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Report of the Expert Consultation Workshop on Management Strategy Evaluation

WCPFC-SC12-2016/MI-WP-05

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Executive Summary

The Western and Central Pacific Fisheries Commission (WCPFC) is developing a harvest strategy framework for the management of skipjack, bigeye, yellowfin, South Pacific albacore, Pacific bluefin and North Pacific albacore. As part of this process it is proposed to test the performance of candidate harvest control rules using management strategy evaluation (MSE). In order to plan the work ahead and to prioritise the issues that will need to be addressed, SPC held an expert consultation workshop made up of practitioners in MSE, from a range of fisheries fora. The workshop made recommendations on the general aspects of developing an MSE framework as well as specific recommendations for skipjack and albacore. In addition, the workshop considered the future requirements for technical working groups and stakeholder consultation meetings that will be necessary to implement the MSE approach.

General Considerations and Recommendations

The MSE simulation framework has two main components: an operating model, that represents the true underlying dynamics of the resource and the fishery, as well as the relationships between the underlying state variables and the data; and a management strategy, that comprises the methods used to estimate the status of the stock and the harvest control rules (HCRs) that determine what management action should be taken for a given estimated stock status.

Developing and conditioning the **operating model** is a complex and lengthy process. A primary consideration when designing and building an operating model is to identify all of the sources of uncertainty regarding the dynamics of the stock, the operations of the fishery and the quality of the data to be used as inputs to the candidate management strategies.

MULTIFAN-CL is a useful tool for developing the operating model, but will require modifications to enable data to be generated and management strategies used to set future management actions. The uncertainty grid was a useful starting point for capturing the key uncertainties and the workshop identified a range of general and species specific issues that should be considered.

A range of methods for determining management actions can be considered for use within the **management strategy**, which can be either empirical (model free) or model-based (e.g. based on a stock assessment). Both empirical and model based methods should be considered during the initial phases of developing an MSE.

The **risk** of falling below the LRP be presented as a performance statistic so that a decision on the acceptable level of risk can be made based upon the relative trade-off with other management objectives. The workshop noted that a decision on the acceptable probability of falling below the LRP was tabled for 2016 in the Agreed Work Plan and also scheduled on the agenda of WCPFC-SC12. It considered that an interim probability value could be agreed at this stage, but may subsequently be revisited as the likely trade-offs among management objectives becomes more apparent as the MSE process progresses. The workshop advised that the lack of an agreed level of risk of falling below the LRP at this stage would not constrain the development of the MSE.

Economic metrics can be calculated post-hoc and presented as performance statistics to allow comparison of the economic performance of candidate management procedures.

Communication with and participation of all stakeholders is a critical component of the MSE process. Procedures for identifying exceptional circumstances (i.e. situations that were not contemplated during the MSE) and the process to be followed in the event of exceptional circumstances are important issues that require stakeholder consultation and input.

Skipjack

The workshop considered that a management strategy based on a model based estimator (eg. a stock assessment) may be more successful than an empirical (e.g. CPUE trends) based approach for skipjack. However, the skipjack assessment is heavily reliant on two sources of information (pole and line CPUE data and tag release and recapture data). The future availability of both sources of information is uncertain. The potential lack of future monitoring data is of considerable concern, and may jeopardise the development of an MSE for skipjack as well as the continued ability to conduct a stock assessment.

South Pacific Albacore

The workshop considered that both empirical and model-based management strategies could be tested for South Pacific albacore [or the southern longline fishery]. The workshop discussed options for the development of an index based upon standardised longline CPUE that could be used in an empirical management strategy, and noted a number of issues that would need to be addressed:

- the extent to which fisheries target specific species and methods for estimating targeting;
- varying spatial and temporal coverage of the logbook data and approaches for calculating regional weightings;
- access to operational data to develop a region-wide index, and the implications for a management strategy of the loss of this information;
- The potential to develop an index from a sub-region of the operating model.

Future arrangements

The workshop discussed the current arrangements and future requirements of WCPFC for gathering the appropriate technical expertise, achieving an effective dialogue with stakeholders and delivering appropriate advice to the Commission. The workshop recommended:

- a dedicated technical working group be formed to focus on the technical aspects of developing the operating models for MSE testing. It was suggested that this group should report formally to the Scientific Committee for technical discussion and review. It was felt that the Scientific Committee meeting in its current format is a very large, formal meeting and unlikely to be the best forum for the necessary detailed technical discussions.
- the development of a second interactive working group for development of candidate management strategies. Involvement of stakeholders is key in the process. This working group would focus on development of harvest control rule options, implementation measures, performance statistics, etc. and would consider the outputs of the resulting evaluations for subsequent review by the Commission.
- the continued involvement of external experts to provide scientific and technical expertise on MSE and review of the process.

We invite the Scientific Committee to note the recommendations of the expert consultation workshop contained in this report and specifically:

1. to note the concern of the workshop on the future availability of data for skipjack and to consider how these data can continue to be provided in the future and what alternative data may be available to support the assessment and MSE,
2. to note that that both empirical and model-based management strategies could be tested for South Pacific albacore but that CPUE based methods may be dependent on access to operational longline logbook data,
3. to note the recommendation of the workshop for a dedicated technical working group and a second interactive working group to facilitate the development of the operating models and management procedure components of the MSE.

Introduction

The Western and Central Pacific Fisheries Commission (WCPFC) is developing a harvest strategy framework for the management of skipjack, bigeye, yellowfin, South Pacific albacore, and under the auspices of the ISC, Pacific bluefin and North Pacific albacore. As part of this process it is proposed to test the performance of candidate management procedures using management strategy evaluation (MSE). This work will take place between 2016 and 2018, with an initial focus on South Pacific albacore and skipjack. Attachment Y in the WCPFC Summary Report (Agreed Work Plan for the adoption of harvest strategies under CMM2014-06) outlines a draft work plan for the adoption of harvest strategies by the WCPFC. The WCPFC is in the process of defining management objectives, including the specification of reference points, for the targeted tuna stocks.

In order to help plan the work ahead and to prioritise the issues that will need to be addressed, SPC held an MSE Expert Consultation Workshop at SPC Headquarters, Noumea, New Caledonia on 28-30 June 2016, involving practitioners in MSE from a range of fisheries fora. Ten experts from the wider fisheries science community attended the workshop which was chaired by John Annala. The primary purpose of the workshop was to develop an initial work plan and schedule for an MSE process that will enable SPC to provide appropriate advice to the WCPFC within the timeframe specified by the Agreed Work Plan. The workshop focussed on the technical aspects of developing an MSE modelling framework for fisheries in the WCPO, drawing from experts' experience. This report outlines the considerations and recommendations arising from the workshop discussions both in terms of general recommendations that apply to the MSE approach, as well as specific recommendations that are of particular relevance to albacore and skipjack. The list of invited experts is given in Appendix A and the workshop agenda is given in Appendix B.

We do not attempt to provide a full description of the MSE process here, in part because it is a particularly broad topic and would result in an overly long report, but also because a number of such descriptions already exist both in the scientific literature and through more accessible media. The terminology used throughout this report is based on that given in ISSF Technical Report 2013-03 (WCPFC-SC9-2013/MI-IP-01). Appendix C of this report contains a selected glossary of terms from that ISSF report.

General Considerations and recommendations

MSE is a process for evaluating the relative performance of a range of alternative management strategies through simulation. In essence, the MSE simulation framework (Figure 1) has two main components:

- an operating model, that represents the true underlying dynamics of the resource and the fishery, as well as the relationships between the underlying state variables and the data; and
- a management strategy, that comprises the methods used to estimate the status of the stock and the harvest control rules (HCRs) that determine what management action should be taken for a given estimated stock status.

There are likely to be multiple instances of the operating model, each one representing an alternative plausible hypothesis about the "true" underlying fishery, resource dynamics and data collection procedures. Similarly, there will be multiple management strategies to test alternative HCRs or different methods for estimating the status of the stock or the fishery.

Operating Model

The operating model is the mathematical representation of the system to be managed. It represents the biological components of the resource as well as the fishery that operates on the modelled population. It also includes models for the generation of data and the procedures for implementation of management regulations.

Conditioning of the operating model is the process of fitting the operating models to the available data to generate a set of plausible representations of the hypotheses for the stock and fishery. Simulated data are generated from these operating models to apply the candidate management strategies in the simulations. Conditioning is a critical phase of the development of the operating model. The workshop noted the considerable work required in conditioning operating models, especially when these are spatially explicit. In particular, it stressed the importance of and difficulty associated with simulating data noting that simulated data rarely had the same characteristics and properties of real observations. Very often simulated data are too well behaved and the true level of uncertainty is very often under-estimated. Uncertainty resulting from alternative methods for pre-processing data inputs (e.g. for CPUE standardization) or different weights placed on the different kinds of data can be incorporated by conditioning the operating model using a set of alternative methods.

The workshop noted the current features available in MULTIFAN-CL and the developments planned for the future, including the implementation of approaches to simulate 'pseudo-data' direct from the MULTIFAN-CL software, and considered it to be a useful tool for developing the operating model. In turn, the approach used by WCPFC to capture uncertainty in assessment results through the 'uncertainty grid' was felt to provide a starting point for capturing key uncertainties within the operating model (see below).

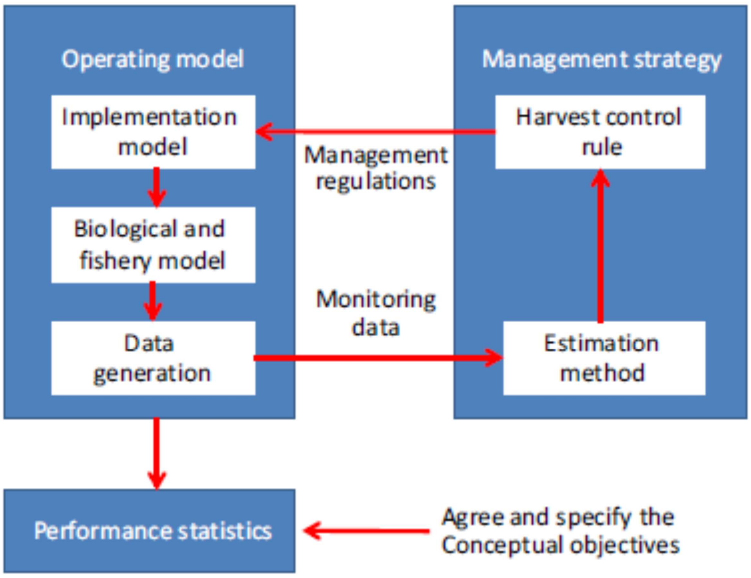

Figure 1. Conceptual overview of the management strategy evaluation process (from Punt *et al.*, 2016)

Uncertainty

The operating model (or suite of operating models) should encompass the full range of uncertainty pertinent to the system being managed. A primary consideration, therefore, when designing and building the operating model is to identify all of the sources of uncertainty regarding the dynamics of the stock and the operations of the fishery, including the collection of data from that fishery, and the way that management actions are implemented by the fishery (e.g. based upon effort or catch controls, closed areas or seasons, etc.).

The list of the sources of uncertainty is typically very large and may be separated into a "reference set" of the most plausible situations/hypotheses and a "robustness set" of less likely, though not impossible situations/hypotheses that would have substantial implications for the performance of a management strategy if they occurred. The robustness set is important when evaluating the existence and impact of “exceptional circumstances” (see below). The workshop stressed the importance of identifying all sources of uncertainty and recommended that a record of the full list of identified uncertainties be maintained. The workshop also recommended that during the work, explicit statements be made about which uncertainties have been addressed in the reference and robustness sets and which have not been addressed.

The uncertainty to be considered within the operating model can be categorised into the following four types:

1. **process error**, associated with the underlying stochasticity in the dynamics of the stock and the fishery (e.g. recruitment variability)
2. **model error**, arising from misspecification of model parameter values (e.g. steepness or natural mortality) or of the structural design of the model (e.g. spatial configuration).
3. **outcome error**, due to differences between the intended and actual effects of management decisions
4. **parameter error**, associated with the ability of models to estimate parameter values

The workshop considered that parameter error was unlikely to impact the performance of management strategies as much as the first three types of error. Consequently, focus should be on these sources of error, at least during the initial phases of developing the operating model. Error can be introduced either as random variation about a fixed mean value or as a directional trend (that may also be subject to random variation). The workshop noted that trends, or non-stationarity, in parameter values were typically more important factors for determining the performance of a management strategy than random variability unless auto-correlation in the process was high.

The workshop stressed the importance of considering outcome error (implementation error) and noted that it can arise through a variety of situations including the circumvention of management regulations through illegal activity, such as catch or effort misreporting, but also through perfectly legal activities. For example a HCR may determine an effort reduction that is assumed to apply equally to all fleets, but in practice is unevenly distributed amongst fleets potentially changing the overall characteristics of the fishery in terms of its spatial distribution, catchability, selection pattern etc. The historical behaviour of fisheries may be informative for compiling the likely form of these types of error. The workshop further noted that the degree of error may be defined by the type of management mechanism. For example, errors may be greater for large scale measures than for closely monitored individual measures.

The workshop noted that misspecification of spatial structure was an important source of uncertainty and potentially more important than local depletion effects. It noted the considerable work involved in changing the spatial structure in the operating model, which would require the construction of revised fishery definitions, area weightings, CPUE series and tag release and recapture input data. The workshop discussed the potential problems associated with spatially-structured models and the potential sources of uncertainty and recommended that misspecification of spatial structure be investigated through a number of approaches. The sensitivity to the use of alternative spatial areas in the assessment component of the management strategy could be investigated by using a different spatial structure in the operating model to that assumed by the management strategy. However, a second and potentially more important source of uncertainty was the existence of sub-structure or meta-populations within the stock. An approach using multiple parallel operating models, similar to the multi-species approach described below, could be employed to investigate the effects of unaccounted sub-structure in the population.

The workshop participants completed a questionnaire to survey their considerations of the importance and feasibility of including various sources of uncertainty in the operating model. This was based upon their experience in developing MSEs for other fisheries, and did not necessarily reflect their opinions on the tropical purse seine and southern longline (skipjack and albacore) fisheries under consideration here. The results of the survey are shown in Appendix D and provide a rough guide for the prioritisation of factors to be included noting however, that the development of any operating model and the relative importance of different forms of uncertainty are likely to be case specific and may not follow the table precisely.

It was noted that operating model development is largely a scientific exercise, although key stakeholder input is involved in the identification of uncertainties to be included. In other tRFMOs, this work has been the focus of specifically designed scientific meetings or working groups, and/or developed through the Scientific Committee. This is discussed further under the Future Arrangements section of this report.

Management Strategy

The management strategy comprises the formally specified combination of data collection methods, an analysis method (or estimator) and a harvest control rule that are used to determine the resulting management actions. The workshop noted that the performance of a particular HCR is conditional on the methods used to collect data from the fishery and to estimate stock status, and that these components should be considered as a whole when evaluating the performance of a management strategy.

Estimation method

The workshop discussed the various approaches for assessing changes in stock status within the management strategy, noting that these could be either empirical or model based. Empirical (model-free) methods might use data collected directly from the fishery, such as CPUE, to determine whether future catches or effort should increase or decrease whereas model-based approaches rely on analytical methods, such as stock assessment models, for estimating stock status. The complexity of the stock assessment model can vary substantially from relatively simple biomass dynamic models to much more complex, age-structured models.

Empirical methods have the advantage of being relatively simple to develop and implement and typically require very little computer power for testing. Model based approaches allow for formal estimation of stock status and may perform better at managing a fishery or stock towards a target, especially if the assessment model can “learn” about the target (e.g. some MSY-related parameter). Empirical methods can also include an empirical target but this tends to be a fixed parameter. The lag time between data collection, estimation of stock status and management action may also be affected by choice between empirical or model-based approaches. The workshop recommended that both empirical and model-based management strategies should be considered, at least during the initial phases of developing an MSE.

Harvest Control Rules

The workshop made several recommendations with specific regard to the development and application of harvest control rules. With specific reference to potential outcome uncertainty, it stressed the importance of considering whether the application of a particular harvest control rule would result in significantly different dynamics in the fishery to what has been observed historically. For example if the harvest control rule specifies spatial closures or significant effort reductions in parts of the fishery that have previously not been subject to such controls then the previous dynamics and behaviour of the fishery may not be a useful predictor of its future response to the harvest control rule.

A potential source of outcome error occurs where the allocation of catch or effort, as determined by the harvest control rule, applies differently in reality to that assumed by the management strategy. The workshop noted the importance of considering how the implicit assumptions of the management strategy might differ from reality, particularly where a single harvest control rule is applied to the whole fishery and not to just one component of the fishery.

With regards to nomenclature, the workshop noted the importance to distinguish between reference points (e.g. F_{MSY}, 20% $SB/SB_{F=0}$, etc) and the biomass or fishing mortality break points in the harvest control rule for which the term control parameters was suggested.

The role of defined target and limit reference points within the process should be clarified. The workshop noted that while reference points are essential for evaluating performance, they may or may not be included as parameters of the harvest control rule. For example, in the case of an empirical estimation method based upon absolute catch rate levels, any target reference point would not necessarily feature within the harvest control rule. However, it would be examined as a key performance statistic drawn from the operating model, to ensure the HCR maintained the stock around the TRP on average (see below).

Performance Statistics

The workshop recommended the use of the term performance statistic (or performance measure) instead of performance indicator to distinguish the statistics from actual indicators (e.g. ecosystem indicators). Performance statistics should be chosen to relate readily to the fishery and to the management objectives and should be constructed, to the extent possible, so as to be easily interpreted. The workshop discussed the development of performance statistics with specific reference to communicating the level of risk associated with a given management strategy and how economics could be incorporated into the MSE process.

To facilitate evaluation of relative performance of several candidate management strategies over multiple dimensions, parameters of the different harvest control rules may be “tuned” so that all candidate strategies achieve a pre-defined set of values on one of the performance statistics. For example, candidate rules may be tuned to achieve a given target biomass (median or average over some period) expressed as a proportion *p* of the target reference point, where *p* takes a set of fixed values.

Risk

An acceptable level of risk of falling below the limit reference point (LRP) has not yet been agreed by WCPFC. The workshop noted the difficulty in deciding on a specific value of risk in advance of detailed evaluations to determine the consequences of falling below the LRP and what relative trade-offs in other performance statistics might be associated with different levels of risk. For example, if falling below the LRP would lead to significant effort cuts and a lengthy stock rebuilding program then managers may prefer a more precautionary policy with a lower probability of occurrence, whereas, if the stock were able to recover quickly with only small effort reductions then a higher likelihood of occurrence may be acceptable. Similarly if a 1% reduction in the probability of falling below the LRP would lead to either a 2% reduction or a 20% reduction in yield, managers might view this decision on the appropriate level of risk very differently. The workshop recommended that the probability of falling below the LRP be presented as a performance statistic for the MSE so that a decision on the acceptable level of risk can be made based upon the relative trade-off with other management objectives.

The workshop noted that a decision on the acceptable probability of falling below the LRP was tabled for 2016 in the Agreed Work Plan and also scheduled on the agenda of WCPFC-SC12. It considered that an interim probability value could be agreed at this stage, but may subsequently be revisited as the likely trade-offs among management objectives becomes more apparent as the MSE process progresses. The workshop advised that the lack of an agreed level of risk of falling below the LRP at this stage would not constrain the development of the MSE.

Quantification of the probability of rare events (of requiring management strategies to have a very low probability of breaching the LRP) may require a prohibitively large number of simulations. The number of simulation replicates to conduct depends on the nature of the performance metrics and the way the random numbers are tracked in the code implementing the operating model. For example, the number of replicates may need to be large if there is a constraint that no management strategy will be considered for adoption unless it satisfies some performance criterion such as "there should not be more than a 0.05 probability that spawning biomass drops below 20% of the unfished level" simply because the precision of estimating a proportion depends on both the proportion and the number of replicates.

It is thus more common to compare management strategies in a relative sense, i.e. "strategy A outperforms strategy B on performance metric X". When comparisons are made in a relative sense, efficiency is maximized when the same set of random deviates are used to capture uncertainty (process, observation, and parameter uncertainty). The workshop noted that ways to achieve this include:

1. Use the same set of parameter vectors for all management strategies for a given operating model specification, to allow direct comparability between runs.
2. Reset the random number seed at the start of each simulation replicate (ideally keep the set of seeds in a file), to allow re-creation of particular runs.
3. Consider using different random number seeds / random number generators for each type of process and observation uncertainty to avoid random deviates getting out of sequence.
4. Carefully check how the generators used for generating multinomial / Dirichlet random variables work. It may be necessary to use a different random number generator for generating these types of variables.

The extent to which uncertainty is included in fisheries models can be somewhat subjective and the interpretation of risk must be related to the extent to which uncertainty has been included (see for example Figure 2). To the extent possible, the range of uncertainties considered in a MSE should be sufficiently broad so that new information, collected after the management strategy is implemented, should reduce rather than increase the range (Punt and Donovan 2007).

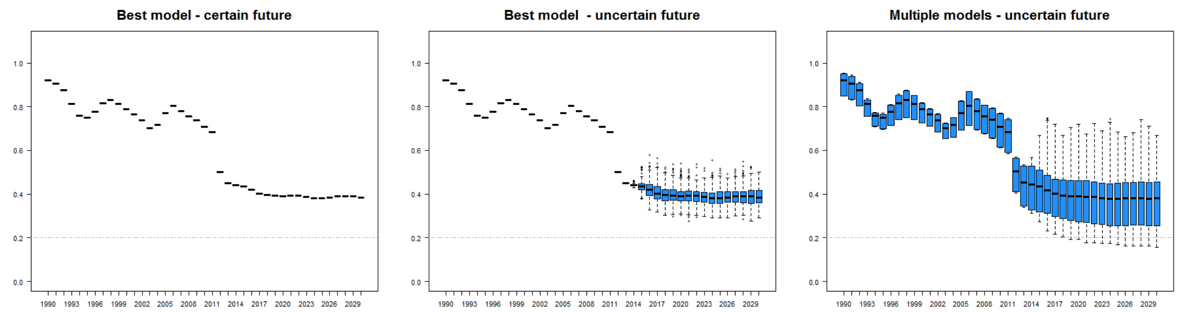

Figure 2. Plots demonstrating the impact of including different types of uncertainty within the risk analyses. Left panel: assumption of 'perfect' knowledge of current status (i.e. output from the single 'best' assessment model run) and no variability in the future (e.g. constant recruitment). Middle panel: assumption of 'perfect' knowledge of current status ('best' model run) but include uncertainty arising in the future due to e.g. recruitment variability. Right panel: include uncertainty in our knowledge of current status (i.e. outputs from a number of model runs) as well as uncertainty in the future due to e.g. recruitment variability.

Economics

It was noted that many of the management objectives identified during the discussions of the WCPFC Management Objectives Workshops were based on economic considerations, particularly for the southern longline fishery for South Pacific albacore. The workshop discussed various approaches for incorporating economics within a MSE, noting that the value of other economically valuable non-target species must also be considered.

Economics can play a direct role within the management strategy, driving decisions at the end of each management period. An example is Australian northern prawn (Punt et al., 2011), where the fishing effort for the next year is set to maximize predicted net present value. However, it was noted that the incorporation of economics within a management strategy was a complex and time consuming process, as (for example) optimum economic fishing levels had to be identified across the fisheries being dynamically controlled. In turn, uncertainty in future cost and price levels must be captured within the process, itself a non-trivial exercise. The expert group recommended that this be a step to be considered much later within the development of WCPFC MSE.

The alternative approach is to capture economics as a performance statistic to allow comparison of the economic consequences of candidate management strategies. In this case, catch/effort/CPUE resulting from the MS would be output, and the economic performance statistics calculated post-hoc (e.g. Pilling et al., 2016).

A key consideration within this approach is to capture the multispecies nature of the fishery to ensure all valuable non-target species are captured by the economic performance statistics. As such, economic performance statistics need to be fishery- rather than species-based. Another key consideration will be the selection of the economic performance statistics to be used, for example, total revenue, total profit, revenue per unit of effort/catch and profit per unit of effort/catch. As desired economic outcomes will likely vary between stakeholders, a range of economic performance statistics is likely to be required. In addition, how a chosen statistic is measured will also need consideration. For example, is total profit to be measured only across vessels that are active in the fishery or should it include vessels that are displaced from the fishery under a given MP?

The workshop noted the considerable complexity involved in developing multi-species models, and briefly discussed the multi-species capability of MULTIFAN-CL. It recommended that for situations where it is important to consider a range of different species that a number of single species operating models should be developed, one for each species, and run in parallel within the simulation. In this way the outcomes of a single management strategy can be applied to each species allowing both species-specific and aggregated performance statistics to be created.

Monitoring

The workshop briefly discussed the various aspects of monitoring strategies, noting that there are two aspects of monitoring the performance of the management strategy once implemented:

- One is to track the actual performance of the management strategy and to determine whether outcomes are within the range predicted by the evaluations. For example, in the case of a management strategy that was designed to rebuild spawning biomass to a particular level, it would be desirable to check that the adult biomass is indeed increasing over time and at an appropriate rate.
- The second aspect involves periodically revisiting the operating model to check that the data and the assumptions remain appropriate. As new data become available or as the dynamics of the fishery change in response to new management it may be necessary to revise the design and the assumptions of the operating model.

Both aspects of the monitoring strategy can be addressed by periodically revisiting the operating model, which can involve both a thorough investigation of the available data and modelling approaches and re-conditioning the operating model. The workshop recommended that for the first few years of developing an MSE, the monitoring and stock assessment processes could be run simultaneously. An asynchronous monitoring and assessment timetable may be preferred thereafter to reduce the workload in any one year.

Exceptional Circumstances

Part of the monitoring strategy is to test for exceptional circumstances. Exceptional circumstances specify those situations where the recommendations of a particular management strategy may be over-ridden. They are considered to occur when current or future data fall outside the range indicated for the projections considered in the MSE. The workshop recommended that checks for exceptional circumstances be conducted routinely and using pre-specified criteria for the input data series, as is the case for southern bluefin tuna for which annual checks are made, although the frequency of checks will also depend on the metric being considered.

The workshop stressed the importance of discussing exceptional circumstances throughout the consultation process to highlight that in spite of our best predictions the future remains uncertain and that the MSE should not be considered a crystal ball.

Communication and Participation

The workshop noted that communication and participation of all stakeholders was a critical component of the MSE process. Initially, this may relate more to capacity building, but ultimately should focus on the key interaction in eliciting stakeholder opinion and effective transfer of information between all parties during the development of the MSE. Here the term stakeholder includes not only fishery managers and policy makers, but also members of different industry sectors, NGOs, and scientists.

Ensuring that all stakeholders are engaged with, or at least aware of, the process from an early stage was considered key. An important component of capacity building early in the CCSBT process was a 'roadshow' where an eminent scientist visited all member countries to inform them on the MSE process and its implementation. This ensures that members were at least familiar with the process and the necessary stages involved.

It was noted that the development of a management strategy was an iterative process, and that dedicated meetings would be required to gather feedback from stakeholders on the results of analyses, and to allow the resulting outputs to be presented. The workshop recommended that a dedicated form of meeting be developed for this process within WCPFC. The potential for that meeting to include external experts was discussed. It was noted that, as an example, IOTC has developed a 'Technical Committee' to take the MSE process forward and improve scientist/manager dialogue.

Related to this, approaches to clearly communicate the results of the MSE were also critical to ensure understanding and appropriate interpretation of the results so that feedback could be efficiently obtained. Translating the technical outputs into economic and social outcomes was suggested as being key.

The need for a common vocabulary was stressed, to avoid confusion particularly for those members that may attend other tRFMOs that are developing MSE approaches. The use of the ISSF vocabulary (Appendix C) was suggested.

Species specific considerations

In addition to the general considerations regarding the development of an MSE process described above, the workshop also considered a number of issues that are of specific relevance to the development of an MSE process for WCPO skipjack and South Pacific albacore.

Skipjack

The WCPO skipjack fishery comprises a wide variety of gear types, but is mostly made up of purse seine in the equatorial waters and pole and line fisheries that operate throughout the WCPO. As a whole, the fishery is managed predominantly through effort controls. The management objectives for the skipjack fishery (that have been discussed so far) encompass a range of biological, economic, social and ecosystem objectives (Cartwright *et al.*, 2013), but essentially aim to maintain the stock biomass around the interim target reference point TRP, maintain CPUE at levels consistent with economic viability of the fishery and stability in effort.

The principal data sources that are used to assess the stock are catch and effort data, fishery specific length frequency data, CPUE time series and a considerable quantity of tag release and recapture information. The workshop noted that CPUE for the commercial purse seine fisheries was not generally used in the assessment due to the difficulty in determining any consistent relationship with abundance and that, in the absence of other usable data, the Japanese pole and line CPUE series and tagging data were particularly important sources of information for the assessment.

The workshop considered that a management strategy based on a model based estimator (e.g. a stock assessment) may be more successful than an empirical (e.g. CPUE trends) approach. However, the workshop expressed concern regarding the future ability to adequately assess the stock in the light of a diminishing Japanese pole and line fishery and a sporadic and spatially-restricted tagging program. The potential lack of future data is of considerable concern, not just for the development of an MSE for skipjack but also for the continued ability to conduct a stock assessment.

The workshop briefly discussed what other data might become available in the future and how the potential loss of key CPUE series could be addressed in the assessment. It noted that at present there is very little information available to scientists on FADs but that sectors of the fishing industry were collecting information that may be useful in better defining indices of abundance. The workshop recommended the possibility of gaining access to these data be further explored. With regard to future tagging programs the workshop noted the example of CCSBT where that Commission had provided funds to undertake the necessary genetic tagging experiments to support the assessment of, and management procedure for southern Bluefin tuna.

South Pacific Albacore

Albacore is primarily caught in the southern longline fishery along with important catches of bigeye, yellowfin and swordfish. These species are caught in different proportions by different sectors of the fishery. Consequently it is difficult to consider albacore in isolation. Catch limits are considered to be an appropriate management quantity for the fishery and some Pacific Island Countries have already discussed zone-based catch allocations. Management objectives for the southern longline fishery include a range of biological, economic, social and ecosystem objectives (Cartwright *et al.*, 2013), but generally focus on economic outcomes such as achieving profitability, optimising fishing capacity and maintaining stability and continuity in market supply.

The principal data sources that are used to assess the stock include fishery specific length frequency data and standardised CPUE time series from operational long-line log-book data for each region of the assessment. It was noted that catches of small albacore in the NZ troll fishery may provide an index of recruitment however, further work would be necessary to determine the utility of these data.

The workshop considered that both empirical and model-based management strategies could be tested for South Pacific albacore [or the southern longline fishery]. The workshop discussed options for the development of an index based upon standardised longline CPUE that could be used in an empirical management strategy, and noted a number of issues that would need to be addressed:

- the extent to which individual fisheries target specific species and the various methods for estimating targeting;
- methods to address varying spatial and temporal coverage of the logbook data and approaches for calculating regional weightings, particularly where they may be used to raise an index to area based density estimates;
- The issue of access to operational data for segments of the fishery to develop a region-wide index, and the implications for a management strategy of the loss of this information for e.g. operational reasons;
- The potential to develop an index from a sub-region of the operating model, noting the potential uncertainty in its representativeness (which could be tested within MSE) and the potential biases that might arise (e.g. Brouwer et al., 2015).

Some of these issues are discussed in greater detail in the supporting documentation for the 2015 assessment of South Pacific albacore provided to SC11 (Tremblay-Boyer *et al*., 2015). The workshop further discussed options for using multiple CPUE series in a single effort control rule and recommended that, when alternative CPUE series are used for conditioning the operating models, a single historical CPUE series needs to be selected for input to the management strategy in order to account for the uncertainty and possible model misspecification in the choice of index that drives management decisions.

Future arrangements

The WCPFC Management Objective Workshops addressed an initial requirement for capacity building and high level stakeholder engagement. The workshop noted that WCPFC was progressing beyond this initial stage. Noting the practices of other tRFMOs where dedicated working groups have been set up to progress the development of an MSE framework, the workshop discussed the current arrangements and future requirements of WCPFC for gathering the appropriate technical expertise, achieving an effective dialogue with stakeholders and delivering appropriate advice to the Commission. The workshop recommended:

- a dedicated technical working group be formed to focus on the technical aspects of developing the operating models for MSE testing. It was suggested that this group should report formally to the Scientific Committee for technical discussion and review. It was felt that the Scientific Committee meeting in its current format is a very large, formal meeting and unlikely to be the best forum for the necessary detailed technical discussions.
- the development of a second interactive working group for development of candidate management strategies. Involvement of stakeholders is key in the process. This working group would focus on development of harvest control rule options, implementation measures, performance statistics, etc. and would consider the outputs of the resulting evaluations for subsequent review by the Commission.
- the continued involvement of external experts to provide scientific and technical expertise on MSE and review of the process.

We invite the Scientific Committee to note the recommendations of the expert consultation workshop contained in this report and specifically:

1. to note the concern of the workshop on the future availability of data for skipjack and to consider how these data can continue to be provided in the future and what alternative data may be available to support the assessment and MSE,
2. to note that that both empirical and model-based management strategies could be tested for South Pacific albacore but that CPUE based methods may be dependent on access to operational longline logbook data,
3. to note the recommendation of the workshop for a dedicated technical working group and a second interactive working group to facilitate the development of the operating models and management procedure components of the MSE.

Acknowledgments

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Appendix A

Workshop Participants

John Annala (chair)	MPI, Wellington, New Zealand	Invited expert
Nokome Bentley	Trophia Ltd, New Zealand	Invited expert
Rob Campbell	CSIRO, Melbourne, Australia	Invited expert
Campbell Davies	CSIRO, Hobart, Tasmania, Australia	Invited expert
Nick Davies	Te Takina Ltd. New Zealand	SPC consultant
John Hampton	SPC, Noumea, New Caledonia	SPC
Shelton Harley	MPI, Wellington, New Zealand	Invited expert
Graham Pilling	SPC, Noumea, New Caledonia	SPC
Chris Reid	FFA, Honiara, Solomon Islands	FFA
Victor Restrepo	ISSF, Washington DC, USA	Invited expert
Robert Scott	SPC, Noumea, New Caledonia	SPC
SungKwon Soh	WCPFC, Kolonia, Pohnpei	WCPFC
Ana Parma	Centro Nacional Patagonico, Puerto Madryn Chubut, Argentina	Invited expert
André Punt	University of Washington, Seattle, USA	Invited expert

Appendix B

MSE Expert Consultation Workshop Draft Agenda

SPC, Noumea
28th-30th June 2016

Tuesday 28th		
09:00 – 10:00	Introductions and general meeting arrangements Aims for the workshop (desired outcomes, report for SC12) Overview of Background information • **Indian Ocean skipjack MSE** o *General approaches taken* o *OM specific development* • **Existing WCPFC assessment and management procedures and expectations of the harvest strategy approach** o *WCPFC region: EEZs, archipelagic waters, high seas, PNA, VDS* o *VMS, observer coverage, electronic reporting, tagging, …* o *The MOW/HSW process so far and PNA activities* o *LRPs, TRPs, management objectives* o *WCPFC harvest strategy schedule for 2016 onwards* • **Modelling approaches** o **MULTIFAN-CL Developments and pseudo-data generation** ▪ *Current capabilities* ▪ *Developing capability for generating pseudo-observations* ▪ *Other proposed developments*	JH NB JH/GP ND
10:30 – 12:00	o **SEAPODYM** ▪ *Data simulation* ▪ *Multi-species capabilities* ▪ *Ecosystem drivers – ENSO; IPCC models?* Overview of Background information contd. • **Current approaches used by SPC for testing HCRs** o *Methods and supporting software* o *Examples of analyses conducted for PNA SKJ* ▪ *Types of HCRs examined* ▪ *Performance indicators and results dissemination.* • **WCPO Skipjack stock assessment (data, assumptions, methods, etc)** o *Data type, quantity, strengths and weaknesses* o *Trends in stock status and fishery dynamics (eg fishery structure)* o *Spatial extent, seasonality,* o *Assessment uncertainty – uncertainty grid* • **South Pacific Albacore stock assessment** o *Data type, quantity, strengths and weaknesses* o *Trends in stock status and fishery dynamics (eg fishery structure)* o *Spatial extent, seasonality,* o *Assessment uncertainty – uncertainty grid* • **Multi-species and mixed fishery issues** o *Spatial and spp composition issues*	JH RS SM GP JH
Lunch		
13:00 – 14:30	Overview of Background information contd. • **Economic aspects of WCPO fisheries** o *Data availability and modelling capacity* ▪ *Region/fleet/nation specific data* o *Linkages between economic objectives and indicators and monitoring* Operating Model Considerations • **Introduction to OM considerations** o *Overview of key considerations and priorities when developing OMs* • Biological uncertainty and process error o Grid approach for projections o Process error and assessment uncertainty	 CR AP

	• Single species vs multi-species operating models
	  o SKJ, YFT, BET
	  o ALB, YFT, BET, SWO
	• Spatial structure	

15:00 – 17:00	• Fleet dynamics (set type, effort creep, targeting, entry/exit) • Economics (driver of fleet dynamics or just a performance measure?)	
Wednesday 28th		
08:30 – 10:00	Management Procedure Considerations • Methods for determining stock status • Characterising uncertainty in assessing stock status and projections o Retrospective and hindcasting analyses • Observation error • Implementation error	
10:30 – 12:00	Harvest Control Rule Considerations • Stock assessment dependent HCRs vs simple data rules • Tuning HCRs • Performance statistics and HCR comparisons	
Lunch		
13:00 – 14:30	Operating model recommendations • Skipjack • Albacore Management procedure and specific HCR recommendations • Skipjack • Albacore Performance Indicators Monitoring Strategy	
15:00 – 17:00	Time scales • Evaluation period; management periods; monitoring and review schedule Recommendations on time scales Exceptional circumstances	
Thursday 28th		

08:30 – 10:00	Identification of most important sources of uncertainty to include in the evaluations.
	• Minimum requirements for MSE
	  o Skipjack
	  o Albacore
	• Scenarios for robustness testing
	  o Skipjack
	  o Albacore	

10:30 – 12:00	Outline schedule for MSE process and deliverables • 2017 Scientific Committee • 2018 Scientific Committee	
Lunch		
13:00 – 14:30	Agree report structure Finalise recommendations	
15:00 – 17:00		

Appendix C

Selected glossary of terms (ISSF, 2013)

Conditioning
The process of fitting/conditioning an Operating Model (OM) to data as part of a Management Strategy Evaluation (MSE). The level of conditioning of the OM can vary substantially depending on the context and purpose of the MSE and the data and information available for the fishery in question. The aim of conditioning the OM is to develop a set of plausible models/hypotheses of the stock and fishery that are consistent with the data, as distinct to identifying a best assessment.

Decision Analysis
A formal analysis to aid decision-making in the face of uncertainty. A decision analysis usually evaluates the relative likelihood that alternative management actions (e.g. average catch, constancy of catch, probability of rebuilding to a given biomass target, etc.) will achieve the expected outcomes. Decision analysis can also address management consequences under different plausible assumptions about the status of the stock or under different monitoring programs.

Harvest Control Rule (HCR) (also Decision Rule)
An agreed rule (algorithm) that describes how harvest is intended to be controlled by management in relation to the state of some indicator of stock status. For example, a harvest control rule can describe the various values of fishing mortality which will be aimed to be achieved at corresponding values of the stock abundance. Constant catch and constant fishing mortality are two types of simple harvest control rules.

Management Objective
A formally-established, more or less quantitative target that is actively sought and provides a basis for management action. Management objectives need to consider both the manner in which the benefits from the fishery are to be realized, as well as the possible undesirable outcomes that are to be avoided. It is desirable that both the timeframe and likelihood for achieving the target (or avoiding a limit) is included in the formal specification of each management objective. Broad objectives include considerations of long-term interests and the avoidance of irreversible or slowly reversible impacts (e.g. large reductions in recruitment below average levels). Typically, the catches are to be as large as possible, so long as the probability of substantial stock depletion is below an acceptably low level, catches can be kept reasonably steady and catch rates remain profitable. Management objectives are often conflicting (e.g., maximizing yield while avoiding stock depletion) and therefore trade-offs need to be understood. Management Strategy Evaluation provides a valuable framework for exploring these trade-offs and building understanding between managers, stakeholders and scientists.

Management Plan
In a broad fisheries context, it is the strategy adopted by the management authority to reach established management objectives. The management plan generally includes the policy principles and forms of management measures, monitoring and compliance that will be used to regulate the fishery, such as the nature of access rights, allocation of resources to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations), outputs (e.g. quotas, minimum size at landing), and fishing operations (e.g. calendar, closed areas, and seasons). Ideally, the Management plan will also include the formal management/harvest strategy for the fishery or a set of principles and guidelines for the specification, implementation and review of a formal management strategy for target and non-target species.

Management Procedure (MP)
The formally specified combination of monitoring data, analysis method (which may be an assessment) and harvest control rule (decision rule) that are used to calculate the value for a TAC or effort control measure. MPs are derived by simulation and chosen for their performance in meeting the specified management objectives and robustness to the presence of uncertainties. Management Strategy Evaluation is commonly used to evaluate and select MPs. Two types of MP may be distinguished:

- **Empirical MP**: An MP where resource-monitoring data (such as survey estimates of abundance, or standardized CPUE) are input directly into an algorithm (the HCR) that generates a control measure such as a TAC/effort level without an intermediate (typically population--]model based) assessment model;
- **Model-based MP**: An MP where the analysis used to generate a control measure, such as a TAC (this process is sometimes termed a catch limit algorithm or CLA), is a combination of an assessment model (which may be more or less complex) and an HCR.

Management Strategy (also Harvest Strategy)
Is a combination of monitoring, assessment, harvest control rule and management action designed to meet the stated objectives of the fishery. The management actions include choices regarding all or some of the following: limited access, allocation of access rights to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations, seasonal or spatial closures), or controls on outputs (e.g. quotas, minimum sizes). The level of detail specified in the each of the components of a management strategy can vary according to the fishery and the context in which it is being used, in particular the stage of development of the fisheries monitoring and management system. An important characteristic of a management strategy is that it is the performance of the individual components and the propagation of uncertainty among them that determines overall performance of the strategy. Hence, careful consideration of the interaction between monitoring, assessment, HCR and management measures is a major focus of management strategy evaluation (MSE).

Management Strategy Evaluation (MSE) (Also MP Approach)
The process of evaluating the relative performance of a range of management strategies or options and presenting the results in a way that demonstrates the trade-offs in performance and robustness across a range of management objectives. MSE usually involves simulation using (1) a model or models (the ”operating model(s)”) to represent the true underlying dynamics of the resource, the fishery and to generate future monitoring data, (2) an estimation model to assess the state of the stock relative to agreed target and limit reference points based on the data simulated by the operating model, and (3) a harvest control rule to determine management actions (e.g., the TAC) given the results of the estimation model. MSE is a general framework aimed at designing and testing Management strategies. It can be applied at a range of levels from high level harvest policy evaluation to detailed testing of fishery specific operational management procedures. The terms MSE and MP Approach are often used interchangeably, although the latter generally refers to simulation testing of specific management strategies.

Operating Model (OM)
The part of the MSE that represents the true underlying status and dynamics of the population, the fishery and the monitoring regime, including the full range of uncertainty pertinent to that fishery. May include a “Reference Set” of most plausible situations/hypotheses and a ”Robustness Set” of unlikely, but not impossible situations/hypotheses

Performance Measure
Measures of performance used during management strategy evaluations. These are interpreted in relation to reference points and management objectives. For example, performance measures under a given management strategy can measure the probability that the limit reference point is exceeded over a defined period, the expected long-term yield, etc. In the MSE context, they are used to summarize different aspects of the simulation results and to evaluate how well a specific strategy achieves some or all of the general objectives for management for a particular scenario.

Precautionary Approach (PA)
A set of agreed cost--]effective measures and actions, including future courses of action, which ensures prudent foresight, reduces or avoids risk to the resource, the environment, and the people, to the extent possible, taking explicitly into account existing uncertainties and the potential consequences of being wrong . The MSE (MP approach) is a transparent, rigorous way to incorporate uncertainty into the fisheries management process and demonstrate whether a strategy is precautionary.

Reference Points
Benchmarks against which the abundance of the stock, the fishing mortality rate or economic and social indicators can be measured in order to determine its status. These reference points can be used as limits or targets, depending on their intended usage.

- **Limit Reference Point (LRP)**: A benchmark that should not be exceeded with any substantial probability according to a given set of management objectives. It indicates the limit beyond which the state of a fishery and/or a resource is not considered desirable and remedial management action is required. When a stock is at very low abundance, LRPs are often taken as interim rebuilding targets. .
- **Target Reference Point (TRP)**: A benchmark that should be achieved on average according to a given set of management objectives. It corresponds to a state of a fishery and/or a resource which is considered desirable.

Risk Analysis
Analysis (and comparison) of the probability of negative outcomes of alternative actions foreseen in development, harvesting or management strategies.

Uncertainty
Uncertainty results from a lack of perfect knowledge of many factors that affect stock assessments, estimation of biological reference points, and management. Sources of uncertainty include:

- Measurement error (in observed quantities) .
- Process error (or natural population variability, e.g. in future recruitment), .
- Model/structural error (misspecification of assumed values or population model structure) .
- Estimation error (in population parameters or reference points, due to any of the preceding types of errors) .
- Implementation error (or the inability to implement management controls for whatever reason).

Often, it is useful to distinguish between uncertainty that can be quantified, and uncertainty that can only be addressed qualitatively, or through scenario modelling.

Appendix D

Results of the questionnaire of the importance and feasibility of including different sources of uncertainty into the operating model. Respondents were asked to scale the 5 most important sources of uncertainty for each category and provide feasibility estimates for those sources selected to be important. High values indicate high importance and most feasible. (Note that the number of respondents for the importance and feasibility ratings differed and that the robustness trials category was only partially completed).

Process Error	*Importance*	*Feasibility*
Recruitment	4.3	3.4
Catchability	2.9	2.8
Selectivity deviations	2.1	1.7
Natural mortality	1.8	0.6
Growth	1.7	2.1
Movement coefficients	1.4	1.4
steepness	0.8	0.0
Model Error		
Steepness	3.2	2.6
Natural Mortality	2.8	1.9
CPUE	2.6	1.8
Effort Creep	2.0	2.2
Spatial / stock structure	1.9	1.0
Tag mixing	1.0	0.4
Catch / Effort	0.7	0.8
Growth curves	0.5	0.3
Species composition	0.2	0.4
Data weighting	0.2	0.6
SRR formulation	0.0	0.0
Economics	0.0	0.0
Implementation Error		
Mis-reporting (over catch)	4.4	3.4
Effort changes (varying from HCR predicted)	3.3	2.7
FAD vs FS mix	2.6	1.5
Target switching	1.8	1.9
Effort distribution to areas	1.7	1.7
Spatial implementation of mngmt	1.3	0.8
Governance structure	0.0	0.0
Robustness Trials		
Hyperstability	3.0	2.3
Unexpected recruitment failure	2.2	2.4
Alternative spatial structure	2.0	1.4
Tends in M	1.8	1.8
Trend in steepness	1.0	1.7