Simulation testing the red snapper stock assessment: Update on the status of the operating and estimation models

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This document briefly describes the initial stage of creating a simulation framework for the red snapper assessment model. I briefly outline the assessment, the software framework adopted for the simulation, and the process of creating the simulation models.

The assessment model (AM) is an age-structured statistical catch-at-age model written in Stock Synthesis (SS3). The model takes data collected from the fishery and survey and estimates the underlying population dynamics, including both biological and fishery properties of the stock. The original assessment model runs from 1978 to 2013 with one season, 2 sexes, 6 fishing fleets and 1 survey (YOY survey). Natural mortality is fixed at 0.2, and growth is the standard von Bertalanfy with parameters fixed for females but offsets estimated for males. Stock recruitment is Beverton-Holt with steepness fixed at 0.8 but R_0 estimated. Length-based selectivity is used for all fleets, with varying functional forms (logistic, dome-shaped, etc.). The model is fitted to three types of data: indices of abundance, length compositions, and conditional age-at-length compositions. CPUE from fleets run from approximately 1978-2013 and a index from the survey from 1993-2013. There are length compositions for the fleets but not the survey. Instead of traditional age compositions, the assessment uses conditional age-at-length data. This type of data is created by taking lengths and ages of fish and then creating an age distribution for each length bin (e.g. 10-12cm) for each year/fleet.

The properties of the fishery, such as selectivity and effort, are mostly important because of their impact on the estimation process (they obscure our "view" of the biology).. The biological properties (productivity, growth, reproduction, etc.) are considered to be inherent to the stock, and thus would not change under different fishing schemes. As such, for simulation purposes, it is the biological properties that are most important and the complexity of the fishery can likely be simplified down without losing the core biological properties.

The snapper simulation framework will be conducted in `ss3sim`, an R package that facilitates rapid, flexible, and reproducible simulation testing of stock assessment models using SS3. R is used for the entire simulation process from specifying and running the simulations to reading, processing and exploring the results. A `ss3sim` study consists an operating model (OM) used to generate a true underlying population dynamics from which data are generated, and an estimation model (EM) used to estimate the underlying population dynamics from the generated data. `ss3sim` uses R functions to manipulate the OM (e.g. fishing patterns, process error, time-varying trends in parameters, etc.), as well as the EM (data types, turn on/off estimation of parameters, etc.), making it easy to induce structural differences between models. The analyst can thus easily manipulate the models to create combinations of different scenarios for which the performance of a model can be compared.

The OM is derived from the AM, but is not a strict copy for several reasons. First, some aspects of the model inherently need to be changed to be usable as an operating model. For example recruitment deviations need to be inputted directly in the .par file. Second, the `ss3sim` package requires the model to have a certain structure to be usable. The myriad features and conditional options available to SS3 make it challenging to write generic functions to interact with the model. As such, certain features are turned off, such as 2 sexes. These features are not inherently impossible in the `ss3sim` framework but are simply not yet supported. Thus, currently unsupported features could be added for this specific project. Here is a cursory list of some of the more impactful changes made to create the OM:

1. The differences in males were removed, reducing the model to one sex. This affects mortality and

growth, which had estimated offsets for males, but also the data which needed to be inputted by sex. Removing male catches changed the catch patterns in some fleets, since some (apparently) caught more of one sex in different years. (Still need to investigate this).

2. For simplicity in this first phase I removed all but the first fleet and the survey. These can be added back to the model if needed at a later stage.

3. The conditional age-at-length data was replaced with standard age composition data, since the former data type is not currently supported by `ss3sim`, although it will be in the next 6 months. For now `ss3sim` samples from true age and length compositions independently and with out bias, although overdispersion is an option. The next version will contain much more realistic and richer options for supported data. (I am helping develop this part of the package right now, for another project).

The OM has been created, tested, and compared against the original AM. The OM is not a valid model in that it will have a meaningless likelihood value and would not be estimable. It is simply run for a single iteration, using the parameters specified by the analyst, to generate expected values of the population dynamics which can then be sampled to create "data" for use in the EM.

The EM is a copy of the OM with estimation turned back on. Once realistic data are then passed to it, its likelihood will be meaningful and the parameters should be estimable. In their base form, the OM and EM have identical biological and fishery structure – the only difference is on the statistical side. However, the analyst can readily alter either model to create differences. The EM has also been created and tested under some very basic scenarios. The first step is to pass very little recruitment deviation error (process error in SS3) to the OM, and extremely informative data to the EM to ensure that estimates are unbiased and relatively small. The plot folder has some examples of these tests, using a exploitation pattern similar to the fishery (but not exact), and very small recruitment deviations under two data scenarios: "D100" has age and length comps every 2 years with high sample sizes, and "D101" has comps every 4 years with lower sample sizes. We expect both to be unbiased but D101 to have larger relative errors.