Cowcod Rebuilding Analysis

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Introduction

The status of cowcod (*Sebastes levis*) in the Southern California Bight was first assessed by Butler et al. (1999), who concluded that spawning biomass in 1998 was approximately 7% of the unfished biomass. The stock was declared overfished in 2000 and the first rebuilding plan was adopted under Amendment 16-3 (PFMC, 2004). The stock was assessed again in 2005 (Piner et al., 2006) and the original rebuilding plan parameters were supplanted by the rebuilding analysis of Piner (2006). Subsequent assessments and rebuilding analyses were completed by Dick et al. (2007), Dick and Ralston (2008), Dick et al. (2009) and Dick and Ralston (2009). Rebuilding reference points from previous analyses are provided in Table 1. This rebuilding analysis is based on the assessment by Dick and MacCall (2013). Results are derived from outputs of the Bayesian assessment model (Extended Depletion-Based Stock Reduction Analysis, XDB-SRA), and details regarding the rebuilding calculations are provided in this document.

Simulation Model and Rebuilding Calculations

Estimation of Virgin Biomass (B_0)

The base model for the 2013 cowcod stock assessment uses a generalized production function (details in Dick and MacCall, 2011), parameterized in terms of the annual rate of natural mortality (M), the ratios F_{MSY}/M and B_{MSY}/B_0, and stock depletion (Δ) in the year 2000. Given a draw from the joint prior distribution, and a time series of removals since the beginning of the fishery, a value of total (male + female) vulnerable biomass is obtained by numerical solution. Draws from the joint posterior distribution are simulated by repeated resampling from the prior distributions with weights proportional to the likelihood for the abundance indices (i.e. sampling importance resampling). Nominal unfished female spawning biomass (B_0) is reported as half the total (male+female) vulnerable biomass, assuming a 1:1 sex ratio, knife-edge selectivity at age of maturity (11 years), and similar growth for males and females. The posterior median of unfished female spawning biomass is 1549 mt.

Simulation of Future Recruitments

In each rebuilding model run, 15000 simulated trajectories were generated using draws from the joint posterior distribution. Similar to the previous cowcod rebuilding analysis, variability in future recruitment is expressed as a weighted set of different states of nature (parameter values), rather than random deviations from an average stock-recruitment relationship. While the previous rebuilding analysis accounted only for uncertainty in the Beverton-Holt steepness parameter, the current analysis accounts for uncertainty in all estimated model parameters.

Mean Generation Time

Mean generation time for cowcod is estimated from the net maternity function (external to the model) and is 38 years. This is the same estimate for mean generation time as in the 2009 rebuilding analyses (see Table 2 for relevant age-specific quantities).

Recent Management Performance

Estimates of total cowcod mortality have not exceeded the ACL (or OY) in any year since 2003 (Table 3). Under the current SPR harvest rate ($F_{82.7\%}$), which is equivalent to an exploitation rate of 0.007 (catch over age 11+ biomass), $T_{REBUILD}$ is 2020. This is 48 years earlier than the current estimate of T_{TARGET} (2068). Reasons for the change are described in detail by Dick and MacCall (2013).

In recent years, the Council has set the ACL for cowcod in the Monterey & Conception INPFC areas equal to twice the ACL for the area south of Pt. Conception (PFMC and NMFS, 2006). However, there is no separate or distinct tracking of removals north or south of Point Conception.

Description of Model Runs

Model runs presented in this document follow the PFMC's Terms of Reference for the Groundfish Rebuilding Analysis (TOR) (PFMC, September 2012). All runs are based on output produced by the 2013 base model (Dick and MacCall, 2013). Rebuilding run numbers correspond to the list of requested runs in the TOR (PFMC, September 2012, pg. 8). In all models, the catches for 2013 and 2014 were set to the ACL for cowcod in the assessed area (1.5 mt for the region south of Point Conception).

The TOR lists the following minimum set of harvest policies for analysis:

1) eliminate all harvest beginning in the next management cycle (i.e., estimate TF=0),
2) apply the harvest rate that would generate the ACL specified for the current year (i.e., the latest year specified in regulations),
3) apply the spawning potential ratio or relevant harvest control rule in the current rebuilding plan,
4) apply the harvest rate that is estimated to lead to a 50% probability of recovery by the current TTARGET,
5) apply the harvest rate that is estimated to lead to a 50% probability of recovery by the TMAX from the current cycle,
6) apply the harvest rate that is estimated to lead to a 50% probability of recovery by the TMAX from the previous cycle,
7) apply the default (e.g. 40-10 or 25-5) harvest policy, and
8) apply the ABC harvest rate (i.e., FMSY less the uncertainty buffer).

Methods

For all runs, removals in 2013 and 2014 were set to 1.5 mt. Projections were completed through 2024. Due to the time lag in the production model (11 years), production through 2024 is pre-determined in the projections. This allowed us to apply the harvest specifications described in runs 1-8 to each of 15000 trajectories using the posterior draws from the base model.

Run 1
Catches from 2015-2024 were set equal to zero and all trajectories run through 2024.

Run 2
Numerically solved for the exploitation rate generating a median catch of 1.5 mt in 2015.

Run 3
Referred to results from the 2009 rebuilding analysis to determine the harvest rate (0.007; based on catch divided by age 11+ biomass) associated with the SPR target specified in the previous rebuilding analysis (82.7%).

Run 4
An approximation was used to determine the harvest rate that rebuilds the stock by current Ttarget (2068) with 50% probability. First, we determined the harvest rate that produces a steady state (no change in median biomass) from 2015-2024. The associated exploitation rate, biomass, and catch were E = 0.0466, B=1049 mt, and C2015 = 52.2 mt). Since target biomass (Bmsy proxy) is 40% of 3099, or 1239.5 mt, the stock has to grow 1239.5-1049=190.5 mt from 2015 to 2068 (53 years, or 3.5 tons/year). Removing this from the steady state catch (52.2-3.5=48.7 tons) we derive an approximate exploitation rate by multiplying the steady state exploitation rate (0.0466) by the ratio 48.7/52.2, giving a reduced rate of 0.0435.

Run 5
A new TMIN was calculated from the results of Run 1 (future catch =0), with all biomasses increased by 8.2 mt, the total amount caught from 2001 to 2014. For time periods shorter than the age to maturity this catch-correction is consistent with the dynamics model in XDB-SRA. TMIN is 2019. A new TMAX was then calculated by adding 38 years to the new TMIN, giving 2057. The approach is now the same as Run 4, changing the number of years needed to reach the target from 53 to 41. Specifically, 190.5 mt / 41 yr =4.6 mt/yr, giving the ratio (52.2-4.6)/52.2=0.912, and a reduced exploitation rate of 0.912*0.0466=0.0425.

Run 6
This run used the same approach as Run 4, changing the number of years needed to reach the target from 53 to 82. Specifically, 190.5 mt / 82 yr =2.3 mt/yr, and gives the ratio (52.2-2.3)/52.2=0.956, and a reduced exploitation rate of 0.956*0.0466=0.0445.

Run 7
Applied the 40-10 harvest control rule to each trajectory and summarized the results.

Run 8
Applied the ABC harvest rate, 0.04165 (83.3% of the Emsy proxy rate of 0.05), to each trajectory, and summarized the results.

Literature cited

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Table 1. Parameters from previous rebuilding analyses.

	Date of Analysis			
Rebuilding Parameter	**2004**	**2006**	**2008**	**2009**
B_0 [female spawning biomass, mt]	1684	1523	2488	2183
B_{MSY} [mt]	675	609	995	873
T_{MIN}	2062	2035	2060	2059
T_{MAX}	2099	2074	2098	2097
$T_{F=0}$	2062	2035	2061	2060
P_{MAX}	60%	90.6%	66.2%	66.2%
T_{TARGET}	2090	2039	2072	2068
Harvest Control Rule ($F_{\%SPR}$)	$F_{78\%}$	$F_{90\%}$	$F_{79\%}$	$F_{82.7\%}$
Harvest Control Rule (catch / 11+ biomass)	*	*	*	0.007

* not reported

Table 2. Age-specific quantities from the 2009 rebuilding analysis (natural mortality and age-specific fecundity used in calculation of mean generation time).

	Females				Fleet 1		Fleet 2	
Age	Fecundity	M	Init N	Init N Tmin	Weight	Selectivity	Weight	Selectivity
0	0	0.055	21.14480	12.12700	0	0	0	0
1	0	0.055	19.08350	10.92020	0	0	0.00021	0.002
2	0	0.055	17.17440	9.50210	0	0.00005	0.00227	0.009
3	0.00009	0.055	15.40280	8.50067	0.000	0.00059	0.01471	0.038
4	0.00126	0.055	13.75680	8.75935	0.004	0.00427	0.05404	0.105
5	0.00874	0.055	12.22690	8.39472	0.019	0.01840	0.13398	0.214
6	0.03501	0.055	10.80600	8.51984	0.060	0.05302	0.25695	0.349
7	0.09615	0.055	9.48871	7.57525	0.144	0.11464	0.41630	0.489
8	0.20397	0.055	8.27006	7.03875	0.277	0.20253	0.60222	0.618
9	0.36160	0.055	7.37078	5.94612	0.458	0.30968	0.80567	0.726
10	0.56415	0.055	6.62725	4.93306	0.679	0.42609	1.01990	0.812
11	0.80184	0.055	5.75479	4.06880	0.930	0.54175	1.24047	0.876
12	1.06323	0.055	5.13225	4.77038	1.199	0.64862	1.46472	0.921
13	1.33757	0.055	5.26342	5.01929	1.477	0.74137	1.69123	0.952
14	1.61611	0.055	5.01240	6.10020	1.755	0.81741	1.91931	0.972
15	1.89259	0.055	5.04995	6.46118	2.029	0.87650	2.14856	0.984
16	2.16318	0.055	4.45653	5.85213	2.296	0.92006	2.37873	0.991
17	2.42614	0.055	4.11206	4.50618	2.555	0.95053	2.60949	0.995
18	2.68117	0.055	3.45271	3.70317	2.806	0.97075	2.84044	0.997
19	2.92888	0.055	2.85021	2.68034	3.050	0.98348	3.07109	0.999
20	3.17027	0.055	2.34170	1.83116	3.289	0.99107	3.30088	0.999
21	3.40632	0.055	2.73746	1.18960	3.523	0.99537	3.52922	1
22	3.63780	0.055	2.87422	0.71499	3.752	0.99768	3.75554	1
23	3.86519	0.055	3.48807	0.40520	3.977	0.99887	3.97926	1
24	4.08867	0.055	3.69086	0.21926	4.199	0.99946	4.19989	1
25	4.30823	0.055	3.34083	0.11517	4.416	0.99974	4.41697	1
26	4.52370	0.055	2.57145	0.06016	4.63	0.99988	4.63008	1
27	4.73487	0.055	2.11272	0.03201	4.839	0.99994	4.83888	1
28	4.94148	0.055	1.52897	0.01774	5.043	0.99997	5.04307	1
29	5.14331	0.055	1.04448	0.01039	5.242	0.99999	5.24241	1
30	5.34016	0.055	0.67851	0.00651	5.437	0.99999	5.43668	1
31	5.53186	0.055	0.40780	0.00439	5.626	1	5.62574	1
32	5.71826	0.055	0.23111	0.00314	5.809	1	5.80945	1
33	5.89927	0.055	0.12506	0.00238	5.988	1	5.98774	1
34	6.07482	0.055	0.06569	0.00187	6.161	1	6.16054	1
35	6.24488	0.055	0.03431	0.00153	6.328	1	6.32784	1
36	6.40942	0.055	0.01826	0.00128	6.49	1	6.48963	1
37	6.56846	0.055	0.01012	0.00110	6.648	1	6.64799	1
38	6.72610	0.055	0.00592	0.00095	6.803	1	6.8028	1
39	6.87810	0.055	0.00371	0.00084	6.952	1	6.95201	1
40	7.02454	0.055	0.00250	0.00075	7.096	1	7.09569	1
41	7.16549	0.055	0.00179	0.00067	7.234	1	7.23394	1
42	7.30106	0.055	0.00136	0.00061	7.367	1	7.36686	1
43	7.43136	0.055	0.00107	0.00055	7.495	1	7.49457	1
44	7.55650	0.055	0.00087	0.00051	7.617	1	7.61718	1
45	7.67661	0.055	0.00073	0.00047	7.735	1	7.73483	1
46	7.79183	0.055	0.00063	0.00043	7.848	1	7.84764	1
47	7.90229	0.055	0.00054	0.00040	7.956	1	7.95577	1
48	8.00812	0.055	0.00048	0.00037	8.059	1	8.05935	1
49	8.10948	0.055	0.00043	0.00034	8.159	1	8.15852	1
50	8.20650	0.055	0.00038	0.00031	8.253	1	8.25342	1
51	8.29932	0.055	0.00035	0.00029	8.344	1	8.34421	1
52	8.38810	0.055	0.00032	0.00027	8.431	1	8.43102	1
53	8.47297	0.055	0.00029	0.00025	8.514	1	8.51399	1
54	8.55408	0.055	0.00027	0.00023	8.593	1	8.59327	1
55	8.63157	0.055	0.00025	0.00021	8.669	1	8.66899	1
56	8.70556	0.055	0.00023	0.00020	8.741	1	8.74129	1
57	8.77620	0.055	0.00021	0.00018	8.81	1	8.81031	1
58	8.84362	0.055	0.00019	0.00017	8.876	1	8.87617	1
59	8.90795	0.055	0.00018	0.00016	8.939	1	8.93899	1
60	8.96931	0.055	0.00016	0.00015	8.999	1	8.99892	1
61	9.02782	0.055	0.00015	0.00014	9.056	1	9.05605	1
62	9.08361	0.055	0.00014	0.00013	9.111	1	9.11052	1
63	9.13679	0.055	0.00013	0.00012	9.162	1	9.16243	1
64	9.18747	0.055	0.00012	0.00011	9.212	1	9.2119	1
65	9.23575	0.055	0.00011	0.00011	9.259	1	9.25903	1
66	9.28175	0.055	0.00010	0.00010	9.304	1	9.30392	1
67	9.32556	0.055	0.00010	0.00009	9.347	1	9.34667	1
68	9.36728	0.055	0.00009	0.00009	9.387	1	9.38738	1
69	9.40700	0.055	0.00008	0.00008	9.426	1	9.42614	1
70	9.44481	0.055	0.00008	0.00008	9.463	1	9.46303	1
71	9.48080	0.055	0.00007	0.00008	9.498	1	9.49814	1
72	9.51506	0.055	0.00007	0.00007	9.532	1	9.53156	1
73	9.54765	0.055	0.00006	0.00007	9.563	1	9.56335	1
74	9.57867	0.055	0.00006	0.00006	9.594	1	9.5936	1
75	9.60817	0.055	0.00006	0.00006	9.622	1	9.62238	1
76	9.63624	0.055	0.00005	0.00006	9.65	1	9.64975	1
77	9.66293	0.055	0.00005	0.00005	9.676	1	9.67579	1
78	9.68832	0.055	0.00005	0.00005	9.701	1	9.70055	1
79	9.71247	0.055	0.00005	0.00004	9.724	1	9.72409	1
80	9.73543	0.055	0.00059	0.00051	9.746	1	9.74648	1

Table 3. Total mortality (mt) of cowcod by year and area. Commercial mortality estimates (retained + discarded catch) are from the West Coast Groundfish Observer Program and recreational estimates are from RecFIN (weight of catch types A and B1).

	COMMERCIAL		RECREATIONAL					
YEAR	North of 34° 27′	South of 34° 27′	North of 34° 27′	South of 34° 27′	TOTAL	OFL	ABC	OY (ACL)
2003	0.22	0.00	--	0.48	0.70	--	24	4.8
2004	0.54	0.41	--	0.45	1.40	--	24	4.8
2005	1.15	0.00	--	0.15	1.30	--	24	4.2
2006	2.20	0.00	--	0.07	2.27	--	24	4.2
2007	1.93	0.10	0.19	0.11	2.33	--	36	4
2008	0.48	0.00	--	0.25	0.73	--	36	4
2009	1.45	0.00	--	0.21	1.66	--	13	4
2010	1.00	0.00	0.02	0.17	1.20	--	14	4
2011	0.02	0.00	--	0.83	0.85	13.00	8	(3)
2012	0.00	0.00	0.02	0.82	0.84	13.00	8	(3)
Grand Total	**9.00**	**0.51**	**0.23**	**3.53**	**13.28**			

Table 4. Summary of rebuilding reference points for cowcod

Parameter	**Values**
Year declared overfished	2000
Current year	2013
First ACL year	2015
T_{MIN} (re-estimated)	2019
Mean generation time (years)	38
T_{MAX} (re-estimated)	2057
$T_{F=0}$ (beginning in 2015)	2019
B_0 (female spawning biomass, mt)	1549
Rebuilding target ($B_{40\%}$) (mt)	620
Current SPR limit (2013-2014 cycle)	82.7%
Current exploitation limit (catch / 11+ biomass; 2013-2014 cycle)	0.007
Current T_{TARGET} (2013-2014 cycle)	2068
SB_{2013} (mt)	524

Table 5. Rebuilding reference points for requested model runs (see text for run descriptions).

	Run							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	T(F=0)	**current ACL**	**current rate**	**Ttarget**	**Tmax 2057**	**Tmax 2097**	**40-10**	**ABC**
Exploitation Rate in 2015	0.0000	0.0013	0.0070	0.0435	0.0425	0.0445	<0.04165	0.04165
50% prob. recovery by:	2019	2019	2020	2068	2057	2097	(slow)	(slow)
2015 ACL (mt)	0.0	1.5	7.8	48.7	47.5	49.8	46.3	46.6
2015 ABC (mt)	46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6
2016 ACL (mt)	0.0	1.6	8.0	*48.0*	*48.0*	*48.0*	45.5	48.0
2016 ABC (mt)	48.0	48.0	48.0	48.0	48.0	48.0	48.0	48.0
Probability of recovery by								
2019 (new Tmin)	52.2%	51.9%	49.6%	36.8%	38.0%	36.5%	37.2%	37.9%
2059 (old Tmin)	>50%	>50%	>50%	<50%	>50%	<50%	>50%	>50%
2068 (current Ttarget)	>50%	>50%	>50%	~50%	>50%	<50%	>50%	>50%
2057 (new Tmax)	>50%	>50%	>50%	<50%	~50%	<50%	>50%	>50%
2097 (old Tmax)	>50%	>50%	>50%	>50%	>50%	~50%	>50%	>50%

Table 6. Median depletion, female spawning biomass, and probabilities of recovery for model runs 1-8 (see text for descriptions of individual runs).

	Run							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	T(F=0)	**current ACL**	**current rate**	**Ttarget**	**Tmax 2057**	**Tmax 2097**	**40-10**	**ABC**
Median depletion								
2013	33.9%	33.9%	33.9%	33.9%	33.9%	33.9%	33.9%	33.9%
2014	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%
2015	36.0%	36.0%	36.0%	36.0%	36.0%	36.0%	36.0%	36.0%
2016	37.2%	37.2%	37.0%	35.6%	35.7%	35.6%	35.8%	35.7%
2017	38.4%	38.4%	38.0%	35.3%	35.5%	35.3%	35.6%	35.5%
2018	39.6%	39.5%	38.9%	35.0%	35.3%	34.9%	35.5%	35.2%
2019	**40.8%**	**40.6%**	39.9%	34.7%	35.2%	34.6%	35.5%	35.0%
2020	**42.0%**	**41.7%**	**40.8%**	34.5%	35.2%	34.3%	35.6%	34.8%
2021	**43.2%**	**42.9%**	**41.8%**	34.3%	35.4%	34.1%	35.8%	34.7%
2022	**44.5%**	**44.2%**	**42.8%**	34.2%	35.5%	33.9%	36.0%	34.6%
2023	**45.7%**	**45.3%**	**43.8%**	34.0%	35.7%	33.8%	36.2%	34.5%
2024	**46.9%**	**46.5%**	**44.9%**	33.9%	35.9%	33.6%	36.4%	34.5%
Median female SSB (mt)								
2013	524.5	524.5	524.5	524.5	524.5	524.5	524.5	524.5
2014	541.9	541.9	541.9	541.9	541.9	541.9	541.9	541.9
2015	559.4	559.4	559.4	559.4	559.4	559.4	559.4	559.4
2016	577.3	576.6	573.4	553.1	553.7	552.6	555.5	554.2
2017	598.0	596.5	590.3	551.0	553.1	549.8	554.5	553.0
2018	619.1	617.0	607.7	547.2	551.9	545.6	553.7	550.4
2019	638.3	635.5	623.5	545.8	553.2	543.7	555.4	549.7
2020	658.4	655.1	640.0	543.9	555.2	541.2	557.7	548.9
2021	679.0	674.7	657.4	542.2	557.3	539.3	560.1	547.8
2022	700.1	695.0	674.8	541.2	561.3	537.6	563.1	548.0
2023	721.3	715.6	692.6	541.5	566.8	537.3	567.4	549.2
2024	741.2	735.0	709.4	539.6	572.2	534.6	572.9	548.1
Probability of rebuilding								
2013	0.336	0.336	0.336	0.336	0.336	0.336	0.336	0.336
2014	0.363	0.363	0.363	0.363	0.363	0.363	0.363	0.363
2015	0.392	0.392	0.392	0.392	0.392	0.392	0.392	0.392
2016	0.424	0.424	0.419	0.384	0.385	0.384	0.378	0.385
2017	0.454	0.452	0.445	0.375	0.380	0.373	0.372	0.380
2018	0.490	0.487	0.467	0.373	0.381	0.371	0.368	0.379
2019	**0.522**	**0.519**	0.496	0.368	0.382	0.365	0.372	0.379
2020	**0.548**	**0.543**	**0.523**	0.366	0.385	0.363	0.375	0.375
2021	**0.575**	**0.567**	**0.544**	0.364	0.388	0.360	0.378	0.374
2022	**0.600**	**0.593**	**0.565**	0.363	0.398	0.358	0.389	0.375
2023	**0.629**	**0.621**	**0.586**	0.361	0.401	0.357	0.395	0.372
2024	**0.651**	**0.645**	**0.609**	0.360	0.407	0.355	0.404	0.374