Rebuilding Update for Pacific Ocean Perch

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Owen S. Hamel
Groundfish Team, Fishery Resource Analysis and Monitoring Division,
National Marine Fisheries Service
Northwest Fisheries Science Center
2727 Montlake Boulevard East
Seattle, Washington 98112

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 (based upon a rebuilding analysis; August 1999; A. MacCall, pers. comm.) and submitted this plan to NMFS in February 2000. However, NMFS deferred adoption of the plan until the stock assessment was updated and reviewed, which was later that year (Ianelli *et al.* 2000

A new stock assessment for Pacific ocean perch stock was conducted in 2003 (Hamel *et al.*, 2003), and updated in 2005 and 2007 (Hamel 2005, 2007). This assessment, similar to that of Ianelli *et al*. (2000), involved fitting an age-structured population dynamics model to catch, catch-rate, length-frequency, age-composition, and survey data. Ianelli *et al*. (2000), Hamel *et al*. (2003), and Hamel (2005, 2007) presented results based on maximum likelihood and Bayesian estimation frameworks. A rebuilding analysis was conducted by Punt (2002), based upon the estimates corresponding to the maximum of the posterior density function (the MPD estimates) from Model 1c of Ianelli *et al*. (2000) because the STAR panel that evaluated the 2000 Pacific Ocean perch stock assessment selected this model variant as the "best assessment" (PFMC 2000). In contrast, 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 (sampling from the full Bayesian posterior). This rebuilding analysis was updated in 2005. For this update, rebuilding plan parameters are those specified after the rebuilding analysis in 2005.

2. Specifications

2.1 Selection of B_0

The unfished spawning stock biomass, B_0, is determined from the fitted stock-recruitment relationship in order to be more consistent with the assumptions underlying the original stock assessment. The MPD estimate of B_0 is 36,983 mt of spawning output while the posterior median and 90% intervals for B_0 are 34,573 mt and (27,620; 44,097). The values for B_0 are slightly lower than those on which the previous rebuilding analyses were based (Table 1). The MPD depletion estimate at the start of 2007 is 0.275 while the posterior median and 90% intervals are 0.311 (0.228; 0.398)

Table 1. MPD and posterior median estimates of unfished spawning stock biomass (B_0) and depletion for the 2003, 2005 and 2007 stock assessments.

	2003	**2005**	**2007**
B_0 MPD (mt)	39,198	37,838	36,983
B_0 Posterior Median (mt)	37,230	35,371	34,573
B_0 90% Interval) (mt)	29,035 47,393	28,022 44,866	27,620 44,097
Depletion MPD	25.4%	23.4%	27.5%
Depletion Posterior Median	27.7%	27.6%	31.1%
Depletion 90% Intervals	20.1% 38.4%	19.8% 37.1%	22.8% 39.8%

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. The assessment of Pacific ocean perch by Hamel *et al*. (2003) and its updates (Hamel 2005, 2007) include the assumption that, *apriori*, 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.

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. In contrast to recruitment, recruits / spawning output showed an increasing trend over time. The situation was less clear in 2003 and 2005, however in the current analysis there is again an increasing trend in recruits / spawning output over time and the recruitments, while not completely stable, are more consistent across time. Resampling historical recruitment (3 year olds from the years 1965-2005; year classes 1962-2002) is used exclusively for the analyses in this document in order to remain consistent with the adopted rebuilding plan. Figure 1 plots the MPD estimates of recruitment and recruits / spawning output from the assessments conducted by Hamel *et al*. (2003) and Hamel (2005, 2007). Hamel (2007) estimated steepness for Pacific ocean perch to be 0.65.

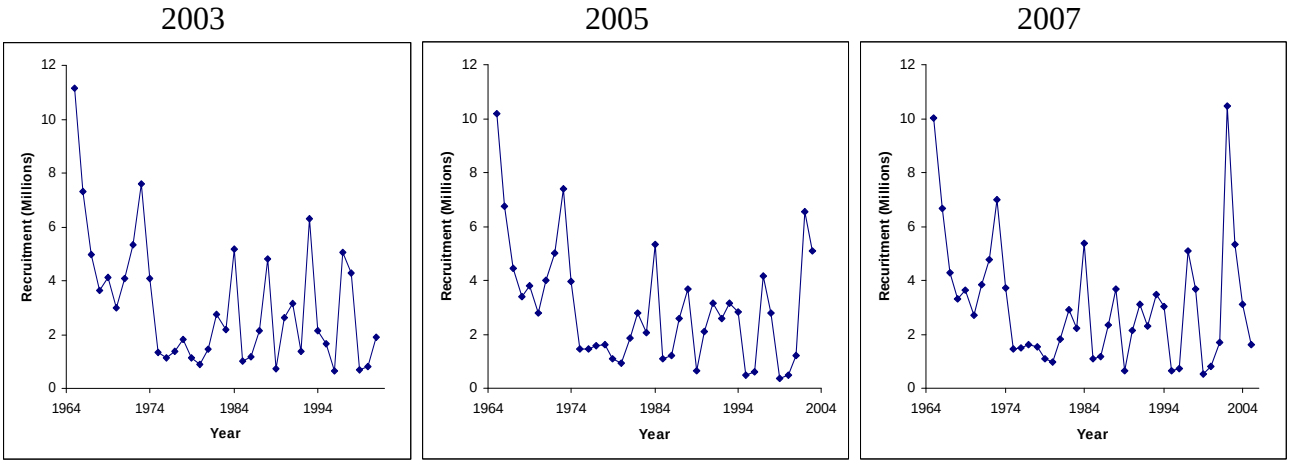

Figure 1: Recruitment from assessments of Pacific ocean perch conducted in 2003, 2005 and 2007.

2.3 Mean generation time

The mean generation time is defined as the mean age weighted by net spawning output (see Figure 2 for a plot of net spawning output *versus* age based on the MPD estimates). The best estimate of the mean generation time for the full posterior is 28 years, and for the MPD it is 29 years. These are unchanged from the 2003 and 2005 rebuilding analyses (see Table 3).

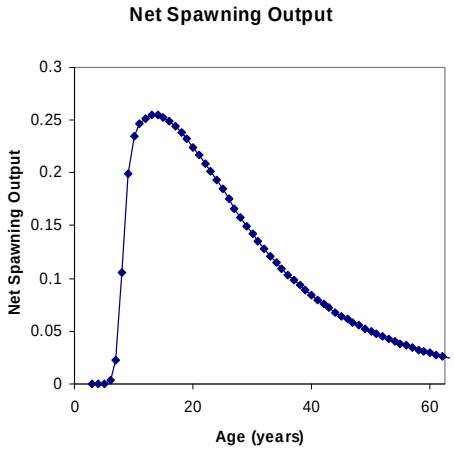

Figure 2*: Relationship between net spawning output and age for Pacific Ocean perch.*

2.4 The harvest strategies

Table 2 summarizes the options considered in the rebuilding analyses. These include a no catch option (case 1), using the calculated SPR from the last rebuilding analysis (case 2), using the implied SPR in the current analysis from the 2007-8 OYs (150 mt; case 3), a 50% probability of rebuilding by T_{target} of 2017 (case 4) or using the ABC harvest rule (Case 5). These 5 cases were requested by the Council in a memorandum dated September 04, 2007. The other 8 cases are intermediate values found by either diminishing T_{target} or, in case 13, picking an intermediate SPR to achieve a doubling of the current OY.

Case	**Name**	**$T_{50\%}$**	**2009 OY**	**SPR**	**P_{2017}**
1	$T_{F=0}$	2010	0	1.000	0.780
2	SPR from 2005 rebuilding	2011	189	0.864	0.721
3	SPR from 2007-8 OYs	2011	164	0.880	0.733
4	T_{target} = 2017 (Current)	2017	971	0.548	0.500
5	ABC rule	2021	1160	0.500	0.477
6	T_{target} = 2010	2010	130	0.903	0.741
7	T_{target} = 2011	2011	432	0.734	0.640
8	T_{target} = 2012	2012	565	0.678	0.600
9	T_{target} = 2013	2013	624	0.655	0.582
10	T_{target} = 2014	2014	744	0.614	0.548
11	T_{target} = 2015	2015	842	0.584	0.526
12	T_{target} = 2016	2016	909	0.565	0.512
13	SPR = 0.800	2011	299	0.800	0.685

2.5 Other specifications

The calculations in this document were performed using Version 2.8 of the rebuilding software developed by Punt (2005) and the results are based on 3,000 Monte Carlo replicates (3 simulations for each of 1,000 samples for the posterior).

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 MPD estimates for the biological and technological parameters and the age-structure of the population at the start of 2000 and 2007. Appendix 2 lists the MPD time-series of recruitment and

spawning output. The input to the rebuilding program is given as Appendix 3. The catch for 2007 and 2008 were set to 150 mt (the Council-selected *OYs* for 2007-2008).

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 2014. 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}, the maximum permissible time period for rebuilding the stock to its target biomass, is 2042 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 and 2005 rebuilding plans and the current analysis for full posterior results. Note that $T_{F=0}$ (zero catch from 2009 onward) is less than T_{min} due to higher than average recruitment in years after y_{decl} (2000) that are not taken into account in the calculation of T_{min}.

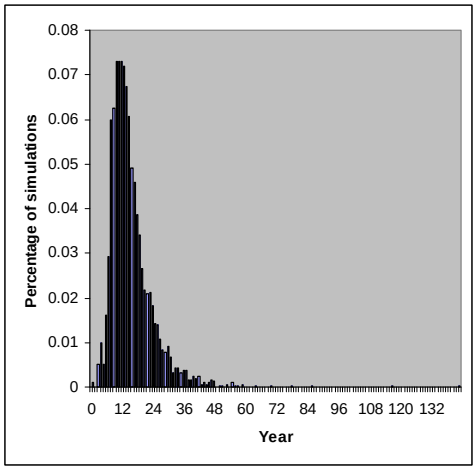

Figure 3: T_{min}, the median year for rebuilding to the target level $0.4B_0$ in the absence of fishing since 2000 for the base-case analysis.

Table 3: Summary statistics

Value	**2003**	**2005**	**2007**
T_{min}	2014	2015	2009
Mean generation time	28 years	28 years	28 years
T_{max}	2042	2043	2037
$T_{F=0}$ (No fishing mortality beginning in 2004, 2007, & 2009, respectively.	2014	2015	2010
P_{MAX}	70.0	92.9	
T_{TARGET}	2027	2017	
SPR_{TARGET}		86.4%	

3.2 OYs and fishing mortalities

Table 4 gives the probabilities of recovery at T_{target} (2017) and T_{max} (2042 (current and 2003 analyses) or 2043 (2005 analysis)), and 10 year projected OY values based on the SPR for each of the 13 cases explored in this rebuilding analysis.

Table 4: Ten year OY/ABC projections.

Case	**1**		**2**		**3**		**4**		**5**	**6**		**7**		**8**		**9**		**10**		**11**		**12**		**13**	
RUN	**F=0**		**SPR'05**		**OY'7-8**		**Ttarget**		**ABC**	**2010**		**2011**		**2012**		**2013**		**2014**		**2015**		**2016**		**SPR0.8**	
SPR	1		0.864		0.88		0.548		0.5	0.903		0.734		0.678		0.655		0.614		0.584		0.565		0.800	
F	0		0.0080		0.0070		0.0412		0.0493	0.0055		0.0183		0.0240		0.0265		0.0316		0.0358		0.0386		0.0127	
T50%	2010		2011		2011		2017		2021	2010		2011		2012		2013		2014		2015		2016		2011	
P2017	78.0		72.1		73.3		50.0		47.7	74.1		64.0		60.0		58.2		54.8		52.6		51.2		68.5	
P2037	97.5		94.4		95.0		65.0		58.3	95.6		86.7		81.8		79.1		74.3		70.1		67.5		91.4	
P2043	98.8		96.4		96.8		67.7		60.5	97.1		89.3		84.6		82.0		77.2		73.2		70.5		94.3	
10 Year projected **OYs** and ABCs at SPR rate above:																									
2009	**0**	1160	**189**	1160	**164**	1160	**971**	1160	**1160**	**130**	1160	**432**	1160	**565**	1160	**624**	1160	**744**	1160	**842**	1160	**909**	1160	**299**	1160
2010	**0**	1227	**200**	1217	**173**	1219	**992**	1181	**1173**	**137**	1220	**452**	1205	**589**	1199	**649**	1196	**769**	1191	**866**	1187	**932**	1184	**314**	1212
2011	**0**	1293	**207**	1275	**180**	1278	**997**	1198	**1179**	**143**	1281	**466**	1250	**602**	1238	**662**	1232	**782**	1221	**877**	1211	**939**	1205	**325**	1263
2012	**0**	1361	**215**	1333	**187**	1337	**1007**	1218	**1185**	**149**	1342	**479**	1296	**616**	1277	**676**	1268	**795**	1251	**888**	1237	**950**	1228	**337**	1316
2013	**0**	1422	**224**	1381	**195**	1387	**1015**	1224	**1183**	**155**	1394	**492**	1330	**630**	1303	**690**	1292	**807**	1268	**900**	1249	**960**	1236	**348**	1358
2014	**0**	1463	**229**	1415	**200**	1422	**1013**	1221	**1172**	**159**	1431	**501**	1353	**638**	1320	**697**	1304	**811**	1275	**900**	1252	**959**	1236	**355**	1388
2015	**0**	1497	**232**	1435	**203**	1443	**1005**	1209	**1151**	**162**	1454	**504**	1361	**641**	1323	**699**	1305	**811**	1271	**896**	1244	**953**	1226	**359**	1403
2016	**0**	1534	**237**	1465	**207**	1475	**1000**	1204	**1139**	**166**	1487	**510**	1381	**646**	1335	**702**	1314	**812**	1276	**896**	1243	**950**	1223	**365**	1426
2017	**0**	1573	**241**	1491	**211**	1502	**996**	1193	**1125**	**169**	1516	**516**	1392	**650**	1339	**707**	1316	**815**	1271	**896**	1237	**948**	1214	**370**	1445
2018	**0**	1602	**246**	1508	**215**	1520	**993**	1187	**1114**	**172**	1537	**521**	1401	**656**	1344	**712**	1321	**818**	1273	**897**	1236	**947**	1211	**376**	1458

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Punt, A.E. 2005. SSC default rebuilding analysis. Technical specifications and user manual. Ver. 2.8.

Appendix 1 : Biological and technological parameters used for the rebuilding analyses based on the MPD estimates.

Age	Fecundity	Weight (kg)	Selectivity	Natural mortality	*N* (2000)	*N* (2007)
3	0.000	0.169	0.001	0.0526	821	1485
4	0.000	0.241	0.003	0.0526	507	1408
5	0.000	0.317	0.011	0.0526	3319	1451
6	0.004	0.396	0.040	0.0526	4328	2670
7	0.028	0.474	0.131	0.0526	592	4336
8	0.137	0.550	0.306	0.0526	495	8038
9	0.274	0.622	0.518	0.0526	2168	1230
10	0.339	0.690	0.688	0.0526	2272	565
11	0.375	0.752	0.805	0.0526	1367	347
12	0.404	0.809	0.880	0.0526	1663	2255
13	0.431	0.861	0.952	0.0526	1006	2912
14	0.454	0.908	1.000	0.0526	271	393
15	0.475	0.950	1.000	0.0526	1307	325
16	0.494	0.987	1.000	0.0526	728	1405
17	0.510	1.021	1.000	0.0526	308	1461
18	0.525	1.050	1.000	0.0526	250	876
19	0.538	1.076	1.000	0.0526	1058	1066
20	0.550	1.099	1.000	0.0526	382	646
21	0.560	1.119	1.000	0.0526	433	174
22	0.569	1.137	1.000	0.0526	234	840
23	0.576	1.153	1.000	0.0526	107	468
24	0.583	1.166	1.000	0.0526	103	198
25+	0.589	1.178	1.000	0.0526	2680	3371

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

Year	Recruitment (age 3)	Spawning output
1956	3819	32748
1957	46795	31570
1958	4087	30490
1959	18633	30125
1960	8804	29944
1961	4153	30193
1962	3540	31992
1963	4867	33654
1964	14059	33291
1965	10012	32946
1966	6655	30407
1967	4295	21651
1968	3321	15806
1969	3639	13893
1970	2703	15520
1971	3842	16286
1972	4778	16609
1973	6986	16729
1974	3716	16357
1975	1466	16053
1976	1478	16073
1977	1616	15985
1978	1552	16311
1979	1079	16099
1980	974	15540
1981	1825	14687
1982	2914	13882
1983	2240	13295
1984	5386	12173
1985	1097	11156
1986	1160	10306
1987	2362	9702
1988	3664	9403
1989	660	9115
1990	2145	8752
1991	3131	8379
1992	2291	7829
1993	3455	7598
1994	3047	7215
1995	650	6917
1996	732	6856
1997	5072	6882
1998	3688	7055
1999	535	7249
2000	821	7331
2001	1691	7489
2002	10467	7826
2003	5353	8428
2004	3127	8791
2005	1612	8910
2006	1485	9210
2007	1485	10168

Appendix 3: Input File (for SPR based on 2007-8 OYs)

```
#Title
POP Re2007
# Number of sexes
1
# Age range to consider (minimum age; maximum age)
3 25
# Number of fleets
1
# First year of projection
2007
# Year declared overfished
2000
# 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)
1
# 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
34
# Fecundity-at-age
# 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
3.84E-06 4.03E-05 0.000392248 0.003560962 0.028260766 0.1374925 0.273954602 0.338584679 0.375081501
0.404469053 0.430553194 0.453991276 0.4749965 0.493739 0.510395 0.52515 0.53818 0.549655 0.559745 0.568595
0.576345 0.58313 0.589055
# Age specific information (Females then males) weight  selectivity

0.169105 0.240603 0.317273 0.395966 0.474162 0.54997 0.62206 0.689572 0.752022 0.80921 0.861146 0.907988
0.949993 0.987478 1.02079 1.0503 1.07636 1.09931 1.11949 1.13719 1.15269 1.16626 1.17811

0.000760479 0.002833075 0.010718648 0.040106885 0.130877235 0.305548059 0.518406886
        0.688311578 0.804965697 0.87984887 0.952139824 1 1 1 1 1
        1 1 1 1 1 1 1
# M and current age-structure

0.0526203 0.0526203 0.0526203 0.0526203 0.0526203 0.0526203 0.0526203
        0.0526203 0.0526203 0.0526203 0.0526203 0.0526203 0.0526203
        0.0526203 0.0526203 0.0526203 0.0526203 0.0526203 0.0526203
        0.0526203 0.0526203 0.0526203 0.0526203
1484.56 1408.46 1450.8 2670.16 4335.9 8037.76 1229.81 564.926 347.218 2255.44 2911.84 392.941 324.523
        1404.86 1460.57 876.037 1066.1 645.747 173.983 839.761 467.917 197.848 3371.03
# Age-structure at declaration

821.335 507.381 3318.95 4327.91 591.682 495.103 2167.85 2272.35 1367.41 1663.14 1005.83 270.812 1307.12
        728.332 307.958 250.322 1058.29 382.287 432.756 233.616 107.428 102.677 2679.78
# Year for Tmin Age-structure
2000
# Number of simulations
3000
#  recruitment and biomass
# Number of historical assessment years
53
# Historical data
# year recruitment spawner in B0 in R project in R/S project
```

1955	4966.98	36982.9	1	0	0
1956	3819.3	32747.8	0	0	0
1957	46795.4	31570	0	0	0
1958	4086.68	30489.7	0	0	0
1959	18633.2	30125.3	0	0	1
1960	8803.5	29944.1	0	0	1
1961	4153.25	30192.5	0	0	1
1962	3539.56	31992.3	0	0	1
1963	4867.19	33654	0	0	1
1964	14059.3	33290.7	0	0	1
1965	10011.5	32945.8	0	1	1
1966	6655.08	30406.7	0	1	1
1967	4294.86	21651.3	0	1	1
1968	3321.22	15805.9	0	1	1
1969	3639.49	13892.8	0	1	1
1970	2703.11	15520.2	0	1	1
1971	3842.36	16285.7	0	1	1
1972	4777.8	16609.3	0	1	1
1973	6986.28	16728.6	0	1	1
1974	3715.97	16356.8	0	1	1
1975	1466.34	16052.5	0	1	1
1976	1478.25	16072.8	0	1	1
1977	1616.46	15985.3	0	1	1
1978	1551.99	16310.5	0	1	1
1979	1078.8	16099.3	0	1	1
1980	974.459	15539.6	0	1	1
1981	1824.85	14687.2	0	1	1
1982	2913.61	13882.1	0	1	1
1983	2239.62	13294.7	0	1	1
1984	5385.86	12172.6	0	1	1
1985	1096.93	11155.5	0	1	1
1986	1160.03	10305.7	0	1	1
1987	2361.52	9701.91	0	1	1
1988	3664.37	9403.31	0	1	1
1989	660.065	9114.8	0	1	1
1990	2144.62	8751.87	0	1	1
1991	3130.65	8378.66	0	1	1
1992	2291.45	7828.84	0	1	1
1993	3454.79	7598.36	0	1	1
1994	3046.79	7214.91	0	1	1
1995	650.304	6916.7	0	1	1
1996	732.357	6855.66	0	1	1
1997	5071.74	6881.98	0	1	1
1998	3687.98	7055.26	0	1	1
1999	534.815	7248.73	0	1	1
2000	821.335	7330.58	0	1	1
2001	1690.86	7488.57	0	1	1
2002	10466.9	7826.34	0	1	1
2003	5353.19	8428.21	0	1	1
2004	3127	8791.06	0	1	1
2005	1611.83	8909.98	0	1	1
2006	1484.56	9209.78	0	0	0
2007	1484.56	10168.2	0	0	0

Number of years with pre-specified catches
2
catches for years with pre-specified catches
2007 150
2008 150

```
# Number of future recruitments to override
0
# Process for overiding (-1 for average otherwise index in data list)
# Which probability to product detailed results for (1=0.5; 2=0.6; etc.)
3
# Steepness sigma-R Auto-correlation
0.652     1          0
# Target SPR rate (FMSY Proxy)
0.5
# Target SPR information: Use (1=Yes) and power
0         20
# 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
# Percentage of FMSY which defines Ftarget
0.9
# Maximum possible F for projection (-1 to set to FMSY)
-1
# Conduct MacCall transition policy (1=Yes)
0
# Defintion of recovery (1=now only;2=now or before)
2
# Results for rec probs by Tmax (1) or 0.5 prob for various Ttargets (2)
1
"# Definition of the ""40-10"" rule"
10        40
# Produce the risk-reward plots (1=Yes)
0
# Calculate coefficients of variation (1=Yes)
0
# Number of replicates to use
10
# Random number seed
-99004
# Conduct projections for multiple starting values (0=No;else yes)
1
# File with multiple parameter vectors
mcmcreb.dat
# Number of parameter vectors
1000
# User-specific projection (1=Yes); Output replaced (1->9)
1         5         0         0.1
# Catches and Fs (Year; 1/2/3 (F or C or SPR); value); Final row is -1
2009      3         0.88
-1        -1        -1
# Split of Fs
2007      1
-1        1
# Time varying weight-at-age (1=Yes;0=No)
0
# File with time series of weight-at-age data
HakWght.Csv
```