Uncertainty and Precautionary Management of Marine Fisheries: Can the Old Methods Fit the New Mandates?

By Hal Weeks and Steve Berkeley

ABSTRACT
Continued stock declines in marine fisheries have resulted in a search for more risk-averse management approaches. In response, the Sustainable Fisheries Act of 1996 mandates habitat protection, bycatch reduction, and stock rebuilding. These changes emphasize precaution, and imply a shift in focus from maximizing yields to minimizing ecological impacts and maintaining long-term biological and economic sustainability. Unfortunately, there is little consensus on how a precautionary approach should be applied in managing overcapitalized marine fisheries, especially considering the substantial uncertainty in our understanding of ecosystem structure and function, and the effects of fishing. Speakers in a half-day symposium at the 1999 AFS Annual Meeting discussed a spectrum of topics relating to analytic and decision-making uncertainty, precautionary management approaches, the social and political context in which decisions must be reached, and the role of management decisions in creating incentives. New approaches within the current decision-making context show some promise for reducing uncertainty and becoming more risk-averse. However, past lessons force us to conclude that the old methods will not satisfy the new mandates for risk-averse management approaches that are robust to both uncertainty regarding the effects of fishing on the ecosystem, and uncertainty regarding the effects of regulations on those being regulated. This paper is a synthesis of the diverse views of nine symposium participants. Speakers and the titles of their papers are shown in the acknowledgments.

Introduction
For most of mankind’s involvement with marine fisheries, marine fish stocks were considered inexhaustible (Kurlansky 1997). Fish stocks rose and fell, not by the hand of humans, but by natural fluctuations in the environment. What little management intervention there was, was based largely on intuitive beliefs that certain fishing practices should be avoided such as the harvesting of immature fish, spawning or egg-bearing females, or molting crustaceans. More active fisheries management has a much more limited history, with three fairly distinct stanzas. In the first, it was thought that even if we could not overfish a resource or affect recruitment, we could affect the yield realized from a fish stock by changing the fishing mortality rate, or the size at which fish were captured (Smith 1994). This was the beginning of quantitative stock assessment and population dynamics, and the “maximum sustainable yield” paradigm that remains the touchstone for fisheries management (Magnuson-Stevens Fishery Conservation and Management Act (M-SFCMA1996, Section 3), despite the epitaph written by Peter Larkin (1977). Most fisheries were still considered self-regulating; with the available technology, fishing would become unprofitable long before there was any biological risk of stock collapse. This was the era of production models and yield-per-recruit analysis, and the theory around these models was rapidly developed.

The second stanza began only recently, as stock collapses became more frequent and evidence accumulated that these collapses were the result of fishing. It became apparent that not only could fishing reduce yields, but fishing could also affect recruitment and biological productivity. Recognizing this, management objectives began to shift from attaining a maximum sustainable yield to maintaining a minimum spawning stock biomass. This did not require a significant change in approach, because the goal was still to obtain the highest possible yield from the stock, but as tempered by the recognition that doing so means maintaining an adequate spawning stock. Despite these more conservative biological targets, both recruitment and growth overfishing have continued with increasing frequency (NRC 1999a).

To address these continued resource declines, a third paradigm, precautionary management, has recently been advanced (FAO 1995). Precautionary management does involve a significant change in approach, because it entails an explicit recognition of uncertainty, and a change in focus from resource yield to the maintenance of ecosystem structure and function. The precautionary approach also implies...
a change in the burden of proof for taking management action. Historically, the burden has been on managers to show that harvest rates are too high (or other elements are detrimental) in order to justify restrictive management measures. The precautionary approach would place the burden on harvesters and managers to show that there is limited risk in maintaining harvest levels and practices. The need for precaution is highlighted by the growing awareness of the limitations of our understanding of marine ecosystems that produce the resources we harvest, and ecological services we depend upon. Uncertainty, or what we do not know or understand, has rarely been the focus of resource management decisions; explicitly recognizing and addressing that uncertainty is integral to implementing a precautionary management approach. Precautionary management is a risk-averse approach for decision-making when scientific understanding is lacking; this is embodied implicitly in the 1996 Sustainable Fisheries Act (amending and reauthorizing the Magnuson Fishery Conservation and Management Act) and explicitly articulated in the National Marine Fisheries Service guidelines for implementation (FAO 1995; Restrepo et al. 1998; NRC 1999a). Uncertainty in fisheries management enters the analytic and decision-making process at several levels. First, there is a great deal of uncertainty due to inadequate data and analyses addressing population size, structure, dynamics, and distribution of the target species (NRC 1998). Second, maintaining productivity by protecting essential fish habitat as now required (M-SFCMA §303(a)(7)) requires a level of understanding of community structure and dynamics well beyond what is now available. Third, there is uncertainty about how fishing affects demographic and genetic diversity within fish stocks, an area that is increasingly understood to be important to stock productivity (Smith et al 1991; Martinsdottir and Thorarinsson 1998; Berkeley and Markle 1999; Secor 2000). Fourth, ocean conditions change on poorly understood short-term and long-term cycles; regime shifts can fundamentally alter productivity patterns (Hofmann and Powell 1998; Steele 1998). Fifth, ecological communities may have multiple steady states, a population reduced through fishing may not “automatically return” to its previous level of abundance even if all fishing is eliminated (Holling 1973; Murawski and Almeida 1998; M. J. Fogarty, NMFS, Woods Hole, Massachusetts, unpublished data), and fishing may result in changes in predator or prey abundance that may impact community structure and function (Overholtz and Tyler 1985; Fogarty and Murawski 1998; Rogers et al. 1998). So, not only do we need more data and analyses of the types that have guided recent decision-making, we also need to collect and incorporate fundamentally new types of information into our decision-making system.

Finally, management decisions to implement biologically risk-averse approaches will have direct financial impacts on fishing fleets, supporting businesses, and their communities. The 10 national standards of the M-SFCMA encompass a spectrum of conditions to be considered. How these elements should be weighted in policy decisions is open to contentious debate. Because many fisheries are overcapitalized, and many fished stocks require urgent conservation efforts, the harvest and fleet reductions that are needed will result in short to intermediate term financial hardship. Economic costs of biologically risk-averse approaches are nearly always immediate and apparent. Ecological and economic benefits are less certain and may accrue decades later, and to a different suite of stakeholders than those who bore the costs initially. This ecological uncertainty creates a great deal of resistance to management changes from resource users, and political and social uncertainty for decision-makers. We lack a thorough understanding of the business implications of many management decisions, and change in management direction comes only through time-consuming dialogue and experience. It is clear that the decision-making mechanisms of the U.S. regional fishery management councils are not well suited to evaluating these risks and uncertainties efficiently, in a manner consistent with a precautionary approach, and as perceived by individuals economically dependent upon marine fisheries (Hanna 1999a).

**Uncertainty and precaution**

A decision-making process that must decide “how much is too much” cannot escape the fact that substantial uncertainty is unavoidable. (Hilborn and Walters 1992; Pickett et al. 1994). Part of this uncertainty results from inadequate data and conceptual models (due to both sampling and process error) at the species and higher-order levels. More data and analysis will reduce some of our inherent uncertainty, particularly for single species analyses. However, a different way of evaluating fishing and prudent harvest levels from broader ecological and social perspectives is also needed. The absence of clear goals, clear questions, coherent data collection, and analytic protocols contribute to this uncertainty. There is also significant uncertainty among many in the fishing industry regarding the goals and procedures of management agencies. Implementation error—the divergence between what managers believe will happen as a result of management actions and what actually happens—is also a confounding element.

Improved scientific understanding will be part, but only part, of the changes necessary to address this uncertainty in marine fisheries. Part of our collective problem in addressing and incorporating uncertainty into analyses and decision-making results from the nature of science and public expectations of scientific analyses and understanding. The M-SFCMA requires that management decisions be based on the best scientific information available. However, limits of funding and time will never allow all necessary data to be collected and all relevant hypotheses to be tested. The best available information is often inadequate to support required decisions because our current understanding of marine resources and ecological processes is insufficient to understand beforehand the effects of given harvest levels on target and nontarget stocks and the broader ecosystem. Precaution entails identifying and avoiding undesired outcomes. Contemporary practice for avoiding overfishing has focused almost exclusively on total mortality. The important need now is to identify other critical limiting factors and
undesirable outcomes at the population or species level (demographic and genetic diversity) and at higher levels of ecological connection (e.g., community structure, habitat characteristics) (Collie 1998; Engel and Kvitek 1998; Gordon et al. 1998; Kaiser 1998; Rogers et al. 1998). Thus, traditional goals of harvesting the maximum sustainable yield and realizing maximum economic benefits from fishery resources need to be integrated into a broader framework that recognizes the need to maintain population, community, and ecosystem structure and function (Hanna 1999b). More directly, our management and scientific approaches must be recast to allow prudent and sustainable harvest levels and methods while keeping the risks of adverse outcomes to acceptably low levels.

Nearly half of the nation's commercially and recreationally important fish stocks (73 of 158 stocks of known status) are overutilized (NMFS 1999). This, combined with overcapitalization of the U.S. fishing fleet, means that managers are increasingly forced to react to unacceptable situations rather than being able to take a more deliberative approach to avoid them. The combination of depressed stocks and overcapitalized fishing fleets results in biological and social conflict: reducing short-term risks to the industry and coastal communities increases the risk to fish stocks and the ecosystem; while addressing ecological concerns for fish stocks and habitat increases the short-term hardship and risk to the fishing industry and coastal communities.

Society in general, and the fishery management process (i.e., all interacting participants including managers, fishers, scientists, processors, related business, and the broader public) in particular, lack a philosophical consensus on what to do when we don't know. The emphasis in law is that decisions be based on the best scientific information available. However, that requirement does not address how decisions should be made when information is inadequate to understand the tradeoffs between the goals we want to achieve, and the outcomes we wish to avoid. Restrepo et al. (1998) suggest that the use of "informed judgement" may be necessary in data-poor situations; however, this does not serve as a guide to how informed yet conflicting opinions and judgements should be weighted and evaluated.

It is easy to paraphrase the law and state that we want to achieve maximum (optimum) economic yields for the nation while avoiding overfishing, habitat damage, and
Reducing analytic and management uncertainty

At specified levels of resolution, such as single species assessments, uncertainty can be reduced through comprehensive data collection, retrospective analyses, and continued updates of analyses with new information. With frequent stock assessments, divergences between empirical data and model results can be recognized and addressed before a wide gulf develops that can lead to erroneous management recommendations. More frequent and extensive surveys will help reduce uncertainty, as will more comprehensive sampling of fishery landings. Data requirements for an “ideal” stock assessment are imposing; yet even with complete data sets, assessment results are likely to diverge (up or down) from the actual state of nature (NRC 1998) (Figure 1). The divergence of many of these stock assessment results from the “true” stock condition in this hypothetical case is sobering, and provides further support for the need for more precautionary management approaches. However, reducing analytic uncertainty is only part of the challenge. Incorporating information about uncertainty into analyses and advice provided to decision-makers is equally important; decision analysis for management choices, and sensitivity analyses and statistical power analyses can and should be incorporated into management advice (Hilborn and Peterman 1995; Bradshaw and Borchers 2000).

Several pragmatic efforts are already in use to incorporate uncertainty into analytic results or into fishery management decisions. For example, the stock assessment for Pacific cod (Gadus macrocephalus) in waters off Alaska has recently employed a type of Bayesian analysis to explicitly consider the uncertainty in two influential model parameters, natural mortality (M) and survey selectivity (q). Bayesian analysis allowed previously acquired understanding to contribute to the interpretation of newly collected data. In this case, the method allowed “prior” probabilities regarding the values of M and q derived from previous studies to inform the maximum likelihood estimates of M and q derived from the available fishery and survey data. This approach resulted in more reasonable estimates of M and q, and a recommended acceptable biological catch (ABC) level that was lower than what would have been recommended had M and q been based on available data alone (Thompson and Dorn 1998).

Providing harvest advice for the Pacific whiting (Merluccius productus) stock off the U.S. West Coast was difficult due to uncertainty in the stock-recruit relationship. Estimated stock-recruit relationships from other stocks and species of merluccid hakes worldwide were used in a Bayesian meta-analysis that explored assumptions about the relatedness among several merluccid stocks and used data from all of the stock-recruit relationships to inform each individual stock recruit relationship. Although this analysis did not appreciably change harvest rate advice from that based on the Pacific whiting data alone, it reduced uncertainty relative to the single-stock analysis and thus provided increased confidence in the recommended harvest rates (Dorn et al. 1999).

Elements of these two approaches have been combined in providing management advice for Pacific Ocean perch (Sebastes alutus) off the U.S. West Coast. In this case, a full Bayesian stock assessment integrated prior distributions for the uncertain parameters M and q as well as the stock-recruit parameters within the model. This analysis produced probability distributions of current and 10-year projected stock biomass that incorporated the uncertainty in model parameters. These distributions were then used to construct a decision table characterizing the trade-offs between harvest policy and resulting projected stock size in a probabilistic format (Ianelli and Zimmerman 1998).

Multiplespecies interactions, specifically predation, are now being incorporated into walleye pollock (Theragra chalcogramma) population models at the Alaska Fisheries Science Center. Walleye pollock are prey for many other fishes, birds and mammals. These models incorporated predation effects and included the uncertainty associated with each effect: uncertainty in the biomass of three different predators, uncertainty in predator consumption rates, and uncertainty in the rate of pollock natural mortality, M, in the absence of the modeled predation. The analytic results supported the previously held expectations that M is not constant (even between years or age classes for the same species), but also demonstrated the potential explosion of analytical uncertainty when accounting for multiple species interactions (Hollowed et al. 2000).
The four examples above illustrate some of the techniques being investigated to formally recognize and incorporate uncertainty and decision theory into assessment modeling. The result is improved quantification and communication of the uncertainty for decision-makers and the public who can then better understand the risks and trade-offs of management decisions.

The North Pacific Fishery Management Council (NPFMC) has adopted a groundfish harvest policy for establishing ABC and overfishing that is linked directly to the levels of information associated with each groundfish stock so that more conservative ABC and overfishing levels are established for stocks about which less is understood. This policy also reduces ABC and overfishing levels when stock size falls below defined thresholds (NPFMC 1999a, 1999b).

The NPFMC has adopted a suite of other management measures in the Bering Sea and Gulf of Alaska to both reduce uncertainty, and provide risk-averse management advice in light of existing uncertainty. The council has implemented an observer program in the groundfish fisheries that provides estimates of all fisheries removals. The council has adopted measures to preclude targeted fishing on important forage species. The council also has closed substantial areas to bottom trawling; areas surrounding the Pribilof Islands, most of Bristol Bay, and much of the eastern Gulf of Alaska may no longer be fished with bottom trawls. Perhaps most uniquely, the NPFMC has operated with an annual 2 million metric ton optimal yield cap for groundfish in the Bering Sea/Aleutian Islands area (BSAI) since 1981. The sum of ABCs for all species managed under the groundfish fishery management plan in the BSAI has often exceeded 3 million metric tons, but the sum of total allowable catches across species is capped at 2 million metric tons annually. This measure provides an additional safety margin in establishing harvest levels, and has resulted in increased stability in actual and expected groundfish harvests: despite changes in stock abundances and management measures, total groundfish harvest in the BSAI has remained largely constant.

**Political and human considerations**

Attempts to address uncertainty must also consider the human dimension. In its most extreme application, the precautionary principle could be interpreted to preclude fishing until an absence of harm can be demonstrated. This is not possible because no activity is risk-free. In practice, a precautionary approach to fisheries management provides for fishing in a cautious manner, while information is collected and analyzed to ascertain whether detrimental changes have resulted. It also provides for implementation of conservation measures when there is uncertainty about whether stocks are being overexploited or habitat is being damaged. In effect, it represents a reversal of the burden of proof (Restrepo et al. 1998).

Addressing competing goals (and unacceptable outcomes) requires decision-makers to distinguish clearly what it is that we are certain about versus that which we are uncertain about. For example, the Georges Bank cod stock is clearly depressed and fishing mortality is excessive. It is certain that effective conservation measures to rebuild the stock to desired levels will require large reductions in fishing mortality. Exactly how large a reduction (e.g., 60% vs. 65%) in fishing mortality is needed to achieve the desired rebuilding outcome may be very uncertain. But it is also irrelevant because it is certain that the necessary reduction is very large. Nevertheless, this uncertainty has been used as a tool to avoid harvest reductions. Retrospective analyses show clearly that the failure to take more conservative measures in the past resulted in significant foregone catch in subsequent years (Figure 2).

Whether the outcomes of management decisions are good or bad are very much in the eye of the beholder. From both psychological and political perspectives, it is important to show the potential for short-term benefits as well as those in the long term. This may be impossible because many fisheries have become increasingly dependent on depressed stocks, and effective rebuilding will require significant reductions in fishing mortality. With our inability to predict recruitment levels, the rebuilding timeframe is itself uncertain even with these reductions. From a human perspective, enduring financial hardship for two years is one thing, but for 10 years is another.
Uncertainty regarding the duration of hardship and the prospect for future relief may be psychologically and politically intolerable. Positive incentives in the short term to achieve long-term goals must be integrated into any package of measures to achieve conservative rebuilding objectives. For example, one can postulate a rebuilding program that "shares" increases in stock biomass between harvesters and the stock itself. This presupposes an adequate understanding of stock size and changes in biomass, and a willingness to accept a slower rate of rebuilding. However such an approach appears contrary to current guidelines for M-SFCMA implementation when a stock is under a legally mandated rebuilding plan (Restrepo et al. 1998). The legal mandates and decision system by which fisheries are managed arise from fundamentally political processes. As such, they bring together divergent and often conflicting values, beliefs and interpretations of the available information. While guided by science, change occurs through dialogue, and this takes time. For example, the M-SFCMA National Standard Nine requires that bycatch and discard mortality be reduced to minimal levels. Implementation has already been proven to be a slow, time-consuming process of negotiation and compromise because of uncertainty and disagreement over the magnitude of bycatch and discard, the inherently political nature of the management decision process, and the difficulty and vagueness of the charge.

Management and implementation considerations

Uncertainty in the scientific understanding and management of fisheries is compounded by the fact that management decisions and implementing regulations create incentives that affect fleet behavior. These incentives can lead to unintended consequences unrelated or even counter to the original management objectives. For example, fleet capacity and demand far in excess of the available catch quotas created a derby-style race for fish off Alaska that led to drastically shortened fishing seasons for several target species. These derbies compromised safety, created economic inefficiencies, and contributed to higher bycatch rates of prohibited species as participants could not afford to take the time to move to other areas or change otherwise productive fishing patterns.

Implementation error is the divergence between what managers and the public believe will happen as a result of management actions and what actually happens. It results from the complexities of human behavior, markets, and technological changes interacting with regulations and the resulting incentives. Recognition of this element requires that management institutions and decisions be structured so that they provide the "right" incentives to meet management objectives. Precautionary management approaches require that undesired outcomes be avoided while working with substantial uncertainty. This requires that we address how management institutions and incentives drive perceptions of economic risk and uncertainty. Closely related issues include whether and how management systems facilitate efficiency (with respect to time, effort, or other factors) in dealing with risk and uncertainty, and whether there is a distinction between how managers and policymakers evaluate risk and uncertainty compared to the fishing industry. The strong potential for implementation error combines with ecological variability and scientific uncertainty to require that decision-makers clearly prioritize fundamental management objectives—there will be tradeoffs between obtaining maximum yield (or some other maximal benefit) from a fishery, minimizing variability in that yield or benefit, and minimizing the risk of unacceptable outcomes.

A. Management decision-making structure

There are several ways to address uncertainty and risk from an individual or business perspective. Two familiar strategies are insurance and portfolio diversity (operations, gear, location, target fisheries, other businesses). Each of these strategies is familiar from other contexts of life. Insurance involves investing some portion of available resources (an insurance premium), to protect against or to reduce the risk of future costs (e.g., stock collapse). In a fisheries context, this could be illustrated by a decision to adopt a much more conservative harvest strategy to reduce the risk of future stock declines or harvest variability. Diversity of operations through participation in several distinct fisheries provides some element of risk reduction by making other resources accessible in case one component of a portfolio is sharply reduced or lost. Each of these tactics has associated costs; all are used to some degree to buffer unknown or unpredicted changes in circumstances.

An important issue is to ascertain the relative tolerance for risk and uncertainty for all participants and from all perspectives in fisheries management and operations. Whether there is a way to characterize the relative risk tolerance of fishermen, fishery managers, and the public leads to the more difficult question of whether and how this risk should be managed. There are market mechanisms for representing the economic value of natural resources including published prices that track transactions between willing buyers and willing sellers. For example, prices of quota shares for Pacific halibut (Hippoglossus stenolepis) and sablefish (Anoplopoma fimbria) off of Alaska are published in the back pages of Pacific Fishing. These prices implicitly incorporate participants' perceptions of financial and management risk inherent in holding quota shares. If markets perceive that managers are not adequately addressing risk and uncertainty, price per share will decrease, leading to increased pressure to adjust management strategies.

Management of fisheries can occur along a spectrum of industry and public involvement. Some centralized processes in other nations allow for very little outside involvement in the decision process. In the United States, the eight regional fishery management councils provide for a pluralistic management process with many views and perspectives. The U.S. process requires that public comments be sought by the councils and NMFS, and that comments on proposed regulations receive responses in the Federal Register. A strong rights-based process—for
example, individual fishing quotas or the Bering Sea pollock cooperatives provided for under the American Fisheries Act of 1998—provides for substantially more industry involvement in the management process.

A recent trend in fisheries management has been toward rights-based systems. Implementation of individual quota management systems in the U.S. and elsewhere have spurred increased interest in individual quotas as a possible mechanism to rationalize overcapitalized fisheries. The 1996 Sustainable Fisheries Act contained a moratorium on further individual quota management schemes through 1 October 2000. (N.B. Reauthorization legislation with language that would lift this moratorium under strict conditions was introduced into the U.S. Senate in July 2000. We expect this to be a focus of congressional negotiations this summer and fall.) A central question is whether rights-based systems are more efficient in dealing with complex and uncertain systems. Under appropriate institutions, markets have a documented ability to efficiently price goods; the price will necessarily include a contingency for uncertainty. In contrast, decision-making by a centralized body (research is also centralized) is not very efficient and tends to ignore users and their body of information and insight, as well as the broader market.

The New Zealand hoki fishery (*Macruronus novaezelandiae*, a gadiform not unlike Pacific whiting of the U.S. West Coast), for example, is managed through a corporation established by individual transferable quota holders. Scientists prepare an assessment of the resource; the corporation then decides how the fishery will be managed and with what quota, provided there is consistency with the stock assessment. The assessment is peer reviewed, and the government analyzes the corporate fishery management plan to ensure it complies with legal mandates. Over the last five years, the hoki fishery corporation has consistently set the allowable catch level some 15% lower than the total allowable catch level (intended to provide a maximum sustainable yield) generated from the assessment. This has hedged against uncertainty while also providing for year-to-year stability by limiting swings in availability.

There are many mechanisms to address uncertainty and risk; an essential question is whether rights-based systems or the current management approach do a better job of providing short and long-term incentives to rationally balance harvest, conservation and risk. An alternative perspective for evaluating rights-based management is to ask whether the implementation uncertainty associated with management decisions made in the U.S. management council system is reduced when some of these decisions are handled through individual transactions. Individual quotas as a management tool will be the subject of intense continuing debate as M-SFCMA reauthorization is considered. Their utility as a management alternative will depend upon the specific needs and objectives of individual fisheries, and the details of any proposed quota-based management program. However, there are significant concerns that the unintended consequences resulting from rights-based management systems will lead to a trade of one form of uncertainty for another (NRC 1999b).

### B. Public involvement

Nongovernmental organizations (NGOs), which represent the interests of at least some of the general public not involved in the business or management of fisheries, have become increasingly involved in fisheries management in recent years. Many see that fisheries are being over-exploited and are concerned that the long-term productivity of marine ecosystems is being compromised (e.g., declining world landings, bycatch, shark finning, and potential direct or indirect impacts on species listed under the federal Endangered Species Act). In their perception, governance of fisheries by affected interests leads to risk-prone management decisions and a tendency to avoid change because uncertainty in understanding prevents clear justification of more ecologically risk-averse approaches. These groups and individuals contend that a complete understanding of a fishery and the resource is not needed to act; rather they are generally looking for fairly simple decision algorithms whose emphasis is on reducing long-term risks to exploited stocks and the ecosystem.

### C. Goal setting

Incorporation of uncertainty into analytic documents, and the use of precautionary principles in management decisions are both laudable and mandatory. But they create continuing conundrums for fishermen and managers attempting to understand and articulate management goals when nearly all inputs and many consequences are uncertain. Resource abundance is driven by dynamic changes in ecological systems and climate regimes in addition to human actions, and it is impossible to manage for maximum yields and biomass levels of all species simultaneously. However, this is what the M-SFCMA amendments seem to require. The interplay of natural change with human influences in marine ecosystems underscores the challenge of disentangling human effects—which can be managed—from natural change, which can only be observed. Data collected from fisheries and resource surveys need to be interpreted in light of the natural changes occurring and observed in the ecological system. This suggests that placing more effort into collecting and compiling observations from fishermen who are on the water in large numbers will be valuable in tracking trends and recognizing patterns. Modifying management institutions and approaches to foster communication and information sharing between management agencies and fishermen will facilitate the collection and interpretation of these data. However, it is also clear that the trends and patterns that result from these observations may still fail to provide managers with a basis for making long-term decisions unless management goals are set into a dynamic context.

### Conclusions

Incorporation of uncertainty into analytic documents, and increased emphasis on precaution in decision-making,
is a growing reality based on both the shortcomings of existing approaches, and the philosophical and legal changes incorporated into the Food and Agriculture Organization technical reports on precaution (1995), and implicitly in the 1996 amendments to the M-SFCA. The high level of interest in the 1999 AFS symposium on uncertainty and precautionary management illustrates the significance of this issue across a wide spectrum of fishery professionals, and illustrates that we are still struggling for insight and guidance in how to implement these principles. A major barrier is the lack of consensus on long-term goals, how natural variability can be handled and disentangled from anthropogenic change in setting prudent fishery specifications, and most significantly and generally, what to do when we don't know.

Rights-based approaches to fisheries management that allow the market to balance some of these risks were actively discussed during the symposium. There is growing interest in other management approaches that provide “insurance” in the face of uncertainty. One such approach, marine reserves (Allison et al. 1998; Lauck et al. 1998), although promising in some contexts, was not discussed during the symposium. In waters off Alaska, significant areas have been closed to bottom trawling, but these are not comparable to no-take reserves (DiCosimo, NPFMC, Anchorage, Alaska, pers. comm.). Marine reserves are the subject of active discussion within the Pacific Fishery Management Council deliberations (PFMC 2000), but off the West Coast and elsewhere, reserves could have significant allocative implications that complicate their consideration.

The efficacy of marine reserves as an insurance policy to help scientists, the fishing industry, and managers address the uncertainty in our understanding of marine resources hinges on how the areas are designed and implemented. Most importantly, their value in guiding future precautionary management will hinge on how well they perform. This will require careful evaluation through collaborative data collection efforts by fishing fleets, scientists, and managers to test appropriate hypotheses concerning reserve area performance. The objectives for reserves, and the relation of these objectives to broader management objectives, will be critical in determining what kinds of evaluations are needed, and whether they can contribute to improved management under uncertainty.

To answer the question posed in the title, we conclude that the old methods are not up to the task of meeting the new mandates. Traditional approaches to fisheries management have fallen short, despite the best of intentions, due to imperfect understanding of complex ecological systems, overly optimistic assumptions of resource productivity, conflicting objectives, a management approach that poorly balances short term and long-term risks, and an institutional and legal context that makes change difficult and time consuming. New approaches show promise in addressing at least some of the problems identified with our current approach. However, no approach will fully resolve the problem—we must make decisions about the use of public resources in the ocean, and the livelihoods of people dependent on those resources, without full prior knowledge of the consequences of those decisions.

Acknowledgments

This paper is a synthesis of talks presented at the symposium “Uncertainty and precautionary management of marine fisheries: can the old methods fit the new mandates?” We acknowledge the speakers and authors from the symposium, including Bill Amaro, New England Fishery Management Council, “Fisheries Management for the 21st Century: The Changes Ahead”; Steve Berkeley, Oregon State University, “Why Traditional Approaches to Fishery Management Fall Short”; Gay Bradshaw, Oregon State University and National Center for Ecological Analysis and Synthesis, “Uncertainty as Information: Narrowing the Science-Policy Gap”; Jane DiCosimo, North Pacific Fishery Management Council, “Applying the Precautionary Principle in Managing Groundfish and Crab Stocks in the North Pacific”; Sarah Gaichas, Alaska Fisheries Science Center, National Marine Fisheries Service, “Integrating Uncertainty in Stock Assessments: Examples from the U.S. West Coast and Alaska”; Steve Murawski, New England Fisheries Science Center, National Marine Fisheries Service, “Uncertain Outcomes with Known Consequences: Practical Considerations in Precautionary Fisheries Management”; Andrew Rosenberg, formerly with the National Marine Fisheries Service (currently with the University of New Hampshire), “Moving from Theory to the Practice of the Precautionary Approach to Fishery Management: Can We Get There from Here?”, Carl Safina, National Audubon Society, “Why do Environmentalists Care About Marine Fisheries?”; and Gil Sylvia, Coastal Oregon Marine Experiment Station, Oregon State University, “Developing Fisheries Institutions in an Uncertain Universe: The Economics of Uncertainty and Risk.” This paper was substantially improved by the comments of Sarah Gaichas, Steve Murawski, Andrew Rosenberg, Gil Sylvia, and three anonymous reviewers on previous drafts. Our organization of and participation in this symposium was supported by Oregon Sea Grant and the AFS Marine Fisheries Section.

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