CHAPTER 23

An overview of the precautionary approach in fisheries and some suggested extensions

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Introduction

Uncertainties in fisheries systems are pervasive and they have important consequences. These uncertainties result from natural variation and our imperfect knowledge of how these systems work, among other factors. Uncertainties are significant because they create risks: biological risks to fish populations, economic risks to those in the fishing industry, and social risks for people in coastal communities who depend on productive aquatic systems. Risks include not just the worst possible event that could happen (e.g. loss of all fish in a stock, loss of all fishing industry jobs), but also less severe events. Estimates of risk consider each of these possible events, taking into account the chance that each of them will occur. Over the past five decades, scientific research on fisheries problems has reduced uncertainty and its affiliated risks but there is still a considerable amount of uncertainty remaining. We must therefore deal with it effectively in our scientific advice and in our management.

Responses by harvesters and managers to uncertainties and risks

The standard responses by harvesters and managers to uncertainties and risks fall into one of three categories. First, people may make an optimistic assumption about how the ecological system might respond to human disturbances; this usually leads to aggressive actions such as high harvest rates or the introduction of non-native species. Second is the often-noted response that, “We know so little about what to do that we should just leave things alone.” This view means that, for example, a decrease in productivity of some stock should not be attributed to fishing until all other alternative explanations such as environmental changes are ruled out. This approach uses uncertainties to maintain the status quo. Another alternative is to make a more pessimistic assumption about the ability of the ecological system to respond to human disturbance, cautiously alter the system, and monitor its response. This third response to uncertainties reflects the view that, with appropriately cautious harvesting and management actions, we might not be able to reduce uncertainties further but we might be able to reduce the resulting risks.

Historical perspective

Techniques for incorporating uncertainty into fisheries management have evolved over the last 50 years. In the 1950s, management quantities such as maximum sustainable yield and optimal escapement were calculated using best-fit estimates from stock assessment models. Later, scientists and managers responded to the recognition of uncertainties in data by adjusting the management goal in an ad hoc way (e.g. MSY spawning abundance plus 20%). In the 1980s and 1990s, scientists became proficient at building stochastic models to calculate probabilistic indicators of consequences of management actions (e.g. the probability of having spawner abundance less than some target level). Methods for calculating target reference points (which are goals towards which we should head) and limit reference points (conditions that we should avoid) also emerged. Harvest decision rules have been used broadly in the past to help avoid crossing those limit reference points. Unfortunately, reference points are difficult to estimate reliably in practice, given the uncertainties in stock assessment data. It is also difficult to determine reliably the status of a stock relative to those reference points. Furthermore, we have often found that in practice, decision rules are not as successful as anticipated for avoiding limit reference points.

This process of becoming more conscious of uncertainties and increasingly accounting for them in analyses and management recommendations eventually evolved into a comprehensive framework that was codified in a 1995 document, published by the Food and Agriculture Organization of the United Nations (FAO), called the "Precautionary Approach to Fisheries Part 1, Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions" (FAO 1995a). This document reflects lessons learned about dealing with uncertainties over the previous five decades in fisheries science and management. It encapsulates these lessons into a framework that can help other agencies implement a precautionary approach, both for managing capture fisheries, and for avoiding problems with species introductions. In particular, the FAO (1995a) guidelines provide specific steps that can be taken to meet the goal of taking a more precautionary approach. This document is only one of the latest steps in the natural evolution of thinking and procedures for dealing with uncertainties in fisheries systems. Changes continue to be made in these procedures.

Precautionary *Principle*

Before discussing the FAO (1995a) precautionary approach document in more detail, it is important to clarify the difference between the precautionary *principle* and the precautionary *approach*. Consider a spectrum of restrictions imposed on human activities, ranging from very severe restrictions to none (Figure 23.1). The precautionary *principle* applies to the extreme end of the spectrum where one assumes that there will be a very damaging response of the ecological system to human activities and where very severe measures are therefore taken to restrict those activities. The first example that led to the application of this precautionary *principle* was the banning of dumping of wastes into the North Sea. In this case, scientists had assumed the chemicals being dumped were inert, when in fact they were toxic and damaged marine ecosystems. The number of these "Type II errors" had risen to the point where it was decided to totally ban the dumping of wastes because there had been too many deleterious surprises. Other examples of applying the precautionary *principle* include the banning of ozone-depleting substances and the banning of commercial fishing on interior British Columbia coho salmon in 1998.

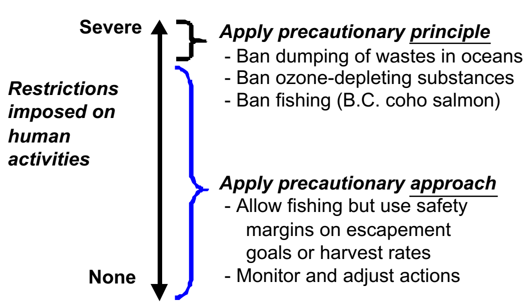

Figure 23.1 Schematic illustration of how applying a precautionary *principle* differs from applying a precautionary *approach*, in terms of the degree of restriction on human activities. Examples are provided.

Precautionary *Approach*
However, fisheries scientists and managers noted that such extreme restrictions were not necessarily appropriate in all cases. For instance, wild fish populations usually exhibit density-dependent growth, reproduction, and/or mortality such that they can rebound from depletions as long as they are not too severe. The precautionary *approach* reflects this knowledge and can refer to any part of the range of restrictions on human activities, between none and severe, but it does not refer specifically to one point on the range (Figure 23.1). For example, to take a precautionary *approach* in a fishery, fishing could be allowed but reduced by "safety margins" on the escapement goals or harvest rates, which would result in harvesting fewer fish than normal. The precautionary *approach* also includes carefully monitoring the responses to our actions, and adjusting actions appropriately. The precautionary *approach* to fisheries management is thus more flexible than simply applying the precautionary *principle* in the presence of major uncertainties. This frequently overlooked distinction is important because it can make the difference between clear communication and misunderstanding among scientists, managers, and stakeholders.

The FAO (1995a) Precautionary Approach document
This section briefly reviews some key parts of the FAO (1995a) document, which describes detailed guidelines for implementing the precautionary approach. Even though this source document for the precautionary approach concept has been available for several years, my informal polling of groups of fisheries scientists and managers indicates that very few people have actually read it. This is unfortunate because most fisheries people use this term widely and sometimes incorrectly, which creates confusion. The brief overview below of this source document should be treated merely as an introduction – I strongly encourage readers to read the full document.

First, the FAO (1995a) document states that we can use fish resources, even in the presence of uncertainties, but only when uncertainties and risks are taken into account explicitly during the scientific analyses and management decisions. Industry’s investments should also consider those uncertainties – the fishing industry takes risks when it makes investments. Managers and those in the fishing industry should apply prudent foresight when evaluating current possible actions in terms of not only short-term effects but also effects on future human generations. As well, the chance of making irreversible changes in the system should obviously be reduced.

A key point in the precautionary approach document is that, if faced with considerable uncertainty and risks, and if it is not clear which action to choose, actions should be chosen to give priority to conserving the biological productivity over the long term rather than satisfying short-term economic or social demands. It is most important to keep the aquatic system productive; only then will economic and social benefits be maintained over the long term. The FAO (1995a) document also discusses considering the effects of fishing on other species. There are also specific implementation guidelines for four different categories of fisheries: new or developing fisheries (which are rare for salmon on the west coast of Canada but occur for other species elsewhere), traditional or artisanal fisheries, fully utilized fisheries, and over-utilized fisheries.

To illustrate the FAO (1995a) implementation guidelines, I give below an example of one of these categories of particular relevance to salmon, over-utilized fisheries. The first step is to develop a recovery plan. Recovery will allow for biological and economic benefits from a more productive fishery. This is already part of the process for the Endangered Species Act in the USA and the Species-At-Risk Act in Canada. Obviously, for over-utilized fisheries, we need to reduce fishing capacity and harvest rates and to give priority to using subsequent large recruitments (abundances of mature adults) to rebuild the spawning stock rather than to reopen the fishery to satisfy pressures from the fishing industry. The document also suggests that we should *not* use artificial propagation as a substitute for these precautionary measures.

The FAO guidelines also suggest removing subsidies for the fishing industry because subsidies change the perception as well as the reality of risks. If the industry assumes that the government will "bail it out" financially if low harvests occur over a long period, then the industry's response to an uncertain abundance of a stock, for instance, is going to be quite different from the response if there were no subsidies. Industry may take a more precautionary approach in the absence of subsidies. Defining reference points to identify recovery goals is another obvious step in the FAO guidelines for the implementation of the precautionary approach for over-utilized fisheries.
It is worth emphasizing that this precautionary approach is applicable to everyone involved in fisheries systems; it does *not* just apply to management agencies. It also applies to harvesters and those involved in altering habitat and carrying out enhancement – however well intentioned their actions might be. For instance, there are many examples of hatcheries not producing the intended beneficial effect; this is also true for habitat restoration activities. Salmon aquaculture should also be considered in the context of the precautionary approach. Stock assessment scientists also need to consider uncertainties and risks explicitly; this does not mean applying a conservative assumption at each step of an analysis, which would result in managers being unclear about the degree of bias, if any, in the scientific advice. Instead, scientists should evaluate each management option for a wide range of hypotheses about parameter values, structural forms of models, and other uncertainties to provide managers with the full range of possible outcomes for each action. Finally, the decision-making step can take a precautionary approach by considering these potential outcomes and uncertainties when ranking actions with clear management objectives.

The precautionary approach is now widely used in fisheries management (Garcia 2000). Several fisheries organizations have applied the approach and adapted it to their own purposes. For instance, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), which used precaution before the term 'precautionary approach' even emerged, has further applied this approach in recent years. The precautionary approach has also been used in other FAO documents. For example, the FAO "Code of Conduct for Responsible Fisheries" (FAO 1995b) applies the precautionary approach to industry, in addition to management agencies, but there is considerable overlap between this and the other FAO (1995a) document. As well, in December 1995, the United Nations "Agreement on Highly Migratory and Straddling Fish Stocks" incorporated many of the recommendations of the earlier FAO (1995a) document on the precautionary approach.

In addition, the FAO (1995a) document has been used as a framework for developing area-specific and species-specific procedures by the International Council for the Exploration of the Sea, the North Atlantic Salmon Conservation Organization, the International Baltic Sea Fishery Commission, the North Atlantic Fisheries Organization, the U.S. National Marine Fisheries Service, and the Canada Department of Fisheries and Oceans. These organizations are at various stages in incorporating concepts of the precautionary approach into their management and assessment procedures.

One question that often arises is how to choose an appropriate level of precaution in a particular situation. We could arbitrarily choose the best action in an *ad hoc* manner, which has often been the case for management targets such as $F_{0.1}$ and F_{med} used in non-salmonid fisheries. In contrast, quantitative risk analyses can help choose the most appropriate action in a consistent, rigorous manner. Such analyses describe a range of alternative hypotheses about how the natural system and the physical system interact. This range of hypotheses includes different structural forms of the underlying models, rather than simply assuming the best-fit model is true. This approach is important because at least parts of the range of alternative models have the potential to create different feedbacks within the system and therefore quite different outcomes from the best-fit model. Risk analysis includes extensive sensitivity analyses to understand how these different assumptions affect the recommended actions (Peterman and Anderson 1999). Despite such analyses, uncertainties will always remain. We therefore want risk analyses and decision analyses to identify actions that are robust (i.e. perform well) across a wide range of assumptions about the uncertain components of an analysis.

Future Extensions to the Precautionary Approach

Although the precautionary approach framework has proven very useful, it is clear that further extensions and adaptations are required. I will discuss only five main extensions here.

Extension 1: Take implementation error into account

In salmon fisheries, implementation error is simply defined as the deviation between the desired (target) and the actual spawner abundances (similarly for harvest rate). The difference between target and actual spawner abundances can be quite large. It is not uncommon to end a fishing season with only half the target abundance of salmon spawners or with more than two or three times the target. Alternatively, in some years, the difference is less than a few percent of the target, which indicates very little implementation error. An important feature of frequency distributions of annual implementation errors over several decades for a given stock is that they are often asymmetric with a long tail at high abundances of salmon (i.e. there are occasional years of large implementation error). Therefore, salmon models should not simply use a random normally distributed variate to represent implementation error. Furthermore, models should reflect whatever structure is in the implementation error. An example for the Kvichak River sockeye salmon stock in Alaska exhibits such structure (Figure 23.2). When the ratio of actual to target abundance of spawners (Y axis of Figure 23.2.) is 1.0, the target is achieved perfectly. Below that value, there are too few spawners; extremely low abundance might create conservation concerns. When the forecasted recruitment of the Kvichak sockeye in different years (data points in Figure 23.2) was larger than the actual recruitment (values > 1.0 on the X axis of Figure 23.2), this usually resulted in too few spawners. This structural form to the implementation error in Figure 23.2 results from an interaction between in-season abundance estimation and management regulations. For instance, by the time the in-season estimates documented that the pre-season forecast was too high, in most years it was too late to achieve the target number of spawners, even if all fishing was shut down. Also, note that in general, underestimated forecasts may be represented more frequently than overestimates, or vice versa, creating a skewed probability distribution of implementation errors.

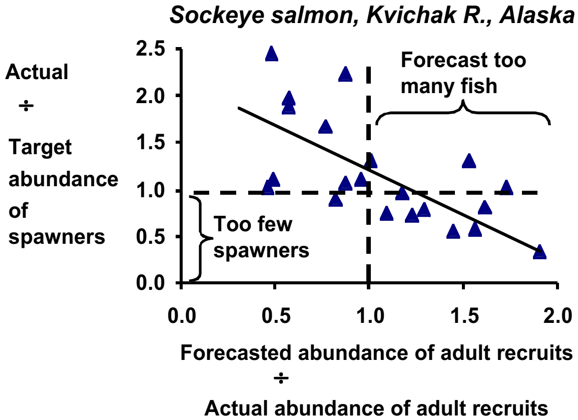

Figure 23.2. Example of implementation error for Kvichak River sockeye salmon, Alaska (each point represents a different year). The X axis is the ratio of the pre-season forecast of abundance of adult recruits of this stock to the actual post-season estimate of abundance of recruits (vertical dashed line represents a perfect forecast). The Y axis is the ratio of actual spawner abundance at the end of the season to the management agency's target abundance of spawners (horizontal dashed line represents a perfect achievement of that target).

Thus, there is asymmetry in the distribution of implementation errors, and they also have a structure, which can be taken into account when including implementation error in stock assessments. However, very few stock assessments for any fisheries, let alone salmon, explicitly consider implementation error. Nevertheless, just like variation in natural mortality or environmental conditions, implementation error is a source of uncertainty that has important management implications.

To better represent implementation error in stock assessment models, the dynamics of human harvesters could be included by considering humans as predators and drawing upon the rich empirical as well theoretical literature about how predators behave. Hilborn (1985) examined the dynamics of salmon harvesters in this context, and many other researchers have done so subsequently. Nevertheless, movement dynamics and in-season, state-dependent changes in harvesting efficiency are still rarely incorporated into stock assessments for salmon.

Extension 2: Reduce implementation error

The second extension to the precautionary approach is to reduce implementation error in the field, not just recognize its existence in stock assessment models. This can be achieved through improving in-season and pre-season estimates of abundance and by communicating the consequences of implementation error more effectively to the fishing industry, so that they understand long-term as well as short-term consequences. Reducing non-compliance of industry with regulations is a difficult challenge; we need to develop the right incentives for harvesters to reduce non-compliance. This might result from certification of fisheries (Peterman 2002), a process by which it will be in the interests of both management agencies and industry to maintain productive stocks over the long term.

Extension 3: Improve communication

The third extension is to develop better communication methods for scientists to discuss risks with both stakeholders and fisheries decision-makers. Although most natural scientists have similar understandings of various concepts related to uncertainties and risks, most managers and stakeholders do not generally have that knowledge because they do not have a quantitative background. Fisheries scientists should therefore learn from the extensive research in cognitive psychology on the topic of how to communicate about uncertainties and risks. One simple example of the need for examining that work in cognitive psychology is that there are six different interpretations of the word "probability" (Tiegen 1994). For instance, it could mean the chance of some event happening, or it could mean the plausibility of somebody's model that calculated that chance, or it could mean a degree of confidence in some statement based on the person's knowledge about the subject. Anderson (1998) discusses applications to resource management of several such findings of cognitive psychologists.

Extension 4: Clear management objectives
The fourth extension to the current precautionary approach is to encourage development of clear, unambiguous management objectives. This includes defining how trade-offs will be made among different components, such as maintaining both rare and endangered stocks and economically viable fishing industries. One technique that has recently emerged in the social science literature, "decision-choice modeling", removes some of the restrictive assumptions of the more commonly used multi-attribute utility analysis. Decision choice modeling is a way of documenting how people quantitatively trade off different indicators when making complex decisions. It has been applied to a few fisheries situations (e.g., Aas et al. 2000). This approach holds considerable promise and should be explored further.

Extension 5: Revise institutional structure
The fifth extension to the precautionary approach deals with institutional structure. In order to make the various elements of a precautionary approach work together successfully, an appropriate set of conditions and enforceable regulations must be present. These are described in detail in Chapters 5 and 6 of a report written for the Royal Society of Canada on marine fisheries (de Young et al. 1999). One recommendation was to improve economic incentives for those in the industry and to clarify property rights and access rights to fisheries in order to reduce the impact of uncertainties on fish stocks in the long term. This included promoting stewardship by helping to align individual interests with long-term goals of sustainability, and providing a positive feedback or incentive among members of the fishing industry to maintain stocks over the long term. Finally, managers and industry should identify some pre-agreed-upon decision guidelines to help reduce the number of delays in taking action caused by consultations that occur in-season in salmon fisheries. These guidelines would identify a range of management actions that would be taken for a given estimated status of a stock. This procedure has been used elsewhere in the world with promising results (e.g. Cochrane et al. 1998); we need to incorporate this method into salmon fisheries management.

Conclusions
Three concluding points will suffice. First, uncertainties are pervasive in salmon systems; they are large and some will always be present despite future research. These uncertainties are important because they create risks – economic, biological, and social risks. Scientific researchers have been reasonably successful over the past four or five decades at improving our understanding about how these aquatic systems work, but uncertainties are still large and the associated risks remain.

Second, there is a significant difference between the precautionary principle (which is generally analogous to complete closures of fisheries or stopping of human activities) and the precautionary approach (which allows some human activities but on a very cautious, limited scale to reduce risks). This difference is not just a trivial issue of semantics. It is important because, for example, people in the fishing industry might assume that managers are talking about completely shutting down a fishery when they hear the term "precautionary approach", when in fact managers mean only restricting its activity to some extent (or *vice versa*). Such miscommunications lead to dysfunctional discussions, but this specific problem can be avoided simply by using the terms as they are used elsewhere in fisheries (e.g., Europe, where the concepts emerged). Also, note that this precautionary approach does not just apply to fisheries management agencies; it applies to everybody involved in manipulating fishery systems, directly or indirectly.

Finally, we need to extend the current precautionary approach, at least as outlined in the FAO (1995a) document, to improve some deficiencies. Specifically, scientists need to take account of implementation error regularly, and managers need to create incentives for the fishing industry to reduce non-compliance with regulations and also implementation error. As well, scientists need to improve communications with stakeholders and decision-makers about uncertainties and risks. Finally, managers must further clarify objectives and the trade-offs among the biological, economic, and social components of complex objectives.

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