Agenda Item H.5
Attachment 9
September 2019

DRAFT

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Status of Cowcod (*Sebastes levis*) in 2019

Photo: R. Lea

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<u>Glossary of Acronyms:</u>

ABC: Acceptable Biological Catch
ACL: Annual Catch Limit
ACT: Annual Catch Target
CAAL: Conditional age at length
CalCOFI: California Cooperative Oceanic Fisheries Investigations
CALCOM: California Cooperative Groundfish Survey
CCGS: California Cooperative Groundfish Survey
CDFW (CDFG): California Department of Fish and Wildlife (formerly Fish and Game)
CPFV: Commercial Passenger Fishing Vessel (aka “party” or “charter” boats)
CPUE: Catch-per-unit-effort
CRFS: California Recreational Fisheries Survey
FED: Fisheries Ecology Division
INPFC: International North Pacific Fisheries Commission
LACSD: Los Angeles County Sanitation District
MRFSS: Marine Recreational Fisheries Statistics Survey
NMFS: National Marine Fisheries Service
NOAA: National Oceanic and Atmospheric Administration
NWFSC: Northwest Fisheries Science Center
OCSD: Orange County Sanitation District
ODFW: Oregon Department of Fish and Wildlife
OFL: Overfishing Limit
PacFIN: Pacific Fisheries Information Network
PFMC: Pacific Fishery Management Council
PSMFC: Pacific States Marine Fisheries Commission
RecFIN: Recreational Fisheries Information Network
SPR: Spawning Potential Ratio
SS: Stock Synthesis
STAR: Stock Assessment Review (Panel)
STAT: Stock Assessment Team
SWFSC: Southwest Fisheries Science Center
WCGBT: NWFSC West Coast Groundfish Bottom Trawl (WCGBT) Survey.
WCGOP: West Coast Groundfish Observer Program
YOY: Young-of-the-year

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Executive Summary

Stock

This is an assessment of *Sebastes levis* ("Cowcod") in the Southern California Bight (SCB), defined as U.S. waters off California and south of Point Conception (34° 27' North latitude). Waters north and south of the SCB are not considered in the assessment due to sparse data. A separate analysis to estimate sustainable yield for areas north of Point Conception is included as an appendix. Hess et al. (2014) used genetic tools to study cowcod population structure from California to Oregon. Specifically, they tested the hypothesis that a phylogeographic boundary exists at Point Conception. Their results supported a hypothesis of two primary lineages with a geographic boundary falling in the vicinity (slightly south) of Point Conception. Both lineages co-occur in the SCB with no clear pattern of depth stratification or spatial structure within the Bight. Within lineages, there is evidence for considerable gene flow across the Point Conception boundary. Cowcod found north of Point Conception consist primarily of a single lineage, also found in northern areas of the SCB. No information is available regarding dispersal between U.S. and Mexican waters.

Catches

Commercial catches of cowcod declined in the 1930s and 1940s due to changes in targeting (effort shifts to shark and sardine fisheries) and the Second World War. Post-war increases in commercial and recreational landings through the early 1980s were followed by rapid declines in catch through the 1990s (Figure A). The stock was declared overfished in 2000 and retention of cowcod was prohibited from January 2001 until January 2011. Since then, a small quota has been allocated to the trawl fishery as part of the Pacific Groundfish Trawl Rationalization Program, but retention remains prohibited in all other sectors. Recreational and commercial catch estimates in this assessment are identical to those in the previous assessment for years prior to 2001. Commercial catches since 2001 and recreational catches since 2005 were updated with the latest available estimates, resulting in only minor changes since the last assessment. Reported total annual removals for cowcod over the last ten years have not exceeded 2 mt, averaging 1.3 mt per year (Table A).

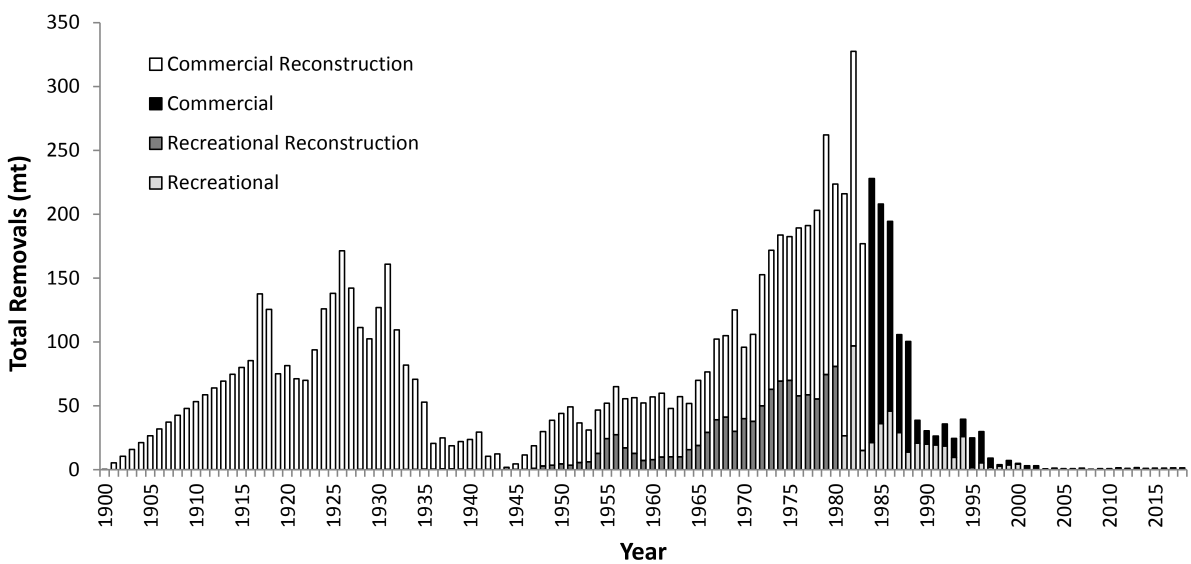

Figure A. Estimated commercial and recreational removals of cowcod in the Southern California Bight, 1900-2018.

Table A: Recent cowcod removals (mt) in the Southern California Bight. Sources: RecFIN (recreational) and WCGOP (GEMM Report). Commercial catch in 2018 was estimated at 1 mt for the assessment.

Year	Recreational	Commercial	Total
2009	0.21	0.66	0.86
2010	0.40	0.42	0.81
2011	1.28	0.17	1.45
2012	0.72	0.32	1.04
2013	1.38	0.41	1.79
2014	0.66	0.43	1.09
2015	0.44	0.97	1.41
2016	0.68	0.61	1.29
2017	0.51	0.95	1.46
2018	0.58	1.00	1.58

Data and assessment

The previous full assessment of cowcod was based on a Bayesian surplus production model (XDB-SRA; Dick and MacCall 2013). The 2019 assessment uses a statistical catch at age model (Stock Synthesis, version 3.30.13.09) that is fit to six fishery-independent data sources: four time series of relative abundance (CalCOFI larval abundance survey, Sanitation District trawl surveys, NWFSC West Coast Groundfish Bottom Trawl (WCGBT) survey, and NWFSC Hook-and-Line survey), as well as two visual survey estimates of absolute abundance conducted by the SWFSC in 2002 and 2012. The 2002 abundance estimate is based on a SWFSC visual (submersible) survey of rocky habitat in the Cowcod Conservation Areas (CCA), and is related to cowcod abundance in the SCB using a prior distribution for catchability. The 2012 abundance estimate is new to this assessment, and is based on a SWFSC visual (ROV) survey stratified by habitat and depth, both inside and outside the CCA. The model is also fit to length composition data from the recreational fishery, NWFSC WCGBT survey, NWFSC Hook-and-Line survey, and Sanitation District surveys. Age composition data from the commercial and recreational fisheries, as well as from the NWFSC WCGBT and Hook-and-Line surveys were included by length bin (conditional age-at-length) to help inform growth. Recruitment deviations were not estimated, as individual year-class strengths were not discernable given the data and model.

The previous assessment (Dick and MacCall, 2013) found increasing trends in all four fishery-independent time series. Updates of these indices do not show increasing trends after 2013 in all cases, but the current base model is most consistent with the high-productivity alternatives presented in the 2013 assessment, largely due to a higher estimated rate of natural mortality ($M = 0.088$ [yr^{-1}], versus $M = 0.055$ in previous assessments). Age data in the assessment are limited in sample size and temporal coverage, with evidence of bias between readers for ages from the fishery (1970s and 1980s) and more recent NWFSC surveys (2003 to 2018). The two SWFSC visual surveys provide independent estimates of cowcod biomass in 2002 and 2012. These estimates are consistent with model predictions based on the other data sets alone (i.e. when excluding the visual surveys from the likelihood). Therefore, while the surveys themselves are not informative about relative stock status, they provide valuable information about population scale. Very little information is available about trends in recent stock abundance from fishery-dependent sources due to regulatory restrictions (retention being prohibited in most sectors since 2001).

Stock biomass

The base case model suggests that spawning output initially decreased until the early 1930s, then increased as effort targeting cowcod declined. The model also suggests a rapid decline in spawning output from the 1970s to mid-1980s, falling below the Minimum Stock Size Threshold (MSST; 25% of unfished spawning output) from 1983 through 2000, dropping to a low of 9% of unfished biomass in 1989. Since then, the base model suggests the stock has increased to 57% of unfished equilibrium biomass (SB_0) in 2019, with a 95% asymptotic interval (hereafter "interval") of 42% to 72% (Table B, Figures B and C). The 2013 assessment predicted stock status in 2013 to be 34% of unfished biomass, with a 95% credible interval of 15%-66%. For comparison, the current base model estimates stock depletion in 2013 was at 47% of unfished (i.e. within the range of uncertainty in the 2013 assessment), but predicts a faster rate of increase due to changes in estimated productivity of the stock (e.g. natural mortality, as noted above). Unfished spawning output in the base model is 285 billion eggs, with a 95% interval of 235-334. Unfished age 10+ biomass (males and females combined) in 2019 is estimated at 3564 mt (95% interval of 2939-4189 mt).

Table B: Recent trend in spawning output and stock depletion (percentage of unfished spawning output)

Year	Spawning Output (eggs x 10^9)	95% Asymptotic Interval	Estimated Depletion (%)	95% Asymptotic Interval
2007	103	72–134	36.2	23.2–49.2
2008	108	76–140	37.9	24.6–51.3
2009	113	81–145	39.7	26.1–53.4
2010	118	86–151	41.5	27.6–55.4
2011	123	90–156	43.3	29.2–57.4
2012	128	95–161	45.1	30.8–59.4
2013	133	100–166	46.9	32.4–61.3
2014	138	105–172	48.6	34.0–63.2
2015	143	110–177	50.4	35.7–65.0
2016	148	115–181	52.1	37.4–66.8
2017	153	120–186	53.8	39.0–68.6
2018	158	125–191	55.5	40.7–70.3
2019	163	130–195	57.1	42.4–71.9

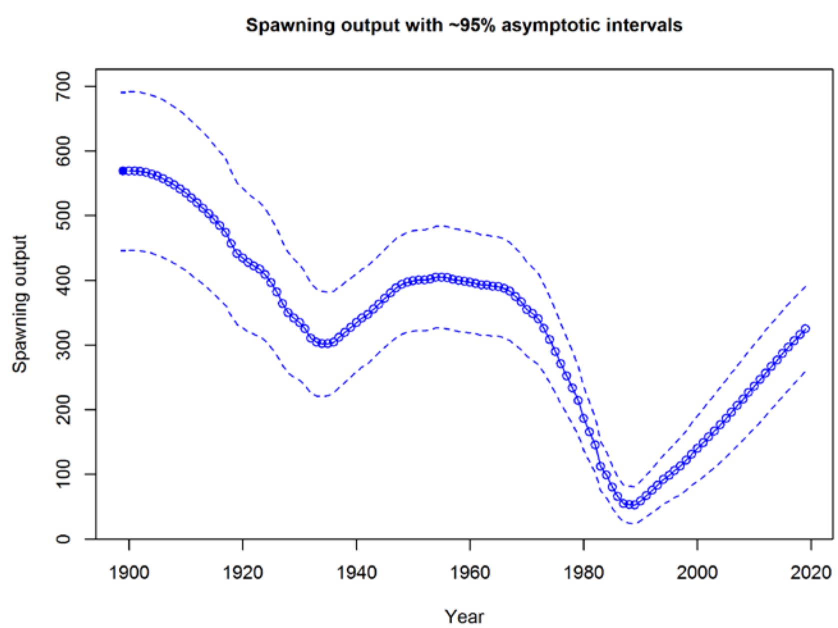

Figure B: Spawning output trajectory with asymptotic 95% intervals. Spawning output as shown is twice the actual value due to the use of a single-sex model.

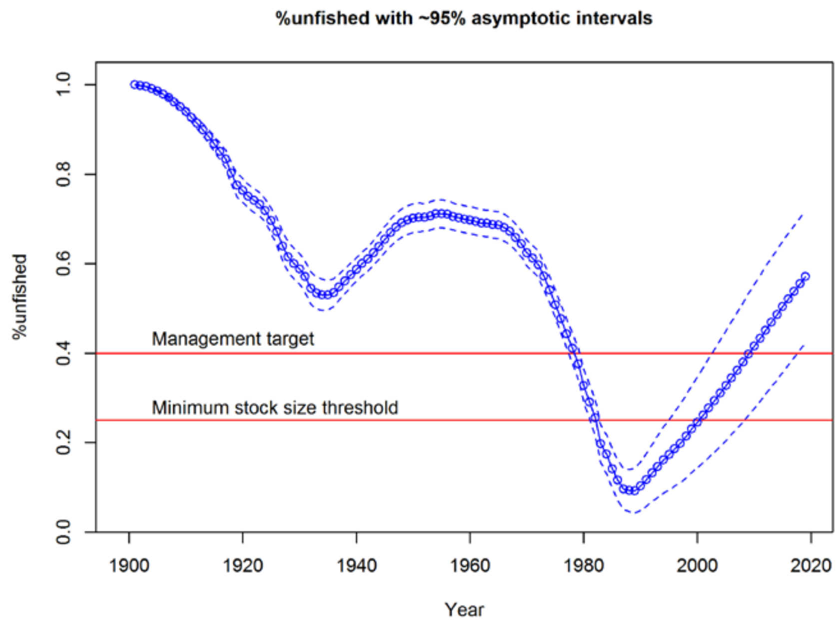

Figure C. Spawning output relative to unfished spawning output (aka "depletion," solid line) with 95% intervals (dashed lines) for the base case assessment model.

Recruitment

Attempts to estimate annual recruitment deviations were not successful, so the base model assumes deterministic recruitment (Figure D, Table C) following a Beverton-Holt stock recruitment relationship with steepness fixed at 0.72 (the prior mean). Alternative, 3-parameter stock-recruitment relationships were explored as part of the transition from the XDB-SRA model (see section 2.2.4). Unfished recruitment in the base model is estimated at 180000 age-0 fish.

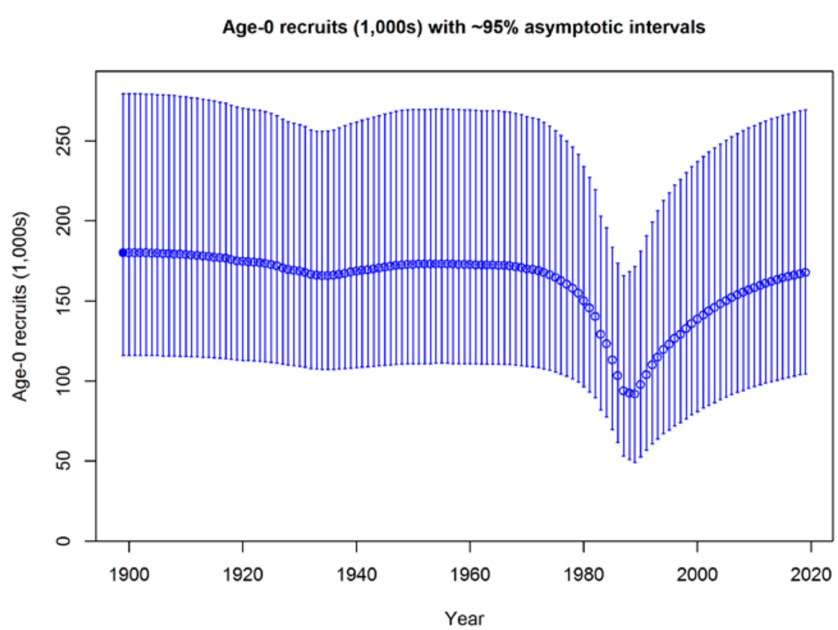

Figure D: Time series of deterministic recruitment with 95% asymptotic confidence intervals.

Table C: Recent deterministic recruitment estimates from the 2019 base model.

Year	Recruitment	95% Asymptotic Interval
2007	154	93–254
2008	155	94–256
2009	157	95–258
2010	158	96–260
2011	160	98–261
2012	161	99–262
2013	162	100–264
2014	163	101–265
2015	164	101–266
2016	165	102–267
2017	166	103–268
2018	167	104–269
2019	168	104–269

Exploitation status

The annual (equilibrium) SPR harvest rate (1-SPR) for cowcod has been less than 4% of target for over a decade (Table D). Historically, the SPR harvest rate reached target levels by 1920-1930, and later regularly exceeded the target for roughly 30 years, from the mid-1960s to the mid-1990s (Figure E). As a percentage of age-10+ biomass (i.e. exploitation rate), harvest rates peaked at around 40% in the 1980s, but have declined to levels below 1% since retention of cowcod was prohibited in 2001 (Figure F). Exploitation history relative to the target SPR harvest rate (0.5) and the target spawning output (40% of unfished spawning output) is shown in Figure G. The estimated $SPR_{50\%}$-based proxy for maximum sustainable yield (MSY) is 73 mt per year, which corresponds to an annual harvest rate of roughly 4% of age 10+ biomass (Figure H, Table E).

Table D. Recent trend in spawning potential ratio (entered as 1-SPR / 1-SPR50%) and Harvest Rate (catch / age 10+ biomass) for cowcod.

Years	Estimated (1-SPR)/(1-SPR_50%) (%)	95% Asymptotic Interval	Harvest Rate (proportion)	95% Asymptotic Interval
2007	3.7	2.14–5.18	0.001	0.001–0.001
2008	1.3	0.81–1.87	0	0.000–0.000
2009	2.1	1.26–2.94	0.001	0.000–0.001
2010	1.9	1.19–2.64	0.001	0.000–0.001
2011	3.3	2.13–4.47	0.001	0.001–0.001
2012	2.3	1.47–3.10	0.001	0.000–0.001
2013	3.8	2.49–5.12	0.001	0.001–0.001
2014	2.2	1.47–3.02	0.001	0.000–0.001
2015	2.8	1.80–3.71	0.001	0.001–0.001
2016	2.5	1.66–3.32	0.001	0.001–0.001
2017	2.7	1.80–3.60	0.001	0.001–0.001
2018	2.9	1.93–3.77	0.001	0.001–0.001
2019	3.6	2.44–4.67	0.001	0.001–0.001

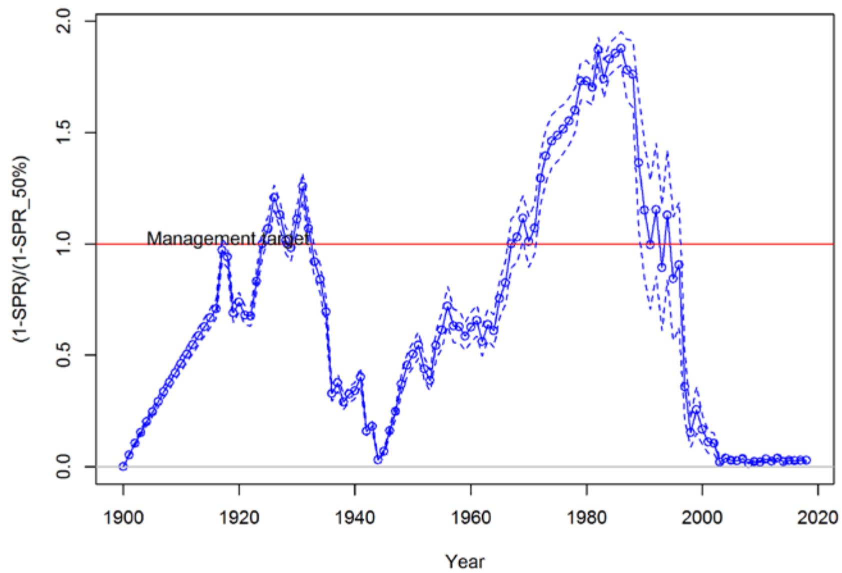

Figure E. Estimated spawning potential ratio (SPR) for the base case model with approximate 95% asymptotic confidence intervals. One minus SPR is plotted so that higher exploitation rates occur on the upper portion of the y-axis. The management target is plotted as red horizontal line and values above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

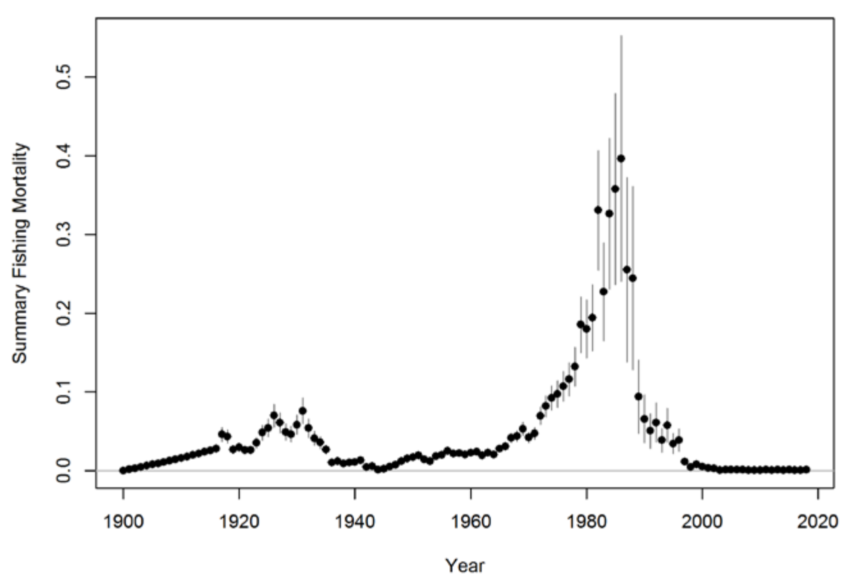

Figure F. Time-series of estimated summary harvest rate (total catch divided by age-10 and older biomass) for the base case model with approximate 95% asymptotic confidence intervals (grey lines).

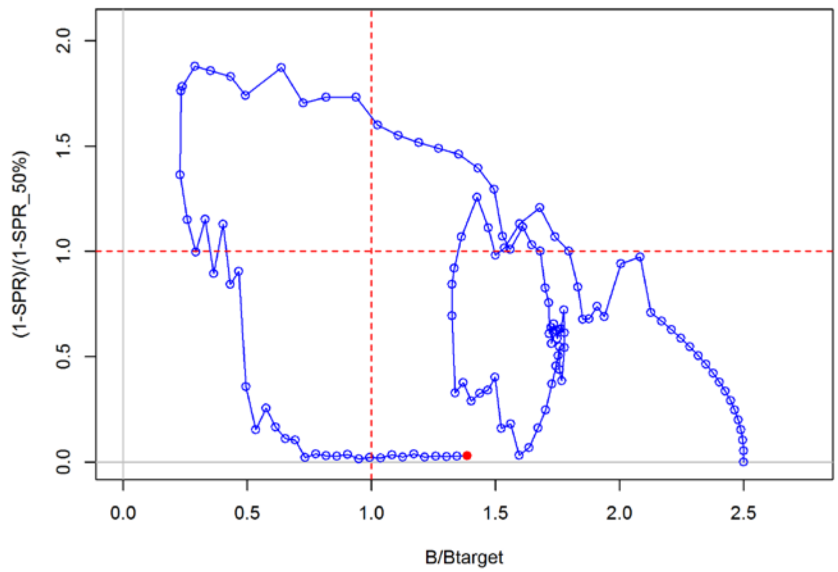

Figure G. Phase plot of estimated relative (1-SPR) vs. relative spawning output for the base case model. The vertical axis is "relative (1-SPR)" or (1-SPR) divided by 0.5 (the SPR target). Relative depletion (B/Btarget) is the annual spawning output divided by the spawning output corresponding to 40% of the unfished spawning output. The red point indicates the year 2018.

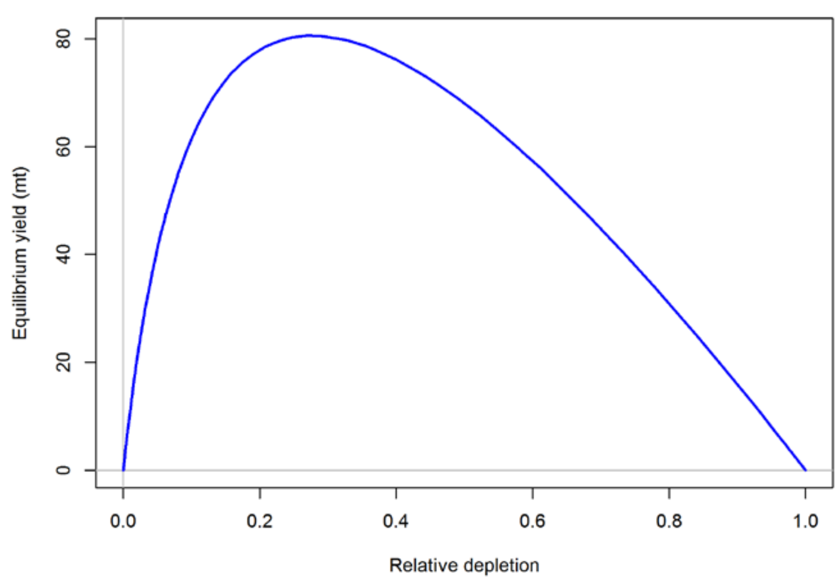

Figure H. Equilibrium yield curve (derived from reference point values reported in Table E) for the base case model. Depletion is relative to unfished spawning output.

Ecosystem considerations

No environmental correlations or food web considerations were considered explicitly in the model.

Reference points

Reference points and management quantities for the 2019 cowcod base case model are listed in Table E. In 2019, spawning output relative to unfished spawning output ("depletion") is estimated at 57% (~95% asymptotic intervals = 42%-72%). Unfished spawning output was estimated at 285 billion eggs (~95% asymptotic intervals = 235-334; Table E), and spawning output at the beginning of 2019 was estimated to be 163 billion eggs (~95% asymptotic intervals = 130-195). The target spawning output ($SB_{40\%}$) is 114 billion eggs, compared to an equilibrium spawning output of 127 billion eggs associated with the proxy $SPR_{50\%}$ harvest rate. Yield at the SPR proxy biomass and harvest rate (i.e. proxy MSY) is 73 mt per year (~95% asymptotic intervals = 63-83 mt), corresponding to a harvest of 4.3% of age 10+ biomass per year.

Table E. Summary of reference points for the base case model.

Quantity	Estimate	95% Asymptotic Interval
Unfished Spawning Output (eggs x 10^9)	285	235–334
Unfished Age 10+ Biomass (mt)	3,564	2,939–4,189
Spawning Output in 2019 (eggs x 10^9)	163	130–195
Unfished Recruitment (R_0, 1000s of age-0 fish)	180	100–260
Depletion (2019 spawning output / unfished spawning output, %)	57	42–72
Reference Points Based $SB_{40\%}$		
Proxy Spawning Biomass ($SB_{40\%}$)	114	94–134
SPR resulting in $SB_{40\%}$	0.458	0.458–0.458
Exploitation Rate Resulting in $SB_{40\%}$	0.05	0.036–0.064
Yield with SPR Based On $SB_{40\%}$ (mt)	76	66–87
Reference Points based on SPR proxy for MSY		
Proxy spawning biomass (SPR_{50})	127	105–149
SPR_{50}	0.5	NA
Exploitation rate corresponding to SPR_{50}	0.043	0.031–0.055
Yield with SPR_{50} at SB_{SPR} (mt)	73	63–83
Reference points based on estimated MSY values		
Spawning biomass at MSY (SB_{MSY})	79	63–95
SPR_{MSY}	0.347	0.337–0.358
Exploitation rate corresponding to SPR_{MSY}	0.074	0.051–0.098
MSY (mt)	81	69–92

Management performance

Total mortality of cowcod has been well below catch targets and limits since 2009 (Table F).

Table F. Annual estimates of total mortality, overfishing limit (OFL), acceptable biological catch (ABC), annual catch limit (ACL), and annual catch target (ACT) for cowcod, 2009-2018. Units are metric tons for total mortality and harvest specifications.

Year	OFL	ABC	ACL	ACT	Total Mortality	Source of Total Mortality Estimate
2018	71	64	10	4	1.58	Approximation (approved by GMT)
2017	70	63	10	4	1.46	WCGOP GEMM Report + RecFIN
2016	68	62	10	--	1.29	WCGOP GEMM Report + RecFIN
2015	67	60	10	--	1.41	WCGOP GEMM Report + RecFIN
2014	12	9	3	--	1.09	WCGOP GEMM Report + RecFIN
2013	11	9	3	--	1.79	WCGOP GEMM Report + RecFIN
2012	13	8	3	--	1.04	WCGOP GEMM Report + RecFIN
2011	13	8	3	--	1.45	WCGOP GEMM Report + RecFIN
2010	--	14	4*	--	0.81	WCGOP GEMM Report + RecFIN
2009	--	13	4*	--	0.86	WCGOP GEMM Report + RecFIN

* The OFL/ABC/ACL framework was adopted in 2011; values in ACL column for 2009-10 are Optimum Yields.

Unresolved problems and major uncertainties

A major issue and uncertainty associated with the cowcod assessment is the lack of data, particularly age data, adequate to estimate recruitment deviations, growth, and natural mortality. The assessment would greatly benefit from improved collection of age data from both commercial and recreational fisheries, as well as from ongoing fishery-independent surveys. These data are needed to improve our understanding of these processes, all of which influence estimates of productivity and yield. Validation of current ageing methods is also needed for this species.

The base model estimates current spawning output to be above target in 2019, and therefore estimates of OFL and ABC may exceed the SPR proxy for MSY (i.e. >73 mt) in the short term. Uncertainty in current stock status and productivity is greatly underestimated by the base model due to lack of sufficient information in estimating natural mortality, the form and parameters of the stock recruitment relationship, recruitment variability, and historical fishery selectivity. As noted in the main text, catch uncertainty affects the precision of population scale (and therefore yield), and is not accounted for in the current assessment (see research recommendations). Therefore, the STAT recommends that target yields be set well below the MSY proxy until data become available to better inform stock productivity and status.

Decision table

Projections of OFL (mt), ABC (mt), age 10+ biomass (mt), spawning output (billions of eggs), and depletion (% of unfished spawning output) are shown for the default harvest control rule in Table G. Catch estimates for 2019 and 2020 are based on GMT recommendations (M. Mandrup, CDFW; pers. comm.), with 0.6 mt for commercial and 2.5 mt for recreational fleets. Projections assume a constant allocation among fleets equal to the recommended catch for 2019 and 2020 (19.35% commercial, 80.65% recreational) for 2021 and beyond.

Table G. Projection of OFL, assumed default harvest control rule catch (ABC = ACL when stock is above 40% SSB_0), age 10+ biomass, spawning output and depletion using the cowcod base case model with 2019-2020 catches set equal to recommendations from the GMT. ABC catches are based on a tier 2 sigma value of 1.0 with a 'p-star' value of 0.45. *Catches for 2019 and 2020 recommended by the STAR panel GMT representative.

Year	Predicted OFL (mt)	ABC Catch (mt)	Age 10+ biomass (mt)	Spawning Output (eggs x 10^9)	Depletion (%)
2019	90.7	3.1*	2125	325	57.1%
2020	92.9	3.1*	2180	334	58.7%
2021	95.0	83.2	2233	343	60.3%
2022	93.9	81.5	2210	340	59.7%
2023	93.0	79.9	2188	337	59.2%
2024	92.0	78.4	2166	334	58.7%
2025	91.2	76.9	2146	331	58.1%
2026	90.4	75.5	2127	328	57.6%
2027	89.6	74.3	2111	325	57.1%
2028	89.0	73.1	2095	323	56.7%
2029	88.5	71.9	2082	321	56.3%
2030	88.0	70.9	2071	319	56.0%

High and low states of nature for a decision table (Table H) were agreed upon during the STAR panel review. The low state of nature set commercial length at 50% selectivity ($L_{50\%}$) at 35 cm with an M of 0.055 (the value of M used in the previous assessment) and the high state of nature at a selectivity of 55 cm with M = 0.098 (the median of the Hamel prior on M given a maximum age of 55). The base model assumed a commercial fleet length at 50% selectivity of 45.6 cm, equal to the maturity ogive, and estimated M = 0.088. Alternative management strategies (catch streams) were identified as the default ABC harvest control rule under each state of nature. Proxy MSY yields vary by state of nature. The base model's SPR proxy for MSY is 73 mt, while the proxy MSY yields given the low and high states of nature are 58 mt and 86 mt, respectively.

Table H. Decision table summarizing 12-year projections (2019 – 2030) for cowcod according to three alternative states of nature varying natural mortality and commercial fishery selectivity (length at 50% selectivity). 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 were proposed by the GMT representative. Catch is in mt, spawning output is in billions of eggs, and depletion is the percentage of spawning output relative to unfished spawning output. Outcomes below target spawning output (40% of unfished spawning output) are shaded in gray.

			State of nature					
			Low		Base case		High	
			M=0.055, $L_{50\%}$=35 cm		M=0.088, $L_{50\%}$=45.6 cm		M=0.098, $L_{50\%}$=55cm	
Management decision	Year	Catch	Spawning Output	Depletion	Spawning Output	Depletion	Spawning Output	Depletion
Low Catch	2019	3.1	308	35.5%	325	57.1%	422	75.6%
	2020	3.1	319	36.8%	334	58.7%	428	76.7%
	2021	45.7	330	38.1%	343	60.3%	434	77.8%
	2022	45.8	335	38.6%	346	60.7%	434	77.8%
	2023	45.9	339	39.1%	348	61.1%	434	77.7%
	2024	45.9	343	39.6%	350	61.4%	433	77.6%
	2025	45.9	347	40.0%	351	61.7%	432	77.4%
	2026	45.8	351	40.5%	353	61.9%	431	77.2%
	2027	45.7	354	40.9%	354	62.1%	429	77.0%
	2028	45.5	358	41.2%	355	62.3%	428	76.7%
	2029	45.4	361	41.6%	355	62.5%	427	76.5%
	2030	45.3	364	42.0%	356	62.6%	425	76.2%
Base Catch	2019	3.1	308	35.5%	325	57.1%	422	75.6%
	2020	3.1	319	36.8%	334	58.7%	428	76.7%
	2021	83.2	330	38.1%	343	60.3%	434	77.8%
	2022	81.5	329	38.0%	340	59.7%	429	76.9%
	2023	79.9	328	37.8%	337	59.2%	423	75.9%
	2024	78.4	326	37.6%	334	58.7%	418	74.9%
	2025	76.9	324	37.3%	331	58.1%	412	73.9%
	2026	75.5	321	37.0%	328	57.6%	407	72.9%
	2027	74.3	318	36.7%	325	57.1%	401	71.9%
	2028	73.1	315	36.3%	323	56.7%	396	71.0%
	2029	71.9	312	36.0%	321	56.3%	391	70.1%
	2030	70.9	309	35.6%	319	56.0%	386	69.2%
High Catch	2019	3.1	308	35.5%	325	57.1%	422	75.6%
	2020	3.1	319	36.8%	334	58.7%	428	76.7%
	2021	128.4	330	38.1%	343	60.3%	434	77.8%
	2022	123.5	322	37.2%	334	58.7%	422	75.6%
	2023	119.0	314	36.2%	325	57.1%	410	73.5%
	2024	114.9	306	35.2%	316	55.5%	399	71.6%
	2025	111.0	297	34.2%	307	54.0%	389	69.8%
	2026	107.5	288	33.2%	299	52.5%	380	68.1%
	2027	104.3	279	32.1%	291	51.1%	372	66.6%
	2028	101.3	270	31.1%	283	49.7%	364	65.3%
	2029	98.5	261	30.1%	276	48.5%	357	64.1%
	2030	96.0	252	29.1%	269	47.3%	351	63.0%

Scientific uncertainty

The estimated asymptotic standard error of the natural logarithm of spawning output in 2018 was 0.11, although this estimate of uncertainty is biased low (see "Unresolved problems and major uncertainties" section). ABC catches in the current draft are based on a tier 2 sigma value of 1.0 with a 'p-star' value of 0.45.

Research and data needs

Specific recommendations for the next cowcod assessment:

1. Evaluating how to structure the NWFSC Hook-and-Line survey index given its expansion into the CCA, also independent analysis of information content in NWFSC Hook-and-Line survey.
2. There are a number of improved data collection efforts that would benefit the next assessment of cowcod:
    - Continue to conduct the NWFSC Hook-and-Line survey which was an important source of fishery independent data for cowcod.
    - Repeated (although not necessarily annual) absolute abundance estimates for cowcod from visual surveys are important to understanding the stock size and status of the stock.
    - Given the lack of biological data for cowcod, it is critical to improve and expand collection of length and age data for fishery and fishery independent data sources.
    - The majority of ages available for cowcod were read by a single age reader. As data collection increases having additional age double reads and age validation information would be beneficial.
    - Rockfish species, particularly in southern California waters, have been observed to produce multiple broods within a single year. Collecting biological data to better understand the potential fecundity for cowcod across size and is important to understanding the reproductive potential of the population.
3. Increased spatio-temporal sampling around Pt Conception to identify stock boundaries.

General recommendations for all assessments:

1. Continued and improved data collection for West Coast groundfish stocks. The NWFSC Hook-and-Line survey offers important data on species that may be infrequently encountered by the NWFSC WCGBTS.
2. Examine uncertainties around historical catch data and methods for incorporating into the assessment.
3. Explore alternate stock recruitment relationships.

Table I. Summary table of the base model results. *OFLs and ACLs prior to 2011 are ABC and OY estimates, respectively.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Estimated total catch (mt)	0.86	0.81	1.45	1.04	1.79	1.09	1.41	1.29	1.46	1.58	NA
OFL (mt)	13*	14*	13	13	11	12	67	68	70	71	
ACL (mt)	4*	4*	3	3	3	3	10	10	10	10	
1-SPR	0.011	0.010	0.017	0.011	0.019	0.011	0.014	0.012	0.014	0.014	NA
Exploitation rate (catch/ age 10+ biomass)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA
Age 10+ biomass (mt)	1510	1574	1639	1702	1765	1827	1888	1949	2009	2067	2125
Spawning Output	113	118	123	128	133	138	143	148	153	158	163
~95% Confidence Interval	81–145	86–151	90–156	95–161	100–166	105–172	110–177	115–181	120–186	125–191	130–195
Recruitment	157	158	160	161	162	163	164	165	166	167	168
~95% Confidence Interval	95–258	96–260	98–261	99–262	100–264	101–265	101–266	102–267	103–268	104–269	104–269
Depletion (%)	39.7	41.5	43.3	45.1	46.9	48.6	50.4	52.1	53.8	55.5	57.1
~95% Confidence Interval	26.1–53.4	27.6–55.4	29.2–57.4	30.8–59.4	32.4–61.3	34.0–63.2	35.7–65.0	37.4–66.8	39.0–68.6	40.7–70.3	42.4–71.9