An alternative version of the base model for EBS Pacific cod with constrained catchability

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Introduction and methods

At the request of an industry representative, an alternative version of the current base model for EBS Pacific cod (Model 19.12) was run. In the base model, the base value of catchability (Q) for the trawl survey is estimated freely at 1.034. In the alternative version, the base value of catchability was fixed at 0.465, which is the value that sets the average of the product of Q and survey selectivity for fish in the 60-81 cm size range equal to 0.47, corresponding to the proportion of the population within that size range estimated by Nichol et al. (2007) to be present within the depth range sampled by the survey gear. Because both Q and selectivity are time-varying, the average is computed by weighting the average in each year by the model's estimated numbers at length in that year, and then averaging across all years in the time series (1982-2019). The data file used in the 2019 assessment was used for both models. The values of the "sigma" terms that constrain the various vectors of annual random deviations were not re-tuned in the alternative version.

Results

Note: Comparisons reported in this section are made with respect to the values obtained last year from Model 19.12 by itself, not the values from last year's model-averaged ensemble.

As expected, fixing Q in the manner described has a substantial impact on projections for 2021:

- The estimate of 2021 relative spawning biomass increases from 0.30 to 0.60 (meaning that the stock goes from being well below, to well above, the kink in the harvest control rule).
- The estimate of $F_{40\%}$ increases from 0.415 to 0.522.
- The estimate of 2021 maxABC (conditional on the 2020 catch being equal to the 2020 ABC) increases from 113,071 t to 371,530 t.

Objective function values, both overall and by major component, are shown in Table 1, where "Change" represents the alternative model value minus the base model value. Overall, the alternative model has an objective function value that is 36.90 points higher than the base model (i.e., it gives a substantially worse fit). The two components with the largest changes are size composition and age composition. These are broken down on by fleet and year in Table 2. Comparison of these values between models is appropriate, because the models use the same data file.

Estimates of time-invariant parameters are shown in Table 3, where "Change" is expressed in *relative* terms (i.e., alternative/base – 1) in the *top* portion of the table, where the parameters are all constrained to be positive; and in *absolute* terms (i.e., alternative – base) in the *bottom* portion of the table, where parameters can be either positive or negative. For the top portion of the table, the largest changes are exhibited by the natural mortality rate (up by 28.0% in the alternative version) and the initial fishing mortality rate (down by 63.4% in the alternative version). For the bottom portion of the table, the largest changes are exhibited by the log-scale mean post-1976 recruitment (up by 1.079 in the alternative version), the log-scale catchability (down by 0.799 in the alternative version), and the log-scale Dirichlet-multinomial parameter for the survey age composition data (down by 0.662 in the alternative version).

Discussion: reviewing the use of the Nichol et al. (2007) proportion in previous assessments

The 2007 and 2008 stock assessments compared the average product of *Q* (internally estimated) and selectivity across the 60-81 cm size range against the estimate of 0.47 obtained by Nichol et al. (2007) as one of the model selection criteria.

The 2009 stock assessment estimated *Q* iteratively by tuning it so that the average product of *Q* and selectivity across the 60-81 cm size range matched the Nichol et al. estimate of 0.47. The resulting estimate (*Q*=0.77) was retained in all assessments through 2015.

The 2016 stock assessment returned to the practice of freely estimating *Q*, based on comments from the BSAI Groundfish Plan Team, the SSC, the 2016 CIE review, and the paper by Weinberg et al. (2016). Some relevant excerpts are shown below:

- BSAI GPT minutes, 9/15: "The fixed survey *Q* (0.77) based on archival tags ... has become less and less credible as careful experiments and analysis performed by RACE have produced no evidence that cod in the path of the survey trawl avoid capture by any means (e.g., vertical distribution or out-swimming). A higher value of catchability, as estimated by the other models, therefore seems more plausible and prudent."
- SSC minutes, 10/15: "The SSC has been on record encouraging the development of an alternative model that estimates *Q*, due to the very weak or non-existent evidence for net avoidance, which has been corroborated by recent work. This makes the fixed value for *Q*, which was always based on weak evidence, even less tenable than before."
- CIE reviewer, 4/16: "It is a mistake to force a given value of *Q* into the assessment since the assumptions on which the calculations are based are quite different.... It is probably more useful to estimate *Q* within the model and regard it as a value that reconciles the assessment scale to the survey scale. Fixing *Q* within the model will add a degree of rigidity that may lead to severely biased estimates of fishing mortality, especially where the catch is treated as a known constant."
- Weinberg et al. (2016): "We agree with Nichol et al. (2007), in that it seems unlikely for the survey trawl to catch 100% of the Pacific cod in its path 100% of the time; however, we cast doubt on the conclusion that more than 50% of large fish swim above the trawl in the presence of trawling activity. Nichol et al.'s study was based on a very small sample, and one could argue that our study similarly lacked broad geographical range, over areas with varying habitat complexity, light intensity, and temperatures that (although never shown) may all have an effect on Pacific cod vertical distributions or perhaps even swimming speeds.... Additional experiments focusing on these factors would shed additional light on the matter."

The assessments conducted since 2016 assessment have estimated *Q* freely.

References

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Weinberg, K. L., C. Yeung, D. A. Somerton, G. G. Thompson, and P. H. Ressler. 2016. Is the survey selectivity curve for Pacific cod (*Gadus macrocephalus*) dome-shaped? Direct evidence from trawl studies. *Fishery Bulletin* 114:360–369.

Table 1. Objective function values in the base model (“Qfree”) and the alternative version (“Qfixed”).

Component	Qfree	Qfixed	Change
Catch	0.00	0.00	0.00
Initial_eq_catch	0.00	0.00	0.00
Survey index	-87.65	-86.31	1.34
Size composition	814.26	827.90	13.64
Age composition	251.33	273.82	22.50
Recruitment	-0.41	1.88	2.30
Initial_eq_recr	5.36	0.51	-4.85
Priors	0.00	0.00	0.00
"Softbounds"	0.02	0.02	0.00
Deviations	97.79	99.76	1.97
Total	1080.68	1117.58	36.90

Table 2. Annual objective function values by fleet and year for compositional data.

	Fishery size composition			Survey size composition			Survey age composition		
Year	Qfree	Qfixed	Change	Qfree	Qfixed	Change	Qfree	Qfixed	Change
1977	0.55	0.40	-0.16						
1978	2.22	1.75	-0.48						
1979	1.99	1.50	-0.49						
1980	0.88	1.03	0.15						
1981	3.51	3.85	0.34						
1982	0.84	0.75	-0.09	20.49	18.74	-1.75			
1983	2.11	2.10	-0.01	10.07	10.07	0.00			
1984	3.05	3.36	0.31	19.85	22.67	2.82			
1985	2.43	2.60	0.17	21.78	20.18	-1.60			
1986	2.79	2.56	-0.23	7.52	7.52	0.00			
1987	5.18	3.93	-1.25	9.87	9.64	-0.22			
1988	6.39	6.35	-0.04	10.81	9.91	-0.89			
1989	6.35	6.74	0.39	16.61	17.88	1.27			
1990	7.17	8.60	1.42	9.21	9.34	0.13			
1991	4.66	5.59	0.93	15.10	13.81	-1.29			
1992	4.15	4.18	0.03	14.03	13.84	-0.19			
1993	3.85	3.19	-0.65	20.15	18.23	-1.92			
1994	4.22	4.09	-0.14	15.35	17.14	1.79	6.29	8.20	1.91
1995	3.40	3.48	0.08	10.29	9.87	-0.42	16.63	14.36	-2.27
1996	7.52	6.94	-0.58	10.84	10.67	-0.17	6.26	8.05	1.79
1997	6.31	5.63	-0.67	14.61	14.22	-0.40	6.36	8.18	1.81
1998	4.23	4.70	0.46	19.20	17.82	-1.38	6.23	7.63	1.40
1999	3.06	3.87	0.81	13.88	13.42	-0.47	6.65	8.52	1.87
2000	3.98	4.39	0.41	9.64	10.24	0.60	10.74	11.65	0.91
2001	4.94	5.97	1.03	11.22	10.48	-0.74	7.89	8.68	0.79
2002	4.25	4.75	0.51	15.43	14.88	-0.55	10.01	11.11	1.10
2003	3.11	3.19	0.08	24.65	23.49	-1.16	6.80	8.64	1.84
2004	4.41	5.12	0.71	7.12	5.48	-1.64	16.79	15.77	-1.02
2005	2.81	2.74	-0.07	23.76	21.79	-1.96	7.71	9.02	1.31
2006	8.33	8.67	0.34	16.86	17.30	0.45	18.44	18.28	-0.15
2007	6.57	7.40	0.83	17.01	13.34	-3.67	13.17	11.83	-1.34
2008	5.57	7.40	1.83	14.53	15.20	0.67	12.35	13.16	0.81
2009	5.21	5.99	0.78	14.35	15.34	0.99	7.84	8.15	0.31
2010	8.23	8.39	0.16	28.52	34.09	5.57	6.64	8.94	2.30
2011	3.15	4.87	1.71	23.57	22.36	-1.21	9.15	8.70	-0.45
2012	3.81	4.51	0.70	28.23	34.63	6.41	12.69	13.25	0.56
2013	6.75	7.10	0.34	49.61	53.49	3.88	11.55	12.54	0.99
2014	4.68	4.46	-0.22	24.90	24.94	0.04	7.68	8.85	1.17
2015	4.11	5.42	1.30	14.34	15.72	1.38	6.80	8.27	1.46
2016	2.78	3.20	0.42	13.74	13.22	-0.52	9.51	10.53	1.03
2017	3.65	3.39	-0.27	14.23	13.62	-0.61	8.42	10.34	1.92
2018	1.82	1.84	0.02	11.53	12.07	0.53	18.73	21.17	2.44
2019	2.61	2.38	-0.23	13.73	12.89	-0.84			
Sum:	177.64	188.35	10.70	636.61	639.55	2.94	251.33	273.82	22.50

Table 3. Estimates of time-invariant parameters.

Parameter	Qfree	Qfixed	Change
Natural_mortality	0.346	0.443	0.280
L_at_1.5_base	14.904	14.671	-0.016
L_infinity	117.310	111.147	-0.053
VonBert_K	0.108	0.111	0.029
Richards_coef	1.467	1.550	0.056
SD_len_at_1	3.511	3.582	0.020
SD_len_at_20	9.860	9.169	-0.070
InitF_main_fsh	0.133	0.049	-0.634
Main_fsh_sel_PeakStart	76.012	76.011	0.000
Main_srv_sel_PeakStart_base	20.797	21.394	0.029
AgeBias_at_1_1977_2007	0.336	0.352	0.016
AgeBias_at_1_2008_2019	0.020	0.015	-0.005
AgeBias_at_20_1977_2007	0.907	0.835	-0.072
AgeBias_at_20_2008_2019	-1.715	-1.794	-0.078
ln(Recr_ave_1977_2018)	13.104	14.183	1.079
ln(Recr_ave_pre1977_offset)	-0.946	-0.397	0.549
lnQ_main_srv_base	0.034	-0.766	-0.799
Main_fsh_sel_lnSD1_base	5.976	5.965	-0.011
Main_fsh_sel_lnSD2	-9.985	-9.994	-0.008
Main_fsh_sel_logitEnd_base	2.006	1.548	-0.459
Main_srv_sel_lnSD1_base	3.499	3.573	0.074
lnDM_size_main_fish	9.990	9.990	0.000
lnDM_size_main_sur	9.984	9.984	0.000
lnDM_age_main_srv	0.099	-0.563	-0.662