**HBM Update for Skeena sockeye stocks**

Based on TWG discussions in December 2021 I’ve implemented a new so called “base case HBM” model run that is based largely on Korman and English’s (2013) HBM model version, is as simple and transparent as possible, uses vague priors for stocks for which limnological information is sketchy, and implements a correction to a minor coding error and also parses out common effects in stock-productivity that are shared across stocks. In my WinBUGS code this is model m23 and results shown for the base case model are denoted by model m23 r3. This base case HBM model includes the following features:

* The same mathematical form of the priors as in Korman and English (2013) HBM for the Ricker a and Ricker b parameters,
* The same hyperprior for the Ricker a parameter as in Korman and English (2013)
* The same prior for the sigma parameter for the likelihood function as in Korman and English (2013),
* A correction to Korman and English’s (2013) coding error in the calculation of the precision of the likelihood function,
* New common year effects from 1960 to 2014 shared across all of the stocks in each year,
* Updates to the Smax priors for the Skeena stocks; this includes
  + vague priors on Smax for the Babine, Asitka, and Morice stocks,
  + summed Smax values for Stephens/Swan/Club
  + summed Smax values for Mcdonell/Aldrich/Dennis
* Upper cutoff points for the Smax for each stock based on a multiple of 5 times the prior central tendency.

I’ve implemented six additional Bayesian model runs based to evaluate different features of the new base case HBM model. See Table 1 for brief descriptions of these additional model runs. The results from these additional runs are summarized further below. Detailed comparisons between results obtained from the additional model runs can be viewed in the associated Excel file.

Table 1. Description of evaluations of the sensitivity of estimation results to model structure and some key inputs.

|  |  |  |
| --- | --- | --- |
| **Sensitivity run** | **Brief description** | **Model version** |
| 1 | HBM base case but including Korman & English’s (2013) error in the code for precision and sigma in the likelihood function | m24 |
| 2 | Same as HBM base case but with no upper bounds on Smax | m25 |
| 3 | Same as HBM base case but leaving out common shared year effects | m26 |
| 4 | Non-hierarchical model run with no common shared year effect but including the same Smax prior information as in the base case HBM | m27 |
| 5 | Same as HBM base case but normal priors on Smax instead of the base case lognormal prior on Ricker b. | m28 |
| 6 | Same as HBM base case but with vague Ricker b priors, but including the upper bounds on Smax | m29 |

**Sensitivity run 1: Effect of Korman and English’s (2013) coding error.**

This error changed very little the posterior results for the Ricker a and b parameters for the 18 stocks. However, the estimates of the sigma parameter by stock was very strongly positively biased for most of the stocks. The upper boundary point on the prior for sigma was hit for some of the stocks and this led to some small differences in estimates for some of the quantities of interest such as Smsy for some stocks. There were some sizeable differences in estimates of the common shared year effects between model versions with and without the coding error and this may have resulted in different estimates of systematic changes in stock productivity. If the error had persisted, any simulations of stock-recruit data using the estimated values for sigma would have led results with excessive variability. It is thus essential for this coding error to be corrected in any further implementations of Korman and English’s (2013) HBM.

**Sensitivity run 2: Same as HBM base case but with no upper bounds on Smax**

When there was no upper bound included for Smax by stock, the estimates of Smax and msy reference points included some extremely high MCMC chain values that were way out in the tails of the Markov chains and very far removed from the range of values with support from the data; for these stocks, posterior means, medians, and probability interval values were highly sensitive to the inclusion of these extreme outlier values in the chains. It is common in implementations of WinBUGS to set bounds on key variables in the model to prevent extreme outlier values in the chains from affecting the posterior calculations and it is thus recommended that upper bounds on the Smax parameter be implemented for each stock to eliminate this source of bias.

**Sensitivity run 3: Same as HBM base case but leaving out common shared year effects**

Significant, strong common shared year effects were estimated for numerous years in the 1960-2014 brood year time series. Separating out this effect provided more precise estimates of Ricker stock recruit parameters for several of the stocks and more precise estimates of management quantities of interest. This also allowed for common shared systematic change in stock productivity to be estimated. The Smsy reference point for example in aggregate across the 18 Skeena River sockeye salmon stocks was about 13% less on average in the final 10 years when common shared year effects were accounted for. Some of the estimated quantities were between about -28% to +48% different when no common shared year effect was included in the HBM. Whenno common shared year effect was included in the HBM, estimates of Ricker stock-recruit parameters and associated management parameters for several of the stocks were less precisely estimated with posterior SDs being about 60-80% larger for estimated quantities for several of the stocks.

**Sensitivity Run 4: Non-hierarchical model run with no common shared year effect but including the same Smax prior information as in the base case HBM**

Whenno common shared year effect was included in the HBM, estimates of Ricker stock-recruit parameters and associated management parameters for several of the stocks were less precisely estimated with posterior coefficients of variation (CVs) on average being about 11-18% larger and for some stocks much larger (up to 139%) for estimated quantities when averaged across the 18 stocks. Percentage differences between the non-hierarchical model and hierarchical model for posterior mean estimates for Ricker and msy parameters ranged by stock between -28% and +45%. These results indicate that on average Ricker and msy parameter estimates are more precisely estimated with the hierarchical model and results for some quantities for some stocks can differ considerably. However, the sum of the Smsy estimates across stocks was only about 8% larger under the non-hierarchical model but the CV was 14% larger than that for the hierarchical model.

**Sensitivity Run 5: Normal priors on Smax instead of the lognormal prior on Ricker b**

When a normal prior for Smax was applied instead of a lognormal prior on the Ricker b parameter, but otherwise using the same input information from the lake productivity analyses, the posterior estimates for several of the quantities became much less precise and posterior estimates differed markedly for some of the quantities. Posterior CVs for several of the estimated quantities were much larger, e.g., between about 50 and 125% larger. Posterior mean estimates differed between the two model runs by -41% to +113%. Though it appears the same information is used in a normal prior for Smax, this prior loses information about the Ricker b parameter compared to a prior for the Ricker b parameter that uses the same Smax information.

**Sensitivity Run 6: Vague Ricker b priors, but including the upper bounds on Smax**

When a vague prior was applied for the Ricker b prior for all 18 Skeena sockeye salmon stocks, posterior estimates for the abundance-based management quantities were much less precise on average with posterior CVs being on average 20-46% larger under the uniformly vague priors. Ricker parameter estimates were between about -27% and +300% different from those obtained under the mixture of informed and vague priors in the base case HBM. Abundance based management benchmarked differed by between -60% and +50% for the run with the uniformly vague priors for the Ricker b parameter. The use of informative priors for the Ricker b parameter based on prior information on Smax via the lake productivity analyses thus combined with the data to provide more precise stock-recruit parameter estimates that in some cases differed from the less precise estimates given by the stock-recruit data.