

# n lessons for conducting stock assessment simulation studies

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## Abstract

Start with a general introduction similar to what we’ve got now. Include a schematic representation of all the steps to a stock assessment simulation. Follow with lessons/rules. Each ‘rule’ would need some shorter header. Then 1-3 paragraphs per rule. Finish with a brief discussion/conclusion.

Model papers:

Nine simple ways to make it easier to (re)use your data:

<https://peerj.com/preprints/7/>

Ten Simple Rules for the Open Development of Scientific Software:

<http://www.ploscompbiol.org/article/info%3Adoi%2F10.1371%2Fjournal.pcbi.1002802>

## Introduction

Stock-assessment simulation is a critical component to evaluating stock assessment methods and understanding their strengths and weaknesses. It is important because it lets us test our assessments on known truths, possible truths we are interested in, and to match (or mismatch) truths and assessment model assumptions. References: Hilborn and Walters (1992) among others; including recent papers on stock-assessment simulation (Maunder, Piner, Lee).

We can divide a stock assessment simulation into four components (Fig. 1). (1) The *conditioning model* is used to ground a stock assessment simulation in some plausible reality. A stock assessment simulation could be conditioned on a specific region and fish stock or it could be conditioned on some generic representation. (2) The *operating model (OM)* represents all the conditions that underly the true state of nature. An operating model might specify, for example, that natural mortality ( $M$ ) varies with some random walk. (3) We then *sample from the OM* output to generate fisheries pseudo-data with observation error. (4) Finally, we run a stock assessment *estimation model (EM)* on the pseudo-data to find out our model would assess the scenario. Steps 2 to 4 are then usually repeated across iterations, adding re-sampled process error and observation error each time, and blocks of iterations are repeated across scenarios, with each scenario representing some different combination of conditioning, operating, sampling, and estimation models. This process differs from a management strategy evaluation (MSE) in that a MSE closes the loop — introducing management decision rules about how to act on stock assessment output. Stock assessment simulation can therefore focus on the mechanics and performance of the stock assessment models themselves.

We’ve arrived at the lessons we suggest in this paper after conducting a series of large-scale stock assessment simulation studies at the University of Washington. These studies are featured in this issue:

- Johnson et al. (2013, this issue) evaluated the ability of Stock Synthesis (SS) to estimate key quantities when a known ‘true’ natural mortality ( $M$ ) was age-specific or age-invariant, but time-varying. Stock assessment methods included models with age-invariant pre-specified  $M$ , age-invariant estimated  $M$ , and age-specific estimated  $M$ .
- Ono et al. (2013, this issue) analysed the ability of SS to estimate management metrics for different life-history types (demersal, long-lived pelagic, and short-lived pelagic) when the same quantity and quality of pseudo-data were used to inform assessment models. They also considered whether the frequency and duration of length- and age-composition data, or catch history, affect the bias or precision of estimates of management quantities for different life-history types.
- Hurtado Ferro et al. (2013, this issue) investigated factors which lead to retrospective patterns in SCAA models. Specifically, they tested how key biological and modelling factors can induce retrospective patterns for various life history types. They explored the potential effects of catch patterns, as well as model miss-specification from time-varying biological parameters, time-varying selectivity and catchability, and their interactions. In those cases where retrospective patterns were observed, they assessed the utility of including time-varying selectivity in the assessment as a means to correct them.

In this paper, we review a series of lessons that we learned through these studies

about conducting large-scale, relevant, and rapid stock assessment simulation studies...

## **1. Choose widely-used and current assessment models**

Stock assessment simulation studies are most relevant to research and management if they focus on the models and tools that are used in practice. In our studies we chose to focus on SS, which is a widely used integrated-assessment modelling framework, now used in all assessments on the West Coast of the United States. In other regions commonly used model frameworks will be different.

When researchers are interested in multiple modelling frameworks they may choose between (1) conducting a study where both the OM and EM are based on the same modelling framework to better understand issues related to model specification or (2) conducting a study where the OM and EM are based on different modelling frameworks to investigate the impact of model-choice uncertainty. Frequently model-choice uncertainty may dwarf other sources of uncertainty (REF).

## **2. Condition the operating model carefully**

The relevance of a stock assessment simulation study depends on the system that the OM is conditioned to reflect. Researchers must choose between specific conditioning, in which the OM might be conditioned for specific species, region, or even stock and (2) generic conditioning in which the OM is conditioned on a general representation of a system. Both types of conditioning have their place in stock assessment simulation but each has their pros and cons. Specific conditioning may result in findings that are relevant to a specific species, region, or stock and may therefore be more likely accepted than generically conditioned models. Generic conditioning, however, may result in findings that are applicable across a wider range of fisheries, but are less applicable to any one stock

## **3. Consider likely or important model misspecifications**

Model misspecification refers to a mismatch between the truth (OM) and our assessment of that truth (EM). For example, an OM might specify time-varying  $M$ , whereas the EM might assume a constant  $M$ . Researchers might deem some forms of model misspecification more likely *a priori* and some types of model misspecification potentially more influential for stock assessment. It is these forms of model misspecification that researchers should focus on first.

## 4. Make your framework reproducible and transparent

Reproducible and transparent simulation studies are critical to the authenticity of work. To achieve these properties simulation study can be written in code format as opposed to by clicking on buttons and a graphical user interface (GUI). Further, researchers might consider writing their code in a formal package or library structure (e.g. Anderson et al. 2013 R package). This makes it easier for future users to understand the code and simulation structure and encourages the code authors to document their work. Researchers can introduce further transparency by developing their code in a version control system such as Git, which provides a history of all code modifications. Finally, by controlling model runs through plaintext control files, researchers and other users can easily understand and reproduce the settings that created their simulations.

## 5. Make your framework flexible

A stock assessments and innovation framework is most useful if it is flexible for the current users as well as for future users who may develop scientific questions with the framework that the original users never considered. One way researchers can make their framework flexible is to build their code around smaller functions that can be mixed and matched at will. Another key element is keeping the input and output files in formats that can be read and process multiple tools (e.g. comma-separated, or tab-delimited text files). Finally, researchers may consider splitting scenarios into different cases so that cases can need mixed and matched into scenarios. For example, a scenario might be comprised of a combination of cases for the M trajectory, F trajectory, and selectivity patterns. If these cases are specified in individual text control files then they can be flexibly combined without duplicating case specification.

## 6. Check your models early and often

The complexity of conducting stock assessment simulations means that the chance of making mistake is high, and our ability to make sense of complicated model output can be limited. Deterministic model checking is therefore vital. To check a model deterministically we can reduce or eliminate process and observation error and check for bias between the OM and EM models. This might mean running the stock assessment simulation with minimal stock-recruit deviations and minimal observation error on survey indices.

An important component model checking is graphical model checking. Many complex problems are unlikely to be detected without graphical model checking (REFs, maybe Gelman). To facilitate model checking these graphics should be rapid and easy to produce. We found the visualization packages `manipulator`, `shiny`, and `ggplot2` to be helpful for this purpose.

## 7. Keep simulation runtime minimal

To discover problems with your simulation and to understand how your simulations are performing you need to build and run the multiple times under a variety of conditions. In addition to using a fast computer and writing code carefully you can minimize runtime by reducing the number of scenarios and iterations. To reduce scenarios, a researcher might consider creating a base-case model and investigating deviations from that model instead of a full factorial design. To reduce iterations, a researcher can inspect test runs with an increasing number of iterations to determine the minimum number of iterations for study conclusions to converge.

Other thoughts: keep folder structure as simple as possible; keep all output; write code so the simulations can be distributed across cores, computers, and researchers

## Discussion and conclusions

- perhaps suggest the kinds of questions that this approach could answer and other steps forward
- ...?

## References

Hilborn, R. W., and Walters, C. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics, and Uncertainty. Chapman and Hall, London.