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Management Strategy Evaluation for Fisheries

Informing the selection of harvest strategies

Overview

Management strategy evaluation (MSE) is a tool that scientists and managers can use to simulate the workings of a fisheries system and allow them to test whether potential harvest strategies—or management procedures—can achieve pre-agreed management objectives. In so doing, MSE helps to determine the harvest strategy likely to perform best. That means the strategy would perform well, regardless of uncertainty, and balance trade-offs amid competing management objectives. Around the world, fisheries are moving toward management based on harvest strategies to increase long-term sustainability, stability and profitability. MSE must be an integral component of the process to ensure that the chosen strategy can achieve its objectives.


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Why MSE?

Fisheries systems are complex, in part because of the complicated biology of the fish stocks being managed and variability in nature but also because managers usually have competing objectives in managing each stock. When using harvest strategies, managers must define a harvest control rule (HCR)—the pre-agreed guidelines for how many fish can be caught based on how well (or poorly) the stock is doing—that will meet the objectives. An untested HCR could prove successful if there is a single management objective, such as maintaining the status quo. However, if the management objectives are numerous, complex and competing, as is the case in most fisheries, testing through MSE provides a critical lens for viewing the performance of proposed HCRs against a variety of objectives.[1]

Adopting an untested harvest strategy without going through the full MSE process sacrifices many benefits of the harvest strategy approach and could jeopardize the fishery's performance. If a full MSE is not completed, managers gamble that the untested harvest strategy will perform better than the existing management approach. At the same time, when managers consider untested harvest strategies, the process is subject to the same controversial negotiations that have long plagued traditional fisheries management; decisions are made based on science fraught with uncertainty.

Using the MSE process brings numerous benefits. For example, an MSE eliminates costly and highly politicized negotiations by providing managers with a tool to thoroughly analyze available information so they can offset natural variability and scientific uncertainty to help select a robust harvest strategy. They can identify the plan most likely to achieve their pre-agreed management objectives, despite the inevitable uncertainty in fisheries management. MSE also helps managers balance trade-offs by weighting some management objectives as more important or some assumptions as more likely. Since it accounts for a range of scenarios, the MSE process also improves long-term market stability and business planning. Critically, MSE enables management bodies to meet commitments to apply the precautionary approach, which then helps fisheries meet one of the Marine Stewardship Council's chief certification criteria.

Who conducts the MSE?

Management strategy evaluation requires relatively complex population and fishery dynamics models. That means advanced quantitative fishery scientists play an important role in MSE development. Fisheries managers, however, also play a major role, with input from stakeholders such as commercial industry, recreational fishermen and conservation groups. The managers, with stakeholder input, set the management objectives against which the results of the MSE are measured.

> "A [harvest strategy] is analogous to an autopilot, with the associated advantages. However, this does not mean that the aircraft should be left without a pilot. The pilot must remain on board to look out for unexpected major course deviations that may not have been factored into the design, including appreciable changes in scientific perceptions concerning the resource."
>
> **Doug S. Butterworth,** *University of Cape Town*[2]

Managers select the reference points, acceptable levels of risk and timelines for the harvest strategy. They also outline the candidate HCRs to be tested in the MSE. Once MSE results are ready, managers review them and, based on how they decide to weigh the trade-offs among the different management objectives, select the HCR and/or harvest strategy. In this way, even though the scientists do the bulk of the analytical and modeling work on the MSE, managers, with the guidance of stakeholders, have control over both the front end of the process (setting management objectives) and the back end (selecting the HCR).

How does MSE work?

There are numerous ways to structure the MSE framework, but one or more operating models (OM) are at the center of the process. These operating models simulate all relevant aspects of the fisheries system and proposed harvest strategy. They include all plausible hypotheses about the biology of the stock, such as recruitment, and aspects of the fishery, such as the level of illegal fishing activity. Because of the many combinations of assumptions, hundreds of scenarios are often tested.

The scientists who conduct the typical MSE modeling process will:

1. Develop multiple OMs that reflect the different hypotheses about the possible states of nature (for example, plausible assumptions about natural mortality and reproductive potential). In this way, the many uncertainties (such as model, observation, process and implementation[3]) are factored into the process.

2. "Condition" the operating models by fitting the available real-world data—such as catch per unit effort data—to the OM in order to eliminate implausible scenarios.

3. Use a "closed-loop simulation" to test the candidate harvest strategies. (See Figure 1.) That process entails:

    a. Generating simulated fishery data (e.g., catch, indices of abundance) from the operating model.

    b. Adding plausible levels of imprecision and bias using the "observation error model" to resemble what happens in a real-world fishery system.

c. Using the data from the observation error model to estimate stock status, either through a traditional stock assessment model or another approach.

d. Comparing the estimated stock status with the candidate harvest strategy to determine the management recommendation (e.g., quota, effort limit, size limit or time-area closure).

e. Subjecting the management recommendation to an analysis of possible implementation error, such as quota overages caused by illegal or unreported catch.

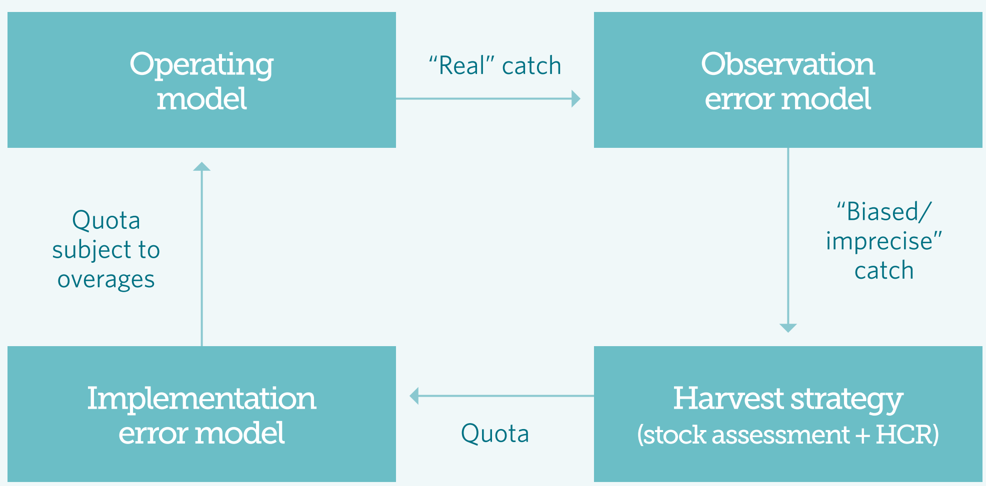
f. Feeding the output of the implementation error model back into the operating model in step 3A and repeating steps A through E iteratively for many years into the future.

4. Compare the results of the closed-loop simulation with the performance indicators—quantitative expression of the management objectives—to determine which candidate harvest strategy balances trade-offs to best achieve the pre-agreed management objectives.

Figure 1

Closed Loop Simulation

The feedback loop of the MSE which simulates the effects of candidate harvest strategies on a stock and fishery into the future



Importantly, the MSE for a fishery can be updated as warranted. After HCRs are selected, they are typically re-evaluated every three to five years and can be modified if they are not performing as expected, if "exceptional circumstances" that were not tested by the MSE occur or if new knowledge requires a revision of the operating models. Similarly, although MSE and harvest strategies decrease the reliance on traditional stock assessments, benchmark assessments are still typically conducted approximately every five years to ensure that the harvest strategy is performing as expected and to ground check the MSE.

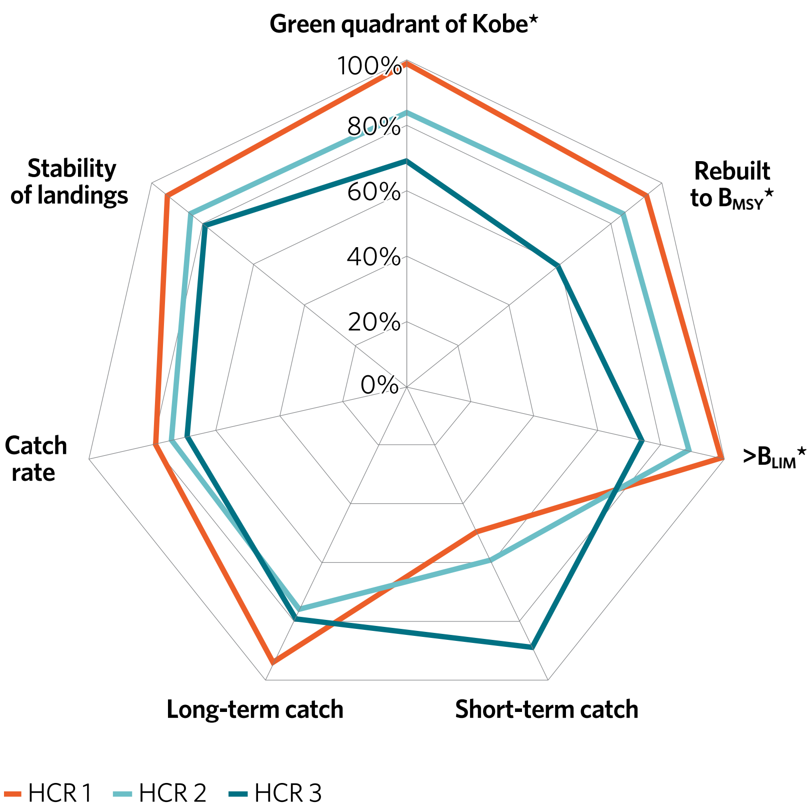
How are MSE results interpreted?

The MSE output gives the likelihood that a candidate HCR will meet a fishery's pre-agreed management objectives, either individually or in combination. There are many different ways of presenting the results, including web diagrams (Figure 2), Pareto frontiers (Figure 3) and decision tables.[4] The results can be presented as the percentage likelihood of achieving an objective, such as a 75 percent chance of not being overfished and not being subject to overfishing, or the likelihood of achieving actual numbers, such as a long-term annual catch of 50,000 metric tons, a maximum inter-annual change in allowable catch of 10 percent or a violation of a limit reference point in 10 out of 20 years.

Figure 2

Sample Web Diagram

Web diagrams can be used to illustrate MSE results on the degree to which candidate harvest strategies achieve numerous management objectives



* For more details and definitions, see pewtrusts.org/harveststrategies.

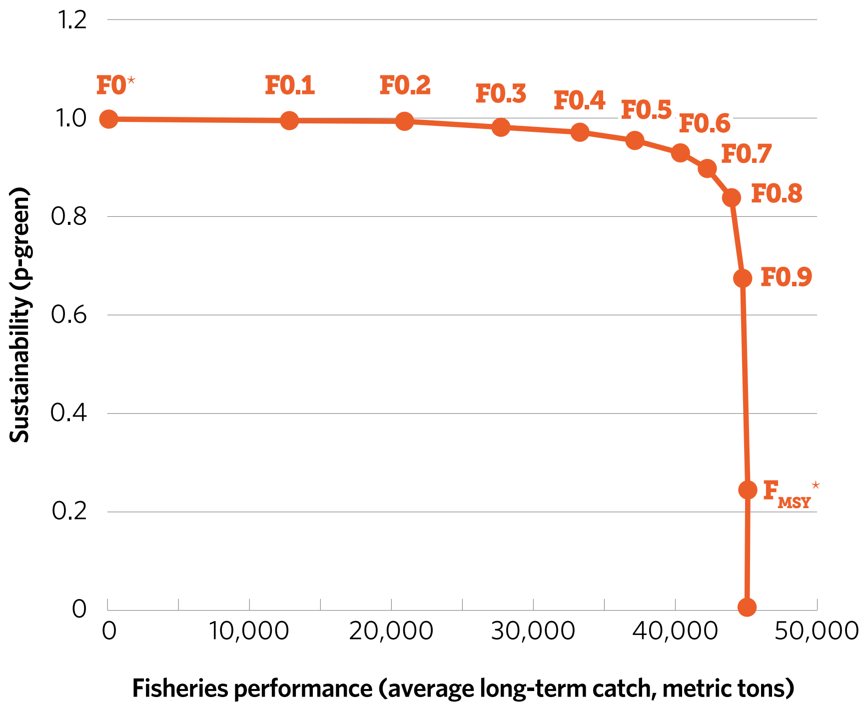
In this example, HCR 1 is preferred as a temporary sacrifice in catch gives maximum long-term benefits.

This web diagram shows the performance of three hypothetical candidate harvest control rules against seven management objectives, each presented on its own spoke. The center indicates no chance of achieving the objective, while the outermost points show 100 percent chance of achieving that spoke's objective.

Figure 3

Sample Pareto Frontier

A Pareto plot can be used to illustrate MSE results on the trade-offs of candidate harvest strategies' ability to achieve competing management objectives



This Pareto frontier shows the performance of a harvest control rule based on eleven different target fishing mortality rates (F0 through F_{MSY}).

Performance is measured in long-term average annual catch and the probability of being in the green quadrant of the Kobe matrix (i.e., not overfished, no overfishing). In this example, F0.7 and F0.8 best balance the tradeoffs in fisheries performance and sustainability.

* For more details and definitions, see pewtrusts.org/harveststrategies.

Source: Gorka Merino et al., "Evaluation of Harvest Control Rules for North Atlantic Albacore Through Management Strategy Evaluation" (2016), SCRS/2016/015

When reviewing the results, managers aim to identify the candidate harvest strategy that best meets all of the objectives, taking into account the trade-offs between sometimes opposing goals, such as maximizing short-term catch and improving stock status. Managers often need to weight some management objectives as more important than others. For example, a small sacrifice in short-term catch may be acceptable to achieve improved stock status and higher long-term catch. The results of the MSE give the managers the information needed to select an HCR or harvest strategy with confidence in its likely success.

Importantly, because the MSE process incorporates uncertainty, the likelihoods of success estimated by the MSE are more informative and reliable than the percentages included in the commonly used Kobe matrices. The breadth of sensitivity analyses conducted in an MSE, which consider all plausible scenarios, cannot be captured in a single stock assessment. Therefore, the MSE does not require selection of a single "best" scenario to model and allows for better accounting of uncertainty.

MSE also benefits the management process by distilling the critical issues and data needs to determine what really matters, and that can help break through impasses among competing interests. For example, certain stock assessment inputs that are often debated, such as maturation age for the stock, may not have much bearing on the results of the MSE, an indication that some of these long-running debates may not need to be resolved. Similarly, MSE highlights which inputs have the most influence on results, helping to prioritize research needs.

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Conclusion

Without management strategy evaluation, the harvest strategy approach loses much of its effectiveness. Implementing an untested HCR is similar to traditional management in that it might be successful in the short term but not in the long term. Long-term fishery stability and profitability would thus be sacrificed, as is often the case under the current management paradigm. However, by taking a range of uncertainties into account through a rigorous MSE process, scientists and managers are more likely to get it right. And that will result in benefits to the fish and the fishermen.

Endnotes

1 Doug S. Butterworth, "An Honest Appraisal of Management Strategy Evaluation (MSE)," presentation to the 7th World Fisheries Congress, Busan, Korea, May 23–27, 2016.

2 Doug S. Butterworth, "Why a Management Procedure Approach? Some Positives and Negatives," *ICES Journal of Marine Science* 64, no. 4 (2007): 613–17, http://dx.doi.org/10.1093/icesjms/fsm003.

3 The Pew Charitable Trusts, "Harvest Strategies" (2015), http://www.pewtrusts.org/~/media/assets/2015/06/harvest_strategies_brief.pdf.

4 Gorka Merino et al., "Evaluation of Harvest Control Rules for North Atlantic Albacore Through Management Strategy Evaluation," SCRS/2016/015 (2016).

For further information, please visit:

pewtrusts.org/harveststrategies

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