North Pacific Fisheries Commission

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Managing uncertainty about Pacific saury population dynamics in HCR analyses (DRAFT to stimulate SSC PS discussion)

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During an intersessional meeting (November 2023), The SSC-MSE-PS planned simulations for analyzing interim harvest control rules (HCRs) in the Pacific saury fishery. Their goal is to **evaluate benefits of adopting a standard Fmsy-based hockey-stick HCR with potential modifications to the annual assessment cycle to address the short lifespan of the species and to prevent large changes in catch from one year to the next**. One important problem is **including an acceptable range of uncertainty in the simulated saury stock while keeping the analysis manageable and completing the work on time**. The comments here are meant to help address both requirements.

The HCR is an "interim" goal because it is likely to be replaced in future and because it is not part of a formal Management Strategy Evaluation (MSE) system. The interim approach is appropriate currently because stock conditions warrant harvest management in the near term while MSE analyses often require years of effort. Fortunately, generic and species-specific HCR simulations have been carried out for many species with results generally applicable to saury. **The small suite of HCRs under consideration for Pacific saury based on Fmsy are well known.** Indeed, they are often adopted and applied by managers without a great deal of additional analysis. **The most important characteristic of modern harvest control rules is that the target F used to set catch quotas is reduced when stock biomass declines below a biomass reference point, usually Bmsy.**

The operating model (OM) in the HCR analysis is a "simple" Bayesian State Space Production Model (BSSPM) which is also used for Pacific saury stock assessments. A more complex age-structured assessment model (probably SS3) is under development and expected to displace the BSSPM at some point in the future. The age-structured model should improve assessments and provide a more complete basis for future MSE and HCR approaches.

HCR's should be robust and function well (maintain relatively high biomass and catches) as long as they have the correct general form and the information used to select them is approximately correct. It is important to remember that the OM for Pacific saury contains approximations and errors that make finding a perfect HCR probably impossible. Of course, it will be possible to improve advice about HCR for Pacific saury as additional information becomes available.

Managing the volume of calculations

The SSC-MSE-PS discussed using MCMC results from a recent assessment as a basis for building uncertainty in simulations. The number of MCMC results from three members running two base case models is, however, overwhelming. In addition, **many results have very low posterior probability and are therefore of little interest. Low probability is exacerbated by uniform prior distributions with, in some cases, wide or overly wide bounds.** The following approaches emphasize MCMC results with high posterior probability so that management advice is based on the most probable assumptions about the saury stock.

Here, an "MCMC draw" is a vector containing the set of all parameter values accepted (kept) in a single MCMC iteration along with the associated posterior probability and a unique identifier (e.g., a sequence number). The unique identifier is for analytical convenience. Other useful information (e.g., likelihood and prior probability) may be useful and included as well.

Analysts should use parameters from a the same MCMC draw in constructing one simulation test scenario. Entire MCMC draws are used in order to preserve correlation between parameter estimates. For example, an accepted MCMC draw with high posterior probability will tend to have a relatively high *r* if *K* is relatively low and vice-versa because the two parameters have opposite mathematical effects in the production function *f=r(1-B/K)*. Such correlations are lost if model parameters are sampled independently from their individual posterior distributions. For example, parameter sets with unlikely combinations of high *K* and high *r* would often be included with independent sampling even though they are improbable for Pacific saury.

Step 1

As a first step, the SSC-MSE-PS can **focus its simulations on MCMC results with relatively high posterior probability by eliminating cases with low probability. The idea being to base management advice on the most probable stock assumptions. For example, use x% of MCMC draws with highest probability.** Some trials will be required to choose x% but **a relatively small fraction, say ± 5 to 25%, may suffice** if the intent is to focus on the most likely stock characteristics. **Samples at various x% values can be evaluated to ensure that the most important ranges and combinations of key parameter values (e.g., high *K* with low *r*, low *r* with high *K*, high and low process error, and see below) are included.**

A more extreme but possibly acceptable alternative would be to use the single MCMC run with the highest posterior probability. Multi-dimensional modes are difficult to estimate but the difficult problem is academic and can be ignored here because the goal is to simulate a saury-like stock recognizing that the OM is imperfect but hopefully useful. The technical

problem of finding the mode of a multi-dimensional distribution is not worth the effort for saury because of the simplifications already made in model development, biological uncertainty and changing environment. The draw with highest posterior probability from many MCMC samples might suffice to construct simulations in this approach.

[Possible short-cut approach to finding mode of multi-dimensional posterior distribution. Use the posterior probability like a likelihood in a simple nonlinear regression function. That is, use the optimization software to find the parameters that maximize the entire posterior probability.]

Step 2

The x% of runs with high probability may still be too large and unwieldly. In step 2, we want to sample across the range of possible parameter combinations in proportion to their relative probability, without necessarily sampling them all. Fortunately, such representative random samples can be drawn using the *sample*() function in R by setting the *prob* argument based on the posterior probability of each draw. For example, use the following code in step 2 to sample *N* sequence numbers with potential replacement from a data frame containing the draws from step 1:

Kk=sample(x=1:nrow(draws), size=N, replace = TRUE, prob=draws posterior/sum(draws$posterior))

Then the actual sample used as a basis for simulations is *draws[Kk,]*. Experience suggests that a relatively small number of runs would be required.

Thus, representative samples of any size can be drawn from the most probable MCMC runs via a simple two step process. It is possible to omit either step. However, a very large number of runs might be included using only step 1 unless x% is very small while small x% values will generate samples with narrow ranges or large gaps in parameter values. Some implausible runs might be included using only step 2.

Key parameters for Pacific saury

Another important question is which model parameters are important in the variability for simulation analyses. The simulations do not include explicit assessment modeling. Instead, lognormal random numbers will be applied to the true underlying biomass to simulate assessment model biomass estimates used to specify harvest levels. Thus, **there is no need to consider survey and CPUE catchability or survey saturation parameters in simulations.**

Initial biomass and carrying capacity will be important in simulations but there may be no need to simulate both independently. Instead, use B/K to measure biomass in the simulations and take initial B/K from MCMC runs. ***[use F from control rule for fishing]***

One or both of the production parameters r and K may be key in simulations, but it is important to consider their natural negative correlation. Correlation will be included automatically if entire sets of MCMC draw parameters are used as a basis. If the simulations are carried out solely in terms of relative biomass (B/K) and only relative results are required, it may suffice to assume K=1 so that variability in both initial B and K are carried in the initial value of initial B/K from MCMC runs.

Process errors are important for Pacific saury, particularly given the possibility of ongoing environmental change. The SSC-MSE-PS decided to base such errors on independent lognormal errors with variances from MCMC runs. The random values **will be modified by simple algebra to simulate periods that are more or less productive.** ***[Need process error variance if algebraic changes are in addition to random variation.]***

The production function asymmetry parameter z can have a strong effect on population dynamics. A realistic range of variability in z should be included.

[What about Fmsy for use in control rule? It is available in MCMC output but can probably be computed from r, z, K=1]

[Key parameters from simulations are only r, B1/K, z, process error variance]