Agenda Item H.5
Attachment 1
September 2019

DRAFT

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Assessing Cabezon (*Scorpaenichthys marmoratus*) stocks in waters off of California and Oregon, with catch limit estimation for Washington State

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DRAFT SAFE (POST-STAR)
08/05/2019

This report may be cited as:

Cope, J.M., Berger, A.M., Whitman, A.D., Budrick, J.E., Bosley, K.M., Tsou, T., Niles, C.B., Privitera-Johnson, K., Hillier, L.K., Hinton, K.E., and Wilson, M.N. 2019. Title. Pacific Fishery Management Council, Portland, OR. Available from http://www.pcouncil.org/groundfish/stock-assessments/

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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

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- <u>California</u>

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.

- <u>Oregon</u>

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.

Years	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

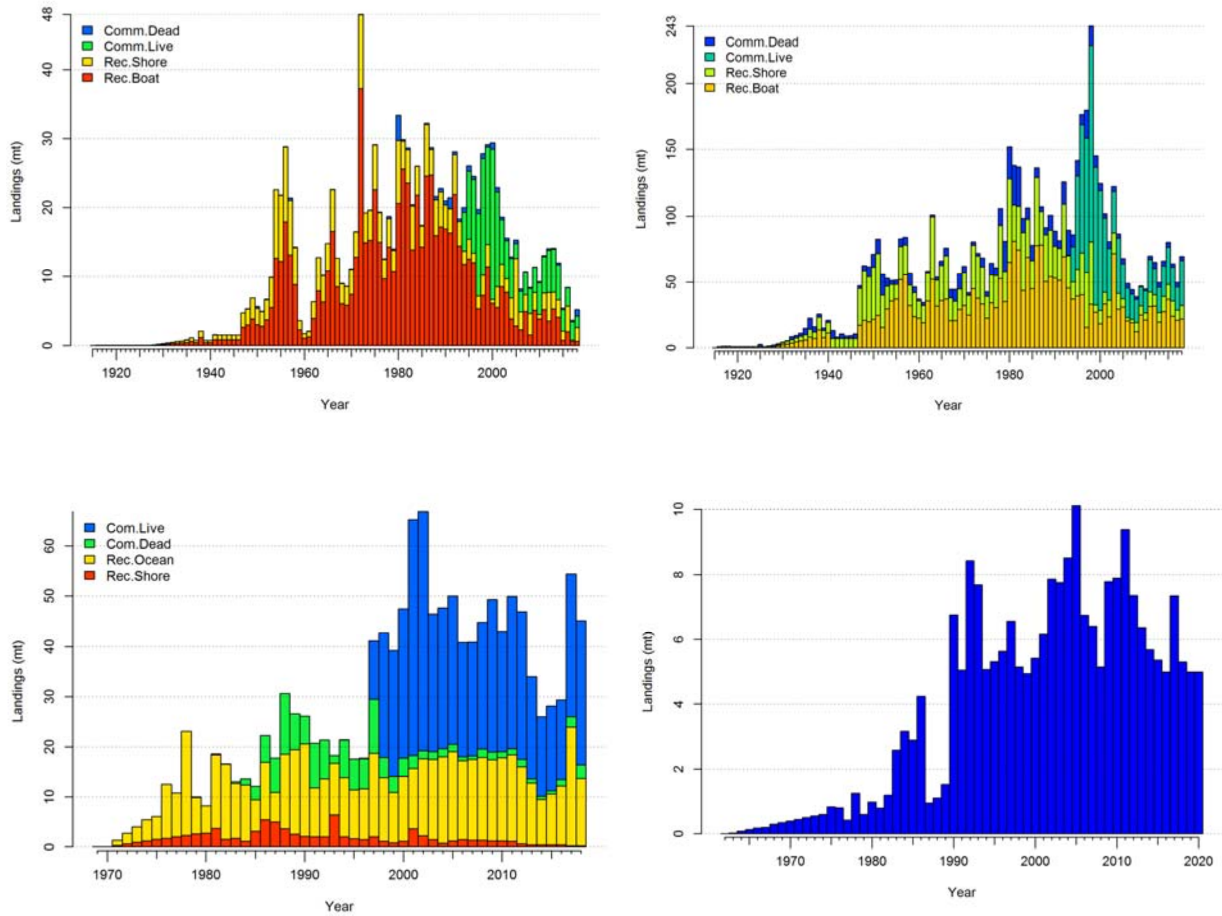


Figure ES1: Catch histories by fleet in the reference models for Southern California (upper left panel), Northern California (upper right panel) Oregon (lower left panel), and Washington (lower right panel, which includes the assumed catch for 2019 and 2020).

- 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%

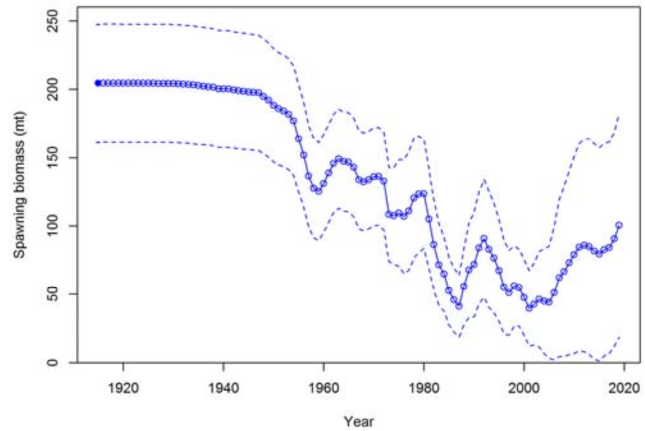
Table ES6. Recent trend in beginning year biomass and depletion for Cabezon in Northern California waters.

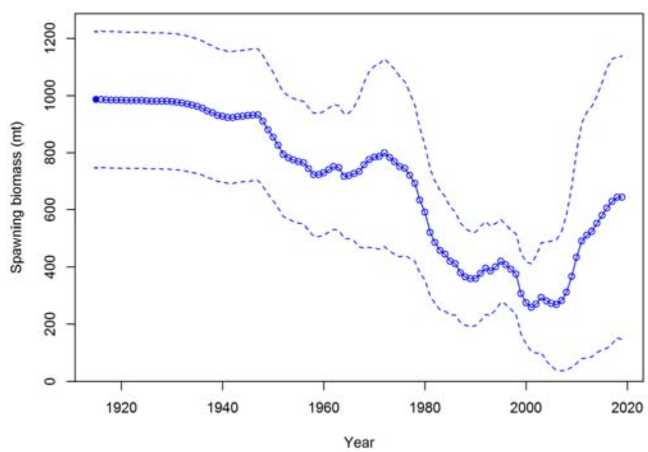
Years	Spawning Output	95% Confidence Interval	Estimated Depletion	95% Confidence Interval
2007	281	36–525	28.4%	5.5–51.4%
2008	310	39–581	31.5%	6.1–56.9%
2009	366	50–681	37.1%	7.5–66.6%
2010	433	62–805	43.9%	9.2–78.7%
2011	491	79–903	49.8%	11.4–88.2%
2012	512	81–942	51.9%	11.9–91.9%
2013	524	85–962	53.1%	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





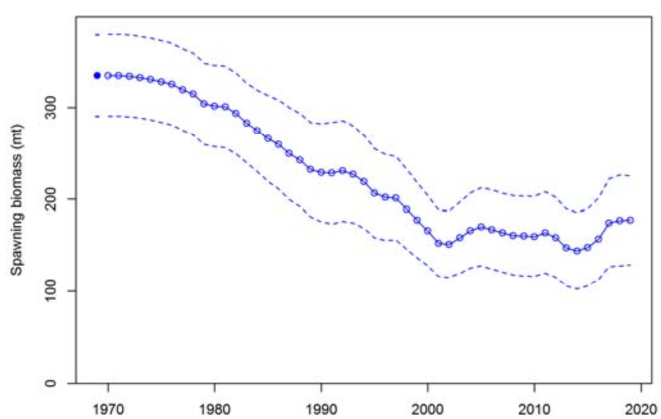


Figure ES2. Recent trends for beginning of the year spawning output (female biomass) with approximate 95% asymptotic confidence intervals (dashed lines) for Cabezon in Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel).

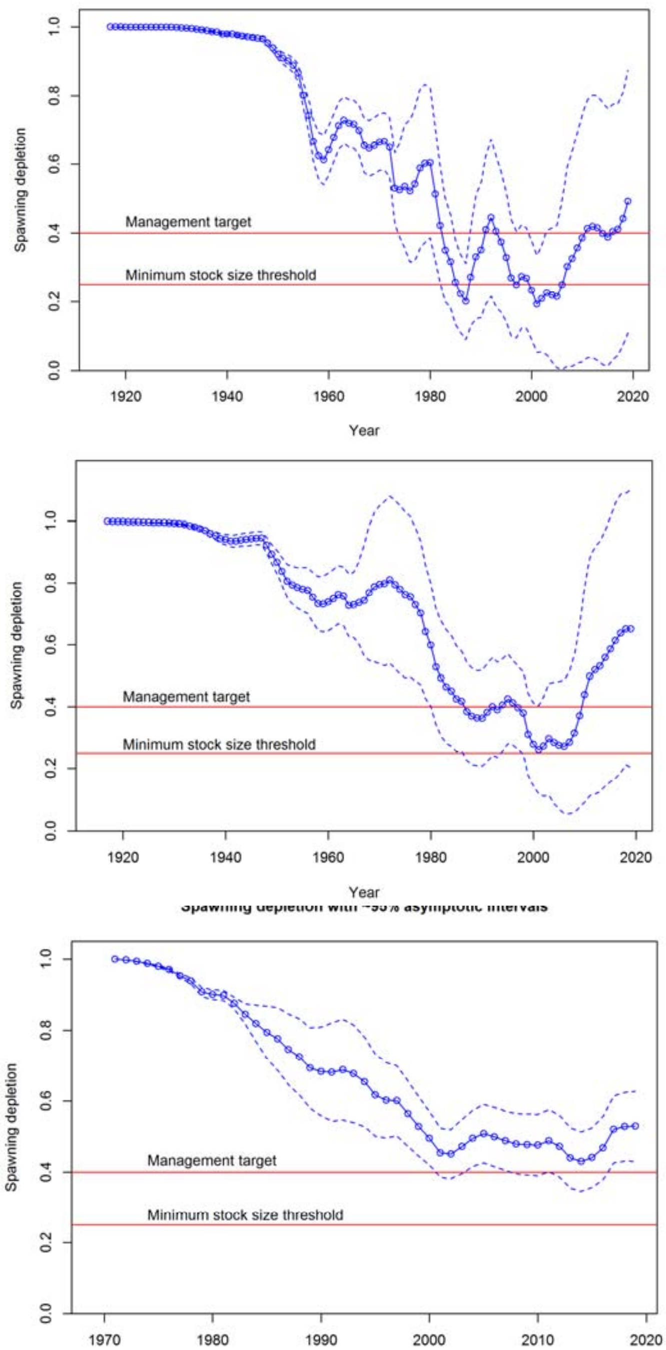


Figure ES3. Estimated relative depletion (spawning output relative to unfished spawning output) with approximate 95% asymptotic confidence intervals (dashed lines) for Cabezon in Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel).

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- 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,

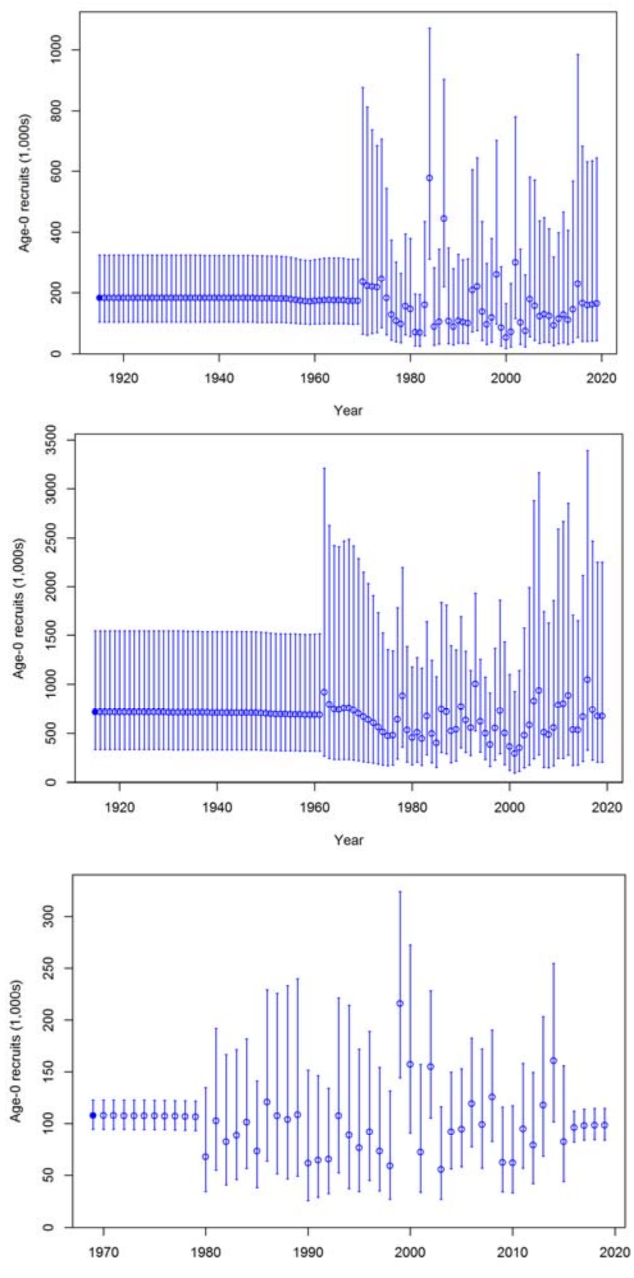

Figure ES4. Recent trend in estimated recruitment with approximate 95% asymptotic confidence intervals (bars) for Cabezon in Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel).

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

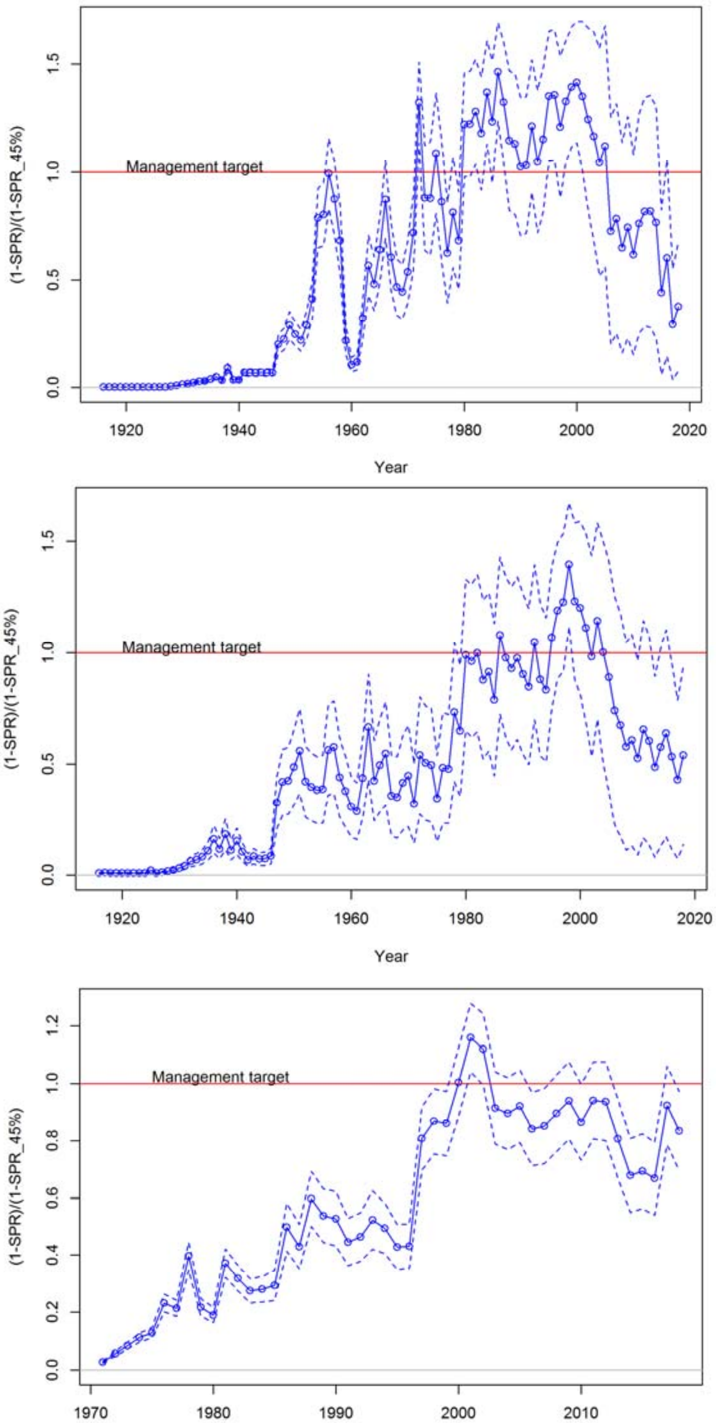

Figure ES5. Estimated spawning potential ratio (SPR) for the Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel) reference models with approximate 95% asymptotic confidence intervals. One minus SPR is plotted so that higher exploitation rates occur on the upper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

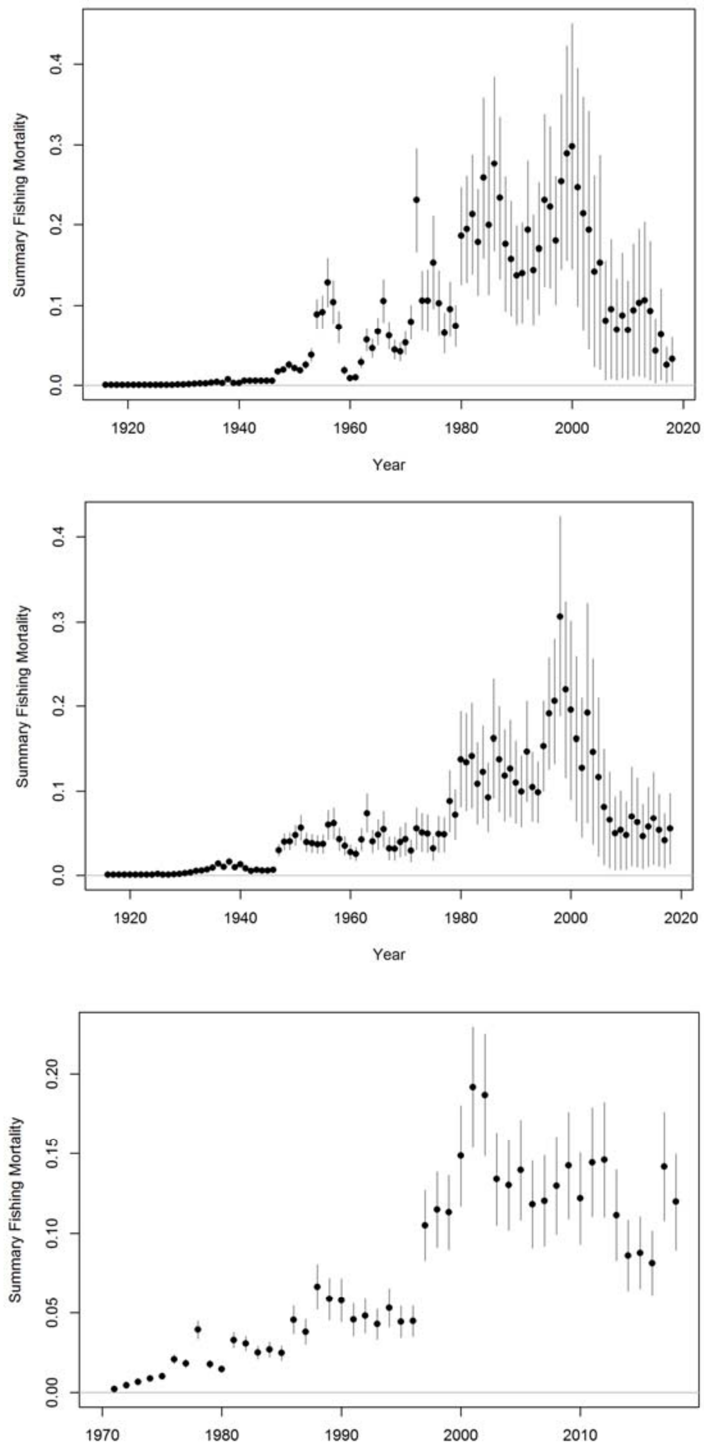

Figure ES6. Time-series of estimated summary harvest rate (total catch divided by age-2 and older biomass) for the Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel) reference models with approximate 95% asymptotic confidence intervals (grey lines).

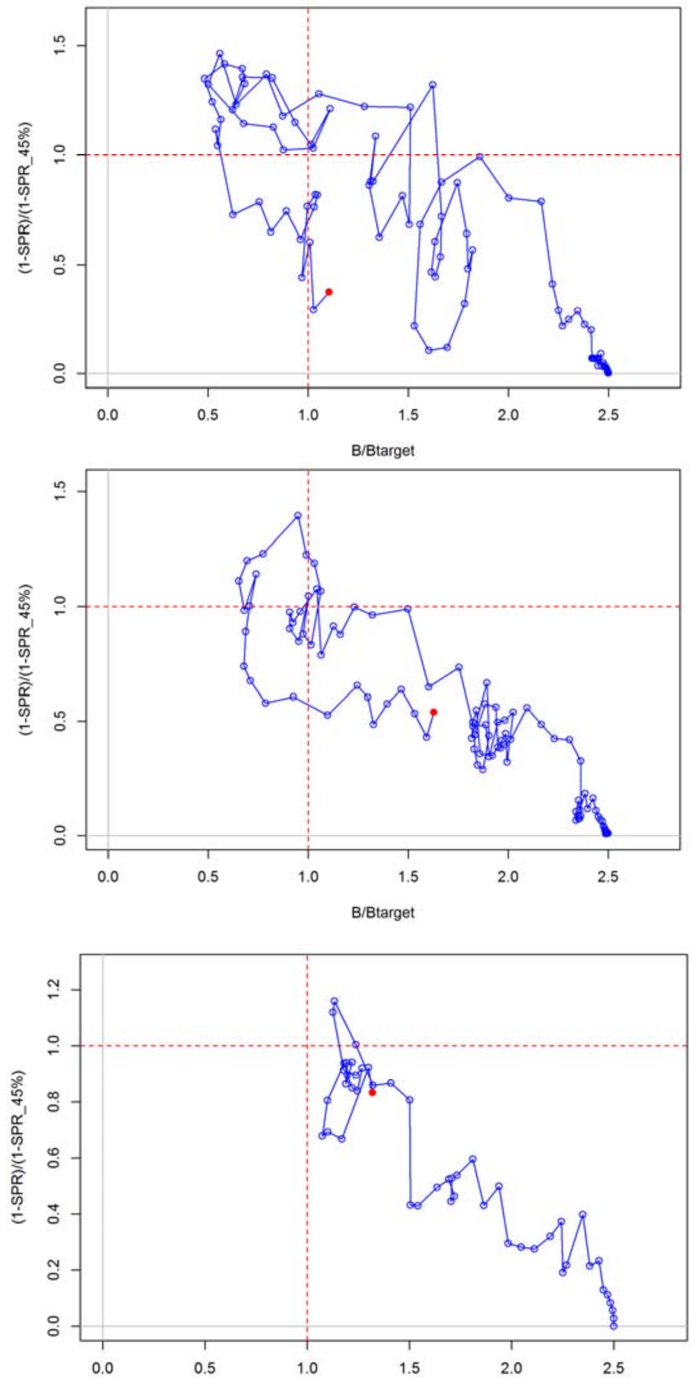

Figure ES7. Phase plot of estimated relative (1-SPR) vs. relative spawning output for the Southern California (upper panel), Northern California (middle panel) and Oregon (lower panel) base models. The relative (1-SPR) is (1-SPR) divided by 0.5 (the SPR target). Relative depletion is the annual spawning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

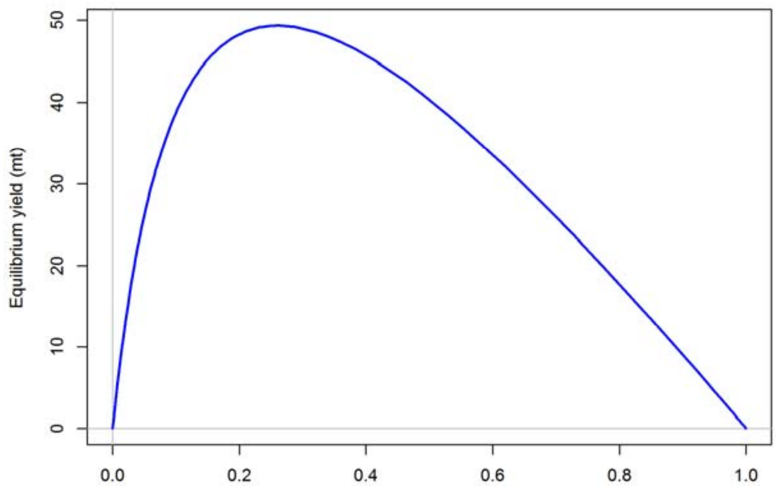

Figure ES8. Equilibrium yield curve (derived from reference point values reported in Tables 10-12, respectively) for the Southern California, Northern California and Oregon reference models. The depletion is relative to unfished spawning output. All areas have the same yield curve as it is determined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

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- 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