Tools for assessing data-limited fisheries and communicating stock status information

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Submitted by

Emily Anna Fisher

BSc (Hons) University of Plymouth, UK

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

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Emily Anna Fisher

Dedication

To my late grandpa
Jack E. Fisher
for the many happy memories
catching crabs off the quay
in Wells-next-the-sea
during my summer school holidays
and, of course,
for providing me with such a
great last name!

ABSTRACT

This PhD study was focused on developing and exploring tools for assessing the status of data-limited fish stocks.

A management strategy evaluation (MSE) framework was developed to explore the effectiveness of alternative strategies for managing fish stocks for which sufficient data are available to allow a catch curve-based assessment, but which lack the reliable time series data on catches and/or catch per unit of effort required for developing an integrated age-structured fishery model. Explorations using the operating model of this framework indicated that, particularly for demersal fish species with limited movements and which suffer high levels of post-release mortality, use of temporal closures throughout the full area of a fishery are likely to be more effective for reducing fishing mortality than reducing daily bag limits, imposing more restrictive size limits, or constraining the areas open to fishing. Implications of differences in biological characteristics of fish species, including longevity, annual recruitment variability and post-release mortality, for the effectiveness of different management controls were explored using the operating model.

The effectiveness of the graphical interface employed by the MSE model in communicating stock assessment information to fisheries managers and stakeholders was evaluated in a "scenario testing" study involving university students. Students viewed model outputs for several hypothetical fish stocks with different biological attributes and initial exploitation states. Based on their perception of the true status of each stock, students then "pulled" various alternative "management levers" available in the program. Analyses of data resulting from the study indicated that, provided the design was not overly complex, the interface of the MSE framework was effective for

communicating stock assessment information. The results of the study illustrated the potential of this type of approach for evaluating and improving the effectiveness of the ways in which stock assessment information is communicated to fisheries managers and other stakeholders.

During the next project phase, several methods for estimating rates of mortality of fish stocks were developed and explored. Maximum likelihood estimates of total mortality, calculated assuming that the age composition of fully-recruited fish was drawn from a geometric distribution and that annual recruitment was variable, had lower root mean squared error (RMSE) than other estimates obtained using traditional methods of catch curve analysis that did not allow for such variability. This catch curve model, which also provided potentially valuable information on recruitment variability, was then extended to allow for a change in total mortality, as might result from a major change to management. Analyses demonstrated that, despite variability in annual recruitment, it was possible to distinguish such a change in mortality in the age composition data if the mortality change was of sufficient magnitude and adequate time had elapsed since the change in mortality. Bias in the estimates of mortality for the two periods was explored.

Next, a model was developed to provide estimates of mortality for fish species which undertake pronounced unidirectional, size-dependent movements during life, *e.g.* a size-dependent, offshore movement of fish to deeper water, when it is only possible to obtain representative samples of age and size compositions from the different areas and not for the overall population. The model was able to "disentangle" the similar, but slightly different, influences of mortality and movement on size and age data. Following simulation testing, the technique was applied to "real" data for a fish species in Western Australia (*Pseudocaranx georgianus*). The model fills a "void" for existing methods for such fish species, particularly if those

species are of insufficient economic value to warrant an expensive, large-scale tagging program.

Areas in which the work presented in this thesis could be expanded are discussed in the light of some likely directions for future fisheries research relating to data-limited fisheries.

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Exploring the use of a fisheries simulation model for communicating stock assessment information

CHAPTER 4
To what extent can mortality estimates produced by catch curve analysis be improved by accounting for variable recruitment and changes in mortality?

COMMON ABBREVIATIONS

AFMA – Australian Fisheries Management Authority

ANOSIM – Analysis of similarity

BPH – Body proportional hypothesis

CV – Coefficient of variation

FAO – Food and Agricultural Organisation (of the United Nations)

FRDC – Fisheries Research and Development Corporation

MDS – Multi-dimensional scaling

MLE – Maximum-likelihood estimator

MLL – Minimum legal length (for retention)

MSC – Marine Stewardship Council

MSE – Management strategy evaluation

PERMANOVA – Permutational multivariate analysis of variance

PERMDISP – Permutational test of homogeneity of multivariate dispersions

RMSE – Root mean square error

SIMPER – Similarity percentage analysis

TAC – Total allowable catch

TL – Total length

WA – Western Australia

WAFIC – Western Australian Fishing Industry Council

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