Further Squid Assessment and Projection Results for a Bayesian Approach to Take Account of Uncertainty in Parameter Values

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Introduction

The squid stock assessment model has recently been updated to be based upon the Baranov catch equations rather than the Pope catch equations used in past analyses as advised by the Panel from the International Stock Assessment Meeting held in November 2012. A Bayesian analysis was attempted given the updated model and the results from this analysis are presented here. The priors used for this Bayesian assessment are shown in Table 1.

Bayesian analysis

For the Bayesian posterior computations a MCMC chain of 200 million samples was run, saving every 2000 resulting in 100000 samples for analysis purposes. Despite the length of the chain the model failed to converge. Time constraints have precluded further analyses of longer chains (which can take days to run) and the 100000 samples from the current chain were analysed to determine whether the lack of convergence would bias the statistic of importance, namely the biomass at the end of the projection period relative to pristine biomass, $\frac{B^*_{2022}}{K}$.

Analysis of the chain

The chain was broken up into 10 parts, each containing 2500 samples and the model was projected forward using each of the 10 sets of samples. The resulting $\frac{B^*_{2022}}{K}$ statistics and associated confidence intervals are plotted in Figure 1 for various fixed effort levels (ranging from 200 000 – 400 000 man-days in intervals of 50 000). It is evident from Figure 1 that the 5th percentile across samples within a given effort level are at similar levels, suggesting that the non-convergence of the chain is not of major concern. This was further investigated by plotting both the median and lower 5th percentile values within each effort level relative to their means and these are shown in Figure 2. It should be noted that sample 1 for each effort value in Figure 2 was omitted from the calculations performed to generate Figure 2 given that the samples from the first part of the chain are clearly different to the rest of the chain (and would have been discarded as burn-in had the chain converged). A slight downward trend is evident for all the scenarios shown in Figure 2, and in some cases this trend is not exactly linear, so it is likely that results derived from this analysis will be slightly on the over-optimistic side.

Final projections

The second half of the chain (50 000 samples) was used to project the resource forward under various constant effort scenarios and the following performance statistics are reported:

- average annual catches by the jig fishery
- average annual variation (AAV) in catch by the jig fishery from one year to the next, where:

$$AAV = \frac{1}{20}\sum_{y=2012}^{y=2021} \left|C_y - C_{y-1}\right|/C_{y-1}$$

- $\frac{B^*_{2022}}{K}$
- $\frac{B^*_{lowest}}{K}$

These results are presented in Figure 3 and indicate that any effort exceeding around 250 000 man-days will result in a probability exceeding 5% of the biomass falling below 20% of pristine in any future year.

Also of interest to the jig fishery would be the projected CPUE and this is shown in Figure 4. The average jig CPUE by the fishery over the period 2008-2012 is also indicated and it is evident that the average projected CPUE would fall below the historic average for effort levels exceeding 250 000 man-days.

Working on an achievable basis of 200 days fishing by a vessel during a season, limiting effort to 250 000 man-days would correspond to limitation of the number of fishers in the fishery to 1250.

The prior and posterior distributions associated with the estimable parameters *h* (steepness of the stock recruit curve), *η* (reflecting the degree to which recruitment is impacted by jigging) and *g* (the composite growth parameter encompassing growth, immigration and emigration) are shown in Figure 5. These plots show that the data available update the priors for *h* and *η* appreciably.

Table 1: Assumed priors for the estimable parameters in Bayesian analysis.

Parameter	**Prior**
ℓnX	~U($-\infty,\infty$)(where R_0 = exp(ℓnX))
h	~U(0.25,1)
η	$\ell n\eta$~U($-\infty,\infty$) where η=exp($\ell n\eta$)
g	~N(1.2,0.1^2)
Stock recruitment residuals, ξ_y	~N(0,σ_R^2) where σ_R is assumed to be 0.3 on input
$F_y^{jig,Jan-Mar}$	~U(0,3.0)
$F_y^{jig,Apr-Dec}$	~U(0,3.0)
$F_y^{trawl,Jan-Mar}$	~U(0,3.0)
$F_y^{trawl,Apr-Dec}$	~U(0,3.0)

Figure 1: Median B_{2022}/K for various effort levels obtained from projecting forward from 10 parts of the chain where each part contains 2500 samples. The 5th and 95th percentiles are also shown.

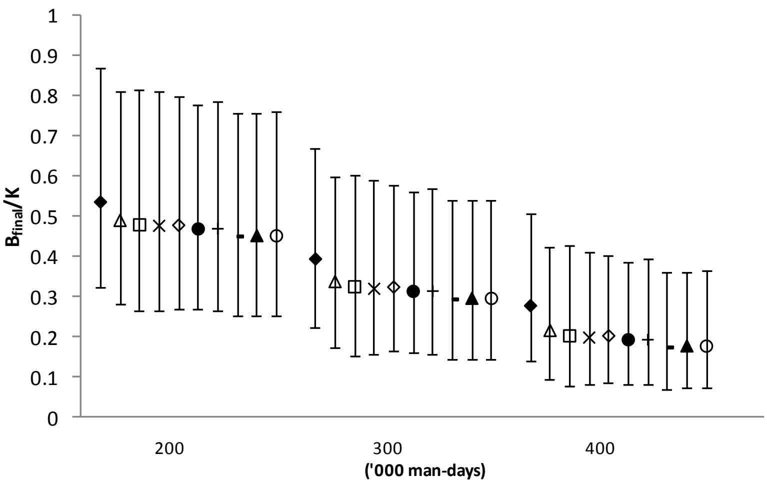

Figure 2: Median B_{2022}/K (left panel) and 5th percentile (right panel) values for nine parts of the chain (the first 2500 samples were discarded as burn-in), normalised by their average.

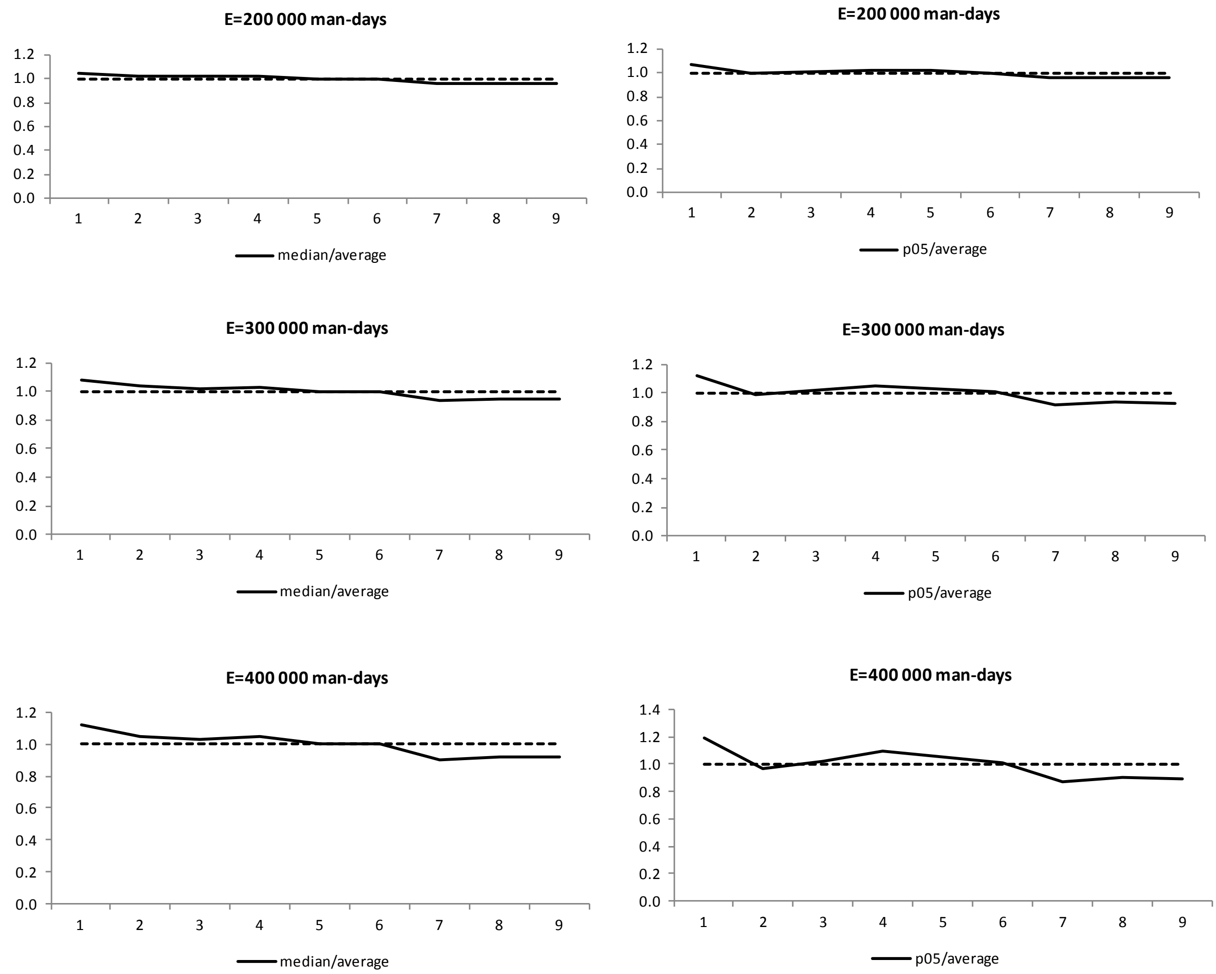

Figure 3: Performance statistics obtained from projecting the resource forward utilizing 50 000 samples. Catches refer to those by the jig fishery. To aid interpretation, dashed horizontal lines at depletions of 0.1 and 0.2 are included in the top two plots.

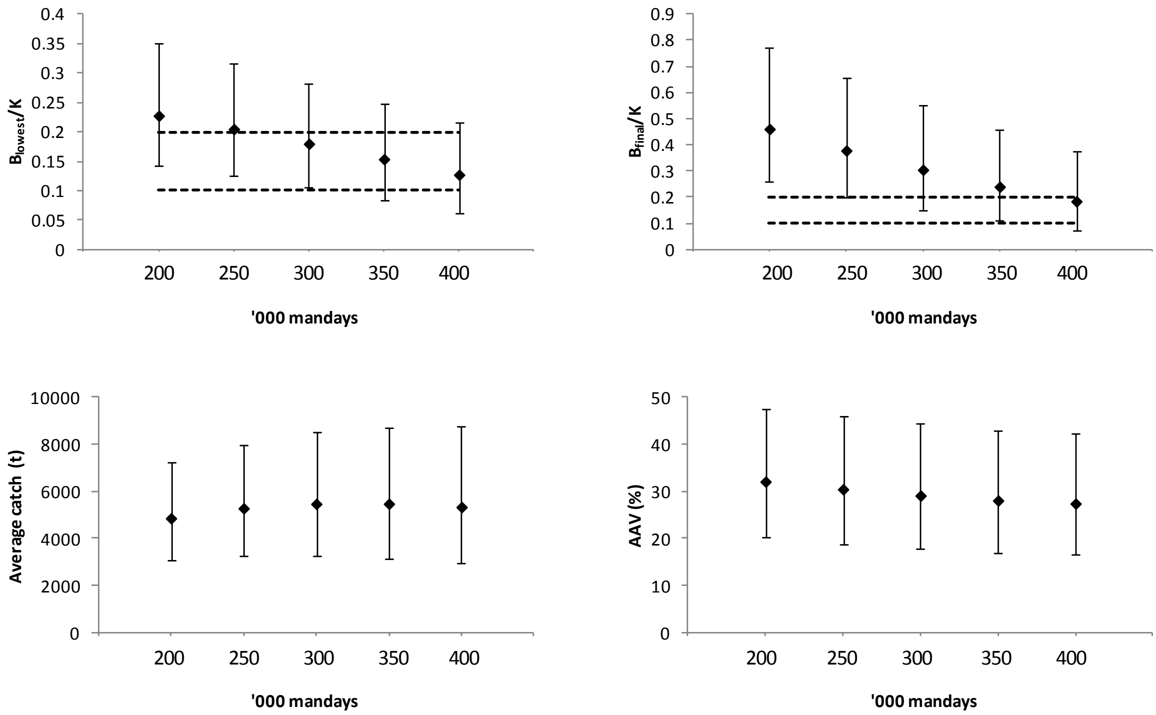

Figure 4: Average jig CPUE over the projection period for various fixed levels of effort. The 5th and 95th percentiles are also shown. The horizontal lines represent the average annual nominal jig CPUE as taken by the fishery over the period 2008 – 2012 (all vessels, restricted to 3≤crew≤20) together with the 5th and 95th percentiles.

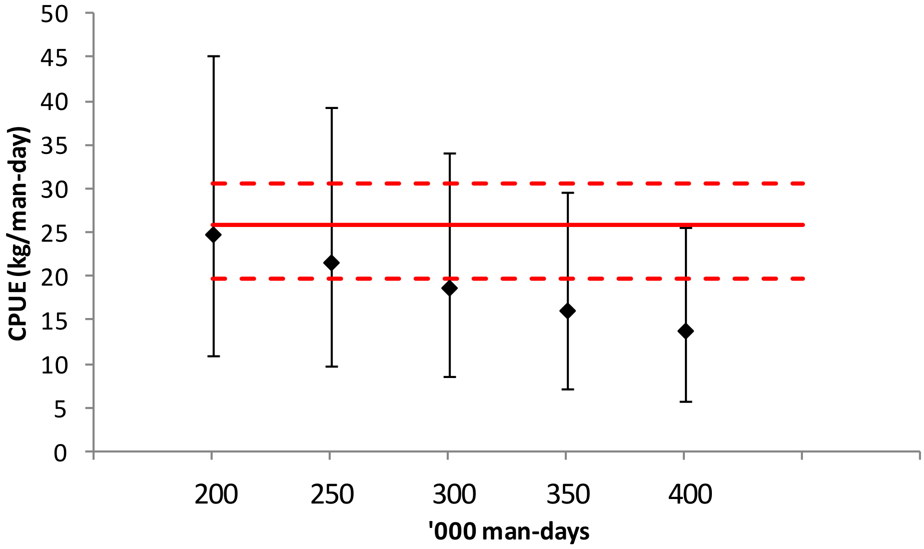

Figure 5: Prior (solid line) and posterior (dashed line) distributions of the estimable parameters *h* (steepness of the stock recruit curve), *η* (reflecting the degree to which recruitment is impacted by jigging) and *g* (the composite growth parameter encompassing growth, immigration and emigration).