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Letter to the Editor

Response to: Comments on incongruous formulations in the SAM (state-space assessment model) model and consequences for fish stock assessment

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ABSTRACT

The state-space model SAM is an open source project and all suggestions are welcome. All models are simplified versions of the real system, and the suggested alternative model by Aldrin et al. (2018) is a different simplification than the one currently used in SAM. The postulated bias issue is already avoided in a different manner in SAM.

All models are wrong, but some are useful. — George Box.

The authors of the state-space assessment model (SAM, (Nielsen and Berg, 2014; Berg and Nielsen, 2016)) welcome any suggestions to improve it. That is the spirit of the team behind SAM and the reason the code is put forward as open source free for anyone to use and modify. In the spirit of open collaboration we encourage the authors of Aldrin et al. (2018) to share their modifications as well.

The SAM model is clearly stated exactly 'as is' and estimation and prediction is done consistently. It is therefore not warranted to describe e.g. the catch equation as 'wrong', nor is it correct that SAM reports biased catches. The SAM model and the modified version proposed by Aldrin et al. (2018) are simply different models. The question of which one is more appropriate should be determined by evaluating the likelihood, i.e. which model is more plausible given a specific set of observations.

1. Random walk on *F* on logarithmic scale

In SAM, the random walk on the fishing mortality is assigned on logarithmic scale, so for instance:

$$\log F_{a,y+1} = \log F_{a,y} + \varepsilon_y, \ \ \varepsilon_y \sim N(0, \sigma_F^2)$$

Assigning a process on logarithmic scale for F is a logical choice, because F itself need to remain positive. If F is not updated by data, then the expectation at the natural scale will increase by $\exp(\sigma_F^2/2)$, which in the illustrated example is around 0.6% per year.

In SAM, the value of F is updated by data every year and a difference in the expectation this small will be unnoticeable. Forecast scenarios are run conditioning on the value of F, so there is no practical implication of this creep.

However, if we imagine that F was not updated by data for a long period, then adding the half-variance constant suggested in the comment would have an unfortunate side effect. Imagine that F was 0.3, and then the process was allow to continue for 100 years, then the distribution on log-scale would be.

$$N(\log(0.3) - 100\sigma_F^2/2, 100\sigma_F^2)$$

This indicates an expectation for F at 0.3 (so the expectation will not creep), but it also indicates a median of $0.3{\cdot}\exp(-100\sigma_f^2/2)$, so half the probability mass will be concentrated more and more closely towards zero (if $\sigma_F = 0.11$ then the median would become ≈ 0.16).

If the suggested half-variance constant is not applied, then the expectation will increase, which is really not surprising when we add noise to a system which is bounded downwards, but the median will stay constant at 0.3.

The pros and cons of having a constant expectation versus having a constant median can be debated, but neither is wrong — it is simply two different models.

2. Postulated bias when predicting catch

The postulated bias in catch estimates in table 3 is incorrect, because in SAM all catch estimates on natural scale, including those used in forecasts and for management advice, are based on the *median* catch rather than the expected catch (see function 'catchtable' in the R-package for example).

SAM represents the catch observation on logarithmic scale, which is the sensible scale to use when assuming a normal distribution. This assumption implies that the expectation on the natural scale increases as a function of the variance, but the median does not. The logarithmic scale is the scale where expectation, mode, and median are identical. If the suggested half-variance term was applied at the logarithmic scale, then the log-catch prediction would be biased compared to expectation, mode, and median.

From a pragmatic point of view it is simply a different model choice, and the scale to model should be chosen based on case-by-case likelihood and model validation (e.g. residuals, Thygesen et al. (2017)). The issue of which observation equations to use, including whether to model expectation or the median, is discussed further in Albertsen et al. (2016).

3. The catch equation

The catch equation presented is interesting and different from the one used in SAM. Both models are simplifications of a more complicated underlying process.

In SAM we can effectively think about the process equation (for N) as a process where mortality rates F and M are assumed constant and applied throughout the year. Then at the end of the year the process noise is added on logarithmic scale. This process noise is the sum of all

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deviations including movements in and out of the study area.

In the proposed model we can effectively think about the process equation as a process where a random deviation is assigned solely to M, and then F and the updated M are used as constant mortalities throughout the year. This process noise does not include movements in and out of the study area. To allow migration, Aldrin et al. (2018) propose a modification of the constraints on mortality rates; however, the modified version does not allow immigration larger than the total mortality.

Both models are simplifications of the true system, where both F and M vary stochastic and continuously over time, and an unknown number of fish move in and out of the study area.

The models are different and it is wrong to interpret a difference between the models as a bias in either of the models.

As an example take standard deviation of the catch-at-age. The standard deviation of catch-at-age in SAM corresponds to the standard deviation of observations when predicted from the corresponding state (F_{ay} and N_{ay}). The standard deviation of catch-at-age in the proposed model is the standard deviation of observations when predicted from the corresponding state (F_{ay} and N_{ay}) and the N-part of the next state N_{a+1y+1} (or equivalently the deviation on M). It is fully expected that these standard deviations should be different, since they are describing two different prediction scenarios. Notice however, that if the proposed model is to be used to predict the next catch beyond the observed time series, then the proposed model will first need to predict the next year's N (including uncertainty and not updated by observations), before the modified catch equation can be used to predict the catch.

Having said that, it is interesting that the AIC seems to favor the suggested catch equation for the North sea cod data set. It will be interesting to see this comparison for more data sets. The modified catch equation has previously been suggested as an improvement (Dr. Noel Cadigan, Centre for Fisheries Ecosystems Research, Marine Institute of Memorial University of Newfoundland, personal correspondence), and we have briefly evaluated the change as having no practical importance. The estimates of SSB, F, and recruitment were almost unchanged, as acknowledged by the authors. Seeing this renewed interest in the subject we will add the proposed alternative catch equation as an option to the SAM R-package in the near future.

As mentioned by the authors the AIC difference (but likely also its significance) should be taken with some caveats. It will be interesting to compare further properties of how the two different models predict observations (e.g. bias in catch one year ahead). Prediction is the real use of assessment models, and hence different formulations should be compared on their ability to predict.

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