Addendum – Estimating among-assessment variation in overfishing limits

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Projection-based approach

Results for requested model runs

The alternative projection-based approach involved 1-year projections across 15 retrospective years (i.e., 1994-2008) for each benchmark assessment available for each stock. The OFL estimates were taken in the retrospective year and projected forward one year. An alternative approach, hereby deemed "method B", set the standard errors for the recruitment deviations for the years before the start of the projection period to those for the estimated recruitment deviations from the most recent (i.e., 10) years of the assessment. This differs from the previously presented stochastic projections, "method A", where the extent of recruitment variation was defined by the actual asymptotic standard errors for the annual recruitment deviations. This change should lead to more realistic uncertainty in estimates of OFL if the assessment had been conducted in the year corresponding to the projection start year. Sigma was calculated based upon the between-assessment variation in the 1-year projected OFLs across all retrospective years.

The stock- and retrospective start year-pooled estimate of σ based on the OFL deterministic 1-year projections was σ=0.562 with approximate 95% confidence intervals $0.412 \leq \sigma \leq 0.887$ (Tables 1 and 2). The stock- and start year-pooled stochastic estimate of σ using method A for recruitment standard errors was σ=0.439 ($0.322 \leq \sigma \leq 0.693$) (Tables 1 and 3). Assuming method B for recruitment standard errors yielded a stock- and start year-pooled estimate of σ=0.439 with approximate 95% confidence intervals $0.321 \leq \sigma \leq 0.692$ for stochastic 1-year projections (Tables 1 and 4). Stock- and retrospective start year-specific estimates of σ are shown in Table 2 for deterministic projections and Tables 3-4 for stochastic projections. The estimate of σ varies with retrospective start year and the scale of effect depends on the stock (Figure 1, method A; Figure 2, method B).

Table 1. Estimates of stock- and start year-pooled σ with 95% confidence intervals. The estimates from the 25-year OFL projections and 3 start years (i.e., 1998, 2003, and 2005) were presented to the SSC in November 2018. The 1-year OFL projections used 15 start years from 1994 to 2008. The alternative assumption for asymptotic standard errors for the annual recruitment deviations is labeled as Stochastic Method B.

25 projection years 3 start years		1 projection year 15 start years		
Deterministic	Stochastic Method A	Deterministic	Stochastic Method A	Stochastic Method B
0.533	0.485	0.562	0.439	0.439

Table 2. Estimates of sigma by stock and start-year as well as start-year and stock-pooled values with 95% confidence intervals based on deterministic OFL projections. Confidence intervals are not provided for stock-specific estimates because they are based on 1-year projections.

Species	1994		1995		1996		1997		1998		1999		2000		2001	
	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI
Pooled	0.59	0.413, 1.04	0.657	0.459, 1.15	0.641	0.448, 1.13	0.54	0.377, 0.948	0.572	0.4, 1.00	0.579	0.404, 1.02	0.604	0.422, 1.06	0.577	0.404, 1.01
	$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$	
Bocaccio	0.100		0.076		0.116		0.113		0.101		0.077		0.075		0.143	
Canary rockfish	1.14		1.31		1.38		1.40		1.35		1.50		1.53		1.42	
Darkblotched rockfish	0.503		0.492		0.487		0.497		0.51		0.497		0.388		0.384	
Petrale sole	0.147		0.138		0.141		0.153		0.171		0.150		0.136		0.121	
Pacific Ocean perch	0.041		0.081		0.002		0.159		0.019		0.593		0.786		0.059	
Widow rockfish	0.423		0.437		0.425		0.421		0.450		0.391		0.371		0.369	
Lingcod	1.17		1.38		1.23		0.267		0.735		0.116		0.541		0.944	

Species	2002		2003		2004		2005		2006		2007		2008		
	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	$\bar{\sigma}$
Pooled	0.585	0.409, 1.03	0.511	0.357, 0.898	0.501	0.350, 0.880	0.565	0.395, 0.991	0.5	0.349, 0.877	0.519	0.363, 0.911	0.451	0.315, 0.791	0.562
	$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\sigma_{y,s}$		$\bar{\sigma}_s$
Bocaccio	0.468		0.403		0.187		0.718		0.450		0.554		0.276		0.327
Canary rockfish	1.20		1.01		0.981		0.848		0.733		1.00		0.340		1.19
Darkblotched rockfish	0.569		0.605		0.509		0.539		0.499		0.504		0.576		0.507
Petrale sole	0.111		0.136		0.169		0.138		0.101		0.101		0.090		0.135
Pacific Ocean perch	0.248		0.288		0.128		0.395		0.748		0.215		0.582		0.389
Widow rockfish	0.383		0.411		0.430		0.427		0.428		0.442		0.467		0.419
Lingcod	0.748		0.040		0.735		0.589		0.349		0.361		0.434		0.751

Table 3. Estimates of sigma by stock and start-year as well as start-year and stock-pooled values with 95% confidence intervals based on stochastic OFL projections and method A for setting the variance of the recruitment deviations.

Species	1994		1995		1996		1997		1998		1999		2000		2001	
	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI
Pooled	0.455	0.44, 0.47	0.505	0.489, 0.522	0.502	0.486, 0.519	0.419	0.405, 0.433	0.444	0.43, 0.459	0.438	0.424, 0.453	0.484	0.468, 0.5	0.451	0.437, 0.466
	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI
Bocaccio	0.12	0.111, 0.13	0.083	0.077, 0.091	0.113	0.105, 0.123	0.129	0.119, 0.14	0.095	0.088, 0.103	0.102	0.095, 0.111	0.12	0.111, 0.13	0.136	0.126, 0.148
Canary rockfish	0.783	0.712, 0.868	0.913	0.832, 1.013	0.962	0.876, 1.067	0.976	0.888, 1.082	0.947	0.862, 1.05	1.047	0.953, 1.161	1.074	0.978, 1.191	0.996	0.907, 1.105
Darkblotched rockfish	0.412	0.385, 0.443	0.396	0.37, 0.426	0.421	0.394, 0.453	0.436	0.407, 0.468	0.433	0.405, 0.465	0.439	0.41, 0.471	0.344	0.321, 0.369	0.314	0.293, 0.337
Petrale sole	0.108	0.099, 0.12	0.11	0.1, 0.122	0.118	0.108, 0.131	0.135	0.123, 0.15	0.142	0.129, 0.157	0.117	0.107, 0.13	0.11	0.1, 0.122	0.101	0.092, 0.112
Pacific Ocean perch	0.065	0.059, 0.072	0.095	0.087, 0.105	0.033	0.03, 0.037	0.136	0.124, 0.151	0.065	0.059, 0.072	0.275	0.25, 0.304	0.65	0.592, 0.721	0.005	0.004, 0.005
Widow rockfish	0.32	0.296, 0.348	0.321	0.298, 0.349	0.325	0.301, 0.353	0.314	0.29, 0.341	0.336	0.311, 0.365	0.296	0.274, 0.322	0.277	0.257, 0.302	0.281	0.26, 0.306
Lingcod	0.847	0.771, 0.94	0.982	0.894, 1.089	0.894	0.814, 0.991	0.191	0.174, 0.212	0.542	0.494, 0.602	0.106	0.097, 0.118	0.38	0.346, 0.422	0.698	0.636, 0.775

Species	2002		2003		2004		2005		2006		2007		2008		
	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	$\bar{\sigma}$
Pooled	0.463	0.448, 0.479	0.4	0.388, 0.414	0.398	0.386, 0.412	0.454	0.439, 0.469	0.395	0.383, 0.409	0.405	0.392, 0.419	0.348	0.337, 0.359	0.439
	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\bar{\sigma_s}$
Bocaccio	0.418	0.387, 0.454	0.399	0.37, 0.434	0.194	0.18, 0.211	0.628	0.582, 0.683	0.408	0.378, 0.444	0.499	0.462, 0.543	0.26	0.241, 0.283	0.3
Canary rockfish	0.834	0.759, 0.925	0.694	0.631, 0.769	0.69	0.628, 0.765	0.592	0.539, 0.657	0.513	0.467, 0.569	0.706	0.643, 0.784	0.227	0.207, 0.252	0.828
Darkblotched rockfish	0.481	0.449, 0.516	0.506	0.473, 0.543	0.464	0.434, 0.498	0.468	0.437, 0.503	0.412	0.385, 0.443	0.41	0.383, 0.44	0.482	0.45, 0.518	0.431
Petrale sole	0.096	0.087, 0.106	0.107	0.098, 0.119	0.123	0.112, 0.137	0.103	0.094, 0.114	0.073	0.066, 0.081	0.076	0.069, 0.084	0.067	0.061, 0.074	0.108
Pacific Ocean perch	0.203	0.185, 0.225	0.213	0.194, 0.236	0.042	0.038, 0.047	0.343	0.312, 0.38	0.573	0.522, 0.636	0.168	0.153, 0.187	0.415	0.378, 0.46	0.291
Widow rockfish	0.292	0.271, 0.318	0.319	0.296, 0.347	0.325	0.301, 0.353	0.326	0.302, 0.354	0.314	0.291, 0.341	0.33	0.305, 0.359	0.349	0.323, 0.379	0.316
Lingcod	0.576	0.525, 0.639	0.013	0.012, 0.014	0.539	0.491, 0.598	0.43	0.392, 0.477	0.267	0.243, 0.296	0.267	0.243, 0.296	0.333	0.303, 0.369	0.549

Table 4. Estimates of sigma by stock and start-year as well as start-year and stock-pooled values with 95% confidence intervals based on stochastic OFL projections and method B for setting the variance of the recruitment deviations.

Species	1994		1995		1996		1997		1998		1999		2000		2001	
	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI
Pooled	0.46	0.446, 0.476	0.512	0.496, 0.529	0.5	0.484, 0.517	0.421	0.407, 0.435	0.446	0.432, 0.461	0.452	0.438, 0.467	0.472	0.457, 0.488	0.451	0.437, 0.466
	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI
Bocaccio	0.082	0.076, 0.089	0.062	0.058, 0.068	0.095	0.088, 0.103	0.093	0.086, 0.101	0.082	0.076, 0.089	0.063	0.058, 0.068	0.061	0.057, 0.067	0.117	0.109, 0.128
Canary rockfish	0.81	0.738, 0.899	0.927	0.844, 1.028	0.975	0.888, 1.082	0.994	0.905, 1.102	0.958	0.872, 1.062	1.06	0.965, 1.176	1.087	0.989, 1.205	1.003	0.913, 1.113
Darkblotched rockfish	0.436	0.408, 0.469	0.426	0.399, 0.458	0.422	0.395, 0.454	0.431	0.403, 0.464	0.443	0.414, 0.476	0.431	0.403, 0.463	0.336	0.314, 0.361	0.333	0.312, 0.358
Petrale sole	0.105	0.095, 0.116	0.098	0.089, 0.108	0.1	0.091, 0.111	0.108	0.099, 0.12	0.121	0.11, 0.134	0.106	0.097, 0.118	0.096	0.087, 0.107	0.086	0.078, 0.095
Pacific Ocean perch	0.029	0.027, 0.033	0.057	0.052, 0.063	0.002	0.001, 0.002	0.112	0.102, 0.125	0.013	0.012, 0.015	0.421	0.383, 0.467	0.557	0.507, 0.618	0.041	0.038, 0.046
Widow rockfish	0.327	0.302, 0.355	0.334	0.309, 0.363	0.327	0.303, 0.356	0.327	0.303, 0.355	0.353	0.326, 0.383	0.308	0.285, 0.335	0.29	0.268, 0.315	0.289	0.267, 0.314
Lingcod	0.829	0.755, 0.92	0.976	0.888, 1.082	0.872	0.794, 0.967	0.189	0.172, 0.21	0.521	0.474, 0.578	0.082	0.075, 0.091	0.384	0.349, 0.426	0.669	0.609, 0.742

Species	2002		2003		2004		2005		2006		2007		2008		
	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	σ_y	CI	$\bar{\sigma}$
Pooled	0.457	0.443, 0.473	0.399	0.386, 0.413	0.391	0.379, 0.405	0.442	0.428, 0.457	0.391	0.378, 0.404	0.406	0.393, 0.419	0.352	0.341, 0.364	0.439
	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\sigma_{y,s}$	CI	$\bar{\sigma_s}$
Bocaccio	0.382	0.354, 0.416	0.33	0.305, 0.359	0.153	0.142, 0.167	0.588	0.544, 0.639	0.368	0.341, 0.4	0.453	0.42, 0.493	0.226	0.209, 0.245	0.267
Canary rockfish	0.849	0.773, 0.941	0.714	0.65, 0.791	0.696	0.633, 0.772	0.601	0.548, 0.667	0.52	0.473, 0.577	0.711	0.648, 0.789	0.241	0.219, 0.267	0.84
Darkblotched rockfish	0.493	0.461, 0.53	0.524	0.49, 0.564	0.441	0.412, 0.474	0.467	0.437, 0.502	0.433	0.405, 0.465	0.437	0.409, 0.47	0.499	0.467, 0.537	0.44
Petrale sole	0.079	0.072, 0.087	0.096	0.088, 0.107	0.12	0.109, 0.133	0.098	0.089, 0.108	0.072	0.065, 0.08	0.072	0.065, 0.08	0.064	0.058, 0.071	0.096
Pacific Ocean perch	0.176	0.16, 0.195	0.204	0.186, 0.227	0.091	0.083, 0.101	0.28	0.255, 0.31	0.53	0.483, 0.588	0.153	0.139, 0.169	0.412	0.375, 0.457	0.276
Widow rockfish	0.301	0.279, 0.327	0.325	0.301, 0.354	0.343	0.317, 0.372	0.343	0.317, 0.373	0.345	0.319, 0.375	0.357	0.331, 0.388	0.379	0.351, 0.412	0.331
Lingcod	0.53	0.483, 0.588	0.028	0.026, 0.031	0.521	0.475, 0.578	0.418	0.38, 0.464	0.247	0.225, 0.274	0.256	0.233, 0.284	0.307	0.28, 0.341	0.533

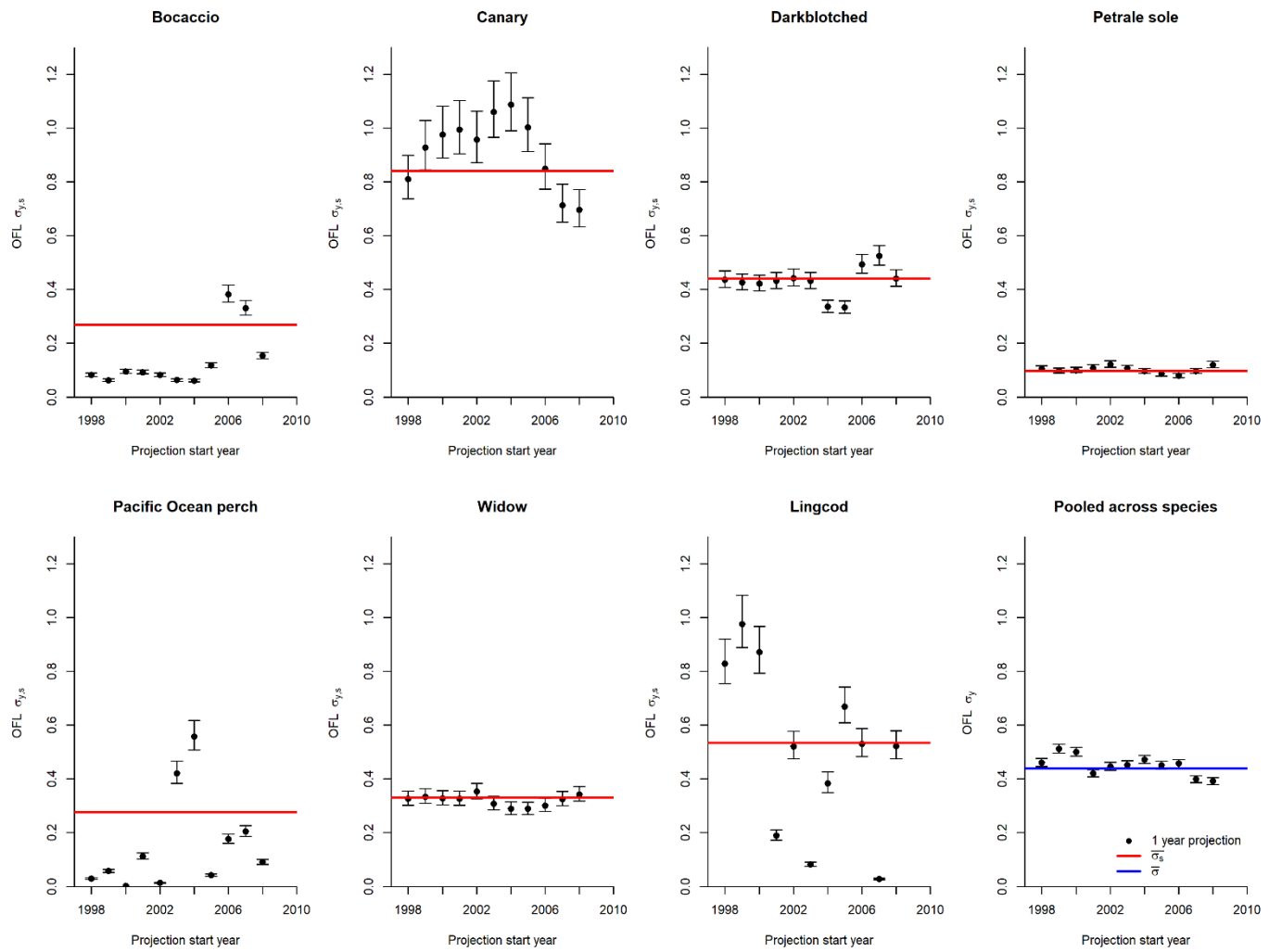

Figure 1. Stock-specific and retrospective start year-specific estimates of sigma based on stochastic (method A) OFL 1-year projections (N=100). The solid red lines are the stock-specific pooled retrospective start year estimates of sigma. The final panel is the retrospective start year-specific estimates of sigma pooled across stocks. The solid blue line indicates the stock-pooled and start year-pooled estimate of sigma.

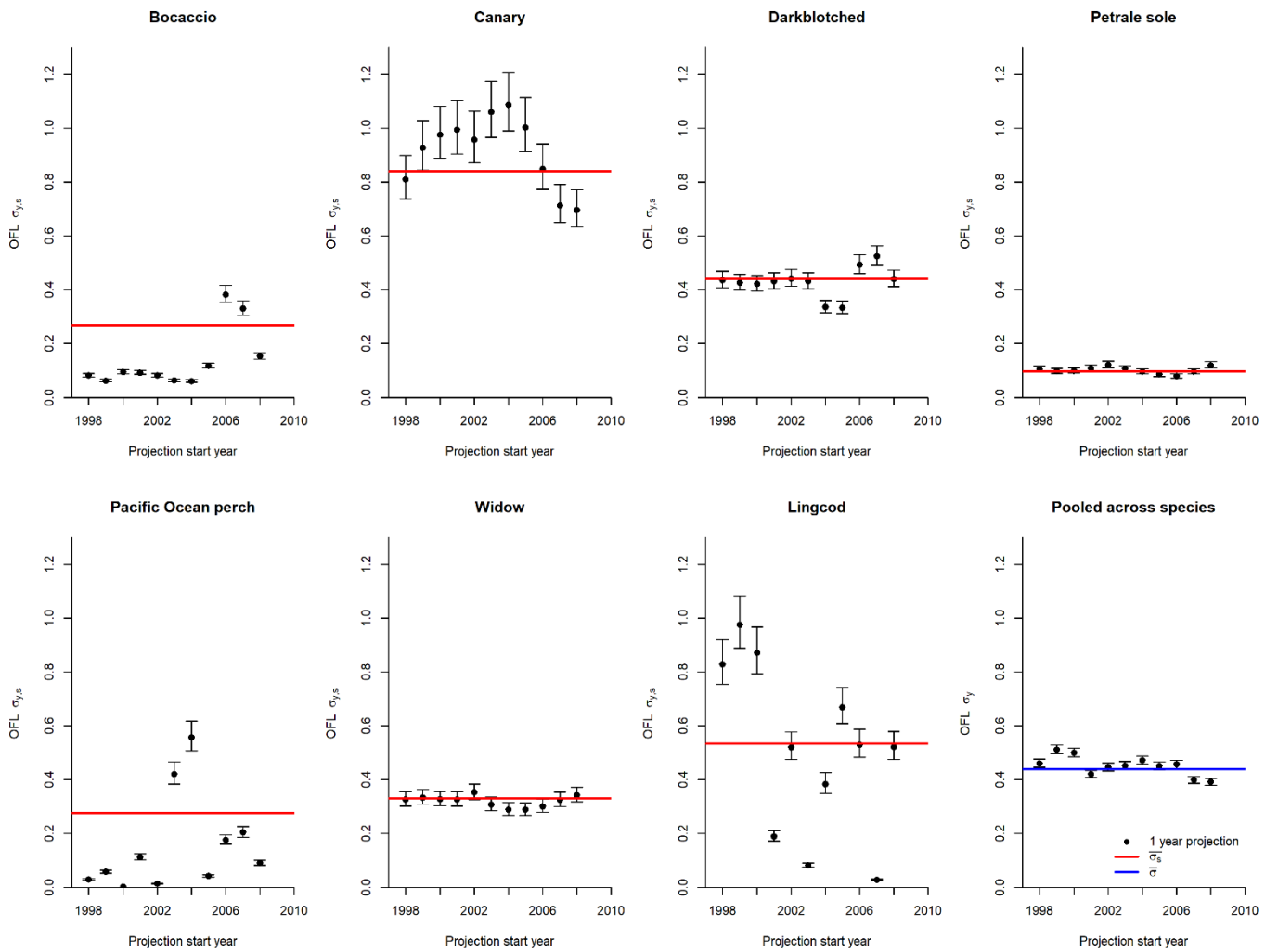

Figure 2. Stock-specific and retrospective start year-specific estimates of sigma based on stochastic (method B) OFL 1-year projections (N=100). The solid red lines are the stock-specific pooled retrospective start year estimates of sigma. The final panel is the retrospective start year-specific estimates of sigma pooled across stocks. The solid blue line indicates the stock-pooled and start year-pooled estimate of sigma.

Historical biomass approach for Category 2 groundfish

Results for Category 2 stocks

The historical biomass approach (*sensu* Ralston et. al) was applied to seven category 2 groundfish and coastal pelagic stocks (Table 1 and Table 2). Pooling across stocks resulted in σ=0.507 with an approximate 95% confidence interval of 0.469 $\leq\sigma\leq$ 0.551 (Table 3).

Table 1. The US west coast groundfish and coastal pelagic stocks benchmark stock assessments used for estimating σ.

Species	**Assessment year**
Blackgill rockfish	2005, 2011
Blue and Deacon rockfishes	2007, 2017
China rockfish	2013, 2015
Cowcod	2007, 2013
Longspine thornyhead	2005, 2013
Pacific sardine	2004, 2007, 2009, 2011, 2014
Pacific mackerel	2004, 2005, 2007, 2009, 2011, 2015

Table 2. Summary of stock-specific analyses using the historical biomass approach.

Common name	Scientific name	No. of assessments	Deviations (n)	Log-scale standard deviation
Blackgill rockfish	*Sebastes melanostomus*	2	28	1.95
Blue and Deacon rockfishes	*Sebastes mystinus* *Sebastes diaconus*	2	20	0.080
China rockfish	*Sebastes nebulosus*	2	36	0.762
Cowcod	*Sebastes levis*	2	30	0.509
Longspine thornyhead	*Sebastolobus altivelis*	2	24	1.05
Pacific sardine	*Sardinops sagax*	5	30	0.509
Pacific mackerel	*Scomber japonicas*	6	20	0.080

Table 3. Summary of pooled and life history group-specific estimates of σ from assessments of groundfish and coastal pelagic stocks.

Group	Number of species	σ	95% CI
rockfish	5	0.548	0.497, 0.610
coastal pelagic	2	0.394	0.329, 0.491
All species	7	0.507	0.469, 0.551

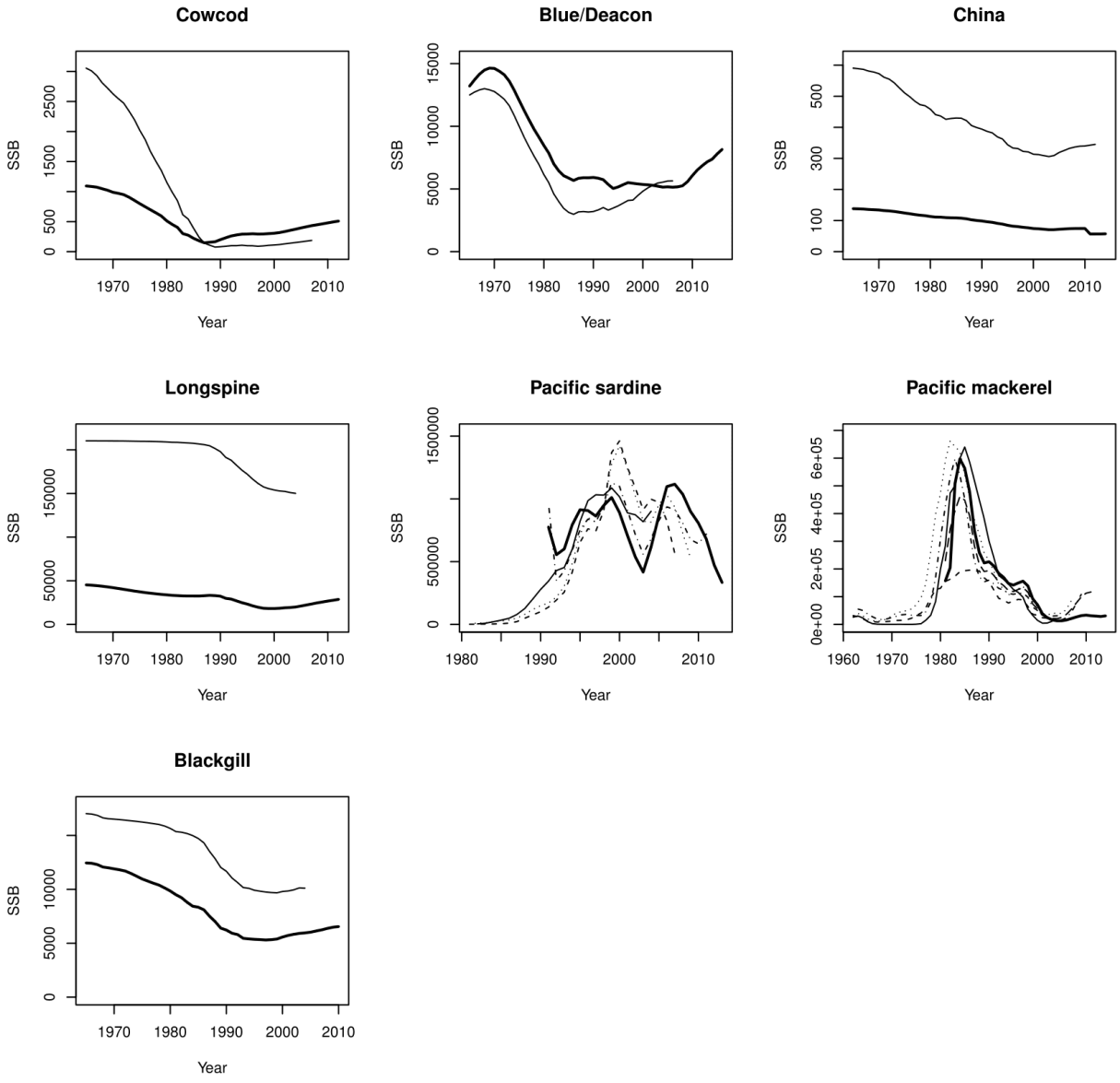

Figure 1. Biomass time series for the seven groundfish and coastal pelagic stocks from stock assessments conducted for the Pacific Fishery Management Council on the west coast of the United States. The thick, solid black line denotes the most recent assessment.

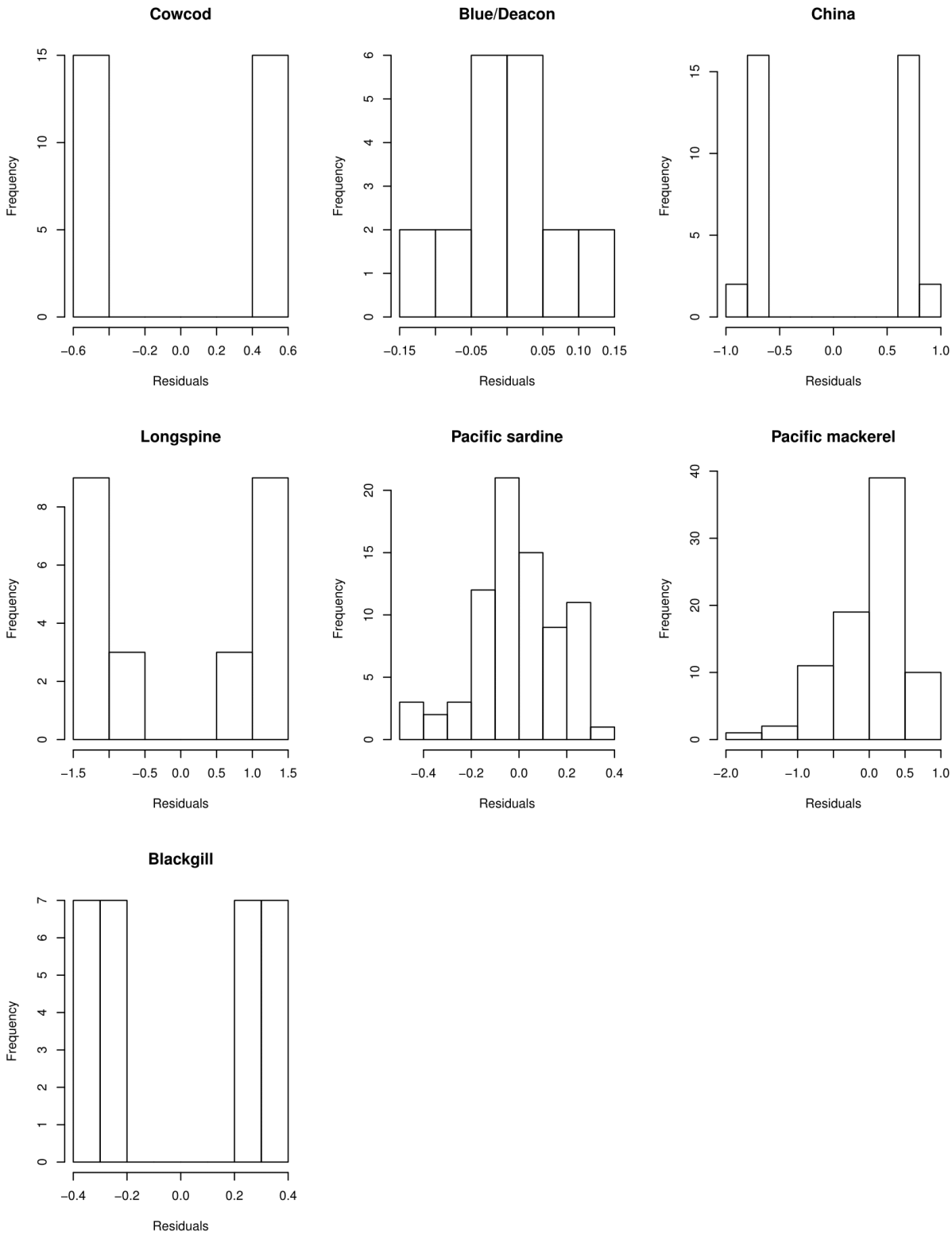

Figure 2. Frequency distributions of log-scale biomass deviations for the seven groundfish and coastal pelagic stocks. Deviations were calculated from annual means taken from the biomass time series presented in Figure 1.

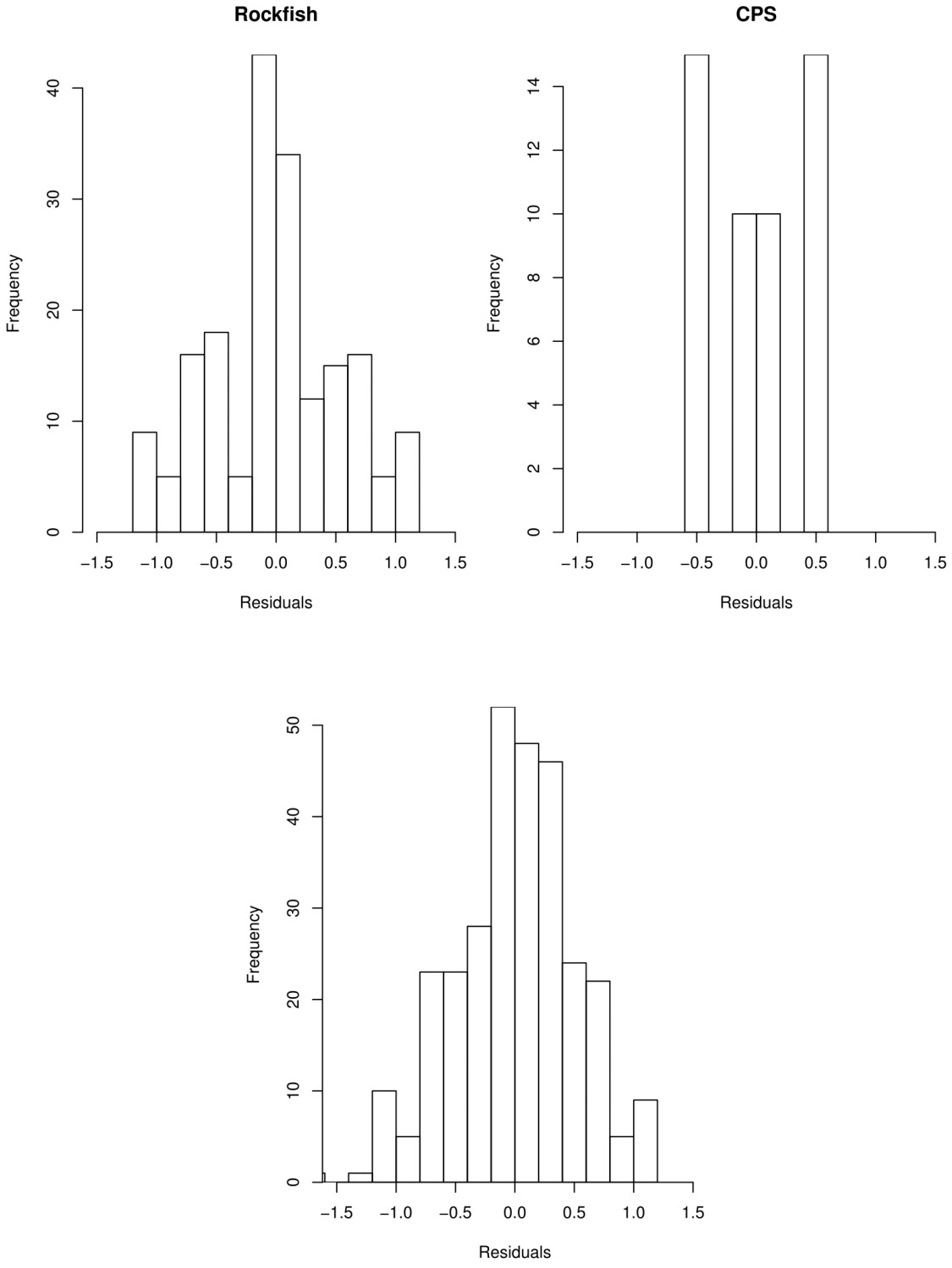

Figure 3. Top row: Composite distributions of log-deviations from the mean, pooled for two life history groupings (rockfish and coastal pelagic stocks). Bottom row: Aggregate distribution of log-deviations pooled over all seven stocks.