

ss3sim: An R package for stock-assessment simulation with Stock Synthesis

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Short title: ss3sim: Stock Synthesis simulation

Abstract

< 300 words

Introduction

Simulation is a critical component to testing fishery stock-assessment methods [1–4]. With simulation, we can evaluate the precision and bias of complex assessment methods in a controlled environment where we know the true state of nature [2]. Recently, simulation studies have been key to improving strategies for dealing with, for example, time-varying natural mortality [5–7], uncertainty in steepness of the stock-recruit relationship [8], and uncertainty in stock productivity [9]. [not necessarily the best examples]

Stock Synthesis [10] is a widely-used stock-assessment framework. It implements statistical age-structured population dynamics modeling using a wide range of minimally-processed data [10,11]. By using this framework, individuals conducting stock assessments and peer reviewers can focus on the underlying science, instead of the model code [10]. Owing to these advantages, SS3 (the third version of the software)

is one of the world’s most commonly-used stock-assessment tools, particularly in the United States and Australia, where it has been used in 35 and 12 stock assessments, respectively, as of 2012 [10].

Although SS is increasingly a standard for fisheries stock assessment, and the programming language R [12] has become the standard for statistical computing and visualization, we lack a generalized framework to link these components in a simulation context. Here, we introduce ss3sim, an R package that facilitates large-scale, rapid, and reproducible stock-assessment simulation with the widely-used SS framework. We begin by outlining the general structure of ss3sim and describing its functions. We then demonstrate the software by developing a simple example. We conclude by discussing how ss3sim complements other stock assessment simulation software and outlining research questions our accessible and general SS simulation framework could address.

The ss3sim framework

Terminology

[TODO abbreviate this paragraph substantially or cut it]

Throughout this paper we refer to a number of terms, which we define here. We use the term *operating model* (OM) [13] to refer to the model that represents the underlying true dynamics of the system (REF). We use the term *estimation method* (EM) to refer to the method used to estimate quantities of interest (REF). We use the term *scenario* to refer to a combination of operating and estimation model *cases*. For example, an OM case might specify that natural mortality follows a random walk, an EM case might estimate a single parameter for natural mortality, and the combination of these cases along with all other specified conditions creates a scenario. We refer to *iterations* or *replicates* as repeated simulations of a scenario, possibly with

48 new process and observation error added each time. A simulation therefore refers to
the combination of all scenarios and iterations.

50 **Design goals of ss3sim**

[This section is too long currently. I don't want to bore people.]

52 We designed ss3sim to be reproducible, flexible, and rapid. *Reproducible:* ss3sim
allows for the simulation to be documented in code and plain-text control files.
54 Further, the plain-text control files refer to individual cases, which allows for the
reuse of control files across scenarios. This reduces the chance for errors and simplifies
56 the exploration of new scenarios.

Flexible: ss3sim allows the user to specify their own OM and EM using all the
58 possible configurations of SS3. ss3sim returns output in standard comma-separated-
value (`.csv`). This means that the output can be easily processed with the package-
60 provided functions or with other tools.

Rapid: First, ss3sim relies on SS3, which uses ADMB as a backend optimization
62 platform — the most rapid and robust optimization software available [14]. Second,
ss3sim allows simulations to be deployed across multiple computers or computer
64 cores. Third, the package provides a number of functions to quickly visualize simu-
lation output. Access to quick visualization tools means that users are more likely
66 to graphically explore their models and are therefore more likely to detect errors and
understand their simulation output as they introduce complexity. Finally, ss3sim
68 minimizes the amount of bookkeeping code that researchers have to write so that
they can concentrate on the science itself.

70 **The general stucture of an ss3sim simulation**

An ss3sim simulation requires three types of input: (1) a base model of the underlying
72 truth (an SS3 OM), (2) a base model of how to assess that truth (an SS3 EM), (3)
and a set of case files describing deviations from these base models. ss3sim works, in
74 general, by converting case file arguments (e.g. a given natural mortality trajectory)
into manipulations of SS3 configuration files (**change** functions), running the OM,
76 sampling pseudo data, and running the EM (**run** functions), and facilitating the
manipulation and visualization of output (**get** and **plot** functions) (Figure 1).

78 **An example simulation with ss3sim**

(unsure how much of this will go in the main paper and how much will just be in the
80 appendix... probably many of these details should be appendix only with just enough
elements to give a flavour for what can be done in the main paper)

82 *Setting up the SS models:*

- choosing a specific conditioning model or generic conditioning type
- 84 • setting up the OM and EM SS models
- things to keep in mind
- 86 • running through SS to format as **.ss_new** files and renaming
- required files

88 *Setting up the configuration files:*

- the (simple) research question (increasing or decreasing survey effort crossed
90 with estimating M or fixing M)
- indicate which arguments to adjust

92 *Deterministic model testing:*

- reduce recdevs, reduce sigma R, bias correction
- 94 • what to plot, what to look for, how good is OK?

Output analysis and visualization:

- 96 • examples using the included functions
- brief take home of what we'd conclude

98 **How ss3sim complements other simulation software**

Probably turn this into a small table:

100 *r4ss*

- Reference 15
- 102 • r4ss has functions to facilitate aspects of simulations, mostly focused on reading and plotting output for stock assessment
- 104 • ss3sim uses r4ss functions for some reading, writing, and bias adjustment

FLR

- 106 • Reference 16 for FLR and Reference 17 for simulation in FLR
- statistical catch-at-age only?
- 108 • not integrated analysis, not SS
- but particularly relevant to Europe

110 “Hooalator”

- <http://fisherysimulation.codeplex.com>, Windows only, GUI..., works on bootstrapped data only, therefore isn't as flexible as ss3sim. Used in:

1. Reference 8
- 114 2. Reference 18
3. Reference 5

116 Research opportunities with ss3sim

- there are lots, we should brainstorm some key ones

118 Conclusions

- benefit of using one well tested and well-understood modeling framework (SS)
120 i.e. benefit to playing with all the switches and understanding one framework well versus having many tools that we superficially understand (based on Rick's
122 comments at the conference)
- why we developed generic low-level functions and high-level functions
- 124 • researchers are free to develop their own low- and high-level functions because in an open-source MIT(?) licensed R package, users are free to modify functions
126 as needed
- (these points are somewhat random at the moment)

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- 132 • Any FISH600 members not listed as authors

Tables

134 Table X: Comparison with related software? Possible columns: software, reference,
platform (e.g. R, GUI...), short description/comparison, examples of papers using it

136 Figures legends

Figure 1: Flow diagram of `run_ss3sim()` stock-assessment simulation steps.

138 Figure 2: Panels with output from the example

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