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The Evolution of Precautionary Approaches to Fisheries Management, with Focus on the United States

by

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What is the Precautionary Approach?

The precautionary approach is derived from the Precautionary Principle, formulated in the 1980s primarily in response to the need to control pollution at the source even in the absence of scientific evidence proving a causal link between emissions and environmental effects. The Precautionary Principle essentially guards against the possibility of making irreversible mistakes through ignorance. In several instances, the Precautionary Principle has been applied in an extreme form, resulting in a complete prohibition of a particular type of industry or technology (e.g., large-scale high seas driftnet fishing was banned by United Nations Resolution 46/215 in 1991). Such interpretations have created a reluctance to embrace the Precautionary Principle in fisheries management where most mistakes have a high probability of being reversible. In contrast, the precautionary *approach* is perceived to be somewhat more flexible, incorporating socio-economic considerations along with requirements to promote the long-term sustainability of natural resources.

However, it is difficult to define the precautionary approach succinctly. As stated by FAO (1995), precaution is required at all levels of fisheries systems: development planning, management, research, technology development and transfer, legal and institutional frameworks, fish capture and processing, fisheries enhancement, and aquaculture. The precautionary approach is a multi-faceted philosophical framework for the management of natural resources. To understand it more fully, it is useful to trace briefly its historical development in fisheries.

Historical Development: The International Context

The concept of precautionary approaches to fisheries development and management is linked to and in some respects synonymous with the concept of responsible fishing practices. Both issues have received increasing national and international attention since the early 1990s.

The need to develop international agreements embodying the precautionary approach gained prominence and urgency as a result of the Rio Declaration and Agenda 21. Principle 15 of the Rio Declaration, formulated at the 1992 United Nations Conference on Environment and Development, states that "in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Between 1991 and 1996, several binding and non-binding agreements embodying the precautionary approach were developed and concluded. The most comprehensive of these is the FAO International Code of Conduct, initiated in 1991 when the nineteenth session of the United Nations Food and Agriculture Organization (FAO) Committee on Fisheries (COFI) highlighted concerns about the necessity for responsible approaches to fisheries management and fishing operations. In 1992 the Government of Mexico, in consultation with FAO, organized the International Conference on Responsible Fishing, which requested FAO to consult with other organizations and draft an International Code of Conduct for Responsible Fisheries. The Code was developed during 1994 and 1995 with the assistance of several working groups and technical consultations convened by FAO, and was adopted by the FAO Conference in late 1995.

The Code of Conduct is a voluntary, non-binding agreement. However, it contains sections that are similar to those in two recently concluded binding agreements: the Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (the Compliance Agreement) and the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (the Straddling Stocks Agreement).

The Compliance Agreement

The Compliance Agreement specifies the obligations of Parties whose fishing vessels fish on the high seas, including the obligation to ensure that such vessels do not undermine international fishery conservation and management measures. Parties must also prohibit their vessels from fishing on the high seas without specific authorization and must enforce the requirements of the Agreement against their vessels. The Compliance Agreement is considered to be an integral part of the Code of Conduct and the precautionary approach. The U.S. implemented the Compliance Agreement through the High Seas Fishing Vessel Compliance Act of 1995.

The Straddling Stocks Agreement

The Straddling Stocks Agreement was negotiated over the period April 1993 through August 1995, much the same as the period of negotiation for the Code of Conduct. Therefore the content and wording on many issues, including those related to the precautionary approach and General Principles, is similar between the two Agreements. Although the Straddling Stocks Agreement is strictly only applicable to straddling fish stocks and highly migratory fish stocks, much of it is also relevant to fishing within national exclusive economic zones (EEZs).

The Straddling Stocks Agreement describes the Precautionary Approach in Article 6 and Annex II. Article 6 requires application of the guidelines set out in Annex II; determination of stock-specific reference points and action to be taken if they are exceeded; use of the best available scientific information; implementation of improved techniques for dealing with risk and uncertainty; account of uncertainties and impacts on non-target and associated or dependent species; and development of appropriate data collection, research, and monitoring programs.

Annex II provides guidelines for the application of precautionary reference points. Paragraph 2 states, "Two types of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points." Paragraph 5 stipulates, "Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low," and imposes the further constraint that target reference points should not be exceeded on average. Paragraph 7 prescribes an important role for maximum sustainable yield (MSY) in the precautionary approach, stating, "The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points."

This combination of requirements implies that fishing mortality should always be well below the level associated with maximum sustainable yield (F_{MSY}). Such a requirement is a profound and significant departure from typical fisheries management practice, where F_{MSY} is usually treated as a target (often exceeded) rather than a limit.

FAO International Code of Conduct

The 1995 FAO International Code of Conduct addresses six key themes: fisheries management, fishing operations, aquaculture development, integration of fisheries into coastal area management, post-harvest practices and trade, and fisheries research. In total, there are 19 general principles and 210 standards in the Code. While a precautionary approach is integral to all themes, it is applied particularly to fisheries management, as detailed in Article 7.5. Paragraph 7.5.1 includes a broad statement to the effect that:

> "States should apply the precautionary approach widely to conservation, management, and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment."

The same paragraph also emphasizes that the absence of adequate scientific information is not a reason for failing to take appropriate conservation and management measures. The remaining paragraphs include similar provisions to those in Article 6 of the Straddling Stocks Agreement; for example, determination of stock-specific target and limit reference points, together with action to be taken if they are exceeded, and the need to take account of uncertainties and impacts on non-target and associated or dependent species. In addition, guidelines are given for adopting a cautious approach in the case of new or exploratory fisheries, and for implementing emergency management measures when resources are seriously threatened due to environmental factors or fishing activity.

During the process of developing the Code of Conduct, FAO and the Government of Sweden held a Technical Consultation and produced guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions (FAO 1995). The guidelines include sections on fisheries management, fisheries research, fishing technology and species introductions. They provide the most comprehensive documentation to date of the many facets of the precautionary approach in fisheries. Key features of the guidelines and examples of precautionary measures are summarized in Tables 1 and 2 respectively (from Mace (1996), based on FAO (1995)).

Applications of the Precautionary Approach Outside the U.S.

The term "precautionary approach" has quickly become an integral part of the vocabulary of fisheries professionals. However, its precise interpretation and operational procedures for its implementation have not yet been formally developed by most governmental and international organizations. The precautionary approach has so many facets that it is possible for fisheries management agencies, both in the U.S. and elsewhere, to claim that they have already adopted the approach, particularly in the case of stocks that have not yet collapsed or are in the process of rebuilding. In this section, rather than providing a comprehensive global overview of attempts at implementing a precautionary approach, attention is focused on a small number of organizations or nations that have already adopted one or more aspects of the approach and as a result have developed successful management systems, or that have recently conducted studies aimed at interpreting or evaluating the approach as it applies to their particular fisheries.

Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR)

CCAMLR, which entered into force in 1982 and currently has 23 members and six acceding states, has one of the longest histories of defining and implementing precautionary approaches, although they may not have been explicitly labeled as such. Most importantly, CCAMLR was the first international organization to specify and implement an ecosystem approach to fisheries management, acknowledging the needs of predators (e.g., whales, seals and birds) and the role of certain prey species (e.g., Antarctic krill) as a critical forage base. According to the Convention, harvesting and associated activities must be conducted so as to (1) prevent any harvested populations from falling below the level that ensures the greatest net annual increment, (2) maintain the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources, (3) restore depleted populations, and (4) prevent or minimize the risk of changes in the marine ecosystem that are not potentially reversible over two to three decades.

From the beginning, CCAMLR took a strong precautionary approach by prohibiting all directed fisheries on several severely depleted stocks of demersal finfish and setting restrictive catch limits for most other exploited stocks. There are currently detailed rules in place for new and exploratory fisheries. For example, at the most recent meeting of the Commission, it was agreed that exploratory fishing on Antarctic toothfish must cease if catches reach levels sufficient to demonstrate commercial potential, at which time a detailed evaluation would need to be conducted before further fishing could be authorized. However, there are also obstacles to full implementation of a precautionary approach in the CCAMLR arena. For example, there are no guidelines to ensure that resumption of harvests in fisheries previously closed for the purpose of rebuilding depleted stocks does not again result in overfishing. There is also no mechanism to prevent fishing on stocks for which TACs have not been set. In addition, the Commission is a consensus body, with any one member having veto power. This often makes it difficult to get strong conservation actions accepted and the Commission is sometimes forced to adopt overly generous management measures rather than have no limits at all.

International Pacific Halibut Commission (IPHC)

Of all international fisheries commissions, the IPHC can be said to have had the longest run of successful management (at least from a conservation perspective, though until recently both the U.S. and Canadian fisheries have been characterized by too many vessels and too few fishing days). The stock has never collapsed and is still providing higher than average yields. Several elements of the precautionary approach (Table 1) are evident in the strategies adopted by the Commission. Maintaining a large spawning biomass has taken precedence over maximizing productivity (McCaughran 1996). Remarkably, the IPHC has set conservative quotas in the face of uncertainty, has not let short-term economic concerns influence decisions, and has not been subject to political interference (McCaughran 1996).

International Commission for the Exploration of the Sea (ICES)

ICES is in the process of developing and implementing the precautionary approach as part of its standard fisheries management advice. A comprehensive report has been developed by a study group (ICES 1997) and the Advisory Committee on Fisheries Management is currently developing a protocol for incorporating precautionary reference points into its assessments of stock status and provision of management advice.

Whereas Annex II of the Straddling Stocks Agreement suggests use of F_{MSY} as the limit reference point, the ICES study group advises setting the limit reference point (F_{lim}) equal to a conservative estimate of F_{crash}, the fishing mortality corresponding to the tangent through the origin of a stock-recruitment relationship (referred to as $F_{extinction}$ or F_{τ} by Mace and Sissenwine (1993) and Mace (1994)), or a related quantity. While this may seem a rather risky reference point, the study group then goes on to suggest that the precautionary fishing mortality should be expressed as $F_{PA}=F_{lim}e^{-2\sigma}$, where σ should take into account several sources of variation and error. If σ is as high as 0.35, F_{PA} will be about half of F_{lim}. For some stocks, this may result in F_{PA} levels quite close to the point estimate of F_{MSY} (e.g., Mace (1994) showed that point estimates of F_{MSY} could be up to 43% of point estimates of F_{τ} for certain life history parameter combinations in deterministic, age-structured fishery models).

The ICES study group also defines B_{lim} as a biomass limit below which the stock is in imminent danger. As with precautionary fishing mortality rates, a precautionary biomass level should be defined based on B_{lim} as modified by some margin of safety. Further details of ICES' proposals are provided by Cornus (paper presented at this meeting).

North Sea Fisheries

The extent to which management of North Sea herring, sandeel and roundfish conform to a precautionary approach was recently evaluated at a seminar held in Norway (Norwegian Ministry of Fisheries 1997). The overall conclusion was that none of these fisheries could be regarded as being managed in accordance with the precautionary approach. The key problems were identified as lack of long-term management objectives, lack of effective regulations and recovery plans, lack of target and limit reference points and triggers for the application of pre-agreed measures, overcapacity of fishing fleets, lack of access controls, poor data, and poor communication between stakeholders. Such problems are common to many fisheries throughout the world.

Canada

Canada has a long history of comprehensive fisheries management, including quota management and limited-entry licensing. Overall, however, Canada's management systems have not been effective at controlling fishing capacity or fishing mortality. For these and related reasons, many stocks are currently at low levels, particularly in Atlantic Canada. However, in the last few years (since collapse of the northern cod stock), Canadian managers have adopted a clearly precautionary approach to enhance prospects for stock recovery: complete fishery closures. With the exception of a small number of individual fisheries, few other national governments have had sufficient foresight and fortitude to completely close entire fisheries in order to accelerate rebuilding.

The collapse of several Canadian fisheries has also prompted the development of a special Canadian code of conduct for responsible fishing operations, led by industry and supported by government.

New Zealand

Numerous reports have identified fleet overcapacity as the most serious issue to resolve in order to rebuild depleted stocks and ensure sustainability of fisheries resources (House of Lords 1996; Mace 1996; Norwegian Ministry of Fisheries 1997). New Zealand has arguably been the most successful country at confronting and heading off potential overcapacity problems before they became severe. This was accomplished by adopting a comprehensive individual transferable quota management system covering most of the major fisheries in 1986. Subsequently, the management system has been altered in a number of ways, including a major devolution of control away from the government to the fishing sector. Along with the transfer of management decisions to the industry, the government has substantially curtailed public funding for fisheries research relevant to stock assessments, and it remains to be seen whether the scientific basis for quota setting will be adequate to prevent overfishing in the future.

Australia

In 1992, Australia formed the Australian Fisheries Management Authority (AFMA), which, although still in a process of evolution, is based on a number of innovative principles that have facilitated adoption of precautionary approaches in several fisheries. These principles include the active and participatory involvement of all stakeholders, the requirement for and integration of good science into the whole process, and a decision-making process one step removed from the political process. This last innovation is particularly important. While the Australian federal government determines overall fisheries policy, the fisheries minister cannot override or veto decisions made by AFMA except under exceptional circumstances, such as the existence of evidence that AFMA has not been sufficiently conservative. As a result, lobbying of politicians by the fishing industry has virtually ceased.

Overview of U.S. Marine Fishery Management Prior to 1996

Federal Legislation and Agency Guidelines

Since 1977, the cornerstone of U.S. marine fishery management has been the Magnuson Fishery Conservation and Management Act (Magnuson Act). Among other things, the Magnuson Act called for the development of fishery management plans (FMPs), documents which govern the management of individual fisheries around the country. The Magnuson Act also required the U.S. National Marine Fisheries Service (NMFS) to issue guidelines designed to assist in the development of these FMPs. Such guidelines were first published in February, 1983. However, a major shortcoming of these initial guidelines soon became apparent: Although a central purpose of the Magnuson Act was to prevent overfishing, the Magnuson Act did not provide a definition of overfishing, nor did most FMPs. As a result, Regional Fishery Management Councils (Councils) often made decisions based primarily on short-term economic and political considerations, with less emphasis placed on the long-term viability of the fishery resource or the fishing industry. In order to assure that the Councils gave appropriate weight to long-term viability, the guidelines were revised in July, 1989. The revision required each FMP to specify an objective and measurable definition of overfishing for each managed stock or stock complex, with an analysis of how the definition was determined and how it related to biological potential. When the 1989 revised guidelines were published, it was assumed that their short-term effect would be restriction of harvests in those fisheries where stocks were overfished, but that their long-term effect would be to prevent the reproductive capacity of any stock from being jeopardized, to rebuild depleted stocks, and to make economically viable harvests available on a continuing basis in the future.

Review of Overfishing Definitions

In 1993, NMFS convened a panel of scientists to review the definitions of overfishing incorporated into FMPs as a result of the NMFS guidelines (Rosenberg et al. 1994). Major issues discussed by the panel included whether overfishing should be defined in terms of a maximum fishing mortality rate, or minimum stock abundance, or both; how to distinguish between management targets and overfishing thresholds; the role of life history characteristics in defining overfishing; the role of uncertainty in developing and using the definitions; and the linkage between the definitions of overfishing and management actions. The panel provided detailed evaluations of 117 definitions that were in use at the time of review.

The most important recommendations of the panel were that overfishing definitions should be measurable, operationally unambiguous, based in sound theory, and biologically sensible; overfishing definitions should specify thresholds that are distinct from management targets, the latter being based on lower fishing mortality rates or higher biomass levels; overfishing definitions should, at the least, prevent recruitment overfishing; and overfishing definitions should be explicitly linked to pre-agreed management actions and rebuilding plans. The panel considered that an ideal definition of overfishing would be applied as a threshold rather than a target, at least neutrally conservative in protecting against recruitment overfishing, measurable, linked to management actions, unambiguous, and biologically sensible, with no obvious improvements evident. Few of the stocks reviewed met all of these criteria, but most were biologically sensible and at least neutrally conservative.

The Rosenberg et al. (1994) review resulted in changes to several definitions of overfishing in U.S. FMPs. For example, the definitions for mid-Atlantic surf clams and ocean quahogs and long-finned and short-finned squid were all revised to incorporate a more sound scientific basis. The definitions for North Pacific groundfish were revised as well, as discussed in detail below following the next subsection.

Effectiveness to Date

The current NMFS guidelines on overfishing have been instrumental in compelling Councils and NMFS to take serious action to address the issue of overfishing and to begin to rebuild depleted fish stocks. As a direct result of the guidelines, most FMPs now specify operational biological reference points associated with overfishing and, in those cases where overfishing has been demonstrated on the basis of such definitions, rebuilding plans designed to restore stocks over a specified time horizon. The requirement for operational definitions of overfishing and associated remedial action in the event of overfishing also provided a legal basis for non-governmental organizations and others to challenge insufficiently conservative management measures. Until recently, overexploitation was particularly severe for several stocks in the New England, South Atlantic, Gulf of Mexico, and U.S. Caribbean areas. Now, eight years after publication of the current agency guidelines, some stocks have almost fully recovered according to their respective overfishing definitions (e.g. king and Spanish mackerel), while others are subject to fishing mortalities which are only a fraction of previous levels and are expected to exhibit strong evidence of rebuilding in the near future.

A Current U.S. Example of the Precautionary Approach in Action

Revised Harvest Policy for Groundfish in the North Pacific

Management of groundfish in the U.S. EEZ portion of the North Pacific (the eastern Bering Sea, Aleutian Islands region, and Gulf of Alaska) has been characterized by a deliberately conservative approach since passage of the original Magnuson Act. During the first several years of management under the Magnuson Act, the mechanisms for maintaining this conservative approach were largely informal. For example, the groundfish FMPs lacked an objective and measurable definition of overfishing. Further, target catch levels were typically based on acceptable biological catch (ABC), which was defined only loosely in the groundfish FMPs. The North Pacific Fishery Management Council (NPFMC) addressed the first of these two problems in 1990 when it adopted an objective and measurable definition of the overfishing level (OFL) for the North Pacific groundfish fisheries. The OFL definition provided an absolute upper limit on the amount of fish that could be harvested in any given year. However, the relationship between this upper limit and ABC remained somewhat nebulous.

As a result of the suggestions made by the Overfishing Definitions Review Panel and its own Scientific and Statistical Committee, the NPFMC revised its definitions of overfishing and ABC for the North Pacific groundfish fisheries in June 1996 (NMFS 1996). The revised definitions provide a clear exposition of the precautionary approach as it relates to fishery management. The new definitions encompass a set of tiers corresponding to the types of data or parameter estimates that might be available for the various stocks covered by the FMPs. The most fully developed tiers are those nearest the top of the hierarchy, that is, those applicable to stocks for which assessment information is the most complete, though not necessarily the most precise. The remainder of this section focuses on how the new definitions of ABC and OFL on the top tier in the hierarchy relate to the precautionary approach.

Intended Target Catch Well Below Absolute Catch Limit

The new ABC/OFL definitions keep catch targets below catch limits by distinguishing between the ABC, or the intended target, and the OFL, or the absolute limit. An explicit buffer is imposed between the two quantities so that inadvertently overshooting the ABC level for Species X by a small amount does not automatically close all other fisheries that might take small amounts of Species X as unavoidable bycatch. It should also be noted that the explicit buffer imposed between ABC and OFL is a minimum buffer, allowing the NPFMC to set a larger buffer for any particular species in any particular year if it wishes. This flexibility is provided by defining the OFL harvest rate as an equality and the ABC harvest rate as an inequality. The new definition does not allow the OFL harvest rate to vary from the formula specified in the FMP, whereas the ABC harvest rate is expressed as an upper bound only, thereby allowing the NPFMC the option of setting a lower target harvest rate and thus a larger buffer.

Depleted Stocks Harvested at Lower Rates than Healthy Stocks

The new ABC/OFL definitions treat depleted stocks more cautiously than healthy stocks by tying the two harvest rates explicitly to stock size. The precise relationships are illustrated for a hypothetical stock in Figure 1. When the stock is above the biomass level associated with maximum sustainable yield (B_{MSY}), neither the ABC nor the OFL harvest rate varies with stock size. However, should the stock fall below B_{MSY}, both the ABC and OFL harvest rates decrease linearly as a function of stock size, down to a value of zero at some very low abundance level (typically 5% of B_{MSY}). Although the absolute magnitudes of the ABC and OFL rates vary, the ratio between them remains constant.

Greater Uncertainty Corresponds to Greater Caution

Before addressing how the new ABC/OFL definitions treat uncertainty, it is helpful to discuss the topic of uncertainty in general. First, if the values of the parameters governing stock dynamics such as population growth rate and carrying capacity could be known with certainty, it would be fairly easy to compute the value of the harvest rate that maximizes sustainable yield, F_{MSY}. However, because their measurements are always subject to error, parameter values are never known with certainty, so the best that can be hoped for in practice is to estimate the relative plausibility of alternative values for F_{MSY}. For example, it might be possible to determine for a particular stock that there is only a 5% chance of F_{MSY} being smaller than about 0.10, that there is only a 5% chance of F_{MSY} being greater than about 0.35, and that the most likely value of F_{MSY} is about 0.16. These particular (hypothetical) probabilities happen to be consistent with the probability density function (PDF) shown in Figure 2. Given a PDF, it is easy to compute an average or expected value for F_{MSY}. The expected value for the curve shown in Figure 2 is 0.20. The expected value, which describes the center of gravity of the PDF, is also called the arithmetic mean. For example, the curves shown in Figure 3 represent four different PDFs, all with an arithmetic mean of 0.20 (the PDF whose peak is furthest to the right is the same curve shown in Figure 2). In a sense, each curve in Figure 3 "balances" at the arithmetic mean of 0.20.

If the value of F_{MSY} is known with a great deal of precision, the PDF will be tightly clustered around the arithmetic mean, whereas if the value of F_{MSY} is known with little precision, the PDF will be much more spread out, indicating a relatively high probability that the true value of F_{MSY} is quite different from the arithmetic mean. The four PDFs in Figure 3, for example, correspond to four different levels of uncertainty. As the level of uncertainty increases, the curve becomes broader and the peak of the curve moves to the left.

One measure of the amount of uncertainty associated with a PDF is the coefficient of variation (CV). The CV measures, on a relative scale, the average amount by which the true value might differ from the arithmetic mean. The curve shown in Figure 2 has a CV of 40%. The curves shown in Figure 3, moving from right to left in order of the location of the peak, have CVs of 40%, 60%, 80%, and 100%, respectively. The higher the CV, the higher the level of uncertainty.

To insure that greater uncertainty regarding a stock's productivity corresponds to greater caution in setting target harvest levels, the new ABC/OFL definitions use the information in a PDF such as those shown in Figure 3 to establish the minimum buffer between the ABC and OFL harvest rates. The new definition accomplishes this by setting the OFL harvest rate at the arithmetic mean of the PDF while capping the ABC harvest rate at the *harmonic* mean. The difference between these two means can be summarized as follows (see Appendix): The arithmetic mean gives the expected value of the points along the horizontal axis, while the harmonic mean gives the reciprocal of the expected value of the reciprocals of the points along the horizontal axis. It can be demonstrated that the harmonic mean of the F_{MSY} PDF is the optimal harvest rate from the viewpoint of risk-averse decision making, at least within the context of one type of mathematical model used in fishery stock assessment (Thompson 1996). Two more general properties of the harmonic mean are that it is always less than the arithmetic mean and that the ratio between the harmonic and arithmetic means decreases as the level of uncertainty increases. For example, the harmonic means of the four PDFs in Figure 3 (all of which have an arithmetic mean of 0.20) behave as described in the table below:

Coefficient of variation:	0.400	0.600	0.800	1.000
Harmonic mean:	0.172	0.147	0.122	0.100
Ratio (harmonic mean to arithmetic mean):	0.862	0.735	0.610	0.500

A convenient rule of thumb for computing the ratio between the harmonic and arithmetic means is

$$\text{Ratio} = \frac{1}{1 + CV^2}.$$

This rule is exact for certain types of PDF, but is only approximate for others (and then only for relatively small CV values, say, CVs of less than 50%). The above rule of thumb is illustrated in Figure 4, with the special cases of CV=0.5 and CV=1.0 highlighted.

Prognosis

Having been adopted only last year, it is difficult to provide an objective evaluation of the likely success of the new North Pacific groundfish harvest policy. For example, standard procedures for obtaining the PDF of F_{MSY} have yet to be adopted. Given this technical limitation, however, one favorable sign is that the NPFMC adhered to the new policy to the fullest extent possible during its inaugural year, even in cases where such adherence necessitated substantial harvest reductions. Evaluation of the long-term effects of the new policy may hinge on whether adjustments to that policy will be necessitated by recent legislative changes, as discussed below.

Recent Changes in U.S. Statutes: The Magnuson-Stevens Act

An important set of amendments to the Magnuson Act was passed by the U.S. Congress in September, 1996. The newly amended Magnuson Act was shortly thereafter renamed the Magnuson-Stevens Fishery Conservation and Magnuson Act (Magnuson-Stevens Act). The Magnuson-Stevens Act introduced or revised definitions for a number of terms and introduced several new requirements for contents of FMPs. Most importantly, the Magnuson-Stevens Act includes new definitions of overfishing, overfished, and optimum yield (OY); requires the establishment of objective and measurable criteria for determining the status of a stock or stock complex; and mandates specific remedial action in the event that overfishing is occurring or that a stock or stock complex is overfished.

The Magnuson-Stevens Act defines both overfishing and overfished as a rate or level of fishing mortality that jeopardizes a fishery's capacity to produce MSY on a continuing basis. Neither term was defined statutorily prior to 1996. The Magnuson-Stevens Act defines optimum yield (OY) as the amount of fish that will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities and taking into account the protection of marine ecosystems; that is prescribed on the basis of the MSY from the fishery, as reduced by any relevant social, economic, or ecological factor; and in the case of an overfished fishery, that provides for rebuilding to a level consistent with producing the MSY in such fishery. The main changes relative to the former definition include the requirement that OY take into account protection of marine ecosystems, the requirement that OY be no greater than MSY, and the requirement that OY for an overfished fishery allow rebuilding to the MSY level.

The Magnuson-Stevens Act requires each FMP to specify objective and measurable criteria for identifying when any fishery to which the plan applies is overfished (also referred to as "criteria for overfishing"), with an analysis of how the criteria were determined and the relationship of the criteria to the reproductive potential of the fishery. If the Secretary of Commerce determines at any time that these criteria have been breached, the Secretary is to notify the Council and request that remedial action be taken. The Council must then prepare an FMP, an FMP amendment, or proposed regulations for the purpose of ending overfishing and rebuilding affected stocks.

One Possible Approach to Interpreting the Magnuson-Stevens Act

While it is clear that a central purpose of the Magnuson-Stevens Act is to provide a strong conservation standard, there are a number of possible ways interpret its specific provisions. This section outlines one such possibility.

Sustainability

Sustainability is a key theme within the Magnuson-Stevens Act. The idea of sustainability is obviously inherent in MSY, a quantity which is central to the Magnuson-Stevens Act's definitions of both overfishing and OY. Closely related to the idea of sustainability is the phrase "on a continuing basis," which is used in the Magnuson-Stevens Act's definition of overfishing. In speaking of a particular level of catch as being sustainable, or as being achievable on a continuing basis, it is clear that a reasonably long time frame is implied. The implied level of constancy within such a time frame is less obvious, however. One possible interpretation is that perfect constancy is implied; that is, a particular level of catch would be referred to as sustainable only if it could be harvested each and every year. Such an interpretation might make sense in the context of a hypothetical, idealized fishery in which no natural variability existed. However, it is well known that no fixed amount of yield can be taken from any real fishery in perpetuity, because natural variability will inevitably cause such a policy to result in fishery collapse. Therefore, a more practical interpretation of sustainability and the phrase "on a continuing basis" would follow the view generally accepted in the fishery science literature, which is cast in terms of the average from a catch time series.

Further, it might be advisable to distinguish between the theoretical concept of MSY as an unconditional maximum independent of management practice and actual estimates of MSY, which are necessarily conditional on some type of (perhaps hypothetical) management practice. Specifically, it is useful to cast the estimation of MSY in the context of "control rules," where an MSY control rule is any hypothetical harvest strategy which, if implemented, would be expected to result in a long-term average catch close to MSY. For example, a Council could choose an MSY control rule in which fishing mortality is held constant over time at an appropriate rate, or one in which escapement is held constant over time at an appropriate level, or something else.

Use of the Terms "Overfishing" and "Overfished"

The relationship between the terms "overfishing" and "overfished" can be confusing. As used (implicitly) in the Magnuson-Stevens Act, the verb "to overfish" means to fish at a rate or level that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis. "Overfishing," then, occurs whenever a stock or stock complex is subjected to any such rate or level of fishing mortality. Interpreting the term "overfished" is more complicated. In the Magnuson-Stevens Act, this term is used in two senses: first, to describe any stock or stock complex that is subjected to overfishing, and second, to describe any stock or stock complex whose size is sufficiently small that a change in management practices is required in order to achieve an appropriate level and rate of rebuilding. To avoid confusion, it might be best to use "overfished" in the second sense only.

Status Determination Criteria

The Magnuson-Stevens Act requires that each FMP specify objective and measurable criteria for identifying when stocks or stock complexes covered by the plan are overfished. One way to fulfill the intent of the Magnuson-Stevens Act might be to require that such status determination criteria contain two components: a maximum fishing mortality threshold and a minimum stock size threshold. The maximum fishing mortality threshold could be set at the fishing mortality rate or level defined by the chosen MSY control rule, and the minimum stock size threshold could be set at one-half the MSY level or the minimum stock size at which rebuilding to the MSY level would be expected to occur within ten years if the stock or stock complex were exploited at the maximum fishing mortality threshold, whichever is greater. When data are insufficient to estimate any of these quantities, reasonable proxies could be used in their place.

Choosing an MSY control rule is thus key to this approach, because it defines the maximum fishing mortality threshold and plays a role in defining the minimum stock size threshold. Any MSY control rule defines a relationship between fishing mortality rate and stock size. In the approach described here, this relationship would constitute the maximum fishing mortality threshold, which could be either a single number or a function. In addition, any MSY control rule would define a rate of rebuilding for stocks below the MSY level. The smallest stock size at which rebuilding to the MSY level is achieved within 10 years would define the minimum stock size threshold for that rule, unless such a stock size were less than one-half the MSY level. The MSY control rule would also define an upper bound on any (optional) OY control rule that might be specified.

Some Possible Implications

The approach outlined here is a conservative one. In some ways it is even more conservative than the approach envisioned by Rosenberg et al. (1994). Chief among these is the role ascribed to MSY. In the approach of Rosenberg et al., MSY was the target reference point, whereas here MSY becomes the limit reference point, with a target reference point specified at some more conservative value. It seems reasonable to assume, therefore, that far fewer existing U.S. overfishing definitions would be deemed satisfactory under the approach developed here than in the evaluation provided by Rosenberg et al. In addition to reductions in both limit and target fishing mortality rates, a likely implication of the approach outlined here is a significant increase in the demands placed on fishery scientists. Both maximum fishing mortality and minimum stock size thresholds must be estimated, with rebuilding schedules incorporated explicitly rather than after the fact. If the chosen MSY control rule has more than one parameter (i.e., if the maximum fishing mortality threshold varies with stock size), the difficulty of estimation increases significantly, as does the potential need for re-estimation due to changes in environmental conditions. For these reasons, implementation of the approach developed here would be a major undertaking, a feature which this approach shares with precautionary approaches in general.

Prospects for Implementing Precautionary Approaches in General

For most national and international fisheries organizations, implementation of the precautionary approach will radically change both the form of scientific advice and the level of conservatism embodied in that advice. For example, the net effect of Annex II of the Straddling Stocks Agreement is to require that F_{MSY} be used as a limit to be avoided rather than a target which is often exceeded. If Annex II guidelines were applied diligently, fishing mortality rates in many commercial fisheries around the world could be reduced by 50% or more. In fact, an earlier draft of the Annex could have required an even higher degree of conservatism by specifying both that fishing mortality not exceed F_{MSY} and that stock biomass be maintained above the biomass level associated with MSY (symbolized here by B_{MSY}). However, unpublished simulation studies undertaken by NMFS indicated that the consequences of keeping fishing mortality below F_{MSY} while maintaining stock biomass above B_{MSY} would have been to set fishing mortality targets so low that they would have been unacceptable to most management agencies. Simple, stochastic, age-structured models showed that, in order to ensure no more than a 5% probability of stock biomass falling below B_{MSY}, fishing mortality would need to be as low as 40-70% of F_{MSY}, even with perfect knowledge and perfect management implementation.

Even if management agencies have the courage and fortitude to adopt such conservative fishing limits, they will encounter tremendous resistance due to the global fleet overcapacity problem, which is the greatest impediment to effective fisheries management and the main reason why a precautionary approach has not yet been adopted (Mace 1996; Norwegian Ministry of Fisheries 1997). Unfortunately, despite two to three decades of various national and international plans for controlling or reducing fishing capacity, solutions to the overcapacity problem generally remain elusive. In many cases, attempts to reduce fleet capacity have been expensive and largely ineffective. It appears that the only exception to these generalizations is in those instances where individual transferable quotas or other forms of property rights systems have been implemented. However, most nations are reluctant to adopt such systems for managing fisheries.

On the positive side, growing public awareness of the need for risk-averse approaches to the exploitation of natural resources may accelerate the adoption of such approaches in the future and may help to resolve the overcapacity problem as well. Public awareness of the causes and consequences of overfishing and the serial depletion of the world's fishery resources has also spurred other initiatives which should hasten adoption of precautionary approaches. One example is the current escalation of eco-labeling, perceived as a market-based solution to the mismanagement of fisheries. In 1996, Unilever (an Anglo-Dutch corporation heavily involved in the international fish market) and the World-Wide Fund for Nature (WWF, a non-governmental organization) joined forces to create the Marine Stewardship Council (MSC), established to develop criteria and procedures for labeling fish from ecologically sustainable fisheries. MSC is currently in the process of establishing a set of principles and standards for sustainable fishing through a series of workshops held throughout the world. WWF and Unilever have already caused leading UK retail chains to refuse to stock products using any material originating from North Sea industrial fisheries.

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Table 1. Elements of the precautionary approach for capture fisheries (summarized from FAO 1995).

- The precautionary approach recognizes that changes in fisheries systems are only slowly reversible, difficult to control, not well understood, and subject to changing environment and human values.

- The precautionary approach involves the application of prudent foresight. Among other things, it requires:

    - consideration of the needs of future generations and avoidance of changes that are not potentially reversible;

    - explicit consideration of undesirable or unacceptable outcomes, including overexploitation of resources, over-development of harvesting capacity, loss of biodiversity, major physical disturbances of sensitive biotopes, or social or economic dislocations;

    - implementation of necessary corrective measures without delay, to achieve their purpose on a timescale not to exceed two or three decades;

    - use of the best scientific evidence available, along with programs to improve data collection and statistics, enhance research on the stock and fisheries, and incorporate uncertainty and risk assessments into the analyses;

    - harvesting and processing capacity commensurate with estimated sustainable levels of the resource, with increases in capacity further constrained when resource productivity is highly uncertain;

    - all fishing activities having prior management authorization and being subject to periodic review;

    - an established legal and institutional framework for fishery management; and

    - appropriate placement of the burden of proof.

- The precautionary approach to fishery management is applicable even with very limited information.

Table 2. Examples of precautionary measures (summarized from FAO 1995).

- Always control access to the fishery early, before problems appear. An open access fishery is not precautionary.
- Place a cap on both fishing capacity and total fishing mortality rate.
- Develop operational target reference points (management goals) and limit reference points (e.g. minimum acceptable biomass or maximum acceptable fishing mortality).
- If limit reference points are exceeded, implement recovery plans immediately to restore the stock.
- Encourage responsible fishing through, for example, some form of tenure of fishing rights.
- Encourage development of fisheries that are economically viable without long-term subsidies.
- Establish data collection and reporting systems.
- Avoid harvesting immature fish, unless there is strong protection of the spawning stock.
- Use area closures to limit risks to the resource and environment by providing refuges for stocks and to protect habitat.
- Develop management plans cooperatively with stakeholders.

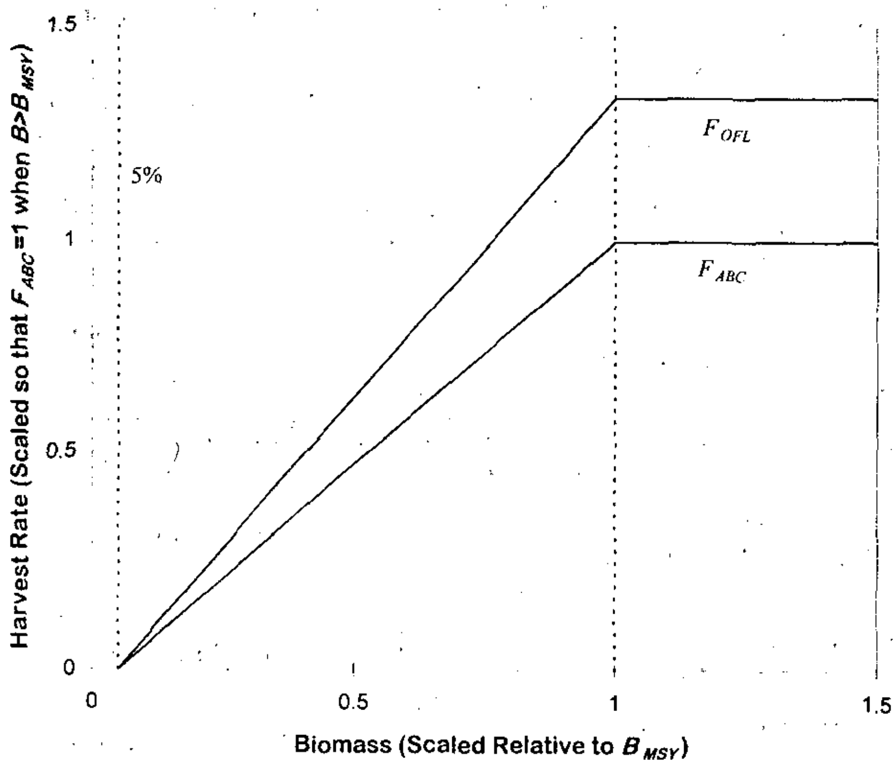

Figure 1. Overfishing rate F_{OFL} and target rate F_{ABC} in terms of biomass B.

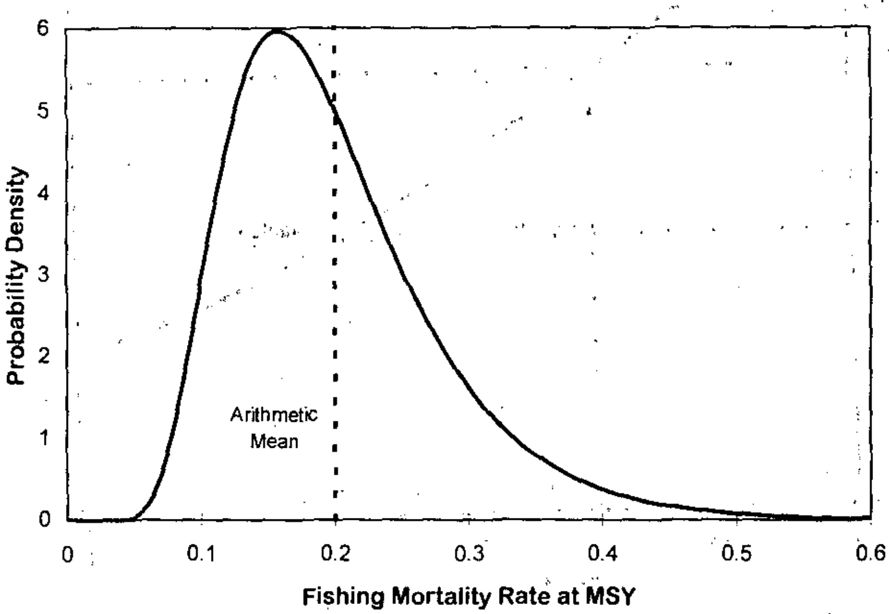

Figure 2. Probability density function of the fishing mortality rate at maximum sustainable yield (MSY) with an arithmetic mean equal to 0.2 and a coefficient of variation equal to 0.4.

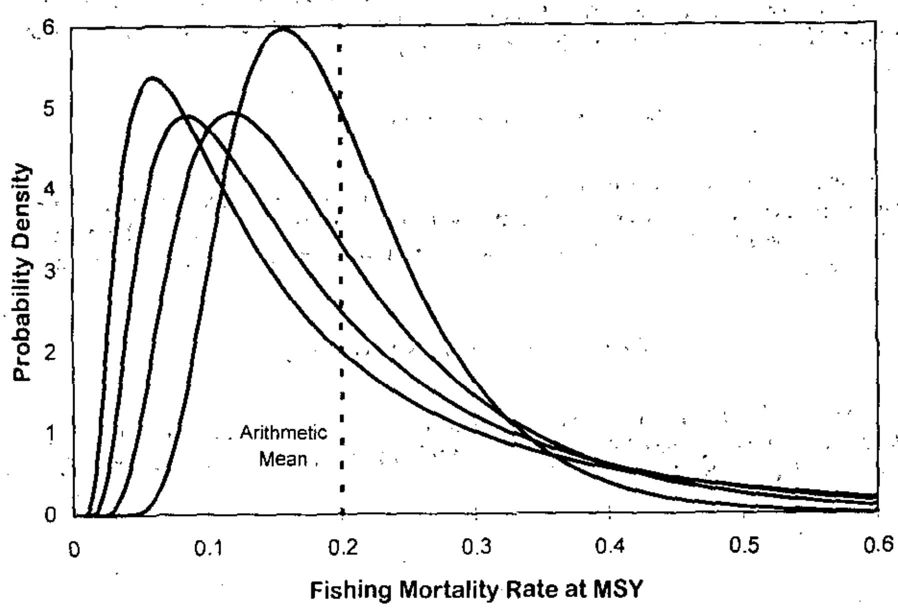

Figure 3. Probability density functions of the fishing mortality rate at maximum sustainable yield (MSY) with coefficients of variation equal to 0.4, 0.6, 0.8, and 1.0 (right to left in order of the peaks of the curves).

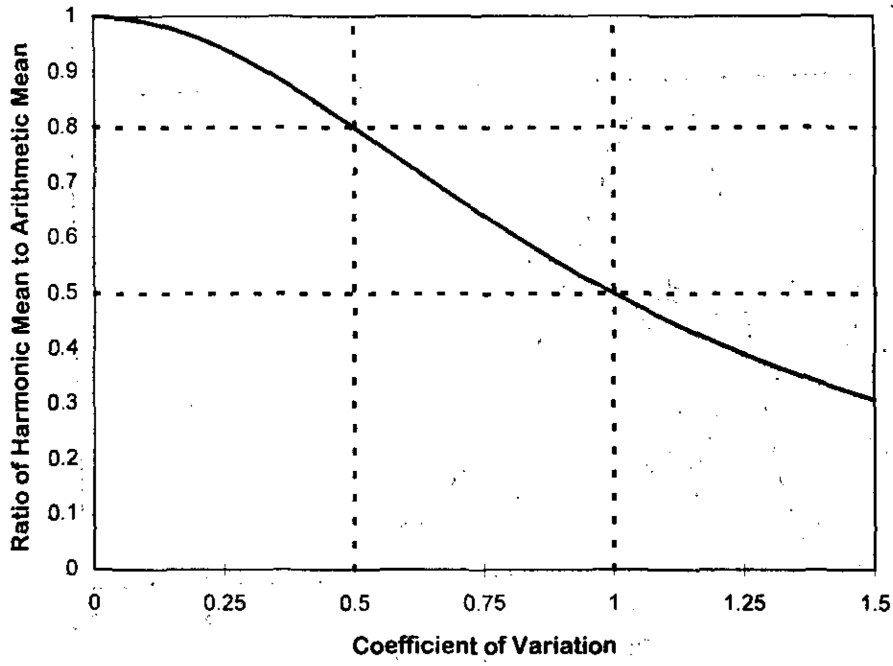

Figure 4. Ratio of harmonic mean to arithmetic mean as a function of the coefficient of variation (CV), with special cases of CV=0.5 and CV=1.0 highlighted.

Appendix: Arithmetic and Harmonic Means

Arithmetic mean: If X is a random variable, the arithmetic mean is the average value of X. For example, consider a game of chance based on a coin flip, where the random variable X denotes the prize associated with the game. The player gets $72 if he or she tosses heads and $24 if he or she tosses tails. The arithmetic mean prize for this game is

$$(50\% \times \$72) + (50\% \times \$24) = \$48.$$

As another example, consider a game of chance based on the toss of a six-sided die, where again the random variable X denotes the prize associated with the game. The player gets $72 if he or she tosses a "1" and $24 if he or she tosses anything else. The arithmetic mean prize associated with this game is

$$(16.667\% \times \$72) + (83.333\% \times \$24) = \$32.$$

Harmonic mean: If X is a random variable, the harmonic mean is 1 over the average value of $1/X$. For example, consider the game of chance based on a coin flip described above. The harmonic mean prize associated with this game is

$$\frac{1}{\frac{50\%}{\$72} + \frac{50\%}{\$24}} = \$36.$$

As another example, consider the game of chance based on the toss of a six-sided die. The harmonic mean prize associated with this game is

$$\frac{1}{\frac{16.667\%}{\$72} + \frac{83.333\%}{\$24}} = \$27.$$

Note that the harmonic mean is less than the arithmetic mean in both of these examples ($36 versus $48 for the coin flip and $27 versus $32 for the die toss). For all practical purposes, this relationship always holds (i.e., the harmonic mean is always less than the arithmetic mean). Thus, if the random variable X represents a fishing mortality rate, the harmonic mean is a more conservative (i.e., lower) rate than the arithmetic mean.