

Some Lessons from Implementing Management Procedures

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The processes needed to implement Management Procedures (MPs) successfully are considered, with particular reference to the International Whaling Commission and South Africa which have the longest experiences with the MP approach. The three most important aspects in implementing MPs are: i) agreement of a Protocol which details specifications concerning data quality and availability, and the special circumstances under which the recommendation provided by an MP might be changed or the regular review of the MP brought forward; ii) structures for regular interaction between scientists and stakeholders during MP development to facilitate consensus buy-in to the outcome; and iii) adherence within the overall development schedule to strict deadlines for completion of the sequential steps of finalisation of past data and then of operating models for use in simulation testing of MPs. Difficulties in the definition of risk are discussed briefly, together with certain aspects of decision rules. For the latter, the importance of TAC variability constraints is emphasised, and a preference for empirical over model-based approaches is suggested based upon reader understanding by lay stakeholders.

KEYWORDS empirical; deadline; management procedures; management strategy evaluation; model-based; review process; risk; robustness; simulation test; uncertainty

1. Introduction

A Management Procedure (MP) is defined as the combination of pre-specified methods of data collection and analysis, and a simulation-tested decision rule which calculates a management recommendation (e.g. a To-

tal Allowable Catch—TAC) for a fishery (Butterworth *et al.* 1997). This process for providing scientific advice contrasts with the traditional approach of basing such a recommendation on a “best” assessment of the resource at the time, coupled to some biological reference point such as a target fishing mortality. (The Appendix provides more

details of this Management Procedure approach.)

The MP approach (alternatively termed Management Strategy Evaluation—MSE; Rademeyer *et al.* (2007) provide a glossary of the terminology that has developed in the field) was pioneered in the International Whaling Commission (IWC) (Punt and Donovan 2007), and its application has spread slowly but steadily. Punt (2006, Table 1) lists 17 resources for which the approach has been, is, or is under consideration for use. In addition the MP approach is the basis for management recommendations for two aboriginal subsistence whaling operations in the IWC, and is planned for North Atlantic bluefin tuna (*Thunnus thynnus*) in the International Commission for the Conservation of Atlantic Tunas (ICCAT) (ICCAT 2006), Southern bluefin tuna (*T. maccoyi*) in the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) (CCSBT 2005), krill (*Euphausia superba*) in the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) (CCAMLR, 2006), and Greenland halibut (*Reinhardtius hippoglossoides*) in the North Atlantic Fisheries Organisation (NAFO) (Miller *et al.* 2007). Furthermore, De Oliveira *et al.* (2008) detail initiatives under way to use the MP approach in Australia, Europe and the USA, while a recent FAO Expert Consultation in relation to Ecosystem Modelling (FAO 2008) considered the approach best practice for the move towards taking account of such models in fisheries management by using them as models of the possible underlying realities (Operating Models—OMs) against which decision rules are simulation tested.

A core motivation for the MP approach is to take formal account of uncertainties as required under the Precautionary Approach (FAO 1995). It relies on feedback to adjust management controls to attempt to move

resource abundance towards target levels, even if the current best assessment of the resource is in error. Schnute *et al.* (2007) consider MSE to be a dominant issue in the future of fisheries stock assessment.

There have been many contributions providing details of the MP approach/MSE, how OMs are best selected and specified, and what are seen as the overall advantages and disadvantages of the approach (such as the positive aspect of providing a structured framework for taking proper account of uncertainties in line with the Precautionary Approach, and the negative aspect of a lengthy development time) (e.g. Butterworth and Punt 1999; Smith *et al.* 1999; Kell *et al.* 2006; Punt 2006; Butterworth 2007; Plagányi *et al.* 2007; Rademeyer *et al.* 2007; Punt, this volume). However, rather less has been said about the associated processes necessary to see MPs successfully implemented in practice.

The IWC and South Africa have the longest experiences with the approach. For the three major South African fisheries, scientific TAC recommendations for hake (*Merluccius* spp.) and for the small pelagics, sardine (*Sardinops sagax*) and anchovy (*Engraulis encrasicolus*), have been provided on this basis for over 15 years, and those for west coast rock lobster (*Jasus lalandii*) for over 10 years. Since the late 1990s, South African decision makers have not modified recommendations based on such procedures unless motivated by scientific justification based on new information, which is suggestive of the approach's success.

This paper seeks to distill some of the lessons learnt concerning implementation, especially in the IWC and South Africa. The paper concentrates primarily on aspects of process, but also includes discussion of issues related to risk and decision rules.

2. Overarching Process-Related Aspects

2.1. Protocols

Conceptually, once an MP is implemented, it can be left to run indefinitely like “clock-work” (Hilborn and Luedke 1987) or an autopilot, to provide future management recommendations; these recommendations will, when implemented, ensure through feedback control that long term objectives for the resource and fishery are met. In practice however, future reviews and possible revisions are necessary to take account of scientific advances in resolving some of the uncertainties against which the original MP was designed to be robust. Furthermore, allowance must be made for possible intervention if circumstances arise which are beyond those for which this “autopilot” was designed to cater.

For the successful implementation of an MP over time, the agreement and documentation of a Protocol setting out procedures associated with these practical aspects is almost as important as agreement on the details of the MP itself. MPs for the South African fisheries function under a set of “Procedures for deviating from OMP [Operational Management Procedure] output for the recommendation for a TAC, and for initiating an OMP review” (see Rademeyer *et al.* (in press), Appendix II). These were developed from similar proposals for such a protocol associated with the MP planned for Southern bluefin tuna (Basson *et al.* 2004; Basson and Polacheck 2005). The specification document for the IWC’s Revised Management Procedure (RMP) for baleen whales (IWC 1999) also contains some such provisions.

The justification for pre-specifying a regular series of reviews to update MP evaluations in the light of new scientific inputs is not contentious. IWC (1999) specifies a five-year interval between these reviews under

the RMP, while South Africa intends a four-year period and the CCSBT (which conceived TAC adjustments only every three years) plans for nine years.

However, allowing for deviation from MP recommendations or bringing MP reviews forward seems dangerous, as it provides an opening for the very tinkering with recommendations that the MP approach is intended to avoid (Butterworth 2007). Consequently it is important to specify that such action may be considered only provided that there is first compelling evidence presented for its necessity. The primary criterion to be satisfied in justifying such *Exceptional Circumstances* is that the resource has moved outside the range over which earlier simulation testing had shown the MP to be robust. To allow such checks to be made, it remains necessary to carry out regular (typically annual, except for very long-lived species) baseline assessments of a resource between the regular MP reviews. Indeed, during the fairly lengthy periods of development of both the SBT (CCSBT, 2004) and the most recent South African hake (Rademeyer *et al.* in press) MPs, a demonstration that an updated assessment showed the resource to be outside the range predicted by the OMs guiding the MP development led to the revision of those OMs before the final MP simulation testing process was conducted.

Reaction to *Exceptional Circumstances* can take two forms. One is an *ad hoc* adjustment to the MP’s recommendation, coupled perhaps with bringing the next scheduled MP review forward. However, for short-lived and highly fluctuating resources (such as the South African sardine and anchovy), simulation-tested metarules may be pre-specified to prescribe the action to be taken in such circumstances. These metarules may take the form of more conservative catch control laws and a suspension of limitations on the extent to which the TAC can be reduced from year to year (e.g. Cunningham and Butterworth 2004). One rationale underlying such

metarules (which correspond to the “jacket” concept in control theory—see Jacobs 1989) is that the MPs for such highly fluctuating resources are designed to secure a low probability of abundance falling below some threshold level, but if that situation nevertheless appears to have occurred, different management measures need to be put in place. These different measures must ensure that there is high probability of resource recovery, while still if possible avoiding the draconian measure of fishery closure with its concomitant negative socio-economic consequences.

In practice, instances of *Exceptional Circumstances* have occurred more frequently than predicted over the period of applying MPs to the major South African fisheries. This outcome is not entirely unexpected, as the range of uncertainties against which MPs are tested is typically based on the past behaviour shown by the resource in question or similar resources elsewhere (for example along the lines of the plausibility ranking scheme of Butterworth *et al.* 1996—see discussion in Punt, this volume), but the resource is not guaranteed to maintain such behaviour in future.

Kolody *et al.* (in press) raise the concern that more frequent instances than expected of *Exceptional Circumstances* may compromise the credibility of MPs, and mention one possible remedy of deliberately expanding the range of uncertainties considered in the simulation testing process to make greater allowance for the associated “unexpected” future events. However, the difficulty with such an approach is that the greater such expansion, the more conservative the MP that will result (almost certainly TACs will be lower in the short term), and stakeholders from industry are consequently virtually guaranteed to take issue with the somewhat arbitrary nature of the choice of the extent by which to expand this range.

On balance, I would argue that risk of a greater frequency of *Exceptional Circum-*

stances declarations when the range of uncertainties is determined by “past behaviour” is worth taking, if only to get an MP accepted by consensus. Formal consensus constitutes buy-in to accept the future TAC changes (whether positive or negative) that feedback control will bring. (Indeed, in South Africa MP parameters have sometimes been set to ensure no substantial TAC change in the first year of implementation as a deliberate “sweetener” to obtain buy-in to such acceptance, which has been seen as the most important strategic goal of the process.) Industry stakeholders in particular, given their financial investments, can be reluctant to tie themselves down to application of the same formula over a lengthy period; the specifications of a regular review process and *Exceptional Circumstances* provisions make the MP package all the more saleable. Over time there seems to have been an increasing appreciation in South African fishing industry circles of the value of the security and transparency provided by MP-based management. The well-defined processes involved are seen as an important counter to possible sudden maverick interventions by interest groups seeking to influence decisions.

2.2. Robustness

The concept of an MP providing recommendations that take account of uncertainties in ensuring management objectives are met is easily advocated, but there are associated practical problems. The source of the difficulty is that no MP can offer such robustness under *every* conceivable hypothesis for resource and fishery dynamics. Thus some allowance for the relative plausibility of the hypotheses underlying the various uncertainties has to be made when selecting a MP.

In practice in South Africa, final selection of MPs has been based primarily on performance under either:

- a Reference Case OM reflecting the “best assessment” of the resource which

takes account only of estimation error in current numbers-at-age estimates and some demographic parameters (sometimes within a Bayesian framework), together with future observation errors in monitoring data and recruitment fluctuations (process error), or

- more recently often a Reference Set of a limited number of OMs which span the major axes of uncertainty and over which performance statistics for the MP are integrated (Plagányi *et al.* 2007; Rademeyer *et al.* 2007). The SBT MP evaluation process followed this same approach (CCSBT, 2004).

Consideration of the results of other robustness tests has been at a qualitative level only (to check in particular that resource abundance projections do not differ dramatically from those under the Reference Case/Set). Furthermore, except in the case of the highly fluctuating sardine and anchovy resources, attainment of resource recovery targets has been assessed in terms of projection medians, with only qualitative consideration given to the associated probability intervals.

As emphasized by Punt and Donovan (2007), typically errors in structural assumptions can have a greater impact on simulated MP performance than process and observation error. Consequently, there is a need for greater emphasis in simulation tests on the implications of alternative stock structures, spatial dynamics and ecosystem effects. Recent MP refinements in South Africa are moving in this direction, with the rock lobster MP taking account of spatial effects by providing zone-specific TAC recommendations. Further, there are plans to examine alternative pelagic fish harvesting strategies so as to investigate their implications for African penguins (*Spheniscus demersus*), which feed on sardine and anchovy, within the MP framework.

Punt and Donovan (2007) also call for the MP Protocol to include a well-specified

process for selecting an MP after simulation tests have been completed, where such a process would take quantitative account of the results of robustness tests and their relative plausibilities. At present only the IWC is well advanced in this respect, with a scheme that effectively “lowers the bar” on target levels for population size at some future date when the hypothesis underlying the trial is accorded a lower plausibility (IWC 2005).

2.3. Scheduling

The process of finalizing an MP is a much more extensive exercise than a typical stock assessment. A particular difficulty is that arguments can arise in mid-process to return to the beginning (backtrack) so that new data or hypotheses can also be taken into account. Both the IWC and CCSBT have experienced such difficulties (Punt and Donovan 2007; Kolody *et al.* in press). The severity of these difficulties has led to the IWC specifying a schedule that sets specific deadlines within a two year time frame from commencement to MP selection (IWC 2005), within which no backtracking is allowed.

Similarly in South Africa, a sequence of deadlines is set to finalise each of these steps, again with no subsequent backtracking, for:

- i) the data to be used in conditioning OMs,
- ii) the OMs and their conditioning, and
- iii) candidate MP testing leading to MP selection.

In practice, however, slippage on the first two of these deadlines has unfortunately proved very difficult to prevent. The second step of OM specification usually leads to the longest overrun, with consequent extreme pressure of time on completing the third step for which the deadline is immovable (given requirements for management advice for the forthcoming season). This slippage has at times led to inadequate opportunity to fully explore alternative options for an MP, with only the robustness tests judged as likely to have the greatest impact being completed in

time for consideration in the selection of the MP.

The reasons that underlie the pressure to extend deliberations for the second step are understandable. Final MP selection is frequently determined primarily by achievement of abundance targets over the medium to long term (10–20 years, or longer for whales) under the Reference Case/Set of OMs. With TACs over the next few years usually highly dependent on this selection, and limited scope for adjustment of the MP in the short term, industry stakeholders and their scientific consultants on the one hand, and NGO interests on the other, will contest Reference Set selection vigorously to try to advance their respective foci on short and longer term goals, and it is difficult to take the overall process forward successfully until consensus has been reached on this aspect.

The broad advice to be given is to ensure that adequate time is allowed for the whole process (15 months has been typical in South Africa), and to err on the generous side in the allocation for the third step given that some slippage at the second stage will probably be unavoidable in practice.

2.4. Objectives

De Oliveira *et al.* (2008) state that a major benefit of the MP approach is that it requires the identification and quantification of management objectives while forcing a longer-term view of resource utilization on decision makers. However, this does not mean that these objectives need to be precisely articulated at the start of the process (Kolody *et al.* in press).

The process of finalizing objectives should be an iterative one, particularly as broad objectives (e.g. maximize catch, minimize risk) often conflict, so that trade-off choices will need to be made. Typically, it is only as computations develop, and the key trade-offs come to be identified and quanti-

fied, that decision makers can become more fully aware of the constraints within which they are limited to operate, and hence become able to meaningfully quantify their objectives.

2.5. Data aspects

MP implementation is based on the premise that resource monitoring data of an adequate quality (e.g. abundance estimates within the levels of bias and precision considered in the simulation testing) will continue to be forthcoming as time proceeds. However assured this continued provision might seem, unanticipated events (e.g. mechanical problems with a research vessel forcing cancellation of a survey) can lead to nonavailability of such data.

Thus the MP Protocol must include clear specifications of the defaults to apply in circumstances where a datum anticipated is not forthcoming, with performance under these defaults preferably having been simulation tested. Depending on the nature of the data concerned, such defaults may be as simple as assuming the value in question to be the same as observed the previous year. Defaults may also incorporate a carrot-and-stick approach, such as the IWC's RMP (IWC, 1999) under which surveys that are more frequent or intensive (hence leading to more precise estimates of abundance) will lead to larger TACs, whereas TACs are continually phased down from the values that would otherwise apply the longer the period that elapses (after a specified minimum) before a further survey takes place.

Another difficulty that can arise is if TACs are undercaught (not reached), particularly if the reasons are administrative delays in finalising and advising quota allocations and quota holders request roll-overs to the following season. MPs do react to undercatches by increasing future TACs above the levels which would otherwise have eventuated. However, typically this "compensation"

is only partial and slow in coming. Once again, the Protocol should specify in advance how such circumstances are to be handled to preempt difficult discussions and *ad hoc* adjustments at the time.

2.6. Organisation

Transparency and standards can be enhanced through the practice of keeping the process of coding simulation tests independent of the use of this code to test candidate MPs. Punt and Donovan (2007) suggest that major gains may be made by having more than one group contribute to the process of developing and testing candidate MPs (as has occurred in both the IWC and CCSBT), and the availability of user-friendly code can facilitate this occurrence.

However, this multi-group involvement may be more readily achieved only at an international level, where the Secretariat of an RFMO can undertake or oversee the coding process, and scientists from member states offer alternative candidate MPs. At national level, lack of resources and expertise make this more difficult, though Schnute *et al.* (2007) suggest that the development of a common conceptual framework, from which standardized open source software for MP testing might emerge, could ameliorate this problem. The development of Fisheries Libraries in R (FLR, www.flr-project.org, Kell *et al.* 2006) is an initiative in this direction.

3. Risk

“Minimising risk” is a readily agreed broad objective for fisheries management, but as Punt (this volume) bemoans, decision makers are seldom willing to provide an agreed definition for “risk” and an associated threshold for acceptability.

One problem is that development of definitions to which lay stakeholders can readily relate has proved difficult. Often the approach used scientifically is to express risk

in terms of the probability of abundance dropping below some threshold level (typically motivated by concerns that below this level, recruitment success could be jeopardized) over a specified period of time (e.g. as used for Antarctic krill (CCAMLR 1994, paras 5.18–5.26) and the South African sardine and anchovy resources (De Oliveira and Butterworth, 2004); in the former case the risk criterion applied is the probability of spawning biomass dropping below 20% of its pre-exploitation median level over a 20 year period of harvesting not exceeding 10%).

Even if one leaves aside the question of whether the computation of such probabilities should be extended beyond a Reference Case OM to integrate over, for example, structural uncertainties and their relative probabilities, it is even then not straightforward to maintain consistency over time with this approach. This is because estimates of key demographic parameters can change over time as further data become available. Figure 1 shows the series of at times rapidly changing estimates of biomass from annual hydroacoustic surveys of the South African sardine resource, and associated recruitment plots. As time progressed, best estimates of adult natural mortality (M) and the extent of variability (σ_R) about a fitted stock-recruitment relationship have changed (Table 1). The lower M or the larger σ_R , the greater the extent to which abundance will fluctuate naturally in the absence of exploitation; hence the lesser the concern that arises if harvesting reduces the resource to a particular level.

Thus acceptable risk thresholds for sardine (and similarly for anchovy) have had to be re-specified over time, because maintaining the same estimated probability of the resource dropping below a particular level (such as 20% of the average abundance in the absence of exploitation) would not correspond to an unchanged biological risk (as it is perceived at any time given the demographic

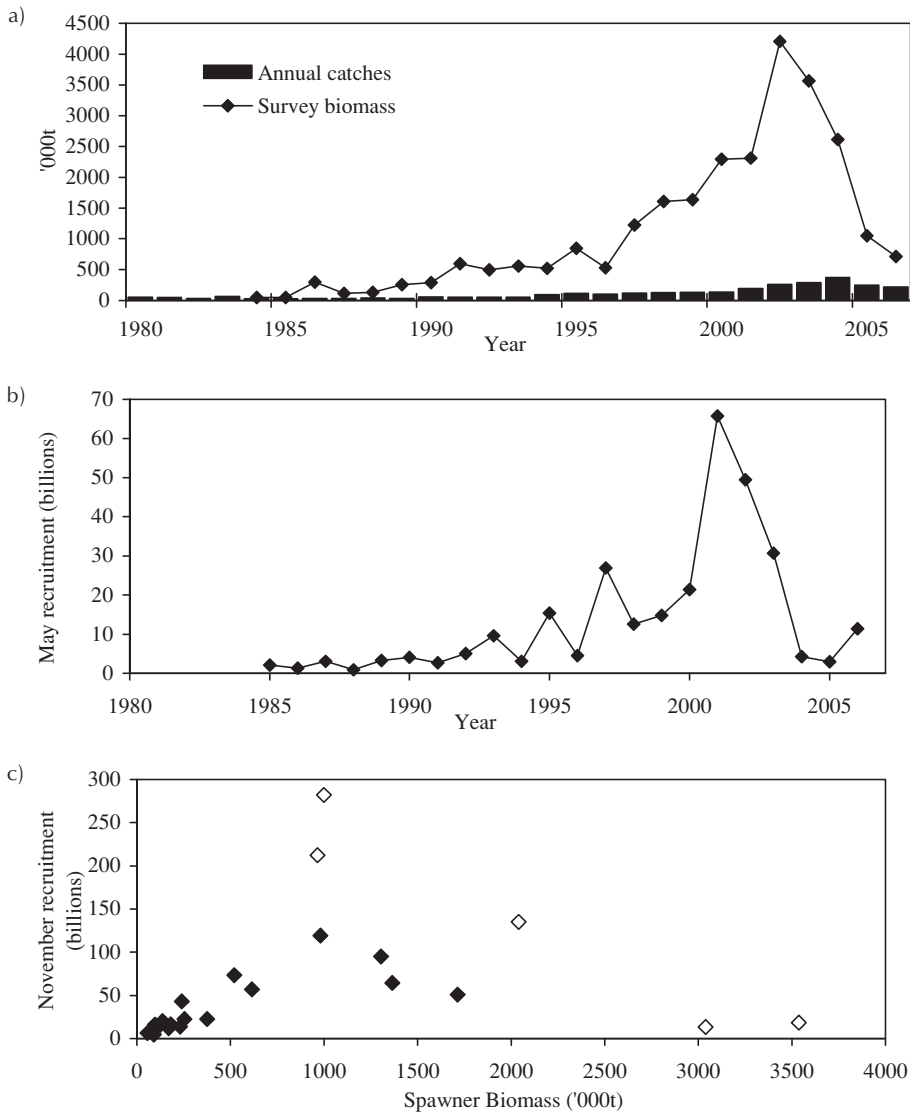


Fig. 1. Time series of **a)** total annual catches and November hydroacoustic survey estimates of biomass and **b)** population model estimates of annual recruitment for the South African sardine, together with **c)** a stock-recruitment plot based on model estimates. The last plot distinguishes points during the period of the recent peak and then decline in abundance.

estimates then available). The changes in estimates of M and σ_R for sardine were mainly increases, suggesting that the acceptable probability of falling below a particular level should be set higher, but by how much? The approach adopted at present to attempt

to maintain a consistent approach to risk given these changing estimates, is to adjust this probability threshold so that under the corresponding MP, the anticipated biomass distribution below the median is moved to the left compared to the pristine distribution

Table 1. The evolution of estimates of demographic parameters to which risk evaluation is particularly sensitive in the Reference Case OMs (denoted by the year of the associated assessment) used in selecting the sequence of MPs adopted for the South African sardine resource. M is adult natural mortality and σ_R the standard deviation of the residuals of log recruitment about a stock recruitment relation, which has been assumed to have a hockey-stick form. (Note that the value of M was initially guessed and later poorly estimated, until the rapid recent decline in abundance (see Fig. 1) provided the contrast for improvement in circumstances where ageing information is not yet considered reliable.)

Assessment year	MP name	M (yr ⁻¹)	σ_R
1993	OMP-94	0.8	0.33
1996	OMP-97	0.6	
1998	OMP-99	0.6	0.51
2001	OMP-02	0.4	0.50
2004	OMP-04	0.4	0.49*
2007	OMP-08	0.8	0.50*

*Bayes posterior median

by about the same relative proportion as was the case for the previous MP under their respective Reference Case OMs (see Fig. 2) (Cunningham and Butterworth 2008).

4. Decision Rules

4.1. Form

Decision rules in MPs frequently take the form of catch control laws which provide TAC recommendations based on estimates of current biomass (B). Figure 3 provides examples of some common forms: constant catch, constant fishing mortality (F) and constant escapement, in the form of both the TAC and of F as a function of B .

Interactions with industry in South Africa have served to emphasise the importance they attach to limiting TAC variability to the extent possible in the interests of enhanced

socio-economic stability. Figure 4 illustrates the rather more complex catch control law for sardine that has evolved in consequence. Notable features of this and the associated limitations on TAC variability are:

- The rule is based on modifications to the constant F approach.
- Over a range of lower values of B , a constant “minimum” TAC applies, as the industry would need substantial restructuring if the TAC fell below this level; note that this means that over this range of B , F increases as B decreases to contain the socio-economic risk.
- The lower end of that range is the *Exceptional Circumstances* threshold; below this F decreases linearly and the TAC quadratically with B , with the limitations on annual reductions in TAC that would otherwise apply falling away.
- There is a maximum TAC, both because of limits on the industry’s catch and processing capacity, and because simulations indicated that a constant F rule when biomass is estimated to be high (and this estimate could be considerably above the true abundance because of survey sampling error) led to greater risk.
- Over an intermediate biomass range, there is a maximum proportional amount by which the TAC can be reduced from the previous year’s value.
- When the previous year’s TAC is above a certain relatively high level, this maximum proportional reduction limitation falls away and is replaced by a specific level to which the TAC can be reduced; this feature of the decision rules is to allow advantage to be taken if sudden peaks in abundance occur by increasing TACs substantially, while still containing risk by also allowing for large and rapid TAC decreases on the downside of such peaks.

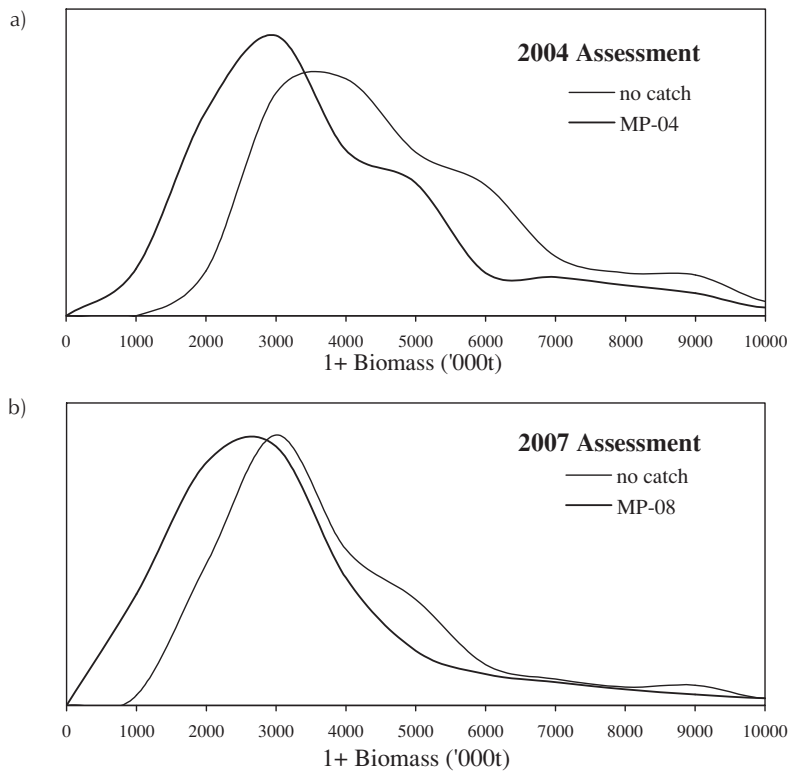


Fig. 2. Biomass distributions inferred from Reference Case OMs for the South African sardine resource under zero catches and under the MP implemented for **a)** the 2004 MP and **b)** the 2008 MP.

4.2. Continuity

Continuity is a necessary and important feature of control rules. Circumstances where a small change in an abundance estimate would lead to a large change in TAC serve only to invite endless haggling over revision of an abundance estimate slightly below (or above) the level at which the discontinuity occurs. An exception to this may be the maintenance of the current TAC unless the change indicated by the control rule is above a certain smallish threshold, simply to avoid the administrative inconvenience brought about by a small TAC change of no real biological consequence. Care needs to be exercised to ensure that the property of continuity is main-

tained when constraints on annual TAC adjustments may alter (e.g. when *Exceptional Circumstances* apply).

4.3. Model-based vs. empirical

MPs may be split into two categories:

- “model-based”: where typically the current abundance of the resource is estimated by applying some assessment procedure to the available data, with that abundance then input to a control rule to provide a TAC recommendation; and
- empirical: where resource monitoring data are entered directly into the control rule (e.g. the TAC is adjusted in proportion to the short-term trend with time of an index of abundance).

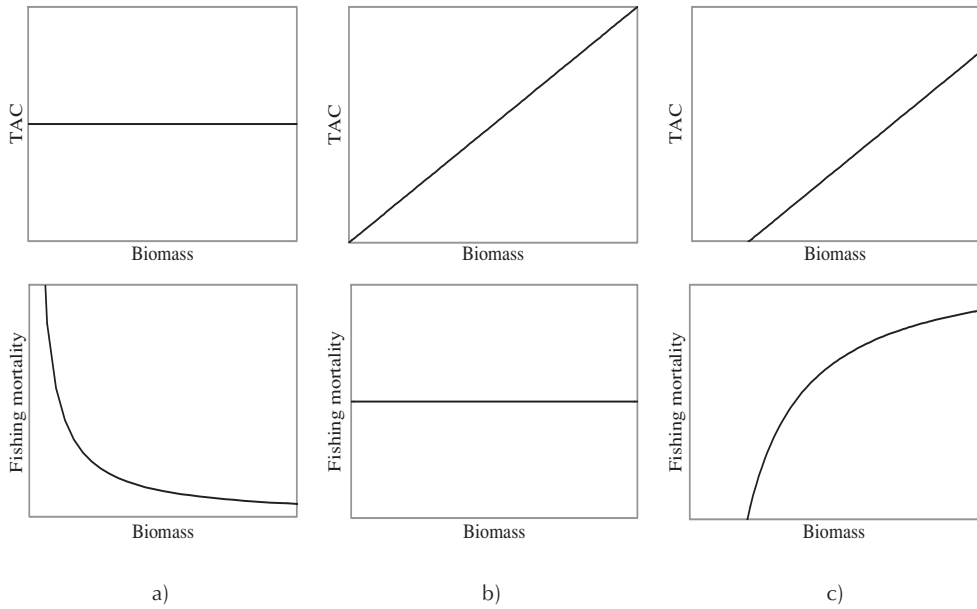


Fig. 3. Illustrative plots of catch control laws that relate TACs (upper panels) and fishing mortality F (lower panels) to biomass B for **a)** constant catch, **b)** constant fishing mortality and **c)** constant escapement approaches.

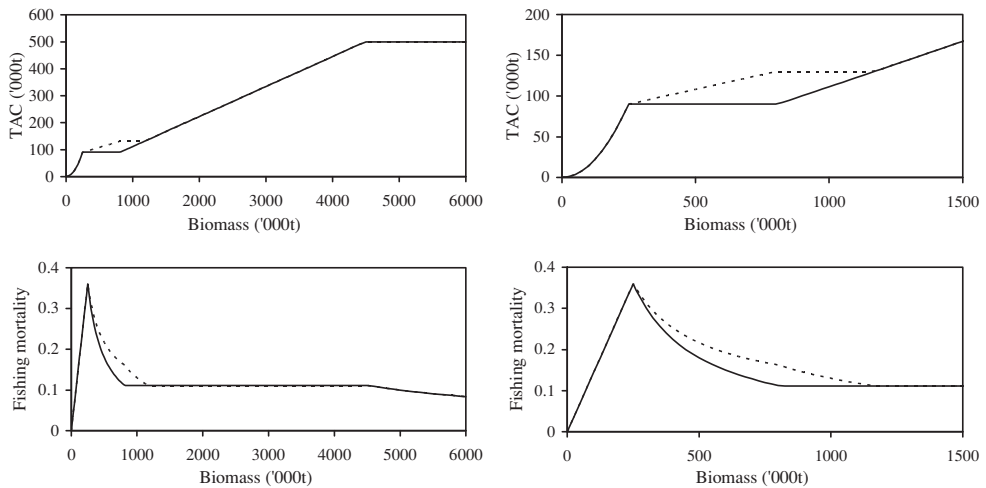


Fig. 4. The catch control law for the South African sardine under the 2008 MP, with the upper panels showing TAC and the lower panels fishing mortality F . The full line reflects the basic law, while the dashed line includes a year-specific adjustment (here applying to 2008) that arises from variability constraints linked to the previous year's TAC.

Model-based MPs tend to result in lesser inter-annual variability in the TAC than empirical approaches at comparable risk and catch levels. This property follows because model-based procedures can make their estimates using more data, as they are able to take account of the complex trends in abundance of the underlying population over a long period. Empirical approaches on the other hand are usually restricted to linear trends because abundance indices typically exhibit high variability, and hence must limit the data used to estimate this trend to a period for which the trend in the true abundance is likely to be well approximated by a straight line. Model-based procedures also make use of improved estimates of resource productivity as more data become available, i.e. they “learn” in a manner that diminishes the extent of a core uncertainty. For these reasons, model-based approaches have been preferred in the IWC (IWC 1992) and CCSBT (CCSBT 2005).

In contrast, however, the recent trend in South Africa has been towards empirical procedures, with the most recently adopted MP for hake being a particular example, succeeding the use of model-based approaches in the past (Rademeyer *et al.* in press). Among the reasons for this change are that model-based approaches are often in practice restricted to relatively simple age-aggregated production model approaches as testing complex models with many estimable parameters would be computationally infeasible. Given long time series of data, these simpler models can prove incapable of reproducing past behaviour, and so may also exhibit multi-modal likelihoods as well as an inability to reflect (and hence have the MP react adequately to) recent changes in abundance index trends.

The particular advantage of empirical approaches is that they are easily comprehended by lay stakeholders, which enhances the transparency and saleability of the MP. Arguably the disadvantages compared to the

model-based approaches can be offset by explicit imposition of limitations on the extent of interannual TAC changes, and having the updating of OM (and hence also possibly of MP control parameters) in the regular review process take care of the “learning” aspect of improving estimates of demographic parameters.

An apparent disadvantage is that target and limit reference points are emergent properties of empirical approaches, whereas they can be explicitly included in the design of the control rules for model-based MPs. However, this “advantage” of the latter category of MPs is really illusory, as even for those MPs, it is performance statistics under simulation that determine the reference points likely to apply in practice, and these points may differ substantially from those implied by the deterministic form of the control rule because of the many stochastic aspects within the process.

5. Discussion

While the material presented above paints a fairly positive picture regarding MP implementation to link with affirmative appraisals of the advantages in principle of the MP approach itself as referenced earlier, one should not be blind to some reality checks.

- In ICCAT and CCSBT, the work towards MP development for bluefin tuna is on hold, having been overtaken by more pressing imperatives related to establishing effective bluefin tuna catch controls in the Eastern Atlantic and Mediterranean and to evidence of substantial under-reporting of catches over the past 10–20 years (CCSBT 2006).
- The IWC RMP is yet to be applied in practice (although Norway is implementing a variant thereof domestically to provide catch limits for its Northeast Atlantic minke whale harvests). The continuation of the IWC’s moratorium on commercial whaling allows its Scientific

Committee the luxury of considerable time to spend on a very thorough MP evaluation process at the analysis level. However it is unclear whether this degree of attention to detail would be sustainable under the typical pressures of time and requests for analyses that would arise if a large number of whale populations again came under commercial harvest.

- Proper and continued application of the approach need resources and a relatively high level of expertise, which are not available in many countries.
- The South African “success story” of a decade of unaltered implementation by decision makers of MP-generated TAC recommendations may be an artifact of pre-occupation during this period with a process of rights allocation in local fisheries (DEAT 2002, 2004a, b; Moola and Kleinschmidt 2008). With disputes focusing on whether past rights holders had too much of TAC taken from them, or whether new rights holders were entitled to a greater proportion of the TAC, scientific working groups constituted by the responsible arm (Marine and Coastal Management) of the Government’s Department of Environmental Affairs effectively took over a structural vacuum that had developed in the process of recommending what the size of the TAC should be. However, with this re-allocation process now near completion, there are signs of this (science-centrally-speaking) honeymoon period coming to an end, with some of those unsuccessful in the process seeking alternative approaches to getting a share of the TAC, and supposedly short-term *ad hoc* enlargement of the TAC seemingly being contemplated as a possible solution.

Nevertheless, one benefit of the somewhat atypical *modus operandi* for TAC advice generation that developed over the last

decade in South Africa was that the larger fishing companies, noting where the key decisions were being developed regarding TAC advice, made full use of their options for attendance as observers with speaking rights at meetings of scientific working groups. While initially turbulent, and sometimes still involving robust discussions, this mix did provide the opportunities for the effective interactions needed to develop improved mutual understanding and consensus buy-in by stakeholders to MPs, the associated processes, and the subsequent TAC recommendations arising from these MPs.

The South African situation may be atypical of that in a number of first world countries in that non-governmental conservation groups have to date played hardly any role in this aspect of marine resource management. These groups’ impact could be similar to that ascribed to the industry above, except that they would typically exert pressures in the opposite direction, with a greater long and lesser short term focus together with a more risk-averse emphasis. Nevertheless, conclusions above about the importance of structures for effective interactions and potential advantages from the MP approach would seem to apply in similar manner to conservation groups.

6. In Summary

- Agreement of a Protocol which covers matters such as data quality, action to take if anticipated resource monitoring data fail to become available, and the specification of regular reviews and the circumstances under which there may be deviations from recommendations output by an MP, or its review brought forward, is a necessary and important component of successful MP implementation.
- Structures for regular and effective interactions between scientists and stakeholders are essential for achieving

consensus buy-in to the MP eventually adopted.

- There must be strict deadlines to complete first the data and then the OM finalisation steps within the MP development process, with no backtracking allowed, to ensure that a timetable for eventual adoption will be met.
- The readier lay understanding of empirical compared to model-based MPs may prove important in securing consensus acceptance of an MP; the negative aspect of absence of explicit refinement of resource productivity estimates in empirical MPs may be offset by adjustment of OMs and MP control parameter values in the regular MP review process.
- TAC variability constraints are important to industry. Catch control laws need to be continuous in terms of abundance

estimates, and may need to be relatively complex particularly to dovetail with TAC variability considerations.

- Areas requiring further attention are appropriate measures of risk to which lay decision makers can readily relate, and the development of approaches to better incorporate the results from robustness tests in MP selection processes, while also expanding these tests to encompass spatial and stock structure together with ecosystem aspects to a greater extent.

Acknowledgements

My thanks go to Carryn Cunningham and Rebecca Rademeyer who assisted in the preparation of this paper, and to a number of colleagues who provided helpful suggestions on earlier drafts, as well as to an anonymous reviewer for comments.

References

- Basson M, Polacheck T, Kolody D. Discussion of scientific issues related to metarules and the implementations of a management procedure for southern bluefin tuna. Unpublished document, Committee on the Commission for the Conservation of the Southern Bluefin Tuna CCSBT-MP/0404/05. 2004: 9 pp.
- Basson M, Polacheck T. Metarules and implementation: Notes for discussion of the scientific issues. Unpublished document, Committee on the Commission for the Conservation of the Southern Bluefin Tuna CCSBT-MP/0505/05. 2005: 10 pp.
- Butterworth DS. Why a Management Procedure approach? Some positives and negatives. *ICES J. Mar. Sci.* 2007; **64**: 613–617.
- Butterworth DS, Punt AE, Smith ADM. On plausible hypotheses and their weighting, with implications for selection between variants of the Revised Management Procedure. *Rep. Int. Whal. Comm.* 1996; **46**: 637–640.
- Butterworth DS, Punt AE. Experiences in the evaluation and implementation of management procedures. *ICES J. Mar. Sci.* 1999; **56**, 985–998.
- CCAMLR. Report of the thirteenth meeting of the Scientific Committee, Hobart, Australia, 24–28 October 1994. Commission for the Conservation of Antarctic Marine Living Resources. 1994; 93 pp.
- CCAMLR. Report of the workshop on management procedures, Walvis Bay, Namibia, 17–21 July 2006. Commission for the Conservation of Antarctic Marine Living Resources document WG-EMM-06/40. 2006; 36 pp.
- CCSBT. Report of the Third Meeting of the Management Procedure Workshop. Busan, Republic of Korea, 19–24 April 2004; 86 pp. [Online]. Available from the World Wide Web: <www.ccsbt.org/docs/pdf/meeting_reports/ccsbt_11/Report_of_mpws3.pdf> [Accessed January 2008].
- CCSBT. Report of the Tenth Meeting of the Scientific Committee. Narita, Japan, 9 September 2005; 90 pp. [Online]. Available from the World Wide Web: <www.ccsbt.org/docs/pdf/meeting_reports/ccsbt_12/report_of_SC10.pdf> [Accessed January 2008].
- CCSBT. Report of the Thirteenth Annual Meeting of the Commission. Miyazaki, Japan, 10–13 October 2006; 135 pp. [Online]. Available from the World Wide Web: <www.ccsbt.org/docs/pdf/meeting_reports/ccsbt_13/report_of_CCSBT13.pdf> [Accessed January 2008].

- Cunningham CL, Butterworth DS. Further Exceptional Circumstances testing for OMP-04. Marine and Coastal Management, South Africa. Unpublished document. WG/DEC2004/PEL/02. 2004; 7 pp.
- Cunningham CL, Butterworth DS. Re-evaluation of risk thresholds for sardine and anchovy. Marine and Coastal Management, South Africa. Unpublished document. WG/2008/JAN/SWG-PEL/01 2008; 7 pp.
- DEAT. Where have all the fish gone? Measuring Transformation in the South Fishing Industry, Department of Environmental Affairs and Tourism, South Africa. October 2002; 28 pp.
- DEAT. Transformation and the South African Fishing Industry: The TAC Controlled Fisheries. Department of Environmental Affairs and Tourism, South Africa. January 2004a; 28 pp.
- DEAT. Transformation and the South African Fishing Industry: The TAE Controlled Fisheries. Department of Environmental Affairs and Tourism, South Africa. November 2004b; 32 pp.
- De Oliveira JAA, Butterworth DS. Developing and refining a joint management procedure for the multispecies South African pelagic fishery. *ICES J. Mar. Sci.* 2004; **61**: 1432–1442.
- De Oliveira JAA, Kell LT, Punt AE, Roel BA, Butterworth DS. Managing without best predictions: the Management Strategy Evaluation framework. In: *Advances in Fisheries Science*. 50 years on from Beverton and Holt, Blackwell Publishing, Oxford. 2008; 104–134.
- FAO. Precautionary approach to fisheries. Part 1: Guidelines on the precautionary approach to capture fisheries and species introductions. Elaborated by the Technical Consultation on the Precautionary Approach to Capture Fisheries (Including Species Introductions). Lysekil, Sweden, 6–13 June 1995 (A scientific meeting organized by the Government of Sweden in cooperation with FAO). FAO Fisheries Technical Paper. No. 350, Part 1. Rome, FAO. 1995; 52 pp.
- FAO. Fisheries and Aquaculture Department. 2. The ecosystem approach to fisheries. 2.1. Best practices in ecosystem modelling for informing an ecosystem approach to fisheries. FAO Fisheries Technical Guidelines for Responsible Fisheries. No. 4, Suppl.2, Add. 1. Rome, FAO. 2008; 42 pp.
- Hilborn R, Luedke W. 1987. Rationalizing the irrational—a case-study in user group participation in Pacific salmon management. *Can. J. Fish. Aquat. Sci.* 1987; **44**: 1796–1805.
- ICCAT. Report of the 2005 ICCAT Planning Meeting For Bluefin Tuna Research Madrid, Spain, June 27–30, 2005. *ICCAT Coll. Vol. Sci. Pap.* 2006; **59**: 717–749.
- IWC. Report of the Scientific Committee, Annex D. Report of the Sub-Committee on Management Procedures. *Reports of the International Whaling Commission* 1992; **42**: 87–136.
- IWC. The Revised Management Procedure (RMP) for Baleen Whales. *J. Cetacean Res. Manage.* 1999; **1**(suppl.): 251–258.
- IWC. Report of the Scientific Committee. Annex D. Report of the Sub-Committee on the Revised Management Procedure. Appendix 2. Requirements and guidelines for Implementation. *J. Cetacean Res. Manage.* 2005; **7**(suppl.): 84–92.
- Jacobs O. Management Procedure from the point of view of stochastic control theory. *Reports of the International Whaling Commission* 1989; **11**(Spec. Iss.): 27–28.
- Kell LT, De Oliveira JAA, Punt AE, McAllister MK, Kuikka S. Operational Management Procedures: An introduction to an evaluation framework. In: Motos L, Wilson D (eds). *The Knowledge Base for Fisheries Management*. Elsevier. 2006; 379–407.
- Kolody D, Polacheck T, Basson M, Davies C. Salvaged pearls: lessons learned from a floundering attempt to develop a management procedure for southern bluefin tuna. *Fish. Res.* (in press).
- Miller DCM, Shelton PA, Healey BP, Morgan JM, Brodie WB. Management strategy evaluation for Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO Subarea 2 and Divisions 3LKMNO. Northwest Atlantic Fisheries Organisation document NAFO SCR Doc. 07/58. 2007; 27 pp.
- Moolla S, Kleinschmidt HGH. FishInc. A guide to the South African commercial fishing industry. Feike Natural Resource Management Advisers, Cape Town, South Africa. 2008; 31 pp.
- Plagányi ÉE, Rademeyer, RA, Butterworth DS, Cunningham CL, Johnston SJ. Making management procedures operational—innovations implemented in South Africa. *ICES J. Mar. Sci.* 2007; **64**: 626–632.
- Punt AE. The FAO Precautionary Approach after almost 10 years: Have we progressed towards implementing simulation-tested feedback-control management systems for fisheries management? *Nat. Res. Model.* 2006; **19**: 441–464.
- Punt AE. Refocusing stock assessment in support of policy evaluation. In: Tsukamoto K, Kawamura T, Takeuchi T, Beard TD, Jr, Kaiser MJ (eds). *Fisheries for Global Welfare and Environment*, 5th World Fisheries Congress 2008. TERRAPUB, Tokyo. 2008; 139–152.
- Punt AE, Donovan G. 2007. Developing management procedures that are robust to uncertainty: Lessons from the International Whaling Commission. *ICES J. Mar. Sci.* 2007; **64**: 603–612.

- Rademeyer RA, Plagányi EE, Butterworth DS. Tips and tricks in designing management procedures. *ICES J. Mar. Sci.* 2007; **64**: 618–625.
- Rademeyer RA, Butterworth DS, Plagányi EE. A history of recent bases for management and the development of a species-combined Operational Management Procedure for the South African hake resource. *Afr. J. Mar. Sci.* (in press).
- Smith ADM, Sainsbury KJ, Stevens RA. Implementing effective fisheries-management systems—management strategy evaluation and the Australian partnership approach. *ICES J. Mar. Sci.* 1999; **56**: 967–979.
- Schnute JT, Maunder MN, Ianelli JN. Designing tools to evaluate fishery management strategies: Can the scientific community deliver? *ICES J. Mar. Sci.* 2007; **64**: 1077–1084.

Appendix: Basic Elements of the Management Procedure Approach

The traditional approach to providing a scientific recommendation for the TAC for a fishery starts with the development of an assessment. All available information with a bearing on the dynamics of the resource harvested is analysed within the framework of a model which is able to integrate this information to provide estimates of resource productivity and current abundance. The results from what is considered to provide the best representation of the actual situation from amongst a number of alternative hypotheses (models) of the dynamics of the resource and fishery—the “best assessment”—are then fed into a catch control law (decision rule). This law could, for example, reflect a constant fishing mortality approach—e.g. harvest the resource at a fishing mortality F that will (in due course) yield the maximum sustainable yield (MSY) on average. This rate is termed F_{MSY} , and taken together with the results from the best assessment for the current abundance of the resource, would yield a TAC recommendation.

This traditional approach gives rise to a number of difficulties. For example, it takes no direct account of uncertainty—that the model selected may not constitute the best representation of the actual resource dynamics. Furthermore, while projections of abundance based on the “best assessment” can take account of model estimation error, to-

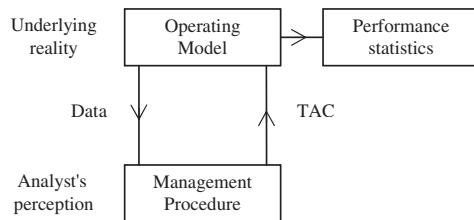


Fig. A1. Schematic representation of the process of simulation testing of a Management Procedure.

gether with future recruitment variability, they typically have to be based on constant catch or F assumptions. These overestimate risk, as they take no account of the information from resource monitoring that will become available in the future. This information will “feedback” into decisions to modify TACs (e.g. downwards if the trend in resource abundance indices is down) to attempt to change that trend back towards a management reference point such as a target abundance (an approach generally known as “feedback control”).

The Management Procedure (MP) approach seeks to rectify this by simulating the annual process of TAC determination, and checking whether it can be expected to attain management goals if kept in place over a period of time (typically 10–20 years for other than very long-lived populations).

Figure A1 illustrates the calculation process used. An Operating Model (OM) is developed to represent the possible underlying dynamics of the resource (e.g. the “best

assessment” could be used for one such OM). This model generates resource monitoring data (e.g. abundance survey results, catch per unit effort values) of the type (and with the same error structure) as would be available in practice. These data are fed into a formula (the MP) which determines the TAC recommendation. The formula may be complex (e.g. replicating the standard annual assessment plus catch control law basis for TAC recommendation), or simple such as a fixed fraction of the most recent survey estimate of abundance. Importantly, computer evaluations are structured so that the formula (MP) is allowed no knowledge of or direct input from the actual underlying dynamics of the resource (current values of variables of the OM) except as reflected in the data available for assessment purposes, as would be the case in practice.

The TAC calculated is input to the OM, so that the dynamics can be updated by one year, and then the loop within Fig. A1 is repeated until the end of the projection period under consideration. The “performance” of the MP is then summarised by performance measures drawn from the underlying reality, the OM, such as the average annual catch achieved over the period, and the final population abundance compared to an intended management target level. To take account of estimation imprecision, random noise in future data generated from the OM, and future variation in recruitment, this whole process is repeated typically 100 times, so that performance outputs take the form of statistical distributions, rather than single values.

The choice of a final formula from amongst a number of candidate MPs is determined by a consideration of trade-offs amongst such performance statistics, e.g.

which formula provides the greatest average annual catch without a lower percentile for resource abundance dropping below some limit value which could result in a threat to successful future recruitments.

However, the issue of uncertainty about the underlying dynamics remains to be addressed (typical examples might involve the choice of functional form for the stock recruitment relationship, or alternative assumptions about the time series of catches which could, for instance, be uncertain because of illegal activities or incomplete records of discarding practices). This is done by repeating the set of simulations described above for other OM—ones that represent different, but still plausible representations of the resource and fishery dynamics. To be acceptable for implementation, a candidate MP must not only achieve management targets in simulations where the OM represents the “best assessment”, but also come reasonably close to doing so under these other OM, i.e. it must demonstrate robust performance. In this way the concerns of the Precautionary Approach—taking due account of uncertainties—are addressed.

This process of “simulation testing” of a decision rule is the critical component required to consider it classified as a MP. MPs are able to perform robustly because of their feedback nature—the decision rule self-corrects by, for example, typically decreasing TACs if abundance trends are downward and *vice versa*. This can result in management targets for abundance still being near attained, even though the underlying reality differs from the best assessment which may have guided the choice of control parameter values for the MP decision rule.