Uncertainty in age-structured stock assessment of Icelandic saithe: Effect of different assumptions, methods, and excluding data components

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Summary
This study touches on several common challenges in stock assessment, highlighting the causes and effects of estimation problems, and describes possible approaches to tackle them.

Introduction
Stock assessment of Icelandic saithe is based on similar data as the cod and haddock, but is subject to greater uncertainty. This is apparent from large residuals between the data and model fit, as well as retrospective estimation errors (ICES 2013, Hjörleifsson and Björnsson 2013). To provide the best management advice, the modeller should explore both model uncertainty (assumptions about the true dynamics) and estimation uncertainty (probability statements about stock status). The objective is to understand and utilize the information contained in the data, and to avoid making the advice overly sensitive to violated assumptions.

In this study, the saithe data are analyzed using a suite of related statistical catch-at-age models, applying different uncertainty methods to quantify the uncertainty. The results are interpreted in light of previous studies based on simulations, focusing on what makes fisheries data informative (Hilborn 1979, Magnusson and Hilborn 2007) and the use of different uncertainty methods (Patterson *et al.* 2001, Magnusson *et al.* 2013).

Materials and Methods
The saithe data are described in ICES (2013), and the models and uncertainty methods are described in Magnusson and Hilborn (2007) and Magnusson *et al.* (2013).

Results and Discussion
The Icelandic saithe assessment demonstrates that a data-rich fishery, where age data have been sampled intensively for decades from the fishery and annual surveys, does not necessarily mean informative data. This can be caused by the biological characteristics of the stock (vertical and long-distance migrations), as well as changes in the fleet behavior between years (time-varying selectivity).

In stock assessment, it is useful to run a variety of models to explore model uncertainty and to test the effects of different assumptions. Model comparison can also help identify how informative the data are, to separate the information contained in each data component (Magnusson and Hilborn 2007), and examine contradictory data sources (Schnute and Hilborn 1993). Thus, model comparison is not only about selecting the best model, but forms an essential part of analyzing stock assessment data.

The fishing history greatly affects how informative the data are. A high fishing mortality tends to be informative, especially when it varies greatly between years. When this is the case, annual changes in survey indices are more likely to correspond to annual changes in the catches. This improves our ability to estimate management quantities of interest. In some fisheries, data are available from the early years when catches were still very low. This can be very informative about quantities such as natural mortality rate and the current stock size relative to its maximum size. Finally, when fisheries data involve several years of very high and very low stock size, they are informative about the stock-recruitment relationship.

The delta method, bootstrap, and MCMC are commonly used to evaluate uncertainty in stock assessment. These uncertainty methods have different strengths and weaknesses, and several variations are available for each method. For a given stock assessment, it is better to compare the results from more than one method, rather than just using one arbitrarily chosen uncertainty method. Like with model comparison, expert judgement is required to select the best uncertainty method for a given assessment. Uncertainty analysis is not only about evaluating probabilities and confidence intervals, but can also identify highly correlated or ill-defined parameters, as well as lack of model convergence. Iterative simulation methods like the bootstrap and MCMC can also find a new global optimum, resulting in an improved model fit to the data.

Several parameters describing fish population dynamics are known to be problematic for statistical estimation, which can have a large effect on the resulting management advice. These include stock-recruitment steepness, natural mortality, and dome-shaped selectivity (Thompson 1994, Magnusson and Hilborn 2007). Bayesian priors on estimated parameters can be used instead of fixing such parameters at arbitrary values. These priors can be subjective, or borrow information from similar stocks.

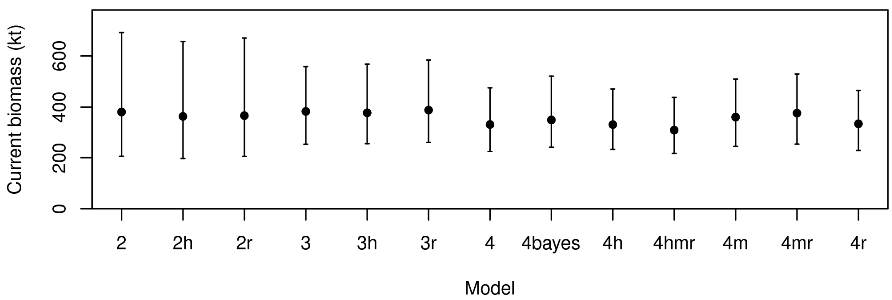

Figure 1. Current saithe biomass from different estimation models. Error bars show 90% confidence intervals, evaluated using MCMC.

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