

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

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## 8 Introduction

Paragraph 1: What is stock assessment simulation? Why is it increasingly critical?

- 10 • stock assessment simulation is...
- stock-assessment simulation is a critical component to evaluating stock assess-  
12 ment methods and understanding their strengths and weaknesses. ...
- important because it lets us test our assessments on known truths
- 14 • further, it lets us explore truths we are interested in and match (or mismatch)  
truths and assessments
- 16 • refs: Hilborn and Walters (1992) among others; recent papers on stock-assessment  
simulation

18 Paragraph 2: What is SS3, why is it important, why simulate with it?

- Stock synthesis is a modelling framework... Integrated analysis — models  
20 population dynamics using a wide range of data (Maunder and Punt, 2012)
- SS3 is the 3rd version of the software using this framework
- 22 • SS software ref: Methot and Wetzel (2012)
- ADMB software ref: Fournier et al. (2012)
- 24 • Importance of integrated analysis with SS as an example: Maunder and Punt  
(2012)
- 26 • most widely used now world wide (?) and especially on West Coast of United  
States
- 28 • facilitates rapid, reproducible analyses... focus on peer-review of the science  
not the modelling code

- 30 • allows a separation of research from stock assessment that informs management  
(Methot and Wetzel, 2012)
- 32 • been instrumental to investigating new stock assessment concepts: e.g. Piner  
et al. (2011), Methot and Taylor (2011)
- 34 • been used in XX stock assessments world wide (~60 as of 2012 - ask Rick) and  
involved in many more currently
- 36 • Piner et al. (2011) example of stock-assessment simulation research with SS3
- Methot and Taylor (2011) example of stock-assessment research with SS

38 Methot and Wetzel (2012):

40 A comprehensive modeling framework such as SS enhances communi-  
cation, efficiency, and education in the fishery assessment community  
(Methot, 2009). Communication is enhanced by creating a familiarity  
42 among users, reviewers, and clients regarding terminology and approach.  
Reviewers who are already familiar with SS can quickly focus on key is-  
44 sues for the assessment being reviewed, rather than spend time learning  
the features of a novel assessment model.

46 Therefore there are two benefits to simulating with SS: (1) much of the model  
has already been built and checked (research can then progress rapidly and with less  
48 chance of errors) (2) the results are directly applicable to the tools used by stock  
assessment scientists — in fact, used by all Western US assessments (REF?).

50 There are, however, many complications to conducting large-scale, rapid, and  
reproducible stock-assessment simulations. Complications include how to manage  
52 data and file structure, how to avoiding coding errors, how to repeatedly manipulate

simulation models to ask specific questions, and how to translate models and ques-  
54 tions across stocks and species. [Maybe delete this or go into how most solutions are  
GUI right now] Further, while the statistical software R has become the standard for  
56 data analysis and visualization, and the stock-assessment framework Stock Synthe-  
sis is increasingly the standard for fisheries stock assessment, we lack a generalized  
58 framework to link the two in a simulation context.

In this paper we introduce ss3sim, a software package for the popular statistical  
60 programming language R that facilitates large-scale, rapid, and reproducible stock-  
assessment simulation with the widely-used SS framework. We begin by outlining  
62 the general philosophy of ss3sim, and describing its functions. Then, to demon-  
strate how a researcher might conduct a stock-assessment simulation with ss3sim,  
64 we work through an example starting at a research question and ending with plots  
and interpretation of the output. Our example includes considerations for setting  
66 up operating and estimation models, choosing a folder structure, model testing, and  
output manipulation and plotting. We conclude by discussing how ss3sim comple-  
68 ments other stock assessment simulation software and outlining research questions  
our accessible and general SS simulation framework could address.

## 70 **The ss3sim framework**

### **Terminology**

72 Throughout this paper we refer to a number of terms which we define here. We use  
the term *operating model* (OM) to refer to the model that represents the underlying  
74 true dynamics of the system. We use the term *estimation model* (EM) to refer  
to the model used to estimate quantities of interest. Whereas the OM refers to

76 the underlying truth, the EM generates our perception of that truth. We use the  
term *scenario* to refer to a combination of operating and estimation model *cases*.  
78 For example, an OM case might be natural mortality that follows a random walk,  
an EM case might be estimating a fixed parameter for natural mortality, and the  
80 combination of these two cases along with all other specified conditions creates a  
scenario. We refer to *iterations* or *replicates* as repeated simulations of a scenario  
82 with potentially new process and observation error added each time. A simulation  
therefore refers to the combination of all scenarios and iterations.

## 84 **General philosophy**

We designed ss3sim to be reproducible, flexible, and rapid. *Reproducible*: ss3sim al-  
86 lows for the simulation to be documented in code and plaintext control files. Further,  
the plaintext control files refer to individual cases, which allows researchers to reuse  
88 control files as much as possible across scenarios. This reduces the chance for errors  
and makes the exploration of new scenarios rapid and simple. ss3sim then retains  
90 all SS3 output files as well as generating its own log files for documentation.

*Flexible*: ss3sim allows the user to specify their own OM and EM using all the  
92 possible configurations of SS3. ss3sim can take input in a number of forms (in R list  
format or through control files), and return output in a standard comma-separated-  
94 value (.csv) format allowing researchers to work with the output either using the  
package provided functions or their own tools.

96 *Rapid*: First, ss3sim relies on SS3, which uses ADMB as a backend optimization  
platform — the most rapid and robust optimization software available today (REF).  
98 Second, we built ss3sim so that it is easy to deploy across multiple computers or  
multiple researchers and re-combine the output. The scenarios are stored in a flat

100 folder structure so they can be easily re-combined. Third, the package provides a  
number of functions to make visualization fast and easy. Access to quick visualization  
102 tools means that users are more likely to graphically explore their models and are  
therefore more likely to detect errors and understand their simulation output as  
104 they introduce complexity. Finally, ss3sim minimizes the amount of bookkeeping  
simulation code that researchers have to write so that they can concentrate on the  
106 science itself.

## General structure

108 An ss3sim simulation requires three types of input: (1) a base model of the underlying  
truth (an SS3 OM), (2) a base model of how you will assess that truth (an SS3 EM),  
110 (3) and a set of cases that deviate from these base models that you want to compare  
(configuration arguments provide as R list objects or plaintext control files). ss3sim  
112 works, in general, by converting simulation arguments (e.g. a given natural mortality  
trajectory) into manipulations of SS3 configuration files at an appropriate stage along  
114 with running the OM and EM as needed.

## Low-level generic ss3sim functions

116 See Table 1 for description of the main functions. We show how the functions fit into  
the general structure of a stock assessment simulation in Figure 1. ss3sim functions  
118 are divided into three types of functions:

1. Functions that manipulate SS configuration files. These manipulations gener-  
120 ate an underlying “truth” (OM) and control our assessment of those models  
(EM).

- 122 2. Functions that conduct simulations. These functions generate a folder struc-  
ture, call manipulation functions, run **SS3** as needed, and save the output.
- 124 3. Functions for analyzing and plotting simulation output.

## High-level tailored **ss3sim** functions

- 126 • **run\_ss3sim** also see **run\_fish600** for an example custom wrapper function for  
a specific set of projects
- 128 • because it relies on manipulation of these configuration files, it's important the  
config files match a specific format
- 130 • general framework, because you start with your own OM and EM, and a wide  
variety of questions are then available through manipulations of ..., ...

## 132 An example simulation with **ss3sim**

(unsure how much of this will go in the main paper and how much will just be in  
134 the 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)

## 136 Setting up the **SS** models

- choosing a specific conditioning model or generic conditioning type
- 138 • setting up the OM and EM **SS** models
- things to keep in mind
- 140 • running through **SS** to format as **.ss\_new** files and renaming

## File and folder setup

- 142 • required files
- Why we chose a flat-file structure
- 144 • see vignette

## Translating research questions into configuration files

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

## Deterministic model testing

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

## Output analysis and visualization

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

## Discussion

- 156 • Other sections?
- how we validated it
- 158 • benefit of using one well tested and well-understood modeling framework (SS) (but disadvantages too) — i.e. benefit to playing with all the switches and un-



160       derstanding one framework well versus having many tools that we superficially  
understand (based on Rick’s comments at the conference)

## 162   **How ss3sim complements other generic stock-assessment sim- ulation software**

- 164       • focus on “generic” software, e.g. not software the just works for salmon simu-  
lation

### 166   **r4ss**

- Taylor et al. (2013)
- 168       • r4ss has functions to facilitate aspects of simulations, mostly focused on reading  
and plotting output for stock assessment
- 170       • ss3sim uses r4ss functions for some reading, writing, and bias adjustment

## **FLR**

- 172       • Kell et al. (2007) for FLR and Hillary (2009) for simulation in FLR
- statistical catch-at-age only?
- 174       • not integrated analysis, not SS
- but particularly relevant to Europe

### 176   **“Hooilator”**

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

1. Lee et al. (2012)

180

2. Piner et al. (2011)

3. Lee et al. (2011)

182

## **The need for balance between generalizing and tailoring in simulation software**

184

- maybe?

- why we developed generic low-level functions and higher level functions

186

- but researchers are free to develop their own higher level functions

- because in an open-source MIT(?) licensed R package, users are free to modify

188

- functions as needed

## **Research opportunities with ss3sim**

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- there are lots, we should brainstorm some key ones

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192

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194

- son, ...

## Figure captions

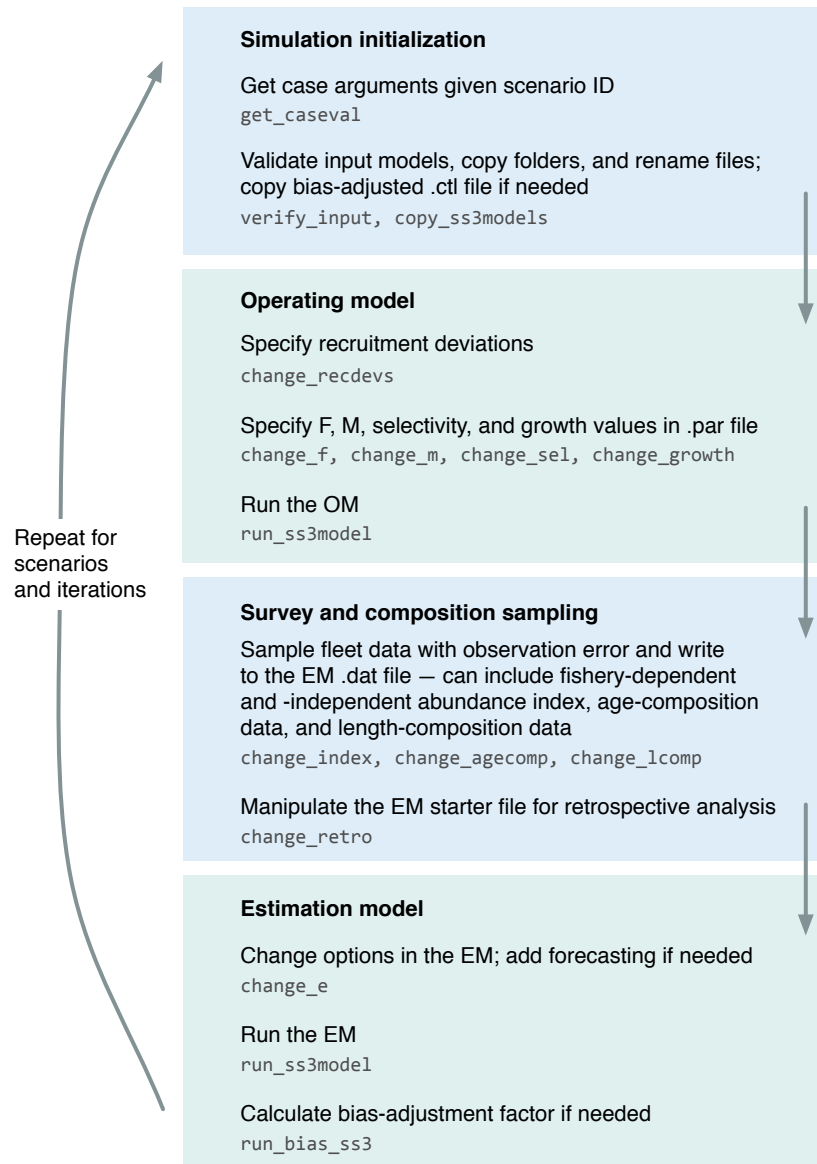


Figure 1: Flow diagram of `run_ss3sim` stock-assessment simulation steps.



## Tables

198 Table 1: User-facing ss3sim functions and a description of their purpose. This is now  
a bit redundant with Fig. 1, the main body text, and the package documentation  
200 itself.

Function name	Description
<code>change_f</code>	Changes the fishing mortality
<code>change_m</code>	Adds time-varying natural mortality features
<code>change_growth</code>	Adds time-varying growth features
<code>change_sel</code>	Adds time-varying selectivity
<code>change_e</code>	Controls what and how parameters are estimated
<code>change_lcomp</code>	Controls how length composition data are sampled
<code>change_agecomp</code>	Controls how age composition data are sampled
<code>change_index</code>	Controls how the fishery and survey indices operate
<code>change_rec_devs</code>	Substitutes recruitment deviations
<code>change_retro</code>	Controls the number of years to discard for a retrospective analysis
<code>run_ss3sim</code>	Master function that runs an ss3sim simulation
<code>run_fish600</code>	Wrapper function that facilitates one particular simulation setup

<code>get_results_all</code>	Extract results from a series of scenarios
<code>get_results_scenario</code>	Extract the results for a single scenario
<code>plotting functions!!</code>	Plot the output...

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202 Table X: Comparison with related software? - maybe a table with the possible columns: software, reference, platform (e.g. R, GUI...), Short description/comparison, examples of papers using it

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