Marine Policy 74 (2016) 279–287

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

How many of Australia's stock assessments can be conducted using stock assessment packages?

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ARTICLE INFO

Keywords:
CASAL
Stock Synthesis
Stock assessment
Funding
Uncertainty

ABSTRACT

Most of the stock assessments conducted in the USA and in New Zealand are based on packages that have been developed for generic use, are well documented, and have been tested using simulation. However, this is not the case for assessments conducted in Australia and many other countries. This paper reviews all of the model-based stock assessments for Australian fisheries to evaluate how many of these assessments could have been conducted using the publicly-available stock assessment packages used widely in the USA and New Zealand. The 76 model-based assessments reflect 37% of the 2013 catch recorded in Australia's Status for Key Australian Fish Stocks Reports (or 34% of the total catch in 2013). All but 18 (or 24 if full rather than approximate age-size-structured models need to be used) of the stock assessments could have been conducted using stock assessment packages used in the United States and New Zealand. Adoption and use of packages for more stocks in Australia should increase the likelihood that results are based on correctly-coded models whose estimation performance is widely understood, reduce the time needed to conduct assessments, and speed up the peer-review process. The availability of training, manuals, and example data sets for stock assessment packages should partially address their additional complexity. Additional benefits, in terms of numbers of assessed stocks, could occur if Australian stock assessment scientists develop a forum to collaborate and share methods. These results are applicable to many other jurisdictions that undertake stock assessments.

1. Introduction

Fisheries in Australia are considered amongst the world's best managed. While attempts to rank nations in terms of their ability to successfully implement fisheries (and Ocean) management should be interpreted with extreme care, Australia is consistently ranked very highly. For example, Australia was ranked 7th in terms of managing marine ecosystems [1], 4th in terms of compliance with the FAO Code of Conduct for Responsible Fisheries [2], and 7th in terms of overall performance in terms of ecosystem based management [3]. Moreover, only 6.4% of the 170 assessed Australian stocks are considered to be overfished [4]. Fishery management in Australia is, however, not without major challenges. Specifically, the amount of government funding available for monitoring is lower than in the USA and western Europe, and Australia has many low value data-limited species and fisheries [5]. This can be attributed partially to the low volume (and total value) of fisheries in Australia [4], and that most jurisdictions use partial cost recovery from the industry for fisheries management, i.e. a user pays system.

Notwithstanding the limited resources for monitoring, assessments and management, most jurisdictions in Australia (six State, one Territory, and the Federal (Commonwealth) government) have adopted an approach to management that involves conducting quantitative assessments based on fitting population dynamics models for stocks considered to be of recreational and commercial importance, and applying some form of harvest control rule to determine management actions. This is most clearly formulated at the Commonwealth level where a Harvest Strategy Policy has been developed [6], which specifies the need for target and limit reference points, and provides defaults for these reference points and the maximum probability that stocks are reduced below the limit reference point. The target reference point for Australian Commonwealth managed fisheries is B_{MEY}, the biomass corresponding to Maximum Economic Yield, which is generally larger than the conventional target for fisheries management, the biomass

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http://dx.doi.org/10.1016/j.marpol.2016.09.033
Received 5 August 2016; Received in revised form 26 September 2016; Accepted 26 September 2016

corresponding to Maximum Sustainable Yield, B_{MSY}. The Australian Commonwealth Harvest Strategy Policy allows for the use of proxies for B_{MEY} ($1.2\times B_{MSY}$), where the proxy for B_{MSY} is taken to be $0.4B_0$, or 40% of the pre-fishery spawning biomass [7] if these reference points cannot be estimated using a quantitative model. Management actions justified based on economic considerations and quantitative model-based stock assessments are also common at the Australian state level [e.g. [8,9]]. A National Harvest Strategy Guideline [10] has been developed and, although it has not been widely adopted as of writing, it has been endorsed by the heads of the Australian and state and territory government agencies responsible for fisheries through the Australian Fisheries Management Forum. No specific reference points are prescribed in this Guideline.

The trend in the USA, Europe and New Zealand and in Regional Fisheries Management Organizations is towards stock assessments being conducted using a small number of stock assessment packages (see, for example, the review of stock assessment packages used in the USA by Dichmont et al. [11]). Dichmont et al. [11] identify the benefits of using packages rather than user-developed software as: (a) substantially increased flexibility to explore alternative assessment configurations, (b) ease of peer-reviewing, (c) increased confidence that the assessment is correctly coded and tested, (d) the availability of tools to explore uncertainty and summarize model fits to data, (e) increased collaboration amongst assessment scientists on generic questions related to stock assessment practice given a common software platform is being used, (f) faster development time for an assessment, (g) increased ability for a new analyst to take over a stock assessment because they are familiar with the package, and (h) a large user base to facilitate further development and improvement (and to detect errors).

However, as will be shown in this paper, only a relatively small proportion of Australian assessments are currently being conducted using stock assessment packages, and only in one region of Australia. This paper provides a summary of the model-based stock assessments used in Australia (these being the most demanding in terms of data requirements as well as the need for skilled analysts and that support management of the most valuable fisheries), and examines the extent to which it would be possible to conduct assessments in Australia using the stock assessment packages used most commonly for conducting 'integrated' assessments, particularly those packages available in the USA and New Zealand, since fisheries management in these countries aligns most closely to the Australian policy environment. The lessons learnt from this review will help Australia plan a 'business model' for how to provide ongoing scientific fisheries management advice.

2. Materials and methods

2.1. Survey questionnaires

A two-step survey process was undertaken. The first step involved contacting each Australian fisheries research organisation (or individuals within consulting companies) that had undertaken stock assessments in the past decade to obtain a list of the species (and stocks within species) with assessments and the primary contact for the assessment. For the purposes of this study, stocks assessments were defined as "model-based assessments used for tactical fisheries management that includes an optimisation component." The second step involved contacting each assessment analyst and requesting information for each assessment. The questionnaire was in the form of an Excel file with default dropdown menus for several questions, but with the ability to provide written comments for all questions (see Supplementary Table 1 for the entire questionnaire). The four categories of questions were:

- an overview of the method of assessment on which the assessment was based, including whether it was designed for generic use (i.e. for multiple fisheries or stocks) and whether it has been subject to peer-review;
- information about the software used to implement the assessment, including whether it is available publically, the language on which it is based, and its ongoing maintenance;
- specifics of the technical aspects of the model on which the assessment is based; and
- information on how uncertainty is characterized.

All the responses were collated into a single file and checked by the authors of this paper. Any queries were sent to the respondents for further comment. Respondents did not always provide references to the methods on which their assessments were based, so these were sourced by the authors and then sent to the respondents for checking.

2.2. Data analysis

The species for which stock assessments are conducted in Australia were categorized into seven broad taxonomic groups: "abalone", "scallops", "crabs", "lobsters", "prawns", "sharks", and "finfish". These represent a subset of the 11 species groups for which species summaries are provided in the Australia's Status for Key Australian Fish Stocks Reports (SAFS; e.g. [4]). The other species groups included in SAFS are pipis, octopus, squids, and bugs, but no tactical model-based assessments are available for species in these groups. The stock assessment methods on which Australia stock assessments were based were categorized in terms of the structure of the population dynamic model underlying the assessment (Table 1). As an initial summary, the assessments were then categorized by: a) jurisdiction, b) research organisation that conducted the assessment, c) programming language used; d) input data required; e) population dynamic structure, and f) how the method and application were documented. The results for c), d) and f) were summarized by population dynamic structure as well as by jurisdiction.

Each assessment was classified as "unique", "semi-generic" or "package" based on the assessment method applied (i.e. whether the assessment method (a) could not be applied to another stock, (b) could, with reasonably minor code and input model adjustments, form the basis for an assessment of another stock or species, or (c) was based on a freely available stock assessment package that can easily be adapted to another similar stock or species without code changes and without need to review the method or code).

The assessments that are currently not based on stock assessment packages (i.e. the "unique" and "semi-generic" assessments) were then linked to available stock assessment packages used in the USA and New Zealand (Table 2) based on the population dynamic structure on which the assessment was based to provide an initial set of packages that could be used to conduct the assessment. A final set of assessments that could be conducted using packages was then identified taking into account the data sources used for parameter estimation and other features of the assessment. Those assessments that cannot be conducted using packages will remain "unique", and the reasons for these cases are identified and discussed.

3. Results

3.1. Representativeness of the data set

The total catch of all marine species by Australia was 152,689 t in 2013, with a value of AUS$1.4 billion. Of this catch, 92% is included in the 2014 SAFS (Table 3). The total catch represented within the 76 model-based stock assessments[1] is 50,776 t. Almost all of the catch of lobsters (75%) is included in stock assessments, while more than 50% of the catch of scallops, prawns and sharks are included in stock

[1] Actually 66 because 10 of the stocks are not included in the SAFS.