Agenda Item H.5
Attachment 1
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Assessing Cabezon (*Scorpaenichthys marmoratus*) stocks in waters off of California and Oregon, with catch limit estimation for Washington State

Prepared by

Jason M. Cope[1*], Aaron M. Berger[2*], Alison D. Whitman[3], John E. Budrick[4], Katelyn M. Bosley[2], Tien-Shui Tsou[5], Corey B. Niles[5], Kristin Privitera-Johnson[6], Lisa K. Hillier[5], Kristen E. Hinton[5], Megan N. Wilson[7]

* Corresponding authors:

[1]Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 2725 Montlake Blvd East, Seattle, WA 98112
[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]Oregon Department of Fish and Wildlife, 2040 SE Marine Science Dr, Newport, OR 97365
[4]California Department of Fish and Wildlife, 350 Harbor Blvd, Belmont, CA 94002
[5]Washington Department of Fish and Wildlife, PO Box 43200, Olympia, WA 98504
[6]University of Washington, SAFS, 1122 NE Boat St, Seattle, WA 98195
[7]Oregon State University, 3029 Cordley Hall, 2701 SW Campus Way, Corvallis, OR 97331

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Photo of Cabezon was downloaded from the RecFIN website (http://www.recfin.org/resources/fishid/) and taken by Vicky Okimura (WDFW).

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Acronyms Used in the Document

ABC – Acceptable Biological Catch
AIC – Akaike Information Criterion
BB – Beach/bank recreational mode
BCER – Big Creek Ecological Reserve
CalCOFI - California Cooperative Oceanic Fisheries Investigation
CALCOM - California Commercial Cooperative Groundfish Program
CAS – California sub-stock
CDFW – California Department of Fish and Wildlife
CFIS – Commercial Fisheries Information System
CI – Confidence interval
CMASTR – Master Commercial Fisheries Database for CDFG
CPFV – Commercial Passenger Fishing Vessel
CPUE – Catch per unit of effort
CRFS – California Recreational Fisheries Survey
CV – Coefficient of variation
EEZ – Exclusive Economic Zone
ENSO – El Niño Southern Oscillation
FMP – Groundfish Fishery Management Plan
GLM – Generalized Linear Model
IRI – Index of Relative Importance
LB-SPR – Length-Based Spawning Potential Ratio
MM – Man-made recreational mode
MLMA – Marine Life Management Act
MLML- Moss Landing Marine Laboratories
MPA – Marine Protected Area
MPD – Maximum of the posterior density function
MRFSS - Marine Recreational Fisheries Statistics Survey
MSY – Maximum Sustainable Yield
mt – Metric tons
NCS – Northern California Sub-stock
NFMP – Nearshore Fishery Management Plan
NMT – Natural Mortality Tool
NWFSC – Northwest Fisheries Science Center
ODFW – Oregon Department of Fish and Wildlife
OFL – Overfishing Limit
ORBS – Ocean Recreational Boat Survey
ORS – Oregon sub-stock
OY- Optimum Yield
PacFIN - Pacific Fisheries Information Network
PBR – Private Boat and Rental recreational mode
PFEL – Pacific Fisheries Environmental Laboratory
PFMC – Pacific Fishery Management Council
PISCO - Partnership for Interdisciplinary Studies of Coastal Oceans
PSMFC – Pacific States Marine Fisheries Commission
RCA – Rockfish Conservation Area
RecFIN – Recreational Fisheries Information Network
SCS – Southern California sub-stock
SLOSEA – San Luis Obispo Science and Ecosystem Alliance
SMURF - Standard Monitoring Units for the Recruitment of (temperate reef) Fishes

SoCAL – Southern California
SS – Stock Synthesis
STAR – Stock Assessment Review (panel)
STAT – Stock Assessment Team
SWFSC – Southwest Fisheries Science Center
TL – Total Length
TOR – Terms of Reference
WAS – Washington sub-stock
WCGOP – West Coast Groundfish Observer Program

Executive Summary

Stock

This assessment reports the status of the Cabezon (*Scorpaenichthys marmoratus* [Ayres]) in U.S. waters off the coast of Southern California, Northern California, and Oregon with consideration for setting catch limits in Washington. This is the fourth full assessment of the population status of Cabezon (for some sub-stocks) off the west coast of the United States, but the first in 10 years. The first assessment was for a state-wide California Cabezon stock in the year 2003 (Cope et al. 2004). The second assessment (Cope and Punt 2006) considered two sub-stocks (the northern California sub-stock (NCS) and the southern California sub-stock (SCS)), demarcated at Point Conception, CA. The third assessment (Cope and Key 2009) retained the two California sub-stocks and added a sub-stock for Cabezon in the waters off of Oregon (ORS). This document represents full assessments for the same three sub-stocks as in the 2009 assessment. The full assessments are limited to the California and Oregon sub-stocks by recommendation of the Pacific Fishery Management Council. This document also includes a data-limited assessment of Cabezon in the waters off of Washington (WAS) and explores uncertainty in its estimates of overfishing limits by varying key assumptions used by those methods, such as the assumed stock depletion. Separation of these spatial sub-stocks is based on distinguishing localized population dynamics, preliminary population genetics results, and is supported by spatial differences in the fishery (e.g., the NCS has been the primary area from which removals have occurred), the ecology of nearshore groundfish species, and is consistent with current state management needs.

Catches

California

Cabezon removals were assigned to four fleets in California (two commercial and two recreational). The California time series begins in 1916, with the onset of commercial landings. Historical recreational removals for California were based on the reconstruction used in Cope and Key (2009). Historically, vessel-based recreational boat fishing has been the primary reported source of biomass removals of Cabezon. Commercial catch became a major source of removals in the last 25 years because of the developing live-fish fishery. Commercial discard mortality is assumed to be low (7%, established by the Groundfish Management Team), due to low mortality (no barotrauma and generally a robust fish) and desirability when caught. Discard removals are directly added into the overall removals of each fleet (Tables ES1 and ES2).

The historical catches are similar to the previous assessment, though a misreporting of recreational catches south of 36 degrees latitude required a reallocation of catches previously assigned to southern California to northern California for years in the 1980s. The main removal period in southern California from the 1980s through the mid-1990s (Figure ES1). The commercial live-fish fishery kept removals elevated from the late 1990s to mid-2000s despite recreational catches significantly decreasing. Catches in southern California have steadily decreased since the early 2000s. Removals north of Pt. Conception have been fairly steady since the 1950s, with a major peak in the mid to late 1990s due to the onset of the live-fish fishery (Figure ES2). Current removals remain around the long-term average.

Oregon

In Oregon, Cabezon is caught predominantly 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 Cabezon (including pot, troll and trawl gear). Catch of Cabezon is often incidental when gear approaches the bottom during jigging or longline sets aimed at Black Rockfish or Lingcod, the primary target species for Oregon nearshore fisheries. Only a limited number of recreational and commercial fishermen explicitly target Cabezon regularly. Two commercial fleets (based on a landed live-fish fishery and a landed dead-fish fishery) and two recreational fleets (based on the aggregation of private and charter trips as an ocean boat fishery and based on captures from shore or estuaries as a shore fishery) were specified for disaggregating total landings. The estimated proportion of dead discards was small relative to total landings, thus the biomass of dead discarded Cabezon was added to the landed biomass to derive final catch estimates by fleet (Table ES3).

Total landings have generally increased through time, including a near doubling of landings with the onset of the commercial live-fish fishery in the late-1990s (Figure ES1). Since that time (post-1996), total landings have largely been between 40-60 mt per year, except during 2013-2016 when total landings were closer to 30 mt. The highest three years of catch across the time series were 2002, 2001, and 2017 (66.8, 65.3, and 54.4 mt, respectively). Recent landings continue to be dominated by the commercial live-fish and recreational ocean boat fleets, collectively representing 94% of the total in 2018 (Table ES3).

Washington

Cabezon has not been targeted by fisheries and annual total removals have been less than 12 mt in Washington (Table ES4). Washington closed state waters to commercial fixed gears, like those used to target Cabezon, in 1995 and to trawling in 1999. The depths preferred by Cabezon are predominantly found within state waters. In response to the development of the live-fish fishery in California and Oregon, Washington took preemptive action in 1999 to prevent the fishery from developing by prohibiting the landing of live-fish.

Annual catches (in numbers) from the recreational fishery (1967, 1975-86) were obtained from historical reports, and landings from 1990-2018 were obtained from the Washington Department of Fish and Wildlife (WDFW) Ocean Sampling Program (OSP). To fill in the missing years, linear interpolations were used to find landed values between 1986 and 1989, and to bring catch down to zero in year 1962 (Table ES4). For years prior to 2002, a 10% discard rate was assumed with the 7% post-released death rate being applied to all years. The sum of retained and dead released Cabezon made up the total removal (in numbers) from the recreational fishery.

Data and Assessment

The southern California, northern California, and Oregon sub-stock assessments all used the Stock Synthesis 3 (version V3.30.13.00) stock assessment modeling platform in association with AD Model Builder version 12.0. Models were fit to the data using maximum likelihood. Models were tuned to account for the weighting of composition data as well as the specification of recruitment variance and recruitment bias adjustments. The Washington assessment used the Simple Stock Synthesis approach (Cope 2013) also using Stock Synthesis (version V.3.30.13.00). This document identifies a single sub-stock specific model for determining current stock status and trends, termed the "reference" model.

Table ES1. Recent landings (mt) for Cabezon in Southern California by fleet.

Year s	Commercial Dead Fleet	Commercial Live Fleet	Recreational Shore Fleet	Recreational Boat Fleet	Total Removals
2007	0.07	3.22	2.47	4.91	10.67
2008	0.16	3.63	3.13	1.53	8.45
2009	0.04	3.6	2.57	5.12	11.33
2010	0.14	4.67	0.63	3.85	9.29
2011	0.13	5.27	2.42	5.2	13.02
2012	0.23	6.11	4.19	3.52	14.05
2013	0.12	6.19	2.45	5.31	14.07
2014	0.3	5.03	2.55	4.08	11.95
2015	0.25	3.12	1.32	0.75	5.44
2016	0.04	2.68	3.73	1.99	8.44
2017	0.21	2.64	0.18	0.62	3.65
2018	0.92	1.66	2	0.62	5.2

Table ES2. Recent landings (mt) for Cabezon in Northern California by fleet.

Years	Commercial Dead Fleet	Commercial Live Fleet	Recreational Shore Fleet	Recreational Boat Fleet	Total Removals
2007	3.44	19.33	2.63	18.94	44.34
2008	2.13	17.64	7.05	12.22	39.04
2009	0.78	14.35	7.2	24.85	47.18
2010	1.43	16.92	5.46	21.04	44.85
2011	2.57	24.56	11.06	31.47	69.66
2012	4.61	19.94	8.7	31.75	65
2013	3.6	19.41	7.33	19.46	49.8
2014	3.92	22.89	11.67	27.54	66.02
2015	3.68	28.27	11.52	36.8	80.27
2016	2.66	25.5	11.86	23.9	63.92
2017	3.29	17.74	7.67	20.96	49.66
2018	3.13	34.23	10.15	21.92	69.43

Table ES3. Recent landings (mt) for Cabezon in Oregon by fleet.

Year	Commercial Live Fleet	Commercial Dead Fleet	Recreational Ocean Boat Fleet	Recreational Shore Fleet	Total Removals
2007	22.71	0.70	16.21	1.32	40.94
2008	25.15	1.67	16.56	1.27	44.65
2009	30.33	1.57	16.20	1.23	49.33
2010	23.86	1.26	16.55	1.18	42.85
2011	30.32	1.23	17.27	1.14	49.96
2012	29.39	1.48	15.36	0.57	46.80
2013	20.38	0.82	12.38	0.41	33.99
2014	15.84	0.62	9.09	0.40	25.95
2015	16.86	0.66	10.22	0.39	28.13
2016	15.85	1.27	11.76	0.37	29.25
2017	28.40	2.11	23.73	0.23	54.47
2018	28.71	2.66	13.45	0.16	44.98

Table ES4. Recent landings (mt) for Cabezon in Washington by fleet. Last two years are assumed catch for Simple Stock Synthesis model.

Year	Total Removals
2009	7.78
2010	7.89
2011	9.37
2012	7.35
2013	6.36
2014	5.68
2015	5.35
2016	4.98
2017	7.34
2018	5.3
2019	4.98
2020	4.98

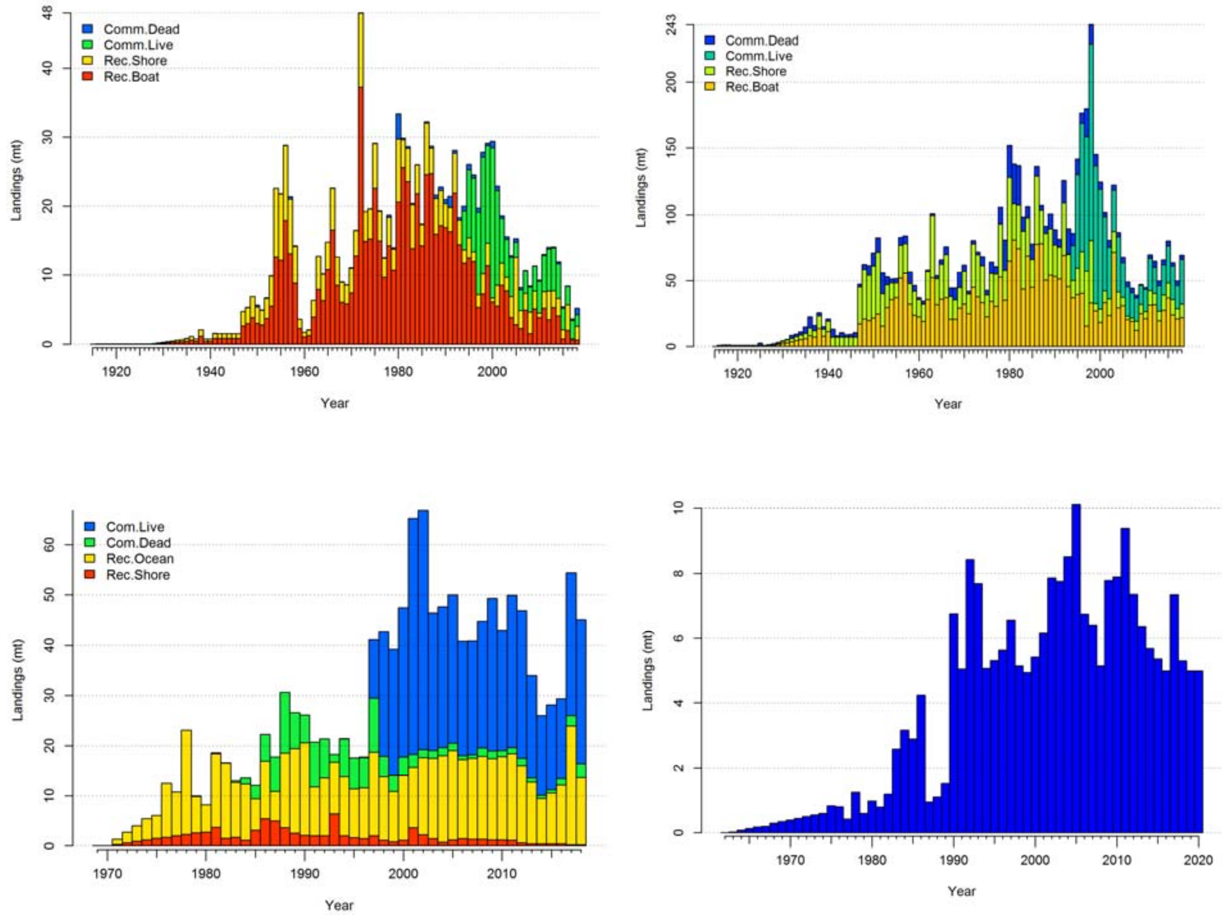

Figure ES1: Catch histories by fleet in the reference models for Southern California (upper left panel), Northern California (upper right panel) Oregon (lower left panel), and Washington (lower right panel, which includes the assumed catch for 2019 and 2020).

California

The 2009 Cabezon assessment (Cope and Key 2009) in California used 2 commercial (dead and live) and 4 recreational fleets (man-made, beach/bank, private boat and charter boat). Model explorations demonstrated that combining the recreational shore (man-made and beach/bank) and boat (private and charter boat) fleets did not change the derived quantities, but made for a more robust model in each stock. Model specification was therefore made to be in line with that of the Oregon model. The SCS and NCS models both retained the 1960-1999 recreational commercial passenger fishing vessel (CPFV) logbook abundance index. Multiple management changes after 1999 did not allow for continued development of the fishery-dependent CPFV logbook index. The NCS model also added the California Collaborative Fisheries Research Program (CCFRP) index for central California for years 2007-2018. All indices were developed using generalized linear model fitting for proportions of presence/absence and positives separately (delta-GLM model). Mean weights were dropped from this year's assessment as they proved of little value in the last assessment. Fishery-dependent length compositions were used for each fleet (except for the commercial dead fishery in the SCS); length compositions were also available for the CCFRP index. The only source of conditional age-at-length data for the NCS model remained from the research of Grebel (2003). No age data was available for the SCS. While growth is estimated in the NCS model and fixed to the NCS values in the SCS model (as in 2009), natural mortality is estimated in both models for the first time. Steepness and recruitment variability remain fixed.

Oregon

Cabezon was last assessed in Oregon in 2009 and estimated to be at 52% of unfished spawning output (Cope and Key 2009). The 2019 assessment is structured as a single, sex- and age-disaggregated, unit population, spanning Oregon coastal waters, and operates on an annual time step covering the period 1970 to 2019. Four fleets, two commercial and two recreational (as discussed previously), are modeled in the assessment. Data used in the assessment includes time series of commercial and recreational landings, four fishery-dependent abundance indices (catch-per-unit-effort; CPUE), length compositions for each fleet, and age compositions from the recreational ocean-boat fleet, the commercial dead fleet, and a collection of research survey ages. Each index of abundance was developed by fitting generalized linear models to the proportion of non-zero records and the catch rate given that the catch was non-zero, and taking the product of the resultant year effects. Changes in management regulations necessitated the separation of the commercial live fleet and the recreational ocean boat fleet into two modeling time periods, pre- and post-2004. While gender-specific growth is estimated in the reference model, natural mortality is fixed, as is steepness and recruitment variability.

Washington

Cabezon in Washington has never been assessed due to the lack of information. A Depletion-Based Stock Reduction Analysis (DBSRA) (Dick and MacCall 2011) was used to assess yield in 2017. Suggested OFLs from that work were 5.25 mt and 5.37 mt for 2019 and 2020, respectively (Cope et al. 2017).

Stock Biomass

The terms “spawning output” and “spawning biomass” are used interchangeably in this document, in reference to total female spawning biomass. For the purpose of this assessment, female spawning biomass is assumed to be proportional to egg and larval production.

California

SCS

SCS Cabezon spawning output was estimated to be 101 mt in 2019 (~95% asymptotic intervals: 19–183 mt), which when compared to unfished spawning output (262 mt) equates to a relative stock status level of 49% (~95% asymptotic intervals: 11–87%; Table ES5) in 2019. In general, spawning output has fluctuated over the past few years after a steady increase since the early 2000s (Figure ES2, top panel). Stock size is estimated to be approaching levels not seen since the 1970s. The stock is estimated to be above the management target of $SB_{40\%}$ (Figure ES3), and has been mostly above this mark since the 2010.

NCS

NCS Cabezon spawning output was estimated to be 643 mt in 2019 (~95% asymptotic intervals: 159–1,126 mt), which when compared to unfished spawning output (986 mt) equates to a relative stock status level of 65% (~95% asymptotic intervals: 22–108%; Table ES6) in 2019. The uncertainty in these quantities are very large. In general, spawning output has increased since the late 2000s (Figure ES2, middle panel). Stock size is estimated to be approaching levels not seen since the 1970s. The stock is estimated to be above the management target of $SB_{40\%}$ (Figure ES3), but measured with high uncertainty, and has been above this mark since around the time of the last assessment in 2009.

Oregon

Cabezon spawning output was estimated to be 177 mt in 2019 (~95% asymptotic intervals:129-226 mt), which when compared to unfished spawning output equates to a depletion level of 53% (~95% asymptotic intervals: 43-63%; Table ES7) in 2019. In general, spawning output had been trending downwards until the early 2000s, after which it became more stable throughout the rest of the time series with a slight increase from 2017 through 2019 due to an above average recruitment estimate for the 2014 year class (Figure ES2). Stock size is estimated to be at the lowest level throughout the historic time series in 2014, but the stock is estimated to be above the management target of $SB_{40\%}$ (Figure ES3).

Table ES5. Recent trend in beginning year biomass and depletion for Cabezon in Southern California waters.

Years	Spawning Output	95% Confidence Interval	Estimated Depletion	95% Confidence Interval
2007	62	4–119	30.3%	1.3–59.3%
2008	67	4–129	32.5%	1.3–63.8%
2009	73	6–140	35.7%	2.2–69.2%
2010	79	7–151	38.5%	2.6–74.4%
2011	84	9–160	41.3%	3.7–78.8%
2012	86	8–164	41.9%	3.7–80.1%
2013	85	6–164	41.4%	2.9–79.9%
2014	82	3–160	39.9%	1.7–78.0%
2015	79	1–157	38.8%	1.2–76.3%
2016	83	5–160	40.3%	3.2–77.4%
2017	84	7–162	41.1%	4.4–77.7%
2018	90	12–169	44.2%	7.5–80.9%
2019	101	19–183	49.2%	11.0–87.4%

Table ES6. Recent trend in beginning year biomass and depletion for Cabezon in Northern California waters.

Years	Spawning Output	95% Confidence Interval	Estimated Depletion	95% Confidence Interval
2007	281	36–525	28.4%	5.5–51.4%
2008	310	39–581	31.5%	6.1–56.9%
2009	366	50–681	37.1%	7.5–66.6%
2010	433	62–805	43.9%	9.2–78.7%
2011	491	79–903	49.8%	11.4–88.2%
2012	512	81–942	51.9%	11.9–91.9%
2013	524	85–962	53.1%	12.6–93.5%
2014	551	100–1,001	55.8%	14.5–97.1%
2015	579	110–1,047	58.7%	15.9–101.4%
2016	605	115–1,094	61.3%	16.8–105.8%
2017	628	130–1,127	63.7%	18.7–108.7%
2018	643	151–1,135	65.2%	21.2–109.1%
2019	643	159–1,126	65.1%	22.4–107.9%

Table ES7. Recent trend in beginning year biomass and depletion for Cabezon in Oregon waters.

Year	Spawning Output	95% Confidence Interval	Estimated Depletion	95% Confidence Interval
2007	163	120–206	48.8	40.4–57.2
2008	160	117–204	47.9	39.4–56.4
2009	160	116–203	47.7	39.1–56.3
2010	159	116–203	47.6	39.0–56.2
2011	164	119–208	48.8	40.1–57.5
2012	158	115–202	47.2	38.6–55.9
2013	147	105–189	44	35.5–52.4
2014	144	102–185	42.9	34.6–51.3
2015	148	106–189	44	35.6–52.4
2016	157	112–201	46.8	37.9–55.6
2017	174	126–222	52	42.6–61.4
2018	177	127–226	52.8	43.1–62.4
2019	177	128–226	52.8	43.0–62.7

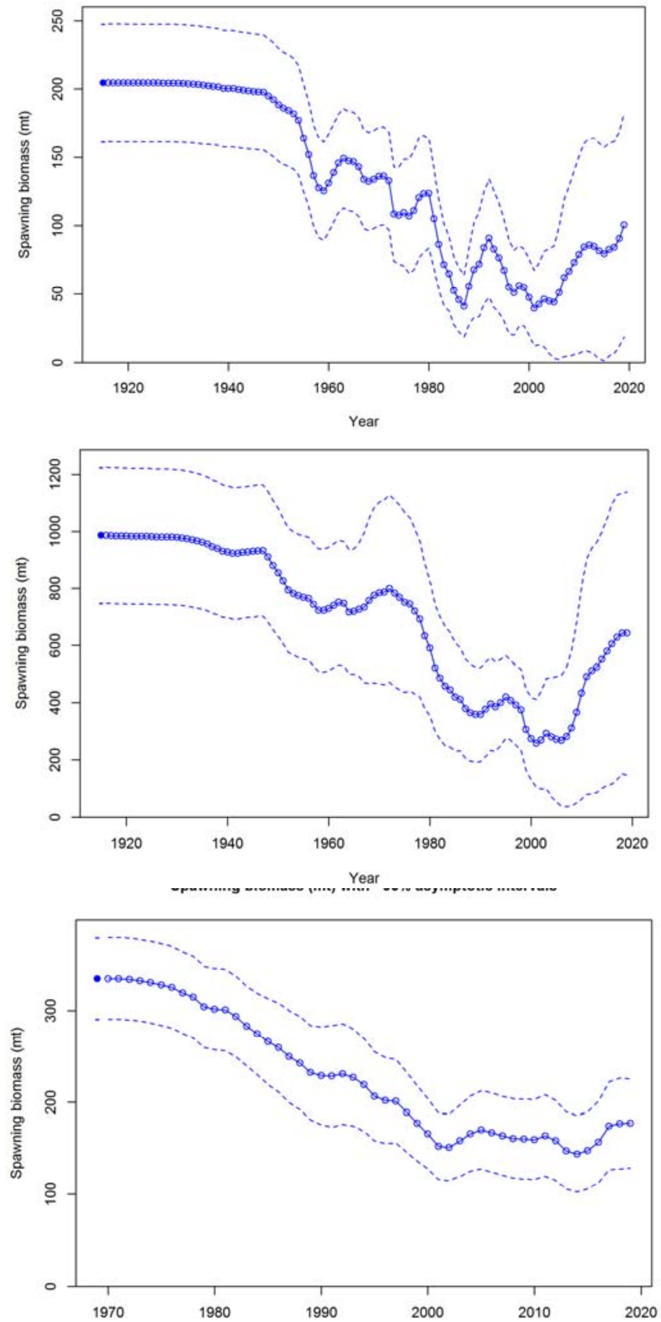

Figure ES2. Recent trends for beginning of the year spawning output (female biomass) with approximate 95% asymptotic confidence intervals (dashed lines) for Cabezon in Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel).

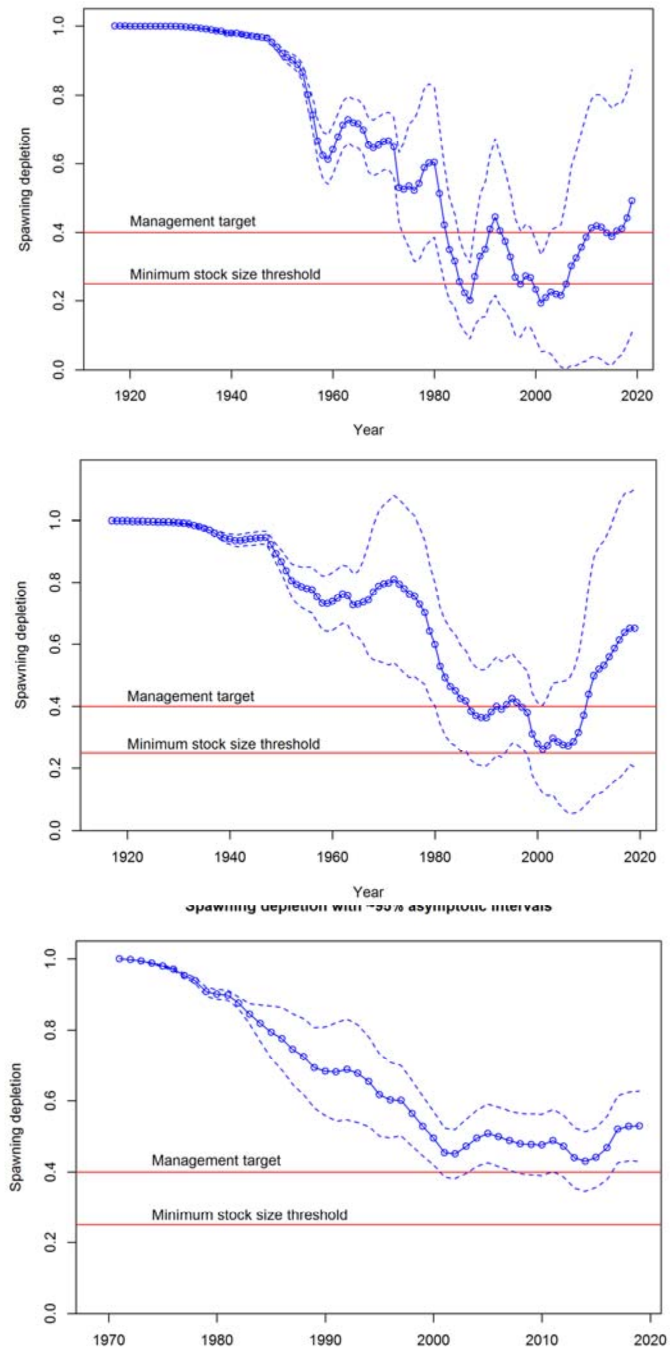

Figure ES3. Estimated relative depletion (spawning output relative to unfished spawning output) with approximate 95% asymptotic confidence intervals (dashed lines) for Cabezon in Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel).

Recruitment

California

SCS

Since strong recruitment events in the late 1990s and early 2000s, recent recruitment has been mostly lower or around average (Table ES8; Figure ES4). This recruitment is informed mostly by length composition data, but removal history also influences the estimates. The 2009 stock assessment also suggested similar recruitment dynamics. Despite the drop in relative stock status to levels around the limit reference point in the early 1980s and the large spike in recruitment during that same time, there is not enough information in the assessment to estimate recruitment compensation (steepness), thus all recruitment is based on a fixed assumption of steepness and recruitment variability.

NCS

Recruitment patterns in central and northern California are much different from that estimated in southern California. Recent recruitment is a mix of positive and negative recruitments, with a very large recruitment detected in 2016, the last year a recruitment deviation was estimated (Table ES9; Figure ES4). Recruitment estimation uncertainty is high, and recruitment is informed mostly by length composition data, with some contribution from the survey index and removal history. Recruitments are much more muted compared to the 2009 stock assessment, though with similar peaks. These lower in magnitude recruitments lead to a steeper drop in the population biomass at the peak of the live-fish fishery before the more recent recruitments allow for a rapid population increase. Despite these fluctuations in biomass, there is not enough information in the assessment to estimate recruitment compensation (steepness), thus all recruitment is based on a fixed assumption of steepness and recruitment variability.

Oregon

A recent, above average, recruitment event in 2014 contributed to the recent increase in Cabezon biomass in Oregon (Table ES10; Figure ES4). This recruitment is informed by composition data, two relative abundance indices, and corresponds to reports from fishermen and port biologists of a recent increase in Cabezon. Other years with relatively high estimates of recruitment were 1999, 2000, and 2002. The 2009 stock assessment also suggested that 1999 was an above average year class. The Cabezon sub-stock in Oregon has not been depleted to levels that would provide considerable information on how recruitment changes with spawning output at low spawning output levels (i.e., inform the steepness parameter).

Exploitation Status

California

SCS

SCS fishing intensity showed a steady increase from the 1960s to peak levels in the 1980s through the mid-1990s. From that time fishing intensity steadily declined to the low levels seen in the early 1960s. The maximum relative fishing rate ((1-SPR)/ (1-$SPR_{45\%}$)) was 1.46 in 1986, well above the target level. Current relative fishing rates are much lower and generally decreasing, fluctuating around 0.50 (Table ES11, Figure ES5). Summary fishing mortality rates have jumped around 0.03 and 0.07 in recent years (Figure ES6). Figure ES7 shows the dual trajectory of relative biomass and fishing intensity with a path

Table ES8. Recent trend in estimated recruitment for Cabezon in Southern California waters.

Years	Recruitment (1000s of fish)	95% Confidence Interval	Recruitment Deviations	95% Confidence Interval
2007	123	34–438	-0.074	-1.172–1.024
2008	130	38–448	-0.037	-1.058–0.985
2009	124	37–412	-0.107	-1.057–0.843
2010	93	27–319	-0.418	-1.453–0.617
2011	114	33–399	-0.223	-1.281–0.835
2012	129	36–465	-0.126	-1.247–0.996
2013	111	30–407	-0.288	-1.462–0.887
2014	146	38–568	-0.025	-1.312–1.262
2015	230	54–985	0.417	-1.028–1.861
2016	166	41–683	0.066	-1.320–1.453
2017	160	40–631	0.003	-1.371–1.377
2018	162	41–634	0	-1.372–1.372
2019	165	42–644	0	-1.372–1.372

Table ES9. Recent trend in estimated recruitment for Cabezon in Northern California waters.

Years	Recruitment (1000s of fish)	95% Confidence Interval	Recruitment Deviations	95% Confidence Interval
2007	509	149–1,742	-0.06	-0.849–0.730
2008	485	144–1,628	-0.141	-0.896–0.614
2009	557	167–1,860	-0.05	-0.827–0.727
2010	789	240–2,593	0.256	-0.489–1.000
2011	802	241–2,671	0.242	-0.560–1.044
2012	885	274–2,858	0.33	-0.415–1.074
2013	535	168–1,708	-0.183	-0.959–0.594
2014	534	172–1,652	-0.198	-0.921–0.524
2015	667	210–2,117	0.012	-0.775–0.800
2016	1,050	325–3,391	0.454	-0.401–1.309
2017	741	222–2,470	0.096	-0.873–1.064
2018	676	203–2,253	0	-0.980–0.980
2019	676	203–2,249	0	-0.980–0.980

Table ES10. Recent trend in estimated recruitment for Cabezon in Oregon waters.

Year	Recruitment (1000s of fish)	95% Confidence Interval	Recruitment Deviations	95% Confidence Interval
2007	98.8	56.8–172.1	0.11	-0.439–0.658
2008	125.5	82.7–190.4	0.352	-0.061–0.765
2009	62.3	33.5–115.8	-0.348	-0.967–0.271
2010	61.9	32.7–117.0	-0.354	-0.990–0.281
2011	94.6	56.7–158.1	0.066	-0.449–0.581
2012	79.1	41.9–149.3	-0.107	-0.736–0.522
2013	117.9	68.4–203.3	0.307	-0.226–0.840
2014	160.7	101.4–254.6	0.622	0.172–1.071
2015	82.4	43.6–155.9	-0.051	-0.679–0.577
2016	95.9	82.1–111.9	0	0.000–0.000
2017	97.9	84.1–113.9	0	0.000–0.000
2018	98.1	84.2–114.4	0	0.000–0.000
2019	98.2	84.1–114.6	0	0.000–0.000

that moved to fishing above the reference fishing intensity, leading to relative biomass below target relative biomass, then decreasing fishing intensity leading to a building of biomass. The equilibrium curve is shifted left (Figure ES8), as expected from the fixed steepness, showing a more productive stock ($SPR_{35\%}$) than the $SPR_{45\%}$ reference point would suggest (Table ES14).

NCS

NCS fishing intensity showed a steady increase from the 1950s to a distinct peak in 1998, then steadily declined to the low levels seen in the early 1970s (Figure ES5 and ES6). The maximum relative fishing rate ((1-SPR)/ (1-$SPR_{45\%}$)) was 1.39 in 1998, well above the target level. Current relative fishing rates are much lower, fluctuating around 0.60 (Table ES12, Figure ES5). Summary fishing mortality rates have been around 0.06 in recent years (Figure ES6). Figure ES7 shows the dual trajectory of relative biomass and fishing intensity with a path that moved to fishing above the reference fishing intensity, leading to relative biomass below target relative biomass, then decreasing fishing intensity leading to a building of biomass. Interestingly, the path is one of longer exposures to rising fishing intensity so fewer years of above target fishing intensity are needed to send the biomass below target. The equilibrium curve is shifted left (Figure ES8), as expected from the fixed steepness, showing a more productive stock ($SPR_{33\%}$) than the $SPR_{45\%}$ reference point would suggest (Table ES15).

Oregon

Harvest rates in Oregon have generally increased through time until reaching a more stable (but still variable from year to year) level beginning in the 2000s. The maximum relative harvest rate was 1.16 in 2001 (or 116% of the target level) before declining again to around 0.80 in recent years (Table ES13,

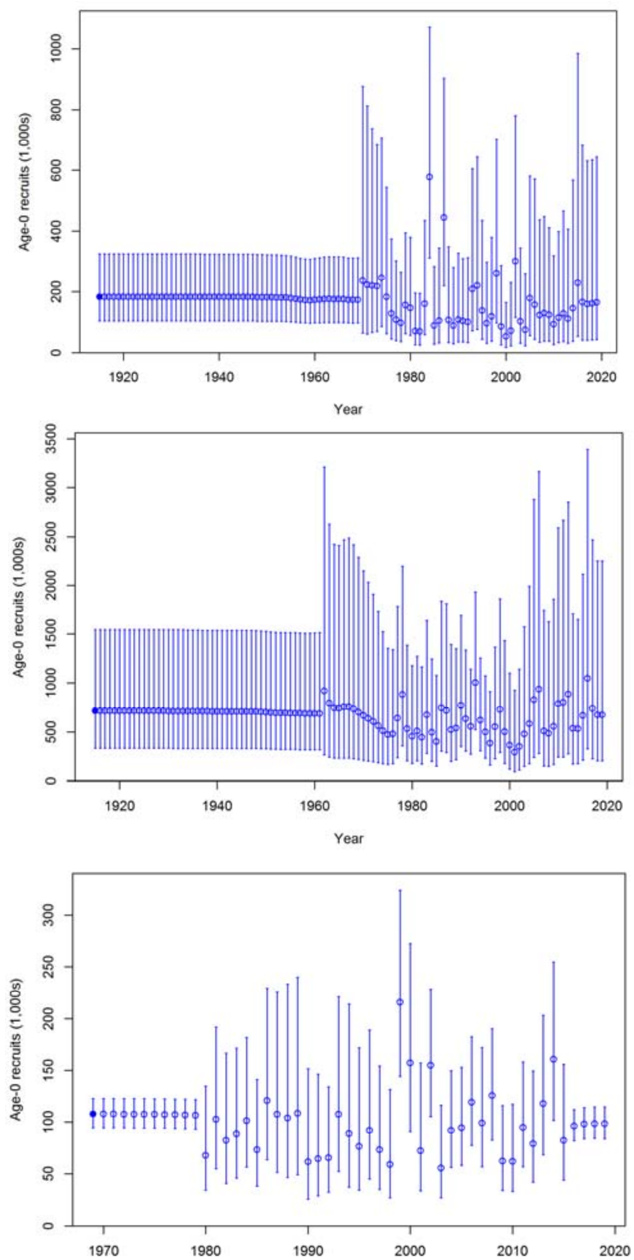

Figure ES4. Recent trend in estimated recruitment with approximate 95% asymptotic confidence intervals (bars) for Cabezon in Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel).

Figure ES5). Summary fishing mortality (harvest) rates have been around 0.10 in recent years (Figure ES6). Fishing intensity is estimated to have been below the target throughout most of the time series [(1-SPR) / (1-$SPR_{45\%}$) < 1, except from 2000-2002]. In 2018, Oregon Cabezon biomass is estimated to have been 1.32 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 (Figure ES8), as expected from the high fixed steepness, showing a more productive stock ($SPR_{28\%}$) than the $SPR_{45\%}$ reference point would suggest (Table ES16).

Table ES11. Recent trend in spawning potential ratio (entered as 1-SPR / 1-SPR45%) and exploitation (catch divided by biomass of age-2 and older fish) for Cabezon in Southern California waters. Estimates for 2019 assume catch is equal to the default harvest control rule level of catch.

Years	(1-SPR)/ (1-SPR_45%)	95% Confidence Interval	Harvest Rate (proportion)	95% Confidence Interval
2007	78.4%	25.1–131.8%	0.095	0.008–0.182
2008	64.9%	16.0–113.7%	0.07	0.006–0.133
2009	74.4%	22.9–125.8%	0.087	0.009–0.165
2010	61.6%	15.1–108.2%	0.069	0.008–0.131
2011	76.2%	25.2–127.1%	0.094	0.011–0.176
2012	81.7%	28.7–134.7%	0.103	0.011–0.194
2013	81.8%	28.0–135.5%	0.106	0.009–0.203
2014	76.5%	22.8–130.2%	0.093	0.006–0.179
2015	44.1%	5.9–82.3%	0.043	0.003–0.083
2016	60.2%	14.5–105.9%	0.064	0.006–0.121
2017	29.3%	3.4–55.2%	0.025	0.003–0.048
2018	37.5%	7.8–67.3%	0.033	0.006–0.060
2019	67.9%	23.9–111.9%	0.075	0.015–0.135

Table ES12. Recent trend in spawning potential ratio (entered as 1-SPR / 1-SPR45%) and exploitation (catch divided by biomass of age-2 and older fish) for Cabezon in Northern California waters. Estimates for 2019 assume catch is equal to the default harvest control rule level of catch.

Years	(1-SPR)/ (1-SPR_45%)	95% Confidence Interval	Harvest Rate (proportion)	95% Confidence Interval
2007	67.4%	17–118%	0.066	0.009–0.123
2008	57.8%	11–104%	0.05	0.006–0.094
2009	60.6%	13%–108%	0.054	0.007–0.100
2010	52.6%	9%–96%	0.047	0.007–0.088
2011	65.5%	17%–114%	0.07	0.011–0.129
2012	60.3%	14%–107%	0.063	0.010–0.116
2013	48.6%	8%–89%	0.046	0.008–0.085
2014	57.5%	13%–102%	0.057	0.011–0.104
2015	63.7%	17%–110%	0.068	0.013–0.122
2016	53.3%	11%–95%	0.054	0.011–0.097
2017	43.0%	7%–79%	0.041	0.009–0.074
2018	53.9%	14%–94%	0.055	0.014–0.097
2019	57.9%	17%–99%	0.061	0.016–0.105

Table ES13. Recent trend in spawning potential ratio (entered as 1-SPR / 1-SPR45%) and exploitation (catch divided by biomass of age-2 and older fish) for Cabezon in Oregon waters. Estimates for 2019 assume catch is equal to the default harvest control rule level of catch.

Year	(1-SPR) / (1-SPR45%)	95% Confidence Interval	Harvest Rate (proportion)	95% Confidence Interval
2007	85.1%	71.96–98.27	0.12	0.092–0.149
2008	89.6%	76.13–103.08	0.13	0.099–0.160
2009	94.0%	80.45–107.51	0.142	0.109–0.176
2010	86.5%	73.10–99.81	0.122	0.093–0.151
2011	94.1%	80.65–107.52	0.144	0.110–0.179
2012	93.7%	79.92–107.48	0.146	0.110–0.182
2013	80.6%	66.73–94.45	0.111	0.083–0.140
2014	67.8%	54.87–80.77	0.086	0.064–0.108
2015	69.3%	56.25–82.39	0.088	0.065–0.110
2016	66.7%	53.95–79.50	0.081	0.061–0.101
2017	92.3%	78.57–106.11	0.142	0.108–0.176
2018	83.4%	69.52–97.24	0.12	0.090–0.150
2019	96.9%	96.82–96.98	0.154	0.147–0.162

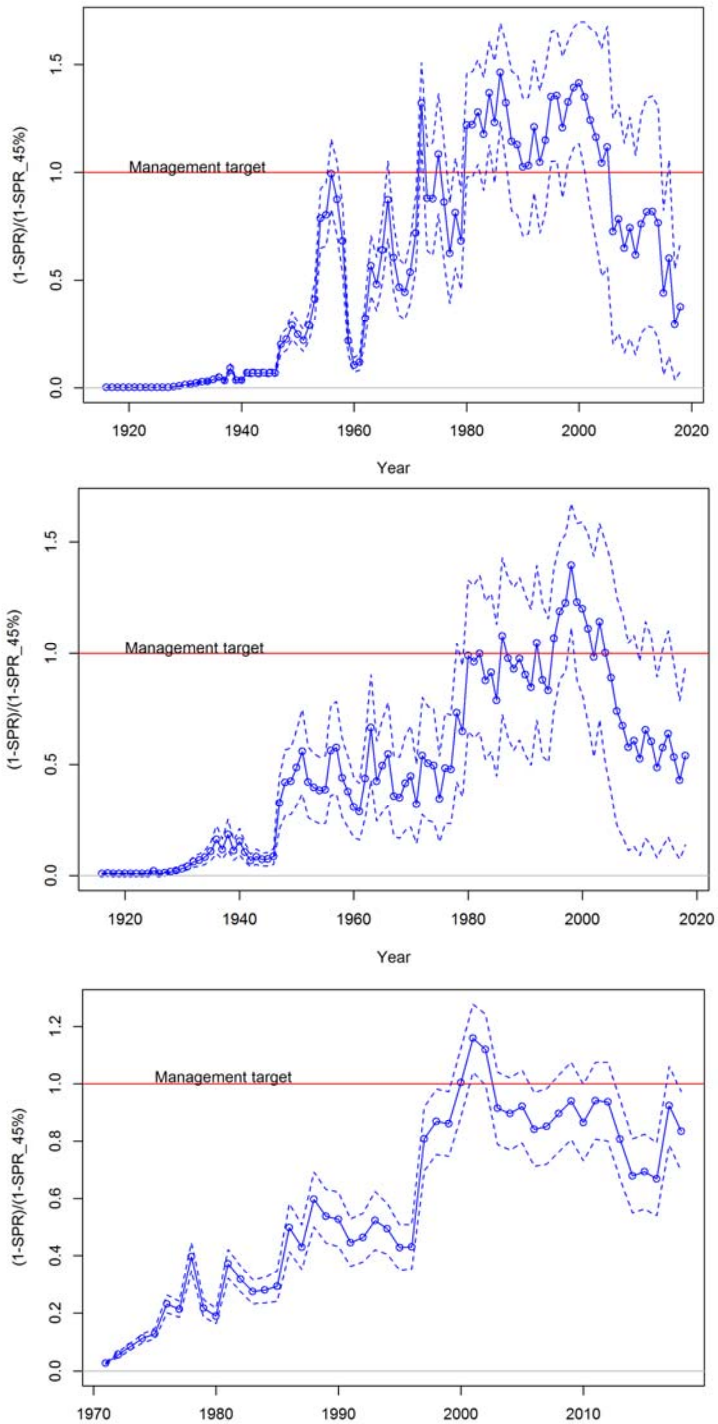

Figure ES5. Estimated spawning potential ratio (SPR) for the Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel) reference models with approximate 95% asymptotic confidence intervals. One minus SPR is plotted so that higher exploitation rates occur on the upper 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 SPR45%.

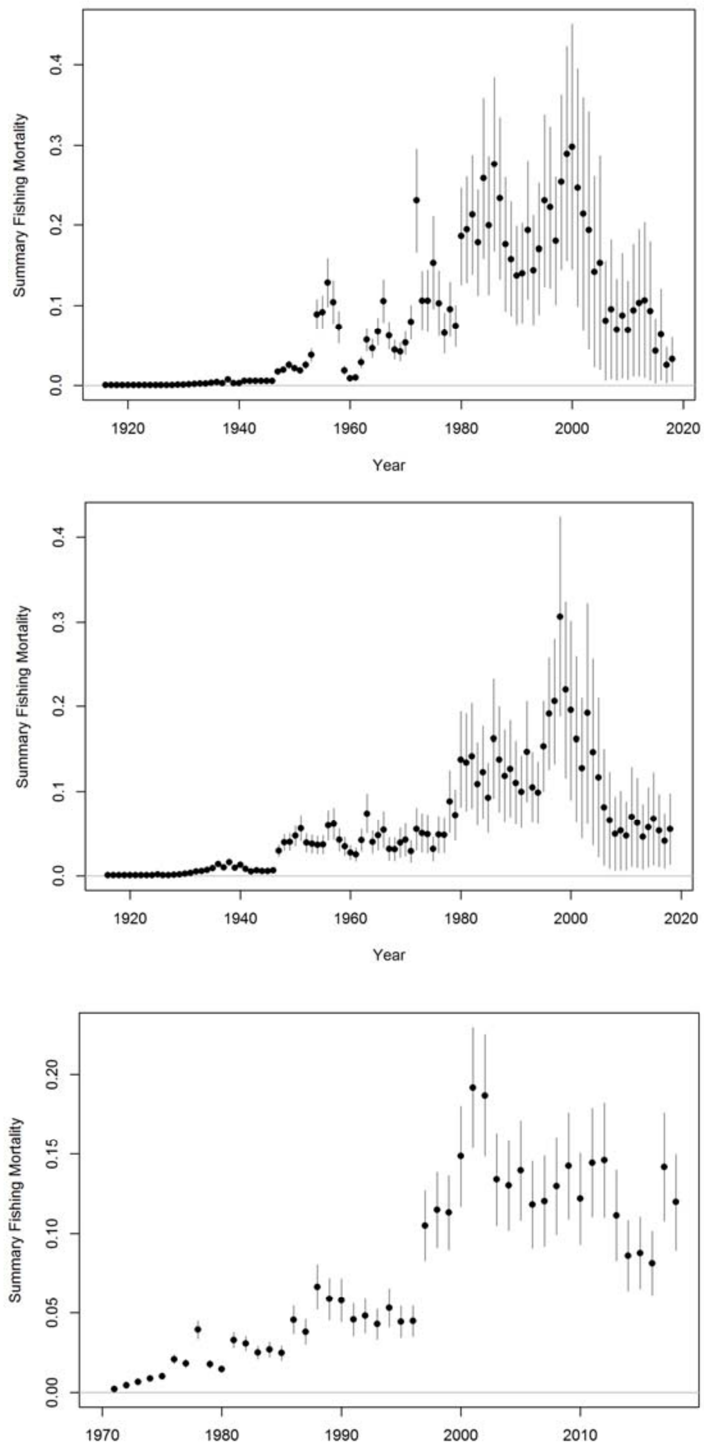

Figure ES6. Time-series of estimated summary harvest rate (total catch divided by age-2 and older biomass) for the Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel) reference models with approximate 95% asymptotic confidence intervals (grey lines).

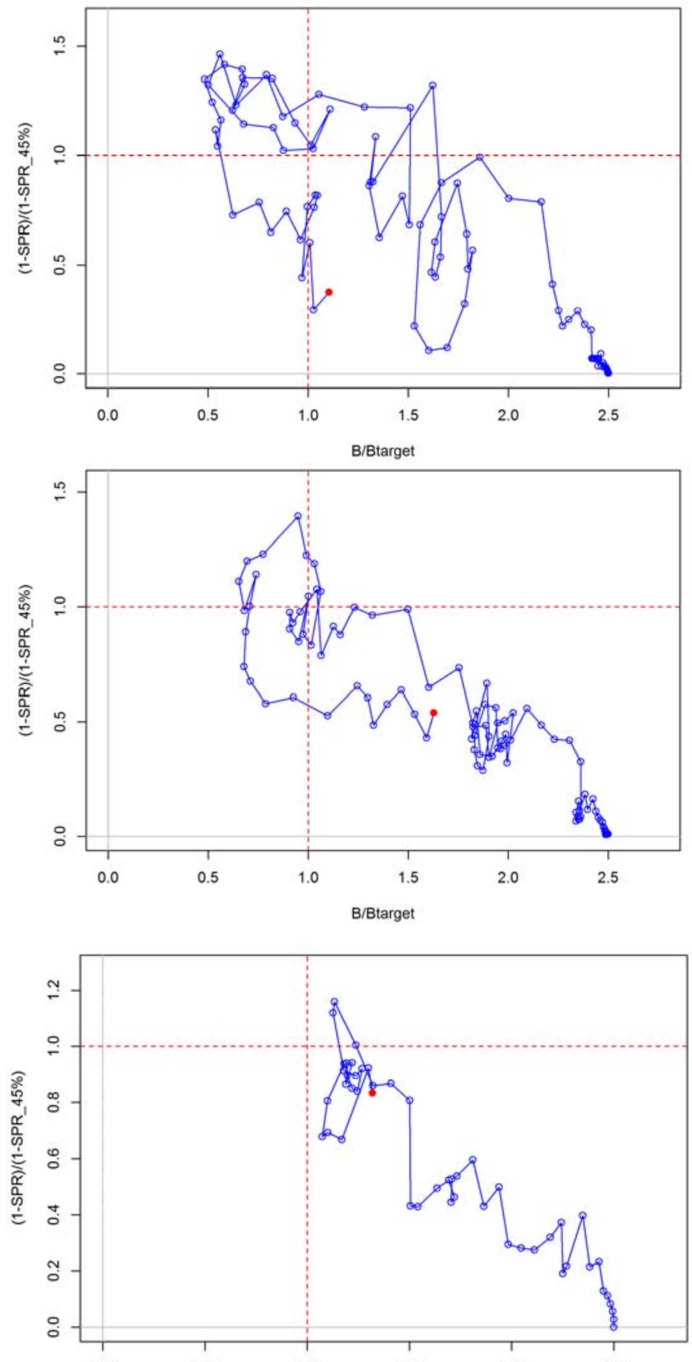

Figure ES7. Phase plot of estimated relative (1-SPR) vs. relative spawning output for the Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel) base models. The relative (1-SPR) is (1-SPR) divided by 0.5 (the SPR target). Relative depletion is the annual spawning output divided by the spawning output corresponding to 40% of the unfished spawning output. The red point indicates the year 2018.

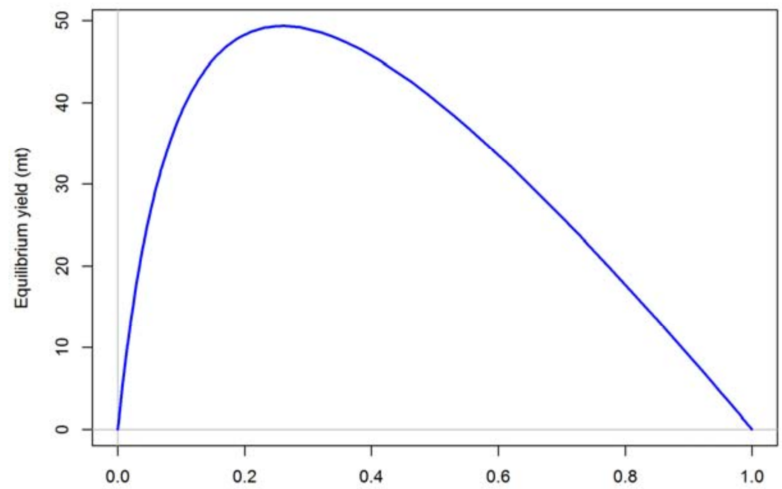

Figure ES8. Equilibrium yield curve (derived from reference point values reported in Tables 10-12, respectively) for the Southern California, Northern California and Oregon reference models. The depletion is relative to unfished spawning output. All areas have the same yield curve as it is determined by the steepness value that is the same for all stocks.

Ecosystem Considerations

Ecosystem data were not explicitly included in Cabezon assessment models. Cabezon are primarily a nearshore species found intertidally, among jetty rocks, and in and around kelp forests and rocky reefs out to depths of greater than 110 m. The nearshore distribution of this species makes it accessible to a greater portion of coastal populations and users of marine resources. This proximity to land also makes Cabezon habitat susceptible to terrestrial land use outfalls, ocean acidification, and other coastal disturbances. Large-scale climate conditions (e.g., ENSO warming events) could influence adult reproductive condition or habitat use. Pelagic juveniles feed primarily on small crustaceans, while larger pelagic juveniles and adults also feed on fish, algae, crabs, molluscs, and other organisms near the bottom. Cabezon are important prey species for a variety of nearshore marine vertebrates, including larger Cabezon and Lingcod. Cabezon are not thought to redistribute over long distances.

Reference Points

California

SCS

Reference points and management quantities for the SCS Cabezon reference model are listed in Table E14. Relative stock status is currently estimated above the biomass target reference point (40%), and is estimated to be at 49% (~95% asymptotic intervals = 11-87%) in 2019. Unfished spawning output was estimated at 205 mt (~95% asymptotic intervals = 161–248 mt; Table E14), and spawning output at the beginning of 2019 was estimated to be 101 mt (~95% asymptotic intervals = 19–183 mt). The target spawning output based on the biomass target ($SB_{40\%}$) is 82 mt, which corresponds to a catch of 17 mt. Equilibrium yield at the proxy F_{MSY} proxy ($SPR_{45\%}$) is 17 mt and the yield at the estimated F_{MSY} (SPR=35%) is 18 mt.

NCS

Reference points and management quantities for the NCS Cabezon reference model are listed in Table ES15. Relative stock status is currently estimated above the biomass target reference point (40%), and is estimated to be at 65% (~95% asymptotic intervals = 22–108%) in 2019. Unfished spawning output was estimated at 986 mt (~95% asymptotic intervals = 748–1,225 mt; Table ES15), and spawning output at the beginning of 2019 was estimated to be 643 mt (~95% asymptotic intervals = 159–1,126 mt). The target spawning output based on the biomass target ($SB_{40\%}$) is 395 mt, which corresponds to a catch of 116 mt. Equilibrium yield at the proxy F_{MSY} proxy ($SPR_{45\%}$) is 118 mt and the yield at the estimated F_{MSY} (SPR=33%) is 127 mt.

Oregon

Reference points and management quantities for the Oregon Cabezon reference model are listed in Table ES16. Spawning biomass has generally declined throughout the early part of the time series before becoming more stable (though still with year to year fluctuations) after the early 2000s. Recently, there has been a slight increase in spawning biomass from 2017 to 2019 due to an above average recruitment event in 2014. Stock status has remained above the biomass target reference point (40%) and is estimated to be at 53% (~95% asymptotic intervals = 43%-63%) in 2019. Unfished spawning output was estimated at 335 mt (~95% asymptotic intervals = 291-379 mt; Table E16) and spawning output at the beginning of 2019 was estimated to be 177 mt (~95% asymptotic intervals = 129-226 mt). The target spawning output based on the biomass target ($SB_{40\%}$) is 134 mt, which corresponds to a catch of 46 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{45\%}$ is also 46 mt.

Washington

OFLs for 2021 and 2022, estimated by Simple Stock Synthesis (SSS), are 22.8 mt and 17.3 mt, respectively, given a 2018 depletion of 65% estimated using length-based spawning potential ratio (LBSPR). Uncertainty in these OFL estimates is also explored and presented in the main document using 15 different scenarios that use three different catch history and five different depletion assumptions. In addition to reporting the median OFLs from each scenario, the scenarios are also combined into two ensembles. One ensemble treats all scenarios as equally plausible and the other weights the 65% depletion assumption and base catch history as more likely. The ensembles only differ by 0.1-0.3 mt from the OFLs produced by the 65% depletion and base catch history SSS run but show much wider uncertainty surrounding the median OFLs.

Management Performance

California

Currently, Cabezon has a 15 inch size limit in California for both the commercial and recreational fisheries. The recreational bag limit, seasons and depth restrictions have varied since 1999 to keep catch of Cabezon and co-occurring constraining species within harvest limits (Appendix B). Most recently, a three fish bag limit has been in place since 2011 for recreational anglers. Cabezon experienced emergency commercial closures for some portion of the year from 2001-2005 once the OY had been exceeded. Since then, cumulative trip limits have been reduced from 900 pounds to 200-300 pounds (inseason adjustment) so the commercial fishery could remain open and not exceed the state-wide OY (Table E17). Even though

Table ES14. Summary of reference points and management quantities for the Southern California reference case model.

Quantity	Estimate	95% Confidence Interval
Unfished Spawning biomass (female biomass)	205	161–248
Unfished Age 2+ Biomass (mt)	287	233–341
Spawning Biomass (2019, female biomass)	101	19–183
Unfished recruitment (R_0, thousands of recruits)	184	77–291
Depletion (2019, % of unfished spawning biomass)	49%	11–87%
Reference points based on $SB_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	82	65–99
SPR resulting in $B_{40\%}$	0.464	0.464–0.464
Exploitation rate resulting in $B_{40\%}$	0.123	0.101–0.146
Yield at $B_{40\%}$ (mt)	17	13–22
Reference points based on SPR proxy for MSY		
Proxy spawning biomass ($SPR_{45\%}$)	79	62–95
$SPR_{45\%}$	0.45	NA
Exploitation rate corresponding to $SPR_{45\%}$	0.129	0.105–0.152
Yield with $SPR_{45\%}$ at $SBSPR_{45\%}$ (mt)	17	13–22
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY})	56	43–69
SPR_{MSY}	0.353	0.343–0.362
Exploitation rate corresponding to SPR_{MSY}	0.174	0.141–0.208
MSY (mt)	18	14–23

Table ES15. Summary of reference points and management quantities for the Northern California reference case model.

Quantity	Estimate	95% Confidence Interval
Unfished Spawning biomass (female biomass)	986	748–1,225
Unfished Age 2+ Biomass (mt)	1,677	1,305–2,049
Spawning Biomass (2019, female biomass)	643	159–1,126
Unfished recruitment (R_0, thousands of recruits)	715	141–1,288
Depletion (2019, % of unfished spawning biomass)	65%	22%–108%
Reference points based on $SB_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	395	299–490
SPR resulting in $B_{40\%}$	0.464	0.464–0.464
Exploitation rate resulting in $B_{40\%}$	0.133	0.103–0.164
Yield at $B_{40\%}$ (mt)	116	67–165
Reference points based on SPR proxy for MSY		
Proxy spawning biomass ($SPR_{45\%}$)	379	287–470
$SPR_{45\%}$	0.45	NA
Exploitation rate corresponding to $SPR_{45\%}$	0.14	0.108–0.171
Yield with $SPR_{45\%}$ at $SBSPR_{45\%}$ (mt)	118	68–168
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY})	246	179–314
SPR_{MSY}	0.33	0.317–0.344
Exploitation rate corresponding to SPR_{MSY}	0.205	0.154–0.257
MSY (mt)	127	71–183

Table ES16. Summary of reference points and management quantities for the Oregon reference case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning biomass (female biomass)	335	290.8–379.2
Unfished Age 2+ Biomass (mt)	621	538.1–704.0
Spawning Biomass (2019, female biomass)	177	128.5–225.6
Unfished recruitment (R_0, thousands of recruits)	107.6	93.4–121.7
Depletion (2019, % of unfished spawning biomass)	52.84	42.96–62.72
Reference points based on $SB_{40\%}$		
Proxy spawning biomass ($B_{40\%}$)	134	116.3–151.7
SPR resulting in $B_{40\%}$	0.464	0.464–0.464
Exploitation rate resulting in $B_{40\%}$	0.154	0.147–0.161
Yield at $B_{40\%}$ (mt)	45.7	39.8–51.7
Reference points based on SPR proxy for MSY		
Proxy spawning biomass ($SPR_{45\%}$)	128.6	111.7–145.6
$SPR_{45\%}$	0.45	NA
Exploitation rate corresponding to $SPR_{45\%}$	0.161	0.154–0.169
Yield with $SPR_{45\%}$ at $SBSPR_{45\%}$ (mt)	46.4	40.4–52.5
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY})	87.2	76.0–98.4
SPR_{MSY}	0.34	0.335–0.344
Exploitation rate corresponding to SPR_{MSY}	0.233	0.223–0.244
MSY (mt)	49.4	42.9–55.8

the 2009 assessment of Cabezon was split into two sub-stocks, resulting in depletion levels of 45.2% (NCS) and 34% (SCS), the State of California continued to manage Cabezon on a state-wide level. Management measures were sufficiently restrictive to keep mortality within the harvest limits (Table E17). With attainment below 59% since 2010, the cumulative trip limit was increased to 500 lbs/2 month period in 2019, though the fishery remains closed in March and April, as has been the case since 2001.

Oregon

In Oregon, the Oregon Department of Fish and Wildlife (ODFW) manages Cabezon under a state harvest guideline set within or at the federal ACL, with specific allocations for the recreational and commercial sectors. Since 1976, recreational bag limits have been used for Cabezon either indirectly through multi-species bag limits (range = 5 - 25) or directly through Cabezon specific sub-bag limits (1 fish since 2011). A 16 inch minimum size limit has been in place since 2004 as well as the use of inseason closures. The commercial fishery for Cabezon largely developed with the onset of the live-fish market near the turn of the century, and have been managed through a limited entry permit system since 2004. Bimonthly trip limits with inseason adjustments are also used for intraannual management. Minimum size limits of 14 and 16 inches were implemented in 2000 and 2004, respectively.

The Oregon model infers that no level of overfishing has occurred since 2002, with recent harvest rates being around 80% of the management target (Figure ES5). Historically, Oregon Cabezon was an individual component species in the Other Fish complex. However, in 2011, Oregon Cabezon was pulled out of this complex and stock-specific harvest specifications for Oregon Cabezon had been specified up until 2018, at which point Cabezon was moved into a complex with Kelp Greenling. A history of harvest limits (ACLs), complex impacts and Cabezon impacts are detailed in Table E17. ACLs are typically set at the ABC for Cabezon. Total fishing mortality for Cabezon was within specified ACL/ABC harvest levels in each year and stock with one exception (Table E17). In 2017, the Cabezon ACL/ABC and OFL were exceeded in Oregon. Fisheries managers in Oregon have taken multiple management actions to prevent future Cabezon impacts from exceeding harvest specifications.

Washington

Cabezon was managed in a fifteen-groundfish daily limit until 2010 for Washington coastal areas. In 2011, WDFW implemented a two- fish daily limit for all coastal marine catch areas. Later, more restrictive regulations were implemented for the northern Washington coast - daily limit was reduced to one fish in 2013; and a 18” minimum size requirement was established in 2014. Cabezon ACLs for 2017 and 2018 were 3.8 mt and 4.0 mt, respectively. Catches in Washington exceeded these harvest guidelines. In response, the Council reduced the daily limit to one Cabezon in all marine areas and removed the minimum size requirement effective 2019. Based on 2017 DBSRA analysis, ABCs for 2019 and 2020 were set at 4.6 mt and 4.5 mt, respectively (83.4% of OFLs). Cabezon have been managed in the Other Fish complex up until 2018, at which point they were moved into a species management complex with Kelp Greenling.

Unresolved Problems and Major Uncertainties

California

SCS

The SCS model suffers greatly from a lack of data to free up estimation of growth parameters. As of now, fixing growth to the estimates from the NCS model greatly constrains the model’s ability to estimate uncertainty. This can also be said for the fixed selectivity parameters of the commercial dead fishery (also fixed to the NCS model estimates), though the magnitude of removals (rarely over a metric ton in any given year) is generally small, therefore the effect size of this issue is likely also small. Length composition sampling is also generally sparse for the recreational fisheries and could improve. The live-fish fishery is fairly well sampled, but is only more recent in the time series. Indices of abundance remain fishery-dependent with essentially little information content in the stock assessment, thus length compositions carry the greatest weight in the stock assessment. The limited biological data causes some concern about where the information content for the estimated recruitments are derived, with a nontrivial possibility being the distinctive removal time series. The choice of not estimating recruitment deviations would result in a higher relative stock status due to a higher estimate of current stock biomass.

Table ES17. Summary of recent management history for Cabezon relative to harvest limits (mt) in California and Oregon. Impacts are from WCGOP total fishing mortality annual reports. In 2010, Oregon Cabezon was a part of the "Other Fish" complex and impacts include Washington recreational. All other OY/ACLs are state-specific.

Stock	Year	Control Rule	Harvest Limit	Complex Impacts (mt)	Cabezon Impacts (mt)	Cabezon % Complex Impacts	Complex Impacts % of Limit	Cabezon % Of Limit
California	2010	OY	79	-	47	-	-	59%
	2011	ACL	179	-	50	-	-	28%
	2012	ACL	168	-	74	-	-	44%
	2013	ACL	163	-	68	-	-	42%
	2014	ACL	158	-	82	-	-	52%
	2015	ACL	154	-	90	-	-	58%
	2016	ACL	151	-	78	-	-	52%
	2017	ACL	157	-	55	-	-	35%
	2018	ACL	156	-	*	-	-	*
	2019	ACL	147	-	*	-	-	*
Oregon	2010	OY	5600	2231	49	2%	40%	-
	2011	ACL	50	-	48	-	-	96%
	2012	ACL	48	-	47	-	-	98%
	2013	ACL	47	-	34	-	-	73%
	2014	ACL	47	-	27	-	-	58%
	2015	ACL	47	-	27	-	-	58%
	2016	ACL	47	-	28	-	-	60%
	2017	ACL	49	-	51	-	-	104%
	2018	ACL	49	-	*	-	-	*
	2019	ACL	47	-	*	-	-	*

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

NCS

The NCS model presents a remarkable amount of current relative stock status and biomass uncertainty. The estimation of natural mortality, growth parameters and recruitment results in biomass estimates near 0 to 2 times the median value, and relative stock status from near extinction to well over unfished levels. This asymptotic variance would benefit from a Bayesian consideration to see if the uncertainty is non-asymptotic (very likely) and more on the higher end of the biomass and relative stock status levels. There is a large amount of variance attributed to length variability, and more coupled age and length data could help determine if current estimates are too high, thus causing high uncertainty in biomass. Likewise, more contemporary age and length sampling could help reconcile the large uncertainty in recent recruitment estimates that is adding to the uncertainty in estimating recent biomass, and thus relative stock status. Much of the model information is coming from the commercial live-fish length compositions. Not estimating recruitments makes the population seem more productive, with a smaller estimate of initial biomass. While the within-model variation is high, there is still some question about how much uncertainty is left unexplored by the reference model through fixed parameters. This is especially true for steepness that demonstrates a very low estimated value and a generally uninformed likelihood profile. There is unsurprising sensitivity to natural mortality, and several possible variants on values used in the past Cabezon assessments or methods used in other groundfish stock assessments would suggest a stock at a higher relative stock size due mostly to higher current stock size. So while the asymptotic estimate of within-model uncertainty is large, many of the explored sensitivities demonstrate a population with median current biomass higher than the reference model and thus at a higher stock status.

Oregon

The most significant uncertainty for the 2019 Oregon Cabezon assessment model is the size of the population scale and the treatment and value of natural mortality. This assessment is generally consistent with the scale of population size estimated in the 2009 assessment (unfished spawning biomass 335 mt and 409 mt, respectively); however, the associated scale parameter (R_0) was sensitive to alternative data and model structure assumptions examined in this assessment. The treatment of natural mortality was a major structural consideration that was explored in the development of the base model. In particular, alternative approaches to estimating or fixing female and male natural mortality based on prior information or life history relationships were evaluated. There was little information in the data to estimate gender-specific selectivity patterns, so population differences by gender were based solely on differences in growth and natural mortality. Another source of potential uncertainty was the use and development of fishery-dependent indices of abundance. There are no fishery-independent surveys available for Cabezon that provide an adequate spatiotemporal resolution for the coastal Oregon population. The development of a comprehensive fishery-independent index of abundance would help to resolve uncertainty in population scale and relieve the assumption that fishery-based CPUE is proportional to stock abundance. The catch history for recreational fishing fleets in years prior to 1979 and for the shore- (and estuary-) specific fleet in recent years (2006-2014) has been inferred as the best available information through communication with the Oregon Department of Fish and Wildlife (ODFW) but remains quite uncertain. Steepness, while fixed, is still highly uncertain for Cabezon. Stock structure and its relationship to the current political/management boundaries are also not fully understood. In addition, uncertainty around the size of the estimated above average, but highly uncertain, 2014 year class and the approach used to weight composition data had an impact on quantities (e.g., stock status and OFLs) used to inform current and future management decisions.

Harvest Projections and Decision Table

Forecasted population projections (Tables ES18-ES23) for the California (SCS, Tables ES18 and ES19; NCS, Tables ES20 and ES21) and Oregon (Tables ES22 and ES23) are shown using a $F_{SPR=0.45}$ to calculate the OFL and a ‘base’ sigma of 0.5 along with either a P* = 0.40 or a P* = 0.45 for the ABCs. The 40-10 harvest control rule is also triggered once spawning biomass decreases below $SB_{40\%}$. Projected ABCs through 2030 are calculated using an incremental increase in sigma through time (as directed by the PFMC Scientific and Statistical Committee) to account for increasing uncertainty as projections progress through time and assue full attainment. The resulting change in the ABC buffer applied during the forecast period is reported in each table. The 2019 and 2020 removal values are fixed to the harvest specification for the current management cycle.

Decision tables for the California (SCS, Table ES24; NCS, Table ES25) and Oregon (Table ES26) substocks include three states of nature and three catch considerations. The middle state is the reference model, with the low biomass state and high biomass state achieved through changing female natural mortality (while estimating male natural mortality) until the spawning biomass in the terminal year is approximates the 12.5% and 87.5% percentile values based on the asymptotic uncertainty of the terminal year spawning biomass from the reference model. Three catch streams, each one representing the 12-year projection for each state of nature considered, were subsequently applied to each state of nature to construct a 3x3 decision table.

Table ES18. Projection of Cabezon OFL, catch, biomass, and depletion using the Southern California reference model projected with total projected catch equal to 21.9 and 22.8 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by $F_{SPR=45\%}$. This projection assumes a sigma = 0.5 with a P*=0.40 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	21.9	1	12.9	203.6	100.6	49.2%
2020	22.8	1	12.9	206.3	106.4	52.0%
2021	23.3	0.873	20.4	169.6	110.5	54.0%
2022	22.6	0.864	19.6	170.4	108.0	52.8%
2023	22.0	0.856	18.8	171.1	105.1	51.4%
2024	21.5	0.848	18.2	171.8	102.4	50.0%
2025	21.1	0.84	17.7	172.5	100.2	49.0%
2026	20.8	0.832	17.3	173.2	98.5	48.2%
2027	20.7	0.824	17.0	173.9	97.4	47.6%
2028	20.5	0.817	16.8	174.5	96.6	47.2%
2029	20.5	0.809	16.5	175.3	96.0	46.9%
2030	20.4	0.801	16.3	176.0	95.6	46.8%

Table ES19. Projection of Cabezon OFL, catch, biomass, and depletion using the Southern California reference model projected with total projected catch equal to 21.9 and 22.8 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by $F_{SPR=45\%}$. This projection assumes a sigma = 0.5 with a P*=0.45 for calculating buffers, which is the default P* value for cabezon.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	21.9	1	12.9	203.6	100.6	49.2%
2020	22.8	1	12.9	206.3	106.4	52.0%
2021	23.3	0.935	21.9	164.1	110.5	54.0%
2022	22.5	0.93	21.0	164.5	107.0	52.3%
2023	21.7	0.926	20.1	164.8	103.1	50.4%
2024	21.0	0.922	19.5	165.1	99.6	48.7%
2025	20.5	0.917	18.9	165.5	96.7	47.3%
2026	20.2	0.913	18.5	165.8	94.5	46.2%
2027	19.9	0.909	18.2	166.1	92.8	45.4%
2028	19.7	0.904	17.9	166.5	91.5	44.7%
2029	19.5	0.9	17.7	166.8	90.5	44.3%
2030	19.4	0.896	17.5	167.2	89.8	43.9%

Table ES20. Projection of Cabezon OFL, catch, biomass, and depletion using the Northern California reference model projected with total projected catch equal to 194.1 and 197.3 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by $F_{SPR=45\%}$. This projection assumes a sigma = 0.5 with a P*=0.40 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	194.1	1	77.8	1281.6	639.3	65.1%
2020	197.3	1	77.8	1301.7	652.6	66.4%
2021	201.8	0.873	176.2	1312.2	672.5	68.5%
2022	189.5	0.864	163.8	1235.8	627.4	63.9%
2023	178.4	0.856	152.7	1172.1	585.7	59.6%
2024	168.8	0.848	143.1	1121.1	550.7	56.1%
2025	161.2	0.84	135.4	1081.8	523.8	53.3%
2026	155.5	0.832	129.4	1052.1	504.2	51.3%
2027	151.4	0.824	124.7	1029.8	490.2	49.9%
2028	148.4	0.817	121.2	1012.9	480.0	48.9%
2029	146.1	0.809	118.2	999.9	472.5	48.1%
2030	144.4	0.801	115.7	990.0	467.0	47.6%

Table ES21. Projection of Cabezon OFL, catch, biomass, and depletion using the Northern California reference model projected with total projected catch equal to 194.1 and 197.3 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by $F_{SPR=45\%}$. This projection assumes a sigma = 0.5 with a P*=0.45 for calculating buffers, which is the default P* value for cabezon.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	194.1	1	77.8	1281.6	639.3	65.1%
2020	197.3	1	77.8	1301.7	652.6	66.4%
2021	201.8	0.935	188.7	1312.2	672.5	68.5%
2022	187.6	0.93	174.5	1226.0	620.2	63.1%
2023	175.0	0.926	162.0	1155.1	573.2	58.4%
2024	164.3	0.922	151.5	1098.8	534.3	54.4%
2025	155.9	0.917	143.0	1055.6	504.8	51.4%
2026	149.7	0.913	136.7	1023.0	483.4	49.2%
2027	145.2	0.909	132.0	998.1	467.9	47.6%
2028	141.7	0.904	128.1	978.9	456.4	46.5%
2029	139.2	0.9	125.2	963.8	447.7	45.6%
2030	137.1	0.896	122.9	951.7	440.9	44.9%

Table ES22. Projection of Cabezon OFL, catch, biomass, and depletion using the Oregon reference model projected with total projected catch equal to 47.1 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by FSPR=45% (ABC=ACL). This projection assumes a base sigma = 0.5 with a P*=0.40 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	60.9	1	47.1	372.5	177.0	0.53
2020	59.5	1	47.1	365.4	173.4	0.52
2021	58.3	0.873	50.9	358.5	169.4	0.51
2022	56.7	0.864	48.9	349.0	163.9	0.49
2023	55.5	0.856	47.5	342.2	159.8	0.48
2024	54.7	0.848	46.4	337.5	157.0	0.47
2025	54.2	0.84	45.5	334.1	155.0	0.46
2026	53.8	0.832	44.8	331.7	153.7	0.46
2027	53.5	0.824	44.1	330.2	152.8	0.46
2028	53.4	0.817	43.6	329.3	152.3	0.45
2029	53.3	0.809	43.1	328.8	152.1	0.45
2030	53.3	0.801	42.7	328.8	152.1	0.45

Table ES23. Projection of Cabezon OFL, catch, biomass, and depletion using the Oregon reference model projected with total projected catch equal to 47.1 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment . The predicted OFL is the calculated total catch determined by FSPR=45% (ABC=ACL). This projection uses a base sigma = 0.5 with a P*=0.45 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	60.9	1	47.1	372.5	177.0	0.53
2020	59.5	1	47.1	365.4	173.4	0.52
2021	58.3	0.935	54.5	358.5	169.4	0.51
2022	56.1	0.93	52.2	345.8	162.0	0.48
2023	54.5	0.926	50.5	336.6	156.5	0.47
2024	53.4	0.922	49.3	329.8	152.4	0.45
2025	52.6	0.917	48.2	324.7	149.5	0.45
2026	52.0	0.913	47.4	320.9	147.3	0.44
2027	51.5	0.909	46.8	318.0	145.7	0.43
2028	51.1	0.904	46.2	315.9	144.5	0.43
2029	50.9	0.9	45.8	314.3	143.6	0.43
2030	50.7	0.896	45.4	313.2	143.0	0.43

Table ES24. Decision table summarizing 12-year projections (2019 – 2030) for the Southern California Cabezon substock. The alternative low and high states of nature (columns) are defined by setting natural mortality to achieve 12.5% and 87.5% terminal year spawning biomass values based on the reference model asymptotic variance. Rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2019 and 2020 are allocated to each fleet based on ACL set in the harvest specifications. A sigma of 0.5 was used with a P* of 0.45 to assign yearly buffer multipliers.

			State of Nature					
			Low		Reference		High	
			Female M = 0.18		Female M = 0.26		Female M = 0.35	
Catch stream	Year	Catch (mt)	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
Low state projections	2019	77.81	54	22%	101	49%	143	73%
	2020	77.81	56	23%	101	49%	134	68%
	2021	76.59	58	24%	98	48%	123	62%
	2022	80.39	63	26%	95	47%	112	57%
	2023	82.75	68	28%	92	45%	103	52%
	2024	83.93	72	30%	90	44%	96	49%
	2025	84.33	76	31%	88	43%	92	46%
	2026	84.56	79	33%	86	42%	88	45%
	2027	84.72	82	34%	85	41%	86	44%
	2028	84.78	85	35%	84	41%	84	43%
	2029	84.89	87	36%	83	41%	82	42%
	2030	84.92	89	37%	82	40%	81	41%
Reference model projections	2019	77.81	54	22%	101	49%	143	73%
	2020	77.81	56	23%	106	52%	151	77%
	2021	188.71	58	24%	111	54%	155	79%
	2022	174.46	54	22%	107	52%	149	76%
	2023	162.01	50	21%	103	50%	143	73%

	2024	151.48	47	20%	100	49%	138	70%
	2025	142.99	46	19%	97	47%	135	68%
	2026	136.70	44	18%	94	46%	133	67%
	2027	131.95	43	18%	93	45%	131	66%
	2028	128.14	42	17%	92	45%	130	66%
	2029	125.23	41	17%	91	44%	129	65%
	2030	122.85	40	17%	90	44%	128	65%
High state projections	2019	77.81	54	22%	101	49%	143	73%
	2020	77.81	56	23%	106	52%	151	77%
	2021	424.33	58	24%	111	54%	155	79%
	2022	353.19	43	18%	95	46%	138	70%
	2023	304.02	31	13%	82	40%	124	63%
	2024	270.91	22	9%	73	36%	113	57%
	2025	249.51	15	6%	67	33%	105	53%
	2026	236.17	9	4%	63	31%	100	51%
	2027	227.05	4	2%	60	30%	96	49%
	2028	219.87	0	0%	58	28%	93	47%
	2029	214.26	0	0%	56	27%	91	46%
	2030	209.63	0	0%	54	26%	90	46%

Table ES25. Decision table summarizing 12-year projections (2019 – 2030) for the Northern California Cabezon substock. The alternative low and high states of nature (columns) are defined by setting natural mortality to achieve 12.5% and 87.5% terminal year spawning biomass values based on the reference model asymptotic variance. Rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2019 and 2020 are allocated to each fleet based on ACL set in the harvest specifications. A sigma of 0.5 was used with a P* of 0.45 to assign yearly buffer multipliers.

			State of Nature					
			Low		Reference		High	
			Female M = 0.18		Female M = 0.24		Female M = 0.346	
Catch stream	Year	Catch (mt)	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
Low state projections	2019	77.81	352	33%	639	65%	939	91%
	2020	77.81	361	34%	585	60%	752	73%
	2021	76.59	379	36%	554	56%	659	64%
	2022	80.39	395	37%	527	54%	595	58%
	2023	82.75	405	38%	500	51%	544	53%
	2024	83.93	411	39%	476	48%	507	49%
	2025	84.33	414	39%	456	46%	480	46%
	2026	84.56	416	39%	440	45%	461	45%
	2027	84.72	418	40%	428	44%	447	43%
	2028	84.78	421	40%	419	43%	436	42%
	2029	84.89	423	40%	412	42%	428	41%
	2030	84.92	425	40%	406	41%	422	41%
Reference model projections	2019	77.81	352	33%	639	65%	939	91%
	2020	77.81	361	34%	653	66%	945	91%
	2021	188.71	379	36%	673	68%	961	93%
	2022	174.46	336	32%	620	63%	903	87%
	2023	162.01	302	29%	573	58%	849	82%

	2024	151.48	276	26%	534	54%	804	78%
	2025	142.99	258	24%	505	51%	770	75%
	2026	136.70	246	23%	483	49%	747	72%
	2027	131.95	238	23%	468	48%	731	71%
	2028	128.14	232	22%	456	46%	720	70%
	2029	125.23	227	22%	448	46%	712	69%
	2030	122.85	223	21%	441	45%	707	68%
High state projections	2019	77.81	352	33%	639	65%	939	91%
	2020	77.81	401	38%	691	70%	945	91%
	2021	424.33	456	43%	746	76%	961	93%
	2022	353.19	265	25%	550	56%	784	76%
	2023	304.02	135	13%	409	42%	662	64%
	2024	270.91	57	5%	313	32%	584	56%
	2025	249.51	20	2%	249	25%	537	52%
	2026	236.17	15	1%	207	21%	509	49%
	2027	227.05	0	0%	176	18%	491	48%
	2028	219.87	0	0%	148	15%	478	46%
	2029	214.26	0	0%	122	12%	468	45%
	2030	209.63	0	0%	97	10%	460	45%

Table ES26. Decision tables summarizing 12-year projections (2019 – 2030) for the Oregon Cabezon substock. The alternative low and high states of nature (columns) are defined by setting natural mortality to achieve 12.5% and 87.5% terminal year spawning biomass values based on the reference model asymptotic variance. Rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2019 and 2020 are allocated to each fleet based on ACL set in the harvest specifications. A sigma of 0.5 was used with a P* of 0.45 to assign yearly buffer multipliers.

			State of Nature					
			Low		Reference		High	
			Female M = 0.19		Female M = 0.24		Female M = 0.27	
Catch stream	Year	Catch (mt)	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
	2019	47.1	146.4	0.42	177.0	0.53	206.1	0.60
	2020	47.1	142.0	0.41	173.4	0.52	202.7	0.59
	2021	34.8	137.4	0.40	169.4	0.51	198.6	0.58
	2022	35.1	138.2	0.40	172.0	0.51	201.0	0.59
	2023	35.2	139.0	0.40	174.6	0.52	203.5	0.60
Low state	2024	35.2	139.7	0.40	177.0	0.53	205.7	0.60
projections	2025	35.1	140.3	0.40	179.2	0.53	207.6	0.61
	2026	35.1	140.8	0.41	181.2	0.54	209.4	0.61
	2027	35.0	141.3	0.41	183.0	0.55	211.0	0.62
	2028	34.9	141.8	0.41	184.8	0.55	212.5	0.62
	2029	34.8	142.3	0.41	186.6	0.56	214.0	0.63
	2030	34.7	142.8	0.41	188.3	0.56	215.4	0.63
	2019	47.1	146.4	0.42	177.0	0.53	206.1	0.60
	2020	47.1	142.0	0.41	173.4	0.52	202.7	0.59
	2021	50.9	137.4	0.40	169.4	0.51	198.6	0.58
	2022	48.9	131.2	0.38	162.0	0.48	192.9	0.56
	2023	47.5	126.5	0.36	156.5	0.47	189.2	0.55
Reference	2024	46.4	123.1	0.35	152.4	0.45	186.9	0.55
model	2025	45.5	120.6	0.35	149.5	0.45	185.6	0.54
projections	2026	44.8	118.9	0.34	147.3	0.44	185.0	0.54
	2027	44.1	117.6	0.34	145.7	0.43	185.0	0.54
	2028	43.6	116.7	0.34	144.5	0.43	185.3	0.54
	2029	43.1	116.1	0.33	143.6	0.43	185.9	0.54
	2030	42.7	115.9	0.33	143.0	0.43	186.8	0.55

	2019	47.1	146.4	0.42	177.0	0.53	206.1	0.60
	2020	47.1	142.0	0.41	173.4	0.52	202.7	0.59
	2021	65.1	137.4	0.40	169.4	0.51	198.6	0.58
	2022	60.9	123.9	0.36	156.6	0.47	183.5	0.54
	2023	57.9	113.5	0.33	147.4	0.44	172.5	0.50
High state	2024	55.7	105.7	0.30	141.0	0.42	164.7	0.48
projections	2025	54.1	99.7	0.29	136.6	0.41	159.3	0.47
	2026	52.8	94.9	0.27	133.6	0.40	155.4	0.46
	2027	51.7	90.9	0.26	131.5	0.39	152.6	0.45
	2028	50.9	87.4	0.25	130.0	0.39	150.4	0.44
	2029	50.1	84.4	0.24	129.2	0.39	148.9	0.44
	2030	49.5	81.8	0.24	128.7	0.38	147.7	0.43

Research and Data Needs

There are several areas for further research that were identified while conducting these 2019 sub-stock assessments that could result in information useful to future Cabezon assessments. The list below is believed to represent strategic pieces of information that would likely help to resolve key uncertainties associated with assessing Cabezon. Many would provide the necessary information to evaluate basic life history parameters and spatiotemporal population and fleet dynamics. Not all listed data and research needs may apply to all sub-stocks.

1. Fishery-independent surveys. A fishery-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. Continued support and development of current fishery-independent nearshore surveys is needed to extend the time series and increase spatial coverage.
2. Improve estimates of natural mortality. All sub-stocks show significant sensitivity to natural mortality, a parameter difficult to estimate in assessment models and often assumed known and invariant across space and time. Estimates of natural mortality may be derived from tag-recapture studies or the comparison of biological information (e.g., length compositions) inside and outside marine protected areas for relatively sedentary species.
3. Male incorporated definition of spawning potential (spawning output/biomass). The nest-guarding behavior of Cabezon males gives added reproductive importance to their abundance, relative to most other groundfish species. A metric other than female spawning biomass may be needed to incorporate the status of the male portion of the population into reference points. Further investigation is needed to identify how paternal effects influence reproductive success and appropriate ways (if warranted) those can be incorporated into metrics for evaluating population status.
4. Defining the stock structure of Cabezon. Current work on Cabezon stock structure needs continued attention to better understand the connectivity between Cabezon sub-stocks identified in this

assessment within the California Current Ecosystem. This would help focus or inform future sampling design to provide data for assessment purposes as well as refining sub-stock boundaries.

5. Changes in batch fecundity with age. Batch fecundity in Cabezon is recognized, but it is not understood how and if batch fecundity changes with age. Understanding whether the number of batches increases with age will help specify the fecundity relationship in the assessment model.
6. Collection of gender-specific data. Gender-specific information from the recreational fishery should be collected for Cabezon given differences in growth and potentially natural mortality by gender. Evidence presented at the STAR panel demonstrated that non-invasive sexing is possible and should be done. 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 Cabezon and other species important to recreational fisheries.
7. The effects of climate on Cabezon population dynamics. Links between prevailing oceanographic conditions and Cabezon recruitment strength should be explored further to help increase the understanding of spatially-explicit recruitment responses and inform future recruitment events. For example, recruitment pattern similarities among sub-stocks suggest a possible link between environmental forcing and population dynamics.
8. Accurate accounting of removals for the recreational shore fleets (estuary-boat and shore fishing modes). Fisheries exploited by the recreational sector are traditionally hard to monitor. Since 2005, there has been limited comprehensive information collected about catch or effort or biological information from the shore (and estuary) fishing fleet. The increased effort to monitor this fleet in recent years should continue. Although the shore fleet does not represent a major fleet component for Cabezon in terms of landed catch, it does tend to catch smaller individuals. Biological data on smaller individuals is a data gap for Cabezon and many other nearshore species.
9. Age and growth determination. Differences in the estimated growth parameters between Oregon and California (particularly the growth coefficient, k) and among external sources deserve further attention. Further attention to ageing Cabezon in California is needed to increase spatial understanding of Cabezon growth along the coast. Age samples from each fishery in California would also help to define growth and selectivity, while further informing recruitment patterns and helping to decrease the uncertainty in the scale (absolute abundance) of each sub-stock. Continued age sampling from each fishery in Oregon is encouraged.
10. Discard length composition. Future research to evaluate the best way to incorporate discard length data in stock assessments is recommended to garner benefit from substantial sample sizes available for some species, while minimizing adverse effects on model complexity.
11. Alternative Fishery Dependent Indices of Abundance. While the CPFV logbook index of abundance provides information on the trend in the period prior to 2000, many regulations affecting catch rates were implemented (ie, bag, season, depth and length restrictions) went into effect thereafter that the limited data associated with the logbook cannot resolve. Private boat, CPFV dockside and onboard CPFV data from the MRFSS and CRFS programs can be analyzed using the Stephens and MacCall (2004) filter or methods implemented in geographic information systems developed Monk et al. (2013) to account for some of these changes. Current lack of data availability from RecFIN on the trip level, prevented further exploration in this assessment. A workshop or methodology review evaluating the application of these methods to develop best practices and development of preformatted data bases to facilitate their application to nearshore stocks would be streamline application in future stock assessments.
12. Integrated stock assessment for Washington state. The intermediate step to leverage information from limited length samples using LBSPR to inform an important input of the catch estimator method SSS was a strong step forward. Additionally, the move from DBSRA to SSS also explicitly sets up the inclusion of index information and length compositions into future modelling work.

There should be a strong consideration that the next iteration of the Washington state substock model be a fully integrated Stock Synthesis model.

Table ES28. Summary of reference model results for Cabezon in Southern California waters. The unit for spawning output is female biomass.

					Spawning Output		Recruitment (000's)		Depletion	
Year	Total removals (mt)	1-SPR	Exploit. rate	Age 2+ Biomass	Est.	~95% CI	Est.	~95% CI	Est.	~95% CI
2007	10.66	0.78	0.1	112	62	4–119	123	34–438	30.3%	1.3–59.3%
2008	8.45	0.65	0.07	121	67	4–129	130	38–448	32.5%	1.3–63.8%
2009	11.34	0.74	0.09	130	73	6–140	124	37–412	35.7%	2.2–69.2%
2010	9.28	0.62	0.07	135	79	7–151	93	27–319	38.5%	2.6–74.4%
2011	13.02	0.76	0.09	139	84	9–160	114	33–399	41.3%	3.7–78.8%
2012	14.06	0.82	0.1	137	86	8–164	129	36–465	41.9%	3.7–80.1%
2013	14.08	0.82	0.11	132	85	6–164	111	30–407	41.4%	2.9–79.9%
2014	11.95	0.77	0.09	129	82	3–160	146	38–568	39.9%	1.7–78.0%
2015	5.44	0.44	0.04	127	79	1–157	230	54–985	38.8%	1.2–76.3%
2016	8.44	0.6	0.06	133	83	5–160	166	41–683	40.3%	3.2–77.4%
2017	3.66	0.29	0.03	143	84	7–162	160	40–631	41.1%	4.4–77.7%
2018	5.2	0.38	0.03	159	90	12–169	162	41–634	44.2%	7.5–80.9%
2019	-	NA	NA	204	101	19–183	165	42–644	49.2%	11.0–87.4%

Table ES29. Summary of reference case model results for Cabezon in Northern California waters. The unit for spawning output is female biomass.

Year	Total removals (mt)	1- SPR	Exploit. rate	Age 2+ Biomass	Spawning Output		Recruitment (000s)		Depletion	
					Est.	~95% CI	Est.	~95% CI	Est.	~95% CI
2007	44.34	0.67	0.07	674	281	36–525	509	149–1,742	28.4%	5.5–51.4%
2008	39.05	0.58	0.05	783	310	39–581	485	144–1,628	31.5%	6.1–56.9%
2009	47.18	0.61	0.05	880	366	50–681	557	167–1,860	37.1%	7.5–66.6%
2010	44.85	0.53	0.05	947	433	62–805	789	240–2,593	43.9%	9.2–78.7%
2011	69.66	0.65	0.07	996	491	79–903	802	241–2,671	49.8%	11.4–88.2%
2012	65	0.6	0.06	1031	512	81–942	885	274–2,858	51.9%	11.9–91.9%
2013	49.81	0.49	0.05	1,077	524	85–962	535	168–1,708	53.1%	12.6–93.5%
2014	66.02	0.58	0.06	1,149	551	100–1,001	534	172–1,652	55.8%	14.5–97.1%
2015	80.28	0.64	0.07	1,186	579	110–1,047	667	210–2,117	58.7%	15.9–101.4%
2016	63.92	0.53	0.05	1,190	605	115–1,094	1050	325–3,391	61.3%	16.8–105.8%
2017	49.66	0.43	0.04	1,200	628	130–1,127	741	222–2,470	63.7%	18.7–108.7%
2018	69.44	0.54	0.06	1,251	643	151–1,135	676	203–2,253	65.2%	21.2–109.1%
2019	-	-	-	1,299	643	159–1,126	676	203–2,249	65.1%	22.4–107.9%

Table ES30. Summary of reference model results for Cabezon in Oregon waters. The unit for spawning output is female biomass.

Year	Total Removals (mt)	1 - SPR	Exploit. rate	Age 2+ Biomass	Spawning Output Est.	Spawning Output ~95% CI	Recruitment (000s) Est.	Recruitment (000s) ~95% CI	Depletion Est.	Depletion ~95% CI
2007	40.94	0.85	0.12	339.8	163.4	120.4–206.4	98.8	56.8–172.1	48.8	40.4–57.2
2008	44.65	0.9	0.13	344.9	160.4	117.2–203.6	125.5	82.7–190.4	47.9	39.4–56.4
2009	49.33	0.94	0.14	346.1	159.9	116.4–203.3	62.3	33.5–115.8	47.7	39.1–56.3
2010	42.85	0.86	0.12	352.3	159.4	115.8–203.0	61.9	32.7–117.0	47.6	39.0–56.2
2011	49.96	0.94	0.14	345.9	163.5	119.3–207.8	94.6	56.7–158.1	48.8	40.1–57.5
2012	46.8	0.94	0.15	321.1	158.2	114.6–201.7	79.1	41.9–149.3	47.2	38.6–55.9
2013	33.99	0.81	0.11	305.2	147.3	105.1–189.4	117.9	68.4–203.3	44	35.5–52.4
2014	25.95	0.68	0.09	301.8	143.8	102.3–185.4	160.7	101.4–254.6	42.9	34.6–51.3
2015	28.13	0.69	0.09	320.5	147.5	105.6–189.4	82.4	43.6–155.9	44	35.6–52.4
2016	29.25	0.67	0.08	360.9	156.6	112.3–201.0	95.9	82.1–111.9	46.8	37.9–55.6
2017	54.47	0.92	0.14	383.9	174.2	126.5–222.0	97.9	84.1–113.9	52	42.6–61.4
2018	44.98	0.83	0.12	376.3	176.7	127.5–226.0	98.1	84.2–114.4	52.8	43.1–62.4
2019	-	-	-	372.5	177	128.5–225.6	98.2	84.1–114.6	52.8	43.0–62.7

1 Introduction

The Cabezon (*Scorpaenichthys marmoratus,* Ayers 1880) is a demersal, solitary, nearshore finfish belonging to the family Cottidae. Cabezon is one of the largest species of cottid, reaching 99 cm TL, and is common in nearshore rocky reefs from the intertidal to depths of 82 m (Miller and Lea 1972, Eschmeyer and Herald 1983). The geographic range of this species spans the west coast of North America from Sitka, Alaska to Punta Abreojos, Baja California, Mexico (Miller and Lea 1972). Cabezon are relatively long lived; otolith analyses have suggested that males live up to 17 years and females up to 16 years (Lauth 1987, O'Connell 1953).

The population status of Cabezon in California waters was last assessed in 2009, and the spawning output was estimated to be near 40% of the unfished spawning output for the northern California sub-stock and near 28% for the southern California sub-stock, but there was considerable uncertainty, especially for the southern California sub-stock (Cope and Key 2009). Cabezon are currently managed as part of a nearshore complex of fishes that include several species of rockfishes and greenlings.

A glossary of terms commonly used in this document appears in Appendix A.

1.1 Basic Information

1.1.1 Species Distribution

Cabezon is distributed along the entire west coast of the continental United States. It ranges from central Baja California north to Sitka, Alaska (Quast 1968; Miller and Lea 1972; Love et al. 2005). Cabezon are primarily a nearshore species found intertidally, among jetty rocks, and in and around kelp forests and rocky reefs out to depths of greater than 110 m (Miller and Lea 1972; Love et al. 2005). The majority of the commercial and recreational catch is taken inside of 15–20 fm (and approximately 99% within 30 fm; Feder et al. 1974) and along the central California coast up through Oregon. The nearshore distribution of this species makes it accessible to a greater portion of coastal populations and users of marine resources. This proximity to land also makes Cabezon habitat susceptible to terrestrial land use outfalls.

1.1.2 Stock Structure

The need for increased spatial resolution in the assessment of Cabezon was recognized during the STAR panel review of the first Cabezon assessment (Lai et al. 2003). This need was addressed in the second assessment by distinguishing two stocks in California waters, to the north and south of Point Conception (Figure 1): the northern (NCS) and southern (SCS) California sub-stocks. This designation was based on distinct fishing histories, the distribution of fishing effort, patchy and discrete habitat, and perceived low dispersal and movement of Cabezon in all life stages (Mireles et al 2012).

The last stock assessment of this species took place in 2009. At this time, a study of Cabezon population genetics by Villablanca and Nakamura (2008) suggested the existence of seven distinct subpopulations: six subpopulations in California (three north and three south of Point Conception) and one in southern Oregon (areas sampled: Cape Blanco, Orford Reef, and Humbug Mountain). Washington (Neah Bay and Puget Sound) sample sizes were likely insufficient to provide evidence for additional population structure. Additional evidence using a cluster analysis (Cope and Key 2009) of spatial-resolved catch-per-unit effort data supports two California subpopulations (north and south of Pt. Conception) and a distinct Oregon subpopulation. After separating northern and southern California, there was evidence for a subpopulation split north and south of Monterey. However, data and management limitations suggested maintaining just two subpopulations in California and one in Oregon. Since then, no additional genetic studies have been conducted to clarify genetic structure in Oregon or Washington. The modelling efforts reported in this document therefore applies the above information on genetics, local population dynamics and removal histories to distinguish four substocks: Southern California Substock (SCS), Northern California Substock (NCS), Oregon Substock (ORS) and Washington Substock (WAS).

1.2 Map

A map of the assessment region with selected coastal features is provided as Figure 1.

1.3 Life History

Cabezon are known to spawn in recesses of natural and manmade objects, and males demonstrate nest-guarding behavior (Lauth 1987; Feder et al. 1974). Cabezon have a polygynous mating system, though the degree of extra pair fertilization and thus genetic mixing is unknown. Based on the presence of larvae in ichthyoplankton surveys and ovary condition, spawning in California begins in November and ends in March, with a peak in January and February (O'Connell 1953). Interestingly, spawning in Washington begins in November and ends in September, with a peak in March and April (Lauth 1989). The timing of spawning in Oregon, from samples collected in Newport and Depoe Bay, more closely align with the timing in Washington rather than California (Hannah et al. 2009). Macro and microscopic evaluation of ovaries from California, Oregon, and Washington provide evidence for at least two spawning events per spawning season. Lauth suggests that females have a 'reserve' of eggs to support at least one spawning event per season, and the number of additional spawning events and number of eggs released depends on energy available for reproduction given physical and biological constraints (1989). The increase or decrease in fecundity with each batch, at different times of the year, and with increasing female age is unknown, but current research at Oregon State University is assessing batch fecundity through the reproductive season (M. Wilson and S. Sponaugle, OSU; unpublished data). The tendency toward year-round batch spawning may follow a latitudinal gradient, as females in British Columbia were recorded to spawn in batches continuously throughout the year (Lauth 1987, 1989). The timing of spawning in males has received little attention, except to note that mature males are ripe for the duration of the spawning season.

Cabezon eggs are sticky and adhere to the surface where deposited. They range from 1.4-1.9 mm in diameter and contain one to four oil globules (O'Connell 1953). In the Puget Sound, fertilized eggs incubate from 25-49 days (averaging 34 days) before hatching. Nests are observed to be 48 cm in diameter, and 5-10 cm thick (Feder et al. 1974). Little is known about latitudinal variation in incubation time or effects of other environmental conditions (temperature, salinity, dissolved oxygen) on egg development.

Newly hatched larvae range from 4.4-6.5 mm and flexion occurs around 7.5-8.7 mm (Materese et al. 1989). Cabezon larvae are obligate inhabitants of the neuston, the top 10-20 cm of the ocean (Shenker 1988, Doyle 1992, Richardson and Pearcy 1977). Cabezon larvae are heavily pigmented, likely an adaptation to the extreme ultraviolet radiation characteristic of the neuston layer (Zaitsev 1970). Larvae inhabit the plankton for 3-4 months (Love 2011).

The transformation stage (from the beginning of metamorphosis to the completion of fin ray development and onset of squamation) marks the beginning of the juvenile stage and occurs at 14 mm (Materese et al. 1989). Juveniles remain pelagic until at least 35 mm (Materese et al. 1989) but pelagic juveniles collected via Standard Monitoring Units for the Recruitment of Fishes (SMURFs) have ranged from 20-60 mm in Oregon (Ottmann et al. 2018).

The timing and magnitude of recruitment has often been measured via SMURFs. In a 7-year and ongoing collaboration between Oregon State University and ODFW Marine Reserves Program, a time series of Cabezon recruitment has been established (see Ottmann et al. 2018). Cabezon occur throughout the recruitment season (April through September). This time series shows interannual variation in recruitment magnitude. These findings are consistent with a study in central California showing similar patterns in the recruitment timing of Cabezon (Wilson et al., 2008). These recruitment patterns may be due to plasticity in early life history traits, environmental conditions, and/or spawning period. Ongoing research at Oregon State University (M. Wilson, S. Sponaugle, K. Grorud-Colvert, OSU; unpublished data) may elucidate patterns and mechanisms structuring this unique recruitment pattern using otolith daily growth, gut contents, and individual condition analysis.

Benthic juveniles have been observed year-round in low tide pools (Yoshiyama 1986, Moring 1990), shallow subtidal areas, rock cobbles and associated drift algae, eelgrass, and oil platforms (Love 2011). It has been suggested that juvenile Cabezon are voracious predators of the intertidal zone, using the habitat as a nursery zone before moving to deeper nearshore reefs. Current research at Oregon State University is investigating trait-mediated selective pressure, in terms of magnitude and direction, under different environmental conditions (M. Wilson, S. Sponaugle, K. Grorud-Colvert, OSU; unpublished data). This approach may enable the identification of traits that confer success through state transitions, and ultimately, shape adult population dynamics.

1.4 Ecosystem Considerations

Studies from surface trawls in the Sannich Inlet, Vancouver Island, British Columbia, found that Cabezon larvae between 8-10 mm feed on barnacle larvae, copepods, amphipods, decapods, krill, and fish (Barraclough and Fulton 1968). Pelagic juveniles feed primarily on small crustaceans including copepods, isopods, gammarid amphipods, and mysid shrimp (Love 2011). Larger benthic juveniles feed on crustaceans (cancroid and spider crabs, shrimp), fish (including juvenile rockfishes), algae (red and green), and molluscs (gastropods, cephalopods, bivalves) (Quast 1968). Adults consume their prey whole and are limited by gape size. They feed on fish, fish eggs, crabs, shrimp, and molluscs (notably, many species of abalone).

Little is known about the identify of larval Cabezon predators but common predators of larval fish in general include chaetognaths, gelatinous zooplankton, and other larval fishes. It is possible that Cabezon are consumed during their pelagic to benthic transition by piscivorous adult fishes including many species of rockfish, Lingcod, Cabezon, and other sculpins. Benthic juveniles and adults are consumed by fishes (rockfishes, salmon, steelhead, white sharks), mammals (river and sea otters, harbor seals), and many birds (bald eagles, cormorants, pigeon guillemots, sooty shearwaters) (Love 2011).

Little is known about non-trophic interactions with Cabezon. Their eggs are toxic to humans (Hubbs and Wick 1951) and have been observed to be avoided by birds, mink, and raccoons (Pillsbury 1957).

Cabezon are obligate inhabitants of the neuston and surface convergence zones likely increase productivity and contact rate with prey items, but also potentially increase contact rates with predators. Macrophytic algae is likely an important habitat utilized during the transition from offshore pelagic to nearshore benthic inhabitant. Adult Cabezon exhibit high site fidelity (Hartmann 1987, Lea et al. 1999); one study in central California calculated the average home range of Cabezon to be 960 m^2 and found a strong homing ability following a translocation experiment (Mireles et al. 2012). Adults utilize rocky nearshore habitats and are also found in tidepools (MacGinitie and MacGinitie 1949) and on oil platforms (Helvey 2002). MacGinitie and MacGinitie (1949) observed that some adult Cabezon enter tidepools at high tide to feed.

In an *in vitro* rearing experiment, Merrill and Collins found that trade-offs in investment in growth, reproduction, condition, and immune function were sex- and temperature-dependent (2015). In cold water, immune function was depressed and overall size was smaller, but gonadosomatic index (GSI) was higher for females. There was a negative relationship between condition and GSI only in females, and GSI and hepatosomatic index were negatively correlated for females and positively correlated in males. In a study of the effect of fishing and SST on larval fish distributions over the California Cooperative Oceanic Fish Investigation study region, Cabezon were shown to shift their southern boundary in relation to SST (Hsieh et al. 2008). In an *in vitro* experiment, Cabezon exposed to single and multiple stressor treatments of elevated carbon dioxide and low dissolved oxygen showed no change in body condition or cellular metabolism. However, their ability to successfully feed on juvenile rockfish is diminished in the high CO^2 and low DO treatment, suggesting negative impacts on predatory behavior (Davis et al. 2018).

The current Cabezon assessment did not incorporate environmental correlations, food web interactions, or other ecosystem processes into the model.

1.5 Fishery Information

1.5.1 California

Historically, the recreational sector has been the main source of Cabezon removals. Though Cabezon is a prized sportfish, it is seldom specifically targeted but rather caught by anglers fishing more generally for reef dwelling species including rockfish and lingcod. They are caught by anglers fishing from boats or from shore as well as being targeted by spear divers. Cabezon have been a very minor component of the catch in commercial fisheries for more than a century (Jordan and Everman 1898). The earliest modern commercial fishery information (O'Connell 1953) indicates that a small amount of Cabezon was being sold in fish markets in the San Francisco area by the 1930s with incidental take recorded back to 1916. However, it was not until the 1990s that a truly directed commercial fishery for Cabezon was established in the waters of California.

The most significant change in the fishery for Cabezon has been the development of the live-fish/premium commercial fishery that, in addition to Cabezon, targets several other nearshore fishes (CDFG 2002). This fishery started in southern California in the late 1980s and spread northward during the late 1990s to Oregon (Starr et al. 2002). Fishermen routinely obtain much higher prices for fish brought back to markets alive. Cabezon are not subject to barotrauma because they lack a swim bladder and are usually found in shallow nearshore waters accessible to many fishers. These traits make Cabezon an ideal target for both the live-fish and recreational fisheries. Gears that take Cabezon include hook and line and pot/trap type gears, as they are successful at bringing up fish with relatively little damage. Cabezon continues to be an important component of the live-fish fishery, even with increased restrictions on the live-fish catch, especially as the allowable catches of other marketable groundfish species have been reduced.

1.5.2 Oregon

Cabezon are harvested in both commercial and recreational fisheries, primarily with hook and line gear, but also with commercial bottom longline and pot gear as well. Historically, the majority of Cabezon landings in Oregon have been from the recreational ocean boat fishery with a limited amount from recreational shore fishing (Figure 2). ODFW provided reconstructed estimates of ocean boat and shore and estuary landings for Cabezon (See Section 2.4.2). Currently, recreational ocean removals continue to be a major source of landings in Oregon. Though generally popular with recreational anglers, Cabezon is commonly considered an incidental species within the recreational fishery that mainly targets rockfish and Lingcod (L. Mattes, ODFW; pers. comm.). Retention rates average 76% in recent years when Cabezon seasons are open (C. Heath, ODFW; pers. comm.). Management of Cabezon in Oregon has become increasingly complex as effort in the recreational groundfish fishery has increased over the years (Section 1.6.2), primarily due to a decline in salmon fishing opportunities and accelerated attainment of Pacific halibut quotas (Schindler et al 2015).

Within the last two decades, however, Cabezon has become a major component of the Oregon commercial nearshore live-fish fishery. The live-fish fishery developed initially in California and moved northwards into Oregon in the 1990s (Starr et al. 2002). The expansion of this fishery within

Oregon was rapid and illustrated well by Cabezon landings (ODFW 2002). For example, in 1997, roughly 46,000 pounds of Cabezon was landed by commercial nearshore fishermen, with approximately half of those landed live. Four years later, in 2001, over 102,000 pounds was landed and 95% was landed live. In 2004, following a series of management recommendations by ODFW, a state limited entry permit program was implemented to manage effort and landings in this fishery (Rodomsky et al. 2018; See Section 1.6.2). In Oregon, this fishery is a small boat fleet (averaging approximately 25 ft) that harvests year-round on shallow nearshore rocky reefs. Permit holders typically participate in a number of fisheries including the nearshore live-fish fishery. Cabezon is unique within this fishery as the primary target of commercial pot gear, though the majority are still landed using hook and line or bottom longline gear (Rodomsky et al. 2018). The majority of permit holders and effort in this fishery are concentrated on Oregon's south coast, primarily in Port Orford.

1.5.3 Washington

Cabezon has not been targeted by fisheries in Washington and annual total removals have been less than 12 mt since 1967, the earliest available official record. Washington closed state waters to commercial fixed gears in 1995 and to trawling in 1999. In response to the development of the live-fish fishery in California and Oregon, Washington took preemptive action in 1999 to prevent the fishery from developing by prohibiting the landing of live-fish. Cabezon is mostly harvested by recreational fishers off northern Washington coast and sport regulations for Cabezon have become more restrictive in the past 15 years.

1.6 Summary of Management History

The Pacific Fishery Management Council (PFMC) and NOAA Fisheries have management responsibility for the groundfish species included in the Groundfish Fishery Management Plan (FMP) out to the boundary of the 200 mile Exclusive Economic Zone (EEZ). Cabezon is one of six groundfish actively managed under the PFMC Groundfish Fishery Management Plan (PFMC 2016). Cabezon is also one of many nearshore species, that fall primarily within the 3-mile limit of states' waters are also included in state-specific Nearshore Fishery Management Plans (NFMP). NFMPs are currently implemented in California and Oregon in response to the increased commercial take of the live-fish fishery (CDFG 2002, ODFW 2002). In addition, Cabezon has been designated as a strategy species, under Oregon's Nearshore Strategy (ODFW 2006), which identifies species in greatest need of management, though Cabezon is not listed as a strategy species under California's State Wildlife Action Plan (Gonzales and Hoshi 2015).

1.6.1 California Management History

No management regulations existed for Cabezon in California before 1982 when a size limit (12 inches) was set for recreationally and commercially caught Cabezon (see Appendix B for a complete list of California regulations). This limit was raised to 14 inches in 1999 for the commercial fishery, and extended to include recreationally retained fish in 2000. It was increased further to 15 inches in 2001 for both the commercial and recreational fisheries. Recreational bag limits have been 10 fish/day in California since 2002; however, bag limits changed from 10 to 3 in different areas of the coast in 2004 and 2005, with one inseason change. From 2005 to 2008, there was a one fish bag limit for recreational anglers, which was increased to 2 fish in 2009, then to 3 fish in 2011 to present. Cabezon are currently included in the California recreational regulatory complex Rockfish, Cabezon, and Greenlings (the RCG complex) and subject to seasonal closures for recreational fishers. Season and depth restrictions for the RCG complex have varied since 2000 (see Appendix B) prior to which the season was open year round and fishing was allowed in all depths.

Historically, commercial landings of Cabezon were monitored as part of a stock complex called, Other Fish. At the time, this group of species included sharks, skates, rays, grenadiers and other groundfish. This group has been defined historically as groundfish species that do not have directed or economically important fisheries. The coastwise ABC for the Other Fish complex was 14,700 mt during 1999–2002 (5,200 mt for the Eureka, Monterey and Conception INPFC areas and 9,500 mt for the Columbia and Vancouver INPFC areas). In California, the Cabezon fishery is currently independently monitored and regulated by analyzing two-month cumulative landing limits within the Cabezon, Greenlings and California sheephead (CGS) complex. From 2001-2005 there were emergency closures for Cabezon, but more recently, the fishery has been open all year, with cumulative landing limits reduced from 900 pounds down to 200 or 300 pounds (see Appendix B). With attainment below 59% since 2010, the cumulative landing limit was increased to 500 lbs/2 month period in 2019, though the fishery remains closed in March and April, as has been the case since 2001.

1.6.2 Oregon Management History

In Oregon, the ODFW manages Cabezon under a state harvest guideline set within or at the federal ACL, with specific allocations for the recreational and commercial sectors. Regulations affecting Cabezon in the waters off Oregon can be found in Appendix C.

Though generally popular with recreational anglers, Cabezon is commonly considered an incidental species within the recreational fishery that mainly targets rockfish and Lingcod (L. Mattes, ODFW; pers. comm.). In particular, management of Cabezon within the recreational fishery has become increasingly complex over time with multiple management tools in use. Direct management of Cabezon in Oregon began with the inclusion of Cabezon in Oregon's recreational marine fish bag limit in 1976. Cabezon have also been subject to sub-bag limits both individually and with other species groups. As an example, from 1978 to 1993, Cabezon were included with rockfish and greenling in a sub-bag limit of 15 fish. Currently, a sub-bag limit of one Cabezon has been in place since 2011. A minimum size limit for Cabezon was first implemented in 2003 and the current minimum size of 16 inches has remained in place since 2004. During this time period, inseason closures for Cabezon began to occur annually, with Cabezon typically becoming prohibited in late summer or early fall in each year. As inseason closures began to be necessary earlier in the summer, a season for Cabezon was established in 2012 with Cabezon open for recreational fishing only from April 1 – September 30. In the following year, the season was modified to July 1 – December 31, which has remained as the current season structure since. However, an inseason closure for Cabezon still occurred in 2018 to remain under the recreational harvest guideline of Cabezon. Additionally, recreational fishery closures for all groundfish species occurred in 2016 and 2017. The ODFW continues to evaluate the use of multiple management tools to appropriately regulate recreational harvest of Cabezon.

Commercially, Cabezon are a large component of the commercial nearshore live-fish fishery that developed in the 1990s and early 2000s, though Cabezon have been recorded on commercial fish tickets since 1979. In 2000, a minimum size limit of 14 inches was implemented for Cabezon, though this was increased to 16 inches in 2004 - 2018. A limited entry permit system was implemented in 2004 with two permit types that allow for harvest of 21 nearshore species, including Cabezon (Rodomsky et al. 2018). Cabezon are only harvested under the Black and Blue permit with a Nearshore endorsement and are managed with an individual commercial harvest guideline. Cabezon are primarily landed live and targeted by both hook and line and longline gear in this fishery (Rodomsky et al. 2018). Bimonthly trip limits are implemented on an annual basis and subject to inseason management changes to reduce or increase attainment of the harvest guideline. For Cabezon, bimonthly trip limits have ranged from 1,500 to 4,000 lbs/two month period, though are generally set at 1,500 lbs/period in recent years (Table 1).

In 2008, ODFW began implementation of a marine reserve system along the Oregon coast. Following an extensive process with substantial local community engagement, five sites were selected and fishing restrictions were initiated from 2012 - 2016, following a pre-restriction monitoring period of two years (ODFW 2017). These include Redfish Rocks (2012), Otter Rock (2012), Cascade Head (2014), Cape Perpetua (2014), and Cape Falcon (2016). Each site is unique in both the structure of the reserve and the regulations that are in effect. All sites have a marine reserve area where all take of animals is prohibited. Four of the five sites have adjacent marine protected areas where some fishing restrictions are in place but these differ by location. Extensive monitoring of the marine reserve system is ongoing by ODFW (ODFW 2017).

1.6.3 Washington Management History

Washington closed state waters to commercial fixed gears, like those used to target Cabezon, in 1995 and to trawling in 1999. In contrast to California and Oregon, live-fish fishery was never developed in Washington. Sport regulations for Cabezon have became more restrictive in the past 15 years. Before 2013, Cabezon was managed under a 15-bottomfish daily limit and no minimum size restriction and fishing was open year round. In 2013 and 2014, a 2-Cabezon daily limit was implemented for marine catch areas 1-3. For marine catch area 4, daily limit was 1 Cabezon with 18” minimum size. Fishing season remained year round. In 2015, the fishing season was shortened to March to October, daily limits and 18” minimum size restriction remained the same. Effective 2019, the daily limit is reduced to one Cabezon in all marine areas and the minimum size requirement is removed.

1.7 Management Performance

Following the implementation of results from the 2009 Cabezon assessment (Cope and Key 2009), harvest specifications since 2011 have been set annually for the California and Oregon stocks separately. Historically, specifications have been set as a component of the Other Fish complex.

In 2010, Oregon Cabezon was an individual component species in this complex, and fishing mortality was reported as the sum of Oregon Cabezon impacts and Washington recreational impacts. However, in 2011, Oregon Cabezon was pulled out of the Other Fish complex and stock-specific harvest specifications for both Oregon and California Cabezon have been set since. Washington Cabezon remains an individual species component of this complex, and though individual species components have had harvest specifications produced since 2015, impacts are managed to the complex level. A history of harvest limits (ACLs), complex impacts and Cabezon impacts are detailed in Table 2.

The total fishing mortality was compared to annual harvest specifications for each stock of Cabezon from 2011 - 2017 (Table 3). Total fishing mortality was from annual reports produced by the NWFSC West Coast Groundfish Observer Program (WCGOP). Total mortality estimates are not yet available for 2018 or 2019. The estimate of total fishing mortality includes landings from the commercial, recreational and research sectors and estimated discard mortality based on a combination of capture depth and discard mortality rates. Recreational mortality in the WCGOP annual reports is provided directly from individual states. More detailed information on how WCGOP collects fishery data and estimates total mortality is available in the most recent annual report (Somers et al. 2018). Total fishing mortality for Cabezon was within specified ACL/ABC harvest levels in each year and stock with one exception (Table 3). In 2017, the Cabezon ABC and OFL were exceeded in Oregon. Extreme effort levels of recreational fishing in Oregon were recorded in 2017, including an unprecedented number of angler trips in August (C. Heath, ODFW; pers.comm.). Recreational fishery managers from Oregon have implemented multiple management actions to ensure future Cabezon impacts stay within harvest specifications (M. Sommer, ODFW; pers.comm.).

Fishing mortality by sector is detailed in Table 4. Commercial fishing mortality is dominated by the nearshore fixed gear sector. Recreational fishing mortality is reported for all three states, as is mortality from research. Total annual fishing mortality in Table 3 differs from Table 4 as Cabezon mortality from Washington is accounted for under the Other Fish complex.

1.8 Fisheries off Canada, Alaska, and/or Mexico

Alaska

Cabezon have been reported as far north as Sitka in southeast Alaska (Miller and Lea 1972). The Alaska Department of Fish and Game does not directly manage or assess Cabezon, though it is caught in the recreational fisheries (A. Olsen, ADFG; pers. comm.). Catches of Cabezon are tracked as only as part of an “Other Fish” category. There are no recreational bag or possession limits, or size limits in place for finfish not specifically listed in regulations (ADFG 2019a), and there are no limits on harvest as an unspecified personal use or subsistence bottomfish (ADFG 2019b). Cabezon is not a federally managed groundfish in the Gulf of Alaska (NPFMC 2018) and is not known to occur in federal waters off of Alaska.

Canada

Cabezon are encountered in British Columbia commercial groundfish fisheries, though there is generally little directed effort for Cabezon specifically (G. Workman, DFO; pers. comm.). A small trawl fishery in the Strait of Georgia targets several species of sculpin, including Cabezon, for Asian markets. Trawl landings peaked in 2003 with 1.2 mts (Fisheries and Oceans Canada 2019). Though landings are consistent, they typically average less than 0.5 mts annually (1996 – 2018). Non-trawl landings peaked in 1997 with 11.8 mts, but have since declined to nearly zero in recent years due to changes in the management licensing structure (Fisheries and Oceans Canada 2019). Though encountered, there's very little information on Cabezon in British Columbia's recreational fisheries (M. Surry, DFO; pers. comm.). As a *Cottidae* species, Cabezon are managed as part of the sculpin species group for recreational fisheries in British Columbia, with a current daily bag limit of eight fish and specific gear limitations (Minister of Justice 2017).

Mexico

Encounters of Cabezon in Baja California are limited, though some small numbers have been observed on the northwest coast (Stepien et al. 1991). Small scale, artisan fisheries constitute the vast majority of the Mexican commercial fleet (Fernandez et al. 2011). Annual landings on the Pacific coast, including Baja California, are roughly double those from Gulf of Mexico and Caribbean (Fernandez et al. 2011). These fisheries typically target a variety of species and encounter multiple incidental species as well. Cabezon are not documented as a target or incidental species in the Pacific commercial fisheries (Fernandez et al. 2011); however, Cabezon could be encountered in the nearshore dive fisheries for abalone, conch, urchins and other invertebrates while male Cabezon guard their nests. Incidental catches are often not reported for commercial fisheries (Fernandez et al. 2011). Collections specifically from the northern Baja peninsula commercial artisanal fleet ("pangas") indicate a reliance on a variety of groundfish species, though Cabezon was not observed (Rosales-Casian and Gonzalez-Camacho 2003). There is no available information on Cabezon encounters in the recreational fishery. In Baja California, the recreational fishery operates primarily for foreign tourists (Lopez-Lopez et al. 2006) and typically targets large pelagic species, such as marlin, dorado and tuna (e.g. Jensen et al. 2010), as opposed to groundfish.

2 Assessment Data

Data used in the northern California, southern California, and Oregon Cabezon sub-stock assessments are summarized in Figure 3. These data include both fishery-dependent and fishery-independent sources of varying quantity and quality. Types of data that inform the model include catch, indices of abundance and length and age frequency data from commercial and recreational fishing fleets. The following sections detail the treatment and ultimate inclusion of the data types for each sub-stock.

2.1 Commercial landings and discards

Commercial fisheries landings by state, year and gear were extracted from the Pacific Fisheries Information Network (PacFIN), the central repository for West coast commercial landings. An overview of PacFIN is provided in Sampson and Crone (1997). Commercial landings, including historical catch reconstructions and discard estimates, are described in detail by sub-stock in the following sections.

2.1.1 California

The historical commercial catch reconstruction by sub-stock uses the same approach as in Cope and Key (2009) back to 1916 (the first year of required reporting in the commercial fishery):

- **Years 1981 - 2018:** The round weight was downloaded from PacFIN in metric tons for the live and dead fish landings north and south of Point Conception.
- **Years 1931– 1980**: The CALCOM database provides annual landings (in pounds) by gear. Methodology can be seen in Ralston et al. (2010). Data was extracted on 9 June, 2009 for the previous assessment. Additional allocation of landings to the live-fish fishery was available using the price per pound filed in the CFIS-CMASTR database. This analysis was provided by Bob Leos (CDFG).
- **Year 1930**: The Pacific Fisheries Environmental Laboratory (PFEL) live access server (http://las.pfeg.noaa.gov:8080/las_fish1/servlets/dataset) provide electronic summaries of CDFG fish ticket receipts originally reported in the Fish Bulletin series (available electronically at: http://ceo.ucsd.edu/fishbull/).
- **Years 1916–29:** The publication *California Fish and Game* (vols 1–16) are the original source of landing reports before the Fish Bulletin series and are used for this time period. During 1916–29, Cabezon was included in the category "sculpin" which included California scorpionfish. Given the limited northern range of the scorpionfish (Love et al. 1987), 100% of the "sculpin" catch from Monterey north was assumed to be Cabezon. Fish Bulletins 74 (CDFG 1949) and 149 (Heimann and Carlisle 1970) provide summarized commercial Cabezon landings for 1916–47 and 1916–69, respectively, and were used to cross-compare Cabezon catches from the *California Fish and Game* volumes. Both sources provided the same estimates of total Cabezon landings.
- **Years 1916–30 adjusted**: Due to the spatial resolution of landings during this time period, an adjustment was made. Landings for the port complex "Santa Barbara" (including Morro Bay of the NCS and Santa Barbara of the SCS) were allocated to the appropriate sub-stock using the geometric mean of the ratio of the Morro Bay to Santa Barbara landings for the years 1978–82 from CALCOM.

Commercial landings reported in pounds were converted to metric tons for this assessment. Two fleets are modeled within the assessment: 1) vessels landing dead fish (non-live-fishery), and 2) vessels landing live-fish (live-fish fishery). Cabezon are caught commercially using a variety of gears-types, but have been taken almost exclusively by hook-and-line and pots since the 1990s. All catches are assumed to be taken using a single gear-type for the purposes of this assessment

California landings of Cabezon were low until the early- to mid-1990s when the live-fish/premium finfish fishery began targeting Cabezon. Commercial Cabezon landings reached a peak of over 150 mt in 1998 and averaged more than 80 mt since the mid-1990s, most of which came from the NCS.

There have also been spatial and temporal patterns in Cabezon commercial landings. Historically, much of the landings were reported in the late winter/early spring months, but much of the catch has been taken in the summer and fall months since the start of the live-fish fishery. All catch is assumed to be taken in the middle of the year for the purposes of the assessment.

Commercial Discards in California

Commercial discard mortality estimates are provided by the West Coast Groundfish Observer Program total mortality reports (WCGOP) and rates of mortality for discarded Cabezon are assumed to be 100% for all trawl-related gear and 7% for the live-fish fishery. Cabezon are not as susceptible to discard mortality as many other fish because they live in shallow habitat, do not have swim bladders, and do not appreciably suffer from barotrauma. Recent information regarding discards in the nearshore live-fish fishery were available from WCGOP the Total Mortality Reports for 2004-2016, which were applied to each respective year. The harmonic mean discard ratio of 2% for south of 40°10’ N lat. was applied back to 1916 and in to landings for 2017 and 2018 in California.

Total Removals

The landings and discards for each respective year were combined to provide an estimate of total removals. Estimated commercial total removals for each sub-stock are given in Cabezon_Supplementary_tables “Catch time series_CA” tab. Figure 2 illustrates the historical pattern of total Cabezon removals north and south of Point Conception.

2.1.2 Oregon

Commercial landings of Cabezon in Oregon spanned the years 1979 - 2018 (Table 6). Historical commercial landings for Cabezon were provided by ODFW from 1979 to 1986 (Karnowski et al. 2014). Though the historical data source, the “Pounds and Values” reports from ODFW, extends back to 1969 (Karnowski et al. 2014), Cabezon were not recorded on commercial fish tickets until 1979. Cabezon were not recorded on any data sources prior to 1979, though this is not surprising, given the dominance of trawl landings in Oregon historically in which Cabezon would have been rarely encountered (P. Mirick, ODFW; pers. comm.).

Landings from 1987 – 2018 are available on PacFIN and were extracted on March 7, 2019 for this assessment. Cabezon is one of several targeted species of the nearshore, primarily live-fish fixed gear fishery centered on Oregon’s southern coast. Cabezon is landed primarily with hook and line gear, including jig, dinglebar and cable gear, but a substantial portion is also landed with bottom longline gear as well (Table 6). On average, 91% of Cabezon landings are from these two gear types over the period 1987 to 2018. Landings from fish pots are minimal relative to hook and line and longline gears (7.0% on average, 1987 - 2018). All other gear types combined average less than 2% of landed catch annually (1987 – 2018). Commercial landings for Cabezon increased gradually from 1979 to the early 1990s (Table 6; Figure 2). With the development of the live-fish fishery in Oregon during the late 1990s, landings peaked in 2001 at 46.3 mt, followed closely by 2002 with 46.0 mt. At this time, ODFW implemented a state-permitted limited access fishery that regulated fleet size, time period landing limits, and minimum size limits (Rodomsky et al. 2018). From 2003 to 2018, landings have fluctuated between approximately 15 and 30 metric tons annually, averaging 24.4 mt annually. Landings in 2018 were 29.3 mt.

The amount of discarded Cabezon relative to retained Cabezon was estimated by the Groundfish Expanded Mortality Multiyear (GEMM) report. Discard ratios were available from 2002 to 2017 for the nearshore fixed-gear fishery (in waters < 50 fathoms). Mortality rates associated with discarded Cabezon are specified by depth bins following the approved levels specified by the Pacific Fisheries Management Council – Groundfish Management Team (see Somers et al. 2017). This corresponds to a 7.0% discard mortality rate for depths in which Cabezon inhabitat. The average commercial discard rate for Cabezon from 2002 to 2017 was 10.0%, and after multiplying by the discard mortality rate results in an average dead discard rate of 0.7% for the management area north of 40°10' north latitude. The dead discard rate was used to calculate total discarded catch by applying it to annual estimates of commercial landings by fleet over the time series (1979-2018; Table 6).

2.1.3 Washington

Commercial landings in Washington have been low. The highest annual landing was 1.5 mt in 1989. Washington closed its state waters to commercial fixed gears in 1995 and to trawling in 1999. Cabezon habitat is predominantly found in state waters. The state preemptively banned landings of live-fish in 1999. Since then, Cabezon commercial landings have been less than 0.6 mt annually. The four treaty tribes of the Washington coast fish under separate rules and are not subject to the state nearshore regulations. Cabezon landings by treaty fishers are reported in a sculpin market category that is not sampled for species composition. Treaty landings in the sculpin category have averaged only 192 lbs over 2009-2018 with a high of 654 lbs. These landings are included in the data limited assessment.

2.2 Commercial length and age data

Available length and age data collected from commercial fisheries were extracted from PacFIN for each sub-stock region.

2.2.1 California

Cabezon otoliths and other ageing structures have not been collected routinely during port sampling. Therefore, the only information on the biological structure of the catch is from length and weight measurements. Sex is not recorded when sampling for length or weight, so all of the catch length-compositions considered in this assessment are sex-aggregated. Limited catch length-compositions were developed for each sub-stock, fishery sector, and fleet. Only length composition for fish landed live was available for the SCS for 2002-2018 (n = 4,120 from 2,118 trips), with the exception of 2004 and 2007 (Table 12, Figure 4). The commercial length composition for fish landed live for 1997-2018 (n = 274,459, for 9,579 trips) and fish landed dead for 1993-2000 (n = 22, 918 from 6,118 trips) are available for the NCS (Table 13, Figure 5).

2.2.2 Oregon

Commercial Cabezon length samples are available from PacFIN from 1998 – 2018 (n = 14,158; Table 14). These samples were extracted on March 26, 2019. Approximately 57% of these samples are from unsexed fish (n = 8,253, with 19% (n = 2,768) and 23.0% (n = 3,382) from females and males, respectively. The majority (78%) are from the southern Oregon coast, centered in Port Orford (56%) and Gold Beach (24%), where the majority of permit holders for the commercial nearshore fishery are based and where most of the landings are made. Greater than 95% of the length samples are from Cabezon landed live. 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 4 cm to 70 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 14).

There were some small differences in the aggregate length composition data between landed and discarded fish, with discarded fish being smaller on average. However, the comparatively low amount of dead discarded fish relative to landed fish resulted in near indistinguishable catch-weighted length frequencies. Thus, lengths from landed fish were used to represent the length composition of the commercial catch by fleet.

Age composition samples are available from PacFIN from 2003 and 2007 – 2018 (extracted March 26, 2019). All commercial Cabezon were aged by ODFW. The availability of otoliths to age commercial samples is limited (n = 364) due to the majority of Cabezon being landed live and destined for live-fish markets. A total of 184 females, 165 males and 15 unknown gender samples were aged. These constitute all readable samples available from the commercial fishery. Special research project samples collected and aged by ODFW staff from the commercial fishery are provided from 2004 – 2005, 2008, 2010 and 2018 (n = 13). Samples by year and gender are available in Table 15.

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. The initial sample sizes used for each year were the number of aged fish by gender (Table 15).

2.3 Commercial Abundance Indices (Catch per Unit Effort)

2.3.1 Oregon Logbook Index (2004-2018)

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 2018 were available for 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 17). 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 three (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 13,327 compliant trips (41.8% of the submitted logbook data set) which represented 36.9% of recorded catch from 91 vessels (Figure 6).

Initial data analyses identified levels or limits of filtering variables to identify trips representative of Cabezon catch while maintaining adequate sample sizes. Ports retained in the dataset were Port Orford, Gold Beach and Brookings as these ports are where most commercially caught Cabezon are landed. Trips using only hook and line jig gear were included because this gear was used to commercially catch 82% of Cabezon in the dataset. Only limited-entry permitted trips were retained because these trips are allowed to keep more than incidental amounts of these species. After filters, data were considered representative trips for Cabezon catch using jigs, the main gear type used to catch Cabezon in Oregon's commercial fishery.

Logbook CPUE Standardization: Model Selection, Fits, and Diagnostics

The full model considered the covariates month, port, season (two-month intervals), vessel, trip limit regulation, target species specification, and number of crew on CPUE (Figure 7). All covariates were specified as categorical variables Month and season were included to account for different levels of interannual variation in catch rates observed by commercial fishers. Trip limits and specifically targeting Cabezon were included to consider differences in fishing and target strategies associated with different levels of access and regulation to nearshore species. Number of crew was included to account for differences in fishing efficiency and potential hook oversaturation. Vessel was included to account for differences in fishing capacity. Model covariates were selected with standard information criterion for relative goodness of fit (Akaike Information Criterion, AIC). 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 logbook 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 average discard weight of four pounds. Effort was defined by multiplying the number of hooks by hours fished. A gamma distribution for the positive catch component as well as power transformation were also explored, but based on graphical diagnostics they 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 AIC, the model with year, month, port, number of crew, trip limit, and target species was selected as the best predictor of presence/absence of Cabezon, while the model with year, month, port, number of crew, vessel, and target species was selected as the best predictor of positive catch rates (Table 18). 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 8, top panel). The lognormal component of the model that fits to positive catches also fit the data well (Figure 8, bottom panel).

To estimate the 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. The "rstanarm" package in R was used 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 combining model components) can be applied to posterior draws, preserving the correlation structure and propagating uncertainty into the final index (Figure 9; Table 19). As an additional diagnostic, we generated replicate datasets from the posterior predictive distribution, and compared the maximum likelihood estimates from the positive model component to the median estimates from the posterior distribution. As expected, this model closely matches the distribution from replicate data (Figure 10).

2.4 Recreational landings

2.4.1 California

The mortality estimates for the California recreational fishery from sampling by the California Recreational Fisheries Survey (CRFS) including landed and fish discarded dead (assuming a 7% discard mortality rate) for each fishing mode mode including beach and bank, man made, party/charter boats and private boats were downloaded from the RecFIN website for years 2009-2018. For the beach and bank mode, estimates were not available for 2018 since sampling was not conducted due to funding constraints. As a result the average of the preceding five years were used. These data were combined with the time series data for 1916-2008 from the catch reconstruction for the 2009 stock assessment.

The historical catch for 1916 to 2008 was reconstructed as described in the previous assessment (Cope and Key 2009), an overview of which follows. Catch estimates for all modes from the

CRFS survey were downloaded from RecFIN, for the years 2004-2008. Where available the estimates of mortality for 1980-2003 from the Marine Recreational Fishery Survey (MRFSS) for the man made, beach and bank and private boat modes. Estimates of statewide catch in numbers of fish for the party/charter boat mode from 1936-1980 were obtained from logbooks assuming full compliance in submission or from short-term surveys/studies where available assuming no discard mortality, both of which were allocated north and south of Point Conception based on estimates available for 1979. A linear ramp from values provided from estimates for 1935 to 1928 using values from 1936 to zero in 1928. Estimates for the party/charter boat mode were assumed to be zero from 1928 to 1916. The ratio of the estimates from the party/charter boat mode to those for the other three modes for 1980 to 2008 were averaged where estimates were available. The resulting average ratio was multiplied by the historical estimates for the party/charter boat mode for each year prior to 1980 to provide estimates for the other three modes. The exception was 1957-1961 to the north of Point Conception for which estimates were available from a study for each mode. The resulting estimates in numbers of fish were then multiplied by the average weight in kg from the MRFSS and CRFS sampling from 1980-2008 for each mode, then converted to tons.

Given the changes to the structure of the 2019 model, the estimated mortality for the man made and beach and bank modes were summed to provide a single estimate for the shore modes and similarly, the estimates for the private boat and party/charter modes were summed to provide a single estimate for the boat modes given similarities in selectivity.

The MRFSS era catch estimates from 1980 – 1995 were based on stratification of California at 36° N Lat. as opposed to Point Conception (34 27’ N. Lat.) for the remainder of the time series making the estimates for these years inconsistent with the stratification of the assessment. This would result in underestimation of catch in the north in the NCS model area and overestimation of removals to the south in the SCS model area, as the catch from the ports of Morro Bay and Avila were included in the southern assessment area during this time period. To address this discrepancy, the catch estimates for each fleet for 1996-1999 were used to estimate the proportion expected to occur to the north and south of Point Conception in each year and the harmonic mean was used to reapportion statewide catch in each year from 1980-1995. The resulting revised catch estimates are reflected in Figure 2 and Cabezon_Supplementary_tables “Catch time series_CA” tab. Sensitivity to using the old recreational catch allocations was explored.

Subsequent catch estimates for 2000 to 2018 were subject to multiple fishing regulations, including differing depth restrictions and season lengths north and south of Point Conception that would bias estimates of the proportion north and south of Point Conception during the unregulated fishery from 1980-1995. The fishery was open to all depths in 1996-1999 and this time period was deemed most representative of the proportional removals for use in reallocating catch to be consistent with assessment areas. The resulting reallocated catch north and south of Point Conception for the shore and boat modes supplanted the original estimates in the revised reference model.

This is an emergent issue for catch history reconstruction for this and other species previously assessed and scheduled for assessment in 2019, including gopher/black and yellow rockfish for which this was first identified as being a concern. In the future a workshop evaluating the methods used in reallocation of catch at Point Conception or geographic post stratification of catch history in general would be beneficial to develop best practices advising historical catch reconstruction. Future update assessments and catch based updates may need to consider addressing this discrepancy in the stratification within the time series where pertinent.

2.4.2 Oregon

Historical Ocean Boat Landings (1970 – 1978)

Ocean boat estimates from 1973 – 1978 that were constructed for the 2009 assessment (Cope and Key 2009) were used in this assessment (Table 8). A linear ramp was used to interpolate ocean boat landings beginning in 1970 (0 mt) to 1973 (3.1 mt). Prior to 1970, catch of Cabezon is assumed to be negligible.

Historical Reconstruction of Ocean Boat Landings (1979 – 2000)

Recently, the ODFW undertook an effort to comprehensively reconstruct all marine fish recreational ocean boat landings prior to 2001 (A. Whitman, ODFW; pers. comm.). Reconstructed catch estimates from the Oregon Recreational Boat Survey (ORBS) improve upon estimates from the federal Marine Recreational Fisheries Statistical Survey (MRFSS), which have known biases related to effort estimation and sampling (Van Voorhees et al. 2000) that resulted in catch estimates considered implausible by ODFW. However, the ORBS sample estimates are known to lack the comprehensive spatial and temporal coverage of MRFSS. Addressing this coverage issue is a major part of this reconstruction. In general, the base data and methodology for these reconstructed estimates are consistent with recent assessments for other nearshore species (Dick et al. 2016, Dick et al. 2018, Haltuch et al. 2018).

Prior to 2001, ORBS monitored marine species in both multi-species categories, such as rockfish, flatfish, and other miscellaneous fishes, and as individual species, such as Lingcod or Pacific Halibut. For this comprehensive reconstruction, four species categories were selected to reconstruct, including rockfishes, Lingcod, flatfishes and miscellaneous, which constitute the bulk of the managed marine fish species. Cabezon are a major component of the miscellaneous species category.

Category-level estimates were expanded to account for gaps in sampling coverage in two separate pathways. First, estimates from five major ports were expanded to include unsampled winter months in years lacking complete coverage. Expansions were based on available year-round sampling data and excluded years where regulations may have impacted the temporal distribution of catch. Second, all other minor port estimates were expanded to include seasonal estimates in years lacking any sampling based on the amount of minor port catch as compared to all major port estimates. A subset of landings were sampled by ORBS for species compositions within these categories. Once category-level landings were comprehensive in space and time, species compositions were applied for the three multi-species categories, including rockfish, flatfish and miscellaneous fish. Borrowing rules for species compositions were specific to the category and determined based on a series of regression tree analyses that detailed the importance of each domain (year, month, port and fishing mode) to variability in compositions.

Ocean boat estimates from 1979 – 2000 in numbers of Cabezon were provided by ODFW from the above described methods. Yearly estimates of numbers of Cabezon varied between approximately 3,800 and 10,400 fish during this time period, averaging 6,853 fish annually (Table 9). The annual average weights of Cabezon from MRFSS biological samples (1980 - 1989, 1993 - 2000; Section 2.5.2) were applied to these numbers to produce biomass (Table 8). The average of the annual average weight from 1989 and 1993 was used to fill in the years 1990 - 1992, and the 1980 average weight was used for 1979.

Modern Ocean Boat Landings (2001 – 2018)

Recreational landings for the ocean boat fleet from 2001 – 2018 are available from RecFIN (extracted 3/4/2019; Table 8). Both retained and released estimates of mortality are included in landings, though retained mortality contributes the vast majority to total mortality. Release mortality is estimated from angler-reported release rates and the application of discard mortality rates from the PFMC. From 2001 – 2016, landings averaged 14.8 mt, ranging from 9.1 to 17.8 mt. Recent landings peaked in 2017 with an estimated mortality of 23.7 mt. In 2018, landings were 13.5 mt. Discard mortality was incorporated in the landing estimates obtained from RecFIN from 2001 onwards. Discard mortality was assumed negligible prior to 2001.

Shore (and Estuary) Landings (1970 – 1980)

A linear ramp was used to interpolate shore (and estuary) fleet landings beginning in 1970 (0 mt) to 1980 (2.7 mt). Prior to 1970, catch of Cabezon is assumed to be negligible.

Shore (and Estuary) Landings (1980 – 2018)

ODFW provided reconstructed estimates of shore and estuary landings for Cabezon from 1980 – 2018 (Table 8), using a methodology similar to recent assessments (Berger et al. 2015, Dick et al. 2018). Data sources include MRFSS, the Shore and Estuary Boat Survey (SEBS), Oregon angler license sales and ODFW Cabezon angling regulations. Numbers of fish were provided by MRFSS from 1980 – 1989 and 1993 – June 2003, and by SEBS from July 2003 – June 2005. An annual fishing mode-specific average weight was applied to numbers of Cabezon from 1980 – 1989 and 1993 – 2005. Separate weights were calculated for shore and estuary boat modes, and excluded extreme outliers and imputed values. This reconstruction also applied two scaling factors to remove bias towards freshwater sampling and underestimation of estuary boats, as detailed in Dick et al. (2018). To estimate Cabezon landings from July – December 2005, an expansion was developed using the five year average of the ratio between the first six months of the year and the total annual landings from MRFSS landings from 1998 – 2002. Separate expansions were developed for shore mode and estuary boat modes.

The relationship between annual license sales and shore and estuary Cabezon landings from 1980 – 2005 was used to estimate landings from 2006 – 2018, with corrections for regulatory closures and Cabezon seasons. This relationship was also used to estimate landings from 1990 – 1992 when MRFSS was not sampling. Shore and estuary boat landings were combined into one fleet (Shore). Landings peaked in 1993 with 6.4 mt. Additional peaks occurred in 1986 with 5.4 mt and 2001 with 3.6 mt. Landings average 1.8 mt annually from 1980 – 2018 and are generally considered a minor source of Cabezon mortality. Mortality from discarded fish was assumed negligible.

2.4.3 Washington

Annual catches (in numbers) from the Washington recreational fishery for 1967 and 1975-86 come from WDFW historical annual sport catch reports. Catches for 1990-2018 are from WDFW's Ocean Sampling Program (OSP). We used linear interpolation for missing years. Estimates for number of released catch are available from 2002 to 2008. A 10% discard rate was applied to historical catches estimates. Discard mortality of 0.07 was applied to the released fish. (Table 10 and Table 11).

2.5 Recreational length and age data

2.5.1 California

Recreational length data for the shore and boat based modes from the CRFS sampling program for 2009-2018 were downloaded from RecFIN and added to the data available from the previous assessment for 1980-2008. The effective sample size for the beach and bank and man-made modes is provided at the angler level, while the private boat and party/charter boat mode data reflects the number of trips the lengths originated from. Length composition data for 2009-2018 were added to those extracted for the 2009 assessment.

The catch length compositions for each state and year for the recreational fisheries were obtained from RecFIN (extracted on 16 March, 2009). RecFIN expands the sampled length proportions by port, fishing fleet (mode), and wave (bi-monthly period) to estimate the proportions-at-length for the entire year. In the 2005 assessment, not all lengths retrieved from RecFIN were used because they were not true lengths, they were either converted from weights or another measurement of length (i.e. RecFIN converts total lengths (TL) into fork lengths (FL) for user downloads). For this reason, we used the sample lengths (in TL) where no conversions from weight were made. This increased samples substantially, especially in the 1980s. Comparison between the sampled and expanded length compositions showed no significant differences; using the sample data increased the number of measured fish that were otherwise disregarded due to sample strata.

Additional sources of length composition from two northern California CPFV studies were evaluated for use in this assessment. The first was a CDFG CPFV onboard observer program from 1987-98 that monitored catch north of Point Conception. The second was a more recent study in the Morro Bay area (CalPOLY) from 2003-08. Even though samples for Cabezon were low in these studies, the composition data were still used to help support more recent evaluation of the CPFV fishery. In the past, the CPFV fishery has not been sampled as much as the other recreational fishing modes; however, the CRFS program has made efforts to increase this effort since 2004.

Regarding SCS, information from two CDFG CPFV studies in southern California was also included in that model, representing the time periods from 1975-78 and 1986-89. Lastly, information from the Groundfish Disaster Relief Program in southern California from 2002-05 was used. Fish from this study were caught by hook and line on chartered CPFVs.

The number of lengths collected each year for the shore (NCS n = 1,753, SCS n = 189) and boat (NCS n = 14,294, SCS n = 2,972) based fishing fleets as well as the effective sample size in each region are provided in Table 12 and are portrayed in Figure 4 for the SCS and in Table 13 and Figure 5 for the NCS.

No ages were available from the recreational fishery.

Examination of Discard Lengths

Since 2003 the lengths of discarded fish have been recorded for a subset discarded fish encountered during onboard sampling of CPFVs as part of the MRFSS and CRFS programs. During this time period, Cabezon were subject to a 15 inch minimum length restriction resulting in regulatory discards. Accounting for discard length data would provide an indication of recruitment in recent years not yet represented by the lengths of retained fish. For a relatively fast growing species like Cabezon, the benefit would only provide a few years earlier indication of recent recruitment strength given that fish may not recruit to the gear until two to three years of age in any case. The available samples were evaluated for use in the assessment to capture recent recruitment.

Incorporation of length discard lengths with the retained lengths would have resulted in disproportionate weighting given differences in sampling frequency for onboard CPFV sampling trips/anglers observed and the low discard mortality compared to landed catch. We considered integration the discard length composition data as either a separate sector associated with discard mortality, as a ghost fleet without associated mortality or a using a retention curve. The sample size associated with each region was low with only 68 individuals from the NCS and 358 individuals from the SCS collected between 2003 and 2018. An additional 58 samples could not be assigned to sub-stock due to issues with coding in RecFIN. Given the additional parameters for selectivity or other associated complexity to the model at the cost to parsimony of the overall model, it was decided that the data should be omitted. Future research to evaluate the best way to incorporate discard data in other stock assessments is recommended to garner benefit from substantial sample sizes available for some species, while minimizing adverse effects on model complexity.

2.5.2 Oregon

Recreational length samples were obtained from three sources: MRFSS, RecFIN (ORBS) and ODFW special project sampling. From 1980 – 1989 and from 1993 – 2000, the MRFSS program collected samples from both ocean and inland (estuary) areas (n = 2,245). ODFW provided MRFSS samples with the addition of a column that flagged length values imputed from weights to allow for selection of only directly measured values. Only lengths measured directly or were converted from fork lengths were used in this assessment. From 1980 – 1989, total lengths (mm) were collected by MRFSS, which were converted to fork length. From 1993 – 2000, fork length (mm) was collected. Length samples from 2001 – 2018 from the ORBS sampling program are available on RecFIN (n = 22,038). ODFW provided these samples extracted from RecFIN with the addition of trip information. All ORBS samples are by fork length (mm). While ORBS does sample some limited number of estuary trips, the majority of recreational samples from this time period are from ocean sampling (< 0.1% from estuary trips). Special projects samples collected by ODFW staff from the recreational fishery are provided from 1999 – 2001, 2011 and 2018 (n = 95). Table 14 details sample sizes by year and fishery. All length samples are from unsexed fish, unless age is available. Length compositions were tabulated by 2-cm length bins ranging from 4 cm to 70 cm, with accumulator bins at each end. The initial annual sample sizes used in the assessment for the recreational fishery length-composition data were the number of trips (Table 14).

Age compositions were available from the recreational ocean-boat fleet for 2005 – 2018. A total of 961 female, 1357 male, and 10 unknown gender samples were aged (n = 2,328 samples) for developing compositional data. Table 15 details sample sizes by gender and fleet. Overall, approximately 81.6% of samples are from charter fishing mode and 18.4% from private boats, though this varies somewhat by port of landing. All aging was completed by ODFW. 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 15). 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. 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.

2.5.3 Washington

Limited length and age data are available for Washington. We used these data to generate growth and natural mortality parameters needed for SSS model. Length compositions from 2002 to 2018 are used in the length-based spawner potential ratio (LBSPR; Hordyk 2019) model to provide 2018 depletion estimates for SSS model runs.

2.6 Recreational Abundance Indices (Catch per Unit Effort)

2.6.1 California

Past Cabezon stock assessments have used the CPFV logbooks time series to develop a CPUE abundance index for both the SCS and NCS models. The advantages of this time series is its length (a common effort measure, angler hour, began in 1960), its spatial coverage and the fact that Cabezon, while rare, are unlikely to be misidentified or unrecorded. This assessment retains the exact time series as developed in Cope and Key (2009) as it stops in 1999 due to the often varying time and spatial restriction conducted in the California nearshore fishery form 2000 onward. Specific details are recorded in Cope and Key (2009), but the approach consists of using generalized linear models (GLMs) fit to first the proportion of zero and non-zero records using a binomial distribution, and then to the non-zero catch rates (number of Cabezon per total angler hours) using either a gamma or lognormal distribution assumption. The product of the year effects from each GLM produces the index of abundance and is a long-standing approach to developing CPUE-based abundance indices. Factors considered were year, month, and location. The final fixed-effects model chosen for both the SCS and NCS included all factors using the lognormal model for positive CPUE (Table 16). Diagnostic plots for the base case CPFV indices are provided in Figure 11 and Figure 12. Time series plots for the indices are provided in Figure 13 and Figure 14.

2.6.2 Oregon

2.6.2.1 Oregon Onboard Observer Index (2001, 2003-2018)

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 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 2018. 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 total encounters. This is particularly appropriate for Cabezon, given the assumed high rates of regulatory discards.

Observer CPUE Data Preparation, Filtering, and Sample Sizes

Filters for depth, fishing time, distance of drift from reef center, and reefs without at least 10 positive drifts were applied (Table 24). Additionally, the recreational fishery in Oregon primarily targets Black Rockfish (*Sebastes melanops*), though other rockfish species, Lingcod, Kelp Greenling and Cabezon are all commonly encountered. Cabezon strongly associate with rocky reef structure and are rarely seen off bottom. While Black Rockfish associate with rocky habitat, they are a schooling, midwater species. Fishermen specifically targeting Black Rockfish may not drop their lines to the seafloor, or may encounter Black Rockfish and other midwater species before their lines can reach the seafloor. To address this issue, drifts for which encounters (retained plus discarded) consisted of greater than 89% Black, Blue (*S. mystinus*) and Yellowtail (*S. flavidus*) Rockfishes were filtered out of the dataset. These three rockfish are the most commonly occuring midwater rockfish species. This resulted in a decrease in the number of drifts by 4,490, only 17 of which observed Cabezon. The final filtered dataset included 7,005 drifts, with 656 (9.4%) drifts with positive encounters.

Observer CPUE Standardization: Model Selection, Fits, and Diagnostics

The selected data contained categorical variables for year (17 levels), month (8 levels), and ten meter depth bins (5 levels; Figure 29). Raw catch rate data suggested that trends in CPUE over time were not similar by reef (Figure 30), so a model with interaction terms year:reef were included in the set of candidate models.

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. The lognormal model was chosen over a gamma model as model fit and diagnostics were improved. In both submodels, stepwise AIC removed the year:reef interaction term that would have necessitated an area-weighted index. The final positive model without interactions retained year and reef, and the binomial portion retained year, depth and reef (Table 25). 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 which fits to encounters (presence/absence) is a reasonable approximation of the data (Figure 31, top panel). The lognormal component of the model which fits to positive catches also fit the data reasonably well (Figure 31, bottom panel).

To estimate the 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. The rstanarm package in R was used 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 combining model components) can be applied to posterior draws, preserving the correlation structure and propagating uncertainty into the final index (Figure 32; Table 19). 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. As expected, the model closely matches the distribution from replicate data (Figure 33).

2.6.2.2 Oregon ORBS Dockside Index (2001-2018)

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 2001-2018, when species composition of the catch is available. Trip-level catch-per-unit-effort data from ORBS dockside sampling was obtained from ODFW on 2/15/2019.

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 that was fished. CPUE, expressed in terms of fish per angler-hour, was calculated by multiplying the number of anglers and the adjusted travel time. 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 Cabezon (i.e. identify trips that were likely to catch the species), we used the method of Stephens and MacCall (2004) to predict the probability of catching a Cabezon given the occurrence of other species in the catch. The unfiltered data set contained 659,773 trips, but after several initial filters to remove outliers and data not suitable for an index 95,424 trips remained (Table 22) for applying the Stephens and MacCall method. Species that are rarely encountered will provide little information about the likelihood of catching Cabezon, so we identified 47 "indicator" species that were caught in at least 30 Oregon trips (Figure 22). 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 six species with a high probability of co-occurrence with Cabezon include Buffalo Sculpin, Red Irish Lord, Starry Flounder, Black Rockfish, Lingcod, and Rock Greenling, all of which are commonly associated with rocky reef and kelp habitats in nearshore waters. The top six species were all strongly associated with Cabezon (significantly different from zero at the alpha = 0.05 level). The six species with the lowest probability of co-occurrence were Rosy Rockfish, Greenstriped Rockfish, Rosethorn Rockfish, Bocaccio, Silvergrey Rockfish and Blue Rockfish. These species are not commonly caught during the same trip as Cabezon, presumably due to different habitat associations and fishing techniques. The Area Under the Characteristics curve (AUC) for this model is 0.705; Figure 23), 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 (FP) and false negatives(FN). The threshold probability that balances FP and FN excludes 69,354 trips that did not catch a Cabezon (79.0% of the pre-filtered trips) and 10,175 trips (10.7% of the pre-filtered trips) that caught a Cabezon. We retained the FN trips, assuming that catching a Cabezon indicates that a non-negligible fraction of the fishing effort occurred in habitat where the species occurs. Only "true negatives" (the 69,354 trips that neither caught a Cabezon, 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 season, bag limit, effort, and catch rate attributes (Table 22). Removed from the final data set were trips that met criteria for irrational effort reporting, and extreme catch rates. Trips where the total catch of Cabezon was greater than or equal to the bag sub-limit for all anglers were removed to minimize trips with inflated fishing effort for Cabezon as a result of target switching. Finally, trips that had an observer on board were removed were if they were used to develop the Oregon Onboard Observer Index (Section 2.6.1).

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 24) in order to facilitate data categories conducive to exploring interactions between subregion and year. Apart from differences in catch rate among subregion, season, month, and year, we also considered changes associated with boat type (charter and private; Figure 24). Raw catch rate data suggested that trends in CPUE over time were not similar by subregion, so we included a model with interaction terms year:subregion in the set of candidate models (Figure 25).

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. Based on the Akaike Information Criterion, we selected a model as the best predictor of ORBS catch rates included year, month, subregion, boat type, and the year:subregion interaction term (Table 23). 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 which fits to encounters (presence/absence) is a reasonable approximation of the data (Figure 26, top panel). The lognormal component of the model which fits to positive catches also fit the data reasonably well (Figure 26, bottom 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. Treating CPUE as proportional to density, we multiplied annual predicted CPUE in each subregion by habitat 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 (confirmed by ODFW) 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 within 50 fathoms (approximate depth limit for Cabezon encounters) and then normalized to sum to one, with roughly 56% found in northern nearshore waters (north of Lane County, OR) and 44% found in southern Oregon nearshore waters.

To estimate the 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. The rstanarm package in R was used 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 combining model components) can be applied to posterior draws, preserving the correlation structure and propagating uncertainty into the final index (Figure 27; Table 19). 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. As expected, the model closely matches the distribution from replicate data (Figure 28).

2.6.2.3 Oregon MRFSS Dockside Index (1980-1989; 1993-2000)

Trip-level catch-per-unit-effort data ("Type 3 data") from MRFSS dockside sampling of ocean boats was provided by ODFW on February 5, 2019. These data are derived from fish sampled in angler bags following completion of a trip. Trips were defined by individual ID codes in the database. A trip aggregating algorithm has been developed by Braden Soper (University of California, Santa Cruz), however a preliminary analysis conducted by ODFW indicated that the Soper algorithm may be underestimating the number of trips. A final determination on the aggregating procedure was unavailable at the time of this assessment, so the previously used approach (ID code) was retained for this assessment. 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 Cabezon (i.e. identify trips that were likely to catch Cabezon), the method of Stephens and MacCall (2004) was used to predict the probability of catching a Cabezon given the occurrence of other species in the catch. The unfiltered data set contained 1,831 trips. Species that are rarely encountered will provide little information about the likelihood of catching a Cabezon, so 21 "indicator" species were identified that were caught in at least 30 Oregon trips (Figure 15). 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 Cabezon include Black rockfish, Kelp Greenling, Lingcod, China Rockfish, and Sand Sole, all of which are associated with rocky reef and kelp habitats in nearshore waters. The first four species were all strongly associated with Cabezon (significantly different from zero at the alpha = 0.05 level). The five species with the lowest probability of co-occurrence were Rosethorn Rockfish, Greenstriped Rockfish, Pacific Halibut, Silvergray Rockfish, and Widow Rockfish. These species are not commonly caught during the same trip as Cabezon, presumably due to different habitat associations and fishing techniques. The Area Under the Characteristic curve (AUC) for this model is 0.798 (Figure 16), 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 Cabezon based on the species composition of the catch, but did not. False negatives (FN) are trips that were not predicted to catch a Cabezon, given the catch composition, but caught at least one. The threshold probability that balances FP and FN excludes 959 trips that did not catch a Cabezon (52% of the trips), and 245 trips (13% of the data) that caught a Cabezon. We retained the latter set of trips (FN), assuming that catching a Cabezon indicates that a non-negligible fraction of the fishing effort occurred in habitat where Cabezon occur. Only "true negatives" (the 959 trips that neither caught Cabezon, 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 20).

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 17). Apart from differences in catch rate among subregion and year, we also considered changes associated with 2-month 'waves', season (three per year), and biannual (half-year periods; Figure 18). 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.

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. Based on the Akaike Information Criterion, the model with an intercept was selected as the best predictor of presence/absence of Cabezon, while the model with year and wave was selected as the best predictor of positive catch rates (Table 21). 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 19, top panel). The lognormal component of the model that fits to positive catches also fit the data reasonably well (Figure 19, bottom 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 (following procedures outlined in Section 2.6.2.2 above).

To estimate the 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. The rstanarm package in R was used 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 combining model components) can be applied to posterior draws, preserving the correlation structure and propagating uncertainty into the final index (Figure 20; Table 19). 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. As expected, this model closely matches the distribution from replicate data (Figure 21). Nonetheless, it was deemed during the STAR panel that the uncertainty (CV) associated with this index was unrealistically low, and thus was fixed at a CV consistent with other Oregon recreational indices (CV = 0.162).

2.7 Fishery-Independent Data

2.7.1 California

California Collaborative Fisheries Research Program Nearshore Survey

The 2009 Cabezon assessment highlighted several potential fishery-independent recruitment indices and adult surveys for inclusion. For reasons such as limited spatial coverage or lack of Cabezon presence in the data set, these indices were rejected for use in the stock assessment. One potential survey-- the California Collaborative Fisheries Research Program (CCFRP) nearshore survey-- was being developed off central and northern California, but was in its infancy in 2009. It has since built a 10+ year time series (2007-2018) and is considered for inclusion in the reference model.

The CCFRP index is a nearshore hook-and-line survey that applies a stratified random sampling design to sample nearshore groundfishes inside and outside of marine protected areas in waters from Morro Bay up to Cape Mendocino (Starr et al. 2015). These areas are not equally sampled, and the main section of sampling extends from Morro Bay to Ano Nuevo. There is a total of 5924 samples over the 12 years, 5% of which sampled Cabezon. Filters were applied to remove the small amount of sample south of Pt. Conception, retain depth between 25 and 100 feet in the months of August and September and only in the four above main sampling areas (Table 26). The retained samples (3323) contained 6% positive Cabezon catch.

A series of generalized linear models (GLMs) was fit first to the proportion of zero and non-zero records using a binomial distribution, and then to the non-zero catch rates (number of Cabezon per total angler hours) using either a gamma or lognormal distribution assumption. The product of the year effects from each GLM produces the index of abundance. In addition to Year, Month, Site (reference or marine protected area (MPA)) and Depth were explored as factors (Table 27). Model selection using AIC was applied to find the model best supported by the data. The final models all supported Year and Depth as best supported by the data (Table 27). The Reference and MPA sites showed no significant effect. A jackknife routine was used to determine the uncertainty in the indices. The final indices were almost identical between the gamma and lognormal distributions (Table 28; Figure 36). The gamma model was ultimately chosen for inclusion in the NCS stock assessment.

Length composition for the years 2007-2018 were also available for the CCFRP survey in order to estimate survey selectivity (Table 13). Individual fish were used for the length composition and number of trips were used to define the yearly effective sample size.

Research Age Compositions

Catch age-composition that represent fishery data remain unavailable to the assessments and no new ages were available for California outside the Grebel (2003) study described in greater detail in Section 2.8.4, providing 578 otoliths between 1991 and 2002 from Fort Bragg to Morro Bay, California. While 337 were from females, 224 were from males and 17 were unknown, they were aggregated for use in the assessment. Though the primary focus of the study was maturity and growth rate estimation, the samples were also used to represent age composition in the NCS for individuals sampled during the 6 years over which the samples were collected. The effective sample size and number of lengths provided by the study are provided in Table 29.

2.7.2 Oregon

A collection of research project samples collected by ODFW and through the Standard Monitoring Units for the Recruitment of Fishes (SMURFS) program were used to provide information on length at age (conditional age-length compositions) for young fish to help inform growth curves. A total of 28 samples for fish of age-0 or age-1 were used in this assessment (out of a total of 112 available; Table 15). ODFW samples were aged within their lab, and SMURFS samples were aged by an Oregon State graduate student (M. Wilson). Samples used covered the years 2001, 2012, 2015, 2016, and 2018.

2.8 Biological Data and Parameters

Biological parameters used in the population models are either derived outside the model and fixed, or estimated within the model. Fixed parameters lack the propagation of parameter uncertainty, thus uncertainty reported for derived stock assessment quantities does not include any uncertainty in these parameters. Sensitivity in the value of these parameters is subsequently performed via sensitivity analysis, though even estimated parameters may warrant additional sensitivity exploration. Main biological parameters and methods used to derive these parameters in the assessment are described below.

2.8.1 Natural Mortality (*M*)

The Natural Mortality Tool (NMT: https://github.com/shcaba/Natural-Mortality-Tool; http://barefootecologist.com.au/shiny_m.html) offers multiple ways to estimate *M* based on a variety of life history characteristics, and includes the Hamel estimator (Hamel 2015) that has been used in other groundfish assessments. Fourteen estimators where considered (Table 32) and were based on longevity, von Bertalanffy parameters, age at maturity, water temperate and one based on the relationship found in the FishLife application (Thorson et al. 2017b) . The value for each input for each Cabezon stock is given in Table 32. The resultant prior was a weighted density function that downweighted each estimator within a particular class of estimators (e.g., based on longevity or growth parameters) so their weights sum to 1 within each method grouping. The posterior for each prior by sex and stock are given in Figure 37.

2.8.2 Length-Weight Relationship

Weight-length relationships for Cabezon are provided in O'Connell (1953; central California), Lauth (1987; Puget Sound, WA), and Lea et al. (1999; central California) for both sexes combined. Lea et al. (1999) also provide relationships for females and males separately, in central California only. Raw length-weight data used in Grebel (2003) provide sub-stock- and sex-specific length-weight information with larger sample sizes than the earlier studies and are used for the California assessments.

For Oregon, Cabezon length-weight relationships were estimated outside of the assessment model using data from the Oregon Sport Boat Survey (ORBS) biological database (recreational) and PacFIN (commercial). The weight-length parameters represent an aggregation of females and males, because of limited gender-specific data and, given that available, no difference was detected. A total of 54,980 individual Cabezon were used to estimate the parameters: α = 1.90x10-5 and β = 2.99, following the standard power function formulation below.

For Washington, length-weight data were collected from 929 sport caught individuals - 254 females, 219 males, and 456 unknown. For female: a = 1.00x10-5 and b = 3.16; male a = 1.11x10-5 and b = 3.11; all sex combined a = 1.40x10-5 and b = 3.07.

Length-weight curves were fitted with the sexes combined using the following relationship:

$$W = aL^b$$

Where W is individual weight (kg), L is total natural length (cm) and a and b are coefficients used as constants. Stock-specific length-weight relationships are shown in Figure 39.

2.8.3 Maturity and Fecundity

Maturity ogives (Figure 38) for all California sub-stocks were estimated using the California Department of Fish and Game (CDFG) visual inspection codes and the data used by Grebel (2003). Females with gonads that had early-yolk-stage eggs were assumed to be mature, although it is possible that some of these fish were maturing, but not yet mature. This will lead to a more optimistic interpretation of the rate at which Cabezon mature (younger and at smaller sizes).

Oregon maturity ogive (Figure 38) was estimated using samples obtained from the ports of Newport, Depoe Bay, and Port Orford. Methods and details of the data collection and maturity determination are found in Hannah et al. 2009.

The number of eggs spawned appears to increase with fish size (weight or length) (O'Connell 1953; Lauth 1989). However, the actual relationship between age / size and number of eggs spawned is uncertain because of the possibility of multiple spawnings per year. For the purposes of this assessment, reproductive output is defined to be proportional to the product of maturity-at-age and body weight at the start of the year. Unless number of batches changes by age (of which we have no information or way of parameterizing the effects), this assumption seems robust.

2.8.4 Growth

Age and growth of Cabezon in California is extremely limited. In particular, The most recent and extensive study is found in Grebel (2003) and Grebel and Cailliet (2010) wherein 377 female and 239 male individuals were aged. These studies explored several ageing structures (sectioned otoliths, pectoral fin rays, dorsal fin rays, dorsal spines, and vertebrae), but used thin-sectioned otoliths on which to base growth estimates. Fixing growth parameters to growth estimates from the 2009 stock assessment as well as fixing the growth parameters to those report in Grebel and Cailliet (2010) were explored as sensitivities.

A recent study conducted by Rasmuson et al. (2019) estimated Cabezon growth by gender in Oregon waters using alternative ageing error assumptions, model assumptions (e.g., fix $t_0 = 0$), and alternative data sources (e.g., inclusion of age-0 fish). Using the base ageing error assumption, there remained a considerable range of estimates across alternative model assumptions and data use (range for females: L_{inf} = 57.97-73.14, k = 0.12-0.67, t_0 = -0.58-0.40; range for males: L_{inf} = 52.23-60.48, k = 0.16-0.86, t_0 = -0.59-0.41). Conditional age-at-length data were used to estimate growth internally in assessment models. Growth was specified to follow a von Bertalanffy growth function re-formulated by Schnute (1981) and governed by five parameters: length at minimum age (age-0); length at maximum age (L_{inf}), growth coefficient (k), and the variation (CV) around the length at minimum and maximum ages.

2.8.5 Stock-Recruitment Relationship

The California and Oregon sub-stock assessments assume a Beverton-Holt stock-recruit relationship (Beverton and Holt 1957) for Cabezon 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. 2018). However, no explicit prior has been developed for Cabezon. Therefore, steepness was fixed at 0.70 for all sub-stock models; the same value used in the 2009 assessment (Cope and Key 2009). Estimating steepness was attempted through sensitivity model runs, but a lack of contrast in exploitation (among other things) lead to little information about steepness so the influence of alternative fixed steepness values was assessed using likelihood profiles.

2.8.6 Age Structures

Age composition data in California remains limited to the research of Grebel (2003). These samples cover the NCS assessment area only and years 1996-2002. As done in the 2009 stock assessment these data were used in the NCS stock assessment as conditional age-at-length compositions in order to allow for growth estimation. Ageing error matrices are also carried over from the 2009 assessment. Growth parameters estimates from the NCS model are then fixed in the SCS model as growth estimation is not possible in the SCS model.

In Oregon, Cabezon otoliths were collected from the recreational ocean-boat fleet, the commercial landed dead fleet, and from research survey samples (Table 15). Otoliths were aged using a combination of the break and burn preparatory method and the thin sectioning preparatory method by the ODFW ageing lab. The break and burn method was used for all ages (1,810 or 68% of the total) except for those from the recreational ocean boat fleet during the years 2005-2008 (885 or 33%). Both the break and burn and thin section methods are generally considered to be more precise than surface reads (Beamish 1979, Kimura et al. 1979). A total of 2,328 Cabezon were aged from the recreational ocean boat fishery (2005-2018), 367 from the commercial landed dead fishery (2003, 2007-2018), and 28 age-0 and age-1 fish from research survey collections (2001, 2012, 2015, 2016, and 2018) that were used for this assessment.

In Washington, 184 otoliths were collected from sport landings and aged by two age readers and two ageing methods - break and burn and thin slice. These ages were used to estimate growth parameters for SSS inputs.

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) for comparison of alternative age reading methods (thin section, reader 1; and break and burn, reader 2). The latter approach also evaluated potential ageing error bias associated with ageing method. Recent analyses (Rasmuson et al. 2019) were conducted to estimate within reader and method ageing error as well as among method ageing bias using a subset of the Cabezon samples used in the assessment. Samples to be double read are systematically selected to obtain a 20% resampling rate of the annual total. Average percent agreement across available years was 50.0% (range: 25.0% - 73.9%), with an average percent plus bias of 17.2% and an average minus bias of 32.8%. Between method bias was also calculated for the case when the break and burn approach was assumed unbiased relative to the thin section approach, as well as the reverse situation. Thus, four ageing error matrices were developed, a set (break and burn and thin section) for each case depending on which was assumed unbiased relative to the other, and all included within method/reader error (Table 30). The reference assessment model assumed that the break and burn approach was unbiased, however a sensitivity model run was completed to examine the case when the thin section reads was assumed unbiased.

2.8.7 Relative Stock Status in Washington State

The Simple Stock Synthesis Washington state sub-stock model requires as an input the value of current relative stock status, in addition to natural mortality and steepness. It is common to either assume current stock status as the biomass target (40% for Cabezon), use expert opinion, or set it to other ancillary data, such as productivity-susceptibility analysis or similar stock assessments. The former DBSRA application for the WAS made the assumption that the Washington and Oregon sub-stock were at the same depletion level before management in the two states diverged and the live-fish fishery began in Oregon, thus setting 1997 as the common relative stock status year (62% unfished; Cope et al. 2017). This application took a different approach and uses length composition data in the most recent year to get an estimate of the current spawning potential ratio using the Length-Based Spawning Potential Ratio method of Hordyk et al. 2016. LB-SPR uses size/length data and life history parameters (L_∞, M/k ratio, length at maturity) to produce estimates of selectivity and spawning potential ratio (SPR). The SPR estimates from LB-SPR are coarse measures of relative stock status used to establish the prior for SSS.

Input life history parameters used the age and growth estimates from Washington data (female L_∞= 70.89) and natural mortality estimates (section 2.8.1) to obtain a value of M/k = 1.5. Length of 50% maturity was borrowed from Oregon (43 cm) with length at 95% maturity assumed at 45 cm. The coefficient of variation at length was assumed to be 0.1. SPR was estimated for length composition sample years 2014-2018 was explored (Table 33). Biological samples represent four WDFW marine coastal areas. Length samples by area have not been proportionate to catch. For example, 65.1% of the catch came from Marine Area 4 yet only 39.7% of the length samples were taken from that area. Rules such as minimum size limits for Cabezon and depth restrictions have also differed among the areas. For this or other reasons, the average fish length differs between northern and southern areas. Samples were therefore weighted by proportions of catch by area when creating the length frequencies.

LB-SPR estimates of SPR for use to develop a prior of relative stock status in the current year (2019) are provided in Table 34. The past 5 years were examined for dynamics and variance in the estimate and a value of 65% was chosen as the mean of the prior. Several alternative relative stock status values were also explored in SSS given the LB-SPR approach may underestimate true relative stock status for two notable reasons: a) given it is a measure of SPR, not spawning biomass and b) LB-SPR assumes asymptotic selectivity, with any deviation towards a dome-shaped selectivity curve causing an underestimated SPR values.

2.9 Data Sources Evaluated, but Not Used in the Assessment

Fishery-Independent Data

NMFS Fishery-Independent Trawl Surveys

Cabezon are poorly sampled in fishery-independent bottom trawl surveys. Cabezon only were reported in 7 of 14,822 trawl sets conducted from 1977-2018 between the two main U.S. West Coast shelf surveys, the AFSC/NWFSC West Coast Triennial Shelf Survey and the NWFSC West Coast Groundfish Bottom Trawl Survey. Out of the 7 tows that observed Cabezon, only 4 had associated biological data collected, a single fish by year (in 2008, 2016, 2017, and 2018). These 4 samples were at depths ranging of 60-102 m measuring fish ranging in lengths between 13.5-67 cm. The AFSC/NWFSC West Coast Triennial Shelf Survey observed a single Cabezon in 3 years (1989, 1992, and 1995) captured at depths of 71, 104, and 88 m, respectively. No biological data were collected from these fish.

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 fish density at those sites. However, ROV surveys are not conducive to evaluating Cabezon due to their association and general camouflage with surrounding rocky habitat and their lie and wait predatory behavior. Methods to evaluate detection/sighting probabilities and camera happy/shy behavior are being explored for other species, but at this time the ROV survey is not expected to be a pragmatic approach for surveying Cabezon (Hannah and Blume 2012).

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)
The Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) adult survey (1999-2018), conducted SCUBA surveys predominantly in the Monterey region. Since 2007, they have extended their survey area monitoring inside and outside MPAs in central and southern California to a lesser or greater extent as funding allowed. This index was not included in any of the current or past California base case models for two reasons: 1) SCUBA surveys may not provide reliable abundance indices for cryptic species such as Cabezon; and 2) the spatial coverage of these surveys, which is limited, is such that abundance indices based on them may not be representative of state-wide trends (Cope and Punt 2006).

Marine Reserve Program (ODFW)/ Oregon State University SMURF Surveys
Joint SMURF (standardized monitoring unit of recruitment of fish) surveys were conducted by Oregon State University and the ODFW Marine Reserves Program from 2011 – 2018. More detailed information on SMURFs and their deployment can be found in Ottmann et al. 2018. SMURFs were deployed in two regions (central and southern Oregon coast) with one set of moorings deployed in a state marine reserve and another set at a nearby comparison area. Comparison areas are specifically selected for each marine reserve to be similar in location, habitat and depth to the reserve but are subject to fishing pressure. The marine reserve sites include Otter Rock in the central coast and Redfish Rocks on the southern coast, and their associated comparison areas, Cape Foulweather and Humbug Mountain, respectively. Sampling in the central region occurred from 2011 – 2018 and in the southern region from 2014 – 2018. SMURFs are typically deployed in early spring and monitored relatively regularly from April or May to September. The unit of the recruitment rate is termed number of fish per trap/day. A preliminary assessment by ODFW of the utility of these data to the Cabezon 2019 assessment is presented in Appendix D.

SMURF surveys were considered for inclusion in the Cabezon assessment for several reasons, though time did not allow for the full development of a recruitment index from these data. Cabezon are present in a high number of sampling events (Appendix D; 56% of unfiltered sampling events). Cabezon appear to regularly recruit throughout the sampling season, as opposed to other groundfish such as rockfishes (*Sebastes* spp.), which tend to have large, episodic recruitment events juxtaposed with many zero catches (Ottmann et al. 2018). SMURF sampling in Oregon's marine reserve system represents a relatively long-term and well-established data collection program with a statistically robust sampling design. Nearshore settlement of juvenile groundfishes are not well monitored along the west coast and further development of recruitment indices could provide additional context for stock assessments for nearshore species. For example, raw annual recruitment rates support the large 2014 year class estimated by the Oregon reference model

(Appendix D). Length compositions from captured Cabezon in SMURFs confirm that captured fish are between 20 and 60mm (Appendix D), typical post-settlement size for Cabezon (Materese et al. 1989, Ottmann et al. 2018). Though not available for this assessment cycle, the SMURF network, which includes additional long-term monitoring sites in California, is in the process of merging datasets to provide a coastwide nearshore recruitment dataset for potential use in future assessments (J. Watson, ODFW; pers. comm.).

Marine Reserve Program (ODFW) Hook and Line Surveys
The Marine Reserve Program at the ODFW routinely monitors state marine reserves and associated comparison areas with a wide variety of tools, including hook and line surveys, since 2011. Comparison areas are specifically selected for each marine reserve to be similar in location, habitat and depth to the reserve but are subject to fishing pressure. A preliminary assessment by ODFW of the utility of these data to the Cabezon 2019 assessment is presented in Appendix E.

The Oregon Marine Reserve system encompasses five reserves and numerous comparison areas. Hook and line surveys presented in Appendix E include surveys in four marine reserves and ten comparison areas from 2011 - 2018. Not all sites are sampled in each year, due to the gradual implementation of the marine reserve system and available staff to execute surveys. Hook and line surveys are modeled after recreational charter trips with contracted charter vessels and common charter fishing gear, but with a statistically robust sampling design and volunteer angles. Five-hundred meter square grids are overlaid on the site to define the sampling unit or cell. Cells are randomly selected and three replicate drifts are completed in each cell. Over time, cells with inappropriate habitat for groundfish have been removed so that only cells with a reasonable expectation of encountering focal species are sampled. Three to five cells are sampled daily in the spring and fall sampling seasons. Catch rates (CPUE) are defined as the number of fish per angler hour within a cell-day combination.

Though unable to include in the current assessment due to time constraints, hook and line surveys from Oregon's marine reserves were considered for inclusion as a fishery-independent survey index of abundance. Relatively high positive catch rates of Cabezon (Appendix E; 25% of unfiltered cell-days) indicate that these surveys reliably encounter Cabezon, though annual proportions of positives can vary. The practice of filtering for cells with appropriate habitat based on expert, local knowledge and detailed habitat information may preclude the relatively time consuming efforts of assessors to filter to appropriate sample units for an index of abundance. The robust sampling design is another favorable attribute of this dataset, though irregular spatio-temporal sampling may require additional consideration. Finally, Cabezon are captured in relatively small numbers in this dataset (Appendix E), despite a relatively high positive encounter rate, making this dataset a good candidate for assessments of other nearshore species that are commonly encountered in recreational fisheries.

Fishery-Dependent Data

Pikitch study
The primary goal of the Pikitch study (Pikitch et al. 1990) 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). Cabezon 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.

Research Project Age Collections (ODFW)
ODFW opportunistically sampled and aged Cabezon intermittently from 1999-2018 (Table 15). Of these, only age-0 and age-1 fish (n=8) were used in the assessment to provide observations for small (young) fish to inform the growth curve near the origin. Another 20 samples of age-0 fish from SMURF collections were also included to help inform growth estimation. The remaining 84 samples collected by ODFW (ages ranging from 2-12) were not used because they were a mix of fish captured from targeted survey collections as well as fish used for research-based ageing procedures from samples acquired through the recreational and commercial fisheries.

2.10 Environmental or Ecosystem Data

Ecosystem considerations were not explicitly included in this assessment. While ecosystem studies are progressing in the California Current, there is a lack of specific data relevant to Cabezon population dynamics for inclusion in this stock assessment.

3 Assessment Model

3.1 History of Modeling Approaches Used for this Stock

The first Cabezon assessment was performed in 2003 and attempted to model California and Oregon/Washington as separate areas (Cope et al. 2004). The Oregon/Washington model was found to be too data-limited to complete the assessment, so management was only based on the California results. Two fisheries (commercial and recreational fleets) were modelled and assumed to have logistic selectivity. Multiple recreational fishery-based indices were developed and used, as well as a spatially-restricted recruitment index. Length composition were the only biological data available. Natural mortality (0.25), steepness (0.7), and growth parameters (based on Grebel 2003) were all fixed. This model did not use the current length-based version of Stock Synthesis, but instead was a statistical catch-at-age model written in AD Model Builder. It was this AD Model Builder code (“cab”) that was used as the seed code to later make Stock Synthesis 2.

The second assessment of Cabezon was done in 2005 and focused on California and initiated the break of sub-stocks at the Pt. Conception border (NCS and SCS) based on the very different exploitation histories of each area (Cope and Punt 2006). This stock assessment also introduced more resolution in fleets, with two commercial and four recreational fleets. These fleets would have a mix of logistic and dome-shaped selectivity for the first time as well. The California catch history was completely reconstructed from old reports and moved back to start in 1916. The NCS model only uses the CPFV logbook index, whereas the SCS model used the CPFV logbook and two recruitment indices. This assessment also pointed out that lengths in the early time series of the MRFSS recreational biological sampling that recorded lengths were actually weights. Mean weights were therefore included in the assessment in order not to lose the early biological samples. Growth parameters were again fixed in both models, as was natural mortality (though sex-specific this time) and steepness. The modelling framework applied the newly developed Stock Synthesis 2, a closely related, but much enhanced version of the model used in the previous assessment.

The third assessment of the Cabezon resource off the California coast was performed in 2009 (Cope and Key 2009). This assessment retained the two California stocks and as well as successfully assessed the Oregon stock. The six fleet structure was retained in California, but catch histories differed in the recreational fisheries due to changes in the weight and numbers of fish reported. The Oregon model has two commercial and two recreational fleets. The treatment of discards also differed from the previous. While discards were not considered in the previous assessment this assessment considered data from the WCGOP. Where the past assessment did not use any RecFIN lengths prior to 1993 because the lengths were derived from weights, this assessment recovered the measured lengths included the full time series of RecFIN length compositions for all modes in each of the sub-stocks. This effectively excluded the need for the mean weights, though they were still retained in the model. Data-weighting was achieved using the harmonic mean approach. Age-at-length data were treated conditional to length so as to allow the estimation of growth parameters internal to the model for the first time. Natural mortality and steepness remained fixed. This assessment used Stock Synthesis 3.03A.

This current stock assessment represents the fourth overall assessment for Cabezon in California and second for Cabezon in Oregon waters. It also represents the second estimation of overfishing limits for Cabezon in Washington with the first coming in 2017 (Cope et al. 2017). This assessment uses the newest version of Stock Synthesis (SS 3.30.13.00, Methot et al. 2018). This document identifies a single sub-stock specific model for determining current stock status and trends, termed the “reference” model.

In addition to the full stock assessment in California and Oregon, there has been one application of a catch estimator approach in Washington (Cope et al. 2017). Depletion-Based Stock Reduction Analysis (Dick and MacCall 2011) was applied to estimate OFL values for 2019 and 2020. This category 3 assessment is revisited here using the Simple Stock Synthesis approach (Cope 2013) to provide additional flexibility in treatment of selectivity and using steepness in order to keeps it productivity in common with the other two states.

3.2 Response to STAR Panel Recommendations from Previous Assessment

The following are the STATs responses (in italics) to research and data recommendations listed in the 2009 STAR panel report. The report can be found at: (https://www.pcouncil.org/ wp-content/uploads/Cabezon_STAR_2009_Final.pdf).

1. M seems high for both genders for a species of that size, shape and life habits. The current high estimates could be due to higher values at some ages or length. Tag – recapture studies currently being conducted are expected to be useful in that respect and should be used to estimate M. Information would be expected for the assessment cycle after the next.

The STAT agrees that auxiliary information on natural mortality, such as that obtained from tagging experiments, should be encouraged. Such studies should be designed to either directly *estimate natural mortality or able to separate mortality from fishing and all other causes, and ideally be representative of one or more sub-stocks (given spatial differences in assessment estimates of M). The STAT is unaware of any tagging studies that have directly estimated (e.g., Brownie dead recovery or Jolly-Seber mark-recapture models) Cabezon natural mortality for use in the sub-stock assessments. Ssee response to #2 below for further details on known Cabezon tagging studies.*

2. Further tagging studies should be conducted to estimate growth, natural mortality, migration and to investigate stock structure, including for a larger portion of the distribution range.

The STAT is aware of three tagging studies involving Cabezon, all conducted in California waters. Mireles et al (2012) looked at home ranges of Cabezon around southern California reefs by tagging 1,240 adults and recapturing 23% with maximum time at liberty being 1,000 days. This paper indicates that Cabezon tend to not move long distances (81% of recpatures within 100 m of tagging location and home ranges estimated to be 1,000 m^2 on average). Hanan and Curry (2012) tagged 32 species of groundfish in southern California; however, only six Cabezon were recovered of the 300 tagged. A Bachelor of Science senior thesis was conducted by C. Yorke (Yorke 2011) that used tagging data to inform the calculation of a Cabezon growth curve in central California (available at: https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi? article= 1014&context=biosp).

Although useful for identifying localized life history strategies, none of these studies were deemed extensive enough to warrant inclusion in the 2019 stock assessment. Nonetheless, the results from these studies were considered as supplementary information and cited in this document and the STAT continues to support furthering such studies.

3. Confirm/re-estimate the landings in 1980 in the RecFIN PBR which should include correcting the RecFIN database to avoid using unrealistic landings for that year in future assessments. Including the catch reconstruction from 1980 onwards, similar to what was done for Lingcod.

This was not possible as the MRFSS data set on the old RecFIN server is no longer available. We therefore are restricted to using the data from the past assessment.

In Oregon, updated recreational catch reconstructions were completed for this assessment (see Section 2.4.2).

4. Explore the shorter yet more detailed logbook data (digitized by license number) for CA from 1980 onwards (CPFV).

As of the time of writing, the State of California and NOAA Fisheries are still in negotiation to set up a data-sharing agreement for data containing confidential information. This information was not available to the STAT team in time to do this analysis, but should still be considered in the future.

Commercial logbooks were used to create an index of relative abundance for the Oregon sub-stock spanning 2004-2018 (see [*Section 2.3.1*]*).*

5. BMSY is very close to the limit reference point. This suggests that further general investigation of target and limit reference point is warranted. Reference points need to be re-evaluated.

Reference point evaluation/alteration is a Pacific Fishery Management Council (PFMC) decision. The STAT would be happy to work with the PFMC to evaluate alternative reference points relative to Cabezon population dynamics specified in these sub-stock assessments. Related, the STAT also acknowledges that given a fixed steepness of 0.70 there is a slight disconnect between the assumed population dynamics for Cabezon and the PFMC reference points used for management of this species. This disconnect is present for many (nearly all) PFMC managed stocks due to the generality (not species-specific) of council specified reference levels.

6. Develop at least one reliable fishery independent survey possibly using longline or trap (no rockfish bycatch) survey. This could be a combined Cabezon and Lingcod pot survey designed to adequately cover the inshore distribution area and the closed areas.

The CCFRP hook and line survey in California does provide a design-based fishery-independent survey that does encounter Cabezon at a level worthy of consideration for an index. While the ultimate index is mostly constrained to the central California coast, this area is one of major Cabezon historical abundance, thus is a reasonable indicator of population status.

The development of a reliable fishery independent survey remains a top priority for Cabezon and other nearshore species (see [*Section 7*]*). Hook and line and Scuba transect (SMURF) surveys were evaluated as potential fishery independent surveys of the Oregon sub-stock. Although these surveys provide useful information to the assessment (length-age relationships of small/young fish for estimating growth, site specific correlations with CPUE trends [hook and line] and recruitment [SMURF]), they were not deemed spatially extensive enough or did not sample many Cabezon to adequately track the Oregon sub-stock.*

7. Continue to develop alternative management procedures that do not require traditional stock assessment.

Since the 2009 assessment, several alternative approaches for data-limited and non-traditional stock assessments have been developed. The multiple methods (LB-SPR and SSS) used to estimate overfishing limits for the Washington sub-stock despite severe data-limitations that exemplify this progress.

8. Look at environmental covariates for recruitment and time-varying growth and availability inshore.

At the time of this assessment, no analyses were available linking environmental covariates to recruitmetn or growth at a scale indicative for southern California, northern California, Oregon, or Washington sub-stocks. Several ongoing (or recently initiated) research projects are underway *looking at spatiotemporal synchrony of recruitment for nearshore and non-nearshore species, including a study looking at the effect of oceanographic conditions as drivers of nearshore species recruitment.*

9. Investigate the implications of the male guarding behaviour (re-defining spawning output).

The STAT spent a considerable amount of time looking into re-defining spawning output to include a measure for male contribution to recruitment potential within the capabilities of Stock Synthesis. Although progress was made, the STAT deemed it critical to fully test the proposed alternatives before implementing them into this stock assessment, given such an endeavor may require a major restructuring of the assessment model files and possible new additions to Stock Synthesis itself. The STAT continues to believe this is an area of important future research for species that nest guard, such as Cabezon, or where males otherwise have a significant role in recruitment success, and recommends continued work on this topic (see Section 7).

10. Investigate non-lethal methods to determine gender and collecting sex-specific data.

Color has been subsequently investigated, but has not proven to be conclusive. The STAT is not aware of any other work on non-lethal identification methods for Cabezon.

11. Investigate further the abundance and distribution of Cabezon larvae and juveniles in existing databases to better understand stock structure and linkages.

Past Cabezon stock assessment have considered these types of data sets, but samples sizes of larval or juvenile Cabezon continue to be limited. In cases where samples are more readily available (e.g., Oregon SMURF survey) the spatio-temporal scope is limited. Although not used in the assessment directly, the SMURF recruitment data for Cabezon were used to cross check Oregon sub-stock assessment estimates of above average recruitment in 2014.

12. Investigate the usefulness of catches of Cabezon in the man-made fishery on piers and jetties as an index of recruitment.

California and Oregon sub-stock shore fleets, of which includes fishing from man-made structures, take a very small proportion of the total catch relative to other fleets and are the least aggressively monitored fleet component. Catch estimates from the shore fleet are rarely measured directly, but rather inferred through correlations with fishing license sales, thus effort would be extremely difficult to estimate.

3.3 Transition to the Current Sub-Stock Assessments

Ten years have passed between the last (SS v3.03a) and current (SS v3.30.13) stock assessment for Cabezon. In those 10 years, Stock Synthesis has gone through major advancements, including configuring of the main input files. The change logs from that time to the current version is just under 50 pages and can be found on the Stock Synthesis distribution site (https://vlab.ncep.noaa.gov/group/stock-synthesis). The following steps were conducted to bridge the former model to the most current version:

- Update the 3.03 files to the new 3.30 format.
- Fix all parameter values to the 3.03 reference model values.
- Run model with no estimation (Model 3.03 in 3.30)
- Run model this time estimating parameters and derived quantities (Model 3.30)
- Compare the outputs from Model 3.03 (original 2009 outputs), Model, 3.03 in 3.30, and Model 3.30.

3.3.1 California models

Comparisons for each California sub-stock are given in Figure 42 (SCS) and Figure 43 (NCS). The population dynamics are still essentially the same in both versions of Stock Synthesis. The estimation model also resulted in almost identical values in the SCS model (Figure 42), and very similar in the NCS model (Figure 43). Differences come from slightly different estimated growth parameters (values that are fixed in the SCS model), but amount to non-significant differences in model output.

3.3.2 Oregon model

Comparisons for the Oregon sub-stock are provided in Figure 44 and Figure 45. Updating to the latest version of Stock Synthesis lead to unexpected results. Overall, the scale of the population declined as did the trend in stock status, particularly throughout the 2000s. Initial explorations into model behavior uncovered that the key differences were associated with fitting the index of abundance and resulting recruitment deviations. Further bridging model evaluations also uncovered that fixing parameters for the initial fishing mortality to 2009 estimates resulted in an updated Stock Synthesis bridge model that gave similar results to the 2009 assessment (Figure 45), suggesting some interaction with the initial fishing mortality parameters as well. Many statistically rigorous additions and corrections, as well as matters of convenience, have occurred within Stock Synthesis over the past decade. This, combined with many model specifications that have also changed for the Oregon sub-stock assessment since 2009 (see Section 3.4.2), lead the STAT to not be overly concerned with these differences.

3.3.3 Washington model

The 2017 estimation of OFLs for Cabezon used Depletion-Based Stock Reduction Analysis (DBSRA; Dick and MacCall 2011). This approach applies a delay difference population dynamics model and a hybrid stock-recruitment relationship to calculate future overfishing levels. It requires annual removals, age at maturity, assumes selectivity equals maturity, and explores uncertainty through the following parameters: relative stock status for a given year y (SB_y/SB_0), natural mortality (M), the ratio of the fishing rate at maximum sustainable yield to M (F_{MSY}/M) and the ratio of spawning biomass at MSY to initial spawning biomass (SB_{MSY}/SB_0). The final two parameters represent the productivity of the population and are analogs to using steepness in the Beverton-Holt steepness. Cope et al. 2015 demonstrated that the default values of F_{MSY}/M and SB_{MSY}/SB_0 presume a much lower productivity stock than the common steepness values used in west coast groundfishes. Punt and Cope (2017) confirmed this behavior and extended the capacity of Stock Synthesis to use the same productivity parameterization as DBSRA in a new stock recruit curve called the Ricker Power relationship.

In order to bridge the methods from DBSRA to SSS, the Ricker power curve was applied in SSS, allowing the SSS model to be specified in the same way as the 2017 DBSRA analysis (Cope et al. 2017). Cope et al. 2017 used current year as 1997 for the relative stock status measure, and established the prior on that value using the relative stock status in that year from 2009 Oregon model. It also used the female M value and maturity from the 2009 Oregon model, and default values for F_{MSY}/M (0.8) and SB_{MSY}/SB_0 (0.4). The differences in the SSS configuration is that it also requires the growth parameter specification (used the current estimates of growth in Washington) and weight-length relationships (also Washington specific values used in the new SSS model). Both comparisons used the same catch scenario (#2) from Cope et al. 2017.

Results comparing summary statistics of the 2019 and 2020 OFL from both methods are given in Table 35. Despite the slight model difference, median OFL values are within 1 mt with highly overlapping distributions, confirming the SSS model can reproduce the DBSRA values. The steepness estimates from the Ricker Power function (median of 0.45) also confirm that the prior analysis assumed an effective steepness much lower than the current application (0.7 to match the other state models).

3.4 Model Specifications

3.4.1 California

Both California sub-stock models use Stock Synthesis v.3.30.13 (released 13 March, 2019) configured as an area separated sex-specific age-structured population dynamics model. Major model specification are listed below, including how they are different from the 2009 stock assessment.

- Model time coverage starts from the last stock assessment (1916) and continues through 2018.
- Two sexes are retained, as growth is very different between females and males.
- The yearly time step with 12 months is retained, though 6 subseason were defined in order to allow for more flexibility in the treatment of fleets.
- The accumulator age was dropped from 35 to 25 in both models to reduce model dimensions. Given the likely natural mortality range, 35 years was a very high consideration.
- The number of fleets was reduced to 4 from the previous 6. This reduction came from combining the man-mad and beach/bank mode into a shore mode, and combining the private and charter boat modes into a boat mode. Model development showed similar length compositions between the modes and no appreciable difference in model outputs when using 6 vs 4 fleets. The reduction in fleets, though, did reduce the number of estimated selectivity parameters as well as increase sample size for within year length compositions.

- Historical catch times series remained largely the same from the last model, with new catches being added to complete the time series. Difference came in the reallocation of recreational catches from SCS to NCS in the years 1980-1995 and the new pull of recreational data from 2004-2008. Another change was in the timing assigned to the catches. The previous assessment assigned catch to the month 1, whereas the new assessment assigned them to the mid-year month 6.
- The CPFV indices were retained in both the SCS and NCS model, but a new fishery-independent index (CCFRP hook and line survey) was added in the NCS and covered the most recent time period.
- Mean weights were excluded from the new assessment. Mean weights had been reduced last assessment with the recovery of some true length measures in the early MRFSS time period. Once that happened the final reference models showed low information content in the remaining mean weights, justifying removal from the current model.
- Length compositions again were similar to the previous assessment, with the addition of new years. Month assignment was switched from 1 to 6, as done in the catches. Additional lengths for the CCFRP survey were also used in the new assessment. The same length bin structure was retained from the last assessment.
- Conditional-age-at-length samples from the previous assessment remained the only available samples for the current assessment. One change in treatment was to put all ages in the NCS model, as the very few samples that were in the past SCS model were not used in estimation. The inclusion of the full data set in the NCS model contributed to the estimation of the growth parameters that were then used in the SCS model.
- Block years were slightly adjusted in the new model to better match changes in the length compositions and known management changes. Numbers of blocks remained the same.
- Natural mortality was estimated in both areas, whereas they had been fixed in the previous model.
- Growth was again estimated in the NCS model and fixed to the NCS values in the SCS model. One difference is that the current NCS model estimated the length at age 0 to be close to 0 for both sexes, so that parameter was subsequently fixed, which improved model estimation.
- Additional biological parameters were fixed to the same values as in the previous model.
- Steepness and recruitment variability were fixed to the same values as in the previous model
- Recruitment estimation differed as the current assessment used the method of Methot and Taylor (2011) to identify years of recruitment estimation and the treatment of bias adjustment to make it more consistent with the assumed recruitment variability. The previous assessments assumed all estimated recruitment years received a full bias adjustment (=1), with years of estimated recruitment 1970-2006 in both models. The current NCS model estimated recruitments from 1962-2016, with the ramp from 0 in bias adjustment starting in 1964 and reaching its maximum value of 0.63 from years 1983-1998 (years of peak information), ramping again down to 0 in 2017. The current SCS model estimated recruitments from 1970-2016, with the ramp from 0 in bias adjustment starting in 1970 and reaching its maximum value of 0.45 from years 1977-2011, ramping again down to 0 in 2017.
- Change from Pope's approximation of F to the hybrid method.

- Both the previous and current model analytically calculated the catchability coefficient for each survey. Additional variance was also estimated for both CPFV surveys, but was set to 0 for the CCFRP survey as attempts to estimate this parameter always resulted in a value close to 0.
- Selectivity curves treatments remained the same from the previous assessment: The commercial dead and recreational shore and boat fleets were estimated as asymptotic; the commercial live fleet was allowed to be dome-shaped. Selectivity for the new length composition data from the CCFRP survey was also free to go dome-shaped. Time-varying blocks were applied to the commercial live and the recreational boat fleets.
- Data-weighting was treated differently than the previous model. The 2009 model used the harmonic mean approach (McAllister and Ianelli 1997) whereas the Francis method (Francis 2011) was applied in the current models. A sensitivity to this choice of data weighting (as well as no data weighting) was explored as model sensitivities.

A maximum likelihood approach was again used to determine parameter estimates and derived model output. Likelihood components minimized in the overall fitting procedure include

1. Fleet-specific catch
2. Survey data fits (assumed log-normally distributed)
3. Length composition fits (assumed multinomial distribution)
4. Conditional age-at-length composition fits (not in the SCS model; assumed multinomial distribution,
5. Recruitment deviations (assumed log-normally distributed)
6. Parameter prior penalties (penalties on deviations from the prior distribution)
7. Parameter soft-bound penalties.

Initial model explorations utilized individual and combined likelihood values to assist in model development.

3.4.2 Oregon

The Oregon sub-stock assessment is structured as a single, sex-disaggregated, unit population, spanning Oregon marine waters. There is little information available on Cabezon movement rates within Oregon or among adjacent states, although Cabezon are not known to move long distances, with home ranges around 1,000 m^2 (Mireles et al. 2012).

Major model specification changes made during the development of this Oregon sub-stock assessment relative to the 2009 Oregon sub-stock assessment include:

- Model start year was moved to 1970 (previously 1973) and a linear ramp of recreational ocean boat catch from 1970 to 1973 and shore catch (1970 to 1979) was used rather than estimating initial fishing mortality parameters for these fleets;
- Population length bins spanned 4 cm to 70 cm (previously 6 cm to 92 cm) and the accumulator age was set to age-20 (previously age-35);
- Updated female and male weight/length relationship using additional data;
- Fix male and female natural mortality parameters based on estimates produced from the 2019 NCS model (result of STAR panel);

- Update the estimation period for recruitment deviates given the addition of more composition data;
- Add three more fishery-dependent indices of relative abundance (previously one was used);
- Selectivity time blocks were reduced from three to two in the current assessment, because of indistinguishable differences between two of the previously specified time blocks (i.e., drop one of the previous time blocks; 2000-2003); and
- Change the data weighting ('tuning') method from the harmonic mean (McAllister and Ianelli 1997) approach used for all composition data in the previous assessment to the Francis (Francis 2011) approach for length composition data and the harmonic mean approach for conditional-age-at-length data in this assessment.

In addition to the above model specifications, data were also updated through 2018, including the incorporation of many more age and length observations and the addition of new recreational fleet catch reconstructions (Table 8).

More specifically, the assessment model operates on an annual time step covering the period 1970 to 2019 (not including forecast years), assumes negligible catch prior to that time, and thus assumes a stable equilibrium population prior to 1970. Population dynamics are modeled for ages 0 through 20, with age-20 being a potential accumulator age. The maximum observed age was 17 for males and 17 for females; however, ninety-nine percent of observed male and female ages were at or below age-14. Ages were collected from 1999-2018, which temporally coincides with relatively high catch. Population bins were set every 2 cm from 4 to 70 cm, as were the data bins. The model tracks catch across two sectors (commercial and recreational) and four fleets, and is informed by four fishery-dependent 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 17. All catch was assumed to be known without error. Model sensitivity to alternative data and model structural assumptions were explored.

Fleets were specified for recreational and commercial sectors similar to the last assessment. The recreational sector was split into two main fleets: an ocean-boat fleet and a shore fleet. The shore fleet is a compilation of fishing by boat in estuaries, fishing from man-made 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 dominated commercial live fleet (fish kept alive destined for the live market) and commercial dead fleet (fish landed and sold to the non-live market). Landings and discards (when available) were combined due to low levels of estimated total discard mortality as Cabezon are resilient to hooking and release. Selectivity was assumed to be asymptotic or dome-shaped depending on fleet (see Section 3.5.2 for details), and was gender invariant. Sensitivity to selectivity assumptions were explored during reference model development.

The time-series of data used in this assessment is summarized in Figure 3. Sample sizes for length composition and age composition are also summarized (Table 14 and Table 15, respectively). 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 reference assessment model using the Francis weighting method (Francis 2011). The Francis method resulted in down-weighting of all length composition sample sizes (Table 36).

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. The Francis method for weighting conditional age-at-length data resulted in iteratively unstable weightings and a continual upweighting of the commercial dead fleet samples. Therefore, 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 36). Alternative approaches to weighting were explored through sensitivity evaluations (see Section 3.9).

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 reference model.

Several approaches were evaluated during reference model development (and during the STAR panel) to estimate natural mortality, including the specification of prior distributions on male and female natural mortality (Table 32; Figure 37, and Figure 41). Estimating natural mortality resulted in unmanageable amounts of uncertainty associated with some derived management quantities and unreasonably high estimates given Cabezon life history. Therefore, female and male natural mortality was fixed at values informed by the 2019 NCS model estimates (0.24 and 0.28 in the Oregon model, respectively). Sensitivity to natural mortality assumptions are evaluated in Section 3.9.2. Natural mortality was fixed at 0.25 for females and 0.3 for males in the 2009 assessment.

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 the most recent version of Stock Synthesis 3 (version V3.30.13.00; Methot et al. 2018), which was provided by Rick Methot (NOAA-NWFSC) and Chantel Wetzel (NOAA-NWFSC). 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 are provided electronically and can be found on the Pacific Fisheries Management Council website (http://www.pcouncil.org/groundfish/ stock-assessments/).

3.4.3 Washington

The Washington model uses the Simple Stock Synthesis approach (Cope 2013), and applies Stock Synthesis v.3.30.13 (released 13 March, 2019). This approach fixes all parameters except for initial recruitment, and uses a Monte Carlo randomization method to draw and fix values for natural mortality, steepness and stock status. The estimation of initial recruitment establishes the population scale and the fixed selectivity determines the translation of proxy F_{MSY} ($SPR_{45\%}$) and population sale to calculate an OFL value with uncertainty determined by the uncertainty in the three drawn parameter distributions and the exclusion of any population trajectories that trigger a catch penalty, indicating populations near extinction. Major model specifications are listed below

- SSS is used instead of DBSRA. The change allowed for exploration of selectivity different than assuming it equal to maturity (and not knife-edged), applying sex-specific growth values and allows for the use of the F_{MSY} proxy to calculate the OFL.
- This is a two sex model with the same length and age population structure as the California, which is very similar to the Oregon model.
- There is one recreational fleet represented in the model
- This method uses no measured indices of abundance (it does use a “stock status survey” as described below) or biological data.
- The relative stock status input is implemented as a survey with high precision that forces the model to match a specific stock status in a given year and drawn from a distribution specified by the user. A beta distribution is used to express the uncertainty in the relative stock status, with the LB-SPR SPR estimates used to establish a range of relative stock status values. A beta distribution was used as it was in the previous OFL estimation, but the source of stock status year and prior are different. The previous method borrowed stocks status from Oregon in year 1997 (before the live fish fishery started in Oregon), whereas the current application uses length compositions from Washington to establish a value in 2019.
- Natural mortality a normal distribution and prior was established using the Natural Mortality Tool. The last application used the 2009 female value with a default value of 0.4.
- Growth parameters are fixed to the values estimated for Washington state.
- Maturity are assumed equal to values reported in the Cabezon sub-stock in Oregon waters (Cope and Key 2009; Table 2).
- Steepness is used instead of F_{MSY}/M and SB_{MSY}/SB_0, which are the productivity parameters as expressed in DBSRA. The steepness value is the one assumed for the other stock assessments. Steepness values used on the west coast are often more productive than the default F_{MSY}/M and SB_{MSY}/SB_0, values used last time (see Section 3.3.3 for more information).
- Selectivity is set asymptotic at the 18-inch (45.7 cm) minimum size limit and the length of 50% maturity is set to 43.7 cm in Washington.

3.5 Model Parameters

3.5.1 California

The list of parameters and their treatment in the NCS and SCS models can be found in the supplemental table found in the Cabezon_Supplementary_tables "Parameter_CA" tab. A total of 87 and 112 active parameters were estimated for the SCS and NCS models respectively, the majority being recruitment deviations.

Biological parameters were either estimated or fixed to be constant through time. The new natural mortality prior assumed a lognormal distribution and was used to estimate natural mortality in both California models for the first time (Figure 37). The variety of empirical estimators used to formulate the prior created a variety of possible natural mortality values. Those based on maximum age tended to be lower than those based on the von Bertalanffy parameters. Sensitivities to this uncertainty in using past fixed natural mortality, fixing to the Hamel prior (an example of a maximum age approach), and to using the average of the Von Bertalanffy based estimators was explored.

Von Bertalanffy parameters were estimated for the NCS model, then used as fixed parameters in the SCS model. All growth parameters were estimated in the NCS except length at age 0 for both males and females, which was fixed at 0 as attempts to estimate the value returned a value near 0, but with much added computational overhead. All parameters had uniform priors with wide bounds except male growth coefficient *k* which used a normal prior with mean and standard deviation set to the value from Grebel and Cailliet 2010. The remaining biological parameters of maturity, fecundity and weight length were fixed.

The stock-recruit relationship assumed the Beverton-Holt relationship, which requires the parameterization of steepness. Attempts were made to estimate steepness, but the estimated value (0.28) was very low, so the reference model again fixed steepness to 0.7, the same value that has been used in all Cabezon stock assessments. Model profiling was conducted over steepness to further gauge the level of information content and uncertainty in the models. Recruitment variability was also fixed in both models (0.7 for SCS and 0.5 for NCS).

Recruitment deviations were estimated in each California sub-stock model following the method of Methot and Taylor (2011) to determine years to estimate and the bias adjustment treatment. The NCS model estimated recruitments from 1962-2016, with the ramp from 0 in bias adjustment starting in 1964 and reaching its maximum value of 0.63 from years 1983-1998 (years of peak information), ramping again down to 0 in 2017 (Figure 47). The SCS model estimated recruitments from 1970-2016, with the ramp from 0 in bias adjustment starting in 1970 and reaching its maximum value of 0.45 from years 1977-2011, ramping again down to 0 in 2017 (Figure 47).

Variances in the CPFV CPUE indices of abundance from the index standardization process were between 10-20%, which is smaller than expected for recreationally-based fishery-dependent opportunistically sampled data. Extra variance was estimated for these indices in both models. The CCFRP had large variances resulting from the jackknifing routine. No additional variance was estimated for this index in the NCS model.

Selectivity was estimated in two forms for each of the California models: commercial dead and recreational boat assume logistic selectivity; commercial live, recreational shore and CCFRP (NCS only) were allowed to go dome-shaped. The estimated commercial live in both sub-stocks and the recreational shore fleet in the SCS do express a dome-shape. The NCS recreational shore-based and the CCFRP survey estimated an asymptotic selectivity curve. No length compositions were available for the commercial dead fleet in the SCS, so NCS estimated parameters were fixed in the SCS model. Blocks estimates maintained the same curve shapes, but moved to larger average sizes found in the data from 2004 onward.

3.5.2 Oregon

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 the attached e-file: Cabezon_Supplementary_tables "Parameter_OR" tab.

A total of 62 parameters were estimated in the reference model. Time-invariant growth parameters (Brody growth coefficient, length at maximum 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. Length at minimum age was fixed at 0.1 for females and males. Recruitment deviates were estimated in the reference model from 1980 – 2015 and the initial (equilibrium) recruitment was also estimated. Natural mortality was fixed to unique female and male values informed by the 2019 NCS model estimates.

The reference model assumed a stock-recruitment steepness of 0.7, which was the value used in the 2009 Cabezon assessment. 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.

Oregon maturity ogive (Figure 38) was externally estimated using samples obtained from the ports of Newport, Depoe Bay and Port Orford and input into the model as fixed values. Methods and details of the data collection and maturity determination are found in Hannah et al. 2009. Fecundity was assumed proportional to weight (Section 2.8.3) and fixed in the model. Cabezon length-weight relationships for Oregon were estimated outside of the assessment model using data from the Oregon Sport Boat Survey (ORBS) biological database (recreational) and PacFIN (commercial). The weight-length parameters were gender invariant because of limited gender-specific data and fixed in the reference model.

Selectivity was assumed to be asymptotic and related to length by a logistic function for the recreational ocean boat fleet and the commercial landed-dead fleet, and dome-shaped for the commercial landed-live fleet and recreational shore fleet. Selectivity for the special projects research surveys assumed that all small Cabezon 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 major reductions in bag (recreational ocean boat fleet) and trip limits (commercial landed-live fleet) for

Cabezon in 2004. Despite having the flexibility to be domed shape, selectivity during the time block (post-2004) for the commercial landed-live-fishery was estimated as asymptotic. This change matches reports from port biologists and fishermen that large (greater than the traditionally desired plate-sized fish) still fetch a lucrative price per pound at market and thus are being landed by fishermen. Sensitivity to the addition of a third time block (2015) for the commercial live-fish fleet was explored, but not adapted, during the STAR panel.

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. The error level for the Oregon ORBS index was exceedingly low (CV<5% on the log scale) so an extra standard deviation parameter was estimated for that index only (Table 13). An extra standard deviation parameter was explored for the MRFSS index (also low index CV), but was estimated to be on the lower bound (i.e., no extra variance added when fitting the model) and thus was removed. Instead, the MRFSS index CV was artificially increased to a level consistent with the other Oregon recreational indices as a result of discussions during the STAR panel.

Several of the parameterization decisions were further examined through sensitivity analysis (see Section 3.9.2 and the attached e-file: Cabezon_Supplementary_tables "Sensitivities" tabs).

3.6 Reference Model Selection and Evaluation

3.6.1 California

3.6.1.1 Key Assumptions and Structure Choices

The structure of the reference models attempt to balance model realism and parsimony, including parameter behavior and data load (i.e., removal of old data no longer informative). An extensive model exploration phase was conducting that included evaluation of a large number of model formulations. Structural choices were generally made to be as objective as possible while building off the results of prior Cabezon stock assessments, and follow generally accepted methods of approaching similar modeling problems and data issues. Recording all relative effects of every model exploration is impractical and not a direct path to a reference model. Despite this challenge, extensive efforts were made to evaluate the effects of structural choices on model output prior to selecting the reference model.

No new evidence of stock structure was available, so the same spatial treatment as the previous stock assessment was used. There was no exploration of a single model, multiple areas approach as the recruitment patterns have proven very different among areas. A two-sex model was also maintained as growth and other biological parameters are distinct between females and males.

The fleet structure was revisited and a simplified approach to the recreational fishery-- combining the two shore-based fisheries into one fleet and combining the two boat-based fleets into one fleet-- was taken. Overall length compositions were similar in the combined fleets, justifying this simplification (Figure 48). The adjusted fleet structure also lead to less parameter estimation and combining of low samples to mitigate data noise. This structure also matches that done in the Oregon model.

Most parameters were constant through time, though two fisheries (the commercial live-fish and the recreational boat fleets) were allowed to vary in time blocks. These time blocks match management changes and changes in mean lengths, and are similar to the previous assessment with slight adjustments.

The choice of fixing or estimating parameters came down to data availability and model capacity to estimate parameters (Cabezon_Supplementary_tables "Parameters_CA" tab). Parameter estimates near bounds necessitated fixing in order to improve model estimation behavior. This occurred with the length at age 0 for males and females, as well as the extra variance parameter for the CCFRP survey. Natural mortality was estimated for the first time and for both California models. Length-weight, maturity and fecundity were all fixed as is customary is Stock Synthesis models. An attempt to estimate steepness was rejected as values were below those likely evolutionarily viable (He et al. 2006). Recruitment variability were retained from the past stock assessment (0.7 for SCS and 0.5 for NCS). These values were confirmed to be consistent with the residual error in recruitment deviations in the reference models. Recruitment deviations were estimated for a selected amount of years and bias adjustment was applied in a ramping fashion after the method of Methot and Taylor (2011), the accepted approach in Stock Synthesis.

Selectivity was assumed length-based for all fleets, asymptotic for the commercial dead and recreational shore and boat fleets and the, and allowed to be dome-shaped for the commercial landed-live fishery. Females and males assumed the same length-based selectivity curve.

3.6.1.2 Evaluation of Model Parameters

Model parameters were evaluated for information content, stability, and precision, along likelihood profile gradients (Section 3.9.1.3), and against the main assumptions in each sub-stock reference model (Section 3.8.1). Stability was examined by ensuring that model parameters were not up against a lower or upper bound (see supplementary e-file: Cabezon_Supplementary_tables "Parameters_CA" tab). Parameter precision was also monitored by looking at estimated standard deviations to assess the variability associated with point estimates. Overall parameter values are not inconsistent with values from past Cabezon stock assessments. Additional exploration using likelihood profiles was used to evaluate reference model uncertainty in natural mortality, steepness and initial recruitment size (Section 3.9.1.3).

3.6.1.3 Residual Analysis

Residuals to surveys, length composition and age composition fits to the model were explored at each step of model development. The reference SCS and NCS models produced reasonable fits, in general, to all data sets. Survey fits are found in Figure 49 (SCS), Figure 56 and Figure 57 (NCS). The CPFV survey fit improved over the previous assessment; the NCS model showed a similar fit to the last assessment. The extra variance estimates are large for these surveys, and model fits are missing many of the dynamic portions of the time series, but the general trend is captured. The fit to the CCFRP survey (Figure 56) is also in line with the trend of the series. This data set had a large variance inherent to the CPUE standardization and similar to the level that was estimated as the total variance (input + extra variance estimate) of the CPFV series (Cabezon_Supplementary_table "Parameters_CA" tab).

Fits to length composition data were acceptable in both models (Figure 50 and Figure 58), with exceptional fits to all length data sources in the NCS model. The quality of the fits in the SCS were not as good as the NCS model due to limited sample sizes. Within year fits for the SCS (Figure 51-Figure 53) and NCS (Figure 59-Figure 63) models demonstrate variable quality due to low sample sizes . In general, the commercial live and recreational boat fleets demonstrated the best fits. There were no major patterns in residuals among fleets in either models (SCS: Figure 54; NCS: Figure 64). The presence of large residuals was again an artifact of low sample size in a bin, not of a major mis-fitting of the composition data. The selectivity blocking helped with the fit to the composition data. Patterns in mean length were also successfully fit in all fleets in both models (SCS: Figure 55; NCS: Figure 65) and provided the justification for data weighting (Francis 2011).

The only set of conditional age-at-length data was in the NCS model. Fits to the conditional ages were reasonably for most years (Figure 67). Residuals were small with no strong patterns (Figure 68). Mean ages were well fit and balanced in the model, with no notable runs in residuals (Figure 69).

3.6.1.4. Convergence

Model convergence was checked for all models during development of a reference model by ensuring that the final gradient of the likelihood surface was less than 0.001 and produced asymptotic standard deviations (i.e, the Hessian matrix would invert). All estimated parameter values were also checked to ensure they were not hitting a minimum or maximum bound. The ability for the reference model to recover the same likelihood estimates when initialized from dispersed starting points (i.e, the jitter option in SS) was performed using 100 'jittered' starting values (Methot 2009). Jitter magnitudes of 0.05 and 0.1 were explored. This perturbs the initial values used for minimization with the intention of causing the search to traverse a broader region of the likelihood surface. Summarized results for "jitter" runs are presented for the SCS model (Figure 90) and for the NCS model (Figure 91). Jittering at either value did not find a lower likelihood for either of the substock models. The SCS model jittered at 0.1 and 0.05, respectively, returned the reference model 3% and 2% of the time, with 42% and 48% of the models returning a statistically non-significantly different model (i.e., < 2 log likelihood units). These statistical similar alternative models produced very similar model outputs as the reference model. The remaining 55% and 50% of the models returned significantly different likelihoods. The NCS model jittered at 0.1 and 0.05 returned the reference model 23% and 20% of the time, respectively, with 36% and 43% of the models returning a statistically non-significantly different model (i.e., < 2 log likelihood units). These statistically similar alternative models also produced very similar model outputs as the reference model. The remaining models (41% and 37%) often returned unconverged and/or significantly different likelihoods. The range of the search and resultant likelihoods indicate that the jitter was sufficient to search a large portion of the likelihood surface, increasing the chance that the reference model is in a global minimum.

3.6.2 Oregon

3.6.2.1 Key Assumptions and Structure Choices

Many of the key assumptions and structural choices made in the Oregon sub-stock assessment were evaluated through sensitivity analysis (Section 3.9.2). 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 Cabezon and differences in natural mortality. Data inputs available for this assessment arise from fisheries that predominantly occur in the nearshore zone (< 30 fathoms).

Major assumptions included fixing the steepness stock recruitment parameter and the variability parameter associated with recruitment deviations (σ_r), fixing gender-specific natural mortality parameters, and estimating gender invariant selectivity parameters (see efile: Cabezon_Supplementary_tables "Parameters_ORS" tab). Female and male natural mortality were fixed in the reference model to values informed by the 2019 NCS model estimates (0.24 and 0.28, respectively). Other values were explored including fixing it to the median of the prior predictive distribution following methods of Hamel (2015) and based on a maximum age of 17 for both females and males. The median of the calculated prior distribution was 0.314 for females and males (male log offset = 0), which is slightly higher than values estimated for the northern California sub-stock (0.27 for females and 0.23 for males) and within the range of values estimated for the southern California sub-stock (0.35 and 0.25, respectively). Population-level maximum age was determined from the maximum observed aged fish. This was considered a reasonable estimate of maximum age for this exploration, balancing the relatively high level of age determination uncertainty associated with reading otoliths of older individual (ageing error; Table 30), the fact that ages were sampled during a relatively high catch period (1999-2018; Figure 2), and reports of mostly smaller maximum ages for Cabezon in the literature and from various media sources.

Selectivity was assumed to be asymptotic following a logistic function for the commercial landed-dead and recreational ocean-boat fleets, and was assumed to be dome-shaped for the commercial landed-live and recreational shore fleets. Male and female selectivity curves were assumed to be equivalent in the reference model. Exploratory model runs were conducted that included differences in selectivity by gender. There was insufficient information in the data to produce reasonable estimates for gender-specific selectivity. A time block was used to capture changes in selectivity as a result of the implementation of a bag limits (recreational ocean fleet) and trip limits (commercial landed-live fleet) in 2004, which influenced the size of fish landed in the observed data. Although the time block (2004-2018) associated with the commercial landed-live fleet was also allowed to be dome-shaped, the model reverted to estimates indicating an asymptotic selectivity curve. The reconstruction of the historical catch time series for the shore fleet , the ocean-boat fleet, and the commercial landed-dead fleet were based on particular assumptions including: catch proportional to Oregon fishing license sales, linear ramp of catch, catch interpolated using recent average catch, and discards as a constant proportion of landings (see Sections 2.1.2 and 2.4.2).

3.6.2.2 Evaluation of Model Parameters

Model parameters were evaluated for stability, precision, along likelihood profile gradients (section 3.9.2.3), and against the main assumptions in the Oregon reference model (section 3.6.2.1). Stability was examined by ensuring that model parameters were not up against a lower or upper bound (see supplementary e-file: Cabezon_Supplementary_tables "Parameters_ORS" tab), and that the addition or removal of parameters associated with dome-shaped versus asymptotic selectivity improved model fit. During model development, the commercial landed-live fleet during the second time block (2004-2018) was changed from being dome-shaped to asymptotic, because the estimation of domed-shape parameters went to values consistent with asymptotic selectivity. 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. The treatment of natural mortality and recruitment was also refined during model development, with alternatives explored during sensitivity runs (see section 3.9.2). There was little information in the data to accurately estimate natural mortality, and thus it was fixed in the Oregon reference model. Further, the length at minimum age (L_{min}) was fixed at 0.1, a value consistent with external estimates of growth (t_0 in Rasmuson et al. 2019), assumed lengths when L_{min} is specified for fish at age-0 (as in the reference model), and informed by model runs where L_{min} for females was estimated but males fixed (due to parameter boundary issues).

3.6.2.3 Residual Analysis

Residuals to length composition and age composition fits to the model were explored throughout model development. The identification of residual patterns helped to determine which set of *a priori* time-varying selectivity blocks were the most appropriate given the data. Several alternative model configurations were also explored during model development in an attempt to minimize residual trends (e.g., reducing the maximum population length bin from 92 cm to 70 cm).

The base model produced reasonable fits, in general, to length and age composition data, and in particular to data sources with large sample sizes. Across all years, the fit to length composition information was best for the recreational ocean boat fleet and the commercial landed-live fleet (Figure 71), which is not surprising because a large proportion of the composition data comes from these two fleets (Table 14). In general, annual fits to length composition information were adequate, with the average observed distribution matching well the predicted distributions (Figure 72, Figure 73, Figure 74, Figure 75). The main exceptions were the fit of the largest male Cabezon observed in the commercial live-fishery relative to females and smaller males (Figure 72), and the largest and smallest individuals (unsexed) in the recreational shore (and estuary) fishery which did not fit as well as those with intermediate lengths (Figure 75) or with larger sample sizes (very small sample post-2004; Table 14). Evaluations of alternative/additional time blocks during the STAR panel to improve residual patterns did not result in a more parsimonious model according to model selection criteria (e.g., AIC). Mean length for all the fleets followed the main trends through time (Figure 76 - Figure 79), but the model essentially had a smoothing effect in some cases because of small sample sizes and, for the case of the recreational ocean boat fleet, resulted in residual patterns for parts of the second half of the time series (2001-2018; Figure 74, Figure 78). The recreational shore fleet had small composition sample sizes, which resulted in lack of fit in some years (2003-2017; Figure 79).

Age compositions that resulted from fitting conditional age-at-length data matched reasonably well with the observed age compositions from the recreational ocean boat fleet (Figure 82) but the fits were not as good for the commercial dead fleet, presumably because of the lower number samples (Table 15). Generally, model fits to the research-based age compositions were as expected given the truncated range of ages sampled (Figure 83). Fits to the recreational ocean boat landings conditional age composition data shows generally good agreement between observed and expected ages at length, with some exceptions when sample sizes were relatively low (e.g. 2007, 2010, 2012; Figure 85). Fits to commercial dead fleet conditional age composition data were also reasonable, especially given the relatively low sample numbers in some years (Figure 84).

The model was able to track mean age for the ocean-boat fleet well, capturing the overall trend and also abrupt annual changes (Figure 87). Generally, mean age was underestimated (relative to the distribution median) in earlier years, whereas the mean age was overestimated in later years but always fell within the range of uncertainty around the observed mean. Mean age for the commercial dead fleet also tracked reasonably well during years with adequate sample sizes (2008 onwards; Figure 86). Overall, there was no clear pathological pattern in the residuals for the recreational ocean boat conditional age-at-length fits (Figure 89), nor for the commercial conditional age-at-length fits (Figure 88), however for both data sets, the somewhat larger positive residuals appear in the midrange of the age distributions for both males and females across all years. No extreme residuals were observed in the conditional age-at-length fits.

3.6.2.4 Convergence

Model convergence was checked for all models during development of a reference 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 (0.05 and 0.1) starting values. A total of 100 jittered runs were performed for each model and level of jittering. Across all jittered runs, the lowest likelihoods of each respective model matched the reference model likelihood (Figure 92). Additionally, no potential jittering issues (e.g., hitting bounds) were detected using the jitter diagnostic output reported in the r4ss (R package) jitter info table.

3.7 Response to STAR Panel Recommendations

The STAR panel provided an extensive review of all models and analyses, with discussion leading to some changes for the California and Oregon substock reference models brought to the STAR panel. The changes are outlined below. Further details can be found in the 2019 Cabezon STAR panel report; https://www.pcouncil.org/groundfish/stock-assessments/by-species/cabezon/.

3.7.1 California

Prior to the STAR Panel, but after the models were submitted to the STAR review, the STAT team identified the need to confront misreporting in the spatial allocation of recreational catches (see Section 2.4.1 for details).The STAR panel agreed with the STAT team that this new recreational time series in California should be the reference model recreational time series for both California substocks. The STAT team also noticed unstable model estimation in model exploration with unreasonably low natural mortality values under some explorations. A normal prior on natural mortality had originally been used, but it was agreed that a lognormal prior (commonly used for natural mortality) should be used. There were additional minor changes to the substock specific models.

- SCS: Shore-based fishery selectivity assumed logistic (extra parameters still estimated logistic selectivity, thus number of estimated parameters simply reduced) and years with effective sample sizes <5 were removed.
- NCS: estimate VBGF parameter k with an uninformed prior.

3.7.2 Oregon

Prior to the STAR Panel, but after the models were submitted to the STAR review, the STAT team identified double counting of recreational ocean boat discards from 2001-2018. The STAT presented corrected model runs during the STAR panel, and the panel agreed that the Oregon reference model should include the corrected total catch (landed plus discarded) time series for this fleet. The STAT team continued to have difficulty during the STAR panel estimating natural mortality. Data conflicts in the composition data resulted in unreasonably high estimates of natural mortality that were deemed by the STAT and the STAR as not reliable. Therefore, natural mortality was fixed using information from the NCS model (see Section 3.4.2 for details). There were additional minor changes to the Oregon reference model including dropping an interaction term from the model-based ORBS fishery-dependent index of abundance,and fixing the CV for the MRFSS model-based fishery-dependent index of abundance to a more reasonable (higher) value informed by the other Oregon recreational index CVs.

3.8 Reference Model Results

3.8.1 California

SCS

Parameter estimates for the SCS model can be found in the Cabezon_Supplementary_tables "Parameters_CA" tab. Estimated natural mortality values are in line with the prior information (i.e., not pushing to lower or upper prior distributions) and the fixed values used in past assessments, though the natural mortality for males is higher than the 2009 model (0.48 in current model vs 0.3 in 2009).

Recruitment estimates (Figure 94 and Figure 95) demonstrate strong recruitment events in the 1980s, late 1990s and early 2000s. The more recent period informed by the new data show a decade of mostly negative recruitment. Uncertainty in the recruitment deviations is fairly constant across the estimated recruitment period (Figure 94). Recruitment is informed mostly by length composition data, but removal history also influences the estimates. The stock recruit relationship demonstrates the largest variability at lower stock sizes (Figure 96). Despite this contrast, the model is not able to estimate steepness (see Section 3.9.1.3).

Selectivity curves were estimated for three of four fleets (Figure 97), whereas survey abundance index selectivity was mirrored to the recreational boat fleet. The fixed parameters of the commercial dead fleet and the estimated parameters of the recreational shore and boat fleet were asymptotic curves. Dome-shaped selectivity was estimated for the commercial live fleet. A time block on selectivity to adjust for management measures indicated a shift in the length at peak selectivity for the commercial live-fish and recreational boat fleets (Figure 98), Estimated selectivities are consistent with the technical interaction expected in each of the fisheries.

SCS Cabezon initial spawning output was estimated to be 205 mt (95% asymptotic intervals: 161-248 mt) and 101 (95% asymptotic intervals: 19-183 mt) in 2019, leading to an estimate of current relative stock status of 49% (95% asymptotic intervals: 11-87%) in 2019 (see e-file: Cabezon_Supplementary_tables "Derived output time series SCS" tab for the entire time series). Spawning biomass showed precipitous decline in the 1980s to around overfished levels, building back near target levels in the 1990s, with another increase since the mid-2000s (Figure 99). Mean ages tend to be a couple of years beyond the age at maturity and have stayed mostly steady for the time series, though strong recruitments produced strong signals in mean age (Figure 100). Population increases are mostly do to large recruitments, though catches and subsequent fishing intensity (Figure 101) and mortality (Figure 102) have decreased in recent years. Two periods of peak fishing intensity did notably surpass the proxy level suggesting possible overfishing occurred during intense recreational take in the 1980s and the strong development of the live-fish fishery in the late 1990/early 2000s (Figure 101; Figure 103). The equilibrium curve is shifted left (Figure 104), as expected from the moderately high fixed steepness, showing a slightly more productive stock than the $SPR_{45\%}$ reference point would suggest ($SPR_{45\%}$; Table 38).

NCS

Parameter estimates for the NCS model can be found in the Cabezon_Supplementary_tables "Parameters_CA" tab. Estimated natural mortality values are in line with the prior information (i.e., not pushing to lower or upper prior distributions) and the fixed values used in past assessments. Natural mortality for females and males are slightly lower than the 2009 model (0.24 and 0.28 in current model vs 0.25 and 0.3 in 2009 for females and males respectively).

Recruitment estimates in the NCS reference model (Figure 105 and Figure 106) show a distinct recruitment series compared to the SCS model, with less overall dynamics. Yearly deviates tended to alternate between positive and negative values instead of runs of positive and negative periods. Uncertainty in the recruitment deviations is fairly constant across the estimated recruitment period (Figure 105). Recruitment is informed mostly by length composition data, but removal history also influences the estimates. The stock recruit relationship also shows similar variability across stock sizes (Figure 107). The NCS model was also unable to estimate steepness (see Section 3.9.1.3).

Selectivity curves were estimated for the four fleets and the CCFRP survey (Figure 108); the CPFV abundance index selectivity was mirrored to the recreational boat fleet. The commercial dead fleet and the recreational boat fleet were estimated asymptotic curves. Dome-shaped selectivity was estimated for the commercial live fleet and the recreational shore fleet. A time block on selectivity to adjust for management measures did not cause a shift in selectivity as seen in the SCS model. The commercial live-fishery showed a less dome-shaped relationship than the first time block while the recreational boat fleet changed very little (Figure 109), Estimated selectivities are consistent with the technical interaction expected in each of the fisheries.

NCS Cabezon initial spawning output was estimated at 986 mt (95% asymptotic intervals: 748–1,225 mt) and 643 (95% asymptotic intervals: 159–1,126 mt) in 2019, leading to an estimate of current relative stock status of 65% (95% asymptotic intervals: 22-108%) in 2019 (see e-file: Cabezon_Supplementary_tables "Derived output time series NCS" tab for the entire time series). Spawning biomass showed steady decline to around the early 2000s at levels nearing overfished. From the mid-2000s a strong incline has brought the population back well above the target (Figure 110). Uncertainty in these most recent years are extremely high. Mean ages tend to be a couple of years beyond the age at maturity and have stayed mostly steady for the time series (Figure 111). Recent population increases are influenced by positive recruitment deviations, but also from lower levels of catches and decreasing fishing intensity (Figure 112) and mortality (Figure 113). Peak fishing intensity did surpass the proxy level suggesting possible overfishing occurred during the late 1990s with the strong development of the live-fish fishery (Figure 112; Figure 114). The equilibrium curve is shifted left (Figure 115), as expected from the moderately high fixed steepness, showing a slightly more productive stock than the $SPR_{45\%}$ reference point would suggest ($SPR_{45\%}$; Table 39).

3.8.2 Oregon

The Oregon sub-stock reference model estimated reasonable growth parameters (*k*, length at maximum age, and *CV* young/old) for ages-0 and older fish. Male parameters were an offset of female parameters, with the exception that the length at minimum age for males and females were fixed at the same value (as discussed in Section 3.6.2.2). Growth was estimated beginning at age-0, because there was information in the conditional age-at-length data from the research collections. Asymptotic length (L_{inf}) was estimated to be 64.4 cm for females and 57.4 cm (offset = -0.12) for males (Figure 116; see e-file: Cabezon_Supplementary_tables "Parameters_OR" tab for table).

The fit to the relative abundance indices was reasonable, given index uncertainty and fishery-dependent data, for the commercial logbook index (Figure 9), recreational onboard observer index (Figure 32), and the MRFSS dockside index (Figure 20). The ORBS dockside index also fit moderately well with the addition of an extra variance parameter (Figure 27). Additional variance (standard deviation) was only estimated for the ORBS index (0.02). From 2011 to 2014, the fit to these indices showed a downward trend in abundance, followed by a considerable increase, though variable among indices, in recent years (Figure 34).

The base model produced reasonable fits in general to length and age composition data, and in particular to data sources with large sample sizes (see Section 3.6.2.3). Length composition fits are good for the recreational ocean-boat fleet and the commercial landed-live fleet, which combined represent the bulk of the data and Cabezon catch since the early 2000s. The fits were not as good for the largest male Cabezon observed in the commercial live-fishery relative to females and smaller males. Fits to the weighted conditional age-at-length compositions show generally good agreement between observed and expected values, though fits were not as good for the commercial dead fleet during periods of low sample size (see Section 3.6.2.3).

Selectivity curves were estimated for all four fleets (Figure 117, Figure 118), whereas survey abundance index selectivity was mirrored to the relevant fleet. An asymptotic curve following the logistic function was used for the recreational ocean boat fleet and the commercial landed dead fleet. Dome-shaped selectivity was estimated for the commercial landed-live fleet and the recreational shore fleet. A time block on selectivity to adjust for the large decrease in bag (recreational) and size (recreational and commercial) limits in 2004 indicated a slight shift in the length at peak selectivity for the commercial live and ocean boat fleets (Figure 119 and Figure 120, respectively), as well as a pattern switch to asymptotic selectivity (from dome-shaped) for the commercial live 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.

Cabezon spawning output was estimated to be 177 mt in 2019 (~95% asymptotic intervals:128-226 mt), which when compared to unfished spawning output equates to a depletion level of 53% (~95% asymptotic intervals: 43-63%) in 2019 (see e-file: Cabezon_Supplementary_tables "Derived output time series ORS" tab for the entire time series). Depletion is a ratio of the estimated spawning output in a particular year relative to estimated unfished, equilibrium spawning output. In general, spawning output had been trending downwards until the early 2000s, after which it became more stable throughout the rest of the time series with a slight increase from 2017 through 2019 due to an above average recruitment estimate for the 2014 year class (Figure 121). Stock size is estimated to be at the lowest level throughout the historic time series in 2014, but has since risen and estimated to be well above the management target of $SB_{40\%}$ (Figure 122).

A recent, above average, recruitment in 2014 contributed to the recent increase in Cabezon biomass in Oregon (Figure 123). This recruitment is informed by composition data, two relative abundance indices, and corresponds to reports from fishermen and port biologists of a recent increase in Cabezon, and is apparent in the predicted numbers-at-age (Figure 125). Other years with relatively high estimates of recruitment were 1999, 2000, and 2002. The 2009 stock assessment also suggested that 1999 was an above average year class. The Cabezon sub-stock in Oregon has not been depleted to levels that would provide considerable information on how recruitment changes with spawning output at low spawning output levels (i.e., inform the steepness parameter; Figure 124).

Harvest rates in Oregon have generally increased through time until reaching a more stable (but still variable from year to year) level beginning in the 2000s. The maximum relative harvest rate was 1.16 in 2001 (or 116% of the target level) before declining again to around 0.80 in recent years (Figure 126; see e-file: Cabezon_Supplementary_tables "Derived output time series ORS" tab for the entire time series). Summary fishing mortality (harvest) rates have been around 0.10 in recent years (Figure 127). Fishing intensity is estimated to have been below the target throughout most of the time series [(1-SPR) / (1-$SPR_{45\%}$) < 1, except from 2000-2002]. In 2018, Oregon Cabezon biomass is estimated to have been 1.32 times higher than the target biomass level, and fishing intensity remains lower than the SPR fishing intensity target (Figure 128). The equilibrium curve is shifted left (Figure 129), as expected from the moderately high fixed steepness, showing a slightly more productive stock than the $SPR_{45\%}$ reference point would suggest ($SPR_{45\%}$; Table 40).

3.9 Evaluation of Uncertainty

3.9.1 California

3.9.1.1 Sensitivity to Assumptions

Several model specification assumptions were explored for each of the California models. Below is a list of model specification sensitivities scenarios and justification. Each is for both California models unless otherwise stated.

Natural mortality (*M*) scenarios are meant to highlight possible alternative treatments of *M*.
- Fix to 2009 model
- Fix to the NMT prior
- Fix to the Hamel value
- Fix to the average value from thee VBGF-based *M* estimators
- Fix to the Oregon estimated value
- Use a normal instead of lognormal prior

Growth and maturity
- Fix to 2009 VBGF parameter values (a sensitivity to parameter values found previously)
- Fix to the Grebel and Cailliet (2010) VBGF values (these are potential values if it is not believed the model can estimated growth)
- Fix to Oregon maturity (maturity is at a larger size than estimated in California)

Spawner-recruit relationship and recruitment scenarios
- Estimate steepness (evaluate information contained in the model)
- Estimate all recruitment deviations (this has been done in other assessments)
- No recruitment deviations estimated (a hypothesis used when it is believed the model contains no real information to estimate recruitments)
- Use the highest estimated bias adjustment (an alternative to the ramping approach)

Data-weighting scenarios
- Use the harmonic mean approach
- Use the Dirichlet estimation
- Assume all data have a weight = 1

Selectivity block scenarios

- No blocks
- Start block in 2000

Alternative recreational catch scenario

- Use MRFSS catch allocation to SCS and NCS from 2009 model.

Results for these scenarios compared to the reference model for the SCS model are presented in Figure 130 and the Cabezon_Supplementary_tables "Sensitivities_ModSpecs_SCS" tab; results for the NCS model are found in Figure 131 and the Cabezon_Supplementary_tables "Sensitivities_ModSpecs_NCS" tab.

SCS

The SCS model was robust to most explored scenarios (Figure 130).

NCS

The NCS model showed more sensitivity than the SCS model (Figure 131; Cabezon_Supplementary_tables "Sensitivities_ModSpecs_NCS" tab). The most notable sensitivity results was estimating steepness, which caused much higher estimates of initial spawning biomass and very low relative spawning biomass (below the limit), though the model showed no ability to estimate steepness. Strangely, the model was not robust, as it was in the SCS model to using the high value of length at maturity used in Oregon. for In general, the natural mortality and VBGF scenarios all lead to larger spawning biomass and yield, and higher relative spawning biomass and sustainable fishing rates.

3.9.1.2 Sensitivity to Data and Weighting

Likelihood component sensitivity scenarios were conducted by removing each data contribution in turn, then removing the full likelihood component to capture data contribution to the reference model. Likelihood component sensitivity results for the SCS model are presented in (Figure 132) and Cabezon_Supplementary_tables "Sensitivities_Like Comps_SCS" tab; results for the NCS model are presented in (Figure 133) and Cabezon_Supplementary_tables "Sensitivities_Like Comps_NCS" tab.

SCS

The SCS model showed little sensitivity to the exclusion of the CPFV survey data, commercial live length composition, or the recreational shore compositions. Exclusion of the recreational boat data did produce significant sensitivities to the measure of spawning biomass by increasing the absolute scale of biomass as well as increasing relative spawning biomass (Figure 132). The productivity of the stock was also significantly higher. Removing all length composition unsurprisingly destabilized the model even more, leading to significantly lower values of spawning biomass and relative spawning biomass. Data weighting choices also mattered little. Only when assuming all data sets are equally weighted did the model estimate current biomass extremely low and near the uncertainty bound, thus causing current stock status to also be very low (Figure 130; Cabezon_Supplementary_tables "Sensitivities_ModSpecs_SCS" tab).

NCS

The NCS model had more data sources and demonstrated more sensitivity to likelihood component exclusions (Figure 133; Cabezon_Supplementary_tables "Sensitivities_Like Comps_NCS" tab). Exclusion of the indices made little difference. The model was also robust to the removal of individual length compositions, though removal of all length compositions caused the current biomass to crash. This played through the model in the form of very different selectivity, natural mortality and growth parameter estimates. The removal of the age data causes significantly lower estimates of spawning biomass and an increase in productivity. The lack of age data cause differences in estimates of the growth parameters for females (Cabezon_Supplementary_tables "Sensitivities_Like Comps_NCS" tab). Using the harmonic mean weighting approach made no difference, but the Dirichlet dropped biomass estimates and raised the stock status to almost unfished level. Inspection of this model indicated very high female natural mortality estimates.

3.9.1.3 Parameter Uncertainty

Likelihood profile was explored for natural mortality, steepness, and log initial recruitment, $\ln(R_0)$, for both California models. The natural mortality profile looked across female values with the male natural mortality being estimated.

SCS

The SCS model demonstrated an informed estimate of natural mortality for values of M between 0.2 and 0.35 for females (Figure 134). This corresponded to a relative spawning biomass at the low end of around the target biomass reference point of 25% and a high value of just under 80%. Estimated male mortality maintains a distinct higher offset for all profiled M values. Likelihood component contributions to the profile indicate length composition and recruitment and prior penalties provide the most information to the M estimation, all supporting a similar profile (Figure 135). The recreational fisheries provided the most information for the length compositions, with the boat fleet compositions support higher M values (Figure 136).

The steepness profile for the SCS model clearly indicates the data and model specification cannot inform steepness, but derived quantities are sensitive to the steepness value (Figure 137). Likelihood components do not agree on what uninformed value is most likely (compare indices and recruitment penalties in Figure 138). The commercial and recreational length data also oppose each other in which end of the steepness bound to support (Figure 139). Steepness is also clearly a key parameter in determining the scale and relative status of the population, though it would take a fairly low steepness (<0.5) to drop the population below the target reference point ($SB_{40\%}$), and an extremely low steepness (<0.4) to have it go below the limit reference point ($SB_{25\%}$).

The initial recruitment profile (lnR_0) was highly (Figure 140) and consistently (Figure 141) informed. This behavior is likely help by the fixed growth parameters. The range of well-informed $\ln R_0$ values estimated relative spawning biomass values near the limit biomass reference point up to near 80% unfinished spawning biomass. Estimates of current spawning biomass tended to rise faster than initial spawning biomass (Figure 140). The commercial and recreational length composition components give different signals of support for lnR_0 values (Figure 142).

The variability in the spawning stock biomass in 2019 from the SCS reference model is *CV* = 0.416 and uncertainty in the OFL_{2019} = 0.459. This level of uncertainty suggests the default category 1 sigma of 0.5 for calculating ABC buffers regardless of which metric is used. However, uncertainty is greatly underestimated in the reference model due to fixing some model parameters, selecting a single reference model for inference, and misspecifying or unknown population dynamics (lower than otherwise expected parameter uncertainty, model uncertainty and process errors, respectively).

NCS

The NCS model demonstrated more uncertainty than the SCS model in the estimate of natural mortality. Significantly similar values of *M* where between 0.18 and 0.33 for females (Figure 143). This corresponds to a relative spawning biomass at the low end of ~30% and a high value > 80%. At the highest profiled *M* values, the female values switch to be higher than males. The prior and recruitment penalties contain the most information on *M*, whereas the survey and length data minimize drives *M* to the lower bound, demonstrating no real information (Figure 144). The CPFV survey and all length compositions fleets except the recreational shore fleet are consistent in supporting the lower bound of *M* (Figure 145).

The steepness profile for the NCS model shows the data and model specification only weakly inform steepness (Figure 146). The lowest likelihood value supports a very low steepness value (0.28), but significantly similar value extend to *h* = 0.6. It takes a steepness value of <0.64 to drop the population below the limit reference point. This stark drop is current biomass is not explained by significant changes in natural mortality. Index data have the strongest contrast in likelihood values, but is still weak (Figure 147). Within the fleet length composition, commercial live fishery likelihood opposes the other fleets, but to a very small degree (Figure 148).

The initial recruitment ($\ln R_0$) profile was also weakly informed, with statistically similar relative stock status values ranging from <20% to ~90% (Figure 149). Recruitment and prior penalties showed the strongest pull away from lower $\ln R_0$ values (Figure 150). The recreational boat length composition data contained the most information on $\ln R_0$ compared to the other data sources (Figure 151).

The variability in the spawning stock biomass in 2019 from the NCS reference model is *CV* = 0.384 and uncertainty in the OFL_{2021} = 0.519. This level of uncertainty suggests a category 1 sigma of 0.5 for calculating ABC buffers if using spawning biomass, and possibly slightly higher if basing it on OFL. Acknowledged again is uncertainty is greatly underestimated in the reference model due to fixing some model parameters, selecting a single reference model for inference, and misspecifying or unknown population dynamics (lower than otherwise expected parameter uncertainty, model uncertainty and process errors, respectively).

3.9.1.4 Retrospective Analysis

Retrospective scenarios for both California sub-stock models considered removing the following years of data: 1, 2, 3, 4, 5 and 10.

SCS

There was no severe retrospective pattern in the SCS model (Figure 152). Absolute and relative spawning biomass showed small changes in the time series when data are removed, but no directional pattern. Recruitment dynamics are similar in the retrospective scenarios (Figure 153). Fishing intensity (Figure 154) was weakly affected, but initial recruitment estimation did show differences (Figure 155). Overall, these scenarios demonstrate the new data did not mark a drastic change in the stock assessment model, but did give more resolution to current dynamics.

NCS

There was no severe retrospective pattern in the NCS model (Figure 156). Despite such large uncertainty in the NCS model, the average spawning biomass and relative spawning biomass values were very consistent over the data removal scenarios. Recruitment dynamics were largely consistent across scenarios (Figure 157). Fishing intensity (Figure 158) and initial recruitment estimation (Figure 159) were also strongly consistent. These scenarios demonstrate the new data did not mark a drastic change in the stock assessment model, but gave a better notion of current dynamics.

3.9.1.5 Historical Analysis

The two California sub-stock models showed notable differences from their 2009 counterparts.

SCS

The SCS models (reference or minus 10 years of data) demonstrated large differences from the 2009 assessment (Figure 160). Divergence began with the onset of the recruitment estimates in the 1970s (Figure 161). The large recruitment in the early 1970s are tied to the large catches that have subsequently been realloacted to the NCS model. The current treatment of the recruitment estimates using the ramping approach is much different than before, and likely another contributor to the differences in recruitment patterns. The 2009 model dynamics are so highly variable, they reside outside the uncertainty bounds of the current reference model.

NCS

The NCS model demonstrated more similarities in the spawning biomass measures among the historical comparisons (Figure 162). The biggest difference again comes in the bump in biomass in the late 1970s in the 2009 model. Overall the previous model shows less of a decline in biomass. Recruitment differences are notable and likely a prominent contributor to the spawning biomass differences (Figure 163). The treatment of the start of the recruitment estimation stands out as a major difference, as does the treatment of bias correction in the models. The 2009 model shows highest absolute recruitments, though recruitment deviations for the previous assessment tend to be more extreme (both positive and negative deviations) than the current models. Despite these interesting differences, the 2009 model trajectories are captured within the uncertainty of the new reference model.

3.9.1.6 Alternate Models

Many data treatments and model specifications were explored for the California sub-stock models. In general, model sensitivity to the parameterization and estimation of biological parameters including growth, natural mortality, steepness, selectivity, recruitment deviates, data inputs, and composition weighting were explored.

Natural mortality and steepness are major structural considerations with large impacts on the model derived outputs. The alternative hypotheses for natural mortality were not symmetric around the reference model and tended to estimated relative stock status to be higher than the reference model. The model was also able to reasonable estimate natural mortality for both sub-stock models. Steepness is greatly unknown and inestimable in these models, but highly influential. Variation at length is also another source of high uncertainty in the model. The latter two may be worth further consideration when trying to incorporate further model uncertainty beyond what is asymptotically estimated in the model.

3.9.2 Oregon

3.9.2.1 Sensitivity to Assumptions

Sensitivity to alternative model specifications and assumptions included model runs associated with natural mortality, growth, and recruitment (in addition to data weighting and other data-related sensitivities described in Section 3.9.2.2). Sensitivities were structured as 'one-off' (change one structural assumption relative to the reference model) analyses to clearly identify the impact of a single structural assumption. A table showing model results (likelihood contribution, parameter estimates, and key derived quantities) of all structural assumption sensitivities is provided electronically (see e-file: Cabezon_Supplementary_tables "Sensitivities..." tabs). The following is a list of the specific model structure-related sensitivities examined relative to the reference model. Parenthetical text indicates the name (i.e., column header) of the specific sensitivity run for cross-referencing with the supplemental e-file spreadsheet.

- *M*: Estimate using the Hamel prior (Est. *M* Hamel Prior)
- *M*: Estimate using the NMT longevity-based meta-analysis prior (Est. M Meta Prior)
- *M*: Estimate females using the Hamel prior and fix males=females (Est. M Female (M=F))
- *M*: Fix female and estimate male offset (Fix M Female Est. Male)
- *M*: Fix female and male to 2009 model estimates (Fix M 2009 Model)
- *M*: Fix female and male to 2019 SCS model estimates (Fix M SCS Model)
- *M*: Fix female and male to 2019 NCS model estimates (Fix M NCS Model)
- *M*: Fix at the mean of the NMT longevity-based meta-analysis prior (Fix M Meta Mean)
- *M*: Fix at the 25% quantile value from NMT longevity-based meta-analysis distribution (Fix M Meta 25% Quantile)
- *M*: Fix at the 75% quantile value from NMT longevity-based meta-analysis distribution (Fix M Meta 75% Quantile)
- Growth: Fix to 2009 assessment estimates (Growth Fix 2009 Model)
- Growth: Fix to Rasmuson et al. (2019) estimates - their table 11, column 3 (Growth Fix ODFW)

- Growth: Fix the L_{min}_*CV* parameter to the (lower) value estimated in the 2009 assessment (Growth: Fix Lmin_CV)
- Recruit: Estimate steepness of the BH stock-recruitment function (Recruit Est. Steepness)
- Recruit: Start rec devs ten years earlier - in 1970 (Rec.Devs Start 1970)
- Recruit: No estimation of rec devs (Rec.Devs No Est.)
- Recruit: Rec dev maximum bias adjustment increased (Rec.Devs High Bias Adj.)

In general, the reference case model was the most sensitive (i.e., estimates beyond the 95% confidence interval for the reference model) to models that estimated natural mortality, used the Francis data weighting approach for all composition data, and fixed growth to external estimates when considering estimates of stock size (SSB) and status (depletion) in 2019 (Figure 165). Population scale (SB_0) was also quite sensitive relative to the reference model when estimating natural mortality (three of four sensitivity runs that estimated *M* resulted in considerably higher values) and growth. Estimates of *M* from these sensitivities ranged from 0.40 to 0.43 for females and 0.39 to 0.40 for males, and resulted in derived management quantities with impractical levels of uncertainty (e.g., SSB). The inability to reliably estimate *M* within an integrated assessment without considerable contrast in the data through time or auxiliary information (e.g., from a representative tagging experiment) is not too surprising. Current estimates of stock size and stock status were also much higher for the cases when *M* was estimated (Figure 171). Alternative approaches for fixing gender-specific *M* resulted in more similar stock sizes (all within the 95% confidence interval from the reference model, with the exception of fixing it at the gender-specific 75% quantile of the NMT prior distribution) and very similar estimates of the overall trend in stock status (Figure 171). Natural mortality is a major source of uncertainty in the Oregon sub-stock assessment and should be considered as a decision-table axis describing alternative states of nature.

The reference model was sensitive to alternative model assumptions and specifications related to growth. Fixing growth at the 2009 assessment model estimates suggested a considerable decrease in overall stock size (unfished biomass lower by nearly a quarter) as well as the trend and recent estimates of stock status (0.28 compared to 0.53 for the reference model in 2019; Figure 170). Conversely, fixing growth at external estimates from Rasmuson et al. (2019) resulted in a considerable increase in overall stock size (unfished biomass nearly 6-fold) as well as the trend and recent estimates of stock status (stock at 1.04 times the unfished level in 2019 compared to 0.53 times the unfished level for the reference model). Artificially lowering the variability (*CV*) around the length at minimum age (age-0) to a level consistent with the 2009 assessment had little impact on results (Figure 170).

The reference model was relatively insensitive to alternative model assumptions and specifications related to stock productivity and recruitment (i.e., all sensitivity runs were within the 95% confidence interval of the reference model; Figure 172). Steepness was estimated at the upper bound of one, suggesting that there is no relationship between spawning output and recruitment. This isn't overly surprising given the lack of data points to inform the average level of Cabezon recruitment at low stock sizes. The largest recruitment-related difference in estimated stock size was when no recruitment deviates were estimated (6% increase in current spawning biomass). All recruitment sensitivities that estimated recruitment deviates indicated that the 2014 year class was above average (Figure 172).

3.9.2.2 Sensitivity to Data and Weighting

Sensitivity to the main sources of data-related uncertainty included the removal of individual data sources (i.e., "one-off" approach where one data source is removed relative to the reference model) and all data sources within a specific data source type (indices, length composition, and age composition). This approach to conducting model sensitivities was used to clearly identify the impact of a single piece (or type) of information. A table showing model results (likelihood contribution, parameter estimates, and key derived quantities) of all data source sensitivities is provided electronically (see e-file: Cabezon_Supplementary_tables "Sensitivities..." tabs). The following is a list of the specific data-related sensitivities examined relative to the reference model. Parenthetical text indicates the name (i.e., column header) of the specific sensitivity run for cross-referencing with the supplemental e-file spreadsheet.

- Removal of the commercial logbook fishery-dependent index (Index -Logbook)
- Removal of the recreational onboard observer fishery-dependent index (Index -Observer)
- Removal of the recreational ORBS dockside fishery-dependent index (Index -ORBS)
- Removal of the recreational MRFSS dockside fishery-dependent index (Index -MRFSS)
- Removal of all four fishery-dependent indices (Index -All)
- Removal of the commercial landed-live length compositions (L.Comp -Live)
- Removal of the commercial landed-dead length compositions (L.Comp -Dead)
- Removal of the recreational ocean boat length compositions (L.Comp -Ocean)
- Removal of the recreational shore length compositions (L.Comp -Shore)
- Removal of all length compositions (L.Comp -All)
- Removal of the commercial landed-dead age compositions (A.Comp -Dead)
- Removal of the recreational ocean boat age compositions (A.Comp -Ocean)
- Removal of the research project based age compositions (A.Comp -Research)
- Removal of all age compositions (A.Comp -All)
- Data: All composition weighting using harmonic mean (Data Weight All HM)
- Data: All composition weighting using Francis (Data Weight All Francis)
- Data: All composition weighting using Dirichlet (Data Weight All Dirichlet)
- Data: All composition weights set to one (Data Weight All one)
- Data: Alternative ageing error (Alt. Age Error)

In general, the reference case model was the most sensitive (i.e., estimates beyond the 95% confidence interval for the reference model) to removing all information for a given data type (index, lengths, or ages) and omitting specifically ocean boat lengths or ages when considering estimates of stock size (SSB) and status (depletion) in 2019 (Figure 164 and Figure 165). The omission of the MRFSS index impacted the stock trajectory from 1990 through the early 2000s, and had a moderate influence (lower) on current stock status (Figure 166). Leaving out any one index did not alter the results beyond the 95% confidence interval of the reference model; however, removing all indices resulted in current stock status to be well below the management target and near the minimum stock size threshold (Figure 166). For length composition data, removing the recreational ocean boat lengths had the largest impact on stock status (lower; Figure 167). Removing the recreational ocean boat ages also had the largest impact on stock size and status (both higher than the reference model; Figure 168). Collectively, these results, along with reference model likelihood profiles, indicate that each data type is informative to the integrated assessment.

The approach to weighting length composition data (Francis method in the reference case model) and age composition data (harmonic mean in the reference case model) did not have a major impact on stock trend or status until the final few years in the time series, at which point the Francis only method suggested a drastic increase in both stock size (near 45% increase relative to the reference model) and status (near 40% increase; Figure 169). When using only the harmonic mean method for weighting, results were more similar to the reference model (Figure 165). The dirichlet method of data weighting (Thorson et al. 2017a) was explored, but the STAT did not have time to operationalize and test this method for use in this assessment. Regardless of the method for weighting composition data, the Oregon sub-stock is estimated to be above the management target, and spawning stock biomass is estimated to be at or above 135 mt at the beginning of 2019.

The alternative ageing error sensitivity had a large impact on results relative to the reference model. Due to large predicted biases between break and burn and thin section ageing methods, as well as considerable within method error and the general difficulty ageing Cabezon (Rasmuson et al. 2019), it is not surprising that switching the level of estimated bias (i.e., which method is biased relative to the other assumed 'true' method) has an impact on results (mostly population scale, through estimates of R_0). The reference model assumes the more recent ageing using the break and burn method is unbiased relative to the thin section method used from 2005-2008.

3.9.2.3 Parameter Uncertainty

Likelihood profiles were performed across three major sources of uncertainty: natural mortality (M), initial recruitment (R_0), and steepness (h). An individual profile was completed for each data source and parameter combination to identify the relative importance of each data set to the parameter estimation. The profile over the initial scale of the population (lnR_0) indicated a relatively low gradient from a lnR_0 value of 4.2 to 5.4 (Figure 173). Recruitment and age data were the most important for estimating lnR_0 (Figure 174). The influence of lnR_0 on derived quantities for absolute levels of biomass was nonlinear, with large changes in biomass predicted from small changes in lnR_0 (Figure 173), especially at higher levels of lnR_0. The lnR_0 values between 4.5 and 4.8 approximately spanned the range within two likelihood units of the reference model (lnR_0=4.68), which covered a range of current depletion estimates from 49% to 59% (Figure 173). The values of lnR_0 ranging from 4.2 - 5.4 all resulted in 2019 depletion being above the management target (Figure 175). Fishery-dependent indices had very little influence on population scale, and there was not considerable conflict among the different indices. Profiles over the steepness parameter (h) indicated that steepness was difficult to estimate given the available data sources which pushed steepness to an upper bound of one (Figure 176). Steepness was fixed at 0.7 in the reference model which was the value applied in the 2009 assessment (Cope and Key 2009).

Although female and male natural mortality (M) were fixed in the reference model, several profiles were examined across alternative female and male parameter values. First, profiles were created over female natural mortality while the natural mortality rate for males was estimated as an offset to females. Results showed that natural mortality was influenced mostly by age composition (recreational ocean boat) and recruitment data, with the other data sources being weakly informative (Figure 178). Additionally, abundance indices were somewhat informative, with the MRFSS dockside index suggesting higher values of *M*, where the ORBS dockside index suggests lower values of *M* (Figure 179). Estimates of male *M* were linearly-related to female *M*, with the values specified in the reference model being consistent with estimates of male natural mortality being higher than females (Figure 177).

Next, a profile over female *M* was conducted across a range of values while fixing the male offset at zero, such that male and female *M* were equivalent. The impact on derived quantities was similar to those produced when the offset for male *M* was estimated (Figure 180). Results showed that natural mortality was influenced mostly by age composition (recreational ocean boat) and recruitment data, and also to a lesser extent, length data (Figure 181). Abundance indices were similarly informative as the male estimated case previously (Figure 182). Estimates of depletion showed a linear trend with *M* up to about 0.40, where the rate of increase in the depletion estimate slowed for values above 0.40 (Figure 180). The values explored for *M* ranged from 0.1 - 0.6, with *M* values above 0.18 all resulting in 2019 depletion being above the management target (Figure 183).

Estimating natural mortality resulted in unreasonably high estimates that stood in conflict with Cabezon life history and also unmanageable amounts of uncertainty associated with some derived management quantities. Thus, natural mortality was fixed for females and males in the Oregon reference model at values (0.24 and 0.28, respectively) informed by the 2019 NCS model estimates (see Section 2.8.1 for more details). Sensitivity to natural mortality assumptions are evaluated in Section 3.9.2. During model development, the detection of high levels of imprecision associated with selectivity parameters was used to assist model development. In addition, alternative data weighting schemes resulted in general similarities in stock trajectory and status, with the exception in the final few years (Figure 169), resulting in uncertainty arising from the choice of data weighting scheme.

A moderate amount of uncertainty in current (2019) spawning stock biomass was estimated from the reference assessment model ($CV = 0.14$). This level of uncertainty suggests a category 1 sigma of 0.5 for calculating ABC buffers. However, uncertainty is greatly underestimated in the reference model due to fixing some model parameters, selecting a single reference model for inference, and misspecifying or unknown population dynamics (lower than otherwise expected parameter uncertainty, model uncertainty and process errors, respectively).

3.9.2.4 Retrospective Analysis

A retrospective analysis was conducted by sequentially removing 1 through 10 years of data from the reference model starting with 2018. The reference model was generally centered within the range of stock size and depletion estimates from models with sequentially less data (Figure 184). The large predicted 2014 recruitment event was first estimated using 2017 data, and the estimated size of the 2014 recruitment deviate positively increased with the addition of 2018 data (Figure 184). 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. Year class strength is not established until Cabezon are at least four years old, but up to age-5 or older for some cohorts (Figure 185), because fleets only begin to encounter Cabezon at age-3 or age-4, a high degree of ageing error with Cabezon, and there is no explicit recruitment index to provide cohort strength information earlier. For these same reasons, the reference model sets recruitment according to the stock-recruitment curve during recent years (2016-2019; i.e., recruitment deviation = 0).

3.9.2.5 Historical Analysis

A comparison of the 2009 Oregon sub-stock assessment model to the 2019 reference model is shown in (Figure 186). The main difference is the adjusted (downwards) scale of the population and a larger decline in stock status during the late-1990s to early 2000s in the 2019 model relative to the 2009 model. Both models estimate the 1999 year class to be well above average.

3.9.2.6 Alternate Models

Many other model parameterizations were explored for the Oregon sub-stock assessment (e.g., gender-specific and shape of selectivity curves and the estimation of growth and natural mortality parameters) during the development of the reference model and for sensitivity analysis relative to the reference 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 inclusion of different data sources were explored.

The treatment of natural mortality was a major structural consideration that was explored in the development of the reference 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 reference model. In addition to natural mortality, alternative models particularly focused on the inclusion or omission of fishery-dependent relative abundance indices, alternative data weighting, and the time period for estimating recruitment deviates.

4 Reference Points

4.1 California

SCS

Reference points and management quantities for the SCS Cabezon reference model are listed in Table 38. Relative stock status is currently estimated above the biomass target reference point ($SB_{40\%}$), and is estimated to be at 49% (~95% asymptotic intervals = 11-87%) in 2019. Unfished spawning output was estimated at 205 mt (~95% asymptotic intervals = 161–248 mt; Table 38), and spawning output at the beginning of 2019 was estimated to be 101 mt (~95% asymptotic intervals = 19–183 mt). The target spawning output based on the biomass target ($SB_{40\%}$) is 82 mt, which corresponds to a catch of 17 mt. Equilibrium yield at the proxy F_{MSY} proxy ($SPR_{45\%}$) is 17 mt and the yield at the estimated F_{MSY} (SPR=35%) is 18 mt.

NCS

Reference points and management quantities for the NCS Cabezon reference model are listed in Table 39. Relative stock status is currently estimated above the biomass target reference point (40%), and is estimated to be at 65% (~95% asymptotic intervals = 22–108%) in 2019. Unfished spawning output was estimated at 986 mt (~95% asymptotic intervals = 748–1,225 mt; Table 39), and spawning output at the beginning of 2019 was estimated to be 643 mt (~95% asymptotic intervals = 159–1,126 mt). The target spawning output based on the biomass target ($SB_{40\%}$) is 395 mt, which corresponds to a catch of 116 mt. Equilibrium yield at the proxy F_{MSY} proxy ($SPR_{45\%}$) is 118 mt and the yield at the estimated F_{MSY} (SPR=33%) is 127 mt.

4.2 Oregon

Spawning output (female spawning biomass) has generally declined throughout the early part of the time series before becoming more stable (though still with year to year fluctuations) after the early 2000s. Recently, there has been a slight increase in spawning biomass from 2017 to 2019 due to an above average recruitment event in 2014 (Figure 121 and Figure 123). Stock status has remained above the biomass target reference point (40%), though just above the target since the mid-2000s, and is estimated to be at 53% (~95% asymptotic intervals = 43%-63%) in 2019 (Figure 122). Unfished spawning output was estimated at 335 mt (~95% asymptotic intervals = 291-379 mt; see Cabezon_Supplementary_tables "Derived output time series ORS" tab), and spawning output at the beginning of 2019 was estimated to be 177 mt (~95% asymptotic intervals = 129-226 mt). Cabezon recruitment has fluctuated over the time series, with strong recruitment estimated for 1999, 2000, 2002, and 2014 (Figure 123). The above average 2014 year class contributed to the recent increase in Cabezon biomass. Fishing intensity has been below the $SPR_{45\%}$ rate throughout most of the time series (exceptions from 2000-2002), peaking at a relative SPR level of 1.16 (where 1.0 = SPR target rate) in 2001 (Figure 126). The phase plot shows the interaction of fishing intensity and biomass targets (Figure 128), and shows that spawning output in 2018 is estimated to have been 1.32 times higher than the target level, while experiencing fishing intensity 1.28 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 $SPR_{45\%}$ reference point would suggest (Figure 129). The target stock size based on the spawning output target ($SB_{40\%}$) is 134 mt, which corresponds to a catch of 46 mt. Equilibrium yield at the proxy F_{MSY} harvest rate corresponding to $SPR_{45\%}$ is also 46 mt.

5 Harvest Projections and Decision Tables

Cabezon projections are shown using a $F_{SPR=0.45}$ to calculate the OFL and a 'base' sigma of 0.5 along with either a P* = 0.40 or a P* = 0.45 for the ABCs. The 40-10 harvest control rule is also triggered once spawning biomass decreases below $SB_{40\%}$. Projected ABCs through 2030 are calculated using an incremental increase in sigma through time (as directed by the PFMC Scientific and Statistical Committee) to account for increasing uncertainty as projections progress through time and assue full attainment. The resulting change in the ABC buffer applied during the forecast period is reported in each table. The 2019 and 2020 removal values are fixed to the harvest specification for the current management cycle for each substock.

Decision tables include three states of nature and three catch considerations. The middle state is the reference model, with the low biomass state and high biomass state achieved through changing female natural mortality (while estimating male natural mortality) until the spawning biomass in the terminal year is approximates the 12.5% and 87.5% percentile values based on the asymptotic uncertainty of the terminal year spawning biomass from the reference model. Three catch streams, each one representing the 12-year projection for each state of nature considered, were subsequently applied to each state of nature to construct a 3x3 decision table.

5.1 California

SCS

Forecasted projections for the SCS cabezon stock under a P*=0.4 is found in Table 41 and under P*=0.45 in Table 42. Natural mortality values that achieved the low and high terminal spawning biomass states were $M = 0.18$ and $M = 0.35$, respectively. Decision table results for the default P* value (0.45) are presented in Table 47.

NCS

Forecasted projections for the SCS cabezon stock under a P*=0.4 is found in Table 43 and under P*=0.45 in Table 44. Natural mortality values that achieved the low and high terminal spawning biomass states were $M = 0.18$ and $M = 0.346$, respectively. Decision table results for the default P* value (0.45) are presented in Table 48.

5.2 Oregon

Forecasted projections for the Oregon cabezon stock under a P*=0.4 is found in Table 45 and under P*=0.45 in Table 46. Natural mortality values that achieved the low and high terminal spawning biomass states were female $M = 0.19$ and $M = 0.27$, respectively (fixed male offset to females). Decision table results for the default P* value (0.45) are presented in Table 49.

5.3 Washington

Three catch scenarios (based on the average weight of fish used to expand numbers to biomass, and the same scenarios as the 2017 DBSRA application) and five relative stock status values (40%, 55%, 65%, 75% and 90%) were explored for OFL calculation using SSS (for a total of fifteen scenarios). The middle relative stock status value is the mean SPR value from the LB-SPR analysis, with the other values presenting a balanced look at more or less probable relative stock status values, including one at the target biomass (40%). Preliminary attempts to isolate the female length composition data showed SPR values >65%, so the current centering of the SPR around 65% could be considered precautionary. Each SSS scenario was run 1,000 times to produce OFL values in 2021 and 2022 (Table 50). The middle value of the decision table is the presumed reference scenario and indicates a median OFL four times higher than the previous estimates (see Section 3.3.3).

In addition to presenting each scenario individually, the 15 scenarios are also presented as two different ensembles. One ensemble weights each scenario equally, thus simply combining all scenarios into one distribution. The other weighting schemes assumes the middle catch scenario is twice as likely as the other two and the relative stock status scenarios weights are based on the standardized density values determined by the SPR estimate (mean 0.65 with sd = 0.075). Results for these ensembles are given in Table 51 and Figure 187. These results return similar distributions with medians also similar to the reference scenario, but with much wider uncertainty. The equal weights scenario demonstrated the largest uncertainty.

6 Regional Management Considerations

Historically, Cabezon were federally managed as part of the "Other Fish" species complex, where a total complex optimum yield was specified as a multi-species benchmark for management. Thus, overfishing limits were not set specifically for Cabezon at that time. Since 2005, Cabezon in California waters were removed from this complex and managed according to stock-specific management specifications (e.g., OFL and ABC). In 2011, Cabezon in Oregon waters were removed from the complex and managed specifically to that sub-stock until 2018. Starting in 2019, Oregon Cabezon are managed in a complex with Oregon Kelp Greenling. Washington Cabezon were also moved into a complex with Washington Kelp Greenling, transitioning from the "Other Fish" complex, in 2019.

Spatial sub-stocks of Cabezon were chosen for stock assessment purposes to distinguish regional population dynamics, given preliminary population genetics results, and to incorporate spatial differences in the fisheries, the ecology of nearshore groundfish species, and current state management regulations and needs. Cabezon are also not believed to move or migrate long distances. Thus, the current State-level regional management scale seems appropriate, and allocating harvest by management area is then straightforward given State-level sub-stock assessments. Further research is desirable to better flush out spatiotemporal differences in Cabezon biological parameters, investigate ways to incorporate males into measures of spawning output (potential), and several other related topics (see Section 7).

7 Research Needs

There are several areas for further research that were identified while conducting these 2019 sub-stock assessments that could result in information useful to future Cabezon assessments. The list below is believed to represent strategic pieces of information that would likely help to resolve key uncertainties associated with assessing Cabezon. Many would provide the necessary information to evaluate basic life history parameters and spatiotemporal population and fleet dynamics. Not all listed data and research needs may apply to all sub-stocks.

1. Fishery-independent surveys. 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. Continued support and development of current fishery-independent nearshore surveys is needed to extend the time series and increase spatial coverage.

2. Improve estimates of natural mortality. All sub-stocks show significant sensitivity to natural mortality, a parameter difficult to estimate in assessment models and often assumed known and invariant across space and time. Estimates of natural mortality may be derived from tag-recapture studies or the comparison of biological information (e.g., length compositions) inside and outside marine protected areas for relatively sedentary species.
3. Male incorporated definition of spawning potential (spawning output/biomass). The nest-guarding behavior of Cabezon males gives added reproductive importance to their abundance, relative to most other groundfish species. A metric other than female spawning biomass may be needed to incorporate the status of the male portion of the population into reference points. Further investigation is needed to identify how paternal effects influence reproductive success and appropriate ways (if warranted) those can be incorporated into metrics for evaluating population status.
4. Defining the stock structure of Cabezon. Current work on Cabezon stock structure needs continued attention to better understand the connectivity between Cabezon sub-stocks identified in this assessment within the California Current Large Marine Ecosystem. This would help focus or inform future sampling design to provide data for assessment purposes as well as refining sub-stock boundaries.
5. Changes in batch fecundity with age. Batch fecundity in Cabezon is recognized, but it is not understood how and if batch fecundity changes with age. Understanding whether the number of batches increases with age will help specify the fecundity relationship in the assessment model.
6. Collection of gender-specific data. Gender-specific information from the recreational fishery should be collected for Cabezon given differences in growth and potentially natural mortality by gender. Evidence presented at the STAR panel demonstrated that non-invasive sexing is possible and should be done. 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 Cabezon and other species important to recreational fisheries.
7. The effects of climate on Cabezon population dynamics. Links between prevailing oceanographic conditions and Cabezon recruitment strength should be explored further to help increase the understanding of spatially-explicit recruitment responses and inform future recruitment events. For example, recruitment pattern similarities among sub-stocks suggest a possible link between environmental forcing and population dynamics.
8. 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 limited comprehensive information collected about catch or effort or biological information from the shore (and estuary) fishing fleet. The increased effort to monitor this fleet in recent years should continue. Although the shore fleet does not represent a major fleet component for Cabezon in terms of landed catch, it does tend to catch smaller individuals. Biological data on smaller individuals is a data gap for Cabezon and many other nearshore rockfish species.
9. Age and growth determination. Differences in the estimated growth parameters between Oregon and California (particularly the growth coefficient, *k*) and among external sources

deserve further attention. Further attention to ageing Cabezon in California is needed to increase spatial understanding of Cabezon growth along the coast. Age samples from each fishery in California would also help to define growth and selectivity, while further informing recruitment patterns and helping to decrease the uncertainty in the scale (absolute abundance) of each sub-stock. Continued age sampling from each fishery in Oregon is encouraged.

10. Discard length composition. Future research to evaluate the best way to incorporate discard length data in stock assessments is recommended to garner benefit from substantial sample sizes available for some species, while minimizing adverse effects on model complexity.
11. Alternative Fishery Dependent Indices of Abundance. While the CPFV logbook index of abundance provides information on the trend in the period prior to 2000, many regulations affecting catch rates were implemented (ie, bag, season, depth and length restrictions) went into effect thereafter that the limited data associated with the logbook cannot resolve. Private boat, CPFV dockside and onboard CPFV data from the MRFSS and CRFS programs can be analyzed using the Stephens and MacCall (2004) filter or methods implemented in geographic information systems developed Monk et al. (2013) to account for some of these changes. Current lack of data availability from RecFIN on the trip level, prevented further exploration in this assessment. A workshop or methodology review evaluating the application of these methods to develop best practices and development of preformatted data bases to facilitate their application to nearshore stocks would be streamline application in future stock assessments.
12. Integrated stock assessment for Washington state. The intermediate step to leverage information from limited length samples using LBSPR to inform an important input of the catch estimator method SSS was a strong step forward. Additionally, the move from DBSRA to SSS also explicitly sets up the inclusion of index information and length compositions into future modelling work. There should be a strong consideration that the next iteration of the Washington state substock model be a fully integrated Stock Synthesis mode

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10 Auxiliary Files

Several auxiliary files are associated with the sub-stock assessments in this document. These include:

- Cabezon_Supplementary_tables.xlsx
- Southern California reference model files:
    - SCScab_control.ss
    - SCScab_data.ss
    - SCScab_forecast.ss
    - SCScab_Report.ss
    - SCScab_starter.ss
    - SCScab_plots (folder containing r4ss plots)
- Northern California reference model files:
    - NCScab_control.ss
    - NCScab_data.ss
    - NCScab_forecast.ss
    - NCScab_Report.ss
    - NCScab_starter.ss
    - NCScab_plots (folder containing r4ss plots)
- OR reference model files:
    - ORcab_control.ss
    - ORcab_data.ss
    - ORcab_forecast.ss
    - ORcab_Report.ss
    - ORcab_starter.ss
    - ORcab_plots (folder containing r4ss plots)
- Washington model files:
    - WAcab_control.ss
    - WAcab_data.ss
    - WAcab_forecast.ss
    - WAcab_Report.ss
    - WAcab_starter.ss
    - WA_SSS.DMP

11 Tables

11.1 Data Tables

Table 1. State of Oregon commercial bimonthly period trip limit history for Cabezon. Inseason changes implemented are in parentheses.

Year	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
2003	-	-	-	2,000	2,000	2,000
2004	2,000	2,000	2,000	2,000	2,000	2,000 (Closed)
2005	2,000	2,000	2,000	2,000	2,000	2,000
2006	1,000	1,000	1,000	1,000 (2,000)	1,000 (2,000)	1,000 (2,000)
2007	2,000	2,000	2,000	2,000	2,000 (4,000)	2,000 (4,000; Closed)
2008	2,500	2,500	2,500	2,500	2,500	2,500
2009	2,500	2,500	2,500	2,500 (1,250)	2,500 (Closed)	2,500 (Closed)
2010	1,500	1,500	1,500	1,500	1,500 (1,600)	1,500 (1,600)
2011	1,500	1,500	1,500	1,500	1,500	1,500
2012	1,500	1,500	1,500	1,500	1,500	1,500 (100)
2013	1,500	1,500	1,500	1,500	1,500 (2,000)	1,500 (2,000)
2014	1,500	1,500	1,500	1,500	1,500	1,500
2015	1,500	1,500	1,500	1,500	1,500	1,500
2016	1,500	1,500	1,500	1,500 (2,000)	1,500 (2,000)	1,500 (2,000)
2017	2,000	2,000	2,000	2,000	2,000	2,000
2018	2,000	2,000	2,000 (1,500)	2,000 (500)	2,000 (500)	2,000 (45)

Table 2. Summary of recent management history for Cabezon relative to harvest limits (mt) in California and Oregon. Impacts are from WCGOP total fishing mortality annual reports. Oregon Cabezon in 2010 was a part of the Other Fish complex and impacts include WA recreational. All other OY/ACLs are state-specific.

Stock	Year	Control Rule	Harvest Limit	Complex Impacts (mt)	Cabezon Impacts (mt)	Cabezon % Complex Impacts	Complex Impacts % of Limit	Cabezon % Of Limit
California	2010	OY	79	-	47	-	-	59%
	2011	ACL	179	-	50	-	-	28%
	2012	ACL	168	-	74	-	-	44%
	2013	ACL	163	-	68	-	-	42%
	2014	ACL	158	-	82	-	-	52%
	2015	ACL	154	-	90	-	-	58%
	2016	ACL	151	-	78	-	-	52%
	2017	ACL	157	-	55	-	-	35%
	2018	ACL	156	-	*	-	-	*
	2019	ACL	147	-	*	-	-	*
Oregon	2010	OY	5600	2231	49	2%	40%	-
	2011	ACL	50	-	48	-	-	96%
	2012	ACL	48	-	47	-	-	98%
	2013	ACL	47	-	34	-	-	73%
	2014	ACL	47	-	27	-	-	58%
	2015	ACL	47	-	27	-	-	58%
	2016	ACL	47	-	28	-	-	60%
	2017	ACL	49	-	51	-	-	104%
	2018	ACL	49	-	*	-	-	*
	2019	ACL	47	-	*	-	-	*

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

Table 3. Evaluation of management performance of Cabezon. Total mortality estimates are based on annual reports from the NWFSC WCGOP, for which only years up through 2017 are available. All values are in metric tons. Years for which total mortality exceeded harvest specifications are in bold. Specifications in italics indicate the stock is managed as an individual species component of a complex for which harvest specifications are set at the complex level.

Stock	Year	Total Mortality	ACL	ABC	OFL
California	2011	50	179	179	187
	2012	74	168	168	176
	2013	68	163	163	170
	2014	82	158	158	165
	2015	90	154	154	161
	2016	78	151	151	158
	2017	55	150	150	157
	2018	--	149	149	156
	2019	--	147	147	154
Oregon	2011	48	50	50	52
	2012	47	48	48	50
	2013	34	47	47	49
	2014	27	47	47	49
	2015	27	47	47	49
	2016	28	47	47	49
	2017	**51**	47	47	49
	2018	--	47	47	49
	2019	--	47	47	49
Washington *	2011	7	No harvest specifications set for individual component species within a complex		
	2012	8			
	2013	6			
	2014	4			
	2015	4	*4*	*4*	*5*

2016	3	*4*	*4*	*5*
2017	6	*4*	*4*	*5*
2018	--	*4*	*4*	*5*
2019	--	*5*	*5*	*6*

* Washington total mortality is reported from within the WCGOP Other Groundfish category but harvest specifications are set under the Other Fish complex.

Table 4. Total mortality of Cabezon by sector from NWFSC WCGOP total mortality annual reports for 2010 - 2017. Commercial landings include estimated discard mortality. Incidental fisheries mortality is included in All other gear sector.

Year	Commercial fisheries		Recreational fishing mortality			Research	Estimated Total Fishing Mortality
	Nearshore Fixed Gear	All other gears	WA	OR	CA		
2010	46.87	0.06	5.40	19.60	23.80	0.00	95.73
2011	62.26	0.08	6.79	18.30	17.60	0.02	105.05
2012	59.55	0.08	7.97	17.78	43.25	--	128.63
2013	48.86	0.05	6.00	14.40	39.27	0.00	108.58
2014	46.86	0.26	4.16	11.50	50.81	0.01	113.60
2015	51.80	0.02	4.30	10.88	54.91	--	121.91
2016	46.53	0.43	2.96	11.74	46.70	0.06	108.42
2017	46.25	6.41	6.05	22.31	31.34	0.01	112.37

Table 5. History of major changes in recreational bag limits and bag limit species group for Cabezon in Oregon waters. Values in parentheses are sub-bag limits for Cabezon. Inseason management changes are not included.

Year	Bag Limit Species Group	Daily Bag Limit
Pre-1976	N/A	N/A
1976	Other Fish	25
1978	Rockfish, Cabezon and Greenling	15
1994	Other Fish	25
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
2012	Rockfish, Cabezon, Greenling, and Other Marine Species	7 (1)
2018	Rockfish, Cabezon, Greenling, and Other Marine Species	5 (1)

Table 6. Oregon commercial landings from 1979 - 2018 (metric tons) by gear for the landed dead fleet. Historic landings from 1979 - 1986 are from Oregon's commercial reconstruction (Karnowski et al. 2014). Landings from 1987 - 2018 were extracted from PacFIN (3/7/2018) and separated by fish condition.

Year	Historical Reconstruction - Dead Fishery				Dead Fishery				Dead Fishery Landings	Dead Fishery Discards	Dead Fishery Total
	Hook & Line	Longline	Fish Pot	Other	Hook & Line	Longline	Fish Pot	Other			
1979	0.00	-	0.04	0.05	-	-	-	-	0.09	0.01	0.10
1980	-	-	-	0.03	-	-	-	-	0.03	0.00	0.03
1981	0.02	-	-	0.11	-	-	-	-	0.14	0.01	0.15
1982	0.00	-	-	0.06	-	-	-	-	0.06	0.00	0.07
1983	0.04	-	-	0.28	-	-	-	-	0.32	0.02	0.34
1984	0.52	-	-	0.62	-	-	-	-	1.14	0.08	1.22
1985	1.37	0.48	-	0.73	-	-	-	-	2.58	0.18	2.76
1986	2.44	1.65	-	0.89	-	-	-	-	4.97	0.35	5.32
1987	-	-	-	-	3.31	1.31	-	1.75	6.37	0.45	6.82
1988	-	-	-	-	7.83	1.18	-	2.32	11.33	0.79	12.13
1989	-	-	-	-	5.46	0.11	-	1.13	6.70	0.47	7.17
1990	-	-	-	-	3.43	0.41	-	1.32	5.16	0.36	5.52
1991	-	-	-	-	6.26	1.40	-	0.66	8.32	0.58	8.90
1992	-	-	-	-	6.59	0.09	0.01	0.54	7.23	0.51	7.74
1993	-	-	-	-	1.22	0.04	-	0.17	1.43	0.10	1.53
1994	-	-	-	-	5.10	1.24	-	0.65	6.99	0.49	7.48
1995	-	-	-	-	2.38	2.98	-	0.36	5.72	0.40	6.12
1996	-	-	-	-	3.39	2.08	-	0.17	5.65	0.40	6.04
1997	-	-	-	-	3.44	6.34	-	0.30	10.08	0.71	10.79
1998	-	-	-	-	0.99	2.28	-	0.43	3.70	0.26	3.96
1999	-	-	-	-	1.42	1.46	-	0.13	3.00	0.21	3.21
2000	-	-	-	-	1.44	1.19	-	0.75	3.39	0.24	3.62
2001	-	-	-	-	1.09	0.96	0.22	0.11	2.38	0.17	2.55
2002	-	-	-	-	1.31	0.10	0.02	0.08	1.51	0.11	1.62
2003	-	-	-	-	1.34	0.01	0.01	0.09	1.45	0.10	1.55
2004	-	-	-	-	1.09	0.39	-	0.04	1.51	0.11	1.61
2005	-	-	-	-	0.79	0.52	-	0.09	1.39	0.10	1.49
2006	-	-	-	-	0.52	0.18	-	0.05	0.75	0.05	0.80
2007	-	-	-	-	0.42	0.21	0.01	0.02	0.65	0.05	0.70
2008	-	-	-	-	0.29	1.24	-	0.03	1.56	0.11	1.67
2009	-	-	-	-	0.35	1.08	-	0.04	1.47	0.10	1.57
2010	-	-	-	-	0.47	0.70		0.01	1.18	0.08	1.26
2011	-	-	-	-	0.34	0.78	0.04	-	1.15	0.08	1.23

2012	-	-	-	-	0.40	0.99	-	-	1.38	0.10	1.48
2013	-	-	-	-	0.40	0.37	-	-	0.77	0.05	0.82
2014	-	-	-	-	0.27	0.31	-	-	0.58	0.04	0.62
2015	-	-	-	-	0.39	0.14	0.08	-	0.62	0.04	0.66
2016	-	-	-	-	0.62	0.48	-	0.09	1.19	0.08	1.27
2017	-	-	-	-	0.86	1.12	-	-	1.97	0.14	2.11
2018	-	-	-	-	1.39	1.09	0.01	-	2.48	0.17	2.66

Table 7. Oregon commercial landings and discards from 1979 - 2018 (metric tons) by gear for the landed live fleet. Landings from 1987 - 2018 were extracted from PacFIN (3/7/2018) and separated by fish condition.

Year	Live Fishery				Live Fishery Landings	Live Fishery Discards	Live Fishery Total
	Hook & Line	Longline	Fish Pot	Other			
1979	-	-	-	-	0.00	0.00	0.00
1980	-	-	-	-	0.00	0.00	0.00
1981	-	-	-	-	0.00	0.00	0.00
1982	-	-	-	-	0.00	0.00	0.00
1983	-	-	-	-	0.00	0.00	0.00
1984	-	-	-	-	0.00	0.00	0.00
1985	-	-	-	-	0.00	0.00	0.00
1986	-	-	-	-	0.00	0.00	0.00
1987	-	-	-	-	0.00	0.00	0.00
1988	-	-	-	-	0.00	0.00	0.00
1989	-	-	-	-	0.00	0.00	0.00
1990	-	-	-	-	0.00	0.00	0.00
1991	-	-	-	-	0.00	0.00	0.00
1992	-	-	-	-	0.00	0.00	0.00
1993	0.01	-	-	0.02	0.03	0.00	0.03
1994	0.03	-	-	0.01	0.04	0.00	0.04
1995	0.03	-	-	0.00	0.03	0.00	0.03
1996	0.01	-	-	0.05	0.06	0.00	0.07
1997	7.43	3.41		0.03	10.87	0.76	11.63
1998	9.16	13.77	0.12	0.14	23.19	1.62	24.82
1999	14.66	8.75	-	0.05	23.46	1.64	25.10
2000	21.65	5.74	-	0.41	27.80	1.95	29.75
2001	27.05	9.95	6.85	0.09	43.94	3.08	47.01
2002	35.39	1.37	7.64	0.11	44.50	3.12	47.62
2003	22.68	0.35	2.45	0.07	25.55	1.79	27.34
2004	22.76	0.61	2.82	0.02	26.21	1.83	28.04
2005	22.05	4.93	0.60	-	27.58	1.93	29.51
2006	12.79	5.98	2.52	0.01	21.30	1.49	22.79
2007	13.11	4.99	3.12	-	21.22	1.49	22.71
2008	10.78	9.63	3.10	-	23.50	1.65	25.15
2009	10.13	16.02	2.19	-	28.35	1.98	30.33
2010	11.28	9.62	1.40	-	22.30	1.56	23.86
2011	14.77	11.77	1.80	-	28.34	1.98	30.32
2012	15.26	10.84	1.36	-	27.46	1.92	29.39
2013	10.62	6.81	1.61	-	19.05	1.33	20.38

2014	9.13	4.94	0.74	-	14.81	1.04	15.84
2015	10.97	3.66	1.14	-	15.76	1.10	16.86
2016	7.39	5.51	1.92	-	14.81	1.04	15.85
2017	12.03	11.74	2.77	-	26.54	1.86	28.40
2018	15.33	10.41	1.10	-	26.84	1.88	28.71

Table 8. Oregon recreational landings and discards from 1970 - 2018 (metric tons) by fleet. Historical reconstruction estimates are from the ODFW reconstruction for the 2009 Cabezon assessment (Cope and Key 2009). ORBS estimates are from RecFIN (extracted 3/4/2019). MRFSS/SEBS reconstruction and ODFW estimates are from an ODFW reconstruction.

Year	Ocean Boats				Shore & Estuary			
	Historical Inferred	Historical Reconstruction	ORBS	Total Catch	Historically Inferred	MRFSS/SEBS Reconstruction	ODFW	Total Catch
1970	0.0	-	-	0.0	0.0	-	-	0.0
1971	1.0	-	-	1.0	0.3	-	-	0.3
1972	2.1	-	-	2.1	0.6	-	-	0.6
1973	3.1	-	-	3.1	0.9	-	-	0.9
1974	4.2	-	-	4.2	1.2	-	-	1.2
1975	4.6	-	-	4.6	1.5	-	-	1.5
1976	10.8	-	-	10.8	1.7	-	-	1.7
1977	8.8	-	-	8.8	2.0	-	-	2.0
1978	20.8	-	-	20.8	2.3	-	-	2.3
1979	-	7.3	-	7.3	2.6	-	-	2.6
1980	-	5.5	-	5.5	-	2.7	-	2.7
1981	-	14.7	-	14.7	-	3.7	-	3.7
1982	-	15.0	-	15.0	-	1.5	-	1.5
1983	-	11.0	-	11.0	-	1.7	-	1.7
1984	-	11.3	-	11.3	-	1.1	-	1.1
1985	-	6.3	-	6.3	-	3.1	-	3.1
1986	-	11.5	-	11.5	-	5.4	-	5.4
1987	-	5.9	-	5.9	-	5.0	-	5.0
1988	-	14.9	-	14.9	-	3.6	-	3.6
1989	-	16.9	-	16.9	-	2.5	-	2.5
1990	-	18.5	-	18.5	-	2.1	-	2.1
1991	-	9.8	-	9.8	-	2.0	-	2.0
1992	-	11.6	-	11.6	-	2.0	-	2.0
1993	-	10.3	-	10.3	-	6.4	-	6.4
1994	-	11.9	-	11.9	-	2.0	-	2.0
1995	-	9.8	-	9.8	-	1.6	-	1.6
1996	-	10.2	-	10.2	-	1.4	-	1.4
1997	-	16.7	-	16.7	-	2.0	-	2.0
1998	-	12.8	-	12.8	-	1.1	-	1.1
1999	-	10.1	-	10.1	-	0.8	-	0.8
2000	-	13.0	-	13.0	-	1.1	-	1.1
2001	-	-	12.1	12.1	-	3.6	-	3.6

2002	-	-	15.4	15.4	-	2.2	-	2.2
2003	-	-	16.1	16.1	-	1.4	-	1.4
2004	-	-	17.3	17.3	-	0.7	-	0.7
2005	-	-	17.8	17.8	-	1.2	-	1.2
2006	-	-	15.8	15.8	-	-	1.4	1.4
2007	-	-	16.2	16.21	-	-	1.3	1.32
2008	-	-	16.6	16.56	-	-	1.3	1.27
2009	-	-	16.2	16.20	-	-	1.2	1.23
2010	-	-	16.6	16.55	-	-	1.2	1.18
2011	-	-	17.3	17.27	-	-	1.1	1.14
2012	-	-	15.4	15.36	-	-	0.6	0.57
2013	-	-	12.4	12.38	-	-	0.4	0.41
2014	-	-	9.1	9.09	-	-	0.4	0.40
2015	-	-	10.2	10.22	-	-	0.4	0.39
2016	-	-	11.8	11.76	-	-	0.4	0.37
2017	-	-	23.7	23.73	-	-	0.2	0.23
2018	-	-	13.5	13.45	-	-	0.2	0.16

Table 9. Estimated numbers of Cabezon from the ODFW historical recreational reconstruction for 1979 - 2000 from the ocean boat fishery in Oregon.

Year	Numbers of fish
1979	5159.0
1980	3861.0
1981	9673.0
1982	9500.3
1983	8196.9
1984	7295.1
1985	4117.3
1986	7647.6
1987	3649.2
1988	8696.4
1989	9941.8
1990	10408.6
1991	5500.8
1992	6506.9
1993	5541.8
1994	7106.2
1995	5679.8
1996	6237.5
1997	8643.8
1998	6253.7
1999	4551.3
2000	6611.5

Table 10. Calculation of total removals for Cabezon in Washington state 1963-1989.

	Cabezon recreational removals										
Year	Retained	Released	Dead released	#s	mt[1]	mt[2]	mt[3]	Comm. Removals	Total removals (mt)[1]	Total removals (mt)[2]	Total removals (mt)[3]
1963	10	1	0	10	0.02	0.02	0.03	0	0.02	0.02	0.03
1964	31	3	0	31	0.07	0.07	0.08	0	0.07	0.07	0.08
1965	51	5	0	52	0.12	0.12	0.14	0	0.12	0.12	0.14
1966	72	7	1	73	0.17	0.17	0.2	0	0.17	0.17	0.2
1967	80	8	1	81	0.19	0.19	0.22	0	0.19	0.19	0.22
1968	114	11	1	115	0.26	0.26	0.31	0	0.26	0.26	0.31
1969	135	13	1	136	0.31	0.31	0.37	0	0.31	0.31	0.37
1970	156	16	1	157	0.36	0.36	0.42	0	0.36	0.36	0.42
1971	177	18	1	178	0.41	0.41	0.48	0	0.41	0.41	0.48
1972	197	20	1	199	0.46	0.46	0.54	0	0.46	0.46	0.54
1973	218	22	2	220	0.51	0.51	0.59	0	0.51	0.51	0.59
1974	239	24	2	241	0.55	0.55	0.65	0	0.55	0.55	0.65
1975	330	33	2	332	0.76	0.76	0.9	0	0.76	0.76	0.9
1976	316	32	2	318	0.73	0.73	0.86	0	0.73	0.73	0.86
1977	165	17	1	166	0.38	0.38	0.45	0	0.39	0.39	0.45
1978	449	45	3	452	1.04	1.04	1.22	0.11	1.15	1.15	1.34
1979	239	24	2	241	0.55	0.55	0.65	0	0.55	0.55	0.65
1980	390	39	3	393	0.9	0.9	1.06	0.13	1.04	1.04	1.19
1981	313	31	2	315	0.72	0.72	0.85	0	0.72	0.72	0.85
1982	473	47	3	476	1.1	1.1	1.29	0	1.1	1.1	1.29
1983	1029	103	7	1036	2.38	2.38	2.8	0	2.38	2.38	2.8
1984	1248	125	9	1257	2.89	2.89	3.39	0.02	2.91	2.91	3.42
1985	1153	115	8	1161	2.67	2.67	3.13	0	2.67	2.67	3.13
1986	1673	167	12	1685	3.87	3.87	4.55	0.02	3.89	3.89	4.57
1987	NA	NA	NA	1704	3.92	3.92	4.6	0.95	4.87	4.87	5.55
1988	NA	NA	NA	1852	4.26	4.26	5	1.1	5.36	5.36	6.1
1989	NA	NA	NA	2001	4.6	4.6	5.4	1.52	6.13	6.13	6.93

(yellow)	Linearly interpolated using years 1967,1975-1982.
(blue)	Assumes discard rate of 10%.
(grey)	Assumes death rate of 7%.
1	Average weights assumed 2.3 kg for all years
2	Average weights assumed 2.3 (1963-2002) and 2.7 kg (2003-2018)
3	Average weights assumed 2.7 kg for all years
(orange)	Linearly interpolated using years

Table 11. Calculation of total removals for Cabezon in Washington state 1990-2020.

	Cabezon recreational removals										
Year	Retained	Released	Dead released	#s	mt[1]	mt[2]	mt[3]	Comm. Removals	Total removals (mt)[1]	Total removal s (mt)[2]	Total removals (mt)[3]
1990	2447	245	17	2464	5.67	5.67	6.65	0.59	6.25	6.25	7.24
1991	1923	192	13	1936	4.45	4.45	5.23	0.2	4.65	4.65	5.43
1992	3207	321	22	3229	7.43	7.43	8.72	0.34	7.76	7.76	9.06
1993	2817	282	20	2837	6.52	6.52	7.66	0.75	7.27	7.27	8.4
1994	1941	194	14	1955	4.5	4.5	5.28	0.21	4.71	4.71	5.49
1995	2088	209	15	2103	4.84	4.84	5.68	0.11	4.94	4.94	5.78
1996	2260	226	16	2276	5.23	5.23	6.14	0	5.23	5.23	6.14
1997	2684	268	19	2703	6.22	6.22	7.3	0	6.22	6.22	7.3
1998	2066	207	14	2080	4.79	4.79	5.62	0	4.79	4.79	5.62
1999	1962	196	14	1976	4.54	4.54	5.33	0	4.54	4.54	5.33
2000	1963	196	14	1977	4.55	4.55	5.34	0.53	5.07	5.07	5.86
2001	2445	245	17	2462	5.66	5.66	6.65	0	5.66	5.66	6.65
2002	3155	515	36	3191	7.34	8.62	8.62	0	7.34	8.62	8.62
2003	3074	734	51	3125	7.19	8.44	8.44	0	7.19	8.44	8.44
2004	3352	1041	73	3425	7.88	9.25	9.25	0.06	7.94	9.31	9.31
2005	4089	1036	73	4162	9.57	11.24	11.24	0.03	9.6	11.27	11.27
2006	2652	643	45	2697	6.2	7.28	7.28	0	6.21	7.29	7.29
2007	2451	778	54	2506	5.76	6.77	6.77	0.18	5.94	6.94	6.94
2008	2032	594	42	2073	4.77	5.6	5.6	0.01	4.78	5.61	5.61
2009	3107	615	43	3150	7.24	8.5	8.5	0	7.25	8.51	8.51
2010	3103	958	67	3170	7.29	8.56	8.56	0.01	7.3	8.57	8.57
2011	3682	994	70	3752	8.63	10.13	10.13	0.03	8.66	10.16	10.16
2012	2900	865	61	2961	6.81	7.99	7.99	0.12	6.93	8.11	8.11
2013	2477	962	67	2545	5.85	6.87	6.87	0	5.86	6.87	6.87
2014	2166	1527	107	2273	5.23	6.14	6.14	0.03	5.26	6.17	6.17
2015	2038	1107	77	2115	4.86	5.71	5.71	0	4.86	5.71	5.71
2016	1897	1244	87	1984	4.56	5.36	5.36	0.01	4.58	5.37	5.37
2017	2616	1485	104	2719	6.25	7.34	7.34	0	6.25	7.34	7.34

2018	1850	1599	112	1962	4.51	5.3	5.3	0	4.51	5.3	5.3
2019			0	0					4.6	4.6	4.6
2020			0	0					4.5	4.5	4.5

Assumes discard rate of 10%.

Assumes death rate of 7%.

1 Average weights assumed 2.3 kg for all years

2 Average weights assumed 2.3 (1963-2002) and 2.7 kg (2003-2018)

3 Average weights assumed 2.7 kg for all years

Harvest specifications ACLs

Table 12. SCS model length sample sizes and number of trips sampled by fleet.

	Commercial Live		Recreational Shore		Recreational Boat	
Year	Trips	Lengths	Trips	Lengths	Trips	Lengths
1975					32	79
1976					63	96
1977					44	76
1978					51	101
1979						
1980			13	7	73	189
1981			2	2	39	57
1982			2	4	33	54
1983			2	6	47	61
1984			2	10	42	61
1985			2	6	25	39
1986			2	1	93	138
1987			2	10	83	130
1988			2	1	54	88
1989			2	14	89	133
1990						
1991						
1992						
1993			2	1	12	17
1994					18	25
1995						
1996			2	3	22	34
1997			1	2	13	13
1998			5	10	18	31
1999			9	16	28	50
2000			4	14	10	13
2001			3	5	7	8
2002	122	200	3	4	29	34

2003	56	260	3	3	75	188
2004			8	8	112	203
2005	32	32	9	12	103	158
2006	68	68	6	7	94	128
2007			2	2	83	104
2008	226	301	5	5	66	76
2009	118	145	2	2	60	80
2010	186	309	7	11	49	68
2011	100	255	2	3	63	78
2012	212	491	7	7	79	98
2013	152	311	4	4	101	124
2014	78	134	2	2	67	87
2015	306	524			19	21
2016	240	636	4	6	17	21
2017	198	353			6	6
2018	24	100	1	1	5	5

Table 13. NCS model length sample sizes and number of trips sampled by fleet.

	Commercial Dead		Commercial Live		Recreational Shore		Recreational Boat		CCFRP	
Year	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths
1980					62	91	51	81		
1981					55	95	29	59		
1982					65	89	27	38		
1983					77	144	32	50		
1984					47	57	43	86		
1985					52	84	34	56		
1986					58	95	60	107		
1987					44	59	42	91		
1988					29	51	52	135		
1989					16	25	52	141		
1990							6	11		
1991							13	18		
1992							16	30		
1993	60	91			60	97	97	179		
1994	18	18			20	30	59	110		
1995	412	3639					18	37		
1996	3392	3739			49	85	103	254		
1997	1563	5766	245	13248	30	69	74	138		
1998	511	4084	2179	123379	32	70	89	153		
1999	130	2398	2828	71145	23	47	55	74		
2000	107	2563	4324	66687	15	21	44	63		
2001			2149	2964	15	29	46	118		
2002			472	677	14	24	21	43		
2003			110	185	8	15	107	206		
2004			456	827	26	38	340	531		
2005			226	226	32	39	661	933		
2006			371	371	11	14	582	756		
2007			566	622	15	15	452	597	17	19

2008	286	286	26	29	406	548	25	28
2009	252	252	34	38	531	728	17	22
2010	374	391	17	18	410	591	12	18
2011	196	196	18	20	527	794	29	39
2012	282	282	33	43	519	743	21	25
2013	52	52	27	36	554	754	17	18
2014	32	32	11	13	614	888	22	27
2015	312	485	40	57	930	1378	17	31
2016	314	408	39	53	742	1031	28	35
2017	174	175	34	46	639	890	40	56
2018	186	186	14	17	589	854	15	29

Table 14. Oregon length sample sizes and number of trips sampled by fleet. These data only include direct measurements. Interviews are substituted for trips with recreational data from 1980 - 2000.

Year	Commercial		Recreational Ocean		Recreational Shore	
	Trips	Lengths	Trips	Lengths	Trips	Lengths
1980			14	18	47	69
1981			22	31	30	44
1982			27	46	31	40
1983			17	26	25	33
1984			31	59	22	27
1985			45	84	50	64
1986			30	65	59	71
1987			43	98	32	51
1988			79	136	33	50
1989			35	73	17	22
1993			59	86	52	83
1994			57	81	41	56
1996			42	63	25	29
1997			74	144	35	42
1998	5	57	112	189	9	12
1999	7	40	121	187	9	10
2000	178	802	77	139	15	17
2001	261	1228	420	520	13	17
2002	336	1295	1003	1257	21	26
2003	110	777	788	1196	10	12
2004	142	776	677	1020	1	1
2005	88	599	882	1480	1	1
2006	130	595	894	1595	2	3
2007	127	813	835	1510		
2008	185	400	1193	1898	2	2
2009	96	415	1403	1965		
2010	160	778	1186	1670		
2011	197	841	875	1400	1	1
2012	154	665	749	1279	1	1
2013	160	601	508	915		
2014	161	678	378	640		
2015	156	606	333	690		
2016	150	751	431	880		
2017	157	944	674	1163	1	2
2018	124	742	503	893	1	1

Table 15. Oregon age samples by gender and fleet. ODFW special samples include samples collected outside regular sampling protocols from both the commercial and recreational fisheries.

Year	Commercial			Recreational			Research Projects		
	Female	Male	Unknown	Female	Male	Unknown	Female	Male	Unknown
1999							6	5	
2000							2	2	
2001							16	35	1
2003	2	5	1						
2004							1		
2005				28	40		4		
2006				117	195	1			
2007		1		63	114				
2008		1		157	168	2		1	
2009	14	6		191	230	2			
2010	6	3		2	4				
2011	22	11		104	223	2			
2012	18	22	3	1	4				1
2013	9	14	1	44	103	1			
2014	11	17	1	39	32				
2015	9	7		45	46	1			7
2016	27	25	4	54	64				12
2017	34	31	3	58	77	1			
2018	34	23	2	58	57		8	11	
TOTAL	186	166	15	961	1357	10	37	54	21

Table 16. **Model selection summary across representative candidate models evaluated for the CPFV indices for the NCS and SCS assessments. Chosen models are shaded and bolded.**

	AIC			ΔAIC		
Model	Binomial	Lognormal	Gamma	Binomial	Lognormal	Gamma
NCS CPFV						
Yr	21097	-41134	-39331	1135	1285	1552
Yr+Loc	20305	-42193	-40530	343	226	353
Yr+Mo	20844	-41305	-39724	882	1114	1159
Yr+Mo+Loc	***19962***	***-42419***	**-40883**	**0**	**0**	**0**
SCS CPFV						
Yr	15416	-39359	-37549	1061	1036	1405
Yr+Loc	14961	-40205	-38643	606	190	311
Yr+Mo	14864	-39509	-37847	509	886	1107
Yr+Mo+Loc	***14355***	***-40395***	**-38954**	0	0	0

Table 17. Oregon commercial logbook data filtering criteria and resulting sample sizes.

Filter	**Criteria**	**Total Records**	**# positive**	**% positive**
All Data	Full data set aggregated to trip	31,892	18,125	56.8
Depth min	Ensure depth ≥ 1 fathom	29,638	16,996	57.3
Fishermen	Ensure fishermen > 0	29,245	16,798	57.4
Gear ID	Gear ID is present	28,934	16,713	57.8
Secondary Gear ID	Secondary Gear ID is present	27,803	15,998	57.5
Gear	Hook and line gear using jigs only	22,730	13,401	59
Port	Port Orford south only	16,910	11,867	70.2
Depth max	Ensure depth ≤ 30 fathoms	16,890	11,859	70.2
CPUE outliers	Remove outlier values	16,244	11,288	69.4
Permit type	Nearshore endorsed vessels only	13,905	10,468	75.3
Vessel	Vessel fished at least 3 years	13,327	10,088	75.7

Table 18. Model selection summary across representative candidate models evaluated for the Oregon commercial logbook index. Final models used for index development are shaded.

Model	Binomial		Positive (lognormal)	
(delta-GLM)	AIC	delta AIC	AIC	delta AIC
YEAR	14514	743	28794	2436
YEAR+PORT	14010	239	28618	2260
YEAR+SEASON	14377	606	28757	2399
YEAR+MONTH	14328	557	28736	2378
YEAR+PEOPLE	14383	612	28392	2034
YEAR+LIMIT	14508	737	28795	2437
YEAR+TARGET	14379	608	28718	2360
YEAR+VESSEL	-	-	26758	400
YEAR+MONTH+PORT+PEOPLE+LIMIT+TARGET	13771	0	28151	1793
YEAR+MONTH+PORT+VESSEL+PEOPLE+TARGET	-	-	26358	0
YEAR+SEASON+PORT+VESSEL+PEOPLE+TARGET	13810	39	26386	28

Note: Vessel was removed from consideration within the binomial model due to extremely high estimated standard and widely dissimilar inference using AIC versus BIC model selection criteria

Table 19. Model-based abundance indices for Oregon Cabezon from the four fishery-dependent CPUE data sources.

	MRFSS Dockside		ORBS Dockside		Onboard Observer		Logbook	
Year	Mean	logSD	Mean	logSD	Mean	logSD	Mean	logSD
1980	0.86	0.162	-	-	-	-	-	-
1981	0.88	0.162	-	-	-	-	-	-
1982	0.93	0.162	-	-	-	-	-	-
1983	0.82	0.162	-	-	-	-	-	-
1984	0.83	0.162	-	-	-	-	-	-
1985	0.84	0.162	-	-	-	-	-	-
1986	0.82	0.162	-	-	-	-	-	-
1987	0.85	0.162	-	-	-	-	-	-
1988	0.83	0.162	-	-	-	-	-	-
1989	0.82	0.162	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-
1993	0.81	0.162	-	-	-	-	-	-
1994	0.81	0.162	-	-	-	-	-	-
1995	0.79	0.162	-	-	-	-	-	-
1996	0.80	0.162	-	-	-	-	-	-
1997	0.81	0.162	-	-	-	-	-	-
1998	0.79	0.162	-	-	-	-	-	-
1999	0.80	0.162	-	-	-	-	-	-
2000	0.80	0.162	-	-	-	-	-	-
2001	-	-	0.81	0.071	-	-	-	-
2002	-	-	0.84	0.061	0.85	0.177	-	-
2003	-	-	0.80	0.076	0.93	0.155	-	-
2004	-	-	0.84	0.063	0.90	0.161	4.05	0.209
2005	-	-	0.90	0.048	1.06	0.156	4.36	0.215
2006	-	-	0.87	0.053	0.99	0.148	3.30	0.199
2007	-	-	0.89	0.049	0.93	0.139	3.17	0.201
2008	-	-	0.85	0.059	1.02	0.143	3.12	0.203
2009	-	-	0.84	0.063	1.04	0.161	2.73	0.195
2010	-	-	0.87	0.056	1.18	0.153	2.80	0.187
2011	-	-	0.81	0.072	1.03	0.140	3.17	0.195
2012	-	-	0.77	0.083	1.02	0.155	3.30	0.199
2013	-	-	0.73	0.094	0.98	0.184	2.69	0.188
2014	-	-	0.74	0.093	0.81	0.222	2.59	0.186
2015	-	-	0.82	0.068	1.17	0.188	2.56	0.190
2016	-	-	0.97	0.025	1.25	0.168	2.60	0.185
2017	-	-	0.89	0.047	0.96	0.162	3.24	0.201
2018	-	-	0.78	0.079	1.42	0.145	4.08	0.210

Table 20. Oregon MRFSS recreational dockside index data filtering criteria and resulting sample sizes.

Filter	Criteria	Total Records	# positive	% positive
Full Data set	All data	1831	627	34.24
Trip - species assoc.	Apply Stephens & MacCall method to remove non-associated trips	872	627	71.90
Year 2003	Remove year 2003 due to low sample size	862	621	72.04
Year 2002 and 2001	Remove years post bag limit change from 15 to 10	722	533	73.82
High catch rate	Remove outlier catch rates	721	532	73.79
County	Remove counties with little data	718	530	73.82

Table 21. Model selection summary across representative candidate models evaluated for the Oregon MRFSS dockside index. Final models used for index development are shaded.

Model	Binomial		Positive (lognormal)	
(delta-GLM)	AIC	delta AIC	AIC	delta AIC
YEAR	828	0	1258	6
YEAR+WAVE	836	8	1252	0
YEAR+SEASON	832	4	1255	3
YEAR+BIANNUAL	830	2	1258	6
YEAR+SUBREGION	829	1	1260	8
INTERCEPT	828	0	1323	71
YEAR+BIYEAR+YEAR:BIYEAR	849	21	1275	23
YEAR+SUBREGION+YEAR:SUBREGION	836	8	1262	10
YEAR+WAVE+SUBREGION	837	9	1254	2
YEAR+WAVE+YEAR:WAVE	-	-	1315	63

Table 22. Oregon ORBS recreational dockside index data filtering criteria and resulting sample sizes.

Filter	Criteria	Total Records	# positive	% positive
Full Data set	All data	659773	22017	3.34
Trip Type	Retain only Trips targeting bottomfish	152328	19073	12.52
Ocean Estuary	Remove estuary trips	147719	18913	12.80
Trip Hours	Remove trips > 12 hours in duration	147577	18902	12.81
Trip Hours	Remove trips < 1 hour in duration	145739	18865	12.94
Interview Time	Remove trips with misreported interview time	124045	16357	13.19
Bar to Reef Distance	Remove trip with BartoReefDist >=30 miles	95424	15889	16.65
Species Composition	Apply Stephens & MacCall method to remove non-associated trips	26070	15889	60.95
Season	Remove trips that occurred during the closed season	21271	15664	73.64
Bag Limit	Remove trips that have catches that equal or exceed the bag limit per angler	20421	14814	72.54
Effort	Remove unrealistic effort reporting	20413	14810	72.55
Catch Rate	Remove questionable catch rate (above 99.9% quantile)	20392	14789	72.52
Observed Trips	Remove trips that were observed and were used for the Onboard Observer Index	18773	13547	72.16

Table 23. Model selection summary across representative candidate models evaluated for the Oregon ORBS dockside index. Final models used for index development are shaded.

Model	Binomial		Positive (lognormal)	
(delta-GLM)	AIC	delta AIC	AIC	delta AIC
YEAR	21825	189	35207	5664
YEAR+SUBREGION	21800	164	35022	5479
YEAR+SEASON	21827	191	35203	5660
YEAR+MONTH	21790	154	35155	5612
YEAR+BOAT TYPE	21760	124	29828	285
YEAR+MONTH+BOAT TYPE	21728	92	29755	212
YEAR+MONTH+BOAT TYPE+SUBREGION	21659	23	29583	40
YEAR+MONTH+BOAT TYPE+SUBREGION + YEAR:SUBREGION	21636	0	29543	0

Table 24. Oregon onboard observer recreational index data filtering criteria and resulting sample sizes.

Filter	Criteria	Total Records	# positive	% positive
Full Data set	All data	15576	823	5.28
Reefs	Remove offshore reefs deeper than 40 fm	15267	823	5.39
Time Fishing	Remove drifts in upper and lower 2.5% of drift times	13974	747	5.35
Distance from reefs	Remove drifts >95% quantile (45.6m) distance from reefs	12781	708	5.54
Remove reefs	Remove drifts associated with reefs that have < 10 drifts with Cabezon	11617	674	5.80
Midwater groundfish	Remove drifts where catch was >89% midwater species	7127	657	9.22
Depth	Remove driftsin 10m depth bin > 50m	7005	656	9.36

Table 25. Model selection summary across representative candidate models evaluated for the Oregon onboard observer index. Final models used for index development are shaded.

Model (delta-GLM)	Binomial AIC	Binomial delta AIC	Positive (lognormal) AIC	Positive (lognormal) delta AIC
YEAR	4287	191	1089	21
YEAR+DEPTH	4235	139	1081	13
YEAR+MONTH	4218	122	1079	11
YEAR+REEF	4202	106	1068	0
YEAR+DEPTH+REEF	4096	0	1072	4
YEAR+MONTH+REEF	4140	44	1069	1
YEAR+DEPTH+MONTH+REEF	4103	7	1072	4
YEAR+DEPTH+MONTH+REEF+YEAR:REEF	-	-	1124	56

Table 26. CCFRP index data filtering criteria and resulting sample sizes.

Filter	Criteria	Samples	# positive	% positive
None	All data	5924	303	5%
Latitude	Retain north of 34.4486 latitude	5354	286	5%
Depth	Retain between 25 and 100 feet at 25 ft intervals	4381	239	5%
Month	Retain August or September	3463	202	6%
Site	Retain Año Nuevo, Piedras Blancas, Pt Buchon, Pt Lobos	3323	190	6%

Table 27. Model selection summary across representative candidate models evaluated for the CCFRP index. Final models used for index development are shaded and bolded.

Model	AIC Binomial	AIC Lognormal	AIC Gamma	ΔAIC Binomial	ΔAIC Lognormal	ΔAIC Gamma
Year	1450	-80	-52	47	0	4
Year+Month	1452	-78	-51	49	2	5
Year+Site	1452	-79	-52	49	1	4
Year+Depth	**1403**	**-80**	**-56**	**0**	**0**	**0**
Year+Month+Site	1454	-78	-51	51	2	5
Year+Month+Depth	1405	-78	-55	2	2	1
Year+Site+Depth	1404	-78	-54	1	1	2
Year+Month+Site+Depth	1406	-77	-53	3	3	3

Table 28. **CCFRP index and coefficient of variation (CV) for time series for each positive catch distribution. Gamma was ultimately used in the assessment model.**

	Gamma		Lognormal	
Year	Index	CV	Index	CV
2007	0.013457	36%	0.013465	34%
2008	0.024116	28%	0.024704	27%
2009	0.025001	38%	0.024108	36%
2010	0.026107	34%	0.02363	34%
2011	0.042909	21%	0.044398	21%
2012	0.029373	27%	0.029334	26%
2013	0.018729	28%	0.019761	27%
2014	0.026721	26%	0.026388	26%
2015	0.041041	25%	0.041657	25%
2016	0.038705	21%	0.039684	20%
2017	0.038763	25%	0.038492	24%
2018	0.030897	40%	0.03215	39%

Table 29. Age samples by gender for the NCS model.

Year	Female	Male	Unknown
1991			1
1993			1
1996	34	14	
1997	49	64	
1998	27	32	
1999	5	10	
2000	114	75	6
2001	23	16	9
2002	85	13	
TOTAL	337	224	17

Table 30. Estimated ageing error (standard deviation) when the Oregon ageing lab break and burn (BB) method was assumed unbiased and when it was assumed biased relative to the Oregon ageing lab thin section (TS) method. Ages are shown as midyear values.

Break and Burn Unbiased				Thin Section Unbiased			
Break and Burn		Thin Section		Thin Section		Break and Burn	
Age	SD	Age	SD	Age	SD	Age	SD
0.5	0.18	1.1	0.19	0.5	0	0	0
1.5	0.18	2.1	0.19	1.5	0	0.5	0
2.5	0.36	3.2	0.38	2.5	0.12	1.5	0.15
3.5	0.54	4.3	0.56	3.5	0.29	2.4	0.33
4.5	0.72	5.4	0.75	4.5	0.46	3.3	0.5
5.5	0.9	6.6	0.94	5.5	0.63	4.2	0.66
6.5	1.08	7.7	1.12	6.5	0.8	5.1	0.8
7.5	1.26	9	1.31	7.5	0.96	6	0.95
8.5	1.44	10.2	1.5	8.5	1.11	6.8	1.09
9.5	1.61	11.4	1.69	9.5	1.26	7.6	1.23
10.5	1.79	12.7	1.87	10.5	1.41	8.4	1.37
11.5	1.97	14.1	2.06	11.5	1.55	9.2	1.5
12.5	2.15	15.4	2.25	12.5	1.7	10	1.64
13.5	2.32	16.8	2.43	13.5	1.84	10.7	1.78
14.5	2.49	18.2	2.62	14.5	1.98	11.4	1.91
15.5	2.65	19.6	2.81	15.5	2.12	12.2	2.05
16.5	2.76	21.1	3	16.5	2.27	12.9	2.19
17.5	2.79	22.6	3.18	17.5	2.41	13.5	2.32
18.5	2.61	24.2	3.37	18.5	2.55	14.2	2.46
19.5	1.92	25.8	3.56	19.5	2.69	14.9	2.6
20.5	0.06	27.4	3.75	20.5	2.83	15.5	2.73

Table 31. Annual mean weight (kg) across all available biological samples in Oregon.

Year	Mean Weight
2000	2.051
2001	2.186
2002	2.188
2003	2.527
2004	2.507
2005	2.615
2006	2.718
2007	2.77
2008	2.562
2009	2.455
2010	2.46
2011	2.596
2012	2.702
2013	2.873
2014	2.76
2015	2.996
2016	2.836
2017	2.677
2018	2.644

Table 32. **Input parameters and Methods used in the Natural Mortality tool to estimate the natural mortality priors for each Cabezon stock.**

	SCS		NCS		ORS		WAS	
Input	Female	Male	Female	Male	Female	Male	Female	Male
Parameter								
Longevity	17	17	17	17	17	17	20	18
L_∞	64.72	44.07	64.72	44.07	59.93	52.98	70.89	65.32
k	0.17	0.35	0.17	0.35	0.51	0.65	0.165	0.1571
t_0	-1.74	-1.49	-1.74	-1.49	-0.13	-0.12	-1.616	-2.551
age at maturity	-	-	-	-	3.87	-	-	-
water temp. (C°)	14	14	13	13	13	13	12	12
Method								
Then_Amax 1	0.365	0.365	0.365	0.365	0.365	0.365	0.3144	0.3463
Then_Amax 2	0.301	0.301	0.301	0.301	0.301	0.301	0.2555	0.2838
Then_Amax 3	0.318	0.318	0.318	0.318	0.318	0.318	0.2702	0.3005
Hamel_Amax	0.318	0.318	0.318	0.318	0.318	0.318	0.2700	0.3000
AnC	0.255	0.122	0.255	0.122	0.059	0.030	0.1980	0.2440
Then_VBGF	0.133	0.256	0.133	0.256	0.305	0.379	0.1264	0.1253
Jensen_VBGF 1	0.255	0.525	0.255	0.525	0.765	0.975	0.2475	0.2357
Jensen_VBGF 2	0.272	0.560	0.272	0.560	0.816	1.040	0.2640	0.2514
Pauly_lt	0.344	0.614	0.305	0.545	0.640	0.776	0.2920	0.2890
Chen-Wat	0.235	0.406	0.235	0.406	0.719	0.868	0.2243	0.2084
Roff	NA	NA	NA	NA	0.247	NA	NA	NA
Jensen_Amat	NA	NA	NA	NA	0.426	NA	NA	NA
Ri_Ef_Amat	NA	NA	NA	NA	0.414	NA	NA	NA
User input	0.399	0.399	0.399	0.399	0.399	0.399	NA	NA

Table 33. Years, number of samples and summary statistics for the length compositions considered in the LB-SPR analysis for WA Cabezon.

Year	Samples	Mean length (cm)	CV
2002	83	48.86	14.3%
2003	93	50.05	15.6%
2004	103	49.41	16.7%
2005	212	52.06	16.7%
2006	130	52.76	14.3%
2007	107	49.98	17.7%
2008	49	47.9	20.8%
2009	104	49.82	14.7%
2010	122	49.25	13.5%
2011	157	52.73	14.4%
2012	88	53.08	14.4%
2013	61	54.43	12.9%
2014	207	52.39	14.9%
2015	114	51.61	15.6%
2016	282	53.26	14.0%
2017	440	51.89	13.7%
2018	507	51.62	17.5%

Table 34. **SPR and selectivity estimates from the LB-SPR analysis for the WA sub-stock.**

	SPR		SL50		SL95	
Years	mean	95% CI	mean	95% CI	mean	95% CI
2014	0.62	(0.49 - 0.75)	49.24	(46.39 - 52.09)	57.91	(53.37 - 62.45)
2015	0.67	(0.48 - 0.85)	46.47	(44.01 - 48.93)	53.45	(49.16 - 57.74)
2016	0.63	(0.51 - 0.74)	48.88	(46.46 - 51.3)	57.22	(53.37 - 61.07)
2017	0.48	(0.41 - 0.55)	48.25	(46.37 - 50.13)	57.93	(54.99 - 60.87)
2018	0.67	(0.57 - 0.78)	44.16	(42.75 - 45.57)	52.19	(49.8 - 54.58)

11.2 Model Tables

Table 35. Comparison of OFL values in years 2019 and 2020 derived from DBSRA and SSS using the Ricker Power stock recruit function.

		OFL values					
Model	OFL year	Mean	2.50%	25%	50%	75%	97.50%
DBSRA	2019	5.75	0.02	2.49	4.87	7.88	16.94
SSS Ricker Power	2019	4.19	0.21	1.46	3.59	5.92	12.60
DBSRA	2020	5.68	0.00	2.32	4.81	7.88	17.00
SSS Ricker Power	2020	4.22	0.37	1.80	3.77	5.84	11.69

Table 36. Relative weights used for fitting compositional data in the Oregon reference model.

Data Source	Likelihood Component	Weighting Method	Relative Weight
Commercial live fleet	Lengths	Francis	0.283
Commercial dead fleet	Lengths	Francis	0.479
Recreational ocean fleet	Lengths	Francis	0.085
Recreational shore/estuary fleet	Lengths	Francis	0.346
Commercial dead fleet	Conditional Age-at-Length	Harmonic Mean	0.749
Recreational ocean Fleet	Conditional Age-at-Length	Harmonic Mean	0.318
Research survey	Conditional Age-at-Length	Harmonic Mean	0.395

Table 37. Von Bertalanffy parameter estimates, standard error, and sample sizes for female and male Cabezon in Oregon. Males were parameterized as an offset to females [offset=ln(male/female)].

Parameter	Female Estimate	Female Standard Error	Male Estimate	Male Standard Error
Length at minimum age (0)	0.1	-	0.1	-
Length at Linf	64.42	1.1	57.38	1.2
k (min length to max length)	0.329	0.019	0.391	0.028
CV young	0.346	0.044	0.292	0.068
CV old	0.064	0.011	0.069	0.014

Table 38. Summary of reference points and management quantities for the SCS Cabezon reference case model.

Quantity	Estimate	95% Confidence Interval
Unfished Spawning biomass (female biomass)	205	161–248
Unfished Age 2+ Biomass (mt)	287	233–341
Spawning Biomass (2019, female biomass)	101	19–183
Unfished recruitment (R0, thousands of recruits)	184	77–291
Depletion (2019, % of unfished spawning biomass)	49%	11–87%
Reference points based on SB40%		
Proxy spawning biomass (B40%)	82	65–99
SPR resulting in B40%	0.464	0.464–0.464
Exploitation rate resulting in B40%	0.123	0.101–0.146
Yield at B40% (mt)	17	13–22
Reference points based on SPR proxy for MSY		
Proxy spawning biomass (SPR45%)	79	62–95
SPR45%	0.45	NA
Exploitation rate corresponding to SPR45%	0.129	0.105–0.152
Yield with SPR45% at SBSPR50% (mt)	17	13–22
Reference points based on estimated MSY values		
Spawning biomass at MSY (SBMSY)	56	43–69
SPRMSY	0.353	0.343–0.362
Exploitation rate corresponding to SPRMSY	0.174	0.141–0.208
MSY (mt)	18	14–23

Table 39. Summary of reference points and management quantities for the NCS Cabezon reference case model.

Quantity	Estimate	95% Confidence Interval
Unfished Spawning biomass (female biomass)	986	748–1,225
Unfished Age 2+ Biomass (mt)	1,677	1,305–2,049
Spawning Biomass (2019, female biomass)	643	159–1,126
Unfished recruitment (R0, thousands of recruits)	715	141–1,288
Depletion (2019, % of unfished spawning biomass)	65.15	22.37–107.93
Reference points based on SB40%		
Proxy spawning biomass (B40%)	395	299–490
SPR resulting in B40%	0.464	0.464–0.464
Exploitation rate resulting in B40%	0.133	0.103–0.164
Yield at B40% (mt)	116	67–165
Reference points based on SPR proxy for MSY		
Proxy spawning biomass (SPR45%)	379	287–470
SPR45%	0.45	NA
Exploitation rate corresponding to SPR45%	0.14	0.108–0.171
Yield with SPR45% at SBSPR50% (mt)	118	68–168
Reference points based on estimated MSY values		
Spawning biomass at MSY (SBMSY)	246	179–314
SPRMSY	0.33	0.317–0.344
Exploitation rate corresponding to SPRMSY	0.205	0.154–0.257
MSY (mt)	127	71–183

Table 40. Summary of reference points and management quantities for the Oregon Cabezon reference case model.

Quantity	Estimate	~95% Confidence Interval
Unfished Spawning biomass (female biomass)	335	290.8–379.2
Unfished Age 2+ Biomass (mt)	621	538.1–704.0
Spawning Biomass (2019, female biomass)	177	128.5–225.6
Unfished recruitment (R0, thousands of recruits)	107.6	93.4–121.7
Depletion (2019, % of unfished spawning biomass)	52.84	42.96–62.72
Reference points based on SB40%		
Proxy spawning biomass (B40%)	134	116.3–151.7
SPR resulting in B40%	0.464	0.464–0.464
Exploitation rate resulting in B40%	0.154	0.147–0.161
Yield at B40% (mt)	45.7	39.8–51.7
Reference points based on SPR proxy for MSY		
Proxy spawning biomass (SPR45%)	128.6	111.7–145.6
SPR45%	0.45	NA
Exploitation rate corresponding to SPR45%	0.161	0.154–0.169
Yield with SPR45% at SBSPR50% (mt)	46.4	40.4–52.5
Reference points based on estimated MSY values		
Spawning biomass at MSY (SBMSY)	87.2	76.0–98.4
SPRMSY	0.34	0.335–0.344
Exploitation rate corresponding to SPRMSY	0.233	0.223–0.244
MSY (mt)	49.4	42.9–55.8

Table 41. Projection of Cabezon OFL, catch, biomass, and depletion using the Southern California reference model projected with total projected catch equal to 21.9 and 22.8 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by $F_{SPR=45\%}$. This projection assumes a sigma = 0.5 with a P*=0.40 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	21.9	1	12.9	203.6	100.6	49.2%
2020	22.8	1	12.9	206.3	106.4	52.0%
2021	23.3	0.873	20.4	169.6	110.5	54.0%
2022	22.6	0.864	19.6	170.4	108.0	52.8%
2023	22.0	0.856	18.8	171.1	105.1	51.4%
2024	21.5	0.848	18.2	171.8	102.4	50.0%
2025	21.1	0.84	17.7	172.5	100.2	49.0%
2026	20.8	0.832	17.3	173.2	98.5	48.2%
2027	20.7	0.824	17.0	173.9	97.4	47.6%
2028	20.5	0.817	16.8	174.5	96.6	47.2%
2029	20.5	0.809	16.5	175.3	96.0	46.9%
2030	20.4	0.801	16.3	176.0	95.6	46.8%

Table 42. .Projection of Cabezon OFL, catch, biomass, and depletion using the Southern California reference model projected with total projected catch equal to 21.9 and 22.8 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by $F_{SPR=45\%}$. This projection assumes a sigma = 0.5 with a P*=0.45 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	21.9	1	12.9	203.6	100.6	49.2%
2020	22.8	1	12.9	206.3	106.4	52.0%
2021	23.3	0.935	21.9	164.1	110.5	54.0%
2022	22.5	0.93	21.0	164.5	107.0	52.3%
2023	21.7	0.926	20.1	164.8	103.1	50.4%
2024	21.0	0.922	19.5	165.1	99.6	48.7%
2025	20.5	0.917	18.9	165.5	96.7	47.3%
2026	20.2	0.913	18.5	165.8	94.5	46.2%
2027	19.9	0.909	18.2	166.1	92.8	45.4%
2028	19.7	0.904	17.9	166.5	91.5	44.7%
2029	19.5	0.9	17.7	166.8	90.5	44.3%
2030	19.4	0.896	17.5	167.2	89.8	43.9%

Table 43. Projection of Cabezon OFL, catch, biomass, and depletion using the Northern California reference model projected with total projected catch equal to 194.1 and 197.3 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by $F_{SPR=45\%}$. This projection assumes a sigma = 0.5 with a P*=0.40 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	194.1	1	77.8	1281.6	639.3	65.1%
2020	197.3	1	77.8	1301.7	652.6	66.4%
2021	201.8	0.873	176.2	1312.2	672.5	68.5%
2022	189.5	0.864	163.8	1235.8	627.4	63.9%
2023	178.4	0.856	152.7	1172.1	585.7	59.6%
2024	168.8	0.848	143.1	1121.1	550.7	56.1%
2025	161.2	0.84	135.4	1081.8	523.8	53.3%
2026	155.5	0.832	129.4	1052.1	504.2	51.3%
2027	151.4	0.824	124.7	1029.8	490.2	49.9%
2028	148.4	0.817	121.2	1012.9	480.0	48.9%
2029	146.1	0.809	118.2	999.9	472.5	48.1%
2030	144.4	0.801	115.7	990.0	467.0	47.6%

Table 44. Projection of Cabezon OFL, catch, biomass, and depletion using the Northern California reference model projected with total projected catch equal to 194.1 and 197.3 mt for 2019 and 2020 (average catch from 2011-2018), thereafter with full attainment. The predicted OFL is the calculated total catch determined by $F_{SPR=45\%}$. This projection assumes a sigma = 0.5 with a P*=0.45 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	194.1	1	77.8	1281.6	639.3	65.1%
2020	197.3	1	77.8	1301.7	652.6	66.4%
2021	201.8	0.935	188.7	1312.2	672.5	68.5%
2022	187.6	0.93	174.5	1226.0	620.2	63.1%
2023	175.0	0.926	162.0	1155.1	573.2	58.4%
2024	164.3	0.922	151.5	1098.8	534.3	54.4%
2025	155.9	0.917	143.0	1055.6	504.8	51.4%
2026	149.7	0.913	136.7	1023.0	483.4	49.2%
2027	145.2	0.909	132.0	998.1	467.9	47.6%
2028	141.7	0.904	128.1	978.9	456.4	46.5%
2029	139.2	0.9	125.2	963.8	447.7	45.6%
2030	137.1	0.896	122.9	951.7	440.9	44.9%

Table 45. Projection of Cabezon OFL, catch, biomass, and depletion using the Oregon reference model projected with total projected catch equal to 47.1 mt for 2019 and 2020 (average catch from 2011-2018), thereafter full attainment. The predicted OFL is the calculated total catch determined by FSPR=45% (ABC=ACL). This projection assumes a baseline sigma=0.5 with a P*=0.40 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	60.9	1	47.1	372.5	177.0	0.53
2020	59.5	1	47.1	365.4	173.4	0.52
2021	58.3	0.873	50.9	358.5	169.4	0.51
2022	56.7	0.864	48.9	349.0	163.9	0.49
2023	55.5	0.856	47.5	342.2	159.8	0.48
2024	54.7	0.848	46.4	337.5	157.0	0.47
2025	54.2	0.84	45.5	334.1	155.0	0.46
2026	53.8	0.832	44.8	331.7	153.7	0.46
2027	53.5	0.824	44.1	330.2	152.8	0.46
2028	53.4	0.817	43.6	329.3	152.3	0.45
2029	53.3	0.809	43.1	328.8	152.1	0.45
2030	53.3	0.801	42.7	328.8	152.1	0.45

Table 46. Alternative projection of Cabezon OFL, catch, biomass, and depletion using the Oregon reference model projected with total projected catch equal to 47.1 mt for 2019 and 2020 (average catch from 2011-2018), thereafter full attainment. The predicted OFL is the calculated total catch determined by FSPR=45% (ABC=ACL). This projection assumes a baseline sigma=0.5 with a P*=0.45 for calculating buffers.

Year	Predicted OFL (mt)	ABC Multiplier (1-Buffer)	ABC Catch (mt)	Age 2+ Biomass (mt)	Spawning Biomass (mt)	Depletion (%)
2019	60.9	1	47.1	372.5	177.0	0.53
2020	59.5	1	47.1	365.4	173.4	0.52
2021	58.3	0.935	54.5	358.5	169.4	0.51
2022	56.1	0.93	52.2	345.8	162.0	0.48
2023	54.5	0.926	50.5	336.6	156.5	0.47
2024	53.4	0.922	49.3	329.8	152.4	0.45
2025	52.6	0.917	48.2	324.7	149.5	0.45
2026	52.0	0.913	47.4	320.9	147.3	0.44
2027	51.5	0.909	46.8	318.0	145.7	0.43
2028	51.1	0.904	46.2	315.9	144.5	0.43
2029	50.9	0.9	45.8	314.3	143.6	0.43
2030	50.7	0.896	45.4	313.2	143.0	0.43

Table 47. Decision table summarizing 12-year projections (2019 – 2030) for the Southern California Cabezon substock. The alternative low and high states of nature (columns) are defined by setting natural mortality to achieve 12.5% and 87.5% terminal year spawning biomass values based on the reference model asymptotic variance. Rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2019 and 2020 are allocated to each fleet based on ACL set in the harvest specifications. A sigma of 0.5 was used with a P* of 0.45 to assign yearly buffer multipliers.

			State of Nature					
			Low		Reference		High	
			Female M = 0.18		Female M = 0.26		Female M = 0.35	
Catch stream	Year	Catch (mt)	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
Low state projections	2019	77.81	54	22%	101	49%	143	73%
	2020	77.81	56	23%	101	49%	134	68%
	2021	76.59	58	24%	98	48%	123	62%
	2022	80.39	63	26%	95	47%	112	57%
	2023	82.75	68	28%	92	45%	103	52%
	2024	83.93	72	30%	90	44%	96	49%
	2025	84.33	76	31%	88	43%	92	46%
	2026	84.56	79	33%	86	42%	88	45%
	2027	84.72	82	34%	85	41%	86	44%
	2028	84.78	85	35%	84	41%	84	43%
	2029	84.89	87	36%	83	41%	82	42%
	2030	84.92	89	37%	82	40%	81	41%
Reference model projections	2019	77.81	54	22%	101	49%	143	73%
	2020	77.81	56	23%	106	52%	151	77%
	2021	188.71	58	24%	111	54%	155	79%
	2022	174.46	54	22%	107	52%	149	76%

	2023	162.01	50	21%	103	50%	143	73%
	2024	151.48	47	20%	100	49%	138	70%
	2025	142.99	46	19%	97	47%	135	68%
	2026	136.70	44	18%	94	46%	133	67%
	2027	131.95	43	18%	93	45%	131	66%
	2028	128.14	42	17%	92	45%	130	66%
	2029	125.23	41	17%	91	44%	129	65%
	2030	122.85	40	17%	90	44%	128	65%
High state projections	2019	77.81	54	22%	101	49%	143	73%
	2020	77.81	56	23%	106	52%	151	77%
	2021	424.33	58	24%	111	54%	155	79%
	2022	353.19	43	18%	95	46%	138	70%
	2023	304.02	31	13%	82	40%	124	63%
	2024	270.91	22	9%	73	36%	113	57%
	2025	249.51	15	6%	67	33%	105	53%
	2026	236.17	9	4%	63	31%	100	51%
	2027	227.05	4	2%	60	30%	96	49%
	2028	219.87	0	0%	58	28%	93	47%
	2029	214.26	0	0%	56	27%	91	46%
	2030	209.63	0	0%	54	26%	90	46%

Table 48. Decision table summarizing 12-year projections (2019 – 2030) for the Northern California Cabezon substock. The alternative low and high states of nature (columns) are defined by setting natural mortality to achieve 12.5% and 87.5% terminal year spawning biomass values based on the reference model asymptotic variance. Rows range over different assumptions of total catch levels corresponding to the forecast catches from each state of nature. Catches in 2019 and 2020 are allocated to each fleet based on ACL set in the harvest specifications. A sigma of 0.5 was used with a P* of 0.45 to assign yearly buffer multipliers.

			State of Nature					
			Low		Reference		High	
			Female M = 0.18		Female M = 0.24		Female M = 0.346	
Catch stream	Year	Catch (mt)	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
Low state projections	2019	77.81	352	33%	639	65%	939	91%
	2020	77.81	361	34%	585	60%	752	73%
	2021	76.59	379	36%	554	56%	659	64%
	2022	80.39	395	37%	527	54%	595	58%
	2023	82.75	405	38%	500	51%	544	53%
	2024	83.93	411	39%	476	48%	507	49%
	2025	84.33	414	39%	456	46%	480	46%
	2026	84.56	416	39%	440	45%	461	45%
	2027	84.72	418	40%	428	44%	447	43%
	2028	84.78	421	40%	419	43%	436	42%
	2029	84.89	423	40%	412	42%	428	41%
	2030	84.92	425	40%	406	41%	422	41%
Reference model projections	2019	77.81	352	33%	639	65%	939	91%
	2020	77.81	361	34%	653	66%	945	91%
	2021	188.71	379	36%	673	68%	961	93%
	2022	174.46	336	32%	620	63%	903	87%

	2023	162.01	302	29%	573	58%	849	82%
	2024	151.48	276	26%	534	54%	804	78%
	2025	142.99	258	24%	505	51%	770	75%
	2026	136.70	246	23%	483	49%	747	72%
	2027	131.95	238	23%	468	48%	731	71%
	2028	128.14	232	22%	456	46%	720	70%
	2029	125.23	227	22%	448	46%	712	69%
	2030	122.85	223	21%	441	45%	707	68%
High state projections	2019	77.81	352	33%	639	65%	939	91%
	2020	77.81	401	38%	691	70%	945	91%
	2021	424.33	456	43%	746	76%	961	93%
	2022	353.19	265	25%	550	56%	784	76%
	2023	304.02	135	13%	409	42%	662	64%
	2024	270.91	57	5%	313	32%	584	56%
	2025	249.51	20	2%	249	25%	537	52%
	2026	236.17	15	1%	207	21%	509	49%
	2027	227.05	0	0%	176	18%	491	48%
	2028	219.87	0	0%	148	15%	478	46%
	2029	214.26	0	0%	122	12%	468	45%
	2030	209.63	0	0%	97	10%	460	45%

Table 49. Decision tables summarizing 12-year projections (2019 – 2030) for Oregon Cabezon according to three alternative states of nature based on female natural mortality. Male natural mortality was a consistent offset (0.154) of that for females. 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 2019 and 2020 are allocated to each fleet based on an average total catch (47.1 mt) and proportion of catch by fleet over a recent period (2011-2018) as suggested by the GMT. <u>A sigma of 0.5 was used with a P* of 0.45 to assign buffers for these forecasts.</u>

			State of Nature					
			Low		Reference		High	
			Female M = 0.19		Female M = 0.24		Female M = 0.27	
Catch stream	Year	Catch (mt)	Spawning Biomass	Depletion	Spawning Biomass	Depletion	Spawning Biomass	Depletion
	2019	47.1	146.4	0.42	177.0	0.53	206.1	0.60
	2020	47.1	142.0	0.41	173.4	0.52	202.7	0.59
	2021	34.8	137.4	0.40	169.4	0.51	198.6	0.58
	2022	35.1	138.2	0.40	172.0	0.51	201.0	0.59
	2023	35.2	139.0	0.40	174.6	0.52	203.5	0.60
Low state	2024	35.2	139.7	0.40	177.0	0.53	205.7	0.60
projections	2025	35.1	140.3	0.40	179.2	0.53	207.6	0.61
	2026	35.1	140.8	0.41	181.2	0.54	209.4	0.61
	2027	35.0	141.3	0.41	183.0	0.55	211.0	0.62
	2028	34.9	141.8	0.41	184.8	0.55	212.5	0.62
	2029	34.8	142.3	0.41	186.6	0.56	214.0	0.63
	2030	34.7	142.8	0.41	188.3	0.56	215.4	0.63
	2019	47.1	146.4	0.42	177.0	0.53	206.1	0.60
	2020	47.1	142.0	0.41	173.4	0.52	202.7	0.59
	2021	50.9	137.4	0.40	169.4	0.51	198.6	0.58
	2022	48.9	131.2	0.38	162.0	0.48	192.9	0.56
	2023	47.5	126.5	0.36	156.5	0.47	189.2	0.55
Reference	2024	46.4	123.1	0.35	152.4	0.45	186.9	0.55
model	2025	45.5	120.6	0.35	149.5	0.45	185.6	0.54
projections	2026	44.8	118.9	0.34	147.3	0.44	185.0	0.54
	2027	44.1	117.6	0.34	145.7	0.43	185.0	0.54
	2028	43.6	116.7	0.34	144.5	0.43	185.3	0.54

	2029	43.1	116.1	0.33	143.6	0.43	185.9	0.54
	2030	42.7	115.9	0.33	143.0	0.43	186.8	0.55
High state projections	2019	47.1	146.4	0.42	177.0	0.53	206.1	0.60
	2020	47.1	142.0	0.41	173.4	0.52	202.7	0.59
	2021	65.1	137.4	0.40	169.4	0.51	198.6	0.58
	2022	60.9	123.9	0.36	156.6	0.47	183.5	0.54
	2023	57.9	113.5	0.33	147.4	0.44	172.5	0.50
	2024	55.7	105.7	0.30	141.0	0.42	164.7	0.48
	2025	54.1	99.7	0.29	136.6	0.41	159.3	0.47
	2026	52.8	94.9	0.27	133.6	0.40	155.4	0.46
	2027	51.7	90.9	0.26	131.5	0.39	152.6	0.45
	2028	50.9	87.4	0.25	130.0	0.39	150.4	0.44
	2029	50.1	84.4	0.24	129.2	0.39	148.9	0.44
	2030	49.5	81.8	0.24	128.7	0.38	147.7	0.43

Table 50. Median ABC (Category 3 buffered OFL values) values for five relative stock status (rows) and three catch (columns) scenarios for the Washington Cabezon stock.

Median 2021 OFL

Relative stock status	Low Catch	Base Catch	High Catch
40%	6.7	7.4	8.4
55%	11.7	12.8	14.2
65%	17	18.5	20.3
75%	27.7	30.4	32.9
90%	112.4	122.4	132.3

Median 2022 OFL

Relative stock status	Low Catch	Base Catch	High Catch
40%	6.4	6.9	7.8
55%	10	10.9	12
65%	13.7	15	16.3
75%	21.4	23.4	25.3
90%	87.7	95.9	103.1

Table 51. Ensemble ABC (Category 3 buffered OFL values) estimates for the Washington Cabezon stock using two different model weighting schemes: 1) Equal weighting among all scenarios; 2) Weighted according to the stock status prior and catch weight scenarios.

		OFL values					
Ensemble	OFL year	Mean	2.5%	25.0%	50.0%	75.0%	97.5%
weighted	2021	22.4	6.8	13.1	18.4	26.9	60.7
unweighted	2021	39.3	4.2	10.7	18.3	38.5	190.5
weighted	2022	17.5	6.6	11.3	14.9	20.6	42.8
unweighted	2022	29.6	4.5	9.4	14.9	29.0	130.5

12 Figures

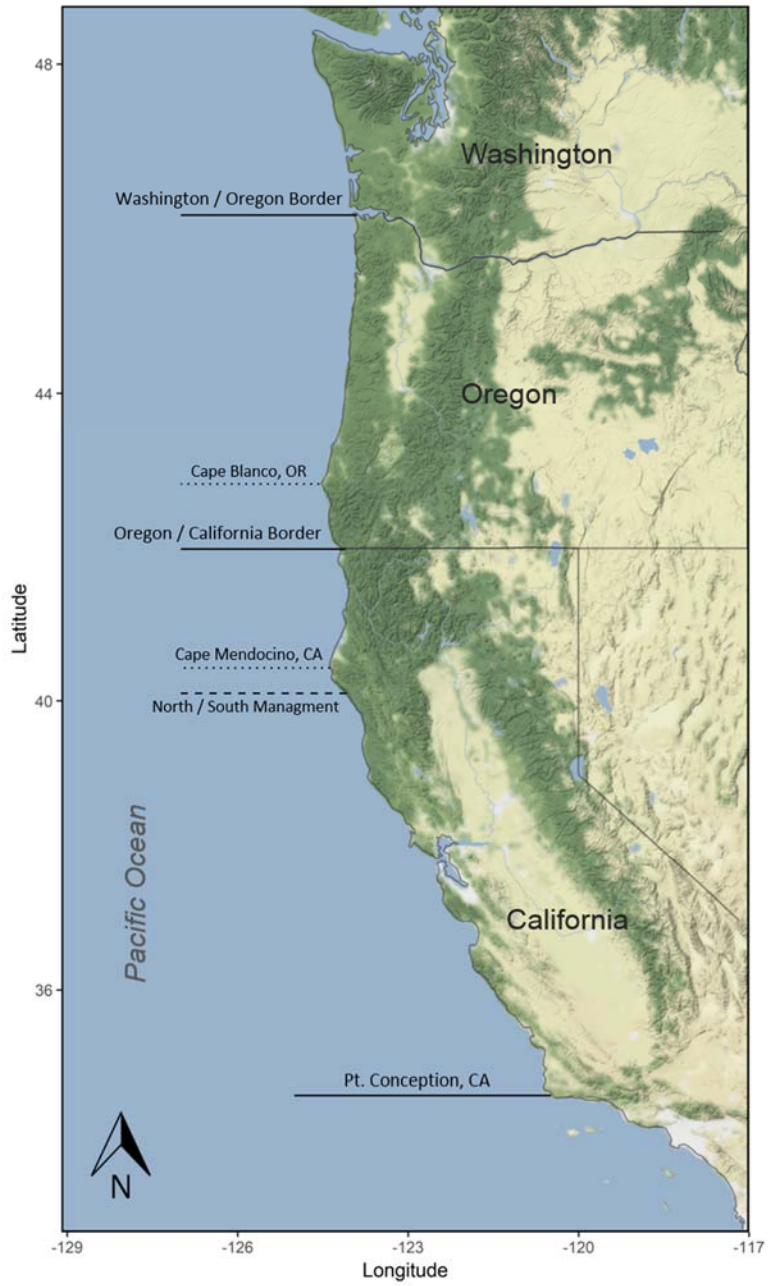


Figure 1. Map of the Cabezon sub-stock assessment areas (represented by solid lines). Two important headlands are distinguished by dotted lines. The North/South management area is shown with the broken line and is also the border between the California Department of Fish and Game's Northern and Central California Marine Management regions. Point Conception divides the Central and Southern Marine Management regions.

12.1 Data Figures

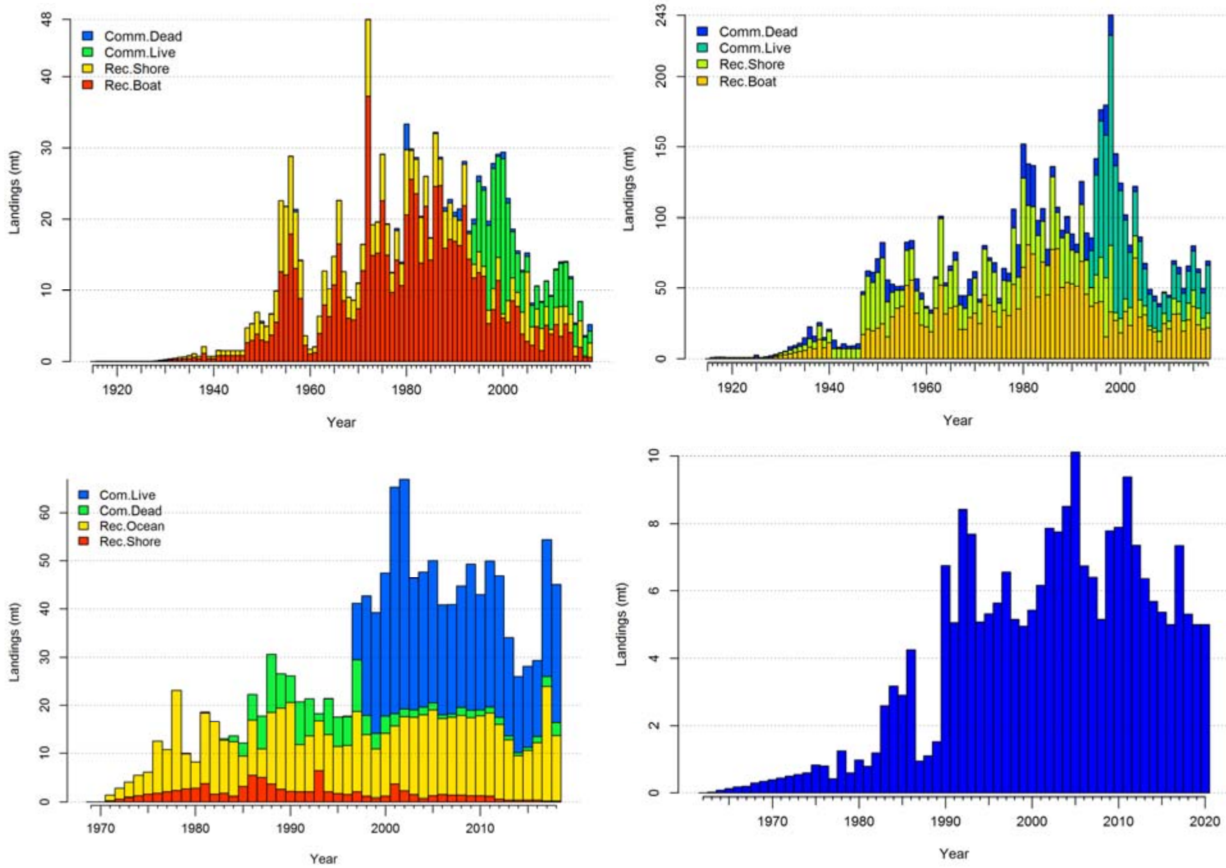
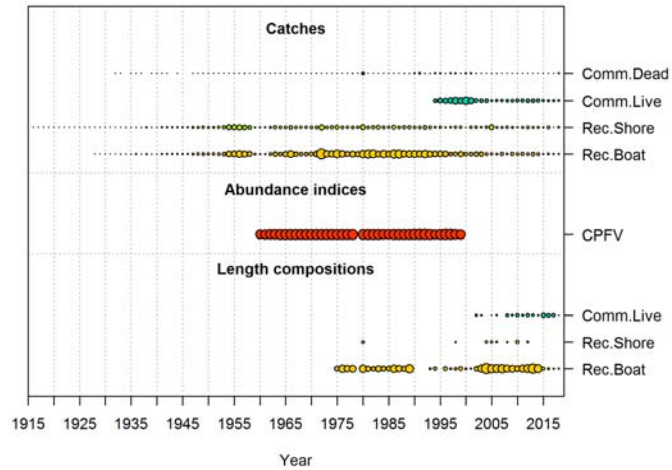
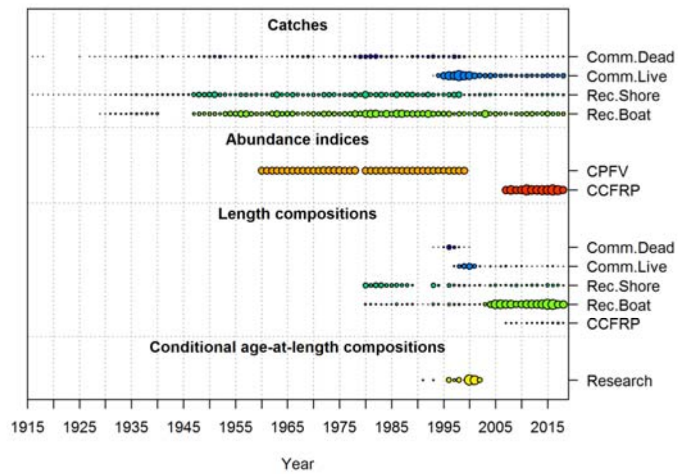


Figure 2. Stacked time series of Cabezon removals (landings + discards in mt) used in the southern California (top left panel), northern California (top right panel), Oregon (bottom left panel) and Washington (bottom right panel, which includes the assumed catch for 2019 and 2020) assessment models.

SCS



NCS



ORS

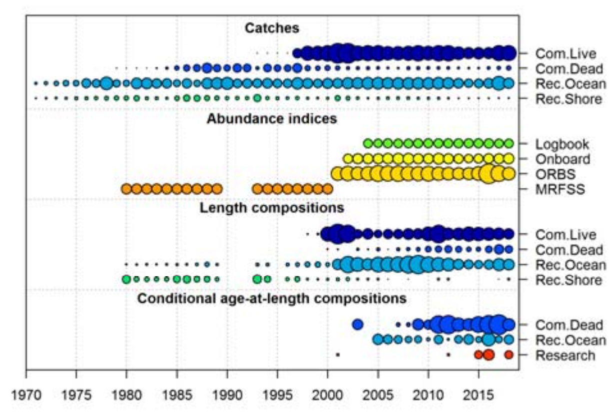


Figure 3. Summary of data types and length of time series used in the SCS, NCS and ORS Cabezon stock assessments. The size of the circles provide a relative indication of sample sizes or total catch.

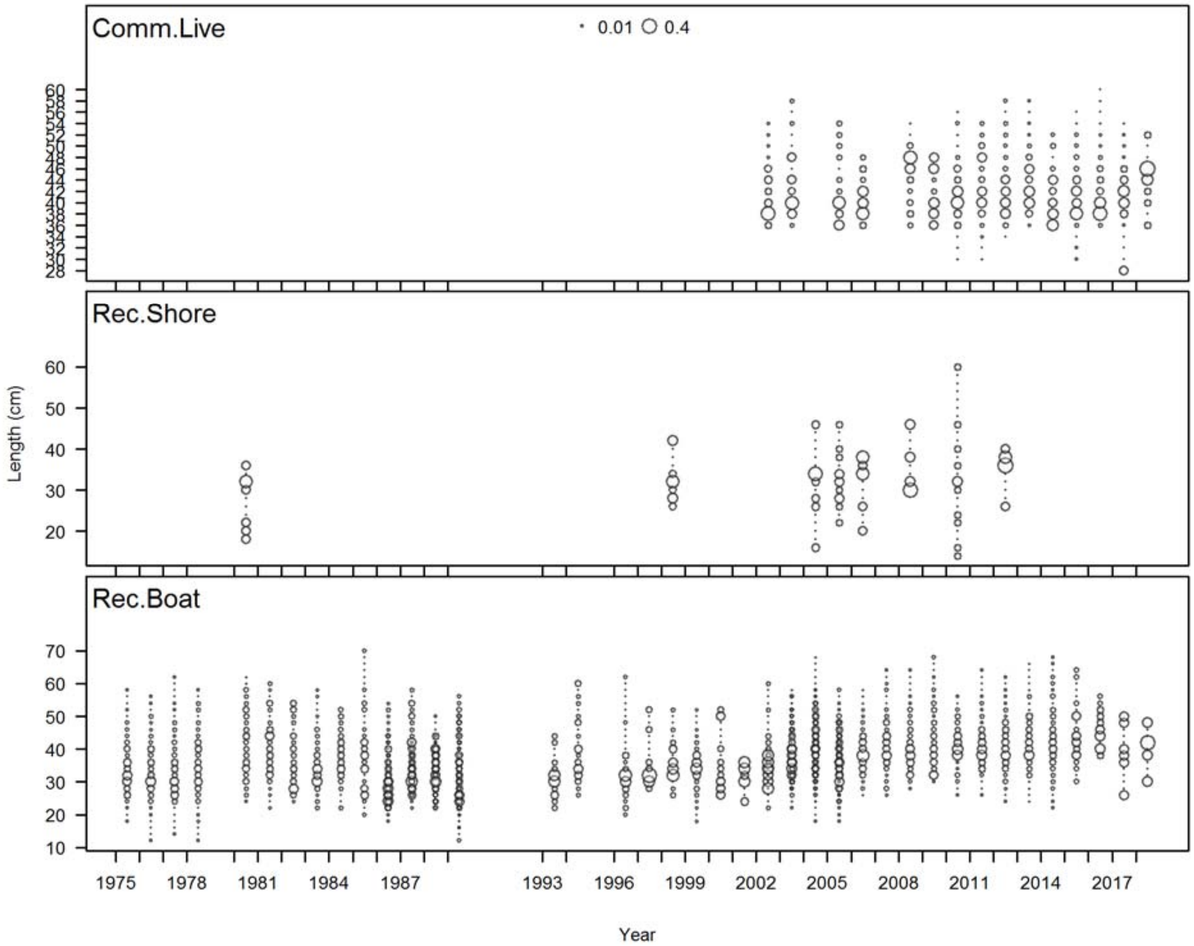


Figure 4. Reference model time-aggregated Cabezon length composition data for all SCS fleets.

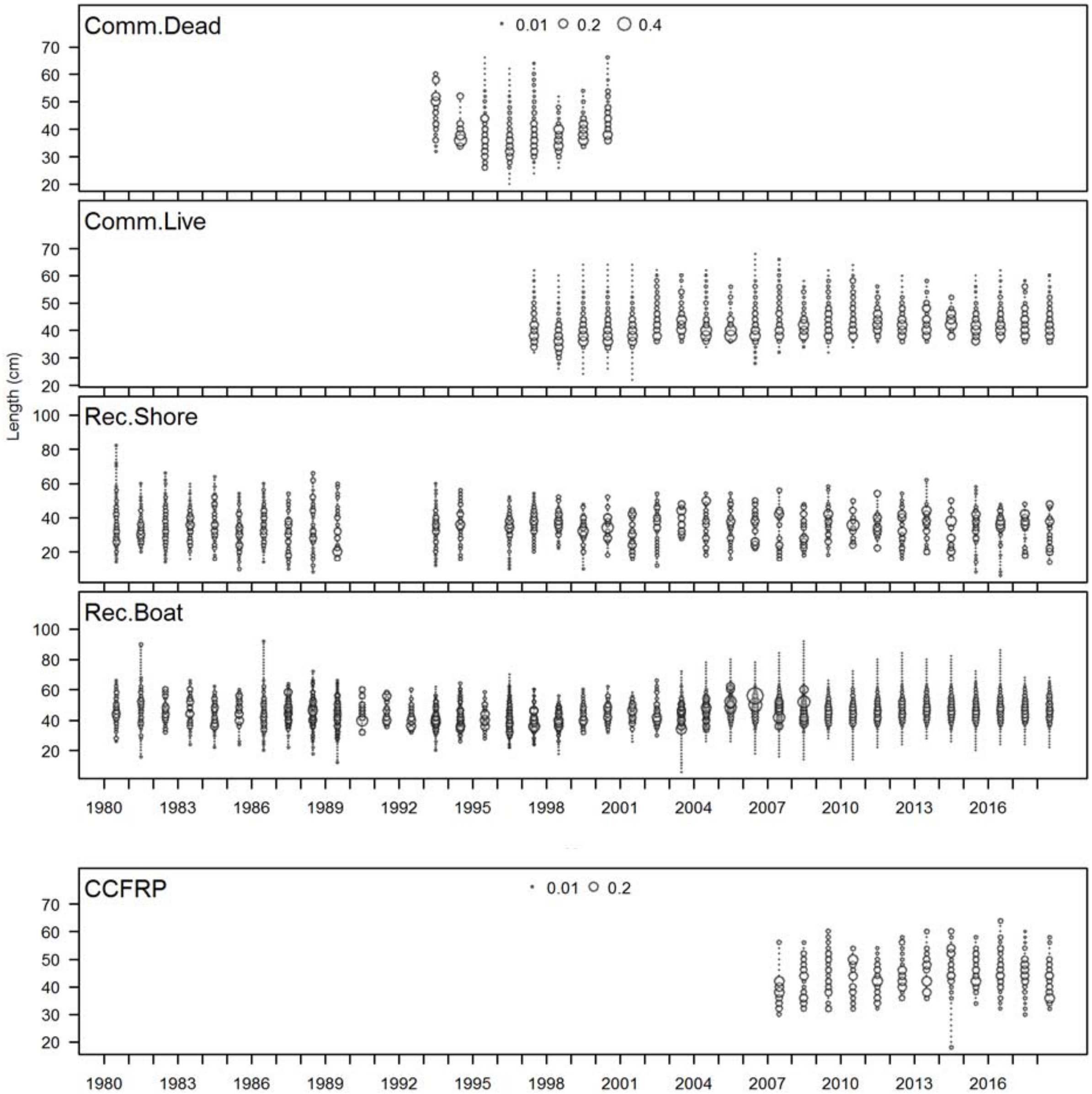


Figure 5. Reference model time-aggregated Cabezon length composition data for all NCS fleets.

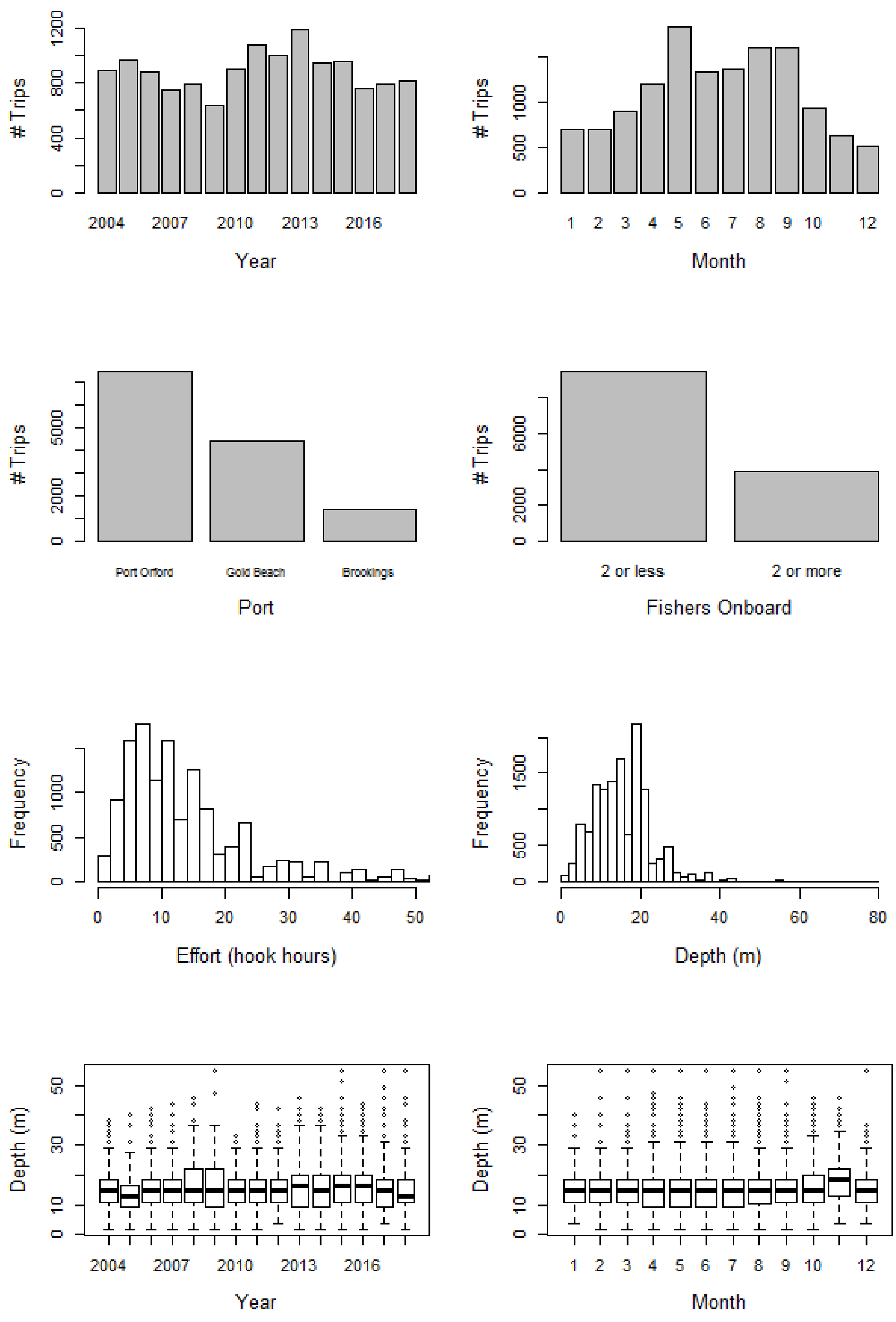


Figure 6. Characterization of the final subset of commercial logbook data used in the delta-GLM analyses to develop an index for Oregon Cabezon.

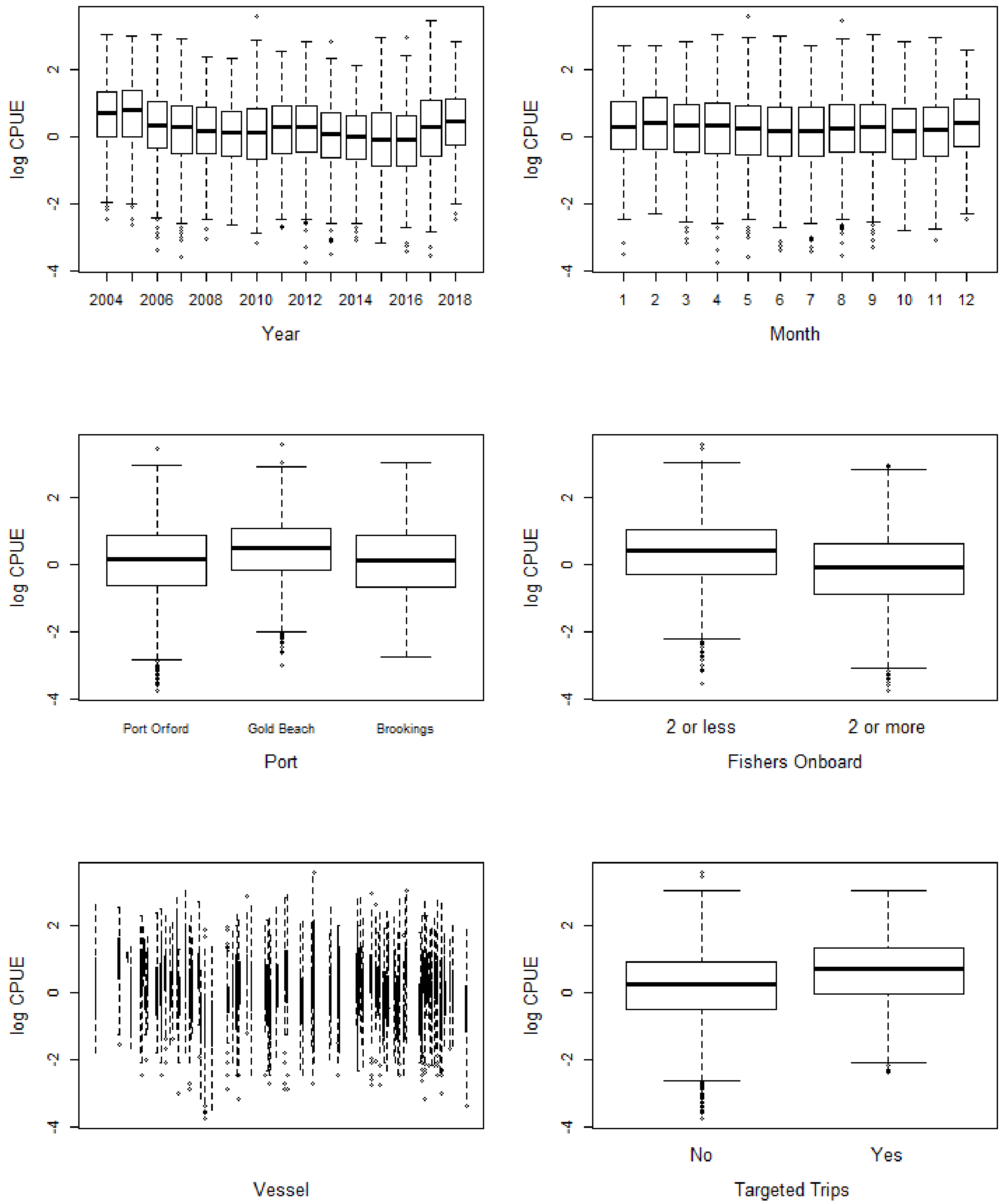


Figure 7. The distribution of set-level raw positive catch CPUE for the commercial logbook data relative to potential covariates evaluated in the Oregon Cabezon delta-GLM analysis.

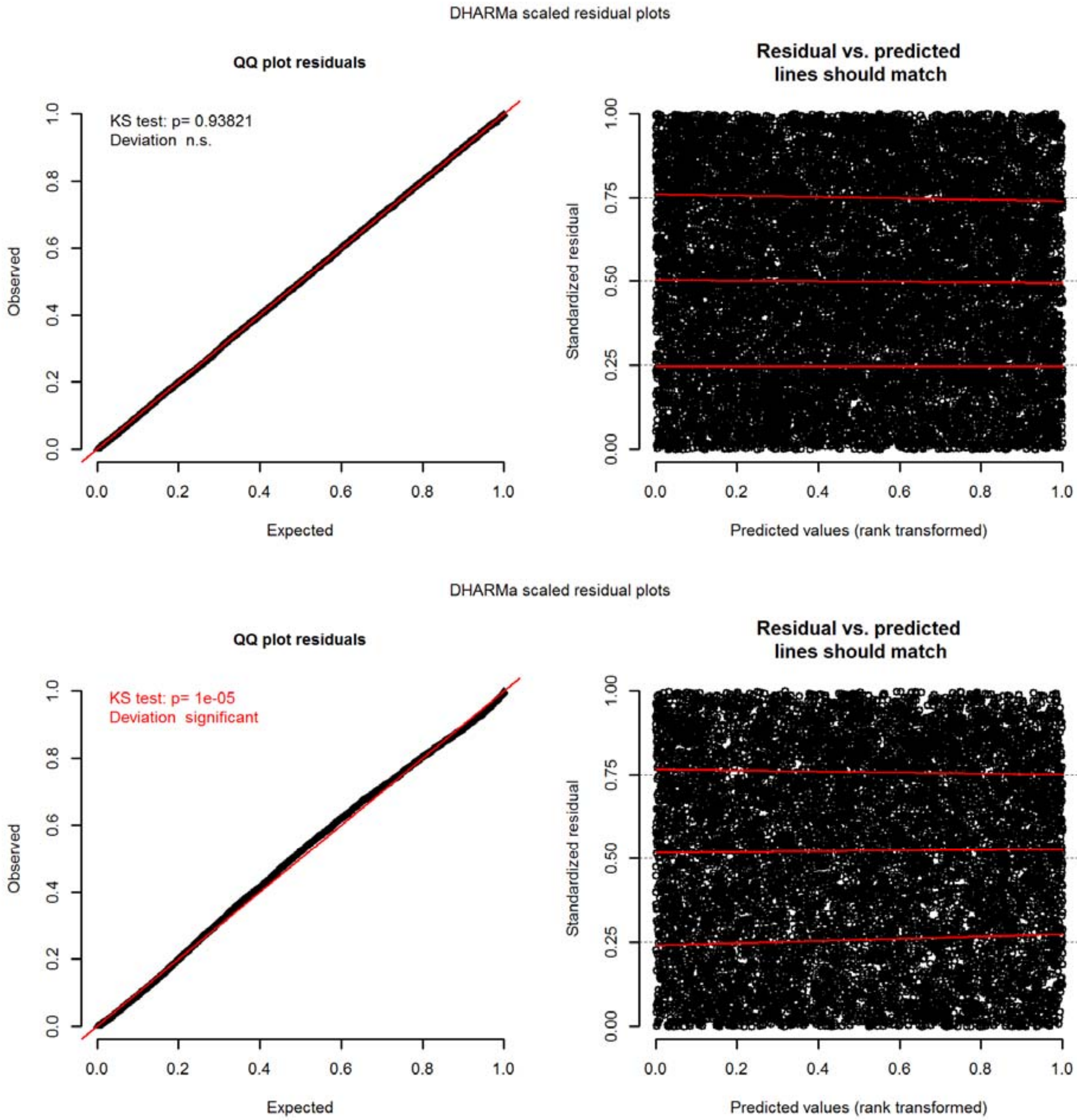


Figure 8. Diagnostic QQ and residual plots for Oregon commercial logbook binomial (top) and positive catch (bottom) model components for the delta-GLM model.

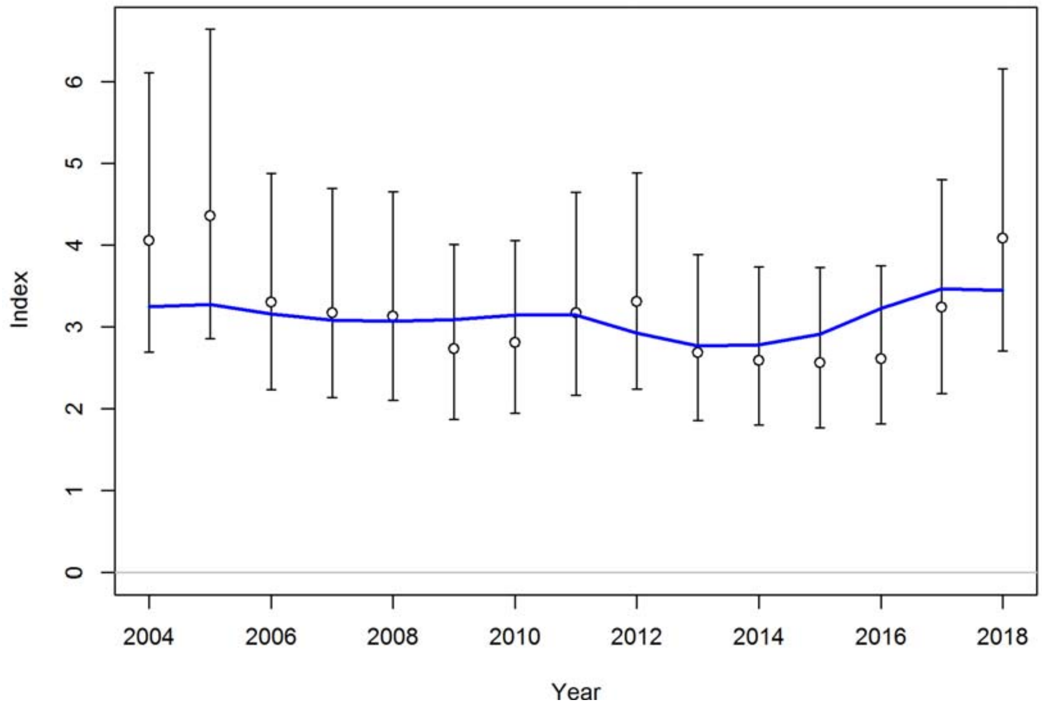


Figure 9. Assessment model fit to the Oregon commercial logbook index.

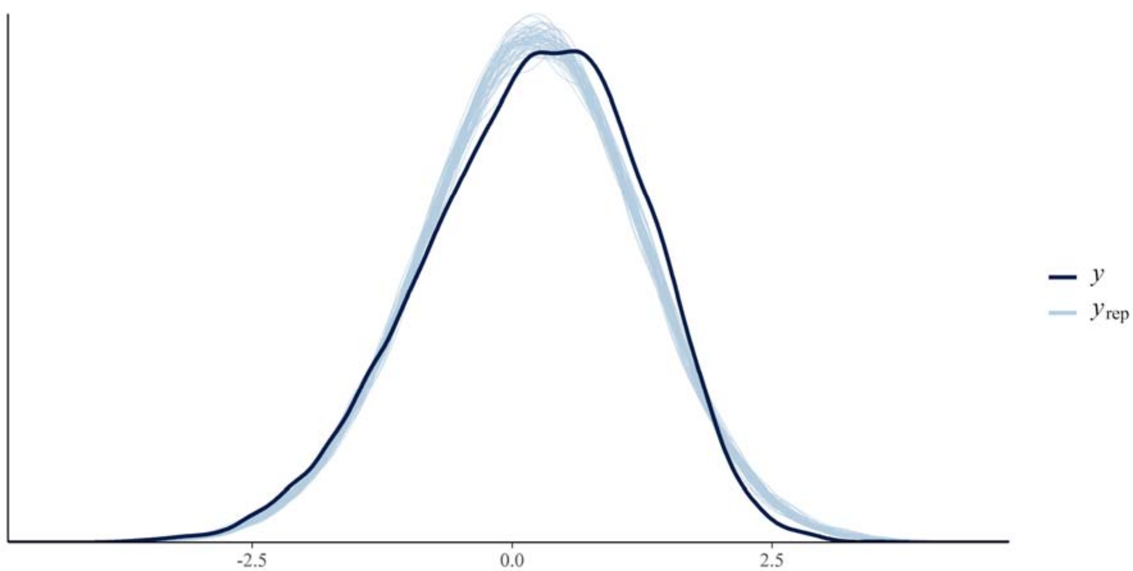


Figure 10. Comparison of data distribution for Oregon commercial logbook CPUE to model-generated replicate data sets used to evaluate uncertainty.

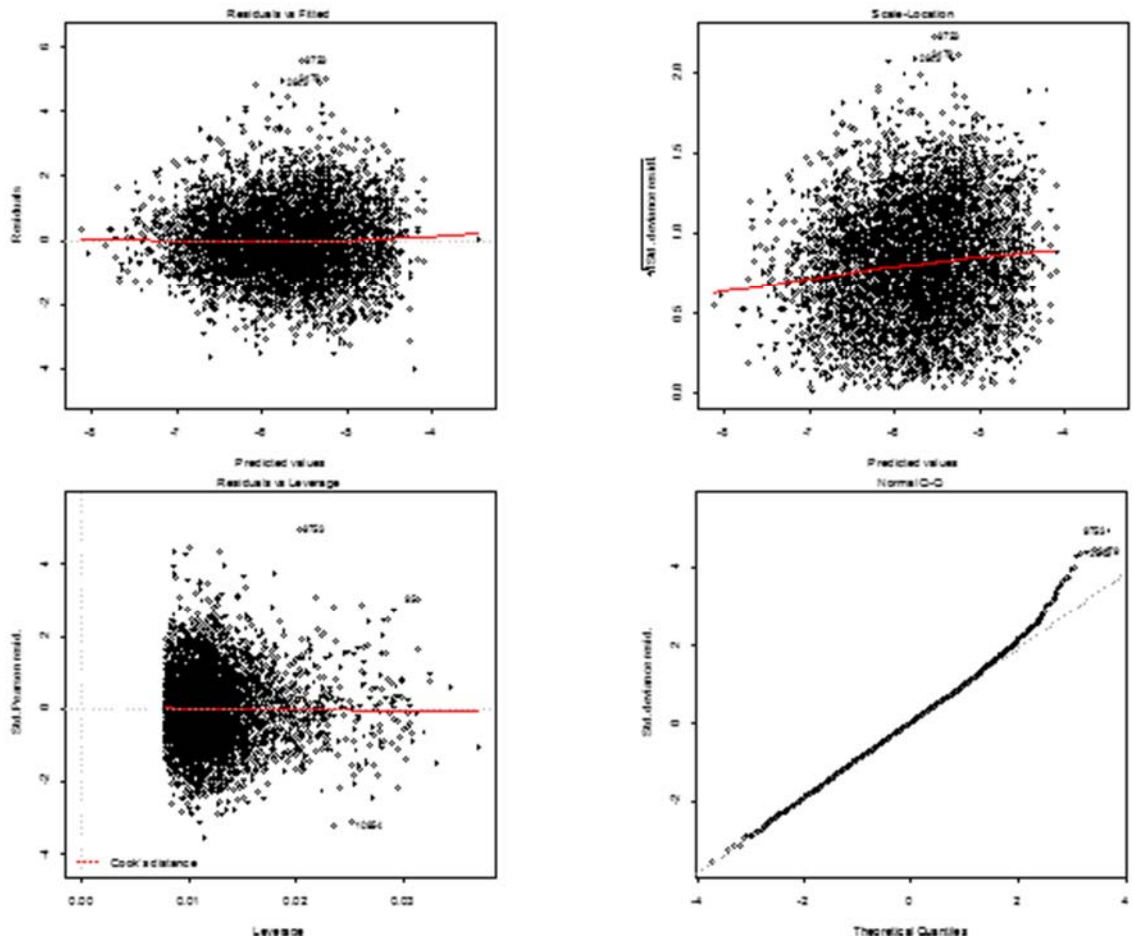


Figure 11. Diagnostic plots of the GLM-fit to the positive records for the NCS CPFV index.

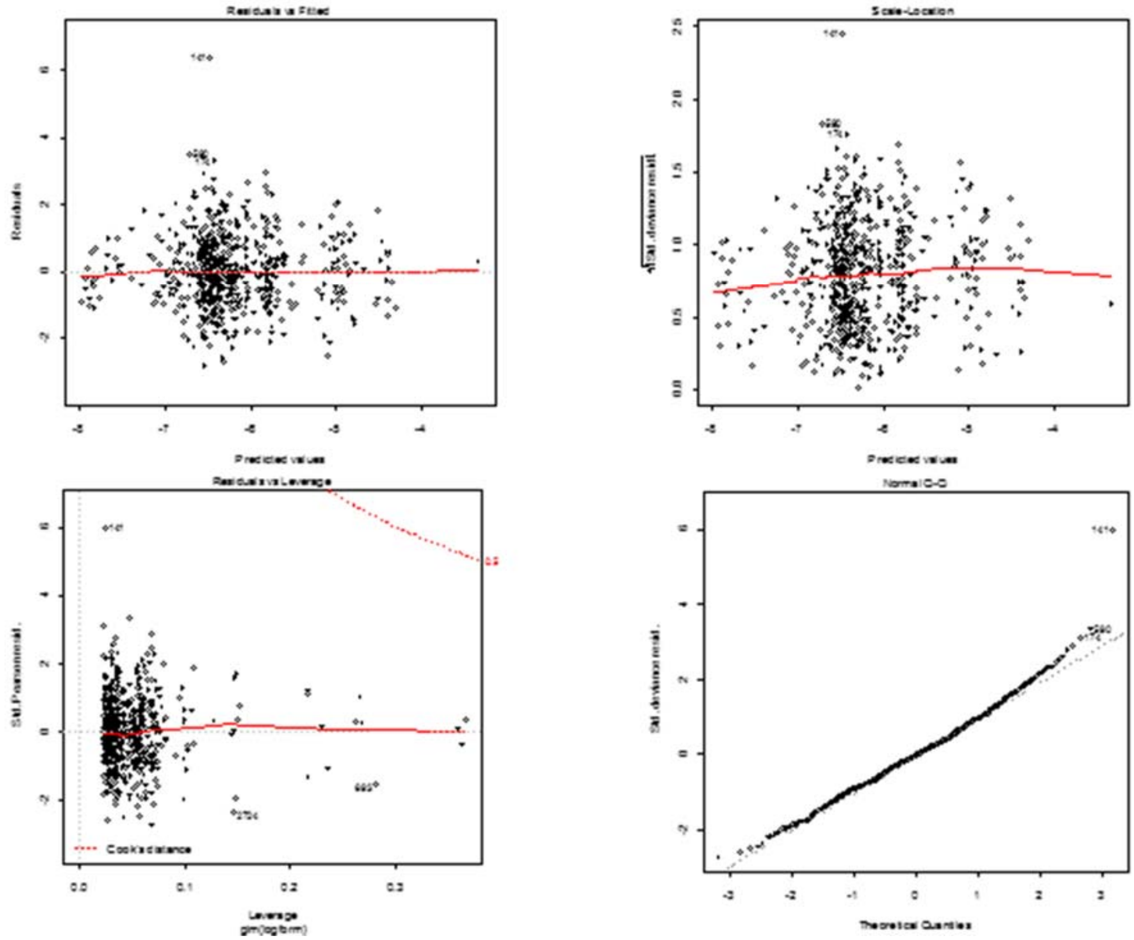


Figure 12. Diagnostic plots of the GLM-fit to the positive records for the SCS CPFV index.

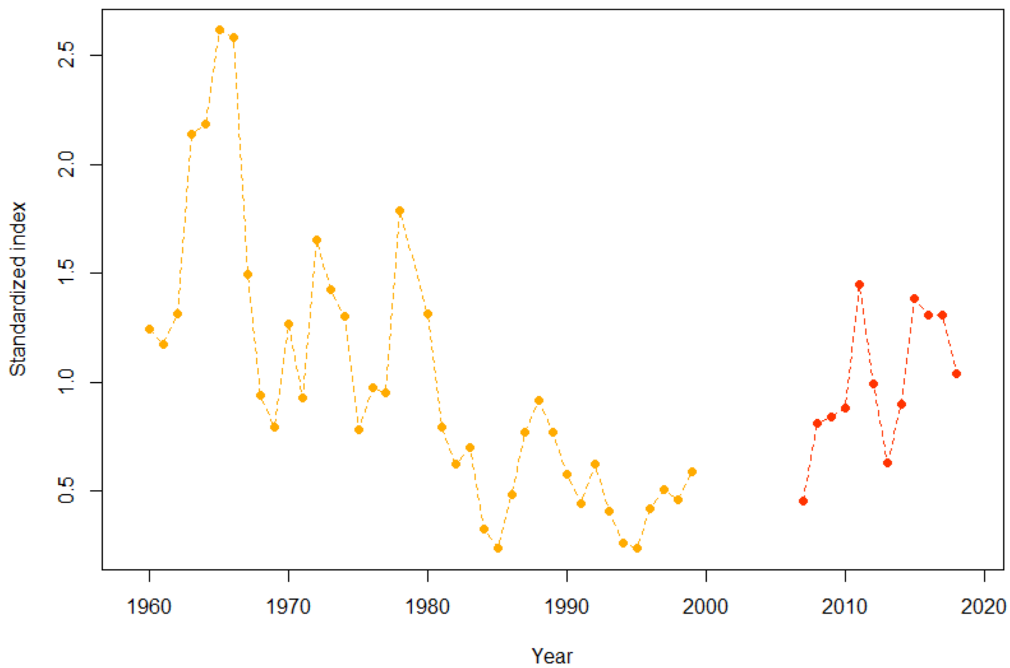


Figure 13. Abundance indices (CPFV 1960-1999 and CCFRP 2007-2018) used in the Cabezon NCS model.

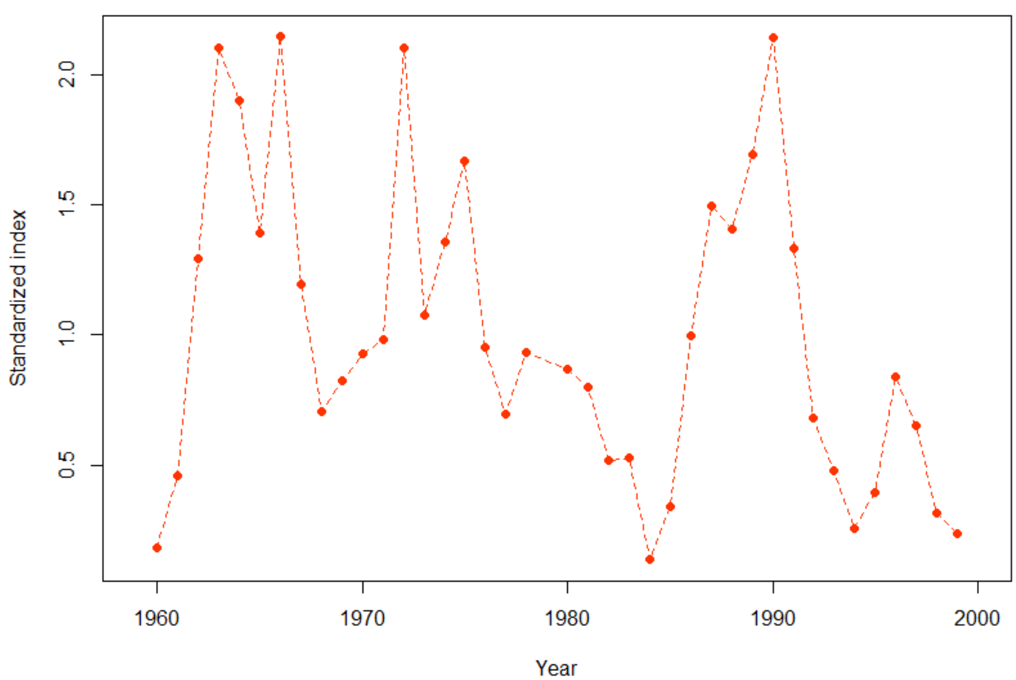


Figure 14. Abundance indices (CPFV 1960-1999) used in the Cabezon SCS model.

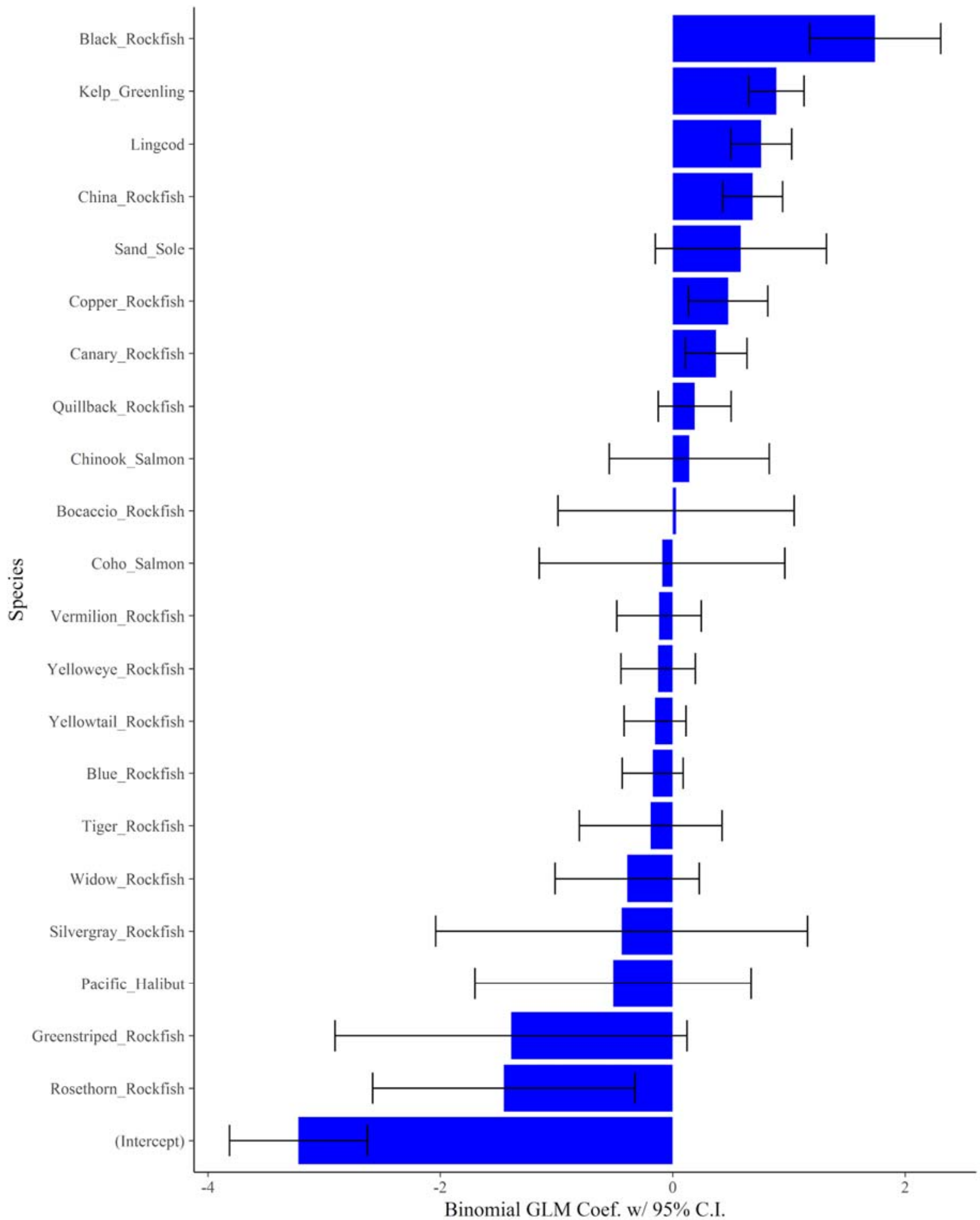


Figure 15. Species coefficients for the Stephens-MacCall filter of the Oregon MRFSS ocean-boat data.

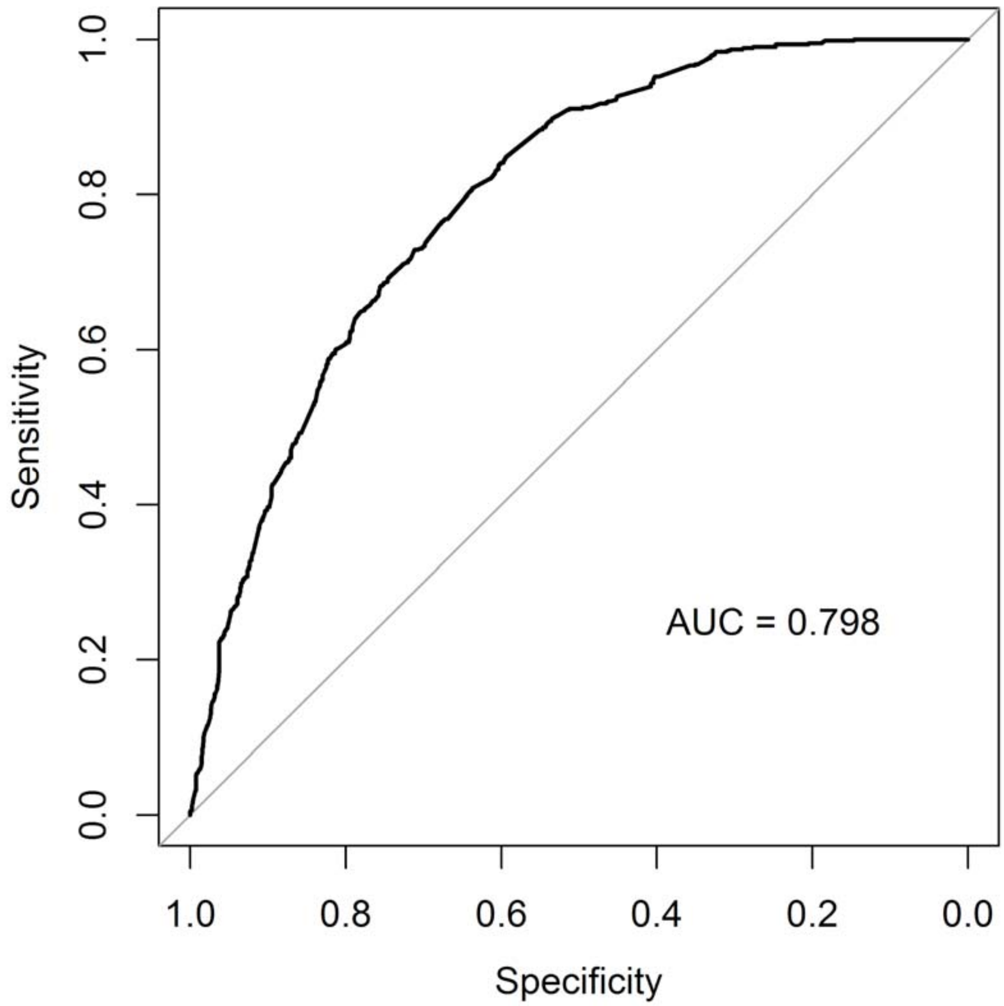


Figure 16. The Oregon MRFSS area under the characteristic curve (AUC) plot, which represents the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence. Values much greater than 0.5 indicate a significant improvement over a random classifier (AUC = 0.5).

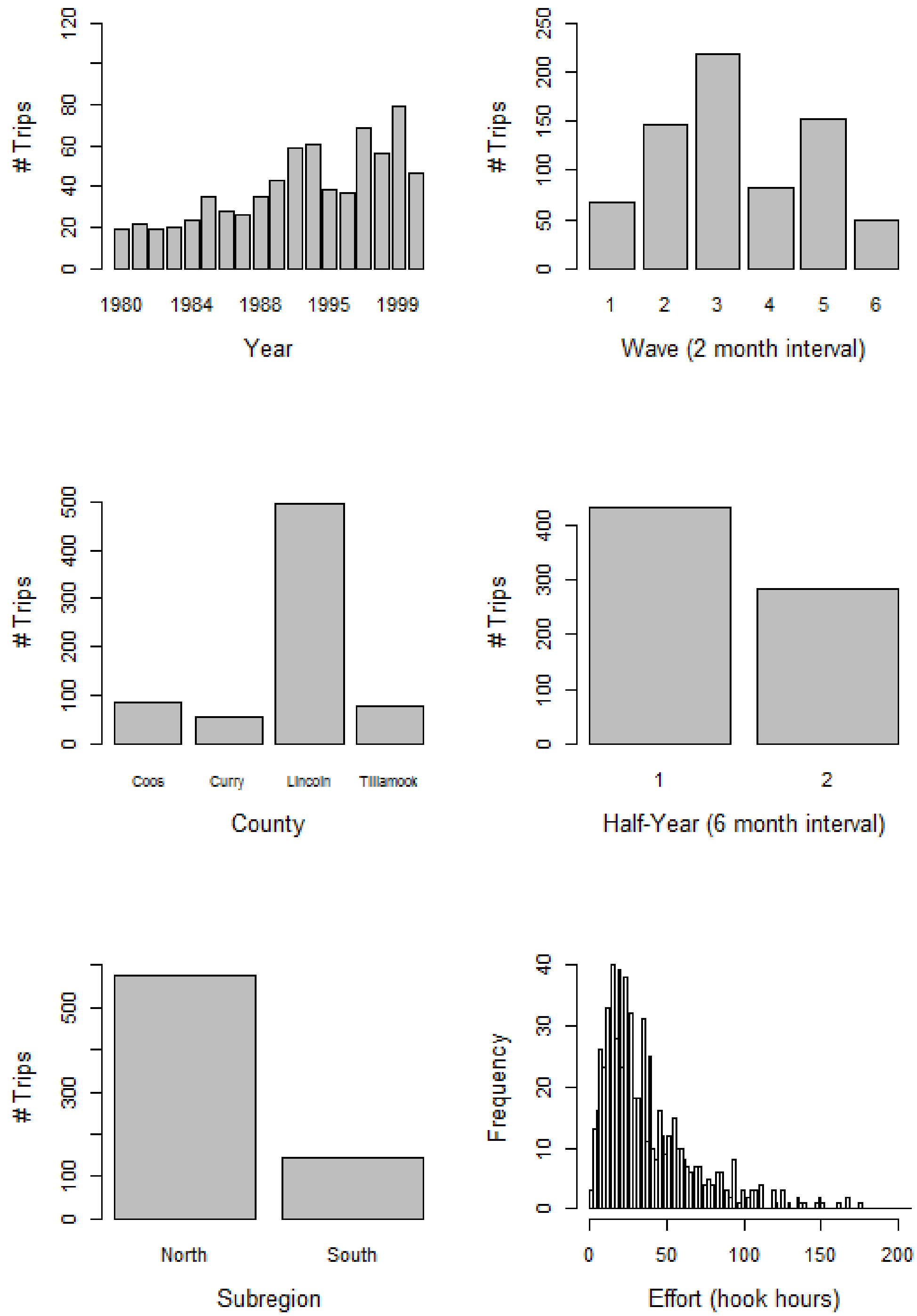


Figure 17. Characterization of the final subset of MRFSS data used in GLM analyses for Oregon Cabezon.

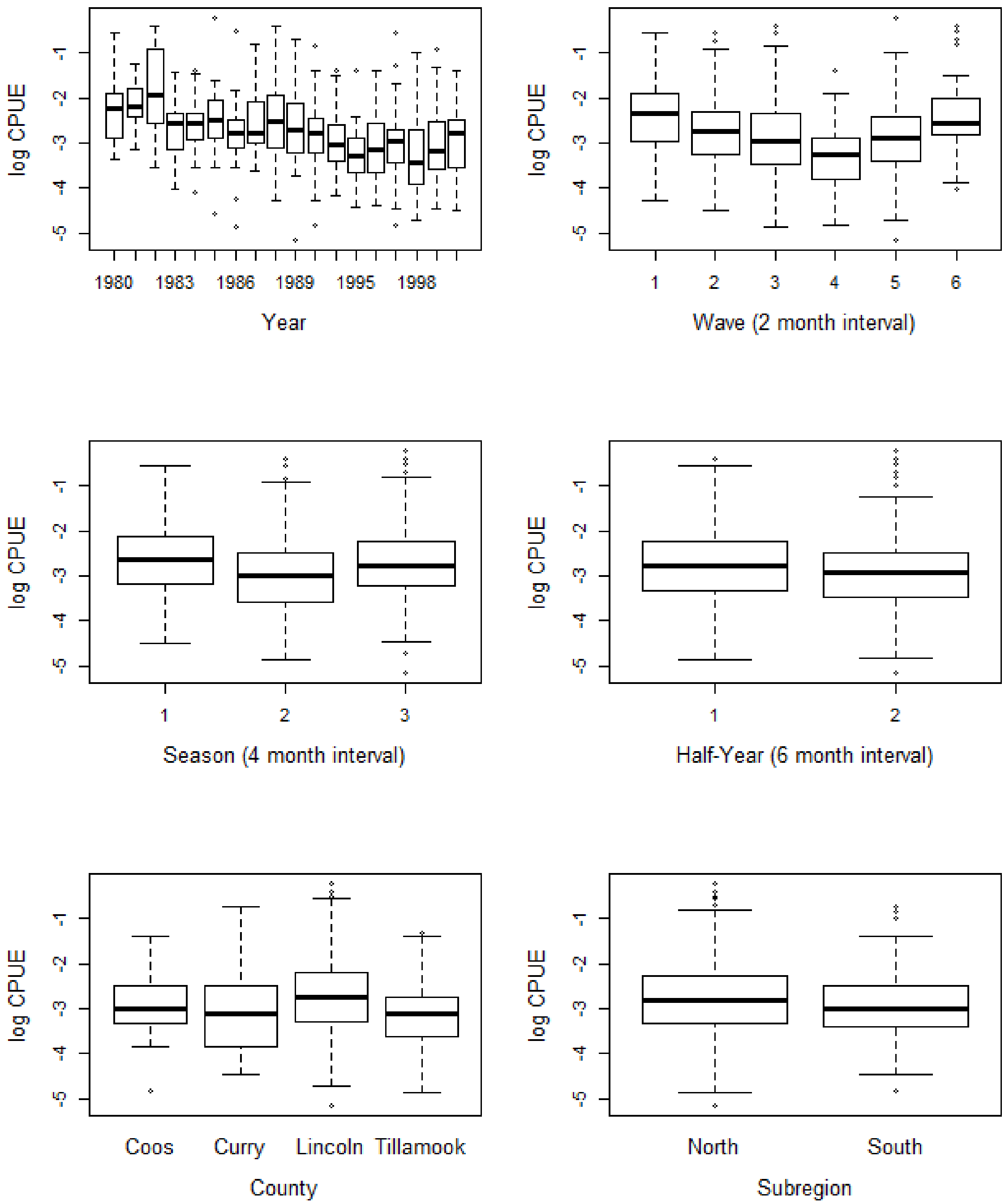


Figure 18. The distribution of trip-level raw positive catch CPUE data for the Oregon MRFSS data relative to potential covariates evaluated in the GLM analysis for Cabezon.

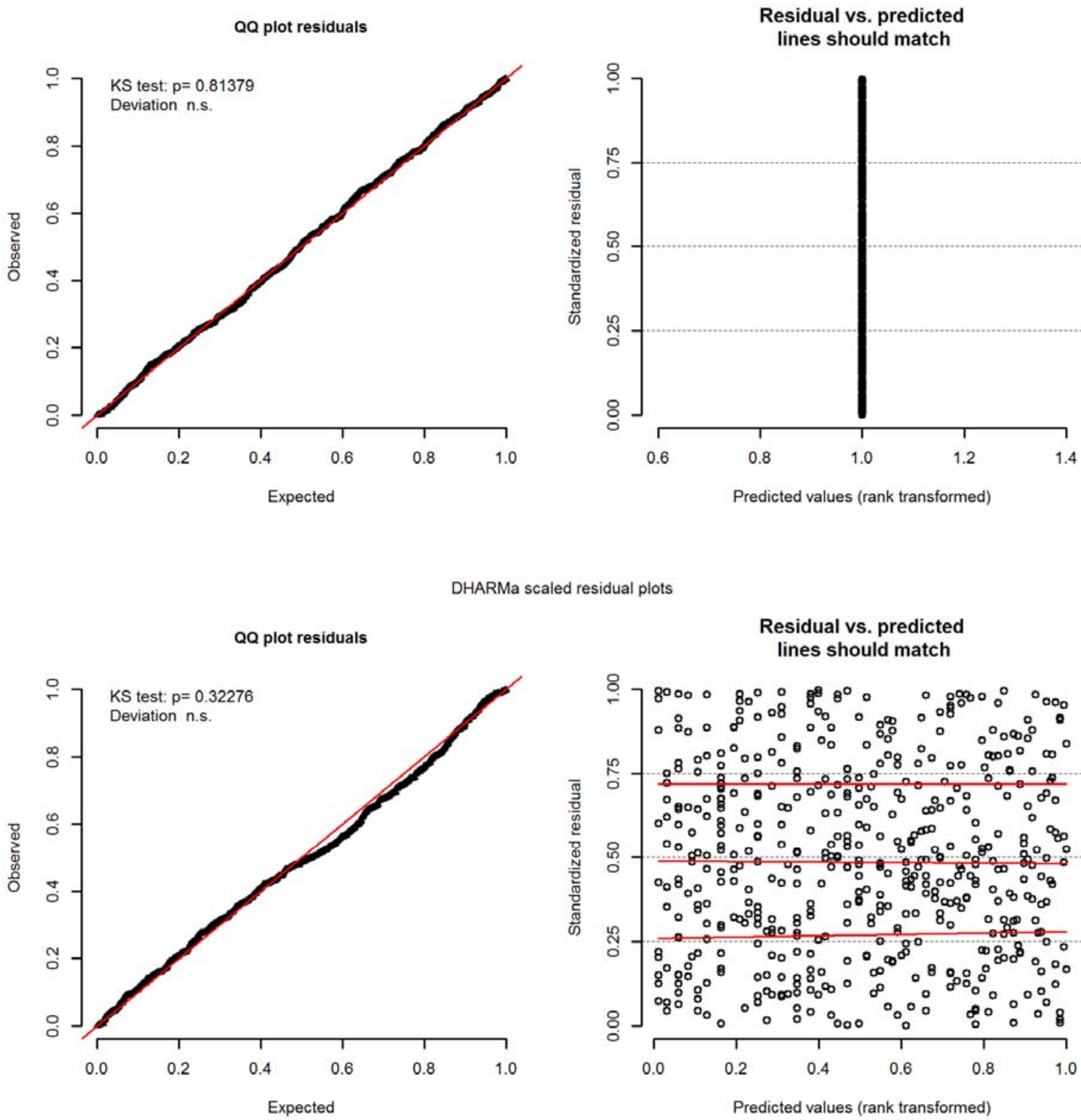


Figure 19. Diagnostic QQ and residual plots for Oregon MRFSS dockside binomial (top) and positive catch (bottom) model components for the delta-GLM model.

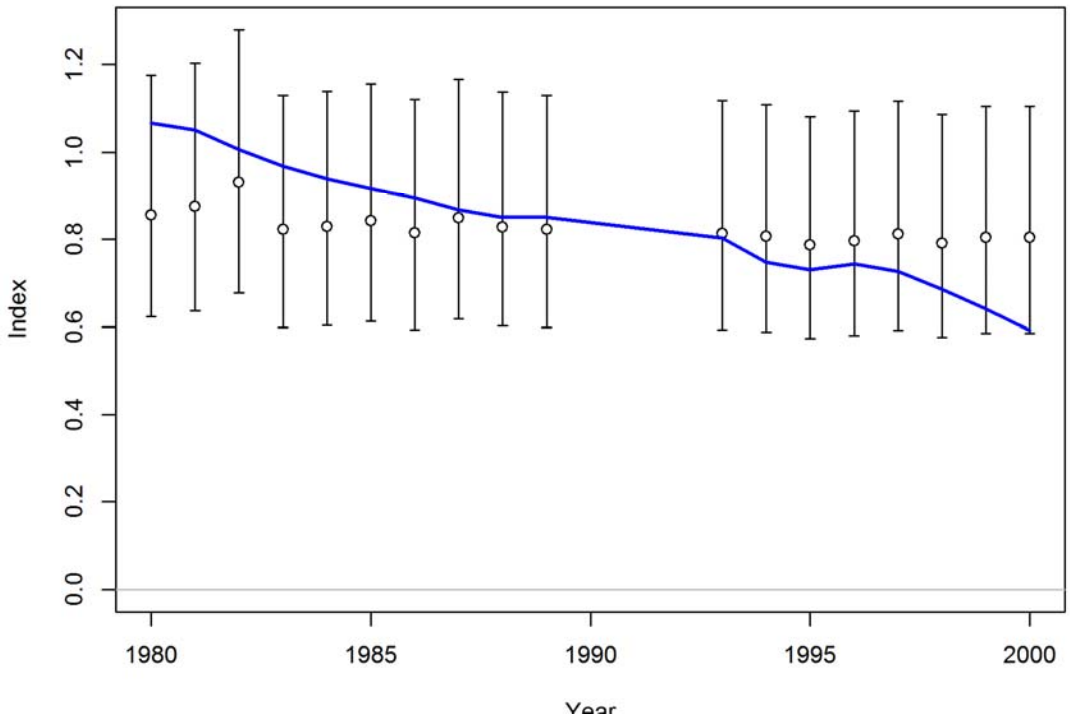


Figure 20. Assessment model fit to the Oregon MRFSS dockside interview index.

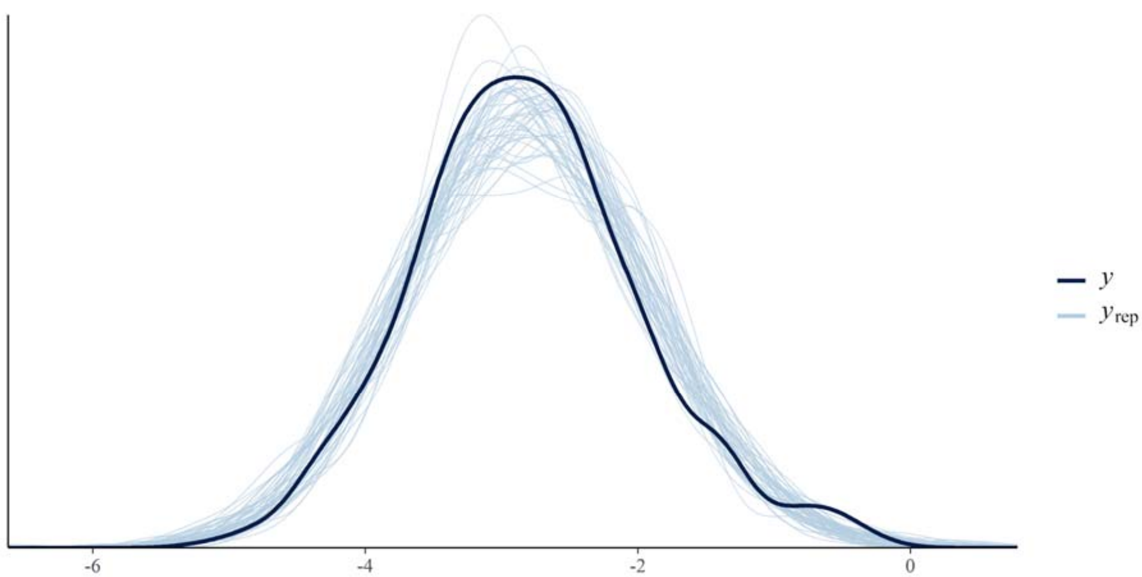


Figure 21. Comparison of data distribution for Oregon MRFSS dockside CPUE to model-generated replicate data sets used to evaluate uncertainty.

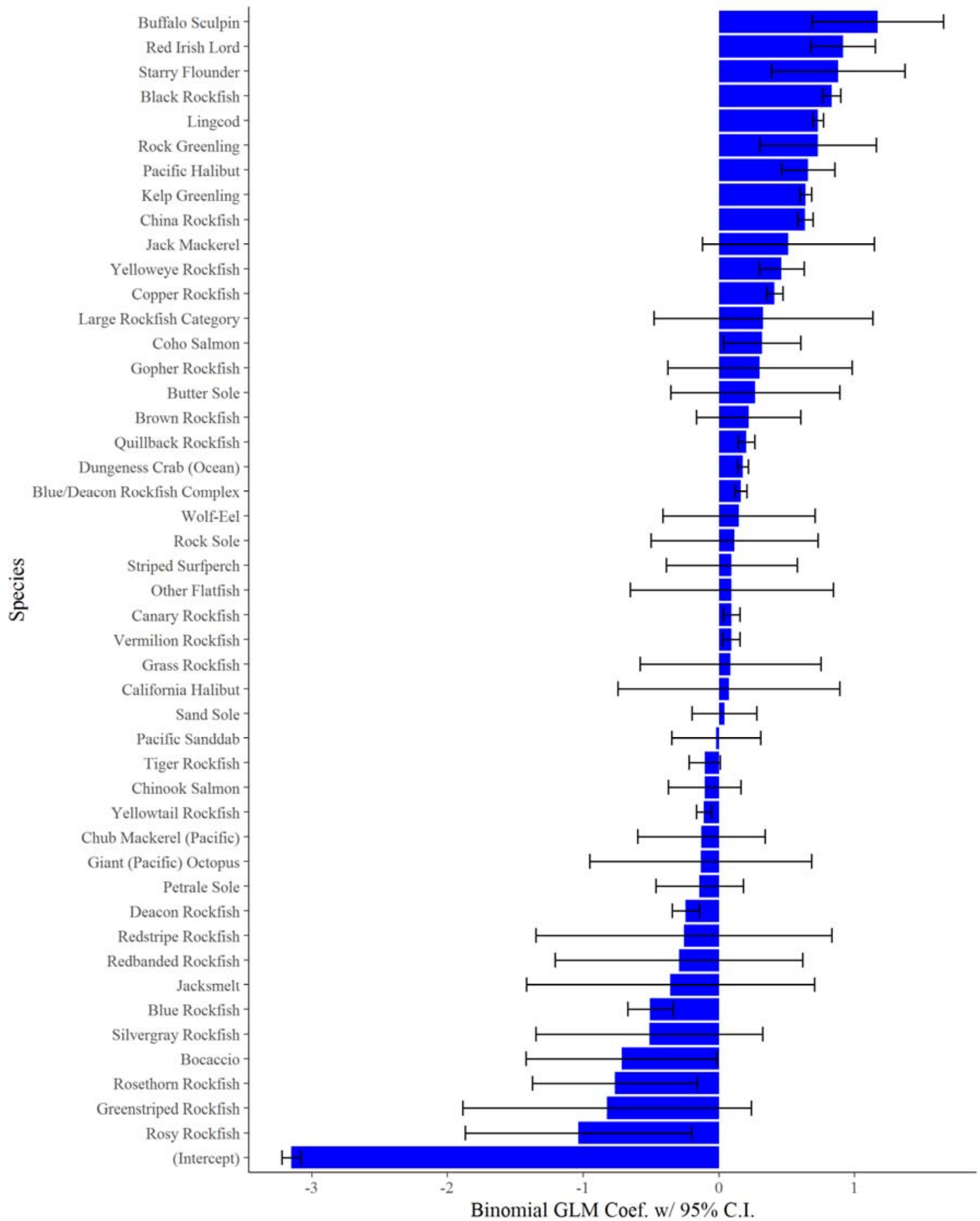


Figure 22. Species coefficients for the Stephens-MacCall filter of the Oregon ORBS dockside ocean-boat data.

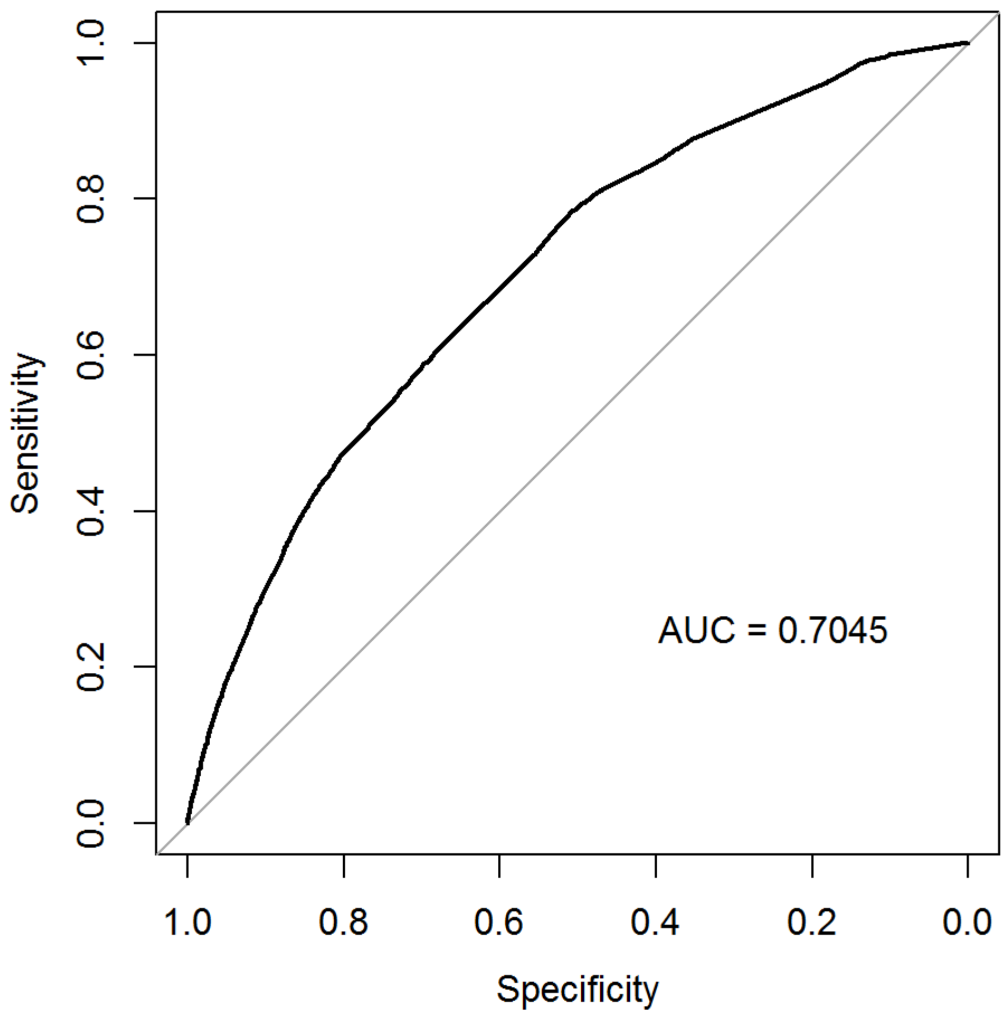


Figure 23. The Oregon ORBS area under the characteristic curve (AUC) plot, which represents the probability that a randomly chosen observation of presence would be assigned a higher ranked prediction than a randomly chosen observation of absence. Values much greater than 0.5 indicate a significant improvement over a random classifier (AUC = 0.5).

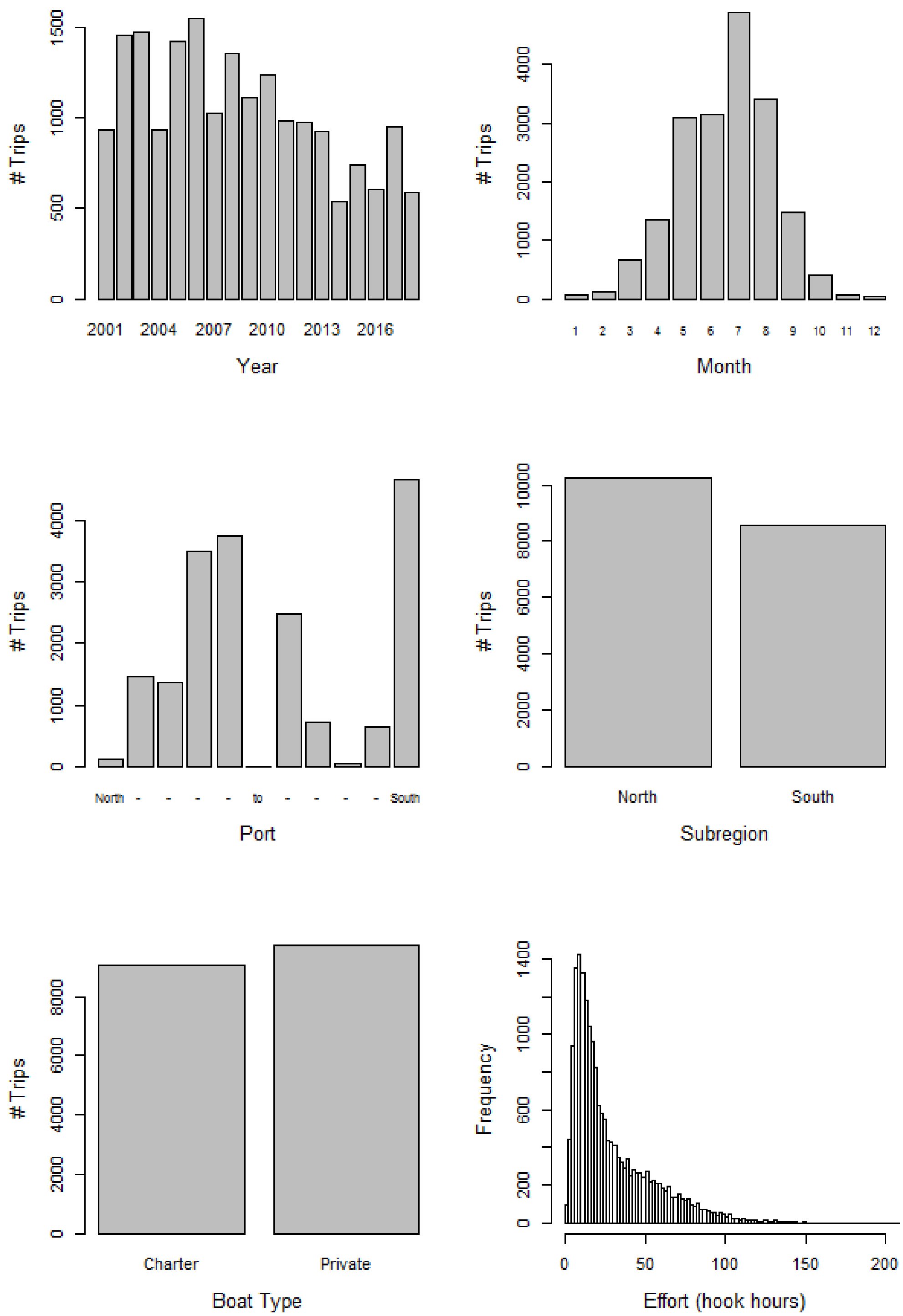


Figure 24. Characterization of the final subset of ORBS data used in GLM analyses for Oregon Cabezon.

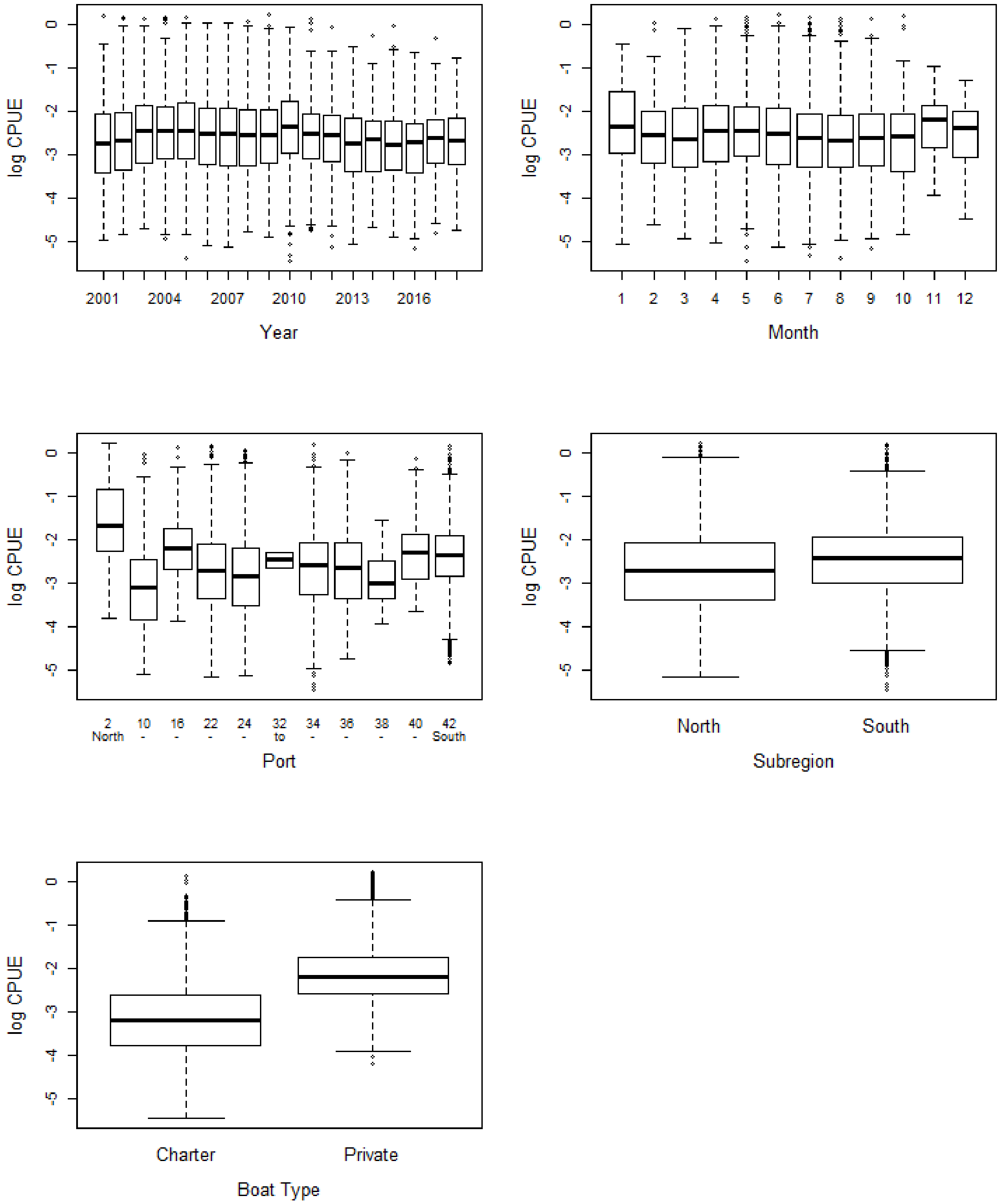
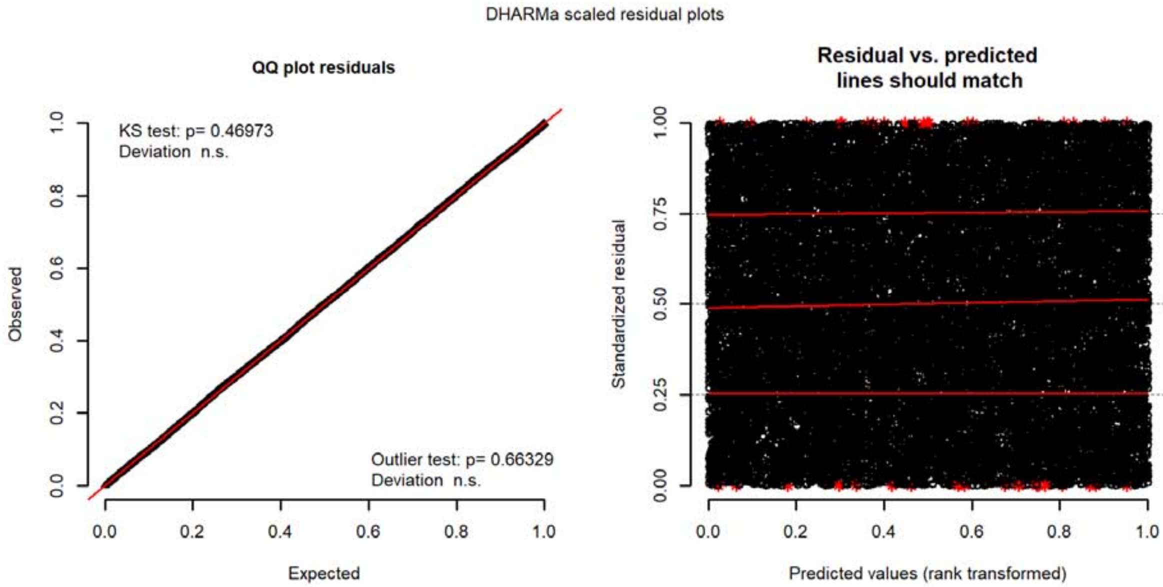


Figure 25. The distribution of trip-level raw positive catch CPUE data for the ORBS data relative to potential covariates evaluated in the Oregon Cabezon GLM analysis.



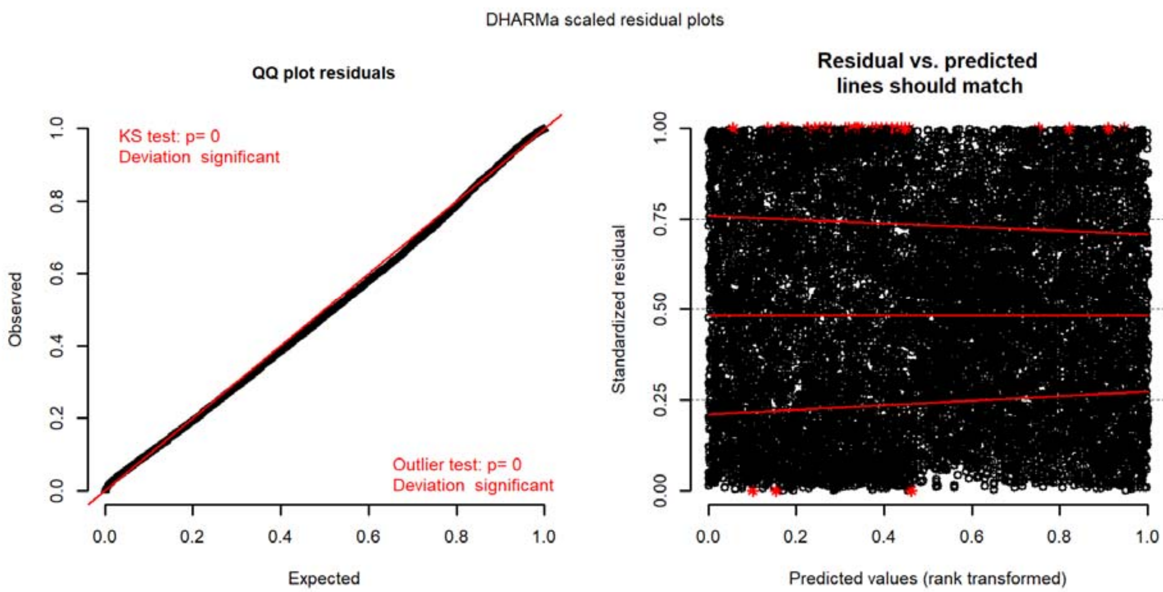


Figure 26. Diagnostic QQ and residual plots for Oregon ORBS dockside binomial (top) and positive catch (bottom) model components for the delta-GLM model.

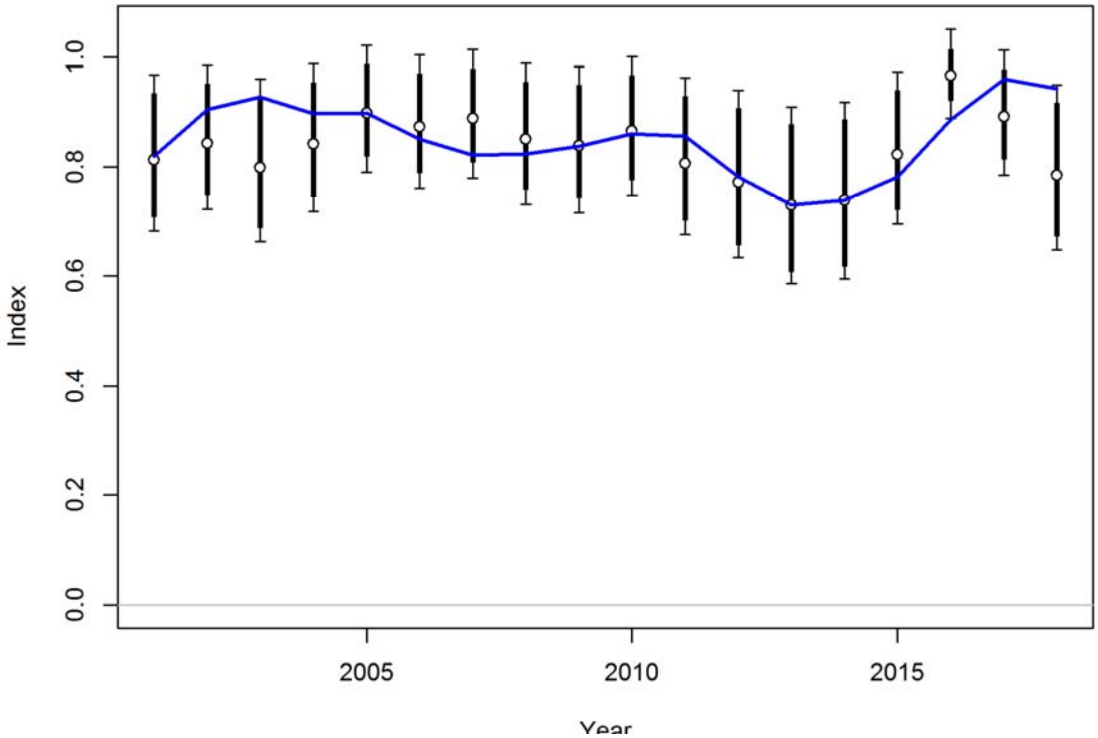


Figure 27. Assessment model fit to the Oregon ORBS dockside interview index.

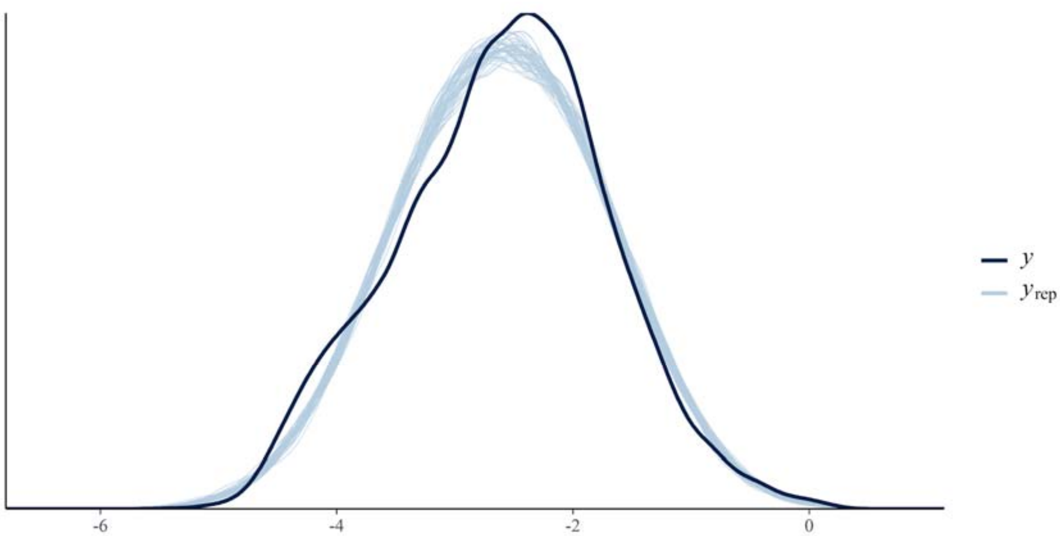


Figure 28. Comparison of data distribution for Oregon ORBS dockside CPUE to model-generated replicate data sets used to evaluate uncertainty.

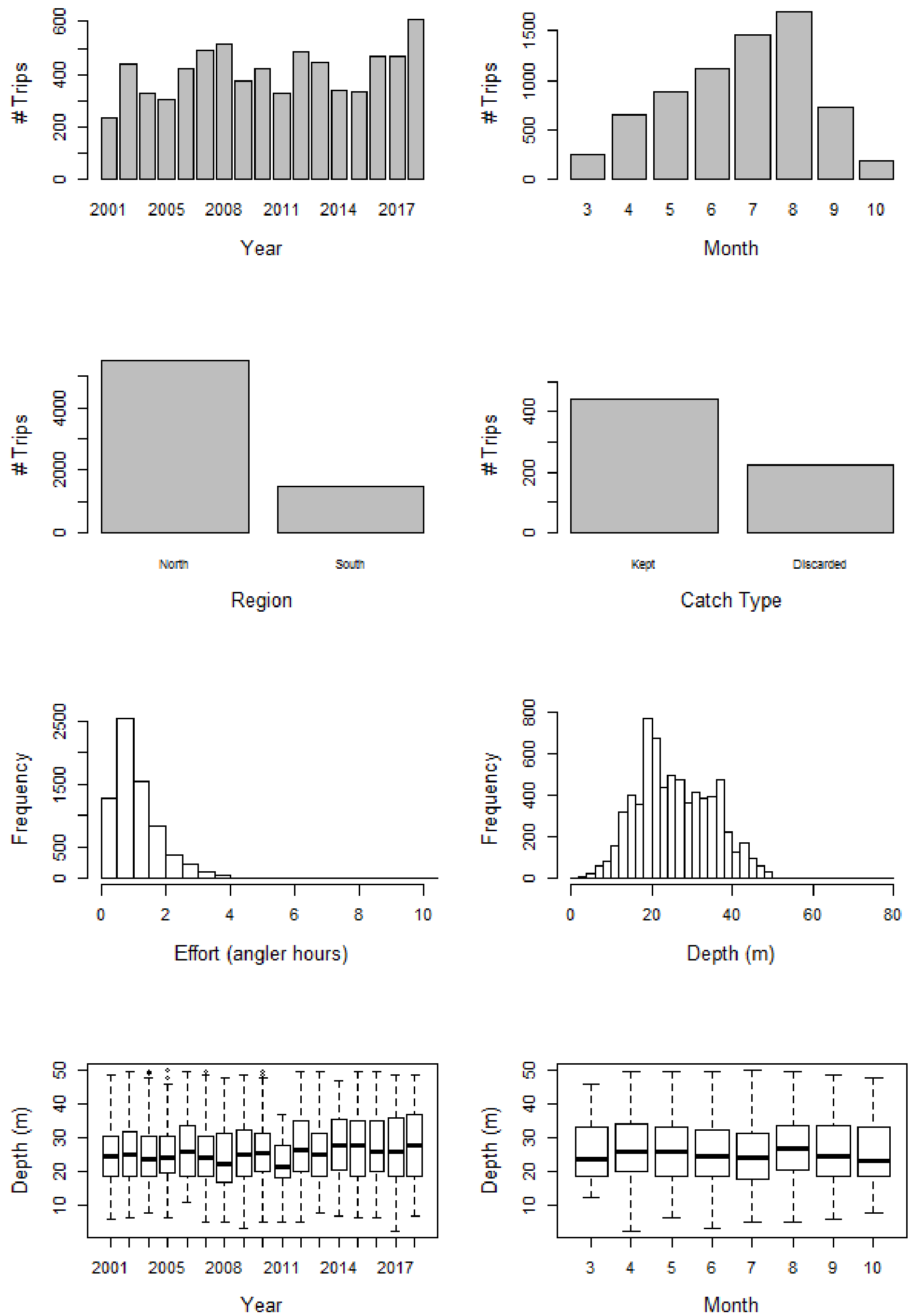


Figure 29. Characterization of the final subset of Onboard Observer data used in GLM analyses for Oregon Cabezon.

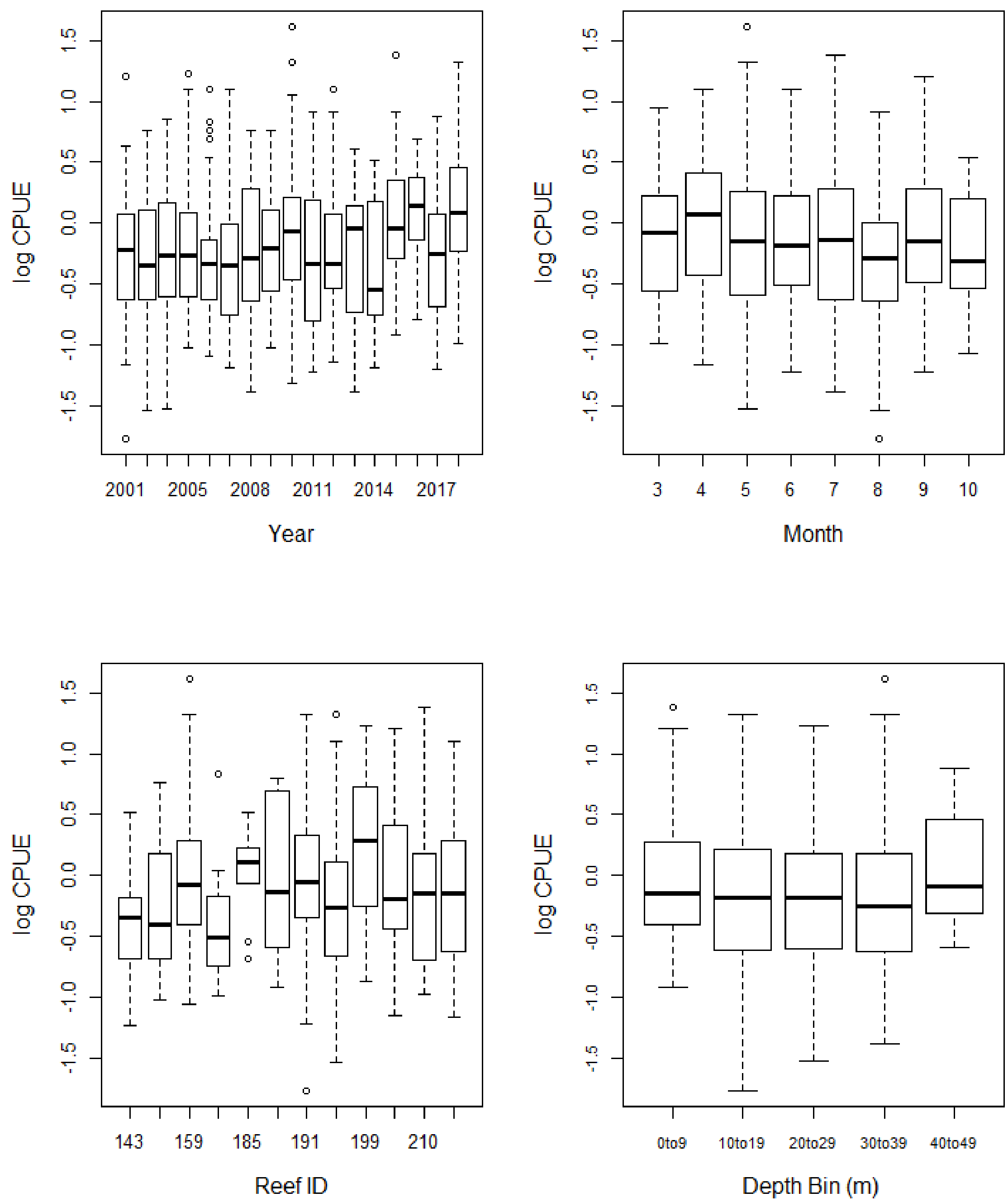


Figure 30. The distribution of trip-level raw positive catch CPUE data for the Onboard Observer data relative to potential covariates evaluated in the Oregon Cabezon GLM analysis.

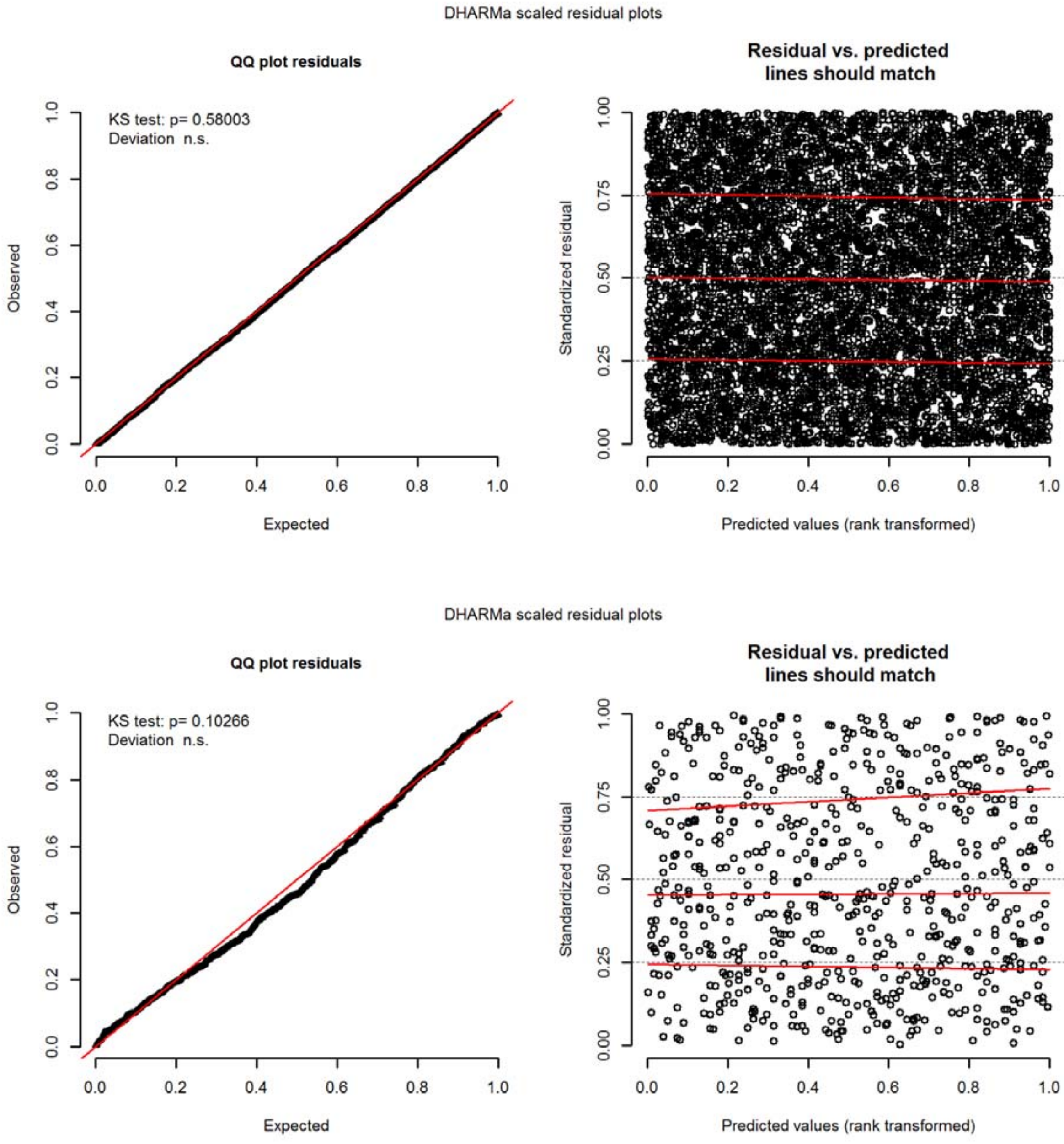


Figure 31. Diagnostic QQ and residual plots for Oregon Onboard Observer binomial (top) and positive catch (bottom) model components for the delta-GLM model.

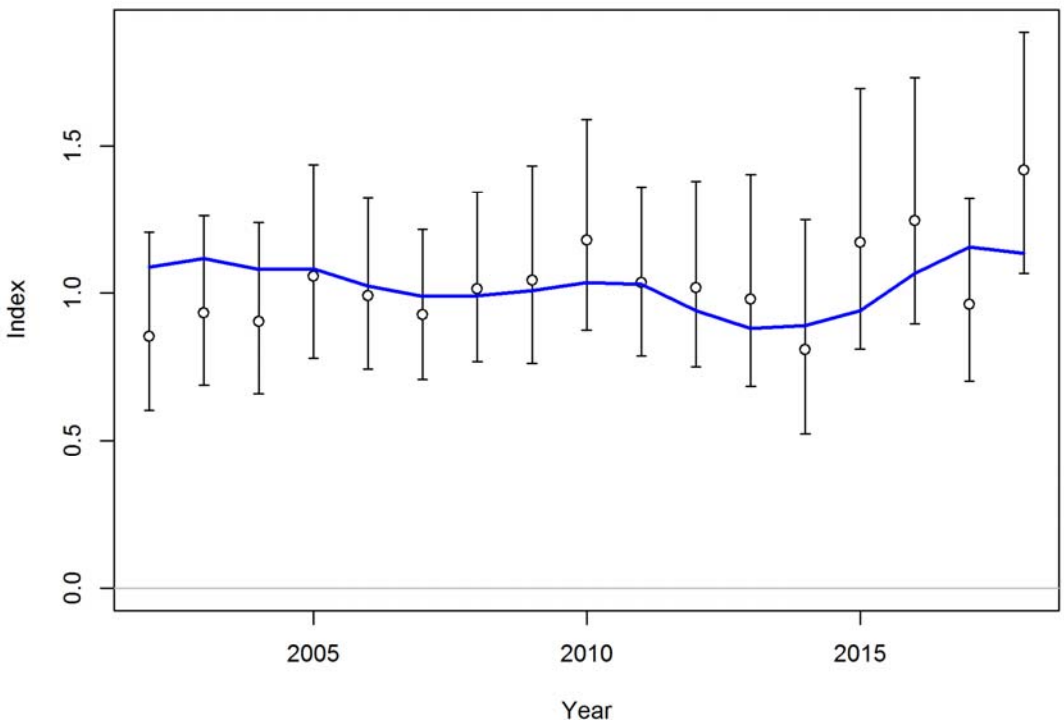


Figure 32. Assessment model fit to the Oregon Onboard Observer index.

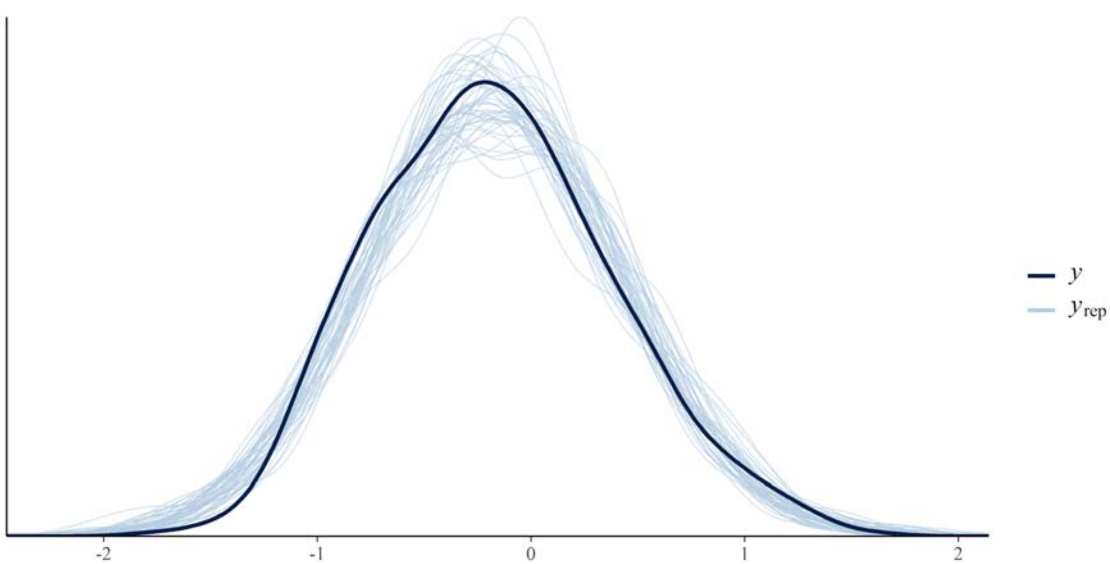


Figure 33. Comparison of data distribution for Oregon Onboard Observer CPUE to model-generated replicate data sets used to evaluate uncertainty.

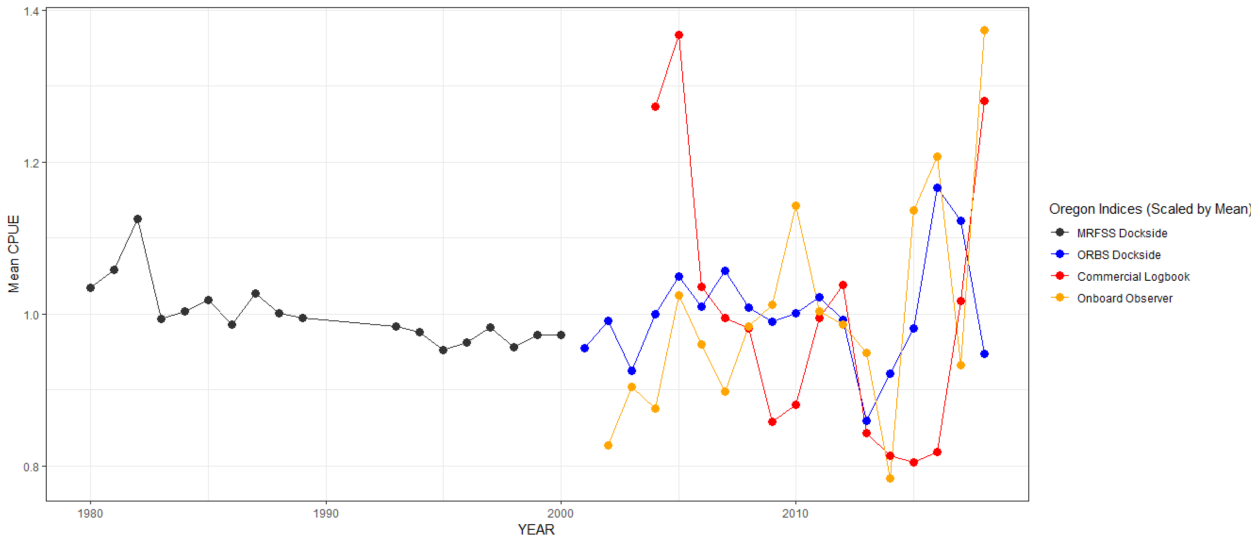


Figure 34. Comparison of standardized and rescaled (by the mean) indices of relative abundance for each of the four fishery-dependent datasets used in the Oregon reference model.

A) Gamma distribution B) Lognormal distribution

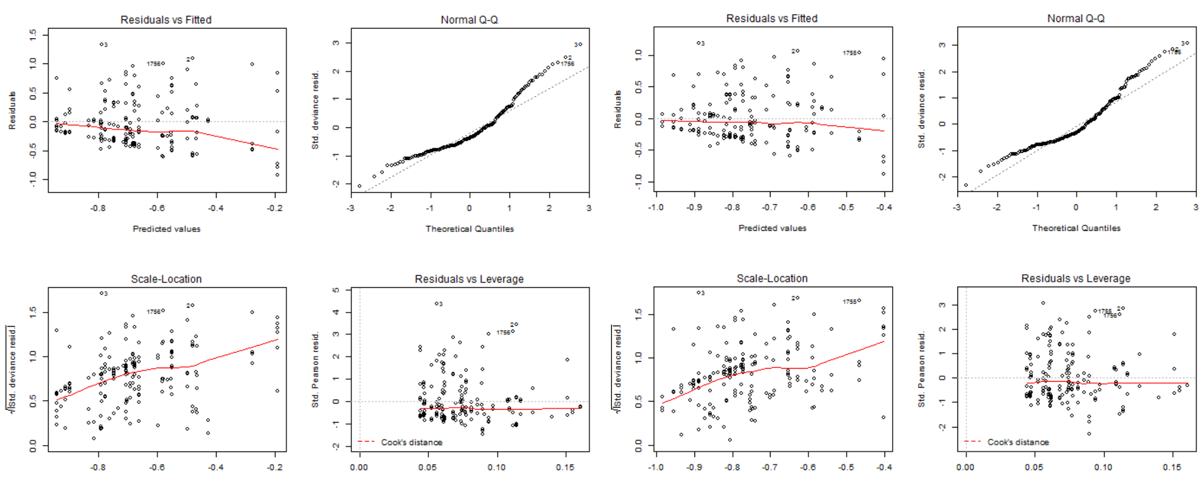


Figure 35. Diagnostic plots for the positive the Cabezon catch component in the delta-GLM model assuming a gamma (left sided plots) or lognormal (right-sided plots) distribution for the CCFRP survey. These are used to evaluate model fit (top left), assumptions of normality (top right), assumptions of constant variance (bottom left), and the presence of outliers (bottom right).

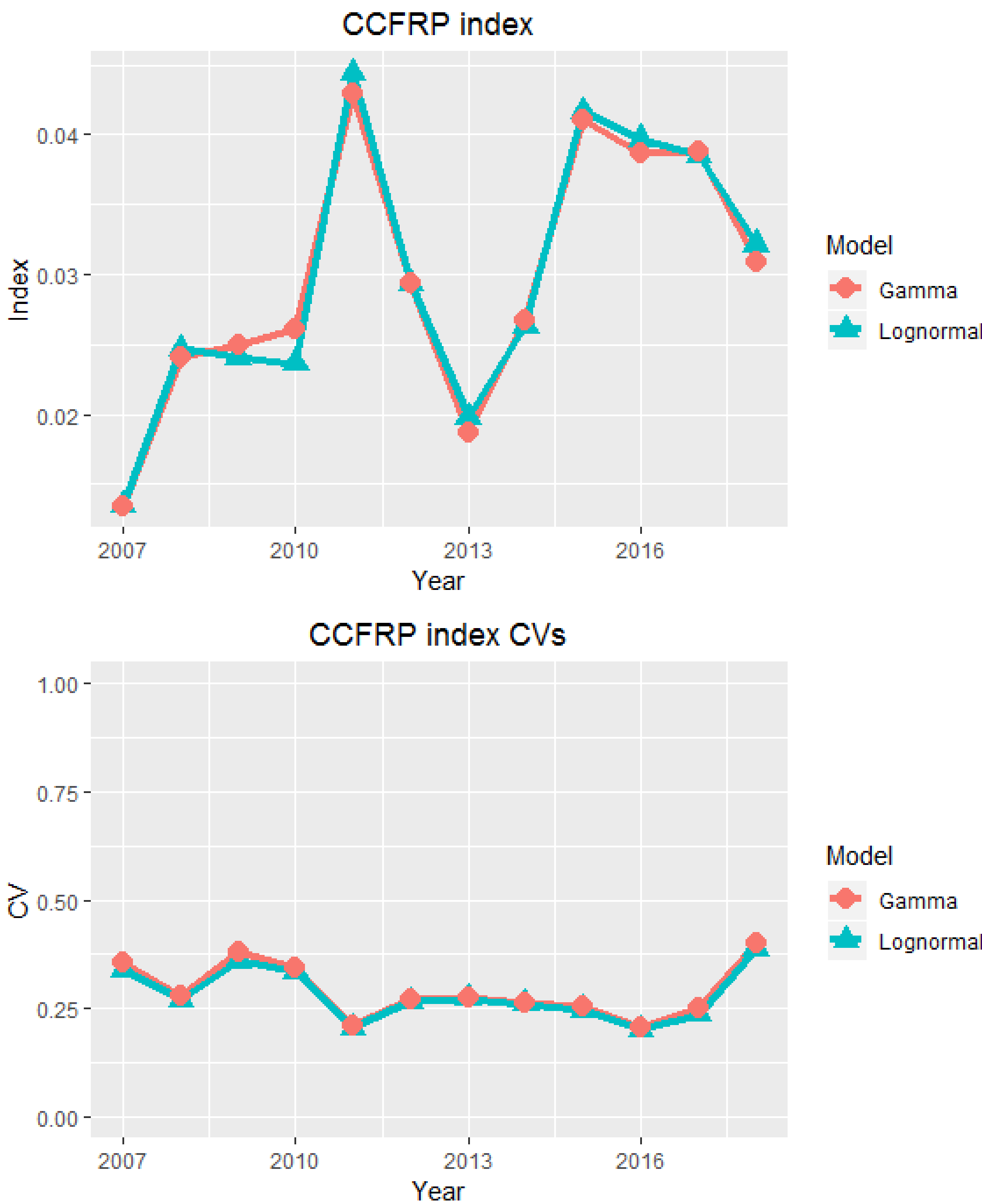


Figure 36. **Top panel: Comparison of index fits for two approaches (the delta-GLM assuming either gamma or lognormal distributions) for the Cabezon CCFRP index. The chosen model uses the gamma distribution. Bottom panel: Uncertainty (reported as the coefficient of variation (CV)) in each model.**

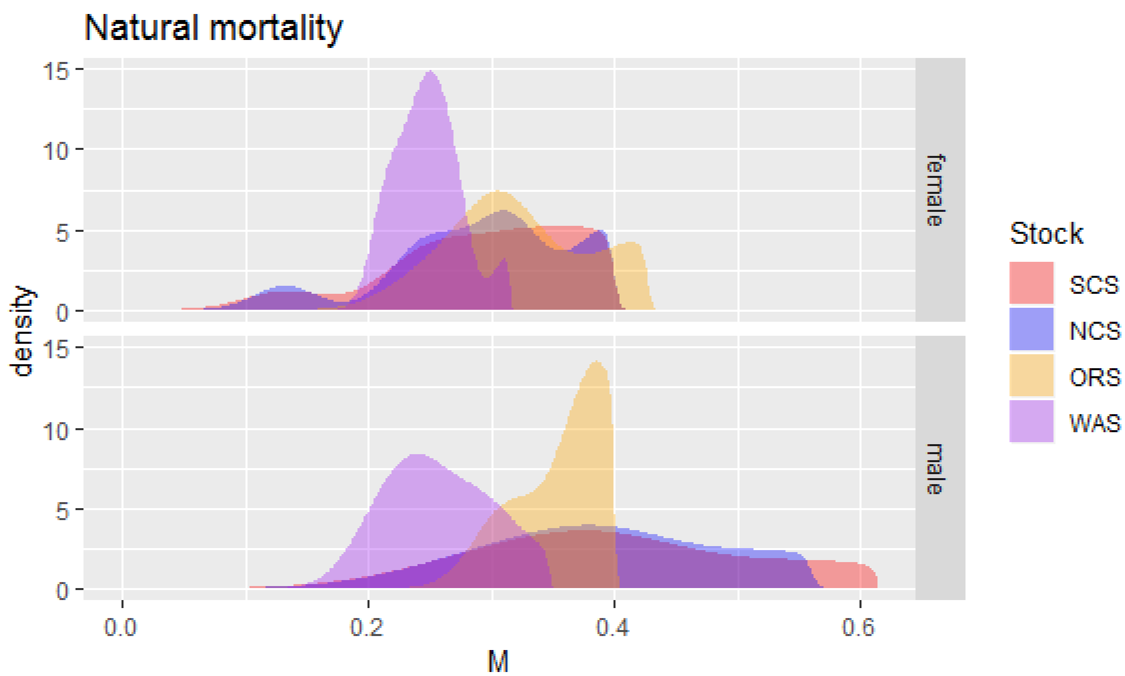


Figure 37. Distriubtion of natural mortality values by stock and sex produced using the Natural Mortality Tool.

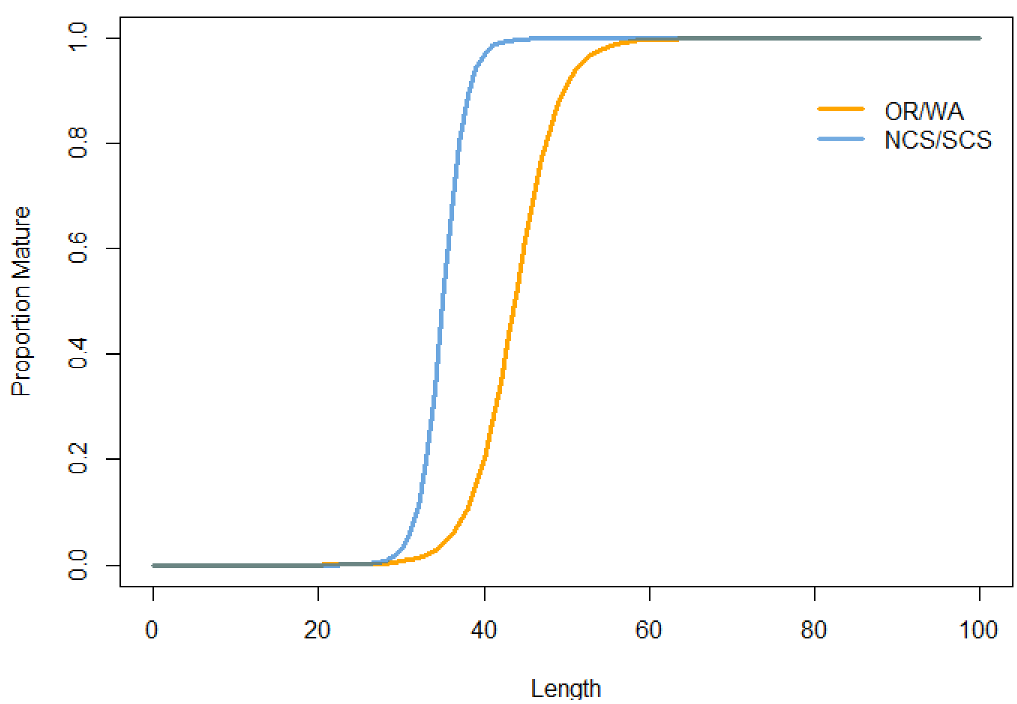


Figure 38. Cabezon maturity ogive used in the California, Oregon, and Washington assessments models.

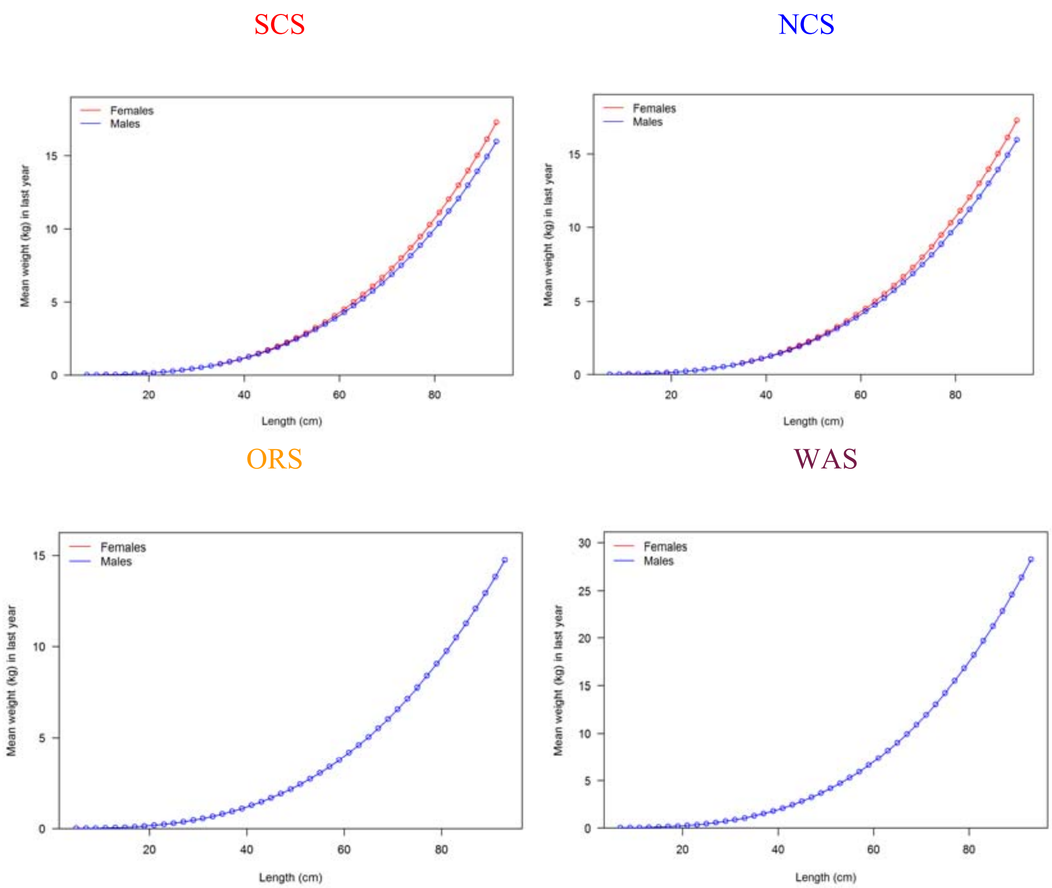


Figure 39. Weight-length relationship for Cabezon in SCS, NCS, ORS and WAS stocks.

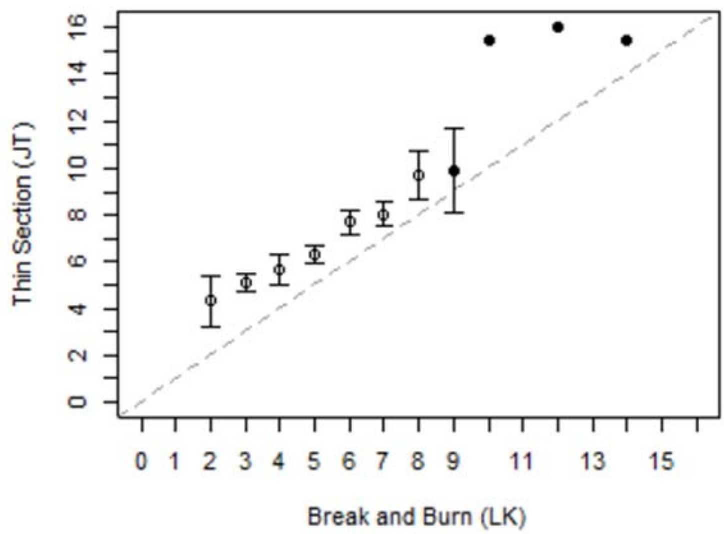


Figure 40. Comparison of methods for reading Cabezon otoliths used in the Oregon assessment. The break and burn method was assumed unbiased in the reference model relative to the thin section method. A sensitivity run was conducted were the thin section method was assumed unbiased. Figure used with permission from Rasmuson et al. 2019.

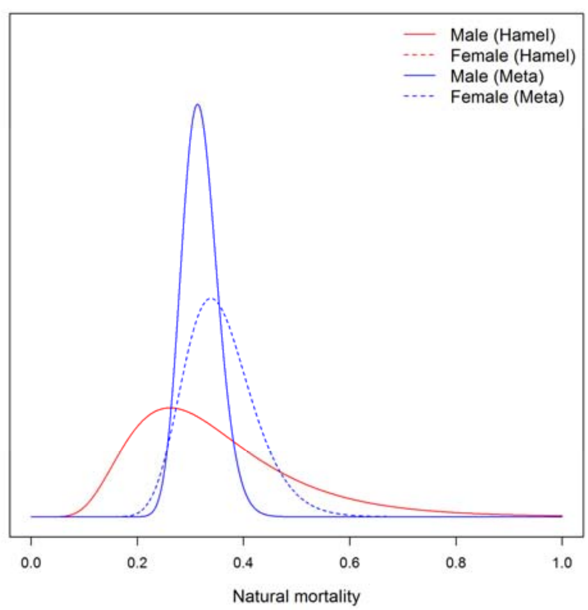


Figure 41. Alternative prior distributions for natural mortality of male and female Cabezon in Oregon waters based on Hamel (2017, pers. comm.) and based on a meta-analysis of alternative species longevity informed approaches for calculating natural mortality (meta).

12.2 Model Figures

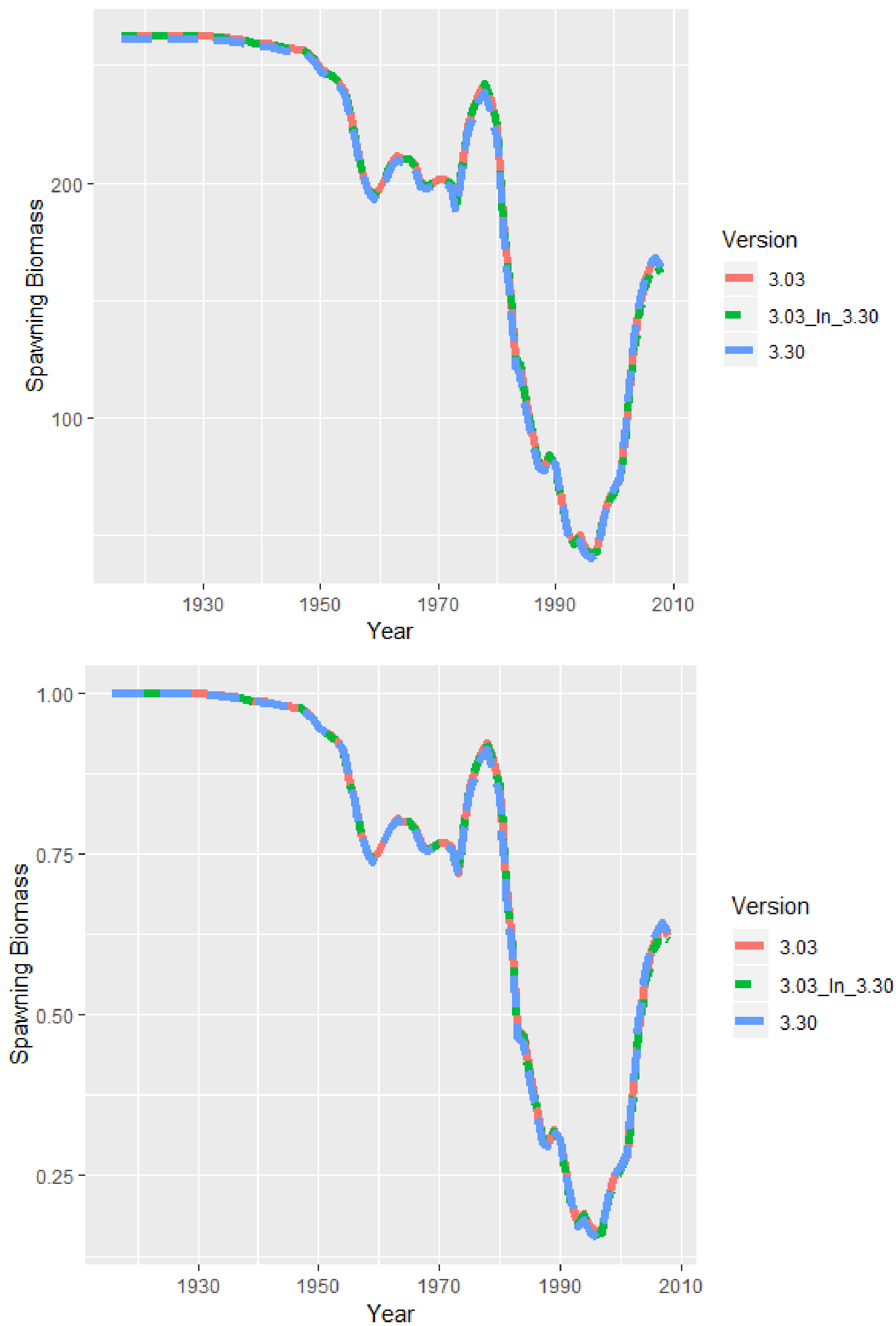
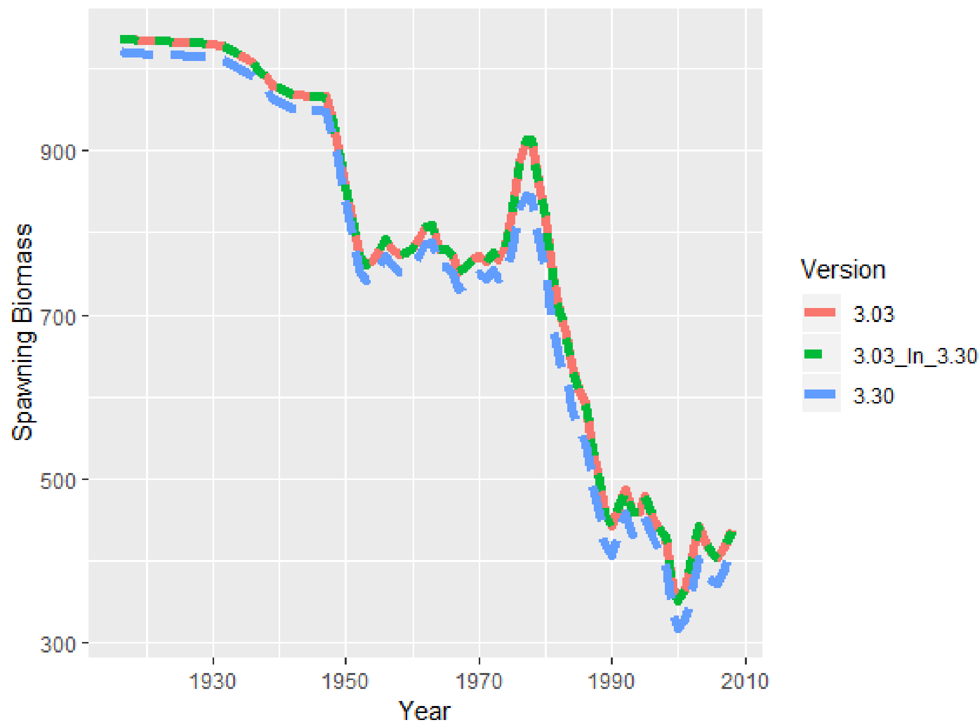


Figure 42. Bridge models from the 2009 to current version of Stock Synthesis for the SCS model. Metrics of spawning biomass (top panel) and relative spawning biomass (bottom panel).



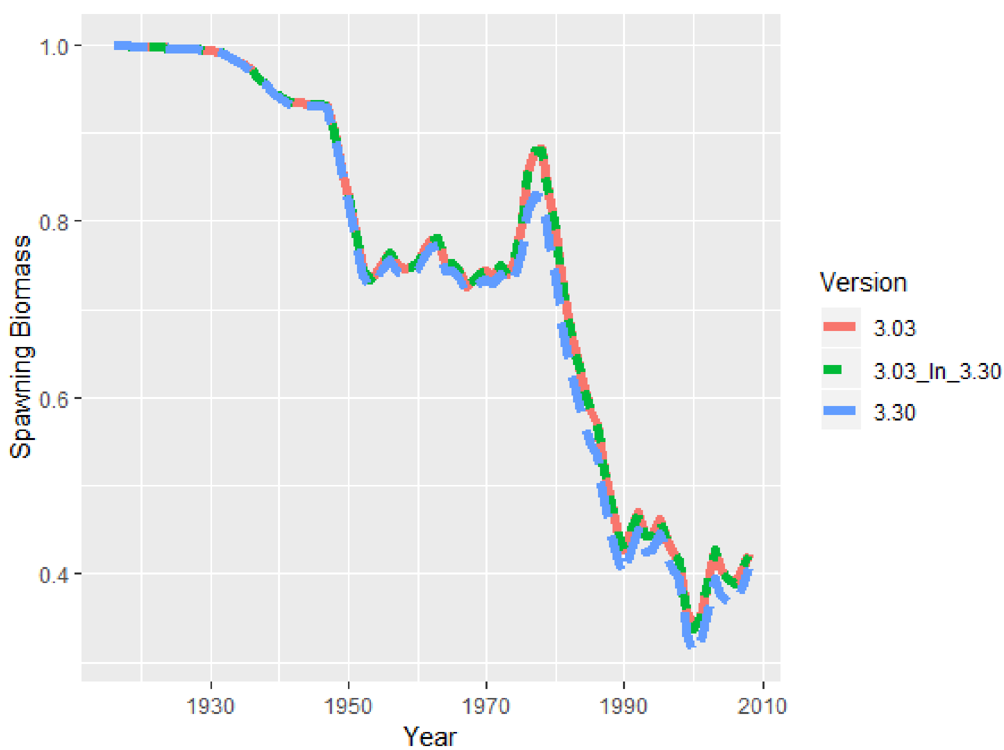


Figure 43. Bridge models from the 2009 to current version of Stock Synthesis for the SCS model. Metics of spawning biomass (top panel) and relative spawning biomass (bottom panel).

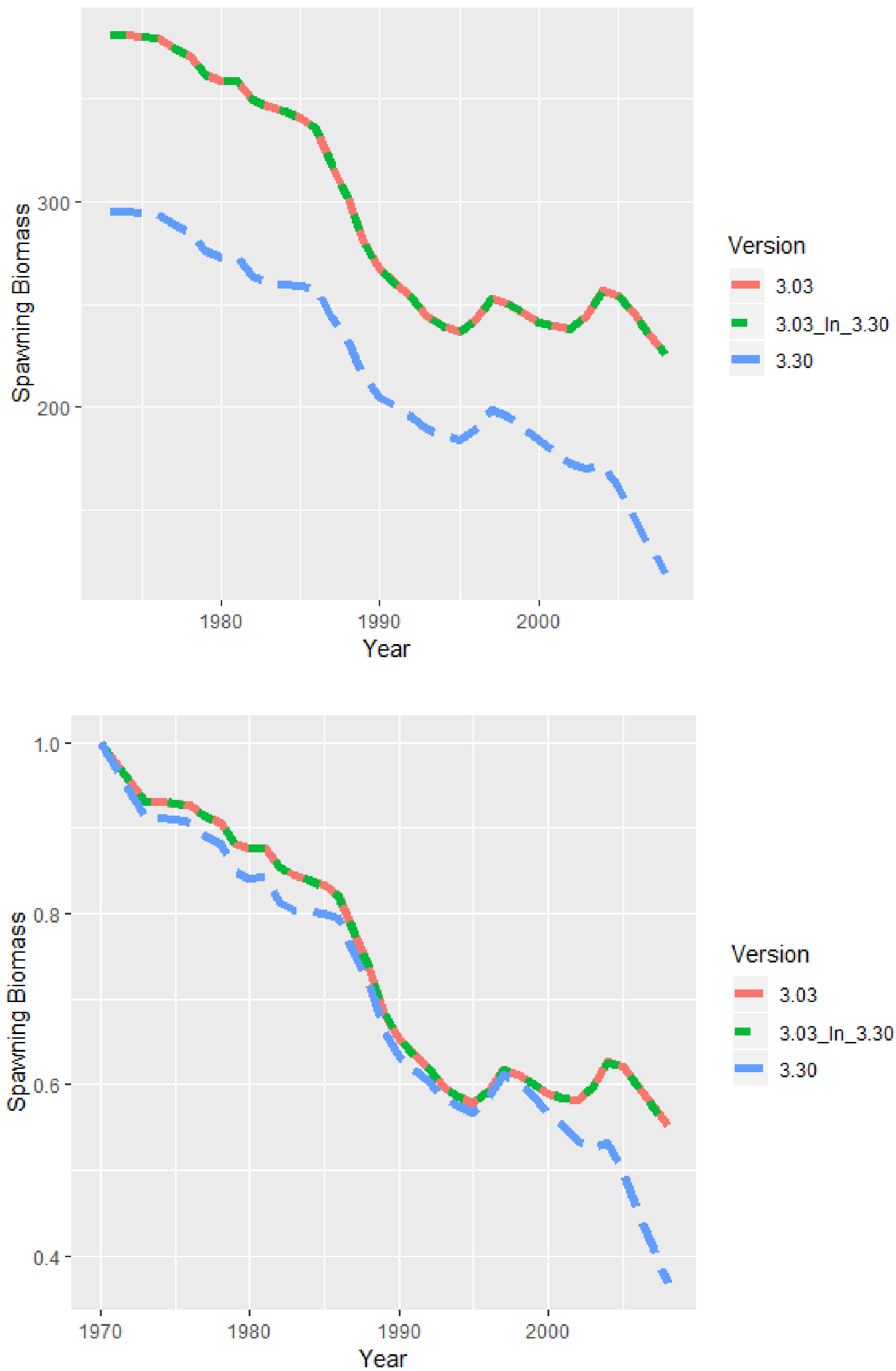


Figure 44. Bridge models from the 2009 to current version of Stock Synthesis for the ORS model. Metrics of spawning biomass (top panel) and relative spawning biomass (bottom panel).

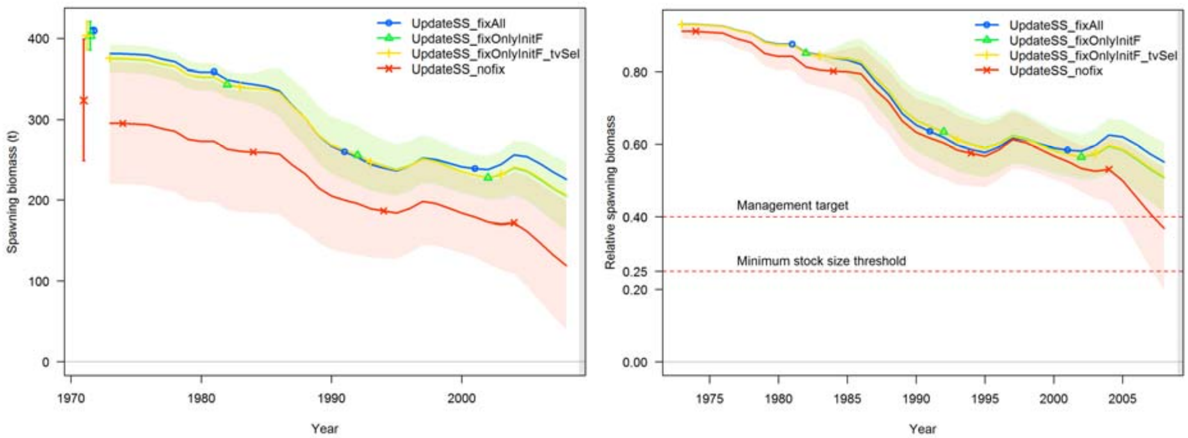


Figure 45. Additional model runs showing the impact of updating Stock Synthesis from version 3.03 (used in the 2009 assessment; blue lines) to version 3.30.12 (used in this assessment; red lines) on Oregon stock trends (left panel) and stock status (right panel). Fixing the parameters for initial fishing mortality (initF; green and yellow lines) in the updated software version remedied some of the differences.

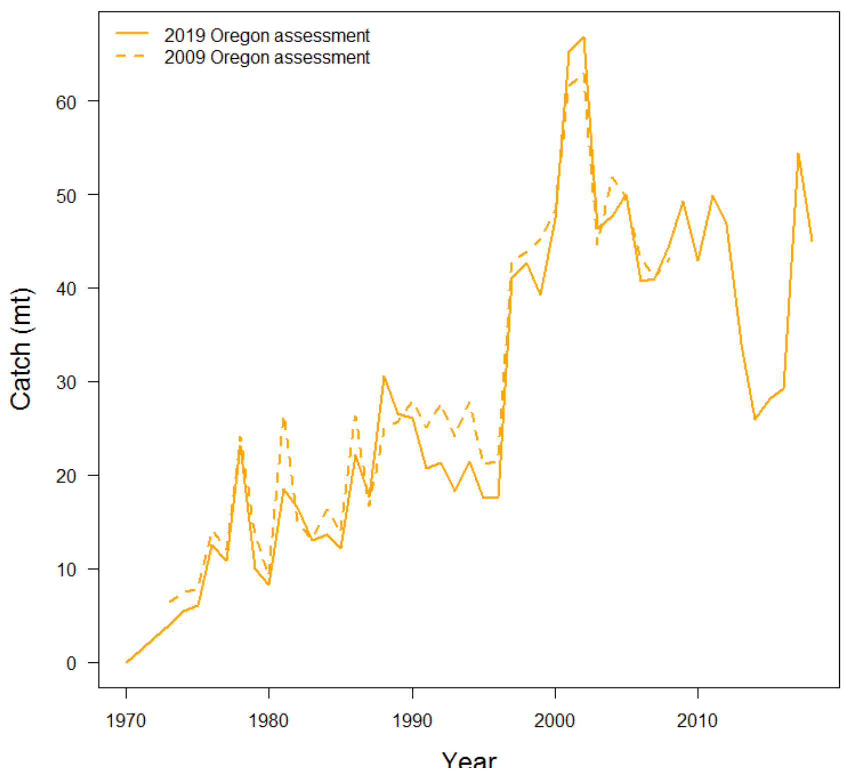


Figure 46. Comparison of total Oregon catch (all fleets) of Cabezon used in 2019 and 2009 assessments (bold and dashed lines, respectively).

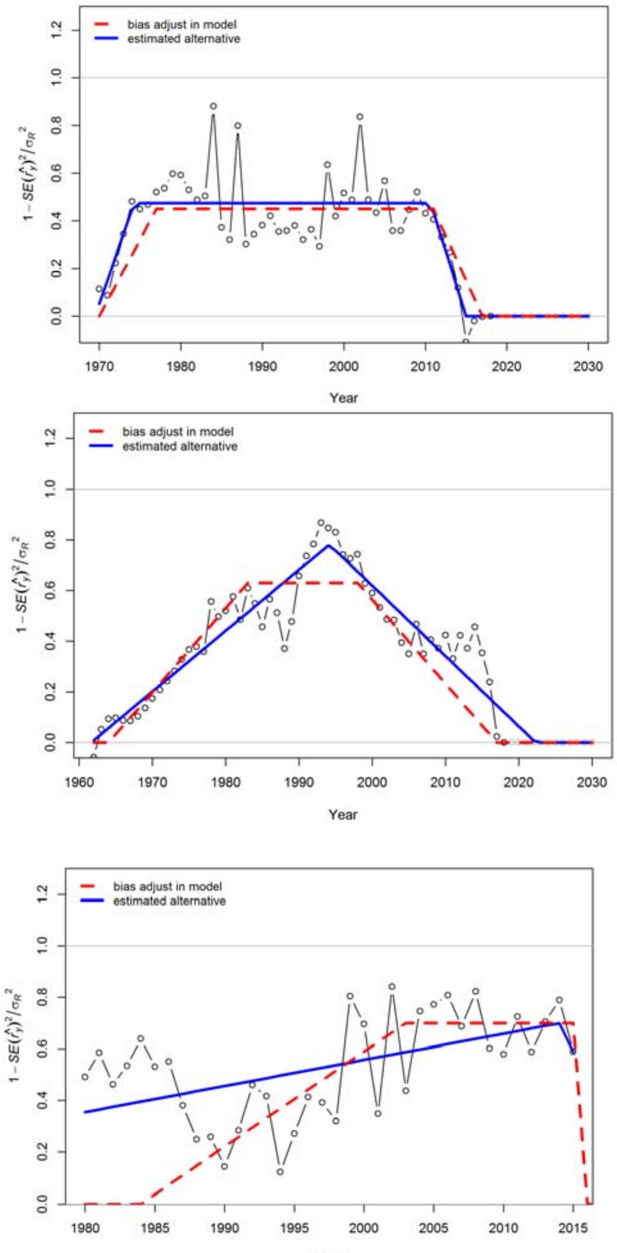


Figure 47. Estimated years of recruitment and the treatment of bias adjustment in the SCS (top panel) NCS (middle panel), and Oregon (bottom panel) reference models.

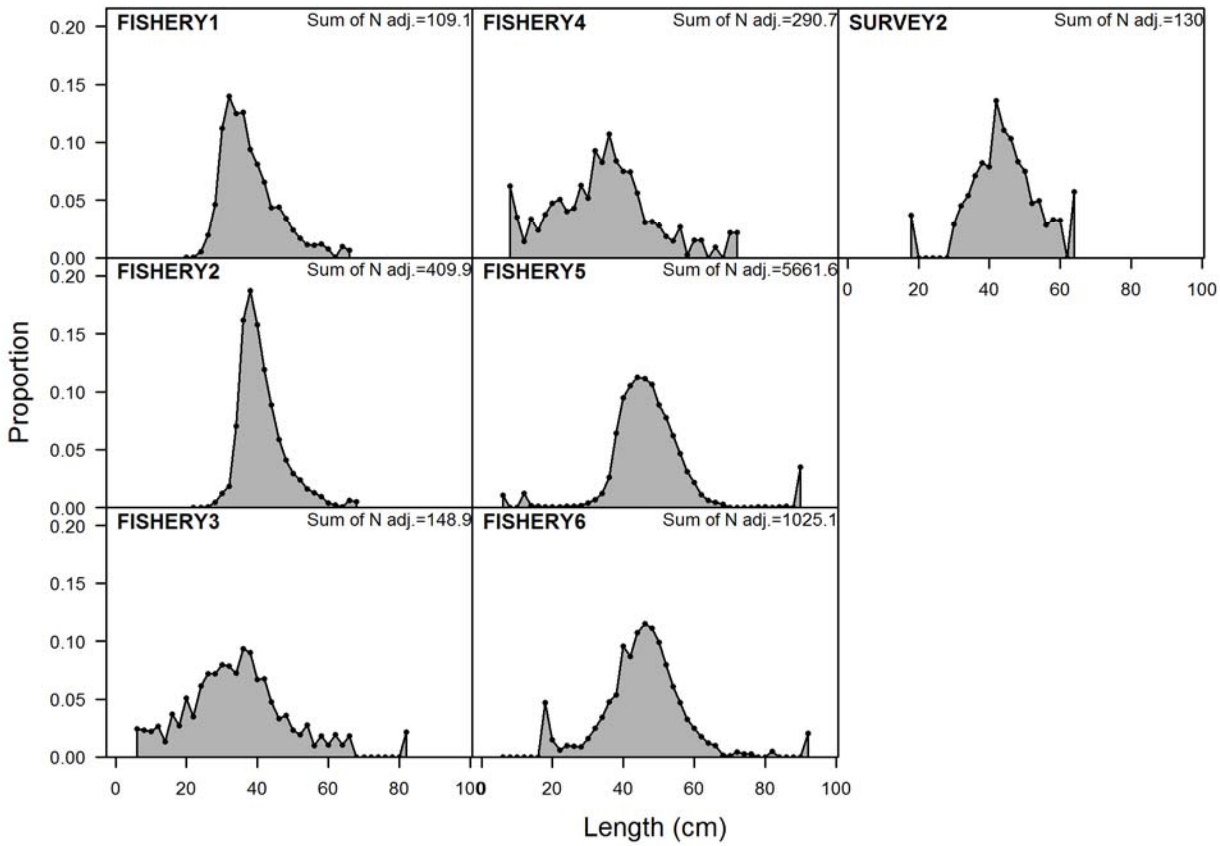


Figure 48. Length compositions of the 6 removal fleets for the NCS model. Comparison of Fishery3 (man-made mode) to Fishery4 (beach/bank mode) and Fishery5 (private boat and rentals) to Fishery6 (commercial passenger fishing vessels) led to the combining of Fishery3 and Fishery4 into one fleet (shore mode), and Fishery5 and Fishery6 into one fleet (boat mode).

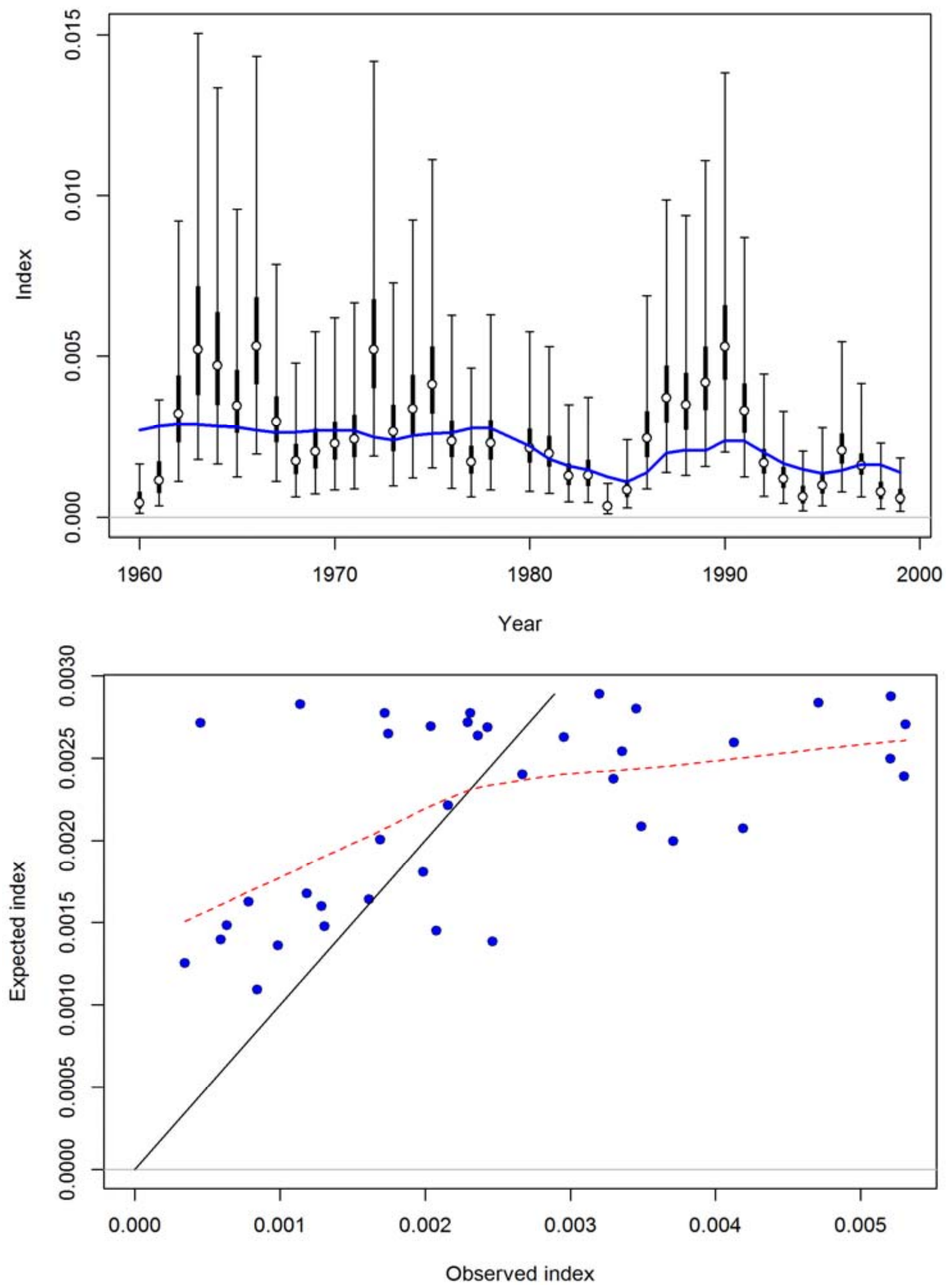


Figure 49. Fits to the CPFV relative abundance time series (top panel) and the 1:1 points to observed and expected index values (bottom panel) used in the SCS reference model.

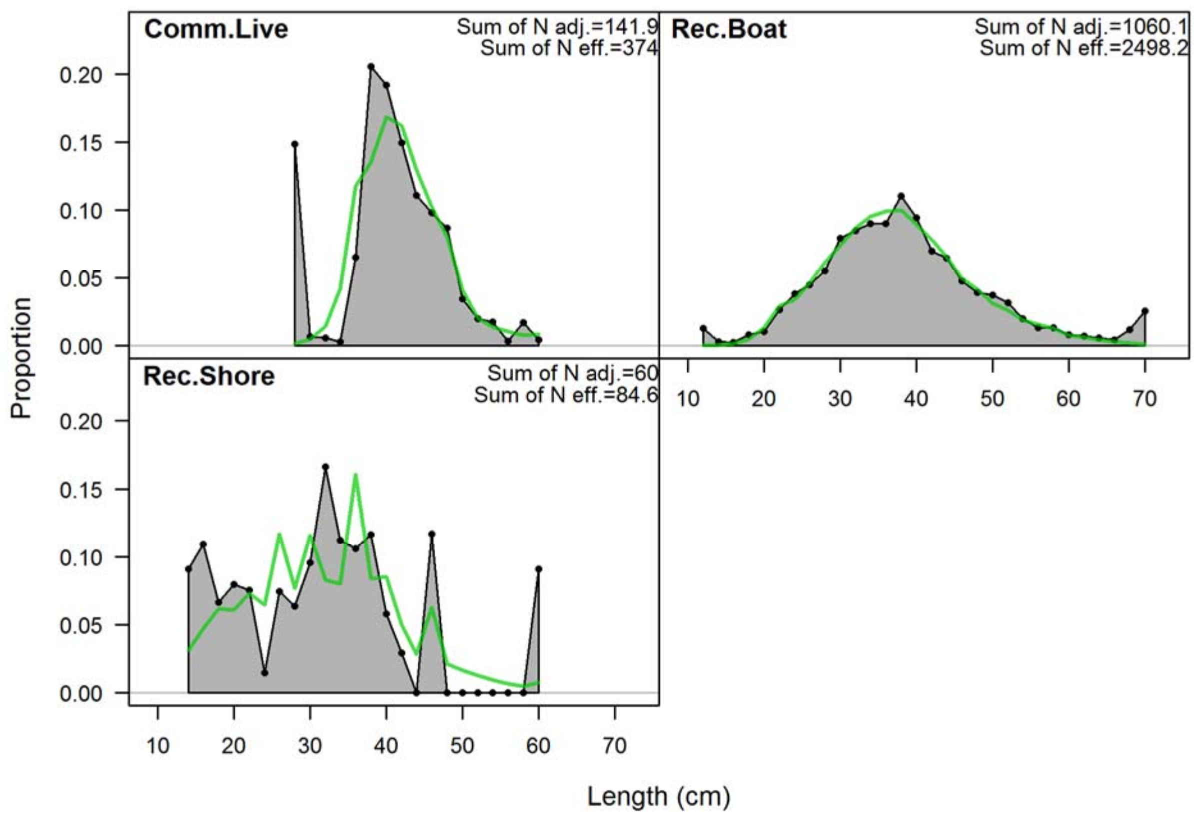


Figure 50. Reference model fit to time-aggregated Cabezon length compositions for all SCS fleets.

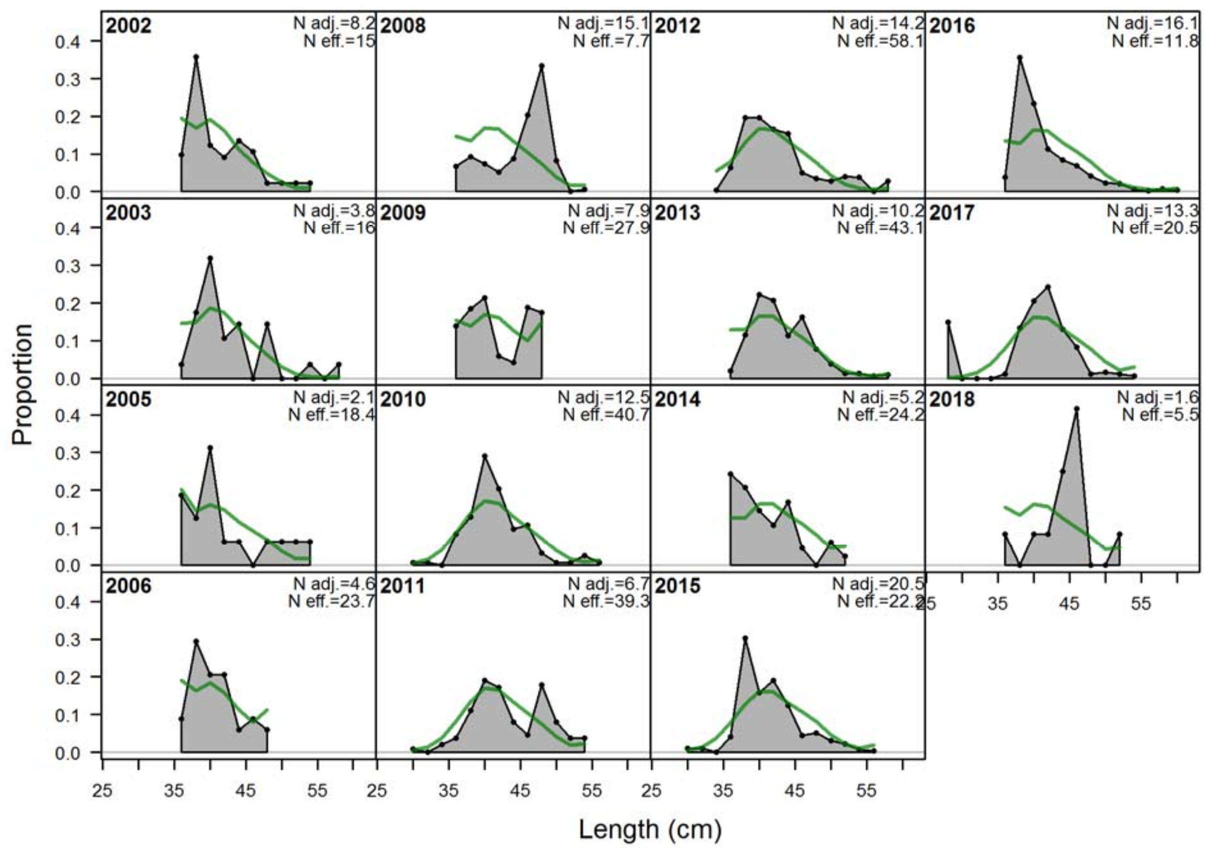


Figure 51. Observed (gray density plot) and model-predicted fits (green line) to length composition by year for the SCS live fish fleet.

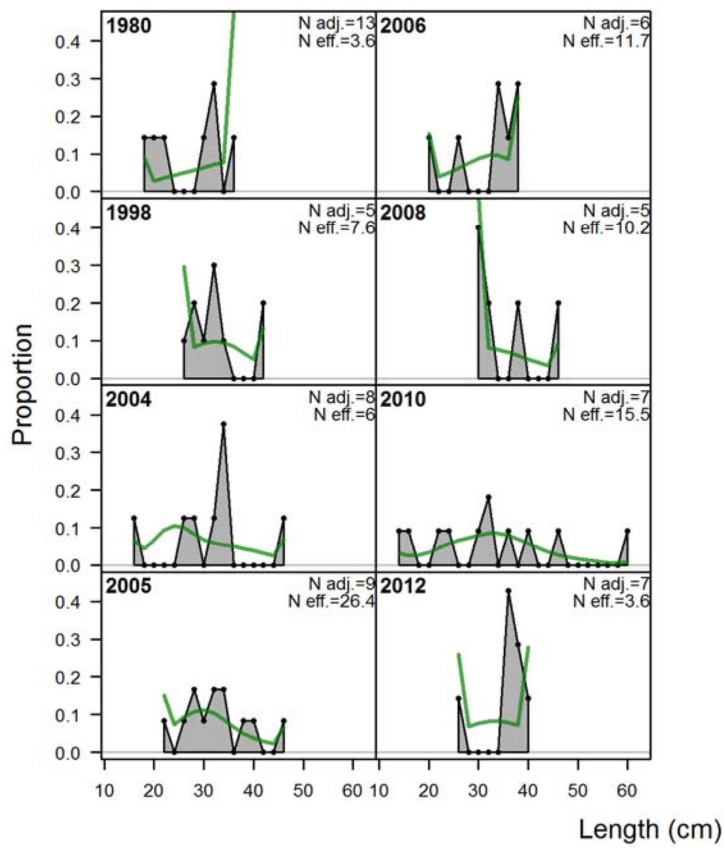
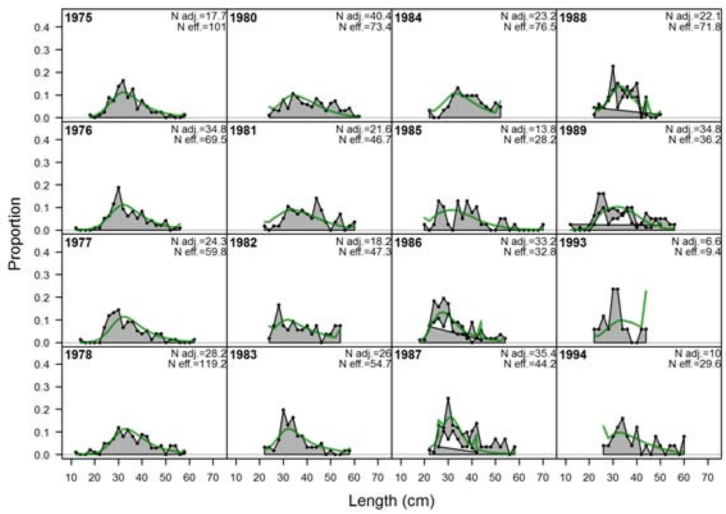
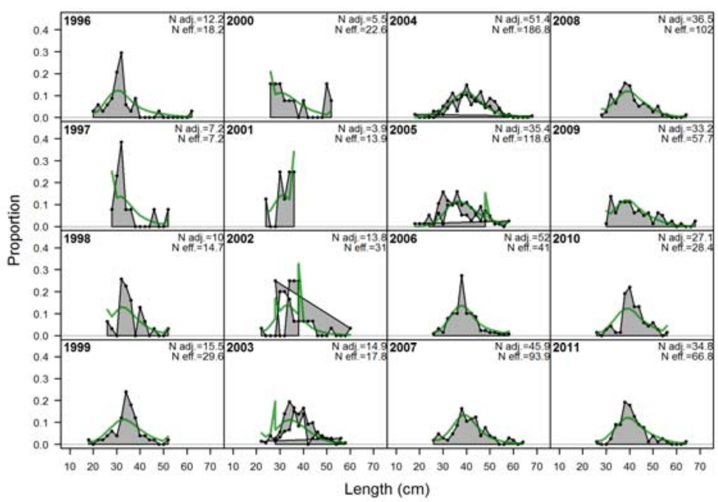


Figure 52. Observed (gray density plot) and model-predicted fits (green line) to length composition by year for the SCS shore fleet.





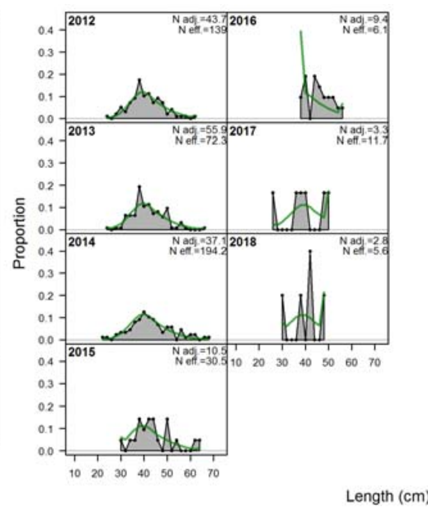


Figure 53. Observed (gray density plot) and model-predicted fits (green line) to length composition by year for the SCS boat fleet.

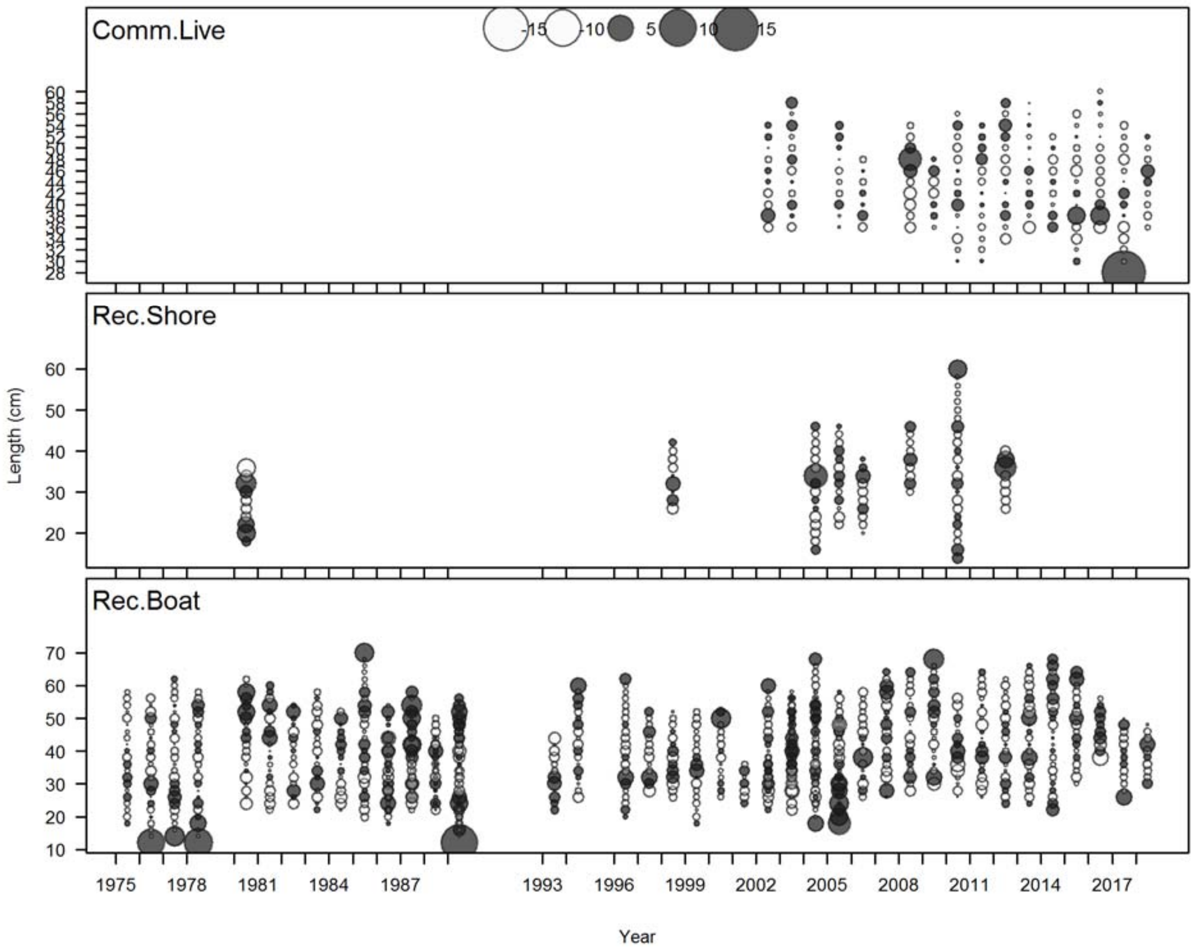


Figure 54. Pearson residuals to length composition fits for three fleets in the SCS reference model.

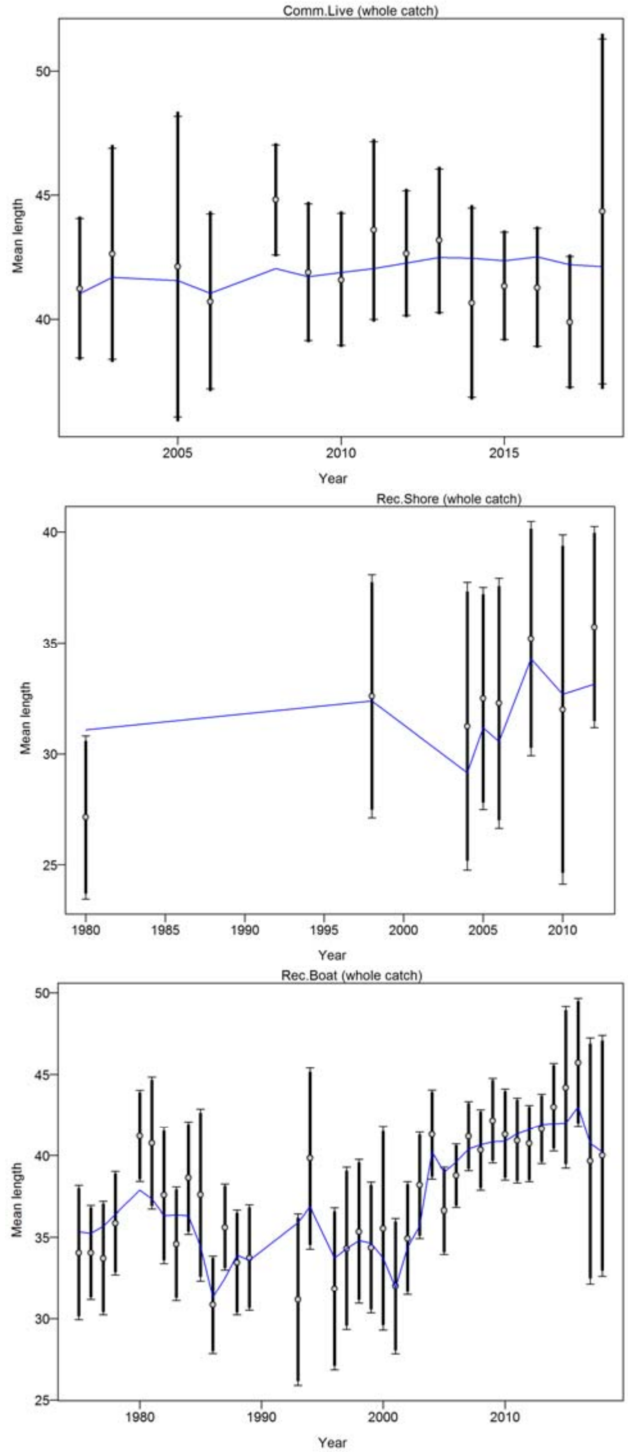


Figure 55. Mean lengths and estimates (blue line) for each fleet with length composition data in the SCS model. The fits are used in the Francis data weighting approach.

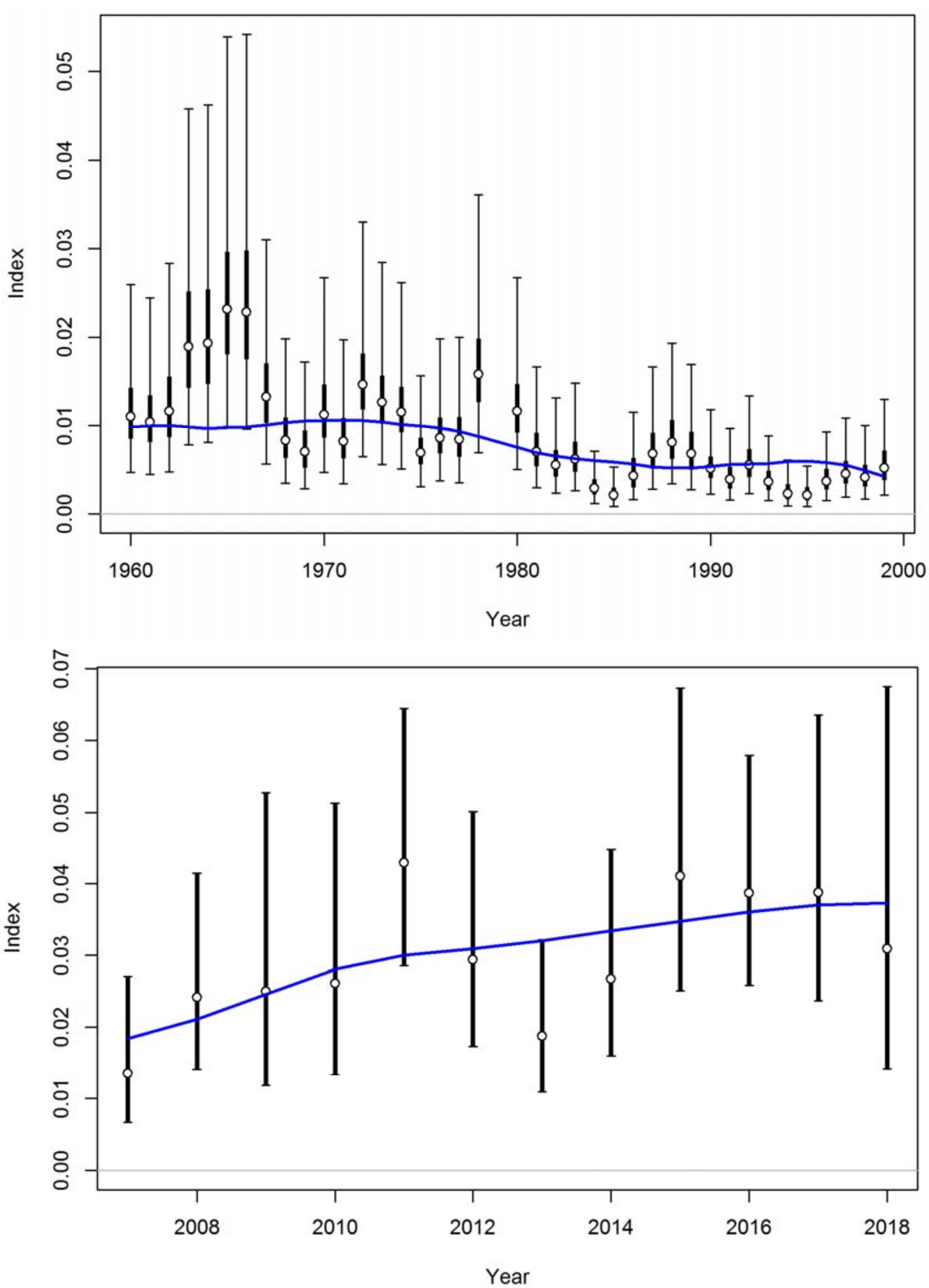


Figure 56. Fits to the CPFV (top panel) and CCFRP (bottom panel) relative abundance time series in the NCS model.

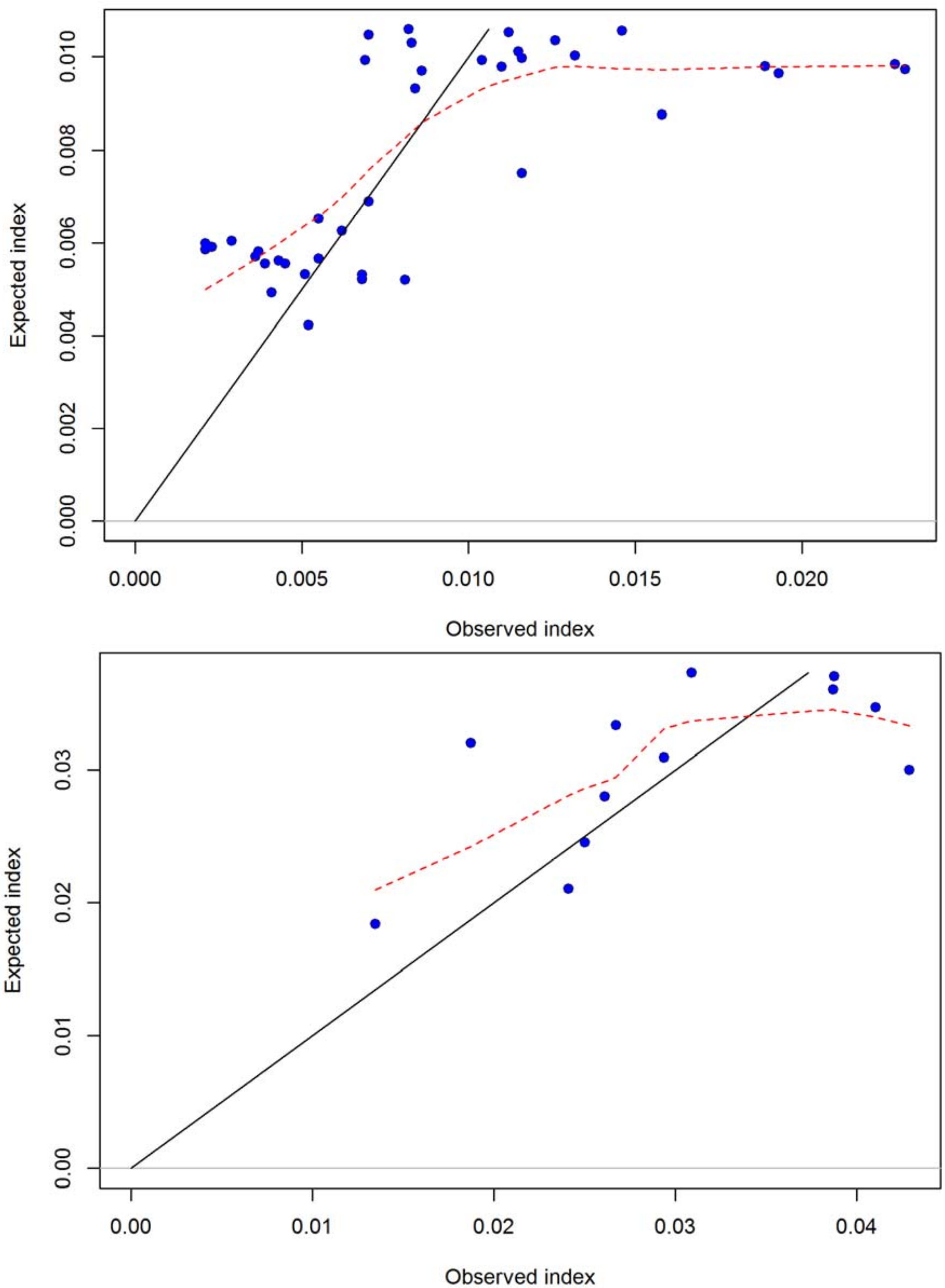


Figure 57. Observed vs expected index values for the CPFV (top panel) and he CCFRP (bottom panel) surveys used in the NCS reference model.

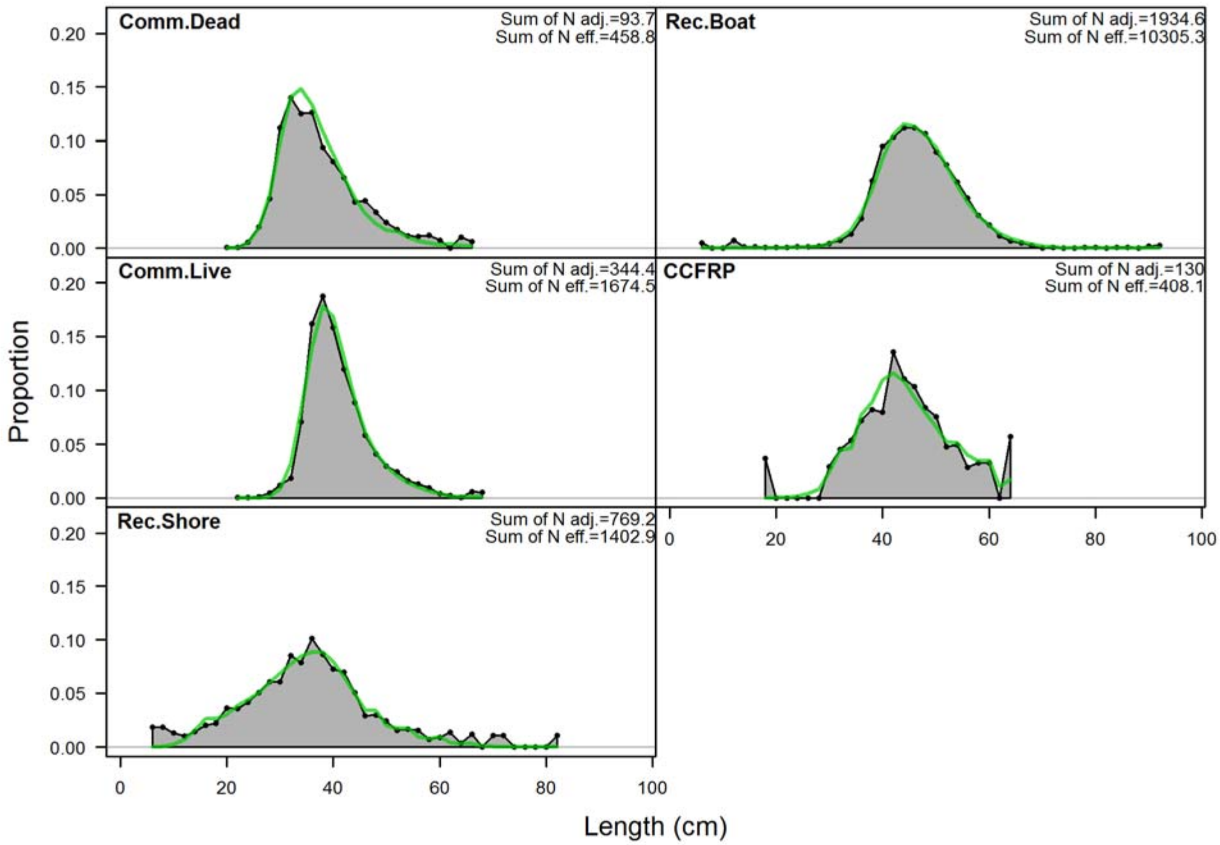


Figure 58. Base model fit to time-aggregated Cabezon length compositions for all NCS fleets.

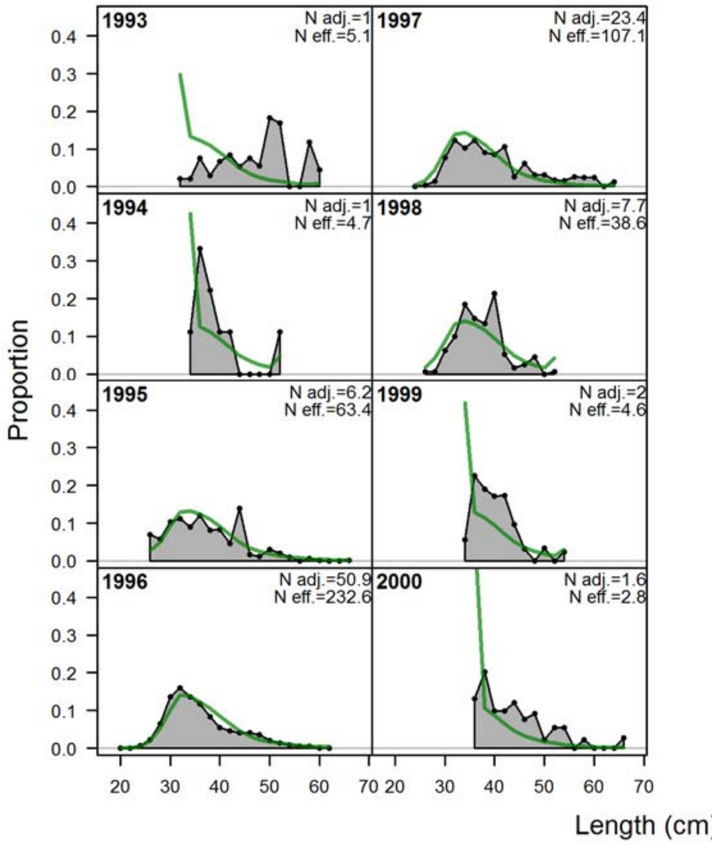


Figure 59. Observed (gray density plot) and model-predicted fits (green line) to length composition by year for the NCS commercial dead fleet.

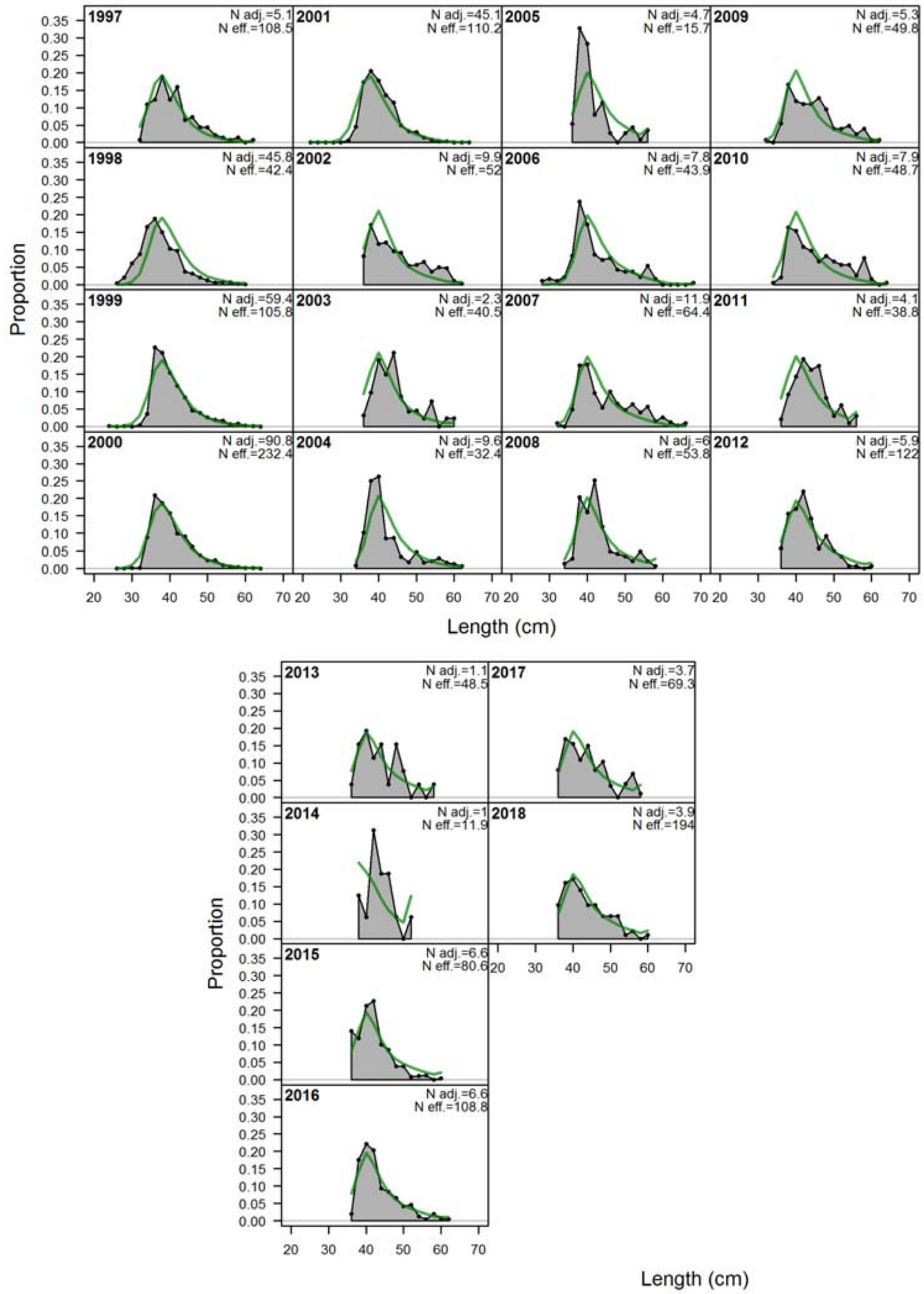


Figure 60. Observed (gray density plot) and model-predicted fits (green line) to length composition by year for the NCS commercial live fleet.

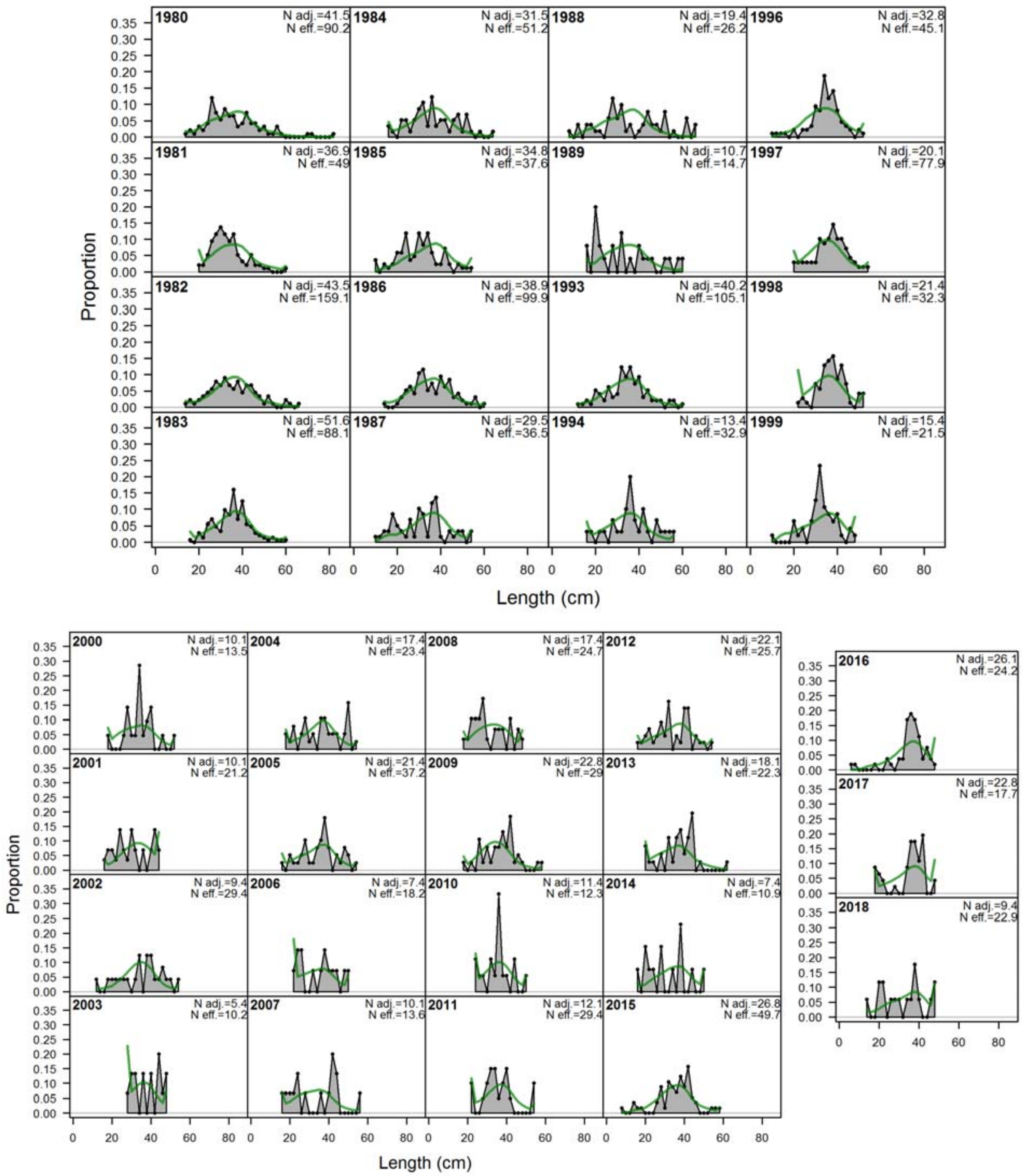


Figure 61. Observed (gray density plot) and model-predicted fits (green line) to length composition by year for the NCS recreational shore fleet.

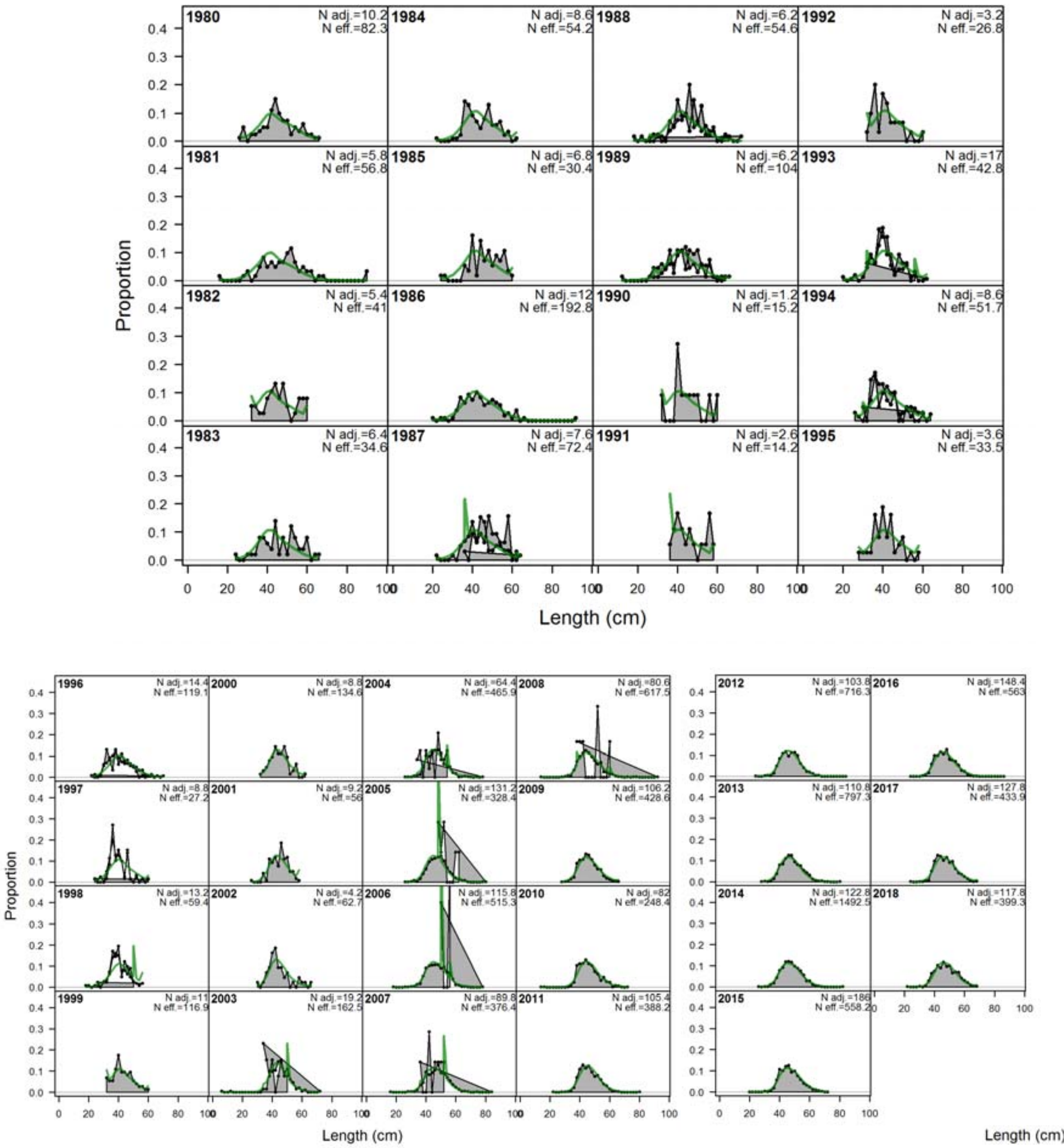


Figure 62. Observed (gray density plot) and model-predicted fits (green line) to length composition by year for the NCS recreational boat fleet.

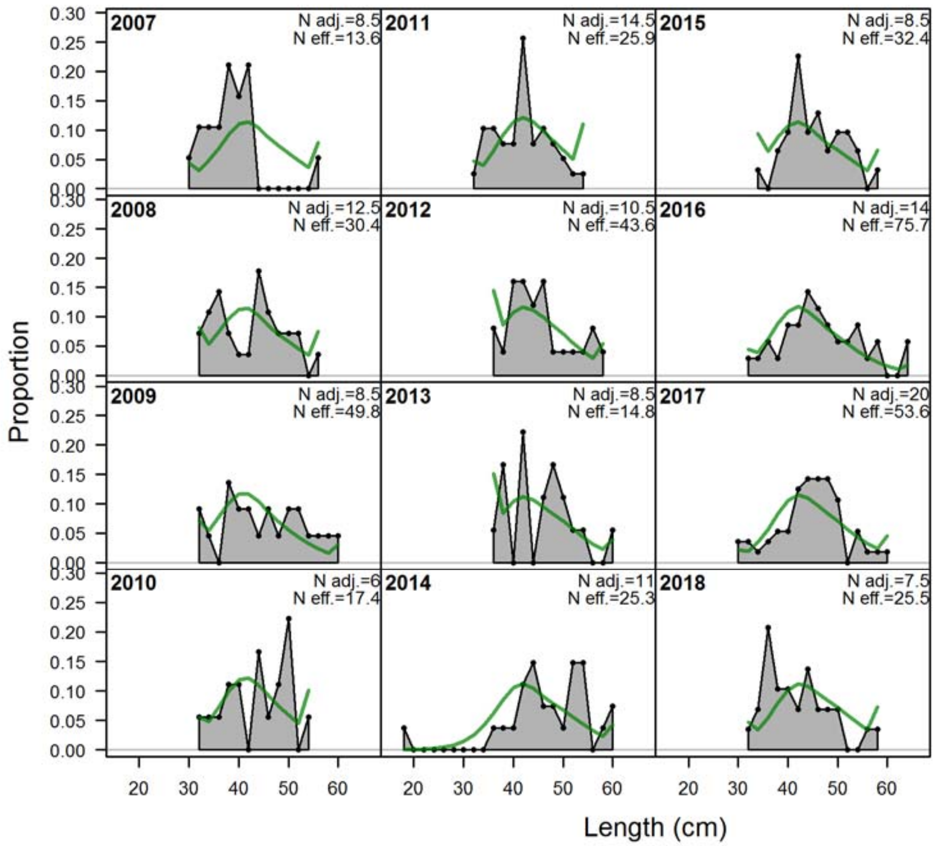


Figure 63. Observed (gray density plot) and model-predicted fits (green line) to length composition by year for the NCS CCFRP survey.

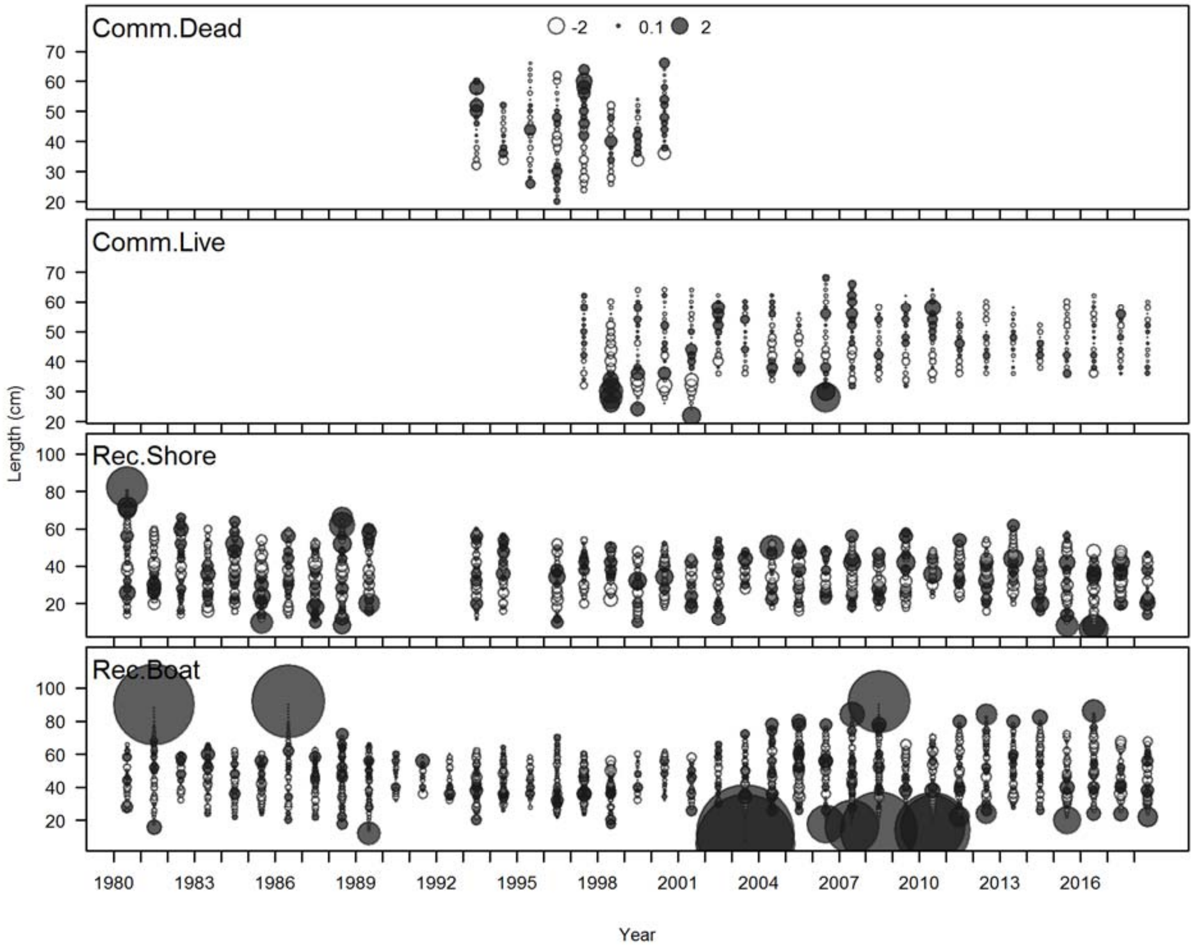


Figure 64. Pearson residuals to length composition fits for fleets in the NCS reference model.

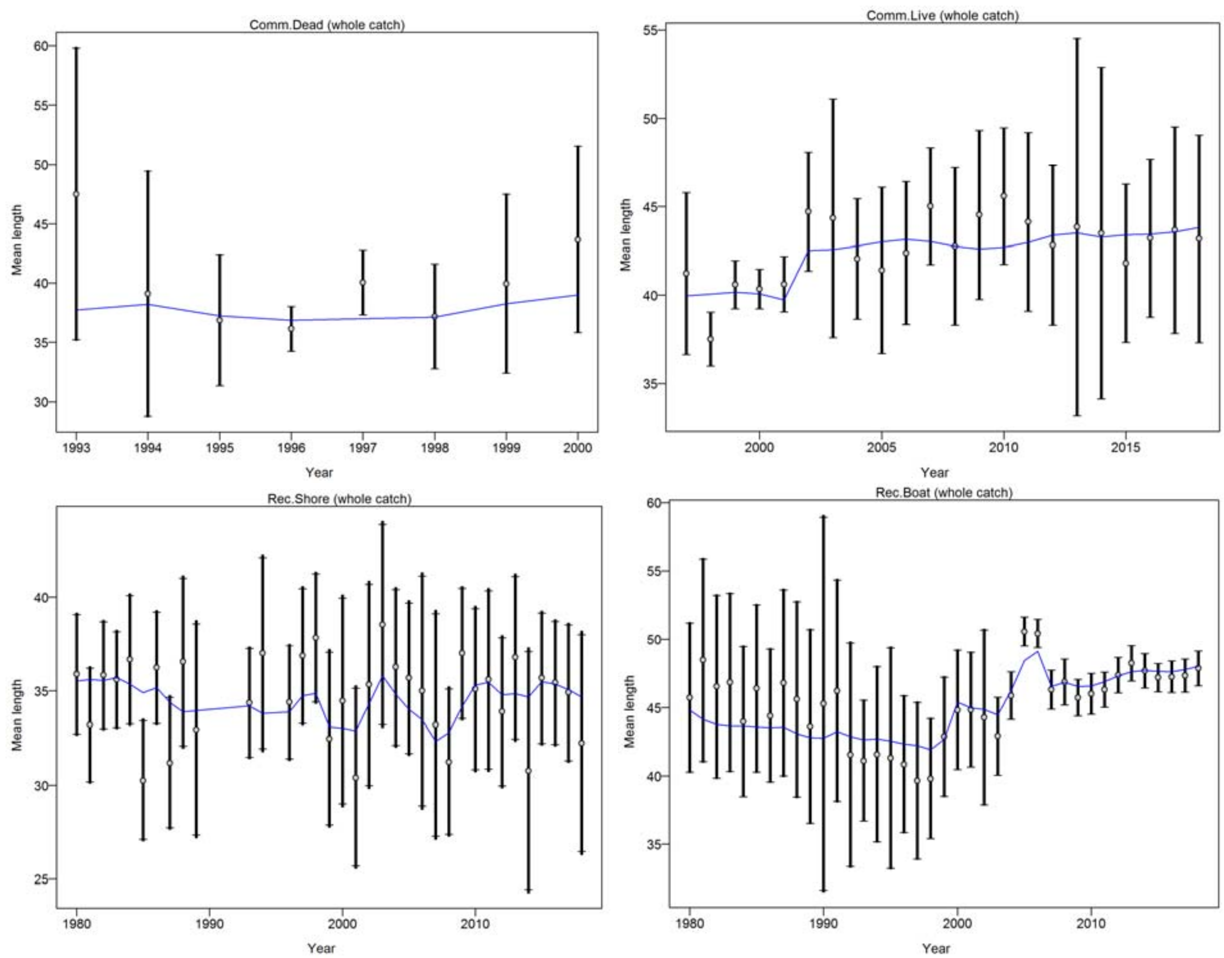


Figure 65. Mean lengths and estimates (blue line) for each fleet with length composition data in the NCS model.

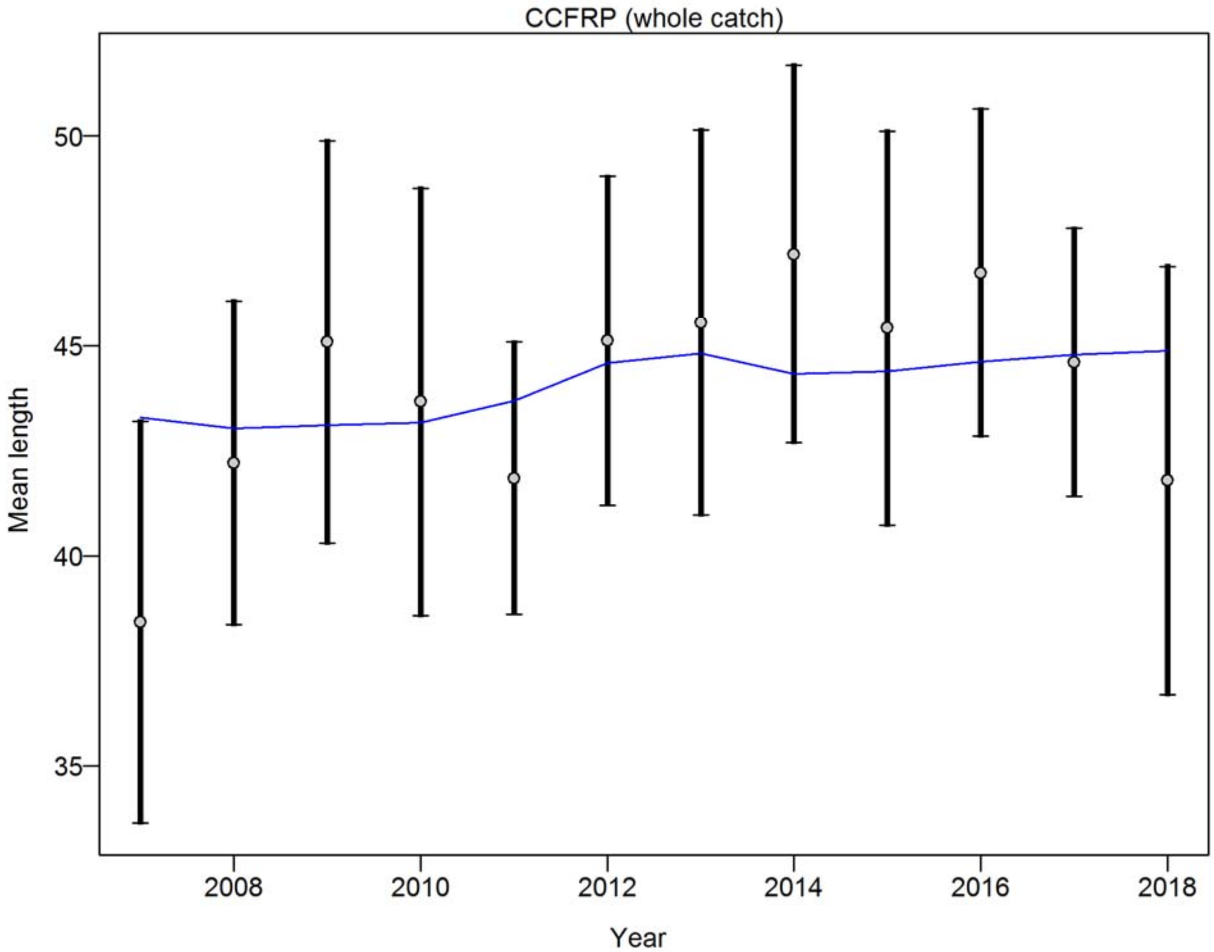


Figure 66. Mean lengths and estimates (blue line) for the CCFRP survey in the NCS model.

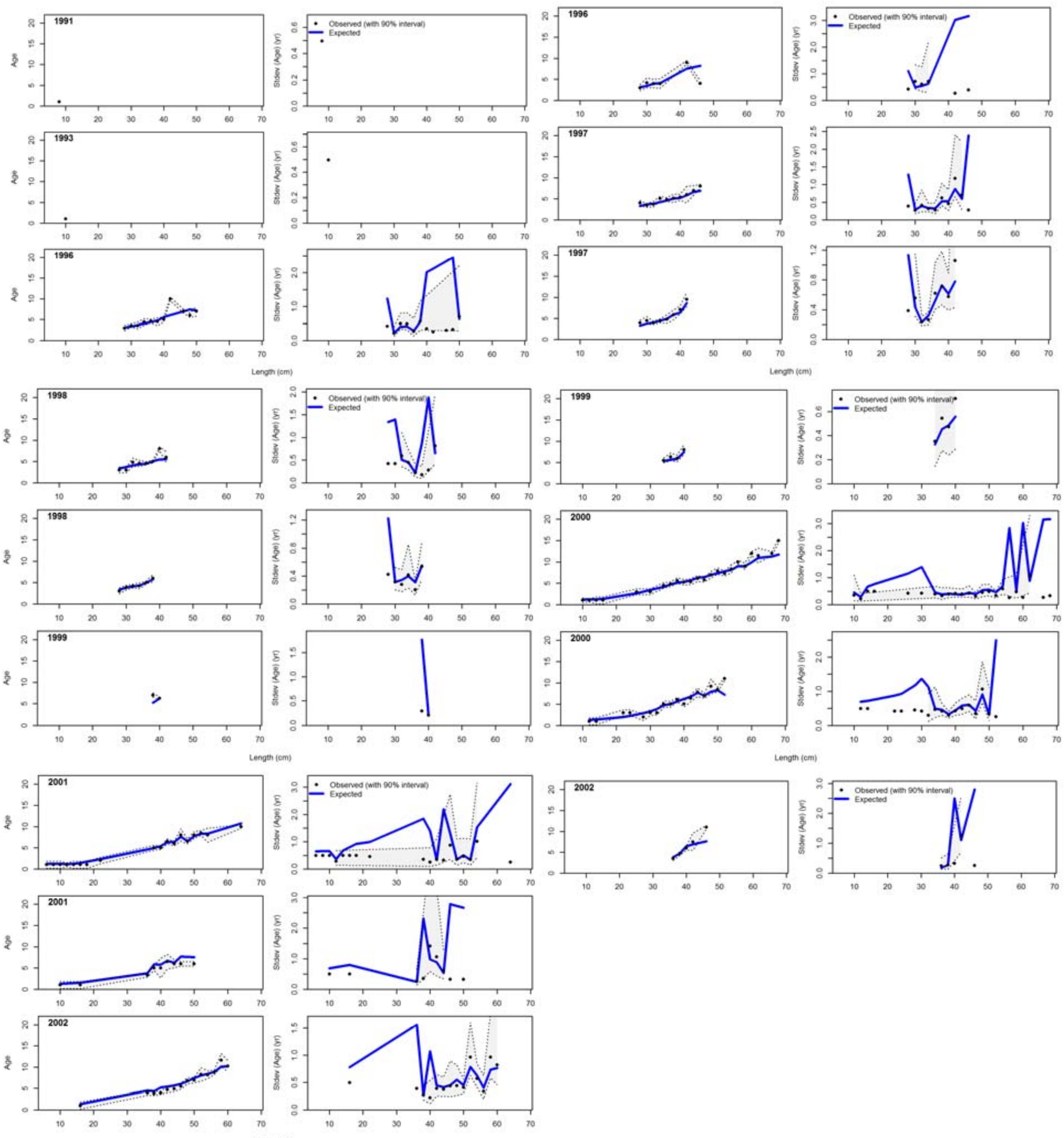


Figure 67. Conditional age-at-length fits in the NCS model.

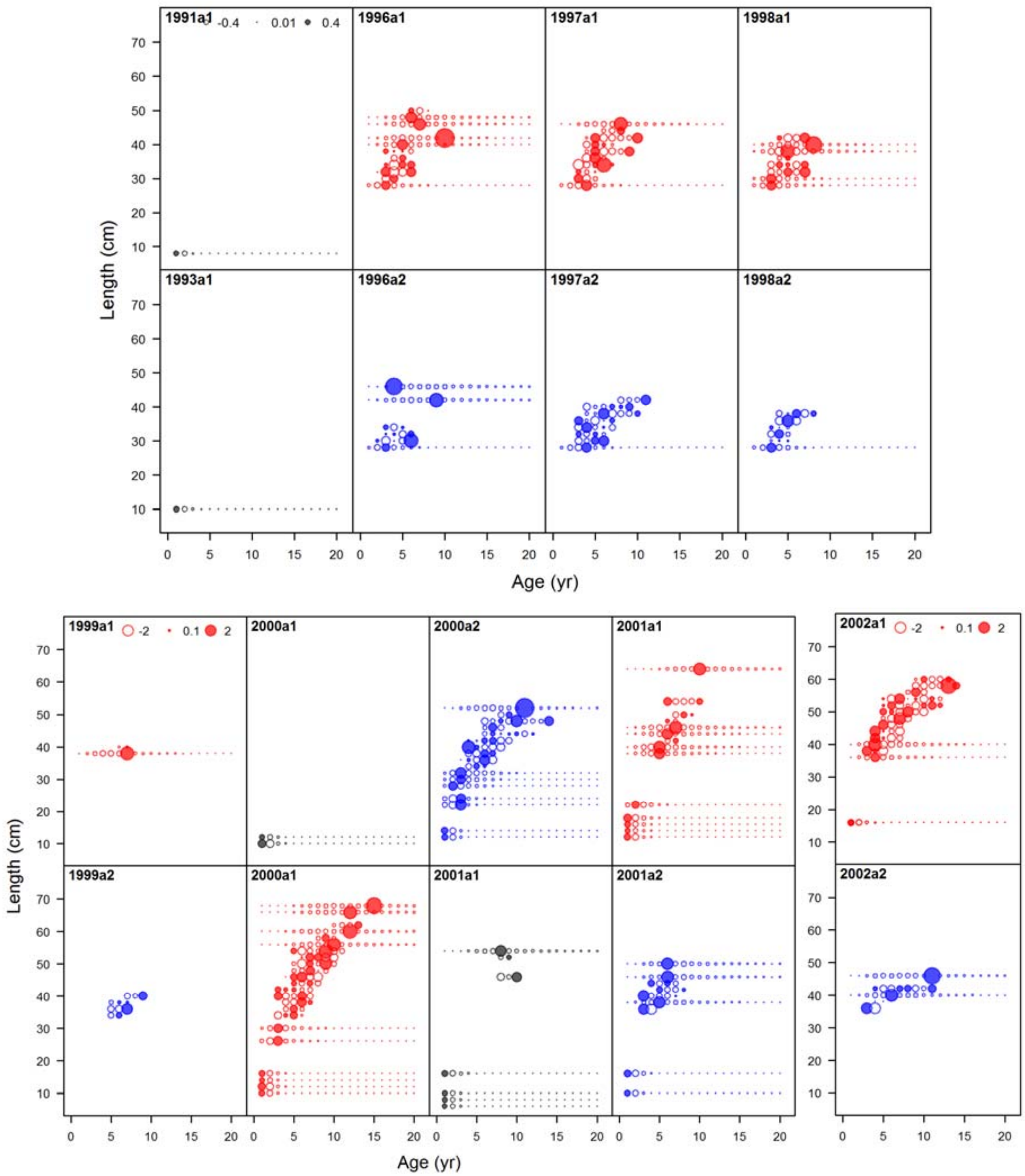


Figure 68. Pearson residuals for the fits to the conditional age-at-length data in the NCS model.

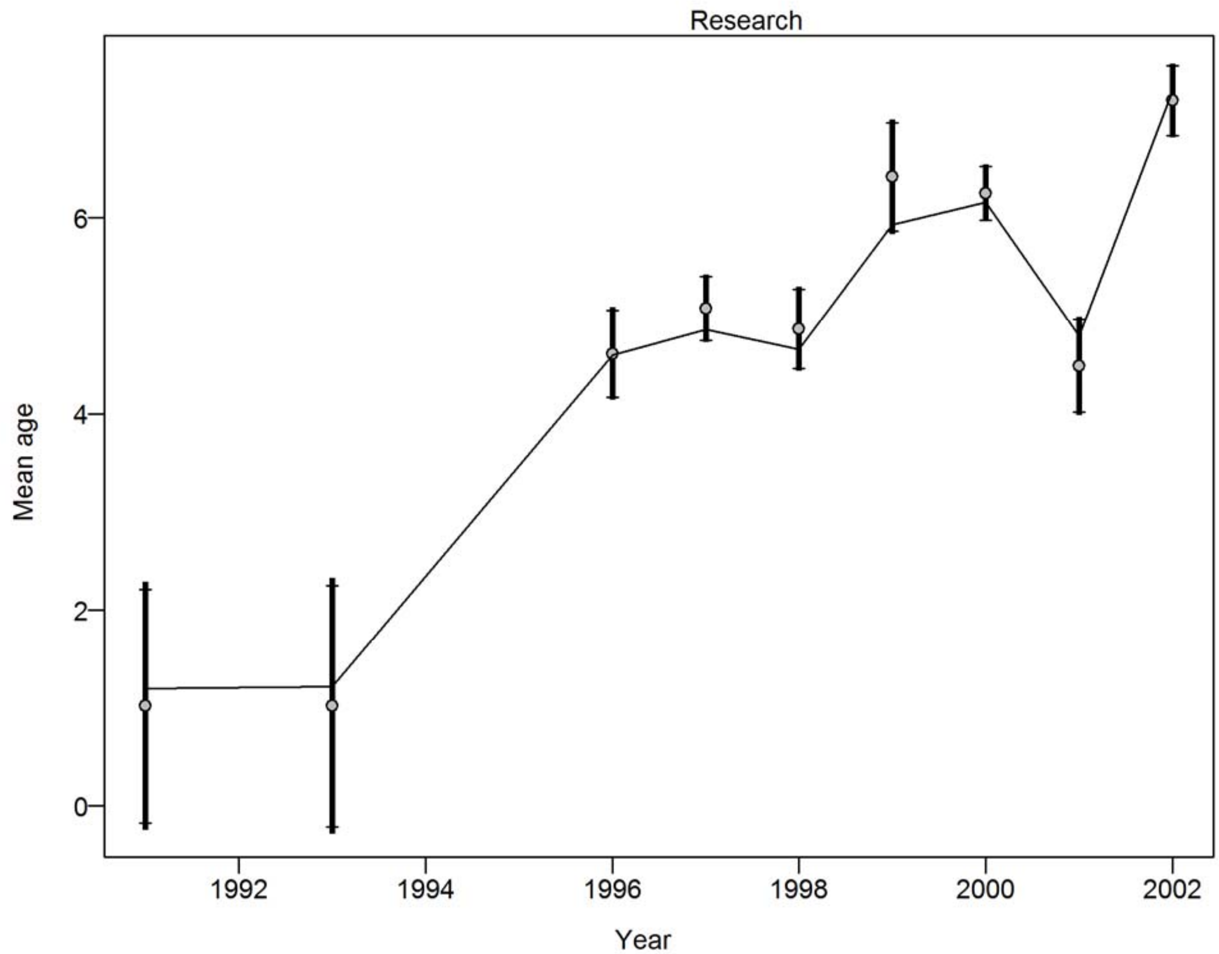


Figure 69. Mean age fits in the NCS model.

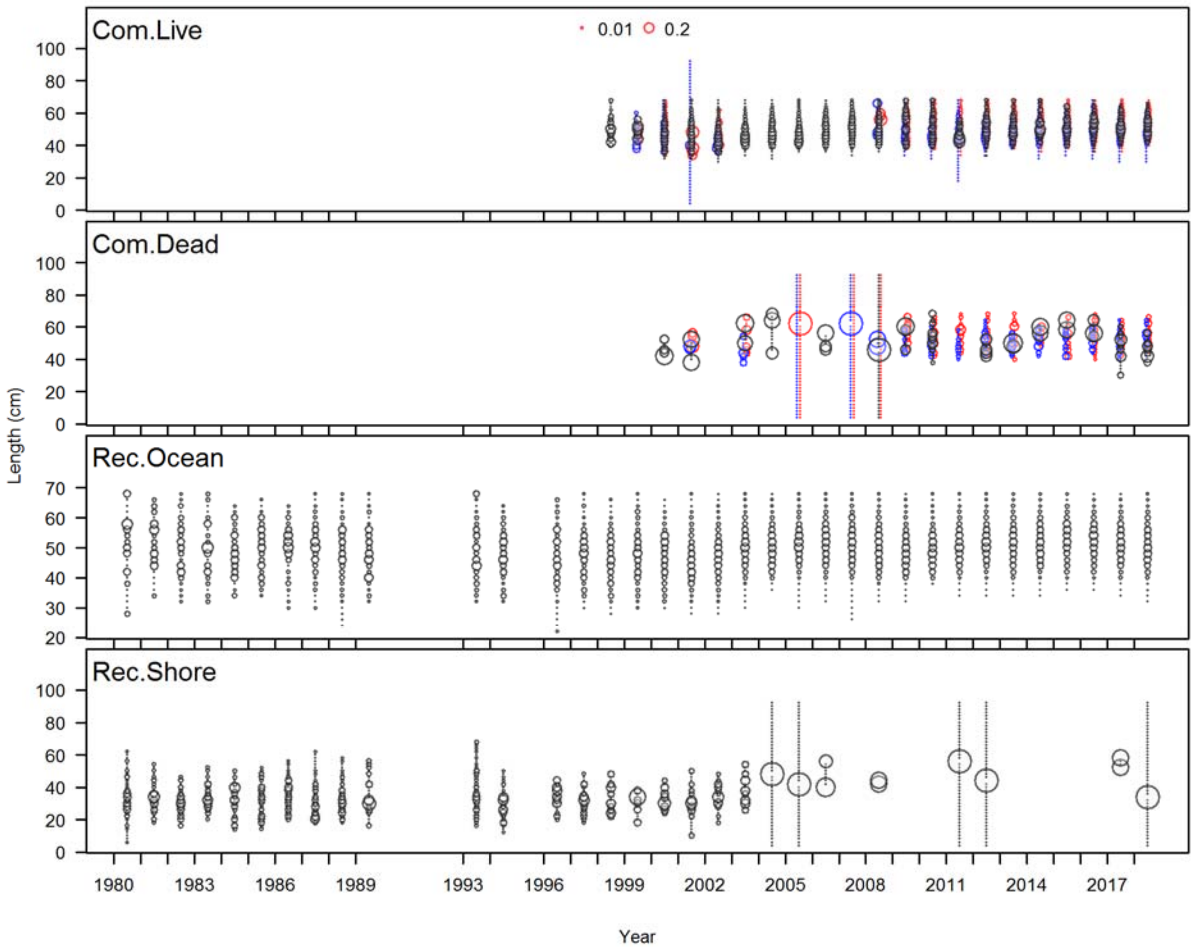


Figure 70. Reference model time-aggregated Cabezon length composition data for all Oregon fleets.

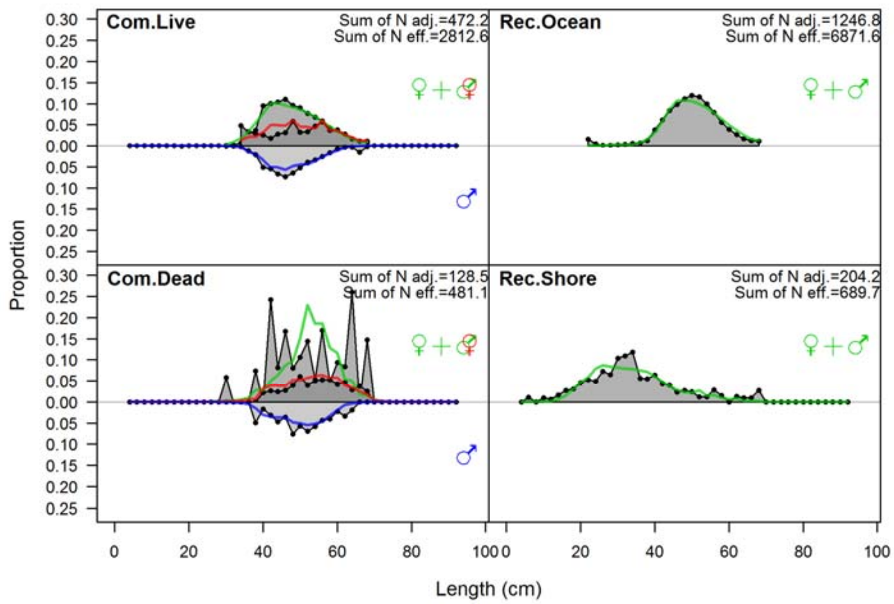


Figure 71. Reference model fit to time-aggregated Cabezon length compositions for all Oregon fleets.

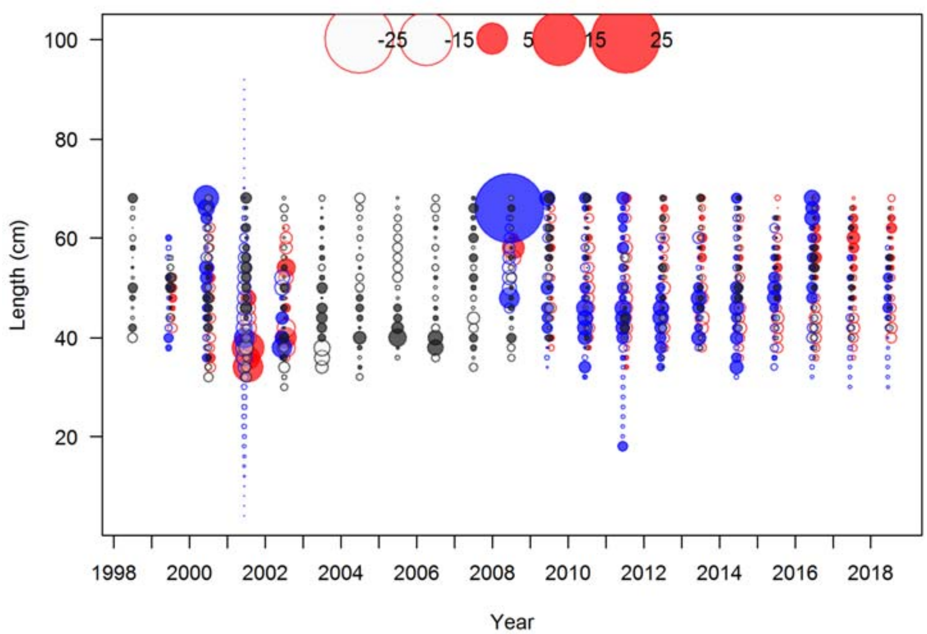


Figure 72. Pearson residuals for the fit to length composition data for the Oregon commercial live landed fleet.

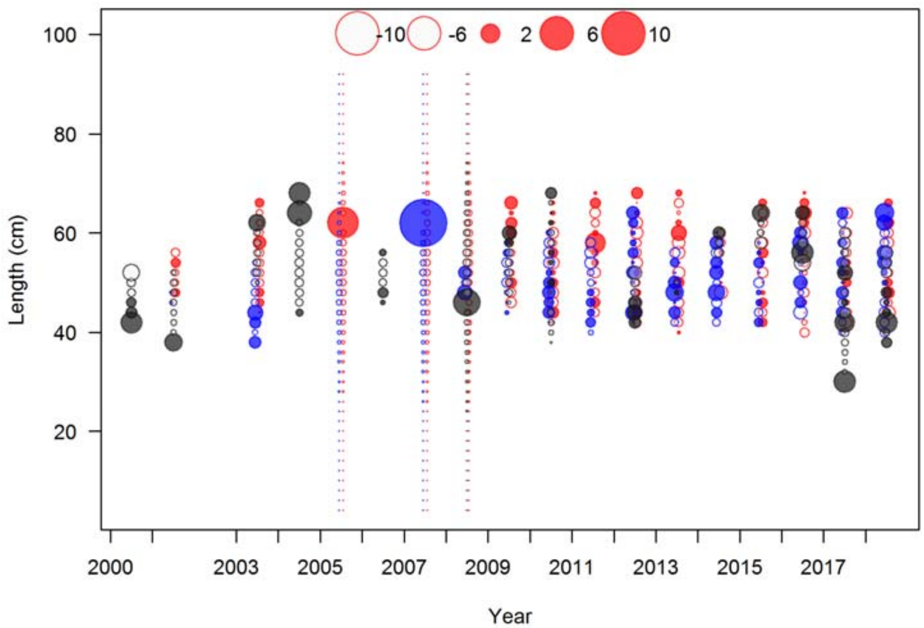


Figure 73. Pearson residuals for the fit to length composition data for the Oregon commercial dead landed fleet.

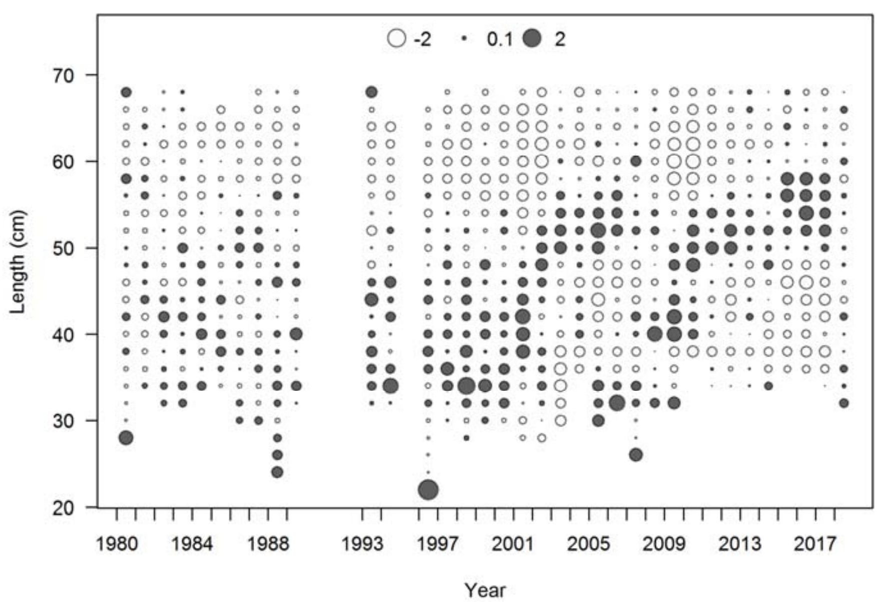


Figure 74. Pearson residuals for the fit to length composition data for the Oregon recreational ocean boat fleet.

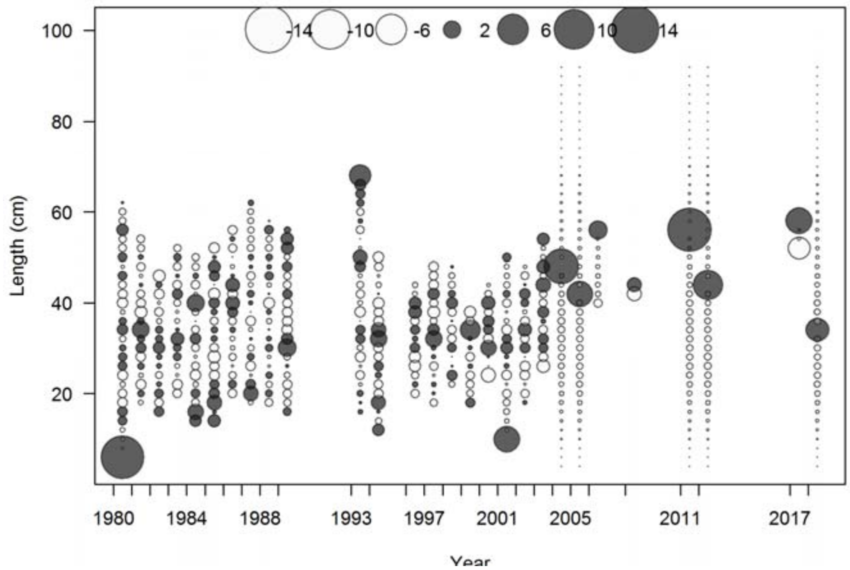


Figure 75. Pearson residuals for the fit to length composition data for the Oregon recreational shore/estuary fleet.

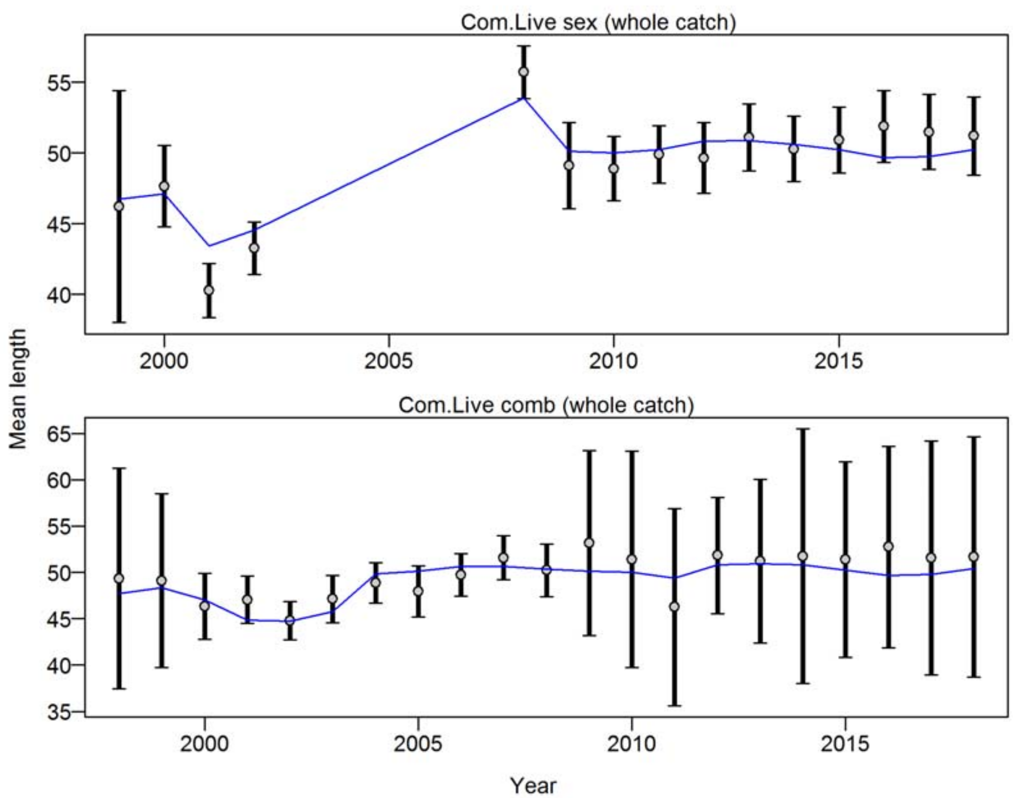


Figure 76. Base model fit to mean Oregon Cabezon lengths for the commercial live fleet.

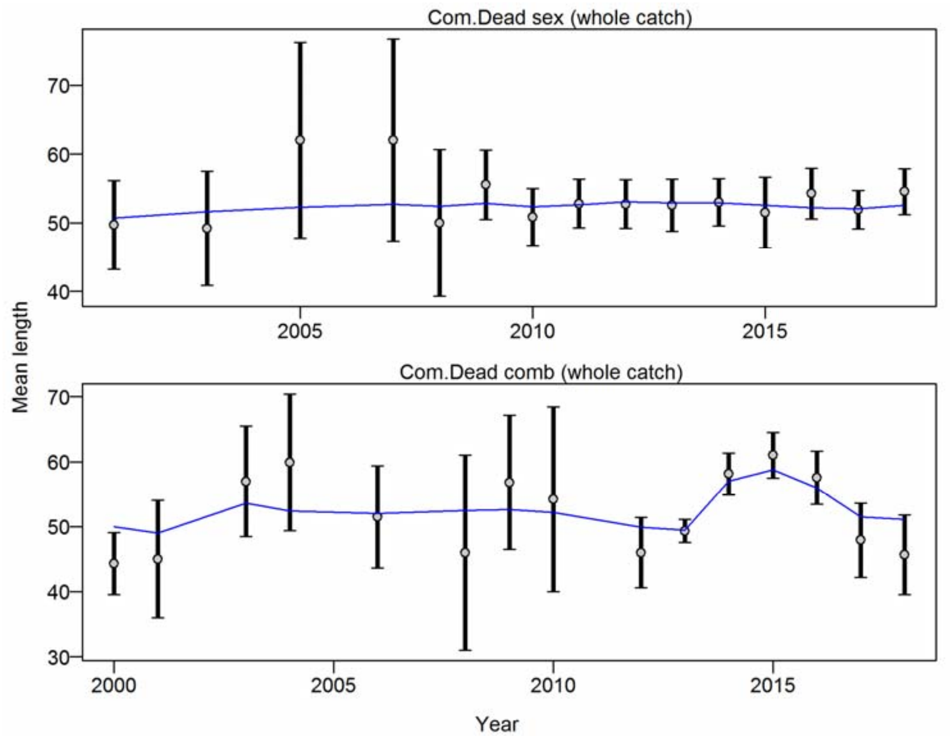


Figure 77. Base model fit to mean Oregon Cabezon lengths for the commercial dead fleet.

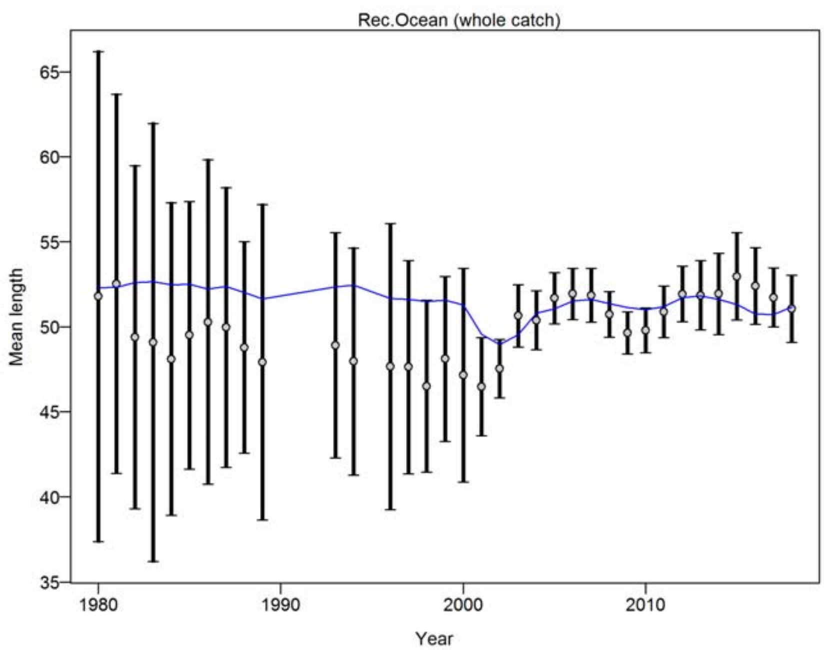


Figure 78. Base model fit to mean Oregon Cabezon lengths for the recreational ocean boat fleet.

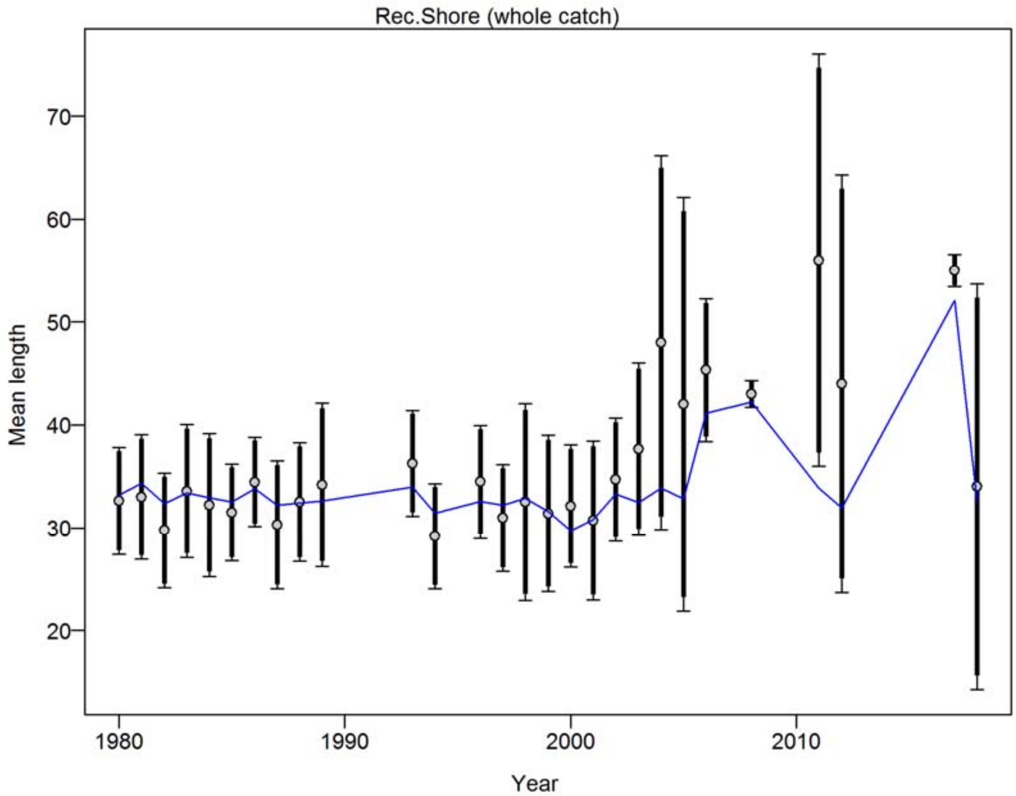


Figure 79. Base model fit to mean Oregon Cabezon lengths for the recreational shore/estuary fleet.

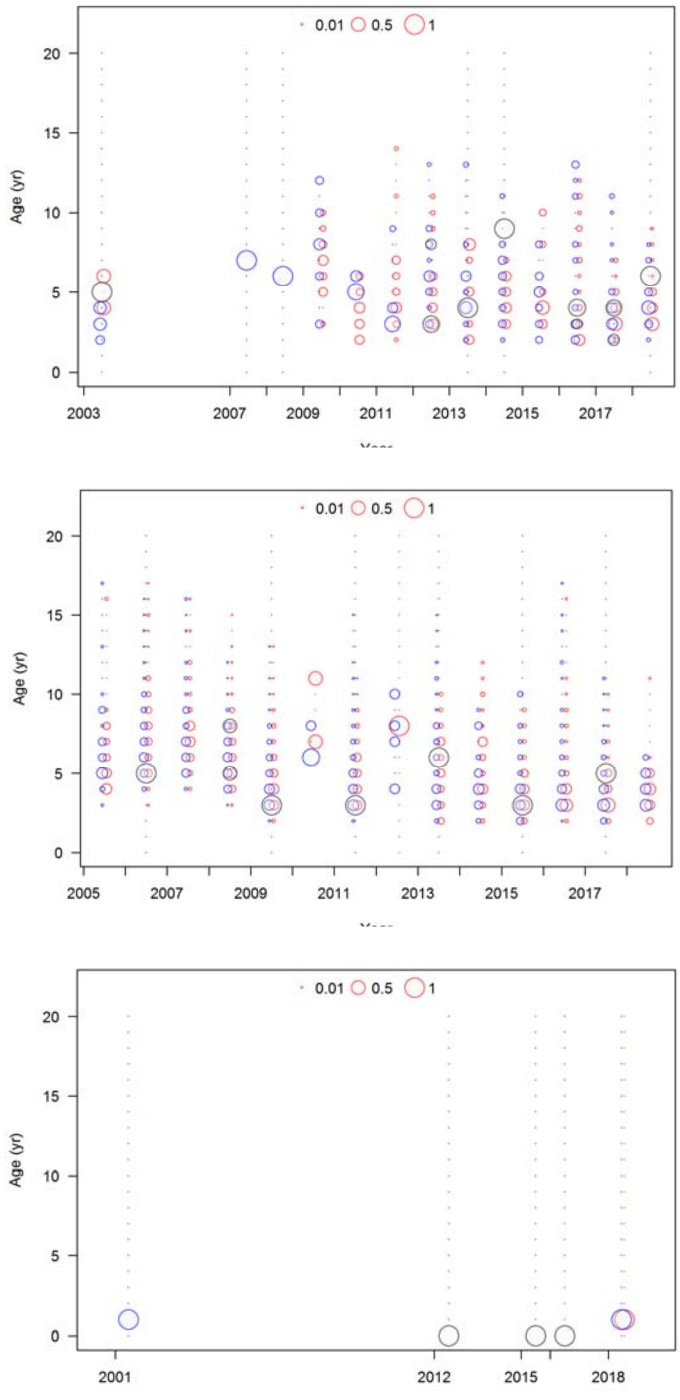


Figure 80. Reference model time-aggregated Cabezon age composition data for the commercial dead fleet (top), recreational ocean boat fleet (middle), and from research samples (bottom) in Oregon.

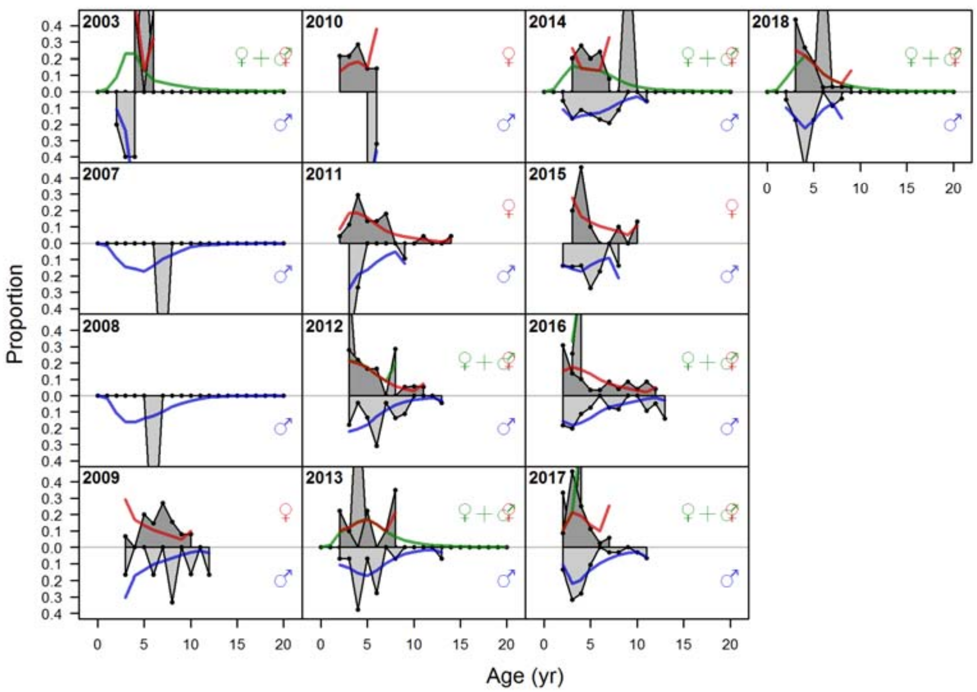


Figure 81. Resulting deviations in age composition patterns from fitting conditional age-at-length data for the Oregon commercial dead fleet.

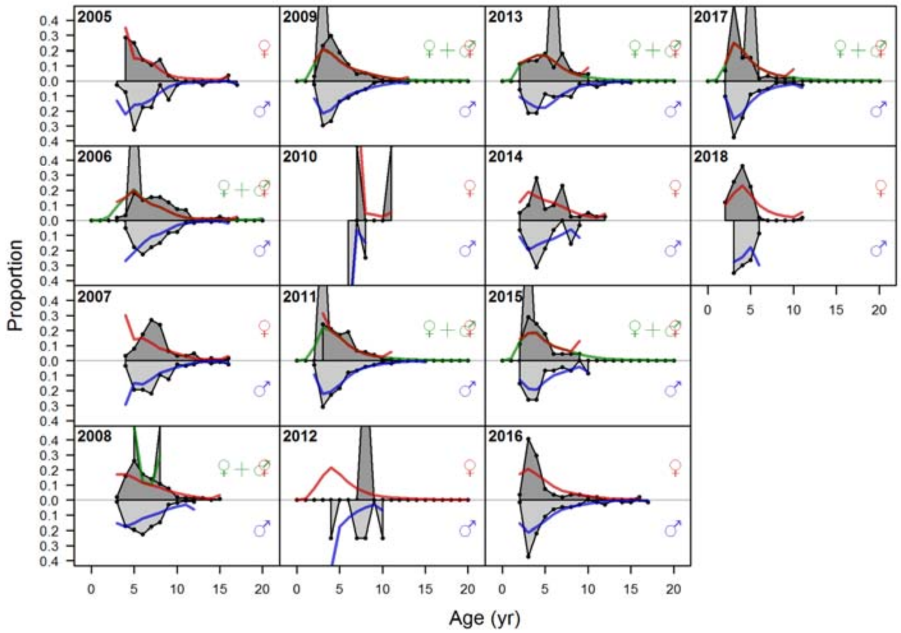


Figure 82. Resulting deviations in age composition patterns from fitting conditional age-at-length data for the Oregon recreational ocean boat fleet.

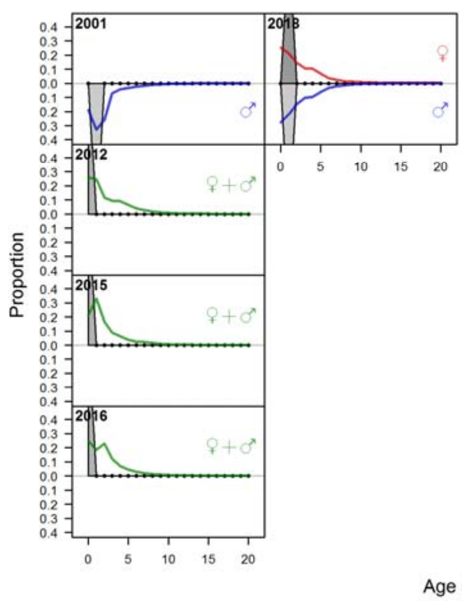


Figure 83. Resulting deviations in age composition patterns from fitting conditional age-at-length data for the Oregon research-based age collection.

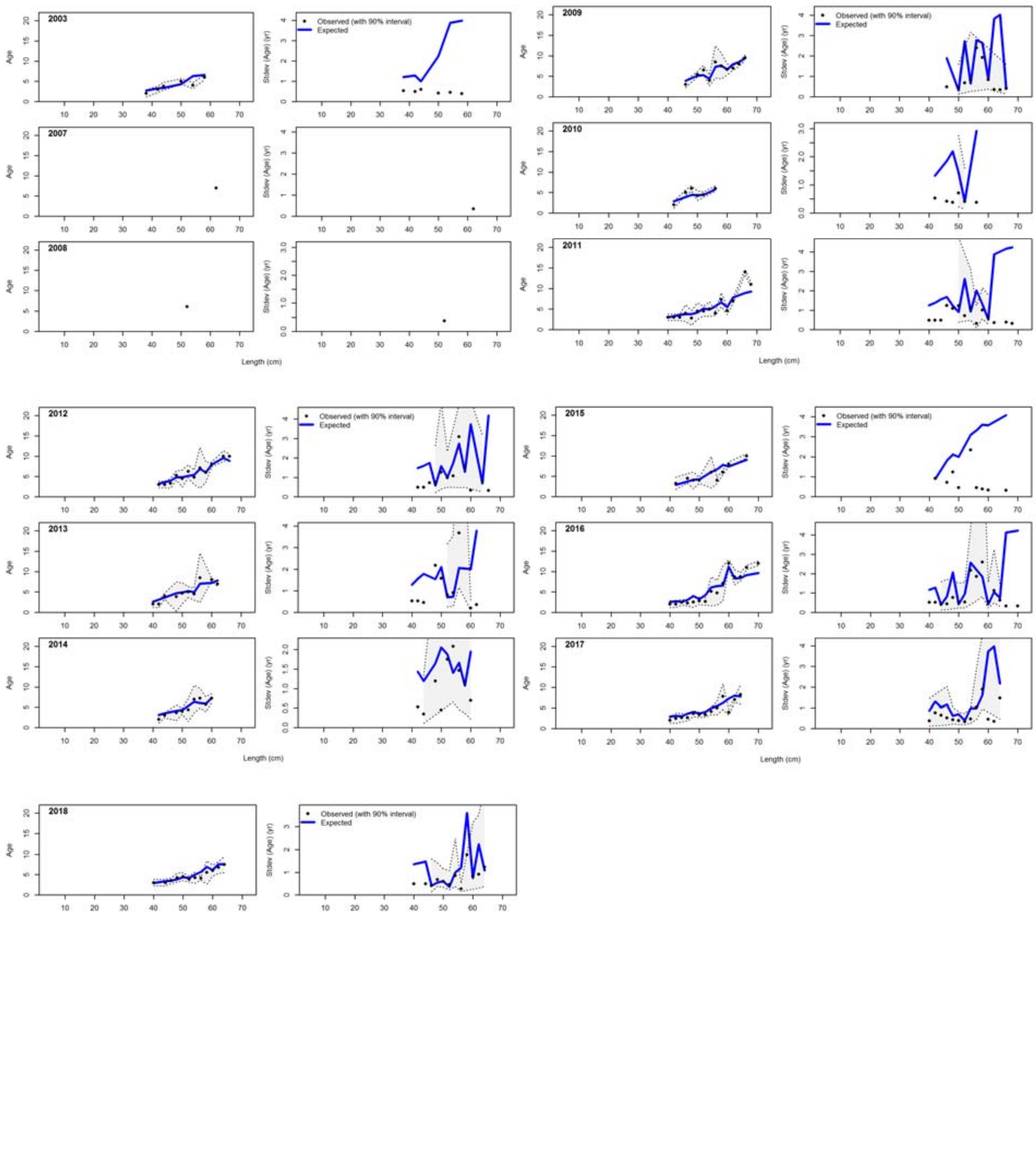


Figure 84. Base model fits to conditional age-at-length data for the Oregon commercial dead fleet.

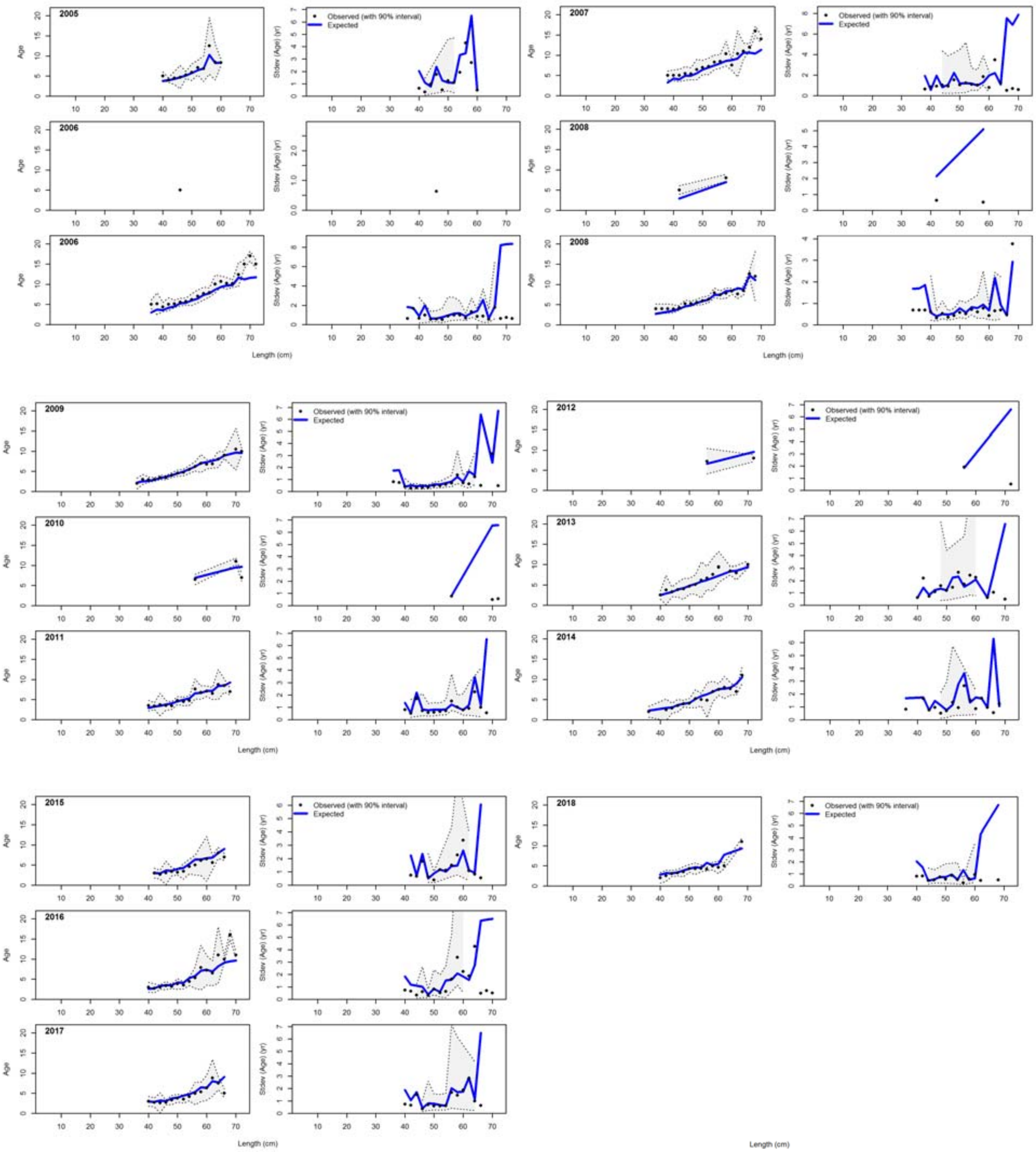


Figure 85. Base model fits to conditional age-at-length data for the Oregon recreational ocean boat fleet.

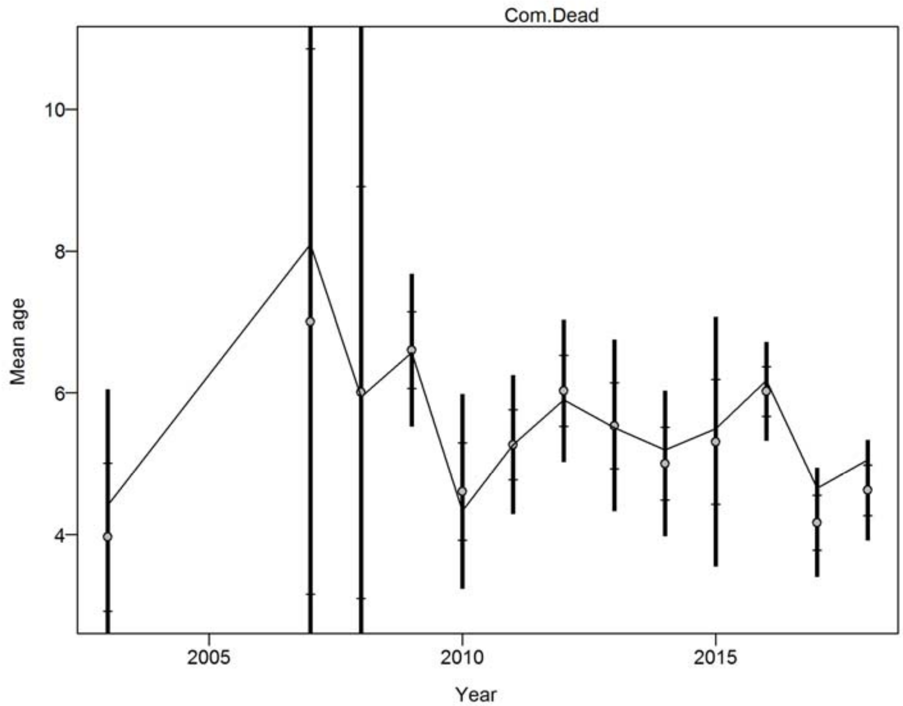


Figure 86. Base model fit to Oregon Cabezon mean age for the commercial dead fleet.

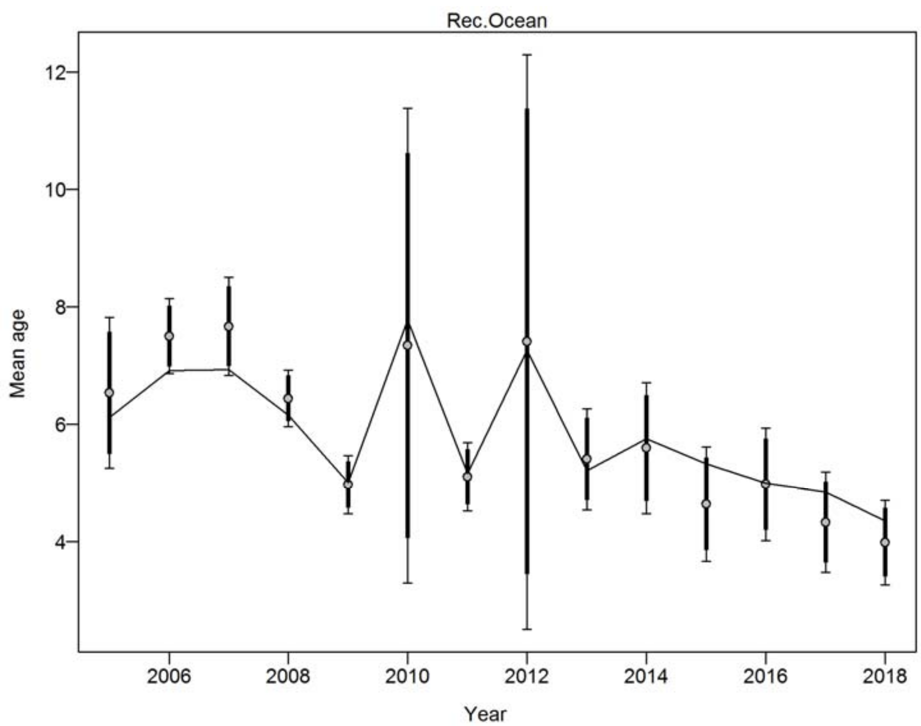


Figure 87. Reference model fit to Oregon Cabezon mean age for the recreational ocean boat fleet.

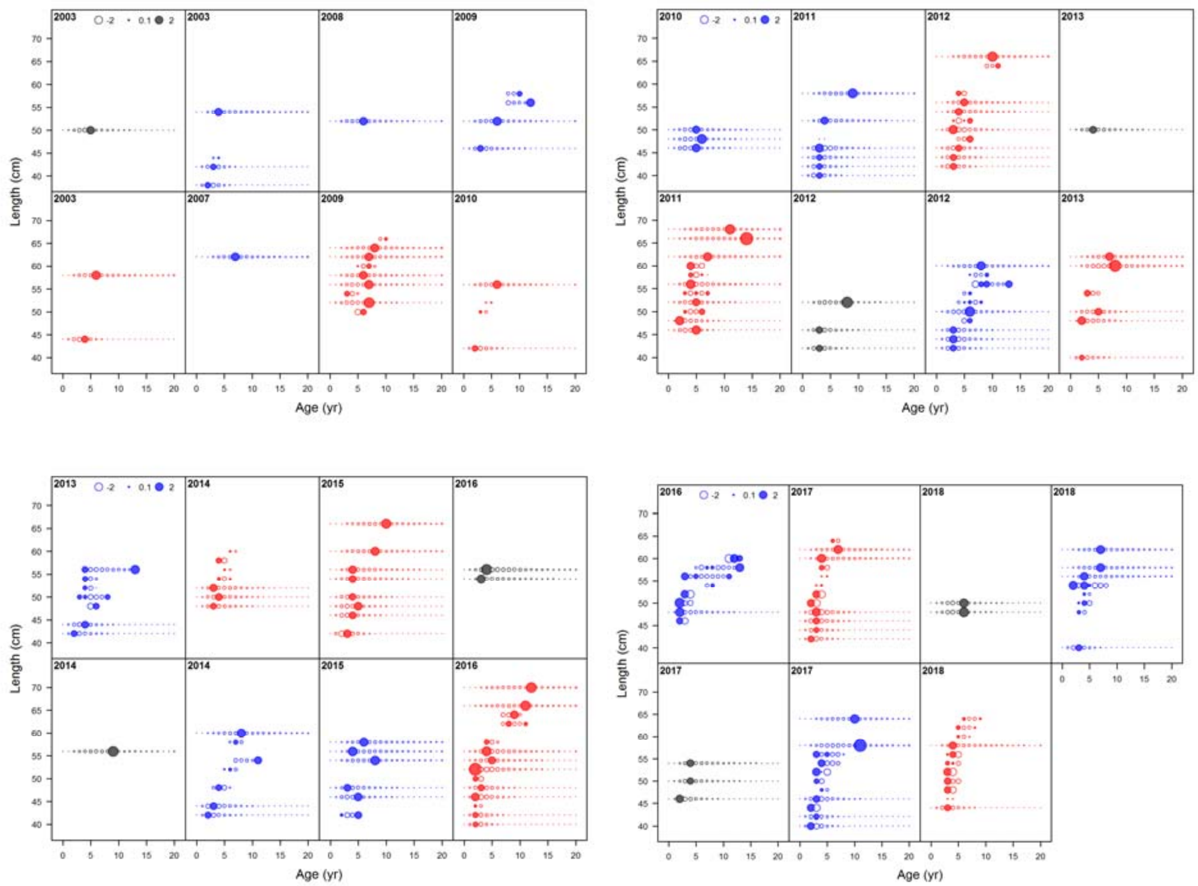


Figure 88. Pearson residuals from the base model fit to conditional age-at-length data in the Oregon commercial dead fleet.

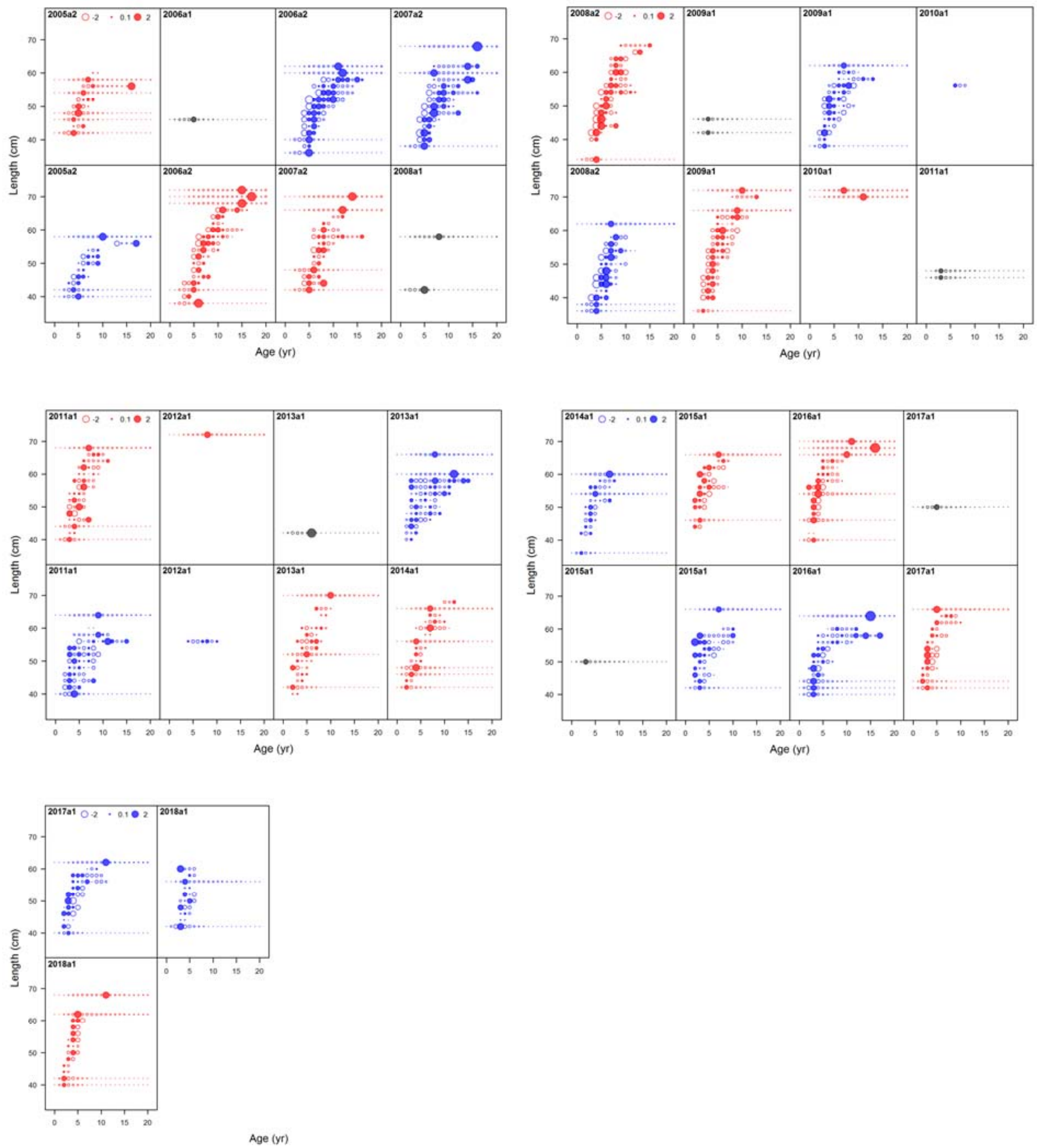


Figure 89. Pearson residuals from the reference model fit to conditional age-at-length data in the Oregon recreational ocean boat fleet.

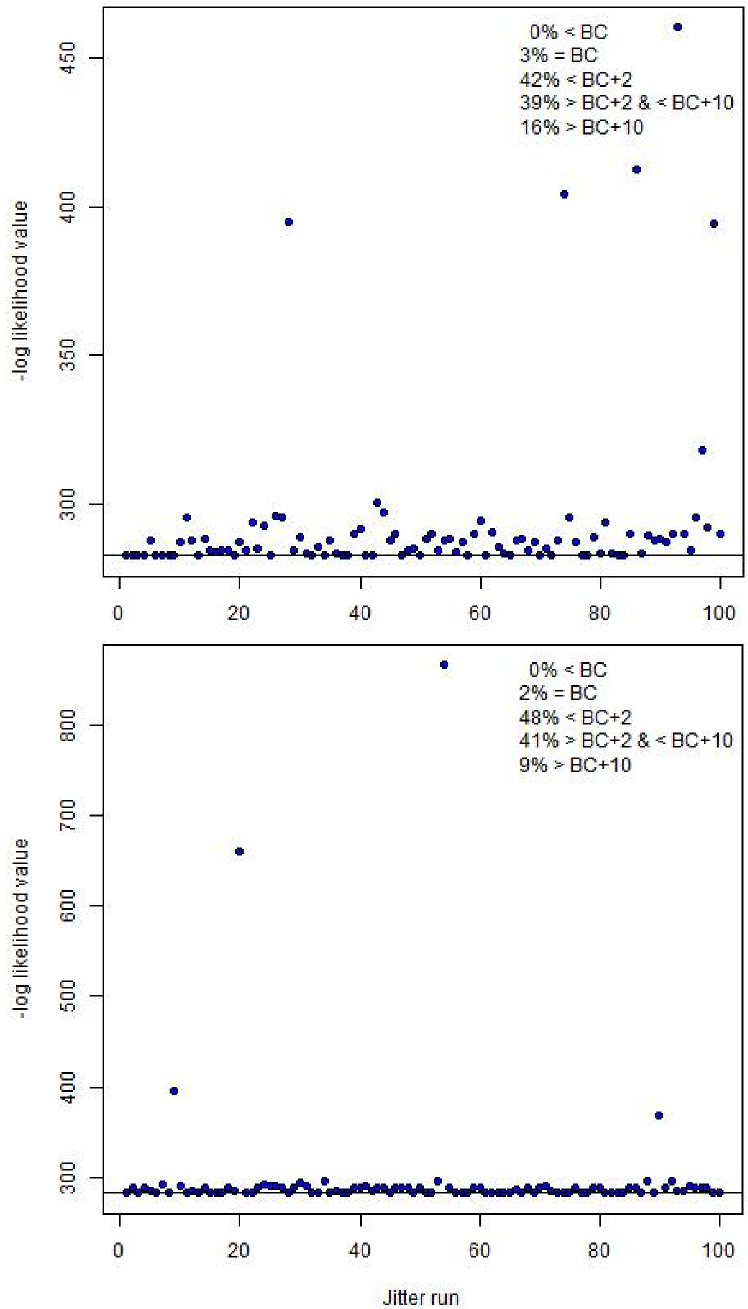


Figure 90. Results from 100 SCS reference model runs when starting parameter values are jittered by 0.1 (top panel) and 0.05 (bottom panel) units. Horizontal line indicates reference model value.

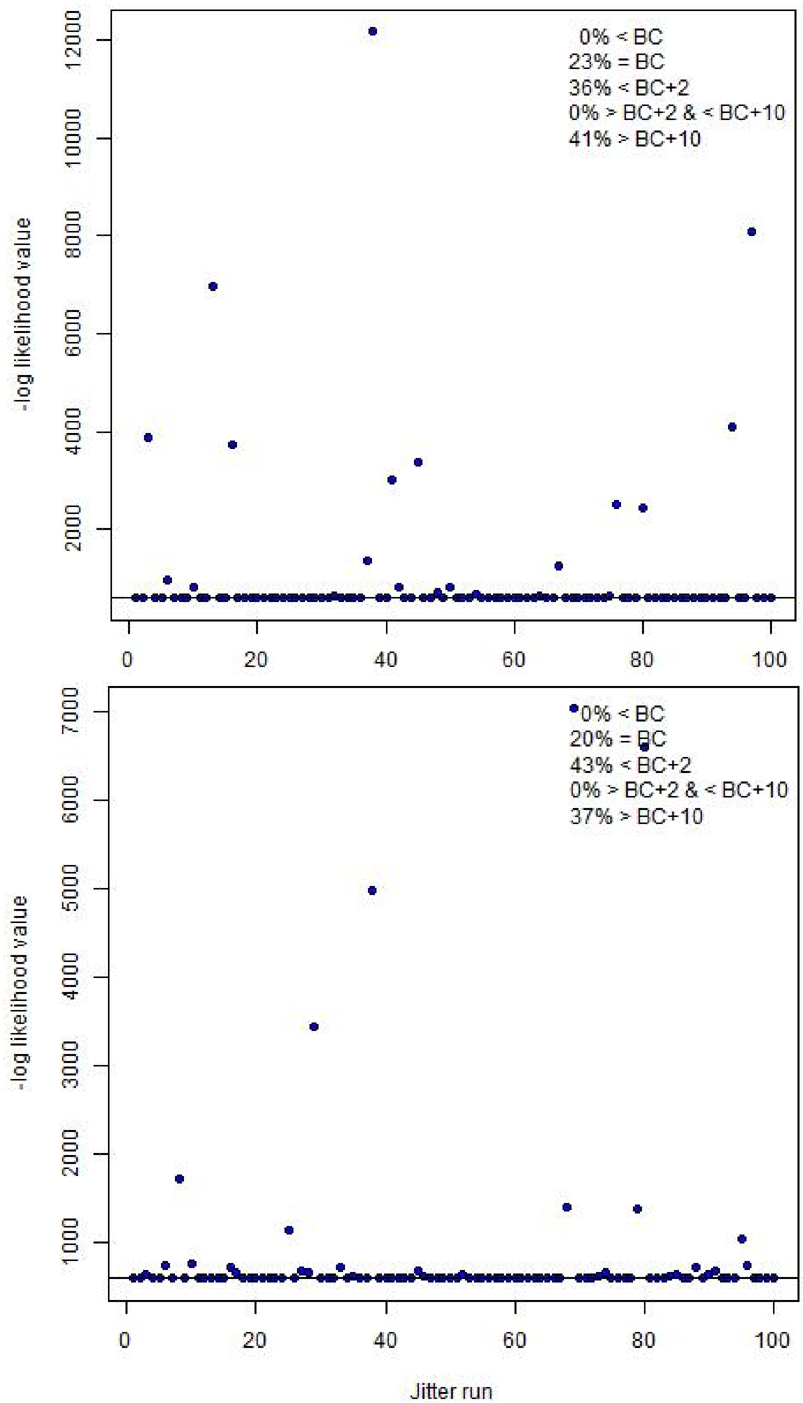


Figure 91. Results from 100 NCS reference model runs when starting parameter values are jittered by 0.1 (top panel) and 0.05 (bottom panel) units. Horizontal line indicates reference model value.

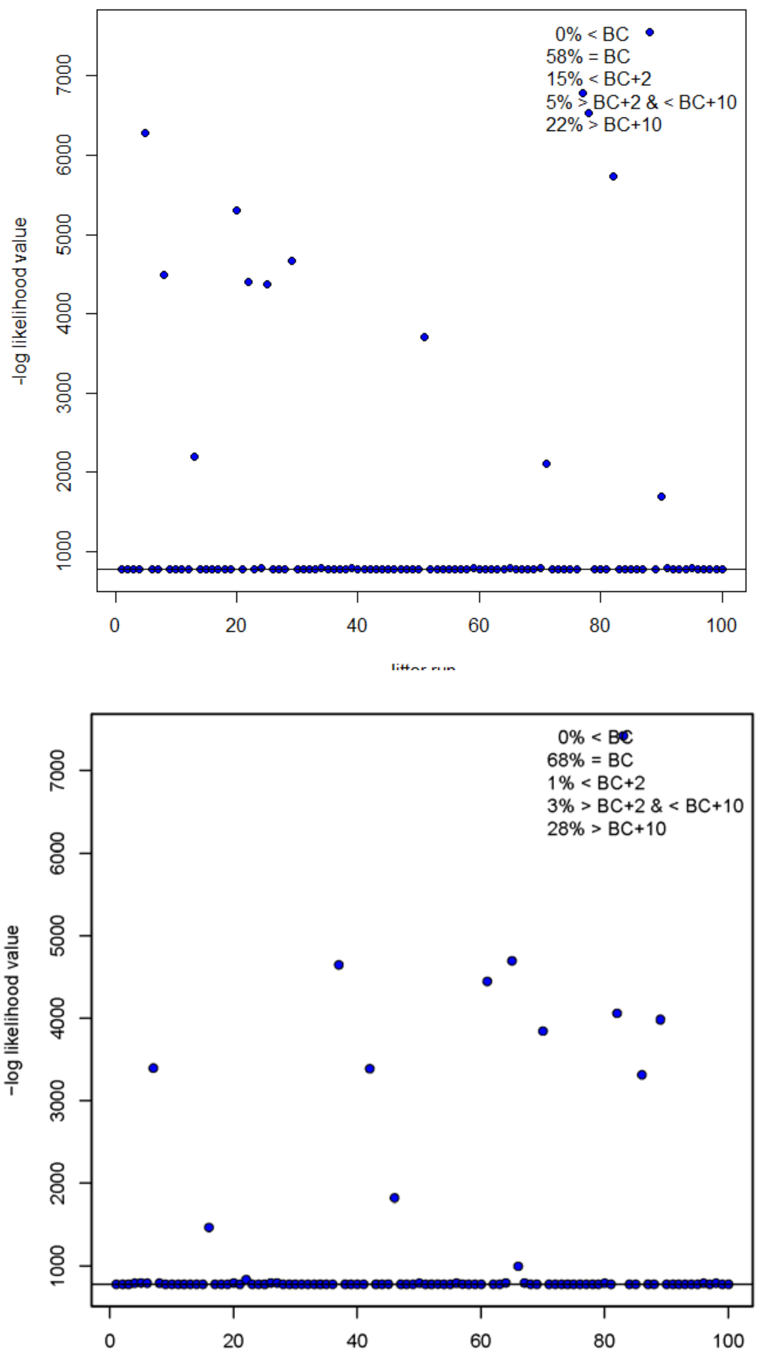


Figure 92. Results from 100 Oregon reference model runs when starting parameter values are jittered by 0.1 (top panel) and 0.05 (bottom panel) units. Horizontal line indicates reference model value.

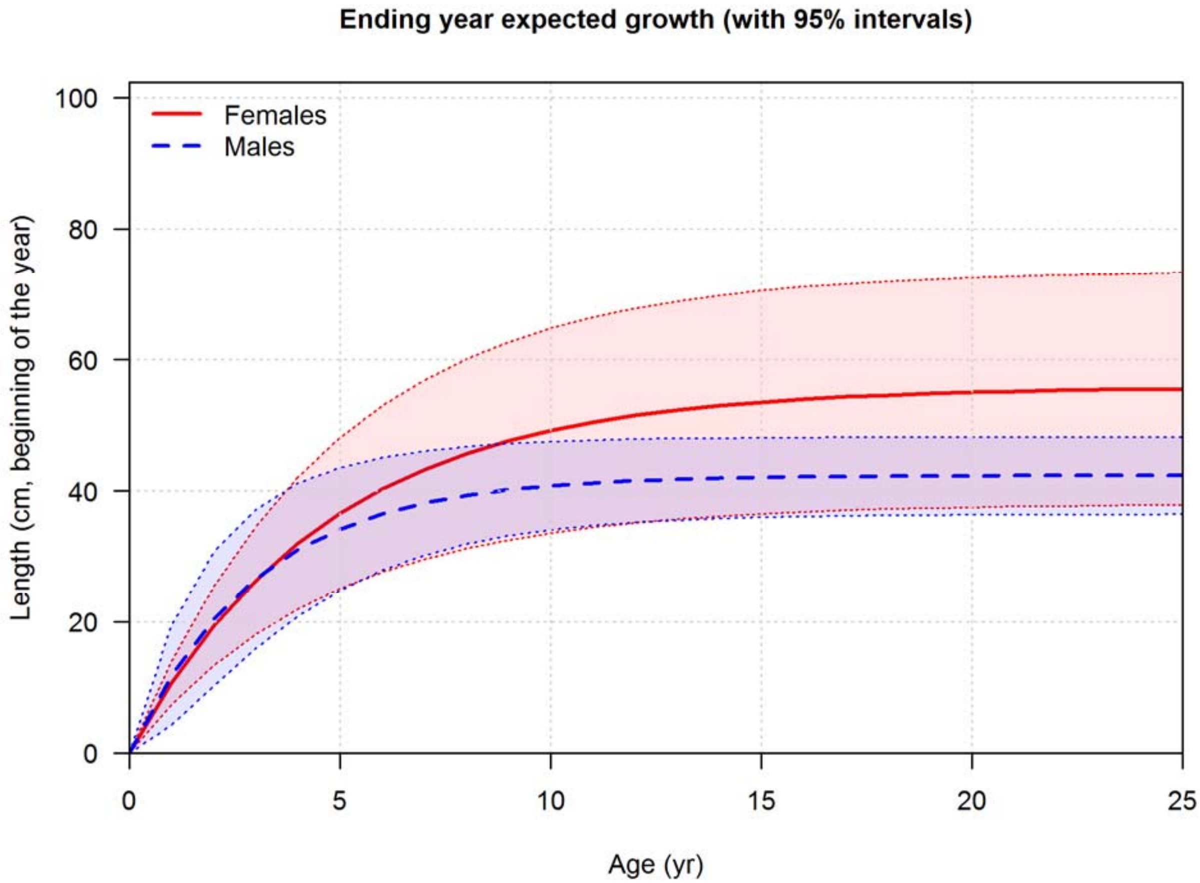


Figure 93. Estimated (NCS) and fixed (SCS) growth curves for female and male Cabezon in California.

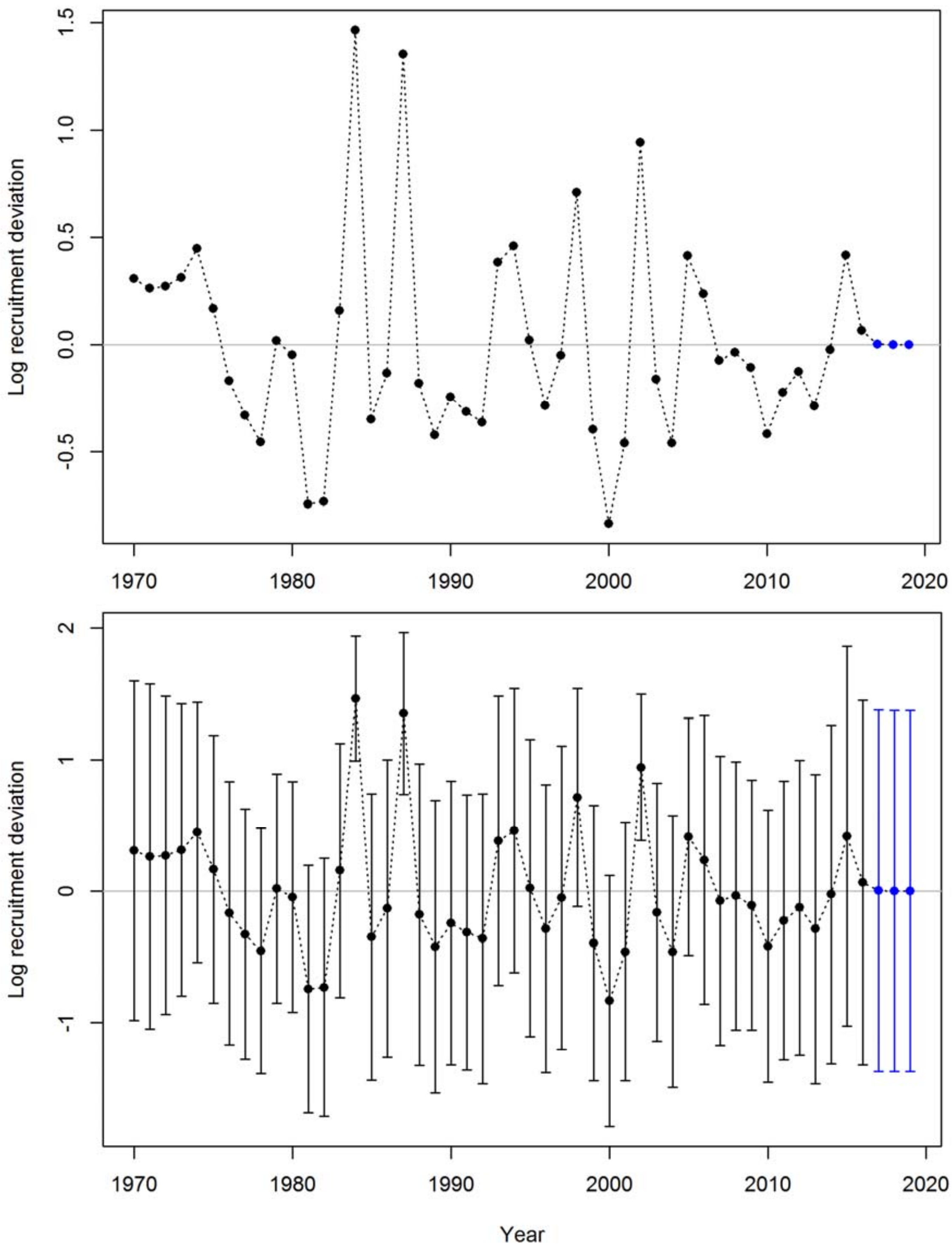


Figure 94. Deviations (top panel) with 95% uncertainty intervals (bottom panel) in recruitment for the SCS model.

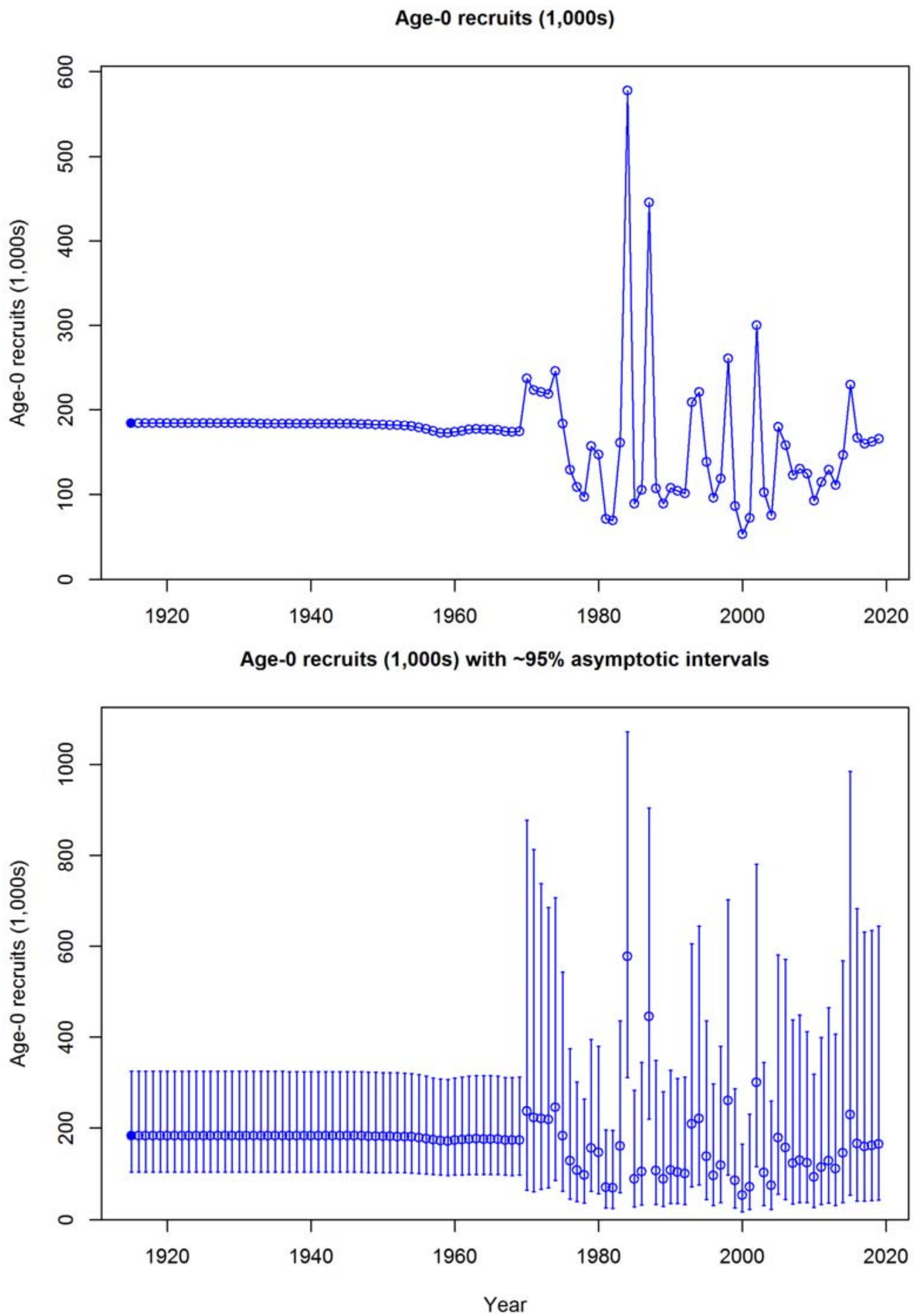


Figure 95. Estimated age-0s (top panel) with 95% uncertainty intervals (bottom panel) in the SCS model.

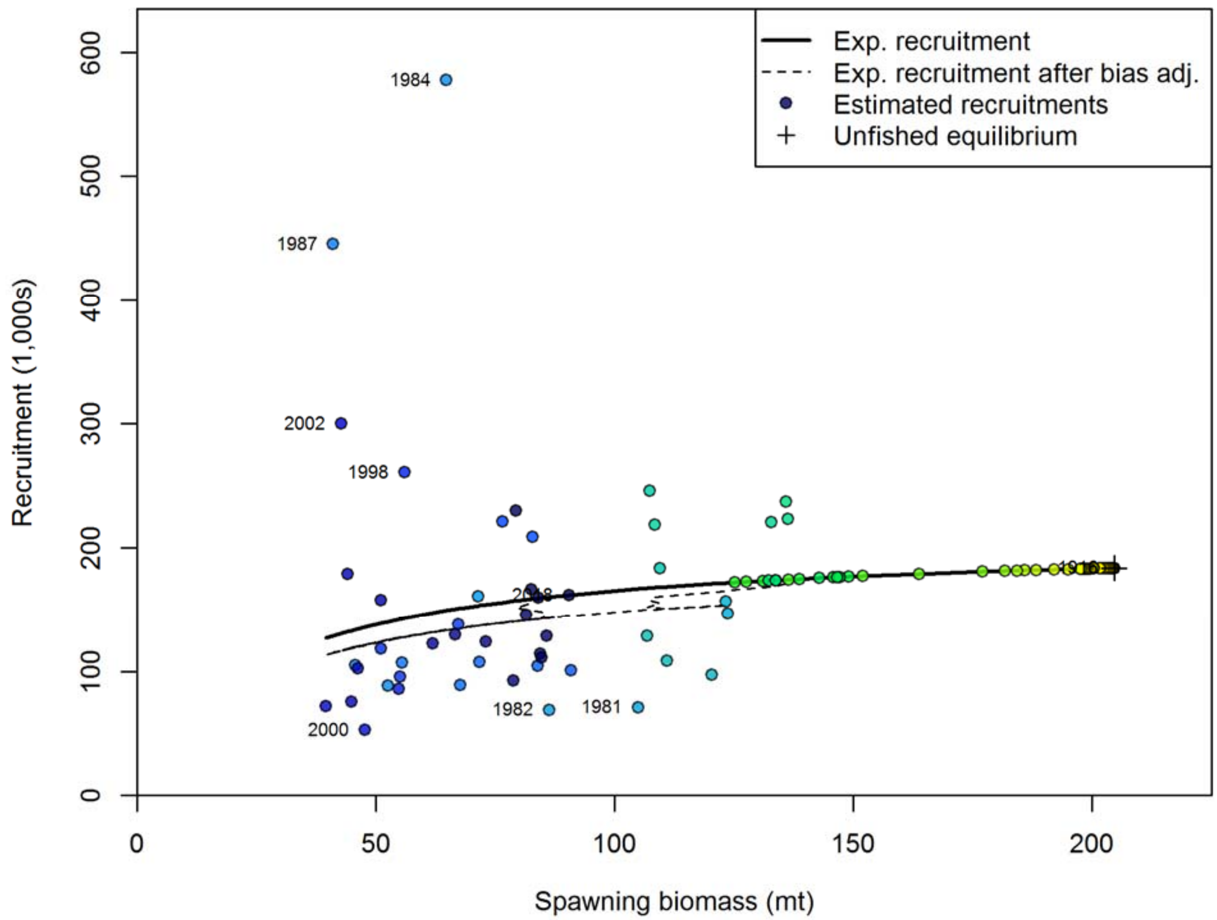
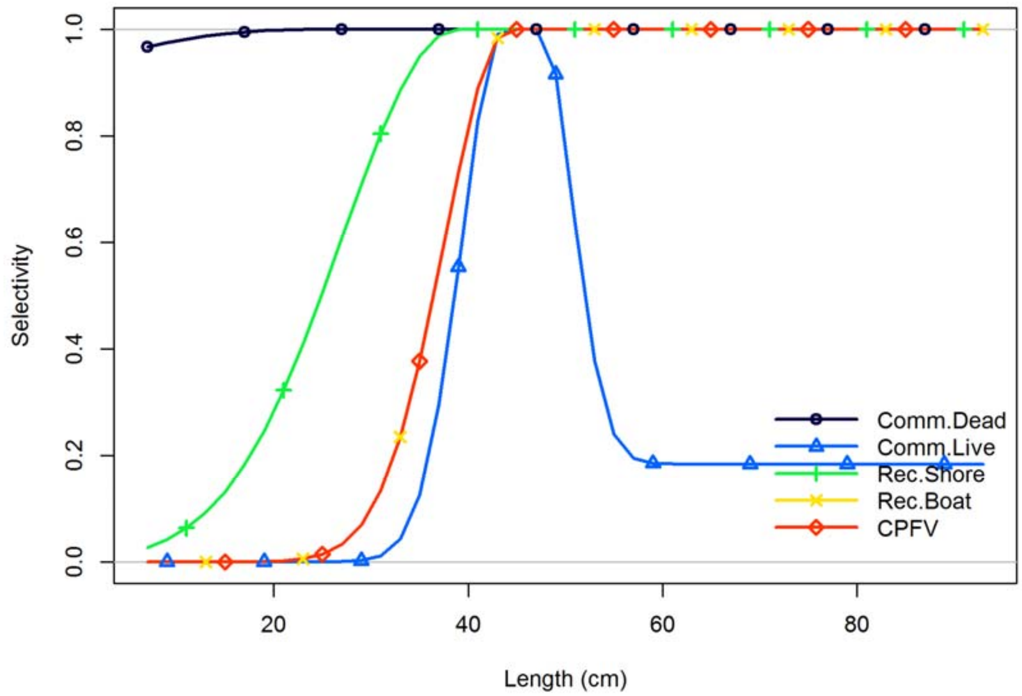


Figure 96. Stock recruit relationship for the SCS model.



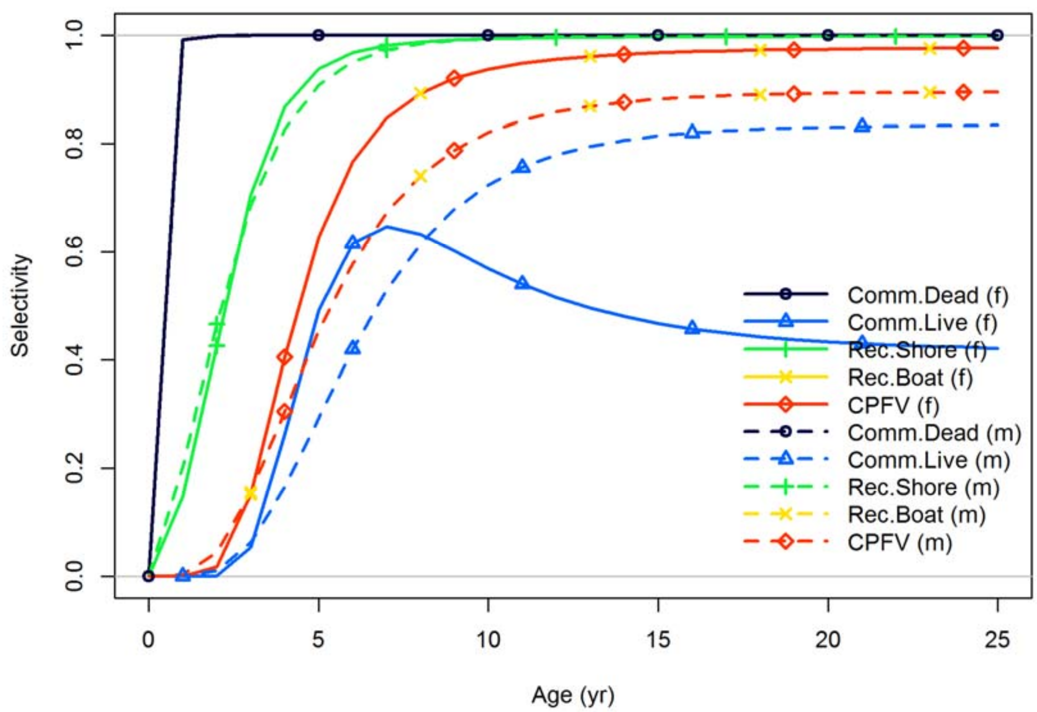


Figure 97. Estimated and fixed (Comm. Dead) selectivity curves (top panel: length; bottom panel: age-derived from length) in the SCS model.

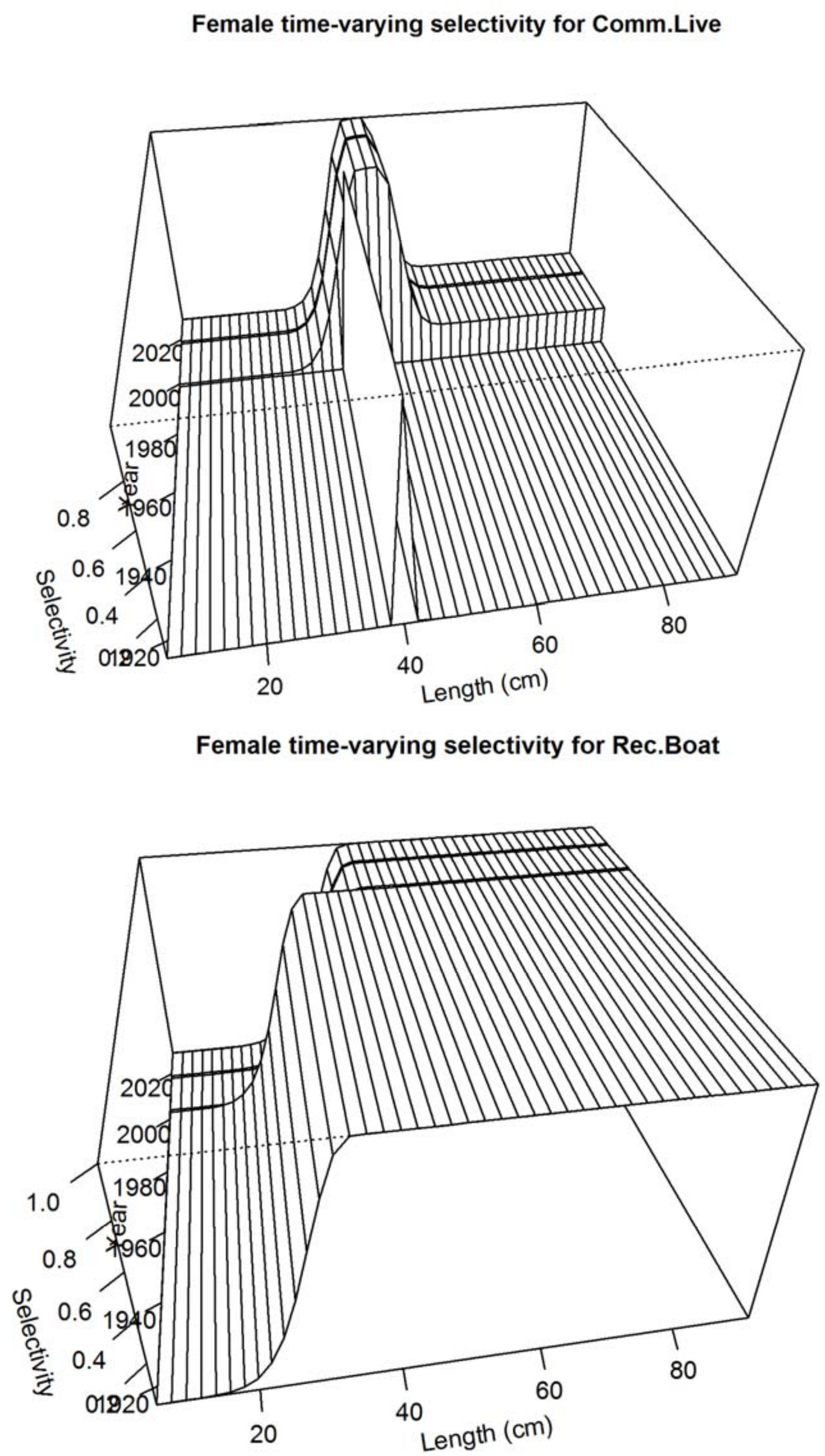


Figure 98. Changes in selectivity by block for the commercial live (top panel) and recreational boat (bottom panel) fleets in the SCS model.

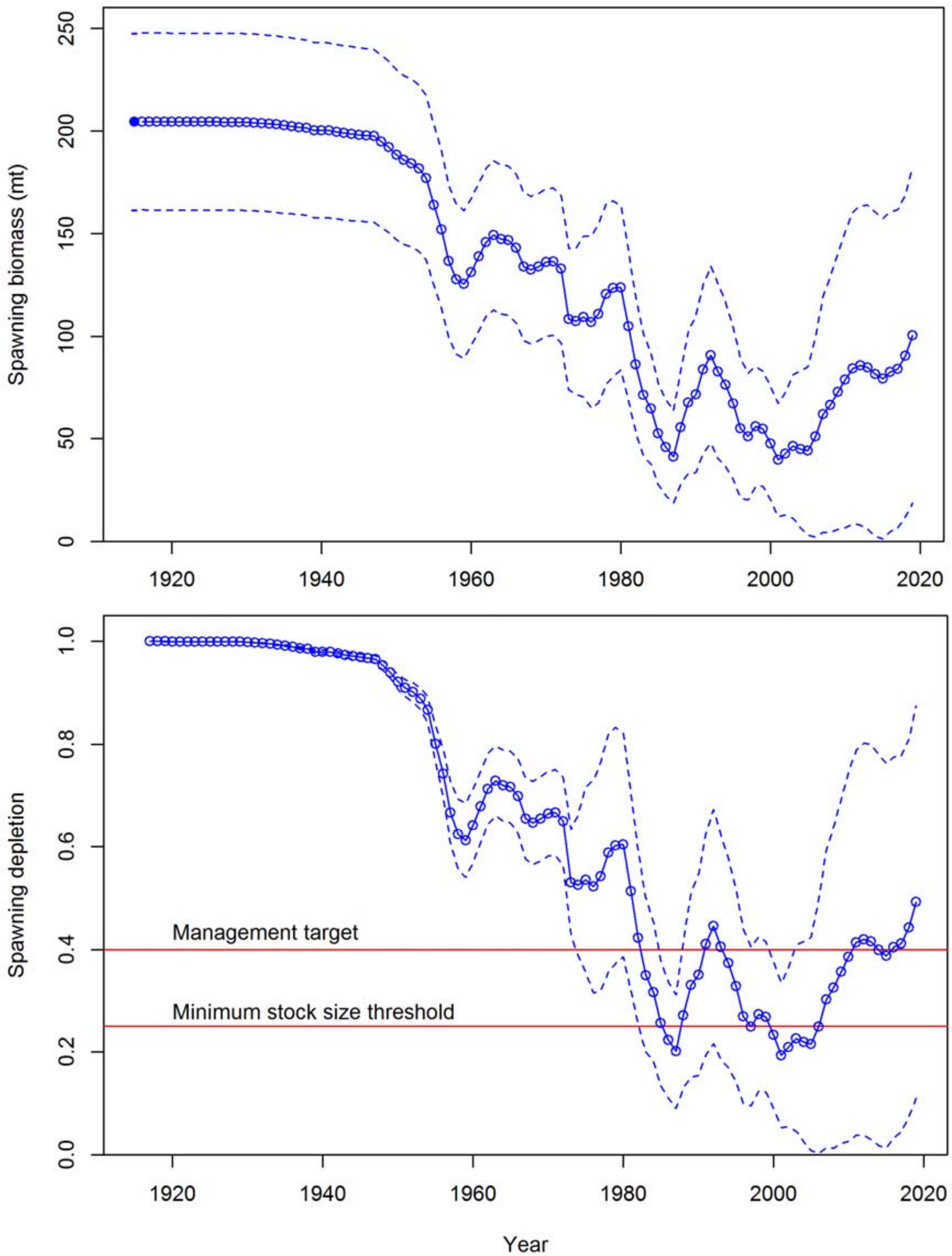


Figure 99. Cabezon spawning biomass (top panel) and depletion (bottom panel) derived from the SCS model. Uncertainty envelopes indicate 95% asymptotic uncertainty.

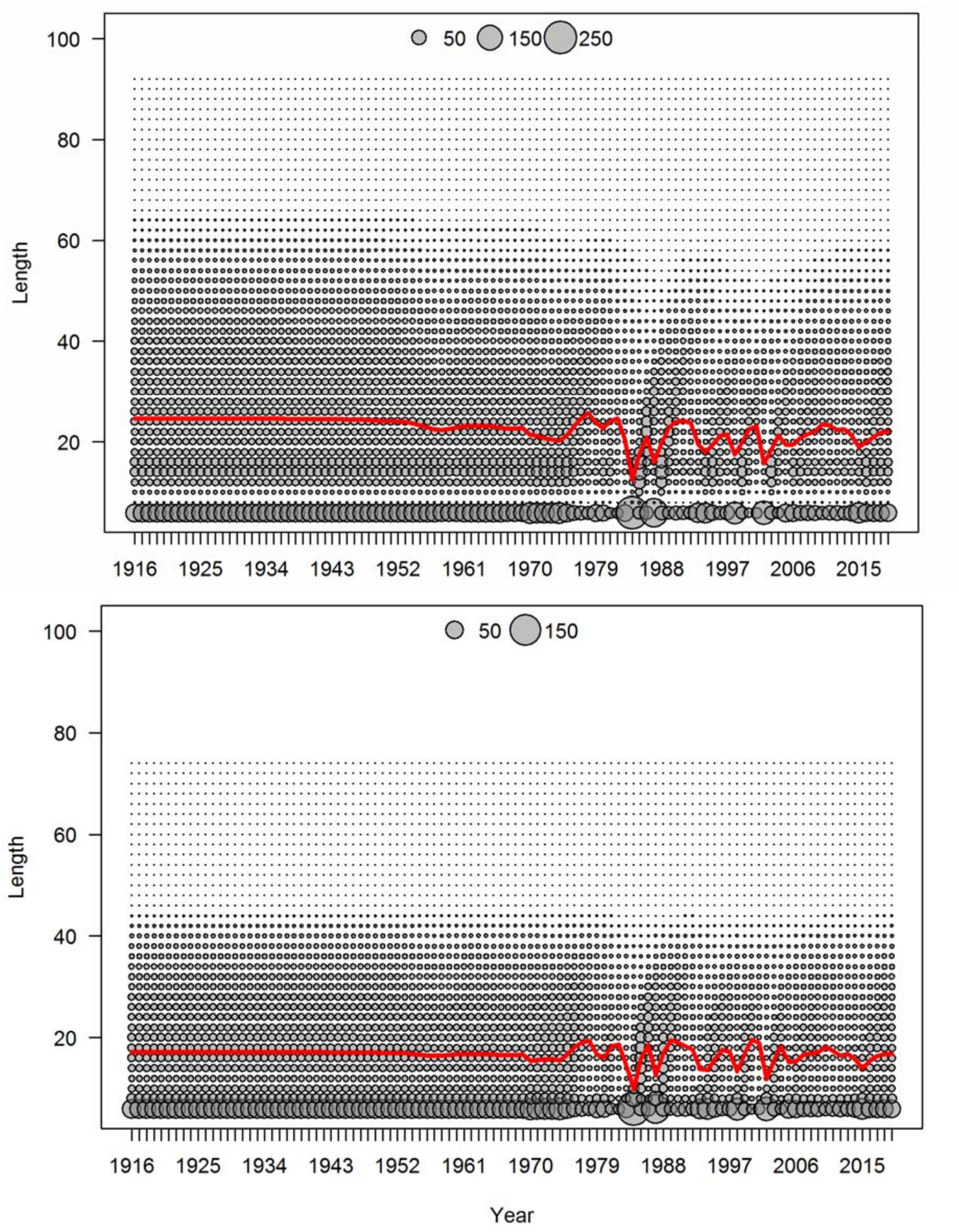


Figure 100. Numbers at age through time for females (top panel) and males (top panels) for the SCS model.

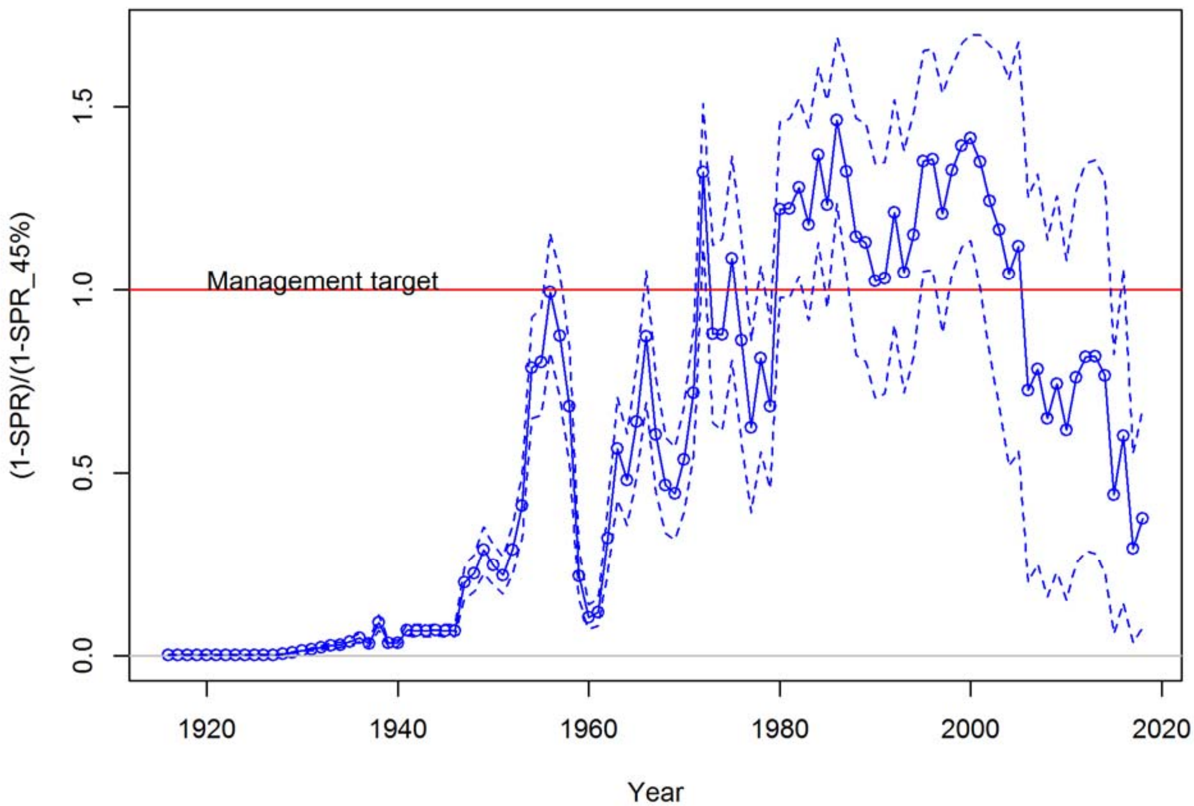


Figure 101. Estimated relative spawning potential ratio (SPR) for the SCS Cabezon reference model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{45\%}$ harvest rate.

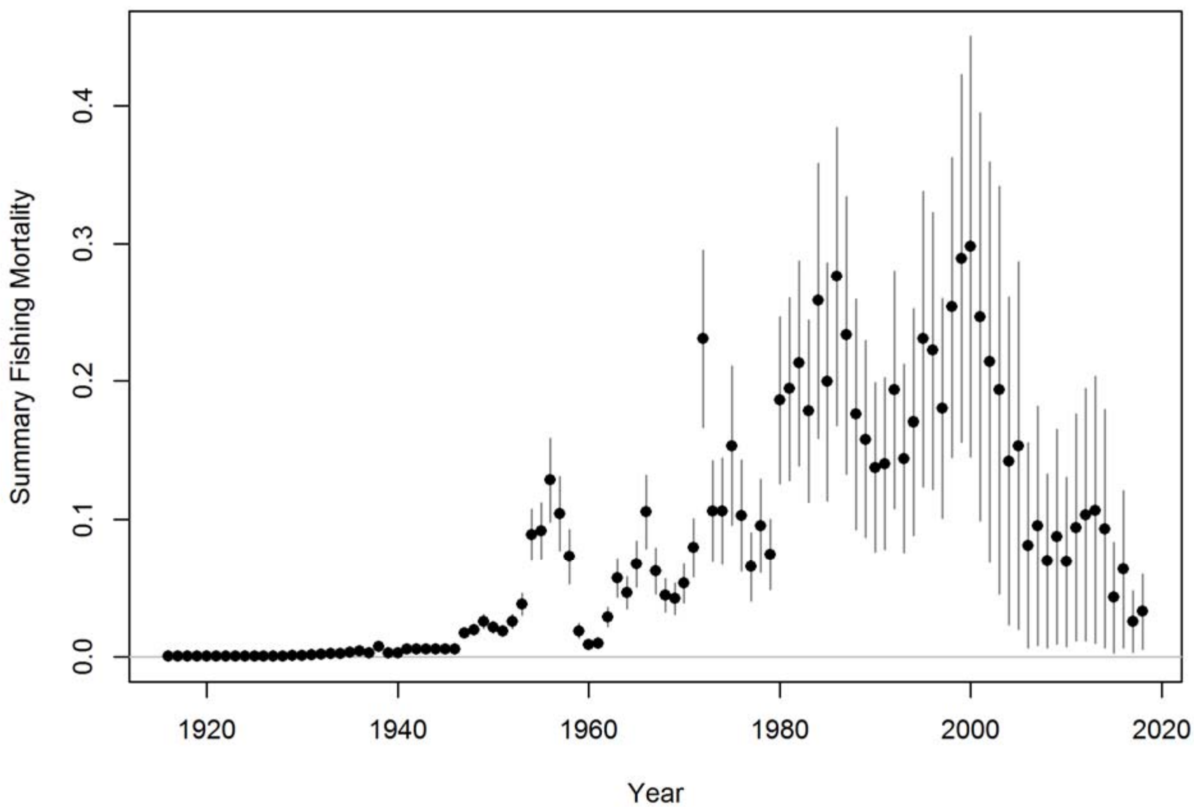


Figure 102. Time-series of estimated summary fishing mortality for the SCS reference model with approximate 95% asymptotic confidence intervals (grey lines).

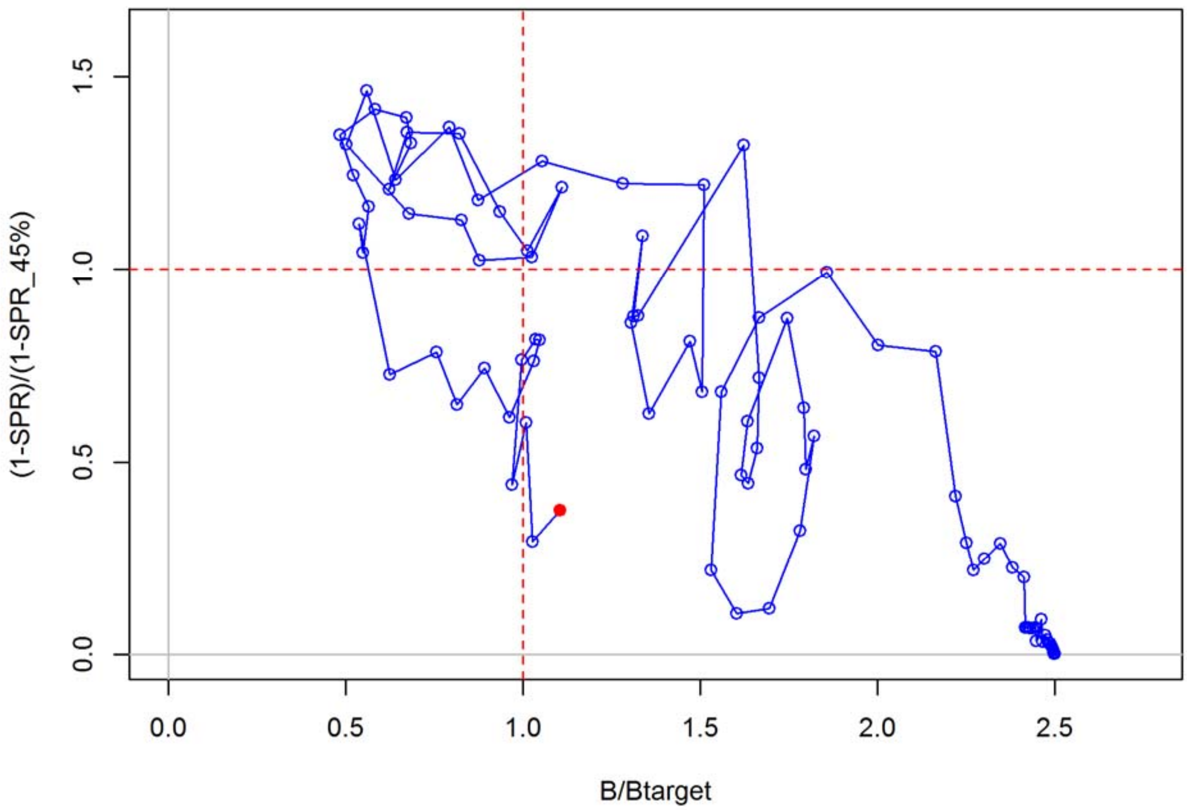


Figure 103. Phase plot of relative spawning output vs fishing intensity for the SCS Cabezon reference model. The relative fishing intensity is (1-SPR) divided by 45% (the SPR target). The vertical red line is the relative spawning output target defined as the annual spawning output divided by the spawning output corresponding to 40% of the unfished spawning output. The red dot corresponds to 2018.

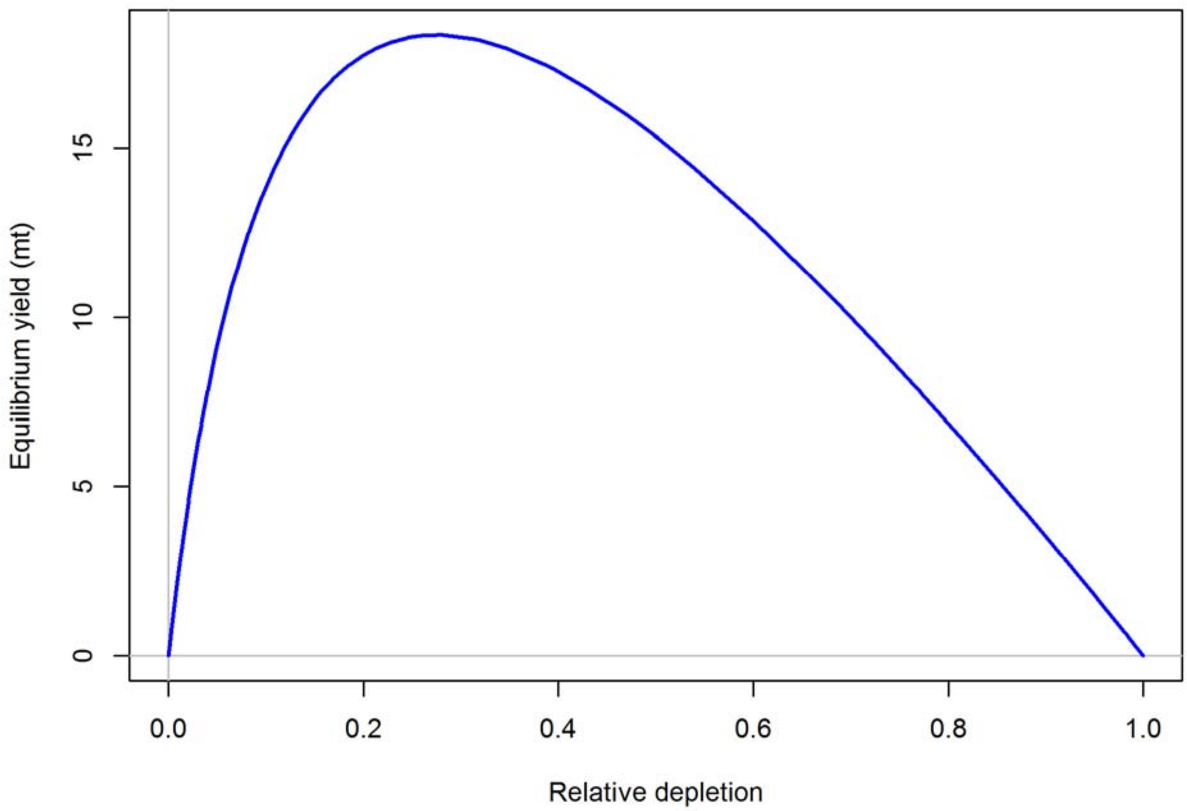


Figure 104. Equilibrium yield curve for the SCS Cabezon reference model. Values are based on 2018 fishery selectivity and distribution with steepness fixed at 0.70. The depletion is relative to unfished spawning output.

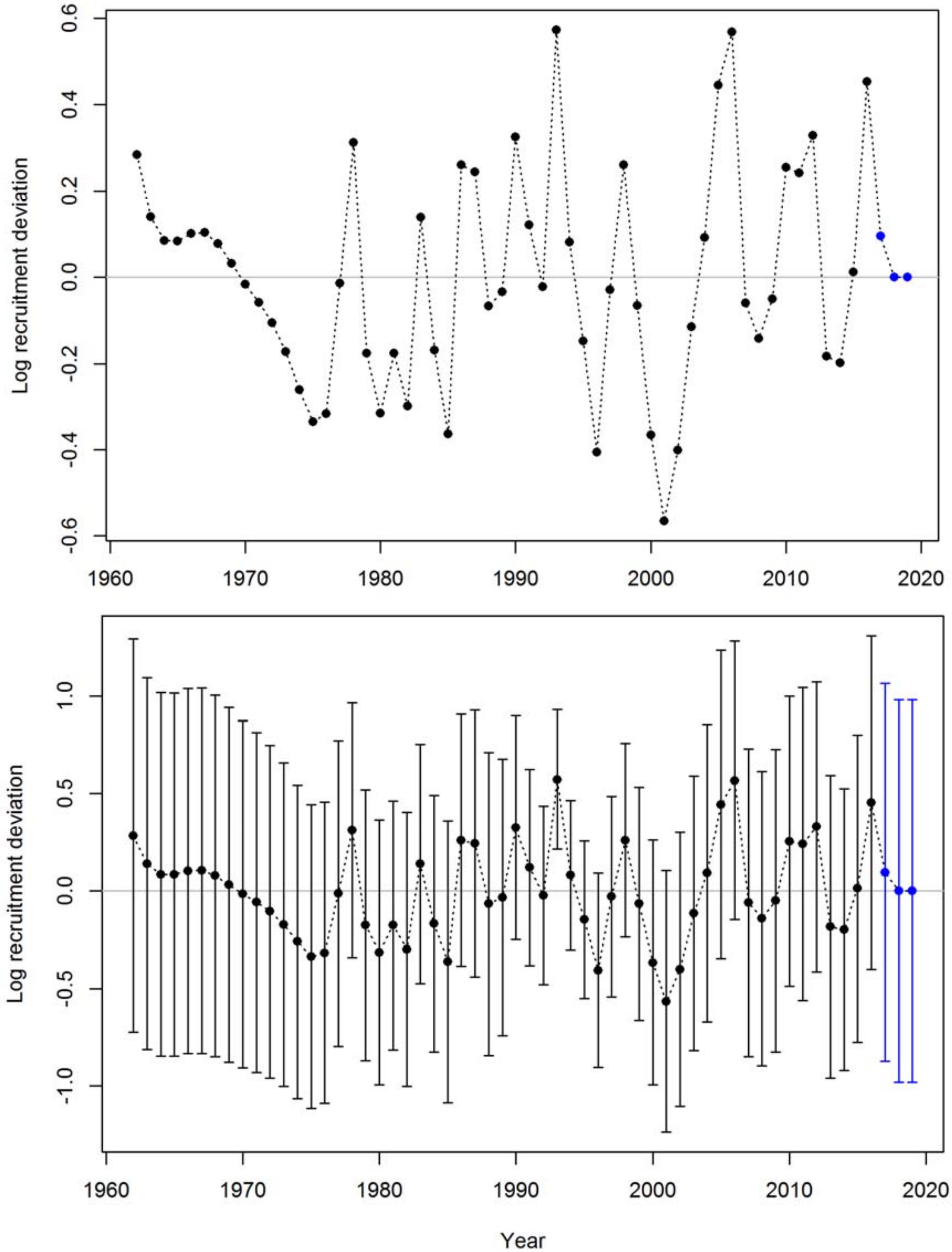


Figure 105. Deviations (top panel) with 95% uncertainty intervals (bottom panel) in recruitment for the NCS model.

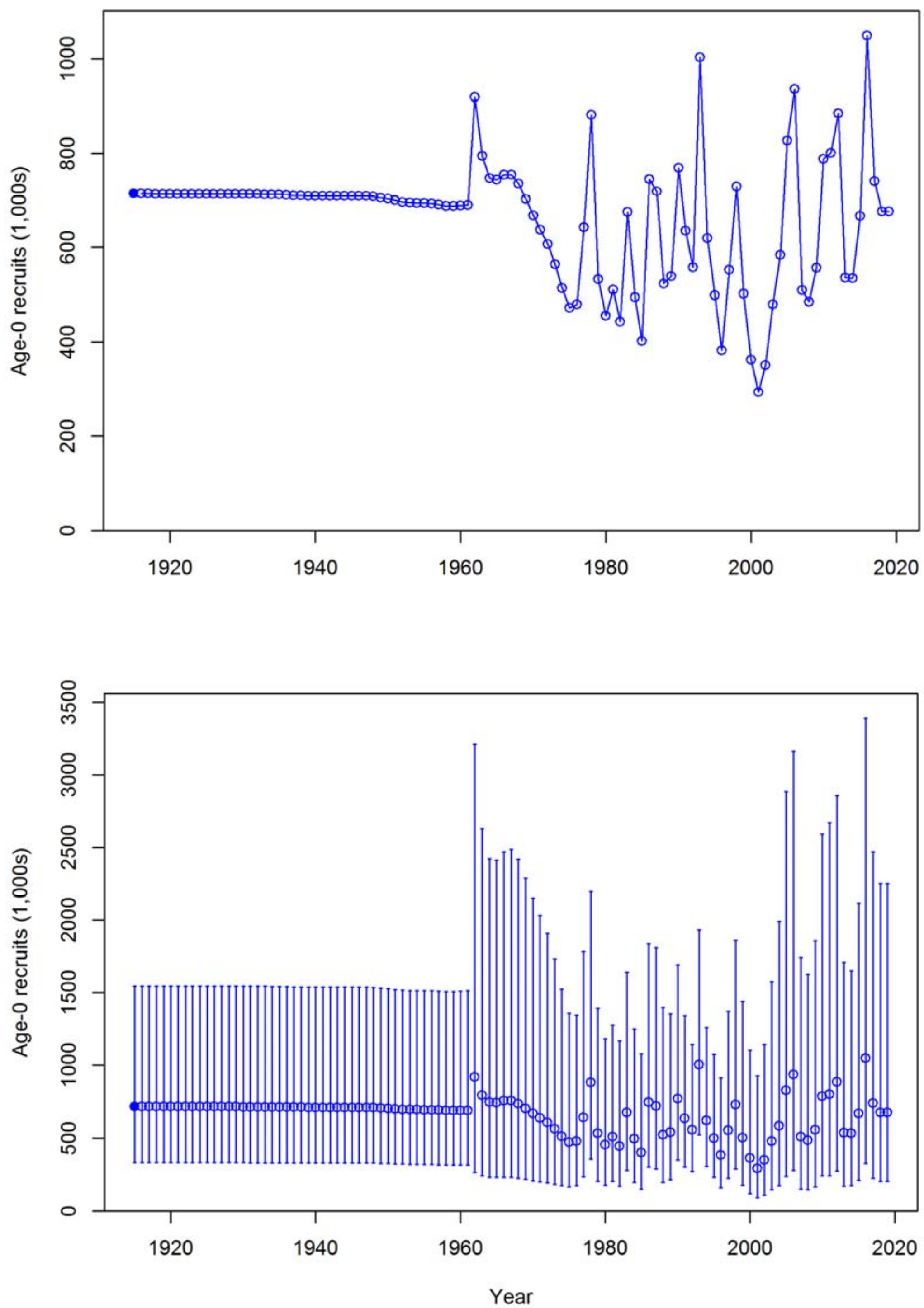


Figure 106. Estimated age-0s (top panel) with 95% uncertainty intervals (bottom panel) in the NCS model

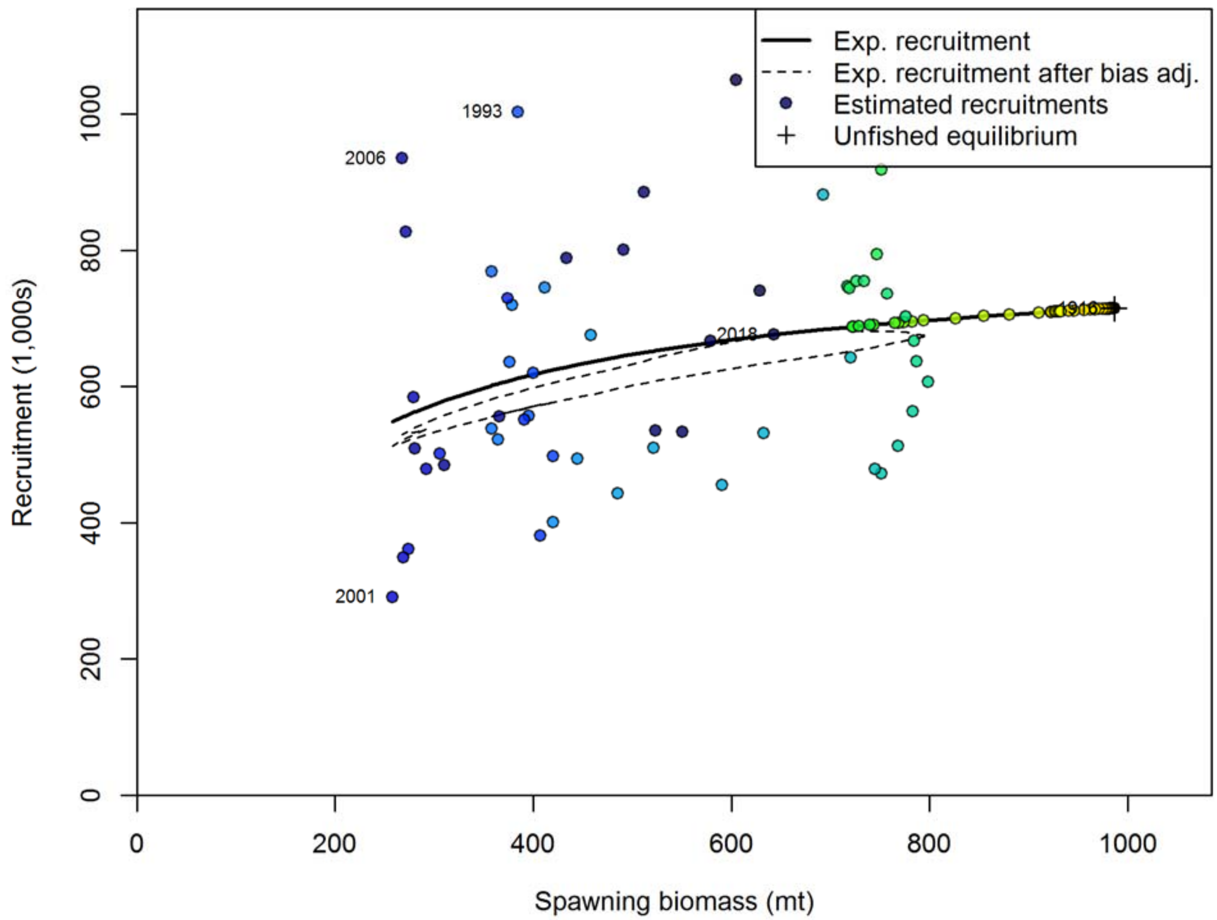


Figure 107. Stock recruit relationship for the NCS model.

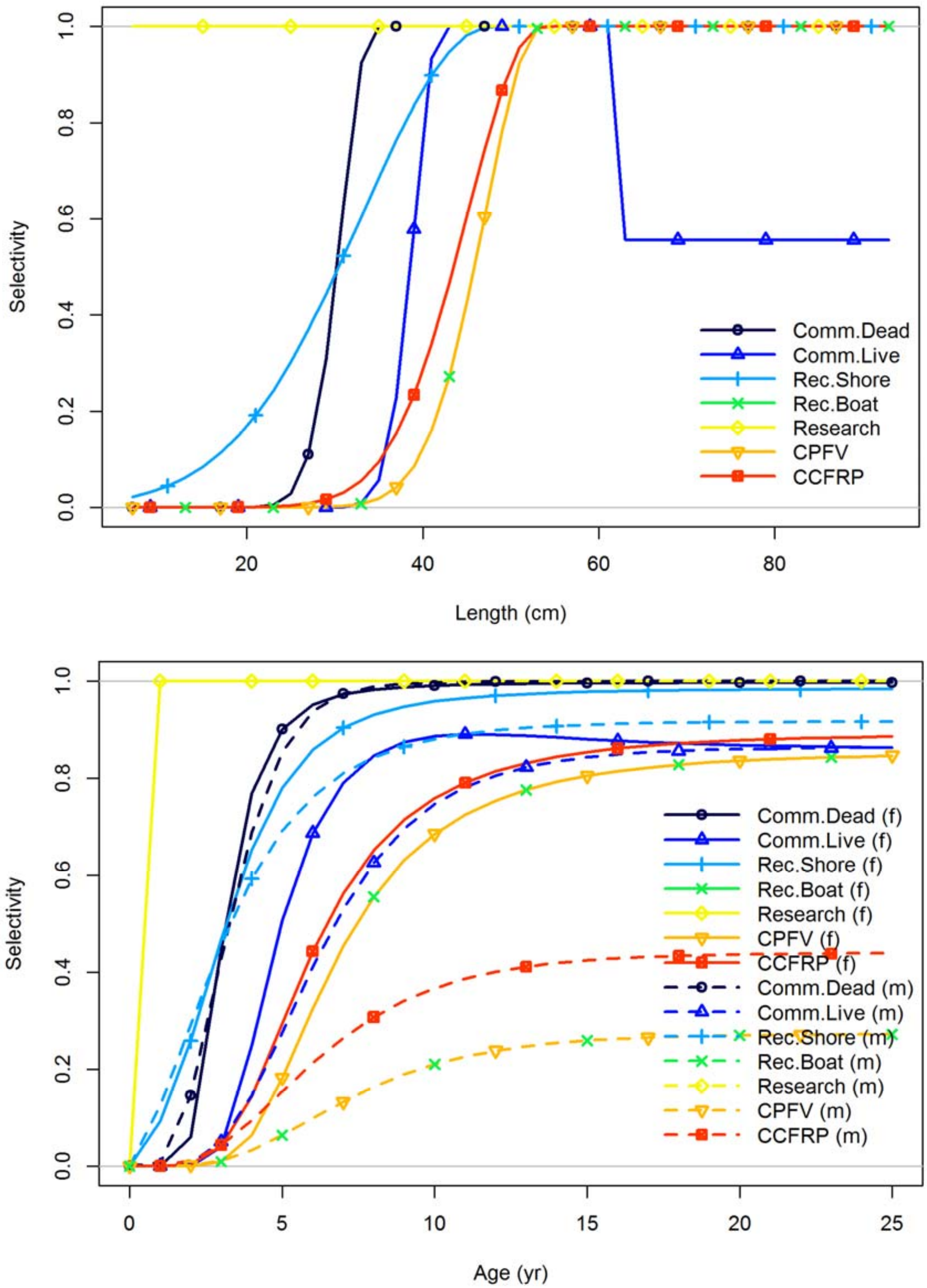


Figure 108. Estimated selectivity curves (top panel: length; bottom panel: age-derived from length) in the NCS model.

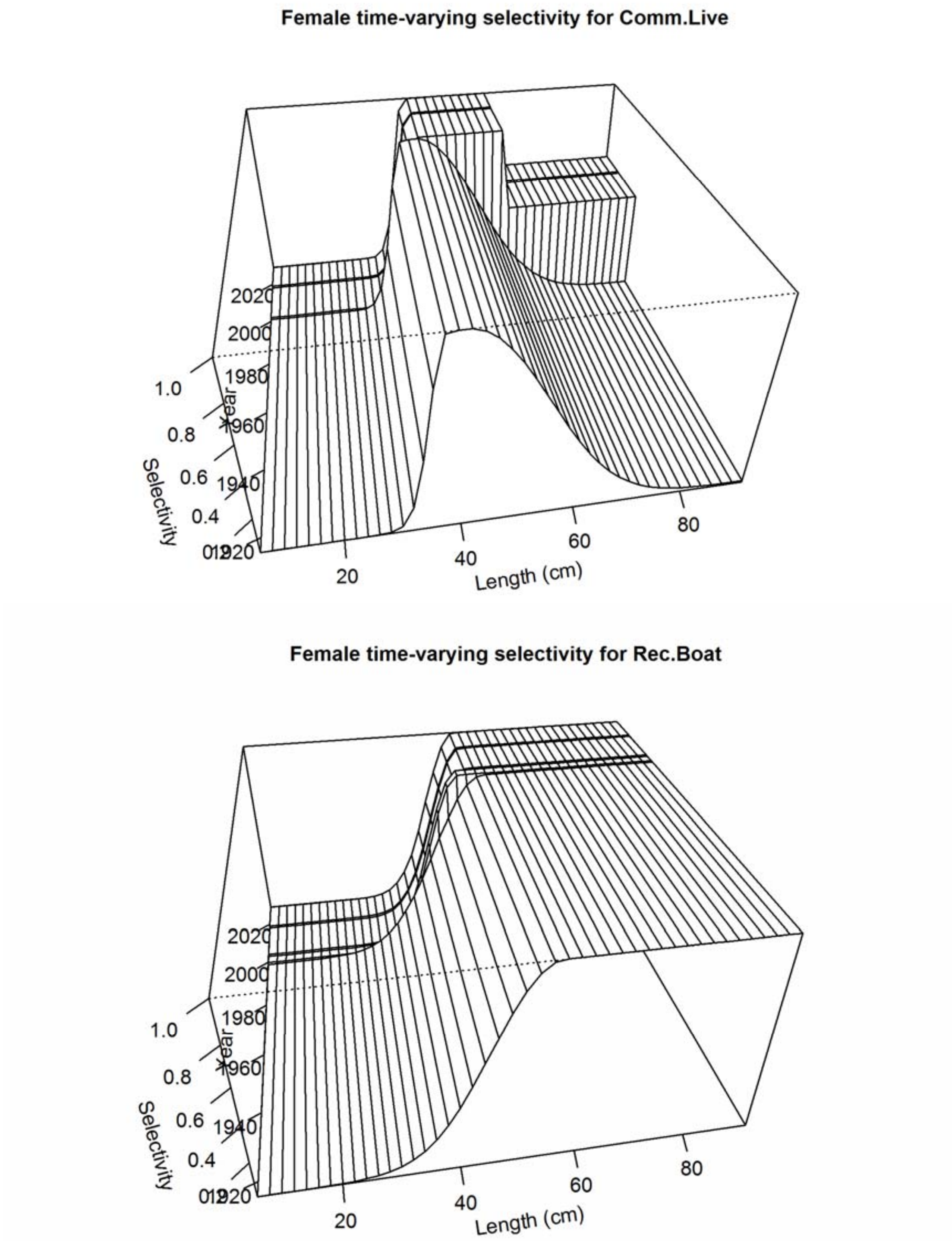


Figure 109. Changes in selectivity by block for the commercial live (top panel) and recreational boat (bottom panel) fleets in the NCS model.

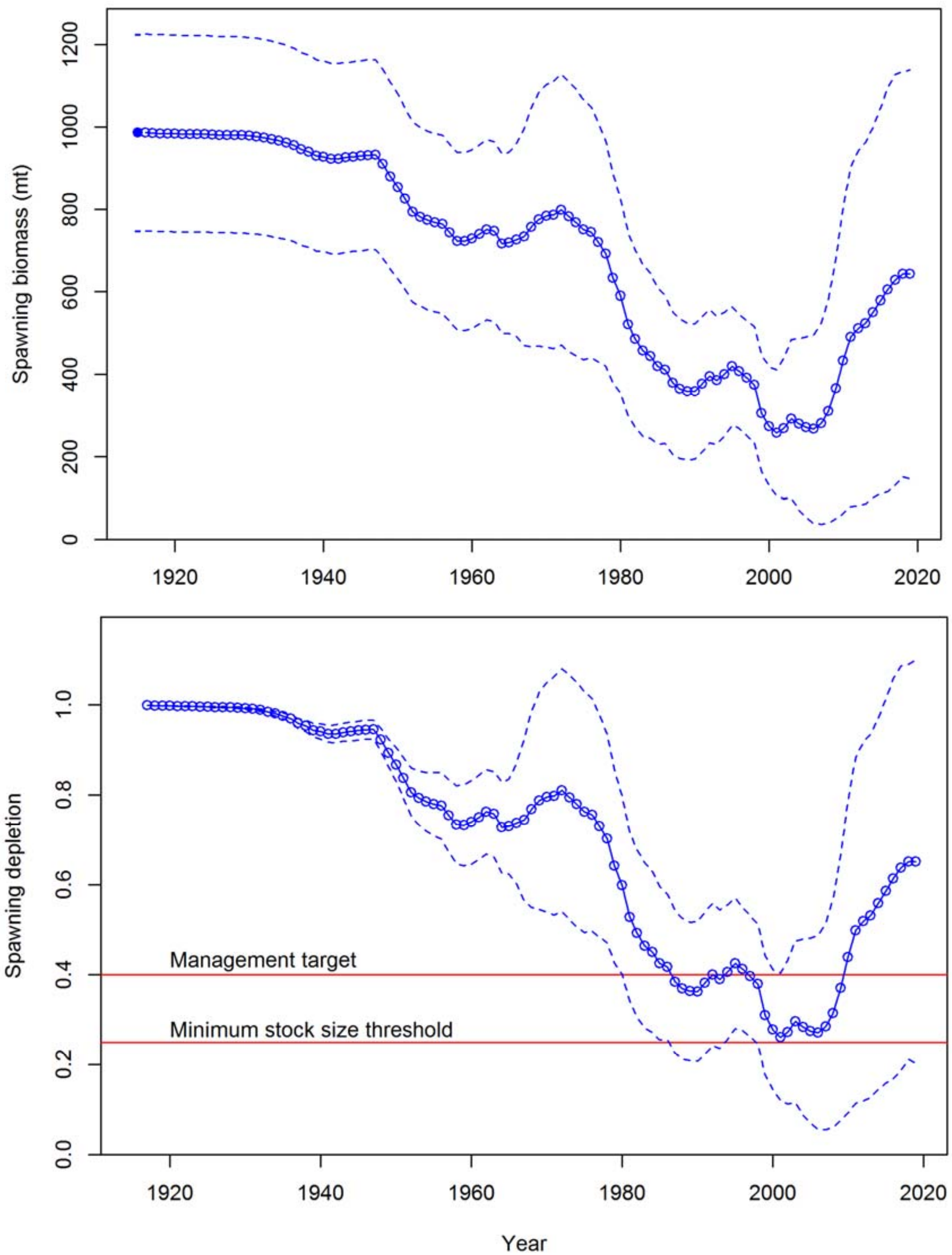


Figure 110. Cabezon spawning biomass (top panel) and depletion (bottom panel) derived from the NCS model. Uncertainty envelopes indicate 95% asymptotic uncertainty.

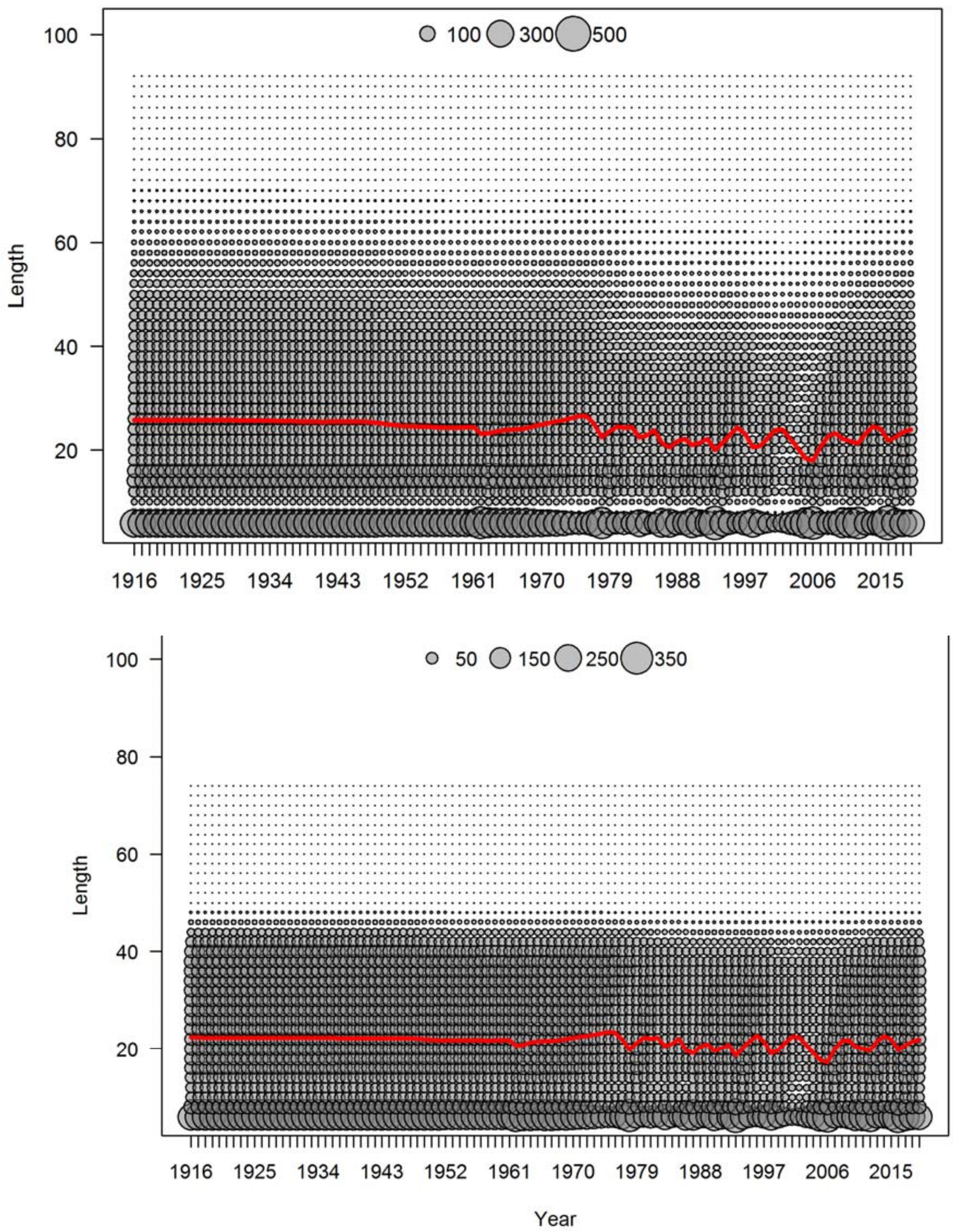


Figure 111. Numbers at age through time for females (top panel) and males (top panels) for the NCS model.

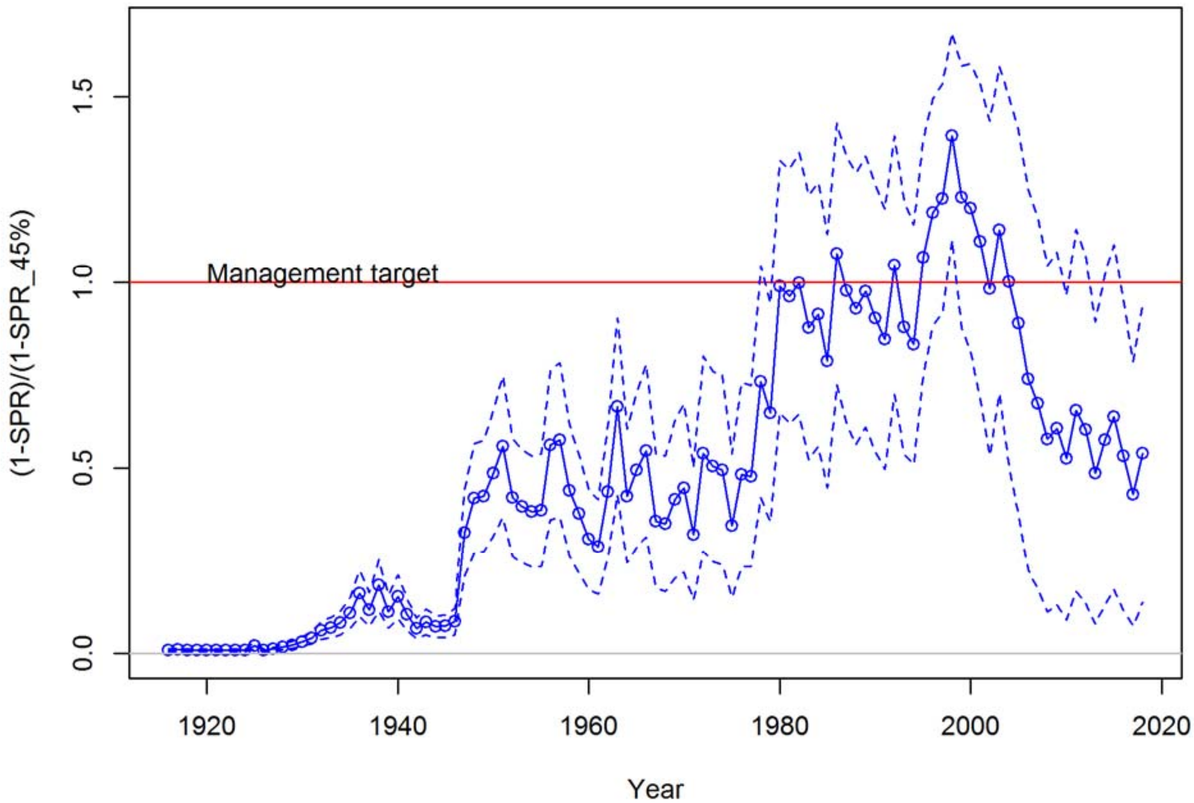


Figure 112. Estimated relative spawning potential ratio (SPR) for the NCS Cabezon reference model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the $SPR_{45\%}$ harvest rate.

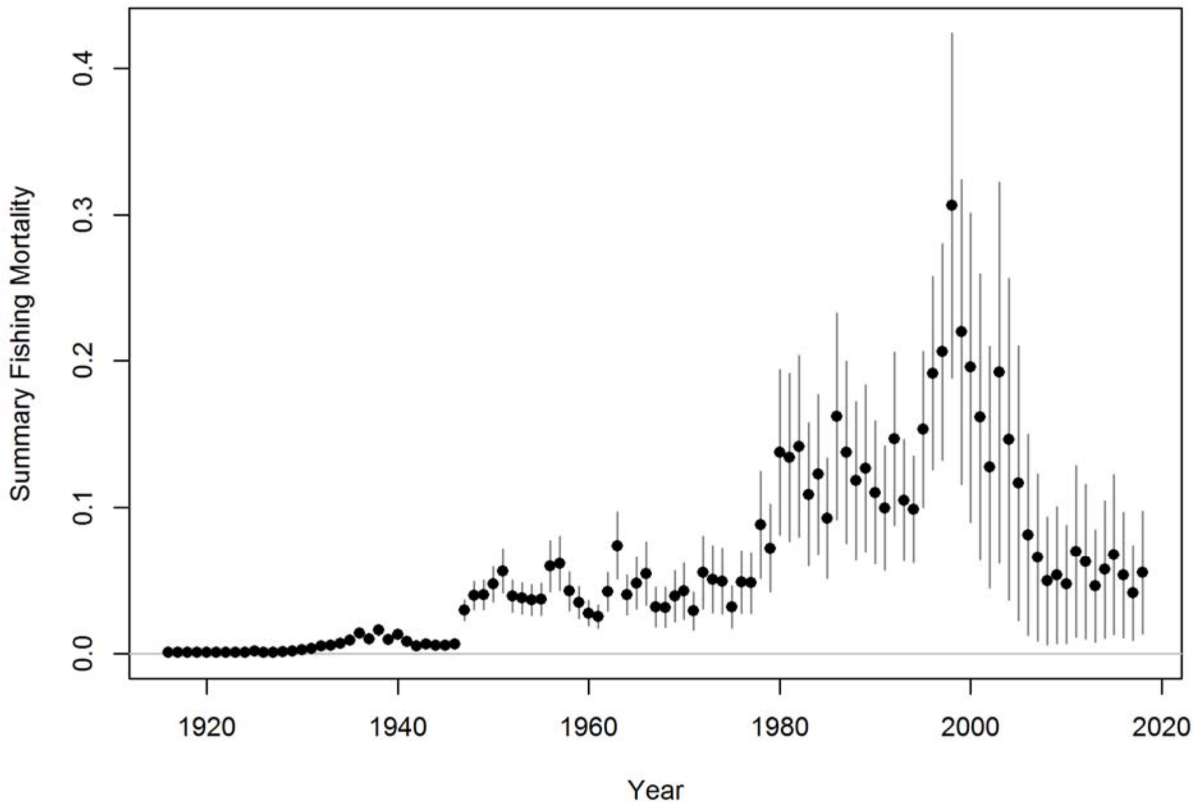


Figure 113. Time-series of estimated summary fishing mortality for the NCS reference model with approximate 95% asymptotic confidence intervals (grey lines).

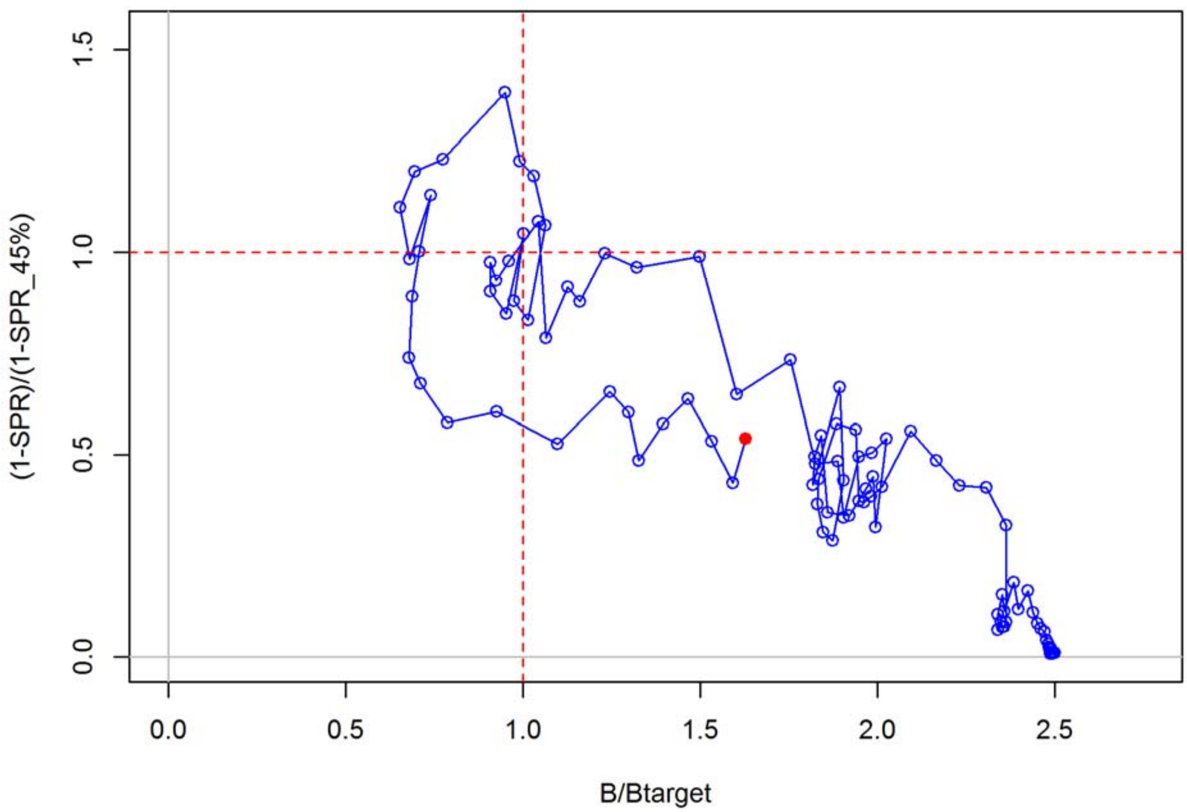


Figure 114. Phase plot of relative spawning output vs fishing intensity for the NCS Cabezon reference model. The relative fishing intensity is (1-SPR) divided by 45% (the SPR target). The vertical red line is the relative spawning output target defined as the annual spawning output divided by the spawning output corresponding to 40% of the unfished spawning output. The red dot corresponds to 2018.

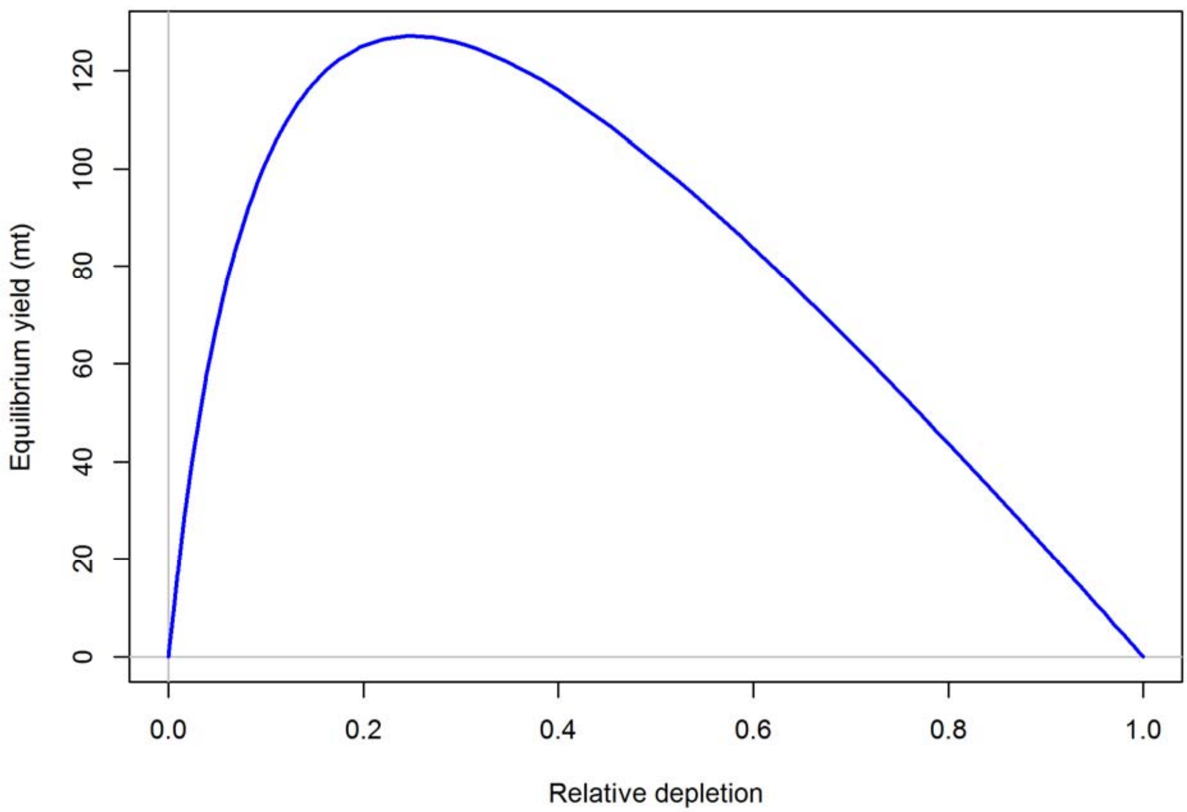


Figure 115. Equilibrium yield curve for the NCS Cabezon reference model. Values are based on 2018 fishery selectivity and distribution with steepness fixed at 0.70. The depletion is relative to unfished spawning output.

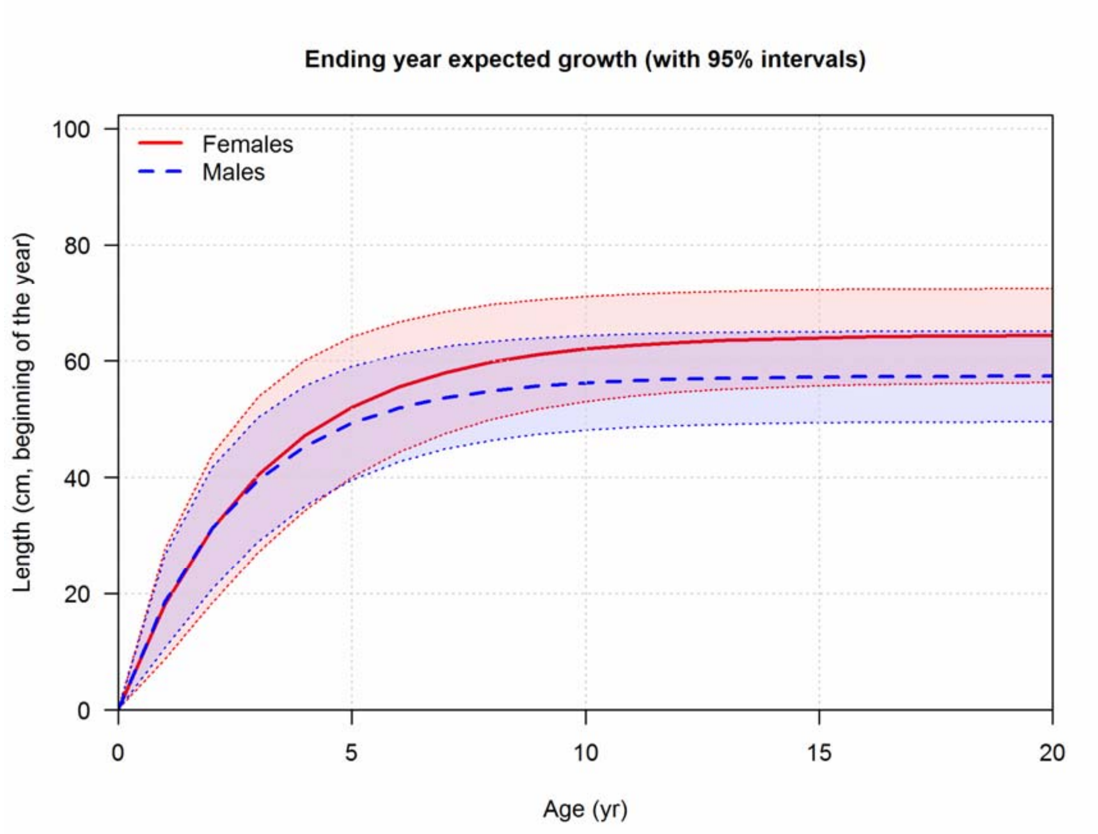


Figure 116. Growth curve for male and female Cabezon in Oregon with age-0 set as the minimum age for growth estimation.

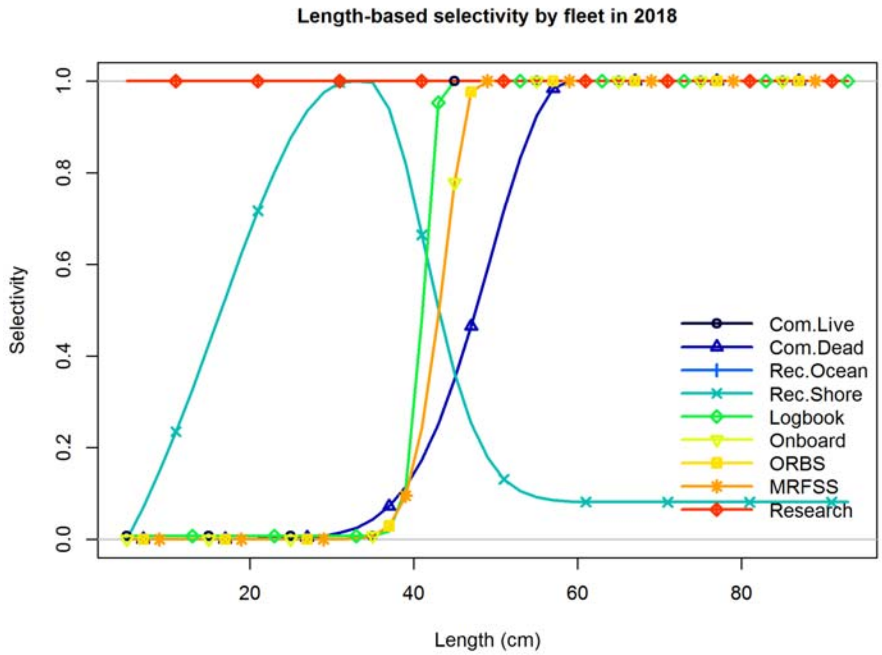


Figure 117. Selectivity curves for fisheries and surveys structured in the reference Oregon Cabezon model.

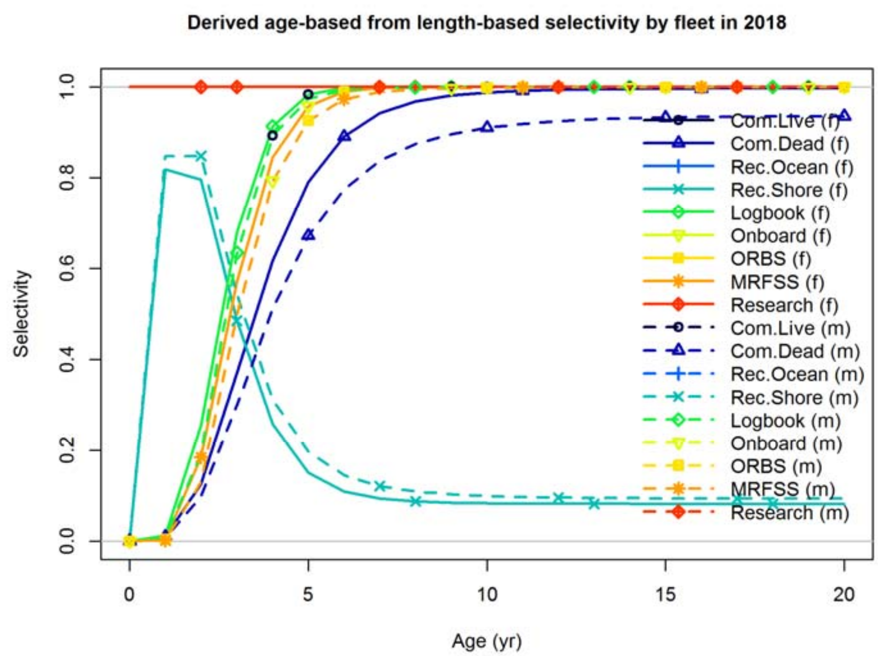


Figure 118. Derived age-based selectivity from length-based selectivity for the fisheries and surveys structured in the reference Oregon Cabezon model.

Female time-varying selectivity for Com.Live

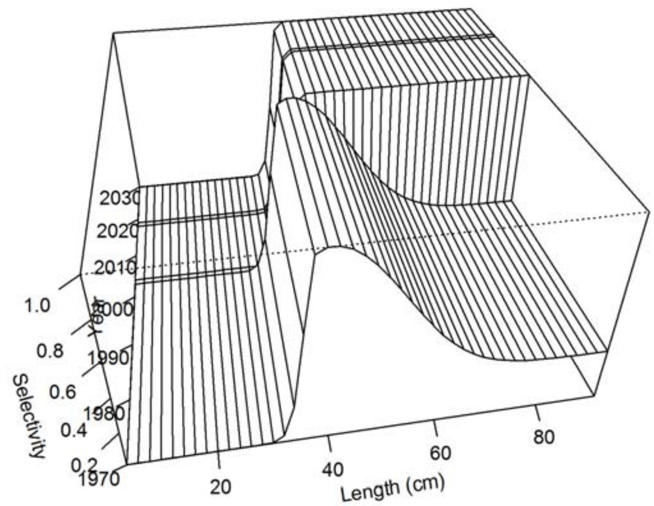


Figure 119. Time-varying selectivity patterns (time blocks before and after 2004) for the Oregon commercial live fleet. Selectivity was modeled as gender invariant.

Female time-varying selectivity for Rec.Ocean

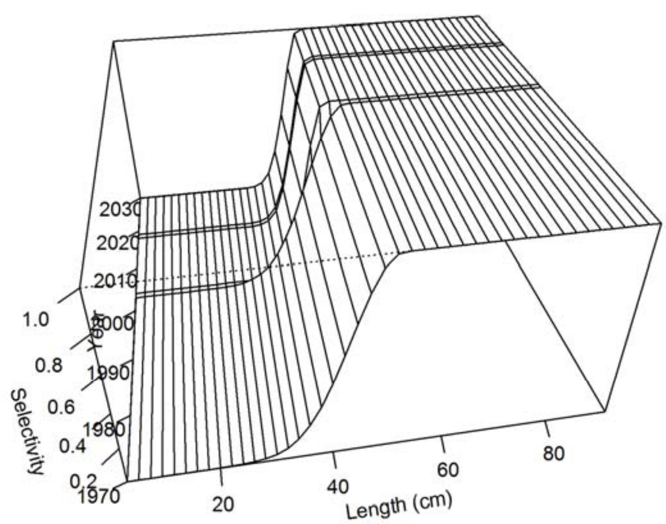


Figure 120. Time-varying selectivity patterns (time blocks before and after 2004) for the Oregon recreational ocean boat fleet. Selectivity was modeled as gender invariant.

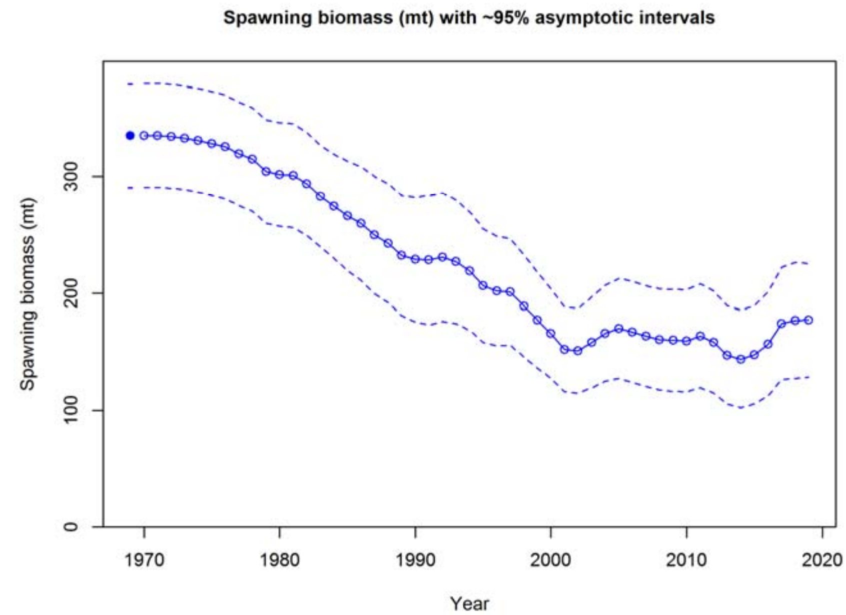


Figure 121. Estimated spawning (female biomass) output time series from the reference Oregon Cabezon model with ~95% confidence intervals.

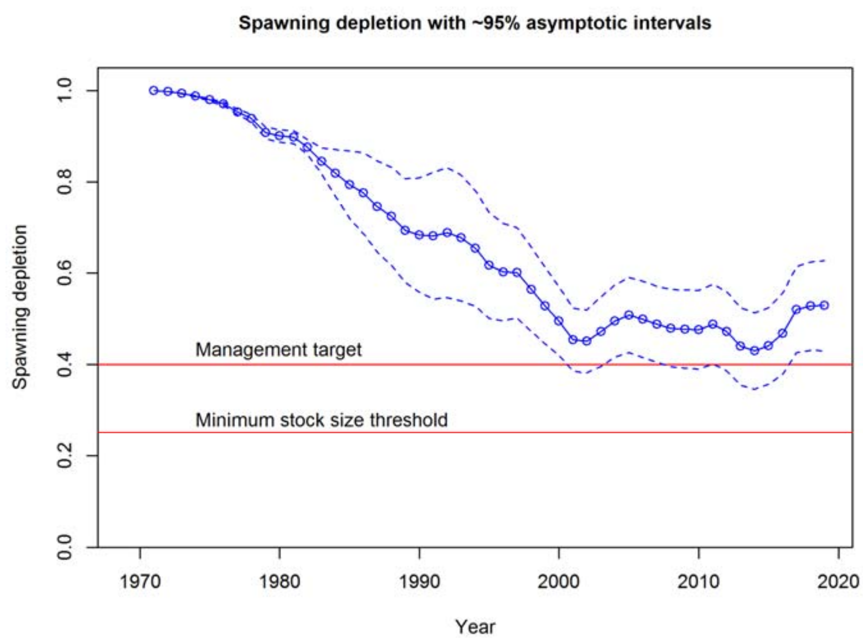


Figure 122. Estimated spawning (female biomass) output depletion relative to unfished levels for the Oregon reference model with ~95% confidence intervals.

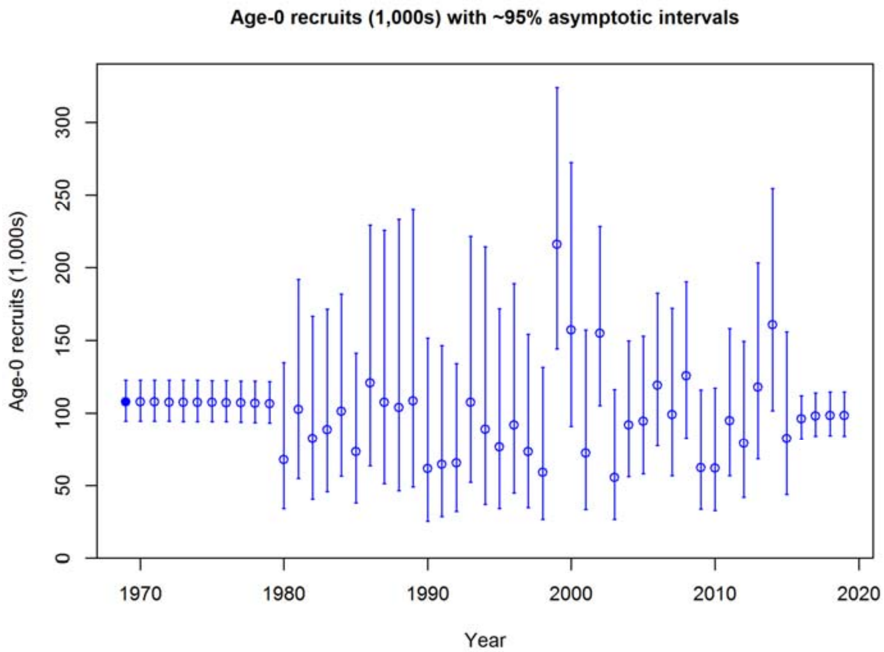


Figure 123. Oregon base model estimates of age-0 recruitment with ~95% confidence intervals.

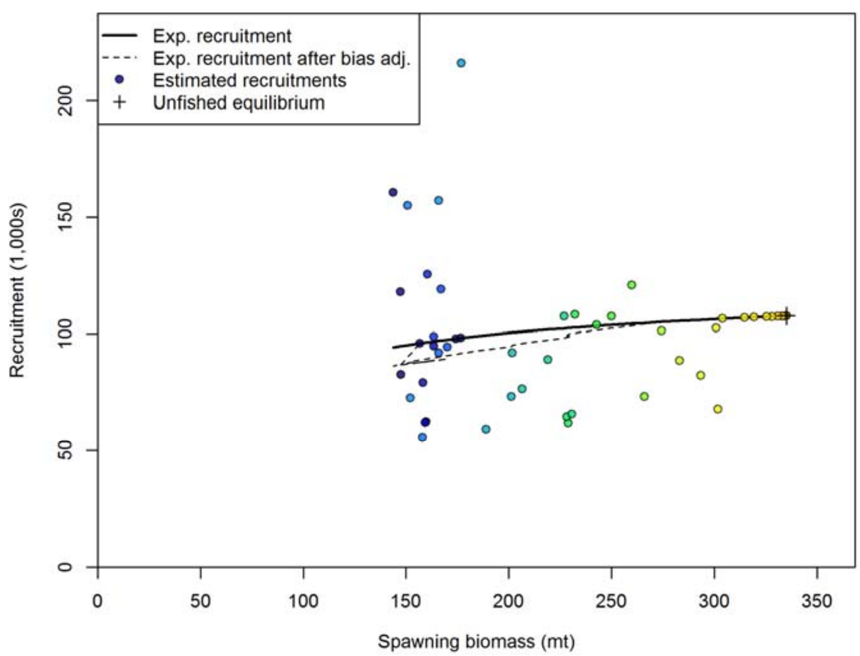


Figure 124. Beverton-Holt stock recruitment relationship for the Oregon Cabezon reference model.

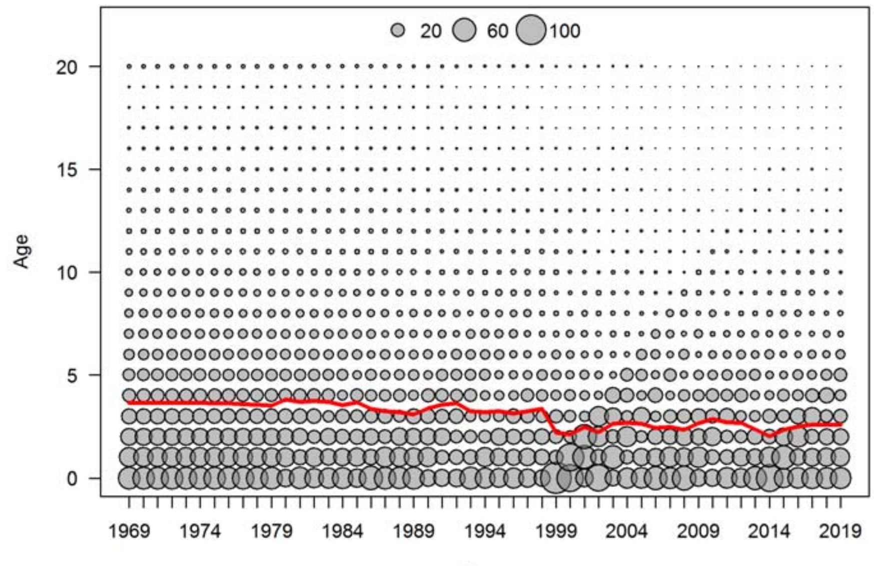


Figure 125. Distribution of numbers at age estimated across the time series (1970-2019) from the reference Oregon model. The size of the circle relates to the number of fish (thousands) and for brevity are only shown for females (though model assumes 50:50 sex ratio).

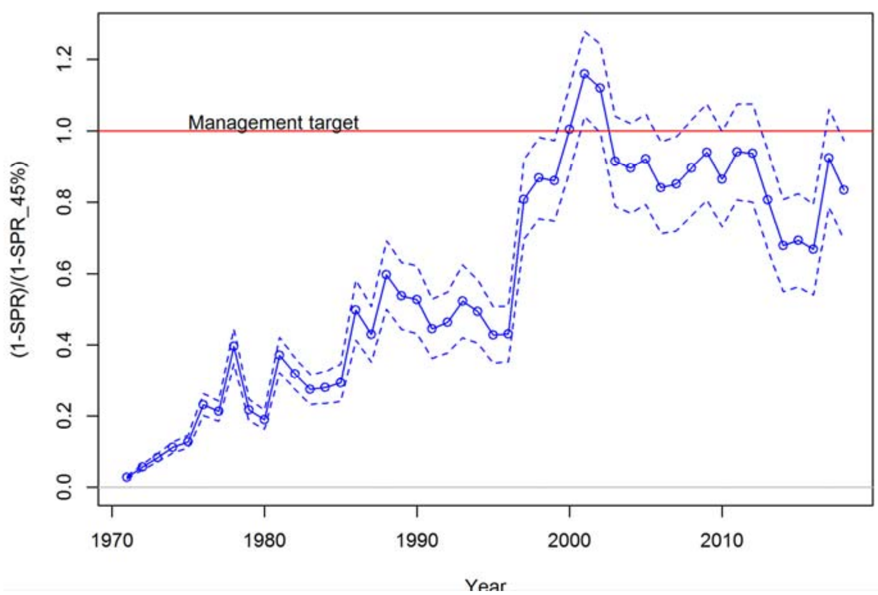


Figure 126. Estimated spawning potential ratio (SPR) for the Oregon Cabezon reference model. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as a red horizontal line and values above this reflect harvests in excess of the overfishing proxy based on the SPR45% harvest rate. The last year in the time series is 2018.

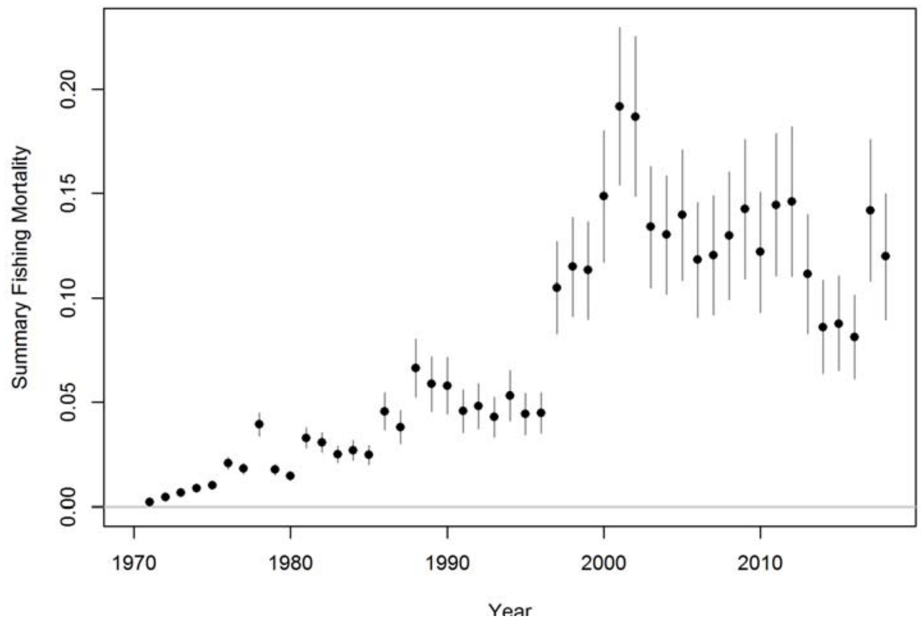


Figure 127. Time-series of estimated summary harvest rate (total catch divided by age-2 and older biomass) for the Oregon reference model with approximate 95% asymptotic confidence intervals (grey lines).

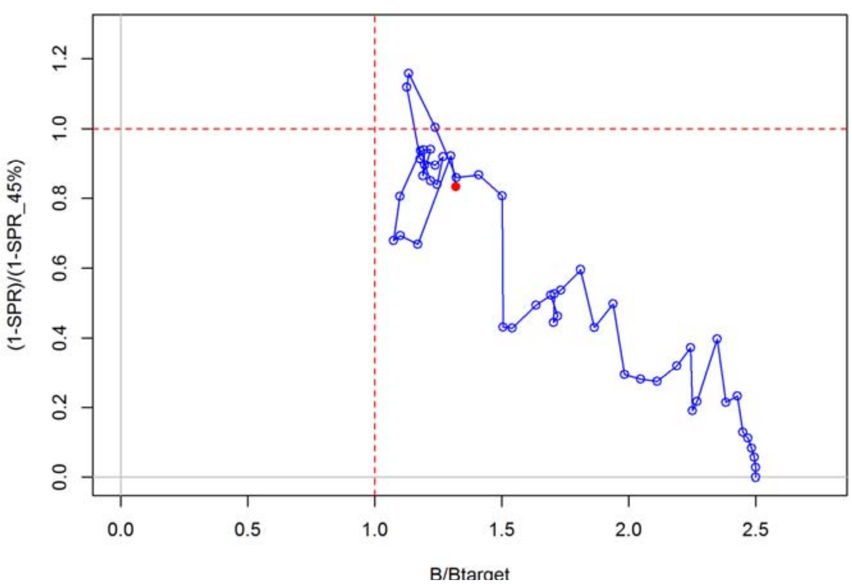


Figure 128. Phase plot of relative spawning output vs fishing intensity for the Oregon Cabezon reference model. The relative fishing intensity is (1-SPR) divided by 45% (the SPR target). The vertical red line is the relative spawning output target defined as the annual spawning output divided by the spawning output corresponding to 40% of the unfished spawning output. The red dot corresponds to 2018.

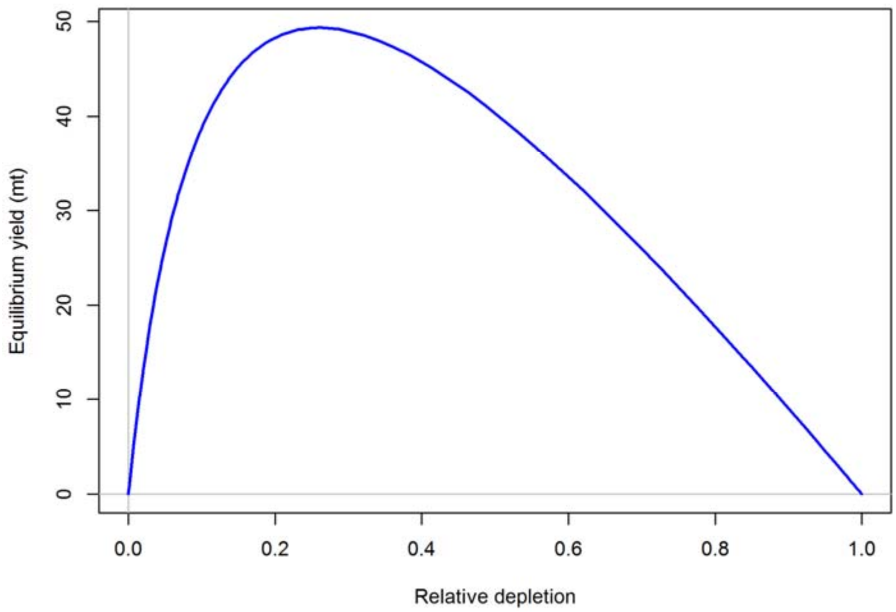


Figure 129. Equilibrium yield curve for the Oregon Cabezon reference model. Values are based on 2018 fishery selectivity and distribution with steepness fixed at 0.70. The depletion is relative to unfished spawning output.

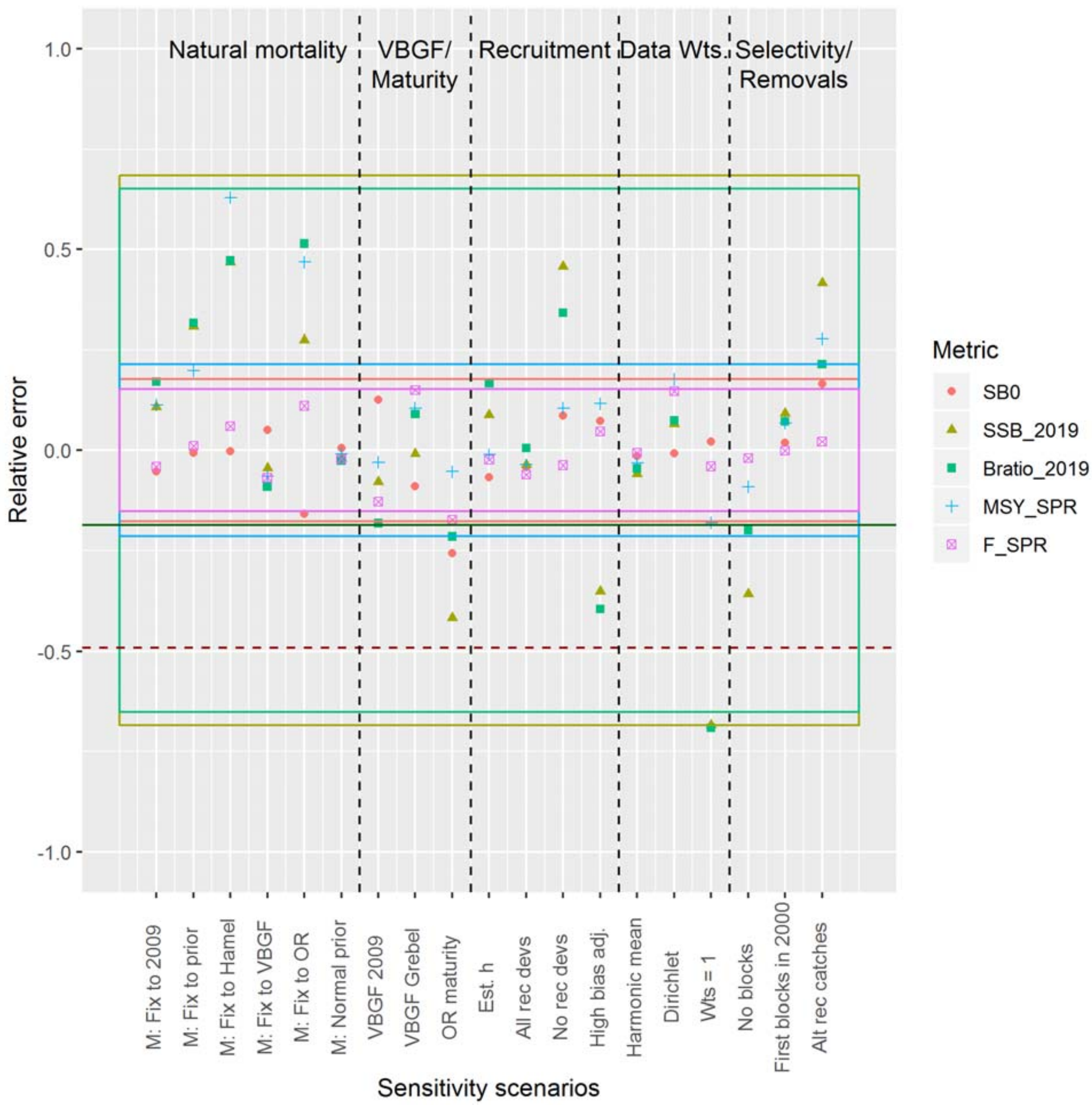


Figure 130 Sensitivity plot for model specifications in the SCS model for 5 derived model outputs. Sensitivity is measured in error relative to the bse model (0 value means equivalency to the reference model). Colored rectangles mark the 95% asymptotic interval of the same colored derived output, therefore symbols outside their respective box indicates a scenario significantly different from the reference model. X-axis labels indicate model specification scenarios.

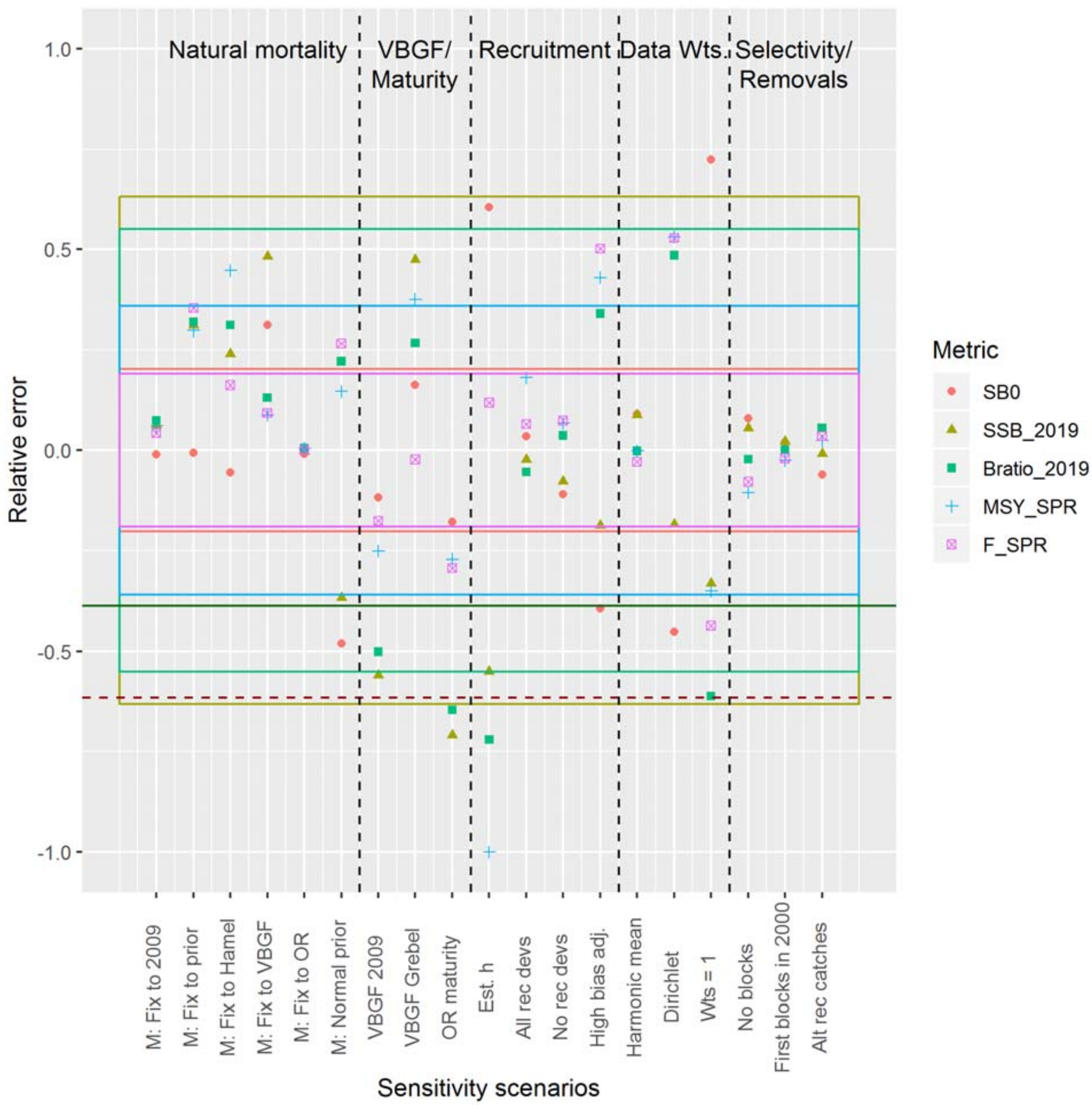


Figure 131. Sensitivity plot for model specifications in the NCS model for 5 derived model outputs. Sensitivity is measured in error relative to the bse model (0 value means equivalency to the reference model). Colored rectangles mark the 95% asymptotic interval of the same colored derived output, therefore symbols outside their respective box indicates a scenario significantly different from the reference model. X-axis labels indicate model specification scenarios.

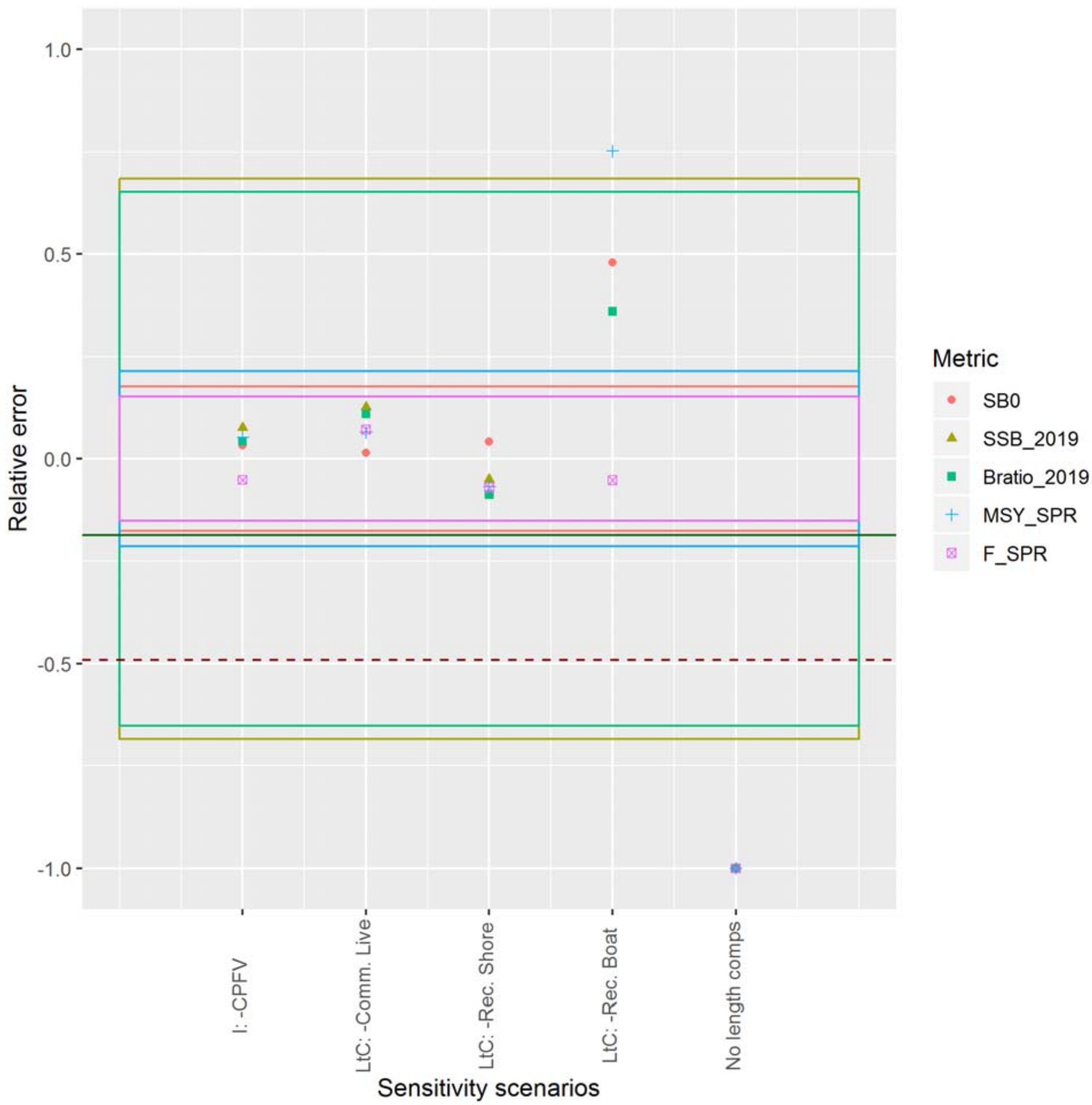


Figure 132. Sensitivity plot for the likelihood components in the SCS model for 5 derived model outputs. Sensitivity is measured in error relative to the bse model (0 value means equivalency to the reference model). Colored rectangles mark the 95% asymptotic interval of the same colored derived output, therefore symbols outside their respective box indicates a scenario significantly different from the reference model. X-axis labels indicate which likelihood component is removed.

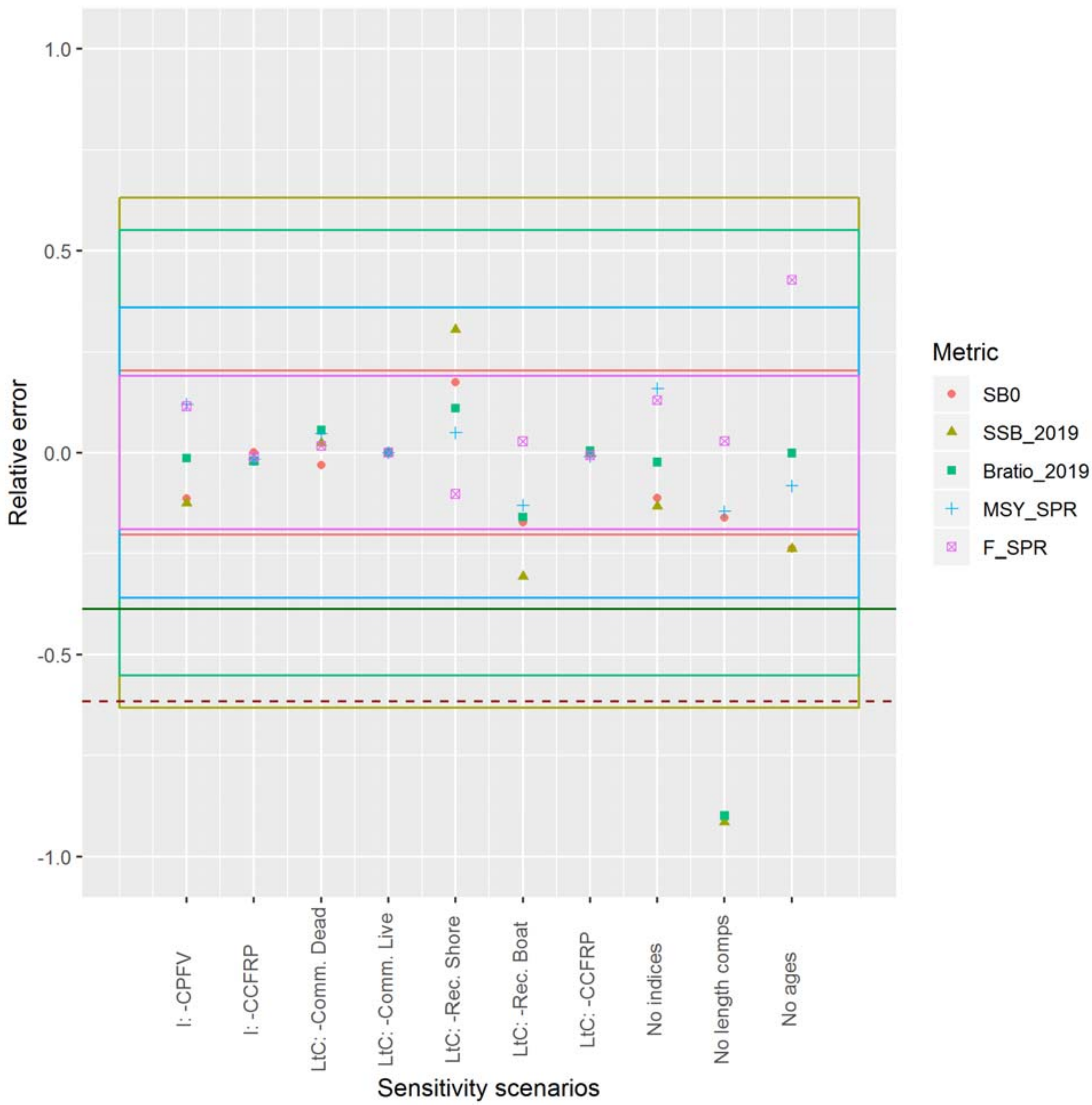


Figure 133. Sensitivity plot for the likelihood components in the NCS model for 5 derived model outputs. Sensitivity is measured in error relative to the bse model (0 value means equivalency to the reference model). Colored rectangles mark the 95% asymptotic interval of the same colored derived output, therefore symbols outside their respective box indicates a scenario significantly different from the reference model. X-axis labels indicate which likelihood component is removed.

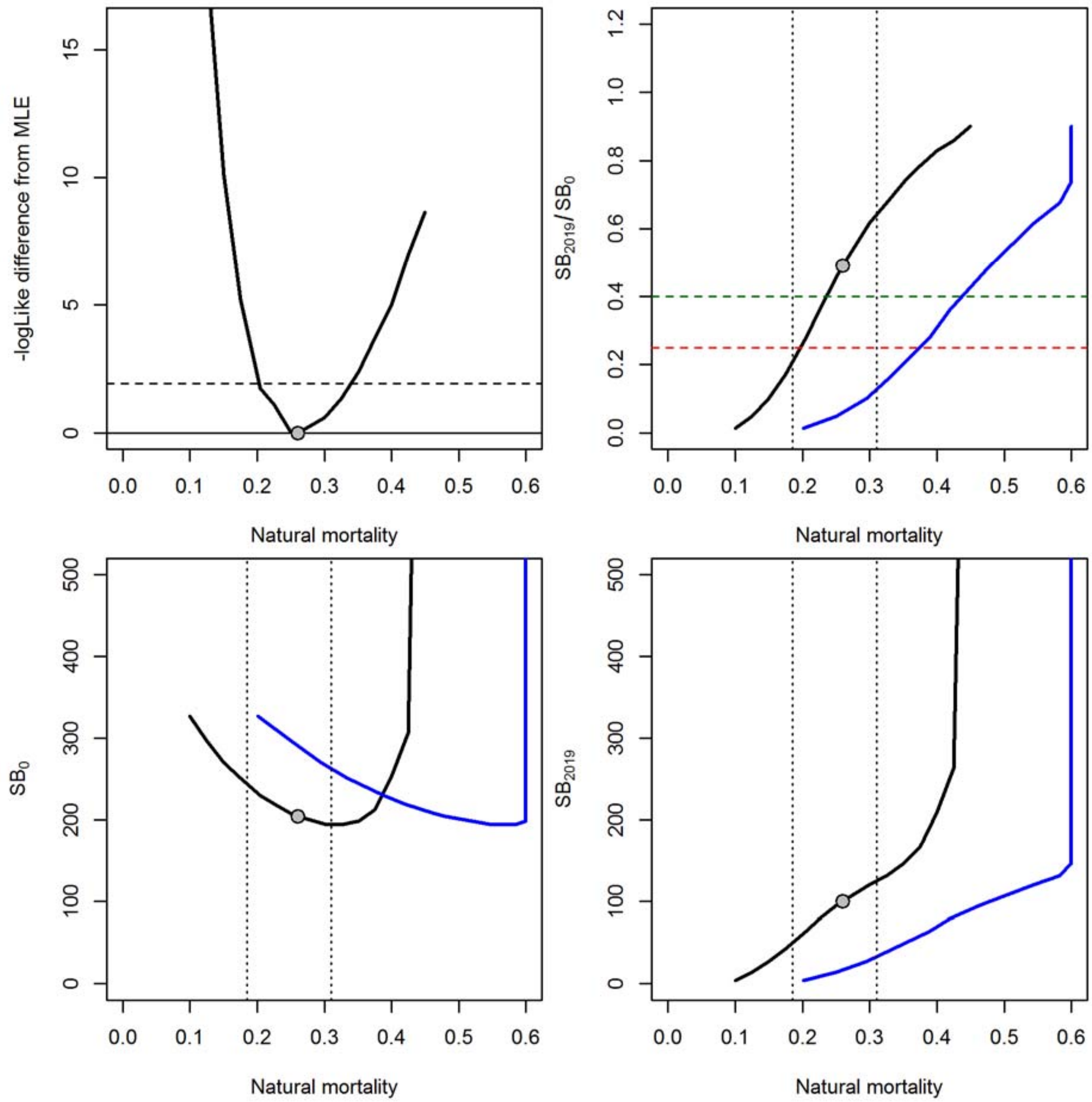


Figure 134. Likelihood profile for natural mortality for the SCS model, with associated changes in stock status in the current year (SB_{2019}/SB_0; top right panel), initial spawning biomass (SB_0; bottom left panel), and current year spawning biomass (SB_{2019}; bottom right panel). Points indicate the base model MLE estimate. Blue lines are the estimated male natural mortality values. Vertical dotted lines denote lower and upper significant levels.

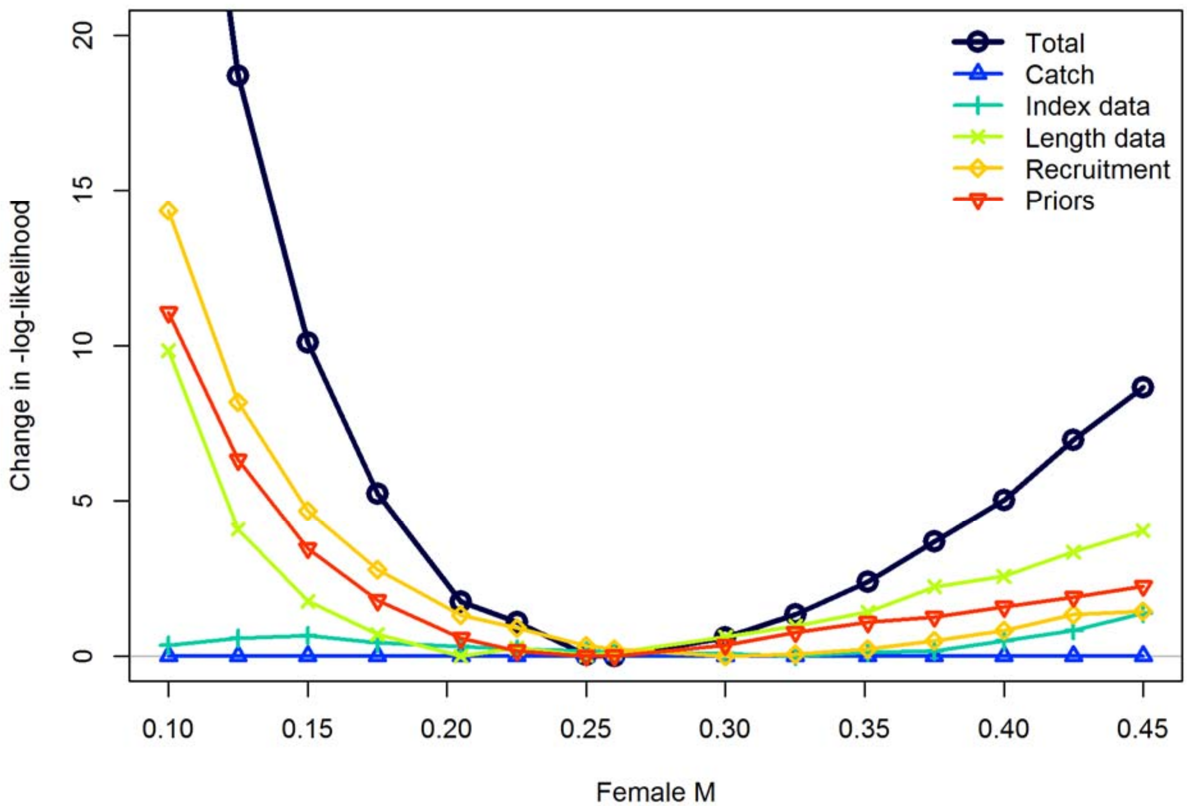


Figure 135. Likelihood profile for natural mortality (top panel: female; bottom panel: male) by likelihood component for the SCS model.

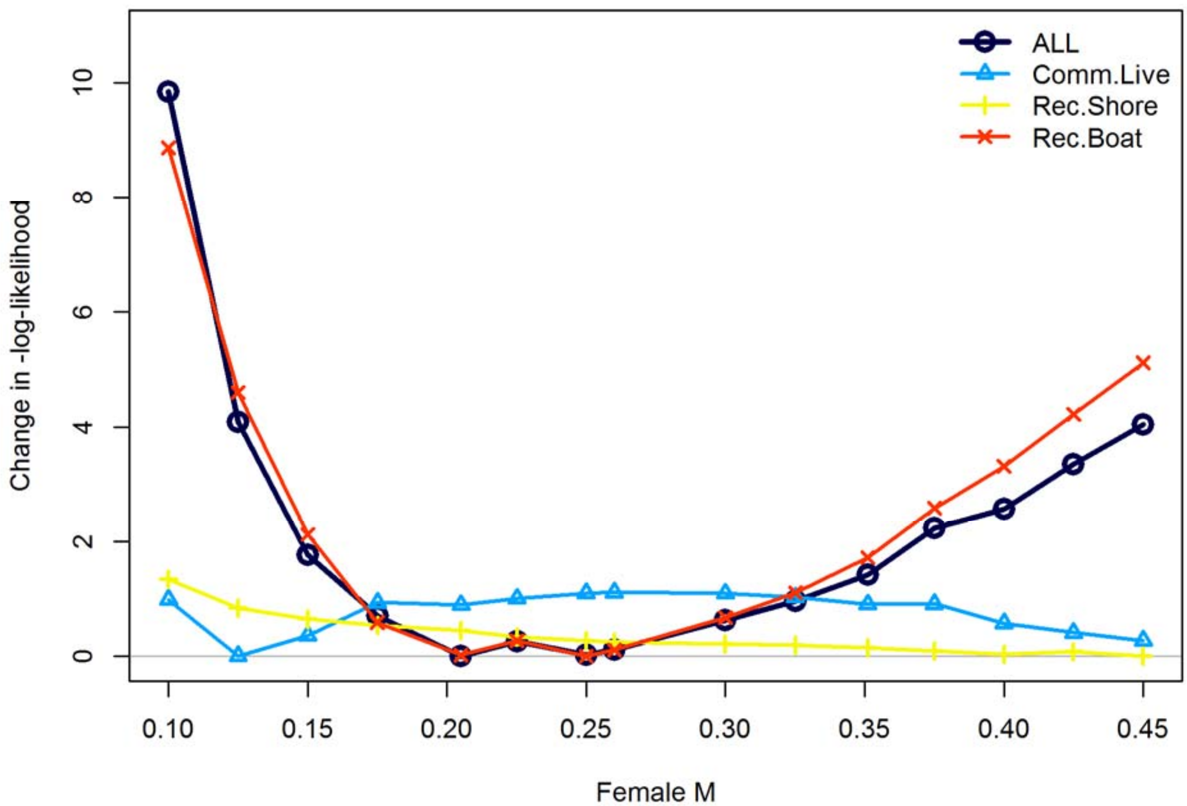


Figure 136. Likelihood profile of female natural mortality for fleets within length composition likelihood components for the SCS models.

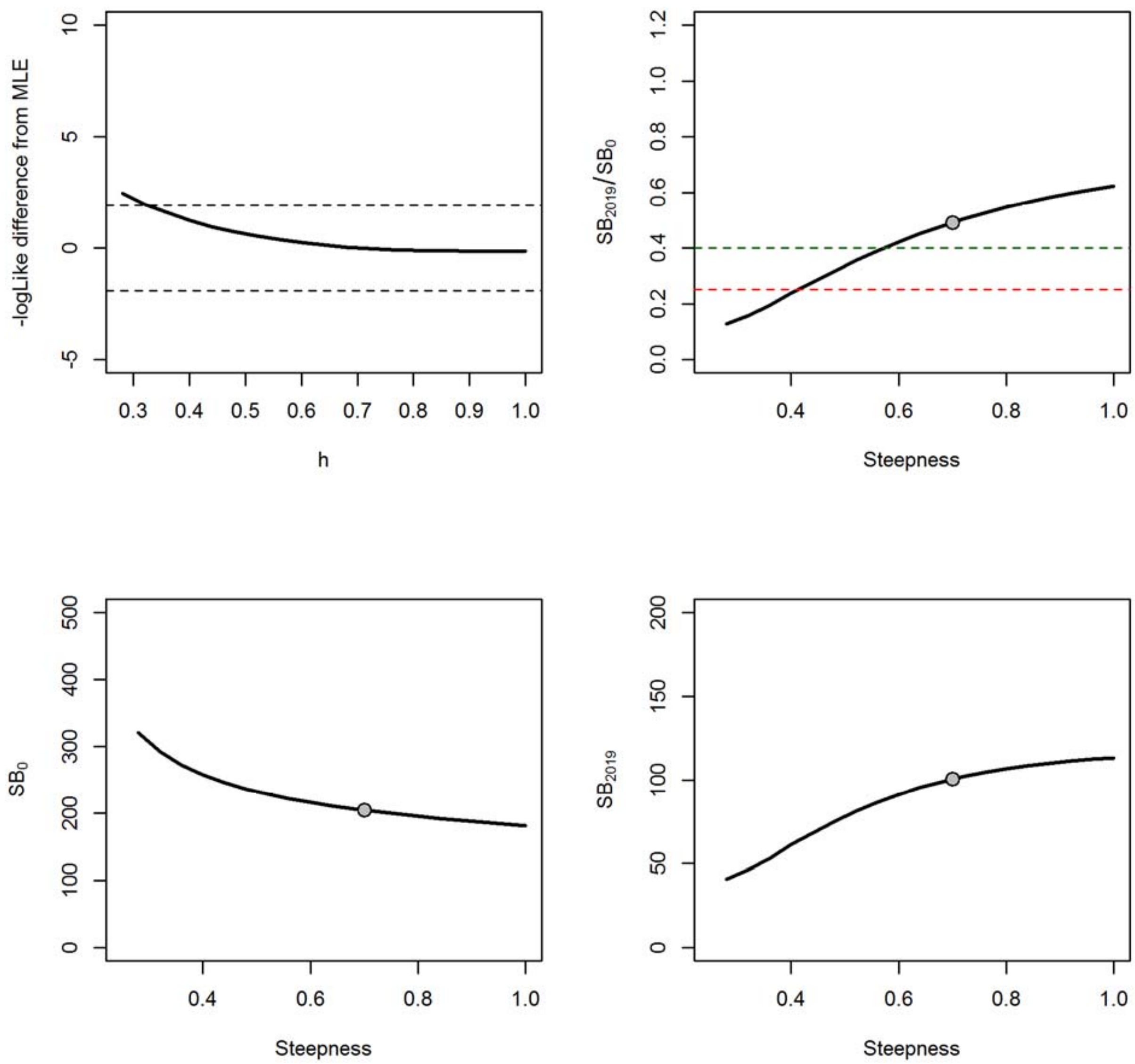


Figure 137. Likelihood profile (top left panel) for steepness (*h*) for the SCS model, with associated changes in stock status in the current year (SB_{2019}/SB_0; top right panel), initial spawning biomass (SB_0; bottom left panel), and current year spawning biomass (SB_{2019}; bottom right panel). Points indicate the base model MLE estimate.

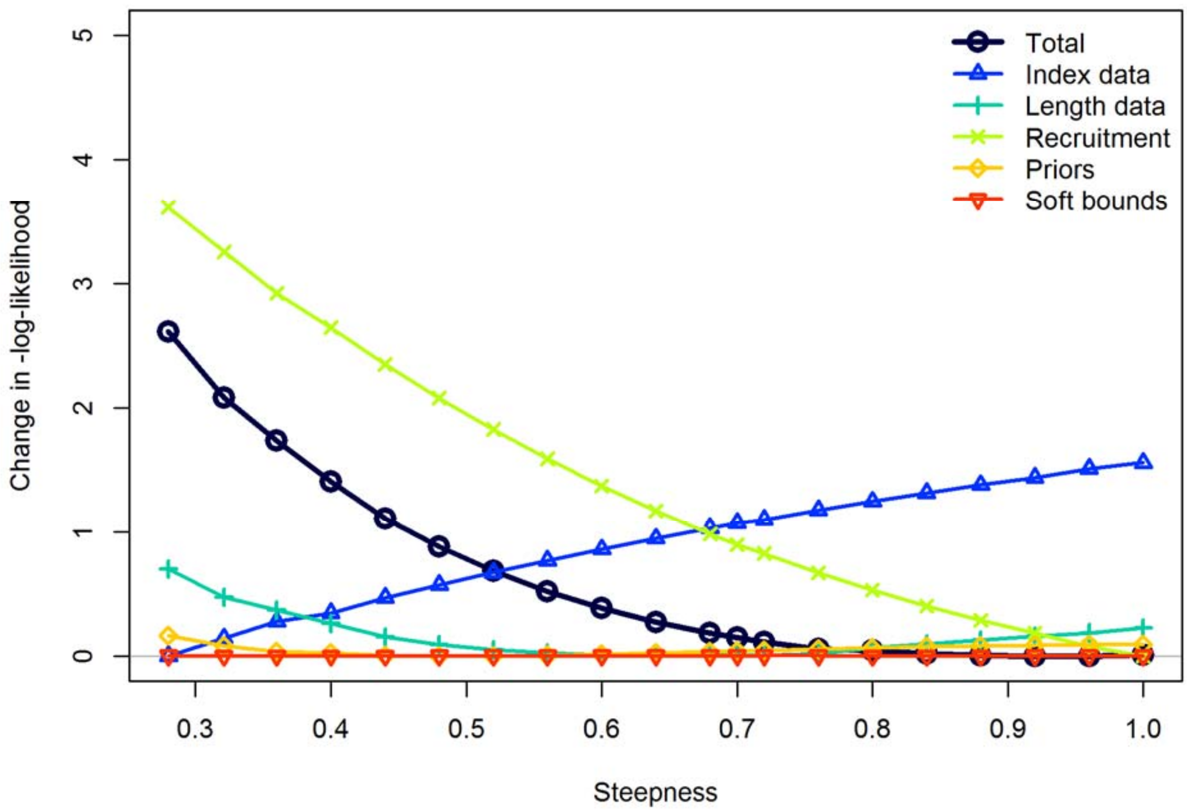


Figure 138. Likelihood profile for steepness (*h*) by likelihood component for the SCS model.

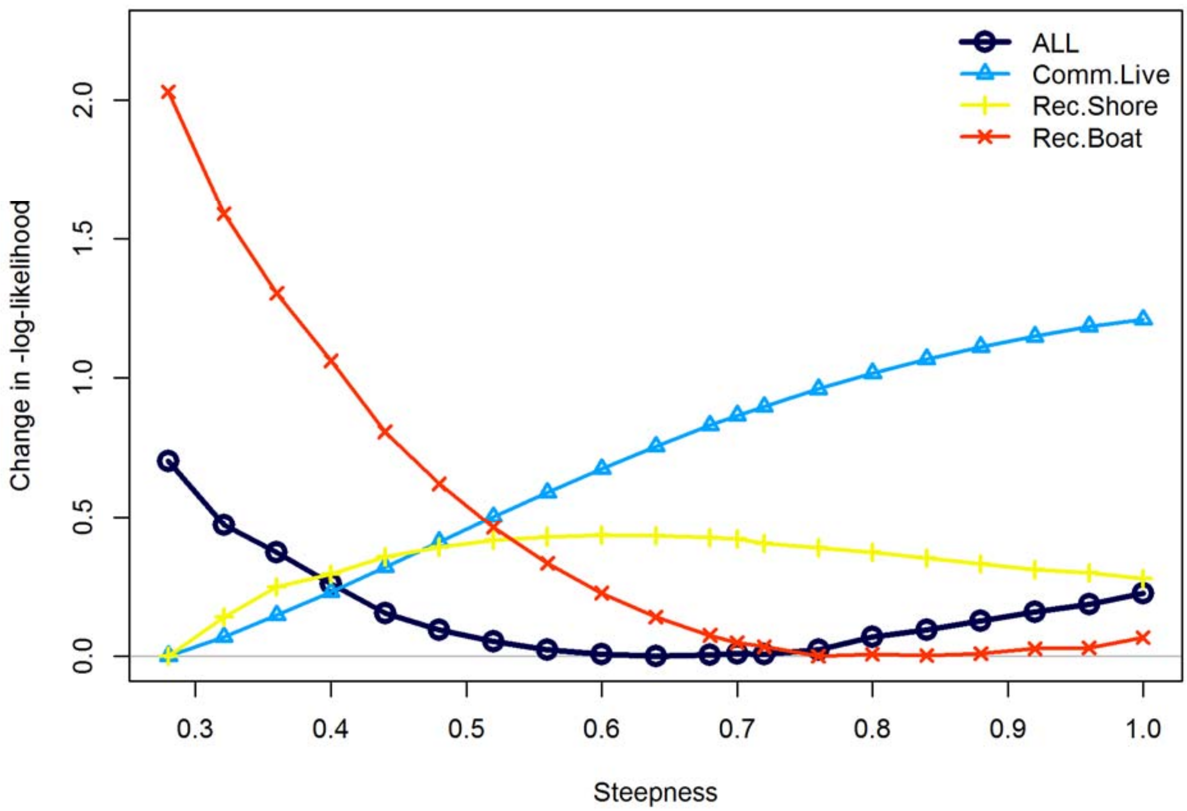


Figure 139. Likelihood profile of steepness for fleets within the length composition likelihood components for the SCS models.

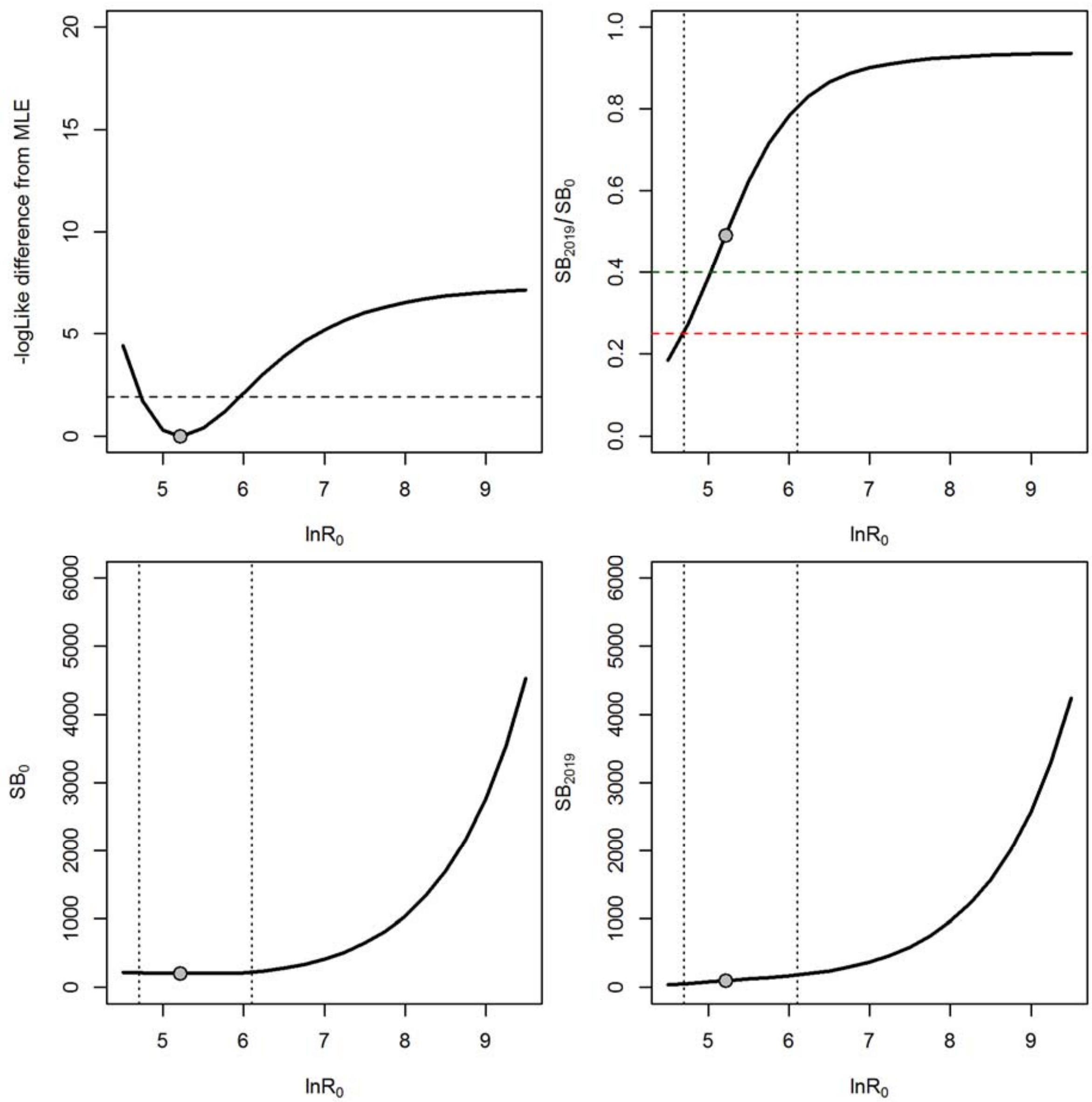


Figure 140. Likelihood profile (top left panel) for log initial recruitment, ln(R_0), in the SCS model, with associated changes in stock status in the current year (SB_{2019}/SB_0; top right panel), initial spawning biomass (SB_0; bottom left panel), and current year spawning biomass (SB_{2019}; bottom right panel). Points indicate the base model MLE estimate. Vertical dotted lines denote lower and upper significant levels.

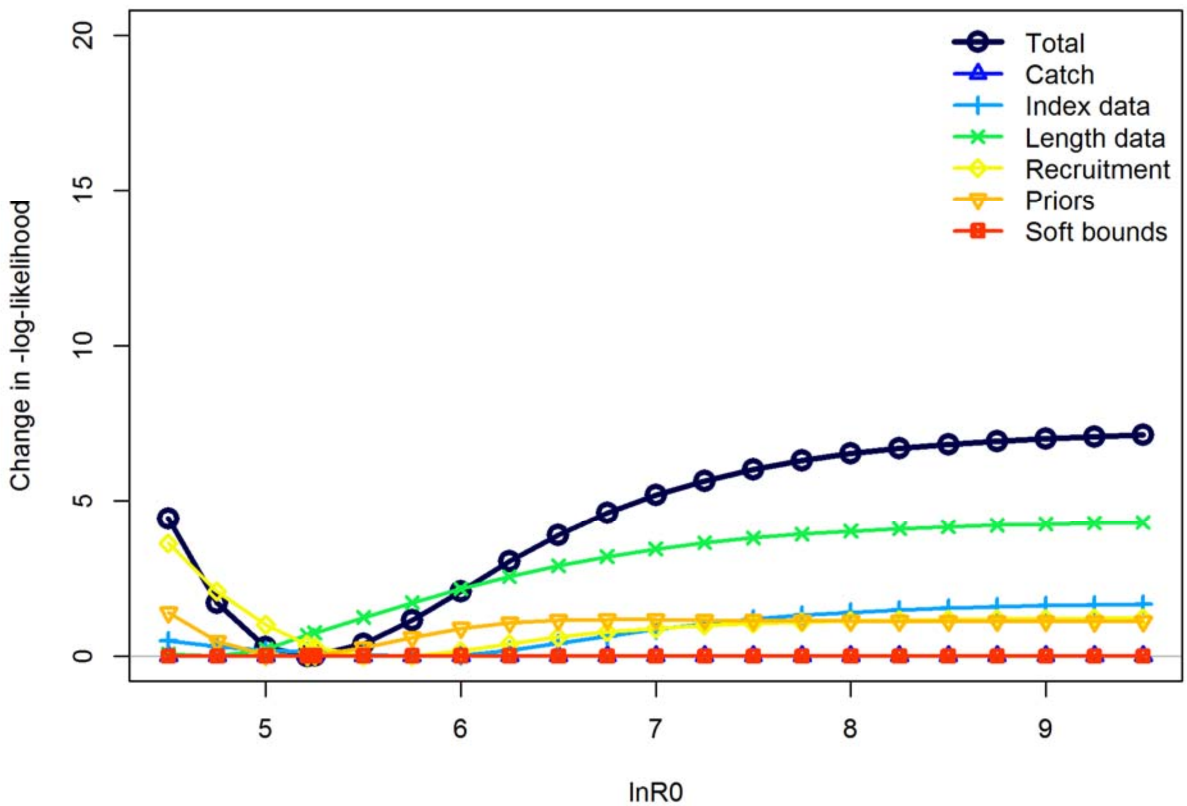


Figure 141. Likelihood profile for log initial recruitment ,ln(*R_0*) by likelihood component in the SCS model.

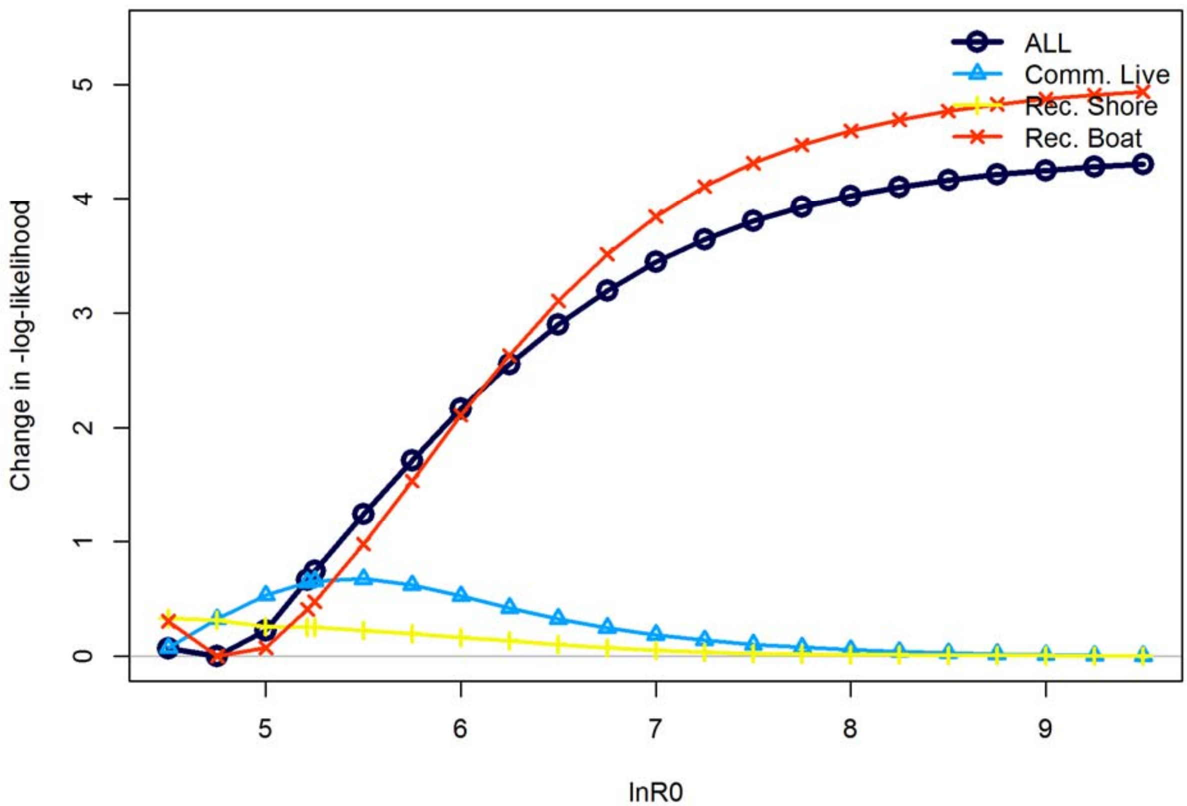


Figure 142. Likelihood profile of steepness for fleets within the length composition likelihood components for the SCS models.

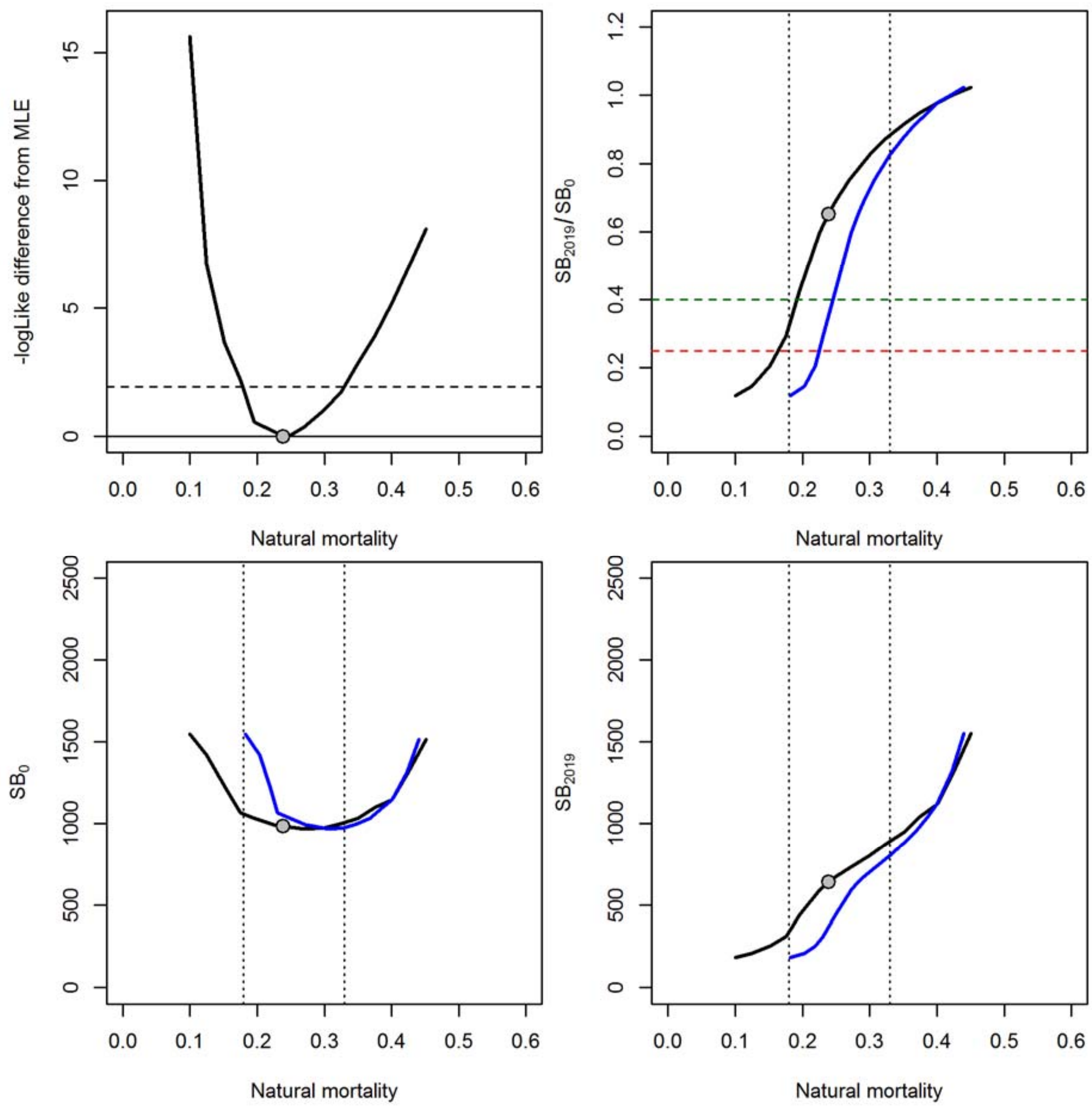


Figure 143. Likelihood profile for natural mortality for the NCS model, with associated changes in stock status in the current year (SB_{2019}/SB_0; top right panel), initial spawning biomass (SB_0; bottom left panel), and current year spawning biomass (SB_{2019}; bottom right panel). Points indicate the base model MLE estimate. Blue lines are the estimated male natural mortality values. Vertical lines denote the lower and upper significance lines.

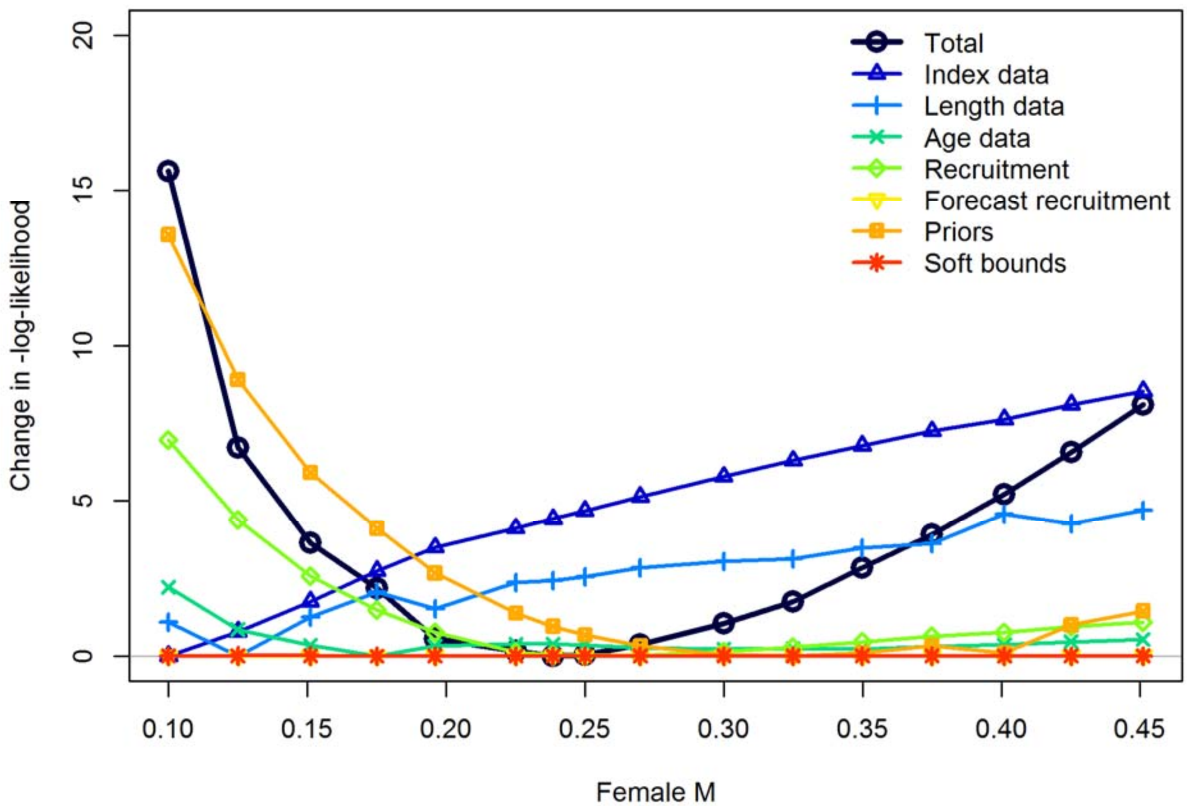


Figure 144. Likelihood profile for female natural mortality by likelihood component for the NCS model.

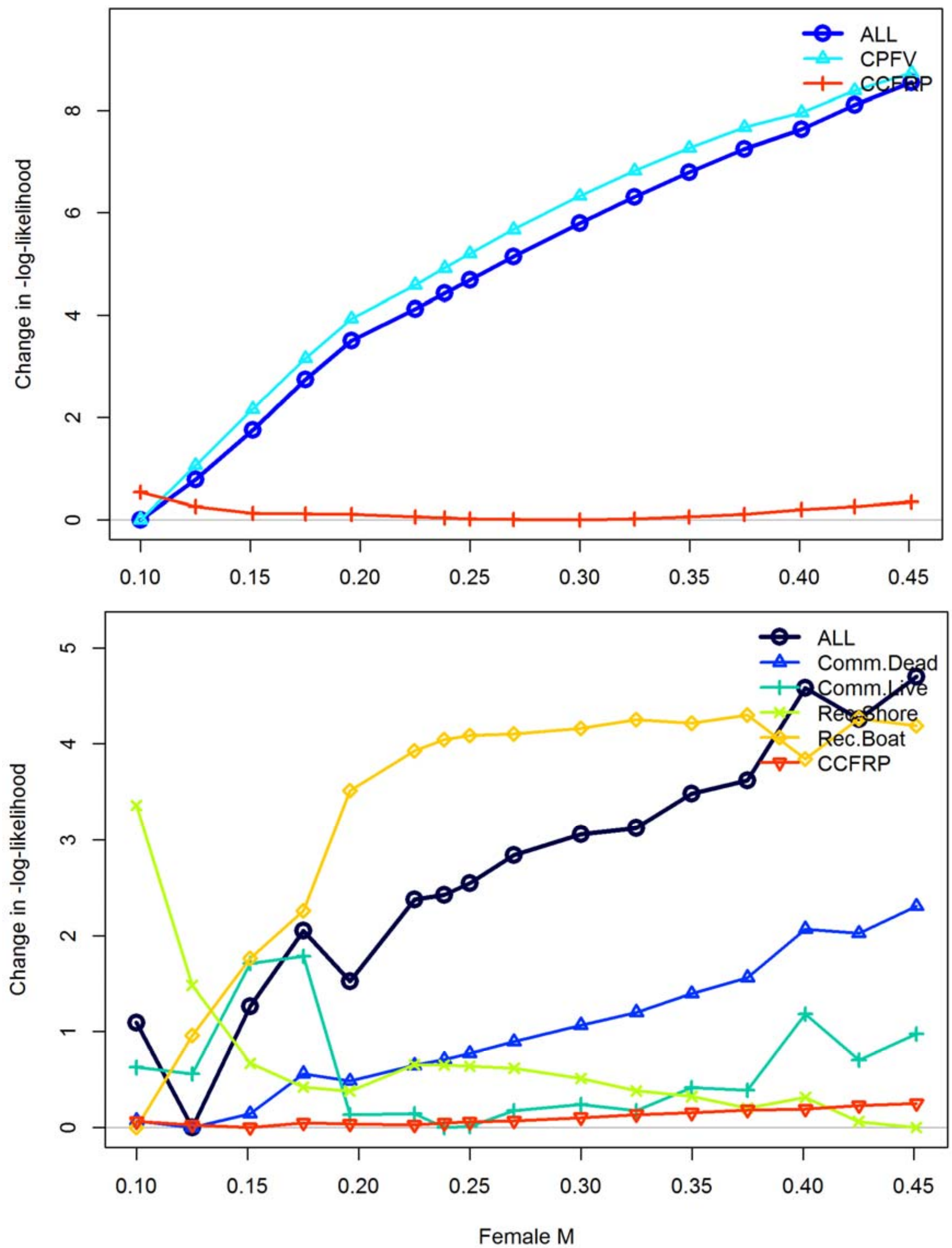


Figure 145. Likelihood profile of female natural mortality for fleets within survey (top panel) and length composition (bottom panel) likelihood components for the NCS models.

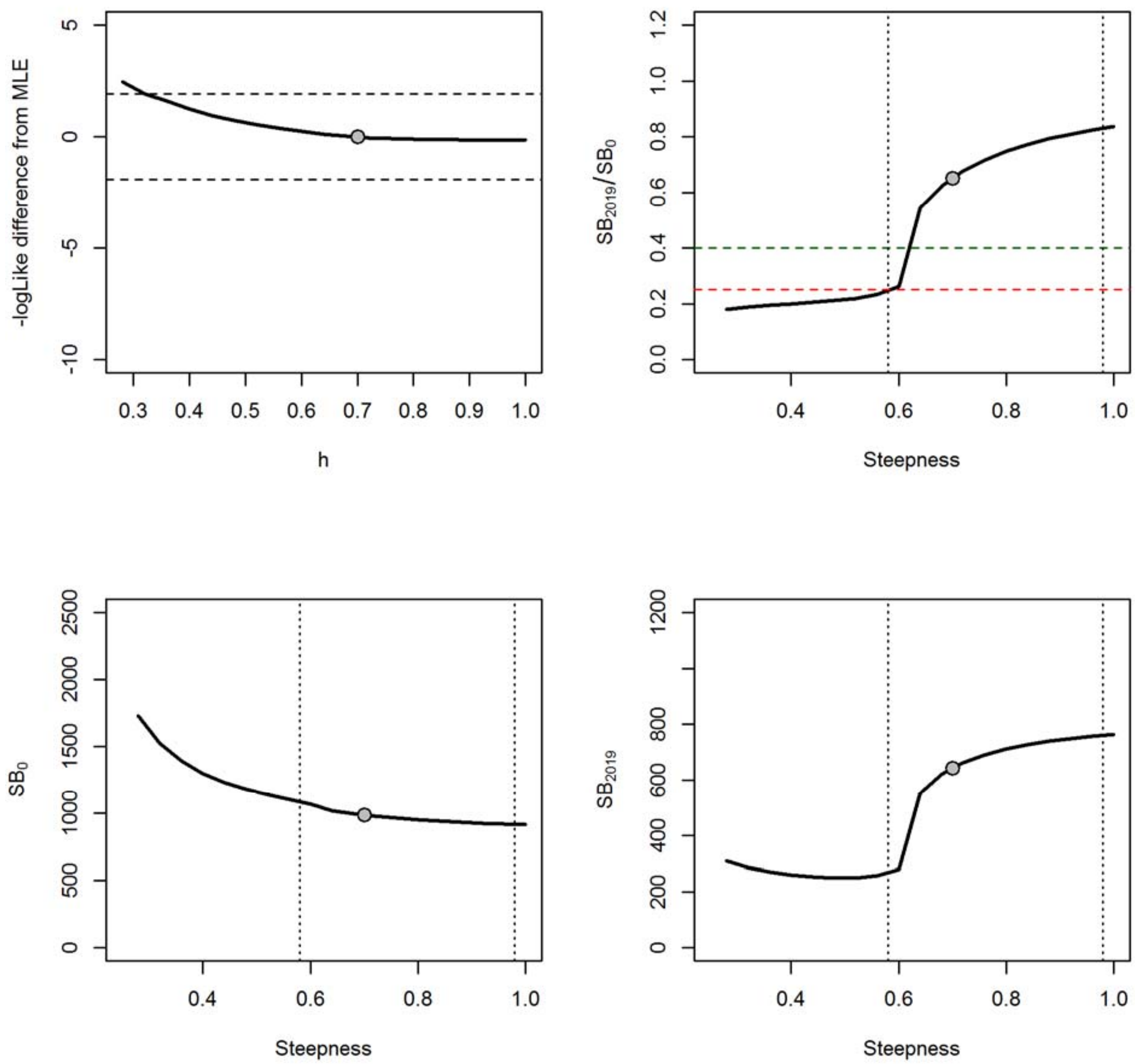


Figure 146. Likelihood profile (top left panel) for steepness (*h*) for the NCS model, with associated changes in stock status in the current year (SB_{2019}/SB_0; top right panel), initial spawning biomass (SB_0; bottom left panel), and current year spawning biomass (SB_{2019}; bottom right panel). Points indicate the base model MLE estimate. Vertical dotted lines denotes lower significance line.

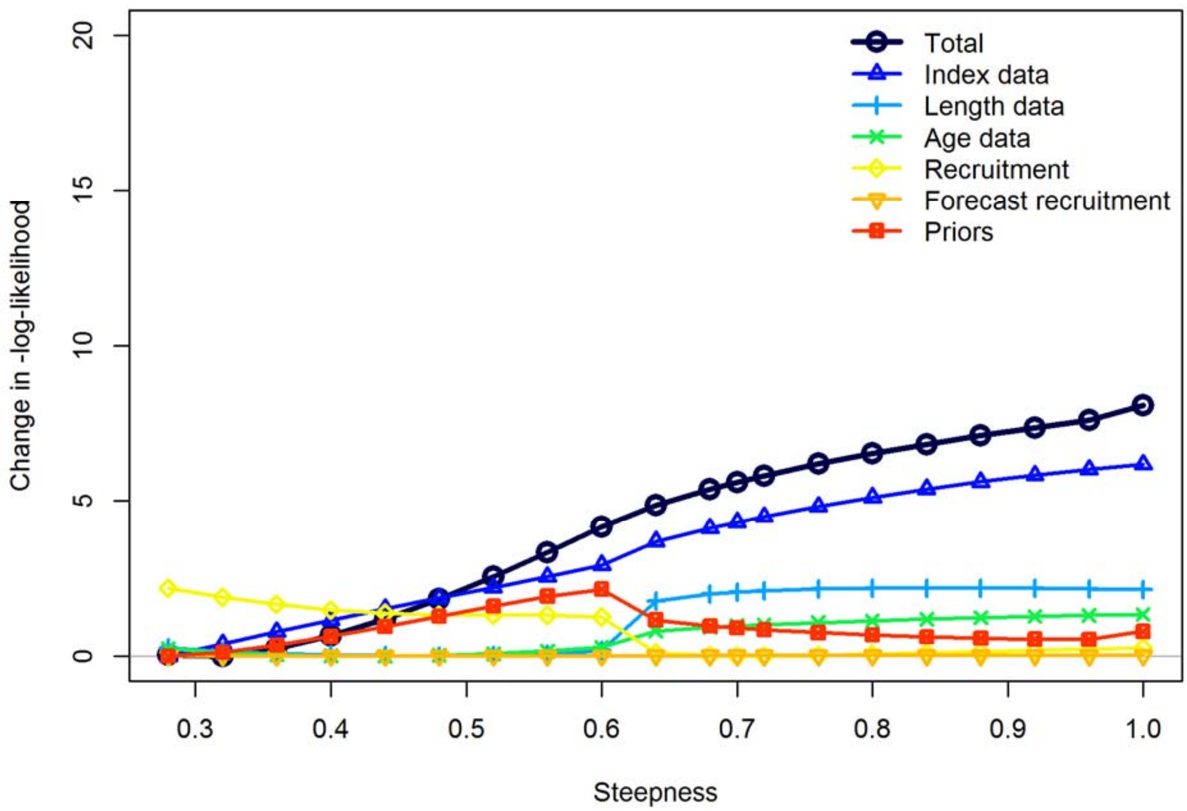


Figure 147. Likelihood profile for steepness (*h*) by likelihood component for the NCS model.

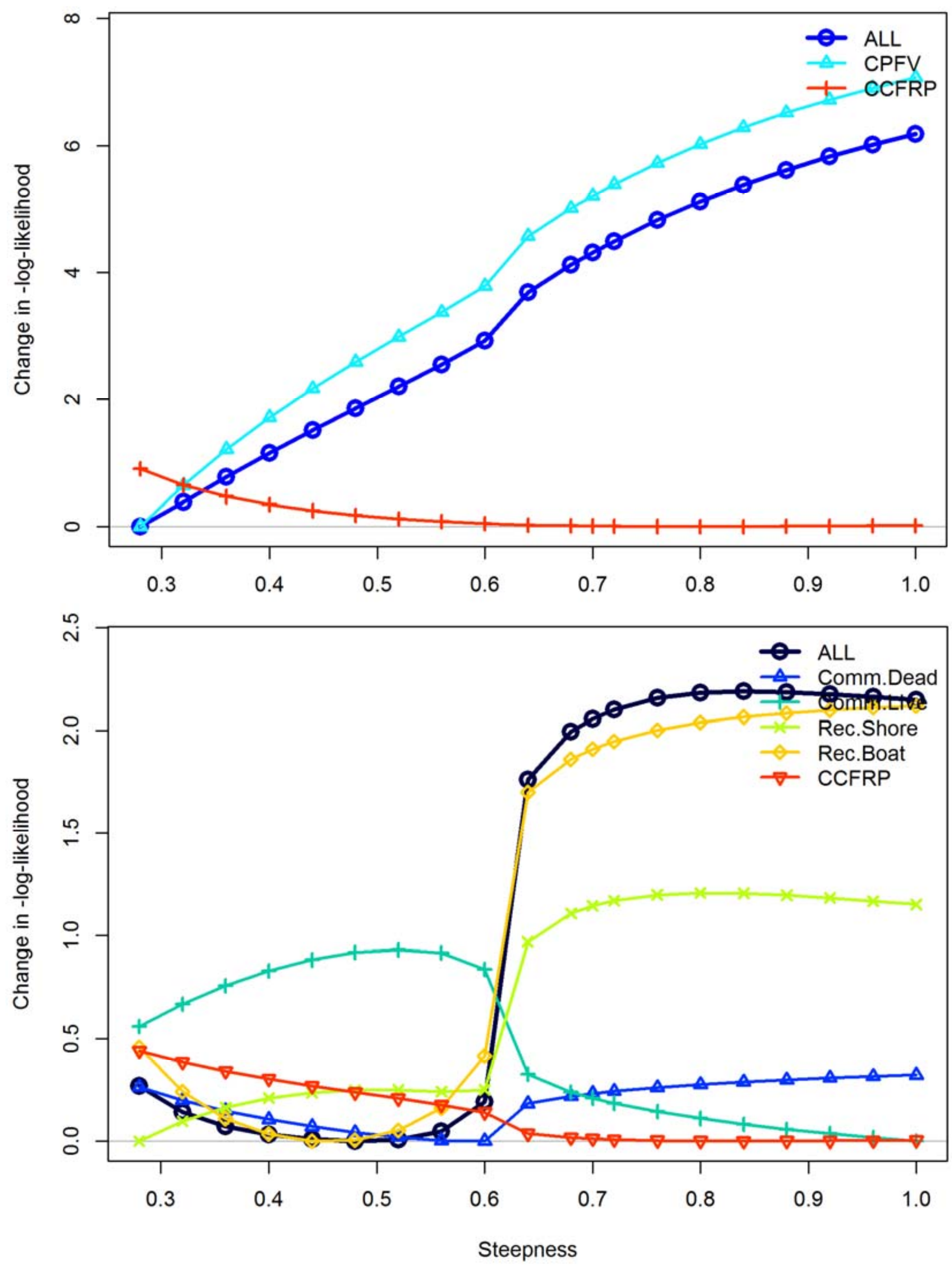


Figure 148. Likelihood profile of steepness for fleets within survey (top panel) and length composition (bottom panel) likelihood components for the NCS models.

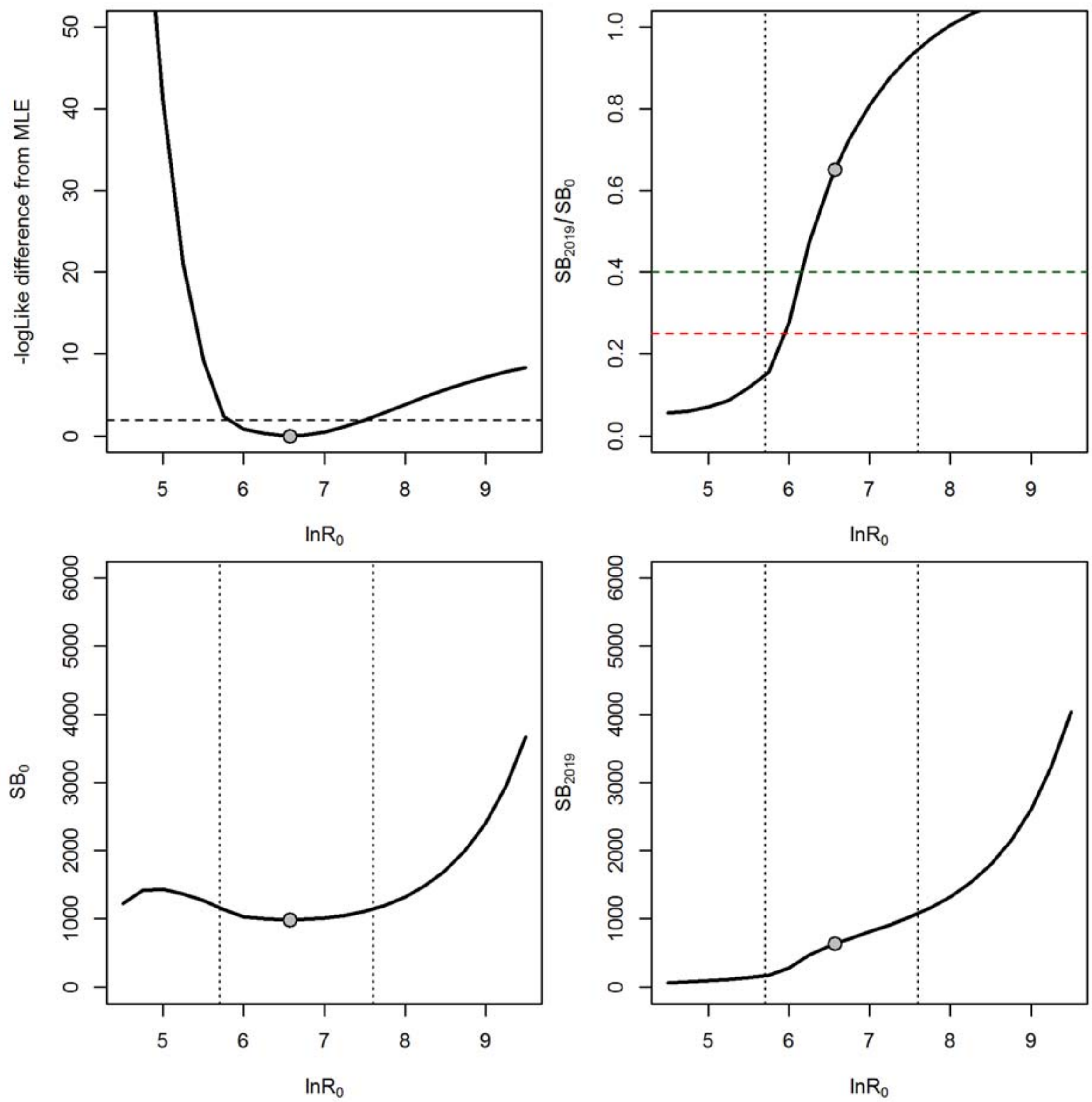


Figure 149. Likelihood profile (top left panel) for log initial recruitment, ln(*R_0*), in the NCS model, with associated changes in stock status in the current year (SB_{2019}/SB_0; top right panel), initial spawning biomass (SB_0; bottom left panel), and current year spawning biomass (SB_{2019}; bottom right panel). Points indicate the base model MLE estimate. Vertical dotted lines denote lower and upper significant values.

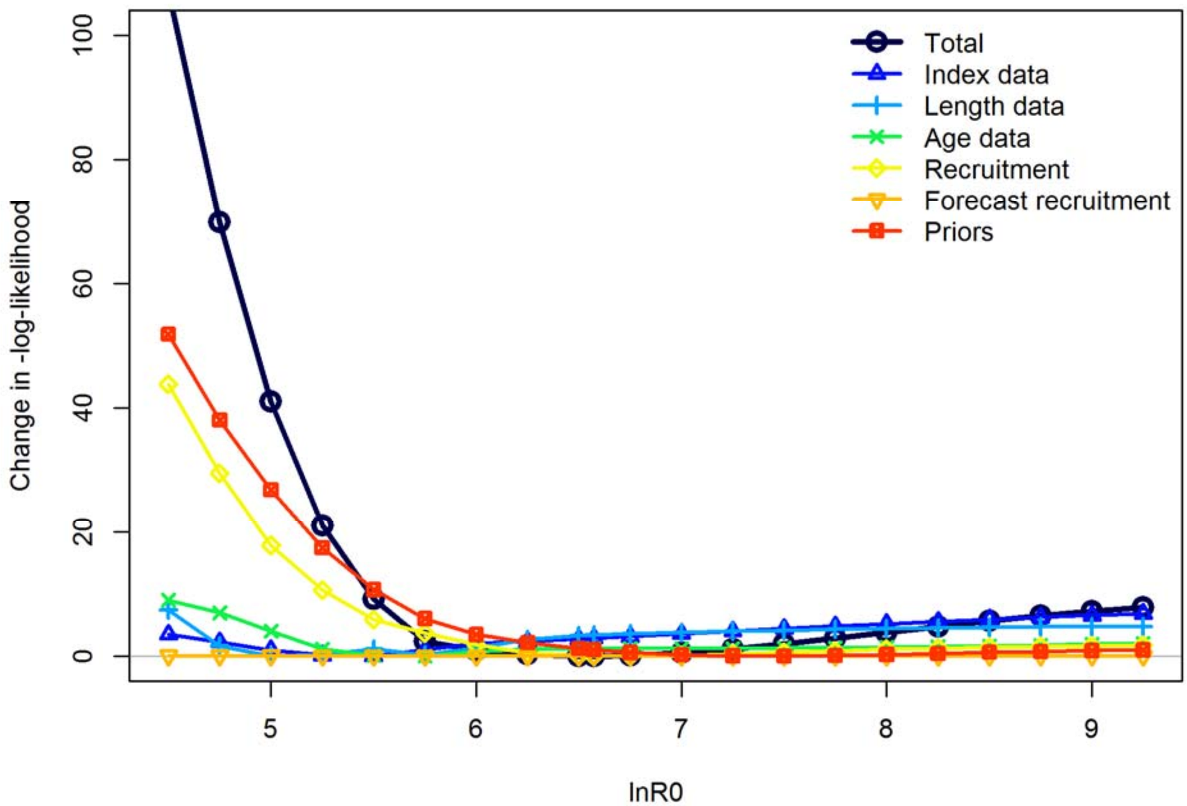


Figure 150. Likelihood profile for log initial recruitment, ln(R_0), by likelihood component in the NCS model.

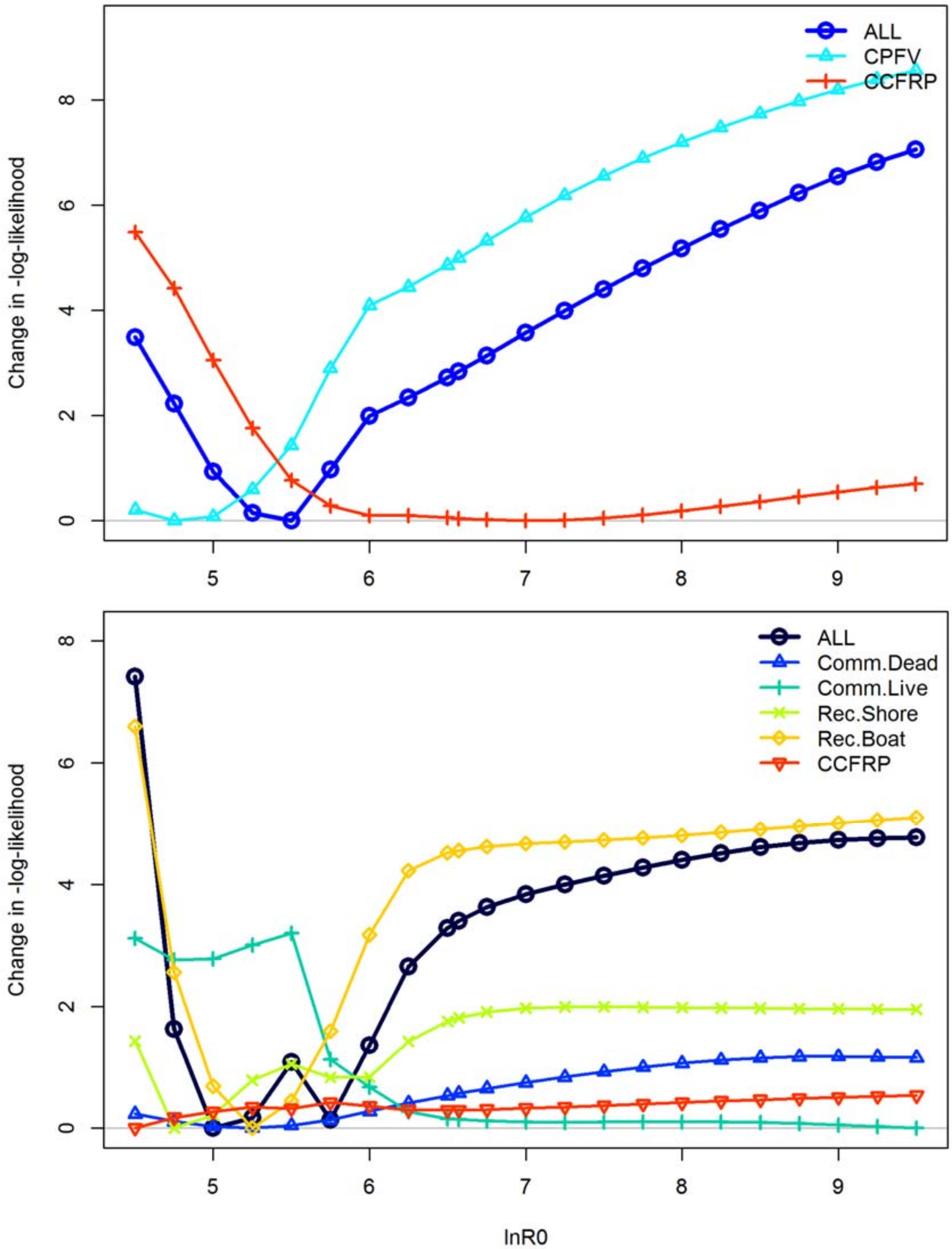


Figure 151. Likelihood profile of ln(R_0) for fleets within survey (top panel) and length composition (bottom panel) likelihood components for the NCS models.

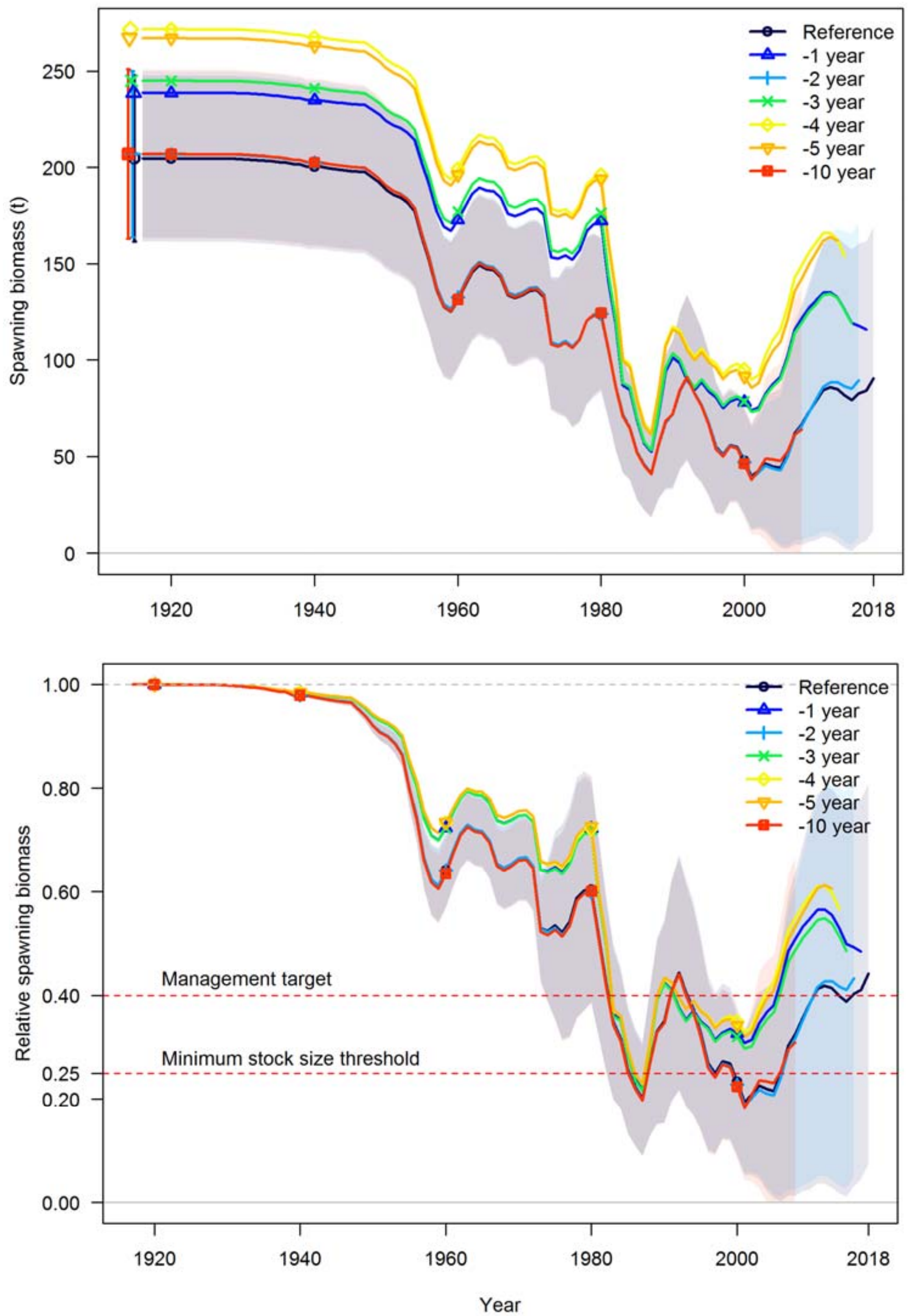
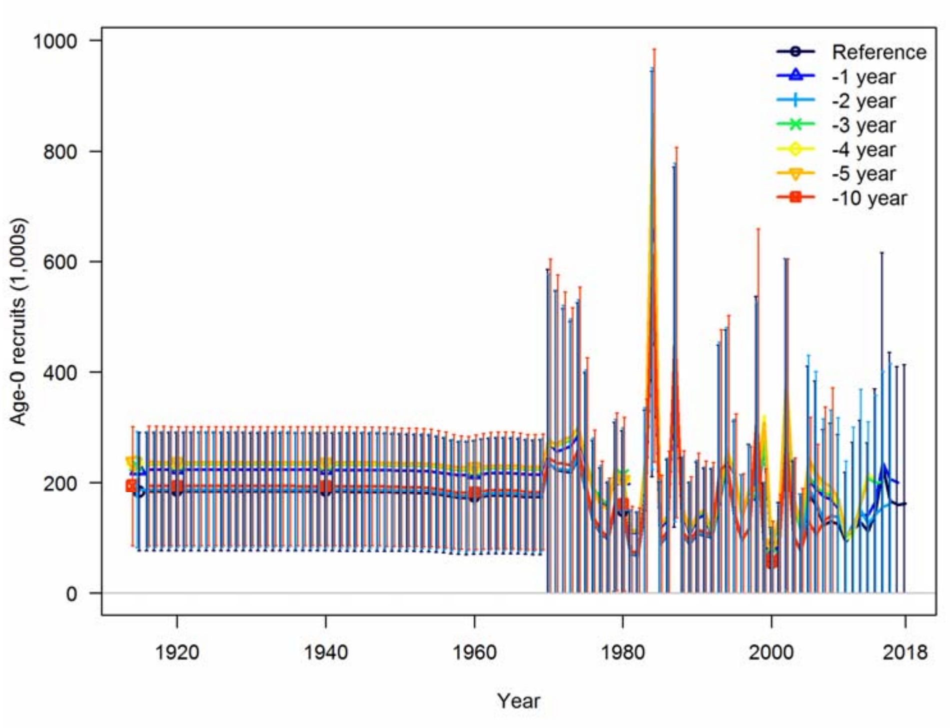


Figure 152. Spawning biomass (top panel) and relative spawning biomass (bottom panel) from the retrospective analysis for the SCS model. Gray shaded area indicates 95% asymptotic interval of the reference model.



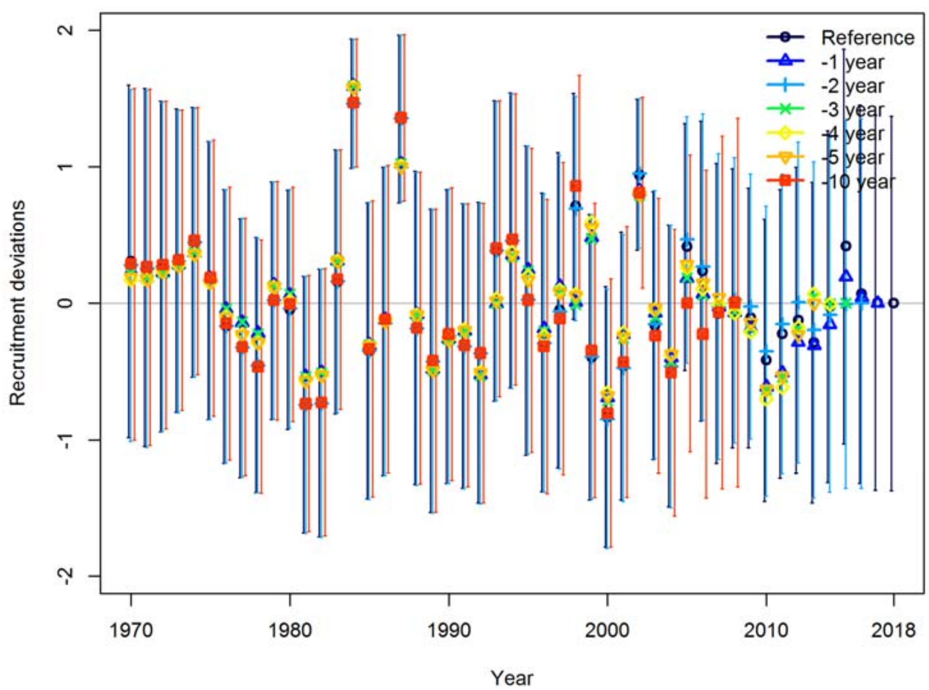


Figure 153. Recruitments (top panel) and recruitment deviations (bottom panel) time series from the retrospective analysis for the SCS model. Vertical bars indicate 95% asymptotic interval of the reference model.

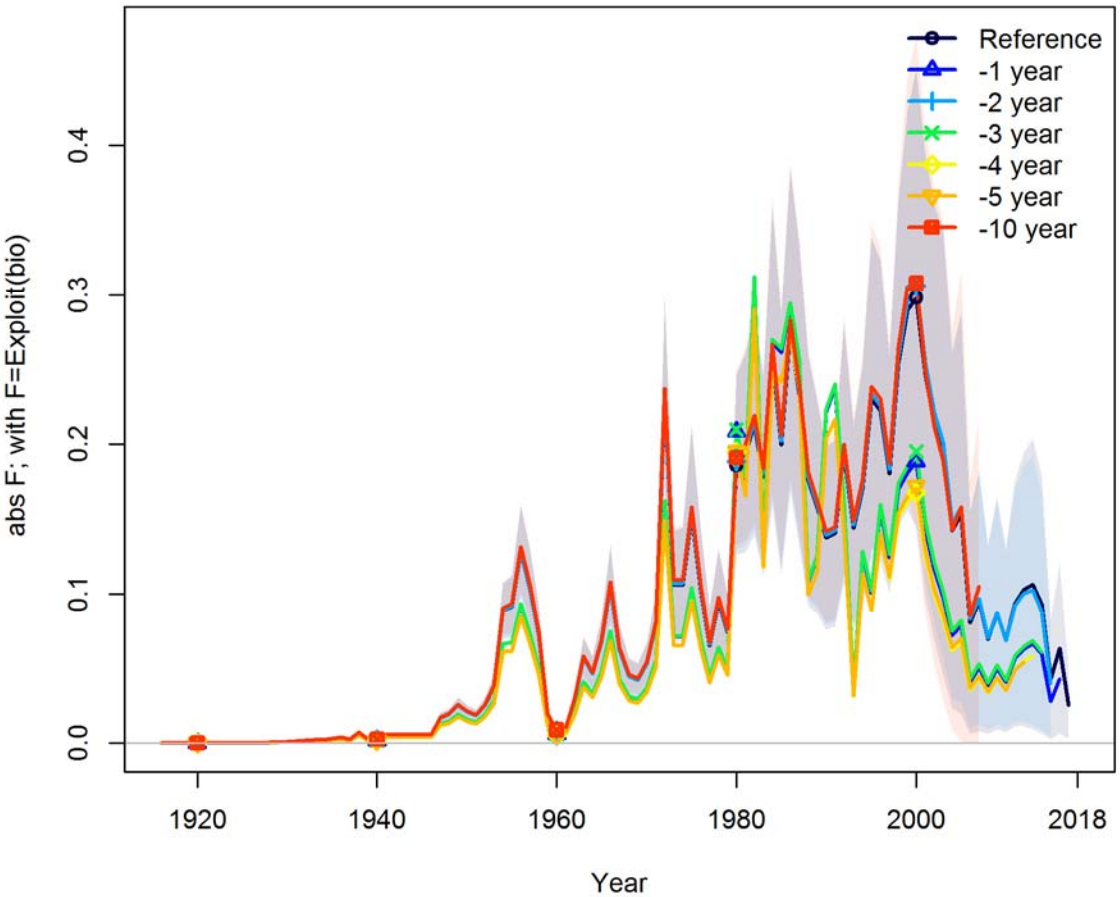


Figure 154. Fishing intensity time series from the retrospective analysis for the SCS model . Gray shaded area indicates 95% asymptotic interval of the reference model.

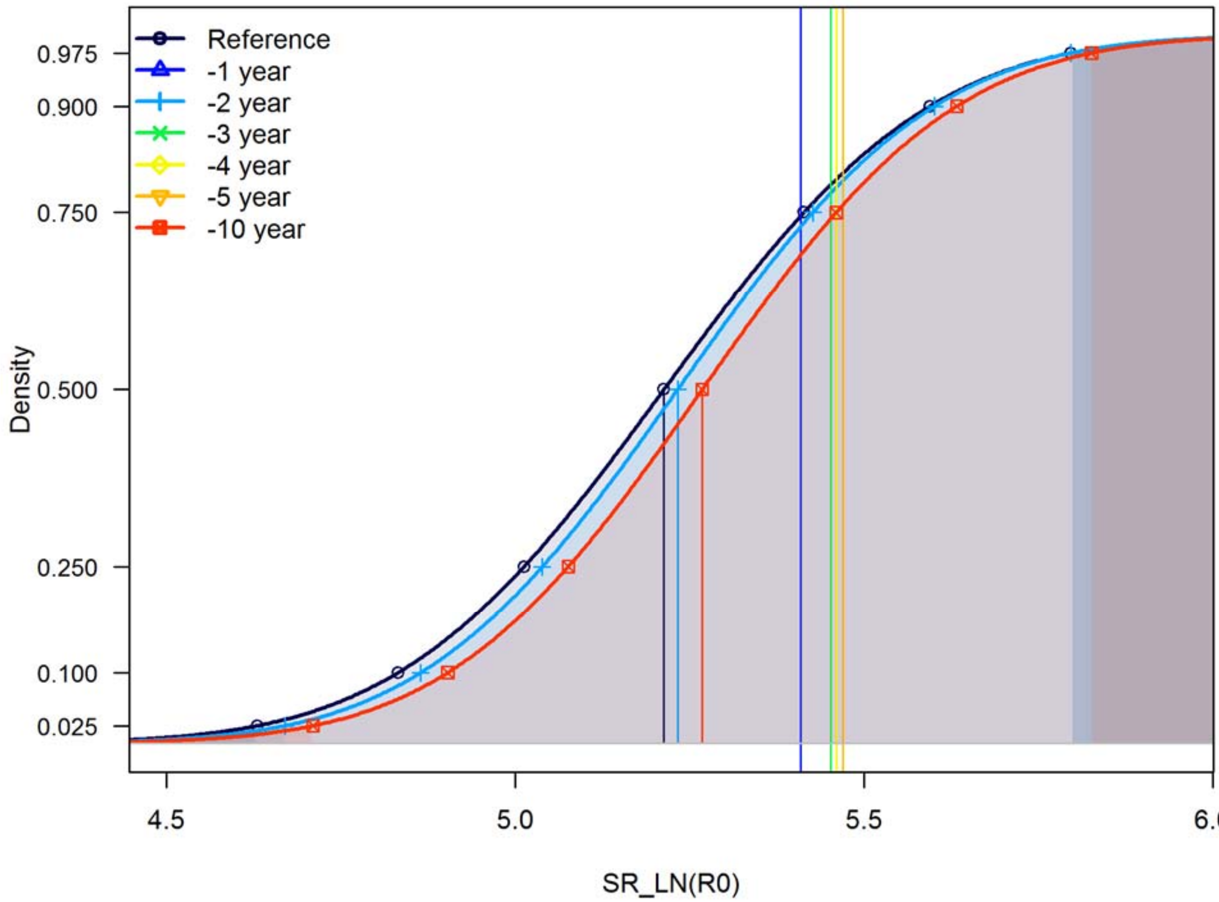


Figure 155. Estimated initial recruitment (*R_0*) from the retrospective analysis for the SCS model. Distribution is from the reference model and dark shaded ends indicate 95% asymptotic interval of the reference model.

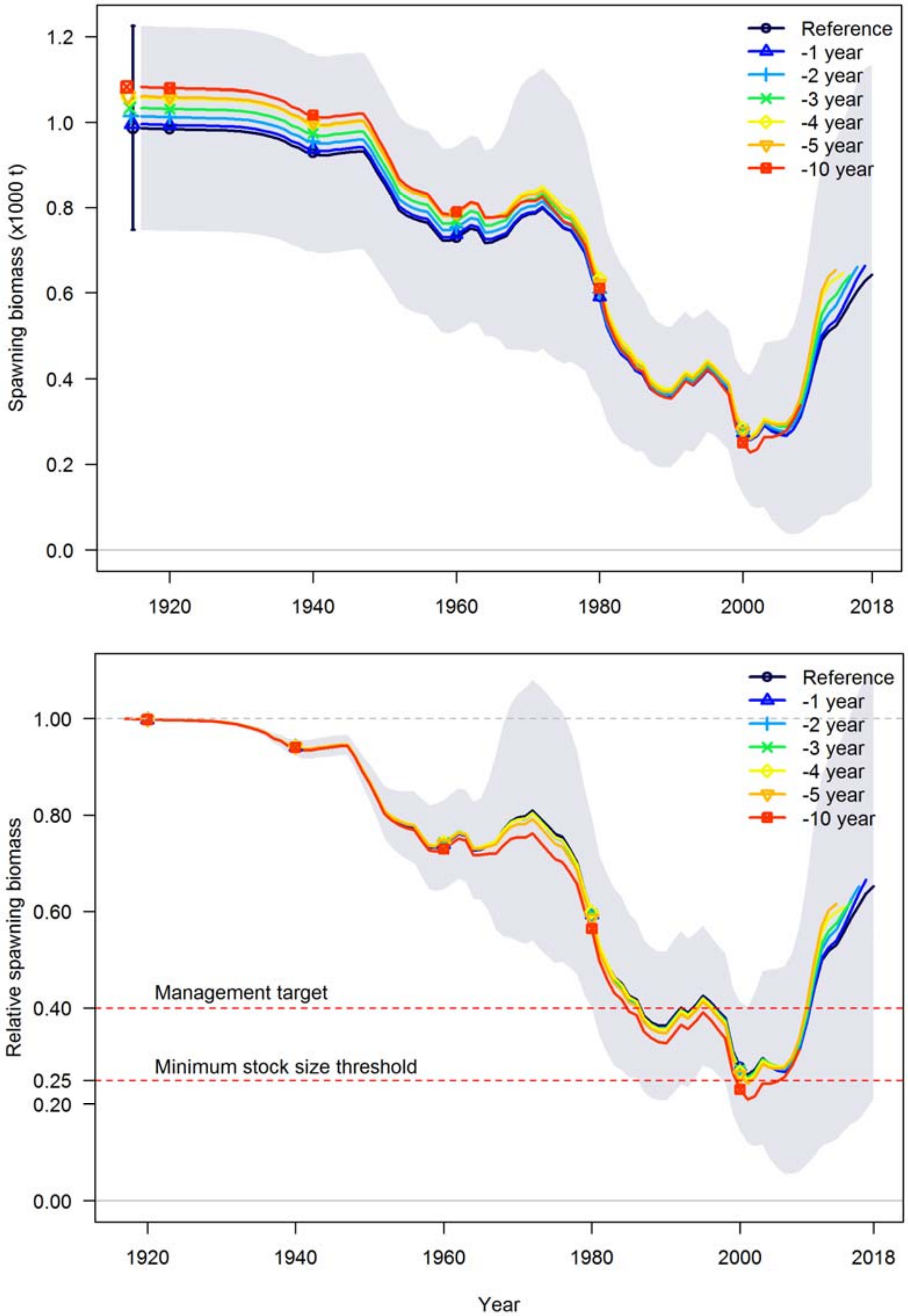


Figure 156. Spawning biomass (top panel) and relative spawning biomass (bottom panel) from the retrospective analysis for the NCS model. Gray shaded area indicates 95% asymptotic interval of the reference model.

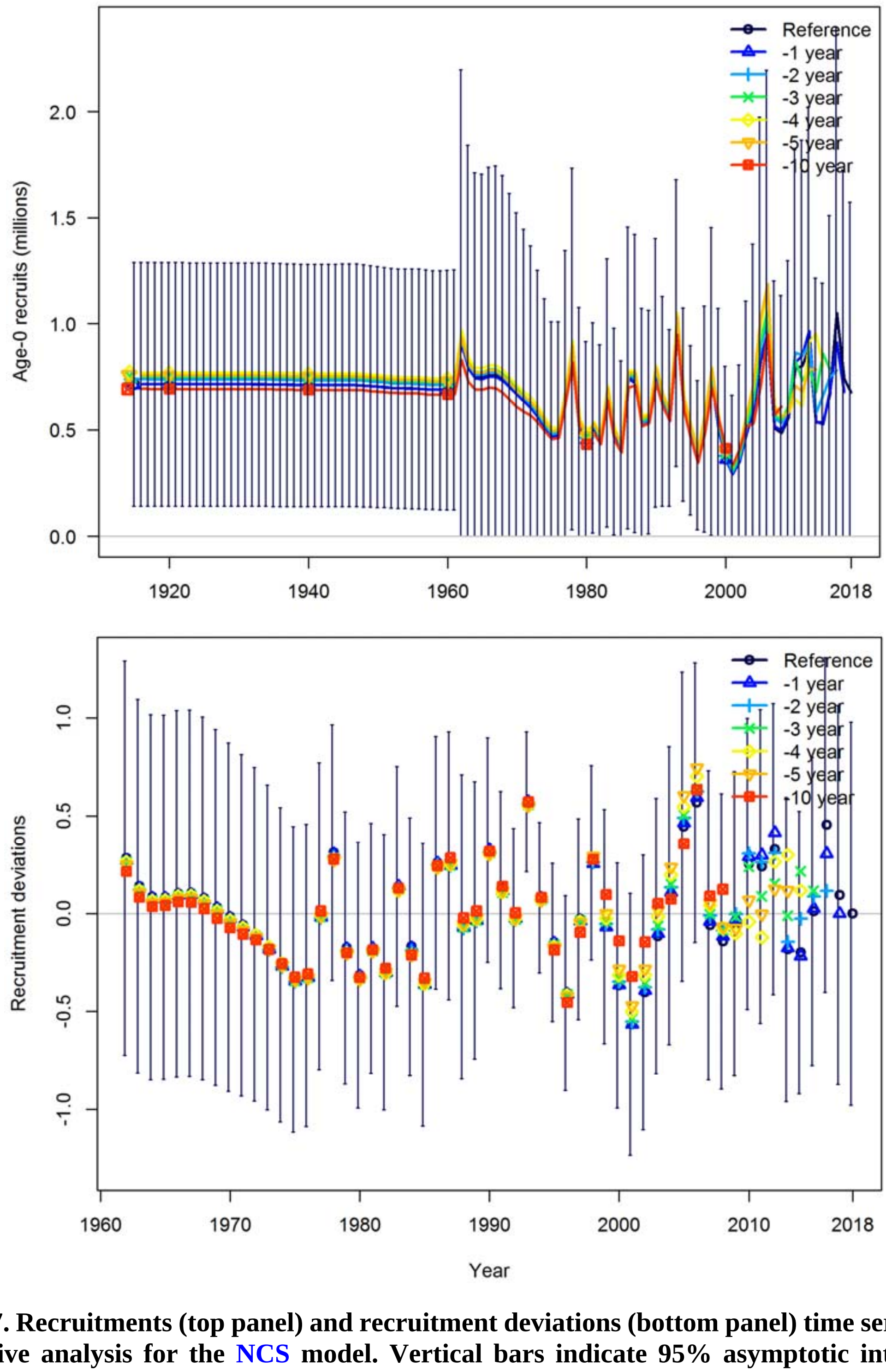


Figure 157. Recruitments (top panel) and recruitment deviations (bottom panel) time series from the retrospective analysis for the NCS model. Vertical bars indicate 95% asymptotic interval of the reference model.

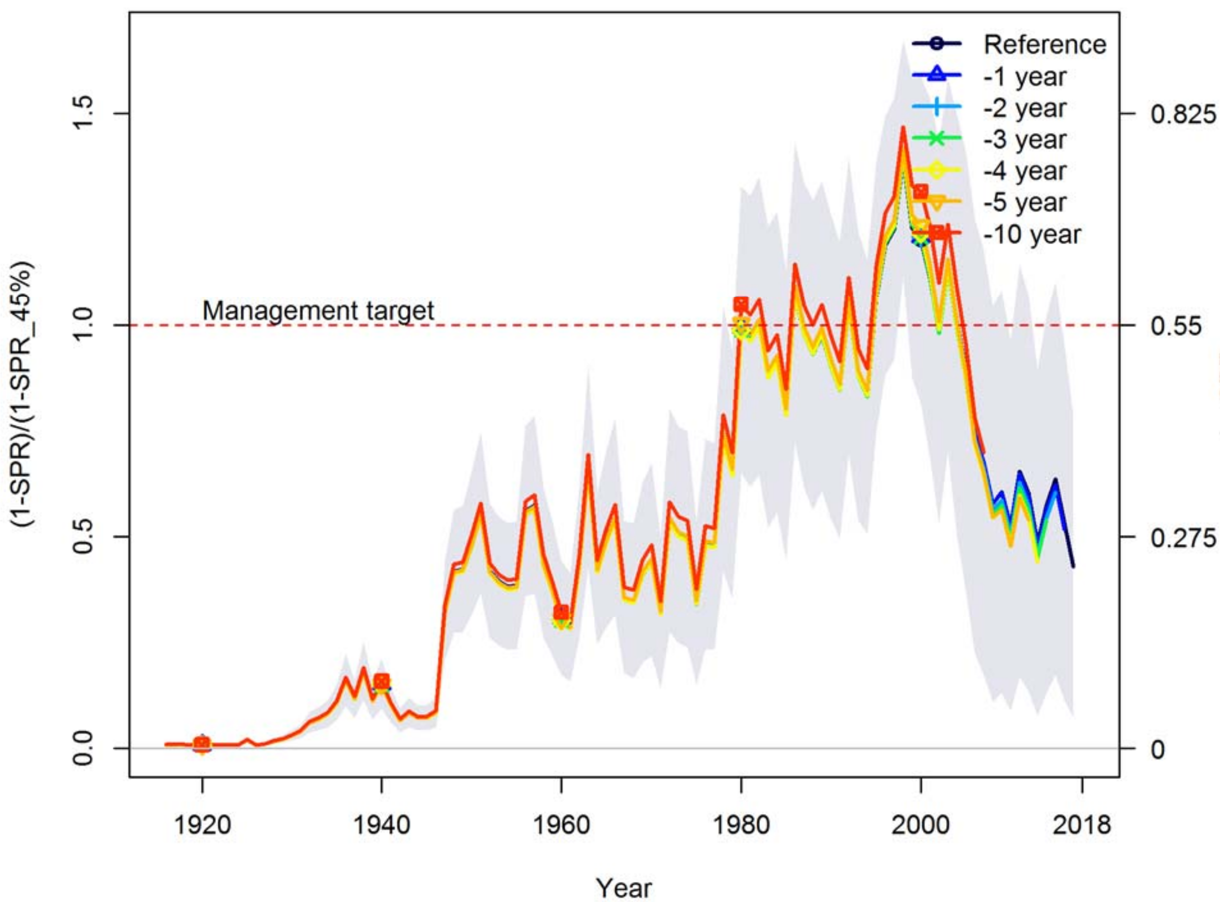


Figure 158. Fishing intensity time series from the retrospective analysis for the NCS model . Gray shaded area indicates 95% asymptotic interval of the reference model.

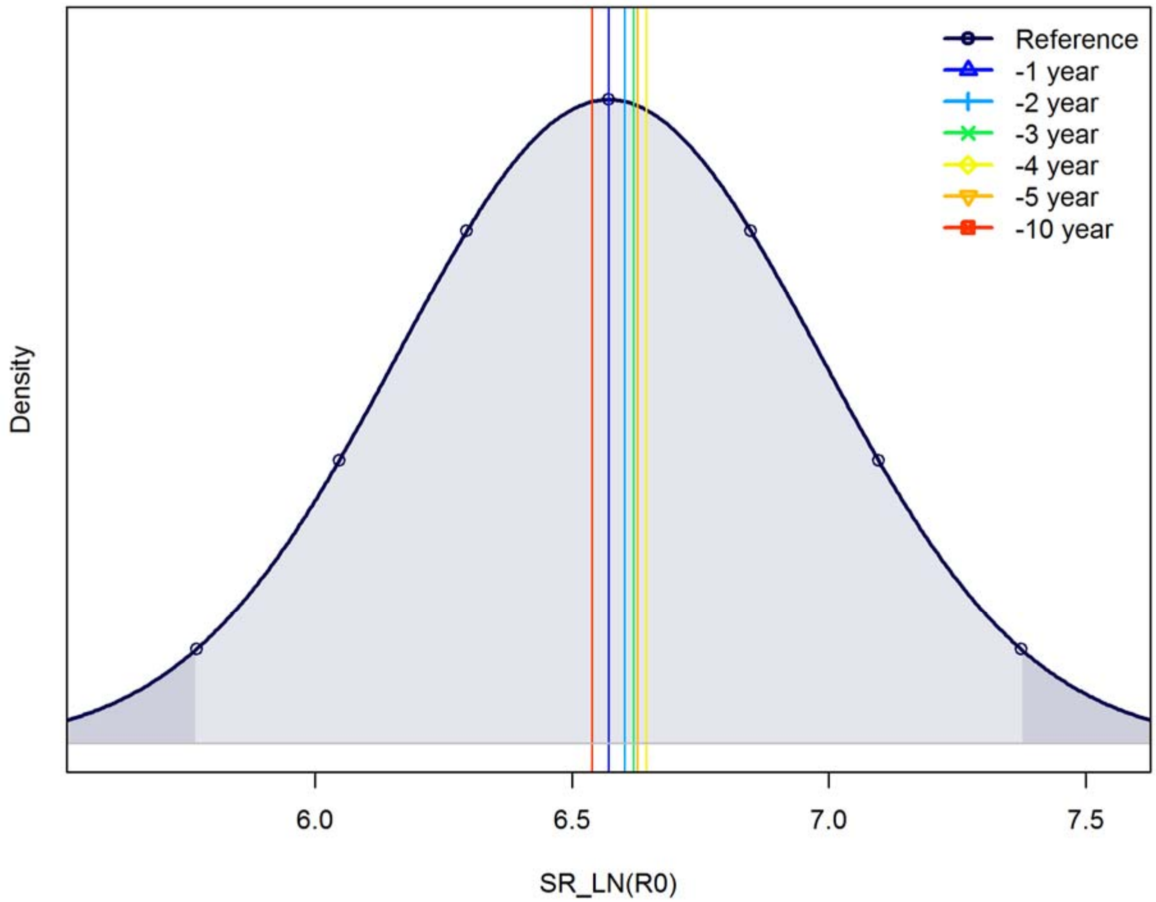


Figure 159. Estimated initial recruitment (*R_0*) from the retrospective analysis for the NCS model. Distribution is from the reference model and dark shaded ends indicate 95% asymptotic interval of the reference model.

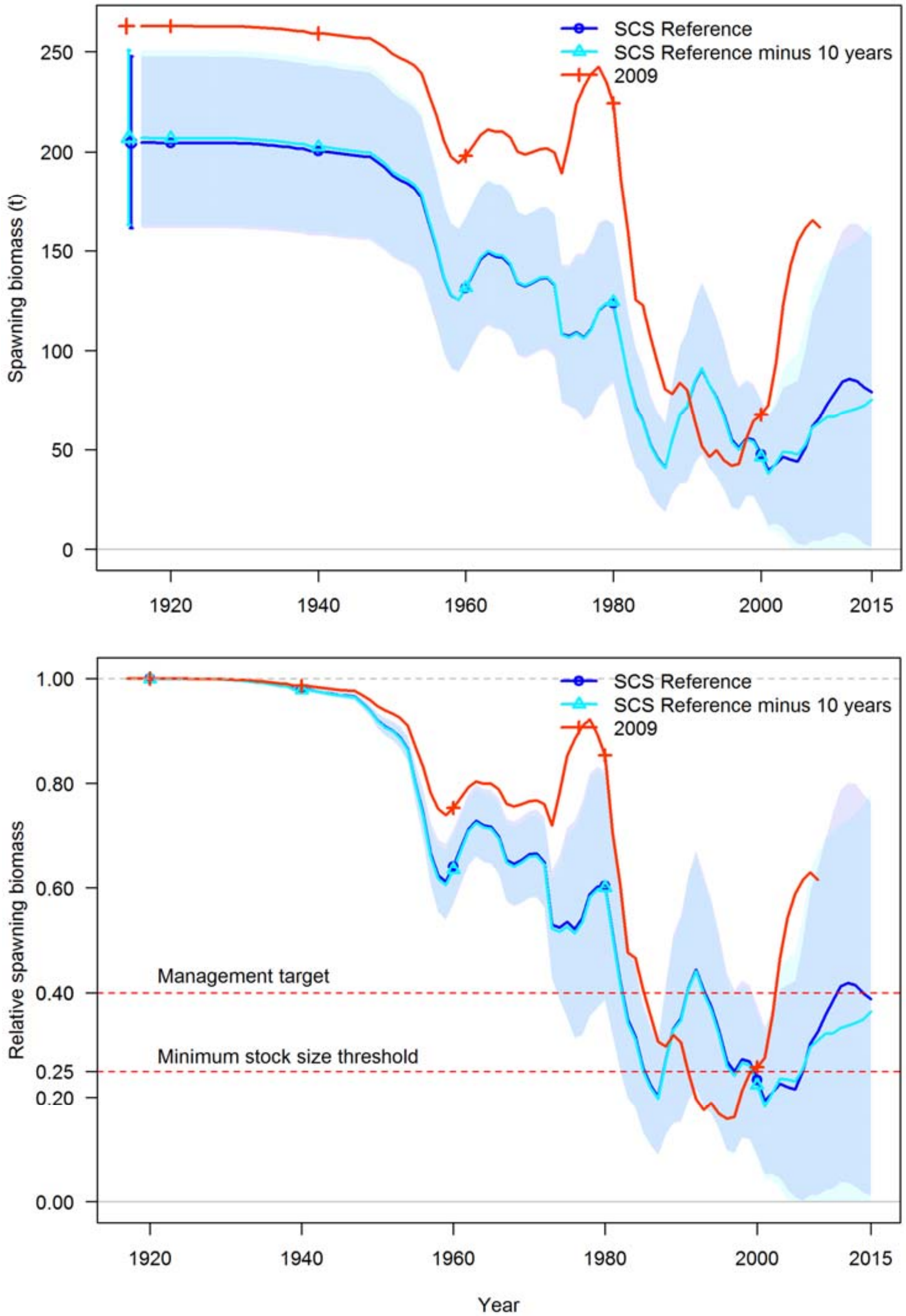


Figure 160. Comparisons of spawning biomass (top panel) and relative spawning biomass (bottom panel) among the current SCS reference model, current reference model minus 10 years (back to the data availability of the 2009 assessment), and the 2009 assessment.

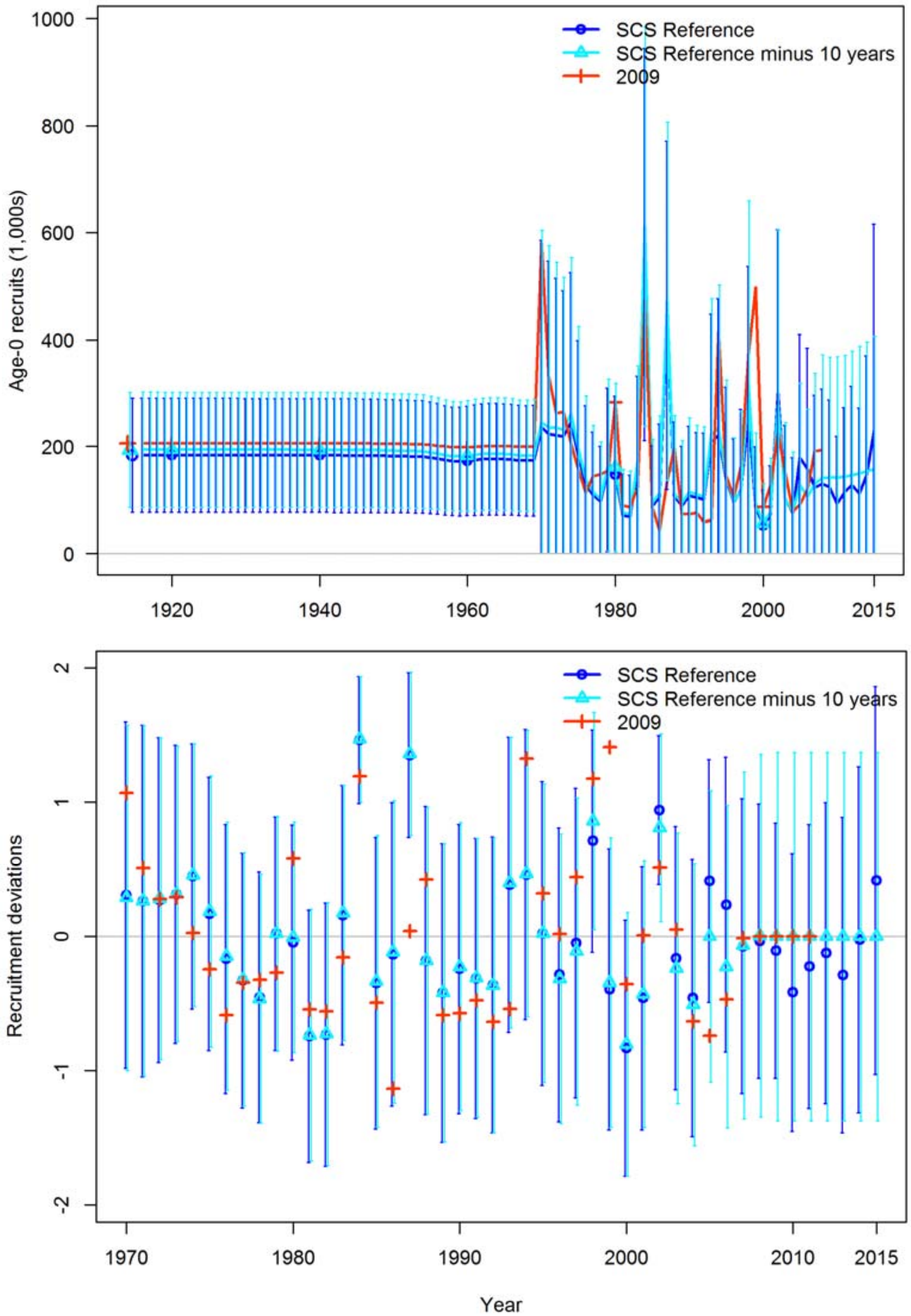


Figure 161. Comparisons of age-0 recruits (top panel) and recruitment deviations (bottom panel) among the current SCS reference model, current reference model minus 10 years (back to the data availability of the 2009 assessment), and the 2009 assessment.

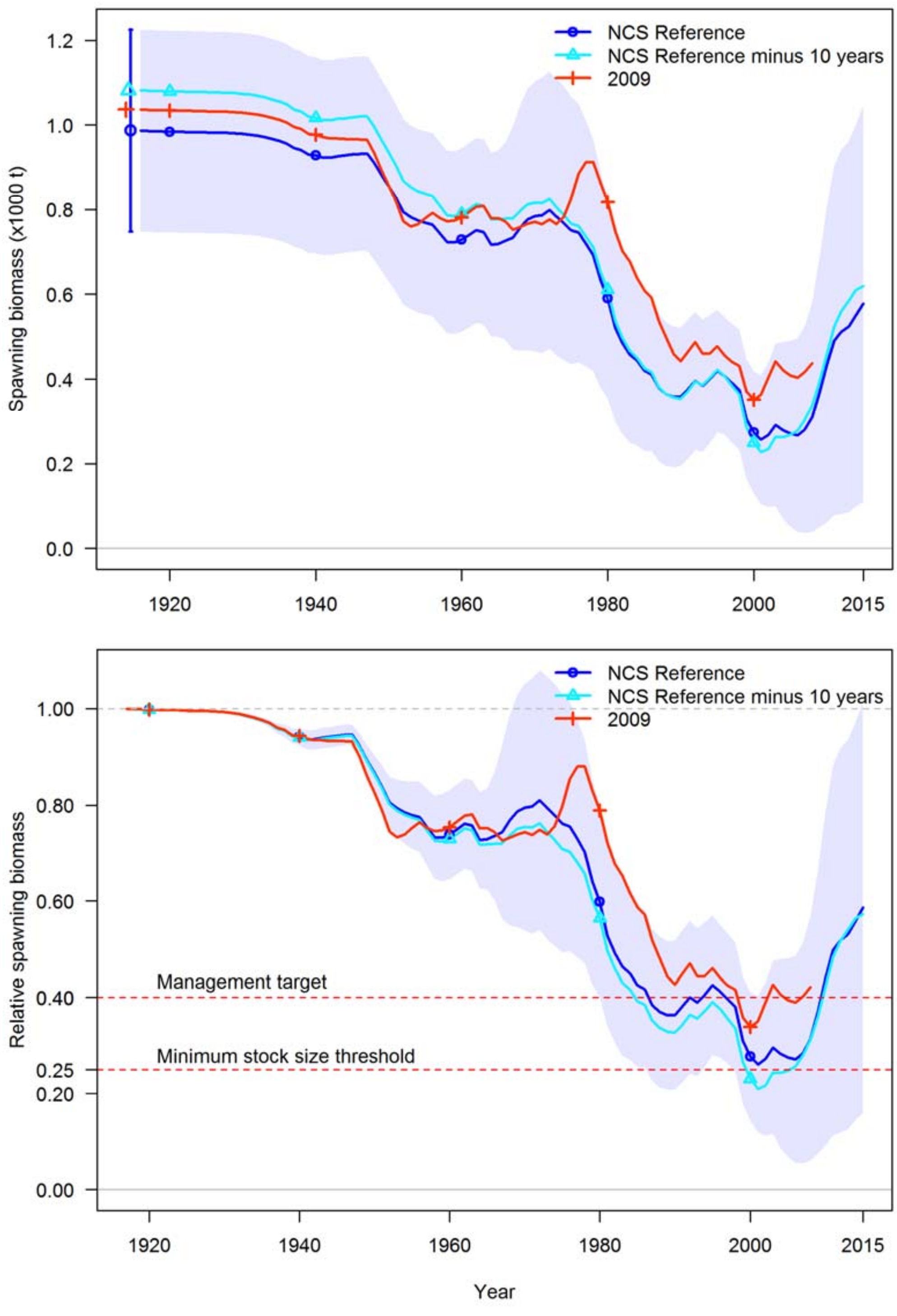


Figure 162. Comparisons of spawning biomass (top panel) and relative spawning biomass (bottom panel) among the current NCS reference model, current reference model minus 10 years (back to the data availability of the 2009 assessment), and the 2009 assessment.

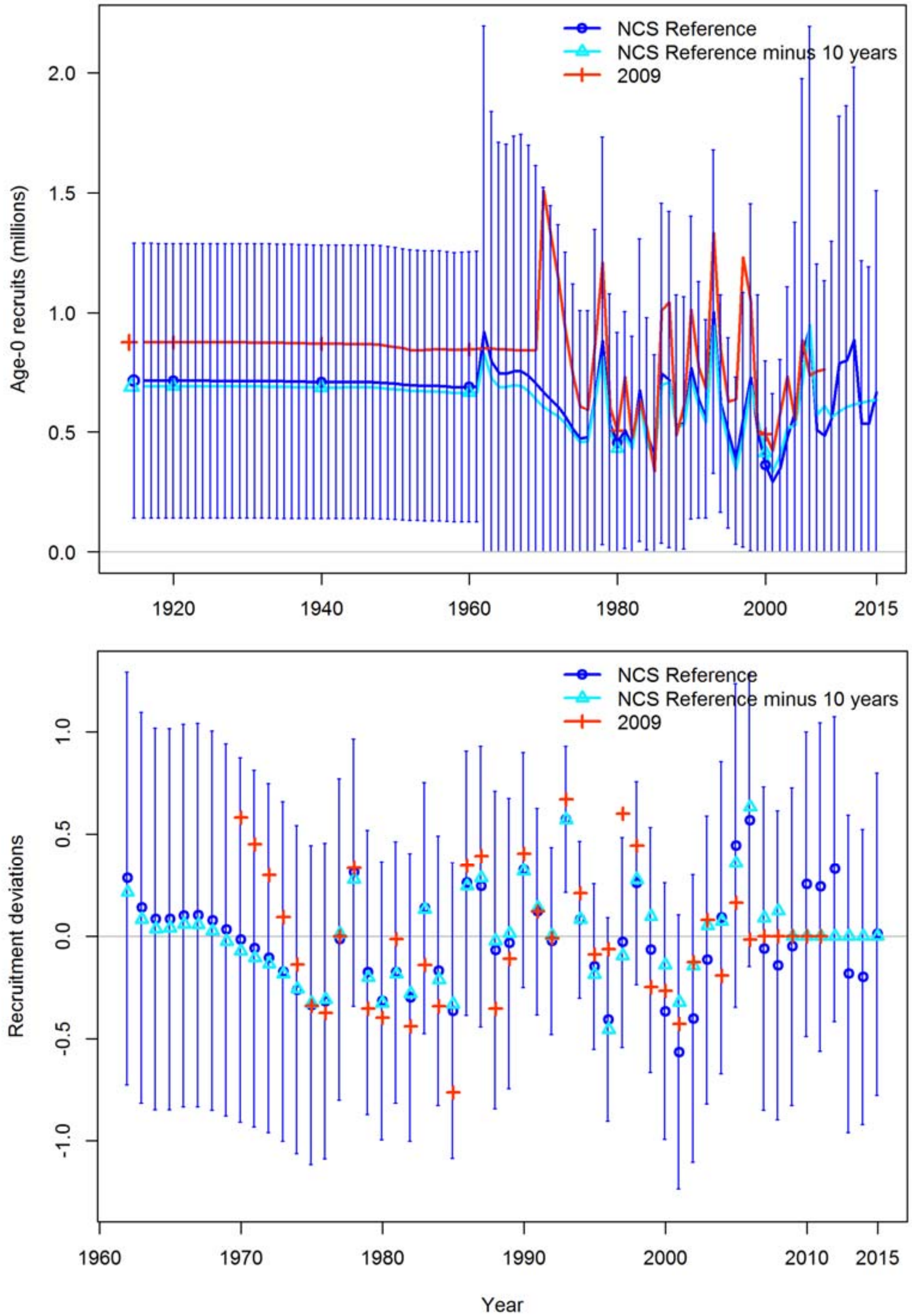


Figure 163. Comparisons of spawning biomass (top panel) and relative spawning biomass (bottom panel) among the current NCS reference model, current reference model minus 10 years (back to the data availability of the 2009 assessment), and the 2009 assessment.

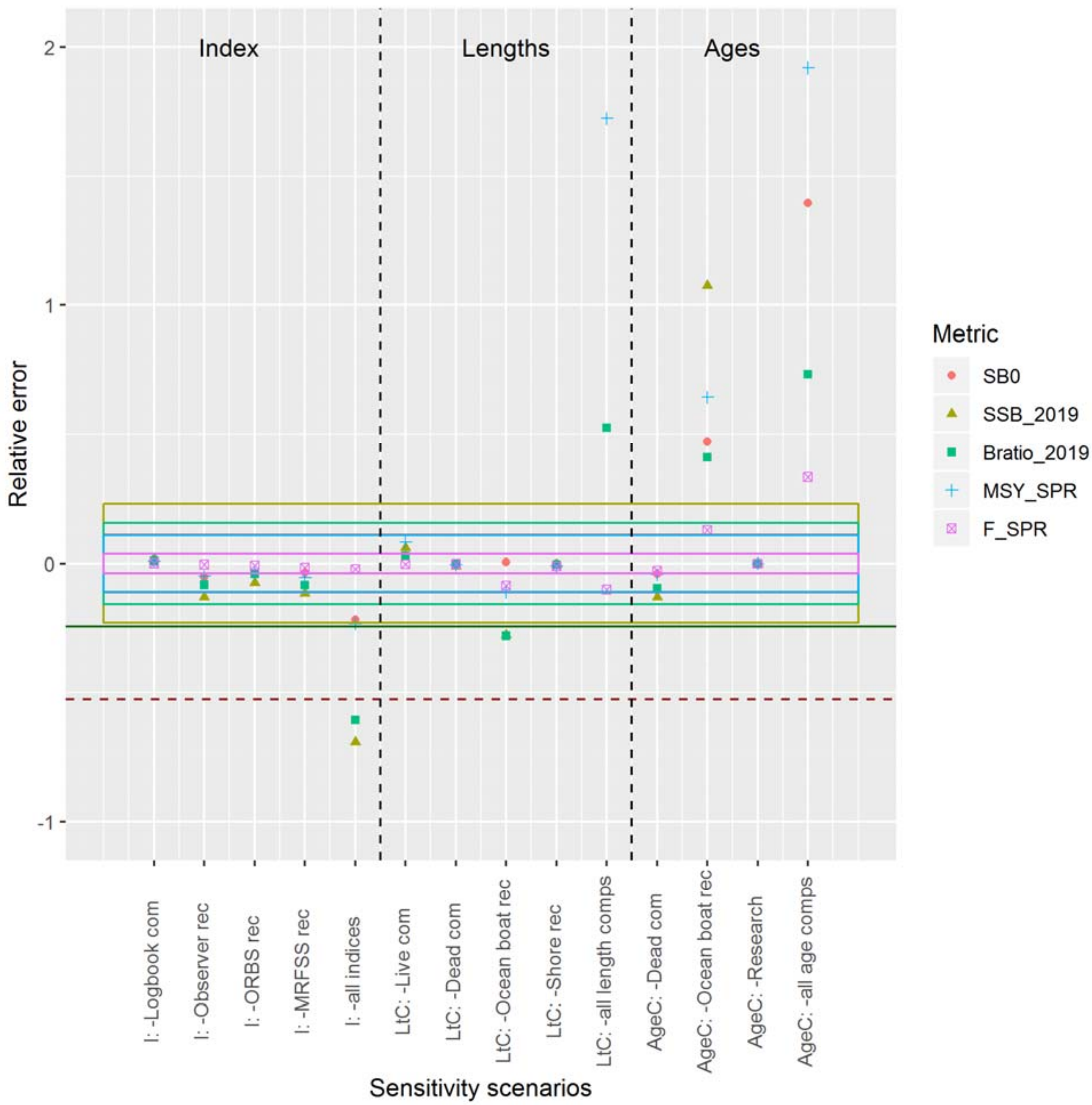


Figure 164. Differences between the Oregon Cabezon reference model and likelihood component sensitivity runs (relative error) for key derived parameters. Runs without (-) a particular data source are indicated on the x-axis. Rectangles show levels of uncertainty relative to the reference model. Symbols not shown have a relative error greater than 2.

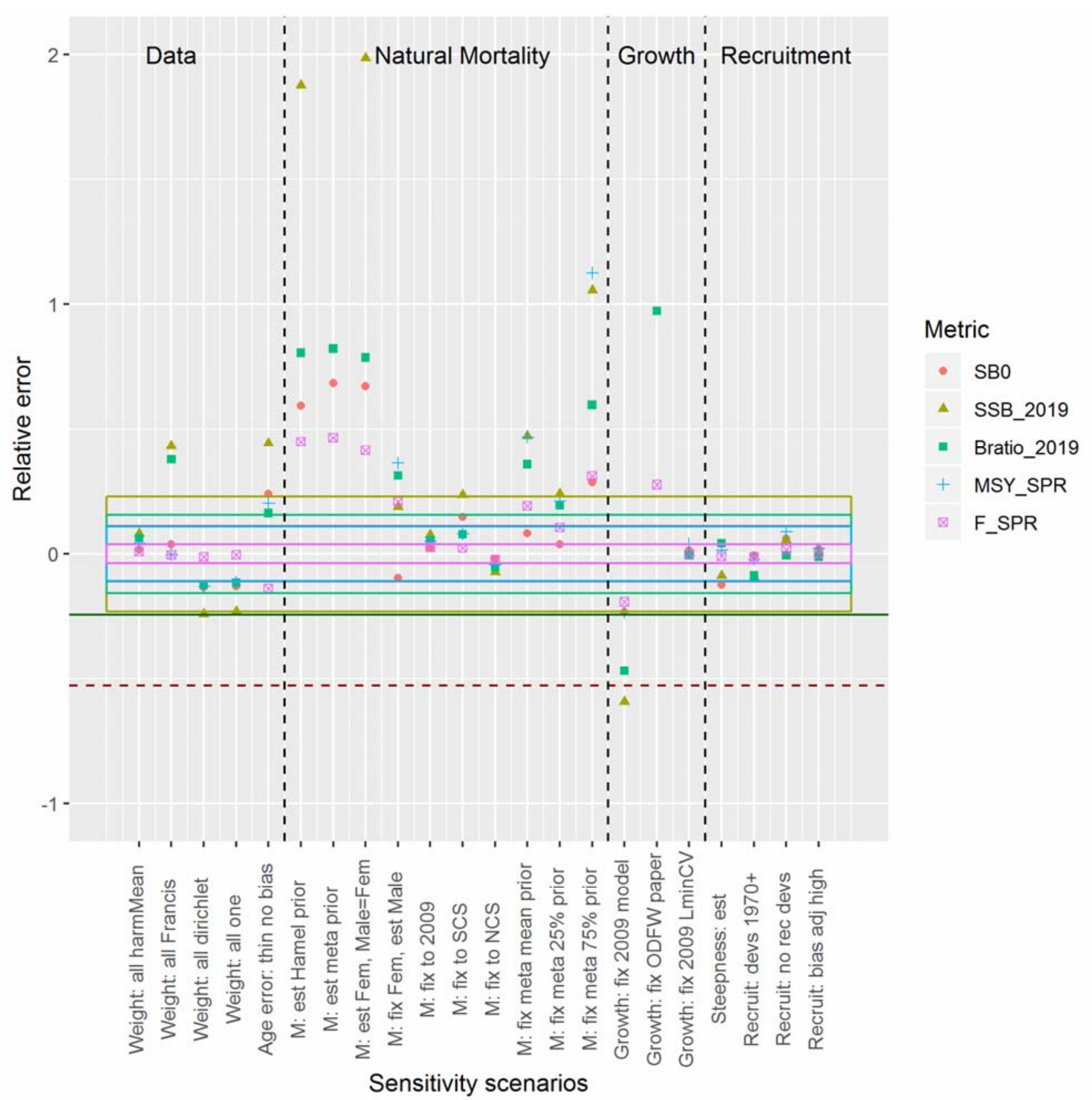


Figure 165. Differences between the Oregon Cabezon reference model and alternative structural modeling considerations specified by relative error for key derived parameters. Rectangles show levels of uncertainty relative to the reference model. Symbols not shown have a relative error greater than 2.

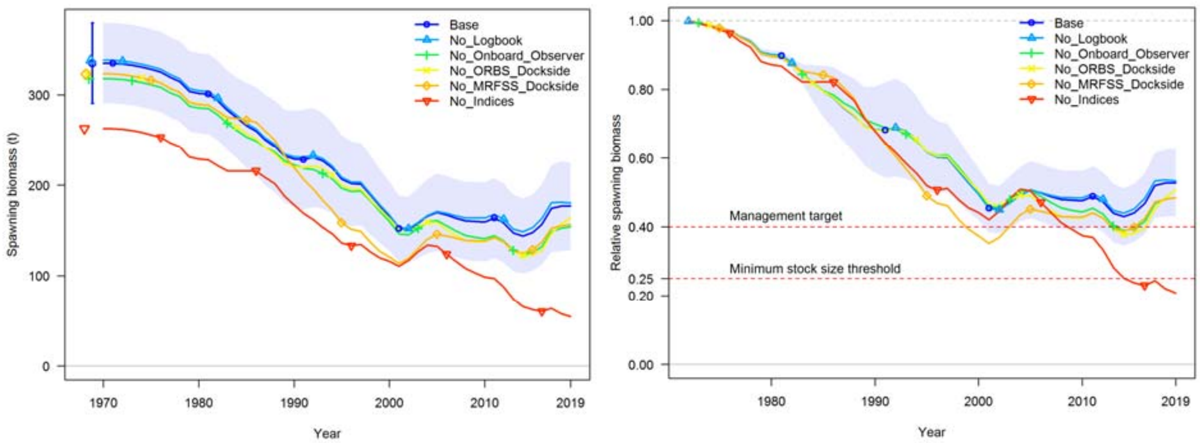


Figure 166. Comparison of spawning output (left) and depletion (right) trends for the Oregon reference (Base) model and alternative sensitivity model runs with indices removed.

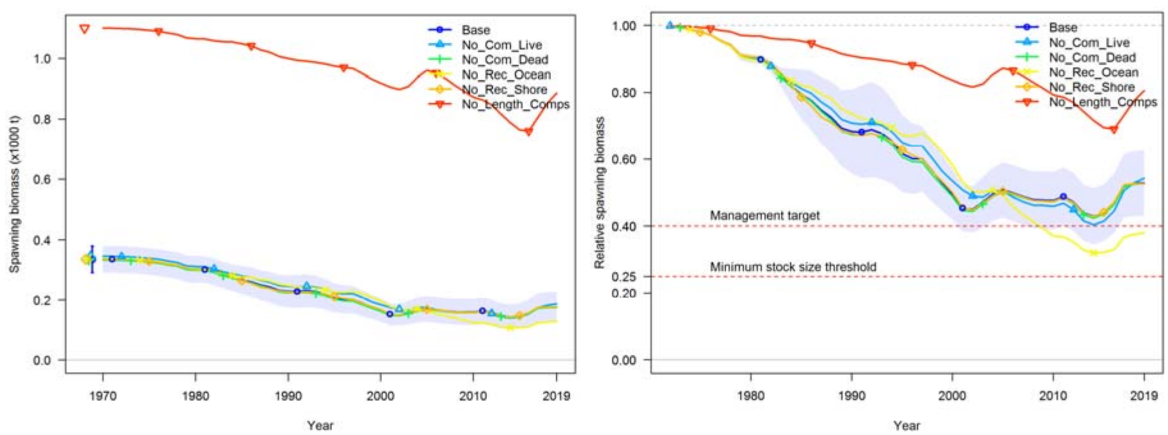


Figure 167. Comparison of spawning output (left) and depletion (right) trends for the Oregon reference (Base) model and alternative sensitivity model runs with length composition data sources removed.

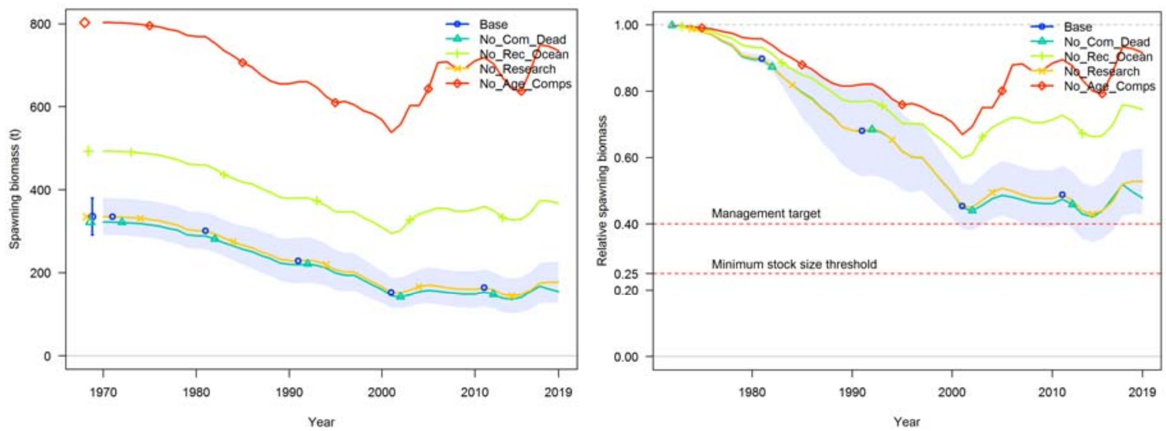


Figure 168. Comparison of spawning output (left) and depletion (right) trends for the Oregon reference (Base)model and alternative sensitivity model runs with age composition data sources removed.

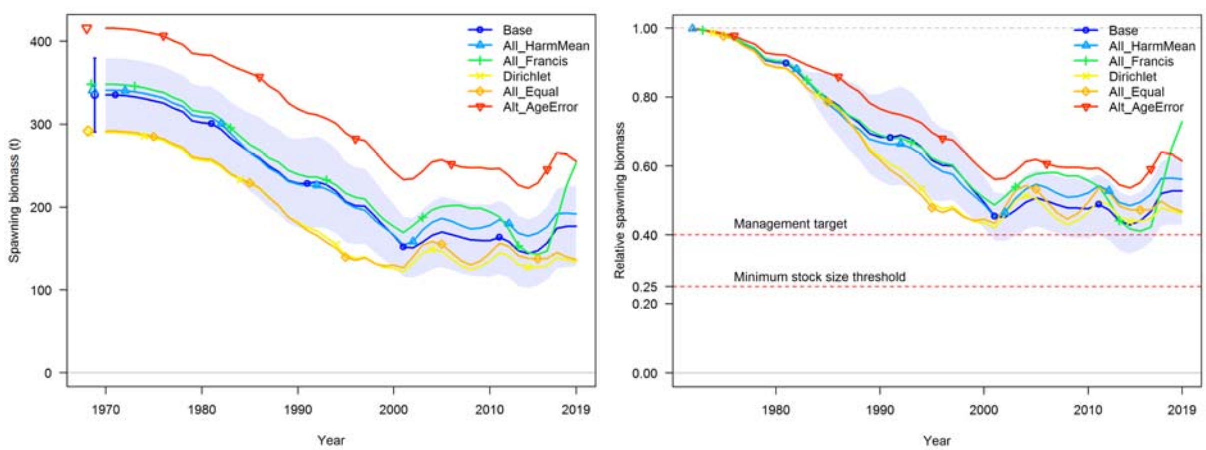


Figure 169. Comparison of spawning output (left) and depletion (right) trends for the Oregon reference (Base) model and sensitivity model runs with alternative approaches to data weighting, length composition expansions, and ageing error.

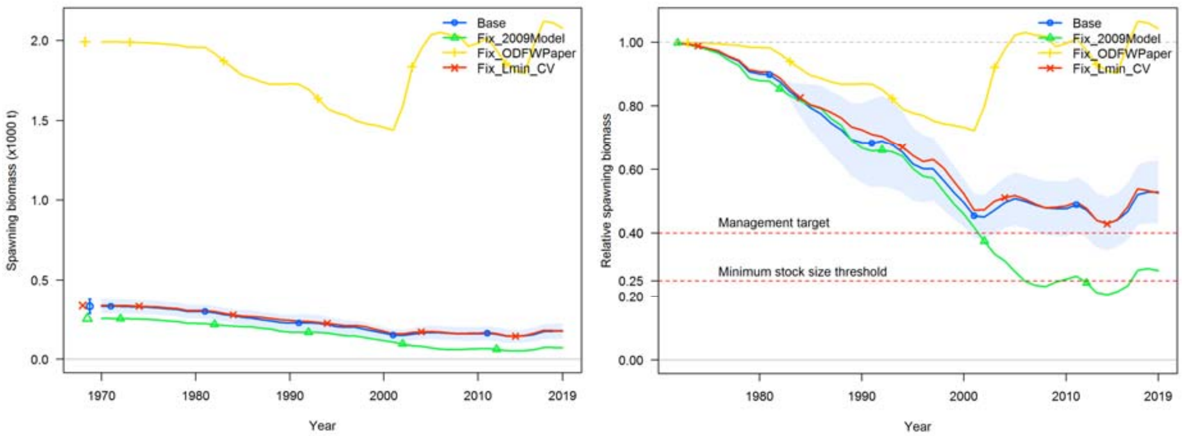


Figure 170. Comparison of spawning output (left) and depletion (right) trends for the Oregon reference (Base) model and sensitivity model runs with alternative approaches to modeling growth: fixing growth estimates to that in the last assessment (2009), to that in a recent Oregon Department of Fish and Wildlife paper (Rasmuson et al. 2019), and when reducing the variability around the length at age-0 (L_{min}_CV).

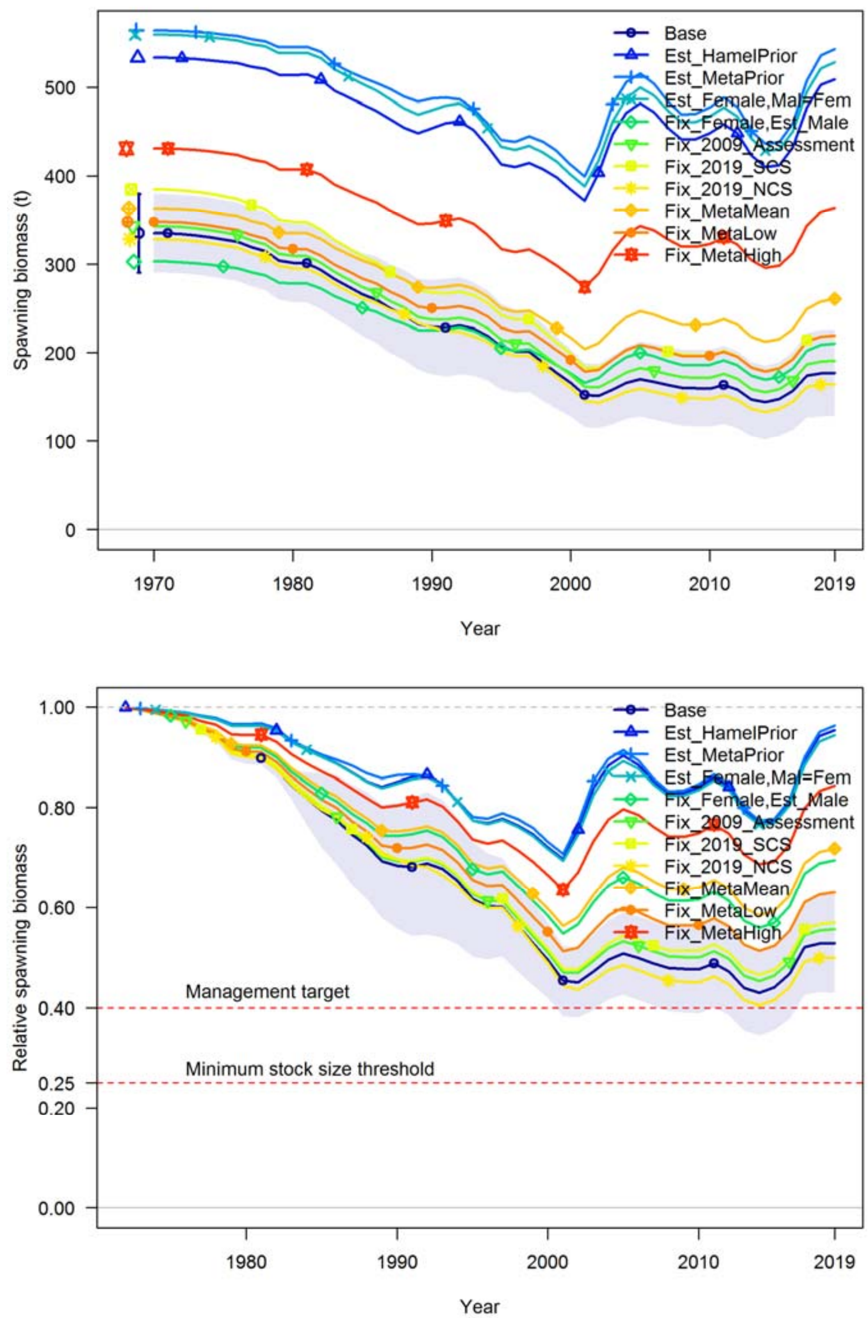


Figure 171. Comparison of spawning output (top) and depletion (bottom) trends for the Oregon reference (Base) model and sensitivity model runs with alternative approaches for estimating or fixing natural mortality including: estimating male and female using the Hamel prior or the meta-analysis prior; estimating gender invariant (Mal=Fem); and fixing it to the mean of the meta-analysis prior (MetaMean) as well as at low (25%; MetaLow) and high (75%; MetaHigh) quantiles of the prior distribution.

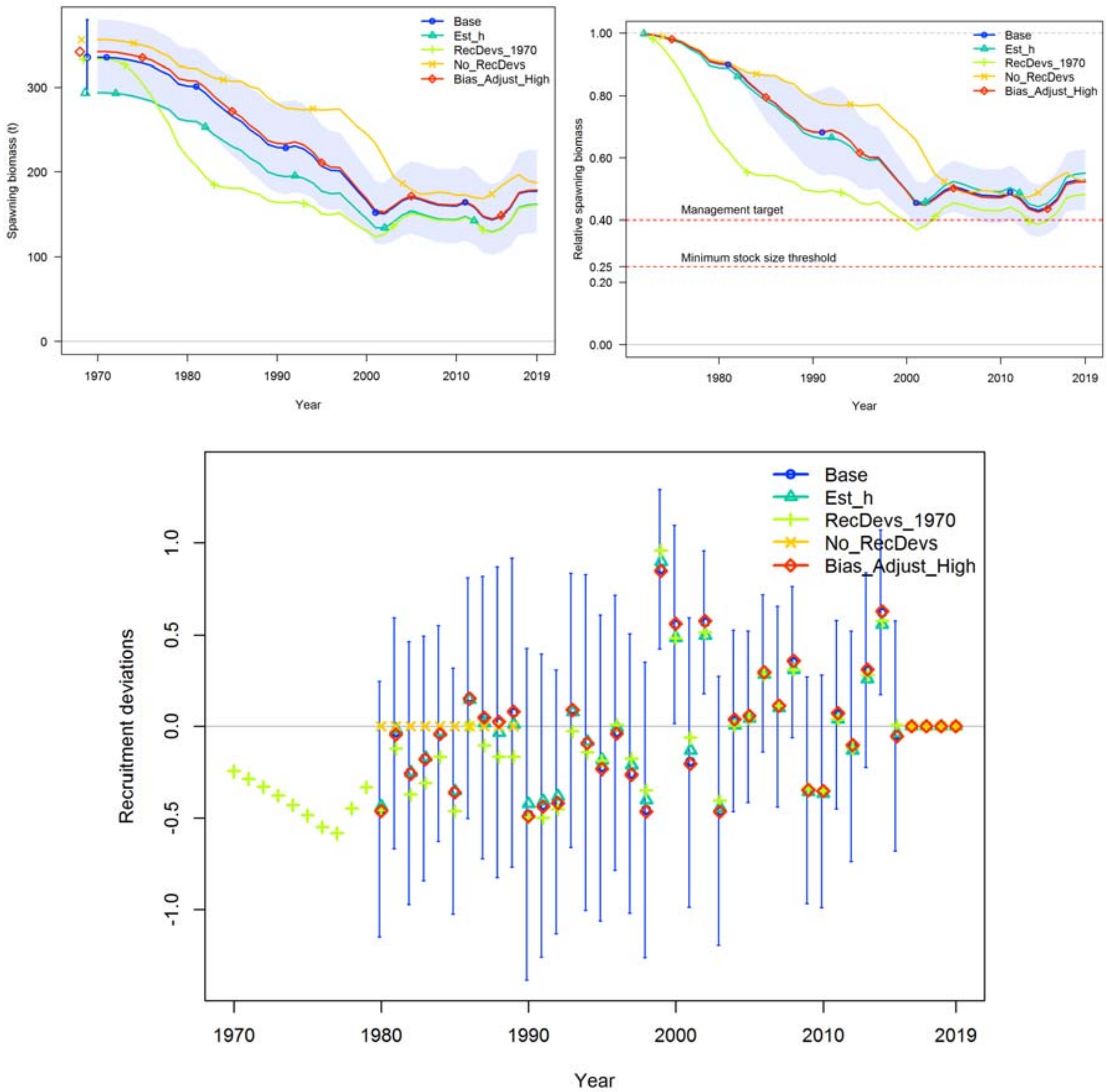


Figure 172. Comparison of spawning output (top left), depletion (top right), and recruitment (bottom) trends for the Oregon reference (Base) model and sensitivity model runs with alternative approaches for estimating recruitment, including: estimating steepness (*h*); extending the recruitment deviate estimation period back to 1970; not estimating any recruitment deviates; and increasing the recruitment deviation bias adjustment factor.

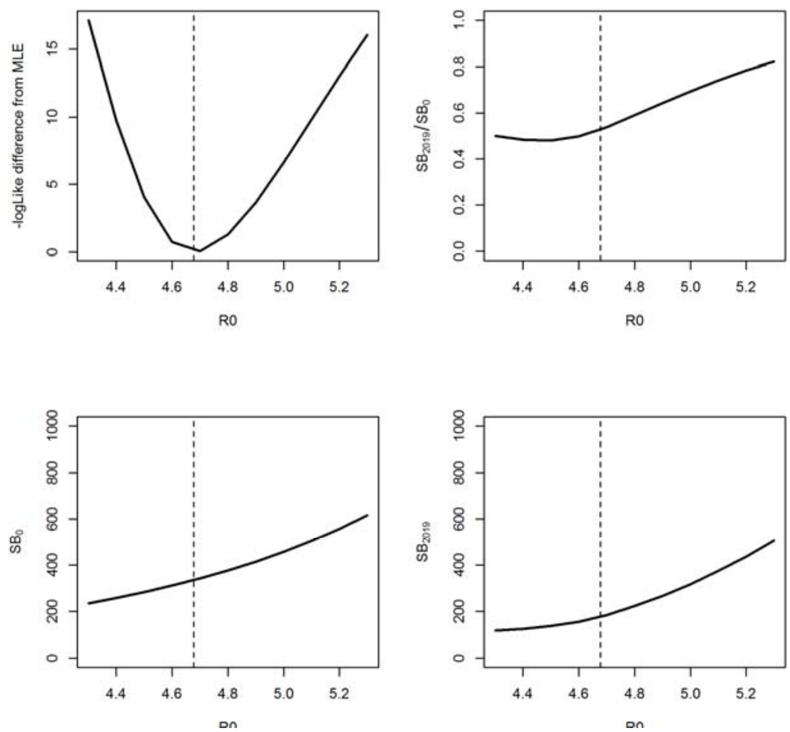


Figure 173. Likelihood profile for initial equilibrium recruitment (ln(R_0)) and resultant derived quantities for the Oregon reference model.

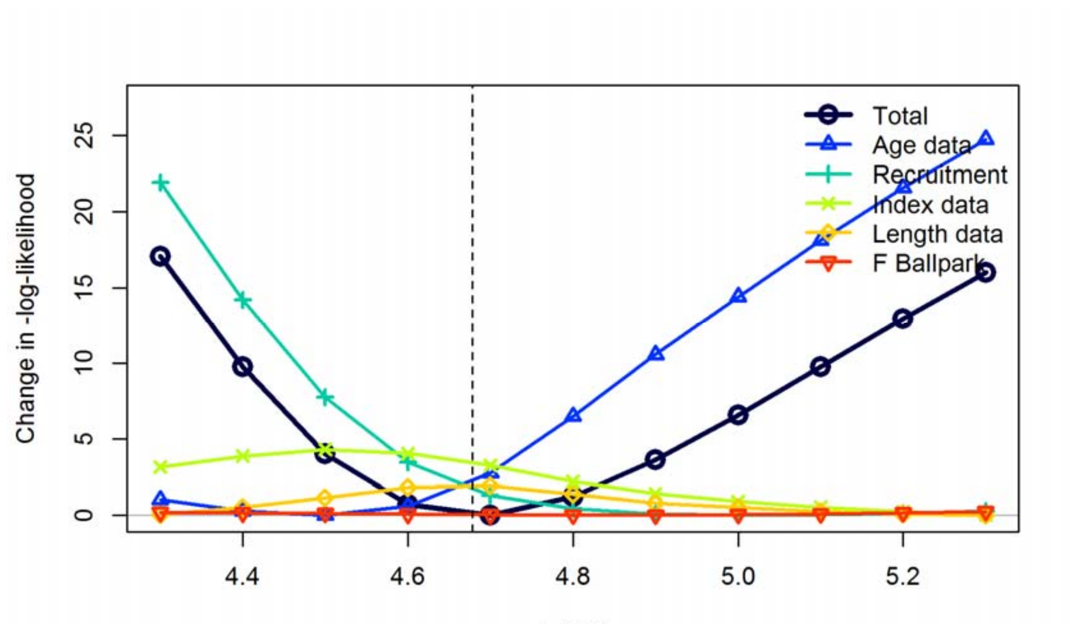


Figure 174. Likelihood profile across data sources for initial equilibrium recruitment (ln(R_0)) for the Oregon reference model.

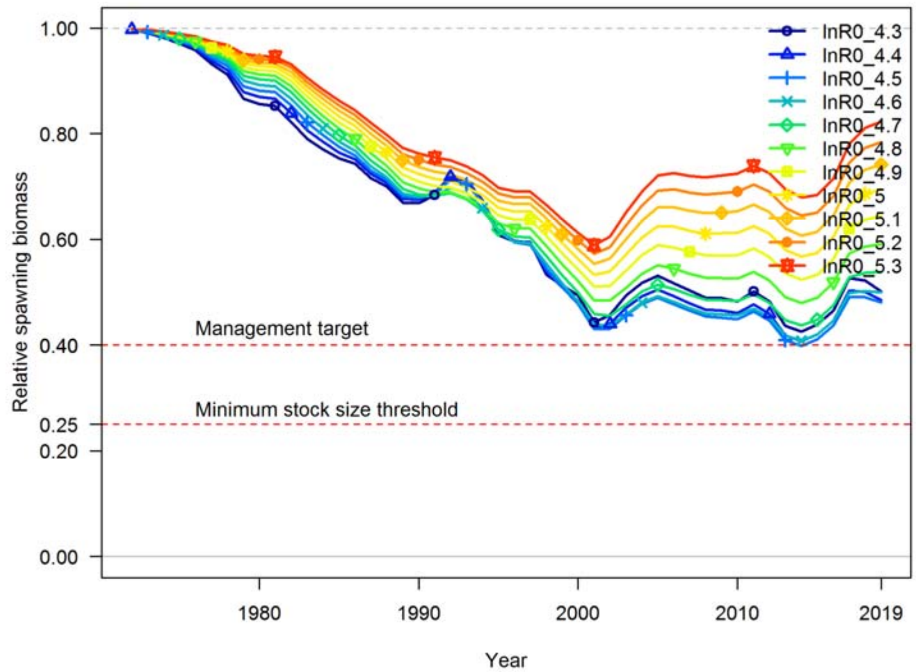


Figure 175. Comparison of the depletion time series across initial equilibrium recruitment (ln(R_0)) values used in likelihood profiles (range = 4.3 – 6.3) for the Oregon reference model.

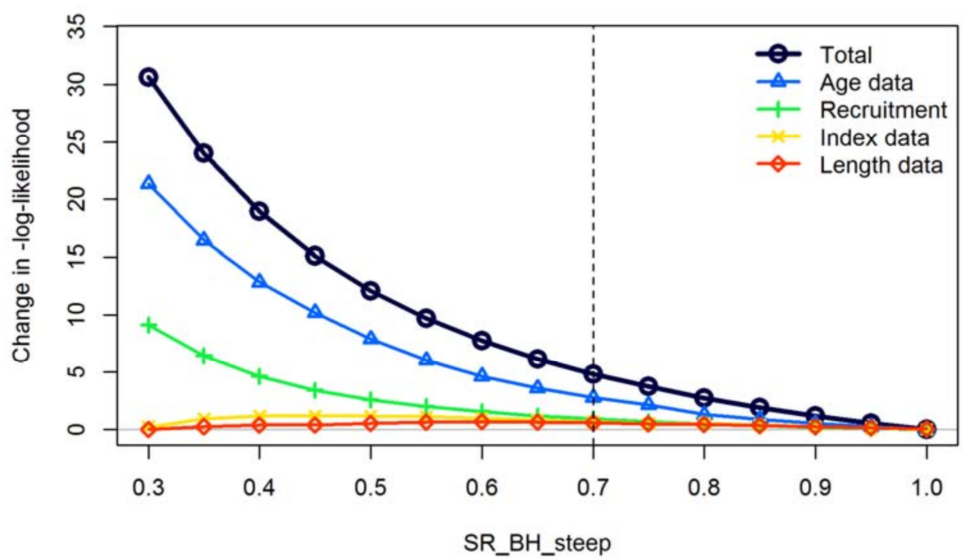


Figure 176. Likelihood profile across data sources for steepness (*h*) for the Oregon reference model.

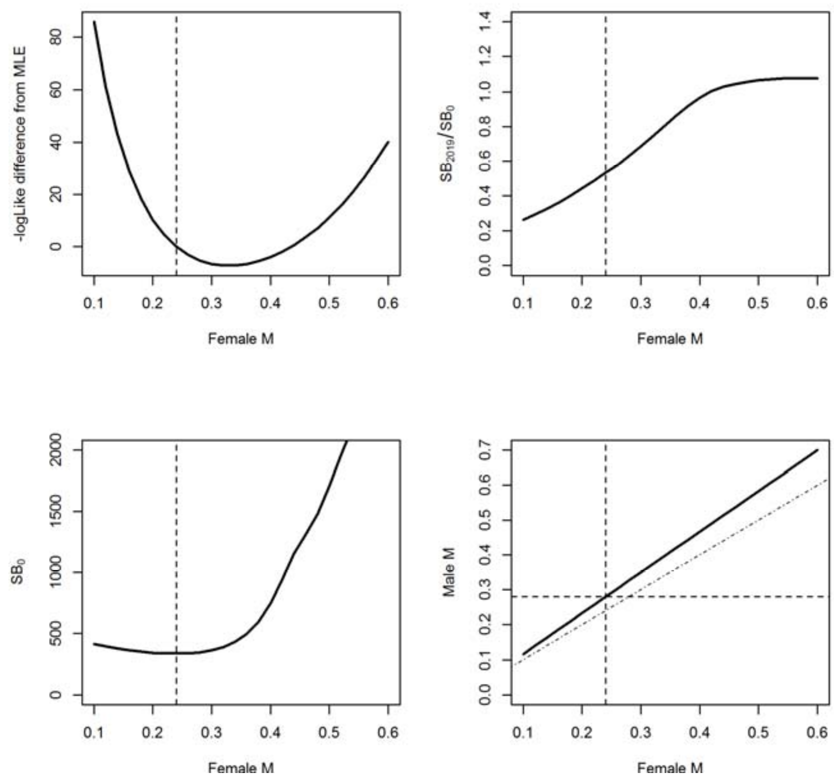


Figure 177. Likelihood profile for female natural mortality (for the case when the male natural mortality offset is estimated) and resultant derived quantities. Female and male natural mortality were fixed in the Oregon reference model.

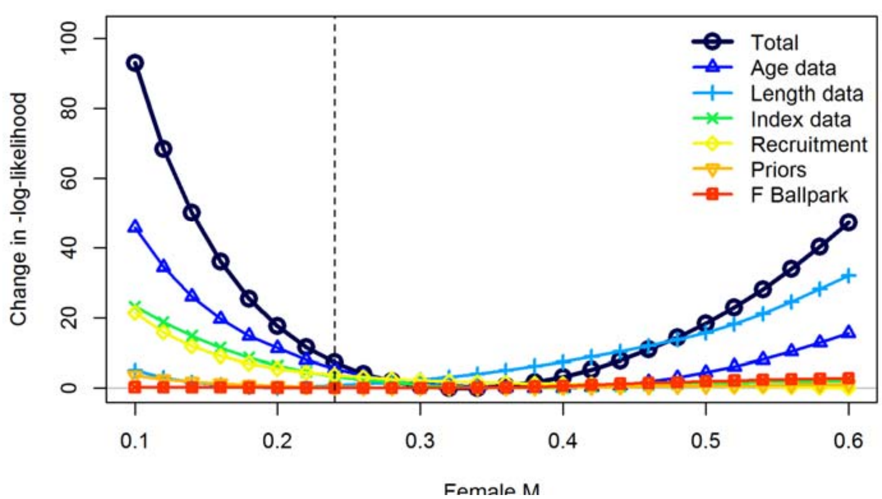


Figure 178. Likelihood profile across data sources for female natural mortality (estimated male natural mortality offset). Female and male natural mortality were fixed in the Oregon reference model.

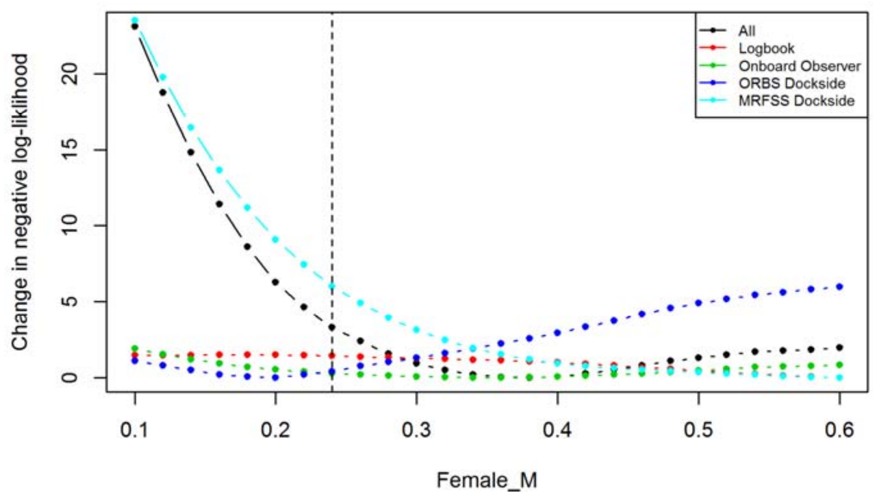


Figure 179. Likelihood profile across specific indices for female natural mortality (estimated male natural mortality offset). Female and male natural mortality were fixed in the Oregon reference model.

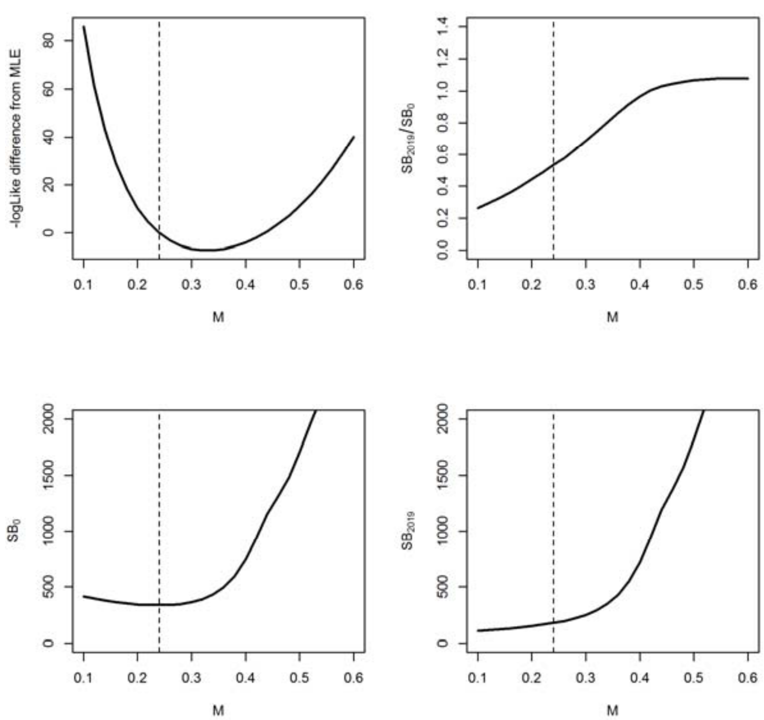


Figure 180. Likelihood profile for female natural mortality (for the case when the male natural mortality offset is fixed equal to female) and resultant derived quantities. Female and male natural mortality were fixed in the Oregon base model.

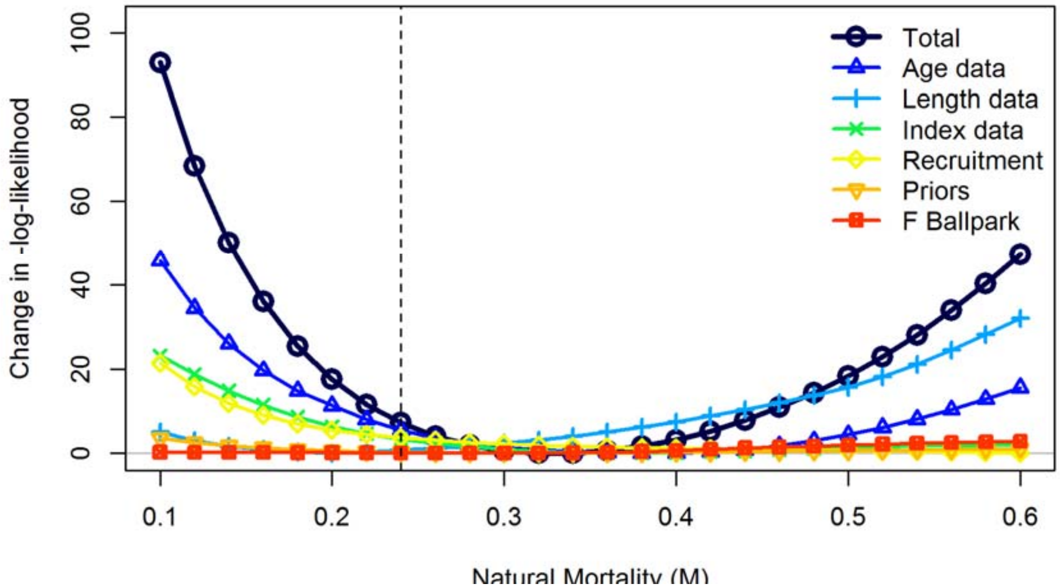


Figure 181. Likelihood profile across data sources for female natural mortality (fixed male natural mortality equal to female). Female and male natural mortality were fixed in the Oregon reference model.

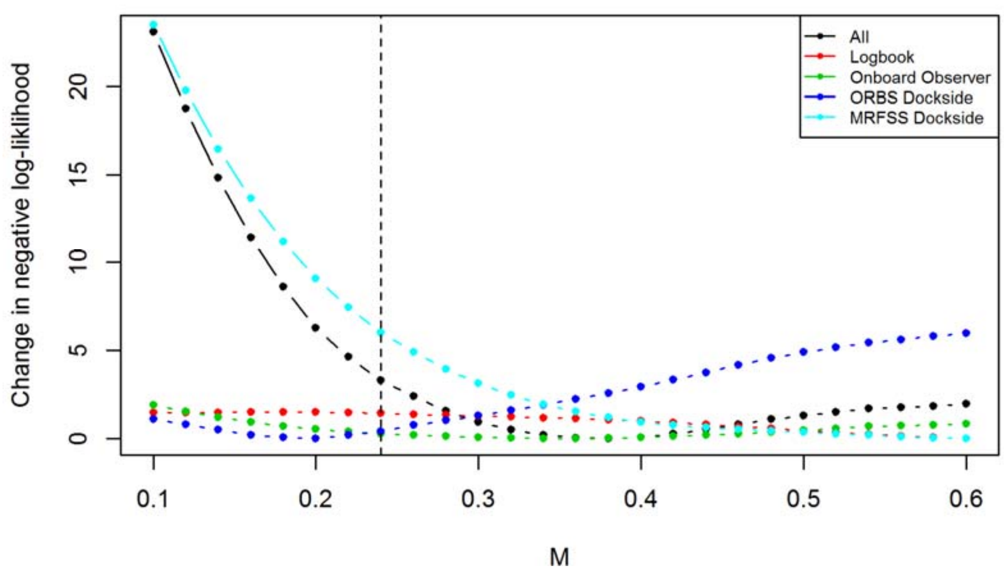


Figure 182. Likelihood profile across specific indices for female natural mortality (fixed male natural mortality equal to female). Female and male natural mortality were fixed in the Oregon reference model.

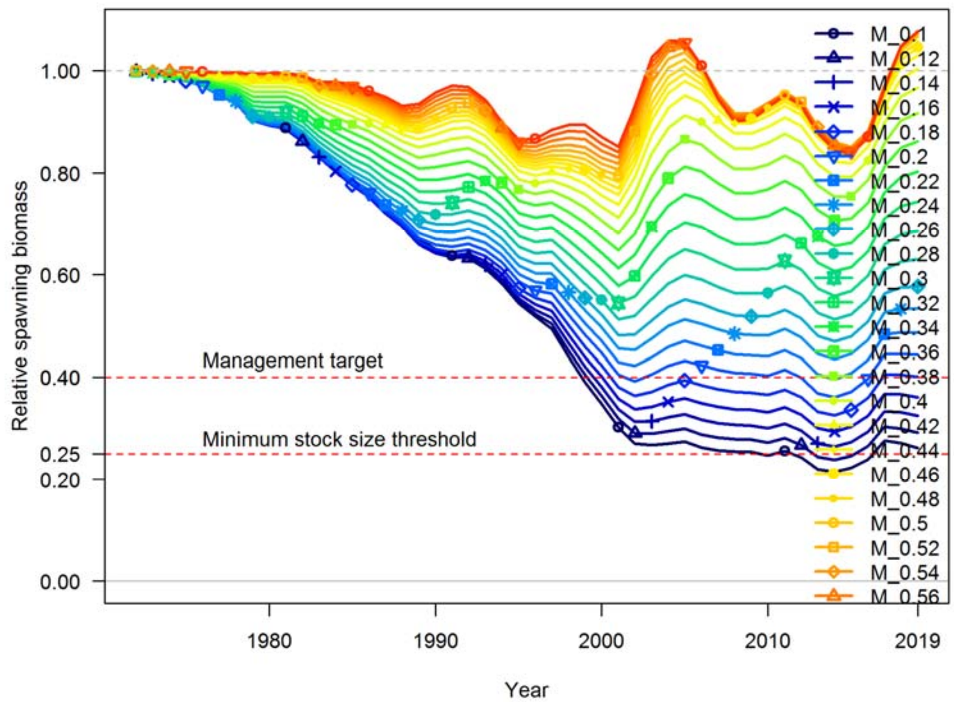


Figure 183. Comparison of the depletion time series across alternative female natural mortality values (male natural mortality equal to female) used in likelihood profiles (range = 0.2 – 0.6) for the Oregon base model.

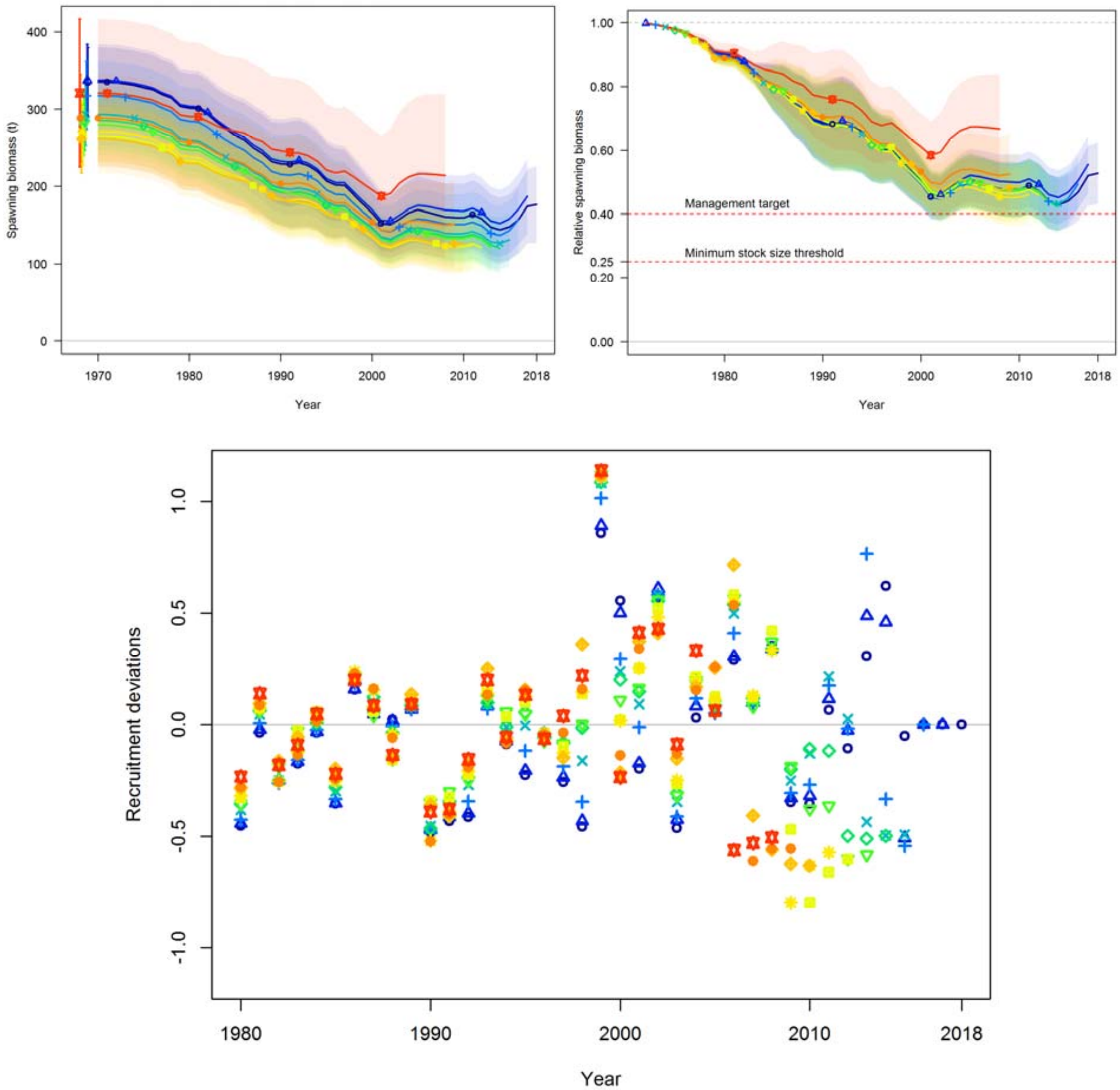


Figure 184. Retrospective model runs (present, darkest line, to -10 years, red line) for the reference model relative to Oregon Cabezon spawning output (top left), depletion (top right), and recruitment deviations (bottom). Shaded regions are approximate 95% confidence interval for the reference model.

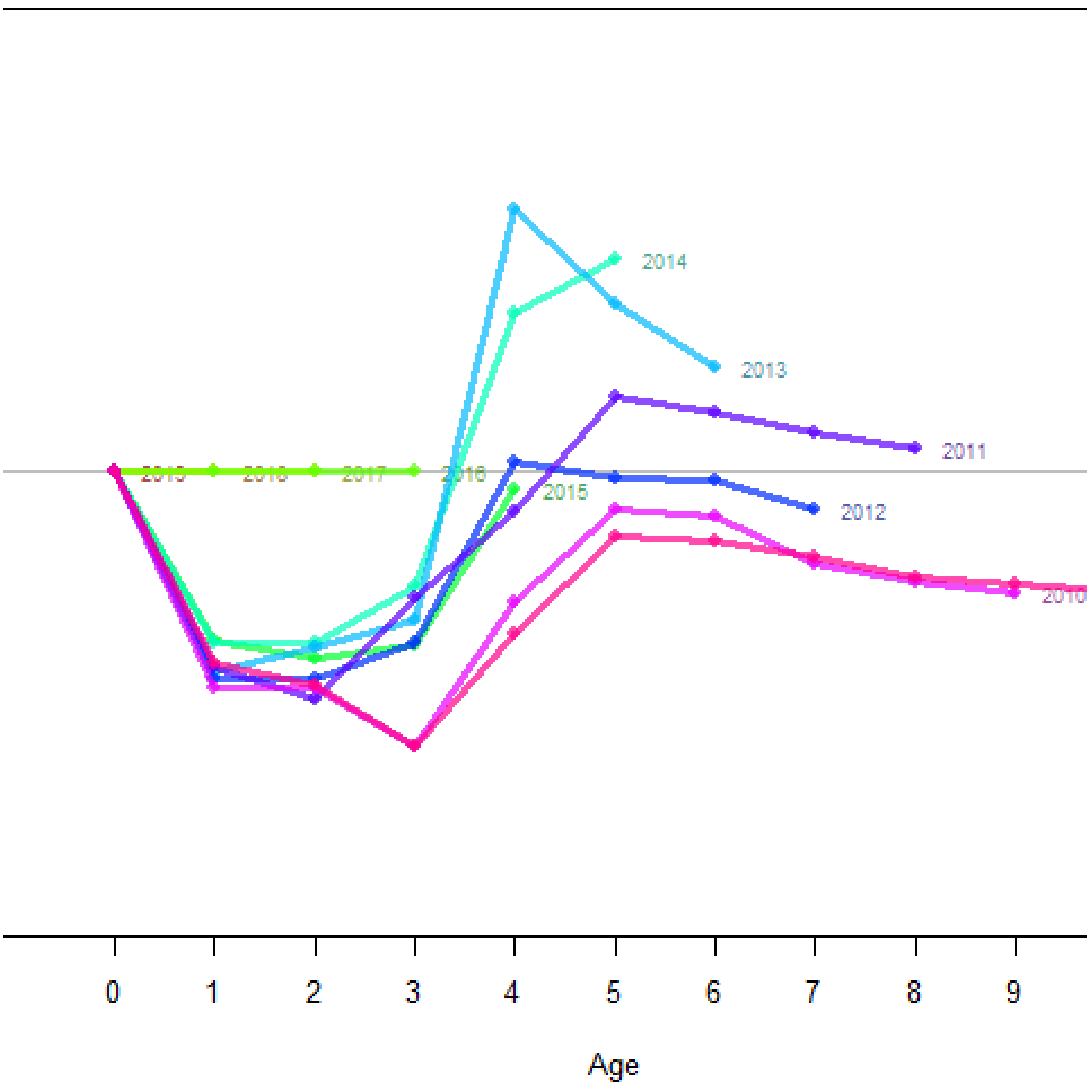


Figure 185. Retrospective analysis of recruitment deviations from the Oregon reference model over the last 10 years. Recruitment deviations are the log-scale differences between recruitment estimated by the model and expected recruitment from the spawner-recruit relationship. Lines represent estimated recruitment deviations for cohorts from 2009 to 2019, with cohort birth year marked at the right of each color-coded line. Values are estimated by models using data available only up to the year in which each cohort was a given age. There is no information in the data to estimate recruitment deviations prior to age-4, which is why the reference model sets recruitment according to the stock-recruitment curve during recent years (2016-2019; i.e., recruitment deviation = 0). Thus, retrospective recruitment deviation estimates, as shown in this figure, are only informative for ages greater than 3.

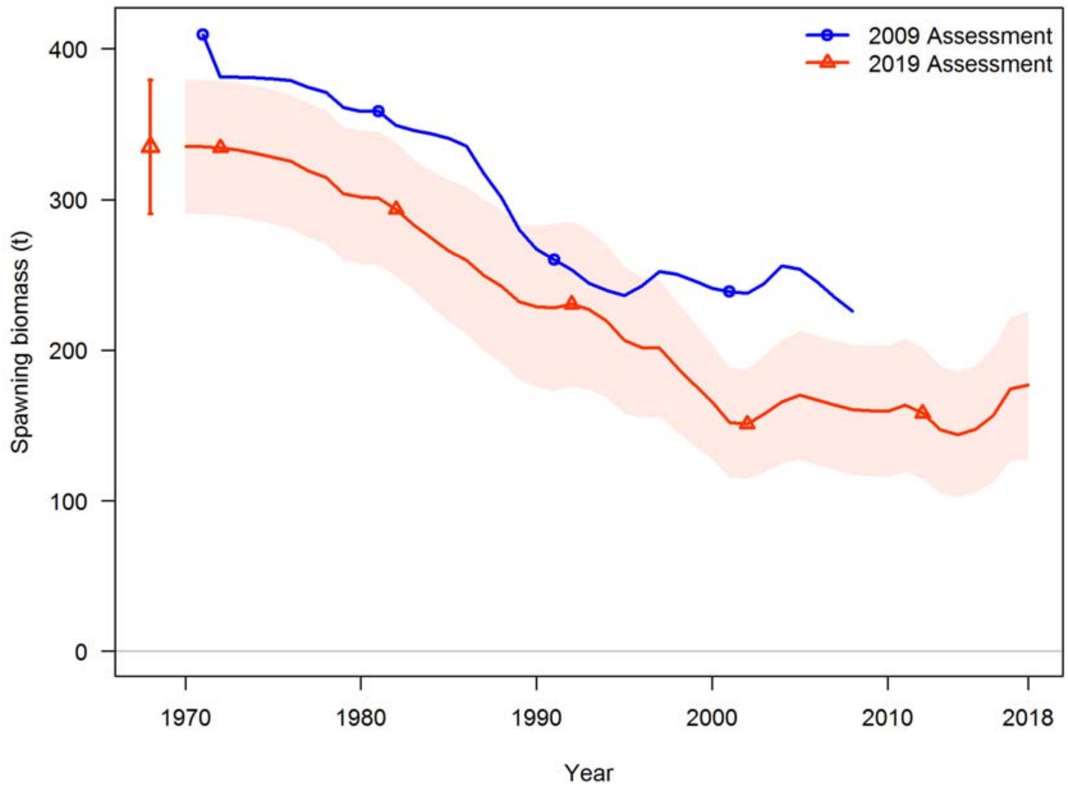


Figure 186. Summary of historical Cabezon assessment estimates of spawning biomass for the Oregon sub-stock . Shading represents the approximate 95% confidence range from the 2019 base model.

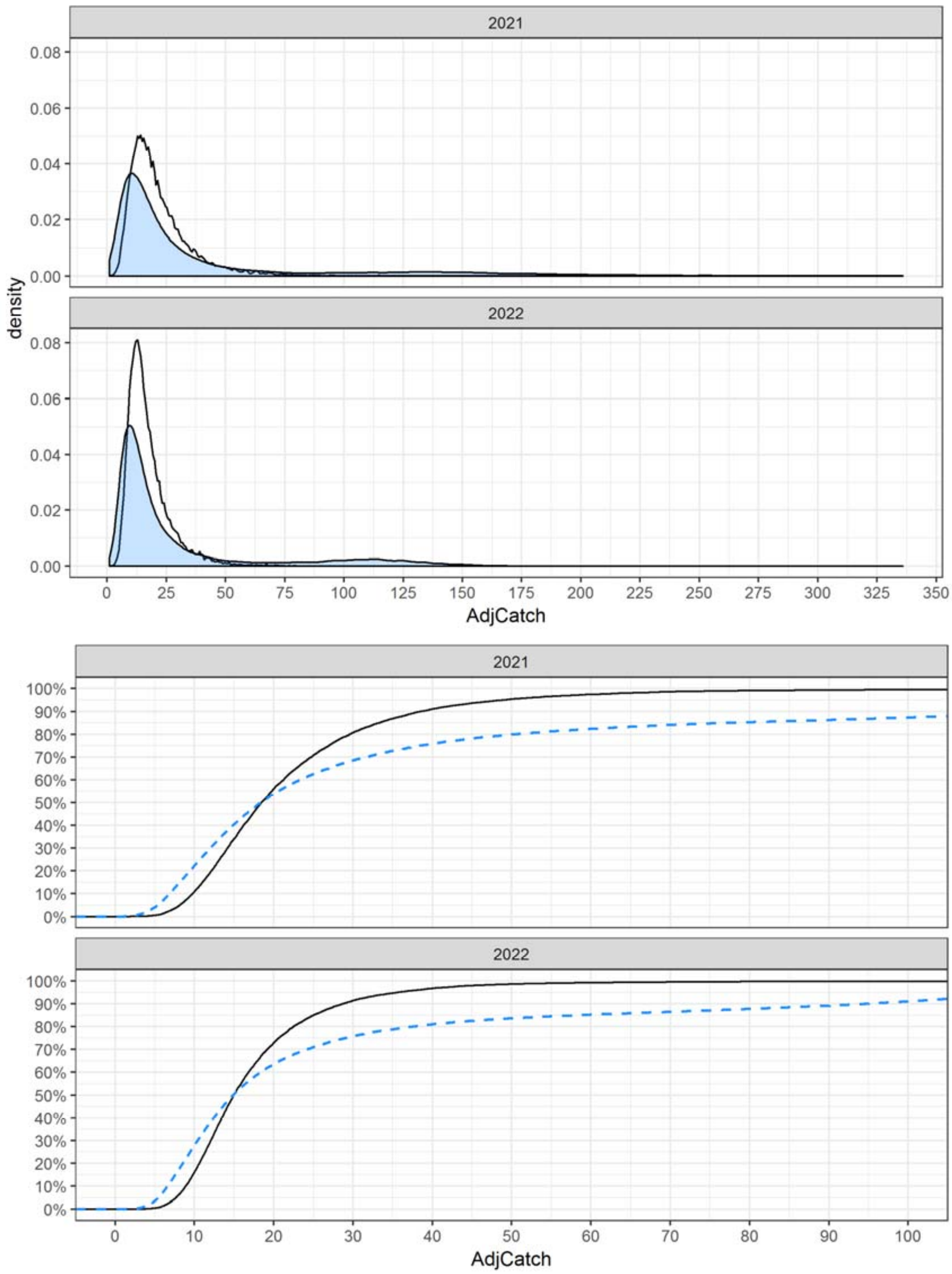


Figure 187. Weighted and unweighted (shaded) ensemble OFL distributions (top panels) and cumulative curves (bottom panels; weighted- solid lines; unweighted- blue dashed lines) of OFL values in years 2021 and 2022 for the Washington cabezon stock.

Appendix A. Glossary of Common Terms and Acronyms Used in This Document

40:10 adjustment: a reduction in the overall annual catch limit (ACL) that is triggered when the female spawning output (defined as female biomass here) falls below 40% of its unfished equilibrium level. This adjustment reduces the ACL on a straight-line basis from the 40% level such that the ACL would equal zero when the biomass is at 10% of its unfished equilibrium level. This is one component of the default harvest policy (see below).

Acceptable biological catch (ABC): The acceptable biological catch is a scientific calculation of the sustainable harvest level of a fishery used to set the upper limit for fishery removals (OFL, see below) by the Pacific Fishery Management Council. It is calculated by incorporating stock-specific life history information, reproductive potential, vulnerability to fishing, and the amount of uncertainty associated with scientific estimates.

Annual catch limit (ACL): The amount of fish allowed to be caught by fishermen over the period of one year (also referred to as total allowable catch; TAC). The ACL cannot exceed the ABC.

B_0: The unfished equilibrium female spawning output (female biomass here).

$B_{10\%}$: The level of female spawning biomass corresponding to 10% of unfished equilibrium female spawning biomass, i.e. $B_{10\%} = 0.10B_0$. This is the level below which the ACL is set to 0, based on the 40:10 adjustment (see above).

$B_{40\%}$: The level of female spawning output (female biomass here) corresponding to 40% of unfished equilibrium female spawning biomass, i.e. $B_{40\%} = 0.40B_0$. This is the level below which the calculated ACL is decreased from the value associated with F_{SPR}=45%, based on the 40:10 adjustment (see above).

B_{MSY}: The estimated female spawning biomass which theoretically would produce the maximum sustainable yield (MSY) under equilibrium fishing conditions (constant fishing and average recruitment in every year). Also see B40% (above).

California Current Ecosystem: The waters of the continental shelf and slope off the west coast of North America, commonly referring to the area from central California to southern British Columbia.

Catchability (q): The parameter defining the proportionality between a relative index of stock abundance and the estimated stock abundance available to that survey (as modified by selectivity) in the assessment model.

Catch-per-unit-effort (CPUE): A raw or (frequently) standardized and model-based metric of fishing success based on the catch and relative effort expended to generate that catch. Catch-per- unit-effort is often used as an index of stock abundance in the absence of fishery-independent indices and/or where the two are believed to be proportional.

Catch target: A general term used to describe the catch value used for management. Depending on the context, this may be a limit rather than a target, and may be equal to an ACL, an ABC, the median result of applying the default harvest policy, or some other number.

Cohort: A group of fish born in the same year. Also see recruitment and year-class.

Constant catch: A catch scenario used for forecasting in which the same catch is used in successive years.

CPUE: Catch-per-unit-effort (see above).

CV: Coefficient of variation. A measure of uncertainty defined as the standard deviation (SD, see below) divided by the mean.

Default harvest policy (rate): The application of F_{SPR}=45% (see below) with the 40:10 adjustment (see above). Having considered any advice provided by the SSC, and other advisory committees, the council may recommend a different harvest rate if the scientific evidence demonstrates that a different rate is necessary to sustain the resource.

Depletion: Term used for relative spawning output (see below; female spawning biomass here), which is the ratio of the beginning-of-the-year female spawning output to the unfished equilibrium female spawning output (B_0, see above). Thus, lower values are associated with a lower amount of spawning potential (e.g., fewer mature female fish).

Exploitation fraction: A metric of fishing intensity that represents the total annual catch divided by the estimated population biomass over a range of ages assumed to be vulnerable to the fishery (set to ages 2+ in this assessment). This value is not equivalent to the instantaneous rate of fishing mortality (see below) or the spawning potential ratio (SPR, see below).

F: Instantaneous rate of fishing mortality (or fishing mortality rate); see below.

F_{SPR}=45%: The rate of fishing mortality estimated to give a spawning potential ratio (SPR, see below) of 45%. Therefore, by definition this satisfies that 0.45 equals the ratio between spawning biomass per recruit with a fishing level of F_{SPR}=45% and the spawning biomass per recruit with no fishing, thus SPR (F_{SPR}=45%) = 45%. The 45% value is specified by the council.

Female spawning output: The spawning output at the beginning of the year. Sometimes abbreviated to spawning biomass and defined as the biomass of mature female fish in this assessment.

Fishing intensity: A measure of the magnitude of fishing, defined for a fishing rate F as: fishing intensity for $F = 1-\mathrm{SPR}_{(F)}$, where $\mathrm{SPR}_{(F)}$ is the spawning potential ratio for the value of F. Often given as a percentage. Relative fishing intensity is the fishing intensity relative to that at the SPR target fishing rate F_{SPR}=45%, where F_{SPR}=45% is the F that gives an SPR of 45% such that, by definition, SPR(F_{SPR}=45%) = 45% (the target spawning ratio). Therefore relative fishing intensity for $F = 1-\mathrm{SPR}_{(F)}$ / $1-\mathrm{SPR}(F_{SPR}$=45%).

Fishing mortality rate, or instantaneous rate of fishing mortality (F): A metric of fishing intensity that is usually reported in relation to the most highly selected ages(s) or length(s), or occasionally as an average over an age range that is vulnerable to the fishery. Because it is an instantaneous rate operating simultaneously with natural mortality, it is not equivalent to exploitation fraction (or percent annual removal; see above) or the spawning potential ratio (SPR, see below).

F_{MSY}: The rate of fishing mortality estimated to produce the maximum sustainable yield (MSY) from the stock.

Harvest control rule: A process for determining an ABC from a stock assessment. Also see default harvest policy (above).

Maximum likelihood estimate (MLE): A statistical method used to estimate a single value for each of the parameters and derived quantities.

Maximum sustainable yield (MSY): An estimate of the largest sustainable annual catch that can be continuously taken over a long period of time from a stock under equilibrium ecological and environmental conditions.

MLE: Maximum likelihood estimate (see above).

MSY: Maximum sustainable yield (see above).

mt: Metric ton(s). A unit of mass (often referred to as weight) equal to 1,000 kilograms or 2,204.62 pounds.

q: Catchability (see above).

R_0: Estimated annual recruitment at unfished equilibrium.

Recruits/recruitment: the estimated number of new members in a fish population born of the same age. In this assessment, recruitment is reported at age-0. See also cohort and year-class.

Recruitment deviation: The offset of the recruitment in a given year relative to the stock-recruit function; values occur on a logarithmic scale and are relative to the expected recruitment at a given spawning output (see below).

Relative fishing intensity: See definition of fishing intensity.

Relative spawning biomass: The ratio of the beginning-of-the-year female spawning output to the unfished equilibrium female spawning output (B_0, see above). Thus, lower values are associated with fewer mature female fish in this assessment.

SD: Standard deviation. A measure of variability within a sample.
Spawning biomass: Abbreviated term for female spawning biomass (see above).
Spawning biomass per recruit: The expected lifetime contribution of an age-0 recruit, calculated as the sum across all ages of the product of spawning biomass at each age and the probability of surviving to that age. See Figure B.2 for a graphical demonstration of the calculation of this value, which is found in both numerator and denominator of the Spawning potential ratio (SPR, see below).

Spawning potential ratio (SPR): The ratio of the spawning biomass per recruit under a given level of fishing to the estimated spawning biomass per recruit in the absence of fishing; i.e. for
fishing mortality rate *F*: $\text{SPR}_{(F)}$ = spawning biomass per recruit with *F* / spawning biomass per recruit with no fishing. Often expressed as a percentage, it achieves a value of 100% in the absence of fishing and declines toward zero as fishing intensity increases.

SPR: Spawning potential ratio (see above).

$SPR_{40\%}$: See target spawning potential ratio.

SS: Stock Synthesis (see below).

Steepness (*h*): A stock-recruit relationship parameter representing the proportion of R_0 expected (on average) when the female spawning output is reduced to 20% of B_0 (i.e., when relative spawning biomass is equal to 20%).

Stock Synthesis (SS): The age-structured stock assessment model framework (software) used in this stock assessment.

Target spawning potential ratio ($SPR_{45\%}$): The spawning potential ratio of 45%, where the 45% relates to the default harvest rate of F_{SPR}=45% specified by the Council. Even under equilibrium conditions, F_{SPR}=45% would not necessarily result in a spawning biomass of $B_{40\%}$ because F_{SPR}=45% is defined in terms of the spawning potential ratio which depends on the spawning biomass *per recruit*.

Vulnerable biomass: The demographic portion of the stock available for harvest by the fishery.

Year-class: A group of fish born in the same year. See also 'cohort' and 'recruitment'.

Appendix B: California Management Measures Relevant to Cabezon

Year	Description	Effective Date
1982	Recreational & commercial size limit 12" (30.5 cm), TL	1/1/1982
1984	Recreational Bag Limit of 10 fish w/in 20 fish aggregate	**3/1/1984**
Pre-1996	Recreational Regulations Recreational fillet length size limit of 12" (30.5 cm)	3/1/1996?
1999	Nearshore Fisheries Management Act gives Fish and Game Commission (FGC) additional authority to regulate fisheries (FG Code §8585.5)	1/1/1999
1999	After January 1, 1999 FGC may adopt regulations to regulate nearshore fish stock and fisheries (FG Code §8587.2)	1/1/1999
1999	Trawl caught dead nearshore (including Cabezon) are exempt from size limits (FG Code §8588 (a))	1/1/1999
1999	Commercial size limit 14" (35.6 cm), TL (trawl caught dead nearshore fishes exempt)	1/1/1999
1999	Nearshore fish stock defined with a nearshore fishery permit requirement to take Cabezon	4/1/1999
2000	Recreational size limit 14" (35.6 cm), TL	1/1/2000
2000	Recreational Regulations Shall not be filleted on a boat	3/1/2000
2000	FGC fixes Cabezon OY at 67,132 pounds (37.6%) recreational; 111,596 pounds (62.4%) commercial; Total = 178,728 pounds	10/2000
2000	FGC changes Cabezon OY at 63,608 pounds (40.3%) recreational; 94,398 pounds (59.7%) commercial; Total = 158,006 pounds	12/2000
2001	Establishes a December 31, 1999 control date to qualify for the Restricted Access program (CCR Title 14 §150 (d))	10/13/2000

2001	Prohibit take from Thursday to Sunday, inclusive (except north of 40°10' – near Cape Mendocino)	01/2001
2001	Recreational Regulations Central and Southern Management Areas; Recreational Fishery open year round; no depth restrictions, except no take in Cowcod Closure area in southern management area in waters 20 fm or greater.	1/1/2001
2001	Size limit increased to 15" (38.1 cm), TL (recreational and commercial)	3/1/2001
2001	FGC fixes Cabezon OY at 63,608 pounds recreational; 94,398 pounds commercial; Total OY = 158,006 pounds in emergency regulations	9/1/2001
2001	FGC enacts emergency action to close commercial fishery for the remainder of the calendar year	9/24/2001
2001	Limitation on the number of hooks (150) used to take nearshore stocks and the number of hooks per line (15)	3/5/2001
2001	Defines nearshore fish stocks (including Cabezon), nearshore fisheries, nearshore waters, and shallow nearshore rockfish (CCR Title 14 §1.90 (a)(b))	3/5/2001
2001	Prohibits the take of Cabezon in the northern rockfish and Lingcod management area during March and April or in the southern rockfish and Lingcod management area in January and February (CCR Title 14 §150.16 (a)	3/5/2001
2001	Commercial seasonal closures for Cabezon shall apply that are consistent with federal seasonal closures for minor nearshore rockfishes, as noticed in the Federal Register by the National Marine Fisheries Service or defined in Title 50, Code of Federal Regulations (CFR), Parts 600 and 600, for ocean waters south of 40°10' (CCR Title 14 §150.06 (c)	3/5/2001
2002	Finfish traps required to have rigid 5" rings in entrance	1/8/2002
2002	FGC fixes Cabezon OY at 84,330 pounds (47.2%) recreational; 94,398 (52.8%) pounds commercial; Total OY = 178,728 pounds reaffirming emergency action	2/4/2002

2002	FGC enacts emergency action to close commercial fishery for the remainder of the calendar year	7/01/2002
2002	Recreational Regulations Recreational Area Mgmt areas changed	1/10/2002
2002	Recreational Regulations Emergency Sportfishing Closure for Cabezon in waters deeper than 20 fm for all boat-based anglers south of 40º10' N lat.	7/29/2002
2003	FGC fixes Cabezon OY at 84,330 pounds (47.2%) recreational; 94,398 (52.8%) pounds commercial; Total OY = 178,728 pounds	1/1/2003
2003	Recreational Regulations Recreational rockfish, Cabezon, and greenling (RCG) complex; 10 fish bag-limit regulation established in the Central and Southern Management Areas	1/1/2003
2003	Recreational Regulations Northern Management Area (CA/OR border to 40º10' N lat.): recreational bag limit remains at 10 fish (outside the rockfish bag limit); Open year round; No depth Restriction North-Central, South-Central and Southern Management Areas (40º10' N lat. to US/Mexico border): recreational bag limit 3 fish with in the RCG bag limit; Open July-Dec; 20 fm or less	1/3/2003
2003	Cumulative trip limits set for two-month periods, includes a two month closure from March to April.	
2003	FGC regulatory changes enacted as follows: Seasons: Jan-Feb – open Mar-Apr – closed May-Dec – open (or until the TAC allocation has been reached) Cumulative trip limits per nearshore permittee for January and February set at 200 pounds	1/1/2003
2003	Participants must have a valid 2003-2004 nearshore fishery permit for one regional management area (CCR Title 14 § 52.04)	2/8/2003

2003	CCR Title 14 §150 (c) defines nearshore fishes (including Cabezon) used for landings qualifications and their respective market category codes	3/10/2003
2003	Commercial RCAs 42° N lat. to 40°10' N lat. – closed 27 fm to 100 fm South of 40°10 N lat. January – June – closed 20 fm to 150 fm July-August – closed 20 fm to 150 fm, except between a line drawn due south from Point Fermin and a line drawn due west from Newport South Jerry, vessels fishing with hook and line and/or trap(or pot) gear may operate from shore to a boundary line approximating 50 fm September to December – 20 fm to 150 fm	5/7/2003
2003	Participants must have a valid 2003-2004 nearshore fishery permit for one management region.	4/1/2003
2003	FGC enacts emergency action to close commercial fishery for the remainder of the calendar year	7/10/2003
2003	Recreational Regulations Emergency sportfishing closure for Cabezon statewide for all boat-based angers	12/8/2003
2003	Changes to Commercial RCAs 40°10' N lat to 34°27' N lat – closed 20 fm to 150 fm south of 34°27' N lat July-August – closed 20 fm to 150 fm (special open area in Pt. Fermin/Newport South Jetty area) September to December – closed 30 fm to 150 fm	9/5/2003
2003	Weekday commercial closures repealed	12/3/2003
2003	Changes to Commercial RCAs South of 42° N lat.– November to December – closed shoreline to 150 fm	11/26/2003

2003	Additional Cabezon cumulative trip limit regulations affecting the commercial take are defined. Cumulative two-month trip limits for the entire year are listed (CCR Title 14 § 150.16 (e)(6)(A))	12/7/2003
2004	FGC fixes Cabezon OY at 118,300 pounds (61%) recreational; 75,600 pounds (39%) commercial; Total OY = 193,300 pounds	12/3/2003
2004	Seasonal closure periods in alignment with federal nearshore rockfish (north and south of 40°10' N lat) (repealed and new subsection)	1/15/2004
2004	Recreational Regulations Northern Management Area (CA/OR border to 40º10' N lat.): recreational bag limit remains at 10 fish (outside the rockfish bag limit); Open year round; No depth Restriction Central Management Area (40º10' N lat. to Point Conception): recreational bag limit 3 fish within the RCG bag limit; Open Jan-Feb (30 fm or less), May-Aug (20 fm or less), and Sep-Dec (30 fm or less) Southern Management Area (Point Conception to US/Mexico border): recreational bag limit 3 fish within the RCG bag limit; Open Mar-Dec; 60 fm or less	1/1/2004

2004	Recreational Regulations Northern Management Area (CA/OR border to 40º10' N lat.): recreational bag limit 3 fish within the RCG bag limit; Open Jun-Dec; 30 fm or less North-Central Management Area (40º10' N lat. to Point Lopez): recreational bag limit 3 fish within the RCG bag limit; Open Aug-Oct; 30 fm or less South-Central Management Area (40º10' N lat. to Point Lopez): recreational bag limit 3 fish within the RCG bag limit; Open Jun (30 fm or less), Aug (30 fm or less), Sep-Dec (20 fm or less) Southern Management Area (Point Conception to US/Mexico border): recreational bag limit 3 fish within the RCG bag limit; Open Jun-Aug (60 fm or less), Sep-Oct (30 fm or less), Nov-Dec (60 fm or less)	6/4/2004
2004	Commercial Regulations 42° N lat. to 40°10' N lat - closed 30 fm to 100 fm 40°10' N lat to 34°27' N lat. January to April – closed 30 fm to 150 fm May to August – closed 20 fm to 150 fm September to December – closed 30 fm to 150 fm South of 34°27' N lat. – closed 60 fm to 150 fm	1/8/2004
2004	FGC enacts emergency action to close commercial fishery for the remainder of the calendar year	9/4/2004
2005	FGC fixes Cabezon OY at 92,800 pounds (61%) recreational; 59,300 pounds (39%) commercial; Total OY = 152,100 pounds	1/1/2005

2005	Commercial Regulations 42° N lat. to 40°10' N lat - closed 30 fm to 100 fm 40°10' N lat to 34°27' N lat. January to April – closed 30 fm to 150 fm May to August – closed 20 fm to 150 fm September to December – closed 30 fm to 150 fm South of 34°27' N lat. – closed 60 fm to 150 fm	1/1/2005
2005	Recreational Regulations 42° N lat to 40°10' N lat - Open Jul1–Oct 31 40 fm restriction, 3 Cabezon sub bag limit 40°10' N lat. to 37°11' N lat. - Open Jul 1–Nov 30 20 fm restriction, 3 Cabezon sub bag limit 37°11' N lat. to 36° N lat. - Open Jul 1–Nov 30 20 fm restriction, 3 Cabezon sub bag limit 36° N lat. to 34°27' N lat. - Open May 1–Sep 30 between 20-40 fm, 3 Cabezon sub bag limit South of 34°27' N lat. - Open Mar 1–Jun 30 between 30-60 fm; Jul 1-Sep 30, 40 fm restriction, 3 Cabezon sub bag limit	1/1/2005
2005	Revised cumulative two month commercial trip limits established January – February – 300 lb/ 2 months March – April – closed May – June – 250 lb/2 months July – August – 150 lb/2 months September - October – 900 lb/2 months November - December – 100 lb/2 months	3/31/2005
2005	Recreational Regulations Recreational sub bag limit reduced from 3 fish to one fish	4/1/2005

2005	Recreational Regulations 42° N lat to 40°10' N lat – extend season to May through Dec, 30 fm depth restriction 40°10 N lat. to 36° N lat. – extend season to July through Dec 36° N lat. to 34°27' N lat – liberalize the RCA to 40 fm (instead of only open between 20 and 40) South of 34°27' N lat. – extend season from March through December depth restrictions: March – status quo – open 30-60 fm April – August – 60 fm restriction Sept – Oct – 30 fm restriction Nov-Dec – 60 fm restriction	5/1/2005
2005	FGC enacts emergency action to close commercial fishery for the remainder of the calendar year	10/01/2005
2005	Recreational Regulations Emergency sportfishing closure – the Northern and North-Central Management Area closed Oct-Dec for all anglers	10/18/2005
2006	FGC fixes Cabezon OY at 92,800 pounds (61%) recreational; 59,300 pounds (39%) commercial; Total OY = 152,100 pounds	1/1/2006

2006	Recreational Regulations 42° N lat to 40°10' N lat - Open Jul 1–Oct 31 40 fm restriction, 1 Cabezon sub bag limit 40°10' N lat. to 37°11' N lat. - Open Jul 1–Nov 30 20 fm restriction, 1 Cabezon sub bag limit 37°11' N lat. to 36° N lat. - Open Jul 1–Nov 30 20 fm restriction, 1 Cabezon sub bag limit 36° N lat. to 34°27' N lat. - Open May 1–Sep 30 between 20-40 fm, 1 Cabezon sub bag limit South of 34°27' N lat. - Open Mar 1–Jun 30 between 30-60 fm; Jul 1-Sep 30, 40 fm restriction, 1 Cabezon sub bag limit	1/1/2006
2006	Commercial Sep-Oct cumulative trip limit reduced from 900 lb to 200 lb (inseason) to remain within TAC	9/1/2006
2007	FGC fixes Cabezon OY at 92,800 pounds (61%) recreational; 59,300 pounds (39%) commercial; Total OY = 152,100 pounds	1/1/2007
2007	Commercial RCAs – 42° N lat. to 40°10'N lat. - closed 30 fm to 100 fm 40°10'N lat. to 34°27' N lat – closed 30 fm to 150 fm South of 34°27' N lat. - closed 60 fm to 150 fm	1/1/2007
2007	Recreational Regulations 42° N lat. to 40°-10' N lat. – open May 1–Dec 31 30 fm restriction, 1 Cabezon sub bag limit 40°10' N lat. to 37°11' N lat. – open Jun 1–Nov 30 30 fm restriction, 1 Cabezon sub bag limit 37°11' N lat. to 34°27' N lat. – open May 1–Nov 30 40 fm restriction, 1 Cabezon sub bag limit South of 34°27 N lat. – open Mar1–Dec 31 60 fm restriction, 1 Cabezon sub bag limit	1/1/2007

2007	Commercial September-October cumulative trip limit reduced from 900 lb to 200 lb (inseason) to remain within TAC	9/1/2007
2007	Recreational Regulations Emergency sportfishing closure north of 37°11’ N lat (North and North-Central management Areas)	10/1/2007
2008	FGC fixes Cabezon OY at 92,800 pounds (61%) recreational; 59,300 pounds (39%) commercial; Total OY = 152,100 pounds	1/1/2008
2008	Recreational Regulations Emergency sportfishing regulations – changed the maximum depth restriction north of 37°11’ N lat. to 20 fm (from 30 fm)	5/10/2008
2008	Commercial September-October cumulative trip limit reduced from 900 lb to 300 lb (inseason) to remain within TAC	9/1/2008
2008	Commercial RCA 42° N lat. to 40°10’ N lat – close 30 fm to 100fm	9/1/2008
2008	Recreational Regulations Emergency sportfishing closure north of Point Arena (38°57.5’ N lat.) and created a new management area (split the North-Central into two areas)	9/2/2008
2009	FGC fixes Cabezon OY at 92,800 pounds (61%) recreational; 59,300 pounds (39%) commercial; Total OY = 152,100 pounds	3/1/2009
2009	Change to commercial RCA – 42° N lat. to 40°10’ N lat. – close 20 fm -100 fm	3/1/2009

2009	Recreational Regulations 42° N lat. to 40°-10’ N lat. – open May 15–Sep 15 20 fm restriction, 2 Cabezon sub bag limit 40°10’ N lat. to 38°57.5’ N lat. – open May 15–Aug 15 20 fm restriction, 2 Cabezon sub bag limit 38°57.5’ N lat. to 37°11’ N lat. – open Jun 13–Oct 31 30 fm restriction, 2 Cabezon sub bag limit 37°11’ N lat. to 34°27’ N lat. – open May 1–Nov 15 40 fm restriction, 2 Cabezon sub bag limit South of 34°27 N lat. – open Mar 1–Dec 31 60 fm restriction, 2 Cabezon sub bag limit	3/1/2009
2011	Recreational Regulations 42° N lat. to 40°-10’ N lat. – open May 15–Oct 31 20 fm restriction, 3 Cabezon sub bag limit 40°10’ N lat. to 38°57.5’ N lat. – open May 15–Aug 15 20 fm restriction, 3 Cabezon sub bag limit 38°57.5’ N lat. to 37°11’ N lat. – open June 1–Dec 31 30 fm restriction, 3 Cabezon sub bag limit 37°11’ N lat. to 34°27’ N lat. – open May 1–Dec 31 40 fm restriction, 3 Cabezon sub bag limit South of 34°27 N lat. – open Mar 1–Dec 31 60 fm restriction, 3 Cabezon sub bag limit	3/1/2011
2012	Recreational Regulations South of 34°27 N lat. – open Mar 1–Oct 31 60 fm restriction, 3 Cabezon sub bag limit South of 34°27 N lat. – open Oct 1–Oct 31 50 fm restriction, 3 Cabezon sub bag limit	3/1/2012

2013	Recreational Regulations 42° N lat. to 40°-10' N lat. – open May 15–Oct 31 20 fm restriction, 3 Cabezon sub bag limit 40°10' N lat. to 38°57.5' N lat. – open May 15–Sep 1 20 fm restriction, 3 Cabezon sub bag limit 38°57.5' N lat. to 37°11' N lat. – open June 1–Dec 31 30 fm restriction, 3 Cabezon sub bag limit 37°11' N lat. to 34°27' N lat. – open May 1–Dec 31 40 fm restriction, 3 Cabezon sub bag limit South of 34°27 N lat. – open Mar 1–Dec 31 50 fm restriction, 3 Cabezon sub bag limit	3/1/2013
2015	Recreational Regulations 42° N lat. to 40°-10' N lat. – open May 15–Oct 31 20 fm restriction, 3 Cabezon sub bag limit 40°10' N lat. to 38°57.5' N lat. – open May 15–Oct 31 20 fm restriction, 3 Cabezon sub bag limit 38°57.5' N lat. to 37°11' N lat. – open Apr 5–Dec 31 30 fm restriction, 3 Cabezon sub bag limit 37°11' N lat. to 34°27' N lat. – open Apr 1–Dec 31 40 fm restriction, 3 Cabezon sub bag limit South of 34°27 N lat. – open Mar 1–Dec 31 60 fm restriction, 3 Cabezon sub bag limit	3/1/2015

2017	Recreational Regulations 42° N lat. to 40°-10’ N lat. – open May 15–Oct 15 30 fm restriction, 3 Cabezon sub bag limit 42° N lat. to 40°-10’ N lat. – open Oct 16–Dec 31 20 fm restriction, 3 Cabezon sub bag limit 40°10’ N lat. to 38°57.5’ N lat. – open May 15–Dec 31 20 fm restriction, 3 Cabezon sub bag limit 38°57.5’ N lat. to 37°11’ N lat. – open Apr 15–Oct 15 40 fm restriction, 3 Cabezon sub bag limit 38°57.5’ N lat. to 37°11’ N lat. – open Oct 16–Dec 31 30 fm restriction, 3 Cabezon sub bag limit 37°11’ N lat. to 34°27’ N lat. – open Apr 1–Oct 15 50 fm restriction, 3 Cabezon sub bag limit 37°11’ N lat. to 34°27’ N lat. – open Oct 16–Dec 31 40 fm restriction, 3 Cabezon sub bag limit South of 34°27 N lat. – open Mar 1–Dec 31 60 fm restriction, 3 Cabezon sub bag limit	3/1/2017 10/16/2017

2018	Recreational Regulations 42° N lat. to 40°-10' N lat. – open May 15–Aug 24 30 fm restriction, 3 Cabezon sub bag limit 42° N lat. to 40°-10' N lat. – open Aug 25–Dec 31 20 fm restriction, 3 Cabezon sub bag limit 40°10' N lat. to 38°57.5' N lat. – open May 15–Dec 31 20 fm restriction, 3 Cabezon sub bag limit 38°57.5' N lat. to 37°11' N lat. – open May 15–Aug 24 40 fm restriction, 3 Cabezon sub bag limit 38°57.5' N lat. to 37°11' N lat. – open Aug 25–Dec 31 30 fm restriction, 3 Cabezon sub bag limit 37°11' N lat. to 34°27' N lat. – open May 15–Aug 24 50 fm restriction, 3 Cabezon sub bag limit 37°11' N lat. to 34°27' N lat. – open Aug 25–Dec 31 40 fm restriction, 3 Cabezon sub bag limit South of 34°27 N lat. – open Mar 1–Dec 31 60 fm restriction, 3 Cabezon sub bag limit	3/1/2017 8/25/2017
2019	Commercial cumulative trip limit per individual per two-month period increased to 500 lb.	1/2/2019

Appendix C: Oregon Sport Regulations Relevant to Cabezon

Year	Effective Jan. 1 (regulations set preseason)	Inseason Change and Effective Date
2018	General marine species: 5 fish daily bag limit, no sub-bag limits except for Cabezon. Cabezon open July 1 – Dec. 31, 1 fish sub-bag limit (of the 5 general marine species bag limit), and 16" min. Ocean closed seaward of the 30-fathom curve April 1-Sept. 30.	7/1 The general marine fish daily bag limit is reduced to 4. 8/18 Cabezon closed.
2017	General marine species: 7-fish daily bag limit of which no more than one may be a Cabezon (when Cabezon is open). Cabezon is closed January - June. Ocean closed seaward of the 30-fathom curve April 1-Sept. 30.	9/18 Retention prohibited of Lingcod, any species of rockfish, Cabezon, greenling, and bottomfish other than flatfish species.
2016	Rockfish, Cabezon (16" min.), greenlings, and other marine species not listed under Marine Zone in the Oregon Sport Fishing Regulations: 7 daily in aggregate of which no more than 1 may be a Cabezon July 1 – Dec 31. Cabezon closed Jan- June. 30-fathom curve: Seaward closed April 1-Sept. 30 [for groundfish group]. North of Humbug Mt.: Retention of any groundfish species other than sablefish and Pacific cod is prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	7/15 Offshore of 20-fm closed for bottom fishing due to yelloweye rockfish impacts 10/1 Groundfish reopen at all depths
2013 - 2015	Rockfish, Cabezon (16" min.), greenlings, and other marine species not listed under Marine Zone in the Oregon Sport Fishing Regulations: 7 daily in aggregate of which no more than 1 may be a Cabezon July 1 – Dec 31. Cabezon closed Jan- June. 30-fathom curve: Seaward closed April 1-Sept. 30 [for groundfish group].	

	North of Humbug Mt.: Retention of any groundfish species other than sablefish and Pacific cod is prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	
2012	Rockfish, Cabezon (16" min.), greenlings, and other marine species not listed under Marine Zone in the Oregon Sport Fishing Regulations: 7 daily in aggregate of which no more than 1 may be a Cabezon April 1 – Sept. 30. Cabezon closed Jan-March and Oct-Dec 30-fathom curve: Seaward closed April 1-Sept. 30 [for groundfish group]. North of Humbug Mt.: Retention of any groundfish species other than sablefish and Pacific cod is prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	7/21 Cabezon closed for boats
2011	Rockfish, Cabezon (16" min.), greenling, and other marine species not listed under Marine Zone in the Oregon Sport Fishing Regulations: 7 daily in aggregate of which no more than 1 may be a Cabezon April 1 – Sept. 30. 40-fm curve: Seaward closed April 1-Sept. 30. North of Humbug Mt.: Retention of any groundfish species other than sablefish and Pacific cod is prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	7/21 Offshore of 20-fm line closed due to yelloweye rockfish impacts 7/21 Cabezon closed for boats
2010	Rockfish, Cabezon (16" min.), greenling, and other marine species not listed: 7 40-fm curve: Seaward closed April 1-Sept. 30. North of Humbug Mt.: Retention of any groundfish species other than sablefish and Pacific cod is prohibited on all-depth P. halibut days when P. halibut is aboard vessel. "Rockfish" *et al* bag limit: 7 (misprinted in regulations booklet as 6) Definition of "groundfish group" added.	7/24 Offshore of 20-fm line closed through Dec. 31 due to yelloweye rockfish impacts 7/24 Cabezon closure for boats

2009	Rockfish, Cabezon (16" min.), greenling, and other marine species not listed: 6 40-fm curve: Seaward closed April 1-Sept. 30. North of Humbug Mt.: Retention of any groundfish species other than sablefish and Pacific cod is prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	5/1 Rockfish *et al* bag limit increased to 7 (in permanent rule). 9/14 Cabezon prohibited for boats.
2008	Rockfish, Cabezon (16" min.), greenling, and other marine species not listed: 6 40-fm curve: Seaward closed April 1-Sept. 30. North of Humbug Mt.: Retention of any groundfish species other than sablefish is prohibited on all-depth P. halibut days when P. halibut is aboard vessel. North of Cape Falcon: Retention of any groundfish species other than sablefish and Pacific cod is prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	7/7 "Rockfish" *et al* bag limit reduced from 6 to 5 and closed outside 20-fm line *through Dec. 31* 8/21 Cabezon prohibited for boats
2007	Rockfish, Cabezon (16" min.), greenling, and other marine species not listed: 6 40-fm curve: Seaward closed April 1-Sept. 30. North of Humbug Mt.: Retention of any groundfish species other than sablefish is prohibited on all-depth P. halibut days when P. halibut is aboard vessel. North of Cape Falcon: Retention of any groundfish species other than sablefish and Pacific cod is prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	8/11 Cabezon prohib. for boats
2006	Rockfish, Cabezon (16" min.), greenling, flounder, sole and other marine species not listed: 6 40-fm curve: Seaward closed June 1-Sept. 30. North of Humbug Mt.: Retention of any groundfish species other than sablefish is prohibited on all-depth P. halibut days when P. halibut is aboard vessel. North of Cape Falcon: Retention of any groundfish species other than sablefish and Pacific cod is	9/23 Cabezon prohibited for boats

	prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	
2005	Rockfish, Cabezon (16" min.), greenling, flounder, sole and other marine species not listed: 8 40-fm curve: Seaward closed June 1-Sept. 30. North of Humbug Mt.: Retention of any groundfish species other than sablefish is prohibited on all-depth P. halibut days when P. halibut is aboard vessel.	7/16 Rockfish *et al* bag limit reduced to 5 8/11 Cabezon prohibited for boats
2004	Rockfish, Cabezon, greenling, flounder, sole and other marine species not listed: 10 Cabezon minimum size: 16” 40-fm curve: Seaward closed June 1-Sept. 30.	8/18 Cabezon prohibited
2003	Rockfish, Cabezon, greenling, flounder, sole and other marine species not listed: 10 Cabezon minimum size: 15”	11/21 Ocean closed to groundfish outside 27-fm line
1994 - 2002	Other fish: 25 [including Cabezon and greenling]	
1993 - 1979	Other fish: 25 Rockfish, Cabezon and greenling: 15	
1978	Other fish: 10	4/1 Rockfish, Cabezon and greenling: 15
1976 - 1977	Other fish: 25	No bag limits prior to 1976

Appendix D: Oregon Marine Reserves/OSU SMURF Survey

Summarized by A. Whitman, Oregon Department of Fish and Wildlife
2019 Cabezon Stock Assessment
01/23/19

Background on SMURF Survey

Joint SMURF surveys were conducted by Oregon State University and the ODFW Marine Reserves Program from 2011 – 2018. More information on SMURFs and their deployment can be found in Ottmann et al. 2018. SMURFs (standardized monitoring unit of recruitment of fish) were deployed in two regions with one set of moorings inside a state marine reserve and another set at a nearby comparison area. Comparison areas are specifically selected for each marine reserve to be similar in location, habitat and depth to the reserve but are subject to fishing pressure. The marine reserve sites include Otter Rock in the central coast and Redfish Rocks on the southern coast, and their associated comparison areas, Cape Foulweather and Humbug Mountain, respectively. Sampling in the central region occurred from 2011 – 2018 and in the southern region from 2014 – 2018.

SMURFs are typically deployed in early spring and monitored relatively regularly from April or May to September. Eight moorings are typically deployed within a region; however, in 2011 – 2012, fewer moorings were utilized. Intervals between sampling are recorded and ranged from 7 to 30 days; however, monitoring was attempted roughly every two weeks. The unit of the recruitment rate is termed number of fish per trap/day. The number of sampling events for each site is found in Table D1.

Cabezon SMURF Results

Of the total 865 sampling events in four sites, 482 (55.7%) had positive Cabezon catches (Table D2). The number of Cabezon caught in a sampling event (sampled from a single SMURF) ranged from 0 to 57, though the intervals between sampling varied. Recruitment rate was calculated as the number of Cabezon per individual SMURF per day, using the interval between sampling events and ranged from 0.0 to 1.9 fish/day. A histogram of the positive catches of Cabezon is provided in Figure D1.

Sites (marine reserve vs. comparison area) differ in geographic location and the level of fishing pressure allowed. Given the recent implementation of the marine reserves, it was suggested that data could be aggregated to the region level as representative of a reef complex. Table D3 provides sample sizes and positive Cabezon catch information by region and year. Sampling in the central region occurred from 2011 - 2018, whereas sampling only occurred from 2014 - 2018 in the southern region.

Recruitment rates in Figure D2 include data from June – August, which are the only months that were sampled in each site and year. Future iterations might want to examine this, especially if grouped by region, as the trends seem to differ by region when looking at the raw recruitment rates (Figure D2). Rates do not appear to vary greatly throughout the sampling season (Figure D3).

While Cabezon are encountered throughout the sampling season, in order to be consistent, we may want to consider removing certain years or months in order to have a consistent annual sampling time frame. In particular, the early years do not have as many sampling events and sampling only occurred in one region. By excluding the months of April and May, over half of the Cabezon are removed (total of 985 vs 2147 fish), though the rates of positive catches by region and year do not change dramatically (Table D4).

Length of Cabezon from Oregon SMURF sampling was also provided. Cabezon range in size from approximately 20 - 60 mm (Figure D4), typical of late pelagic larval and settlement stages. There also appears to be some variation in settlement timing by year, though as mentioned previously, Cabezon recruit throughout the sampling season. Size ranges and timing do not appear to differ greatly by site (Figure D5).

ODFW staff recommendation

Given the high rate of positives and the robust sampling design, ODFW staff recommends moving forward with including a recruitment index from the ODFW/OSU SMURF dataset if time allows. Delineating by region should be given consideration, as the peak of the raw recruitment rates in 2014 and 2015 appears to be driven by the southern region. Additionally, standardizing the annual timeframe of sampling might be advantageous. Though this will reduce overall sample size, the rate of positive sampling events does not change appreciably at the region-year level.

Table D1. Numbers of sampling events at each site and year by SMURF sampling in Oregon's marine reserves.

Site	2011	2012	2013	2014	2015	2016	2017	2018	Total
Central Region									
Cape Foulweather	10	10	29	32	44	44	47	40	256
Otter Rock	16	25	32	32	44	44	48	40	281
Southern Region									
Humbug Mountain				28	36	36	36	28	164
Redfish Rocks				28	36	35	37	28	164

Table D2. Number of positive sampling events, number of sampling events, proportion of positives and the number of Cabezon captured in each year by SMURF sampling in Oregon.

	2011	2012	2013	2014	2015	2016	2017	2018	Total
Number of Positive Sampling Events	10	12	38	76	113	94	58	81	482
Total Sampling Events	26	35	61	120	160	159	168	136	865
Proportion of Positives	0.385	0.343	0.623	0.633	0.706	0.591	0.345	0.596	0.557
Total Number of Cabezon Caught	25	24	127	297	847	487	91	249	2147

Table D3. Number of positive sampling events, number of sampling events, proportion of positives and the number of Cabezon captured in each year and region by SMURF sampling in Oregon.

Region	Year	Number of Positive Sampling Events	Total Sampling Events	Proportion of Positives	Total Number of Cabezon Caught
Central	2011	10	26	0.385	25
	2012	12	35	0.343	24
	2013	38	61	0.623	127
	2014	31	64	0.484	65
	2015	49	88	0.557	241
	2016	48	88	0.545	267
	2017	31	95	0.326	46
	2018	48	80	0.600	110
	TOTAL	**267**	**537**	**0.497**	**905**
South	2014	45	56	0.804	232
	2015	64	72	0.889	606
	2016	46	71	0.648	220
	2017	27	73	0.370	45
	2018	33	56	0.589	139
	TOTAL	**215**	**328**	**0.655**	**1242**

Table D4. Number of positive sampling events, number of events, proportion of positives and the number of Cabezon captured by SMURF sampling in Oregon from June - August in each year.

Region	Year	Number of Positive Sampling Events	Total Sampling Events	Proportion of Positives	Total Number of Cabezon Caught
Central	2011	9	20	0.450	24
	2012	9	28	0.321	17
	2013	31	47	0.660	79
	2014	28	56	0.500	59
	2015	17	48	0.354	28
	2016	25	56	0.446	83
	2017	20	55	0.364	33
	2018	20	40	0.500	33
	TOTAL	**159**	**350**	**0.449**	**356**
South	2014	43	48	0.896	230
	2015	41	48	0.854	261
	2016	21	40	0.525	49
	2017	18	50	0.360	31
	2018	24	40	0.600	58
	TOTAL	**147**	**226**	**0.647**	**629**

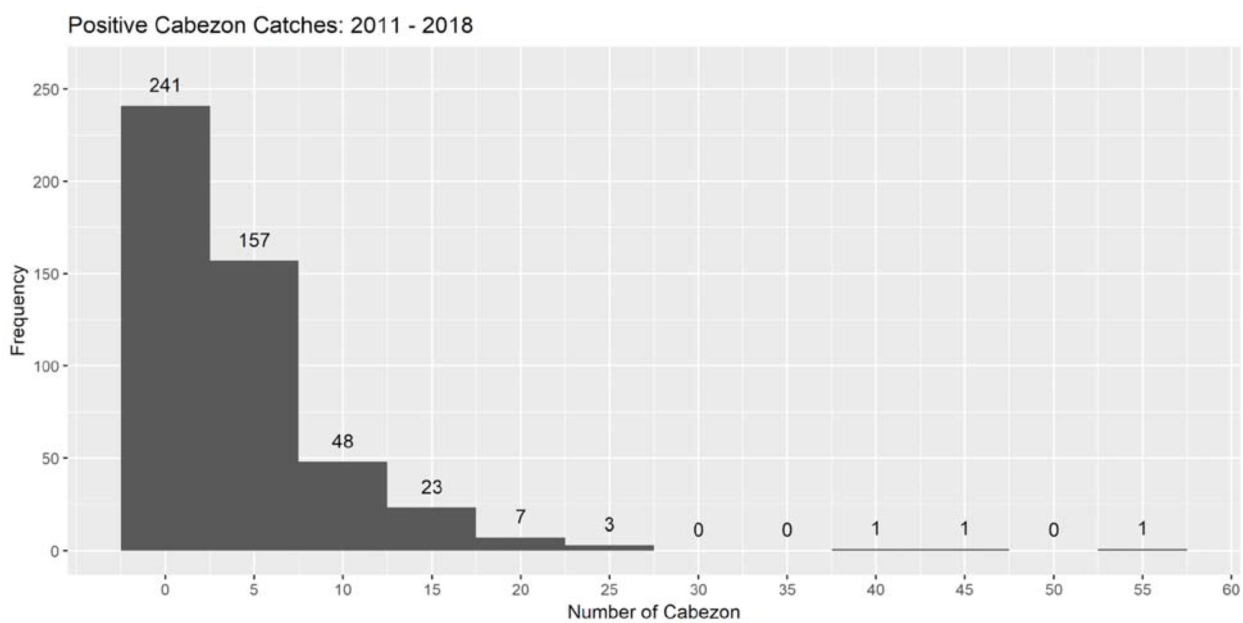


Figure D1. Histogram of positive Cabezon catches from SMURF sampling in Oregon from 2011 - 2018.

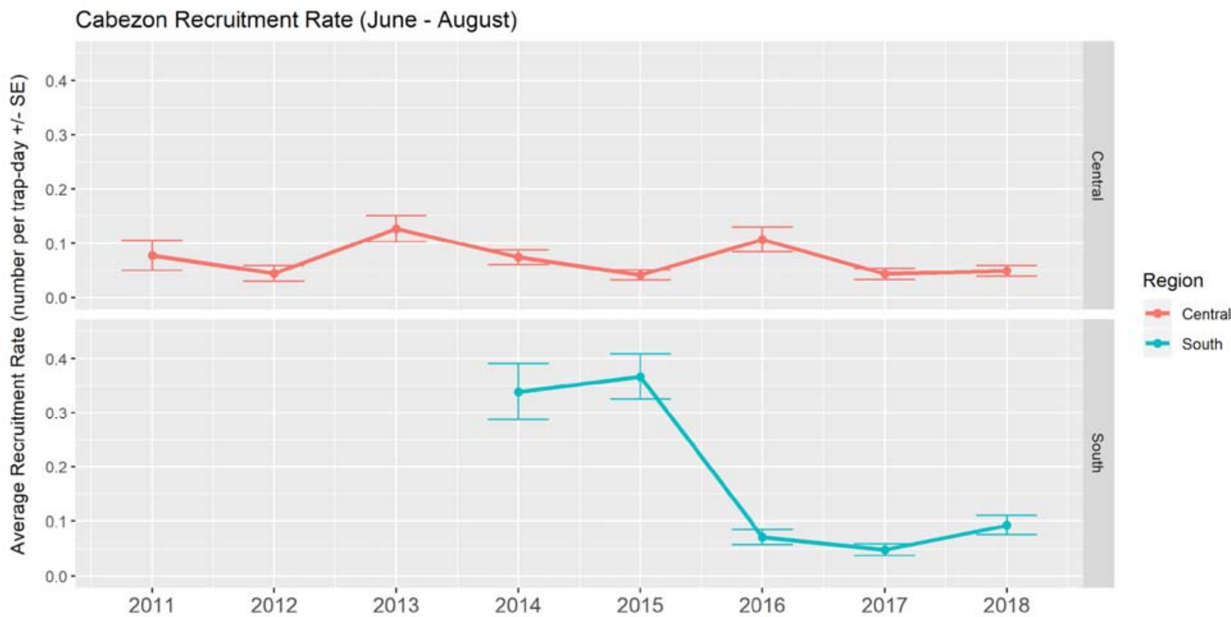


Figure D2. Raw average annual Cabezon recruitment rate (fish/day) by sampling region with standard error. Data includes only events from June - August.

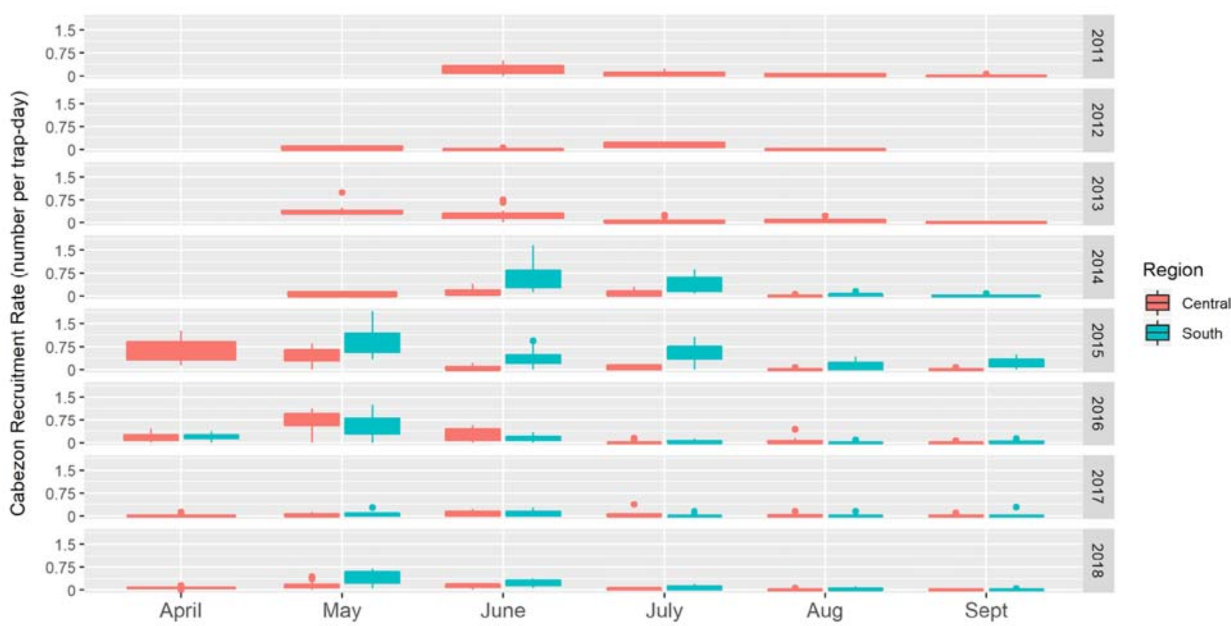


Figure D3. Cabezon recruitment rates by month, region and year.

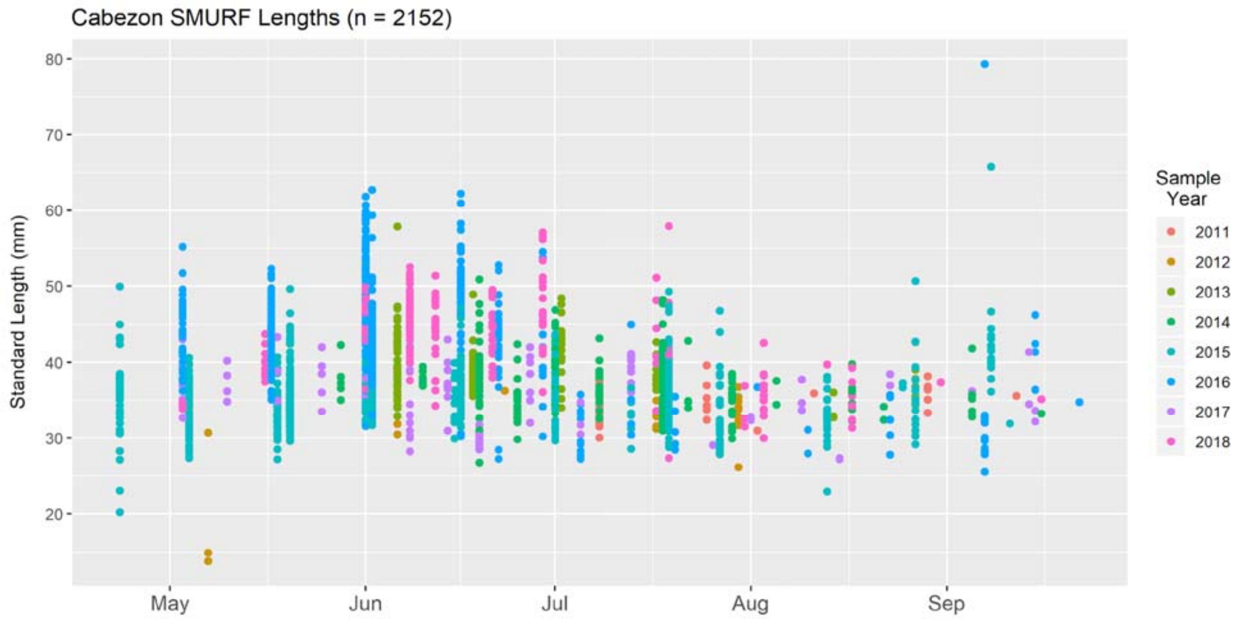


Figure D4. Length of Cabezon (SL mm) captured in SMURF sampling in Oregon by year (n = 2152).

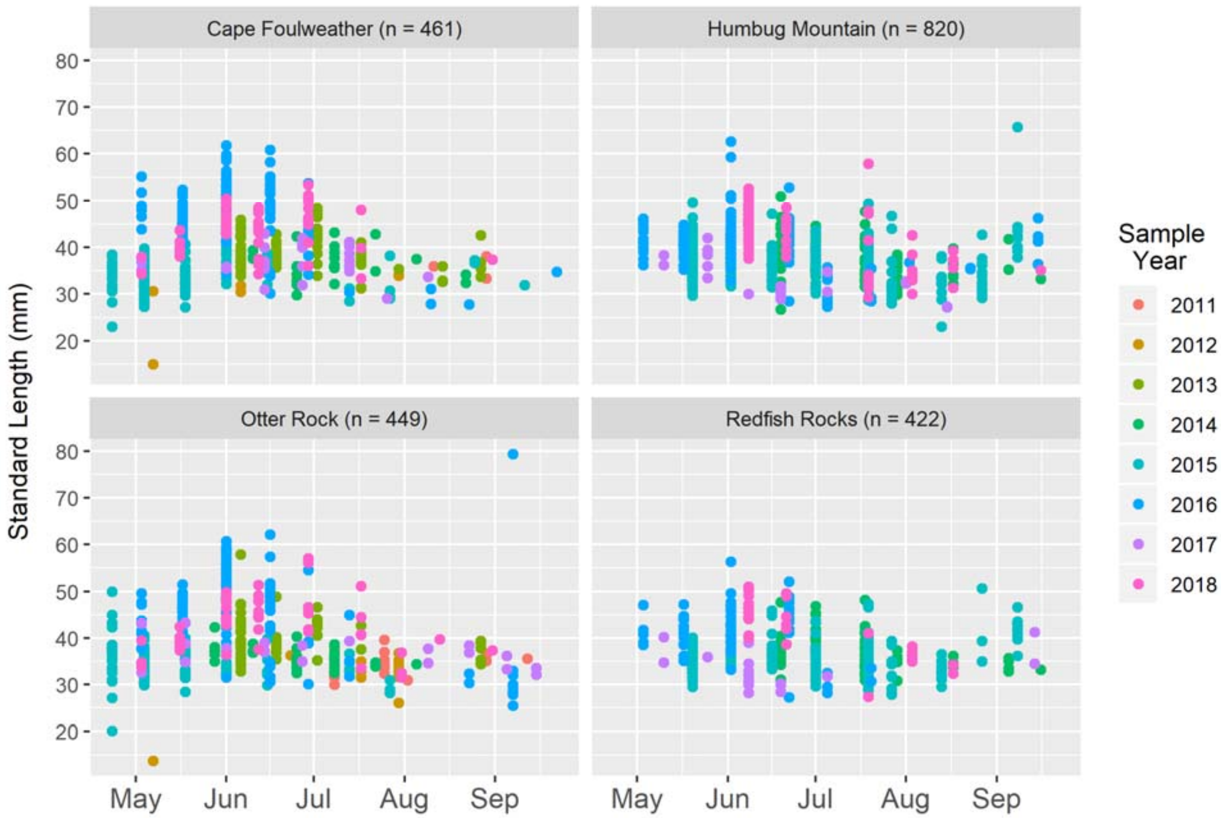


Figure D5. Length of Cabezon (SL mm) captured in SMURF sampling in Oregon by site. Marine reserve sites are the lower panels and the comparison areas are the upper panels. Panels on the left are in the central region and those on the right are in the southern.

Appendix E: Oregon Marine Reserves Hook and Line Survey

Summarized by A. Whitman, Oregon Department of Fish and Wildlife
2019 Cabezon Stock Assessment
11/20/2018

Background on Hook and Line Survey

The Marine Reserve Program in the Oregon Department of Fish and Wildlife (ODFW) has routinely monitored state marine reserves and associated comparison areas since 2011. Data from the hook and line survey from 2011 - 2018 are presented in this summary. Surveys in 2011 and 2012 only visited a single site, Redfish Rocks. Surveys from 2013 – 2018 include reserves and comparison areas from four sites: Redfish Rocks, Cape Falcon, Cape Perpetua and Cascade Head. Each of these four sites has a marine reserve and one to three comparison areas. Comparison areas are specifically selected for each marine reserve to be similar in location, habitat and depth to the reserve but are subject to fishing pressure. Not all sites are sampled in each year, due to both the gradual implementation of the reserve network and the available staff to execute surveys. Sites and areas sampled that are included in Table E1.

A 500 meter square grid overlaid on the area defines the sampling units or cells. Cells are randomly selected within a marine reserve or comparison area for each sampling event. Three replicate drifts are executed in each cell. The specific location of the drifts within the cell is selected by the captain. Over time, cells without appropriate habitat for the focus species, mainly groundfish, have been removed from the selection procedures, and those presented in this dataset include only those that are currently "active". The number of cells visited in a day can vary slightly and range from three to five. Data are aggregated to the cell-day level.

Cabezon Hook and Line Results

Of the 880 total cell-days at 14 areas, 218 (24.7%) of those had positive Cabezon catches (Table E2). The number of Cabezon caught ranged from one to 22 fish in a cell-day. A histogram of positive catches is included (Figure E1). Areas differ in both geographic location and the level of fishing pressure experienced or allowed. Staff from the Marine Reserves Program suggested that the treatment of an area (reserve vs. comparison area) may not be a delineating factor for the catch of Cabezon due to the recent implementation of the reserves. It was suggested that data could be aggregated to the site level, functioning at the level of a reef complex, to examine patterns at different locations along the coast. However, this may not be possible with the sample size available at some sites (Table E3).

Another consideration is excluding data from the recreational fishery season for Cabezon, which has been closed for part of each year since 2012. These data in this summary include sampling events from April to October, which is the typical annual sampling season of the hook and line survey. If data from the summer season (June – August) was excluded to only include data outside the time of year that the recreational fishery was typically open for Cabezon, it would exclude 20.2% of the positive catches and 29.1% of the total cell days (Table E4).

Catch per unit effort (CPUE) was calculated by the number of fish per angler hour. The number of anglers and hooks are standardized for each survey. Angler hours have been adjusted for non-fishing time (i.e. travel time, etc.). Raw CPUE varied by year for Cabezon (Figures E2 and E3), indicating that this survey could capture interannual variability in Cabezon abundance.

ODFW Staff Recommendation

Based on the annual proportion of positive cell-days, there may enough data to move forward with a time series at a coastwide level. Additional filtering may not be necessary, as the filtering for "active" cells has already likely removed any unsuitable sampling units, based on habitat, depth and local knowledge. Summer sampling events should be retained at this point to boost sample size but as more data is available in the future, we could consider removing these to specifically capture catch rates outside of the summer recreational fishery season.

Table E1. Sites and areas (marine reserves and comparison areas), years sampled and total years sampled for Oregon Marine Reserves hook and line survey.

Site	Area	Years Sampled	Total Years Sampled
Redfish Rocks	Humbug CA	2011 - 2017	7
Redfish Rocks	Redfish Rocks MR	2011 - 2017	7
Redfish Rocks	Orford Reef CA	2014, 2015, 2017	3
Cape Falcon	CA Adjacent to Cape Falcon MR	2014, 2015, 2017	3
Cape Falcon	Cape Falcon MR	2014, 2015, 2017	3
Cape Falcon	Cape Meares CA	2014, 2015, 2017	3
Cape Falcon	Three Arch Rocks CA	2014, 2015, 2017	3
Cape Perpetua	CA Outside Cape Perpetua MR	2016, 2018	2
Cape Perpetua	Cape Perpetua MR	2013, 2014, 2017, 2018	4
Cape Perpetua	Postage Stamp CA	2013, 2014, 2017, 2018	4
Cascade Head	Cape Foulweather CA	2015, 2016, 2018	3
Cascade Head	Cascade Head MR	2013 - 2016, 2018	5
Cascade Head	Cavalier CA	2013, 2015, 2016, 2018	4
Cascade Head	Schooner Creek CA	2013 - 2016, 2018	5

Table E2. Number of positive catch cell-days (sample unit), total cell-days, proportion of positives and the total number of Cabezon caught by sample year.

	2011	2012	2013	2014	2015	2016	2017	2018	Total
Number of Positive Catch Cell-Days	10	4	19	28	38	30	44	45	218
Total Cell-Days	65	79	97	141	167	112	103	116	880
Proportion of Positives	0.15	0.05	0.20	0.20	0.23	0.27	0.43	0.39	0.25
Total Number of Cabezon Caught	12	4	23	61	78	61	97	165	501

Table E3. Site-specific number of positive catch cell-days (sample unit), total cell-days, proportion of positives and the total number of Cabezon caught by sample year.

Site	Year	Number of Positive Catch Cell-Days	Total Cell-Days	Proportion of Positives	Total Number of Cabezon Caught
Redfish Rocks	2011	10	65	0.154	12
	2012	4	79	0.051	4
	2013	9	28	0.321	9
	2014	7	46	0.152	10
	2015	18	57	0.316	39
	2016	1	7	0.143	3
	2017	27	56	0.482	44
	Total	**76**	**338**	**0.225**	**121**
Cape Falcon	2014	3	18	0.167	6
	2015	7	51	0.137	13
	2017	17	47	0.362	53
	Total	**27**	**116**	**0.233**	**72**
Cape Perpetua	2013	2	34	0.059	2
	2014	6	34	0.176	11
	2016	5	42	0.119	11
	2018	8	41	0.195	20
	Total	**21**	**151**	**0.139**	**44**
Cascade Head	2013	8	35	0.229	12
	2014	12	43	0.279	34
	2015	13	59	0.22	26
	2016	24	63	0.381	47
	2018	37	75	0.493	145
	Total	**94**	**275**	**0.342**	**264**

Table E4. Number of positive catch cell-days (sample unit), total cell-days, proportion of positives and the total number of Cabezon caught by sample year and season.

	Fall	Spring	Summer	Proportion of Summer to Total
Number of Positive Catch Cell-Days	100	74	44	0.20
Total Cell-Days	375	249	256	0.29
Proportion of Positives	0.27	0.30	0.17	
Total Number of Cabezon Caught	218	205	78	0.16

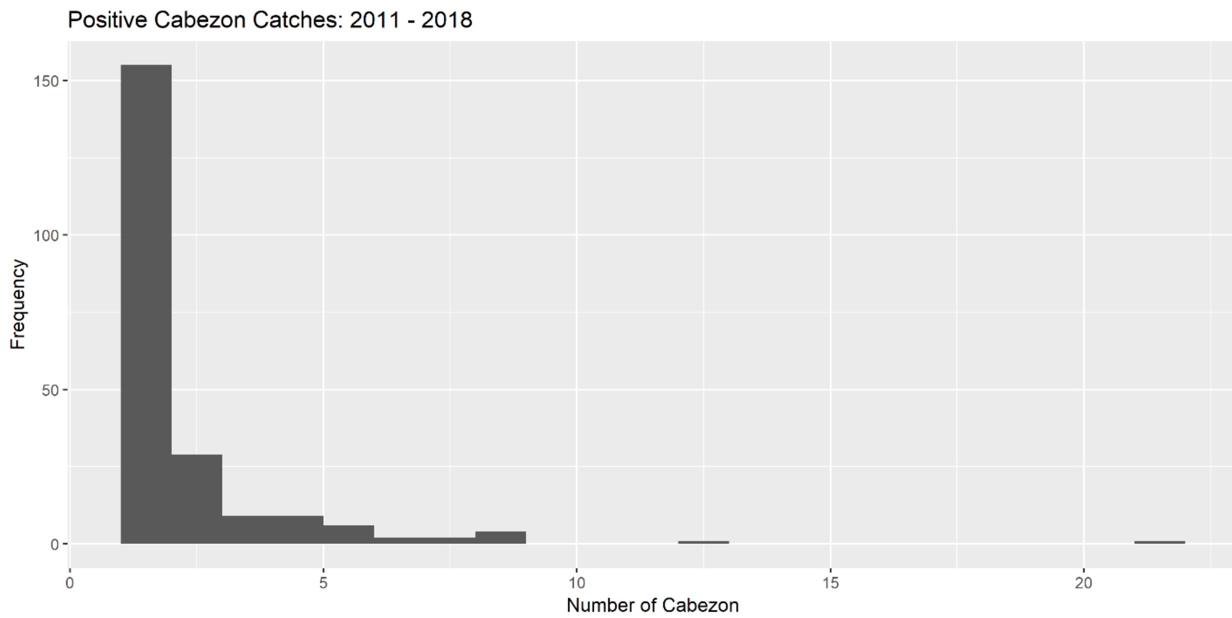


Figure E1. Histogram of positive Cabezon cell-days (sample unit) from ODFW Marine Reserves hook and line surveys.

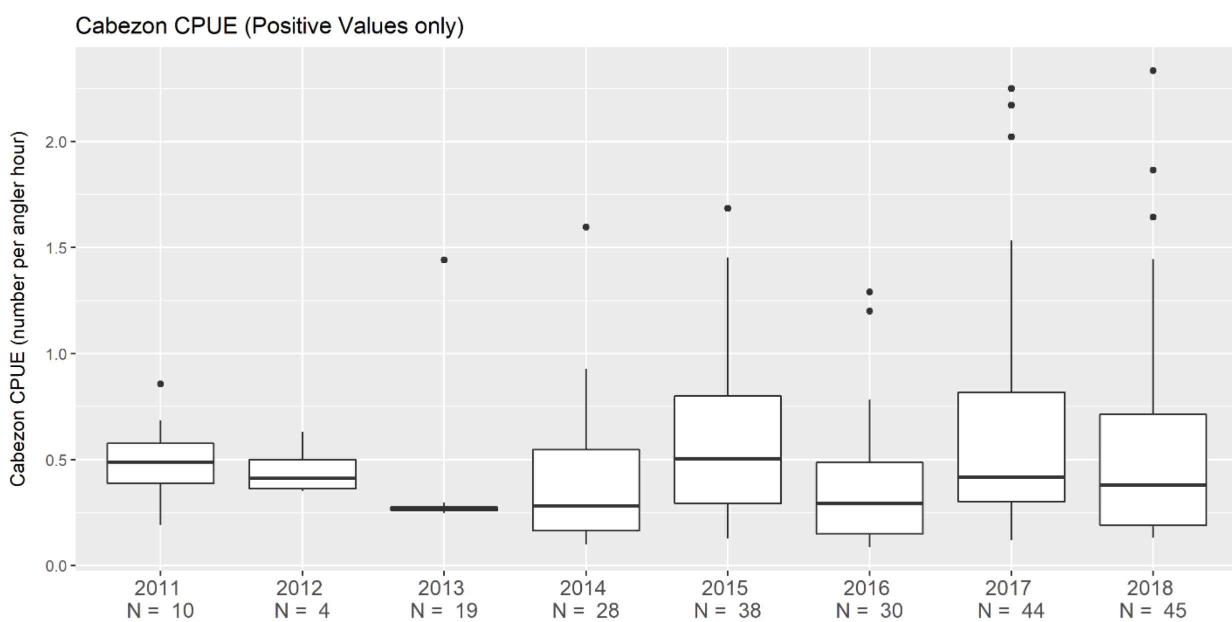


Figure E2. Raw CPUE from positive Cabezon cell-days (sample units) by year.

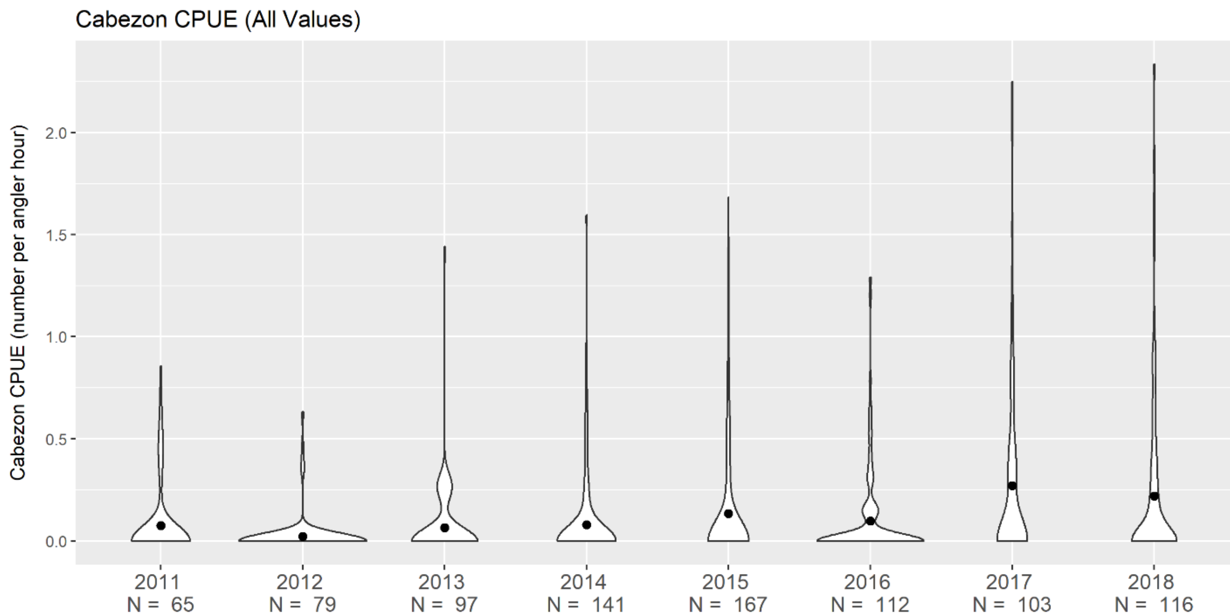


Figure E3. Raw CPUE violin plot for ODFW Marine Reserves hook and line survey.