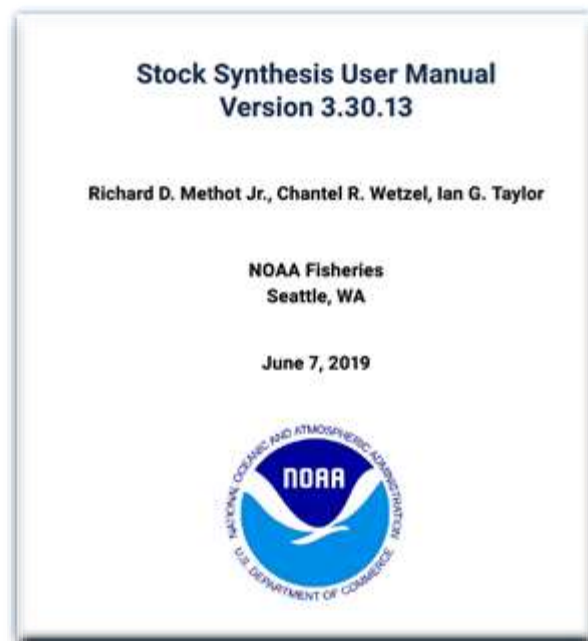




# Custom training and technical support for the fishery stock assessment software 'stock synthesis'



M. F. O'Neill, R. Lovett, P. Bessell-Browne, S. Streipert, G. Leigh, A. Campbell, A. Northrop, J. Wortmann, F. Helidoniotis, W.-H. Yang, M. Holden and S. French.

2020

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2018-168

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

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DAF and UQ staff also thank the CSIRO, and the teachers Professor Andre Punt and Dr Jemery Day. Andre's and Jemery's efforts and enthusiasm in preparation and supply of the customised training package was exceptional and greatly appreciated. DAF are also thankful to the CSIRO for their support in contracting and timely supply of the training. The event has resulted in connecting the DAF and CSIRO-Hobart stock assessment groups.

Recognition also goes to staff for their long hours spent in data and study preparations for the training workshop. The case study assessments and data preparations, led by Pia, Robyn, Sabrina, Alex, George, and Fay, was vital to the success of the training.

The authors would also like to acknowledge Janine Tennant and Sue Helmke for their workshop support, through organising the venue, and staff travel, accommodation and catering.

Finally, we would like to thank the FRDC reviewers, Dr Paul Palmer, Sue Helmke, and the project team for reviewing and providing comments on parts of the draft report.

Financial and in-kind funding for the training was from the Australian Government through the Fisheries Research and Development Corporation, Queensland Department of Agriculture and Fisheries, and The University of Queensland.

# Glossary

ADMB	AD Model Builder using automatic differentiation in optimisation.
ABARES	The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), the science and economics research division of the Department of Agriculture, Australian Government.
AFMA	The Australian Fisheries Management Authority is the Australian Government agency responsible for the efficient management and sustainable use of Commonwealth fish resources on behalf of the Australian community.
ASQ	Animal Science Queensland is a division within DAF.
CARM	Centre for Applications in Natural Resource Mathematics, School of Mathematics and Physics, The University of Queensland.
CSIRO	The Commonwealth Scientific and Industrial Research Organisation is an independent Australian federal government agency responsible for scientific research.
DAF	The Queensland Government Department of Agriculture and Fisheries.
FQ	Fisheries Queensland is a division within DAF.
MCMC	Markov Chain Monte Carlo is a statistical computer simulation method for estimating population model parameters and their variance.
NOAA	National Oceanic and Atmospheric Administration within the United States Department of Commerce.
RPN	Research Providers Network. The RPN is a committee made up of the research directors of both state and Commonwealth agencies involved in fisheries and aquaculture (eg state agencies, CSIRO, ABARES, AFMA), as well as groups such as the FRDC Indigenous Reference Group, Oceanwatch and the Australian Society of Fish Biology. The aim of the network is to ensure better research coordination and collaboration across jurisdictions.
4rSS	R software functions and plotting code for use with stock synthesis.
SFS	Sustainable Fisheries Strategy.
SS	Stock synthesis.

# Executive Summary

## What is the report about?

This is a report on ‘stock synthesis’ software training by CSIRO. Noted are training outputs and learnings, together with an assessment of what role stock synthesis (SS) may play in Department of Agriculture and Fisheries (DAF) fish stock assessments. Findings suggest SS could potentially assess 50–60% of the fish species currently listed for Queensland stock assessment.

Reports on SS herein represent initial views after training. SS views may change in time with individuals, and with more use and learnings of the software.

## Background

In order to achieve commitments made under the Sustainable Fisheries Strategy to conduct more regular stock assessments of finfish, and for more species, DAF scientists are investigating the use of off-the-shelf stock-assessment models. After consideration of a number of off the shelf stock assessment packages, DAF sought staff training in the stock assessment software SS, which is used by other organisations such as CSIRO in Australia and NOAA overseas in the USA. SS has become the basis for a large fraction of USA assessments and many other assessments around the world.

Training and use of SS may support delivery of recurring assessment information to assist fishery management, to progress Queensland’s Sustainable Fisheries Strategy and adoption of recommendations by FRDC project [2014-039](#) – Review and assess stock assessment methods used in Australia.

The aim for this training is to build stock assessment systems for DAF and help support similar national needs in Australia.

## Objectives

The objectives were for DAF scientists to learn SS methodology and assumptions, complete a 5-day training course, and publish on success, outputs and findings of SS.

## Methodology

SS is an age-structured population model applied to a variety of fish stock assessments globally (Methot and Wetzel, 2013). The software package has analysed a range of demersal and pelagic fish species such as tuna, marlin, snapper, cod, flatfish, and many U.S. ground fish species. CSIRO use the software to assess a number of AFMA managed finfish fisheries, which have ongoing fish age-length monitoring programs.

SS combines many different kinds of fishery and survey data. This normally includes, but is not limited to, annual harvest, catch rate, fish age-length and biological data. The analysis of this data estimates time series of spawning biomass and management quantities for setting recommended biological harvests.

SS has a range of options in terms of data inputs and model settings. Very simple to complex models can be defined through these inputs. This is via large and complex text input files. The input files define the detail of length- and age- dynamics, the biology and life history characteristics of the species such as longevity, natural mortality rates, growth rates and reproduction, and functions for fish recruitment, selectivity and catchability.

The software operates from a MS-Windows dos-command-prompt, and must use four input text files – starter, data, control and forecast.

Contract services were with CSIRO to provide a 5-day training course, and annual support in using the software. The training investigated six finfish stock assessments through the 5-day course.

## Results/key findings

The SS training was successful. All staff completed certification of achievement in the use of SS, the instructors provided a high level of training, six finfish stock assessments were trialled through the 5-day course, and individual feedback reported on the species/fisheries for which SS will be able to assess. All trained staff are now familiar with the SS methodology and assumptions. Further applied work is required to attain proficiency. The one-week training exercise was costly tallying about \$77,000, mostly for CSIRO teaching; and staff time on top of this.

SS can play an important role in DAF stock assessments. It is estimated that SS could potentially be used to assess 50–60% of all the species listed for future stock assessments. However, some time ( $\geq 2$  months) is required to verify any new SS application against current DAF models. This is to ensure the complex data input files operate correctly.

For any SS training nationally, different jurisdictions would need to clarify their expected use of the software. For finfish, the potential use of SS by other jurisdictions could be expected to be similar to DAF given the similarities in available data. In addition, to justify staff cost and time investments in the SS software, stock assessment outputs need to have relevance to the management procedures of those jurisdictions. This was the case in Queensland for DAF. Initially, DAF does not expect SS to speed up stock assessments. However, reassessments with streamlining should reduce the time to complete stock assessment work in the future.

Expansion of this course into a nationwide training package would be challenging. It is complex software. Our presenters noted that our DAF group made more training progress than others initially have, but still capability was limited after a full, intensive week of training. DAF has a current team of eight stock assessment scientists, which is probably more than most other jurisdictions in Australia. We believe that we have the critical mass to continue to educate ourselves about SS from here, but other jurisdictions may not. We have found that, to continue to learn SS, we will have to rely on each other for help. It would be difficult for a single individual scientist to continue to learn SS even after a course such as this.

From the training workshop, we suggest that SS is not well suited to short-lived species ( $< 3$  or  $4$  years longevity). Short-lived species require seasonal population dynamics (e.g. monthly), whereas annual dynamics are more usual in SS, matched by fish catch, catch rate, age-length data and growth curves.

Core features in SS appear solid, and r4ss provides important visualisation to review SS outputs. SS use would be quite tedious without this. SS supports DAF data and reference points, but initial setup of data and control files are labour intensive. However, DAF have tested code to streamline creation of the SS data input file. This was applied in the case study stock assessments in the training workshop. The control file requires continued checking to reduce the chances of errors and maintain consistency of outputs.

Overall, it appears that SS can potentially provide a national platform for finfish stock assessment. However, this does require further discussion, which aligns with the FRDC 2014-039 recommendation - national committee for stock assessment collaborations and review processes.

It is anticipated that this SS training will help build stock assessment systems for DAF and help support similar national needs in Australia that:

- Are streamlined or semi-automated.
- Produce regular quantitative evidence for quota setting, stock status classification and ecological risk assessments.
- Provide timely and contemporary data for web-dashboard reporting.

## Implications for relevant stakeholders

Adoption and use of SS may inform new management procedures designed under the Queensland Government's Sustainable Fisheries Strategy.

## **Recommendations**

DAF and FRDC through the National Research Providers Network discuss ideas for a national platform for stock assessments. This relates to FRDC 2014-039 recommendation - national committee established for stock assessment collaborations and review processes. This suggestion has not yet been actioned. Questions on stock assessment methods, consistency, repeatability, review and modernisation preferably need national views. Discussions on national SS use and training ideas are relevant. A national species stock-assessment schedule and list of data and suitable methodology (such as using SS) would support national discussions and collaborations.

In 2020–2021, DAF to further investigate and apply SS on species conducive to the software methodology.

## **Keywords**

Stock synthesis, stock assessment, training, reference points, management, age-structured population dynamics, Queensland, Australia, fish, Barramundi, Coral Trout, Gemfish, Tailor, Mullet, Mackerel.



# 1 Introduction

## 1.1 Background and need

### *Background*

The future of profitable commercial and enjoyable recreational fisheries relies on the sustainability of our natural resources. To verify this and evaluate fishery status, management processes need timely assessment information of sustainability indicators. This is to ensure our fisheries resources are used in a sustainable way to benefit the Australian community.

Queensland Department of Agriculture and Fisheries (DAF) scientists use fisheries data to develop and apply stock assessment models to predict sustainability indicators and sustainable catch limits. Collectively, these results contribute to assessments of the [status of fish stocks](#) conducted by DAF and collated by FRDC, and underpin the success of fisheries management arrangements.

Under the DAF Sustainable Fisheries Strategy (SFS) and FRDC's national [Status of Australian Fish Stocks](#) reporting, DAF needs to deliver more regular (annual/biennial) stock assessments, and assessments for more species. This is to provide the information needs of harvest strategy developments and harvest control rules. Creating efficiencies in the stock assessment process will help meet these needs.

In some cases, off-the-shelf packaged software can simplify and speed up the stock assessment process. This creates opportunities for automation to develop increased and more regular outputs. Packaged software may provide efficiencies, freeing up resources for DAF scientists to deliver more frequent assessments.

To conduct more stock assessments of finfish, Fisheries Queensland and the SFS expert panel directed DAF scientists to investigate the use of off-the-shelf stock-assessment models. In this regard, DAF sought staff training in the stock assessment software 'stock synthesis'. SS was selected as the software is used by other organisations such as CSIRO in Australia and NOAA in the United States of America. SS has become the basis for a large fraction of U.S. assessments and many other assessments around the world (Methot et al., 2019).

It was expected that training and use of 'Stock Synthesis', would support delivery of recurring assessment information to assist fishery management, progress Queensland's adoption of FRDC recommendations and research: project 2014-039, and help demonstrate the FRDC national goal that 'Australian fishing and aquaculture products are sustainable and acknowledged to be so'.

Stock Synthesis training is also expected to help build stock assessment systems for DAF and help support similar national needs in Australia that:

- Are semi-automated.
- Produce regular quantitative evidence for quota setting, stock status classification and ecological risk assessments.
- Provide timely and contemporary data for web-dashboard reporting.

### *Need*

The Queensland Government's Department of Agriculture and Fisheries (DAF) aims to manage fisheries utilising the best available science and taking into account environmental, economic, social and cultural impacts.

Through the Government's Sustainable Fisheries Strategy (SFS, 2018–2020), plans are being actioned to establish regular stock assessments (ongoing annually or at least every two years) to provide the science for assessing key fishery stocks against reference points.

To conduct regular stock assessments of finfish, Fisheries Queensland and the SFS expert panel directed DAF staff to investigate the use of off-the-shelf stock-assessment models. This recommendation is for delivery of recurring information to support fishery harvest strategies, and followed a review to support the

use of common stock assessment methods and models (FRDC Research Code: 2014-039; see Fish magazine: fish-vol-26-3/skills-shortage-forecast-for-stock-assessments). This present work progresses Queensland's adoption of FRDC recommendations and research from project 2014-039.

The aim for this training was to build stock assessment systems for DAF and help support similar national needs in Australia.

## 1.2 Software

Stock synthesis (SS) is an age-structured population model applied to a variety of fish stock assessments globally (Methot and Wetzel, 2013). It might be one of the most widely used fish stock assessment packages in the world (A. Punt pers. comm.). SS has continued to evolve and change over decades of development.

The software package has analysed a range of demersal and pelagic fish species such as tuna, marlin, snapper, cod, flatfish, and many U.S. ground fish species. Surprisingly, the software has also assessed species of shark, shrimp and surf clams in the U.S., which have unique biological differences to fish. CSIRO use the software to assess a number of AFMA managed finfish fisheries which have ongoing fish age-length monitoring programs.

SS combines many different kinds of fishery and survey data. This normally includes, but is not limited to, annual harvest, catch rate, fish age-length and biological data. The analysis of this data estimates time series of spawning biomass and management quantities for setting recommended biological harvests. Advanced analyses can include extra data, for example discard tonnages and tag-recapture data. The software propagates uncertainty, and can run Markov Chain Monte Carlo (MCMC) simulations to generate confidence intervals on estimates.

SS has a flexible range of options in terms of data inputs and model settings. Very simple, to complex models, can be defined through the inputs. This is via large and complex text input files. The input files define the detail of length- and age- dynamics, the biology and life history characteristics of the species such as longevity, natural mortality rates, growth rates and reproduction, and functions for fish recruitment, selectivity and catchability (**Error! Reference source not found.**). In the population dynamics, fish numbers-at-age can be modelled by biological morphs (growth patterns, birth seasons, areas) according to model parameters, split male:female populations with specified ratios, further split among sub-morphs with specified ratios, and each group of animals retains biological characteristics when they move among areas.

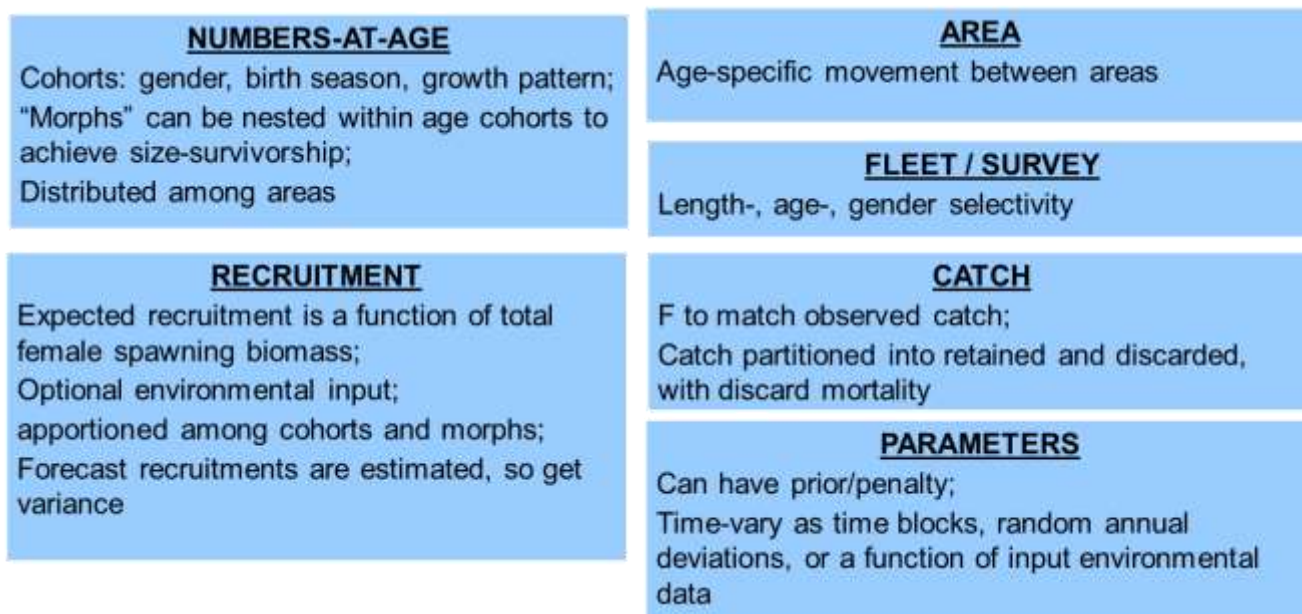


Figure 1. SS structure.

The software (file ss.exe) is run from a MS-Windows dos-command-prompt, and must use four input text files (Figure 2):

- Starter.ss
- Data file (must match name in Starter.ss)
- Control file (must match name in Starter.ss)
- Forecast.ss

Starter.ss specifies the data and control file names and other set-up specifications. This txt file has about 40 lines of code including comment lines. It defines settings for outputs, MCMC/bootstrapping, and jittering of parameters to test maximum likelihood solutions.

The 'Data file' specifies the information on which the assessment will be based (and the initial sample sizes and CVs) for the data. This file, including comment lines, can be very long dependent on the amount of data (> 200 lines of code). The file also defines the number of years, seas, seasons, genders, areas, fleets and units of the data.

The 'Control file' specifies the model that will be fitted to the data (growth, selectivity, recruitment, etc.) as well as how the data will be weighted. This file is about 300 lines of code including comments. Understanding of the settings in this file is critical for an accurate stock assessment. Example settings include time varying blocks and parameters, and setup for natural mortality, growth, maturity, fecundity, recruitment distribution, selectivity and movement.

Forecast.ss has about 60 lines of code, including comments lines, to specify the reporting outputs. Here the operator specifies the reference points, type and years of forecasting. This is tailored for USA harvest control rules, but is also suitable for Queensland harvest strategies. The target and limit biomass reference points, such as  $B_{60\%}$  and  $B_{20\%}$  can be specified.

SS is written in AD Model Builder (ADMB) and reads whatever it is given. Correctly specified and aligned input files are critical. Input errors are identified using messages on the screen and methodically reviewing 'echoinput.sso' (Figure 2). This file shows what SS thought you were telling it. The .SS\_new files are replicates of its input files to error check. 'Report.sso' contains the results and best reviewed using the graphics codes in r4ss.

The R code in the r4ss package represents an ongoing development to integrate output plotting, statistics and diagnostics. It is critical prior to use the user checks the outputs to verify there are no mistakes in the SS operation. No warranty or guarantee is given for using SS or r4ss. Examples of r4ss outputs are illustrated in the case studies, from page 36 onwards, in report-section 4.3.

Before learning to run SS, understanding of Methot and Wetzel (2013) and the associated technical appendix A is advised. All programmers of SS need to follow the 210 page user manual (Methot et al., 2019). Methot Jr and Taylor (2011) is also another key SS learning document.

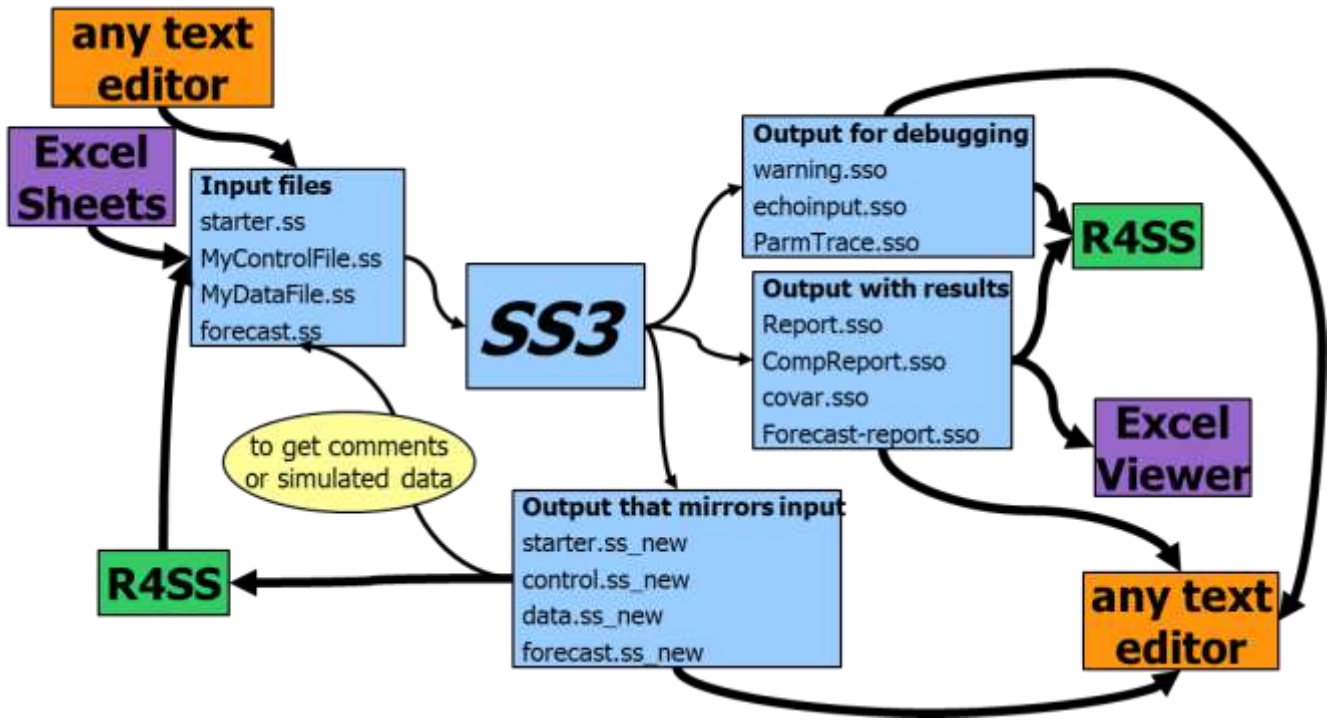


Figure 2. The SS version 3 framework, illustrating associated inputs, outputs and tools like r4ss.

## 2 Objectives

The objectives as stated in the proposal were:

1. DAF scientists to learn SS methodology and assumptions.
2. After 5-day course, DAF scientists to be proficient in the use of SS software with R.
3. Produce 3–4 updated DAF finfish stock assessments through the 5-day course.
4. Publish on success, outputs and findings of SS.
5. Improve speed on future reassessments of fish stocks.

# 3 Methods and materials

The approach of the project was to go to open tender for the services of SS training and the text below constitutes the terms of reference for the tender. CSIRO were successful in the tender.

## 3.1 Contract services

The Supplier must provide the Services specified below to the Customer, in accordance with the Course Requirements described in this Schedule.

### (a) Background

The Queensland Government's Department of Agriculture and Fisheries (DAF) aims to manage fisheries utilising the best available science taking into account environmental, economic, social and cultural impacts.

Through the Government's Sustainable Fisheries Strategy (SFS, 2018–2020), plans are being actioned to establish regular ongoing stock assessments to provide the science for assessing key fishery stocks against reference points.

To conduct regular stock assessments of finfish, Fisheries Queensland and the SFS expert panel directed DAF staff to investigate the use of off-the-shelf stock-assessment models. This recommendation is for delivery of recurring information to support fishery harvest strategies, and followed a review to support the use of common stock assessment methods and models (FRDC Research Code: 2014-039; <http://www.frdc.com.au/media-and-publications/fish/fish-vol-26-3/skills-shortage-forecast-for-stock-assessments> ).

### (b) Choice of software

DAF assessed the suitability of available software, CASAL (C++ Algorithmic Stock Assessment Laboratory, <https://www.niwa.co.nz/fisheries/tools-resources/casal>) or Stock Synthesis (SS) were considered the best for finfish stock assessment. Dr Andre Punt, Professor University of Washington (pers. comm.; emailed dated 9/11/2018) stated, "the development team for SS is larger and there is a bit more of a community, but CASAL is in some senses more flexible (until you need to compute management quantities)".

The need for local software support/community and ease to calculate management reference points is important to support harvest strategies. Additionally, SS is used by CSIRO.

Therefore, initial training is for the stock synthesis (SS) software. CASAL training will occur later as needed and if funding becomes available.

Training was organised for 10 scientists (from DAF Agri-Science Qld, DAF Fisheries Qld and the University of Queensland), those already experienced in stock assessment, mathematics and statistics and fisheries science.

### (c) The software

Method RD, Wetzel CR (2013) Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fish Res* 142:86-99

*Abstract:*

Stock synthesis (SS) is a statistical age-structured population modelling framework that has been applied in a wide variety of fish assessments globally. The framework is highly scalable from data-weak situations where it operates as an age-structured production model, to complex situations where it can flexibly incorporate multiple data sources and account for biological and environmental processes. SS implements compensatory population dynamics through use of a function relating mean recruitment to spawner reproductive output. This function enhances the ability of SS to operate in data-weak situations and enables it to estimate fishery management quantities such as fishing rates that would provide for maximum sustainable yield and to

employ these rates in forecasts of potential yield and future stock status. Complex model configurations such as multiple areas and multiple growth morphs are possible, tag-recapture data can be used to aid estimation of movement rates among areas, and most parameters can change over time in response to environmental and ecosystem factors. SS is coded using Auto-Differentiation Model Builder, so inherits its powerful capability to efficiently estimate hundreds of parameters using either maximum likelihood or Bayesian inference. Output processing, principally through a package developed in R, enables rapid model diagnosis. Details of the underlying population dynamics and the statistical framework used within SS are provided.

**(d) Objectives**

1. DAF scientists to learn SS methodology and assumptions.
2. After 5-day course, DAF scientists to be proficient in the use of SS software with R.
3. Produce 3–4 updated DAF finfish stock assessments through the 5-day course.
4. Publish on success, outputs and findings of SS.
5. Improve speed on future reassessments of fish stocks.

**Terms of reference and deliverables**

**(e) *Instructors capability***

- Training was to be by highly experienced Instructors (*with a science background*) who can guide workflows, techniques and software features.
- Instructors needed to be experts in SS and have used SS extensively over the last ten years.
- Instructors needed to be able to teach and customise training, based on attendees' learning styles and abilities. It was preferable to have an associate helper to support the main instructor with training and course material.
- Instructors needed to be able to explain SS components, theory/methodology, objective functions and assumptions. This was to support demonstrations on SS model fitting, fixing/estimating parameters, deriving covariance matrices, MCMC simulations, confidence intervals on predicted quantities, yield curves, reference points, quota calculations, projections and output processing through R.

**(f) *Course requirements***

- Supply a five-day (face-to-face) high-level custom training course. Potential instructors to provide a detailed programme-proposal outlining the training course and costings, including instructors' credentials and referees (2–3).
- Training to be for about 10 scientists, already experienced in stock assessment, mathematics and statistics and fisheries science.
- The training to take place at the Maroochy Research Facility (MRF) located in Nambour Queensland, Australia. Each trainee to have one win10 laptop computer. A laptop-projector connection to be available for instructor/s use.
- Course materials to include: training manuals, course notes, exercises and examples provided on USB drive one month prior to training.
- Instructors to supply SS software files and installation procedures one-month prior, for DAF IT installation (including for R packages and ADMB as needed).

- Course content created to meet DAF goals (as provided) and include both non-DAF and DAF fishery examples. Accordingly, training to include DAF real data sets (3–4); data supplied and setup before training course.
- Training to include worked (real) examples. Detailed stock assessment and data input considerations to include – multi-fleet, commercial/recreational fishing, annual harvests, catch rates, fish age-length frequencies. Data to be supplied and setup before training course.
- 12 months ongoing support for software use and maintenance, and stock assessment support with SS. This support to be available within two business days of request. Support to be via either Skype/Zoom, telephone or email as needed.
- Certification of Competency for each trainee in the use of SS.

**(g) Cost**

A cost estimate (itemised budget) was to be provided to cover the training terms of reference. DAF was to provide the final approval to commence the training contract based on the proposal (course outline) and costings supplied.

Training budget was to consider the following costs:

- 1) Preparation and course time,
- 2) Accommodation,
- 3) Travel expenses,
- 4) Materials; and
- 5) 12 month technical and SS support.

**(h) Timeframe (Negotiable)**

Training was to be completed by 31 August 2019

**(i) Location**

Sunshine Coast, Queensland, Australia.

Maroochy Research Facility (MRF), 47 Mayers Road, Nambour Qld 4560

<https://www.daf.qld.gov.au/business-priorities/research/stations-facilities/maroochy-research-facility2>

**(j) DAF contact information**

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**(k) Tender Process**

Potential instructors were to be invited through an open-tender competitive process with submission of an Expression of Interest (EOI) addressing the detailed course requirements and specifications. EOIs were assessed against the evaluation criteria as per the conditions and guidelines for procurement of services for Queensland Government Departments.



In applying, potential instructors needed to disclose any potential or perceived conflict of interests.

### **(l) Intellectual Property**

Course intellectual property was to be negotiated. This included the training courses and training materials, the training course notebook, and training course examples and exercises. DAF required a non-exclusive, royalty free, worldwide licence to use communicate, reproduce publish, adapt and modify outcomes of the contracted services and for its own internal, non-commercial purposes.

Any legal licensing or approvals for training SS were to be arranged by the instructors.

### **(m) Insurances**

Workers compensation insurance (or equivalent) if applicable, as required by law, needed to be maintained for the duration of the Contract Term.

Public liability and products liability insurance to a minimum of \$10,000,000 per claim needed to be maintained for the duration of the Contract Term.

Professional indemnity insurance to the specified amount needed to be maintained for the Duration of the Contract Term (required for professional / consultancy services).

## **3.2 Pre-class material provided by CSIRO**

### **ASSEMBLING DATA FOR USE IN STOCK SYNTHESIS ASSESSMENTS: A PRIMER**

The training workshop on Stock Synthesis (SS) was to include sections relating to specifying the data, specifying the model, calculating model diagnostics, and projections / reference points. The focus for the data section discussion was to be on inputting the data into the .DAT file. Trainees were to provide some example data sets that ‘work’. However, to facilitate effective learning, each participant in the class was expected to work on an example application as part of a group. The aim was to have a ‘working’ model by the end of the class, which could be further refined after the class.

The training was associated with the use of Stock Synthesis 3.3 to conduct assessments. However, assembling (and formatting) the data was expected to be a larger task than developing the assessment and fitting models. Thus, trainees were provided with a Primer document (and the associated spreadsheets) so participants could arrive at the workshop with data extracted from databases that was (approximately) correctly formatted. The spreadsheet ExampleData.XLS provided a form for the most common data types. Participants were asked to make a copy of this spreadsheet and replace the example data with their own data. During the workshop, participants pasted the data into the .DAT file (and removed any resulting errors).

#### *Preliminaries*

There are some decisions an analyst using SS needs to make prior to extracting data. These “structure” the assessment. It is desirable to have a database that can change how data are extracted (e.g. changing the bins for size-composition can be very time-consuming if software to do this automatically is not available). For simplicity, the workshop focused on assessments that are based on one spatial area (and hence no movement among areas) and one season – but some discussion of models with multiple seasons and areas occurred on the last day. Other preliminary considerations included factors such as:

- Range of years to include in the assessment. SS is easiest to apply if catches are available for all years from the start of the fishery. However, catches are not always available for all years and a more recent start-year is often selected.
- Number of genders. Most assessments are based on two sexes because growth often differs among the sexes. However, SS can also handle single-sex models (and they run faster).

- Maximum age. The maximum age should be ‘as low as possible’ but not too low. A guideline for selecting the maximum age is that it should be the age after which growth, fecundity and selectivity are close to being independent of age. Setting a maximum age that is too low will lead to biased outcomes, and a maximum age that is too high will slow the time needed to run the model.
- Fleets. Fleets are key to SS. Fleets can be divided into:
  - Commercial fleets. These fleets have associated catches
  - Survey fleets: These are fleets that do not have associated catches.

Selecting fleets in SS is one of the places where iteration is often required (and hence a need for a flexible data extraction process). SS uses the fleets-at-areas approach (e.g. Berger et al., 2012; Hurtado-Ferro et al., 2014; Waterhouse et al., 2014) to represent spatial structure. Some guidelines for selecting fleets are:

1. Different gear types / operations, e.g. commercial trawl, commercial gillnet, recreational.
2. Differences in population structure among areas. For example one may have an inshore trawl fleet and an offshore trawl fleet, if population age- / size-structure differs inshore / offshore, even though the gear is the same.
3. Actual fishery-independent surveys

The number of fleets will determine the results. It is best to start with many fleets and aggregate them later. The modelling cost of many (unnecessary) fleets is longer run times and potentially more parameters, but too few fleets can lead to substantial bias. Fleets can be used for several “tricks” in SS. For example, one may wish to model a ‘discard fleet’ when landings of the species are prohibited.

### *Landed catch data*

The landed catches are provided by fleet and year. There are two “types” of catch.

- Each fleet can be provided with an equilibrium catch (year -999). The equilibrium catch for a fleet is the average catch for that fleet prior to the first year in the model. This is a way to allow the model to start in a fished state prior the first year with actual catches.
- The annual catches. Note that catches must be provided for all years in the sense that you can’t have “unknown” catches. If catches are unknown for some fleets (e.g. recreational), you need to create scenarios regarding those catches and explore sensitivity to alternative assumptions. Some jurisdictions have developed techniques for ‘catch reconstruction’ to help with this.

The format for the catches is given in the sheet “Catches” in the Example Data.xls spreadsheet. The fields are:

- Year. This is either -999 or a year in the selected range of years.
- Season. We will set this to 1 for this class.
- Fleet. This is the number of the fleet concerned. We tend to have the lowest numbered fleets being those with catches and the higher numbered fleets being the surveys.
- Catch. This is the catch. You need to choose a unit for all catches (e.g. tonnes) but then you need to make sure that other inputs (e.g. the parameters of the weight-length regression) are in the correct units too.

- SE. This is the standard error of the catches. In principle, SS can handle uncertain catches but the performance of this feature is not well tested so it is best to assume a low SE (e.g. 0.01) to ensure that the model matches the catches well.

### *Index data*

It is desirable for every assessment to include at least one index of abundance, although some data-poor implementations of SS use only catch and age-/size-composition data. Many types of indices can be included in a SS assessment. However, the most common are fishery-dependent or –independent indices. Indices can be in numbers or in biomass and can relate to one of many population components (e.g. CPUE indices usually refer to selected biomass or selected numbers while Daily Egg Production Estimates pertain to female or total spawning biomass). Note that the population component to which the index refers must be the same for all years (i.e. one cannot have a CPUE index in numbers for 1980-91 and in biomass for 1992-2009) – if this happens you need to create multiple indices for the index, each with different units. If you have two indices for the same fleet, you need to create a “ghost fleet” for the 2<sup>nd</sup> index. This is just a survey, the selectivity pattern for which will eventually be set so both indices refer to the same component of the populations. The details on the population component to which each index refers is documented in the CTL file. In this regard, workshop participants were advised to initially just provide the basic data.

The format for the catches is given in the sheet “Catches” in the Example Data.xls spreadsheet. The fields are:

- Year. This must be a year in the selected range
- Month. It is best to set this to 7 for a single-season model.
- Fleet. This is the index of the fleet
- Obs. The index value
- STERR. This is the standard error for the index if the index is assumed to be normally distributed or the CV of the index is assumed to be log-normal. It is not uncommon for surveys to provide standard errors/CVs but this is not always the case (usually) for commercial or recreational CPUE data. If analysts don’t have estimates of standard errors or CVs, they are advised to provide a nominal value (e.g. a CV of 0.1), and not to forget to allow SS to estimate extra variance based on how well the model can mimic the index data – this was covered in workshop discussions for the CTL file.

### *Discard data*

Many commercial (and recreational) fisheries discard some of the catch (some of which will subsequently die). SS can use discard data to estimate the probability of retaining a fish given that it was captured, and discard data may provide information on recruitment (if the discards are of small fish). Discard data can be in the form of an amount discarded (numbers or biomass) or the fraction of the total catch that is discarded. Unlike landed catches, discard is usually estimated from observer programs and can be subject to considerable uncertainty.

The format for the discards is given in the sheet “Discard” in the Example Data.xls spreadsheet. The fields are:

- Year. This must be a year in the selected range
- Month. It is best to set this to 7 for a single-season model.
- Fleet. This is the index of the fleet

- Obs. This is either a fraction (proportion discarded) or an absolute amount (the amount discarded).
- STERR. This is the standard error for the observation if the discard data are assumed to be normally distributed or the CV if the observation is assumed to be log-normal. In principle, this value can be determined from observer programs.

### *Size-composition data*

A key input to a SS assessment is size- and age-composition data. The analyst should first decide the size-classes (the size-classes are defined by the lower limit of the size-class; with the final size-class a “plus-group”). For example, a size class from 23-25.99 would be denoted “23”. The size-classes need not all be of the same length. It is common to have more size-classes for smaller animals when growth is rapid. The speed of SS drops rapidly with larger numbers of size-classes.

Size-composition can be specified by fleet and for males/females/sex combined. In addition, size-composition data can be provided for landings, discards, or total landings. It is necessary to provide an estimate of “stage-1” effective sample sizes. These are usually nominal measures of sample size (e.g. number of hauls or trips sampled). The stage-1 effective sample sizes are updated during the model fitting as specified in the CTL file. The format for the size-composition is given in the sheet “Size Comps” in the Example Data.xls spreadsheet. The fields for each row of size-composition data are:

- Year. This must be a year in the selected range.
- Month. It is best to set this to 7 for a single-season model.
- Fleet. This is the index of the fleet.
- Sex. 0 for both sexes combined; 1 for females; 2 for males.
- Part. “2” for retained catch; “1” for discard catch; “0” for total catch.
- The stage-1 effective sample size.
- The data themselves (either proportions or numbers). For a two-sex model, there need to be twice as many entries as size-classes. The first set of data are for females or both sexes combined and the second set of data are for males. Care should be taken when combining raw length-frequency data when there are data for multiple shots or hauls. The usual approach is weight by the catch (in numbers).

### *Age-composition data*

The age-composition data in SS includes two types of data:

- True age-composition. The proportion of sampled animals by age-class.
- Conditional age-at-length. For a given size-class, the proportion of sampled animals from a size-class (or range of size-classes) by age-class.

The age-classes for which data are reported needs to be specified. It is usual for the age-classes to be each age in the model, but you may wish to provide fewer age-classes of data, especially if you have fewer age estimates for the older ages. The age-classes as specified as the lower integer value of the age, i.e. age “1” is for animals that are between age 1 and age 1.99. SS allows ages to be measured with error. It is possible for each age-composition to have a different specification regarding ageing error. Ageing error is specified for

each age, by providing the expected assigned age and the standard error of the assigned age. To specify that an age (say age 5) is aged correctly, one would enter “5.5 0.001” for expected age and its standard error.

The format for the age-composition data is given in the sheet “Age Comps” in the Example Data.xls spreadsheet. The fields are:

- Year. This must be a year in the selected range.
- Month. It is best to set this to 7 for a single-season model.
- Fleet. This is the index of the fleet.
- Sex. 0 for both sexes combined; 1 for females; 2 for males.
- Part. “2” for retained catch; “1” for discard catch; “0” for total catch.
- Age\_Err. This is a pointer to the ageing error matrix to use. This will usually be “1” because there is usually only one ageing error matrix. However, it is possible to have multiple age-reading errors; for example because some of the age estimates are based on whole otoliths and others on sectioned otoliths.
- Low and High lengths. How this field is entered depends on whether the data are age-composition or conditional age-at-length data.
  - For age-composition data, you enter the entire range of length-classes (not lengths) in the model or -1 for both inputs (see line 8 of example input file).
  - For conditional age-at-length data, you enter the range of length-classes for which the composition data apply. The two numbers relate to the length-classes for which the supplied composition data pertain to (see lines 13-14 of the example input file).
- The stage-1 effective sample size.
- The data themselves (either proportions or numbers). For a two-sex model, there needs to be twice as many entries as size-classes. The first set of data are for females or both sexes combined and the second set of data are for males. In principle, care needs to be taken when aggregating data across shots and hauls, but sample sizes are seldom large enough to justify a complex scheme.

#### *Other data inputs*

Stock synthesis can make use of other data sources, such as mean size-at-age (with standard errors), environmental variables, and weight-frequency data. However, these are unusual data types. and should be dealt with on an as-needed basis.

#### References

Berger, A.M., Jones, M.L., Zhao, Y., Bence, J.R., 2012. Accounting for spatial population structure at scales relevant to life history improves stock assessment: The case for Lake Erie walleye *Sander vitreus*. *Fish. Res.* 115-116, 44–59.

Hurtado-Ferro, F., Punt, A.E., Hill, K.T., 2014. Use of multiple selectivity patterns as a proxy for spatial structure. *Fish. Res.* 158, 102-115.

Waterhouse, L., Sampson, D.B., Maunder, M., Semmens, B.X., 2014. Using areas-as-fleets selectivity to model spatial fishing: Asymptotic curves are unlikely under equilibrium conditions. *Fish. Res.* 158, 15–25.

### 3.3 Training schedule by CSIRO

#### Day 1: Afternoon: set-up and intro

13:00: Welcome  
13:30: Software check (DOS, Rstudio)  
14:00: A. The structure of SS (DAT, CTL, STARTER; r4ss) – model building  
15:00: Coffee Break  
15:15: Short presentations on examples (students need to bring the data in the correct format)  
16:00: B: The data file (part 1)  
17:00: Start updating the data file (Assignment 1A)  
17:30: Close

#### Day 2:

09:00: Recap from Day 1  
09:45: C: The data file (Continued)  
10:30: Coffee break  
10:15: Updating the data file (Assignment 1B)  
12:30: Lunch  
13:15: D: The Control file (parameter setting; basic inputs; growth)  
15:00: Coffee break  
15:15: Updating the control file (Assignment 2A)  
17:30: Close

#### Day 3:

09:00: Recap from Day 2  
09:15: E: Spawning and recruitment, F method  
09:45: F: Catchability, selectivity, and retention  
10:45: Coffee break  
11:00: Updating the control file (Assignment 2B)  
12:30: Lunch  
13:15: G: Data weights  
13:45: Updating the control file (Assignment 2C)  
14:15: H: Forecast file  
15:00: Coffee Break  
15:15: Lets get this model to run  
17:30: Close

#### Day 4: Diagnostics and projections

09:00: I: Introduction to r4ss (Jemery)  
10:15: Coffee break  
10:30: J: Tuning models  
12:30: Lunch  
13:15: K: Examples-1: A model with an environmental driver  
14:30: L: Looking at the report file  
15:15: Coffee break  
15:30: M: Other files  
16:00: N: Forecasts and the forecast-report.sso file  
16:45: O: Examples-2: A spatial model (with movement)  
17:30: Close

#### Day 5: Wrap-up

09:00: Presentation of class examples  
10:00: Questions and problems  
10:45: Coffee break  
11:00: Wrap-up and final questions  
12:00: Close

The level of CSIRO training against the schedule was rated from a ‘survey monkey’ web form (questions and template on page 72, appendix 10.3). Individual perspectives on the SS software were reported separately to the success of CSIRO training.

# 4 Results/Discussion

## 4.1 Training evaluation

FRDC performance indicators for SS training were:

- Certification of Competency for each staff participant in the use of SS.
- High level of training provided by instructors, based on course feedback form.
- Run 3–4 updated DAF finfish stock assessments through the 5-day course.
- Reporting on the species/fisheries for which SS will be able to assess.

CSIRO awarded participants ‘Certificates of Achievement’ for completing, understanding and performing the SS training. Each staff’s certificate was for successfully demonstrating the ability to create a fisheries assessment in SS3. See example certificate on page 82, appendix 10.4.

A high level of training was provided by the CSIRO instructors (Figure 3 and Table 1). The rating was from a ‘survey monkey’ web form (questions and template on page 72, appendix 10.3). All (100%) participants said the course was intellectually stimulating and stretched their thinking. The training expanded people’s stock assessment and SS knowledge, understanding of the software’s capability and many dimensions, and the wide variety of potential applications dependent on the data.

Aspects that contributed to successful learning and the training were:

- Instructors knowledge,
- Visual running of SS and viewing outputs through the r4ss package,
- Learning with capable people,
- Using own (Queensland) datasets, and
- Interactive troubleshooting of SS data and settings.

Improvements to the course relate to more training time. This was not possible with CSIRO at this time, and would compound training costs. Irrespective, some suggested improvements to the course were:

- Staged learning (beginners, intermediate and advanced) over multiple training sessions and weeks. This may be better for learning, but between-agency agreements need to control costs. Ongoing collaborative arrangements are required.
- Introduce assignments, with time to work through tasks before training sessions. This is contingent on a base level of SS knowledge.
- Provide more local and non-local worked examples, example across agencies, with time to study and discuss.
- The SS complex setup of text input files (data and control) requires more time to study. Any slight misspecification or alignment of code can introduce errors. Importantly, the text file approach needs revision in new versions of the SS software. The software has evolved to cover many research/fishery aspects, rather than remain focused on key assessment needs for fishery management.

Further comments on the training are summarised from page 72 onwards, in appendix 10.3.



# How did you find the following aspects of the course?

Answered: 12 Skipped: 0

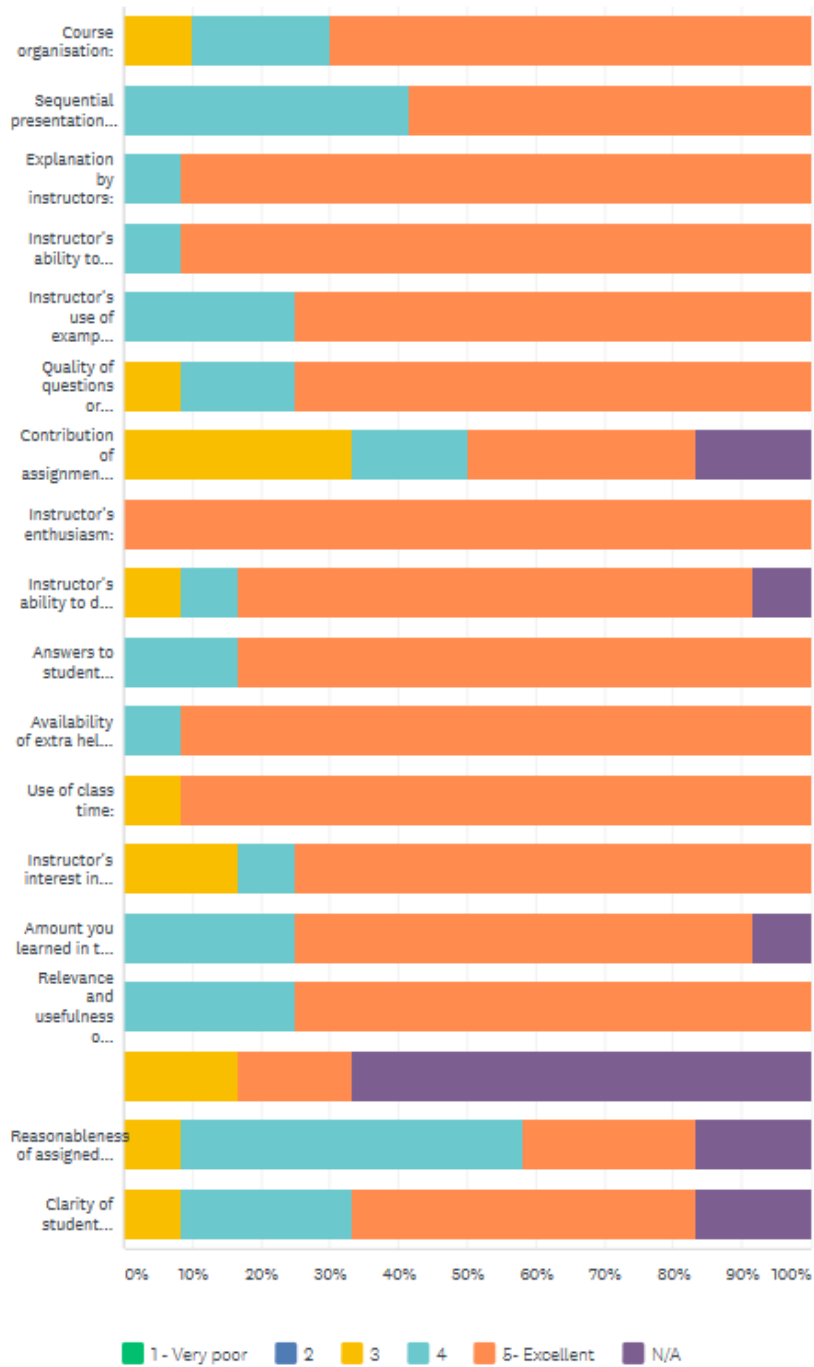


Figure 3. Training scores.

Table 1. Tabulated training scores. Each row aligns with Figure 3 rows.

	1- VERY POOR	2	3	4	5- EXCELLENT	N/A	TOTAL	WEIGHTED AVERAGE
Course organisation:	0.00% 0	0.00% 0	10.00% 1	20.00% 2	70.00% 7	0.00% 0	10	4.60
Sequential presentation of concepts:	0.00% 0	0.00% 0	0.00% 0	41.67% 5	58.33% 7	0.00% 0	12	4.68
Explanation by instructors:	0.00% 0	0.00% 0	0.00% 0	8.33% 1	91.67% 11	0.00% 0	12	4.92
Instructor's ability to present alternative explanations when needed:	0.00% 0	0.00% 0	0.00% 0	8.33% 1	91.67% 11	0.00% 0	12	4.92
Instructor's use of examples and illustrations:	0.00% 0	0.00% 0	0.00% 0	25.00% 3	75.00% 9	0.00% 0	12	4.75
Quality of questions or problems raised by the instructor:	0.00% 0	0.00% 0	8.33% 1	16.67% 2	75.00% 9	0.00% 0	12	4.67
Contribution of assignments to understanding course content:	0.00% 0	0.00% 0	33.33% 4	16.67% 2	33.33% 4	16.67% 2	12	4.00
Instructor's enthusiasm:	0.00% 0	0.00% 0	0.00% 0	0.00% 0	100.00% 12	0.00% 0	12	5.00
Instructor's ability to deal with student difficulties:	0.00% 0	0.00% 0	8.33% 1	8.33% 1	75.00% 9	8.33% 1	12	4.73
Answers to student questions:	0.00% 0	0.00% 0	0.00% 0	16.67% 2	83.33% 10	0.00% 0	12	4.83
Availability of extra help when needed:	0.00% 0	0.00% 0	0.00% 0	8.33% 1	91.67% 11	0.00% 0	12	4.92
Use of class time:	0.00% 0	0.00% 0	8.33% 1	0.00% 0	91.67% 11	0.00% 0	12	4.83
Instructor's interest in whether students learned:	0.00% 0	0.00% 0	16.67% 2	8.33% 1	75.00% 9	0.00% 0	12	4.68
Amount you learned in the course:	0.00% 0	0.00% 0	0.00% 0	25.00% 3	66.67% 8	8.33% 1	12	4.73
Relevance and usefulness of course content:	0.00% 0	0.00% 0	0.00% 0	25.00% 3	75.00% 9	0.00% 0	12	4.75
Evaluative and grading techniques (tests, papers, projects, etc.):	0.00% 0	0.00% 0	16.67% 2	0.00% 0	16.67% 2	66.67% 8	12	4.00
Reasonableness of assigned work:	0.00% 0	0.00% 0	8.33% 1	50.00% 6	25.00% 3	16.67% 2	12	4.20
Clarity of student	0.00% 0	0.00% 0	8.33% 1	25.00% 3	50.00% 6	16.67% 2	12	4.50

## 4.2 Some individual perspectives

Post training, staff provided their individual opinions on using SS. They commented on:

- What role SS may play in DAF stock assessments, in light of the reform process and the SFS?
- Report on success and findings of SS. Will SS improve the speed and information in future assessments?
- From the DAF stock assessment schedule, which species will SS be able to assess? If not, why?
- Does the training address the recommendations from 2014-039 “Review and assess stock assessment methods used in Australia”? <https://www.frdc.com.au/Archived-Reports/FRDC%20Projects/2014-039-DLD.pdf>
- What opportunities do you see to turn the training activity into a nationwide-wide training package?
- Likes/dislikes, Pros/cons of SS.

A summary of commonalities across perspectives is in the report executive summary. Commentary on SS suitability for particular species is in the report conclusion and Table 6.

The following texts are the individual unaltered reports on SS, providing initial comments only, which represent personal views of individuals after training. SS views obviously may change in time, and with more use and learnings of the software. Individual reports by non-DAF staff are labelled.

### 4.2.1 Alex Campbell

Before discussing the role I think SS can play in meeting the objectives of the SFS and within QDAF stock assessment generally, I think it is important to highlight two concerns. One is technical and one practical.

1. Technical: SS encourages the use of so-called “deviation” parameters within a statistical framework (“classical” maximum likelihood, by which I mean maximum likelihood that does not use “integrated likelihoods”) which I believe is not suited for them. In my opinion, they should be integrated out (e.g. using MCMC). This enables them to be treated like pure “process error” (model error) and thus broadens the final confidence intervals appropriately.
2. Practical: the source code is unavailable to the end user (i.e. us), the documentation is far from comprehensive, and based on Andre’s comments and the experience a number of people had during the course (e.g. running Andre’s “textbook” examples and getting different behaviour on different runs with identical inputs), it seems to have some bugs. Any one of these could offset the others. For example, a program with a bug for which the source code is available can be debugged at will; alternatively if the documentation was thorough it could indicate which parts of the program had been heavily tested and which features would require vigilance and potentially a communication channel with the developers. The net combination of the current level of the doco, the unavailability of source code and the level of bugs (anecdotal and observed) makes me somewhat uneasy.

Despite these concerns, I think SS can be a very valuable tool in our toolbox for the following reasons:

1. I believe that the “core” SS features are indeed heavily tested and are solid.
2. I think that we have a strong need for a “sufficiently reliable” and “sufficiently respected” \*baseline\* method: something we can submit all our stocks to (at least all that have age data) as a first pass to give a provide a starting point for discussion, for triage/prioritisation, and for building the case that something more is needed (whether that something more is SS with more features turned on, or something hand coded).
3. I think SS passes the “sufficiently reliable” test as long as we stick to the core features (and we can always check in with Jemery and Andre on what these are), and I believe it is also well respected from a management and stakeholder perspective because of its widespread use in US assessments. Therefore, I think it clears the bar for use as a baseline method. Given this, it confers a number of advantages:

4. It has good visualisation of inputs and outputs, available without requiring any additional programming, and these are very valuable for diagnosing a range of scientific and data issues. They are also very valuable for engaging non-technical people in those discussions. They are not perfect but they will be the same kind of plot each time, which builds familiarity amongst non-assessment folk.
5. The length-age setup matches quite well with the way our data is collected, for example in terms of the conditional age at length being the preferred input and in having good support for two sex models. While our Long Term Monitoring Program caution against sex-specific ALKs for sample size reasons, it seems that SS can use the data intelligently in the sense that non-sexed and sexed data can contribute appropriately to the overall composition.
6. It provides a common interface target for direct connection to our databases, and therefore can probably be run across all our stocks for which we have age data relatively quickly, given a few default switches (e.g. single/two-fleet, single/two-sex, age-and-length/conditional-age-at-length). Some work needs to be put into finding sensible values for biologicals but this should not be hard. (If have conditional age-at-length then growth CVs should be able to be estimated, so just need initial values).
7. Harvest Control Rules (HCR). SS has HCR forward projections built-in (configured through the forecast.ss file), and this part of the program is relatively intuitive and the documentation is actually quite good. See the CT outputs for a projection to 60% biomass by 2027. Building sensible HCRs can be non-trivial and a significant amount has been written on this topic. It is helpful that SS has a lot of hard-won knowledge already factored in.
8. Initially I was confused about how uncertainty was handled in SS based on Andre's comments about it being just the point estimate on which the decision to shut the fishery at 0.2B0 is made. But this is an exceptional case, and the normal way of operating SS is with statistical uncertainty feeding into things like variance adjustments and the HCRs. It appears that the confidence intervals come from inverting the hessian, so essentially a linear approximation to the curvature of the likelihood surface. Again, not ideal, but I believe fit for purpose as a baseline, and a case should be made for something more sophisticated.
9. So, one important role for these confidence intervals is to help set the fraction of the OFL (overfishing limit – essentially fishing at  $F_{msy}$ ) that the ABC (allowed biological catch) is set at. In our forecast.ss defaults, this is set at 0.75, and from what I've seen online this appears to be a common setting, but in principle it should be set based on the internal assessment uncertainty (from say the confidence interval on the biomass in the last year) and the assessment to assessment uncertainty when the stock is assessed in different years by different lead authors potentially with different software packages.
10. Another important advantage of SS is that it encourages us out of the mindset that always working with one set of problems can induce. For example, other jurisdictions struggle with significant amounts of discarding that are not selectivity related, and therefore SS has this feature built-in. Perhaps we do need to consider this, perhaps not, but it is refreshing to have other ways of doing things brought up so we can mentally reset and ask the right questions.
11. Finally, I think it will integrate well with our streamlined assessment framework, and it will also help to provide a useful target for database extraction.

#### **4.2.2 Amanda Northrop**

*What role SS may play in DAF stock assessments, in light of the reform process and the SFS*

I believe SS will have a major role to play towards obtaining our SFS targets, if the correct data are available and it is appropriate to the biology then it should be the first method tested.

*Report on success and findings of SS. Will SS improve the speed and information in future assessments*

The SS software appeared to be successful in initial modelling of Spanish mackerel in the Gulf of Carpentaria, Mullet, Tailor and one population of Barramundi.

Many SS components are extremely well tested with robust theory behind it. The forecast file for running MSEs is quite powerful. SS has been developed by numerous scientists worldwide, as such comes with the knowledge, testing, contribution and peer review of hundreds of scientists worldwide. The output from SS is comprehensive, resulting in the ability to do a “deep dive” into the model diagnostics and tune it appropriately. The standard output from the modelling creates a situation where peer-review can happen quickly and efficiently.

There are limitations. For example, though it has a “hermaphrodite” section built into stock synthesis, it has not been comprehensively developed nor tested. This was not obvious from the manual nor the literature. Were it not for the course, we would have been unaware of this and may have used it without caution. There are other components that have not been well used nor tested, though it is often unclear which components they are. This is a potential risk in our stock assessments. The documentation is variable – extremely comprehensive in some areas, though severely lacking in others, and knowledge gained from “word of mouth” appears to be key in doing a reasonable assessment.

There is an opportunity to do stock assessments in shorter periods, depending on the complexities in the stock biology and the data. Added complexities such as a spatial model would mean the model would take much longer to develop.

*From our Stock Assessment schedule, which species will SS be able to assess? If not, why?*

Stock synthesis will work best for stocks that FQ have age structure data for. It works best for standard “white fish” such as mullet, snapper and pearl perch. Stock synthesis is not appropriate for shell fish that are difficult to age. That being said, if length frequency is available and accurate growth curve information is available, SS should be tested.

Testing will need to be done to determine if it is appropriate for a highly spatial, hermaphroditic and locally density dependent fish populations such as coral trout and red throat emperor.

*Does the training address the recommendations from 2014-039 “Review and assess stock assessment methods used in Australia”?*

FRDC 2014-039 report states:

“The “black box” problem should not be under-stated. Most of the packages reviewed will provide an answer that will look correct, and in package with many options, the possibility of mistakes by non-experts and experts alike remains a concern. The packages differ in the types of data they can use and their complexity. Packages with the most options and greatest flexibility (such as Stock Synthesis and MULTIFAN-CL) are the most difficult to use and hence likely most susceptible to mis-use. The large number of model specifications available in the most sophisticated packages can also lead to mistakes, even from experts. In some cases, poor documentation contributes to this problem. While a “terms of reference” guideline for assessments, multiple assessment authors for one assessment, along with peer-review of resulting assessments, can help, the importance of adequate training of assessment analysts cannot be over-emphasized. As new features are added to packages, training must be ongoing. Development of best practice guidelines for the use of stock assessment packages, particularly those that have many options, will also help to ensure that the “black box” problem is avoided.”

This training has provided the FQ team with initial training. We have also been given ongoing support from Andre Punt which will be key to our skills development until that contract expires. However, future training should still be supported by Fisheries Queensland.

*What opportunities do you see to turn the training activity into a nationwide training package?*

I believe there is definite scope and interest in other states to have the Stock Synthesis course rolled out across Australia. Jemery Day was excellent at keeping the work practical and applicable to our own data and stocks, for this reason I strongly recommend he be included as a trainer in any future training course. The three full days (Tuesday, Wednesday and Thursday) with a half day on either side (Monday and Friday)

worked well. Andre did suggest a half a day break somewhere in the middle, as the course content is quite heavy. However it may be difficult to enforce a proper half day “break” with government employees that are expected to work particular hours.

I would strongly recommend Andre conduct future courses as his depth of knowledge and experience in Stock Synthesis is substantial.

*Other notes:*

- There is a “Simple Stock Synthesis” available for data limited situations.
- There is a Ransom Myers (RAM) Stock Assessment Database that is a compilation of stock assessment results from around the world. It is available in R.
- Andre Punt does not use catch rates derived from commercial logbook data, as he believes it “shows how fishers change behaviour, not how fish react to fishing”. He uses survey catch rates instead.
- For spatial modelling – a fish from a certain area (with a corresponding growth curve relating to that area) will retain that growth curve even if moving to another area.
- There is a translator file that alters old SS files (made for previous SS versions) to new SS files.
- If a fishing fleet goes from being Incidental to Target then back to Incidental – split it into 2 fleets i.e. Incidental – F1 and Target F2
- It is possible to run SS without abundance indices, it essentially becomes a catch curve analysis.
- When updating a stock assessment, first run exactly the same data from the past in the most recent version of SS to ensure you get the same results. Then make one change (each dataset) at a time to understand the new results. If the results are different from previous assessments, report on which dataset is responsible.
- Hermaphrodite and tagging components of SS are not well tested.

### 4.2.3 Fay Helidoniotis

*What role SS may play in DAF stock assessments, in light of the reform process and the SFS?*

Can be applied to a wide variety of fish stocks that are age based, with different fleet dynamics including different gear types and spatial areas.

*Report on success and findings of SS. Will this improve the speed and information provided in future assessments?*

The setup of the data file and control files are initially labour intensive but once it is setup for standard ‘vanilla’ type age based assessments it could improve the speed.

*From our SA schedule, which species will SS be able to assess? If not, why?*

Species that are not suitable are

1. those that are difficult to age such as abalone and lobster and any other species where length based assessment are more suitable.
2. Species that have fast variable growth rates such as some species of tuna might not be suitable because it is difficult to estimate k.
3. Species that live up to a year, such as prawns.

*What opportunities do you see to turn the training activity into a nationwide-wide training package?*

There are good opportunities with possibilities to form a network of subject matter experts that could exchange skills and information.

*Likes/dislikes, Pros/cons of SS.*

Likes: it is a standard method for stock assessments

Pros:

- Being part of a standard toolbox of method might make it easier for peer review.
- It is portable between assessors
- it enable a common communication platform
- It allows for multiple data sources
- It is organised

Cons:

There are bugs in the software. The consequence is that all stock might be affected but on the other hand when the bug is fixed it's fixed for all stocks. With the error being consistent across all stocks this might minimise the labour intensive task of looking for different bugs within each stock assessment. The chance of encountering a bug (if such there be) might be higher with multiple users. However it appears that technicians are available to fix bugs at short notice

Other comments:

What harvest control rule is QLD going to use and if it's different to the one already in SS can it be implemented in SS.

#### 4.2.4 George Leigh

Stock Synthesis (SS) is a very capable software package, used by a large community of scientists and maintained by a substantial dedicated team.

One of the best features of SS is the associated R package "r4ss" which produces a multitude of result summaries and plots. Moreover, these are in a standard format so that any experienced SS user could interpret them without any prior knowledge about the stock being assessed.

SS should be suitable for assessments of many finfish species in Queensland. Examples include mackerels, tunas and many species of coral-reef fish. SS appears to be designed for assessment of finfish with moderate to long life spans, for which an annual population model is appropriate. As an example, we plan to use it for red throat emperor (RTE, *Lethrinus miniatus*) on the Great Barrier Reef in 2019–20. Prior to the workshop we were not sure that SS had the features needed to model RTE:

- regional populations with very different ages of recruitment to the fishery; and
- allowance for tropical cyclones that seem to cause premature recruitment of young fish, presumably from deep water where they would not ordinarily be available to the fishery.

The major current limitations of SS appear to be the following:

- The population models are purely age-based, not length-based. Length can be included to a degree by the use of "morphs" and "platoons" but these are complex features of SS, can be seen as somewhat clumsy, and still do not fully solve the problem. SS may therefore be unsuitable for species in which length is important, such as:
  - Tailor *Pomatomus saltatrix*, in which recruitment to the ocean-beach fishery is strongly length-dependent rather than age-dependent: larger fish of age 1+ (age group 2) are present in the ocean-beach fishery, but smaller fish of the same age are not.
  - Species in which individuals may be exposed to heavy fishing immediately upon attaining their minimum legal size (MLS); e.g., yellowfin bream *Acanthopagrus australis*, sand whiting *Sillago ciliata* and dusky flathead *Platycephalus fuscus*.
  - Species in which catch rates, used as measures of abundance, depend markedly on the MLS and the MLS changes over time. For example, of the Queensland species mentioned above, the MLS of dusky flathead increased from 30 cm to 40 cm in 2003, and the MLSs of tailor and bream increased from 30 cm to 35 cm and from 23 cm to 25 cm total length respectively,

both in 2010. We note that the effect of MLS on catch rates is less of a problem in the USA where fishery-independent catch rates are generally available from boats operated by scientific establishments, whereas in Australia the catch rates are often fishery-dependent, calculated from fishery logbook data.

- SS is not widely used to assess short-lived species such as prawns, for which we currently use monthly models.
- The source code of SS is not accessible. It is therefore impossible for us to see how features have been programmed by the developers of SS, and impossible for us to edit the code to change existing features or insert features that we want. Users outside of the USA are completely reliant on the SS development and maintenance team to include new features.
- The user manual is difficult to read and does not document all the features of SS. The “helper” spreadsheets on the NOAA website are extremely helpful and, in my case, vitally necessary additional resources. I am indebted to my colleague Robyn Lovett for pointing them out to me.

Our course presenter also stated that the lack of random effects for recruitment deviations is a drawback for him, and he hopes that random effects will be included in either SS or a future stock assessment software package. Random effects are less of a problem for us because we are happy to use Markov chain Monte Carlo (MCMC) with an implied Bayesian framework to gauge uncertainty. In the USA it is legislated that maximum-likelihood parameter estimates must be used. In that setting with SS the recruitment deviations become neither random variables nor true parameters, and so don't follow a true frequentist statistical model.

Some quirks about the user and literature of SS could be noted here and may make life easier for readers who want to learn SS:

- SS users seem to spend most of their time editing the control file rather than working on input data or designing the model. This time could be viewed as unproductive but once the control file is right it is generally easy to generate the answers. It is our group's intention to write R scripts to generate the data files and control files for future stock assessments that we conduct in SS, in order to avoid manual editing of control files.
- Terminology is specialised and can be confusing. For example, SS users often use the term “block” to mean “block pattern” rather than an individual block, and use the term “discard” instead of “discard mortality rate”. Discarding is handled as a two-stage process, with four “retain” parameters for the retention function and then another four “discard” parameters for the actual discard mortality of non-retained fish.
- A “block pattern” has one base block which is not explicitly defined but consists of all years not assigned to any particular block. The explicitly-defined blocks are additional. Our course presenter said he usually circumvents this setup by defining all blocks explicitly, but I found it easier to accept SS's design. The control row for the base block contains fourteen entries, including specification of environmental variables and the block pattern. Control rows for other blocks each contain only seven entries.
- The term “mirroring” refers to the use of parameters from one fleet for another fleet, to make parameters common between fleets and avoid having to estimate another set of parameters.

Expansion of our course into a nationwide training package would be challenging. It is complex software, our presenters noted that our group made more progress than they expected, but still our capability was limited after a full, intensive week of training. Queensland has a current team of eight stock assessment scientists, which is probably more than most other jurisdictions in Australia. We believe that we have the critical mass to continue to educate ourselves about SS from here, but other jurisdictions may not. We have found that, to continue to learn SS, we have to lean on each other for help, and I doubt that it would be feasible for a single individual scientist to expect to continue to learn SS even after a week-long course such as ours.

Our course presenter Prof. André Punt, ably assisted by Dr Jemery Day, was inspirational and provided us with great enthusiasm to continue to learn SS. Also, our presenters are available to answer our queries about SS for one year after the workshop. Such a feature would be essential if the course were rolled out nationwide.



## 4.2.5 Joanne Wortmann

*What role SS may play in DAF stock assessments, in light of the reform process and the SFS?*

SS could play a role in both new stock assessments and existing stock assessments already coded in another language. Existing assessments could be updated and at the same time the data could be run through stock synthesis in order to compare model predictions. We would need to decide if we would adopt stock synthesis only for new stock assessments. Andre mentioned this would take at least one year per assessment, and even then we may find the species does not work in stock synthesis.

Stock synthesis does produce reference points and harvest control rules for the SFS.

*Report on success and findings of SS. Will SS improve the speed and information in future assessments?*

Stock synthesis will increase the likelihood that results are based on a correctly-coded model whose estimation performance is widely understood. The peer review of stock assessments will be less challenging if the reviewers are familiar with the SS assessment method. To run the model reviewers need to be emailed four input files and can then run the input files through stock synthesis.

A new stock assessment scientist would be able to take over a stock assessment easily because they are familiar with stock synthesis.

Stock synthesis produces all the graphs and diagnostics so this will save time in coding graphs for reports.

*Does the training address the recommendations from FRDC 2014-039 “Review and assess stock assessment methods used in Australia”?*

1. Recommendation – to use off the shelf packages. This course has trained us in stock synthesis.
2. Recommendation – joining shareware community. By adopting stock synthesis we would be able to join user groups and share information and methods.
3. Recommendation – need for streamlining tools. Stock synthesis is one such tool.
4. Recommendation – develop a national stock assessment community to share ideas.
5. Recommendation – need for better data. The training course highlighted the need for more-frequent recreational data, and efficient methods to clean and prepare data for stock assessment.
6. Recommendation – reduce the cost of stock assessments. Stock synthesis is free so that is one way to reduce cost.

*What opportunities do you see to turn the training activity into a nationwide-wide training package?*

This is definitely a possibility. We could develop an online training course. If stock synthesis is adopted in other organisations and states, Australian stock assessment scientists could develop a forum to collaborate and share methods.

*Likes/dislikes, Pros/cons of SS.*

### **Likes, pros:**

I like that it has four input data files. This is very useful for sharing the model between team members. It will be very easy for the model to be reviewed because the reviewer could be emailed the input files and run the model themselves in stock synthesis.

We don't have to write any code (although also a dislike). Everything is coded for us including reference points and forward projections.

The package r4ss is very useful and produces all the graphs and diagnostics that you need.

Stock synthesis has more features than I initially thought – e.g. it can include a spatial factor, and most of the parameters are able to change over time.

### **Dislikes/cons:**

The version of stock synthesis provided to us for the first exercise did not work on my laptop. The next morning it worked perfectly without any changes (reran the same thing). That worries me about the package. I had a similar problem later on in the week where my Tailor model would not run in stock synthesis. I copied another ss.exe from a different directory of mine into the tailor directory and the model ran fine. Andre Punt did not know why this happened.

The input data files are incredibly complex. The manual helped a little, but there still seemed to be gaps in the explanations provided by the manual. This worries me when I have to set up my own input files. I will definitely need help.

I am not confident I would be able to set up an input file for stock synthesis. During the training course if we wanted to add something to the input files even the expert lecturers had to look up data settings at times.

We cannot see the code so what the package produces is what we will get, we cannot code the program to do anything extra or different.

Stock synthesis needs continuous estimates of catch going back to the start of the fishery. This is a problem for the recreational fishing fleet. There is a way to model the recreational fleet using a continuous time series of effort as the catch data but the lecturer would have to look this up and let us know how to set this up in the data files. This does sound complex to do and I could not find it in the manual.

### **4.2.6 Matthew Holden (CARM)**

SS will likely improve the standardisation and robustness of more routine stock assessments in DAF. All code, especially pieces written for a very specific purpose, that aren't reused, tend to have a high probability of containing major bugs. Well tested and calibrated software can reduce the frequency of these bugs and provide a unifying framework for which stock assessments can be compared.

However, I doubt that SS will significantly reduce the time spent producing stock assessments. The program replaces time which would typically be spent coding and developing the model with time allocated towards modifying input files with many options. Getting an option wrong can fatally derail a stock assessment and therefore, tinkering with the data and control files would easily take several months (a comparable amount of time to building a simple stock assessment model from scratch). I therefore doubt that SS will improve on time efficiency of stock assessments to a point that anyone could call them "rapid". However, I do think it can improve the standardisation and is therefore a valuable tool to consider.

SS is likely inappropriate for anything that requires a spatial model. While spatial models do exist in SS, they are poorly tested and debugged compared to the more heavily used non-spatial models. Because they require more computation they are also more prone to numerical error. For example, the SS spatial model files during the workshop ran smoothly on some machines, but produced a non-positive definite hessian on other machines. This is extremely concerning when the same code with the same data produces different results depending on the hardware of the user. It is possible that is due to differences in the C++ compiler on different machines, but if the C++ compiler version changes the results that is a red flag. I would be uncomfortable with any spatial model in SS, if the example models presented in the workshop do not produce consistent results, how can we expect it to work on our non-idealised data.

There is potential to turn the training we went through into a national package. However, I'd estimate that 70% of the benefit of the workshop came from preparing our own data to work with in SS using the species we were interested in (rather than the canned examples prepared by the instructors). Many errors came up in preparing this data, and modifying the control files appropriately. The course would need at least some support from an actual person, trained in SS, who would be financially supported to help people watching the training debug their files. A remote program which could automate the training would likely be possible to reduce the time and cost of an in person portion of the course, but I don't think it could replace it entirely.

As other participants have mentioned, I really dislike the lack of source code. While the documentation and papers describing the equations and options in SS are excellent resources, they are far from sufficient for debugging the input files. This is especially true for options that are untested or underused. The manual simply does not come with complete information on topics like including environmental variables, and spatial models.

I think it is important to standardise many of our simple stock assessments to reduce human/coding errors and the lack of the ability to compare results between species. SS provides an adequate way to do this for some species, despite my general reservations.

#### **4.2.7 Michael O'Neill**

*What role SS may play in DAF stock assessments, in light of the reform process and the SFS?*

I believe SS can play a role in the stock assessment and management of Queensland's fisheries. This will be for fish species with annual age-length monitoring. The SS software estimates all the relevant spawning biomass indicators. SS can compute biomass reference points for the SFS.

At this time, initially, SS should use simple settings and structures. This is to gain confidence and better understanding of the software. However, use of more complex options could develop quickly with practise. SS needs to be compared with current DAF stock assessment models to verify consistent outputs and recommendations. This is necessary given SS complex text input files, which can easily be prone to undetermined errors.

*Will SS improve the speed of information provided in future assessments?*

Maybe yes, but similar to other setup models.

The use of SS alone will not initially increase the number of stock assessments produced per year by DAF. However, once SS is setup, outputs verified, and data inputs automated, then updated assessments may take 2–3 months each depending on the complexity of the fishery. This process is being investigated. Some Queensland fish species require complex assessments given their spatial biology, patchiness of data, no surveys, multiple fishing sectors, and fishery biases in data.

*From our SA schedule, which species will SS be able to assess? If not, why?*

Many aspects of fish modelling seem possible with SS. The trick is how to make the input settings run SS properly, and not violate the biological settings of the software.

For Queensland, fish species with annual age-length monitoring data seem most suitable for SS. At a minimum for SS, a growth curve is required if the amount of age-length data are few.

SS analysis of short-lived species, such as prawns, scallops, blue and mud crabs, which require increased time steps with weekly/lunar/monthly population dynamics, do not appear appropriate. SS setup to run such dynamics is difficult.

*Does the training address the recommendations from 2014-039 "Review and assess stock assessment methods used in Australia"?*

Yes. Specifically recommendations 1, 2 and 8c.

FRDC 2014-039 listed 13+ recommendations. I note as the current Queensland representative on the national Research Provider Network (RPN), that many of these recommendations still need discussion/actioning, e.g. national committee established for stock assessment collaborations and review processes.

Of relevance here, the training has created a greater understanding of SS. Its structure and outputs are similar to DAF age-based assessments, and fits well into Qld and Australian government policies. The training has increased collaboration with CSIRO, and connected DAF with NOAA's shareware SS community VLAB. SS, with r4ss, provides a consistent platform for communicating results and review. The SS package will

benefit DAF's custom stock assessments, to compare and verify stock assessment results/advice, and decide on which models are best for the stock assessment task.

*What opportunities do you see to turn the training activity into a nationwide-wide training package?*

Through FRDC and the RPN, CSIRO and DAF course learnings can extend nationally. The baseline training materials are now there. Nation-wide training just needs design, promotion, jurisdictional support and action (do!). In doing so, CAPAM plans for the next generation stock assessment model need to be considered (<http://www.capamresearch.org/>), which will utilise SS. I note that a single training program will not overcome the difficulty in using SS complex input files. Only time through use will help this.

*Likes/dislikes, Pros/cons of SS.*

The primary advantage of SS is the ability to explore many assessment settings and questions, and through r4ss it allows for a consistent review platform. However, its many options and complex text input files, are costly to setup, difficult to use, and difficult to identify errors. SS does have a learning curve.

#### **4.2.8 Pia Bessell-Browne**

*What role SS may play in DAF stock assessments, in light of the reform process and the SFS?*

Stock synthesis (SS) has the potential to play a key role in the future of some Qld stock assessments and the move to regular, repeatable assessments. The SFS action 2.2 clearly states that FQ will 'undertake regular stock assessments (annually or at least every two years) for key stocks to assess the fisheries status against the sustainable target and limit reference points'.

Initially a list of key stocks, with adequate data for assessment, needs to be determined. Adequate data for use with SS is age and length structures, collected over a number of years. From these stocks there will be a number that are impacted by environmental variables or have strange life history traits that make them difficult for assessment with SS. Barramundi is an example of such a species that due to complex interactions with freshwater environments and requirements on river flow for recruitment would be challenging to model successfully in SS.

The remaining priority stocks would be well suited for assessment using SS, and using SS for these instances should increase certainty in results. This increased certainty is due to the platform having been rigorously tested and used for assessments globally. It will also the timing and cost associated with peer review as reviewers are likely to be familiar with the software and able to assess the data used and assumptions made, rather than coding of the specific custom model.

Using SS will also produce consistent outputs, both between updates of assessments and also between different stocks. This consistency of outputs will increase understanding by stakeholders and hopefully improve engagement with results. This increased engagement will also hopefully further increase trust in the results and therefore support of the assessment program.

From these points, it appears that SS, along with a range of other model options for more complex assessments, could be a key tool to use for future assessments of various species across Qld to help support the SFS reform process and increase the frequency that stock assessments are conducted for key species across the state.

*Report on success and findings of SS. Will this improve the speed and information provided in future assessments?*

SS provides a platform where some increase in the speed to completing assessments may be realised. These increased speeds may result from less time spent altering source code, so more time can be dedicated to ensuring good model fits and sensitivity testing assumptions that have been made within each assessment.

The r4ss 'R' package should also decrease the time spent plotting results and model diagnostics. This package has a wide variety of plots that can be automatically generated after the model is run and very little additional programming is required to produce these, whereas in the past changing models has meant that longer is spent producing model outputs and diagnostics.

While these specific areas should speed up the stock assessment process when using SS, it is important to note that considerable time is still required to set up the model and ensure proper model fits with the specified parameters. This will be particularly evident when an assessment is run for the first time and a base model needs to be developed, while time savings will be more apparent when an agreed base model is rerun.

SS will not make it possible to increase the number of assessments to the number proposed in the current work plan. To assess species with sufficient rigour and at regular intervals to use for management purposes (i.e. harvest strategies), a lesser number of species is required than has currently been proposed.

*From our SA schedule, which species will SS be able to assess? If not, why?*

Further testing is required to determine specific species that will be able to be assessed with SS. Running upcoming assessments with SS as a 'base case' for those species with available data on age structures through time would be a beneficial first step to develop a more comprehensive list of species that are suitable to be assessed with SS. A brief list of species that may be difficult for assessment with SS are listed below:

- Barramundi and the threadfins are most likely not going to work due to their complex relationships with rivers and freshwater systems.
- Coral trout requires a highly spatial model and SS does not offer this feature currently.
- Sharks are assessed as a species complex and this is not supported in SS.
- Species that are not easily aged, this includes prawn and bug species, tropical rock lobster, sea cucumbers etc.
- Species that only have available length structure information rather than age information will be difficult to assess with confidence.

*Does the training address the recommendations from 2014-039 "Review and assess stock assessment methods used in Australia"?*

The training directly addressed recommendation 3 from report 2014-039. This recommendation suggested that 58 assessments across Australia could have utilised off the shelf packages for assessment and use of these packages should increase the likelihood that assessments are based on correctly coded models, reduce the time needed to conduct assessments and speed up the peer review process.

Recommendation 12 also has relevance to the training, where it suggested that a guideline for stock assessment best practice is developed for use across Australia. Such a guideline would be a valuable tool when using both off the shelf models for assessments and also when using bespoke models. Adhering to these guidelines would also increase confidence from both managers and other stakeholders in results.

In light of this, the training provided valuable knowledge in the use of Stock Synthesis which appears to be one of the most widely used stock assessment packages globally. SS should be able to be used for the assessment of numerous species across Qld and will hopefully increase the speed in which stock assessments can be completed. It is important to note that time is still required to run and check the model, and time savings should be realised in the peer review process and when repeating a base model.

*What opportunities do you see to turn the training activity into a nationwide-wide training package?*

There would be many advantages of making available nation wide training in SS. This would enable similar assessments to be completed between jurisdictions, facilitating collaboration for species that form stocks across state borders. It could also help to develop a network that could peer review assessments of other jurisdictions to reduce cost. In addition, increased collaboration may lead to breakthroughs in methodology and allow for an increased number of species and stocks to be assessed on a regular basis.

When developing a nation wide training package it would be beneficial to offer different levels of training. This would further progress the skill set of those that currently use SS along with increasing the number of people using the software.

Recommendation 13 also has particular relevance for Qld in regards to automation. The report cautions the move to automated processes as you lose the ability to check model outputs. The authors suggest that a balance is required between automated and manual processes and that these need to be addressed on a case by case basis.

*Likes/dislikes, Pros/cons of SS.*

Cons:

- It is complicated to use, there are many options and lots of ways to go wrong if you do not know what you are doing.
- You can't see or alter source code.
- Caution is required when using options that are not commonly utilised, a way to easily determine which features are not well tested would also be beneficial.
- Does not work well with tagging data– Qld does not currently use tagging data so this is less of an issue.
- Close kin data is also not supported – Qld does not currently use this data so this is less of an issue.
- Uses USA harvest control rules and more difficult to implement custom ones – this should be considered as FQ develop harvest control rules.

Pros:

- Provides a stable platform to repeat assessments.
- Is trusted and used globally, assessments are not going to be challenged based on the model or coding itself rather just the data and assumptions used.
- Speeds up the peer review process.
- Provides comprehensive outputs without the need for additional work or code.
- Provides a framework to automatically test sensitivity to parameters and assumptions.

Overall, I found the training to be very beneficial and improved my knowledge to a point where I now feel competent in building a model in SS and knowing which options may be suitable for a specific species. The presenters were very knowledgeable and happy to tailor the speed and content of the workshop to specific requests.

I think SS will be a valuable tool to be utilised within Fisheries Queensland to allow for an increased number of assessments to be delivered to support the implementation of harvest strategies as part of the reform process implementing the Sustainable Fisheries Strategy. It is important to note that full automation of stock assessments will never provide suitable outcomes for management of species as there is always uncertainty that will need to be addressed by someone trained and proficient in using population dynamics models. Also, the number of species that have been shortlisted to be assessed is not feasible and a priority list of species for these more complex assessments needs to be developed to reduce the number to an appropriate and achievable size.

#### **4.2.9 Sabrina Streipert (CARM)**

As an age-structured population tool, the stock synthesis software seems capable of capturing at least basic aspects of the barramundi population. In fact, given the numerous model options in the stock synthesis software, the tool should be able to replicate the results of the recent barramundi stock assessments from 2017 and 2018.

However, given that barramundi are a complex species, claiming salt and fresh water as habitats, changing sex from male to female and other non-standard biological traits, the software should be applied with care and its results considered with caution.

Nevertheless, the software seems to be able to cover the following, not necessarily standard, features of the barramundi population and its associated fishery:

A dome-shaped selectivity to explain gillnet fishing,

Time-varying minimum and maximum legal sizes,

Environment dependent parameters such as  $L_{\infty}$  and others.

Some aspects may require the support of Andre Punt and possibly the coding of new functions into the software. For example barramundi change sex from male to female, and the hermaphrodite component of Stock Synthesis is not well developed. The movements of barramundi between salt and fresh-water may require coding of additional capabilities, even though spatial models are already available in the software.

This report contains details of the first steps towards an application of the Stock Synthesis software to the barramundi Southern Gulf stock, initiated at the Nambour Stock Synthesis workshop.

#### **4.2.10 Samara French**

I thought I could give my experience on learning SS, from someone who hasn't done a stock assessment before but is wanting to learn more.

I thought the course as a whole was great. Even though I didn't understand all the underlying concepts of a stock assessment, I could follow along with Andre's explanation of Stock Synthesis. I found all the lecture slides really informative, and it was useful the way Andre would further explain formulas and graphs on the whiteboard instead of just talking. I also thought it was great the way anyone could ask a question at any time, often this also lead to a tangent conversation which would help further explain another part of Stock Synthesis.

The only thing that would have been extra help for me in the course would be to have a wider range of examples showing how all the options in the control and forecast files can be put into action and why/when they should be used. Since I learn more when I can practise a problem instead of just an explanation, more practical problems would have helped me. I'm not sure to what detail Andre and Jemery went into for the r4ss and tuning of models sections because I was trying to get r4ss to work and got a bit lost but again would have really benefited from specific examples of what to looking for in diagnostics and tuning. Sorry if that was covered and I just missed that part.

As I can't really compare SS to manual stock assessments, my only thought on the software is I think although the files can be quite extensive, each section is well explained and easy to use (once you understand the software). I also think it is great that you can get plots straight from the output instead of having to manually produce the plots.

I had a great week and feel it was a valuable learning experience.

#### **4.2.11 Sue Helmke**

*Observations:*

- Training was conducted by world renowned experts in stock assessment and stock synthesis Prof Andre Punt and Dr Jemery Day.
- Feedback from the presenters was that the participants were very well prepared for the workshop and accomplished much more in the week long training than the presenters had anticipated.
- The workshop consisted of working through the input file structure, analysis control file structure and the outputs of stock synthesis.

- Participants were allocated to groups that progressed the assessment of tailor, sea mullet, Spanish mackerel, coral trout and snapper.
- As the workshop ran ahead of schedule, participants were able to showcase their assessments and the presenters and other participants were able to assist with trouble shooting the input and control files to work towards a reliable model.
- Stock synthesis will not be suitable for all fisheries assessments. Length and age data is required to run the stock synthesis models. The stocks also need to be fairly generic with few complications such as localised recruitment into the fishery as is notable in common coral trout.
- Although stock synthesis provides a standardised platform to conduct assessments it is still a time consuming process (several months) to complete the assessments.
- Prof Andre Punt provided some valuable insights into the process the United States use to assess their stock and define the stock status.
- Dr Jemery Day provided valuable insight into how the CSIRO assess Australian fish stocks.

#### *Benefits*

- The software is accepted by the United States Fisheries and many other fisheries organisations as a robust model for assessing fisheries.
- There is a global community to support software development.
- There are support forums that can assist with trouble shooting.
- It uses a common language for reporting.
- Outputs to review the data used are generic and stock assessment team members can assist each other with trouble shooting and developing models.

#### *Restrictions*

- Not suitable for
  - short lived species
  - species with no age data
  - multi-stock fisheries.
  - data poor fisheries
- There are some bugs in the software that are usually resolved quickly when they are discovered.
- Staff cannot see the underlying code and thereby they don't feel as confident that it is faultless.
- Even though stock synthesis may be considered suitable for some species, after beginning the assessment it may prove an inappropriate tool and more custom models will need to be considered.

### **4.2.12 Robyn Lovett**

*What role SS may play in DAF stock assessments, in light of the reform process and the SFS?*

In light of the reform process and the SFS, SS will be a useful addition to our toolbox to get some regular, standardised reporting happening for those species that are suitable for stock synthesis



*Report on success and findings of SS. Will this improve the speed and information provided in future assessments?*

Probably. In particular once we get used to the standard format that is required for a stock assessment through stock synthesis things will speed up. There will still be a need to spend a while tuning parameters and fitting the model – even for repeat assessments. Writing the report will still take time.

*From our SA schedule, which species will SS be able to assess? If not, why?*

Species that can't be aged such as Blue swimmer crab and trawl.

Multispecies models would not be suitable, such as sharks.

*Does the training address the recommendations from 2014-039 "Review and assess stock assessment methods used in Australia"?*

Not all the recommendations, but those pertaining to the use of packages for stock assessment.

*What opportunities do you see to turn the training activity into a nationwide-wide training package?*

The training was very good and I think would be useful for any stock assessment team that would like to learn stock synthesis.

*Likes/Pros of SS*

- All information from the model is easily available for if we want to make our own standard plots
- Management target and projections available through the forecast file
- Ability to have both length based and age based selectivity – which was relevant for sea mullet
- The system of making control/data files for SS is very similar to what we have already been doing with our use of ADMB
- Calculates MSY in the model
- Time blocks – once we figure out how to do them properly
- Morphs – once we figure them out
- Environmental changes – need to figure out how to use these
- I think the system will be good once we understand it
- R4ss package is good and gave a great snapshot of how the model is doing and where it needs tweaking

*Dislikes/Cons*

- Some of the standard plots that were output from r4ss are not how we would want them. E.g. The biomass plot does not include a 20% line as well as a 60% line
- I also think some of the standard r4ss plots could have looked a bit nicer. E.g. The biomass trajectory for mullet was difficult to read if I showed confidence intervals
- We can't access code to check if a feature means/is doing what we think it is
- SS is thinking about changing its platform. It will take time to learn it this way & then it will all change & we will have to learn it again.

#### **4.2.13 Wen-Hsi Yang (CARM)**

*My learnings on Stock Synthesis (SS). Pros/cons of SS.*

I think SS is a powerful and flexible package for age-based stock modelling. However, SS is not a user-friendly software. Here are my opinions about SS.

Pros:

1. SS is a well-tested package and has been applied for at least 16 assessments (Dichmont et al., 2016).

2. SS provides many features/options such as selectivity functions and recruitment functions for users to construct and develop stock models.
3. The associated R package “r4ss” provides simple tools for users to summarise and diagnose the SS results easily and quickly.
4. Results are reproducible as long as the developed stock models are stable.
5. It is easy to build multiple models and to validate them.
6. SS is still evolving.

Cons:

1. The learning curve is steep for new users because the format of the SS input files is complicated. Errors can happen any time without being noticed.
2. SS is not open-source software. What processing behind is unclear.
3. Preparing the input files is time-consuming. Specifically, tuning the content of the control file is challenging.
4. Detecting whether SS does the right thing and produces outputs from the wanted model is uneasy and costs time.

In sum, SS can become a handy tool once we are familiar with it. However, we should always be cautious of what SS is capable and what SS is incapable.

*Report on success and findings of SS. Will this improve the speed and information provided in future assessments?*

In the workshop, Robyn and I applied SS for mullet. At the time, we did not get any sensible results from SS. We were at a status of tuning the content of the control file. Even though I found out that the R package “r4ss” is handy for visually checking whether the data are imported correctly and diagnosing the model outputs.

*What role SS may play in DAF stock assessments, in light of the reform process and the SFS?*

SS can be used to build a class of base stock models (i.e., age-based stock models) for species on the DAF list. The base models should be built by using the widely used SS features because those features have been tested intensely. Although making the first SS model for a species is painful, I think following stock assessments should be more straightforward. Note that this is not a “push button” stock assessment.

However, the SS base stock models may not be able to explain the real fisheries of the studying species. To be more realistic, developing custom models are still necessary. The custom models will need to be compared with the base models for verifying hypotheses.

*From our stock assessment schedule, which species will SS be able to assess? If not, why?*

Although I am not sure what species are on the schedule, I suggest starting from species having relatively complete data and biological information.

*Does the training address the recommendations from 2014-039 “Review and assess stock assessment methods used in Australia”?*

Yes. The training creates a room for the attendees to share ideas and personal experiences on stock assessment and learn Stock Synthesis together, one of the packages suggested in the FRDC 2014-039 report. Learning Stock Synthesis can help realise a recommendation about having a national clearinghouse for stock assessment code and other streamlining tools.

*What opportunities do you see to turn the training activity into a nationwide training package?*

The workshop brought the DAF and CARM scientists together to learn Stock Synthesis, share their ideas and experiences in stock assessment, and solve problems. Generally speaking, the workshop was successful. It is possible to turn the training activity into a nationwide training package.

Many factors were leading to the success of the Stock Synthesis workshop. I think three factors are crucial. First, prior preparation is essential and help maintain the progressing pace of the workshop. Second, most attendees have experiences and understand problems in stock assessment even though they were assessing different species. In another word, the attendees share “the same language.” Third, using the data with which attendees are familiar helps the learning on new assessing tools such as Stock Synthesis. The three factors improve the performance of the workshop and can help push the training activity into a nationwide training package.

Besides, there are a few cases of stock assessment using Stock Synthesis (SS) for species in Australia waters. Using SS for species in Queensland waters can extend the capacity of SS to be Australia related. This gives opportunities for DAF (and CARM) people to cooperate with the NOAA fisheries scientists to shape and extend SS for species in Queensland waters. With more successful examples of Queensland’s species, the SS training activity can turn into a nationwide training package easily.

Dichmont, C.M., Deng, R.A. & Punt, A.E., 2016, How many of Australia's stock assessments can be conducted using stock assessment packages?, *Marine Policy*. 74: 279-287.

## 4.3 Case study SS stock assessments

The following texts are the unaltered case study reports from the training. The results were for SS training only, and not for fisheries management. SS results and commentary obviously may change in time for the case study species.

### 4.3.1 Barramundi

*Investigators: S. Streipert, A. Campbell, and A. Northrop.*

During the Stock Synthesis Workshop, the *Barramundi working group* used the stock synthesis software with the input of the barramundi catch from the Southern Gulf of Carpentaria, which consisted of the compulsory fisheries logbook entries from 1989 to 2017 as well as estimated historical catch data from 1945 to 1988. The latter was obtained from the barramundi stock assessment in 2017 (Campbell et al., 2017). Additionally, barramundi length-at-age data, provided by Fisheries Queensland for the Southern Gulf, served as input to the stock synthesis tool. These data ranged from 2000 to 2017 and covered the length classes of 50cm to 120cm in width-steps of 5cm. As abundance index input to the software, we used the catch-per-unit-effort time series from 1989 to 2017 derived for the 2018 stock assessment (Streipert et al., 2019).

To get the model to run, we first chose very simplistic assumptions, many of which were default settings in the software, such as a logistic selectivity and certain fixed growth parameters.

Given that one of the more advanced features of the barramundi fishery are time-varying legal changes, Andre Punt showcased our barramundi stock synthesis model to illustrate how to include a time-varying minimum legal size. To simplify the presentation, only one legal change from a minimum legal size of 0cm to 58cm in 1992 was considered. Although this does not include all legal changes, a first run with many other default setting of the software led to outputs that, surprisingly, fit quite well to the age- and length-composition. However, the estimated abundance index did not indicate a reasonable fit to the observed index. The obtained results should not be considered reasonable as the default settings were not adjusted to represent the barramundi fishery. One of these settings included the  $L_{\infty}$  parameter, which was fixed at 110cm, far below the 150cm assumed in Campbell et al. (2017) and 130cm estimated in Streipert et al. (2019). Hence, the model may have underestimated the larger barramundi population, resulting in a reduction of estimated egg production.

Consequently, the first step was to adjust that specific growth parameter by fixing  $L_{\infty}$  at 150cm. This changed the corresponding output figures, leading to poor fits of the age-composition and length-composition data. A reason for this observed misfit could be the default selectivity assumption, which was a logistic function. Since gillnets indicate a dome-shaped selectivity, the selectivity shape was adjusted to an appropriate selectivity pattern (option 25<sup>1</sup>). As the dome-shape maps selectivity of fish with length below 58cm (minimum legal size) and above 120cm (maximum legal size) to a value close to zero, minimum and maximum legal sizes could be removed<sup>2</sup>. Hence, instead of adding further time blocks in Andre Punt's version of the barramundi stock assessment<sup>3</sup>, the time block for the minimum legal size change was removed and the default option of one time block re-implemented. Although the age-composition and length-composition fits improved, they were still not sufficiently good and a pattern in the residuals was recognizable. We therefore changed the length-width from 5cm to 1cm and included all length and ages that were observed. The smallest length bin was now associated to 38cm and the largest length bin referred to 135cm. The ages reached now up to 35 (36 age bins) not the 19 assumed before.

We have fitted the following parameters:

- $\kappa, L_0$  (von Bertalanffy growth parameters  $\kappa$  and length at age 0)
- $R_0$  (initial recruitment)
- $q$  (catchability parameter)

---

<sup>1</sup> The selectivity option 24 did not result in the desired selectivity curve. Following the provided excel sheet for this option, the parameter values have been picked to follow a dome shape but were not in concordance with the selectivity curve created by ``r4ss'' plots even though the selectivity parameters were fixed and not estimated.

<sup>2</sup> This approach was applied in the Barramundi Stock Assessment by Campbell et al. (2017)

<sup>3</sup> Andre Punt only included one change of minimum legal size from 0cm to 58cm in 1991.

-  $Sel_{p1}$  (one of three selectivity parameters determining the ascending rate of the selectivity curve)

and considered, multiplicatively, log-normally distributed stock recruitment deviations from 1989 to 2014.

The code to the latest version is stored in the version control repository in the branch called “pistachio-ss”.

As a first pass, the “bio” plots, produced by “r4ss”, were investigated. The length-at-age distribution seems reasonable, so does the maturity at length and spawning output at length, raising no immediate flags in this section. The selectivity at length seems reasonable but could be improved as the current right-skewed distribution does not capture entirely a dome-shape.

Regarding the fits, the age-composition fits relatively well, especially for the years 2000 to 2015, as illustrated in Figure 4.

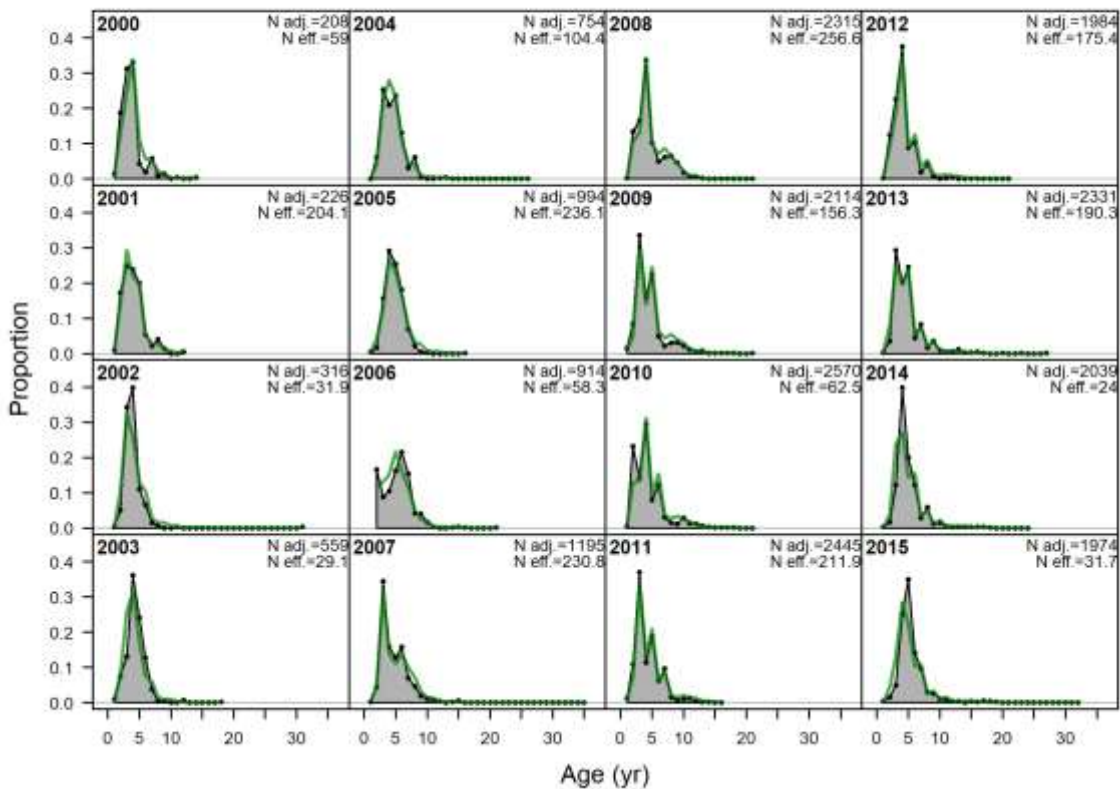
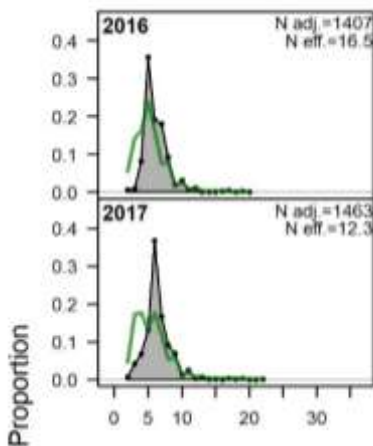


Figure 4. Age-composition fit produced by “r4ss”.



The fits to the years 2016 and 2017 show more deviations, see Figure 5, and indicate that the model needs improvement.

Figure 5. Age-composition fit produced by “r4ss”.

The length-composition data fits better than the age-composition data but could also be improved. Even though not strong, the residuals of the age-composition do show a pattern, especially for the years past 2010, see Figure 6.

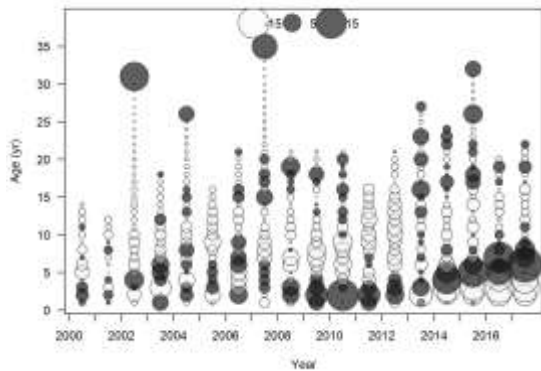


Figure 6. Age-composition fit residuals produced by 'r4ss'.

This suggests that another model choice might lead to a better fit. Additionally, the estimated catchability parameter is close to the lower bound. In a first step, these concerns could be addressed by revisiting the growth and selectivity parameter choices and increasing the bounds on the parameter  $q$ .

Potential future steps include the exploration of the selectivity parameters and the precise inclusion of minimum and maximum legal sizes. Once a reasonable fit to the data has been achieved, more advanced adjustments could be implemented such as the sex-change and environmentally driven population parameters. The latter is crucial given that barramundi are known to be environmentally driven which was already mentioned in Campbell et al. (2017) and Streipert et al. (2019).

## References

Campbell, A.B., Robins, J. and O'Neill, M.F., 2017. Assessment of the barramundi (*Lates calcarifer*) fishery in the Southern Gulf of Carpentaria, Queensland, Australia.

Streipert, S., Filar, J., Robins, J. and Whybird, O., 2019. Stock assessment of the barramundi (*Lates calcarifer*) fishery in Queensland, Australia. May 2019.

### 4.3.2 Coral trout

*Investigator: A. Campbell.*

Key considerations in input file:

- Single sex model (ignore hermaphroditism)
- Main block of length-age data was provided in a way that precludes the construction of conditional age at length, so composition data is entered as two separate comps: age and then length. May be able to revise this if a full data set is obtained.
- Single area model (SS has the capability for multi-area models but this is probably not a useful extension without incorporating region-specific density dependence (which SS cannot do and which we already have in the DAF model))
- Selectivity is age-based logistic, and estimated
- Growth is von-Bert, and estimated apart from CVs (for which we would need conditional age at length). CVs are fixed as in Table A.1 of Little (2016)
- Natural mortality and steepness are fixed at 0.45 and 0.5 respectively, as in Table A.1 of Little (2016)
- Maturity is age based, input as a vector, and follows Leigh (2014); Fecundity is parametric and also as in Leigh (2014)

- Weight at length is given by a log linear regression of weight on length from the ELF data
- Stock recruit log R0 is estimated; SR sigma is fixed at 0.3.
- Recruitment deviations have been truncated to finish in 2005 as per discussion with Jemery, Andre and Pia, and follow the “advanced” setup which has ramp-like bias adjustment

All code to generate input data in the “pistachio-ss” branch of our repo.

General thoughts on utility:

- Not as flexible as the model developed by George (mainly because of regional depletion / density dependence issue), but a useful comparison nonetheless.
- Some important points for CT came out of / were highlighted by the exercise:
  - o Conditional age-at-length data is powerful and QDAF really should be in possession of the raw ELFSim sampling data.
  - o May want to consider dome-shaped vulnerability, perhaps with the double normal selectivity curve being partially fixed and an offset approach used to test significance
  - o Recreational selectivity may not be identical to commercial. The SS offset approach may be able to be used to test this, if sufficient rec data exists
  - o It may be useful to try the hermaphroditism option if the raw ELF data comes through, be aware that there may be SS bugs in this module

Outputs:

	Value	Phase	Min	Max	Init	Status	Parm_StDev	Gradient	Afterbound	
L_at_Amin_Fem_GP_1	28.556300	3	1.00	40.0	10.430	OK	0.5454820	No_prior	OK	
L_at_Amax_Fem_GP_1	48.921600	3	40.00	100.0	54.050	OK	0.2242640	No_prior	OK	
VonBert_K_Fem_GP_1	0.204131	4	0.05	0.5	0.339	OK	0.0083404	No_prior	OK	
SR_LN(R0)	17.006800	1	10.00	32.0	12.000	OK	0.0478627	No_prior	OK	
Age_inflection_FISHERY(1)	3.064820	2	0.10	12.0	5.000	OK	0.0192591	No_prior	OK	
Age_95%width_FISHERY(1)	1.184920	2	0.10	5.0	1.000	OK	0.0159585	No_prior	OK	

Fraction of unfished with forecast with ~95% asymptotic intervals

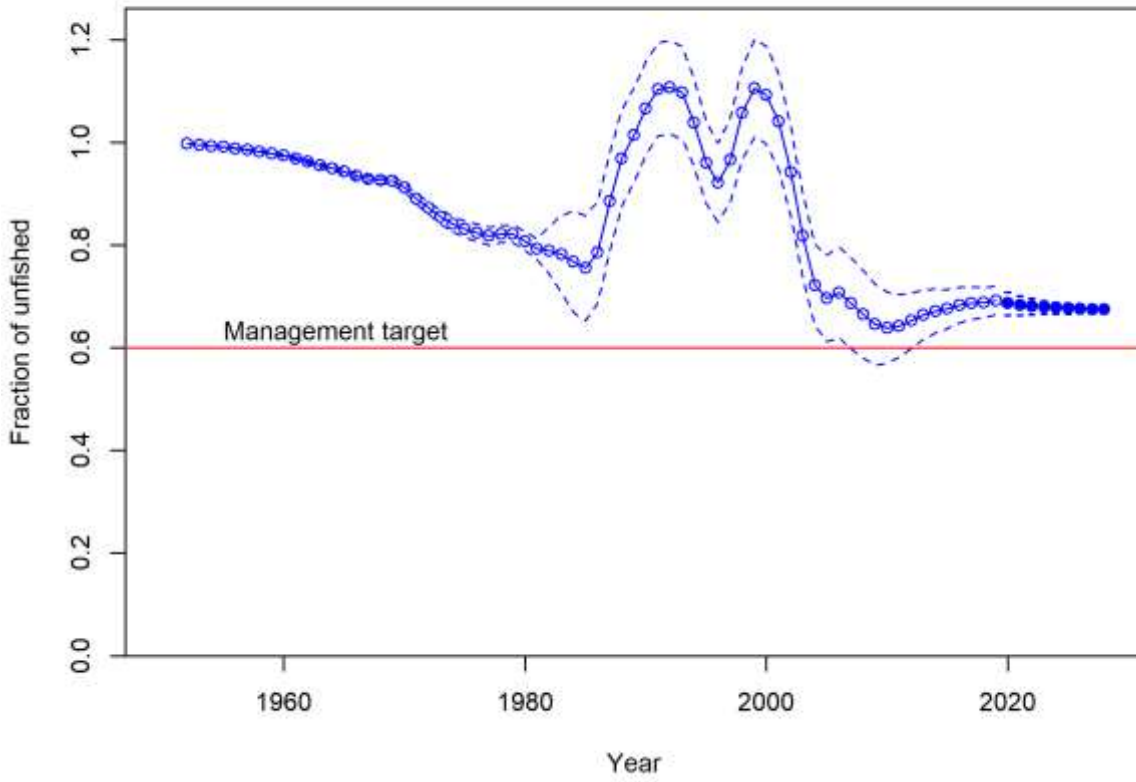


Figure 7. Forecast TACs to attain 60% by 2027 with scientific uncertainty buffer (“Allowed Biological Catch”):

2019: 1158 t

2020: 1149 t

2021: 1144 t

2022: 1141 t

2023: 1139 t

2024: 1137 t

2025: 1135 t

2026: 1133 t

2027: 1132 t



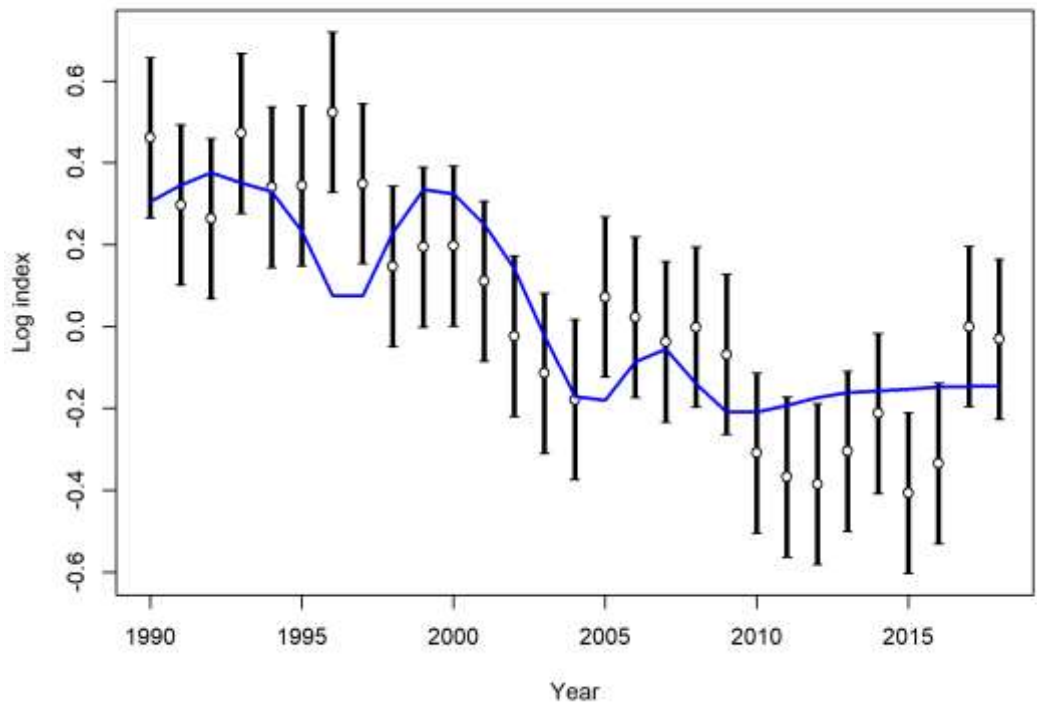


Figure 8. Catch rate fit, log scale.

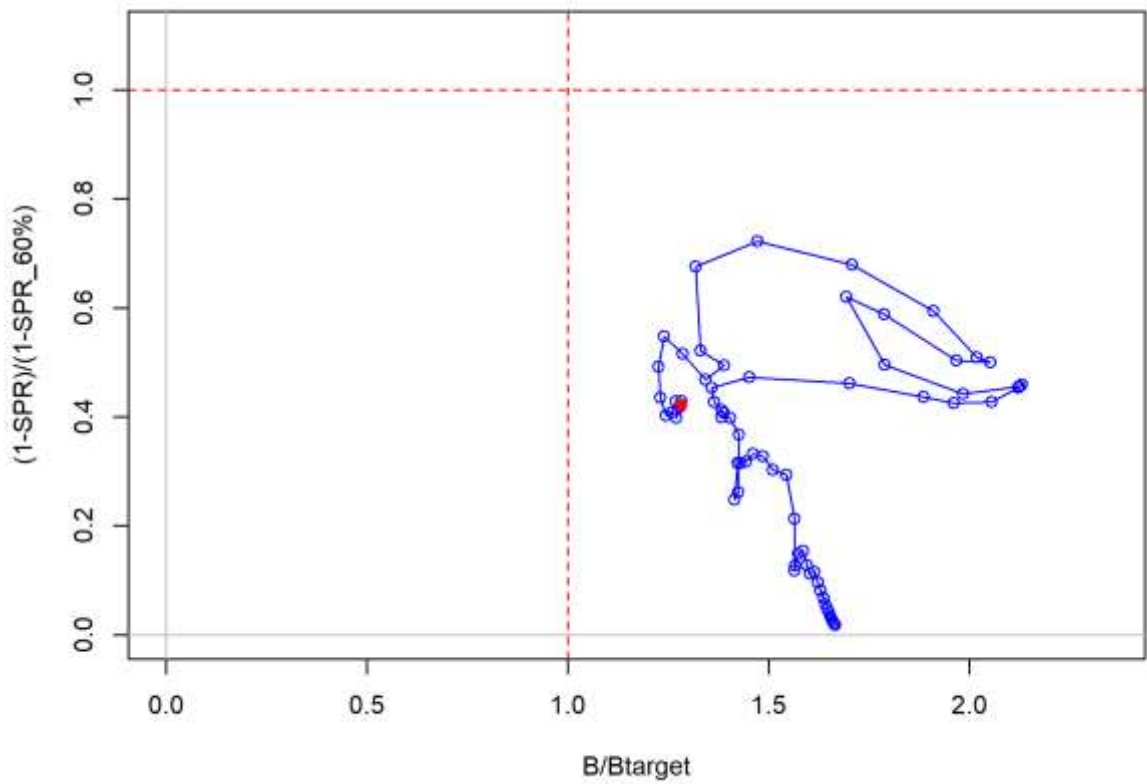


Figure 9. Phase plot, with  $B_{target} = 60\%$  and the spawner-per-recruit index measuring fishing pressure relative the target.

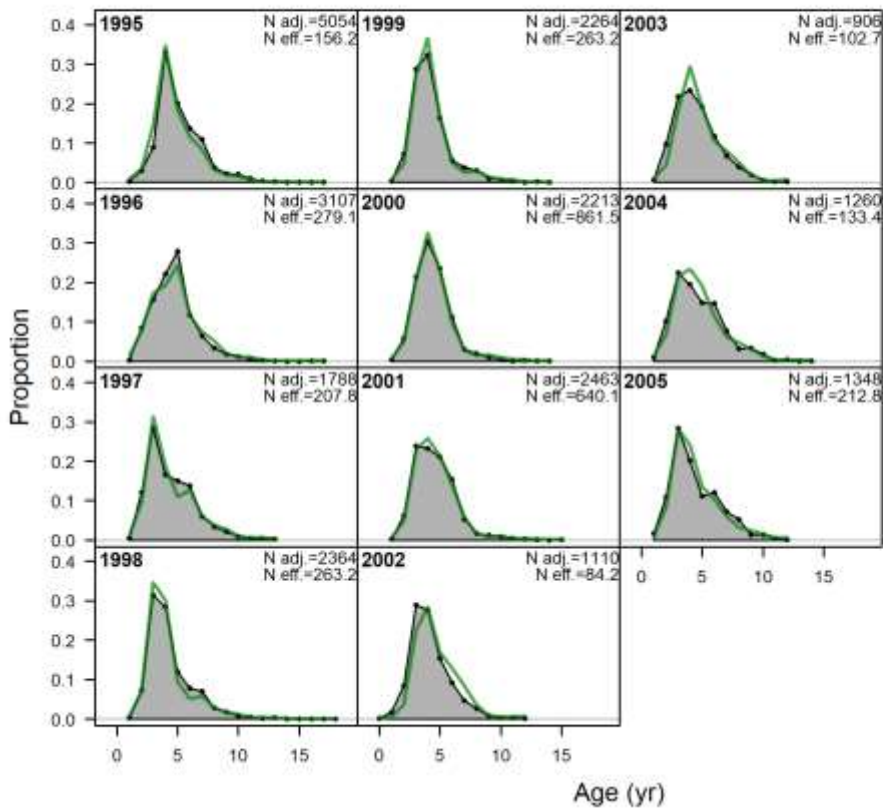


Figure 10. Age composition fits.

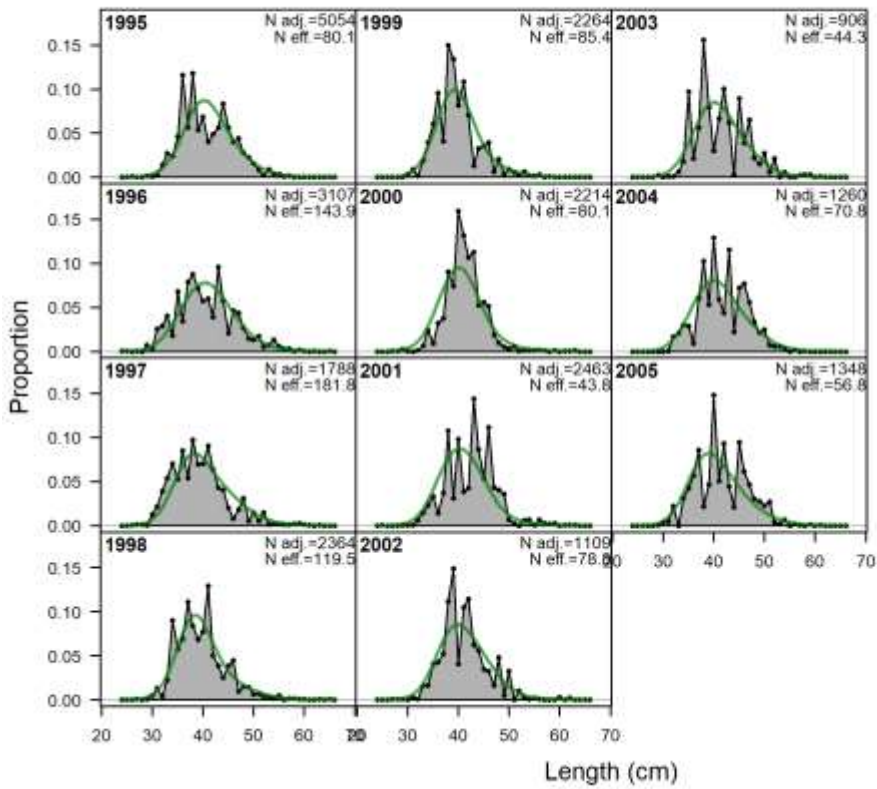


Figure 11. Length composition fits.

### 4.3.3 Western gemfish

Case Study: Assessment of western gemfish using Stock synthesis 3.30.13

The data were from CSIRO up to 2015.

*Investigator: F. Helidoniotis.*

#### *Summary*

An assessment was conducted for western gemfish (*Rexea solandri*) using a recent version of Stock Synthesis SS.30.13. The current analysis was developed during a workshop of Stock Synthesis, held by the QLD Department of Agriculture and Fisheries, and using a fished stock from the Commonwealth fishery as a training dataset.

This report details the tuning of the preliminary base model, and results of preliminary sensitivity analyses. The base-case estimated a spawning biomass depletion at 34% for 2015 which is lower than what was previously reported 43% of  $B_0$  using an earlier version of version of Stock synthesis (V24v).

In addition to the base case model scenario of different estimates of natural mortality are also presented to examine the likelihood of the model.

The sensitivity analyses were conducted by adjusting natural mortality between 0.1-0.7. As NatM decreased the likelihood continued to improve and M of 0.1 resulted in the lowest likelihood of 822.987. However an M of 0.1 is considered implausible. One possible reason for the implausible result is that there might not be enough information to inform the lower M values (i.e M= 0.1 – 0.4). This might suggest that the length data is not as informative as it could be. It is possible that the data is not representative of the fishery. The finding in this assessment may help to inform what sources of data could be improved.

#### *Introduction*

Gemfish (*Rexea solandri*) occurs in southern Australia from northern New South Wales to south western Western Australia and around New Zealand. Gemfish are benthopelagic (bottom dwelling migratory species), and on the continental shelf and slope they have been captured at depths between 100 to 700 metres, although they are usually caught between 300 and 500 metres.

The assessment consisted of a single fleet two sex model. The main data sources include catch per unit effort and ageing, however several issues remain with various data sources. One of them is the paucity of length frequency data that is evident since 2006. In addition the biology is assumed to be similar to eastern gemfish and there has been no biological data collected specifically for western gemfish i.e no growth or size at maturity or length to weight data. There is also a need to better understand the effect of unreported discarding on historic CPUE and differences in length frequency of catch targeted at different depth levels and spawning aggregations.

This report will address the following:

1. Differences in spawning biomass depletion between version of Stock Synthesis.
2. Varying natural mortality and the effect this has on the likelihood.
3. Identifying uncertainties in the model.
4. A stock that includes discards.

#### *Method*

The methods used for inputting the data, developing the assessment and tuning the model are consistent with standard practice as applied to other integrated assessments using Stock Synthesis

The base case model is a two sex model using separately aged otoliths from males and females. Analyses of growth of eastern gemfish indicate that females grow faster and have greater asymptotic length than males. The same growth model was assumed for the western gemfish stock.

*Results and Discussion*

The data sources for the Western gemfish assessment include catch (landings plus discards), standardized commercial CPUE, age composition data from the Integrated Scientific Monitoring Program (ISMP) and length composition data from the ISMP (keeping port sampling separate from the on-board sampling) (Figure 12).

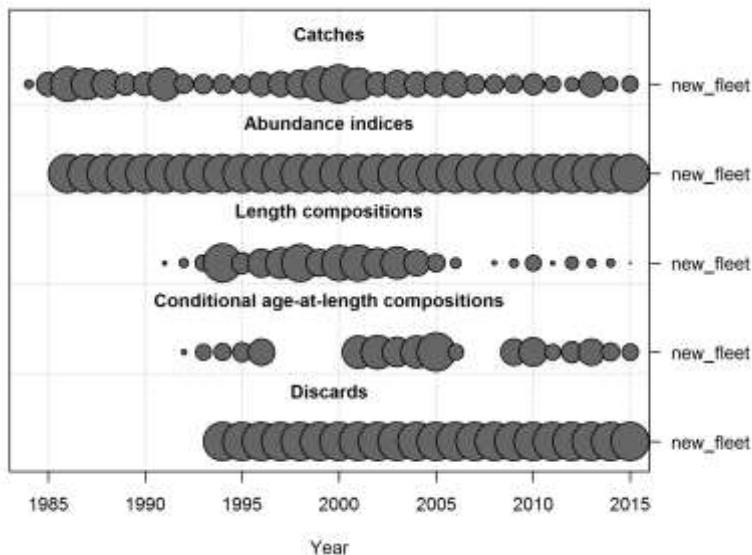


Figure 12. Data sources by type and year. This defines the full data set as used in the balanced base-case scenario.

Over the history of the fishery catches have varied with relatively high catch in 1987 and again in 2000 (Figure 13). This was followed by a successive period of low catches, and catches have been below the Total allowable catch. For this sector of the fishery the TAC for western gemfish was set at between 300 t and 330 t until 2005. In 2006, the TAC was decreased to 167 t and was further decreased each year to a low of 94 t in 2011 before increasing to 141 t in 2012. The most recent TAC is approximately 220 tonnes.

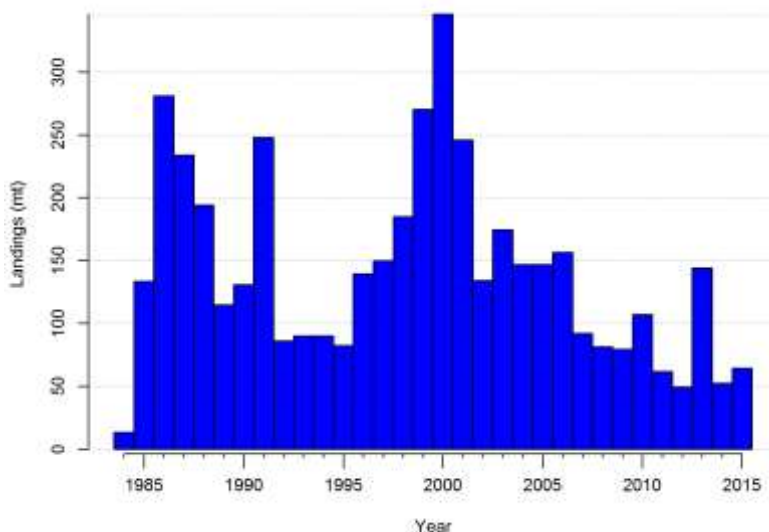


Figure 13. Landed catches of western gemfish in one area of the fishery. Data does not include discards.

Total annual gemfish catch is estimated within SS3 as a function of the retained catch and the discard fractions are then estimated based on the length structure of the catch as well as the selectivity and the retention ogives (Figure 14).

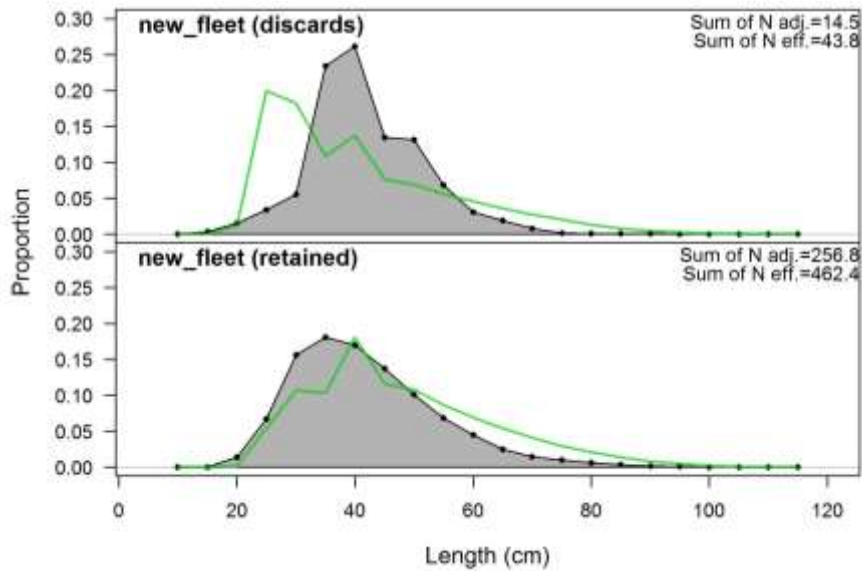


Figure 14. Length data aggregated across time for discards and retained catch.

The spawning biomass depletion has remained above the limit reference point of 0.2SB0 and below the target reference point of 0.48 SB0 (unfished spawning biomass, Figure 15)

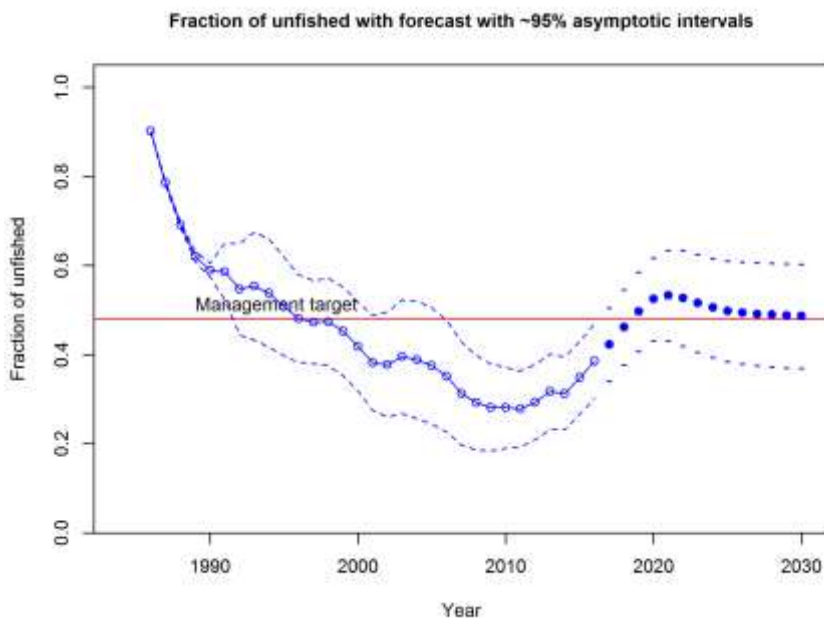


Figure 15. Spawning biomass depletion from the base case model where  $M = 0.3$ . The red line is the management target of 0.48 Spawning biomass depletion used in the Commonwealth fishery. The solid blue dots represent the forecast depletion levels

An analysis was conducted to examine the sensitivity of natural mortality. Estimates of natural mortality were selected on the basis of the maximum age that would result in the population (Table 2). These natural mortality selected ranged between 0.1 – 0.7. These values resulted in maximum ages ranging between 12 – 47 (Table 2). A mortality of 0.3 was used in the base case model which implies a maximum age of 24 which is consistent with the accumulator age of 20 used in the model. When natural mortality varied the likelihood was better when  $M = 0.1$  (likelihood = 822.987 Figure 16). However at  $M = 0.1$  the maximum age of 47 years old might be implausible for this species. A likelihood ratio test would indicate that a likelihood greater than 824.907 ( $822.987 + 1.92$ , chi square distribution 95% limit) would be significantly different. The corresponding  $M$  value at a likelihood greater than 824.907 is where  $M$  is greater than 0.55 (approx., Table 2). The likelihood changed very little between 0.1-0.4 (Figure 16) and the trend in Figure 16 is unusual in that the likelihood continues to improve (i.e decrease) with decreasing  $M$  which results in implausible

maximum age. One possible reason is that there might not be enough information to inform the lower M values (i.e  $M=0.1 - 0.4$ ). This might suggest that the length data is not as informative as it could be. This may indicate uncertainty in the assessment. Results indicate that the length data was poorly represented from about 2005 onwards (Figure 12). In light of these uncertainties, an MCMC might ‘fall over’ if there is a uniform prior on M because the model will continue to fit at level below  $M=0.1$  and result in a high likelihood. There is no information on the lower bound of M because such a low M implied as a maximum age of 47 which seem biologically implausible for this stock.

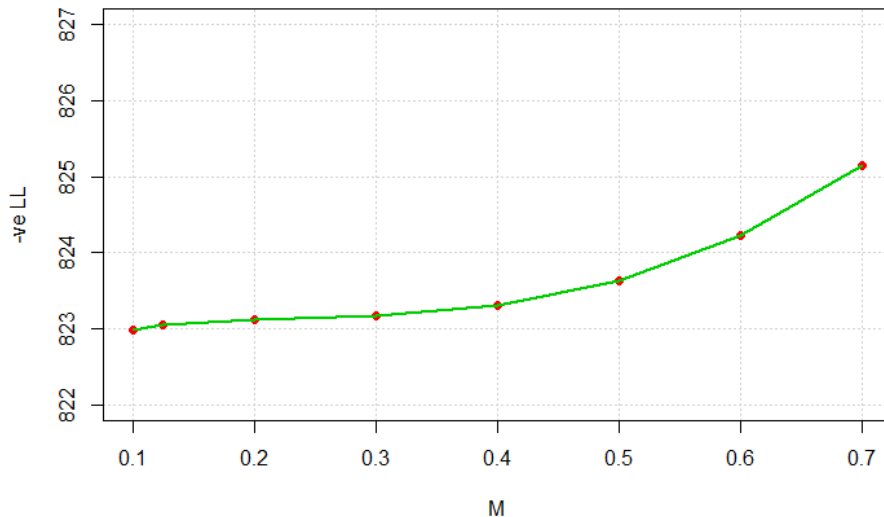


Figure 16. The relationship between Natural Mortality ( $M$ ) and resulting likelihood ( $-veLL$ ). A lower negative log likelihood indicates a better fit.

Table 2. The estimated maximum age for each value of natural mortality.

Mortality	0.1	0.125	0.2	0.3	0.4
Max age	47	37	35	24	12

In addition the discards were not fitted very well. The spread of the length frequencies of the discards were similar to those of the retained and this might make it difficult for the model to fit discards. It is possible that the data is not representative of the fishery.

#### 4.3.4 Tailor

*Investigators: G. Leigh, J. Wortmann, S. French and R. Lovett.*

Our case study of tailor *Pomatomus saltatrix* emphasises the use of the “block” feature to model the changes in minimum legal size (MLS) over the years. Our model used calendar years running from 1945 to 2018 and contained four fleets: Queensland line fishing, New South Wales (NSW) line fishing, Queensland gillnet fishing and NSW gillnet fishing. The model fitted to standardised, fishery-dependent catch rates, and fishery-dependent age and length data.

The “mirroring” setup was quite detailed: the NSW line-fishing selectivity mirrored Queensland line fishing (the fishing method being much the same), Queensland gillnet-fishing retention and discard mortality mirrored Queensland line fishing (the MLS being the same for both sectors) and NSW gillnet-fishing retention and discard mortality mirrored NSW line fishing (again the MLS being the same).

Queensland has a changeable history of MLS on tailor: it had been set at 10 inches (25.40 cm) total length since 1914, then increased to 12 inches (30.48 cm) in 1957, was abolished altogether in 1977, set at 30 cm in 1993 and increased to 35 cm in 2010. In NSW there was no MLS until 1993 when it was set at 30 cm total length. Our model actually used fork length which is about 10% shorter than total length and is the length for which scientific measurements are made.

We succeeded in setting these MLS values for the retention function, using blocks. It is important to note that the base block should be the setting pertaining to the final model year because that base value is the one used for forecasting into the future. Therefore, we gave the Queensland MLS a base value of 35 cm total length and made the other four values into blocks. In NSW, the base value was 30 cm total length and there was only one block, with the value zero. Instead of zero, we actually used a value of 5 cm total length, as we did not believe that fishers would retain tailor shorter than that.

It appeared, however, that SS did not use the MLS values to adjust the catch rates. Instead it wanted to fit dramatically decreasing recruitment deviations to the years 2010–2018 when the MLS was larger and the catch rates were consequently lower. We believed that the use of recruitment deviations in this manner was unrealistic and therefore switched them off, so we used only deterministic recruitment.

The results show the results of heavy fishing of tailor in the 1980s and 1990s and then a recovery after the harvest was reduced from about 2000 onwards. The SS results are not too far away from those of the most recent stock assessment (Leigh et al., 2017), although the SS results may understate the degree to which the period of heavy fishing affected the tailor population. The “steepness” or recruitment-compensation parameter hit its upper bound of 0.9, so the SS model was unable to determine any relationship between spawning stock size and recruitment.

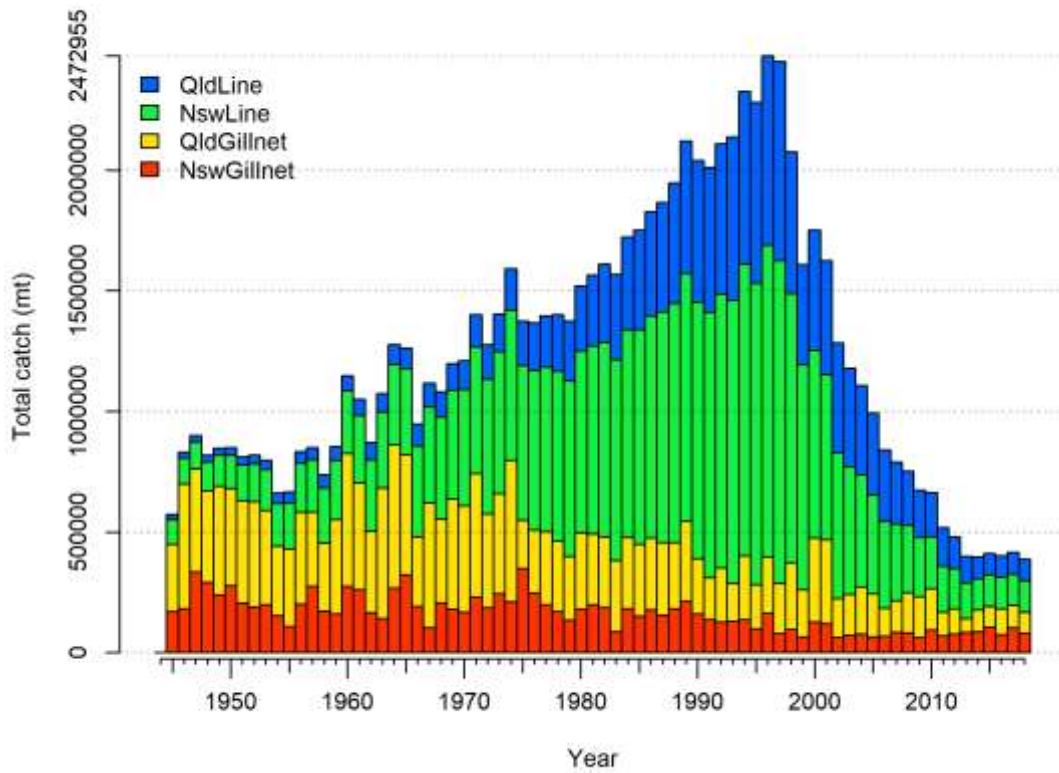


Figure 17. Total harvest size by sector, plotted automatically by Stock Synthesis. Units are in kg.

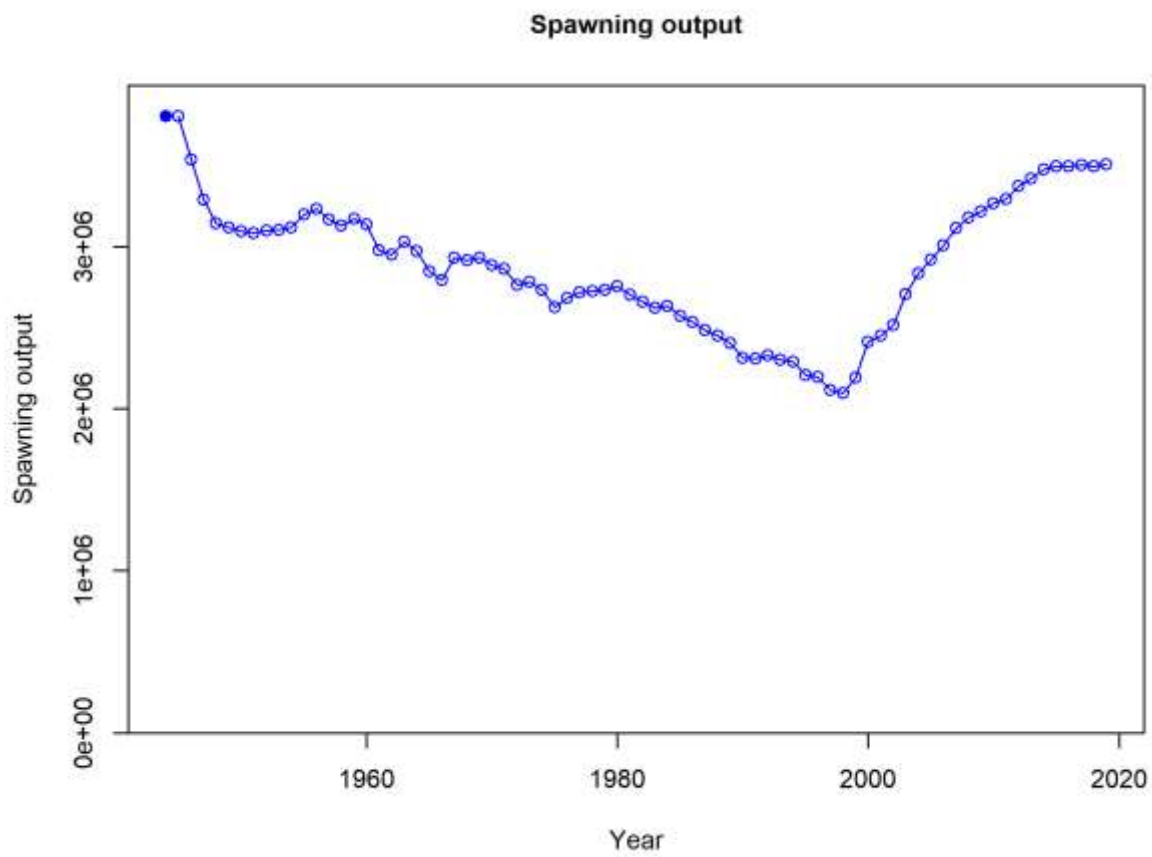


Figure 18. Estimated spawning output (kg biomass) from the SS model for tailor.



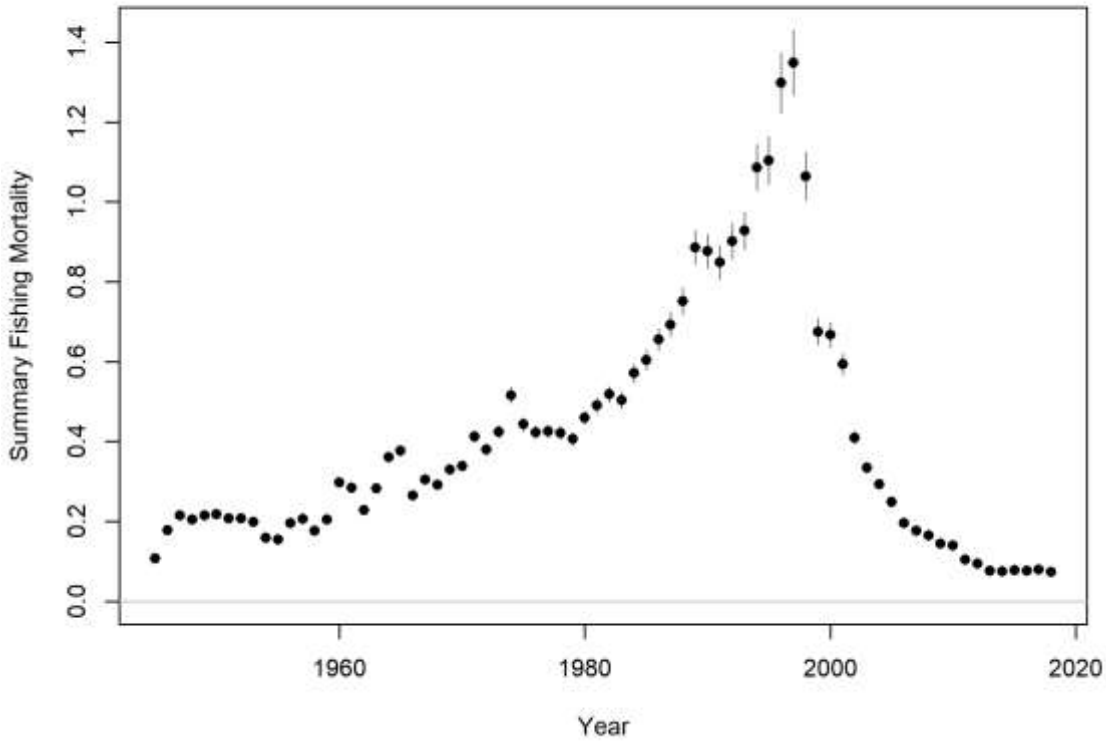


Figure 19. Fishing mortality estimates from the SS model for tailor, showing high fishing in the 1990s and then a sharp decrease in the 2000s (units believed to be  $yr^{-1}$ ).

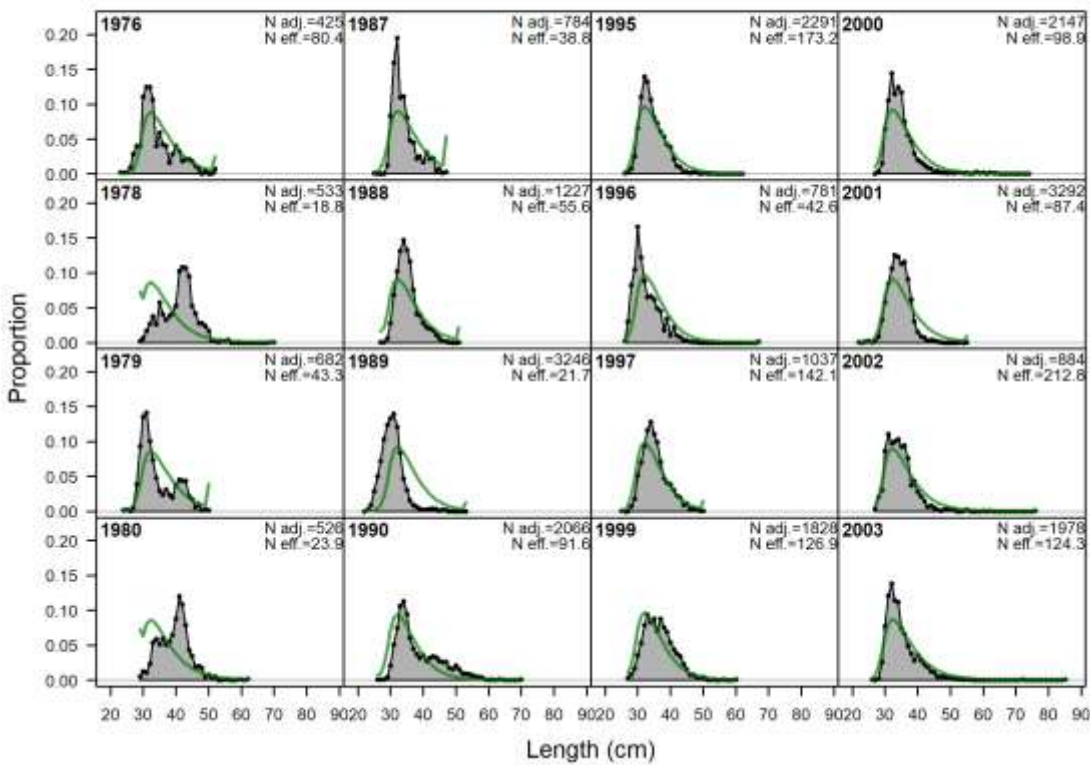


Figure 20. Fits to length distributions, part 1, from the SS model for tailor, years 1976–2003. The 1978 and 1980 length data are also poorly fitted by our own stock assessments but they do establish that schools of large tailor were present at Fraser Island in

those years for a great fraction of the year than they have been subsequently. Currently, schools of large tailor occur only in late September and October. Length is fork length, about 10% shorter than total length on which minimum legal sizes are set.

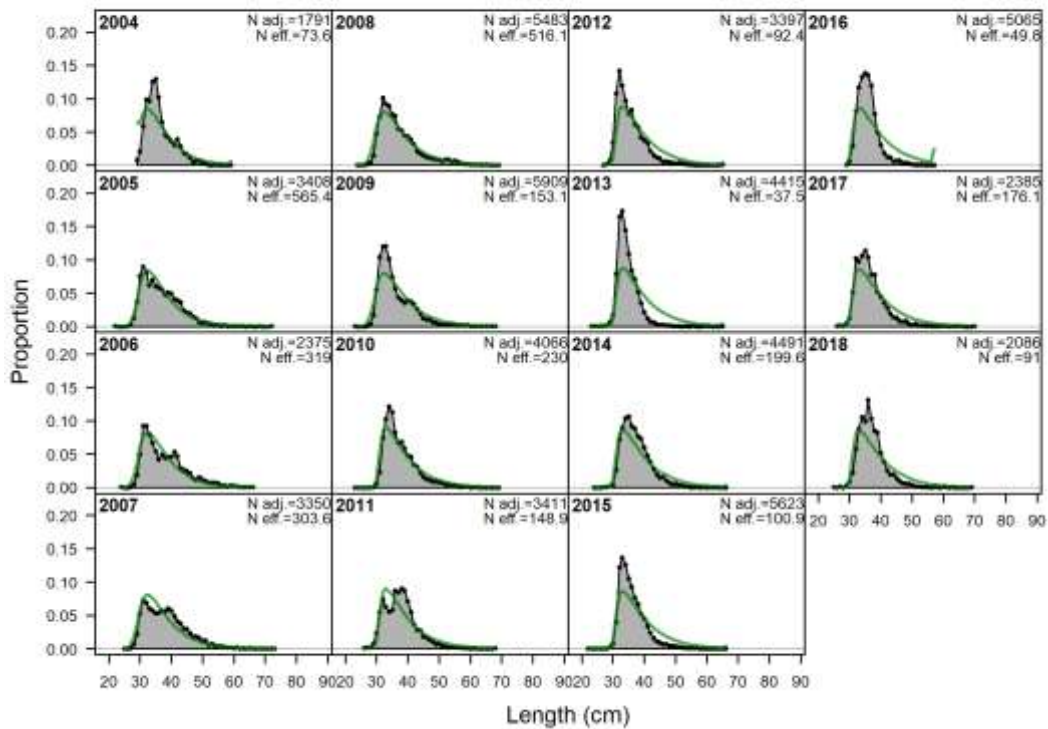


Figure 21. Fits to length distributions, part 2, for the SS model for tailor, years 2004–2018.

Table 3. Parameter estimates for the SS model for tailor

	Value	Phase	Min	Max	Init Status	Parm_StDev	Gradient	Pr_type	Afterbound
NatM_p_1_Fem_GP_1	1.08434	3	0.20	2.5	1.1500 OK	0.0041023	-6.79873e-05	No_prior	OK
SR_LN(R0)	16.74690	1	10.00	30.0	12.0000 OK	0.0115405	0.000292316	No_prior	OK
SR_BH_steep	0.90000	4	0.21	0.9	0.6600 HI	0.0000034	2.60333e-06	No_prior	CHECK
LnQ_base_QldLine(1)	-14.44700	1	-20.00	1.0	-6.0000 OK	0.0368022	7.07849e-05	No_prior	OK
LnQ_base_NswLine(2)	-14.37760	1	-20.00	1.0	-6.0000 OK	0.0512464	-0.000130861	No_prior	OK
LnQ_base_QldGillnet(3)	-14.25910	1	-20.00	1.0	-6.0000 OK	0.0365769	3.95301e-05	No_prior	OK
LnQ_base_NswGillnet(4)	-14.37760	1	-20.00	1.0	-6.0000 OK	0.0546859	9.61235e-05	No_prior	OK
Size_inflection_QldLine(1)	30.02970	4	24.00	34.0	29.9349 OK	0.0236461	1.09361e-05	No_prior	OK
Size_95%width_QldLine(1)	2.93878	4	1.50	10.0	1.6137 OK	0.0344605	-1.1406e-05	No_prior	OK
Size_inflection_QldGillnet(3)	27.45650	4	24.00	34.0	29.9349 OK	0.0270966	4.03088e-05	No_prior	OK
Size_95%width_QldGillnet(3)	2.76927	4	1.50	10.0	1.6137 OK	0.0288509	-7.91697e-06	No_prior	OK

## References

Leigh, G.M., O'Neill, M.F., Stewart, J., 2017. Stock assessment of the Australian east coast tailor (*Pomatomus saltatrix*) fishery. Department of Agriculture and Fisheries, Brisbane.

### 4.3.5 Sea mullet

Investigators: R. Lovett, W.-H. Yang, and F. Helidoniotis.

#### Introduction

Sea mullet (*Mugil cephalus*) are found in tropical and subtropical waters around the world. On the east coast of Australia, sea mullet occur as one continuous stock between Baffle Creek in Queensland (QLD) and Eden in New South Wales (NSW). They inhabit coastal, estuarine and freshwaters and undertake annual migrations along ocean beaches to spawn.

The majority of sea mullet are harvested either by gill net or beach seine net (also known as ocean beach net). Mullet typically mature from three to four years of age. This age range constitutes a high proportion of the catch taken during the winter spawning run.

A stock assessment for sea mullet has previously been performed using data up to 2016.

The purpose of this report is to use the Australian east coast sea mullet as a case study for the use of Stock Synthesis as an assessment tool. Comparisons may then be drawn between Stock synthesis and the previous assessment in terms of the methodology, outputs, suitability and general ease of use. Data inputs from the previous assessment have been repurposed here for this case study.

#### Materials and Methods

##### Data

Harvest and biological monitoring composition data for the two fishing methods were used for the analysis. The fishing data were included with harvest and abundance index, and the monitoring data with length, age and age at length compositions. The index data were supported from QLD and NSW. Figure 22 illustrates timeline for each type of data and the harvest data of the two fishing methods in QLD from 1898 to 2016.

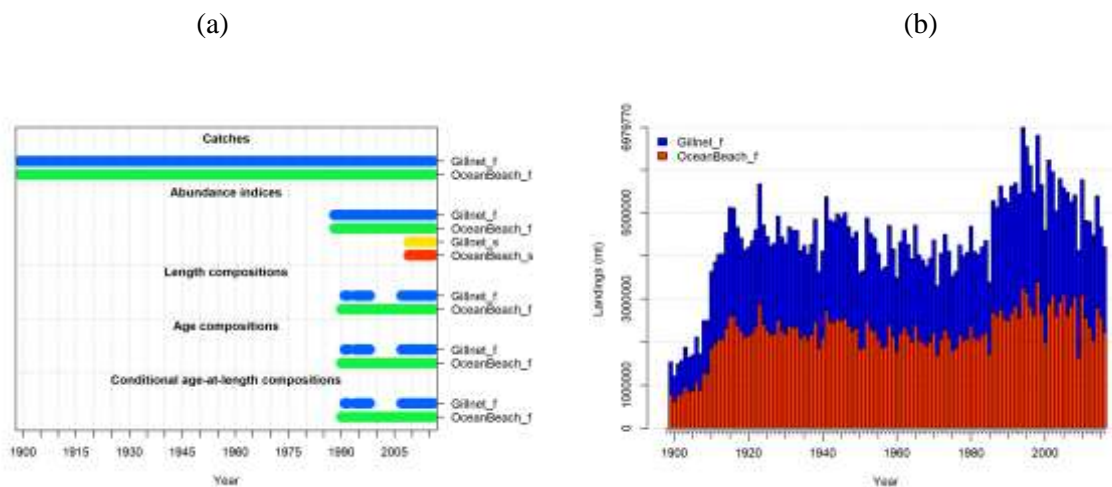


Figure 22. (a) Timeline for each type of data and (b) The harvest data for QLD in 1899-2016. Gillnet\_f and OceanBeach\_f represent gill net and ocean beach net for QLD, respectively; Gillnet\_s and OceanBeach\_s for NSW.

Additional model inputs include:

- Fecundity vector (calculated as maturity  $\times$  female weight at age, then scaled to maximum of 1)
- von Bertalanffy growth parameters
- Allometric growth parameters

#### Model structure

The stock model is age- and sex-based for explaining the annual variation of the mullet population. The following list indicates some major components of the model:

- The model has two fleets; one for each fishing method (gill net and ocean beach net).
- There are four indices of abundance (a NSW and a QLD for each fishing method). This led to the creation of two survey fleets (one for each fishing method). Queensland catch rates were input to the model as standard fleets and NSW catch rates were input as survey fleets.
- Selectivity is both length based and age/sex based for each fishing method:
- Length based selectivity follows a logistic curve satisfying the minimum legal size requirement of 30 cm total length ( $\approx$  27 cm fork length).
- Age based selectivity follows a random walk with male/female offsets regarding fish behaviour at maturity.
- Uses the Beverton-Holt recruitment function with steepness fixed at 0.75.
- Recruitment deviations are calculated for 1988–2015 (age-length monitoring data is present for this period).
- The parameters of the von Bertalanffy growth function are given, but the associated variance is unknown.

## Results

### Estimated parameters

Growth parameters were calculated outside the model and fixed. This model estimates variance for von Bertalanffy growth curves.

Other estimated parameters include natural mortality  $M$  for males and females, the log of virgin recruitment ( $\ln(R_0)$ ) and CV of the growth curves are represented in Table 4

Table 4. Estimated model parameters for sea mullet.

Parameter	Estimate	Standard error
$\ln(R_0)$	17.368	0.025
$M$ (females)	0.347	0.006
$M$ (males)	0.326	0.006
CV_young_growth (females)	0.075	0.001
CV_old_growth (females)	0.140	0.001
CV_young_growth (males)	0.122	0.001
CV_old_growth (males)	0.092	0.001

### Selectivity

Derived selectivity curves for each fishing method and sex are shown in Figure 23. Selectivity for gill net fishing is shown to occur at an earlier age than ocean beach net fishing.

Derived age-based from length-based selectivity by fleet in 2016

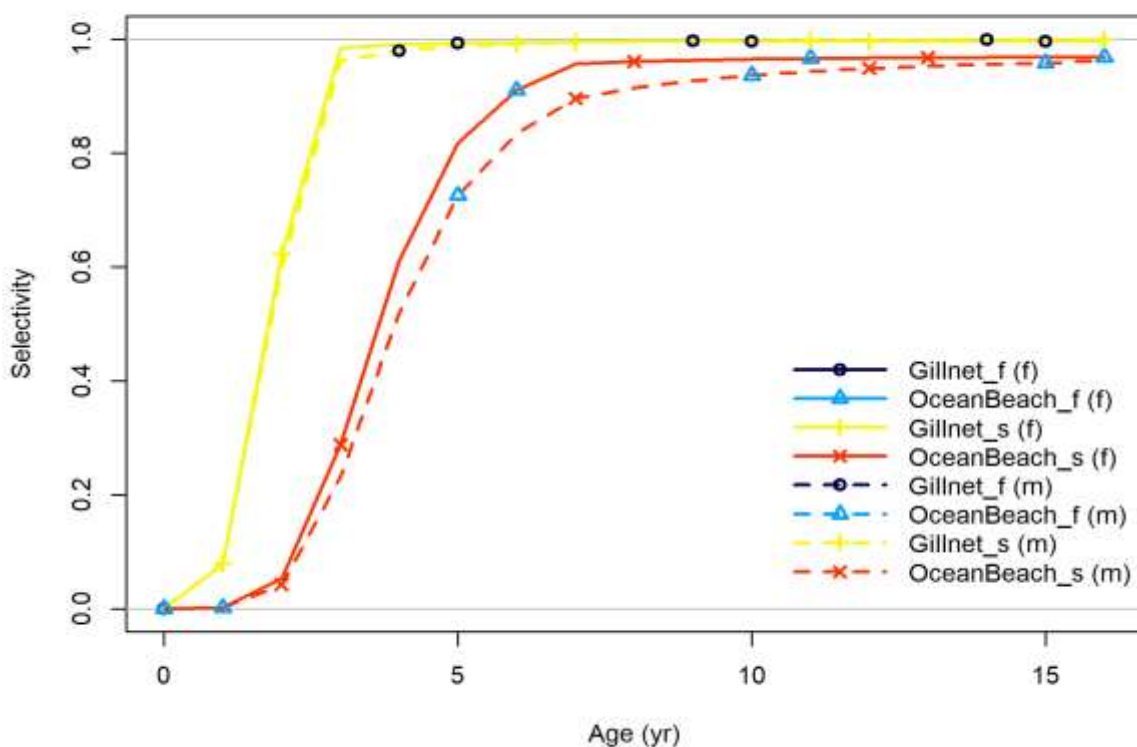
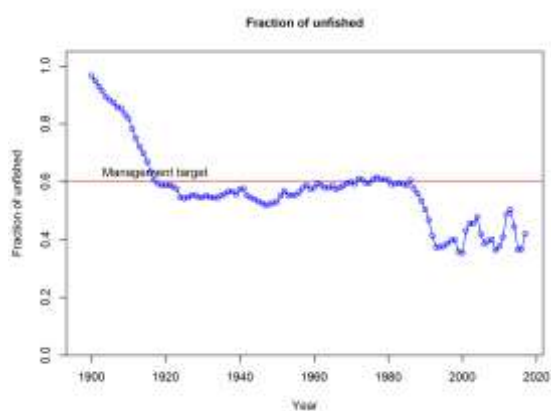


Figure 23. Age and length based selectivity for each fishing method and sex. Note that fleets denoted with an s (eg. Gillnet\_s) are a repeated selectivity for each fleet

**Biomass and spawning potential ratio**

The time series of the predicted sea mullet biomass fraction relative to virgin biomass and spawning potential ratio (SPR) are shown in Figure 24. Figure 24a shows that sea mullet biomass shows an initial decline from the start of the time series, leveling to around 60% unfished until the late 1980s. Following the advent of high fishing in the late 1980s, the trend is shown to drop and then follow a cyclic pattern at around 40%. Figure 24b indicates that SPR drops lower than 60% since late 1980s, hit the lowest level around mid-1990s and has increased slowly since then.

(a)



(b)



Figure 24. Predicted (a) biomass fraction and (b) spawning potential ratio (SPR) time series. Management target in red represents 60% of virgin biomass in (a) and 60% of reproductive output per recruit in virgin years.

## Catch rates

Figure 25 shows model fits to QLD and NSW catch rates (index of abundance) for each fishing method. Queensland catch rates were input to the model as standard fleets and NSW catch rates were input as survey fleets. The current model is struggling to explain some variations of the four abundance indices.

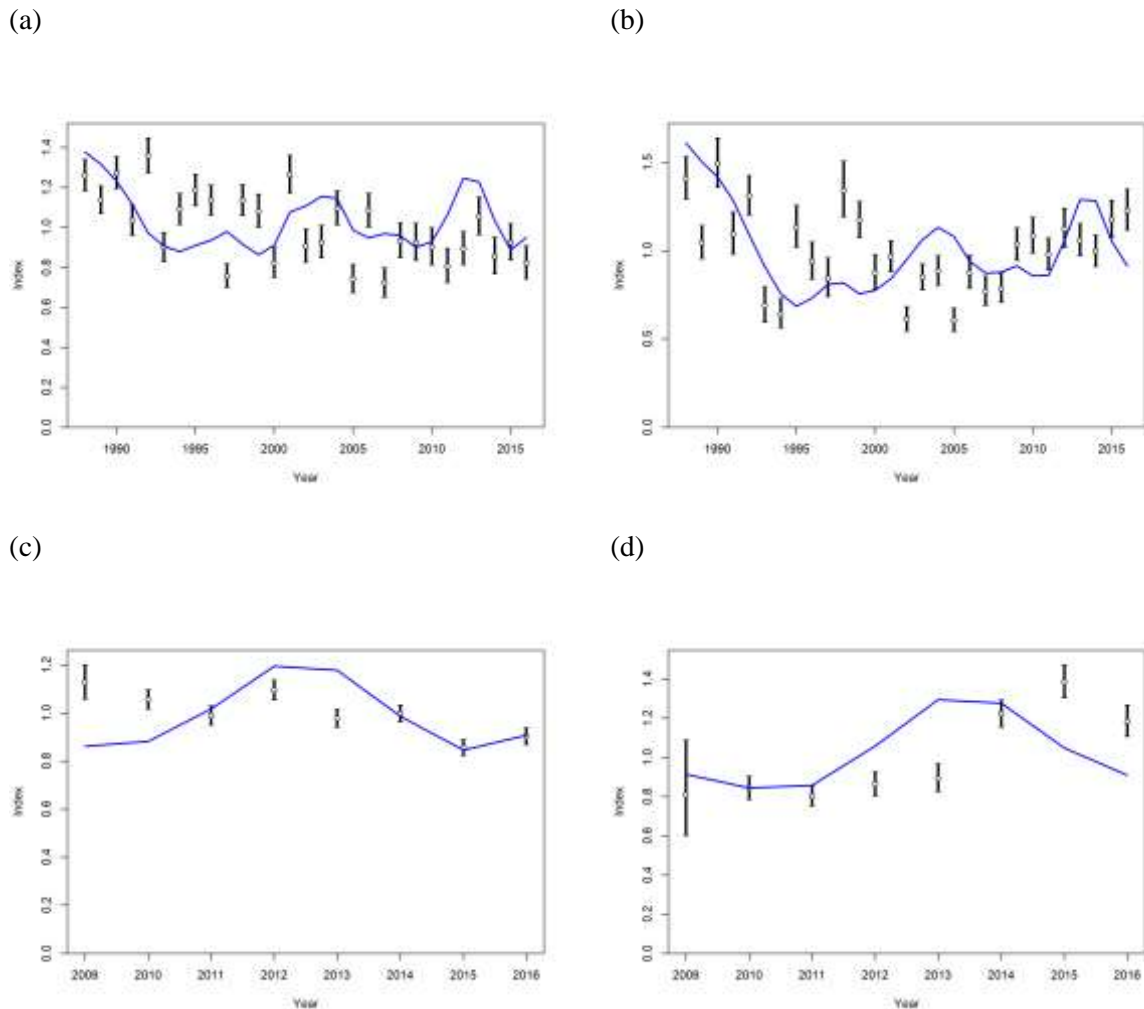


Figure 25. Model fit to the abundance indices for QLD, (a) gill net and (b) ocean beach net; for NSW, (c) gill net and (d) ocean beach net.

## Discussion

This assessment was performed in a rudimentary way as a test case for the use of stock synthesis. From this initial attempt, stock synthesis appears to be a potential tool for performing stock assessments for sea mullet.

Further work on this assessment would be required to ensure optimal results for publication. This may include:

- Further work on estimating growth parameters,
- Using a four fleet model where each fleet represents a fishing method and state,
- A sensitivity analysis for different Beverton-Holt steepness levels.

### 4.3.6 Gulf Spanish mackerel

Investigators: P. Bessell-Browne, M. F. O'Neill, and M. Holden.

#### Introduction

The Queensland (Qld) Gulf of Carpentaria (GoC) Spanish mackerel (*Scomberomorus commerson*) was used as an example stock during the Stock Synthesis training in August 2019. Spanish mackerel are large pelagic predators that are located throughout the Indo-Pacific region, particularly in tropical and sub-tropical waters of northern Australia. They can grow to over 40kg and live for in excess of 20 years. They are a popular species for recreational fishers and a valuable commercial species. In the GoC, Spanish mackerel are predominantly commercial line and net caught. Recreational line harvest estimates are uncertain and believed small based on available information.

#### Methods

Data included in the assessment included combined commercial, recreational and charter harvest. Total harvest was reconstructed prior to 1988 and an additional 250t were included between 1978 and 1987 to account for fishing by Taiwanese in this area and period. Fishing was assumed to commence in 1940. Standardised catch rates were calculated between 1992 and 2018 from commercial logbook data from line fishers. Length and age data collected by the Fisheries Queensland (FQ) monitoring team was included between 2007 and 2018. Time periods of data used in the assessment are illustrated in Figure 26.

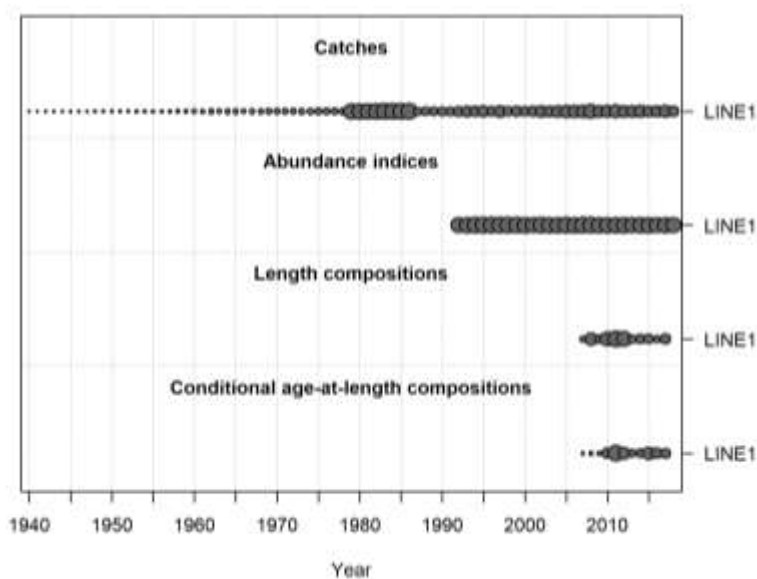


Figure 26. Data types included in the assessment and the years over which this data covers. The size of each bubble represents the relative size of the data.

#### Results

Throughout the week of the training the model was run numerous times with various settings and the results presented here represent the best model at the end of the training week, however further improvements are required before this analysis can be used for management.

Twelve model parameters were estimated by the assessment and estimated parameters are presented in Table 5. These parameters included the growth curve parameters for both male and females, with the exception of the minimum length parameter for males, which was fixed to be the same as the estimate for females.

Table 5. Parameter estimates from the best fitting model.

Parameter	Phase	Estimate	Standard deviation
Length at $A_{\min}$ female	2	64.79	0.49
Length at $A_{\max}$ female	2	125.48	1.36
Kappa female	2	0.24	0.01
CV young female	4	0.11	0.00
CV old female	4	-0.49	0.08
Length at $A_{\max}$ male	3	-0.19	0.11
Kappa male	3	0.46	0.05
CV young male	4	-0.61	0.07
CV old male	4	0.06	0.09
$\ln(R_0)$	1	12.37	0.018
Selectivity - $L_{50}$	3	91.03	0.29
Selectivity – 95% width	3	12.01	0.21

Recruitment compensation or the steepness parameter was fixed at 0.6, while natural mortality for both females and males was fixed at 0.35. Additional biological parameters were fixed based on published empirical relationships from Australia.

Estimated growth curves for both females and males are illustrated in the supplementary information, Figure 29. The selectivity at age also showed differences between males and females (Figure 30). Fits to length and conditional age at length data were good (Figure 32, Figure 33, Figure 34, Figure 35, and Figure 36). Fits to the standardised catch rates were less precise and further work is required to improve these before the assessment is finalised, particularly over the past 10 years (Figure 31).

The estimated biomass trajectory shows a gradual decline in biomass from 1940 to 1980, following a steep decline to approximately 20% in 1985 (Figure 27). Biomass increased until 2004, where it reached the target reference point of 60% of unfished biomass (Figure 27). Between 2004 and 2018 biomass has declined to the limit reference point of 20% unfished biomass. Forecast predictions generated to determine total harvest limits to rebuild the population to the target reference point in the next 10 years are illustrated in solid blue points (Figure 27).



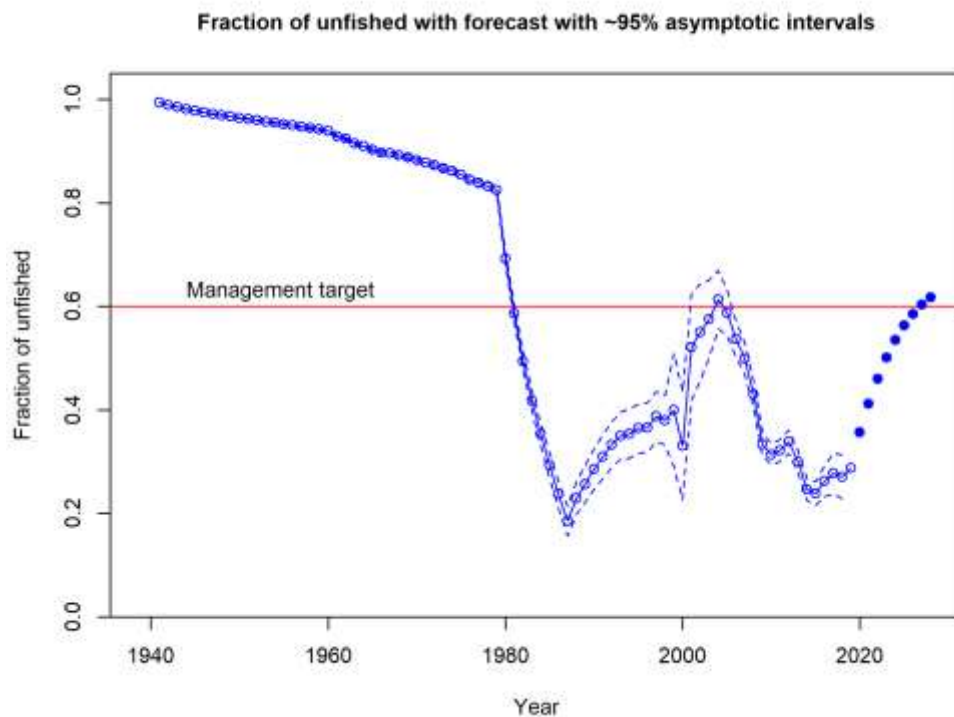


Figure 27. Estimated biomass trajectory (hollow points) between the estimated virgin state in 1940 and 2018. 95% confidence intervals are illustrated with the dashed lines. Forecast to rebuild the stock to the 60% management target in the next 10 years is also depicted (solid blue points).

### Discussion

In the time available during the workshop, relatively good fits to the data were obtained and with some further work it looks like Spanish mackerel in the GoC is a good candidate to be assessed with SS again in future updates.

Some important points to note that the results currently do not include any data from the Northern Territory (NT). There is some ambiguity surrounding the stock structure in northern Australia, however, it is important to test how including data from the western GoC impacts on results. Before results are finalised, data from the NT should be included as an additional fleet.

Sensitivity testing to various fixed parameters within the model is also required. In addition, the impact on the reconstruction of total harvest also needs to be tested to see how this impacts upon results. This testing will improve confidence in results.

Further work is also required to improve model fits, recommendations include:

- Investigate the 2013 length data and see if there is any pattern in the small peak at low lengths. Determine whether this was all from one region etc.
- Tuning the model with values from the Francis plots.
- Increase the early Taiwanese harvest to settle recruitment deviations (Figure 37).
- Try and increase the standard error in the years with Taiwanese harvest, noting that this function is not well tested
- Change total harvest from kg to t
- Investigate which data is driving poor fits to standardised catch rate data over the past 10 years

Overall, Stock Synthesis appears to be an appropriate tool to model the population of Spanish mackerel in the GoC and most likely also in other stocks across Qld. The framework provides an easy way to test

sensitivity to both fixed parameters and data inputs which should improve certainty in results and improved confidence from stakeholders. Testing the results from this platform and models currently used in Qld should provide further insight into the validity of results.

*Supplementary Information*

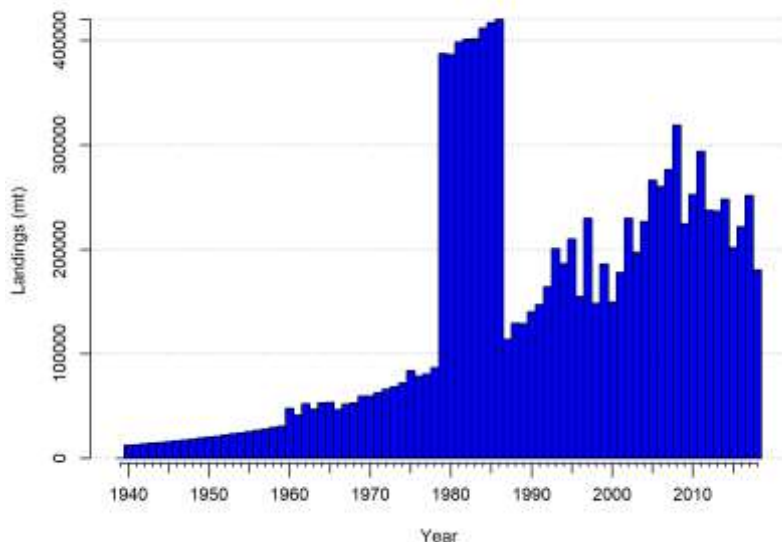


Figure 28. Total harvest (in kg not mt) used for analysis in the model. Data includes harvest from commercial line and net, recreational line and charter. Commercial data recorded in logbooks began in 1988 and harvest reconstructed was between 1940 and 1987. Additional harvest by Taiwanese gillnet fleets was estimated between 1978 and 1987.

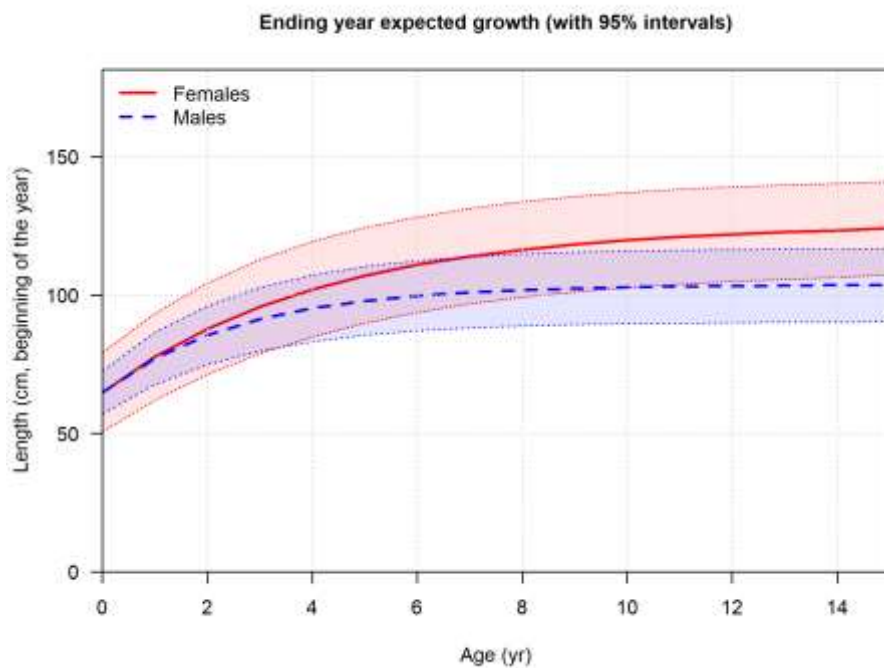


Figure 29. Growth curve fork length for both female (red) and male (blue) fish estimated within the model. Estimated parameters are in Table 5. Shaded areas represent 95% confidence intervals.

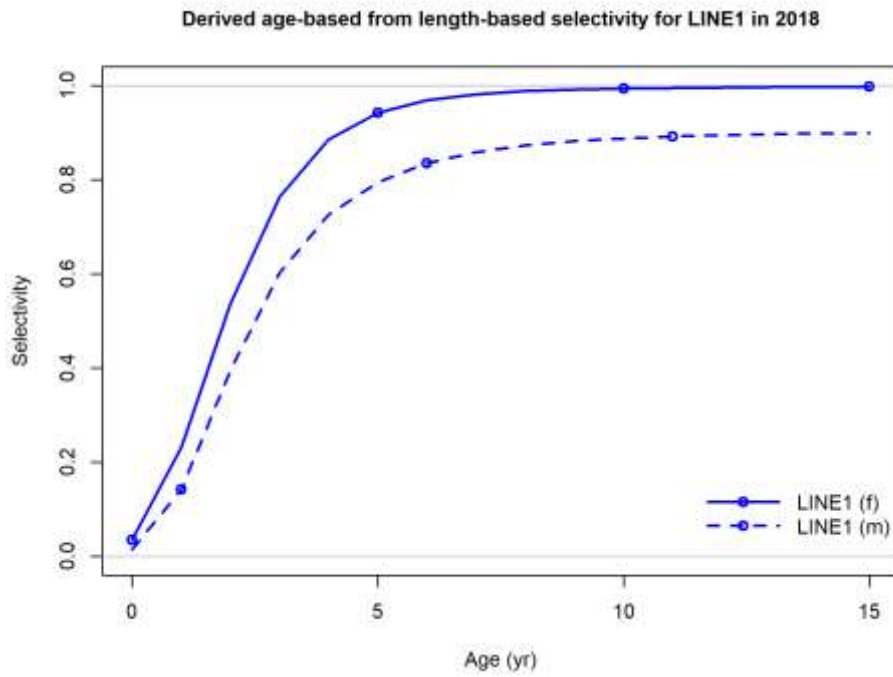


Figure 30. Estimated selectivity at age for females (solid line) and males (dashed line).

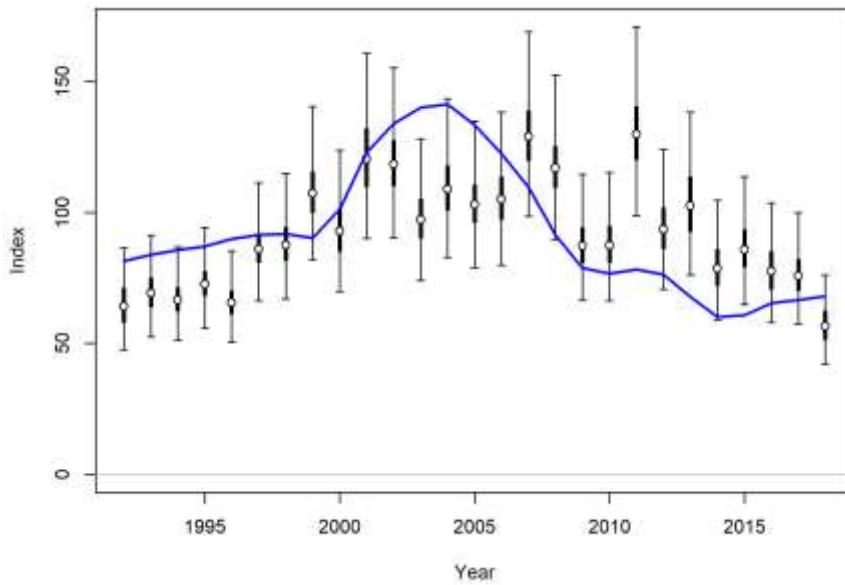


Figure 31. Model fit to standardised catch rates. Points and dark lines represent the estimate and calculated confidence intervals. Extra thin error bars represent the additional error included in the model. Model fits are illustrated with the blue line.

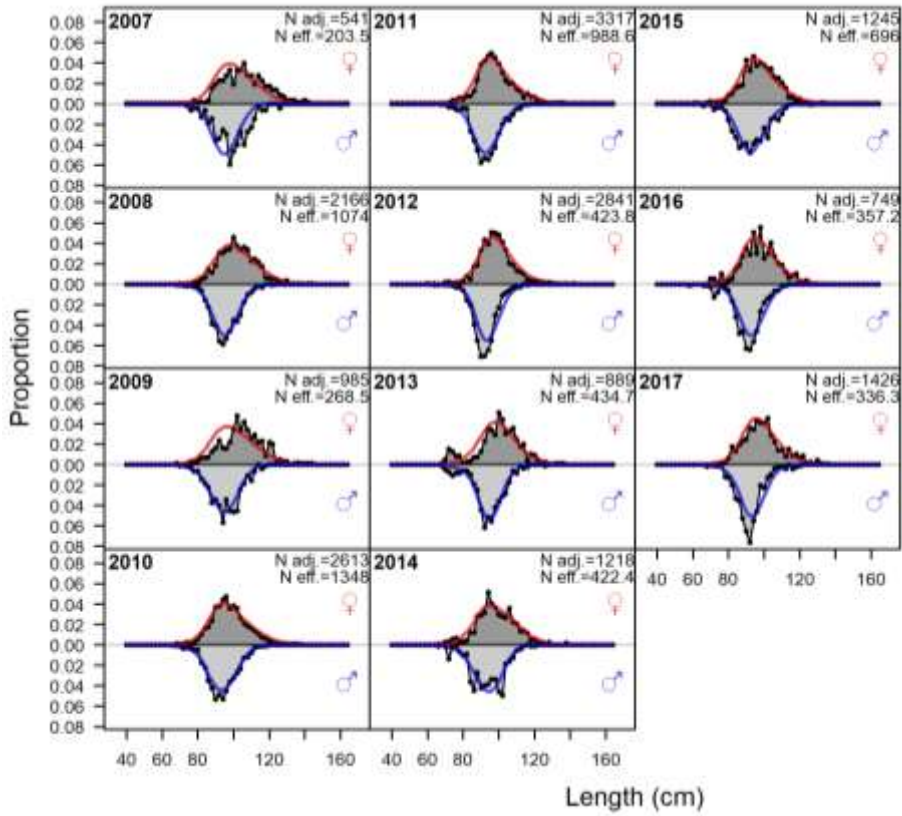


Figure 32. Model fit to length structure data for both females (red) and males (blue). Measured lengths are the shaded areas, while lines depict the model fit to the data. Stage 1 and adjusted effective sample sizes are listed for each year.

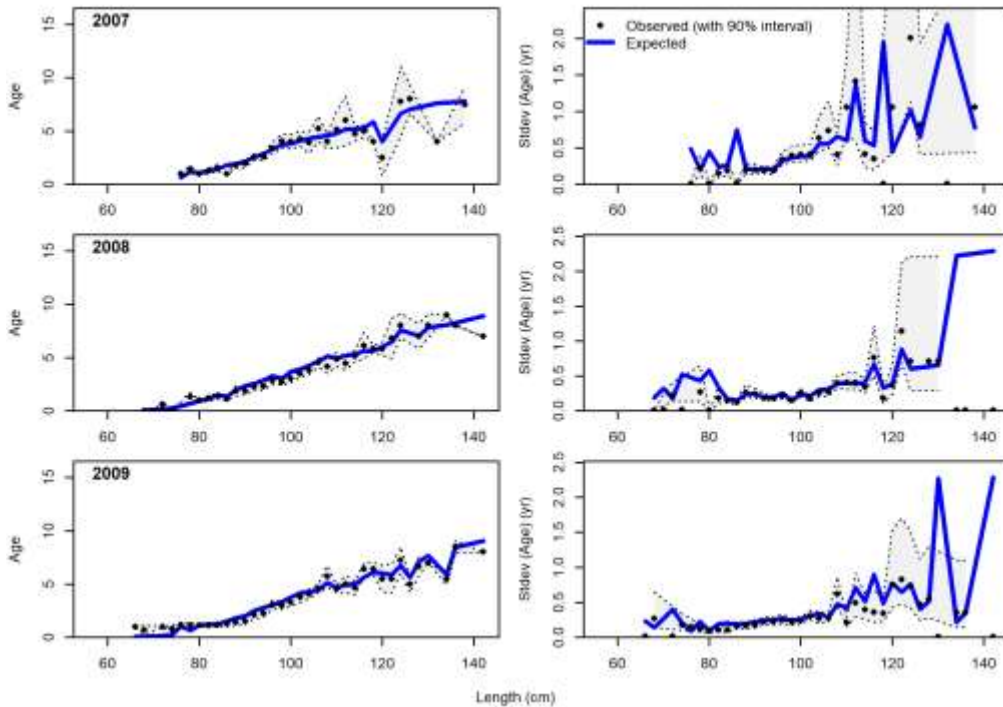


Figure 33. Model fit to conditional age at length data between 2007 and 2009. Left panels depict model fit to the data, while right hand panels depict changes in standard error with age and length.

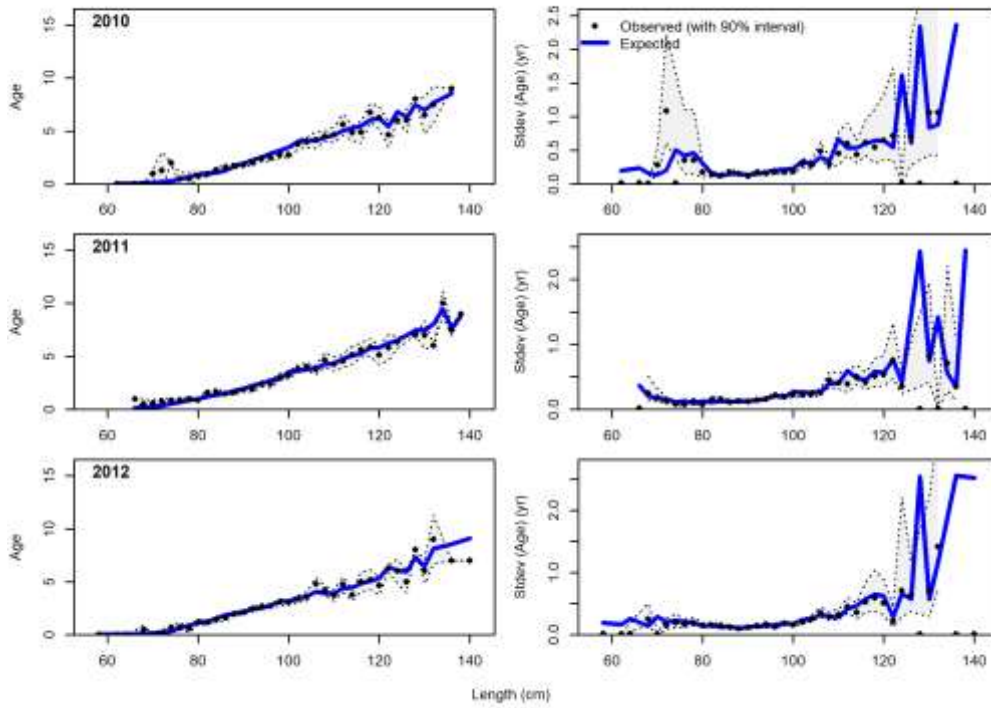


Figure 34. Model fit to conditional age at length data between 2010 and 2012. Left panels depict model fit to the data, while right hand panels depict changes in standard error with age and length.

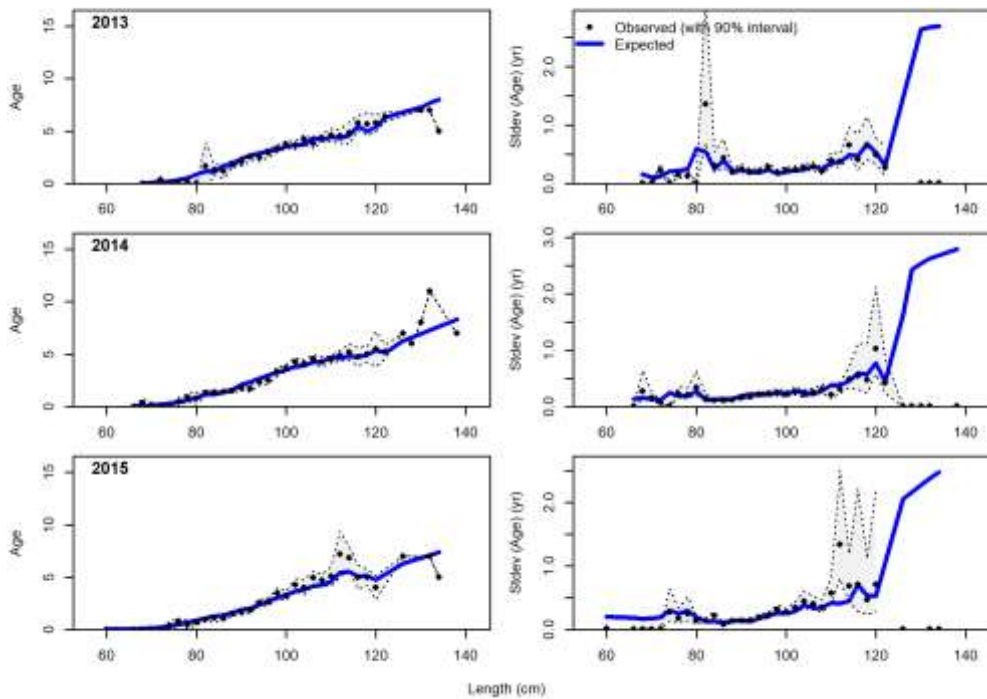


Figure 35. Model fit to conditional age at length data between 2013 and 2015. Left panels depict model fit to the data, while right hand panels depict changes in standard error with age and length.

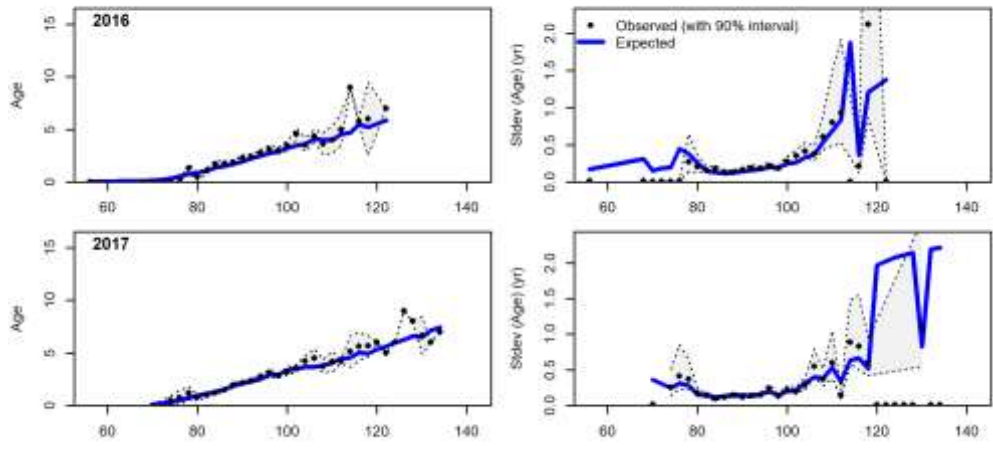


Figure 36. Model fit to conditional age at length data between 2016 and 2017. Left panels depict model fit to the data, while right hand panels depict changes in standard error with age and length.

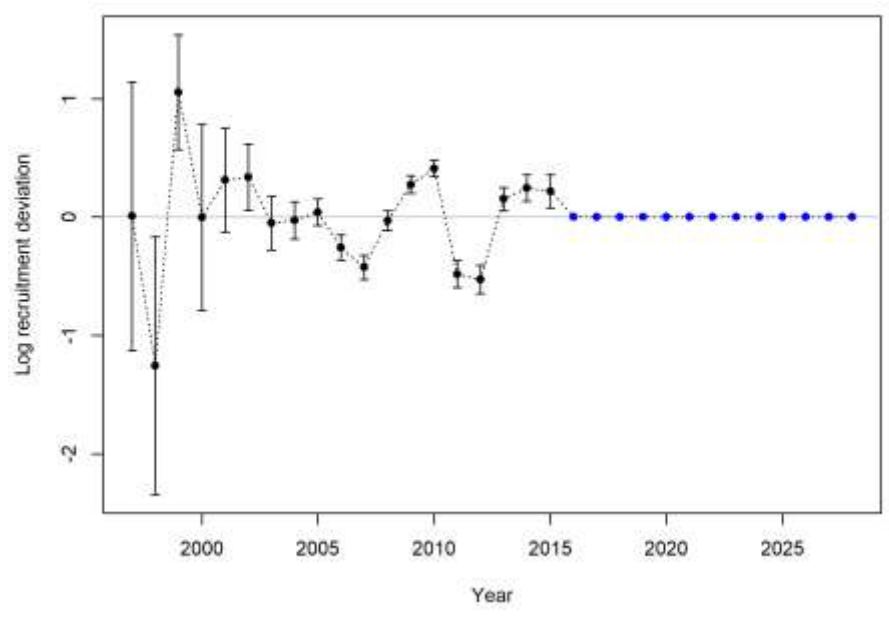


Figure 37. Estimated log recruitment deviations by the model.

# 5 Conclusion

The SS training was successful. All staff completed certification of achievement in the use of SS, the instructors provided a high level of training, six finfish stock assessments were trialled through the 5-day course, and individual feedback reported on the species/fisheries for which SS will be able to assess. All DAF and CARM staff are familiar with the SS methodology and assumptions. Further applied work is required to attain proficiency. The one-week training exercise was costly tallying about \$77,000, mostly for CSIRO teaching; and staff time on top of this.

SS can play an important role in DAF stock assessments. Based on DAF's initial list for stock assessment, SS could potentially assess 50–60% of the species (Table 6). However, some time ( $\geq 2$  months) is required to verify any new SS application against current DAF models. This is to ensure the complex data input files operate correctly.

For any SS training nationally, other jurisdictions need to clarify their expected use of the software (like in Table 6). For finfish, the potential use of SS by other jurisdictions might be similar to Qld DAF. In addition, stock assessment outputs need to have relevance in management procedures, to justify staff cost and time investment in the SS software. This is the case for Qld DAF. Initially, DAF does not expect SS to speed up stock assessments. However, reassessments with streamlining should reduce the time to complete stock assessment work.

From the training workshop, we suggest species for SS should not be short-lived ( $< 3$  or  $4$  years longevity). Short-lived species require seasonal population dynamics (e.g. monthly). Annual dynamics are more usual in SS, matched by fish catch, catch rate, age-length data and growth curves.

Core features in SS appear solid, and r4ss provides important visualisation to review SS outputs. SS use would be quite tedious without it. SS supports DAF data and reference points. Initial setup of data and control files are labour intensive. However, DAF have tested code to streamline creation of the SS data input file. This was applied in the case study stock assessments in the training workshop. The control file requires continued checking to reduce the chance of errors and maintain consistency of outputs.

Overall, SS can potentially provide a national platform for finfish stock assessment. However, this does require further discussion under the FRDC 2014-039 recommendation - national committee established for stock assessment collaborations and review processes; this suggestion has not yet been actioned.

Table 6. Example list of DAF stock assessment species and potential SS application. Custom = DAF model, SS = Stock Synthesis, to be verified against any existing DAF model, and SPR signifies spawner-per-recruit evaluation for the data limited species with no existing assessment model and SS might be applicable.

No.	Species	Model
1	Banana prawn	Custom
2	Barramundi	SS
3	Black jewfish	SPR or SS
4	Blue swimmer crab	Custom
5	Coral trout	Custom or SS
6	Crimson snapper	SS
7	Dusky flathead	SS
8	Eastern king prawn	Custom
9	Grey mackerel	SS
10	King threadfin	SPR or SS
11	Moreton Bay Bug	Custom
12	Mud crab	Custom
13	Other prawns	Custom
14	Pearl perch	SS
15	Red Emperor	SS
16	Red throat emperor	SS
17	Saddletail snapper	SS
18	Sand whiting	SS
19	Saucer scallop	Custom
20	School mackerel	SS
21	Sea cucumber	Custom
22	Sea mullet	SS
23	Sharks	Custom
24	Snapper	SS
25	Spangled emperor	SPR or SS
26	Spanish mackerel	SS
27	Spanner crab	Custom
28	Spotted mackerel	SS
29	Stout whiting	SS
30	Stripey snapper	SPR or SS
31	Tailor	SS
32	Tiger prawn	Custom
33	Tropical rock lobster	Custom
34	Yellowfin bream	SS



# 6 Implications

It was difficult to quantify the outcomes of the research in terms of dollar value. However, adoption and use of SS may result in the following:

1. Outputs from SS assessment will inform new management procedures; designed under the Queensland Government's Sustainable Fisheries Strategy.
2. Consistency of outputs due to the r4ss package, which will increase stakeholder understanding.
3. Increased confidence in our work using globally recognised methodology.
4. Increased ability to collaborate cross jurisdictionally due to shared understanding of model inputs, outputs and model techniques.
5. Easier of peer review process.

# 7 Recommendations

Most of the following recommendations are for DAF, but also relevant for national ideas on stock assessment. Aspects maybe important for the national Research Providers Network (RPN defined in the glossary).

1. DAF and FRDC through the National Research Providers Network discuss ideas for a national platform for stock assessment. This relates to FRDC 2014-039 recommendation - national committee established for stock assessment collaborations and review processes. This suggestion has not yet been actioned. Questions on stock assessment methods, consistency, repeatability, review and modernisation preferably need national views. Discussions on national SS use and training ideas are relevant. A national species stock-assessment schedule and list of data and suitable methodology such as using SS would support national discussions and collaborations.
2. DAF to develop an assessment schedule based on staff availability and the most appropriate assessment method (completed and available from Sue Helmke).
3. For the interim, awaiting on recommendation 1, DAF to continue developing new assessments that are not suitable for stock synthesis. Key stock assessment modellers and stock assessment managers will determine the process of deciding if a stock is not suitable for stock synthesis.
4. Investigate the implementation of a peer review system for stock assessments.
5. DAF to develop a guide for what is required for a new stock assessment, an improved stock assessment and a stock assessment update.
6. Continue to work towards streamlining stock assessments and data inputs, and reporting components of stock assessments.
7. Investigate an annual team session to showcase recent assessments, provide advice on improvements and plan future assessments.
8. Obtain a copy of the USA stock assessment process Terms of Reference.

## 8 Extension and Adoption

Detailed extension activities are not required for the training course. However, the following is noted.

The project was, and will continue to be extended and communicated to the end users, such as fishery managers, other researchers and agencies, industry, and where applicable the broader community.

The direct beneficiaries of the SS training, by completing future stock assessments, are Fisheries Queensland, the SFS fishery working groups, and the fishing sectors. Fisheries Queensland know the findings from the SS training. Internal DAF media was published on the 19<sup>th</sup> September (see below, Figure 38). In addition, a public media article may be published by FRDC on success and findings of SS training.

From this report, the outcomes from the training will be extended to FRDC, FRDC Qld RAC, and the DAF SFS expert panel. DAF is attending the November CAPAM meeting in November 2019 New Zealand. Our experiences with SS will help discuss next generation stock assessment models.

The training provided a number of benefits, and updated our understanding and expectations of stock assessment. Principally, this was:

- Detailed specifications for future stock-assessment using SS. This will enable Government and industry to better plan and use outputs through a harvest strategy framework (HS).
- Aspects herein have, and will continue to help stock assessment procedures. This includes improved procedures for indicators, reference points and harvest control rules.

# The science behind sustainable fisheries

19 Sep 2019

Queensland's leading fisheries scientists recently attended a workshop on stock synthesis software.

Like 7 likes

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DAF and University of Queensland workshop attendees

At the end of August, scientists from Fisheries Queensland, Agri-Science Queensland and The University of Queensland attended a workshop on stock synthesis software at the Maroochy Research Facility.

The workshop was conducted by internationally recognised fisheries modeller Professor Andre Punt (University of Washington) through CSIRO, and was jointly funded by the Fisheries Research and Development Corporation and the Department of Agriculture and Fisheries (with Agri-Science Queensland a key contributor).

Fish stock assessments require the analysis of a wide range of data to describe fish populations and estimate quota harvest levels, helping to set sustainable levels of fishing. Fisheries Queensland and University of Queensland scientists currently use several off-the-shelf and custom fisheries software packages to conduct these stock assessments.

Stock synthesis is a statistical age-structured population model that is used to manage a wide variety of fisheries around the world. It can operate in data-weak situations, uses simple or complex models, and estimates fishery management quantities (such as recommended harvests). During the five-day workshop, the software was tested on coral trout, barramundi, sea mullet, Spanish mackerel and tailor.

Fisheries Queensland will be using this software in upcoming stock assessments.

## For more information

Author:	Danielle Jones
Email:	danielle.jones@daf.qld.gov.au
Business unit:	Department of Agriculture and Fisheries
Approving Manager:	Claire Andersen

Report this story

Last updated 19 September 2019

Figure 38. Internal DAF media on SS training.

## 9 References

- Methot Jr, R. D., and Taylor, I. G. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. *Canadian Journal of Fisheries and Aquatic Sciences*, 68: 1744-1760.
- Methot, R. D., and Wetzel, C. R. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. *Fisheries Research*, 142: 86-99.
- Methot, R. D., Wetzel, C. R., and Taylor, I. G. 2019. Stock synthesis user manual version 3.30.13. NOAA Fisheries. U.S. Department of Commerce. Last accessed 19/09/2019, <https://vlab.ncep.noaa.gov/web/stock-synthesis>. p. 210.

# 10 Appendices

## **10.1 List of researchers and project staff**

**Dr Michael O'Neill**, Senior Principal Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Ms Sue Helmke**, Manager Stock Assessment, Department of Agriculture and Fisheries, Queensland.

**Ms Robyn Lovett**, Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Dr Pia Bessell-Browne**, Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Dr Sabrina Streipert**, Lecturer, Centre for Applications in Natural Resource Mathematics (CARM) School of Mathematics and Physics, The University of Queensland.

**Dr George Leigh**, Principal Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Dr Alex Campbell**, Principal Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Ms Amanda Northrop**, Senior Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Dr Joanne Wortmann**, Senior Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Dr Fay Helidoniotis**, Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Dr Wen-Hsi Yang**, Research Fellow, CARM, The University of Queensland.

**Dr Matthew Holden**, Lecturer, CARM, The University of Queensland.

**Ms Samara French**, Fisheries Scientist, Department of Agriculture and Fisheries, Queensland.

**Dr Paul Palmer**, Senior Principal Scientist, Department of Agriculture and Fisheries, Queensland.

## **10.2 Intellectual property**

The project produced no marketable intellectual property.

# 10.3 Training feedback form – Survey Monkey

## Stock Synthesis training workshop feedback

1. How did you find the following aspects of the course?

	1 - Very poor	2	3	4	5 - Excellent	NA
Course organisation:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sequential presentation of concepts:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Explanation by Instructors:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Instructor's ability to present alternative explanations when needed:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Instructor's use of examples and illustrations:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quality of questions or problems raised by the instructor:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contribution of assignments to understanding course content:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Instructor's enthusiasm:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Instructor's ability to deal with student difficulties:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Answers to student questions:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Availability of extra help when needed:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Use of class time:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Instructor's interest in whether students learned:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Amount you learned in the course:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relevance and usefulness of course content:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Evaluative and grading techniques (tests, papers, projects, etc.):	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reasonableness of assigned work:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Clarity of student responsibilities and requirements:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

\* 2. Was the course intellectually stimulating?

- Yes
- No

Why or why not?

3. Did the course stretch your thinking?

- Yes
- No

Why or why not?

4. What aspects of the course contributed most to your learning?

5. What aspects of the course detracted from your learning?

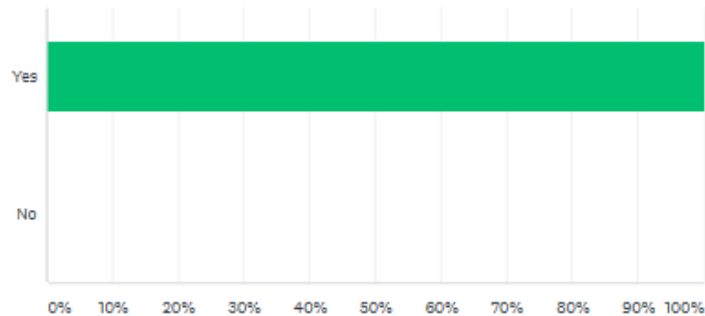
6. What suggestions do you have for improving the course?





## Was the course intellectually stimulating?

Answered: 12 Skipped: 0



ANSWER CHOICES	RESPONSES
Yes	100.00% 12
No	0.00% 0
<b>TOTAL</b>	<b>12</b>

[Comments \(7\)](#)

Showing 7 responses

The course helped me expand my knowledge about fisheries modelling. Stock Synthesis provides many tools, such as recruitment and selectivity functions, for users to develop stock models for their fisheries. From this course, I learned many new functions which I did not know before.

9/10/2019 1:09 PM

[View respondent's answers](#) [Add tags](#)

Applied and relevant

9/3/2019 6:35 PM

[View respondent's answers](#) [Add tags](#)

Yes, As well as being technical and focussed for the QLD fishery the course also factored in a wide variety of applications for different fish stocks both domestically and internationally. As well as being scientifically focused it we received valuable insights into how it aligned to management and Policy

9/2/2019 10:02 AM

[View respondent's answers](#) [Add tags](#)

Throughout the course the instructor kept us all engaged and wanting to learn more and improve our skills further.

Andre walked the balance of being theoretical as well as practical.

8/30/2019 2:45 PM

[View respondent's answers](#)

[Add tags](#)

Although I wasn't part of the training I found the course very engaging.

8/30/2019 11:38 AM

[View respondent's answers](#)

[Add tags](#)

The presenters described not only the course material but a lot of background about how things are done in their parts of the world and how the software was developed to meet their needs.

8/30/2019 11:33 AM

[View respondent's answers](#)

[Add tags](#)

Q3

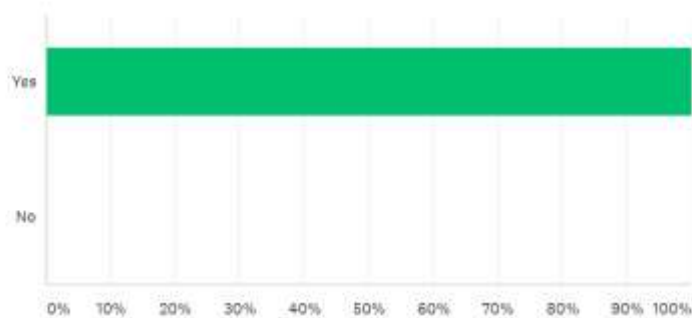


Customize

Save as

## Did the course stretch your thinking?

Answered: 12 Skipped: 0



ANSWER CHOICES	RESPONSES
Yes	100.00% 12
No	0.00% 0
<b>TOTAL</b>	<b>12</b>

Stock modelling comprises the information of the biology and management for the studying fisheries. Stock modelling also integrates the information of data from commercial and recreational fishing as well as surveys. So, it is important to examine whether the developed model reflects the biology and management of the fisheries as expected. And, it is critical but difficult to identify if the model grasps right data information to reveal the abundance of the studying population. A complete stock assessment should cover these two tasks.

9/10/2019 1:09 PM

[View respondent's answers](#)

[Add tags](#)

Some new theory and concepts. Plus provided overseas context.

9/3/2019 5:35 PM

[View respondent's answers](#)

[Add tags](#)

yes because I didn't realise that stock synthesis could do as much as it could. And this was made possible by being in a team/group environment as well as the depth of knowledge and experience of the instructors

9/2/2019 10:02 AM

[View respondent's answers](#)

[Add tags](#)

**There was always something new to learn after solving a problem.**

9/2/2019 7:32 AM

[View respondent's answers](#)

[Add tags](#) ▼

---

**Andre explained concepts extremely well.**

8/30/2019 2:45 PM

[View respondent's answers](#)

[Add tags](#) ▼

---

**Some of the concepts and approaches to understanding the fishery dynamics were very interesting.**

8/30/2019 11:38 AM

[View respondent's answers](#)

[Add tags](#) ▼

---

**We learnt about the capabilities of the software.**

8/30/2019 11:33 AM

[View respondent's answers](#)

[Add tags](#) ▼

---


# What aspects of the course contributed most to your learning?

Answered: 10 Skipped: 2

**RESPONSES (10)** WORD CLOUD TAGS (0)

 Sentiments: OFF 

Apply to selected ▾ Filter by tag ▾

Search responses 

Showing 10 responses

- The two instructors' knowledge and experiences in using Stock Synthesis for fisheries stock assessments were helpful for my learning.  
9/10/2019 1:09 PM [View respondent's answers](#) Add tags ▾
- Visual running of SS  
9/3/2019 5:35 PM [View respondent's answers](#) Add tags ▾
- Being with a group made up of enthusiastic and capable people. Being taught by world class instructors  
9/2/2019 10:02 AM [View respondent's answers](#) Add tags ▾
- Working through our specific species example.  
9/2/2019 9:45 AM [View respondent's answers](#) Add tags ▾

Background of how and why the software was developed. Appreciation of how users generally do things, e.g., directly editing the control file.

8/30/2019 11:33 AM

[View respondent's answers](#) [Add tags](#) ▼

---

Harvest control rule discussion and quick responses to questions

8/30/2019 11:28 AM

[View respondent's answers](#) [Add tags](#) ▼

---

The helpfulness of instructors when I came across a problem or something I didn't understand.

9/2/2019 7:32 AM

[View respondent's answers](#) [Add tags](#) ▼

---

working with our own data sets

9/1/2019 11:24 PM

[View respondent's answers](#) [Add tags](#) ▼

---

All of it contributed

8/30/2019 2:45 PM

[View respondent's answers](#) [Add tags](#) ▼

---

The explanation of the outputs and also troubleshooting Qld assessments

8/30/2019 11:38 AM

[View respondent's answers](#) [Add tags](#) ▼

---

Nothing.  
9/2/2019 7:32 AM [View respondent's answers](#) [Add tags](#) ▼

---

There were no detractions  
8/30/2019 2:45 PM [View respondent's answers](#) [Add tags](#) ▼

---

Not being able to work on a particular assessment. :)  
8/30/2019 11:38 AM [View respondent's answers](#) [Add tags](#) ▼

---

None  
8/30/2019 11:33 AM [View respondent's answers](#) [Add tags](#) ▼

---

## What aspects of the course detracted from your learning?

Answered: 9 Skipped: 3

**RESPONSES (9)** WORD CLOUD TAGS (0)

 Sentiments: OFF 

Apply to selected Filter by tag ▼

Search responses 

Showing 9 responses

- |                          |   |                    |   |   |
|--------------------------|---|--------------------|---|---|
| <input type="checkbox"/> | None.   | 9/10/2019 1:09 PM  | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |
| <input type="checkbox"/> | Unsure if everyone was keeping up. I was worried about this. And a bit rushed in parts.   | 9/3/2019 5:35 PM   | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |
| <input type="checkbox"/> | the issue with software compatibility (r4ss being incompatible with Rstudio) and computer power might have been temporarily detracting. However this had nothing to do with the course content itself | 9/2/2019 10:02 AM  | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |
| <input type="checkbox"/> | By the second half of the afternoon I battled to concentrate.   | 9/2/2019 9:45 AM   | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |
| <input type="checkbox"/> | Nothing.  | 9/2/2019 7:32 AM   | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |
| <input type="checkbox"/> | There were no detractions   | 8/30/2019 2:45 PM  | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |
| <input type="checkbox"/> | Not being able to work on a particular assessment. :)   | 8/30/2019 11:38 AM | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |
| <input type="checkbox"/> | None  | 8/30/2019 11:33 AM | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |
| <input type="checkbox"/> | Lack of clarity in what to focus on   | 8/30/2019 11:28 AM | <a href="#">View respondent's answers</a> | <a href="#">Add tags <span style="font-size: 0.8em;">▼</span></a> |


## What suggestions do you have for improving the course?

Answered: 7 Skipped: 5

**RESPONSES (7)** WORD CLOUD TAGS (0)

 Sentiments: OFF 

Apply to selected ▾ Filter by tag ▾

Search responses 

Showing 7 responses

The instructors were excellent, and the in-class materials were well prepared. However, I think this course is good for people having experiences in stock assessments. People with no experience will have difficulties to digest in class. The input files of Stock Synthesis are very complicated. Users need time to be familiar with those files. I wonder whether in the future the Stock Synthesis course can provide two levels: introduction and intermediate level.

9/10/2019 1:09 PM

[View respondent's answers](#) [Add tags](#) ▾

More time. Two or three separate training sessions needed.

9/3/2019 5:35 PM

[View respondent's answers](#) [Add tags](#) ▾

I think that assignment K was a good way to start delving into different methods, incorporating environmental features. The good thing about assignment K is that it was organised in bite sized tasks. So more bite size tasks like this might be helpful

9/2/2019 10:02 AM

[View respondent's answers](#) [Add tags](#) ▾



Have the course for longer, with shorter days and an afternoon off in the middle for time to revise and process the information presented.

9/2/2019 9:45 AM

[View respondent's answers](#) [Add tags](#) ▼

---

A wider range of worked through examples, as Stock Synthesis has many options it would have been helpful to see how and why a wider range of these options should be used.

9/2/2019 7:32 AM

[View respondent's answers](#) [Add tags](#) ▼

---

Maybe distribute some example control files that illustrate how to do certain things. These examples don't have to be worked through in class.

8/30/2019 11:33 AM

[View respondent's answers](#) [Add tags](#) ▼

---

Clearer separation between time spent learning from provided material and time dedicated to progressing own assessments. Perhaps a greater focus on the latter for a group like ours

8/30/2019 11:28 AM

[View respondent's answers](#) [Add tags](#) ▼

---

## 10.4 Training certificates



# Certificate of Achievement

Awarded to

**Dr Michael O'Neill**

for successfully demonstrating the ability  
to create a fisheries assessment in Stock  
Synthesis 3

26-30 August 2019

Nambour, Queensland

Andre Punt, Jemery Day  
Oceans & Atmosphere

CSIRO Australia's National Science Agency

