

STOCK ASSESSMENT TOOLBOX

This web site provides links to, and a summary of, most of the freely-available packages to conduct stock assessments for fish and invertebrate stocks. Many stock assessment methods have been developed. This web site provides a summary of those methods that have been assembled into 'packages' (broadly defined as software that can be run by a user other than the developer(s) of the package).

[ACCESS TOOLBOX RESOURCES](#)

A Stock Assessment Toolbox for Australian Fisheries

Dichmont, C.M., Deng, R.A., Dowling, N., Punt, A.E., Tsang, A.

FRDC Project No 2018-148



1. Package Specification

This allows you to search for packages, find out more about them and links to download or install. Each package has been classified into a package type and our view of Recommended packages have been added.



2. Simulated Test Data

If you want to test different methods, we supply a dataset with known characteristics. It is aimed at Australian Fisheries. So for example, Australian fisheries tend not to have fishery independent survey data.



3. Installation Guidelines

We selected a few packages to test out our own simulated dataset. The R code and test datasets are available for your use so you can test the package yourself. This complements the package developer resources.



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Researcher Contact Details

Name: Cathy Dichmont
Address: 69 Headsail Drive, Banksia Beach, Qld, 4507
Phone: 0419 950 076
Fax:
Email: cathydichmont@gmail.com

FRDC Contact Details

Address: 25 Geils Court
Deakin ACT 2600
Phone: 02 6122 2100
Email: frdc@frdc.com.au
Web: www.frdc.com.au

In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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Executive Summary

Summary

Stock assessment scientists from CSIRO and Cathy Dichmont Consulting designed a web-based tool that collated freely available stock assessment packages (<http://toolbox.frdc.com.au/>). Web searches and global consultation with assessment scientists identified more than 100 assessment packages. These were assigned to one of 10 classes of assessments and evaluated as to whether they were state-of-the-art within their class. The website provides a novel feature that allows searching and filtering for packages based on specific features from the extensive model specifications that are provided in a consistent manner between packages (<http://toolbox.frdc.com.au/toolbox/>). Test data and instructions for some packages are also provided as downloadable files (<http://toolbox.frdc.com.au/instructions/>) for a scientist to run locally on their computer. The test data can also be used to simulation test other assessment methods since these simulated data have been produced from specified, and therefore known, population status and biology. An ability to link a specific stock assessment report to the web site is also provided so that users can search for past assessments reports. Presently there are more than 70 Australian stock assessment reports linked within this repository. This project's work is also available as a journal publication (Dichmont et al. 2020; <https://doi.org/10.1016/j.fishres.2020.105844>).

Background

Stock assessments are integral to fisheries management, and the demand for stock assessments based on population dynamics models continues to increase. Historically, stock assessments have been based on bespoke methods and software. There is now a trend towards the use of flexible, documented, tested and maintained software packages because use of such packages increases efficiency and consistency in assessments and should lead to more reliable and repeatable assessment outcomes.

A recently completed project (FRDC 2014-039 - Stock Assessment Integration: a review) reviewed the range of packages used to conduct assessments of fish and invertebrate stocks in the USA, as USA assessments tend to have common goals to those in Australia, and need to provide similar outputs for decision making. The report also reviewed all model-based assessments undertaken in Australia specifically to evaluate how many assessments could have been conducted using the publicly available stock assessment packages used widely in the USA and New Zealand. It was found that all but 18 (or 24 if full rather than approximate age-size-structured models need to be used) of the 76 stock assessments could have been conducted using stock assessment packages used in the USA or New Zealand.

However, stock assessment is severely capacity limited in the present climate as demand for assessments, especially those that are data-limited, increases. Impediments to the uptake of packages was found to include lack of time to transition, lack of knowledge of what is available and where, lack of sharing within the stock assessment community, and lack of investment in training.

Objectives

This project addressed the above issues by a) linking all freely available international packages into a single framework within FRDC's web system, b) providing guidance as to which package is more appropriate for what kind of situations, and c) linking to resources created by the authors of packages such as test data and models.

Methodology

The approach used was to define what is a stock assessment package, search the web and approach stock assessment scientists globally to identify a list of packages, categorise the packages into classes (removing those that are no longer supported by the developer or is not a stock assessment as defined for this

project), and then connect with the assessors (see Acknowledgements) to obtain detailed specifications for each package.

Test data, and installation and use instructions were developed for two each of the data-limited and data-moderate Classes. These were created using a data simulation feature within the package Stock Synthesis using specifications for the (therefore known) population dynamics and stock status. In addition, a facility was created for people to add their stock assessment reports to the website.

Results

In total, about 64 (of more than 130 identified) packages were included on the website with over 70 model specifications listed. These were placed into 10 classes, being Catch curves, Catch only, Delay difference, Depletion model, Integrated approach, Length-only, Mean length, Size-structured, Surplus Production and Virtual Population Analysis (VPA). Presently, there are 67 stock assessment reports from Australian fisheries linked to the web site.

Implications

The final product is a website that collates available stock assessment packages (from data-limited to data-rich) to provide assessment analysts with a single platform that summarizes the features of the currently available packages in a consistent manner. We also highlight current state-of-the-art packages and those that are no longer supported or are superseded. In addition to providing the packages, the website facilitates users of packages to provide feedback to developers regarding which features of other packages could be included in future versions of their packages. We see this effort as a way to support the design of the next generation stock assessment package.

Recommendations

It is essential that this website is regularly updated so that it does not become out of date. Its existence should also be extended in this process so that its full potential can be realised.

Keywords

Stock assessment; packages; specifications; toolbox; website

Introduction

Quantitative stock assessments based on fitting population dynamics models to monitoring data are integral to modern fisheries management. They are used to assess stock status relative to biological reference points, assess whether stocks are subject to overfishing or are in overfished state, form the basis for application of harvest control rules, and act as operating models to evaluate candidate management strategies using management strategy evaluation (Punt et al., 2020).

The most appropriate method of assessment depends on the data available, whether the model on which the assessment method is based adequately captures the population and fishery dynamics, and the methods for estimating the parameters of the model and quantifying uncertainty. 'Integrated approaches' (e.g., Fournier and Archibald, 1982; Maunder and Punt, 2013) are the preferred assessment paradigm when data are available on removals, there is an index of relative abundance, and data are available on size- and/or age-composition from fishery-dependent and -independent monitoring, thereby allowing exploration of many aspects of the populations dynamics and how the data pertain to the modelled population. However, there are often insufficient data to apply integrated approaches, resulting in use of alternative methods such as surplus production models, catch curve methods, and catch- or length-only methods.

Historically, assessments were conducted using bespoke methods implemented using user-developed software that were designed for specific fisheries and tailored to their particular needs. However, there is now a trend towards the use of software packages that implement assessment methods (Dichmont et al., 2016a). Assessment packages are intended to be user-friendly applications that enable users to apply established assessment methods using their own data, without the need to code a bespoke model. Where existing methods are applicable to a fishery's circumstances, the use of the associated packages avoids redundancy, reduces the time and resource cost of conducting the assessment, and eliminates the potential for programming errors, all of which are associated with the development of bespoke methods (Wilson et al., 2014). Bespoke models have their place, but the features of packages are important in the decision of whether to use a package or develop a bespoke model.

Dichmont et al. (2016a) identified 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 analysts 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).

Dichmont et al. (2016b) noted that 76 model-based stocks assessments were conducted in Australia at time of their review (reflecting 34% of the total catch in 2013), and that all but 18 could have been conducted using stock assessment packages developed in New Zealand and the United States. Apart from legitimate technical reasons, a common reason identified for not using packages was that there is no central repository for stock assessment packages, to allow analysts to identify the package most appropriate to their stock.

There are now many stock assessment packages, some of which (a) implement methods now considered not to be state-of-the-art, (b) are rarely updated and maintained, (c) do not have reliable or comprehensive documentation, or (d) have been subject only to limited testing. Some packages are not well known while others are widely used e.g., Stock Synthesis (Methot and Wetzel, 2013). The packages can be available from online repositories or platforms, or can be limited to individual countries or institutions. Moreover, the same method may be implemented in more than one package, for example a statistical catch-at-age approach using empirical weight-at-age data is implemented in ASAP (NOAA Toolbox, 2016) and AMAK (NOAA Toolbox, 2016). Consequently, analysts wishing to transition existing bespoke assessments, or undertake a new assessment, using a package, may be confronted with an overwhelmingly large number of methods and packages that are spread over a wide range of web and/or version control sites, with little or no guidance on which package is most appropriate for their stock and is most up to date. The FishPath decision support tool (Dowling et al., 2016) provides information about which method is appropriate given an assessor's specific fishery circumstances. However, at present FishPath concentrates on data-limited assessment methods.

Even when users are confident of their choice of method, a package may be difficult to download or implement given the available documentation or support provided. Data formatting and post-assessment analyses can be challenging for many of the more complex packages without good documentation, and pre- and post-processing tools such as r4ss (<https://github.com/r4ss/r4ss>) and ASAPplots (<https://github.com/cmlegault/ASAPplots>). Moreover, in the absence of a centralised, global repository, analysts may be unaware of the options for methods and packages, or may have cultural preferences for packages and methods that have less to do with scientific rigor and more to do with the constraint of what is known or familiar (Privitera-Johnson and Punt, 2020).

Objectives

1. Develop a resource for housing and linking to Australian and International stock assessment packages (the Toolbox).
2. Provide material that will value add expertise to aid use of the packages within the Toolbox.
3. Provide a platform for Australian assessments (with their associated resources) to be housed.

Methods

We collated the available assessment packages and provided links to them using a website <http://toolbox.frdc.com.au/>. A multi-prong approach to identify packages was used, starting with web searches using Google, Google Scholar and library abstract search engines such as Aquatic Sciences and Fisheries Abstracts; search terms included “stock assessment packages” and combinations thereof. The resources provided by the Center for Advancement of Population Assessment Methodology (CAPAM) workshops (Maunder et al., 2014, 2016, 2017; Sharma et al., 2019; Cadrin et al., 2020) were also used to identify data-rich approaches. Assessment reports from organisations such as NOAA and ICES were investigated for package use. Finally, resources in the latest version of NOAA Toolbox (<https://noaa-fisheries-integrated-toolbox.github.io/>) and the FishPath decision support tool (<https://tool.fishpath.org>) were considered.

Although we have tended to be as inclusive as possible, we have not included packages that:

- (a) were not an assessment by our definition (i.e., a method that estimated biomass or fishing mortality),
- (b) involved software that is not freely available, and
- (c) had not been supported for more than two years.

The aim of the website is to provide analysts with the range of possible packages within a standardised, curated platform, enabling them to directly compare package attributes, broadly identify those packages most likely to lead to the most robust results given available data and knowledge, and generally increase the use of state-of-the-art packages as well as the number of assessments that an assessor can undertake compared to the (usually) more time-consuming bespoke models. For some data-poor and data-moderate methods, the website includes installation details and instructions of how to apply the package, using a common test data set. The FishPath tool would be a valuable resource to be used alongside the website to guide an assessor to an assessment method and package, and this website with more model specification details and the package’s location.

Type of assessment methods

Stock assessments involve many forms of analyses, ranging from assembly of catch, compositional and catch-rate time series, plotting of data to identify changes in fisher behaviour, to applying population dynamics models to determine stock status and the implications of management actions. We focus on the methods used to conduct model-based stock assessments, which we define as estimating biomass and/or fishing mortality, either in absolute terms and/or relative to reference points. Thus, packages to fit growth curves, conduct catch-effort (aka catch rate) standardization or apply yield-per-recruit analysis are consequently not considered for inclusion on the website. We also do not include whole-of-ecosystem models such as Ecopath with Ecosim (Christensen and Walters, 2004), which can be fitted to data (e.g., Gaichas et al., 2011; Heymans et al., 2016), but are not used to provide tactical advice for fisheries management.

The assessment packages are categorized into ten classes based primarily on the types of data used for parameter estimation (Table 1).

Table 1: The ten classes of assessment method included on the website.

Class	Description	Number
Catch curve	Estimates the total mortality of a stock from the relative numbers present in each age- or length-class.	4
Catch only	Uses mainly or only catch data to assess the status of a stock	16
Delay difference	Intermediate in complexity between surplus production models and full age-structured assessments.	2
Depletion model	Models in-season catch dynamics	2
Integrated approach	Based on age- or length- structured (or both) population dynamics models and integrates data from various sources into a single framework for parameter estimation.	18
Length-only	Data-limited or -moderate approaches that use length data to estimate mortality and length-based reference points.	7
Mean length	Uses a time series of mean lengths to estimate mortality and length-based reference points	2
Size-structured	Data-rich Integrated approaches that are similar to age-based Integrated approaches, but are tailored towards hard-to-age species such as crustaceans and abalone for which the key data source is size-frequency data.	1
Surplus production	One of the simplest approaches that nevertheless represent stock dynamics by modelling the population in a dynamic pool.	10
VPA	Class of age-structured models that are based on the assumption that the catch-at-age data are known with negligible error.	2

A flow diagram links the data to the package type, with a few package examples (Figure 1).

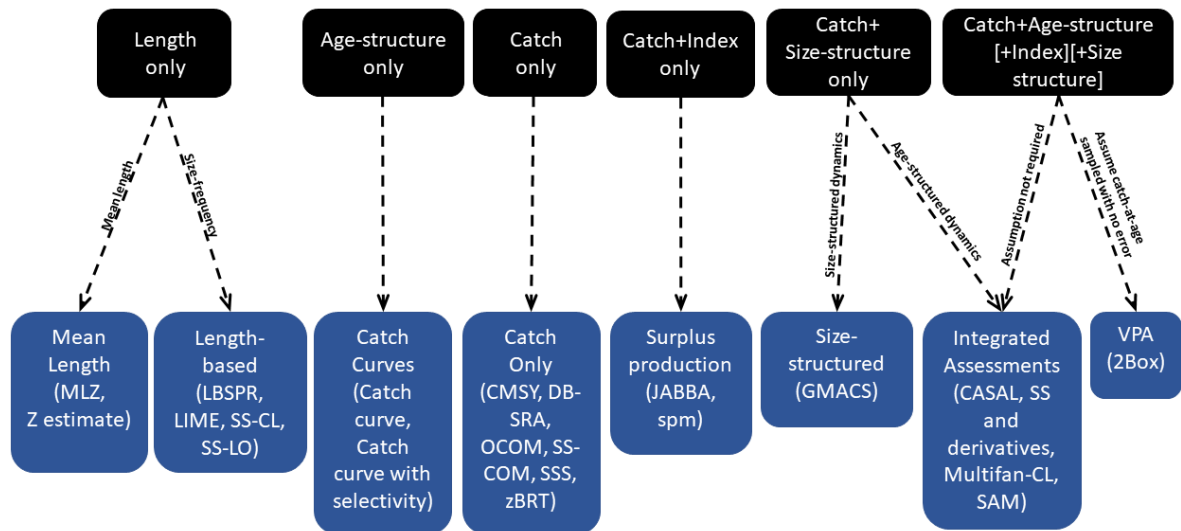


Figure 1: Flow diagram linking the data type (top row) to the package type (bottom row). Examples of the “Supported and Recommended” packages are provided in brackets.

The assessment types range from catch- and length-only methods that require only a time-series of catches or a snapshot of length-composition data, along with assumptions and priors, to the packages such as CASAL (Bull et al., 2012) and GADGET (Begley, 2014) that can simultaneously model multiple stocks and fit to many types of data sets. The choice of these categories was driven by past use in textbooks (e.g., Hilborn and Walters, 1992), decision support tools such as FishPath (tool.fishpath.org), and the types of packages in our database. We separated a) methods based on mean length from length-only methods, and b) integrated analysis assessments based on size-structured vs age-structured models, as we considered these were important to distinguish. The website provides the user with a summary of the features of each assessment package, including information collected for the CAPAM workshops (Maunder et al., 2014, 2016, 2017; Sharma et al., 2019; Cadrin et al., 2020).

The features (see Supplementary Appendix A: List of the features summarised on the website) are categorized into general issues, including the technical knowledge needed to apply the package, whether a Graphical User Interface (GUI)/ R interface is available, whether documentation and training are available, the nature of the population dynamics model on which the method is based, the data that can be used for parameter estimation, and the types of outputs (reference points and projections; all methods provide either estimates of fishing mortality or biomass). The website does not include details of required input parameters, or the assumptions that underlie each method, but includes the ability to filter the packages based on criteria such as, for example, user skill level, or whether sex structure is accounted for.

What makes a good stock assessment package?

The website identifies which packages appear to be supported (because there is evidence that the package is being maintained and is occasionally being updated) as well as indicating which packages are no longer being maintained, or are still under development (see Table 2 for the categorizations used). We also identify packages that are available online but have been superseded, either by other methods or other packages, for which we express a preference. We reviewed methods that have been published in the peer-reviewed literature, but those that are not currently available online were not included on the website. We downloaded and ran each package, if it was possible.

Table 2: How the packages were categorized.

Package status	Description	Number of packages
Supported	A package that is maintained and is based on a statistically and mathematically appropriate analysis method.	20
Supported and Recommended	Those methods (by class) that best satisfy the criteria in Table 3.	23
Inactive	The package has not been modified for several years.	3
Not evaluated	Packages that are very new and are not yet actively used or peer-reviewed by the assessment community.	2
Still under development	A new package that will replace an existing package, but the process is not yet complete.	1
Superseded	The method is no longer being updated by the developer, but is still being used in some cases	15

We also classified some of the packages within each class of assessment methods as ‘Supported and Recommended’ using the following qualitative criteria (Table 3; noting that not all criteria are applicable to all types of assessments):

- their support of multiple functional forms for biological processes (e.g., types of selectivity patterns for methods based on age- and size-structured models; whether allowance can be made for process and observation error for surplus production models), and the breadth of the types of data that can be used for parameter estimation;
- whether the packages / methods have been subjected to testing using simulation by analysts other than the package developers and are being applied in more than a single fishery;
- whether documentation is available in the form of peer-reviewed publications;
- whether a technical user manual and documentation are available;
- the size of the current user base that identifies potential bugs and provides suggestions for updates, and the responsiveness of the development team to these comments; and
- whether the method applies state-of-the-art statistical estimation methods and can adequately quantify the uncertainty of model outputs.

When multiple implementations of the same basic approach are available, we have recommended the version we have found easiest to use with our test data set. Note that the packages are recommended within assessment class and hence all the ‘Supported and Recommended’ packages are not equally likely to lead to robust results. For example, we would always advocate the use of assessment methods that utilize all of the available data (the integrated approaches) over methods (packages) that rely only on catch data (see Table 1 of Punt et al., 2020). In addition, the desire to highlight flexible packages means that some of the ‘Supported and Recommended’ packages are amongst the most complex and hence difficult to apply without training within their classes (e.g., Stock Synthesis [Methot and Wetzel, 2013], CASAL and Multifan-CL [Fournier et al., 1998]).

We provide installation and use instructions for two of the ‘Supported and Recommended’ packages in each of the data-limited and -moderate package classes, with the intention of expanding this resource over time. There are extensive developer resources for most of the more complex methods such as those based on integrated approaches, and we defer to these.

Lack of training in the use of packages was cited as another reason why analysts did not use packages (Dichmont et al., 2016b). In addition, how to diagnose the model fits and interpret the results, is critical. Some of the packages include Graphical User Interfaces (GUIs) or associated packages for plotting the results, but none of the packages can be applied without an understanding of the assumptions of the underlying methods, and a knowledge of how to detect when a method has not performed as well as expected. The series of workshops conducted by the CAPAM (Maunder et al., 2014, 2016, 2017; Sharma et al., 2019; Cadrin et al., 2020) and the associated *Fisheries Research* Special Issues provide initial best practice guidelines related to modelling of growth and selectivity, as well as data weighting (with a focus on integrated analysis approaches).

Table 3: Example of the rubric used to identify the “supported and recommend” packages. Note that the levels for each selection criterion (and their evaluation) are qualitative. The selection of a package for an actual application will also involve factors other than those we considered such as ease of use. Note that no package was “ideal” for all criteria. We provide some examples (in parenthesis) for how we interpreted each level for the age-structured integrated analysis methods.

Criterion	Level		
	Desirable	High desirable	Ideal
Features	Includes the basic features for the class of method (can fit to age-composition and index data; logistic and age-specific selectivity)	Extends the method to include a broad range of options for most processes (multiple selectivity options, including double-normal; spline; time-varying selectivity and growth; fits to length and conditional age-at-length data).	Most of the features in Punt et al. (2020) included (environmental drivers of most parameters; spatial structure; capture age and size/stage dynamics simultaneously yet computationally efficiently, scale from data-rich to data-poor, include some multi-species capability, and/or more appropriately deal with temporal variation (e.g., random effects and state-space models))
Evaluation	Limited testing of the method and only in ideal circumstances (comparisons of results for example data sets with those from other packages; use of self-tests)	As for ‘desirable’ but using self- and cross-tests; testing is conducted primarily by developers of the package (published simulation study; inclusion in the study by Deroba et al., 2015).	Extensive testing including by analysts other than the developers, including testing in which there is severe model mis-specification and in the context of feedback control (examples for Stock Synthesis include: Punt et al., 2015 [Model mis-specification]; Fulton et al., 2020 [feedback control when the operating model includes technical and biological interactions]).
Documentation and training	Documentation is available but it is limited primarily to use by the developer / for a publication	Documentation in the form of a user manual and example data sets are available.	Extensive documentation (publications and user guides) as well as training material (ideally online) is available.
User base	Used and developed primarily in one region	Used globally but the development work is primarily regional	Used globally, with a process for obtaining suggestions for extensions / corrections of errors.
Statistical approach	Traditional approaches are used (maximum likelihood and penalized maximum likelihood; data weights are pre-specified or tuned)	Traditional approaches but with advanced approaches (weights for the data can be estimated; estimation within Bayesian framework)	Estimation is state of the art (inclusion of the ability to estimate parameters using state-space and Bayesian estimation methods)

Results

The final list of the recommended and support packages is provided in Table 4.

Table 4: The ‘Supported and Recommended’ packages in the 10 classes.

Class	Package	Example reference
Catch curve	Catch curve tropfish	Sparre and Venema (1998)
Catch only	Catch survey with selectivity	Haddon et al. (2019)
	cMSY	Haddon et al. (2019)
	COM-SIR	Vasconcellos and Cochrane (2005)
	DB-SRA	Dick and MacCall (2011)
	OCOM	Zhou et al. (2017a)
	SS-COM	Thorson et al. (2013)
	SSS	Cope (2013)
	zBRT	Zhou et al. (2017b)
Delay-difference	DD_TMB	Carruthers and Hordyk (2018)
Depletion model	CatDyn	Roa-Ureta (2012).
Integrated approach	CASAL	Bull et al. (2012)
	Multifan-CL	Fournier et al. (1998)
	SAM	Nielsen and Berg (2014)
	Stock Synthesis	Methot and Wetzel (2013)
	XSSS	Wetzel and Punt (2015)
Length-only	LB-SPR	Hordyk et al. (2016)
	LIME	Rudd and Thorson (2017)
	SS-CL	Rudd et al. (2020)
Mean length	None	
Size-structured	None	
Surplus production	JABBA	Winker et al. (2018)
	Spm	Haddon et al. (2019)
VPA	None	

Website use

Entry onto the website for the first time displays a Disclaimer that one needs to Accept to enter the home screen (Figure 2).

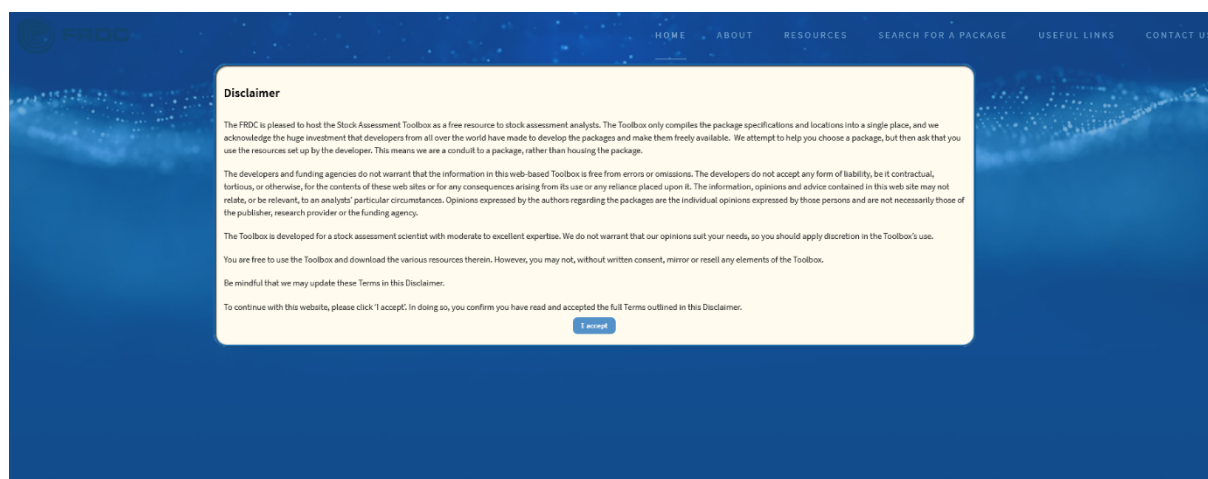


Figure 2: Snapshot of the Disclaimer on entry to the Toolbox to the home screen (www.toolbox.frdc.com.au)

The home landing page displays the major resources in two ways through a set of menus at the top (Figure 3) and with some explanation if one scrolls down (Figure 4).

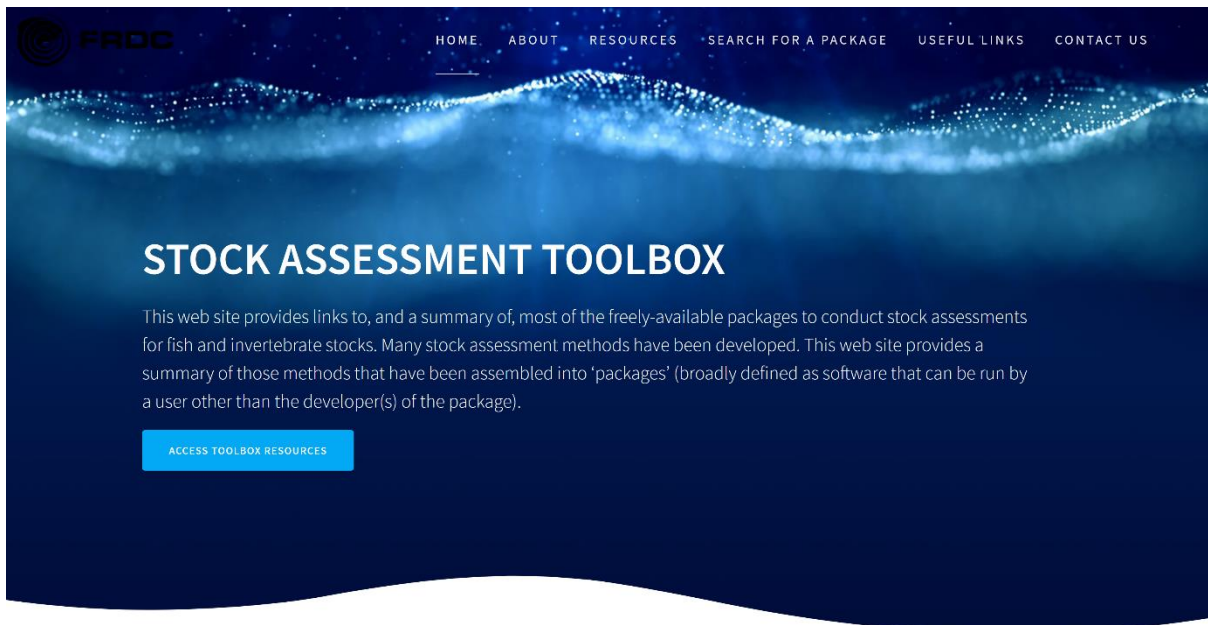
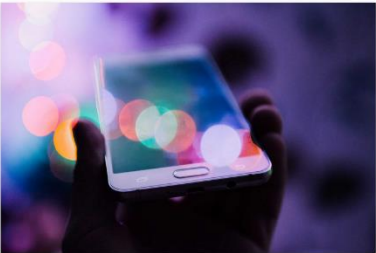


Figure 3: Top of the Home landing page, showing the top levels of the menus available on the web page

Toolbox Resources


This toolbox has a series of resources we hope you will find useful. See the [Purpose of the Site](#) for more details.



1. Package Specification

This allows you to search for packages, find out more about them and links to download or install. Each package has been classified into a package type and our view of Recommended packages have been added.


[learn more](#)



2. Simulated Test Data

If you want to test different methods, we supply a dataset with known characteristics. It is aimed at Australian Fisheries. So for example, Australian fisheries tend not to have fishery independent survey data.

[learn more](#)



3. Installation Guidelines

We selected a few packages to test out our own simulated dataset. The R code and test datasets are available for your use so you can test the package yourself. This complements the package developer resources.

[learn more](#)

Figure 4: On the home page, but a scroll down from the top provides an explanation of the three main resources in the website.

The menu structure (Figure 5) consists of six high level menus, of which three have sub-menus. The “ABOUT” section gives a preamble on the purpose (and not) of the website and the project team that developed it.

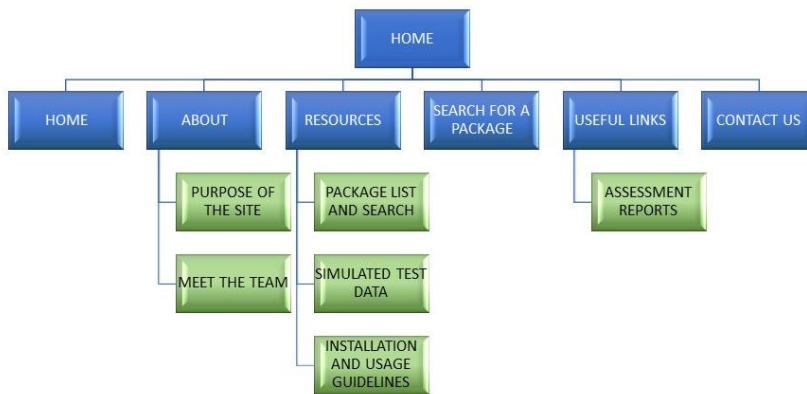


Figure 5: Menu structure of the website

One can search for a package in several ways from the home screen:

1. scrolling down to the block entitled “1. Package specification”,
2. selecting the “RESOURCES” menu and clicking on “PACKAGE LIST AND SEARCH”, or
3. selecting the “SEARCH FOR A PACKAGE” menu.

Links to over 70 Australian stock assessment reports are provided under “USEFUL LINKS”.

There are several ways to contact the project team:

1. the “CONTACT US” menu allows a simple message to be sent to FRDC;
2. on the “PACKAGE LIST AND SEARCH” page, under the heading *Package specifications* there is a link to a SurveyMonkey™ survey where either a new package’s information can be added or the information on an existing package can be updated - although the survey is extensive, only six pieces of information, e.g., package name, is required; and
3. if there is a missing report a user would like to add or notify the project team about (these are not restricted to Australia), then a survey link is also provided on the “ASSESSMENT REPORTS” page; as for missing or incorrect packages, full or partial information can be provided.

Purpose of the website

This page provides information on what the website is and is not:

- **What the web site is about**
This web site provides links to, and is a summary of, most of the freely-available packages to conduct stock assessments for fish and invertebrate stocks.
- **What is Stock Assessment?**
Stock assessment includes the activities related to the data collection, analysis, and scientific review components of the fishery management process. At its core, stock assessment involves using statistical and mathematical models and available data to make quantitative predictions about the abundance and trends of fish stocks and of fishing intensity. Stock assessments can make use of many tools – this website is focused on tools for analysing data collected from a fishery to estimate biomass (B) and fishing intensity (F), in absolute terms and relative to [reference points](#) typical used to summarize stock status.
- **What is the purpose of this website?**
Many stock assessment methods have been developed. This web site provides a summary of the methods that have been assembled into ‘packages’ (broadly defined as software that can be run by a user other than the developer of the method).

- **How do you use the website?**

The [Package List and Search](#) page provides a table to help users identify the most appropriate packages for their stock. For each package, we provide summary information and detailed specifications, complementing the survey of US stock assessment packages by [Dichmont et al. \(2016\)](#). Many implementations are available for some methods and we provide suggestions for which implementation we prefer. For a sub-set of the packages, we provide [Guidelines for package installation](#) and use an example data set to undertake an assessment using the relevant package. As a separate resource, the full [simulated test data set](#) can also be downloaded if you want to use it as a test set for a selected package or your own assessment.

- **Funding and support**

The FRDC provided the funding for the website development and partial funding for the assembly of the content, including the guidance documents. In-kind contributions have been provided by the Commonwealth Scientific and Industrial Research Organisation and Cathy Dichmont Consulting.

- **Caveats**

We include as many packages as possible, noting that packages are continually under development, and that a package may be available from multiple repositories.

Meet the Team page

- **Funding**

This work has been funded by FRDC, CSIRO and Cathy Dichmont Consulting.

- **Project staff**

[Dr Cathy Dichmont](#) has a national and international reputation in stock assessment, modeling natural systems, natural resource management, shared fisheries stocks, and management strategy evaluation (MSE) and has been Principal Investigator in numerous collaborative and multi-disciplinary projects over her career. She has over 25 years of experience in temperate and tropical marine ecosystems at international and regional levels. She was the lead contributor to bio-economic modelling that rejuvenated prawn fishing in the Gulf of Carpentaria for which she won the CSIRO medal for Research Achievement.

[Dr André Punt](#) is a Senior Principal Investigator at CSIRO and a Professor at the University of Washington where he is the Director. The research conducted by his lab relates to the development and testing of methods for assessing the past and current status of fish, invertebrate and marine mammal populations. They use these assessments as the basis for forecasts that evaluate which methods for managing these populations will best achieve the goals established by society for those populations. They are exploring how to manage marine populations in the face of changing societal goals, climate change, ocean acidification, and the lack of data which is typical of the marine environment.

[Dr Natalie Dowling](#) is a Senior Fisheries Scientist, with CSIRO Oceans and Atmosphere in Hobart, Tasmania, Australia. Her main current area of interest, in which she has worked both nationally and internationally, is in developing harvest strategies in data-limited contexts. Dr Dowling was a member of the National Center for Ecological Analysis and Synthesis' Science for Nature and People Project (SNAPP) Working Group, "Managing Data Limited Fisheries for Economic and Biological Objectives". Within this Working Group, she initiated and helped to develop the [FishPath](#) decision support system. Dr. Dowling works closely with The Nature Conservancy (USA) and NOAA as a core member of the FishPath team. Together, this team continues to develop, expand, refine, and apply the FishPath tool to fisheries globally.

[Mr Roy Deng](#) is a Fishery Scientist within CSIRO Oceans and Atmosphere in Brisbane, Queensland, Australia. His strengths is in fishery model programming, spatial analysis and fishery data management. He has been primarily working on the development of stock assessment models, Management Strategy Evaluation (MSE) models and the ecosystem models for Australia Northern Prawn Fishery (NPF) and he is currently taking pivot roles in maintaining the models and conducting the annual NPF tiger prawn stock assessment. He has also involved in development of various other fishery and ecosystem related models including MSE model and Harvest control rules analysis for

Torres Straight Rock Lobster fishery, MSE analysis for the NPF white banana prawns, the stock assessment model for NPF red-leg banana prawns and related red-leg banana prawn MSE model. He also takes over responsibilities to conduct the annual NPF pre-season fishery independent surveys results analysis to provide critical analytic results to support the project.

The web site was designed by [Angela Tsang](#) from FRDC.

Searching for a package

The first two methods of searching for a package move the user to the top of the page where there is extensive text to explain the origin of the package list, the package type, some information on the package specifications and package status, before explaining the table filters and showing the table itself. Once a user has read the headings, it is useful to be able to move directly to the table which is the reason for the “SEARCH FOR A PACKAGE” menu.

Package name	Web link	Model type	Package status	Comment	Full Name
2BOX	https://nmfs-fish-tools.github.io/2BOX/	VRM	Supported	Not ideal for Australian fisheries, because the package needs catch-at-age data for every year. Statistical Catch-at-Age models such as SS or CASAL can utilise datasets with missing years of catch-at-age data	Dual Zone Virtual Population Analysis
AMAK	https://github.com/nmfs-tools/amak	Integrated assessment	Supported	Supported, although SAM, SS or CASAL may be alternatives as they have more features. Designed for Alaskan fisheries.	Assessment Method For Alaska
ASAP	https://nmfs-fish-tools.github.io/ASAP/	Integrated assessment	Supported	Supported, although SAM, SS or CASAL may be alternatives as they have more features. Used mainly within the USA.	ASAP
ASPIC	https://nmfs-fish-tools.github.io/ASPIC/	Surplus production	Superseded	Superseded, we recommend JABBA and aspm	A Stock Production Model Incorporating Covariates (ASPIC)
aspm	https://github.com/haddowm/datalimSA	Surplus production	Supported	Unlike most surplus production models, this version based on an age-structured surplus	Age-structured production model

Figure 6: Screen shot of the top part of the packages table in the “SEARCH FOR A PACKAGE” or “PACKAGE LIST AND SEARCH” menus.

When one arrives at the package table, there are several issues to consider. Firstly, the date at the top shows when last a *major* change has been made to the package list. Given that most of the packages are already in the system and many of them remain unchanged, we would not expect this date to be changed less often than every 6 months.

Secondly, there are several ways by which the data may be filtered:

1. package name,
2. model type,
3. package status,
4. expertise required,
5. programming language (of the package),
6. GUI – whether the package can be run through a Graphical User Interface,
7. whether sex structure is considered in the package,
8. whether tagging data can be included when fitting the model,
9. whether spatial structure (e.g., two zones, single area, flexible etc.) is considered,
10. whether stock structure (Yes or No) can be included,
11. whether the package requires catch data (an important consideration in data-limited approaches),

12. whether the package can include an abundance index, and
13. whether the package can be used on short-lived species.

Some further basic instructions about the table:

1. users can sort by any of the column headings,
2. users can filter various aspects of the table - the filter options allow users to select more than one option,
3. users can search for words in the table - this search is quite broad,
4. package status may be useful to shorten the list of packages, noting that the category “Supported and Recommended” are packages we recommend - this filter can be combined with the filter “Type” which will help to further reduce the final list of packages, and
5. the full table of package information is downloadable at the bottom of the web page under the table.

There are two columns with live links:

1. the last column (Details) links to a detailed description and associated specifications of the chosen package, and
2. the second column (Web link) links to the package.

Using the simulated test data

Many packages provide their own worked examples as part of their user help. However, issues can arise when users confront packages with their own data. We have developed our simulated dataset (using Stock Synthesis) for two purposes:

1. an independently generated dataset increases the likelihood that the user will experience pitfalls or difficulties related to either formatting issues or missing data, or to the nature of the data itself (e.g., whether there is adequate “contrast” in the data) - as such, we can therefore provide advice from our own experience of confronting packages with independently-derived data, and
2. having a common dataset applied across all packages enables direct comparison of the outcomes of alternate assessments.

Our dataset was developed for a “codoid-like” finfish stock with full specifications provided on the web site. Datasets in the .csv files can be downloaded for use. Using the test data without reading the specification provides another way of testing a stock assessment approach independent from the packages on the website. The full input and output files in Stock Synthesis format are also provided.

Installation and Usage Guidelines

We decided to test a few packages using the simulated data set – two packages in each of the data-limited and -moderate model types that fell into our Supported and Recommended list. This is not to replace the developer’s tools, but as a complementary resource using data that have not been produced for the specific package’s purpose. We hope this helps assessors obtain further information and support regarding the downloading and use of the package.

We excluded the data-rich assessments, such as integrated assessments, given their complexity and requirement for large amounts of guidance. In these cases, it is best to use the developer’s resources.

The main coding resources we have used is R Markdown, which is a specific file type from the freely available statistical package R (R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria).

R Markdown is useful in that users can see our code and also find out in a step-by-step manner how to access the specific package and use our data to undertake an assessment. Users can download the *.rmd file and data from the website to run the model and modify the text. We have not tried to write the neatest R code. This is partly a reflection of our skill and is also because, often, very good R code is difficult for a novice R user to understand. We try also not add too many additional libraries beyond what is needed.

The packages with installation and usage guidelines are:

- **Catch curve methods**
 - Catch curve with selectivity (from the *datalowSA* package) – catch-at-age data and R Markdown Script
 - Catch Curve (from the *TropfishR* package) – catch-at-age, length composition data and R Markdown Script
- **Catch only methods**
 - cMSY (from the *datalowSA* package) – catch data and R Markdown Script
 - DB-SRA (from the *fishmethods* package) – catch data and R Markdown Script
- **Length-based methods**
 - LBSPR – length composition data and R Markdown Script
 - LIME – length composition data, and can also use catch-at-age data; R Markdown Script
- **Surplus production methods**
 - JABBA – catch and cpue data; R Markdown Script
 - SPM (from the *datalowSA* package) – catch and cpue data; R Markdown Script

Searching for a past stock assessment report

It is possible to search for stock assessment reports from the page “ASSESSMENT REPORTS (Figure 7), by country (presently only Australian reports are there), management jurisdiction (e.g. Federal, Northern Territory), common name of species, target species (the scientific name of the species), assessment type (e.g. Integrated assessment, surplus production) and the package name (if a package has been used); multiple options can be selected together.

Assessment Reports 1 April 2021

ASSESSMENT REPORTS

Country:

Jurisdiction:

Common Name:

Target species:

Assessment Type:

Package Name:

Search:

Country ▲	Jurisdiction ▲	Main Fisheries ▲	Common Name ▲	Target Species ▲	Assessment Type ▲	Package Name ▲	Author(s) ▲	First Author Affiliation ▲	Date ▲	Web link of assessment report ▲
Australia	CCAMLR	Heard Island and McDonald Islands	Patagonian Toothfish	Disostichus eleginoides	Integrated assessment	CASAL	Ziegler, P. and Welsford, D.	Australian Antarctic Division	2015	https://www.afma.gov.au/sites/default/files/uploads/2014/02/Patagonian-toothfish-stock-assessment-with-TAC-rec-for-2015-16-and-2016-17-fishing-...pdf

Figure 7: Screen shot showing the top of the table to review or search past stock assessment reports.

Discussion

There has been much work to evaluate alternative stock assessment methods in both data-rich and data-limited contexts. Our website fulfils a practical need to collate, characterise, and compare the packages (from data-limited to data-rich) that may be employed to apply any given method. It thus provides a standardised platform so that analysts may make informed choices as to the most effective and efficient way to undertake their stock assessment. The website also contributes to an understanding of the evolution of packages and methods by enabling ready identification of obsolete, superseded, preferred and evolving packages.

The collation of packages highlights the considerable work conducted to date by method developers to provide their methods to the general assessment community. To be effective, the website needs to be a 'living document' that is revised and updated given feedback on new packages, and revisions to existing packages. As such, it should be subject to regular maintenance and renewed application of the criteria in Table 4.

Most of the available packages either implement data-poor catch-only methods or data-rich integrated approaches (Table 1). The large number of catch-only methods reflects the considerable work being undertaken to support decision making for stocks for which data are lacking. However, the outcomes of all catch-only methods depend critically on their assumptions and user-imposed constraints (e.g., Wetzel and Punt, 2011; Rosenberg et al., 2014; Free et al., 2020; Pons et al., 2020). Thus, while we provide these packages, they should be used with considerable care. For example, packages that impose priors on depletion (biomass relative to unfished biomass) should not be used as the basis for estimating depletion given there is no data (only assumptions) to formally update the priors. The increasing number of methods for conducting assessments using time-series of length-frequency data (e.g., LBSPR, SS-CL and LIME) is pleasing given that most previous length-only assessment methods (e.g., the Beverton-Holt method; Beverton and Holt, 1957) make assumptions (such as that the population is in equilibrium) that are likely to be violated to a substantial extent.

Testing of methods is key to stock assessment science and some packages (e.g., Stock Synthesis) have been tested extensively (see Table 6 of Dichmont et al., 2016a). However, this is not the case for most packages, which, if they have been tested at all, have only been subject to 'self tests' in which the method is applied to data that were generated using the model on which the assessment is based. Future work to enhance the ability to select the best method /package would involve collating the results of past simulation studies (although these often are non-comparable owing to each study being based on a different set of questions / study species), and summarizing the results of the application of multiple methods to a set of common data sets (and ideally comparing the results of applying assessment methods that use fewer data to those that use all of the available; e.g. Rudd et al., 2020).

The large number of packages implementing integrated approaches largely reflects methods developed in response to local needs (Dichmont et al., 2016a). The 4-8 November 2019 CAPAM workshop on Next Generation Stock Assessments (<http://capamresearch.org/Next-Gen-SAM>) examined the features needed by the assessment community and the software development tools available. Punt et al. (2020) conducted a review of existing packages based on integrated approaches and found that none had all the features desired by the assessment community in a general framework, and that most packages were not developed using current software engineering standards. A key next step is the development of packages that include all (or at least most) of the features of the existing packages, including improved and more efficient parameter estimation methods, and that are written by software engineers in collaboration with analysts. We anticipate the increased collaboration among users and developers will better identify those features of any next-generation stock assessment methods.

The availability of packages may increase the sophistication of the methods used to analyse the available data, and hence increase the likelihood of making the best use of the available data, but in and of themselves do not increase the amount of data. Thus, use of new and more sophisticated assessment packages should be linked to attempts to collect additional data, if required. Specifically, catch-only methods should be

considered to be methods of last resort and not the *de facto* standard for assessments, simply because a package is available.

The collation of assessment packages is only a first step in improving stock assessments. There is a need for a forum for analysts to provide reasons for changing from one package to another or why they prefer one package to others, as well as to comment on existing packages. The comments could be related to (a) technical improvements to the methods to increase their applicability, (b) diagnostics and model output, (c) the quality of the available training and user community, (d) ease of use given the available documentation (and gaps/error in the documentation), and (e) the applicability and relevance of the package to their circumstances.

Finally, our website, while providing details on the characteristics and required data for each package, is not a decision support tool per se, and is of most benefit when utilised by analysts with a reasonable degree of expertise. The website should be ideally used in conjunction with decision support tools such as FishPath. Analysts could then compare the shortlist of viable methods from FishPath against the packages on our website.

Conclusion

The website created to collate existing stock assessment packages is not the first nor only website of this kind. The NOAA Toolbox (<https://noaa-fisheries-integrated-toolbox.github.io/>) has been available in various forms for decades, highlighting NOAA developed packages while several R packages (e.g., SS-DL or MSETool) have been developed that include multiple assessment methods. However, ours is the first that attempts to include all of the packages used globally (with English documentation) to conduct model-based stock assessments and compare them using a common set of metrics. We anticipate that the website will contribute to improving the quality and quantity of stock assessments, and provide information related to the development of next-generation stock assessment packages.

Implications

The website addresses a direct need within Australia where there is an increasing demand for stock status advice, but a limited number of scientists who are able to conduct them. This website allows time-constrained assessors to investigate in detail the different off-the shelf and freely available stock assessment packages accessible globally. The packages span the data-limited, -moderate and -rich classes — an important aspect since there is a growing need for assessments in all three these categories of assessment types. If the assessor is unsure which package to focus on, some advice is provided by the project team. Several additional resources that are useful to assessors and managers, such as simulated test data and links to many past Australian stock assessment reports, are also an essential part of the website.

The implications are therefore that we now have a ‘one-stop shop’ website that clearly lays out all of the packages and their specifications explicitly. It saves time and redundant effort expended scouring the literature or the internet to apply (potentially inappropriately) whatever is available based on limited experience or exposure. The hand-held guidance on key packages is a unique feature which also saves an enormous amount of time and trouble shooting, and can help build capacity and confidence in a package’s application.

Recommendations

1. The website should be regularly updated past this project to keep it relevant. Users should be told of changes and updates at least annually to keep them aware of the Toolbox and its uses.
2. Investment in training using real-world data should be continued to be supported with emphasis from data-limited to data-rich fisheries.
3. Next steps are detailed in the Further development section below.

Further development

Although the website will help people decide which package to use and where to find packages resources, it will not convince some stock assessors that packages are useful. The message is nuanced in that bespoke models are important and it is not an 'either or' option. Best practice is to use a package when available, and only develop bespoke models when absolutely required. Practitioners are strongly encouraged to firstly check whether the intended model already exists, because it often does.

Thus, the next steps would be:

1. Every 6 months check the data on the website add new packages, delete ones superseded and check which are recommended. The Guidelines scripts should also be updated. This will keep the Toolbox relevant and in date.
2. Assessment scientists have a long history of working under pressure and high demand, which has often meant they have had no available time to invest in their own skills and, more importantly, share what they have learnt. To try and create an environment that will produce cultural change through increased contact between Australian assessment scientists (to share and, if appropriate, use and contribute to packages) - and also international assessors - will require:
 - i. Bringing social science skills onto a project team such as this one to look at the behavioural economics to understand and help overcome the impediments and barriers to change in assessment scientists sharing of skills and package use/development,
 - ii. The creation of a forum for Australian scientists to link together and link with key international scientists.
 - iii. To undertake another Stock Synthesis course if needs demand,
 - iv. To undertake further training aimed at assessors on data-limited and -moderate tools that use as its basis Stock Synthesis, thus allowing full use of Stock Synthesis.
 - v. To add some fun element in stock assessment by undertaking a competition where assessors test their model against a simulated dataset. The winner would have the closest estimate to the actual.

Extension and Adoption

During the development stage, a link to the website was provided to key stock assessment scientists in Australia for their comment. Many detailed comments were received, and most were incorporated into the current version of the website.

There have been numerous interactions with international developers especially Dr. Jason Cope who is involved with FishPath (as is Dr. Dowling) as well as developing many data-limited and moderate methods.

The project team had a video hook-up with the development team of the NOAA/NMFS team that maintains their assessment Toolbox (to which we provide links) to discuss whether they would highlight our resources. Although this link was not created, the team felt the resource would be useful and would be highlighted to others.

A final email to stock assessment scientists globally were sent in March 2021.

The intention, should the abstract be accepted, is to show the workings of the website at the World Fisheries Congress in Adelaide, 2021.

Project coverage

The Toolbox was highlighted in FRDC's FISH magazine Volume 28 <http://frdc.com.au/media-publications/fish/fish-vol-28-3/a-strategic-approach-to-stock-assessment-software>

Project materials developed

The project has a publication in Fisheries Research: Dichmont, C.M., Deng, R.A., Dowling, N.A., Punt, A.E. 2021. Collating stock assessment packages to improve stock assessments. *Fisheries Research*. 236: 105844.

The main resource is a website found at <http://toolbox.frdc.com.au/>

An Excel sheet with detailed specifications (beyond those shown on the website) is also available for download on the web site.

Appendices

Supplementary Appendix A: List of the features summarised on the website

Feature	Description
<i>General</i>	
Name	The package name
Web link	Web site where the package/information is available
Type	The type (class) of stock assessment method
Single multiple spp	Single species or multiple species
Package status	Our assessment of the package status and the degree support
Comment	Our comments about the package status.
Full Name	The full name of the package
Description	Description of the package
Developers	The developers of the package
Organization	Owner of the package if there is one
Training	Is training available for the package?
Expertise	Level of expertise to be able to use the package
Citation	References
Peer reviewed	Has the method been published in the peer-reviewed literature?
Programming language	Program language
GUI	Is graphical user interface available?
R package	Is the package in an R package?
<i>Features</i>	
Temporal resolution	What is the time step?
Sex structure	Does the model allow for sex structure?
Multi-species technical interactions	Can the package handle multiple species with technical interaction?
Growth platoons	Can the model represent growth platoons?
Tagging	Can the model represent tagged populations?
Area structure	Can the population model include multiple areas?
Spatial resolution	What is the spatial resolution of the mode?
Stock structure	Can multiple stocks be modelled?
Seasonal	Can seasonal structure be modelled?
Short-lived species	Appropriate for short-lived species with highly variable recruitment?
Options for selectivity	
Logistic	Logistic selectivity
Double normal	Double normal selectivity
Spline.1	Spline selectivity
Parameter for each age nonparametric	Selected parameter for each age
Other	Other
Estimation framework	
Maximum likelihood	Estimation using ML (or penalized ML) available?
Bayesian	Estimation using Bayesian methods available?
Random effects state space	Is this a true state-space model
Normal approximation	Are uncertainty measures based on the delta method?
Parameter uncertainty	Are measures of uncertainty provided for model outputs?

Feature	Description
Model outputs	
MSY	
F_{MSY}	
SPR _x	
Spawning biomass per recruit	
Biomass target	
Dynamic B_0	
Random deviates	
Fishery impact plots	
Data for parameter estimation	
Catch	Catch time-series
Retained	Can data from retained catches be provided
Discarded	Can data from discarded catches be provided?
Sex	Can data be provided by sex?
Aging error	Can ageing error be accounted for?
Length composition	
Age composition	
Weight composition	
Conditional age-at-length	
Mean weight-at-age	
Mean length-at-age	
Morph composition	
Custom composition	
Stock origin	
Index of abundance	
Index of effort	
Fishing mortality estimates	
Absolute estimates of abundance	
Environmental index	
Mark recapture data	
Growth increments	
Other	

Supplementary Appendix B: Current list of packages by type

Package name	Type
2BOX	VPA
AMAK	Integrated approach
ASAP	Integrated approach
ASPIC	Surplus production
aspm	Surplus production
BAM	Integrated approach
BSM	Surplus production
CASAL	Integrated approach
Catch curve (datalowSA)	Catch curve
Catch curve (fishe)	Catch curve
Catch curve (TropFish)	Catch curve
Catch curve with selectivity	Catch curve
CatchMSY (datalimited)	Catch only
CatchMSY (fishmethods)	Catch only
CatchMSY (Martell)	Catch only
CatchMSY (MSEtool)	Catch only
CatDyn	Depletion model
CC-SRA	Length-based
CEDA	Surplus production
cmsy (Froese)	Catch only
cMSY (datalowSA)	Catch only
cmsy2 (datalimited2)	Catch only
Coleraine_Awatea	Integrated approach
COM-SIR	Catch only
CSA	Delay difference
DB-SRA (DLMTTool)	Catch only
DB-SRA (fishmethods)	Catch only
DD_TMB	Delay difference
Depletion analysis	Depletion model
FLa4a (FLR)	Integrated approach
FLAssess (FLR)	Integrated approach
frasyr	VPA
GADGET	Integrated approach
GMACS	Size structured
JABBA	Surplus production
LBRP	Length-based
LBSPR	Length-based
LBSPR (barefootecologist)	Length-based
LBSPR (MSEtool)	Length-based
LIME	Length-based
MLZ	Mean length
MS-cMSY	Catch only
Multifan-CL	Integrated approach
OCOM	Catch only
SAM	Integrated approach
SCA	Integrated approach
SCA2	Integrated approach999
SCALE	Integrated approach
Schaefer Biomass dynamics (FISHE)	Surplus production
SP	Surplus production
SP_SS	Surplus production
spm	Surplus production
SRA	Catch only
SS	Integrated approach
SS-COM	Catch only
SSS	Catch only
STATCAM	Integrated approach
WHAM	Integrated approach
XDB-SRA	Surplus production

XSSA	Integrated approach
XSSS	Integrated approach
Z estimate	Mean length
zBRT	Catch only
SS-CL (SS-DL)	Length-based

Project team

Dr Catherine M. Dichmont (Principal Investigator)

Mr Roy A. Deng (Co-Investigator)

Dr Natalie Dowling (Co-Investigator)

Dr André E. Punt (Co-Investigator)

Intellectual property

The website provided by this project is open access. The raw data behind the web site is also available as an excel sheet to download at the bottom of the Table on <http://toolbox.frdc.com.au/toolbox/>. It is requested that users acknowledge the source of this data by using the citation at the top of this report or Dichmont, C.M., Deng, R.A., Dowling, N.A., Punt, A.E. 2021. Collating stock assessment packages to improve stock assessments. Fisheries Research. 236: 105844 <https://doi.org/10.1016/j.fishres.2020.105844>

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