Western and Central Pacific Fisheries Commission

SCIENTIFIC COMMITTEE
TWENTY-FIRST REGULAR SESSION

Nuku'alofa, Tonga
13–21 August 2025

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

WCPFC-SC21-2025/SA-WP-01
17 July 2025

A. Magnusson[1], **N. Davies**[2], **G. Pilling**[1], **P. Hamer**[1]

[1]Oceanic Fisheries Programme of the Pacific Community
[2]TeTakina Ltd

Contents

1 Executive summary

The 3-year Project 123 aims to evaluate features and capabilities that will be important in future tuna assessments, explore fitting models to tuna data using existing software platforms, guide decisions on the type of new software development required, and establish collaboration with tuna Regional Fisheries Management Organizations (RFMOs) and research labs to achieve these goals.

At SC20, ISG-09 reviewed the scoping of next-generation tuna stock assessment software and supported prioritizing practical tasks, including transitioning swordfish and striped marlin assessments to Stock Synthesis and testing simplified models for yellowfin tuna. Members acknowledged the need to focus on immediate assessment priorities while keeping longer-term software development under consideration, depending on available resources and capacity. (SC20 Summary Report, Attachment E).

SC21 will review the progress of Project 123, which explores the transition to next-generation stock assessment software for tuna fisheries. The project report i) evaluates the benefits, limitations, uncertainties, and resource implications associated with each software platform under consideration; ii) evaluates the feasibility of analyzing tagging data independently from the main stock assessment models, a potential strategy to reduce model complexity while maintaining scientific robustness; and iii) identifies key analytical features and technical capabilities that future stock assessment platforms should incorporate, such as support for spatial structure, tagging integration, and flexibility for multi-species and multi-fleet assessments, to ensure that WCPFC assessments remain scientifically credible, transparent, and adaptable to evolving fishery and management needs.

SC21 will provide feedback on the progress of the project as needed.

We invite SC21 to:

- note that over the next 5+ years, MULTIFAN-CL will begin to be phased out as a software platform for WCPFC tuna and billfish stock assessments;
- note that in 2025, the two billfish stock assessments, swordfish and striped marlin, transitioned from MULTIFAN-CL to Stock Synthesis; and
- review and comment on two suggested software development work streams, described in this report, providing feedback that will guide the preparation of project proposals to be presented to SC22.

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 practitioners experienced in 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 also for other tuna RFMOs, 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

This initial scoping project is scheduled from 1 Feb 2024 to 31 Dec 2026. It will:

- Evaluate features and capabilities that will be important in future tuna assessments
- Explore fitting models to tuna data using existing software platforms
- Guide decisions on what kind of new software development will be required
- Establish collaboration with tRFMOs and research labs to achieve these goals

Additional projects can be launched in parallel to develop and test new software.

It is recommended that from 2027 onwards, the scoping project becomes a coordination project, until all stocks have transitioned from MULTIFAN-CL and Stock Synthesis to new software platforms.

The project is divided into stages, as follows:

Year 2024

1. Review and identify important features for tuna assessments.
2. Identify existing software platforms that have these features or can be extended.
3. Reach out to and initiate collaboration with model developers.

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

4. Explore and compare existing platforms, fitting to SPC tuna data.
5. Determine which platforms can be considered viable candidates.
6. If viable candidate platforms have been identified, plan transition.
7. If any stocks do not have a viable candidate platform for future assessments:
   ⇒ Launch software development projects to extend platforms or create new ones.

Years 2027–2029 (~~anticipating that the scoping project becomes a coordination project~~)

8. ~~Coordinate~~ ~~projects developing new software for tuna assessments.~~
9. ~~Coordinate tests and model explorations, applying existing and new software platforms to SPC datasets.~~
10. Support transition of MULTIFAN-CL ~~and Stock Synthesis~~ tuna and billfish stock assessments to new software platforms.

See also the project terms of reference in Section A.1.

3 General plan

3.1 Requirements for future assessment software

3.1.1 CAPAM 2019

The CAPAM 2019 Workshop on Next Generation Assessment Models provided an overview and discussion of existing software, as well as recommendations for further software development. The review paper resulting from this CAPAM workshop (Punt et al. 2020) identified a number of model features considered important in future stock assessment software. The abstract of the review paper lists these features:

- Ability to to capture age and size dynamics simultaneously yet computationally efficiently, while also offering the option to run a model as purely age-structured for a simple and fast model
- Scale from data-rich to data-poor
- Include some multispecies capability
- More appropriately deal with temporal variation, e.g., random effects and state-space models
- Better handling of tagging data, e.g., release-conditioned or recapture-conditioned model
- Ability to use close-kin mark-recapture data
- Efficient methods to share parameter priors among stocks, borrowing information from similar stocks where more data have been collected
- Training programs and documentation
- Data entry system that is well documented
- Does not require specification of inputs that will not be used in an application
- Expert system to configure default settings based on best practices
- Automatic production of diagnostic statistics

The summary table in Punt et al. (2020) adds the following features:

- Spatial structure
- Multiple fisheries and surveys
- Flexible parametrization of the initial conditions
- Multiple time steps within a year
- Flexible parametrization of growth
- Flexible parametrization of natural mortality

- Flexible parametrization of fecundity
- Flexible parametrization of movement
- Multiple recruitment functional forms, including nonparametric
- Selectivity as a function of age, size, or both
- Multiple selectivity functional forms, including dome-shaped and asymptotic
- Incorporation of ageing error
- Ability to simulate datasets for management strategy evaluation
- Prefer statistically based likelihood weighting over subjective choices
- Ability to evaluate uncertainty using a variety of statistical methods
- Allow time-varying processes, both in biology and fishing processes

Further in the text, Punt et al. (2020) add the following features:

- Allow for density-dependence at the spatial area level, as well as at the stock level
- Allow for nesting of spatial scales such that a population model can appropriately utilize data types collected at fine scale and coarse spatial resolutions
- Allow for multiple movement types including advection, diffusion, and that movement responds to environmental drivers
- Account for multiple hypotheses regarding movement, including age- and sex-specific processes processes, as well as density-dependent and time-varying movement

3.1.2 International Expert Meeting 2024

At the launch of this scoping project in 2024, an international expert meeting was held in two sessions. As a background for the meeting discussion, the conveners (Magnusson and Davies 2024) highlighted model features that can be especially relevant in tuna assessments:

Incorporating data

- Fit to length comps
- Fit to weight comps
- Fit to tagging data
- Fit to CKMR data
- Estimate growth curve using otolith data
- Utilize tag-recapture growth increment to estimate growth

Specifics

- Age-specific M
- Length-specific selectivity
- Sex-specific growth and M
- Region-specific growth

Dimensions

- Explicit regions with movement
- Tracking age and length in population
- Time steps within a year

Ecology

- Multispecies interactions
- Climate change

Implementation

- Random effects, state space
- Parallel computing
- Computation time

3.1.3 Conclusion

3.2 Possible outcomes and options

3.3 SPC plan for transitioning to new software

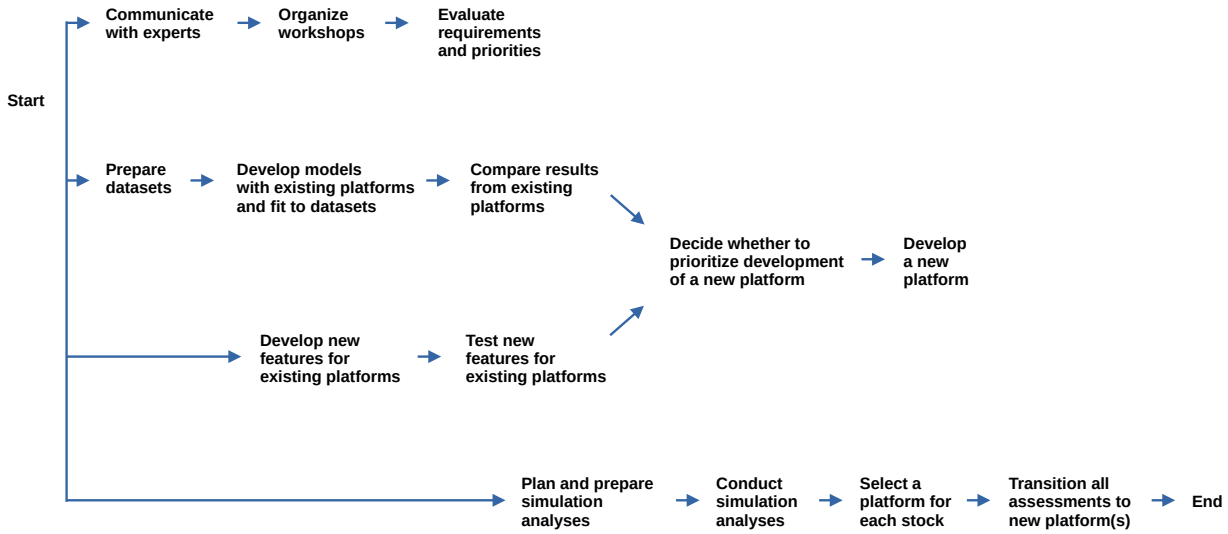

Figure 1: Overview of steps related to the next generation of tuna stock assessment software. Project 123 will focus on the first line of scoping tasks (communicate, organize, evaluate) and prepare the ground for subsequent lines of tasks (the main project), which will require additional funding and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

4 Evaluation of existing software

4.1 Stock Synthesis

Stock Synthesis 3 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 be phased out in the not-too-distant future. On the other hand, increasing the 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 assessments would allow closer comparisons of assessments conducted across RFMOs and also SPC and the ISC. Stock Synthesis has a large user community that is relevant for peer reviews and discussing technical decisions. It also comes with an exceptionally complete suite of tools useful for diagnostics, as well as automated plots and tables for assessment reports. A possible avenue of collaborative development is to explore the possibility of enhancing the tag module, see Section 5.

4.2 Gadget

Gadget 3 is the latest version of Gadget stock assessment platform, implemented in TMB. It is an age-length structured platform and 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 a possible avenue of collaborative development is to test the use of Gadget for a tuna assessment.

4.3 sbt

Used in the assessment of southern bluefin tuna by CCSBT. This package, implemented in RTMB, 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. A possible avenue of collaborative development is to explore the possibility of adding multiregion functionality to the software.

4.4 Other

- Casal 2 is the latest version of 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 a possible avenue of collaborative development is to test the use of Casal for a tuna assessment.
- Stock Synthesis + CKMR is an experimental add-on to Stock Synthesis (A.E. Punt, pers. comm), adding CKMR as a data type in Stock Synthesis. This was successful as a proof of concept, but it is unlikely to be added to the core software.
- ALSCL is a recent model (Zhang and Cadigan 2022) that has two important features: state-space formulation and age-length structure. It is implemented in TMB, but the software currently fits only to survey data and does not include commercial catches or fleets. A possible avenue of collaborative development is to explore the ability of this model to analyze a simplified tuna dataset. This would provide insights into the dynamics of fitting state-space age-length models in general and also be a first step before considering extensions to the model further, see ALSCL + Fleets below.

5 Evaluation of software in early development

5.1 FIMS

Fisheries Integrated Modeling System (FIMS) is a NOAA project that coordinates the development of a next-generation framework of stock assessment models based on TMB. So far, model development within FIMS has focused on models fitting to age data. It is not clear at this point whether the FIMS project will lead to stock assessment software that can be used in tuna

assessments, but given the considerable resources and collaborative nature of the project, SPC will communicate and interact with the FIMS project to share development progress and ideas.

5.2 DTU Movement Model

5.3 Other

- WHAM + Length is a recent software development (Correa et al. 2023) extending the state-space stock assessment software WHAM (Stock and Miller 2021) to fit to length data. A possible avenue of collaborative development is to experiment with fitting the WHAM+Length model to an SPC tuna assessment dataset.
- ALSCL + Fleets is a potential software development extending the ALSCL model to address the primary shortcomings of the current ALSCL model as candidate software for tuna stock assessments. A possible avenue of collaborative development is to explore the possibility of adding commercial catches and fleets as software features.

6 Overview of project activities

6.1 Reaching out to the scientific community

International expert meeting 2024

Two online meetings were held on 13 May and 18 June 2024, inviting stock assessment and software development experts from around the world. 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 relevant programming environments (ADMB, RTMB, TMB). See participant list in Section A.2.

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.

Format

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. 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

Outcomes

The following recommendations emerged from the discussions at the international expert meeting:

- Tuna assessment software. 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 as a lean software development paradigm. 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. Another recommendation from the TMB/RTMB development team, given the streamlined nature of RTMB model implementation is for SPC to consider writing specific models for each species, rather than a general platform for all species and tRFMOs. A specific RTMB model requires a very small codebase that is easy to maintain and modify. Parts of code can still be reused between species, either as code blocks or functions.
- State-space formulation. 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. Gadget models explicitly track the population by age and length, 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 using a very basic model ALSCL (Zhang and Cadigan 2022) indicate improved es-

timation 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.

- Simple models. SPC challenges were outlined and discussed at the meeting, focusing on the upcoming paradigm change in how stock assessments are conducted at SPC. The MFCL Team (Dave Fournier, John Hampton, Nick Davies) will be retiring in the 2020s. Other stock assessment staff tend to have a relatively quick turnover rate, often consisting of young scientists with relatively few years of stock assessment experience before they start their job at SPC. It takes many years to become an expert in MFCL, with John Hampton typically making the main modeling decisions and guiding new staff, with the help of Nick Davies. Generally, it is preferable to have some long-term staff in the stock assessment team, but it is precautionary and prudent to prepare for an era where there might be no long-term staff, only short-term. In software design terms, this would favor not only a simple and intuitive user interface but also simpler assessment models than have been used in the past.

- Collaboration between tuna RFMOs. For undertaking tuna assessments that fit to length composition data from multiple fisheries, SPC uses MFCL, while other tuna RFMOs use primarily Stock Synthesis. Both software platforms are currently in a sunset phase, heading towards end of life in the coming years. Development of new features in MFCL and Stock Synthesis is slowing down, with resources being allocated to succession plans. For SPC, it would be preferable to avoid developing and maintaining major software products that are not used outside of SPC. The statistical challenges of analyzing tuna data are comparable between the tuna RFMOs, noting some differences like degree of tagging data, so it makes sense to coordinate and collaborate in succession plans and new software development.

The discussion at the international expert meeting covered several other topics, but the above recommendations are particularly relevant for initial explorations and development. The presentations from the international expert meeting are available online (Section A.4). 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.

6.2 Reaching out to tuna RFMOs

There are significant potential benefits for the tuna RFMOs to coordinate together and collaborate on succession plans and new software development (expert meeting recommendation 6.1). Coordination and collaboration has already begun between tuna stock assessment scientists, with one-on-one consultation meetings before and after the 2024 international expert meeting.

The next step is for the tRFMOs to discuss financial and staff commitments to formalize and strengthen collaboration related to succession plans and new software development. Projects to accomplish the tasks laid out in Figure 1 will require considerable resources. To achieve the desired rate of progress and scientific quality of the end result, each tRFMO could hire/assign one full-time person to the project for five years, or until assessments have been transitioned to the new software.

6.3 Reaching out to the WCPFC Scientific Committee

SC20 in 2024

Possible tasks for SPC to prioritize

This section discusses core areas for ongoing work, and proposed activities to be considered in each area. We reiterate that progression from MFCL to an alternative software is not a 'side project' that can be subsumed within the current SSP resourcing. For this reason we suggest that a small informal working group could be convened by the SC to discuss and prioritise activities that would require additional resources, and develop TORs for priority activities.

Migrate assessments to existing software

1. Move the swordfish assessment to Stock Synthesis. The Southwest Pacific swordfish assessment model is relatively simple compared to other SPC assessments and would be a good candidate to be the first to migrate from MFCL. The 2025 swordfish assessment could be developed in a stepwise progression: previous MFCL diagnostic ⇒ catch-conditioned MFCL ⇒ Stock Synthesis.

2. Move the striped marlin assessment to Stock Synthesis. The striped marlin assessment model is also relatively simple and would be a good candidate to migrate from MFCL. The next striped marlin assessment, currently scheduled in 2029, could be developed in a stepwise progression: previous catch-conditioned MFCL diagnostic ⇒ Stock Synthesis.

Model exploration using existing software

3. Conduct model exploration to fit Casal/Gadget/Stock Synthesis to albacore tuna. The South Pacific albacore assessment model is simpler than the other tuna species and therefore a candidate to be the first tuna stock assessment to consider for migration from MFCL. Also, for the next South Pacific albacore assesmsent there may be CKMR information available to incorporate in the assessment.

4. Conduct model exploration to fit Casal/Gadget/Stock Synthesis to the original five-region yellowfin tuna dataset. The yellowfin assessment is a good candidate to test the capabilities of these software platforms for tuna assessments involving multiple regions, tags, and a large number of fisheries. The yellowfin tuna assessment is similar to bigeye tuna but runs slightly faster, thanks to the simpler five-region structure that was adopted in the 2023 assessment.

5. Conduct model exploration to fit models using a variety of existing software to a simplified single-region yellowfin tuna dataset. Models of interest include ALSCL, Casal, Gadget, MFCL, sbt, Stock Synthesis, and WHAM + Length.

Extend existing software

The benefits and rationale of the following software extensions are described in Section 5. The prioritization and duration of these tasks may depend on the initial findings of these and other tasks, available resources, and the availability of external scientists involved.

6. ALSCL + Fleets. Scientists involved could include Fan Zhang (Shanghai Ocean University) and Nick Davies (SPC consultant).

7. WHAM + Length. Scientists involved could include Giancarlo Correa (AZTI) and Arni Magnusson (SPC).

Design and develop new software for tuna assessments

10. Initial explorations using RTMB, starting with simple model development and gradually adding complexity and tests. Scientists involved could include Nick Davies (SPC consultant) and Arni Magnusson (SPC).

6.4 Workshops

The first steps in the scoping project 123 have involved a review of software needs and existing software, an evaluation of options, establishing collaborative ties with research labs, and reaching out to scientists from the other tRFMOs for coordination and consultation. We expect that presentation of the outcomes so far at SC21 will facilitate discussion and the feedback from SC will guide which of the tasks will be prioritized. Discussions at SC should help guide TORs for each year's successive work.

Hands-on technical workshops will be conducted in 2024–2026 to strengthen collaboration ties and make stepwise progress on tasks that have been selected as priorities. If prioritized, the work on migrating billfish assessments (Tasks 1–2 in the list of tas will be conducted by SPC scientists independent of project 123 workshops. Progress with model exploration using alternative software (Tasks 3–5) and software development (Tasks 6–9), if prioritized, will depend on the resources and number of staff and consultants engaged in those tasks. Another factor is the availability and commitment of external scientists and other tRFMOs.

Project 123 includes a budget that can be used to invite selected external scientists to attend technical workshops to collaborate with SPC scientists on selected tasks. A workshop might be organized for a week, either at SPC headquarters or at another convenient venue, and collaborative work conducted before, during, and after a workshop.

The first hands-on technical workshop had been planned at SPC headquarters around October–November 2024, inviting two scientists. However, the unrest in New Caledonia in 2024 will prevent such a workshop being conducted at that time.

Instead, the first hands-on technical workshop will take place in New Zealand on 23–30 August 2024, with Nick Davies (SPC consultant) and Arni Magnusson (SPC) meeting directly after the SC meeting in Manila. The main objectives are to test the functionality and capabilities of RTMB on simple models and to conduct exploratory runs of the ALSCL model. The 2024 workshop will evaluate RTMB as a programming environment and paradigm for further software development, exploring technical aspects such as whether it would be practical to organize the majority of source code behind an assessment model as scripts, a package, or more than one package. This would determine how code is maintained and shared between assessments of different species.

6.5 Evaluation of RTMB as a programming environment

6.6 Model explorations

6.7 External tagging analysis

6.8 Prototype FIMS modules

The scoping project activities related to exploring prototype FIMS modules are outlined as an initial step in a recommended work stream on developing tuna-specific FIMS modules (Section 7.1).

6.9 Outline of a possible simulation analysis

6.10 Timeline 2024–2029

Year 2024

Pre-assessment workshop 2024

An initial outline and discussion of project 123 was presented (Magnusson and Davies 2024a) at the pre-assessment workshop at SPC headquarters on 28 March 2024. It provided a summary of existing software platforms and ongoing software development projects, a roadmap of the project, and highlighted the need for increased resources needed to conduct model exploration and software development.

7 Recommended development work streams and required resources

7.1 Tuna-specific FIMS modules

Initial exploration

The FIMS project aims to provide a modular and flexible design paradigm, allowing scientists to choose and link together code modules to produce a stock assessment model that is tailored for a particular assessment. The project has currently developed a core module that allows the construction and fitting of age-structured models. Early FIMS exploratory case studies have focused on fitting to catch-at-age data, and the project is likely to initially prioritize the needs of NOAA stock assessments in U.S. waters.

For the purposes of tuna assessments, it might be possible to design and develop specific code modules to link with the FIMS core modules. Such tuna modules could potentially provide a variety of features, adding basic model extensions and/or introducing fundamental changes in the model structure.

A first step, before designing and developing full-featured code modules, is to explore the technical procedures and programming interface involved in producing FIMS modules. This initial exploration should focus on very simple additions or model modifications as a demonstration. After the technical exploration of such prototype FIMS modules, the advantages and disadvantages of tuna-specific FIMS modules can be evaluated against other forms of tuna stock assessment software development.

Development project to be launched in 2026

A preliminary outcome of the current scoping project is to recommend the development of tuna-specific code modules that can be linked with core FIMS modules to produce a model that is tailored for tuna stock assessment. Possible examples of tuna-specific FIMS modules might provide some of the following features:

- Reference points specific for a tuna RFMO
- Improved handling of tagging data
- Explicit regions with fish movement coefficients
- Explicit age-length structured population array, rather than age only

As of mid 2025, it is too early to lay out a precise work plan and budget for the development of tuna-specific FIMS code modules. However, recent milestones reached by FIMS project and discussions between SPC and the FIMS team indicate that initial explorations based around a workshop could start in late 2025 or early 2026. The SC21 meeting is an opportune time to discuss the possible prioritization and funding of this work stream that can be launched in 2026, a software development project focusing on tuna-specific FIMS modules. For this reason, we suggest that a small informal working group could be convened by the SC to discuss the potential scope, deliverables, timeline,

resources, and draft TORs for this work stream, which has the potential to lead to the development of stock assessment software to be used in future tuna assessments.

The development work on tuna-specific FIMS modules could be carried out by a consultant, working at SPC headquarters or remotely.

7.2 DTU spatio-temporal full assessment model

Initial development

A workshop in 2025 initiated a collaboration between SPC and statisticians at the Technical University of Denmark (DTU), Tobias Mildenberger and Anders Nielsen, to employ a spatio-temporal movement model to analyze tuna tagging data. The workshop and subsequent discussions focus on WCPO skipjack tagging data and using the spatio-temporal model to produce abundance indices that can be used in any stock assessment software. The DTU team had earlier worked with IATTC on analyzing EPO skipjack data, where abundance indices coming from the external tagging data analysis were successfully incorporated in the 2024 stock assessment of EPO skipjack tuna.

The earlier EPO skipjack analysis had been carried out using bespoke TMB scripts, but the DTU team is currently developing an R package that will be used to conduct the analysis of the WCPO skipjack data. The package is based on a newer RTMB framework and will be intended for general use to analyze animal migrations of aquatic and terrestrial animals, as well as birds.

As of mid 2025, the R package providing the DTU Movement Model is in a relatively early stage of development. It can estimate preference functions that determine the effect of environmental variables on fish movement, but it does not yet have the capability to produce the abundance indices. The development and refinements of the DTU Movement Model software is an activity that the DTU team is working on and does not strictly depend on the SPC-DTU collaboration. The completion of the core functionality of the package is relevent, however, for a possible follow-up development project described below.

Development project to be launched in 2026 

During the 2025 SPC-DTU workshop in Copenhagen, the team of DTU team raised an important point that could become increasingly relevant for future tuna assessments. Not only is the DTU Movement Model a useful tool for analyzing tagging data externally from the assessment model to produce abundance indices, which can faciliate transitioning tuna assessments from MULTIFAN-CL to other software. In addition to this, the DTU Movement Model could conceivably be extended considerably to become a full stock assessment model.

As a spatio-temporal model operating at a high resolution, it keeps track of key quantities such as M and F at each location. Thus, it already contains key elements of a population model, if processes such as recruitment and fitting to length composition data could be added. It is worth noting that the wider DTU team is responsible for designing and implementing the latest generation of models

used in current European stock assessments, such as SAM and SPiCT. This means that their current speculations about extending the Movement Model to become a full assessment model should be taken seriously and might become highly relevant for future tuna assessments. Unlike existing stock assessments, this would be a statistical framework that incorporates movement and environmental covariates at a fine scale, rather than modelling bulk movement between very large rectangular regions as is done in today's tuna assessments.

A preliminary outcome of the current scoping project is to recommend funding the DTU team to design and develop the considerable extensions required to convert the current spatio-temporal movement model into a full stock assessment model. While the DTU team might possibly direct research efforts into this new domain in fisheries science with or without our involvement, there might be important benefits of contributing direct funding and research collaboration. Firstly, this would make it more likely that operational stock assessment software would be successfully developed. Secondly, funding and collaboration would make it more likely that the resulting software would have the design focus and features that directly address the requirements of WCPFC tuna assessments.

As of mid 2025, it is too early to lay out a precise work plan and budget for the development of a spatio-temporal full assessment model. The RTMB package currently under development is now close to having the core features of the basic movement model in place, a required first step before work can start to potentially extend the model. The SC21 meeting is an opportune time to discuss the possible prioritization and funding of this work stream that can be launched in 2026, a software development project focusing on a spatio-temporal full assessment model. For this reason, we suggest that a small informal working group could be convened by the SC to discuss the potential scope, deliverables, timeline, resources, and draft TORs for this work stream, which has the potential to lead to the development of stock assessment software to be used in future tuna assessments.

The development work on a spatio-temporal full assessment model would be carried out by the team of statisticians at the Technical University of Denmark, based in Copenhagen.

8 Acknowledgements

We thank WCPFC and ISSF for funding this scoping project. We are also grateful for the valuable input of the scientists and software developers who joined the online meetings of the 2024 international expert meeting. Mark Maunder at IATTC has provided insightful feedback as we reach out to him with new discussion topics on a regular basis. The teams of scientists at DTU and FIMS have also been very positive responding to our queries related to the scoping of the next generation of tuna stock assessment software.

9 References

Correa, G.M., C.C. Monnahan, J.Y. Sullivan, J.T. Thorson, and A.E. Punt. 2023. Modelling time-varying growth in state-space stock assessments. ICES J. Mar. Sci.80:2036–2049.

Fournier, D.A., J. Hampton, and J.R. Sibert. 1998. MULTIFAN-CL: A length-based, age-structured model for fisheries stock assessment, with application to South Pacific albacore, *Thunnus alalunga*. Can. J. Fish. Aquat. Sci. 55:2105–2116.

Kristensen, K. 2024. RTMB: R bindings for TMB. R package version 1.5. https://cran.r-project.org/package=RTMB.

Kristensen, K. A. Nielsen, C.W. Berg, H. Skaug, and B.M. Bell. 2016. TMB: Automatic differentiation and Laplace approximation. J. Stat. Softw. 70(5):1–21.

Magnusson, A. and N. Davies. 2024a. Scoping the next stock assessment platform, P123: Background and discussion. Presented at the SPC pre-assessment workshop, 28 March 2024. 13 pp. Available online.

Magnusson, A. and N. Davies. 2024b. Scoping the next stock assessment platform, stage I: Reaching out to tuna RFMOs and the scientific community. Presented at the SPC international expert meeting, 13 May and 18 June 2024. 31 pp. Available online.

Nielsen, A. and C.W. Berg. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fish. Res. 158:96–101.

Punt, A.E., A. Dunn, B.Þ. Elvarsson, J. Hampton, S.D. Hoyle, M.N. Maunder, R.D. Methot, and A. Nielsen. 2020. Essential features of the next-generation integrated fisheries stock assessment package: A perspective. Fish. Res. 229:105617.

Stock, B.C. and T.J. Miller. 2021. The Woods Hole Assessment Model (WHAM): A general state-space assessment framework that incorporates time- and age-varying processes via random effects and links to environmental covariates. Fish. Res. 240:105967.

Zhang, F. and N.G. Cadigan. 2022. An age-and length-structured statistical catch-at-length model for hard-to-age fisheries stocks. Fish and Fish. 23:1121–1135.

A Appendices

A.1 Terms of reference

The nature of the scoping project is exploratory in nature. This means that focus topics may emerge and be prioritized between SC meetings. The project reaches out to the Scientific Committee members at to seek guidance and involvement in assigning project priorities.

Below are the scoping project terms of reference as of SC20 (August 2024).

2024

1. Review and identify a list of necessary features for software to do tuna stock assessments and identify existing software platforms that have these features or capacity to develop these.
2. 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 communicate the scoping project, upcoming model explorations, and succession plans for MFCL and Stock Synthesis, to seek advice from the scientific community, and to seek collaboration with tRFMOs and various research labs.
3. Explore the new RTMB programming environment and how it could be used in future tuna assessments. Specifically, how to modularize and organize code in RTMB models, on one hand code that is specific to one assessment and on the other hand code that is shared between assessments.
4. Establish collaboration with NOAA scientists to explore the feasibility of enhancing the tagging module in Stock Synthesis, making it more similar to the tagging module in MFCL.

2025

5. Provide support to the stock assessment team transitioning the 2025 swordfish assessment from MFCL to Stock Synthesis. Also, coordinate with the 2024/2025 striped marlin assessment team to start preparing for the transition of that assessment to Stock Synthesis in 2029.
6. Compare a variety of software platforms using a simplified single-region WCPO yellowfin tuna dataset. The comparison will evaluate available features, run time speed, auxiliary tools, time and skills required to develop and diagnose models, and other characteristics.
7. Prepare alternative workplans and budget scenarios for the larger implementing (main) project to go beyond scoping. The scoping project will be expected to transition into the main implementing project based on the discussions at SC21, budget considerations, and funding availability. It is expected that the work leading up SC21 will inform the implementing workplan options and budget estimations.

8. Communicate with tuna RFMOs and other research labs to establish which RFMOs and labs are willing and able to commit scientist time to collaborate on specific tasks of the scoping project, as well as the upcoming main project.

9. Communicate with tuna RFMOs and the FIMS project team to evaluate whether joint software development by tuna RFMOs could produce FIMS code modules, with the aim to develop future tuna assessment models using FIMS modules.

A.2 Participants in the international expert meeting 2024

Name	Affiliation	Country
Agurtzane Urtizberea	AZTI	Spain
Ai Kimoto	ICCAT	Spain
Alistair Dunn	Ocean Environmental	NZ
Anders Nielsen	DTU Aqua	Denmark
Andre Punt	Univ Washington	USA
Andrea Havron	NOAA	USA
Arni Magnusson	SPC	New Caledonia
Bjarki Elvarsson	MFRI	Iceland
Carolina Minte-Vera	IATTC	USA
Christopher Cahill	Michigan State Univ	USA
Claudio Castillo Jordán	SPC	New Caledonia
Colin Millar	ICES	Denmark
D'Arcy Webber	Quantifish	NZ
Fan Zhang	Shanghai Ocean Univ	China
Finlay Scott	SPC	New Caledonia
Giancarlo Correa	AZTI	Spain
Graham Pilling	SPC	New Caledonia
Haikun Xu	IATTC	USA
Hilario Murua	ISSF	Spain
Jamie Lentin	Shuttle Thread	UK
Jemery Day	SPC	New Caledonia
Jim Ianelli	NOAA	USA
John Hampton	SPC	New Caledonia
Johnoel Ancheta	Univ Hawaii	USA
Kelli Johnson	NOAA	USA
Laura Tremblay-Boyer	CSIRO	Australia
Mark Maunder	IATTC	USA
Matthew Vincent	NOAA	USA
Michael Schirripa	NOAA	USA
Nan Yao	SPC	New Caledonia
Nathan Taylor	ICCAT	Spain
Nicholas Ducharme-Barth	NOAA	USA
Nick Davies	TeTakina	NZ
Noel Cadigan	Memorial Univ	Canada

Name	Affiliation	Country
Paul Hamer	SPC	New Caledonia
Rich Hillary	CSIRO	Australia
Rick Methot	NOAA	USA
Rob Scott	SPC	New Caledonia
Sam McKechnie	SPC	New Caledonia
Scott Rasmussen	Waddle	NZ
Shelton Harley	Ministry Primary Ind	NZ
Simon Hoyle	Hoyle Consulting	NZ
Thomas Teears	SPC	New Caledonia
Tim Miller	NOAA	USA

A.3 Single-region yellowfin tuna model as a testbed

A.4 List of project deliverables

Project website

https://github.com/PacificCommunity/ofp-sam-transition-plan

Presentations

2024

Magnusson, A. and N. Davies. 2024a. Scoping the next stock assessment platform, P123: Background and discussion. Presented at the SPC pre-assessment workshop, 28 March 2024. 13 pp. Available online.

Magnusson, A. and N. Davies. 2024b. Scoping the next stock assessment platform, stage I: Reaching out to tuna RFMOs and the scientific community. Presented at the SPC international expert meeting, 13 May and 18 June 2024. 31 pp. Available online.

Davies, N. 2024. MULTIFAN-CL: Longevity and valuable features for tuna dynamics. Presented at the SPC international expert meeting, 13 May and 18 June 2024. 8 pp. Available online.

Reports

2024

Magnusson, A., N. Davies, G. Pilling, and P. Hamer. Scoping the next generation of tuna stock assessment software: Progress report and outline of options (project 123). WCPFC-SC20-2024/SA-WP-01. 19 pp. Available online.