Agenda Item E.1.a
Attachment 8
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Rebuilding Analysis for Pacific Ocean Perch in 2011

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1. Introduction

The Pacific Fishery Management Council (PFMC) adopted Amendment 11 to its Groundfish Management Plan in 1998. This amendment established a definition for an overfished stock of 25% of the unfished spawning biomass ($0.25B_0$). NMFS determined that a rebuilding plan was required for Pacific ocean perch (*Sebastes alutus*) in March 1999 based on the most recent stock assessment at that time (Ianelli and Zimmerman 1998). The PFMC began developing a rebuilding plan for Pacific ocean perch and submitted this plan to NMFS in February 2000. However, NMFS deferred adoption of the plan until the stock assessment was updated and reviewed, later that year (Ianelli *et al.* 2000).

A full stock assessment for then U.S. West Coast Pacific ocean perch stock was conducted in Stock Synthesis (Version 3, R. Methot) in 2011 (Hamel and Ono, 2011). This was the first full assessment of Pacific ocean perch since 2003 (Hamel *et al.*, 2003), as that assessment had been updated every two years (Hamel 2005, 2007, 2009). The current assessment involves fitting an age-structured population dynamics model to catch, catch-rate, length-frequency, age-composition, and survey data, similar to previous assessments. Ianelli *et al*. (2000), Hamel *et al*. (2003), and Hamel (2005, 2007, 2009) presented results based on maximum likelihood and Bayesian estimation frameworks. The STAR panel that evaluated the 2003 assessment of Pacific ocean perch endorsed both the MPD estimates and the distributions for the model outputs that arose from the application of the MCMC algorithm to sample equally likely parameter vectors from the posterior distribution (PFMC 2003). Punt et al. (2003) conducted a rebuilding analysis with runs based upon both the MPD estimates and the MCMC outputs. The PFMC adopted a rebuilding plan based upon the results of the MCMC analysis. This rebuilding analysis was updated in 2005, 2007 and 2009. The 2011 STAR panel endorsed a MPD estimate with fixed natural mortality and steepness values, and an MCMC was therefore not appropriate for the final model. Therefore the current rebuilding analysis is based upon the decision table from the 2011 assessment.

Management under rebuilding has been effective. Total estimated catch (landings + model-estimated discard) for 2000-2009 (1,597 mt) was only 51% of the combined ACLs (Formerly OYs; 3,127 mt; Table 1). Assuming the GMT scorecard catch for 2010 (141 mt out of an ACL of 200 mt), the catch for 2000-2010 represents 52% of the combined ACLs.

Table 1. Management history since 2000. The modeled catch is the sum of the landings and the model-estimated discards based on discard rate and discard size composition information. These do not always match the Total Mortality report, the metric used to determine if overfishing has occurred.

Year	OFL	ACL (OY)	Total Mortality Report	Modeled Catch
2000	713	270	-	156
2001	1,541	303	-	*310*
2002	640	350	-	176
2003	689	377	-	157
2004	980	444	151.7	144
2005	966	447	76.2	76
2006	934	447	80.3	86
2007	900	150	**156.7**	*156*
2008	911	150	130.7	134
2009	1,160	189	180.5	*202*
2010	1,173	200	141.0	141

2. Specifications

2.1 Selection of B_0

The unfished spawning output, B_0, is determined from the fitted stock-recruitment relationship in order to be more consistent with the assumptions underlying the original stock assessment. For the base model, the estimate of B_0 is 65,560 units of spawning output (10^8 eggs) with current spawning output being 12,532 units. The values of B_0 for the high and low states of nature are similar to the base, with current output being 26,088 and 7,987 units. Summary (3+) biomass estimated for by the base model in 2011 is 25,482 mt, which is within 5% of the value estimated by an update of the old model (conducted for comparison; 26,839 mt). However, since the estimated unfished summary biomass is much larger (119,914 mt vs. 83,850 mt), and therefore, so is the unfished spawning output, the estimated depletion level of 19.1% in 2011 is much lower than the value of 28.6% (in 2009) from the 2009 assessment, or 31.5% (in 2011) which an update of the old model produced. The new assessment is considered an improvement upon the old assessment model which estimated an anomalously large recruitment in the early 1950s to allow for adequate biomass for the foreign fishery removals in the late 1960s. The current model estimates a larger B_0, coupled with somewhat larger average recruitments in the 1950s. The result is a similar current estimated biomass, but a higher B0 when compared to the old model. A comparison of recent and current model results is shown in Table 2.

Table 2. MPD and posterior median estimates of unfished spawning stock biomass or output (2011) (B_0) and depletion for the 2005, 2009 and 2011 stock assessments, as well as comparing the result of an update of the old model.

	2005	**2009**	**2011 Update**	**2011 New**
Unfished 3+ biomass	83,709	83,786	83,850	119,914
Ending year 3+ biomass	22,440	23,844	26,839	25,482
Unfished spawning biomass or *output*	37,838	37,780	37,838	*65,560*
Ending year spawning biomass or *output*	8,846	10,794	11,935	*12,532*
Depletion (Spawning biomass or output)	23.4%	28.6%	31.5%	19.1%

2.2 Generation of future recruitment

Recruitment in the assessment and projection models for Pacific ocean perch relate to the abundance of 3 year olds. This and recent assessments of Pacific ocean perch include the assumption that, *a priori*, recruitment is related to spawning output according to a Beverton-Holt stock-recruitment relationship. The rebuilding analysis conducted by Punt et al. (2003) included three different approaches: 1) basing the projections on resampling historical recruitments or from those for the years 1965-2001, 2) basing the projections on resampling historical recruits per spawner for those same years, and 3) assuming a Beverton-Holt spawner recruit relationship. The first approach was chosen by the Council for the final rebuilding plan in 2003 and was used in subsequent rebuilding analyses (for 2009: 3 year olds from the years 1965-2007; year classes 1962-2004).

The rationale for generating future recruitment by sampling historical recruitment for the rebuilding analysis conducted by Punt (2002) was that 1965-1998 was a period of relative stability in recruitment. For comparison, figure 1 plots the estimates of recruitment and recruits / spawning output from the assessments conducted by Hamel (2009) and Hamel and Ono (2011). The large but uncertain 2008 year class makes this approach less attractive, and the current norm is to use the stock-recruit relationship, so approach 3 above is used in the current rebuilding analysis. While

Hamel (2009) estimated steepness for Pacific ocean perch to be 0.51, the current assessment estimates then fixes steepness at 0.40. This does not reflect reduced current productivity so much as a higher historical stock level and therefore higher relative historical productivity.

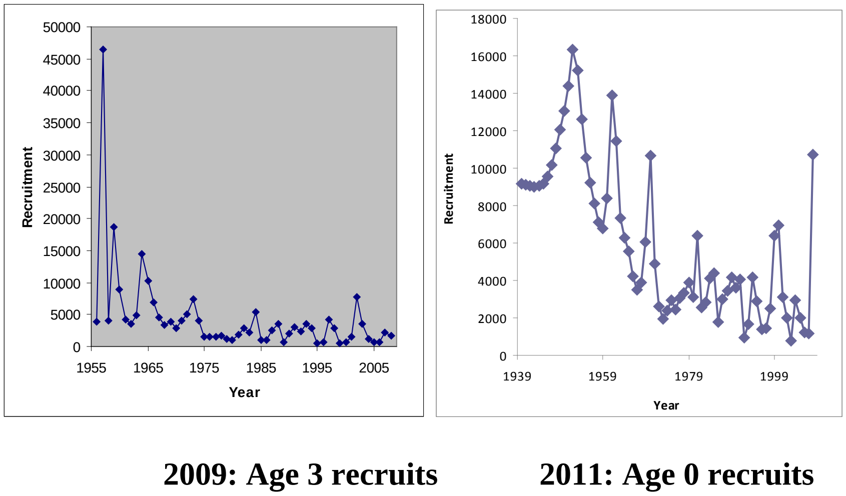

Figure 1: Recruitment: Pacific ocean perch assessments conducted in 2009 and 2011.

2.3 Mean generation time

The mean generation time is defined as the mean age weighted by net spawning output (see Figure 2 for net spawning output *versus* age.) The best estimate of the mean generation time is 31 years. This is 3 years longer than from the previous rebuilding analyses (Table 3).

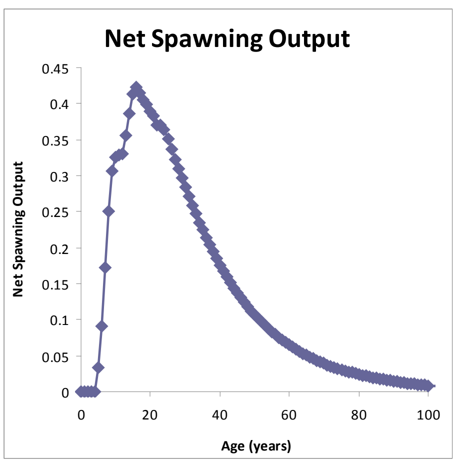

***Figure 2**: Relationship between net spawning output and age for Pacific Ocean perch.*

Table 3: Summary Statistics

Value	**2003**	**2005**	**2007***	**2009**	**2011**
T_{min}	2014	2015	2009	2017	2040
Mean generation time	28 years	28 years	28 years	28 years	31 years
T_{max}	2042	2043	2037	2045	2071
$T_{F=0}$ (No fishing mortality beginning in 2004, 2007, 2009, 2011 or 2013)	2014	2015	2010	2018	2043
P_{MAX}	70.0	92.9			
T_{TARGET}	2027	2017	2011	2020	TBD
SPR_{TARGET}		0.864	0.864	0.864	TBD

*** Note that a small data error in 2007 resulted in a slightly more optimistic rebuilding schedule compared to 2003 2005 or 2009.**

2.4 The harvest strategies

Table 4 summarizes the options considered in the rebuilding analyses. These include a no catch option (case 1), using the SPRs adopted for ACTs and ACLs from the last rebuilding analysis (cases 3 and 4), using the implied SPR in the current analysis from the 2011-12 ACTs (157/157 mt; case 5) or ACLs (180/183, case 6), or using the 40-10 (case 11) or OFL harvest rule (Case 12). The other 7 cases using values of $T_{rebuild}$ being the old T_{max} (2045), and a spread of cases up to the updated T_{max} (cases 7-10). I report the probability of recovering by 2045 and 2071, being the old and recalculated T_{max}.

Table 4. The 12 Scenarios explored in this rebuilding analysis including 2013 and 2014 Annual Catch (AC).

Case	**Name**	**$T_{50\%}$**	**2013 AC**	**2014 AC**	**SPR**	**P_{2045}**	**P_{2071}**
1	$T_{F=0}$	2043	0	0	1.000	57.3%	85.5%
2	$T_{rebuild}$ = 2045 (old T_{MAX})	2045	58	60	0.943	50.0%	81.1%
3	SPR for 2011-12 ACTs	2050	131	134	0.880	40.2%	75.0%
4	Rebuilding SPR 2005/7/9	2051	150	153	0.864	38.7%	73.2%
5	SPR from 2011-12 ACTs	2052	158	161	0.858	37.9%	72.6%
6	SPR from 2011-12 ACLs	2054	182	186	0.839	35.8%	70.1%
7	$T_{rebuild}$ = 2055	2055	199	203	0.826	34.4%	68.0%
8	$T_{rebuild}$ = 2060	2060	247	251	0.792	31.0%	62.0%
9	$T_{rebuild}$ = 2065	2065	291	295	0.762	29.3%	55.8%
10	$T_{rebuild}$ = 2071 (T_{MAX})	2071	328	333	0.738	27.9%	50.0%
11	40-10 (applied to OFL)	*	554	565	>=0.500	25.0%	25.3%
12	OFL	*	844	838	0.500	25.0%	25.2%

2.5 Other specifications

The calculations in this document were performed using 3.12b of the rebuilding software developed by Punt (2010) and the results are based on 2,000 Monte Carlo replicates (500 from each of the high and low states, and 1000 from the base case).

The definition of “recovery by year *y*” in this analysis is that the spawning output reaches $0.4B_0$ by year *y* (even if it subsequently drops below this level due to recruitment variability). Appendix 1 lists the estimates for the biological and technological parameters and the age-structure of the population at the start of 2000 and 2011. Appendix 2 lists the MPD time-series of recruitment and spawning output. The input to the rebuilding programs is given as Appendix 4. The catch for 2011 and 2012 were set to 180 and 183 mt (the Council-selected *ACLs* for 2011-2012).

3. Results

3.1 Time-to-recovery

The median year for rebuilding to the target level in the absence of fishing since the year of overfished declaration, T_{min}, is 2040. Figure 3 shows the distribution for the number of years beyond the year 2000 that it would have taken to recover to $0.4B_0$ had there been no harvest since 2000. $T_{\max}$ (T_{min} + one generation time) formerly the maximum permissible time period for rebuilding the stock to its target biomass, is 2071 when using the new information on the depletion level and the age-structure of the population in 2000. Table 3 gives summary statistics from the 2003, 2005, 2007 and 2009 rebuilding plans and the current analysis for full posterior results. The difference between the 2007 and 2009 results are largely due to the relatively low NWFSC trawl survey indices for POP in 2007 and 2008, coupled with a small data error in the 2007 assessment which was corrected in the 2009 assessment. The results for the 2011 rebuilding analysis relatively far from any of the previous analyses. While the rebuilding timeline has changed substantially from the 2009 version, the resulting catch from a SPR = 0.864 (ACL) or SPR = 0.88 (ACT) policy has a much smaller change (Table 5), since the change in timeline is due to an increase in B_0, and therefore an increase in the rebuilding target, rather than a decrease in current estimated biomass. $T_{F=0}$ (assuming zero catch from 2013 onward; 2043) is greater than T_{min} due to a dozen years with catch in the interim.

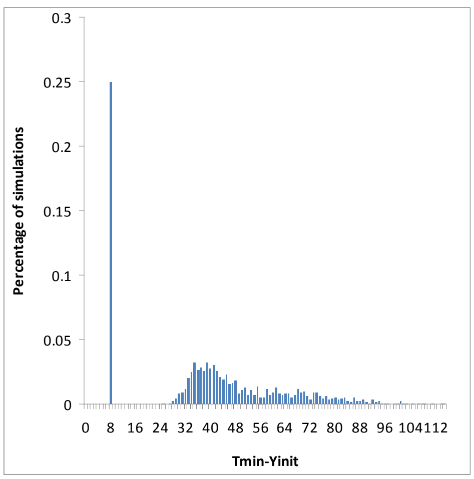

Figure 3: Distribution of time to recovery used to calculate T_{min}, the median year for rebuilding to the target level $0.4B_0$ in the absence of fishing since 2000 for the base-case analysis. The spike at 10 years indicates that for 25% of the simulations (those using the most optimistic state of nature) rebuilding occurs within 10 years.

3.2 OYs and fishing mortalities

Table 5 gives the probabilities of recovery at the old and new T_{max} (2045 and 2071) and 10 year projected Annual Catch (AC) and OFL values based on the SPR for each of the 12 cases explored in this rebuilding analysis.

Table 6 gives the ACs and OFLs for 2013 and 2014 along with the probability of rebuilding by a range of years from 2012 to 2071 given the three weighted models from the decision table and the 12 scenarios. Appendix 3 provides a similar table for strategies to provide for rebuilding by the years 2043 through 2055.

Table 5: Ten year AC/OFL projections.

Case	1		2		3		4		5		6		7		8		9		10		11		12
RUN	**F=0**		**2045**		**SPR for ACTs**		**SPR for ACLs**		**SPR from ACTs**		**SPR from ACLs**		**2055**		**2060**		**2065**		**2071**		**40-10**		**OFL**
SPR	1		0.943		0.880		0.864		0.858		0.839		0.826		0.792		0.762		0.738		>=0.500		0.500
T50%	2043		2045		2050		2051		2052		2054		2055		2060		2065		2071		*		*
P2045	57.3%		50.0%		40.2%		38.7%		37.9%		35.8%		34.4%		31.0%		29.3%		27.9%		25.0%		25.0%
P2071	85.5%		81.1%		75.0%		73.2%		72.6%		70.1%		68.0%		62.0%		55.8%		50.0%		25.3%		25.2%
10 Year projected **Catch levels** and OFLs at SPR rate above:																							
	AC	OFL	**AC**	OFL	**AC**	OFL	**AC**	OFL	**AC**	OFL	**AC**	OFL	**AC**	OFL	**AC**	OFL	**AC**	OFL	**AC**	OFL	**AC**	OFL	**AC=OFL**
2013	**0**	844	**58**	844	**131**	844	**150**	844	**158**	844	**182**	844	**199**	844	**247**	844	**291**	844	**328**	844	**554**	844	**844**
2014	**0**	867	**60**	865	**134**	862	**153**	861	**161**	861	**186**	860	**203**	860	**251**	858	**295**	857	**332**	855	**565**	848	**838**
2015	**0**	899	**62**	895	**138**	890	**158**	889	**166**	888	**191**	887	**209**	885	**258**	882	**303**	879	**341**	877	**586**	861	**842**
2016	**0**	935	**64**	929	**143**	922	**164**	919	**172**	919	**198**	916	**216**	915	**266**	910	**312**	905	**350**	901	**607**	878	**850**
2017	**0**	969	**66**	961	**147**	951	**169**	948	**177**	947	**204**	944	**222**	941	**273**	935	**320**	929	**359**	924	**623**	892	**856**
2018	**0**	999	**68**	988	**151**	976	**173**	972	**182**	971	**209**	967	**227**	964	**280**	956	**327**	948	**366**	942	**632**	901	**858**
2019	**0**	1025	**70**	1012	**154**	997	**177**	993	**185**	991	**213**	986	**232**	983	**285**	973	**332**	964	**372**	956	**635**	907	**857**
2020	**0**	1048	**71**	1033	**157**	1015	**180**	1010	**189**	1009	**217**	1003	**235**	999	**289**	987	**337**	977	**376**	968	**637**	911	**854**
2021	**0**	1071	**73**	1054	**160**	1034	**183**	1028	**192**	1026	**220**	1019	**239**	1015	**293**	1002	**341**	990	**381**	980	**643**	915	**852**
2022	**0**	1095	**74**	1076	**163**	1053	**187**	1047	**195**	1044	**224**	1037	**243**	1032	**298**	1017	**346**	1004	**386**	993	**651**	919	**850**

Table 6. Detailed management table for Pacific ocean perch.

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
RUN	**F=0**	**2045**	**SPR for ACTs**	**SPR for ACLs**	**SPR from ACTs**	**SPR from ACLs**	**2055**	**2060**	**2065**	**2071**	**40-10**	**OFL**
AC (2013)	0.0	58.4	130.8	150.4	157.9	182.2	199.0	246.9	290.8	328.1	553.6	843.9
OFL (2013)	843.9	843.9	843.9	843.9	843.9	843.9	843.9	843.9	843.9	843.9	843.9	843.9
AC (2014)	0.0	59.8	133.6	153.5	161.1	185.8	202.7	251.0	295.2	332.5	565.2	837.7
OFL (2014)	866.6	864.6	862.1	861.5	861.2	860.4	859.8	858.2	856.6	855.4	847.6	837.7
50% Prob. Yr	2043.0	2045	2050.0	2051.0	2052.0	2054.0	2055.0	2060.0	2065.0	2071.0	NA	NA
SPR	1.000	0.943	0.880	0.864	0.858	0.839	0.826	0.792	0.762	0.738	>0.500	0.500
Probability of recovery by pre-specified years												
2012	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
2020	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
2030	25.4	25.4	25.2	25.2	25.2	25.2	25.2	25.2	25.2	25.1	25.0	25.0
2040	43.7	25.2	32.2	30.9	30.6	29.5	28.8	27.5	26.4	26.0	25.0	25.0
2045	57.3	28.8	40.2	38.7	37.9	35.8	34.4	31.0	29.3	27.9	25.1	25.0
2050	66.4	59.7	50.6	48.5	47.2	43.5	42.1	36.7	33.4	31.0	25.1	25.0
2060	76.8	72.1	65.7	64.0	62.9	58.9	56.8	50.0	44.6	39.7	25.1	25.0
2071	85.5	81.1	75.0	73.2	72.6	70.1	68.0	62.0	55.8	50.0	25.3	25.2

References

Hamel, O.S. and K. Ono. 2011. Stock Assessment of Pacific Ocean Perch in Waters off of the U.S. West Coast in 2011. Pacific Fishery Management Council, Portland, OR.

Hamel O.S. 2009. Rebuilding update for Pacific Ocean Perch. Pacific Fishery Management Council, Portland, OR.

Hamel, O.S. 2009. Status and future prospects for the Pacific Ocean Perch resource in waters off Washington and Oregon as assessed in 2009. Pacific Fishery Management Council, Portland, OR.

Hamel O.S. 2007. Rebuilding update for Pacific Ocean Perch. Pacific Fishery Management Council, Portland, OR.

Hamel, O.S. 2007. Status and future prospects for the Pacific Ocean Perch resource in waters off Washington and Oregon as assessed in 2007. Pacific Fishery Management Council, Portland, OR.

Hamel O.S. 2005. Rebuilding update for Pacific Ocean Perch. Pacific Fishery Management Council, Portland, OR.

Hamel, O.S. 2005. Status and future prospects for the Pacific Ocean Perch resource in waters off Washington and Oregon as assessed in 2005. Pacific Fishery Management Council, Portland, OR.

Hamel, O.S., Stewart, I.J. and A.E. Punt. 2003. Status and future prospects for the Pacific Ocean Perch resource in waters off Washington and Oregon as assessed in 2003. Pacific Fishery Management Council, Portland, OR.

Ianelli, J.N., Wilkins, M. and S. Harley. 2000. Status and future prospects for the Pacific Ocean Perch resource in waters off Washington and Oregon as assessed in 2000. Pacific Fishery Management Council, Portland, OR.

Ianelli, J.N. and M. Zimmerman. 1998. Status and future prospects for the Pacific Ocean perch resource in waters off Washington and Oregon as assessed in 1998. Pacific Fishery Management Council, Portland, OR.

Pacific Fishery Management Council. 2011. Pacific Ocean Perch STAR Panel Report.
Pacific Fishery Management Council. 2003. Pacific Ocean Perch STAR Panel Report.
Pacific Fishery Management Council. 2000. Pacific Ocean Perch STAR Panel Report.

Punt, A.E. 2010. SSC default rebuilding analysis. Technical specifications and user manual. Ver. 3.12b

Punt, A.E. 2002. Revised Rebuilding Analysis for Pacific Ocean Perch (July 2002). Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR.

Punt, A.E., O.S. Hamel and I.J. Stewart. Rebuilding Analysis for Pacific Ocean Perch for 2003. Pacific Fishery Management Council, Portland, OR.

Appendix 1: Biological and technological parameters used for the rebuilding analyses based on the MPD estimates. The female natural mortality rate (*M*) is 0.05 for all ages, while male *M* is 0.0514

Age	Fecundity	Female Weight	Male Weight	Female Selectivity	Male Selecitivity	*N (2000)* F	*N (2000)* M	*N (2011)* F	*N (2011)* M
0	0.000	0.006	0.007	0.000	0.000	3472	3472	1803	1803
1	0.000	0.030	0.032	0.061	0.061	3044	3040	1707	1704
2	0.000	0.087	0.090	0.061	0.061	1118	1115	1219	1216
3	0.000	0.168	0.173	0.063	0.063	615	613	4603	4584
4	0.000	0.258	0.265	0.084	0.086	559	556	488	485
5	0.042	0.362	0.363	0.164	0.168	1102	1094	486	482
6	0.123	0.450	0.442	0.325	0.321	1501	1488	745	738
7	0.244	0.523	0.506	0.521	0.505	571	565	1023	1013
8	0.374	0.585	0.559	0.692	0.668	295	291	267	264
9	0.481	0.641	0.604	0.805	0.785	1165	1152	622	615
10	0.537	0.690	0.644	0.859	0.854	927	917	917	905
11	0.569	0.736	0.677	0.875	0.888	972	960	1942	1914
12	0.602	0.779	0.707	0.869	0.900	717	707	1692	1665
13	0.682	0.819	0.732	0.855	0.898	551	543	618	607
14	0.778	0.856	0.754	0.839	0.891	285	279	337	331
15	0.874	0.889	0.774	0.824	0.882	622	608	304	298
16	0.940	0.920	0.790	0.811	0.872	510	496	594	580
17	0.972	0.946	0.804	0.800	0.863	310	300	801	782
18	0.998	0.970	0.816	0.792	0.856	245	236	303	295
19	1.030	0.991	0.826	0.785	0.849	548	523	155	151
20	1.058	1.008	0.834	0.779	0.844	237	224	613	596
21	1.093	1.024	0.841	0.775	0.839	261	246	488	473
22	1.115	1.037	0.847	0.771	0.835	201	187	512	496
23	1.169	1.049	0.852	0.769	0.832	164	152	378	365
24	1.209	1.059	0.856	0.766	0.830	117	108	291	280
25	1.223	1.067	0.859	0.764	0.827	127	116	150	145
26	1.236	1.075	0.862	0.763	0.826	92	84	329	315
27	1.246	1.081	0.864	0.762	0.824	67	60	270	257
28	1.255	1.086	0.866	0.760	0.823	80	71	164	156
29	1.263	1.091	0.868	0.760	0.822	135	120	130	122
30	1.270	1.095	0.869	0.759	0.821	263	232	291	271
31	1.276	1.098	0.870	0.758	0.821	134	118	126	116
32	1.280	1.101	0.871	0.758	0.820	78	67	139	127
33	1.285	1.103	0.872	0.757	0.820	62	54	106	97
34	1.288	1.105	0.872	0.757	0.819	66	56	87	79
35	1.291	1.107	0.873	0.757	0.819	76	65	62	56
36	1.294	1.109	0.873	0.756	0.819	77	65	67	60
37	1.296	1.110	0.874	0.756	0.819	79	67	49	43
38	1.298	1.111	0.874	0.756	0.818	105	88	35	31
39	1.300	1.112	0.874	0.756	0.818	103	86	42	37
40+	1.302	1.113	0.874	0.756	0.818	668	495	981	785

Appendix 2: MPD historical series of spawning output and recruitment.

Year	Recruitment (age 3)	Spawning output	Year	Recruitment (age 3)	Spawning output
1940	9,165	65,471	1976	2,450	18,508
1941	9,121	65,414	1977	3,071	18,275
1942	9,054	65,353	1978	3,340	17,968
1943	9,010	65,287	1979	3,871	17,094
1944	9,029	65,180	1980	3,115	16,269
1945	9,189	65,025	1981	6,407	15,227
1946	9,541	64,812	1982	2,540	14,624
1947	10,159	64,634	1983	2,837	14,282
1948	11,056	64,476	1984	4,098	13,691
1949	12,075	64,309	1985	4,387	13,091
1950	13,051	63,941	1986	1,763	12,596
1951	14,391	63,439	1987	3,006	12,124
1952	16,361	62,869	1988	3,460	11,855
1953	15,234	61,596	1989	4,180	11,425
1954	12,630	60,799	1990	3,586	10,973
1955	10,547	59,700	1991	4,078	10,706
1956	9,197	59,103	1992	942	10,253
1957	8,105	58,028	1993	1,688	9,827
1958	7,085	57,420	1994	4,147	9,500
1959	6,759	57,282	1995	2,870	9,303
1960	8,366	57,598	1996	1,378	9,237
1961	13,869	57,284	1997	1,438	9,202
1962	11,467	56,260	1998	2,478	9,209
1963	7,358	54,465	1999	6,400	9,168
1964	6,283	51,763	2000	6,945	9,178
1965	5,534	48,823	2001	3,096	9,405
1966	4,229	45,083	2002	1,985	9,569
1967	3,527	35,015	2003	805	9,795
1968	3,891	27,493	2004	2,921	10,072
1969	6,062	23,076	2005	2,017	10,438
1970	10,641	22,744	2006	1,250	10,941
1971	4,909	22,032	2007	1,193	11,509
1972	2,584	21,317	2008	10,709	11,985
1973	1,937	20,554	2009	2,696	12,318
1974	2,397	19,366	2010	3,589	12,450
1975	2,960	18,567	2011	3,606	12,532

Appendix 3. Table representing SPRs and catch levels for 2013 and 1014 for lowest SPRs (highest fishing rates) while achieving $T_{Rebuild}$ = 2043 through 2055.

$T_{Rebuild}$	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055
ACL(2013)	16	35	58	74	89	106	122	136	150	163	175	187	199
OFL(2013)	844	844	844	844	844	844	844	844	844	844	844	844	844
ACL(2014)	17	36	60	76	91	108	124	139	153	167	178	190	203
OFL(2014)	866	865	865	864	864	863	863	862	862	861	861	860	860
50% Year	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055
SPR	0.984	0.965	0.943	0.929	0.916	0.901	0.888	0.876	0.864	0.854	0.845	0.835	0.826
Probability of recovery by pre-specified years													
2012	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
2020	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
2030	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
2040	41%	39%	37%	36%	35%	34%	33%	32%	31%	30%	30%	29%	29%
2045	56%	53%	50%	47%	46%	43%	41%	40%	39%	37%	36%	35%	34%
2050	65%	63%	60%	57%	56%	54%	52%	50%	49%	47%	44%	43%	42%
2060	75%	74%	72%	71%	70%	68%	67%	65%	64%	62%	60%	58%	57%
2071	84%	83%	81%	79%	78%	77%	76%	75%	73%	72%	71%	70%	68%

Appendix 4: Input File Ver. 2.8 (2005) (for SPR based on 2007-2010 specifications)

```
#Title
POP2011DecisionTableSPRs
# Number of sexes
2
# Age range to consider (minimum age; maximum age)
0 40
# Number of fleets
1
# First year of projection (Yinit)
2011
# First Year of rebuilding period (Ydecl)
2000
# Number of simulations
2000
# Maximum number of years
300
# Conduct projections with multiple starting values (0=No;else yes)
1
# Number of parameter vectors
4
# Is the maximum age a plus-group (1=Yes;2=No)
1
# Generate future recruitments using historical recruitments (1)  historical recruits/spawner (2)  or
a stock-recruitment (3)
3
# Constant fishing mortality (1) or constant Catch (2) projections
1
# Fishing mortality based on SPR (1) or actual rate (2)
1
# Pre-specify the year of recovery (or -1) to ignore
-1
# Fecundity-at-age
# 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
36 37 38 39 40
 0 0 0 0 0 0.0420226 0.122927 0.24357 0.373559 0.480615 0.53664 0.568945 0.602341 0.681994 0.777746
0.873797 0.940049 0.972004 0.998125 1.02996 1.05773 1.09338 1.11452 1.16857 1.20902 1.22332 1.23565
1.24625 1.25535 1.26314 1.26982 1.27554 1.28043 1.28461 1.28819 1.29124 1.29385 1.29608 1.29799
1.29962 1.30191 #female fecundity; weighted by N in year Y_init across morphs and areas
# Age specific selectivity and weight adjusted for discard and discard mortality
#wt and selex for "gender fleet:" 1 1
0.00608269 0.0300204 0.086782 0.167835 0.258423 0.362366 0.450207 0.522858 0.585365 0.640505 0.690281
0.736195 0.77904 0.818978 0.855834 0.889393 0.919546 0.946332 0.969911 0.990522 1.00844 1.02396
1.03735 1.04888 1.05879 1.0673 1.0746 1.08085 1.0862 1.09077 1.09469 1.09803 1.10089 1.10333 1.10541
1.10719 1.10871 1.11001 1.11111 1.11206 1.11339
0 0.0606962 0.0608449 0.0629117 0.0836812 0.164472 0.324523 0.521415 0.692429 0.80453 0.859415
0.874945 0.869329 0.855023 0.838812 0.823743 0.810857 0.800264 0.791717 0.784869 0.77939 0.774995
0.771454 0.768588 0.766255 0.764361 0.762818 0.761545 0.760489 0.759611 0.758877 0.758263 0.757747
0.757313 0.756947 0.756638 0.756377 0.756156 0.755968 0.755809 0.755586
#wt and selex for "gender fleet:" 2 1
0.00678297 0.0320324 0.0900501 0.173222 0.265429 0.363317 0.442136 0.505662 0.558966 0.604481 0.64363
0.677477 0.706852 0.732374 0.754498 0.773586 0.789957 0.803912 0.815739 0.825713 0.834089 0.841098
0.846947 0.851817 0.855863 0.859223 0.86201 0.864316 0.866224 0.867801 0.869104 0.87018 0.871068
0.871801 0.872406 0.872905 0.873317 0.873656 0.873936 0.874167 0.874458
0 0.0606525 0.0608469 0.0632023 0.0859328 0.167995 0.321138 0.504983 0.668267 0.784919 0.854447
0.888322 0.899554 0.898279 0.891078 0.881736 0.872223 0.863445 0.855742 0.849167 0.843644 0.83905
0.835248 0.832112 0.82953 0.827411 0.825677 0.824253 0.823085 0.822126 0.821338 0.82069 0.820157
0.819718 0.819357 0.81906 0.818816 0.818614 0.818448 0.818312 0.81814
# M and current age-structure in year Yinit: 2011
 # gender = 1
0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05
        0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05
        0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05
        0.05
1803.23 1706.78 1219.21         4603.39 487.627 485.555 744.636 1023.03 266.863 622.383 917.146 1942.38
        1691.68 617.703 337.465 304.163 593.896 801.277 302.587 155.39  613.284 488.039 511.871 377.923
        290.912 150.457 328.811 269.79  164.317 129.849 290.655 125.591 138.624 106.387 87.0691 62.1805
        67.4315 49.0583 35.4553 42.218  980.563
# gender = 2
 0.051378187    0.051378187    0.051378187    0.051378187    0.051378187    0.051378187    0.051378187
        0.051378187    0.051378187    0.051378187    0.051378187    0.051378187    0.051378187
        0.051378187    0.051378187    0.051378187    0.051378187    0.051378187    0.051378187
```

```
       0.051378187    0.051378187    0.051378187    0.051378187    0.051378187    0.051378187
       0.051378187    0.051378187    0.051378187    0.051378187    0.051378187    0.051378187
       0.051378187    0.051378187    0.051378187    0.051378187    0.051378187    0.051378187
       0.051378187    0.051378187    0.051378187    0.051378187
1803.23 1704.43 1215.86 4584.4  484.945 482.211 738.465 1013.18 263.967 614.92  905.072 1914.22 1664.53
       606.74  330.887 297.715 580.319 781.603 294.666 151.109 595.665 473.404 495.69  365.169 280.33
       144.524 314.647 256.935 155.572 122.115 271.34  116.341 127.419 97.059  78.8642 55.9074 60.1615
       43.4342 31.168  36.8741 785.162
# Age-structure at Ydeclare= 2000
 3472.26 3044 1118.23 615.115 559.015 1101.96 1500.78 570.977 294.566 1164.86 927.126 971.644 716.572
550.955 284.653 621.538 509.606 310.197 245.014 548.234 236.818 261.329 200.517 164.079 117.161
127.041 92.4177 66.7867 79.5205 135.114 262.669 134.413 77.5107 62.239 65.7769 75.9145 76.8051
79.1912 105.07 103.392 668.477
 3472.26 3039.8 1115.15 612.578 555.936 1094.27 1487.99 565.393 291.494 1152.49 917.076 960.384
707.193 542.517 279.484 608.036 496.193 300.273 235.588 523.273 224.287 245.579 187.024 151.937
107.693 115.873 83.6474 60.0197 71.0031 119.896 231.579 117.672 67.3753 53.7464 56.4578 64.7591
65.0679 66.5809 87.7738 86.1482 494.515
# 20) Year for Tmin Age-structure (set to Ydecl by SS)
2000
#  recruitment and biomass
# 21) Number of historical assessment years
73
# 22) Historical data
# year recruitment spawner in B0 in R project in R/S project
1939 1940 1941 1942 1943 1944 1945 1946 1947 1948 1949 1950 1951 1952 1953 1954 1955 1956 1957 1958
1959 1960 1961 1962 1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978
1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 #years (with first value
representing R0)
9328.97 9165.24 9121.09 9053.5  9009.7  9028.94 9189.39 9540.83 10158.5 11055.6 12075.1 13051.4 14391.3
       16360.7 15233.6 12629.9 10547.4 9196.69 8104.83 7084.76 6758.58 8366.46 13868.6 11466.7 7357.65
       6282.58 5533.99 4229.29 3527.37 3891.32 6061.71 10641.1 4908.72 2584.03 1936.56 2396.92 2960.05
       2449.93 3070.59 3340.45 3871.02 3114.83 6407.03 2539.6  2836.8  4097.79 4386.62 1762.89 3005.85
       3459.93 4180.4  3585.82 4077.68 942.258 1687.9  4147.09 2870.49 1378.22 1437.7  2478.1  6400.13
       6944.52 3096.09 1984.91 804.669 2920.91 2017.25 1249.79 1193.05 10708.6 2696.09 3588.57 3606.47
65559.7 65470.6 65414   65352.8 65287.2 65179.7 65025   64811.5 64634.3 64476.1 64309.2 63941   63438.5
       62868.7 61595.9 60799.3 59700.3 59103.1 58028   57419.6 57282.3 57598.2 57284.2 56259.6 54465.2
       51762.9 48822.6 45083.4 35014.9 27492.7 23075.5 22743.8 22032.4 21316.7 20554.3 19365.7 18566.9
       18508.4 18275   17967.6 17093.5 16268.5 15226.7 14624.4 14282   13691.3 13091.3 12596.2 12124.4
       11854.7 11424.9 10972.7 10706.3 10252.6 9826.99 9500.05 9303.17 9237.28 9202.24 9209.29 9167.72
       9178.16 9405.45 9569.44 9794.51 10072.3 10438.4 10940.5 11509.2 11985.3 12318.2 12450.3 12532.1 #
spbio; first value is S0 (virgin)
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  # in Bzero
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 # in R project
0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 # in R/S project
# 23) Number of years with pre-specified catches
2
# 24) catches for years with pre-specified catches go next
2011 180
2012 183
# 25) Number of future recruitments to override
12
# Process for overiding (-1 for average otherwise index in data list)
2000  1 2000
2001  1 2001
2002  1 2002
2003  1 2003
2004  1 2004
2005  1 2005
2006  1 2006
2007  1 2007
2008  1 2008
2009  1 2009
2010  1 2010
2011  1 2011
# 27) Which probability to produce detailed results for (1=0.5; 2=0.6; etc.)
3
# Steepness sigma-R Auto-correlation
0.4 0.7 0
# Target SPR rate (FMSY Proxy); manually change to SPR_MSY if not using SPR_target
```

```
0.5
# Discount rate (for cumulative catch)
0.1
# Truncate the series when 0.4B0 is reached (1=Yes)
0
# Set F to FMSY once 0.4B0 is reached (1=Yes)
0
# Maximum possible F for projection (-1 to set to FMSY)
-1
# Defintion of recovery (1=now only;2=now or before)
2
# Projection type
4
# Definition of the 40-10 rule
10 40
# 37) Calculate coefficients of variation (1=Yes)
0
# Number of replicates to use
10
# Random number seed
-99004
# File with multiple parameter vectors
DecTabfourstates.SSO
# User-specific projection (1=Yes); Output replaced (1->9)
1  6
# 42) Catches and Fs (Year; 1/2/3 (F or C or SPR); value); Final row is -1
2013 3 0.839
-1 -1 -1
# Fixed catch project (1=Yes); Output replaced (1->9); Approach (-1=Read in else 1-9)
0 2 -1
# Split of Fs
2011  1
-1 1
# 45) Yrs to define T_target for projection type 4 (a.k.a. 5 pre-specified inputs)
2045 2055 2060 2065 2071
# Eight years for probability of recovery
2012 2020 2030 2040 2045 2050 2060 2071
# Time varying weight-at-age (1=Yes;0=No)
0
# File with time series of weight-at-age data
none
# Use bisection (0) or linear interpolation (1)
0
# Target Depletion
0.4
# CV of implementation error
0
```