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ADDENDUM

Further SCAA/ASPM Assessments of Gulf of Maine Cod Including Data for 2007 and Exploring the Impact of Age-Dependence in Natural Mortality

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INTRODUCTION

Deadlines for the submission of the main text of this paper did not allow time for the computation of F_{rebuild} statistics. This statistic is reported here for the one case amongst the 16 assessment options of the main paper for which the estimate of spawning biomass for 2007 was less than B^{*sp}_{MSY} : Beverton-Holt D (the “default” case with flat survey selectivity and M = 0.2), together with an explanation of the methodology used for the computation.

Further, the main text indicated that rather than considering the mechanisms of domed survey selectivity, a higher age-independent M, or M increasing with age in isolation to account for the relative paucity of older cod in the surveys and fishery, this could be similarly achieved by considering these in combination. To illustrate this possibility, the results for one such combination (assessment Ricker I defined below) are presented here.

METHODOLOGY

Computation of F_{rebuild} requires an ability to project assessment results into the future, taking account of their estimation imprecision, to determine the value of a constant F from 2009 onwards which will achieve a 50% probability that B^{sp} exceeds B^{*sp}_{MSY} by 2014. Given that the SCAA/ASPM assessment approach applied here incorporates a parametric stock-recruitment function, this same approach has been continued for projections.

Taking account of estimation imprecision for the starting numbers-at-age vector for the projections, as well as other pertinent estimated parameters of the assessment, was achieved via a Bayesian estimation approach. This required the specification of prior distributions for these estimable parameters. In almost all cases, uniform distributions were assumed for these: the bounds for those distributions are set out in Table 1. These distribution choices were intended to reflect an absence of further information, except perhaps as implied by the distribution bounds. The exception is the (logged) stock-recruitment residuals which were assumed to be normally distributed with a fixed known variance.

The initial parameter vector use to start the MCMC computational process used was the mode of the posterior. The chain was “thinned” by taking every 200th value in the chain, and the results of the first 1

000 000 iterations were discarded to allow for a "burn-in" period. A chain of 5 million iterations (including the burn-in period) was run, which required about 24 hours of computing time.

RESULTS AND DISCUSSION

Table 2 compares the MLE results for assessment Beverton-Holt D of the main text with those for the equivalent Bayesian estimator. Fig.1 shows traces for some of the estimable parameters. It is clear from the trace for steepness *h* that the chain was not sufficiently long and thinned to achieve true convergence. It was impractical to run the computations for a longer time period, but the fact that the Hessian based CV's for the MLE estimates and the Bayesian posterior CV's in Table 2 are generally similar suggests that the MCMC results are nevertheless reasonably adequate for the process for which they are required here.

The resultant F_{rebuild} for assessment Beverton-Holt D is 0.28, compared to an F_{MSY} estimate of 0.33.

Table 3 compares results for the selected assessment Ricker G of the main text with a Ricker I option which sets M=0.25 up to age 4, allows a relatively small slope in survey selectivity at larger ages of 0.1, and then estimates the extent of the assumed exponential increase in M with age above age 4. As would be expected, this extent is less for Ricker I than for Ricker G. Otherwise, however, estimates for the two options are very similar, except that biomass measures in absolute terms (tons) tend to be somewhat higher for Ricker I.

Table 1: Prior distributions assumed for estimable model parameters for the Bayesian assessment.

Parameter	Distribution
h	U[0.2, 0.98)
θ	U[0, 0.95]
$\ln(K^{sp})$	U[8, 15]
Selectivities-at-age	U[0, 1]
Recruitment residuals	$N(0, \sigma_R^2)$

Table 2 Estimates of management quantities for the Gulf of Maine cod for assessment Beverton-Holt D. Values in bold are inputs, and those in parentheses are CV's. Mass units are '000 tons.

	Flat survey selectivity, M=0.2 (D)			
	MLE and Hessian based CV		Posterior median and CV from MCMC	
'-lnL:overall	62.1			
'-lnL:Survey	-7.8			
'-lnL:CAA	-35.8			
'-lnL:CAAsurv	54.4			
'-lnL:RecRes	51.3			
h	0.98*	-	0.97	(0.00)
γ	**1.00**	-	**1.00**	-
θ	0.24	(0.12)	0.25	(0.10)
ϕ	**0.10**	-	**0.10**	-
K^{sp}	164.0	(0.07)	167.3	(0.08)
$B^{sp}{}_{2007}$	31.1	(0.14)	32.8	(0.17)
$B^{sp}{}_{2007}/K^{sp}$	0.19	(0.14)	0.20	(0.15)
MSYL^{sp}	0.18	(0.04)	0.17	(0.06)
$B^{sp}{}_{\mathrm{MSY}}$	29.6	(0.08)	28.3	(0.09)
$B^{*sp}{}_{\mathrm{MSY}}$	35.6	(0.08)	32.9	(0.10)
$B^{sp}{}_{2007}/B^{*sp}{}_{\mathrm{MSY}}$	0.87	(0.14)	0.99	(0.16)
MSY	9.7	(0.07)	9.7	(0.08)
MSY*	11.6	(0.07)	11.2	(0.08)
F_{MSY}	0.30	(0.00)	0.33	(0.06)
$F_{rebuild}$			0.28	-
F_{2007}	0.25	(0.17)	0.24	(0.20)
F_{2007} (av ages 4-5)	0.37	(0.16)	0.23	(0.19)
$F_{40\%}$	0.14	(0.00)	0.15	(0.04)
$B^{*sp}{}_{\mathrm{MSY}}$_40%	60.0	(0.06)	60.9	(0.03)
MSY*_40%	9.4	(0.05)	9.2	(0.03)
C_{2008}	**5.6**	-	**5.6**	-
C_{2009} (F_{MSY})	13.8	(0.17)	15.0	(0.22)
C_{2009} ($F_{\text{status quo}}$)	7.1	(0.03)	7.0	(0.04)
C_{2009} (F_{rebuild})			12.81	(0.21)
q spring	0.51	(0.09)	0.49	(0.04)
q autumn	0.53	(0.08)	0.51	(0.04)
Slope_com 7/8	0.03	(0.15^{+})	0.10	(0.61)
Slope_surv 7/8	**0.00**	-	**0.00**	-
$\sigma_R$out	0.61	(0.03)	0.55	(0.03)
M1	**0.20**		**0.20**	
M2	**0.20**		**0.20**	
M3	**0.20**		**0.20**	
M4	**0.20**		**0.20**	
M5	**0.20**		**0.20**	
M6	**0.20**		**0.20**	
M7	**0.20**		**0.20**	
M8	**0.20**		**0.20**	
M9	**0.20**		**0.20**	
M10	**0.20**		**0.20**	
M11+	**0.20**		**0.20**	

* Constraint boundary
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Table 3 Estimates of management quantities for the Gulf of Maine cod Ricker G and I. Values in bold are inputs, and those in parentheses are Hessian based CV's. Mass units are '000 tons.

	Ricker G		*M*=0.25 incr from age 4, survey slope fixed, Ricker I	
'-lnL:overall	23.8		21.8	
'-lnL:Survey	-12.1		-12.4	
'-lnL:CAA	-39.5		-39.5	
'-lnL:CAAsurv	35.9		34.5	
'-lnL:RecRes	39.5		39.2	
h	0.99	(0.16)	1.04	(0.16)
γ	**1.00**	-	**1.00**	-
θ	0.95*	-	0.95*	-
ϕ	**0.10**	-	**0.10**	-
K^{sp}	69.3	(0.09)	76.9	(0.09)
$B^{sp}{}_{2007}$	44.5	(0.13)	47.4	(0.13)
$B^{sp}{}_{2007}/K^{sp}$	0.64	(0.14)	0.62	(0.14)
$MSYL^{sp}$	0.39	(0.13)	0.38	(0.14)
$B^{sp}{}_{MSY}$	27.3	(0.10)	29.0	(0.11)
$B^{*sp}{}_{MSY}$	31.5	(0.10)	33.4	(0.11)
$B^{sp}{}_{2007}/B^{*sp}{}_{MSY}$	1.41	(0.14)	1.42	(0.14)
MSY	11.7	(0.10)	11.6	(0.10)
*MSY**	13.5	(0.10)	13.4	(0.10)
F_{MSY}	0.43	(0.00)	0.43	(0.00)
$F_{rebuild}$	N/A		N/A	
F_{2007}	0.18	(0.15)	0.19	(0.15)
F_{2007} (av ages 4-5)	0.18	(0.14)	0.18	(0.14)
$F_{40\%}$	0.33	(0.00)	0.30	(0.00)
$B^{*sp}{}_{MSY\_40\%}$	33.4	(0.04)	37.5	(0.05)
*MSY**_40%	10.8	(0.03)	10.3	(0.03)
C_{2008}	**5.6**	-	**5.6**	-
C_{2009} (F_{MSY})	23.3	(0.15)	22.7	(0.15)
C_{2009} ($F_{status\ quo}$)	6.9	(0.04)	6.8	(0.04)
C_{2009} ($F_{rebuild}$)	N/A		6.48	(0.15)
q spring	0.32	(0.10)	0.34	(0.11)
q autumn	0.34	(0.08)	0.36	(0.10)
Slope_com 7/8	0.12	(1.18)	0.27	(0.46)
Slope_surv 7/8	**0.00**	-	**0.10**	-
σ_R out	0.54	(0.03)	0.53	(0.03)
M1	**0.20**		**0.25**	
M2	**0.20**		**0.25**	
M3	**0.20**		**0.25**	
M4	**0.20**		**0.25**	
M5	0.25		0.27	
M6	0.30		0.30	
M7	0.37		0.33	
M8	0.46		0.37	
M9	0.56		0.40	
M10	0.69		0.44	
M11+	0.85		0.49	

* Constraint boundary

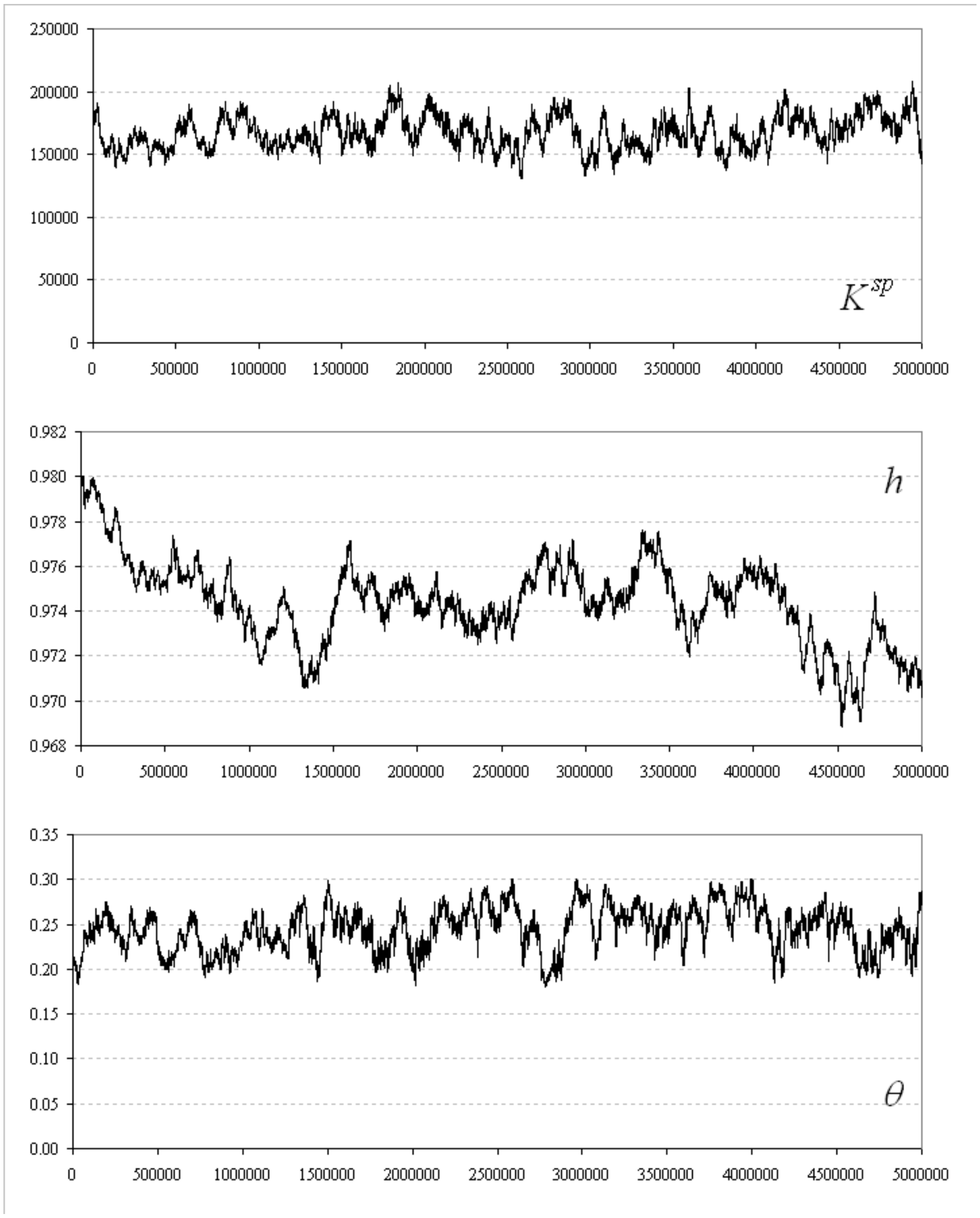

Fig. 1: MCMC chains for three estimable parameters for the Beverton-Holt D assessment of the Gulf of Maine cod.