18.65	0.59	0.00	0.30	55.48	0.89	56.38
1992	181.41	0.01	0.04	91.87	19.52	8.37	14.12	273.33	42.01	315.34
1993	133.83	0.33	0.01	67.93	19.02	4.80	12.06	202.10	35.89	237.99
1994	71.95	0.03	0.42	36.65	1.71	4.95	3.37	109.05	10.03	119.08
1995	28.44	0.00	6.25	17.56	14.17	0.00	7.18	52.26	21.35	73.60
1996	44.02	0.08	0.03	22.34	2.64	0.00	1.34	66.46	3.97	70.44
1997	62.67	0.02	1.00	32.24	1.92	0.39	1.17	95.93	3.49	99.42
1998	47.53	0.02	0.35	24.25	0.57	0.00	0.29	72.13	0.86	73.00
1999	35.51	0.06	0.17	18.10	0.16	0.00	0.08	53.84	0.24	54.09
2000	12.51	0.00	0.30	6.49	0.22	0.00	0.11	19.30	0.33	19.62
2001	16.08	0.00	0.08	8.18	0.13	0.00	0.07	24.34	0.20	24.54
2002	15.14	0.00	0.07	7.70	0.39	0.00	0.20	22.91	0.58	23.49
2003	6.60	0.00	0.06	3.37	0.18	0.00	0.09	10.03	0.27	10.30
2004	12.10	0.00	0.01	6.13	0.21	0.00	0.11	18.24	0.32	18.56
2005	17.67	0.00	0.10	9.00	0.18	0.00	0.09	26.76	0.27	27.03
2006	18.73	0.00	0.04	9.50	0.29	0.00	0.14	28.27	0.43	28.70
2007	13.14	0.18	0.08	6.78	0.08	0.00	0.04	20.18	0.11	20.29
2008	26.02		0.31	13.33	0.87	0.00	0.44	39.66	1.32	40.98
2009	7.28		0.07	3.72	0.29	0.00	0.15	11.06	0.43	11.49
2010	4.92		0.01	2.49	0.04	0.00	0.02	7.42	0.06	7.47
2011	7.10		0.02	3.60	0.02	0.00	0.01	10.72	0.04	10.75
2012	6.62		0.02	3.36	0.06	0.00	0.03	9.99	0.09	10.08
2013	6.05		0.05	3.09	0.19	0.00	0.10	9.19	0.29	9.48
2014	5.88		0.02	2.99	0.49	0.00	0.25	8.89	0.74	9.63
2015	9.15		0.03	4.65	0.84	0.13	0.49	13.82	1.46	15.28
2016	7.10		0.06	3.62	0.65	0.00	0.33	10.78	0.97	11.75

Table 7: California length composition sample sizes (trips and lengths) by year, area, and data source.

	Commercial Hook and Line		Commercial Net Gears		Commercial Discard		Rec CPFV Karpov et al.		Rec CPFV Coop. Survey		Rec CPFV MRFSS/CRFS		Rec Private MRFSS/CRFS		Rec CPFV Obs. Discard		Rec CPFV Obs. Retained	
Year	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths
1959	-	-	-	-	-	-	67	2015	-	-	-	-	-	-	-	-	-	-
1960	-	-	-	-	-	-	421	12629	-	-	-	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	54	1615	-	-	-	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	187	5598	-	-	-	-	-	-	-	-	-	-
1963	-	-	-	-	-	-	328	9839	-	-	-	-	-	-	-	-	-	-
1964	-	-	-	-	-	-	98	2926	-	-	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-			-	-	-	-	-	-	-	-	-	-
1966	-	-	-	-	-	-	44	1306	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	59	1775	-	-	-	-	-	-	-	-	-	-
1968	-	-	-	-	-	-	53	1575	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	65	1964	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	78	2328	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	40	1213	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	33	990	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	-	-	4	85	-	-	-	-	57	266	-	-	-	-	-	-	-	-
1979	4	33	1	10	-	-	-	-	106	1628	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	200	1104	71	1223	173	901	-	-	-	-
1981	-	-	-	-	-	-	-	-	133	816	42	1198	133	889	-	-	-	-
1982	2	10	-	-	-	-	-	-	139	867	46	977	176	1215	-	-	-	-
1983	-	-	-	-	-	-	-	-	182	1824	52	1302	184	1177	-	-	-	-
1984	-	-	-	-	-	-	-	-	92	879	98	1485	231	1223	-	-	-	-
1985	-	-	2	32	-	-	-	-	-	-	147	2044	214	1142	-	-	-	-
1986	-	-	-	-	-	-	-	-	-	-	82	638	189	791	-	-	-	-
1987	-	-	-	-	-	-	-	-	-	-	37	466	128	581	-	-	42	1513
1988	-	-	-	-	-	-	-	-	-	-	52	587	91	385	-	-	131	5788
1989	-	-	1	16	-	-	-	-	-	-	41	635	93	515	-	-	154	5028
1990	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	51	1000
1991	4	82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	59	2897
1992	88	1239	-	-	-	-	-	-	-	-	-	-	-	-	-	-	163	7819
1993	200	3616	-	-	-	-	-	-	-	-	13	419	453	2986	-	-	168	7888
1994	134	1732	-	-	-	-	-	-	-	-	18	430	241	1104	-	-	180	6618
1995	83	586	-	-	-	-	-	-	-	-	41	628	167	520	-	-	188	8553
1996	88	976	-	-	-	-	-	-	-	-	134	2327	170	679	-	-	157	8140
1997	50	866	-	-	-	-	-	-	-	-	158	14817	92	434	-	-	205	18447
1998	23	460	-	-	-	-	-	-	-	-	127	7365	139	688	-	-	138	12460
1999	86	996	-	-	-	-	-	-	-	-	85	3265	178	802	-	-	-	-
2000	19	98	-	-	-	-	-	-	-	-	25	581	92	429	-	-	-	-
2001	12	82	-	-	-	-	-	-	-	-	45	735	33	66	-	-	-	-
2002	11	243	-	-	-	-	-	-	-	-	58	2237	108	563	-	-	-	-
2003	3	35	-	-	-	-	-	-	-	-	75	3462	173	766	77	1274	-	-
2004	10	105	-	-	90	817	-	-	-	-	200	5934	887	3042	133	3784	-	-
2005	15	150	-	-	63	535	-	-	-	-	128	5223	1238	4568	67	1190	-	-
2006	13	140	-	-	66	632	-	-	-	-	115	6058	1742	7211	74	1062	-	-
2007	25	294	-	-	67	588	-	-	-	-	140	5159	1118	4165	59	438	-	-
2008	20	136	-	-	44	418	-	-	-	-	133	3963	1058	3298	28	232	-	-
2009	19	168	-	-	43	461	-	-	-	-	138	1735	771	1794	28	88	-	-
2010	9	68	-	-	48	361	-	-	-	-	120	2206	639	1766	20	108	-	-
2011	16	325	-	-	65	415	-	-	-	-	145	2622	699	1815	28	76	-	-
2012	21	723	-	-	55	326	-	-	-	-	212	2591	728	1971	16	68	-	-
2013	20	439	-	-	38	198	-	-	-	-	289	5287	1241	3744	31	132	-	-
2014	16	295	-	-	47	276	-	-	-	-	262	5100	1272	4416	44	186	-	-
2015	31	718	-	-	103	422	-	-	-	-	120	3257	1968	7366	35	135	-	-
2016	13	176	-	-	-	-	-	-	-	-	117	2831	1396	4971	66	544	-	-

Table 8: Estimated California recreational landings and discard by year, area, and fleet.

	Northern California			Southern California			Recreational Totals		
Year	CPFV	Private	Discard	CPFV	Private	Discard	North	South	All
1928	1.45	5.85	0.15	0.03	0.08	0.00	7.44	0.11	7.55
1929	2.89	11.69	0.29	0.05	0.17	0.00	14.87	0.22	15.10
1930	3.32	13.44	0.34	0.08	0.25	0.01	17.10	0.34	17.43
1931	4.43	17.91	0.45	0.11	0.33	0.01	22.79	0.45	23.24
1932	5.54	22.39	0.56	0.13	0.42	0.01	28.49	0.56	29.05
1933	6.65	26.87	0.67	0.16	0.50	0.01	34.19	0.67	34.86
1934	7.76	31.35	0.78	0.19	0.58	0.02	39.89	0.78	40.67
1935	8.87	35.83	0.89	0.21	0.66	0.02	45.59	0.89	46.48
1936	9.97	40.31	1.01	0.21	0.66	0.02	51.29	0.89	52.18
1937	11.82	47.78	1.19	0.32	0.73	0.02	60.79	1.07	61.86
1938	11.63	46.99	1.17	0.29	0.87	0.02	59.79	1.19	60.98
1939	10.17	41.09	1.03	0.26	0.77	0.02	52.29	1.05	53.34
1940	14.64	59.18	1.48	0.19	0.61	0.02	75.30	0.82	76.12
1941	13.53	54.70	1.36	0.18	0.57	0.01	69.60	0.76	70.35
1942	7.19	29.05	0.72	0.09	0.30	0.01	36.97	0.40	37.37
1943	6.88	27.79	0.69	0.09	0.29	0.01	35.36	0.38	35.74
1944	5.65	22.81	0.57	0.07	0.24	0.01	29.03	0.32	29.34
1945	7.53	30.42	0.76	0.10	0.31	0.01	38.71	0.42	39.13
1946	12.96	52.36	1.31	0.17	0.54	0.01	66.62	0.72	67.34
1947	10.25	41.42	1.03	0.60	2.96	0.07	52.70	3.64	56.34
1948	20.45	82.67	2.06	1.43	4.23	0.11	105.18	5.77	110.96
1949	26.51	107.14	2.67	1.80	5.07	0.14	136.32	7.01	143.33
1950	32.31	130.56	3.26	2.17	7.85	0.20	166.12	10.21	176.34
1951	48.16	149.12	3.95	1.85	6.04	0.16	201.22	8.05	209.27
1952	41.90	129.75	3.43	2.34	9.64	0.24	175.08	12.22	187.30
1953	35.68	110.49	2.92	2.77	10.03	0.26	149.10	13.06	162.16
1954	44.36	137.36	3.63	6.26	22.88	0.58	185.36	29.73	215.09
1955	52.88	163.75	4.33	11.07	46.77	1.16	220.97	59.00	279.97
1956	59.05	182.84	4.84	12.91	48.08	1.22	246.73	62.21	308.94
1957	57.60	178.98	4.73	7.54	29.24	0.74	241.32	37.51	278.83
1958	94.57	297.26	7.84	5.08	23.93	0.58	399.67	29.60	429.27
1959	79.05	244.39	6.47	2.98	11.50	0.29	329.91	14.76	344.68
1960	61.21	189.94	5.02	3.07	10.06	0.26	256.17	13.40	269.57
1961	46.26	140.60	3.74	3.51	11.12	0.29	190.60	14.93	205.52
1962	60.68	159.71	4.41	3.40	9.66	0.26	224.80	13.32	238.12
1963	69.81	169.24	4.78	3.45	13.20	0.33	243.84	16.98	260.82
1964	64.43	116.96	3.63	4.85	22.98	0.56	185.02	28.39	213.41
1965	94.19	190.57	5.70	12.64	32.10	0.89	290.45	45.64	336.10
1966	105.91	192.70	5.97	25.23	33.89	1.18	304.57	60.31	364.88
1967	111.95	185.67	5.95	37.62	42.52	1.60	303.57	81.75	385.32
1968	122.13	203.27	6.51	47.63	48.98	1.93	331.91	98.53	430.44
1969	132.39	211.22	6.87	47.34	37.03	1.69	350.48	86.06	436.54
1970	155.86	259.39	8.30	72.52	52.49	2.50	423.55	127.51	551.06
1971	141.92	198.66	6.81	72.56	45.52	2.36	347.39	120.44	467.83
1972	172.12	274.28	8.93	100.98	62.42	3.27	455.32	166.67	622.00

Table 8: (continued) Estimated California recreational landings and discard by year, area, and fleet.

	Northern California			Southern California			Recreational Totals		
Year	CPFV	Private	Discard	CPFV	Private	Discard	North	South	All
1973	201.96	325.72	10.55	124.78	76.17	4.02	538.23	204.97	743.20
1974	213.66	344.65	11.17	155.52	81.97	4.75	569.47	242.24	811.71
1975	213.49	302.65	10.32	159.57	85.65	4.90	526.46	250.12	776.58
1976	233.16	338.45	11.43	132.24	59.19	3.83	583.04	195.25	778.30
1977	222.74	277.14	10.00	125.98	63.04	3.78	509.87	192.81	702.68
1978	213.23	219.30	8.65	123.85	61.27	3.70	441.19	188.82	630.01
1979	227.88	237.68	9.31	177.91	76.27	5.08	474.87	259.26	734.13
1980	228.17	250.85	9.58	198.07	84.95	5.66	488.61	288.67	777.28
1981	554.63	265.75	16.41	140.06	217.26	7.15	836.78	364.47	1201.25
1982	427.13	223.53	13.01	160.52	277.19	8.75	663.68	446.46	1110.14
1983	358.89	181.38	10.81	46.58	173.88	4.41	551.07	224.88	775.95
1984	230.13	195.40	8.51	36.85	97.07	2.68	434.05	136.60	570.64
1985	140.44	120.83	5.23	40.22	100.25	2.81	266.49	143.28	409.77
1986	32.88	91.29	2.48	38.59	111.38	3.00	126.66	152.97	279.63
1987	49.63	208.89	5.17	42.24	92.07	2.69	263.69	136.99	400.68
1988	109.45	196.14	6.11	35.92	39.26	1.50	311.70	76.69	388.39
1989	80.68	149.54	4.60	30.01	28.78	1.18	234.82	59.97	294.79
1990	81.87	227.26	6.18	22.61	21.80	0.89	315.32	45.29	360.61
1991	83.07	304.99	7.76	15.21	14.82	0.60	395.82	30.62	426.44
1992	84.27	382.71	9.34	7.80	7.83	0.31	476.32	15.95	492.27
1993	85.46	460.43	10.92	0.40	0.85	0.03	556.81	1.28	558.09
1994	86.66	164.85	5.03	6.92	8.69	0.31	256.54	15.92	272.47
1995	87.86	102.71	3.81	3.24	1.85	0.10	194.38	5.19	199.57
1996	89.05	73.25	3.25	33.19	1.97	0.70	165.54	35.87	201.42
1997	215.93	79.43	5.91	23.21	0.11	0.47	301.27	23.79	325.05
1998	116.84	132.25	4.98	13.23	0.51	0.27	254.07	14.01	268.08
1999	106.24	90.12	3.93	10.88	1.31	0.24	200.29	12.43	212.71
2000	99.96	47.96	2.96	1.86	0.24	0.04	150.87	2.15	153.02
2001	74.62	38.21	2.26	0.58	0.55	0.02	115.08	1.15	116.24
2002	68.76	78.72	2.95	0.68	1.79	0.05	150.43	2.52	152.94
2003	47.59	171.56	4.38	3.20	6.06	0.19	223.53	9.44	232.97
2004	98.24	51.40	2.99	12.46	2.14	0.29	152.63	14.89	167.53
2005	209.25	62.44	5.43	23.03	2.59	0.51	277.13	26.13	303.26
2006	174.21	109.94	5.68	7.00	1.64	0.17	289.83	8.81	298.64
2007	95.03	39.88	2.70	10.64	2.48	0.26	137.61	13.39	151.00
2008	47.11	28.77	1.52	6.49	1.62	0.16	77.39	8.27	85.66
2009	21.49	16.89	0.77	5.54	0.76	0.13	39.15	6.42	45.57
2010	28.93	21.56	1.01	1.01	0.61	0.03	51.50	1.65	53.15
2011	34.97	23.53	1.17	2.43	0.20	0.05	59.67	2.68	62.36
2012	30.12	18.54	0.97	2.67	0.20	0.06	49.63	2.93	52.56
2013	66.84	35.95	2.06	3.01	0.38	0.07	104.84	3.46	108.30
2014	64.38	49.37	2.27	18.97	1.06	0.40	116.02	20.43	136.45
2015	91.73	63.91	3.11	18.97	1.84	0.42	158.74	21.22	179.96
2016	81.23	41.79	2.46	18.51	1.33	0.40	125.48	20.23	145.72

Table 9: Analysis of dead discard as a fraction of retained catch for California. Catch and discard are in units of metric tons, data are CRFS estimates of dead discard and retained catch from 2005-2016.

region	mode	Retained Catch	Dead Discard	Discard/Retained
North	CPFV	1933	33	0.017
	Private	879	38	0.043
South	CPFV	324	12	0.038
	Private	32	2	0.066
Grand Total		3168	85	0.027

Table 10: California age composition sample sizes (number of aged structures) by year, sex, and data source.

	Coop. Groundfish Survey		Schmidt research		Abrams research	
Year	Female	Male	Female	Male	Female	Male
1980	222	85				
1981	185	121				
1982	260	104				
1983	210	51				
1984	328	142				
2010			300	50	163	76
2011			319	89	128	41

Table 11: Data filters applied to the California MRFSS dockside CPFV index. See Section 2.2.3.1 for details regarding specific filter steps.

Data Filter	Number of Trips
[unfiltered, Northern California data only]	2923
Remove trips that caught albacore	2883
Stephens-MacCall filter	1667
Drop Del Norte and Humboldt Counties	1646
Drop years 1993-94, 1997-98, and post-1999	1086

Table 12: Sample size (number of trips) by year and subregion for the California MRFSS dockside CPFV index. MendoSomo = Mendocino and Sonoma counties; MontereySC = Monterey and Santa Cruz counties; SFBayArea = Alameda, Contra Costa, Marin, San Francisco, San Joaquin, and San Mateo counties; SLO = San Luis Obispo county.

	SUBREGION				
YEAR	MendoSono	MontereySC	SFBayArea	San Luis Obispo	Subtotal
1980	15	40	14	18	87
1981	15	12	14	10	51
1982	22	19	11	6	58
1983	16	31	9	7	63
1984	14	72	12	22	120
1985	25	73	34	33	165
1986	10	37	20	37	104
1987	12	6	19	14	51
1988	2	23	16	24	65
1989	4	4	27	10	45
1995	10	11	8	16	45
1996	21	38	38	41	138
1999	12	23	36	23	94
Subtotal	178	389	258	261	1086

Table 13: Proportion of trips that caught Blue/Deacon rockfish by year and subregion for the California MRFSS dockside CPFV index. Subtotals are the sum of positive trips divided by the total number of trips in a given year or subregion. MendoSomo = Mendocino and Sonoma counties; MontereySC = Monterey and Santa Cruz counties; SFBayArea = Alameda, Contra Costa, Marin, San Francisco, San Joaquin, and San Mateo counties; SLO = San Luis Obispo county.

	SUBREGION				
YEAR	MendoSono	MontereySC	SFBayArea	San Luis Obispo	Subtotal
1980	0.933	0.700	0.857	0.944	0.816
1981	0.667	0.833	0.857	1.000	0.824
1982	0.636	0.842	0.909	1.000	0.793
1983	0.750	0.806	0.889	1.000	0.825
1984	0.786	0.861	0.583	0.818	0.817
1985	0.920	0.808	0.912	0.939	0.873
1986	0.900	0.784	0.750	0.784	0.788
1987	0.750	0.333	0.632	1.000	0.725
1988	1.000	0.957	0.688	0.583	0.754
1989	0.750	1.000	0.889	1.000	0.911
1995	0.900	1.000	0.750	0.875	0.889
1996	0.905	0.947	0.974	0.927	0.942
1999	0.750	0.826	0.944	0.957	0.894
Subtotal	0.809	0.830	0.849	0.881	0.843

Table 14: Akaike Information Criteria for alternative models of catch-per-unit-effort based on California MRFSS dockside CPFV data. All models include an effort offset term (log of angler hours).

Negative Binomial Model	Parameters	AIC-AIC$_{min}$	AIC
Intercept only	2	129.2	8224.1
Year	14	76.2	8171.1
Year + Subregion	17	61.7	8156.7
Year + Subregion + Wave	22	63.4	8158.4
Year + Subregion + Distance	18	43.2	8138.2
Year + Subregion + Distance + (Year x Subregion)	54	0.0	8094.9

Table 15: California MRFSS dockside CPFV Index, with log-scale standard errors and 95% highest posterior density (HPD) intervals.

Year	Mean	logSE	HPD_lower	HPD_upper
1980	1.601	0.219	0.964	2.335
1981	1.945	0.290	0.981	3.169
1982	2.795	0.405	1.111	5.416
1983	2.351	0.315	1.155	3.953
1984	1.744	0.256	1.017	2.734
1985	1.115	0.151	0.799	1.456
1986	0.396	0.184	0.267	0.547
1987	0.758	0.225	0.447	1.109
1988	1.417	0.436	0.585	2.700
1989	0.886	0.297	0.462	1.448
1995	0.816	0.278	0.429	1.319
1996	1.478	0.168	1.037	1.992
1999	1.274	0.173	0.862	1.710

Table 16: Data filters applied to the Northern California CRFS private boat dockside index.

Data Filter	Number of Trips
[unfiltered, Northern California data only]	62178
Drop trips that caught Albacore or Pacific bonito	61220
Stephens-MacCall filter (keeping false negatives)	27725
Drop waves 1 and 2 (Jan-Apr); no samples 2005-2013	27235
Drop Area_X = 2 (outside 3nm); no samples 2004-2011	26981

Table 17: Sample size (number of trips) by year and subregion for the Northern California CRFS private boat dockside index. SLO = San Luis Obispo county; MontereySC = Monterey and Santa Cruz counties; SFBayArea = Alameda, Contra Costa, Marin, San Francisco, San Joaquin, and San Mateo counties; MendoSono = Mendocino and Sonoma counties; DelNorte-Humboldt = Del Norte and Humboldt counties.

	SUBREGION					
YEAR	SLO	Monterey-SC	SFBayArea	Mendo-Sono	DelNorte-Humboldt	Subtotal
2004	577	398	219	189	279	1662
2005	537	647	424	257	437	2302
2006	629	672	1012	513	552	3378
2007	540	474	398	235	407	2054
2008	443	395	339	423	324	1924
2009	312	309	477	375	333	1806
2010	391	222	349	105	235	1302
2011	431	458	366	86	251	1592
2012	405	520	226	81	281	1513
2013	621	845	318	119	195	2098
2014	709	920	351	151	179	2310
2015	654	1161	479	300	247	2841
2016	792	706	284	208	209	2199
Subtotal	7041	7727	5242	3042	3929	26981

Table 18: Proportion of trips that caught Blue/Deacon rockfish in the Northern California CRFS private boat dockside index. SLO = San Luis Obispo county; MontereySC = Monterey and Santa Cruz counties; SFBayArea = Alameda, Contra Costa, Marin, San Francisco, San Joaquin, and San Mateo counties; MendoSono = Mendocino and Sonoma counties; DelNorte-Humboldt = Del Norte and Humboldt counties.

	SUBREGION					
YEAR	SLO	Monterey-SC	SFBayArea	Mendo-Sono	DelNorte-Humboldt	Subtotal
2004	0.898	0.802	0.644	0.831	0.842	0.824
2005	0.857	0.872	0.693	0.720	0.883	0.821
2006	0.844	0.871	0.836	0.903	0.900	0.865
2007	0.813	0.627	0.487	0.609	0.759	0.673
2008	0.704	0.681	0.546	0.716	0.799	0.690
2009	0.490	0.553	0.591	0.485	0.628	0.552
2010	0.340	0.572	0.433	0.629	0.813	0.513
2011	0.445	0.541	0.497	0.651	0.749	0.544
2012	0.294	0.562	0.429	0.531	0.790	0.511
2013	0.548	0.675	0.541	0.748	0.769	0.630
2014	0.623	0.760	0.718	0.762	0.609	0.700
2015	0.731	0.796	0.656	0.713	0.781	0.747
2016	0.812	0.606	0.563	0.601	0.775	0.690
Subtotal	0.676	0.711	0.624	0.704	0.792	0.696

Table 19: Akaike Information Criteria for alternative models of catch-per-unit-effort based on Northern California CRFS private boat dockside index. All models include an effort offset term (log of anglers).

Negative Binomial Model	Parameters	AIC-AIC$_{min}$	AIC
Intercept only	2	5023.8	129108.4
Year	14	1802.8	125887.4
Year + Subregion	18	1536.3	125620.9
Year + Subregion + Wave	21	1144.7	125229.3
Year + Subregion + Distance + (Year x Subregion)	69	0.0	124084.6

Table 20: Northern California CRFS private boat dockside index, with log-scale standard errors and 95% highest posterior density (HPD) intervals.

Year	Mean	logSE	HPD_lower	HPD_upper
2004	1.481	0.038	1.376	1.593
2005	1.348	0.033	1.262	1.434
2006	1.805	0.029	1.705	1.913
2007	0.887	0.034	0.827	0.946
2008	0.723	0.036	0.674	0.774
2009	0.468	0.036	0.434	0.501
2010	0.451	0.050	0.408	0.497
2011	0.498	0.045	0.452	0.540
2012	0.452	0.048	0.411	0.496
2013	0.571	0.042	0.523	0.616
2014	0.743	0.038	0.690	0.801
2015	0.846	0.033	0.791	0.901
2016	0.830	0.037	0.773	0.893

Table 21: Data filters applied to the Southern California CRFS private boat dockside index.

Data Filter	Number of Trips
[unfiltered, Ventura and Santa Barbara counties only]	10125
Drop trips that caught Yellowtail Amberjack or Pacific bonito	9324
Stephens-MacCall filter (keeping false negatives)	1733
Drop wave 1 (Jan-Feb); 4 samples	1729
Drop Area_X = 2 (outside 3nm); no samples 2004-2011	1669

Table 22: Sample size (number of trips) by year and subregion for the Southern California CRFS private boat dockside index.

	COUNTY		
YEAR	Santa Barbara	Ventura	Subtotal
2004	32	150	182
2005	43	119	162
2006	46	158	204
2007	47	211	258
2008	23	159	182
2009	24	69	93
2010	10	40	50
2011	10	22	32
2012	7	42	49
2013	18	85	103
2014	11	92	103
2015	15	118	133
2016	21	97	118
Subtotal	307	1362	1669

Table 23: Proportion of trips that caught Blue/Deacon rockfish in the Southern California CRFS private boat dockside index.

	COUNTY		
YEAR	Santa Barbara	Ventura	Subtotal
2004	0.594	0.833	0.791
2005	0.791	0.790	0.790
2006	0.630	0.690	0.676
2007	0.511	0.621	0.601
2008	0.696	0.572	0.588
2009	0.417	0.652	0.591
2010	0.400	0.650	0.600
2011	0.400	0.364	0.375
2012	0.429	0.262	0.286
2013	0.389	0.165	0.204
2014	0.636	0.511	0.524
2015	0.867	0.746	0.759
2016	0.476	0.784	0.729
Subtotal	0.586	0.635	0.626

Table 24: Akaike Information Criteria for alternative models of catch-per-unit-effort based on Southern California CRFS private boat dockside index. All models include an effort offset term (log of anglers).

Negative Binomial Model	Parameters	AIC-AIC$_{min}$	AIC
Intercept only	2	186.8	6406.9
Year	14	9.1	6229.2
Year + County	15	9.2	6229.3
Year + County + Wave	19	11.5	6231.6
Year + County + (Year x County)	27	0.0	6220.1

Table 25: Southern California CRFS private boat dockside index, with log-scale standard errors and 95% highest posterior density (HPD) intervals.

Year	Mean	logSE	HPD_lower	HPD_upper
2004	1.115	0.097	0.906	1.326
2005	1.239	0.099	1.012	1.489
2006	0.853	0.094	0.699	1.009
2007	0.681	0.084	0.570	0.795
2008	0.570	0.104	0.458	0.688
2009	0.538	0.154	0.385	0.700
2010	0.799	0.191	0.525	1.117
2011	0.249	0.334	0.098	0.412
2012	0.146	0.289	0.071	0.229
2013	0.109	0.219	0.064	0.157
2014	0.500	0.140	0.371	0.643
2015	0.927	0.113	0.729	1.141
2016	0.881	0.120	0.684	1.094

Table 26: Number of fishing stops sampled by onboard CPFV observers, 1987-1998, by year and 'mega reef' in Central and Northern California. See text for definitions of mega reefs.

	"Mega Reef" Number								
Year	1	2	3	4	5	6	7	8	Subtotal
1987	0	0	249	44	0	0	0	0	293
1988	0	55	151	66	26	5	0	98	401
1989	3	74	101	117	57	9	2	78	441
1990	1	35	12	48	1	1	0	15	113
1991	4	45	21	24	1	16	0	18	129
1992	4	83	83	196	21	31	0	33	451
1993	3	90	144	123	39	22	11	69	501
1994	6	110	164	153	29	12	9	109	592
1995	40	260	164	167	31	44	0	121	827
1996	30	319	237	166	116	30	0	137	1035
1997	33	319	161	114	301	0	0	475	1403
1998	43	176	176	185	203	0	0	223	1006
Subtotal	167	1566	1663	1403	825	170	22	1376	7192

Table 27: Number of fishing stops sampled by California onboard CPFV observers, by year (1988-1998) and area based on the final spatial stratification (aggregated mega-reefs).

	"Mega Reef" Number					
Year	1-2	3	4	5-6	8	Subtotal
1988	53	134	48	31	77	343
1989	77	89	81	66	46	359
1990	36	10	36	2	14	98
1991	49	16	21	17	12	115
1992	86	79	140	52	21	378
1993	93	139	105	61	37	435
1994	116	163	135	41	84	539
1995	300	159	160	75	115	809
1996	349	232	140	146	125	992
1997	352	160	107	301	357	1277
1998	218	176	183	203	191	971
Subtotal	1729	1357	1156	995	1079	6316

Table 28: Proportion of positive fishing stops by year (1988-1998) and area based on the final spatial stratification (aggregated mega-reefs).

	"Mega Reef" Number					
Year	1-2	3	4	5-6	8	Subtotal
1988	0.792	0.597	0.750	0.742	0.143	0.560
1989	0.857	0.618	0.605	0.667	0.457	0.655
1990	0.694	0.900	0.500	1.000	0.714	0.653
1991	0.755	0.688	0.619	0.941	0.167	0.687
1992	0.872	0.620	0.343	0.846	0.238	0.585
1993	0.871	0.698	0.476	0.639	0.108	0.623
1994	0.871	0.589	0.533	0.683	0.214	0.584
1995	0.603	0.679	0.513	0.440	0.435	0.561
1996	0.547	0.608	0.521	0.822	0.344	0.573
1997	0.730	0.725	0.579	0.731	0.283	0.592
1998	0.702	0.682	0.716	0.631	0.351	0.617
Subtotal	0.699	0.650	0.548	0.701	0.308	0.594

Table 29: Akaike Information Criteria for alternative models of catch-per-unit-effort based on California onboard CPFV observer data, 1988-1998. All models include an effort offset term (log of angler hours).

Negative Binomial Model	**Parameters**	**AIC-AIC$_{min}$**	**AIC**
Intercept only	2	2304.1	36503.7
Year	12	2055.3	36254.8
Year + MegaReef	16	1614.0	35813.6
Year + MegaReef + Depth	19	194.7	34394.3
Year + MegaReef + Depth + Wave	24	137.2	34336.8
Year + MegaReef + Depth + Wave + (Year x MegaReef)	64	0.0	34199.6

Table 30: Central California onboard CPFV observer (1988-1998) Index, with log-scale standard errors and 95% highest posterior density (HPD) intervals.

Year	Mean	logSE	HPD_lower	HPD_upper
1988	3.710	0.155	2.597	4.843
1989	2.775	0.139	2.053	3.563
1990	1.872	0.405	0.771	2.663
1991	3.243	0.242	1.909	4.896
1992	4.223	0.140	3.136	5.439
1993	3.478	0.128	2.652	4.378
1994	2.581	0.139	1.906	3.306
1995	1.958	0.100	1.586	2.350
1996	2.574	0.107	2.032	3.116
1997	4.557	0.096	3.692	5.408
1998	5.392	0.100	4.371	6.486

Table 31: Data filters applied to the onboard CPFV observer data for Northern California, 1999-2016.

Data Filter	**Number of Trips**
[unfiltered, Northern California data only]	21897
Exclude drifts >1 km from reef	20836
Exclude drifts outside 2 to 45 fathoms	20471
Drop trips catching <50% groundfish	19619
Drop drifts with fishing time <3 min and >100min	19453
Drop 1999 and 2000 due to regulatory changes	19453
Drop first trimester (no samples 2005-2014)	18445

Table 32: Number of drifts by aggregated reef area (“Mega Reefs”) and year in the Northern California onboard CPFV observer index.

	"Mega Reef" Number					
Year	1-2	3	4	5-6	8	Subtotal
2001	66	19	211	5	17	318
2002	99	44	161	33	4	341
2003	830	94	183	118	28	1253
2004	1088	91	165	113	24	1481
2005	617	83	173	45	44	962
2006	841	88	233	59	83	1304
2007	850	125	167	65	97	1304
2008	496	105	180	286	87	1154
2009	420	175	201	394	37	1227
2010	1014	145	156	292	29	1636
2011	704	241	304	212	63	1524
2012	617	166	213	199	57	1252
2013	585	182	210	242	65	1284
2014	498	118	223	302	23	1164
2015	367	173	168	198	50	956
2016	664	88	163	297	73	1285
Subtotal	9756	1937	3111	2860	781	18445

Table 33: Proportion of positive drifts by aggregated reef area (“Mega Reefs”) and year in the Northern California onboard CPFV observer index.

	"Mega Reef" Number					
Year	1-2	3	4	5-6	8	Subtotal
2001	0.318	0.632	0.199	0.200	0.059	0.242
2002	0.828	0.886	0.410	0.758	1.000	0.633
2003	0.666	0.915	0.552	0.356	0.321	0.631
2004	0.797	0.868	0.667	0.619	0.583	0.770
2005	0.723	0.940	0.757	0.311	0.773	0.731
2006	0.699	0.932	0.803	0.847	0.819	0.748
2007	0.682	0.728	0.311	0.431	0.629	0.623
2008	0.502	0.838	0.383	0.441	0.402	0.491
2009	0.367	0.491	0.303	0.198	0.270	0.317
2010	0.167	0.648	0.295	0.332	0.690	0.260
2011	0.176	0.560	0.434	0.335	0.333	0.317
2012	0.086	0.373	0.385	0.296	0.632	0.233
2013	0.315	0.560	0.467	0.140	0.615	0.357
2014	0.406	0.610	0.439	0.397	0.522	0.433
2015	0.477	0.630	0.625	0.389	0.260	0.501
2016	0.538	0.534	0.325	0.273	0.192	0.430
Subtotal	0.492	0.652	0.461	0.340	0.502	0.481

Table 34: Model selection criteria for Northern California, 2001-2016.

Negative Binomial Model	Parameters	$AIC\text{-}AIC_{min}$	AIC
Intercept only	2	5130.3	70235.6
Year	17	2104.8	67210.1
Year + Depth	19	2046.3	67151.6
Year + Depth + MegaReef	23	1534.8	66640.1
Year + Depth + MegaReef + Trimester	24	1349.2	66454.5
Year + MegaReef + Depth + Wave + (Year x MegaReef)	26	1213.3	66318.7
Year + MegaReef + Depth + Wave + (Year x MegaReef)	86	0.0	65105.3

Table 35: CPFV observer index for Northern California, 2001-2016.

Year	Mean	logSE	HPD_lower	HPD_upper
2001	0.289	0.260	0.166	0.448
2002	1.269	0.179	0.883	1.724
2003	0.703	0.065	0.614	0.793
2004	1.579	0.071	1.359	1.799
2005	1.378	0.079	1.168	1.591
2006	2.220	0.114	1.747	2.726
2007	0.736	0.079	0.625	0.850
2008	0.719	0.066	0.631	0.816
2009	0.253	0.065	0.221	0.285
2010	0.381	0.077	0.325	0.439
2011	0.282	0.068	0.246	0.321
2012	0.278	0.079	0.236	0.321
2013	0.473	0.065	0.415	0.536
2014	0.514	0.062	0.451	0.575
2015	0.650	0.069	0.564	0.738
2016	0.571	0.059	0.506	0.636

Table 36: Sampling effort (tows) and proportion positive observations for the NMFS SWFSC pelagic juvenile rockfish midwater trawl survey. “Total fish (100 day)” is the expected number of 100-day-old fish after adjusting for mortality (see text for details).

	Conception to CA/OR border				South of Conception			
	positive tows	total tows	% positive	total fish (100 day)	positive tows	total tows	% positive	total fish (100 day)
2001	37	150	25%	129	0	3	0%	0
2002	70	145	48%	829	0	5	0%	0
2003	54	179	30%	372	1	4	25%	2
2004	58	192	30%	919	0	32	0%	0
2005	10	198	5%	33	0	38	0%	0
2006	0	219	0%	0	0	36	0%	0
2007	15	211	7%	32	0	28	0%	0
2008	6	132	5%	8	0	30	0%	0
2009	49	189	26%	162	0	16	0%	0
2010	8	114	7%	15	1	19	5%	4
2011	10	88	11%	29	no data			0
2012	0	79	0%	0	0	15	0%	0
2013	58	121	48%	5088	1	23	4%	1
2014	29	139	21%	169	0	14	0%	0
2015	10	131	8%	77	0	38	0%	0
2016	5	109	5%	78	3	31	10%	36

Table 37: NMFS SWFSC pelagic juvenile rockfish midwater trawl survey index for Northern California.

Year	Index	CV
2001	4.062	0.351
2002	8.811	0.252
2003	6.743	0.262
2004	11.514	0.254
2005	3.102	0.423
2006	1.200	0.665
2007	4.223	0.422
2008	2.400	0.665
2009	3.464	0.364
2010	3.629	0.552
2011	4.343	0.433
2012	1.200	0.665
2013	19.777	0.334
2014	4.964	0.373
2015	4.474	0.486
2016	4.764	0.505

Table 38: Number of bongo tows, number positive for this species complex, number of total larvae identified, and the percentage of positive tows for CalCOFI Ichthyoplankton data.

	total tows	total positives	total larvae	% positive
1998	34	0	0	0.0%
1999	18	2	3	11.1%
2000	36	1	1	2.7%
2001	34	4	21	11.7%
2002	36	1	2	2.7%
2003	35	0	0	0.0%
2004	34	2	11	5.8%
2005	42	7	39	16.6%
2006	41	1	1	2.4%
2007	44	5	30	11.3%
2008	38	5	22	13.1%
2009	44	6	17	13.6%
2010	39	4	36	10.2%
2011	45	7	43	15.5%
2012	44	4	12	9.0%
2013	42	13	102	30.9%

Table 39: CalCOFI Ichthyoplankton (larval abundance) index for Southern California.

year	index	logSE
1999	1.339	1.431
2001	6.641	0.924
2005	13.775	0.654
2007	14.733	0.837
2008	5.995	0.645
2009	9.417	0.673
2010	11.066	0.729
2011	10.147	0.650
2012	3.142	0.624
2013	24.915	0.570

Table 40: Estimates of von Bertalanffy growth parameters by sex (rows 1-2), sex and species (rows 3-6), and sex/species/region (rows 7-14). Estimates of growth parameters for female Blue Rockfish (S. mystinus) north and south of Point Conception are shown in rows (15-17). Units for L_∞ are cm, fork length.

Species	Sex	Region	*n*	$L\infty$	k	t_0
Both	Female	Oregon, California	3589	37.48	0.209	-1.42
Both	Male	Oregon, California	1367	30.13	0.382	-0.41
Blue	Female	Oregon, California	1142	36.27	0.197	-1.60
Blue	Male	Oregon, California	203	29.99	0.398	-0.51
Deacon	Female	Oregon, California	2447	37.55	0.228	-0.99
Deacon	Male	Oregon, California	1164	29.88	0.401	-0.69
Blue	Female	Oregon	610	38.39	0.196	-1.89
Blue	Male	Oregon	117	29.99	0.398	-0.51
Blue	Female	California	532	35.54	0.149	-3.04
Blue	Male	California	86	30.95	0.185	-2.30
Deacon	Female	Oregon	2119	37.76	0.217	-1.51
Deacon	Male	Oregon	1010	29.88	0.401	-0.69
Deacon	Female	California	328	41.34	0.126	-2.81
Deacon	Male	California	154	33.77	0.157	-2.91
Blue	Female	California	404	34.50	0.168	-2.64
Blue	Female	Northern California	292	34.16	0.165	-2.44
Blue	Female	Southern California	112	37.30	0.125	-5.08

Table 41: Number of PISCO dive survey transects by site and year, Northern California.

Site	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
BIG_CREEK	24	36	36	36	36	36	36	36	36	36	36	24					
BLUEFISH	24	24	24	36	24	36	36	36	36	36	36	36	36	24	36	36	36
CAMBRIA	36	24	36	36	30	34	36	36	36	36							
ESALEN	24	36	36	36	36	36	36	33	36	36	36	24					
HOPKINS	24	24	24	24	36	36	36	36	36	36	36	36	36	24	26	36	36
JALAMA	27	34	46	27	33	33	36	21	36	30							
LOPEZ	24	36	36	36	36	35	36	33	36	36	36						
MACABEE	24	24	24	36	36	36	36	36	36	36	36	36	24	24	36	24	
MALPASO	36	36	36	36	36	36	24	36	24	24							
MONASTERY	24	24	24	36	24	36	36	36	36	36	36	36	36	24	24	24	24
PESCADERO	36	36	36	36	36	36	36	36	36	24	36	36					
SANDHILL	27	24	24	36	29	36	36	36	36	33	33	36					
STILLWATER	24	24	24	36	36	36	36	36	36	36	36	36	36	24	36	36	
TERRACE	24	24	36	24	33	36	36	24	36	36	35	36					
WESTON	24	36	24	36	36	36	36	36	36	36	36	24	36	24	24		
WHITE_ROCK	36	24	36	36	36	30	36	36	36	36							

Table 42: PISCO dive survey sample sizes (number of transects) by year, with counts and percentages of transects that encountered young-of-the-year (YOY) Blue/Deacon Rockfish.

Year	transects	positives	% positive	Total YOY
1999	147	61	41.50%	1693
2000	195	54	27.69%	605
2001	298	107	35.91%	3943
2002	502	234	46.61%	12603
2003	416	204	49.04%	4719
2004	501	157	31.34%	2880
2005	537	108	20.11%	474
2006	566	53	9.36%	151
2007	520	17	3.27%	36
2008	555	33	5.95%	54
2009	537	155	28.86%	1809
2010	536	172	32.09%	1818
2011	540	115	21.30%	724
2012	210	68	32.38%	633
2013	230	180	78.26%	20938
2014	252	171	67.86%	7357
2015	288	161	55.90%	2930

Table 43: PISCO dive survey index for Northern California.

Year	Index	log(SE)
1999	2.004	0.2723
2000	0.489	0.2876
2001	2.504	0.2150
2002	9.051	0.1428
2003	2.938	0.1572
2004	0.735	0.1716
2005	0.084	0.2262
2006	0.022	0.2746
2007	0.004	0.4112
2008	0.006	0.2734
2009	0.405	0.1632
2010	0.706	0.2028
2011	0.133	0.2046
2012	0.132	0.2551
2013	33.831	0.1310
2014	9.895	0.1423
2015	1.459	0.1815

Table 44: Tenera dive survey: sample sizes (number of transects) by Settlement Year and Settlement Period.

	Period	
Settlement Year	**Early**	**Late**
1977	17	9
1978	11	12
1979	21	11
1980	6	18
1981	6	3
1982	12	4
1983	8	13
1984	8	10
1985	9	4
1986	12	3
1987	10	7
1988	9	10
1989	9	12
1990	13	14
1991	12	6
1992	13	11
1993	6	7
1994	12	9
1995	9	6
1996	6	3
1997	6	3
1998	6	11
1999	17	14
2000	14	16
2001	16	15
2002	16	16
2003	16	8
2004	15	10
2005	21	13
2006	16	18
2007	17	8
2008	19	25
2009	16	9
2010	17	15
2011	16	16
2012	16	16
2013	16	19
2014	19	13
2015	20	6

Table 45: Tenera dive survey: AIC and leave-one-out information criterion (looic) values from model selection.

Model	AIC	looic
nb1.glm: null	3509.851	NA
nb2.glm: SetYear	3191.677	NA
nb3.glm: SetPer	3511.296	NA
nb4.glm: SetYear+SetPer	3192.903	NA
nb5.glm: SetYear+SetPer+SetYear:SetPer	3197.908	NA
nb6.glm: LocType	3505.146	NA
nb7.glm: LocSite	3480.684	NA
nb8.glm: LocSite+LocType	3480.684	NA
nb9.glm: LocSite+LocType+LocSite:LocType	3480.684	NA
nb10.glm: SetYear+LocSite	3035.769	3024.7
nb11.glm: SetYear+LocSite, with LocSite as a random effect	NA	3080.8
nb12.glm: SetYear:LocSite, with the interaction as a random effect	NA	3044.5
nb14.glm: SetYear+LocSite+SetYear:LocSite, interaction as random effect	NA	3044.4

Table 46: Index of juvenile Blue and Deacon rockfish relative abundance based on Tenera Dive Survey Data.

Year	Index	log(SD)
1977	19.91	0.428
1978	8.76	0.461
1979	40.96	0.400
1980	10.73	0.443
1981	4.17	0.684
1982	0.41	0.735
1984	5.17	0.509
1985	9.72	0.583
1986	2.29	0.557
1987	1.38	0.562
1988	3.30	0.493
1989	0.81	0.582
1990	4.26	0.430
1991	23.07	0.489
1992	3.16	0.446
1993	0.13	0.897
1998	0.66	0.560
1999	1.97	0.410
2000	0.50	0.471
2001	0.41	0.444
2002	0.82	0.390
2003	0.34	0.521
2004	0.10	0.707
2005	0.05	0.764
2008	0.11	0.530
2009	0.40	0.512
2010	0.15	0.538
2011	0.17	0.520
2012	1.54	0.397
2013	114.28	0.376
2014	23.19	0.384
2015	4.21	0.366

Table 47: VenTresca dive survey filtering criteria and resulting sample sizes used for Blue Rockfish. Bold value indicates the final transect-level sample size used for the Bayesian negative binomial regression model.

Filter	Criteria	Sample Size
Full Dataset	All data (Grouped by TRANS_ID)	2,873
Transect Type	Timed, benthic transects	1,886
Maturity Stage`	Recently settled YOY (Stage 1) or YOY (Stage 2)	**1,351**

Table 48: VenTresca dive survey sample sizes (number of transects in the filtered dataset) by year and region.

Year	North	South
1990	192	150
1991	72	118
1992	86	69
1993	185	96
1994	71	45
1995	55	0
1996	62	2
1997	95	2
1998	23	0
1999	28	0

Table 49: Log-likelihoods based on successive versions of Stock Synthesis, used to update software from the 2007 assessment.

	SS Version			
Likelihood Component	**3.30.03.07**	**3.30beta**	**3.24z**	**2.00c**
TOTAL	1333.7	1337.9	1338.3	1338.8
Equil_catch	0	0	0	0
Survey	61.66	61.60	61.14	61.18
Length_comp	623.9	624.2	624.9	625.3
Age_comp	599.0	603.0	602.8	603.1
Recruitment	49.10	49.18	49.37	49.25
Forecast_Recruitment	0	0	0	0
Parm_priors	0	0	0	0
Parm_softbounds	0.002314	0.002308	0.002309	NA
Parm_devs	0	0	0	0
Crash_Pen	0	0	0	NA

Table 50: Relative weights used for fitting compositional data in the California base case model. Weights were capped at a value of 1.

Data Source	Likelihood Component	Weighting Method	Relative Weight
REC_CPFV_N	Lengths	Francis	0.130
REC_PRIV_N_MRFSS	Lengths	Francis	0.070
REC_PRIV_N_CRFS	Lengths	Francis	0.035
REC_DISC_N	Lengths	Francis	0.199
COM_HKL_N	Lengths	Francis	0.326
COM_NET_N	Lengths	Francis	1.000
COM_OTH_N	Lengths	Francis	1.000
COM_DISC_N	Lengths	Francis	0.350
ONBOARD_CPFV_CenCA_N	Lengths	Francis	0.620
JUV_SWFSC_N	Lengths	Francis	1.000
ONBOARD_CPFV_01_16_N	Lengths	Francis	1.000
SCHMIDT_N	Lengths	Francis	0.270
ABRAMS_N	Lengths	Francis	0.810
REC_CPFV_N	Conditional Age-at-Length	Harmonic Mean	0.240
SCHMIDT_N	Conditional Age-at-Length	Harmonic Mean	0.320
ABRAMS_N	Conditional Age-at-Length	Harmonic Mean	0.210

Table 51: Description of parameters used in the California base case assessment model.

Parameter	Number Estimated	Bounds (low, high)	Prior (Mean, SD) - Type	Value	SE
Biology					
Natural mortality (M) -*female*	1	(0.001,0.4)	(-2.027,0.438) - Lognormal	0.119	0.014
Natural mortality (M) -*male (offset)*	1	(-3,3)	-	0.315	0.069
Ln (R_0)	1	(5,12)	-	8.438	0.253
Steepness (h)	1	(0.201,0.999)	(0.718,0.158) - Full Beta	0.645	0.114
Sigma-R	0	-	-	0.5	-
Growth					
Length at age 1 - *female*	1	(10,30)	-	17.36	0.329
Length at age 30 - *female*	1	(25,45)	-	37.35	0.575
von Bertalnaffy k - f*emale*	1	(0.01,0.3)	-	0.118	0.011
CV of length at age 1 - *female*	1	(0.01,0.5)	-	0.114	0.007
CV of length at age 30 - *female*	1	(0.01,0.5)	-	0.095	0.012
Length at age 1 - *male (offset)*	1	(-3,3)	-	-0.034	0.034
Length at age 30 - *male (offset)*	1	(-3,3)	-	-0.199	0.090
von Bertalnaffy k - *male (offset)*	1	(-3,3)	-	-0.003	0.411
CV of length at age 1 - *male (offset)*	1	(-3,3)	-	0.091	0.208
CV of length at age 30 - *male (offset)*	1	(-3,3)	-	0.762	0.421
Indices					
Extra SD - MRFSS CPFV dockside	1	(0,0.75)	-	0.223	0.092
Extra SD - CRFS private dockside	1	(0,0.75)	-	0.555	0.127
Extra SD - onboard CPFV 1988-1998	1	(0,0.75)	-	0.175	0.071
Extra SD - SWFSC juv. survey	1	(0,0.75)	-	0.197	0.122
Extra SD - onboard CPFV 2001-2016	1	(0,0.75)	-	0.689	0.147
Selectivity					
Recreational CPFV					
Length at peak	1	(20,50)	-	33.900	1.127
Ascending width	1	(1,10)	-	3.986	0.159
Length at peak (time block 1)	1	(20,50)	-	31.406	1.258
Length at peak (time block 2)	1	(20,50)		33.344	1.178
Recreational Private Boat					
Length at peak	1	(20,50)	-	35.586	0.836
Ascending width	1	(1,10)	-	4.013	0.113
Length at peak (time block 2)	1	(20,50)		31.861	0.823
Recreational Discard					
Length at peak	1	(14,30)	-	22.474	0.976
Ascending width	1	(1,10)	-	3.617	0.364
Decending width	1	(1,10)	-	3.752	0.362
Commercial Hook and Line					
Length at peak	1	(20,50)	-	39.223	1.508
Ascending width	1	(1,10)	-	4.063	0.171
Commercial Net Gears					
Length at peak	1	(20,50)	-	42.389	4.203
Ascending width	1	(1,10)	-	3.056	0.964
Commercial Discard					
Length at peak	1	(14,50)	-	27.561	0.872
Ascending width	1	(1,10)	-	3.748	0.205
Decending width	1	(1,10)	-	4.426	0.514
Recreation - onboard CPFV 1988-1998					
Length at peak	1	(20,50)	-	29.972	0.741
Ascending width	1	(1,10)	-	3.518	0.140
Research -- Schmidt study					
Length at peak	1	(20,50)	-	33.102	6.002
Ascending width	1	(1,10)	-	4.767	0.813
Research -- Abrams study					
Length at peak	1	(20,50)	-	34.089	5.019
Ascending width	1	(1,10)	-	4.558	0.631

Table 52: Von Bertalanffy parameter estimates and standard errors for female and male BDR in the California base model.

Parameter	Female Estimate	Female Standard Error	Male Offset	Male Estimate	Male Standard Error
Length at minimum age (2)	17.36	0.329	-0.03	16.77	0.034
Length at maximum age (30)	37.35	0.575	-0.20	30.61	0.094
k (min length to max length)	0.12	0.011	0.00	0.117	0.432
CV young	0.11	0.007	0.09	0.125	0.211
CV old	0.09	0.012	0.76	0.203	0.419

Table 53: Response to STAR panel request #4. Summary of abundance index characteristics in the 2017BDR assessment.

Region	Fleet	Years	Index Name	Fishery-independent	Filtering	Standardization Model
CA	1	1980-89, 1995-96, 1999	Dockside MRFSS CPFV CPUE	No	Stephens-MacCall, county, year	Negative Binomial
CA	3	2004-2016	Dockside CRFS Private Boat CPUE	No	Stephens-MacCall, wave, inside/outside 3nm	Negative Binomial
CA	9	1988-1998	Onboard Central CA CPFV CPUE	No	year, area, depth, catch rate (extremes)	Negative Binomial
CA	11	2001-2016	Onboard CDFW CPFV CPUE	No	Distance from reef, depth, % groundfish, drift duration, year, trimester	Negative Binomial
CA	10	2001-2016	NMFS SWFSC Pelagic Juvenile Rockfish	Yes	None	Delta-GLM
OR	1	2004-2014	Commercial logbook CPUE	No	depth, fishermen, gear ID, bag limit change year, port, effort, permit type, vessel	Delta-GLM
OR	3	2001, 2003-2016	Onboard observer number encountered CPUE	No	offshore reefs, reef distance, depth, % groundfish	Negative Binomial
OR	3	2001-2016	ORBS dockside charter and private CPUE	No	Trip type, port, estuary, trip hours, interview time, reef distance, species composition, bag limit	Negative Binomial
OR	3	1980-1989, 1993-2000	MRFSS dockside CPFV CPUE	No	species composition, low sample size year, bag limit change years, county	Negative Binomial

Table 54: Summary of reference points and management quantities for the California BDR base case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning Output (millions of eggs)	2,178	1,763–2,593
Unfished Age 0+ Biomass (mt)	11,536	9,140–13,932
Spawning Output (2017, millions of eggs)	812	0–1,661
Unfished recruitment (R0, thousands of recruits)	4,617	2,328–6,907
Depletion -- (2017, % of unfished spawning output)	37	0–78.54
Reference points based on SB $_{40\%}$		
Proxy spawning output ($B_{40\%}$, millions of eggs)	871	705–1,037
SPR resulting in $B_{40\%}$	0.483	0.402–0.563
Exploitation rate resulting in $B_{40\%}$	0.048	0.036–0.059
Yield at $B_{40\%}$ (mt)	312	222–402
Reference points based on SPR proxy for MSY		
Proxy spawning output ($SPR_{50\%}$, millions of eggs)	915	722–1,108
$SPR_{50\%}$	0.5	NA
Exploitation rate corresponding to $SPR_{50\%}$	0.045	0.040–0.051
Yield with $SPR_{50\%}$ at $SB_{SPR50\%}$ (mt)	306	230–381
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY}, millions of eggs)	567	286–847
SPR_{MSY}	0.362	0.180–0.544
Exploitation rate corresponding to SPR_{MSY}	0.069	0.032–0.105
MSY (mt)	339	216–461

Table 55: Time-series of population estimates for BDR in California from the base case model.

Year	Total Biomass (mt)	Spawning Biomass (eggs x10^6)	Depletion	Age-0 Recruits (000s)	Total Catch (mt)	Relative Exploitation Rate	SPR
1900	11,536	2178	1.00	4,618	0.0	0.00	1.00
1901	11,536	2178	1.00	4,618	1.7	0.00	1.00
1902	11,534	2177	1.00	4,617	3.3	0.00	1.00
1903	11,532	2176	1.00	4,617	5.0	0.00	0.99
1904	11,528	2175	1.00	4,617	6.6	0.00	0.99
1905	11,522	2174	1.00	4,616	8.3	0.00	0.99
1906	11,516	2172	1.00	4,616	10.0	0.00	0.99
1907	11,509	2170	1.00	4,615	11.6	0.00	0.98
1908	11,500	2167	1.00	4,615	13.3	0.00	0.98
1909	11,491	2165	0.99	4,614	14.9	0.00	0.98
1910	11,481	2162	0.99	4,613	16.6	0.00	0.98
1911	11,470	2159	0.99	4,612	18.3	0.00	0.97
1912	11,459	2155	0.99	4,611	19.9	0.00	0.97
1913	11,447	2152	0.99	4,610	21.6	0.00	0.97
1914	11,434	2148	0.99	4,609	23.3	0.00	0.97
1915	11,421	2144	0.98	4,608	24.9	0.00	0.97
1916	11,408	2140	0.98	4,606	26.8	0.00	0.96
1917	11,393	2136	0.98	4,605	41.9	0.00	0.94
1918	11,367	2128	0.98	4,603	49.8	0.00	0.93
1919	11,335	2119	0.97	4,600	33.7	0.00	0.95
1920	11,320	2115	0.97	4,599	34.6	0.00	0.95
1921	11,305	2110	0.97	4,597	28.9	0.00	0.96
1922	11,296	2107	0.97	4,596	24.8	0.00	0.96
1923	11,291	2105	0.97	4,596	26.4	0.00	0.96
1924	11,286	2104	0.97	4,595	15.9	0.00	0.98
1925	11,290	2105	0.97	4,595	20.9	0.00	0.97
1926	11,289	2104	0.97	4,595	32.4	0.00	0.95
1927	11,279	2101	0.96	4,594	29.5	0.00	0.96
1928	11,271	2099	0.96	4,594	41.1	0.00	0.94
1929	11,254	2095	0.96	4,592	43.6	0.00	0.94
1930	11,236	2090	0.96	4,591	58.1	0.01	0.92
1931	11,206	2081	0.96	4,588	58.5	0.01	0.92
1932	11,177	2073	0.95	4,586	58.6	0.01	0.92
1933	11,150	2066	0.95	4,583	51.1	0.00	0.93
1934	11,132	2061	0.95	4,582	66.7	0.01	0.91
1935	11,101	2052	0.94	4,579	78.3	0.01	0.89
1936	11,061	2041	0.94	4,575	109.0	0.01	0.86
1937	10,997	2024	0.93	4,570	114.6	0.01	0.85
1938	10,933	2006	0.92	4,564	97.2	0.01	0.87
1939	10,888	1993	0.92	4,559	69.8	0.01	0.90
1940	10,871	1987	0.91	4,557	94.2	0.01	0.87
1941	10,832	1976	0.91	4,554	82.0	0.01	0.88
1942	10,808	1969	0.90	4,551	43.0	0.00	0.94

Table 55 (continued): Time-series of population estimates for BDR in California from the base case model.

Year	Total Biomass (mt)	Spawning Biomass (eggs x10^6)	Depletion	Age-0 Recruits	Total Catch (mt)	Relative Exploitation Rate	SPR
1943	10,820	1972	0.91	4,552	44.9	0.00	0.93
1944	10,829	1974	0.91	4,553	56.9	0.01	0.92
1945	10,828	1973	0.91	4,552	100.8	0.01	0.86
1946	10,789	1962	0.90	4,549	130.2	0.01	0.83
1947	10,725	1945	0.89	4,543	75.7	0.01	0.89
1948	10,714	1941	0.89	4,541	142.7	0.01	0.81
1949	10,643	1923	0.88	4,535	161.9	0.02	0.79
1950	10,561	1901	0.87	4,527	211.8	0.02	0.73
1951	10,435	1868	0.86	4,514	246.6	0.02	0.70
1952	10,281	1829	0.84	4,499	211.1	0.02	0.73
1953	10,149	1800	0.83	4,488	170.5	0.02	0.77
1954	10,027	1782	0.82	4,480	208.3	0.02	0.72
1955	9,848	1757	0.81	4,470	238.6	0.02	0.69
1956	9,636	1725	0.79	4,456	296.5	0.03	0.63
1957	9,401	1679	0.77	4,436	288.4	0.03	0.64
1958	9,256	1633	0.75	4,414	441.0	0.05	0.51
1959	9,076	1551	0.71	4,374	358.8	0.04	0.56
1960	9,145	1489	0.68	4,341	270.9	0.03	0.62
1961	9,390	1451	0.67	4,319	201.4	0.02	0.69
1962	9,719	1438	0.66	4,312	233.0	0.02	0.66
1963	10,078	1435	0.66	4,310	252.9	0.03	0.65
1964	10,503	1446	0.66	4,316	191.2	0.02	0.72
1965	11,067	1485	0.68	4,339	298.7	0.03	0.62
1966	11,571	1518	0.70	4,356	314.7	0.03	0.62
1967	12,014	1560	0.72	4,379	311.7	0.03	0.63
1968	12,343	1617	0.74	4,407	338.3	0.03	0.62
1969	12,496	1681	0.77	4,437	372.2	0.03	0.61
1970	12,472	1746	0.80	4,465	451.4	0.04	0.57
1971	12,252	1793	0.82	4,485	402.5	0.03	0.60
1972	11,970	1839	0.84	4,503	529.0	0.04	0.53
1973	11,474	1840	0.85	4,504	687.4	0.06	0.46
1974	10,774	1788	0.82	4,483	763.3	0.07	0.42
1975	9,981	1699	0.78	4,445	744.8	0.07	0.41
1976	9,207	1594	0.73	4,396	691.7	0.08	0.40
1977	8,471	1483	0.68	4,338	633.2	0.07	0.41
1978	7,769	1372	0.63	4,272	510.2	0.07	0.44
1979	7,165	1279	0.59	4,210	561.7	0.08	0.39
1980	6,524	1169	0.54	4,127	567.1	0.09	0.36
1981	5,923	1054	0.48	4,026	937.5	0.16	0.21
1982	5,065	856	0.39	3,808	755.7	0.15	0.22
1983	4,494	702	0.32	3,581	658.4	0.15	0.21
1984	4,114	575	0.26	3,337	473.6	0.12	0.24
1985	3,935	496	0.23	3,148	544.7	0.14	0.22

Table 55 (continued): Time-series of population estimates for BDR in California from the base case model.

Year	Total Biomass (mt)	Spawning Biomass (eggs x10^6)	Depletion	Age-0 Recruits	Total Catch (mt)	Relative Exploitation Rate	SPR
1986	3,735	415	0.19	2,911	150.6	0.04	0.50
1987	3,892	423	0.19	2,938	276.1	0.07	0.33
1988	3,925	420	0.19	2,928	323.5	0.08	0.30
1989	3,897	415	0.19	2,912	282.2	0.07	0.34
1990	3,898	420	0.19	2,929	358.2	0.09	0.27
1991	3,843	415	0.19	2,913	451.3	0.12	0.22
1992	3,737	394	0.18	2,845	749.65	0.20	0.12
1993	3,420	323	0.15	2,579	758.9	0.22	0.10
1994	3,152	254	0.12	2,261	365.6	0.12	0.19
1995	3,219	245	0.11	2,215	246.6	0.08	0.27
1996	3,320	259	0.12	2,287	232.0	0.07	0.30
1997	3,380	282	0.13	2,399	397.2	0.12	0.20
1998	3,265	287	0.13	2,421	326.2	0.10	0.24
1999	3,185	301	0.14	2,484	254.1	0.08	0.30
2000	3,143	320	0.15	2,565	170.2	0.05	0.41
2001	3,154	344	0.16	2,663	139.4	0.04	0.48
2002	3,180	368	0.17	2,753	173.3	0.05	0.43
2003	3,185	381	0.18	2,799	233.6	0.07	0.36
2004	3,196	378	0.17	2,790	170.9	0.05	0.44
2005	3,273	383	0.18	2,807	303.9	0.09	0.29
2006	3,287	362	0.17	2,731	318.1	0.10	0.27
2007	3,326	340	0.16	2,647	157.8	0.05	0.44
2008	3,457	351	0.16	2,690	117.1	0.03	0.52
2009	3,810	375	0.17	2,778	50.2	0.01	0.74
2010	4,312	416	0.19	2,915	58.9	0.01	0.73
2011	4,789	459	0.21	3,046	70.4	0.01	0.71
2012	5,149	509	0.23	3,182	59.6	0.01	0.76
2013	5,491	573	0.26	3,332	114.0	0.02	0.65
2014	5,725	638	0.29	3,464	124.9	0.02	0.65
2015	6,093	703	0.32	3,582	172.6	0.03	0.59
2016	6,421	757	0.35	3,668	136.3	0.02	0.67
2017	6,654	812	0.37	3,749	0.00	0.00	0.53

Table 56: "One-off" sensitivities for the BDR California Pre-STAR base model, dropping one fleet at a time.

	Base case	Fleet Removal										
		CPFV	Private	Rec_Disc	HKL	NET	Com_Disc	88-98	YOY	01-16	Schmidt	Abrams
Total Likelihood	741.566	300.34	689.72	714.13	703.32	739.30	710.92	735.94	741.11	736.99	573.50	670.94
Survey Likelihood Components	-7.325	-20.76	-11.25	-6.32	-7.18	-7.50	-7.36	-7.08	-6.06	-11.03	-20.44	-9.56
MRFSS CPFV, 1980-1999	-3.800	--	-1.98	-3.86	-3.83	-3.87	-3.88	-3.30	-3.71	-3.81	-3.18	-3.99
CRFS Private, 2004-2016	0.067	-8.03	--	0.42	0.09	0.06	-0.08	-2.70	0.27	0.51	-3.50	-0.69
Onboard CPFV, 1988-1998	-7.315	-4.07	-4.072	-7.368	-7.27	-7.39	-7.39	--	-7.18	-7.33	-7.33	-7.61
SWFSC Pelagic Juvenile	-0.648	-8.21	-5.30	-0.22	-0.53	-0.67	-0.25	-3.17	--	-0.39	-7.78	-0.99
Onboard CPFV, 2001-2016	4.371	-0.45	0.56	4.70	4.36	4.37	4.25	2.10	4.56	--	1.36	3.72
Length Likelihood Components	249.266	154.92	205.43	224.07	212.03	246.75	218.32	244.00	249.15	249.12	237.14	246.91
Rec CPFV	84.107	--	85.15	83.49	84.31	83.92	83.76	92.52	83.65	84.01	85.06	86.26
Rec Private, MRFSS	23.337	20.74	--	23.63	23.63	23.29	23.25	22.74	23.38	23.34	22.87	23.23
Rec Private, CRFS	23.092	21.14	--	22.93	22.75	23.08	22.83	24.40	22.62	22.97	22.09	24.09
Rec Discard	24.799	21.04	23.16	--	24.68	24.80	24.67	24.29	25.18	25.10	21.52	24.34
Commercial, hook and line	36.907	38.27	39.38	36.91	--	36.86	36.83	36.86	36.96	36.91	35.90	36.99
Commercial, net gears	2.179	2.27	2.19	2.18	2.15	--	2.18	2.24	2.18	2.18	2.32	2.21
Commercial, discard	30.183	30.33	30.43	30.21	30.14	30.18	--	29.93	30.54	30.08	25.61	30.53
Onboard CPFV, 1988-1998	13.815	12.94	13.98	13.851	13.67	13.79	13.74	--	13.82	13.80	15.32	13.69
Schmidt research	5.489	3.06	5.69	5.51	5.39	5.48	5.61	5.54	5.39	5.42	--	5.56
Abrams research	5.358	5.14	5.45	5.37	5.32	5.35	5.44	5.47	5.44	5.32	6.46	--
Age Likelihood Components	489.490	170.58	488.18	487.14	488.86	489.49	488.73	488.44	487.30	488.07	351.74	426.12
Rec CPFV	285.256	--	279.61	284.32	284.76	285.47	286.64	280.49	285.38	285.03	282.79	283.05
Schmidt research	143.391	117.82	150.69	142.76	143.39	143.17	140.92	145.01	141.50	142.74	--	143.07
Abrams research	60.844	52.76	57.88	60.06	60.71	60.85	61.17	62.94	60.42	60.29	68.95	--
Parameters												
NatM_p_1_Fem_GP_1	0.117	0.076	0.079	0.116	0.117	0.120	0.117	0.209	0.116	0.118	0.220	0.121
L_at_Amin_Fem_GP_1	17.347	17.211	17.235	17.328	17.284	17.349	17.354	17.290	17.263	17.329	16.698	17.647
L_at_Amax_Fem_GP_1	37.326	35.014	37.519	37.273	37.295	37.326	37.273	37.280	37.358	37.340	34.714	37.435
VonBert_K_Fem_GP_1	0.119	0.156	0.122	0.120	0.119	0.118	0.120	0.116	0.119	0.118	0.157	0.107
CV_young_Fem_GP_1	0.114	0.108	0.118	0.113	0.115	0.114	0.113	0.115	0.115	0.114	0.092	0.115
CV_old_Fem_GP_1	0.095	0.126	0.096	0.096	0.092	0.095	0.093	0.097	0.094	0.095	0.139	0.096
NatM_p_1_Mal_GP_1	0.318	1.282	0.562	0.323	0.316	0.308	0.317	0.110	0.318	0.310	-0.150	0.279
L_at_Amin_Mal_GP_1	-0.034	-0.068	-0.018	-0.031	-0.032	-0.033	-0.022	-0.055	-0.036	-0.034	-0.152	-0.044
L_at_Amax_Mal_GP_1	-0.207	-0.346	-0.165	-0.190	-0.188	-0.214	-0.218	-0.132	-0.211	-0.207	-0.327	-0.165
VonBert_K_Mal_GP_1	0.021	1.156	0.001	-0.030	-0.077	0.041	0.029	-0.284	0.012	0.007	1.081	-0.197
CV_young_Mal_GP_1	0.082	-0.006	0.005	0.080	0.112	0.074	0.039	0.236	0.100	0.087	-0.206	0.166
CV_old_Mal_GP_1	0.800	0.068	0.561	0.722	0.731	0.826	0.902	0.375	0.827	0.800	0.820	0.586
SR_LN(R0)	8.372	8.061	7.693	8.394	8.361	8.406	8.377	12*	8.367	8.413	12*	8.467
SizeSel_P1_REC_CPFV_N(1)	33.819	20.007	32.795	33.812	33.994	33.887	33.770	34.169	33.848	33.914	39.385	34.044
SizeSel_P3_REC_CPFV_N(1)	3.977	8.398	3.866	3.971	3.984	3.983	3.969	4.006	3.959	3.976	4.554	4.019
SizeSel_P4_REC_CPFV_N(1)	--	--	--	--	--	--	--	--	--	--	--	--
SizeSel_P6_REC_CPFV_N(1)	--	--	--	--	--	--	--	--	--	--	--	--
SizeSel_P1_REC_PRIV_N_MRFSS(2)	35.515	36.715	20.007	35.580	35.717	35.526	35.446	34.950	35.610	35.608	37.571	35.414
SizeSel_P3_REC_PRIV_N_MRFSS(2)	4.008	4.127	4.878	4.016	4.016	4.005	4.000	3.894	4.006	4.005	4.132	3.995
SizeSel_P4_REC_PRIV_N_MRFSS(2)	--	--	--	--	--	--	--	--	--	--	--	--
SizeSel_P6_REC_PRIV_N_MRFSS(2)	--	--	--	--	--	--	--	--	--	--	--	--
SizeSel_P1_REC_DISC_N(4)	22.490	21.902	22.024	14.002	22.564	22.526	22.519	23.025	22.475	22.575	21.938	22.540
SizeSel_P3_REC_DISC_N(4)	3.621	3.517	3.604	7.613	3.614	3.625	3.649	3.568	3.605	3.622	3.525	3.662
SizeSel_P4_REC_DISC_N(4)	3.749	3.860	3.747	1.003	3.758	3.751	3.746	3.727	3.759	3.756	4.055	3.762
SizeSel_P1_COM_HKL_N(5)	39.212	40.407	40.943	39.306	20.077	39.201	39.171	36.711	39.265	39.239	39.433	38.933
SizeSel_P3_COM_HKL_N(5)	4.060	4.196	4.278	4.070	8.084	4.055	4.053	3.836	4.062	4.058	4.000	4.023
SizeSel_P4_COM_HKL_N(5)	--	--	--	--	--	--	--	--	--	--	--	--
SizeSel_P6_COM_HKL_N(5)	--	--	--	--	--	--	--	--	--	--	--	--
SizeSel_P1_COM_NET_N(6)	42.401	42.036	42.121	42.415	42.540	34.520	42.451	42.682	42.378	42.375	42.401	42.367
SizeSel_P3_COM_NET_N(6)	3.060	2.982	3.059	3.059	3.070	1.212	3.066	3.075	3.060	3.056	2.893	3.030
SizeSel_P4_COM_NET_N(6)	--	--	--	--	--	--	--	--	--	--	--	--
SizeSel_P6_COM_NET_N(6)	--	--	--	--	--	--	--	--	--	--	--	--
SizeSel_P1_COM_DISC_N(8)	27.547	27.476	27.120	27.558	27.642	27.581	29.348	27.720	27.621	27.644	28.567	27.626
SizeSel_P3_COM_DISC_N(8)	3.744	3.816	3.752	3.751	3.742	3.744	0.205	3.677	3.744	3.744	3.985	3.757
SizeSel_P4_COM_DISC_N(8)	4.405	4.710	4.430	4.420	4.471	4.408	0.173	4.337	4.427	4.435	5.160	4.357
SizeSel_P1_ONBOARD_CPFV_88_98_N(9)	30.009	29.900	29.199	29.987	30.262	30.050	30.080	35.000	30.002	30.022	31.502	30.091
SizeSel_P3_ONBOARD_CPFV_88_98_N(9)	3.521	3.593	3.516	3.521	3.534	3.522	3.531	5.500	3.518	3.519	3.720	3.517
SizeSel_P1_SCHMIDT_N(12)	33.007	34.103	33.302	33.200	33.178	33.049	32.897	32.780	32.847	33.207	35.000	32.658
SizeSel_P3_SCHMIDT_N(12)	4.761	5.015	4.968	4.766	4.744	4.757	4.727	4.654	4.663	4.747	5.500	4.736
SizeSel_P1_ABRAMS_N(13)	33.949	36.067	34.610	34.177	34.185	33.985	33.718	33.609	33.710	34.182	41.482	35.002
SizeSel_P3_ABRAMS_N(13)	4.547	4.851	4.737	4.558	4.546	4.544	4.505	4.453	4.463	4.545	5.241	5.499
SizeSel_P1_REC_CPFV_N(1)_BLK1repl_1899	31.390	37.604	29.171	31.200	31.398	31.542	31.398	33.464	31.221	31.373	39.459	31.917
SizeSel_P1_REC_CPFV_N(1)_BLK1repl_1972	33.298	30.257	31.371	33.191	33.478	33.384	33.300	33.599	33.178	33.320	40.523	33.865
SizeSel_P1_REC_PRIV_N_MRFSS(2)_BLK2repl_1899	31.846	32.385	49.280	31.834	32.174	31.876	31.853	31.077	31.838	31.855	33.859	31.953
Q_extraSD_REC_CPFV_N(1)	0.215	0.375	0.290	0.213	0.215	0.213	0.212	0.218	0.219	0.215	0.223	0.207
Q_extraSD_REC_PRIV_N_CRFS(3)	0.572	0.289	0.375	0.589	0.573	0.572	0.565	0.455	0.582	0.593	0.425	0.538
Q_extraSD_ONBOARD_CPFV_88_98_N(9)	0.168	0.269	0.254	0.167	0.169	0.166	0.166	0.375	0.172	0.168	0.172	0.161
Q_extraSD_JUV_SWFSC_N(10)	0.189	0.000	0.024	0.201	0.195	0.188	0.204	0.086	0.375	0.198	0.000	0.171
Q_extraSD_ONBOARD_CPFV_01_16_N(11)	0.706	0.491	0.530	0.723	0.706	0.706	0.700	0.599	0.716	0.375	0.567	0.674
Derived Quantities												
SB_0	2120	3200	2531	2206	2087	2097	2121	18704	2142	2157	14724	2093
SB_{2107}	945	64	153	1004	803	973	974	22174	938	1038	15487	1029
SB_{2017}/SB_0	0.446	0.020	0.061	0.455	0.384	0.464	0.459	1.186	0.438	0.481	1.052	0.492
Yield at $SPR_{50\%}$	309	260	212	311	303	313	310	6351	309	319	7055	320

Table 57: Additional sensitivities for the BDR Pre-STAR California base model.

		Selectivity		Tuning		Estimate
	Base case	Dome-Rec fleets	Dome-Com fleets	All Francis	All harmonic mean	Steepness (0.648)
Total Likelihood	741.566	737.56	741.40	495.82	1288.23	741.37
Survey Likelihood Components	-7.325	-8.49	-7.31	-4.96	-12.51	-7.80
MRFSS CPFV, 1980-1999	-3.800	-4.10	-3.80	-3.38	-1.97	-3.63
CRFS Private, 2004-2016	0.067	-0.20	0.07	0.67	-5.05	-0.30
Onboard CPFV, 1988-1998	-7.315	-7.71	-7.31	-8.11	-4.93	-7.09
SWFSC Pelagic Juvenile	-0.648	-0.67	-0.65	0.99	-1.12	-0.82
Onboard CPFV, 2001-2016	4.371	4.19	4.37	4.87	0.56	4.04
Length Likelihood Components	249.266	245.20	249.05	240.80	759.31	249.18
Rec CPFV	84.107	83.12	84.06	87.62	311.52	84.38
Rec Private, MRFSS	23.337	23.71	23.33	24.40	107.88	23.21
Rec Private, CRFS	23.092	19.04	23.10	23.44	65.23	22.93
Rec Discard	24.799	24.74	24.80	24.92	57.40	24.64
Commercial, hook and line	36.907	36.42	36.89	38.24	89.11	36.88
Commercial, net gears	2.179	2.18	2.02	2.45	2.20	2.18
Commercial, discard	30.183	30.28	30.18	21.84	69.11	30.20
Onboard CPFV, 1988-1998	13.815	14.84	13.81	8.82	23.73	13.86
Schmidt research	5.489	5.45	5.49	4.84	24.31	5.51
Abrams research	5.358	5.41	5.36	4.23	8.83	5.38
Age Likelihood Components	489.490	489.28	489.53	246.15	512.58	490.02
Rec CPFV	285.256	285.55	285.30	38.16	297.12	285.08
Schmidt research	143.391	142.88	143.40	6.93	160.03	143.98
Abrams research	60.844	60.85	60.84	201.06	55.42	60.96
Parameters						
NatM_p_1_Fem_GP_1	0.117	0.122	0.117	0.174	0.096	0.120
L_at_Amin_Fem_GP_1	17.347	17.253	17.349	15.756	16.777	17.359
L_at_Amax_Fem_GP_1	37.326	37.639	37.326	37.840	37.173	37.344
VonBert_K_Fem_GP_1	0.119	0.117	0.118	0.164	0.137	0.118
CV_young_Fem_GP_1	0.114	0.115	0.114	0.104	0.107	0.114
CV_old_Fem_GP_1	0.095	0.092	0.095	0.070	0.094	0.095
NatM_p_1_Mal_GP_1	0.318	0.305	0.318	0.140	0.266	0.313
L_at_Amin_Mal_GP_1	-0.034	-0.034	-0.034	-0.121	-0.071	-0.034
L_at_Amax_Mal_GP_1	-0.207	-0.200	-0.208	-0.485	-0.177	-0.200
VonBert_K_Mal_GP_1	0.021	-0.056	0.026	1.524	0.266	0.003
CV_young_Mal_GP_1	0.082	0.115	0.080	-0.379	0.084	0.086
CV_old_Mal_GP_1	0.800	0.821	0.803	2.281	0.957	0.766
SR_LN(R0)	8.372	8.451	8.371	8.751	7.693	8.448
SizeSel_P1_REC_CPFV_N(1)	33.819	33.233	33.826	33.755	33.365	33.904
SizeSel_P3_REC_CPFV_N(1)	3.977	3.905	3.978	3.964	3.949	3.986
SizeSel_P4_REC_CPFV_N(1)	--	5.120	--	--	--	--
SizeSel_P6_REC_CPFV_N(1)	--	6.808	--	--	--	--
SizeSel_P1_REC_PRIV_N_MRFSS(2)	35.515	35.807	35.519	35.209	36.113	35.586
SizeSel_P3_REC_PRIV_N_MRFSS(2)	4.008	4.046	4.008	3.978	4.123	4.012
SizeSel_P4_REC_PRIV_N_MRFSS(2)	--	-8.492	--	--	--	--
SizeSel_P6_REC_PRIV_N_MRFSS(2)	--	0.393	--	--	--	--
SizeSel_P1_REC_DISC_N(4)	22.490	22.543	22.492	22.372	21.517	22.492
SizeSel_P3_REC_DISC_N(4)	3.621	3.596	3.622	3.470	3.409	3.621
SizeSel_P4_REC_DISC_N(4)	3.749	3.720	3.750	3.797	3.732	3.751
SizeSel_P1_COM_HKL_N(5)	39.212	38.390	39.210	39.267	40.078	39.221
SizeSel_P3_COM_HKL_N(5)	4.060	3.984	4.059	4.049	4.208	4.061
SizeSel_P4_COM_HKL_N(5)	--	--	4.566	--	--	--
SizeSel_P6_COM_HKL_N(5)	--	--	7.073	--	--	--
SizeSel_P1_COM_NET_N(6)	42.401	42.174	43.154	42.171	41.807	42.386
SizeSel_P3_COM_NET_N(6)	3.060	3.052	3.182	3.022	3.036	3.055
SizeSel_P4_COM_NET_N(6)	--	--	-2.106	--	--	--
SizeSel_P6_COM_NET_N(6)	--	--	-6.048	--	--	--
SizeSel_P1_COM_DISC_N(8)	27.547	27.434	27.553	27.505	26.611	27.570
SizeSel_P3_COM_DISC_N(8)	3.744	3.711	3.744	3.718	3.697	3.747
SizeSel_P4_COM_DISC_N(8)	4.405	4.305	4.406	4.329	4.613	4.424
SizeSel_P1_ONBOARD_CPFV_88_98_N(9)	30.009	29.862	30.017	30.409	29.236	29.990
SizeSel_P3_ONBOARD_CPFV_88_98_N(9)	3.521	3.481	3.522	3.550	3.499	3.520
SizeSel_P1_SCHMIDT_N(12)	33.007	32.422	33.018	33.421	33.039	33.139
SizeSel_P3_SCHMIDT_N(12)	4.761	4.696	4.761	4.789	4.934	4.773
SizeSel_P1_ABRAMS_N(13)	33.949	33.201	33.960	34.407	34.931	34.126
SizeSel_P3_ABRAMS_N(13)	4.547	4.470	4.547	4.582	4.777	4.563
SizeSel_P1_REC_CPFV_N(1)_BLK1repl_1899	31.390	31.085	31.395	31.875	30.420	31.433
SizeSel_P1_REC_CPFV_N(1)_BLK1repl_1972	33.298	32.791	33.305	33.916	32.355	33.355
SizeSel_P1_REC_PRIV_N_MRFSS(2)_BLK2repl_1899	31.846	32.532	31.851	32.227	31.672	31.867
Q_extraSD_REC_CPFV_N(1)	0.215	0.203	0.215	0.226	0.286	0.222
Q_extraSD_REC_PRIV_N_CRFS(3)	0.572	0.560	0.572	0.601	0.374	0.555
Q_extraSD_ONBOARD_CPFV_88_98_N(9)	0.168	0.158	0.168	0.144	0.238	0.174
Q_extraSD_JUV_SWFSC_N(10)	0.189	0.187	0.189	0.276	0.184	0.182
Q_extraSD_ONBOARD_CPFV_01_16_N(11)	0.706	0.698	0.706	0.732	0.531	0.690
Derived Quantities						
SB_0	2120	2140	2121	1551	1712	2178
SB_{2107}	945	1061	944	972	138	822
SB_{2017}/SB_0	0.446	0.496	0.445	0.626	0.081	0.377
Yield at $SPR_{50\%}$	309	319	309	349	223	309

Table 58: Data weighting sensitivity for the Northern California Pre-STAR base case model; Francis weights applied to all composition data (lengths and conditional-age-at-length).

Fleet	Starting value	Iteration #1	Iteration #2	Iteration #3	Iteration #4	Fleet name
1	1	0.1573	0.1571	0.1549	0.1547	#_REC_CPFV_N
2	1	0.0865	0.0865	0.0865	0.0865	#_REC_PRIV_N_MRFSS
3	1	0.0529	0.0396	0.0386	0.0386	#_REC_PRIV_N_CRFS
4	1	0.2270	0.2270	0.2270	0.2270	#_REC_DISC_N
5	1	0.3461	0.3461	0.3461	0.3461	#_COM_HKL_N
6	1	1.0000	1.0000	1.0000	1.0000	#_COM_NET_N
8	1	0.2684	0.2684	0.2684	0.2684	#_COM_DISC_N
9	1	0.3635	0.3635	0.3635	0.3635	#_ONBOARD_CPFV_88_98_N
12	1	0.2984	0.2238	0.2238	0.2238	#_SCHMIDT_N
13	1	0.6644	0.6644	0.6644	0.6644	#_ABRAMS_N
1	1	0.0455	0.0267	0.0224	0.0208	#_REC_CPFV_N
12	1	0.0182	0.0116	0.0104	0.0099	#_SCHMIDT_N
13	1	1.0000	1.0000	1.0000	1.0000	#_ABRAMS_N

Table 59: Data weighting sensitivity for the Northern California pre-STAR base case model; harmonic mean weights applied to all composition data (lengths and conditional-age-at-length).

Fleet	Starting value	Iteration #1	Iteration #2	Iteration #3	Fleet name
1	1	0.6924	0.6924	0.6924	#_REC_CPFV_N
2	1	0.3622	0.3622	0.3622	#_REC_PRIV_N_MRFSS
3	1	0.1269	0.1129	0.1119	#_REC_PRIV_N_CRFS
4	1	0.5126	0.5126	0.5126	#_REC_DISC_N
5	1	0.8181	0.8181	0.8181	#_COM_HKL_N
6	1	1.0000	1.0000	1.0000	#_COM_NET_N
8	1	0.8274	0.8274	0.8274	#_COM_DISC_N
9	1	1.0000	1.0000	1.0000	#_ONBOARD_CPFV_88_98_N
12	1	1.0000	1.0000	0.9922	#_SCHMIDT_N
13	1	1.0000	1.0000	1.0000	#_ABRAMS_N
1	1	0.2347	0.2284	0.2279	#_REC_CPFV_N
12	1	0.2999	0.2797	0.2759	#_SCHMIDT_N
13	1	0.2052	0.2052	0.2052	#_ABRAMS_N

Table 60: Bivariate likelihood profile over female natural mortality rate and Beverton-Holt steepness parameters in the post-STAR panel California base model. Panel (a) shows negative log-likelihood values for each parameter combination, panel (b) shows estimated depletion, and panel (c) shows 2017 spawning output. The model run with M=0.12 and h=0.65 (boxed cell) is closest to the estimates in the base model.

a)

Female Natural Mortality	Beverton-Holt Steepness								
	0.3*	**0.4**	**0.5**	**0.6**	**0.65**	**0.7**	**0.718**	**0.8**	**0.9****
0.08	807.91	777.83	759.31	750.13	748.33	747.99	748.11	748.82	749.90
0.09	789.09	762.98	749.84	745.36	745.27	745.62	745.71	746.10	747.37
0.10	773.94	753.26	745.01	743.84	744.02	744.07	744.11	744.57	745.96
0.11	763.01	747.63	743.41	743.31	743.21	743.24	743.31	743.92	745.31
0.12	755.67	745.13	743.53	743.04	$\boxed{742.97}$	743.10	743.20	743.89	745.19
0.13	751.31	744.85	743.86	743.25	743.27	743.47	743.58	744.25	745.41
0.14	749.33	745.66	744.32	743.86	743.94	744.15	744.26	744.85	745.83
0.15	749.16	746.48	745.08	744.75	744.83	745.02	745.10	745.56	746.35
0.16	750.12	747.34	746.08	745.79	745.83	745.94	745.99	746.31	746.92
0.17	751.23	748.36	747.20	746.84	746.81	746.83	746.86	747.03	747.46
0.18	752.23	749.48	748.30	747.80	747.68	747.61	747.60	747.63	747.91

* A population with steepness of 0.3 would be driven to extinction by F(SPR_50%)
** All models with steepness = 0.9 gave warnings of poor convergence in Fmsy estimate

b)

Female Natural Mortality	Beverton-Holt Steepness								
	0.3*	**0.4**	**0.5**	**0.6**	**0.65**	**0.7**	**0.718**	**0.8**	**0.9****
0.08	0.02	0.02	0.03	0.04	0.04	0.06	0.07	0.16	0.29
0.09	0.02	0.03	0.03	0.05	0.07	0.13	0.15	0.27	0.39
0.10	0.03	0.03	0.05	0.09	0.16	0.24	0.26	0.37	0.49
0.11	0.03	0.04	0.07	0.19	0.28	0.35	0.38	0.48	0.58
0.12	0.03	0.05	0.13	0.31	$\boxed{0.39}$	0.46	0.48	0.58	0.67
0.13	0.04	0.08	0.25	0.42	0.50	0.56	0.58	0.67	0.74
0.14	0.05	0.14	0.37	0.53	0.60	0.66	0.67	0.75	0.81
0.15	0.07	0.27	0.48	0.63	0.69	0.74	0.76	0.82	0.88
0.16	0.12	0.39	0.59	0.73	0.78	0.83	0.84	0.89	0.94
0.17	0.23	0.51	0.70	0.82	0.87	0.90	0.92	0.96	0.99
0.18	0.36	0.64	0.81	0.91	0.95	0.98	0.98	1.02	1.04

* A population with steepness of 0.3 would be driven to extinction by F(SPR_50%)
** All models with steepness = 0.9 gave warnings of poor convergence in Fmsy estimate

c)

Female Natural Mortality	Beverton-Holt Steepness								
	0.3*	**0.4**	**0.5**	**0.6**	**0.65**	**0.7**	**0.718**	**0.8**	**0.9****
0.08	59	76	82	96	112	147	170	390	663
0.09	79	85	96	128	177	303	362	610	851
0.10	88	96	118	213	372	542	598	815	1020
0.11	97	112	162	442	619	767	814	999	1168
0.12	109	137	296	693	$\boxed{843}$	969	1009	1162	1299
0.13	125	190	565	915	1042	1147	1180	1307	1417
0.14	149	346	822	1117	1223	1311	1338	1443	1536
0.15	195	643	1059	1310	1400	1474	1498	1587	1668
0.16	318	937	1293	1509	1587	1651	1671	1750	1824
0.17	634	1236	1546	1735	1805	1863	1882	1957	2029
0.18	1030	1576	1850	2023	2090	2148	2167	2243	2319

* A population with steepness of 0.3 would be driven to extinction by F(SPR_50%)
** All models with steepness = 0.9 gave warnings of poor convergence in Fmsy estimate

Table 61: Bivariate likelihood profile over female natural mortality rate and Beverton-Holt steepness parameters in the post-STAR panel California base model. Panel (a) shows the overfishing limit (OFL), and panel (b) shows the SPR50% proxy MSY yield. The model run with M=0.12 and h=0.65 (boxed cell) is closest to the estimates in the base model.

a)

Female Natural Mortality	Beverton-Holt Steepness								
	0.3*	**0.4**	**0.5**	**0.6**	**0.65**	**0.7**	**0.718**	**0.8**	**0.9****
0.08	22	23	23	26	29	37	43	94	157
0.09	26	27	29	37	49	82	97	160	221
0.10	31	33	38	65	110	158	174	234	291
0.11	37	40	55	142	197	242	257	313	364
0.12	43	52	106	241	291	332	346	396	441
0.13	53	76	215	344	390	427	439	485	525
0.14	67	146	338	454	496	531	541	583	620
0.15	93	290	470	578	617	648	658	697	732
0.16	159	455	622	722	759	789	799	836	871
0.17	337	649	807	903	938	968	978	1017	1055
0.18	591	898	1049	1145	1183	1215	1226	1269	1311

* A population with steepness of 0.3 would be driven to extinction by F(SPR_50%)

** All models with steepness = 0.9 gave warnings of poor convergence in Fmsy estimate

b)

Female Natural Mortality	Beverton-Holt Steepness								
	0.3*	**0.4**	**0.5**	**0.6**	**0.65**	**0.7**	**0.718**	**0.8**	**0.9****
0.08	--	159	228	237	233	229	229	234	235
0.09	--	167	234	242	241	246	249	254	254
0.10	--	173	239	252	262	269	271	274	274
0.11	--	177	245	275	285	291	292	295	296
0.12	--	181	259	300	308	313	314	318	321
0.13	--	185	285	323	331	337	338	343	349
0.14	--	198	310	348	358	364	366	374	383
0.15	--	220	337	378	390	399	402	413	425
0.16	--	242	367	416	431	443	447	463	480
0.17	--	267	407	467	487	504	510	532	555
0.18	--	300	465	542	570	593	601	632	664

* A population with steepness of 0.3 would be driven to extinction by F(SPR_50%)

** All models with steepness = 0.9 gave warnings of poor convergence in Fmsy estimate

Table 62: Response of the pre-STAR base model (fixed steepness) to reductions in the apical male selectivity parameters.

Female M and Male M both estimated

Quantity / Estimate	**Apical = 1.0 (Base)**	Apical = 0.9	Apical = 0.8	Apical = 0.7	Apical = 0.6	**Apical = 0.5**	Apical = 0.4	Apical = 0.3
Negative Log-Likelihood	741.566	738.209	735.075	732.362	730.364	**729.556**	730.78	735.712
Female M	0.117	0.117	0.117	0.118	0.119	0.121	0.125	0.133
Female L(2)	17.35	17.35	17.34	17.32	17.31	17.29	17.26	17.24
Female L(30)	37.33	37.28	37.24	37.21	37.18	37.16	37.15	37.15
Female k	0.119	0.120	0.121	0.122	0.123	0.124	0.125	0.125
Female CV{L(2)}	0.114	0.113	0.113	0.113	0.112	0.112	0.112	0.112
Female CV{L(30)}	0.095	0.094	0.094	0.094	0.093	0.092	0.092	0.091
Male M	0.161	0.158	0.155	0.152	0.147	0.143	0.137	0.129
Male L(2)	16.77	16.87	16.92	16.96	16.97	16.97	16.94	16.91
Male L(30)	30.35	30.26	30.15	30.01	29.83	29.59	29.29	28.92
Male k	0.121	0.130	0.139	0.149	0.161	0.175	0.193	0.216
Male CV{L(2)}	0.123	0.118	0.113	0.110	0.107	0.104	0.101	0.099
Male CV{L(30)}	0.211	0.210	0.210	0.209	0.210	0.210	0.211	0.211

Table 63: Oregon commercial landings and discards (mt) by source.

Year	Historical Reconstruct	PacFIN Land in OR 'BLUR'	PacFIN Land in CA 'BLUR'	PacFIN Land in OR 'BLU1'	PacFIN Land in CA 'BLU1'	PacFIN Land in OR 'DEAC'	PacFIN Land in OR 'URCK'	Total Landings	Total Discards
1892	0.2155	-	-	-	-	-	-	0.2155	0.0533
1893	0.2155	-	-	-	-	-	-	0.2155	0.0533
1894	0.2155	-	-	-	-	-	-	0.2155	0.0533
1895	0.0554	-	-	-	-	-	-	0.0554	0.0137
1896	0.0133	-	-	-	-	-	-	0.0133	0.0033
1897	0.0136	-	-	-	-	-	-	0.0136	0.0034
1898	0.0077	-	-	-	-	-	-	0.0077	0.0019
1899	0.0130	-	-	-	-	-	-	0.0130	0.0032
1900	0.0183	-	-	-	-	-	-	0.0183	0.0045
1901	0.0237	-	-	-	-	-	-	0.0237	0.0058
1902	0.0290	-	-	-	-	-	-	0.0290	0.0072
1903	0.0343	-	-	-	-	-	-	0.0343	0.0085
1904	0.0396	-	-	-	-	-	-	0.0396	0.0098
1905	0.0449	-	-	-	-	-	-	0.0449	0.0111
1906	0.0503	-	-	-	-	-	-	0.0503	0.0124
1907	0.0556	-	-	-	-	-	-	0.0556	0.0137
1908	0.0609	-	-	-	-	-	-	0.0609	0.0150
1909	0.0662	-	-	-	-	-	-	0.0662	0.0164
1910	0.0716	-	-	-	-	-	-	0.0716	0.0177
1911	0.0769	-	-	-	-	-	-	0.0769	0.0190
1912	0.0822	-	-	-	-	-	-	0.0822	0.0203
1913	0.0875	-	-	-	-	-	-	0.0875	0.0216
1914	0.0928	-	-	-	-	-	-	0.0928	0.0229
1915	0.0982	-	-	-	-	-	-	0.0982	0.0243
1916	0.1035	-	-	-	-	-	-	0.1035	0.0256
1917	0.1088	-	-	-	-	-	-	0.1088	0.0269
1918	0.1141	-	-	-	-	-	-	0.1141	0.0282
1919	0.1194	-	-	-	-	-	-	0.1194	0.0295
1920	0.1248	-	-	-	-	-	-	0.1248	0.0308
1921	0.1301	-	-	-	-	-	-	0.1301	0.0321
1922	0.1354	-	-	-	-	-	-	0.1354	0.0335
1923	0.1407	-	-	-	-	-	-	0.1407	0.0348
1924	0.1460	-	-	-	-	-	-	0.1460	0.0361
1925	0.1514	-	-	-	-	-	-	0.1514	0.0374
1926	0.1567	-	-	-	-	-	-	0.1567	0.0387
1927	0.1593	-	-	-	-	-	-	0.1593	0.0394
1928	0.2658	-	-	-	-	-	-	0.2658	0.0657
1929	0.5163	-	-	-	-	-	-	0.5163	0.1276
1930	0.5252	-	-	-	-	-	-	0.5252	0.1298
1931	0.3992	-	-	-	-	-	-	0.3992	0.0986
1932	0.1060	-	-	-	-	-	-	0.1060	0.0262
1933	0.1947	-	-	-	-	-	-	0.1947	0.0481
1934	0.2049	-	-	-	-	-	-	0.2049	0.0506
1935	0.1692	-	-	-	-	-	-	0.1692	0.0418
1936	0.4668	-	-	-	-	-	-	0.4668	0.1153
1937	0.6865	-	-	-	-	-	-	0.6865	0.1696
1938	0.7150	-	-	-	-	-	-	0.7150	0.1767
1939	0.5604	-	-	-	-	-	-	0.5604	0.1385
1940	0.9438	-	-	-	-	-	-	0.9438	0.2332
1941	1.0324	-	-	-	-	-	-	1.0324	0.2551
1942	1.4222	-	-	-	-	-	-	1.4222	0.3514
1943	3.3170	-	-	-	-	-	-	3.3170	0.8196
1944	1.5694	-	-	-	-	-	-	1.5694	0.3878
1945	0.9849	-	-	-	-	-	-	0.9849	0.2434
1946	1.2619	-	-	-	-	-	-	1.2619	0.3118
1947	1.0205	-	-	-	-	-	-	1.0205	0.2522
1948	3.3156	-	-	-	-	-	-	3.3156	0.8193
1949	3.1551	-	-	-	-	-	-	3.1551	0.7796
1950	1.4228	-	-	-	-	-	-	1.4228	0.3516
1951	2.2121	-	-	-	-	-	-	2.2121	0.5466
1952	2.5114	-	-	-	-	-	-	2.5114	0.6206

Table 63 (continued): Oregon commercial landings and discards (mt) by source.

Year	Historical Reconstruct	PacFIN Land in OR 'BLUR'	PacFIN Land in CA 'BLUR'	PacFIN Land in OR 'BLU1'	PacFIN Land in CA 'BLU1'	PacFIN Land in OR 'DEAC'	PacFIN Land in OR 'URCK'	Total Landings	Total Discards
1953	1.2152	-	-	-	-	-	-	1.2152	0.3003
1954	9.5865	-	-	-	-	-	-	9.5865	2.3688
1955	9.1372	-	-	-	-	-	-	9.1372	2.2578
1956	22.2275	-	-	-	-	-	-	22.2275	5.4924
1957	10.9712	-	-	-	-	-	-	10.9712	2.7110
1958	2.0594	-	-	-	-	-	-	2.0594	0.5089
1959	2.4163	-	-	-	-	-	-	2.4163	0.5971
1960	6.8669	-	-	-	-	-	-	6.8669	1.6968
1961	5.4302	-	-	-	-	-	-	5.4302	1.3418
1962	5.3031	-	-	-	-	-	-	5.3031	1.3104
1963	2.4458	-	-	-	-	-	-	2.4458	0.6044
1964	7.9473	-	-	-	-	-	-	7.9473	1.9638
1965	3.9118	-	-	-	-	-	-	3.9118	0.9666
1966	3.2757	-	-	-	-	-	-	3.2757	0.8094
1967	4.5541	-	-	-	-	-	-	4.5541	1.1253
1968	3.3897	-	-	-	-	-	-	3.3897	0.8376
1969	4.3674	-	-	-	-	-	-	4.3674	1.0792
1970	2.6642	-	-	-	-	-	-	2.6642	0.6583
1971	3.5084	-	-	-	-	-	-	3.5084	0.8669
1972	3.1454	-	-	-	-	-	-	3.1454	0.7772
1973	3.3526	-	-	-	-	-	-	3.3526	0.8284
1974	3.9355	-	-	-	-	-	-	3.9355	0.9725
1975	1.9751	-	-	-	-	-	-	1.9751	0.4881
1976	2.4850	-	-	-	-	-	-	2.4850	0.6140
1977	6.9377	-	-	-	-	-	-	6.9377	1.7143
1978	4.1571	-	-	-	-	-	-	4.1571	1.0272
1979	8.9291	-	-	-	-	-	-	8.9291	2.2064
1980	5.8469	-	-	-	-	-	-	5.8469	1.4448
1981	5.1115	-	-	-	-	-	-	5.1115	1.2630
1982	9.9387	-	-	-	-	-	-	9.9387	2.4559
1983	19.5690	-	-	-	-	-	-	19.5690	4.8355
1984	13.2422	-	-	-	-	-	-	13.2422	3.2721
1985	12.8195	-	-	-	-	-	-	12.8195	3.1677
1986	10.1636	-	-	-	-	-	-	10.1636	2.5114
1987	-	-	-	-	0.0240	-	12.8273	12.8513	3.1756
1988	-	-	-	-	-	-	7.2928	7.2928	1.8021
1989	-	-	-	-	0.0005	-	12.1552	12.1556	3.0037
1990	-	-	-	-	-	-	21.0144	21.0144	5.1926
1991	-	5.5681	-	-	-	-	15.2230	20.7912	5.1375
1992	-	48.8583	0.0284	-	-	-	1.6721	50.5587	12.4931
1993	-	26.2236	-	-	-	-	4.2310	30.4546	7.5253
1994	-	20.6079	-	-	-	-	1.6538	22.2618	5.5009
1995	-	13.7849	0.0001	-	-	-	0.7572	14.5423	3.5934
1996	-	5.1227	0.0042	-	-	-	3.0781	8.2050	2.0274
1997	-	1.4669	-	-	-	-	1.9670	3.4338	0.8485
1998	-	10.8324	-	-	-	-	2.4837	13.3161	3.2904
1999	-	2.4937	-	-	-	-	0.6254	3.1191	0.7707
2000	-	4.8414	-	1.0433	-	-	-	5.8847	1.4541
2001	-	4.1843	-	1.0151	-	-	-	5.1995	1.2848
2002	-	2.9929	-	0.9675	-	-	-	3.9604	0.9786
2003	-	3.4138	-	2.2748	-	-	-	5.6886	1.4056
2004	-	5.1936	-	0.6881	-	-	-	5.8817	1.4534
2005	-	2.0716	-	3.1062	-	-	-	5.1778	1.2794
2006	-	3.5449	-	1.1331	-	-	-	4.6779	1.1559
2007	-	3.6238	-	0.6328	-	-	-	4.2566	1.0518
2008	-	1.9065	-	0.8355	-	-	-	2.7420	0.6776
2009	-	2.5779	-	0.2685	-	-	-	2.8465	0.7034
2010	-	3.6159	-	0.4205	-	-	-	4.0364	0.9974
2011	-	6.2837	-	0.2917	-	-	-	6.5753	1.6248
2012	-	5.9979	-	0.8414	-	-	-	6.8393	1.6900
2013	-	4.7471	-	0.4023	-	-	-	5.1495	1.2724
2014	-	3.5037	-	0.4704	-	-	-	3.9741	0.9820
2015	-	0.7886	-	0.2790	-	0.4455	-	1.5130	0.3739
2016	-	0.7613	-	0.0803	-	1.2160	-	2.0576	0.5084

Table 64: Sample sizes for the number of fish and trips sampled for length by ODFW for each fleet.

	Commercial Fleet Landings		Recreational Ocean Fleet Landings		Recreational Shore Fleet Landings		Commercial Fleet Discards		Recreational Ocean Fleet Discards	
Year	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths
1980	-	-	43	260	12	28	-	-	-	-
1981	-	-	31	129	16	40	-	-	-	-
1982	-	-	34	131	11	29	-	-	-	-
1983	-	-	23	154	2	9	-	-	-	-
1984	-	-	53	355	6	13	-	-	-	-
1985	-	-	45	178	2	3	-	-	-	-
1986	-	-	28	179	3	5	-	-	-	-
1987	-	-	53	253	14	29	-	-	-	-
1988	-	-	120	593	11	20	-	-	-	-
1989	-	-	49	413	2	8	-	-	-	-
1990	-	-	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-	-	-
1993	-	-	134	1251	16	140	-	-	-	-
1994	-	-	110	625	3	3	-	-	-	-
1995	-	-	93	642	9	37	-	-	-	-
1996	-	-	115	1298	12	39	-	-	-	-
1997	-	-	147	1527	5	14	-	-	-	-
1998	-	-	239	1564	4	19	-	-	-	-
1999	4	13	197	1724	6	30	-	-	-	-
2000	16	243	162	1146	7	24	-	-	-	-
2001	17	97	581	3529	3	10	-	-	-	-
2002	15	78	719	2490	3	7	-	-	-	-
2003	25	172	719	2508	12	21	-	-	32	209
2004	50	227	511	1533	2	3	13	61	25	226
2005	33	169	921	2728	18	53	50	426	50	307
2006	44	186	1109	3318	-	-	111	677	31	157
2007	59	375	1111	3981	-	-	78	320	40	188
2008	31	128	1293	4505	-	-	84	382	50	296
2009	35	165	1185	4210	-	-	81	323	36	138
2010	72	427	1427	5157	-	-	97	491	24	131
2011	97	612	1300	4403	-	-	96	325	23	88
2012	91	496	1431	4832	-	-	110	356	29	136
2013	120	673	1360	3876	-	-	105	382	23	96
2014	127	625	1137	3195	-	-	95	317	31	79
2015	73	272	1356	3946	-	-	123	409	33	106
2016	29	68	1193	3616	-	-	-	-	46	237

Table 65: Sample sizes for the number of fish by gender sampled for age by ODFW for each fleet.

	Commercial Fleet			Recreational Ocean Fleet			ODFW Research Samples		
Year	Female	Male	Unknown	Female	Male	Unknown	Female	Male	Unknown
1999	-	-	-	90	83	-	-	-	-
2000	27	5	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-	-
2002	-	-	-	-	-	-	-	-	-
2003	47	9	-	-	-	-	-	-	-
2004	-	-	-	99	47	-	-	-	-
2005	29	3	-	-	-	-	-	-	-
2006	-	-	-	-	-	-	-	-	-
2007	136	23	-	-	-	-	-	-	-
2008	-	-	-	393	133	-	-	-	-
2009	126	20	-	333	128	-	-	-	-
2010	-	-	-	294	114	1	-	-	-
2011	230	59	-	243	173	20	-	-	-
2012	-	-	-	314	173	32	-	-	-
2013	574	61	-	330	122	6	-	-	-
2014	545	47	-	375	115	3	-	-	-
2015	229	34	-	390	117	4	57	53	14

Table 66: Oregon commercial logbook filtering criteria and resulting sample sizes used for BDR. Bold value indicates the final trip-level sample size used for delta-GLM analysis.

Filter	Criteria	Samples	# pos	% pos
Full data set	All data	29669	8257	27.8
Depth_min	Ensure start depth variable is present and > 1 fathom	27678	7809	28.2
Fishermen	Ensure number of fishermen variable present and > 0	27211	7710	28.3
Gear ID	Ensure gear id variable present	27065	7679	28.4
Secondary Gear ID	Ensure secondary gear id variable present	25675	7274	28.3
CPUE	Ensure cpue (lbs caught/hook hours) is present	25105	7166	28.5
Year 2015	Remove 2015 due to large change in limit	21958	6320	28.8
Gear	Retain only hook and line gear using jigs	18178	5596	30.8
Port	Remove ports with little to no data	17642	5541	31.4
Depth_max	Remove starting depths > 30 fathom	17635	5540	31.4
Hook hour	Remove outlier hook and hour counts	17631	5539	31.4
Permit type	Remove unpermitted trips	17534	5528	31.5
Vessel	Remove vessels that fished < 3 years	15767	5035	32.0
Trip	Aggregate to trip level	**13280**	4157	31.3

Table 67: Model selection summary across representative candidate models evaluated for the Oregon commercial logbook index.

Commercial Logbook Index (delta-GLM model)				
	Binomial		Positive	
Model	AIC	ΔAIC	AIC	ΔAIC
YEAR	16802	3166	14174	1123
YEAR+SUBREGION	16755	3119	14105	1054
YEAR+MONTH	16551	2915	13958	907
YEAR+VESSEL	14086	450	13337	286
YEAR+CREW	16426	2790	14151	1100
YEAR+DEPTH_BIN	16784	3148	14159	1108
YEAR+PERMIT_TYPE	16802	3166	14129	1078
YEAR+RUGOSITY	16799	3163	14167	1116
YEAR+VESSEL+MONTH	13816	180	13138	87
YEAR+VESSEL+MONTH+SUBREGION	13818	182	13140	89
YEAR+VESSEL+MONTH+SUBREGION+YEAR:SUBREGION	13726	90	13080	29
YEAR+VESSEL+MONTH+SUBREGION+CREW+YEAR:SUBREGION	13661	25	13053	2
YEAR+VESSEL+MONTH+SUBREGION+CREW+DEPTH_BIN+ YEAR:SUBREGION	13637	1	13051	0
YEAR+VESSEL+MONTH+SUBREGION+CREW+DEPTH_BIN+ PERMIT_TYPE+YEAR:SUBREGION	13636	0	13053	2

Table 68: Model-based abundance indices for BDR in Oregon from the four fishery-dependent CPUE data sources. Logbook indices are derived from commercial fishery data.

	MRFSS Dockside		ORBS Dockside		Onboard Observer		Logbook	
Year	Mean	logSD	Mean	logSD	Mean	logSD	Mean	logSD
1980	3.45	0.264	-	-	-	-	-	-
1981	1.32	0.280	-	-	-	-	-	-
1982	1.49	0.325	-	-	-	-	-	-
1983	5.41	0.292	-	-	-	-	-	-
1984	1.75	0.242	-	-	-	-	-	-
1985	0.17	0.273	-	-	-	-	-	-
1986	0.37	0.299	-	-	-	-	-	-
1987	0.65	0.277	-	-	-	-	-	-
1988	1.02	0.218	-	-	-	-	-	-
1989	1.09	0.235	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-
1993	2.95	0.212	-	-	-	-	-	-
1994	0.79	0.215	-	-	-	-	-	-
1995	1.76	0.216	-	-	-	-	-	-
1996	3.37	0.207	-	-	-	-	-	-
1997	3.91	0.204	-	-	-	-	-	-
1998	3.11	0.211	-	-	-	-	-	-
1999	2.12	0.209	-	-	-	-	-	-
2000	1.51	0.224	-	-	-	-	-	-
2001	-	-	0.30	0.047	1.13	0.205	-	-
2002	-	-	0.15	0.051	-	-	-	-
2003	-	-	0.23	0.043	1.80	0.193	-	-
2004	-	-	0.24	0.058	1.94	0.216	0.89	0.149
2005	-	-	0.26	0.038	1.94	0.192	0.91	0.144
2006	-	-	0.16	0.046	1.11	0.223	0.96	0.144
2007	-	-	0.14	0.048	0.87	0.189	0.90	0.145
2008	-	-	0.12	0.048	1.66	0.204	0.97	0.150
2009	-	-	0.15	0.049	0.86	0.210	1.01	0.142
2010	-	-	0.18	0.043	1.23	0.227	1.28	0.141
2011	-	-	0.18	0.050	1.40	0.290	1.25	0.131
2012	-	-	0.17	0.046	1.80	0.244	0.97	0.146
2013	-	-	0.13	0.047	0.98	0.275	0.70	0.140
2014	-	-	0.13	0.051	0.79	0.284	0.85	0.141
2015	-	-	0.11	0.046	0.53	0.247	-	-
2016	-	-	0.11	0.049	0.78	0.228	-	-

Table 69: Oregon recreational landings and discards (mt) by source.

	Landings - Ocean Fleet				Landings - Shore Fleet			Discards - Ocean Fleet		
Year	Historical Reconstruct	ORBS	Adapted MRFSS	Total Landings	Historical Reconstruct	MRFSS/ SEBS	Total Landings	Historical Reconstruct	ORBS	Total Discards
1915	-	-	-	-	0.1167	-	0.1167	-	-	-
1916	-	-	-	-	0.1116	-	0.1116	-	-	-
1917	-	-	-	-	0.1075	-	0.1075	-	-	-
1918	-	-	-	-	0.1070	-	0.1070	-	-	-
1919	-	-	-	-	0.1299	-	0.1299	-	-	-
1920	-	-	-	-	0.1410	-	0.1410	-	-	-
1921	-	-	-	-	0.0855	-	0.0855	-	-	-
1922	-	-	-	-	0.0769	-	0.0769	-	-	-
1923	-	-	-	-	0.0925	-	0.0925	-	-	-
1924	-	-	-	-	0.1056	-	0.1056	-	-	-
1925	-	-	-	-	0.1077	-	0.1077	-	-	-
1926	-	-	-	-	0.1133	-	0.1133	-	-	-
1927	-	-	-	-	0.1138	-	0.1138	-	-	-
1928	-	-	-	-	0.1153	-	0.1153	-	-	-
1929	-	-	-	-	0.1185	-	0.1185	-	-	-
1930	-	-	-	-	0.1221	-	0.1221	-	-	-
1931	-	-	-	-	0.1141	-	0.1141	-	-	-
1932	-	-	-	-	0.0893	-	0.0893	-	-	-
1933	-	-	-	-	0.0808	-	0.0808	-	-	-
1934	-	-	-	-	0.1039	-	0.1039	-	-	-
1935	-	-	-	-	0.1083	-	0.1083	-	-	-
1936	-	-	-	-	0.1213	-	0.1213	-	-	-
1937	-	-	-	-	0.1335	-	0.1335	-	-	-
1938	-	-	-	-	0.1366	-	0.1366	-	-	-
1939	-	-	-	-	0.1442	-	0.1442	-	-	-
1940	-	-	-	-	0.1513	-	0.1513	-	-	-
1941	-	-	-	-	0.1651	-	0.1651	-	-	-
1942	-	-	-	-	0.1710	-	0.1710	-	-	-
1943	-	-	-	-	0.1875	-	0.1875	-	-	-
1944	-	-	-	-	0.1828	-	0.1828	-	-	-
1945	-	-	-	-	0.1984	-	0.1984	-	-	-
1946	-	-	-	-	0.2550	-	0.2550	-	-	-
1947	-	-	-	-	0.2854	-	0.2854	-	-	-
1948	-	-	-	-	0.3167	-	0.3167	-	-	-
1949	-	-	-	-	0.3299	-	0.3299	-	-	-
1950	-	-	-	-	0.3282	-	0.3282	-	-	-
1951	-	-	-	-	0.3750	-	0.3750	-	-	-
1952	-	-	-	-	0.3981	-	0.3981	-	-	-
1953	-	-	-	-	0.4030	-	0.4030	-	-	-
1954	-	-	-	-	0.4182	-	0.4182	-	-	-
1955	-	-	-	-	0.4123	-	0.4123	-	-	-
1956	-	-	-	-	0.4224	-	0.4224	-	-	-
1957	-	-	-	-	0.4397	-	0.4397	-	-	-
1958	-	-	-	-	0.4292	-	0.4292	-	-	-
1959	-	-	-	-	0.4259	-	0.4259	-	-	-
1960	-	-	-	-	0.4408	-	0.4408	-	-	-
1961	-	-	-	-	0.4522	-	0.4522	-	-	-
1962	-	-	-	-	0.4568	-	0.4568	-	-	-
1963	-	-	-	-	0.4851	-	0.4851	-	-	-
1964	-	-	-	-	0.5071	-	0.5071	-	-	-
1965	-	-	-	-	0.5268	-	0.5268	-	-	-

Table 69 (continued): Oregon recreational landings and discards (mt) by source.

	Landings - Ocean Fleet				Landings - Shore Fleet			Discards - Ocean Fleet		
Year	Historical Reconstruct	ORBS	Adapted MRFSS	Total Landings	Historical Reconstruct	MRFSS/ SEBS	Total Landings	Historical Reconstruct	ORBS	Total Discards
1966	-	-	-	-	0.5492	-	0.5492	-	-	-
1967	-	-	-	-	0.5536	-	0.5536	-	-	-
1968	-	-	-	-	0.5129	-	0.5129	-	-	-
1969	-	-	-	-	0.5516	-	0.5516	-	-	-
1970	-	-	-	-	0.5931	-	0.5931	-	-	-
1971	1.1522	-	-	1.1522	0.6034	-	0.6034	-	-	-
1972	2.3044	-	-	2.3044	0.6578	-	0.6578	-	-	-
1973	3.4567	-	-	3.4567	0.7141	-	0.7141	-	-	-
1974	4.6089	-	-	4.6089	0.7175	-	0.7175	-	-	-
1975	5.7611	-	-	5.7611	0.7440	-	0.7440	-	-	-
1976	6.9133	-	-	6.9133	0.7177	-	0.7177	-	-	-
1977	8.0656	-	-	8.0656	0.7132	-	0.7132	-	-	-
1978	9.2178	-	-	9.2178	0.7702	-	0.7702	-	-	-
1979	-	-	10.3717	10.3717	0.7979	-	0.7979	0.0905	-	0.0905
1980	-	-	19.7402	19.7402	-	0.8135	0.8135	0.1723	-	0.1723
1981	-	-	18.5301	18.5301	-	1.8579	1.8579	0.1618	-	0.1618
1982	-	-	10.3764	10.3764	-	0.8377	0.8377	0.0906	-	0.0906
1983	-	-	22.8049	22.8049	-	0.6233	0.6233	0.1991	-	0.1991
1984	-	-	29.3135	29.3135	-	0.4651	0.4651	0.2559	-	0.2559
1985	-	-	15.9803	15.9803	-	0.0847	0.0847	0.1395	-	0.1395
1986	-	-	4.4907	4.4907	-	1.1225	1.1225	0.0392	-	0.0392
1987	-	-	6.7356	6.7356	-	1.5576	1.5576	0.0588	-	0.0588
1988	-	-	7.1582	7.1582	-	1.2976	1.2976	0.0625	-	0.0625
1989	-	-	11.7689	11.7689	-	0.4624	0.4624	0.1027	-	0.1027
1990	-	-	21.2022	21.2022	0.9390	-	0.9390	0.1851	-	0.1851
1991	-	-	14.9032	14.9032	0.9467	-	0.9467	0.1301	-	0.1301
1992	-	-	23.5955	23.5955	0.9544	-	0.9544	0.2060	-	0.2060
1993	-	-	67.3212	67.3212	-	1.8382	1.8382	0.5877	-	0.5877
1994	-	-	7.7533	7.7533	-	0.0612	0.0612	0.0677	-	0.0677
1995	-	-	21.3519	21.3519	-	3.0089	3.0089	0.1864	-	0.1864
1996	-	-	26.4976	26.4976	-	1.2509	1.2509	0.2313	-	0.2313
1997	-	-	59.7900	59.7900	-	0.6088	0.6088	0.5220	-	0.5220
1998	-	-	58.4811	58.4811	-	0.3316	0.3316	0.5105	-	0.5105
1999	-	-	37.0330	37.0330	-	2.9321	2.9321	0.3233	-	0.3233
2000	-	-	35.0391	35.0391	-	0.8201	0.8201	0.3059	-	0.3059
2001	-	33.2031	-	33.2031	-	1.1262	1.1262	0.4923	-	0.4923
2002	-	15.3444	-	15.3444	-	0.4739	0.4739	-	0.0808	0.0808
2003	-	23.2110	-	23.2110	-	0.5550	0.5550	-	0.2300	0.2300
2004	-	19.0616	-	19.0616	-	0.0463	0.0463	-	0.2251	0.2251
2005	-	31.1020	-	31.1020	-	2.1650	2.1650	-	0.7588	0.7588
2006	-	11.5153	-	11.5153	1.0622	-	1.0622	-	0.2994	0.2994
2007	-	16.1612	-	16.1612	1.0699	-	1.0699	-	0.5649	0.5649
2008	-	15.1366	-	15.1366	1.0776	-	1.0776	-	0.6751	0.6751
2009	-	15.2810	-	15.2810	1.0853	-	1.0853	-	0.9439	0.9439
2010	-	21.1712	-	21.1712	1.0930	-	1.0930	-	0.7853	0.7853
2011	-	20.4400	-	20.4400	1.1007	-	1.1007	-	0.7645	0.7645
2012	-	25.1157	-	25.1157	1.1084	-	1.1084	-	0.7085	0.7085
2013	-	23.0646	-	23.0646	1.1161	-	1.1161	-	0.7774	0.7774
2014	-	18.1077	-	18.1077	1.1238	-	1.1238	-	0.6220	0.6220
2015	-	28.0401	-	28.0401	1.1315	-	1.1315	-	1.6787	1.6787
2016	-	19.9528	-	19.9528	1.1392	-	1.1392	-	0.7111	0.7111

Table 70: MRFSS data filtering criteria and resulting sample sizes used for BDR in Oregon. Bold value indicates the final trip-level sample size used for negative binomial GLM analysis.

Filter	Criteria	Samples	# pos	% pos
Full data set	All data	1831	1108	60.5
Trip - species association	Stephens and MaCall trip filter	1387	1108	80.0
Year 2003	Remove year 2003 due to low sample size	1374	1096	80.0
Year 2002 and 2001	Remove years post bag limit change from 15 to 10	1258	1007	80.0
High catch rate	Remove outlier catch rates	1256	1005	80.0
County	Remove counties with little data	**1254**	1004	80.0

Table 71: Model selection summary across representative candidate models evaluated for the Oregon MRFSS index.

MRFSS Dockside Index (negative binomial model with effort offset)		
Model	AIC	ΔAIC
YEAR	8878.6	116.6
YEAR+WAVE	8877.1	115.1
YEAR+SUBREGION	8873.7	111.7
YEAR+NEARSHORE_AREA	8875.2	113.2
YEAR+WAVE+SUBREGION	8763.5	1.5
YEAR+WAVE+NEARSHORE_AREA	8776.5	14.5
YEAR+COUNTY+NEARSHORE_AREA	8820.1	58.1
YEAR+SUBREGION+NEARSHORE_AREA	8869.1	107.1
YEAR+SUBREGION+WAVE+YEAR:SUBREGION	8861.7	99.7
YEAR+WAVE+SUBREGION+NEARSHORE_AREA	8762.0	0

Table 72: ORBS data filtering criteria and resulting sample sizes used for BDR in Oregon. Bold value indicates the final trip-level sample size used for negative binomial GLM analysis.

Filter	Criteria	Samples	# pos	% pos
Full data set	All data	575113	32671	5.7
Trip Type	Bottomfish only	131900	28949	22.0
Port	Remove Astoria	121789	28887	23.7
Ocean/Estuary (OcnEst)	Remove estuaries	117950	28659	24.3
Trip Hours	Remove trips > 12 hours	117881	28645	24.3
Trip Hours	Remove trips < 1 hour	116374	28573	24.6
Interview Time (IntvTime)	Remove interviews that occur within one minute of each other	83768	20881	24.9
Bar to Reef Distance	Remove BartoReefDist >= 30 miles	69520	20556	30.0
Species Composition	Stephens and MaCall approach: remove non-associated fishing trips	30057	20556	68.4
Port	Remove ports with sparse data (32 and 38)	29901	20453	68.4
Effort	Remove unrealistic effort reporting (angler hours)	29880	20436	68.4
Bag Limit	Remove cases where blue/deacon catch >= bag limit for all anglers	29751	20307	68.3
Catch Rate	Remove questionable catch rates (above 99.9% quantile)	**29721**	20277	68.2

Table 73: Model selection summary across representative candidate models evaluated for the ORBS index.

ORBS Dockside Index (negative binomial model with effort offset)		
Model	AIC	ΔAIC
YEAR	132736	2323
YEAR+BOAT_TYPE	132698	2285
YEAR+SUBREGION	132562	2149
YEAR+SEASON	131067	654
YEAR+SEASON+BOAT_TYPE	131063	650
YEAR+SEASON+SUBREGION	130751	338
YEAR+SEASON+BOAT_TYPE+SUBREGION	130638	225
YEAR+SEASON+SUBREGION+YEAR:SUBREGION	130534	121
YEAR+SEASON+SUBREGION+BOAT_TYPE+YEAR:SUBREGION	130413	0

Table 74: Onboard observer data filtering criteria and resulting sample sizes used for BDR in Oregon. Bold value indicates the final trip-level sample size used for the negative binomial GLM analysis.

Filter	Criteria	Samples	# pos	% pos
Full data set	All data	13501	2392	17.7
Reefs	Remove offshore reefs	13222	2382	18.0
Distance from reefs	Remove drifts >1000 meters from reefs	12919	2373	18.4
Depths	Remove drifts at depths <3 & >34 fathoms	12877	2369	18.4
Midwater groundfish	Remove drifts with < 20% groundfish in total catch	**11701**	2359	20.2

Table 75: Model selection summary across representative candidate models evaluated for the Oregon onboard observer index.

Onboard Observer Index (negative binomial model with effort offset)		
Model	AIC	ΔAIC
YEAR	19010	734
YEAR+WAVE	18776	500
YEAR+DEPTH_BIN	18956	680
YEAR+SEASON	19011	735
YEAR+MONTH	18743	467
YEAR+SUBREGION	18697	421
YEAR+WAVE+SUBREGION	18434	158
YEAR+MONTH+SUBREGION	18387	111
YEAR+SEASON+SUBREGION	18698	422
YEAR+WAVE+DEPTH_BIN	18727	451
YEAR+MONTH+DEPTH_BIN	18699	423
YEAR+SEASON+DEPTH_BIN	18957	681
YEAR+WAVE+SUBREGION+DEPTH_BIN	18416	140
YEAR+MONTH+SUBREGION+DEPTH_BIN	18374	98
YEAR+SEASON+SUBREGION+DEPTH_BIN	18677	401
YEAR+WAVE+SUBREGION+DEPTH_BIN+YEAR:SUBREGION	18305	29
YEAR+MONTH+SUBREGION+DEPTH_BIN+YEAR:SUBREGION	18276	0
YEAR+SEASON+SUBREGION+DEPTH_BIN+YEAR:SUBREGION	18560	284

Table 76: Estimated ageing error when the Oregon ageing lab was assumed unbiased and when it was assumed biased relative to the California ageing lab.

Age	OR Ageing Lab (unbiased)		OR Ageing Lab (biased)	
	SD	CV	SD	CV
0	0.06	0.06	0.13	0.13
1	0.06	0.06	0.13	0.13
2	0.12	0.06	0.26	0.13
3	0.18	0.06	0.39	0.13
4	0.24	0.06	0.53	0.13
5	0.29	0.06	0.66	0.13
6	0.35	0.06	0.79	0.13
7	0.41	0.06	0.92	0.13
8	0.47	0.06	1.05	0.13
9	0.53	0.06	1.18	0.13
10	0.59	0.06	1.31	0.13
11	0.65	0.06	1.45	0.13
12	0.71	0.06	1.58	0.13
13	0.77	0.06	1.71	0.13
14	0.83	0.06	1.84	0.13
15	0.88	0.06	1.97	0.13
16	0.94	0.06	2.10	0.13
17	1.00	0.06	2.23	0.13
18	1.06	0.06	2.36	0.13
19	1.12	0.06	2.50	0.13
20	1.18	0.06	2.63	0.13
21	1.24	0.06	2.76	0.13
22	1.30	0.06	2.89	0.13
23	1.36	0.06	3.02	0.13
24	1.42	0.06	3.15	0.13
25	1.47	0.06	3.28	0.13
26	1.53	0.06	3.42	0.13
27	1.59	0.06	3.55	0.13
28	1.65	0.06	3.68	0.13
29	1.71	0.06	3.81	0.13
30	1.77	0.06	3.94	0.13
31	1.83	0.06	4.07	0.13
32	1.89	0.06	4.20	0.13
33	1.95	0.06	4.34	0.13
34	2.01	0.06	4.47	0.13
35	2.06	0.06	4.60	0.13

Table 77: Annual BDR mean weight across all available biological samples in Oregon.

Year	Mean Weight
2001	0.696
2002	0.661
2003	0.731
2004	0.738
2005	0.797
2006	0.738
2007	0.754
2008	0.706
2009	0.678
2010	0.696
2011	0.686
2012	0.684
2013	0.714
2014	0.726
2015	0.777
2016	0.717

Table 78: Relative weights used for fitting compositional data in the Oregon base case model.

Data Source	Likelihood Component	Weighting Method	Relative Weight
Commercial fleet - landings	Lengths	Francis	0.503
Commercial fleet - discards	Lengths	Francis	0.101
Recreational ocean Fleet - landings	Lengths	Francis	0.077
Recreational ocean Fleet - discards	Lengths	Francis	1.045
Recreational shore fleet	Lengths	Francis	0.393
Commercial fleet - landings	Conditional Age-at-Length	Harmonic Mean	0.136
Recreational ocean Fleet - landings	Conditional Age-at-Length	Harmonic Mean	0.108
Research survey	Conditional Age-at-Length	Harmonic Mean	0.250

Table 79: Description of parameters used in the Oregon base case assessment model.

Parameter	Number Estimated	Bounds (low, high)	Prior (Mean, SD) - Type	Value	SD
Biology					
Natural mortality (*M*) -*female*	0	(0.001,0.4)	(-1.84,0.438) - Lognormal	0.159	-
Natural mortality (*M*) -*male (offset)*	0	(-3,3)	-	0.159	-
Ln (R_0)	1	(5,12)	-	7.041	0.283
Steepness (*h*)	0	-	-	0.718	-
Sigma-R	0	-	-	0.500	-
Growth					
Length at age 1 - *female*	1	(10,30)	-	13.06	0.44
Length at age 30 - *female*	1	(25,45)	-	38.10	0.25
von Bertalnaffy k - f*emale*	1	(0.01,0.3)	-	0.203	0.007
CV of length at age 1 - *female*	1	(0.01-0.5)	-	0.074	0.005
CV of length at age 30 - *female*	1	(0.01-0.5)	-	0.080	0.006
Length at age 1 - *male (offset)*	0	(-3,3)	-	0.00	-
Length at age 30 - *male (offset)*	1	(-3,3)	-	-0.25	0.02
von Bertalnaffy k - *male (offset)*	1	(-3,3)	-	0.487	0.086
CV of length at age 1 - *male (offset)*	0	-	-	0.000	-
CV of length at age 30 - *male (offset)*	0	-	-	0.800	-
Indices					
Extra SD - commercial: logbook	1	(0,1)	-	0.04	0.04
Extra SD - ocean: onboard observer	1	(0,1)	-	0.07	0.05
Extra SD - ocean: ORBS dockside	1	(0,1)	-	0.15	0.04
Extra SD - ocean: MRFSS dockside	1	(0,1)	-	0.59	0.14
Selectivity					
Commercial fleet (landed)					
Length at peak	1	(20,50)	-	38.65	1.22
Ascending width	1	(1,10)	-	3.58	0.16
Length at peak (time block)	1	(20,50)	-	37.77	0.80
Commercial fleet (discarded)					
Length at peak	1	(14,45)	-	35.53	4.56
Ascending width	1	(1,10)	-	5.21	0.60
Recreation - ocean fleet (landed)					
Length at peak	1	(20,50)	-	37.05	0.96
Ascending width	1	(1,10)	-	3.81	0.13
Length at peak (time block)	1	(20,50)	-	35.32	0.77
Recreation - ocean fleet (discarded)					
Length at peak	1	(14,40)	-	29.60	0.86
Ascending width	1	(1,10)	-	4.06	1.58
Decending width	1	(1,10)	-	3.26	0.20
Length at peak (time block)	1	(14,40)	-	26.17	0.53
Recreation - shore fleet					
Length at peak	1	(10,40)	-	22.03	2.37
Ascending width	1	(1,10)	-	3.75	0.91

Table 80: Von Bertalanffy parameter estimates, standard error, and sample sizes for female and male BDR in Oregon.

Parameter	Female Estimate	Female Standard Error	Male Estimate	Male Standard Error
Length at minimum age (1)	13.06	0.44	0.00	-
Length at maximum age (30)	38.10	0.25	-0.26	0.02
k (min length to max length)	0.203	0.007	0.487	0.086
CV young	0.074	0.005	0.000	-
CV old	0.080	0.006	0.800	-

Table 81: Summary of reference points and management quantities for the Oregon BDR base case model.

Quantity	**Estimate**	**~95% Confidence Interval**
Unfished Spawning Output (millions of eggs)	431	187–675
Unfished Age 0+ Biomass (mt)	2,199	963–3,435
Spawning Output (2017, millions of eggs)	296	64–527
Unfished recruitment (R0, thousands of recruits)	1142	508–1,777
Depletion (2017, % of unfished spawning output)	68.56	52.25–84.87
Reference points based on SB $_{40\%}$		
Proxy spawning output ($B_{40\%}$, millions of eggs)	172	75–270
SPR resulting in $B_{40\%}$	0.459	0.459–0.459
Exploitation rate resulting in $B_{40\%}$	0.063	0.060–0.066
Yield at $B_{40\%}$ (mt)	83	36–130
Reference points based on SPR proxy for MSY		
Proxy spawning output ($SPR_{50\%}$, millions of eggs)	192	84–301
$SPR_{50\%}$	0.50	NA
Exploitation rate corresponding to $SPR_{50\%}$	0.056	0.053–0.058
Yield with $SPR_{50\%}$ at $SB_{SPR50\%}$ (mt)	78	34–123
Reference points based on estimated MSY values		
Spawning output at MSY (SB_{MSY}, millions of eggs)	97	41–152
SPR_{MSY}	0.3	0.296–0.305
Exploitation rate corresponding to SPR_{MSY}	0.1	0.097–0.104
MSY (mt)	95	41–148

Table 82: Time-series of population estimates for BDR in Oregon from the base case model.

Year	Total Biomass (mt)	Spawning Biomass (eggs x10^6)	Depletion	Age-0 Recruits (000s)	Total Catch (mt)	Relative Exploitation Rate	SPR
1892	2,199	431	-	1,142	0.3	0.00	1.00
1893	2,199	431	1.00	1,142	0.3	0.00	1.00
1894	2,199	431	1.00	1,142	0.3	0.00	1.00
1895	2,199	431	1.00	1,142	0.1	0.00	1.00
1896	2,199	431	1.00	1,142	0.0	0.00	1.00
1897	2,199	431	1.00	1,142	0.0	0.00	1.00
1898	2,199	431	1.00	1,142	0.0	0.00	1.00
1899	2,199	431	1.00	1,142	0.0	0.00	1.00
1900	2,199	431	1.00	1,142	0.0	0.00	1.00
1901	2,199	431	1.00	1,142	0.0	0.00	1.00
1902	2,199	431	1.00	1,142	0.0	0.00	1.00
1903	2,199	431	1.00	1,142	0.0	0.00	1.00
1904	2,199	431	1.00	1,142	0.1	0.00	1.00
1905	2,199	431	1.00	1,142	0.1	0.00	1.00
1906	2,199	431	1.00	1,142	0.1	0.00	1.00
1907	2,199	431	1.00	1,142	0.1	0.00	1.00
1908	2,199	431	1.00	1,142	0.1	0.00	1.00
1909	2,199	431	1.00	1,142	0.1	0.00	1.00
1910	2,199	431	1.00	1,142	0.1	0.00	1.00
1911	2,199	431	1.00	1,142	0.1	0.00	1.00
1912	2,199	431	1.00	1,142	0.1	0.00	1.00
1913	2,199	431	1.00	1,142	0.1	0.00	1.00
1914	2,199	431	1.00	1,142	0.1	0.00	1.00
1915	2,199	431	1.00	1,142	0.2	0.00	1.00
1916	2,198	431	1.00	1,142	0.2	0.00	1.00
1917	2,198	431	1.00	1,142	0.3	0.00	1.00
1918	2,198	431	1.00	1,142	0.3	0.00	1.00
1919	2,198	431	1.00	1,142	0.3	0.00	1.00
1920	2,198	431	1.00	1,142	0.3	0.00	1.00
1921	2,198	431	1.00	1,142	0.3	0.00	1.00
1922	2,198	431	1.00	1,142	0.3	0.00	1.00
1923	2,198	431	1.00	1,142	0.3	0.00	1.00
1924	2,197	431	1.00	1,142	0.3	0.00	1.00
1925	2,197	430	1.00	1,142	0.3	0.00	1.00
1926	2,197	430	1.00	1,142	0.3	0.00	1.00
1927	2,197	430	1.00	1,142	0.3	0.00	1.00
1928	2,197	430	1.00	1,142	0.5	0.01	1.00
1929	2,197	430	1.00	1,142	0.8	0.01	1.00
1930	2,196	430	1.00	1,142	0.8	0.01	1.00
1931	2,196	430	1.00	1,142	0.6	0.01	1.00
1932	2,196	430	1.00	1,142	0.2	0.00	1.00
1933	2,196	430	1.00	1,142	0.3	0.00	1.00
1934	2,196	430	1.00	1,142	0.4	0.00	1.00
1935	2,196	430	1.00	1,142	0.3	0.00	1.00
1936	2,196	430	1.00	1,142	0.7	0.01	1.00
1937	2,196	430	1.00	1,142	1.0	0.01	0.99
1938	2,195	430	1.00	1,142	1.0	0.01	0.99
1939	2,195	430	1.00	1,142	0.8	0.01	0.99
1940	2,194	429	1.00	1,142	1.3	0.02	0.99
1941	2,194	429	1.00	1,142	1.5	0.02	0.99
1942	2,193	429	1.00	1,142	1.9	0.02	0.99

Table 82 (continued): Time-series of population estimates for BDR in Oregon **from the base case model.**

Year	Total Biomass (mt)	Spawning Biomass (eggs x10^6)	Depletion	Age-0 Recruits	Total Catch (mt)	Relative Exploitation Rate	SPR
1943	2,192	429	0.99	1,142	4.3	0.05	0.97
1944	2,189	428	0.99	1,141	2.1	0.03	0.99
1945	2,188	427	0.99	1,141	1.4	0.02	0.99
1946	2,188	427	0.99	1,141	1.8	0.02	0.99
1947	2,188	427	0.99	1,141	1.6	0.02	0.99
1948	2,187	427	0.99	1,141	4.5	0.05	0.97
1949	2,185	426	0.99	1,141	4.3	0.05	0.97
1950	2,182	425	0.99	1,141	2.1	0.03	0.99
1951	2,182	425	0.99	1,141	3.1	0.04	0.98
1952	2,181	425	0.99	1,141	3.5	0.04	0.98
1953	2,180	424	0.98	1,141	1.9	0.02	0.99
1954	2,180	425	0.99	1,141	12.4	0.14	0.93
1955	2,171	422	0.98	1,140	11.8	0.14	0.93
1956	2,164	419	0.97	1,139	28.1	0.30	0.85
1957	2,143	412	0.96	1,137	14.1	0.16	0.92
1958	2,137	409	0.95	1,136	3.0	0.04	0.98
1959	2,141	410	0.95	1,137	3.5	0.04	0.98
1960	2,144	411	0.95	1,137	9.0	0.11	0.95
1961	2,142	411	0.95	1,137	7.2	0.09	0.96
1962	2,142	411	0.95	1,137	7.1	0.09	0.96
1963	2,142	411	0.95	1,137	3.5	0.04	0.98
1964	2,144	412	0.96	1,137	10.4	0.12	0.94
1965	2,141	411	0.95	1,137	5.4	0.07	0.97
1966	2,142	411	0.95	1,137	4.6	0.06	0.97
1967	2,144	412	0.96	1,137	6.2	0.08	0.96
1968	2,144	412	0.96	1,137	4.7	0.06	0.97
1969	2,146	413	0.96	1,137	6.0	0.07	0.96
1970	2,146	413	0.96	1,064	3.9	0.05	0.98
1971	2,148	414	0.96	1,041	6.1	0.07	0.96
1972	2,143	414	0.96	1,019	6.9	0.08	0.96
1973	2,133	413	0.96	997	8.4	0.10	0.95
1974	2,118	413	0.96	971	10.2	0.12	0.94
1975	2,098	411	0.95	942	9.0	0.11	0.95
1976	2,075	410	0.95	920	10.7	0.13	0.94
1977	2,046	407	0.94	914	17.4	0.20	0.90
1978	2,010	401	0.93	1,097	15.2	0.18	0.91
1979	1,976	395	0.92	1,440	22.4	0.26	0.87
1980	1,948	387	0.90	1,133	28.0	0.32	0.84
1981	1,940	377	0.87	1,315	26.9	0.32	0.84
1982	1,940	367	0.85	1,080	23.7	0.29	0.86
1983	1,956	359	0.83	1,025	48.0	0.52	0.74
1984	1,947	347	0.81	1,196	46.6	0.52	0.74
1985	1,936	340	0.79	1,183	32.2	0.39	0.80
1986	1,942	340	0.79	1,133	18.3	0.24	0.88
1987	1,960	346	0.80	1,258	24.4	0.30	0.85
1988	1,972	349	0.81	1,450	17.6	0.23	0.89
1989	1,995	353	0.82	1,091	27.5	0.33	0.83
1990	2,020	354	0.82	925	48.5	0.52	0.74
1991	2,016	350	0.81	964	41.9	0.47	0.77
1992	2,005	348	0.81	1,294	87.81	0.80	0.60

Table 82 (continued): Time-series of population estimates for BDR in Oregon **from the base case model.**

Year	Total Biomass (mt)	Spawning Biomass (eggs x10^6)	Depletion	Age-0 Recruits	Total Catch (mt)	Relative Exploitation Rate	SPR
1993	1,945	334	0.78	2,001	107.7	0.92	0.54
1994	1,887	319	0.74	1,925	35.6	0.44	0.78
1995	1,942	322	0.75	2,011	42.7	0.50	0.75
1996	2,022	322	0.75	1,313	38.2	0.46	0.77
1997	2,128	321	0.75	1,280	65.2	0.68	0.66
1998	2,189	318	0.74	618	75.9	0.75	0.63
1999	2,217	319	0.74	685	44.2	0.49	0.76
2000	2,219	338	0.78	674	43.5	0.47	0.77
2001	2,181	358	0.83	546	41.3	0.43	0.78
2002	2,113	376	0.87	724	20.8	0.24	0.88
2003	2,039	391	0.91	1,261	31.1	0.33	0.83
2004	1,952	392	0.91	1,296	26.7	0.29	0.85
2005	1,898	386	0.90	1,039	40.5	0.43	0.78
2006	1,856	370	0.86	369	18.7	0.23	0.88
2007	1,841	358	0.83	959	23.1	0.29	0.86
2008	1,799	344	0.80	1,290	20.3	0.26	0.87
2009	1,770	337	0.78	591	20.9	0.27	0.86
2010	1,758	334	0.78	1,211	28.1	0.36	0.82
2011	1,726	330	0.77	654	30.5	0.39	0.81
2012	1,711	322	0.75	738	35.5	0.45	0.78
2013	1,677	312	0.72	2,233	31.4	0.41	0.79
2014	1,654	307	0.71	1,054	24.8	0.34	0.83
2015	1,702	304	0.71	960	32.7	0.44	0.78
2016	1,737	299	0.69	1,095	24.4	0.35	0.83
2017	1,773	296	0.69	1,093	-	-	-

Table 83: Exploration of fixing the apical parameter for male maximum selectivity relative to female maximum selectivity for the Oregon BDR model presented to the STAR panel.

Quantity / Estimate	**Base (Apical=1.0)**	Apical = 0.9	Apical = 0.8	Apical = 0.7	Apical = 0.6	Apical = 0.5	Apical = 0.4	Apical = 0.3	Apical = 0.2	Apical = 0.1
Negative Log-Likelihood	573.956	573.229	572.511	571.749	570.845	569.585	568.215	567.033	566.626	568.707
Female M	0.142	0.140	0.131	0.125	0.111	0.109	0.109	0.117	0.133	0.164
Female L(1)	14.49	14.42	14.32	14.22	14.03	13.91	13.80	13.72	13.61	13.45
Female L(30)	37.71	37.80	37.98	38.10	38.24	38.28	38.30	38.31	38.33	38.37
Female k	0.193	0.192	0.191	0.190	0.191	0.192	0.193	0.193	0.193	0.192
Female CV{L(2)}	0.078	0.079	0.081	0.083	0.086	0.087	0.087	0.087	0.088	0.090
Female CV{L(30)}	0.098	0.096	0.091	0.087	0.081	0.079	0.077	0.076	0.075	0.073
Male M	0.199	0.197	0.191	0.186	0.178	0.172	0.164	0.157	0.145	0.124
Male L(1)	12.21	12.19	12.18	12.17	12.17	12.16	12.15	12.17	12.25	12.65
Male L(30)	31.00	31.17	31.49	31.80	32.39	32.74	33.05	33.24	33.46	33.77
Male k	0.301	0.296	0.287	0.278	0.262	0.255	0.250	0.247	0.244	0.237
Male CV{L(2)}	0.078	0.079	0.081	0.083	0.086	0.087	0.087	0.087	0.088	0.090
Male CV{L(30)}	0.098	0.096	0.091	0.087	0.081	0.079	0.077	0.076	0.075	0.073

Table 84: Sensitivity of the BDR Oregon base case model to alternative data source configurations and model structural assumptions.

		Index removal				Length composition removal					Age composition removal		
	Base case	Logbook	Onboard	ORBS	MRFSS	Com-L	Com-D	RecO-L	RecO-D	Shore	Com	RecO	Survey
		1	2	3	4	5	6	7	8	9	10	11	12
Total Likelihood	603.64	616.71	614.25	621.04	597.59	530.12	588.65	552.84	544.59	557.21	460.45	404.50	523.37
Number of Parameters	72	72	72	72	72	72	72	72	72	72	72	72	72
Survey Likelihood Components													
Logbook CPUE	-13.18	-	-13.26	-13.45	-13.19	-13.94	-13.12	-13.56	-12.98	-13.09	-13.15	-13.70	-13.18
Onboard CPUE	-10.73	-10.81	-	-10.36	-10.75	-10.81	-10.74	-11.45	-10.82	-10.77	-10.70	-10.71	-10.73
ORBS CPUE	-17.70	-17.94	-17.39	-	-17.69	-18.05	-17.72	-17.89	-17.68	-17.83	-17.69	-17.28	-17.70
MRFSS CPUE	5.91	5.90	5.89	5.92	-	5.75	5.92	6.12	5.98	5.46	6.15	6.14	5.91
Length Likelihood Components													
Commercial - Landing	67.58	67.67	67.55	67.29	67.42	-	67.17	65.60	65.60	67.76	65.63	65.09	67.58
Commercial - Discard	14.81	14.87	14.81	14.79	14.82	14.56	-	15.08	16.16	14.97	15.42	14.67	14.81
Recreational Ocean _ Landing	45.87	45.77	45.68	45.91	45.92	47.35	45.85	-	46.98	45.92	44.92	43.87	45.87
Recreational Ocean - Discard	55.41	55.61	55.35	55.37	55.47	52.67	55.86	56.27	-	55.04	54.97	53.13	55.41
Recreational Shore	45.38	45.47	45.34	45.24	44.98	45.73	45.53	45.90	44.92	-	45.42	44.84	45.38
Age Likelihood Components													
Commercial - Landing	140.29	140.27	140.39	140.48	140.46	138.56	140.47	139.49	139.05	140.33	-	141.67	140.29
Recreational - Landing	191.45	191.05	191.49	191.69	191.68	188.82	191.15	189.97	190.01	190.66	192.05	-	191.45
Research	80.27	80.27	80.27	80.27	80.27	80.27	80.27	80.27	80.27	80.27	80.27	80.27	-
Parameters													
NatM_p_1_Fem_GP_1	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159
L_at_Amin_Fem_GP_1	13.055	13.042	13.057	13.069	13.051	12.746	12.914	13.022	13.783	12.853	12.145	13.269	13.055
L_at_Amax_Fem_GP_1	38.102	38.103	38.107	38.101	38.101	38.600	38.068	37.626	38.172	38.062	38.036	37.492	38.102
VonBert_K_Fem_GP_1	0.203	0.203	0.203	0.202	0.202	0.196	0.204	0.208	0.194	0.205	0.210	0.215	0.203
CV_young_Fem_GP_1	0.074	0.074	0.074	0.074	0.074	0.082	0.073	0.076	0.072	0.073	0.073	0.064	0.074
CV_old_Fem_GP_1	0.080	0.080	0.080	0.080	0.080	0.062	0.081	0.073	0.082	0.080	0.086	0.098	0.080
NatM_p_1_Mal_GP_1	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159
L_at_Amin_Mal_GP_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
L_at_Amax_Mal_GP_1	-0.255	-0.255	-0.254	-0.254	-0.256	-0.274	-0.256	-0.227	-0.249	-0.253	-0.262	-0.272	-0.255
VonBert_K_Mal_GP_1	0.487	0.488	0.483	0.484	0.490	0.600	0.488	0.383	0.423	0.486	0.474	0.802	0.487
CV_young_Mal_GP_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CV_old_Mal_GP_1	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
SR_LN(R0)	7.041	6.993	7.109	7.160	7.003	7.006	7.035	6.864	6.997	7.035	6.791	7.144	7.041
SR_BH_steep	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718
SizeSel_P1_COM_L(1)	38.649	38.601	38.615	38.658	38.695	37.103	38.699	40.256	38.945	38.669	38.787	39.196	38.649
SizeSel_P3_COM_L(1)	3.583	3.569	3.580	3.584	3.583	2.560	3.581	3.743	3.577	3.590	3.593	3.643	3.583
SzSel_Male_Peak_COM_L(1)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P4_COM_L(1)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P6_COM_L(1)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P1_COM_D(2)	35.527	35.470	35.491	35.686	35.683	34.996	28.685	38.485	36.082	35.630	36.318	39.837	35.527
SizeSel_P3_COM_D(2)	5.211	5.202	5.210	5.221	5.217	5.220	1.616	5.466	5.156	5.212	5.268	5.780	5.211
SizeSel_P4_COM_D(2)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P6_COM_D(2)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P1_REC_O_L(3)	37.049	37.032	36.826	36.988	37.124	36.352	37.118	32.691	37.462	37.014	37.225	38.114	37.049
SizeSel_P3_REC_O_L(3)	3.806	3.802	3.797	3.813	3.811	3.728	3.805	1.011	3.797	3.807	3.825	3.964	3.806
SizeSel_P4_REC_O_L(3)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P6_REC_O_L(3)	-	-	-	-	-	-	-	-	-	-	-	-	-
SzSel_Male_Peak_REC_O_L(3)	-	-	-	-	-	-	-	-	-	-	-	-	-
SzSel_Male_Descend_REC_O_L(3)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P1_REC_O_D(4)	29.599	29.631	29.555	29.542	29.638	29.530	29.599	29.505	29.762	29.562	29.673	29.620	29.599
SizeSel_P3_REC_O_D(4)	4.061	4.059	4.061	4.062	4.061	4.068	4.076	4.039	1.169	4.062	4.085	4.202	4.061
SizeSel_P4_REC_O_D(4)	3.255	3.254	3.253	3.253	3.256	3.307	3.250	3.276	1.313	3025883.000	3.249	3.359	3.255
SizeSel_P6_REC_O_D(4)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P1_REC_S(5)	22.032	22.024	22.006	22.026	22.078	21.866	21.995	22.050	22.480	12.260	22.267	21.480	22.032
SizeSel_P3_REC_S(5)	3.748	3.749	3.738	3.740	3.760	3.708	3.745	3.738	3.834	5.501	3.858	3.723	3.748
SizeSel_P4_REC_S(5)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P6_REC_S(5)	-	-	-	-	-	-	-	-	-	-	-	-	-
SizeSel_P1_COM_L(1)_BLK3	37.772	37.694	37.749	37.798	37.805	20.150	37.774	39.054	37.861	37.783	37.920	38.375	37.772
SizeSel_P1_REC_O_L(3)_BLK3	35.320	35.295	35.278	35.395	35.378	34.859	35.327	30.210	35.416	35.286	35.555	36.468	35.320
SizeSel_P1_REC_O_D(4)_BLK3	26.168	26.162	26.179	26.208	26.184	25.973	26.209	26.152	27.386	26.117	26.299	25.926	26.168
Q_extraSD_Logbook(6)	0.042	-	0.041	0.038	0.042	0.030	0.049	0.036	0.045	0.043	0.042	0.034	0.042
Q_extraSD_Onboard(7)	0.073	0.072	-	0.080	0.073	0.072	0.073	0.060	0.071	0.073	0.074	0.074	0.073
Q_extraSD_Dock_ORBS(8)	0.154	0.151	0.158	-	0.154	0.149	0.153	0.151	0.154	0.152	0.154	0.159	0.154
Q_extraSD_Dock_MRFSS(9)	0.590	0.590	0.589	0.591	-	0.583	0.591	0.601	0.594	0.570	0.602	0.601	0.590
Derived Quantities													
SB$_0$	431.027	411.289	461.671	484.962	414.414	425.483	428.131	345.553	408.200	429.010	337.068	468.478	431.027
SB$_{2107}$	295.514	274.403	326.636	353.438	280.786	283.807	294.285	221.990	279.935	293.801	208.037	334.396	295.514
SB$_{2017}$/SB$_0$	0.686	0.667	0.708	0.729	0.678	0.667	0.687	0.642	0.686	0.685	0.617	0.714	0.686
Yield at SPR$_{50\%}$	78.128	74.496	83.690	87.999	75.088	74.751	77.615	65.024	73.901	76.995	60.274	89.061	78.128

Table 84 (continued): Sensitivity of the BDR Oregon base case model to alternative data source configurations and model structural assumptions.

		Tuning		Natural Mortality			Ageing Error	Productivity
	Base case	All harmonic mean	All Francis	Est. F, fix M offset (avg.)	Est. F, fix M offset (high)	Estimate M and F	OR ageing biased	Estimate Steepness
		13	14	15	16	17	23	27
Total Likelihood	603.64	885.42	883.05	599.94	599.56	599.42	618.62	603.51
Number of Parameters	72	72	72	73	73	74	72	73
Survey Likelihood Components								
Logbook CPUE	-13.18	-13.58	-12.85	-13.23	-13.66	-13.56	-13.20	-13.19
Onboard CPUE	-10.73	-10.49	-10.87	-10.63	-10.72	-10.66	-10.76	-10.73
ORBS CPUE	-17.70	-17.26	-17.93	-18.02	-18.14	-18.05	-17.70	-17.68
MRFSS CPUE	5.91	6.37	5.61	5.97	6.57	6.35	6.12	5.87
Length Likelihood Components								
Commercial - Landing	67.58	137.29	68.51	64.10	62.50	62.92	67.09	67.60
Commercial - Discard	14.81	78.31	15.15	15.22	15.52	15.43	15.76	14.81
Recreational Ocean _ Landing	45.87	81.70	47.34	46.01	45.17	45.45	43.64	45.85
Recreational Ocean - Discard	55.41	111.64	46.64	56.79	56.89	56.89	56.11	55.42
Recreational Shore	45.38	100.01	45.25	45.58	45.69	45.65	45.96	45.42
Age Likelihood Components								
Commercial - Landing	140.29	141.54	314.74	139.11	139.17	139.08	147.29	140.25
Recreational - Landing	191.45	188.64	337.35	189.94	190.62	190.31	201.30	191.43
Research	80.27	80.27	43.34	80.27	80.27	80.27	80.27	80.27
Parameters								
NatM_p_1_Fem_GP_1	0.159	0.159	0.159	0.159	0.159	0.121	0.159	0.159
L_at_Amin_Fem_GP_1	13.055	13.183	13.140	12.876	12.869	12.863	11.977	13.053
L_at_Amax_Fem_GP_1	38.102	37.909	38.370	38.211	38.203	38.209	38.277	38.103
VonBert_K_Fem_GP_1	0.203	0.206	0.196	0.204	0.205	0.205	0.204	0.203
CV_young_Fem_GP_1	0.074	0.072	0.079	0.076	0.076	0.076	0.060	0.074
CV_old_Fem_GP_1	0.080	0.088	0.068	0.075	0.075	0.075	0.086	0.080
NatM_p_1_Mal_GP_1	0.159	0.159	0.159	0.342	0.524	0.461	0.159	0.159
L_at_Amin_Mal_GP_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
L_at_Amax_Mal_GP_1	-0.255	-0.264	-0.238	-0.215	-0.204	-0.206	-0.257	-0.255
VonBert_K_Mal_GP_1	0.487	0.554	0.424	0.318	0.280	0.288	0.516	0.486
CV_young_Mal_GP_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CV_old_Mal_GP_1	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
SR_LN(R0)	7.041	6.997	7.073	6.641	5.835	6.053	7.007	7.039
SR_BH_steep	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.824
SizeSel_P1_COM_L(1)	38.649	38.729	38.566	37.988	37.875	37.886	38.715	38.642
SizeSel_P3_COM_L(1)	3.583	3.605	3.561	3.593	3.612	3.605	3.596	3.582
SzSel_Male_Peak_COM_L(1)	-	-	-	-	-	-	-	-
SizeSel_P4_COM_L(1)	-	-	-	-	-	-	-	-
SizeSel_P6_COM_L(1)	-	-	-	-	-	-	-	-
SizeSel_P1_COM_D(2)	35.527	36.287	34.511	32.158	31.527	31.667	35.730	35.496
SizeSel_P3_COM_D(2)	5.211	5.302	5.073	4.877	4.882	4.874	5.282	5.208
SizeSel_P4_COM_D(2)	-	-	-	-	-	-	-	-
SizeSel_P6_COM_D(2)	-	-	-	-	-	-	-	-
SizeSel_P1_REC_O_L(3)	37.049	37.082	36.987	35.203	34.606	34.760	37.098	37.040
SizeSel_P3_REC_O_L(3)	3.806	3.851	3.776	3.588	3.512	3.531	3.821	3.805
SizeSel_P4_REC_O_L(3)	-	-	-	-	-	-	-	-
SizeSel_P6_REC_O_L(3)	-	-	-	-	-	-	-	-
SzSel_Male_Peak_REC_O_L(3)	-	-	-	-	-	-	-	-
SzSel_Male_Descend_REC_O_L(	-	-	-	-	-	-	-	-
SizeSel_P1_REC_O_D(4)	29.599	29.704	29.580	29.203	29.045	29.086	29.495	29.598
SizeSel_P3_REC_O_D(4)	4.061	4.065	4.016	3.958	3.957	3.955	4.092	4.060
SizeSel_P4_REC_O_D(4)	3.255	3.281	3.233	3.166	3.156	3.157	3.274	3.255
SizeSel_P6_REC_O_D(4)	-	-		-	-	-	-	-
SizeSel_P1_REC_S(5)	22.032	22.392	21.841	21.646	20.791	21.076	21.992	22.042
SizeSel_P3_REC_S(5)	3.748	3.838	3.655	3.573	3.386	3.450	3.795	3.749
SizeSel_P4_REC_S(5)	-	-	-	-	-	-	-	-
SizeSel_P6_REC_S(5)	-	-	-	-	-	-	-	-
SizeSel_P1_COM_L(1)_BLK3	37.772	37.994	37.564	37.222	37.108	37.126	37.856	37.767
SizeSel_P1_REC_O_L(3)_BLK3	35.320	35.710	35.012	33.611	33.029	33.176	35.405	35.311
SizeSel_P1_REC_O_D(4)_BLK3	26.168	26.134	26.113	26.025	25.877	25.920	26.091	26.166
Q_extraSD_Logbook(6)	0.042	0.036	0.047	0.041	0.034	0.036	0.042	0.042
Q_extraSD_Onboard(7)	0.073	0.078	0.070	0.075	0.074	0.075	0.073	0.073
Q_extraSD_Dock_ORBS(8)	0.154	0.159	0.151	0.150	0.148	0.149	0.154	0.154
Q_extraSD_Dock_MRFSS(9)	0.590	0.612	0.576	0.593	0.623	0.612	0.600	0.588
Derived Quantities								
SB_0	431.027	409.786	446.524	363.789	281.278	291.649	413.233	430.427
SB_{2107}	295.514	281.535	313.070	216.424	103.434	127.500	280.111	299.578
SB_{2017}/SB_0	0.686	0.687	0.701	0.595	0.368	0.437	0.678	0.696
Yield at $SPR_{50\%}$	78.128	74.964	81.244	55.516	30.622	35.556	73.138	82.609

Table 84 (continued): Sensitivity of the BDR Oregon base case model to alternative data source configurations and model structural assumptions.

		Selectivity			Recruitment Deviations		Catch Series		
	Base case	Com All Dome	Rec All Dome	Est. Male offset	None estimated	Estimate post-2010	Historical double	Historical halved	Recent shore double
		18	19	20	21	22	24	25	26
Total Likelihood	603.64	602.59	615.73	589.61	686.02	679.69	603.74	603.62	603.57
Number of Parameters	72	76	75	76	39	32	72	72	72
Survey Likelihood Components									
Logbook CPUE	-13.18	-13.00	-13.24	-13.34	-14.43	-14.43	-13.21	-13.16	-13.16
Onboard CPUE	-10.73	-10.70	-5.74	-10.01	-8.48	-8.44	-10.70	-10.75	-10.75
ORBS CPUE	-17.70	-17.72	-17.40	-17.51	-12.78	-12.75	-17.64	-17.73	-17.73
MRFSS CPUE	5.91	5.89	5.87	5.87	6.09	6.09	5.86	5.94	5.91
Length Likelihood Components									
Commercial - Landing	67.58	66.46	68.09	61.56	68.46	68.33	83.34	67.57	67.54
Commercial - Discard	14.81	14.88	14.81	14.30	15.43	14.32	14.27	14.81	14.81
Recreational Ocean _ Landing	45.87	45.18	46.48	39.55	63.42	63.01	52.46	45.77	45.88
Recreational Ocean - Discard	55.41	55.53	55.31	54.38	62.88	58.70	59.56	55.41	55.43
Recreational Shore	45.38	45.24	45.23	45.78	44.85	44.82	45.59	45.36	45.38
Age Likelihood Components									
Commercial - Landing	140.29	140.61	140.62	139.67	158.06	158.11	140.22	140.33	140.30
Recreational - Landing	191.45	191.62	191.53	190.40	222.25	222.55	191.39	191.50	191.42
Research	80.27	80.27	80.27	80.27	80.27	80.27	80.27	80.27	80.27
Parameters									
NatM_p_1_Fem_GP_1	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159
L_at_Amin_Fem_GP_1	13.055	13.065	13.061	12.809	13.067	13.152	13.049	13.058	13.054
L_at_Amax_Fem_GP_1	38.102	38.198	38.196	38.220	38.030	38.026	38.105	38.101	38.103
VonBert_K_Fem_GP_1	0.203	0.201	0.201	0.202	0.202	0.201	0.203	0.203	0.203
CV_young_Fem_GP_1	0.074	0.074	0.074	0.078	0.075	0.074	0.074	0.074	0.074
CV_old_Fem_GP_1	0.080	0.082	0.081	0.073	0.079	0.079	0.080	0.080	0.080
NatM_p_1_Mal_GP_1	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159
L_at_Amin_Mal_GP_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
L_at_Amax_Mal_GP_1	-0.255	-0.259	-0.258	-0.225	-0.248	-0.249	-0.254	-0.255	-0.255
VonBert_K_Mal_GP_1	0.487	0.498	0.496	0.412	0.455	0.466	0.485	0.488	0.487
CV_young_Mal_GP_1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CV_old_Mal_GP_1	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
SR_LN(R0)	7.041	7.076	7.130	7.058	7.728	7.727	7.075	7.024	7.039
SR_BH_steep	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718	0.718
SizeSel_P1_COM_L(1)	38.649	38.711	38.435	38.852	38.652	38.690	38.628	38.659	38.653
SizeSel_P3_COM_L(1)	3.583	3.571	3.558	3.837	3.581	3.583	3.582	3.583	3.582
SzSel_Male_Peak_COM_L(1)	-	-	-	2.347	-	-	-	-	-
SizeSel_P4_COM_L(1)	-	3.592	-	-	-	-	-	-	-
SizeSel_P6_COM_L(1)	-	-9.980	-	-	-	-	-	-	-
SizeSel_P1_COM_D(2)	35.527	35.554	35.343	34.075	37.742	37.756	35.450	35.561	35.545
SizeSel_P3_COM_D(2)	5.211	5.208	5.191	5.161	5.456	5.450	5.204	5.214	5.211
SizeSel_P4_COM_D(2)	-	8.984	-	-	-	-	-	-	-
SizeSel_P6_COM_D(2)	-	-9.998	-	-	-	-	-	-	-
SizeSel_P1_REC_O_L(3)	37.049	36.810	36.860	31.297	37.326	37.377	37.029	37.055	37.050
SizeSel_P3_REC_O_L(3)	3.806	3.771	3.803	2.892	3.843	3.855	3.804	3.806	3.806
SizeSel_P4_REC_O_L(3)	-	-	9.897	-	-	-	-	-	-
SizeSel_P6_REC_O_L(3)	-	-	-9.947	-	-	-	-	-	-
SzSel_Male_Peak_REC_O_L(3)	-	-	-	8.116	-	-	-	-	-
SzSel_Male_Descend_REC_O_L(3	-	-	-	-16.662	-	-	-	-	-
SizeSel_P1_REC_O_D(4)	29.599	29.626	29.575	29.189	29.156	29.248	29.590	29.602	29.605
SizeSel_P3_REC_O_D(4)	4.061	4.063	4.063	3.989	4.134	4.109	4.059	4.061	4.060
SizeSel_P4_REC_O_D(4)	3.255	3.248	3.247	3.290	3.269	3.283	3.254	3.256	3.255
SizeSel_P6_REC_O_D(4)	-	-	-9.012	-	-	-	-	-	-
SizeSel_P1_REC_S(5)	22.032	22.054	22.023	21.735	21.889	21.892	22.081	21.993	22.036
SizeSel_P3_REC_S(5)	3.748	3.753	3.742	3.649	3.794	3.800	3.759	3.739	3.748
SizeSel_P4_REC_S(5)	-	-	-	-	-	-	-	-	-
SizeSel_P6_REC_S(5)	-	-	-	-	-	-	-	-	-
SizeSel_P1_COM_L(1)_BLK3	37.772	37.718	37.599	37.916	37.868	37.898	37.756	37.779	37.775
SizeSel_P1_REC_O_L(3)_BLK3	35.320	35.107	35.332	29.956	35.611	35.693	35.300	35.326	35.326
SizeSel_P1_REC_O_D(4)_BLK3	26.168	26.199	26.204	25.743	26.468	26.395	26.166	26.169	26.173
Q_extraSD_Logbook(6)	0.042	0.045	0.041	0.039	0.023	0.022	0.041	0.042	0.042
Q_extraSD_Onboard(7)	0.073	0.074	0.375	0.088	0.121	0.122	0.074	0.073	0.073
Q_extraSD_Dock_ORBS(8)	0.154	0.153	0.157	0.156	0.226	0.226	0.154	0.153	0.153
Q_extraSD_Dock_MRFSS(9)	0.590	0.589	0.589	0.588	0.599	0.599	0.588	0.592	0.590
Derived Quantities									
SB_0	431.027	449.474	474.003	441.573	844.930	843.353	446.180	423.675	430.026
SB_{2107}	295.514	311.279	337.255	282.733	756.209	752.910	308.697	289.297	292.888
SB_{2017}/SB_0	0.686	0.693	0.712	0.640	0.895	0.893	0.692	0.683	0.681
Yield at $SPR_{50\%}$	78.128	80.775	85.270	64.694	154.663	154.383	80.885	76.792	77.692

Table 85: Projection of BDR OFL, catch, biomass, and depletion using the Oregon BDR base case model projected with total projected catch equal to 28.6 mt for 2017 and 2018. The predicted OFL is the calculated total catch determined by FSPR=50% (ABC=ACL). Total catch in 2017 and 2018 were set to the average over the most recent two years (2015 – 2016).

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 0+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	109.1	28.6	1773	295.51	0.686
2018	110.1	28.6	1801	294.04	0.682
2019	112.3	103.0	1824	300.59	0.697
2020	108.8	99.8	1776	289.61	0.672
2021	105.7	96.9	1734	278.67	0.647
2022	102.6	94.1	1696	267.80	0.621
2023	99.7	91.4	1664	257.97	0.598
2024	97.2	89.1	1637	249.51	0.579
2025	95.0	87.1	1614	242.46	0.563
2026	93.2	85.5	1594	236.65	0.549
2027	91.7	84.1	1577	231.88	0.538
2028	90.4	82.9	1562	227.93	0.529

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.72 with a multiplier of 0.9135 applied to the OFL.*

Table 86: Projection of BDR OFL, catch, biomass, and depletion using the Oregon BDR base case model projected with total projected catch equal to 28.6 mt for 2017 and 2018. The predicted OFL is the calculated total catch determined by the catch levels specified by the STAR panel GMT representative (i.e., 2019-2028 catches set to average historical, 2005-2014, catch level). Total catch in 2017 and 2018 were set to the average over the most recent two years (2015 – 2016).

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 0+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2017	109.1	28.6	1773	295.51	0.686
2018	110.1	28.6	1801	294.04	0.682
2019	112.3	27.4	1824	300.59	0.697
2020	115.1	27.4	1842	309.95	0.719
2021	117.5	27.4	1857	317.07	0.736
2022	119.3	27.4	1869	322.07	0.747
2023	120.6	27.4	1879	325.87	0.756
2024	121.6	27.4	1887	328.89	0.763
2025	122.3	27.4	1895	331.35	0.769
2026	122.9	27.4	1901	333.41	0.774
2027	123.5	27.4	1907	335.19	0.778
2028	123.9	27.4	1912	336.75	0.781

Note: projection assumes a category 2 assessment as a result of assessing a complex, with a P=0.45 and sigma = 0.72 with a multiplier of 0.9135 applied to the OFL.*

Table 87: Decision table summarizing 12-year projections (2017 – 2028) for Oregon BDR according to three alternative states of nature based on equilibrium unfished recruitment. Columns range over low, medium, and high state of nature, and rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2017 and 2018 are allocated to each fleet based on the percentage of landing for each fleet averaged over the period 2015-2016.

			State of nature					
			Low		Base case		High	
			$\ln(R_0)$ = 6.453		$\ln(R_0)$ = 7.047		$\ln(R_0)$ = 7.641	
Relative probability of states of nature:			0.25		0.5		0.25	
Management decision	Year	Catch (mt)	Spawning Biomass (mt)	Depletion	Spawning Biomass (mt)	Depletion	Spawning Biomass (mt)	Depletion
	2017	28.6	117	0.49	298	0.69	636	0.80
	2018	28.6	115	0.48	297	0.68	633	0.80
	2019	41.7	116	0.49	303	0.70	645	0.82
Catches from	2020	41.4	115	0.48	309	0.71	657	0.83
low SSB,	2021	41.2	114	0.48	312	0.72	665	0.84
Default Harvest	2022	41.0	113	0.47	314	0.72	669	0.85
Control Rule	2023	40.9	112	0.47	315	0.73	672	0.85
(40-10)	2024	40.9	112	0.47	315	0.73	673	0.85
	2025	40.9	112	0.47	316	0.73	674	0.85
	2026	41.0	112	0.47	316	0.73	674	0.85
	2027	41.1	112	0.47	315	0.73	674	0.85
	2028	41.1	112	0.47	315	0.73	674	0.85
	2017	28.6	117	0.49	296	0.69	636	0.80
	2018	28.6	115	0.48	294	0.68	633	0.80
	2019	103.0	116	0.49	301	0.70	645	0.82
Catches from	2020	99.8	100	0.42	290	0.67	640	0.81
median (base	2021	96.9	86	0.36	279	0.65	633	0.80
case) SSB,	2022	94.1	74	0.31	268	0.62	624	0.79
Default Harvest	2023	91.4	64	0.27	258	0.60	615	0.78
Control Rule	2024	89.1	57	0.24	250	0.58	608	0.77
(40-10)	2025	87.1	52	0.22	242	0.56	601	0.76
	2026	85.5	48	0.20	237	0.55	595	0.75
	2027	84.1	44	0.19	232	0.54	590	0.75
	2028	82.9	41	0.17	228	0.53	586	0.74
	2017	28.6	117	0.49	298	0.69	636	0.80
	2018	28.6	115	0.48	297	0.68	633	0.80
	2019	214.6	116	0.49	303	0.70	645	0.82
Catches from	2020	204.8	73	0.31	263	0.61	610	0.77
high SSB,	2021	196.0	42	0.17	227	0.52	576	0.73
Default Harvest	2022	187.7	21	0.09	196	0.45	545	0.69
Control Rule	2023	180.4	10	0.04	170	0.39	518	0.65
(40-10)	2024	174.1	4	0.02	149	0.34	494	0.62
	2025	168.8	1	0.01	133	0.31	475	0.60
	2026	164.5	0	0.00	120	0.28	460	0.58
	2027	160.9	0	0.00	109	0.25	447	0.57
	2028	157.9	0	0.00	101	0.23	437	0.55
	2017	28.6	117	0.49	296	0.69	636	0.80
	2018	28.6	115	0.48	294	0.68	633	0.80
	2019	27.4	116	0.49	301	0.70	645	0.82
	2020	27.4	119	0.50	310	0.72	661	0.84
Constant Catch,	2021	27.4	121	0.51	317	0.74	673	0.85
average catch	2022	27.4	123	0.52	322	0.75	680	0.86
from 2005-2014	2023	27.4	125	0.52	326	0.76	685	0.87
	2024	27.4	127	0.53	329	0.76	690	0.87
	2025	27.4	129	0.54	331	0.77	693	0.88
	2026	27.4	131	0.55	333	0.77	695	0.88
	2027	27.4	133	0.56	335	0.78	697	0.88
	2028	27.4	135	0.57	337	0.78	699	0.88

12 Figures

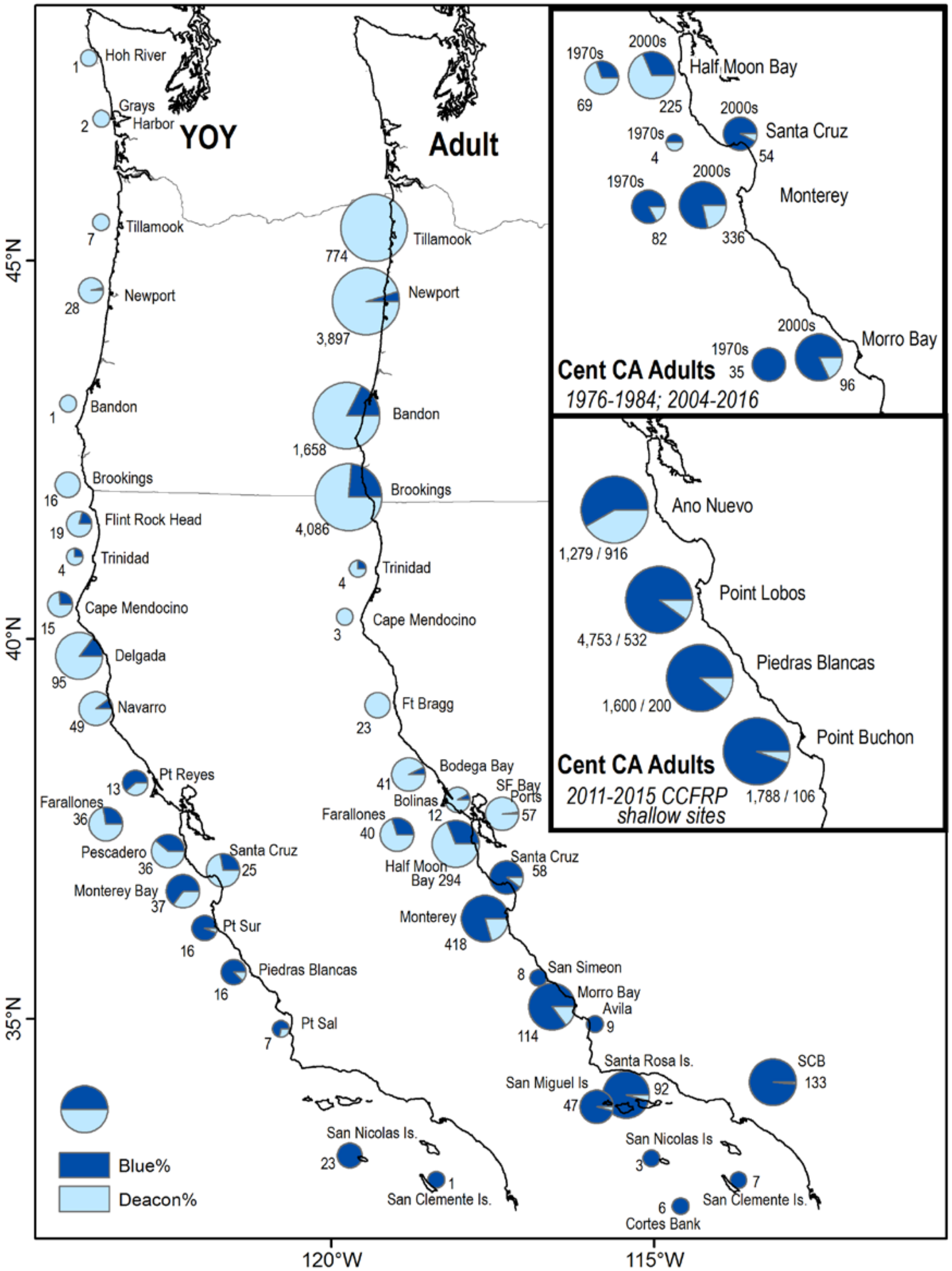


Figure 1: Spatial patterns in species composition of Blue and Deacon Rockfishes by life stage (YOY and Adult, main panel), time period (upper inset), and Marine Protected Area (lower inset).

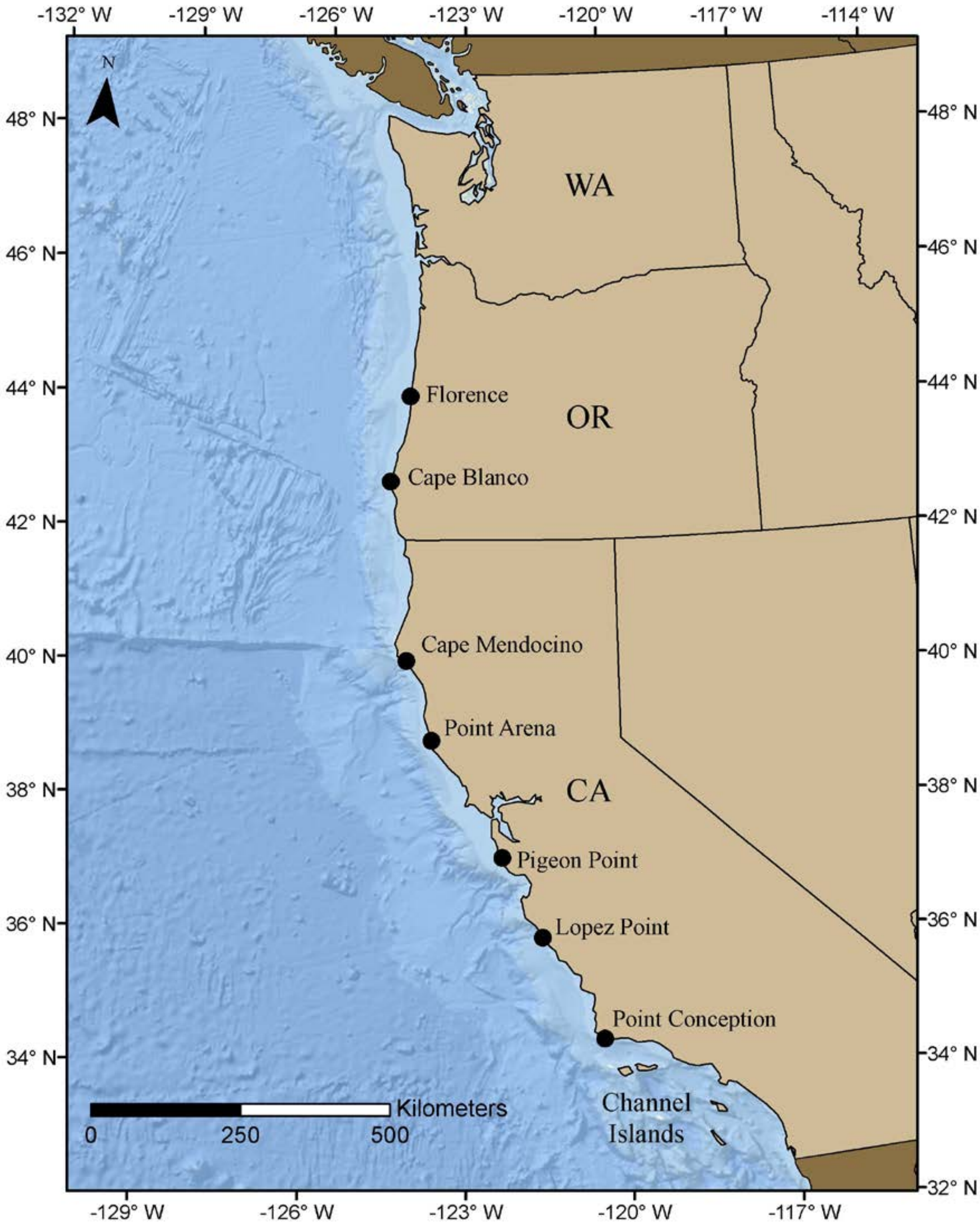


Figure 2: Map of selected coastal features in the California and Oregon assessment of Blue and Deacon Rockfishes.

12.1 California Figures

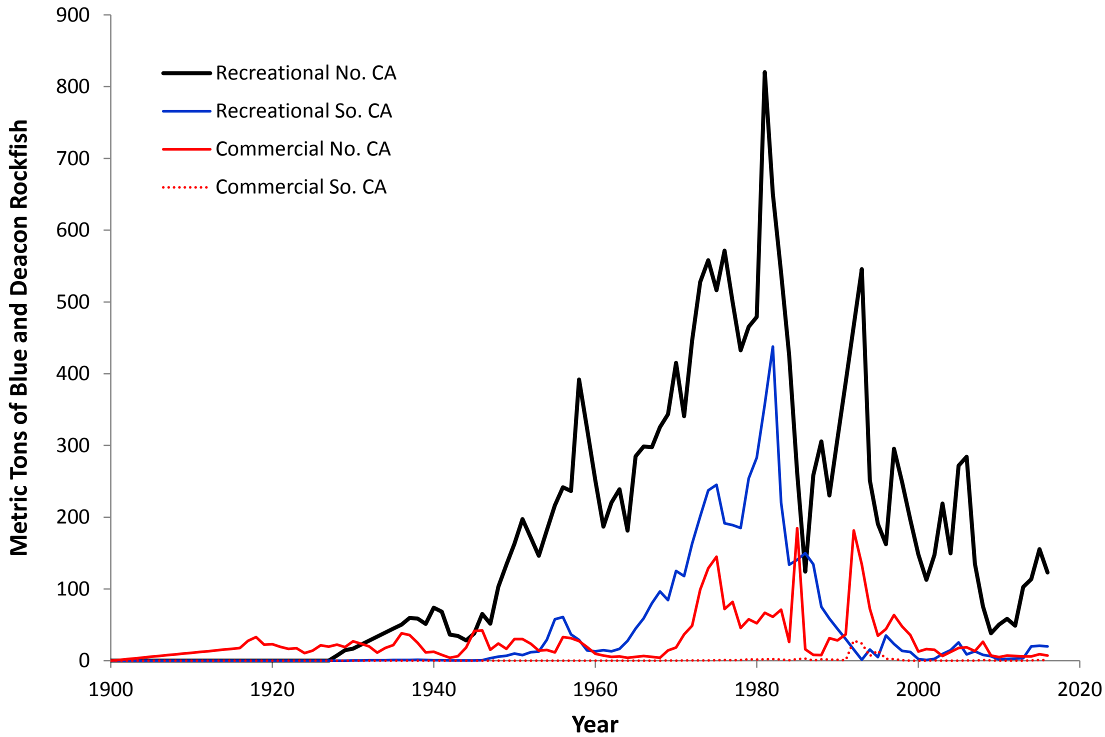


Figure 3: Summary of Blue and Deacon rockfish removals by sector (recreational and commercial) and area (North and South of Point Conception, California).

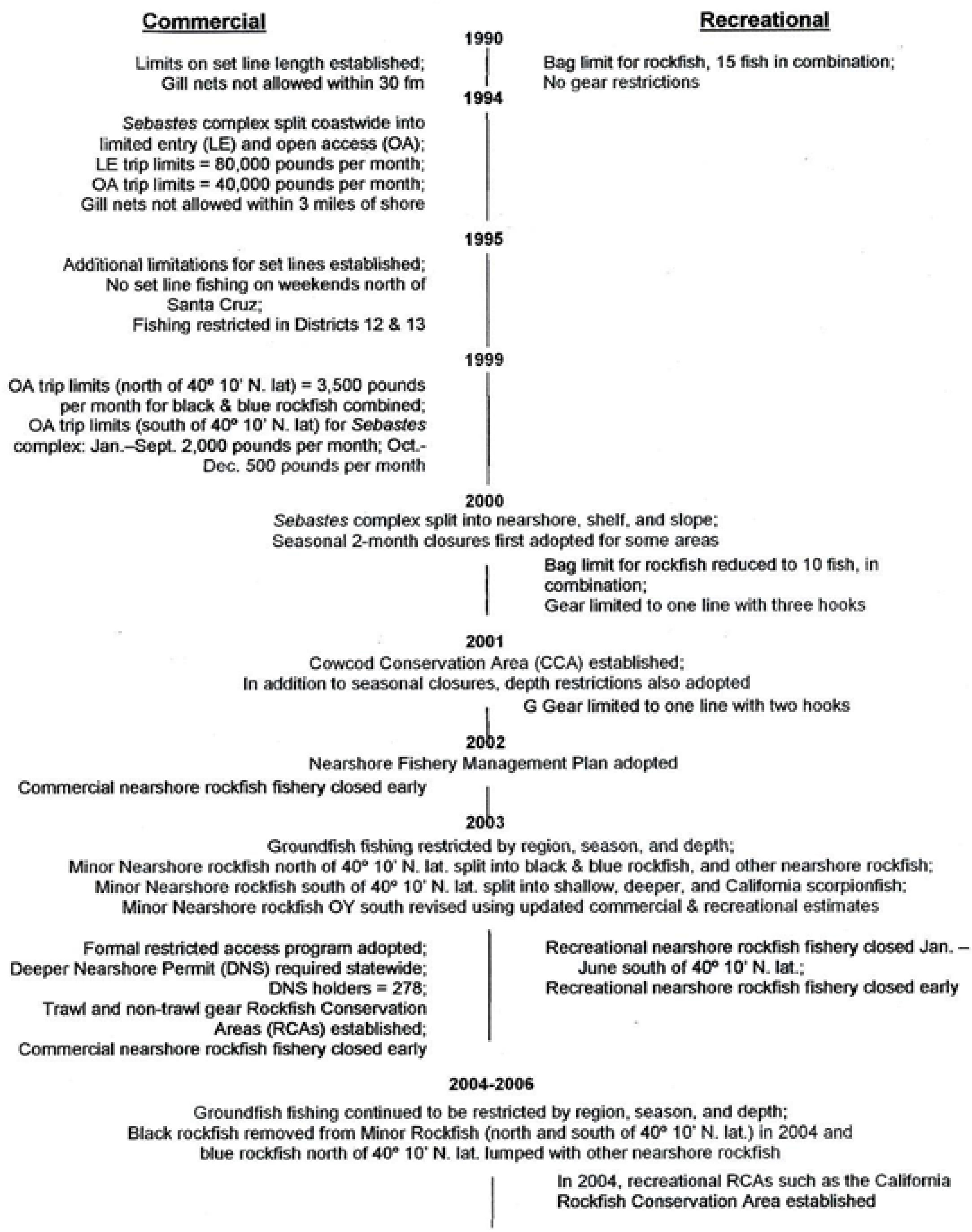


Figure 4: California regulations that applied to Blue [and Deacon] rockfish from 1990-2006. Source: Key et al. 2008

Date	Latitude 32.53 - 34.45	34.45 - 36	36 - 37.18	37.18 - 38.95	38.95 - 40.17	40.17 - 42
Jan-01	0	open	open	open	open	open
Feb-01	0	open	open	open	open	open
Mar-01	open	0	0	0	0	open
Apr-01	open	0	0	0	0	open
May-01	open	20	20	20	20	open
Jun-01	open	20	20	20	20	open
Jul-01	open	open	open	open	open	open
Aug-01	open	open	open	open	open	open
Sep-01	open	open	open	open	open	open
Oct-01	open	open	open	open	open	open
Nov-01	20	20	20	20	20	open
Dec-01	20	20	20	20	20	open
Jan-02	0	open	open	open	open	open
Feb-02	0	open	open	open	open	open
Mar-02	open	0	0	0	0	open
Apr-02	open	0	0	0	0	open
May-02	open	20	20	20	20	open
Jun-02	open	20	20	20	20	open
Jul-02	20	20	20	20	20	open
Aug-02	20	20	20	20	20	open
Sep-02	20	20	20	20	20	open
Oct-02	20	20	20	20	20	open
Nov-02	0	0	0	0	0	open
Dec-02	0	0	0	0	0	open
Jan-03	0	0	0	0	0	open
Feb-03	0	0	0	0	0	open
Mar-03	0	0	0	0	0	open
Apr-03	0	0	0	0	0	open
May-03	0	0	0	0	0	open
Jun-03	0	0	0	0	0	open
Jul-03	20	20	20	20	20	open
Aug-03	20	20	20	20	20	open
Sep-03	30	20	20	20	20	open
Oct-03	30	20	20	20	20	open
Nov-03	30	20	20	20	20	open
Dec-03	0	0	0	0	0	0
Jan-04	0	30	30	30	30	open
Feb-04	0	30	30	30	30	open
Mar-04	60	0	0	0	0	open
Apr-04	60	0	0	0	0	open
May-04	60	20	0	0	0	30
Jun-04	60	20	0	0	0	30
Jul-04	60	0	0	0	0	30
Aug-04	60	20	20	20	20	30
Sep-04	30	20	20	20	20	30
Oct-04	30	20	20	20	20	30
Nov-04	60	20	0	0	0	30
Dec-04	60	20	0	0	0	30
Jan-05	0	0	0	0	0	0
Feb-05	0	0	0	0	0	0
Mar-05	60	0	0	0	0	0
Apr-05	60	0	0	0	0	0
May-05	60	40	0	0	0	30
Jun-05	60	40	0	0	0	30
Jul-05	60	40	20	20	20	30
Aug-05	60	40	20	20	20	30
Sep-05	30	40	20	20	20	30
Oct-05	30	0	20	20	20	30
Nov-05	60	0	20	20	20	30
Dec-05	60	0	20	20	20	30
Jan-06	0	0	0	0	0	0
Feb-06	0	0	0	0	0	0
Mar-06	60	0	0	0	0	0
Apr-06	60	0	0	0	0	0
May-06	60	40	0	0	0	30
Jun-06	60	40	0	0	0	30
Jul-06	60	40	30	30	30	30
Aug-06	60	40	30	30	30	30
Sep-06	60	40	30	30	30	30
Oct-06	60	40	30	30	30	30
Nov-06	60	0	30	30	30	30
Dec-06	60	0	30	30	30	30

Date	Latitude 32.53 - 34.45	34.45 - 36	36 - 37.18	37.18 - 38.95	38.95 - 40.17	40.17 - 42
Jan-07	0	0	0	0	0	0
Feb-07	0	0	0	0	0	0
Mar-07	60	0	0	0	0	0
Apr-07	60	0	0	0	0	0
May-07	60	40	40	0	0	30
Jun-07	60	40	40	30	30	30
Jul-07	60	40	40	30	30	30
Aug-07	60	40	40	30	30	30
Sep-07	60	40	40	30	30	30
Oct-07	60	40	40	0	0	0
Nov-07	60	40	40	0	0	0
Dec-07	60	0	0	0	0	0
Jan-08	0	0	0	0	0	0
Feb-08	0	0	0	0	0	0
Mar-08	60	0	0	0	0	0
Apr-08	60	0	0	0	0	0
May-08	60	40	40	0	0	20
Jun-08	60	40	40	20	20	20
Jul-08	60	40	40	20	20	20
Aug-08	60	40	40	20	20	20
Sep-08	60	40	40	20	0	0
Oct-08	60	40	40	20	0	0
Nov-08	60	40	40	20	0	0
Dec-08	60	0	0	0	0	0
Jan-09	0	0	0	0	0	0
Feb-09	0	0	0	0	0	0
Mar-09	60	0	0	0	0	0
Apr-09	60	0	0	0	0	0
May-09	60	40	40	0	20	20
Jun-09	60	40	40	20	20	20
Jul-09	60	40	40	20	20	20
Aug-09	60	40	40	20	20	20
Sep-09	60	40	40	20	0	20
Oct-09	60	40	40	20	0	0
Nov-09	60	40	40	0	0	0
Dec-09	60	0	0	0	0	0
Jan-10	0	0	0	0	0	0
Feb-10	0	0	0	0	0	0
Mar-10	60	0	0	0	0	0
Apr-10	60	0	0	0	0	0
May-10	60	40	0	0	20	20
Jun-10	60	40	20	20	20	20
Jul-10	60	40	20	20	20	20
Aug-10	60	40	20	20	20	20
Sep-10	60	40	20	20	0	20
Oct-10	60	40	20	20	0	0
Nov-10	60	40	0	0	0	0
Dec-10	60	0	0	0	0	0
Jan-11	0	0	0	0	0	0
Feb-11	0	0	0	0	0	0
Mar-11	60	0	0	0	0	0
Apr-11	60	0	0	0	0	0
May-11	60	40	40	0	20	20
Jun-11	60	40	40	30	20	20
Jul-11	60	40	40	30	20	20
Aug-11	60	40	40	30	20	20
Sep-11	60	40	40	30	0	20
Oct-11	60	40	40	30	0	20
Nov-11	60	40	40	30	0	0
Dec-11	60	40	40	30	0	0

Date	Latitude 32.53 - 34.45	34.45 - 36	36 - 37.18	37.18 - 38.95	38.95 - 40.17	40.17 - 42
Jan-12	0	0	0	0	0	0
Feb-12	0	0	0	0	0	0
Mar-12	60	0	0	0	0	0
Apr-12	60	0	0	0	0	0
May-12	60	40	40	0	20	20
Jun-12	60	40	40	30	20	20
Jul-12	60	40	40	30	20	20
Aug-12	60	40	40	30	20	20
Sep-12	60	40	40	30	0	20
Oct-12	60	40	40	30	0	20
Nov-12	50	40	40	30	0	0
Dec-12	50	40	40	30	0	0
Jan-13	0	0	0	0	0	0
Feb-13	0	0	0	0	0	0
Mar-13	50	0	0	0	0	0
Apr-13	50	0	0	0	0	0
May-13	50	40	40	0	20	20
Jun-13	50	40	40	30	20	20
Jul-13	50	40	40	30	20	20
Aug-13	50	40	40	30	20	20
Sep-13	50	40	40	30	20	20
Oct-13	50	40	40	30	0	20
Nov-13	50	40	40	30	0	0
Dec-13	50	40	40	30	0	0
Jan-14	0	0	0	0	0	0
Feb-14	0	0	0	0	0	0
Mar-14	50	0	0	0	0	0
Apr-14	50	0	0	0	0	0
May-14	50	40	40	0	20	20
Jun-14	50	40	40	30	20	20
Jul-14	50	40	40	30	20	20
Aug-14	50	40	40	30	20	20
Sep-14	50	40	40	30	20	20
Oct-14	50	40	40	30	0	20
Nov-14	50	40	40	30	0	0
Dec-14	50	40	40	30	0	0
Jan-15	0	0	0	0	0	0
Feb-15	0	0	0	0	0	0
Mar-15	60	40	40	0	0	0
Apr-15	60	40	40	30	0	0
May-15	60	40	40	30	20	20
Jun-15	60	40	40	30	20	20
Jul-15	60	40	40	30	20	20
Aug-15	60	40	40	30	20	20
Sep-15	60	40	40	30	20	20
Oct-15	60	40	40	30	20	20
Nov-15	60	40	40	30	0	0
Dec-15	60	40	40	30	0	0
Jan-16	0	0	0	0	0	0
Feb-16	0	0	0	0	0	0
Mar-16	60	40	40	0	0	0
Apr-16	60	40	40	30	0	0
May-16	60	40	40	30	20	20
Jun-16	60	40	40	30	20	20
Jul-16	60	40	40	30	20	20
Aug-16	60	40	40	30	20	20
Sep-16	60	40	40	30	20	20
Oct-16	60	40	40	30	20	20
Nov-16	60	40	40	30	0	0
Dec-16	60	40	40	30	0	0

Description of Latitude Bins

32.53 - 34.45	U.S. / Mexico Border to Point Conception
34.45 - 36	Point Conception to Lopez Point
36 - 37.18	Lopez Point to Pigeon Point
37.18 - 38.95	Pigeon Point to Point Arena
38.95 - 40.17	Point Arena to Cape Mendocino
40.17 - 42	Cape Mendocino to the California/Oregon Border

Figure 5: California recreational depth limits (fathoms) for nearshore rockfish, 2001-2016, by month and latitude. Depths shown are the maximum fishable depth in a given month/area combination. Closed periods for a given area are represented by a zero, and periods with no depth restriction are indicated as "open."

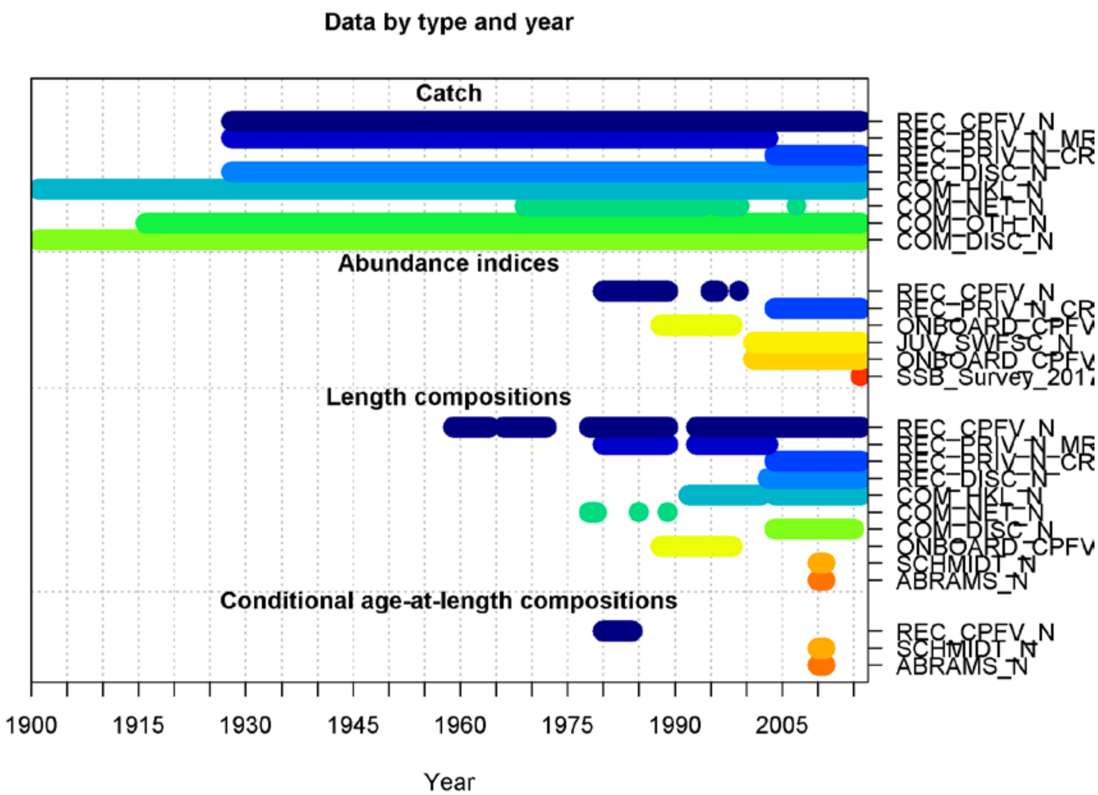


Figure 6: Summary of data sources in the California base case model

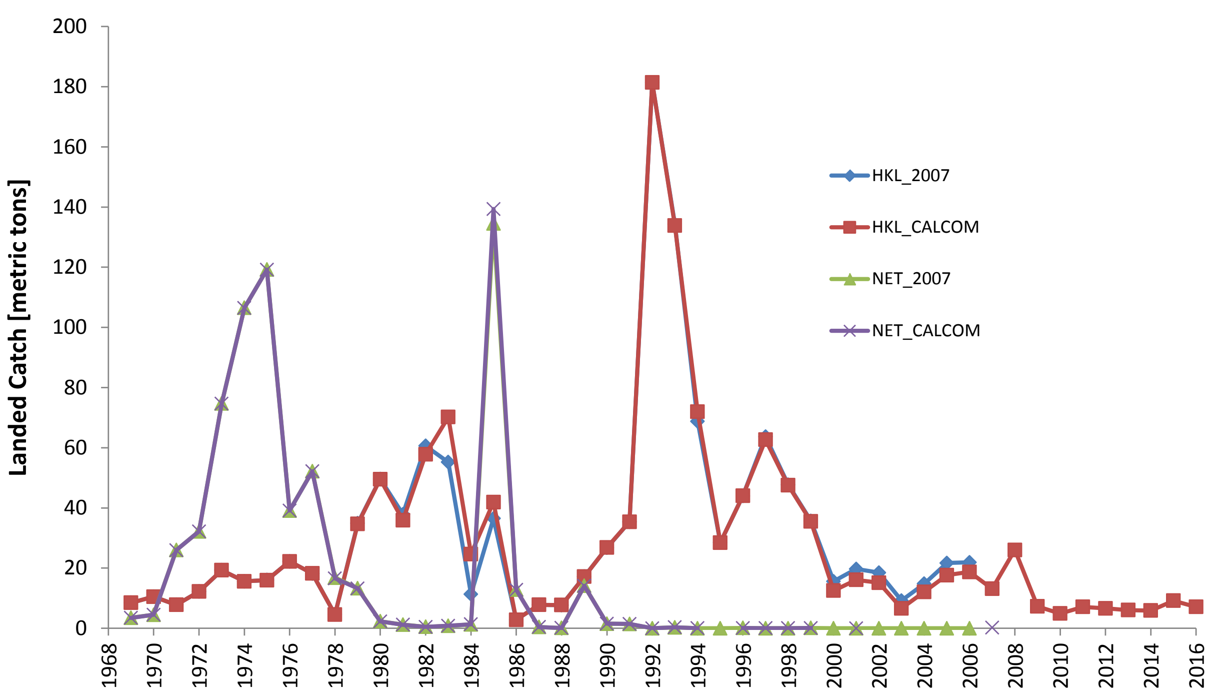


Figure 7: Comparison of hook and line (HKL) and net gear (NET) landings from the 2007 and current assessments.

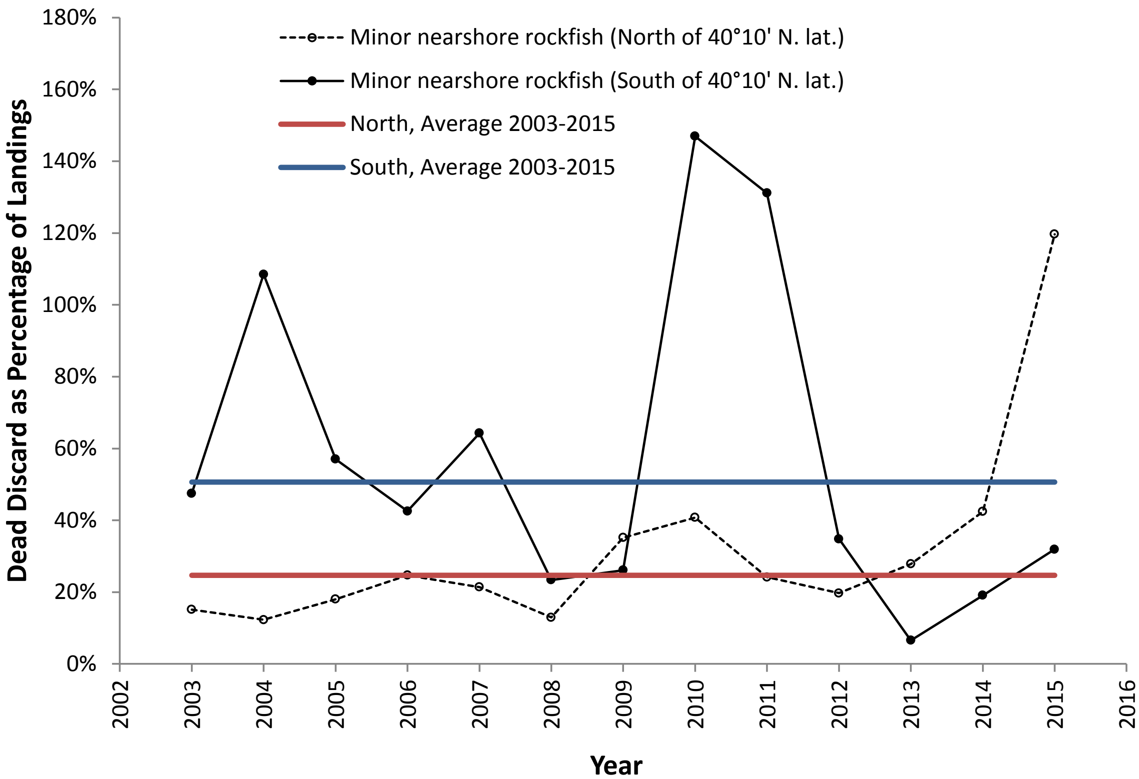


Figure 8: Commercial discard ratios (dead discard as a percentage of landings, by year and management area) used to estimate discard in the California (50.63%) and Oregon (24.71%) base models.

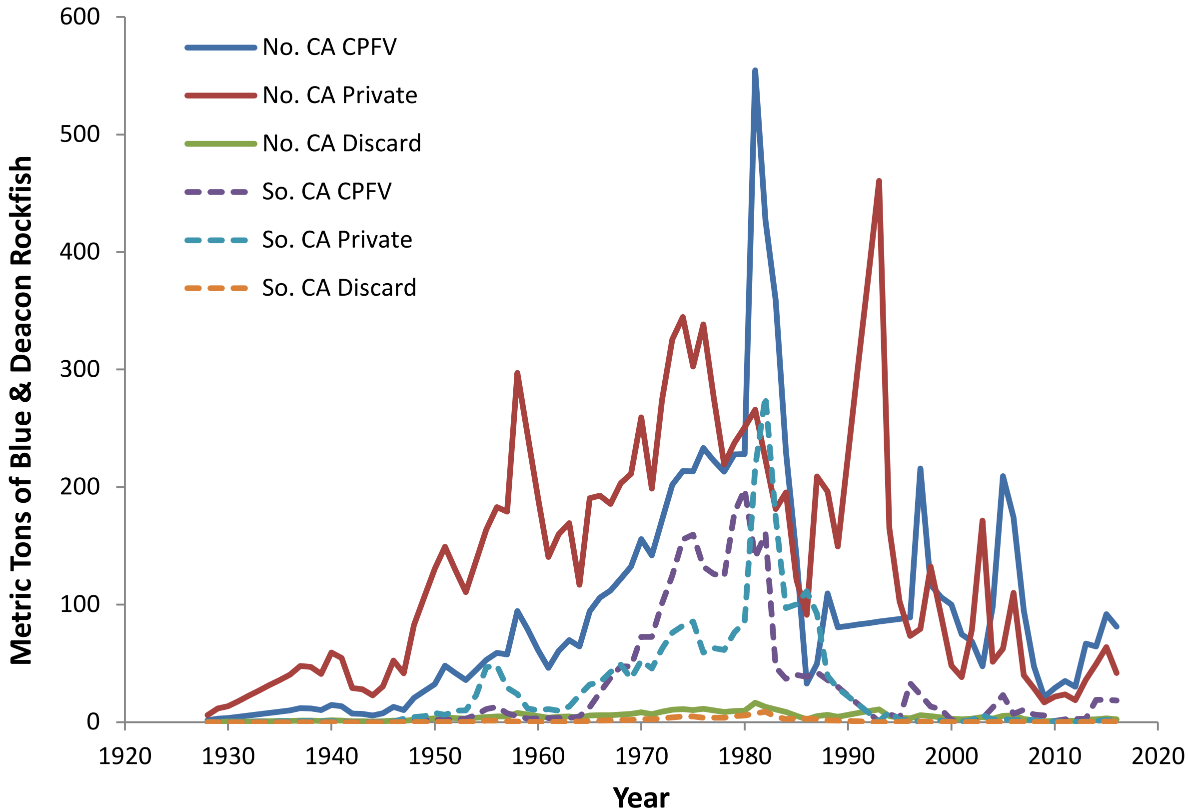


Figure 9: Summary of BDR recreational landings and discard in California.

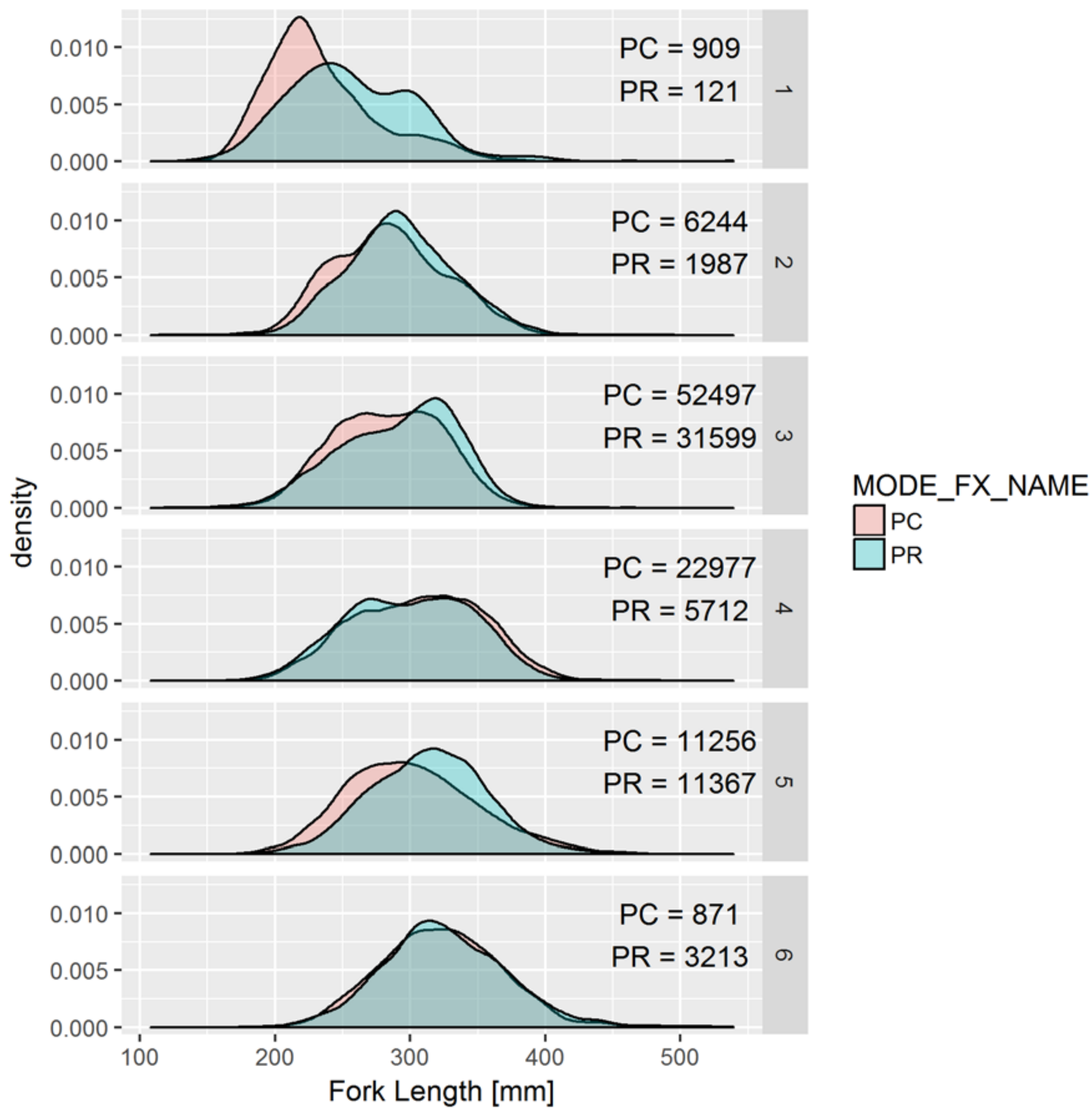


Figure 10: Distributions of fork length for BDR retained catch, 1980-2013, by CRFS district and boat mode with sample sizes (PC = CPFV and PR = private).

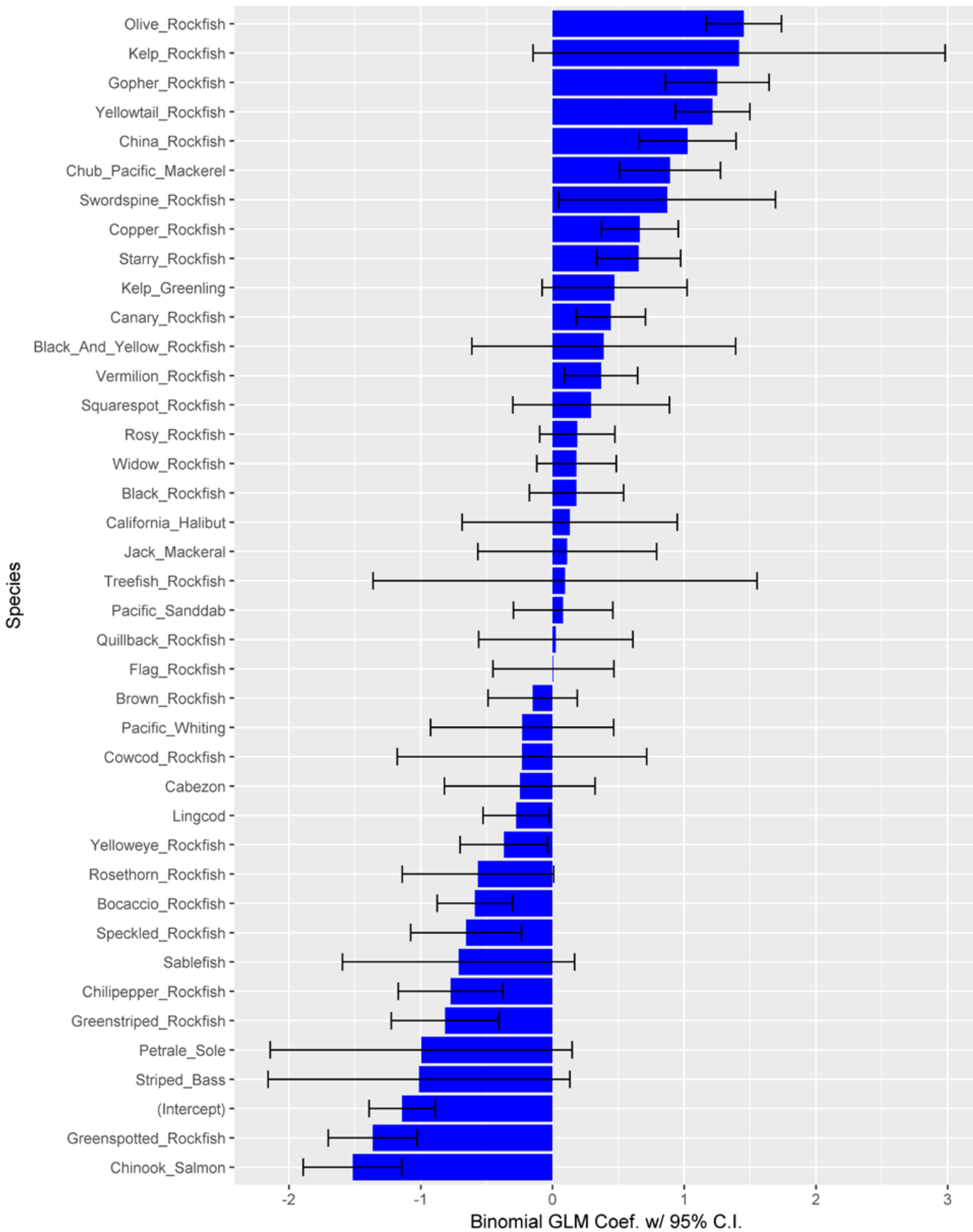


Figure 11: Species coefficients (blue bars) from the binomial GLM for presence/absence of Blue/Deacon rockfish in the MRFSS data for California north of 34°27′ N. latitude. Horizontal black bars are 95% confidence intervals.

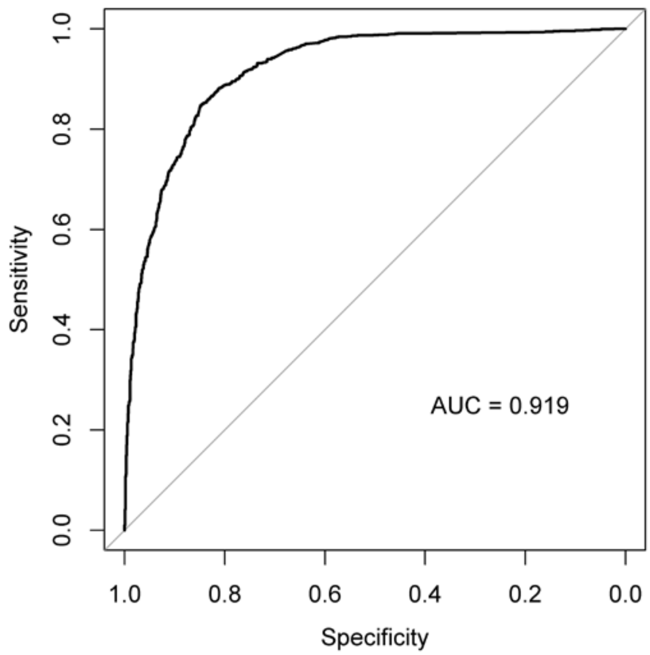


Figure 12: MRFSS Northern California Receiver Operating Characteristic (ROC) curve for Stephens-MacCall logistic regression model. AUC is the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence.

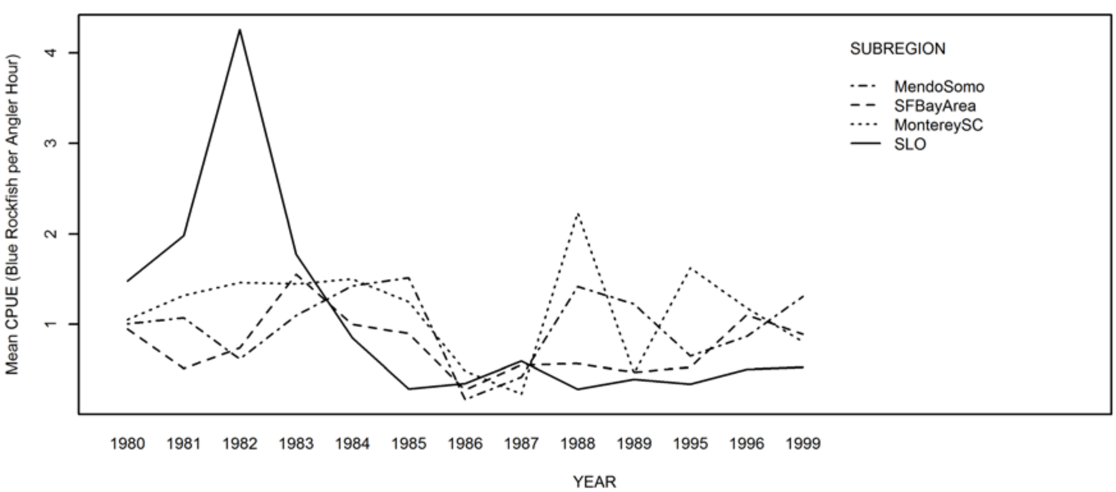


Figure 13: MRFSS Northern California CPFV catch rates (observed fish per angler hour) of Blue and Deacon Rockfish by year and subregion.

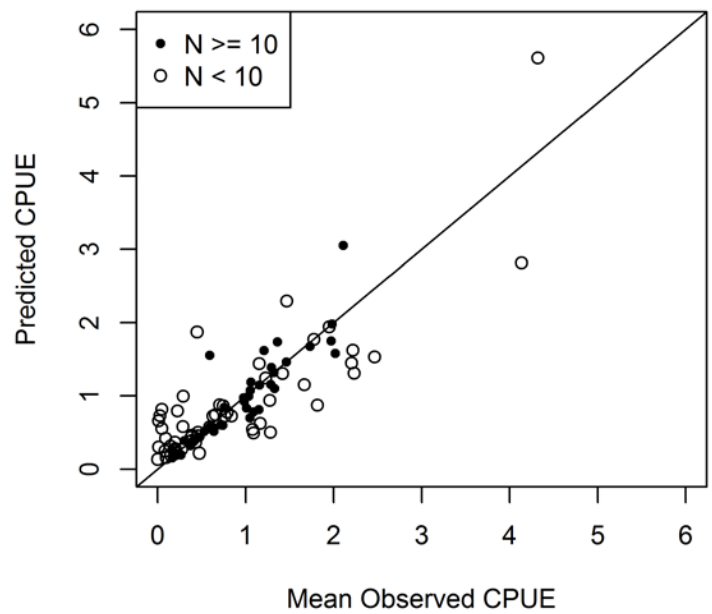


Figure 14: Predicted mean CPUE from the MRFSS Northern California CPFV negative binomial model vs. mean observed CPUE. Open circles indicate strata with fewer than 10 samples.

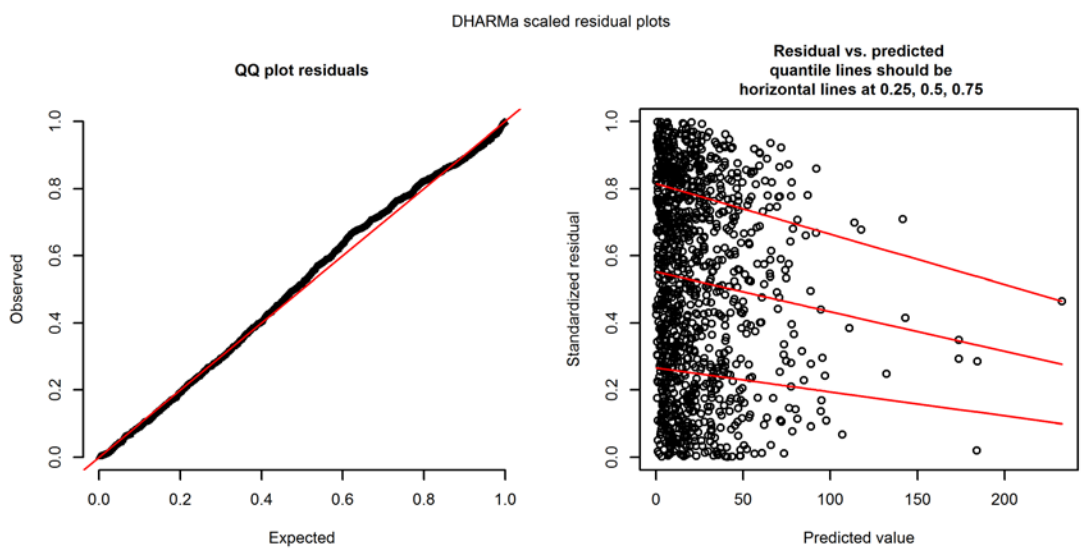


Figure 15: Diagnostic check of distributional assumptions in the best-fit negative binomial model for MRFSS Northern California CPFV data.

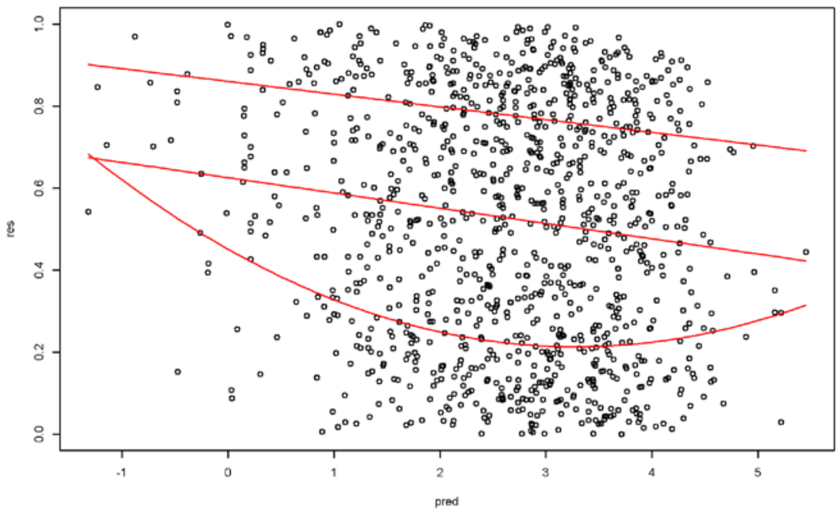


Figure 16: Standardized (quantile) residuals vs. link-scale predictions from the negative binomial model for MRFSS Northern California CPFV data. Due to the highly skewed distribution of catches, patterns in scaled residuals are clearer on the link scale.

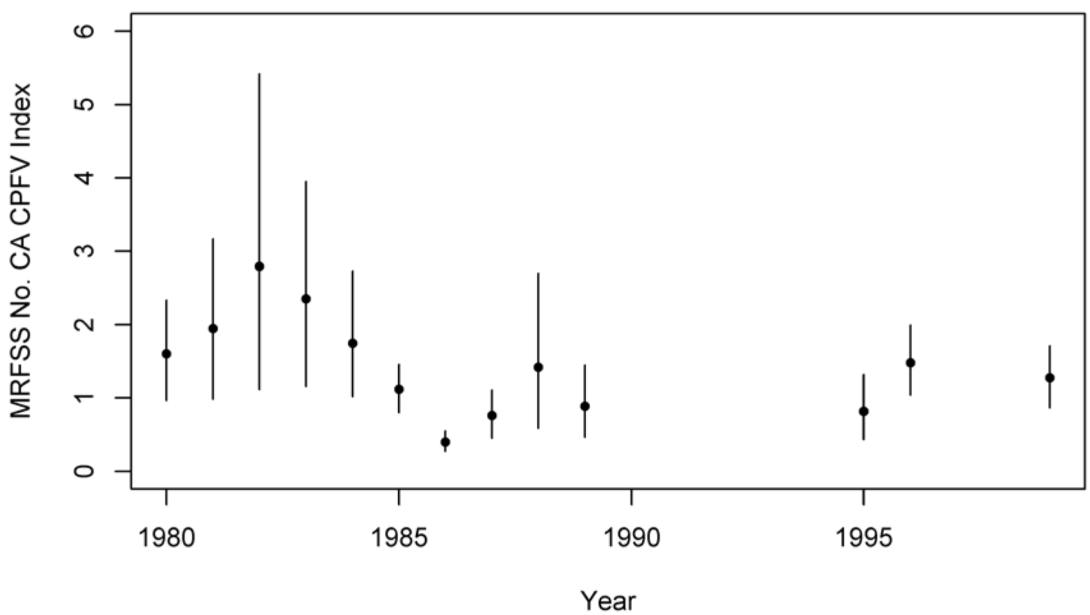


Figure 17: MRFSS Northern California CPFV index with 95% highest posterior density intervals.

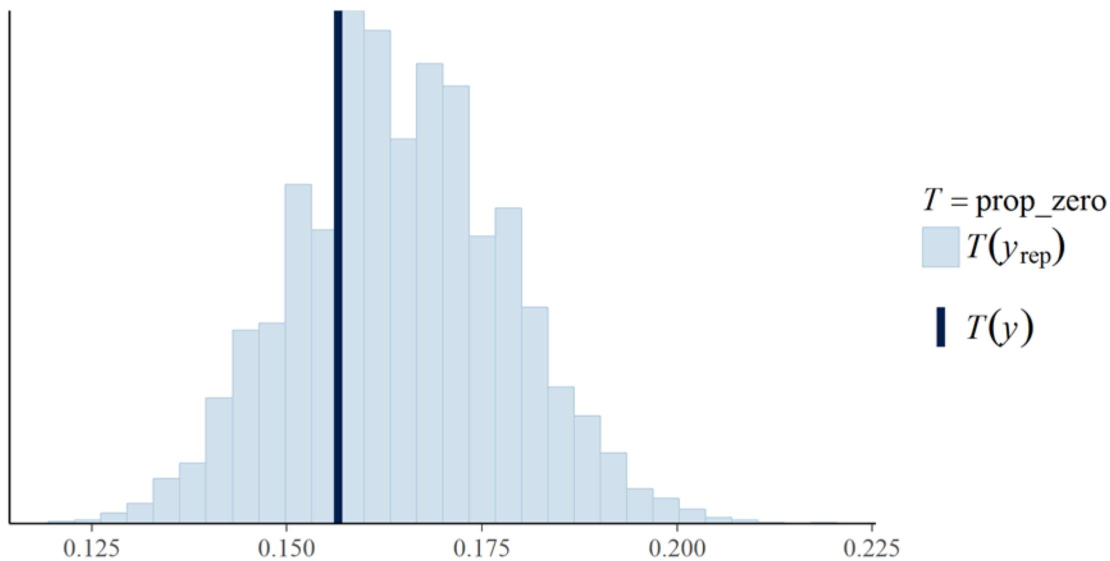


Figure 18: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for MRFSS Northern California CPFV data.

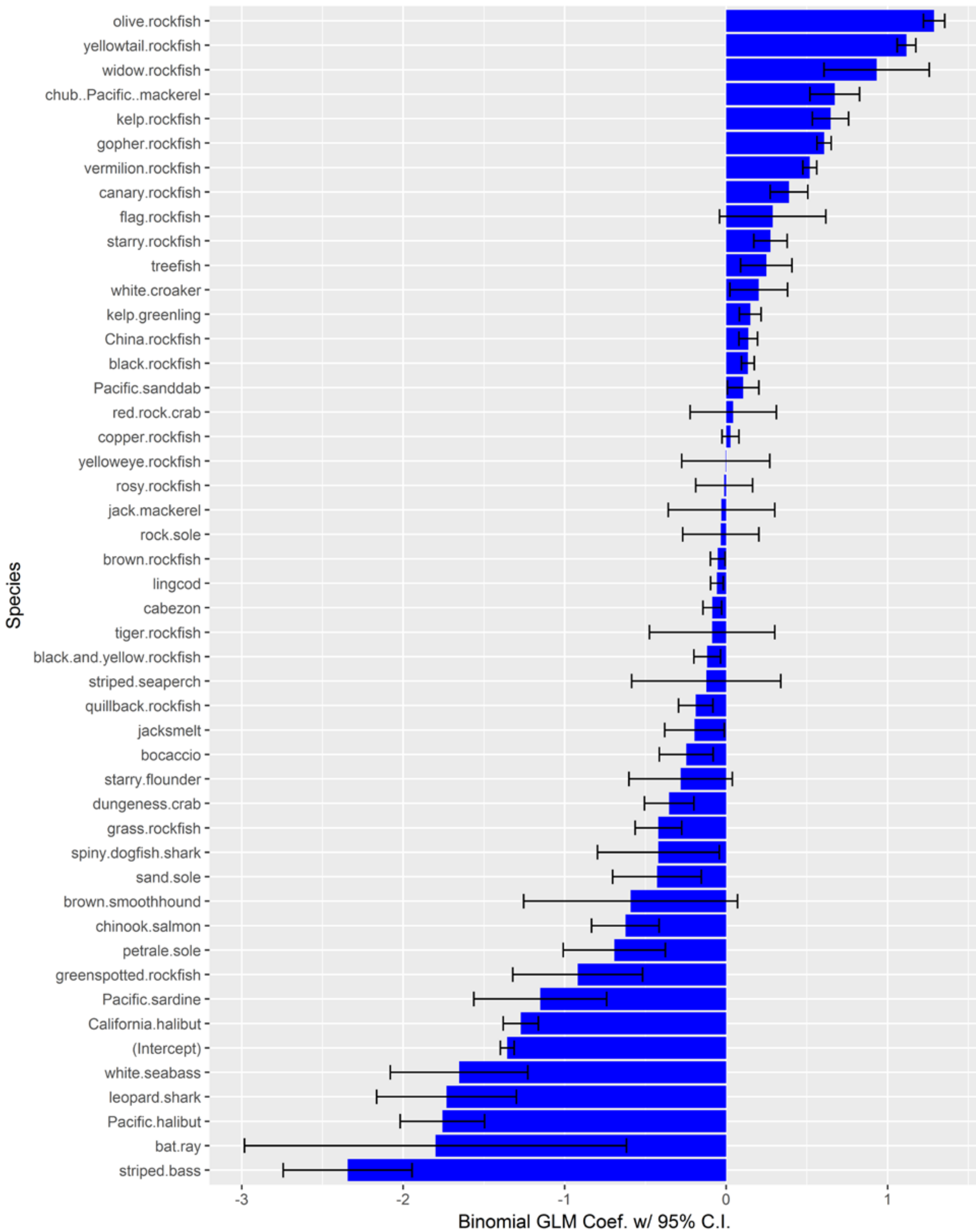


Figure 19: Species coefficients (blue bars) from the binomial GLM for presence/absence of Blue/Deacon rockfish in the CRFS private boat data for California north of 34°27′ N. latitude. Horizontal black bars are 95% confidence intervals.

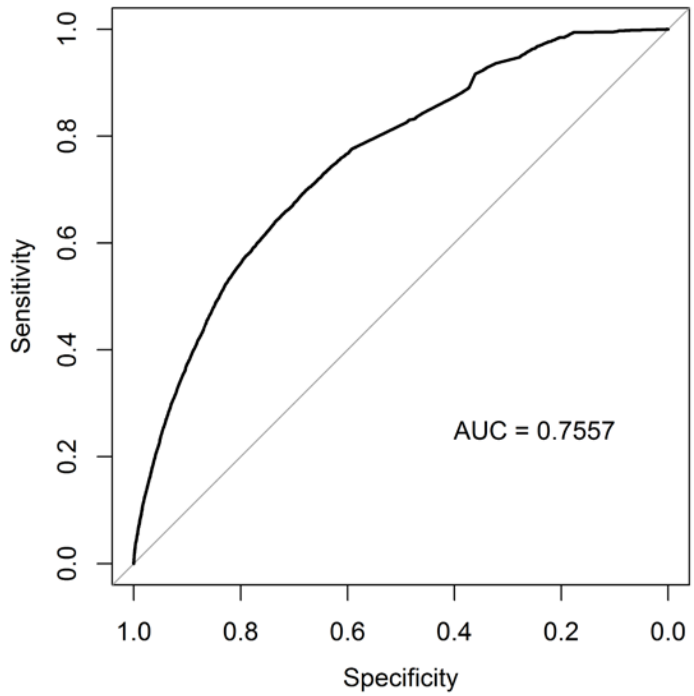


Figure 20: CRFS private boat (Northern California) Receiver Operating Characteristic (ROC) curve for Stephens-MacCall logistic regression model.

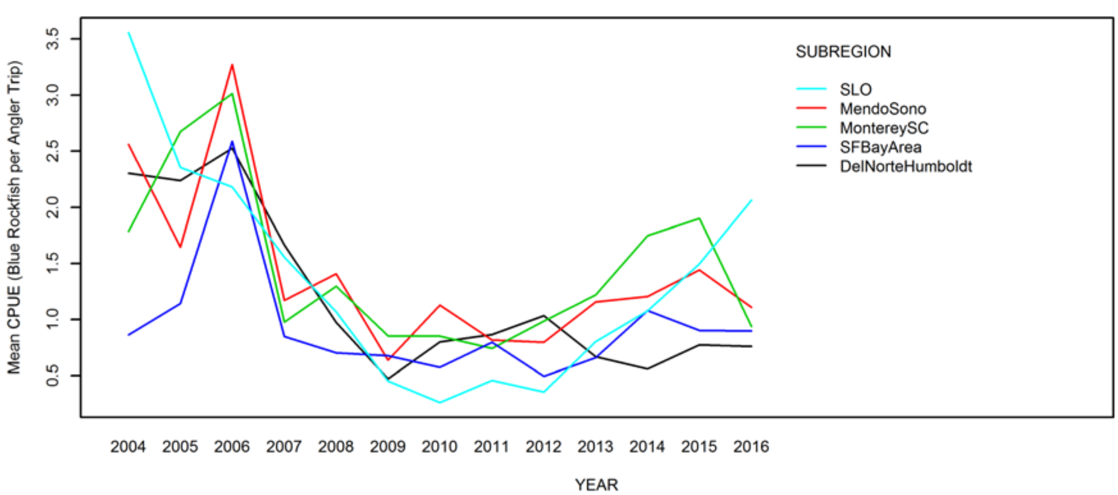


Figure 21: CRFS private boat Northern California catch rates (observed fish per angler hour) of Blue and Deacon Rockfish by year and subregion.

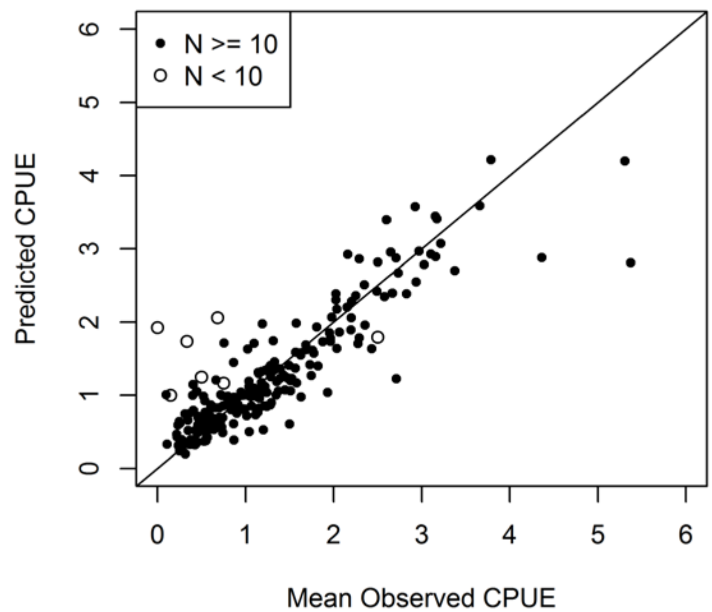


Figure 22: Predicted mean CPUE from the CRFS private boat Northern California negative binomial model vs. mean observed CPUE. Open circles indicate strata with fewer than 10 samples.

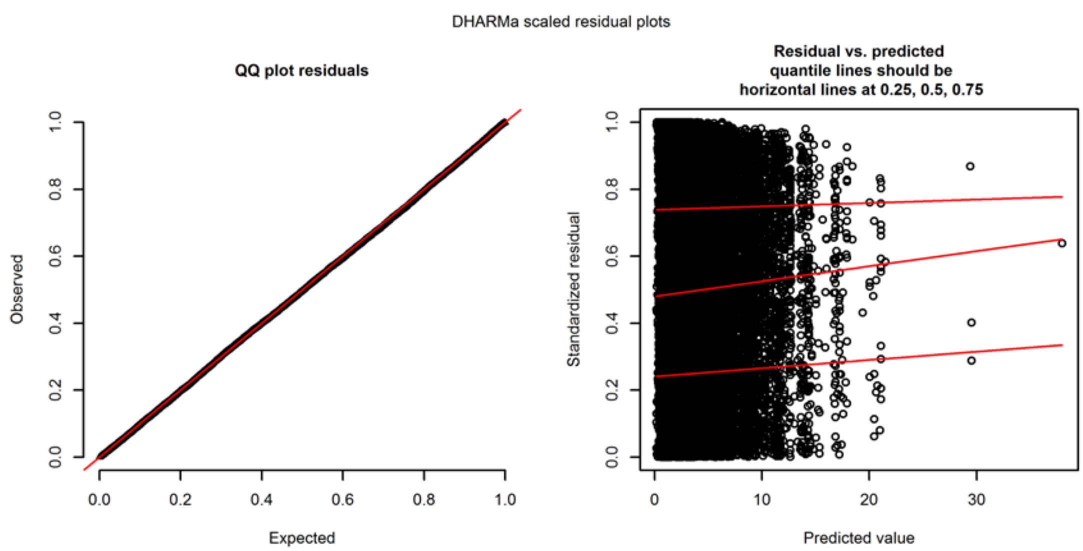


Figure 23: Diagnostic check of distributional assumptions in the best-fit negative binomial model for CRFS private boat data.

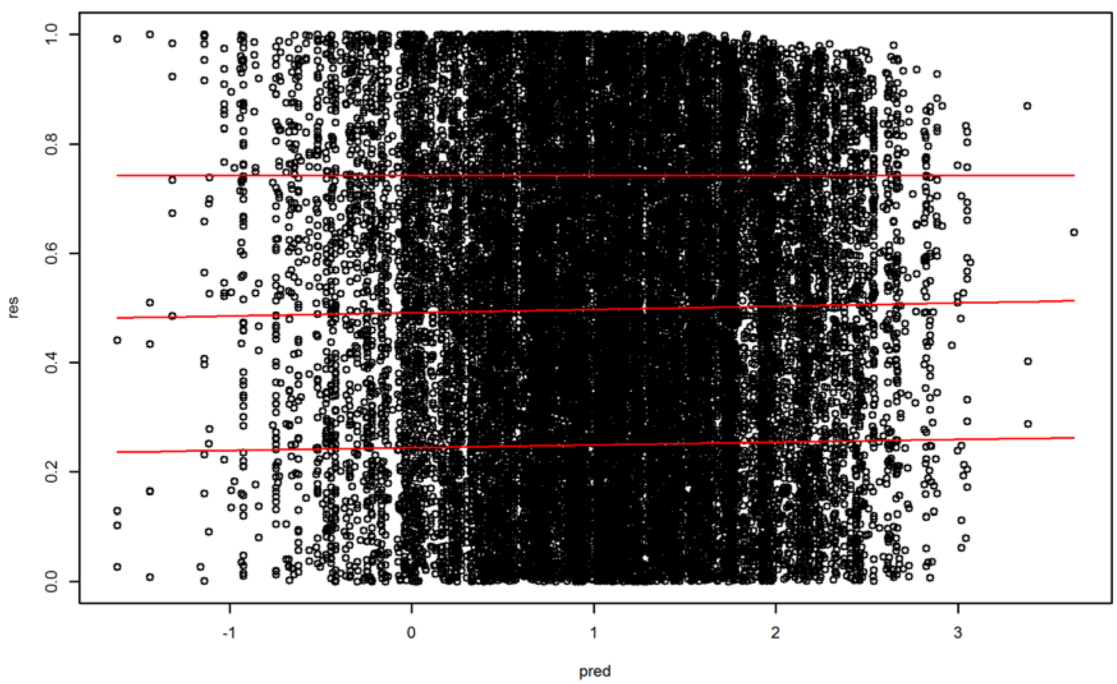


Figure 24: Standardized (quantile) residuals vs. link-scale predictions from the negative binomial model for CRFS private boat Northern California data.

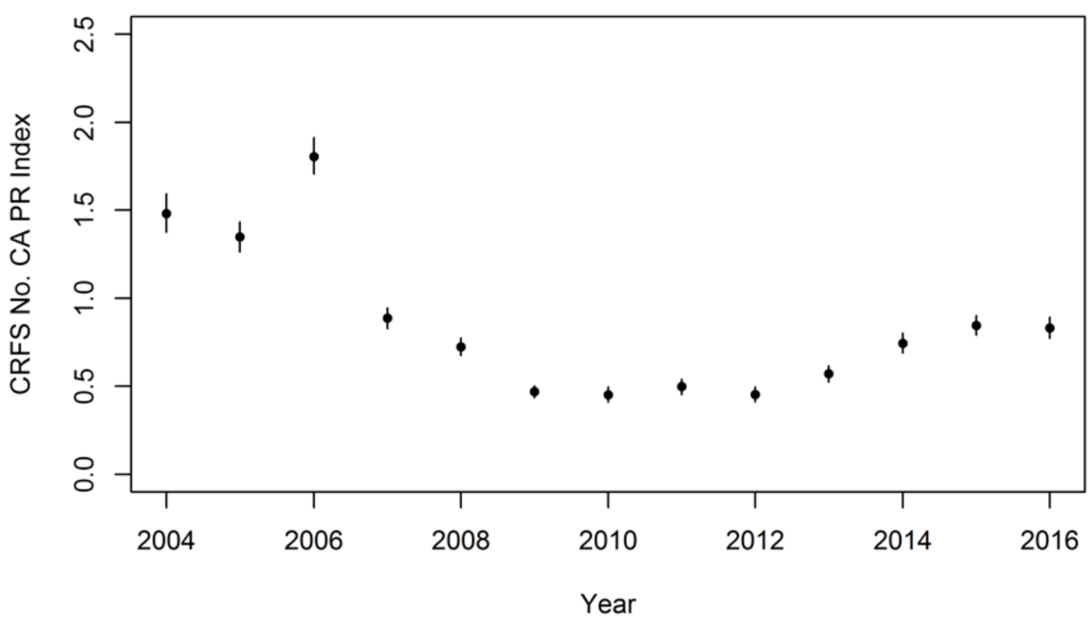


Figure 25: CRFS private boat Northern California index with 95% highest posterior density intervals.

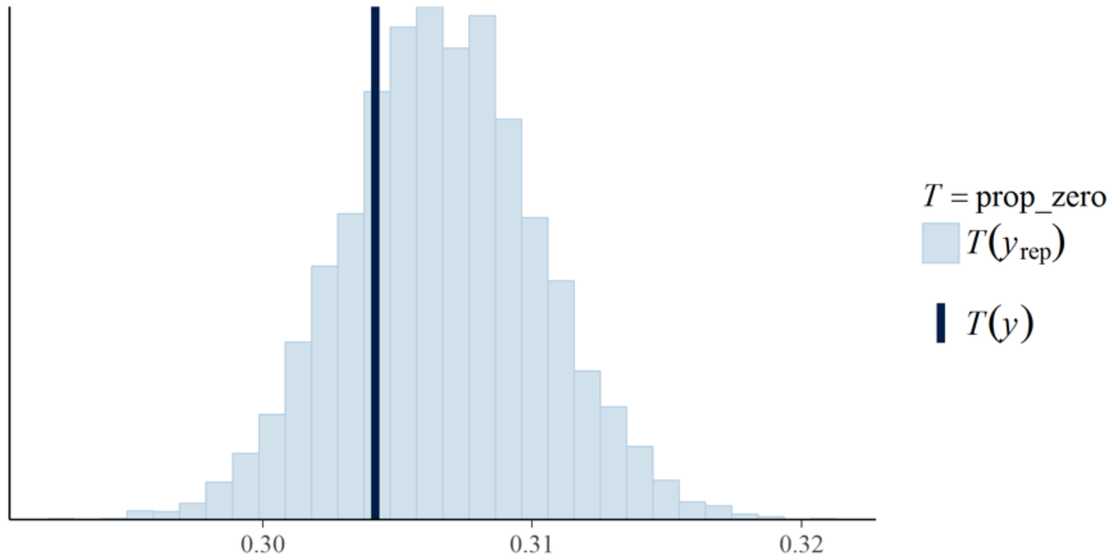


Figure 26: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for CRFS private boat Northern California data.

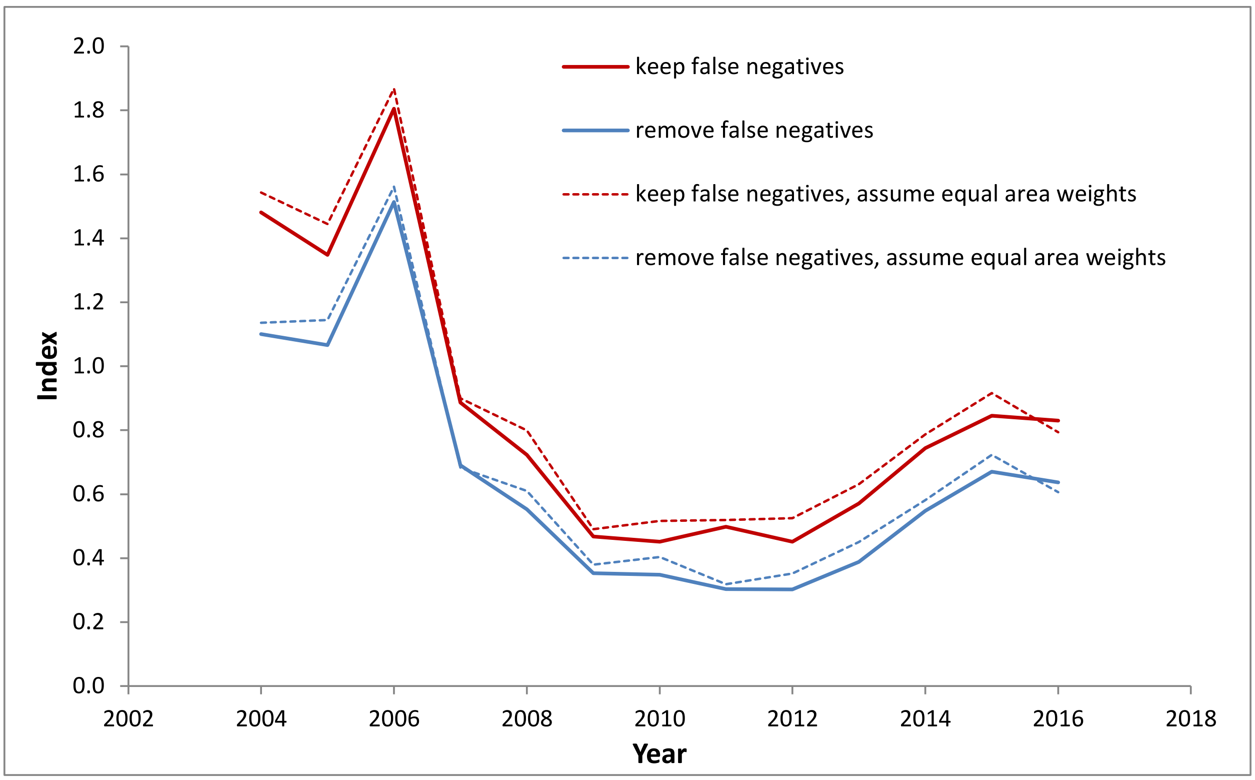


Figure 27: Sensitivity of CRFS private boat index to assumptions about data filtering and area weights.

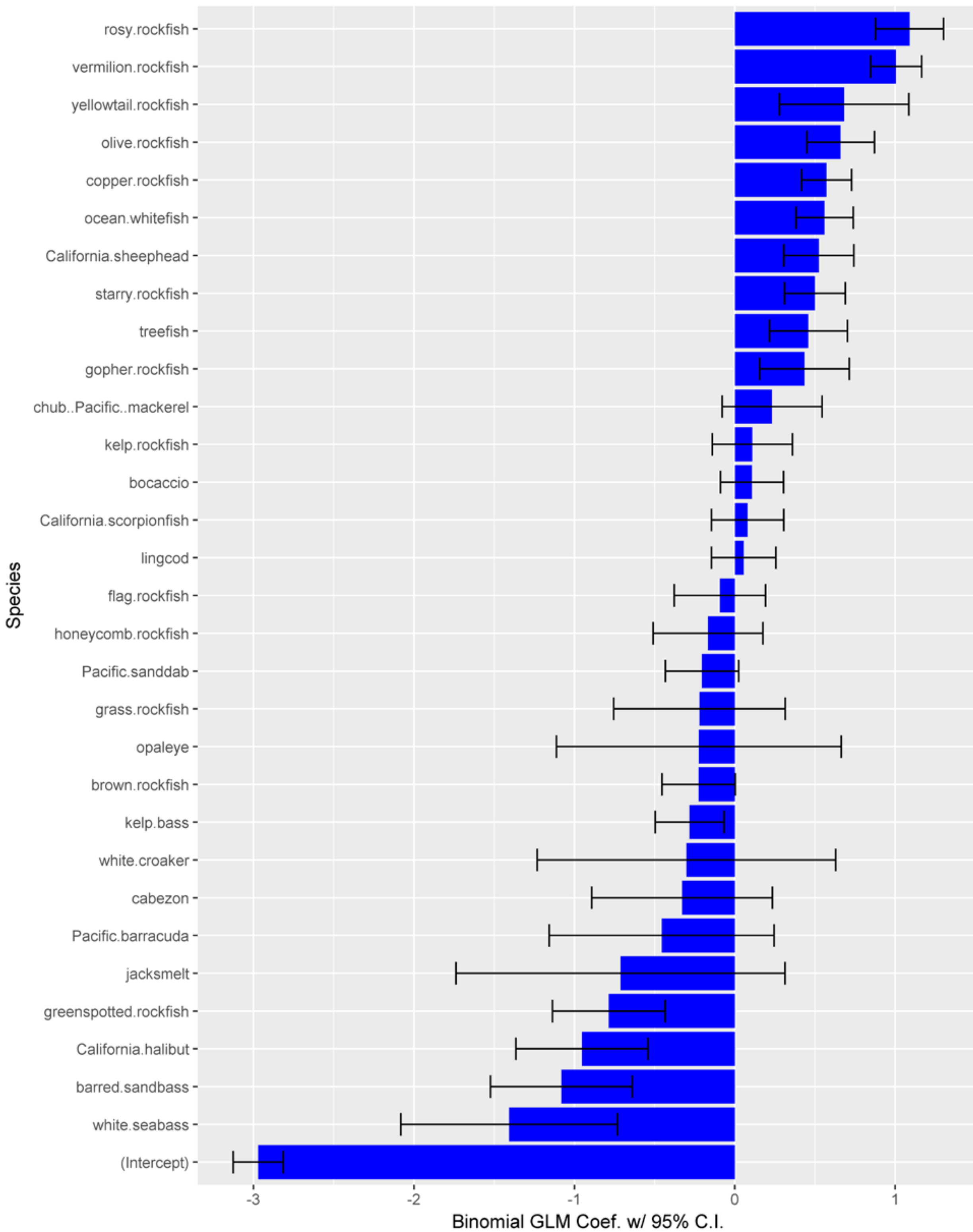


Figure 28: Species coefficients (blue bars) from the binomial GLM for presence/absence of Blue/Deacon rockfish in the CRFS private boat data for Santa Barbara and Ventura counties (Southern California). Horizontal black bars are 95% confidence intervals.

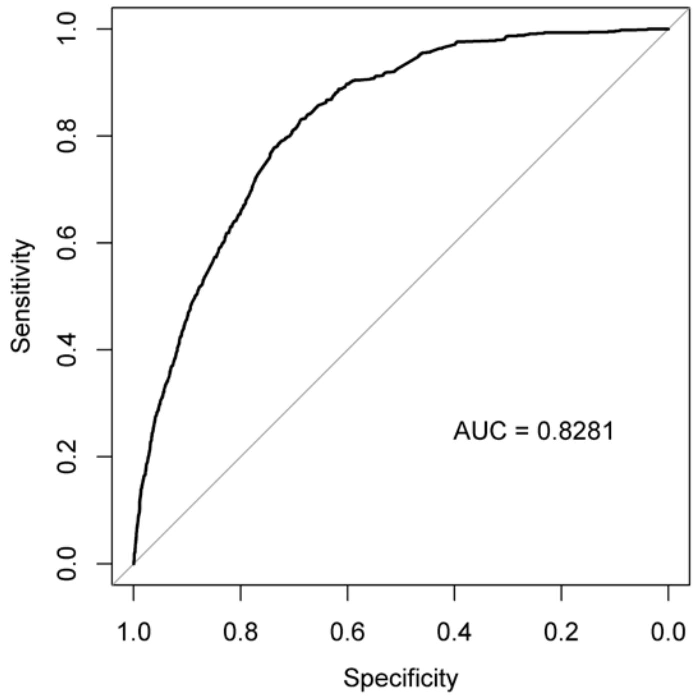


Figure 29: CRFS private boat (Santa Barbara and Ventura counties, Southern California) Receiver Operating Characteristic (ROC) curve for Stephens-MacCall logistic regression model.

Figure 30: CRFS private boat Southern California catch rates (observed fish per angler hour) of Blue and Deacon Rockfish by year and county.

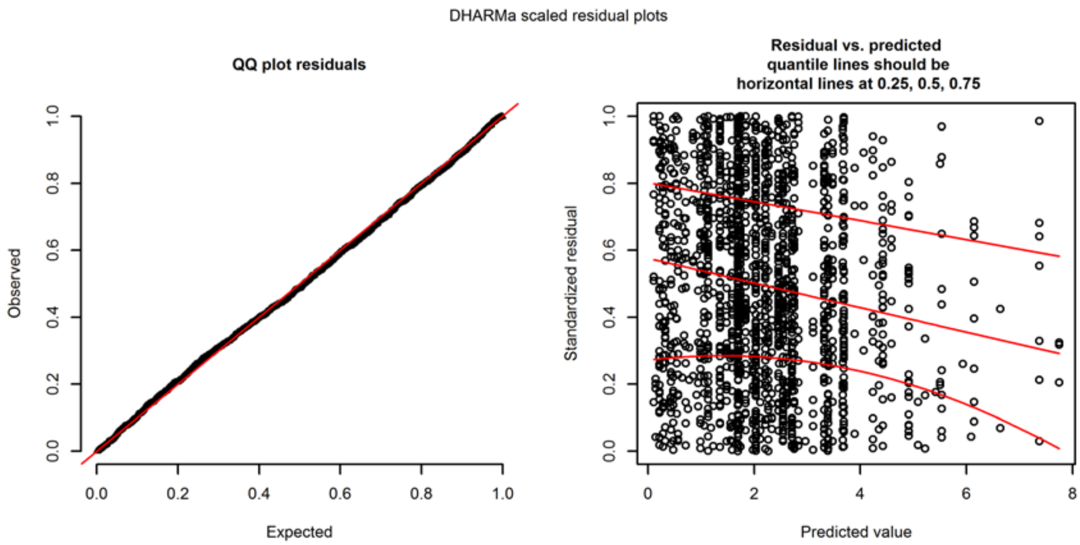


Figure 31: Diagnostic check of distributional assumptions in the main effects negative binomial model for CRFS Southern California (Santa Barbara and Ventura counties) private boat data.

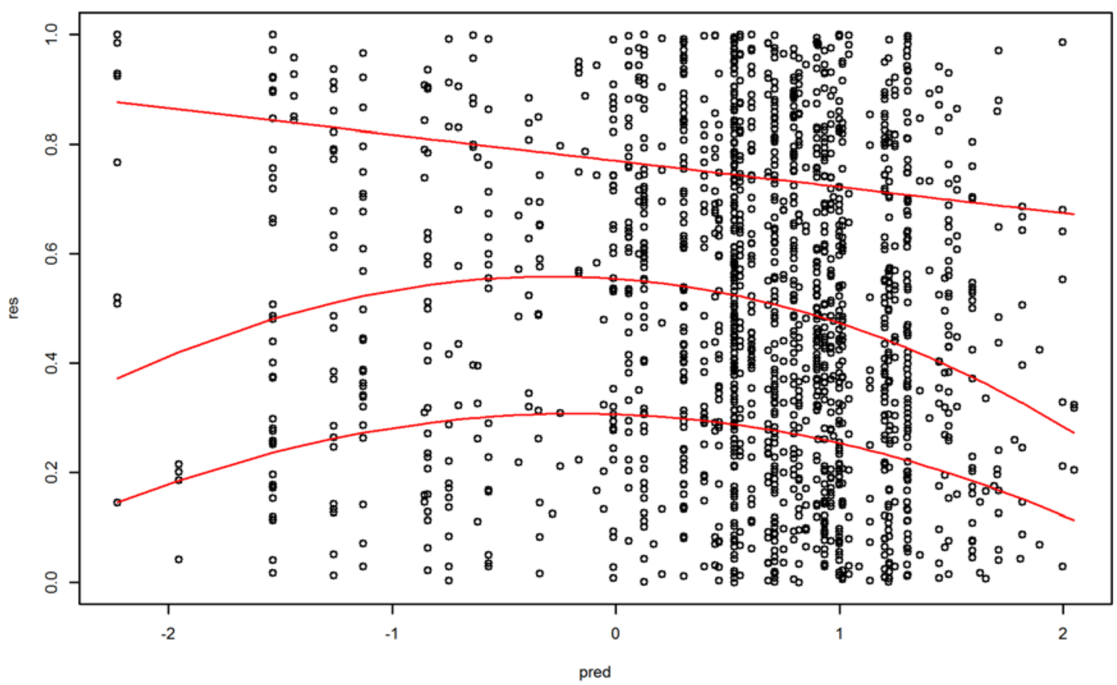


Figure 32: Standardized (quantile) residuals vs. link-scale predictions from the negative binomial model for CRFS Southern California (Santa Barbara and Ventura counties) private boat data.

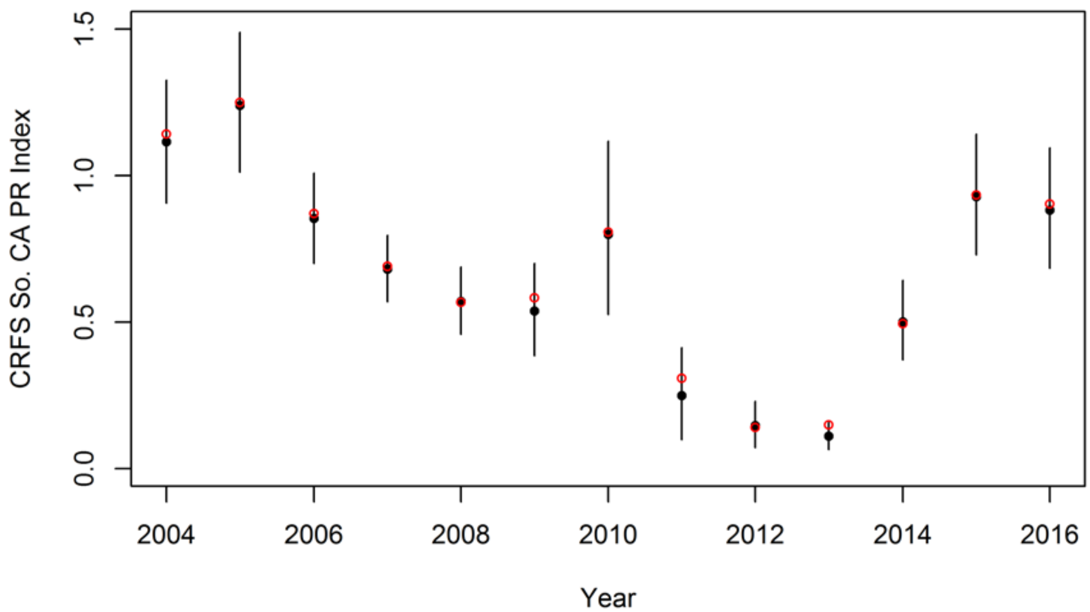


Figure 33: CRFS private boat Southern California index (solid black circles) with 95% highest posterior density intervals. Red circles are raw, annual mean catch-per-angler-hour. Data are limited to Santa Barbara and Ventura counties.

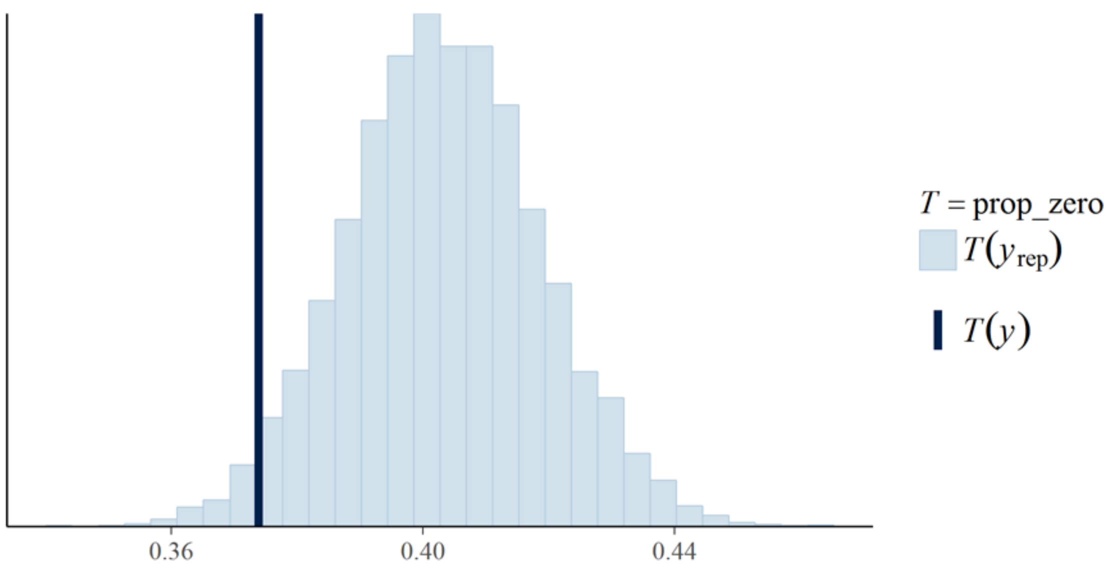


Figure 34: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for CRFS private boat Southern California data (Santa Barbara and Ventura counties).

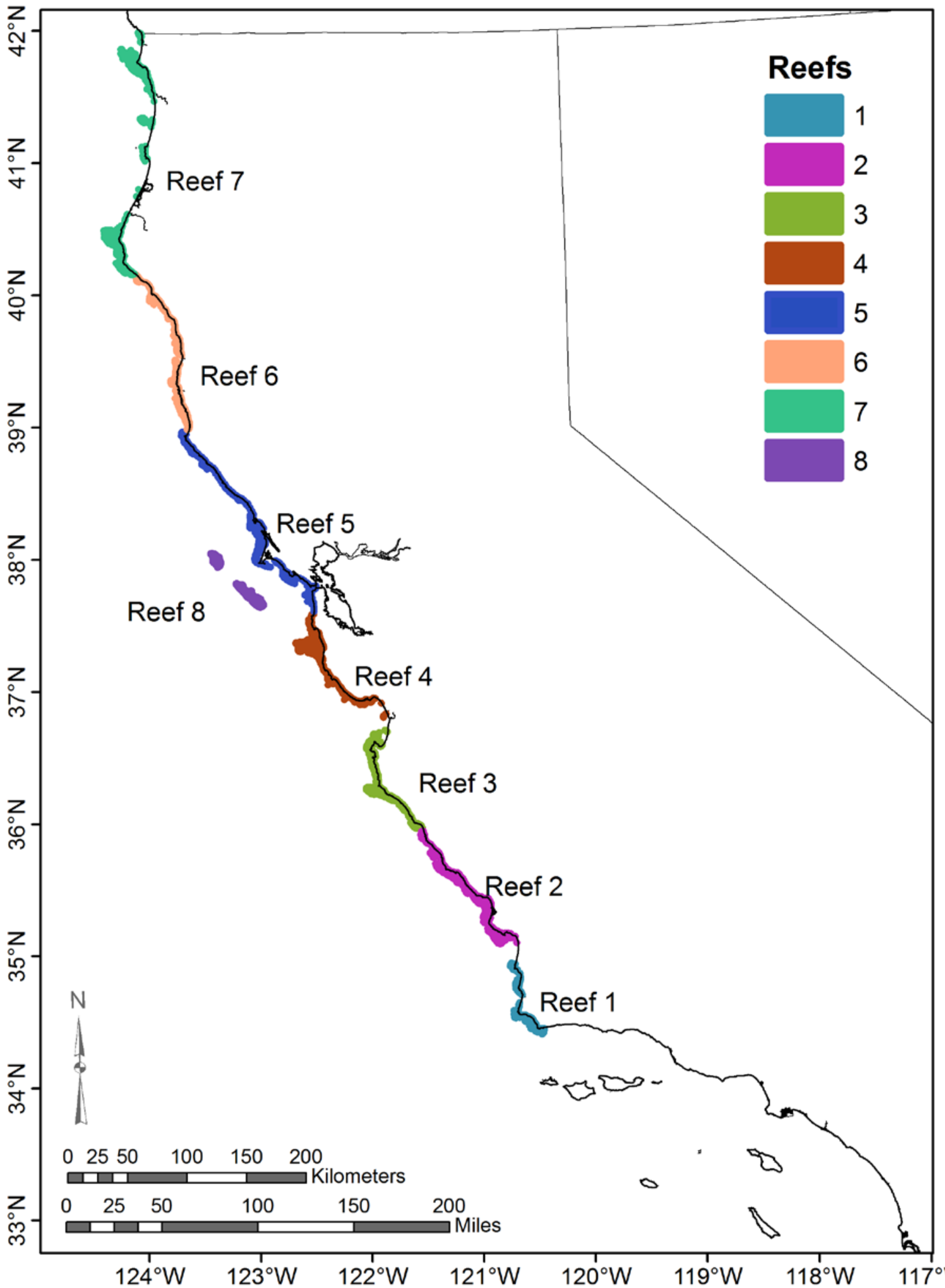


Figure 35: Rocky reef habitat between Point Conception and the CA/OR border, partitioned into 8 "mega reefs" and used for spatial stratification of onboard CPFV abundance indices.

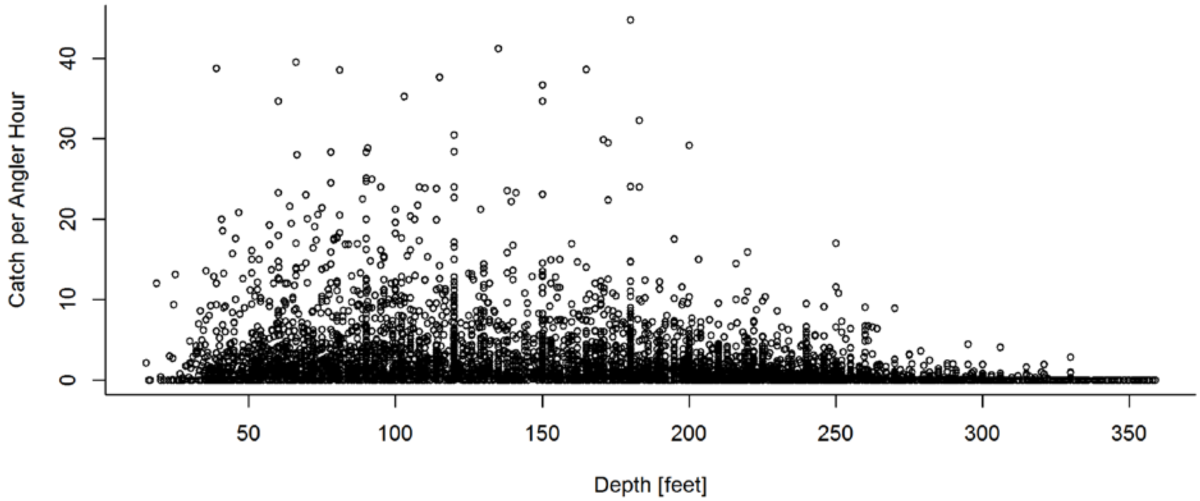


Figure 36: Catch per angler hour versus depth from the Central California onboard observer index, 1988-1998.

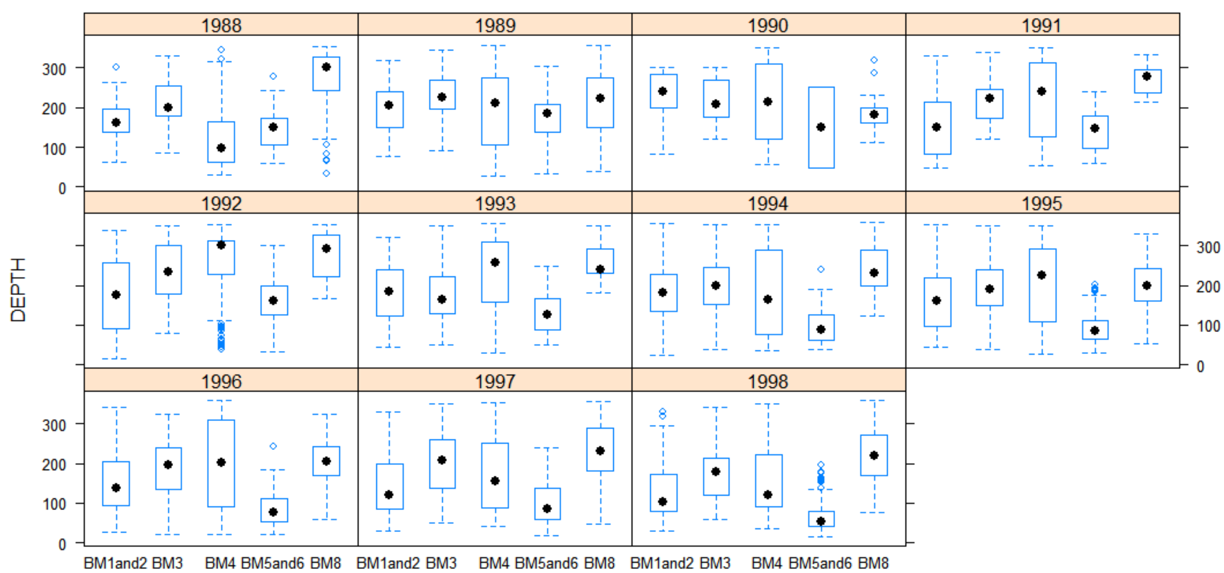


Figure 37: Observed depths fished (in feet) by year and area, Central California onboard observer index, 1988-1998.

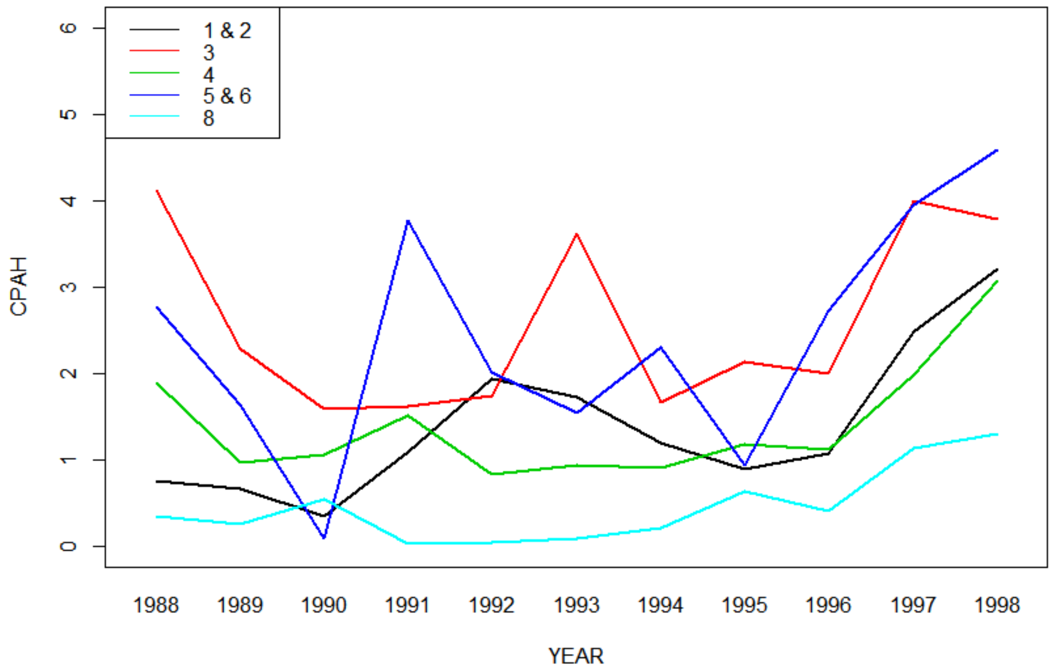


Figure 38: Mean catch-per-angler-hour (CPAH) by year and "mega reef" area, Central California onboard CPFV observer data, 1988-1998.

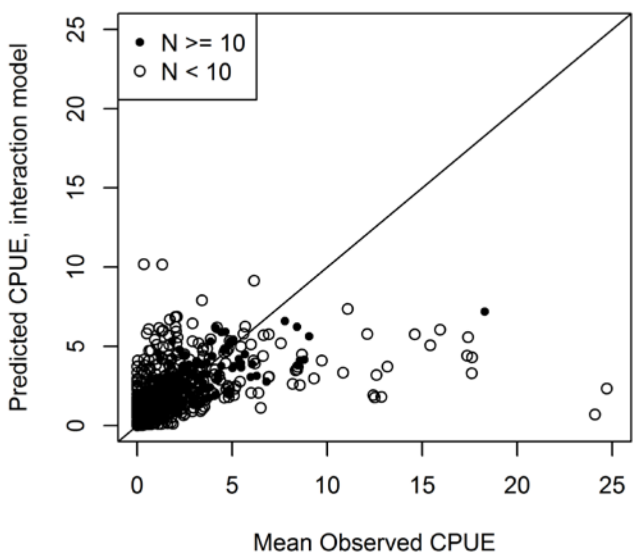


Figure 39: Predicted vs. observed mean CPUE from the Central California onboard CPFV observer data (1988-1998) negative binomial model. Open circles indicate strata with fewer than 10 samples.

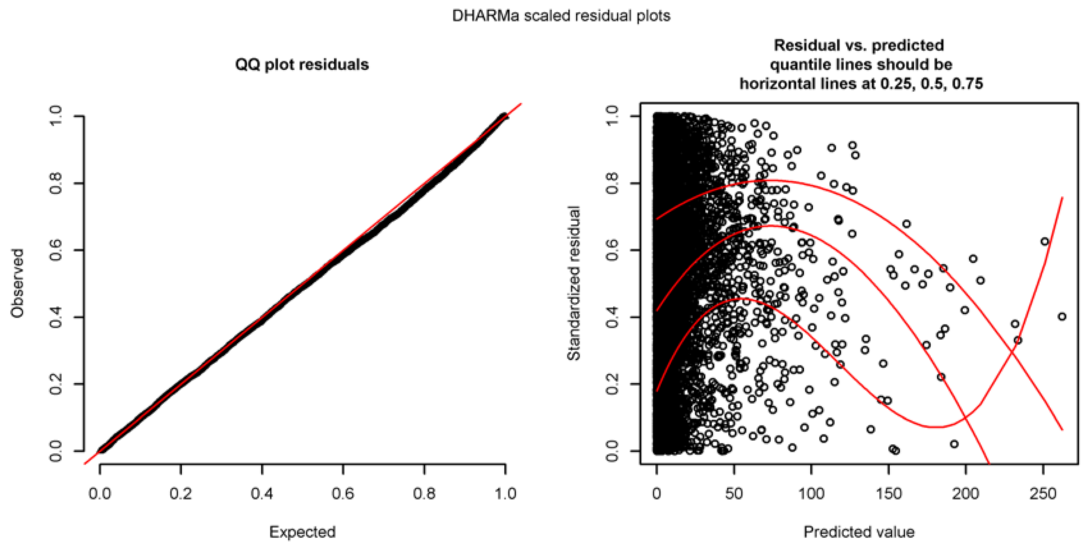


Figure 40: Diagnostic check of distributional assumptions in the best-fit negative binomial model for Central California onboard CPFV observer data (1988-1998).

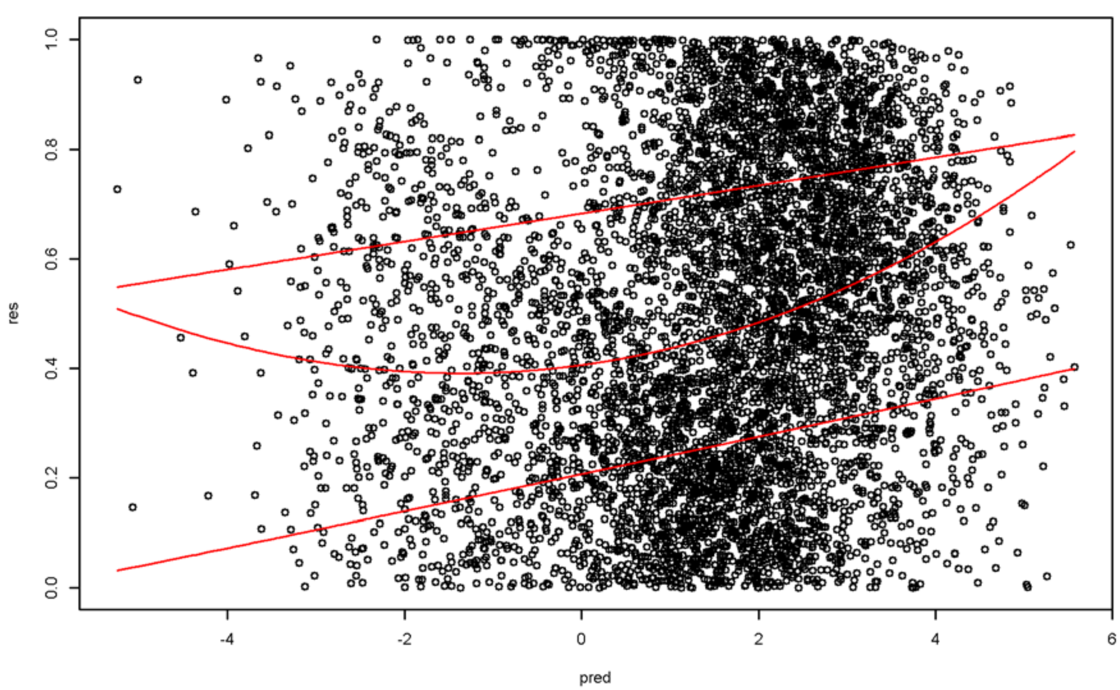


Figure 41: Standardized (quantile) residuals vs. link-scale predictions from the negative binomial model for Central California onboard CPFV observer data (1988-1998). Due to the highly skewed distribution of catches, patterns in scaled residuals are clearer on the link scale.

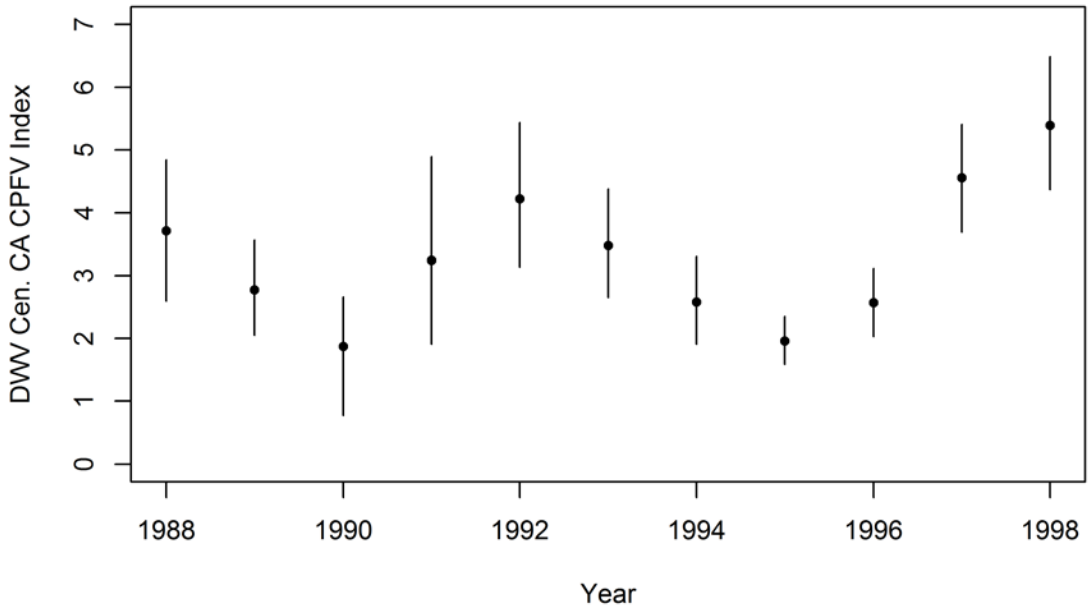


Figure 42: Central California onboard CPFV observer (1988-1998) index with 95% highest posterior density intervals.

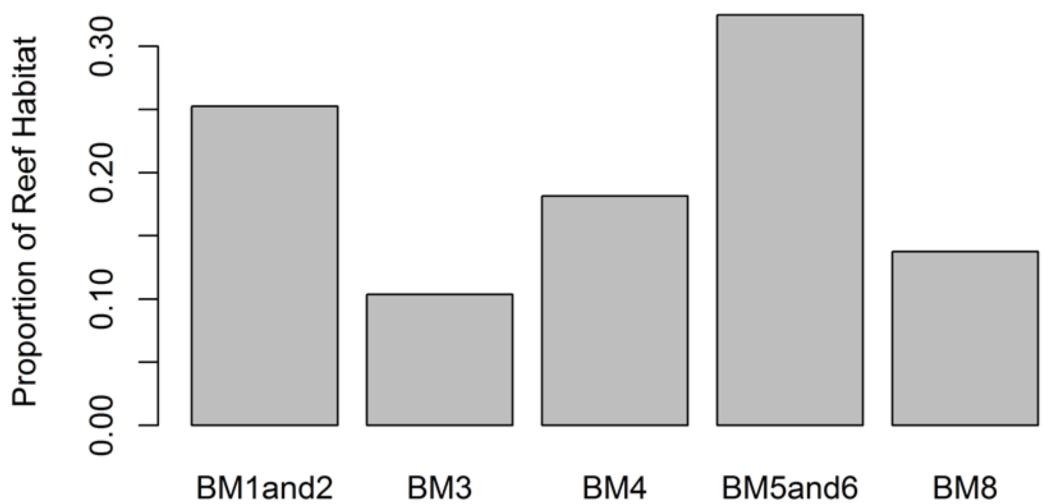


Figure 43: Mega-reef normalized area weights used in Central California onboard CPFV observer (1988-1998) index.

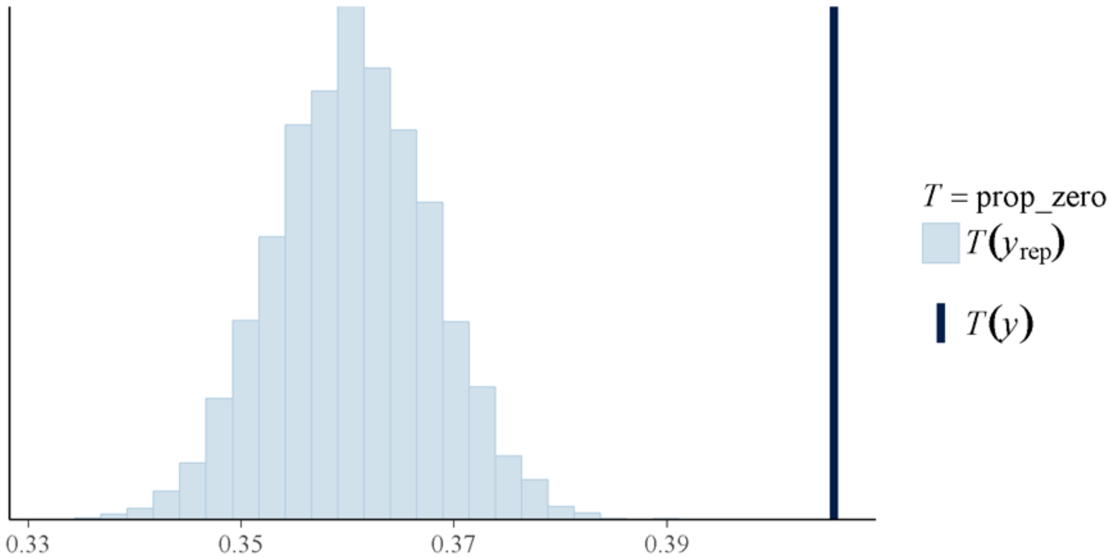


Figure 44: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for Central California onboard CPFV observer data (1988-1998).

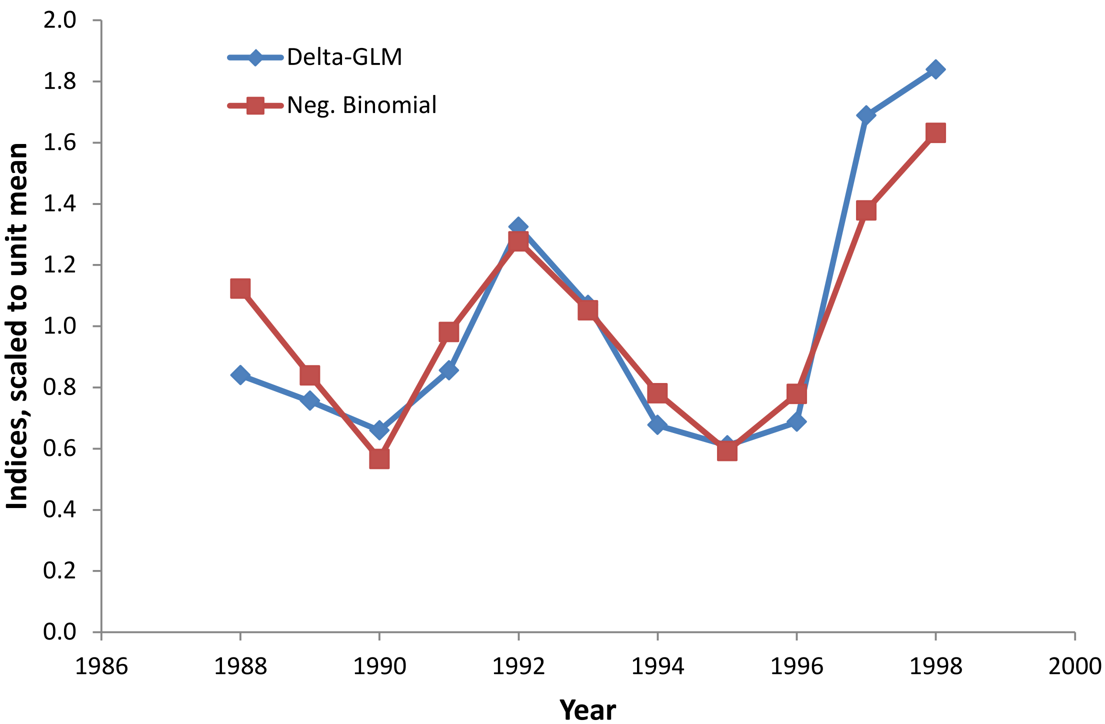


Figure 45: Negative binomial and delta-GLM models for Central California onboard CPFV observer data (1988-1998).

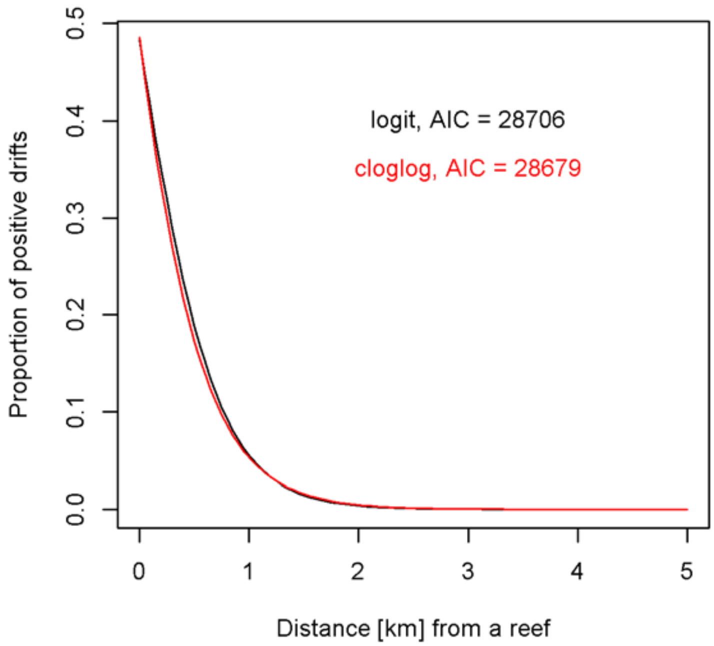


Figure 46: Probability of catching at least one Blue or Deacon Rockfish as a function of distance [km] to the nearest reef.

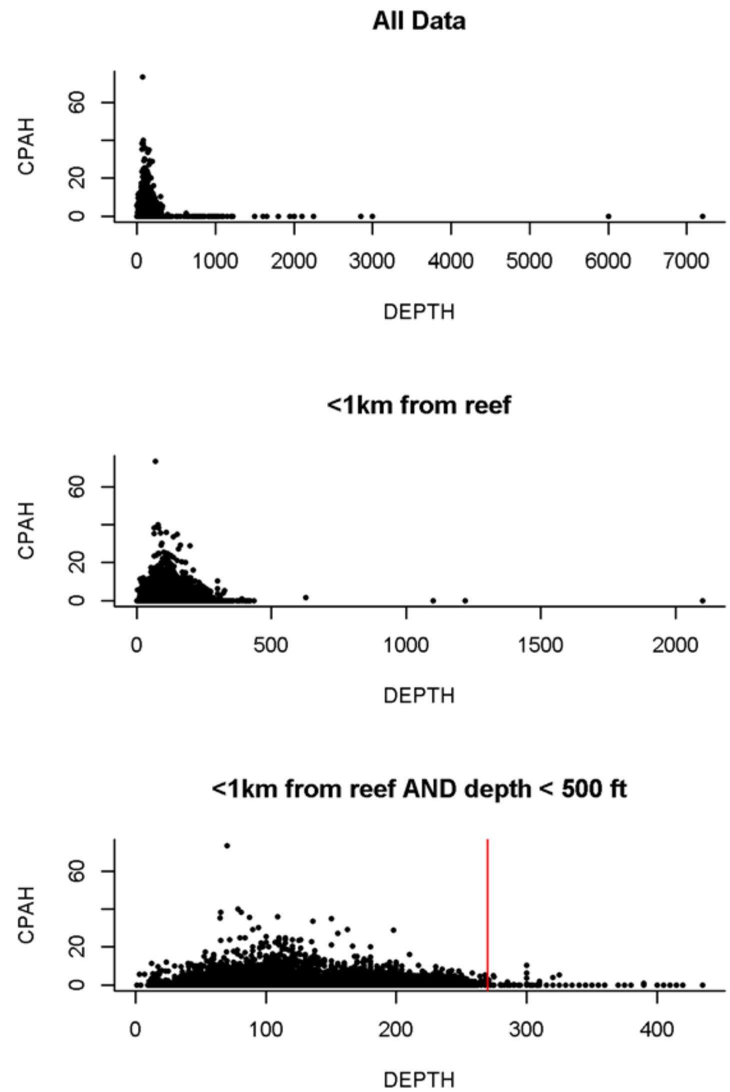


Figure 47: Catch per angler hour (CPAH) as a function of depth (feet). Upper panel: all data, middle panel: data filtered to drifts <1km from reef, lower panel: drifts <1km from reef and in depths < 500 ft. Red vertical line indicates depth (270 feet; 45 fathoms) above which drifts were excluded.

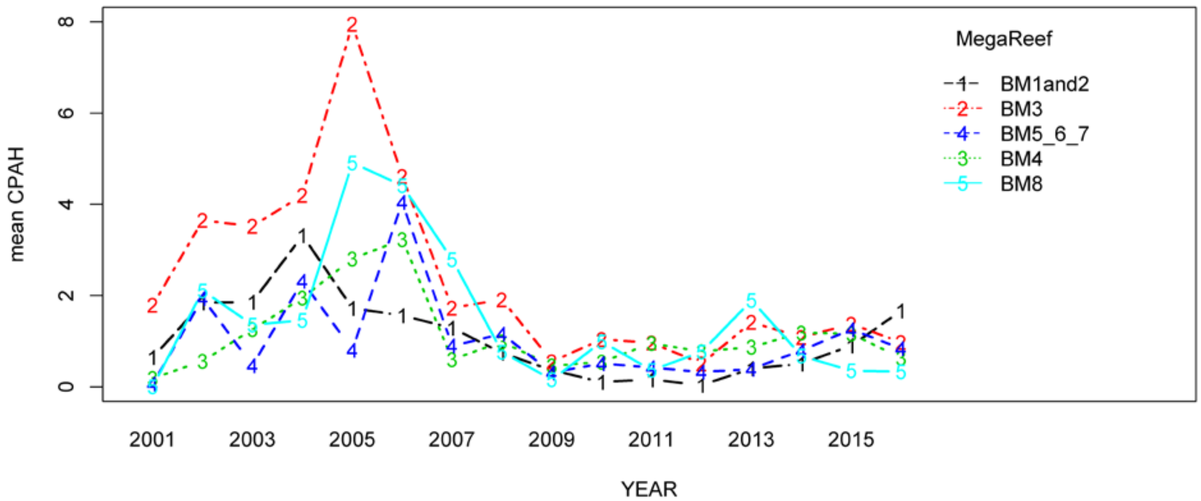


Figure 48: Observed mean catch per angler hour (CPAH) by year and reef area ("MegaReef") for the Northern California onboard CPFV observer index data set.

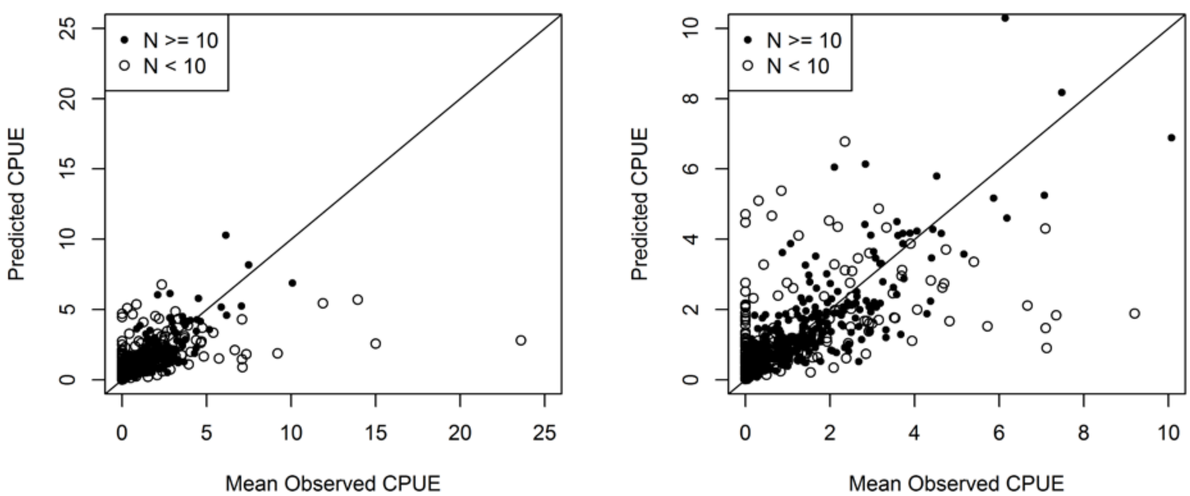


Figure 49: Predicted vs. Observed CPAH ("CPUE") for the negative binomial GLM for Northern California onboard CPFV observer data, 2001-2016. Left-panel: full range of observed mean CPAH; Right panel: detail of CPAH values between 0 and 10 fish per angler hour. Note small sample sizes for large observed catch rates.

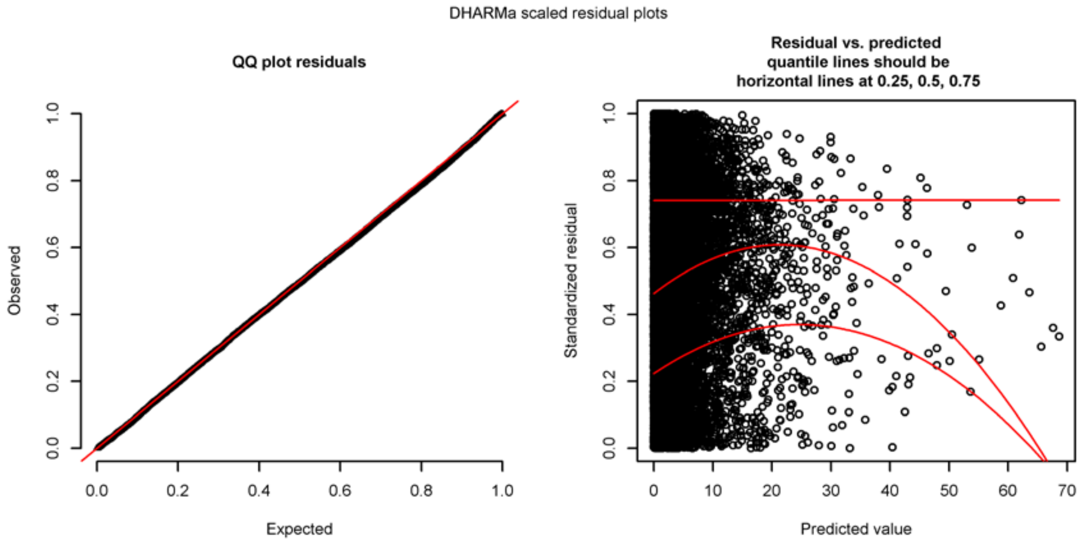


Figure 50: Diagnostic check of distributional assumptions in the best-fit negative binomial model for Northern California onboard CPFV observer data, 2001-2016.

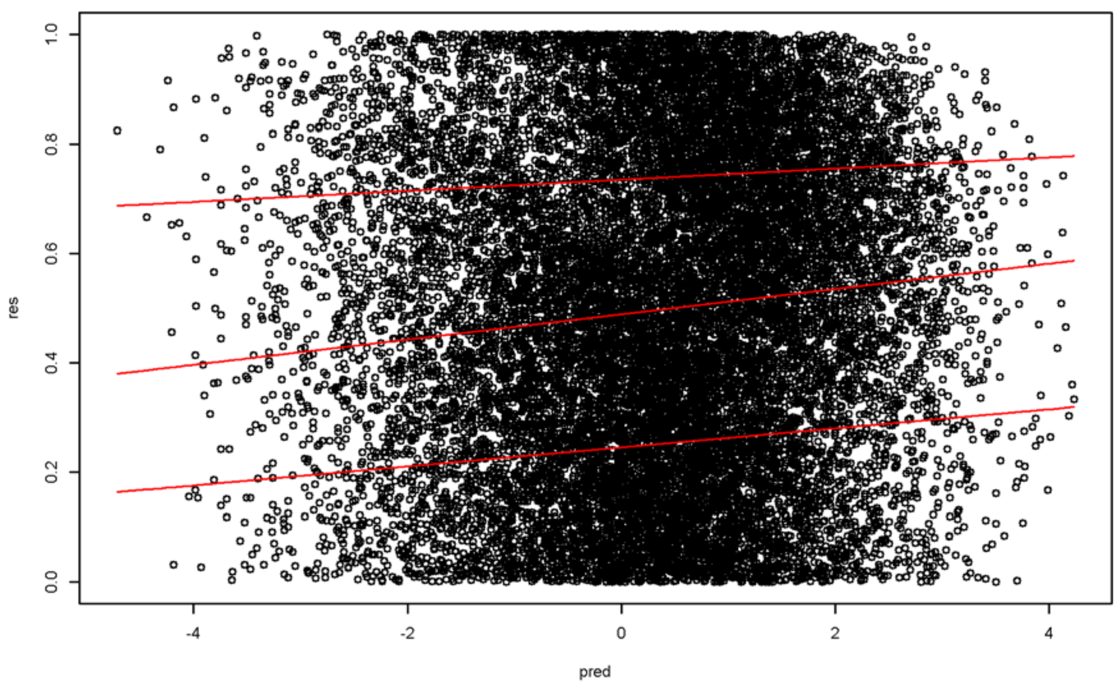


Figure 51: Standardized (quantile) residuals vs. link-scale predictions from the negative binomial model for Northern California onboard CPFV observer data, 2001-2016. Due to the highly skewed distribution of catches, patterns in scaled residuals are clearer on the link scale.

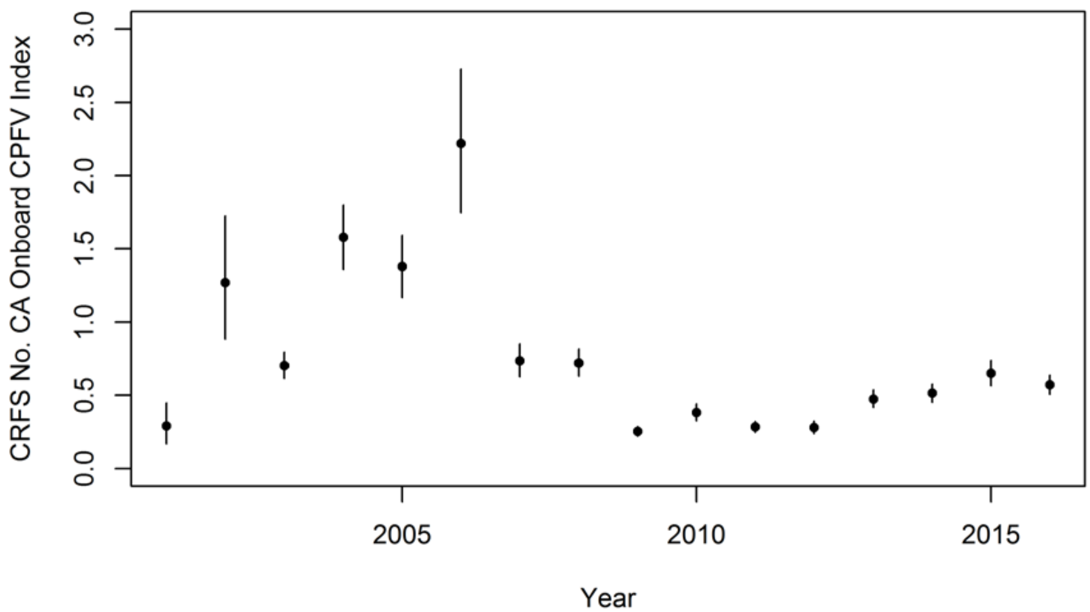


Figure 52: CDFW Onboard CPFV Observer Index for Northern California.

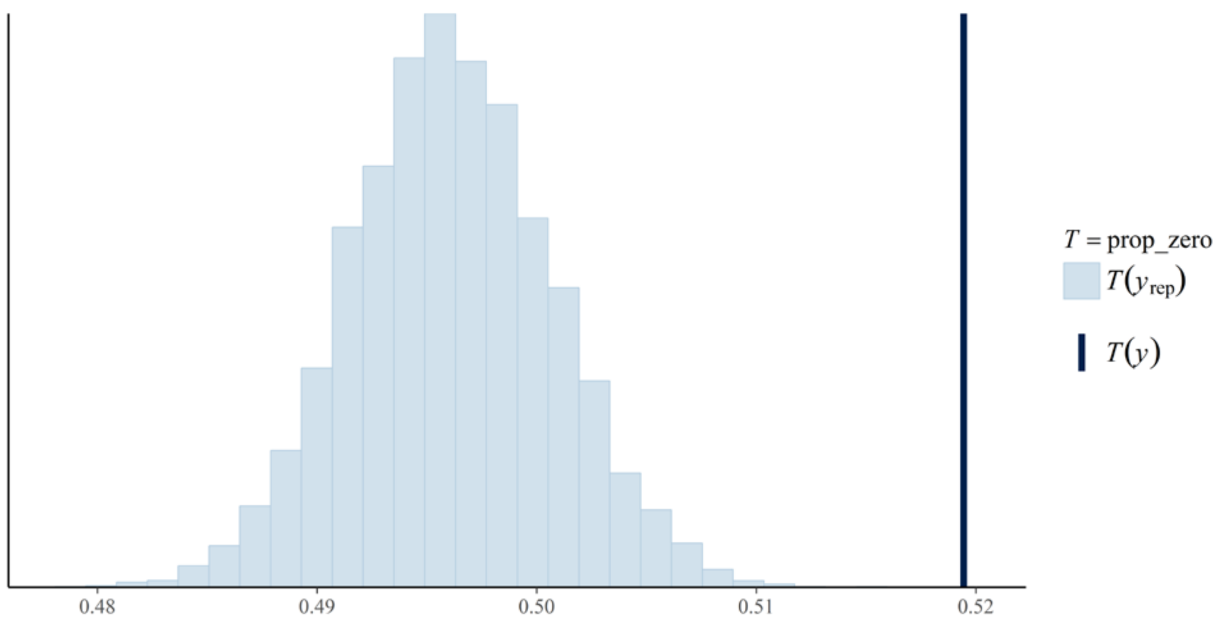


Figure 53: Posterior predictive distribution of the proportion of zero observations in replicate data sets generated by the negative binomial model for the CDFW Onboard CPFV Observer Index for Northern California.

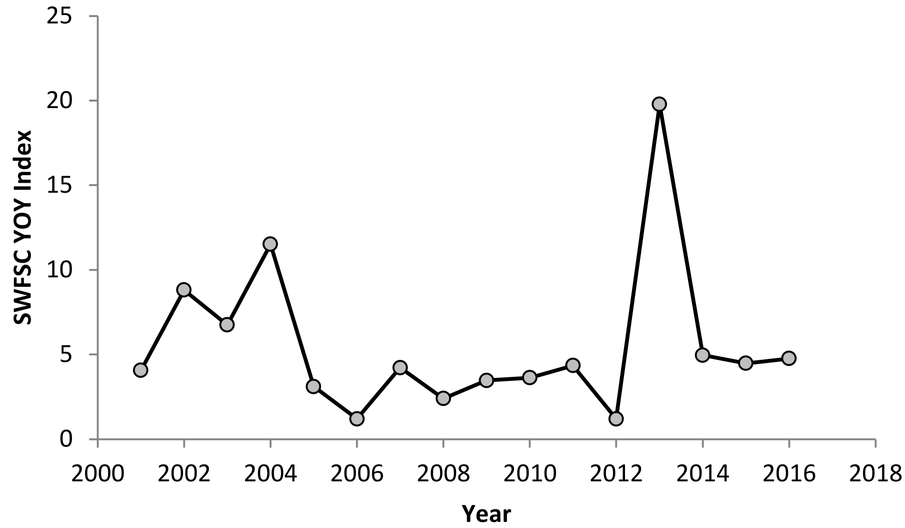


Figure 54: NMFS SWFSC pelagic juvenile index for Blue and Deacon Rockfishes.

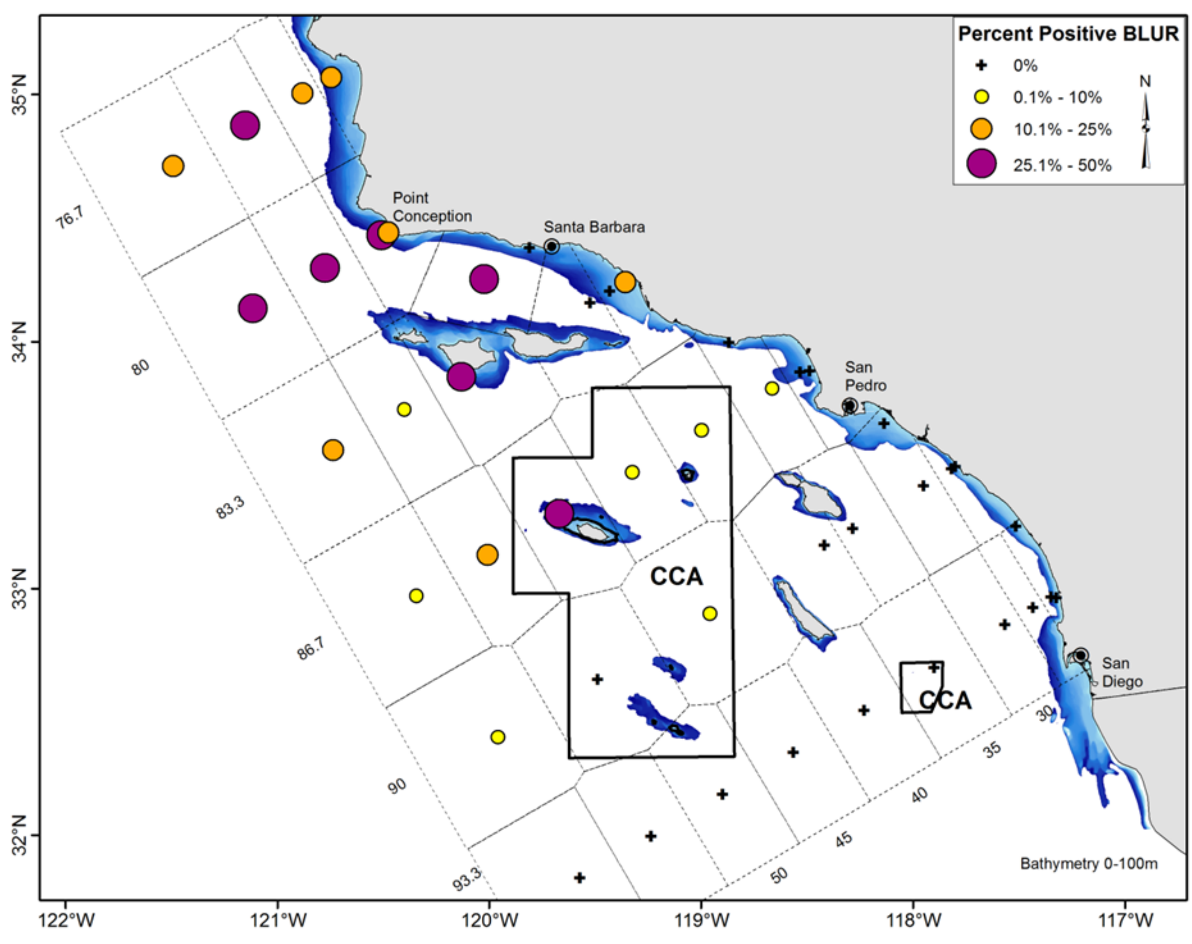


Figure 55: Station locations, with proportion positive by station over the CalCOFI index time period.

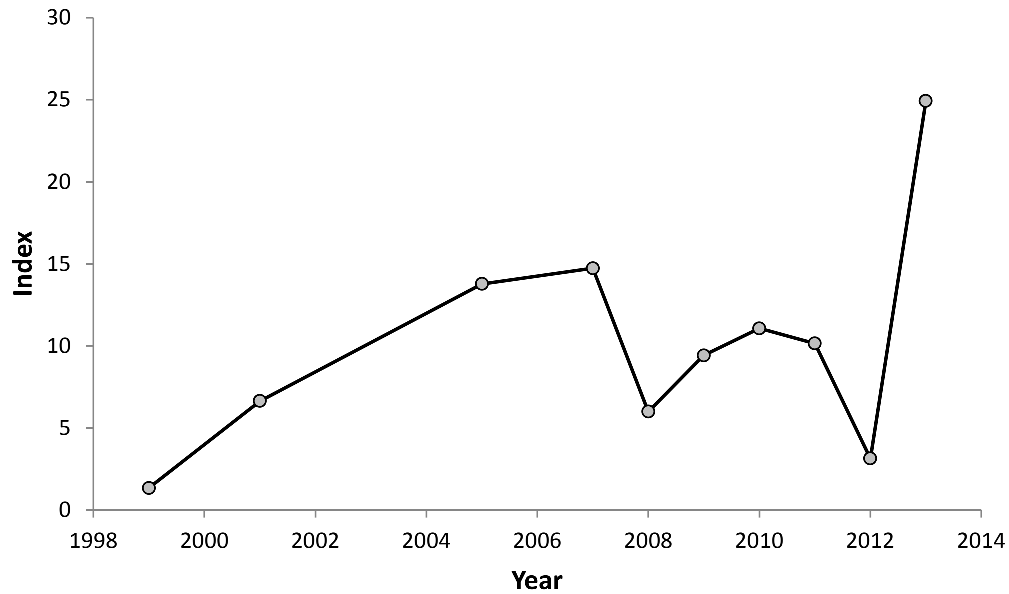


Figure 56: CalCOFI larval abundance index for Southern California.

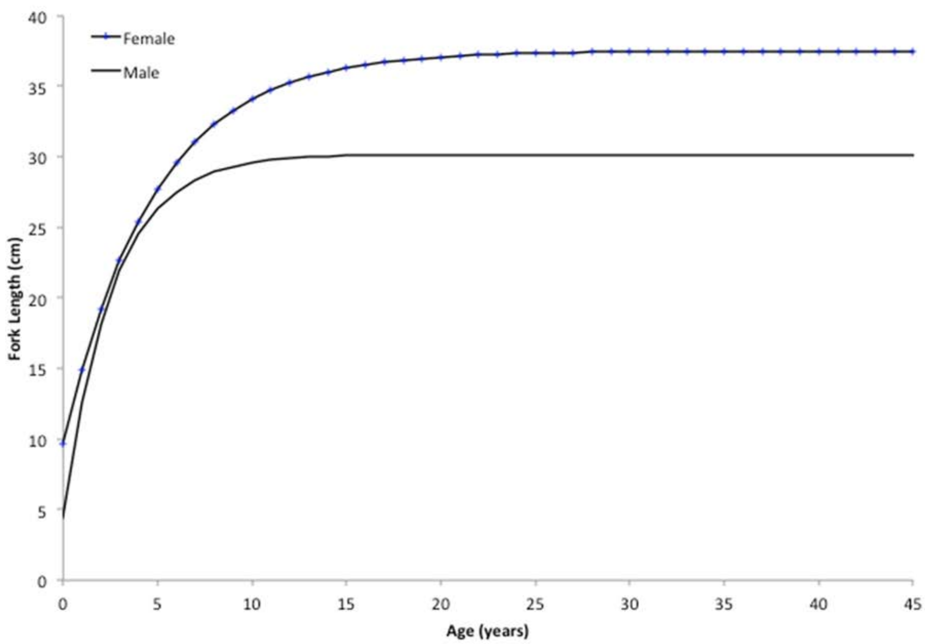


Figure 57: Fitted von Bertalanffy growth curves for female (n = 3589) and male (n = 1367) Blue Rockfish (*Sebastes mystinus*) and Deacon Rockfish (*S. diaconus*) collected throughout California and Oregon waters.

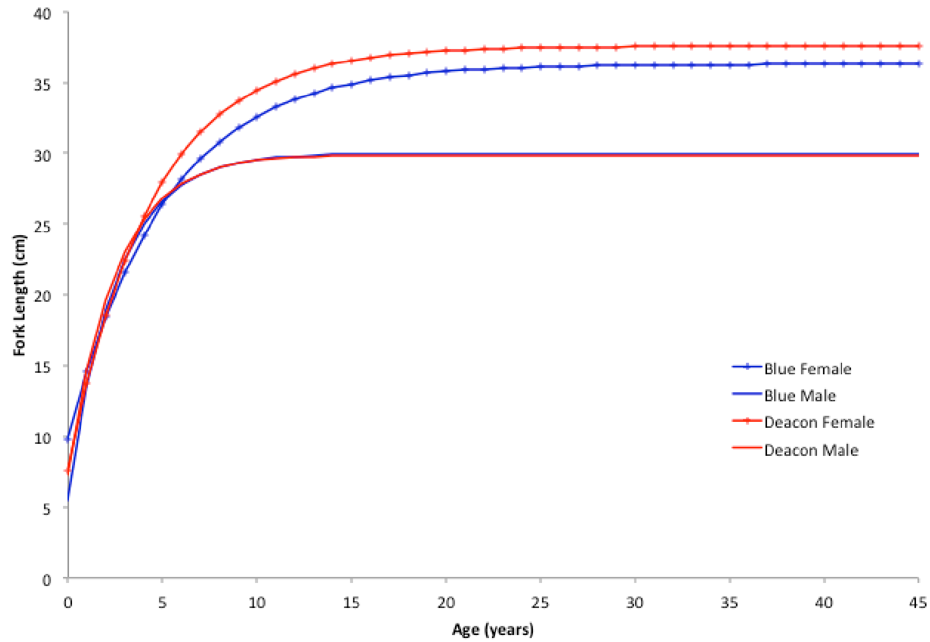


Figure 58: Fitted von Bertalanffy growth curves for female (n = 1142) and male (n = 203) Blue Rockfish (*Sebastes mystinus*) and female (n = 2447) and male (n = 1164) Deacon Rockfish (*S. diaconus*) collected throughout California and Oregon waters.

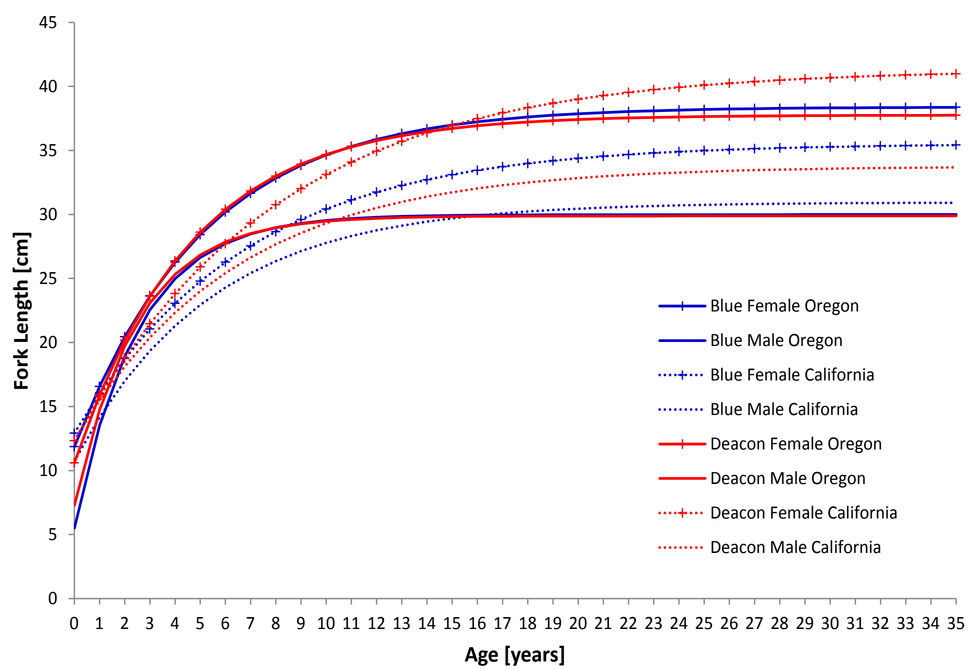


Figure 59: Fitted von Bertalanffy growth curves for female (n_{CA} = 532, n_{OR} = 610) and male (n_{CA} = 86, n_{OR} = 117) Blue Rockfish (*Sebastes mystinus*) and female (n_{CA} = 328, n_{OR} = 2119) and male (n_{CA} = 154, n_{OR} = 1010) Deacon Rockfish (*S. diaconus*) collected from either California or Oregon waters.

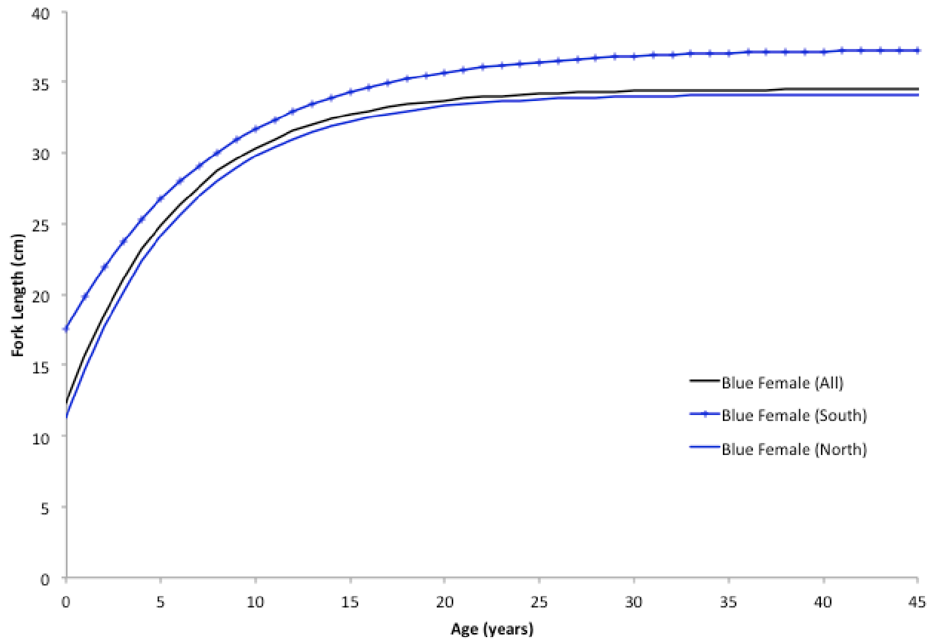


Figure 60: Fitted von Bertalanffy growth curves for female Blue Rockfish (*Sebastes mystinus*) collected south of Point Conception (n = 112), north of Point Conception (n = 292), and from both regions combined (n = 404).

Age (years), Read 2 / Age (years), read 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Frequency, Read 2
Frequency, Read 1	1	13	35	58	41	42	78	64	35	41	33	33	19	18	20	12	13	11	4	4	3	1	6	1		1	587
33																								1			1
32																											
31																											
30																											
29																											
28																											
27																										1	1
26																											
25																											
24																							2				2
23																							1				1
22																							2				2
21																			1	1							2
20																	1		1	2	1	1	1				7
19																	1	3	1		2						7
18																	3	2									5
17								1							2	5	2	3									13
16						1		1					1	1	1	4	2		1	1							13
15								1						4	11	2	2	2									22
14										1	1	2		6	2		1										13
13										1	2	5	11	2	2	1											24
12							1		1	1	4	20	6	4	1												38
11							1	1		3	17	5					1										28
10								4	2	22	5		1														34
9						1	6	10	21	8	2	1		1													50
8						1	7	39	8	4	1																60
7						4	56	5	2	1								1									69
6					2	31	5	2							1												41
5				2	34	3			1																		40
4			2	45	4	1	2				1																55
3		2	30	9	1																						42
2		11	3	2																							16
1	1																										1

Figure 61: Within-reader ageing agreement (D. Pearson, NMFS, SWFSC) for Blue and Deacon Rockfishes.

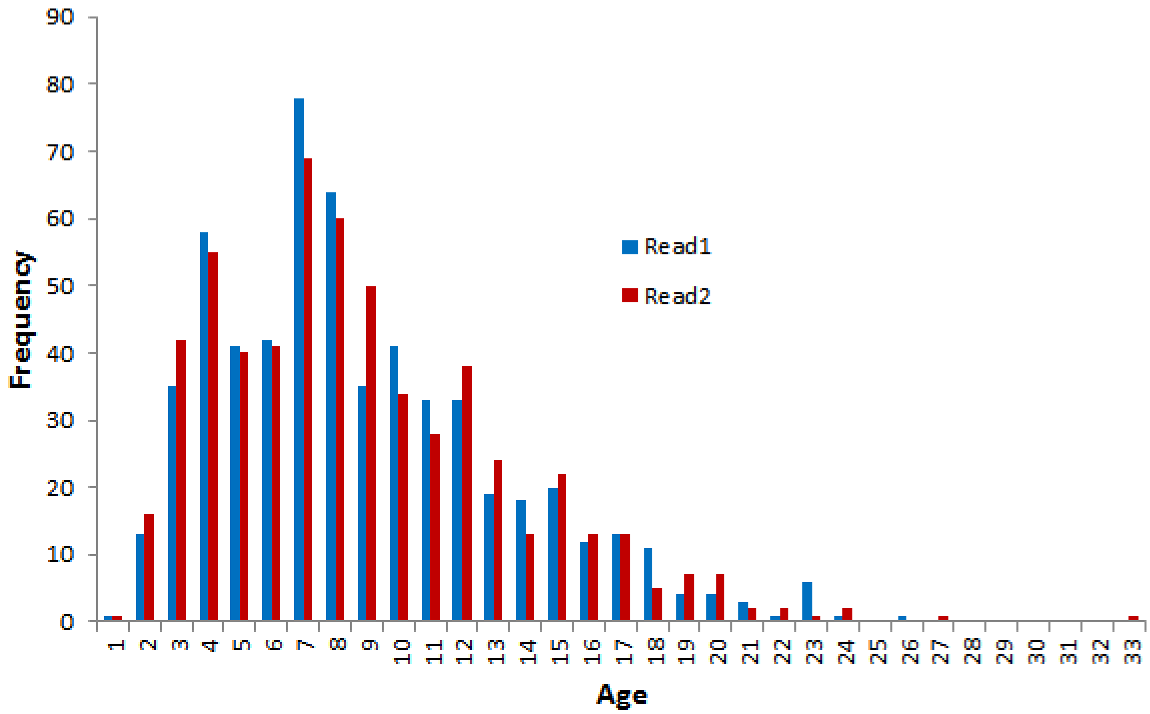


Figure 62: Comparison of age frequency distributions from first and second age reads (D. Pearson, NMFS, SWFSC) for Blue and Deacon Rockfishes.

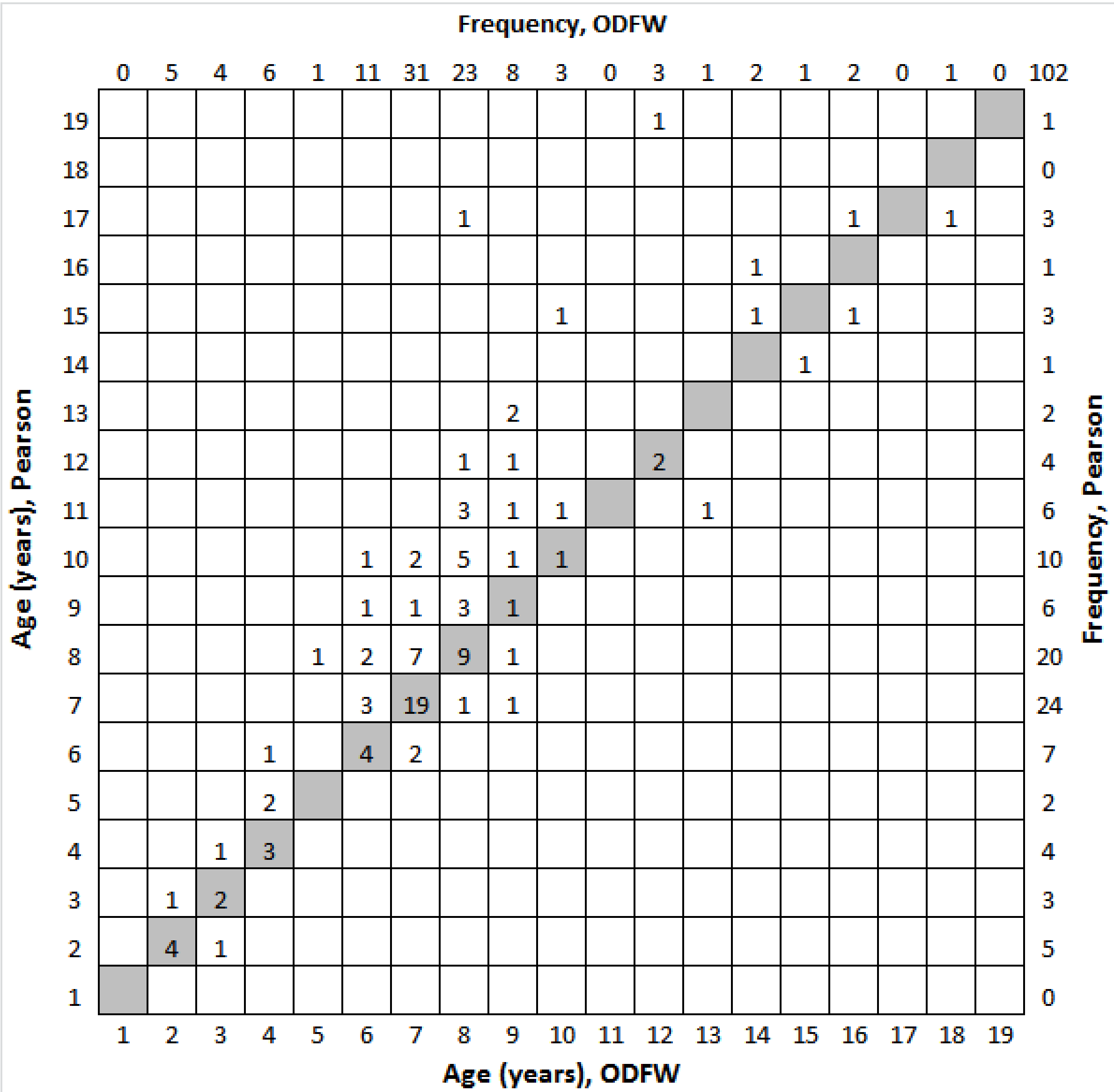


Figure 63: Among-reader ageing agreement (L. Kautzi, ODFW, and D. Pearson, NMFS, SWFSC) for Blue and Deacon Rockfishes.

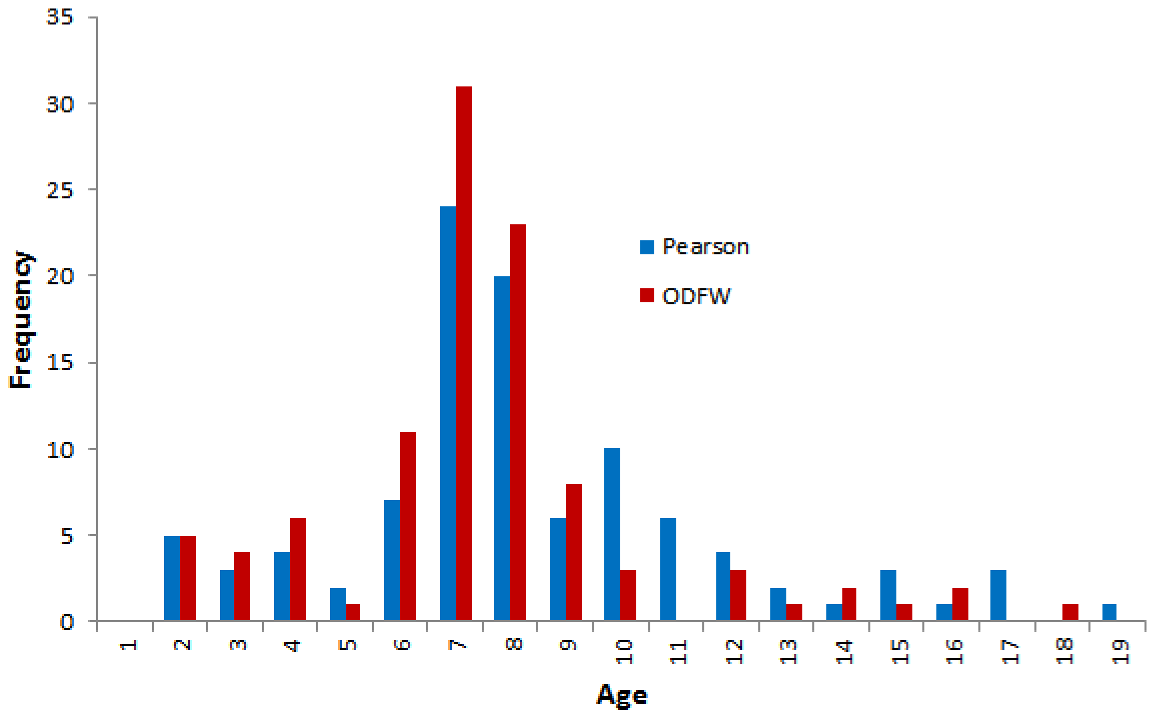


Figure 64: Comparison of age frequency distributions from two agers (L. Kautzi, ODFW, and D. Pearson, NMFS, SWFSC) for Blue and Deacon Rockfishes.

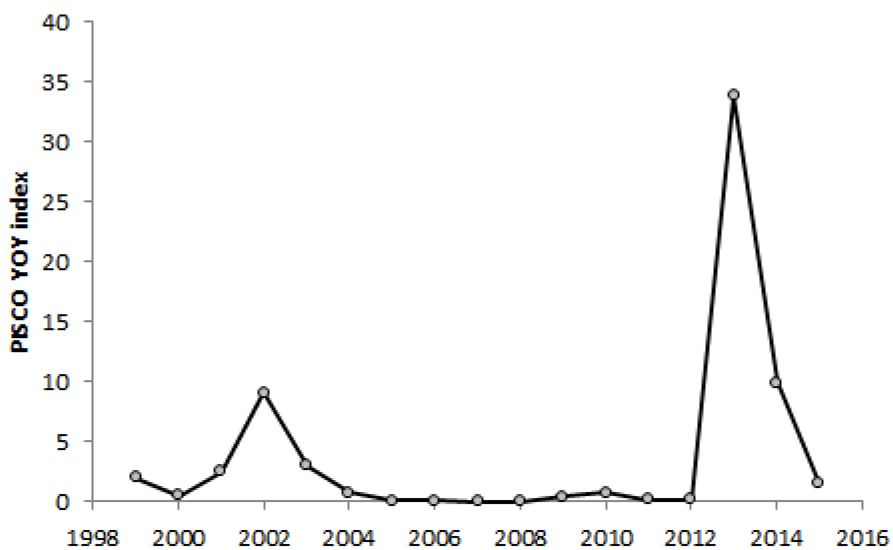


Figure 65: PISCO YOY index for Northern California.

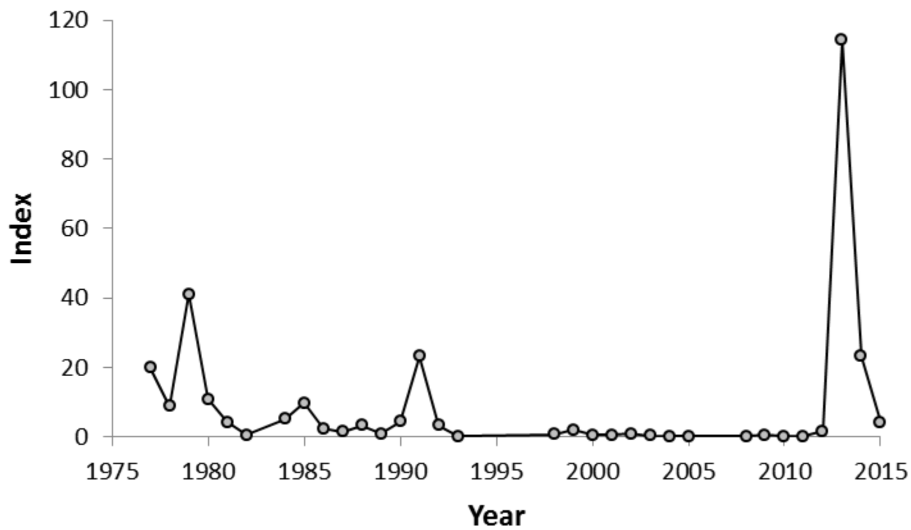


Figure 66: Index of Blue and Deacon rockfish juvenile relative abundance based on Tenera Dive Survey Data.

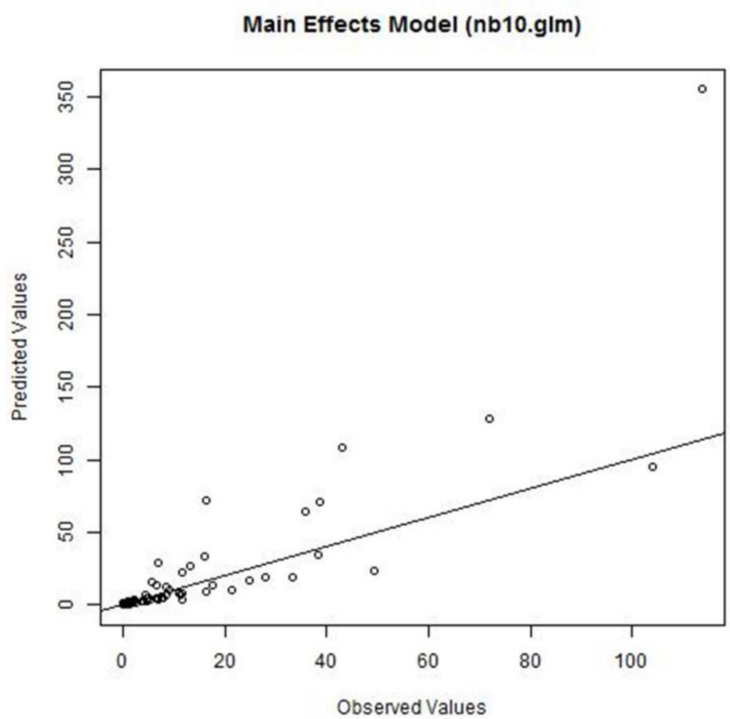


Figure 67: Tenera dive survey, comparison of final model predictions (mean fish per transect) to observed means in each stratum (Set Year and Location Site). The 1:1 line is plotted for reference.

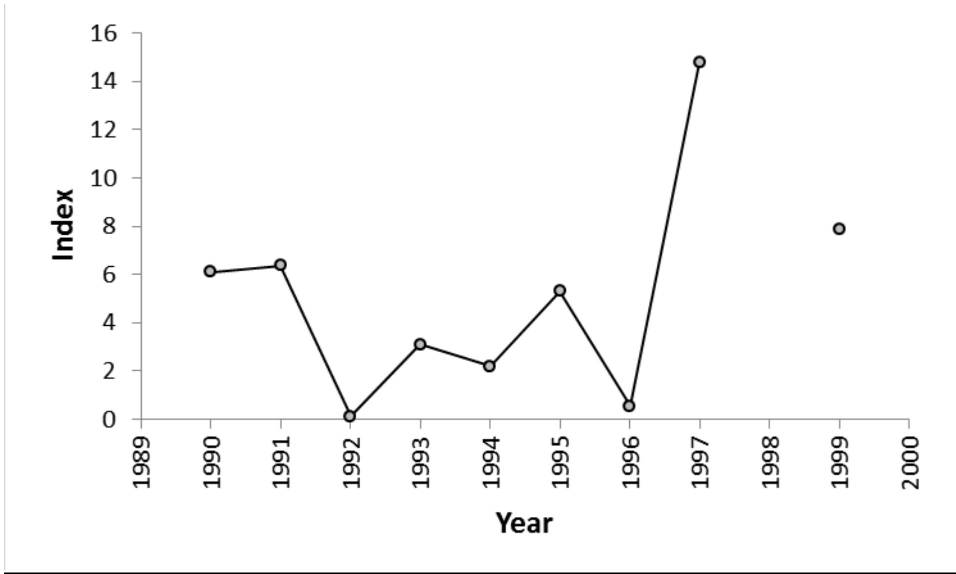


Figure 68: Juvenile abundance index based on CDFW/ VenTresca Dive Surveys.

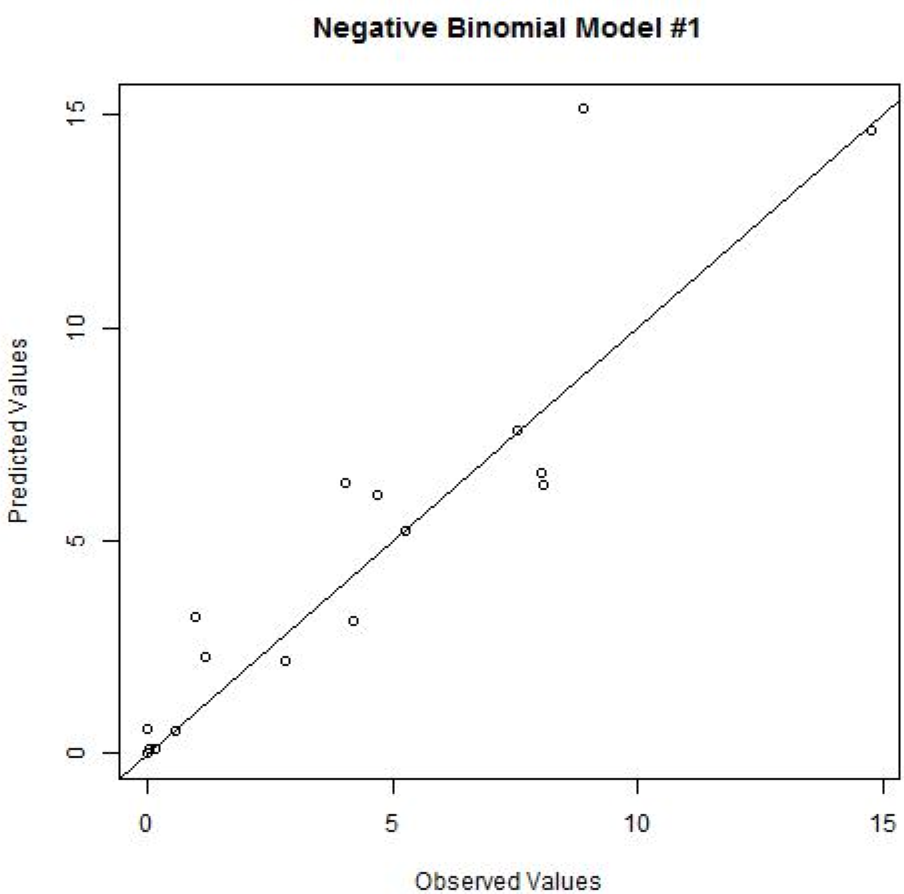


Figure 69: VenTresca dive survey: comparison of negative binomial model predictions (CPUE) to observed means in each stratum (Year and Region). The 1:1 line is plotted for reference.

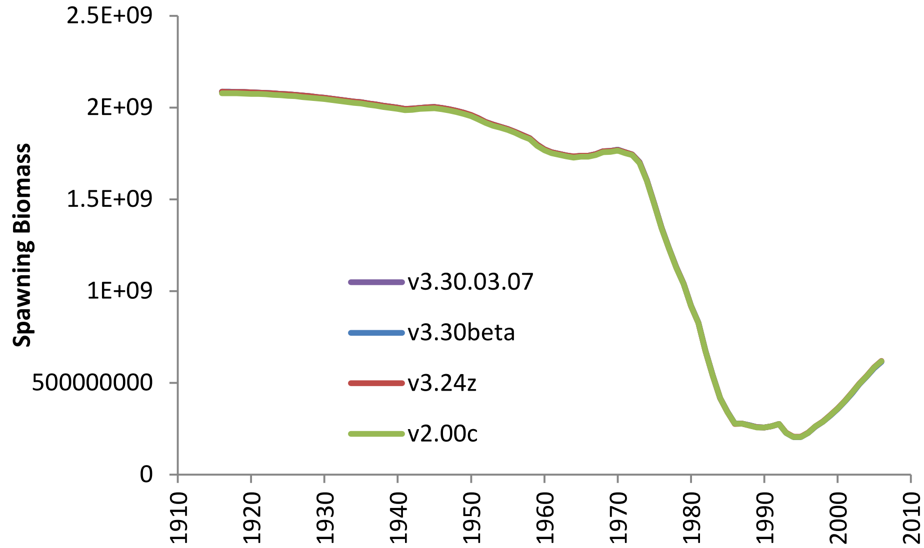


Figure 70: Spawning output trajectories associated with successive versions of Stock Synthesis (versions after "v2.00c" are similar enough to be hidden behind the green line).

Figure 71: Coefficients of variation of lengths as a function of age, by sex, for Blue and Deacon Rockfish (species combined).

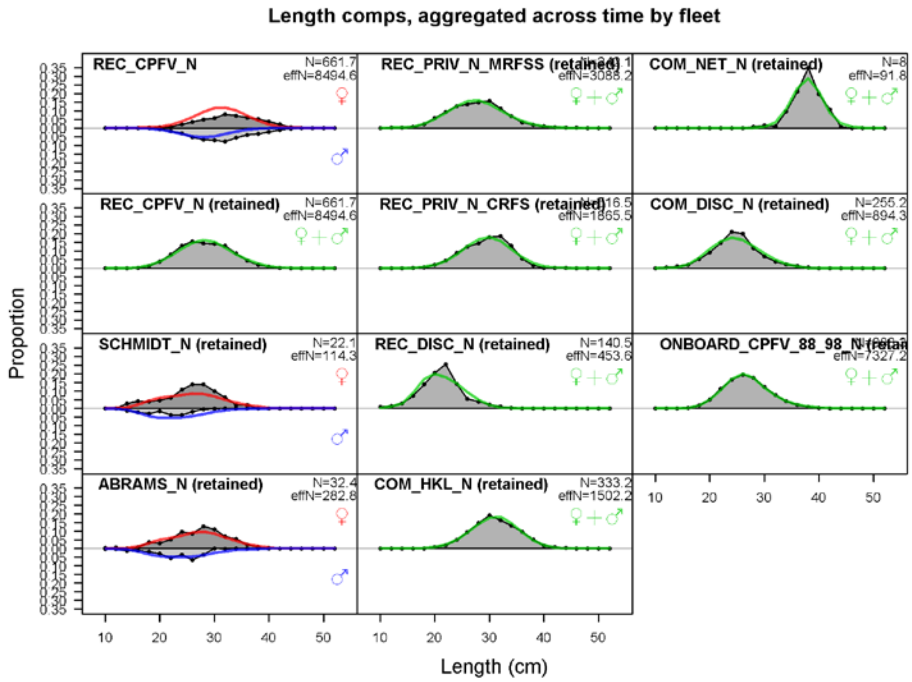


Figure 72: Base model fit to time-aggregated California BDR length compositions for all fleets

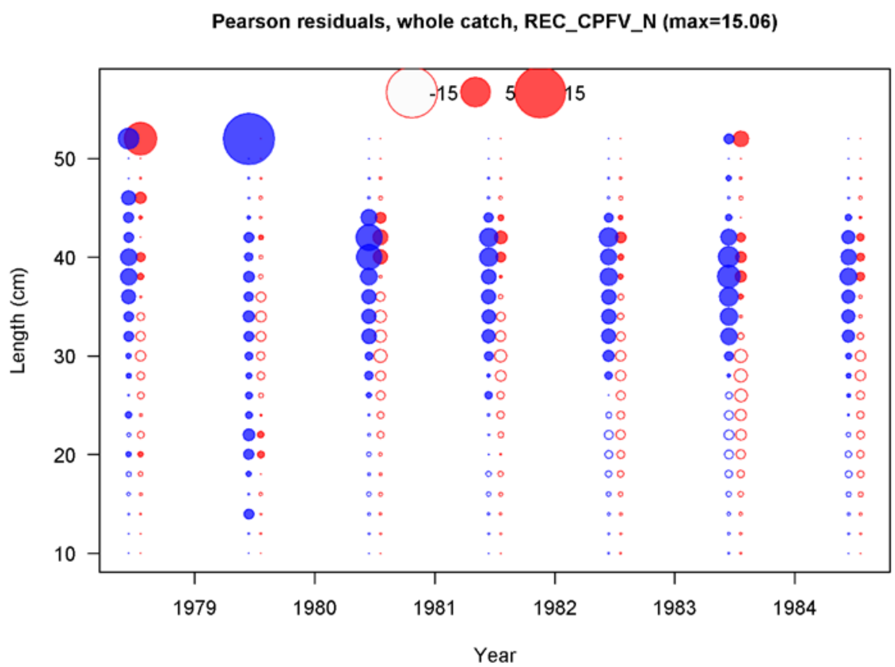


Figure 73: Pearson residuals for the fit to length composition data associated with the California cooperative survey sampling of CPFVs

Figure 74: Pearson residuals for the fit to length composition data associated with the California research data from K. Schmidt (marginal lengths associated with recent age data).

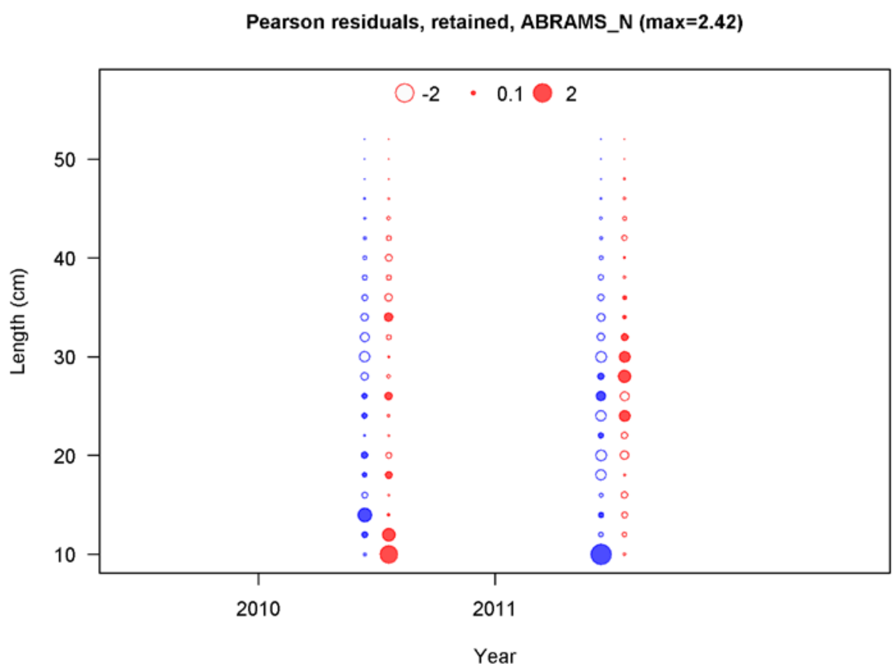


Figure 75: Pearson residuals for the fit to length composition data associated with the California research data from J. Abrams (marginal lengths associated with recent age data).

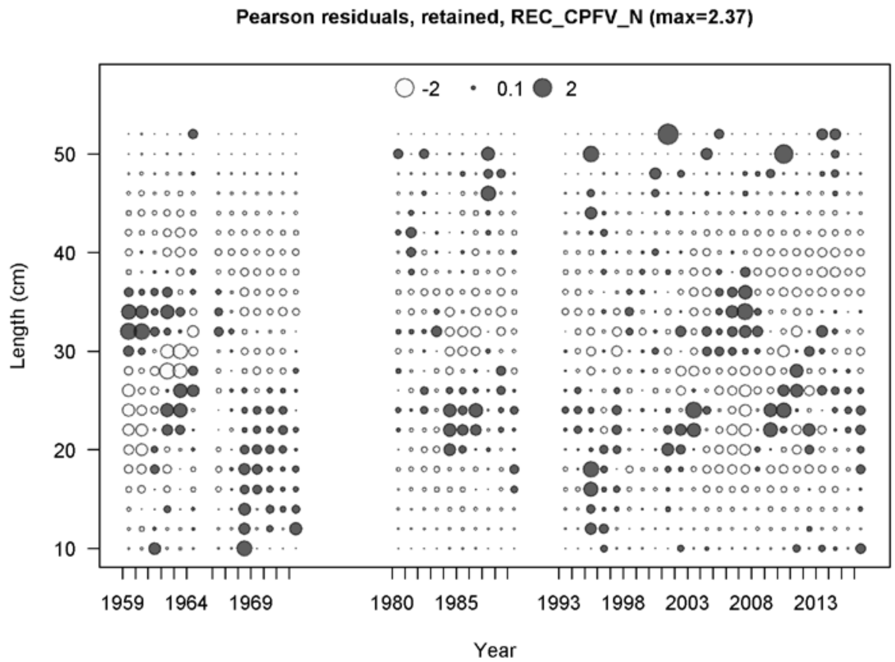


Figure 76: Pearson residuals for the fit to length composition data associated with the California recreational CPFV fleet.

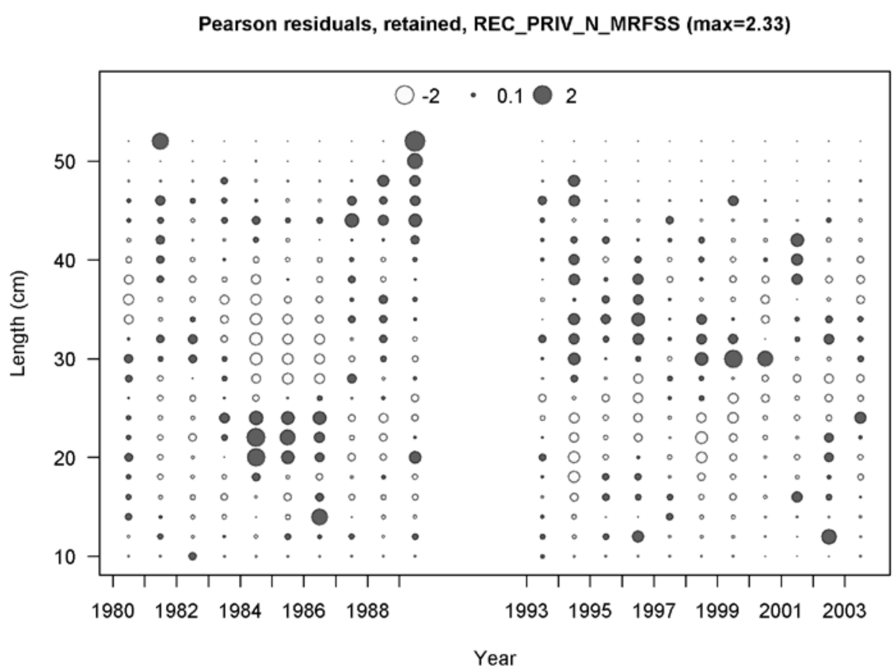


Figure 77: Pearson residuals for the fit to length composition data associated with the California recreational private boat fleet, 1980-2003.

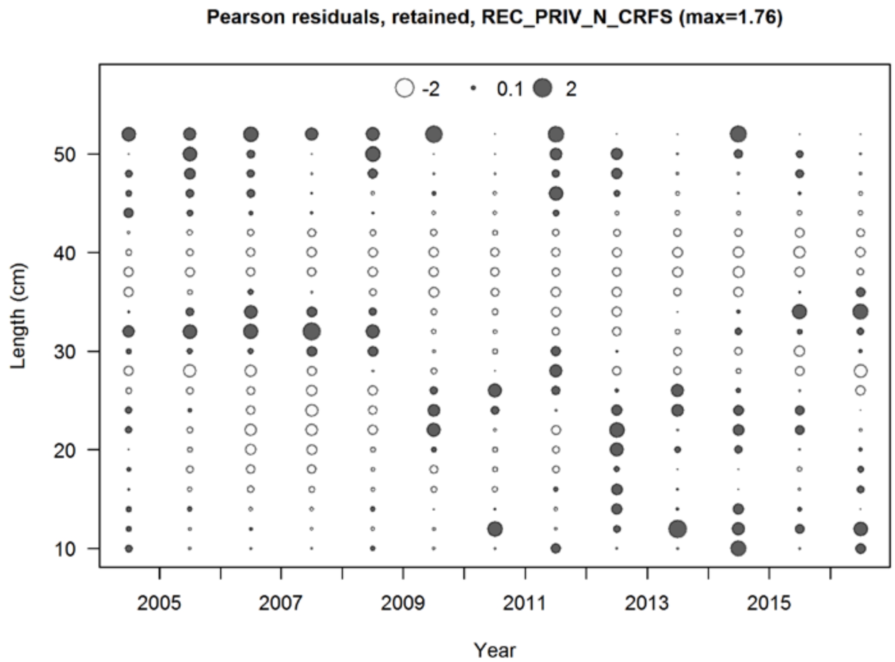


Figure 78: Pearson residuals for the fit to length composition data associated with the California recreational private boat fleet, 2004-2016

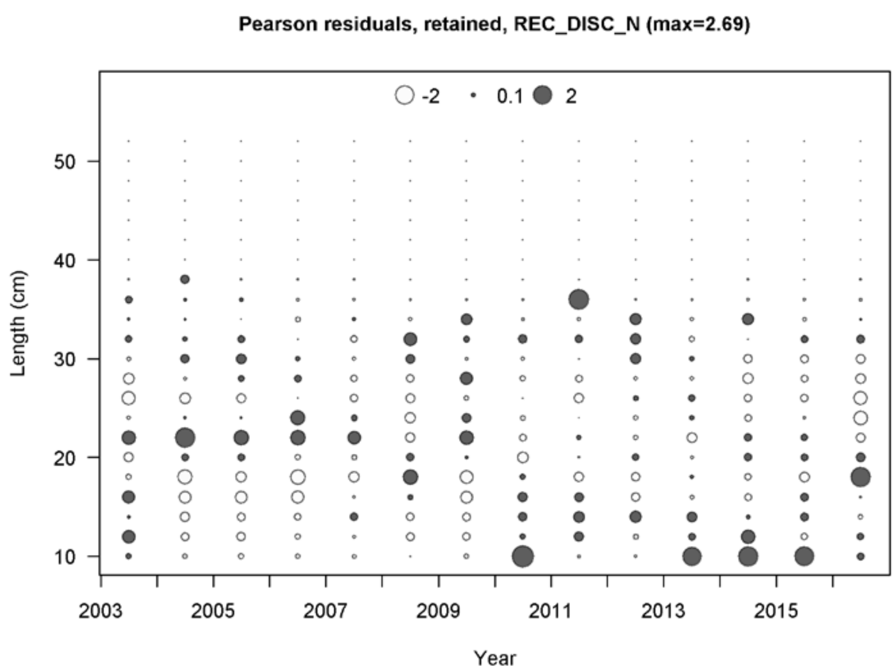


Figure 79: Pearson residuals for the fit to length composition data associated with the California recreational discard fleet.

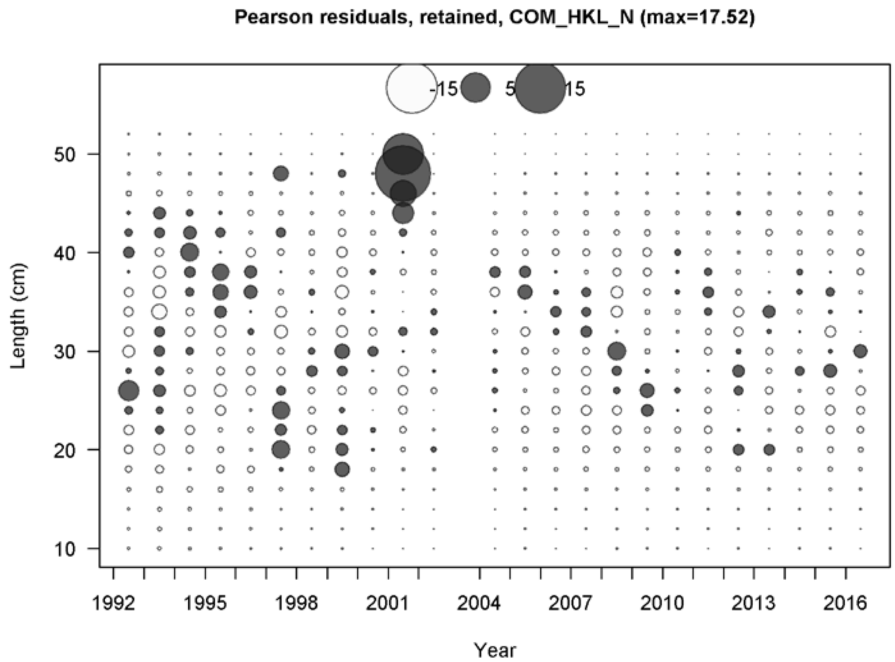


Figure 80: Pearson residuals for the fit to length composition data associated with the California commercial hook and line fleet.

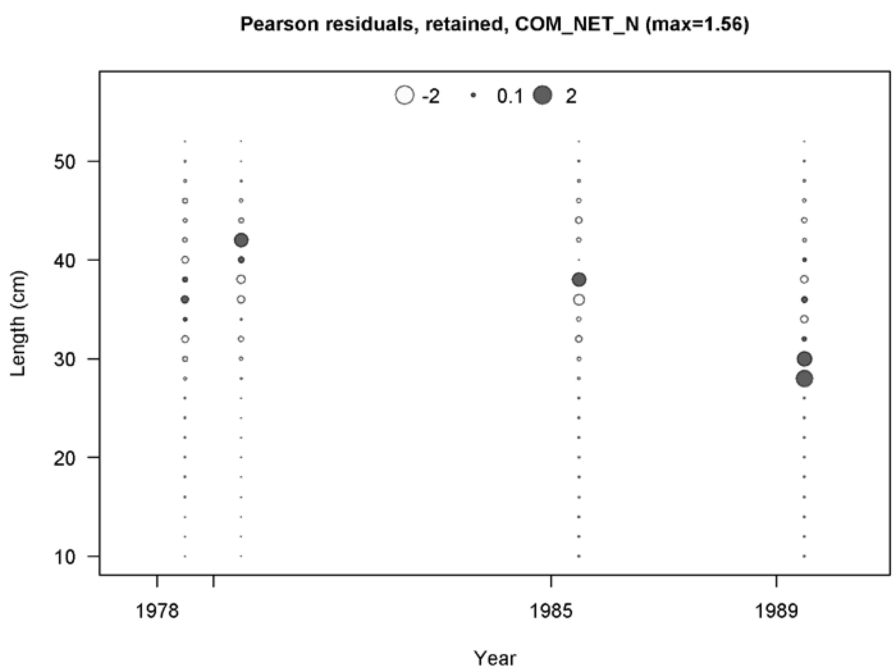


Figure 81: Pearson residuals for the fit to length composition data associated with the California commercial net gear fleet.

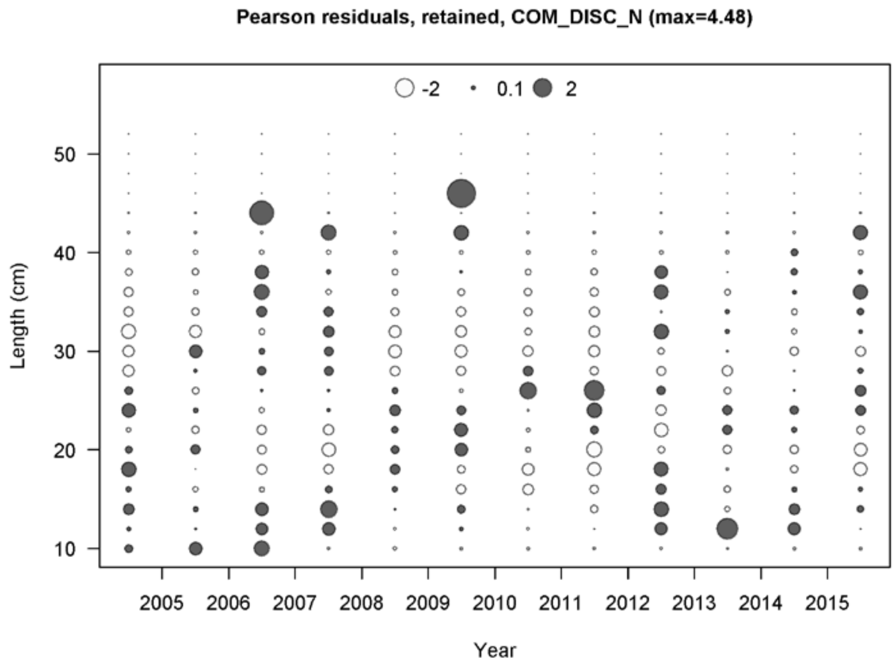


Figure 82: Pearson residuals for the fit to length composition data associated with the California commercial discard fleet.

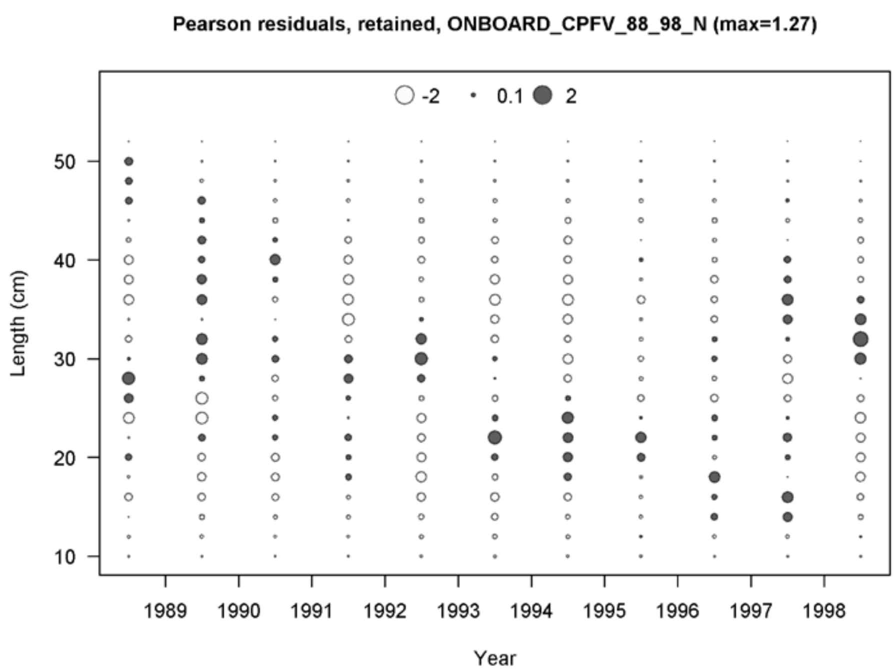


Figure 83: Pearson residuals for the fit to length composition data associated with the California onboard CPFV observer data, 1988-1998.

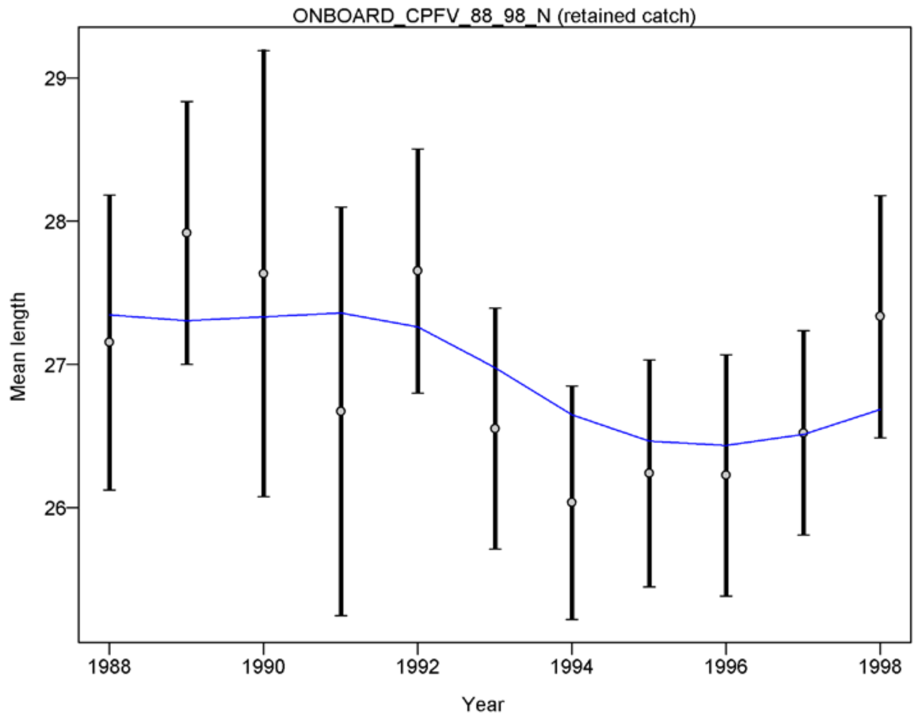


Figure 84: Base fit to mean BDR lengths for the California onboard CPFV observer data, 1988-1998

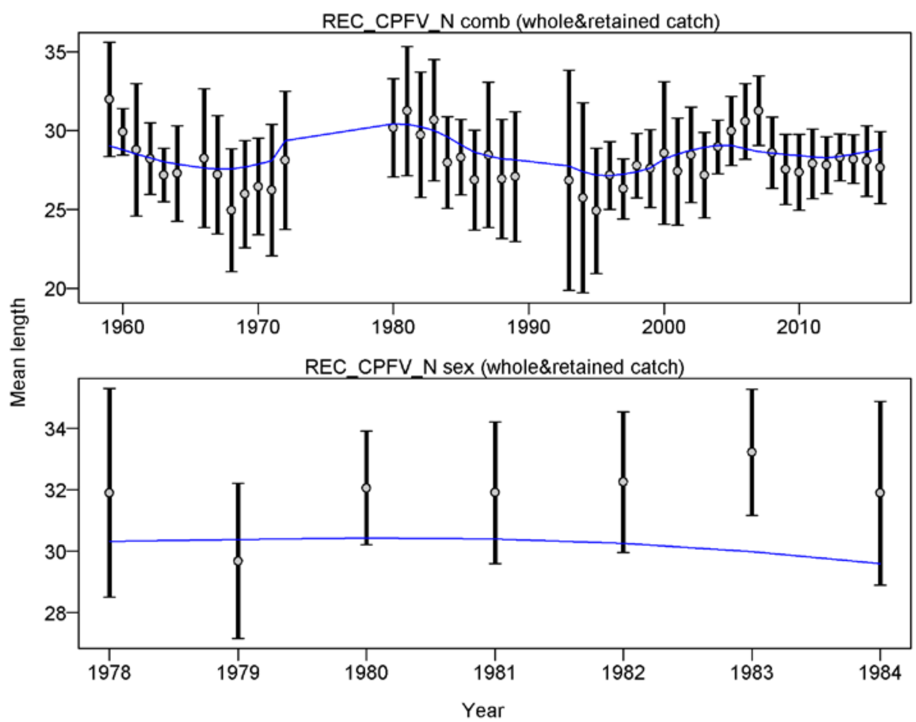


Figure 85: Base fit to mean BDR lengths for the California recreational CPFV fleet

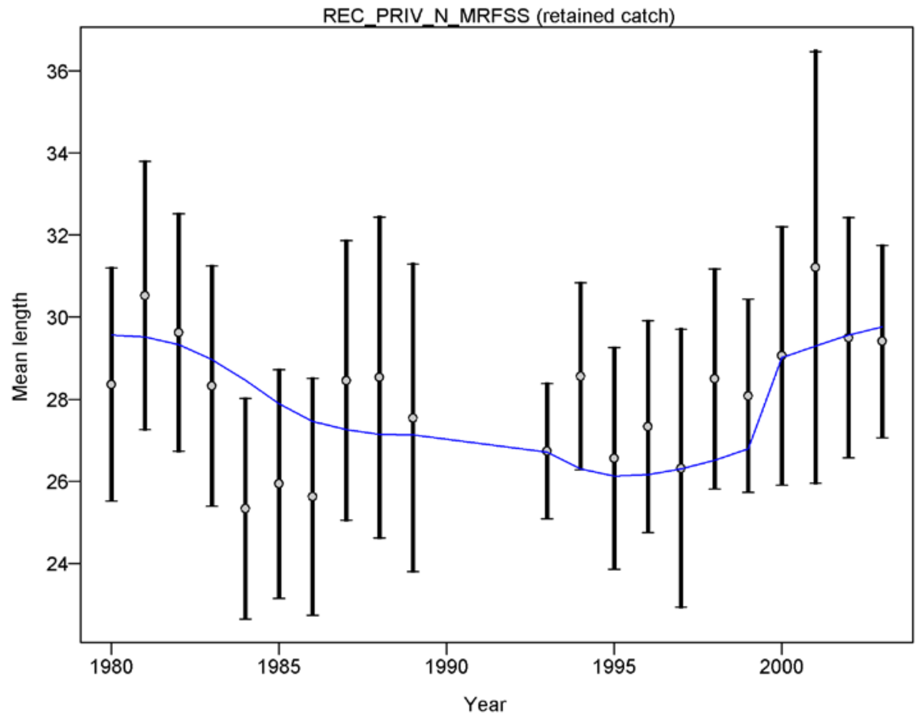


Figure 86: Base fit to mean BDR lengths for the California recreational private boat fleet, 1980-2003

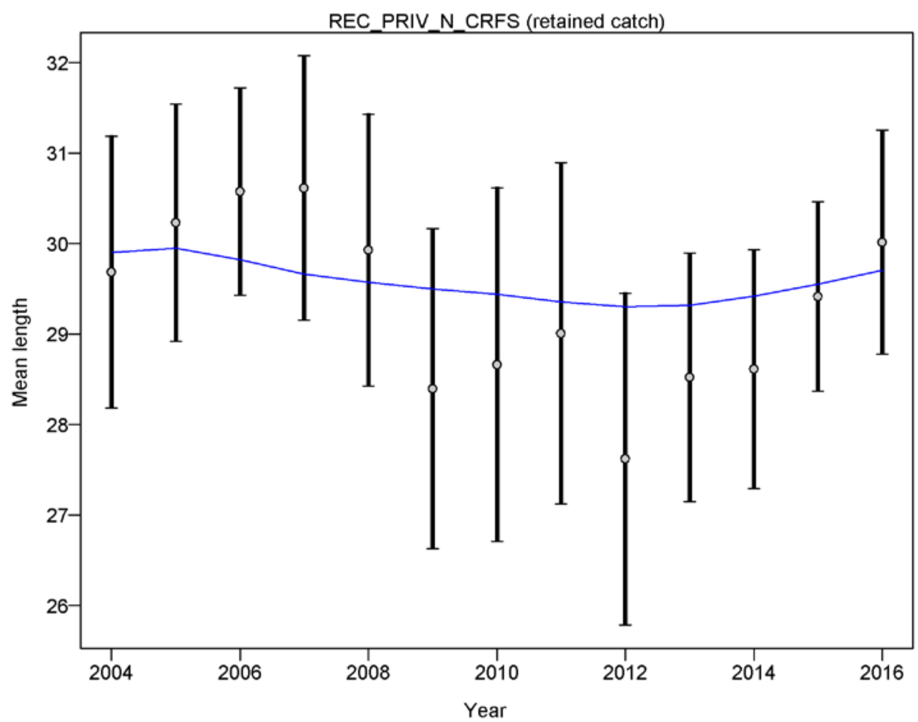


Figure 87: Base fit to mean BDR lengths for the California recreational private boat fleet, 2004-2016

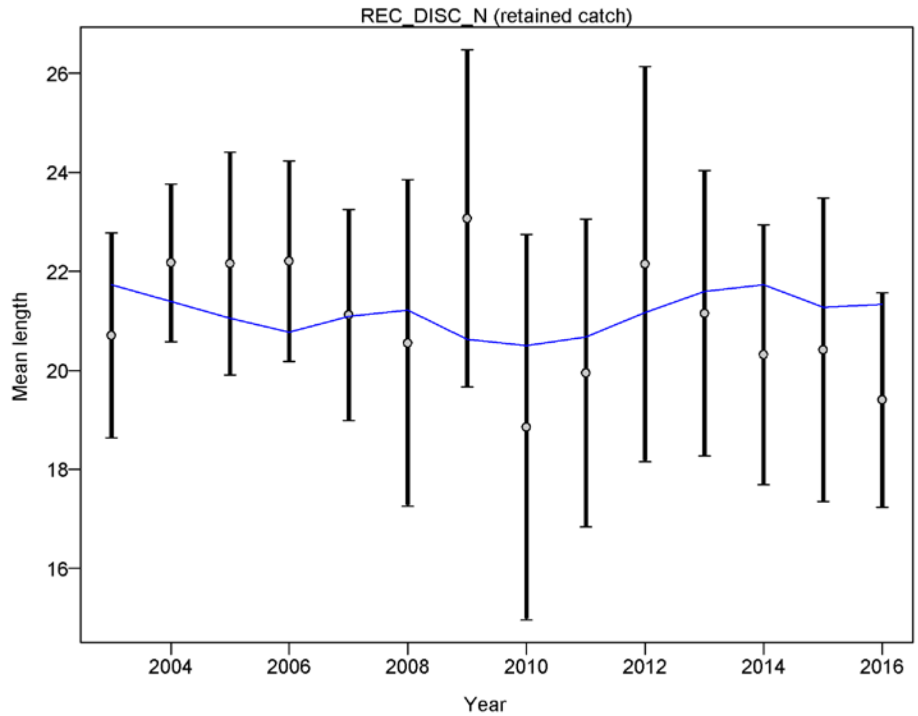


Figure 88: Base fit to mean BDR lengths for the California recreational discard fleet

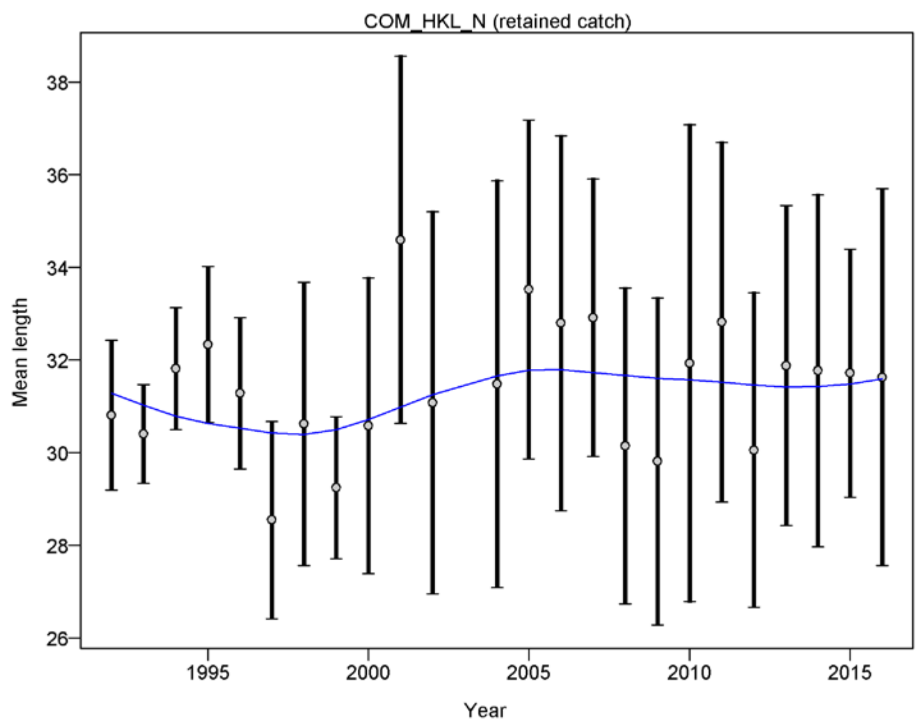


Figure 89: Base fit to mean BDR lengths for the California commercial hook and line fleet

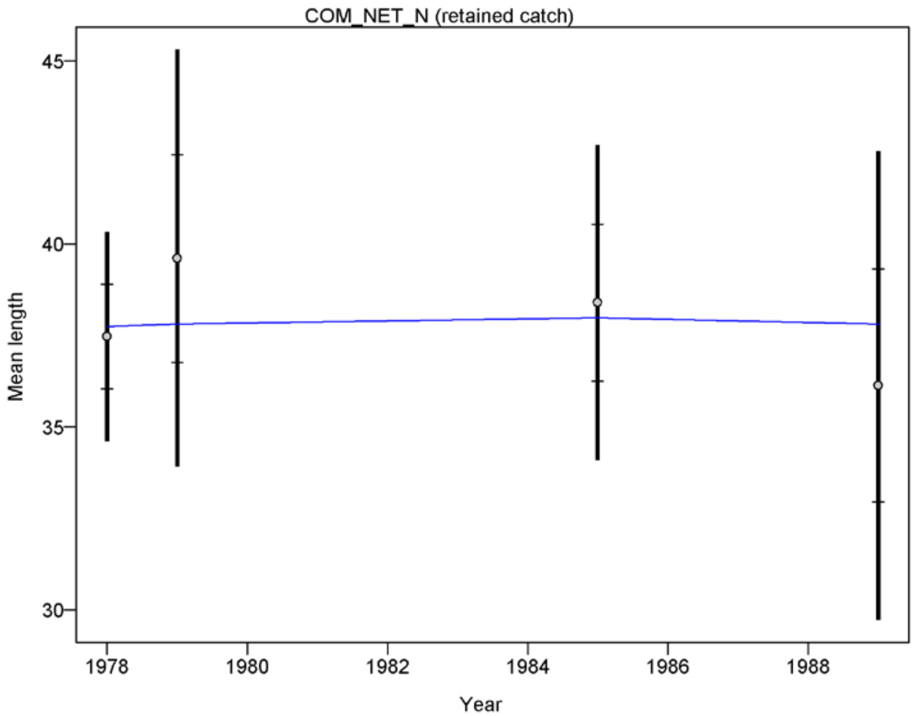


Figure 90: Base fit to mean BDR lengths for the California commercial net gear fleet

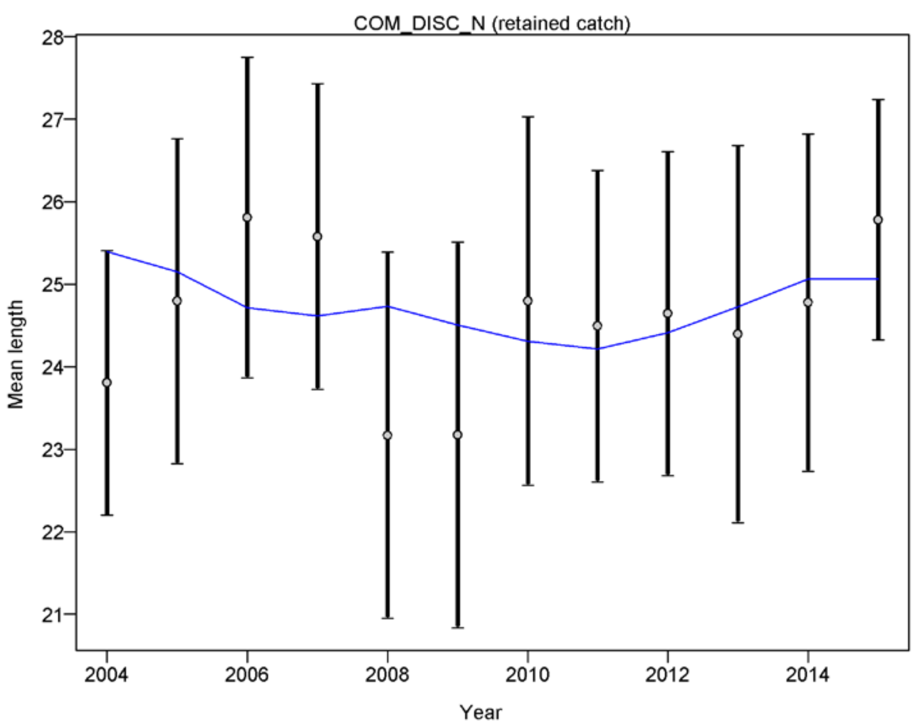


Figure 91: Base fit to mean BDR lengths for the California commercial discard fleet

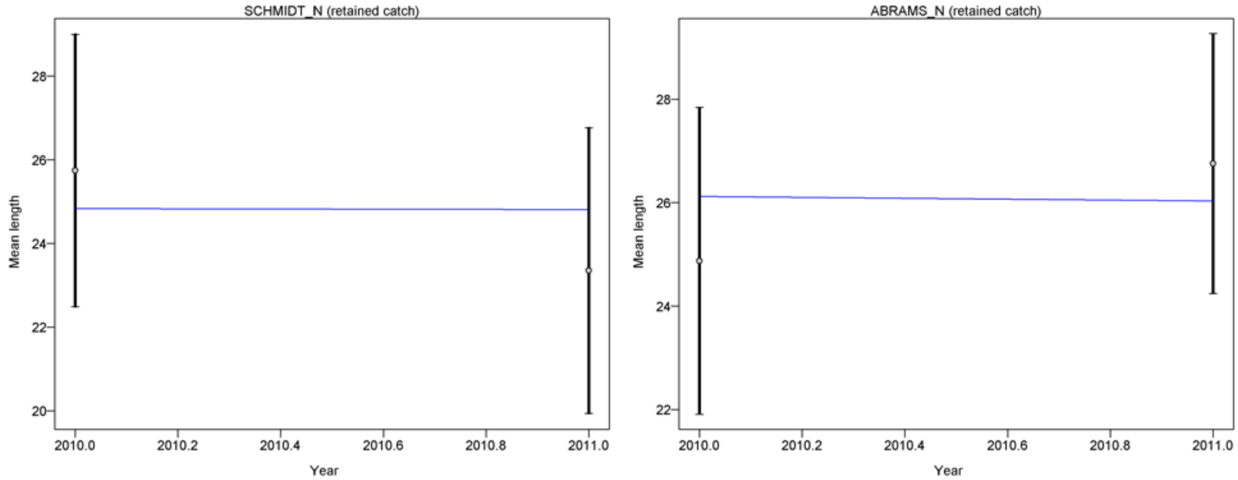


Figure 92: California base fit to mean BDR lengths for the Schmidt (left panel) and Abrams (right panel) research data, 2010-2011.

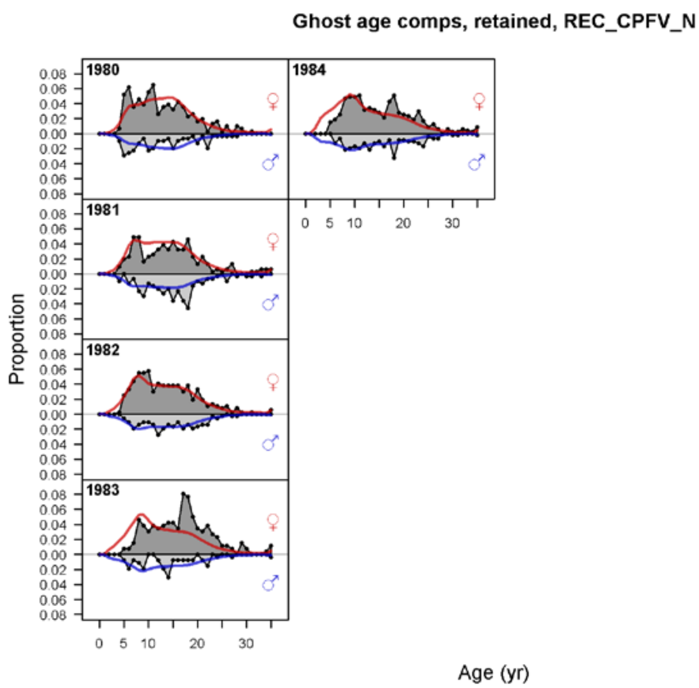


Figure 93: Fits to marginal age composition data for the cooperative survey CPFV data in the California base model.

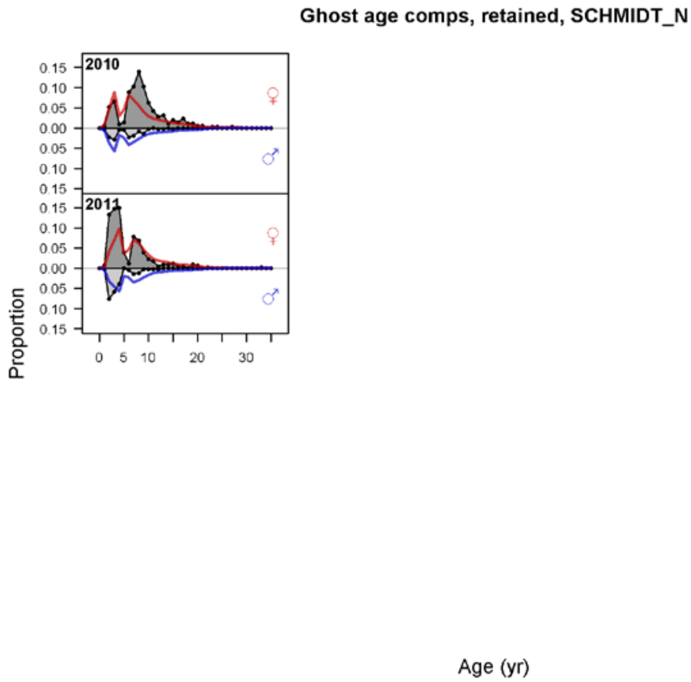


Figure 94: Fits to marginal age composition data for the K. Schmidt research data in the California base model.

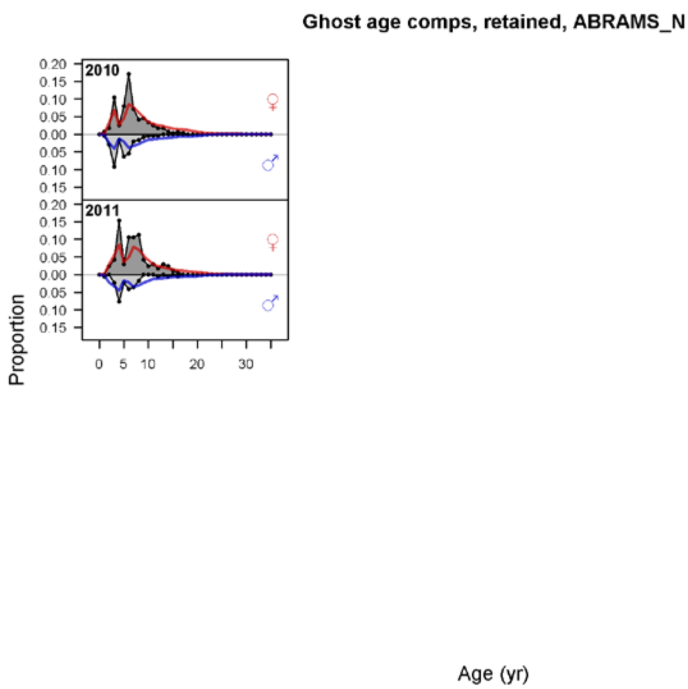


Figure 95: Fits to marginal age composition data for the J. Abrams research data in the California base model.

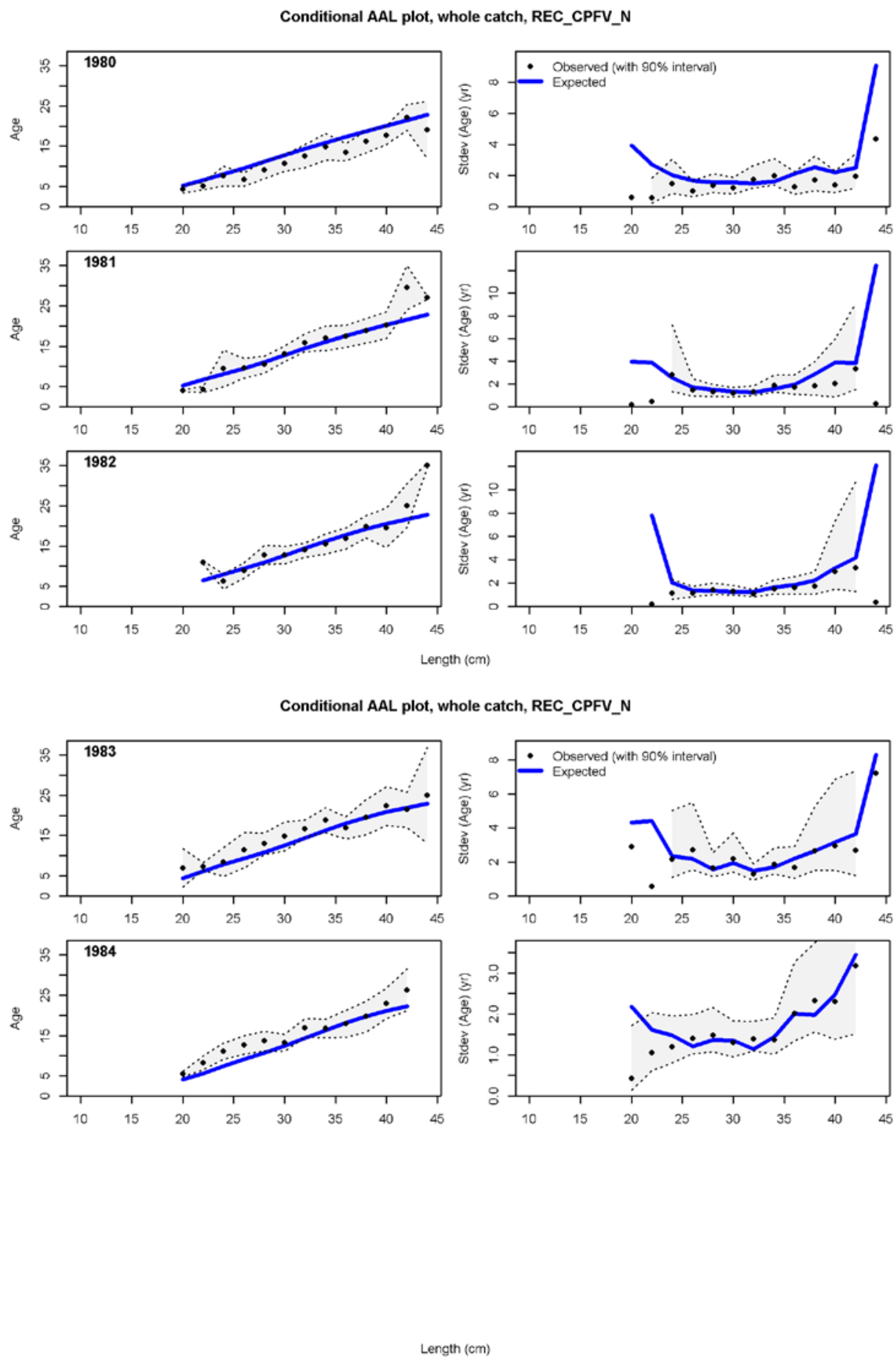


Figure 96: Fits to conditional age at length data for the cooperative survey CPFV data

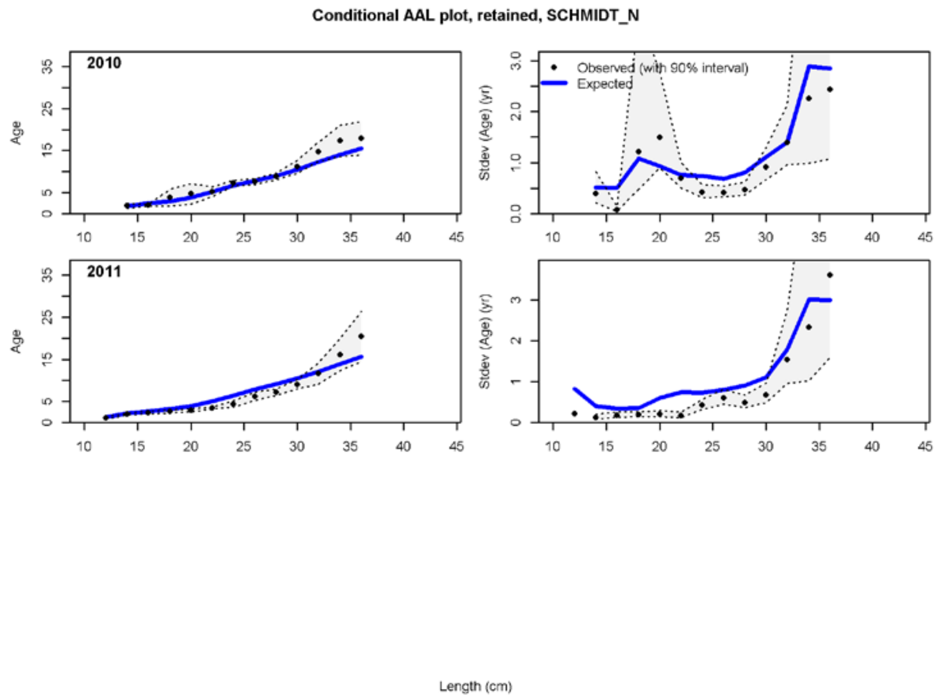


Figure 97: Fits to conditional age at length data for the K. Schmidt research data

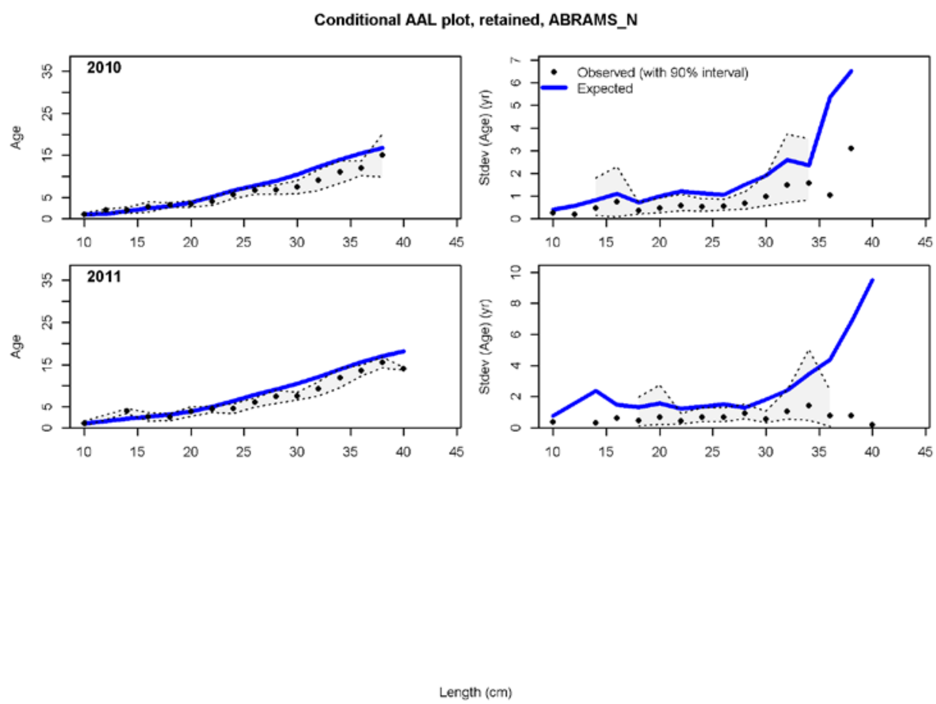


Figure 98: Fits to conditional age at length data for the J. Abrams research data

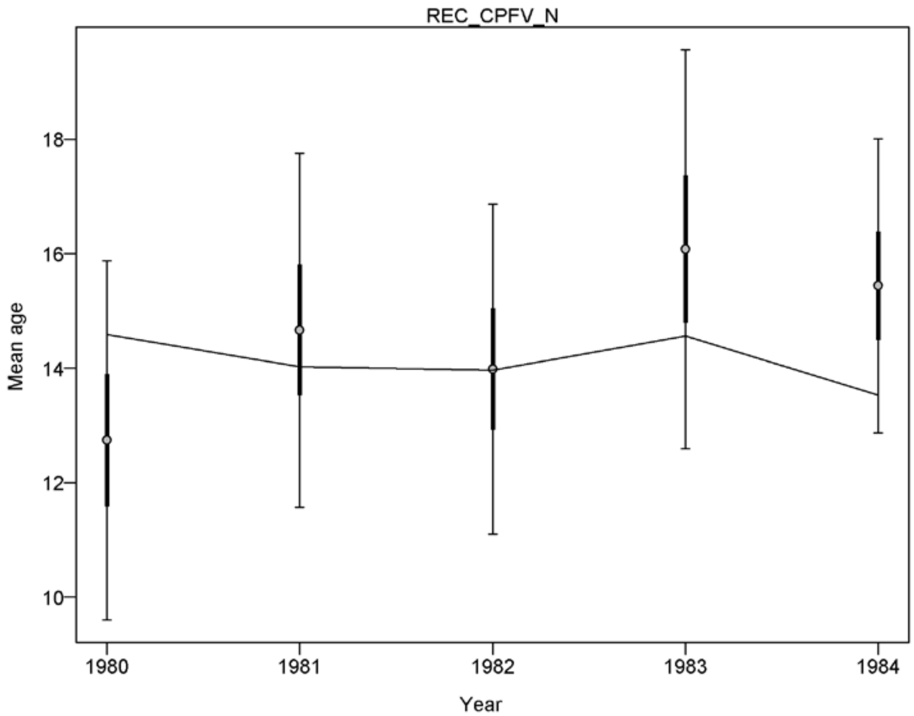


Figure 99: Base model fit to California BDR mean age for the cooperative survey CPFV age data.

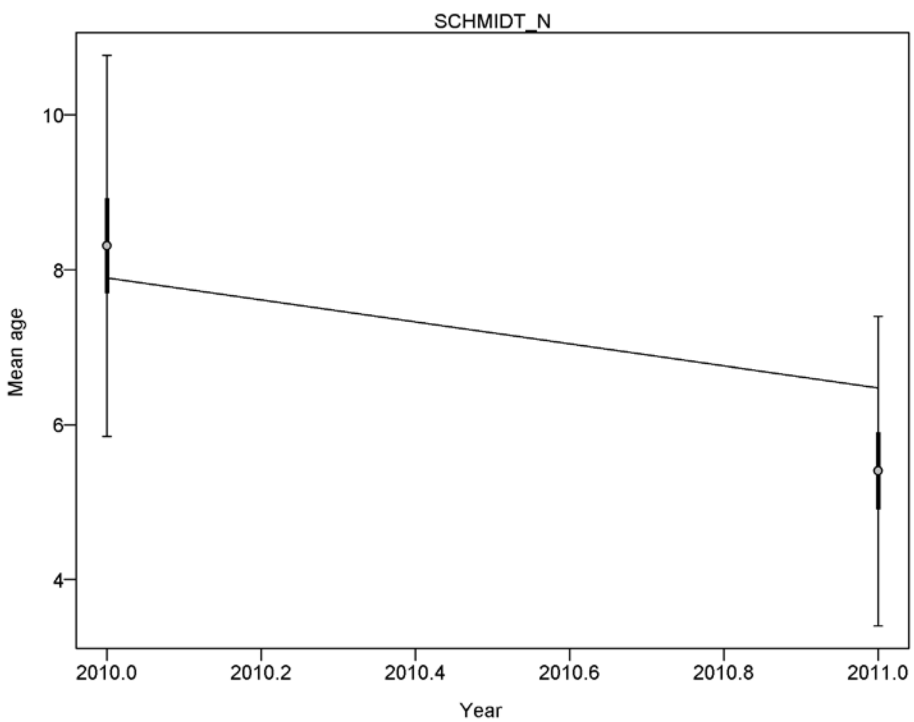


Figure 100: Base model fit to California BDR mean age for the K. Schmidt research age data

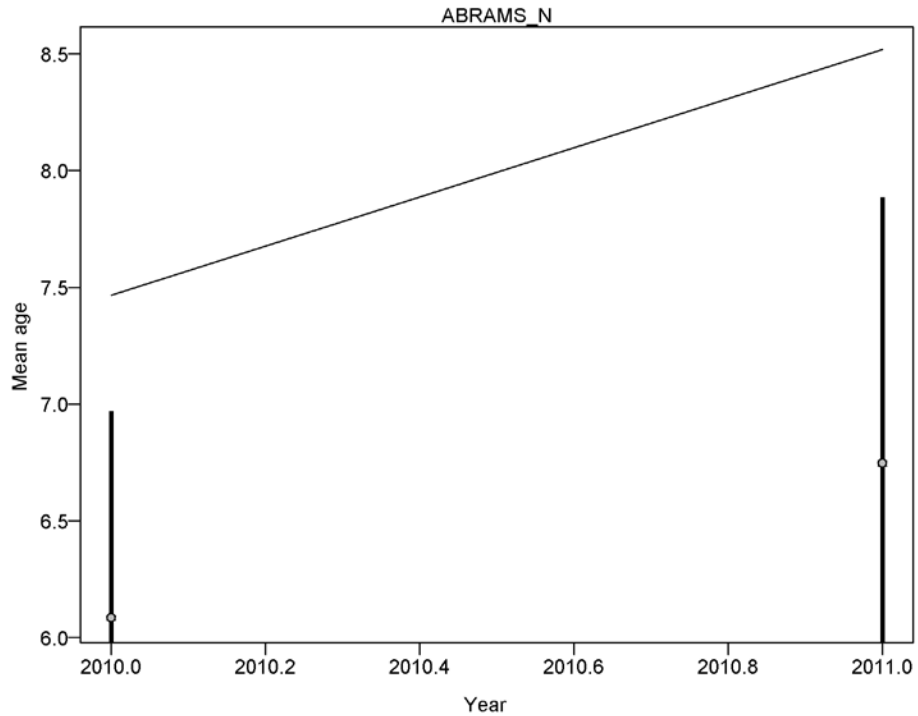
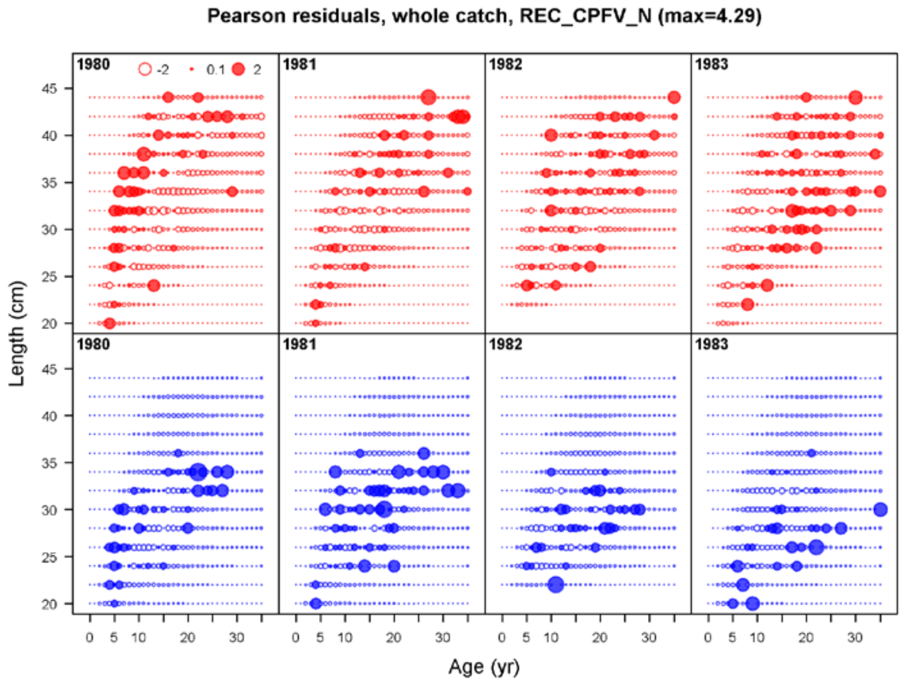


Figure 101: Base model fit to California BDR mean age for the J. Abrams research age data



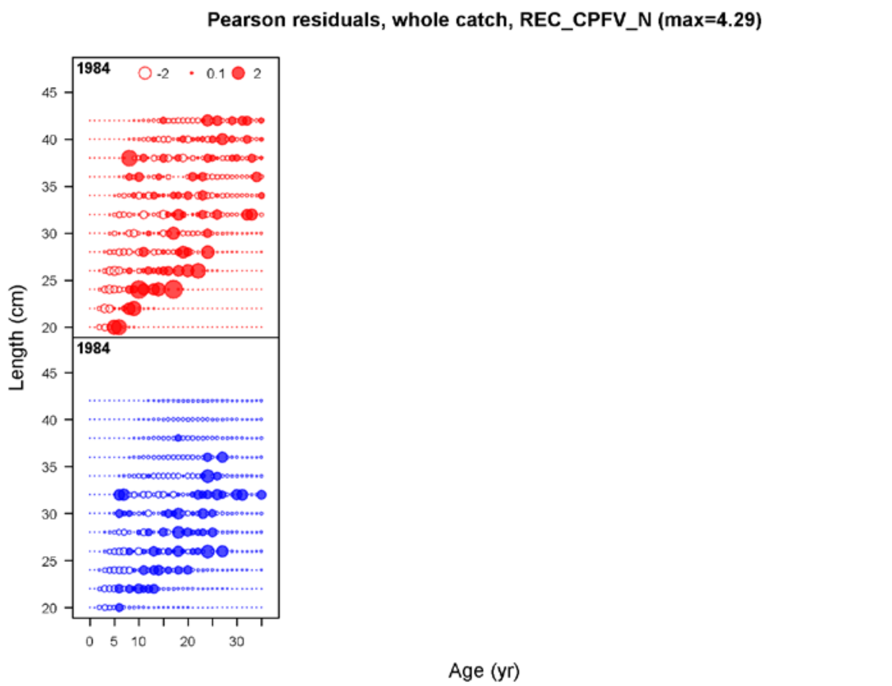


Figure 102: Pearson residuals from the California base model fit to conditional age-at-length data in the recreational CPFV fleet.

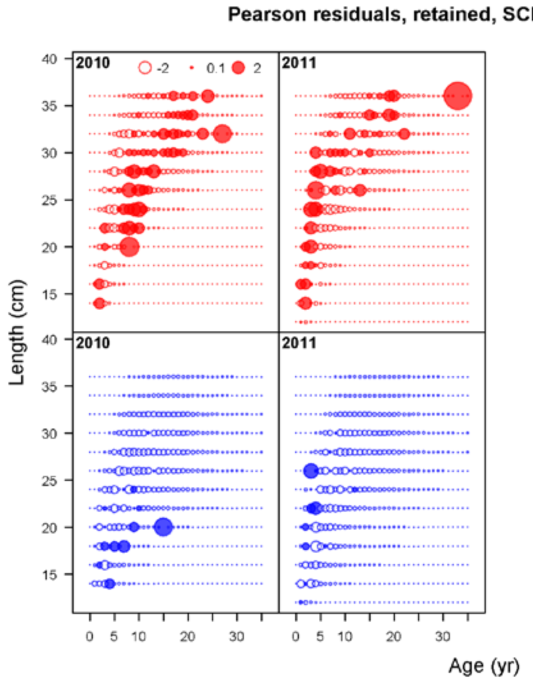


Figure 103: Pearson residuals from the California base model fit to conditional age-at-length data in the K. Schmidt research data.

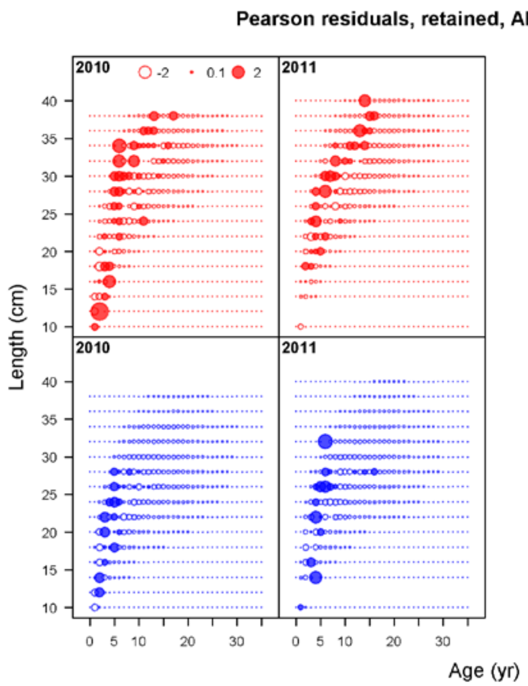


Figure 104: Pearson residuals from the California base model fit to conditional age-at-length data in the J. Abrams research data.

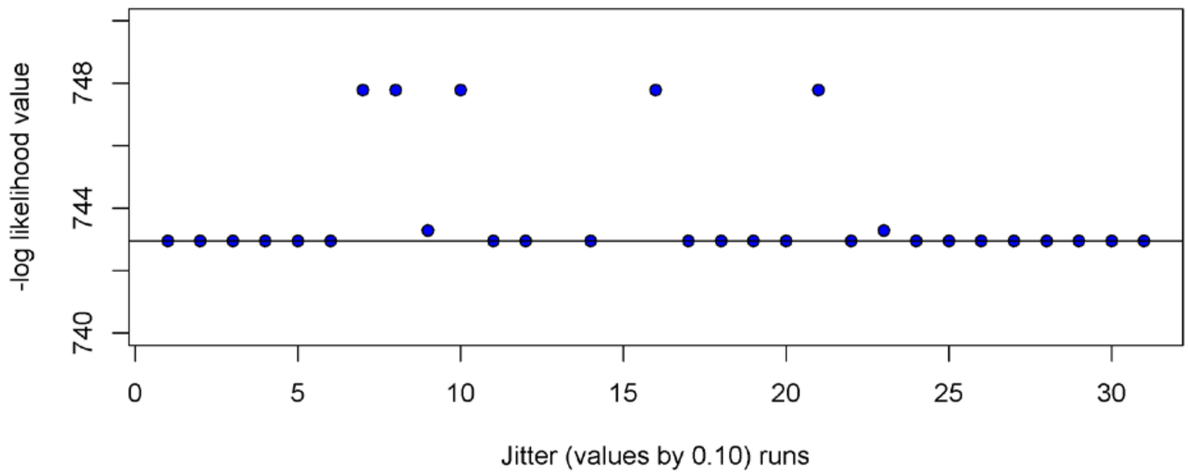


Figure 105: Results from 30 California model base case runs when starting values are jittered (a uniform draw, +/-0.1 standard deviations). Horizontal line indicates base model value.

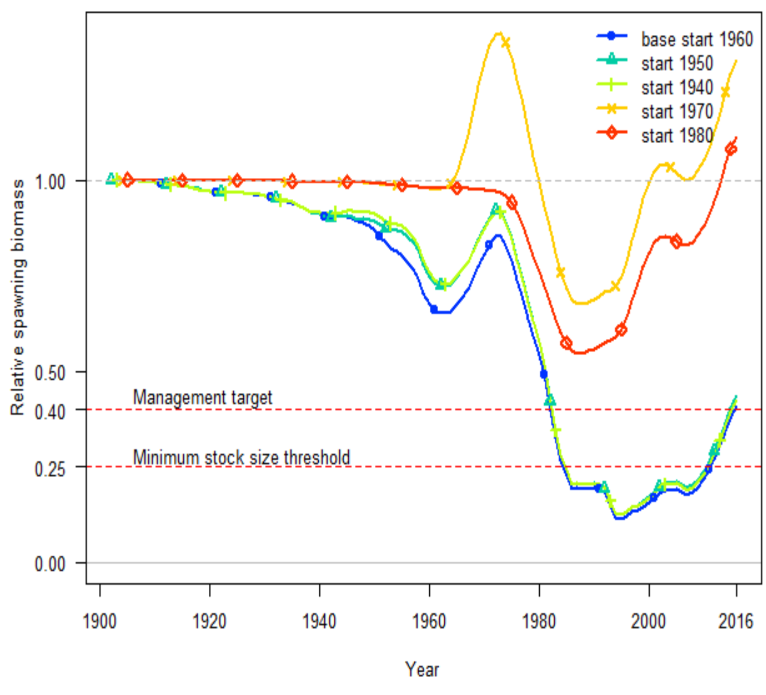
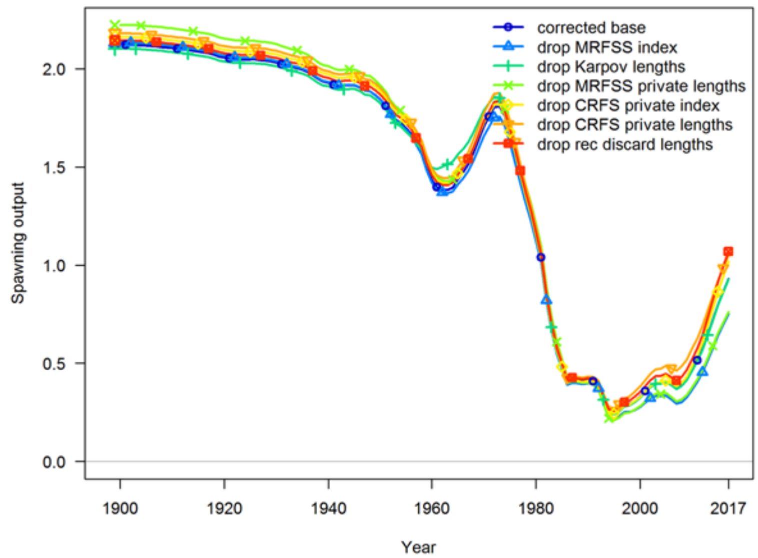


Figure 106: Response to STAR Panel Request #1. Changes to the start date of recruitment deviations had little effect when moved earlier in the time series, but substantial effects when moved later, coupled with unrealistic estimates of natural mortality (~0.22) given the maximum observed age of BDR.



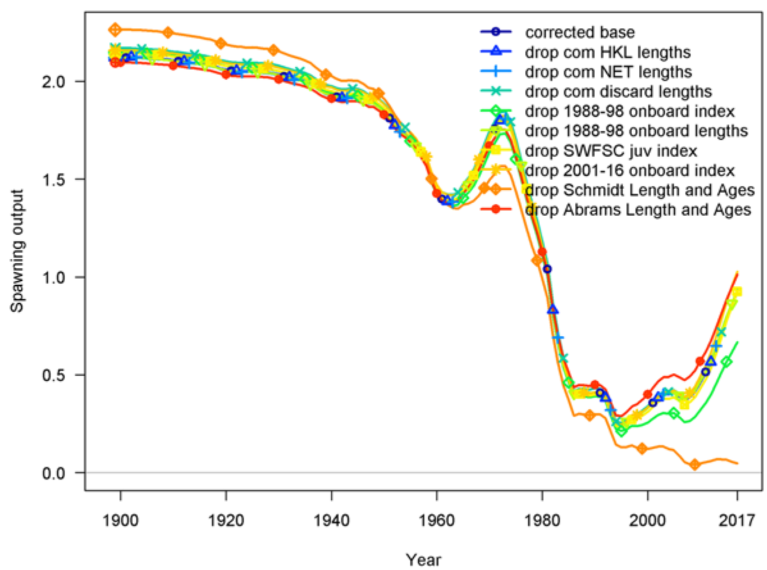


Figure 107: Response to STAR Panel Request #2. Removal of individual data sources (from pre-STAR base) rather than removing all data associated with a fleet. Removal of the Schmidt age data resulted in a severely depleted stock.

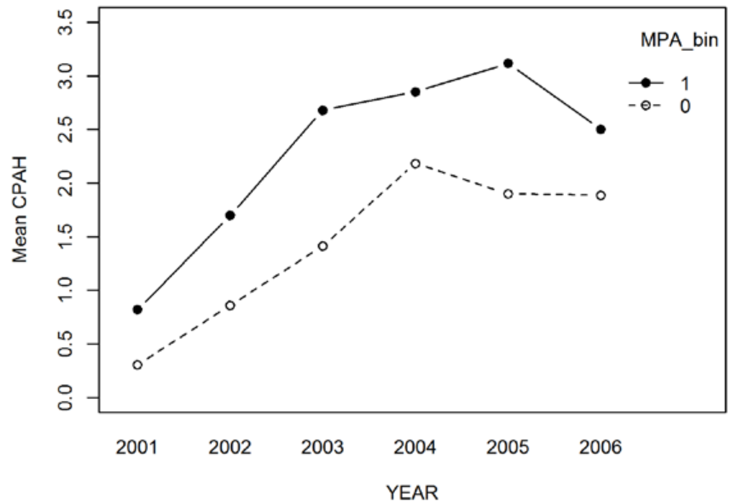


Figure 108: Response to STAR Panel Request #7. Differences in raw CPUE inside (1) and outside (0) areas that were later classified as Marine Protected Areas, 2001-2006. Data are drift-level CPUE from the CRFS onboard CPFV observer program.

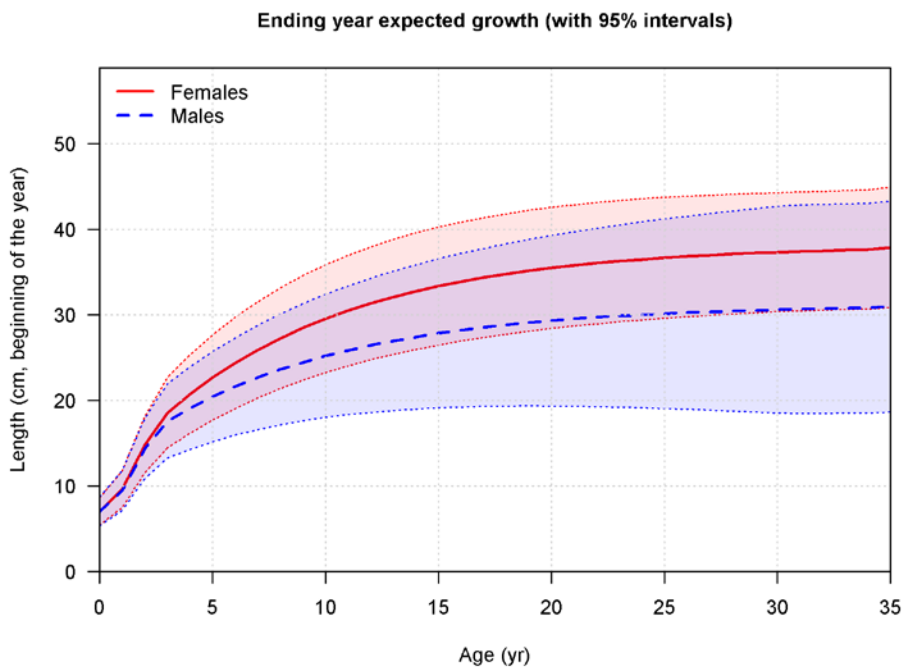


Figure 109: Estimated von Bertalanffy growth curve for male and female California BDR.

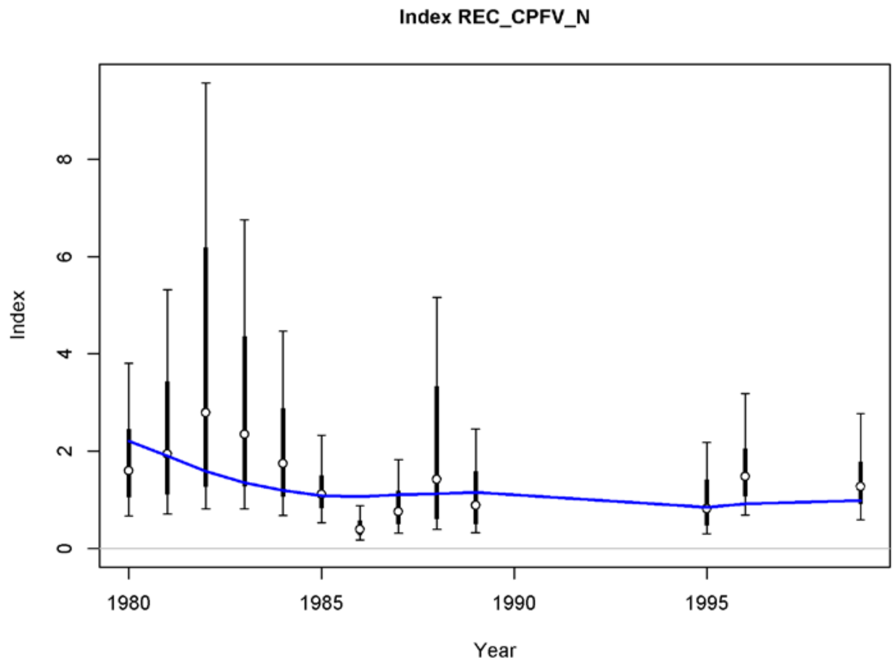


Figure 110: California base model fit to the dockside MRFSS CPFV index.

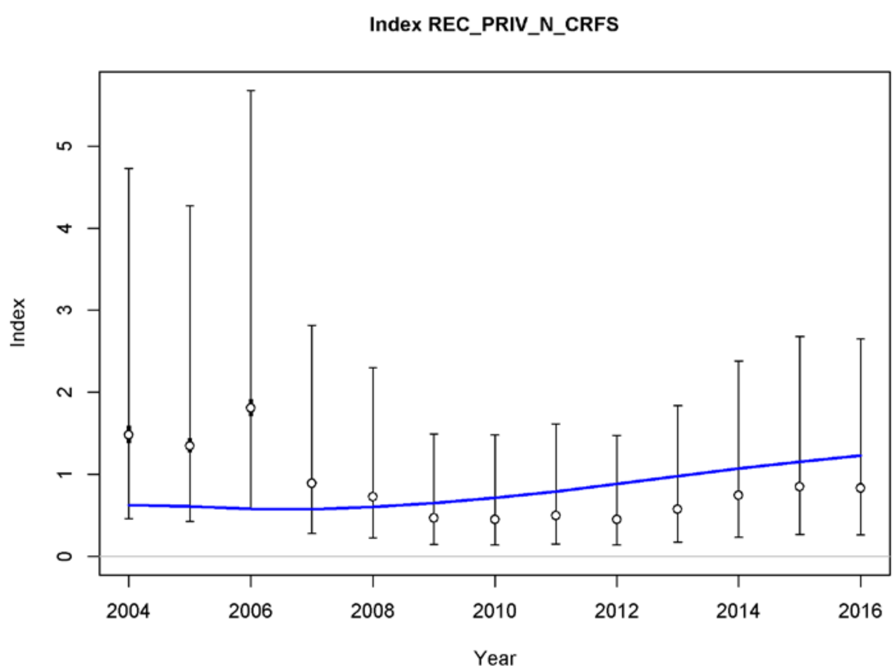


Figure 111: California base model fit to the dockside CRFS private boat index.

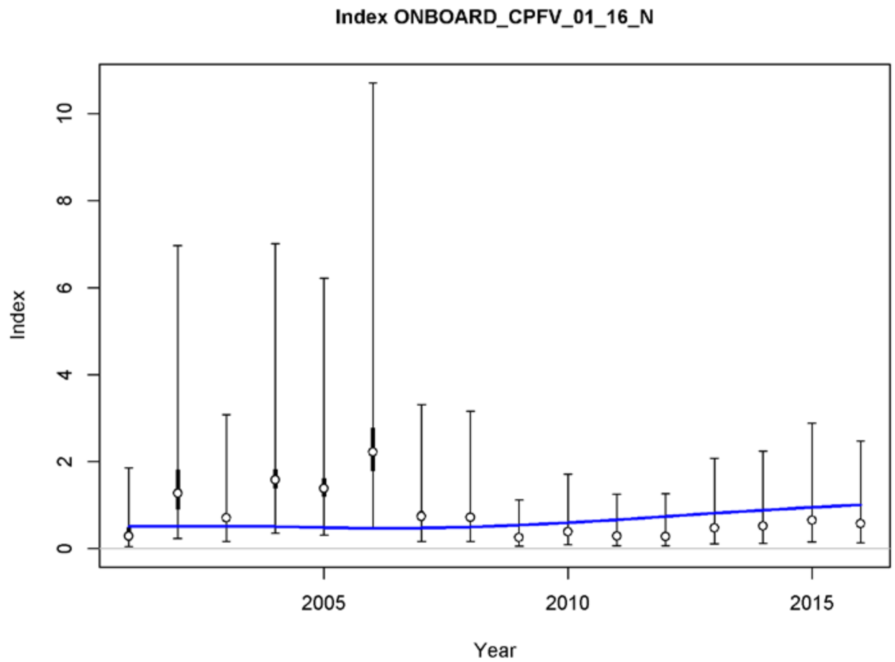


Figure 112: California base model fit to the CRFS onboard CPFV observer index, 2001-2016.

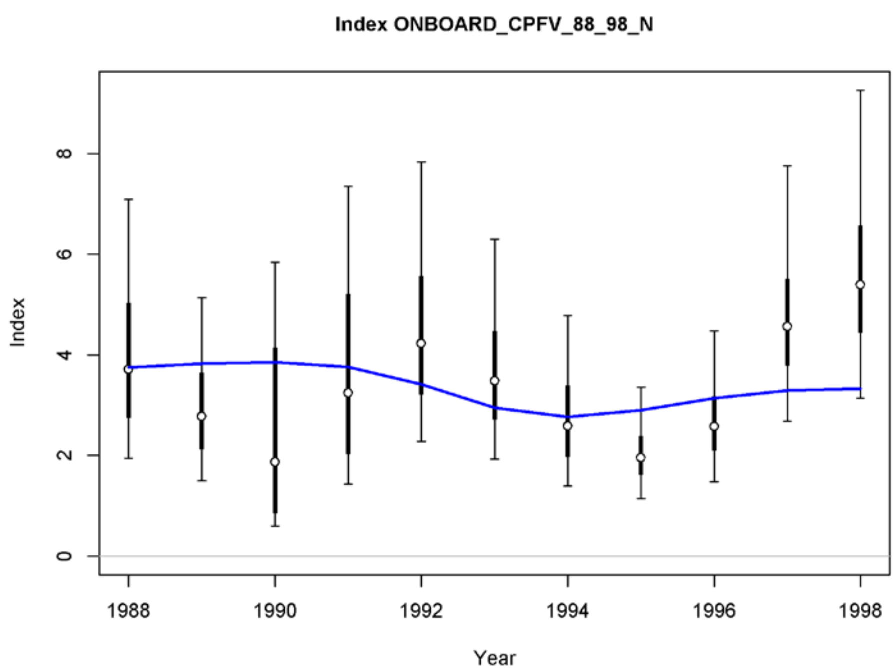


Figure 113: California base model fit to the onboard CPFV index, 1988-98.

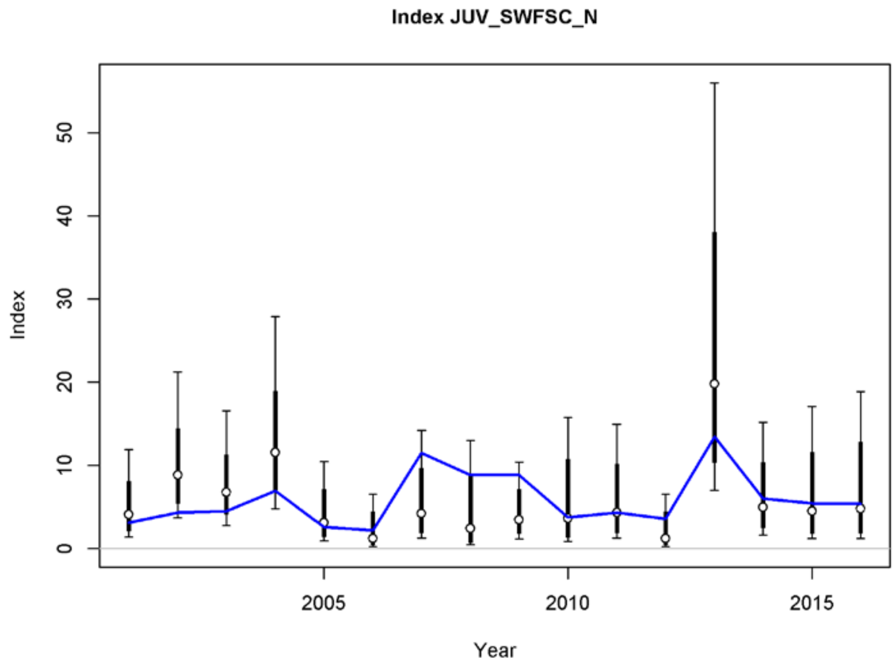


Figure 114: California base model fit to the SWFSC juvenile index.

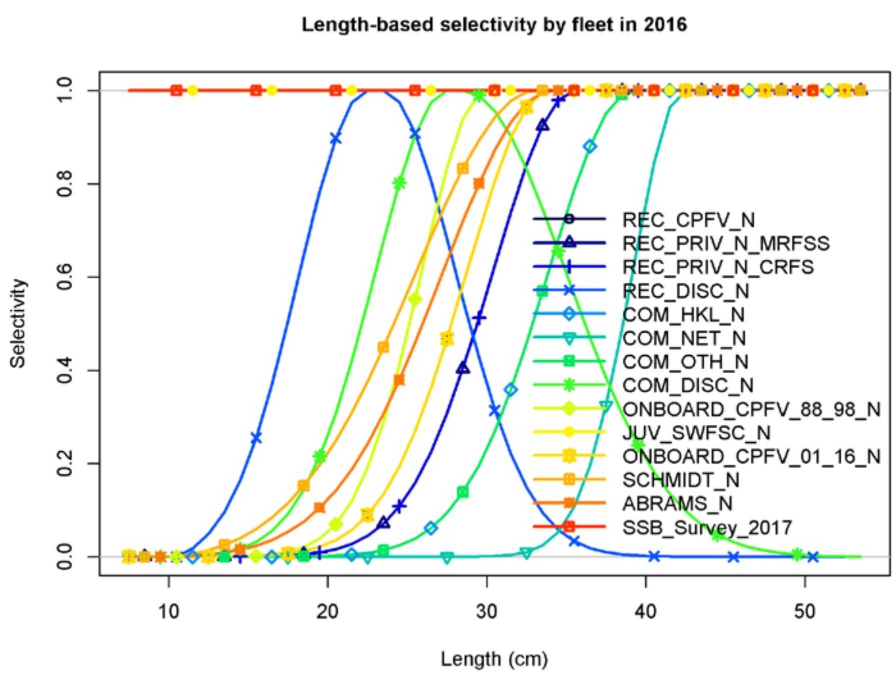


Figure 115: Selectivity curves for fisheries and surveys structured in the base case California BDR model.

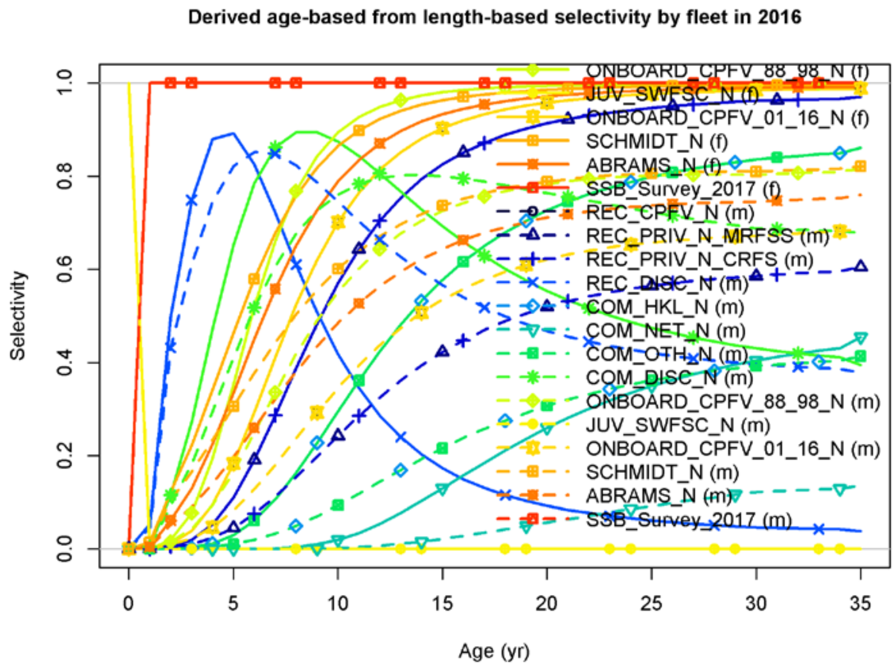


Figure 116: Derived age-based selectivity from length-based selectivity for the fisheries and surveys structured in the base case California BDR model.

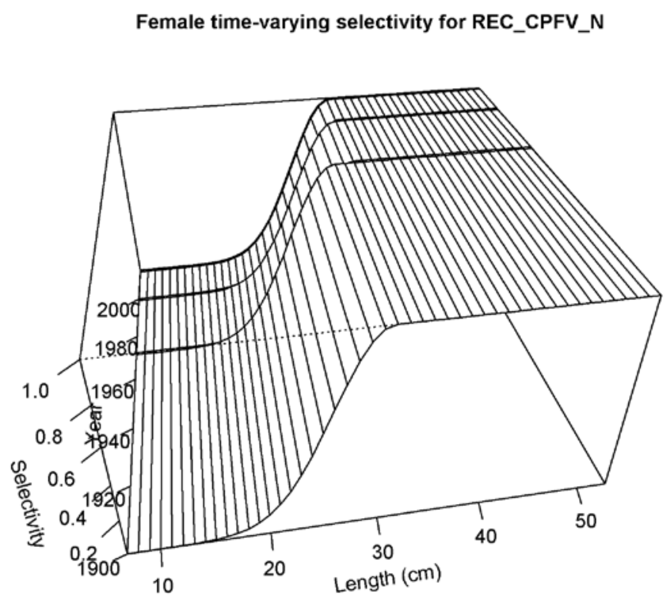


Figure 117: Time-blocked selectivity for the recreational CPFV fleet. Changes in peak selectivity are associated with daily bag limit changes (20 fish to 15 fish in 1971, and 15 fish to 10 fish in 2000).

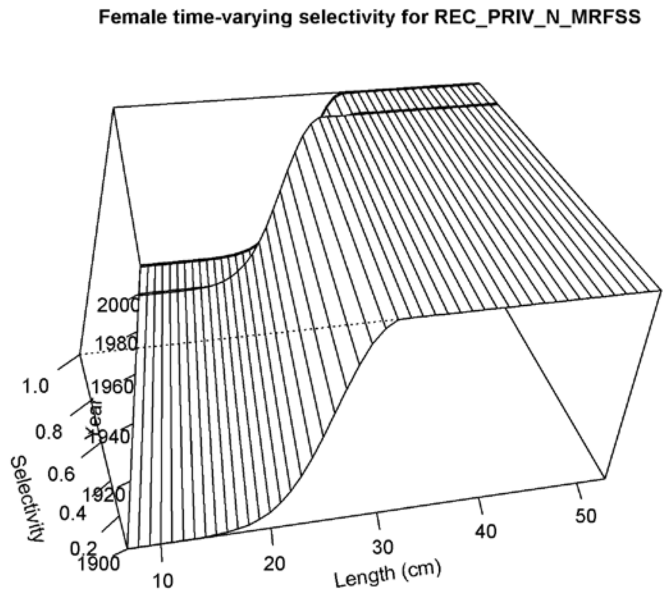


Figure 118: Time-blocked selectivity for the recreational private boat fleet. The change in peak selectivity is associated with a daily bag limit changes (15 fish to 10 fish) in 2000. Length data were not available to inform a selectivity change in 1971 for the private boat fishery.

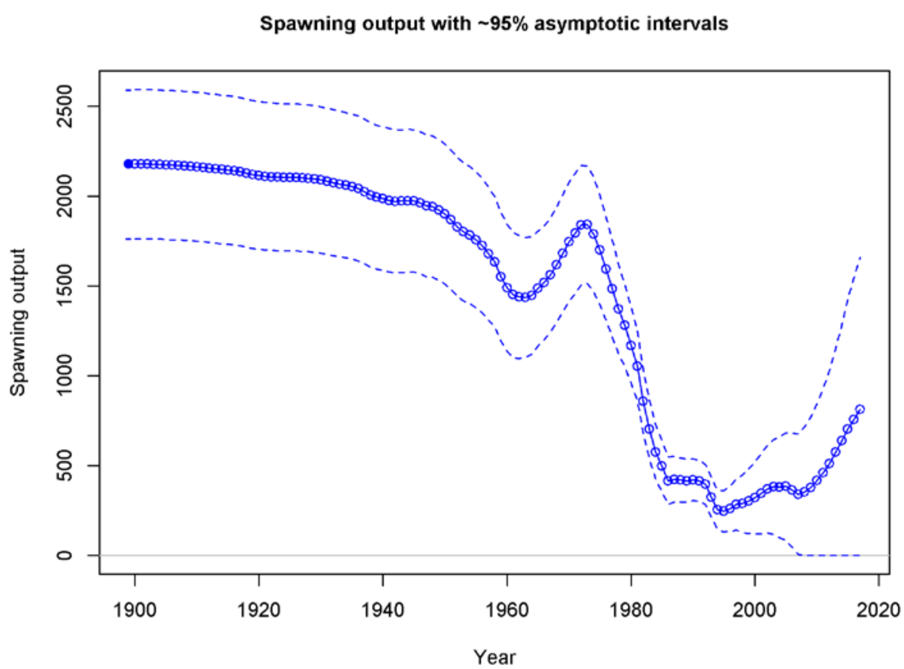


Figure 119: Estimated time series of spawning output (millions of eggs/larvae) from the base case California BDR model with ~95% confidence intervals.

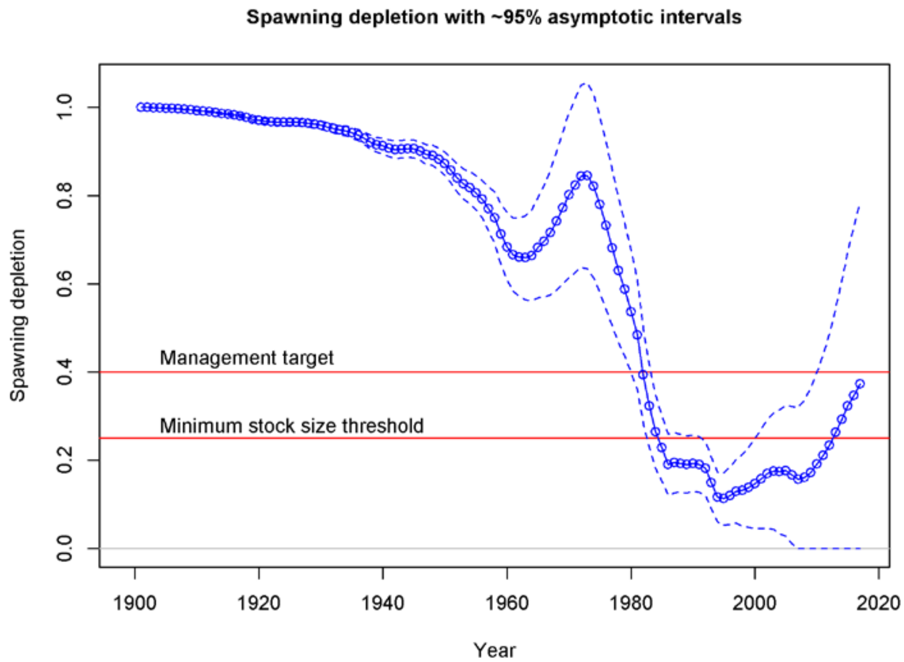


Figure 120: Estimated spawning output depletion relative to unfished levels for the California base case model with ~95% asymptotic confidence intervals.

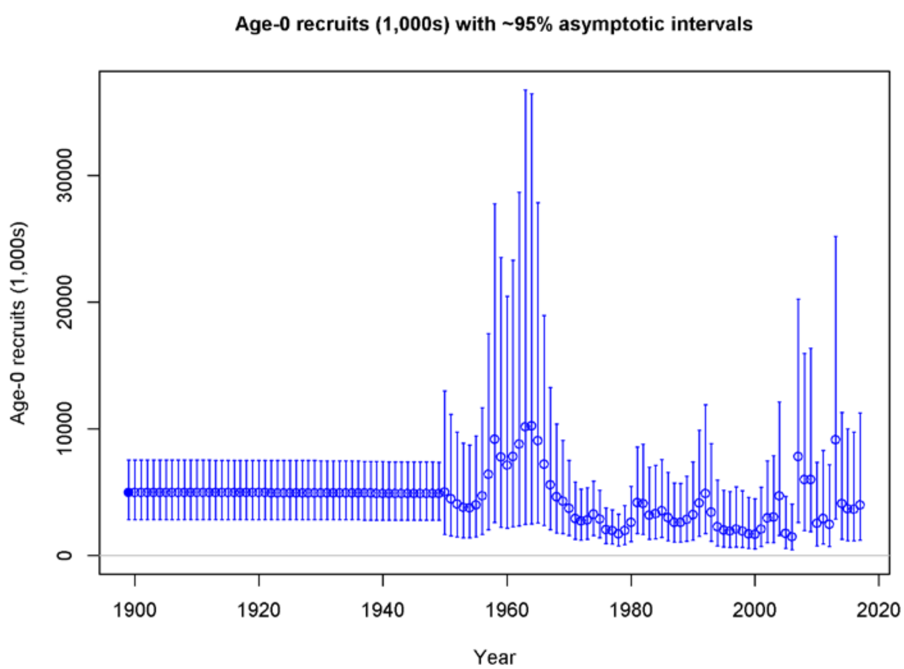


Figure 121: California base model estimates of age-0 recruitment with ~95% confidence intervals.

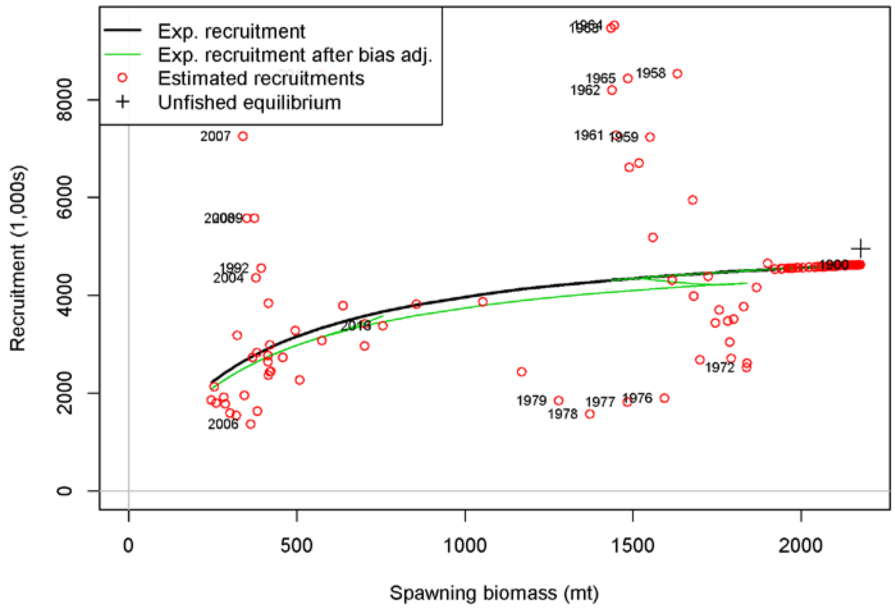


Figure 122: Beverton-Holt stock recruitment relationship for the California BDR base case model. Large estimated recruitment for 2013 is hidden by legend (behind "recruitments").

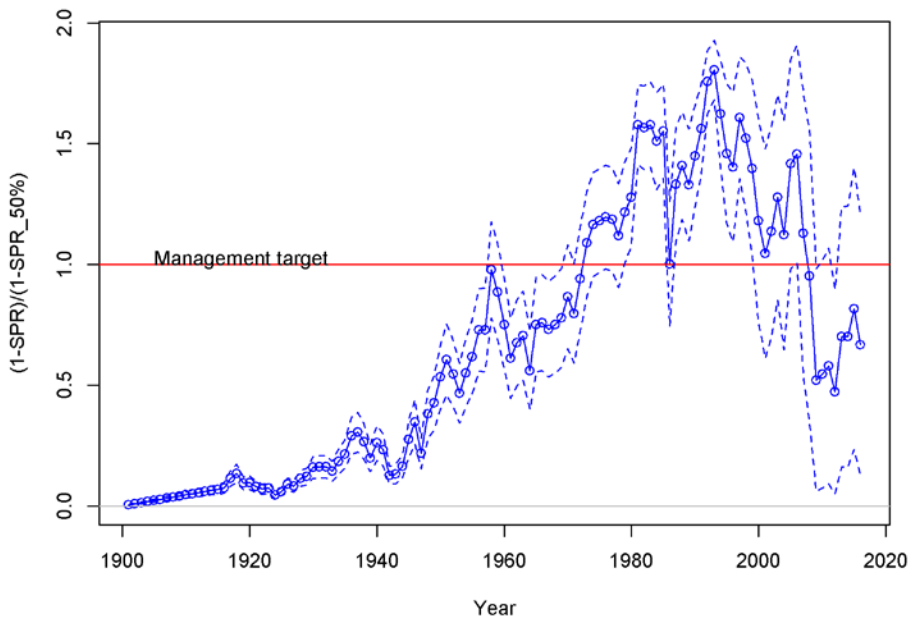


Figure 123: Estimated spawning potential ratio (SPR) for the California BDR base case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR50% harvest rate.

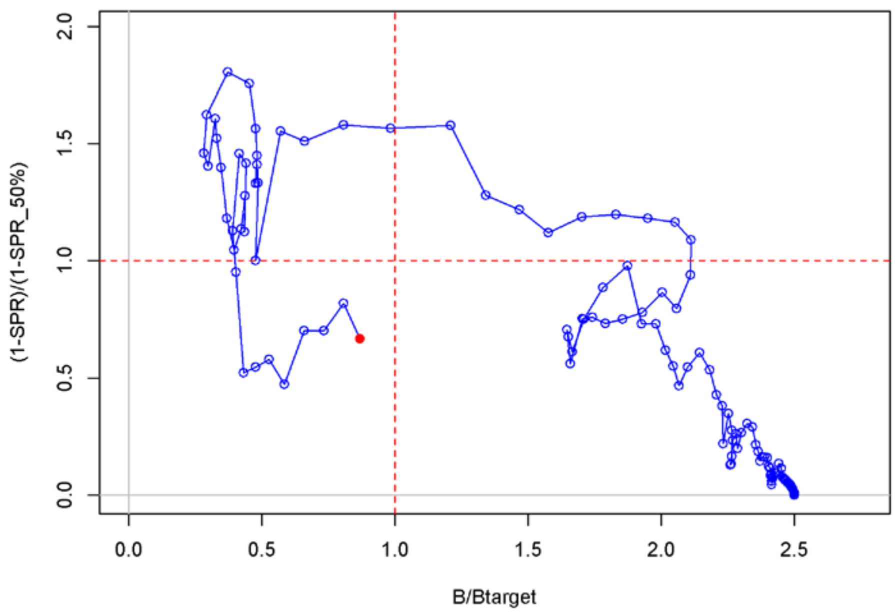


Figure 124: Phase plot of relative spawning output vs fishing intensity for the California BDR base case model. The relative fishing intensity is (1-SPR) divided by 50% (the SPR target). The vertical red line is the relative spawning output target defined as the annual spawning output divided by the spawning output corresponding to 40% of the unfished spawning output.

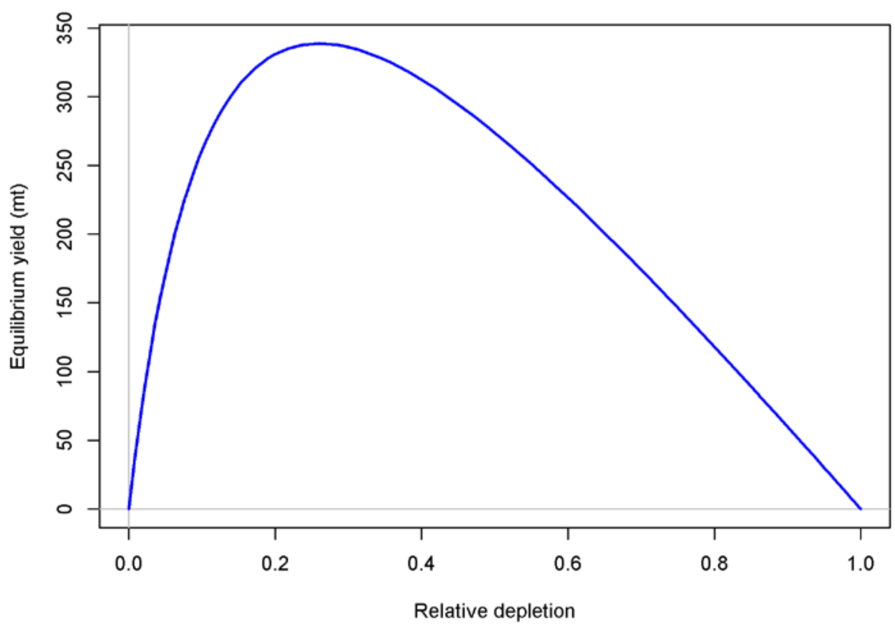


Figure 125: Equilibrium yield curve for the California BDR base case model. Values are based on 2016 fishery selectivity and distribution with steepness estimated to be 0.645. Depletion (x-axis) is relative to unfished spawning output. Maximum sustainable yield is 339 mt. The $SPR_{50\%}$ proxy yield is 306 mt.

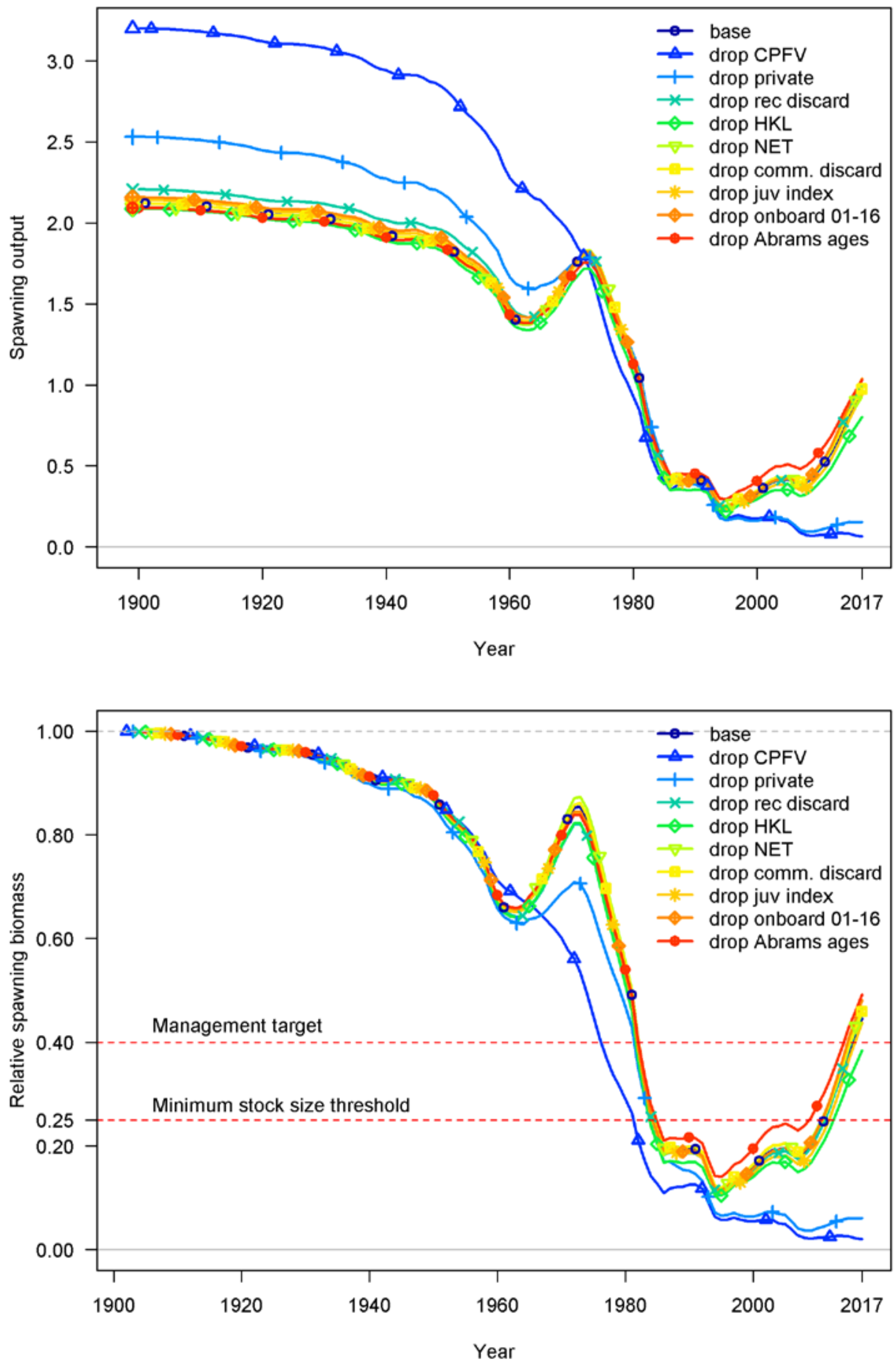


Figure 126: Time series of spawning output (top) and relative depletion (bottom) from California Pre-STAR base model, excluding data (trends, lengths, and ages) one fleet at a time. Fleets 2 & 3 both represent the recreational private boat fleet, and were both dropped in the same sensitivity run. Runs that dropped the majority of recent age data (Schmidt ages) and the 1988-98 onboard CPFV observer data did not converge and are not shown.

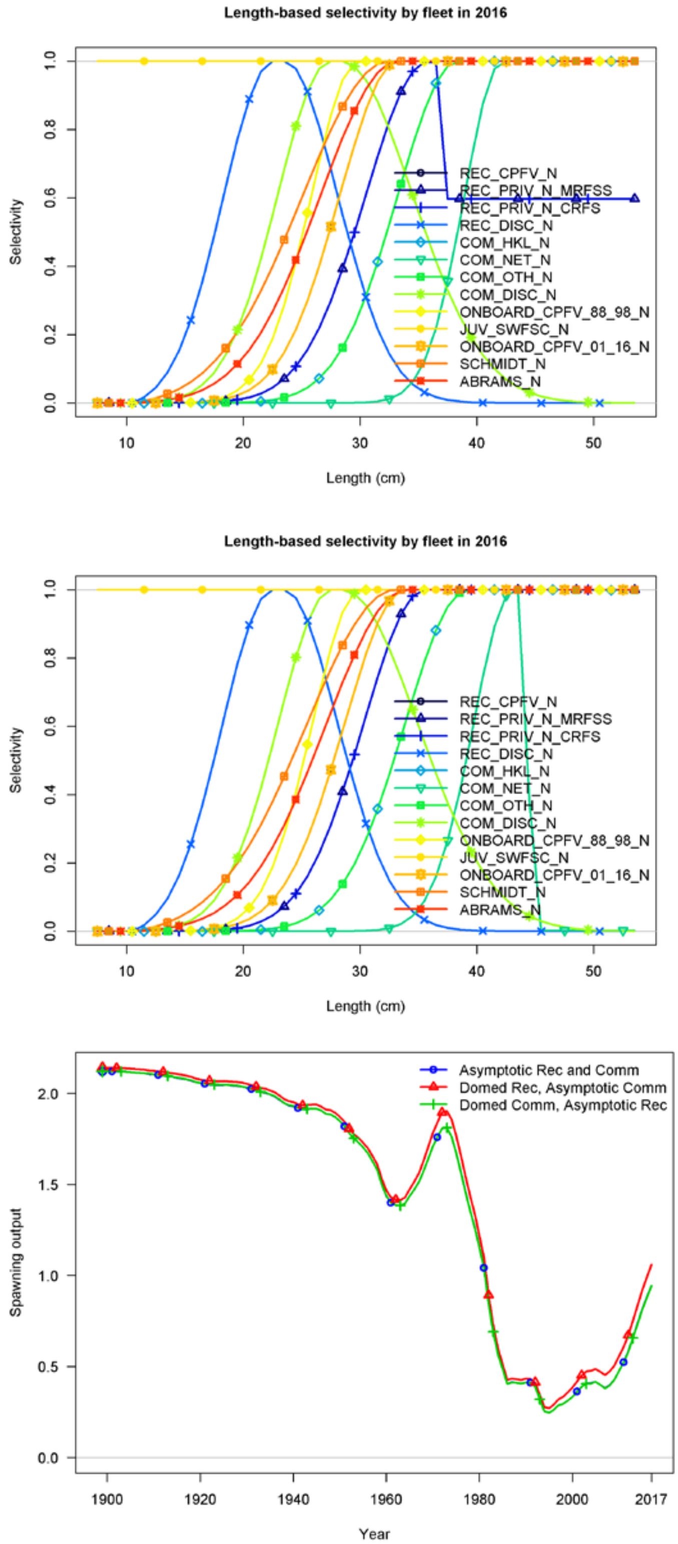


Figure 127: Sensitivity to more flexible (dome-shaped) selectivity curves in the California recreational fleets (top panel) and commercial fleets (middle panel). Either model produced little change in spawning output trajectories (bottom panel).

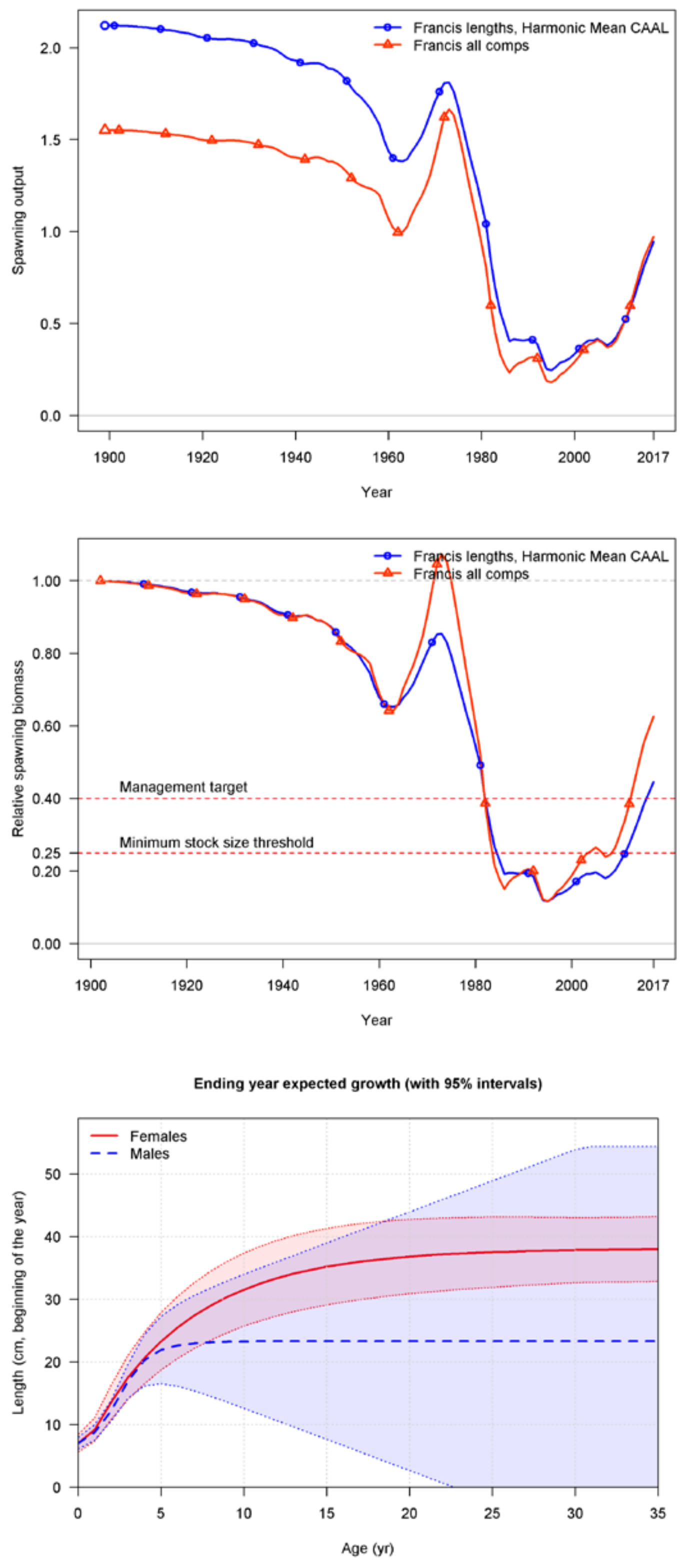


Figure 128: Comparison of California spawning output (top panel) and depletion (middle panel) trajectories for the base case model (blue line) and a model with Francis weights applied to all composition data (red line). The model with all Francis weights produced unreasonable estimates of male growth (bottom panel).

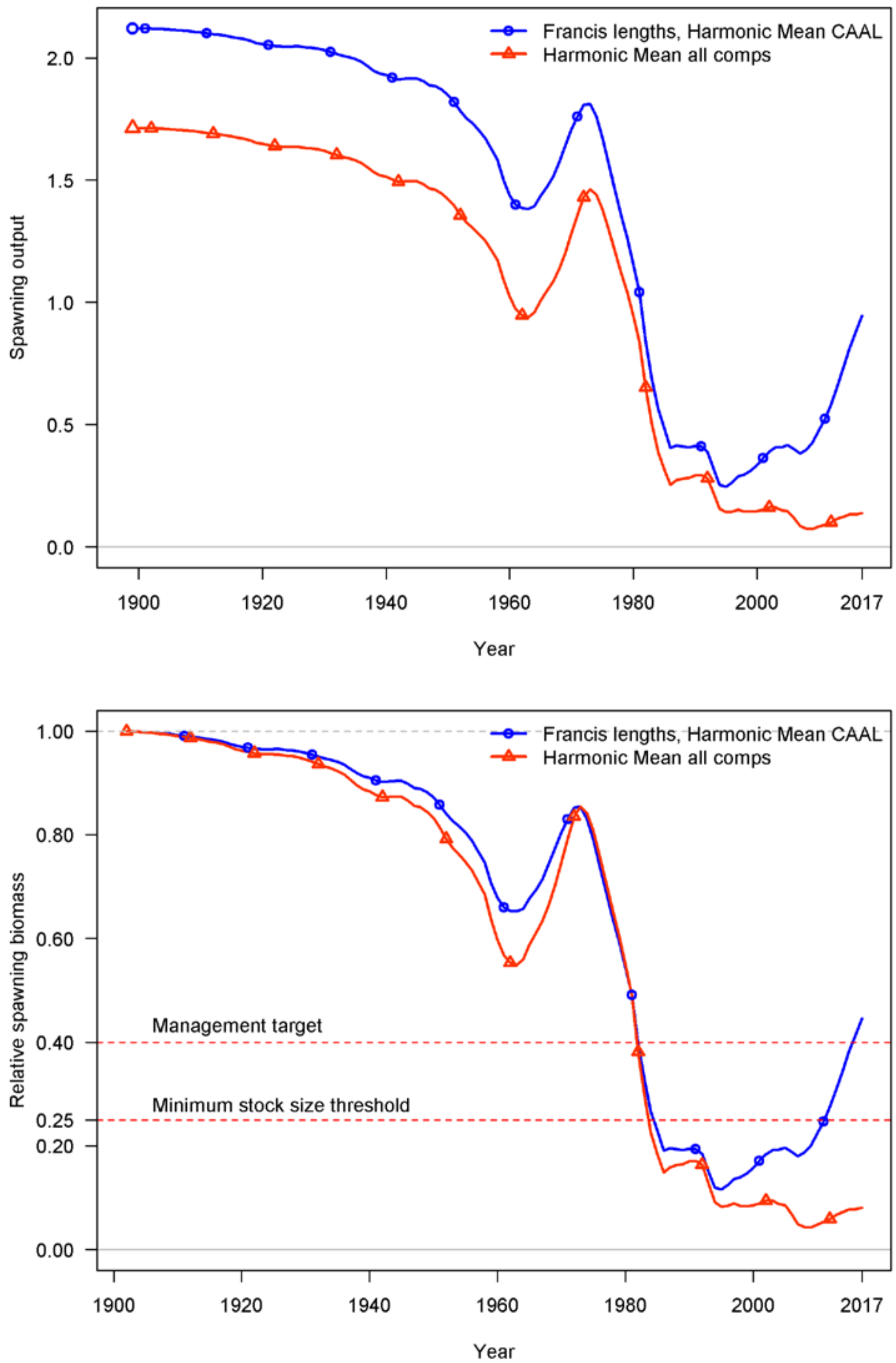


Figure 129: Comparison of California spawning output (top panel) and depletion (bottom panel) trajectories for the base case model (blue line) and a model with harmonic mean weights applied to all composition data (red line).

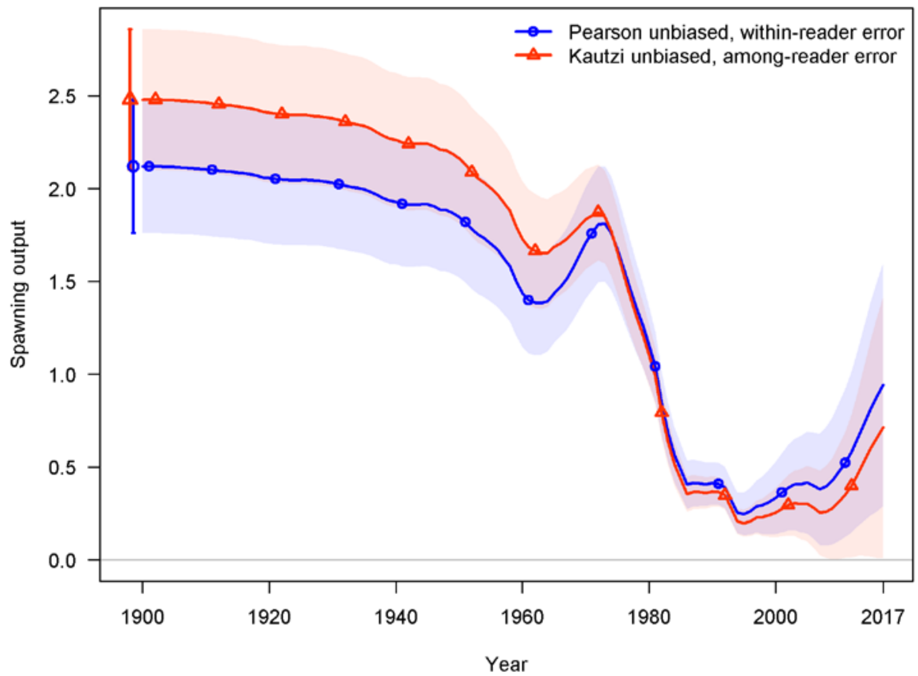


Figure 130: Comparison of spawning output trajectories based on alternative ageing error matrices in the pre-STAR base model.

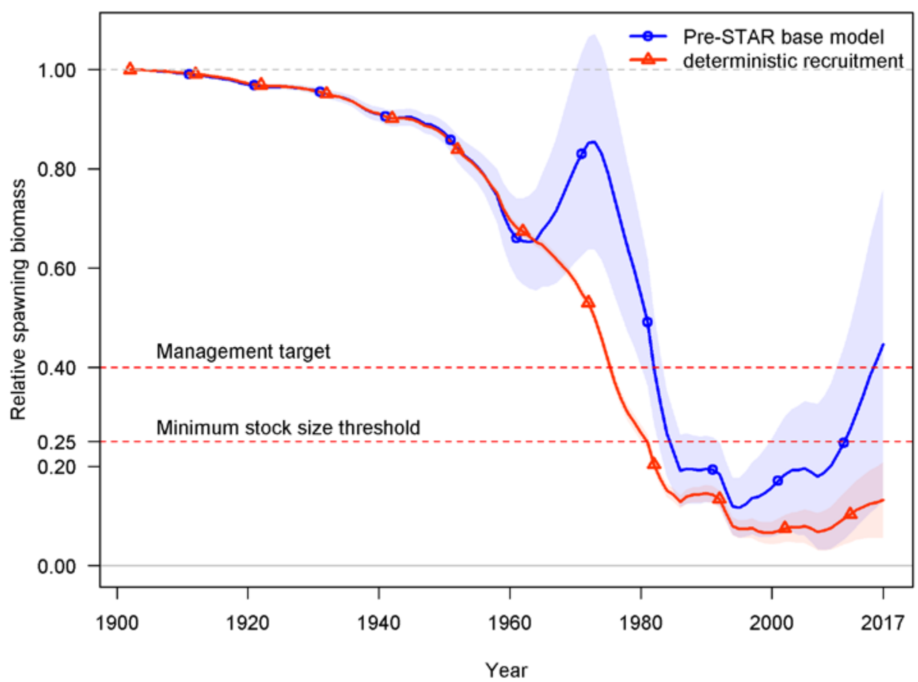


Figure 131: Comparison of pre-STAR base models with and without recruitment deviations.

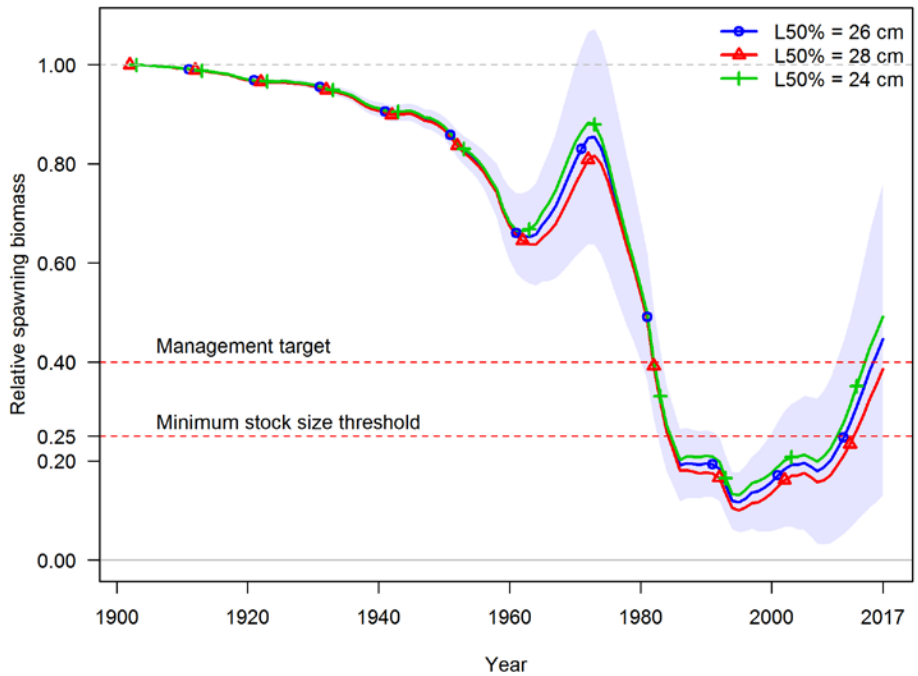


Figure 132: Sensitivity of stock depletion to changes in length at 50% maturity in the pre-STAR base model.

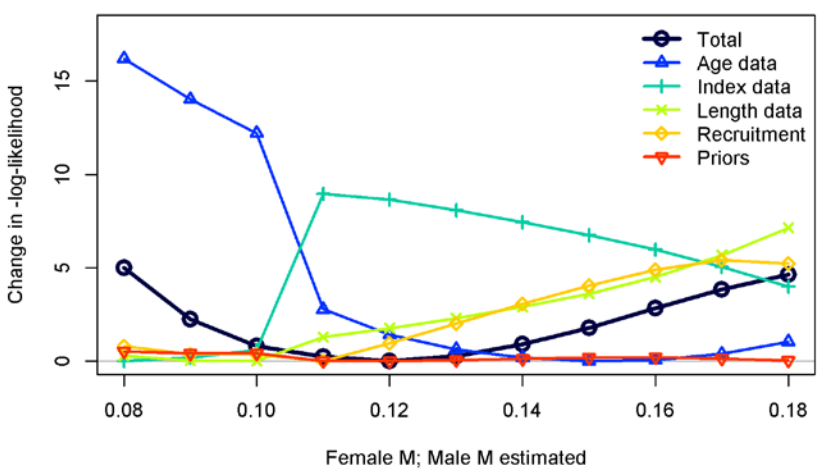


Figure 133: Likelihood profiles by data category over assumed values of the female natural mortality rate, M, for the California model. Male M (estimated as an exponential offset) is allowed to vary in this profile.

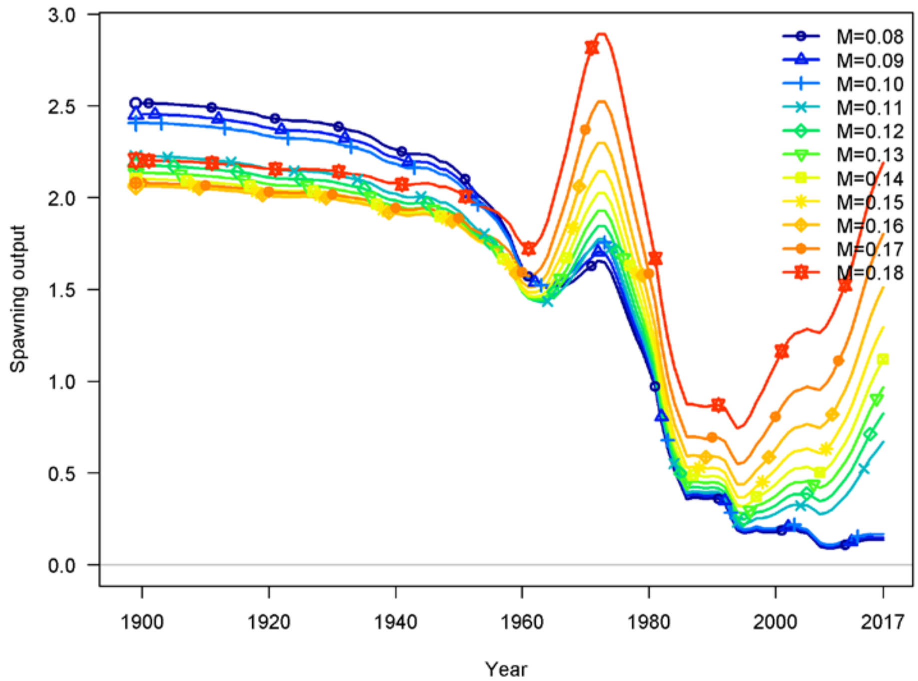


Figure 134: Time series of spawning output associated with profiles over female natural mortality rate, M, for the California base model. Male M (estimated as an exponential offset) is allowed to vary in this profile.

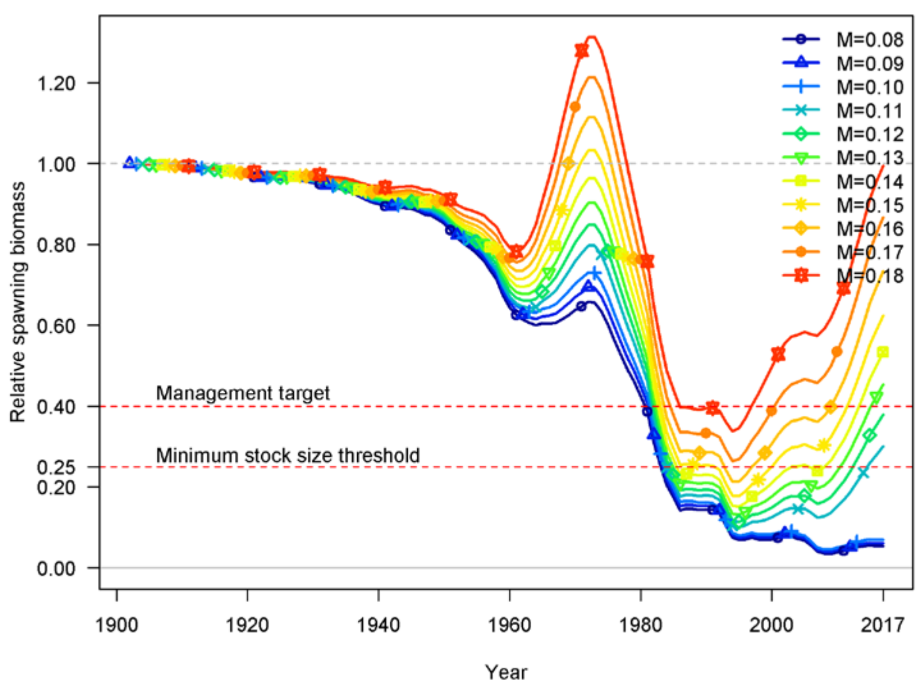


Figure 135: Time series of spawning output, relative to unfished spawning output ("depletion"), associated with profiles over female natural mortality rate, M, for the California base model. Male M (estimated as an exponential offset) is allowed to vary in this profile.

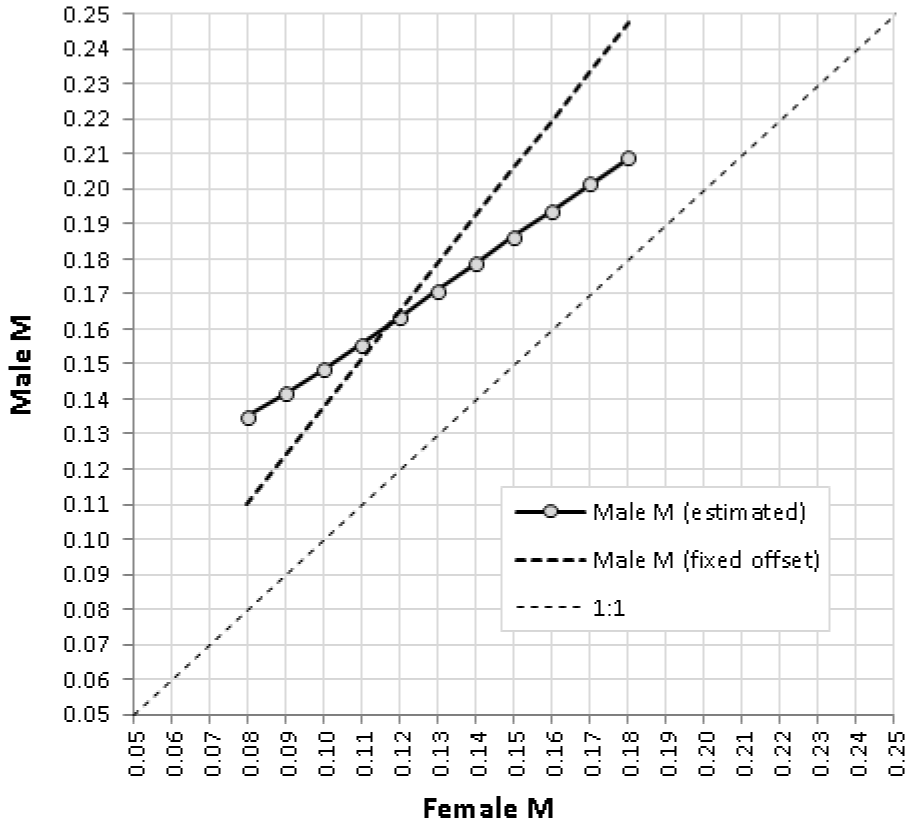


Figure 136: Male natural mortality rate estimates from a profile over female natural mortality (0.08 – 0.18 yr^{-1}) in the California pre-STAR base model (solid line with open circles). Shown for comparison are male M derived from a fixed, exponential offset set equal to the base case estimate (thick dashed line), and the 1:1 line (thin dashed line). Steepness was fixed at 0.718 in all runs.

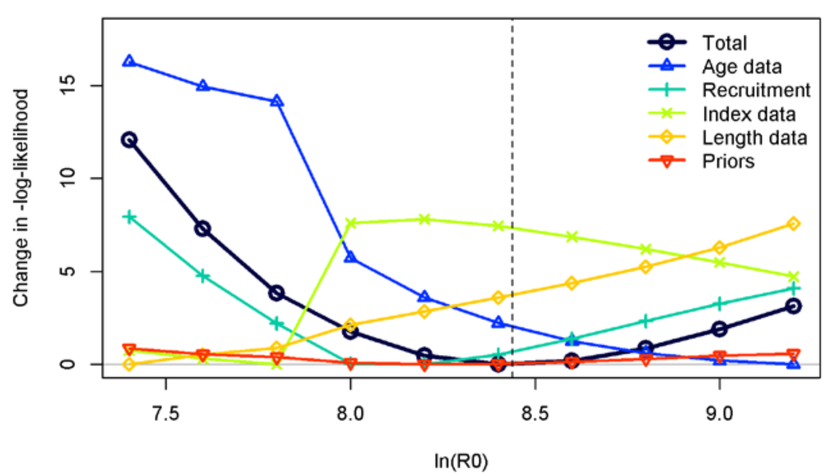


Figure 137: Likelihood profiles by component type over assumed values of log unfished recruitment, ln(R0), for the California base model. The vertical dashed line indicates the estimated value in the base case model.

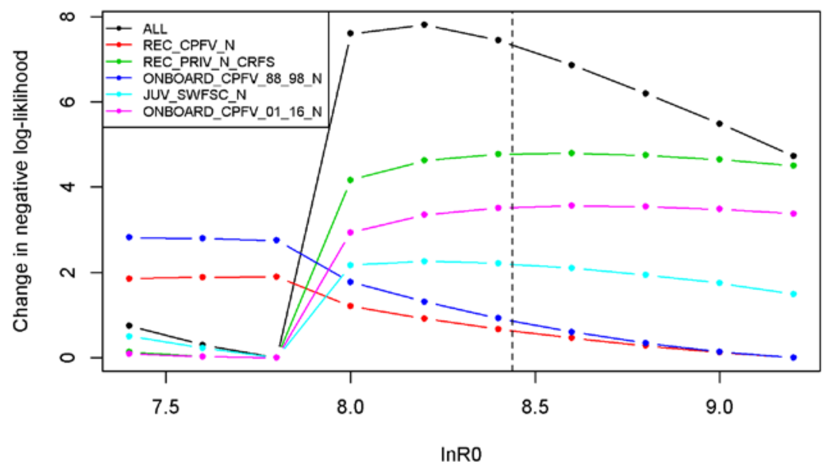


Figure 138: Likelihood profiles over the log of unfished recruitment, ln(R0), by fleet and survey for abundance indices in the California base model. Vertical dashed line = estimated base case value.

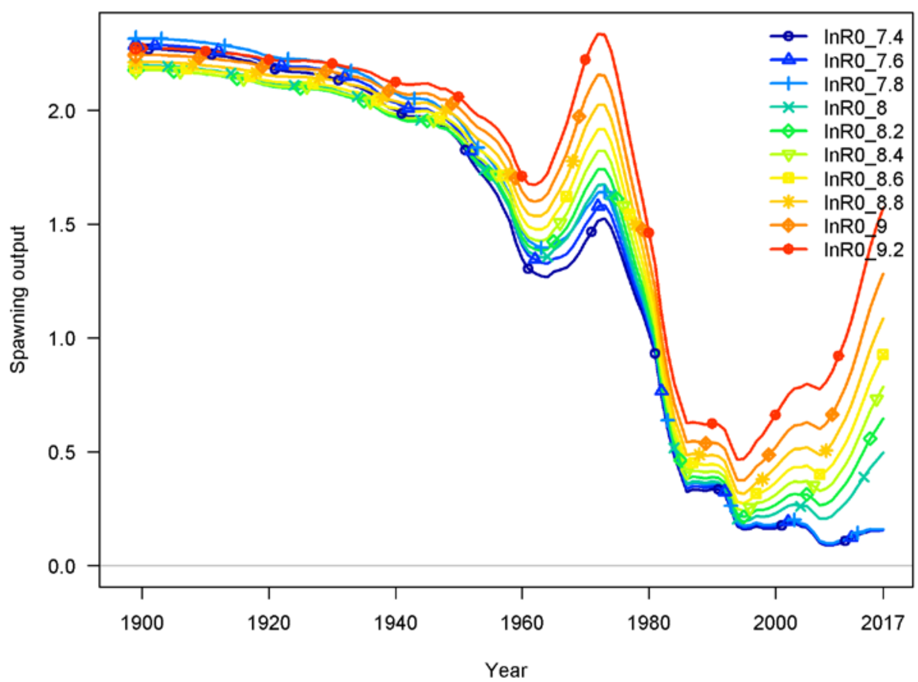


Figure 139: Time series of spawning output associated with profiles over the log of unfished equilibrium recruitment, ln(R0), for the California base model.

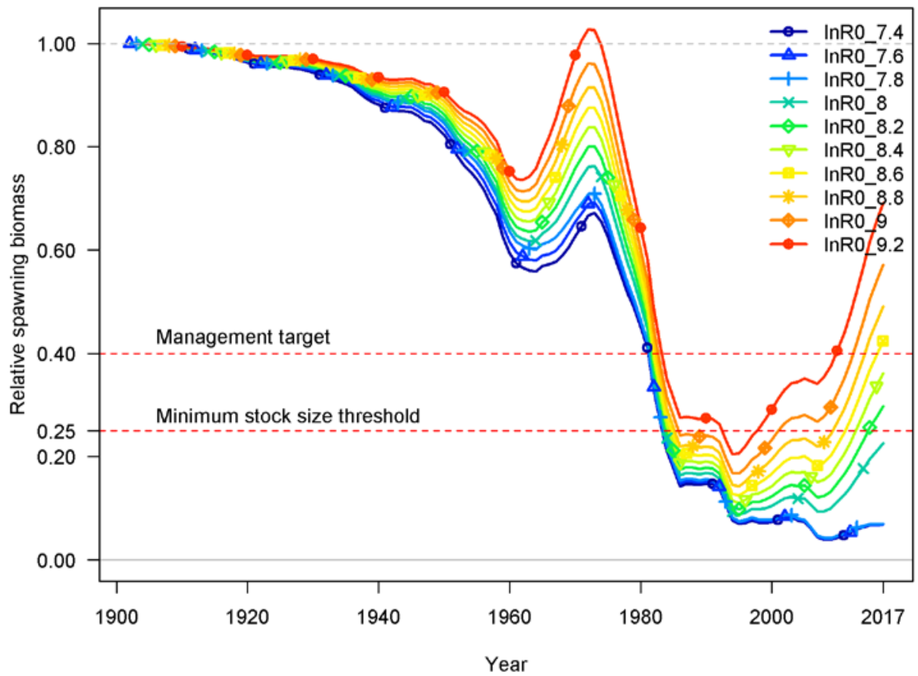


Figure 140: Time series of spawning output relative to unfished spawning output ("depletion") associated with profiles over the log of unfished equilibrium recruitment, ln(R0), for the California base model

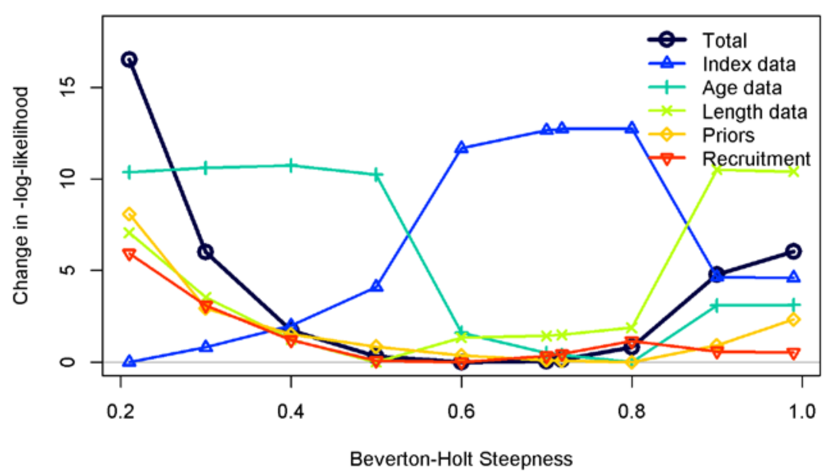


Figure 141: Likelihood profiles by data category over assumed values of the Beverton-Holt steepness parameter, h, for the California base model. The horizontal dashed line indicates the value in the base case model. Models with steepness values of 0.9 and 0.99 hit the upper bound of R0 and are not plotted in time series plots.

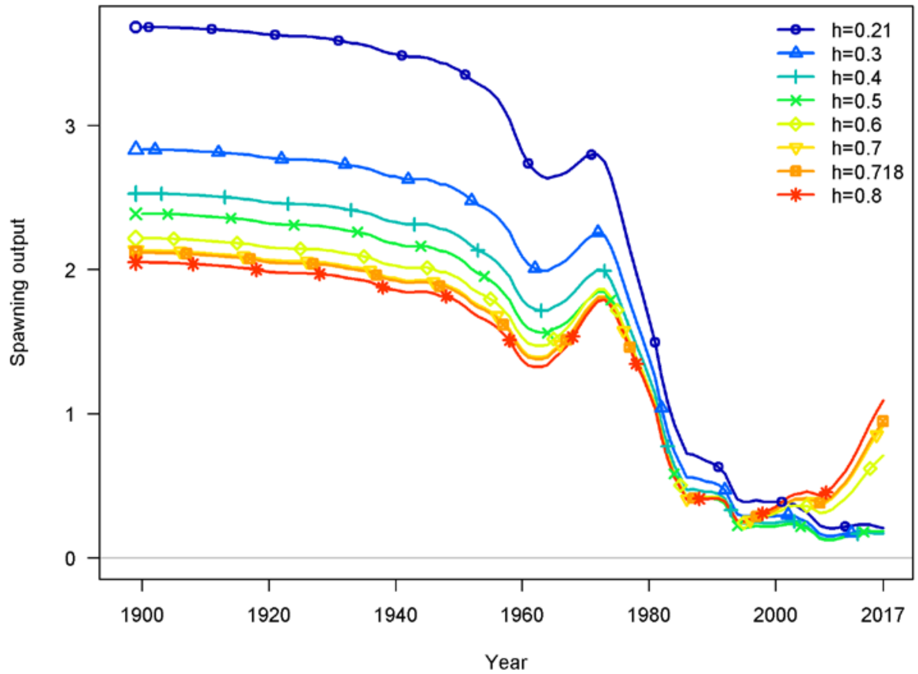


Figure 142: Time series of spawning output associated with profiles over the Beverton-Holt steepness parameter, for the California base model.

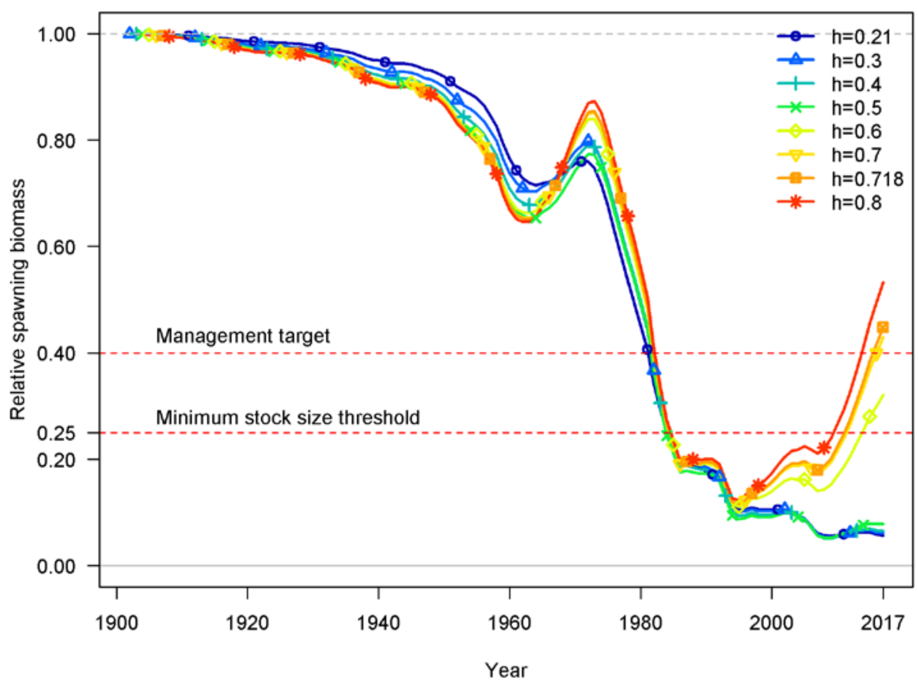


Figure 143: Time series of spawning output relative to unfished spawning output ("depletion") associated with profiles over the log of unfished equilibrium recruitment, ln(R0), for the California base model

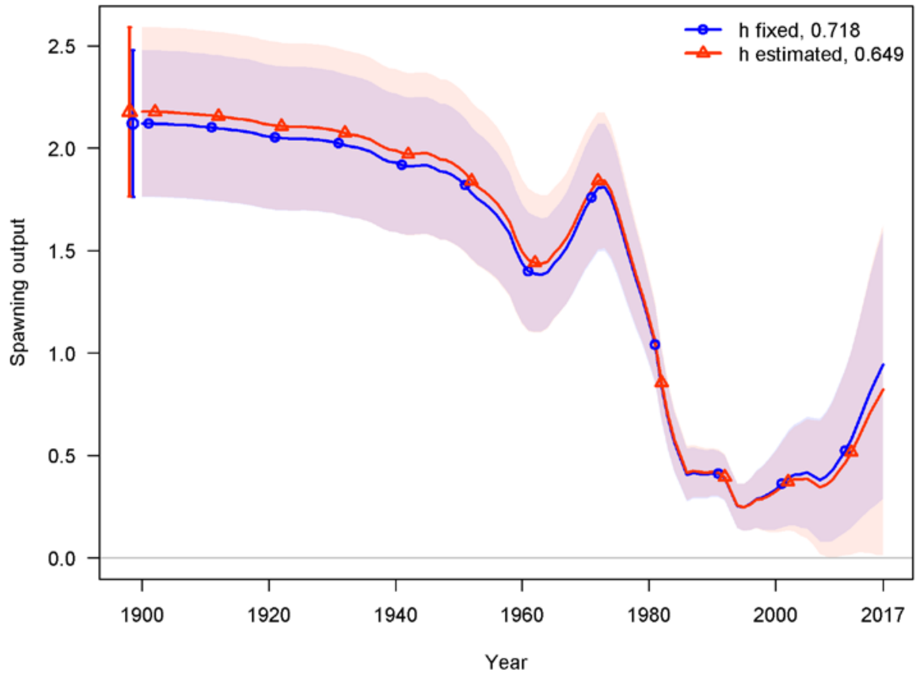


Figure 144: Comparison of spawning output trajectories for the pre-STAR California base model with fixed Beverton-Holt steepness parameter (h = 0.718) and the same model with estimated steepness (h = 0.649).

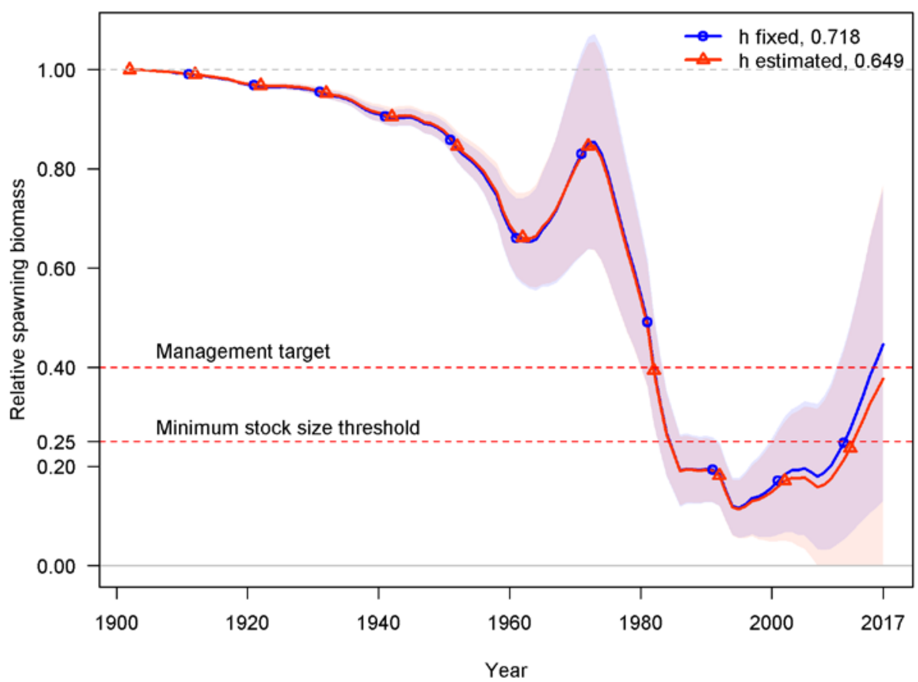


Figure 145: Comparison of spawning output relative to unfished spawning output ("depletion") trajectories for the pre-STAR California base model with fixed Beverton-Holt steepness parameter (h = 0.718) and the same model with estimated steepness (h = 0.649).

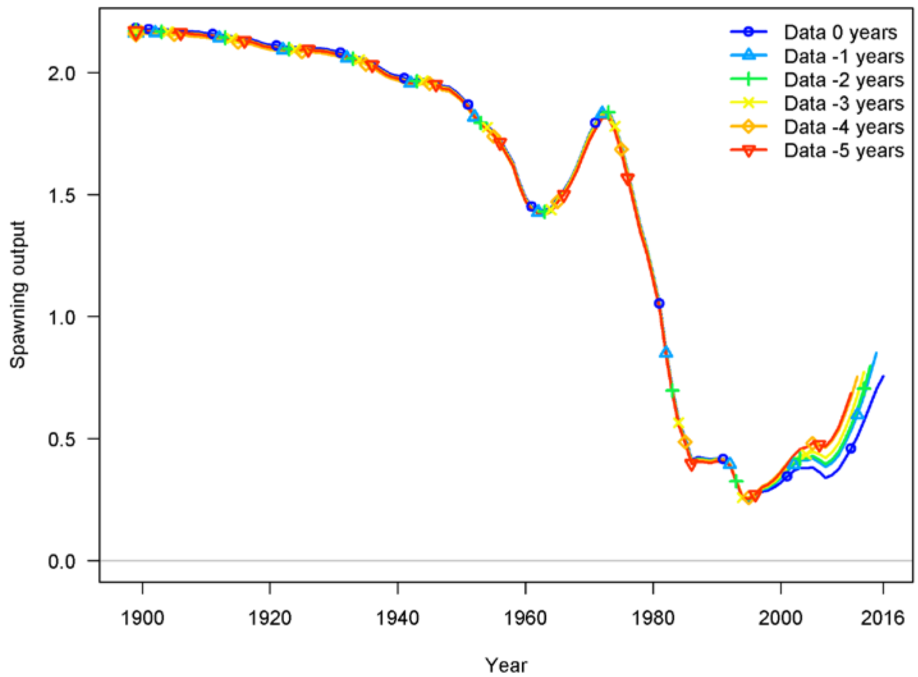


Figure 146: Time series of spawning output from California base model retrospective analysis; sequential removal of five years' data.

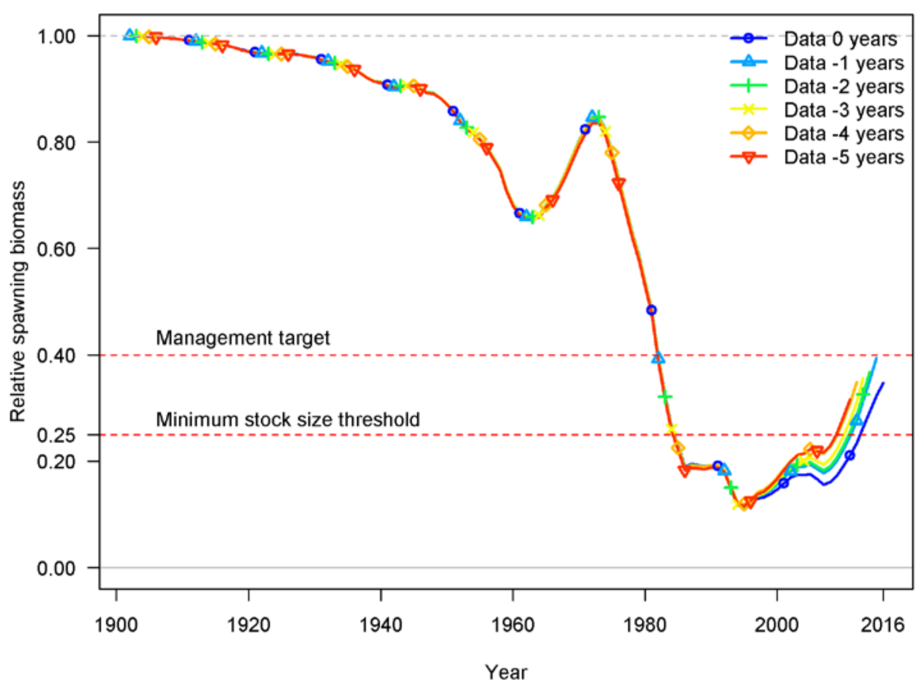


Figure 147: Time series of relative spawning output ("depletion") from California base model retrospective analysis; sequential removal of five years' data.

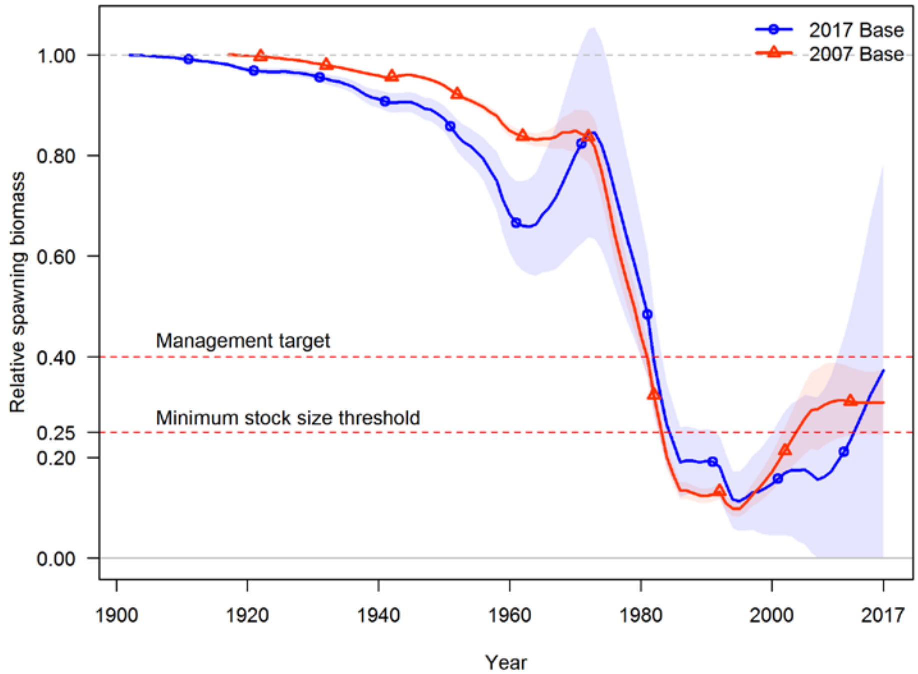


Figure 148: Comparison of relative spawning output ("depletion") time series from the 2007 and 2017 base case models for California. The depletion time series from the 2007 assessment includes forecast years through 2017. Increased uncertainty in the post-STAR 2017 results is due in large part to estimation of natural mortality and steepness parameters, which were fixed (i.e. not estimable) in the 2007 assessment.

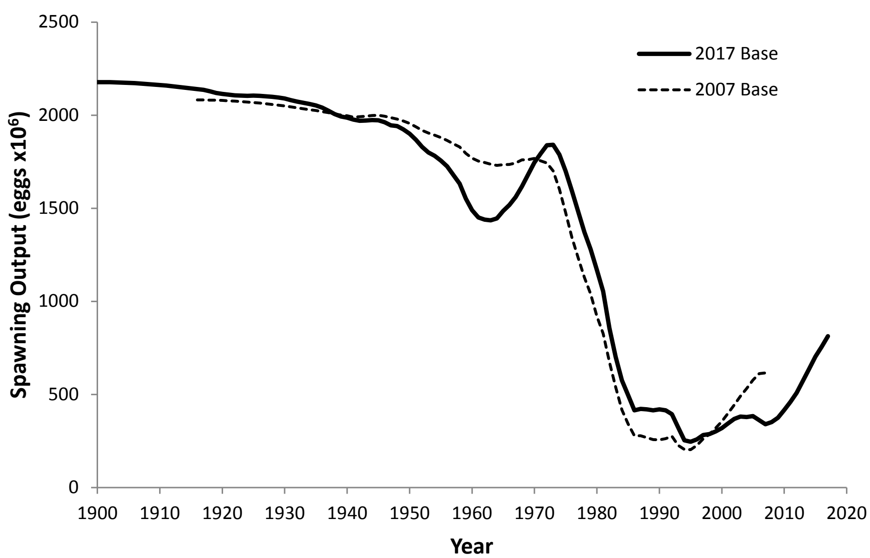


Figure 149: Comparison of spawning output time series from the 2007 and 2017 base case models for California (rescaled to common units; millions of eggs), showing similarities between assessments in terms of population scale.

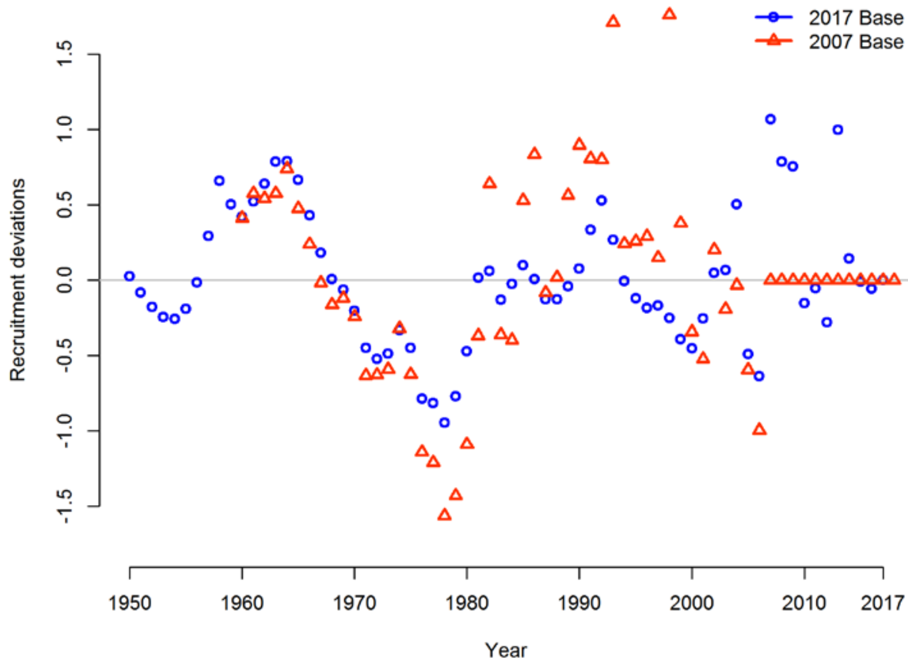


Figure 150: Comparison of recruitment deviations from the 2007 and 2017 base case models for California.

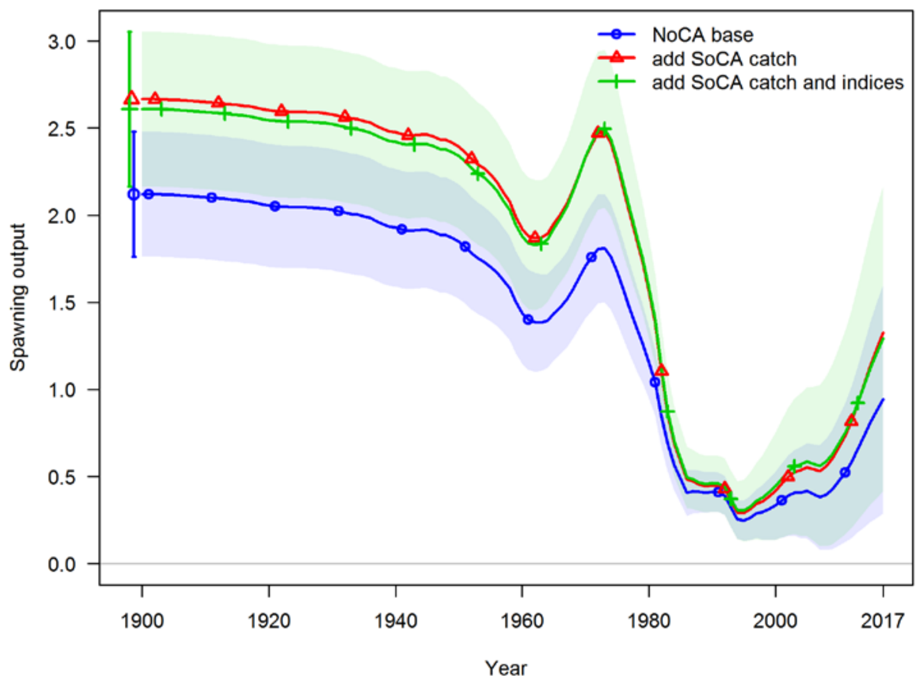


Figure 151: Spawning output trajectories showing the cumulative effect of adding Southern California data to the Pre-STAR California base model (i.e. using a "fleets as areas" approach).

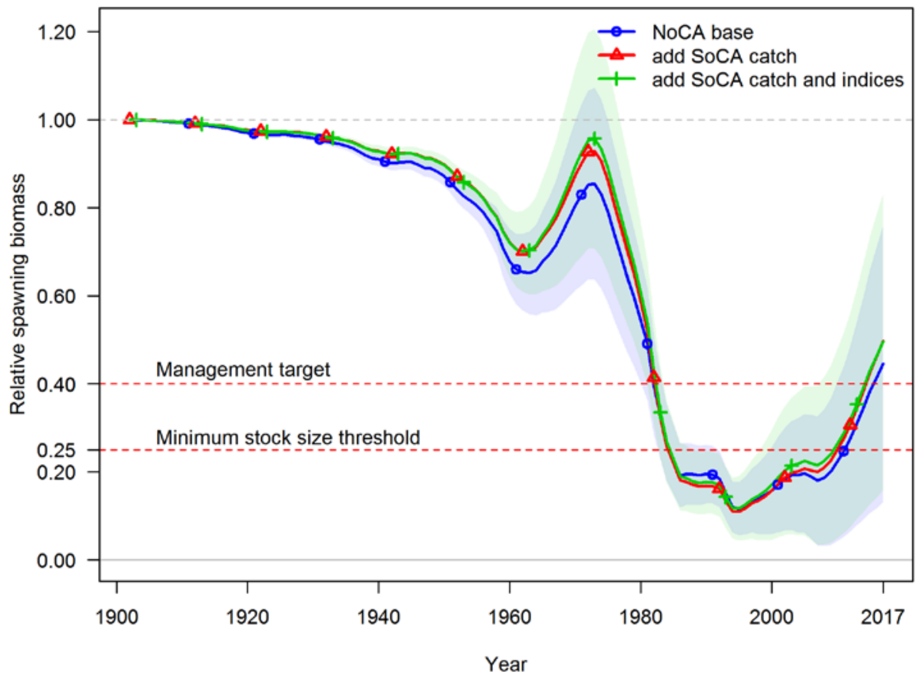


Figure 152: Relative spawning output ("depletion") trajectories showing the cumulative effect of adding Southern California data to the Pre-STAR California base model (i.e. using a "fleets as areas" approach).

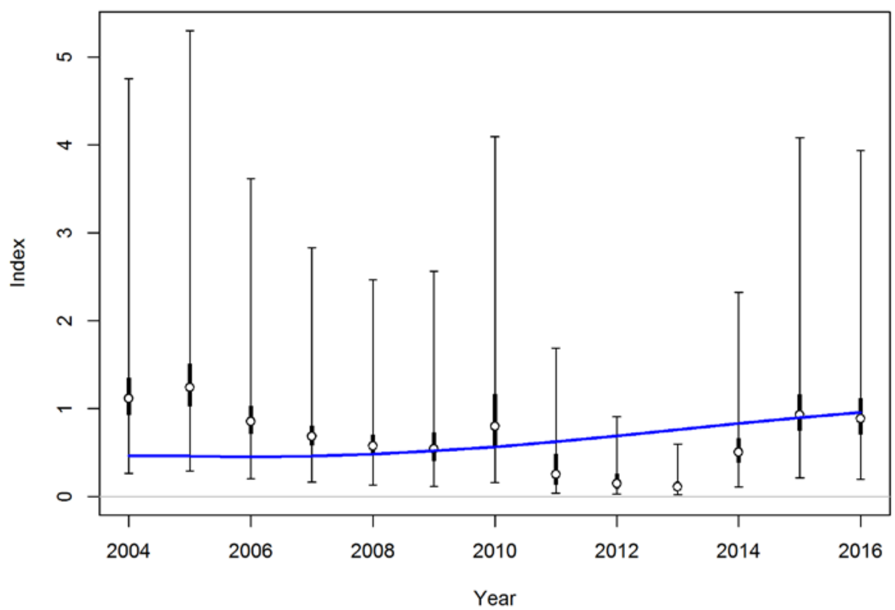


Figure 153: Pre-STAR base model fit to the southern California CRFS private boat index.

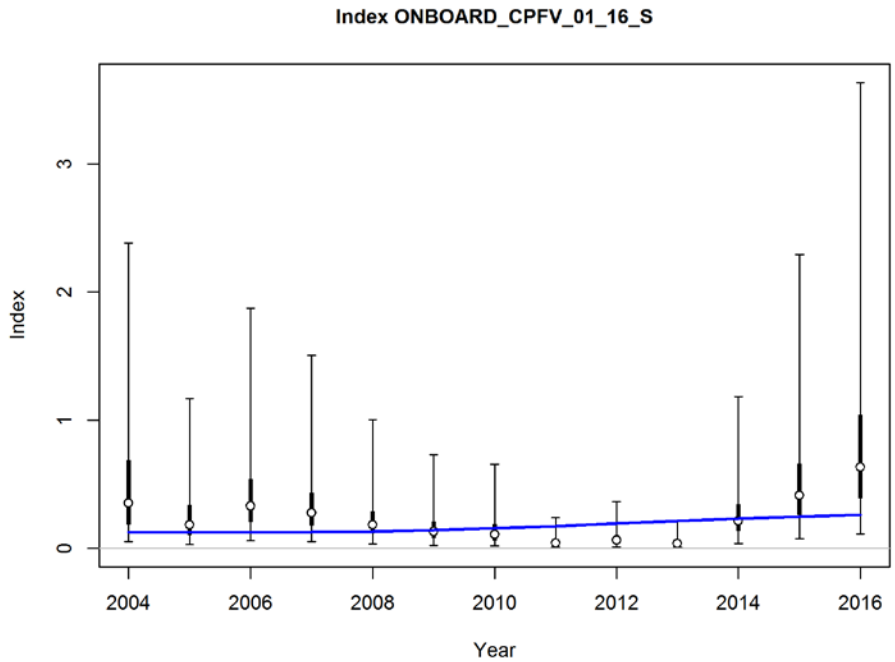


Figure 154: Pre-STAR base model fit to the southern California CRFS onboard CPFV index.

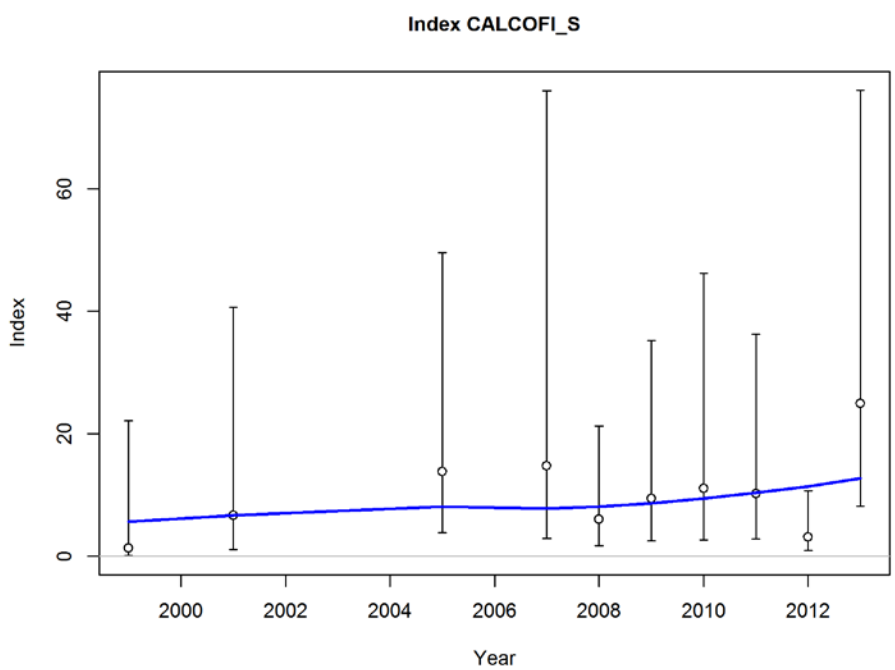


Figure 155: Pre-STAR base model fit to the southern California CalCOFI spawning output index.

12.2 Oregon Figures

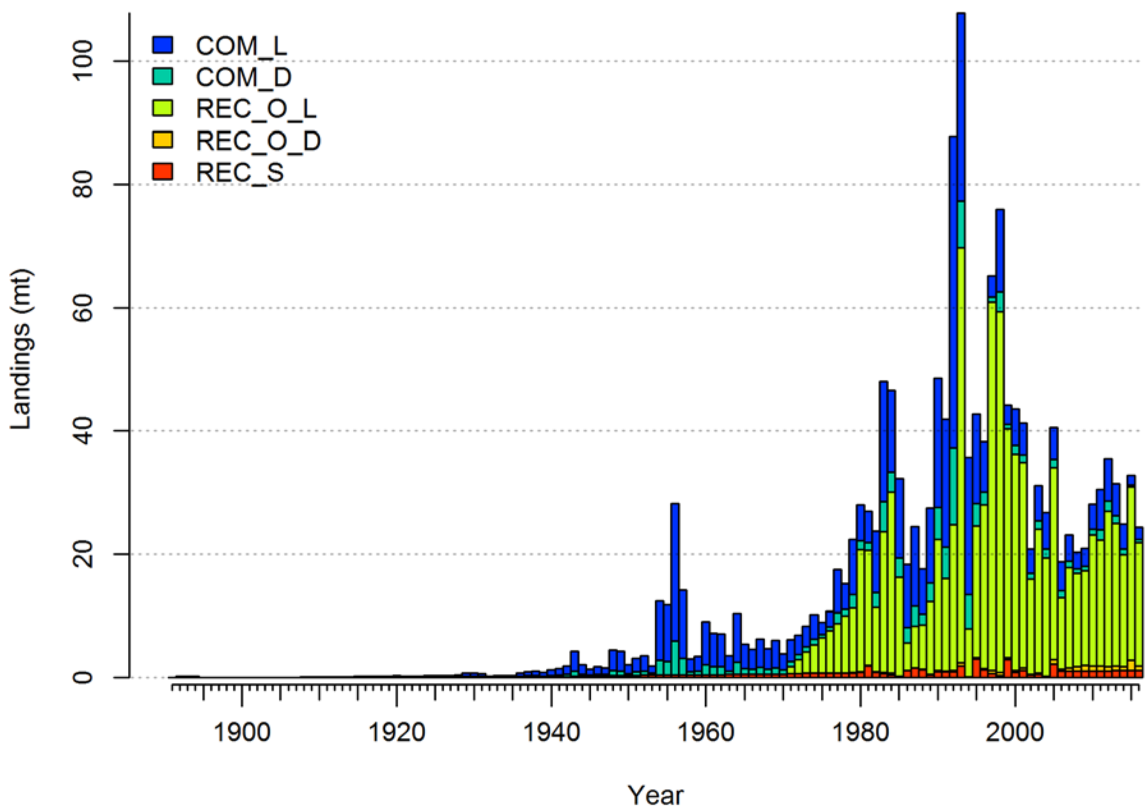


Figure 156: Stacked time series of Oregon BDR landings (mt) by fleet for Oregon waters.

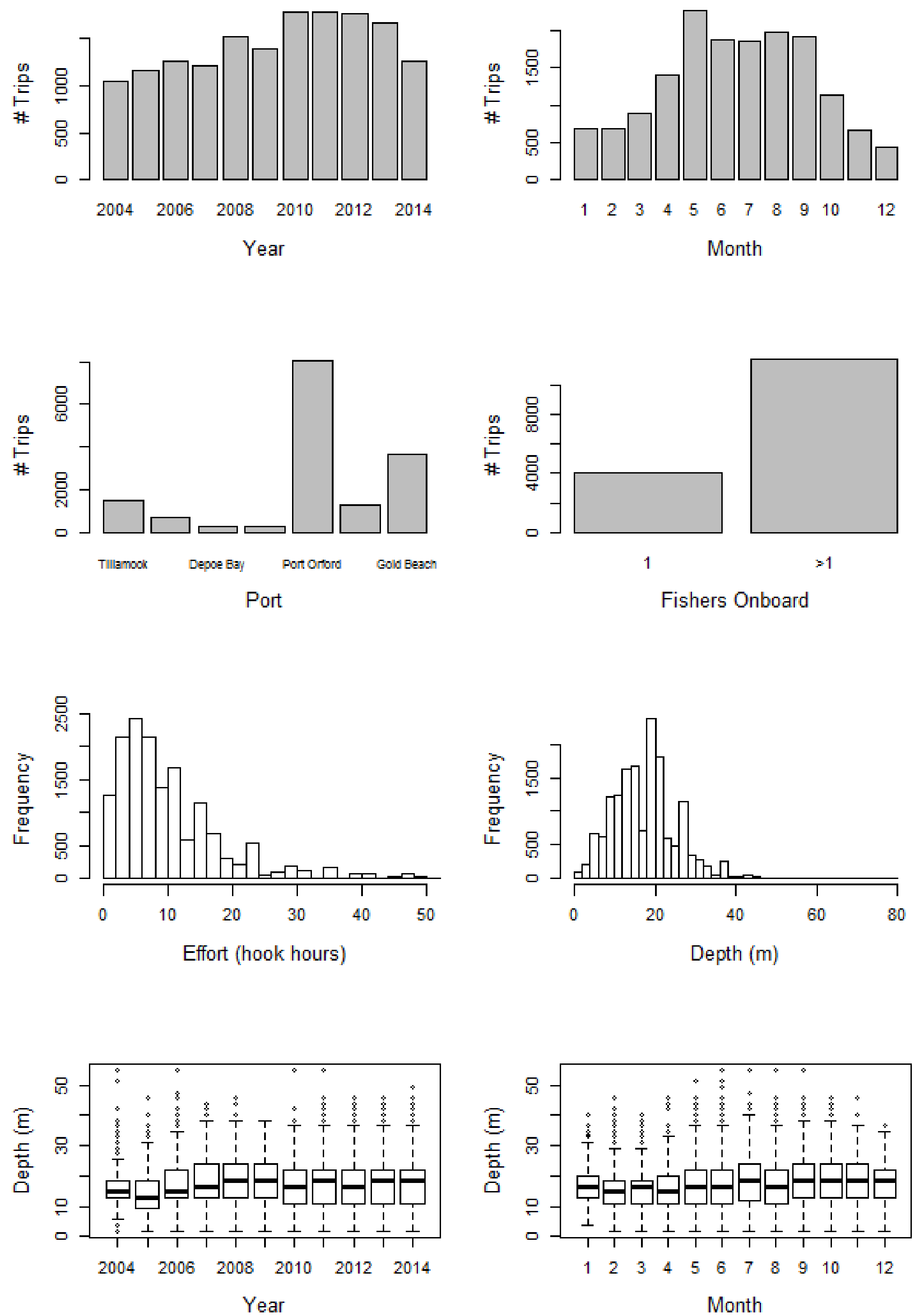


Figure 157: Characterization of the final subset of logbook data used in delta-GLM analyses for Oregon BDR

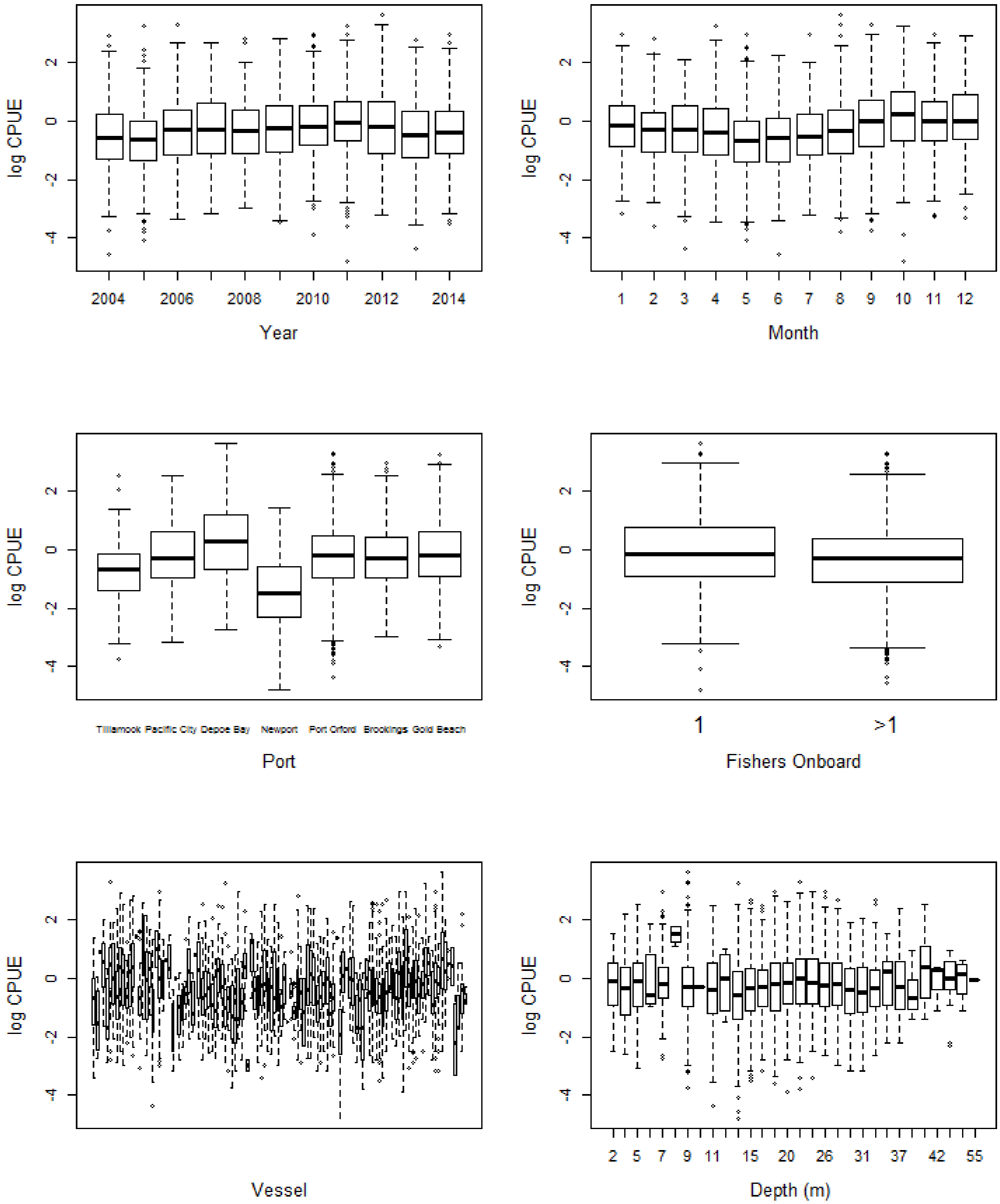


Figure 158: The distribution of set-level raw positive catch CPUE data for the commercial logbook data relative to potential covariates evaluated in the Oregon BDR delta-GLM analysis

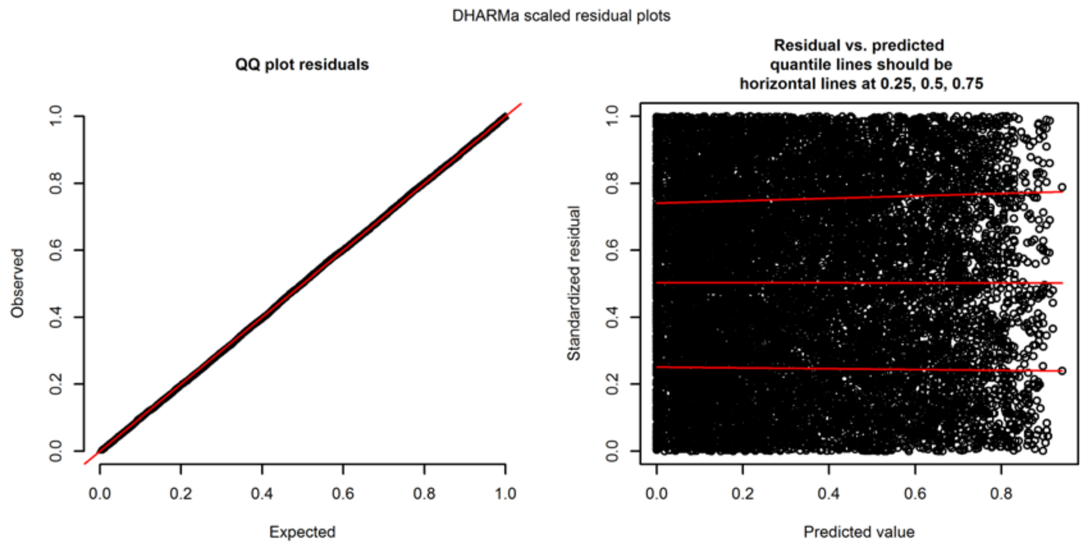


Figure 159: Diagnostic QQ and residual plots for Oregon BDR commercial logbook binomial model component for the delta-GLM model.

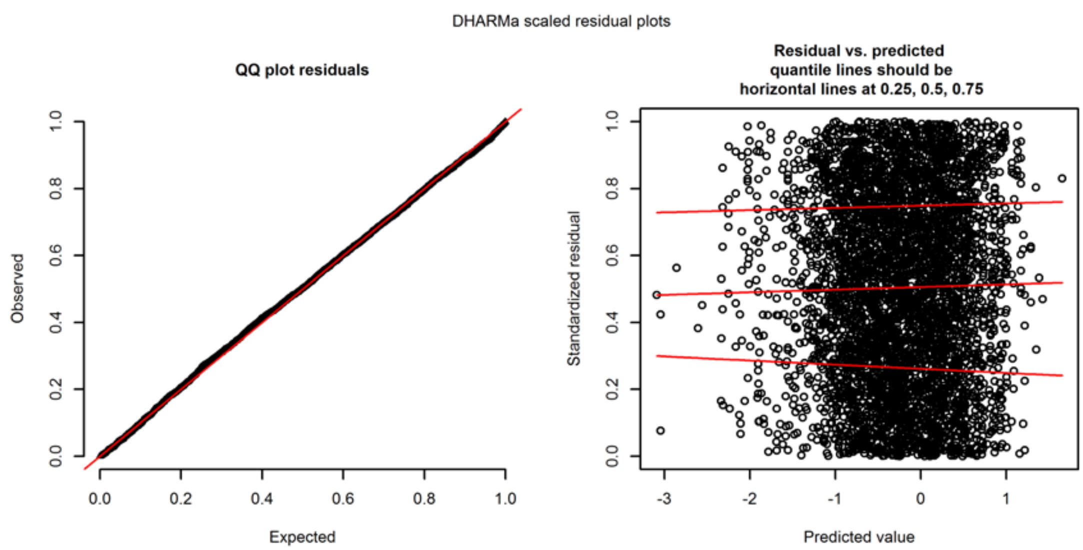


Figure 160: Diagnostic QQ and residual plots for Oregon BDR commercial logbook positive catch model component for the delta-GLM model

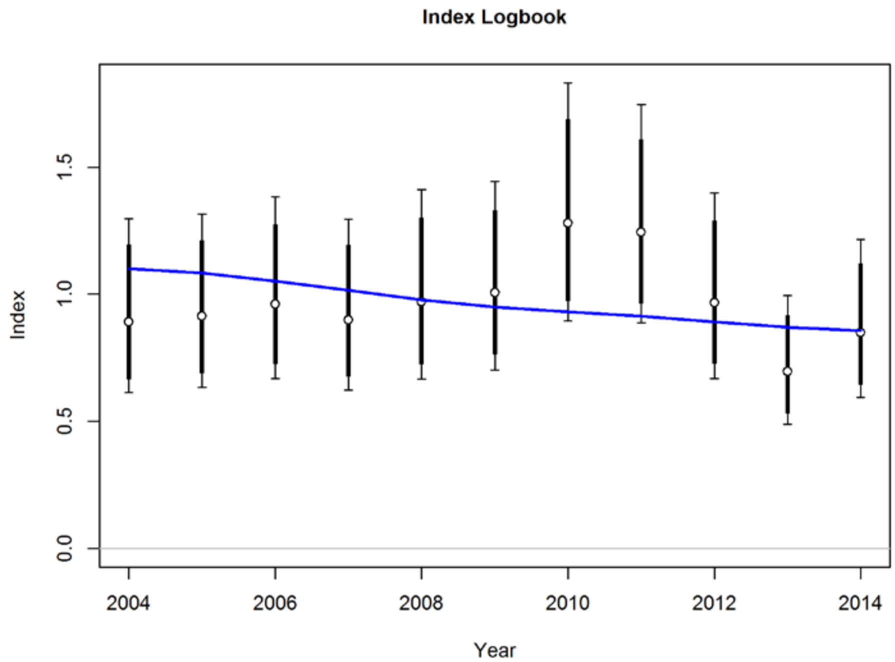


Figure 161: Model fit to the Oregon commercial logbook index.

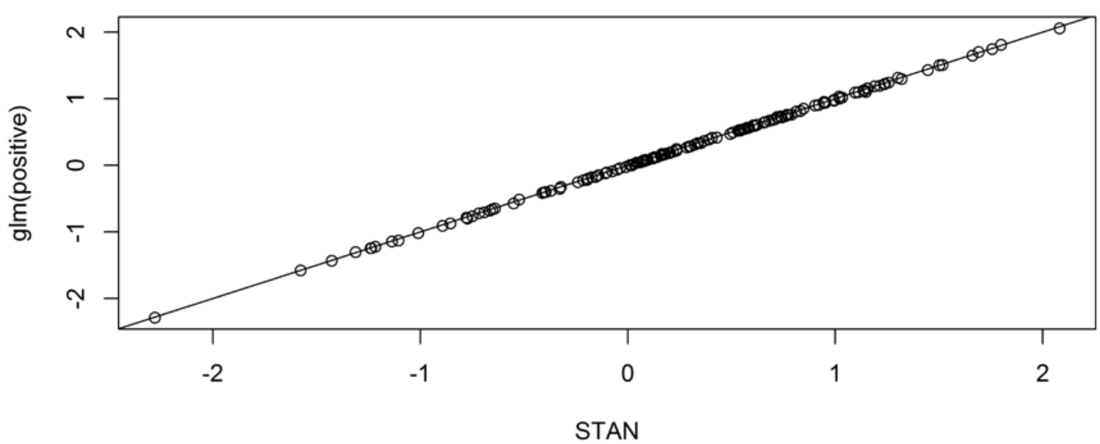


Figure 162: Correspondence between the maximum likelihood estimates from the GLM analysis to the STAN Bayesian regression model approach used to estimate 95% prediction credible intervals from the posterior predictive distribution.

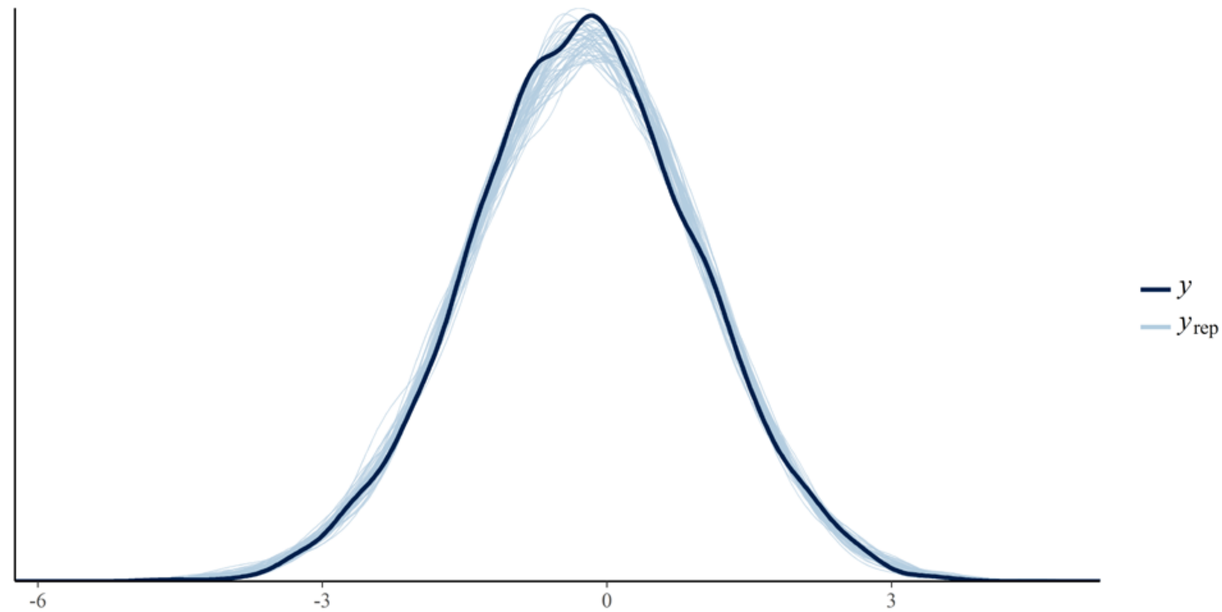


Figure 163: Comparison of data distribution for commercial logbook CPUE to model-generated replicate data sets.

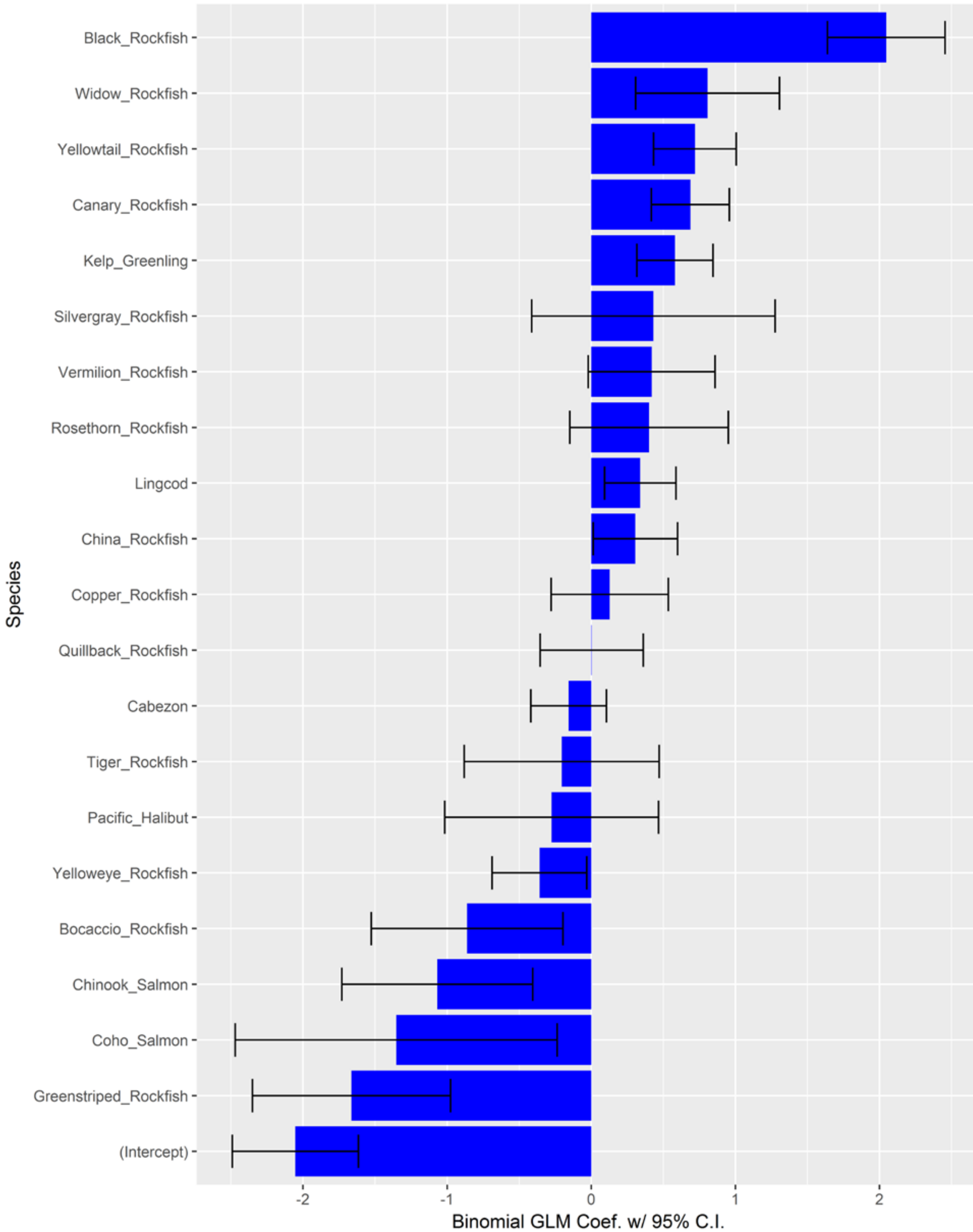


Figure 164: Species coefficients for the Stephens-MacCall filter of the Oregon MRFSS ocean-boat data.

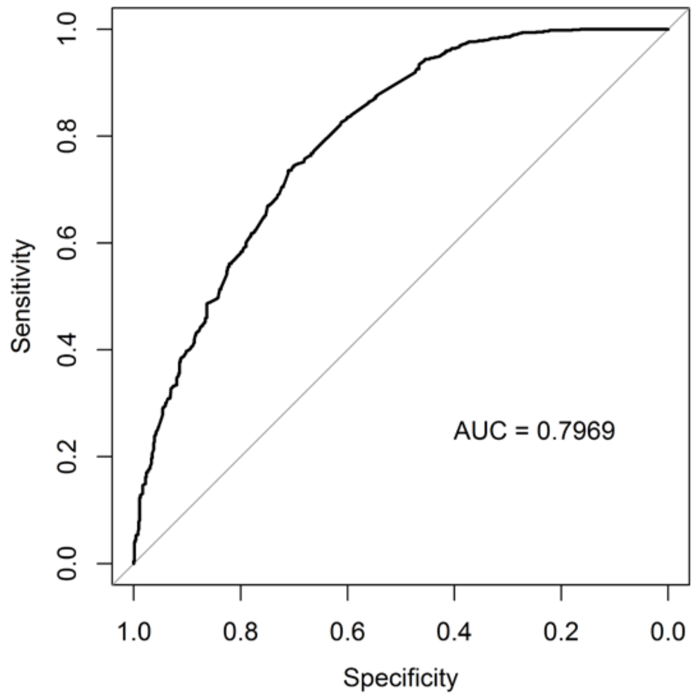


Figure 165: The Oregon MRFSS area under the characteristic curve (AUC) plot, which represents the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence. Values much greater than 0.5 indicate a significant improvement over a random classifier (AUC = 0.5).

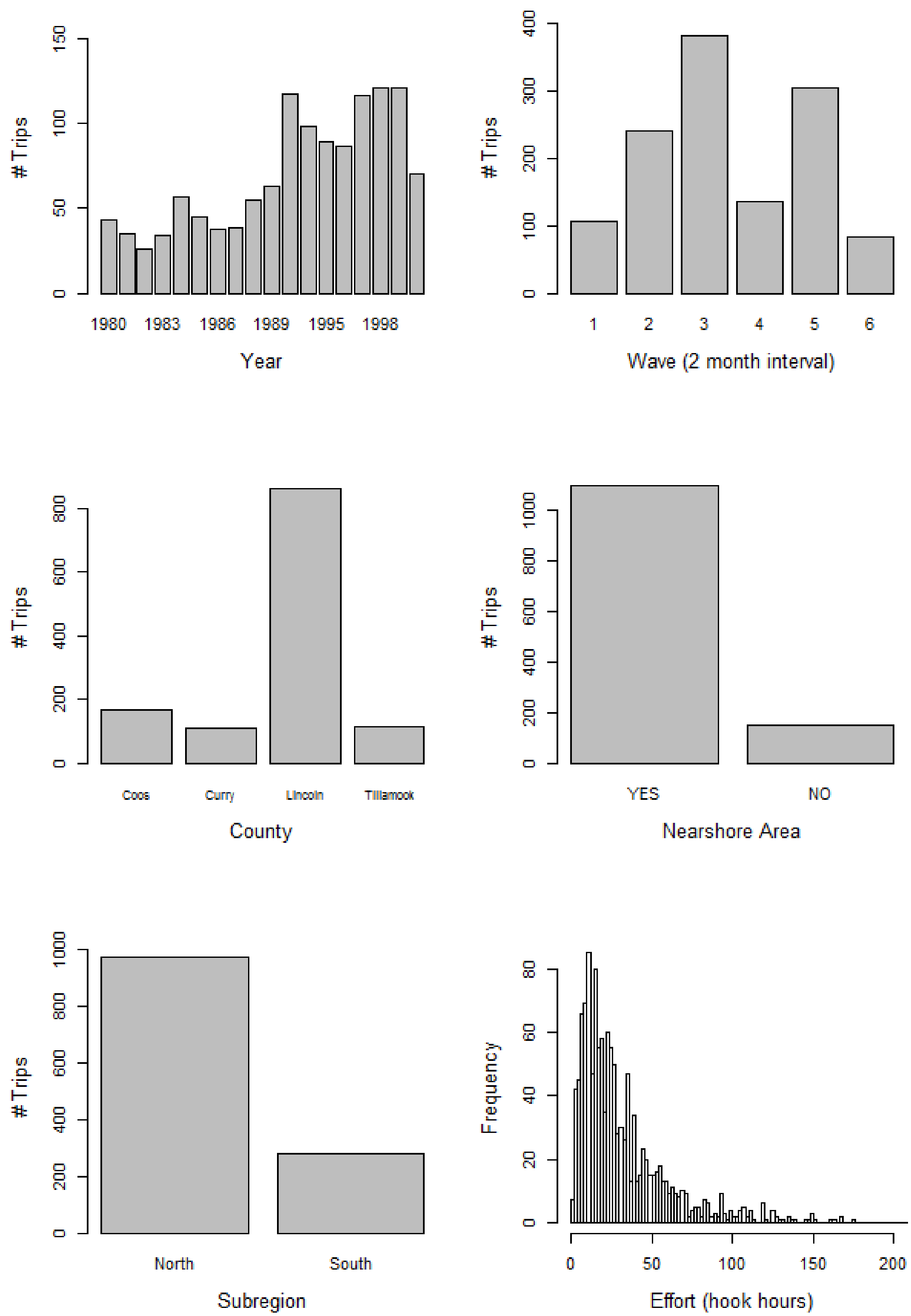


Figure 166: Characterization of the final subset of MRFSS data used in GLM analyses for Oregon BDR.

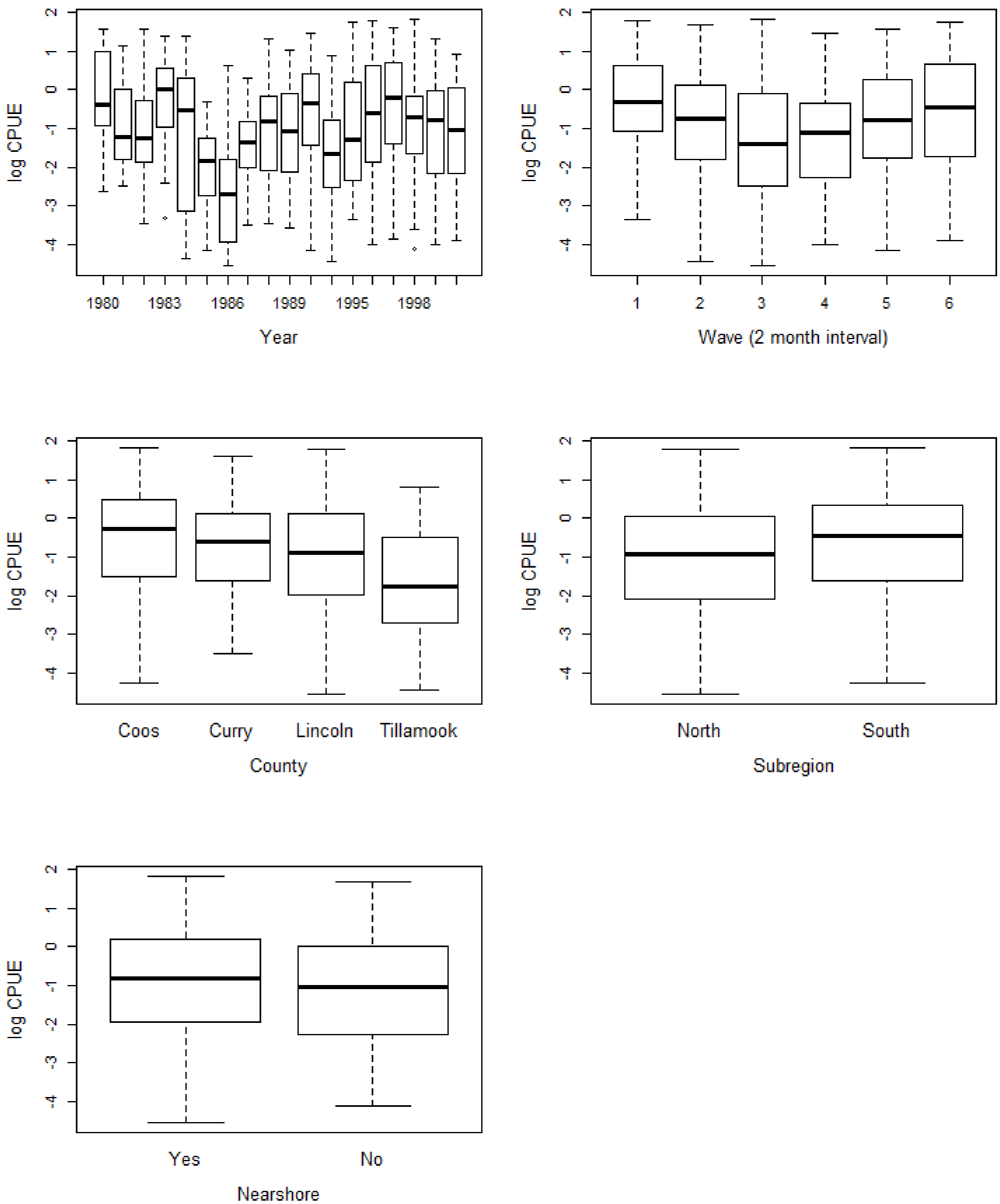


Figure 167: The distribution of trip-level raw positive catch CPUE data for the Oregon MRFSS data relative to potential covariates evaluated in the BDR GLM analysis.

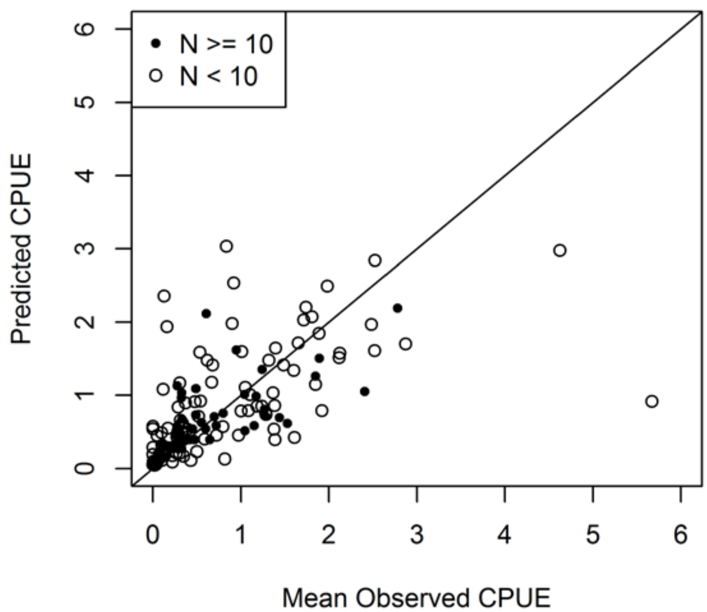


Figure 168: Predicted versus observed CPUE by sample size for each strata in the negative binomial GLM used to estimate the Oregon MRFSS abundance index.

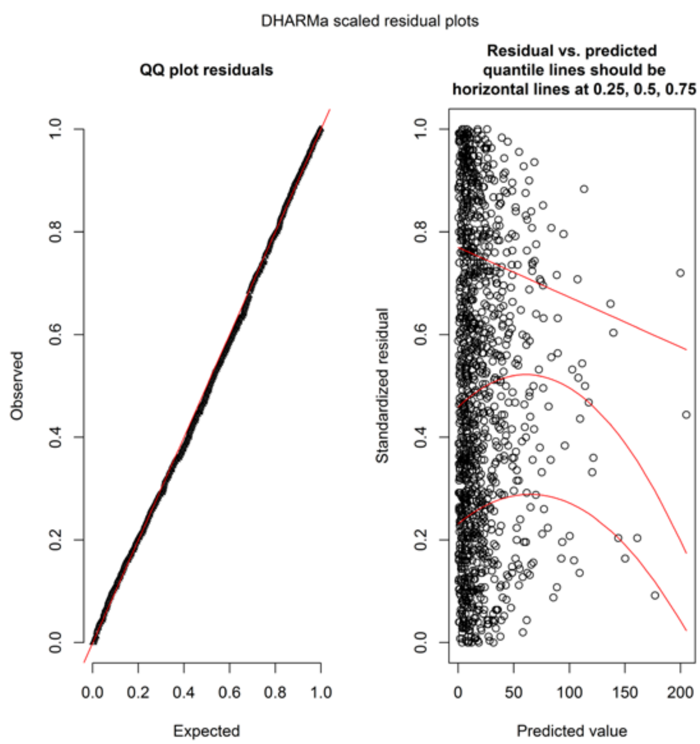


Figure 169: Diagnostic QQ and residual plots for the Oregon BDR MRFSS negative binomial GLM.

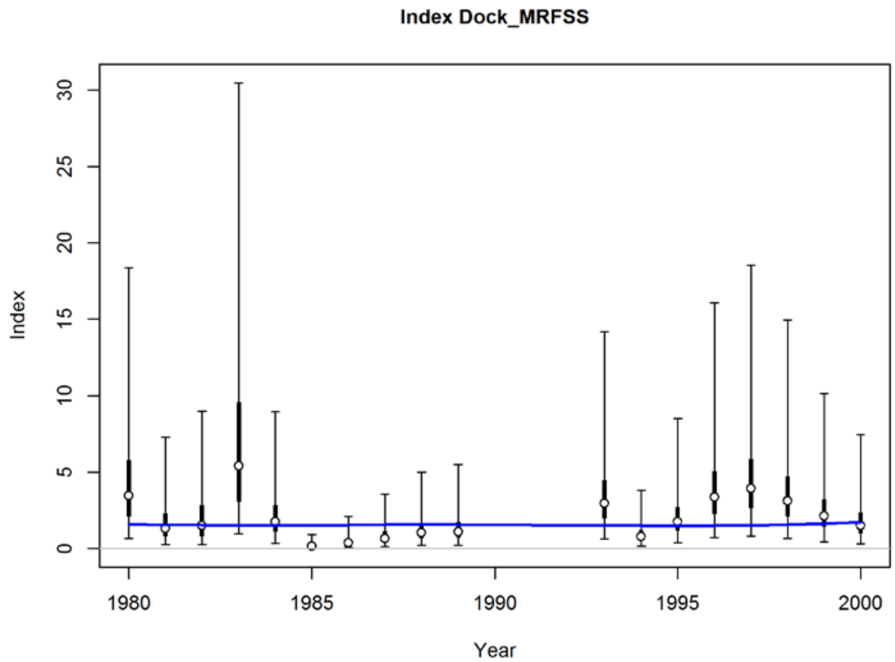


Figure 170: Model fit to the Oregon MRFSS index.

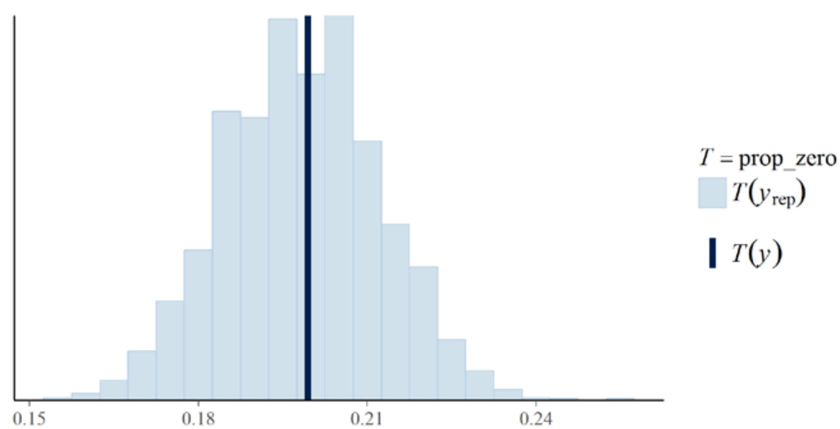


Figure 171: Comparison of the proportion of zeros in the observed Oregon MRFSS data set relative to 2,000 sample data sets drawn from the posterior predictive distribution.

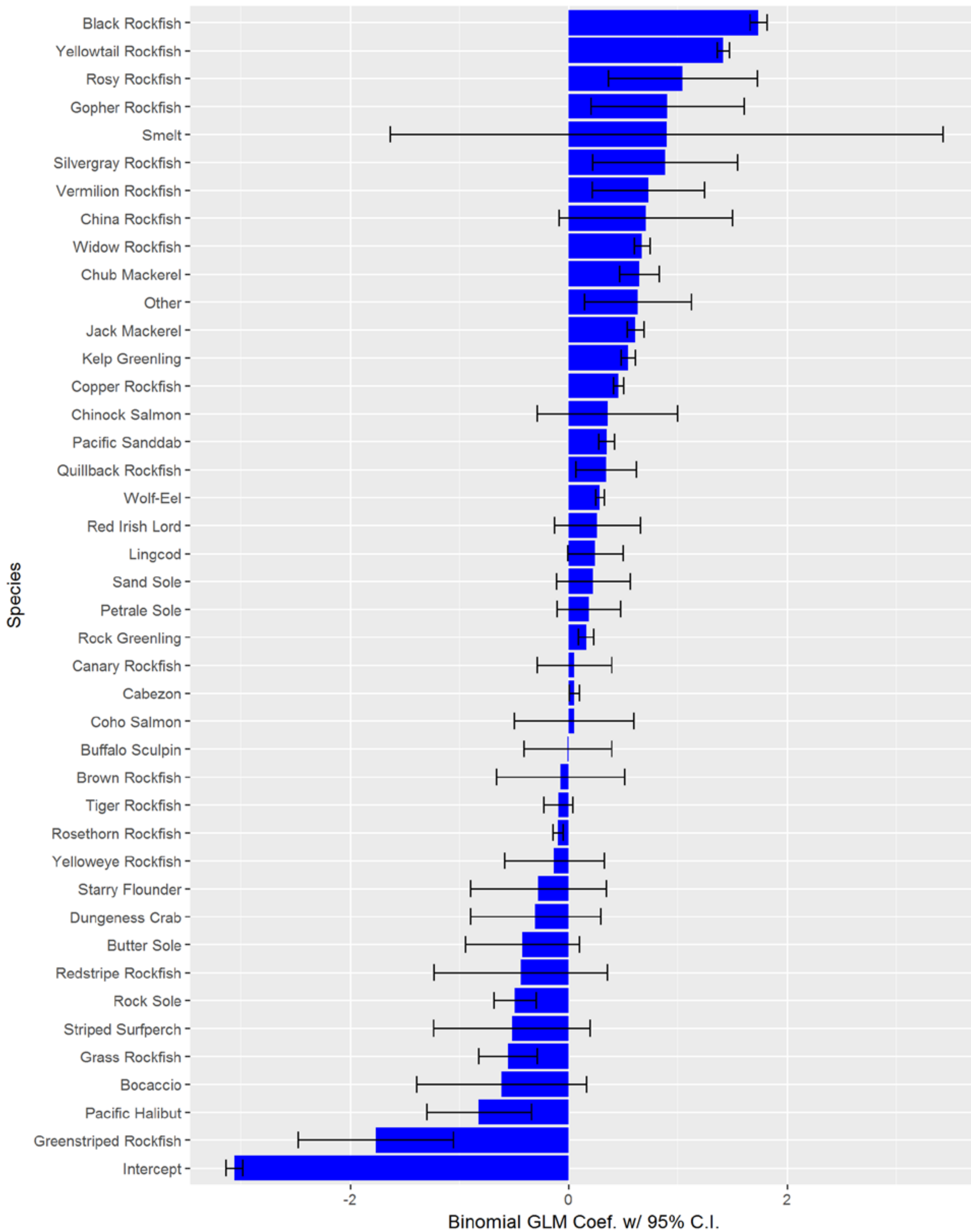


Figure 172: Species coefficients for the Stephens-MacCall filter of the Oregon ORBS ocean-boat data.

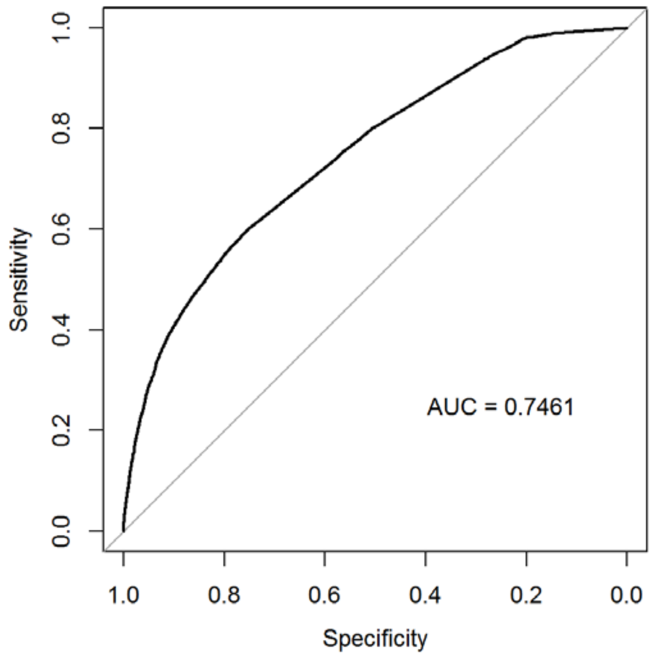


Figure 173: The ORBS area under the characteristic curve (AUC) plot, which represents the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence. Values much greater than 0.5 indicate a significant improvement over a random classifier (AUC = 0.5).

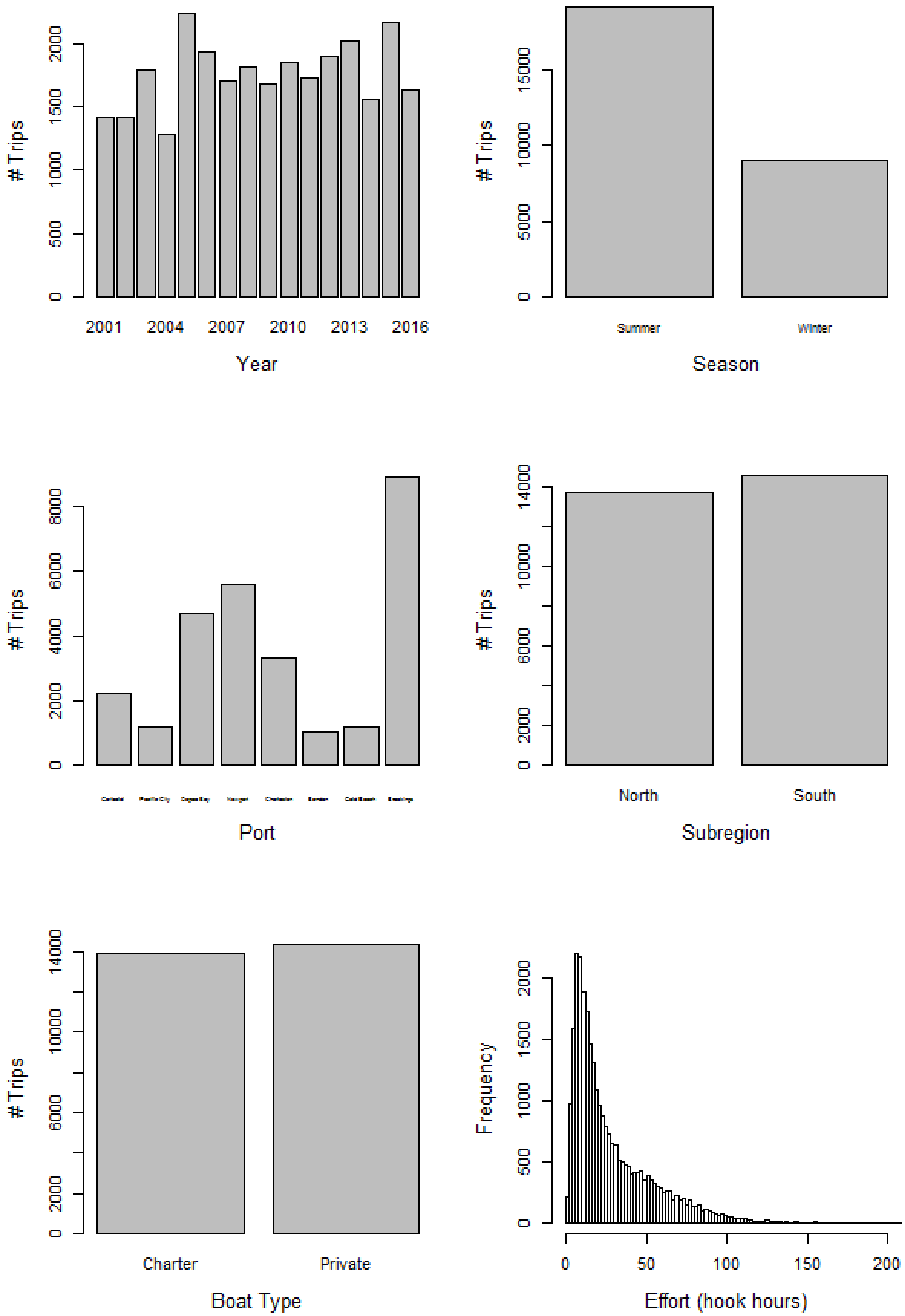


Figure 174: Characterization of the final subset of ORBS data used in GLM analyses for Oregon BDR.

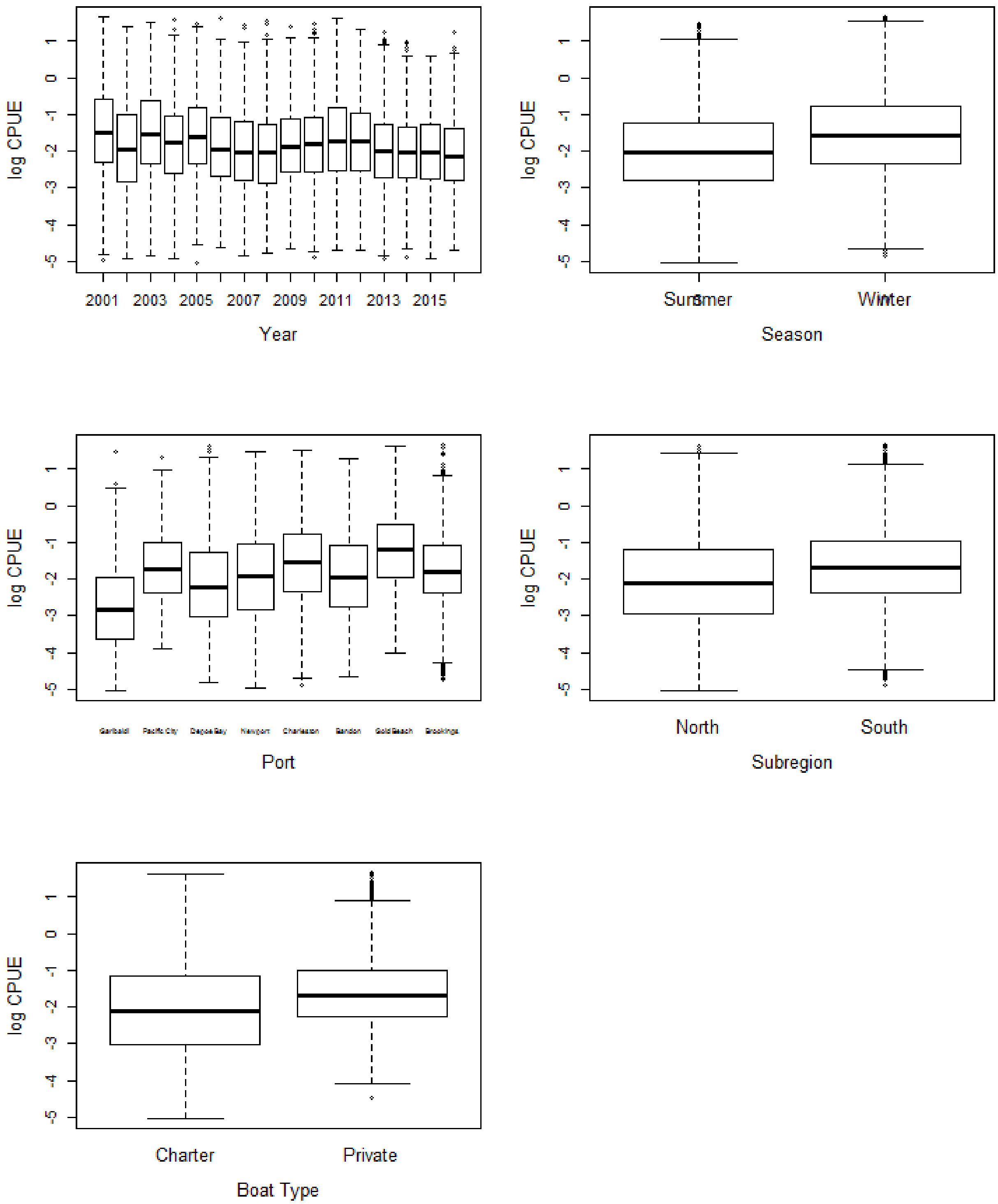


Figure 175: The distribution of trip-level raw positive catch CPUE data for the ORBS data relative to potential covariates evaluated in the Oregon BDR GLM analysis.

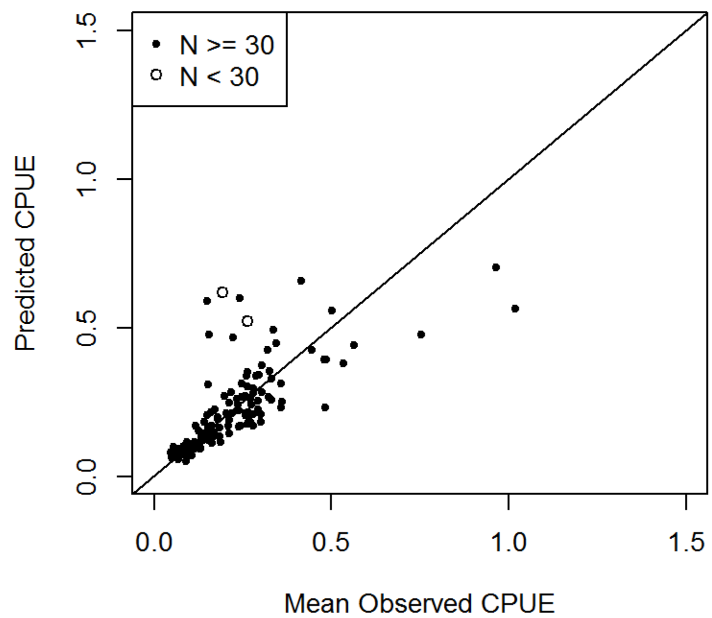


Figure 176: Predicted versus observed CPUE by sample size for each stratum in the negative binomial GLM used to estimate the Oregon ORBS abundance index.

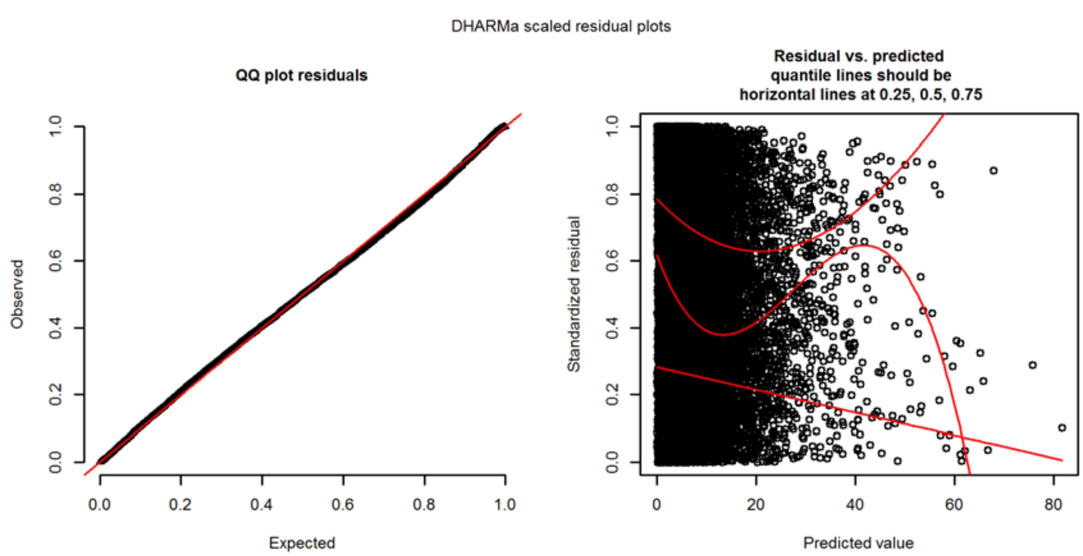


Figure 177: Diagnostic QQ and residual plots for the Oregon BDR ORBS negative binomial GLM.

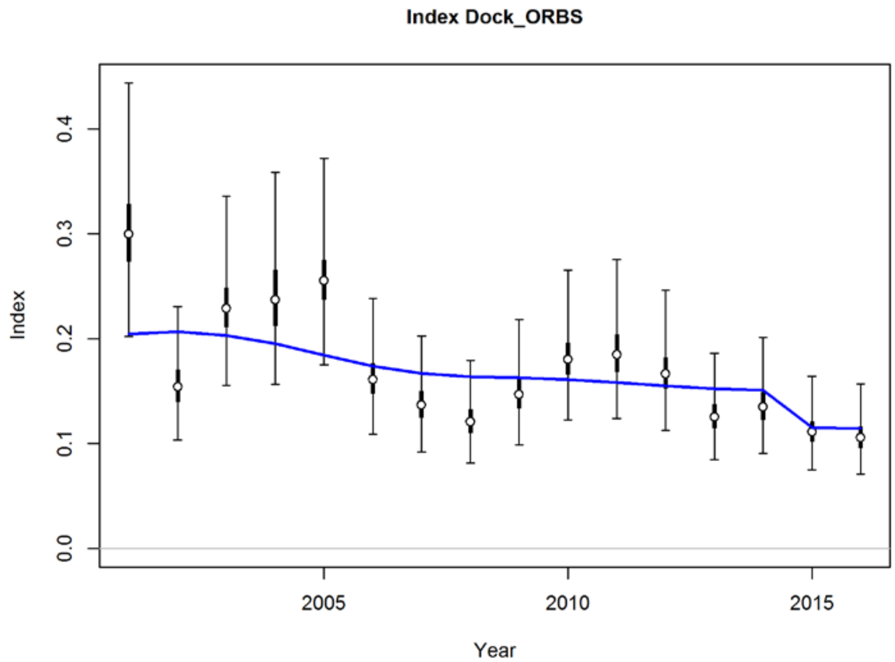


Figure 178: Model fit to the Oregon BDR ORBS dockside index.

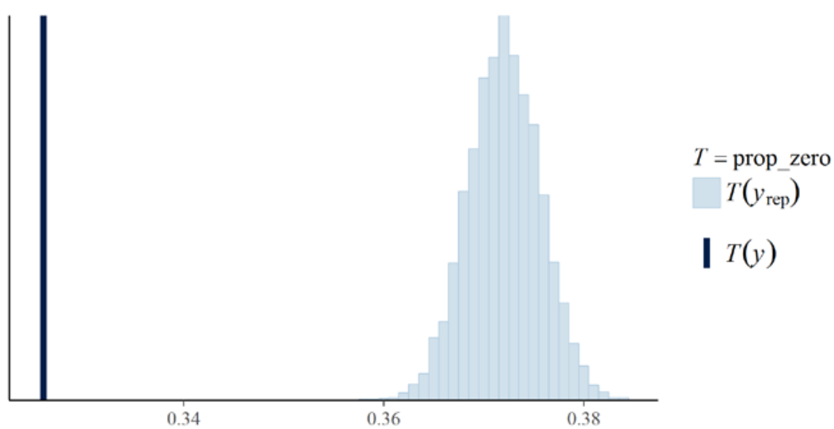


Figure 179: Comparison of the proportion of zeros in the observed Oregon ORBS data set relative to 2,000 sample data sets drawn from the posterior predictive distribution.

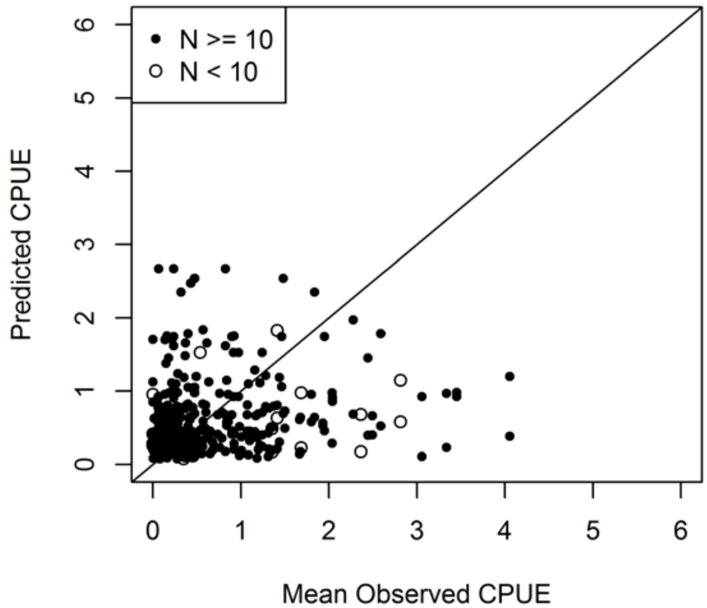


Figure 180: Predicted versus observed CPUE by sample size for each strata in the negative binomial GLM used to estimate the Oregon onboard observer abundance index.

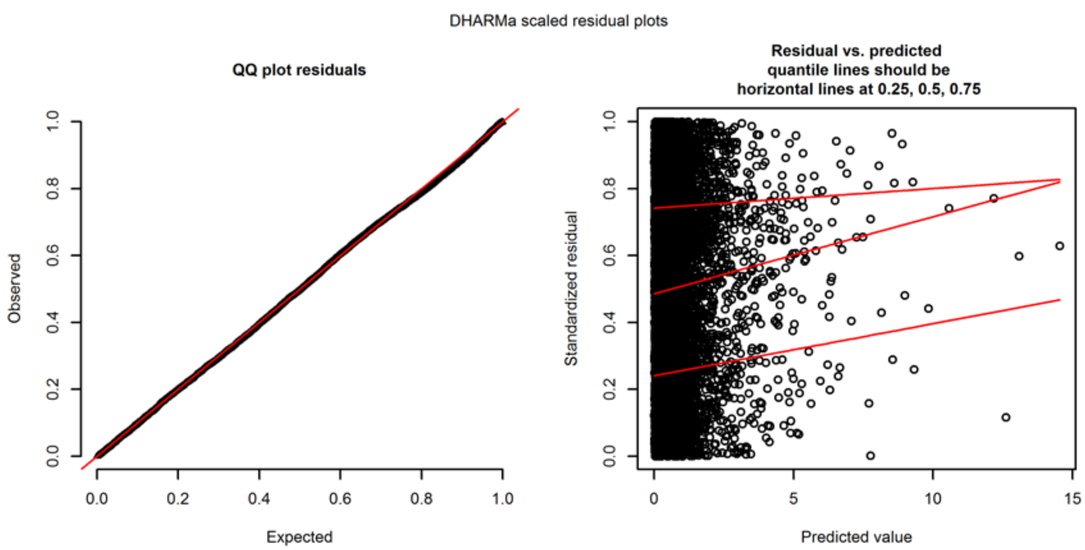


Figure 181: Diagnostic QQ and residual plots for the Oregon BDR onboard observer negative binomial GLM.

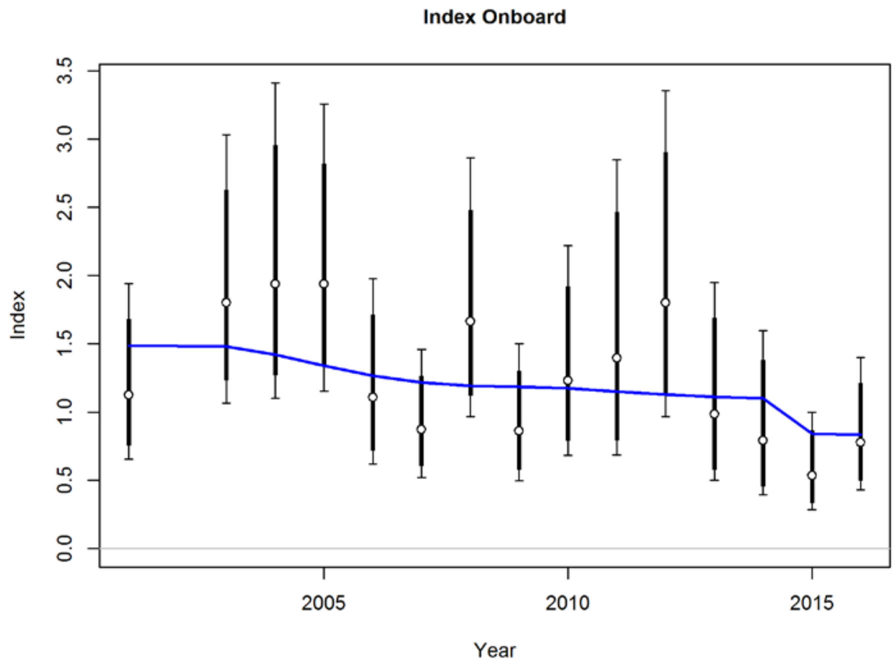


Figure 182: Model fit to the Oregon onboard observer (OBO) index.

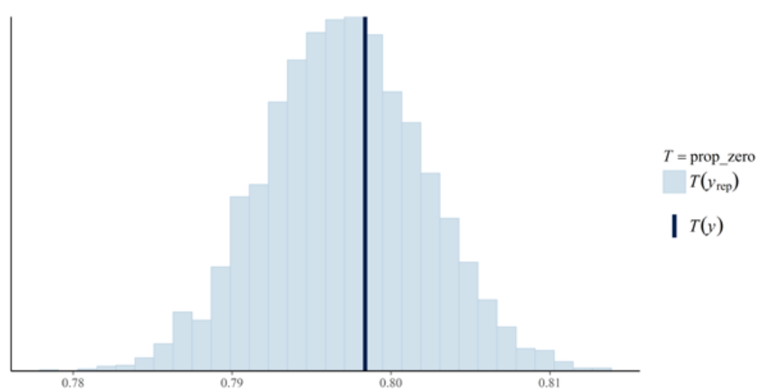


Figure 183: Comparison of the proportion of zeros in the observed Oregon onboard observer data set relative to 2,000 sample data sets drawn from the posterior predictive distribution.

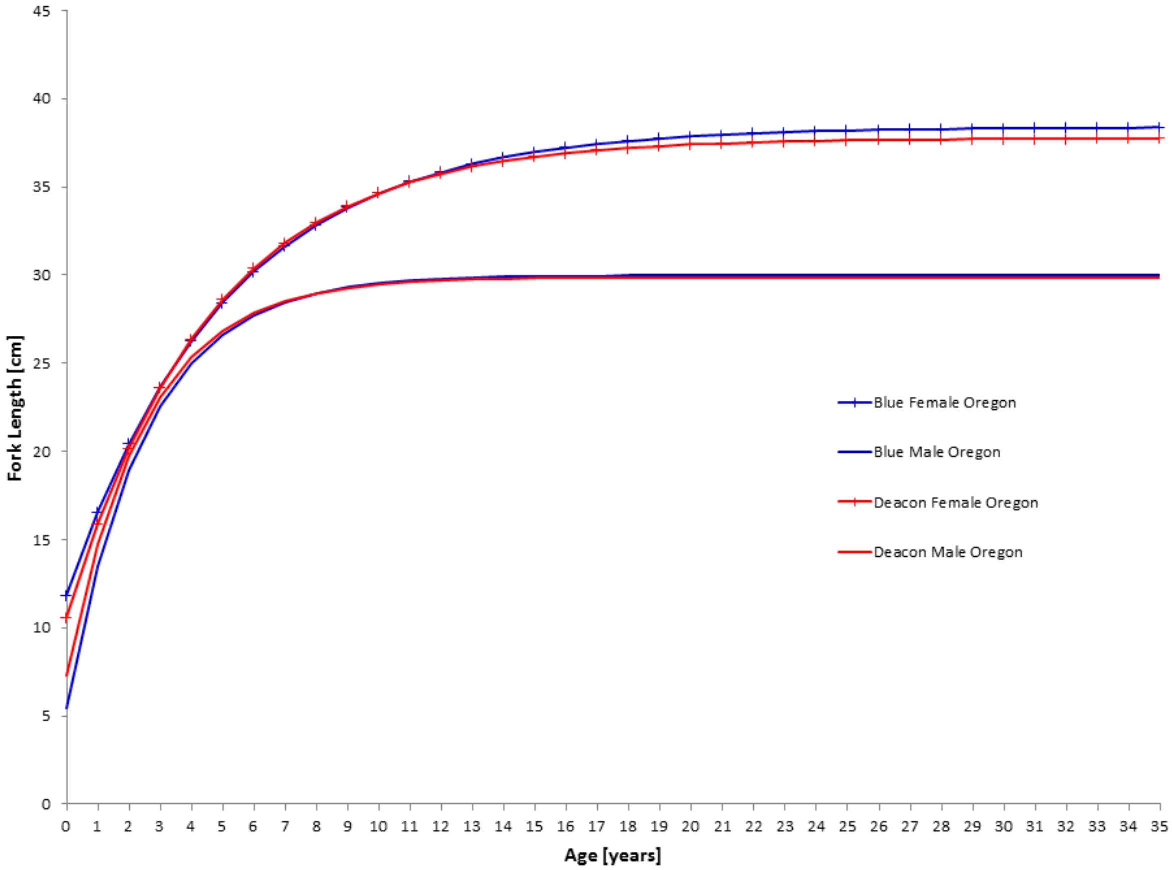


Figure 184: Growth curves estimated outside of the assessment model by gender and species for the Oregon BDR complex.

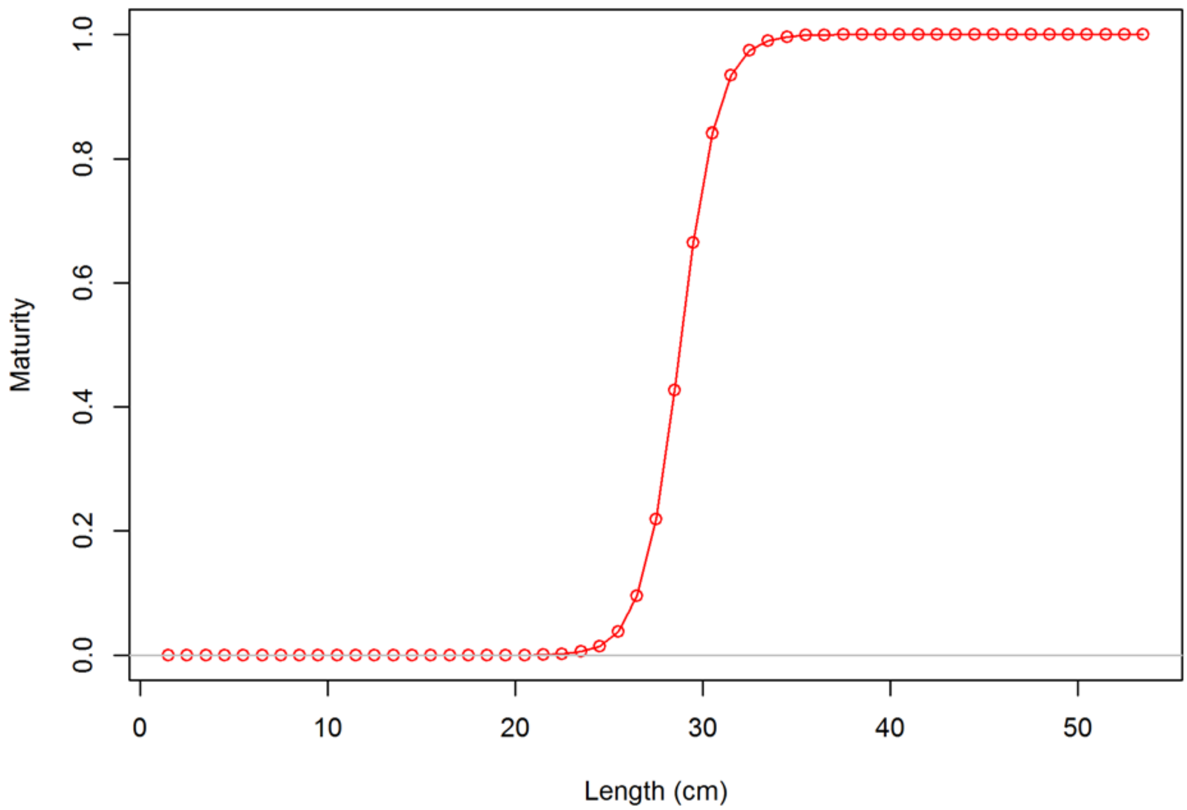


Figure 185: Maturity ogive used in the assessment for BDR in Oregon waters.

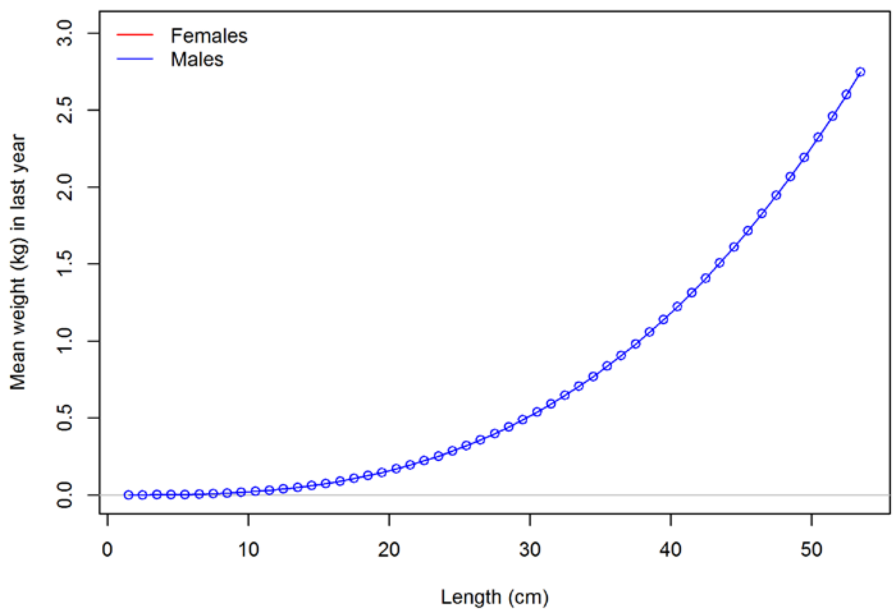


Figure 186: Weight-length relation for BDR in Oregon waters.

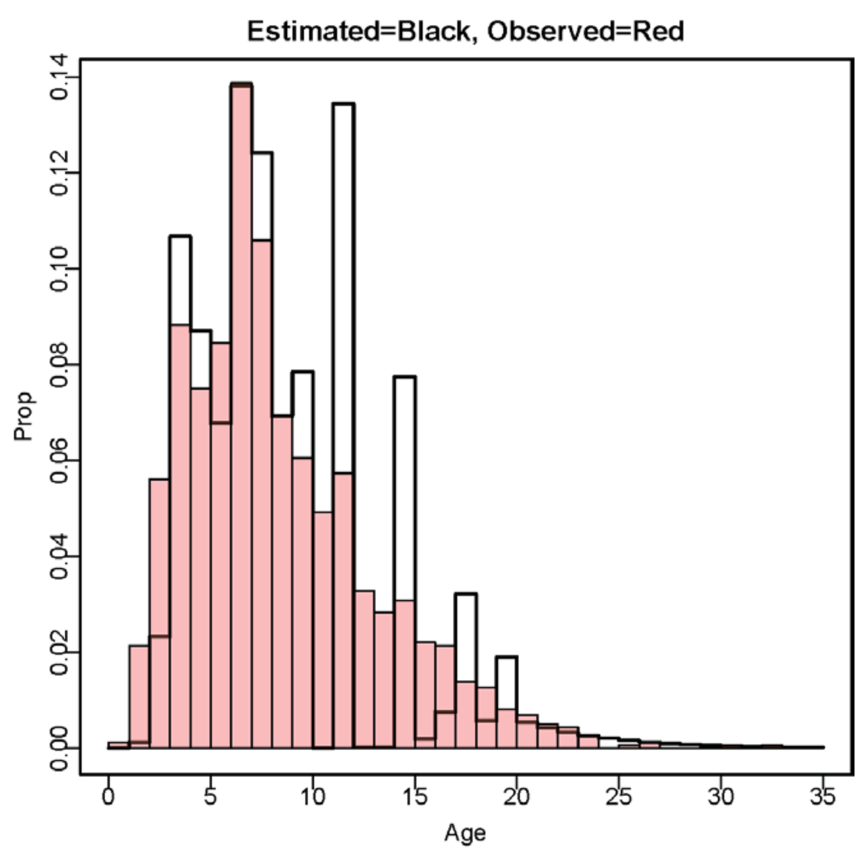


Figure 187: Comparison of observed versus estimated ages from Oregon ageing lab double reads of otoliths, where a single reader conducted multiple reads.

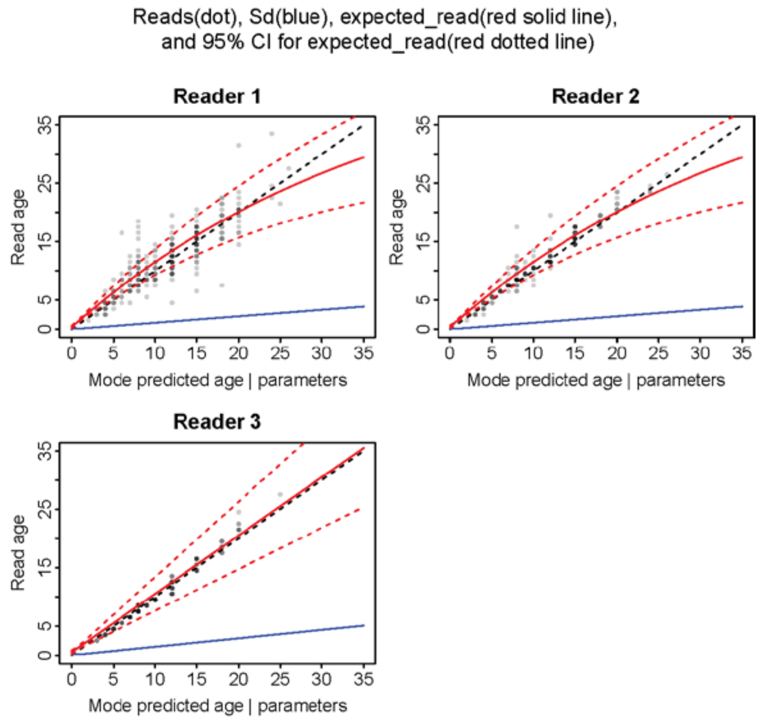


Figure 188: Plots comparing double read otoliths, where each read was conducted either by the same individual or by a separate ageing laboratory (Oregon and California). In this case, Reader 3 is assumed to be unbiased, relative to reader 3. Reader 2 is the second read of reader 1.

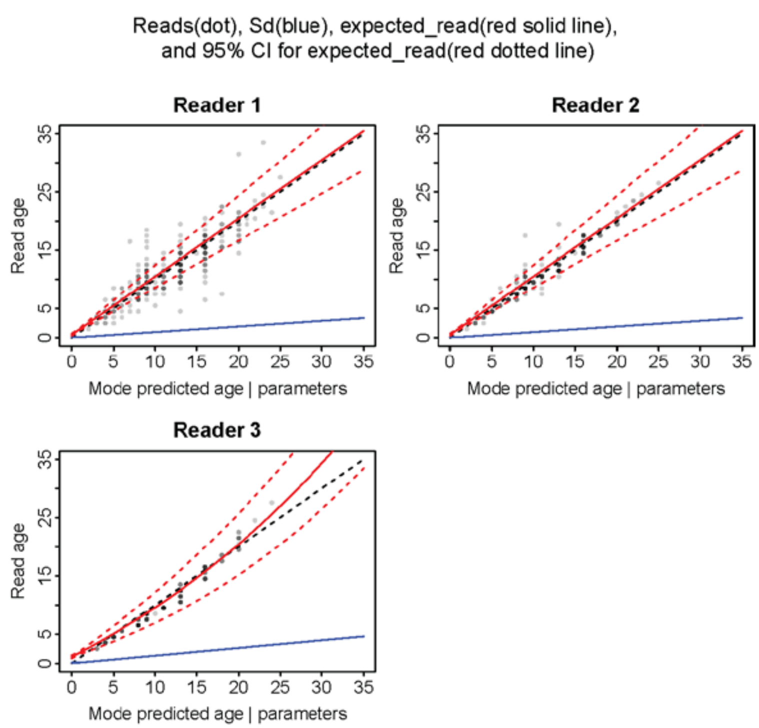


Figure 189: Plots comparing double read otoliths, where each read was conducted either by the same individual or by a separate ageing laboratory (Oregon and California). In this case, Reader 1 is assumed to be unbiased, relative to reader 3. Reader 2 is the second read of reader 1.

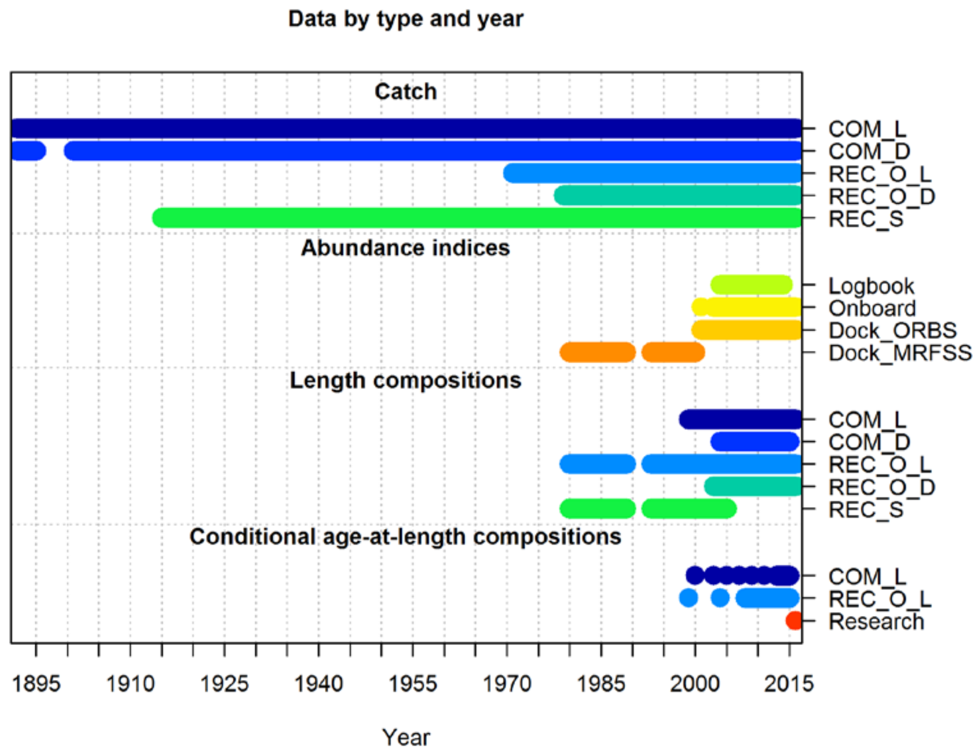


Figure 190: Summary of the data types and the duration of available time series that were used in the Oregon BDR stock assessment.

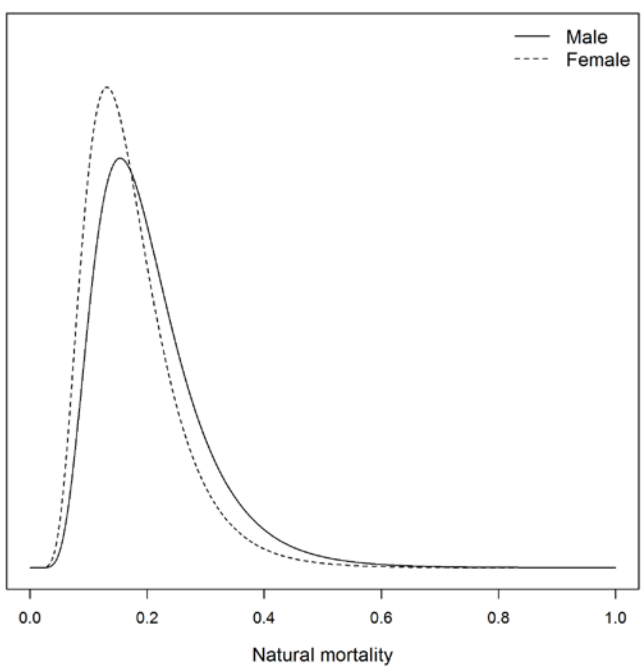


Figure 191: Prior distribution for natural mortality of male and female BDR in Oregon waters based on Hamel (2017, pers. comm.).

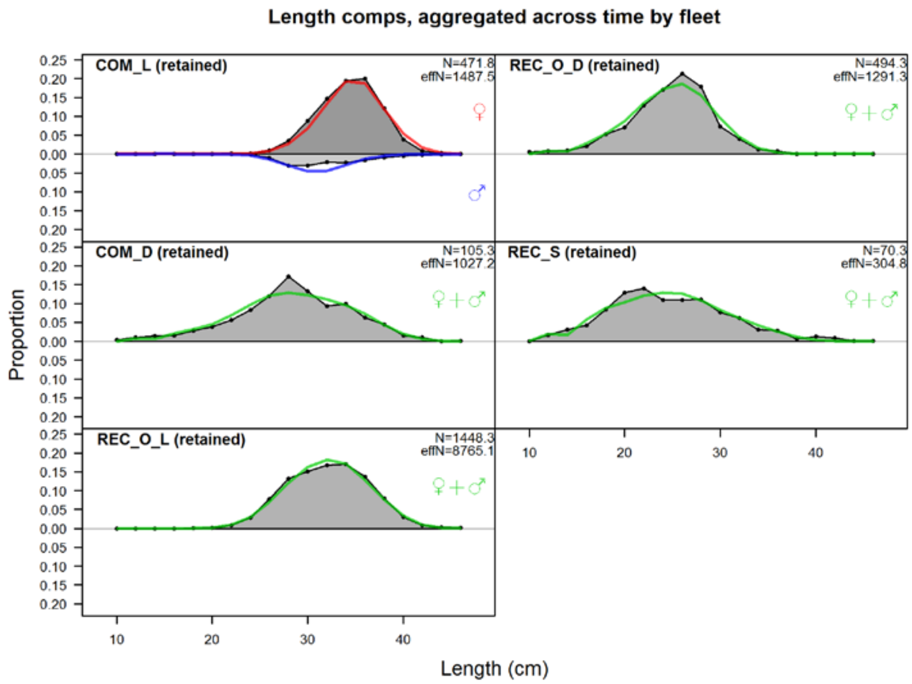


Figure 192: Base fit to time-aggregated Oregon BDR length compositions for all fleets.

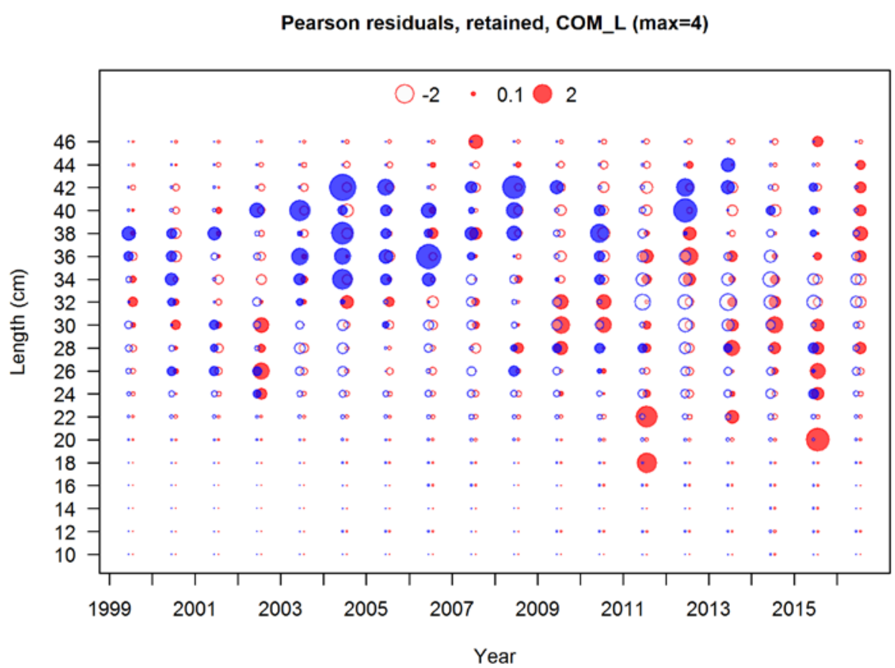


Figure 193: Pearson residuals for the fit to length composition data for the Oregon commercial landings fleet.

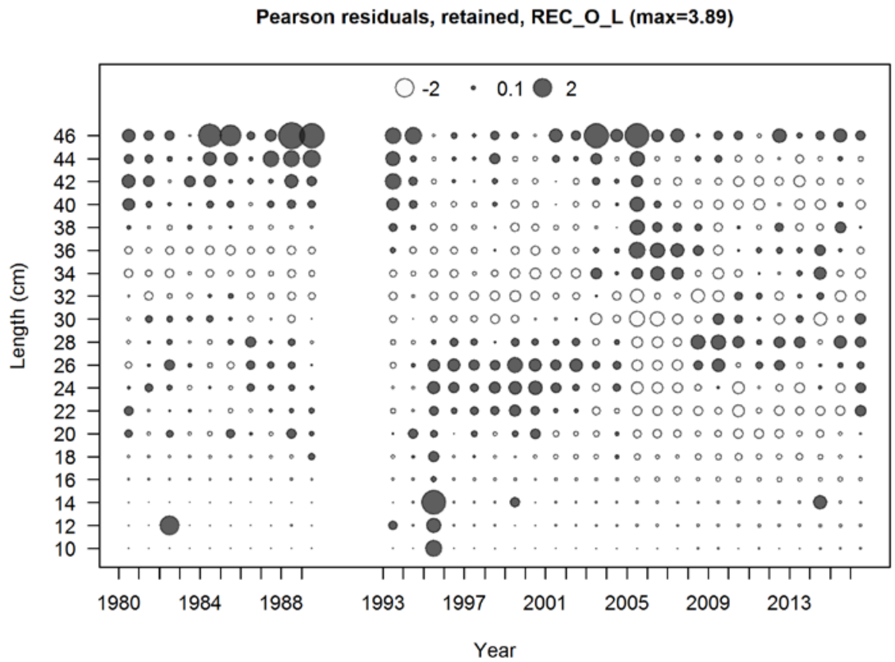


Figure 194: Pearson residuals for the fit to length composition data for the Oregon recreational ocean-boat landings fleet.

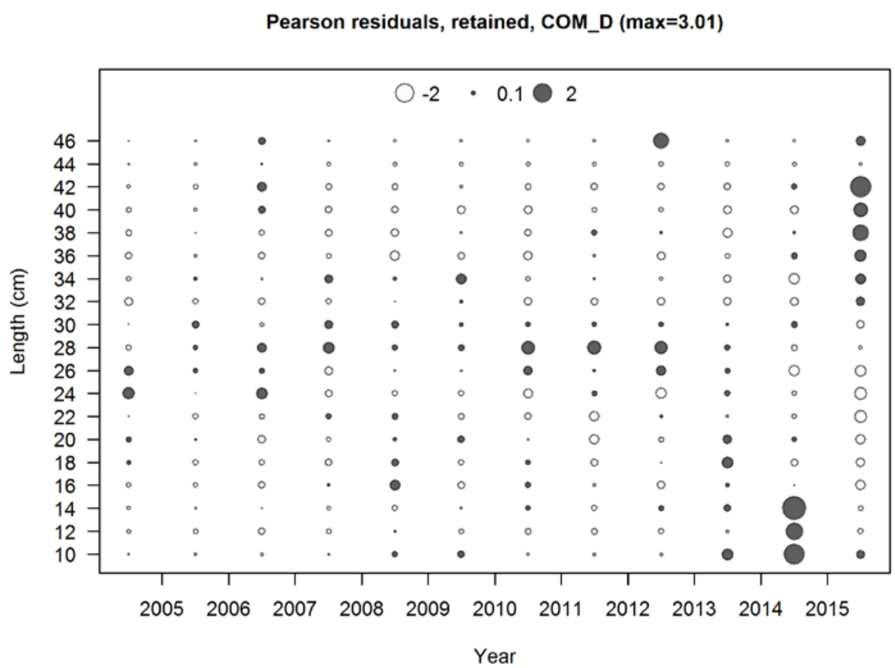


Figure 195: Pearson residuals for the fit to length composition data for the Oregon commercial discards fleet.

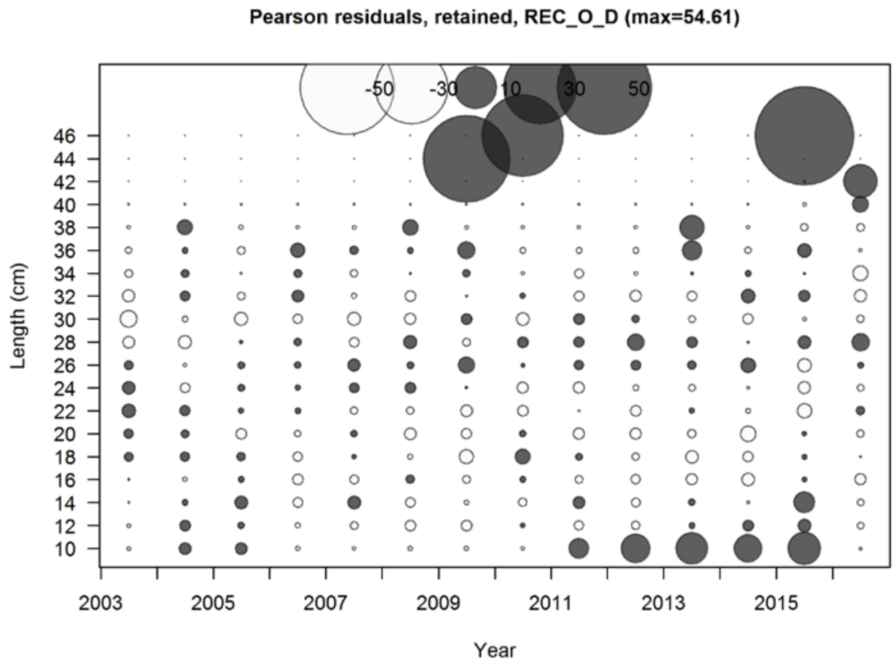


Figure 196: Pearson residuals for the fit to length composition data for the Oregon recreational ocean-boat discards fleet.

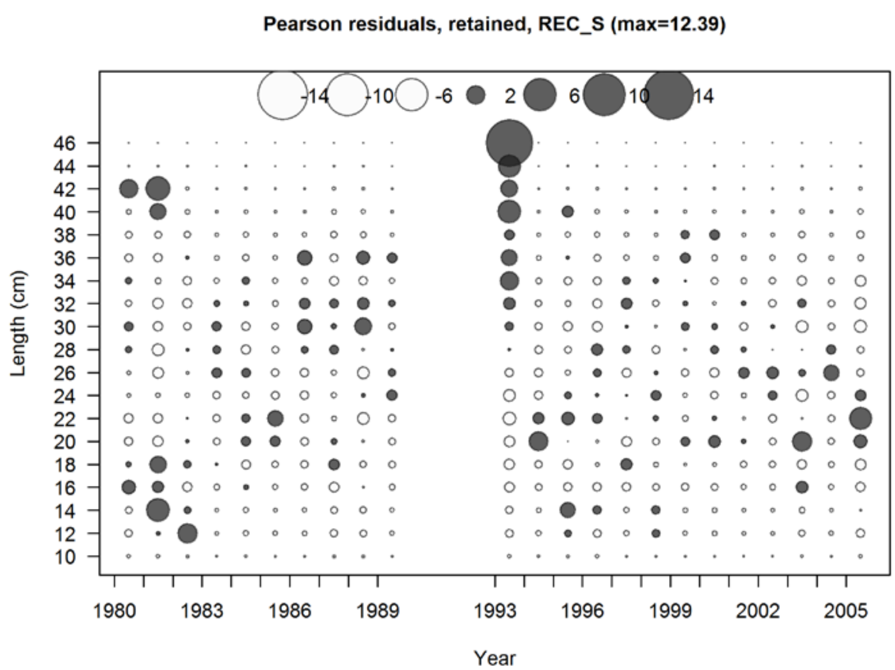


Figure 197: Pearson residuals for the fit to length composition data for the Oregon shore fleet.

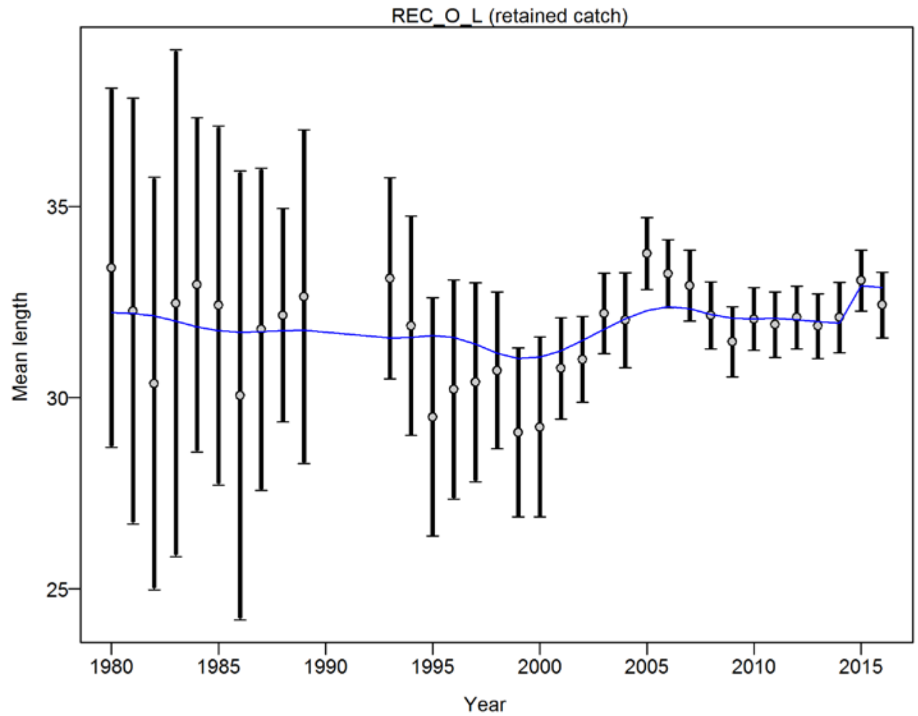


Figure 198: Base fit to mean Oregon BDR lengths for the recreational ocean-boat landings fleet.

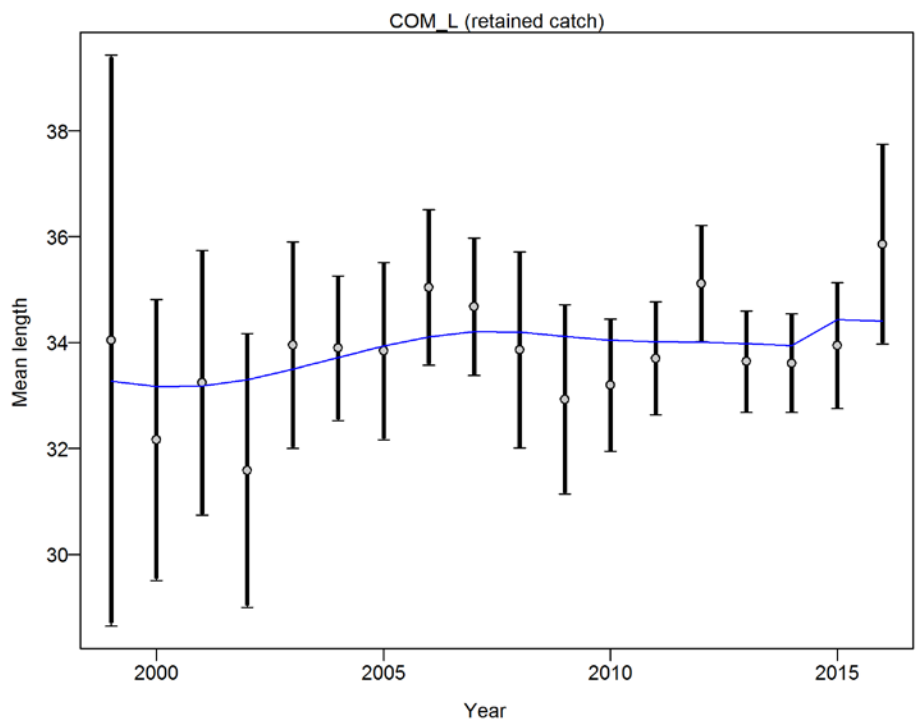


Figure 199: Base fit to mean Oregon BDR lengths for the commercial landings fleet.

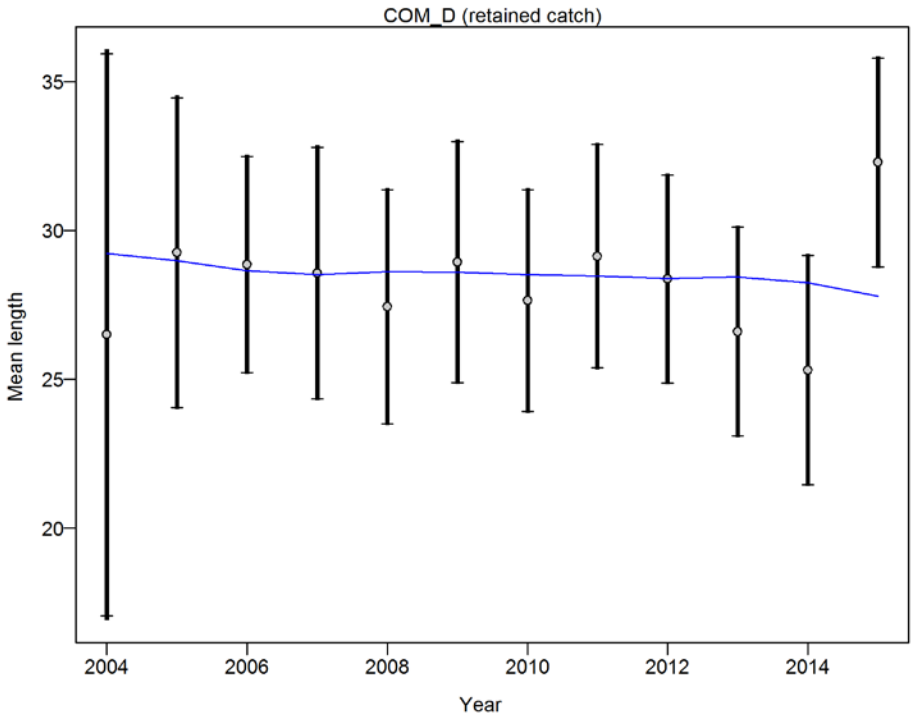


Figure 200: Base fit to mean Oregon BDR lengths for the commercial discards fleet.

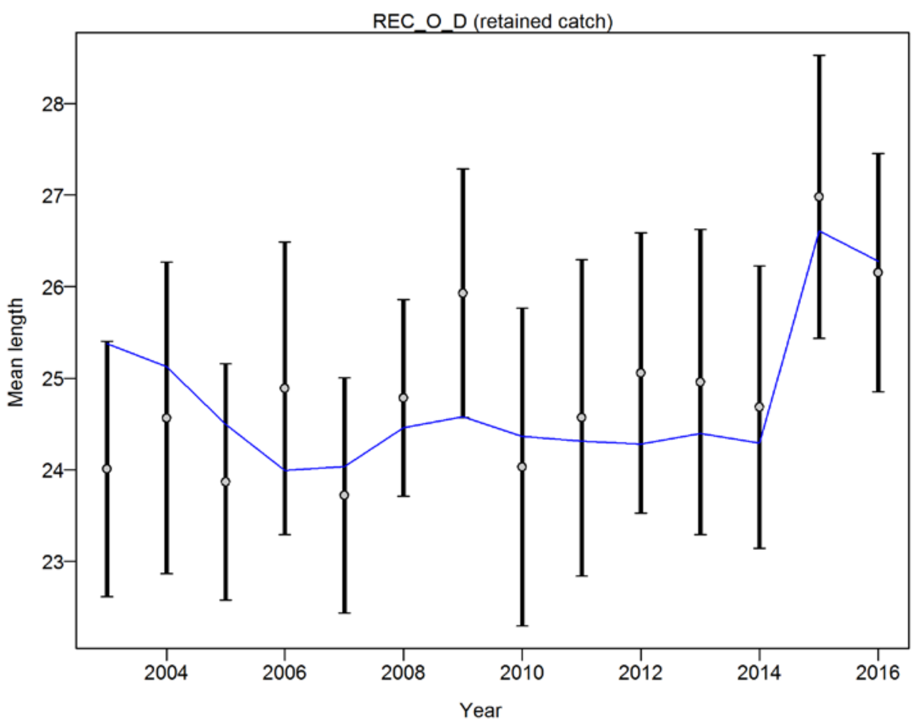


Figure 201: Base fit to mean Oregon BDR lengths for the recreational ocean-boat discards fleet.

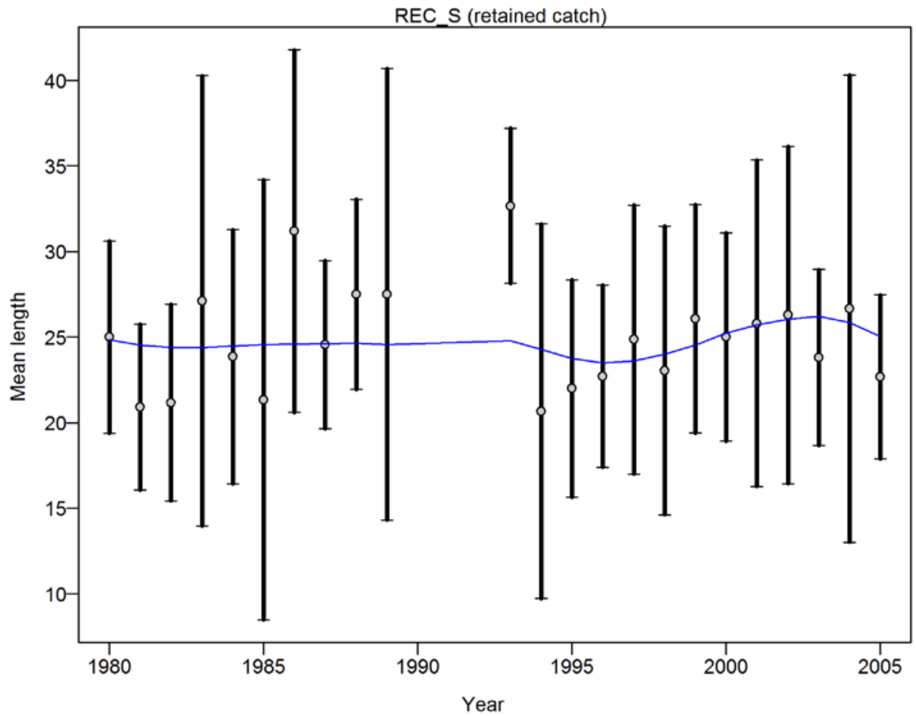


Figure 202: Base fit to mean Oregon BDR lengths for the shore fleet.

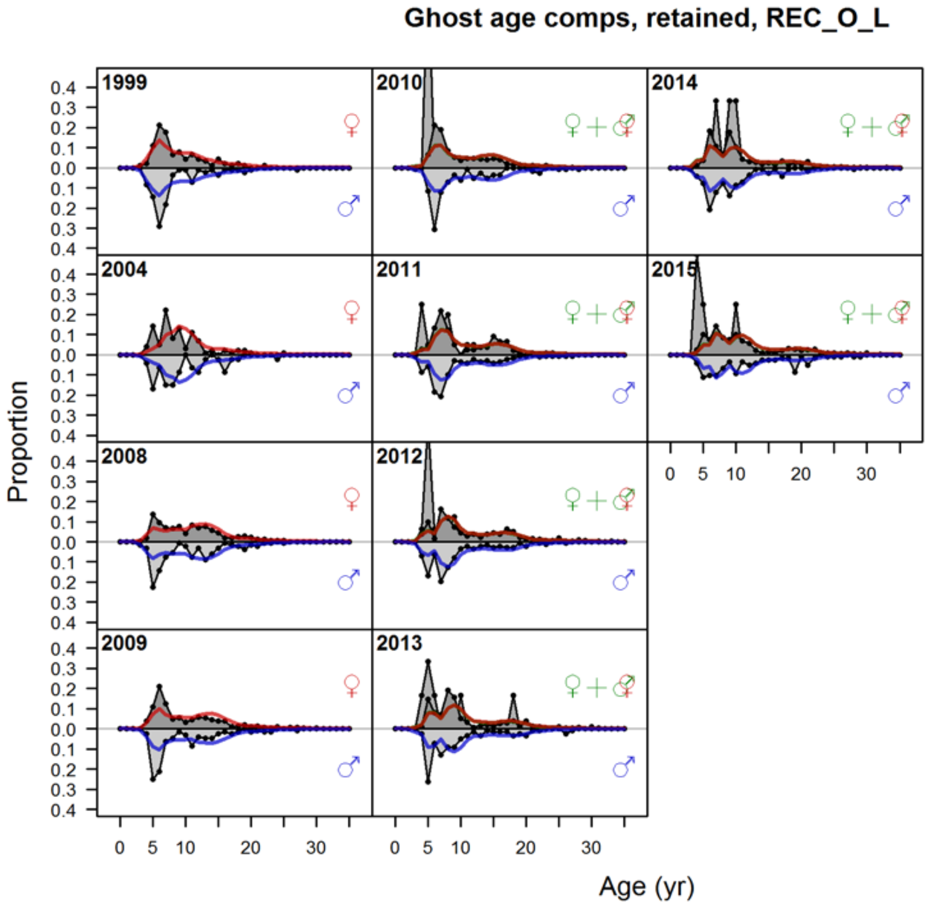


Figure 203: Resulting deviations in age composition patterns from fitting conditional age-at-length data for the Oregon recreational landings fleet.

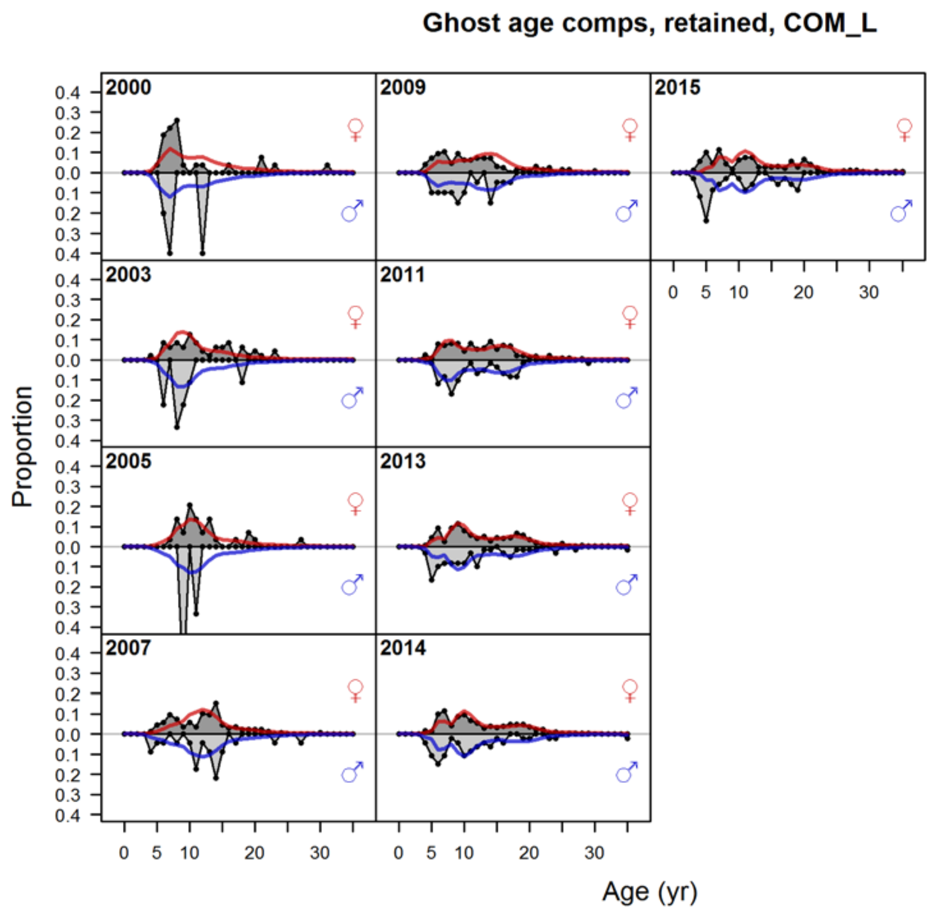


Figure 204: Resulting deviations in age composition patterns from fitting conditional age-at-length data for the Oregon commercial landings fleet.

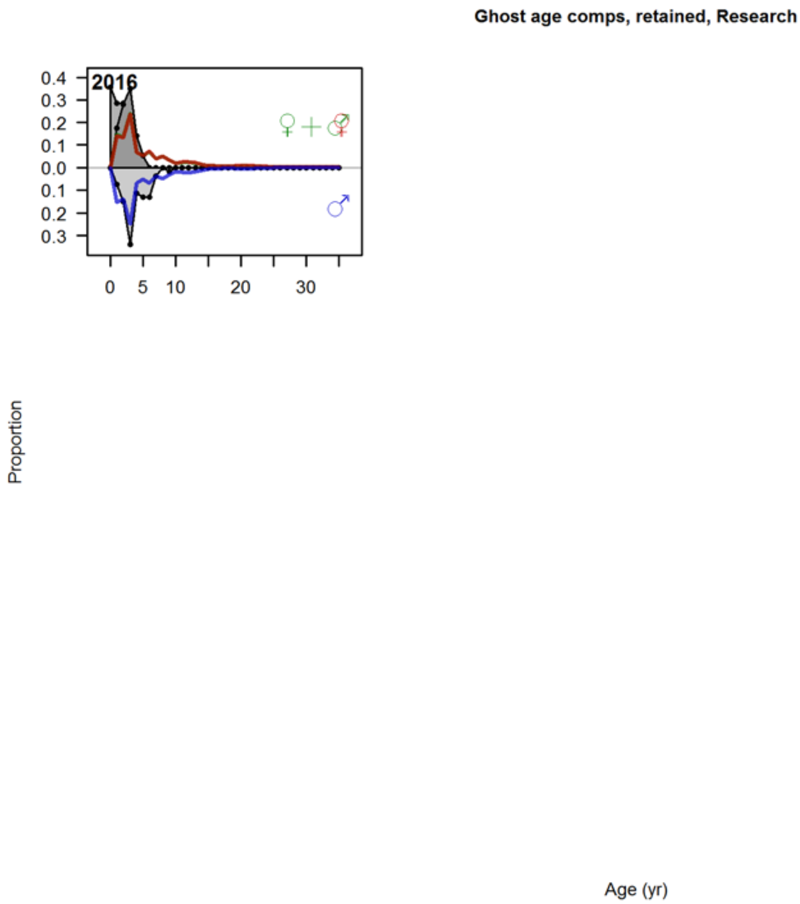


Figure 205: Resulting deviations in age composition patterns from fitting conditional age-at-length data for the Oregon research survey.

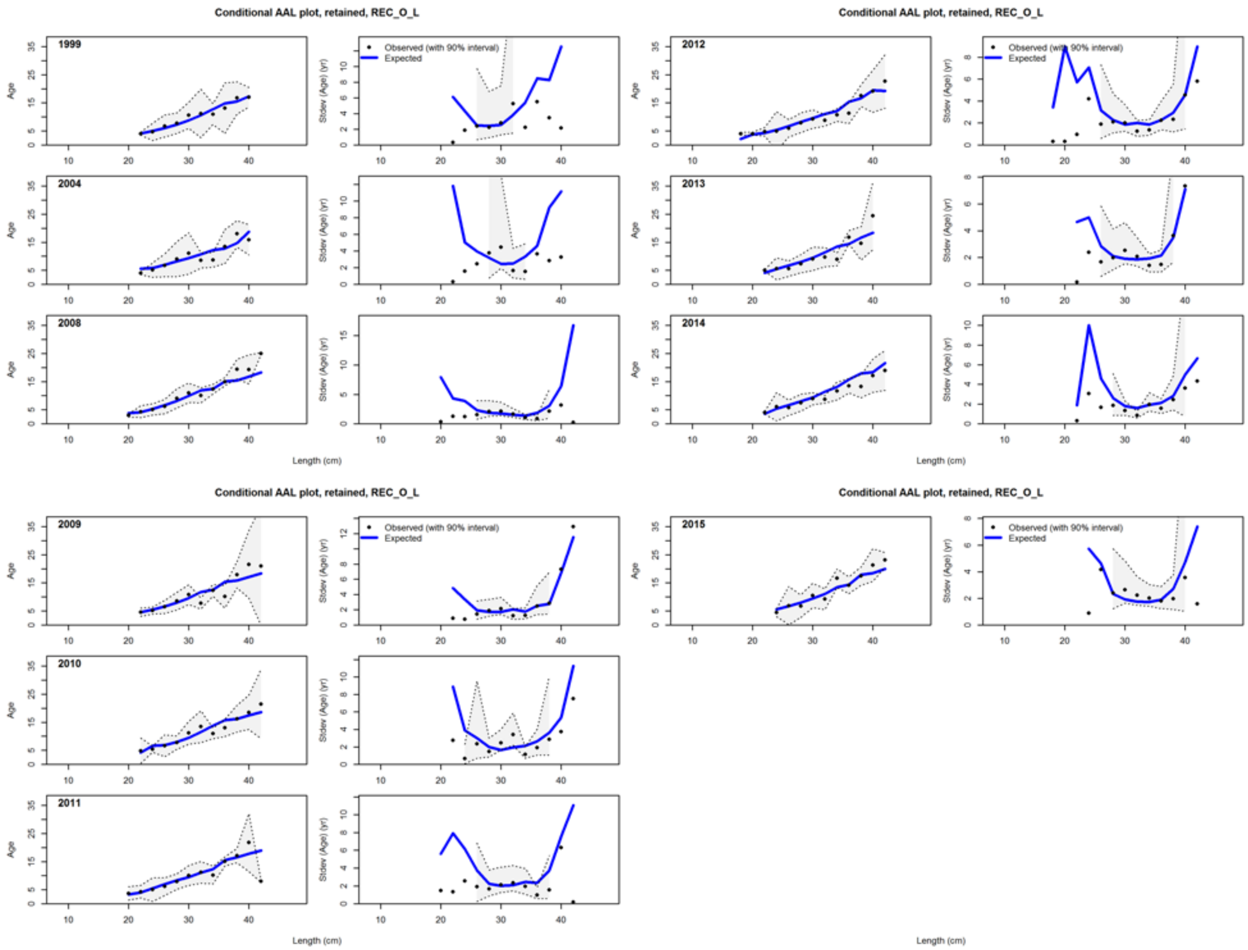


Figure 206: Base model fits to conditional age-at-length data for the Oregon recreational ocean-boat landings fleet.

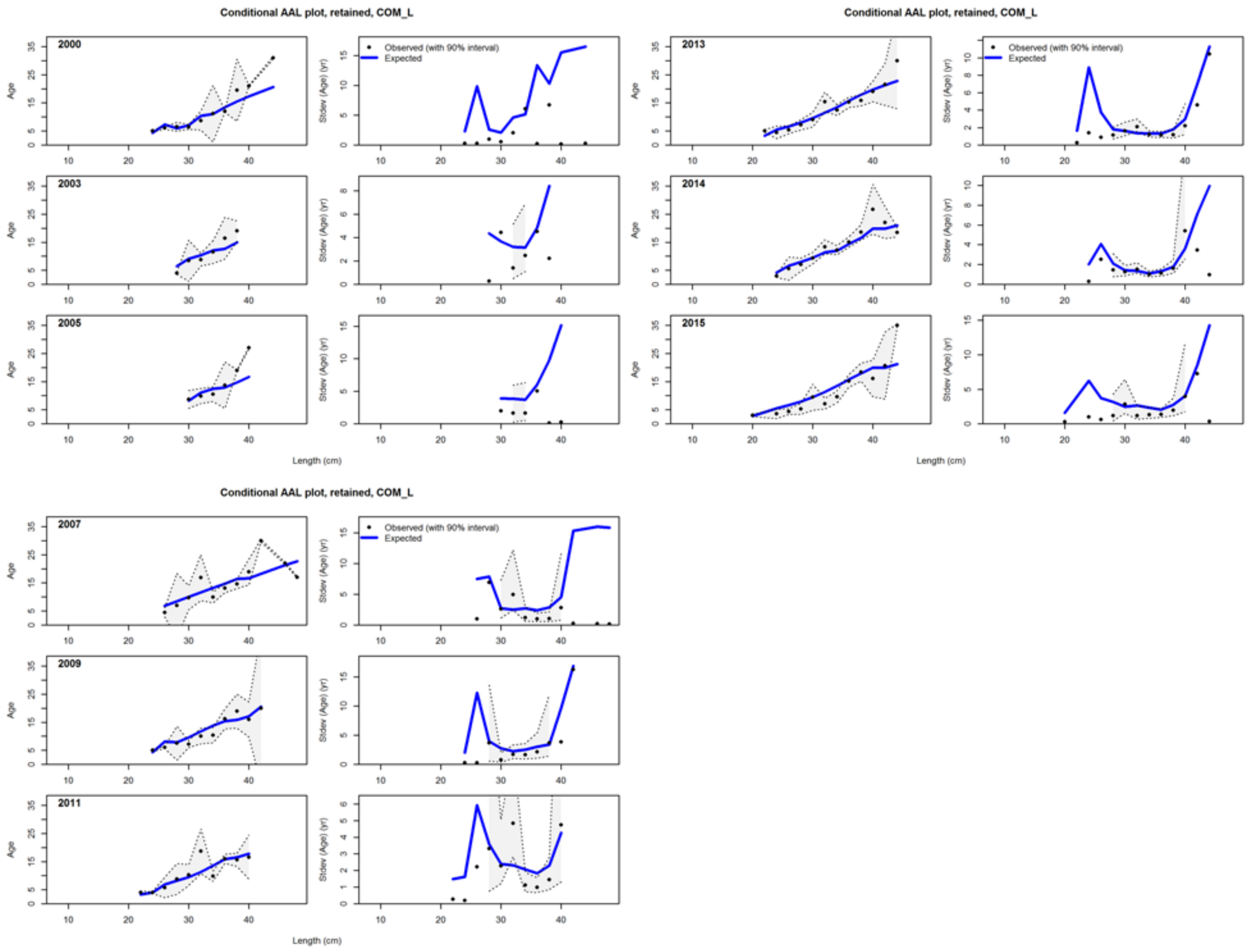


Figure 207: Base model fits to conditional age-at-length data for the Oregon commercial landings fleet.

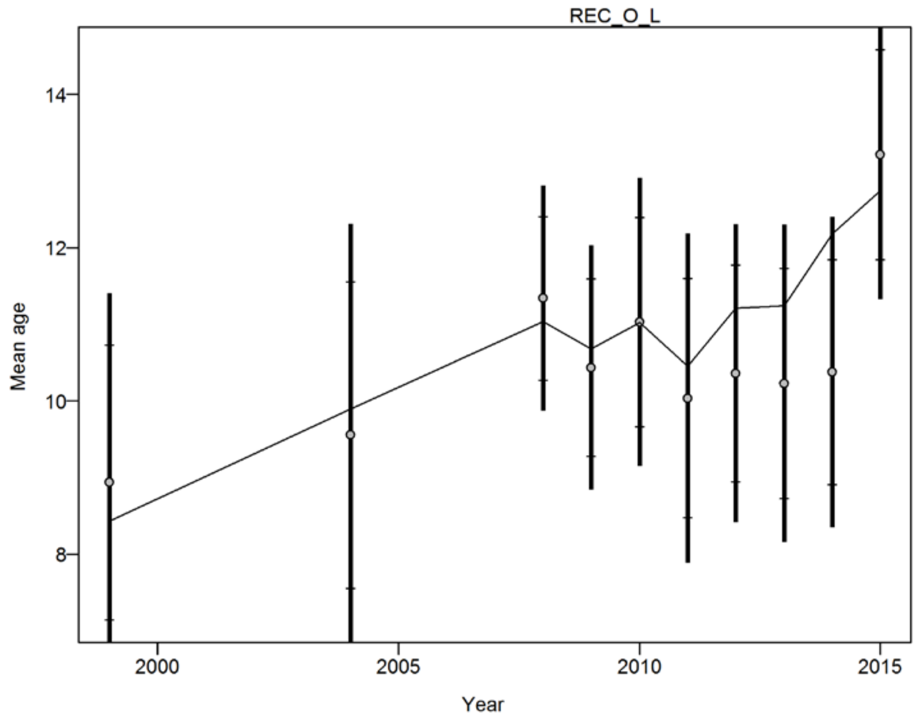


Figure 208: Base model fit to Oregon BDR mean age for the recreational ocean-boat landings fleet.

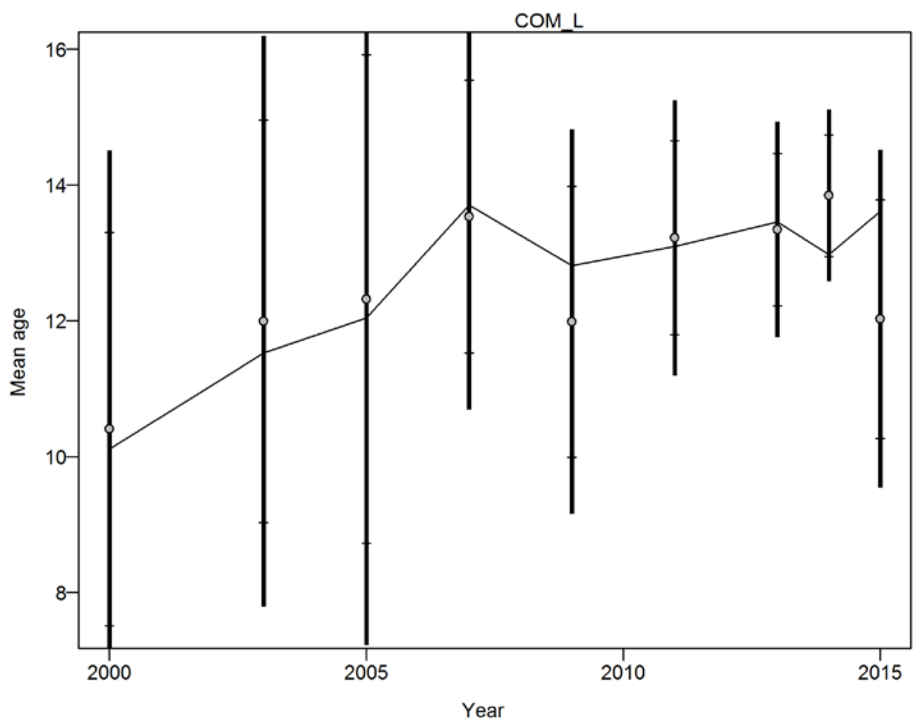


Figure 209: Base model fit to Oregon BDR mean age for the commercial landings fleet.

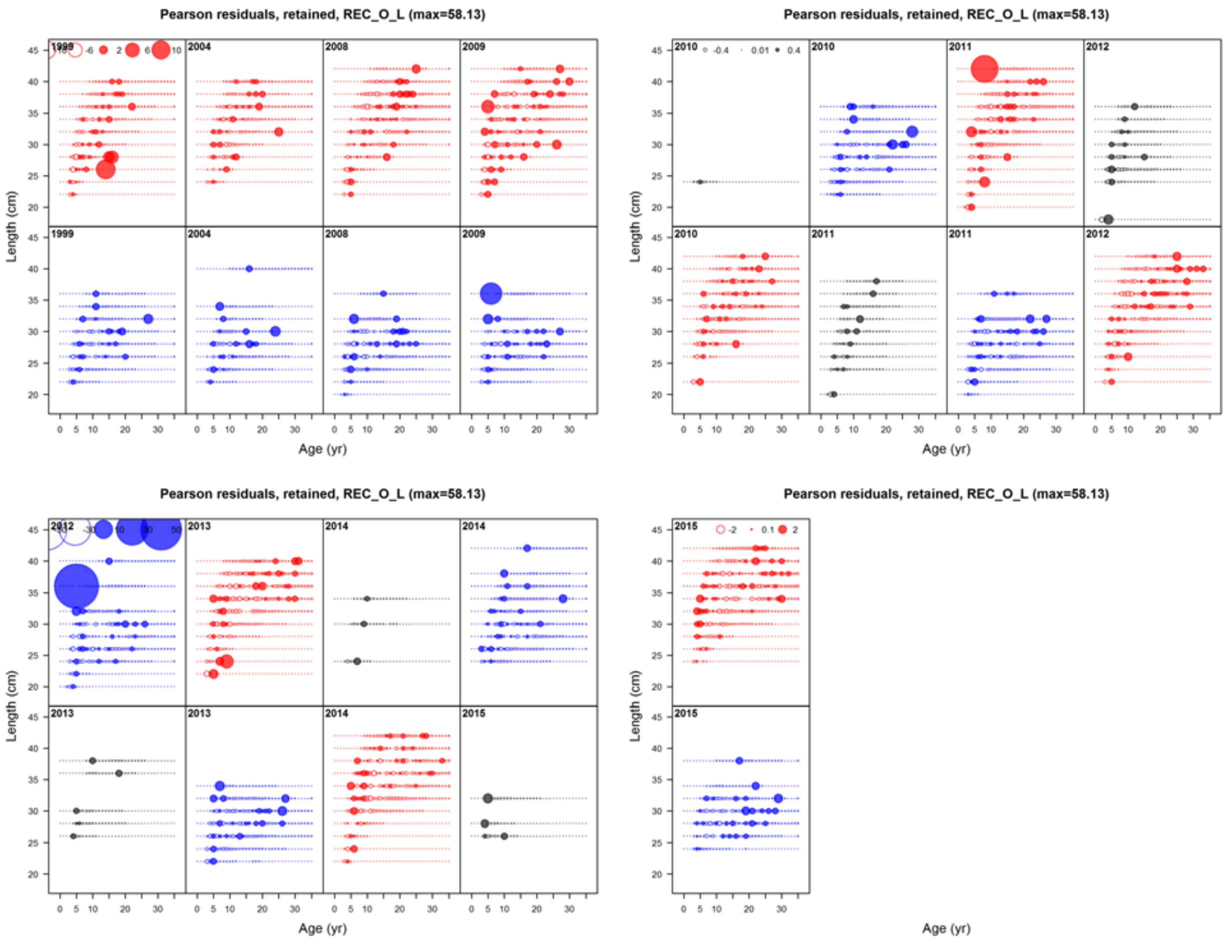


Figure 210: Pearson residuals from the base model fit to conditional age-at-length data in the Oregon recreational ocean-boat landings fleet.

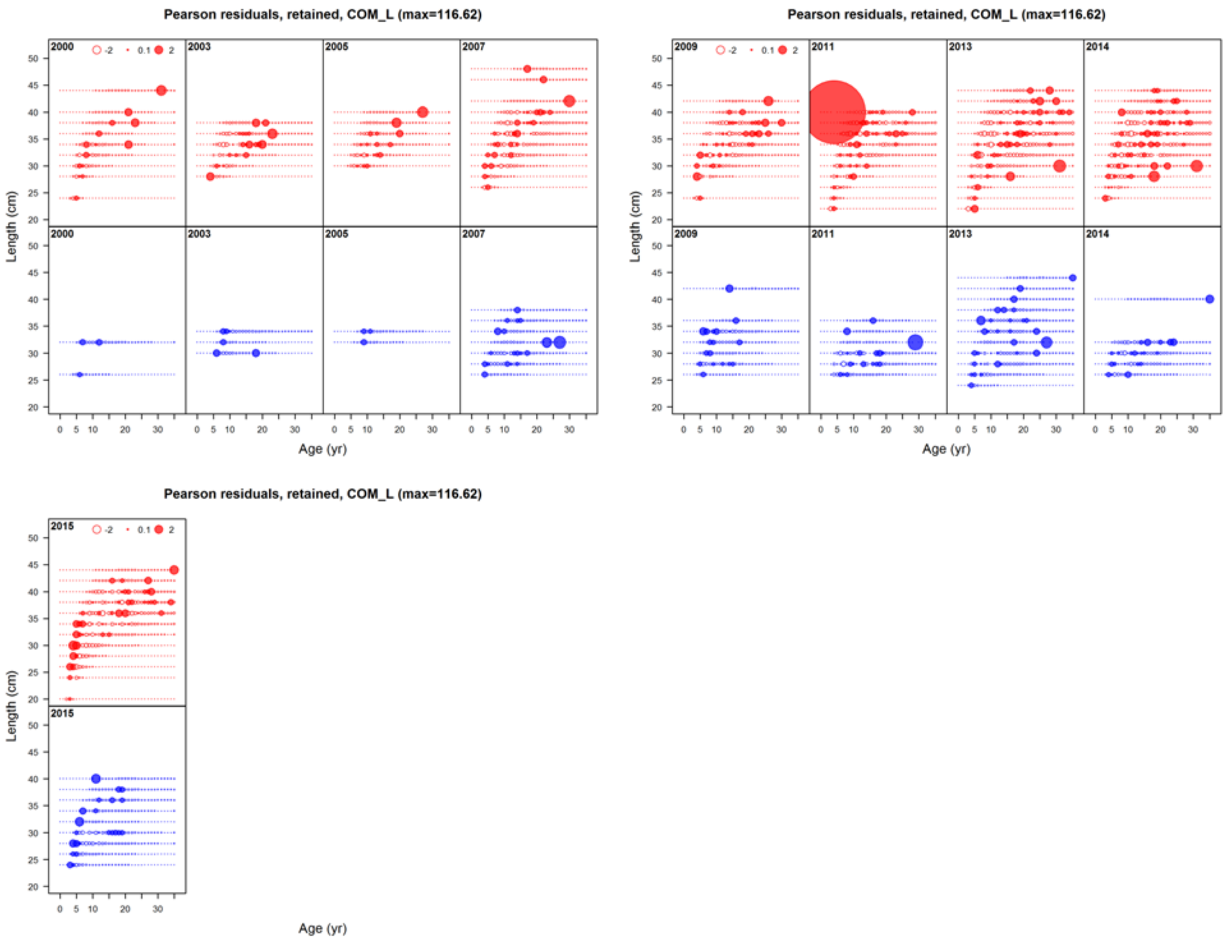


Figure 211: Pearson residuals from the base model fit to conditional age-at-length data in the Oregon commercial landings fleet.

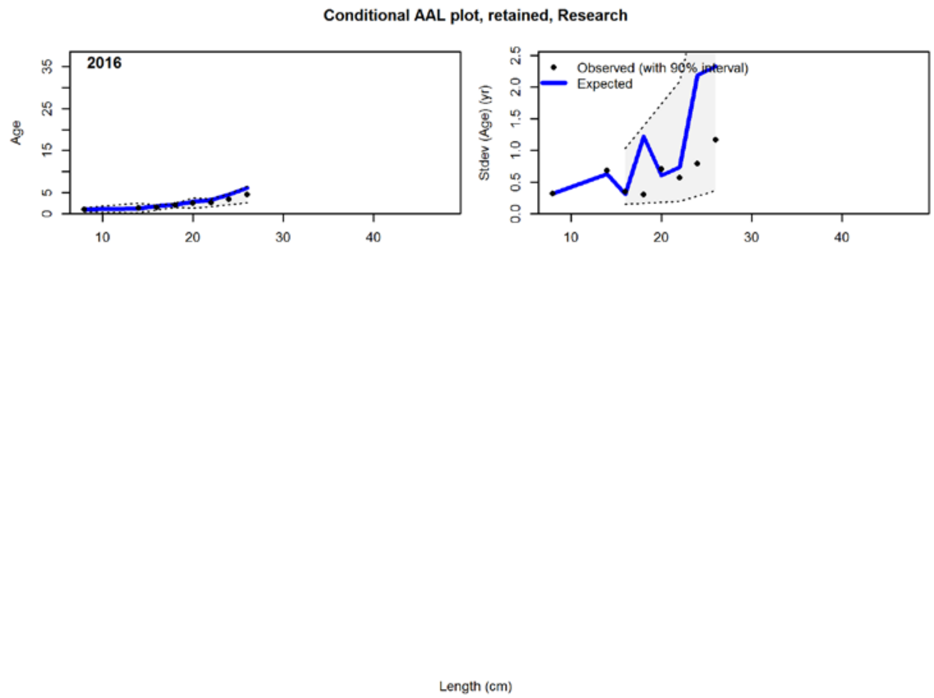


Figure 212: Base model fits to conditional age-at-length data for the Oregon research survey

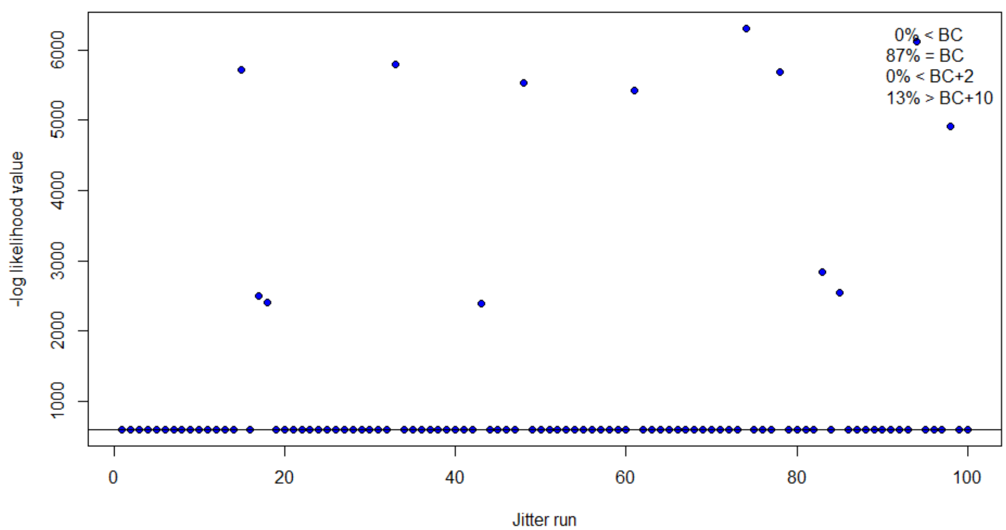


Figure 213: Results from 100 Oregon model base case runs when starting values are jittered (0.1). Horizontal line indicates base model value.

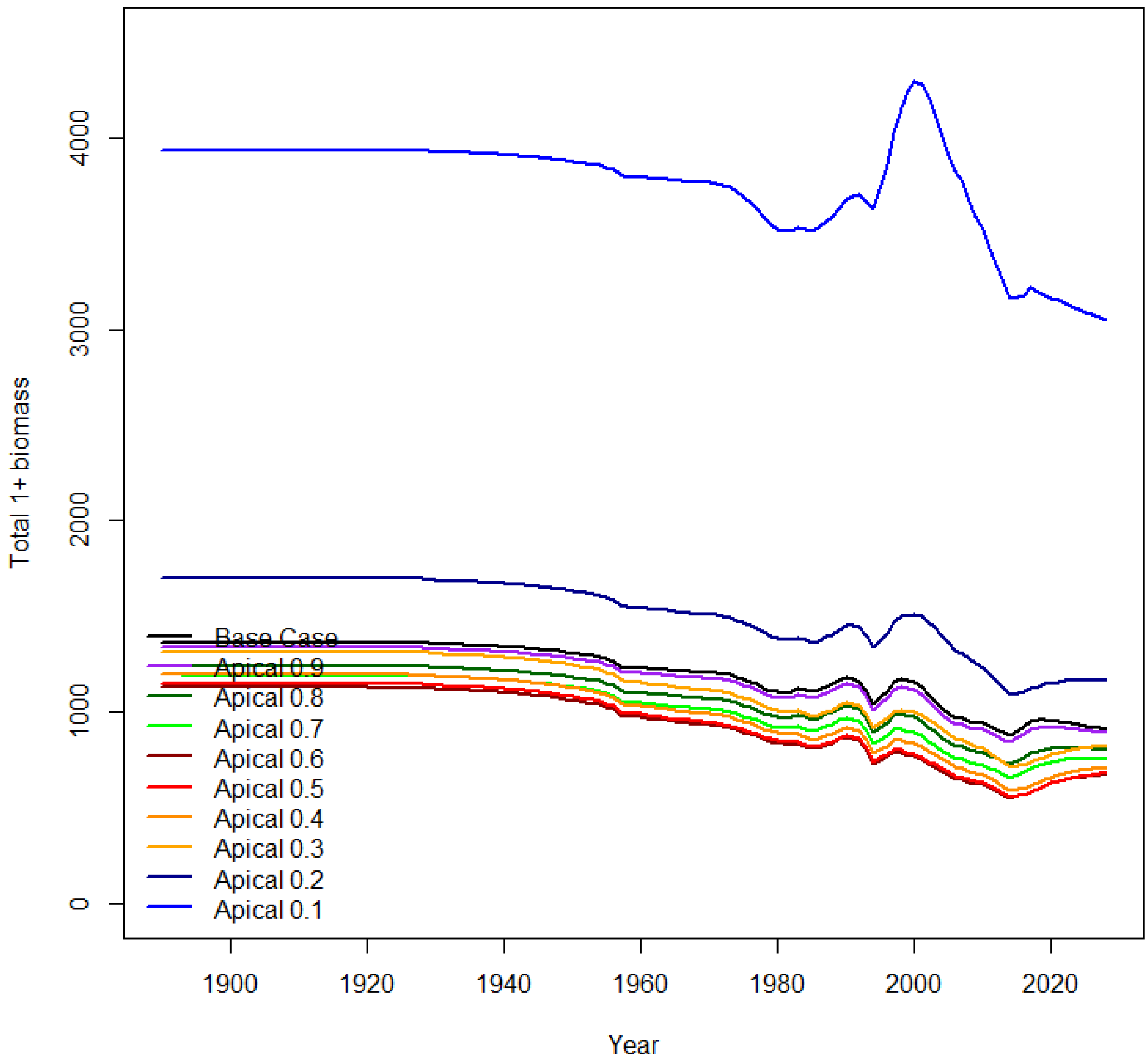


Figure 214: 1Alternative Oregon BDR model runs conducted during the STAR panel (with respect to request 10) to explore the influence of fixing the male selectivity 'apical' parameter (maximum male selectivity relative to female maximum selectivity) for all fleets on the total biomass (age-1+) time series.

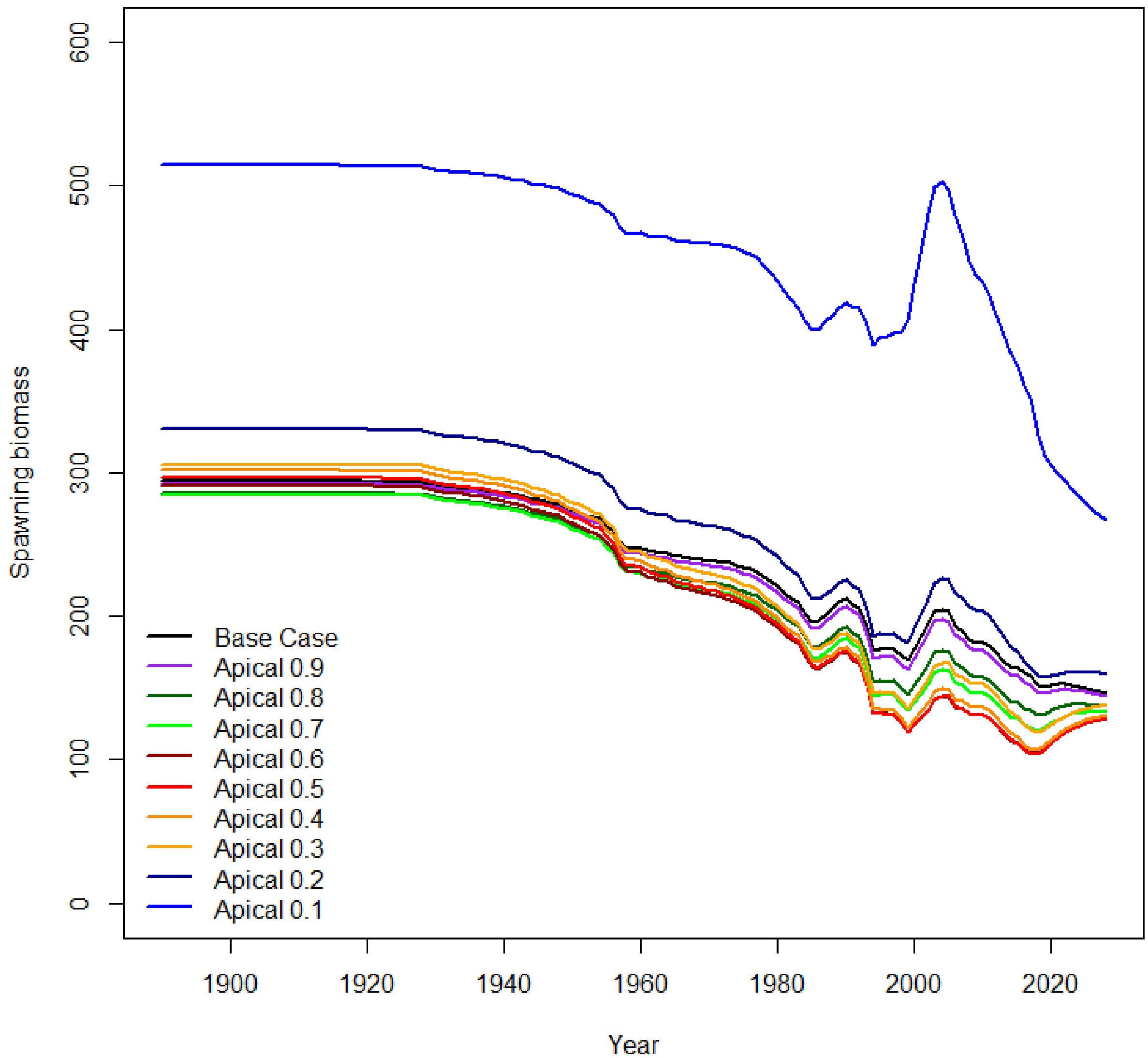


Figure 215: Alternative Oregon BDR model runs conducted during the STAR panel (with respect to request 10) to explore the influence of fixing the male selectivity 'apical' parameter (maximum male selectivity relative to female maximum selectivity) for all fleets on the total spawning output (millions of eggs) time series.

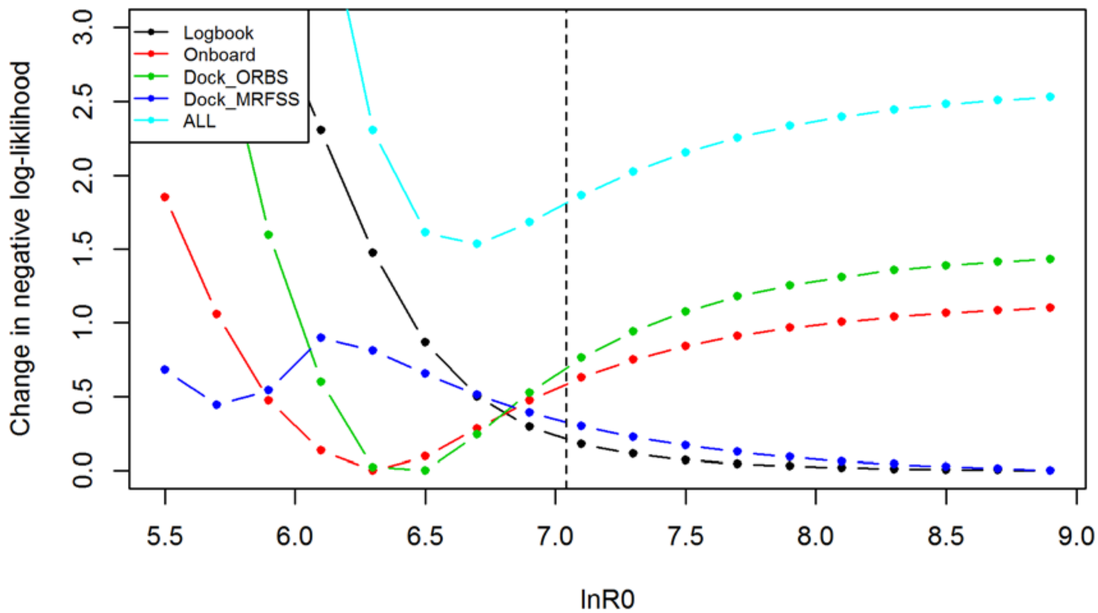


Figure 216: Likelihood profile for individual fishery-dependent indices across initial equilibrium recruitment ($\ln(R_0)$) values relative to the Oregon base case model estimate (dashed vertical line). This figure was produced in response to request 13 during the STAR panel to explore the influence of each index.

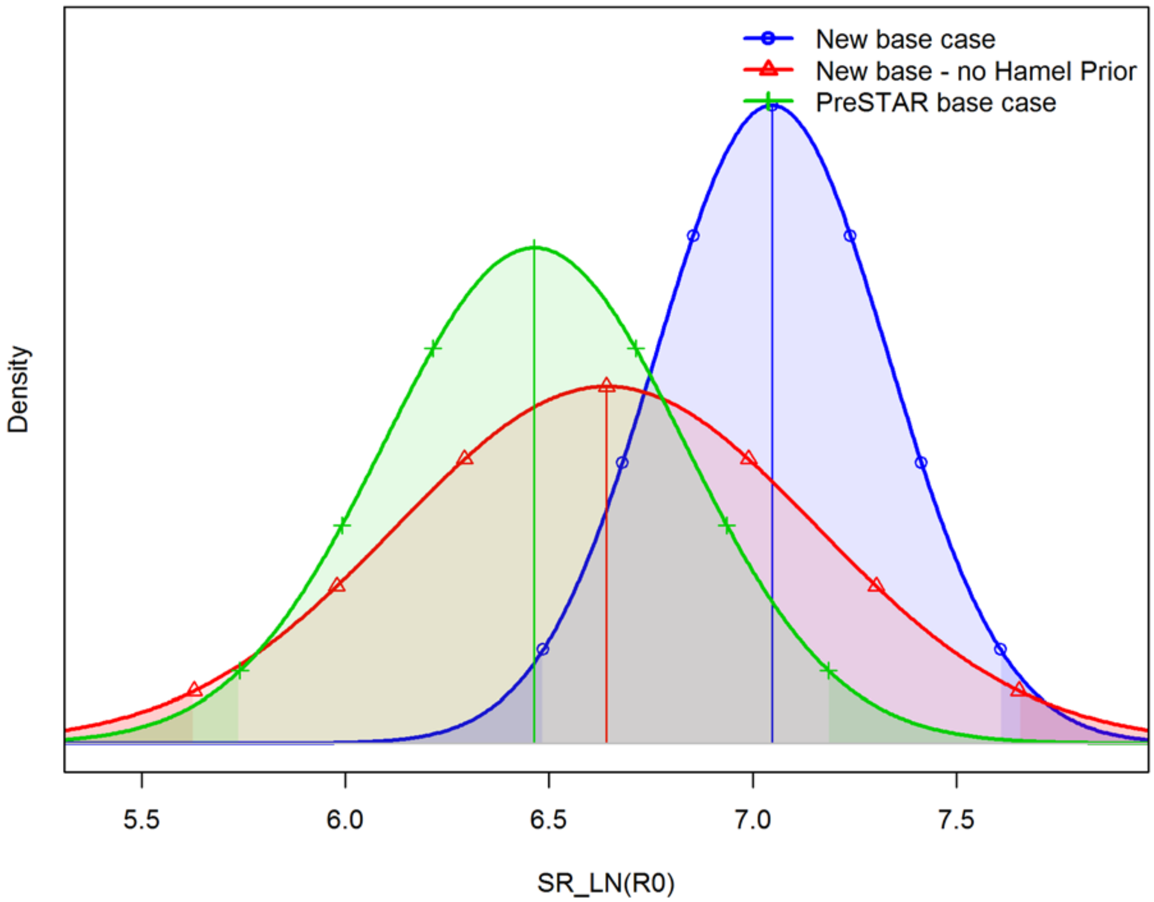


Figure 217: Distribution of the estimate for ln(R_0) across three key Oregon model runs: the base model presented to the STAR (Pre-STAR base model), the new base model developed during the STAR panel (New base case), and the new base model with the exception that natural mortality was estimated using the pre-STAR base model approach . This figure was produced in response to STAR panel request 16.

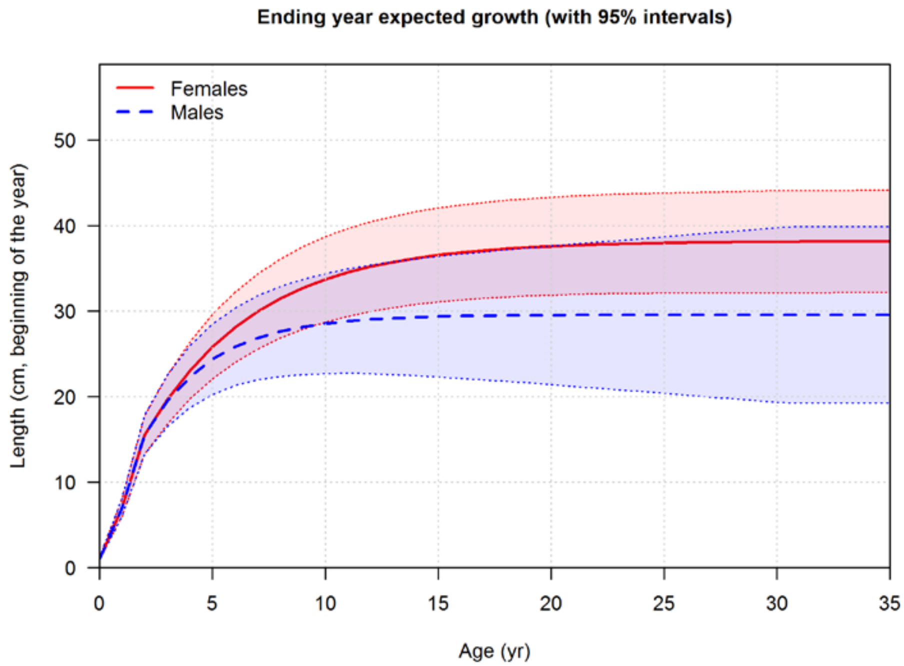


Figure 218: Growth curve for male and female Oregon BDR with age-1 set as the minimum age for growth estimation.

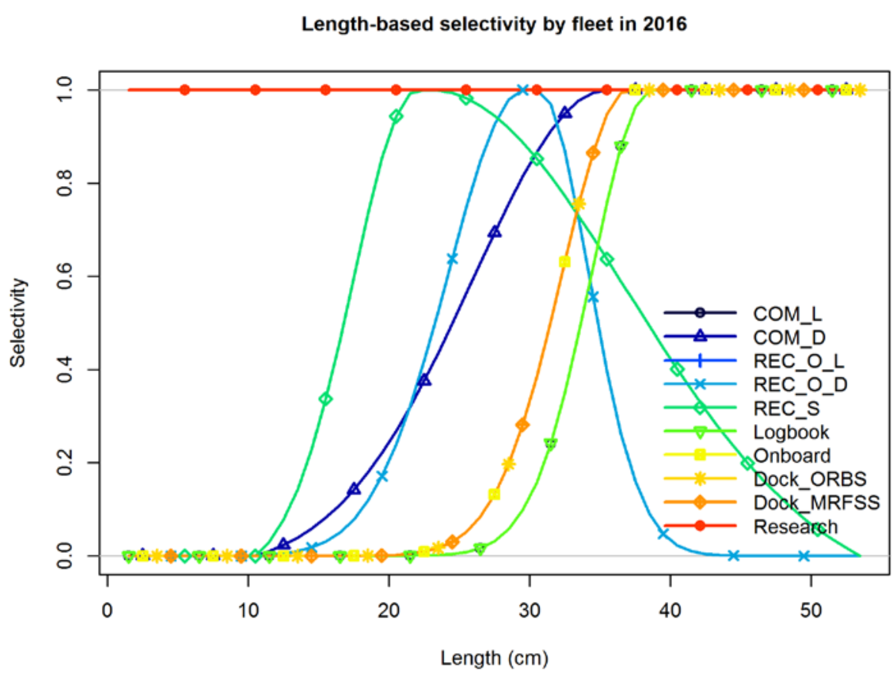


Figure 219: Selectivity curves for fisheries and surveys structured in the base case Oregon BDR model.

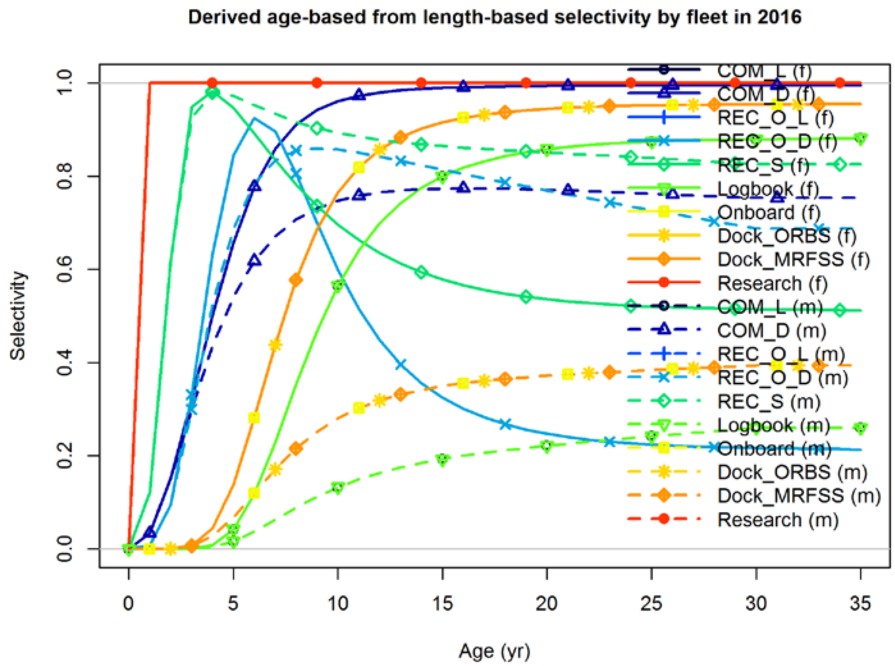


Figure 220: Derived age-based selectivity from length-based selectivity for the fisheries and surveys structured in the base case Oregon BDR model.

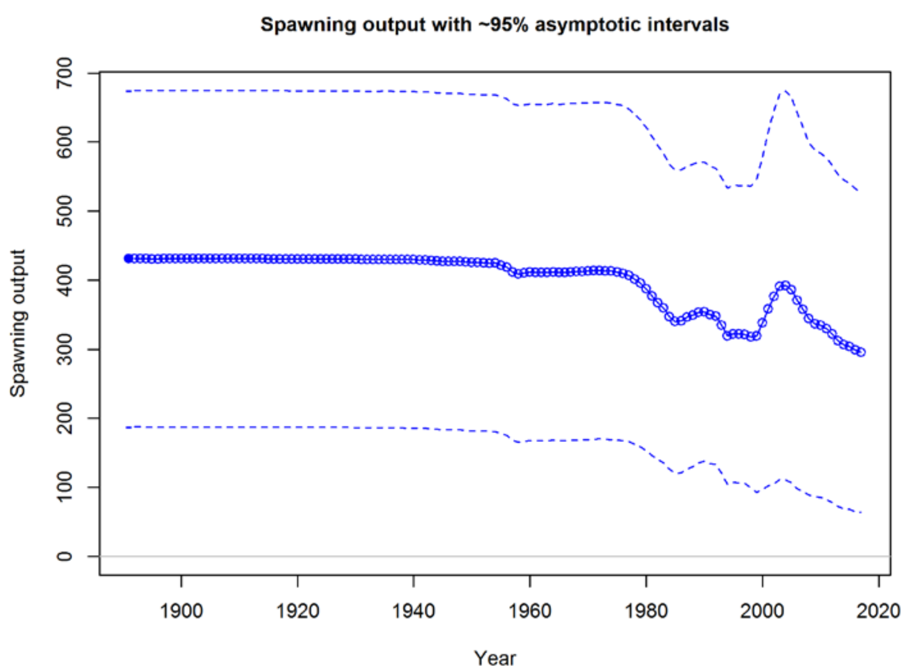


Figure 221: Estimated spawning output time series from the base case Oregon BDR model with ~95% confidence intervals.

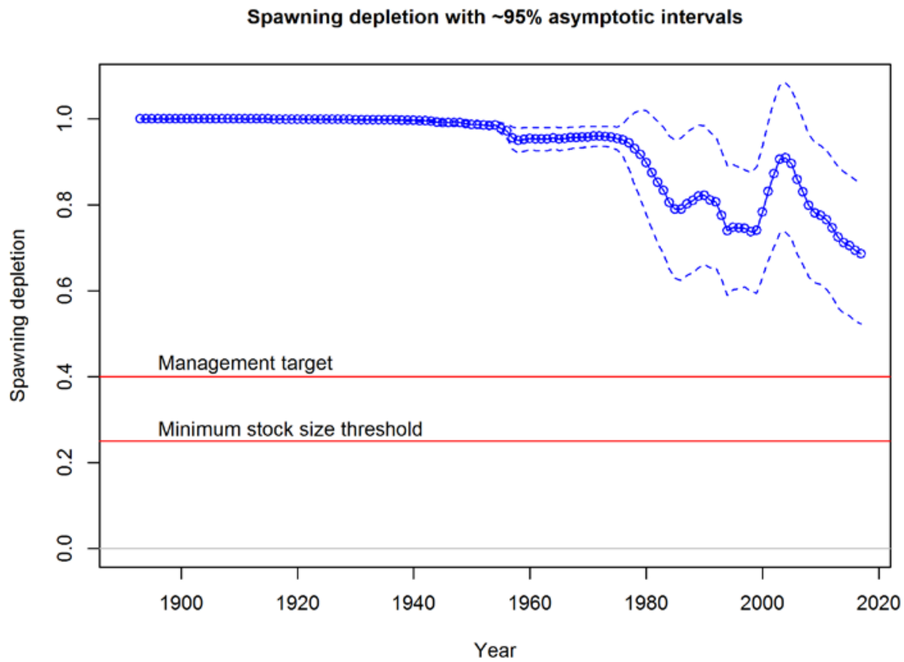


Figure 222: Estimated spawning output depletion relative to unfished levels for the Oregon base case model with ~95% confidence intervals.

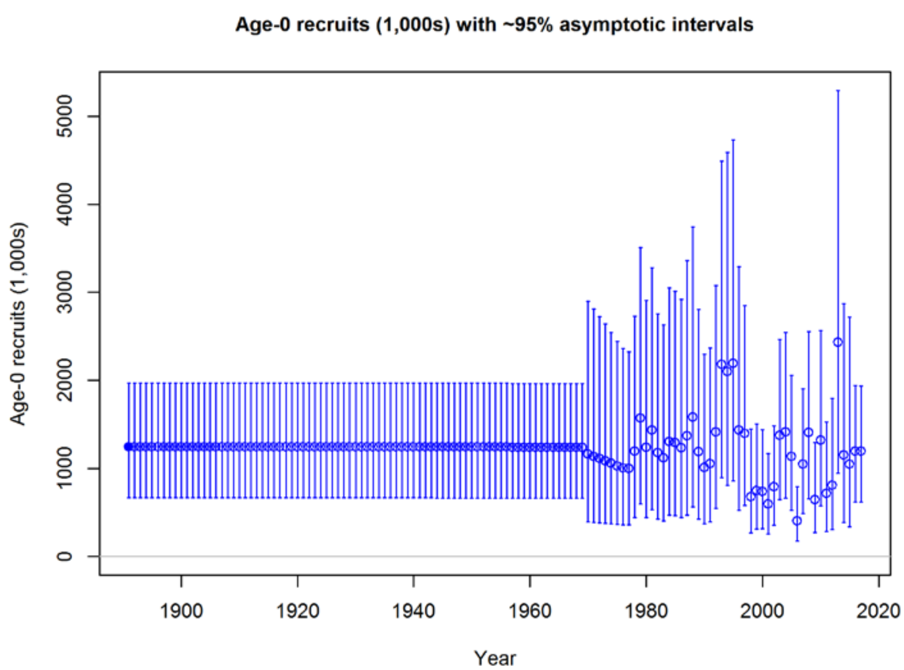


Figure 223: Oregon base model estimates of age-0 recruitment with ~95% confidence intervals.

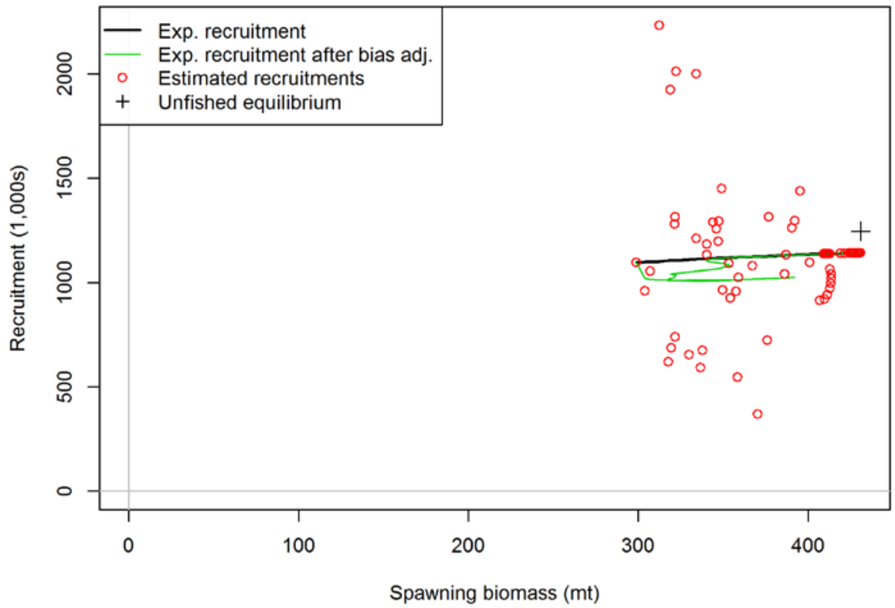


Figure 224: Beverton-Holt stock recruitment relationship for the Oregon BDR base case model.

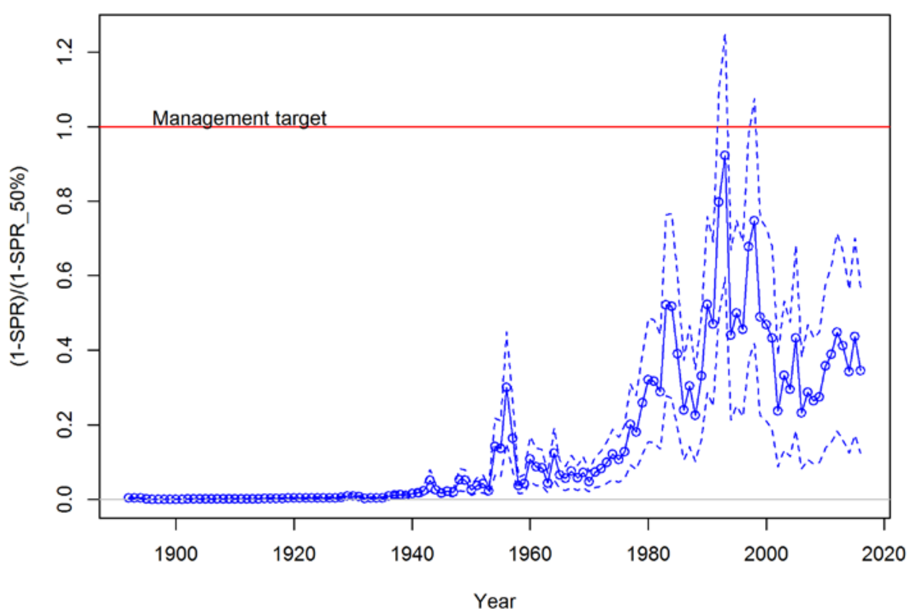


Figure 225: Estimated spawning potential ratio (SPR) for the Oregon BDR base case model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR50% harvest rate. The last year in the time series is 2016.

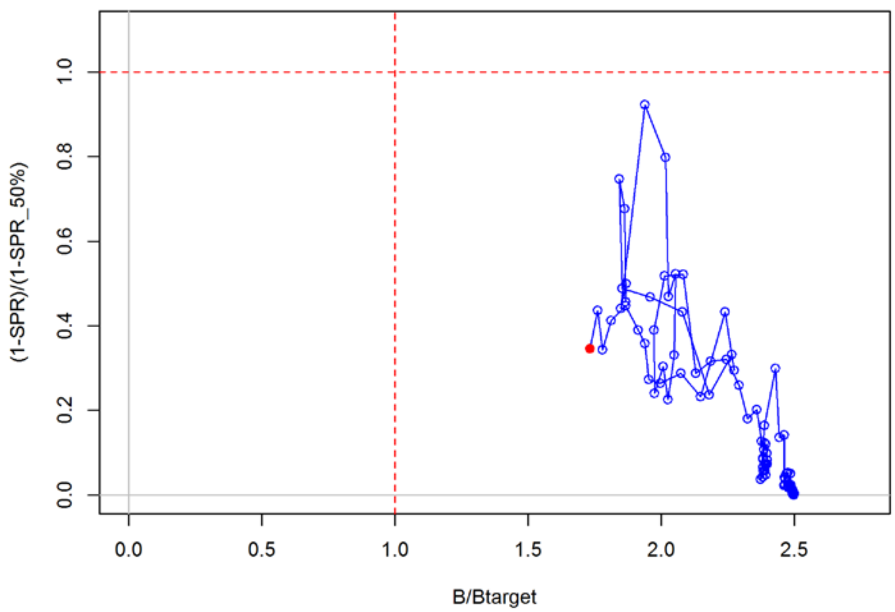


Figure 226: Phase plot of relative spawning output vs fishing intensity for the Oregon BDR base case model. The relative fishing intensity is (1-SPR) divided by 50% (the SPR target). The vertical red line is the relative spawning output target defined as the annual spawning output divided by the spawning output corresponding to 40% of the unfished spawning output.

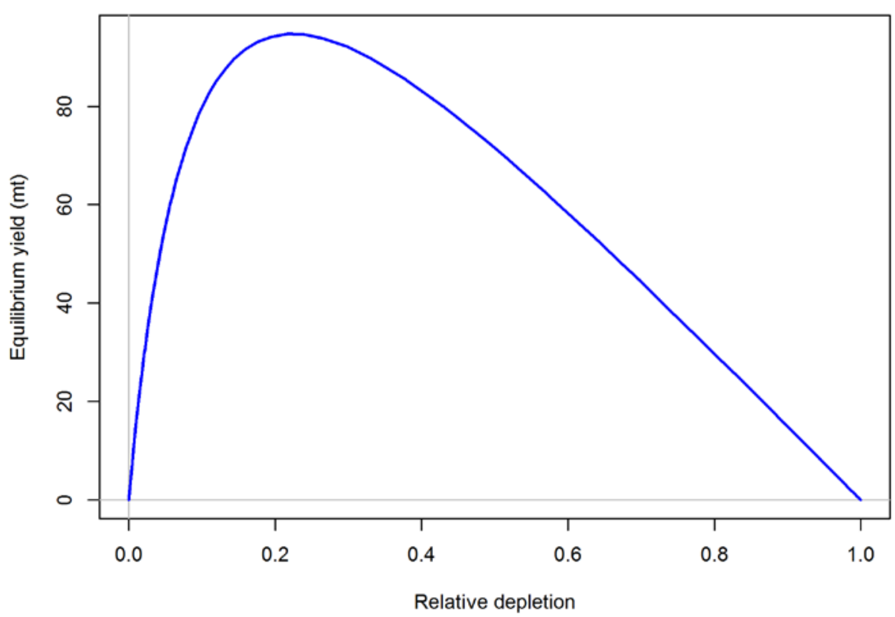


Figure 227: Equilibrium yield curve for the Oregon BDR base case model. Values are based on 2016 fishery selectivity and distribution with steepness fixed at 0.718. The depletion is relative to unfished spawning output.

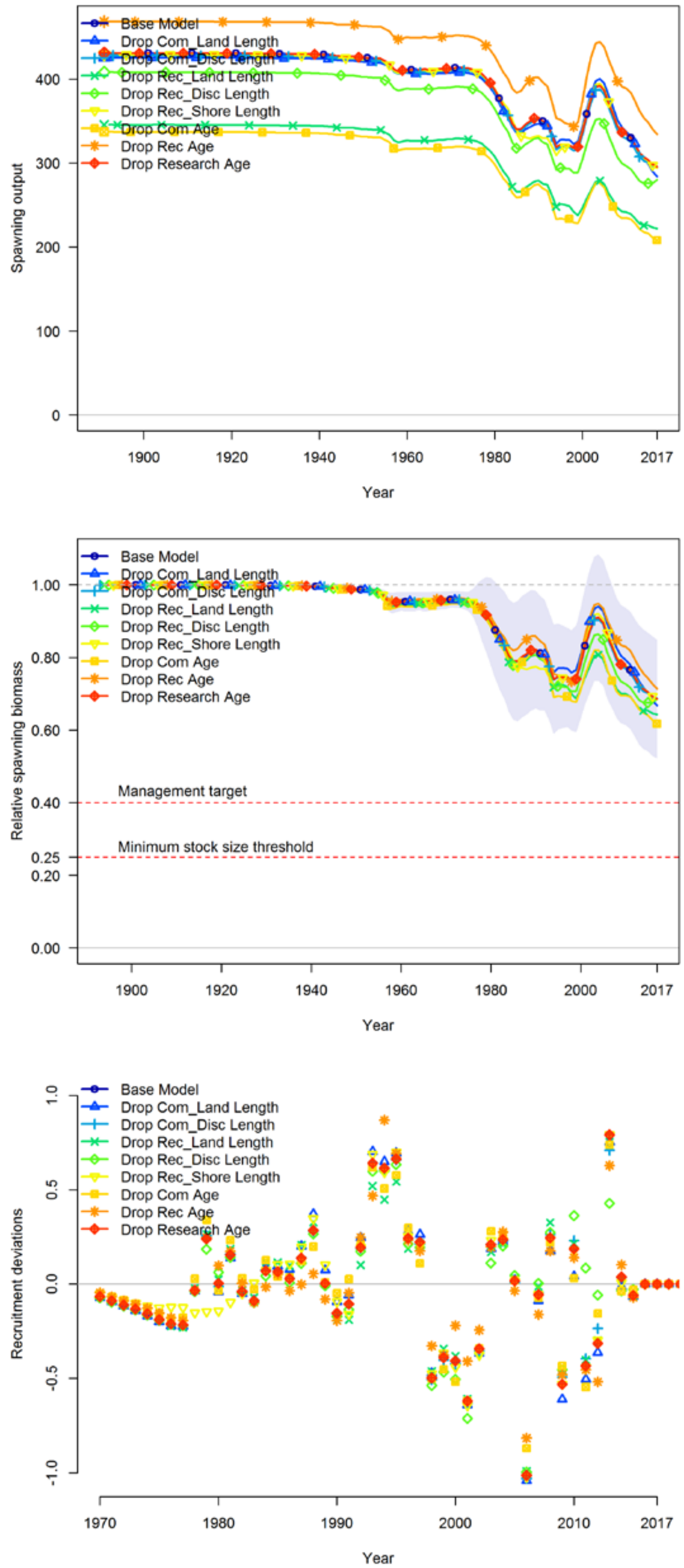


Figure 228: Comparison of spawning output (top), depletion (middle), and recruitment deviations (bottom) for the Oregon base model and alternative composition data source sensitivity runs. The final year in the time series is 2016.

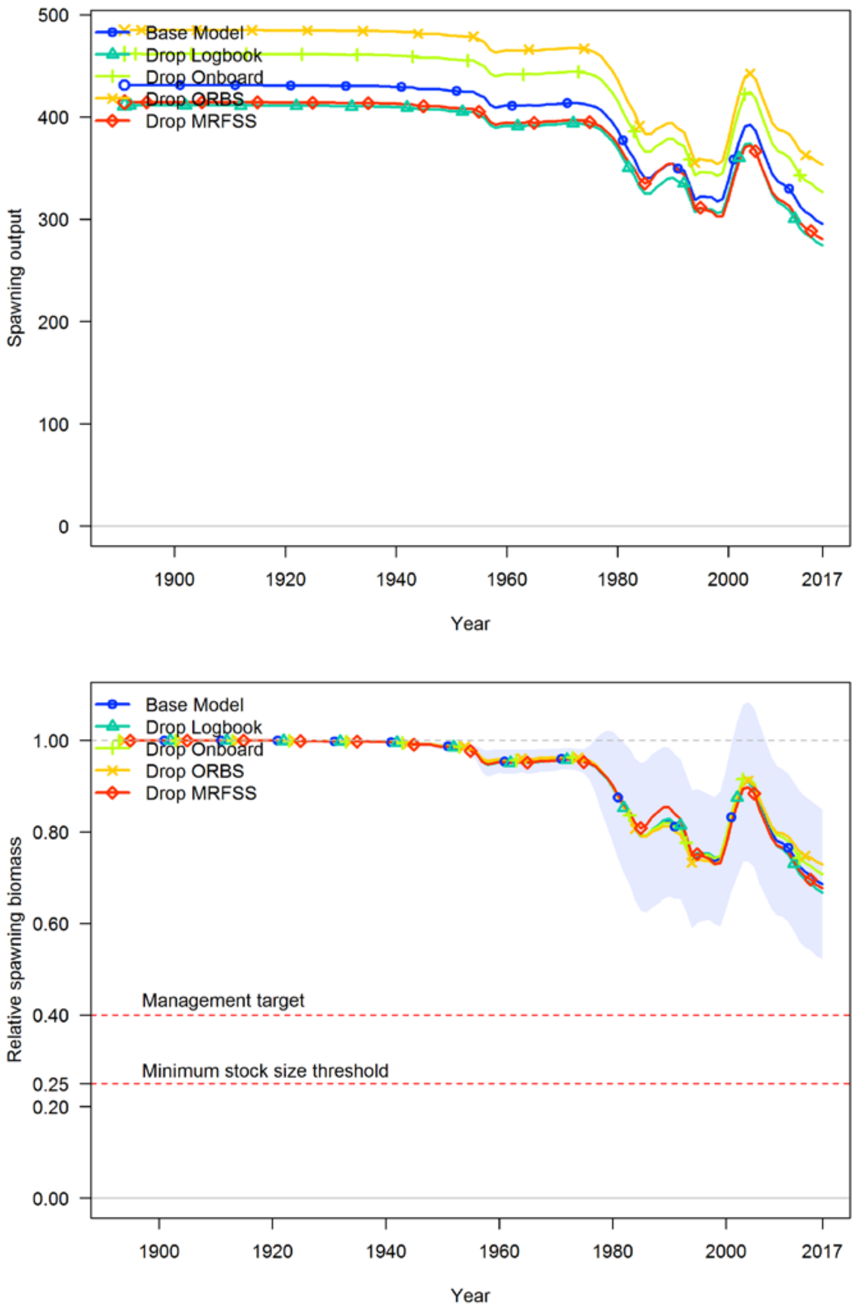


Figure 229: Comparison of spawning output (top) and depletion (bottom) trends for the Oregon base model and alternative index data source sensitivity runs. The final year in the time series is 2016.

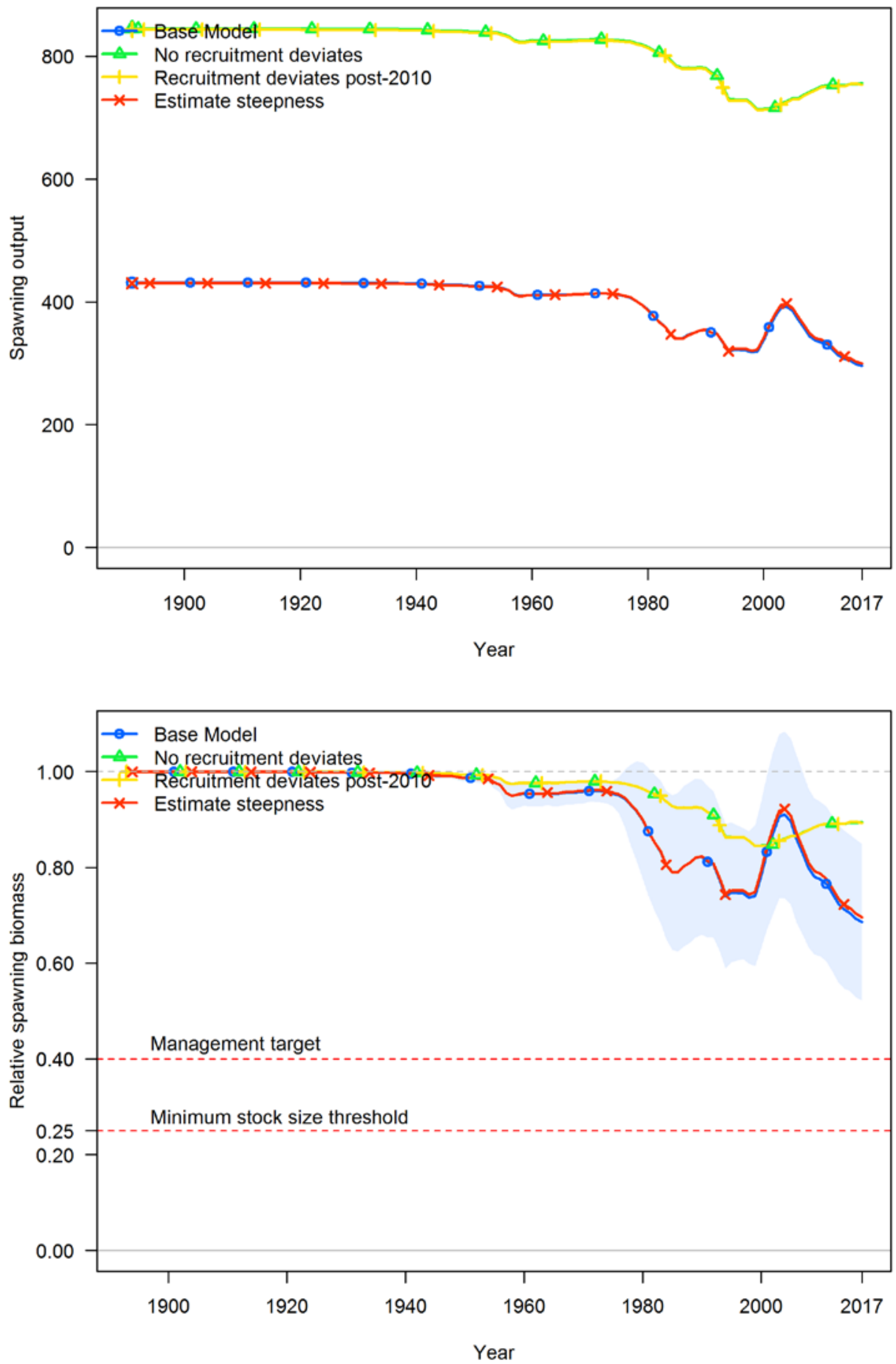


Figure 230: Comparison of spawning output (top) and depletion (bottom) trends for the Oregon base model and alternative recruitment deviation and steepness sensitivity runs. The final year in the time series is 2016.

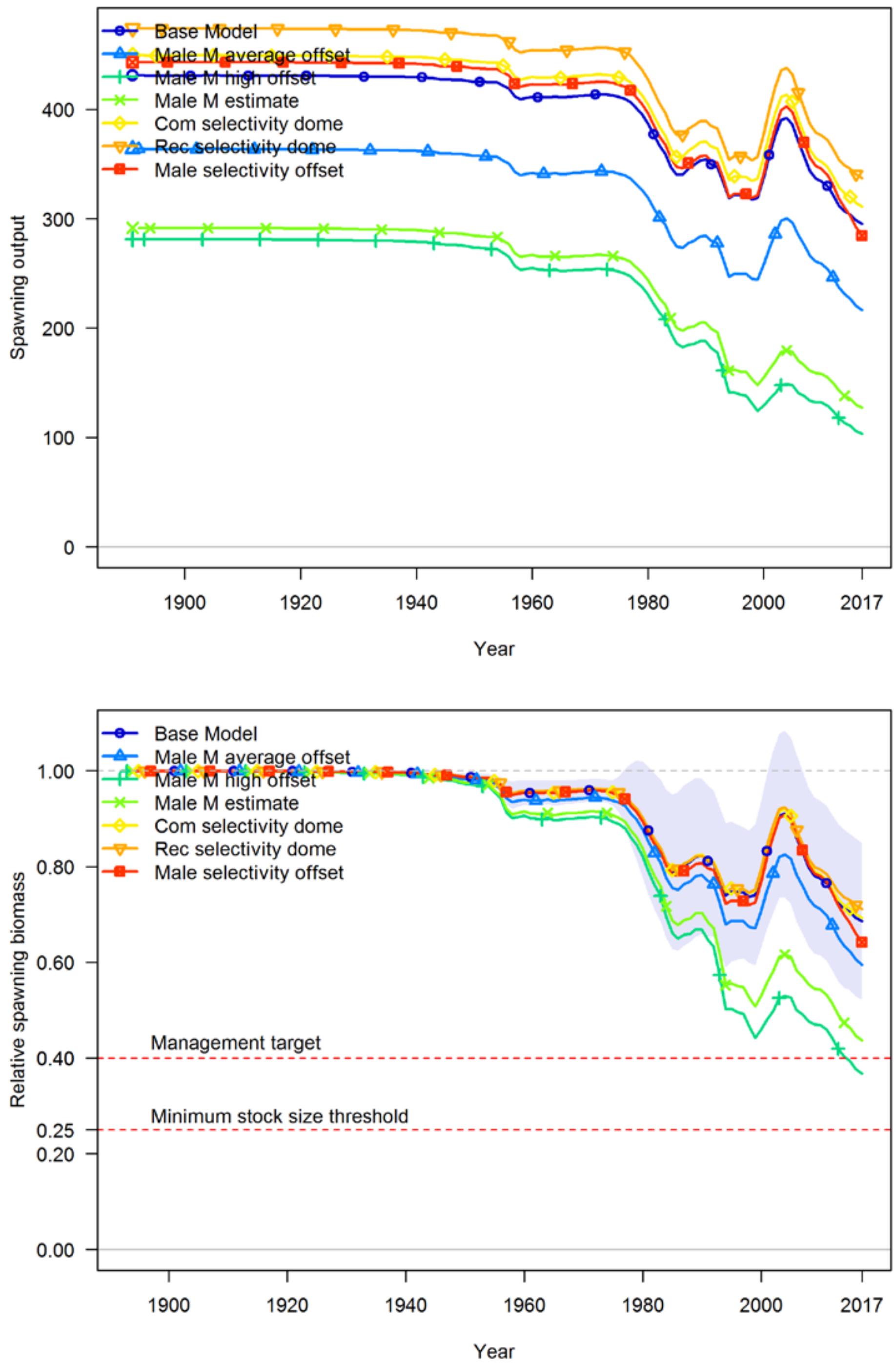


Figure 231: Comparison of spawning output (top) and depletion (bottom) trends for the Oregon base model and alternative natural mortality and selectivity runs. The final year in the time series is 2016.

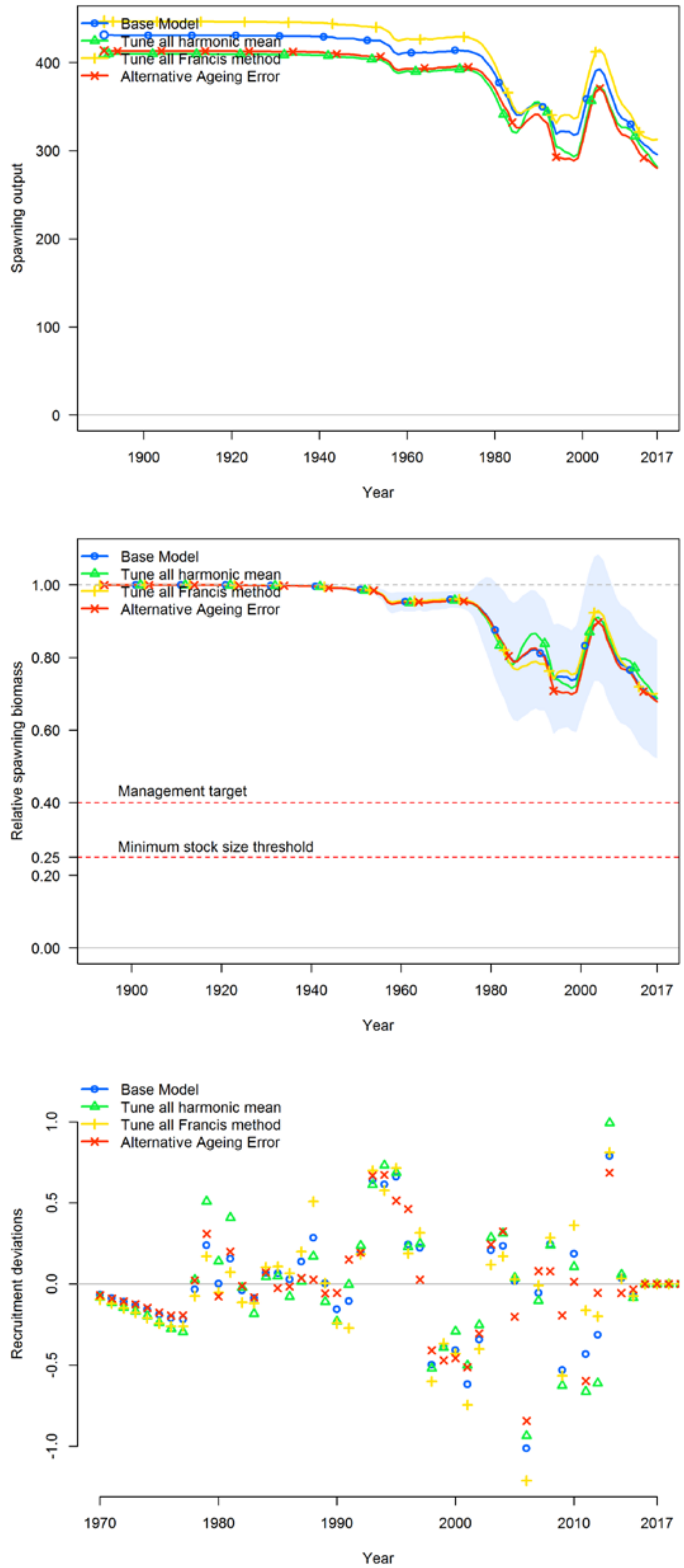


Figure 232: Comparison of spawning output (top), depletion (middle), and recruitment deviations (bottom) or the Oregon base model and alternative model composition data tuning and ageing error runs. The final year in the time series is 2016.

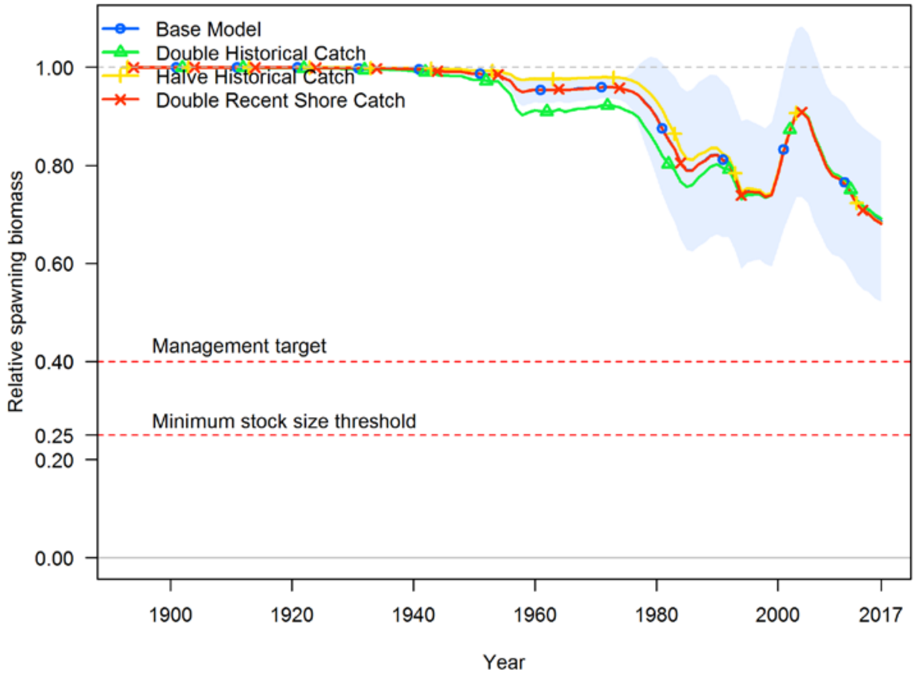


Figure 233: Comparison of depletion trends for the Oregon base model and alternative catch history sensitivity runs. The final year in the time series is 2016.

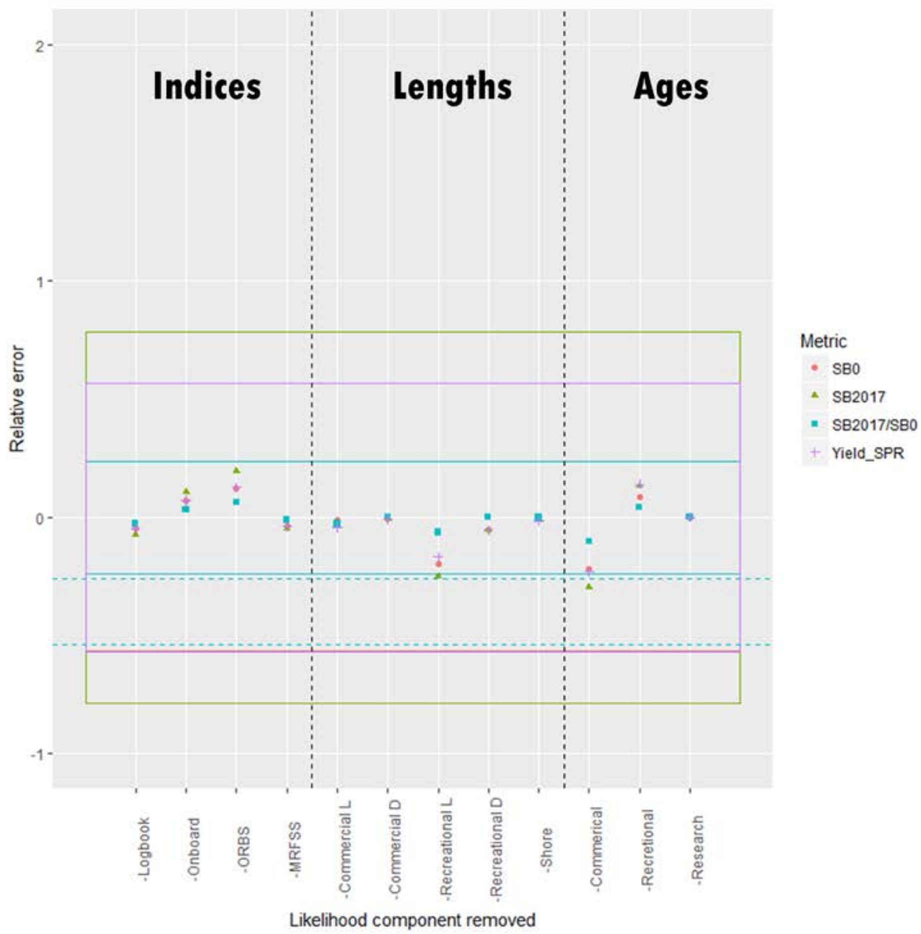


Figure 234: Differences between the Oregon BDR base model and likelihood component sensitivity runs (relative error) for key parameters. Rectangles show the uncertainty associated with the base model.

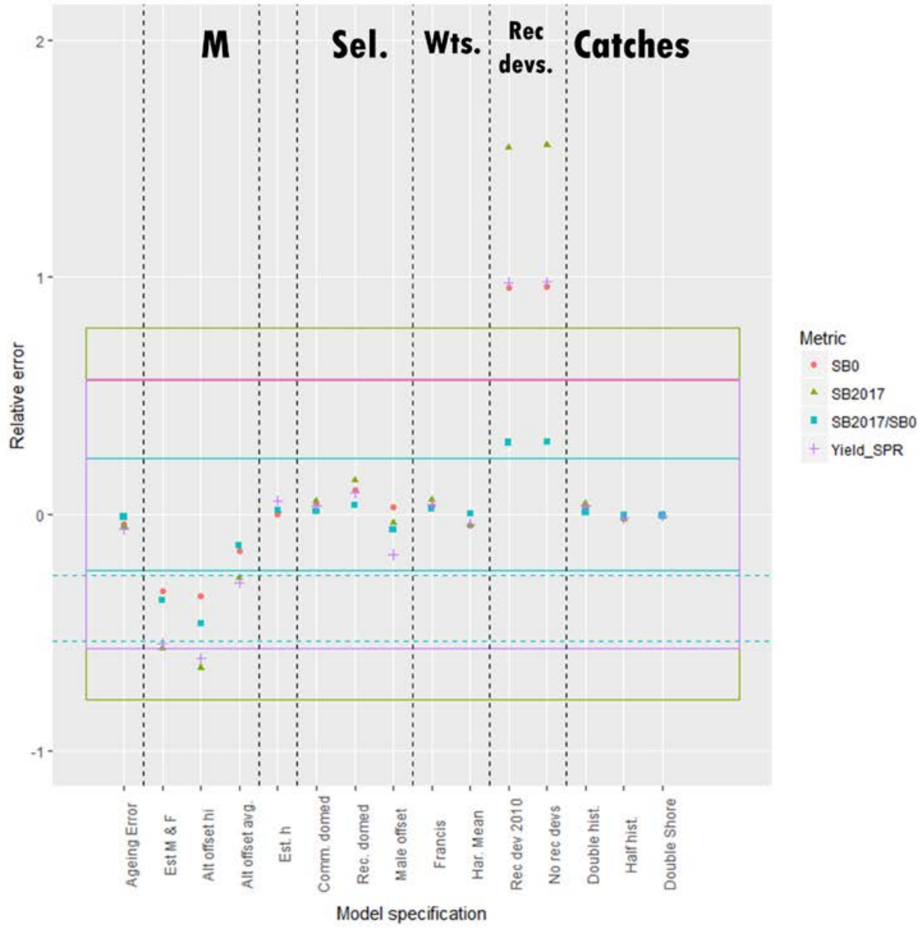


Figure 235: Differences between the Oregon BDR base model and model specification sensitivity runs (relative error) for key parameters. Rectangles show the uncertainty associated with the base model.

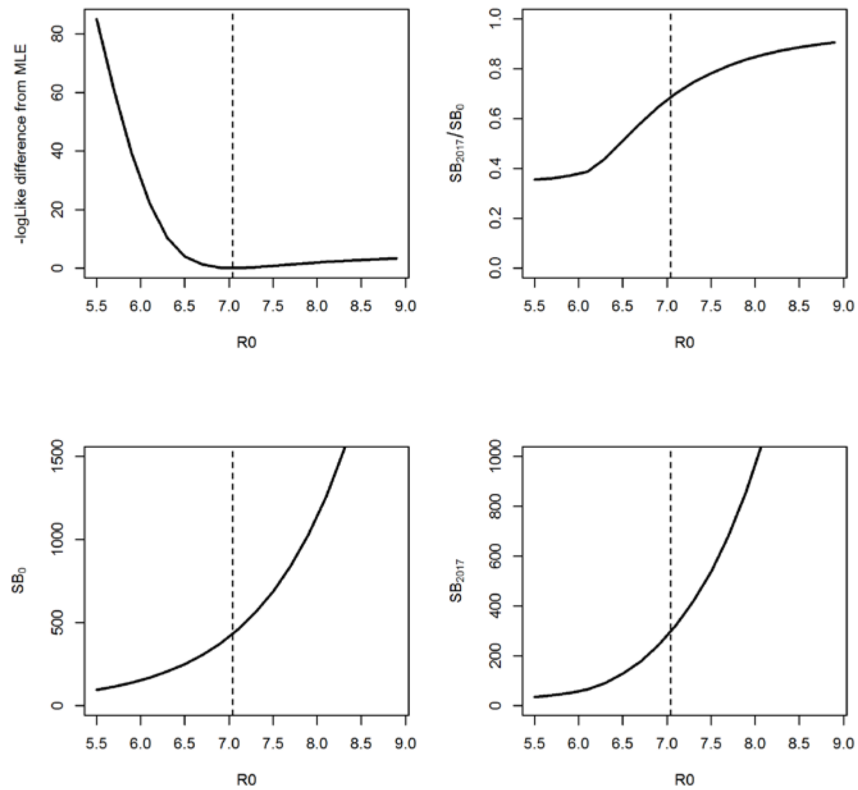


Figure 236: Likelihood profile for initial equilibrium recruitment ($\ln(R_0)$) and resultant derived quantities for the Oregon base case model.

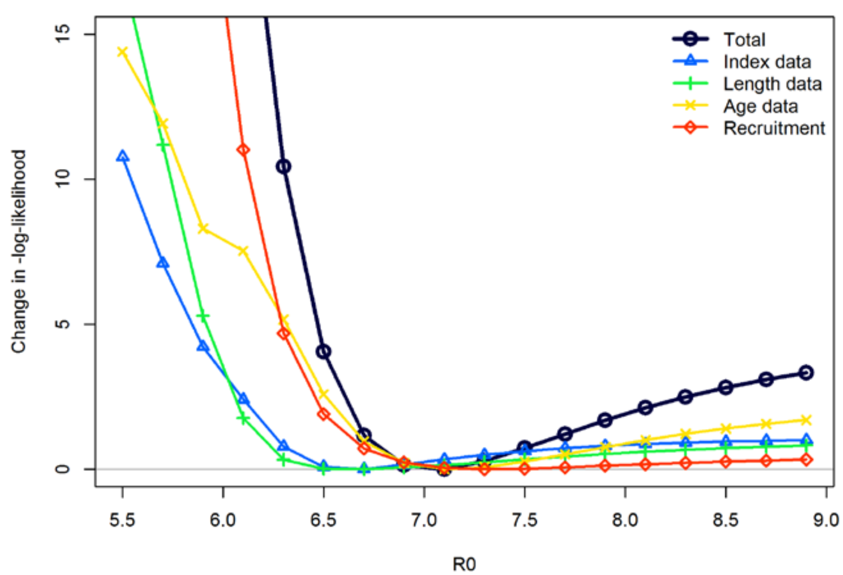


Figure 237: Likelihood profile across data sources for initial equilibrium recruitment ($\ln(R_0)$) for the Oregon base case model.

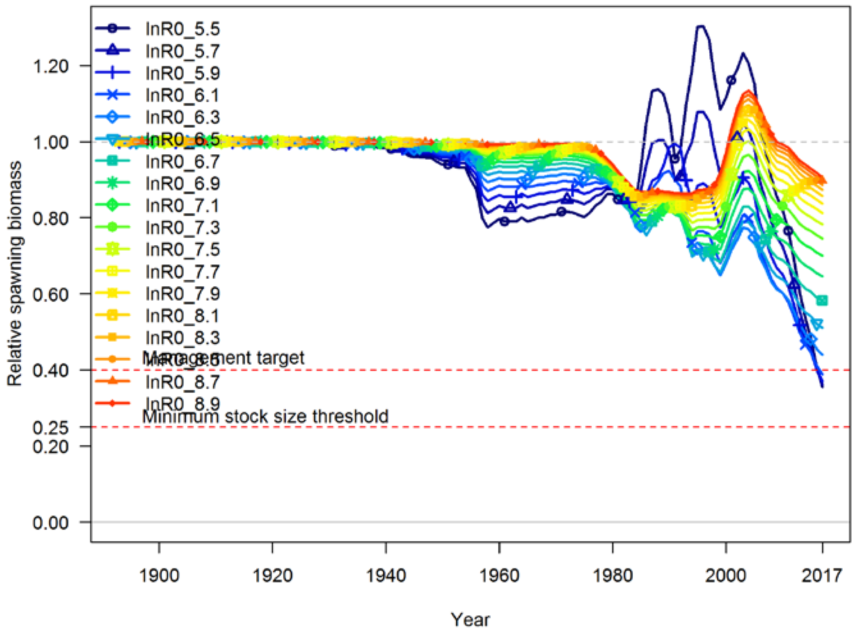


Figure 238: Comparison of the depletion time series across initial equilibrium recruitment ($\ln(R_0)$) values used in likelihood profiles (range = 6.0 – 9.0) for the Oregon base case model.

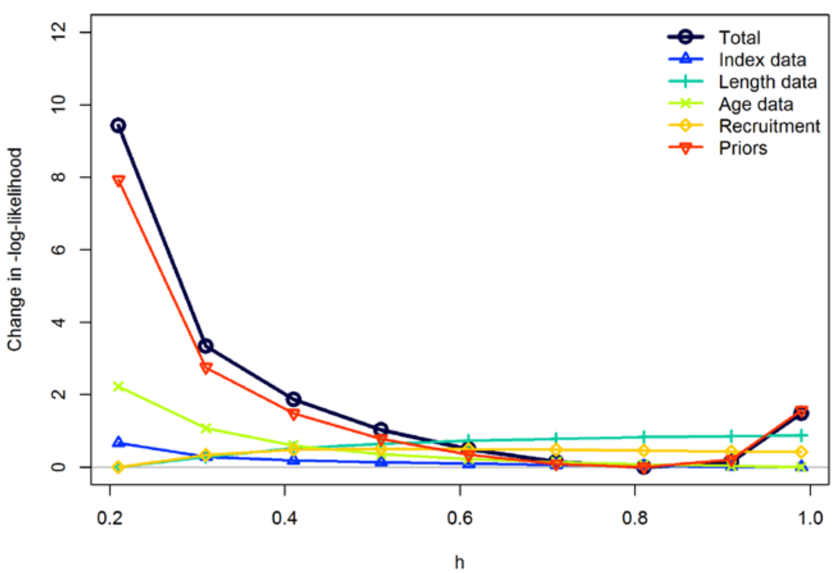


Figure 239: Likelihood profile across data sources for steepness (h) for the Oregon base case model.

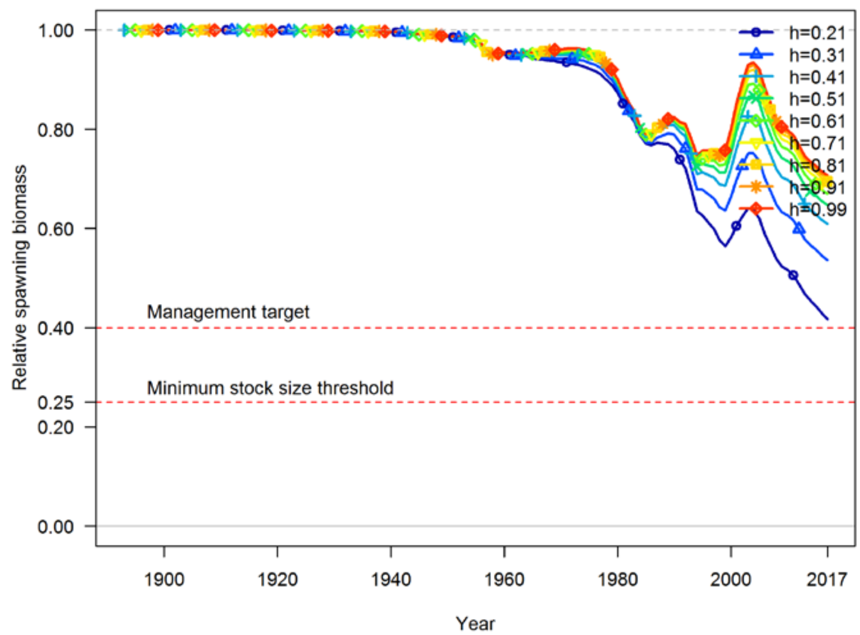


Figure 240: Comparison of the depletion time series across steepness (h) values used in likelihood profiles for the Oregon base case model.

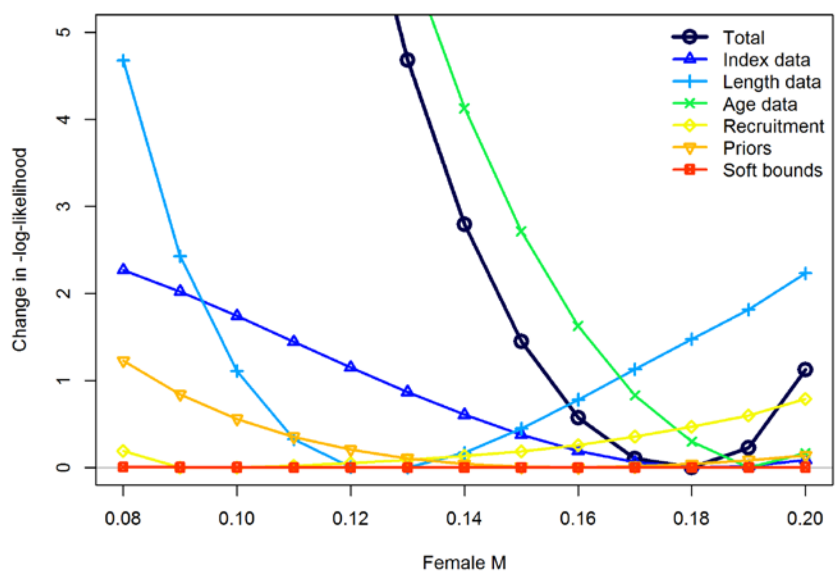


Figure 241: Likelihood profile across data sources for female natural mortality (fixed male natural mortality offset). Female and male natural mortality were fixed in the Oregon base case model.

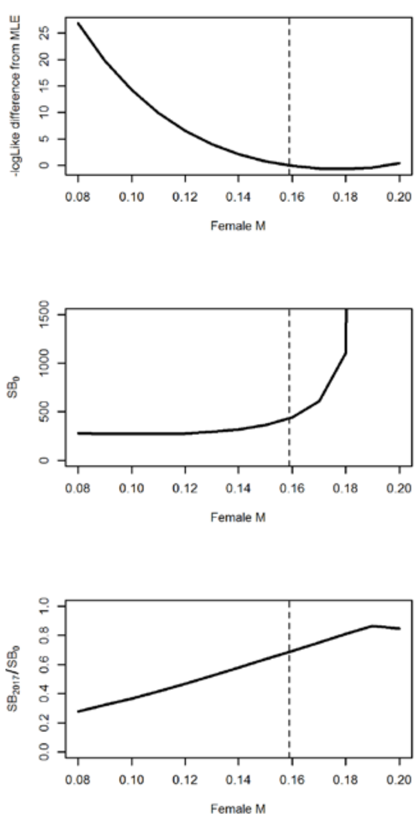


Figure 242: Likelihood profile for female natural mortality (for the case when the male natural mortality offset is fixed) and resultant derived quantities. Female and male natural mortality were fixed in the Oregon base case model.

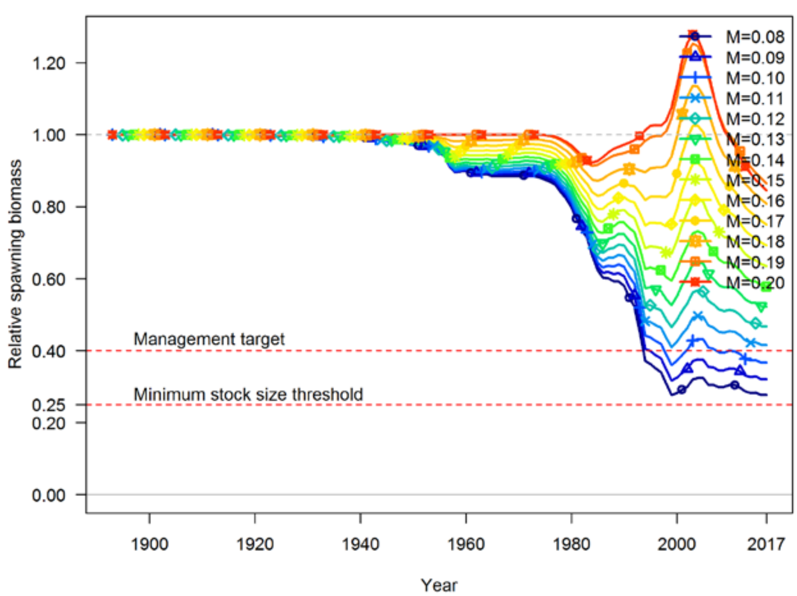


Figure 243: Comparison of the depletion time series for female natural mortality (fixed male natural mortality offset) values used in likelihood profiles. Female and male natural mortality were fixed in the Oregon base case model.

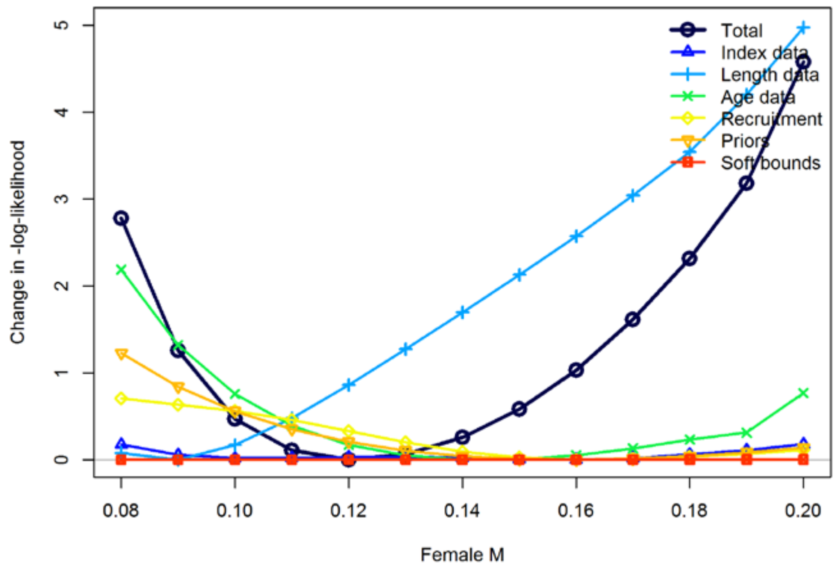


Figure 244: Likelihood profile across data sources for female natural mortality when male natural mortality was estimated each time. Male natural mortality was not estimated in the Oregon base case model.

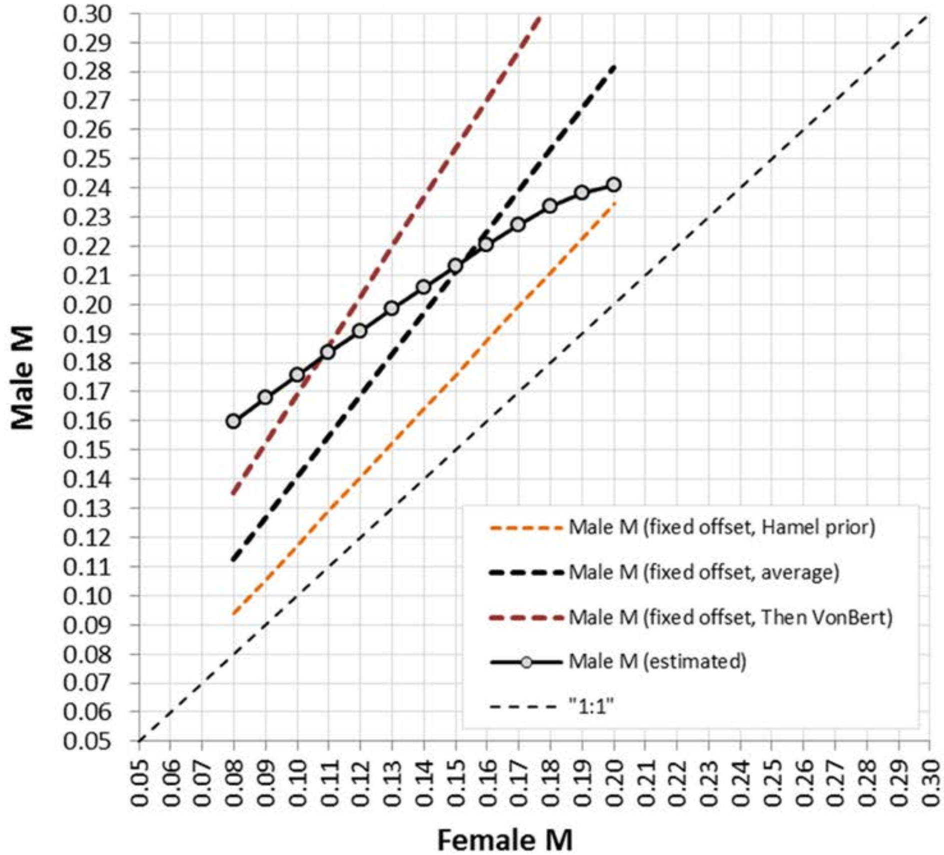


Figure 245: Profile across female natural mortality values for cases when male natural mortality was fixed at three alternative offset values and when male natural mortality was estimated. Female and male natural mortality were fixed in the Oregon base case model.

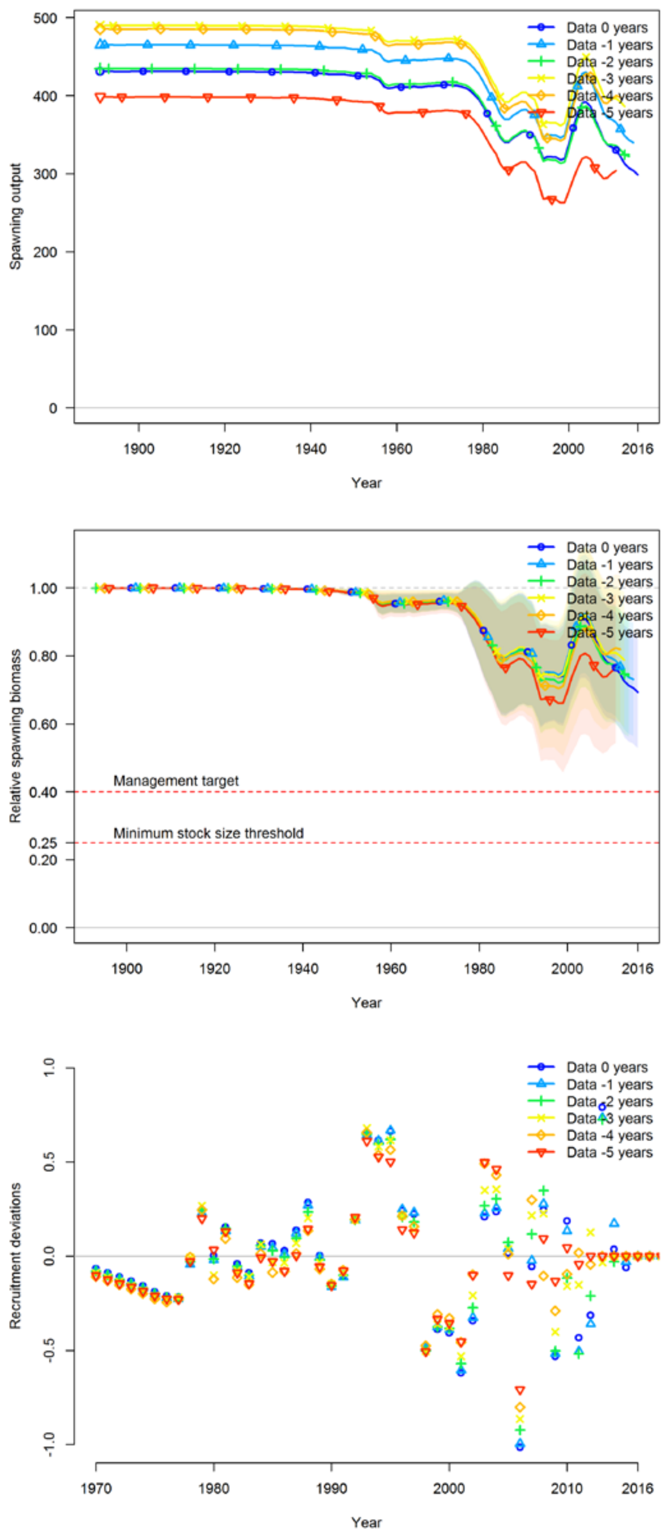


Figure 246: Retrospective model runs (present to -5 years) for the base case model relative to Oregon BDR spawning output (top), depletion (middle), and recruitment deviations (bottom). Shaded regions are approximate 95% confidence intervals.

Appendix A. Genetic identification of Blue Rockfish cryptic species

Elizabeth A. Gilbert-Horvath
NOAA SWFSC Fisheries Ecology Division
Santa Cruz, California

Summary of Findings

- Nominal Blue Rockfish adults and juveniles were genetically identified as Blue or Deacon rockfish to inform the Blue Rockfish stock assessment
- DNA sources included modern fin tissues (n=1,356) and a relatively novel source, historic otoliths (n=1,632)
- Approximately 90% of modern samples were identified to species
- About 40% of otolith samples yielded species identifications, indicating that historic samples can be a viable source of genetic material for analysis
- Individuals having low sample quality usually could not be identified to species
- Concordance between visual and genetic identification was high, though not 100%
- Among adults, Deacon rockfish comprised a majority of samples caught from Oregon to Half Moon Bay, and were uncommon in southern California
- Blue rockfish were more common than Deacon rockfish from Monterey Bay to southern California
- Multiple population genetic analyses describe Blue and Deacon rockfish as a significantly diverged species pair, but this divergence is shallow relative to their congeners
- Assignment tests and phylogenetic results indicate very little geographic structure within both Blue and Deacon rockfish
- Details can be found in the following sections

See Addendum #4 below for the most recent results.

Here I summarize results from a project to genetically identify cryptic species of Blue Rockfish (*Sebastes mystinus*), recently described by Frable et al. (2015) as separate species: Blue (*S. mystinus*) and Deacon rockfish (*S. diaconus*). The lab work and preliminary analysis were performed by Michaella McFarland, as part of her NOAA EPP 2016 summer scholarship (mentors Garza and Gilbert-Horvath). I re-analyzed the data she collected in a more rigorous manner for this report, which is intended to inform the upcoming Blue Rockfish stock assessment. Per an agreement between the Molecular Ecology and Groundfish Analysis teams, additional samples will be added to this Blue Rockfish dataset in fall/winter 2016. The genetic identification (ID) results for individual fish can be found in the file blue_rockfish_sppID_results_forGF.xlsx, in column V.

Samples

A total of 833 Blue Rockfish were analyzed in the Molecular Ecology laboratory for this project. Of these, the majority (n=809) were fin tissue samples from Katie Schmidt's MLML thesis project; each of these samples had an associated visual identification. Fin tissue had been stored in ethanol. The remaining 24 samples consisted of otoliths from which DNA was extracted as a test of DNA yield and quality from a decades-old source (Groundfish Analysis team; collection date not available at the time of writing).

Molecular Methods in brief

DNA was extracted from samples using our standard protocol, a Qiagen DNeasy 96 Tissue Kit, to obtain purified DNA, which was then used as template for genotyping using PCR (polymerase chain reaction). Nine microsatellite markers—the rockfish species ID panel—were amplified and the products analyzed on an ABI 3730 capillary sequencer. Allele calling was performed using GeneMapper v4.0 software (Applied Biosystems, Inc.), to produce the multi-locus genotype dataset.

Genetic Analysis Methods

Genetic assignment tests were employed to classify individuals to species, using a previously constructed reference species baseline. Because the two Blue Rockfish types had not previously been included in the baseline dataset, it was necessary to add them, as part of this project. For this purpose I used Schmidt's "verified Blue Rockfish" (n=24) and "verified Deacon Rockfish" (n=29) as the reference individuals for the two types. Three of the Deacon rockfish yielded insufficient data for analysis, and thus 26 were included in the baseline. After the inclusion of the two Blue Rockfish types, the reference dataset contained 44 *Sebastes* species.

To assess the robustness of species assignment results, three assignment analyses were conducted using two software programs, GeneClass2 (Piry et al. 2004) and gsi_sim (Anderson et al. 2008), employing different assignment algorithms. In GeneClass2, a Bayesian method (Rannala and Mountain 1997) and a frequency-based method (Paetkau et al. 2004) were used. Gsi_sim uses a Bayesian MCMC simulation method for assignment. The three sets of results were then compared to arrive at a consensus species identification for each individual. Assignment scores of 90% and above were considered high confidence, and scores below 90%, low confidence. Because low confidence assignments are potentially inaccurate, only the high confidence species assignments were considered as reasonable IDs. Individuals having a low confidence assignment in one or more of the three methods were classified as having low confidence overall. Accordingly, only those individuals with concordant, high confidence species assignments in all three methods were "assigned" a species ID. This conservative approach was taken to minimize or avoid spurious species assignments.

Data was analyzed using a fractional ancestry program, Structure v2.3.4 (Pritchard et al. 2000), to determine the degree of genetic distinctiveness of the two cryptic species, and to evaluate the samples for evidence of hybridization. This analysis differs from the assignment tests in that it estimates ancestry of individuals, given the sample as a whole, and does not compare the unknowns to a reference dataset. Thus, the Structure analysis provides a quasi-independent estimation of genetic species classifications. Analysis parameters included 50,000 burn-in sweeps, 150,000 analysis replicates without replacement, and five runs each for K = 2-4. The Structure output was plotted using programs CLUMPP (Jakobsson and Rosenberg 2007) and DISTRUCT (Rosenberg 2004), and was subjected to Evanno et al. (2005) analysis as implemented in Structure Harvester web v0.6.94 (Earl and vonHoldt 2012) to determine the most probable value of K, i.e., most likely number of groups in the dataset. The Structure output from the most probable K was then compared to the assignment test results, to assess concordance in species ID between the different analyses.

The final genetic species ID was made based on a comparison of the assignment and ancestry results. Individuals having concordant, high confidence IDs with both methods were called either Blue or Deacon, as appropriate. Individuals having a high confidence result in one method and a low confidence or ambiguous result in the other method were designated "possible" species, but these results should be interpreted with caution. Individuals with non-concordant results and/or low confidence results in both methods were ambiguous, i.e., species could not be determined for these fish.

Results

Genetic species assignment

Of the 780 individuals genotyped as unknowns, about 5% (n=35) were not successfully genotyped: 9 of these yielded no data (none were otolith samples), 20 had low data (14 of these were otoliths), and 6 showed evidence of cross-contamination or degradation. In spite of this, 14 of the data-poor 35 still gave high confidence consensus assignments. The following results are based on the n=771 dataset, omitting the 9 individuals without data.

Overall, 96% (n=741) of the samples assigned to Blue (n=382) or Deacon (n=359) rockfish, concordant across all three assignment methods, and at all confidence levels (Figure A). Of the assignments to Blue or Deacon, 93.5% (n=693) were at high confidence. The remaining 30 samples gave ambiguous results in the form of discrepant species IDs among the three assignment methods, and thus species was not given for these individuals (Figure A). All but two of these non-concordant individuals had low confidence assignments, but, curiously, two assigned with high confidence to both Blue and Deacon in the different assignment methods, despite having nearly complete genotypes and visually not being indicated as potential hybrids.

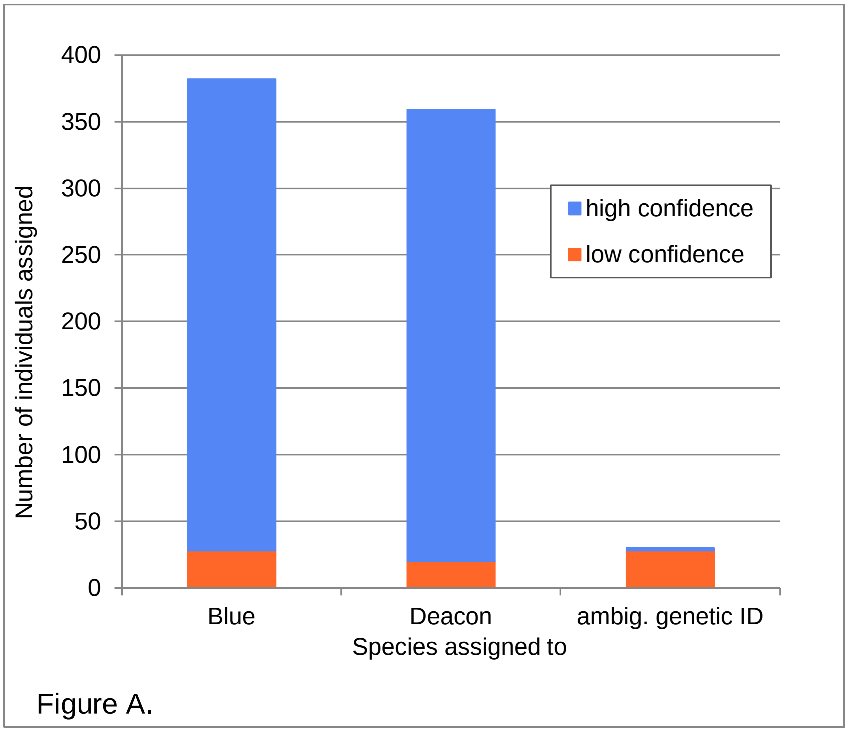


Figure A. Genetic species assignment results for Blue and Deacon rockfish, from consensus of three assignment methods. High confidence, individuals assigned at 90% confidence and higher; low confidence, assigned at 89% and below; ambiguous genetic IDs include individuals with discrepant assignments in the different methods.

Ancestry analysis

Structure results provided another layer of quality control in the species assignments. At K = 2, two distinct groups of individuals appeared, while groupings at K = 3 and 4 were poorly resolved (Figure B). Per the Evanno method, K = 2 had the highest likelihood estimate ($\boxed{K}$= 3346.9), indicating that statistical support for two groups was high.

replicate runs in which the displayed ancestry pattern was obtained.

Using a minimum threshold of 0.90 (on a 0-1 scale) for inclusion in one of the two groups, 713 of 771 unknowns could be categorized as belonging to one of the arbitrarily named groups 1 or 2. Based on the assignment results, ancestry group 1 (n=379) corresponded to Blue and group 2 (n=334) to Deacon rockfish. The remaining 58 uncategorized individuals appeared to have mixed or poorly resolved ancestry. Some of the mixed ancestry could be explained by low data leading to a lack of resolution, but most (n=46+) of these individuals had complete or nearly complete genotypes. Comparing the individuals in groups 1 and 2 to the consensus assignment results, concordance was very high (Figure C). In almost all cases, the Structure IDs corroborated both the high and low confidence assignment results, although 17 individuals identified to species with the ancestry method gave ambiguous results in the species assignment, and 13 fish gave ambiguous results in both methods. In addition, five fish classified as Blue in the ancestry analysis were identified as Deacon with the assignment method, but the latter results were low confidence; four of these five were visually identified as Blue.

	Structure ID		
Assign. ID	Blue	Deacon	mixed
Blue HC	343		11
Blue LC	16		12
Deacon HC		328	11
Deacon LC	5	4	11
ambig.	15	2	13

Figure C. Matrix summarizing concordance in species IDs between the consensus assignments (Assign. ID) and the Structure results (Structure ID). Numbers in cells indicate number of individuals in each category; HC, high confidence; LC, low confidence; ambig, fish not assigned to species in the assignment tests; mixed, individuals having mixed ancestry in the Structure analysis.

Comparison of visual and genetic species IDs

The visual and genetic IDs matched in roughly 90% of the samples for which a visual ID was available. Considering only the high confidence genetic IDs (n=676 for visual-assignment ID; n=693 for visual-Structure ID), over 97% of the visual and genetic identities were concordant (Figure D*a* and D*b*). The discrepant visual-genetic IDs were greatly skewed toward genetic Deacon rockfish being visually identified as Blue rockfish (n=17 or 15, depending on the method), whereas only one or two genetic Blue rockfish were visually identified as Deacon. Two individuals visually noted as possible hybrids were genetically identified as Deacon rockfish by both methods (Figure D*a* and D*b*).

	a) Assignment ID			*b*) Structure ID		
Visual ID	Blue	Deacon	ambig.	Blue	Deacon	mixed
Blue	341	17	33	362	15	34
Deacon	1	317	12	2	314	18
Hybrid		2			2	

Figure D. Matrices comparing species identification of Blue and Deacon rockfish for *a*) visual ID and assignment consensus method, and *b*) visual ID and Structure ancestry method. Hybrid, individuals visually noted as hybrids; ambig., low confidence genetic assignments to either species; mixed, undefined ancestry in Structure results. The total number of species IDs differs between matrices *a* and *b* due to a number of individuals with non-concordant results in the assignment tests that yielded no genetic species ID and thus no visual-genetic ID comparison.

Summary of genetic species IDs

High confidence genetic species identifications to Blue or Deacon rockfish were made for 87% of the 771 unknowns, using the combined assignment and ancestry analysis results (Figure E). A small additional number of unknowns were putatively identified as Blue (n=27) or Deacon (n=15). About 7.5% of the samples could not be identified to species even at low confidence.

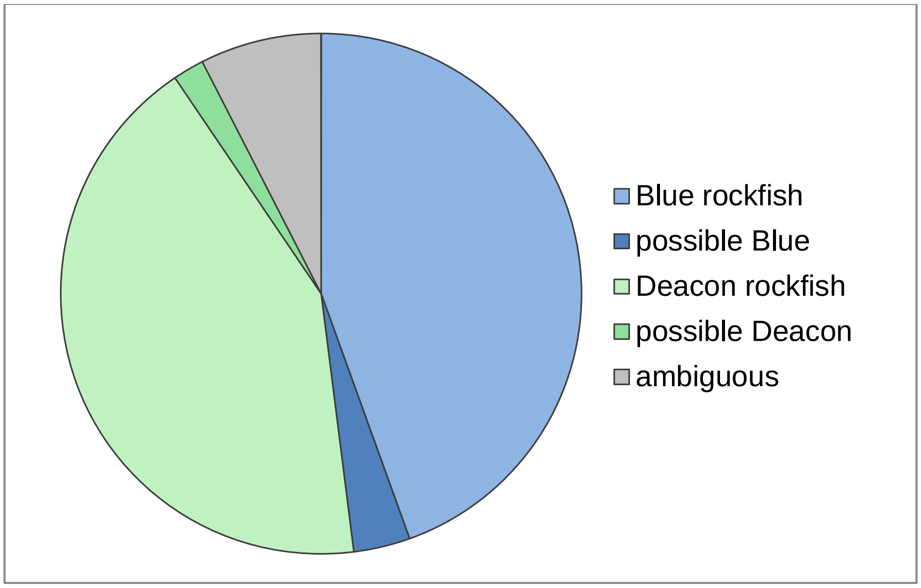


Figure E. Proportion of genetic species IDs obtained in 771 Blue Rockfish unknowns, using combined assignment and ancestry results. Blue and Deacon rockfish IDs, high confidence; "possible" IDs, low to moderate confidence; ambiguous, no genetic species ID was made.

Discussion

Despite rigorous criteria for accepting a genetic species assignment, the vast majority of Blue Rockfish “unknowns” were identified with high confidence as either Blue or Deacon rockfish using our microsatellite marker-based species ID tool. Additionally, most of the visual species IDs matched the genetic IDs, indicating that the morphological characters used to distinguish these cryptic species are generally robust, and the phenotypic differences are associated with detectable, underlying genetic differences.

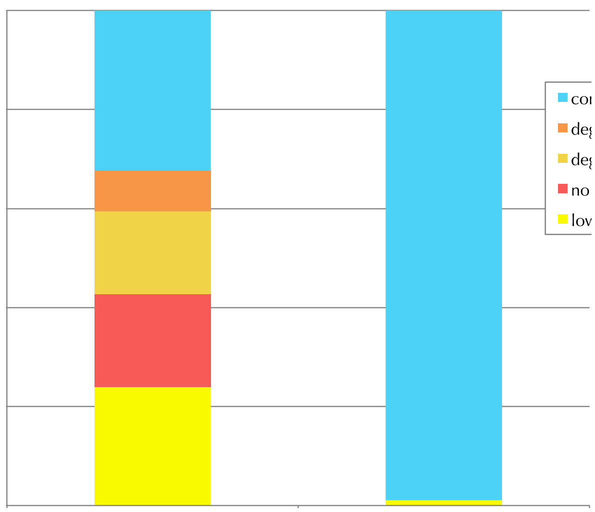
More attention may be needed concerning the visual ID of the Deacon rockfish, as almost all of the visual-genetic ID discrepancies involved genetic Deacons that were visually identified as Blue. It could be the case that, in order to obtain accurate IDs in the field, additional Deacon rockfish meristic or morphometric characters are warranted. The genetic results suggest that the absence of currently recognized phenotypic characteristics of Deacon rockfish should not necessarily imply Blue identity.

The Structure ancestry analysis showed two distinct groups that corresponded to the high confidence Blue and Deacon rockfish assignments, with only a few exceptions. The ancestry results also corroborated the majority of visual IDs. The genetic species assignments with low confidence had mis-matches with both the visual IDs and the other genetic ID methods, underscoring the importance of using consensus methods, such as those used here, to confidently determine species and, conversely, to decline to make a species classification when confidence is low. Mixed ancestry was found in some individuals, including many that had low-confidence species assignments in the consensus method. One potential explanation for mixed ancestry is hybridization between the two cryptic species; further investigation would be needed to explore this possibility.

Addendum#1, 13-14 October 2016

Pilot project: DNA from otoliths

One component of this project concerns DNA extracted from decades-old otolith samples, collected in 1976-1984 and genotyped in 2016. Because low-quality DNA from this source was likely to be an issue, it was deemed prudent to assess the data yield and quality on a larger sample than the 24 otoliths initially genotyped, before proceeding with the processing of several hundred more otoliths. Specific otoliths were selected by Field and Pearson to represent a range of putative ages and collection time periods. Pearson picked the otoliths into extraction tubes (n=192), and Mol Ecol lab staff extracted DNA per our usual protocol. Genotyping was carried out in the manner described above. Figure F below compares genetic data quality obtained from DNA extracted from otoliths vs. air-dried fin tissue from adults: only 31 of 96 otolith samples yielded reasonably complete multi-locus genotypes, whereas 95 of 96 fin samples (collected in 2012-2014) gave complete genotypes.



ow data,

individual genotyped at 4 or fewer loci.

Addendum#2, 19-20 January 2017

Expansion of temporal and spatial Blue Rockfish samples

Following the moderate success of the pilot project, the Blue Rockfish species ID dataset has been increased to include an additional 864 samples spanning 40 sampling years (1976 to 2016), bringing the project grand total to n=1,697. The new samples were processed in the laboratory as described above, and included “historic” otoliths from adults (n=480, including 192 described in Addendum#1) collected in 1976-1984, and “modern” fin clip samples (n=384) from juveniles and adults collected in 2010-2016. It should be noted that while the fin clips were collected using protocols conducive to extracting high quality DNA (sterile technique and rapid drying), the otoliths were collected before genetic analysis was commonplace, and consequently were not handled in a manner that would necessarily avoid cross-contamination or DNA degradation (Pearson, pers. comm.).

Genotyping and analysis of these samples was carried out as for the first set of samples, with one difference pertaining to assignment confidence. The high confidence species assignment threshold was increased to 95% (from 90%), and individuals assigned with confidence scores of 90-94% were considered to have low confidence species IDs. Samples yielding assignment scores below 90% in any of the three assignment methods were said to have failed to meet assignment criteria and therefore were categorized as ambiguous. Increased rigor was applied to the interpretation of the assignment results due to the potential for spurious results in degraded historic samples, and because corroborative visual IDs were not available for the majority of the samples in this set. The results below summarize only the new set of samples (n=864), pending a more thorough report on all of the Blue Rockfish samples analyzed for this project to date.

Results—Data Quality

Unsurprisingly, DNA quality of the historic and modern samples differed substantially. Cross-contamination or DNA degradation was noted in 34% (n=165) of the historic (otolith) samples, compared to only 3% of the modern samples (n=11, all of which were taken from juvenile fish). Genotyping success also differed greatly between the two DNA sources. Complete amplification failure across all 9 loci occurred in 10% (n=48) of historic samples, whereas only two of the modern samples failed entirely. Low data, defined as amplification at four or fewer loci, was prevalent among the historic samples (n=~200) but affected only 8 of the modern samples (primarily from juveniles).

Similarly, species assignment success was strongly influenced by the DNA source. Among modern samples, 82% (n=316) yielded high confidence species assignments, and 28 samples were categorized as ambiguous (Figure G). In comparison, only 42% (n=203) of otolith samples had high confidence species assignments, with about half (52%) of samples failing the genetic species ID process.

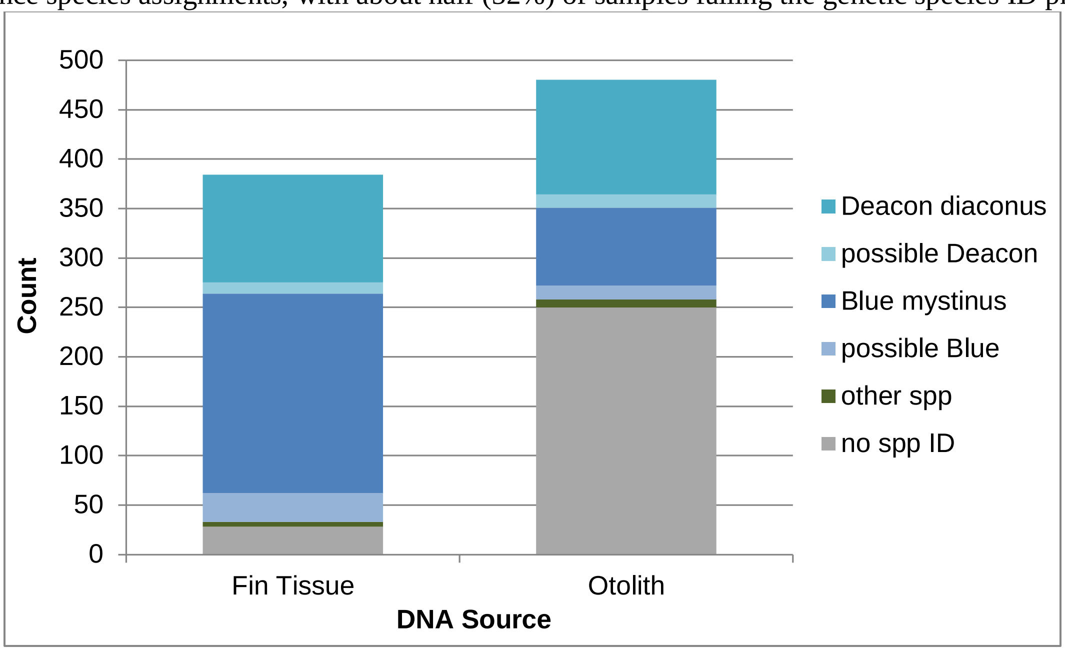


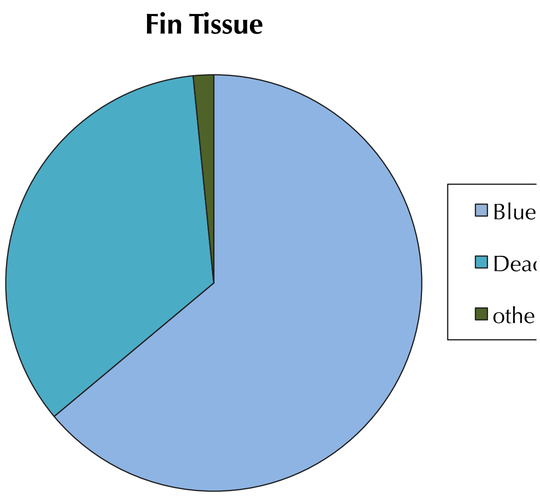
Figure G. Blue rockfish genetic species ID results for sample set 2, by DNA source: fin tissue (n=384) and otolith (n=480). Deacon, Blue and other species assignments (three darkest colors) are high confidence; other refers to species other than Deacon or Blue. Possible Deacon and Blue are low confidence assignments. The no spp ID category includes all individuals that could not be assigned unambiguously to a species for any reason.

Results—Species Composition

Considering only those samples yielding high confidence genetic species assignments (n=506), the relative proportions of Blue and Deacon rockfish differed between the historic and modern samples

(Figure H). The modern fin tissue samples were somewhat dominated by Blue rockfish (64%), and the historic otolith samples by Deacon rockfish (57%). When both DNA sources were combined, the proportion of each species was nearly equivalent, with Blue rockfish comprising 56% of the overall sample. As these are general results, these data should be analyzed in depth to explore spatial distribution patterns and to test for age-related patterns (presumably to be included in models incorporating the genetic IDs found here) within and among the individuals genetically identified as Blue and Deacon rockfishes. There did not appear to be a relationship between sex and species assignment (results not shown, but see results file), although the number of samples with associated sex data was relatively small.

A small number of individuals visually or putatively identified as Blue Rockfish were genetically assigned with moderate to high confidence to other *Sebastes* species in the reference baseline. Six individuals were identified as *S. melanops* (all otolith samples except one), and two as *S. flavidus* (1981 and 2014 samples). One individual each was classified as *S. entomelas*, *S. nebulosus*, *S. serranoides*, *S. caurinus* and *S. hopkinsi*, the latter two at high confidence. It is not known whether these assignments are the result of visual mis-identification, data recording error, or genotyping error. In any case, it would be beneficial to examine these results in a phylogenetic context.



nt to *Sebastes* species other than *mystinus* or *diaconus*.

The relative proportion of Blue and Deacon rockfish varied between sampling years (Figure I) and might be associated with sampling location (geographic data not analyzed yet). Deacon rockfish comprised a majority of the high confidence assignments primarily within the historic sampling period (in 1978, 1981, 1984 and 2012), while relatively few Deacon rockfish were identified in other years (1976, 1983, 2010 and 2016). Blue rockfish were identified in all sampling years except 1978 and 1982.

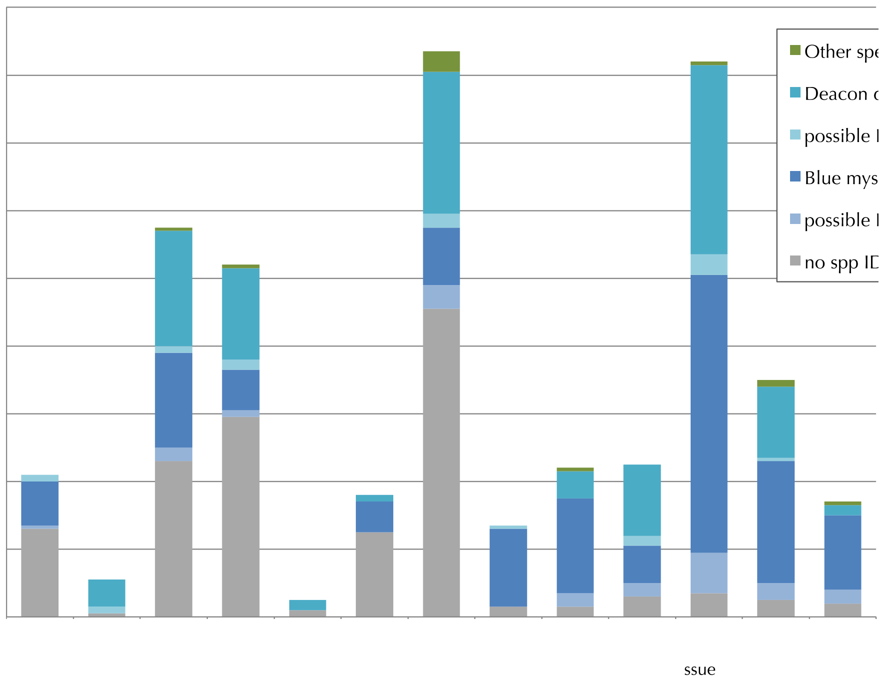


Figure I. Genetic species ID of Blue Rockfish by year of sampling; height of bar corresponds to number of samples genotyped per sample year. Deacon *diaconus* and Blue *mystinus* categories reflect high confidence assignments (95+% consensus confidence scores); "possible" assignments are moderate confidence (90-94%). The no spp ID category includes individuals that could not be assigned to species for one or more of the following reasons: ambiguous and discrepant IDs, low data and cross-contaminated/degraded DNA. "Other" indicates species other than Blue or Deacon.

Visual vs. Genetic Species IDs

A comparison of visual and genetic IDs was possible for a subset of 96 individuals that had been putatively assigned to one of the two blue types based on morphology. It should be noted that a different pair of common names were used by the ELH team to describe the morphological Blue and Deacon rockfish: True Blue and Northern Blue, respectively. For consistency, here I use the former naming convention when referring to the two types. Concordance between the visual and genetic IDs was high, with only one discrepant ID (visual Blue genetically identified as Deacon) among the 90 individuals that were assigned to a genetic species. The overall assignment rate was also high: genetic IDs were made for all but six visually identified individuals. None of the 96 individuals stood out as hybrids, either visually or genetically.

	Consensus Genetic ID		
Visual ID	Blue	Deacon	ambig.
Blue	50	1	4
Deacon	0	39	2

Figure J. Assignment matrix comparing visual and consensus genetic species IDs of Blue and Deacon rockfish, sample set 2. Numbers in Blue and Deacon columns, high confidence genetic assignments; cell totals also include 11 Blue and 2 Deacon moderate-confidence but still concordant IDs. Ambig., individuals that were visually identified but could not be assigned to a genetic species (as above).

Discussion

In spite of the numerous challenges presented by genotyping historic tissue samples, high confidence consensus species IDs were obtained from about 40% of the DNA samples extracted from the surface of rockfish otoliths. While this modest assignment success rate is roughly half that obtained from modern, well-preserved fin tissue samples, it demonstrates that historic samples (e.g., otoliths and scales), even those not originally intended for genetic analysis, are a viable source of genetic material for phylogenetic analysis. Moreover, as shown here, data generated from historic and modern samples can be used in concert to inform applied projects such as the current Blue Rockfish stock assessment, or studies of long-term population genetic trends related to environmental change.

LGH note 012317: see file blue_rockfish_sppID_results_forGF_rev_n1644.xlsx for species ID results by individual; contains combined results for sample sets 1 & 2, n=1644.

Addendum #3, April 2017

Further expansion of temporal and spatial Blue Rockfish samples

In early 2017, an additional 1,344 Blue Rockfish samples ("set 3") were subjected to genetic analysis for species identification, using the methods described in Addendum #2 above. Continuing our focus on analyzing historical samples, the majority of set 3 consisted of otoliths collected in 1976-1984 (n=1,152). The remainder of set 3 was composed of modern fin clips from adults (n=192) in Oregon (NWFSC samples) and California, collected in 2012 or more recently. This phase of the project was funded by a NOAA Fisheries FY17 Stock Assessment (ISA) grant; award notification was given on 28 March 2017.

The results summarized below cover first the data quality of set 3, and second, population genetic analysis of sets 2 and 3 combined. This analysis should be considered preliminary in that sample set 1 and juvenile samples are excluded. A more final summary for all three sample sets will follow in the future.

LGH note 042117: species ID results by individual, for all three sample sets combined, were sent to the Groundfish Analysis team on 12 April 2017: blue_rockfish_sppID_results_forGF_n2988.xlsx.

Results—Data Quality, Sample Set 3

DNA and genotype quality continued to be an issue among the otolith samples, but even so, many of these samples yielded reasonably complete genotype data and high confidence species assignments. Among otolith samples, 215 provided no data and 559 low data (4 or fewer loci amplified). Four of the 192 fin samples yielded no data. Cross-contamination or degraded DNA was observed in 259 otolith samples and 3 fin clip samples; 170 of these 262 also yielded no or low data. All told, almost two-thirds of set 3 samples (n=870) were affected by data quality issues, although this did not always preclude species assignments.

Assignment success was strongly influenced by DNA source, as was the case for sample set 2. The majority (91%) of fin tissue samples gave low/moderate to high confidence species assignments to Blue, Deacon or other *Sebastes* species, whereas only 42% of the otolith samples could be genetically assigned to a species (Figure K). Among the 657 individuals for whom species could be genetically determined, the assignment tests and Structure software analysis results were in agreement for all but one. One individual assigned with high confidence to Deacon rockfish but grouped with the Blue cluster in the Structure analysis. Although low confidence species ID discrepancies were common (resulting in no species ID), this was the only instance of a high confidence species ID discrepancy, and this individual was therefore included in the ambiguous ID category because it failed to meet the consensus ID criteria.

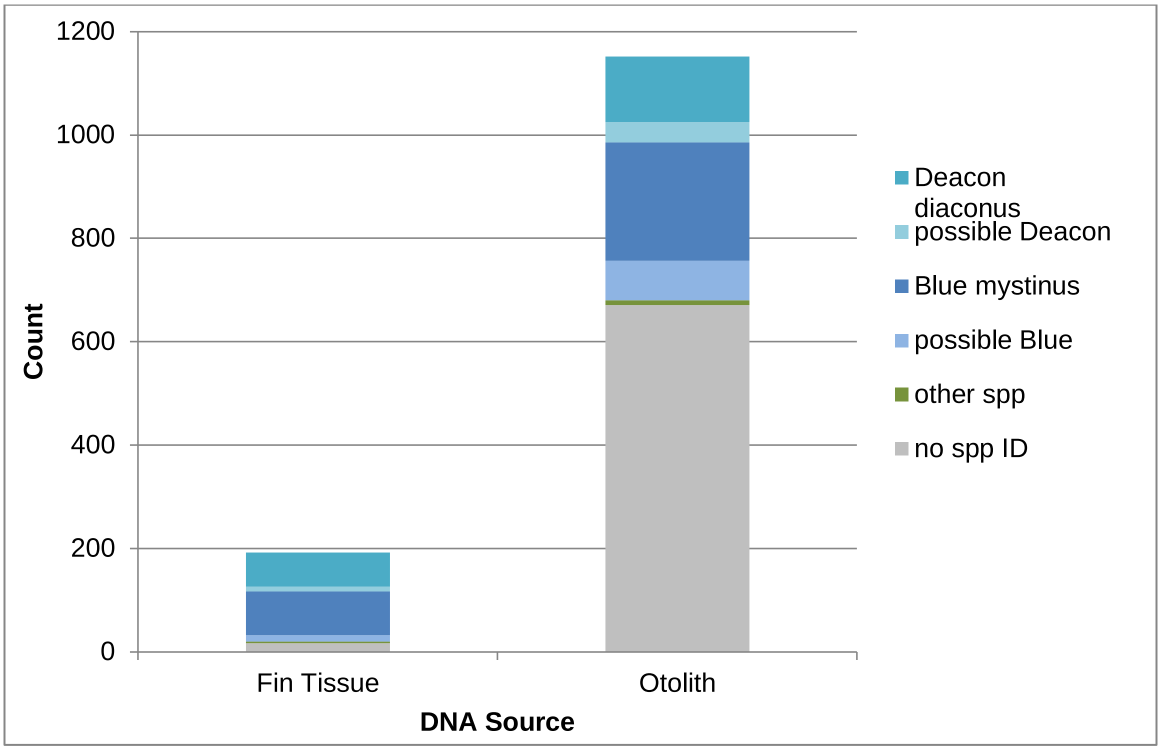


Figure K. Blue rockfish genetic species ID results for sample set 3, by DNA source: fin tissue (n=192) and otolith (n=1,152). Deacon, Blue and other species assignments (three darkest colors) are high confidence; other refers to species other than Deacon or Blue. Possible Deacon and Blue are low/moderate confidence assignments. The "no spp ID" category includes all individuals that could not be assigned unambiguously to a species for any reason.

Visual vs. Genetic Species IDs, Sample Set 3

Most of the samples in set 3 did not have an associated visual ID, having been collected before the cryptic Blue Rockfish species had been recognized, but a comparison of visual and genetic IDs was possible for the modern samples (n=192). Concordance between visual and genetic ID was high, with only three discrepancies: two individuals visually identified as Blue rockfish were genetic Deacon rockfish, and one visual Deacon was a genetic Blue. In addition, 17 visually identified individuals could not be unambiguously assigned to a genetic species. Three of the modern samples in set 3 were visually identified as rockfish species other than Blue/Deacon, and these individuals also gave concordant, high-confidence genetic-visual IDs: two *S. entomelas* and one *S. pinniger*.

	Consensus Genetic ID		
Visual ID	Blue	Deacon	ambig.
Blue	96	2	14
Deacon	1	73	3

Figure L. Assignment matrix comparing visual and consensus genetic species IDs of Blue and Deacon rockfish, sample set 3. Numbers in Blue and Deacon cells denote medium/high confidence genetic assignments. Ambig., individuals that were visually identified but could not be genetically assigned to a species. Other *Sebastes* species not included in this table.

Results—Species Distribution, Sample Sets 2 & 3

Sampling location information was incorporated into the analysis at this stage, combining sample sets 2 and 3 (n=2,208). Population genetic analyses were carried out for individuals that had been given a genetic species ID and for which sampling location was also available (n=1,209). Both high confidence and putative IDs were included in this analysis. Juveniles were also analyzed, but were grouped only by species and not spatially, pending GPS coordinates for sampling locations. Samples were organized by species and sampling location ("population"), and descriptive statistics calculated by population (Table 1). Many location-species combinations yielded small samples (n<10 individuals) and thus their results are not considered robust enough for inference. However, many sites had reasonably large samples for either Blue or Deacon, and three sites had relatively large samples of both species: Farallon Islands, Half Moon Bay and Monterey Bay.

Qualitatively, the proportion of genetically identified Blue and Deacon rockfish adults differed by geographic region, although both species were detected in many of the fishing regions. Generally, Deacon rockfish were not common in samples from the southern sites, and Blue rockfish were infrequently found in the northern California and Oregon sites. Blue rockfish comprised a vast majority of the samples from southern California, Morro Bay and Monterey Bay. Deacon rockfish outnumbered Blue rockfish in samples from locations north of and including Half Moon Bay: Farallon Islands, Bodega Bay, Fort Bragg, and Port Orford and Seal Rock in Oregon (Table 1).

Table 1. Sampling locations, population codes and sample size (n) for genetically identified Blue and Deacon rockfish. Loci typed, number of loci successfully amplifed in each sample grouping; He, expected heterozygosity Ho, observed heterozygosity; n alleles, mean number of alleles across all loci.

Sampling Site	Genetic Species ID	Population Code	n	Loci typed	He	Ho	n alleles
Avila Beach CA	Blue (mystinus)	AvilB	18	9	0.426	0.383	3.67
Bodega Bay CA	Blue (mystinus)	BodegB*	6	9	0.464	0.513	2.89
Bodega Bay CA	Deacon (diaconus)	BodegD	54	9	0.507	0.503	5.44
Brookings OR	Blue (mystinus)	BrookB*	1	9	0.556	0.556	1.56
Catalina Isl. CA	Blue (mystinus)	CataB*	9	9	0.434	0.418	3.44
Cortes Bank CA	Blue (mystinus)	CrtesB*	4	9	0.533	0.537	2.78
Cortes Bank CA	Deacon (diaconus)	CrtesD*	1	9	0.444	0.444	1.44
Farallon Isl. CA	Blue (mystinus)	FaraB	15	9	0.548	0.510	4.67
Farallon Isl. CA	Deacon (diaconus)	FaraD	42	9	0.515	0.471	4.89
Fort Bragg CA	Deacon (diaconus)	FBrgD	23	8	0.576	0.386	4.13
Half Moon Bay CA	Blue (mystinus)	HMBB	55	9	0.484	0.410	6.11
Half Moon Bay CA	Deacon (diaconus)	HMBD	136	9	0.519	0.445	6.78
many; juveniles	Blue (mystinus)	JuvB	113	9	0.506	0.503	7.11
many; juveniles	Deacon (diaconus)	JuvD	61	9	0.496	0.488	5.44
Monterey Bay CA	Blue (mystinus)	MontB	189	9	0.513	0.433	7.67
Monterey Bay CA	Deacon (diaconus)	MontD	51	9	0.517	0.480	5.44
Morro Bay CA	Blue (mystinus)	MorroB	45	9	0.473	0.386	4.78
Moss Landing CA	Blue (mystinus)	MossB*	7	8	0.468	0.369	2.75
Moss Landing CA	Deacon (diaconus)	MossD*	3	7	0.548	0.595	2.43
Port Hueneme CA	Deacon (diaconus)	PHueD*	1	9	0.667	0.667	1.67
Port Orford OR	Blue (mystinus)	POrfoB*	7	9	0.480	0.468	3.11
Port Orford OR	Deacon (diaconus)	POrfoD	28	9	0.512	0.499	4.78
Point Conception CA	Blue (mystinus)	PtConB*	5	9	0.410	0.422	3.00
Santa Barbara Isl. CA	Blue (mystinus)	SBarB	19	9	0.470	0.452	4.67
Santa Barbara CA	Blue (mystinus)	SBB	15	9	0.538	0.565	4.44
Santa Barbara CA	Deacon (diaconus)	SBD*	1	9	0.556	0.556	1.56
Santa Cruz Isl. CA	Blue (mystinus)	SCIB	16	9	0.467	0.482	4.33
Santa Cruz Isl. CA	Deacon (diaconus)	SCID*	1	9	0.556	0.556	1.56
San Clemente Isl. CA	Blue (mystinus)	SClemB	16	9	0.473	0.462	4.00
Santa Cruz CA	Deacon (diaconus)	SCrzD*	7	8	0.626	0.501	3.25
Seal Rock OR	Blue (mystinus)	SealRB*	8	9	0.538	0.528	3.56
Seal Rock OR	Deacon (diaconus)	SealRD	33	9	0.522	0.513	4.78
off San Francisco Bay CA	Deacon (diaconus)	SFD	38	9	0.509	0.465	4.89
San Miguel Isl. CA	Blue (mystinus)	SMigB	97	9	0.457	0.409	6.67
San Miguel Isl. CA	Deacon (diaconus)	SMigD*	4	9	0.610	0.676	3.00
Santa Monica Bay CA	Blue (mystinus)	SMoniB	12	9	0.534	0.585	4.56
San Nicolas Isl. CA	Blue (mystinus)	SNicB*	7	9	0.552	0.457	3.44
San Pedro Bay CA	Blue (mystinus)	SPedB*	1	9	0.667	0.667	1.67
Santa Rosa Isl. CA	Blue (mystinus)	SRosB	50	9	0.470	0.450	5.33
Santa Rosa Isl. CA	Deacon (diaconus)	SRosD*	3	9	0.589	0.667	2.56
Stonewall OR	Deacon (diaconus)	StonwD*	3	9	0.474	0.593	2.22
Tanner Bank CA	Blue (mystinus)	TannB*	4	9	0.439	0.389	2.56

* small sample size, not useful for population genetic inference unless pooled with other populations

Results – Population Structure and Phylogeography, Sample Sets 2 & 3

Population structure and species-level divergence were evaluated through F_{ST} permutation tests and construction of phylogenetic trees. Population pairwise F_{ST} estimates were calculated using Genetix v4.05 software (Belkhir et al. 2004), and significance assessed with 500 permutations. Neighbor-joining and bootstrap consensus trees were generated using PHYLIP v3.69 (Felsenstein 2005).

Almost all of the interspecific F_{ST} comparisons were highly significant, while only a few of the intraspecific comparisons indicated divergence between populations (Table S1; population codes defined in Table 1). Within Blue rockfish, 2.9% of comparisons were highly significant following Bonferroni correction; within Deacon rockfish, this number was 1.4%. Most of the significant within-species comparisons involved the Moss Landing populations, but larger sample sizes would be required to draw conclusions about whether this population is truly divergent. Between species, 56% of pairwise F_{ST} comparisons were highly significant. Mean F_{ST} was an order of magnitude larger between Blue and Deacon (F_{ST} = 0.1627) than within either species (F_{ST} = 0.0130 and 0.0148, respectively). Distributions of pairwise F_{ST} estimates within and between species (Figure M) showed a bimodal pattern with an area of overlap that suggests a small amount of population structure within species. Of 271 between-species comparisons, all but two exceeded F_{ST} = 0.1.

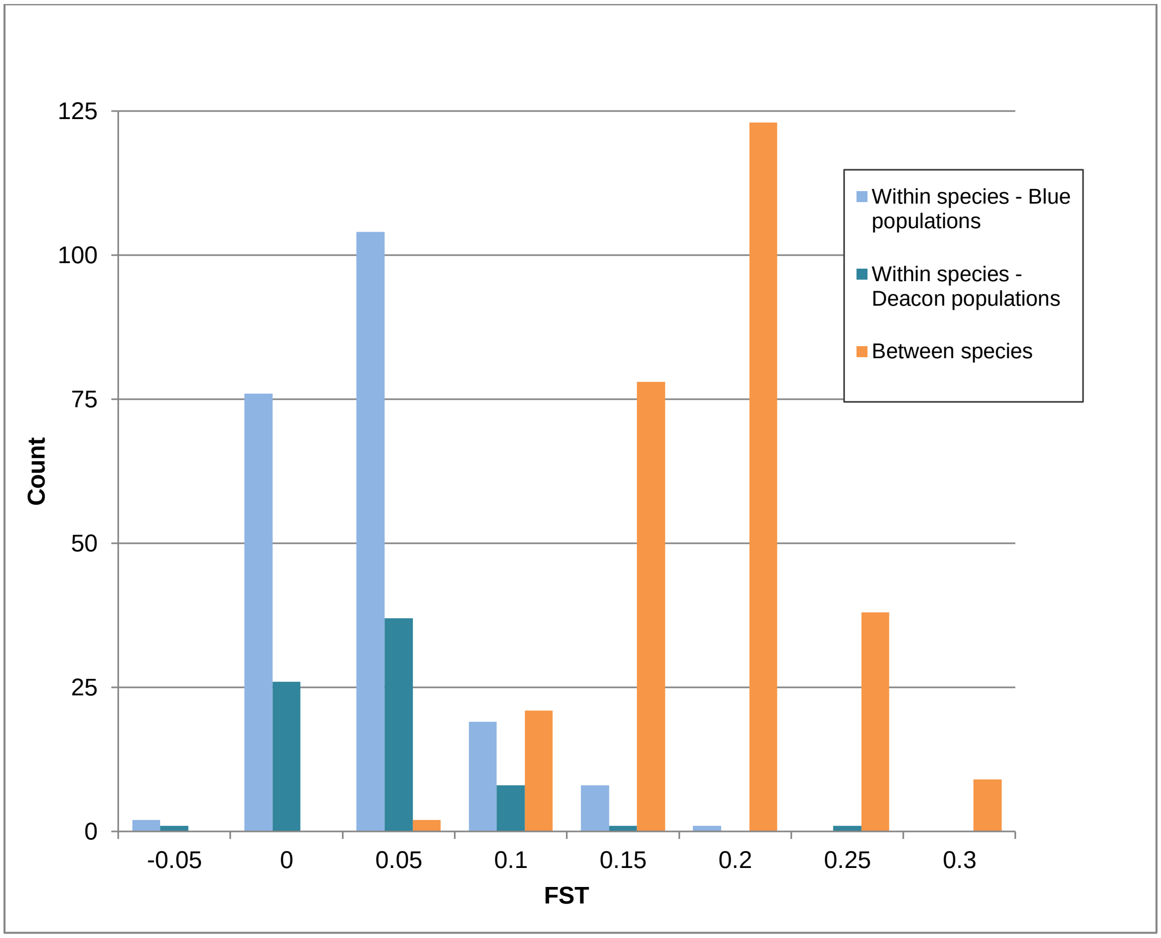


Figure M. Distributions of pairwise F_{ST} estimates between populations of Blue rockfish (blue bars), between populations of Deacon rockfish (teal), and between populations of Blue and Deacon rockfish (orange).

It should be noted that for some species-population combinations, evaluation of fine-scale population structure was confounded by small sample sizes that could hinder the estimation of allele frequencies and the assessment of statistical significance. For this reason, the phylogenetic tree analysis was conducted using, in most cases, regionally pooled samples, and omitting juveniles (revised n=1,053 for tree building). Four other *Sebaste*s species identified among the Blue Rockfish samples were included as outgroups (see Figure N caption for details).

Blue and Deacon rockfish populations occupied different branches of the phylogenetic tree, with strong bootstrap support on the nodes between the species (Figure N). Blue rockfish populations clustered together with 97% bootstrap support, to the exclusion of all other species, but within this species there was little support for structured populations, aside from 57% bootstrap support for the branch that included Oregon and Half Moon Bay. Deacon rockfish, with the exception of one individual from Cortes/Tanner Bank, grouped together with 98% bootstrap support. Deacon rockfish populations appeared more geographically structured than Blue, with moderate to high bootstrap support for Southern California Bight, Monterey Bay (98%) and a branch including Half Moon Bay and all populations north of there (55%). This pattern was somewhat suggestive of a latitudinal structure, (Cortes/Tanner Bank is the southernmost site, followed by Southern California Bight, etc.), with apparently more differentiation between the southern populations of Deacon rockfish than among the northern ones. (It will be interesting to know whether this pattern holds as more data are added. One possible reason for this finding is lower absolute abundance of Deacon than Blue rockfish in southern California, leading to low mate encounter rates and population fragmentation. However, a sampling bias due to depth segregation of Blue and Deacon rockfish could also produce such a pattern, if fishing effort differentially targeted Blue rockfish population centers—and Deacon population fringes—in particular locations.)

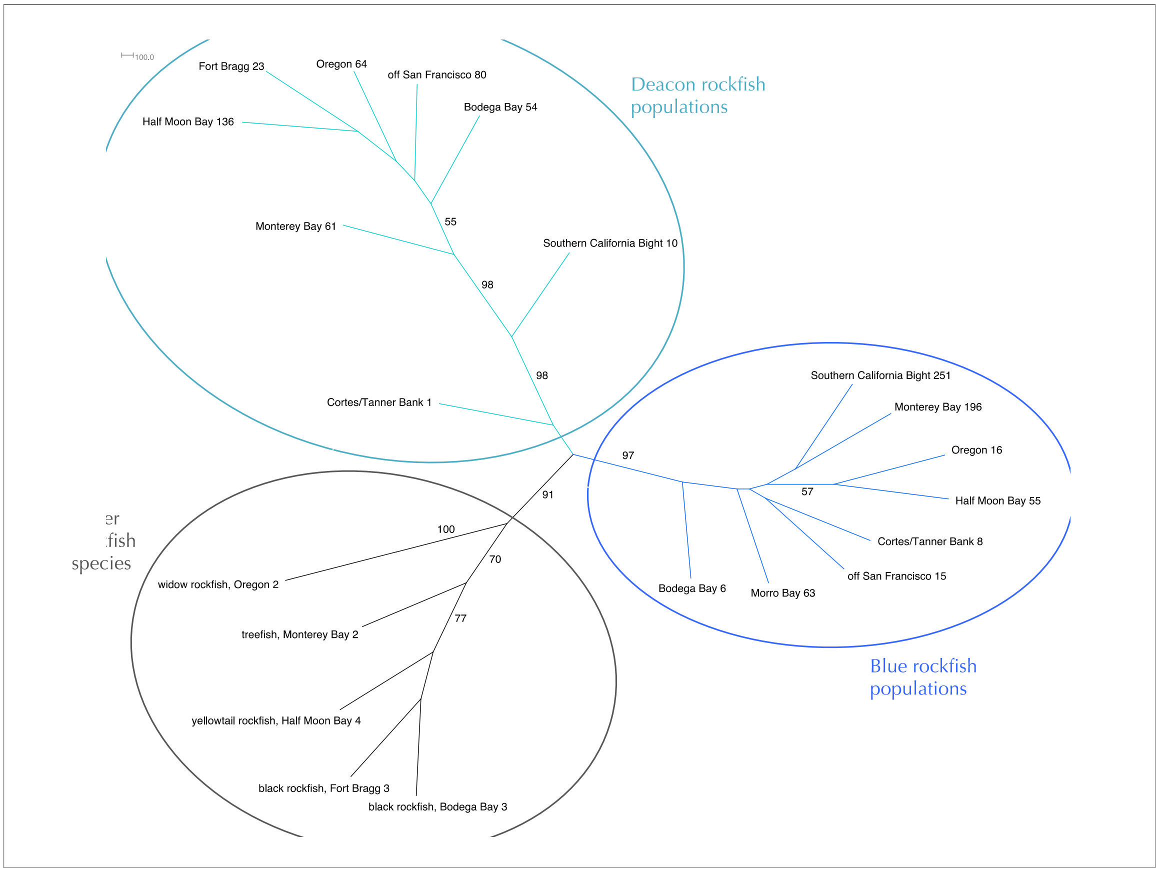


Figure N. Bootstrap consensus tree for populations of genetically identified Blue (blue), Deacon (teal) and other rockfish species (gray). Numbers on internal branches indicate percent bootstrap support (>50%) for the branching arrangement shown (1000 bootstrap replicates). Blue and Deacon branch nodes are labeled with sampling region and number of samples; other species are labeled with common name, location and sample size. Other species include widow rockfish (*Sebastes entomelas*), treefish (*S. serriceps*), yellowtail rockfish (*S. flavidus*) and black rockfish (*S. melanops*).

The outgroups consisting of widow rockfish, treefish, yellowtail rockfish and black rockfish occupied a separate branch of the tree, with 91% bootstrap support. Support was high for widow rockfish, and moderate for treefish and the yellowtail-black rockfish branch. The two populations of black rockfish grouped together on a terminal node. The lack of strong support for some outgroup species could be due to the small numbers of samples from which allele frequencies were estimated (this can be rectified in the complete analysis by including more individuals).

Addendum #4, May 2017

Population genetic analysis of sample sets 1, 2 and 3

Following on from the preliminary population genetic analyses described in Addendum #3, sample sets 1, 2 and 3 were combined into a "complete" dataset, and sampling locations of juveniles were incorporated into the dataset, for a more complete analysis of spatial patterns in Blue and Deacon rockfish. In addition, outgroups consisting of seven other *Sebastes* species added phylogenetic context to the analysis (n=222). Of the 2,988 samples in the complete dataset, 1,903 yielded consensus species IDs as Blue or Deacon *and* had sufficient sampling site information to be included in the spatial analysis (n=1,909 included six fish identified as other *Sebastes* species).

In the spatial analysis I grouped samples of each species either by "population" (sampling location; finest geographic scale available) or by "region" (coarser geographic scale). The first-pass analysis was conducted at the scale of populations, to assess the degree of differentiation between populations, and to determine whether pooling of samples from adjacent locations would be appropriate. The regional grouping corresponded very roughly to latitudinal bands, with the divisions between regions being determined by a combination of discontinuous sampling coverage and/or the presence of known or suspected biogeographic breaks (e.g., Cape Mendocino, Point Conception). For several reasons—lack of precise location metadata for some samples, small population samples, absence of distinct boundaries in the ocean—results from the regional spatial scale analysis are generally more informative and meaningful than those from the population scale.

Genetic analyses of both the populations and regions included F_{ST} permutation tests in Genetix v4.05 (1,000 permutations; Belkhir et al. 2004) and phylogenetic tree building in PHYLIP v3.69 (5,000 bootstrap replicates; Felsenstein 2005), as described in Addendum #3 above. In addition, assignment tests by region were conducted using gsi_sim (Anderson et al. 2008).

Results – Population Structure and Phylogeography, Complete Dataset

Sampling sites (populations) by species and lifestage, descriptive genetic statistics and region codes are given in Table 1, revised to include data from all three sample sets.

Table 1 revised. Sampling locations, population codes, lifestage and sample size (n) for genetically identified Blue and Deacon rockfish and other rockfishes. Loci typed, number of loci successfully amplifed in each sample grouping; He, expected heterozygosity; Ho, observed heterozygosity; n alleles, mean number of alleles across all loci; where n<10, sample is not useful for population genetic inference unless pooled with other populations. Population and region codes refer to groupings of samples for analysis, as described in text.

Sampling Site	Genetic Species ID	Population Code	Pop. n	Loci typed	He	Ho	n alleles	Lifestage	Latitude	Region Code
Stonewall Bank OR	widow (entomelas)	StonwW	2	9	0.1667	0.1667	1.33	Adult	44.56466	Oreg
Stonewall Bank OR	Deacon (diaconus)	StonwD	3	9	0.4741	0.5926	2.22	Adult	44.56466	Oreg
Seal Rock OR	Blue (mystinus)	SealRB	8	9	0.5380	0.5278	3.56	Adult	44.50132	Oreg
Seal Rock OR	Deacon (diaconus)	SealRD	33	9	0.5216	0.5134	4.78	Adult	44.50132	Oreg
Port Orford OR	Blue (mystinus)	POrfoB	7	9	0.4802	0.4683	3.11	Adult	42.71888	Oreg
Port Orford OR	Deacon (diaconus)	POrfoD	28	9	0.5119	0.4986	4.78	Adult	42.71888	Oreg
Brookings OR	Blue (mystinus)	BrookB	1	9	0.5556	0.5556	1.56	Adult	42.02975	Oreg
Point St George CA	Blue (mystinus)	PSGB	3	8	0.5250	0.5833	2.63	Adult	41.75736	NCal
Point St George CA	Deacon (diaconus)	PSGD	6	9	0.4731	0.4444	3.00	Adult	41.66253	NCal
Flint Rock Head CA	Blue (mystinus)	FlinJB	1	9	0.7778	0.7778	1.78	Juvenile	41.50000	NCal
Flint Rock Head CA	Deacon (diaconus)	FlinJD	11	9	0.5160	0.4768	3.67	Juvenile	41.50000	NCal
Trinidad Head CA	Blue (mystinus)	TrinJB	1	9	0.5556	0.5556	1.56	Juvenile	41.00000	NCal
Trinidad Head CA	Deacon (diaconus)	TrinJD	3	9	0.4333	0.4630	2.11	Juvenile	41.00000	NCal
Cape Mendocino CA	Deacon (diaconus)	CMenD	4	9	0.5000	0.5000	2.67	Adult	40.31281	Mend
Cape Mendocino CA	Deacon (diaconus)	CMenJD	1	9	0.5556	0.5556	1.56	Juvenile	39.83333	Mend
Delgada (Cape Mendocino) CA	Blue (mystinus)	DelgJB	1	9	0.4444	0.4444	1.44	Juvenile	39.83333	Mend
Delgada (Cape Mendocino) CA	Deacon (diaconus)	DelgJD	1	9	0.4444	0.4444	1.44	Juvenile	39.83333	Mend
Fort Bragg CA	Blue (mystinus)	FBrgB	1	9	0.5556	0.5556	1.56	Adult	39.43309	Mend
Fort Bragg CA	Deacon (diaconus)	FBrgD	23	8	0.5761	0.3861	4.13	Adult	39.43309	Mend
Navarro (Point Arena) CA	Blue (mystinus)	NavJB	2	9	0.5926	0.4444	2.44	Juvenile	39.13333	Mend
Navarro (Point Arena) CA	Deacon (diaconus)	NavJD	20	9	0.5008	0.4789	4.33	Juvenile	39.13333	Mend
Navarro (Point Arena) CA	widow (entomelas)	NavJW	1	5	0.4000	0.4000	1.40	Juvenile	39.13333	Mend
Fort Ross CA	Blue (mystinus)	RossJB	1	7	0.7143	0.7143	1.71	Juvenile	38.46667	Bode
Bodega Bay CA	Blue (mystinus)	BodegB	6	9	0.4645	0.5130	2.89	Adult	38.26623	Bode
Bodega Bay CA	Deacon (diaconus)	BodegD	61	9	0.5110	0.5078	5.56	Adult	38.26623	Bode
Point Reyes CA	yellowtail (flavidus)	PReY	1	9	0.3333	0.3333	1.33	Adult	38.16667	Bode
Point Reyes CA	Blue (mystinus)	PReyJB	7	9	0.6032	0.5926	3.67	Juvenile	38.16667	Bode
Point Reyes CA	Deacon (diaconus)	PReyJD	5	9	0.4691	0.4889	2.78	Juvenile	38.16667	Bode
Farallon Isl. CA	Blue (mystinus)	FaraJB	3	9	0.4926	0.3889	2.33	Juvenile	37.78333	Fara
Farallon Isl. CA	Deacon (diaconus)	FaraJD	2	9	0.4444	0.5000	2.00	Juvenile	37.78333	Fara
off San Francisco Bay CA	Deacon (diaconus)	SFD	38	9	0.5089	0.4653	4.89	Adult	37.72705	Fara
Farallon Isl. CA	Blue (mystinus)	FaraB	15	9	0.5483	0.5099	4.67	Adult	37.70025	Fara
Farallon Isl. CA	Deacon (diaconus)	FaraD	42	9	0.5147	0.4711	4.89	Adult	37.70025	Fara
Half Moon Bay CA	Blue (mystinus)	HMBB	148	9	0.5222	0.4955	8.22	Adult	37.47868	HMB
Half Moon Bay CA	Deacon (diaconus)	HMBD	353	9	0.5216	0.4892	7.56	Adult	37.47868	HMB
Half Moon Bay CA	yellowtail (flavidus)	HMBY	4	8	0.4128	0.4271	2.25	Adult	37.47868	HMB
Pescadero CA	Blue (mystinus)	PescJB	12	9	0.5084	0.5715	4.11	Juvenile	37.28333	HMB
Pescadero CA	black (melanops)	PescJBK	1	4	0.2500	0.2500	1.25	Juvenile	37.28333	HMB
Pescadero CA	Deacon (diaconus)	PescJD	5	9	0.4617	0.4000	2.89	Juvenile	37.28333	HMB
Davenport CA	Blue (mystinus)	DavJB	4	9	0.5516	0.5833	3.00	Juvenile	36.98333	Mont
Davenport CA	Deacon (diaconus)	DavJD	6	9	0.5168	0.4815	3.00	Juvenile	36.98333	Mont
Santa Cruz CA	Blue (mystinus)	SCrzB	1	9	0.6667	0.6667	1.67	Adult	36.93718	Mont
Santa Cruz CA	Deacon (diaconus)	SCrzD	10	9	0.5447	0.5133	3.44	Adult	36.93718	Mont
Moss Landing CA	Blue (mystinus)	MossB	7	8	0.4682	0.3688	2.75	Adult	36.80191	Mont
Moss Landing CA	Deacon (diaconus)	MossD	3	7	0.5476	0.5952	2.43	Adult	36.80191	Mont
Monterey Bay CA	Blue (mystinus)	MontJB	22	9	0.5153	0.5060	4.89	Juvenile	36.70000	Mont
Monterey Bay CA	Deacon (diaconus)	MontJD	3	9	0.4963	0.5926	2.33	Juvenile	36.70000	Mont
Monterey Bay CA	Blue (mystinus)	MontB	355	9	0.4975	0.4560	8.44	Adult	36.68361	Mont
Monterey Bay CA	Deacon (diaconus)	MontD	124	9	0.5220	0.5153	6.44	Adult	36.68361	Mont
Point Sur CA	Blue (mystinus)	PSurJB	16	9	0.4520	0.4606	4.22	Juvenile	36.30000	Sur
Point Sur CA	Deacon (diaconus)	PSurJD	1	9	0.5556	0.5556	1.56	Juvenile	36.30000	Sur
Piedras Blancas CA	Blue (mystinus)	BlancJB	14	9	0.5169	0.5368	4.78	Juvenile	35.70000	Sur
Piedras Blancas CA	Deacon (diaconus)	BlancJD	1	9	0.6667	0.6667	1.67	Juvenile	35.70000	Sur
Piedras Blancas CA	squarespot (hopkinsi)	BlancJQ	1	9	0.6667	0.6667	1.67	Juvenile	35.70000	Sur
Morro Bay CA	Blue (mystinus)	MorrB	135	9	0.4932	0.4611	7.00	Adult	35.37136	Morr
Morro Bay CA	Deacon (diaconus)	MorrD	26	9	0.5076	0.5250	5.00	Adult	35.37136	Morr
Avila Beach CA	Blue (mystinus)	AvilB	18	9	0.4258	0.3833	3.67	Adult	35.15918	Morr
Point Sal CA	Blue (mystinus)	PSalJB	5	9	0.4296	0.4667	3.11	Juvenile	35.00000	Morr
Point Sal CA	Deacon (diaconus)	PSalJD	2	9	0.4630	0.5556	1.89	Juvenile	35.00000	Morr
Point Conception CA	Blue (mystinus)	PtConB	5	9	0.4099	0.4222	3.00	Adult	34.44506	SBC
Santa Barbara CA	Blue (mystinus)	SBB	15	9	0.5383	0.5653	4.44	Adult	34.30576	SBC
Santa Barbara CA	Deacon (diaconus)	SBD	1	9	0.5556	0.5556	1.56	Adult	34.30576	SBC
Port Hueneme CA	Deacon (diaconus)	PHueD	1	9	0.6667	0.6667	1.67	Adult	34.13049	SBC
San Miguel Isl. CA	Blue (mystinus)	SMigB	97	9	0.4575	0.4089	6.67	Adult	34.05762	SBC
San Miguel Isl. CA	Deacon (diaconus)	SMigD	4	9	0.6095	0.6759	3.00	Adult	34.05762	SBC
Santa Cruz Isl. CA	Blue (mystinus)	SCIB	16	9	0.4666	0.4816	4.33	Adult	34.05704	SBC
Santa Cruz Isl. CA	Deacon (diaconus)	SCID	1	9	0.5556	0.5556	1.56	Adult	34.05704	SBC
Santa Rosa Isl. CA	Blue (mystinus)	SRosB	50	9	0.4701	0.4499	5.33	Adult	34.02736	SBC
Santa Rosa Isl. CA	Deacon (diaconus)	SRosD	3	9	0.5889	0.6667	2.56	Adult	34.02736	SBC
Santa Monica Bay CA	Blue (mystinus)	SMoniB	12	9	0.5337	0.5847	4.56	Adult	33.94231	SBC
San Pedro Bay CA	Blue (mystinus)	SPedB	1	9	0.6667	0.6667	1.67	Adult	33.71793	SCal
Santa Barbara Isl. CA	Blue (mystinus)	SBarB	19	9	0.4698	0.4522	4.67	Adult	33.47698	SCal
Catalina Isl. CA	Blue (mystinus)	CataB	9	9	0.4340	0.4182	3.44	Adult	33.42101	SCal
San Nicolas Isl. CA	Blue (mystinus)	SNicJB	23	9	0.5015	0.4592	5.00	Juvenile	33.38333	SCal
San Nicolas Isl. CA	Blue (mystinus)	SNicB	7	9	0.5517	0.4571	3.44	Adult	33.25382	SCal
San Clemente Isl. CA	Blue (mystinus)	SClemB	16	9	0.4728	0.4616	4.00	Adult	32.92929	SCal
San Clemente Isl. CA	Blue (mystinus)	SClemJB	1	9	0.3333	0.3333	1.33	Juvenile	32.71667	SCal
Cortes Bank CA	Blue (mystinus)	CrtesB	4	9	0.5325	0.5370	2.78	Adult	32.49447	SCal
Cortes Bank CA	Deacon (diaconus)	CrtesD	1	9	0.4444	0.4444	1.44	Adult	32.49447	SCal
Tanner Bank CA	Blue (mystinus)	TannB	4	9	0.4394	0.3889	2.56	Adult	32.47014	SCal
Total			1909							

Results of the pairwise F_{ST} permutation tests, between all populations shown in the revised Table 1, are given in Table S1 revised (separate file). As in the preliminary F_{ST} permutation test, almost all pairwise F_{ST} estimates between populations of Blue and Deacon rockfish, i.e., between the cryptic species, were highly significant, whereas the within-species comparisons were generally not significant, indicating low or no population genetic structure within each of those species. The F_{ST} estimates between Blue or Deacon and other rockfishes (*S. entomelas, S. flavidus and S. melanops*) were three- to four-fold higher than the estimates between Blue and Deacon, suggesting an overall lower—but still significant—divergence between the cryptic species than among the long-recognized species. This finding is consistent with an incipient species pair that has recently become reproductively isolated and is likely still undergoing the process of speciation.

Although both Blue and Deacon rockfish were genetically identified in samples from all regions except one, the proportion of each of the types showed a striking geographic pattern (Figure O), when grouped by region and lifestage (as defined in Table 1 revised). Among adults, Deacon rockfish were more common in the northern regions, and Blue more common in the southern regions. The inflection point appeared somewhat abruptly between Half Moon Bay, where Deacon comprised ~70% of the sample, and Monterey Bay, where Blue constituted ~73% of the sample. Among juveniles, the pattern was similar, but the distribution north-shifted; Deacon rockfish constituted a majority of the regional samples from the Mendocino coast region north. However, among juveniles, the small sample sizes and temporally narrow sampling might bias the inferred species distributions. Although the samples analyzed here do not necessarily represent a random draw from each location, the observed differences in species distribution are corroborated by other studies (e.g., Burford and Bernardi 2008) and by anecdotal evidence from fishers.

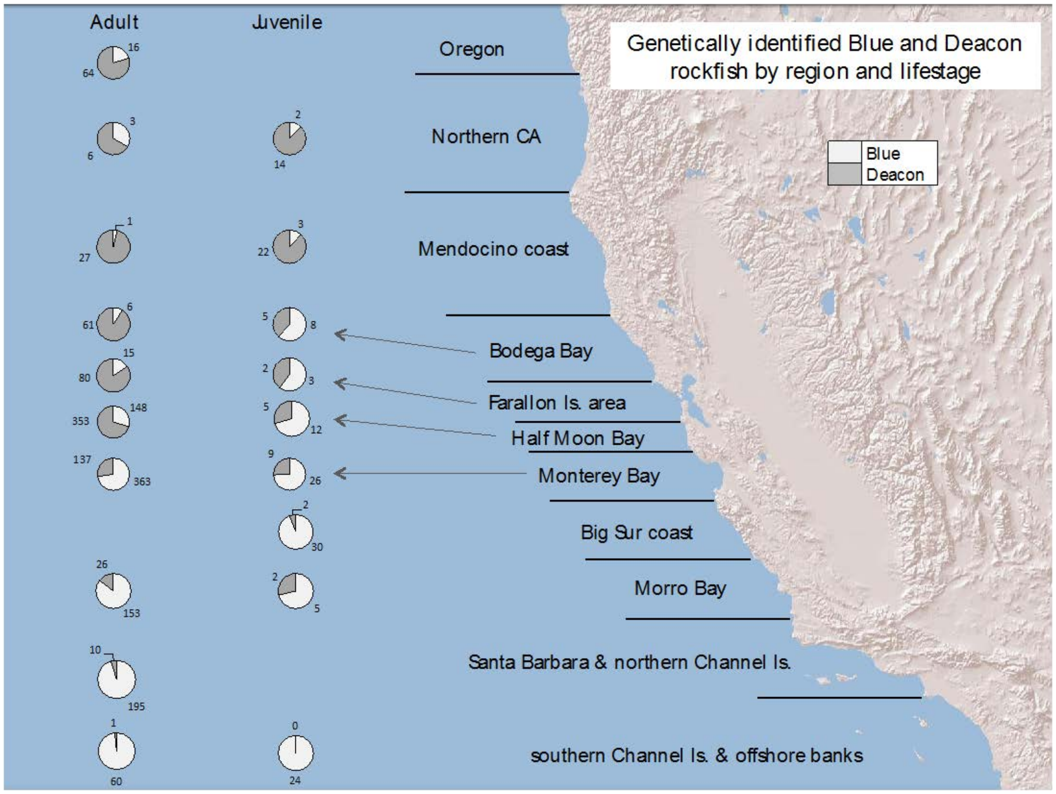


Figure O. Genetically identified Blue and Deacon rockfish (n=1,903) in the north Pacific Ocean, grouped by lifestage and coastal region off California and Oregon. Pie charts show the proportion of each species identified in each region; numbers denote sample size of each segment. Both lifestages were sampled in all locations except Oregon, Santa Barbara (no juveniles), and Big Sur coast (no adults).

Regional genetic structure was minimal within both Blue and Deacon rockfish adults. In the assignment test, all but 12 individuals assigned correctly to species, but only 300 of 1,725 assigned to region of origin (Figure P). In addition, only two individuals assigned with high confidence, and both were mis-assignments within species. In contrast, among the outgroups, the vast majority of individuals (217 of 222) were assigned with high confidence, and the only mis-assignments were between S. *flavidus* and *S. melanops*, a closely related species pair within the *Sebastomus* subgenus. The phylogeographic tree has three main branches, with strong bootstrap support for each: Blue regions, Deacon regions and *Sebastes* species outgroups (Figure Q). Within each group, bootstrap support is generally low, with only a few exceptions, often involving small sample sizes. In Deacon rockfish, there is some evidence for genetic structure between southern California and Morro Bay, and adjacent regions cluster together (Monterey and Half Moon Bay, Farallon Islands and Bodega, Mendocino and northern California), but the degree of structuring could be characterized as mild. Blue rockfish showed similarly mild structuring between Half Moon Bay and Oregon, and the two southern California regions shared a terminal node, followed by Morro Bay and Monterey Bay branches. The assignment and phylogenetic results together indicate very little geographic structure within both Blue and Deacon rockfish.

Region/blue type or *Sebastes* species	Oregon Blue	Oregon Deacon	N Cal Blue	N Cal Deacon	Mendocino Blue	Mendocino Deacon	Bodega Blue	Bodega Deacon	Farallon Is. Blue	Farallon Is. Deacon	Half Moon Bay Blue	Half Moon Bay Deacon	Monterey Blue	Monterey Deacon	Morro Bay Blue	Morro Bay Deacon	Santa Barb. Chan. Blue	Santa Barb. Chan. Deacon	southern Chan. Is. Blue	southern Chan. Is. Deacon	*S. caurinus*	*S. serriceps*	*S. entomelas*	*S. flavidus*	*S. melanops*	*S. pinniger*	*S. serranoides*
Oregon Blue	6										5		2		2		1										
Oregon Deacon		13		2		6		6		10		7		6		10		4									
N Cal Blue											1		1				1										
N Cal Deacon						2						1		2		1											
Mendocino Blue																			1								
Mendocino Deacon		4		4	2	4		2		1		3		3		2		2									
Bodega Blue	1								1		1				2		1										
Bodega Deacon		7		3		5		12		13		5		7		8		1									
Farallon Is. Blue							1		3		3		2		2		1		3								
Farallon Is. Deacon		14	1	9		5		9	1	18		7		3		7		5		1							
Half Moon Bay Blue	26		9				5		6	1	46		15		15		15		10								
Half Moon Bay Deacon		35		24	1	42		33		47		47		50		57		11		6							
Monterey Blue	43		12		7		8		17		47/1		40		57		72		59	1							
Monterey Deacon		20		7		19/1		17		11		21		25		12		5									
Morro Bay Blue	11		8		1		11		8		13		21		19		24		36	1							
Morro Bay Deacon		3	2	2		1		3		3		6		4		2											
Santa Barb. Chan. Blue	14		6				5		12		16		21		35		59		39	1							
Santa Barb. Chan. Deacon		3						1		1	1	2		2													
southern Chan. Is. Blue	2		2				1		5		6		5		10		10		6								
southern Chan. Is. Deacon												1															
S. caurinus																					29						
S. serriceps																						10					
S. entomelas																							51				
S. flavidus																								30/29	1		
S. melanops																								1	26/24		
S. pinniger																										24	
S. serranoides																											50

Figure P. Assignment of Blue and Deacon rockfish to regions (defined in Table 1 rev.), inner square; species assignment of seven outgroups (outer square) included for reference. First column, true region or species; top row, region or species assigned to. Shaded cells, self-assignment; bold numbers, high confidence assignments (>90%); regular text, assignment at all confidence levels. Only two Blue/Deacon individuals assigned with high confidence.

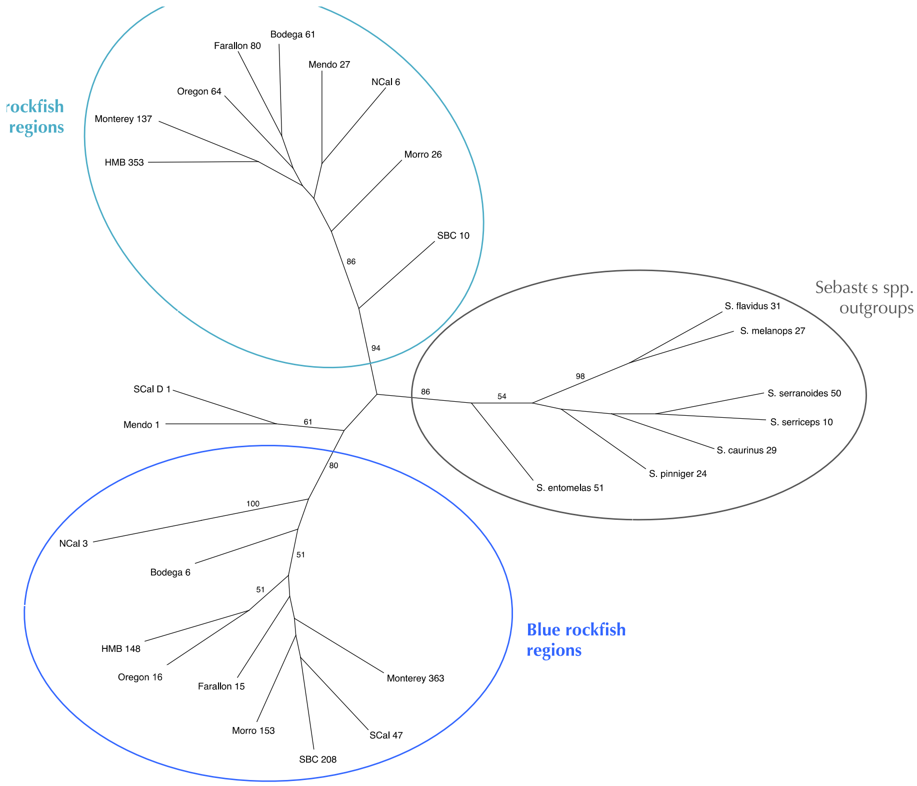


Figure Q. Neighbor-joining tree showing bootstrap support values >50% (of 5,000 replicates) for Blue (blue) and Deacon (teal) rockfish regions (adults only) and seven *Sebastes* species outgroups (gray). Names on terminal nodes denote regions (as defined in Table 1 rev.); numbers indicate sample size.

Summary—population genetics

Multiple population genetic analyses describe Blue and Deacon rockfish as a significantly diverged species pair, but this divergence is shallow relative to their congeners. Within each species, geographic structuring is minimal, which is perhaps not surprising given the schooling behavior of these species. As the name Northern (Deacon) Blue suggests, Deacon Rockfish are more common than Blue in northern regions (northern California and Oregon), while Blue Rockfish comprise the majority of blue types sampled in central and southern California.

References (Appendix A)

Anderson, Eric C., Robin S. Waples, and Steven T. Kalinowski. "An improved method for predicting the accuracy of genetic stock identification." Canadian Journal of Fisheries and Aquatic Sciences 65, no. 7 (2008): 1475-1486.

Belkhir, K., P. Borsa, L. Chikhi, N. Raufaste, and F. Bonhomme. 1996-2004. GENETIX 4.05, WindowsTM software for population genetics. Genome Laboratory, Populations, Interactions, CNRS UMR 5171, Université de Montpellier II, Montpellier, France.

Burford, M.O. and G. Bernardi. 2008. Incipient speciation within a subgenus of rockfish (*Sebastomus*) provides evidence of recent radiations within an ancient species flock. *Marine Biology* 154: 701-717.

Earl, D.A. and B.M. vonHoldt. 2012. STRUCTURE HARVESTER: a website and program for visualizing STRUCTURE output and implementing the Evanno method. Conservation Genetics Resources 4 (2): 359-361.

Evanno, G., S. Regnaut, and J. Goudet. 2005. Detecting the number of clusters of individuals using the software STRUCTURE: a simulation study. Molecular Ecology 14: 2611-2620.

Felsenstein, J. 2005. PHYLIP (Phylogeny Inference Package) version 3.6. Distributed by the author. Department of Genome Sciences, University of Washington, Seattle.

Jakobsson, M., and N.A. Rosenberg. 2007. CLUMPP: A cluster matching and permutation program for dealing with label switching and multimodality in analysis of population structure. Bioinformatics 23 (14): 1801-1806.

Paetkau, D., R. Slade, M. Burden, and A. Estoup. 2004. Genetic assignment methods for the direct, real-time estimation of migration rate: a simulation-based exploration of accuracy and power. Molecular Ecology 13: 55-65.

Piry, S., A. Alapetite, J. M. Cornuet, D. Paetkau, L. Baudouin, and A. Estoup. 2004. GENECLASS2: A software for genetic assignment and first-generation migrant detection. Journal of Heredity 95 (6): 536-539.

Pritchard, J.K., M. Stephens, and P. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics 155: 945-959.

Rannala, B., and J.L. Mountain. 1997. Detecting immigration by using multilocus genotypes. Proceedings of the National Academy of Science 94: 9197-9201.

Rosenberg, N.A. 2004. DISTRUCT: a program for the graphical display of population structure. Molecular Ecology Notes 4: 137-138.

Appendix B. Federal Commercial Regulation History

Federal commercial regulations, 1983-2014, relevant to stock complexes that have contained, or currently contain, Blue Rockfish.

Year	Date	Location	Regulation
1983	9/10/1983	4300 South	Continued 40,000-pound trip limit on *Sebastes* complex south of 43N latitude; no limit on number of trips.
1984	1/1/1984	4300 South	Continued 40,000-pound trip limit on *Sebastes* complex south of 4300 (changed to 4250 on February, 12, 1984); no limit on trip frequency.
1984	5/6/1984	ALL	Specified that fishing for groundfish on a *Sebastes* complex trip may occur on only one side of Cape Blanco (4250), which allows southern caught fish to be landed north of Cape Blanco using the southern trip limit of 40,000 pounds with appropriate declaration of intent.
1984	5/6/1984	Eureka Monterey Conception	Recommended no change in *Sebastes* complex trip limit of 40,000 pounds in the Eureka, Monterey, and Conception areas.
1984	8/1/1984	ALL	Vessel operators on combined groundfish/*Sebastes* complex trips allowed to fish on both sides of a line at 4250 N latitude (Cape Blanco), but landings of *Sebastes* complex in excess of 3,000 pounds controlled by the trip limit/trip frequency in effect north of the line (Vancouver and Columbia areas). Appropriate advance declaration of intent required.
1985	1/10/1985	Cape Blanco South	For *Sebastes* complex south of Cape Blanco, established a 40,000-pound trip limit without a trip frequency.
1985	1/10/1985	ALL	If fishers fish on both sides of the Cape Blanco line during a trip, the northern limit on *Sebastes* complex applies.
1985	1/10/1985	ALL	Landings of *Sebastes* complex and widow rockfish smaller than 3,000 pounds unrestricted.
1985	9/1/1985	ALL	Changed the management boundary line separating northern and southern trip limits for the *Sebastes* complex from Cape Blanco (4250' N latitude) northward 30 miles to the north jetty at Coos Bay (4322' N latitude).
1986	1/1/1986	ALL	For *Sebastes* complex north of Coos Bay, established 25,000-pound weekly trip limit of which no more than 10,000 pounds may be yellowtail rockfish (or 50,000 pounds biweekly of which no more than 20,000 pounds may be yellowtail rockfish, or 12,500 pounds twice per week of which no more than 5,000 pounds may be yellowtail rockfish; biweekly and twice weekly landings require appropriate declaration to state in which fish are landed). For *Sebastes* complex south of Coos Bay, established 40,000-pound trip limit; no trip frequency. Landings of less than 3,000 pounds of *Sebastes* complex and widow rockfish unrestricted. Fishers fishing the *Sebastes* complex on both sides of the Coos Bay line during a trip must conform with the northern (more restrictive) trip limit.
1987	1/1/1987	Coos Bay South	For *Sebastes* complex south of Coos Bay, established 40,000-pound trip limit; no trip frequency limit.
1987	5/3/1987	ALL	Changed the definition of fishing week from Sunday through Saturday to Wednesday through Tuesday for *Sebastes* complex and widow rockfish.

1988	1/1/1988	ALL	For *Sebastes* complex north of Coos Bay, established a 25,000-pound weekly trip limit of which no more than 10,000 pounds may be yellowtail rockfish (or 50,000 pounds biweekly of which no more than 20,000 pounds may be yellowtail rockfish, or 12,500 pounds twice per week, of which no more than 5,000 pounds may be yellowtail rockfish; biweekly and twice weekly landings require appropriate declaration to state in which fish are landed). No restriction on landings less than 3,000 pounds. For *Sebastes* complex south of Coos Bay, established a 40,000-pound trip limit; no trip frequency restriction.
1989	1/1/1989	Coos Bay South	For *Sebastes* complex south of Coos Bay, established a 40,000-pound trip limit; no trip frequency restriction.
1989	7/26/1989	ALL	Reduced the trip limit for yellowtail rockfish to 3,000 pounds or 20% of the *Sebastes* complex, whichever is greater.
1990	1/1/1990	Coos Bay South	For *Sebastes* complex south of Coos Bay, established the trip limit at 40,000 pound; no trip frequency restriction.
1990	7/25/1990	ALL	Reduced the weekly trip limit for yellowtail rockfish caught with any gear north of Coos Bay to 3,000 pounds or 20% of the *Sebastes* complex, whichever is greater. Biweekly and twice weekly landing options remain in effect.
1991	1/1/1991	Coos Bay South	For *Sebastes* complex south of Coos Bay, the trip limit established at 25,000 pounds, including no more than 5,000 pounds of bocaccio; no trip frequency restriction; harvest guideline for bocaccio set at 1,100 mt (ABC = 800 mt).
1992	1/1/1992	4030 South	For the *Sebastes* complex, established a cumulative landing limit per specified 2 week period of 50,000 pounds. Within this 50,000 pounds, no more than no more than 10,000 pounds cumulative may be bocaccio landed south of Cape Mendocino, California (4030 latitude). All landings count toward the 50,000-pound limit.
1992	1/1/1992	All cape lookout	For the *Sebastes* complex, established a cumulative landing limit per specified 2 week period of 50,000 pounds. Within this 50,000 pounds, no more than 8,000 pounds cumulative may be yellowtail rockfish landed north of Cape Lookout. All landings count toward the 50,000-pound limit.
1993	1/1/1993	Cape Mendocino Coos Bay	For *Sebastes* complex established a cumulative landing limit per specified 2-week period of 50,000 pounds between Cape Mendocino and Coos Bay. All landings count toward the cumulative limits. If a vessel fishes in the more restrictive area at any time during the 2-week period, the more restrictive limit applies for that vessel.
1993	1/1/1993	4030 South	For *Sebastes* complex established a cumulative landing limit per specified 2-week period of 50,000 pounds. Within this 50,000 pounds, no more than 10,000 pounds cumulative may be bocaccio caught south of Cape Mendocino, California (4030 latitude). All landings count toward the cumulative limits. If a vessel fishes in the more restrictive area at any time during the 2-week period, the more restrictive limit applies for that vessel.
1994	1/1/1994	4030 South	For *Sebastes* complex, bocaccio and yellowtail, cumulative limit of 80,000 pounds per calendar month, no more than 30,000 pounds may be bocaccio caught south of Cape Mendocino, California (4030 latitude).
1994	9/1/1994	4030 South	Increased the cumulative trip limit for the *Sebastes* complex caught south of Cape Mendocino, California (4030 latitude) in the limited entry groundfish fishery from 80,000 pounds to 100,000 pounds per calendar month.
1995	1/1/1995	4030 South	For *Sebastes* complex, cumulative limit of 100,000 pounds per month south of Cape Mendocino.

1995	1/1/1995	4030 South	For bocaccio, the cumulative limit is 30,000 pounds per month south of Cape Mendocino, and no limit north of Cape Mendocino (other than the limit on the *Sebastes* complex).
1995	1/1/1995	4030 4530	Cumulative limit for *Sebastes* Complex of 50,000 pounds per month between Cape Lookout and Cape Mendocino, California (4030 latitude), no more than 30,000 pounds may be yellowtail rockfish
1995	5/1/1995	Cape lookout South	For *Sebastes* complex, bocaccio and yellowtail, cumulative limit of 80,000 pounds per calendar month, no more than 30,000 pounds may be yellowtail rockfish caught south of Cape Lookout.
1995	8/1/1995	ALL	Increased the monthly cumulative trip limit for canary rockfish from 6,000 pounds (2,722 kg) to 9,000 pounds (4,082 kg). The *Sebastes* complex limit was not increased.
1996	1/1/1996	ALL	For fishing in areas with different trip limits for the same species: Trip limits for a species or species complex may differ in different geographic areas along the coast. The following "crossover" provisions apply to all vessels (limited entry and open access) operating in different geographical areas with different cumulative or "per trip" limits for the same species, except for species with daily-trip-limits (nontrawl sablefish, open access thornyhead), black rockfish off Washington State, or those otherwise exempted by a State declaration procedure (yellowtail rockfish and the *Sebastes* complex off Washington and Oregon).
1996	1/1/1996	ALL	*Sebastes* complex and bocaccio 200,000 pounds per 2-months south of Cape Mendocino. For bocaccio, the cumulative limit is 60,000 pounds per 2-months south of Cape Mendocino, and no limit north of Cape Mendocino (other than the limit on the *Sebastes* complex).
1996	1/1/1996	Cape Lookout Cape Mendocino	*Sebastes* complex and yellowtail 100,000 pounds per 2-months between Cape Lookout and Cape Mendocino, California (4030 latitude), no more than 70,000 pounds may be yellowtail rockfish caught between Cape Lookout and Cape Mendocino
1996	11/1/1996	Cape Lookout Cape Mendocino	The cumulative trip limit for the *Sebastes* complex taken between Cape Mendocino and Cape Lookout is 50,000 pounds per month, of which no more than 35,000 pounds may be yellowtail rockfish and no more than 9,000 pounds may be canary rockfish
1996	11/1/1996	4030 North	All *Sebastes* limits north of Cape Mendocino will be one-month cumulative limits to maintain the continuity of the Cape Lookout declaration option. The cumulative trip limit for the *Sebastes* complex taken and retained north of Cape Lookout is 35,000 pounds per month, of which no more than 6,000 pounds may be yellowtail rockfish and no more than 9,000 pounds may be canary rockfish.
1997	1/1/1997	4030 North	*Sebastes* Complex limited entry fishery cumulative limit of 30,000 pounds per specified 2-month period north of Cape Mendocino, California (4030 latitude), no more than 6,000 pounds may be yellowtail rockfish
1997	5/1/1997	4030 South	*Sebastes* Complex (Including Yellowtail Rockfish and Bocaccio) reduced the two-month cumulative limit on bocaccio to 10,000 pounds south of Cape Mendocino.
1997	10/1/1997	4030 North	*Sebastes* Complex (Including Yellowtail Rockfish and Bocaccio) changed from two-month limits to one-month limits for *Sebastes*. Increase *Sebastes* one month limits to 20,000 pounds north of Cape Mendocino no more than 5,000 pounds of which may be yellowtail rockfish north of Cape Mendocino
1997	10/1/1997	4030 South	changed from two-month limits to one-month limits for *Sebastes* complex 75,000 pounds south of Cape Mendocino, no more than 5,000 pounds of which may be bocaccio south of Cape Mendocino, and no more than 10,000 pounds of which may be canary rockfish coastwide
1997	10/1/1997	ALL	*Sebastes* complex coastwide no more than 10,000 pounds of which may be canary rockfish

1998	1/1/1998	4030 North	*Sebastes* Complex (Including yellowtail, canary and bocaccio rockfish): limited entry fishery Cumulative limit of 40,000 pounds per specified two-month period north of Cape Mendocino, California (4030 latitude), Within the cumulative two-month limits for the *Sebastes* complex, no more than 11,000 pounds may be yellowtail rockfish caught north of Cape Mendocino
1998	1/1/1998	4030 South	*Sebastes* Complex (Including yellowtail, canary and bocaccio rockfish): limited entry fishery Cumulative limit of 150,000 pounds per two-months south of Cape Mendocino. For bocaccio, the cumulative limit is 2,000 pounds per two-months south of Cape Mendocino, and no limit north
1998	5/1/1998	4030 North	*Sebastes* Complex: Limited Entry: increased cumulative limit for yellowtail to 13,000 pounds per specified two-month period north of Cape Mendocino.
1998	7/1/1998	4030 South	Limited Entry *Sebastes* Complex: south of Cape Mendocino, decreased the 2-month cumulative limit to 40,000 pounds.
1998	7/1/1998	ALL	Open Access Rockfish: removed overall rockfish monthly limit and replaced it with limits for component rockfish species: for *Sebastes* complex, monthly cumulative limit is 33,000 pounds, for widow rockfish, monthly cumulative trip limit is 3,000 pounds, for Pacific Ocean Perch, monthly cumulative trip limit is 4,000 pounds.
1998	10/1/1998	4030 South	*Sebastes* complex South of Cape Mendocino: Limited Entry: decreased monthly limit to 15,000 pounds.
1999	1/1/1999	4030 North	for the limited entry fishery *Sebastes* Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio):North of Cape Mendocino, California (4030 latitude), Phase 1: 24,000 pounds per period, for this period, the *Sebastes* complex limit north of Cape Mendocino equals the sum of the yellowtail and canary rockfish limits, a vessel may not exceed the overall *Sebastes* limit, regardless of the amount of yellowtail and/or canary rockfish landed within that limit; Phase 2: 25,000 pounds per period; Phase 3: 10,000 pounds per period
1999	1/1/1999	4030 South	For the limited entry fishery *Sebastes* Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio): South of Cape Mendocino, California, Phase1: 13,000 pounds per period; Phase 2: 6,500 pounds per period; Phase 3: 5,000 pounds per period.
1999	1/1/1999	4030 North	For the limited entry fishery *Sebastes* Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio): Yellowtail Rockfish: north of Cape Mendocino, Phase 1: 15,000 pounds per period; Phase 2: 13,000 pounds per period; Phase 3: 5,000 pounds per period.
1999	1/1/1999	4030 South	for the limited entry fishery *Sebastes* Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio):Bocaccio: south of Cape Mendocino, Phase 1: 750 pounds per month; Phase 2: 750 pounds per month; Phase 3: 750 pounds per month
1999	1/1/1999	4030 North	For open access gear: *Sebastes* complex: north of Cape Mendocino, 3,600 pounds per month.
1999	1/1/1999	4030 South	For open access gear: *Sebastes* complex: south of Cape Mendocino, 2,000 pounds per month.
1999	1/1/1999	ALL	for the limited entry fishery *Sebastes* Complex (including Yellowtail Rockfish, Canary Rockfish, and Bocaccio):Canary Rockfish: coastwide, Phase 1: 9,000 pounds per period; Phase 2: 9,000 pounds per period; Phase 3: 3,000 pounds per period

1999	4/1/1999	ALL	For “A” Platoon Vessels: Limited Entry and Open Access *Sebastes* complex: north and south of Cape Mendocino, if a vessel takes and retains, possesses, or lands any splitnose or chilipepper rockfish south of Cape Mendocino, then the more restrictive *Sebastes* complex cumulative trip limit applies throughout the same cumulative limit period, no matter where the *Sebastes* complex is taken and retained, possessed, or landed.
1999	4/1/1999	4030 South	For “A” Platoon Vessels: Limited Entry Canary Rockfish: south of Cape Mendocino, decreased 2-month cumulative limit from 9,000 pounds to 6,500 pounds. Landings of canary rockfish south of Cape Mendocino are limited by and count against the overall *Sebastes* complex 2-month cumulative limit south of Cape Mendocino, which is 6,500 pounds.
1999	4/1/1999	4030 North	For “A” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, increased overall monthly limit from 3,600 pounds to 12,000 pounds;
1999	4/1/1999	4030 North	For “A” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, Yellowtail Rockfish, increased cumulative limit from 2,600 pounds to 6,500 pounds per month;
1999	4/1/1999	4030 North	For “A” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, Canary Rockfish, increased cumulative limit from 1,000 pounds to 2,000 pounds per month;
1999	4/1/1999	4030 North	For “A” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, Combined Black Rockfish and Blue Rockfish cumulative limit is 3,500 pounds per month;
1999	4/1/1999	4030 North	For “A” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, No more than 2,000 pounds per month may be species other than yellowtail, canary, black, and blue rockfish.
1999	4/16/1999	4030 South	For “B” Platoon Vessels: Limited Entry and Open Access *Sebastes* complex: north and south of Cape Mendocino, if a vessel takes and retains, possesses, or lands any splitnose or chilipepper rockfish south of Cape Mendocino, then the more restrictive *Sebastes* complex cumulative trip limit applies throughout the same cumulative limit period, no matter where the *Sebastes* complex is taken and retained, possessed, or landed.
1999	4/16/1999	4030 South	For “B” Platoon Vessels: Limited Entry Canary Rockfish: south of Cape Mendocino, decreased 2-month cumulative limit from 9,000 pounds to 6,500 pounds. Landings of canary rockfish south of Cape Mendocino are limited by and count against the overall *Sebastes* complex 2-month cumulative limit south of Cape Mendocino, which is 6,500 pounds.
1999	4/16/1999	4030 North	For “B” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, increased overall monthly limit from 3,600 pounds to 12,000 pounds;
1999	4/16/1999	4030 North	For “B” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, Canary Rockfish, increased cumulative limit from 1,000 pounds to 2,000 pounds per month;
1999	4/16/1999	4030 North	For “B” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, Yellowtail Rockfish, increased cumulative limit from 2,600 pounds to 6,500 pounds per month;
1999	4/16/1999	4030 North	For “B” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, Combined Black Rockfish and Blue Rockfish cumulative limit is 3,500 pounds per month;
1999	4/16/1999	4030 North	For “B” Platoon Vessels: Open Access *Sebastes* complex: north of Cape Mendocino, No more than 2,000 pounds per month may be species other than yellowtail, canary, black, and blue rockfish.

1999	6/1/1999	4030 North	Limited Entry, Platoon "A": *Sebastes* complex: north of Cape Mendocino, 2 month cumulative trip limit for the periods June 1 through July 31 and August 1 through September 30 increased from 25,000 pounds to 30,000 pounds, within which: (1) yellowtail rockfish north of Cape Mendocino, 2-month cumulative trip limit increased from 13,000 pounds to 16,000 pounds, and (2) canary rockfish north of Cape Mendocino, 2-month cumulative trip limit increased from 9,000 pounds to 14,000 pounds.
1999	6/1/1999	4030 South	Limited Entry, Platoon "A": *Sebastes* complex: south of Cape Mendocino, limited entry 2 month cumulative trip limit for the periods June 1 through July 31 and August 1 through September 30 decreased from 6,500 pounds to 3,500 pounds, within which: (1) Bocaccio monthly trip limit of 750 pounds decreased and changed to a 2-month cumulative trip limit of 1,000 pounds with a 500 pounds per trip limit, and (2) canary rockfish 2-month cumulative trip limit decreased to 3,500 pounds.
1999	6/1/1999	4030 North	Limited Entry, Platoon "B": *Sebastes* complex: north of Cape Mendocino, 2 month cumulative trip limit for the periods June 1 through July 31 and August 1 through September 30 increased from 25,000 pounds to 30,000 pounds, within which: (1) yellowtail rockfish north of Cape Mendocino, 2-month cumulative trip limit increased from 13,000 pounds to 16,000 pounds, and (2) canary rockfish north of Cape Mendocino, 2-month cumulative trip limit increased from 9,000 pounds to 14,000 pounds.
1999	6/1/1999	4030 South	Limited Entry, Platoon "B": *Sebastes* complex: south of Cape Mendocino, limited entry 2 month cumulative trip limit for the periods June 1 through July 31 and August 1 through September 30 decreased from 6,500 pounds to 3,500 pounds, within which: (1) Bocaccio monthly trip limit of 750 pounds decreased and changed to a 2-month cumulative trip limit of 1,000 pounds with a 500 pounds per trip limit, and (2) canary rockfish 2-month cumulative trip limit decreased to 3,500 pounds.
1999	8/1/1999	4030 North	*Sebastes* complex, Limited Entry, Platoon "A": north of Cape Mendocino, 2 month cumulative trip limit for the period August 1 through September 30 increased from 30,000 pounds to 35,000 pounds, within which: (1) yellowtail rockfish, north of Cape Mendocino, 2-month cumulative trip limit increased from 16,000 pounds to 20,000 pounds; (2) canary rockfish, north of Cape Mendocino, 2-month cumulative trip limit remains at 14,000 pounds; and (3) added 2-month cumulative trip limit of 10,000 pounds for rockfish other than yellowtail rockfish and canary rockfish north of Cape Mendocino.
1999	8/16/1999	4030 North	*Sebastes* complex, Limited Entry, Platoon "B": north of Cape Mendocino, 2 month cumulative trip limit for the period August 16 through October 15 increased from 30,000 pounds to 35,000 pounds, within which: (1) yellowtail rockfish, north of Cape Mendocino, 2-month cumulative trip limit increased from 16,000 pounds to 20,000 pounds; (2) canary rockfish, north of Cape Mendocino, 2-month cumulative trip limit remains at 14,000 pounds; and (3) added 2-month cumulative trip limit of 10,000 pounds for rockfish other than yellowtail rockfish and canary rockfish north of Cape Mendocino.
1999	10/1/1999	4030 North	Limited Entry *Sebastes* Complex, "A" platoon: decreased 1-month cumulative trip limits from 10,000 pounds (north of Cape Mendocino)
1999	10/1/1999	4030 South	Limited Entry *Sebastes* Complex, "A" platoon: decreased 1-month cumulative trip limits from 5,000 pounds (south of Cape Mendocino) to a coastwide limit of 500 pounds per month.

1999	10/1/1999	ALL	Limited Entry, "A" platoon: The 1-month cumulative trip limits for canary rockfish, coastwide; Bocaccio, south of Cape Mendocino; and other species in the *Sebastes* complex, which count together towards the overall *Sebastes* complex limit, may not exceed the 500-pound cumulative monthly limit.
1999	10/16/1999	ALL	Limited Entry, "B" platoon: The 1-month cumulative trip limits for canary rockfish, coastwide; Bocaccio, south of Cape Mendocino; and other species in the *Sebastes* complex, which count together towards the overall *Sebastes* complex limit, may not exceed the 500-pound cumulative monthly limit.
1999	10/16/1999	4030 North	Limited Entry *Sebastes* Complex, "B" platoon: decreased 1-month cumulative trip limits from 10,000 pounds (north of Cape Mendocino)
1999	10/16/1999	4030 South	Limited Entry *Sebastes* Complex, "B" platoon: decreased 1-month cumulative trip limits from 5,000 pounds (south of Cape Mendocino) to a coastwide limit of 500 pounds per month.
2000	1/1/2000	3600 South	Minor Nearshore rockfish, Open Access gear except exempted trawl, closed
2000	1/1/2000	3600 South	Minor Nearshore rockfish, limited entry fixed gear, closed
2000	1/1/2000	4010 North	Limited entry trawl, small footrope or midwater trawl only, minor nearshore rockfish, 200 lbs per month
2000	1/1/2000	4010 North	Minor Nearshore rockfish, Open Access gear except exempted trawl, 1000 lbs per 2 months of which no more than 500 lbs may be species other than black rockfish or blue rockfish, the Washington per trip limit for Black rockfish also applies
2000	1/1/2000	4010 North	Minor Nearshore rockfish, limited entry fixed gear, 2400 lbs per 2 months of which no more than 1200 lbs may be species other than black rockfish or blue rockfish, the Washington per trip limit for Black rockfish also applies
2000	1/1/2000	4010 South	Limited entry trawl, small footrope or midwater trawl only, minor nearshore rockfish, 200 lbs per month
2000	3/1/2000	3600 South	Minor Nearshore rockfish, limited entry fixed gear, 1000 lbs per 2 months
2000	3/1/2000	3600 South	Minor Nearshore rockfish, Open Access gear except exempted trawl, 550 lbs per 2 months
2000	5/1/2000	3600 South	Minor Nearshore rockfish, limited entry fixed gear, 1000 lbs per 2 months
2001	1/1/2001	4010 North	Minor nearshore rockfish, open access, 3000 lbs per 2 months, no more than 900 lbs may be species other than blue rockfish or black rockfish with the per trip limit for black rockfish in Washington applying
2001	1/1/2001	4010 North	Minor nearshore rockfish, limited entry fixed gear, 10000 lbs per 2 months, no more than 4000 lbs of species other than blue rockfish or black rockfish with the per trip limit for Washington black rockfish also applying
2001	1/1/2001	4010 North	Minor Nearshore Rockfish, limited entry trawl, small footrope or midwater trawl only, 200 lbs per month
2001	1/1/2001	3427 South	Minor nearshore rockfish, open access, shoreward of 20 fathoms - 1800 lbs per 2 months, otherwise closed
2001	1/1/2001	3427 South	Minor nearshore rockfish, limited entry fixed gear, 2000 lbs per 2 months shoreward of 20 fathoms; otherwise closed
2001	1/1/2001	4010 South	Minor Nearshore Rockfish, limited entry trawl, small footrope or midwater trawl only, 200 lbs per month
2001	1/1/2001	ALL	Nearshore flatfish, open access, included in other flatfish limit
2001	3/1/2001	3427 South	Minor nearshore rockfish, open access, 1800 lbs per 2 months
2001	4/1/2001	3427 South	Minor nearshore rockfish, limited entry fixed gear, 2000 lbs per 2 months
2001	7/1/2001	3427 South	Minor nearshore rockfish, limited entry fixed gear, 2000 lbs per 2

			months
2001	7/1/2001	3427 South	Minor nearshore rockfish, open access, 1800 lbs per 2 months
2002	1/1/2002	3427 South	Minor nearshore rockfish, open access, closed
2002	1/1/2002	3427 South	Minor nearshore rockfish, limited entry fixed gear, closed
2002	1/1/2002	4010 South	minor nearshore rockfish, limited entry trawl, midwater or small footrope only, 300 lbs per month
2002	1/1/2002	4010 North	Minor nearshore rockfish, open access, 3000 lbs per 2 months, no more than 1200 lbs of which may be a species other than blue rockfish or black rockfish
2002	1/1/2002	4010 North	Minor nearshore rockfish, limited entry fixed gear, 5000 lbs per month, no more than 2000 lbs of species other than blue rockfish or black rockfish
2002	1/1/2002	4010 North	minor nearshore rockfish, limited entry trawl, midwater or small footrope only, 300 lbs per month
2002	3/1/2002	3427 South	Minor nearshore rockfish, open access, 1200 lbs per 2 months
2002	5/1/2002	3427 South	Minor nearshore rockfish, limited entry fixed gear, 2000 lbs per 2 months
2002	5/1/2002	4010 North	Minor nearshore rockfish, open access, 4000 lbs per 2 months, no more than 1600 lbs of which may be a species other than blue rockfish or black rockfish
2002	11/1/2002	4010 North	Minor nearshore rockfish, open access, 3000 lbs per 2 months, no more than 1200 lbs of which may be a species other than blue rockfish or black rockfish
2002	11/1/2002	3427 South	Minor nearshore rockfish, limited entry fixed gear, closed
2002	11/1/2002	3427 South	Minor nearshore rockfish, open access, closed
2003	1/1/2003	4010 North	minor nearshore rockfish, open access gears, 3000 lbs per 2 months, no more than 900 lbs of which may be species other than blue or black rockfish
2003	1/1/2003	4010 North	minor nearshore rockfish, Limited entry trawl gear, small footrope or midwater trawl only, 300 lbs per month
2003	1/1/2003	4010 South	minor nearshore rockfish - shallow nearshore, open access gear, 200 lbs per 2 months
2003	1/1/2003	4010 South	minor nearshore rockfish - deeper nearshore, open access gear, 200 lbs per 2 months
2003	1/1/2003	4010 North	minor nearshore rockfish, limited entry fixed gear, 3000 lbs per 2 months, no more than 900 lbs of which may be species other than blue or black rockfish
2003	1/1/2003	4010 South	minor nearshore rockfish - California scorpionfish, open access gear, closed
2003	1/1/2003	4010 South	minor nearshore rockfish, shallow nearshore, limited entry fixed gear, 200 lbs per 2 months
2003	1/1/2003	4010 South	minor nearshore rockfish, deeper nearshore, limited entry fixed gear, 200 lbs per 2 months
2003	1/1/2003	4010 South	minor nearshore rockfish, California scorpionfish, limited entry fixed gear, closed
2003	1/1/2003	4010 South	minor nearshore rockfish, limited entry trawl, small footrope or midwater trawl only, 300 lbs per month
2003	3/1/2003	4010 South	minor nearshore rockfish, deeper nearshore, limited entry fixed gear, closed
2003	3/1/2003	4010 South	minor nearshore rockfish, shallow nearshore, limited entry fixed gear, closed
2003	3/1/2003	4010 South	minor nearshore rockfish - deeper nearshore, open access gear, closed
2003	3/1/2003	4010 South	minor nearshore rockfish - shallow nearshore, open access gear, closed
2003	5/1/2003	4010 South	minor nearshore rockfish - shallow nearshore, open access gear, 400 lbs per 2 months

2003	5/1/2003	4010 South	minor nearshore rockfish - deeper nearshore, open access gear, 200 lbs per 2 months
2003	5/1/2003	4010 South	minor nearshore rockfish - California scorpionfish, open access gear, 800 lbs per 2 months
2003	5/1/2003	4010 South	minor nearshore rockfish, shallow nearshore, limited entry fixed gear, 400 lbs per 2 months
2003	5/1/2003	4010 South	minor nearshore rockfish, deeper nearshore, limited entry fixed gear, 200 lbs per 2 months
2003	5/1/2003	4010 South	minor nearshore rockfish, California scorpionfish, limited entry fixed gear, 800 lbs per 2 months
2003	5/1/2003	4010 South	lingcod, 24 inch size limit, open access gear, 300 lbs per month when nearshore open
2003	5/1/2003	4010 South	Lingcod, limited entry fixed gear, 24 inch size limit, 400 lbs per month when nearshore open
2003	7/1/2003	4010 South	minor nearshore rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2003	7/1/2003	4010 South	minor nearshore rockfish, shallow nearshore, limited entry fixed gear, 400 lbs per 2 months
2003	7/1/2003	4010 North	minor nearshore rockfish, limited entry fixed gear, 4000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2003	7/1/2003	4010 South	minor nearshore rockfish - deeper nearshore, open access gear, 500 lbs per 2 months
2003	7/1/2003	4010 South	minor nearshore rockfish - shallow nearshore, open access gear, 400 lbs per 2 months
2003	7/1/2003	4010 North	minor nearshore rockfish, open access gears, 4000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2003	9/1/2003	4010 South	minor nearshore rockfish - shallow nearshore, open access gear, 300 lbs per 2 months
2003	9/1/2003	4010 South	minor nearshore rockfish - deeper nearshore, open access gear, 300 lbs per 2 months
2003	9/1/2003	4010 South	minor nearshore rockfish - California scorpionfish, open access gear, closed
2003	9/1/2003	4010 South	minor nearshore rockfish, shallow nearshore, limited entry fixed gear, 300 lbs per 2 months
2003	9/1/2003	4010 South	minor nearshore rockfish, deeper nearshore, limited entry fixed gear, 300 lbs per 2 months
2003	9/1/2003	4010 South	minor nearshore rockfish, California scorpionfish, limited entry fixed gear, closed
2003	11/1/2003	4010 South	minor nearshore rockfish, deeper nearshore, limited entry fixed gear, 200 lbs per 2 months
2003	11/1/2003	4010 South	minor nearshore rockfish, shallow nearshore, limited entry fixed gear, 200 lbs per 2 months
2003	11/1/2003	4010 South	minor nearshore rockfish - deeper nearshore, open access gear, 200 lbs per 2 months
2003	11/1/2003	4010 South	minor nearshore rockfish - shallow nearshore, open access gear, 200 lbs per 2 months
2004	1/1/2004	4010 North	minor nearshore rockfish, open access gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue rockfish or black rockfish
2004	1/1/2004	4010 North	minor nearshore rockfish, limited entry fixed gear, 5000 lbs per months no more than 1200 lbs may be species other than blue rockfish or black rockfish
2004	1/1/2004	4010 North	minor nearshore rockfish, large footrope, limited entry trawl, closed
2004	1/1/2004	4010 North	minor nearshore rockfish, small footrope, limited entry trawl, 300 lbs per month
2004	1/1/2004	4010 South	minor nearshore rockfish, limited entry trawl, large footrope or midwater trawl, closed
2004	1/1/2004	4010 South	minor nearshore rockfish, limited entry trawl, small footrope, 300 lbs

			per month
2004	1/1/2004	3427 South	minor nearshore rockfish shallow, limited entry fixed gear, closed
2004	1/1/2004	3427 South	minor nearshore rockfish - shallow nearshore, open access gear, closed
2004	1/1/2004	3427 South	minor nearshore rockfish - deeper nearshore, open access gear, closed
2004	1/1/2004	3427 South	minor nearshore rockfish deeper, limited entry fixed gear, closed
2004	3/1/2004	3427 South	minor nearshore rockfish deeper, limited entry fixed gear, 500 lbs per 2 months
2004	3/1/2004	3427 South	minor nearshore rockfish - deeper nearshore, open access gear, 500 lbs per 2 months
2004	3/1/2004	3427 South	minor nearshore rockfish - shallow nearshore, open access gear, 300 lbs per 2 months
2004	3/1/2004	3427 South	minor nearshore rockfish shallow, limited entry fixed gear, 300 lbs per 2 months
2004	5/1/2004	3427 South	minor nearshore rockfish shallow, limited entry fixed gear, 500 lbs per 2 months
2004	5/1/2004	3427 South	minor nearshore rockfish - shallow nearshore, open access gear, 500 lbs per 2 months
2004	5/1/2004	3427 South	minor nearshore rockfish - deeper nearshore, open access gear, 600 lbs per 2 months
2004	5/1/2004	3427 South	minor nearshore rockfish deeper, limited entry fixed gear, 600 lbs per 2 months
2004	5/1/2004	4010 South	lingcod, 24 inch size limit, open access gear, 300 lbs per 2 months when nearshore open
2004	5/1/2004	4010 South	lingcod, 24 inch size limit, limited entry fixed gear, 400 lbs per month when nearshore open
2004	7/1/2004	3427 South	minor nearshore rockfish - shallow nearshore, open access gear, 600 lbs per 2 months
2004	7/1/2004	3427 South	minor nearshore rockfish shallow, limited entry fixed gear, 600 lbs per 2 months
2004	9/1/2004	3427 South	minor nearshore rockfish shallow, limited entry fixed gear, 500 lbs per 2 months
2004	9/1/2004	3427 South	minor nearshore rockfish - shallow nearshore, open access gear, 500 lbs per 2 months
2004	11/1/2004	3427 South	minor nearshore rockfish - shallow nearshore, open access gear, 300 lbs per 2 months
2004	11/1/2004	3427 South	minor nearshore rockfish deeper, limited entry fixed gear, 400 lbs per 2 months
2004	11/1/2004	3427 South	minor nearshore rockfish - deeper nearshore, open access gear, 400 lbs per 2 months
2004	11/1/2004	3427 South	minor nearshore rockfish shallow, limited entry fixed gear, 300 lbs per 2 months
2004	11/1/2004	4010 South	minor nearshore rockfish, limited entry trawl, small footrope, closed
2004	11/1/2004	4010 North	minor nearshore rockfish, small footrope, limited entry trawl, closed
2005	1/1/2005	4010 North	minor nearshore rockfish and black rockfish, limited entry trawl gear, large and small footrope, closed
2005	1/1/2005	4010 North	minor nearshore rockfish and black rockfish, limited entry trawl gear, selective flatfish gear, 300 lbs per month
2005	1/1/2005	4010 North	minor nearshore rockfish and black rockfish, limited entry trawl gear, multiple bottom trawl gear, closed
2005	1/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, open access gear, 300 lbs per 2 months
2005	1/1/2005	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, large footrope or midwater trawl, closed

2005	1/1/2005	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, small footrope trawl, 300 lbs per month
2005	1/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 300 lbs per 2 months
2005	1/1/2005	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2005	1/1/2005	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2005	1/1/2005	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months no more than 1200 lbs of which may be species other than blue or black rockfish
2005	1/1/2005	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, open access gear, 300 lbs per 2 months
2005	1/1/2005	4200 North	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2005	1/1/2005	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months no more than 1200 lbs of which may be species other than blue or black rockfish
2005	3/1/2005	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, open access gear, closed
2005	3/1/2005	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed
2005	3/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2005	3/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, open access gear, closed
2005	5/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, open access gear, 500 lbs per 2 months
2005	5/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 500 lbs per 2 months
2005	5/1/2005	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2005	5/1/2005	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, open access gear, 600 lbs per 2 months
2005	5/1/2005	4010 South	lingcod, 24 inch size limit, open access gear, 300 lbs per 2 months when nearshore open
2005	7/1/2005	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 6000 lbs per 2 months no more than 1200 lbs of which may be species other than blue or black rockfish
2005	7/1/2005	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 6000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2005	7/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2005	7/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, open access gear, 600 lbs per 2 months
2005	9/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, open access gear, 500 lbs per 2 months
2005	9/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 500 lbs per 2 months
2005	11/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 300 lbs per 2 months

2005	11/1/2005	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, open access gear, 300 lbs per 2 months
2005	11/1/2005	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 400 lbs per 2 months
2005	11/1/2005	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, open access gear, 400 lbs per 2 months
2006	1/1/2006	3427 South	minor nearshore rockfish including black rockfish deeper nearshore, open access gear, 500 lbs per 2 months
2006	1/1/2006	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2006	1/1/2006	4010 4200	minor nearshore rockfish including black rockfish, open access gear, 6000 lbs per 2 months, no more than 1200 lbs of which can be species other than blue or black rockfish
2006	1/1/2006	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 6000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2006	1/1/2006	4010 South	minor nearshore rockfish including black rockfish shallow nearshore, open access gear, 300 lbs per 2 months
2006	1/1/2006	4010 North	minor nearshore rockfish including black rockfish , limited entry trawl, large and small footrope gear, closed
2006	1/1/2006	4010 North	minor nearshore rockfish including black rockfish , limited entry trawl, selective flatfish trawl gear, 300 lbs per month
2006	1/1/2006	4010 North	minor nearshore rockfish including black rockfish , limited entry trawl, multiple bottom trawl gear, closed
2006	1/1/2006	4200 North	minor nearshore rockfish including black rockfish, open access gear, 6000 lbs per 2 months, no more than 1200 lbs of which can be species other than blue or black rockfish
2006	1/1/2006	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2006	1/1/2006	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 300 lbs per 2 months
2006	1/1/2006	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, large footrope and midwater trawl, closed
2006	1/1/2006	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, small footrope, 300 lbs per month
2006	3/1/2006	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2006	3/1/2006	4010 South	minor nearshore rockfish including black rockfish shallow nearshore, open access gear, closed
2006	3/1/2006	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed
2006	3/1/2006	3427 South	minor nearshore rockfish including black rockfish deeper nearshore, open access gear, closed
2006	5/1/2006	3427 South	minor nearshore rockfish including black rockfish deeper nearshore, open access gear, 600 lbs per 2 months
2006	5/1/2006	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2006	5/1/2006	4010 South	minor nearshore rockfish including black rockfish shallow nearshore, open access gear, 500 lbs per 2 months
2006	5/1/2006	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 500 lbs per 2 months
2006	5/1/2006	4010 South	lingcod, 24 inch size limit, open access gear, 300 lbs per month when nearshore open

2006	7/1/2006	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2006	7/1/2006	4010 South	minor nearshore rockfish including black rockfish shallow nearshore, open access gear, 600 lbs per 2 months
2006	9/1/2006	4010 South	minor nearshore rockfish including black rockfish shallow nearshore, open access gear, 500 lbs per 2 months
2006	9/1/2006	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 500 lbs per 2 months
2006	11/1/2006	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 300 lbs per 2 months
2006	11/1/2006	4010 South	minor nearshore rockfish including black rockfish shallow nearshore, open access gear, 300 lbs per 2 months
2006	11/1/2006	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 400 lbs per 2 months
2006	11/1/2006	3427 South	minor nearshore rockfish including black rockfish deeper nearshore, open access gear, 400 lbs per 2 months
2007	1/1/2007	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2007	1/1/2007	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2007	1/1/2007	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 6000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2007	1/1/2007	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 500 lbs per 2 months
2007	1/1/2007	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2007	1/1/2007	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2007	1/1/2007	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 6000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2007	1/1/2007	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, large footrope or midwater trawl, closed
2007	1/1/2007	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, small footrope trawl, 300 lbs per month
2007	1/1/2007	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, large and small footrope gear, closed
2007	1/1/2007	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, selective flatfish trawl, 300 lbs per month
2007	1/1/2007	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, multiple bottom trawl gear, closed
2007	1/1/2007	4200 North	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2007	3/1/2007	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2007	3/1/2007	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, closed
2007	3/1/2007	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed

2007	3/1/2007	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, closed
2007	5/1/2007	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2007	5/1/2007	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2007	5/1/2007	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 600 lbs per 2 months
2007	5/1/2007	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2007	7/1/2007	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 900 lbs per 2 months
2007	7/1/2007	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 900 lbs per 2 months
2007	9/1/2007	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2007	9/1/2007	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2007	11/1/2007	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2007	11/1/2007	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2008	1/1/2008	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2008	1/1/2008	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 500 lbs per 2 months
2008	1/1/2008	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 6000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2008	1/1/2008	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2008	1/1/2008	4200 North	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2008	1/1/2008	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, large and small footrope gear, closed
2008	1/1/2008	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, selective flatfish trawl, 300 lbs per month
2008	1/1/2008	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, multiple bottom trawl gear, closed
2008	1/1/2008	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, large footrope or midwater trawl, closed
2008	1/1/2008	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, small footrope trawl, 300 lbs per month
2008	1/1/2008	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 6000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2008	1/1/2008	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2008	1/1/2008	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months

2008	3/1/2008	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, closed
2008	3/1/2008	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed
2008	3/1/2008	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, closed
2008	3/1/2008	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2008	5/1/2008	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2008	5/1/2008	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 600 lbs per 2 months
2008	5/1/2008	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2008	5/1/2008	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2008	7/1/2008	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 900 lbs per 2 months
2008	7/1/2008	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 900 lbs per 2 months
2008	9/1/2008	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2008	9/1/2008	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2008	11/1/2008	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2008	11/1/2008	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2009	1/1/2009	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2009	1/1/2009	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 500 lbs per 2 months
2009	1/1/2009	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 6000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2009	1/1/2009	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2009	1/1/2009	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2009	1/1/2009	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2009	1/1/2009	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 6000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2009	1/1/2009	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, large footrope or midwater trawl, closed
2009	1/1/2009	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, small footrope trawl, 300 lbs per month
2009	1/1/2009	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, large and small footrope gear, closed

2009	1/1/2009	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, selective flatfish trawl, 300 lbs per month
2009	1/1/2009	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, multiple bottom trawl gear, closed
2009	1/1/2009	4200 North	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2009	3/1/2009	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, closed
2009	3/1/2009	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed
2009	3/1/2009	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, closed
2009	3/1/2009	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2009	5/1/2009	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2009	5/1/2009	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 600 lbs per 2 months
2009	5/1/2009	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2009	5/1/2009	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2009	7/1/2009	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 900 lbs per 2 months
2009	7/1/2009	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 7000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2009	7/1/2009	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 900 lbs per 2 months
2009	9/1/2009	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2009	9/1/2009	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2009	11/1/2009	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2009	11/1/2009	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2010	1/1/2010	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2010	1/1/2010	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 6000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2010	1/1/2010	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 500 lbs per 2 months
2010	1/1/2010	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2010	1/1/2010	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2010	1/1/2010	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, large footrope or midwater trawl, closed

2010	1/1/2010	4010 South	minor nearshore rockfish including black rockfish, limited entry trawl, small footrope trawl, 300 lbs per month
2010	1/1/2010	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 6000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2010	1/1/2010	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2010	1/1/2010	4200 North	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2010	1/1/2010	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, large and small footrope gear, closed
2010	1/1/2010	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, selective flatfish trawl, 300 lbs per month
2010	1/1/2010	4010 North	minor nearshore rockfish including black rockfish, limited entry trawl, multiple bottom trawl gear, closed
2010	3/1/2010	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 7000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2010	3/1/2010	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, closed
2010	3/1/2010	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed
2010	3/1/2010	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, closed
2010	3/1/2010	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 7000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2010	3/1/2010	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2010	5/1/2010	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2010	5/1/2010	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 600 lbs per 2 months
2010	5/1/2010	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2010	5/1/2010	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2010	7/1/2010	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 900 lbs per 2 months
2010	7/1/2010	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 7000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2010	7/1/2010	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 900 lbs per 2 months
2010	9/1/2010	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2010	9/1/2010	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 800 lbs per 2 months
2010	9/1/2010	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 800 lbs per 2 months
2010	9/1/2010	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months

2010	11/1/2010	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2010	11/1/2010	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2011	1/1/2011	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2011	1/1/2011	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 500 lbs per 2 months
2011	1/1/2011	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 6000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2011	1/1/2011	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2011	1/1/2011	4010 South	Minor nearshore rockfish and black rockfish, limited entry trawl, non-IFQ, 300 lbs per month
2011	1/1/2011	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2011	1/1/2011	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 6000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2011	1/1/2011	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2011	1/1/2011	4010 North	Minor nearshore rockfish and black rockfish, limited entry trawl, non-IFQ, 300 lbs per month
2011	1/1/2011	4200 North	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2011	3/1/2011	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 8500 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2011	3/1/2011	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, closed
2011	3/1/2011	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed
2011	3/1/2011	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 8500 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2011	3/1/2011	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, closed
2011	3/1/2011	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2011	5/1/2011	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2011	5/1/2011	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 600 lbs per 2 months
2011	5/1/2011	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2011	5/1/2011	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2011	7/1/2011	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 900 lbs per 2 months
2011	7/1/2011	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 900 lbs per 2 months
2011	7/1/2011	3427 South	minor nearshore rockfish including black, deeper nearshore, open

			access gear, 900 lbs per 2 months
2011	7/1/2011	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 900 lbs per 2 months
2011	9/1/2011	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2011	9/1/2011	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2011	11/1/2011	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2011	11/1/2011	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2012	1/1/2012	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2012	1/1/2012	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 500 lbs per 2 months
2012	1/1/2012	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 8500 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2012	1/1/2012	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2012	1/1/2012	4010 South	Minor nearshore rockfish and black rockfish, limited entry trawl, non-IFQ, 300 lbs per month
2012	1/1/2012	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2012	1/1/2012	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 8500 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2012	1/1/2012	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2012	1/1/2012	4200 North	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2012	1/1/2012	4010 North	Minor nearshore rockfish and black rockfish, limited entry trawl, non-IFQ, 300 lbs per month
2012	3/1/2012	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, closed
2012	3/1/2012	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed
2012	3/1/2012	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, closed
2012	3/1/2012	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2012	5/1/2012	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2012	5/1/2012	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 600 lbs per 2 months
2012	5/1/2012	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2012	5/1/2012	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2012	7/1/2012	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 900 lbs per 2 months

2012	7/1/2012	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 900 lbs per 2 months
2012	7/1/2012	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 900 lbs per 2 months
2012	7/1/2012	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 900 lbs per 2 months
2012	9/1/2012	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2012	9/1/2012	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2012	11/1/2012	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 1000 lbs per 2 months
2012	11/1/2012	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 1000 lbs per 2 months
2013	1/1/2013	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 600 lbs per 2 months
2013	1/1/2013	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 500 lbs per 2 months
2013	1/1/2013	4010 4200	minor nearshore rockfish including black rockfish, limited entry fixed gear, 8500 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2013	1/1/2013	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 500 lbs per 2 months
2013	1/1/2013	4010 South	Minor nearshore rockfish and black rockfish, limited entry trawl, non-IFQ, 300 lbs per month
2013	1/1/2013	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 600 lbs per 2 months
2013	1/1/2013	4200 North	minor nearshore rockfish including black rockfish, limited entry fixed gear, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than blue or black rockfish
2013	1/1/2013	4010 4200	minor nearshore rockfish including black rockfish, open access gears, 8500 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2013	1/1/2013	4010 North	Minor nearshore rockfish and black rockfish, limited entry trawl, non-IFQ, 300 lbs per month
2013	1/1/2013	4200 North	minor nearshore rockfish including black rockfish, open access gears, 5000 lbs per 2 months, no more than 1200 lbs per 2 months may be species other than blue or black rockfish
2013	3/1/2013	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, closed
2013	3/1/2013	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, closed
2013	3/1/2013	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, closed
2013	3/1/2013	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, closed
2013	5/1/2013	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2013	5/1/2013	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 600 lbs per 2 months
2013	5/1/2013	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 600 lbs per 2 months
2013	5/1/2013	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months

2013	7/1/2013	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 900 lbs per 2 months
2013	7/1/2013	3427 South	minor nearshore rockfish including black rockfish, deeper nearshore, limited entry fixed gear, 900 lbs per 2 months
2013	7/1/2013	3427 South	minor nearshore rockfish including black, deeper nearshore, open access gear, 900 lbs per 2 months
2013	7/1/2013	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 900 lbs per 2 months
2013	9/1/2013	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 800 lbs per 2 months
2013	9/1/2013	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 800 lbs per 2 months
2013	11/1/2013	4010 South	minor nearshore rockfish including black, shallow nearshore, open access gear, 1000 lbs per 2 months
2013	11/1/2013	4010 South	minor nearshore rockfish including black rockfish, shallow nearshore, limited entry fixed gear, 1000 lbs per 2 months
2013	12/3/2013	4010 South	Minor nearshore rockfish, limited entry fixed gear, 1000 lbs per months (includes landings in November)
2013	12/3/2013	4010 South	Minor nearshore rockfish including black rockfish, open access gear, 1000 lbs per 2 months
2014	1/1/2014	4010 North	limited entry trawl for non-IFQ species, minor nearshore rockfish and black rockfish, 300 lbs per month
2014	1/1/2014	4010 South	limited entry trawl for non-IFQ species, minor nearshore rockfish and black rockfish, 300 lbs per month
2014	1/1/2014	4200 North	non-trawl, limited entry, minor nearshore rockfish and black rockfish, 5000 lbs per 2 months, no more than 1200 lbs of which may be species other than black rockfish or blue rockfish
2014	1/1/2014	4010 4200	non-trawl, limited entry, minor nearshore rockfish and black rockfish, 8500 lbs per 2 months, no more than 1200 lbs of which may be species other than black rockfish or blue rockfish
2014	1/1/2014	4010 South	non-trawl, limited entry, minor shallow nearshore rockfish and black rockfish, 600 lbs per 2 months
2014	1/1/2014	3427 South	non-trawl, limited entry, minor deeper nearshore rockfish and black rockfish, 500 lbs per 2 months
2014	1/1/2014	3427 South	non-trawl, open access, minor deeper nearshore rockfish including black rockfish, 500 lbs per 2 months
2014	1/1/2014	4200 North	non-trawl, open access, minor nearshore rockfish including black rockfish, 5000 lbs per 2 months of no more than 1200 lbs may be species other than black rockfish
2014	1/1/2014	4010 4200	non-trawl, open access, minor nearshore rockfish including black rockfish, 8500 lbs per 2 months of no more than 1200 lbs may be species other than black rockfish
2014	1/1/2014	4010 South	non-trawl, open access, minor shallow nearshore rockfish including black rockfish, 600 lbs per 2 months
2014	3/1/2014	4010 South	non-trawl, open access, minor shallow nearshore rockfish including black rockfish, closed
2014	3/1/2014	3427 South	non-trawl, open access, minor deeper nearshore rockfish including black rockfish, closed
2014	3/1/2014	3427 South	non-trawl, limited entry, minor deeper nearshore rockfish and black rockfish, closed
2014	3/1/2014	4010 South	non-trawl, limited entry, minor shallow nearshore rockfish and black rockfish, closed
2014	5/1/2014	4010 South	non-trawl, limited entry, minor shallow nearshore rockfish and black rockfish, 800 lbs per 2 months
2014	5/1/2014	3427 South	non-trawl, limited entry, minor deeper nearshore rockfish and black rockfish, 600 lbs per 2 months
2014	5/1/2014	3427 South	non-trawl, open access, minor deeper nearshore rockfish including

			black rockfish, 600 lbs per 2 months
2014	5/1/2014	4010 South	non-trawl, open access, minor shallow nearshore rockfish including black rockfish, 800 lbs per 2 months
2014	7/1/2014	4010 South	non-trawl, open access, minor shallow nearshore rockfish including black rockfish, 900 lbs per 2 months
2014	7/1/2014	3427 South	non-trawl, open access, minor deeper nearshore rockfish including black rockfish, 900 lbs per 2 months
2014	7/1/2014	3427 South	non-trawl, limited entry, minor deeper nearshore rockfish and black rockfish, 900 lbs per 2 months
2014	7/1/2014	4010 South	non-trawl, limited entry, minor shallow nearshore rockfish and black rockfish, 900 lbs per 2 months
2014	9/1/2014	4010 South	non-trawl, limited entry, minor shallow nearshore rockfish and black rockfish, 800 lbs per 2 months
2014	9/1/2014	4010 South	non-trawl, open access, minor shallow nearshore rockfish including black rockfish, 800 lbs per 2 months
2014	11/1/2014	4010 South	non-trawl, open access, minor shallow nearshore rockfish including black rockfish, 1000 lbs per 2 months
2014	11/1/2014	3427 South	non-trawl, open access, minor deeper nearshore rockfish including black rockfish, 1000 lbs per 2 months
2014	11/1/2014	3427 South	non-trawl, limited entry, minor deeper nearshore rockfish and black rockfish, 1000 lbs per 2 months
2014	11/1/2014	4010 South	non-trawl, limited entry, minor shallow nearshore rockfish and black rockfish, 1000 lbs per 2 months

Appendix C. Estimated Area of California and Oregon Reefs by Depth

The 2017 assessment of Blue and Deacon Rockfishes ("BDR") uses estimates of habitat (reef area) to inform indices of abundance (see methods for CPUE indices in the main text). Other uses of habitat area information include allocation of yield estimates for California into Federal management areas (i.e. north and south of 40° 10′ N. latitude, roughly Cape Mendocino, CA) and consideration of the relative amount of nearshore versus offshore habitat in each state. Depth is an important determinant of suitable habitat for many species, including Blue and Deacon Rockfishes. Catch rates decline beyond depths of roughly 50 fathoms, although few direct observations exist to inform differences in density by depth for these two species (see Research Recommendations in the main text). We stratify area estimates in this appendix by state (Oregon and California north of Point Conception), depth bin, and management area within California (north and south of 40° 10′ N). Area estimates within Oregon are stratified north and south of Florence, OR, as this was used for development of abundance indices (see main text).

We used the best-available habitat layers for this analysis, however it is important to emphasize that both the habitat mapping resolution and coverage are different between the two states. California has continuous coverage of 2 m resolution mapping to the 3-nm line from Point Conception to the Oregon border. Whereas, approximately 60% of Oregon nearshore to the 3-nm line has been mapped at a 2 m resolution (See http://activetectonics.coas.oregonstate.edu/state_waters.htm). The area of Oregon nearshore selected to be mapped (60%) was based on multiple priorities including fisheries habitat, navigation, wave energy projects and natural disaster preparation. Beyond the 3 nm line in both California and Oregon, very few areas have been mapped at a 2m resolution. Instead, these habitat areas were interpreted and mapped using a synthesis of various data sources including side-scan sonar, bottom samples, seismic data, and multibeam bathymetry. Therefore, we do not recommend comparison of habitat areas between states based on these estimates.

California Reefs: data sources and area estimation

California Rocky reefs were identified using bathymetry and substrate data from the California Seafloor Mapping Project (CSMP) ('Tier 2' Product access 3/2013). A 5 m buffer was applied to the 'reef' shapefile to allow for potential error in positional accuracy. This layer is identical to the reef layer used in the China Rockfish assessment (Dick et al 2015 –see appendix F for further information)

For reefs beyond the 3 nm line, we used the 2004 Essential Fish Habitat map (PSMFC, 2004). Reefs were identified with the term 'hard' (see column 'IND'); this includes habitat types, Rocky Slope, Rocky Slope/Canyon Walls, Rocky Shelf, and Rocky Slope Gully.

Area (km^2) and proportion of reef within each fathom depth bin was calculated using zonal stats (Tables C1 and C2). Tables C3 and C4 report reef area associated with each of the 2 data sources (within 3 nm and beyond 3 nm). We overlaid the California reef polygon with the 90 m NOAA Coastal Relief Model (2011), set to 40, 50, 75, and 250 fathoms. The 40 fm line is a common management depth restriction for rockfish, and the 50 fm line corresponds to the maximum depth at which Blue and Deacon Rockfishes most often occur (Love et al. 2002). The 75 fm line approximates the depth limit at which BDR have been observed. The 250 fm line was selected for purposes of comparison to a similar analysis by ODFW (see "Oregon Reefs" section, below). We used zonal stats to calculate the depth pixel area for each reef within each depth strata. Due to time limitations this method was preferred because it can be performed quickly on polygons with large file sizes. Data was projected at NAD 1983 UTM Zone 10 N. We compared the reef area by the two different data sources. Approximately 61% of the reef area is from the high resolution CSMP (nearshore 0-3 nm) data source. Beyond the 3 nm line, reefs using the EFH data source were primarily located within the very deep 75 – 250 fm depth strata, located near the Mendocino fracture zone, Monterey Bay, and Santa Lucia Bank (near Morro Bay) (See Tables C3 and C4).

The greatest percentage of reef area (62%) is within the shallowest depth bin (0 – 40 fm), while 23% of reef area occurs at the deepest depth bin (75 - 250 fm). As noted above, depth is an important consideration when defining habitat. Although Blue and Deacon Rockfish are known to occur to at least 75 fathoms, reefs deeper than 75 fathoms are thought to have lower densities relative to shallower reefs (Miller and Geibel 1973, Love et al. 2002).

To estimate the fraction of total reef area by Federal management area in California, we calculated the proportion of habitat from shore to consecutively deeper maximum depths. The fraction of habitat north of Cape Mendocino is relatively stable out to 75 fathoms, ranging from 15% to 17% depending on the assumed maximum depth (Table C5).

Table C1: Summary of California reef area (km^2) by depth strata

	Km^2			
California Reefs	**0-40 fm**	**40-50 fm**	**50-75 fm**	**75-250 fm**
N. of Conception	953.9	115.4	116.0	360.1
South 40 10'	791.0	102.8	114.8	289.9
North 40 10'	162.9	12.6	1.1	70.1

Table C2: Percentage of California reef area (km^2) by depth strata

	percent			
California Reef	**0-40 fm**	**40-50 fm**	**50-75 fm**	**75-250 fm**
N. of Conception	61.7%	7.5%	7.5%	23.3%
South 40 10'	60.9%	7.9%	8.8%	22.3%
North 40 10'	66.0%	5.1%	0.5%	28.4%

Table C3: California Reef area (Point Conception to the California-Oregon border) by depth strata using the 2m high resolution CSMP data located within 3-nm.

Source: 2m CSMP				
	Km2			
California Reef	**0-40 fm**	**40-50 fm**	**50-75 fm**	**75-250 fm**
N. of Conception	945.5	112.4	59.2	1.8
South 40 10'	782.6	99.8	58.1	1.8
North 40 10'	162.9	12.6	1.1	0.0

Table C4: California Reef area (Point Conception to the California-Oregon border) by depths using the EFH data located beyond 3-nm.

Source: EFH 2004				
	Km2			
California Reef	**0-40 fm**	**40-50 fm**	**50-75 fm**	**75-250 fm**
N. of Conception	8.35	3.00	56.71	358.23
South 40 10'	8.35	3.00	56.71	288.13
North 40 10'	0.00	0.00	0.00	70.11

Table C5. Proportions of California reef area (all sources) by maximum depth and Federal management area, Point Conception to the California-Oregon Border. Reefs deeper than 75 fathoms are assumed to contain a negligible fraction of the stock.

	Proportion of Reef Habitat	
Depth (fathoms)	**South of 40° 10' N. Lat.**	**North of 40° 10' N. Lat.**
0-40	0.829	0.171
0-50	0.836	0.164
0-75	0.851	0.149

Oregon Reefs: data sources and area estimation

Rocky Reefs in Oregon were identified using “Benthic habitat characterization offshore the Pacific Northwest” Version 4 polygon shapefile (Goldfinger, 2014). Underlying lithology types included as ‘rocky reef’ are, boulder, cobble, cobble mix, hard, mixed, rock, and rock mix (see column ‘V4_Lith1’). A 5 m buffer was applied to ‘reef’ shapefile to allow for potential error in positional accuracy (Dick et al 2015 –see appendix F).

Area (km^2) and proportion of reef within each fathom depth bin was calculated using ArcGIS ‘split’ tool (Tables C6 and C7). . We overlaid the California Reef Polygon with the 90 m NOAA Coastal Relief Model (2011), set to 40, 50, 75, and 250 fathoms. The 40 and 50 fm lines were selected because this is a common management depth restriction for rockfish. The 250 fm line was selected as this is the deepest encounter of a Blue rockfish (Love et al, 2002). Here, the split tool in ArcGIS editor split the features of the reef polygon to each depth bin and area was calculated. Data was projected at NAD 1983 UTM Zone 10 N.

In Oregon, approximately 17% of the reef area is within 0- 40 fm line, while 38% of the reef area is within the deepest depth bin of 75 -250 fm (Table C5). A greater proportion of the deeper water reef is north of Florence, whereas a greater proportion of the shallow (0- 40 fm) reef is south of Florence. The total area of rocky reef identified in this appendix was very similar to area estimates provided by ODFW as supplemental materials to the Stock Assessment Review (STAR) panel (ODFW 2017).

Table C6: Summary of Oregon reef area (km^2) by depth strata

	Km^2			
Oregon Reefs	**0-40 fm**	**40-50 fm**	**50-75 fm**	**75-250 fm**
All of Oregon	394.5	240.7	812.9	884.0
N. Florence	178.4	176.3	614.7	740.1
S. Florence	216.0	64.4	198.2	143.9

Table C7: Percentage of Oregon reef area (km^2) by depth strata

	percent			
	0-40 fm	**40-50 fm**	**50-75 fm**	**75-250 fm**
All of Oregon	16.9%	10.3%	34.9%	37.9%
N. Florence	10.4%	10.3%	36.0%	43.3%
S. Florence	34.7%	10.3%	31.8%	23.1%

References:

Dick, E.J., M. Monk, I. Taylor, M. Haltuch, T.S. Tsou, P. Mirick. 2016. Status of China rockfish off the U.S. Pacific Coast in 2015. Pacific Fishery Management Council.

Goldfinger, C., S.K. Henkel, C. Romsos, B. Havron, and B. Black. 2014. Benthic habitat characterization offshore the Pacific Northwest Volume 1: evaluation of continental shelf geology. US Dept. of the Interior, Bureau of Energy Management, Pacific OCS Region, OCS Study BOEM 662 (2014):161.

Love, M.; Yoklavich, M., Thorsteinson L. 2002. The rockfishes of Northeast Pacific. University of California Press. Berkeley. 416 pp.

Miller, D. and J. Geibel. 1973. Summary of Blue Rockfish and Lingcod Life Histories; A Reef Ecology Study; and Giant Kelp, *Macrocystis pyrifera*, experiments in Monterey Bay, California Department of Fish and Game Fish Bulletin 158, 137 p.

NOAA. National Geophysical Data Center. 2011. Coastal Relief Model. Available from http://ngdc.noaa.gov/mgg/coastal/crm.html

Oregon Department of Fish and Wildlife, 2017. Quantifying Oregon Near- and Offshore Rocky Reef Substrates in Estimation of Potential BDR Habitat. Report submitted to the Pacific Fishery Management Council's Stock Assessment Review Panel for Blue and Deacon Rockfish. Electronic submission-- OR_BDR_Substrate appendix.docx *ftp://ftp.pcouncil.org/pub/GF_STAR3_2017_Blue_Deacon_CAScorp/Draft%20Blue-Deacon%20Assessment/*

Pacific States Marine Fisheries Commission, 2004, West Coast Benthic Habitat Map: Pacific States Marine Fisheries Commission/Pacific Fishery Management Council Map, Edition 1.0, Portland, OR, USA.

Appendix D. Allocation of Yield Among Federal Management Areas

The 2017 California base model for Blue and Deacon Rockfishes (BDR) represents U.S. waters between 34° 27′ N. latitude (roughly Point Conception, California) and the California-Oregon border (42° N. latitude). Federal management of the minor nearshore rockfish, which includes BDR, is based on areas north and south of 40° 10′ N latitude, near Cape Mendocino. Therefore, yield estimates from the California base model must be divided between the northern and southern management areas in order to determine the contribution of BDR to the minor nearshore rockfish overfishing limit (OFL).

Allocation of the OFL could, ideally, be based on a fishery-independent survey of abundance, but lacking that information several alternatives exist. Previous allocations have used catch as a proxy for abundance when no other information was available (Dick and MacCall, 2010; Dick et al. 2011). Recent catches of BDR in the recreational and commercial sectors suggest that roughly 2.1% and 41.7%, respectively, of catches in these sectors are landed north of Cape Mendocino (Tables D1 and D2). Since removals from the recreational sector are so much larger than the commercial sector, the total removals in the northern management area (recreational and commercial combined) are approximately 4% of the total removals taken north of Point Conception over the period 2013-2015 (7.64 + 8.84 = 16.48 mt out of 371.88 + 21.18 = 393.06 mt, total). This is an approximation due to 1) differences in area fished vs. port of landing and 2) inconsistencies between CRFS district boundaries, commercial port complexes, and Federal management areas, but further refinement would likely not result in major changes in a purely catch-based allocation.

Table D1. California recreational catch (types A and B1) by CRFS District, 2013-2015. District 6 occurs mainly north of Cape Mendocino. Source: RecFIN.

	Recreational (A+B1) catch [mt] by CRFS District					
Year	**District 3**	**District 4**	**District 5**	**District 6**	**District 3-6**	**District 6 as % of total**
2013	49.69	34.99	15.79	2.32	102.79	2.3%
2014	76.66	25.10	10.57	1.42	113.75	1.2%
2015	93.80	42.31	15.33	3.89	155.34	2.5%
Grand Total	**220.15**	**102.40**	**41.69**	**7.64**	**371.88**	**2.1%**

Table D2. Commercial landings of BDR at California port complexes located north (“CRS+ERK”) and south (“MRO-BRG”) of Cape Mendocino. Source: CALCOM.

	Commercial Landings [mt]			
Year	**CRS+ERK**	**MRO-BRG**	**Total**	**CRS+ERK as % of total**
2013	3.37	2.73	6.10	55.3%
2014	1.90	4.00	5.90	32.2%
2015	3.57	5.61	9.18	38.9%
Grand Total	8.84	12.34	21.18	41.7%

Recent advances in habitat mapping allow us to estimate the relative amount of reef habitat in each area (e.g. the California Seafloor Mapping Project, https://walrus.wr.usgs.gov/mapping/csmp/). If we assumed that average density of BDR is constant over the assessed area, the fraction of BDR occurring north of Cape Mendocino would be equal to the fraction of habitat in the same area: approximately 16.4% (see

Appendix C for details). However, the assumption of equal density may not be accurate, and no direct estimates of density are available from a fishery-independent survey with adequate spatial coverage.

We propose an alternative approach that combines existing habitat information with a proxy for fish density – catch per unit effort. Although data from the CRFS onboard CPFV observer program are more precise in terms of total catch, effort, and location, relatively few samples have been taken north of Cape Mendocino. Sampling coverage for the dockside survey is spatially more complete, in that numerous samples exist in the northern management area. We therefore used the private boat CPUE data to develop a spatial index (with CPUE assumed proportional to density), and multiplied the area-specific CPUE estimates by the amount of habitat to produce a spatial index of relative abundance.

Data were filtered using the same methods detailed in the assessment for the CRFS private boat dockside index. Years prior to 2013 were subsequently dropped, to create an index that is representative of recent catch rates in each area. Sample sizes (number of trips) for the final data set are shown in Table D3.

Table D3. Number of trips by year and subregion in the CRFS private boat spatial CPUE index.

	YEAR				
SUBREGION	**2013**	**2014**	**2015**	**2016**	**Total**
DelNorte-Humboldt	195	179	247	209	830
Mendocino-Sonoma	119	151	300	208	778
S.F. Bay Area	318	351	479	284	1432
Monterey-Santa Cruz	845	920	1161	706	3632
San Luis Obispo	621	709	654	792	2776
Total	**2098**	**2310**	**2841**	**2199**	**9448**

We modeled CPUE (BDR per angler trip) using a negative binomial regression with subregion (defined as county groups, see Table D3) as a qualitative covariate and pooling data across years 2013-2016. Including the subregion covariate reduced AIC by 291 points relative to the null (intercept-only) model. CPUE in the Del Norte – Humboldt subregion was lower than the other subregions in the model (Table D4). When CPUE is multiplied by the percentage of habitat area north of 40 10 North latitude, the expected percentage of the stock that occurs north of Cape Mendocino drops to 10.1%, compared to the habitat-based estimate of 16.4% (Table D4).

Table D4. Estimated CPUE, % Habitat Area, and Relative Abundance by Subregion

Subregion	CPUE	Area (%)	CPUE x Area	Relative Abundance
DelNorte-Humboldt	0.67	16.4%	0.110	10.1%
Mendocino-Sonoma	1.24	14.2%	0.176	16.2%
S.F. Bay Area	0.87	33.9%	0.296	27.2%
Monterey-Santa Cruz	1.50	10.2%	0.153	14.1%
San Luis Obispo	1.39	25.4%	0.352	32.4%

This approximation assumes that CPUE in Del Norte and Humboldt counties is representative of CPUE north of 40° 10′ North latitude, although the Federal management boundary lies slightly to the north of the southern border of Humboldt County. The estimated percentage of habitat area north of 40° 10′ North latitude (16.4%) is based on the correct Federal management boundary, not the county borders.

This analysis assumes the amount of habitat area is known without error. CPUE is assumed proportional to local density, and regional differences in factors unrelated to CPUE are not accounted for in this analysis. Also, while the amount of reef habitat area north of Cape Mendocino is fairly constant out to a depth of roughly 75 fathoms (which is thought to include the majority of BDR habitat) estimates do vary slightly depending on the maximum depth chosen (See Table C5 in Appendix C). Further research is needed on changes in BDR density with depth to better understand what fraction of the stock may occur in deeper water, and whether depth distributions vary by species.

If the Council chooses to manage Blue and Deacon Rockfishes as a component of the northern and southern Minor Nearshore Rockfish complexes, the STAT recommends that 10% of the yield from the California base model be allocated to the northern complex, with the remaining 90% allocated to the southern complex. The STAT views this as an improvement over allocations based solely on catch or habitat and a reasonable approximation of the spatial distribution of the stock, given the results in Table D4 and the above-mentioned uncertainties. As noted in the research recommendations, this estimate could be further improved by establishing a fishery-independent survey of nearshore stocks.

Literature cited in this appendix

Dick, E. J. and A. D. MacCall. 2010. Estimates of sustainable yield for 50 data-poor stocks in the Pacific coast groundfish fishery management plan. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-460, 201 p.

Dick, E.J., S. Ralston, and D. Pearson. 2011. Status of Greenspotted Rockfish, *Sebastes chlorostictus*, in U.S. waters off California. Pacific Fisheries Management Council, Portland, OR, 360 p.

Appendix E. CDFW Aerial Survey Kelp Index, 2002-2016

Morgan Ivens-Duran
California Department of Fish and Wildlife

Rationale
The 2007 Blue Rockfish assessment (Key et al. 2008) identified incorporation of environmental factors as a research need, particularly with respect to explaining recruitment patterns in the Southern California Bight (SCB). The 2007 assessment authors identified kelp cover as a potential environmental link and constructed a kelp index due to the purported habitat association by young-of-the-year (YOY) Blue Rockfish. For the 2017 assessment of Blue and Deacon Rockfishes, we took advantage of more recent data to assess trends in kelp abundance from 2002 – 2016 in the SCB.

Prior Assessment
The 2007 assessment kelp index relied on historical survey data collected by Kelco (ISP Alginates[1]). Surveys were flown multiple times each year from 1957-1962 and 1968-2007. Data were collected at the level of California Department of Fish and Wildlife (CDFW)-defined kelp beds and include the estimated total kelp biomass and estimated total harvestable biomass. The 2007 assessment authors created an index of kelp abundance based on 17 of the beds within the SCB (focusing on the Santa Barbara Channel; Figure E1) via the following process:

1. Calculated an annual average kelp biomass for each bed (i.e. for each bed, averaged the biomass estimates from all surveys conducted during that year). This generated an estimate of mean kelp biomass for each bed*year combination.
2. Calculated the long-term average annual per-bed biomass (averaged the values in Step 1 across all years)
3. Calculated an annual per-bed index as the value in Step 1 divided by the value in Step 2 (i.e. annual average bed biomass divided by the long-term average per-bed biomass). This generated a time series for each bed, each having a mean of one.
4. Calculated an annual index as the average of the values in Step 3 across all beds for that year (i.e. average of the per-bed fraction across beds).

[1] Reed, D. C. . 2010. SBC LTER: Reef: Historical Kelp Database for giant kelp (*Macrocystis pyrifera*) biomass in California and Mexico. Santa Barbara Coastal LTER. doi:10.6073/pasta/74d5336cf9f1297b475db8ec6ed08819. For a more detailed methodology description, visit: http://sbc.lternet.edu/external/Reef/Protocols/Historical_Kelp/Historical_Kelp_Overview.pdf

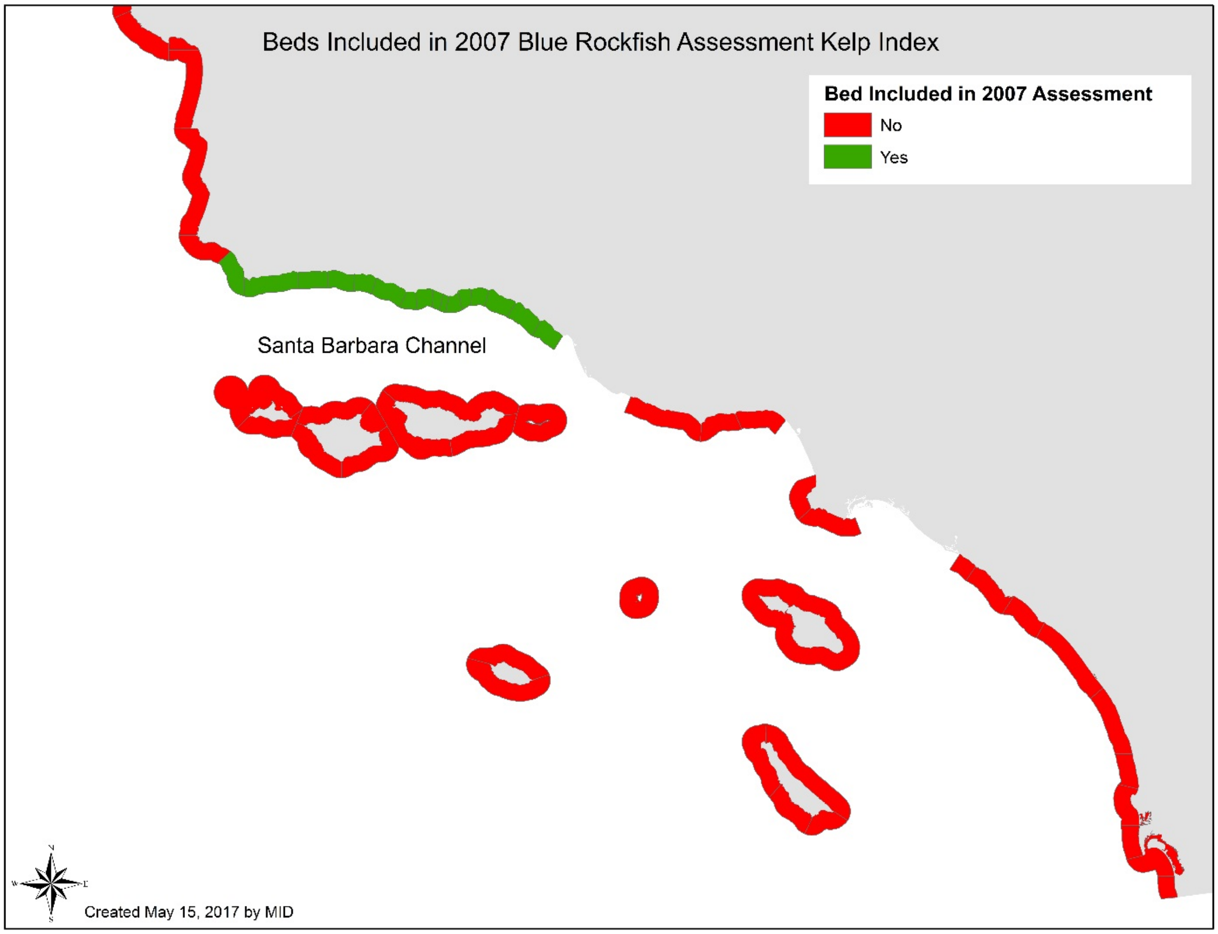


Figure E1. Kelp Beds included in the 2007 Blue Rockfish Assessment index.

A declining trend in this kelp index was presented as evidence that the declining catches of Blue Rockfish in the SCB could be due to a recruitment failure (i.e. loss of YOY habitat), but there are limitations to the analysis. Data from the Kelco surveys is only available through 2007 (which did not present constraints to the assessment at the time, but does pose an issue for the 2017 assessment). The 2007 assessment authors appear to have used the biomass estimates to generate an index of kelp canopy area, however there is no quantified relationship presented which would support converting the estimated amount of biomass within each kelp bed (kg) to spatial extent of the kelp canopy (m^2). In addition, the index only used information from the Santa Barbara Channel, and therefore presents an incomplete picture of dynamics in the SCB. Surveys were only flown south of Point Conception, preventing northern expansion of the kelp index beyond the SCB. Lastly, the index relies on visual estimates of biomass preventing any subsequent validation or quantification of error.

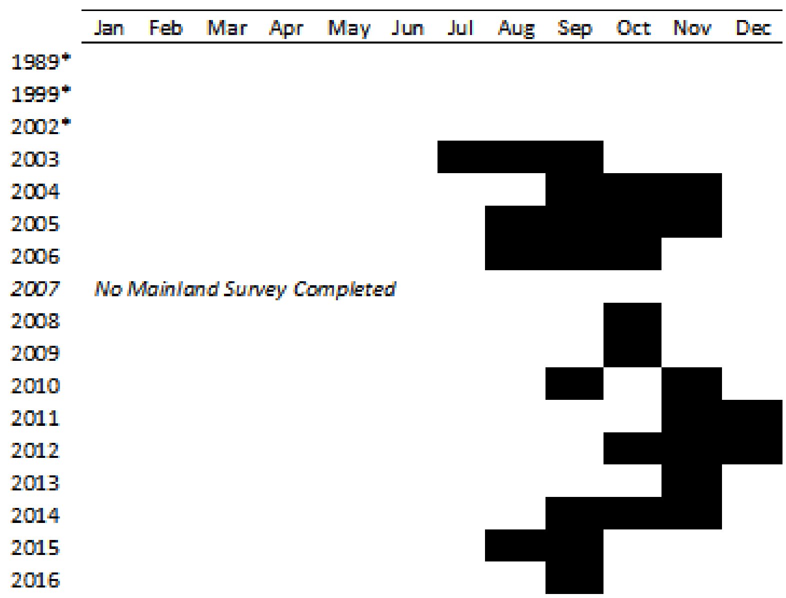
2017 Assessment

Given the termination of the Kelco surveys in 2007, for the 2017 assessment we examined trends in kelp abundance using recent aerial surveys of kelp cover conducted by the California Department of Fish and Wildlife (CDFW 2016).

Data Collected, Methodology

The first CDFW aerial survey was conducted in 1989, with another survey in 1999; annual surveys began in 2002. While attempts were made to fully survey the entirety of the SCB, in any given year discrete areas may not have been sampled; thus, calculations of kelp cover likely underestimate total kelp presence. A similar caveat applies to the central and northern California areas as well. Data from multiple flights was combined to generate a single geospatial data file (shapefile) showing kelp distribution during the time of the survey. Individual survey flights generally took place from mid-summer through mid-fall, prior to the onset of winter storms (Table E1).

Table E1. Timing of CDFW aerial kelp survey flights. For years marked with an *, survey timing was not identified in the publically available metadata. In 2007, only the Channel Islands were surveyed.



The 1999-2016 shapefiles were created from digital multispectral imagery with red, green, blue and near-infrared bands. The 2002-07 photographs were taken from 10,500 feet using Partenavia aircraft (occasionally, portions of the shapefile were digitized from jpeg files available from other surveys in the area). From 2008 – 2016, surveys were flown at 12,500-14,000 feet with new camera systems and software which allowed for separation of both surface and subsurface kelp. Surveys were timed to coincide with periods of minimal change between high and low tides to avoid strong tidally-induced currents; surveys were also timed to avoid glare from overhead sun.

As the subsurface canopy information is only available for the latter portion of the time series and is not representative of a consistent position within the water column (it varies depending on turbidity and other environmental conditions), only surface kelp canopy information was used.

Spatial Extent of Analysis

In order to evaluate the spatial heterogeneity of kelp abundance trends, CDFW kelp beds (as described in Reed et al., 2010) were grouped into seven regions (Figure E2):

Table E2. CDFW beds comprising each region within the Southern California Bight.

Region	CDFW Kelp Bed Numbers
South Coast	1-10
Santa Monica	13-17
Santa Barbara	18-34
E Catalina Islands	101-106
San Nicolas	107-108
E Channel Islands	109-112
W Channel Islands	113-118

Probable kelp habitat in the Southern California Bight was defined as areas which (1) occurred within the CDFW kelp beds mentioned above and 2) were shallower than 35m. These filters were originally applied to prevent artificially deflated calculations of percent cover and excluded gaps between CDFW kelp beds, representing areas without rocky substrate suitable for kelp colonization (CSCMP 2009), and water depths exceeding those where *Macrocystis* is typically found in Southern California (Foster and Schiel 1985).

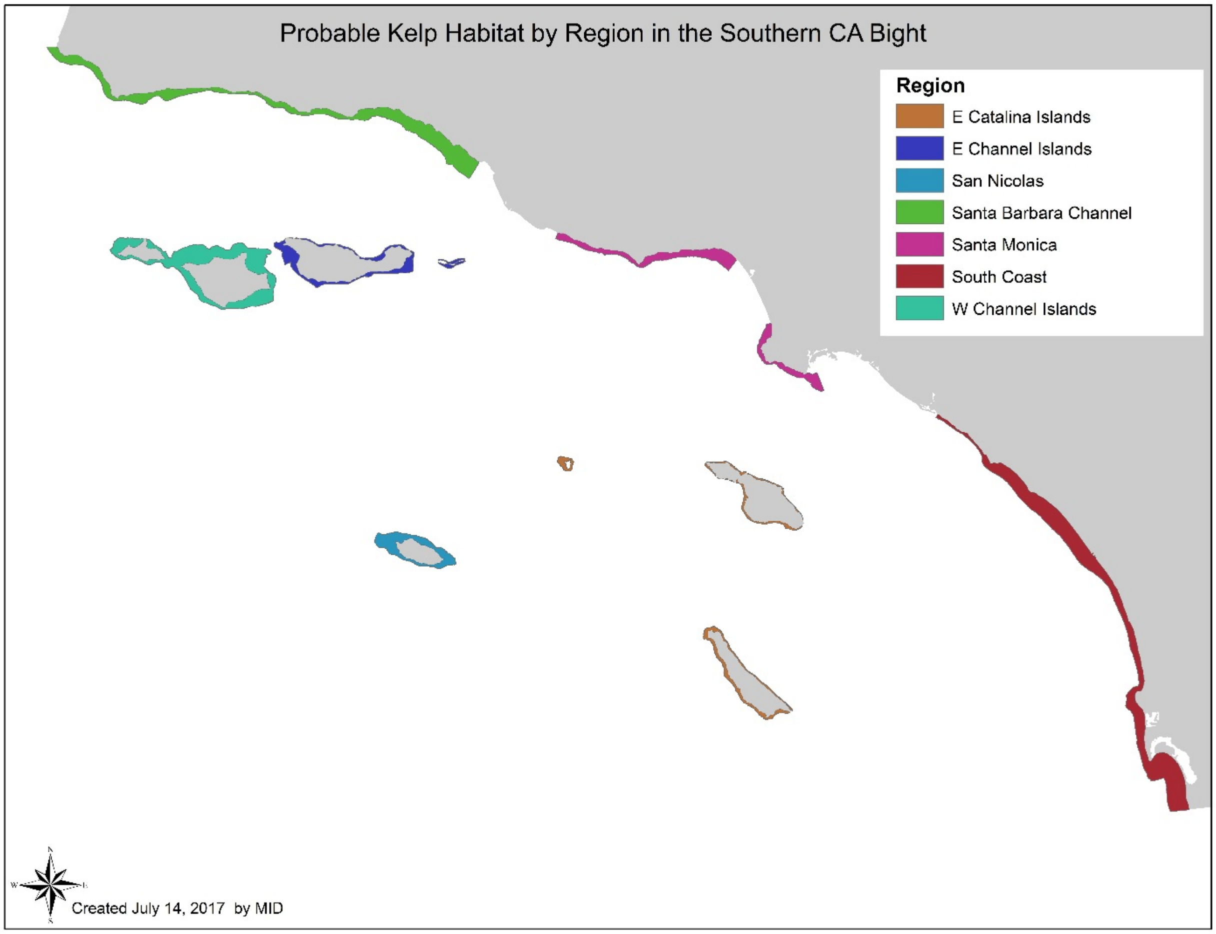


Figure E2. Probable Kelp Habitat by Region in the Southern California Bight.

In the final analysis, trends in kelp abundance were assessed as total surface area rather than percent cover. However, since the vast majority of kelp canopy identified in the aerial survey was contained with the boundaries defining probable kelp habitat, the filtered versions of the annual surveys were used in those calculations.

Kelp Canopy Cover

Aerial survey shapefiles were downloaded from the CDFW FTP server. The Clip, Join, Dissolve, and Calculate Geometry tools in ESRI ArcGIS (version 10.3) were used to calculate the total area (in square meters) of kelp for each Region within the probable kelp habitat boundaries. Trends in kelp cover (in hectares) were plotted using the ggplot2 package in R (version 3.3.3) for all regions (Figure E3) and for only the three regions in the northern portion of the Southern California Bight (Figure E4), as catch rates of Blue (and Deacon) Rockfish appear to be greatest in the northern Bight (see main text). While kelp cover varies from year to year and between regions, there is a general downward trend evident in all regions and very low kelp cover is seen in 2013 (which the available recruitment indices and base model identify as a high recruitment year).

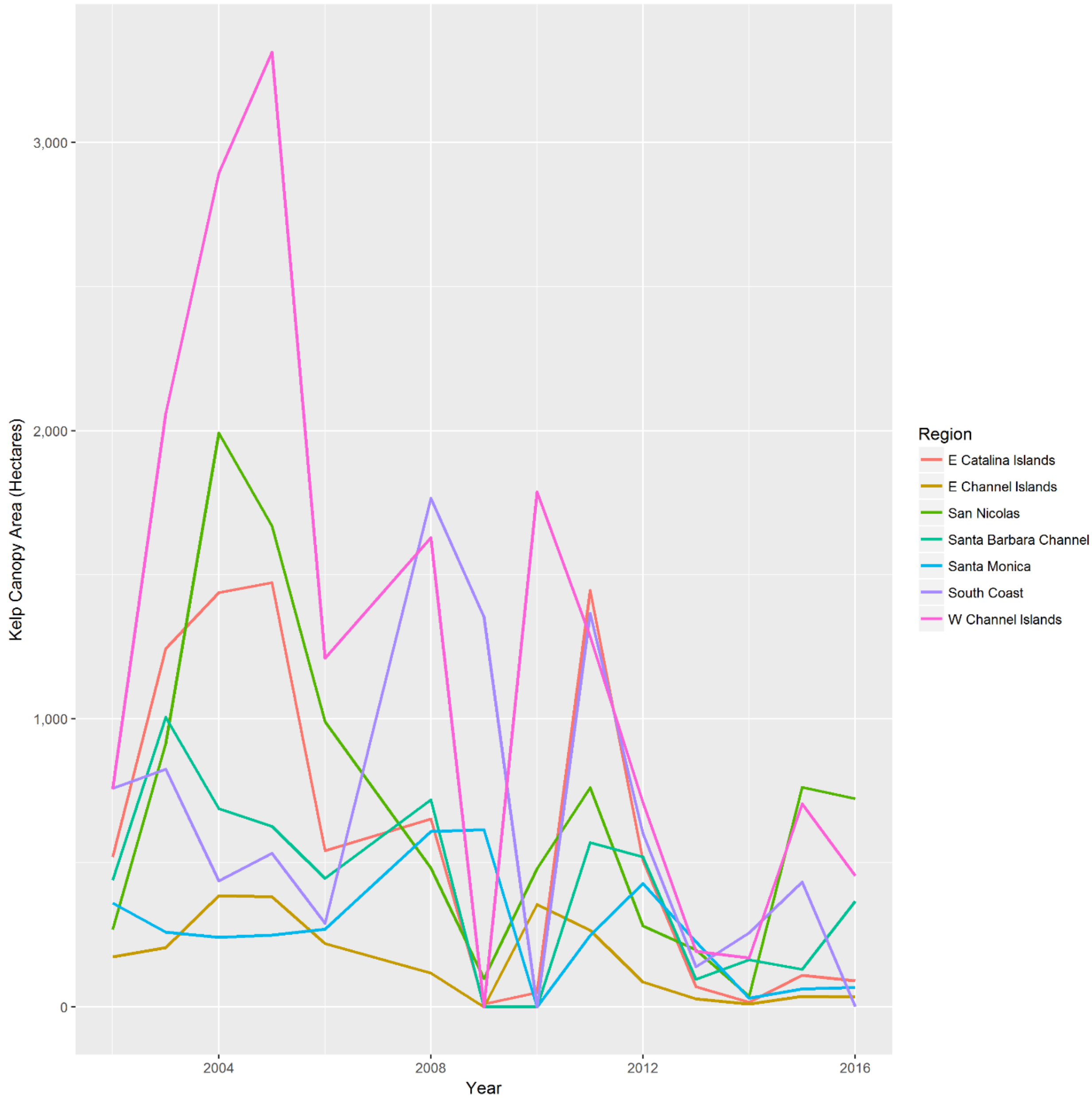


Figure E3. Trends in kelp canopy cover (hectares) in the Southern California Bight by Region, 2002 – 2016. Note that data from 2007 is not included.

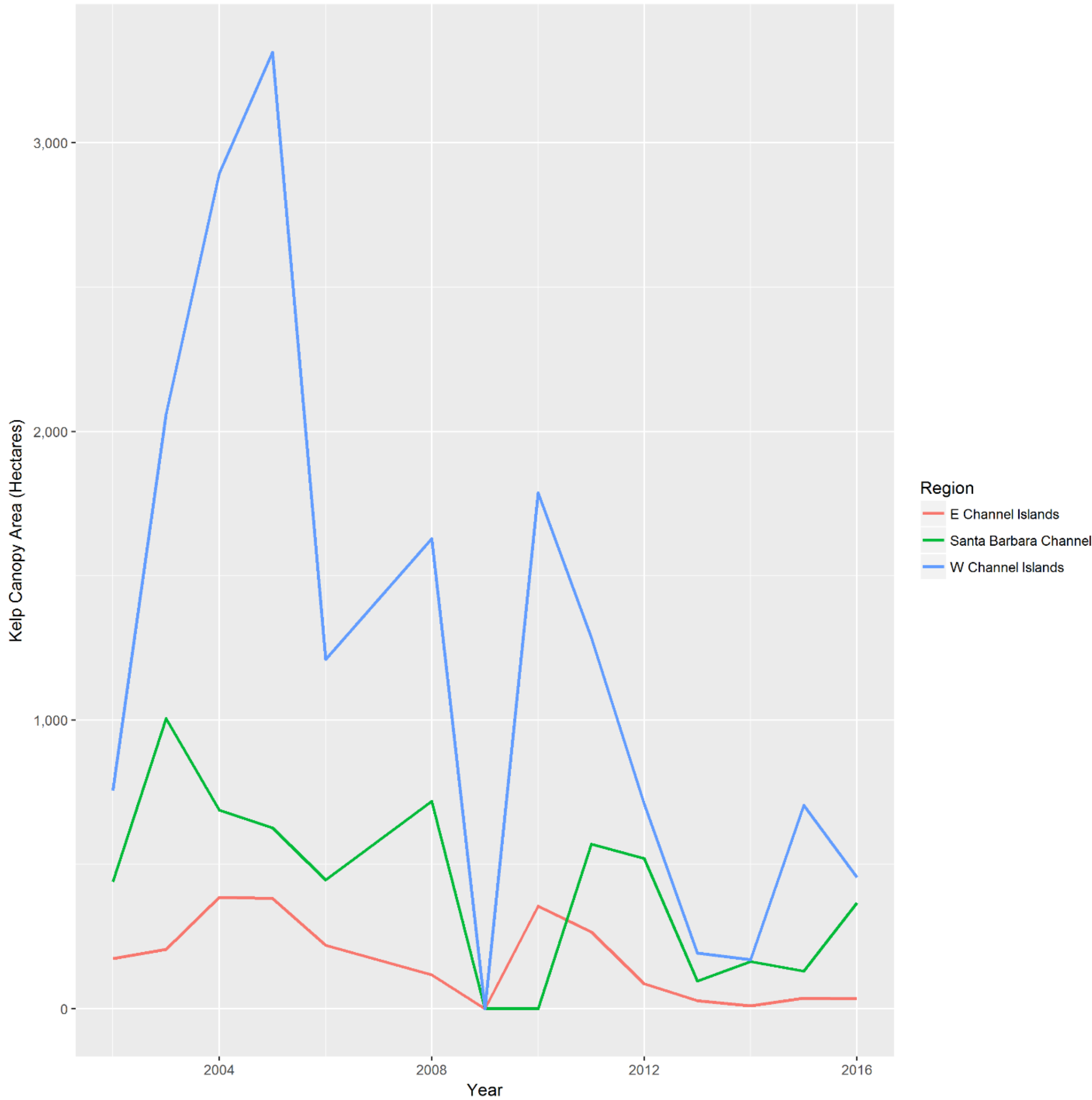


Figure E4. Trends in kelp canopy cover (hectares) in the northern Southern California Bight by Region, 2002 – 2016. Note that data from 2007 is not included.

Summary of Findings

As noted by Love et al. (2002), YOY Blue Rockfish may associate briefly with the kelp canopy, but generally associate with rocky substrate early after settlement. The 2007 assessment presented an index of kelp canopy as part of an investigation into factors contributing to stock productivity. Aerial survey data over the past 10-15 years show a declining trend in kelp canopy cover in the Southern California Bight. This is in contrast to increases in newly-developed indices of stock abundance from the area (e.g. CalCOFI and recreational CPUE indices; see main text) and strong recruitment years (e.g. 2013) in the Southern California Bight appear to occur despite low levels of kelp cover. However, the CalCOFI index is a measure of spawning stock biomass, not recruitment, and data informing recruitment in the base model are limited to areas north of Point Conception. These results suggest that estimates of kelp canopy cover from CDFW aerial surveys are a poor indicator of long-term trends in stock productivity for Blue and Deacon Rockfishes. Further investigation into physical processes (e.g. temperature, upwelling) that may influence factors affecting the productivity of these species, such as recruitment, post-settlement mortality, and growth is recommended.

REFERENCES

California Department of Fish and Wildlife. 2016. Aerial Kelp Survey. ftp://ftp.dfg.ca.gov/R7_MR/BIOLOGICAL/Kelp/

California Seafloor and Coastal Mapping Program. 2009. Predicted Substrate of Southern California. https://map.dfg.ca.gov/arcgis/rest/services/Project_Marine/Marine_Habitat/MapServer/45

Cavanaugh, K.C., D.A. Siegel, D.C. Reed and T.W. Bell. 2014. SBC LTER: Time series of kelp biomass in the canopy from Landsat 5, 1984 -2011. Santa Barbara Coastal LTER. doi:10.6073/pasta/329658f19d5e61dda0be5ee883cd1c41

Foster, M.S. and D.R. Schiel. 1985. The ecology of giant kelp forests in California: a community profile. U.S. Fish Wild. Serv. Biological Report 85(7.2):1-152.

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

Appendix F. Model Evaluation to Determine an OFL for BDR in Washington Waters

Blue and Deacon Rockfishes are currently federally managed as part of the minor nearshore rockfish complex. The management area north of 40° 10′ N. includes northern California, Oregon, and Washington. The component overfishing limits (OFLs) for BDR in Oregon and Washington have previously been developed using estimates from a 2011 depletion corrected average catch (DCAC) analysis. State specific minor nearshore rockfish OFLs were then, in part, based on the proportion of projected impacts for nearshore stocks.

The full stock assessment for BDR in Oregon waters presented in this document provides an independent estimate of stock size, stock status, and thus OFLs for Oregon, leaving a need to develop a component OFL for BDR in Washington waters. There are several possible approaches for determining a Washington OFL for BDR, some of which include:

1. status quo – a continuation of the Washington component OFL developed using the 2011 DCAC analysis, where the Oregon and Washington combined OFL would be split using catch proportions over recent years;

2. conduct a new data limited analysis, such as DBSRA or DCAC, to directly estimate an OFL for Washington; and

3. add Washington BDR catches to the Oregon base model to evaluate the increase in OFL that results.

The analysis presented here uses approach 3 because of the relatively low amount of BDR catch in Washington coupled with the ability to use the integrated Oregon assessment as a statistical tool to provide an OFL estimate based on the available Washington catch data (Table F1).

There is only an appreciable amount of BDR catch from the Washington recreational fishery so estimates of recreational landings and discards were added to the two associated fleets (recreational ocean boat landings fleet and recreational ocean boat discards fleet) used in the Oregon base assessment model. Estimates of recreational landings in Washington were available from 1990 to 2016. A landings catch ramp was then assumed from 1970 to 1989, where catch in 1989 was set at the average catch from 1990 to 1991. Estimates of recreational discards in Washington were available from 2002 to 2016, where dead discards were estimated by applying GMT discard mortality rates by depth for Blue Rockfish (18% for depths 0-10 fm, 30% for 11-20 fm, 43% for 21-30 fm, and 100% for greater than 30 fm). Dead discards from 1990 to 2001 were set to the average level of discard mortality from 2002 to 2016 (0.28 mt). Discard mortality previous to 1990 was assumed to be negligible.

The amount of Washington catch relative to Oregon catch that was added to the Oregon base assessment model was small (4.6% over the last 10 years; Figure F1). The combined Oregon and Washington catch model resulted in a slightly higher estimate of spawning output (318 million eggs compared to 296 million eggs for the Oregon base model) and similar depletion (69% for both models) in 2017 (Figure F2). Estimates of selectivity were essentially unchanged between the two models. The estimated Washington OFL is 8.7 mt for 2019 and 8.4 mt for 2020 when using the default harvest policy where the OFL is the calculated total catch determined by FSPR=50% (ABC=ACL; Table F2). The predicted Washington OFL when using catch levels specified by the GMT (i.e., 2019-2028 catches set to average historical, 2005-2014, catch level for Oregon and Washington) is 8.7 mt for 2019 and 8.9 mt for 2020 (Table F3).

Table F1. Oregon and Washington recreational landings (mt) and discards (mt) for the ocean boat fleet.

	Oregon Recreational Ocean Boat		Washington Recreational Ocean Boat		Combined Recreational Ocean Boat	
Year	Landings	Discards	Landings	Discards	Landings	Discards
1970	0.00	0.00	0.00	0.00	0.00	0.00
1971	1.15	0.00	0.25	0.00	1.40	0.00
1972	2.30	0.00	0.50	0.00	2.80	0.00
1973	3.46	0.00	0.74	0.00	4.20	0.00
1974	4.61	0.00	0.99	0.00	5.60	0.00
1975	5.76	0.00	1.24	0.00	7.00	0.00
1976	6.91	0.00	1.49	0.00	8.40	0.00
1977	8.07	0.00	1.74	0.00	9.80	0.00
1978	9.22	0.00	1.98	0.00	11.20	0.00
1979	10.37	0.09	2.23	0.00	12.60	0.09
1980	19.74	0.17	2.48	0.00	22.22	0.17
1981	18.53	0.16	2.73	0.00	21.26	0.16
1982	10.38	0.09	2.97	0.00	13.35	0.09
1983	22.80	0.20	3.22	0.00	26.03	0.20
1984	29.31	0.26	3.47	0.00	32.78	0.26
1985	15.98	0.14	3.72	0.00	19.70	0.14
1986	4.49	0.04	3.97	0.00	8.46	0.04
1987	6.74	0.06	4.21	0.00	10.95	0.06
1988	7.16	0.06	4.46	0.00	11.62	0.06
1989	11.77	0.10	4.71	0.00	16.48	0.10
1990	21.20	0.19	5.52	0.07	26.72	0.26
1991	14.90	0.13	3.90	0.07	18.80	0.20
1992	23.60	0.21	6.30	0.07	29.89	0.28
1993	67.32	0.59	8.59	0.07	75.91	0.66
1994	7.75	0.07	2.55	0.07	10.31	0.14
1995	21.35	0.19	2.51	0.07	23.86	0.26
1996	26.50	0.23	3.27	0.07	29.77	0.31
1997	59.79	0.52	4.31	0.07	64.10	0.60
1998	58.48	0.51	4.01	0.07	62.49	0.58
1999	37.03	0.32	4.58	0.07	41.61	0.40
2000	35.04	0.31	2.64	0.07	37.68	0.38
2001	33.20	0.49	1.89	0.07	35.10	0.57
2002	15.34	0.08	0.88	0.03	16.23	0.11
2003	23.21	0.23	0.90	0.02	24.11	0.25
2004	19.06	0.23	1.24	0.03	20.31	0.26
2005	31.10	0.76	2.25	0.07	33.35	0.83
2006	11.52	0.30	2.00	0.09	13.52	0.39
2007	16.16	0.56	1.56	0.07	17.72	0.64
2008	15.14	0.68	1.15	0.02	16.29	0.69
2009	15.28	0.94	0.67	0.04	15.95	0.99
2010	21.17	0.79	2.13	0.18	23.30	0.96
2011	20.44	0.76	1.11	0.11	21.55	0.87
2012	25.12	0.71	1.31	0.07	26.43	0.77
2013	23.06	0.78	0.74	0.13	23.80	0.91
2014	18.11	0.62	0.51	0.04	18.62	0.66
2015	28.04	1.68	1.16	0.06	29.20	1.74
2016	19.95	0.71	2.02	0.17	21.97	0.88

Table F2. Projection of BDR OFL for the Oregon BDR base case model, the same model but with Washington recreational catch added, and the difference between the two model runs. The total projected catch used for 2017 and 2018 was 30.3 mt, which was the average over the most recent two years (2015 – 2016; See Table F1). The predicted OFL is the calculated total catch determined by FSPR=50% (ABC=ACL).

Year	Oregon OFL (mt)	Oregon (add Wash. catch) OFL (mt)	Inferred Wash. OFL (mt)
2017	109.1	117.4	8.4
2018	110.1	118.5	8.5
2019	112.3	121.0	8.7
2020	108.8	117.2	8.4
2021	105.7	113.8	8.1
2022	102.6	110.4	7.8
2023	99.7	107.3	7.6
2024	97.2	104.6	7.4
2025	95.0	102.2	7.2
2026	93.2	100.3	7.0
2027	91.7	98.6	6.9
2028	90.4	97.3	6.8

Table F3. Projection of BDR OFL for the Oregon BDR base case model, the same model but with Washington recreational catch added, and the difference between the two model runs. The total projected catch used for 2017 and 2018 was 30.3 mt, which was the average over the most recent two years (2015 – 2016; See Table F1). The predicted OFL is the calculated total catch determined by FSPR=50% (ABC=ACL). The predicted OFL is the calculated total catch determined by the catch levels specified by the GMT (i.e., 2019-2028 catches set to average historical, 2005-2014, catch level).

Year	Oregon OFL (mt)	Oregon (add Wash. catch) OFL (mt)	Inferred Wash. OFL (mt)
2017	109.1	117.4	8.4
2018	110.1	118.5	8.5
2019	112.3	121.0	8.7
2020	115.1	124.0	8.9
2021	117.5	126.6	9.1
2022	119.3	128.5	9.3
2023	120.6	129.9	9.4
2024	121.6	131.0	9.4
2025	122.3	131.8	9.5
2026	122.9	132.5	9.6
2027	123.5	133.1	9.6
2028	123.9	133.6	9.6

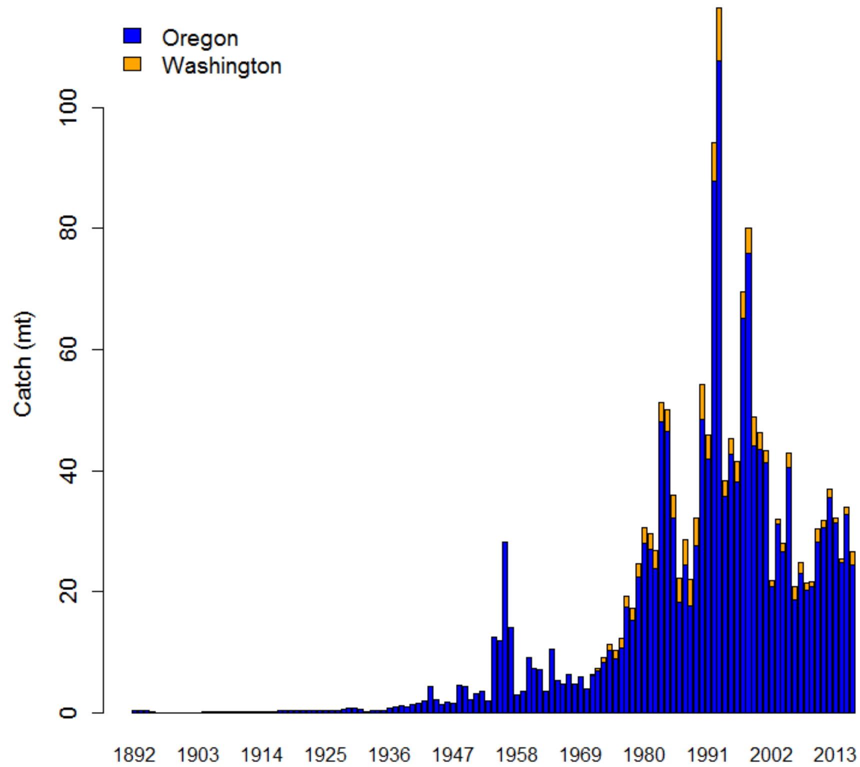


Figure F1. Stacked time series showing total Oregon and total Washington catch (mt) used in this analysis.

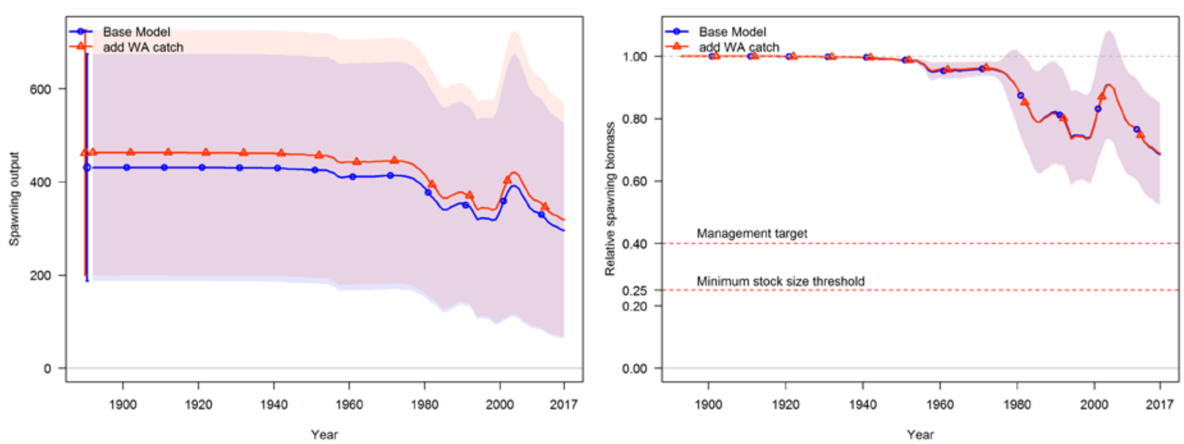


Figure F2. Comparison of spawning output (left) and depletion (right) for the Oregon base model and the Oregon base model with added Washington catch.

Appendix G. Depletion-Corrected Average Catch (DCAC) Estimate of Sustainable Yield for Blue & Deacon Rockfishes south of Point Conception, California.

E.J. Dick, NOAA Fisheries, SWFSC
edward.dick@noaa.gov

The 2007 assessment of blue rockfish (Key et al. 2008) included data for two species, now formally recognized as Blue and Deacon Rockfishes (BDR), and did not include portions of the stock in U.S. waters south of Point Conception, California (roughly 34° 27′ North latitude). Key et al. argued that a decline in kelp habitat caused by increasing ocean temperatures since the 1990s contributed to the observed decline in catches. Subsequently, the contribution of the BDR stock south of Point Conception to the Overfishing Limit (OFL) was estimated at 73 mt based on the Depletion-Corrected Average Catch method (DCAC; MacCall 2009; Dick 2011).

Similar to the work of Key et al. (2008), the 2017 BDR assessment (Dick et al. 2017) excluded the area south of Point Conception. Although the exact mechanisms are not clear, landings in the southern area have remained low relative to historical estimates for the area (Dick et al. 2017). Trends in catch-per-unit-effort (CPUE) and indices of spawning output (CalCOFI) in the southern area are increasing (Dick et al. 2017), although indices of kelp abundance have shown continued declines (CDFW 2016). During the 2017 Stock Assessment Review Panel, it was decided that factors influencing stock dynamics south of Point Conception were sufficiently different to warrant excluding the area from the base model, consistent with the 2007 assessment. Southern California removals were added to the BDR California base model, as a sensitivity analysis, but this approach was thought to produce biased results as a result of differences in exploitation history between the two areas and the potential for differences in stock productivity. Also, a dramatic decline in catch south of Point Conception in the early 1990s was not associated with a proportional decline in effort.

This report provides an alternative approach to estimating the southern stock's contribution to the OFL for BDR. Unlike the previous DCAC estimate, this approach does not use historical removals (1953-1999) as the basis for estimating sustainable yield. Instead, recent removals (2007-2016) are used as a basis, and status of the stock is assumed to increase over that period of time, consistent with observed trends in CPUE and the CalCOFI index (Dick et al. 2017). As noted by MacCall (2009), DCAC will produce estimates of sustainable yield that are larger than average catch when stock size increases over the period of interest, i.e. when MacCall's $\Delta < 0$.

I calculated DCAC using the formulation of Dick and MacCall (2010):

$$DCAC = \frac{\sum C_t}{n + \Delta \cdot \left[B_{MSY}\left(\frac{F_{MSY}}{M}\right)M\right]^{-1}}$$

Removals (landings and discard) of BDR in the Southern California Bight from 2007 – 2016 were estimated by Dick et al. (2017; Table G1). Average catch was 10.62 mt over the 10-year period. If one assumes that change in stock status mirrors trends in California north of Point Conception, then estimates of depletion (annual spawning output as a percentage of unfished) in 2007 (15.6%) and 2017 (37.3%) suggest a point estimate for Δ = -0.217. In other words, stock status is assumed to increase by 21.7% of unfished biomass over the period 2007-2017, as in the California base model. An estimate of natural mortality combining the approaches of Hamel (2015) and Then et al. (2015) is obtained using

$M = 5.4/A_{max}$, yielding M = 0.132 based on a maximum age of 41 years. Point estimates of B_{MSY} and F_{MSY}/M are assumed to follow previous applications of DCAC, with values of 0.4 and 0.8, respectively (Dick and MacCall, 2010).

Table G1. Recent removals [mt] of Blue and Deacon Rockfish south of Pt Conception. Source: Dick et al. 2017 (Tables 6 and 8).

Year	Recreational	Commercial	Total
2007	13.39	0.11	13.50
2008	8.27	1.32	9.58
2009	6.42	0.43	6.86
2010	1.65	0.06	1.71
2011	2.68	0.04	2.72
2012	2.93	0.09	3.02
2013	3.46	0.29	3.74
2014	20.43	0.74	21.16
2015	21.22	1.46	22.68
2016	20.23	0.97	21.21

Using point estimates for each parameter, an estimate of DCAC for BDR South of Point Conception is

$$DCAC = \frac{106.18}{10 + (-0.217) \cdot [0.4(0.8)0.132]^{-1}} = 21.8\,mt$$

This estimate of sustainable yield is roughly double the average catch over the period 2007-2016, and could serve as a proxy for the OFL contribution for the BDR stock south of Point Conception. Ideally, distributions of each parameter (rather than point estimates) could be incorporated into the analysis. However, when assuming that biomass increases ($\Delta < 0$) over a short period of interest, uncertainty in parameter estimates can result in nonsensical (negative) estimates of DCAC, and a simple approximation using point estimates is recommended.

References

California Department of Fish and Wildlife. 2016. Aerial Kelp Survey. ftp://ftp.dfg.ca.gov/R7_MR/BIOLOGICAL/Kelp/

Dick 2011. “Revisions to OFL Contributions for Category 3 Stocks.” Report submitted to the Pacific Fishery Management Council, available at http://www.pcouncil.org/wp-content/uploads/2017/07/Revisions_to_OFL_Contributions_from_Category_3_Stocks.pdf

Dick, E. J. and A. D. MacCall. 2010. Estimates of sustainable yield for 50 data-poor stocks in the Pacific coast groundfish fishery management plan. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-460, 201 p.

Dick, E.J., A. Berger, J. Bizzarro, K. Bosley, J. Cope, J. Field, L. Gilbert-Horvath, N. Grunloh, M. Ivens-Duran, R. Miller, K. Privitera-Johnson, and B.T. Rodomsky. 2017. The Combined Status of Blue and Deacon Rockfishes in U.S. Waters off California and Oregon in 2017. Pacific Fishery Management Council, Portland, OR. 396 p.

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

Key, M., MacCall, A.D., Field, J.C., Aseltine-Neilson, D., and Lynn, K. 2008. The 2007 assessment of blue rockfish (*Sebastes mystinus*) in California. Pacific Fishery Management Council, Portland, OR.

MacCall, A. D. 2009. Depletion-corrected average catch: a simple formula for estimating sustainable yields in data-poor situations. ICES Journal of Marine Science 66:2267–2271.

Then, A.Y., J.M. Hoenig, N.G. Hall, and D.A. Hewitt. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES J. of Mar. Sci. 72, 82-92.