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Source: Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 2009(2009) : 391-401

Published By: American Fisheries Society

URL: https://doi.org/10.1577/C08-044.1

Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1:391–401, 2009

DOI: 10.1577/C08-044.1

Contrasting Paradigms for Fisheries Management Decision Making: How Well Do They Serve Data-Poor Fisheries?

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Abstract.—We contrast two paradigms for fisheries management decision making: the "assessment" paradigm, which is based around stock assessments, and the "procedural" paradigm, which is based around management procedures. The assessment paradigm has difficulty in providing management for data-poor stocks, and we illustrate this in the New Zealand context. In contrast, the procedural paradigm has the potential to be useful for the data-poor stocks. However, to date, it has not served data-poor fisheries well because most of the development of management procedures has been for high-value, data-rich stocks. This may be because several aspects of the procedural paradigm are misunderstood or neglected. Giving appropriate attention to these aspects will improve the application of fisheries management procedures, particularly for data-poor stocks. For example, more attention needs to be given to the method for presenting evaluation results to decision makers in ways that more easily allow them to make trade-offs among multiple management objectives. We also argue that the design, evaluation, and selection of management procedures should be treated as an exercise in engineering, particularly by applying generic solutions to data-poor cases for which specific solutions are usually not readily developed.

Fisheries management is like any other form of management: it involves deciding what actions to take to achieve prespecified objectives. The decision-making process is paramount. Good analyses are worthless without effective decisions. Decision making can be divided hierarchically into strategic and tactical phases. Strategic decision making involves choosing the plan to achieve objectives, while tactical decision making involves choosing the actions to achieve the plan. Regardless of the phase, the ultimate focus of all management decision making is achieving objectives.

Although fisheries management is fundamentally similar to other forms of management, it differs in one important aspect: uncertainty. There are few other forms of management that have to incorporate such high levels of uncertainty into the decision-making process. This characteristic has necessitated unique approaches to the practice of fisheries management. A possible consequence of this is that people may have forgotten some of the intrinsic decision-making aspects of fisheries management and focused on the means rather than the ends. The means that have been developed often cannot be applied to fisheries that are low in value and thus for which few data are typically collected. For these fisheries, management decision making is effectively disabled.

In this article, we characterize two paradigms for fisheries management decision making: the "assessment paradigm," which is based around stock assessments, and the "procedural paradigm," which is based around management procedures. We call these paradigms because they are much more than simply approaches or methods; they involve particular ways of *thinking* about fisheries management decision making. For each paradigm, we analyze the decision-making processes involved, their focus on objectives, and their success in providing management for data-poor fisheries. Our intension here is not to provide a detailed critique of either paradigm but instead to highlight their fundamental differences. Our characterizations are thus intentionally polarized and will probably be inaccurate in detail for many real-world fisheries management systems.

Much of what we say about these paradigms has been said before. Several authors called for a change in the approach to fisheries management over a decade ago (e.g., Stephenson and Lane 1995; de la Mare 1996, 1998; Stokes and Kell 1996; Lane and Stephenson 1998; Cooke 1999). Although progress has been made in the directions proposed by these authors, some of their points have been largely ignored. Therefore, while trying to avoid repetition, we seek to remind the

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Received November 28, 2008; accepted July 19, 2009
Published online December 31, 2009

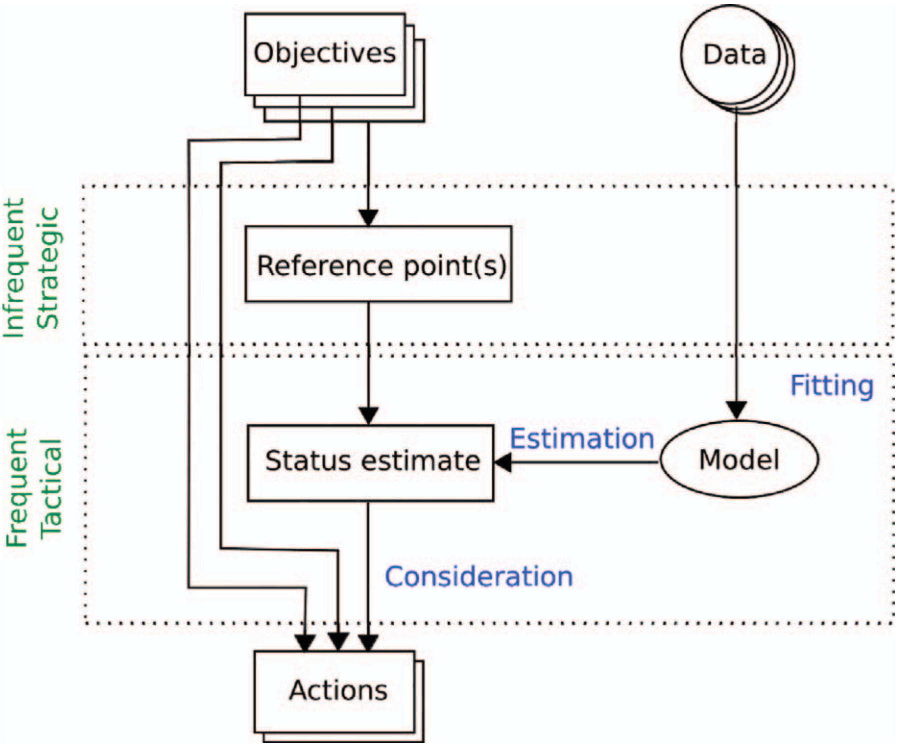

FIGURE 1.—Decision-making elements and processes under the assessment paradigm.

fisheries management community of some of the more fundamental, but often ignored, aspects of the procedural paradigm.

We refer to "data-poor" fisheries, but in general we prefer the term "low information." Many fisheries are rich in data yet remain low in information. Information is derived from data but is dependent on the quality of the data collected and the methods used to extract information. We make this distinction because the work on data-poor fisheries remains relevant also to many data-rich fisheries.

Our intended audience is all those involved with fisheries management, including fisheries managers, stakeholders, and scientists. However, for brevity, we presume some familiarity with both fisheries stock assessments and fisheries management procedures.

The Assessment Paradigm

The most common approach to fisheries management decision making is the assessment paradigm, which attempts to achieve management objectives through repeated decision making based on repeated estimates of the status of the fishery (Figure 1). Under this paradigm, there is one strategy: repeatedly estimate the status of the stock and make decisions on management actions by considering these estimates in relation to management objectives. Because there is only one strategy, there is essentially no strategic decision making. There may be some element of strategy in the choice of reference point(s), but almost all decision making is tactical.

The assessment paradigm tends to focus on one or a few of the management objectives of fisheries management, usually related to maximizing yield. Objectives other than yield, such as minimizing variability in catches and minimizing management costs, are taken into consideration in a less-formal and more opaque way during decision-making processes (Hilborn 2007).

Often, one or a few management objectives are represented in biological reference points. For example, the management objective "maximize yield" might be represented by the reference point "biomass at maximum sustainable yield" (B_{msy}) and the management objective "sustainability" might be represented by aiming to maintain a stock above "10% of the unexploited biomass" with high probability. Reference points usually relate to yield or biology. Other management objectives, such as "economic viability" and "cost-efficient management," are usually not represented in reference points even if they are explicitly included in legislation.

In following the assessment paradigm, a model of the fishery is fitted to data from the fishery to determine the most likely values for parameters of the stock's dynamics and current state. These values are used to provide estimates of the status of the stock relative to the reference points (e.g., current biomass relative to B_{msy}). Uncertainty in these estimates is presented as probabilities (e.g., probability that current biomass is below B_{msy}), as confidence intervals, or as probability distributions. Short-term projections may also be performed to look at the consequences of any proposed management actions. The decision-making process can be opaque because of the complexity of stock assessments, for which estimates often rely on numerous and often obscure judgments (Hilborn 2002).

Often, there are not enough data or available personnel resources to complete a formal stock assessment, so more subjective assessments are made based on the trends in data from the fishery (typically catch per unit effort). The results of assessments are communicated to fisheries managers, who take account of those management objectives not represented in reference points or considered in the assessment (such as economic viability) and make recommendations as to changes in total allowable catch (TAC) and other management actions. Politicians or officials with final decision-making powers hear representations from various interested parties, weigh the various arguments, and set TACs and other regulations. All of this happens regularly and in some jurisdictions annually.

For valuable stocks with dedicated data collection, stock assessments can provide a clear basis for making tactical decisions aimed at achieving articulated goals and objectives. The approach has demonstrably worked at reversing stock decline in a number of fisheries where the rebuild goals are clear. However, in the absence of clear strategic direction and preagreement as to how decision making should adapt and respond to indicators, such a tactical approach may not deliver the most cost-efficient management.

The assessment paradigm is dependent on regular and extensive data inputs and the availability of stock assessment practitioners to develop and update assessments and provide relevant estimates. Because of this, the assessment paradigm is particularly inappropriate for fisheries that have little data or that are low in information. The inability of the assessment paradigm to deal with data-poor stocks is illustrated in the New Zealand Quota Management System (NZQMS). There are currently 629 "Fishstocks" (a Fishstock is a quota management area for a species) in the NZQMS. Only 37 of these stocks have "quantitative" assessments (those that provide estimates of the current status of the stock relative to B_{msy} or other reference points). The remainder either have no assessment of their status, are assumed to be close to virgin levels (because catches to date have been low relative to the assumed size of the stock), or have a "qualitative" assessment (one that uses words such as "likely to be" or "believed to be"). Unsurprisingly, those fisheries that have quantitative assessments tend to be the ones with the highest value (Figure 2).

It is indeed appropriate that the highest-value fisheries be given priority for quantitative assessment. It is also true that for many of the lowest-value fisheries, a formal quantitative stock assessment would cost more than the entire value of the fishery. However, these arguments ignore the fact that in many areas, the combined economic and social value of low-value, data-poor fisheries that are not being dealt with by the assessment paradigm are substantial. Under the NZQMS, for example, there is no assessment at all for about 80% of Fishstocks, constituting approximately 65% of TAC and 51% of total fisheries value. (These percentages are based on 385 Fishstocks with a TAC of at least 15 metric tons—that is, they exclude the large number of Fishstocks that are "administrative artifacts" and have very small TACs).

Given the legal framework for fisheries management in New Zealand, for the large number of data-poor, low-value fisheries the assessment paradigm effectively says, "We can't estimate the status of this fishery, so we can't make decisions about managing it." Furthermore, for several of the Fishstocks that do have a quantitative assessment, the uncertainty around the assessments is so high that they are of little practical use to decision making. We expect that a similar situation exists in other fisheries jurisdictions.

Drawing on the New Zealand case further, under the assessment paradigm it is often logistically impossible to provide annual or even frequent advice on all stocks. While there are 629 stocks currently in the NZQMS, it is only possible logistically to consider 5–10 stocks for TAC review annually given legislated consultation requirements, stock assessment resources, governmental resources required for drafting, and other considerations. Even with perfect data and information for stock assessments, if all stocks were considered individually and in turn, it would only be possible to consider each approximately every 60–120 years! Even if only stocks with quantitative assessments were reviewed, it would only be possible to consider them roughly every 3–6 years. The need for an alternative, strategic approach is clear.

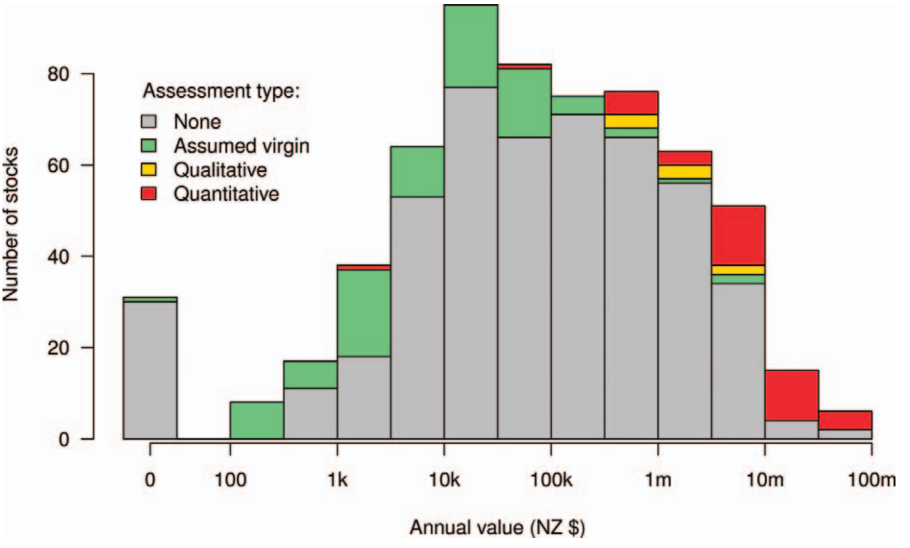

FIGURE 2.—Types of assessments for New Zealand Fishstocks (quota management areas) according to annual value (NZ$). Classifications of assessment type are based on unpublished work by Chris Francis and Sophie Mormede (National Institute of Water and Atmospheric Research), with some additions and alterations. The annual value is based on the total allowable catch (TAC) and port price for 2007–2008. There are typically between 1 and 10 Fishstocks for each species. The total number of Fishstocks represented in the figure is 621. Some Fishstocks are excluded because their assessment status is unknown. The value of some Fishstocks is zero because their TAC is zero.

The Procedural Paradigm

The more technical aspects of the evaluation and application of procedures for fisheries management have been described well by others (e.g., Butterworth and Punt 1999; Smith et al. 1999; Butterworth 2007; Punt and Donovan 2007; Rademeyer et al. 2007). Our aim here is not to repeat these descriptions but rather to provide a simplified analysis of the types of decision making involved in this paradigm and to contrast those with the decision-making processes involved in the assessment paradigm.

In contrast to the assessment paradigm, the procedural paradigm attempts to achieve management objectives through the choice of an appropriate management procedure. A management procedure consists of an exactly specified set of data collection methods, analyses, and rules about what and when management actions should be taken in response to changes in fishery indicators. An evaluation of alternative candidate management procedures is carried out by using a simulation model of the fishery, which outputs expected values of performance measures representing each management objective. These performance measures are used by stakeholders and decision makers to select a management procedure to implement. The chosen management procedure is operated on an annual basis, and the management actions arising from the procedure are taken (Figure 3).

Thus, under the procedural paradigm, the management procedure effectively takes over the role of tactical decision making. Human decision making is elevated to strategy; that is, selecting the best procedure given the management objectives and the attributes of the fishery. This requires the use of scientific knowledge to evaluate the likely outcomes, in terms of management objectives, of alternative candidate management procedures. The procedural paradigm is thus simply a form of quantitative policy analysis and has analogs in other fields. What fisheries has termed "management strategy evaluation" (e.g., Sainsbury et al. 2000) is a very similar technique to what industrial engineering calls "operations research" (e.g., Taha 2006) and what business management calls "management science" (e.g., Anderson et al. 2008).

The procedural paradigm shares some of the same problems of the assessment paradigm. For example, it relies on a simulation model of the fishery that can often incorporate many obscure and often subjective decisions, which can result in a loss of transparency. Ensuring an accurate representation of uncertainty around the dynamics and status of the stock is a key challenge of the approach (Kolody et al. 2008; Rochet and Rice 2009). Due to the complexity of the simulation models used, stakeholders and decision makers often find management procedure evaluation

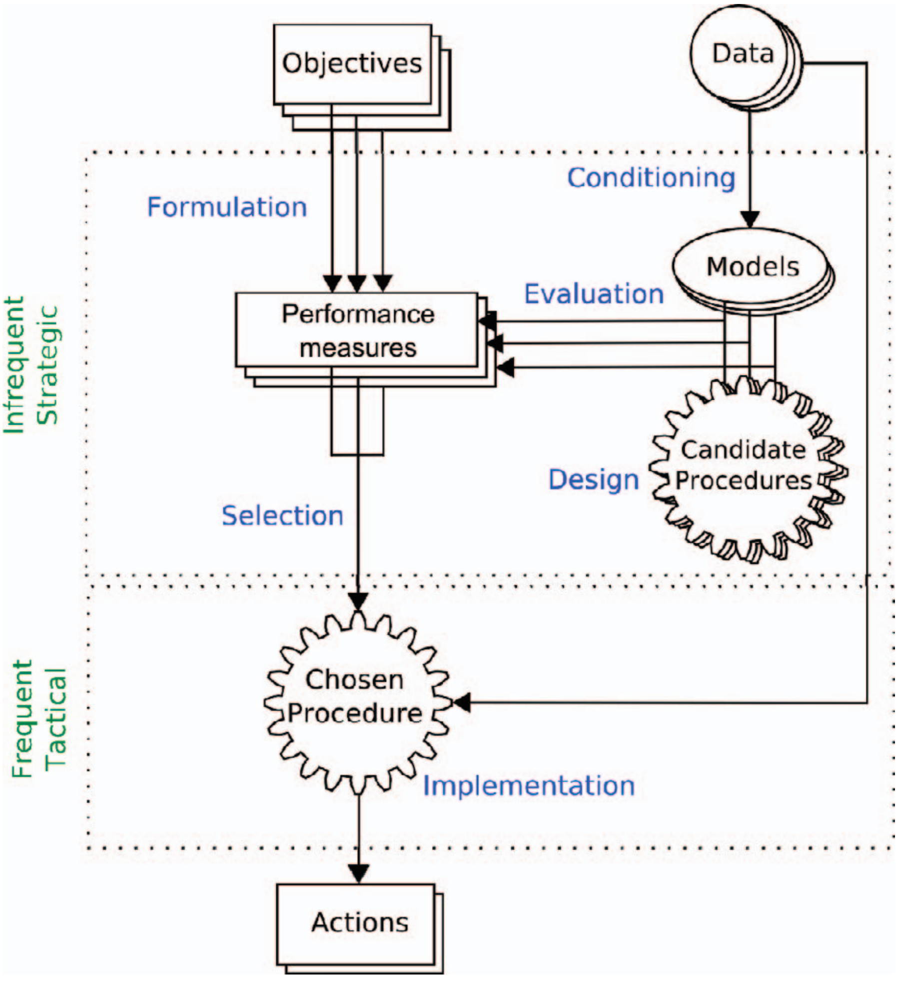

FIGURE 3.—Decision-making elements and processes under the procedural paradigm.

(MPE) difficult to understand, particularly if the results are presented in an overly technical manner.

An evaluation of alternative management procedures usually requires as much technical expertise as a stock assessment and as such is often equally expensive. Probably because of this, management procedures to date have mostly been developed for high-value, relatively data-rich stocks. For example, in New Zealand, the majority of management procedure development has been done for rock lobster *Jasus edwardsii* fisheries (e.g., Breen et al. 2009).

Nonetheless, we believe that the procedural paradigm holds promise for the management of data-poor fisheries. We suggest that its infrequent application to data-poor stocks has more to do with a poor understanding of the approach and perhaps deficiencies in its execution rather than any fundamental flaws. In the following section, we attempt to address some of these issues.

Improving the Understanding and Execution of the Procedural Paradigm

Despite substantial progress in the area of MPE, some of the most fundamental—and in our view most important—aspects of the procedural paradigm seem to have been neglected. The paradigm encompasses far more than just MPE; principally, it is about making decision making more strategic, effective, and cost efficient. Unfortunately, the habits that we in the fisheries management community have formed have been hard to shake, and there is a risk that we are replacing one scientifically driven technique (stock assessment) with another (MPE). The danger in this is that we will not fully realize the benefits of the procedural paradigm. As Keynes (1935) suggested, "The difficulty lies, not in the new ideas, but in escaping from the old ones, which ramify, for those brought up as most of us have been, into every corner of our minds."

There are many differences between the two paradigms, but in this section we will focus on three differences that we believe are not fully understood, or at least not fully appreciated:

- Evaluation over estimation;
- Performance over standards; and
- Robust and adaptive over precautionary.

We go on to describe several important dualities that are inherent in the procedural paradigm but for which only one has thus far been the focus of practitioners:

- Science and engineering;
- Research and monitoring;
- Evaluation and selection; and
- Specific and generic.

We highlight these in the hope that the full potential of the procedural paradigm can be realized and that it is not hobbled by how we have "been brought up."

Evaluation Over Estimation

The basis of the assessment paradigm is estimation: repeated estimates of the status of the stock are the focus of decision making. In contrast, the basis of the procedural paradigm is evaluation: evaluations of the performance of alternative management procedures. While this difference may seem obvious, it is often not properly understood. For example, some suggest that management procedures should ideally involve the estimation of quantities, such as current stock status relative to B_{msy}. This misses the point of the procedural paradigm: using simulation to evaluate how well the alternative management procedures perform with respect to performance measures rather than estimating those measures along the way. Butterworth (2008) and Schnute and Haigh (2006) used analogies drawn from physics to illustrate this difference in approach. We resort to a perhaps more widely familiar metaphor to reinforce the difference: the holidaying motorist who wishes leisurely to drive south for a holiday to enjoy some scenery while not using too much fuel.

The assessment paradigm says, "We will achieve our objectives by repeatedly estimating our current state and then acting accordingly." This involves repeatedly estimating the status of the stock and making decisions based on these estimates, taking into account multiple management objectives. In the case of the holidaying driver, it is analogous to the following strategy: at each intersection, stop the car, get out, use a compass to determine which way is south, then choose the road that is heading in the direction closest to south but also take into account the apparent scenic value of the road (based just on looking at what can immediately be seen of it). Eventually, the holidaying driver would reach the destination but in doing so would take a lot of time, use a lot of fuel, and go down some roads that were not particularly scenic.

The procedural paradigm says, "We will evaluate how well alternative plans achieve our objectives and then operate the plan that we expect to perform best given those evaluations." For our holidaying driver, this means that before setting out, he uses a map and other information to evaluate alternative routes in terms of time spent, fuel used, and scenic beauty. Based on these evaluations, decisions about the trade-offs between the performance measures would be made and one route would be chosen. That route would subsequently be drawn on the map and then followed by turning, as shown on the map and as indicated by road names. At no time would the driver actually need to determine the direction of the destination; the route would just be followed in order to get there.

In reality, fisheries management does not have a perfect map that can be used to determine a perfect route. Under the procedural paradigm, it is still necessary to estimate the dynamics and current state of the stock and the uncertainty around these estimates. As we discuss below, the procedural paradigm is still reliant on science. However, the point of our analogy is to illustrate that you do not necessarily need to know how well you are performing in order to perform well. In other words, estimates are not a requirement for tactical decision making as long as you have evaluated many alternative procedures and chosen the one that is likely to perform best. The procedural paradigm does not necessarily exclude estimation of stock status. Such estimates may be useful parts of a management procedure. Although stock status estimation may be appropriate in some circumstances, it is not necessary under the paradigm, and in many cases it will be inappropriate because of high bias, imprecision, and/or the cost of making those estimates.

Performance Over Standards

The procedural paradigm provides a framework under which a large range of management objectives can be formally included. Decision makers need not restrict themselves to a few standards based on quantities such as B_{msy} and coarsely considering whether we are "below," "at," or "above" them while at the same time trying informally to weigh this up against other objectives, such as economic viability and the cost of management. Instead, the paradigm emphasizes a gradient of performance based on several management objectives and focusing more on "better" or "worse" than "pass" or "fail."

Under the procedural paradigm, there is only really one pass or fail mark—the one that relates to sustainability. A management procedure must be shown to have a low probability of collapsing the stock or, put another way, to have a high probability of not reaching a level at which the stock is unable to replenish itself (Bravington et al. 2000; Punt 2000). If that condition is met, then stakeholders should be able to collectively choose the management procedure that maximizes the expected achievement of their management objectives. As we describe below, the challenge is to continually design *and* implement management procedures that improve performance with respect to those management objectives.

We agree with Butterworth (2008) that observable performance measures should be preferred over those that are required to be calculated from simulations. Butterworth's (2008) use of a quote from Dirac (1930) in relation to physics is so pertinent it bears repeating: "Variables not observable should not be introduced merely because they are required for the description of phenomena according to ordinary classical notation." In fisheries, we are at risk of holding on to concepts from the assessment paradigm because they fit into "classical notation." Biomass at maximum sustainable yield is a reference point rooted in the concept of maximizing long-term yield, but there may be simpler ways of measuring that management objective: by using average annual yield and the risk of fishery collapse as performance measures.

Robust and Adaptive Over Precautionary

Over the last few decades, the assessment paradigm has increasingly acknowledged the large degree of uncertainty that is typical of estimates of stock status. The response has been for scientists to quantify and clearly express uncertainty in estimates and for decision makers to take this into account by acting with precaution (Richards and Maguire 1998). However, acting with precaution is neither the only way nor necessarily the best way of dealing with uncertainty (Dovers and Handmer 1995). Charles (1998) describes three attributes of fisheries management that can be used to cope with uncertainty: robust (insensitive to uncertainty); adaptive (responds to changes); and precautionary (errs on the side of caution).

The procedural paradigm emphasizes performance being insensitive to uncertainty and decision makers responding to changes and favors these over erring on the side of caution. Adaptability is inherent in most management procedures, with implicit rules for how management actions should be taken in response to changes in the fishery. Robustness is also a key, powerful feature of the procedural paradigm. When management procedures are evaluated, they are evaluated by using a simulation model and a large number of alternative "states of nature," representing the various forms of uncertainty about the dynamics and current state of the fishery (Butterworth and Punt 1999). As such, the resulting performance measures represent the average expected performance of the management procedure given current levels of uncertainty. Management procedures that perform well across that range of uncertainty are preferred over those that may only perform well given certain assumptions.

This is not to say that the procedural paradigm does not allow for precaution in the sense of "prudent foresight" or "circumspection." In this sense, precaution should be applied when evaluating management procedures via an honest appraisal of the uncertainties and, when selecting among management procedures, via consideration to performance measures such as risk to sustainability.

Science and Engineering

Understanding and development of the procedural paradigm may be improved if we distinguish between the roles of science and engineering in fisheries management. In general usage, these words mean the following:

> Science: (from the Latin *scientia* for knowledge) the systematic creation of knowledge about the physical world through observation and experimentation (based on Random House 2006).
>
> Engineering: the application of scientific knowledge to design and implement materials, structures, machines, devices, systems, and processes that realize a desired objective and meet specified criteria (based on Wikipedia 2008).

In these definitions, there is a clear distinction between the roles of the two disciplines. Science is about finding the truth to develop knowledge. Engineering is about developing solutions to realize objectives.

The assessment paradigm is based on science; it aims to estimate the true status of the stock and act accordingly. It does not include a role for engineering. In contrast, within the procedural paradigm, there are clear roles for both science and engineering. Engineering relies on science; poor scientific knowledge leads to poor engineering solutions. With the context of the procedural paradigm, science and engineering could be defined as follows:

> Science: the systematic creation of knowledge about the fishery through observation and experimentation.

> Engineering: the application of scientific knowledge to design and evaluate management procedures that best realize management objectives.

Distinguishing between these roles is important. It allows each discipline to focus on what it should be doing without being impeded by other expectations. Fisheries science should focus on the creation of knowledge; fisheries management engineering should focus on the design of solutions. In many ways, fisheries assessment science has been expected to fulfill both roles and as a consequence may have done neither very well. "The interface between fisheries management and science seems to have frozen into a set piece, which satisfies neither managers nor scientists" (Hoydal 2007).

Fisheries science is a search for truth: it attempts to characterize the true biological and economic dynamics of the fishery. This means using the experience and technology from decades of fisheries assessments to estimate the underlying dynamics and current state of the fishery. This needs to be done with a full and honest appraisal of the uncertainty associated with these estimates. As such, the keywords of fisheries scientists should include "measurement," "bias," "precision," and "uncertainty." Linking fisheries science too closely with fisheries management may, intentionally or unintentionally, lead to a suppression of scientific uncertainty (Hutchings et al. 1997).

In contrast, fisheries management engineering is a search for performance: it attempts to find the management procedure that performs best in delivering management objectives. This means using the estimates of the dynamics and state of the fishery as produced by fisheries science to maximize the performance of fisheries management. Whereas fisheries science is responsible for quantifying the uncertainty around estimates, fisheries management engineering is charged with designing management procedures that are robust to these uncertainties. As such, the keywords of fisheries management engineers should include "performance," "optimality," "efficiency," and "robustness."

The interface between fisheries science and fisheries management engineering is the simulation model of the fishery. It is used by fisheries scientists to represent knowledge of the fishery and by engineers to apply that knowledge to inventing solutions. In addition to this formal role in the design of management procedures, a simulation model can also serve as a useful education tool for the managers and stakeholders by allowing a better understanding of the consequences of alternative management actions.

De la Mare (2006) provides a far more detailed examination of the lessons that fisheries (and wildlife) management can learn from the profession of engineering. Among other things, he notes that engineering is more focused on outcomes and deals better with uncertainty. We agree with much of de la Mare's (2006) analysis, but we suggest that fisheries management should attempt to go further than simply learning from engineering and that it should establish the discipline of, or at least the concept of, "fisheries management engineering." The science and engineering aspects of fisheries management do not necessarily need to be pursued by different people, but it may help and probably does no harm since the cognitive approaches required for each are so fundamentally different. Fisheries science should not concern itself with management outcomes, but fisheries management engineering certainly should.

Research and Monitoring

Thus far, most work under the procedural paradigm has assumed a given, constant stream of data from the fishery of a particular type. This ignores an important aspect of the procedural paradigm: that it potentially provides a framework under which the costs of alternative data collection and monitoring programs can be evaluated against their benefits.

It is also useful to distinguish between two forms of data collection and analysis: that which is done for science, for which we use the term "research"; and that which is done for implementation of the management procedure, for which we use the term "monitoring."

"Fisheries monitoring" is the collection and analysis of data for a management procedure. It is not optional, it is a core part of the business of managing a fishery; it is "a cog in the TAC machine" (Schwach et al. 2007). Fisheries monitoring is to fisheries management what a speedometer is to driving a car or a stethoscope is to a doctor.

The type, intensity, and frequency of monitoring are all necessary attributes of a management procedure. As with other attributes of the procedure, it is the job of the engineer to optimize these attributes to best realize management objectives. These objectives will usually incorporate the cost of management. There will be strong trade-offs between the costs of monitoring and the benefits that it brings in terms of increased performance (e.g., yield and other performance measures).

"Fisheries research" is the collection and analysis of data for fisheries science—that is, to improve the knowledge of the dynamics and state of the fishery. It will be done in response to identified uncertainties in the knowledge of the fishery. As such, research may be done in bursts as holes in knowledge are identified and filled. Fisheries monitoring will also be of use to fisheries science but is not designed for that purpose.

As with fisheries monitoring, fisheries research can be evaluated in terms of benefit to the achievement of management objectives. Large uncertainty in the dynamics of the fishery will favor the selection of procedures that are robust, performing well over a range of possible dynamics. However, these procedures are likely to perform less well for the true but unknown dynamics of the fishery. Fisheries research that reduces uncertainty about the dynamics of the fishery will usually lead to the selection of management procedures that perform well under those particular dynamics.

Evaluation and Selection

The procedural paradigm is principally about applying the most appropriate management procedure to best achieve multiple management objectives. The most appropriate choice of management procedure for a fishery depends not only the attributes of the fishery but also on the relative importance that stakeholders place on each management objective. A key aspect of strategic decision making under the procedural paradigm is the way in which stakeholders make trade-offs between conflicting management objectives. In this section, we argue that this aspect has not been given enough attention.

In the last few decades, MPE (also known as management strategy evaluation) has become increasingly sophisticated, with increasingly more realistic simulation models being used. New, spatially explicit, multispecies and ecosystem-based models provide the degree of realism necessary to address cross-area and cross-species management effects (Smith et al. 2007). Nevertheless, it must be remembered that the procedural paradigm involves much more than MPE, and in our view as much rigor and formality should be placed on the selection phase of the paradigm as on the evaluation phase. It is after all equally as important in determining the final management procedure that will be implemented in the fishery.

Several authors have noted the importance of communicating the results of MPE to stakeholders, but to date the methods for this have not been well developed (Butterworth and Punt 1999; Rademeyer et al. 2007). This lack of progress is somewhat puzzling given that there are well-developed techniques for aiding decision making when there are alternative choices and multiple objectives. The field of multi-criteria decision making (MCDM; Keeney and Raiffa 1993) specifically addresses the problem and had some early applications in fisheries (Hilborn and Walters 1977; Keeney 1977). In the mid- to late 1990s, several authors suggested that fisheries management should apply the techniques of MCDM to the choice of management procedures (e.g., Stephenson and Lane 1995; Stokes and Kell 1996; Lane and Stephenson 1998). Indeed, there are more recent applications of MCDM techniques in fisheries (see Leung 2006 for a review and see Xue and Lane 2008 for a recent example). However, most of these applications do not incorporate uncertainty in simulation parameters as is typical of MPE and which is necessary to assess robustness and estimate risk.

The high uncertainty of fisheries systems may require that MCDM techniques be customized to the fisheries context. However, the substantial body of work in other fields should not be ignored by those wanting to improve the strategic decision making involved in the procedural paradigm.

Specific and Generic

The assessment paradigm requires fishery-specific estimates of status as a basis for decision making: we cannot use the estimate of status from fishery A to make decisions about fishery B. The procedural paradigm does not have the same specificity: a management procedure that performs well for fishery A may also perform well for fishery B. The potential to apply the same management procedures to a number of fisheries is a powerful attribute of the procedural paradigm.

Evaluation is an essential feature of the paradigm, but there is no inherent requirement that it be conducted on a case-specific basis. The vast majority of work on the design and evaluation of management procedures has been carried out on a case-specific basis. This may have given the false impression that it is not possible to use management procedures for data-poor stocks. It is true that for a particular fishery, a custom-made management procedure will usually perform better than a generic one. Generic procedures may fail to accommodate the specific characteristics of a fishery or the particular performance preferences of its stakeholders. In the International Whaling Commission, for example, the use of case-specific management procedures rather than a generic one accelerated the achievement of management objectives for relatively data-rich fisheries (Punt and Donovan 2007).

For many fisheries, however, case-specific engineering of management procedures is inappropriate because the cost of doing so is high relative to the value of the fishery or is infeasible because there is a shortage of capacity for doing the work. Even for high-value, data-rich species, the cost of developing specific management procedures should not be underestimated (Kolody et al. 2008).

Where possible, specific is best; when the choice is between nothing and something generic, perhaps the latter should prevail. As we have noted in the context of stock assessment, fisheries management often sets high standards for itself but, in doing so, often fails to deliver for data-poor stocks. With management procedures, there is an opportunity to take a less-binary approach. We can apply generic management procedures, which may not necessarily be the best possible for a particular fishery but are probably better than doing nothing. As Chesterton (1910) noted, "If a thing is worth doing, it is worth doing badly."

Caution must be taken to ensure that whatever generic management procedures are applied must actually be "less bad" than doing nothing at all. We do not advocate the wholesale application of one-size-fits-all, unevaluated management procedures. Instead, we advocate the engineering of a suite of generic management procedures that can be applied to fisheries *in lieu* of case-specific work (Punt and Donovan 2007).

If generic management procedures are to be applied, there needs to be a clear means for identifying which one to choose for a specific fishery. If you cannot afford a tailor-made suit, then it is useful to have labels indicating small, medium, large, and extra large in order to know which one to pull off the rack. Those fisheries most in need of generic procedures will usually be those with little data. Thus, the means to identify the most appropriate management procedure should only depend on easily discerned characteristics of the fishery. These will not necessarily be limited to the characteristics of the species involved. As Andrew et al. (2007) asked, "Are there particular combinations of biological, social, and economic attributes that predispose certain forms of management?" We hope that methods will be developed for answering this sort of question and for identifying a core set of fishery characteristics that are both easily discerned and influential in the relative performance of management procedures.

Studies that take a generic approach are useful not only because they add to the potential suite of generic management procedures but also because they give us an understanding of what aspects of management procedures work under different circumstances. They can also potentially provide a bird's-eye view that will be useful when designing management procedures for specific fisheries.

Acknowledgments

This work was funded by the New Zealand Seafood Industry Ltd., and Seafood Innovations Ltd. We are grateful for the comments of the reviewers.

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