

# MANAGEMENT STRATEGY EVALUATION - THE LIGHT ON THE HILL

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## **Introduction**

Management strategy evaluation (MSE) in the broad sense involves assessing the consequences of a range of management strategies or options and presenting the results in a way which lays bare the tradeoffs in performance across a range of management objectives. In contrast to some previous approaches to fisheries assessment, it does not seek to proscribe an optimal strategy or decision. Instead it seeks to provide the decision maker with the information on which to base a rational decision, given their own objectives, preferences, and attitudes to risk.

The key ingredients to this approach include:

- a clearly defined set of management objectives;
- a set of performance criteria related to the objectives;
- a set of management strategies or options to be considered; and
- a means of calculating the performance criteria for each strategy.

In addition, MSE can (and should) also deal with a range of sources of uncertainty in predicting the consequences of alternative management actions. These predictions are needed to measure the performance criteria for each strategy, and generally involve simulating the application of each strategy to a model of the resource.

Successful MSE involves a collaborative effort between the decision maker(s) (managers and/or industry), technical experts (e.g. scientists with a knowledge of the dynamics of the resource) and an "MSE analyst". The latter may be an individual or a team. The role of this "MSE analyst" is to:

- elicit and clarify objectives;
- turn broad objectives into specific performance criteria;
- identify a range of strategy choices;
- identify and quantify uncertainties;
- evaluate outcomes;
- communicate the results, highlighting the tradeoffs.

## **Objectives and performance criteria**

Most current objectives in fisheries management, if stated at all, are vague. For example Commonwealth fisheries management objectives are to ensure conservation of the resource, to maximize economic efficiency and to extract a resource rent for use of a community resource (DPIE 1989). This is more a broad policy framework than a set of specific objectives which could be used, for example, to decide on a harvest rate strategy for a particular stock. Taking the resource conservation objective as an example, what does this actually mean? Prevent

biological extinction? Or economic extinction? Maintain the stock above some threshold level? If so, what level, how should it be determined and by whom?

In turning broad objectives into specific performance criteria, the first rule is to keep the criteria or attributes simple. For example, an objective which is often stated (sometimes implicitly) by fishermen, is to maintain stable catches. For a scientist, the natural performance criterion may be the variance in the catch, but for fishermen and politicians this may be quite an obscure measure. A much better one may be the "average change in catch from one year to the next". Similarly, stock sizes expressed as absolute quantities may not mean much, but expressed relative to unfished levels may be much more easily understood. Another good "rule of thumb" is to limit the number of performance criteria as much as possible, consistent with spanning the range of objectives which are likely to be considered relevant or important.

### Management Strategies

It is in selecting the range of strategies to be evaluated that the MSE analyst has perhaps the most important role to play. For the moment, consider the problem of deciding on an appropriate harvest strategy for a particular fish stock. By harvest strategy, we mean in this case a rule for setting an annual quota, the total allowable catch (TAC), for the fishery on that stock. (Other management strategies, such as effort controls or zonal management, could equally well be considered). The following considerations are important in selecting a range of strategies to evaluate.

First, the choice of time frame is important. This will depend on the nature of the problem, including the life history characteristics of the species, and economic and political considerations. For example, in some instances it may be appropriate to consider very short-term out-

comes (will the quota set under a particular strategy be likely to result next year in an increase or decrease in a depleted stock?). For very long-lived species (whales, orange roughy) a much longer evaluation period may be appropriate, although the use of discount rates for economic performance indices may effectively limit the time frame considered for economic objectives.

Second, the harvest strategy considered may be either adaptive or non-adaptive (*sensu* Walters 1986). An adaptive (or feedback) strategy is one where the decision at each time step is conditional on the data that are available up to that time (e.g. an  $F_{0.1}$  strategy for setting quotas will be conditional on the latest estimate of stock size). It is not possible to specify what the future TACs will be, only the rule for choosing them. A non-adaptive management strategy would specify a future time series of TACs (e.g. the TAC reduction scenarios of Francis 1992).

Third, supposing the strategy is of the adaptive or feedback form, the decision rule itself may be more or less complex. Most decision rules considered to date have been very simple. For example, the  $F_{0.1}$  rule sets the TAC as a simple proportion of the current estimate of stock size. However there is no reason why more complex decision rules should not be evaluated, particularly if they perform better than the simple rules in terms of performance criteria. For example, Smith (1993) considers a decision rule for exploiting new resources which starts as a constant exploitation rate strategy and switches to a constant escapement strategy once the stock (and the uncertainty about stock size) is reduced to a target level. In addition, there is a constraint on the amount that the TAC can vary from one year to the next.

In practice, the strategies themselves are likely to evolve during the course of the evaluation as the results indicate directions for improvement in the strategies already considered. Indeed, the management objectives themselves may be refined during the evaluation.

## Evaluating and communicating outcomes

Evaluation of alternative management strategies involves predicting the values of the performance criteria for each strategy. This will generally involve simulating the application of the strategies to a model of the resource. In practice, a range of uncertainties must be considered in predicting the outcomes for each performance criterion. These uncertainties may be grouped into the following broad categories:

- model specification error, e.g. failure of assumptions, inappropriate choice of functional forms, mis-specification or generalisation of parameters (e.g.  $M=0.2!$ );
- process noise, e.g. recruitment variability;
- observation error, e.g. ageing error, biomass survey sampling variance;
- bias in estimators, e.g. Ludwig and Walters (1989);
- lack of contrast in data, e.g. catch and effort data (Hilborn 1979);
- failure to achieve the management target, e.g. failure to control over-runs on quotas.

The presence of these uncertainties means that in the first instance outcomes for performance indices will be presented as expected or mean values (e.g. mean catch across a large number of simulations). Of course some performance indices may themselves be probabilistic (e.g. the probability that the stock falls below some threshold value) and in that sense directly reflect some aspects of the uncertainty. For other indices, though, a second level of detail may need to be provided, such as a frequency distribution of outcomes. A third level of detail may be detailed output from the simulations themselves. However the primary information provided to the decision maker will generally be in the form of a decision table with strategies along one "axis" and objectives or performance indices along the other. The elements in the table will contain the expected values of the performance indices, or some relative ranking of achievement of objectives,

for each strategy/objective combination (Table 1.)

## A hypothetical example

Consider the problem of determining a harvest rate strategy for a particular stock. The strategies to be considered include a constant catch strategy, a constant harvest rate strategy, and a constant biomass strategy. The constant catch strategy is further divided into a high and low catch scenario. Figure 1 shows the relationship for each strategy between the estimated stock size, and the TAC or catch selected. For the constant catch strategy, the catch is independent of stock size (although if stock size is low enough the TAC may actually exceed the size of the resource and will be unable to be taken). For the constant harvest rate strategy the catch is a constant fraction of biomass. For the constant biomass strategy the catch is taken which would result in maintaining the biomass at a constant level. For this strategy there is a threshold biomass below which the TAC will be set to zero.

There are three objectives which are considered in this example. The first is to maximize the catch which is taken (over some specified period of time, e.g. ten or twenty years). The second objective is to minimize the variability in catch from year to year. The third objective is to minimize the risk (probability) that the stock will fall below some specified threshold (e.g. a stock size below which the probability of recruitment collapse greatly increases). In this example, the performance of each strategy against each objective is rated as good, moderate or poor. A more quantitative evaluation would provide specific levels for performance indices related to each objective such as mean catch, average change in catch, and relative frequency of exceeding the threshold, based on the outcomes of a set of simulations. The purpose of the current example is just to indicate the general nature and form of an MSE analysis.

Table 1 shows a decision table relating to the example just outlined. The results can be explained as follows. The constant catch strategies will obviously perform well with respect to minimizing the variability in the catch, although the high catch strategy runs the risk of driving the stock to such low levels that catches can not be maintained. However they are likely to perform more poorly with respect to risk, since catches will not be reduced in the face of evidence of declining stock sizes. At the other extreme, the constant biomass strategy is the least risky (since no catch is taken at low stock sizes) but results in very variable catches. However the mean catch (especially in the longer term) is highest with this strategy. The constant harvest rate strategy performs moderately well across all objectives.

The point of presenting the results in this way becomes apparent if one considers a range of ways in which the multiple objectives of the decision maker might be reconciled. To begin with, there is no one strategy that "dominates" all the rest, that is, there is no strategy which performs better than all other strategies across all the objectives. Another way of saying this is that there are tradeoffs to be made between meeting the various objectives, and in particular between minimizing the variability in the catch and minimizing the risk to the stock.

A consequence of this lack of a dominant strategy is that the choice of "best" strategy will depend on the importance or weight which is given to each of the objectives. For example, if over-riding importance is attached to minimizing risk to the stock, then the constant biomass strategy will be chosen. Alternatively, if the most important objective is to minimize the variability in catch then the low constant catch strategies will be chosen. Another decision maker may wish to choose a strategy which does not perform poorly for any of the objectives. The constant harvest rate strategy would then be chosen.

Although there is no single strategy which dominates all the rest across all objectives, the constant harvest rate strategy dominates the constant high catch strategy. To that extent the latter might be excluded from further consideration.

## Discussion

In some respects, the MSE approach represents a natural extension of approaches to fisheries assessment and management that have been developing over the past two decades. An extended development of the topic can be found in Hilborn and Walters (1992). Perhaps the key feature is the extent to which it focuses on the needs of the decision maker by providing a basis for choice between alternative decisions or strategies, rather than seeking to identify an "optimal" decision. However it does put greater pressure on decision makers to be explicit about management objectives and targets.

The MSE approach need not be confined to addressing issues in the area of fisheries assessment and management. The approach has equal potential for application in the area of marine environmental management, and for decision making in the management of renewable resources in general.

## References

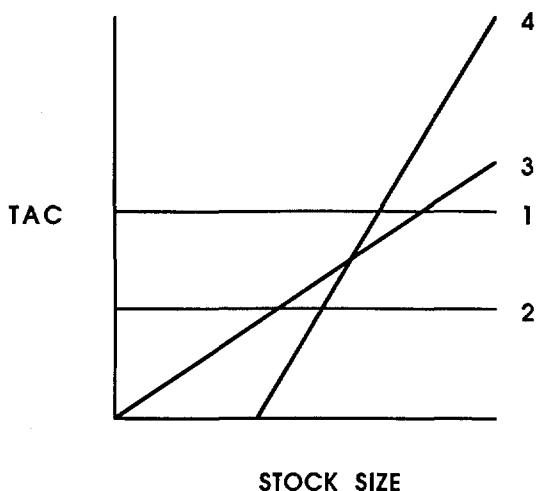
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**Figure 1.** TAC as a function of estimated stock size for the four harvest strategies: 1) constant high catch; 2) constant low catch; 3) constant harvest rate; and 4) constant biomass.

**Table 1. Performance of strategies against objectives.**

STRATEGY	OBJECTIVE		
	Maximize catch	Minimize variability	Minimize risk
Constant high catch	Moderate	Moderate	Poor
Constant low catch	Poor	Good	Moderate
Constant harvest rate	Moderate	Moderate	Moderate
Constant biomass	Good	Poor	Good