Catch-based estimates of sustainable yield for kelp greenling (*Hexagrammos decagrammus*) in waters off Oregon and Washington

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This report describes yield estimates for kelp greenling (*Hexagrammos decagrammus*) in Oregon and Washington, based on the Depletion-Based Stock Reduction Analysis model (DB-SRA; Dick and MacCall 2011). The Groundfish Subcommittee of the PFMC's SSC recently recommended the following approach to estimating OFLs for kelp greenling: "An Oregon model would use the updated historical catches and the prior on 2005 depletion based on the 2005 Kelp Greenling assessment off of Oregon (Cope and MacCall 2005), while the Washington model would use the prior on 1997 depletion (the year before the increased removals in Oregon started) from the Oregon model." Results from a DB-SRA model for Oregon kelp greenling are presented in this report, as well as a separate model for Washington kelp greenling which assumes that the distribution of stock depletion in 1997 matches the Oregon substock.

Annual commercial landings (metric tons, mt) of kelp greenling were queried from the PacFIN database. The first reported commercial landings in Oregon were in 1988; no commercial landings were reported for Washington (Table 1). Early commercial landings for Oregon (1950-1987) were set equal to the average of reported landings from 1988-1996 (0.13 mt), to approximate the equilibrium catch assumption in the 2005 stock assessment (Cope and MacCall, 2005).

Oregon recreational catch estimates (1980-89, 1993-2012) were provided by the Oregon Department of Fish and Wildlife (ODFW; A. Dauble, pers. comm.). Estimates from 1981-1983 and 1990-1992 were replaced with interpolated values due to possible errors and missing data, respectively. Oregon recreational removals from 1950-1979 were assumed equal to the average catch from 1980-1989, after linear interpolation of values for 1981-1983 (Table 1, Figure 1).

Recreational catch (numbers of fish, 1975-86 and 1990-2011) for Washington were provided by the Washington Department of Fish and Wildlife (WDFW; T. Tsou, pers. comm.) and converted to catch in weight assuming an average weight of 0.67 kg per fish. Removals from 1987-1989 were estimated using linear interpolation of removals in 1986 and 1990, and an estimate for 2012 was taken to be the average of removals in 2010 and 2011. Catches from 1950-1974 were assumed equal to the average catch from 1975-1984 (Table 1, Figure 2).

The DB-SRA model for kelp greenling in Oregon assumes that age 4+ biomass in 2005 was 48.8% of unfished biomass on average, following the 2005 assessment (Cope and MacCall, 2005). Point estimates of (female) natural mortality and age at maturity were obtained from the Oregon assessment. Sensitivity analyses were conducted for alternative ages at maturity (2, 3, and 4 years) and equilibrium catch assumptions (see Table 2 for a description of all base model input parameters). The Oregon base model assumed an age of maturity equal to 4 years, similar to the 2005 assessment.

The overfishing limit (OFL) distribution from the Oregon DB-SRA base model has a median of 14 mt (Table 3). Changing the assumed age-at-maturity to 3 years had little effect on median OFL (14.4 mt), but a value of 2 years increased the median OFL to 16.7 mt (Table 3). Removing the equilibrium catch approximation reduced the median OFL to 13.7 mt.

The OFL for kelp greenling in Washington was calculated using DB-SRA with Washington catches (only) and estimates of delta based on the 1997 depletion distribution from the Oregon model (median depletion in 1997 = $0.9B_0$). All other input parameters were identical to the Oregon base model. Given

this set of assumptions, the median OFL for the Washington substock is 31.4 mt. The large increase in OFL is due to the implicit assumption that the substock is near unfished biomass in 2015 (median biomass is 92% of unfished). It is worth noting that median MSY for the Washington substock, under the DB-SRA model, is 13.6 mt. Given the uncertainty in the MSY harvest rate, and since no trend information is available to validate the assumptions about stock status, median MSY could be considered as an alternative ABC control rule for data-limited stocks above target biomass.

Reliability of yield estimates for these substocks, in particular the Washington substock, would be greatly improved by development of informative time series of relative abundance or estimates of absolute abundance.

Literature Cited

Cope, J.M. and A.D. McCall. 2005. Status of Kelp Greenling (Hexagrammos decagrammus) in Oregon and California Waters as Assessed in 2005. Pacific Fishery Management Council, 7700 Ambassador Place NE, Suite 200, Portland, OR 97220. 158 pp.

Dick, E. J. and A. D. MacCall. 2011. Depletion-Based Stock Reduction Analysis: A catch-based method for determining sustainable yields for data-poor fish stocks. Fisheries Research 110: 331-341.

TABLES AND FIGURES

Table 1. Reconstructed annual catches of kelp greenling in Washington and Oregon. Extrapolated and interpolated values are in italics.

	Oregon			Washington
Year	**Recreational**	**Commercial**	**Total (OR)**	**Recreational**
1950	***5.385***	***0.130***	***5.515***	***1.630***
1951	***5.385***	***0.130***	***5.515***	***1.630***
1952	***5.385***	***0.130***	***5.515***	***1.630***
1953	***5.385***	***0.130***	***5.515***	***1.630***
1954	***5.385***	***0.130***	***5.515***	***1.630***
1955	***5.385***	***0.130***	***5.515***	***1.630***
1956	***5.385***	***0.130***	***5.515***	***1.630***
1957	***5.385***	***0.130***	***5.515***	***1.630***
1958	***5.385***	***0.130***	***5.515***	***1.630***
1959	***5.385***	***0.130***	***5.515***	***1.630***
1960	***5.385***	***0.130***	***5.515***	***1.630***
1961	***5.385***	***0.130***	***5.515***	***1.630***
1962	***5.385***	***0.130***	***5.515***	***1.630***
1963	***5.385***	***0.130***	***5.515***	***1.630***
1964	***5.385***	***0.130***	***5.515***	***1.630***
1965	***5.385***	***0.130***	***5.515***	***1.630***
1966	***5.385***	***0.130***	***5.515***	***1.630***
1967	***5.385***	***0.130***	***5.515***	***1.630***
1968	***5.385***	***0.130***	***5.515***	***1.630***
1969	***5.385***	***0.130***	***5.515***	***1.630***
1970	***5.385***	***0.130***	***5.515***	***1.630***
1971	***5.385***	***0.130***	***5.515***	***1.630***
1972	***5.385***	***0.130***	***5.515***	***1.630***
1973	***5.385***	***0.130***	***5.515***	***1.630***
1974	***5.385***	***0.130***	***5.515***	***1.630***
1975	***5.385***	***0.130***	***5.515***	2.628
1976	***5.385***	***0.130***	***5.515***	1.244
1977	***5.385***	***0.130***	***5.515***	1.347
1978	***5.385***	***0.130***	***5.515***	2.462
1979	***5.385***	***0.130***	***5.515***	1.516
1980	5.598	***0.130***	5.728	1.894
1981	***5.687***	***0.130***	5.817	1.148
1982	***5.776***	***0.130***	5.906	1.395
1983	***5.865***	***0.130***	5.995	1.253
1984	5.954	***0.130***	6.084	1.412
1985	5.821	***0.130***	5.951	1.126
1986	5.013	***0.130***	5.143	2.302
1987	5.048	***0.130***	5.178	***3.135***
1988	5.351	0.080	5.431	***3.969***
1989	3.739	0.077	3.816	***4.802***
1990	***4.157***	0.003	4.160	5.635
1991	***4.574***	0.023	4.597	3.821
1992	***4.992***	0.016	5.007	6.271
1993	5.409	0.083	5.492	6.059
1994	5.996	0.181	6.177	3.725
1995	3.375	0.038	3.413	3.952
1996	3.724	0.665	4.389	4.288
1997	4.992	10.571	15.563	3.309
1998	3.433	9.834	13.267	2.070
1999	5.711	24.621	30.332	2.602
2000	5.240	19.404	24.644	2.640
2001	3.941	28.896	32.837	2.818
2002	4.349	53.483	57.832	3.477
2003	6.752	20.092	26.844	2.986
2004	5.762	22.926	28.689	4.045
2005	4.729	20.757	25.486	4.315
2006	3.139	14.513	17.652	2.813
2007	3.505	18.337	21.842	2.289
2008	3.621	21.859	25.480	2.217
2009	4.214	20.575	24.789	2.757
2010	6.826	18.335	25.161	3.994
2011	7.355	20.799	28.154	3.016
2012	6.876	18.991	25.867	***3.505***
2013			***27.011***	***3.261***
2014			***27.011***	***3.261***

Table 2. Parameter values/distributions used in catch-based models for kelp greenling in Oregon. All parameters in the Washington model were the same except for delta (see text for details). Means are arithmetic means, standard deviations with an * are log-scale standard deviations. Values that are fixed (assumed known without error) are shown in parentheses.

Parameter/Qty.	Distribution	Mean (Value)	SD	Bounds
M	Lognormal	0.26	0.4*	0,Inf
F_{MSY}/M	Lognormal	0.8	0.1*	0,Inf
B_{MSY}/B_0	Beta	0.4	0.05	0.05,0.95
Δ	Beta	0.512	0.1	0.01,0.99
Δ-year	n/a	(2005)	n/a	n/a
Age at maturity	n/a	(4)	n/a	n/a

Table 3. Percentiles of DB-SRA yield estimates for kelp greenling in Oregon

Percentile	DB-SRA (Oregon base)	DB-SRA (Oregon, A_{MAT}=3)	DB-SRA (Oregon, A_{MAT}=2)	DB-SRA (Oregon, no equilibrium catch)
2.5%	1.1	1.0	1.5	1.0
25%	7.9	8.0	9.3	7.6
50% (median)	**14.0**	**14.4**	**16.7**	**13.7**
75%	22.0	22.9	25.9	21.7
97.5%	44.3	46.2	51.5	43.8

Table 4. Percentiles of DB-SRA yield estimates for kelp greenling in Washington. Assumes depletion in 1997 equal to depletion in Oregon model, A_{MAT} = 4, and equilibrium catch of 1.63 mt per year since 1950.

Percentile	DB-SRA (Washington base)
2.5%	16.0
25%	24.6
50% (median)	31.4
75%	40.3
97.5%	65.7

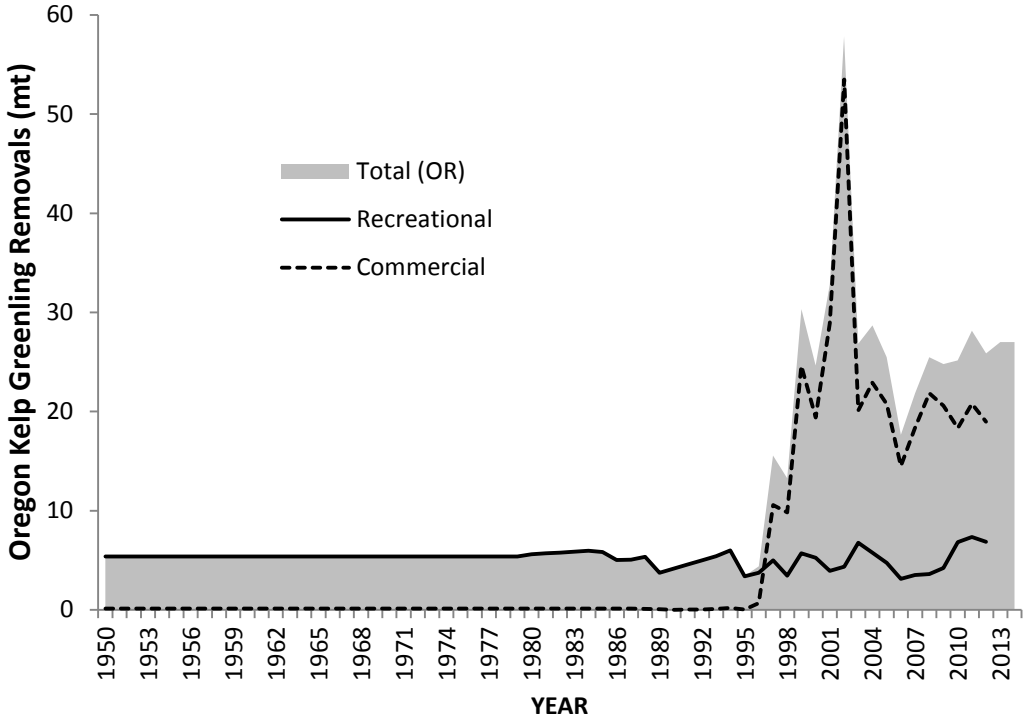

Figure 1. Removals (mt) of kelp greenling in Oregon (Sources: PacFIN, ODFW).

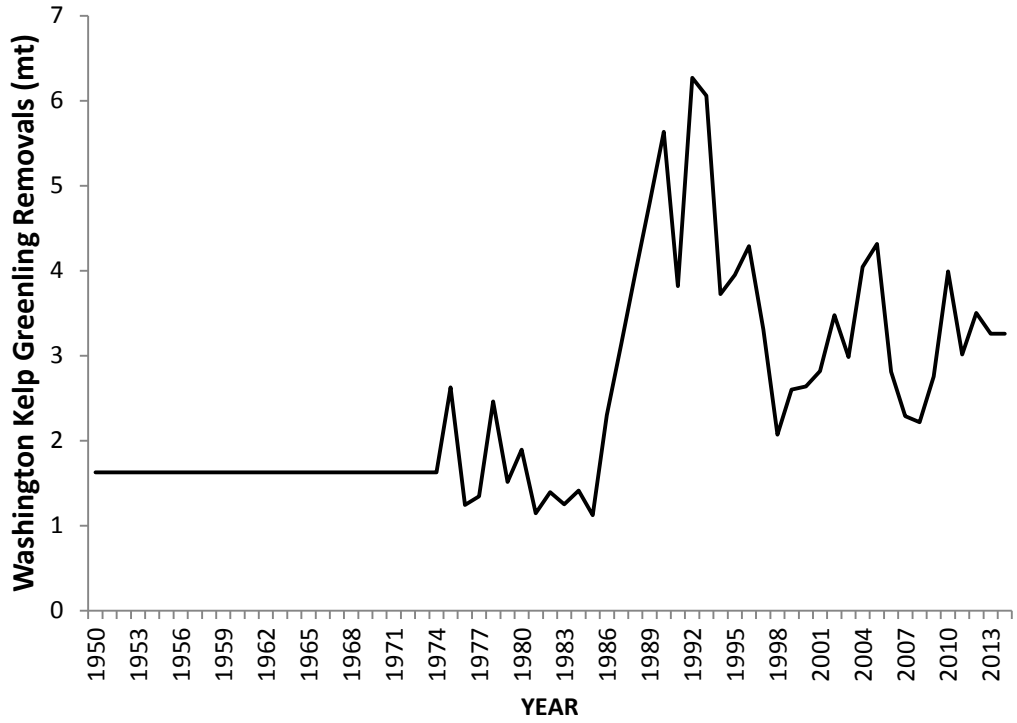

Figure 2. Recreational catch (mt) of kelp greenling in Washington (Sources: WDFW).