# Simulation experimental design for assessing candidate stock assessment modelling frameworks for undertaking WCPO tuna stock assesssments

This is a concept summary of discussions during the August 2024 workshop of the P123 project that explores options for transitioning from the MULTIFAN-CL software to an alternative future framework for undertaking WCPO tuna stock assessments.

## Operating model (OM)

* Formulates the desired features for the WCPO tuna population models (see slide 19 2024\_05\_13\_experts\_scoping.pdf)
* Has sufficient complexity to implement complex and realistic biological processes with environmental interactions on temporal and spatial dimensions
* Having this complexity to allow exploration of potential scenarios reflecting current or future population processes, e.g. spatio-temporal effects due to environmental covariates in response to climate change.
* Preferably not one of the candidate stock assessment frameworks (SS3, CASAL, MULTIFAN-CL, etc.)
* Includes tagged population dynamics
* Generates simulation pseudo-observations typical of the inputs to a WCPO tuna MULTIFAN-CL model

A strong candidate for the OM is a modelling framework that is a “relative” of that used for the NOAA-NIWA spatial modelling simulation project of 2020-21. This is an agent-based model (ABM) largely developed from the SPM framework (Dunn et al., 2015), called the C++ Agent Based Model (CABM) (Marsh, 2022). The CABM OM is an agent-based model that expresses a fish stock as a collection of agents defined as one or more fish with homogeneous characteristics, i.e. length, weight and sex. If the agent = 1 fish, the ABM becomes an individual-based model (IBM). The CABM used functions to grow, move, create, and kill agents over time, termed as agent dynamics. When summaries are made over all agents, stock level quantities are derived, consistent with those of a standard age-, length-, or age-length-structured model. Simulating a population with this high level of detail allows heterogeneity in key dynamics such as growth and mortality, thus facilitating spatio-temporal variation in key biological and fishery-related processes. A main advantage of the CABM is that the model is capable of dealing reliably with age-length structures in the model and observational data (Marsh et al. 2024)

Conditioning the OM upon a WCPO tuna stock assessment would be undertaken using an existing solution obtained using MULTIFAN-CL that readily facilitates the OM to have consistent parameterisation. This task would be undertaken with the developers and users of CABM including NIWA (Jeremy McKenzie, Richard Bian) and the SPM framework (Alistair Dunn, Scott Rasmussen).

Pseudo-observations would be generated for the existing data types input to a WCPO stock assessment, including:

* Size compositions
* Conditional age-lengths
* CPUE time series
* Tagging studies

The dimensions, sample sizes and observation error would be consistent with that of WCPO tuna input data to a typical MULTIFAN-CL stock assessment. These data would be generated for a large (100+) number of simulations.

## Estimation models

Candidate estimation models include those listed in the P123 project as potential options for transitioning to, including: Stock Synthesis (Methot, ###), CASAL2 (Rasmussen et al. 2016), SAM (*ref.*), WHAM (*ref.*), Gadget3 (*ref.*), and, perhaps, a bespoke rTMB model.

The identical OM simulation data sets for all scenarios will be provided to each of the candidates.

Support will be sought from the tRFMOs and agencies responsible for the candidate modelling frameworks, for applying their candidate to the simulation study. Their analysts most familiar with applying the framework are best suited for its implementation in the study, and will assist with resourcing this aspect of the project.

## Simulation design

The main design component is that of the OM in respect of its structure and the scenarios to be explored.

### Structure

Typical of a contemporary complex WCPO tuna population model but including length-based population processes. Includes most or all of the desired model features (see slide 19 2024\_05\_13\_experts\_scoping.pdf)

* Population state is structured in respect of age and length
* Sex-structured
* 5 – 9 regions
* Multiple annual time-steps
* Movement
* Processes with spatio-temporal variation capability and length-based:
  + Growth
  + Natural mortality (may also be age-specific)
* Length-based fishing mortality
* Time-variant selectivity
* Tagged population
* Multiple fisheries

Given the complexity limitations the desired feature of generating close-kin mark-recapture (CKMR) pseudo-observations is unlikely to be possible.

### Scenarios

A range of scenarios will be explored from relatively simple (constant in time and space) to complex (spatio-temporal variation). The purpose of these are to explore biological and fishery processes not currently described by the current range of candidate modelling frameworks

Candidate scenarios could include:

* Constant growth and natural mortality in time and space
* Spatial variation in growth
* Spatial variation in growth and natural mortality
* Spatio-temporal variation in growth and natural mortality
* Strongly length-based selectivities under high fishing mortality
* Strong and consistent spatio-temporal trends in growth, mortality and recruitment covariates (emulating climate change effects)

### Performance indicators

Those model quantities of management interest to the Western and Central Pacific Fisheries Commission (WCPFC), in particular the Scientific Committee, comprise the main indicators of the candidate estimation model framework performance. These include:

*Frecent/FMSY* Average fishing mortality-at-age for a recent period (e.g. 2017–2020) relative to *FMSY*.

*SBrecent/SBF=0* Spawning biomass for a recent period (e.g. 2018–2021) relative to the average spawning biomass predicted to occur in the absence of fishing for the 10-year period preceding by a one-year lag, (e.g. 2011–2020).

*SBrecent/SBMSY* Spawning biomass for a recent period (e.g. 2018–2021) relative to the spawning biomass that produces maximum sustainable yield (MSY).

Other dependent variables may be considered as performance indicators, such as: absolute adult biomass; and, relative distribution of absolute abundance among regions. Certain independent variable estimates will be considered as indicators, such as: selectivity patterns; recruitment distribution, and, movement rates.

## References

Dunn, A., Rasmussen, S., and Mormede, S. 2015. Spatial population model user manual, spm v1.1.2016-03-04 (re.1278). Technical Report 138, National Institute of Water and Atmospheric Research Ltd (NIWA)

Marsh, C. (2022). C++ Agent Based Model (CABM) UserManual. <https://github.com/Craig44/CABM/blob/master/Documentation/UserManual/CABM.pdf>

Marsh, C., McKenzie, J.R., and Langley, A.D. (2024). Simulation testing recruitment productivity shifts based on the 2021 SNA 8 stock assessment. New Zealand Fisheries Assessment Report 2024/24. 27 p.

Rasmussen, S., Doonan, I., Dunn, A., Marsh, C., Large, K., and Mormede, S. 2016. Casal2 user manual. Technical Report 139, National Institute of Water and Atmospheric Research Ltd (NIWA)