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Scoping the Next Generation of Tuna Stock Assessment Software: Progress Report and Outline of Options (Project 123)

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1 Executive summary

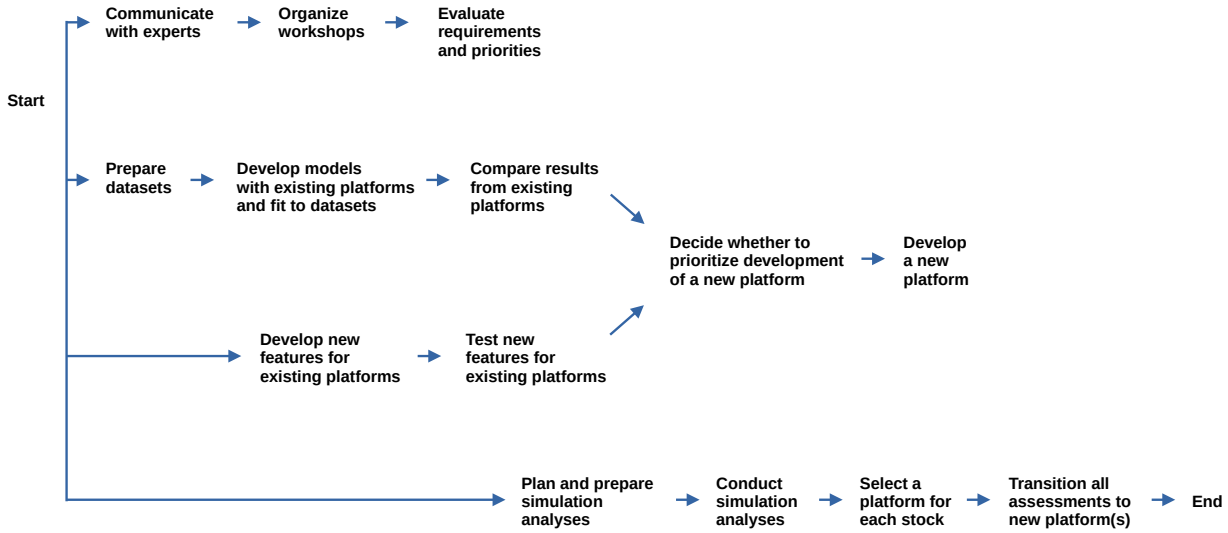

Figure 1: Overview of tasks related to the next generation of tuna stock assessment software. Project 123 will focus on the first line of scoping tasks (communicate, organize, evaluate) and prepare the ground for subsequent lines of tasks (the main project), which will require additional funding and resources.

2 Introduction

2.1 The need to migrate to new software

Following the retirement of the lead developer of MULTIFAN-CL (MFCL), Dave Fournier, future advances to the MFCL software are not expected to be as mathematically innovative as they were in the past. While this does not render MFCL obsolete in the medium-term, it flags the need to plan and identify whether alternative existing software exists, or new software must be developed in the longer-term, to continue to support the specificities and future requirements of WCPFC tuna stock assessments.

While MFCL (Fournier et al. 1998) continues to be improved to service the WCPFC tuna assessment needs over at least the next 5+ years, it is important to start on a phased approach to its replacement. An initial scoping phase is required to assess what features and capabilities will be important in future assessment software for tunas. This scoping phase will benefit from input from stock assessment scientists across global tuna RFMOs. Once this scoping phase is conducted, consideration of available software packages in relation to the desired features and capabilities can be conducted. This may identify suitable existing software that has potential to provide the desired features and/or has potential to be developed further. Alternatively, it may indicate whether embarking on development of a new software package is recommended.

There has also been discussion around the need to explore, through modeling/simulation exercises, the benefits of applying alternative assessment structures (i.e., length-age structured versus the traditional length-based age-structured approach of MFCL and Stock Synthesis) before embarking on major software developments or changing methodology. Similar can be said about exploring benefits of state-space models and their use of random variables. Simulation exercises to explore the benefits or drawbacks of alternative model structures or approaches will also require collaboration across tuna RFMOs and experienced practitioners using the alternative approaches and/or software.

An important outcome of this work would be to ultimately have a software package that has the desired functionality for tuna assessments, not only for WCPFC, but globally, thus creating a user community and ongoing development support capacity, so as to avoid the current situation we are facing with MFCL. Wider collaboration in this venture is essential to achieving this and is expected to be encouraged through this project.

2.2 Project outline

The project is divided into stages, as follows:

Year 2024

1. Review and identify a list of necessary and desired features for software to conduct tuna stock assessments.
2. Identify existing software platforms that have some or all these features or can be extended to add such features.
3. Reach out to and initiate collaboration with developers who are already exploring extensions to current age-structured catch-at-age and state-space models that would allow those models to fit to length data.
4. Conduct two workshops with selected experts from other tuna RFMOs and or with relevant expertise. The first workshop can be remote (prior to SC20) and the second one potentially in person (post SC20). The main goal will be to plan and document collaborative simulation studies to evaluate the performance of candidate software platforms for tuna stock assessments.

Years 2025 and 2026 (subject to SC advice and funding approvals by WCPFC)

5. Conduct the simulation studies outlined in stage 4, in collaboration with experts that are supported by other agencies/RFMOs.
6. Based on the results from simulation studies, determine which, if any, software platforms can be considered viable candidate platforms for WCPFC tuna assessments.
7. If a viable candidate platform has been identified, provide a plan to transition assessments to this software. Evaluate which transitioned assessments could replace old MFCL assessments and build the transition into the WCPFC assessment schedule.

8. If no viable candidate platform is identified, further extensions to existing platforms may be required, or the development of a new assessment software platform. The design process for a new platform would require additional development workshops and involvement of software developers (additional funds likely required) and could include identification of MFCL features and algorithms that can be borrowed and ported across to a new framework.

2.3 Existing software

The CAPAM 2019 Workshop on Next Generation Assessment Models (Punt et al. 2020) provided an overview and discussion of existing software, as well as recommendations for further software development.

For the purposes of tuna assessments, the most relevant existing software (other than MFCL) includes:

- **Stock Synthesis** is used in tuna assessments by the IATTC, IOTC, and ICCAT. Migrating SPC assessments to Stock Synthesis would lose some of the features provided by MFCL and this would be transitioning to another platform that is expected to phased out in the not-too-distant future. On the other hand, increased use of Stock Synthesis at SPC would facilitate collaboration between the tRFMOs, including development of future models. It would also shorten the training time for new SPC stock assessors and make their skills and experience more transferable to subsequent workplaces. Stock Synthesis has a large user community that is relevant for peer reviews and discussing technical decisions. It also comes with a suite of tools useful for diagnostics and automated plots and tables for assessment reports.
- **sbt** is used in the assessment of southern bluefin tuna by CCSBT. This package, implemented in TMB, stands out as the primary stock assessment software that is built around close-kin mark-recapture (CKMR) which is a new and important data type in upcoming SPC tuna assessments. The `sbt` R package is designed for a single-region assessment and would require some additional development to be used for a multiregion assessment.
- **Gadget3** is the Gadget stock assessment platform implemented in TMB. Porting the software to TMB has resulted in a significant performance gain in terms of computational time. Gadget has a wide range of features relevant for tuna assessments and there is interest from SPC and the Gadget maintainers to test its use for a tuna assessment.
- **Casal2** is the Casal stock assessment platform rewritten with an improved design and user interface. Casal has a wide range of features relevant for tuna assessments and there is interest from SPC and the Casal maintainers to test its use for a tuna assessment.

2.4 Ongoing and upcoming software development

Some ongoing software development projects are of particular interest in the context of the next SPC tuna assessment models:

- **ALSCL** is a basic model that has two important features: state-space formulation and age-length structure. The current implementation fits only to survey data and does not include commercial catches or fleets.
- **Stock Synthesis with Enhanced Tags**
- **WHAM with Tags**
- **SAM with Tags**

3 Possible tasks for SPC to prioritize

3.1 Migrating assessments to existing software

3.2 Developing new software

4 Timeline

4.1 International expert meeting 2024

4.1.1 Objectives

The meeting objectives were:

1. Communicate SPC scoping project and upcoming explorations, decisions, and development.
2. Discuss succession plans for MULTIFAN-CL as well as Stock Synthesis.
3. Seek advice from the scientific community.
4. Seek collaboration with tuna RFMOs and various research labs.

4.1.2 Format

Two online meetings were held on 13 May and 18 June, inviting stock assessment and software development experts from around the world. The two sessions had the same format and agenda, but one was centered on European time zones and the other on North American time zones. Around 40 participants represented the tuna RFMOs (CCSBT, IATTC, ICCAT, IOTC, WCPFC), stock assessment software projects (ALSCL, CASAL, FIMS, Gadget, MFCL, SAM, sbt, Stock Synthesis, WHAM), and maintainers of relevant programming languages (ADMB, RTMB, TMB).

The meeting agenda covered the following discussion topics:

- Platforms currently used in tuna stock assessments
- Common challenges for all tuna RFMOs, longevity of Stock Synthesis and MULTIFAN-CL, succession plans
- SPC challenges and project plan

- Features of current and future platforms
- Discussion on platform features most relevant for tuna
- State-space models and latest developments
- What do you think is the best way forward for SPC?
- Summary of discussions, next steps, collaboration

4.1.3 Outcomes

There was a consensus among the experts that the goal should be to design and develop a model specific for tuna assessments, rather than a general model for global usage and all species. The advice was to start with a lean design and get a simple model up and running before adding all the features required for an assessment. In general, the cost of adding features is much greater than the implementation cost, as each layer complexity makes long-term maintenance and future modifications of the software more difficult and costly.

RTMB (Kristensen 2024) is a new alternative interface for developing TMB (Kristensen et al. 2017) models. RTMB provides a leaner development paradigm than TMB. The recommendation from the TMB/RTMB development team, articulated at the expert meeting, was to develop the next tuna stock assessment model in RTMB rather than TMB.

State-space models are a statistically and computationally efficient way to allow time-varying processes in stock assessment models, such as time-varying selectivity. Other statistical approaches exist, but the successful track record of using state-space models in production assessments, e.g., across a variety of Atlantic groundfish stocks, indicates that state-space formulation can be recommended for new model development.

Age-length structure is explicitly tracked in Gadget models, accounting for the fact that fast-growing individuals are caught by the fishery and the slow-growing individuals in the cohort remain in the population. Casal and Stock Synthesis have optional model features with a similar aim. This leads to an improved level of realism, and simulations with a very basic model ALSCL (Zhang and Cadigan 2022) indicate improved estimation accuracy.

It is worth noting that the ALSCL simulation study involved a single-area model with survey data and no commercial catch data or fleets, which is quite far from the model complexity of tuna assessments.

An important drawback is that tracking the population structure in terms of age and length, instead of age only, comes at a considerable computational cost. The SPC tuna assessment models that are currently run in MFCL are already very computationally heavy, with models requiring to run overnight before results are available. The recommendation is to explore the feature of incorporating full age-length structure in the next tuna assessment models, considering estimation performance

and the difference in the resulting management advice, as well as computational time, required software development, and maintenance cost.

The discussion at the international expert meeting covered several other topics, but the above recommendations are particularly relevant for upcoming explorations and initial development. In addition to the discussion and recommendations, an important outcome of the international expert meeting was to establish collaboration with various research labs related to the development of new tuna assessment models. See next section.

4.2 Workshop activities in 2024–2026

4.3 Launching the main project

5 Required resources

5.1 Collaboration with other tRFMOs

5.2 SPC staff positions, consultants

6 References

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