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Linking the performance of a data-limited empirical catch rule to life-history traits*

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SUMMARY: Many fish stocks are data-limited but nevertheless require management advise. An empirical catch rule was tested with a simulation approach and the rule's performance could be linked to a growth parameter of fish stocks. This allowed the definition of a threshold for when the rule can be applied. It was shown that a single generic catch rule cannot be applied across all life histories, management should instead be linked to life-history traits and ensure that fisheries are MSY compliant and precautionary.

INTRODUCTION

In Europe, the International Council for the Exploration of the Sea (ICES) provides catch advice for many fish stocks. For the majority of these stocks, data are limited and catch advice can only be based on simple catch rules using available information. The currently applied decision framework can rather be regarded as an interim solution and does not include any target references levels and therefore does not provide management options compliant with the maximum sustainable yield (MSY) principle.

The work presented here evaluates an alternative data-limited catch rule, which provides catch advice for data-limited stocks and includes an MSY target, by means of a Management Strategy Evaluation (MSE, Punt *et al.*, 2016).

An MSE is a simulation framework which uses an operating model to represent a fish stock and the fisheries operating on it. In an operating model, resource dynamics are simulated and pseudo-data is generated which is fed into a management procedure. The management procedure uses these data, together with an algorithm to set a management measure, such as catch. This, in turn, is then removed from the operating model in a feedback loop.

RESULTS

The performance of the catch rule differed between the simulated stocks. A penalized regression model revealed that the performance of the catch rule was mostly influenced by the von Bertalanffy growth parameter k and better performance was linked to lower values of k.

A time-series cluster analysis of the relative stock sizes (SSB/B_{MSY}) could group the stocks into several clusters depending on the stock trajectories and this could be linked back to k (Figure 1). All stocks with $k \geq 0.32$ year^{-1} (the fast-growing stocks) collapsed during the projection, whereas the remaining stocks survived and the catch rule displayed reasonable performance.

Additional tuning, such as the inclusion of catch multipliers, catch constraints and reduction of time lags in the data, could improve the performance for the lower-to-medium-k stocks.

METHODS

Twenty-nine fish stocks were simulated based on life-history parameters (e.g. for growth). These stocks were then subjected to a management procedure which is based on a simple empirical catch rule:

$$C_{y+1} = C_{y-1}\, r\, f\, b,$$

where C_{y+1} is the new catch advice, C_{y-1} is the previous catch, r provides information about the stock development from a biomass index, f is a proxy for the exploitation relative to MSY derived from catch length sampling and b is a stock size safeguard reducing the catch if the biomass index falls below a threshold.

This catch rule was applied to the 29 stocks for a period of 100 years in a stochastic MSE simulation.

The performance of the catch rule was measured with summary statistics, which included the stock size, exploitation levels, catch, risk of falling below reference points and catch variability.

The source code for the simulations and analysis is available on GitHub at: https://github.com/shfischer/wklifeVII/.

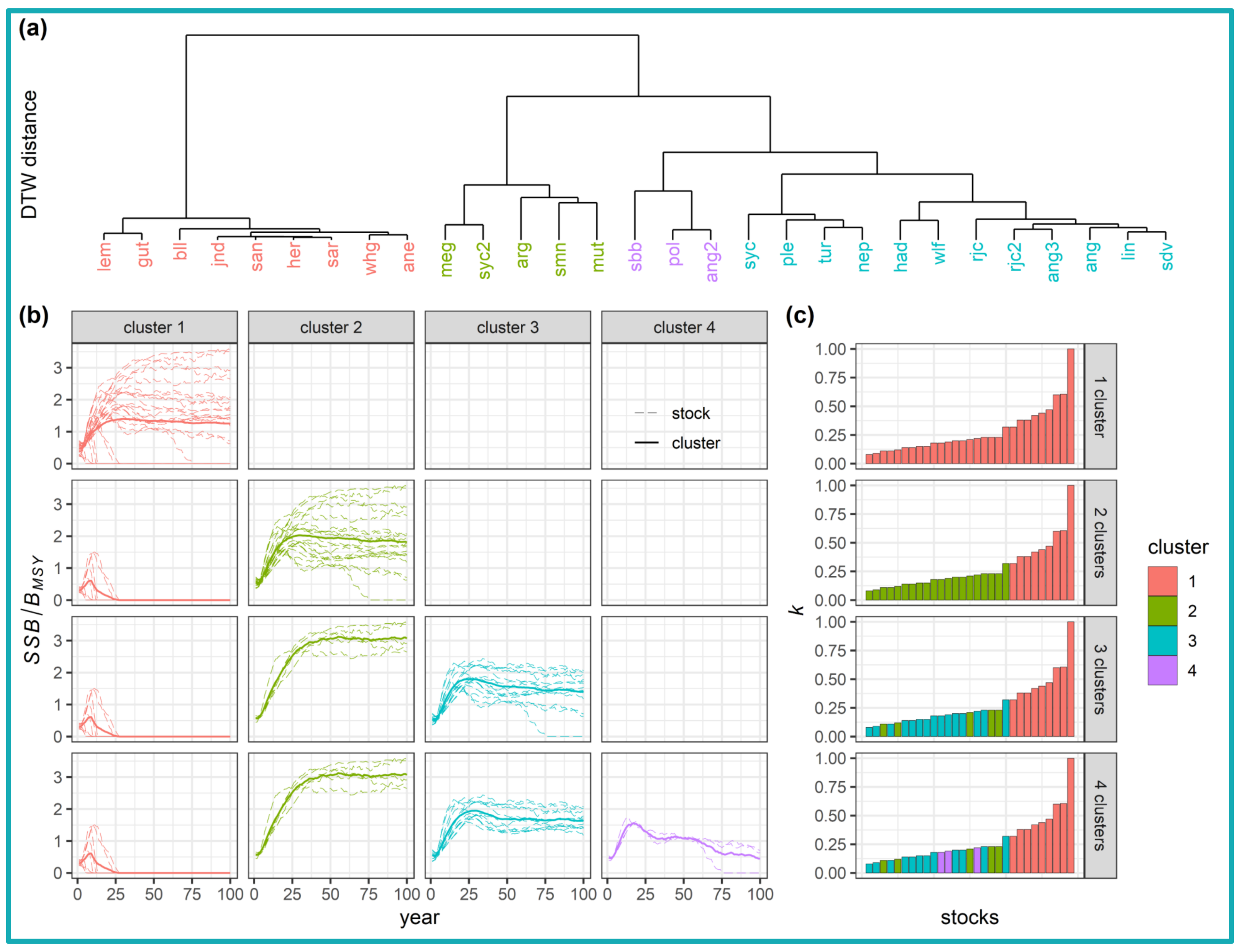

Figure 1. Results of the hierarchical time-series clustering analysis of relative stock size (SSB/B_{MSY}) using dynamic time warping (DTW). (a) A dendrogram of the time series for the 29 stocks, (b) the stock trajectories split into 1-4 clusters, rows represent the number of clusters and each column is one cluster, (c) the growth parameters k, sorted in ascending order and colour-coded for the clusters in (b).

CONCLUSION

This study simulation tested a simple catch rule, making use of proxy MSY reference points for a range of data-limited fish stocks. The main result was that the performance of the catch rule was stock specific and could broadly be linked to life-history characteristics, with the von Bertalanffy growth parameter k emerging as the most important factor. The catch rule provides a robust management option but should not be applied for fast-growing stocks with $k \geq 0.32$.

It was shown that a single generic catch rule cannot be applied across all life histories, and management should instead be linked to life-history traits, and in particular, the nature of the time series of stock metrics. The lessons learnt can help future work to shape scientific research into data-limited fisheries management and to ensure that fisheries are MSY compliant and precautionary.

REFERENCES

- Punt, A. E., Butterworth, D. S., de Moor, C. L., De Oliveira, J. A. A., and Haddon, M. 2016. Management strategy evaluation: best practices. Fish and Fisheries, 17: 303–334.

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