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**Approaches used to undertake management projections of WCPO tuna stocks based upon MULTIFAN-CL stock assessments**

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# Summary

Stock projections are increasingly used within WCPFC to evaluate the potential implications of management measures. Questions raised by managers about the future implications of measures range from their short-term impacts, that occur over the next three to five years, to longer-term considerations of risk or stock rebuilding. In order to answer the specific question being posed by managers a number of different projection approaches have been applied. For example, with an increasing focus on future risk levels, there has been a move from deterministic projections that present the stock status that may result ‘on average’ in the future, to stochastic projections that better capture our uncertainty of what may happen in the future.

This paper aims to act as an aide memoire for future Scientific Committee meetings. It summarises the common settings used in projection approaches to provide a basis for future work and captures discussions undertaken within OFP in the development of these approaches to answer different management questions. We use specific examples in the form of case studies to highlight the types of approaches and the range of assumptions and decisions that need to be made when conducting such projections. We note key considerations when undertaking MULTIFAN-CL-based stock projections to ensure they appropriately address the management question posed.

# Introduction

Stock projections are increasingly used within WCPFC to evaluate the potential implications of management measures. The management measures under evaluation may be existing measures for which management targets have not yet been realised or potential future management actions that are currently under consideration but have not yet been implemented. Questions raised by managers about the future implications of measures range from their short-term impacts, that occur over the next three to five years, to longer-term considerations of risk or stock rebuilding. In order to answer the specific question being posed by managers a number of different projection approaches have been applied. For example, with an increasing focus on future risk levels, there has been a move from deterministic projections that present the stock status that may result ‘on average’ in the future, to stochastic projections that better capture our uncertainty of what may happen in the future.

This paper summarises the common settings used in projection approaches to provide a basis for future work and captures discussions undertaken within OFP in the development of these approaches to answer different management questions. We use specific examples in the form of case studies to highlight the types of approaches and the range of assumptions that need to be made when conducting such projections. It also acts as an aide memoire for future Scientific Committee meetings.

## Projection components

When projecting stocks, there are a number of individual biological and fishery components for which assumptions need to be made on their future values. In almost all cases those decisions are informed by historical observations or estimates, and how those historical patterns may continue into the future. For example some biological characteristics such as growth and maturity schedules have been observed to change only very slowly over time. For this reason growth, maturity and natural mortality are often fixed at constant values throughout the projection period. Other characteristics of the fishery, however, can change much faster. The overall selection pattern, at the population level, will be determined by the relative effort levels of the individual fleets operating in the fishery and these can change markedly on a seasonal and annual basis as well as over longer periods. The current options and assumptions within WCPO projections are discussed below.

An important consideration when conducting projections is the likely level of future recruitment, as this can often have a substantial impact on future stock status and hence the likely consequences of management action. Here too, we rely on historical observations to inform our assumptions of what might occur in the future both in terms of the average level of future recruitment and the degree of variation.

Deterministic projections, that do not take future variability into account, often assume that future recruitment follows the stock-recruitment relationship, or is fixed at a constant value based on the arithmetic mean of previous recruitment observations calculated over a specified time period. The time period over which to calculate the mean can vary and will be influenced by many factors including the occurrence of step changes in recruitment levels, the degree of temporal variability, or on the confidence of the stock assessor in the ability of the assessment model to estimate recruitment for a given period. Alternatively, future recruitment can be assumed to conform to the stock-recruitment relationship estimated within the relevant stock assessment.

Stochastic projections more fully capture uncertainty by performing a large number of projections with future values randomly drawn from a distribution derived from historical estimates. Variability can be incorporated into any of the projection settings although in many cases the sole source of stochasticity is in future recruitment values (although see below). There are several different methods (parametric and non-parametric) for generating future recruitments from an observed distribution of historical values. In the majority of cases one of two approaches will be employed: future recruitments can be randomly resampled from the ‘actual’ historical estimates for each year or quarter; or they can be applied as deviates to the predictions of the stock-recruitment relationship (SRR). In the latter case it is important to ensure that the period over which the SRR is fitted is consistent with the period from which deviates are randomly sampled. Where seasonal patterns in recruitment are evident, future recruitment is generated from an “annualised” SRR, plus the random deviate, which is then allocated to each seasonal period according to the average seasonal recruitment distribution, thus maintaining seasonal recruitment patterns into the future.

Catchability (or gear efficiency) relates the catch per unit effort (CPUE) to the abundance of the stock and is typically assumed to be fixed at some constant value such that the quantity of catch attained for a given level of effort and a given stock size is constant through time. However, catchability can change over time with changes in, for example, the behaviour of the fish, environmental conditions and fishing practices. These changes can occur over medium to longer term time-scales, or as random variability (noise) from period to period. All MULTIFAN-CL assessments estimate this random component of catchability variation (termed “effort deviations”), while some assessments also include estimation of seasonal variation as well as long-term trends in catchability for the historical period. Within projections, the long-term future catchability level is assumed constant, generally at the level estimated in the last year of the assessment, but excluding the effect of effort deviations. Dependent upon the characteristics of the seasonality in catch and fishing effort within the fishery, seasonal variation in catchability may also be applied. Stochastic projections may also include the random variability in catchability consistent with effort deviations estimated for the historical period (see below).

Projections conducted with MULTIFAN-CL are conditional on future fleet-specific catch or effort values (either catch or effort must be specified for a given fleet, but not both). The choice of using either catch or effort can depend on the characteristics of the fleet in question but is more often based on the metrics used to manage the fishery. Longline fisheries have been managed by catch constraints whilst purse seine fisheries are typically subject to effort constraints (e.g. CMM 2015-01). Consequently projections for longline fleets often use catch as the basis for future fishing levels, whilst those for purse seine often use effort. The baseline level for the future has generally been the conditions in the final year of the stock assessment (e.g. 2012 catch or effort levels for the tropical tuna stock assessments performed in 2014). However, for specific analyses, a recent average of fishing levels (e.g. the average catch or effort over the period 2010-2012) has been used to ensure that unusual fishing patterns in one particular year do not dominate projection results.

## Running projections from MULTIFAN-CL

Projections conducted in MULTIFAN-CL are integrated into the stock assessment analysis; that is, the projections are run from the same files generated by the stock assessment with the only modification being the addition of fleet specific future catch or effort in the *.frq* file. This approach has a number of advantages both in terms of the practical application of the software and in maintaining a scientifically rigorous approach to conducting projections. Specifically, it ensures that recruitment and effort deviations during the projection period are derived from legitimate sources of process error and are appropriately incorporated into estimates of confidence intervals for projection variables.

For stochastic projections MULTIFAN-CL currently supports three sources of variability:

* variation in future recruitment (as discussed above);
* variation in the numbers at age in the first year of the projection period (taken from a parametric distribution); and
* variation in future catchability, through randomly-selected future effort deviations (sampled from a parametric distribution with user-specified standard deviation based on the estimated historical effort deviations).

At present only the first of these has been fully tested and is therefore the only source of stochasticity currently included in projections. Once tested, the additional sources of uncertainty should be included in the future to better capture the range of uncertainties, and better represent risk.

A final element of future uncertainty that relates to MULTIFAN-CL stochastic projections is model uncertainty. Model uncertainty is currently captured through the uncertainty framework approach endorsed by SC10 (WCPFC, 2014; Attachment G), which has identified assessment model runs with different input parameter or structural assumptions that aim to capture key uncertainties within our understanding of the stock and fishery. SC10 also applied expert opinion to define weights for the outputs of projections from those different model runs to reflect their considered plausibility.

We also note that it is potentially possible to represent other sources of variability in future projections related to the ways in which the fisheries occur or management is implemented. For example, for purse seine fisheries there is variability from year to year in how effort is distributed among model regions and between associated and unassociated set types. It would be relatively easy to replicate this sort of variability in projections if warranted by the particular analysis being undertaken.

# Case Studies

We present three case studies in which projections have been used to address management questions that range from short- to long-term considerations, and which examine both existing and potential future management actions. We loosely define the short-term as being three to five years, the medium-term as ten to fifteen years, and the long-term as twenty to thirty years.

### Case study 1: FAD vs free-school effort allocation in the skipjack purse seine fishery

The analysis investigated the allocation of varying proportions of fishing effort to either associated or unassociated set types to inform on the effects on relative stock status in the short- to medium- and long-term. (e.g. Hampton and Pilling, 2015)

#### Projection Settings

|  |  |
| --- | --- |
| Projection type | Deterministic |
| Projection period | 20 years |
| Projection basis | Reference case assessment model |
| Catch/Effort scalers | Purse seine fisheries projected with effort (varying between FAD and free school)Longline projected with catch held constant at 2012 levels |
| Growth, maturity, mortality | Fixed at stock assessment estimates |
| Recruitment | Beverton-Holt SRR (fitted to the period 1981:2011 within the stock assessment) |
| Catchability  | Constant at terminal assessment year values |

### Case study 2: Short-term stochastic projections for skipjack, yellowfin and bigeye tunas.

The analysis conducted short-term stochastic projections from the reference case assessment for each of the tropical tuna stocks to inform on the likely stock status resulting from recent catches in between stock assessments. (Scott et al., 2015)

#### Projection Settings

|  |  |
| --- | --- |
| Projection type | Stochastic (200 iterations), variation in future recruitment |
| Projection period | 3 years |
| Projection basis | Reference case assessment models |
| Catch/Effort scalers | All fisheries projected with catch (based on the observed catch for each fleet) |
| Growth, maturity, mortality | Fixed at stock assessment estimates |
| Recruitment | Re-sampled recruitment from recent historical estimates (2002-2011) |
| Catchability  | Constant at terminal assessment year values |

### Case study 3: Evaluation of CMM 2014-01 for bigeye tuna

The analysis used the purse seine associated effort and longline catch scalars estimated to result from the Measure within bigeye tuna stock projections to evaluate long-term outcomes in relation to the stated objectives of the CMM regarding bigeye tuna. (SPC OFP, 2015)

#### Projection Settings

|  |  |
| --- | --- |
| Projection type | Stochastic (200 iterations), variation in future recruitment |
| Projection period | 20 years |
| Projection basis | Multiple projections from each assessment in the uncertainty grid – weighted using SC10 values |
| Catch/Effort scalers | Purse seine (ASS) projected with effort, Longline projected with catch, based on the assumed catch and effort levels that will exist in 2017 as a consequence of the measure |
| Growth, maturity, mortality | Fixed at stock assessment estimates |
| Recruitment | SRR with deviates re-sampled from recent period (2002-2011) to reflect recent positive recruitment estimates |
| Catchability  | Constant at terminal assessment year values |

# Discussion

The choice of projection approach (deterministic or stochastic) will depend largely on the management questions being addressed.

For example in Case Study 1 the primary interest was in the average, long-term response of the stock to varying levels of FAD (associated) vs free-school (unassociated) effort. The application of stochasticity would have obscured the overall relationship and added little to the analysis.

For projections answering questions related to risk and probability, stochastic projections should be performed. For example, for Case Study 3 stochasticity was a central component of the analysis which examined whether the CMM would realise its objectives and the potential risk of the bigeye stock remaining below the adopted limit reference point, and the period of time it would take to achieve objectives. Future recruitment levels and variability are very important in this respect.

The decision to use either the stock recruitment relationship or recent recruitment estimates as the basis for future recruitment will be influenced by the length of the projection period. For short-term projections, the most recent recruitments may more closely represent the potential levels of recruitment in the near future (this is consistent with recommendations of SC6; WCPFC, 2010). For longer term projections, the assumption of recent recruitments may be less appropriate, particularly where the change in adult biomass levels might imply very different future recruitment levels from those observed at the end of the assessment (i.e. a recovery of the stock under which the SRR would imply increases in recruitment, or alternatively a reduction in biomass that could reduce average recruitments). In those cases, incorporation of the underlying stock recruitment relationship (potentially using recent recruitment deviates where stochastic projections are performed) should be considered. For stochastic projections it should be noted, however, that re-sampling over a very short period of recent recruitments (i.e. a limited sample size) can lead to biased or bimodal distributions for output projection variables.

A special case for projections has been the bigeye ‘Run 21’ scenario. This was a specific run within the 2011 bigeye stock assessment (Davies et al., 2011), where recent recruitments from 1989-2009 were considered as best representing future productivity of the bigeye stock, and were used to derive the Beverton-Holt stock-recruitment relationship and therefore equilibrium yield estimates. This was due to trends in the estimated recruitment levels seen over the period of the stock assessment and a suspicion that recruitment estimates from the early part of the assessment period may be negatively biased (related to the start of purse seine fishing part way through the model period, which provides greater information on smaller fish numbers and hence more information from which MULTIFAN-CL can estimate recruitment levels). This same logic of assuming future recruitments will mirror recent levels or follow a SRR specifically fitted to recent recruitments has been used within bigeye stock projections as the ‘preferred’ option in recent years.

While the use of stochastic projections has increased within WCPFC work, the drawback of the approach is that the process takes more time and becomes less practical where a wide range of scenarios needs to be examined (as for Case Study 3). This problem can potentially be mitigated through distributed processing across a large array of computer processing units. Where computer resources are limited, the evaluation of a large range of scenarios is more practical through deterministic projections, e.g. when identifying different levels of fishing in alternative gears that achieve a particular stock status (e.g. Case Study 1). We note that deterministic projection outputs will generally reflect the ‘average’ position of the stock in the future under set conditions, in the case where the distribution of the estimated recruitments over the period used within stochastic projections are ‘normally’ distributed.

# References

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