The Precautionary Approach and risk management: can they increase the probability of successes in fishery management?[1]

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Abstract: Considerable progress has been made in the implementation of the Precautionary Approach to the protection of fish stocks, but applying the Precautionary Approach to the protection of fishing communities lags considerably. The principle of intergenerational equity, one of the main tenets of the Precautionary Approach, and the principle of sustainable utilization both imply that the Precautionary Approach should explicitly incorporate the protection of fishing communities, not only the resources they depend on. Risk assessment aims primarily at evaluating the consequences of various harvest strategies in terms of probabilistic statements about future trends in yields, biomass, and dangers to the stock, while risk management involves finding and implementing management policies, strategies, and tactics that reduce the risk to the communities exploiting them. Not all fishery management approaches deal equally well with risk, with some compounding rather than reducing risk. Portfolio management, whereby fishing enterprises have the ability to choose among a diverse portfolio of harvestable resources, would mitigate against the risk of fluctuations in the abundance, availability, or price of individual species. Although much remains to be achieved in better assessing risk, fishery management agencies should immediately implement risk management.

Résumé : Des progrès considérables ont été réalisés dans la mise en œuvre de l'Approche de Précaution pour la protection des stocks de poissons, mais son application à la protection des communautés de pêche traîne considérablement. Le principe d'équité entre les génération, un des fondements de l'Approche de Précaution, et le principe d'utilisation soutenue impliquent tous les deux que l'Approche de Précaution doive incorporer de manière explicite la protection des communautés de pêche, pas seulement les ressources dont elles dépendent. Les évaluations de risque visent principalement à estimer les conséquences de diverses stratégies d'exploitation en terme de probabilité de l'évolution future des rendements, de la biomasse, et des dangers pour le stock. La gestion du risque, d'autre part, consiste à trouver et à mettre en œuvre des politiques, stratégies, et tactiques qui réduisent le risque pour les communautés qui exploitent les ressources halieutiques. Les approches de gestion des pêches ne sont pas toutes équivalentes en terme de gestion du risque, certaines l'augmentant même plutôt que le diminuer. La gestion par portefeuille, grâce à laquelle les entreprises de pêche auraient la possibilité de choisir à même un portefeuille diversifié de ressources, atténuerait le risque qu'entraînent les fluctuations d'abondance, de disponibilité et du prix de l'une ou l'autre espèce. Bien qu'il reste beaucoup à faire pour mieux évaluer le risque, les agences de gestion des pêches devraient immédiatement mettre en œuvre la gestion du risque.

Introduction

The 1990s have seen an increased awareness of the difficulties of fishery management. While fishery collapses had happened before, most notably for herring on Georges Bank, in the North Sea, off Iceland, and in the Norwegian Sea in the late 1960s and mid-1970s, they were attributed to the fragility of pelagic schooling species, immaturity of fisheries science, and failure to implement recommended management measures. This could not be said of the widely publicized collapse of the Northern cod fishery off Newfoundland in 1992: Canada had a fully developed scientific process, extensive monitoring control and surveillance, and an elaborate fishery management advisory process, and cod was not considered a species particularly sensitive to exploitation. Yet, those substantial human and financial resources did not prevent the collapse of the cod fishery. Other examples include the near collapse of Northeast Arctic cod in the late 1980s and again in the second half of the 1990s, of North Sea herring for a second time in less than 20 years, and the severe declines of traditional groundfish resources off New England. Clearly, the uncertainties in fishery science and the difficulties of implementing management measures, particularly catch controls, are substantially greater than previously believed.

The recognition of those uncertainties and difficulties, combined with a gloomy assessment of the world fishery's scene (FAO 1994), helped reach agreement on several

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international instruments in the 1990s stipulating that the Precautionary Approach should be applied to management of the environment and of fisheries (the Rio Declaration, the Cancun summit, the United Nations (UN) Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks, the UN Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries, the Treaty of the European Union). Although states have moral, and in some cases legal, obligations to implement the Precautionary Approach, the more compelling reason is because the long-term consequences of the results of human intervention on the environment, be it through removing animals from the oceans or through releasing substances, in the atmosphere or in water, are largely unknown. Indeed, if the results of human intervention on the environment were perfectly known and management measures to prevent negative impacts could be perfectly implemented without delay, there would be little risk of irreversible damage and the Precautionary Approach would not be needed.

The developments on the international scene listed above were politically led at the highest government echelon. Concurrently, fishery science, accepting that uncertainties were considerably larger than previously believed, and building on technical development in integrated and Bayesian assessment methodologies, was developing more formal methods of risk assessment by calculating and evaluating the probabilistic consequences of various combinations of assessment assumptions, data treatment, and management measures. This was recognition that fishery management is a problem in decision-making under uncertainty (Smith et al. 1993; Rosenberg and Restrepo 1994; Punt and Hilborn 1997) with the decisions to be made pursuing multiple objectives; the formal analysis is therefore complex.

In this paper, we will briefly review progress on the implementation of the Precautionary Approach in some countries and organizations with which we are or have been personally involved. We will argue that applying the Precautionary Approach to the protection of the resources may lead to unnecessary fishery closures causing irreversible damage to fishing communities, thereby making it impossible to meet the objective of intergenerational equity inherent in the Precautionary Approach; therefore, the Precautionary Approach should explicitly include the protection of fishing communities. We will submit that this should be done by explicitly implementing risk management through risk assessment to evaluate and implement management measures that will reduce the risk that fishing communities are exposed to. We will evaluate various management approaches and their implications with respect to risk management, and we will discuss the implementation of risk management.

Implementation of the Precautionary Approach

In this section, we will first provide a description of the Precautionary Approach and we will then review how the definition has been operationalized in some countries and organizations with whom we are or have been personally involved.

Several definitions of the Precautionary Approach exist, with some differing very little from the Precautionary Principle (Garcia 1996). We believe that the definition below, prepared by the FAO expert consultation on the Precautionary Approach to Fisheries Management (FAO 1996, p. 6), summarizes the main points of what the Precautionary Approach means:

> The precautionary approach involves the application of prudent foresight. Taking account of the uncertainties in fisheries systems and the need to take action with incomplete knowledge, it requires, *inter alia*: (*a*) consideration of the needs of future generations and avoidance of changes that are not potentially reversible; (*b*) prior identification of undesirable outcomes and of measures that will avoid them or correct them promptly; (*c*) that any necessary corrective measures are initiated without delay [...]; (*d*) that where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource; (*e*) that harvesting and processing capacity should be commensurate with estimated sustainable levels of resource [...]; (*f*) all fishing activities must have prior management authorization and be subject to periodic review; (*g*) an established legal and institutional framework for fisheries management, within which management plans that implement the above points are instituted for each fishery; and (*h*) appropriate placement of burden of proof by adhering to the requirements above.

FAO (1996, p. 7) also suggests that “the standard of proof to be used in decisions regarding authorization of fishing activities should be commensurate with the potential risk to the resource, while also taking into account the expected benefits of the activities.”

The implementation of the Precautionary Approach in the fora that we reviewed shares common features, following the template provided by Annex II of the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks with emphasis on attempting to quantify uncertainties and on defining reference points and preagreed harvest control rules.

Annex II of the UN Agreement calls for two types reference points: “conservation, or limit, reference points and management, or target, reference points” and suggests that “the fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points.” Having had a long history of unsuccessfully trying to agree on targets with management agencies, the International Council for the Exploration of the Sea (ICES), who took an early lead on implementing the Precautionary Approach among the fora that we reviewed, chose to define limit reference points in terms of the maximum fishing mortality and minimum biomass thresholds associated with stock collapses rather than with maximum sustainable yield (MSY). Such limit reference points were considered entirely within the scientific purview and did not need to be discussed with management agencies. Consequently, ICES took it upon itself to set limit reference points.

To have a high probability of avoiding the limit reference points and the associated stock collapses, management action must be taken before the limit reference points are approached. However, deciding on precautionary reference points where management action was required in order to avoid the limits is not only a scientific question related to the uncertainties in the assessment and management implementation, but is also a sociopolitical question related to the degree of risk acceptable to the fishery management agency. Therefore, ICES *suggested* precautionary reference points. These are still to be agreed to by the fishery management agencies, but since 1998, ICES has been using both the limit and the precautionary reference points to frame its advice to the European Commission, the International Baltic Sea Fisheries Commission, the Northeast Atlantic Fisheries Commission, and the North Atlantic Salmon Conservation Organization. Most suggested that these precautionary reference points still need to be formally accepted.

The Northwest Atlantic Fisheries Organization developed a system of reference points closely related to the ICES one with the exception that it adheres strictly to article 7 of Annex II of the UN Agreement and sets the fishing mortality corresponding to the MSY (F_{MSY}) as a limit reference point. The International Commission of the Conservation of Atlantic Tunas has not yet made a decision on targets and limit reference points, but its convention specifies MSY as a management objective.

In these fora, as well as in Canada and the United States, the adoption of reference points (or of overfishing definitions in the United States) is closely linked to preagreement on decisions to be made when the reference points are reached. In other words, agreeing on the reference points implicitly brings with it agreement on harvest control rules. The details vary between the various fora, but the basic framework is similar: taking uncertainty into account, assess the size of the stock and associated fishing mortality, compare with reference points in terms of F (where F is the instantaneous rate of fishing mortality) and biomass, and make decisions on management measures. An interesting modification is being developed in Canada where several indicators other than F and biomass are evaluated for their usefulness in making management decisions (Halliday 2000).

The International Pacific Halibut Commission (IPHC) is one of the rare fishery management organizations whose activities have met with success. The resource has gone through natural cycles, but the productive capacity has been protected and the IPHC has been able to reduce or raise catch as the biological health of the population fluctuated. While IPHC has not *formally* adopted the Precautionary Approach, the management strategy followed by IPHC is chosen (and periodically reevaluated) in a way that is consistent with the Precautionary Approach, that is, by analysing likely consequences of alternative control rules under different scenarios about future trends in productivity consistent with historical experience (Sullivan et al. 1999; Parma 2000). Control rules involving target harvest rates and minimum size limits have been adopted after open discussions among scientists, managers, and stakeholders, which attempt to account for the different sources of uncertainty affecting management decisions. While no definition of overfishing has ever been attempted, and limit reference points are not part of the implemented harvest control rule, target harvest rates below F_{MSY} have been chosen so as to lower the risk of reducing biomass below historical records, even though recruitment overfishing was never experienced at those low biomasses. Conservative targets have been supported by the fishing industry, as fishers are the first interested in avoiding the low biomasses (and catch rates) experienced in the past.

Generally, progress has been led by science with significant developments in quantifying uncertainty, defining reference points, and proposing harvest control rules. Fishery management agencies have not been particularly proactive. Yet, it is precisely because of large uncertainties in fishery science and management implementation that fishery management itself should be more precautionary.

Towards a broader implementation of the Precautionary Approach

The initiatives described above to implement the Precautionary Approach have been mostly driven by fishery science with its traditional emphasis on fish population dynamics and reference points. It is therefore not surprising that the focus has been on protecting the fish resources and the environment that they live in. As a consequence, most advances have been made in the technical aspect of developing harvest control rules based on conservative reference points for fishing mortality and stock biomass and on how to use them to provide fishery management advice in the context of the Precautionary Approach. From a practical perspective, such emphasis in the implementation of the Precautionary Approach has lead to more stringent advice, sometimes with implied severe consequences for the fishing communities. Indeed, the implementation of the Precautionary Approach by ICES in its advice was harshly criticized by the U.K. House of Commons Select Committee on Agriculture for not taking into account the effects on the fishing industry (http://www.publications.parliament.uk/pa/cm199899/cmselect/cmagric/141/14105.htm#a5).

The Precautionary Approach to fisheries management requires much more than the implementation of precautionary harvest control rules. Its scope should be much larger (Richards and Maguire 1998), emphasizing that a precautionary system needs data collection, evaluation of the results of past management, response mechanisms to adjust management action as appropriate, effective enforcement of regulations, and a process that facilitates communication and fosters cooperation among the different sectors involved with and affected by management. Such a precautionary system would be more consistent with the early description of the Precautionary Approach provided by FAO (1996) than most implementations so far.

The international instruments do not explicitly state the scope of the Precautionary Approach, but they generally refer to it in the context of protecting the resources and the environment. The broader context, however, is sustainable development with its cornerstone concept of intergenerational equity. An interesting discussion of intergenerational equity can be found at http://www.unu.edu/unupress/unupbooks/uu25ee/uu25ee0z.htm (p. 5) where the three principles of conservation of options, conservation of quality, and conservation of access are proposed key elements of the concept. “The proposed principles recognize the right of each generation to use Earth’s resources for its own benefit, but constrain the actions of the present generation in doing so. Within these constraints they do not dictate how each generation should manage its resources. They do not require that the present generation predict the preference of future generations, which would be difficult if not impossible." This implies sustainable use, consistent with our view that the goal of fisheries management is not to conserve fish stocks for conservation sake but rather to achieve long-term sustainability of both the fish resource and the fishing communities. Therefore, we believe that the protection of fishing communities is a component of the Precautionary Approach that should be made more explicit. This is consistent with the proposed conservation of options principles where "Conserving the diversity of natural and cultural resource bases is designed to give our descendants a robust and flexible heritage with which to try to achieve a decent and healthy life." (http://www.unu.edu/unupress/unupbooks/uu25ee/uu25ee0z.htm, page 5). Standard 8 of the U.S. Magnuson-Stevens Fishery Conservation and Management Act requiring that, consistent with the conservation requirements of the law, the plans provide for the sustained participation of fishing communities and minimize adverse economic impacts on these communities is consistent with this principle.

Protecting the harvestable resources could be argued to be sufficient to protect the fishing communities de facto. After all, it is necessary to have resources to exploit in order to have fishing communities. But this is a specious argument. The exclusive focus on the resource would naturally lead to choosing management measures that have the highest probability of protecting the resource, even though some other measure, with perhaps marginally smaller probability of resource protection, would have considerably less negative impacts on the communities. Explicit consideration of the fishing communities is consistent with the proposal for fishery management science by Stephenson and Lane (1995) to replace the excessively biological orientation of traditional fishery science and with the proposal by DeYoung et al. (1999, p. 114) that the "management objectives must include not only the central and overriding objective of maintaining ecosystem integrity, but also the secondary objectives of social and economic well-being."

The exclusive focus on the resource makes us forget the real objective of fishery management: to achieve long-term sustainable fisheries that provide jobs, economic opportunity, food, and stable communities. Some countries and jurisdictions may emphasize jobs, others may emphasize economic profit, and others food production, but by and large the purpose of fisheries is to catch fish on a sustained and profitable basis. If this perceived main objective is met, then we have greater confidence that intergenerational equity will also be achieved.

Risk

Risk assessment

Risk assessment involves evaluation of the consequences of alternative management actions under uncertainty and has been applied almost exclusively to decisions regarding total allowable catches. The following example illustrates the dilemma between risk to the fishery and risk to the fish stock. Imagine a fishery where the stock is approaching a historically low biomass following several years of low recruitment and high exploitation rates. Scientific analysis suggests that if fishing is not curtailed, there is a 50% probability that the stock will collapse, and the fishery would therefore cease for lack of fish, perhaps for an extended period. In this hypothetical example, the 50% probability of stock collapse unless fishing mortality is reduced to close to zero is the average of the risks estimated under two hypotheses given equal credibility. Hypothesis A: recruitment is closely related to spawning stock biomass; because spawner abundance has been reduced by fishing, recruits have become progressively less numerous in a vicious circle that will end with severe stock depletion and complete closure of the fishery. Hypothesis B: recruitment is environmentally driven; the experienced poor recruitment is the result of prolonged unfavourable environmental conditions; strong year-classes will only be produced when environmental conditions improve.

As implied by the fishery management objectives stated earlier, fishery management wants to avoid the destruction of the fishery, the loss of jobs, the bankruptcies, and personal distress associated with a major fishery closure. If the fishery is closed in a "precautionary" fashion, there is a 100% probability that the fishery is destroyed in the short term. If continued fishing is allowed, there is a 50% probability under the scenarios above that the fishery will be destroyed in the short term. For most "traditional" fishery management arrangements, the answer would seem clear: take the chance that hypothesis B is correct rather than destroying the fishery for sure by halting fishing. While this may appear to be an adequate response to short-term socioeconomic pressures, it may only result in a more acute crisis later on (National Research Council (NRC) 1998*a*).

In reality, the situation would never be that simple. Longer-term consequences, both biological and to the fishing communities involved, would need to be taken into account. If recruitment did depend on spawning biomass (hypothesis A), the fishery could reopen in the medium to long term, yielding higher catches than heretofore. Under the close fishery option, the fishery would soon reopen for stocks with high growth rates and revenues would increase rapidly. For stocks with low growth rates, however, the recovery time could be so long that the fishing communities would not be able to survive to benefit from the recovery. Under the environmentally driven hypothesis, on the other hand, there still could be longer-term benefits in reducing fishing in order to take better advantage of good recruitment when environmental conditions improve. Another complicating factor is that even if recruitment were indeed mostly controlled by the environment, it would seldom be the case that a biological collapse could be totally ruled out if fishing continued as in the example above. There has to be some low spawning biomass below which recruitment would be seriously compromised no matter what the environmental conditions are. Very little is known about how populations behave at very low abundance, and quantifying the biological risks as the "probability of collapse" is an oversimplification. The severity of the collapse and the probability of recovery from it would also be affected by the management decisions in ways that would be difficult to anticipate. Experience with some of the major fishery collapses shows that it often takes at least a decade for stocks to recover (Georges Bank herring, North Sea herring, Northern cod).

Risk management

At best, risk assessment will tell us the appropriate probabilities and details about the consequences of various management actions, including no action. But in the end, the choice will be a gamble — how will the fishery management agency balance the risk of *assured* social and economic dislocation if the fishery is closed against the *possible* longer-term social economic dislocation of a fishery-induced stock collapse and the biological threat of such a collapse. Risk analysis and risk assessment do not provide better policy choices, they only evaluate them. It is therefore necessary to move from risk assessment to risk management.

Fishing can be regulated by technical measures (gear type, mesh sizes, time and area closures, etc.), by input controls (number, type and size of vessels, number of gear or time units each is allowed to fish, etc.), and by output controls (the various forms of catch controls including individual, vessels, and community quotas whether transferable or not). One or more elements of each approach are normally used and it is not uncommon to have a quota-regulated fishery also including time and area closures, gear type, and mesh size regulations as well as an upper limit on days at sea. All these approaches are compatible with risk management, but their usage in the past has sometimes increased the risk to fishing enterprises rather than decreasing it.

Fishery management is not the only form of human activity that has to make decisions in the face of uncertainty. Farming, the stock market, and the medical field, to give a few examples, have to make decisions in the face of very high uncertainty and possible severe adverse consequences. These fields have already moved beyond risk assessment to include risk management. The simplest form of risk management is risk sharing with common mechanisms including diversification of portfolios in the stock market. Insurance is a second form of risk management in which the risk of loss is shared with the broad pool of insurance purchasers.

Management of risk has been given relatively little consideration in the fisheries literature. Emphasis has been on the need for economic diversification and provision of nonfishery employment alternatives to relieve pressure on the fish resources as primary sources of livelihood (Smith 1981; Charles 1994). Portfolio theory has recently been applied also to support diversification of tools used in fisheries management, such as the use of marine reserves as an insurance against failure of conventional methods based on effort or catch controls (Lauck 1996; Lauck et al. 1998). Our focus here is rather on the need to diversify fishing opportunities available to the industry. This relates to enhancing the mobility of fishing capital and labour, which in turn should ameliorate “the exit problem” (John 1994) when fishers are locked into a fishery for lack of alternative species to exploit (possibly because of limited-entry programs). Risk management can take several forms, such as insurance to individual fishers, directly or through private companies, as is already done for crop insurance for farmers. Such insurance schemes would take into account the expected variability in abundance, price, and whatever other variables fishers wished to be insured against. Interestingly, risk management appears to have been better studied with respect to aquaculture (Bacon et al. 1993; Paquotte and Antona 1993; Secretan and Nash 1989) than to capture fisheries.

Diversification, herein referred to as portfolio management, appears to be a particularly effective means of managing risk in fisheries. Artisanal fishers often fish a wide range of species and stocks, so that when abundance or price is bad for one species the effort can be shifted to another one. This is becoming increasingly difficult, however, because governments’ limited-entry programs and capacity adjustments through fishing licenses withdrawal force fishers to become specialized in one or in a small number of fisheries, thereby preventing them from using a traditional means of risk management through diversification. This, however, is not so much a problem with limiting entry per se, which is essential if harvesting is to be controlled, but in the way entry has been limited. For many fisheries, limited-entry systems have simply restricted participation to historical fishers once overcapacity had already been reached and limited vessels to operate only in a fishery for which they have a license. It is usually economically impossible to afford licenses for multiple fisheries. A more sophisticated and workable limited-entry system that would maintain greater flexibility includes entry and exit rules so that it is possible to control the number of participants without eliminating the possibility of moving from one fishery to another. Individual transferable quota systems have entry and exit rules set by the marketplace and need not provide any barriers to movement of vessels between fisheries. Individuals have the option under most systems of using their fishing skills in one fishery while owning quota in other fisheries and leasing it out. Most fishers do not do this, but they do have the option to do so. Fishery cooperatives, such as those recently set up in Alaska under the American Fisheries Act, control entry and exit decisions for individual participants through the cooperative structure.

Portfolio management seems a logical choice given that the overall productivity of fishery systems is more stable than individual species are. Consider, for example, that the economic value of fishery products landed in eastern Canada, split into three major groups, groundfish, pelagics, and shellfish (http://www.ncr.dfo.ca/communic/statistics/stat_e.htm), has been stable or increased since 1989. The nearly complete closure of the groundfish fishery, which has led to a billion dollar (Canadian) per year compensation package to the fishers and fish plant workers, did not cause a decrease in the total value of fisheries landings in eastern Canada since 1992, on the contrary. The boom in catch and economic value of snow crab, shrimp, and lobster has more than made up for the loss of groundfish. In New England, the value of fisheries has remained relatively high, although not as high as it would be if the overfished stocks were fully rebuilt (Edwards and Murawski 1993), partly by switching to a much larger range of target species and diversification into other fisheries and partly because of large increases in prices over the last two decades. Other examples are numerous. While the crab fisheries of Alaska collapsed, the salmon and groundfish fisheries blossomed. While chinook and coho salmon in British Columbia collapsed, sockeye, pink, and chum salmon did well.

Thus, even though as a whole, the “fisheries” of eastern

Canada and New England have been stable, the communities have seen enormous social and economic changes. In Canada, while the fishers catching snow crab and shrimp have enjoyed great success, their neighbours who used to fish groundfish have had to diversify into nontraditional groundfish species such as rays and monkfish and downsize their operations considerably or leave the industry altogether. Arguably, the problems faced by Canadian east coast groundfish fishers would have been less severe if they had had the possibility of diversifying in the lucrative shrimp and snow crab fisheries, which they were prevented from doing in the early years of the closure. Lately, the Canadian Department of Fisheries and Oceans has attempted a better sharing of the wealth through issuance of new licenses for shrimp or snow crab fishing or through other mechanisms for revenue sharing. Application of the Precautionary Approach through appropriate controls in place early in the development of the groundfish fishery, and with industry and political support, could have probably avoided large declines and collapses. With adequate risk management, their effects would have been minimized when they did occur. Individual fishers already practice risk management in one way or another to the extent that it is possible in the fishery management processes that they are involved in. They have to hedge against natural changes in resource abundance and decreases in price, but also against government-driven risks. The purse seine fisheries for herring roe on the west coast of North America present a very high risk. The fisheries are very short, sometimes lasting no more than 15 min, and it is common for the competing fishing vessels to either do very well and capture a large number of fish — individual vessels have caught \$1 million worth of fish in a single set of the net — or more commonly catch nothing. Not too surprisingly, many west coast herring fishers choose to manage the risk by joining various forms of catch collectives: individuals with a high risk aversion might pool their catch among many vessels, while risk-prone individuals might do no pooling.

Another mechanism for risk management is community-based management in which a community has user privileges, either by tradition or by legal right, on some fish resources or fishing grounds, and thus the entire community shares risk. Some traditional fisheries management systems engage in this (Berkes 1989; Johannes 1998). The advent of community development quotas (CDQs) in Alaska (NRC 1999), now being considered elsewhere in the United States, provides a possible mechanism. With CDQs, communities are given the right to harvest a fixed amount of fish and the community can either allocate the catch among its residents or lease the fishing rights. CDQs are currently in place for Pacific halibut, sablefish, and pollock in Alaskan communities. If communities owned a mixed portfolio of fishing rights, then the community, as a whole, would be buffered against fluctuations in harvest or price in any individual species or group of species.

The original New Zealand individual transferable quota (ITQ) system in which individual fishers owned the right to harvest a fixed amount of a given species was an attempt at risk management by the government. If the fishery management agency determined that the total allowable commercial catch needed to be lowered, the government would buy back quota at market rates. If there was the potential to increase total commercial catch, the government auctioned off the additional quota. This system buffered the commercial fishers from fluctuations in abundance in that only those people willing to sell their quota would have to catch less fish in the future, but it did not provide protection from fluctuations in price or costs of fishing. Because the original experiment was terminated prematurely, the behaviour of the market in the case of a major fishery decline requiring a nearly total halt to fishing remains unknown.

In principle, in the original New Zealand ITQ fishery, the government managed the risk and protected the fishers from fluctuations in allowable harvest. In practice, the New Zealand government did auction additional quota when it raised allowable catches on hoki and orange roughy, but when quota reductions were deemed necessary, the government was unwilling to purchase quota back and instead changed the laws so that the fishers owned a percent share of the total allowable commercial catch rather than an absolute amount. This was effectively transferring the risk from the government to the fishers. This change in the law was the subject of litigation, and fishers were eventually compensated for a period of time for any quota reductions.

Thus, the original New Zealand ITQ experiment may be viewed as a failed attempt at governmental risk management. No analysis of the revenues from the New Zealand government ITQ system is publicly available, but could it be possible that the income from quota sales balanced the expected costs from quota reductions and the government simply took the opportunity to take a quick profit, like many investors would?

However, the New Zealand ITQ system, like the ITQ systems in many other places, does provide several avenues for individual-based risk management. First, an ITQ holder is assured of his or her share of the total allowable catch and thus is shielded from many risks in an “Olympic” system where each fisher has to “race” to catch his share before the total allowable catch is exhausted. Equipment breakdown and illness pose particular risks in “Olympic” systems because they prevent individual fishers from partaking in the “race”, while the ITQ owner has the right to harvest the fish no matter how long it takes. ITQ systems also provide an opportunity for risk management by permitting individuals to split their ownership across different species. Thus, a fisher who owns quota in one species can in principle reduce risk by buying or leasing quotas in other species and perhaps reducing ownership in his own species. Many New Zealand firms now hold very diverse portfolios of quota, buffering them from fluctuations in total allowable commercial catch of individual species. We do not know if this is a common practice among individual fishers and quota holders in New Zealand.

The overshooting of trip limits or allocation normally results in the offender being fined, sometimes substantially. ITQ systems also protect against the risk of being fined for having overfished one’s quota by allowing one to buy quota on the market.

Some form of risk management therefore appears to be compatible with most management systems currently in place. We believe that individual fishers, and therefore the communities that they live in, would be better protected if current fishery management arrangements concentrated their effort explicitly on devising ways to implement efficient risk management.

Implementation of risk management

The current situation in fishery management agencies is the result of decades of evolution. The extension of fishery jurisdiction in 1976–1978 saw a rapid expansion of the fishery management mandate of responsible agencies in both Canada (Department of the Environment 1976) and the United Stated. A standalone department was created in Canada in 1977 with considerable new resources to tackle the daunting but potentially very rewarding challenge of managing Canada's fisheries (Parsons 1993). Before extension of jurisdiction, active management was essentially limited to a few offshore fisheries under the purview of the International Commission for Northwest Atlantic Fisheries, but after extension of jurisdiction, scientists and resource allocation officers were identified for *all* resources, including small inshore stocks.

The main impediment to implementing the Precautionary Approach and risk management is the inertia in the fishery management process itself and the fact that most fisheries are either overcapitalized or overharvested. Excess capacity to harvest the available resource undermines diversification of fishing effort to manage risk, particularly because of the absence of entry and exit mechanisms mentioned above. For overfished stocks where severe declines are likely to occur or already have, the risk could be already out of control and it might be difficult to effectively manage it. On the other hand, crisis situations sometimes make it easier to implement drastic solutions.

A related point, illustrated perhaps by the original New Zealand ITQ program described above, is that governments are probably not the best party to implement risk management. They should, however, design and implement management systems that allow it to happen and encourage its implementation. Individual businesses, communities, or sectors should manage risk with systems tailored to their own needs.

Limited-entry systems have usually been introduced into fisheries on a catch history basis, often a recent catch history. Thus, only individuals who have been actively involved in a particular fishery in the recent past have been given limited-entry licenses. Managers have often forced mixed-gear boats to choose a single gear; for example, in the Btitish Columbia salmon fishery, mixed troll/gillnet boats have been systematically eliminated from the fishery by licensing. In other cases, such as on the Atlantic coast, unused licenses were retired in the early 1990s when the groundfish collapse was well under way in order to reduce latent fishing capacity. In a sense, this measure was penalizing those that had *not* contributed to groundfish (over)exploitation.

Economic pressures, linked to the fishery management measures in place, also forced specialization: as fishing efficiency increased and fishing seasons have become shorter, individuals needed to increase their specialized capital in order to maintain their share of the catch. Mixed-gear boats simply could not effectively compete with the newer specialized boats.

Government institutions also promote specialization: research and management are often divided along the lines of types of fisheries, i.e., groundfish, pelagics, invertebrates. This promotes the mindset of specialization (i.e., managers thinking of "their" fishers), and in fisheries where understanding the government system is important to success, individuals have increasing difficulty in balancing a portfolio across different types of fishing. By the early 1980s, the Department of Fisheries and Oceans could count on a large workforce of fishery managers (resource allocation officers), fishery officers (monitoring, control, and surveillance), and fishery scientists, dominated by biologists but including economists as well. The responsibilities were largely structured by species, which meant that in each administrative region (there were four on the Canadian Atlantic coast), there was one or more lobster scientists, scallop scientists, shrimp scientists, cod scientists, herring scientists, etc., and resource allocation officers by species groups (groundfish, pelagics, invertebrates). This meant that the small-scale inshore fisher who had implemented portfolio management and had fishing licenses for groundfish, herring, mackerel, lobster, and perhaps scallop or snow crab had to deal with at least two resource allocation officers and probably more than four scientists. By the mid-1990s, after the groundfish stocks collapsed, strict application of limited-entry licensing led to the situation described above where in many villages, groundfish fishers had incomes from government that put them barely above the poverty line, while lucky fishers who held on to their now very lucrative fishing licenses for invertebrates earned up to a million dollars a year before the recent decrease in the price of snow crab.

The trend towards area licensing reduces the options for risk management, as it can result in fishers being locked into a location when conditions there deteriorate (John 1994). It is the geographical equivalent of limited entry on a species basis. In Alaskan and now Canadian fisheries for Pacific salmon, individual licenses are limited to specific areas. In former times, individuals could manage their risk by moving from area to area; now they generally must choose a single or small number of areas to fish, which in turn forces higher risk upon them. Area licensing has recently been introduced into the British Columbia groundfish fishery.

Other trends in fisheries management force specialization and thus increase the risk rather than improve on the ability to mitigate against risk. Obviously, catch fluctuations for individuals would be lowest if all fishers had a stake in a wide range of fisheries. However, many aspects of fisheries management are facilitated by smaller groups of stakeholders and therefore act counter to this. It is our experience that when dealing with smaller number of stakeholders, there is more long-term perspective, individuals recognize the self-interest in obeying regulations, and it is easier to discuss and implement new and different management approaches. The smaller and more uniform the stakeholders, the fewer internal conflicts there are between individuals, and the more likely the stakeholders are to cooperate. Unfortunately, the smaller the stakeholder group, the higher the risk each individual stakeholder must take because they must be more specialized in species and area.

Risk can be decreased by using conservative harvest guidelines, but it can and should also be managed. One way of reducing risk is by reducing fishing pressure in order to have larger average stock sizes, which would serve as a buffer for natural fluctuations. This may not prevent naturally induced "collapse" but it would better utilize the resource base and would provide a more stable planning environment for the fishing and marketing interests. In times of hardship, whether a result of overfishing or naturally induced, maintaining a diversified portfolio of options open to the fishing industry should alleviate social and economic tensions and facilitate implementation of needed fishing restrictions.

Discussion

Most progress in the implementation of the Precautionary Approach has been in the adoption of conservative harvest guidelines that would prevent overfishing and stock collapses. However, society's interest is also with the fishers, the fish plant workers, and the communities who depend on them. We submit that fishery management on the Canadian east coast should be considered to have failed not only because fish stocks have collapsed, but also because it failed to provide sustained and dignified employment to fishers and fish plant workers and because it created social inequities and social unrest in fishing communities. Indeed, the biological productivity of the east coast resources could have provided for sustainable fishing communities if the management system had been properly structured. We propose that portfolio management, where individual fishers are allowed to fish several species rather than being restricted to only one or a few species group such as groundfish, would have diverted fishing effort to other species and might perhaps have prevented total closures. Even if portfolio management had not had such desirable biological side effect, it would have certainly led to more equitable income distribution and less social unrest.

If the implementation of the Precautionary Approach continues to be a techno/scientific/bureaucratic-driven process, and the well being of fishing communities is not taken into account explicitly, the process will fail. Therefore, implementing the Precautionary Approach must imply the application of risk management to reduce the risk of collapse of fishing communities.

What should fisheries managers do? Should the trend towards small stakeholder groups, area licensing, etc., be reversed and should we go back to encouraging generalization rather than specialization? We doubt that there is any widely applicable solution. We have discussed a mixed bag of tools that can be used for risk management, but certainly the time is right for the development of novel approaches, given the serious downsides of the prevailing trend towards specialization. We suggest that management agencies put the topic on their political agenda — we have seen little evidence of consideration of risk management in major fisheries, with manager and politician interests focused primarily on avoiding risk rather than managing it.

Risk may be assessed and decreased, but not avoided. The lessons of the major fish collapses of the last 30 years (Walters and Maguire 1996) and the growing recognition of limitations of conventional assessment methods and management tools (NRC 1998*b*) and of the great uncertainty surrounding management decisions suggest that risk is unavoidable — at best, we can understand the odds of the gambles that we are taking, but fisheries management is a gamble and on occasion, we are going to have stocks in trouble. If we are to succeed at management — if we are to maintain stable fishing communities — we have to begin to manage risk.

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