Estimating uncertainty in data-limited stock assessments

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Summary
Sustainable management of marine resources requires knowledge of the current exploitation level and a reference point. Traditional assessment methods are not applicable for a plethora of stocks because of data limitations; e.g. lack of age information, time-series and reference points. New approaches are required that are validated and quantify uncertainty. Here, we validate a recent size-based steady-state method that estimates the stock status $F/F_{msy}$. The method requires only catch-at-size frequencies. The underlying model is formulated using life-history invariants that are not estimated, borrowing values from well assessed stocks ('Robin Hood' approach). The life-history invariant mostly affecting the results is the physiological mortality (natural mortality to growth ratio). Uncertainty estimates are obtained by repeating the assessment for different values of physiological mortality. Data-rich stocks are used to validate the method and identify its limits. Our results are compared with the official age-based assessments. Qualitatively our results agree to the official assessments. Further, temporal variations are well captured, although no time-series were used: the data of each year are treated in isolation. The uncertainty is a factor of two around the median estimate. The novel data-limited assessment method is a viable candidate for fisheries lacking long time-series and age information.

Introduction
Limitations of information about fish populations hinder the already difficult task of stock assessment. Especially in cases of small scale or developing fisheries where time-series and information about the age of individuals are not available. Thus, the sophisticated age-based stock assessment methods are unable to be used. Alternative methods have to be developed making use of all available information. Validation of novel methods is necessary; a way to perform such validation is by doing assessment of data-rich stocks using a fraction of the available data. In this way the data limited assessments have a comparison standard to be checked against, i.e. the official age-based assessments.

The aspect of uncertainty seems to be overlooked for most of the data-limited assessments. Nevertheless, it is something that needs to be investigated to achieve sustainable management of data-limited stocks (FAO, 1995).

Here, we validate a recent data-limited stock assessment method using four cod ($Gadus morhua$) stocks from the Northeast Atlantic and provide a method of estimating uncertainty of the assessment.

Materials and Methods
A recent single-species size-structured steady-state assessment method is based on the life-history invariant theory of exploited fish stocks (Andersen and Beyer, 2013) and is described in detail in Kokkalis
et. al. (2014). The life history invariants are not estimated from the data, but borrowed from well assessed data-rich stocks in a “Robin Hood” approach. The physiological mortality, i.e. the ratio of natural mortality to growth, is the invariant affecting the results the most. Therefore, the assessment is repeated for different values of physiological mortality to get an uncertainty estimation of the assessment. The observed distribution of physiological mortality in assessed stocks is sampled to provide the values of physiological mortality. Main output of the method is the stock status quantified by the ratio of fishing mortality (F) to Fmsy. This ratio is calculated from the same data. The assessment method is validated using data from data-rich stocks treated as data-limited. The data used in this study are yearly commercial catch-at-size of five Atlantic cod (Gadus morhua) stocks are used, i.e. North Sea, Northeast Arctic, Icelandic and Faroe Plateau. Yearly landings and official assessment results, i.e. fishing mortality and spawning-stock biomass, are downloaded from the ICES Stock Assessment database (ICES, 2014).

Results and discussion
The official assessments fall well within the uncertainty bounds for all four cod stocks and all years. The median of the estimation is close to the age-based assessment for the North Sea cod and the Northeast Arctic cod. The data limited assessment shows the Faroe Plateau stock in worse condition and the Icelandic cod in better condition compared to the official assessment. In all case studies, the temporal trends of stock status are well captured by the steady state model. The fact is remarkable considering the fact that each year of data is treated in isolation, thus no time-series are used. The assessment output is the ratio F/Fmsy and the estimated value of fishing mortality and the reference point Fmsy are not meaningful separately. Nevertheless F/Fmsy provides the necessary information for successful management. The uncertainty bounds are very wide spanning from half to twice the median. This reflects the fact of using a very wide distribution of physiological mortality. Further investigation is needed to reveal if using only related (e.g. phylogenetically or geographically) data-rich stocks would lead to more accurate assessments with narrower uncertainty.

References

