# What is it in fisheries data that tells us about population abundance?

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## *Introduction*

Fisheries management relies on stock assessment models to provide estimates of population abundance and to shed light on the underlying dynamics. The uncertainty about model estimates reflects the information contained in the data, but also depends in a complex way on the choice of model and implicit assumptions that are made.

Despite theoretical and practical advances in the field of stock assessment, our ability to answer some key questions remains limited. In particular:

1. What is the real level of uncertainty about estimated abundance and reference points used in fisheries management? What is it in the data that tells us the stock is not 10 times smaller or larger than our estimate?

2. What kinds of data are particularly informative in stock assessments, and how is this influenced by model assumptions? Is "informative data" only a qualitative term, or can this notion be measured quantitatively?

## *Methods*

Data from two gadid fisheries: southern blue whiting (*Micromesistius australis*) from Campbell Island Rise, New Zealand, and cod (*Gadus morhua*) around Iceland. Landed catch, commercial catch at age, and survey abundance index.

Statistical catch-at-age stock assessment model, Coleraine 3.2. Predicts proportional catch at age (robust Fournier likelihood), survey index (lognormal), and deviations from Beverton-Holt recruitment (lognormal). Estimates catchability coefficient and selectivity shape parameters.

MCMC posterior simulations quantify uncertainty about predictions. Statistical R packages scape (in development) and coda for diagnostics of model fit and convergence.

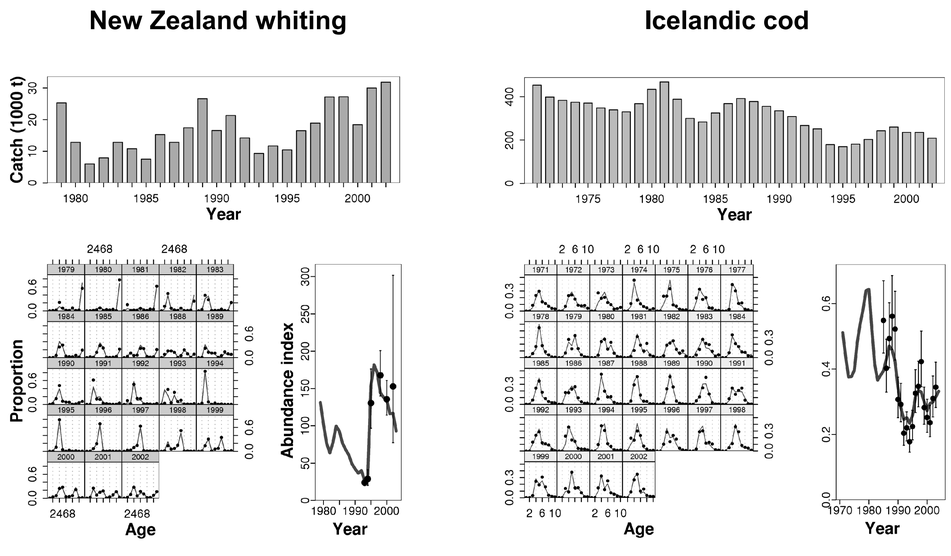


**Figure 1.** Stock assessment data and model fit from two fisheries: southern blue whiting (*Micromesistius australis*) from Campbell Island Rise, New Zealand, and cod (*Gadus morhua*) around Iceland. For each fishery, the top panel shows the annual landed catch, the left panel shows commercial catch at age, and the right panel shows survey abundance index. Dots are observed data, lines are model fit, and error bars indicate one unit of standard error about each observation.

## *Results*

New Zealand whiting fishery was first dominated by old fish and later by a large 1991 cohort. Icelandic cod model is unable to capture the biomass fluctuations shown by the abundance index, but fits the catch at age well.

New Zealand whiting model predicts current biomass with reasonable accuracy, even when survey data or commercial catch-at-age data are excluded from the model. Iceland cod model requires both data sources.

When the models incorporate all data, the objective function covaries highly with the catch-at-age likelihood, but less with other components.

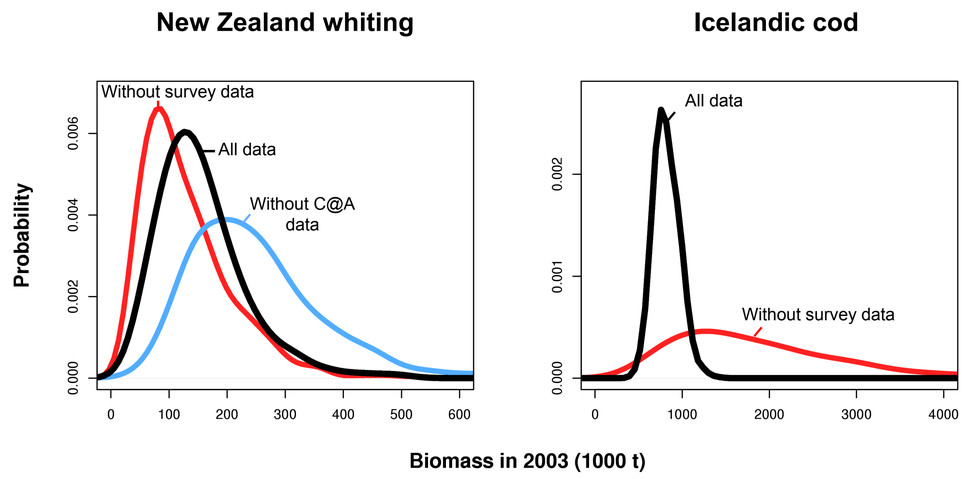


**Figure 2.** Probability distribution of current biomass when all data are used (black lines), when the survey abundance index is excluded from the model (red), and commercial catch-at-age data are excluded (blue). The Icelandic cod model did not converge without catch-at-age data.

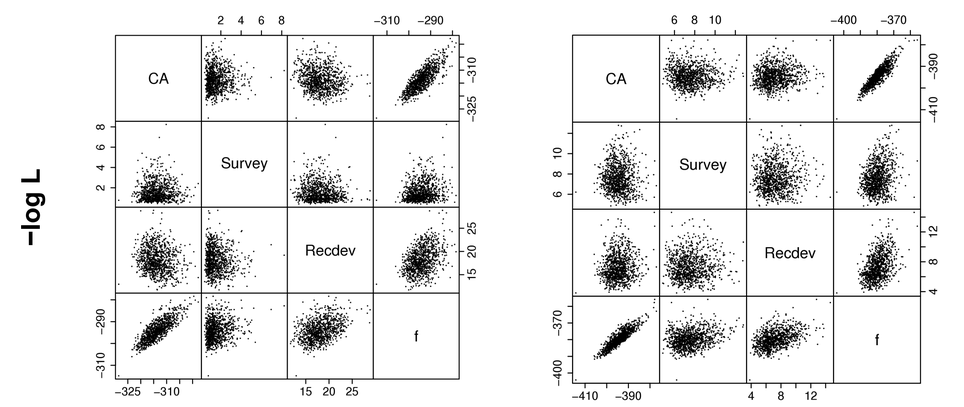


**Figure 3.** Scatterplot matrices showing the negative log likelihood value of model components in each MCMC draw. CA is the catch-at-age likelihood component, Survey is the abundance index, Recdev is deviations from deterministic recruitment, and f is the objective function (sum of all likelihood components). Left panel is New Zealand whiting and right panel Icelandic cod.

## *Discussion*

Two novel ways were developed for measuring information content in each data component. The first approach is simple: remove a component (Figure 2) from the model and see how that changes the perceived uncertainty. The second approach looks at how the objective function covaries with each data component (Figure 3). High correlation means high information content.

The perceived uncertainty is highly dependent on assumptions that are made. The model excluding catch-at-age data (blue in Fig. 2) is constrained by simplistic assumptions and fixed parameter values, and the model excluding survey abundance index (red in Fig. 2) only converges if natural mortality is assumed known.

The statistical catch-at-age family of models is a flexible platform for analyzing fisheries data. They have provided rational techniques to answer old questions, but also given rise to new ones.

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