STOCK PROJECTIONS IN IOTC MANAGEMENT ADVICE

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Abstract

Since 2010, the IOTC Working Parties have provided stock assessment advice that includes a Kobe 2 Strategy Matrix (K2SM). This is a management decision table that presents the estimated probability of exceeding MSY-related reference points in the future, when alternative management actions are pursued. To date, comprehensive efforts to quantify all sources of uncertainty in future projections have not been undertaken for IOTC stocks, so the uncertainty in the K2SM is understated, and some have questioned whether it is appropriate. This document attempts to briefly summarize advantages and disadvantages of providing management advice to the Commission on the basis of the K2SM. Overall, we recommend the continued careful use of the K2SM because: i) it emphasizes the importance of uncertainty quantification in both stock assessments and projections, and ii) it represents a useful tool for illustrating the consequences of management options. Within the IOTC, the K2SM has always been presented in the same format, however, it should be recognized that it could be modified to compare a wider range of management options on the basis of alternative performance measures that may be more appropriate for the Commission. Use of the K2SM represents a positive step toward the longer term commitment of the IOTC toward implementation of the precautionary approach and the use of Management Strategy Evaluation (MSE) as a tool for actively managing the inevitable uncertainties.

Introduction

Since 2010, the IOTC Working Parties have provided stock assessment advice that includes a Kobe 2 Strategy Matrix (K2SM). This is a decision table that describes the future probability of exceeding MSY-related reference points for a range of possible management options (eg. Table 1). At least one K2SM has now been provided for each of the main target species assessed by the IOTC (YFT, BET, SKJ, SWO and ALB).

Table 1. Example Kobe 2 Stratey Matrix.

Reference point and projection timeframe	Alternative catch projections (relative to current year) and weighted probability (%) scenarios that violate reference point				
	60%	**80%**	**100%**	**120%**	**140%**
$Pr(SB_{current+3y} < SB_{MSY})$	xxx	xxx	xxx	xxx	xxx
$Pr(F_{current+3y} > F_{MSY})$	xxx	xxx	xxx	xxx	xxx
$Pr(SB_{current+10y} < SB_{MSY})$	xxx	xxx	xxx	xxx	xxx
$Pr(F_{current+10y} > F_{MSY})$	xxx	xxx	xxx	xxx	xxx

At the 2011 WPTT, concerns were expressed by some participants about the K2SM:

> *192 (of draft WPTT report). The WPTT **AGREED** to undertake deterministic projections of stock status according to the Kobe management strategy matrix … There was considerable discussion on the ability of the WPTT to do this. On one hand it is clear that the true uncertainty is unknown and that the current characterization may not be complete. On the other hand the projections may provide a relative ranking of outcomes that might be useful to the Commission.*

Discussions at the Kobe III meeting were cited as a main source of doubt about the appropriateness of the K2SM. The main text of the draft Kobe III report noted:

> *Kobe III participants agreed that the K2SM is a useful tool for evaluating management strategies or options, provided that the uncertainties in assessments can be adequately quantified. Participants acknowledged that considerable work remains to be done both to reduce uncertainty in stock assessments, and to develop common standards or guidelines for how uncertainty is reflected…*

and the draft Kobe III report recommended:

> *(2) Emphasizing the potential of the Kobe II Strategy Matrix (K2SM) to communicate efficiently among all stakeholders and to assist in the decision-making process according to different levels of risk, but also recognizing that substantial uncertainties still remain in the assessments, Kobe III participants recommended that the Scientific Committees and Bodies of the tRFMOs develop research activities to better quantify the uncertainty and understand how this uncertainty is reflected in the risk assessment inherent in the K2SM.*

These discussions have led some IOTC Working Party participants to conclude that it may not be appropriate to include the K2SM in IOTC management advice at this time. Advantages and disadvantages for inclusion of the K2SM are discussed below.

Argument for NOT including K2SM in IOTC Management Advice

The main argument for not including the K2SM in the management advice for some or all stocks primarily stems from the inability of the scientists to represent the full uncertainty in future projections. The main sources of uncertainty that affect future fishery dynamics include:

i. Uncertainty in the current state of the population and reference points (i.e. as estimated by the stock assessment models). This includes parameter estimation uncertainty (i.e. how well can we estimate the parameters for a given population model?) and the model selection uncertainty (i.e. how well can we specify the model in the first place, or choose among competing models?)
ii. Uncertainty about future biology (e.g. how well can we describe future recruitment?).
iii. Uncertainty about how the fishing fleets will operate in the future (e.g. how will the fleet respond to different management measures?).

Projections can also be time-consuming. Given the limited resources and tight timeframes available for the IOTC assessment process, it may not be worth trying to produce projections if they are not going to be useful in the management advice.

Counter-arguments for including K2SM in IOTC Management Advice

1. Should we even try to predict the future?

It is impossible to consistently predict what is going to happen in the future in any complex system. However, we must believe that past experience can tell us something about the future, or else there would be no point in conducting stock assessments, or providing management advice on the basis of the assessment. Management advice will always be based on some kind of projection model, either mathematical models that are concisely defined (and subject to criticism and review), or qualitative models derived within the heads of individuals (which are difficult to communicate and evaluate). What the scientists call probability in this context is not perfect. However, the mathematical models are at least guided by data and theory, and are transparent and reproducible. The scientists provide probability statements that at least attempt to be consistent with the available data,

conditional on the stated assumptions. If the scientists fail to provide any probability estimates for future outcomes, the managers are left with no option other than providing their own implicit assessments of likely outcomes.

2. How much uncertainty is enough?

Failure to recognize important sources of uncertainty can lead to misleading management advice in the K2SM, but it is not easy to decide how much uncertainty to include. If there is concern about the uncertainty quantification in the current state of the stock and basic biological parameters (or the assessment model is conspicuously misleading), then it follows that there will also be concerns about the projections. The WPs should be emphasizing the need to improve the overall quality and uncertainty quantification in the assessment, not just the projections. However, one needs to be careful here in recognizing that the 'perfect assessment' is not attainable. Even with the most comprehensive efforts at uncertainty quantification (e.g. as employed in Management Strategy Evaluation), it is recognized that things can still go wrong. As long as the most important sources of uncertainty have been admitted into the analysis, the projections should provide a useful indication of the relative performance expected for different management options.

Figure 1 provides a conceptual illustration of how the inclusion of more sources of uncertainty leads to a broader range of outcome probabilities, as summarized in the corresponding K2SM (Table 2). In this particular case, all of the uncertainty options might lead to the same recommendation by managers (e.g. 'do not increase catch'). However, we would probably feel much more comfortable with the results that at least include the substantial current stock status uncertainty. We probably should not have a lot of confidence in any single set of stock status point estimates, e.g. especially with respect to MSY-related reference points that we know are difficult to estimate reliably.

Most of the IOTC projections to date have involved deterministic recruitment and emphasized the current stock status uncertainty. This is probably reasonable for short-medium term projections of long-lived species, because the cohort size of most of the vulnerable population will have already been estimated in the assessment. For short-lived species, it is probably reasonable when there is very large uncertainty about the current stock status and productivity of the stock (e.g. Figure 1 might represent such a case). Deterministic recruitment will be most inadequate for short-lived stocks with high recruitment variability. But even in this latter case, the relative performance of different management options might not change very much (e.g. because all options perform poorly when recruitment is poor). However, projections with stochastic recruitment would be preferable. Recruitment projections are often criticized because of a lack of confidence in the stock recruitment relationship. There are a couple points to consider here:

i. The relationship between spawning biomass and recruitment is difficult to quantify. To some extent this can be addressed by admitting alternative relationships (e.g. Beverton-Holt steepness) in the projections. However, in general it should also be a management priority to keep the spawning biomass at a high enough level that there is a low risk of recruitment overfishing (lessening the importance of steepness).
ii. Often there may appear to be systematic lack-of-fit in the estimated stock-recruit relationship due to time series trends in recruitment that are not associated with changes in spawning biomass. This could lead to overly optimistic or pessimistic projections which are not consistent with recent recruitment observations. This can be accounted for in the short-medium term, by fixing recruitment at recently observed levels (as was done for YFT in 2011), or including an auto-correlation term that links the recruitment deviate estimates from the most recent years to the future deviates in the projections (e.g. CCSBT operating model).

Table 2. Example Kobe 2 Strategy Matrix (SSB component only) illustrating the implications of including the different sources of uncertainty from the hypothetical example illustrated in Figure 1.

Reference point and projection timeframe	Alternative catch projections and weighted probability (%) scenarios that violate reference point		
	Reduced Catch	**Current Catch**	**Increased Catch**
	No current stock status uncertainty, deterministic projections		
$Pr(SB_{current+10y} < SB_{MSY})$	**0**	**0**	**100**
	No current stock status uncertainty, stochastic projections		
$Pr(SB_{current+10y} < SB_{MSY})$	**0**	**4**	**96**
	Current stock status uncertainty, deterministic projections		
$Pr(SB_{current+10y} < SB_{MSY})$	**3**	**27**	**73**
	Current stock status uncertainty, stochastic projections		
$Pr(SB_{current+10y} < SB_{MSY})$	**8**	**32**	**68**

3. K2SM as a stepping stone to Management Strategy Evaluation

The K2SM, as used by the IOTC to date, is only one example of a management decision table. It may not be the most appropriate decision table for the IOTC, but it does provide a useful interface between science and management, and can be improved over time. The K2SM is extremely limited in that it only reports the probability of exceeding default MSY-related reference points. It could be expanded to include other management objectives (e.g. economic considerations like total catches, catch rates or catch stability). Similarly, the K2SM only evaluates the outcomes of alternative constant catch projections, but can easily be expanded to include other management options (e.g. dynamic harvest control rules that respond differently as stock status changes). This simple extension of the K2SM results in the sort of decision table that might be used to represent much more comprehensive Management Strategy Evaluation (MSE) results[1] (e.g. Table 3). Use of the K2SM represents a positive step toward the longer term commitment of the IOTC toward implementation of the precautionary approach and the use of Management Strategy Evaluation (MSE) as a tool for actively managing the inevitable uncertainties.

[1] However, it should be emphasized that the MSE process represents much more than a simple modification to a K2SM decision table:

- The K2SM represents a management decision table that might be updated every year. It describes the outcome of constant catch projections as an indication of the expected trend in the stock given the estimated productivity and current age structure of the fish population, but there is no real expectation that managers will hold catches constant for 10 years. The decision table that is used to choose a Harvest Control Rules (HCR) in MSE looks similar, but the interpretation is very different. The MSE decision table also compares predicted long-term management performance, but unlike the K2SM, it is not updated every year. The expectation is that MSE and the HCR selection process should only be undertaken once every few years, because the HCR is designed, tested and selected to deliver reasonable performance over a long time period.
- MSE also involves a comprehensive Operating Model (OM) for projections. The OM may be conditioned to the data in a manner that is similar to an assessment model, but it includes a strong emphasis on uncertainty quantification, including projection scenarios that describe challenging situations that may not have been observed in the fishery before. This ensures that HCRs provide management performance that is robust to a wide range of plausible uncertainties (has a high probability of avoiding the worst outcomes).
- MSE should be viewed as a process that requires interaction among all stakeholders (including scientists, managers, industry NGOs, etc.), to define sensible management options and to carefully examine the trade-offs among performance objectives. While the initial process can be time consuming and technically challenging, it often becomes evident that satisfactory management outcomes can be achieved with simple and transparent decision rules.

Table 3. Generalized example of a Management Decision Table. The K2SM is the subset of the table highlighted in the top left corner. This table also resembles the sort of summary of results that might be used to select a Harvest Control Rule through Management Strategy Evaluation.

Management Performance Indicators	Management Options					
	Constant Catch (80% of Current)	Constant Catch (100% of Current)	Constant Fishing Mortality $F=0.5F_{MSY}$	Constant Fishing Mortality $F=0.8F_{MSY}$	Closed Area (1 month)	Closed Area (3 months)
$Pr(SB_{2014} < SB_{MSY})$	xxx	xxx	xxx	xxx	xxx	xxx
$Pr(F_{2014} > F_{MSY})$	xxx	xxx	xxx	xxx	xxx	xxx
$Pr(SB_{2020} < SB_{MSY})$	xxx	xxx	xxx	xxx	xxx	xxx
$Pr(F_{2020} > F_{MSY})$	xxx	xxx	xxx	xxx	xxx	xxx
SB_{2014}/SB_0	xxx	xxx	xxx	xxx	xxx	xxx
SB_{2020}/SB_0	xxx	xxx	xxx	xxx	xxx	xxx
Mean Catch (2012:2014)	xxx	xxx	xxx	xxx	xxx	xxx
Mean Catch (2012:2020)	xxx	xxx	xxx	xxx	xxx	xxx
Catch Stability (2012:2014)	xxx	xxx	xxx	xxx	xxx	xxx
Catch Stability (2012:2020)	xxx	xxx	xxx	xxx	xxx	xxx
Mean CPUE (2012:2014)	xxx	xxx	xxx	xxx	xxx	xxx
Mean CPUE (2012:2020)	xxx	xxx	xxx	xxx	xxx	xxx
others…						

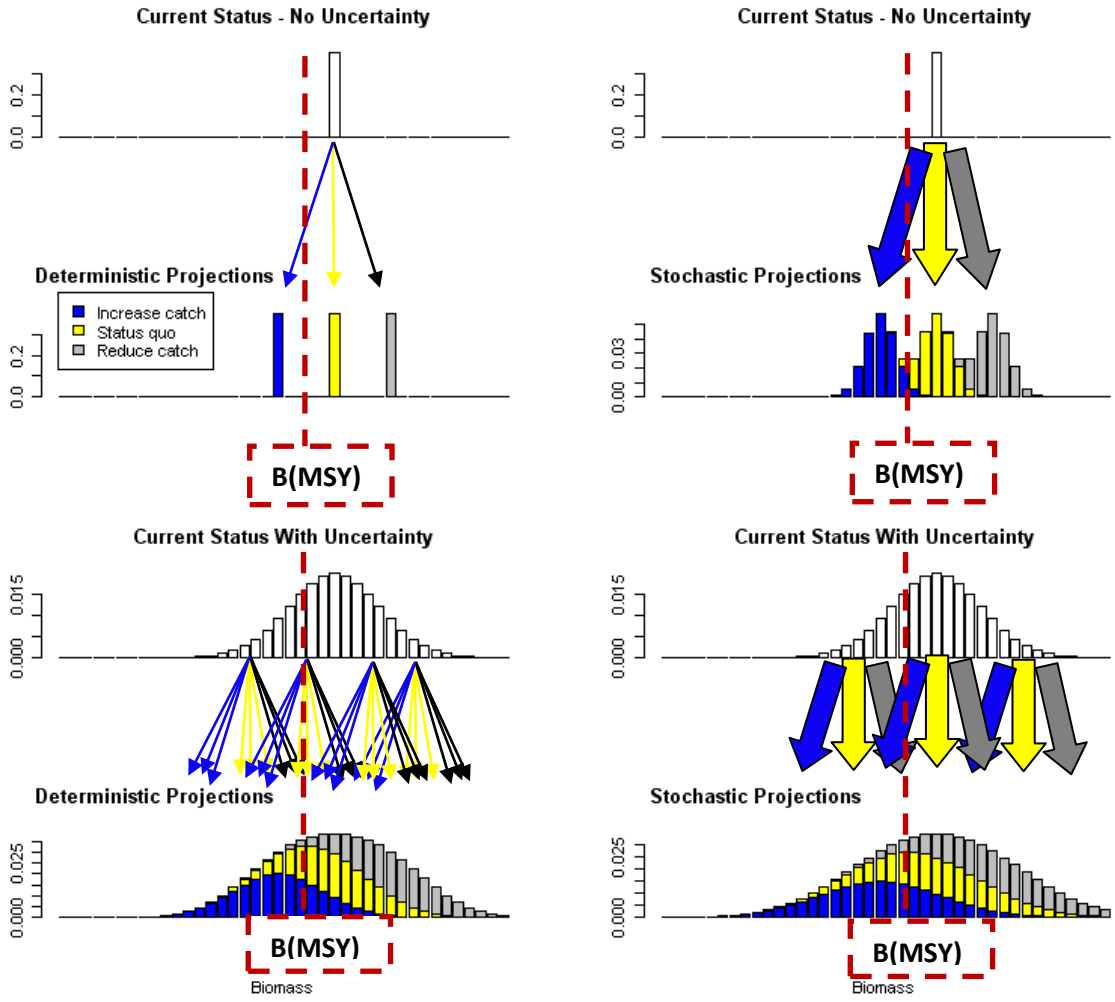

Figure 1. Conceptual illustration of how different sources of uncertainty affect the biomass projections used in the Kobe 2 Strategy Matrix (Table 2). X-axis represents biomass, Y-axis represents relative probabilities. White bars indicate the estimated current biomass from 4 scenarios, with simulated projection results below for three different management options represented by the blue, yellow and grey bars.